

**TULLYTOWN RESOURCE RECOVERY FACILITY LANDFILL:
INVESTIGATION OF PUBLIC HEALTH AND ODOR ISSUES IN THE
FLORENCE-ROEBLING AREA**

Prepared for:

**Waste Management of Pennsylvania, Inc.
Tullytown, PA**

Prepared by:

**CPF Associates, Inc.
Bethesda, MD**

**Environmental Information Logistics, LLC
Caledonia, Michigan**

**SCS Engineers
Carlsbad, California**

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ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AERMOD	American Meteorological Society/USEPA Regulatory Model
AEGL	Acute Exposure Guideline Level
ATSDR	Agency for Toxic Substances and Disease Registry
CALEPA	California Environmental Protection Agency
CALMIM	California Landfill Methane Inventory Model
CAS#	Chemical Abstract Service Number
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CV	Health-Based Comparison Value
D/T	Dilution-to-odor threshold ratio
EPCRA	Emergency Planning and Community Right-to-Know Act
ERPG	Emergency Response Planning Guideline Level
HEAST	Health Effects Assessment Summary Tables
HQ	Hazard quotient
IRIS	USEPA's Integrated Risk Information System
IUR	Inhalation unit risk
LANDGEM	USEPA's Landfill Gas Emissions Model
MRL	Minimum Risk Level
MSDS	Material Safety Data Sheet
MSW	Municipal Solid Waste
NIOSH	National Institute for Occupational Safety and Health
NMOCs	Non-methane organic compounds
NSPS	New Source Performance Standards
OSHA	Occupational Safety and Health Administration
PADEP	Pennsylvania Department of Environmental Protection
PPRTV	Provisional Peer-Reviewed Toxicity Values
REL	Reference Exposure Level
RSL	Regional Screening Level
SDS	Safety Data Sheet
TEEL	Temporary Emergency Exposure Limit
TRRF	Tullytown Resource Recovery Facility
TSCA	Toxic Substances Control Act
UCL	Upper Confidence Limit
URF	Unit Risk Factor
USEPA	United States Environmental Protection Agency
USGS	United States Geological Service
VOCs	Volatile Organic Compounds
WM	Waste Management, Inc.
WMPA	Waste Management of Pennsylvania, Inc.

UNITS OF MEASURE

Measures of mass or weight

mg	Milligrams
µg	Micrograms (1,000 µg = 1 mg)

Measures of concentration

mg/m ³	Milligrams of chemical per cubic meter of air
µg/m ³	Micrograms of chemical per cubic meter of air (1,000 µg/m ³ = 1 mg/m ³)
ppm & ppmv	Parts per million by volume
ppb & ppbv	Parts per billion by volume (1,000 ppb = 1 ppm)

SCIENTIFIC NOTATION

Scientific notation is a method of presenting numbers. It is particularly useful for numbers that are very small or very large. Some examples are shown below.

Number	Scientific Notation	
100	1×10 ²	1E+02
10	1×10 ¹	1E+01
0.1	1×10 ⁻¹	1E-01
0.01	1×10 ⁻²	1E-02
0.001	1×10 ⁻³	1E-03
0.0001	1×10 ⁻⁴	1E-04
0.00001	1×10 ⁻⁵	1E-05
0.000001	1×10 ⁻⁶	1E-06

EXECUTIVE SUMMARY

In May 2015, the Pennsylvania Department of Environmental Protection (PADEP) renewed the solid waste disposal permit for Waste Management of Pennsylvania's (WMPA) Tullytown Resource Recovery Facility (TRRF) Landfill. The permit required that a plan of study be prepared and implemented "to evaluate air emissions related to landfill gas, working face odors and odor control chemicals emanating from the landfill and travelling to the Florence-Roebling areas on the prevailing winds." PADEP also requested that the study include collection of actual air monitoring data and an analysis of odor threshold and health risk levels.

This report presents the results of the study required by PADEP. It was conducted in accordance with a study plan approved by PADEP, and relied on methodologies developed by regulatory and public health agencies.

Three investigations were conducted to address the permit condition: an air modeling study to evaluate potential landfill gas and working face emissions; an air monitoring program both on-site and in the Florence-Roebling area; and an evaluation of odor control products used at the landfill. These investigations assess the potential for public health risks and odors in the Florence-Roebling area.

The air modeling study evaluated the potential for public health risks and odors in the Florence-Roebling area. It was performed using a U.S. Environmental Protection Agency-approved (USEPA) model that calculated air concentrations of 47 compounds commonly present in landfill gas and working face gas emissions. This is what the study concluded:

- Adverse health effects are not expected in Florence-Roebling. Based on the landfill conditions addressed in the study, the emissions data collected at TRRF and the dilution and dispersion of emissions as they move away from a source, the calculated concentrations in Florence-Roebling were more than 100 times below regulatory and health-based criteria relied on by PADEP and USEPA for protection of public health.
- Odors are not expected to be detected in Florence-Roebling by a person of typical sensitivity. However, transient odors could be detected at times depending on landfill and weather conditions and on the odor sensitivity of an individual in the community.

The modeled odor assessment results should not automatically be expected to correspond to odor surveys. Differences in results from different odor investigation methods can occur for many reasons, especially if the investigations are not carefully matched to the same time period. For example, this study relied on a quantitative, scientifically-based method which calculated air concentrations for compounds that may be present in landfill gas and working face gas. In contrast, odor surveys rely on subjective perceptions of odor and provide qualitative results. Perceptions of odor are known to be extremely variable because they are affected by numerous biological and psychological factors, such as genetics, age, medical conditions, pre-existing attitudes and personal beliefs.

A three-month air monitoring program, from July to October 2015, was conducted in Florence-Roebling to investigate potential air impacts from the landfill. The air monitoring program

measured concentrations of hydrogen sulfide, a common landfill gas compound, at nine locations in Florence-Roebling and at several locations very close to the landfill surface.

- All of the 555 hydrogen sulfide concentrations measured in Florence-Roebling were well below levels considered to be protective of public health by USEPA and PADEP. An analysis of the Florence-Roebling data relative to wind direction did not show a consistent pattern of hydrogen sulfide concentrations that indicated a clear landfill-related impact.
- On the landfill site, all of the more than 200 hydrogen sulfide concentrations measured within a few inches of the landfill surface were substantially below occupational standards and criteria developed for protection of workers and below the Pennsylvania ambient air quality standard. One value at the surface of the landfill was barely above the most restrictive public health protection level set by California. When considering the dilution and dispersion that occurs during movement of air away from the landfill, no adverse health effects to the public are expected.

The potential for public health risks and odors in Florence-Roebling associated with odor control product use at the landfill also was evaluated. In accordance with the PADEP-approved study plan, the assessment focused on odor control products used at the landfill from June 2014 to September 2015. This evaluation concluded that:

- Adverse health effects would not have been expected in Florence-Roebling as a result of potential air emissions of odor control products. This conclusion was based on evaluation of the ingredients in the odor control products, available health effects criteria for these ingredients, the dilution of odor control products with air or water before use, the locations of use, and the dilution and dispersion that occurs as air travels away from an emissions source.
- Fragrances associated with odor control products used at TRRF could have been detected at times in the Florence-Roebling area, depending on the location of use, weather conditions at the time of use and the odor sensitivity of an individual in the community. These detections are likely to be related to the presence of fragrances in odor control products used at landfills, including lemon, lime, orange and pine oils.

Based on the landfill conditions addressed, and air and emissions data collected at TRRF and at nine locations in Florence-Roebling, this study concludes that no adverse public health effects are expected in Florence-Roebling as a result of landfill gas and working face gas emissions, and odor control product use. The study also found that an individual in Florence-Roebling with typical odor sensitivity is not likely to detect landfill gas and working face gas odors. Fragrances associated with past odor control product use at the landfill may have been detected at times depending on landfill and weather conditions and on the odor sensitivity of an individual in the community.

Based on the results of the air modeling study and the monitoring program, additional air monitoring in Florence-Roebling is not recommended.

**TULLYTOWN RESOURCE RECOVERY FACILITY LANDFILL:
INVESTIGATION OF PUBLIC HEALTH AND ODOR ISSUES IN THE FLORENCE-ROEBLING AREA**

1.0 INTRODUCTION

A solid waste disposal renewal permit was issued to Waste Management of Pennsylvania, Inc. (WMPA) by Pennsylvania Department of Environmental Protection (PADEP) for the Tullytown Resource Recovery Facility (TRRF) Landfill on May 21, 2015. Condition 45(B) of that permit states:

- (B) As soon as practicable, but in no case later than 90 days after the issuance date of this permit, the Permittee shall submit a plan of study to evaluate air emissions related to landfill gas, working face odors and odor control chemicals emanating from the landfill and traveling to the Florence-Roebling areas on the prevailing winds. The plan of study shall include provisions to characterize landfill emission parameters and chemical constituents of potential concern and to collect actual monitoring data, both at the landfill and in the surrounding communities. The plan shall be developed to enable the Permittee to provide an analysis of the odor threshold and health risk levels of the parameters and chemical constituents of potential concern identified by the study. Upon approval of the plan of study by DEP, the Permittee shall conduct the study and submit a final report containing monitoring data collected and analysis of the data in accordance with the schedule approved therein. Monitoring data and analysis shall be made part of the TRRF Landfill's operating record and the evaluation report shall be submitted to the DEP, Florence Township, and also generally made available to the public.

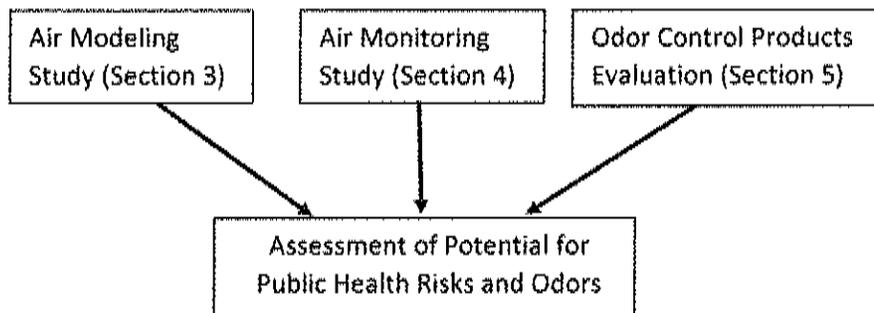
This document presents the study that was conducted for permit condition 45(B) in accordance with a PADEP-approved plan. A draft plan of study was submitted to PADEP on August 19, 2015 and resubmitted on October 29, 2015 (CPF/EIL 2015) in response to PADEP comments. PADEP approved the revised study plan on November 13, 2015 with a few additional suggestions which have been addressed in this report (Wentzel 2015, see Appendix A). Unless otherwise noted, all of the methods used in this study followed the PADEP-approved study plan.

Three related investigations were conducted to address permit condition 45(B), as shown in Figure 1: an air modeling study to evaluate potential landfill gas and working face emissions; an air monitoring program both on site and in the Florence-Roebling area; and an evaluation of odor control products used at the landfill. Each investigation relied on methodologies developed by regulatory and public health agencies. Collectively, these investigations allow for an assessment of the potential for public health risks and odors in the Florence-Roebling area.

To conduct this study, WMPA engaged a team of three independent environmental consulting firms - CPF Associates, Inc., Environmental Information Logistics, LLC (EIL) and SCS Engineers. CPF is a Maryland-based scientific research and consulting firm that specializes in environmental impact and public health studies of the management of solid and hazardous waste. Ms. Foster, a Principal with CPF, was the Principal Investigator for this project. EIL is an environmental consulting, engineering, and information management firm with specialized expertise in landfill gas management, engineering and air dispersion modeling. Michael

Niemann, Landfill Gas Program Technical Director at EIL, was responsible for the modeling of landfill gas emissions and the air dispersion modeling. SCS Engineers provides professional services in the fields of chemical risk management, air quality, odor science, atmospheric modeling/transport and atmospheric tracer science. From SCS Tracer, Mr. Thomas Rappolt, Program Director and Vice President, was responsible for the working face gas sampling program and assistance in the evaluation of potential odor impacts. Biographies for these investigators are provided in Appendix B.

Figure 1
Investigations Conducted to Address Permit Requirement 45(B)



2.0 BACKGROUND INFORMATION

2.1 Landfill Description

The TRRF Landfill is located in the Borough of Tullytown and Falls Township, Bucks County, Pennsylvania. Since 1988, the facility has been owned and permitted as a municipal solid waste (MSW) disposal facility by WMPA. The facility is located just north of the Delaware River, with the New Jersey towns of Florence and Roebing to the south across the river and Tullytown and Levittown to the west and northwest (see Figure 2).

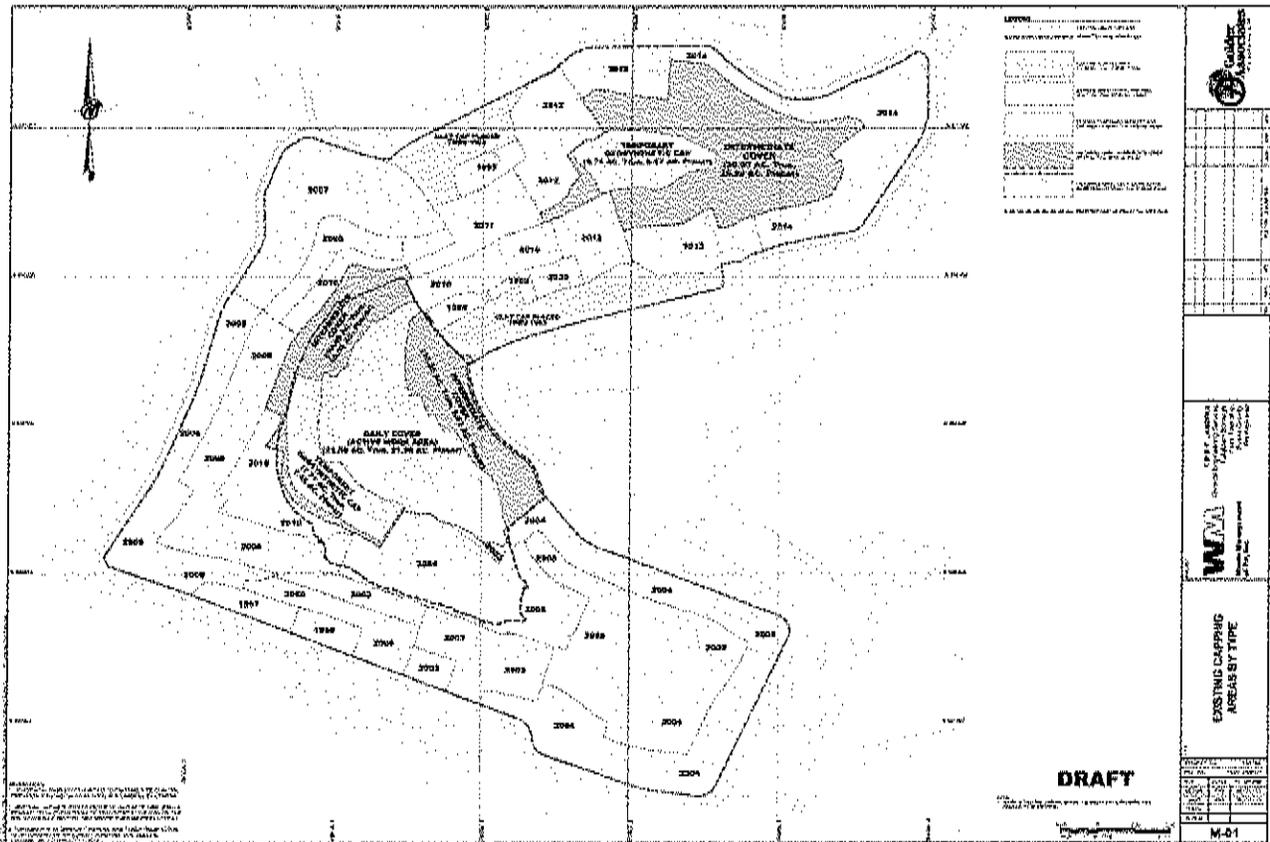
The total area of the TRRF Landfill is approximately 412 acres, of which 307 acres have been permitted by PADEP for waste disposal operations. Disposal operations have progressed from the original landfill to the Southern Expansion area, the Western Expansion area, the Eastern Expansion area, and most recently the Valley Fill Expansion area. Except as noted below, most of the 307 acres is no longer used for waste disposal and is covered with intermediate soil cover, a clay cap, a temporary geomembrane cover or a final geomembrane cover (see Figure 3).

On May 21, 2015, PADEP renewed the TRRF Landfill solid waste management permit for a period not to exceed two years. Disposal operations permitted during the remaining two years must be limited to the Valley Fill Expansion, which was permitted for use in 2013, and the previously permitted Eastern Expansion areas. The permit also includes closure and post-closure activities necessary for the remaining portions of the TRRF Landfill. Condition 45(B) in this permit is the subject of this report.

Figure 2
Tullytown Landfill and Vicinity



Figure 3
Tullytown Landfill Areas by Cover Type



2.2 Landfill Gas and Odors

Landfill gas is generated at all municipal solid waste (MSW) landfills as a natural by-product of the biological decomposition (biodegradation) of organic materials that have been disposed. 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, to name a few). Some compounds found in landfill gas can be odorous. For example, one common compound associated with odors in landfill gas is hydrogen sulfide which has a rotten egg smell.

Many methods are used to control and limit emissions of landfill gas and odors from MSW landfills throughout the US and worldwide. At TRRF, landfill gas is collected and controlled through an extensive gas collection and control system (GCCS) that currently consists of more than 375 vertical gas extraction wells and more than 4,000 feet of interconnected horizontal underground perforated pipes. The bulk of the collected gas is transported via buried pipeline to the nearby Exelon Power Fairless Hills Steam Generating Station. The Exelon power plant produces some of its energy by combusting the landfill gas in their boilers at high temperature. This not only reduces reliance on fossil fuels, but also converts compounds present in the landfill gas into toxicologically inert materials such as carbon dioxide and water vapor. (Exelon also owns and operates the nearby Pennsbury Power Plant that utilizes two turbines for the destruction of landfill gas and creation of renewable electricity.) TRRF has two enclosed flares which are used as backup (typically less than 500 hours per year) to combust landfill gas in the event the Exelon power plant is off line. Lastly, TRRF utilizes a landfill gas fueled reciprocating engine to consume the remaining collected gas to provide electrical power for on-site usage further off-setting fossil fuel consumption.

Additional methods used to control landfill gas and reduce odors at TRRF are outlined in the facility's Nuisance Minimization and Control Plan, prepared for and approved by PADEP in accordance with regulatory and permitting requirements. These methods include: limiting the size of the working face where newly disposed waste is placed; installing cover materials over waste disposal areas; not accepting odorous waste streams such as biosolids; using odor control products near waste disposal areas; and installing additional interim landfill gas collection wells and horizontal collection pipes. TRRF revised its Nuisance Minimization and Control Plan over the past year, adding enhanced control measures to further reduce odors that may be a result of the landfill. These measures include using additional cover at the working face, sealing the surface of newly placed waste with a roller at the end of each day, accelerating installation of additional interim landfill gas collection wells and piping systems and using additional odor control product misting and direct application systems at the working face.

The installation of gas piping systems and gas collection wells, in addition to those components required to maintain gas collection in accordance with the U.S. Environmental Protection Agency's (USEPA's) New Source Performance Standard (NSPS), is done to minimize and prevent odors. These construction activities may, however, temporarily expose underground areas where landfill gas had previously been well controlled. In these instances, there may be a potential for limited short-term emissions of odors and/or landfill gas from a small area of

activity, until the work is completed, even though the new installations will ultimately provide enhanced odor control. During new well and pipe installation activities, TRRF uses targeted odor control systems to minimize temporary potential odor impacts and also generally requires contractors to use vacuum systems applied to drilling equipment.

The landfill implements routine surveillance and compliance programs to evaluate the performance of the gas collection and control system and the integrity of the landfill cover. This includes monthly monitoring of each gas extraction well and quarterly monitoring of the landfill surface for methane in accordance with Federal regulations. The facility also conducts tuning (well adjustments) of the gas system, as needed, by trained landfill gas technicians; daily monitoring of the on-site landfill gas fueled reciprocating engine power generator; and monitoring of odor control systems and back-up enclosed flares when they are operating. The gas collection and control system is very effective, as demonstrated by the quarterly methane surface scans. Using USEPA's greenhouse gas reporting rule methodology (USEPA 2015a), the overall site-wide collection efficiency was calculated to be 88% (WM 2015) based on the landfill's 2014 configuration. In reality, the collection efficiency is expected to be higher than 88% because more landfill areas now have final cover. Landfill gas boiler power plants similar to the Exelon Fairless Hills power plant and landfill gas flares are at least 98% efficient in destroying non-methane organic compounds present in landfill gas (USEPA 2008).

Odor surveys are also conducted on a daily basis by trained landfill staff and, at times, jointly with PADEP. Landfill staff conduct odor surveys on weekdays, weekends, and after hours in Florence Township, New Jersey. Information from these surveys is communicated to the site so that operations and odor-control activities can be modified if needed.

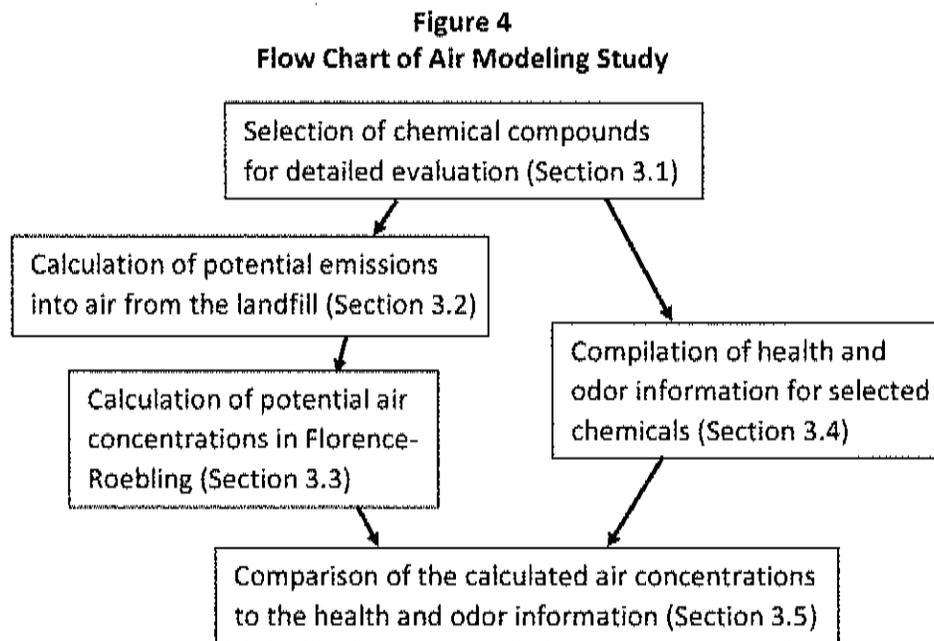
3.0 AIR MODELING STUDY

The air modeling study was conducted to evaluate potential public health risks and the potential for odors to a hypothetical individual in the Florence-Roebling area. The hypothetical individual was assumed to be exposed to emissions transported through the air from TRRF (from landfill gas and working face sources) towards the Florence-Roebling area. This evaluation does not reflect actual individual exposures or risks to residents. Rather, the modeling study, consistent with standard practice, was biased toward health protectiveness and thus is expected to overestimate potential ambient air concentrations and exposures by using compounded conservative assumptions.

The study approach relied on standard methods and guidance from the USEPA and PADEP in addition to applicable scientific research (e.g., USEPA 2009, PADEP 2013, Bogner et al. 2014). Model predicted downwind ambient air concentrations in the Florence-Roebling area that might result from potential TRRF emissions were calculated using a USEPA-approved air dispersion model called AERMOD. Inputs to the air dispersion model included potential emissions related to landfill gas and the working face. Potential landfill gas source emissions were calculated using an extensively validated landfill gas emissions model called CALMIM (California Landfill Methane Inventory Model) (Bogner et al. 2014). Potential working face emissions were characterized based on a targeted sampling program conducted at the working

face of the landfill on December 2, 2015. Available site-specific input parameters were used in the modeling where possible.¹

The modeling study approach is outlined in Figure 4. This approach involved five main steps, each of which is described in the following sections.



3.1 Selection of Chemicals for Detailed Evaluation

The first step of the modeling study was to select chemicals for detailed evaluation. This was accomplished by evaluating raw landfill gas data collected from inside the TRRF Landfill and chemical composition data collected from the working face as part of this study.

3.1.1 Landfill Gas

Typical landfill gas is composed of about 40-60% methane, 40-60% carbon dioxide, 2-5% nitrogen, 0.1-2% oxygen and small amounts of non-methane organic compounds (NMOCs). Generally, the NMOCs, which include many of the compounds evaluated in this study, make up less than one percent (1%) of the volume of landfill gas. In addition, non-organic compounds such as hydrogen sulfide and other reduced sulfur compounds² are typically present at levels well below 0.01% in landfill gas (ATSDR 2001, Williams 2002, USEPA 2008).

¹ An air dispersion model uses mathematical equations to predict the transport of emissions through the atmosphere. These models replicate atmospheric conditions, such as wind speed and direction, air temperature and mixing height, to estimate concentrations of compounds in air as they travel away from an emission source. The AERMOD model (AMS/EPA Regulatory Model) is considered applicable by the USEPA for this type of study. It was developed based on extensive scientific research and validated based on real-world measurements.

² Reduced sulfur compounds are a class of related compounds that include sulfides (e.g., hydrogen sulfide, carbon disulfide and dimethyl sulfide) and mercaptans (e.g., methyl mercaptan, isobutyl mercaptan and propyl mercaptan).

As noted above, the gas collection system at TRRF is highly effective at removing most of the landfill gas which is then transported via pipeline to the Exelon Fairless Hills Steam Generating Station and the site's landfill gas fueled engine power generator. Some landfill gas may, however, escape this system and enter the air from the surface of the landfill instead of being collected. These surface releases through covered landfill areas are the landfill gas emissions that are the focus of this modeling study (along with working face emissions).

The landfill gas composition at TRRF was determined from four landfill gas sampling efforts conducted from 2011 to 2014. Raw landfill gas samples are collected annually from the landfill's main gas collection header pipe and analyzed for more than 50 volatile organic compounds using USEPA Method TO-15 and for seven sulfur compounds using USEPA Method 15/16. The landfill gas testing is conducted in accordance with 25 Pa. Code 273.293(b) and guidance developed through consultation with PADEP. Every compound detected at least once in the 2011-2014 landfill gas data was selected for detailed analysis, resulting in a list of 35 compounds. The compounds detected in TRRF landfill gas are consistent with those commonly reported in MSW landfills around the globe. These compounds result from the waste decomposition process. Table 1 presents the landfill gas data for the detected compounds in the 2011-2014 sampling programs.³

3.1.2 Working Face Gas

At the working face of a municipal solid waste landfill, newly disposed waste is spread and compacted prior to placement of daily cover. The composition of gases at the working face may differ from that in landfill gas, because the waste has not substantially biodegraded unlike older areas of a landfill. At TRRF, the size of the working face is limited at all times to minimize the potential for odors, windblown waste and the area exposed to possible precipitation. The total working face area at TRRF at any given time is generally no more than roughly 200 feet by 250 feet in size (1.1 acres). As soon as possible (as early as 9:00 AM in some cases), cover placement commences to minimize the open area such that by the end of every day, the working face is covered with at least six inches of compacted daily cover material (e.g., soil). The site is currently supplementing the six inches with additional soil as well as recycled asphalt material and smooth drum rolling the surface to seal it as much as possible.

In order to address potential odors and emissions from the working face, and in response to input from PADEP, a targeted sampling program was conducted at TRRF and performed by SCS Engineers to characterize the working face gas composition. This program was carried out on December 2, 2015 in accordance with the PADEP-approved study plan. Working face gas samples were collected from a static non-vented flux chamber (i.e., an isolation chamber)

³ Landfill gas concentrations in Table 1 and elsewhere in this report are presented in units of parts per billion (ppb) and micrograms per cubic meter of air ($\mu\text{g}/\text{m}^3$). Concentrations of chemicals in air are often expressed as the volume of chemical per volume of air with typical units of parts per billion by volume (ppbv) or parts per million by volume (ppmv), with 1 ppmv = 1,000 ppbv. In this report, these units are expressed simply as ppm or ppb. Air concentrations can also be expressed in terms of mass (i.e., weight) of chemical per volume of air with units of micrograms (μg) or milligrams (mg) of chemical per cubic meter (m^3), with $1 \text{ mg}/\text{m}^3 = 1,000 \mu\text{g}/\text{m}^3$. The two systems of reporting concentration are not directly interchangeable. Concentrations can be converted from one system into the other by taking into account molecular weight, temperature and pressure.

which was placed over recently spread and compacted waste prior to application of daily cover. The static flux chamber isolated gas at the surface of the working face from the ambient air, and allowed for direct measurement of concentrations in the working face gas (Eklund 1992). The flux chamber was placed at a location on the working face where the highest odors were noted at the time the sampling team was on site, taking into account worker safety concerns and the representativeness of the newly placed and compacted waste mixture. In this way, the sampling program was biased towards detection of constituents most likely to be associated with odors. The flux chamber monitoring program is described further in Appendix C.

The collected samples were analyzed for a range of compounds within several general chemical groups that are considered likely to be present in working face gas. The selection of these compound groups was informed by work previously performed by SCS Engineers at other landfills and findings in studies of working face gas composition conducted outside of the United States (e.g., Li et al. 2015). For each chemical group, two samples were collected and shipped to a certified independent laboratory for analysis. Standard air sampling methods consistent with USEPA guidelines and incorporating quality assurance procedures were employed (e.g., evaluation of method blanks and laboratory control samples). The chemical groups evaluated, and the sampling and analysis methods for each, are listed in Table 2.

Every compound detected in the working face gas samples was carried forward for evaluation. This resulted in a list of 18 compounds, six of which were already selected based on the landfill gas data. The laboratory reports with the sampling results are provided in Appendix C. Table 3 presents the working face gas sampling results for each detected compound.

3.2 Calculation of Potential Emission Rates

The next step of the study involved the calculation of emission rates for all covered areas of the landfill and for the working face. The CALMIM model was used to calculate emission rates from areas of the landfill with different cover types (e.g., final, intermediate and daily cover). Emission rates from the working face were calculated based on results from the targeted sampling program described above. Each of these emission rate calculation methods is described below.

3.2.1 Potential Emission Rates for Covered Landfill Areas

3.2.1.1 Introduction

Landfill gas models, such as CALMIM, have been developed and used extensively in the US and worldwide to predict landfill gas generation and emission rates (USEPA 2005a, Kamalan et al. 2011, Spokas et al. 2011). While these models are based on methane, an odorless non-toxic compound found in landfill gas, they are also often used to address other compounds including those evaluated in this study. Landfill gas modeling may be performed for regulatory purposes such as to determine when a landfill gas collection and control system needs to be installed or to estimate methane emissions for greenhouse gas reporting. Models may also be used for non-regulatory purposes such as to estimate landfill gas emissions for a public health study,

evaluate the feasibility of a landfill gas energy project or determine system design requirements for a gas collection system.

CALMIM is a validated mathematical model that predicts potential methane emissions through covered landfill areas. It is a more refined model than others that have historically been used to estimate landfill gas emissions such as USEPA's LANDGEM model (e.g., it can incorporate site-specific soil properties and landfill characteristics) and it is being increasingly relied upon to provide more accurate methane emission estimates from MSW landfills (Spokas et al. 2011, Bogner et al. 2014). An overview of the CALMIM modeling is provided below and additional information is presented in Appendix D.

3.2.1.2 CALMIM Modeling

The CALMIM model has been developed to take into account three principal controlling factors influencing landfill methane emissions based on extensive research into this issue: 1) gas extraction rates, 2) cover soil gas transport rates based on cover material physical properties and thickness, and 3) methane oxidation associated with methanotrophs⁴ and seasonal soil microclimates. Published CALMIM validation research indicates that it predicts emissions within the same order of magnitude as field measurements (Bogner et al. 2014).

Since landfills are operated over multiple years with various cover systems installed depending on the stage of construction, emissions can vary over time due to ongoing cover system installation progression – from active fill area to final cover. For this study, potential emissions were calculated using CALMIM for five different cover types: 1) final certified geomembrane cover; 2) final certified clay cover; 3) intermediate soil cover; 4) temporary geomembrane cover; and 5) the active daily cover area. Potential emissions associated with temporary situations, such as installation of gas piping systems and gas collection wells, were not modeled because the locations, durations and configurations of these types of activities are highly variable.

Figure 3 shows the distribution of cover types that were present at TRRF in June 2015 and which were modeled in this study. Since June 2015, some additional areas have been capped with final certified geomembrane cover and temporary geomembrane cover, thereby reducing the landfill area with intermediate soil cover. By modeling the June 2015 cover configuration, calculated potential emissions from TRRF are expected to be overestimated because the area covered with intermediate soil cover has been reduced.

Site-specific input parameters were used in CALMIM where available. Cover systems at TRRF, with thicknesses as prescribed by PADEP, were defined and input to CALMIM. Each cover area shown in Figure 3 was modeled uniquely, with the cover type assumed to be present across the entire area. Site-specific methane concentrations measured directly below several of the cover types were also used as inputs (see below for more information). Other than these site-specific input parameters, CALMIM was run using the default inputs embedded in the model (Bogner et

⁴ Methanotrophs are microbes that are able to metabolize and break down methane as their only source of carbon and energy.

al. 2014). Additional details about the input parameters to CALMIM are provided in Appendix D.

3.2.1.3 Site-Specific Below Cover Methane Concentrations for CALMIM Modeling

As noted above, site-specific methane concentrations measured below several different cover types at TRRF were used as inputs to the CALMIM model. This information was used to refine the lower boundary condition in the model (i.e., CALMIM's default below cover methane concentration was replaced with site-specific data). Specifically, below cover methane measurements at TRRF were collected and used to establish the lower boundary condition of the CALMIM model for the daily cover, intermediate cover and temporary geomembrane cover areas. The default CALMIM lower boundary conditions were used for the final certified geomembrane cover and the final certified clay cover to avoid disturbing these capped and closed areas.

Below cover methane measurements were obtained from a bar punch survey conducted on November 17, 18 and 23, 2015. For this survey, which is described in Appendix D, a sampling grid with approximately 200 foot spacing was overlain on a map of the landfill surface. Using this grid as a guide, and taking into account site conditions, samples were collected from each cover area type. The total number of samples consisted of 16 collected from below the daily cover in the active area, 57 collected from below the cover in intermediate cover areas and 25 collected around the perimeter of the temporary geomembrane area as near to the edge of the membrane as possible without compromising the integrity of the capping system. In order to obtain a methane measurement, a metal rod was extended to the base of the capping system from which a sample was analyzed for methane by an instrument called a Toxic Vapor Analyzer (TVA). Once the sample was collected, the hole was filled with soil.

The bar punch results were used to calculate below cover methane concentrations for input to CALMIM. For the active daily cover area and the intermediate cover area, the input parameter was based on the 95th percent upper confidence limit (95% UCL) of the mean concentration of the bar punch measurements.⁵ To be consistent with the PADEP-approved study plan and PADEP methods (e.g., PADEP 2013), one-half of the detection limit was input for non-detect sample results.⁶ The 95% UCL concentrations were calculated using USEPA's ProUCL5 software which was developed to perform statistical analyses of environmental data (USEPA 2013 a,b). The resulting below cover 95% UCL methane concentrations were 1,156 parts per million (ppm; 0.12%) and 1,876 ppm (0.19%), respectively, for the active daily cover area and the intermediate cover area. For the temporary geomembrane area, since samples were collected from the edges of this area rather than directly below the cover, the highest methane result among the perimeter sampling data was used to define the below cover boundary condition (2,396 ppm; 0.24%). For cover types that could not be sampled at TRRF, the default values in CALMIM for below cover methane concentrations were used (38.5% for final geomembrane cover and final clay cover).

⁵ The 95 percent upper confidence limit (UCL) of a mean is a conservative estimate of the average (or mean) concentration. It is defined as a value that, when calculated repeatedly for randomly drawn subsets of site data, equals or exceeds the true mean 95 percent of the time.

⁶ The TVA detection limit for methane was 1 part per million.

3.2.1.4 CALMIM Model Output

The CALMIM model calculated methane emissions, both with and without oxidation, in units of grams per square meter per day ($\text{g}/\text{m}^2\text{-day}$). These data were converted to grams per square meter per second ($\text{g}/\text{m}^2\text{-sec}$) for use in the subsequent dispersion modeling with AERMOD.

Table 4 presents the CALMIM calculated methane emission rates by cover area and for the entire landfill. The percentage acreage for each cover type was used to establish a source-wide emission rate for the entire landfill to input in AERMOD's area source computational unit. The CALMIM results are expected to reflect typical long-term emissions associated with the June 2015 site layout.

3.2.2 Potential Emission Rates for the Working Face Area

Emission rates for compounds in working face gas were calculated based on the maximum measured concentrations in working face gas, as described above in Section 3.1.2, and the vertical velocity or gas diffusion rate at the working face. The vertical gas velocity was calculated to be 6.4×10^{-5} m/sec based on typical compaction rates of MSW at a landfill working face and the amount of air-filled spaces in the MSW.⁷ Table 5 presents the calculated potential emission rates for the working face. Additional information describing the working face gas velocity is provided in Appendix C.

3.3 Calculation of Potential Ambient Air Concentrations

Concentrations in ambient air were calculated based on the emission rates for covered landfill areas (based on the CALMIM model) and the working face (based on sampling at TRRF), the chemical concentrations in landfill gas and in working face gas, and the AERMOD air dispersion model. For covered areas of the landfill, the AERMOD model calculated methane ambient air concentrations, which were then converted to chemical-specific concentrations by taking into account the concentrations in raw landfill gas of each detected compound relative to methane. For the working face, the AERMOD model calculated ambient air concentrations for each evaluated working face compound based on its potential emission rate.

3.3.1 AERMOD Modeling

The air dispersion analysis was conducted using USEPA AERMOD Version 14134 (released 2014).⁸ AERMOD is an appropriate model for investigation of landfills because it can model potential emissions from area sources (such as an area of a landfill), it was designed to incorporate detailed hourly meteorological information and calculate concentrations close to emission sources (within 50 km), and it can simulate the effects of air flowing over or around

⁷ The October 2015 study plan proposed to use the maximum measured vertical velocity from unpublished laboratory experiments conducted by SCS Engineers (SCS 2014). The maximum measured velocity from these experiments is an upper bound value that is not applicable to real-world operations, and would not be sustainable since there is not enough air volume in deposited solid waste to generate such a gas velocity.

⁸ AERMOD Version 14134 was the version available when the PADEP permit, which included the requirement to conduct a study, was issued.

hills, among other capabilities. The model was used to calculate short-term (1-hour average) and long-term (annual average) concentrations at receptor locations across the Florence-Roebling area.

An overview of the AERMOD modeling is presented below, and additional information is provided in Appendix E. For purposes of this study, a 50 meter spaced Cartesian receptor grid⁹ was placed in the Florence-Roebling area extending from the Delaware River to I-276 to the south and US-130 to the southeast. This produced a grid of 3,164 receptor points at which air concentrations were calculated. A five year record of 43,824 hours of pre-processed meteorological data (January 1, 2010 to December 31, 2014) was used for the AERMOD modeling. Surface weather data were obtained from the Philadelphia Airport meteorological station and upper air data were obtained from the National Weather Service Sterling, VA station. Based on guidance for determining the urban/rural characterization of a source in USEPA's Guideline on Air Quality Models (USEPA 2005b), the area was characterized as urban for the AERMOD modeling.

The landfill source areas, based on the different cover types, were input into AERMOD. The covered area sources closely approximated the June 2015 landfill layout shown in Figure 3 with the exception of the final geomembrane cover which was split into three sections to allow AERMOD to process the data in a timely manner. The working face area was assumed to be 200 feet by 250 feet consistent with typical landfill operations and was placed centrally within the daily cover area. As noted earlier, because of their varying locations, configurations and durations, temporary situations such as the installation of gas piping systems and gas collection wells were not modeled.

The time periods of potential emissions were also input into AERMOD. Emissions from covered landfill areas were assumed to occur 24 hours per day, every day. Emissions from the working face were conservatively assumed to occur from 5 AM-8 PM, Monday through Saturday, assuming operations from 5 AM-6 PM plus an added two hours at the end of each day to accommodate placement of compacted daily cover over the working face area. This timeframe for potential emissions from the working face is expected to overestimate potential air impacts because operating hours on Saturdays were reduced to 7 AM-2 PM in May 2015 and, in the future, the closing time will be further reduced to 1 PM.

The air dispersion modeling took into account terrain elevations in the TRRF vicinity and the elevation of the potential emission sources on site. The terrain data were obtained from the U.S. Geological Survey (USGS) National Geospatial Program 3D Elevation Program. The elevation input into AERMOD for each modeled potential emission source area was 115 feet above mean sea level (MSL). This elevation was selected as a conservative approximate midpoint between the base of the landfill and the landfill apex at approximately 230 feet MSL. Wind blowing over the landfill creates updrafts carrying emissions from lower sections of the landfill to upper areas. Since the vast majority of the landfill at lower elevations is capped final,

⁹ A Cartesian receptor grid is a rectangular area in which receptors are identified by their x (east-west) and y (north-south) coordinates. In this study, the grid had a uniform 50-meter grid spacing (i.e., modeled receptor locations were 50 meters apart from one another).

the quantity of emissions from these areas would be smaller relative to other areas. Emissions from the landfill upper elevations would have a higher buoyancy and lessen downwind concentrations. Therefore, a midpoint elevation was selected as being a representative source height.

3.3.2 Model Output

A methane emission rate of 0.001 g/m²-sec was input into AERMOD for each covered landfill area. For the working face area, a unit emission rate of 0.001 g/m²-sec was also input to AERMOD. The model output at each receptor was thus calculated in units of µg/m³ per 0.001 g/m²-sec.

3.3.3 Calculation of Chemical-Specific Ambient Air Concentrations

Two types of ambient air concentrations were calculated to evaluate the potential for odors and public health risks: short-term 1-hour average concentrations in order to assess the potential for acute short-term health risks and odors and long-term annual average air concentrations in order to assess the potential for chronic long-term health risks.

3.3.3.1 Covered Landfill Areas

The chemical-specific ambient air concentrations associated with potential emissions from covered landfill areas were calculated by post-processing the AERMOD output and relating it to the fractional percentage of each selected compound relative to methane. The AERMOD modeling results based on CALMIM methane emissions with oxidation were used to calculate air concentrations for volatile organic compounds (VOCs). The CALMIM results for methane emissions without oxidation were used to calculate air concentrations for sulfur compounds.

The general post-processing calculation is shown below:

$$Ca_c = Ca_{\text{methane}} * C_{\text{ifg}} / \text{methane}_{\text{ifg}}$$

where

- Ca_c = Chemical-specific concentration in ambient air (µg/m³)
- Ca_{methane} = Methane concentration in ambient air from AERMOD modeling (µg/m³)
- C_{ifg} = Concentration of chemical in raw landfill gas (µg/m³)
- $\text{methane}_{\text{ifg}}$ = Arithmetic average methane concentration in raw landfill gas (µg/m³)

and

$$Ca_{\text{methane}} = [Ca_{(0.001)\text{methane}} / 0.001] * ER_{\text{methane}}$$

where

- $Ca_{(0.001)\text{methane}}$ = Methane ambient air concentration, 1-hour average or annual average, for a 0.001 g/m² sec emission rate (µg/m³ per 0.001 g/m²-sec)
- ER_{methane} = Methane emission rate (g/m²-sec)

A simple ratio approach (i.e., $C_{ifg}/\text{methane}_{ifg}$ as described above), based solely on the ratio of compounds in raw landfill gas to methane in landfill gas is considered likely to overestimate air concentrations for volatile organic compounds (Saquing et al. 2014).

The landfill gas concentrations (i.e., C_{ifg}) used to calculate chemical-specific air concentrations differed depending on the averaging time of the AERMOD modeling result. Short-term 1-hour average air concentrations were calculated using the maximum landfill gas concentration for each selected compound. Annual average air concentrations were, where possible, calculated using the 95% UCL average of the landfill gas concentrations using USEPA's ProUCL5 software (USEPA 2013 a,b). USEPA notes that, because of the uncertainty associated with estimating the true concentration based on a set of data, the 95% UCL of the average should be used when evaluating chronic long-term risks. The UCL is intended to account for uncertainties due to limited sampling data and provide reasonable confidence that the true average will not be underestimated (USEPA 1992a). Calculation of a 95% UCL using ProUCL5 is challenging for small datasets, such as in this case where no more than four samples were available. Although alternative approaches for very small data sets have been proposed (ITRC 2012), for consistency with the PADEP-approved study plan the following data evaluation method was used to calculate landfill gas concentrations for the prediction of annual average air concentrations: USEPA's ProUCL5 was used to calculate a 95% UCL where possible; in cases where a compound was not detected in a landfill gas sample, the concentration of that sample was evaluated at one-half of the detection limit; if one-half of the detection limit for a compound in a given sample was higher than the maximum detected concentration for that compound, the sample was not included in the ProUCL5 analysis; and maximum detected concentrations were selected for use if ProUCL5 could not calculate a 95% UCL or if the 95% UCL was higher than the maximum detected concentration. Following this method, ProUCL5 was able to recommend 95% UCLs for 10 of the 35 selected landfill gas compounds. For the other landfill gas compounds, the maximum detected concentration was used to calculate annual average air concentrations. Table 1 lists the 95% UCL concentrations that were calculated using ProUCL5.

3.3.3.2 Working Face Area

The chemical-specific ambient air concentrations associated with potential emissions from the working face were calculated by multiplying the AERMOD output (in units of $\mu\text{g}/\text{m}^3$ per $0.001 \text{ g}/\text{m}^2\text{-sec}$) by the emission rates calculated from the working face gas sampling program (in units of $\text{g}/\text{m}^2\text{-sec}$), as shown below:

$$C_{ac} = C_{a_{\text{unitized}}} * ER_c / 0.001$$

where

- C_{ac} = Chemical-specific concentration in ambient air ($\mu\text{g}/\text{m}^3$)
- $C_{a_{\text{unitized}}}$ = Unitized AERMOD output concentration, 1-hour average or annual average, for a $1 \text{ g}/\text{m}^2\text{-sec}$ emission rate ($\mu\text{g}/\text{m}^3$ per $0.001 \text{ g}/\text{m}^2\text{-sec}$)
- ER_c = Chemical emission rate from the working face ($\text{g}/\text{m}^2\text{-sec}$) (see Table 5)

3.3.4 Calculation of Five-Minute Average Air Concentrations

The potential for odors was evaluated by comparison to not only 1-hour average ambient air concentrations, but also 5-minute average concentrations because odors may be noticeable on a shorter time scale than one hour. The original study plan did not include this evaluation, but it was added to more fully address the potential for odors and to be consistent with New Jersey Department of Environmental Protection guidance (NJDEP 2009).

The conversion to a 5-minute average concentration was performed according to the following formula:

$$Ca_s = Ca_k \left(\frac{t_k}{t_s} \right)^p$$

where

Ca_s	=	5-Minute average chemical-specific concentration in ambient air ($\mu\text{g}/\text{m}^3$)
Ca_k	=	1-hour average chemical-specific concentration in ambient air ($\mu\text{g}/\text{m}^3$)
p	=	Power exponent
t_k	=	60 minutes (minutes in 1 hour)
t_s	=	5 minutes

The power exponent was obtained from a study conducted by Best et al. (2000) which recommends a value of 0.13 for an area source (such as a landfill) over a several minute to several hour time regime. The net scaling factor (i.e. $(60/5)^{0.13}$) was calculated to be 1.4.

3.4 Compilation of Health-Based Comparison Values (CVs) and Odor Thresholds

3.4.1 Health-Based Comparison Values

The potential for public health risks was evaluated by comparing health-based comparison values (CVs) for the inhalation pathway of exposure to the modeled air concentrations. CVs represent concentrations of compounds in air that are considered to be protective of public health. They are developed by regulatory agencies and public health scientists based on scientific information about the toxicity of chemical substances. When these values are derived, safety factors are generally incorporated to ensure that they are protective of human health.

If a compound's air concentration is lower than its CV, adverse effects are not expected to occur. If a compound's air concentration exceeds its CV, this does not mean that adverse effects will occur among exposed populations because of the conservative assumptions included in both the derivation of the CV and the calculation of air concentrations. Rather it indicates a need for further investigation to help determine whether or not its level in air presents a public health concern.

The sections below summarize the two types of CVs, chronic and acute, that were compiled for this study. Appendix F provides additional information about the CVs and the sources from which they were obtained.

3.4.1.1 Chronic CVs

The potential for long-term chronic health risks resulting from long-term exposures over several years or more can be evaluated using chronic CVs. The chronic CVs in this study were obtained from USEPA's Regional Screening Level (RSL) table which provides health-protective residential air concentrations, referred to as RSLs, for potential long-term inhalation exposure to chemical compounds in air.¹⁰ RSLs are developed by USEPA specifically to perform preliminary screening of chemical concentrations at a site. The hierarchy of data sources used by USEPA is consistent with PADEP's recommended hierarchy (PADEP 2013).

USEPA compiles RSLs for two different types of health effects that can potentially be caused by chronic long-term exposure to chemical compounds -- non-cancer hazards and cancer risks. Non-cancer hazards represent the potential for developing health effects other than cancer. Cancer risks represent the probability that an individual could contract cancer under a set of assumed conditions of chemical exposure, over and above the existing background for developing cancer. The consideration of both types of health effects follows standard USEPA methods for evaluating potential public health risks.

The chronic RSLs compiled for the evaluated compounds are provided in Table 6. The non-cancer RSLs were based on conservative air concentrations set at a level 10 times lower than the typical PADEP and USEPA benchmark used for non-cancer hazards. The cancer risk-based RSLs were also based on a conservative benchmark corresponding to an excess lifetime cancer risk of 1E-06 (one in one million). An excess lifetime cancer risk of 1E-06 represents a chance of one in one million that an individual would develop cancer over a lifetime under the assumed conditions of exposure, above the existing background for developing cancer.¹¹ The 1E-06 cancer risk level is 100 times more conservative (i.e., health protective) than the benchmark risk level of 1E-04 (one in 10,000) generally relied upon by PADEP (PADEP 2013). If RSL air concentrations were available for both non-cancer health effects and cancer risks, the lowest one was used in this study.

3.4.1.2 Acute CVs

The potential for short-term acute inhalation health risks was evaluated using acute CVs. Regulatory agencies and public health scientists develop acute CVs based on animal and human studies that have investigated the health effects that could potentially occur as a result of short inhalation exposures to chemical substances in air. As with chronic CVs, these values generally incorporate safety factors to ensure that they are protective of human health. The acute CVs used in this study were derived for potential short-term, 1-hour exposures to chemical concentrations in air.

¹⁰ USEPA's Risk-Based Screening levels are available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/.

¹¹ In the US, roughly one of every two men and one of every three women will contract cancer over a lifetime. These statistics would translate to probabilities of 0.50 for men and 0.33 for women over a lifetime.

Following the PADEP-approved study plan, several sources were consulted to identify acute CVs (see Appendix F for additional information). These included: acute Reference Exposure Levels (RELs) set by the California Environmental Protection Agency (CALEPA); Acute Exposure Guideline Levels (AEGs) set by USEPA's National Advisory Committee for the Development of Acute Exposure Guideline Levels for Hazardous Substances; Emergency Response Planning Guidelines (ERPGs) set by the American Industrial Hygiene Association; and Temporary Emergency Exposure Limits (TEELs) set by the Department of Energy's Office of Emergency Management. The acute CVs generally reflect concentrations in air at or below which adverse short-term health effects are not anticipated to occur. Table 7 provides the acute CVs used in this study.

