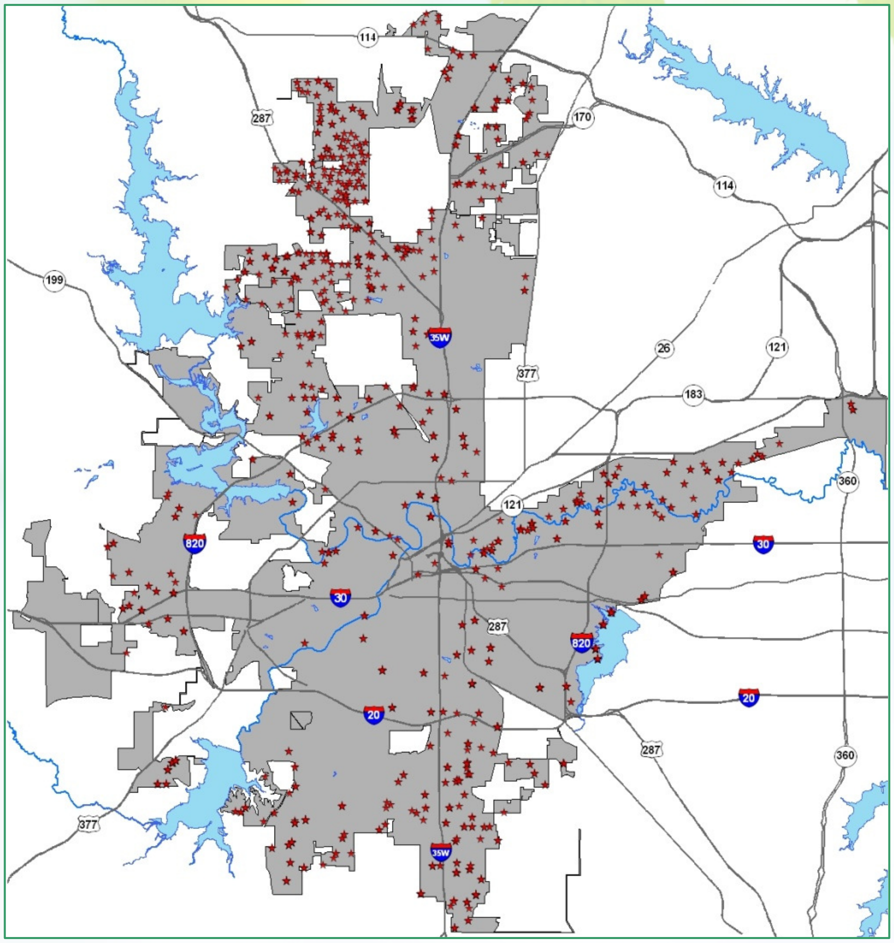
City of Fort Worth
Natural Gas Air Quality Study

Final Report



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Abbreviations

% CH_4	Leak expressed as percent methane
$\mu g/m^3$	Micrograms per cubic meter
AQS	Air Quality Subsystem
ATSDR	Agency for Toxic Substances and Disease Registry
BACT	Best available control technology
BP	Barometric Pressure
Btu	British thermal unit
CCV	Continuing Calibration Verification
CFM	Cubic feet per minute
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
COC	Chain of custody
CV	Coefficient of variation
DNPH	2,4-dinitrophenylhydrazine
DQO	Data Quality Objective
EPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group, Inc.
FID	Flame ionization detector
GC	Gas chromatograph
GC/MS	Gas chromatograph/Mass spectrometer
GIS	Geographic information system
GPS	Global Positioning System
H_2S	Hydrogen sulfide
HAP	Hazardous Air Pollutants
Hg	Mercury
HI	Hi
hp	Horsepower
ID	Identification
IR	Infrared
IRIS	Integrated Risk Information System
kPa	Kilopascals
lb	Pound
lbs/yr	Pounds per year
LCL	Lowest Comparison Level
LCS	Laboratory Control Standard
MDL	Method Detection Limit
mm	Millimeter
NA	Not available/not applicable
NATA	National-Scale Air Toxics Assessment
NESHAP	National Emissions Standard for Hazardous Air Pollutants
NM	Not monitored
NO_x	Oxides of nitrogen
NSPS	New Source Performance Standards

NSR	New Source Review
NWS	National Weather Service
^{o}F	Degrees Fahrenheit
PBR	Permit-by-Rule
PM	Particulate matter
$PM_{2.5}$	Particulate matter with a diameter of 2.5 micrometers or less
PM_{10}	Particulate matter with a diameter of 10 micrometers or less
ppbC	Parts per billion by carbon
ppbv	Parts per billion by volume
ppmv	Parts per million by volume
PRV	Pressure Relief Valve
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RH	Relative Humidity
RRC	Railroad Commission
RSD	Relative standard deviation
S/N	Serial Number
SATMP	Schools Air Toxic Monitoring Program
SCFM	Standard Cubic Feet per Minute
SIM	Selected ion monitoring
SNMOC	Speciated Non-Methane Organic Compounds
SO_2	Sulfur dioxide
SOCMI	Synthetic Organic Chemical Manufacturing Industry
TCD	Thermal Conductivity Detector
TCEQ	Texas Commission on Environmental Quality
TEMP	Temperature
TOC	Total Organic Compounds
tpy	Tons per year
TVA	Toxic Vapor Analyzer
VOC	Volatile Organic Compounds
WBAN	Weather Bureau/Air Force Number
WD	Wind Direction
WS	Wind Speed

Executive Summary

The city of Fort Worth is home to extensive natural gas production and exploration as it lies on top of the Barnett Shale, a highly productive natural gas shale formation in north-central Texas. The Barnett Shale underlies 23 counties, including four (Tarrant, Denton, Wise, and Parker) that lie partly within the Fort Worth city boundaries. Over the last several years, natural gas production in the Barnett Shale has increased dramatically. This increase in activity has been brought about by advancements in drilling technologies, most notably hydraulic fracturing (fracking) and horizontal drilling.

As the Barnett Shale formation is located beneath a highly populated urban environment, extraction of natural gas from it has involved exploration and production operations in residential areas, near public roads and schools, and close to where the citizens of Fort Worth live and work. Due to the highly visible nature of natural gas drilling, fracturing, compression, and collection activities, many individual citizens and community groups in the Fort Worth area have become concerned that these activities could have an adverse effect on their quality of life.

In response to these concerns, on March 9, 2010, the Fort Worth City Council adopted Resolution 3866-03-2010 appointing a committee to review air quality issues associated with natural gas exploration and production. This committee was composed of private citizens, members of local community groups, members of environmental advocacy groups, and representatives from industry. The committee was charged to make recommendations to the City Council on a scope of work for a comprehensive air quality assessment to evaluate the impacts of natural gas exploration and production, to evaluate proposals submitted in response to a solicitation for conducting this study, and to ultimately choose a qualified organization to conduct the study.

Following an open bidding process, Eastern Research Group, Inc. (ERG) was selected to perform the Fort Worth Natural Gas Air Quality Study (FWNGAQS). ERG was asked to design a study that answered four key questions, originally established by the air quality committee. Since that time, ERG has completed extensive sampling activity throughout Fort Worth, and the sampling results support the following main conclusions:

- *How much air pollution is being released by natural gas exploration in Fort Worth?* ERG estimated emissions for 375 well pads, 8 compressor stations, one gas processing plant, a saltwater treatment facility, a drilling operation, a fracking operation, and a completion operation. Summed across all these sites, the total estimated emissions of organic compounds was 20,818 tons per year, with well pads accounting for more than three-fourths of those total emissions. The emissions contained dozens of pollutants with varying toxicities. Pollutants with relatively low toxicities (e.g., methane, ethane, propane, and butane) accounted for the overwhelming majority—approximately 98%—of the city-wide emissions. However, several pollutants with relatively high toxicities (e.g., benzene) were also emitted from these sites, though in considerably lower quantities. At a small subset of sites, the point source testing team noted signs of malfunctioning equipment that likely caused increased emissions. For example, some hatches atop tanks were ajar and not closed, and corrosion had apparently caused a hole to form on the roof of at least one tank. Enhanced inspection and maintenance of equipment at the sites can help ensure that these preventable emissions are greatly reduced or eliminated. ERG also projected future emission rates based on an analysis of market forces, natural gas reserves, and other factors. This analysis found that city-wide emissions from the production of natural gas are projected to peak in 2012 and 2013 at 9% above 2010 levels. More detailed and technical information on emissions from natural gas sites is found in Sections 3 and 7 of this report.

- *Do sites comply with environmental regulation?* Numerous state and federal regulations could apply to natural gas production sites, but applicability of all regulations depends on site-specific nuances. The primary environmental regulation that would apply to natural gas extraction sites is TCEQ's oil and gas "permit-by-rule". This regulation is in the Texas Administrative Code and sets criteria for air permitting, based on the amount and type of emissions from a given facility. Based on the emission rates that ERG calculated for this project, five sites—a processing facility, three compressor stations, and one well pad—had overall emission rates that exceed regulatory thresholds that are supposed to trigger certain permitting requirements. Section 6 of this report identifies these five sites and presents their estimated emission rates.

- *How do releases from these sites affect off-site air pollution levels?* Scientists typically use two different methods when trying to understand how a given air pollution source affects local air quality. One approach is to conduct ambient air monitoring, which is directly measuring air pollution levels that people breathe. Another approach is to use dispersion modeling, which is estimating air pollution levels using models that predict how pollutants move through the air from the point where they are released. ERG used both approaches in the FWNGAQS. The ambient air monitoring program identified actual air pollution levels of nearly 140 pollutants at eight locations throughout the city, and the dispersion modeling study estimated air pollution levels at times when, and locations where, ambient monitoring did not take place.

  A health-screening analysis of the measured and estimated air pollution levels identified three pollutants—acrolein, benzene, and formaldehyde—as the most important from a risk perspective. While Fort Worth residents are exposed to these and other pollutants released from natural gas sites, the measured and estimated air pollution levels did not reach levels that have been observed to cause adverse health effects. Further, the measured benzene and formaldehyde levels in Fort Worth were not unusually elevated when compared to levels currently measured by TCEQ elsewhere in Texas. There was insufficient data available to do a similar comparison for acrolein. ERG recommended focused additional study to ensure that these pollutants do not reach unhealthy levels in the future. Sections 2, 4, and 5 describe the monitoring, modeling, and health-screening analysis in greater technical detail.

- *Are the city's required setbacks for these sites adequate to protect public health?* For the overwhelming majority of sites considered in this study, the modeling analysis indicates that Fort Worth's 600-foot setback distance is adequate. For the relatively few sites with multiple, large line compressor engines, the modeling analysis found some areas beyond the setbacks to have estimated acrolein and formaldehyde concentrations greater than protective health-based screening levels published by TCEQ. However, the estimated air pollution levels did not reach levels that have actually been found to cause symptoms or illness among exposed populations. Because the findings for these two pollutants are based entirely on estimated emission rates and modeled air quality impacts (as opposed to measured values), ERG recommends further evaluations of acrolein and formaldehyde at sites with multiple, large line engines to provide greater confidence in the adequacy and protectiveness of the city's setbacks. Some recent, short-term studies of limited scope have monitored for these pollutants, but a longer-term monitoring program is better suited for confirming this study's findings for acrolein and formaldehyde. Section 5 describes how ERG reached its conclusions regarding the adequacy of the city's setback distances.

Although this study did not reveal any significant health threats beyond setback distances, it is important to remember that the sources of concern for this project—natural gas exploration and production activity—are located in residential settings throughout a metropolitan area. Though the most toxic pollutants these sources emit are released in relatively low quantities, ERG fully supports implementing all reasonable precautions to reduce emissions from the well pads and compressor stations. Our recommendations in Section 8 of this report identify several specific opportunities for reducing emissions from natural gas production sites in Fort Worth.

1.0 Introduction

The city of Fort Worth is home to extensive natural gas production and exploration as it lies on top of the Barnett Shale, a highly productive natural gas shale formation in north-central Texas. The Barnett Shale underlies 23 counties, including four (Tarrant, Denton, Wise, and Parker) that lie partly within the Fort Worth city boundaries. Over the last several years, natural gas production in the Barnett Shale has increased dramatically. This increase in activity has been brought about by advancements in drilling technologies, most notably hydraulic fracturing and horizontal drilling.

As the Barnett Shale formation is located beneath a highly populated urban environment, extraction of natural gas from it has involved exploration and production operations in residential areas, near public roads and schools, and close to where the citizens of Fort Worth live and work. Due to the highly visible nature of natural gas drilling, fracturing, compression, and collection activities, many individual citizens and community groups in the Fort Worth area have become concerned that these activities could have an adverse effect on their quality of life.

In response to these concerns, on March 9, 2010, the Fort Worth City Council adopted Resolution 3866-03-2010 appointing a committee to review air quality issues associated with natural gas exploration and production. This committee was composed of private citizens, members of local community groups, members of environmental advocacy groups, and representatives from industry. The committee was charged to make recommendations to the City Council on a scope of work for a comprehensive air quality assessment to evaluate the impacts of natural gas exploration and production, to evaluate proposals submitted in response to a solicitation for conducting this study, and to ultimately choose a qualified organization to conduct the study.

The goals of the air quality study, as established by the air quality committee, are to help city officials answer the following four questions:

- How much air pollution is being released by natural gas exploration in Fort Worth?
- Do sites comply with environmental regulation?
- How do releases from these sites affect off-site air pollution levels?
- Are the city’s required setbacks for these sites adequate to protect public health?

In order to answer these questions, the air quality committee identified several key tasks that should be included in this study: ambient air monitoring, point source testing, and air dispersion modeling.

Ambient air monitoring was conducted to measure outdoor pollution levels. Ambient air monitoring was included in the Fort Worth Natural Gas Air Quality Study to measure air pollution levels near selected natural gas facilities.

Point source testing was conducted to determine how much air pollution is being released by natural gas production in Fort Worth, and if natural gas extraction and processing sites comply with environmental regulations. Under this task, various types of air testing equipment were used to detect, identify, and quantify the type and amount of air pollutants being emitted.

Air dispersion modeling was used to estimate the incremental air quality impacts caused by emissions from natural gas facilities. The modeling results provide perspective on air pollution levels at locations where, and at times when, ambient air samples were not collected. The results were used to assess whether the city's required setbacks (as published in City Ordinance No. 18449-02-2009) are adequately protective of public health.

Finally, a health evaluation compared the results of the ambient air monitoring program and air dispersion modeling to protective health-based screening levels. For selected pollutants, additional context was provided on toxicity and pollution levels typically observed at other locations in Texas.

This report presents the results of each of these tasks and activities, and is organized into eight sections as follows:

- Section 1 – Introduction. This section provides background information on the study.
- Section 2 – Ambient Air Monitoring. This section describes how the ambient air monitoring network was designed and implemented, and presents the ambient air monitoring results.
- Section 3 – Point Source Testing. This section describes how the point source testing task was conducted, what equipment was used, and how the data obtained was used to estimate emissions. The section also summarizes point source testing results.
- Section 4 – Air Dispersion Modeling. This section describes the air dispersion modeling task. It documents the major inputs, assumptions, site configurations, and results.
- Section 5 – Public Health Evaluation. This section interprets the ambient air monitoring data and the air dispersion modeling data from a public health perspective. It also comments on whether the setbacks are adequately protective of public health.
- Section 6 – Regulatory Assessment. This section provides details on the types of air quality regulations that may apply to natural gas exploration and production activities, and draws conclusions (where appropriate) on whether the sites visited under the point source task comply with applicable regulatory thresholds.
- Section 7 – Full Build-Out Estimates. This section discusses the factors expected to affect the growth of natural gas exploration and production in Fort Worth in the coming years and estimates future peak air emissions in Fort Worth.
- Section 8 – Conclusions and Recommendations. This section draws upon the results of each of the project activities to answer the four questions that defined the overall scope of this study. Several recommendations are also provided.

2.0 Ambient Air Monitoring

This section presents the findings of the ambient air monitoring component of this study, and contains six sub-sections.

- 2.1 Site Selection – Describes how the monitoring sites were identified.
- 2.2 Sampling Protocol – Describes how the ambient air monitoring samples were obtained.
- 2.3 Sample Analysis – Describes how the ambient air moniroting samples were analyzed at the laboratory.
- 2.4 Quality Assurance/Quality Control – This section describes the quality assurance and quality control (QA/QC) procedures employed during collection and analysis of the ambient air samples.
- 2.5 Ambient Air Monitoring Results – The results of the ambient air monitoring program are discussed in this section, including site-by-site study results.
- 2.6 Ambient Air Monitoring Conclusions – This section presents the conclusions of the ambient air monitoring program.