3.4.2 Odor Thresholds

The potential for odors to be detected by a hypothetical individual in the Florence-Roebling area was also evaluated. This was accomplished by comparing the calculated short-term air concentrations in Florence-Roebling to odor thresholds.

3.4.2.1 Perception of Odors

Odors are pervasive in modern life and it is not unusual for odors to elicit complaints (Schiffman and Williams 2005). In order to understand the scientific basis of odor perception and why a potential source, such as a landfill, may result in objectionable odors among some people but not among others, it is necessary to introduce the physiological and psychological basis of odor perception and to define some basic terms in odor science. An odor is a sensation that results when olfactory receptors in the nose are stimulated by a particular substance in air. The substance is often known as an odorant. Olfaction is the sense of smell and the term odor perception is used to describe the ability to become aware of an odor.

Perceptions of odor are known to be extremely variable because they are affected by numerous biological and subjective psychological factors. Scientific studies have clearly documented that biological factors such as personal genetics, age, medical conditions and medications can affect a person's ability to detect odors. Equally important are subjective factors including pre-existing attitudes, beliefs, personal historical experiences, media reports about odors, social media interactions and whether a potential source of odors, such as a landfill, is visible (Greenberg et al. 2013, Herz et al. 2004, Chen and Dalton 2005, Nordin et al. 2013, Larsson et al. 2000).

Physiologically, odors are caused by a complex series of steps each of which can vary substantially from person to person. In general, these steps involve the interaction of odorants (chemical substances) with odor receptors in the nose which send signals through the olfactory nerve to the brain. The signals in the brain are then interpreted to represent a perception of odors. This transformation of an odorant in air into a perceived odor can be further broken down into smaller steps: 1) whether the odorant is available to be inhaled; 2) whether the odorant can reach odor receptors in the nose (odor receptors are located in an area about the size of a postage stamp in the back of the nasal passages); 3) whether the genetic makeup of odor receptors allows the odorant to bind to a receptor; 4) whether the odorant reaches the

odor receptor as the original chemical compound or whether it is metabolized into a different compound; 5) whether the individual is capable of detecting that odor; and 6) whether the individual perceives other attributes of the odor (e.g., pleasant or unpleasant). The perception of odor is not just affected by olfactory nerve signals, but also by signals sent to the brain through the trigeminal nerve (which may convey perceptions of irritation or pungency) and the optic nerve (which may process visual signals) (Brand 2006). These steps for odor perception can vary and change depending on a person's age, health status, use of medications, gender, occupation, and alcohol and smoking behaviors (Greenberg et al. 2013).

In addition to the physiology of odor perception, there are major psychological factors that affect the brain's interpretation of odor signals. A person's perception of odor, and its pleasantness or unpleasantness, is influenced by learning, remembering and emotional associations, and it can change over time (Herz et al. 2004, Dalton et al. 1997). For example, Dalton et al. (1997) report the results of a significant experiment that evaluated the impact of cognitive bias on odor perception. In this experiment, a large group of people was divided into several subgroups that were given information about the nature of an odorant to which they would be exposed. One of the subgroups was given positive information that they were to be exposed to a natural substance that was used in aromatherapy and thought to have positive impacts on mood and health. Another subgroup was told that they were to be exposed to an industrial solvent that purportedly caused health and cognitive problems following long-term exposure. A third group was simply told that they were to be exposed to standard odorants used in research. The groups were then all exposed to acetone, an odorant commonly found in consumer products (and in landfill gas). Subjects who were given a positive characterization of the exposure reported significantly less odor and irritation than subjects given a negative or neutral bias. Similarly, a study by Nordin et al. (2013) compared odor perceptions among groups of people who were exposed to the same chemical (n-butanol) but were told it was either health-enhancing or hazardous. Among the people who were told the chemical was hazardous, the perceived odor was more unpleasant. The ramifications of these experiments are that people who receive information about an odor will experience it differently than people who receive different information. This type of effect can also occur in response to information available from communications media or other individuals.

The familiarity of an odor also results in differences in odor perception. Studies investigating this issue have found positive relationships between familiarity with an odor and perception of its intensity and its pleasantness or unpleasantness (hedonic tone). For example, in a study of people with different ethnicities (Japanese, Mexican and German nationals), Distel et al. (1999) found that perceptions of odor intensity and hedonic tone were correlated with the familiarity of the odorant. The perception of odor can even change by season, as observed in a study that showed perceptions of cinnamon odors to be more familiar and more pleasant during the Christmas season than during the summer (Seo et al. 2009). One significant ramification of this research is that people who have been exposed to odors for long periods of time may perceive them to be more intense than people who were only recently exposed to an odor.

3.4.2.2 Compilation of Odor Thresholds

This study focused on the odor detection threshold which is the lowest concentration of an odorant at which a person can detect the presence of an odor. Because of the large variability in odor perception among people, odor threshold concentrations can vary by orders of magnitude. This means that one person may be able to detect an odor at 1 µg/m³ while another may not be able to perceive the same odorant until the concentration is more than 1,000 µg/m³.

There are a number of other measurement terms related to odor perception besides the odor detection threshold that were not used in this study. These include: the odor recognition threshold (the concentration at which an individual actually recognizes the odorant); odor intensity (the perceived strength of an odor); odor character (the quality that distinguishes one odor from another using descriptors such as tar, leather, ammonia, fruity, musty, etc.); and hedonic tone (a subjective judgment of the pleasantness or unpleasantness of an odor).

Scientific studies are conducted to provide reliable measurements of odor detection thresholds and other odor terms. In experimental studies used to identify odor thresholds, odor panelists are presented with varying levels of chemical concentrations in a laboratory setting. Each panelist indicates when odors are detectable. The threshold is then identified from the combined panelist responses, for example based on the concentration at which 50% of the panelists were able to detect an odor. It should be noted that the level at which a population detects an odor is not necessarily the concentration at which people are motivated to complain or find the odor offensive. That usually occurs at higher odor concentrations.

For this study, odor detection thresholds were compiled for each selected compound from readily available experimental studies and secondary sources (USEPA 1992b, Amoores and Hautala 1983, Ruth 1986, Nagata 2004 and 3M 2013). Since there is no single odor threshold that can be applied to a population, and odor thresholds can vary over several orders of magnitude, potential odor impacts were evaluated by comparison to the geometric mean odor threshold concentrations. The USEPA has concluded that the geometric mean odor threshold concentration is the best estimate of the odor threshold (USEPA 1992b).¹² This study approach focuses on a person of typical, or average, odor sensitivity and the ability to detect an odor. Table 8 presents the odor threshold data for the evaluated compounds.

3.4.2.3 Assessment of Odors Using Chemical-Specific Odor Thresholds

To evaluate whether an odor may be detected, the concentration of a chemical in air can be divided by its odor detection threshold, producing a ratio:

$$CR_c = C_{ac} / OT_c$$

where

¹² The geometric mean is a type of average concentration calculated for data that tends to be very skewed (i.e., data which is lognormally distributed and spans orders of magnitude, such as odor thresholds and environmental concentrations).

CR_c	=	Ratio of concentration to odor threshold (unitless)
Ca_c	=	Chemical-specific concentration in ambient air ($\mu\text{g}/\text{m}^3$)
OT_c	=	Chemical-specific odor threshold ($\mu\text{g}/\text{m}^3$)

A ratio greater than one indicates that detectable odors from that compound may occur, although not necessarily at a high enough level to motivate someone to complain.

To address the fact that chemicals are present in the environment as mixtures, the chemical-specific ratios are also added together ($\sum CR_c$). The sum of chemical-specific ratios for a mixture can help predict the potential for detectable odors, and indicate which compounds are most likely to be associated with odors. This sum does not, however, reflect actual odor impacts. This is because odors associated with a mixture of compounds can differ from those estimated in experimental studies of individual compounds. The assumption of additivity may not reflect how chemicals interact in the environment when producing an odor, such as when one compound in a mixture can mask or reduce the odors associated with other compounds (Greenberg et al. 2013, Kim 2011). In addition, the summed ratio does not address other odor measurement terms such as odor character.

In the field of odor science, odors are typically assessed in units of dilution to threshold volume (D/T). The D/T ratio describes the number of dilutions of odor-free air needed to bring an odorous sample to its odor detection threshold. For example, an air concentration equal to its odor threshold has an odor concentration of 1 D/T. A concentration that is ten times higher than the odor threshold has an odor concentration of 10 D/T, indicating that the odorous sample would need to be diluted by 10 volumes of odor-free air to reach the odor threshold.

The chemical-specific ratios of concentration to odor threshold (CR_c and $\sum CR_c$) provide an approximation of D/T odor concentrations. Accordingly, in this study, these ratios are presented in units of D/T. The reader should keep in mind, however, that these D/T results are not actual odor concentrations in the Florence-Roebling area. Rather, they are chemical-specific calculations based on the conditions addressed in the modeling study. If the results of a modeling assessment such as this indicate a strong potential for odors, a follow-up evaluation should be conducted using direct odor measurements, such as odor emissions from the source in question (rather than chemical-specific emissions) and considering other odor information (such as odor character).

3.5 Comparison of Potential Ambient Air Concentrations to CVs and Odor Thresholds

The final step in the air modeling study was to compare the AERMOD modeling results to the chronic and acute CVs, and to the odor thresholds. Chronic CVs were compared to the modeled annual average air concentrations. Acute CVs were compared to the modeled 1-hour average air concentrations. Odor thresholds were compared to both the modeled 1-hour average concentrations as well as shorter-term 5-minute average concentrations.

Initially, the comparison of modeled ambient air concentrations to CVs and odor thresholds relied only on maximum air concentration results. The maximum concentrations were

calculated by adding together the maximum impact point results for potential emissions from covered landfill areas and the working face which were predicted to occur at two different locations (out of the 3,164 locations that were modeled). For example, the 1-hour average maximum impact locations were about 0.3 miles apart. Although it is not possible for maximum exposure to occur simultaneously at two different locations, these results were conservatively added together for the initial comparison to CVs and odor thresholds.

The chronic CVs were compared to the highest annual average concentrations predicted from among the 3,164 receptor grid locations modeled in the Florence-Roebling area based on the 5-year record of meteorological data input to the AERMOD model. The short-term CVs were compared to the single maximum 1-hour average concentration predicted from among the 43,824 1-hour average concentrations calculated at each of the 3,164 modeled receptor grid locations across the Florence-Roebling area.¹³ The odor thresholds were compared to the single maximum 1-hour average concentration and maximum 5-minute average concentration predicted from among the same 43,824 1-hour average concentrations calculated at each modeled receptor grid location. The concentrations at all other locations in the area were lower than these maximum values.

The comparisons of concentrations to CVs or odor thresholds indicate whether emissions from TRRF may potentially result in public health risks or detectable odors, respectively. If the modeled maximum concentrations do not exceed the CVs or odor thresholds, this indicates that potential landfill gas and working face emissions from the facility are not expected to result in adverse public health effects or to be detectable under the conditions evaluated, respectively. If, on the other hand, a maximum concentration exceeds a CV or odor threshold, this does not mean there is a health risk or odor of concern because of the conservative assumptions incorporated into this assessment. Rather, it means that further examination is needed to more fully evaluate the potential for public health risks or odors.

3.5.1 Potential Chronic Inhalation Health Risks

The potential for chronic health risks was evaluated by calculating the ratio of each compound's maximum annual average modeled concentration to its chronic CV, with ratios less than 1 indicating that adverse effects are not expected to occur.

The results of the chronic health risk evaluation showed that adverse health effects due to potential landfill gas and working face emissions are not expected in Florence-Roebling. As shown in Table 9, every ratio of air concentration to health-based CV was well below 1.

Since inhalation exposure could occur to a mixture of compounds, the sum of the ratios was also calculated separately for those compounds that may have non-cancer health effects and those that are potential carcinogens. Even these summed ratios were well below one indicating that adverse chronic health effects are not expected. The total ratio for non-cancer health effects across all evaluated compounds was 0.05. This means that the total ratio for all

¹³ A total of 43,824 hourly concentrations were calculated at each receptor grid point because 5 years of hourly meteorological data was input to AERMOD for the modeling.

the evaluated compounds combined in this study, regardless of the type of health effect, was more than 100 times lower than the benchmark used by PADEP to evaluate non-cancer hazards (PADEP 2013). The total ratio for all potential carcinogens was 0.001. This means that the total cancer risk for all evaluated compounds was 1,000 times less than one in one million (1E-06), since the CVs for potential carcinogens were based on a one in one million excess lifetime cancer risk. This cancer risk result is thousands of times lower than the risk benchmark considered to be acceptable by PADEP (PADEP 2013).

3.5.2 Potential Acute Inhalation Health Risks

The potential for acute health risks was evaluated by calculating the ratio of each compound's maximum 1-hour average concentration to its acute CV, with ratios less than 1 indicating that adverse effects are not expected to occur.

The results of the acute health risk evaluation showed that adverse acute inhalation health effects due to potential landfill gas and working face emissions are not expected in Florence-Roebling. Table 10 shows that every ratio of air concentration to the acute CV was well below 1. Additionally, the sum of the ratios across all evaluated compounds was 0.01. This result is 100 times lower than the levels at which potential acute inhalation health effects might be of concern.

3.5.3 Potential Odor Impacts

The potential for odors was evaluated by calculating ratios in units of D/T for each compound and summed across all compounds, with D/T values less than 1 indicating that detectable odors are not expected. The D/T ratios were based on the modeled 1-hour and 5-minute average concentrations and the geometric mean odor thresholds. As mentioned above, the D/T results do not reflect actual odor concentrations because potential chemical-specific emissions, rather than odor emissions, were modeled.

3.5.3.1 Odor Assessment Results

The results of the odor assessment, presented in Table 11, showed that odors are not expected to be detected by a person of average odor sensitivity. All of the chemical-specific concentration to geometric mean odor threshold ratios were less than 1 D/T by at least five times. When summed across all compounds, the total ratio was 0.3-0.4 D/T (based on maximum 1-hour average and maximum 5-minute average concentrations, respectively). The dominant contributors were reduced sulfur compounds, accounting for about 90% of the total D/T. For a highly odor sensitive person, transient odors might rarely be detected depending on landfill and weather conditions. For example, under worst-case meteorological conditions and maximum measured landfill gas concentrations, the maximum D/T ratio predicted at any location summed across all compounds for a five-year period is expected to be below 10 D/T; this concentration is lower than background odor levels in the Florence-Roebling area as described below. It should be kept in mind that this odor assessment was based on a constant landfill operating scenario reflecting the June 2015 landfill layout and December 2015 working face gas data and thus it did not address potential emissions and odors associated with

temporary and variable situations, such as installation of gas piping systems and gas collection wells.

The modeled D/T results may be put into some context by comparison to a few odor measurements which are available from the Florence-Roebling area. In May and June 2015, SCS collected six samples of ambient air at several locations when the wind was blowing both towards and away from the landfill. The samples were sent to an independent odor science laboratory to measure D/T and odor character (OSE 2016). Unlike the modeling study, these samples reflect total odor concentrations due to all local and regional sources in the area, rather than just the incremental impact from potential TRRF emissions. When the sampling locations were upwind of the landfill (i.e., winds were blowing from Florence-Roebling towards the landfill), the D/T was 15-16. When the sampling locations were downwind of the landfill, the D/T was 11-12. The odor character of the samples was slightly different. These data highlight the fact that there are background odors in Florence-Roebling, and that D/T may be higher when the area is upwind, rather than downwind, of the landfill.

3.5.3.2 Evaluation of Odor Investigation Methods

A variety of methods are available to investigate potential odors in the environment, providing different types of information with varying levels of complexity. These methods include air dispersion modeling of potential chemical emissions (conducted for this study), air dispersion modeling of potential odor emissions, odor complaint information, detailed odor diaries, periodic odor surveys (conducted at TRRF and in Florence-Roebling), measurement of chemical concentrations in air (conducted for hydrogen sulfide in this study), and measurement of odor concentrations in air.

Some odor investigation methods are objective and quantitative, such as air dispersion modeling and air monitoring. These methods rely on scientifically developed and validated mathematical models and detailed weather data, or sampling and analysis methods, approved by USEPA or other authorities. Other methods are subjective and qualitative, such as odor surveys, odor complaint data, and odor diaries, because they rely on a person's perception of odor without reference to an objective standard. As described earlier, perceptions of odor are known to be extremely variable because they are affected by numerous biological and psychological factors, such as personal genetics, age, medical conditions, pre-existing attitudes, personal beliefs and even social media influences (Greenberg et al. 2013, Herz et al. 2004, Chen and Dalton 2005, Nordin et al. 2013). This variability in odor perception results in odor threshold concentrations that can vary substantially across individuals. Results from odor surveys and diaries can also differ depending on whether the individual has been trained and qualified as a professional odor surveyor. Assessment of odors in the environment is further complicated depending on whether potential emission rates and emission source locations are constant or changing over time, and whether other odor sources are present locally or regionally. The existence of an odor background that is characteristic of the area, independent of the source in question, adds more complexity. This background concentration of odors can add to the perception of source-specific odors. In areas where the odor background concentration is similar to that associated with a specific source, which may be the case in

Florence (OSE 2016), what populations may perceive is a change in odor character that could be judged as offensive and not a change in concentration.

The odor assessment results calculated in this study should not automatically be expected to correspond to odor surveys. Differences in results from different odor investigation methods can occur for many reasons. Odor assessment results calculated using quantitative, objective methods, such as detailed air dispersion modeling, are unlikely to closely correspond to observations from qualitative, subjective odor investigation methods, such as periodic odor surveys, especially if they are not carefully matched to the same time period. As explained above, the significant differences in odor investigation methods, the unique and varying characteristics of potential emission sources, and the presence of other local or regional odor sources, all help explain this lack of correspondence. It is not surprising, then, that qualitative odor survey information from Florence-Roebling collected periodically in 2012-2014 and analyzed by SCS (2015) did not closely correlate with the quantitative modeling results for chemicals calculated in this report. Besides the fact that the odor surveys monitored odors whereas the modeling study evaluated chemical-specific information, other reasons for differences could stem from the assumed conditions addressed in this air modeling study. The landfill layout incorporated in the AERMOD modeling was based on the site's June 2015 configuration and the emission rates from the working face were based on measurements collected in December 2015. The modeled emission rates from covered landfill areas were based on 2011-2014 landfill gas data and are expected to reflect typical long-term operations. Temporary situations that could potentially result in different, short-term emissions were not modeled. For example, as mentioned earlier, the installation of gas piping systems and gas collection wells may temporarily expose underground areas containing landfill gas. There is a possibility that these activities could produce short-term emissions and potential odors depending on the extent and location of the work and weather conditions. During new well and pipe installation activities, however, TRRF uses odor control systems which minimize the potential for odor impacts. Once the work is completed, the new installations will ultimately result in enhanced odor control.

4.0 AIR MONITORING STUDY

Condition 45(B) in the permit specifies that "actual monitoring data" be collected "both at the landfill and in the surrounding communities". This section summarizes the results of actual ambient air monitoring conducted in the Florence-Roebling area and at the landfill from July 17 - October 20, 2015 and discusses the possibility of future monitoring based on the results of the air modeling analysis.

4.1 Indicator Compound Selection

The initial step for the ambient air sampling program was to identify an indicator compound present in landfill gas that could be readily monitored for in ambient air. The indicator compound was identified based on an evaluation of raw landfill gas composition data relative to health-based criteria and odor thresholds. For this type of landfill study, the indicator should be able to meet all four of the following conditions: 1) consistently be detected in raw landfill gas, 2) be most likely to be of public health concern compared to other detected compounds in

landfill gas, 3) have a relatively low odor threshold compared to other compounds detected in raw landfill gas, and 4) have a reliable method available to monitor for low concentrations of the specific compound in ambient air. The landfill gas samples collected from 2011 through 2014 were examined to support selection of an indicator compound (see Table 1). For each of the 35 compounds that were detected at least once in the 2011-2014 data, human health criteria and odor threshold information (see Tables 6 through 8) were evaluated relative to the concentrations measured in the raw landfill gas samples. Based on this evaluation, hydrogen sulfide was identified as the most appropriate indicator compound for ambient air monitoring. This selection is consistent with findings at many other landfills where hydrogen sulfide is present at relatively higher concentrations in raw landfill gas compared to other compounds and may be a source of odor issues and public health concern (e.g., FDOH/ATSDR 2015). Additionally, hydrogen sulfide can be readily measured using a sensitive and accurate handheld monitor called the Jerome 631-X Hydrogen Sulfide Analyzer (Arizona Instrument 2014). The Jerome meter has a very low detection limit of 3 parts per billion (ppb)¹⁴ and, because of its ease of use and sensitivity, it is often relied on to investigate potential emissions of hydrogen sulfide at landfills and its possible presence in ambient air (FDOH/ATSDR 2015).

4.2 Ambient Air Monitoring Program

The air monitoring program was conducted from July 17 - October 20, 2015 with air samples tested for hydrogen sulfide in both the Florence-Roebling area and very close to the landfill surface. Sampling was conducted daily from July 17 through September 4, 2015. Beginning September 8, sampling was conducted every other day, on weekdays, alternating between a Monday/ Wednesday/Friday and Tuesday/Thursday schedule.

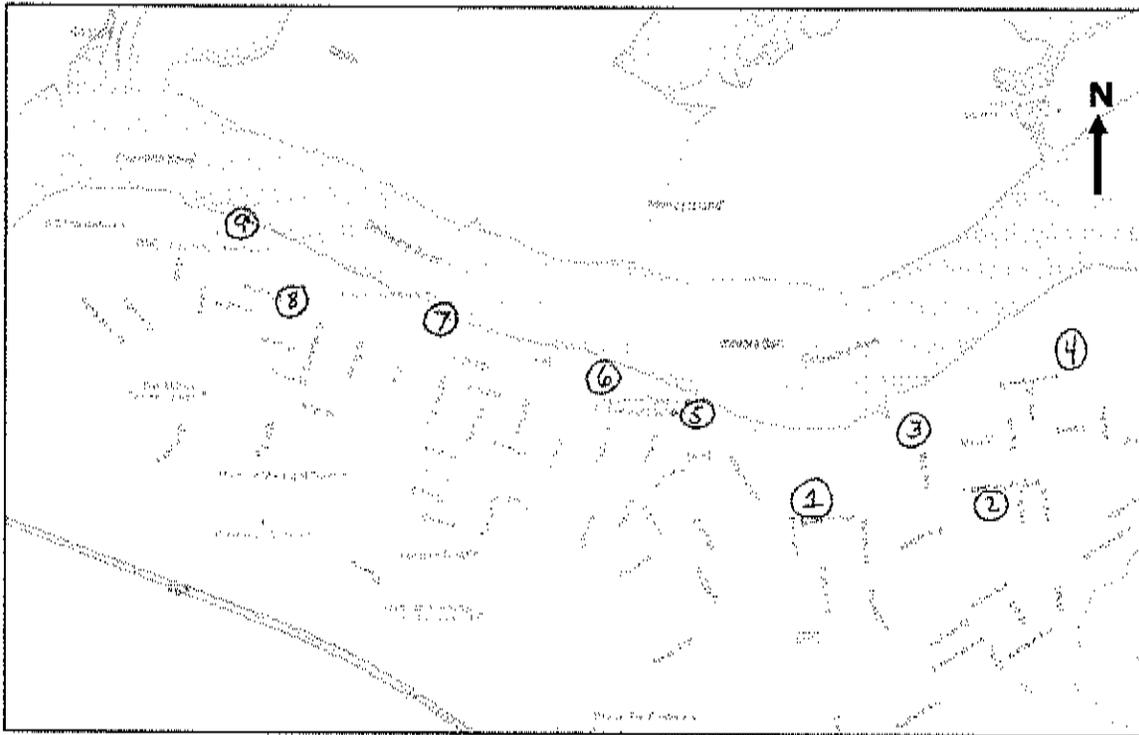
Hydrogen sulfide was measured at the on-site and off-site locations using the Jerome 631-X Hydrogen Sulfide Analyzer (see Appendix G). On-site samples were collected close to the landfill surface (within 4-6 inches) from three different cover type areas – the working face/active area, intermediate cover areas and final geomembrane cover areas (see Figure 3). Samples in the intermediate and final cover areas were usually collected in locations that were not expected to be influenced by active landfill gas capping or construction activities. In addition, samples were collected in the Florence-Roebling community, once or twice per day, at nine locations which are shown on Figure 5. These are the same locations visited for odor surveys that have been regularly conducted by WMPA since 2012 and which continue to be conducted almost every weekday. Community sampling was conducted mostly in the mornings when atmospheric conditions tend to be more stable, with samples collected between waist and chest height (i.e., representative of breathing zone for humans).

The Jerome meter monitoring was conducted by WMPA personnel trained to use the instrument and was performed in general accordance with the procedures specified in the manufacturer's operation manual (see Appendix G). During each monitoring event, the hydrogen sulfide readings from the Jerome meter, weather information and, as necessary, other observations, were documented. For example, wind and weather conditions prior to

¹⁴ For hydrogen sulfide, 3 ppb = 4.2 µg/m³.

sampling were noted based on meteorological data from the landfill's on-site weather station and weather stations in Florence.

Figure 5
Monitoring Locations in Florence-Roebing



Legend

Station Rd (site 1)	Roebing Elementary (site 2)	Main - Tenth (site 3)	Roebing Park (site 4)	E. Front - Oak (site 5)	Florence Sr. HS (site 6)	Florence Yacht (site 7)	Florence Elementary (site 8)	River Edge Park (site 9)
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4.2.1 Sampling Results in Florence-Roebing

A summary of the Jerome meter data collected in Florence-Roebing is shown in Table 12. Over the course of this air monitoring program, a total of 555 measurements for hydrogen sulfide were collected. Each of these measurements was categorized into one of the following groups based on concurrent wind conditions during each sampling event: 1) upwind, 2) downwind, 3) occasionally downwind, 4) neither upwind nor downwind, or 5) not applicable (e.g., calm conditions). Concurrent wind conditions were determined from the on-site landfill meteorological station which records wind direction, wind speed and a variety of additional weather parameters every five minutes. A sample was designated as upwind or downwind when most or all concurrent wind direction readings placed the sample location upwind or downwind of the landfill, respectively. A sample was designated as occasionally downwind when at least one, but not most concurrent wind direction readings placed the sample location downwind of the landfill. A sample was classified as neither upwind nor downwind when the

wind directions were "crosswind" of the landfill, i.e., winds were blowing roughly parallel to the landfill relative to the sample location. The not applicable designation was assigned when winds were calm or light and variable. The number of measurements in each group was 265 for upwind, 90 for downwind, 92 for occasionally downwind, 72 for neither upwind nor downwind, and 36 for not applicable.

Overall, hydrogen sulfide was not detected in most samples regardless of whether the sampling location was upwind, downwind or occasionally downwind of the landfill. In addition, the range of concentrations was essentially the same for the upwind, downwind or occasionally downwind samples. The range of concentrations was from <3-7 ppb for upwind samples, <3-6 ppb for downwind samples, and <3-6 ppb for occasionally downwind samples. Additionally, at some locations (sites 1 through 5), concentrations were detected more frequently when Florence-Roebling was upwind of TRRF (i.e., winds were blowing from Florence-Roebling towards the landfill). Hydrogen sulfide was not detected in any samples when the sampling location was neither upwind nor downwind, or unclassifiable due to light and variable winds. All of the measurements in Florence-Roebling were well below short-term hydrogen sulfide concentrations developed by regulatory and public health agencies to be protective of public health. Short-term health criteria developed by USEPA are 750 ppb (10-minute average), 600 ppb (30-minute average) and 510 ppb (1-hour average). The CALEPA 1-hour average reference exposure level is 30 ppb. PADEP's 1-hour average ambient air quality standard for hydrogen sulfide is 100 ppb. These health-based concentrations relate to averaging times ranging from 10 minutes to one hour, whereas the hydrogen sulfide concentrations measured by the Jerome 631-X instrument are 30-second measurements. All of the measured hydrogen sulfide concentrations were below the USEPA, CALEPA and PADEP health-based concentrations. There is also an added margin of safety for protection of public health because the measurements reflect 30-second averaging times, and they would be even lower if averaged over the longer time periods associated with the health-based criteria (e.g., one hour).

4.2.2 Sampling Results On Site

More than 200 samples of hydrogen sulfide were collected within a few inches of the landfill surface. The results of this sampling showed that hydrogen sulfide was detected fairly frequently within a few inches of the surface of the active/working face area (detected in 41 of 52 samples) and the intermediate cover areas (detected in 54 of 102 samples). Hydrogen sulfide was detected less frequently in the final cover area (detected in 16 of 52 samples). The range of concentrations was from <3-21 ppb in the active/working face area, with the highest concentrations occurring directly atop fresh waste, from <3-33 ppb in the intermediate cover areas, with the highest concentration measured near active capping work, and from <3-10 ppb in the final cover area.

All of the on-site hydrogen sulfide concentrations measured within just a few inches of the landfill surface were substantially below occupational standards and criteria that have been developed for protection of workers.¹⁵ The Occupational Safety and Health Administration (OSHA) enforceable workplace standards for hydrogen sulfide include a ceiling limit of 20,000

¹⁵ Concentrations in the breathing zone (e.g., at roughly 5-6 feet) would be lower than levels measured within a few inches of the landfill surface.

ppb (15-minute average) and a not-to-exceed peak limit of 50,000 ppb. Guidelines for protection of workers have also been set at 10,000 ppb (10-minute ceiling) by the National Institute for Occupational Safety and Health (NIOSH) and at 5,000 ppb (15-minute average) and 1,000 ppb (8-hour average) by the American Conference of Governmental Industrial Hygienists (ACGIH). Even the highest concentrations measured on site were more than 150 – 1,500 times lower than short-term occupational standards and guidelines. Moreover, all of the on-site concentrations were below health-based levels developed for protection of public health except for one value (at 33 ppb) that was barely above the most restrictive level developed by CALEPA (30 ppb).

4.2.3 Sampling Summary

The air sampling results show no consistent and discernable pattern of hydrogen sulfide concentrations in the Florence-Roebling area relative to wind direction that indicates a clear landfill-related impact. The concentrations in Florence-Roebling were similar regardless of whether the wind was blowing towards or from TRRF. Additionally, short-term hydrogen sulfide concentrations measured in air just above the landfill surface would be reduced significantly due to dispersion, oxidation, and dilution during transport from the landfill surface to the Florence-Roebling area (e.g., on the order of at least 100 to 1,000 or more times). This means, for example, that a concentration of 30 ppb measured in air within a few inches of the landfill surface would be reduced to less than 0.3 ppb by the time it reached the Florence-Roebling area (i.e., the incremental concentration due specifically to TRRF would not be detectable). This conclusion is supported by the air modeling results described earlier in this report. The maximum 1-hour average hydrogen sulfide concentration predicted in the Florence-Roebling area, which occurred only by combining the maximum concentration measured in TRRF landfill gas simultaneously with worst-case meteorological conditions, was 0.26 ppb (0.36 $\mu\text{g}/\text{m}^3$) and the maximum 5-minute average was 0.33 ppb (0.46 $\mu\text{g}/\text{m}^3$). These incremental concentrations reflect only potential emissions from TRRF (i.e., they do not include other possible emission sources in the area) and are well below both the measured ambient concentrations and the Jerome meter detection limit of 3 ppb.

After October 20, the sampling program was discontinued because the results showed that hydrogen sulfide levels in the community were well below health-based levels of concern, the detected concentrations directly above the landfill surface were at levels that would be unlikely to produce detectable levels in Florence-Roebling, and there was no consistent and discernable landfill-related impact on the measured concentrations in Florence-Roebling.

4.3 Future Ambient Monitoring

The available hydrogen sulfide sampling data suggest that potential incremental air impacts specifically associated with TRRF in the Florence-Roebling area are very difficult to detect using even advanced techniques. Due to the effects of dilution, dispersion and chemical reactions in air, potential air concentrations of emitted compounds measured just above the landfill surface, whether from covered landfill areas or from the working face, will generally be reduced

by at least 100 to 1,000 or more times during transport from the landfill to surrounding areas.¹⁶ Additionally, there are many facilities (e.g., wastewater treatment plants) and other activities (e.g., agriculture, vehicle emissions) that contribute to existing background levels of compounds and odors in air in the Florence-Roebling vicinity. Since ambient air monitoring measures the concentrations of compounds resulting from all local and regional emission sources combined, the ability to isolate the incremental impact of any one source, such as TRRF, can be almost impossible and extremely costly.

To determine whether additional ambient air monitoring may be warranted, potential air concentrations in Florence-Roebling associated specifically with TRRF emissions (i.e., calculated using the AERMOD model) versus the chronic and acute CVs and odor thresholds were considered. None of the evaluated compounds was predicted to be present in air in the Florence-Roebling area at levels above the CVs or the geometric mean odor thresholds.

The air dispersion modeling results were also evaluated relative to the detection limits achievable by standard monitoring methods. The compounds that dominated the study results, even though none exceeded health-based comparison values or geometric mean odor threshold levels, were reduced sulfur compounds (e.g., hydrogen sulfide, methyl mercaptan). The achievable detection limits for the sulfur compounds using standard methods range from 3 ppb (using a Jerome meter) to roughly 11 ppb (see lab report for sulfur compounds in Appendix C). These detection limits are higher than the maximum short-term modeled air concentrations in Florence-Roebling, indicating that the ambient air concentrations of reduced sulfur compounds attributed to potential TRRF emissions would not be detectable using standard analytical methods.

Additional targeted ambient air monitoring around TRRF is, therefore, not recommended. None of the evaluated compounds was predicted to be present in Florence-Roebling at levels above the CVs and geometric mean odor thresholds. The incremental sulfur compound air concentrations were predicted to be at levels that would not be detectable using standard monitoring and analytical methods. Additionally, potential emissions from the landfill will continue to decrease over time as the facility prepares for closure.

5.0 ODOR CONTROL PRODUCTS

5.1 Introduction

Condition 45(B) in PADEP's May 21, 2015 permit includes a requirement to evaluate air emissions related to "odor control chemicals emanating from the landfill and traveling to the Florence-Roebling areas." This condition was addressed by compiling and evaluating available information regarding the use of odor control products at the landfill and the potential for these products to be associated with off-site odors or health effects.

¹⁶ Potential ambient air concentrations in Florence-Roebling associated with TRRF landfill gas emissions are expected to be more than 100,000 to 1,000,000 times lower than raw landfill gas concentrations measured inside the landfill.

Odor control products are commonly used across the US and worldwide not only at MSW landfills but also at other types of facilities that can have odor issues. These products can combine and react with odorant molecules to reduce odors. Fragrances that may be present in a product can also help “mask” an unpleasant odor with a more pleasant odor. Most odor control products have an intrinsic odor, for example, because they contain fragrant essential oils which are typically extracts from naturally occurring plant material. Some examples of essential oils include lemon, lime, orange, eucalyptus, lemon grass, lavender and citronella.

There are hundreds of odor control products available from commercial suppliers in the US. The US Occupational Health and Safety Administration’s Hazard Communication Standard requires that information about each product be communicated in Safety Data Sheets (SDSs), previously referred to as Material Safety Data Sheets (MSDSs). The SDS includes information such as the physical and chemical properties of the product, and protective measures and safety precautions for handling, storage and transportation. It also includes information about health and environmental hazards, and how to respond effectively to potential exposure situations. In most cases, the detailed composition of a product is not listed on the SDS because it is a proprietary trade secret. The SDS forms are typically prepared by the manufacturer or importer of a product, or by technical consulting firms specializing in this work.

5.2 Odor Control Products

In accordance with the PADEP-approved study plan, this investigation focused on odor control products used at the landfill from June 2014 to September 2015, a time frame which encompasses the period in the summer and fall of 2014 when a number of odor complaints were reported and the site received and responded to a notice of violation from PADEP regarding odors. The receipt of biosolids at the landfill during the summer and fall of 2014 was determined to be the major contributor to odors observed in the Florence-Roebling area. In October 2014, the landfill implemented numerous measures to mitigate odors. These included significantly reducing the amount of biosolids accepted at the facility, reducing the overall amount of waste accepted, installing additional landfill gas extraction wells and capping systems, installing additional odor control devices including misting lines and vapor units, and otherwise reviewing and modifying odor controls used on site. In February 2015, the landfill placed a moratorium on the receipt of biosolids altogether and committed to no longer accepting biosolids for the remaining operational life of the landfill. Capping of additional landfill areas has occurred and will continue through the landfill’s closure in 2017.

5.2.1 Odor Control Products Used at the Landfill

As at other MSW landfills across North America, odor control products have been used at TRRF in various locations and at varying times in order to mitigate and prevent potential odor issues in surrounding areas. Factors that are taken into account when deciding on whether to use an odor control product include weather conditions, odor conditions on site, types of wastes received, and reports of odors in surrounding areas.

The odor control products used at the landfill between June 2014 and September 2015 were provided by two companies, BioTriad and Air Care. These products, which are listed in Table 13, are all commercially available and have been used at landfills in the US. In general, these

products can be divided into categories based on how they were used -- in misting lines, in vapor lines or individual vapor units, and for direct use on the working face. Products used in misting lines are water-based and suitable for above-freezing temperatures. They are diluted with water by at least 1,000 times and often by much more (e.g., 1,000 parts water to 1 part product is a 1000:1 dilution ratio). The misting lines are set at roughly 10 feet high and the diluted product is released via nozzles which are placed at intervals along the length of the line. Misting lines at TRRF have been used along the far northeast edge of the site, around the daily cover and intermediate cover areas and along the top of the ridge at the southern part of the site (see Figure 3). Products used in the vapor lines and vapor units are diluted with very large amounts of air and are suitable for below-freezing temperatures. Vapor lines are set at about 3 feet high and the diluted product is released from holes placed at intervals along the line. At TRRF, vapor lines have been used at the eastern edge of the daily cover area and at the far northeast edge of the site. Vapor units release product that has been diluted into air from nozzles set onto poles about 10 feet high. At TRRF, eight vapor units with two poles each have been used along the ridge at the southern part of the site. Direct use products are diluted with water and applied directly to the working face. As mentioned earlier, odor control products may be used in targeted misting or direct use applications during well and pipe installation activities. During the June 2014 to September 2015 period, the odor control products were used at varying times and locations (i.e., from none to no more than three products at a time).

5.2.2 Evaluation of Odor Control Products

For each odor control product used, SDS forms were obtained along with additional information provided by the vendor about the product. The SDS forms identify components in the product that are included in federal or state lists, such as the USEPA's Toxic Substances Control Act (TSCA) list of chemical compounds manufactured or processed in the United States, and lists of potentially toxic or harmful compounds identified in USEPA's Emergency Planning and Community Right-to-Know Act (EPCRA), the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Clean Air Act (USEPA 2015b, 2016). The TSCA list includes more than 67,000 substances, many of which are naturally occurring essential oils widely used in household and personal care products such as lemon, lime, grapefruit, pine and eucalyptus oils (USEPA 2016). In addition to the SDS forms, BioTriad's products were independently evaluated by Dell Tech Laboratories which confirmed that their products used at TRRF did not contain any components listed on nine regulatory lists.¹⁷

In accordance with the PADEP-approved study plan, identified components in the SDS forms were qualitatively evaluated for their potential to result in odors or health concerns in

¹⁷ Dell Tech confirmed that none of the components in BioTriad's odor control products were on the following lists: 1) List of Hazardous Air Pollutants from Section 112 of the Clean Air Act Amendments of 1990; 2) List of Priority Pollutants of the National Permit Discharge Elimination System (NPDES) Permit Regulations (40 CFR 122) from the EPA Office of Water; 3) Resource Conservation and Recovery Act materials List (includes F, K, P, U and D listings); 4) List of Extremely Hazardous Substances from Section 302 of the Superfund Amendments and Reauthorization Act of 1986 (SARA); 5) List of Toxic Chemicals from Section 313 of SARA; 6) List of Hazardous Substances from the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA); 7) List of Ozone Depleting Substances from Section 602 of the Clean Air Act; 8) List of Hazardous Substances under part 116 of the Federal Water Pollution Control Act (FWPCA); and 9) No component at a level subject to disclosure on the Hazardous Substance List of the Pennsylvania Right-To-Know List.

Florence-Roebling as a result of air emissions. Many of the identified components are used as fragrances, not only in odor control products but also in hundreds of household and personal care products. Examples include lemon, lime, lemongrass, pine, orange and eucalyptus oils. Due to the presence of fragrances in the products used at TRRF, odors associated with the odor control products could have been detected at times in the Florence-Roebling area depending on the location of use and weather conditions at the time of use.

The potential for public health risks resulting from air emissions of odor control products was evaluated by examining many different factors that collectively affect potential air concentrations that might occur in Florence-Roebling and the likelihood of health risks. For example, available health effects criteria for listed components on the SDS forms were identified from many different data sources.¹⁸ In addition, the concentrations in the products along with the amount of dilution of the odor control products with water or air before being released were considered. Dilution with water or air greatly reduces the concentrations of all components that may be present in an odor control product. The types and locations of use at TRRF were also considered, as these can affect the extent to which air emissions of odor control products may be transported to off-site locations. Additionally, the potential for dilution and dispersion between the landfill and the Florence-Roebling area was considered. The concentrations of odor control product components in ambient air at TRRF will be reduced during transport, by at least 100 to 1,000 or more times before reaching the Florence-Roebling area. Based on consideration of these factors, it was determined that adverse public health effects in Florence-Roebling would not be expected to occur as a result of odor control product air emissions at TRRF.

6.0 SUMMARY

6.1 Introduction

This study was conducted to address a requirement in a solid waste disposal renewal permit issued on May 21, 2015 to WMPA by PADEP for the Tullytown Resource Recovery Facility (TRRF) Landfill. Specifically, permit condition 45(B) required that a plan of study be prepared and implemented (after PADEP approval) "to evaluate air emissions related to landfill gas, working face odors and odor control chemicals emanating from the landfill and travelling to the Florence-Roebling areas on the prevailing winds." PADEP also requested that the study include collection of actual air monitoring data and an analysis of odor threshold and health risk levels.

This study was performed in accordance with a PADEP-approved plan. A draft plan of study was submitted to PADEP on August 19, 2015 and resubmitted on October 29, 2015 in response

¹⁸ Information sources consulted for health effects criteria included USEPA's Risk-Based Screening Levels (RSLs), USEPA's Acute Exposure Guideline Levels (AEGs), the American Industrial Hygiene Association's Emergency Response Planning Guidelines (ERPGs), Temporary Emergency Exposure Limits (TEELs) developed by the DOE Office of Emergency Management, CALEPA Reference Exposure Levels (RELs), risk assessments of household cleaning products by Human and Environmental Risk Assessment (HERA 2005, 2009), and screening-level inhalation toxicological thresholds of concern (TTCs) developed to assist in health risk evaluation of flavoring substances in cosmetics and consumer products (EU 2012, Costigan and Meredith 2015).

to PADEP comments. PADEP approved the revised study plan on November 13, 2015 with a few additional suggestions which were addressed in this report.

Three related investigations were conducted to address permit condition 45(B): an air modeling study to evaluate potential landfill gas and working face emissions; an air monitoring program both on site and in the Florence-Roebling area; and an evaluation of odor control products used at the landfill. Each investigation relied on methodologies developed by regulatory and public health agencies. Collectively, these investigations allow for an assessment of the potential for public health risks and odors associated with TRRF in Florence-Roebling.

Three independent environmental consulting firms were engaged by WMPA to conduct this study: CPF Associates, Inc., Environmental Information Logistics, LLC (EIL) and SCS Engineers. This multidisciplinary team of scientists has decades of experience investigating and evaluating potential impacts associated with waste management issues.

6.2 Air Modeling Study

The air modeling study evaluated the potential for public health risks and odors to a hypothetical individual in the Florence-Roebling area. The hypothetical individual was assumed to be exposed to emissions transported through the air from TRRF (from landfill gas and working face sources) towards the Florence-Roebling area. The modeling was performed using a USEPA-approved scientifically developed and validated mathematical model with five years of detailed weather data. The modeling was based on the landfill's June 2015 layout, landfill gas measurements from 2011-2014 and working face gas measurements collected in December 2015. A total of 47 chemical compounds detected in landfill gas and working face gas were assessed.

This evaluation does not reflect actual individual exposures or risks to residents. Rather, the modeling study was biased toward health protectiveness and thus is expected to overestimate potential ambient air concentrations, odors and potential risks by using conservative assumptions.

6.2.1 Health Risk Assessment

The potential for chronic long-term public health risks was evaluated for both non-cancer health effects and cancer risk. Acute short-term health risks associated with short-term inhalation exposures were also addressed. These assessments relied on the mathematically modeled chemical concentrations in air and health-based air concentrations considered to be protective of public health by USEPA and PADEP.

The results of the chronic health risk evaluation showed that no adverse health effects due to potential landfill gas and working face emissions are expected in Florence-Roebling. The modeled ambient air concentrations were more than 100 times below regulatory criteria used by PADEP and USEPA for protection of public health.

The results of the acute health risk evaluation showed that adverse short-term inhalation health effects due to potential landfill gas and working face emissions are not expected in Florence-Roebling. The modeled short-term ambient air concentrations were 100 or more times lower than short-term health-protective levels identified by regulatory and public health agencies.

6.2.2 Odor Assessment

The potential for odors to be detected by a hypothetical individual in the Florence-Roebling area was also evaluated. This assessment relied on the mathematically modeled chemical concentrations in air and chemical-specific odor thresholds.

The evaluation showed that odors are not expected to be detected by a person of typical odor sensitivity under the conditions modeled in this study. However, transient odors could be detected at times by a highly sensitive individual depending on landfill and weather conditions.

The results of this assessment, which relied on quantitative, scientifically-based methods, should not be expected to closely correspond to observations from qualitative, subjective odor investigation methods, such as periodic odor surveys, especially if the studies are not carefully matched to the same time period. Differences in results from the many methods that can be used to investigate potential odors in the environment are likely to occur, particularly when based on odor surveys which rely on subjective perceptions of odor and provide qualitative results. Perceptions of odor are known to be extremely variable because they are affected by numerous biological and psychological factors, such as personal genetics, age, medical conditions, pre-existing attitudes and personal beliefs.

6.3 Air Monitoring Program

An air monitoring program was conducted in Florence-Roebling and at the landfill from July 17 - October 20, 2015. Air samples were tested for hydrogen sulfide at nine locations in Florence-Roebling and at several locations very close to the landfill surface. Hydrogen sulfide was selected as a representative landfill indicator compound because of its presence in landfill gas, its low odor thresholds and health effects criteria, and because it has a reliable and straightforward method for monitoring low concentrations in air.

A total of 555 air measurements for hydrogen sulfide were collected in Florence-Roebling and all were well below levels considered to be protective of public health by USEPA and PADEP. There was no consistent and discernable pattern of hydrogen sulfide concentrations in the Florence-Roebling area relative to wind direction that indicates a clear landfill-related impact. Hydrogen sulfide was not detected in most samples regardless of whether the sampling location was upwind, downwind or occasionally downwind of the landfill. The concentrations in Florence-Roebling were also similar regardless of whether the wind was blowing towards or from TRRF.

More than 200 samples of hydrogen sulfide were collected on site, in the air very close to the landfill surface, and all were substantially below occupational standards and criteria that have

been developed for protection of workers. All of the on-site concentrations were also below health-based levels developed for protection of public health except for one measurement which was barely above the most restrictive public health-protection level developed by CALEPA. Concentrations measured in the air within a few inches of the landfill surface would be reduced by at least 100 to more than 1,000 times during transport to the Florence-Roebling area because of the effects of dispersion, oxidation, and dilution. As a result, hydrogen sulfide due specifically to TRRF would not be expected to be measurable.

Additional targeted ambient air monitoring around TRRF is not recommended for several reasons. None of the evaluated compounds was predicted to be present in Florence-Roebling at levels above the CVs and geometric mean odor thresholds. The incremental sulfur compound air concentrations were predicted to be at levels that would not be detectable using standard monitoring and analytical methods. Additionally, potential emissions from the landfill will continue to decrease over time as the facility prepares for closure.

6.4 Odor Control Products

The potential for public health risks and odors in Florence-Roebling from air emissions related to odor control product use at the landfill was also qualitatively evaluated. In accordance with the PADEP-approved study plan, this evaluation focused on odor control products used at the landfill from June 2014 to September 2015.

Odor control products are commonly used across the US and worldwide not only at MSW landfills but also at other types of facilities that can have odor issues. At TRRF, these products have been used in various locations and at varying times in order to mitigate and prevent potential odor issues in surrounding areas. Factors that are taken into account when deciding on whether to use an odor control product include weather conditions, odor conditions on site, types of wastes received, and reports of odors in surrounding areas.

This evaluation relied on information describing the components present in each product, and the methods and locations of odor control product application at the landfill. During the time period of focus, these products were used at the site in misting lines, in vapor lines or individual vapor units, and for direct use on the working face.

Many of the identified components are used as fragrances, not only in odor control products but also in hundreds of household and personal care products. Examples include lemon, lime, lemongrass, pine, orange and eucalyptus oils. Due to the presence of fragrances in the products used at TRRF, odors associated with the odor control products could have been detected at times in the Florence-Roebling area depending on the location of use and weather conditions at the time of use.

The potential for public health risks resulting from air emissions of odor control products was evaluated by examining many different factors that collectively affect potential air concentrations that might occur in Florence-Roebling and the likelihood of health risks. These factors included the amounts of components in the odor control products, available health effects criteria for these components, the dilution of odor control products with air or water

before use, the locations of use, and the dilution and dispersion that occurs as air travels away from an emissions source. Based on consideration of these factors, adverse public health effects would not have been expected to occur in Florence-Roebling as a result of odor control product use.

6.5 Conclusions

Based on the landfill conditions addressed, and air and emissions data collected at TRRF and at nine locations in Florence-Roebling, this study concludes that no adverse public health effects are expected in Florence-Roebling as a result of landfill gas and working face gas emissions, and odor control product use. The study also found that an individual in Florence-Roebling with typical odor sensitivity is not likely to detect landfill gas and working face gas odors. Fragrances associated with past odor control product use at the landfill may have been detected at times depending on landfill and weather conditions and on the odor sensitivity of an individual in the community.

Based on the results of the air modeling study and the monitoring program, additional air monitoring in Florence-Roebling is not recommended.

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TABLES

Table 1

Landfill Gas Concentrations Measured at the Tullytown Sanitary Landfill

Compound Name	Synonyms	CAS #	MW (g/mol)	Concentrations by Year of Sampling (ppb)				Maximum (ppb) (a)	Average (ppb) (b)	Maximum (ug/m3) (a,d)	Average (ug/m3) (b,d)	95% Upper Confidence Limit (ug/m3) (c)
				2011	2012 (s)	2013	2014					
1,1-Dichloroethane	Ethylene dichloride	75-34-3	98.96	< 170	35	< 170	< 400	35	NC	1.42E+02	NC	NA
1,2,4-Trimethylbenzene		95-63-6	120.20	1,300	900	760	1,900	1,900	1,130	9.34E+03	5.56E+03	NA
1,2-Dichloroethane	Ethylene dichloride	107-06-2	98.96	< 170	370	< 170	< 400	370	185	1.52E+03	7.42E+02	1.33E+03
1,3,5-Trimethylbenzene	Mesitylene	108-67-8	120.20	850	130	180	750	820	103	4.33E+03	2.88E+03	NA
1,4-Dichlorobenzene	p-Dichlorobenzene	106-46-7	147.00	660	30	< 170	< 400	680	254	4.02E+03	1.53E+03	3.98E+03
4-Ethyltoluene	1-Ethyl-4-Methylbenzene, p-Ethyltoluene	622-96-8	120.20	2,200	180	690	430	2,200	925	1.08E+04	4.55E+03	9.73E+03
4-Methyl-2-pentanone	(methyl isobutyl ketone) (MIBK)	108-10-1	100.16	1,700	980	1,300	1,100	1,900	1,298	7.37E+03	5.92E+03	7.04E+03
Acetone	2-Propanone	67-64-1	58.08	43,000	6,100	7,000	30,000	43,000	21,925	1.02E+05	5.11E+04	1.02E+05
Benzene		71-43-2	78.11	6,000	3,800	5,800	9,500	9,500	6,100	3.03E+04	2.01E+04	2.95E+04
Bromomethane	Methyl bromide	74-83-9	94.94	130	< 50	< 170	< 400	730	135	8.93E+02	5.24E+02	NA
Carbon disulfide		75-15-0	76.14	< 430	94	< 430	< 20,000	94	NC	2.03E+02	NC	NA
Chlorobenzene		108-90-7	112.56	< 170	68	< 170	< 400	68	NC	3.13E+02	NC	NA
Ch-1,1-Dichloroethane		196-59-2	96.94	< 170	260	< 170	< 400	260	NC	1.03E+03	NC	NA
Dichloromethane	Methylene chloride	75-09-2	84.93	< 170	380	< 170	750	750	325	2.61E+03	1.12E+03	2.42E+03
Dimethyl sulfide	Methyl sulfide	75-18-3	62.13	..	5,100	4,500	< 10,000	4,200	3,700	1.09E+04	9.40E+03	NA
Ethyl mercaptan	Ethanesithiol	75-08-1	62.14	..	740	670	< 40,000	740	705	1.88E+03	1.79E+03	NA
Ethylbenzene		100-41-4	106.17	5,800	2,100	4,500	5,900	5,800	4,900	7.52E+04	1.95E+04	NA
Ethyl acetate	Acetic ester	141-78-6	88.10	..	2,400	..	..	3,400	NC	8.65E+03	NC	NA
Freon 113 (CFC 113)	1,1,2-trichloro-1,1,2,2,2-hexafluoroethane	76-13-1	187.38	< 170	< 90	< 170	510	510	170	3.91E+03	1.35E+03	3.37E+03
Freon 12 (CFC 12)	Dichlorodifluoromethane	75-71-8	120.91	790	< 50	300	470	470	271	2.32E+03	1.34E+03	NA
Heptane	n-Heptane	142-82-5	100.21	..	1,700	..	..	1,300	NC	4.92E+03	NC	NA
Hexane	n-Hexane	110-54-3	86.18	..	590	..	..	590	NC	2.09E+03	NC	NA
Hydrogen sulfide		7783-06-4	34.08	..	31,000	71,000	120,000	110,000	74,000	1.67E+05	1.03E+05	NA
Isobutyl mercaptan		513-44-0	90.18	..	2,900	..	..	2,900	NC	1.07E+04	NC	NA

Table 1 (continued)

Landfill Gas Concentrations Measured at the Tullytown Sanitary Landfill

Compound Name	Synonyms	CAS #	MW (g/mol)	Concentrations by Year of Sampling (ppb)				Maximum (ppb) (e)	Average (ppb) (b)	Maximum (µg/m ³) (a,d)	Average (µg/m ³) (b,d)	95% Upper Confidence Limit (µg/m ³) (c)
				2011	2012 (c)	2013	2014					
Methyl ethyl ketone	2-Butanone	78-93-3	72.11	40,000	6,100	12,000	29,000	40,000	21,775	1.19E+05	6.42E+04	NA
Methyl mercaptan	Methanethiol	74-93-1	48.11	-	4,100	1,800	< 10,000	4,100	2,950	8.07E+03	5.80E+03	NA
Perchloroethylene	Tetrachloroethylene, tetrachloroethene	127-18-4	165.83	< 170	270	< 170	< 400	270	160	1.83E+03	1.09E+03	1.81E+03
Propanol, 2-	Isopropyl alcohol	67-63-0	60.10	-	6,700	-	-	6,700	NC	1.05E+04	NC	NA
Propyl mercaptan	1-Propanethiol	107-09-9	76.16	-	250	-	-	250	NC	7.79E+02	NC	NA
Styrene		100-42-5	104.15	490	< 50	< 170	< 400	490	200	2.09E+03	8.92E+02	1.89E+03
Tetrahydrofuran		104-98-6	72.11	-	1,300	-	-	1,300	NC	3.83E+03	NC	NA
Toluene	Methyl benzene	108-88-3	92.14	12,000	5,000	9,500	14,000	14,000	10,125	5.28E+04	3.82E+04	NA
Trichloroethylene	Trichloroethene	79-01-6	131.39	< 170	140	< 170	< 400	140	103	7.52E+02	5.54E+02	NA
Vinyl Chloride	Chloroethene	75-01-4	62.50	310	< 50	320	430	430	278	1.10E+03	7.06E+02	NA
Xylenes mixed, m,p		1330-20-7	106.17	13,000	4,800	8,900	18,100	18,100	8,825	5.69E+04	4.27E+04	NA
Xylenes mixed, m,p		1330-20-7	106.17	10,000	3,100	6,900	10,000	10,000	7,550	4.34E+04	3.28E+04	NA
Xylenes mixed, o		95-47-6	106.17	3,000	1,000	2,000	3,100	3,100	2,275	1.88E+04	9.88E+03	NA
Other Compounds												
Methane		16-04		50%	48%	45%	55%	55%	50%	3.28E+08	(average methane concentration)	

Notes:

All landfill gas samples were collected from the common header pipe.

- - - Compound was not analyzed for.

< = Compound was not detected in the sample; the listed value is the reported detection limit.

CAS # = Chemical Abstracts Service Number

MW = Molecular weight

NA = Not available. A 95% UCL could not be calculated. See note (e)

NC = Not calculated. Only one sample had a detected value and, if other sample results were available, all the other samples had detection limits > 1/2 maximum detected concentration.

ppb = Parts per billion by volume in air

µg/m³ = Micrograms per cubic meter of air

(a) Highest detected concentration from four annual landfill gas testing programs (2011 through 2014).

(b) Average of reported concentrations from four annual landfill gas testing programs (2011 through 2014). In accordance with the PADEP approved study plan, non-detected concentrations were evaluated at one-half of the sample reporting limit and non-detect results were not included in calculating the average if one-half of the reporting limit was higher than the maximum detected concentration.

(c) More compounds were analyzed for in 2012 because the landfill had to accept a substantial amount of Hurricane Sandy debris which was not typical for the landfill.

(d) Conversions: µg/m³ = ppb * MW / 24.45. For methane, 50% = 500,000 ppm and µg/m³ = ppm * MW / 24.45 = 1000 µg/m³.

(e) USEPA's ProUCL software was used to calculate 95th percent upper confidence limits (95% UCL) where possible (USEPA 2013 x.3). Landfill gas data evaluation methods compliant with the PADEP approved study plan and used in ProUCL are described in the text. For most compounds, sample sizes were too small and non-detected results too frequent for ProUCL to calculate 95% UCLs.

Table 2
Sampling and Analysis Methods for Working Face Gas

Compounds	Method
Sulfur compounds	ASTM Method D5504
Ammonia	NIOSH Method 6015
Terpenes	NIOSH Method 1552
Volatile organic compounds	USEPA TO-15
Alcohols	USEPA TO-15 (TICs) (a)

(a) TICs are tentatively identified compounds which can be detected by an analytical method even though the method was not specifically targeted for these compounds.

Table 3
Working Face Gas Sampling Results
(Only detected compounds are listed) (a)

Analysis Method and Compound	Sample #2-12-2-2015		Sample #3-12-2-2015	
	Concentration			
	$\mu\text{g}/\text{m}^3$	ppb	$\mu\text{g}/\text{m}^3$	ppb
D5504				
Carbonyl Sulfide	160	64	290	120
Methyl Mercaptan	59	30	65	33
Dimethyl Sulfide	240	95	260	100
Carbon Disulfide	110	35	130	41
Dimethyl Disulfide	150	40	150	38
TO-15				
Ethanol	100,000	54,000	67,000	36,000
Trichlorofluoromethane (CFC 11)	3,000	540	3,000	540
Ethyl Acetate	860,000	240,000	600,000	170,000
Toluene	3,000	810	2,500	650
n-Butyl Acetate	4,400	930	2,200	460
Tetrachloroethene (PERC)	2,500	380	ND	ND
TO-15 Tentatively Identified Compounds (TICs)				
Propane	18,000		16,000	
Isobutane	41,000		38,000	
n-Butane	39,000		34,000	
2-Methylbutane	23,000		22,000	
n-Pentane	16,000		14,000	
n-Propyl acetate	14,000		9,300	
Terpenes (NIOSH Method 1552)				
d-limonene		3900		5300

(a) See Appendix C for additional information about the working face sampling program and its results.

Table 4
CALMIM Modeled Potential Fugitive Methane Emission Rates

Cover Area	Potential Fugitive Methane Emission Rate (g/m ² -s)		Acres
	Without Oxidation	With Oxidation	
Geomembrane Final Cover Area 1	1.26E-07	2.56E-10	216.77
Geomembrane Final Cover Area 2			
Geomembrane Final Cover Area 3			
Clay Final Cover Area 1	1.61E-04	7.09E-07	17.98
Clay Final Cover Area 2			
Intermediate Cover Area 1 ^(a)	6.26E-06	6.16E-06	47.47
Intermediate Cover Area 2 ^(a)			
Intermediate Cover Area 3 ^(a)			
Temporary Geomembrane Cover Area 1 ^(a)	5.99E-10	0 ^(b)	14.52
Temporary Geomembrane Cover Area 2 ^(a)			
Daily Cover Area ^(a)	1.77E-05	1.61E-05	22.5
Total for entire landfill ^(c)	1.13E-05	2.09E-06	319.24

See Appendix D for additional information about the CALMIM modeling.

- (a) Site-specific below cover methane concentrations were used for these areas in the CALMIM model.
- (b) Oxidation of methane in cover materials can yield results, under certain circumstances, less than zero. The model includes a zero emission boundary condition that limits emissions to only positive values.
- (c) The emission rate across the entire landfill is a weighted average (weighted by the acreage of each landfill cover area type).

**Table 5
Potential Emission Rates from the Working Face**

Compound Name	Synonyms	CAS #	Working Face Gas Concentration (a,b)				Maximum Concentration (ug/m ³)	Potential Emission Rate (g/m ² -sec) (c)
			Sample 1		Sample 2			
			(ug/m ³)	(ppb)	(ug/m ³)	(ppb)		
2-Methyl butane	isopentane	78-78-4	23,000	7,794	22,000	7,455	23,000	1.5E-06
Butane	n-butane	106-97-8	39,000	16,407	34,000	14,303	39,000	2.5E-06
Butyl acetate, n-	Butyl ester acetic acid	123-86-4	4,400	930	2,200	460	4,400	2.8E-07
Carbon disulfide		75-15-0	110	35	130	41	130	8.3E-09
Carbonyl sulfide	carbon oxysulfide	463-58-1	160	64	290	120	290	1.9E-08
Dimethyl disulfide	methyl disulfide	624-92-0	150	40	150	38	150	9.6E-09
Dimethyl sulfide	methyl sulfide	75-18-3	240	95	260	100	260	1.7E-08
Ethanol	ethyl alcohol	64-17-5	100,000	54,000	67,000	36,000	100,000	6.4E-06
Ethyl acetate	Acetic ester	141-78-6	860,000	240,000	600,000	170,000	860,000	5.5E-05
Freon 11 (CFC 11)	trichlorofluoromethane, fluorotrichloromethane	75-69-4	3,000	540	3,000	540	3,000	1.9E-07
Isobutane	2-methyl-propane	75-28-5	41,000	17,248	38,000	15,986	41,000	2.6E-06
Limonene	d-limonene	138-86-3 / 5989-27-5	21,730	3,900	29,530	5,300	29,530	1.9E-06
Methyl mercaptan	methanethiol	74-93-1	59	30	65	33	65	4.2E-09
Pentane	n-pentane	109-66-0	16,000	5,422	14,000	4,744	16,000	1.0E-06
Perchloroethylene	tetrachloroethylene, tetrachloroethene	127-18-4	2,500	380	< 2,100	< 310	2,500	1.6E-07
Propane		74-98-6	18,000	9,980	16,000	8,871	18,000	1.2E-06
Propyl acetate	n-propyl acetate, propyl ester acetic acid	109-60-4	14,000	3,352	9,300	2,226	14,000	9.0E-07
Toluene	methyl benzene	108-88-3	3,000	810	2,500	650	3,000	1.9E-07

(a) Data were collected on December 2, 2015 by SCS Engineers.

(b) Conversions between ug/m³ and ppb were not needed for those compounds with data already reported in both sets of units in the laboratory reports (i.e., reduced sulfur compounds, volatile organic compounds). For the other compounds, conversions were as follows: ug/m³ = ppb * MW / 24.45, and ppb = ug/m³ * 24.45 / MW.

(c) Potential emission rate (g/m²-sec) = working face gas concentration (ug/m³) * vertical velocity of gas at the working face (m/sec) * g / 10⁶ ug, where working face gas concentrations were based on the maximum values from sampling conducted at TRRF on December 2, 2015 and vertical gas velocity was determined to be 6.4 x 10⁻⁵ m/sec based on typical compaction rates of municipal solid waste at a landfill working face and the resulting gaseous volume flow that results (See Appendix C).

Table 6
Chronic Long-Term Health-Based Comparison Values (CVs)

Landfill Gas Compounds				Chronic Long-Term Residential Risk-Based Air Screening Level (a)		
Compound Name	Synonyms	CAS #	MW (g/mol)	ug/m ³	ppm (b)	C or NC (c)
1,1-Dichloroethane	Ethylidene dichloride	75-34-3	98.96	1.8	0.00044	C
1,2,4-Trimethylbenzene		95-63-6	120.2	0.73	0.00015	NC
1,2-Dichloroethane	Ethylene dichloride	107-06-2	98.96	0.11	0.000027	C
1,3,5-Trimethylbenzene	mesitylene	108-67-8	120.2	--	--	
2-Methyl butane	isopentane	78-78-4	72.15	--	--	--
4-Ethyltoluene	1-Ethyl-4-Methylbenzene, p-ethyltoluene	622-96-8	120.2	--	--	
4-Methyl-2-pentanone	isopropylacetone, methyl isobutyl ketone (MIBK)	108-10-1	100.16	310	0.076	NC
Acetone	2-propanone	67-64-1	58.08	3200	1.3	NC
Benzene		71-43-2	78.11	0.36	0.00011	C
Bromomethane	Methyl bromide	74-83-9	94.94	0.52	0.00013	NC
Butane	n-butane	106-97-8	58.12	--	--	--
Butyl acetate, n-	butyl ester acetic acid	123-86-4	116.16	--	--	--
Carbon disulfide		75-15-0	76.143	73	0.023	NC
Carbonyl sulfide	carbon oxysulfide	463-58-1	60.076	10	0.0041	NC
Chlorobenzene		108-90-7	112.56	5.2	0.0011	NC
cis-1,2-Dichloroethene	Acetylene dichloride	156-59-2	96.94	6.0	0.0015	NC (d)
Dichlorobenzene - 1,4-Dichlorobenzene	1,4-Dichlorobenzene	p-106-46-7	147	0.26	0.000043	C
Dichloromethane	Methylene chloride	75-09-2	84.93	63	0.018	NC (e)
Dimethyl disulfide	methyl disulfide	624-92-0	94.19	--	--	--
Dimethyl sulfide	Methyl sulfide	75-18-3	62.13	--	--	--
Ethanol	ethyl alcohol	64-17-5	46.07	--	--	--
Ethyl acetate	Acetic ester	141-78-6	88.1	7.3	0.0020	NC
Ethyl mercaptan	Ethanethiol	75-08-1	62.14	--	--	--
Ethylbenzene		100-41-4	106.17	1.1	0.00025	C
Freon 11 (CFC 11)	trichlorofluoromethane, fluorotrichloromethane	75-69-4	137.37	--	--	--
Freon 113 (CFC 113)	1,1,2-trichlorotrifluoroethane	76-13-1	187.38	3100	0.40	NC
Freon 12 (CFC 12)	dichlorodifluoromethane	75-71-8	120.91	10	0.0020	NC
Heptane, n-		142-82-5	100.21	--	--	--
Hexane, n-		110-54-3	86.18	73	0.021	NC

Table 6
Chronic Long-Term Health-Based Comparison Values (CVs)

Landfill Gas Compounds				Chronic Long-Term Residential Risk-Based Air Screening Level (a)		
Compound Name	Synonyms	CAS #	MW (g/mol)	ug/m ³	ppm (b)	C or NC (c)
Hydrogen sulfide		7783-06-4	34.082	0.21	0.00015	NC
Isobutane	2-Methyl propane	75-28-5	58.12	--	--	--
Isobutyl mercaptan		513-44-0	90.18	--	--	--
Limonene	d-limonene	138-86-3	136.24	--	--	--
Methyl ethyl ketone	2-butanone	78-93-3	72.11	520	0.18	NC
Methyl mercaptan	methanethiol	74-93-1	48.11	--	--	--
Pentane, n-		109-66-0	72.15	100	0.034	NC
Perchloroethylene	Tetrachloroethylene, tetrachloroethene	127-18-4	165.83	4.2	0.0006	NC (e)
Propane		74-98-6	44.1	--	--	--
Propanol, 2-	Isopropyl alcohol	67-63-0	60.1	21	0.0085	NC
Propyl acetate	n-propyl acetate, propyl ester acetic acid	109-60-4	102.13	--	--	--
Propyl mercaptan, n-		107-03-9	76.16	--	--	--
Styrene		100-42-5	104.15	100	0.023	NC
Tetrahydrofuran		109-99-9	72.11	210	0.071	NC
Toluene	Methyl benzene	108-88-3	92.14	520	0.14	NC
Trichloroethylene	Trichloroethene	79-01-6	131.39	0.21	0.000039	NC
Vinyl Chloride	chloroethene	75-01-4	62.5	0.17	0.000067	C
Xylenes mixed, m+o+p		1330-20-7	106.17	10	0.002	NC
Xylenes mixed, m+p			106.17	10	0.002	NC
Xylenes mixed, o			106.17	10	0.002	NC

-- = Not available.

(a) Chronic RSLs were based on USEPA Risk-Based Screening Levels, November 2015 version (<http://semspub.epa.gov/work/03/2220587.pdf>). Non-cancer RSLs were based on a benchmark hazard quotient (HQ) of 0.1, which is 10 times lower (i.e., more health-protective) than the criterion typically relied on by PADEP and in health risk assessments. The cancer-based RSLs were based on a benchmark excess lifetime cancer risk of one in one million (1 in 1,000,000 or 1E-6), which is 100 times more conservative (i.e., health protective) than the 1 in 10,000 (1E-4) risk level generally relied upon by PADEP when assessing health risks from chemical compounds in ambient air (PADEP 2013). If RSL air concentrations were available for both non-cancer and cancer health effects, the lowest one was selected.

(b) ppm = ug/m³ * 24.45 / (1,000 * MW)

(c) C = Risk-based level based on an excess lifetime cancer risk of one in one million (1E-06). NC = Risk-based level for non-cancer health effects based on a concentration 10 times lower than PADEP's benchmark level (i.e., a hazard quotient (HQ) of 0.1).

(d) The RSL for cis-1,2-dichloroethene was obtained from the International Toxicity Estimates for Risk (ITER) database because values were not available in USEPA's RSL table. Source: RIVM Provisional tolerable air concentration (https://iter.ctc.com/publicURL/pub_view_list.cfm?crn=156%2D59%2D2).

(e) Screening level based on non-cancer health effect at a non-cancer hazard quotient level of 0.1 (HQ=0.1). At an HQ=1.0, however, the screening level would be based on cancer risk.

**Table 7
Acute Short-Term Health-Based Comparison Values (CVs)**

Landfill Gas Compounds	Acute 1-Hour Average Inhalation Reference Concentrations (a)				Selected Acute 1-Hour Average Inhalation Reference Concentration	
	CALEPA REL (ug/m ³)	EPA AEGL-1 (ug/m ³)	AEGL-1 status	Protective Action Criteria (ug/m ³)	ug/m ³	ppm (b)
1,1-Dichloroethane	--	--	--	1,200,000 (TEEL-1)	1,200,000	300
1,2,4-Trimethylbenzene	--	690,000	final	NA	690,000	140
1,2-Dichloroethane	--	--	--	200,000 (ERPG-1)	200,000	50
1,3,5-Trimethylbenzene	--	690,000	final	NA	690,000	140
2-Methyl butane				8,800,000 (TEEL-1)	8,800,000	3,000
4-Ethyltoluene	--	--	--	15,000 (TEEL-1)	15,000	3.1
4-Methyl-2-pentanone	--	--	--	310,000 (TEEL-1)	310,000	76
Acetone	--	475,000	interim	NA	475,000	200
Benzene	27	170,000	interim	NA	27	0.0085
Bromomethane	3,900	--	final	NA	3,900	1.0
Butane		13,000,000	final	NA	13,000,000	5,500
Butyl acetate, n-	--	--	--	24,000 (ERPG-1)	24,000	5
Carbon disulfide	6,200	42,000	final	NA	6,200	2.0
Carbonyl sulfide				37,000 (TEEL-1)	37,000	15
Chlorobenzene	--	47,000	final	NA	47,000	10
cis-1,2-Dichloroethene	--	554,000	final	NA	554,000	140
Dichlorobenzene - 1,4-Dichlorobenzene	--	--	--	180,000 (TEEL-1)	180,000	30
Dichloromethane	14,000	710,000	interim	NA	14,000	4.0
Dimethyl disulfide				39 (ERPG-1)	39	0.01
Dimethyl sulfide	--	--	--	1,300 (ERPG-1)	1300	0.51
Ethanol				3,400,000 (ERPG-1)	3,400,000	1,800
Ethyl acetate	--	--	--	4,300,000 (TEEL-1)	4,300,000	1,200
Ethyl mercaptan	--	2,500	final	NA	2,500	1.0
Ethylbenzene	--	144,000	interim	NA	144,000	33
Freon 11				760,000 (TEEL-1)	760,000	140
Freon 113 (CFC 113)	--	--	--	9,600,000 (TEEL-1)	9,600,000	1,300
Freon 12 (CFC 12)	--	--	--	15,000,000 (TEEL-1)	15,000,000	3,030
Heptane, n-	--	--	--	2,000,000 (TEEL-1)	2,000,000	490

**Table 7
Acute Short-Term Health-Based Comparison Values (CVs)**

Landfill Gas Compounds	Acute 1-Hour Average Inhalation Reference Concentrations (a)				Selected Acute 1-Hour Average Inhalation Reference Concentration	
	CALEPA REL (ug/m ³)	EPA AEGL-1 (ug/m ³)	AEGL-1 status	Protective Action Criteria (ug/m ³)	ug/m ³	ppm (b)
Hexane, n-	--	--	--	910,000 (TEEL-1)	910,000	260
Hydrogen sulfide	42	710	final	NA	42	0.03
Isobutane				13,000,000 (TEEL-1)	13,000,000	5,500
Isobutyl mercaptan	--	--	--	--	--	--
Limonene				84,000 (TEEL-1)	84,000	15
Methyl ethyl ketone	13,000	586,000	final	NA	13,000	4.4
Methyl mercaptan	--	--	final	9.8 (ERPG-1)	9.8	0.0050
Pentane				8,800,000 (TEEL-1)	8,800,000	3,000
Perchloroethylene	20,000	240,000	interim	NA	20,000	2.9
Propane		9,900,000	final	NA	9,900,000	5,500
Propanol, 2-	3,200	--	--	NA	3200	1.3
Propyl acetate				1,000,000 (TEEL-1)	1,000,000	240
Propyl mercaptan, n-	--	--	--	150 (TEEL-1)	150	0.050
Styrene	21,000	85,000	interim	NA	21,000	4.9
Tetrahydrofuran	--	--	--	290,000 (ERPG-1)	290,000	98
Toluene	37,000	250,000	final	NA	37,000	9.8
Trichloroethylene	--	700,000	interim	NA	700,000	130
Vinyl Chloride	180,000	650,000	final	NA	180,000	70
Xylenes mixed, m+o+p	22,000	560,000	final	NA	22,000	5.1
Xylenes mixed, m+p	22,000	560,000	final	NA	22,000	5.1
Xylenes mixed, o	22,000	560,000	final	NA	22,000	5.1

-- = Not available. NA = Not applicable.

(a) Acute RELs were based on the lowest of available values (as of 10/10/15) from CALEPA RELs and USEPA AEGL-1 values (<http://oehha.ca.gov/air/allrels.html> and http://www2.epa.gov/sites/production/files/2015-07/documents/compiled_aegl_update09jun2015.pdf). If neither of these were available, criteria were based on ERPG-1 values, if available, or DOE TEEL-1 values (http://www.atlintl.com/DOE/teels/teel/Revision_28A_Table4.pdf).

(b) ppm = ug/m³ * 24.45 / (1,000 * MW)

Table 8
Odor Threshold Values

Landfill Gas Compounds		Odor Threshold Information		
Compound Name	Synonyms	Geometric Mean (ug/m ³) (a)	Geometric Standard Deviation (unitless)(b)	Number of Odor Threshold Values (c)
1,1-Dichloroethane	Ethylidene dichloride	689,900	1.5	3
1,2,4-Trimethylbenzene		--	--	--
1,2-Dichloroethane	Ethylene dichloride	110,600	4.3	6
1,3,5-Trimethylbenzene	mesitylene	5,640	2.8	2
2-Methyl butane	isopentane	18,900	10	2
4-Ethyltoluene	1-Ethyl-4-Methylbenzene, p-ethyltoluene	--	--	--
4-Methyl-2-pentanone	isopropylacetone, methyl isobutyl ketone (MIBK)	3,350	14	6
Acetone	2-propanone	76,200	6.6	5
Benzene		46,300	5.3	7
Bromomethane	Methyl bromide	565,700	16	2
Butane	n-butane	206,000	28	5
Butyl acetate, n-	butyl ester acetic acid	2,000	35	5
Carbon disulfide		520	12	5
Carbonyl sulfide	carbon oxysulfide	190	1.5	2
Chlorobenzene		7,050	8.7	5
cis-1,2-Dichloroethene	Acetylene dichloride	36,800	80	3
Dichlorobenzene - 1,4-Dichlorobenzene	1,4-Dichlorobenzene	5,170	20	5
Dichloromethane	Methylene chloride	843,700	2.0	4
Dimethyl disulfide	methyl disulfide	6.7	59	3
Dimethyl sulfide	Methyl sulfide	9.3	3.5	4
Ethanol	ethyl alcohol	10,600	101	5
Ethyl acetate	Acetic ester	4,190	42	5
Ethyl mercaptan	Ethanethiol	0.79	32	5
Ethylbenzene		14,100	13	5
Freon 11 (CFC 11)	trichlorofluoromethane, fluorotrichloromethane	95,700	5.8	4
Freon 113 (CFC 113)	1,1,2-trichlorotrifluoroethane	821,300	3.1	4
Freon 12 (CFC 12)	dichlorodifluoromethane	--	--	--
Heptane, n-		111,700	12	5
Hexane, n-		57,300	9.5	3
Hydrogen sulfide		2.5	4.6	5

**Table 8
Odor Threshold Values**

Landfill Gas Compounds		Odor Threshold Information		
Compound Name	Synonyms	Geometric Mean (ug/m ³) (a)	Geometric Standard Deviation (unitless)(b)	Number of Odor Threshold Values (c)
Isobutane	2-methyl propane	--	--	--
Isobutyl mercaptan		0.46	13	3
Limonene	d-limonene	720	5.7	2
Methyl ethyl ketone	2-butanone	8,270	11	7
Methyl mercaptan	methanethiol	1.2	19	5
Pentane	n-pentane	97,900	19	5
Perchloroethylene	Tetrachloroethylene, tetrachloroethene	75,700	5.5	6
Propane		7,560,000	3.9	5
Propanol, 2-	Isopropyl alcohol	21,900	14	4
Propyl acetate	n-propyl acetate, propyl ester acetic acid	2,720	10	5
Propyl mercaptan, n-		0.85	53	3
Styrene		2,250	28	7
Tetrahydrofuran		17,140	4.8	4
Toluene	Methyl benzene	5,030	7.5	7
Trichloroethylene	Trichloroethene	54,230	16	6
Vinyl Chloride	chloroethene	7,669,000	NA	1
Xylenes mixed, m+o+p		3,040	11	7
Xylenes mixed, m+p		3,040	11	7
Xylenes mixed, o		4,080	10	6

-- = Not available.

NA = Not applicable since only one value was provided in the referenced sources.

(a) The geometric mean (GM) is a type of average concentration calculated for data that tends to be very skewed (i.e., data which is lognormally distributed and spans orders of magnitude, such as odor thresholds and environmental concentrations).

(b) The geometric standard deviation (GSD) describes the dispersion of data around the geometric mean (GM) for a lognormal distribution (i.e., the degree to which the data are spread out or vary around an average value). The GSD is a dimensionless factor, unlike the GM. GSDs close to zero indicate that the data are tightly clustered around the mean while larger GSDs indicate more spread in the data. To determine the value that lies "n" GSDs from the GM, the geometric standard deviation is raised to the nth power and either multiplied by, or divided into, the geometric mean (i.e., (GM)*(GSD)ⁿ or (GM)/(GSD)ⁿ).

(c) Odor thresholds were compiled from the following sources: USEPA (1992), Amoores and Hautala (1983), Ruth (1986), Nagata (2004) and 3M (2013).

Table 9
Chronic Risk Assessment Results:
Evaluation of Potential for Chronic Health Risks in the Florence-Roebling Area

Landfill Gas Compounds		Maximum Annual Average Modeled Concentrations in Florence-Roebling ($\mu\text{g}/\text{m}^3$)	Chronic Health-Based Comparison Values (CVs)		Ratio of Modeled Concentrations to Chronic CVs (Annual Average Concentration / Chronic CV)
Compound Name	Synonyms		Concentrations ($\mu\text{g}/\text{m}^3$)	Basis (C or NC) (a)	
1,1-Dichloroethane	Ethylidene dichloride	1.33E-06	1.8	C	7.4E-07
1,2,4-Trimethylbenzene		5.23E-05	0.73	NC	7.2E-05
1,2-Dichloroethane	Ethylene dichloride	1.31E-05	0.11	C	1.2E-04
1,3,5-Trimethylbenzene	mesitylene	2.71E-05	--	--	--
2-Methyl butane	Isopentane	4.12E-03	--	--	--
4-Ethyltoluene	1-Ethyl-4-Methylbenzene, p-ethyltoluene	9.17E-05	--	--	--
4-Methyl-2-pentanone	isopropylacetone, methyl isobutyl ketone (MIBK)	6.62E-05	310	NC	2.1E-07
Acetone	2-propanone	9.60E-04	3,200	NC	3.0E-07
Benzene		2.72E-04	0.36	C	7.6E-04
Bromomethane	Methyl bromide	4.93E-06	0.52	NC	9.5E-06
Butane	n-butane	6.99E-03	--	--	--
Butyl acetate, n-	butyl ester acetic acid	7.88E-04	--	--	--
Carbon disulfide		3.82E-05	73	NC	5.2E-07
Carbonyl sulfide	carbon oxysulfide	5.20E-05	10	NC	5.2E-06
Chlorobenzene		2.95E-06	5.2	NC	5.7E-07
cis-1,2-Dichloroethene	Acetylene dichloride	9.70E-06	6.0	NC	1.6E-06
Dichlorobenzene - 1,4-Dichlorobenzene	1,4-Dichlorobenzene	3.38E-05	0.26	C	1.3E-04
Dichloromethane	Methylene chloride	2.28E-05	63	NC	3.6E-07
Dimethyl disulfide	methyl disulfide	2.69E-05	--	--	--
Dimethyl sulfide	Methyl sulfide	5.25E-04	--	--	--

Table 9
Chronic Risk Assessment Results:
Evaluation of Potential for Chronic Health Risks in the Florence-Roebling Area

Landfill Gas Compounds		Maximum Annual Average Modeled Concentrations in Florence-Roebling ($\mu\text{g}/\text{m}^3$)	Chronic Health-Based Comparison Values (CVs)		Ratio of Modeled Concentrations to Chronic CVs (Annual Average Concentration / Chronic CV)
Compound Name	Synonyms		Concentrations ($\mu\text{g}/\text{m}^3$)	Basis (C or NC) (a)	
Ethanol	ethyl alcohol	1.79E-02	--	--	--
Ethyl acetate	Acetic ester	1.54E-01	7.3	NC	2.1E-02
Ethyl mercaptan	Ethanethiol	9.12E-05	--	--	--
Ethylbenzene		1.84E-04	1.1	C	1.7E-04
Freon 11	trichlorofluoromethane, CFC 11, fluorotrichloromethane	5.38E-04	--	--	--
Freon 113 (CFC 113)	1,1,2-trichlorotrifluoroethane, 1,1,2-trichloro-1,2,2-trifluoroethane	3.17E-05	3,100	NC	1.0E-08
Freon 12 (CFC 12)	dichlorodifluoromethane	1.26E-05	10	NC	1.3E-06
Heptane, n-		4.63E-05	--	--	--
Hexane, n-		1.96E-05	73	NC	2.7E-07
Hydrogen sulfide		5.25E-03	0.21	NC	2.5E-02
Isobutane	2-methyl propane	7.35E-03	--	--	--
Isobutyl mercaptan		5.44E-04	--	--	--
Limonene	d-limonene	5.29E-03	--	--	--
Methyl ethyl ketone	2-butanone	6.04E-04	520	NC	1.2E-06
Methyl mercaptan	methanethiol	3.07E-04	--	--	--
Pentane	n-pentane	2.87E-03	100	NC	2.9E-05
Perchloroethylene	Tetrachloroethylene, tetrachloroethene	4.65E-04	4.2	NC	1.1E-04
Propane		3.23E-03	--	--	--
Propanol, 2-	Isopropyl alcohol	1.55E-04	21	NC	7.4E-06

Table 9
Chronic Risk Assessment Results:
Evaluation of Potential for Chronic Health Risks in the Florence-Roebling Area

Landfill Gas Compounds		Maximum Annual Average Modeled Concentrations in Florence-Roebling ($\mu\text{g}/\text{m}^3$)	Chronic Health-Based Comparison Values (CVs)		Ratio of Modeled Concentrations to Chronic CVs (Annual Average Concentration / Chronic CV)
Compound Name	Synonyms		Concentrations ($\mu\text{g}/\text{m}^3$)	Basis (C or NC) (a)	
Propyl acetate	n-propyl acetate, propyl ester acetic acid	2.51E-03	--	--	--
Propyl mercaptan, n-		3.96E-05	--	--	--
Styrene		1.78E-05	100	NC	1.8E-07
Tetrahydrofuran		3.61E-05	210	NC	1.7E-07
Toluene	Methyl benzene	8.97E-04	520	NC	1.7E-06
Trichloroethylene	Trichloroethene	5.21E-06	0.21	NC	2.5E-05
Vinyl Chloride	chloroethene	6.64E-06	0.17	C	3.9E-05
Xylenes mixed, m+o+p		4.01E-04	10	NC	4.0E-05
Xylenes mixed, m+p		3.08E-04	10	NC	3.1E-05
Xylenes mixed, o		9.29E-05	10	NC	9.3E-06
Total for Non-Cancer Health Effects (b)					0.05
Total for Excess Lifetime Cancer Risk (b)					0.001

(a) C = Risk-based level based on an excess lifetime cancer risk of one in one million (1E-06).

NC = Risk-based level for non-cancer health effects based on a hazard quotient (HQ) of 0.1.

(b) The sum of ratios for compounds with non-cancer health effects and for potential carcinogens includes all compounds which have CVs for these endpoints (i.e., non-cancer CVs and cancer risk-based CVs, respectively).

Table 10
Acute Risk Assessment Results:
Evaluation of Potential for Acute Health Risks in the Florence-Roebling Area

Landfill Gas Compounds		Maximum 1-Hour Average Modeled Concentrations in Florence-Roebling (ug/m ³)	Acute Health-Based Comparison Values (CVs) (ug/m ³) (a)	Ratio of Modeled Concentrations to Acute CVs (1-Hour Average Concentration / Acute CV)
Compound Name	Synonyms			
1,1-Dichloroethane	Ethylidene dichloride	5.69E-05	1,200,000	4.7E-11
1,2,4-Trimethylbenzene		3.75E-03	690,000	5.4E-09
1,2-Dichloroethane	Ethylene dichloride	6.01E-04	200,000	3.0E-09
1,3,5-Trimethylbenzene	mesitylene	1.74E-03	690,000	2.5E-09
2-Methyl butane	isopentane	2.77E+00	8,800,000	3.2E-07
4-Ethyltoluene	1-Ethyl-4-Methylbenzene, p-ethyltoluene	4.34E-03	15,000	2.9E-07
4-Methyl-2-pentanone	isopropylacetone, methyl isobutyl ketone (MIBK)	2.96E-03	310,000	9.6E-09
Acetone	2-propanone	4.10E-02	475,000	8.6E-08
Benzene		1.22E-02	27	4.5E-04
Bromomethane	Methyl bromide	3.59E-04	3,900	9.2E-08
Butane	n-butane	4.70E+00	13,000,000	3.6E-07
Butyl acetate, n-	butyl ester acetic acid	5.31E-01	24,000	2.2E-05
Carbon disulfide		1.63E-02	6,200	2.6E-06
Carbonyl sulfide	carbon oxysulfide	3.50E-02	37,000	9.5E-07
Chlorobenzene		1.26E-04	47,000	2.7E-09
cis-1,2-Dichloroethene	Acetylene dichloride	4.14E-04	554,000	7.5E-10
Dichlorobenzene - 1,4-Dichlorobenzene	1,4-Dichlorobenzene	1.64E-03	180,000	9.1E-09
Dichloromethane	Methylene chloride	1.05E-03	14,000	7.5E-08
Dimethyl disulfide	methyl disulfide	1.81E-02	39	4.6E-04
Dimethyl sulfide	Methyl sulfide	5.51E-02	1,300	4.2E-05
Ethanol	ethyl alcohol	1.21E+01	3,400,000	3.5E-06
Ethyl acetate	Acetic ester	1.04E+02	4,300,000	2.4E-05
Ethyl mercaptan	Ethanethiol	4.09E-03	2,500	1.6E-06
Ethylbenzene		1.01E-02	144,000	7.0E-08
Freon 11 (CFC 11)	trichlorofluoromethane, fluorotrichloromethane	3.62E-01	760,000	4.8E-07
Freon 113 (CFC 113)	1,1,2-trichlorotrifluoroethane	1.57E-03	9,600,000	1.6E-10
Freon 12 (CFC 12)	dichlorodifluoromethane	9.33E-04	15,000,000	6.2E-11
Heptane, n-		1.98E-03	2,000,000	9.9E-10

Table 10
Acute Risk Assessment Results:
Evaluation of Potential for Acute Health Risks in the Florence-Roebling Area

Landfill Gas Compounds		Maximum 1-Hour Average Modeled Concentrations in Florence-Roebling (ug/m ³)	Acute Health-Based Comparison Values (CVs) (ug/m ³) (a)	Ratio of Modeled Concentrations to Acute CVs (1-Hour Average Concentration / Acute CV)
Compound Name	Synonyms			
Hexane, n-		8.35E-04	910,000	9.2E-10
Hydrogen sulfide		3.63E-01	42	8.7E-03
Isobutane	2-methyl propane	4.94E+00	13,000,000	3.8E-07
Isobutyl mercaptan		2.32E-02	--	--
Limonene	d-limonene	3.56E+00	84,000	4.2E-05
Methyl ethyl ketone	2-butanone	4.74E-02	13,000	3.6E-06
Methyl mercaptan	methanethiol	2.54E-02	10	2.6E-03
Pentane	n-pentane	1.93E+00	8,800,000	2.2E-07
Perchloroethylene	Tetrachloroethylene, tetrachloroethene	3.02E-01	20,000	1.5E-05
Propane		2.17E+00	9,900,000	2.2E-07
Propanol, 2-	Isopropyl alcohol	6.61E-03	3,200	2.1E-06
Propyl acetate	n-propyl acetate, propyl ester acetic acid	1.69E+00	1,000,000	1.7E-06
Propyl mercaptan, n-		1.69E-03	150	1.1E-05
Styrene		8.38E-04	21,000	4.0E-08
Tetrahydrofuran		1.54E-03	290,000	5.3E-09
Toluene	Methyl benzene	3.83E-01	37,000	1.0E-05
Trichloroethylene	Trichloroethene	3.02E-04	700,000	4.3E-10
Vinyl Chloride	chloroethene	4.41E-04	180,000	2.5E-09
Xylenes mixed, m+o+p		2.28E-02	22,000	1.0E-06
Xylenes mixed, m+p		1.74E-02	22,000	7.9E-07
Xylenes mixed, o		5.41E-03	22,000	2.5E-07
Total (Sum of acute ratios)				0.01

Table 11
Odor Evaluation Results:
Evaluation of Potential for Odor Detection in the Florence-Roebling Area

Landfill Gas Compounds	Modeled Ambient Air Concentrations in Florence-Roebling ($\mu\text{g}/\text{m}^3$)		Geometric Mean Odor Threshold (OT) ($\mu\text{g}/\text{m}^3$)	D/T Concentrations	
	Maximum 1-Hour Average	Maximum 5-Minute Average		Maximum 1-Hour Concentration / OT	Maximum 5-Minute Concentration / OT
1,1-Dichloroethane	5.69E-05	7.97E-05	6.90E+05	8.2E-11	1.2E-10
1,2,4-Trimethylbenzene	3.75E-03	5.25E-03	--	--	--
1,2-Dichloroethane	6.01E-04	8.42E-04	1.11E+05	5.4E-09	7.6E-09
1,3,5-Trimethylbenzene	1.74E-03	2.43E-03	5.64E+03	3.1E-07	4.3E-07
2-Methyl butane	2.77E+00	3.88E+00	1.89E+04	1.5E-04	2.1E-04
4-Ethyltoluene	4.34E-03	6.08E-03	--	--	--
4-Methyl-2-pentanone	2.96E-03	4.15E-03	3.35E+03	8.8E-07	1.2E-06
Acetone	4.10E-02	5.74E-02	7.62E+04	5.4E-07	7.5E-07
Benzene	1.22E-02	1.71E-02	4.63E+04	2.6E-07	3.7E-07
Bromomethane	3.59E-04	5.02E-04	5.66E+05	6.3E-10	8.9E-10
Butane	4.70E+00	6.58E+00	2.06E+05	2.3E-05	3.2E-05
Butyl acetate, n-	5.31E-01	7.43E-01	2.00E+03	2.7E-04	3.7E-04
Carbon disulfide	1.63E-02	2.28E-02	5.20E+02	3.1E-05	4.4E-05
Carbonyl sulfide	3.50E-02	4.90E-02	1.90E+02	1.8E-04	2.6E-04
Chlorobenzene	1.26E-04	1.76E-04	7.05E+03	1.8E-08	2.5E-08
cis-1,2-Dichloroethene	4.14E-04	5.80E-04	3.68E+04	1.1E-08	1.6E-08
Dichlorobenzene - 1,4-Dichlorobenzene	1.64E-03	2.30E-03	5.17E+03	3.2E-07	4.4E-07
Dichloromethane	1.05E-03	1.46E-03	8.44E+05	1.2E-09	1.7E-09
Dimethyl disulfide	1.81E-02	2.53E-02	6.70E+00	2.7E-03	3.8E-03
Dimethyl sulfide	5.51E-02	7.71E-02	9.30E+00	5.9E-03	8.3E-03
Ethanol	1.21E+01	1.69E+01	1.06E+04	1.1E-03	1.6E-03
Ethyl acetate	1.04E+02	1.45E+02	4.19E+03	2.5E-02	3.5E-02
Ethyl mercaptan	4.09E-03	5.72E-03	7.90E-01	5.2E-03	7.2E-03
Ethylbenzene	1.01E-02	1.42E-02	1.41E+04	7.2E-07	1.0E-06
Freon 11	3.62E-01	5.06E-01	9.57E+04	3.8E-06	5.3E-06
Freon 113 (CFC 113)	1.57E-03	2.20E-03	8.21E+05	1.9E-09	2.7E-09
Freon 12 (CFC 12)	9.33E-04	1.31E-03	--	--	--
Heptane, n-	1.98E-03	2.77E-03	1.12E+05	1.8E-08	2.5E-08
Hexane, n-	8.35E-04	1.17E-03	5.73E+04	1.5E-08	2.0E-08
Hydrogen sulfide	3.63E-01	5.09E-01	2.45E+00	1.5E-01	2.1E-01

Table 11
Odor Evaluation Results:
Evaluation of Potential for Odor Detection in the Florence-Roebling Area

Landfill Gas Compounds	Modeled Ambient Air Concentrations in Florence-Roebling ($\mu\text{g}/\text{m}^3$)		Geometric Mean Odor Threshold (OT) ($\mu\text{g}/\text{m}^3$)	D/T Concentrations	
	Maximum 1-Hour Average	Maximum 5-Minute Average		Maximum 1-Hour Concentration / OT	Maximum 5-Minute Concentration / OT
Isobutane	4.94E+00	6.92E+00	--	--	--
Isobutyl mercaptan	2.32E-02	3.25E-02	4.60E-01	5.1E-02	7.1E-02
Limonene	3.56E+00	4.98E+00	7.20E+02	4.9E-03	6.9E-03
Methyl ethyl ketone	4.74E-02	6.63E-02	8.27E+03	5.7E-06	8.0E-06
Methyl mercaptan	2.54E-02	3.55E-02	1.23E+00	2.1E-02	2.9E-02
Pentane	1.93E+00	2.70E+00	9.79E+04	2.0E-05	2.8E-05
Perchloroethylene	3.02E-01	4.23E-01	7.57E+04	4.0E-06	5.6E-06
Propane	2.17E+00	3.04E+00	7.56E+06	2.9E-07	4.0E-07
Propanol, 2-	6.61E-03	9.26E-03	2.19E+04	3.0E-07	4.2E-07
Propyl acetate	1.69E+00	2.36E+00	2.72E+03	6.2E-04	8.7E-04
Propyl mercaptan, n-	1.69E-03	2.37E-03	8.50E-01	2.0E-03	2.8E-03
Styrene	8.38E-04	1.17E-03	2.25E+03	3.7E-07	5.2E-07
Tetrahydrofuran	1.54E-03	2.16E-03	1.71E+04	9.0E-08	1.3E-07
Toluene	3.83E-01	5.36E-01	5.03E+03	7.6E-05	1.1E-04
Trichloroethylene	3.02E-04	4.23E-04	5.42E+04	5.6E-09	7.8E-09
Vinyl Chloride	4.41E-04	6.18E-04	7.67E+06	5.8E-11	8.1E-11
Xylenes mixed, m+o+p	2.28E-02	3.20E-02	3.04E+03	7.5E-06	1.1E-05
Xylenes mixed, m+p	1.74E-02	2.44E-02	3.04E+03	5.7E-06	8.0E-06
Xylenes mixed, o	5.41E-03	7.57E-03	4.08E+03	1.3E-06	1.9E-06
Total (sum of D/T concentrations)				0.3	0.4

-- = Not available.

D/T = Dilution-to-odor threshold concentration

OT = Odor threshold

**Table 12
Hydrogen Sulfide Air Sampling Results**

Hydrogen Sulfide Air Sampling in Florence-Roebling: July 17 - October 20, 2015 (a)

Survey Results	Station Rd (site 1)	Roebling Elementary (site 2)	Main - Tenth (site 3)	Roebling Park (site 4)	E. Front - Oak (site 5)	Florence Sr. HS (site 6)	Florence Yacht (site 7)	Florence Elementary (site 8)	River Edge Park (site 9)	Total
Results When Station Was Upwind of Landfill										
Total Number of Measurements	21	31	31	31	30	29	28	29	25	265
Percent Non-Detected Concentrations (<3 ppb)	65%	74%	68%	71%	70%	69%	61%	62%	68%	68%
Percent Detected Concentrations (3 ppb or greater)	35%	26%	32%	29%	30%	31%	39%	38%	32%	32%
Maximum Detected Concentration	5	5	5	5	7	6	5	5	5	7
Results When Station Was Downwind of Landfill										
Total Number of Measurements	6	12	13	13	6	8	16	9	7	90
Percent Non-Detected Concentrations (<3 ppb)	83%	100%	100%	92%	83%	63%	44%	44%	29%	72%
Percent Detected Concentrations (3 ppb or greater)	17%	0%	0%	8%	17%	38%	56%	56%	71%	28%
Maximum Detected Concentration	3	<3	<3	5	5	5	5	5	6	6
Results When Station Was Occasionally Downwind of Landfill										
Total Number of Measurements	13	11	10	10	13	12	12	7	4	92
Percent Non-Detected Concentrations (<3 ppb)	85%	100%	90%	80%	77%	83%	75%	86%	50%	83%
Percent Detected Concentrations (3 ppb or greater)	15%	0%	10%	20%	23%	17%	25%	14%	50%	17%
Maximum Detected Concentration	4	<3	3	4	6	3	5	5	5	6
Results When Station Was Not Upwind or Downwind of Landfill										
Total Number of Measurements	7	4	4	4	9	9	6	15	14	72
Number of Non-Detected Concentrations (<3 ppb)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Results When Station Was Not Classified Due to Light and Variable Winds										
Total Number of Measurements	4	4	4	4	4	4	4	4	4	36
Number of Non-Detected Concentrations (<3 ppb)	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%

(a) Concentrations measured using hand-held Jerome 631-X meter with detection limit of 3 ppb and a 30-second response time. The designation of the sampling site relative to the landfill (upwind, downwind, occasionally downwind or neither) was determined based on concurrent wind direction data reported at the Tullytown (landfill) meteorological station during each community sampling period. A sample was designated as downwind or upwind when most or all concurrent wind direction readings place the location downwind or upwind of the landfill, respectively. A sample was designated occasionally downwind when at least 1, but not most wind direction readings place the location downwind.

Table 13
Odor Control Products Used at TRRF
June 2014 - September 2015

Provider	Product Name	Type of Use (a)
BioTriad	VaporDOX	Misting lines
	OdaBond	Misting lines
	VaporXL-LF	Vapor lines
	ActiveCell-NF	Direct use (on working face)
Air Care	Neutralene 7030SF	Misting lines, vapor units, direct use (on working face)
	Noxorb260	Misting lines and vapor units
	Odor Cover 3020SF	Vapor units
	Neutralene Winter Blend	Vapor units
	Neutralene Winter Blend Plus	Vapor units
	Odor Cover 6040SF	Direct use (intermediate cover area in northeast part of site, one-time test)

APPENDICES

APPENDIX A

**PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
STUDY PLAN APPROVAL**

From: Wentzel, James [jwentzel@pa.gov]
Sent: Friday, November 13, 2015 4:55 PM
To: Brill, Eli
Cc: Sutch, Barry; Hunt, Jessica
Subject: RE: TRRF Plan of Study

Please implement the revised plan of study dated October 29, 2015.

As discussed with Mr. Sutch on November 12th, the study report should be targeted towards the general public as the intended audience. If model results don't reflect observed sampling concentrations and/or the well documented nuisance odor detections that have occurred, the report should also attempt to reconcile these differences. Also, some terms could be further explained, such as the reasons for and the meanings of the odor threshold terms in Table 4 (geometric mean, geometric standard deviation, number of odor threshold values).