Ambient air is the air that people might expect to be exposed to at a road, school, or park near an air pollution emission source, such as a natural gas well pad or compressor station. Ambient air monitors are instruments that measure outdoor pollution levels in the ambient air. In this study, ambient air monitoring was conducted to assess the short-term prevalence and magnitude of concentrations of selected air toxics present in the air outside the property boundaries of air emissions sources such as a natural gas well pad or compressor station.

In this study, air pollution levels of nearly 140 pollutants (including over 40 Hazardous Air Pollutants (HAPs)) were measured over a two-month period with ambient air monitoring stations at eight different locations in Fort Worth. Sampling commenced on September 4, 2010, and concluded on October 31. Data obtained from this ambient air monitoring network can be used to:

- Assist in a better understanding of conclusions drawn from the point source sampling and analysis efforts.
- Characterize exposure to selected air toxics in ambient air at various locations in the city, as related to the proximity to certain natural gas activities (well pads, compressor stations, fracturing operations, etc.).
- Establish a representative determination of the concentration of air toxics, such as benzene, present in the ambient air in the area.
- Allow for a public health evaluation (See Section 5 for the full public health evaluation).

The ambient air monitoring network deployed in the field under this project was implemented in accordance with the *Ambient Air Monitoring Plan*, drafted in August 2010 and finalized on September 15, 2010. The *Ambient Air Monitoring Plan* identifies the goals and objectives of the ambient air monitoring network, provides technical background information (such as historical meteorological data) needed to identify candidate monitoring site locations, specifies the technical approach used to focus the list of candidate monitoring sites, and provides the final list of sites used in the study. Also, prior to implementation of the monitoring study, ERG prepared an approved Level 1 *Ambient Air Monitoring Quality Assurance Project Plan (QAPP)* which provided specific information on the sampling protocols, sampling analyses, and data reporting.

2.1 Site Selection

The final selection of eight monitoring sites occurred in two phases.

In Phase 1, geographic information system (GIS) data was obtained from the city of Fort Worth showing the locations of active and permitted natural gas activities, compressor stations, city property, nearby roadways, meteorological stations, and other features. These data and maps were overlaid to show natural gas activities in relation to residences, schools, businesses, existing (non-natural-gas) emission sources, and city-owned property. Monitoring on city-owned property was desirable for several reasons, including ensuring that the project team had site access seven days a week, maintaining the security of project staff and sampling equipment, and maintaining the integrity of the air sample by limiting the chance of vandalism or other tampering. During Phase 1, 20 potential monitoring site locations were identified.

In Phase 2, project staff visited each potential site to evaluate its suitability as a possible monitoring site location. During these visits, project staff interviewed site personnel and inspected the property, taking particular notice of potential obstructions (trees, buildings, etc.) or limitations (not enough land, no power, etc.) that would disqualify sites. At the end of Phase 2, and after consultation with city staff, eight locations were identified as suitable for inclusion in the ambient air monitoring network. These sites are listed below in Table 2.1-1.

Table 2.1-1. Final Ambient Air Network Monitoring Sites

Site ID	Site Type	Coordinates
S-1	Background	32° 49.114'N 97° 02.953'W
S-2	Mobile sources	32° 33.379'N 97° 13.164'W
S-3A	Pre-production	32° 45.897'N 97° 15.763'W
S-3B	Pre-production	32° 46.569'N 97° 29.638'W
S-4	High-level activity	32° 47.249'N 97° 19.715'W

Table 2.1-1. Final Ambient Air Network Monitoring Sites (Continued)

Site ID	Site Type	Coordinates
S-4C	High-level activity, collocated	32° 47.249'N 97° 19.715'W
S-5	High-level activity	32° 59.044'N 97° 23.131'W
S-5C	High-level activity, collocated	32° 59.044'N 97° 23.131'W
S-6	Moderate-level activity, fence line	32° 33.37'N 97° 18.820'W
S-7	Moderate-level activity, fence line	32° 34.223'N 97° 18.815'W

The technical approach used to finalize the site selection process is described in detail in the *Ambient Air Monitoring Plan*. Figure 2.1-1 shows the ambient air monitoring site locations; each site is described below, along with a figure showing its location in more detail.

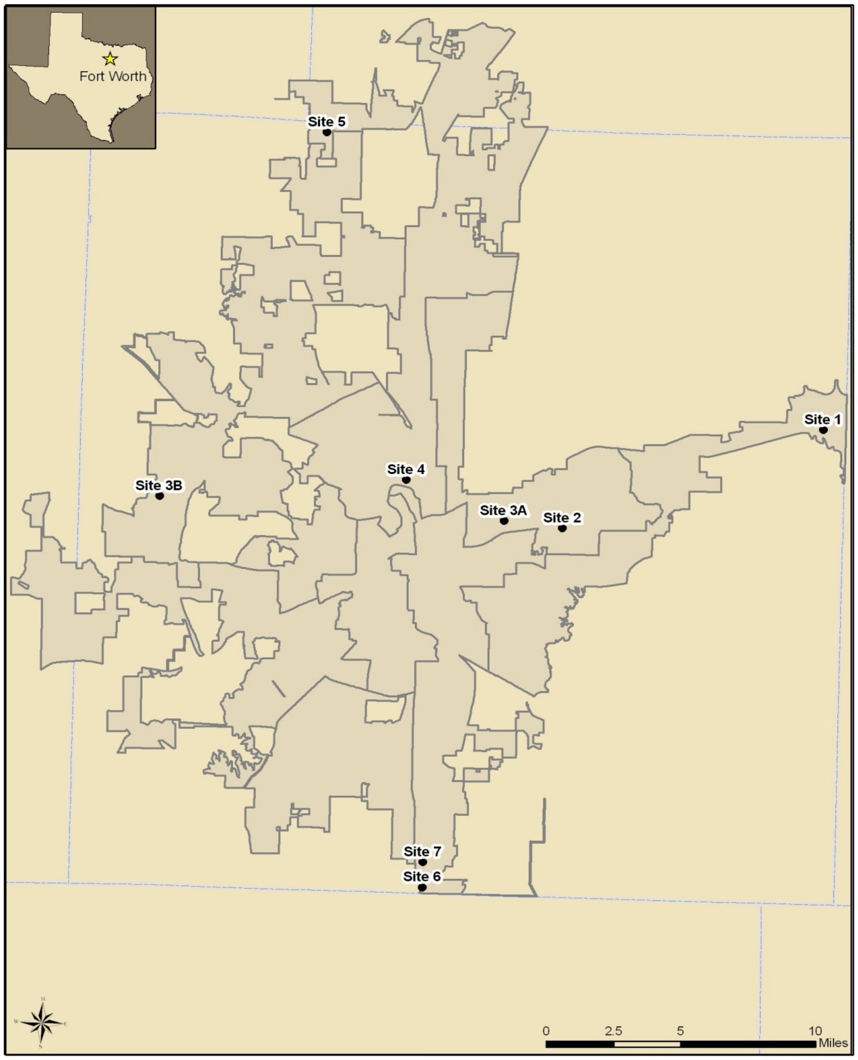
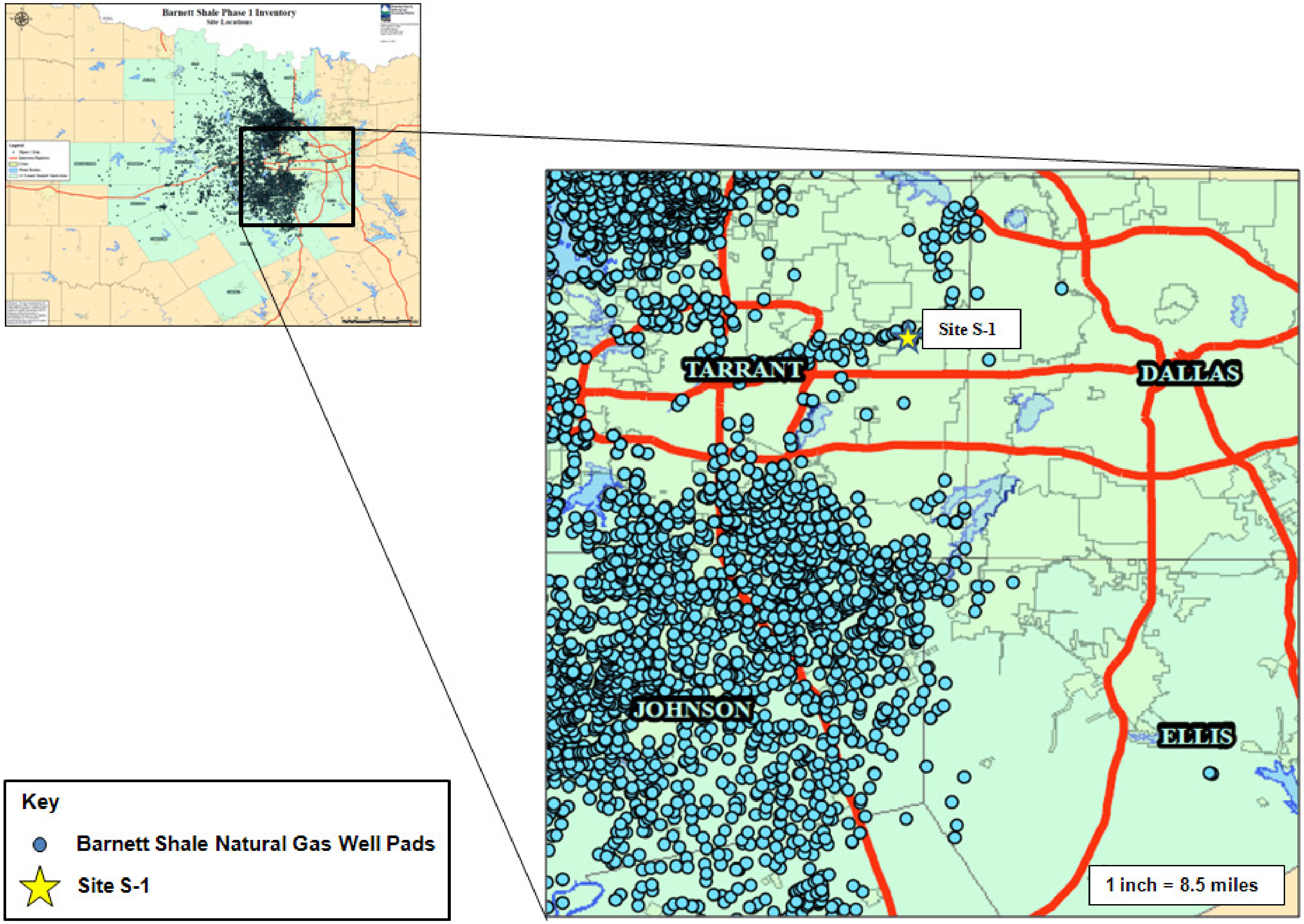


Figure 2.1-1. Ambient Air Monitoring Sites

2.1.1 Site S-1 (Background Site)

Site S-1 is located at Fort Worth Fire Station #33 (Figure 2.1-2), in the easternmost part of the city. Wind at this location predominantly blows from the south and southeast, meaning that there is expected to be minimal influence from natural gas exploration and production activities relative to areas further west (Figure 2.1-3). Therefore, this monitoring site is considered a “background” site, chosen to obtain background information on the air quality within the city of Fort Worth absent any impact from nearby natural gas sources. Speciated organic compounds were characterized at this site using the U.S. Environmental Protection Agency (EPA) Compendium Method TO-15 (see Section 2.3 for a description of EPA Compendium Method TO-15). Twenty samples were obtained from this location using a battery-operated system.

Figure 2.1-2. Aerial Map of Site S-1—Fire Station 33



Source: TCEQ Office of Chief Engineer. Barnett Shale Phase 1 Inventory (http://www.tceq.texas.gov/assets/public/implementation/air/ie/pseiforms/allsites.pdf)

Figure 2.1-3. Overview of Barnett Shale Well Pads Near Site S-1

2.1.2 Site S-2 (Mobile Sources Site)

Site S-2 is located at the city's Environmental Collection Center (Figure 2.1-4), within a half-mile of the intersection of Interstate 820 and Interstate 30. The closest natural gas activity to this site is upwind, approximately 2 miles south of this intersection. Thus, this site was chosen to characterize pollutant concentrations from mobile sources along the two interstates, and to help determine how mobile sources (vehicles) affect ambient air within Fort Worth. Speciated organic compounds were characterized at this site using EPA Compendium Method TO-15. Eighteen samples were obtained from this location using a battery-operated system.

Figure 2.1-4. Aerial Map of Site S-2—Environmental Collection Center

2.1.3 Site S-3 (Pre-Production Site)

Site S-3 was chosen to characterize ambient air quality impacts of "pre-production" activities such as fracturing and flowback operations. The site was moved from one location to another, as described below; speciated organic compounds were characterized at these two locations using EPA Compendium Method TO-15.

Initially, this monitor was located at the Eastside Landfill (Figure 2.1-5), a capped landfill located just off of Interstate 30 to the east of downtown Fort Worth. Depending upon wind direction, this site enabled acquisition of air samples affected by either a fracturing operation (less than a quarter-mile to the south) or the Brentwood Saltwater Disposal Site (0.35 miles to the north). Eight samples were obtained from this location using a battery-operated system. Upon completion of the fracturing job, this site was re-located as described below.

On October 9, 2010, this monitoring site was moved to a Devon Energy lease site west of Fort Worth, approximately 1 mile west of Interstate 820, where fracturing and flowback operations were in process. This was the only site that was not located on city property, but there were no issues of site access from the field technician. Eight samples were obtained from this location using a battery-operated system. The location of this monitor is shown in Figure 2.1-6.

Figure 2.1-5. Aerial Map of Site S-3A—Eastside Landfill

Figure 2.1-6. Aerial Map of Site S-3B—Devon Energy Lease

2.1.4 Site S-4 (High-Level Activity Site, Collocated)

Site S-4, the Brennan Service Center (Figure 2.1-7), was located at a city-owned site north of downtown, less than one-half mile west of Interstate 35. This facility formerly served as a Fire Department Fleet Service Center and currently serves as a residential garbage drop-off station. This site is located within 0.4 miles northwest of one combined well pad and compressor station site, 0.8 miles north of another combined well pad and compressor station site, and 0.2 miles southwest of a well pad site. Concentrations from these natural gas operations, as well as from other sources, were characterized at this site. Speciated organic compounds were characterized at this site using EPA Compendium Method TO-15, and carbonyl compounds (including formaldehyde) were characterized using EPA Compendium Method TO-11A. Twenty volatile organic compound (VOC) and 20 carbonyl samples were obtained from this location using a powered system. This site was also designated as a collocated site, meaning that duplicate VOC and carbonyl samples would be taken at this site periodically. Indicators of sample system data quality are determined using the collocated data.

Figure 2.1-7. Aerial Map of Site S-4—Brennan Service Center

2.1.5 Site S-5 (High-Level Activity Site, Collocated)

Site S-5 was located at Fort Worth Fire Station #34 (Figure 2.1-8), in a residential area in the northern part of Fort Worth. This site's location has a high level of natural gas activity and is within a mile of dozens of natural gas wells upwind of this station. Speciated organic compounds were characterized at this site using EPA Compendium Method TO-15, and carbonyl compounds (including formaldehyde) were characterized using EPA Compendium Method TO-11A. Nineteen VOC and 20 carbonyl samples were obtained from this location using a powered system. This site was also designated as a collocated site.

Figure 2.1-8. Aerial Map of Site S-5—Fire Station 34

2.1.6 Site S-6 (Moderate-Level Activity/Fence line Site)

Site S-6 was located at the Spinks Airport (Figure 2.1-9), in the southern reaches of the city. This site was chosen because the monitor could be placed within 350 feet of an active well pad, making it a useful way to help evaluate the city's setback provisions. Speciated organic compounds were characterized at this site using EPA Compendium Method TO-15, and methane emissions were characterized at this site using EPA Compendium Method TO-14 (see Section 2.3 for a description of EPA Compendium Method TO-14). Nineteen samples were obtained from this location using a battery-operated system.

Figure 2.1-9. Aerial Map of Site S-6—Spinks Airport (South)

2.1.7 Site S-7 (Moderate-Level Activity/Fence line Site)

Site S-7 was also located at the Spinks Airport (Figure 2.1-10) in the southern reaches of the city. This site was also chosen to help evaluate the city's setback provisions, as this monitor was situated within 200 feet of an active well pad. Speciated organic compounds were characterized at this site using EPA Compendium Method TO-15, and methane emissions were characterized at this site using EPA Compendium Method TO-14. Eighteen samples were obtained from this location using a battery-operated system.