Thank you.

From: Brill, Eli [mailto:EBrill@wm.com]
Sent: Thursday, October 29, 2015 2:36 PM
To: Wentzel, James
Cc: Sutch, Barry; Hunt, Jessica
Subject: RE: TRRF Plan of Study

Dear Mr. Wentzel:

Enclosed please find a revised plan of study that takes into account the Department's comments from September 21. This revised plan of study also will be transmitted in hard copy by overnight mail to be received in your office tomorrow.

Sincerely,

Eli Brill
Senior Legal Counsel, EHS
Waste Management
1000 Brandywine Blvd, 3rd Floor
Newtown, PA 18940
215 269 2111 (office)
215 900 0457 (cell)
215 376 6915 (fax)

APPENDIX B

BIOGRAPHIES OF STUDY PARTICIPANTS



**MICHAEL NIEMANN
LFG PROGRAM TECHNICAL DIRECTOR
ENVIRONMENTAL INFORMATION LOGISTICS, LLC**

**130 East Main Street SE
Caledonia, MI 49316
616-891-2591
www.eillc.com**

Mr. Niemann has 30 years' experience in the landfill gas industry. Mr. Niemann is responsible for conducting landfill gas generation modeling, production testing and gas collection system performance assessments including environmental impacts of landfill gas on groundwater and the surrounding soils. In addition, Mr. Niemann has experience in characterizing landfill gas with respect to the volatile organic compound content and other trace components. He has extensive experience in landfill gas collection and control system design for municipal solid waste landfills including landfill gas transmission pipeline design. He is also responsible for providing technical assistance to operating landfill gas energy recovery facilities with respect to annual compliance submittals for air quality, well-field management, gas chromatography and gas flow measurement. Mr. Niemann has experience in evaluating energy recovery technologies with respect to performance on landfill gas. Mr. Niemann works closely with Clients concerning permitting of landfills and landfill gas collection and control systems for compliance with US EPA Air Quality New Source Performance Standards for landfills. Mr. Niemann also works with Clients on Prevention of Significant Deterioration permits including air modeling, Air Quality Non-attainment New Source Review for volatile organic compounds and NO_x from landfills and associated control devices, assessments of Reasonably Available Control Technology, Best Available Control Technology and Lowest Achievable Emissions Reduction technologies for landfills. In addition, Mr. Niemann has had extensive experience in developing and reviewing operating permits for landfills and the associated landfill gas control equipment in accordance with the provisions established in the US Clean Air Act under Title V.

Thomas J. Rappolt, Q.E.P.
Office Director and Vice President – SCS Engineers
Senior Air Quality Meteorologist – Project Director

Education:

M.S. Meteorology - Pennsylvania State University - 1984
B.S. Physics - Moravian College - 1974

Professional Experience:

Mr. Rappolt has over 37 years of program management and technical experience in air quality compliance and pollutant dispersion and air measurement programs. He is considered an expert in atmospheric dispersion and transport of airborne pollutants and odor causing compounds, particularly in the area of complex terrain, including overwater/coastal meteorological regimes, as well as inter and intra building processes. During Mr. Rappolt's career, he has designed and implemented over 80 atmospheric monitoring networks and comprehensive field measurement programs involving toxic chemicals and molds, volatile and semi-volatile organic compounds, metals, odorous compounds, criteria pollutants, and other targeted compounds. Many of these measurement studies required support monitoring of local meteorological parameters, including upper atmospheric data using an array of direct probe and remote sensing devices. Mr. Rappolt has served as an expert witness in the area of meteorology, atmospheric dispersion, and odor impacts on numerous legal cases, hearing boards, and programs which have regulatory significance.

Mr. Rappolt has applied his technical knowledge of pollutant movement and formation in the atmosphere to help assess and mitigate industrial odor issues. Mr. Rappolt has developed a method to assess a specific facility's odor footprint and how that footprint affects compliance to nuisance regulations. This method, which incorporates onsite monitoring, modeling and surveys has been very effective in isolating mitigations to resolve Industrial and facility odor issues. This approach has been successfully utilized at manufacturing facilities, wastewater treatment plants, landfills and composting operations.

Recently, Mr. Rappolt has been active in participating with State and Local regulators regarding the formulation of Greenhouse Gas (GHG) regulations. As a stakeholder representative, Mr. Rappolt is a member of several early action committees for the California Air Resources Board (CARB) regarding the implementation of AB32. In this capacity, Mr. Rappolt has provided testimony before the Air Resources Board regarding the severity of impacts these regulations could have on California businesses and citizens.

In addition to his technical contribution to numerous programs and projects, Mr. Rappolt is a proven manager of major air quality and environmental compliance groups. He has assumed this responsibility throughout his working career as an officer for four separate nationally recognized environmental consulting firms in addition to his founding of Tracer ES&T, Inc. Mr. Rappolt has organized and directed cumulative groups numbering more than 50 technical personnel responsible for millions of dollars of air quality, risk management, safety compliance, and related research programs. He has served as an industry representative on the Board of the Bi-National Air Quality Alliance. Mr. Rappolt is an appointed active member of the San Diego County Air Pollution Control District Hearing Board and has been Chair of that board for over 10 years. As a past member of the California Air Resources Board's Community Health Modeling Working Group Mr. Rappolt assisted the ARB develop models and protocols to assess urban cumulative impacts. Mr. Rappolt has also served on rule making committees as a stakeholder relative to AB32 initiatives.

Mr. Rappolt has authored and co-authored numerous publications and text chapters on atmospheric dispersion and model validation.

Stephen L. Kerrin
Sr. Project Advisor – SCS Engineers
Tracer and Air Measurement Systems

Education:

B.A. Microbiology – California State University, Los Angeles

Professional Experience:

Mr. Kerrin is a Senior Consultant with SCS Tracer Environment, responsible for new detection and monitoring technology development. He participates in a broad spectrum of projects that involve highly sensitive detection of pollutant gases and tracer chemicals. Possessing more than 30 years of experience in numerous technical areas, his primary expertise lies in integration of electronics, analytical chemistry, microprocessor technology, and applied engineering in solution of unique and specified gas detection systems and source characterization.

Mr. Kerrin's expertise in tracer science encompasses air, water, and particulate methods. He was responsible for the design and fabrication of the first dedicated field-portable gas chromatograph for tracer studies and chlorofluorocarbon monitoring. He also developed the first high throughput gas chromatograph for analyzing tracer field samples. Additionally, he designed and built the first realtime perfluorocarbon instrumentation in the U.S. Recent development efforts have resulted in laboratory instrumentation to rapidly analyze field samples for perfluorocarbon tracers to the 10^{-15} concentration level. These include the design and fabrication of the Tracer ES&T Model 2600 TGA.

In applying gaseous tracer science to solution of other problems, he has developed instrumentation and techniques for use in determining leaks in closed systems, remaining life and integrity of activated carbon filtration systems. Specialized instrumentation was developed for testing protective garments and personnel protection equipment for worker protection from chemical exposure. He has also used multiple tracers in the characterization of sub-surface reservoir flow patterns in enhanced oil recovery. Mr. Kerrin developed a system to source test the hydrocarbon combustion efficiency of engines and other energy sources when fired on specialized fuels.

Mr. Kerrin has also developed and demonstrated methods for tagging particulate material to aid in characterization of fugitive dust emissions and other hazardous materials that exist in a fine particulate format. A recent effort has yielded a tracer for use in open water for characterization of flow from outfalls and to tag biogenic materials.

Mr. Kerrin expertise in applied measurement techniques have been useful in determining odor impacts from industrial facilities. In addition to developing specialize tracer gas experiments related to odor impact assessment, Mr. Kerrin has used this technology to determine low flow characteristics of industrial odor sources, especial those found in the components of landfill operations.

Prior to working at SCS Engineers, Mr. Kerrin worked at Tracer ES&T, Science Applications International Corporation, S-Cubed and The Jet Propulsion Laboratories in Pasadena, CA. where he conducted some of the early development work on the Electron Capture Detector.

Mr. Kerrin has authored or co-authored numerous papers in the areas of analytical chemistry and tracer science.

APPENDIX C

WORKING FACE GAS INVESTIGATION

APPENDIX C WORKING FACE GAS INVESTIGATION

This appendix provides information related to the identification of compounds in working face gas and the calculation of potential working face gas emission rates.

WORKING FACE GAS SAMPLING AND ANALYSIS

Introduction

Gas samples were collected by SCS Engineers personnel at the working face by means of a static non-vented flux chamber (i.e., an isolation chamber). The chamber was buried in recently spread and compacted waste prior to application of daily cover. The static flux chamber isolated sampling at the surface of the working face from dilution effects of ambient air flow and allowed for direct measurement of concentrations (not flux) in the working face gas (Eklund 1992). Sampling was accomplished during mid daylight hours (1030 to 1330) on December 2, 2015. The sampling location and its geographical relationship to the landfill and surrounding areas is shown in Figure B-1 below.

Figure B-1. Location of working face gas sampling on December 2, 2015.



The flux chamber was placed at a location on the working face where the highest odors were noted at the time the sampling team was on site, taking into account worker safety concerns and the representativeness of the newly placed and compacted waste mixture. In this way, the sampling program was biased towards detection of constituents most likely to be associated with

odors originating from recently deposited material. Two samples were obtained and their contents analyzed for volatile organic compounds, reduced sulfur compounds, ammonia, and terpenes. Some alcohols would be detected as tentatively identified compounds (TICs). Each sample required about 25 minutes of sampling at a rate of 0.6 liters per minute.

Method

The cylindrical bottom portion of the static flux chamber was buried to a depth of approximately 12-14 inches. This isolated gas at the surface of the working face from the dilution effects of ambient air flow and allowed for direct measurement of concentrations (not flux) in the working face gas (Eklund 1992). The working face gas samples were withdrawn at a flow rate from the headspace of the static flux chamber to ensure capture of representative samples that were not diluted by entrained ambient air. The sampling flow rate was set at a level that essentially matched the rate at which working face gases are estimated to be released, taking into account the size of the flux chamber and the vertical velocity of working face gas.

Figure B-2. Flux chamber buried in working face material. The flux chamber sides extend approximately 12-14 inches into the deposited material.

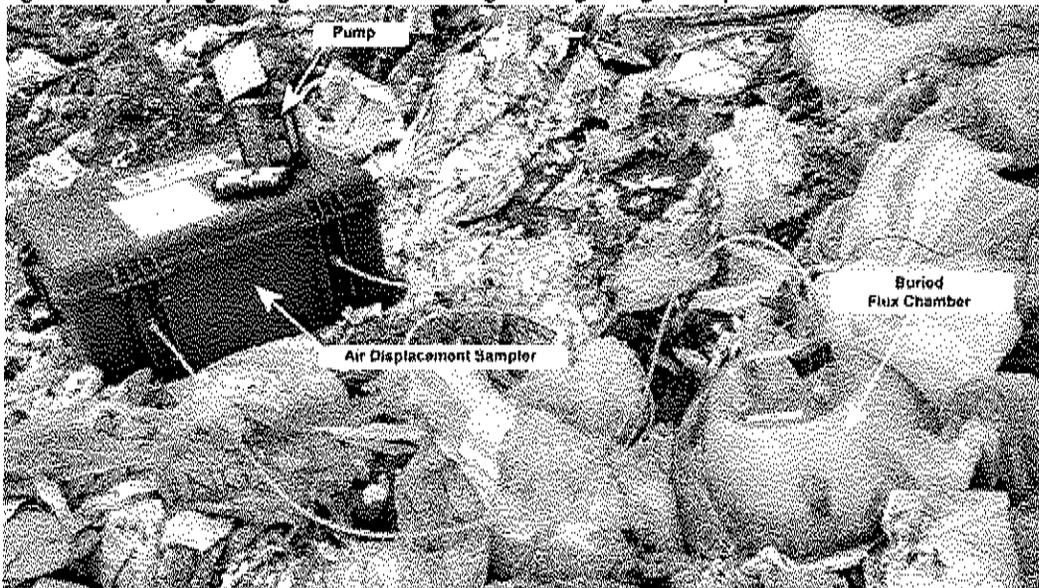


All materials in contact with the sample were stainless steel or polytetrafluoroethylene (PTFE) to minimize any contamination of the sample. An air displacement sampler was used to draw the sample gas into an inert 20 liter capacity Tedlar® bag. The air displacement sampler is frequently described as a "lung" sampler due to its mode of operation. The sample bag is placed in a sealable container and connected through a feed-through fitting to the flux chamber through PTFE tubing. A second fitting is located in the wall of the sample container and is connected to a vacuum pump.

The container is then closed and sealed. As the pump withdraws air from the container, a like volume of air from the flux chamber is drawn into the sample bag. This sampling arrangement is shown in Figure B-3.

The Tedlar® bag was allowed to fill with approximately 15 liters of air. Approximately 1.5 liters of bag contents were then pumped through each of two sorbent tubes for determination of ammonia and terpenes. An evacuated Summa canister was then connected to the bag and allowed to come to ambient pressure with the contents of the sample bag. The Summa canister was used for analysis of volatile organic compounds and reduced sulfur compounds.

Figure B-3. Sampling arrangement for obtaining working face gas samples.



Results

The collected samples were analyzed for a range of compounds within several general chemical groups that are considered likely to be present in working face gas. The general chemical groups are listed in Table B-1. The selection of these compound groups was informed by work previously performed by SCS Engineers at other landfills and findings in studies of working face gas composition conducted outside of the United States (e.g., Li et al. 2015). For each chemical group, two samples were collected and shipped to a certified independent laboratory to be analyzed. Standard air sampling methods consistent with regulatory agency guidelines and with appropriate quality assurance procedures were employed (e.g., use of method blanks and laboratory control blanks). The sampling and analysis methods for each chemical group are listed in Table B-1 and the analytical results summarized in Table B-2. The original laboratory reports are included in this appendix.

Table B-1. Sampling and Analysis Methods for Working Face Gas

Chemical Group	Sample Medium	Reference Method
Reduced Sulfur Compounds	Summa Canister	ASTM D5504
Ammonia	Sorbent Tube	NIOSH 6015
Terpenes	Sorbent Tube	NIOSH 1552
Volatile Organic Compounds	Summa Canister	USEPA TO-15
Alcohols	Summa Canister	USEPA TO-15 (TICs) ¹

¹ TICs are tentatively identified compounds which can be detected by an analytical method even though the method was not specifically targeted for these compounds.

Table B-2. Summary of Laboratory Results for Tullytown Landfill Working Face Gas Analysis

Sample ID	2-12-2-2015		3-12-2-2015	
	µg/m ³	ppb	µg/m ³	ppb
ASTM Method D5504				
Hydrogen Sulfide	ND	ND	ND	ND
Carbonyl Sulfide	160	64	290	120
Methyl Mercaptan	59	30	65	33
Dimethyl Sulfide	240	95	260	100
Carbon Disulfide	110	35	130	41
Dimethyl Disulfide	150	40	150	38
USEPA Method TO-15				
Ethanol	100,000	54,000	67,000	36,000
Trichlorofluoromethane (CFC 11)	3,000	540	3,000	540
Ethyl Acetate	860,000	240,000	600,000	170,000
Toluene	3,000	810	2,500	650
n-Butyl Acetate	4,400	930	2,200	460
Tetrachloroethene (PERC)	2,500	380	ND	ND
Tentatively Identified Compounds (TICs) (TO-15)				
Propane	18,000		16,000	
Isobutane	41,000		38,000	
n-Butane	39,000		34,000	
2-Methylbutane	23,000		22,000	
n-Pentane	16,000		14,000	
n-Propyl acetate	14,000		9,300	
NIOSH Method 6015				
Ammonia	ND	ND	ND	ND
NIOSH Method 1552				
d-Limonene		3900		5300

ND = Not detected.

Weather conditions during the test were reasonable and conducive to testing. Winds were light and variable with overcast skies. Precipitation during the testing at the Tullytown Landfill was zero (0) and temperatures ranged from the upper 40s to low 50s (°F). Table B-3 provides a summary of wind conditions during the test.

Table B-3. Representative Wind Speed and Direction During Sampling

Date/Time (GMT)	Time (EST)	WS (MPH)	WD (deg)
Trenton Airport			
12/2/15 0:00	0900	0	0
12/2/15 10:00	1000	0	0
12/2/15 11:00	1100	3.5	350
12/2/15 12:00	1200	0	0
12/2/15 13:00	1300	0	0
Bristol PADEP			
12/2/2015 14:00	0900	2.1	149
12/2/2015 15:00	1000	1.5	75
12/2/2015 16:00	1100	1.5	114
12/2/2015 17:00	1200	1.4	127
12/2/2015 18:00	1300	0.6	226

ESTIMATION OF VERTICAL GAS VELOCITY FROM THE LANDFILL WORKING FACE

Estimates of potential emission rates from the landfill working face are required for use in an air dispersion model to calculate potential ambient air concentrations in areas surrounding the landfill. The potential working face emission rates were calculated based on the measured concentrations in working face gas, as described above, and the vertical velocity or gas diffusion rate at the working face.

SCS Engineers has performed laboratory experiments to determine the upper bound vertical velocity of working face emissions and is currently authoring a paper for publication (SCS 2014). The experiments were performed to estimate the vertical diffusion velocity in three different covering media: dry wood chips and small sized solid waste, wet wood chips and small sized solid waste, and finally sandy intermediate soil.

As a result of the data obtained from these laboratory experiments, the highest measured vertical diffusion rate, or vertical gas velocity, of 6.35×10^{-3} m/sec was observed. When considering this rate for real-world operational applications, it is clear that this vertical velocity applied over a working face area is not sustainable for long periods of time since there is not enough gaseous air volume in the deposited solid waste to generate such a gas velocity. As a result, the maximum experimental laboratory observation would vastly overestimate the vertical

gas velocity across the working face, and thus overestimate potential working face emission rates.

In typical landfill operations, waste becomes compacted when a force (the weight and motion of the compactor) moves over it, crushing out the air voids, shredding the material and binding it to other waste (Waste Management World Newsletter 2014). In the absence of other emission sources, such as leaks from the landfill gas system, the displacement of air from the void space represents the dominant source of gaseous volume flow related to emissions.

A search of solid waste literature indicates that initial compaction of typical municipal waste is approximately 50%. The waste is generally deposited in lifts that are about 3 feet (0.9 m) or less in depth, and prior to compacting is 50% solid and 50% void space (Hanson et al. 2010). Based upon an operating speed of 3 mph (4,828 m/hr) for a CAT 386 or similar compactor performing two compaction runs, it will take about 50 minutes to 1 hour to complete a working face area of 200 ft x 250 ft (61 m x 76 m). Therefore the average vertical velocity over the hour would be 6.4×10^{-5} m/sec. While this is a conservative value, it is considered reasonably representative of escaping gases from working face areas.

REFERENCES

Eklund, B. 1992. "Practical guidance for flux chamber measurements of fugitive volatile organic emission rates." *J. Air & Waste Management Assoc.* 42:1583-1591.

Li, D., Lu, W., Liu, Y., Guo, H. et al. 2015. "Analysis of relative concentration of ethanol and other odorous compounds (OCs) emitted from the working surface at a landfill in China." *Plos One* 10(3):e0119305.

SCS Tracer Environmental. 2014. Prima Deshecha Landfill Study. "Tracer Experiments to Measure Vertical Diffusion of Gases in Landfill Placements under Moderate Wind Conditions." Orange County Waste and Recycling, Anaheim, CA.

Hanson, J., Yesiller, N., et al. 2010. "Compaction Characteristics of Municipal Waste." http://gwri.calpoly.edu/media/Research_Papers/Compaction_Characteristics_of_Municipal_Solid_Waste.pdf.

Waste Management World Newsletter. 2014. "A compact guide to landfill operation: Machinery, management and misconceptions."



07-Dec-2015

Tom Rappolt
SCS Tracer Environmental
5963 La Place Court
Suite 207
Carlsbad, CA 92008

Tel: (760) 304-5088
Fax:

Re: Tullytown WF

Work Order: 1512207

Dear Tom,

ALS Environmental received 2 samples on 04-Dec-2015 11:15 AM for the analyses presented in the following report.

The analytical data provided relates directly to the samples received by ALS Environmental and for only the analyses requested.

QC sample results for this data met laboratory specifications. Any exceptions are noted in the Case Narrative, or noted with qualifiers in the report or QC batch information. Should this laboratory report need to be reproduced, it should be reproduced in full unless written approval has been obtained from ALS Laboratory Group. Samples will be disposed in 30 days unless storage arrangements are made.

The total number of pages in this report is 7.

If you have any questions regarding this report, please feel free to contact me.

Sincerely,

Shawn Smythe

Electronically approved by: Shawn Smythe

Shawn Smythe
Project Manager

ADDRESS 4388 Glendale Milford Rd. Cincinnati, Ohio 45242 | PHONE (513) 733-5336 | FAX (513) 733-5347

ALS GROUP USA, CORP. Part of the ALS Group. An ALS Limited Company.



www.alsglobal.com

RIGHT SOLUTIONS. RIGHT PEOPLE.

Client: SCS Tracer Environmental
Project: Tullytown WF
Work Order: 1512207

Work Order Sample Summary

<u>Lab Samp ID</u>	<u>Client Sample ID</u>	<u>Matrix</u>	<u>Tag Number</u>	<u>Collection Date</u>	<u>Date Received</u>	<u>Hold</u>
1512207-01	2-58186045442	Air		12/2/2015	12/4/2015 11:15	<input type="checkbox"/>
1512207-02	3-58182045400	Air		12/2/2015	12/4/2015 11:15	<input type="checkbox"/>

ALS Environmental

Date: 07-Dec-15

Client: SCS Tracer Environmental
Project: Tullytown WF
Work Order: 1512207

Case Narrative

The analytical data provided relates directly to the samples received by ALS Laboratory Group and for only the analyses requested.

Results relate only to the items tested and are not blank corrected unless indicated.

QC sample results for this data met laboratory specifications. Any exceptions are noted in the Case Narrative, or noted with qualifiers in the report or QC batch information. Should this laboratory report need to be reproduced, it should be reproduced in full unless written approval has been obtained from ALS Laboratory Group. Samples will be disposed in 30 days unless storage arrangements are made.

ALS Environmental

Date: 07-Dec-15

Client: SCS Tracer Environmental
Project: Tullytown WF

Work Order: 1512207

Analytical ResultsLab ID: 1512207-01A
Client Sample ID: 2-58186045442Collection Date: 12/2/2015
Matrix: AIR

Analyses

AMMONIA BY NIOSH 6015 MOD.	Method: N6015	Air Volume (L): 1.5	Analyst: SBD
Date Analyzed: 12/7/2015	Reporting Limit		
	µg/sample	µg/sample	mg/m3
Ammonia	ND	6.0	<4.0

Lab ID: 1512207-02A
Client Sample ID: 3-58182045400Collection Date: 12/2/2015
Matrix: AIR

Analyses

AMMONIA BY NIOSH 6015 MOD.	Method: N6015	Air Volume (L): 1.5	Analyst: SBD
Date Analyzed: 12/7/2015	Reporting Limit		
	µg/sample	µg/sample	mg/m3
Ammonia	ND	6.0	<4.0

Note:

ALS Environmental

Date: 07-Dec-15

Client: SCS Tracer Environmental
 Work Order: 1512207
 Project: Tullytown WF

QC BATCH REPORT

Batch ID: R124086 Instrument ID: UVVIS1 Method: N6015

MBLK	Sample ID: MB-R124086-R124086		Units: µg/sample		Analysis Date: 12/7/2015					
Client ID:	Run ID: UVVIS1_151207B		SeqNo: 1185155		Prep Date: DF: 1					
Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual

Ammonia ND 6.0

LCS	Sample ID: LCS-R124086-R124086		Units: µg/sample		Analysis Date: 12/7/2015					
Client ID:	Run ID: UVVIS1_151207B		SeqNo: 1185156		Prep Date: DF: 1					
Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual

Ammonia 12.3 6.0 11.4 0 108 26.1-151 0

LCSD	Sample ID: LCSD-R124086		Units: µg/sample		Analysis Date: 12/7/2015					
Client ID:	Run ID: UVVIS1_151207B		SeqNo: 1185159		Prep Date: DF: 1					
Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual

Ammonia 11.3 6.0 11.4 0 99.1 26.1-151 12.3 8.47 20

The following samples were analyzed in this batch: 1512207-01A 1512207-02A

Note: See Qualifiers Page for a list of Qualifiers and their explanation.

Client: SCS Tracer Environmental
Project: Tullytown WF
WorkOrder: 1512207

**QUALIFIERS,
ACRONYMS, UNITS**

<u>Qualifier</u>	<u>Description</u>
*	Value exceeds Regulatory Limit
a	Not accredited
B	Analyte detected in the associated Method Blank above the Reporting Limit
E	Value above quantitation range
H	Analyzed outside of Holding Time
J	Analyte detected below quantitation limit
n	Not offered for accreditation
ND	Not Detected at the Reporting Limit
O	Sample amount is > 4 times amount spiked
P	Dual Column results percent difference > 40%
R	RPD above laboratory control limit
S	Spike Recovery outside laboratory control limits
U	Analyzed but not detected above the MDL

<u>Acronym</u>	<u>Description</u>
DUP	Method Duplicate
E	EPA Method
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
MBLK	Method Blank
MDL	Method Detection Limit
MQL	Method Quantitation Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
PDS	Post Digestion Spike
PQL	Practical Quantitation Limit
SDL	Sample Detection Limit
SW	SW-846 Method

<u>Units Reported</u>	<u>Description</u>
µg/sample	

ALS Environmental

Sample Receipt Checklist

Client Name: SCSTRACER-CARLSBAD

Date/Time Received: 04-Dec-15 11:15

Work Order: 1512207

Received by: SNH

Checklist completed by: Jan Wilcox 04-Dec-15
eSignature Date

Reviewed by: Shawn Smythe 04-Dec-15
eSignature Date

Matrices:

Carrier name: FedEx

- | | | | |
|---|---|-----------------------------|---|
| Shipping container/cooler in good condition? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | Not Present <input type="checkbox"/> |
| Custody seals intact on shipping container/cooler? | Yes <input type="checkbox"/> | No <input type="checkbox"/> | Not Present <input checked="" type="checkbox"/> |
| Custody seals intact on sample bottles? | Yes <input type="checkbox"/> | No <input type="checkbox"/> | Not Present <input checked="" type="checkbox"/> |
| Chain of custody present? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | |
| Chain of custody signed when relinquished and received? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | |
| Chain of custody agrees with sample labels? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | |
| Samples in proper container/bottle? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | |
| Sample containers intact? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | |
| Sufficient sample volume for indicated test? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | |
| All samples received within holding time? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | |
| Container/Temp Blank temperature in compliance? | Yes <input checked="" type="checkbox"/> | No <input type="checkbox"/> | |

Temperature(s)/Thermometer(s):

Cooler(s)/Kit(s):

Water - VOA vials have zero headspace?

Yes No No VOA vials submitted

Water - pH acceptable upon receipt?

Yes No N/A

pH adjusted?

Yes No N/A

pH adjusted by:

Login Notes:

Client Contacted:

Date Contacted:

Person Contacted:

Contacted By:

Regarding:

Comments:

CorrectiveAction:



07-Dec-2015

Tom Rappolt
SCS Tracer Environmental
5963 La Place Court
Suite 207
Carlsbad, CA 92008

Tel: (760) 304-5088
Fax:

Re: Tullytown WF

Work Order: 1512208

Dear Tom,

ALS Environmental received 2 samples on 04-Dec-2015 11:15 AM for the analyses presented in the following report.

The analytical data provided relates directly to the samples received by ALS Environmental and for only the analyses requested.

QC sample results for this data met laboratory specifications. Any exceptions are noted in the Case Narrative, or noted with qualifiers in the report or QC batch information. Should this laboratory report need to be reproduced, it should be reproduced in full unless written approval has been obtained from ALS Laboratory Group. Samples will be disposed in 30 days unless storage arrangements are made.

The total number of pages in this report is 7.

If you have any questions regarding this report, please feel free to contact me.

Sincerely,

Shawn Smythe

Electronically approved by: Shawn Smythe

Shawn Smythe
Project Manager

Client: SCS Tracer Environmental
Project: Tullytown WF
Work Order: 1512208

Work Order Sample Summary

<u>Lab Samp ID</u>	<u>Client Sample ID</u>	<u>Matrix</u>	<u>Tag Number</u>	<u>Collection Date</u>	<u>Date Received</u>	<u>Hold</u>
1512208-01	2-56820743586	Air		12/2/2015	12/4/2015 11:15	<input type="checkbox"/>
1512208-02	3-56820743650	Air		12/2/2015	12/4/2015 11:15	<input type="checkbox"/>

Client: SCS Tracer Environmental
Project: Tullytown WF
Work Order: 1512208

Case Narrative

The analytical data provided relates directly to the samples received by ALS Laboratory Group and for only the analyses requested.

Results relate only to the items tested and are not blank corrected unless indicated.

QC sample results for this data met laboratory specifications. Any exceptions are noted in the Case Narrative, or noted with qualifiers in the report or QC batch information. Should this laboratory report need to be reproduced, it should be reproduced in full unless written approval has been obtained from ALS Laboratory Group. Samples will be disposed in 30 days unless storage arrangements are made.

Client: SCS Tracer Environmental
 Project: Tullytown WF

Work Order: 1512208

Analytical Results

Lab ID: 1512208-01A
 Client Sample ID: 2-56820743586

Collection Date: 12/2/2015
 Matrix: AIR

Analyses

ANALYTE(S) BY GAS CHROMATOGRAPHY		Method: IH-001	Air Volume (L): 1.5	Analyst: TSA
Date Analyzed: 12/7/2015		Reporting Limit		
	µg/sample	µg/sample	ppm	
d-Limonene	33	10	3.9	
Pinene	ND	10	<1.2	

Lab ID: 1512208-02A
 Client Sample ID: 3-56820743650

Collection Date: 12/2/2015
 Matrix: AIR

Analyses

ANALYTE(S) BY GAS CHROMATOGRAPHY		Method: IH-001	Air Volume (L): 1.5	Analyst: TSA
Date Analyzed: 12/7/2015		Reporting Limit		
	µg/sample	µg/sample	ppm	
d-Limonene	44	10	5.3	
Pinene	ND	10	<1.2	

Note:

ALS Environmental

Date: 07-Dec-15

Client: SCS Tracer Environmental

QC BATCH REPORT

Work Order: 1512208

Project: Tullytown WF

Batch ID: 32484 Instrument ID: GC10 Method: IH-001

MBLK		Sample ID: MBLK-32484-32484			Units: µg/sample		Analysis Date: 12/7/2015			
Client ID:		Run ID: GC10_151207A			SeqNo: 1185246		Prep Date: 12/7/2015		DF: 1	
Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
d-Limonene	ND	10								
Pinene	ND	10								

LCS		Sample ID: LCS-32484-32484			Units: µg/sample		Analysis Date: 12/7/2015			
Client ID:		Run ID: GC10_151207A			SeqNo: 1185247		Prep Date: 12/7/2015		DF: 1	
Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
d-Limonene	95	10	84.1	0	113	70-130	0			
Pinene	93.2	10	86.5	0	108		0			

LCSD		Sample ID: LCSD-32484-32484			Units: µg/sample		Analysis Date: 12/7/2015			
Client ID:		Run ID: GC10_151207A			SeqNo: 1185250		Prep Date: 12/7/2015		DF: 1	
Analyte	Result	PQL	SPK Val	SPK Ref Value	%REC	Control Limit	RPD Ref Value	%RPD	RPD Limit	Qual
d-Limonene	91.4	10	84.1	0	109	70-130	95	3.86	20	
Pinene	91.3	10	86.5	0	106		93.2	2.06		

The following samples were analyzed in this batch: 1512208-01A 1512208-02A

Note: See Qualifiers Page for a list of Qualifiers and their explanation.

Client: SCS Tracer Environmental
Project: Tullytown WF
WorkOrder: 1512208

**QUALIFIERS,
ACRONYMS, UNITS**

<u>Qualifier</u>	<u>Description</u>
*	Value exceeds Regulatory Limit
a	Not accredited
B	Analyte detected in the associated Method Blank above the Reporting Limit
E	Value above quantitation range
H	Analyzed outside of Holding Time
J	Analyte detected below quantitation limit
n	Not offered for accreditation
ND	Not Detected at the Reporting Limit
O	Sample amount is > 4 times amount spiked
P	Dual Column results percent difference > 40%
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S	Spike Recovery outside laboratory control limits
U	Analyzed but not detected above the MDL

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LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
MBLK	Method Blank
MDL	Method Detection Limit
MQL	Method Quantitation Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
PDS	Post Digestion Spike
PQL	Practical Quantitation Limit
SDL	Sample Detection Limit
SW	SW-846 Method

<u>Units Reported</u>	<u>Description</u>
µg/sample	

ALS Environmental

Sample Receipt Checklist

Client Name: SCSTRACER-CARLSBAD

Date/Time Received: 04-Dec-15 11:15

Work Order: 1512208

Received by: SNH

Checklist completed by: Jan Wilcox 04-Dec-15
eSignature Date

Reviewed by: Shawn Smythe 07-Dec-15
eSignature Date

Matrices:

Carrier name: FedEx

- Shipping container/cooler in good condition? Yes [checked] No [] Not Present []
Custody seals intact on shipping container/cooler? Yes [] No [] Not Present [checked]
Custody seals intact on sample bottles? Yes [] No [] Not Present [checked]
Chain of custody present? Yes [checked] No []
Chain of custody signed when relinquished and received? Yes [checked] No []
Chain of custody agrees with sample labels? Yes [checked] No []
Samples in proper container/bottle? Yes [checked] No []
Sample containers intact? Yes [checked] No []
Sufficient sample volume for indicated test? Yes [checked] No []
All samples received within holding time? Yes [checked] No []
Container/Temp Blank temperature in compliance? Yes [checked] No []

Temperature(s)/Thermometer(s): [] []

Cooler(s)/Kit(s): []

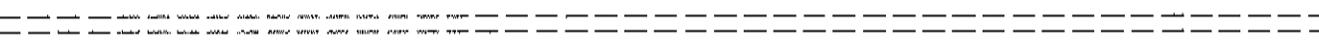
Water - VOA vials have zero headspace? Yes [checked] No [] No VOA vials submitted [checked]

Water - pH acceptable upon receipt? Yes [checked] No [] N/A [checked]

pH adjusted? Yes [checked] No [] N/A [checked]

pH adjusted by: []

Login Notes:



Client Contacted: Date Contacted: Person Contacted:

Contacted By: Regarding:

Comments: []

CorrectiveAction: []



2655 Park Center Dr., Suite A
Simi Valley, CA 93065
T: +1 805 526 7161
F: +1 805 526 7270
www.alsglobal.com

LABORATORY REPORT

December 4, 2015

Steve Kerrin
SCS Tracer
5963 La Place Court, Suite 207
Carlsbad, CA 92008

RE: Trolley Town WF

Dear Steve:

Enclosed are the results of the samples submitted to our laboratory on December 3, 2015. For your reference, these analyses have been assigned our service request number P1505219.

All analyses were performed according to our laboratory's NELAP and DoD-ELAP-approved quality assurance program. The test results meet requirements of the current NELAP and DoD-ELAP standards, where applicable, and except as noted in the laboratory case narrative provided. For a specific list of NELAP and DoD-ELAP-accredited analytes, refer to the certifications section at www.alsglobal.com. Results are intended to be considered in their entirety and apply only to the samples analyzed and reported herein.

If you have any questions, please call me at (805) 526-7161.

Respectfully submitted,

ALS | Environmental

By Sue Anderson at 12:57 pm, Dec 04, 2015
Sue Anderson
Project Manager



2655 Park Center Dr., Suite A
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F: +1 805 526 7270
www.alsglobal.com

Client: SCS Tracer
Project: Trolley Town WF

Service Request No: P1505219

CASE NARRATIVE

The samples were received intact under chain of custody on December 3, 2015 and were stored in accordance with the analytical method requirements. Please refer to the sample acceptance check form for additional information. The results reported herein are applicable only to the condition of the samples at the time of sample receipt.

Sulfur Analysis

The samples were analyzed for twenty sulfur compounds per ASTM D 5504-12 using a gas chromatograph equipped with a sulfur chemiluminescence detector (SCD). All compounds with the exception of hydrogen sulfide and carbonyl sulfide are quantitated against the initial calibration curve for methyl mercaptan. This method is included on the laboratory's NELAP scope of accreditation, however it is not part of the DoD-ELAP or AIHA-LAP accreditation.

Volatile Organic Compound Analysis

The samples were also analyzed for volatile organic compounds and tentatively identified compounds in accordance with EPA Method TO-15 from the Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition (EPA/625/R-96/010b), January, 1999. This procedure is described in laboratory SOP VOA-TO15. The analytical system was comprised of a gas chromatograph / mass spectrometer (GC/MS) interfaced to a whole-air preconcentrator. This method is included on the laboratory's NELAP and DoD-ELAP scope of accreditation, however it is not part of the AIHA-LAP accreditation. Any analytes flagged with an X are not included on the NELAP or DoD-ELAP accreditation.

The upper control criterion was exceeded for Naphthalene in the Continuing Calibration Verification (CCV) analyzed on December 3, 2015 and for 1,2-Dibromo-3-chloropropane, 1,2,4-Trichlorobenzene and Naphthalene in the CCV analyzed on December 4, 2015. Since the apparent problem equates to a potential high bias and the field samples analyzed in this sequence did not contain the analytes in question, the data quality has not been affected. No corrective action was required.

The canisters were cleaned, prior to sampling, down to the method reporting limit (MRL) reported for this project. Please note, projects which require reporting below the MRL could have results between the MRL and method detection limit (MDL) that are biased high.

The results of analyses are given in the attached laboratory report. All results are intended to be considered in their entirety, and ALS Environmental (ALS) is not responsible for utilization of less than the complete report.

Use of ALS Environmental (ALS)'s Name. Client shall not use ALS's name or trademark in any marketing or reporting materials, press releases or in any other manner ("Materials") whatsoever and shall not attribute to ALS any test result, tolerance or specification derived from ALS's data ("Attribution") without ALS's prior written consent, which may be withheld by ALS for any reason in its sole discretion. To request ALS's consent, Client shall provide copies of the proposed Materials or Attribution and describe in writing Client's proposed use of such Materials or Attribution. If ALS has not provided written approval of the Materials or Attribution within ten (10) days of receipt from Client, Client's request to use ALS's name or trademark in any Materials or Attribution shall be deemed denied. ALS may, in its discretion, reasonably charge Client for its time in reviewing Materials or Attribution requests. Client acknowledges and agrees that the unauthorized use of ALS's name or trademark may cause ALS to incur irreparable harm for which the recovery of money damages will be inadequate. Accordingly, Client acknowledges and agrees that a violation shall justify preliminary injunctive relief. For questions contact the laboratory.



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 F: +1 805 526 7270
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ALS Environmental – Simi Valley

CERTIFICATIONS, ACCREDITATIONS, AND REGISTRATIONS

Agency	Web Site	Number
AIHA	http://www.aihaaccreditedlabs.org	101661
Arizona DHS	http://www.azdhs.gov/lab/license/env.htm	AZ0694
DoD ELAP	http://www.pjlabs.com/search-accredited-labs	L14-2-R1
Florida DOH (NELAP)	http://www.doh.state.fl.us/lab/EnvLabCert/WaterCert.htm	E871020
Maine DHHS	http://www.maine.gov/dhhs/mecdc/environmental-health/water/dwp-services/labcert/labcert.htm	2014025
Minnesota DOH (NELAP)	http://www.health.state.mn.us/accreditation	977273
New Jersey DEP (NELAP)	http://www.nj.gov/dep/oqa/	CA009
New York DOH (NELAP)	http://www.wadsworth.org/labcert/elap/elap.html	11221
Oregon PHD (NELAP)	http://public.health.oregon.gov/LaboratoryServices/EnvironmentalLaboratoryAccreditation/Pages/index.aspx	4068-001
Pennsylvania DEP	http://www.depweb.state.pa.us/labs	68-03307 (Registration)
Texas CEQ (NELAP)	http://www.tceq.texas.gov/field/ga/env_lab_accreditation.html	T104704413-15-6
Utah DOH (NELAP)	http://www.health.utah.gov/lab/labimp/certification/index.html	CA01627201 5-5
Washington DOE	http://www.ecy.wa.gov/programs/eap/labs/lab-accreditation.html	C946

Analyses were performed according to our laboratory's NELAP and DoD-ELAP approved quality assurance program. A complete listing of specific NELAP and DoD-ELAP certified analytes can be found in the certifications section at www.alsglobal.com, or at the accreditation body's website.

Each of the certifications listed above have an explicit Scope of Accreditation that applies to specific matrices/methods/analytes; therefore, please contact the laboratory for information corresponding to a particular certification.

ALS ENVIRONMENTAL

DETAIL SUMMARY REPORT

Client: SCS Tracer
 Project ID: Trolley Town WP

Service Request: P1505219

Date Received: 12/3/2015
 Time Received: 10:05

ASTM D 5504-12 - Sulfur Can
 TO-15 - VOC Cans

Client Sample ID	Lab Code	Matrix	Date Collected	Time Collected	Container ID	P11 (psig)	P11 (psig)	ASTM D 5504-12 - Sulfur Can	TO-15 - VOC Cans
2-12-2-2015	P1505219-001	Air	12/2/2015	11:33	AS00199	-5.88	3.89	X	X
3-12-2-2015	P1505219-002	Air	12/2/2015	12:05	AS00113	-5.59	4.22	X	X

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client: SCS Tracer
Client Sample ID: 2-12-2-2015
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P1505219-001

Test Code: ASTM D 5504-12
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Mike Conejo
Sample Type: 6.0 L Silonite Canister
Test Notes:
Container ID: AS00199

Date Collected: 12/2/15
Time Collected: 11:33
Date Received: 12/3/15
Date Analyzed: 12/3/15
Time Analyzed: 12:01
Volume(s) Analyzed: 1.0 ml(s)

Initial Pressure (psig): -5.88 **Final Pressure (psig):** 3.89

Canister Dilution Factor: 2.11

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	ND	15	ND	11	
463-58-1	Carbonyl Sulfide	160	26	64	11	
74-93-1	Methyl Mercaptan	59	21	30	11	
75-08-1	Ethyl Mercaptan	ND	27	ND	11	
75-18-3	Dimethyl Sulfide	240	27	95	11	
75-15-0	Carbon Disulfide	110	16	35	5.3	
75-33-2	Isopropyl Mercaptan	ND	33	ND	11	
75-66-1	tert-Butyl Mercaptan	ND	39	ND	11	
107-03-9	n-Propyl Mercaptan	ND	33	ND	11	
624-89-5	Ethyl Methyl Sulfide	ND	33	ND	11	
110-02-1	Thiophene	ND	36	ND	11	
513-44-0	Isobutyl Mercaptan	ND	39	ND	11	
352-93-2	Diethyl Sulfide	ND	39	ND	11	
109-79-5	n-Butyl Mercaptan	ND	39	ND	11	
624-92-0	Dimethyl Disulfide	150	20	40	5.3	
616-44-4	3-Methylthiophene	ND	42	ND	11	
110-01-0	Tetrahydrothiophene	ND	38	ND	11	
638-02-8	2,5-Dimethylthiophene	ND	48	ND	11	
872-55-9	2-Ethylthiophene	ND	48	ND	11	
110-81-6	Diethyl Disulfide	ND	26	ND	5.3	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client: **SCS Tracer**
 Client Sample ID: **3-12-2-2015**
 Client Project ID: **Trolley Town WF**

ALS Project ID: P1505219
 ALS Sample ID: P1505219-002

Test Code: ASTM D 5504-12
 Instrument ID: Agilent 6890A/GC13/SCD
 Analyst: Mike Conejo
 Sample Type: 6.0 L Silonite Canister
 Test Notes:
 Container ID: AS00113

Date Collected: 12/2/15
 Time Collected: 12:05
 Date Received: 12/3/15
 Date Analyzed: 12/3/15
 Time Analyzed: 12:17
 Volume(s) Analyzed: 1.0 ml(s)

Initial Pressure (psig): -5.59 Final Pressure (psig): 4.22

Canister Dilution Factor: 2.08

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	ND	14	ND	10	
463-58-1	Carbonyl Sulfide	290	26	120	10	
74-93-1	Methyl Mercaptan	65	20	33	10	
75-08-1	Ethyl Mercaptan	ND	26	ND	10	
75-18-3	Dimethyl Sulfide	260	26	100	10	
75-15-0	Carbon Disulfide	130	16	41	5.2	
75-33-2	Isopropyl Mercaptan	ND	32	ND	10	
75-66-1	tert-Butyl Mercaptan	ND	38	ND	10	
107-03-9	n-Propyl Mercaptan	ND	32	ND	10	
624-89-5	Ethyl Methyl Sulfide	ND	32	ND	10	
110-02-1	Thiophene	ND	36	ND	10	
513-44-0	Isobutyl Mercaptan	ND	38	ND	10	
352-93-2	Diethyl Sulfide	ND	38	ND	10	
109-79-5	n-Butyl Mercaptan	ND	38	ND	10	
624-92-0	Dimethyl Disulfide	150	20	38	5.2	
616-44-4	3-Methylthiophene	ND	42	ND	10	
110-01-0	Tetrahydrothiophene	ND	37	ND	10	
638-02-8	2,5-Dimethylthiophene	ND	48	ND	10	
872-55-9	2-Ethylthiophene	ND	48	ND	10	
110-81-6	Diethyl Disulfide	ND	26	ND	5.2	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 1

Client: SCS Tracer
Client Sample ID: Method Blank
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151203-MB

Test Code: ASTM D 5504-12
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Mike Conejo
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Time Collected: NA
Date Received: NA
Date Analyzed: 12/03/15
Time Analyzed: 08:08
Volume(s) Analyzed: 1.0 ml(s)

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
7783-06-4	Hydrogen Sulfide	ND	7.0	ND	5.0	
463-58-1	Carbonyl Sulfide	ND	12	ND	5.0	
74-93-1	Methyl Mercaptan	ND	9.8	ND	5.0	
75-08-1	Ethyl Mercaptan	ND	13	ND	5.0	
75-18-3	Dimethyl Sulfide	ND	13	ND	5.0	
75-15-0	Carbon Disulfide	ND	7.8	ND	2.5	
75-33-2	Isopropyl Mercaptan	ND	16	ND	5.0	
75-66-1	tert-Butyl Mercaptan	ND	18	ND	5.0	
107-03-9	n-Propyl Mercaptan	ND	16	ND	5.0	
624-89-5	Ethyl Methyl Sulfide	ND	16	ND	5.0	
110-02-1	Thiophene	ND	17	ND	5.0	
513-44-0	Isobutyl Mercaptan	ND	18	ND	5.0	
352-93-2	Diethyl Sulfide	ND	18	ND	5.0	
109-79-5	n-Butyl Mercaptan	ND	18	ND	5.0	
624-92-0	Dimethyl Disulfide	ND	9.6	ND	2.5	
616-44-4	3-Methylthiophene	ND	20	ND	5.0	
110-01-0	Tetrahydrothiophene	ND	18	ND	5.0	
638-02-8	2,5-Dimethylthiophene	ND	23	ND	5.0	
872-55-9	2-Ethylthiophene	ND	23	ND	5.0	
110-81-6	Diethyl Disulfide	ND	12	ND	2.5	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE SUMMARY

Page 1 of 1

Client: SCS Tracer
Client Sample ID: Lab Control Sample
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
ALS Sample ID: P151203-LCS

Test Code: ASTM D 5504-12
Instrument ID: Agilent 6890A/GC13/SCD
Analyst: Mike Conejo
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/03/15
Volume(s) Analyzed: NA ml(s)

CAS #	Compound	Spike Amount ppbV	Result ppbV	% Recovery	ALS	Data Qualifier
					Acceptance Limits	
7783-06-4	Hydrogen Sulfide	2,000	1,690	85	65-138	
463-58-1	Carbonyl Sulfide	2,000	1,660	83	60-135	
74-93-1	Methyl Mercaptan	2,000	1,690	85	57-140	

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 4

Client: SCS Tracer
Client Sample ID: 2-12-2-2015
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P1505219-001

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:
Container ID: AS00199

Date Collected: 12/2/15
Date Received: 12/3/15
Date Analyzed: 12/4/15
Volume(s) Analyzed: 0.00050 Liter(s)

Initial Pressure (psig): -5.88 Final Pressure (psig): 3.89

Canister Dilution Factor: 2.11

CAS #	Compound	Result	MRL	Result	MRL	Data Qualifier
		µg/m ³	µg/m ³	ppbV	ppbV	
115-07-1	Propene	ND	2,100	ND	1,200	
75-71-8	Dichlorodifluoromethane (CFC 12)	ND	2,100	ND	430	
74-87-3	Chloromethane	ND	2,100	ND	1,000	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	ND	2,100	ND	300	
75-01-4	Vinyl Chloride	ND	2,100	ND	830	
106-99-0	1,3-Butadiene	ND	2,100	ND	950	
74-83-9	Bromomethane	ND	2,100	ND	540	
75-00-3	Chloroethane	ND	2,100	ND	800	
64-17-5	Ethanol	100,000	21,000	54,000	11,000	
75-05-8	Acetonitrile	ND	2,100	ND	1,300	
107-02-8	Acrolein	ND	8,400	ND	3,700	
67-64-1	Acetone	ND	21,000	ND	8,900	
75-69-4	Trichlorofluoromethane	3,000	2,100	540	380	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	21,000	ND	8,600	
107-13-1	Acrylonitrile	ND	2,100	ND	970	
75-35-4	1,1-Dichloroethene	ND	2,100	ND	530	
75-09-2	Methylene Chloride	ND	2,100	ND	610	
107-05-1	3-Chloro-1-propene (Allyl Chloride)	ND	2,100	ND	670	
76-13-1	Trichlorotrifluoroethane	ND	2,100	ND	280	
75-15-0	Carbon Disulfide	ND	21,000	ND	6,800	
156-60-5	trans-1,2-Dichloroethene	ND	2,100	ND	530	
75-34-3	1,1-Dichloroethane	ND	2,100	ND	520	
1634-04-4	Methyl tert-Butyl Ether	ND	2,100	ND	590	
108-05-4	Vinyl Acetate	ND	21,000	ND	6,000	
78-93-3	2-Butanone (MEK)	ND	21,000	ND	7,200	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 2 of 4

Client: SCS Tracer
Client Sample ID: 2-12-2-2015
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P1505219-001

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:
Container ID: AS00199

Date Collected: 12/2/15
Date Received: 12/3/15
Date Analyzed: 12/4/15
Volume(s) Analyzed: 0.00050 Liter(s)

Initial Pressure (psig): -5.88 Final Pressure (psig): 3.89

Canister Dilution Factor: 2.11

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
156-59-2	cis-1,2-Dichloroethene	ND	2,100	ND	530	
141-78-6	Ethyl Acetate	860,000	4,200	240,000	1,200	
110-54-3	n-Hexane	ND	2,100	ND	600	
67-66-3	Chloroform	ND	2,100	ND	430	
109-99-9	Tetrahydrofuran (THF)	ND	2,100	ND	720	
107-06-2	1,2-Dichloroethane	ND	2,100	ND	520	
71-55-6	1,1,1-Trichloroethane	ND	2,100	ND	390	
71-43-2	Benzene	ND	2,100	ND	660	
56-23-5	Carbon Tetrachloride	ND	2,100	ND	340	
110-82-7	Cyclohexane	ND	4,200	ND	1,200	
78-87-5	1,2-Dichloropropane	ND	2,100	ND	460	
75-27-4	Bromodichloromethane	ND	2,100	ND	320	
79-01-6	Trichloroethene	ND	2,100	ND	390	
123-91-1	1,4-Dioxane	ND	2,100	ND	590	
80-62-6	Methyl Methacrylate	ND	4,200	ND	1,000	
142-82-5	n-Heptane	ND	2,100	ND	520	
10061-01-5	cis-1,3-Dichloropropene	ND	2,100	ND	460	
108-10-1	4-Methyl-2-pentanone	ND	2,100	ND	520	
10061-02-6	trans-1,3-Dichloropropene	ND	2,100	ND	460	
79-00-5	1,1,2-Trichloroethane	ND	2,100	ND	390	
108-88-3	Toluene	3,000	2,100	810	560	
591-78-6	2-Hexanone	ND	2,100	ND	520	
124-48-1	Dibromochloromethane	ND	2,100	ND	250	
106-93-4	1,2-Dibromoethane	ND	2,100	ND	270	
123-86-4	n-Butyl Acetate	4,400	2,100	930	440	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 3 of 4

Client: SCS Tracer
Client Sample ID: 2-12-2-2015
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P1505219-001

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:
Container ID: AS00199

Date Collected: 12/2/15
Date Received: 12/3/15
Date Analyzed: 12/4/15
Volume(s) Analyzed: 0.00050 Liter(s)

Initial Pressure (psig): -5.88 Final Pressure (psig): 3.89

Canister Dilution Factor: 2.11

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
111-65-9	n-Octane	ND	2,100	ND	450	
127-18-4	Tetrachloroethene	2,500	2,100	380	310	
108-90-7	Chlorobenzene	ND	2,100	ND	460	
100-41-4	Ethylbenzene	ND	2,100	ND	490	
179601-23-1	m,p-Xylenes	ND	4,200	ND	970	
75-25-2	Bromoform	ND	2,100	ND	200	
100-42-5	Styrene	ND	2,100	ND	500	
95-47-6	o-Xylene	ND	2,100	ND	490	
111-84-2	n-Nonane	ND	2,100	ND	400	
79-34-5	1,1,2,2-Tetrachloroethane	ND	2,100	ND	310	
98-82-8	Cumene	ND	2,100	ND	430	
80-56-8	alpha-Pinene	ND	2,100	ND	380	
103-65-1	n-Propylbenzene	ND	2,100	ND	430	
622-96-8	4-Ethyltoluene	ND	2,100	ND	430	
108-67-8	1,3,5-Trimethylbenzene	ND	2,100	ND	430	
95-63-6	1,2,4-Trimethylbenzene	ND	2,100	ND	430	
100-44-7	Benzyl Chloride	ND	2,100	ND	410	
541-73-1	1,3-Dichlorobenzene	ND	2,100	ND	350	
106-46-7	1,4-Dichlorobenzene	ND	2,100	ND	350	
95-50-1	1,2-Dichlorobenzene	ND	2,100	ND	350	
5989-27-5	d-Limonene	10,000	2,100	1,900	380	
96-12-8	1,2-Dibromo-3-chloropropane	ND	2,100	ND	220	
120-82-1	1,2,4-Trichlorobenzene	ND	2,100	ND	280	
91-20-3	Naphthalene	ND	2,100	ND	400	
87-68-3	Hexachlorobutadiene	ND	2,100	ND	200	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 4 of 4

Client: SCS Tracer
Client Sample ID: 2-12-2-2015
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
ALS Sample ID: P1505219-001

Tentatively Identified Compounds

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes: T
Container ID: AS00199

Date Collected: 12/2/15
Date Received: 12/3/15
Date Analyzed: 12/4/15
Volume(s) Analyzed: 0.00050 Liter(s)

Initial Pressure (psig): -5.88 Final Pressure (psig): 3.89

Canister Dilution Factor: 2.11

GC/MS Retention Time	Compound Identification	Concentration $\mu\text{g}/\text{m}^3$	Data Qualifier
3.91	Propane	18,000	
4.35	Isobutane	41,000	
4.70	n-Butane	39,000	
5.86	2-Methylbutane	23,000	
6.39	n-Pentane	16,000	
11.36	n-Propyl acetate	14,000	

T = Analyte is a tentatively identified compound, result is estimated.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 1 of 4

Client: SCS Tracer
Client Sample ID: 3-12-2-2015
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P1505219-002

Test Code: EPA TO-15
 Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
 Analyst: Wida Ang
 Sample Type: 6.0 L Silonite Canister
 Test Notes:
 Container ID: AS00113

Date Collected: 12/2/15
 Date Received: 12/3/15
 Date Analyzed: 12/3/15
 Volume(s) Analyzed: 0.00050 Liter(s)

Initial Pressure (psig): -5.59 Final Pressure (psig): 4.22

Canister Dilution Factor: 2.08

CAS #	Compound	MRL		Result		Data Qualifier
		$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$	ppbV	ppbV	
115-07-1	Propene	ND	2,100	ND	1,200	
75-71-8	Dichlorodifluoromethane (CFC 12)	ND	2,100	ND	420	
74-87-3	Chloromethane	ND	2,100	ND	1,000	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	ND	2,100	ND	300	
75-01-4	Vinyl Chloride	ND	2,100	ND	810	
106-99-0	1,3-Butadiene	ND	2,100	ND	940	
74-83-9	Bromomethane	ND	2,100	ND	540	
75-00-3	Chloroethane	ND	2,100	ND	790	
64-17-5	Ethanol	67,000	21,000	36,000	11,000	
75-05-8	Acetonitrile	ND	2,100	ND	1,200	
107-02-8	Acrolein	ND	8,300	ND	3,600	
67-64-1	Acetone	ND	21,000	ND	8,800	
75-69-4	Trichlorofluoromethane	3,000	2,100	540	370	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	21,000	ND	8,500	
107-13-1	Acrylonitrile	ND	2,100	ND	960	
75-35-4	1,1-Dichloroethene	ND	2,100	ND	520	
75-09-2	Methylene Chloride	ND	2,100	ND	600	
107-05-1	3-Chloro-1-propene (Allyl Chloride)	ND	2,100	ND	660	
76-13-1	Trichlorotrifluoroethane	ND	2,100	ND	270	
75-15-0	Carbon Disulfide	ND	21,000	ND	6,700	
156-60-5	trans-1,2-Dichloroethene	ND	2,100	ND	520	
75-34-3	1,1-Dichloroethane	ND	2,100	ND	510	
1634-04-4	Methyl tert-Butyl Ether	ND	2,100	ND	580	
108-05-4	Vinyl Acetate	ND	21,000	ND	5,900	
78-93-3	2-Butanone (MEK)	ND	21,000	ND	7,100	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

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Client: SCS Tracer
Client Sample ID: 3-12-2-2015
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P1505219-002

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:
Container ID: AS00113

Date Collected: 12/2/15
Date Received: 12/3/15
Date Analyzed: 12/3/15
Volume(s) Analyzed: 0.00050 Liter(s)

Initial Pressure (psig): -5.59 Final Pressure (psig): 4.22

Canister Dilution Factor: 2.08

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
156-59-2	cis-1,2-Dichloroethene	ND	2,100	ND	520	
141-78-6	Ethyl Acetate	600,000	4,200	170,000	1,200	
110-54-3	n-Hexane	ND	2,100	ND	590	
67-66-3	Chloroform	ND	2,100	ND	430	
109-99-9	Tetrahydrofuran (THF)	ND	2,100	ND	710	
107-06-2	1,2-Dichloroethane	ND	2,100	ND	510	
71-55-6	1,1,1-Trichloroethane	ND	2,100	ND	380	
71-43-2	Benzene	ND	2,100	ND	650	
56-23-5	Carbon Tetrachloride	ND	2,100	ND	330	
110-82-7	Cyclohexane	ND	4,200	ND	1,200	
78-87-5	1,2-Dichloropropane	ND	2,100	ND	450	
75-27-4	Bromodichloromethane	ND	2,100	ND	310	
79-01-6	Trichloroethene	ND	2,100	ND	390	
123-91-1	1,4-Dioxane	ND	2,100	ND	580	
80-62-6	Methyl Methacrylate	ND	4,200	ND	1,000	
142-82-5	n-Heptane	ND	2,100	ND	510	
10061-01-5	cis-1,3-Dichloropropene	ND	2,100	ND	460	
108-10-1	4-Methyl-2-pentanone	ND	2,100	ND	510	
10061-02-6	trans-1,3-Dichloropropene	ND	2,100	ND	460	
79-00-5	1,1,2-Trichloroethane	ND	2,100	ND	380	
108-88-3	Toluene	2,500	2,100	650	550	
591-78-6	2-Hexanone	ND	2,100	ND	510	
124-48-1	Dibromochloromethane	ND	2,100	ND	240	
106-93-4	1,2-Dibromoethane	ND	2,100	ND	270	
123-86-4	n-Butyl Acetate	2,200	2,100	460	440	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

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Client: SCS Tracer
Client Sample ID: 3-12-2-2015
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P1505219-002

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:
Container ID: AS00113

Date Collected: 12/2/15
Date Received: 12/3/15
Date Analyzed: 12/3/15
Volume(s) Analyzed: 0.00050 Liter(s)

Initial Pressure (psig): -5.59 Final Pressure (psig): 4.22

Canister Dilution Factor: 2.08

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
111-65-9	n-Octane	ND	2,100	ND	450	
127-18-4	Tetrachloroethene	ND	2,100	ND	310	
108-90-7	Chlorobenzene	ND	2,100	ND	450	
100-41-4	Ethylbenzene	ND	2,100	ND	480	
179601-23-1	m,p-Xylenes	ND	4,200	ND	960	
75-25-2	Bromoform	ND	2,100	ND	200	
100-42-5	Styrene	ND	2,100	ND	490	
95-47-6	o-Xylene	ND	2,100	ND	480	
111-84-2	n-Nonane	ND	2,100	ND	400	
79-34-5	1,1,2,2-Tetrachloroethane	ND	2,100	ND	300	
98-82-8	Cumene	ND	2,100	ND	420	
80-56-8	alpha-Pinene	ND	2,100	ND	370	
103-65-1	n-Propylbenzene	ND	2,100	ND	420	
622-96-8	4-Ethyltoluene	ND	2,100	ND	420	
108-67-8	1,3,5-Trimethylbenzene	ND	2,100	ND	420	
95-63-6	1,2,4-Trimethylbenzene	ND	2,100	ND	420	
100-44-7	Benzyl Chloride	ND	2,100	ND	400	
541-73-1	1,3-Dichlorobenzene	ND	2,100	ND	350	
106-46-7	1,4-Dichlorobenzene	ND	2,100	ND	350	
95-50-1	1,2-Dichlorobenzene	ND	2,100	ND	350	
5989-27-5	d-Limonene	7,400	2,100	1,300	370	
96-12-8	1,2-Dibromo-3-chloropropane	ND	2,100	ND	220	
120-82-1	1,2,4-Trichlorobenzene	ND	2,100	ND	280	
91-20-3	Naphthalene	ND	2,100	ND	400	
87-68-3	Hexachlorobutadiene	ND	2,100	ND	200	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

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Client: SCS Tracer
Client Sample ID: 3-12-2-2015
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P1505219-002

Tentatively Identified Compounds

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes: T
Container ID: AS00113

Date Collected: 12/2/15
Date Received: 12/3/15
Date Analyzed: 12/3/15
Volume(s) Analyzed: 0.00050 Liter(s)

Initial Pressure (psig): -5.59 Final Pressure (psig): 4.22

Canister Dilution Factor: 2.08

GC/MS Retention Time	Compound Identification	Concentration µg/m ³	Data Qualifier
3.92	Propane	16,000	
4.35	Isobutane	38,000	
4.71	n-Butane	34,000	
5.87	2-Methylbutane	22,000	
6.40	n-Pentane	14,000	
11.36	n-Propyl acetate	9,300	

T = Analyte is a tentatively identified compound, result is estimated.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

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Client: SCS Tracer
Client Sample ID: Method Blank
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151203-MB

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/3/15
Volume(s) Analyzed: 1.00 Liter(s)

Canister Dilution Factor: 1.00

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
115-07-1	Propene	ND	0.50	ND	0.29	
75-71-8	Dichlorodifluoromethane (CFC 12)	ND	0.50	ND	0.10	
74-87-3	Chloromethane	ND	0.50	ND	0.24	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	ND	0.50	ND	0.072	
75-01-4	Vinyl Chloride	ND	0.50	ND	0.20	
106-99-0	1,3-Butadiene	ND	0.50	ND	0.23	
74-83-9	Bromomethane	ND	0.50	ND	0.13	
75-00-3	Chloroethane	ND	0.50	ND	0.19	
64-17-5	Ethanol	ND	5.0	ND	2.7	
75-05-8	Acetonitrile	ND	0.50	ND	0.30	
107-02-8	Acrolein	ND	2.0	ND	0.87	
67-64-1	Acetone	ND	5.0	ND	2.1	
75-69-4	Trichlorofluoromethane	ND	0.50	ND	0.089	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	5.0	ND	2.0	
107-13-1	Acrylonitrile	ND	0.50	ND	0.23	
75-35-4	1,1-Dichloroethene	ND	0.50	ND	0.13	
75-09-2	Methylene Chloride	ND	0.50	ND	0.14	
107-05-1	3-Chloro-1-propene (Allyl Chloride)	ND	0.50	ND	0.16	
76-13-1	Trichlorotrifluoroethane	ND	0.50	ND	0.065	
75-15-0	Carbon Disulfide	ND	5.0	ND	1.6	
156-60-5	trans-1,2-Dichloroethene	ND	0.50	ND	0.13	
75-34-3	1,1-Dichloroethane	ND	0.50	ND	0.12	
1634-04-4	Methyl tert-Butyl Ether	ND	0.50	ND	0.14	
108-05-4	Vinyl Acetate	ND	5.0	ND	1.4	
78-93-3	2-Butanone (MEK)	ND	5.0	ND	1.7	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

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Client: SCS Tracer
Client Sample ID: Method Blank
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151203-MB

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/3/15
Volume(s) Analyzed: 1.00 Liter(s)

Canister Dilution Factor: 1.00

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
156-59-2	cis-1,2-Dichloroethene	ND	0.50	ND	0.13	
141-78-6	Ethyl Acetate	ND	1.0	ND	0.28	
110-54-3	n-Hexane	ND	0.50	ND	0.14	
67-66-3	Chloroform	ND	0.50	ND	0.10	
109-99-9	Tetrahydrofuran (THF)	ND	0.50	ND	0.17	
107-06-2	1,2-Dichloroethane	ND	0.50	ND	0.12	
71-55-6	1,1,1-Trichloroethane	ND	0.50	ND	0.092	
71-43-2	Benzene	ND	0.50	ND	0.16	
56-23-5	Carbon Tetrachloride	ND	0.50	ND	0.080	
110-82-7	Cyclohexane	ND	1.0	ND	0.29	
78-87-5	1,2-Dichloropropane	ND	0.50	ND	0.11	
75-27-4	Bromodichloromethane	ND	0.50	ND	0.075	
79-01-6	Trichloroethene	ND	0.50	ND	0.093	
123-91-1	1,4-Dioxane	ND	0.50	ND	0.14	
80-62-6	Methyl Methacrylate	ND	1.0	ND	0.24	
142-82-5	n-Heptane	ND	0.50	ND	0.12	
10061-01-5	cis-1,3-Dichloropropene	ND	0.50	ND	0.11	
108-10-1	4-Methyl-2-pentanone	ND	0.50	ND	0.12	
10061-02-6	trans-1,3-Dichloropropene	ND	0.50	ND	0.11	
79-00-5	1,1,2-Trichloroethane	ND	0.50	ND	0.092	
108-88-3	Toluene	ND	0.50	ND	0.13	
591-78-6	2-Hexanone	ND	0.50	ND	0.12	
124-48-1	Dibromochloromethane	ND	0.50	ND	0.059	
106-93-4	1,2-Dibromoethane	ND	0.50	ND	0.065	
123-86-4	n-Butyl Acetate	ND	0.50	ND	0.11	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

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Client: SCS Tracer
 Client Sample ID: Method Blank
 Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151203-MB

Test Code: EPA TO-15
 Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
 Analyst: Wida Ang
 Sample Type: 6.0 L Silonite Canister
 Test Notes:

Date Collected: NA
 Date Received: NA
 Date Analyzed: 12/3/15
 Volume(s) Analyzed: 1.00 Liter(s)

Canister Dilution Factor: 1.00

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
111-65-9	n-Octane	ND	0.50	ND	0.11	
127-18-4	Tetrachloroethene	ND	0.50	ND	0.074	
108-90-7	Chlorobenzene	ND	0.50	ND	0.11	
100-41-4	Ethylbenzene	ND	0.50	ND	0.12	
179601-23-1	m,p-Xylenes	ND	1.0	ND	0.23	
75-25-2	Bromoform	ND	0.50	ND	0.048	
100-42-5	Styrene	ND	0.50	ND	0.12	
95-47-6	o-Xylene	ND	0.50	ND	0.12	
111-84-2	n-Nonane	ND	0.50	ND	0.095	
79-34-5	1,1,2,2-Tetrachloroethane	ND	0.50	ND	0.073	
98-82-8	Cumene	ND	0.50	ND	0.10	
80-56-8	alpha-Pinene	ND	0.50	ND	0.090	
103-65-1	n-Propylbenzene	ND	0.50	ND	0.10	
622-96-8	4-Ethyltoluene	ND	0.50	ND	0.10	
108-67-8	1,3,5-Trimethylbenzene	ND	0.50	ND	0.10	
95-63-6	1,2,4-Trimethylbenzene	ND	0.50	ND	0.10	
100-44-7	Benzyl Chloride	ND	0.50	ND	0.097	
541-73-1	1,3-Dichlorobenzene	ND	0.50	ND	0.083	
106-46-7	1,4-Dichlorobenzene	ND	0.50	ND	0.083	
95-50-1	1,2-Dichlorobenzene	ND	0.50	ND	0.083	
5989-27-5	d-Limonene	ND	0.50	ND	0.090	
96-12-8	1,2-Dibromo-3-chloropropane	ND	0.50	ND	0.052	
120-82-1	1,2,4-Trichlorobenzene	ND	0.50	ND	0.067	
91-20-3	Naphthalene	ND	0.50	ND	0.095	
87-68-3	Hexachlorobutadiene	ND	0.50	ND	0.047	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

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Client: SCS Tracer
Client Sample ID: Method Blank
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
ALS Sample ID: P151203-MB

Tentatively Identified Compounds

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/3/15
Volume(s) Analyzed: 1.00 Liter(s)

Canister Dilution Factor: 1.00

GC/MS Retention Time	Compound Identification	Concentration $\mu\text{g}/\text{m}^3$	Data Qualifier
No Compounds Detected			

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RESULTS OF ANALYSIS

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Client: SCS Tracer
Client Sample ID: Method Blank
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151204-MB

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/4/15
Volume(s) Analyzed: 1.00 Liter(s)

Canister Dilution Factor: 1.00

CAS #	Compound	Result µg/m³	MRL µg/m³	Result ppbV	MRL ppbV	Data Qualifier
115-07-1	Propene	ND	0.50	ND	0.29	
75-71-8	Dichlorodifluoromethane (CFC 12)	ND	0.50	ND	0.10	
74-87-3	Chloromethane	ND	0.50	ND	0.24	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	ND	0.50	ND	0.072	
75-01-4	Vinyl Chloride	ND	0.50	ND	0.20	
106-99-0	1,3-Butadiene	ND	0.50	ND	0.23	
74-83-9	Bromomethane	ND	0.50	ND	0.13	
75-00-3	Chloroethane	ND	0.50	ND	0.19	
64-17-5	Ethanol	ND	5.0	ND	2.7	
75-05-8	Acetonitrile	ND	0.50	ND	0.30	
107-02-8	Acrolein	ND	2.0	ND	0.87	
67-64-1	Acetone	ND	5.0	ND	2.1	
75-69-4	Trichlorofluoromethane	ND	0.50	ND	0.089	
67-63-0	2-Propanol (Isopropyl Alcohol)	ND	5.0	ND	2.0	
107-13-1	Acrylonitrile	ND	0.50	ND	0.23	
75-35-4	1,1-Dichloroethene	ND	0.50	ND	0.13	
75-09-2	Methylene Chloride	ND	0.50	ND	0.14	
107-05-1	3-Chloro-1-propene (Allyl Chloride)	ND	0.50	ND	0.16	
76-13-1	Trichlorotrifluoroethane	ND	0.50	ND	0.065	
75-15-0	Carbon Disulfide	ND	5.0	ND	1.6	
156-60-5	trans-1,2-Dichloroethene	ND	0.50	ND	0.13	
75-34-3	1,1-Dichloroethane	ND	0.50	ND	0.12	
1634-04-4	Methyl tert-Butyl Ether	ND	0.50	ND	0.14	
108-05-4	Vinyl Acetate	ND	5.0	ND	1.4	
78-93-3	2-Butanone (MEK)	ND	5.0	ND	1.7	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

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Client: SCS Tracer
 Client Sample ID: Method Blank
 Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151204-MB

Test Code: EPA TO-15
 Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
 Analyst: Wida Ang
 Sample Type: 6.0 L Silonite Canister
 Test Notes:

Date Collected: NA
 Date Received: NA
 Date Analyzed: 12/4/15
 Volume(s) Analyzed: 1.00 Liter(s)

Canister Dilution Factor: 1.00

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
156-59-2	cis-1,2-Dichloroethene	ND	0.50	ND	0.13	
141-78-6	Ethyl Acetate	ND	1.0	ND	0.28	
110-54-3	n-Hexane	ND	0.50	ND	0.14	
67-66-3	Chloroform	ND	0.50	ND	0.10	
109-99-9	Tetrahydrofuran (THF)	ND	0.50	ND	0.17	
107-06-2	1,2-Dichloroethane	ND	0.50	ND	0.12	
71-55-6	1,1,1-Trichloroethane	ND	0.50	ND	0.092	
71-43-2	Benzene	ND	0.50	ND	0.16	
56-23-5	Carbon Tetrachloride	ND	0.50	ND	0.080	
110-82-7	Cyclohexane	ND	1.0	ND	0.29	
78-87-5	1,2-Dichloropropane	ND	0.50	ND	0.11	
75-27-4	Bromodichloromethane	ND	0.50	ND	0.075	
79-01-6	Trichloroethene	ND	0.50	ND	0.093	
123-91-1	1,4-Dioxane	ND	0.50	ND	0.14	
80-62-6	Methyl Methacrylate	ND	1.0	ND	0.24	
142-82-5	n-Heptane	ND	0.50	ND	0.12	
10061-01-5	cis-1,3-Dichloropropene	ND	0.50	ND	0.11	
108-10-1	4-Methyl-2-pentanone	ND	0.50	ND	0.12	
10061-02-6	trans-1,3-Dichloropropene	ND	0.50	ND	0.11	
79-00-5	1,1,2-Trichloroethane	ND	0.50	ND	0.092	
108-88-3	Toluene	ND	0.50	ND	0.13	
591-78-6	2-Hexanone	ND	0.50	ND	0.12	
124-48-1	Dibromochloromethane	ND	0.50	ND	0.059	
106-93-4	1,2-Dibromoethane	ND	0.50	ND	0.065	
123-86-4	n-Butyl Acetate	ND	0.50	ND	0.11	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 3 of 4

Client: SCS Tracer
Client Sample ID: Method Blank
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151204-MB

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973Inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/4/15
Volume(s) Analyzed: 1.00 Liter(s)

Canister Dilution Factor: 1.00

CAS #	Compound	Result µg/m ³	MRL µg/m ³	Result ppbV	MRL ppbV	Data Qualifier
111-65-9	n-Octane	ND	0.50	ND	0.11	
127-18-4	Tetrachloroethene	ND	0.50	ND	0.074	
108-90-7	Chlorobenzene	ND	0.50	ND	0.11	
100-41-4	Ethylbenzene	ND	0.50	ND	0.12	
179601-23-1	m,p-Xylenes	ND	1.0	ND	0.23	
75-25-2	Bromoform	ND	0.50	ND	0.048	
100-42-5	Styrene	ND	0.50	ND	0.12	
95-47-6	o-Xylene	ND	0.50	ND	0.12	
111-84-2	n-Nonane	ND	0.50	ND	0.095	
79-34-5	1,1,2,2-Tetrachloroethane	ND	0.50	ND	0.073	
98-82-8	Cumene	ND	0.50	ND	0.10	
80-56-8	alpha-Pinene	ND	0.50	ND	0.090	
103-65-1	n-Propylbenzene	ND	0.50	ND	0.10	
622-96-8	4-Ethyltoluene	ND	0.50	ND	0.10	
108-67-8	1,3,5-Trimethylbenzene	ND	0.50	ND	0.10	
95-63-6	1,2,4-Trimethylbenzene	ND	0.50	ND	0.10	
100-44-7	Benzyl Chloride	ND	0.50	ND	0.097	
541-73-1	1,3-Dichlorobenzene	ND	0.50	ND	0.083	
106-46-7	1,4-Dichlorobenzene	ND	0.50	ND	0.083	
95-50-1	1,2-Dichlorobenzene	ND	0.50	ND	0.083	
5989-27-5	d-Limonene	ND	0.50	ND	0.090	
96-12-8	1,2-Dibromo-3-chloropropane	ND	0.50	ND	0.052	
120-82-1	1,2,4-Trichlorobenzene	ND	0.50	ND	0.067	
91-20-3	Naphthalene	ND	0.50	ND	0.095	
87-68-3	Hexachlorobutadiene	ND	0.50	ND	0.047	

ND = Compound was analyzed for, but not detected above the laboratory reporting limit.

MRL = Method Reporting Limit - The minimum quantity of a target analyte that can be confidently determined by the referenced method.

ALS ENVIRONMENTAL

RESULTS OF ANALYSIS

Page 4 of 4

Client: SCS Tracer
Client Sample ID: Method Blank
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
ALS Sample ID: P151204-MB

Tentatively Identified Compounds

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/4/15
Volume(s) Analyzed: 1.00 Liter(s)

Canister Dilution Factor: 1.00

<u>GC/MS</u> <u>Retention Time</u>	<u>Compound Identification</u>	<u>Concentration</u> <u>µg/m³</u>	<u>Data</u> <u>Qualifier</u>
<hr/> No Compounds Detected <hr/>			

ALS ENVIRONMENTAL

SURROGATE SPIKE RECOVERY RESULTS

Page 1 of 1

Client: SCS Tracer
Client Project ID: Trolley Town WF

ALS Project ID: P1505219

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L. Silonite Canister(s)
Test Notes:

Date(s) Collected: 12/2/15
 Date(s) Received: 12/3/15
 Date(s) Analyzed: 12/3 - 12/4/15

Client Sample ID	ALS Sample ID	1,2-Dichloroethane-d4	Toluene-d8	Bromofluorobenzene	Acceptance Limits	Data Qualifier
		Percent Recovered	Percent Recovered	Percent Recovered		
Method Blank	P151203-MB	92	105	107	70-130	
Method Blank	P151204-MB	94	107	109	70-130	
Lab Control Sample	P151203-LCS	86	103	106	70-130	
Lab Control Sample	P151204-LCS	85	105	108	70-130	
2-12-2-2015	P1505219-001	85	106	111	70-130	
3-12-2-2015	P1505219-002	86	104	110	70-130	

Surrogate percent recovery is verified and accepted based on the on-column result.

Reported results are shown in concentration units and as a result of the calculation, may vary slightly from the on-column percent recovery.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE SUMMARY

Page 1 of 3

Client: SCS Tracer
Client Sample ID: Lab Control Sample
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151203-LCS

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/3/15
Volume(s) Analyzed: 0.125 Liter(s)

CAS #	Compound	Spike Amount µg/m ³	Result µg/m ³	% Recovery	ALS	Data Qualifier
					Acceptance Limits	
115-07-1	Propene	196	152	78	49-131	
75-71-8	Dichlorodifluoromethane (CFC 12)	188	160	85	65-117	
74-87-3	Chloromethane	200	183	92	48-132	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	204	190	93	65-122	
75-01-4	Vinyl Chloride	200	188	94	65-128	
106-99-0	1,3-Butadiene	206	158	77	62-143	
74-83-9	Bromomethane	202	205	101	65-130	
75-00-3	Chloroethane	200	192	96	69-126	
64-17-5	Ethanol	998	833	83	57-126	
75-05-8	Acetonitrile	212	159	75	51-134	
107-02-8	Acrolein	214	175	82	55-146	
67-64-1	Acetone	1,080	982	91	57-120	
75-69-4	Trichlorofluoromethane	216	168	78	59-139	
67-63-0	2-Propanol (Isopropyl Alcohol)	418	356	85	59-129	
107-13-1	Acrylonitrile	212	197	93	64-136	
75-35-4	1,1-Dichloroethene	216	204	94	72-123	
75-09-2	Methylene Chloride	222	180	81	63-117	
107-05-1	3-Chloro-1-propene (Allyl Chloride)	218	186	85	50-141	
76-13-1	Trichlorotrifluoroethane	220	214	97	68-118	
75-15-0	Carbon Disulfide	210	163	78	55-143	
156-60-5	trans-1,2-Dichloroethene	210	199	95	69-129	
75-34-3	1,1-Dichloroethane	212	189	89	66-122	
1634-04-4	Methyl tert-Butyl Ether	216	188	87	55-128	
108-05-4	Vinyl Acetate	1,040	1190	114	66-140	
78-93-3	2-Butanone (MEK)	220	210	95	62-127	

Laboratory Control Sample percent recovery is verified and accepted based on the on-column result. Reported results are shown in concentration units and as a result of the calculation, may vary slightly.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE SUMMARY

Page 2 of 3

Client: SCS Tracer
Client Sample ID: Lab Control Sample
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151203-LCS

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/3/15
Volume(s) Analyzed: 0.125 Liter(s)

CAS #	Compound	Spike Amount µg/m ³	Result µg/m ³	% Recovery	ALS Acceptance Limits	Data Qualifier
156-59-2	cis-1,2-Dichloroethene	218	196	90	65-125	
141-78-6	Ethyl Acetate	428	422	99	64-132	
110-54-3	n-Hexane	212	174	82	58-126	
67-66-3	Chloroform	224	195	87	68-117	
109-99-9	Tetrahydrofuran (THF)	220	210	95	64-123	
107-06-2	1,2-Dichloroethane	214	183	86	63-124	
71-55-6	1,1,1-Trichloroethane	210	191	91	68-120	
71-43-2	Benzene	226	200	88	61-110	
56-23-5	Carbon Tetrachloride	230	205	89	65-137	
110-82-7	Cyclohexane	424	390	92	68-122	
78-87-5	1,2-Dichloropropane	216	200	93	67-122	
75-27-4	Bromodichloromethane	218	205	94	71-124	
79-01-6	Trichloroethene	216	204	94	71-121	
123-91-1	1,4-Dioxane	210	227	108	67-122	
80-62-6	Methyl Methacrylate	422	437	104	76-130	
142-82-5	n-Heptane	216	198	92	67-125	
10061-01-5	cis-1,3-Dichloropropene	208	205	99	73-131	
108-10-1	4-Methyl-2-pentanone	220	208	95	66-132	
10061-02-6	trans-1,3-Dichloropropene	210	217	103	76-135	
79-00-5	1,1,2-Trichloroethane	216	213	99	73-121	
108-88-3	Toluene	218	214	98	67-117	
591-78-6	2-Hexanone	220	215	98	59-128	
124-48-1	Dibromochloromethane	220	240	109	73-132	
106-93-4	1,2-Dibromoethane	218	233	107	73-128	
123-86-4	n-Butyl Acetate	226	219	97	61-136	

Laboratory Control Sample percent recovery is verified and accepted based on the on-column result. Reported results are shown in concentration units and as a result of the calculation, may vary slightly.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE SUMMARY

Page 3 of 3

Client: SCS Tracer
Client Sample ID: Lab Control Sample
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151203-LCS

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/3/15
Volume(s) Analyzed: 0.125 Liter(s)

CAS #	Compound	Spike Amount µg/m ³	Result µg/m ³	% Recovery	ALS	Data Qualifier
					Acceptance Limits	
111-65-9	n-Octane	210	191	91	67-124	
127-18-4	Tetrachloroethene	202	209	103	65-126	
108-90-7	Chlorobenzene	220	223	101	68-120	
100-41-4	Ethylbenzene	218	216	99	69-123	
179601-23-1	m,p-Xylenes	428	421	98	67-125	
75-25-2	Bromoform	228	237	104	68-153	
100-42-5	Styrene	222	232	105	68-132	
95-47-6	o-Xylene	210	204	97	67-124	
111-84-2	n-Nonane	204	186	91	60-130	
79-34-5	1,1,2,2-Tetrachloroethane	210	211	100	72-128	
98-82-8	Cumene	208	204	98	67-124	
80-56-8	alpha-Pinene	212	214	101	67-129	
103-65-1	n-Propylbenzene	204	200	98	67-125	
622-96-8	4-Ethyltoluene	214	213	100	66-128	
108-67-8	1,3,5-Trimethylbenzene	214	208	97	65-125	
95-63-6	1,2,4-Trimethylbenzene	218	215	99	62-134	
100-44-7	Benzyl Chloride	220	258	117	74-145	
541-73-1	1,3-Dichlorobenzene	228	229	100	63-133	
106-46-7	1,4-Dichlorobenzene	208	214	103	62-129	
95-50-1	1,2-Dichlorobenzene	220	223	101	62-134	
5989-27-5	d-Limonene	210	221	105	66-137	
96-12-8	1,2-Dibromo-3-chloropropane	218	235	108	71-147	
120-82-1	1,2,4-Trichlorobenzene	230	225	98	60-145	
91-20-3	Naphthalene	218	219	100	56-158	
87-68-3	Hexachlorobutadiene	230	218	95	56-139	

Laboratory Control Sample percent recovery is verified and accepted based on the on-column result.
 Reported results are shown in concentration units and as a result of the calculation, may vary slightly.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE SUMMARY

Page 1 of 3

Client: SCS Tracer
Client Sample ID: Lab Control Sample
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151204-LCS

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/4/15
Volume(s) Analyzed: 0.125 Liter(s)

CAS #	Compound	Spike Amount µg/m ³	Result µg/m ³	% Recovery	ALS	Data Qualifier
					Acceptance Limits	
115-07-1	Propene	196	146	74	49-131	
75-71-8	Dichlorodifluoromethane (CFC 12)	188	158	84	65-117	
74-87-3	Chloromethane	200	174	87	48-132	
76-14-2	1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	204	184	90	65-122	
75-01-4	Vinyl Chloride	200	185	93	65-128	
106-99-0	1,3-Butadiene	206	131	64	62-143	
74-83-9	Bromomethane	202	195	97	65-130	
75-00-3	Chloroethane	200	178	89	69-126	
64-17-5	Ethanol	998	748	75	57-126	
75-05-8	Acetonitrile	212	148	70	51-134	
107-02-8	Acrolein	214	157	73	55-146	
67-64-1	Acetone	1,080	938	87	57-120	
75-69-4	Trichlorofluoromethane	216	157	73	59-139	
67-63-0	2-Propanol (Isopropyl Alcohol)	418	344	82	59-129	
107-13-1	Acrylonitrile	212	186	88	64-136	
75-35-4	1,1-Dichloroethene	216	188	87	72-123	
75-09-2	Methylene Chloride	222	169	76	63-117	
107-05-1	3-Chloro-1-propene (Allyl Chloride)	218	179	82	50-141	
76-13-1	Trichlorotrifluoroethane	220	219	100	68-118	
75-15-0	Carbon Disulfide	210	150	71	55-143	
156-60-5	trans-1,2-Dichloroethene	210	195	93	69-129	
75-34-3	1,1-Dichloroethane	212	187	88	66-122	
1634-04-4	Methyl tert-Butyl Ether	216	189	88	55-128	
108-05-4	Vinyl Acetate	1,040	1210	116	66-140	
78-93-3	2-Butanone (MEK)	220	211	96	62-127	

Laboratory Control Sample percent recovery is verified and accepted based on the on-column result. Reported results are shown in concentration units and as a result of the calculation, may vary slightly.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE SUMMARY

Page 2 of 3

Client: SCS Tracer
Client Sample ID: Lab Control Sample
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151204-LCS

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/4/15
Volume(s) Analyzed: 0.125 Liter(s)

CAS #	Compound	Spike Amount µg/m ³	Result µg/m ³	% Recovery	ALS	Data Qualifier
					Acceptance Limits	
156-59-2	cis-1,2-Dichloroethene	218	194	89	65-125	
141-78-6	Ethyl Acetate	428	424	99	64-132	
110-54-3	n-Hexane	212	177	83	58-126	
67-66-3	Chloroform	224	197	88	68-117	
109-99-9	Tetrahydrofuran (THF)	220	209	95	64-123	
107-06-2	1,2-Dichloroethane	214	181	85	63-124	
71-55-6	1,1,1-Trichloroethane	210	190	90	68-120	
71-43-2	Benzene	226	200	88	61-110	
56-23-5	Carbon Tetrachloride	230	204	89	65-137	
110-82-7	Cyclohexane	424	387	91	68-122	
78-87-5	1,2-Dichloropropane	216	196	91	67-122	
75-27-4	Bromodichloromethane	218	202	93	71-124	
79-01-6	Trichloroethene	216	207	96	71-121	
123-91-1	1,4-Dioxane	210	226	108	67-122	
80-62-6	Methyl Methacrylate	422	440	104	76-130	
142-82-5	n-Heptane	216	197	91	67-125	
10061-01-5	cis-1,3-Dichloropropene	208	202	97	73-131	
108-10-1	4-Methyl-2-pentanone	220	203	92	66-132	
10061-02-6	trans-1,3-Dichloropropene	210	213	101	76-135	
79-00-5	1,1,2-Trichloroethane	216	212	98	73-121	
108-88-3	Toluene	218	219	100	67-117	
591-78-6	2-Hexanone	220	213	97	59-128	
124-48-1	Dibromochloromethane	220	246	112	73-132	
106-93-4	1,2-Dibromoethane	218	240	110	73-128	
123-86-4	n-Butyl Acetate	226	216	96	61-136	

Laboratory Control Sample percent recovery is verified and accepted based on the on-column result. Reported results are shown in concentration units and as a result of the calculation, may vary slightly.

ALS ENVIRONMENTAL

LABORATORY CONTROL SAMPLE SUMMARY

Page 3 of 3

Client: SCS Tracer
Client Sample ID: Lab Control Sample
Client Project ID: Trolley Town WF

ALS Project ID: P1505219
 ALS Sample ID: P151204-LCS

Test Code: EPA TO-15
Instrument ID: Tekmar AUTOCAN/Agilent 5973inert/6890N/MS8
Analyst: Wida Ang
Sample Type: 6.0 L Silonite Canister
Test Notes:

Date Collected: NA
Date Received: NA
Date Analyzed: 12/4/15
Volume(s) Analyzed: 0.125 Liter(s)

CAS #	Compound	Spike Amount µg/m ³	Result µg/m ³	% Recovery	ALS	Data Qualifier
					Acceptance Limits	
111-65-9	n-Octane	210	193	92	67-124	
127-18-4	Tetrachloroethene	202	221	109	65-126	
108-90-7	Chlorobenzene	220	229	104	68-120	
100-41-4	Ethylbenzene	218	221	101	69-123	
179601-23-1	m,p-Xylenes	428	432	101	67-125	
75-25-2	Bromoform	228	246	108	68-153	
100-42-5	Styrene	222	240	108	68-132	
95-47-6	o-Xylene	210	209	100	67-124	
111-84-2	n-Nonane	204	184	90	60-130	
79-34-5	1,1,2,2-Tetrachloroethane	210	214	102	72-128	
98-82-8	Cumene	208	209	100	67-124	
80-56-8	alpha-Pinene	212	219	103	67-129	
103-65-1	n-Propylbenzene	204	205	100	67-125	
622-96-8	4-Ethyltoluene	214	223	104	66-128	
108-67-8	1,3,5-Trimethylbenzene	214	214	100	65-125	
95-63-6	1,2,4-Trimethylbenzene	218	221	101	62-134	
100-44-7	Benzyl Chloride	220	261	119	74-145	
541-73-1	1,3-Dichlorobenzene	228	238	104	63-133	
106-46-7	1,4-Dichlorobenzene	208	223	107	62-129	
95-50-1	1,2-Dichlorobenzene	220	231	105	62-134	
5989-27-5	d-Limonene	210	222	106	66-137	
96-12-8	1,2-Dibromo-3-chloropropane	218	243	111	71-147	
120-82-1	1,2,4-Trichlorobenzene	230	235	102	60-145	
91-20-3	Naphthalene	218	226	104	56-158	
87-68-3	Hexachlorobutadiene	230	230	100	56-139	

Laboratory Control Sample percent recovery is verified and accepted based on the on-column result.
 Reported results are shown in concentration units and as a result of the calculation, may vary slightly.

APPENDIX D

CALMIM MODELING FOR LANDFILL GAS EMISSIONS

Appendix D

CALMIM Modeling for Landfill Gas Emissions

Environmental Information Logistics, LLC

Introduction

Landfill surface emissions are considered fugitive, meaning they are the unintended, irregular release of gases which could not reasonably pass through a point source such as a stack, chimney, vent, or other functionally-equivalent opening (40 CFR 51.165(a)(1)(x)).

Quantifying actual amounts of fugitive emissions are very difficult due to the variability and intermittent nature of emission flow rates from those types of sources. For landfills, fugitive emissions are a function of many factors including the cover system in place, the homogeneity of that cover, landfill gas generation rates, the efficiency of the landfill gas collection system and the age of the landfill. Since landfills are operated over multiple years with various cover systems installed depending on the stage of landfill construction, potential emissions can change to different degrees with ongoing cover system installation progression – from active fill area to final cover. In addition, rainwater surface runoff causing erosion, and construction of gas extraction system components, can affect the intermittent potential release of fugitive emissions.

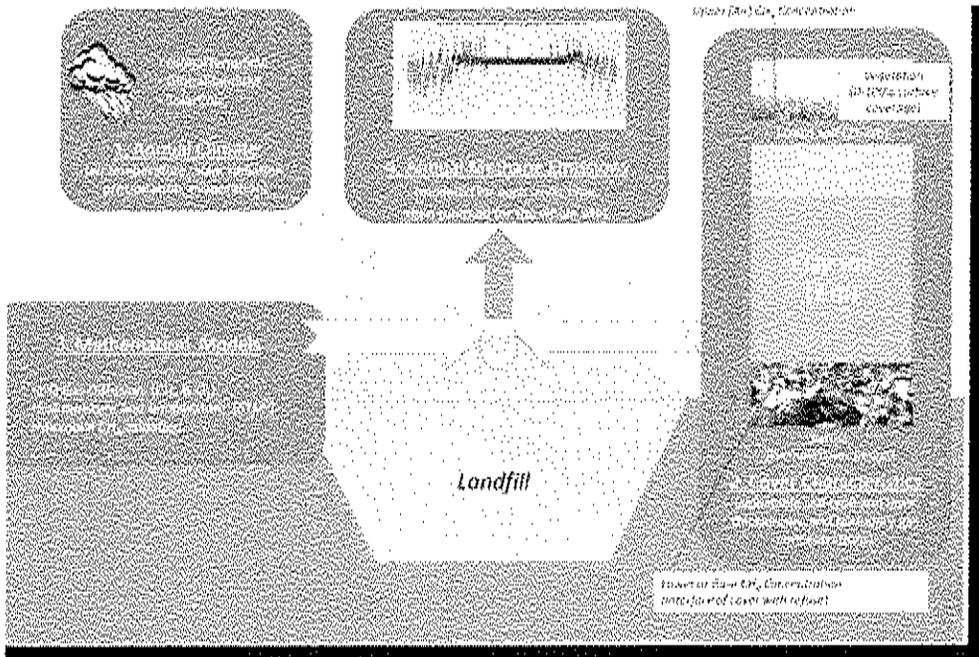
Many landfill gas models have been developed and used extensively in the U.S. and worldwide to predict landfill gas generation and emission rates (USEPA 2005, Kamalan et al. 2011, Spokas et al. 2011). While these models are based on methane, an odorless non-toxic compound found in landfill gas, they are also often used to address other compounds present in landfill gas. For this study, potential fugitive emissions were calculated using the CALMIM model because it predicts the potential flux of methane through various types of landfill cover materials. The CALMIM model output data is also suitable for the AERMOD model which uses area source designations related to each cover type to quantify downwind methane concentrations.

CALMIM Modeling

CALMIM is a field-validated one dimensional methane diffusion flux model which can incorporate site-specific soil property and landfill characteristic input parameters. Gas diffusion through the cap soils was assumed to obey Fick's law ($J = D_s * dC/dz$ where J equals the flux, D_s is the gas diffusion coefficient, dC is the gas concentration and dz is the depth). The CALMIM model [Figure C-1] has been developed to take into account the three principal controlling factors influencing landfill methane flux based on extensive research into this issue: 1) gas extraction rates, 2) cover soil gas transport rates based on cover material physical properties

and thickness, and 3) methane oxidation associated with methanotrophs and seasonal soil microclimates.

Figure C-1: CALMIM Gas Transport Model



(Spokas, Bogner, & Chanton, 2011)

Published CALMIM validation research indicates that CALMIM accurately predicts soil temperature and moisture trends with emission predictions within the same order of magnitude as field measurements. The CALMIM model has also been determined to have statistically equivalent results to field measurements over all cover types (Bogner et al. 2014). Site-specific input parameters were used in CALMIM where available.

Five different cover types were evaluated corresponding to the June 2015 landfill configuration – final certified geomembrane cover, final certified clay cover, intermediate soil cover, temporary geomembrane cover, and the active area daily cover. Since June 2015, some additional areas have been capped with final certified geomembrane cover and temporary geomembrane cover, thereby reducing the landfill area with intermediate soil cover. By modeling the June 2015 cover configuration, calculated potential emissions from TRRF are expected to be overestimated because the area covered with intermediate soil cover has been reduced. Each cover area shown in Figure C-2 was modeled uniquely, with the cover type assumed to be present across the entire area and with thicknesses as prescribed by the Pennsylvania Department of Environmental Protection (PADEP).

Weather data embedded in the CALMIM model (Figures C-3 to C-7) were based on the latitude and longitude of the facility location.

Figure C-3

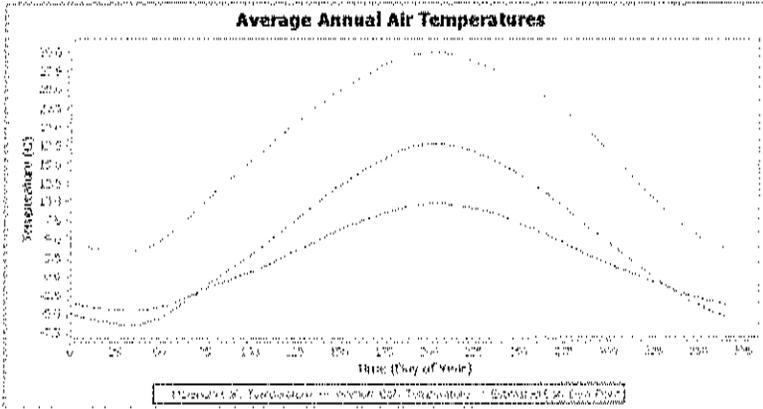


Figure C-4

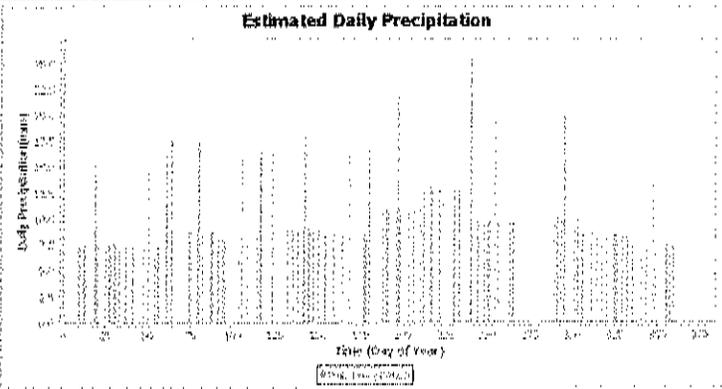


Figure C-5

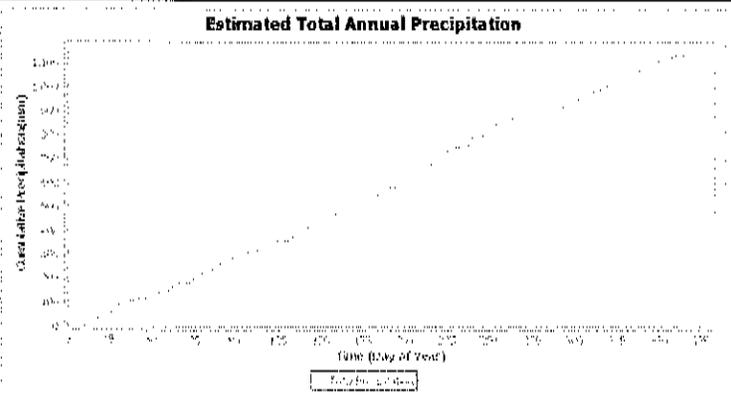


Figure C-6

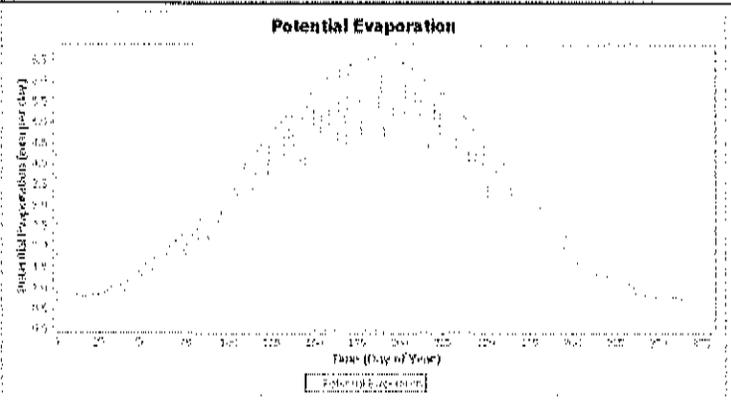
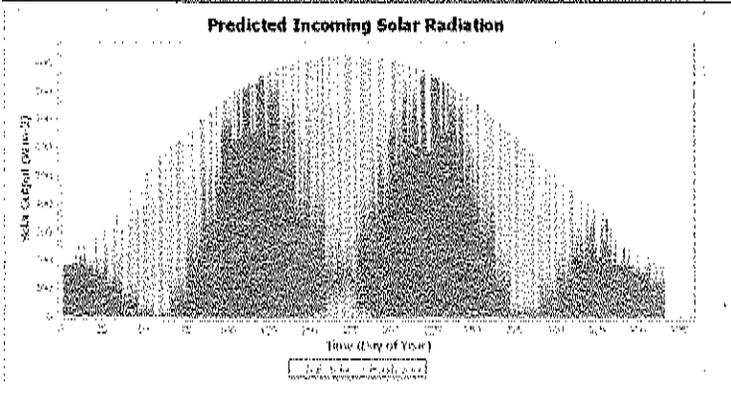


Figure C-7



The above data were used by the model to establish the cover soil climate and consequently the potential for methane oxidation at the facility. CALMIM incorporates SolarCALC, GlobalTempSIM and GlobalRainSIM [Spokas and Forcella, 2006, 2009] to establish 30-year (1961-1990) average cycles of air temperature, precipitation, and solar radiation. These databases were validated and provide data on a 0.5 x 0.5 degree scale (approximately 55 square miles centered on the site). This scale is suitable to define appropriate soil climate variations for the site in the soil temperature and moisture model (STM²) incorporated into CALMIM. According to the research by Spokas and Forcella, both the temperature and precipitation models correlated with observed data based on average Willmott d-indexes of 0.9 and 0.94, respectively (d=1.0 represents total agreement). Similarly, Willmott d-indexes for soil temperature correlations exceeded 0.83.