Figure 2.1-10. Aerial Map of Site S-7—Spinks Airport (North)

2.2 Sampling Protocol

At each of the eight sites, ambient air samples were collected once every three days. This schedule ensured that samples were collected on both weekdays and weekend days. The schedule provided some insights on how air quality varies by day of the week—an important consideration given that traffic patterns and other emission sources can vary from one day to the next.

The collection and analysis of ambient air monitoring samples for this study was performed in accordance with EPA Compendium Methods TO-15,[1] TO-11A,[2] and TO-14.[3] As described in Section 2.1, each of the eight monitoring sites was chosen for a specific reason. Therefore, the sample collection procedure and analytical method used at each site varied. Table 2.2-1 identifies the original sample collection schedule and type of samples obtained at each site. Additional details on these can be found in the *Ambient Air Monitoring Plan*.

Table 2.2-1. Schedule of Collection Events

Date	Concurrent VOC/SNMOC Collection[a]	Carbonyl Collection[b]	VOC/SNMOC Duplicate Samples[a]	Carbonyl Duplicate Samples[b]	Concurrent VOC/Methane Collection[c]
9/4/10	Sites S-1 through S-5	Sites S-4 and S-5	—	—	Sites S-6 and S-7
9/7/10			—	—	
9/10/10			—	—	
9/13/10			From two sites	From two sites	
9/16/10			—	—	
9/19/10			—	—	
9/22/10			—	—	
9/25/10			From two sites	From two sites	
9/28/10			—	—	
10/1/10			—	—	
10/4/10			—	—	
10/7/10			From two sites	From two sites	
10/10/10			—	—	
10/13/10			—	—	
10/16/10			—	—	
10/19/10			From two sites	From two sites	
10/22/10			—	—	
10/25/10			—	—	
10/28/10			—	—	
10/31/10			From two sites	From two sites	

[a] Volatile organic compound/speciated non-methane organic compound (VOC/SNMOC) samples analyzed using EPA Compendium Method TO-15.

[b] Carbonyl samples analyzed using EPA Compendium Method TO-11A.

[c] VOC/methane samples analyzed using EPA Compendium Method TO-15 (VOCs) and EPA Compendium Method TO-14 (methane).

Sampling at Sites S-1 through S-3, S-6, and S-7 was conducted using vacuum-regulated systems. These systems were battery-operated/passive and used pre-cleaned SUMMA® canisters to collect VOC and methane samples. Sampling at Sites S-4 and S-5 was conducted using two automated, mass-flow control systems. These systems are electrically powered and used pre-cleaned, evacuated SUMMA® canisters to collect VOC samples and 2,4-dinitrophenylhydrazine (DNPH) cartridges to collect carbonyl samples. All seven systems incorporated digital timers to ensure that 24-hour integrated samples were obtained (i.e., 00:01 to 23:50).

In order to obtain an integrated air sample for VOC analysis, air was drawn into a cleaned and pre-evacuated passivated SUMMA® canister through a calibrated flow limiting orifice assembly that regulated the rate and duration of sampling. After the air sample was collected, the canister valve was closed automatically. The day following the sample collection, project staff visited each site; inspected the sample media for any errors, inconsistencies, or signs of tampering; and completed a chain-of-custody (COC) form for each of the samples. For each sample that was deemed viable for analysis, the sample and the COC form were shipped together to the laboratory for analysis. The information on the COC form included the following:

- Sample ID number
- Sampling equipment identification
- Sampling date
- Sampling start time
- Sampling end time
- Elapsed time
- Initial flowrate
- End flowrate
- Average flowrate
- Sample volume (total liters)
- Comments (field observations and/or anomalies during sampling)
- Name and signature of field operator releasing samples for shipment
- Condition of custody seal upon receipt by laboratory
- Condition of samples upon receipt by laboratory
- Signature of laboratory representative receiving shipment
- Date of sample receipt at laboratory

The samples obtained at Sites S-1 through S-5 were analyzed at Eastern Research Group's (ERG's) laboratory in Morrisville, North Carolina, while the samples obtained at Sites S-6 and S-7 were analyzed at TestAmerica's™ laboratory in Austin, Texas. Appendix 2-A contains the COC forms for Sites S-1 through S-5, Appendix 2-B contains the analytical results for SNMOCs at Sites S-1 through S-5, Appendix 2-C contains the analytical results for EPA Compendium Method TO-15 at Sites S-1 through S-5, Appendix 2-D contains the analytical results for EPA Compendium Method TO-11A at Sites S-4 and S-5, and Appendix 2-E contains the COC forms and analytical results for Sites S-6 and S-7.

Upon receipt, the canister information was recorded and the sample stored until analysis. Storage times of up to 45 days without compound concentration losses have been demonstrated for many of the VOCs (e.g., benzene, toluene, ethylbenzene, and xylenes) found in urban atmospheres. Although the required turnaround time under the method guidelines is 45 days, an actual turnaround time of approximately 30 days from sample receipt to sample analysis was typical.

2.3 Sample Analysis

Air toxics and SNMOC concentration data for each sample was obtained in accordance with the guidelines presented in EPA Compendium Method TO-15.[1] Method TO-15 provides guidance on sampling and analytical procedures for the measurement of a subset of the 97 VOCs that are included in the 1989 HAPs listed in Title III of the Clean Air Act Amendments of 1990.[4] These VOCs are defined as organic compounds having a vapor pressure greater than 10^{-1} Torr at 25°C and 760 millimeter (mm) mercury (Hg), meaning that they are likely to exist in a gaseous phase under standard atmospheric conditions. Method TO-15 is used to analyze air samples for toxic compounds expected to be released from many air pollution sources, including natural gas production related activities.

Target air toxics species, and their corresponding method detection limits (MDLs) are presented in Table 2.3-1. Target SNMOC species and their corresponding MDLs are presented in Table 2.3-2.

Table 2.3-1. EPA Compendium Method TO-15 Target Compounds and Method Detection Limits

Target Compounds	ppbv [a]	Target Compounds	ppbv
1,1,1-Trichloroethane	0.020	Dibromochloromethane	0.011
1,1,2,2-Tetrachloroethane	0.011	Dichlorodifluoromethane	0.012
1,1,2-Trichloroethane	0.018	Dichlorotetrafluoroethane	0.012
1,1-Dichloroethane	0.017	Ethyl Acrylate	0.011
1,1-Dichloroethene	0.013	Ethyl *tert*-Butyl Ether	0.009
1,2,4-Trichlorobenzene	0.018	Ethylbenzene	0.012
1,2,4-Trimethylbenzene	0.011	Hexachloro-1,3-butadiene	0.012
1,2-Dibromoethane	0.012	*m,p*-Xylene	0.014
1,2-Dichloroethane	0.015	*m*-Dichlorobenzene	0.010
1,2-Dichloropropane	0.025	Methanol	0.255
1,3,5-Trimethylbenzene	0.010	Methyl Ethyl Ketone	0.026
1,3-Butadiene	0.010	Methyl Isobutyl Ketone	0.010
1,4-Dioxane	0.140	Methyl Methacrylate	0.021
Acetylene	0.025	Methyl *tert*-Butyl Ether	0.009
Acrylonitrile	0.027	Methylene Chloride	0.023
Allyl Chloride	0.110	*n*-Butanol	0.144
Benzene	0.019	*n*-Octane	0.011
Bromochloromethane	0.018	*o*-Dichlorobenzene	0.012
Bromodichloromethane	0.021	*o*-Xylene	0.010
Bromoform	0.011	*p*-Dichlorobenzene	0.010
Bromomethane	0.013	Propylene	0.028
Carbon Disulfide	0.011	Styrene	0.010
Carbon Tetrachloride	0.024	*tert*-Amyl Methyl Ether	0.013
Chlorobenzene	0.014	Tetrachloroethylene	0.011
Chloroethane	0.012	Toluene	0.013
Chloroform	0.017	*trans*-1,2-Dichloroethylene	0.014
Chloromethane	0.016	*trans*-1,3-Dichloropropene	0.016
Chloromethylbenzene	0.017	Trichloroethylene	0.017

Table 2.3-1. EPA Compendium Method TO-15 Target Compounds and Method Detection Limits (Continued)

Target Compounds	ppbv	Target Compounds	ppbv
Chloroprene	0.014	Trichlorofluoromethane	0.012
cis-1,2-Dichloroethylene	0.036	Trichlorotrifluoroethane	0.014
1,2-Dichloropropane	0.025	Vinyl Acetate	0.208
cis-1,3-Dichloropropene	0.015	Vinyl Chloride	0.013

[a] ppbv = parts per billion by volume

Table 2.3-2. SNMOC Target Compounds and Method Detection Limits

Target Compound	ppbC	ppbv	Target Compound	ppbC	ppbv
Ethylene	0.38	0.19	Cyclohexane	0.19	0.03
Ethane	0.12	0.06	2-Methylhexane	0.11	0.02
Propane	0.20	0.07	2,3-Dimethylpentane	0.37	0.05
Propyne	0.20	0.07	3-Methylhexane	0.15	0.02
Isobutane	0.13	0.03	1-Heptene	0.37	0.05
Isobutene/1-Butene	0.15	0.04	2,2,4-Trimethylpentane	0.17	0.02
n-Butane	0.17	0.04	*n*-Heptane	0.18	0.03
trans-2-Butene	0.14	0.04	Methylcyclohexane	0.19	0.03
cis-2-Butene	0.18	0.04	2,2,3-Trimethylpentane	0.28	0.04
3-Methyl-1-Butene	0.24	0.05	2,3,4-Trimethylpentane	0.14	0.02
Isopentane	0.19	0.04	2-Methylheptane	0.17	0.02
1-Pentene	0.12	0.02	3-Methylheptane	0.11	0.01
2-Methyl-1-Butene	0.24	0.05	1-Octene	0.28	0.04
n-Pentane	0.09	0.02	1-Nonene	0.24	0.03
Isoprene	0.24	0.05	*n*-Nonane	0.18	0.02
trans-2-Pentene	0.14	0.03	Isopropylbenzene	0.21	0.02
cis-2-Pentene	0.19	0.04	*alpha*-Pinene	0.24	0.02
2-Methyl-2-Butene	0.24	0.05	*n*-Propylbenzene	0.20	0.02
2,2-Dimethylbutane	0.20	0.03	*m*-Ethyltolune	0.15	0.02
Cyclopentene	0.24	0.05	*p*-Ethyltoluene	0.24	0.03
4-Methyl-1-Pentene	0.36	0.06	*o*-Ethyltoluene	0.18	0.02
Cyclopentane	0.12	0.02	*beta*-Pinene	0.24	0.02
2,3,-Dimethylbutane	0.20	0.03	1-Decene	0.24	0.02
2-Methylpentane	0.14	0.02	*n*-Decane	0.23	0.02
3-Methylpentane	0.20	0.03	1,2,3-Trimethylbenzene	0.17	0.02
2-Methyl-1-Pentene	0.36	0.06	*m*-Diethylbenzene	0.24	0.02
1-Hexene	0.36	0.06	*p*-Diethylbenzene	0.14	0.01
2-Ethyl-1-butene	0.36	0.06	1-Undecene	0.22	0.02
n-Hexane	0.24	0.04	*n*-Undecane	0.22	0.02
trans-2-Hexene	0.36	0.06	1-Dodecene	0.29	0.02
cis-2-Hexene	0.36	0.06	*n*-Dodecane	0.29	0.02
Methylcyclopentane	0.14	0.02	1-Tridecene	0.29	0.02
2,4-Dimethylpentane	0.23	0.03	*n*-Tridecane	0.29	0.02

The procedure used to analyze the sample under EPA Compendium Method TO-15 involves extracting a known volume of sample gas from the canister through a mass flow controller to a solid multi-sorbent concentrator. After the concentration step is completed, the VOCs are thermally desorbed, entrained in a carrier gas stream, and then focused in a small volume by trapping on a reduced temperature trap or small volume multi-sorbent trap. The sample is then released by thermal desorption and carried onto two gas chromatographic columns housed in a gas chromatograph (GC). This step separates the individual air toxics and SNMOC species. Air toxics are then measured using a mass spectrometer operated in the selected ion monitoring (SIM) mode. SNMOCs are measured concurrently using a flame ionization detector (FID).

Target carbonyl species from Method TO-11A[2] and their corresponding MDLs are presented in Table 2.3-3. Methane concentration data was obtained for Sites S-6 and S-7 using Method TO-14.[3] The MDL for methane from Method TO-14 is presented in Table 2.3-4.

Table 2.3-3. Carbonyl Target Compounds and Method Detection Limits

Compound	ppbv
Formaldehyde	0.004
Acetaldehyde	0.005
Acetone	0.006
Propionaldehyde	0.002
Crotonaldehyde	0.002
Butyr/Isobutyraldehyde	0.002
Benzaldehyde	0.002
Isovaleraldehyde	0.002
Valeraldehyde	0.002
Tolualdehydes	0.003
Hexaldehyde	0.001
2,5-dimethylbenzaldehyde	0.001

Table 2.3-4. Methane Method Detection Limit

Compound	ppmv
Methane	0.154

A detailed, technical description of the analytical procedures and sample handling procedures used for each sample can be found in the *Ambient Air Monitoring Plan* and in the *Ambient Air Monitoring Quality Assurance Project Plan*, which was originally submitted in August 2010 and revised in October 2010.

2.4 Quality Assurance/Quality Control

Throughout the process of ambient air network design, field implementation, sample collection, and sample analysis, QA/QC procedures were employed to ensure that the resultant data was of the highest quality and that the program would meet the Data Quality Objectives (DQOs) that were established at its onset. These procedures and steps are fully documented in the *Ambient Air Monitoring Plan* and the *Ambient Air Monitoring Quality Assurance Project Plan*. A summary of the QA/QC plan and results are provided below, including a discussion of DQOs, data completeness, measurement precision, and measurement accuracy.

The project DQOs answer the critical question of how good data must be in order to achieve the project goals. DQOs are used to develop the criteria that a data collection effort should satisfy, including where to conduct monitoring, how many sites to use, when to conduct monitoring, what the measurement frequency should be, and acceptable measurement precision and accuracy. DQOs for this air quality study are presented in Table 2.4-1.

Table 2.4-1. Data Quality Objectives

Element	Objective
Where to conduct monitoring	All sites must be located in close proximity to the potentially impacted populations, with the exception of the remote site (Site S-1).
Number of sites required	Eight fixed-location (including two collocated) sampling sites will be used to represent the entire city. Sites will be at city-owned and/or public use areas. They will be recommended by ERG as representative of the potentially impacted area. Final site selection will be accomplished through concurrence of ERG and Fort Worth Transportation and Public Works Department staff.
When to conduct monitoring	Sample collection will be conducted for a two-month duration. Samples will be collected from 00:01 to 23:50 hours (24 hours +/- 1 hour).
Frequency of monitoring	Sample collection episodes will be conducted once every three days. This schedule ensures that sampling is conducted multiple times on all days of the week, across the two-month duration of the program.
Overall completeness	Overall completeness must be 75% data capture at each monitoring site or greater.
Acceptable measurement precision for carbonyls	+/- 30% relative standard deviation (RSD)
Acceptable measurement accuracy for carbonyls	+/- 20% bias
Acceptable measurement precision for VOCs/SNMOCs	+/- 30% RSD
Acceptable measurement accuracy for VOCs	+/- 30% bias

Prior to field deployment, all the measurement systems were certified to ensure that each system provided unbiased results.

2.4.1 Completeness

“Completeness” refers to the number of valid measurements collected compared to the number of scheduled sampling events. Data completeness requirements are included in the reference methods (see QAPP References, Section 21). Monitoring programs that consistently generate valid results have higher completeness than programs that consistently generate invalid samples. The completeness of an air monitoring program, therefore, is a qualitative measure of how effectively the program was managed.

During the two-month study period, the completeness of the monitoring network met or exceeded the DQO of 75% data capture at each site. Overall completeness was 96%. Table 2.4-2 summarizes the data completeness at each monitoring site by measurement system. As shown previously in Table 2.1-2, a total of 20 VOC/SNMOC samples were scheduled for each monitoring site and 20 carbonyl samples were scheduled for Sites S-4 and S-5.