CALMIM Boundary Condition Site-Specific Refinement

The CALMIM boundary conditions for methane concentrations were refined based on site-specific measurement of methane directly below the cap for most of the cover types. The only exceptions were for the final certified geomembrane cover and the final certified clay cover for which the default CALMIM concentration lower boundary conditions were used (to avoid disturbing these capped and closed areas). Specifically, below cover methane measurements collected during a bar punch survey were used to establish the lower boundary condition of the CALMIM model for the daily cover, intermediate cover and temporary geomembrane cover areas. The default CALMIM lower boundary condition for the other cover types, in the absence of site-specific data, was 38.5%.

The bar punch survey was conducted on November 17, 18 and 23, 2015. A sampling location grid with spacing of approximately 200 feet was overlain on a map of the landfill surface (Figure C-8 and C-9).

Figure C-8. Eastern Expansion Area

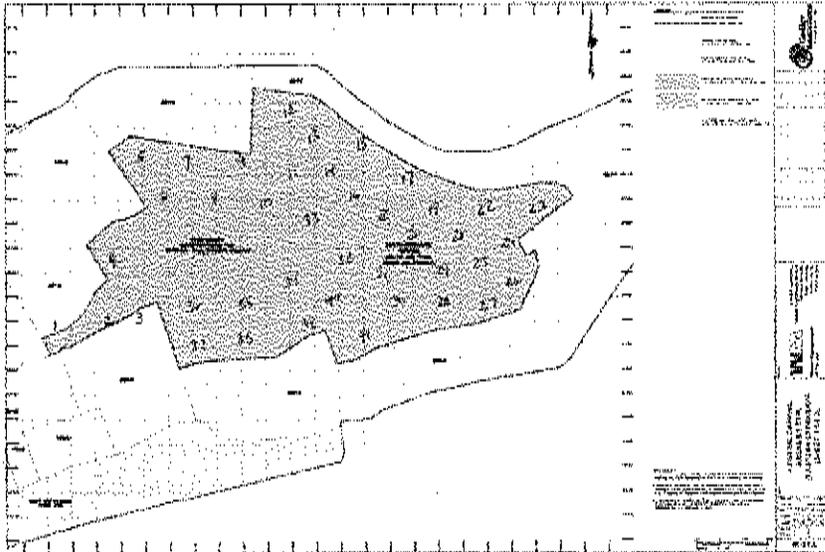
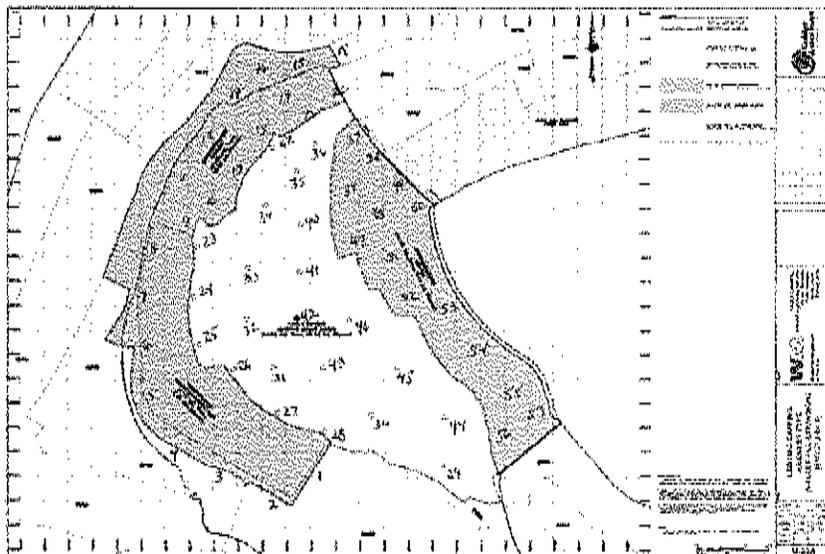


Figure C-9. Valley Fill Area



Using this grid as a guide, and taking into account site conditions, samples were collected from each cover area type (except for the final certified geomembrane and clay cap cover areas). For those areas with daily or intermediate soil cover where a bar punch study can readily be performed (active daily cover area and intermediate cover area), a metal rod was used to extend a bore to the base of the capping system and a Toxic Vapor Analyzer (TVA) was used to determine a methane concentration. The detection limit of the TVA is 1 part per million (ppm) methane. Once the sample was collected, the bore was filled with soil. The temporary geomembrane areas were sampled around the perimeter as near to the edge of the membrane as possible without compromising the integrity of the capping system. The premise for this sampling approach is that gases under the temporary geomembrane area would tend to migrate from an area which is less permeable to the edge of the membrane where there are more permeable surrounding soils. The number of measurements collected for each cover area type was 16 for the active daily cover area, 57 for intermediate cover areas, and 25 for temporary geomembrane cover areas. These data are shown in Tables C-1 and C-2.

Table C-1: TRRF Below Cover Gas Sampling - Eastern Expansion - Fall 2015 (see Figure C-8) Methane Concentrations. Sampled: 11/17/15 & 11/18/15

Bar Hole Location	Base of Intermediate Cover (ppm)	Bar Hole Location	Base of Intermediate Cover (ppm)	Bar Hole Location	Perimeter of Temporary Geomembrane Area (ppm)
1	9300	22*	0.5	3	25
2	2	23*	0.5	4	55
5*	0.5	24*	0.5	6	230
7	6	25*	0.5	8	13
9	8200	26*	0.5	10	23
11	260	27*	0.5	32*	0.5
12*	0.5	28	3	33	32
13*	0.5	29	9	34	7
14	600	30	1	35	20
15	1	31	2	36	1500
16*	0.5	37	90		
17*	0.5	38	31		
18	25	39	5		
19	3	40	7		
20	1	41	5		
21*	0.5				

*½ detection limit
ppm = parts per million

Table C-2: TRRF Below Cover Gas Sampling - Valley Fill - Fall 2015 (see Figure C-9)
Methane Concentrations. Sampled: 11/23/15

<i>Bar Hole Location</i>	Base of Daily Cover (ppm)	<i>Bar Hole Location</i>	Base of Intermediate Cover (ppm)	<i>Bar Hole Location</i>	Perimeter of Temporary Geomembrane Area (ppm)
22	471	10	200	1*	0.5
29	11	11	300	2	8
30	6	12	600	3*	0.5
31	835	13	800	4*	0.5
32	7	14	2600	5	290
33	9	15	411	6*	0.5
34	3209	16	979	7	11
35	219	17	387	8	29
36	323	18	36	9	9
40	461	19	760	23	902
41	474	20	623	24	318
42	354	21	811	25	2396
43	8	37	136	26	384
44	5	38	143	27	600
45	104	39	3	28	361
46	933	47	6		
		48	3		
		49	271		
		50	10		
		51	5		
		52	578		
		53	11		
		54	6		
		55	9		
		56	971		
		57	18		

*½ detection limit
ppm = parts per million

The bar punch measurements provide a scientifically-supportable data base for modeling across all seasons because CALMIM includes a seasonal variability algorithm.

The below cover methane concentration boundary condition input parameter was based on the 95th percentile upper confidence limit (95% UCL) average of the bar punch measurements, inputting one-half of the detection limit for non-detect sample results. The 95% UCL concentrations were calculated using USEPA's ProUCL5 software which was developed to perform statistical analyses of environmental data (USEPA 2013a, 2013b). Data is presented in Table C-3 and C-4 for daily cover and intermediate cover respectively.

The resulting below cover 95% UCL methane concentrations were 1,156 ppm (0.12%) and 1,873 ppm (0.19%), respectively, for the active daily cover area and the intermediate cover area. For the temporary geomembrane area, since samples were collected from the edges of this area rather than directly below the cover, the highest methane result among the perimeter sampling data was used to define the below cover boundary condition (2,396 ppm; 0.24%). For cover types that could not be sampled at TRRF, the default values in CALMIM for below cover methane concentrations were used (38.5% for both final geomembrane cover and final clay cover).

The authors of CALMIM have noted that the embedded features of the model (e.g., zero emissions boundary limit and the use of standard soil databases for gas transport properties) yield a positive bias which will tend to overestimate methane emissions. As a result, the use of CALMIM in this study is expected to overestimate emissions and thus potential ambient air concentrations.

CALMIM Model Output

The CALMIM model produced results of methane emissions (Tables C-3 to C-7), both with and without oxidation, in terms of grams per square meter per day ($\text{g}/\text{m}^2\text{-day}$). These data were converted to grams per square meter per second ($\text{g}/\text{m}^2\text{-sec}$) for use in the subsequent dispersion modeling with AERMOD (see Appendix D). The percentage acreage for each cap was used to establish a source wide emission rate to input in AERMOD's area source computational unit (Tables C-8 to C-10).

Table C-3

CALMM Version: 5.4
 TRRF Final Cover Run 1 - Geosynthetic - Simulated Weather Used
 12/14/2015

Gas Recovery	100 %
Cover Type	Final
Cover area %	100 %
Vegetation Presence (%)	100 %
New Cover	
Layer 1	LOAM 24
Layer 2	Geomembrane (HDPE) 1
Layer 3	SILTY CLAY/LOAM 12
Layer 4	
Layer 5	
Layer 6	
Layer 7	
Layer 8	
Layer 9	
Layer 10	
New Cover	
Methane Concentration Base of Cover	33.5
Oxygen Concentration Base of Cover	0.2
Max. Methanotroph Oxidation Rate (ug/g/day)	400.0
Emission Data	
Methane Emission without Oxidation (g/m ² /day)	0.21
Methane Emission with Oxidation (g/m ² /day)	0.0
Remaining Oxidation Capacity (g/m ² /day)	13.44
% Oxidation	99.62
Site Calculations	
Total Cover Emissions with Oxidation (kg/year)	7.07
Total Cover Emissions without Oxidation (kg/year)	3462.8

Table C-4

CALMM Version: 5.4
 TRRF - Clay Final - Simulated Weather Used
 12/14/2015

Gas Recovery	100 %
Cover Type	Final
Cover area %	100 %
Vegetation Presence (%)	100 %
New Cover	
Layer 1	LOAM 12
Layer 2	CLAY 30
Layer 3	SILTY CLAY/LOAM 12
Layer 4	
Layer 5	
Layer 6	
Layer 7	
Layer 8	
Layer 9	
Layer 10	
New Cover	
Methane Concentration Base of Cover	33.5
Oxygen Concentration Base of Cover	0.2
Max. Methanotroph Oxidation Rate (ug/g/day)	400.0
Emission Data	
Methane Emission without Oxidation (g/m ² /day)	13.82
Methane Emission with Oxidation (g/m ² /day)	0.06
Remaining Oxidation Capacity (g/m ² /day)	117.3
% Oxidation	99.47
Site Calculations	
Total Cover Emissions with Oxidation (kg/year)	1627.11
Total Cover Emissions without Oxidation (kg/year)	368522.21

Table C-5

CALMM Version: 5.4
 TRRF - Intermediate Cover Run 1 - Simulated Weather Used
 12/14/2015

Gas Recovery	100 %
Cover Type	Intermediate
Cover area %	100 %
Vegetation Presence (%)	0 %
New Cover	
Layer 1	SILTY CLAY 12
Layer 2	
Layer 3	
Layer 4	
Layer 5	
Layer 6	
Layer 7	
Layer 8	
Layer 9	
Layer 10	
New Cover	
Methane Concentration Base of Cover	0.15
Oxygen Concentration Base of Cover	15.0
Max. Methanotroph Oxidation Rate (ug/g/day)	400.0
Emission Data	
Methane Emission without Oxidation (g/m ² /day)	0.54
Methane Emission with Oxidation (g/m ² /day)	0.0
Remaining Oxidation Capacity (g/m ² /day)	0.0
% Oxidation	1.95
Site Calculations	
Total Cover Emissions with Oxidation (kg/year)	37504.34
Total Cover Emissions without Oxidation (kg/year)	17327.8

Table C-6

CALMM Version: 5.4
 TRRF Daily Cover Run 1 - Simulated Weather Used
 12/14/2015

Gas Recovery	50 %
Cover Type	Daily
Cover area %	100 %
Vegetation Presence (%)	0 %
New Cover	
Layer 1	CLAY/LOAM 5
Layer 2	
Layer 3	
Layer 4	
Layer 5	
Layer 6	
Layer 7	
Layer 8	
Layer 9	
Layer 10	
New Cover	
Methane Concentration Base of Cover	0.12
Oxygen Concentration Base of Cover	15.0
Max. Methanotroph Oxidation Rate (ug/g/day)	400.0
Emission Data	
Methane Emission without Oxidation (g/m ² /day)	1.50
Methane Emission with Oxidation (g/m ² /day)	1.39
Remaining Oxidation Capacity (g/m ² /day)	0.02
% Oxidation	9.13
Site Calculations	
Total Cover Emissions with Oxidation (kg/year)	4035.16
Total Cover Emissions without Oxidation (kg/year)	22411.39

Table C-7

CALVIN Version 2.4
 TRRF Temporary Geomembrane Cover -- Simulated Weather/Use
 INPUT

Gas Recovery	100%
Cover Type	Intermediate
Cover Area %	100%
Vegetation Presence (%)	0%
Four Cover	
Layer 1	SAND 4
Layer 2	Geomembrane (GPE) 1
Layer 3	CLAY/DAMS
Layer 4	
Layer 5	
Layer 6	
Layer 7	
Layer 8	
Layer 9	
Layer 10	
New Cover	
Methane Concentration Base of Cover	0.24
Oxygen Concentration Base of Cover	13.0
Max. Methanogenic Oxidation Rate (g/g/Day)	400.0
Emission Data	
Methane Emission without Oxidation (g/m ² /Day)	0.0
Methane Emission with Oxidation (g/m ² /Day)	0.0
Remaining Oxidation Capacity (g/m ² /Day)	18.50
% Oxidation	100.0
Site Oxidations	
Total Cover Emissions with Oxidation (kg/year)	0.0
Total Cover Emissions without Oxidation (kg/year)	1.11

Table C-8: TRRF Methane Emissions CALMIM Modeling Cover Description and Area

Lat. 40.13 N
 Long. -74.81 E

Model Run	CALMIM Model	Cover Type	Area (Acres)	Area (sq. m.)
Geomembrane Final Cover	Ver. 5.4	Geosynthetic Cap - Final Cover (12" Base, HDPE, 24" Cover)	216.77	8.77E+05
Final Cover - Clay	Ver. 5.4	Clay Final Cover (12" silty clay, 36" clay, 12" Loam)	17.98	7.28E+04
Daily Cover	Ver. 5.4	Clay Cover (6" - clay loam)	22.5	9.11E+04
Intermediate Cover	Ver. 5.4	Clay Cover (12" - silty clay)	47.47	1.92E+05
Temporary Geomembrane	Ver. 5.4	Temporary Geomembrane, 6" - clay loam	14.52	5.88E+04

Total: 319.24

Model Run	Organic Matter	Vegetation	Gas Recovery	Lower Boundary Methane Concentration	Upper Boundary Methane Concentration
	Low - High	%	%	%	%
Geomembrane Final Cover	Mid	100%	100%	38.5	0.0002
Final Cover - Clay	Mid	100%	100%	38.5	0.0002
Daily Cover	Mid	0%	50%	0.12	0.0002
Intermeadiate Cover	Mid	0%	100%	0.19	0.0002
Temporary Geomembrane	Mid	0%	100%	0.24	0.0002

Model Run	Total Emissions with Oxidation	Total Emissions without Oxidation	CH4 with Oxidation	CH4 without Oxidation	CH4 with Oxidation Weighted by Area	CH4 without Oxidation Weighted by Area
	g/sec	g/sec	g/m ² /sec	g/m ² /sec	g/m ² /sec	g/m ² /sec
Geomembrane Final Cover	2.24E-04	0.11	2.56E-10	1.26E-07	1.74E-10	8.55E-08
Final Cover - Clay	5.16E-02	11.69	7.09E-07	1.61E-04	3.99E-08	9.05E-06
Daily Cover	1.47E+00	1.61	1.61E-05	1.77E-05	1.14E-06	1.25E-06
Intermeadiate Cover	1.18E+00	1.20	6.16E-06	6.26E-06	9.16E-07	9.31E-07
Temporary Geomembrane	0.00E+00*	0.00**	0.00E+00*	5.99E-10	0.00E+00*	2.72E-11

Total 2.09E-06 1.13E-05

*Oxidation of methane in the cover soils can yield results, under certain circumstances, less than zero. The model includes a zero emission boundary condition that limits emissions to only positive values.

**Velocities less than 0.01 g/second are rounded to zero.

Figures C-10 through C-14 illustrate the fluctuation of surface emissions through the year calculated by the CALMIM model.

Figure C-10 – Geomembrane Final Cover

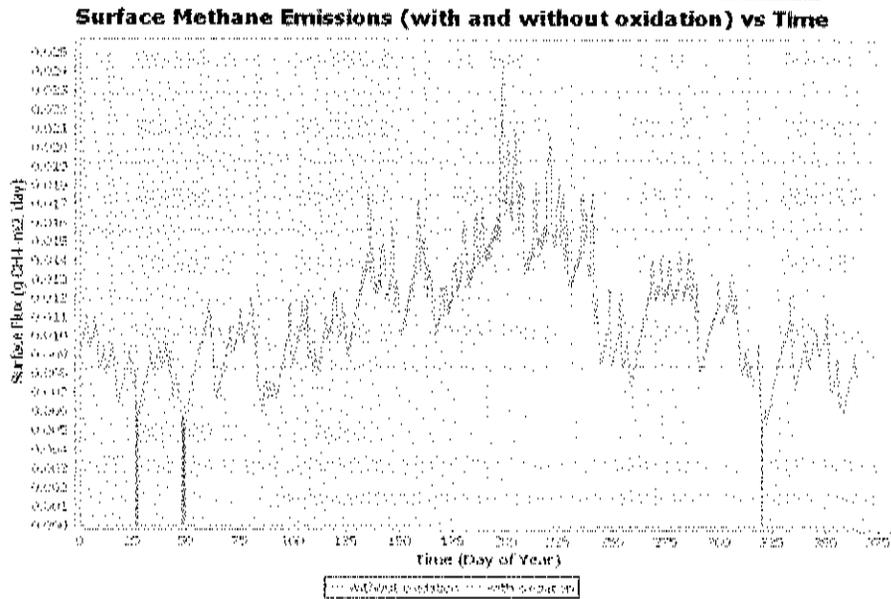


Figure C-11 – Final Cover Clay

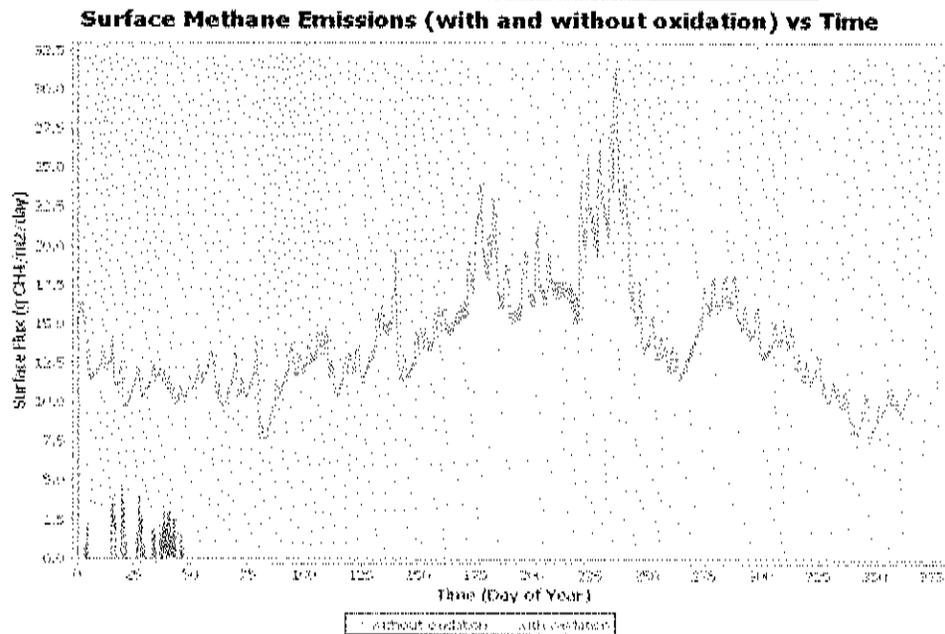


Figure C-12 – Daily Cover

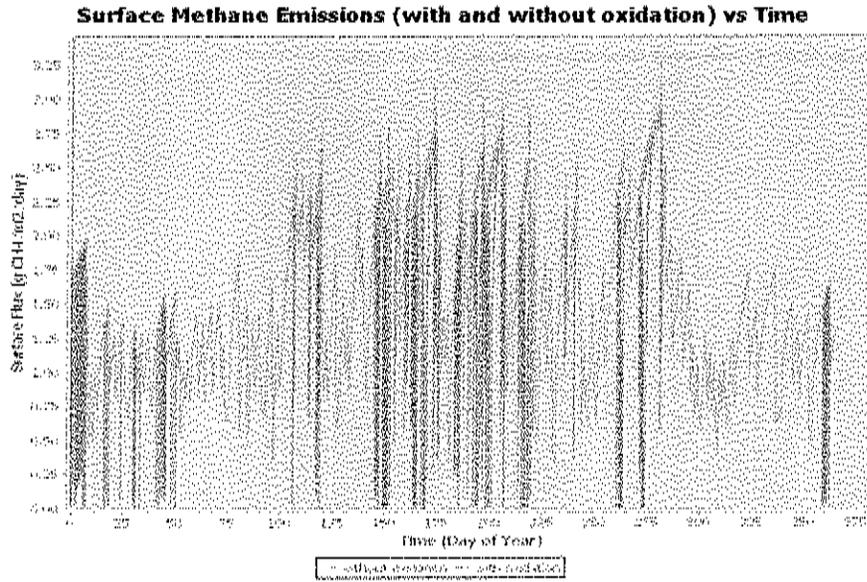


Figure C-13 – Intermediate Cover

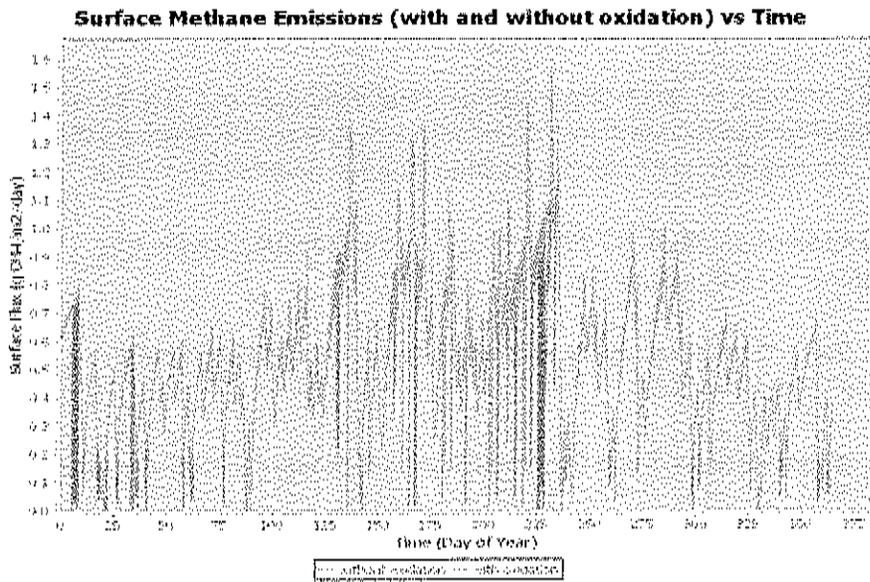
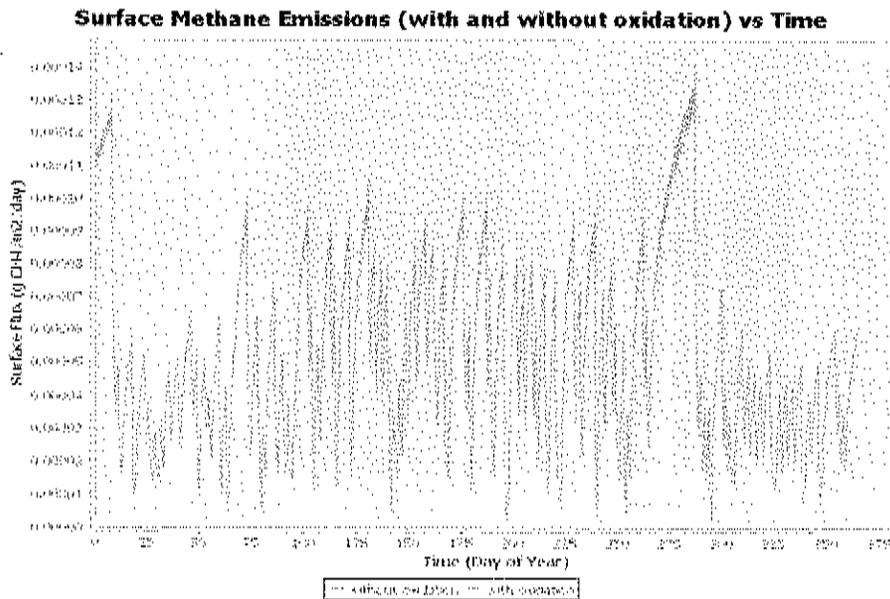


Figure C-14 – Temporary Geomembrane Cover



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APPENDIX E
AERMOD MODELING

Appendix E

AERMOD Modeling

Environmental Information Logistics, LLC

Introduction

Modeled downwind ambient air concentrations in the Florence-Roebling area that might result from potential TRRF emissions were calculated using a U.S. Environmental Protection Agency (USEPA) approved air dispersion model called AERMOD. An air dispersion model uses mathematical equations to predict the transport of emissions through the atmosphere. These models replicate atmospheric conditions, such as wind speed and direction, air temperature and mixing height, to estimate concentrations of compounds in air as they travel away from an emission source. The model used in this study, AERMOD (AMS/EPA Regulatory Model), is considered applicable for this type of study by the USEPA. It was developed based on extensive scientific research and validated based on real-world measurements.

The air dispersion modeling was performed generally in conformance with the following guideline documents, with appropriate modifications based on site-specific data:

- "New Source Review Workshop Manual", Draft October 1990
- "Guidelines on Air Quality Models"; Appendix W of 40 CFR Part 51
- Building Profile Input Program (BPIP), USEPA, 1995
- SCREEN3 User's Guide, September 1995
- AERMOD User's Guide, September 2004, Addendum December 2006
- AERMAP User's Guide, October 2004, Addendum December 2006
- AERMET User's Guide, November 2004, Addendum December 2006
- Supplemental Implementation Guidelines for AERMOD, dated September 25, 2005
- AERMOD Implementation Guide, last revised March 19, 2009
- EPA memorandum RE: Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO₂, National Ambient Air Quality Standard, dated March 1, 2011.

The version of USEPA's AERMOD air dispersion model available when the permit was issued in May 2015 was used for the air quality impact analysis (version 14134, released May 16, 2014). AERMOD is currently USEPA's regulatory approved air dispersion model for industrial sources as per Guidelines on Air Quality Models (Guideline), published in Appendix W to 40 CFR Part 51 (as revised November 9, 2005).

AERMOD is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface

and elevated sources, and both simple and complex terrain. AERMOD tracks plume mass that penetrates into the elevated stable layer and then allows it to re-enter the boundary layer when and where appropriate. For complex terrain, the plume is modeled as either impacting and/or following the terrain. The model calculates short-term and long-term concentrations at selected receptor locations based on source emissions, meteorology and land use in the modeling domain. USEPA has recommended AERMOD to be used for modeling domains up to 50 km from a source.

The AERMOD modeling system includes companion pre-processors. AERMET was used for meteorological data processing, and AERMAP was used for digital terrain processing per USEPA guidelines. Also, USEPA's AERMOD implementation Guide dated March 19, 2009 was used in developing appropriate land use parameters for the model.

The regulatory default option was used in the analysis per USEPA guidelines. The default option includes:

- Use of elevated terrain algorithms requiring input of terrain data;
- Use of stack tip downwash (except for building downwash cases);
- Use of calms processing routines; and
- Use of missing data processing routines.

Section 7.2.3 of the Guideline on Air Quality Models (USEPA 2005b) provides the basis for determining the urban/rural status of a source based on land use and population density.

The land use procedure classifies land use within an area circumscribed by a circle, centered on the source, with a radius of 3 kilometers. Table D-1 acts as a guide to help define the specific types of land use and their corresponding descriptions as defined by Auer (1978). If land use types I1, I2, C1, R2, and R3 account for 50 percent or more of the land use within 3 kilometers of the source, then the modeling regime is considered urban.

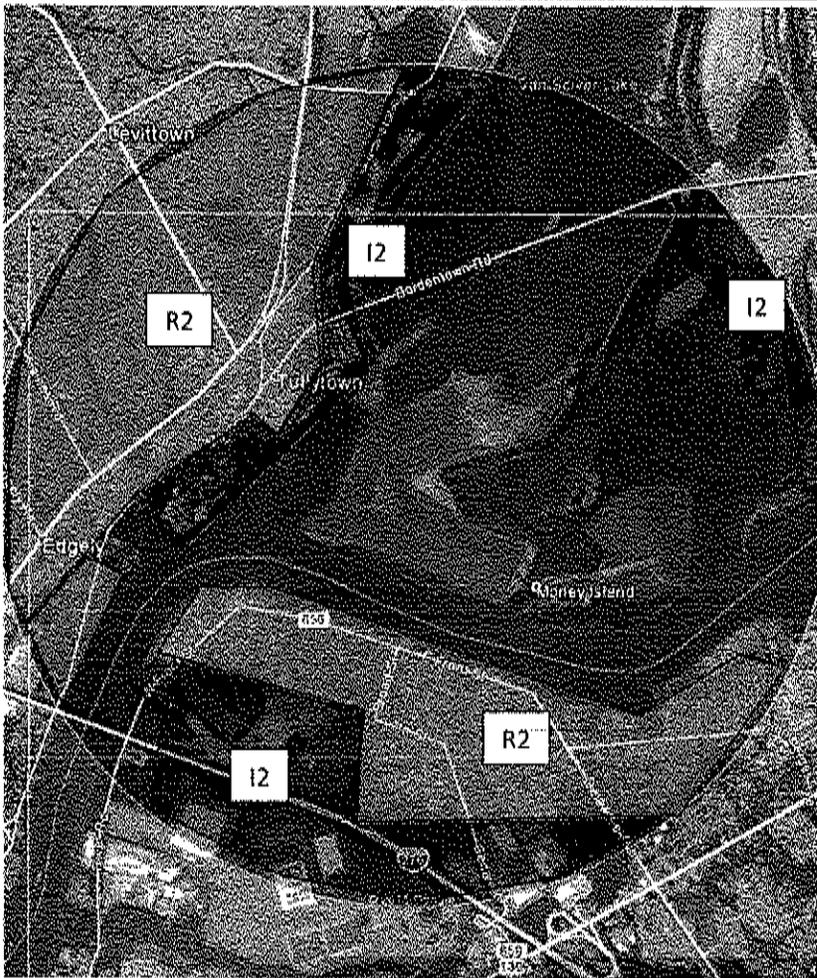
The population density procedure uses the same 3-kilometer circle as described above. The population within the circumscribed area is determined from Census Bureau Enumeration District data. This population is divided by the area of the circle to give the population density around the source. If the population density exceeds 750 people/km², the modeling regime is considered urban. The population used for the 28 km² area around the facility was approximately 40,000 (City-Data.com Census Information) establishing the population density at an estimated 1,400 people/km².

Auer's analysis and the USEPA guidance indicates that the area within 3.0 km of the Landfill is greater than 50% urban (see Figure D-1). Accordingly, an urban coefficient was used to account for heat island effects on nighttime buoyancy. Note that along with the use of the urban coefficient, only the population for the Florence/Roebling area (11,000) was input in AERMOD to ensure a conservative model result.

Table D-1: Identification and Classification of Land Use Types (Auer 1978)

Type	Use and Structure	Vegetation
I1	Heavy industrial Major Chemical, steel & fabrication industries; general 3-5 story buildings, flat roofs.	Grass & tree growth extremely rare. Less than 5% vegetation.
I2	Light-moderate industrial Rail yards, truck depots, warehouses, industrial parks, minor fabrications; generally 1-3 story buildings, flat roofs.	Very limited grass, trees almost totally absent. Less than 5% vegetation.
C1	Commercial Office & apartment buildings, hotels, 10 story heights, flat roofs.	Limited grass & trees. Less than 15% vegetation.
R1	Common residential Single family dwelling with normal easements; generally 1 story, pitched roof structures, frequent driveways.	Abundant common lawns & light-moderate wooded. Greater than 70% vegetation.
R2	Compact residential Single, some multiple, family dwelling with close spacing, generally 2 story, pitched roof structures; garages (via alley) and ashpits, no driveways.	Limited lawn sizes & shade trees. Less than 30% vegetation.
R3	Compact residential Old multi-family dwellings with close (2m) lateral separation; generally 2 story, flat roof structures; garages (via alley) and ashpits, no driveways.	Limited lawn sizes, old established shade trees. Less than 35% vegetation.
R4	Estate residential Expansive family dwelling on multi acre tracts.	Abundant grass lawns & light wooded. Greater than 80% vegetation.
A1	Metropolitan natural Major municipal, state or federal parks, golf courses, cemeteries, campuses; occasional single story structure.	Nearly total grass & lightly wooded. Greater than 95% vegetation.
A2	Agricultural rural	Local crops (e.g., corn, soybeans). Greater than 95% vegetation.
A3	Undeveloped Uncultivated; wasteland.	Mostly wild grasses & weeds, lightly wooded. Greater than 90% vegetation.
A4	Undeveloped rural	Heavily wooded. Greater than 95% vegetation.
A5	Water surfaces Rivers; lakes.	

Figure D-1: Project Location and Land Use



Source Parameters

The landfill is an area source meaning emissions are not from a stack. For this model, the landfill area sources were quantified based on the cover types. The area sources closely approximated the June 2015 landfill layout shown in Figure D-2 with the exception of the final geomembrane cover which was split into three sections to allow AERMOD to process the data in a timely manner. The working face area was assumed to be 200 feet by 250 feet consistent with typical landfill operations and was placed centrally within the daily cover area. Emissions from covered landfill areas were assumed to occur 24 hours per day, every day. Emissions from the working face were assumed to occur from 5 AM-8 PM, Monday through Saturday, assuming operations from 5 AM-6 PM plus an extra two hours at the end of the day to accommodate placement of compacted daily cover over the working face area. The timeframe for potential emissions from the working face used in this study is expected to overestimate potential air impacts because operating hours on Saturdays were reduced to 7 AM-2 PM beginning May 21, 2015 and, in the future, the closing time will be further reduced to 1 PM. Table D-2 includes the specific parameters used in the model for each area.

Building Downwash Analysis

The USEPA Building Profile Input Program with Plume Rise Enhancement (BPIP/PRIME, Version 04274¹) pre-processor for AERMOD, was used for this study. Area sources such as the landfill are not subject to building downwash calculations, however, nearby landfill buildings were evaluated to assess potential impacts none the less. Based on typical building heights (30 feet), only those buildings that are located within the potential influence area equivalent to 5 times the building height were evaluated. Only one building is located closer than 150 feet to the landfill. Figure D-3 shows the Good Engineering Practice (GEP) 360 degree influence (red dashed line) of this building and it does not significantly impinge upon the landfill. The yellow dashed line represents the total building influence area for a single given wind direction. The data shows that downwash from the building has a negligible impact on the landfill.

¹ Version available when the permit was issued in May 2015.

Figure D-2: Area Source Designation

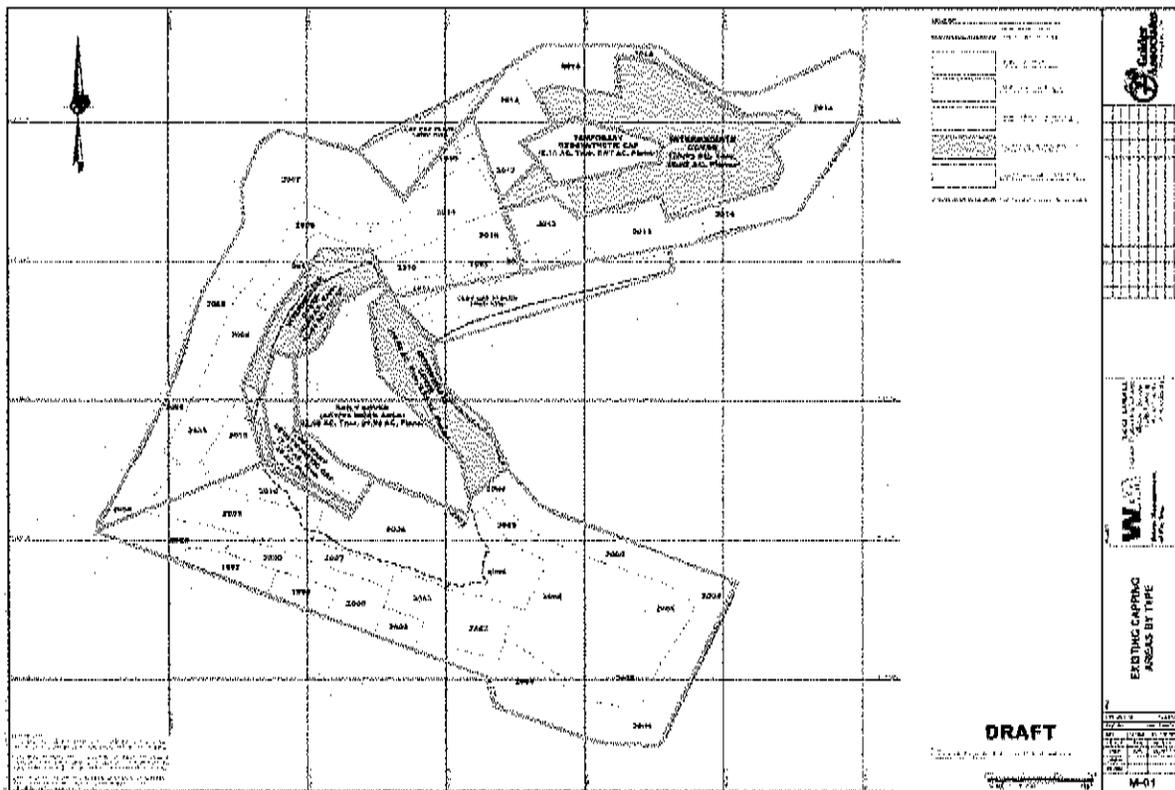


TABLE D-2 – AERMOD Source Input Parameters

AERMOD View - Source Parameters
MS Excel - Lakes Format Version 3.0
Supported Source Types: Point, Rectangular Area, Circular Area, Polygon Area, Volume, Open Pit, Line Volume, Line Area

Parameters	Units	Description
Type		POINT, AREA, AREA_CIRC, AREA_POLY, VOLUME, OPEN PIT, LINE, LINE_VOLUME, LINE_AREA, BUOYLINE
ID		Source ID up to 12 characters
Desc		Optional description
Base Elev	(m)	Source base elevation above mean sea level
Height	(m)	Release height above ground
Length X	(m)	X side length (AREA, VOLUME, OPEN PIT, and LINE_AREA only; optional for VOLUME, will be used to calculate SigmaY)
Length Y	(m)	Y side length (AREA and OPEN PIT only); width for LINE sources
Rotation Angle	(degrees)	Clockwise rotation from North of Y side (AREA and OPEN PIT only)
Emission Rate	(g/s or g/s/m ²)	Emission rate (g/s for POINT, VOLUME, and LINE_VOLUME; g/s/m ² for AREA, AREA_CIRC, AREA_POLY, OPENPIT, LINE, and LINE_AREA)
Num_Coords		Number of coordinate pairs (POINT, AREA, AREA_CIRC, VOLUME, OPENPIT = 1; AREA_POLY = 3; LINE = 2; LINE_AREA, LINE_VOLUME = 4)
X1	(m)	X coordinate of source location (m)
Y1	(m)	Y coordinate of source location (m)
X2	(m)	Secondary X coordinate of source location (m) (AREA_POLY, LINE, LINE_VOLUME, LINE_AREA, BUOYLINE sources only)
Y2	(m)	Secondary Y coordinate of source location (m) (AREA_POLY, LINE, LINE_VOLUME, LINE_AREA, BUOYLINE sources only)
X3	(m)	Additional X coordinate of source location (m) (AREA_POLY, LINE_VOLUME, LINE_AREA only)
Y3	(m)	Additional Y coordinate of source location (m) (AREA_POLY, LINE_VOLUME, LINE_AREA only)
X4	(m)	Additional X coordinate of source location (m) (AREA_POLY, LINE_VOLUME, LINE_AREA only)
Y4	(m)	Additional Y coordinate of source location (m) (AREA_POLY, LINE_VOLUME, LINE_AREA only)
Base Elev_m	(m)	Base Elevation for LINE_VOLUME, LINE_AREA Nodes
Rel_Height_m	(m)	Release height for LINE_VOLUME, LINE_AREA Nodes

NOTE: you may keep adding additional coordinate pairs for an AREA_POLY or LINE_VOLUME sources, be sure to add the headers as well (eg. X5, Y5, etc)

Type	ID	Desc	Base Elev (m)	Height (m)	Length X (m)	Length Y (m)	Rotation Angle (deg)	Emission Rate	Num Coords	X1 (m)	Y1 (m)	
AREA_POLY	PAREA1	Final Clay Cap 2	35.052	0				0.001	4	517408.20	4442773.84	
AREA_POLY	PAREA2	Intermediate Cover 2	35.052	0				0.001	9	516887.87	4442567.56	
AREA_POLY	PAREA3	Final Geomembrane Cap 1	35.052	0				0.001	14	517051.81	4442788.07	
AREA_POLY	PAREA4	Final Geomembrane Cap 2	35.052	0				0.001	17	516146.01	4442156.96	
AREA_POLY	PAREA5	Daily Cover 1	35.052	0				0.001	14	516787.80	4442584.89	
AREA_POLY	PAREA6	Intermediate Cover 3	35.052	0				0.001	16	516514.91	4442293.49	
AREA_POLY	PAREA7	Temporary Geomembrane 1	35.052	0				0.001	9	516534.04	4442307.38	
AREA_POLY	PAREA8	Final Clay Cap 1	35.052	0				0.001	3	516823.32	4442880.31	
AREA_POLY	PAREA9	Final Geomembrane Cap 3	35.052	0				0.001	33	516977.20	4443068.32	
AREA_POLY	PAREA10	Temporary Geomembrane 2	35.052	0				0.001	6	517087.08	4443061.45	
AREA_POLY	PAREA11	Intermediate Cover 1	35.052	0				0.001	24	517116.70	4442958.37	
AREA	AREAT	Daily Cover 1 Sub-Source (Working Face)			0	76.2	60.96	0	0.001	1	516680.21	4442359.70

Figure D-3: Building Downwash



Meteorological Data

A five year record of pre-processed meteorological data (Jan 1, 2010 to Dec 31, 2014) was used for the AERMOD modeling. Surface data were obtained from the Philadelphia Airport meteorological station and upper air data were obtained from the National Weather Service Sterling, VA station.

Table D-4 shows the five year records of pre-processed meteorological (Jan 1, 2010 to Dec 31, 2014) data for AERMOD that were obtained for use in this study:

Table D-4.

Model Versions Used for Met Data Preprocessing

Parameter	Value
AERMET	Version 14134
AERMINUTE	Version 14337
AERSURFACE	Version 13016

Upper Air Station Met Data Information

Parameter	Value
Upper Air Station Name	STERLING(WASH DULLES), VA
Latitude, Longitude	38.98 N, 77.47 W
Station ID (WBAN)	93734
File Format	FSL
Adjustment to Local Time	5 hours

Hourly Surface Station Met Data Information

Parameter	Value
Surface Station Name	NORTHEAST PHILADELPH, PA
Latitude, Longitude	40.07896 N, 75.01335 W
Station ID (WBAN)	94732
ASOS Station?	Yes
File Format	NCDC TD-3505 (ISHD)
Base Elevation	36.3 m
Adjustment to Local Time	5 hours
Anemometer Height	10 m

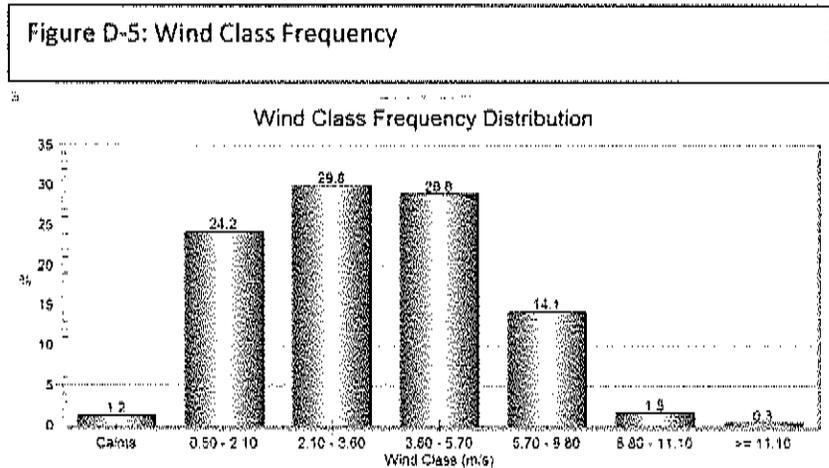
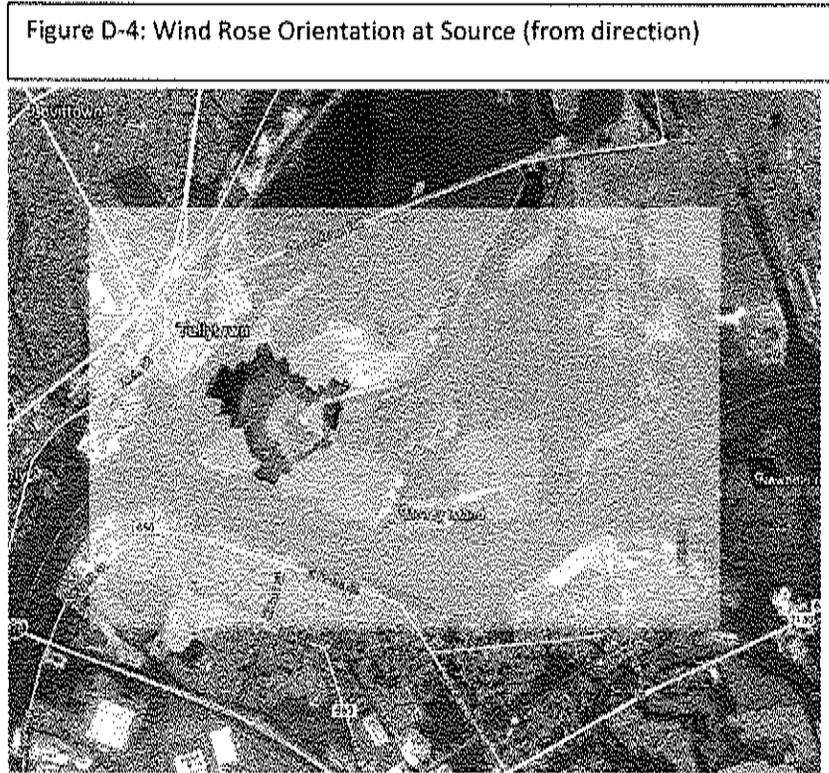
1-Minute ASOS Wind Data Information

Parameter	Value
AERMINUTE Data Used?	Yes
Station Name	NORTHEAST PHILADELPH, PA
Latitude, Longitude	40.07896 N, 75.01335 W
Station Code	PNE
Station ID (WBAN)	94732
File Format	NCDC TD-6405
IFW Installation Date	July 12, 2007

AERSURFACE Parameters

Parameter	Value
Land Use Data File	USGS NLCD92 - Binary Format
Center Lat/Long	40.07896 N, 75.01335 W
Datum	NAD83
Radius for Surface Roughness	1km
Number of Sectors	12 sectors of 30° (starting at 0°)
Period	Monthly
Surface Moisture	Average
Other Settings	Continuous Snow: No Airport Site: Yes Arid Region: No

Figure D-4 shows the wind orientation relative to the landfill for the five-year period of meteorological data used in the study. Figure D-5 shows the wind speed frequency over the data period.



Receptor Layout

For purposes of this study, a 50 meter spaced Cartesian receptor grid was placed in the Florence-Roebling area extending from the Delaware River to I-276 to the south and US-130 to the southeast. This produced a grid of 3,164 receptor points. This spacing is suitable for identifying both maximum 1-hour average and annual average concentrations as well as potential concentrations across the community area. For the 1-hour average modeling results, the full range of hourly concentrations predicted at selected receptor locations was retained for more detailed frequency distribution analysis. The receptor layout is graphically shown for the model in Figure D-6.

Figure D-6: Receptor Grid Layout for Florence/Roebling Area



Terrain Data

The air dispersion modeling took into account land terrain elevations in the TRRF vicinity and the elevation of the potential emission sources on site. The terrain data were obtained from the U.S. Geological Survey (USGS) National Geospatial Program 3D Elevation Program (3DEP). These data were processed with AERMAP, version 11103, a preprocessor of AERMOD modeling system. Digital elevation maps (DEMs) with the highest resolution currently available were used for the area in all directions in AERMAP. Receptor elevations and hill scale heights were determined for receptors based on this preprocessor. In addition, the source elevation for each modeled area (based on cover type) input into AERMOD was 115 feet above mean sea level (MSL). This elevation was selected as a conservative approximate midpoint between the base of the landfill and the landfill apex at approximately 230 feet MSL. Wind blowing over the landfill creates updrafts carrying emissions from lower sections of the landfill to upper areas. Since the vast majority of the landfill at lower elevations is capped final, the quantity of emissions from these areas would be smaller relative to other areas. Emissions from the landfill upper elevations would have a higher buoyancy and lessen downwind concentrations. Therefore, a midpoint elevation was selected as being the most conservatively representative source height.

Results

A methane emission rate of 0.001 g/m²-sec was input into AERMOD for each covered landfill area. For the working face area, a unit emission rate of 0.001 g/m²-sec was also input to AERMOD. The model output at each receptor was thus calculated in units of µg/m³ per 0.001 g/m²-sec. Table D-5 shows the maximum predicted results from the AERMOD model and the locations of each maximum. The maximum results all occurred at different locations.

Table D-5: AERMOD Maximum Modeled Receptor Concentrations (µg/m³ per 0.001 g/m²-sec)

Information	All Landfill Covered Areas	Working Face Area
Annual		
Unit Concentration (µg/m ³ per 0.001 g/m ² -sec)	1474.99	2.80
Location of Maximum (UTM coordinates X,Y)	516226.34, 4441554.12	516026.34, 4441654.12
1-Hr		
Unit Concentration (µg/m ³ per 0.001 g/m ² -sec)	62969.10	1884.00
Location of Maximum (UTM coordinates X,Y)	515576.34, 4441754.12	516126.34, 4441554.12

Covered Landfill Areas

The model results for the whole landfill (i.e., all covered landfill areas) were based on a 0.001 g/m²-sec methane emission rate. This was converted to a compound specific concentration by calculating the ratio of the compound specific landfill gas concentration to the average methane landfill gas concentration (Table D-6) and multiplying the results by the unitized AERMOD concentrations (Table D-5) and the methane emission rates. A description of the methods used to calculate methane emission rates is provided in Appendix C. Additional information about landfill gas concentrations is provided in the main report (Section 3.1.1).