Although the target number of valid samples was not obtained for Sites S-2, S-3, S-5, S-6, or S-7, the actual number of valid samples met or exceeded the DQO, thus providing sufficient data to calculate robust time-period averages. Invalid samples were due to a combination of equipment failure and human error, summarized below:

- On the first sample collection day (September 4), the sample collection program was incorrectly set, resulting in no sample collection at Sites S-2, S-5 (this affected the TO-15 sample only; the TO-11A carbonyl sample was collected successfully), and S-7.
- The sample collection systems at Sites S-6 and S-7 experienced gauge failure on September 7, so no samples were collected at those sites on that day.
- On September 10, the field operator did not fully open the canister valve at Site S-2, and no sample was collected.
- The October 31 sample collected at Site S-3 was never received at the laboratory, so no sample was analyzed for that site for that date.

A suitable location for Site S-3 (which targeted pre-production operations) was not identified until September 14. Therefore, this site only had 16 sample days. Additionally, due to the study duration (two months) and sampling frequency (1-in-3 days), it was not feasible to schedule make-up samples. Table 2.4-2 shows the final number of samples and completion percentage for each site.

Table 2.4-2. DQO: Overall Completeness

Monitoring Site	Measurement System	Number of Samples Collected	Number of Samples Scheduled	Completion Percentage
S-1	VOC/SNMOC	20	20	100%
S-2	VOC/SNMOC	18	20	90%
S-3	VOC/SNMOC	15	16	94%
S-4	VOC/SNMOC	20	20[a]	100%
S-4	Carbonyl	20	20[a]	100%
S-5	VOC/SNMOC	19	20[a]	95%
S-5	Carbonyl	20	20[a]	100%
S-6	VOC/SNMOC	19	20	95%
S-7	VOC/SNMOC	18	20	90%
Total		**169**	**176**	**96%**

[a] Sites S-4 and S-5 had a total target of 40 samples each: 20 VOC samples and 20 carbonyl samples.

2.4.2 Measurement Precision

Measurement precision for this project is defined as the ability to acquire the same concentration from different instruments or samples while they are sampling the same gas stream, with an acceptable level of uncertainty. It is a measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. For this monitoring program, measurement precision for the pollutants was assessed in two ways: system precision (across instrument samplers for collocated samples) and analytical precision (within instrument samplers for collocated and replicated samples).

Measurement precision is expressed as percent relative standard deviation (% RSD), which is calculated as follows:

$$\%RSD = \frac{\sigma}{\overline{X}} \times 100$$

Where:

σ is the standard deviation of the instrument-specific concentration determinations
$\overline{X}$ is the average of all instrument-specific concentration determinations

As summarized in Table 2.4-3, the *system precision* overall RSDs for VOCs, carbonyls, and SNMOCs easily met the DQO of 30% RSD.

Table 2.4-3. DQO: RSD Precision Calculation for Collocated VOC, Carbonyl, and SNMOC Instruments

Method	Number of Collocated Data Sets	RSD Pollutant Ranges (%)	Overall RSD (%)
VOCs	20	2.20–35.85	7.46
Carbonyls	20	6.15–44.43	23.99
SNMOCs	20	0.01–11.31	1.40

Analytical precision of the VOC and SNMOC methods was determined by collecting two sets of duplicate samples at Sites S-4 and S-5 and analyzing them in replicate. As summarized in Table 2.4-4, the analytical precision overall RSDs for VOCs, carbonyls, and SNMOCs easily met the DQO of 30% RSD.

Table 2.4-4. DQO: RSD Precision Calculation for Collocated and Replicate VOC and SNMOC Analyses

Method	Number of Replicate Data Sets	RSD Pollutant Ranges (%)	Overall RSD (%)
VOCs	20	0.01–21.32	4.57
Carbonyls	20	0.36–3.41	1.89
SNMOCs	20	1.07–34.11	9.21

2.4.3 Measurement Accuracy

Measurement accuracy for this project is defined as the ability to acquire the correct concentration data from an instrument or sample analysis with an acceptable level of uncertainty while measuring a reference gas stream of a known concentration. Bias is defined as the systematic or persistent distortion of a measurement process that causes error in one direction. Bias is determined by estimating the positive and negative deviation from the true value as a percentage of the true value.

Accuracy for the VOC and carbonyl analyses was established through audits that EPA prepared and submitted to ERG as a regular function of the EPA National Air Toxics Monitoring Program, which ERG manages and operates for EPA. The most recent audit for VOC HAPs was conducted in March 2010; the most recent audit for carbonyl HAPs was in May 2010. Table 2.4-5 summarizes the audit results for VOC and carbonyl HAPs. As the table shows, the overall percent differences are within 30% for VOC HAPs and 20% for carbonyl HAPs. This meets the DQOs presented in Table 2.4-1.

Table 2.4-5. VOC and Carbonyl HAP Audit Results

Pollutant Group	Method	Proficiency Test Date	Overall % Difference
VOC HAPs	TO-15	March 2010	-1.0
Carbonyl HAPs	TO-11A	May 2010	-11.4

2.5 Ambient Air Monitoring Results

This section presents ambient air concentrations, meteorological data, and spatial/temporal trends for the monitoring sites in this study. It first presents information for all the pollutants measured across the monitoring network, then by monitoring site. Finally, a more detailed analysis of a subset of key pollutants is presented by monitoring site. Nearly 140 different chemicals (including over 40 HAPs) were sampled for and analyzed in this study using EPA-approved sampling and analytical methodologies, as described in Section 2.3 of this report. It is important to note that, due to the configuration and purpose of each monitoring site, not all the same pollutants were sampled at each site. This is described in detail in Section 2.2.

2.5.1 Summary Statistics

This section reviews the monitoring data for the entire network. For each method type, it presents study-wide central tendency and variability statistics of the entire set of ambient air monitoring data collected. In total, over 15,000 data points were generated for this study. Individual measurements are presented in Appendix 2-F.

VOCs

A total of 59 VOCs were sampled, analyzed, and reported for in this study (Table 2.5-1). Eight VOCs had detection rates greater than 90%: benzene (94%), carbon tetrachloride (98%), chloromethane (100%), dichlorodifluoromethane (100%), methyl ethyl ketone (99%), propylene (98%), toluene (99%), and trichlorofluoromethane (100%). Acetone (2.807 ppbv), toluene (0.876 ppbv), and methyl ethyl ketone (0.827 ppbv) were the three VOCs with the highest average detected concentrations.

Table 2.5-1 also presents data distribution statistics, such as the minimum value, the maximum value, and the 25th, 50th, and 75th percentile values for the VOCs. As an indicator of variability of the VOC concentrations across the entire monitoring network, the coefficient of variation (CV) ratio is calculated. The CV ratio is the standard deviation divided by the mean, and is used to compare the relative dispersion in one set of data with the relative dispersion of another set of data. The lower the CV ratio, the less variability in the data measurements. The five VOCs with the lowest CV ratios and a minimum of 70% detects are trichlorofluoromethane (0.09), dichlorodifluoromethane (0.10), trichlorotrifluoroethane (0.10), dichlorotetrafluoroethane (0.13), and carbon tetrachloride (0.14). Conversely, the five VOCs with the highest CV ratios and a minimum of 70% detects are toluene (1.84), carbon disulfide (1.61), dichloromethane (1.39), *m,p*-xylene (1.24), and 1,2,4-trimethylbenzene (1.22).

Carbonyls

A total of 11 carbonyl pollutants were sampled, analyzed, and reported for in this study (Table 2.5-2). As described in Section 2.2, carbonyls were only sampled at Sites S-4 and S-5. Eight carbonyls had detection rates greater than 90%: acetaldehyde (100%), benzaldehyde (95%), butyraldehyde (100%), crotonaldehyde (100%), formaldehyde (100%), hexaldehyde (100%), propionaldehyde (100%), and valeradehyde (93%). Acetaldehyde (2.81 ppbv), formaldehyde (0.931 ppbv), and butyraldehyde (0.110 ppbv) were the three carbonyls with the highest average detected concentrations.

Table 2.5-2 also presents data distribution statistics and CV ratios for the carbonyls. The four carbonyls with the lowest CV ratios and a minimum of 70% detects are crotonaldehyde (0.59), formaldehyde (0.71), acetaldehyde (0.73), and propionaldehyde (0.96). Conversely, the four carbonyls with the highest CV ratios and a minimum of 70% detects are hexaldehyde (1.98), butyraldehyde (1.29), valeraldehyde (1.20), and benzaldehyde (1.11).

Two carbonyls were not detected at either Site S-4 or Site S-5: 2,5-dimethylbenzaldehyde and isovaleraldehyde.

Table 2.5-1. Summary of VOC Measurements Across the Entire Monitoring Network

Pollutant Name	Number of Detects	Average of Detects (ppbv)	Minimum Detected Value (ppbv)	Maximum Detected Value (ppbv)	25th Percentile Concentration (ppbv)	50th Percentile Concentration (ppbv)	75th Percentile Concentration (ppbv)	Coefficient of Variation
Acetone	77	2.807	0.262	8.2	1.23	2.4	4.0	0.64
Acetylene	92	0.716	0.252	3.57	0.445	0.547	0.725	0.74
Acrylonitrile	0	NA[a]						
Allyl Chloride	0	NA[a]						
Amyl Methyl Ether, *tert*-	1	NA[a]						
Benzene	121	0.291	0.0635	1.83	0.154	0.208	0.314	0.96
Bromochloromethane	0	NA[a]						
Bromodichloromethane	3	0.050	0.029	0.075	NA[a]			
Bromoform	0	NA[a]						
Bromomethane	54	0.014	0.01	0.03	0.012	0.014	0.016	0.26
Butadiene, 1,3-	86	0.057	0.01	0.304	0.025	0.039	0.066	0.92
Butanol, *n*-	0	NA[a]						
Carbon Disulfide	92	0.243	0.008	1.64	0.021	0.055	0.179	1.61
Carbon Tetrachloride	126	0.112	0.053	0.142	0.106	0.113	0.121	0.14
Chlorobenzene	1	NA[a]						
Chloroethane	9	0.091	0.015	0.237	0.017	0.086	0.097	0.89
Chloroform	91	0.031	0.014	0.105	0.021	0.026	0.033	0.51
Chloromethane	129	0.618	0.288	0.952	0.586	0.641	0.673	0.20
Chloromethylbenzene	1	NA[a]						
Chloroprene	0	NA[a]						
Dibromochloromethane	6	0.010	0.004	0.017	0.006	0.007	0.014	0.59
Dibromoethane, 1,2-	3	0.099	0.008	0.275	NA[a]			
Dichlorobenzene, *m*-	3	0.210	0.015	0.55	NA[a]			
Dichlorobenzene, *o*-	3	0.187	0.016	0.482	NA[a]			
Dichlorobenzene, *p*-	71	0.058	0.011	0.706	0.0195	0.031	0.0585	1.66

Table 2.5-1. Summary of VOC Measurements Across the Entire Monitoring Network (Continued)

Pollutant Name	Number of Detects	Average of Detects (ppbv)	Minimum Detected Value (ppbv)	Maximum Detected Value (ppbv)	25th Percentile Concentration (ppbv)	50th Percentile Concentration (ppbv)	75th Percentile Concentration (ppbv)	Coefficient of Variation
Dichlorodifluoromethane	129	0.555	0.276	0.667	0.52	0.562	0.596	0.10
Dichloroethane, 1,1-	1	NA[a]						
Dichloroethane, 1,2-	0	NA[a]						
Dichloroethene, 1,1-	2	0.006	0.005	0.007	NA[a]			
Dichloroethylene, *cis*-1,2-	0	NA[a]						
Dichloroethylene, *trans*-1,2-	0	NA[a]						
Dichloromethane (Methylene Chloride)	101	0.168	0.037	2.21	0.086	0.105	0.165	1.39
Dichloropropane, 1,2-	0	NA[a]						
Dichloropropene, *cis*-1,3-	1	NA[a]						
Dichloropropene, *trans*-1,3-	1	NA[a]						
Dichlorotetrafluoroethane	92	0.019	0.008	0.026	0.017	0.018	0.02	0.13
Dioxane, 1.4-	0	NA[a]						
Ethyl Acrylate	0	NA[a]						
Ethyl *tert*-Butyl Ether	1	NA[a]						
Ethylbenzene	94	0.142	0.023	0.935	0.051	0.089	0.173	1.06
Hexachloro-1,3-butadiene	4	0.124	0.008	0.369	NA[a]			
Methanol	37	6.64	3.30	19.40	4.84	5.75	7.69	0.475
Methyl Ethyl Ketone	128	0.827	0.155	8.85	0.405	0.593	0.979	1.15
Methyl Isobutyl Ketone	79	0.079	0.015	0.596	0.034	0.054	0.086	1.12
Methyl Methacrylate	4	0.188	0.031	0.451	NA[a]			
Methyl *tert*-Butyl Ether	0	NA[a]						
Octane, *n*-	94	0.105	0.023	0.844	0.047	0.07105	0.109	1.09
Propylene	127	0.450	0.055	2.38	0.226	0.376	0.547	0.78
Styrene	85	0.074	0.011	0.758	0.025	0.043	0.07	1.52

Table 2.5-1. Summary of VOC Measurements Across the Entire Monitoring Network (Continued)

Pollutant Name	Number of Detects	Average of Detects (ppbv)	Minimum Detected Value (ppbv)	Maximum Detected Value (ppbv)	25th Percentile Concentration (ppbv)	50th Percentile Concentration (ppbv)	75th Percentile Concentration (ppbv)	Coefficient of Variation
Tetrachloroethane, 1,1,2,2-	0	NA[a]						
Tetrachloroethylene	81	0.043	0.01	0.218	0.018	0.03	0.054	0.85
Toluene	128	0.876	0.079	12.6	0.251	0.393	0.828	1.84
Trichlorobenzene, 1,2,4-	8	0.176	0.014	0.842	0.029	0.0335	0.215	1.61
Trichloroethane, 1,1,1-	43	0.030	0.009	0.46	0.012	0.015	0.0215	2.32
Trichloroethane, 1,1,2-	1	NA[a]						
Trichloroethylene	13	0.029	0.008	0.093	0.013	0.014	0.026	0.96
Trichlorofluoromethane	129	0.269	0.128	0.334	0.259	0.273	0.284	0.09
Trichlorotrifluoroethane	103	0.089	0.042	0.107	0.087	0.090	0.093	0.10
Trimethylbenzene, 1,2,4-	94	0.084	0.010	0.732	0.033	0.047	0.097	1.22
Trimethylbenzene, 1,3,5-	90	0.054	0.009	0.584	0.0202	0.027	0.054	1.41
Vinyl Acetate	17	0.248	0.119	0.359	0.206	0.260	0.280	0.272
Vinyl chloride	3	0.031	0.008	0.052	NA[a]			
Xylene, *m,p-*	96	0.406	0.051	3.12	0.121	0.229	0.514	1.24
Xylene, *o-*	94	0.141	0.021	0.94	0.049	0.084	0.179	1.11

NA = not available

[a] Summary statistics were only calculated for pollutants detected in at least six samples.

Table 2.5-2. Summary of Carbonyl Measurements Across the Entire Monitoring Network

Pollutant Name	Number of Detects	Average of Detects (ppbv)	Minimum Detected Value (ppbv)	Maximum Detected Value (ppbv)	25th Percentile Concentration (ppbv)	50th Percentile Concentration (ppbv)	75th Percentile Concentration (ppbv)	Coefficient of Variation
Acetaldehyde	40	2.813	0.83	9.06	1.518	2.050	3.085	0.73
Benzaldehyde	38	0.018	0.01	0.11	0.009	0.011	0.017	1.11
Butyraldehyde	40	0.110	0.02	0.66	0.032	0.049	0.119	1.29
Crotonaldehyde	40	0.061	0.02	0.19	0.037	0.052	0.072	0.59
Dimethylbenzaldehyde, 2,5-	0	NA[a]						
Formaldehyde	40	0.931	0.41	4.45	0.598	0.847	0.981	0.71
Hexaldehyde	40	0.067	0.01	0.55	0.015	0.019	0.024	1.98
Isovaleraldehyde	0	NA[a]						
Propionaldehyde	40	0.088	0.02	0.38	0.023	0.0675	0.119	0.96
Tolualdehydes	10	0.016	0.01	0.05	0.009	0.012	0.017	0.82
Valeraldehyde	37	0.025	0.01	0.14	0.009	0.012	0.019	1.20

NA = not available

[a] Summary statistics were only calculated for pollutants detected in at least six samples.

Methane and Speciated Non-Methane Organics

Methane was detected in each sample taken (100%)—37 samples at Sites S-6 and S-7 (Table 2.5-3). Methane had the highest concentrations of the study analytes (average of detects = 5,686 ppbv). Methane is not a HAP, and the overall CV ratio was 0.24.

A total of 67 SNMOCs were sampled, analyzed, and reported for in this study (Table 2.5-3). Seven speciated organics had detection rates greater than 90%: *n*-butane (93%), ethane (100%), ethylene (99%), isobutane (97%), isobutene/1-butene (97%), *n*-pentane (98%), and propane (100%). Ethane (16.028 ppbv), propane (5.325 ppbv), and isopentane (4.028 ppbv) were the three SNMOCs with the highest average detected concentrations.

Data distribution statistics and CV ratios for methane and the SNMOCs are also presented in Table 2.5-3. The five SNMOCs with the lowest CV ratios and a minimum of 70% detects are 1-hexene (0.48), isoprene (0.63), ethylene (0.69), 3-methylehexane (0.77), and 2-methylheptane (0.85). Conversely, the five VOCs with the highest CV ratios and a minimum of 70% detects are *n*-decane (1.92), *n*-nonane (1.90), isopentane (1.84), *trans*-2-butene (1.83), and *n*-Pentane (1.80).

All SNMOCs were detected at least once during the study period.

2.5.2 Study Period Averaging

This section presents information on the average pollutant concentrations, at each monitoring site, for the study period. Non-detect observations were replaced with zeroes when calculating these averages. This section focuses only on pollutants that were detected in at least 70% of the samples, because average concentrations for these pollutants have the least influence from non-detect observations. Thus, study period averages for pollutants that had more than 30% of their samples as non-detects were not calculated. This averaging technique is consistent with the study period averaging EPA uses in its Schools Air Toxics Monitoring Program (SATMP)[5] and National-Scale Air Toxics Assessment (NATA) model-to-monitor comparison.[6] In addition to the study period average, this section presents the confidence intervals for the study period average concentrations. The confidence interval is calculated using Student's *T*-test at the 95th percentile confidence level.

Table 2.5-3. Summary of Methane and Speciated Non-Methane Organic Compounds Across the Entire Monitoring Network

Pollutant Name	Number of Detects	Average of Detects (ppbv)	Minimum Detected Value (ppbv)	Maximum Detected Value (ppbv)	25th Percentile Concentration (ppbv)	50th Percentile Concentration (ppbv)	75th Percentile Concentration (ppbv)	Coefficient of Variation
Methane	37	5686.486	4180	9890	4670	5570	5720	0.24
Speciated Non-Methane Organic Compounds								
Butane, *n*-	120	3.549	0.149	35.750	0.602	1.566	3.369	1.72
Butene, *cis*-2-	89	0.157	0.020	3.425	0.040	0.052	0.088	2.52
Butene, *trans*-2-	93	0.132	0.018	1.243	0.032	0.042	0.079	1.83
Cyclohexane	97	0.128	0.031	0.708	0.050	0.077	0.141	1.03
Cyclopentane	92	0.171	0.041	1.200	0.054	0.071	0.140	1.46
Cyclopentene	2	0.040	0.030	0.049	NA[a]			
Decane, *n*-	93	0.102	0.012	1.440	0.025	0.037	0.071	1.92
Decene, 1-	3	0.024	0.020	0.031	NA[a]			
Diethylbenzene, *m*-	17	0.020	0.009	0.082	0.011	0.017	0.020	0.85
Diethylbenzene, *p*-	40	0.028	0.009	0.102	0.015	0.022	0.032	0.76
Dimethylbutane, 2,2-	92	0.132	0.031	0.805	0.058	0.079	0.140	1.09
Dimethylbutane, 2,3-	92	0.306	0.040	2.517	0.070	0.098	0.230	1.65
Dimethylpentane, 2,3-	92	0.169	0.041	0.729	0.087	0.122	0.190	0.80
Dimethylpentane, 2,4-	92	0.114	0.020	0.821	0.033	0.045	0.114	1.42
Dodecane, *n*-	90	0.038	0.006	0.327	0.018	0.029	0.038	1.22
Dodecene, 1-	57	0.023	0.006	0.225	0.011	0.016	0.024	1.31
Ethane	129	16.028	2.08	93.2	5.2	9.45	20.7	1.00
Ethyl-1-butene, 2-	9	0.284	0.049	0.870	0.074	0.250	0.395	0.95
Ethylene	128	1.118	0.275	5.400	0.671	0.985	1.270	0.69
Ethyltoluene, *m*-	91	0.054	0.010	0.301	0.026	0.036	0.068	0.92
Ethyltoluene, *o*-	76	0.044	0.012	0.386	0.019	0.027	0.045	1.18
Ethyltoluene, *p*-	90	0.042	0.010	0.340	0.020	0.026	0.043	1.10

Table 2.5-3. Summary of Methane and Speciated Non-Methane Organic Compounds Across the Entire Monitoring Network (Continued)

Pollutant Name	Number of Detects	Average of Detects (ppbv)	Minimum Detected Value (ppbv)	Maximum Detected Value (ppbv)	25th Percentile Concentration (ppbv)	50th Percentile Concentration (ppbv)	75th Percentile Concentration (ppbv)	Coefficient of Variation
Heptane, *n-*	101	0.149	0.038	0.864	0.061	0.092	0.174	0.97
Heptene, 1-	20	0.075	0.016	0.769	0.026	0.028	0.032	2.23
Hexane, *n-*	105	0.445	0.070	3.483	0.131	0.220	0.393	1.46
Hexene, 1-	92	0.049	0.010	0.147	0.033	0.045	0.056	0.48
Hexene, *cis*-2-	26	0.042	0.014	0.262	0.022	0.029	0.035	1.18
Hexene, *trans*-2-	29	0.097	0.013	0.353	0.024	0.042	0.119	1.06
Isobutane	125	1.216	0.150	9.475	0.355	0.648	1.210	1.37
Isobutene/1-butene	125	0.291	0.057	2.285	0.131	0.191	0.281	1.11
Isopentane	92	4.028	0.314	36.400	0.672	1.048	2.925	1.84
Isoprene	92	0.167	0.032	0.498	0.083	0.144	0.228	0.63
Isopropylbenzene	66	0.016	0.008	0.050	0.012	0.015	0.018	0.42
Methyl-1-butene, 2-	72	0.186	0.018	1.656	0.029	0.049	0.117	1.81
Methyl-1-butene, 3-	1	NA[a]						
Methyl-1-pentene, 2-	25	0.077	0.015	0.258	0.022	0.046	0.109	0.95
Methyl-1-pentene, 4-	31	0.051	0.020	0.131	0.035	0.042	0.055	0.49
Methyl-2-butene, 2-	64	0.371	0.015	2.820	0.030	0.077	0.285	1.81
Methylcyclohexane	92	0.170	0.035	0.817	0.073	0.109	0.193	0.89
Methylcyclopentane	92	0.217	0.025	1.389	0.080	0.111	0.212	1.28
Methylheptane, 2-	92	0.065	0.016	0.295	0.032	0.043	0.070	0.85
Methylheptane, 3-	92	0.050	0.012	0.243	0.025	0.033	0.053	0.86
Methylhexane, 2-	92	0.204	0.034	1.786	0.076	0.104	0.183	1.31
Methylhexane, 3-	92	0.288	0.046	1.236	0.156	0.201	0.350	0.77
Methylpentane, 2-	87	0.979	0.091	6.450	0.298	0.460	0.962	1.35
Methylpentane, 3-	92	0.488	0.069	3.767	0.126	0.192	0.388	1.53

Table 2.5-3. Summary of Methane and Speciated Non-Methane Organic Compounds Across the Entire Monitoring Network (Continued)

Pollutant Name	Number of Detects	Average of Detects (ppbv)	Minimum Detected Value (ppbv)	Maximum Detected Value (ppbv)	25th Percentile Concentration (ppbv)	50th Percentile Concentration (ppbv)	75th Percentile Concentration (ppbv)	Coefficient of Variation
Nonane, *n-*	93	0.083	0.015	1.278	0.026	0.034	0.061	1.90
Nonene, 1-	41	0.037	0.009	0.247	0.017	0.021	0.049	1.10
Octene, 1-	52	0.024	0.011	0.055	0.017	0.022	0.027	0.41
Pentane, *n-*	127	1.532	0.131	15.680	0.368	0.620	1.220	1.80
Pentene, 1-	92	0.118	0.024	0.884	0.043	0.054	0.086	1.45
Pentene, *cis*-2-	87	0.123	0.019	1.070	0.028	0.038	0.073	1.76
Pentene, *trans*-2-	89	0.231	0.018	2.100	0.033	0.056	0.136	1.88
Pinene, *alpha-*	80	0.052	0.008	0.423	0.021	0.033	0.064	1.08
Pinene, *beta-*	34	0.040	0.011	0.211	0.015	0.027	0.046	0.99
Propane	129	5.325	0.423	34.667	1.857	2.833	6.333	1.13
Propylbenzene, *n-*	86	0.030	0.009	0.216	0.015	0.020	0.034	0.96
Propyne	1	NA[a]						
Tridecane, *n-*	7	0.017	0.005	0.056	0.008	0.012	0.014	1.06
Tridecene, 1-	5	0.022	0.007	0.068	NA[a]			
Trimethylbenzene, 1,2,3-	71	0.037	0.008	0.280	0.013	0.019	0.034	1.33
Trimethylpentane, 2,2,3-	85	0.078	0.012	0.563	0.025	0.036	0.085	1.24
Trimethylpentane, 2,2,4-	114	0.374	0.029	3.100	0.098	0.168	0.420	1.43
Trimethylpentane, 2,3,4-	92	0.109	0.011	0.785	0.036	0.059	0.121	1.24
Undecane, *n-*	92	0.068	0.009	0.689	0.027	0.038	0.061	1.53
Undecene, 1-	9	0.046	0.007	0.245	0.010	0.017	0.045	1.65

NA = not available

[a] Summary statistics were only calculated for pollutants detected in at least six samples.

The following observations were made:

Key Point: Pollutant Concentrations
Concentrations measured at Site S-4 were generally higher than at other sites. Concentrations measured at Sites S-6 and S-7 were generally lower relative to other sites.

- *Site S-1 (background site):* A total of 71 out of 124 pollutants had at least 70% detects to compute study period averages (Table 2.5-4). The five pollutants with the highest average concentrations were ethane (6.474 ± 3.041 ppbv), propane (3.498 ± 1.207 ppbv), *n*-butane (2.262 ± 1.500 ppbv), isopentane (1.929 ± 1.172 ppbv), and isobutane (1.324 ± 0.727 ppbv). Site S-1 was located in an area with no natural gas wells typically upwind.
- *Site S-2 (mobile sources site):* A total of 73 out of 124 pollutants had at least 70% detects to compute study period averages (Table 2.5-5). The five pollutants with the highest average concentrations were ethane (10.437 ± 4.571 ppbv), propane (4.812 ± 3.222 ppbv), *n*-butane (2.729 ± 1.574 ppbv), toluene (2.311 ± 1.803 ppbv), and isopentane (1.680 ± 0.615 ppbv). Site S-2 was located in an area next to major roadways.
- *Site S-3A (pre-production activity site):* Note that this site conducted only nine samples over a three-week time frame. Thus, the average concentrations presented for this site may not be representative of the study period. Nevertheless, a total of 69 out of 124 pollutants had at least 70% detects to compute three-week averages (Table 2.5-6). The five pollutants with the highest average concentrations were ethane (16.133 ± 10.964 ppbv), propane (4.456 ± 3.073 ppbv), *n*-butane (1.408 ± 1.245 ppbv), ethylene (1.364 ± 0.528 ppbv), and isopentane (1.217 ± 0.627 ppbv). Site S-3A was located in an area downwind of fracturing fluid flowback operations.
- *Site S-3B (pre-production activity site):* When pre-production operations were completed at Site S-3A, this monitoring site was moved to an area where additional pre-production activities were occurring. Thus, this site conducted only six samples over a two-week time frame, and the average concentrations presented for this site may not be representative of the study period. Nevertheless, a total of 63 out of 124 pollutants had at least 70% detects to compute two-week averages (Table 2.5-7). The five pollutants with the highest average concentrations were ethane (22.592 ± 11.170 ppbv), propane (8.844 ± 4.215 ppbv), *n*-butane (3.195 ± 1.526 ppbv), isobutane (1.588 ± 0.769 ppbv), and isopentane (1.087 ± 0.444 ppbv). Site S-3B was located in an area downwind of hydraulic fracturing activities.
- *Site S-4 (high-level activity site):* A total of 82 out of 136 pollutants had at least 70% detects to compute study period averages (Table 2.5-8). The five pollutants with the highest average concentrations were ethane (18.229 ± 8.241 ppbv), isopentane (12.985 ± 5.511 ppbv), *n*-butane (10.993 ± 5.385 ppbv), propane (10.683 ± 4.918 ppbv), and *n*-pentane (5.491 ± 2.336 ppbv). Site S-4 was located in an area with high levels of well pad and compressor station activity.
- *Site S-5 (high-level activity site):* A total of 75 out of 136 pollutants had at least 70% detects to compute study period averages (Table 2.5-9). The five pollutants with the highest average concentrations were ethane (14.077 ± 4.074 ppbv), propane (5.049 ± 1.773 ppbv), *n*-butane (2.072 ± 1.109 ppbv), acetaldehyde (1.824 ± 0.408 ppbv), and

isopentane (1.297 ± 1.262 ppbv). Site S-5 was located in an area with high levels of well pad activity.

- *Site S-6 (medium-level activity site):* A total of 15 out of 137 pollutants had at least 70% detects to compute study period averages (Table 2.5-10). The five pollutants with the highest average concentrations were methane (5,758 ± 796 ppbv), ethane (21.412 ± 9.997 ppbv), propane (2.982 ± 1.154 ppbv), *n*-butane (1.015 ± 0.432 ppbv), and ethylene (0.632 ± 0.155 ppbv). Site S-6 was located in an area with moderate levels of well pad activity, including within 350 feet downwind of a well pad.
- *Site S-7 (medium-level activity site):* A total of 15 out of 137 pollutants had at least 70% detects to compute study period averages (Table 2.5-11). The five pollutants with the highest average concentrations were methane (5,672 ± 650 ppbv), ethane (23.979 ± 11.236 ppbv), propane (3.967 ± 1.854 ppbv), *n*-butane (1.230 ± 0.604 ppbv), and ethylene (0.690 ± 0.173 ppbv). Site S-7 was located in an area with moderate levels of well pad activity, including within 200 feet downwind of a well pad.