The resultant maximum modeled receptor concentrations for annual and 1-hour periods are depicted in Table D-7 and D-8, respectively. The annual average concentrations were calculated using the 95% UCL ratios if available, otherwise they were based on the maximum ratios. The 1-hour average concentrations were based on the maximum ratios. The AERMOD results with oxidation were used for all organic compounds, while the results without oxidation were used for sulfur compounds (sulfides and mercaptans).

Working Face Area

The AERMOD model results for the working face (Table D-5) were multiplied by chemical-specific potential working face gas emission rates to calculate air concentrations. Information describing the calculated potential emission rates associated with working face gas, and the calculated air concentrations, is provided in the main report (Sections 3.1.2 and 3.3.3).

Table D-6: Compound / Methane Ratios For Post-Processing Aermod Results

Compound	Ratio Based on Maximum Landfill Gas Concentration	Ratio Based on Average Landfill Gas Concentration	Ratio Based on 95% Upper Confidence Limit Landfill Gas Concentration
1,1-Dichloroethane	4.32E-07	NC	NA
1,2,4-Trimethylbenzene	2.85E-05	1.69E-05	NA
1,2-Dichloroethane	4.57E-06	2.28E-06	4.24E-06
1,3,5-Trimethylbenzene	1.32E-05	8.77E-06	NA
1,4-Dichlorobenzene	1.25E-05	4.66E-06	1.09E-05
4-Ethyltoluene	3.30E-05	1.39E-05	2.97E-05
4-Methyl-2-pentanone	2.25E-05	1.62E-05	2.15E-05
Acetone	3.11E-04	1.56E-04	3.11E-04
Benzene	9.25E-05	6.14E-05	8.81E-05
Bromomethane	2.72E-06	1.60E-06	NA
Carbon disulfide	8.92E-07	NC	NA
Chlorobenzene	9.54E-07	NC	NA
cis-1,2-Dichloroethene	3.14E-06	NC	NA
Dichloromethane	7.94E-06	3.44E-06	7.38E-06
Dimethyl sulfide	3.33E-05	2.87E-05	NA
Ethyl mercaptan	5.73E-06	5.46E-06	NA
Ethylbenzene	7.68E-05	5.96E-05	NA
Ethyl acetate	2.64E-05	NC	NA
Freon 113	1.19E-05	4.11E-06	1.03E-05
Freon 12	7.09E-06	4.09E-06	NA
Heptane	1.50E-05	NC	NA
Hexane	6.34E-06	NC	NA
Hydrogen sulfide	5.10E-04	3.14E-04	NA
Isobutyl mercaptan	3.26E-05	NC	NA
Methyl ethyl ketone	3.60E-04	1.96E-04	NA
Methyl mercaptan	2.46E-05	1.77E-05	NA
Perchloroethylene	5.58E-06	3.31E-06	5.52E-06
Propanol, 2-	5.02E-05	NC	NA
Propyl mercaptan	2.37E-06	NC	NA
Styrene	6.36E-06	2.60E-06	5.76E-06
Tetrahydrofuran	1.17E-05	NC	NA
Toluene	1.61E-04	1.16E-04	NA
Trichloroethylene	2.29E-06	1.69E-06	NA
Vinyl Chloride	3.35E-06	2.15E-06	NA
Xylenes mixed, m+o+p	1.73E-04	1.30E-04	NA
Xylenes mixed, m+p	1.32E-04	1.00E-06	NA
Xylenes mixed, o	4.10E-05	3.01E-05	NA

NC = Not calculated. Only one sample had a detected value and, if other sample results were available, all the other samples had detection limits > 1/2 maximum detected concentration.

NA = Not applicable. A 95% UCL could not be calculated from the available data.

Table D-7: Calculated Annual Average Concentrations at the Maximum Impact Location for Potential Emissions from Covered Landfill Areas

Compound	Concentration ($\mu\text{g}/\text{m}^3$)
1,1-Dichloroethane	1.33E-06
1,2,4-Trimethylbenzene	5.23E-05
1,2-Dichloroethane	1.31E-05
1,3,5-Trimethylbenzene	2.71E-05
1,4-Dichlorobenzene	3.38E-05
4-Ethyltoluene	9.17E-05
4-Methyl-2-pentanone	6.62E-05
Acetone	9.60E-04
Benzene	2.72E-04
Bromomethane	4.93E-06
Carbon disulfide	1.49E-05
Chlorobenzene	2.95E-06
cis-1,2-Dichloroethene	9.70E-06
Dichloromethane	2.28E-05
Dimethyl sulfide	4.78E-04
Ethyl mercaptan	9.12E-05
Ethylbenzene	1.84E-04
Ethyl acetate	8.14E-05
Freon 113	3.17E-05
Freon 12	1.26E-05
Heptane	4.63E-05
Hexane	1.96E-05
Hydrogen sulfide	5.25E-03
Isobutyl mercaptan	5.44E-04
Methyl ethyl ketone	6.04E-04
Methyl mercaptan	2.95E-04
Perchloroethylene	1.70E-05
Propanol, 2-	1.55E-04
Propyl mercaptan	3.96E-05
Styrene	1.78E-05
Tetrahydrofuran	3.61E-05
Toluene	3.59E-04
Trichloroethylene	5.21E-06
Vinyl Chloride	6.64E-06
Xylenes mixed, m+o+p	4.01E-04
Xylenes mixed, m+p	3.08E-04
Xylenes mixed, o	9.29E-05

Table D-8: Calculated 1-Hour Average Concentrations at the Maximum Impact Location for Potential Emissions from Covered Landfill Areas

Compound	Concentration ($\mu\text{g}/\text{m}^3$)
1,1-Dichloroethane	5.69E-05
1,2,4-Trimethylbenzene	3.75E-03
1,2-Dichloroethane	6.01E-04
1,3,5-Trimethylbenzene	1.74E-03
1,4-Dichlorobenzene	1.64E-03
4-Ethyltoluene	4.34E-03
4-Methyl-2-pentanone	2.96E-03
Acetone	4.10E-02
Benzene	1.22E-02
Bromomethane	3.59E-04
Carbon disulfide	6.36E-04
Chlorobenzene	1.26E-04
cis-1,2-Dichloroethene	4.14E-04
Dichloromethane	1.05E-03
Dimethyl sulfide	2.37E-02
Ethyl mercaptan	4.09E-03
Ethylbenzene	1.01E-02
Ethyl acetate	3.47E-03
Freon 113	1.57E-03
Freon 12	9.33E-04
Heptane	1.98E-03
Hexane	8.35E-04
Hydrogen sulfide	3.63E-01
Isobutyl mercaptan	2.32E-02
Methyl ethyl ketone	4.74E-02
Methyl mercaptan	1.75E-02
Perchloroethylene	7.35E-04
Propanol, 2-	6.61E-03
Propyl mercaptan	1.69E-03
Styrene	8.38E-04
Tetrahydrofuran	1.54E-03
Toluene	2.12E-02
Trichloroethylene	3.02E-04
Vinyl Chloride	4.41E-04
Xylenes mixed, m+o+p	2.28E-02
Xylenes mixed, m+p	1.74E-02
Xylenes mixed, o	5.41E-03

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APPENDIX F

HEALTH-BASED COMPARISON VALUES

APPENDIX F
HEALTH-BASED INHALATION COMPARISON VALUES (CVS)
CPF Associates, Inc.

Introduction

Health-based comparison values (CVs) for the inhalation pathway of exposure are developed by regulatory agencies and public health scientists based on scientific information about the toxicity of chemical substances. CVs are concentrations of compounds in air that are considered to be protective of public health.

If a compound's air concentration is lower than its CV, adverse effects are not expected to occur. If a compound's air concentration exceeds its CV, this does not mean that adverse effects will occur among exposed populations because of the conservative assumptions included in both the derivation of the CV and the calculation of air concentrations. Rather it indicates a need for further investigation to help determine whether or not its level in air presents a public health concern.

In this study, chronic and acute CVs were compiled to assess the potential for both chronic, long-term risks and acute, short-term risks, respectively.

Chronic CVs

The potential for long-term chronic health risks resulting from long-term exposures over several years or more can be evaluated using chronic CVs. The chronic CVs in this study were obtained from USEPA's Regional Screening Level (RSL) table which provides health-protective residential air concentrations, referred to as RSLs, for potential long-term inhalation exposure to chemical compounds in air.¹ RSLs are developed by USEPA specifically to perform preliminary screening of chemical concentrations at a site. The hierarchy of data sources used by USEPA is consistent with PADEP's recommended hierarchy (PADEP 2013). These sources include: USEPA's Integrated Risk Information System (IRIS), Provisional Peer Reviewed Toxicity Values (PPRTVs) derived by USEPA's Superfund Health Risk Technical Support Center for the Superfund program, and other sources such as the Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs) and the California Environmental Protection Agency (CALEPA) Office of Environmental Health Hazard Assessment's Chronic Reference Exposure Levels (RELS).

USEPA compiles RSLs for two different types of health effects that can potentially be caused by chronic long-term exposure to chemical compounds -- non-cancer hazards and cancer risks. The consideration of both types of health effects follows standard USEPA methods for

¹ USEPA's Risk-Based Screening levels are available at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/.

evaluating potential risks. Different approaches are used to address each of these types of health effects, as described below.

Non-Cancer Hazards

Non-cancer hazard represents the potential for developing health effects other than cancer and it is evaluated according to USEPA's methods by comparing a compound's long-term air concentration to its chronic reference air concentration. This comparison results in a value known as the hazard quotient (HQ). A hazard quotient greater than one (1) indicates that there is a potential for a non-cancer effect to occur whereas a hazard quotient of one or less suggests that the concentration is safe (USEPA 1991). This method for evaluating non-cancer hazards is based on the hypothesis that there is a concentration threshold below which toxicity will not occur.

In the case of potential exposure to a mixture of chemicals, USEPA considers that the effects may be additive. This is evaluated by calculating an overall hazard index (HI) which is the sum of the individual chemical-specific hazard quotients:

$$HI = \sum HQ$$

As with the hazard quotients, a hazard index for a mixture that is greater than one (1) indicates the potential for a non-cancer health effect. If this occurs, USEPA risk assessment practice requires separating chemical compounds into subgroups representing effects on various target organs (e.g., respiratory system, liver, etc). The hazard index would then be re-calculated for each subgroup as warranted.

Cancer Risks

A cancer risk refers to the probability that an individual could contract cancer under a set of assumed conditions of chemical exposure and it is calculated by multiplying a compound's concentration in air by a toxicity factor called the inhalation unit risk (IUR). The USEPA and other regulatory and public health agencies develop IURs for compounds that have evidence of carcinogenicity based on consideration of human and animal toxicity studies, and incorporate safety factors to ensure that they are health-protective. This multiplication results in a lifetime cancer risk, over and above the background risk of developing cancer, expressed as a probability. For example, a probability of 1×10^{-6} or 1E-06 represents a chance of one in one million that an individual would develop cancer over a lifetime under assumed conditions of exposure. In essence, this probability represents the upper bound increased lifetime cancer risk associated with an assumed exposure above the existing background for developing cancer. Note that this method does not distinguish between types of cancer, but considers the overall probability of developing cancer. In actuality, different compounds have been associated with different types of cancer or cancer at different sites and target tissues. In the US, roughly one of every two men and one of every three women will contract cancer over a lifetime. These statistics would translate to probabilities of 0.50 for men and 0.33 for women over a lifetime.

The USEPA's method for calculating cancer risks is based on a scientific hypothesis that exposure to any concentration of a potential carcinogen, regardless of how small, will result in some cancer risk (i.e., probability of contracting cancer). These risks are often characterized as "upper bound" due to the statistical techniques that are used in their derivation. This means that the actual cancer risk could be substantially lower than the calculated risk and could even approach zero.

Regulatory agencies use risk-based criteria to evaluate the results of cancer risk assessments. USEPA (1991) considers exposure levels to be acceptable if the resultant lifetime cancer risks are in the range from 1E-06 to 1E-04 (one in one million to one in ten thousand). PADEP generally relies on a cancer risk level of 1E-04 (one in ten thousand) when assessing health risks from chemical compounds in ambient air (PADEP 2013).

Selection of RSLs

The chronic RSLs compiled for all the compounds selected for evaluation are provided in the main report. The non-cancer RSLs were based on a target hazard quotient (HQ) of 0.1. This is 10 times lower (i.e., more health-protective) than the criterion typically used in health risk assessments. The cancer-based RSLs were based on a target excess lifetime cancer risk of 1E-06 (one in one million). This cancer risk level is 100 times more conservative (i.e., health protective) than the 1E-04 risk level generally relied upon by PADEP (PADEP 2013). If RSL air concentrations were available for both non-cancer and cancer health effects, the lowest one was used in this study.

The chronic RSLs for residential inhalation of ambient air assume that exposure occurs 24 hours per day, 350 days per year, for a total of 26 years. This is conservative because the landfill will be closed soon and thus potential emissions will decrease over time. Although there are some exposure assumption differences in USEPA's RSLs compared to PADEP's generally recommended guidance (e.g., an exposure period of 26 years versus 70 years, respectively), these differences are more than offset by using RSLs based on USEPA's more stringent target levels for cancer risk (1E-6 versus 1E-4) and non-cancer hazards (0.1 versus 1.0) and also by not considering the actual remaining landfill operating period.

Acute CVs

The potential for short-term acute inhalation health risks was evaluated using acute CVs. Regulatory agencies and public health scientists develop acute CVs based on animal and human studies that have investigated the health effects that could potentially occur as a result of short inhalation exposures to chemical substances in air. As with chronic CVs, these values generally incorporate safety factors to ensure that they are protective of human health. The acute CVs used in this study were derived for potential short-term, 1-hour exposures to chemical concentrations in air.

Following the PADEP-approved study plan, the main sources of the acute CVs in this study were as follows:

- Reference Exposure Levels (RELs) – The CAL EPA has developed acute RELS designed to protect even sensitive individuals in the population by the inclusion of margins of safety. The acute REL is the concentration level at or below which no adverse health effects are anticipated to occur based on a short-term, 1-hour period of exposure.²
- Acute Exposure Guideline Levels (AEGs) - USEPA's National Advisory Committee for the Development of Acute Exposure Guideline Levels for Hazardous Substances develops AEGs. The AEG values are used by local, state and federal agencies for emergency planning, prevention and response to provide guidance in situations where the general public may be accidentally exposed to certain chemicals. USEPA defines the AEG-1 as the airborne concentration of a compound "above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure."³

If both a REL and an AEG-1 were available for a compound, the lowest value was used. If acute CVs could not be obtained from either the CAL EPA RELs or the USEPA AEGs, other data sources were relied on:

- Emergency Response Planning Guidelines (ERPGs) – If acute CVs were not available from the data sources above, then the search for values was expanded to Level 1 Emergency Response Planning Guidelines (ERPG-1 values) developed by the American Industrial Hygiene Association. The ERPG-1 is defined as "the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor."
- Temporary Emergency Exposure Limits (TEELs) - If values were not available from any of the sources above, acute CVs were based on Temporary Emergency Exposure Limits (TEELs) developed by the Department of Energy's Office of Emergency Management. The TEEL-1 is defined as the air concentration of a compound "above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, nonsensory effects. However, these effects are not disabling and are transient and reversible upon cessation of exposure."

The acute CVs for the compounds selected for evaluation in this study are provided in the main report.

² <http://oehha.ca.gov/air/allrels.html>

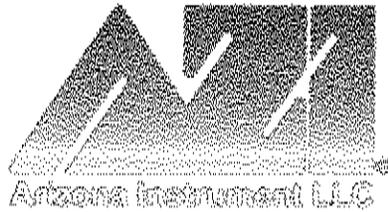
³ Definitions of AEGs, ERPGs and TEELs are provided at: <http://www.atlantl.com/DOE/teels/teel/teeldef.html>.

References

Pennsylvania Department of Environmental Protection (PADEP). 2013. Technical Support Document for Long-Term Ambient Air Monitoring Project Near Permanent Marcellus Shale Gas Facilities Protocol. Appendix F – Toxic Monitoring Section Data Analysis, Risk Assessment and Data Reporting Protocol. Prepared by Bureau of Air Quality. August 1, 2013.

U.S. Environmental Protection Agency (USEPA). 1991. Role of the baseline risk assessment in Superfund remedy selection decisions. OSWER Directive 9355.0-030.

APPENDIX G
JEROME® 631-X HYDROGEN SULFIDE ANALYZER
OPERATION MANUAL



USER MANUAL

JEROME® 631-X
HYDROGEN SULFIDE ANALYZER
OPERATION MANUAL

April 2014

ARIZONA INSTRUMENT LLC
3375 N Delaware Street | Chandler, AZ 85225 USA
800.528.7411 | 602.470.1414 | f 602.281.1745

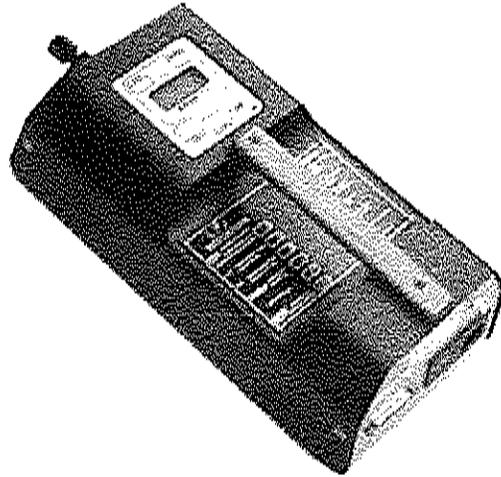
www.azic.com

Email:
General – azi@azic.com
International – intl@azic.com
Customer Service – support@azic.com

ARIZONA INSTRUMENT LLC
3375 N Delaware St | Chandler, AZ 85225
800.528.7411 | sales@azic.com | www.azic.com
MADE IN THE USA

AZI P/N 700-0037-E
Last Update April 2014

JEROME® 631-X
Hydrogen Sulfide Analyzer
Operation Manual



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An up-to-date electronic copy of this manual can be found at:

<http://www.azic.com/downloads.aspx>

I. FOR THOSE WHO CAN'T READ THE WHOLE MANUAL NOW

This manual contains details that will optimize the results and the life of your instrument. Read and refer to the manual for complete details on operation, maintenance and troubleshooting, special voltage inputs and data output.

The Jerome® 631-X is easy to operate and ready for use upon receipt from the factory.

- Remove the instrument from the packing material.



Retain all packaging materials for any future shipment of the instrument.
If the instrument is returned to AZI for any reason, it must be placed in the original packaging materials that have been tested and proven to be effective protection during shipment.



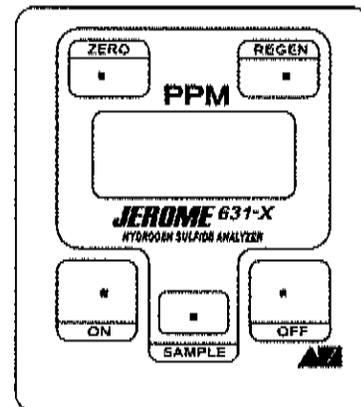
- Call AZI Customer Service at 800-528-7411 or 602-470-1414 for Return Material Authorization (RMA) information prior to returning a unit.
- For all shipments, boxes and packing materials are available from AZI.
- Pack the Jerome® instrument only in a Jerome® shipping container.



AZI WILL NOT BE RESPONSIBLE FOR SHIPPING DAMAGE.
IF YOU RETURN THE INSTRUMENT IMPROPERLY PACKAGED OR SHIPPED,
YOU SHOULD INSURE IT FOR FULL VALUE.



- Check for any damage and confirm receipt of all parts on your packing list. Contact Arizona Instrument Customer Service at (800) 528-7411 or (602) 470-1414 if you have any questions.
- Press the ON button. The display should read 000 in less than one second.
 - A LO BAT message appears briefly in the upper left corner.
 - If the LO BAT light persists, recharge the battery. See page 17.



- Check the voltage setting (110 or 220 VAC) on the back of the instrument. Ensure that it is set to the correct voltage. If the pointer is not aligned to the local voltage, turn the selector to point to the correct voltage.
- 
- Perform a sensor regeneration by following these steps:
 - Connect the line cord between the connector on the back of the 631-X and an AC power outlet.
 - Press the ON switch and then press the REGEN button.
 - ◆ The instrument will begin a 10 minute regeneration cycle, indicated by .H.H.H flashing on the display. **Do not interrupt this cycle.** For a complete description of this process, see page 12.
 - ◆ If any error message, such as .P.P.P, appears on the display, see the “Troubleshooting” section beginning on page 24.
 - When regeneration is complete, zero the sensor by pressing the ZERO button and turning the zero adjust screw, located under the handle, until the display reads 0.
 - The instrument is now ready to sample.
 - To ensure the input to the instrument contains no hydrogen sulfide or mercaptans, use a Zero Air Filter, AZI P/N Z2600 3905. The Zero Air Filter cleans the air sample and should produce sample readings of less than 0.003 ppm. Therefore, use the filter to:
 - Equilibrate the instrument to temperatures that are higher or lower than the instrument. Sample with filter installed until the reading is below 0.003 ppm.
 - Identify contamination within the unit.
 - Confirm the presence of hydrogen sulfide when readings are elevated. Install filter and verify that the readings go down with filter installed.
 - When the instrument measures hydrogen sulfide, the zero display will be replaced with a value.

CAUTION

Do not adjust the ZERO after the instrument has measured hydrogen sulfide or before the next regeneration. (Occasionally the display may drop to .L.L.L (indicating low) between the initial zeroing and the first sample. It is OK to readjust the ZERO if the instrument has not measured hydrogen sulfide.)

- The instrument is designed for ambient air monitoring. **DO NOT allow the probe or the instrument's intake to be exposed to any liquid.**
- The instrument is not explosion proof.
- Press the SAMPLE button to start a 10 second sampling cycle.
- Perform sensor regeneration after each day's testing.
- Perform another sensor regeneration and re-zero the instrument before each day's use.
- Perform sensor regeneration after 30 days of storage or inactivity.

Call AZI Customer Service, at (800) 528-7411 from the United States and Canada or (602) 470-1414 if you have any questions. If you prefer, you may send e-mail to support@azic.com

2. INTRODUCTION

The Jerome® 631-X Hydrogen Sulfide Analyzer is an ambient air analyzer with a range of 0.003 ppm to 50 ppm (parts per million).



CAUTION:

The Jerome® 631-X is for vapor use only.
DO NOT allow the probe or the instrument's intake to be exposed to any liquid, dust or other foreign material.



The 631-X is designed to be easy to operate for quick and accurate analysis of hydrogen sulfide vapor levels. It has few maintenance requirements. However, please take a moment to read this manual before attempting operation. If you have any questions about your application or operation, please call AZI Customer Service at (800) 528-7411 or (602) 470-1414 or e-mail support@azic.com for assistance.

631-X Features

- Accurate analysis of hydrogen sulfide in seconds
- Wide detection range allows multiple applications
- Survey mode for rapid source detection of hydrogen sulfide concentrations
- Rechargeable internal battery pack for portability
- Automatic backlight for LCD during low light conditions
- Microprocessor ensures a linear response throughout the entire range of the sensor
- Inherently stable gold film sensor

Optional Accessories

- Data Logger, P/N Y990-0169, to record field monitoring information
- Jerome® Communication Software Kit, P/N Y990-0168, for unattended fixed-point sampling and downloading information from the data logger to a computer.
- Option Board (factory installed option) for external fresh air solenoid support, auto-zeroing, DC power operation, timed regeneration, 4-20 mA or 0-2 V analog output, and timed sampling
- Functional Test Module (FTM) (P/N Z2600 0918 or Z2600 0930) and Accessory Kit (Y2600 0920), for field verification of instrument functionality.
- Field Carrying Cases, hard sided P/N Y411 0904 or soft P/N 1400 0052, for versatile handling and additional storage
- Maintenance Kit, P/N Y631 0905 for routine maintenance and upkeep

Applications

- Ambient air analysis
- Odor nuisance monitoring
- Regulatory compliance
- Control room corrosion monitoring
- Quality control
- Scrubber efficiency testing
- Accuracy check for other hydrogen sulfide monitors and control systems
- Hydrogen sulfide source detection
- Leak detection
- Portable hydrogen sulfide detection

The Jerome® 631-X can be operated from 100-120 or 200-240 VAC. To change the default voltage range, refer to "Setting the Input Voltage" on page 21.

3. PRINCIPLE OF OPERATION

A thin gold film, in the presence of hydrogen sulfide, undergoes an increase in electrical resistance proportional to the mass of hydrogen sulfide in the sample.

When the SAMPLE button is pressed, an internal pump pulls ambient air over the gold film sensor for a precise period. The sensor absorbs the hydrogen sulfide. The instrument determines the amount absorbed and displays the measured concentration of hydrogen sulfide in ppm. During normal sampling, the ambient air sample is diluted in the flow system at a ratio of 100:1. When sampling in Range 0, (where low levels of hydrogen sulfide are expected) undiluted air samples are drawn across the gold film sensor.

The instrument's microprocessor automatically re-zeroes the digital meter at the start of each sample cycle and freezes the meter reading until the next sample cycle is activated, thus eliminating drift between samples.

During the sample mode cycle, bars on the LCD represent the percentage of sensor saturation. Depending on the concentrations, 50 to 500 samples may be taken before the sensor reaches saturation. At that point, a 10-minute heat cycle must be initiated to remove the accumulated hydrogen sulfide from the sensor. During the sensor regeneration cycle, both solenoids are closed to cause air to pass through a scrubber filter and provide clean air for the regeneration process. The flow system's final scrubber filter prevents contamination of the environment.

The heat generated during the regeneration may cause some low level thermal drift. To ensure maximum sample accuracy, wait 30 minutes after regeneration before zeroing and using the instrument.

Zero Air Filter

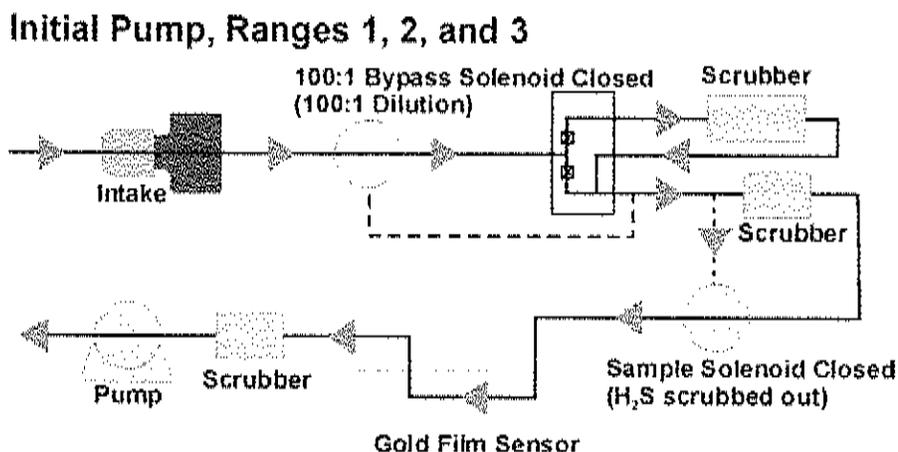
The Zero Air Filter removes mercury vapor, mercaptans, and hydrogen sulfide from the air sample. Readings with the filter installed should be near zero.

Because air that is cooler than the instrument will cause low readings and warmer air will cause higher readings, the Zero Air Filter should be used to equilibrate the unit to ambient air temperature. Continuous sampling with clean air will not cause saturation of the gold film sensor but will equalize temperatures faster to allow accurate analysis to begin sooner. For best results, be sure that the instrument is at the same temperature as the environment before testing.

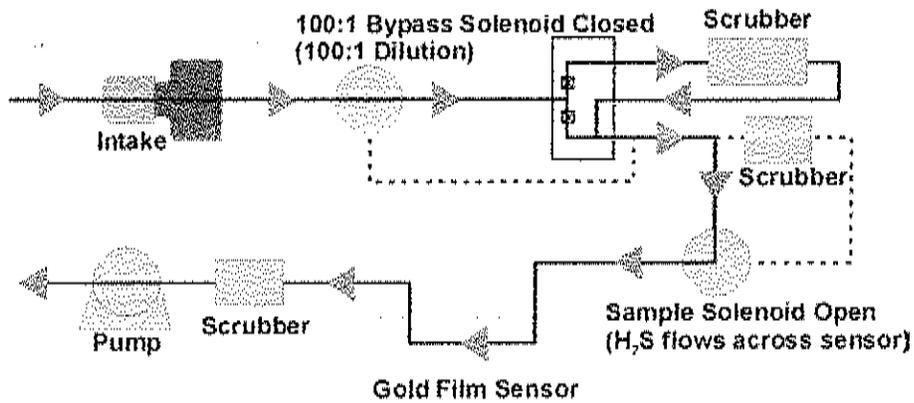
The Zero Air Filter can also be used to identify contamination within the instrument. If the readings do not reduce to near zero with the filter installed, contamination should be suspected. If the readings do drop to near zero with the filter installed but elevate with the filter removed, the presence of hydrogen sulfide at the sampled location is confirmed.

For more information on the use of the Zero Air Filter, contact customer service at 1-800-528-7411, 1-602-470-1414, or visit our web site at <http://www.azic.com>.

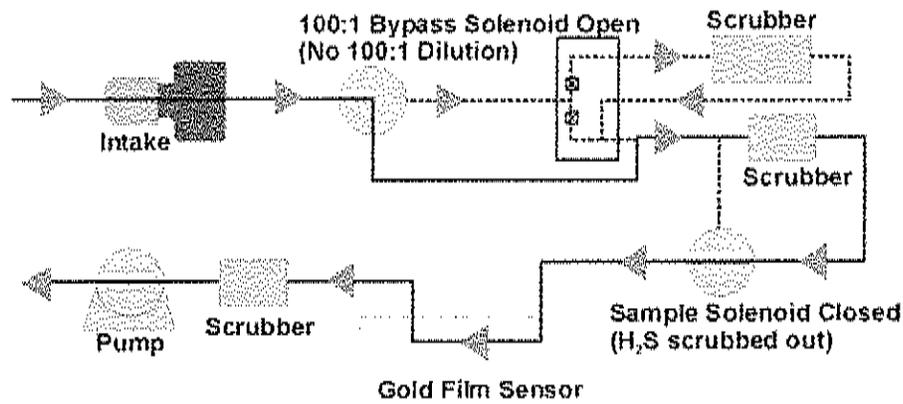
Gas Flow Schematics



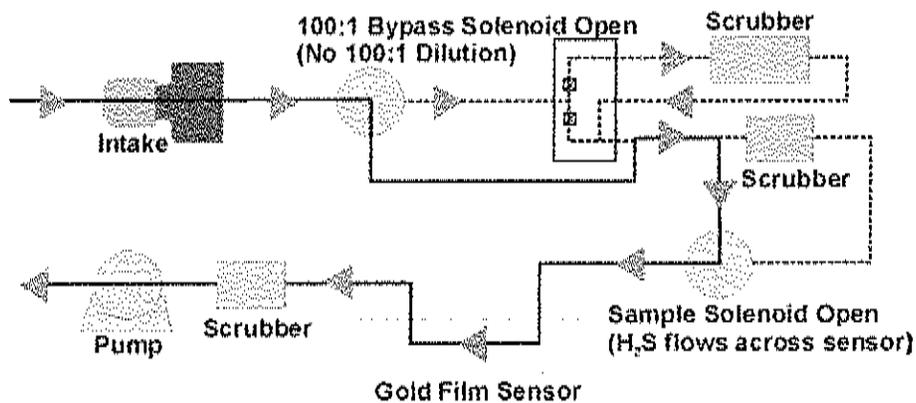
Sample Period, Ranges 1, 2, and 3



Initial Pump, Ranges 0



Sample Period, Ranges 0



4. INSTRUMENT OPERATION

LCD Codes

LCD CODE	EXPLANATION
000	Ready to sample
.000	No hydrogen sulfide reading
.8.8.8	Sensor saturated-regeneration needed (refer to page 12)
.H.H.H	Sensor regeneration in progress (.H.H.H flashes)
.L.L.L	Re-zero needed (refer to page 13)
.P.P.P	Power cord required or low line power, <100 VAC (or 200 VAC) (see pages 16 and 17, Changing the Fuse, if .P.P.P remains on after the cord is connected.)
.LO BAT	Recharge batteries (refer to page 17)
.E.E.E	Same as LO BAT, automatically shuts off
.HL	Very high concentration has been detected. Refer to your safety policy for additional direction to confirm the concentrations."
DURING SAMPLING	
.-	0-25% sensor saturation
.--	25-50% sensor saturation
.---	50-75% sensor saturation
-.---	75-100% sensor saturation
DURING SAMPLING, USING SURVEY MODE	
-	Survey sampling (minus sign flashes continuously)
WHEN ZERO IS DEPRESSED	Adjust to 0 only after sensor regeneration. It is normal for the display to read H after sampling has started.
0	Zero, ready to sample
H	High, turn Zero potentiometer counterclockwise
L	Low, turn Zero potentiometer clockwise

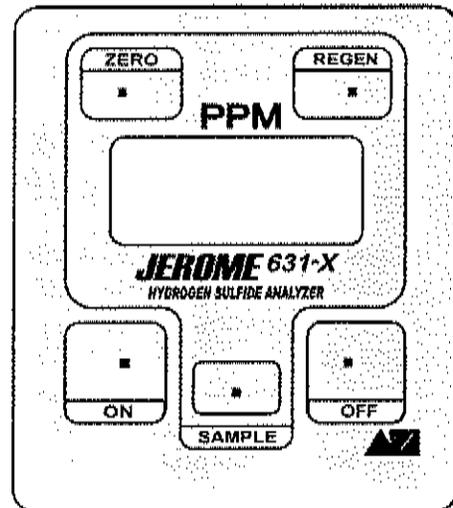
Daily Operations

Before each day's use of the Jerome® 631-X, perform the following steps to verify proper instrument operation:

- Press the power ON button.
 - The digital meter displays 000.
 - ◆ (Disregard the digital meter's initial momentary reading.)
 - ◆ Recharge or replace the battery pack if the LO BAT indicator REMAINS ON. Refer to "Charging Batteries" on page 17 and/or "Replacing the Battery Pack" on page 21.
 - ◆ To ensure the instrument's electronics have stabilized, allow a 1-minute warm up before beginning the next step.
- Use the Zero Air Filter to equilibrate the instrument to ambient air temperature.
 - Install the Zero Air Filter in the instrument's intake.
 - Sample continuously until the readings stabilize.
- Perform sensor regeneration. Refer to page 12 for the procedure.
- Thirty minutes after sensor regeneration is complete, zero the instrument. See page 13.

NOTE: For maximum accuracy, such as when testing with the Functional Test Module, wait 30 minutes after the sensor regeneration cycle to re-zero the unit. For immediate use, the unit can be re-zeroed immediately after sensor regeneration. See the notes on page 13.

- Press the SAMPLE button.
 - During the sample cycle, the digital meter displays bars (-, --, or ---) to indicate the amount of sensor saturation.
- At the end of the sampling cycle, read the digital meter.
 - The number shown on the digital meter is the hydrogen sulfide concentration in ppm.
 - This value remains on the display until the next sample is taken.
 - The digital meter automatically zeroes at the start of each sample.
- At the end of each day's use, perform sensor regeneration as described in the next section.



DO NOT ALLOW HYDROGEN SULFIDE TO STAY ON THE GOLD FILM SENSOR OVERNIGHT.

Sensor Regeneration

Sensor regeneration is needed to clear the 631-X sensor of any accumulated hydrogen sulfide. This simple procedure should be done:

- At the beginning of the day on which the instrument is to be used.
- During the day when the sensor becomes saturated.
- At the end of the day before storing the instrument.



CAUTION:

Ensure the voltage selector on the back of the instrument, near the power cord inlet connector, points to the local AC power value. See "Setting the Input Voltage" on page 21.

To clean and protect the sensor, the supplied AC power must be 100 to 120 VAC or 220 to 240 VAC, depending on the available power source.

Once sensor regeneration is initiated, **DO NOT** interrupt the cycle.



- Attach the power cord to the 631-X and plug it into AC power. AC power is required to thermally regenerate the sensor.
- Press the power ON button.
- Press the REGEN button.
 - The digital meter flashes .H.H.H for the duration of the 10-minute cycle and displays .0.0.0 when the cycle is completed.

DO NOT INTERRUPT THIS CYCLE.

Wait until the cycle is completed before continuing with the next step.

- A minimum 30-minute wait after the sensor regeneration cycle is complete ensures maximum sample accuracy. However, the unit can be used immediately following the sensor regeneration if necessary. When the sensor regeneration is complete, press ZERO and adjust the ZERO ADJUST pot until 0 appears on the display. Install the zero air filter in the intake and take several samples or lock the instrument into survey mode (see page 15). After approximately one minute, stop sampling and check the ZERO. Adjust to 0. Repeat sampling through the zero air filter until reading remains on 0.

NOTE: The digital meter will read .P.P.P after REGEN is activated if the power cord is not plugged in or if the instrument's fuse needs to be replaced. Connect the power cord, or if necessary, replace the fuse. See "Changing the Fuse" on page 22.

Zero Adjust

- To ensure air entering the instrument is clean, install the zero air filter in the instrument's intake and sample until the readings stabilize.
- While pressing the ZERO button, turn the ZERO ADJUST potentiometer (shown at right) using the trimmer tool until the digital meter reads 0.
 - If the LCD reads H, turn the ZERO ADJUST counter-clockwise;
 - If the LCD reads L, turn the ZERO ADJUST clockwise.



NOTE: A minimum 30-minute wait after the sensor regeneration cycle is complete ensures maximum sample accuracy. The unit can be used immediately following the sensor regeneration if necessary. When the sensor regeneration is complete, press ZERO and adjust the ZERO ADJUST pot until 0 appears on the display. Install the zero air filter in the intake and take several samples or lock the instrument into survey mode (see page 15). After approximately one minute, stop sampling and check the ZERO. Adjust to 0 if necessary. Repeat sampling through the zero air filter until sensor remains on 0.

NOTE: When ZERO is pressed, depending upon internal configuration, a number between 00 and 100 may appear on the display instead of H, L, or O. See APPENDIX C - INTERNAL DIP SWITCH SETTINGS, on page 39, for details. If the instrument is configured with an Option Board, see APPENDIX D - JEROME® 631-X OPTION BOARD beginning on page 40.

CAUTION:

Do not turn the ZERO ADJUST potentiometer between samples.

Turn the ZERO ADJUST only after a sensor regeneration cycle, otherwise invalid readings will result.

- Press the power OFF button and disconnect the power cord.
- The Jerome® 631-X is ready for sampling.

CAUTION:

The Jerome® 631-X is intended for vapor use only. DO NOT allow the probe or the instrument's intake to be exposed to liquids, dust or other foreign material. Moisture or liquids drawn into the instrument can damage the sensor and flow system.

Sample Mode

This is the standard operation mode and is used for optimum accuracy.

- Press the power ON button.
 - The LCD displays 000.
 - Disregard the LCD's initial momentary readings.
 - Recharge or replace the battery pack if the LO BAT indicator REMAINS ON, see page 17 and/or page 21 if necessary.
- Allow a 1-minute warm up before beginning the next step to ensure the instrument's electronics have stabilized.
- Press the SAMPLE button.
 - During the sampling cycle, the bar (or bars) shown on the LCD indicates the current percentage of sensor saturation. (Refer to "LCD Codes" on page 10 for code descriptions.)
 - The length of the sample cycle depends on the concentration of hydrogen sulfide.

RANGE	CONCENTRATION	RESPONSE TIME	ACCURACY at MID-RANGE
0	0.001 to 0.099 ppm	30 Seconds	± 0.003ppm at 0.050ppm
1	0.10 to 0.99 ppm	25 Seconds	± 0.03ppm at 0.50ppm
2	1.0 to 9.9 ppm	16 Seconds	± 0.3ppm at 5.0ppm
3	10 to 50 ppm	13 Seconds	± 2ppm at 25ppm

- At the end of the sampling cycle, read the LCD.
 - The number shown on the digital meter is the hydrogen sulfide concentration in ppm.
 - As the instrument auto-ranges, the decimal point moves to the correct position to show the concentration.
 - The value remains displayed until the next sample is taken. The digital meter will then automatically zero before displaying the next sample value.
 - When elevated readings are detected:
 - ◆ Confirm the reading by taking an additional sample.
 - ◆ Install the zero air filter and verify that the readings reduce to zero or very near zero.
 - ◆ Remove the filter and sample the location again to verify that elevated readings do exist.
 - When the sensor is completely saturated, the LCD displays .8.8.8 instead of a value. No further operation is possible until sensor regeneration is performed. (Refer to "Sensor Regeneration" on page 12.)
- Press the power OFF button when not in use.

Note: The Jerome® 631-X operates approximately six (6) hours on a fully charged battery.

Survey Mode

The survey mode takes samples every 3 to 20 seconds automatically. The length of time varies with the hydrogen sulfide concentration. Use this mode to locate the source of hydrogen sulfide, such as a leak, a hot spot, or to assess areas of potentially high hydrogen sulfide concentrations. After the survey mode is activated, the 631-X samples continuously.

- Press the power ON button.
 - The digital meter displays 000.
 - Disregard the LCD's initial momentary readings.
 - Recharge or replace the battery pack if the LO BAT indicator REMAINS ON, see page 17 and/or page 21 if necessary.

- Allow a 1-minute warm up before beginning the next step to ensure the instrument's electronics have stabilized.

- Lock the instrument in the survey mode:
 - Hold the SAMPLE button down until the sensor status indicator bar(s) begin flashing on the display.
 - Press the ZERO button, then release the SAMPLE button.
 - The pump should continue to run and the display should update every survey cycle.

- The instrument remains in the survey mode until one of the following occurs:
 - The sensor is saturated.
 - A LO BAT (low battery) signal is encountered.
 - An HL (high hydrogen sulfide level) is encountered.
 - The instrument is turned OFF.

- Press the power OFF button to end the survey mode.

RANGE	CONCENTRATION	RESPONSE TIME
0	0.001 to 0.099 ppm	20 Seconds
1	0.10 to 0.99 ppm	15 Seconds
2	1.0 to 9.9 ppm	6 Seconds
3	10 to 50 ppm	3 Seconds

NOTE: Approximately 100 samples at 0.5 ppm may be taken before the sensor saturates and regeneration is required.

Operating on AC Power or Generator

- For stationary use, the 631-X may be operated on AC power.
 - Operating the instrument on AC power at all times eliminates the need for the battery pack and its necessary maintenance.
 - The battery may be unplugged or removed completely whenever the instrument is operating on AC power.
- When a generator is used to power the Jerome® 631-X, a high quality line conditioner or voltage regulator is required to ensure a pure sine wave and regulated voltage is applied to the instrument. The gold film sensor may be damaged by voltage that varies in amplitude or by surges, spikes, and/or noise on the power line.

Operating on Internal Battery Power

- For portable use, the 631-X may be operated on Battery power.
 - When you operate the instrument on battery power, please be aware of the following:
 - ◆ A fully charged battery pack, AZI P/N Z4000 0907 (115V) or Z4000 0908 (230V), provides power for a minimum of six (6) hours of operation.
 - ◆ For operating more than six (6) hours, an extra fully charged battery pack is needed.
 - ◆ Complete battery recharging takes 14 hours. Refer to Charging Batteries on page 17.
 - ◆ The 631-X uses a rechargeable Nickel Cadmium (NiCad) battery. Dispose of worn-out batteries properly when you are replacing the battery pack.

External battery power

A special version of the Jerome® 631-X and a DC Power Kit are available to operate the instrument from a secondary DC source. The source may be a car/truck battery or a storage cell used in conjunction with solar panels.

Call AZI Customer Service at 800-528-7411, 602-470-1414, or e-mail support@azic.com for additional information.

Charging Batteries

- Press the power OFF button.
- Connect the AC power cord between the 631-X power receptacle and an AC power source.
 - Complete battery recharging takes 14 hours.
 - The 631-X contains a trickle charger so it may be continually plugged into an AC power source without damaging the battery pack.
- The battery pack may be charged outside the instrument with an optional AZI IDC Battery Charger. (AZI P/N 4000-1011, for 115 VAC, P/N 4000-1012, for 230 VAC)

Obtaining Maximum Battery Life

There are certain inherent limitations to NiCad batteries. The primary limitation is a memory effect that occurs when the batteries are partially discharged and then recharged, repeatedly. This memory leads to a drastic reduction in the usable battery life. To prevent this memory effect, periodically allow the battery pack to discharge completely, and then recharge the battery pack.

- To obtain maximum battery life, follow these three (3) steps:
 - At least once a month wait until LO BAT appears on the digital meter before recharging the battery pack.
 - Charge the battery pack when the LO BAT indicator comes on. Excessive discharge can damage the battery pack.
 - Before storing the instrument verify the power is OFF.
- When the batteries fail to hold a charge, the battery pack should be replaced.
 - Battery life under normal usage is approximately 1 year, depending on the number of charge and discharge cycles.

5. MAINTENANCE

Preventive Maintenance Calendar

To keep the Jerome[®] 631-X operating at peak performance, follow the maintenance schedule below as a guide. Since maintenance is more a function of application and amount of use rather than time, your requirements may be different from the listed schedule. Call AZI Customer Service at 800-528-7411, 602-470-1414, or e-mail support@azic.com for additional guidance for your environment and operation.

PART/COMPONENT	MAINTENANCE CYCLE	REFER TO PAGE
Charge batteries	At least once per month, after 1 month's storage, or when LO BAT appears	Page 17
Change 0.25 inch fritware	Weekly or as needed	Page 19
Change internal filters and tubing	After 6 months of use or as needed	Page 20
Replace zero air filter ¹	Annually	
Factory calibration	Annually	Page 23
Calibration check	Monthly or as needed	Appendix A, Page 36
Replace batteries	Annually or as needed. The battery pack contains NiCad batteries. Dispose of properly.	Page 21

NOTE: Install the zero air filter into the instrument's intake during storage.

¹ Zero air filters, LFS and LFD scrubber filters contain Resisorb[®]. Call AZI Customer Service at 800-528-7411, 602-470-1414, or e-mail support@azic.com for a copy of the Material Safety Data Sheet. Dispose of all filters properly.

Flow System

The Jerome® 631-X's flow system is the crucial link between the sensor and the sample. For the instrument to perform correctly, the flow system must be properly maintained. The user maintainable components of this system are the intake filter (0.25 inch fritware), two scrubber filters and connecting tubing.

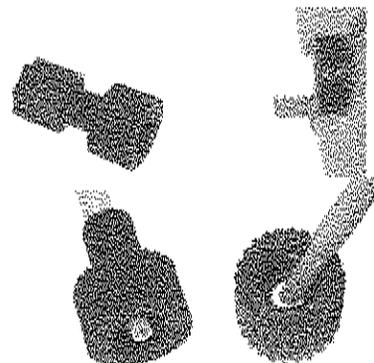
Check the Preventive Maintenance Calendar on page 18, for a suggested schedule for changing fritware and scrubber filters. The Tygon® tubing in the system must be free of crimps for proper flow.

Part	Part Number
Scrubber Filter	Z2600 3930
LFS Scrubber Filter	Z2600 3933
LFD Scrubber Filter	Z2600 3934
0.25 inch Fritware Filter	2600 3039
Tygon® Tubing (clear) 1/8" I.D. (1')	345-0050
Tygon® Tubing (clear) 1/16" I.D. (1')	345-0244
Tygon® Fluran Tubing (black) 1/16" I.D. (6")	345-0257

0.25 inch Fritware Filter

Replace the 0.25 inch fritware filter once each week or as needed. In dusty environments, the fritware filter may need to be replaced as often as once a day. Replacement 0.25-inch fritware filters are available from AZI, Consumable Sales at 800-528-7411 or 602-470-1414.

- Unscrew and remove the intake.
- Push the old fritware filter disc out of the intake with your trimmer tool.
- Avoid touching the new fritware disc with fingers. Use tweezers to insert the new fritware.
- Use the blunt end of the trimmer tool to seat the fritware disc firmly against the inner ledge of the intake.
- Screw the intake back on the Jerome® 631-X.



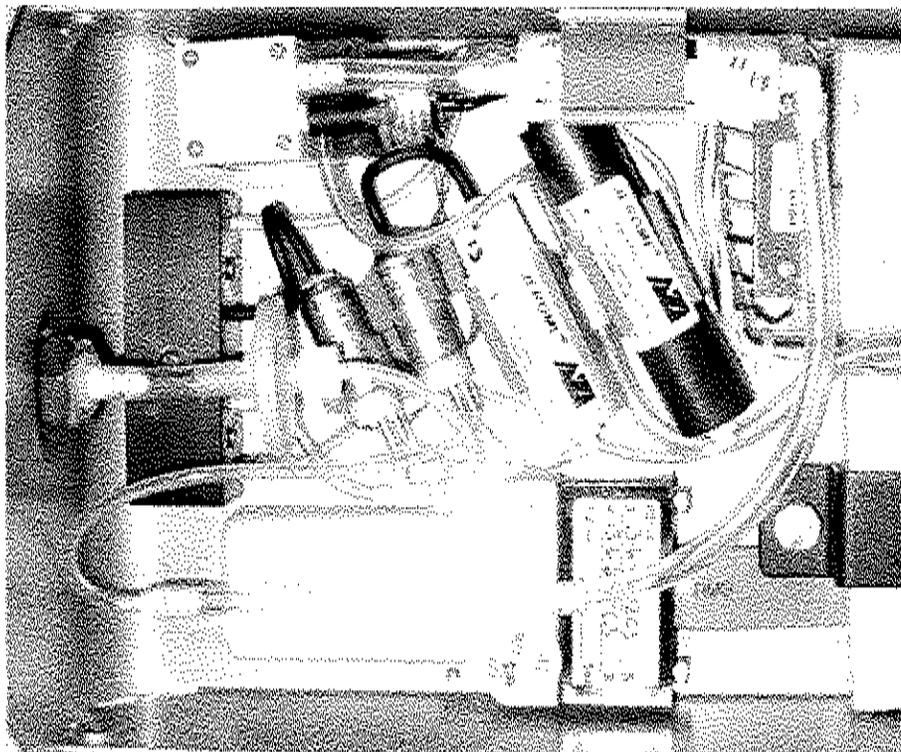
CAUTION:

The stem coming from the instrument onto which the outer intake housing is attached must be securely held in place. If loose, the tubing inside the instrument can become twisted when the intake housing is replaced. It may be necessary to open the instrument and tighten the hold-down nuts inside the instrument. Call AZI Customer Service at 800-528-7411, 601-470-1414, or e-mail support@azic.com if you have any questions



Internal Filters

- Replace the internal filters after six (6) months of use, or as needed.
- Press the power OFF button and unplug the power cord.
- Remove the two (2) side screws from the intake end of the instrument and open the case.
- Carefully disconnect the Tygon[®] tubing from both ends of the filters and discard the old filters.