Table 2.5-4. Site S-1 Pollutant Study Averages

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Acetylene	20	0	0.665	0.177
Benzene	20	0	0.245	0.059
Butadiene, 1,3-	18	2	0.041	0.019
Butane, *n*-	18	2	2.262	1.500
Butene, *cis*-2-	20	0	0.080	0.041
Butene, *trans*-2-	20	0	0.077	0.045
Carbon Disulfide	20	0	0.043	0.026
Carbon Tetrachloride	20	0	0.118	0.006
Chloroform	20	0	0.041	0.011
Chloromethane	20	0	0.661	0.023
Cyclohexane	20	0	0.073	0.024
Cyclopentane	20	0	0.090	0.036
Decane, *n*-	20	0	0.044	0.011
Dichlorobenzene, *p*-	17	3	0.039	0.014
Dichlorodifluoromethane	20	0	0.577	0.020
Dichloromethane	20	0	0.161	0.048
Dichlorotetrafluoroethane	20	0	0.018	0.001
Dimethylbutane, 2,2-	20	0	0.085	0.023
Dimethylbutane, 2,3-	20	0	0.137	0.060
Dimethylpentane, 2,3-	20	0	0.112	0.020
Dimethylpentane, 2,4-	20	0	0.055	0.020
Dodecane, *n*-	20	0	0.035	0.014
Dodecene, 1-	15	5	0.014	0.007

Table 2.5-4. Site S-1 Pollutant Study Averages (Continued)

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Ethane	20	0	6.475	3.041
Ethylbenzene	20	0	0.082	0.023
Ethylene	20	0	1.181	0.271
Ethyltoluene, *m-*	20	0	0.035	0.009
Ethyltoluene, *o-*	16	4	0.024	0.009
Ethyltoluene, *p-*	20	0	0.025	0.005
Heptane, *n-*	20	0	0.086	0.028
Hexane, *n-*	20	0	0.204	0.084
Hexene, 1-	20	0	0.041	0.006
Isobutane	20	0	1.324	0.727
Isobutene/1-Butene	20	0	0.294	0.119
Isopentane	20	0	1.929	1.172
Isoprene	20	0	0.266	0.062
Methyl Ethyl Ketone	20	0	0.817	0.157
Methyl Isobutyl Ketone	18	2	0.046	0.013
Methyl-1-butene, 2-	16	4	0.064	0.047
Methylcyclohexane	20	0	0.106	0.031
Methylcyclopentane	20	0	0.121	0.042
Methylheptane, 2-	20	0	0.037	0.009
Methylheptane, 3-	20	0	0.028	0.007
Methylhexane, 2-	20	0	0.099	0.030
Methylhexane, 3-	20	0	0.202	0.050
Methylpentane, 2-	18	2	0.462	0.204
Methylpentane, 3-	20	0	0.220	0.091
Nonane, *n-*	20	0	0.032	0.008
Pentane, *n-*	20	0	0.939	0.454
Pentene, 1-	20	0	0.075	0.030
Pentene, *cis*-2-	19	1	0.050	0.027
Pentene, *trans*-2-	18	2	0.086	0.057
Pinene, *alpha-*	17	3	0.050	0.019
Propane	20	0	3.498	1.207
Propylbenzene, *n-*	19	1	0.018	0.004
Propylene	20	0	0.478	0.120
Styrene	19	1	0.170	0.095
Tetrachloroethylene	17	3	0.038	0.014
Toluene	20	0	0.544	0.202

Table 2.5-4. Site S-1 Pollutant Study Averages (Continued)

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Trichlorofluoromethane	20	0	0.283	0.011
Trichlorotrifluoroethane	20	0	0.091	0.002
Trimethylbenzene, 1,2,3-	14	6	0.016	0.008
Trimethylbenzene, 1,2,4-	20	0	0.077	0.024
Trimethylbenzene, 1,3,5-	20	0	0.029	0.008
Trimethylpentane, 2,2,3-	17	3	0.035	0.016
Trimethylpentane, 2,2,4-	20	0	0.198	0.086
Trimethylpentane, 2,3,4-	20	0	0.062	0.023
Undecane, *n*-	20	0	0.045	0.018
Xylene, *m,p*-	20	0	0.185	0.063
Xylene, *o*-	20	0	0.073	0.024

Table 2.5-5. Site S-2 Pollutant Study Averages

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Acetylene	18	0	0.707	0.156
Benzene	18	0	0.300	0.043
Butadiene, 1,3-	18	0	0.057	0.017
Butane, *n*-	17	1	2.729	1.574
Butene, *cis*-2-	17	1	0.056	0.011
Butene, *trans*-2-	18	0	0.050	0.009
Carbon Disulfide	18	0	0.034	0.018
Carbon Tetrachloride	18	0	0.117	0.005
Chloroform	18	0	0.025	0.004
Chloromethane	18	0	0.666	0.025
Cyclohexane	18	0	0.095	0.030
Cyclopentane	18	0	0.096	0.027
Decane, *n*-	18	0	0.257	0.174
Dichlorobenzene, *p*-	15	3	0.051	0.047
Dichlorodifluoromethane	18	0	0.584	0.026
Dichloromethane	18	0	0.370	0.244
Dichlorotetrafluoroethane	18	0	0.018	0.001
Dimethylbutane, 2,2-	18	0	0.098	0.021
Dimethylbutane, 2,3-	18	0	0.185	0.069
Dimethylpentane, 2,3-	18	0	0.156	0.037
Dimethylpentane, 2,4-	18	0	0.079	0.026
Dodecane, *n*-	18	0	0.037	0.012
Ethane	18	0	10.437	4.571
Ethylbenzene	18	0	0.239	0.127
Ethylene	18	0	1.379	0.259
Ethyltoluene, *m*-	18	0	0.079	0.034
Ethyltoluene, *o*-	18	0	0.083	0.045
Ethyltoluene, *p*-	18	0	0.069	0.038
Heptane, *n*-	18	0	0.152	0.060
Hexane, *n*-	18	0	0.333	0.140
Hexene, 1-	18	0	0.043	0.009
Isobutane	18	0	0.827	0.320
Isobutene/1-Butene	18	0	0.271	0.049
Isopentane	18	0	1.680	0.615
Isoprene	18	0	0.183	0.044
Methyl Ethyl Ketone	18	0	0.986	0.298
Methyl Isobutyl Ketone	17	1	0.123	0.073

Table 2.5-5. Site S-2 Pollutant Study Averages (Continued)

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Methyl-1-butene, 2-	18	0	0.070	0.024
Methyl-2-butene, 2-	18	0	0.095	0.051
Methylcyclohexane	18	0	0.191	0.080
Methylcyclopentane	18	0	0.152	0.048
Methylheptane, 2-	18	0	0.077	0.031
Methylheptane, 3-	18	0	0.062	0.024
Methylhexane, 2-	18	0	0.173	0.059
Methylhexane, 3-	18	0	0.269	0.070
Methylpentane, 2-	18	0	0.666	0.198
Methylpentane, 3-	18	0	0.321	0.119
Nonane, *n*-	18	0	0.212	0.153
Nonene, 1-	13	5	0.041	0.029
Octane, *n*-	18	0	0.187	0.105
Pentane, *n*-	18	0	0.923	0.297
Pentene, 1-	18	0	0.068	0.012
Pentene, *cis*-2-	18	0	0.055	0.018
Pentene, *trans*-2-	18	0	0.104	0.039
Pinene, *alpha*-	16	2	0.027	0.011
Propane	18	0	4.812	3.222
Propylbenzene, *n*-	18	0	0.047	0.025
Propylene	18	0	0.552	0.116
Styrene	16	2	0.044	0.017
Tetrachloroethylene	18	0	0.061	0.029
Toluene	18	0	2.311	1.803
Trichloroethane, 1,1,1-	13	5	0.050	0.053
Trichlorofluoromethane	18	0	0.281	0.011
Trichlorotrifluoroethane	18	0	0.091	0.003
Trimethylbenzene, 1,2,3-	15	3	0.044	0.033
Trimethylbenzene, 1,2,4-	18	0	0.210	0.116
Trimethylbenzene, 1,3,5-	18	0	0.077	0.042
Trimethylpentane, 2,2,3-	18	0	0.070	0.024
Trimethylpentane, 2,2,4-	18	0	0.345	0.120
Trimethylpentane, 2,3,4-	18	0	0.098	0.026
Undecane, *n*-	18	0	0.125	0.074
Xylene, *m,p*-	18	0	0.728	0.432
Xylene, *o*-	18	0	0.233	0.124

Table 2.5-6. Site S-3A Pollutant Study Averages

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Acetylene	9	0	0.735	0.399
Benzene	9	0	0.301	0.128
Butadiene, 1,3-	8	1	0.049	0.033
Butane, *n*-	7	2	1.408	1.245
Butene, *cis*-2-	8	1	0.046	0.021
Butene, *trans*-2-	9	0	0.139	0.221
Carbon Disulfide	9	0	0.050	0.053
Carbon Tetrachloride	9	0	0.118	0.007
Chloroform	9	0	0.029	0.006
Chloromethane	9	0	0.628	0.040
Cyclohexane	9	0	0.081	0.039
Cyclopentane	9	0	0.069	0.024
Decane, *n*-	9	0	0.034	0.013
Dichlorobenzene, *p*-	9	0	0.030	0.013
Dichlorodifluoromethane	9	0	0.570	0.017
Dichloromethane	9	0	0.169	0.034
Dichlorotetrafluoroethane	9	0	0.017	0.000
Dimethylbutane, 2,2-	9	0	0.070	0.025
Dimethylbutane, 2,3-	9	0	0.121	0.056
Dimethylpentane, 2,3-	9	0	0.122	0.028
Dimethylpentane, 2,4-	9	0	0.055	0.023
Dodecane, *n*-	9	0	0.031	0.008
Ethane	9	0	16.133	10.964
Ethylbenzene	9	0	0.090	0.035
Ethylene	9	0	1.364	0.528
Ethyltoluene, *m*-	9	0	0.044	0.017
Ethyltoluene, *o*-	8	1	0.029	0.012
Ethyltoluene, *p*-	9	0	0.025	0.009
Heptane, *n*-	9	0	0.098	0.053
Hexane, *n*-	9	0	0.241	0.139
Hexene, 1-	9	0	0.046	0.011
Isobutane	9	0	0.820	0.553
Isobutene/1-Butene	9	0	0.236	0.088
Isopentane	9	0	1.217	0.628
Isoprene	9	0	0.149	0.048
Methyl Ethyl Ketone	9	0	0.637	0.182

Table 2.5-6. Site S-3A Pollutant Study Averages (Continued)

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Methyl Isobutyl Ketone	9	0	0.043	0.011
Methyl-1-butene, 2-	8	1	0.041	0.024
Methylcyclohexane	9	0	0.113	0.051
Methylcyclopentane	9	0	0.116	0.042
Methylheptane, 2-	9	0	0.044	0.019
Methylheptane, 3-	9	0	0.035	0.014
Methylhexane, 2-	9	0	0.119	0.054
Methylhexane, 3-	9	0	0.208	0.062
Methylpentane, 2-	8	1	0.497	0.281
Methylpentane, 3-	9	0	0.214	0.107
Nonane, *n*-	9	0	0.030	0.011
Octane, *n*-	9	0	0.065	0.025
Pentane, *n*-	9	0	0.749	0.412
Pentene, 1-	9	0	0.057	0.017
Pentene, *cis*-2-	9	0	0.037	0.014
Pentene, *trans*-2-	9	0	0.067	0.028
Pinene, *alpha*-	9	0	0.114	0.098
Propane	9	0	4.456	3.074
Propylbenzene, *n*-	9	0	0.018	0.006
Propylene	9	0	0.525	0.221
Styrene	9	0	0.042	0.019
Tetrachloroethylene	7	2	0.025	0.014
Toluene	9	0	0.573	0.304
Trichlorofluoromethane	9	0	0.273	0.009
Trichlorotrifluoroethane	9	0	0.089	0.002
Trimethylbenzene, 1,2,4-	9	0	0.080	0.039
Trimethylbenzene, 1,3,5-	9	0	0.030	0.013
Trimethylpentane, 2,2,3-	9	0	0.044	0.022
Trimethylpentane, 2,2,4-	9	0	0.221	0.120
Trimethylpentane, 2,3,4-	9	0	0.071	0.036
Undecane, *n*-	9	0	0.035	0.010
Xylene, *m,p*-	9	0	0.213	0.103
Xylene, *o*-	9	0	0.081	0.038

Table 2.5-7. Site S-3B Pollutant Study Averages

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Acetylene	6	0	0.335	0.058
Benzene	6	0	0.165	0.028
Butane, *n*-	6	0	3.195	1.526
Butene, *cis*-2-	5	1	0.594	1.386
Butene, *trans*-2-	5	1	0.021	0.012
Carbon Disulfide	6	0	0.013	0.004
Carbon Tetrachloride	6	0	0.115	0.008
Chloroform	6	0	0.017	0.002
Chloromethane	6	0	0.641	0.039
Cyclohexane	6	0	0.106	0.034
Cyclopentane	6	0	0.063	0.015
Decane, *n*-	6	0	0.037	0.013
Dichlorodifluoromethane	6	0	0.598	0.031
Dichloromethane	6	0	0.086	0.020
Dichlorotetrafluoroethane	6	0	0.019	0.001
Dimethylbutane, 2,2-	6	0	0.073	0.017
Dimethylbutane, 2,3-	6	0	0.071	0.018
Dimethylpentane, 2,3-	6	0	0.081	0.013
Dimethylpentane, 2,4-	6	0	0.033	0.008
Dodecane, *n*-	5	1	0.017	0.014
Ethane	6	0	22.592	11.170
Ethylbenzene	6	0	0.039	0.008
Ethylene	6	0	0.723	0.329
Ethyltoluene, *m*-	6	0	0.019	0.007
Ethyltoluene, *o*-	5	1	0.021	0.012
Ethyltoluene, *p*-	6	0	0.020	0.006
Heptane, *n*-	6	0	0.143	0.054
Heptene, 1-	5	1	0.031	0.024
Hexane, *n*-	6	0	0.324	0.134
Hexene, 1-	6	0	0.033	0.006
Isobutane	6	0	1.588	0.769
Isobutene/1-Butene	6	0	0.138	0.047
Isopentane	6	0	1.087	0.444
Isoprene	6	0	0.138	0.112
Methyl Ethyl Ketone	6	0	0.484	0.239
Methylcyclohexane	6	0	0.140	0.047
Methylcyclopentane	6	0	0.079	0.018

Table 2.5-7. Site S-3B Pollutant Study Averages (Continued)

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Methylheptane, 2-	6	0	0.070	0.042
Methylheptane, 3-	6	0	0.042	0.013
Methylhexane, 2-	6	0	0.130	0.050
Methylhexane, 3-	6	0	0.173	0.039
Methylpentane, 2-	6	0	0.417	0.206
Methylpentane, 3-	6	0	0.201	0.075
Nonane, *n*-	6	0	0.039	0.010
Octane, *n*-	6	0	0.084	0.029
Pentane, *n*-	6	0	1.010	0.406
Pentene, 1-	6	0	0.038	0.007
Pentene, *trans*-2-	6	0	0.025	0.007
Pinene, *alpha*-	5	1	0.018	0.015
Propane	6	0	8.844	4.215
Propylene	6	0	0.257	0.089
Tetrachloroethylene	5	1	0.013	0.008
Toluene	6	0	0.230	0.055
Trichlorofluoromethane	6	0	0.277	0.015
Trichlorotrifluoroethane	6	0	0.093	0.004
Trimethylbenzene, 1,2,4-	6	0	0.037	0.014
Trimethylbenzene, 1,3,5-	6	0	0.019	0.005
Trimethylpentane, 2,2,3-	6	0	0.023	0.003
Trimethylpentane, 2,2,4-	6	0	0.049	0.013
Trimethylpentane, 2,3,4-	6	0	0.017	0.004
Undecane, *n*-	6	0	0.026	0.012
Xylene, *m,p*-	6	0	0.101	0.026
Xylene, *o*-	6	0	0.035	0.008

Table 2.5-8. Site S-4 Pollutant Study Averages

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Acetaldehyde	20	0	3.802	1.125
Acetone	20	0	1.823	0.589
Acetylene	20	0	1.023	0.392
Benzaldehyde	20	0	0.025	0.012
Benzene	20	0	0.686	0.221
Butadiene, 1,3-	20	0	0.092	0.040
Butane, *n*-	20	0	10.993	5.385
Butene, *cis*-2-	20	0	0.318	0.136
Butene, *trans*-2-	20	0	0.369	0.175
Butyraldehyde	20	0	0.172	0.076
Carbon Disulfide	20	0	0.119	0.022
Carbon Tetrachloride	20	0	0.113	0.006
Chloroform	20	0	0.026	0.004
Chloromethane	20	0	0.688	0.050
Crotonaldehyde	20	0	0.072	0.018
Cyclohexane	20	0	0.296	0.094
Cyclopentane	20	0	0.446	0.172
Decane, *n*-	20	0	0.137	0.092
Dichlorobenzene, *p*-	19	1	0.060	0.022
Dichlorodifluoromethane	20	0	0.581	0.020
Dichloromethane	20	0	0.122	0.032
Dichlorotetrafluoroethane	20	0	0.020	0.001
Dimethylbutane, 2,2-	20	0	0.304	0.106
Dimethylbutane, 2,3-	20	0	0.948	0.366
Dimethylpentane, 2,3-	20	0	0.330	0.094
Dimethylpentane, 2,4-	20	0	0.326	0.114
Dodecane, *n*-	20	0	0.046	0.028
Ethane	20	0	18.229	8.241
Ethylbenzene	20	0	0.238	0.056
Ethylene	20	0	1.778	0.632
Ethyltoluene, *m*-	20	0	0.084	0.028
Ethyltoluene, *p*-	20	0	0.059	0.021
Formaldehyde	20	0	1.140	0.408
Heptane, *n*-	20	0	0.299	0.106
Hexaldehyde	20	0	0.114	0.083
Hexane, *n*-	20	0	1.301	0.507

Table 2.5-8. Site S-4 Pollutant Study Averages (Continued)