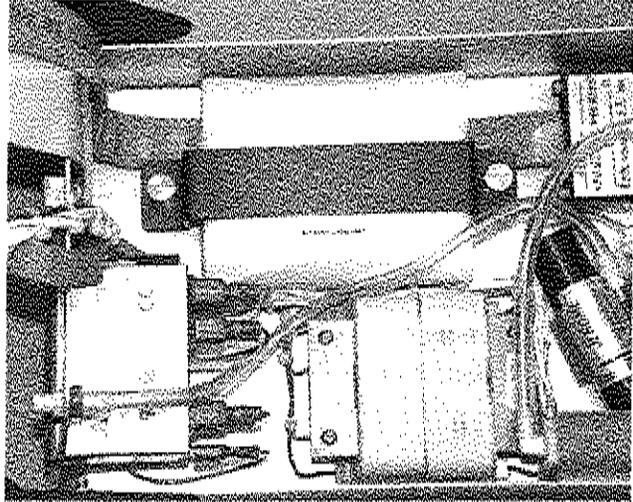
CAUTION:

Scrubber filters contain Resisorb[®]. Used filters, especially the scrubber filter may contain hydrogen sulfide also. Use proper methods when disposing of used filters. Call AZI Customer Service at 800-528-7411, 601-470-1414, or e-mail support@azic.com for a copy of the Resisorb[®] MSDS or for other questions.

- Connect the new filters to the Tygon[®] tubing, ensuring all straight hose barbs point toward the intake/pump corner of the case and elbow hose barbs point toward the sensor housing as shown in the illustration.
 - Push the Tygon[®] as far as it will go onto the filter fittings.
- Push the filters into the mounting clips.
- Remove any crimps or twists in the tubing and ensure that tubing connections are secure. If the tubing is loose, readings may not be accurate. Replace any tubing that has deteriorated due to heat and/or age.
- Close the case and replace the screws.
- Dispose of all filters in accordance with state and federal environmental regulations.

Replacing the Battery Pack

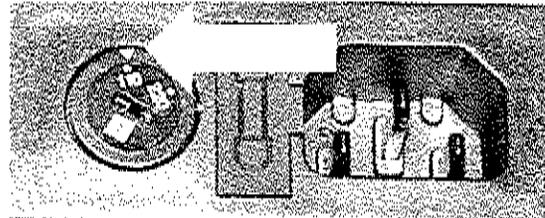
- Press the power OFF button.
- Unplug the power cord.
- Remove the two (2) side screws from the intake end of the instrument and open the case lid.
- Disconnect the battery connector from the board.
- Loosen the two (2) captive screws holding the battery bracket and remove the bracket.
- Remove the old battery pack and replace with a new battery pack.
- Replace the battery bracket and tighten the captive screws.
- Connect the new battery connector to the board.
- Close the case and replace the two (2) side screws.
- Dispose of the old NiCad battery in accordance with state and federal regulations.



Setting the Input Voltage

Instruments are factory set and calibrated to use the power setting requested on the order. However, the voltage setting is easily changed to use either 110 or 220 VAC.

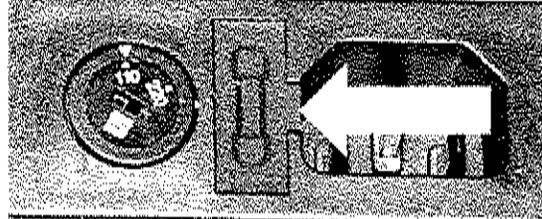
- Ensure the instrument is turned OFF and unplugged.
- Locate the voltage selector on the rear of the instrument.
- Insert a small screwdriver in the voltage selector slot and turn the selector until the arrow points toward your setting choice and a click is heard.



Changing the Fuse

If the instrument display reads .P.P.P when the instrument is connected to AC power or when REGEN is pressed, or if the battery will not charge, the fuse may need to be replaced. The AC line power could also be less than 100 VAC (220 VAC). Check the fuse with an ohmmeter and the AC line power with a voltage meter.

- Locate the power receptacle on the rear of the instrument.
- Insert a small screwdriver in the slot, located in the power receptacle, and gently slide the fuse compartment out.
- If the fuse in the open-sided clip is open, remove and discard it.
- Replace the discarded fuse with the spare fuse located in the slide-out spare fuse compartment.
- Replace the fuse compartment in the power receptacle.
 - As soon as possible, replace the spare fuse with another 1A, 250V, time delay fuse, AZI P/N 5100 1012).



6. CALIBRATION

The Jerome® 631-X's gold film sensor is inherently stable and does not require frequent calibration. The interval between calibrations depends upon the application and frequency of use; however, the recommended interval is every 12 months.

The Jerome® 631-X has been factory calibrated using laboratory equipment containing NIST traceable permeation tubes. In order to calibrate the Jerome® 631-X, a sophisticated calibration system is required that ensures stability of the calibration gas source, eliminates any pressure in the calibration gas stream, and controls the temperature of the calibration environment. Calibration requires the controlled environment, gas source, and computer software available only at the factory or authorized repair/calibration facility.

We strongly recommend you take advantage of our calibration and maintenance service at Arizona Instrument. Call Customer Service at (800) 528-7411 or (602) 470-1414 to arrange re-calibration. A certificate of calibration is issued from AZI when your instrument is factory calibrated.

Verification of Functionality and Quality Control

The Functional Test Module, AZI P/N Z2600 0918 or Z2600 0930, is used to determine if your instrument is functioning correctly between recommended annual factory calibrations. It allows you to have complete confidence in the sample results. This test verifies proper instrument operation through the introduction of a known concentration of hydrogen sulfide into the Jerome® analyzer.

THIS IS A FIELD CHECK OF THE FUNCTIONALITY OF THE INSTRUMENT.

THIS TEST DOES NOT CALIBRATE THE INSTRUMENT.

If your application requires frequent verification of instrument function, this test demonstrates the unit's operation and function. Recording FTM results in an instrument log provides a quality control/quality assurance record of instrument function between regular calibrations. If test results fall within the expected range, you may assume the instrument is functioning correctly.

See APPENDIX A - 631-X FUNCTIONAL TEST MODULE on page 36 for more information about the FTM procedures. Complete instructions for use are supplied with the test kit, AZI P/N Z2600 0918 or Z2600 0930.

To order the FTM, contact your AZI Sales Representative at (800) 528-7411 or (602) 470-1414.

7. 631-X TROUBLESHOOTING

Symptom	Possible Cause	Solution
Power Problems		
Unit does not turn ON. Unit turns on when power cord is plugged in. LCD displays 000 when instrument is operating on AC power.	Discharged battery or Dead battery.	Recharge battery for a minimum of 14 hours. Refer to page 17. Replace battery. Refer to page 21.
Unit does not turn on when connected to AC power cord.	Open fuse. Insufficient power. Internal component failure.	Replace fuse. Refer to page 22. Use a voltmeter to verify there is power to the AC outlet. Call AZI Customer Service for information at 800-528-7411 or 602-470-1414.
Regeneration & Zero Problems		
LCD displays .8.8.8.	Sensor saturated.	Do not attempt to adjust zero pot. The sensor must be regenerated. Refer to page 12 for information.
LCD displays .L.L.L when taking first sample.	Changes in temperature.	Readjust zero pot. See page 13 for information.
LCD displays H at finish of sensor regeneration when zero is pressed.	Internal contamination may redeposit hydrogen sulfide from flow system onto gold film sensor.	Remove and replace fritware filter, intake filter disk, scrubber filters and Tygon [®] tubing. Refer to "Flow System" on page 19. Check tubing for kinks or crimps. Repeat regeneration cycle. Refer to page 12.
Zero adjust pot cannot be adjusted to 0.	Pot not turned sufficiently. Sensor may be ruptured or pot may be broken.	1. Turn zero adjust up to 20 times to reach the end. Pot will "click" softly. 2. If no "0", turn pot slowly in opposite direction until display reads "0". 3. If still unchanged, call AZI Customer Service at (800) 528-7411 or 602-470-1414.

Sampling Problems		
Airflow is restricted during the sensor regeneration cycle, causing possible permanent damage.	Kinks and crimps in the Tygon® tubing.	Periodically check the Tygon® tubing inside the instrument. Refer to page 20.
High erratic results.	Internal hydrogen sulfide contamination.	<ol style="list-style-type: none"> 1. Install zero air filter in intake and tighten intake nut. Press SAMPLE button. After three samples, if readings are over 0.003 ppm, replace fritware filter, intake filter disk, and Tygon® tubing. Refer to page 19. 2. Perform sensor regeneration with the zero air filter in intake. Refer to page 12. Retest if necessary. Replace scrubber filters and Tygon® tubing. Refer to page 20.
High/erratic results	Intake and internal filters may become clogged and need replacement when sampling in a dusty or humid area.	<ol style="list-style-type: none"> 1. Open instrument and check for pinched, crimped or disconnected internal tubing. 2. In extreme conditions, an additional particle filter may be installed on the intake.
High/erratic results Readings vary more than 0.003 ppm when in survey mode.	Loose connections to gold film sensor.	Place a zero air filter into the intake. Place the instrument in survey mode. Move the unit as samples are being taken. Call AZI Customer Service at 800-528-7411 or 602-470-1414 for assistance.
Low response or erratic readings after a long period of non-use.	May need a second regeneration cycle.	<ol style="list-style-type: none"> 1. Wait 30 minutes and perform another sensor regeneration. 2. Test with FTM. Refer to page 36. 3. If still unresponsive,
False readings, may go to .8.8.8 or .L.L.L.	Extremely cold or extremely warm air sampled into unit.	If sampling under these conditions, install zero air filter in intake. Sample until display reads 0.003 ppm or less. This equilibrates sensor temperature with the temperature of the sample air stream. Remove filter and take samples.

Miscellaneous Problems

Display reads .P.P.P when regeneration is attempted.	Power cord not attached.	Check power cord for connection
	Blown fuse.	Replace fuse. Refer to page 22.
	Line voltage less than 100 VAC (or less than 200 VAC for 220V instruments).	Check line voltage settings. Refer to page 21.
	Cycles dipswitch set incorrectly.	Check input cycle settings. Refer to page 39. If fuse and line voltage are OK, it may be circuit board adjustment or component failure. Call AZI Customer Service at 800-528-7411 or 602 470-1414.
Display reads .E.E.E	Very low battery.	Recharge battery. Refer to page 17. Replace battery. Refer to page 21.

8. JEROME® 631-X TECHNICAL SPECIFICATIONS

Range	0.003ppm (3ppb) to 50ppm H ₂ S in four graduated ranges
Sensitivity	0.003ppm H ₂ S
Precision	5% relative standard deviation
Accuracy	Range 0: ± 0.003ppm at 0.050ppm H ₂ S Range 1: ± 0.03ppm at 0.50ppm H ₂ S Range 2: ± 0.3ppm at 5.0ppm H ₂ S Range 3: ± 2ppm at 25ppm H ₂ S
Response time-sample mode	
10 to 50 ppm (Range 3)	13 seconds
1.0 to 10.0 ppm (Range 2)	16 seconds
0.10 to 1.00 ppm (Range 1)	25 seconds
0.001 to 0.100 ppm (Range 0)	30 seconds
Response time-survey mode	
10 to 50 ppm (Range 3)	3 seconds
1.0 to 9.9 ppm (Range 2)	6 seconds
0.10 to 0.99 ppm (Range 1)	15 seconds
0.001 to 0.099 ppm (Range 0)	20 seconds
Flow rate	150 ± 10ml/min (0.15 ± .01 liters/min)
Power requirements	100-120 V~, 50/60 Hz, 1 A or 220-240 V~, 50/60 Hz, 1 A
Fuse	F1A 250V, 5mm X 20mm
Internal battery pack	Rechargeable Nickel Cadmium
Operating environment	0° to 40 °C, non-condensing, non-explosive
Case construction	Aluminum alloy
Dimensions – standard model	33 cm L x 15 cm W x 10 cm H (13" L x 6" W x 4" H)
Dimensions – XE model	35 cm L x 18 cm W x 18 cm H (14" L x 7" W x 7" H)
Weight – standard model	3.18 kilos (7 pounds)
Weight – XE model	3.5 kilos (8 pounds)
Digital meter display	Liquid crystal display (LCD)
Certification	CE mark on 220-240 V~, 631-XE model only.

Optional Communications Capability

Data output	1. RS-232 Serial, Baud Rate 1200 for use with data logger, and/or Jerome [®] communication program. 2. RS-232 Serial data format with 0 & 20mA current logic levels; Baud Rate 1200 (special industrial applications) and Analog 20 mA output.
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"OPTION BOARD" - See APPENDIX D - JEROME[®] 631-X OPTION BOARD on page 40.

Analog output	0 to 2V or 4 to 20 mA
Auto sample interval	5, 15, 30, or 60 minutes ²
Auto regeneration interval	6, 12 or 24 hours

Instrument I/O Interface

The 631-X I/O port (25 pin D-sub) provides the following functions:

- Serial data communication
 - Interface type: RS-232C full duplex, DCE
 - Parameters: 1200 Baud, 1 start bit, 8 data bits, 2 stop bits, no parity
 - Pin assignments:

Pin 1	Protective ground
Pin 2	Data in
Pin 3	Data out
Pin 7	Data ground
- Serial current loop
 - Interface type: 20mA current loop, full duplex
 - Parameters - 1200 Baud, 1 start bit, 8 data bits, 2 stop bits, no parity
 - Pin assignments:

Pin 1	Protective ground
Pin 4	Data out (+)
Pin 5	Data in (+)
Pin 14	Data out (-)
Pin 16	Data in (-)

² When the instrument is used for continuous auto-sampling, the estimated life of the gold film sensor decreases and the sensor will become a maintenance item. For example, sensor life is reduced to approximately six months if the instrument is run continuously with a 30-minute sample interval and a 48-hour regeneration interval or reduced to three months when using a 15-minute sample interval and a 24-hour regeneration interval.

- Switched battery connection for data logger
 - Pin assignments:

Pin 9	Battery (+)
Pin 7	Battery ground (-)
Pin 23	Battery ground (-)

- Unswitched battery connection for external battery pack pin assignments
 - Pin assignments:

Pin 15	Battery (+)
Pin 19	Battery (+)
Pin 7	Battery ground (-)
Pin 23	Battery ground (-)

NOTE: Pins 6, 8, 11, 17, 18, 20 and 21 are non-standard and should not be connected.

Potential Interferences

Potential interferences to the Jerome[®] hydrogen sulfide analyzers are rare and most of these can be eliminated with proper maintenance procedures. However, erroneously high readings can sometimes occur. Here are a few things to be aware of when using the instrument:

The gold film sensors used in the Jerome[®] hydrogen sulfide analyzers do not respond to the following compounds:

- Hydrocarbons
- CO, CO₂, and SO₂
- Water vapor (Note that water vapor condensation on the gold film can cause irreparable harm to the sensor and must be avoided.)

However, the following compounds may cause the gold film sensor to respond:

- Chlorine
- Ammonia
- NO₂
- Most mercaptans (organic sulfur compounds or “thiols”)

Special filters designed to remove chlorine or ammonia gas are available from Arizona Instrument and may be ordered as Chlorine Filter, AZI P/N Z2600-3940 or Ammonia Filter, AZI P/N 990-0183. Visit the “Tech Notes” section at www.azic.com for more information concerning the chlorine and ammonia filters.

Filter replacement at regular intervals, or when unexpectedly high readings are encountered in areas of these potential interferents, may resolve these problems.

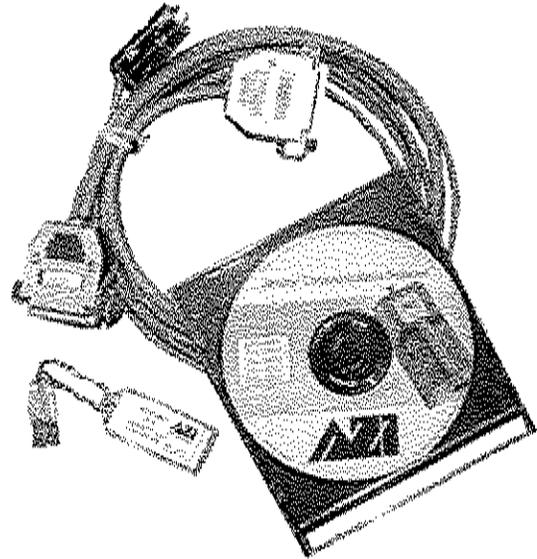
9. ACCESSORIES & MAINTENANCE PARTS

PART #	ITEM DESCRIPTION
Y631 0901	631 Accessory Kit (See pictures beginning on page 32)
	1400 2002 Probe
	1400 3010 Tubing Adapter, 1/4" to 1/8"
	2300 0001 Trimmer Tool
	2600 3039 0.25 Fritware
	6000 4003 Line Cord, 115 VAC - USA and Canada
	Alt. 200-0003 Line Cord, 220-240 VAC - England
	Alt. 200-0008 Line Cord, 220-240 VAC - Europe
	Z2600 3905 Zero Air Filter
Z2600 0918 or Z2600 0930 & Y2600 0920	631 Functional Test Module (FTM) or 631 Low-Level Functional Test Module FTM Accessory Kit (See pictures beginning on page 32)
	1300 0031 1/8" x 3/16" reducer
	1400 3010 Tubing adaptor
	2300 0003 Allen wrench
	345-0050 1' of 1/8" Tygon [®] tubing
	2500 3010 1' of 3/16" Tygon [®] tubing
	2600 3010 Filter cap
	2600 3055 1 Lb. Desiccant
	2800 2044 (2) Guide pins
	6000 4003 115 VAC Line Cord
	Permeation Tube Assembly
	1400 3196 Perm Tube Housing
	2600 3054 0.63" Diameter Fritware
	1300 1025 or Perm Tube (0.250 ppm / 250 ppb) (for Z2600 0918)
	1300 1040 Perm Tube (0.030 ppm / 30 ppb) (for Z2600 0930)
	700-0095 FTM Operation Manual
Y631 0905	631 Maintenance Kit (See pictures beginning on page 32)
	345-0050 1' of 1/8" Tygon [®] clear tubing
	345-0244 2' of 1/16" Tygon [®] clear tubing
	345-0257 6" of 1/16" Tygon [®] Fluran black tubing
	2600 3039 0.25 inch fritware
	Z2600 3905 Zero Air Filter
	Z2600 3930 Scrubber Filter
	Z2600 3933 LFS Scrubber Filter
	Z2600 3934 LFD Scrubber Filter
	Z4000 0907 Battery Pack Assembly

Jerome® Data Logger
Y990-0259 Includes the Jerome® Data
Logger and JCS Software Kit.



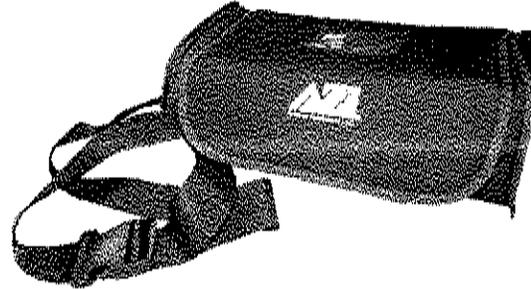
Y990-0257
(JCS kit
without Data
Logger) **Jerome® Communication
Software Kit (JCS)**



Y411 0904 **Hard Side Carry Case**
Includes a molded case with
die cut foam rubber inserts to
hold the Jerome® 631-X and
accessories.



1400 0052 **Soft Field Carrying Case**
Hand/shoulder case with
pockets for accessories.

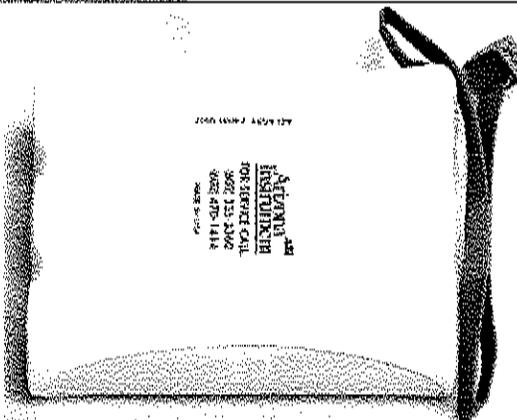


Spare Parts

1400 2002 Probe

2300 0001 Trimmer

1300 0031 1/8" x 3/16" reducer



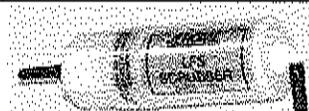
Z4000 0907 Battery Pack Assembly (115V)

Z4000 0908 Battery Pack Assembly (230V)

Z2600 3905 Zero air filter



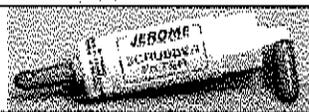
Z2600 3933 LFS scrubber filter

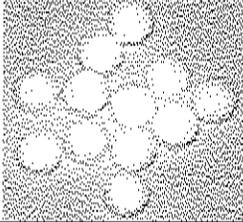
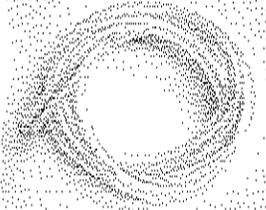
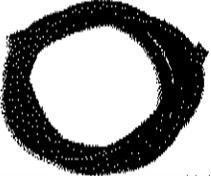


Z2600 3934 LFD scrubber filter

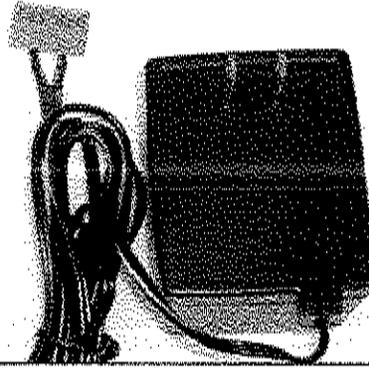


Z2600 3930 Scrubber filter

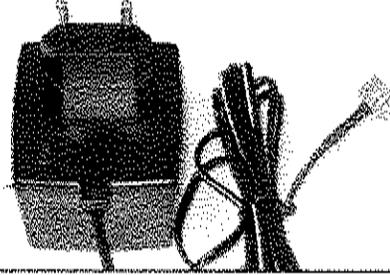


Z2600 3940	Chlorine Filter	
990-0183	Ammonia Filter	
1400 3010	Tubing adapter	
Y2600 3945	Intake Kit	 Includes mounting hardware.
PS-151	Tube Nut	
2600 3039	0.25 inch fritware	
2600 3061	Acrodisc [®] Filter	
345-0050	Tygon [®] tubing 1/8" I.D. (1 foot)	
345-0244	Tygon [®] tubing 1/16" I.D. (1 foot)	
345-0257	Tygon [®] Fluran tubing 1/16" I.D. (6 inches)	

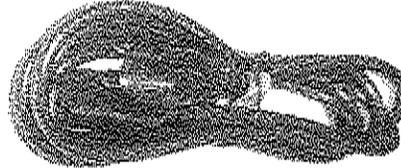
4000 1011 115 VAC IDC battery charger
(Used to charge an uninstalled battery)



4000 1012 230 VAC IDC battery charger
(Used to charge an uninstalled battery)



6000 4003 100-120 VAC Line Cord



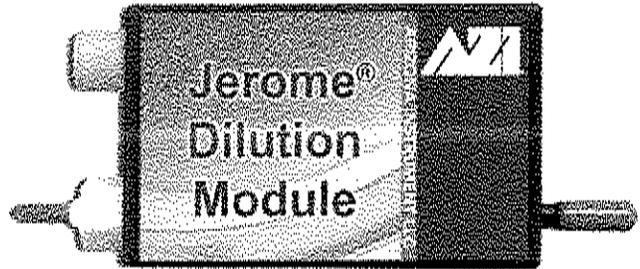
Alternate -- 220-240 VAC Line Cord for
200-0003 England



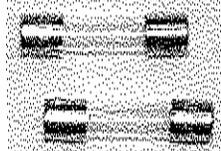
Alternate – 220-240 VAC Line Cord for
200-0008 Europe



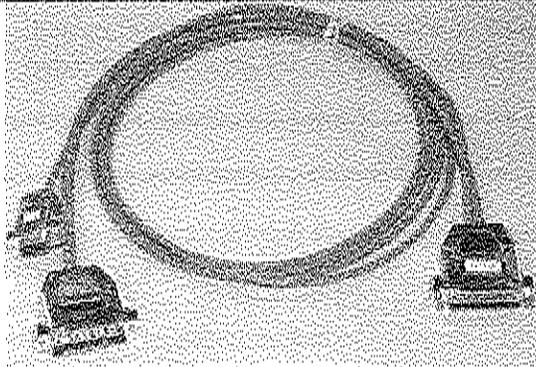
990-0225 10 to 1 Dilution Module



5100 1012 Spare Fuse



6000 1055 Jerome® Communication Cable



For current prices and delivery information, call AZI Customer Service at (800) 528-7411 or (602) 470-1414.

10. Factory Calibration Service

Service includes filter replacement, component testing, and instrument calibration to NIST traceable standards.

For scheduling and shipping authorization, call AZI Customer Service at (800) 528-7411 or (602) 470-1414.

11. APPENDIX A - 631-X FUNCTIONAL TEST MODULE

The Jerome[®] Hydrogen Sulfide Functional Test Module (FTM) provides a fast and easy method of verifying that Jerome[®] 631-X Hydrogen Sulfide Analyzers are functioning correctly.

THIS IS A FIELD CHECK OF THE FUNCTIONALITY OF THE INSTRUMENT.

THIS TEST DOES NOT CALIBRATE THE INSTRUMENT.

The Functional Test Module is beneficial:

- In applications where frequent verification of functionality is required, such as ISO 9000 documentation,
- To verify proper instrument operation when unexpected readings are obtained in normal sampling,
- As part of a weekly maintenance routine, and
- To determine if analyzer calibration is needed.

Simple Operation

The Functional Test Module includes a permeation tube containing hydrogen sulfide. When activated, the test module releases this H₂S from the permeation tube at a specific, known concentration. The H₂S flows over the gold film sensor of the Jerome[®] analyzer, which then measures the amount of exposure to the gas. The flow rate and temperature of this release are factory set to provide a concentration of approximately 250 ppb (0.250 ppm) ±20% when using FTM Z2600 0918 or approximately 30 ppb ± 20% when using the Low-Level FTM (Z2600 0930). The user then compares the reading on the Jerome[®] analyzer with the known concentration from the module. If the H₂S level shown on the analyzer's display falls within the expected range for the FTM being used, the instrument is functioning properly. If the level is not in the expected range, it should be returned to the factory for NIST-traceable calibration.

See page 30 for a list of the components that make up the FTM and its accessory kit.

The FTM, with the exception of the permeation tube, carries a limited one-year warranty to be free from defects or workmanship. The permeation tube is warranted for 90 days. Refer to the FTM Operation Manual AZI P/N 700-0095 for complete operation and warranty information.

12. APPENDIX B - JEROME® COMMUNICATIONS SOFTWARE

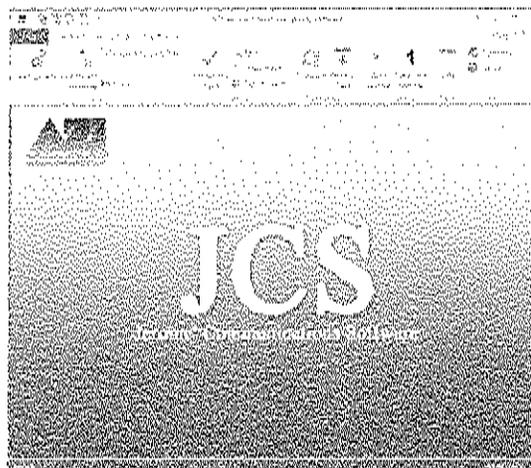
The Jerome® Communications Software (JCS) is used with 631-X Hydrogen Sulfide Analyzers that feature the communications configuration option.

- The JCS allows the user to program the instrument for unattended monitoring and to download recorded data stored in the Jerome® data logger.
- Automatic sampling can be initiated every one (1) to sixty (60) minutes with programmable audible alarm levels.

The Jerome® Communications Software (JCS) operates with the Jerome® 431-X Mercury Vapor and Jerome® 631-X Hydrogen Sulfide Analyzers that have the "Communications Configuration" option installed. The software can control instrument sampling for unattended continuous operation, collect data, graph this data in real time and perform statistical analysis.

The software can also program the Jerome® Data Logger, AZI P/N 6100-0010. This optional accessory enables data storage during manual sampling or portable automatic sampling without being attached to a computer. The data logger initiates automatic sampling, triggers alarms and stores data. The logged data may then be downloaded to the computer when it is convenient. The data logger stores up to 1,000 data points.

The JCS is menu-driven and easy to use. Each display screen is designed for clarity with self-explanatory menu options, such as "Operate Instrument" or "Display Stored Data." Select menu options using either a mouse or a track ball pointing device or a standard keyboard. The user creates records, or files, for computer storage of collected data. Data is easily retrieved for later viewing, graphing, printing or editing with spreadsheet or word processing software (not provided). Data can be used for ongoing record keeping or for fulfilling local regulatory requirements.



Before using this software, familiarization with the operation of the Jerome® Hydrogen Sulfide Analyzer or Mercury Vapor Analyzer is important. Also, prior to installation of this software you should be familiar with the personal computer and operating system you are using. If you have any questions about how to proceed, call AZI Customer Service at (800) 528-7411 or (602) 470-1414 or send an e-mail to support@azic.com for assistance.

JCS Kit Contents

- Jerome[®] Communication Software on CD-ROM with security key
- Jerome[®] Communication Cable, AZI P/N 6000 1055
- User's manual

System Requirements

- Jerome[®] 631-X with the "Communications Option." These Jerome[®] instruments have a DB-25 connector and related internal hardware and firmware.
- Windows[®] 7 or 8
- At least one free serial port (or two free USB ports if using a RS-232/USB converter)
- One free USB port

Optional equipment:

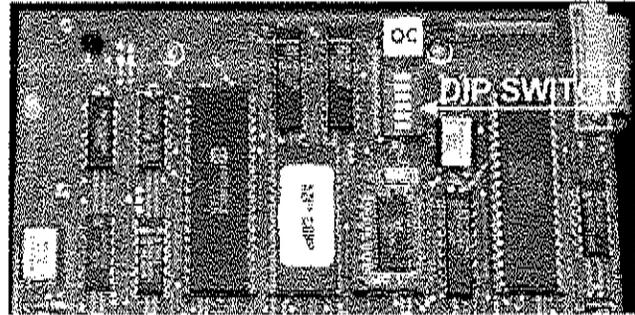
- Jerome[®] Data Logger, AZI P/N 6100 0010 (to capture data without a computer nearby)

Data Logger Option

The software can also program the Jerome[®] Data Logger (AZI P/N 6100 0010) used with the Jerome[®] analyzer. The computer programs the data logger that then attaches to the DB-25 connector on the rear of the instrument. The data logger initiates automatic sampling, triggers alarms and stores data. This optional accessory enables portable automatic sampling without a dedicated computer.

13. APPENDIX C - INTERNAL DIP SWITCH SETTINGS

The DIP switch identified as SW2 on the 631-X control board is located at the top center of the board.



CAUTION:

Switch the instrument's power to OFF before opening the instrument and changing DIP switch settings.



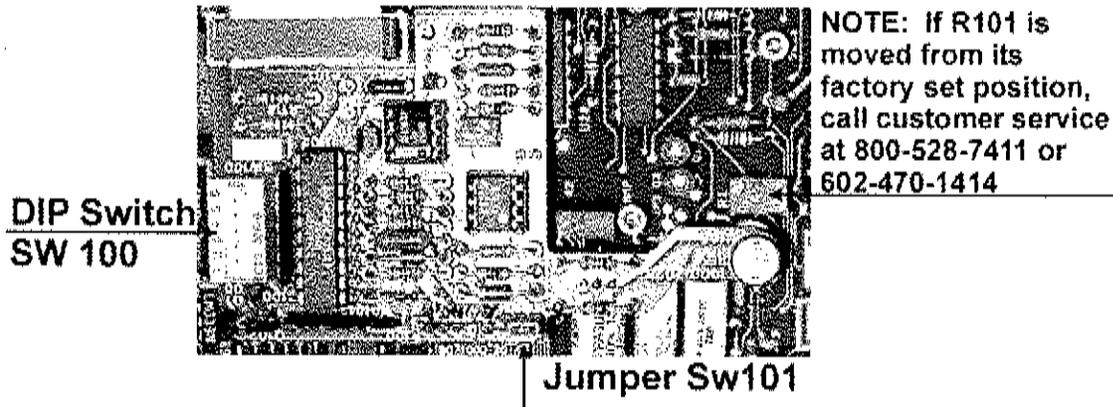
DIP Switch Settings:

Switch #	Position	Function	Comment
1	ON	AUTORANGE	DISABLED (SEE DIP SWITCHES 5 & 6)
1	OFF	AUTORANGE	ENABLED
2	X	NOT USED	
3	X	NOT USED	
4	ON	ZERO DISPLAY: 00-99	
4	OFF	ZERO DISPLAY: L-O-H	

Switch #	Function	Comment
5	RANGE	SAMPLE TIME
ON	0 (.000 - .099PPM)	30 SECONDS
ON	1 (0.10 - 0.99 PPM)	25 SECONDS
OFF	2 (01.0 - 09.9 PPM)	16 SECONDS
OFF	3 (10 - 50 PPM)	13 SECONDS

14. APPENDIX D - JEROME® 631-X OPTION BOARD

Proper use of this board requires that the base instrument be fully functional and set correctly for the intended operation.



Auto-Zero

With the option board installed, the 631-X has a limited auto-zero function. This function cannot be disabled and is transparent to the user. The instrument can be manually zeroed as described in "Zero Adjust" on page 13. However, if the instrument is to be operated by personnel not familiar with the procedure or if it is operated unattended, the auto-zero function should satisfactorily zero the unit after each sensor regeneration.

Instrument Zeroing

The Jerome® 631-X has essentially three ways to zero the sensor reading before samples are taken if the option board is installed.

- The instrument automatically re-zeroes between samples so that each sample is a unique reading. To take a sample, simply press the SAMPLE button.
- The manually adjusted zero, using the switch on the top of the 631-X is used to re-establish a baseline between the reference and sensor gold films **only after a sensor regeneration**. This zero is manually adjusted by pressing the ZERO button and turning the potentiometer on the top of the instrument until the display reads 0. **Adjust only after sensor regeneration**; it is normal for H to be displayed after sampling.
- The 631-X option board provides an auto-zero feature following regeneration that is invisible to the user.

- In some cases, the instrument cannot resume sampling after regeneration. .L.L.L appears on the display when the ZERO button is pressed and the error message “manual bridge adjust needed” is added to the notes column of the JCS text file when the JCS is used. If this problem persists, it may be necessary to re-set the auto-zero.
- When necessary to re-adjust the auto-zero point:
 - Turn the instrument off.
 - Make a note of the original DIP switch settings of SW100 on the option board.
 - On red DIP switch on the control board, SW2, turn DIP switch 4 to ON.
 - Set the switches on the option board’s blue DIP box, SW100, to 1,2,6 OFF; 3,4,5 ON.
 - Turn the instrument ON.
 - Press and hold the ZERO button and adjust the potentiometer on top of the instrument until the number 20 is displayed, then release the ZERO button.
 - Switch option board DIP #1 from OFF to ON three times, leaving it set to ON. (i.e. starting from OFF, switch it ON, OFF, ON, OFF, ON).
 - Press and hold the ZERO button while turning the potentiometer on the option board until the number 20 is displayed. Note the display may flicker one digit.
 - Return all switches to their original position.

NOTE: The higher the auto-zero number, the lower the sensor capacity and the more sensor regenerations are needed.

Timed Regeneration

If the unit is to be operated unattended for extended periods, AZI recommends that the sensor be regenerated regularly. Operation under JCS or data logger control automatically regenerates saturated sensors. Regeneration will not occur as shown when sample streams have a very low concentration of H₂S. The option board controls regeneration on a regular basis, every 6, 12 or 24 hours.

The regeneration intervals are set through a combination of switch settings as shown in the following table:

----- SW100-----		REGENERATION Interval (Hrs.)
Switch #1	Switch #2	
OFF	OFF	OFF
ON	OFF	6
OFF	ON	12
ON	ON	24

Auto-Sample

If a data logger is connected and operating in the manual sampling mode or a data logger is not connected the following automatic sampling rates may be selected with SW100 dip switch settings:

Dip switch settings			Sampling frequency
3	4	5	
ON	ON	ON	No automatic sampling
OFF	ON	ON	5 minutes
OFF	OFF	ON	15 minutes
OFF	ON	OFF	30 minutes
OFF	OFF	OFF	1 hour

This auto-sample function will not function if a data logger is connected and operating in automatic sampler mode programmed through the JCS.

4-20 mA Analog Output

The analog output signal at pin 18 of the 25 pin connector can be configured to provide the instrument's native mode 0-2 Volt output or the optional 4-20 mA output by setting the option board jumper (SW101) to the "V" position for voltage, or the "I" position for current. (Pin 23 is the ground pin for the analog output function. Pin 18 is positive with respect to the ground pin).

- The 0-2 Volt output circuit can drive loads of 10 kilohms or higher.
- The 4-20 mA output is a passive transmitter and requires the connected receiver to supply between 10 and 28 volts DC.

The 631-X must have the auto ranging feature disabled in order to get accurate analog output readings. The approximate range of the H₂S concentration must be known before the instrument can be set into that specific range (0, 1, 2 or 3). The analog output signal is based on each individual range and not the entire range (0-50 ppm).

Note that neither analog output circuit is floating. The negative terminals of both circuits are connected to the instrument's common ground bus.

SW101 Functions:

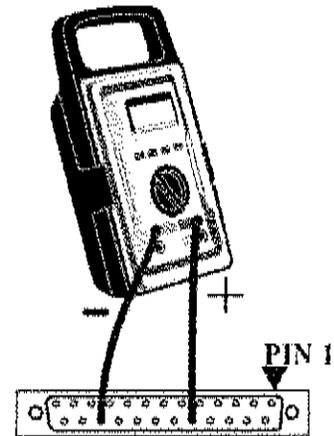
V =	0-2V analog output
I =	4-20 mA analog output

Jerome® 631-X instruments shipped after early 1995 are capable of providing 0-2 volts analog output. Instruments shipped before that time can be upgraded by a firmware update and adjustment.

Instruments that are capable of 0-2 volt output can be upgraded to the 4-20 mA output with the addition of an option board upgrade. This must be installed at the factory.

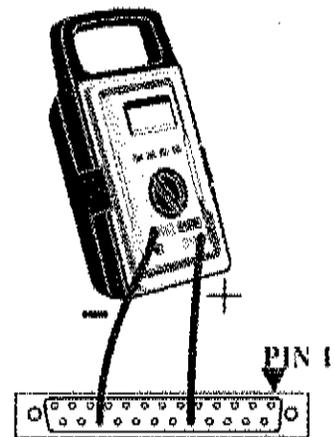
Connection and Setup:

- 0-2 volt devices connect as shown in Figure 1. If the instrument includes an option board, be sure its analog jumper (SW101) is set to the "V" position.



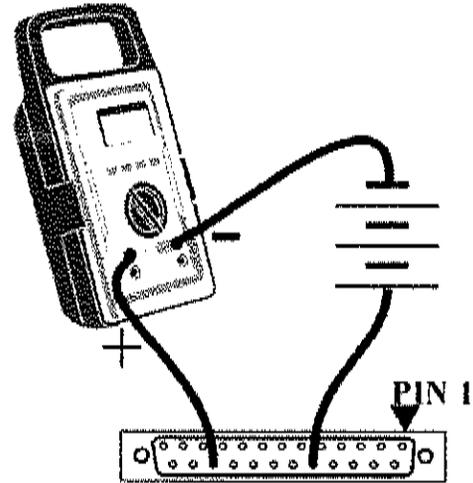
REAR OF CONNECTOR,
CONNECT PINS 18 AND 23 FOR
0-2 VOLT OUTPUT.
JUMPER ON BOARD IS AT "V"
Figure 1

- The 4-20 mA active receivers connect as shown in Figure 2. The active receiver contains a voltage source to power the loop current. The receiver must have an isolated input circuit. That is, it must not be connected to ground or to a voltage source referenced to ground. Be sure that jumper SW101 is set to the "I" position before power is applied.



REAR OF CONNECTOR,
CONNECT PINS 18 AND 23 FOR
4-20 mA OUTPUT.
JUMPER ON BOARD IS AT "I"
Figure 2

- The 4-20 mA passive receivers do not contain a voltage source to power the loop current. They require the addition of a separate isolated power supply. Typically a supply that delivers 15 to 20 volts DC at 50 mA is sufficient. Wire these as in Figure 3. Note that some 12-volt DC wall transformers (as used on portable equipment) may deliver 15 to 20 volts when they are lightly loaded. The Digi-Key TS09-PIP-ND is a commonly available example of a 12 volt 200mA supply that will deliver around 18 volts nominal when loaded below 20 mA.
- Be sure that both the power supply used and the passive receiver are floating (not connected to earth ground). If either is not floating, the circuit will not work and damage may occur.
- Ensure that jumper SW101 is set to the "I" position before power-up.



**REAR OF CONNECTOR,
CONNECT PINS 18 AND 23 FOR
4-20 mA OUTPUT.
JUMPER ON BOARD IS AT "I"
Figure 3**

Example Calculations:

- Example 1: Locked in Range 1 (0.10 to 1.00 ppm)
 - 631-X reading Current
 - 0.10 ppm or less 4mA
 - 1.00 ppm 20mA
 - The formula relating the current to the concentration is:
Concentration = [Range Maximum x (Current - 4)]/16
 - An output current of 12mA (in Range 1) corresponds to a concentration of 0.500 ppm:
Concentration = [1.00 x (12 - 4)]/16 = 0.500 ppm
- Example 2: Locked in Range 2 (1.0 to 10.0 ppm)
 - 631-X reading Current
 - 1.0 ppm or less 4mA
 - 10.0 ppm 20mA
 - The formula relating the current to the concentration is:
Concentration = [Range Maximum x (Current - 4)]/16
 - An output current of 12mA (in Range 2) corresponds to a concentration of 5.00 ppm:
Concentration = [10.0 x (12 - 4)]/16 = 5.00 ppm

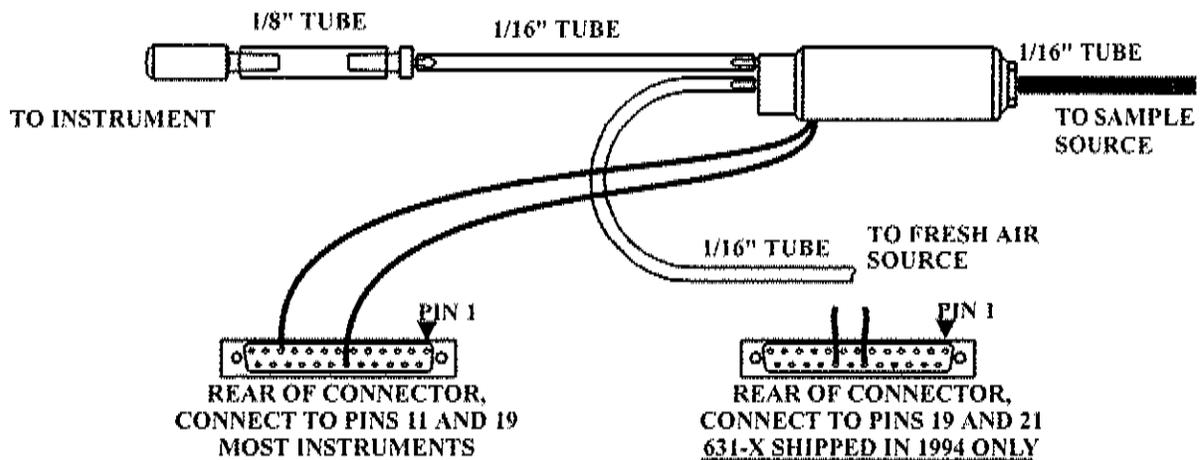
Fresh Air Solenoid

An external three-way solenoid can be used to provide fresh air or conditioned air during sensor regeneration. This may be necessary if the sample stream lacks molecular oxygen. A low current six volt DC solenoid, connected between pins 19 and 11 of the 25 pin rear panel connector, will be energized during the regeneration cycle if the option board SW100 switch 6 is placed in the OFF position.

If needed, the circuit may be built from the following components and configured as shown in the following diagram. It will only function if the option board is installed in the 631-X instrument.

Required Parts:	Suggested Part	Similar AZI P/N
1 solenoid, 6volt 3way	Angar P/N 407569	1300 1004
1/8" to 1/16" tubing adaptor	Any	1300 0025
1/2" clamp, adhesive mount	Any	6000 0013
1/8" tube to instrument adaptor	Any	1400 3010
3" 1/8" clear tubing	Tygon [®] Formula 2375	345-0050
A/R 1/16" clear tubing (for adjacent solenoid ports)	Tygon [®] Formula 2375	345-0244
A/R 1/16" black tubing (for lone solenoid port)	Tygon [®] Fluran	345-0257
1 25 pin male DB-25 connector Solder-cup style	AMP 747912-2	None *
1 connector hood	AMP 749626-2	None *

* These are types not stocked by AZI, but should be available overnight from many AMP stocking distributors such as Digi-Key Corporation. There are multiple suitable alternatives such as Radio Shack's 276-1547 and 276-1549.



DC Power Operation

Instruments with the 631-X option board modification can be used with any +12 VDC source for continuous operation, if the AZI Power Inverter Kit, P/N Y031 0902 is installed along with the option board. To preserve the life of the DC power source, usually a car or truck battery, the power inverter will switch on automatically to supply the AC necessary for regeneration only. The external switch on the inverter should always be OFF to preserve battery life during normal sampling.

To work with the power inverter kit, place option board SW100 DIP Switch #6 to the ON position.

When the instrument starts a regeneration with option board SW100 DIP Switch #6 ON, the instrument sends a signal to close the relay on the DC Power Adaptor, AZI P/N 1000 0089, mounted between the data logger and the instrument. This switches the power inverter ON using the inverter's internal switch.

NOTE: When this mode is enabled, the instrument does NOT check for 115 VAC for the regeneration. If there is no AC power to the instrument, and a regeneration is initiated, the instrument will flash .H.H.H (rather than .P.P.P), however the sensor will not heat, nor will the sensor be cleaned.

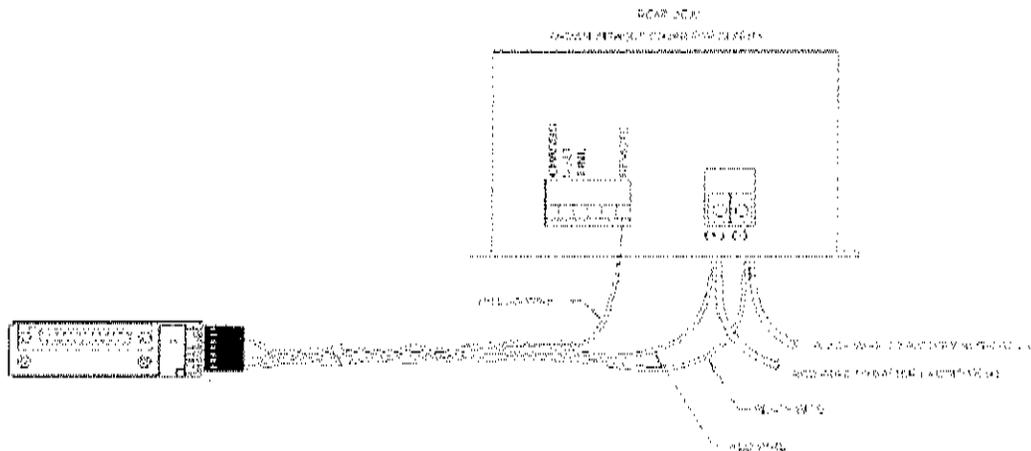
DC Power Adaptor Kit, AZI P/N Y031 0902

- The DC power adaptor kit consists of:
 - DC Power Adaptor, P/N 1000 0089
 - DC Power Inverter, P/N 4000 1021
 - DC Power Cable Assembly, P/N 6000 1093

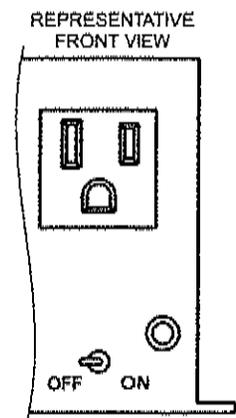
Installation

- Ensure that the instrument's option board switches are set correctly for the intended operation with the option board's SW100 DIP Switch #6 set to "ON" for DC operation.
- Mount the interface board to the rear of the instrument. Tighten the mounting screws.
- Place or mount the DC/AC power inverter in a secure position near the instrument.
- Connect the cable from the DC/AC power inverter to the matching connector on the interface board. Note that the connectors are keyed to prevent improper connection.
- Plug the instrument's AC power cord into the power inverter and connect it to the instrument.

Ensure that the inverter's power switch is in the "OFF" position. LEAVE the power switch in the "OFF" position at all times. The interface board will activate the inverter when necessary. If the inverter power switch is placed in the "ON" position, it will cause a continuous drain on the external 12-volt power system.



- Remove the screws from the rear cover of the inverter and remove the cover.
- Place the wires from the external DC source (battery) and the wires from the DC power cable through the holes in the end plate.
- Connect cables from the external 12-volt power source and the DC power cable assembly to the appropriate positive (+) and negative (-) terminals on the back of the inverter and tighten the hold down screws.
- Connect the yellow wire from the DC power cable to the "REMOTE" terminal on the power inverter and tighten the hold down screw.
- Reinstall the cover.
- If the external 12volt lines are not powered, power them now. (Connect them to the battery)
- Connect the instrument's AC power cord between the instrument and the front of the power inverter.
- Turn the instrument "ON."
- Press the "REGEN" switch on the instrument. Inverter operation can be verified in either of two ways:
 - Immediately after pressing "REGEN" the inverter will intermittently "sing." This tone slowly becomes nearly continuous and then ends after 64 seconds.
 - If the area is noisy, use a voltmeter or test lamp to verify that approximately 115 volts is present for about 64 seconds, starting when the "REGEN" switch is pressed.
- Allow the instrument to complete its regeneration before turning it off.
- With the instrument turned off, complete the installation (i.e. connect data logger, communications cables, or other devices and ensure that the DIP switches for the instrument and option board are set correctly.



15. WARRANTY

Arizona Instrument LLC (seller) warrants to buyer that Jerome[®] products delivered pursuant to this agreement shall, at the time of delivery, and for a period of one (1) year thereafter (the Internal Battery Pack, where applicable, is warranted for a period of ninety [90] days only), to be free from defects in material or workmanship and shall conform to seller's specifications or such other specifications as seller has agreed to in writing. Seller's obligations with respect to claims under this warranty shall be limited, at seller's option, either to the replacement of defective or non-conforming product or to an appropriate credit for the purchase price thereof subject to the provisions of seller's Warranty Policy as amended from time to time, said Policy being incorporated herein by reference.

Returned products under warranty claims will be shipped to seller's plant by buyer at buyer's expense and shall be accompanied by a statement of the reason for the return and an approved Return Material Authorization Number issued by seller. Buyer remains responsible for payment for products not accepted for warranty adjustment, handling costs, and freight costs associated therewith.

Notwithstanding the foregoing, no warranty shall be enforceable in the event that product has been subjected to environmental or stress testing by buyer or any third party without written approval of seller prior to such testing. Further, no warranty shall be enforceable if the alleged defect is found to have occurred because of misuse, neglect, improper installation, repair, alteration, accident, or improper return handling procedure by buyer.

Discontinued product is warranted only for a credit or replacement at seller's option.

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Arizona Instrument LLC
Jerome[®] 631-X Hydrogen Sulfide Analyzer Operation Manual
Part Number 700-0037

If you have any questions regarding the operation of this instrument, please call our toll free number (800) 528-7411. Internationally, call (602) 470-1414 or fax (480) 804-0656.