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Hexene, 1-	20	0	0.074	0.015
Hexene, *trans*-2-	18	2	0.124	0.054
Isobutane	20	0	2.860	1.397
Isobutene/1-Butene	20	0	0.666	0.275
Isopentane	20	0	12.985	5.511
Isoprene	20	0	0.143	0.030
Isopropylbenzene	19	1	0.018	0.005
Methyl Ethyl Ketone	20	0	1.554	0.948
Methyl Isobutyl Ketone	20	0	0.100	0.040
Methyl-1-butene, 2-	20	0	0.499	0.234
Methyl-2-butene, 2-	20	0	0.992	0.430
Methylcyclohexane	20	0	0.309	0.098
Methylcyclopentane	20	0	0.566	0.195
Methylheptane, 2-	20	0	0.111	0.036
Methylheptane, 3-	20	0	0.087	0.027
Methylhexane, 2-	20	0	0.499	0.207
Methylhexane, 3-	20	0	0.538	0.143
Methylpentane, 2-	20	0	2.543	0.930
Methylpentane, 3-	20	0	1.423	0.541
Nonane, *n*-	20	0	0.102	0.048
Octane, *n*-	20	0	0.146	0.045
Octene, 1-	14	6	0.016	0.006
Pentane, *n*-	20	0	5.491	2.336
Pentene, 1-	20	0	0.328	0.127
Pentene, *cis*-2-	20	0	0.382	0.155
Pentene, *trans*-2-	20	0	0.763	0.310
Pinene, *alpha*-	17	3	0.038	0.015
Propane	20	0	10.683	4.918
Propionaldehyde	20	0	0.129	0.035
Propylbenzene, *n*-	20	0	0.040	0.011
Propylene	20	0	0.811	0.264
Styrene	19	1	0.044	0.011
Tetrachloroethylene	20	0	0.048	0.013
Toluene	20	0	1.663	0.540

Table 2.5-8. Site S-4 Pollutant Study Averages (Continued)

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Trichlorofluoromethane	20	0	0.276	0.008
Trichlorotrifluoroethane	20	0	0.090	0.002
Trimethylbenzene, 1,2,3-	20	0	0.051	0.026
Trimethylbenzene, 1,2,4-	20	0	0.218	0.084
Trimethylbenzene, 1,3,5-	20	0	0.073	0.026
Trimethylpentane, 2,2,3-	20	0	0.183	0.067
Trimethylpentane, 2,2,4-	20	0	1.137	0.403
Trimethylpentane, 2,3,4-	20	0	0.279	0.094
Undecane, *n*-	20	0	0.068	0.026
Valeraldehyde	20	0	0.039	0.017
Xylene, *m,p*-	20	0	0.758	0.189
Xylene, *o*-	20	0	0.255	0.066

Table 2.5-9. Site 5 Pollutant Study Averages

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Acetaldehyde	20	0	1.824	0.408
Acetone	20	0	1.263	0.332
Acetylene	19	0	0.567	0.165
Benzaldehyde	18	2	0.009	0.002
Benzene	19	0	0.197	0.035
Butadiene, 1,3-	15	4	0.018	0.007
Butane, *n*-	15	4	2.072	1.109
Butene, *cis*-2-	19	0	0.048	0.007
Butene, *trans*-2-	18	1	0.033	0.008
Butyraldehyde	20	0	0.048	0.035
Carbon Disulfide	19	0	0.944	0.153
Carbon Tetrachloride	19	0	0.108	0.011
Chloroform	18	1	0.033	0.008
Chloromethane	19	0	0.642	0.063
Crotonaldehyde	20	0	0.050	0.014
Cyclohexane	19	0	0.096	0.033
Cyclopentane	19	0	0.119	0.108
Decane, *n*-	19	0	0.031	0.013
Dichlorodifluoromethane	19	0	0.534	0.040
Dichloromethane	19	0	0.102	0.035
Dichlorotetrafluoroethane	19	0	0.019	0.002
Dimethylbutane, 2,2-	19	0	0.080	0.027
Dimethylbutane, 2,3-	19	0	0.081	0.019
Dimethylpentane, 2,3-	19	0	0.117	0.025
Dimethylpentane, 2,4-	19	0	0.039	0.007
Dodecane, *n*-	18	1	0.038	0.034
Ethane	19	0	14.077	4.074
Ethylbenzene	19	0	0.076	0.024
Ethylene	19	0	0.985	0.202
Ethyltoluene, *m*-	18	1	0.033	0.008
Ethyltoluene, *o*-	15	4	0.019	0.012
Ethyltoluene, *p*-	17	2	0.025	0.013
Formaldehyde	20	0	0.723	0.096
Heptane, *n*-	19	0	0.090	0.021
Hexaldehyde	20	0	0.020	0.002
Hexane, *n*-	19	0	0.200	0.056

Table 2.5-9. Site S-5 Pollutant Study Averages (Continued)

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Hexene, 1-	19	0	0.046	0.008
Isobutane	19	0	1.063	0.598
Isobutene/1-Butene	19	0	0.171	0.036
Isopentane	19	0	1.297	1.262
Isoprene	19	0	0.092	0.023
Isopropylbenzene	18	1	0.016	0.003
Methyl Ethyl Ketone	19	0	0.775	0.307
Methylcyclohexane	19	0	0.105	0.024
Methylcyclopentane	19	0	0.106	0.034
Methylheptane, 2-	19	0	0.045	0.006
Methylheptane, 3-	19	0	0.030	0.004
Methylhexane, 2-	19	0	0.094	0.020
Methylhexane, 3-	19	0	0.207	0.066
Methylpentane, 2-	16	3	0.316	0.107
Methylpentane, 3-	19	0	0.160	0.040
Nonane, *n-*	19	0	0.031	0.004
Octane, *n-*	19	0	0.063	0.011
Pentane, *n-*	19	0	1.087	0.929
Pentene, 1-	19	0	0.046	0.009
Pentene, *cis*-2-	18	1	0.032	0.005
Pentene, *trans*-2-	18	1	0.041	0.012
Pinene, *alpha-*	15	4	0.039	0.021
Propane	19	0	5.049	1.773
Propionaldehyde	20	0	0.048	0.035
Propylbenzene, *n-*	16	3	0.019	0.007
Propylene	19	0	0.368	0.084
Styrene	18	1	0.042	0.015
Toluene	18	1	0.446	0.166
Trichlorofluoromethane	19	0	0.255	0.020
Trichlorotrifluoroethane	19	0	0.087	0.007
Trimethylbenzene, 1,2,4-	19	0	0.057	0.017
Trimethylbenzene, 1,3,5-	18	1	0.026	0.007
Trimethylpentane, 2,2,3-	15	4	0.021	0.008
Trimethylpentane, 2,2,4-	19	0	0.103	0.031
Trimethylpentane, 2,3,4-	19	0	0.039	0.010
Undecane, *n-*	19	0	0.064	0.073
Valeraldehyde	17	3	0.008	0.002

Table 2.5-9. Site S-5 Pollutant Study Averages (Continued)

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Xylene, *m,p*-	19	0	0.198	0.060
Xylene, *o*-	19	0	0.071	0.020

Table 2.5-10. Site S-6 Pollutant Study Averages

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Benzene	15	4	0.097	0.036
Butane, *n*-	19	0	1.015	0.432
Carbon Tetrachloride	18	1	0.097	0.013
Chloromethane	19	0	0.510	0.061
Dichlorodifluoromethane	19	0	0.511	0.017
Ethane	19	0	21.412	9.997
Ethylene	18	1	0.632	0.155
Isobutane	17	2	0.418	0.180
Methane	17	0	5758.824	795.537
Methanol	10	0	6.545	1.681
Methyl Ethyl Ketone	18	1	0.427	0.121
Pentane, *n*-	18	1	0.399	0.146
Propane	19	0	2.982	1.154
Propylene	18	1	0.210	0.074
Toluene	19	0	0.305	0.083
Trichlorofluoromethane	19	0	0.257	0.008

Table 2.5-11. Site S-7 Pollutant Study Averages

Pollutant Name	Number of Detects	Number of Non-detects	Study Average (ppbv)	Confidence Interval (ppbv)
Benzene	14	4	0.109	0.043
Butane, *n*-	18	0	1.230	0.604
Carbon Tetrachloride	16	2	0.098	0.019
Chloromethane	18	0	0.523	0.071
Dichlorodifluoromethane	18	0	0.520	0.017
Ethane	18	0	23.979	11.236
Ethylene	18	0	0.690	0.173
Isobutane	16	2	0.481	0.246
Methane	17	0	5672.353	650.290
Methanol	18	0	6.740	1.403
Methyl Ethyl Ketone	18	0	0.512	0.183
Pentane, *n*-	17	1	0.468	0.217
Propane	18	0	3.967	1.854
Propylene	17	1	0.234	0.107
Toluene	18	0	0.314	0.128
Trichlorofluoromethane	18	0	0.259	0.007

2.5.3 Key Pollutants

At the conclusion of the ambient air monitoring data collection, ERG conducted an initial public health screening to determine whether selected pollutants were found at levels indicating an urgent health hazard. This screening was conducted using the same health screening values that EPA uses in its NATA (see Appendix 2-G), which are available for 40 pollutants in this study. In Section 5 of this report, ERG presents a broader health evaluation that considers health screening values for all 138 pollutants considered in the monitoring program, as well as the results of the air dispersion modeling effort discussed in Section 4.

Key Point: Key Pollutants
The key pollutants, based on the ambient monitoring data, were:
- Acetaldehyde
- Benzene
- 1,3-Butadiene
- Carbon tetrachloride
- *p*-Dichlorobenzene
- Formaldehyde
- Tetrachloroethylene

In reviewing this initial screening of key pollutants, note that:

- With one exception, ERG found no pollutant concentrations that exceeded any published short-term health benchmark published by the Texas Commission on Environmental Quality (TCEQ), EPA, or the Agency for Toxic Substances and Disease Registry (ATSDR). A single sample was found to have a hexachloro-1,3-butadiene concentration of 0.369 ppb, which is higher than TCEQ's short-term effects screening level (0.2 ppb). However, this particular sample was not analyzed within the method's required holding time, and the testing laboratory cautioned that the measurement is of limited reliability. Further discussion of this pollutant is found in Section 5.2.
- It is only appropriate to compare annual average concentrations, not individual measurements, to long-term health benchmark values such as the EPA NATA values.
- The study period was only for two months at eight sites; the study period averages at these eight sites are assumed to be an estimate of typical annual conditions. This approach is similar to EPA's SATMP study.
- The initial screening presented in this report only addresses 40 pollutants. The health evaluation in Section 5 presents interpretations for all pollutants considered in this monitoring program.

Tables 2.5-12 through 2.5-19 present average concentration summaries of the key pollutants of interest for each site. Key pollutants are ones whose average concentrations were greater than the Lowest Comparison Levels (LCLs) used in this study. Thus, these tables present a "factor of LCL" for each pollutant, and pollutants with a "factor of LCL" greater than 1 are identified as key. Additionally, Figures 2.5-1 through 2.5-7 present each key pollutant's study average confidence interval, which is useful in identifying statistically significant differences.

The following observations were made:

- Benzene and carbon tetrachloride were key HAPs at each site.
- The average acetaldehyde concentration at Site S-4 was considerably higher than the average acetaldehyde concentration at Site S-5 (Figure 2.5-1).
- The average benzene concentration at Site S-4 was considerably higher than all other average benzene concentrations at the other sites. The average benzene concentrations at Sites S-6 and S-7 were also considerably lower than those for Sites S-1, S-2, S-3A, and S-5 (Figure 2.5-2).
- The average 1,3-butadiene concentrations at Sites S-2 and S-4 were considerably higher than the average 1,3-butadiene concentration at Site S-5 (Figure 2.5-3).
- The average carbon tetrachloride concentration at Site S-1 was only considerably higher than the average carbon tetrachloride concentration at Site S-6 (Figure 2.5-4).
- There were no statistically significant differences in average *p*-dichlorobenzene concentrations across Sites S-1, S-2, S-3A, and S-4 (Figure 2.5-5).
- There were no statistically significant differences in average formaldehyde concentrations across Sites S-4 and S-5 (Figure 2.5-6).
- There were no statistically significant differences in average tetrachloroethylene concentrations across Sites S-1, S-2, S-3A, and S-4 (Figure 2.5-7).

2.5.4 Integration with Meteorology

Meteorological observations, such as wind speed and wind direction, can be useful in helping characterize the behavior of the ambient air monitoring data. For this study, no meteorological towers were placed at the monitoring locations, largely because more than 40 National Weather Service (NWS) and TCEQ meteorological stations in and around the city of Fort Worth operated during this monitoring program. Additionally, another dozen meteorological stations from the Weatherbug Network were available to be used.

Closest Meteorological Station

For each monitoring site, ERG identified the closest meteorological station that was operating during the monitoring timeframe. Table 2.5-20 identifies those stations. If observations were missing, or if a significant portion of a day's observations were identified as "calm" (less than 5 miles per hour), surrogate data was used to supplement the meteorological observations. Surrogate data sources include the NWS 1-minute data, TCEQ meteorological stations, and the Weatherbug Network. Table 2.5-20 also presents the surrogate data locations relative to the monitoring sites. All meteorological observations of wind speed, wind direction, temperature, and precipitation are presented in Appendix 2-H.

Table 2.5-12. Site S-1 Key Pollutant Averages

Pollutant	Units	Mean of Measurements	95% Confidence Interval on the Mean	Factor of EPA LCL[a]
Benzene	ppbv	0.245[b]	0.187–0.304	6.11
1,3-Butadiene	ppbv	0.041[c]	0.022–0.059	2.69
Carbon Tetrachloride	ppbv	0.118[d]	0.112–0.123	4.38
p-Dichlorobenzene	ppbv	0.039[e]	0.025–0.053	2.58
Tetrachloroethylene	ppbv	0.038[f]	0.024–0.052	1.52

[a] LCL refers to the Lowest Comparison Level of cancer and/or noncancer values, as used in EPA's NATA. LCLs for this study are presented in Appendix 2-G. "Factor of EPA LCL" is the pollutant study average (or mean of measurements) divided by its LCL.

[b] The mean of measurements for benzene is the average of all sample results, which include 20 detections that ranged from 0.135 to 0.563 ppbv.

[c] The mean of measurements for 1,3-butadiene is the average of all sample results, which include 18 detections that ranged from 0.01 to 0.137 ppbv, as well as two samples in which no chemical was registered by the laboratory analytical equipment.

[d] The mean of measurements for carbon tetrachloride is the average of all sample results, which include 20 detections that ranged from 0.083 to 0.139 ppbv.

[e] The mean of measurements for *p*-dichlorobenzene is the average of all sample results, which include 17 detections that ranged from 0.013 to 0.118 ppbv, as well as three samples in which no chemical was registered by the laboratory analytical equipment.

[f] The mean of measurements for tetrachloroethylene is the average of all sample results, which include 17 detections that ranged from 0.015 to 0.109 ppbv, as well as three samples in which no chemical was registered by the laboratory analytical equipment.

Table 2.5-13. Site S-2 Key Pollutant Averages

Pollutant	Units	Mean of Measurements	95% Confidence Interval on the Mean	Factor of EPA LCL[a]
Benzene	ppbv	0.300[b]	0.257–0.343	7.48
1,3-Butadiene	ppbv	0.057[c]	0.040–0.073	3.75
Carbon Tetrachloride	ppbv	0.117[d]	0.112–0.122	4.36
p-Dichlorobenzene	ppbv	0.051[f]	0.004–0.098	3.38
Tetrachloroethylene	ppbv	0.061[g]	0.032–0.090	2.44

[a] LCL refers to the Lowest Comparison Level of cancer and/or noncancer values, as used in EPA's NATA. LCLs for this study are presented in Appendix 2-G. "Factor of EPA LCL" is the pollutant study average (or mean of measurements) divided by its LCL.

[b] The mean of measurements for benzene is the average of all sample results, which include 18 detections that ranged from 0.180 to 0.501 ppbv.

[c] The mean of measurements for 1,3-butadiene is the average of all sample results, which include 18 detections that ranged from 0.024 to 0.147 ppbv.

[d] The mean of measurements for carbon tetrachloride is the average of all sample results, which include 18 detections that ranged from 0.090 to 0.133 ppbv.

[e] The mean of measurements for *p*-dichlorobenzene is the average of all sample results, which include 15 detections that ranged from 0.014 to 0.416 ppbv, as well as three samples in which no chemical was registered by the laboratory analytical equipment.

[f] The mean of measurements for tetrachloroethylene is the average of all sample results, which include 18 detections that ranged from 0.012 to 0.218 ppbv.

Table 2.5-14. Site S-3A Key Pollutant Averages

Pollutant	Units	Mean of Measurements	95% Confidence Interval on the Mean	Factor of EPA LCL[a]
Benzene	ppbv	0.301[b]	0.173–0.428	7.50
1,3-Butadiene	ppbv	0.049[c]	0.016–0.082	3.23
Carbon Tetrachloride	ppbv	0.118[d]	0.111–0.125	4.38
p-Dichlorobenzene	ppbv	0.030[e]	0.017–0.043	2.01
Tetrachloroethylene	ppbv	0.025[f]	0.011–0.039	1.00

[a] LCL refers to the Lowest Comparison Level of cancer and/or noncancer values, as used in EPA's NATA. LCLs for this study are presented in Appendix 2-G. "Factor of EPA LCL" is the pollutant study average (or mean of measurements) divided by its LCL.

[b] The mean of measurements for benzene is the average of all sample results, which include nine detections that ranged from 0.157 to 0.636 ppbv.

[c] The mean of measurements for 1,3-butadiene is the average of all sample results, which include eight detections that ranged from 0.023 to 0.123 ppbv, as well as one sample in which no chemical was registered by the laboratory analytical equipment.

[d] The mean of measurements for carbon tetrachloride is the average of all sample results, which include nine detections that ranged from 0.104 to 0.134 ppbv.

[e] The mean of measurements for *p*-dichlorobenzene is the average of all sample results, which include nine detections that ranged from 0.011 to 0.056 ppbv.

[f] The mean of measurements for tetrachloroethylene is the average of all sample results, which include seven detections that ranged from 0.013 to 0.056 ppbv, as well as two samples in which no chemical was registered by the laboratory analytical equipment.

Table 2.5-15. Site S-3B Key Pollutant Averages

Pollutant	Units	Mean of Measurements	95% Confidence Interval on the Mean	Factor of EPA LCL[a]
Benzene	ppbv	0.165[b]	0.137–0.193	4.11
Carbon Tetrachloride	ppbv	0.115[c]	0.107–0.122	4.26

[a] LCL refers to the Lowest Comparison Level of cancer and/or noncancer values, as used in EPA's NATA. LCLs for this study are presented in Appendix 2-G. "Factor of EPA LCL" is the pollutant study average (or mean of measurements) divided by its LCL.

[b] The mean of measurements for benzene is the average of all sample results, which include six detections that ranged from 0.132 to 0.214 ppbv.

[c] The mean of measurements for carbon tetrachloride is the average of all sample results, which include six detections that ranged from 0.103 to 0.122 ppbv.

Table 2.5-16. Site S-4 Key Pollutant Averages

Pollutant	Units	Mean of Measurements	95% Confidence Interval on the Mean	Factor of EPA LCL[a]
Acetaldehyde	ppbv	3.802[b]	2.677–4.927	15.07
Benzene	ppbv	0.686[c]	0.465–0.906	17.08
1,3-Butadiene	ppbv	0.092[d]	0.051–0.132	6.08
Carbon Tetrachloride	ppbv	0.113[e]	0.107–0.118	4.19
p-Dichlorobenzene	ppbv	0.060[f]	0.038–0.083	3.99
Formaldehyde	ppbv	1.140[g]	0.731–1.548	17.50
Tetrachloroethylene	ppbv	0.048[h]	0.034–0.061	1.90

[a] LCL refers to the Lowest Comparison Level of cancer and/or noncancer values, as used in EPA's NATA. LCLs for this study are presented in Appendix 2-G. "Factor of EPA LCL" is the pollutant study average (or mean of measurements) divided by its LCL.

[b] The mean of measurements for acetaldehyde is the average of all sample results, which include 20 detections that ranged from 1.35 to 9.06 ppbv.

[c] The mean of measurements for benzene is the average of all sample results, which include 20 detections that ranged from 0.200 to 1.83 ppbv.

[d] The mean of measurements for 1,3-butadiene is the average of all sample results, which include 18 detections that ranged from 0.015 to 0.304 ppbv.

[e] The mean of measurements for carbon tetrachloride is the average of all sample results, which include 20 detections that ranged from 0.094 to 0.142 ppbv.

[f] The mean of measurements for *p*-dichlorobenzene is the average of all sample results, which include 19 detections that ranged from 0.019 to 0.178 ppbv, as well as one sample in which no chemical was registered by the laboratory analytical equipment.

[g] The mean of measurements for formaldehyde is the average of all sample results, which include 20 detections that ranged from 0.412 to 4.45 ppbv.

[h] The mean of measurements for tetrachloroethylene is the average of all sample results, which include 20 detections that ranged from 0.015 to 0.116 ppbv.

Table 2.5-17. Site S-5 Key Pollutant Averages

Pollutant	Units	Mean of Measurements	95% Confidence Interval on the Mean	Factor of EPA LCL[a]
Acetaldehyde	ppbv	1.824[b]	1.416–2.231	7.23
Benzene	ppbv	0.197[c]	0.162–0.232	4.90
1,3-Butadiene	ppbv	0.018[d]	0.011–0.025	1.20
Carbon Tetrachloride	ppbv	0.108[e]	0.097–0.119	4.03
Formaldehyde	ppbv	0.723[f]	0.626–0.819	11.09

[a] LCL refers to the Lowest Comparison Level of cancer and/or noncancer values, as used in EPA's NATA. LCLs for this study are presented in Appendix 2-G. "Factor of LCL" is the pollutant study average (or mean of measurements) divided by its LCL.

[b] The mean of measurements for acetaldehyde is the average of all sample results, which include 20 detections that ranged from 0.831 to 4.93 ppbv.

[c] The mean of measurements for benzene is the average of all sample results, which include 19 detections that ranged from 0.104 to 0.359 ppbv.

[d] The mean of measurements for 1,3-butadiene is the average of all sample results, which include 15 detections that ranged from 0.011 to 0.051 ppbv, as well as four samples in which no chemical was registered by the laboratory analytical equipment.

[e] The mean of measurements for carbon tetrachloride is the average of all sample results, which include 19 detections that ranged from 0.053 to 0.140 ppbv.

[f] The mean of measurements for formaldehyde is the average of all sample results, which include 20 detections that ranged from 0.474 to 1.32 ppbv.

Table 2.5-18. Site S-6 Key Pollutant Averages

Pollutant	Units	Mean of Measurements	95% Confidence Interval on the Mean	Factor of EPA LCL[a]
Benzene	ppbv	0.097[b]	0.061–0.134	2.42
Carbon Tetrachloride	ppbv	0.097[c]	0.083–0.110	3.59

[a] LCL refers to the Lowest Comparison Level of cancer and/or noncancer values, as used in EPA's NATA. LCLs for this study are presented in Appendix 2-G. "Factor of EPA LCL" is the pollutant study average (or mean of measurements) divided by its LCL.

[b] The mean of measurements for benzene is the average of all sample results, which include 15 detections that ranged from 0.070 to 0.263 ppbv, as well as four samples in which no chemical was registered by the laboratory analytical equipment.

[c] The mean of measurements for carbon tetrachloride is the average of all sample results, which include 18 detections that ranged from 0.071 to 0.127 ppbv, as well as one sample in which no chemical was registered by the laboratory analytical equipment.

Table 2.5-19. Site S-7 Key Pollutant Averages

Pollutant	Units	Mean of Measurements	95% Confidence Interval on the Mean	Factor of EPA LCL[a]
Benzene	ppbv	0.109[b]	0.066–0.152	2.71
Carbon Tetrachloride	ppbv	0.098[c]	0.079–0.117	3.65

[a] LCL refers to the Lowest Comparison Level of cancer and/or noncancer values, as used in EPA's NATA. LCLs for this study are presented in Appendix 2-G. "Factor of EPA LCL" is the pollutant study average (or mean of measurements) divided by its LCL.

[b] The mean of measurements for benzene is the average of all sample results, which include 14 detections that ranged from 0.064 to 0.282 ppbv, as well as four samples in which no chemical was registered by the laboratory analytical equipment.

[c] The mean of measurements for carbon tetrachloride is the average of all sample results, which include 16 detections that ranged from 0.077 to 0.142 ppbv, as well as two samples in which no chemical was registered by the laboratory analytical equipment.

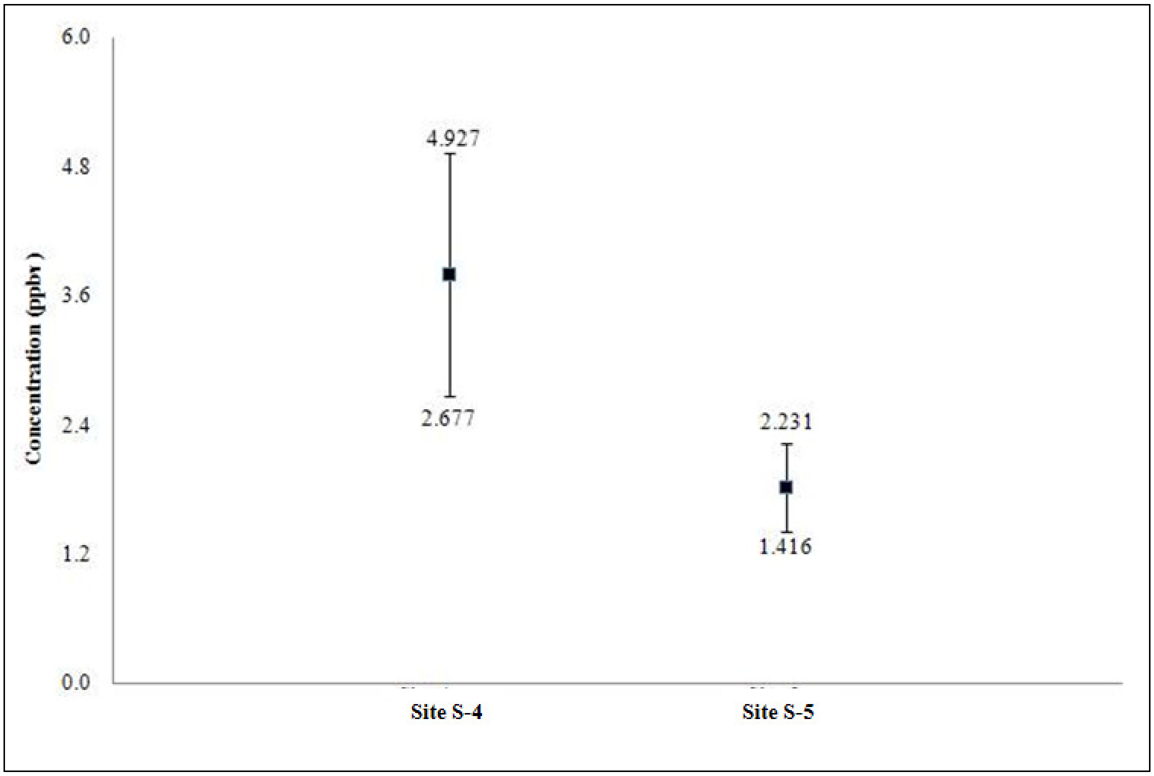


Figure 2.5-1. Acetaldehyde Average Concentrations by Site

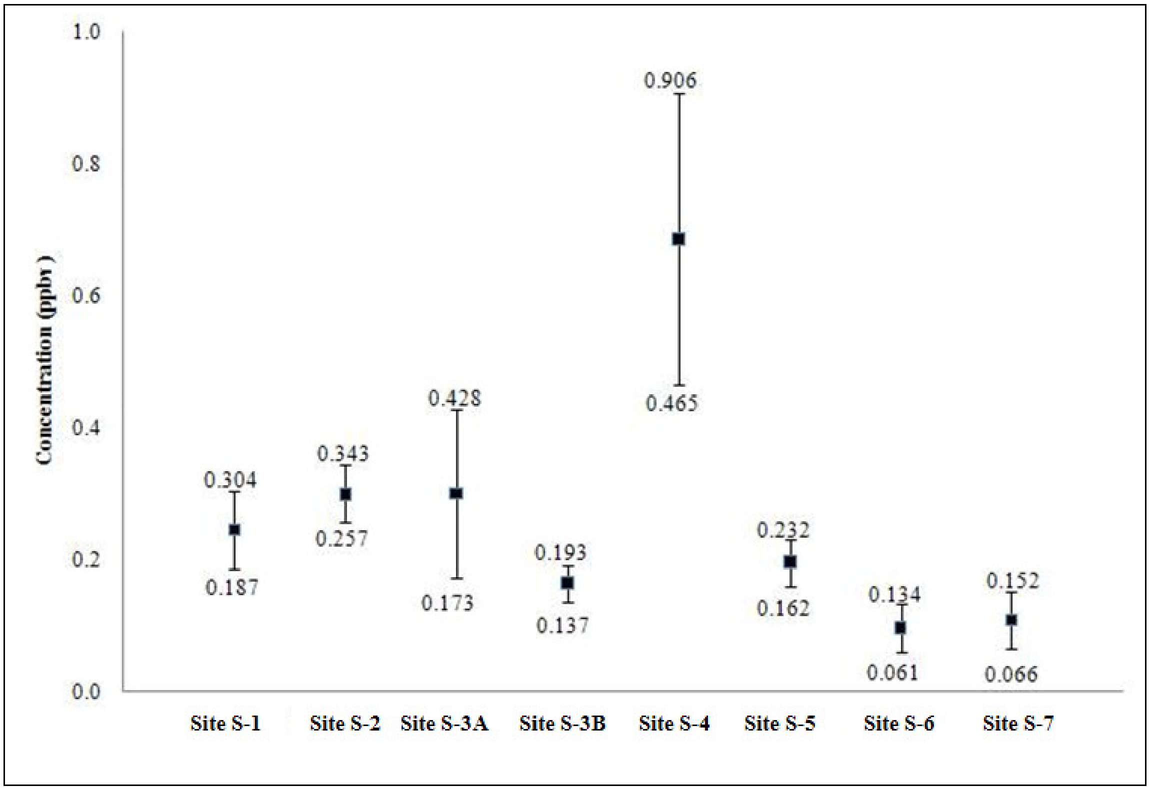


Figure 2.5-2. Benzene Average Concentrations by Site

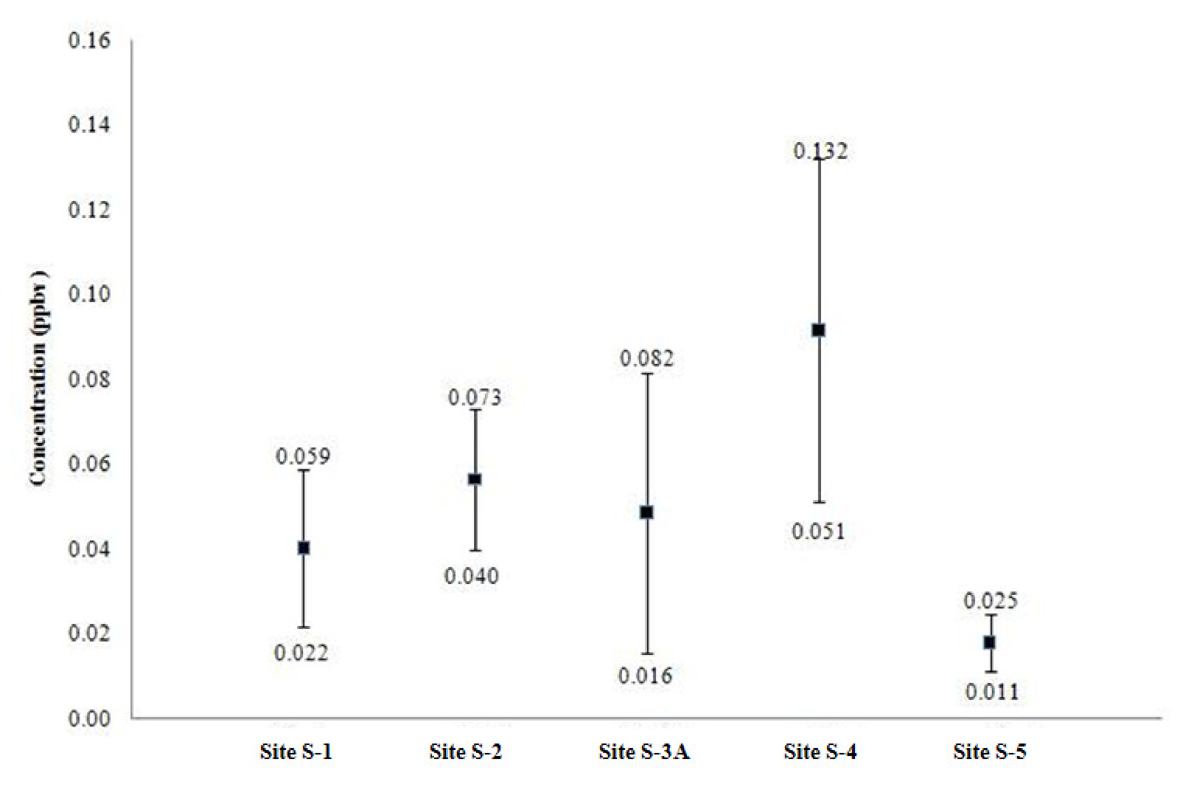


Figure 2.5-3. 1,3-Butadiene Average Concentrations by Site

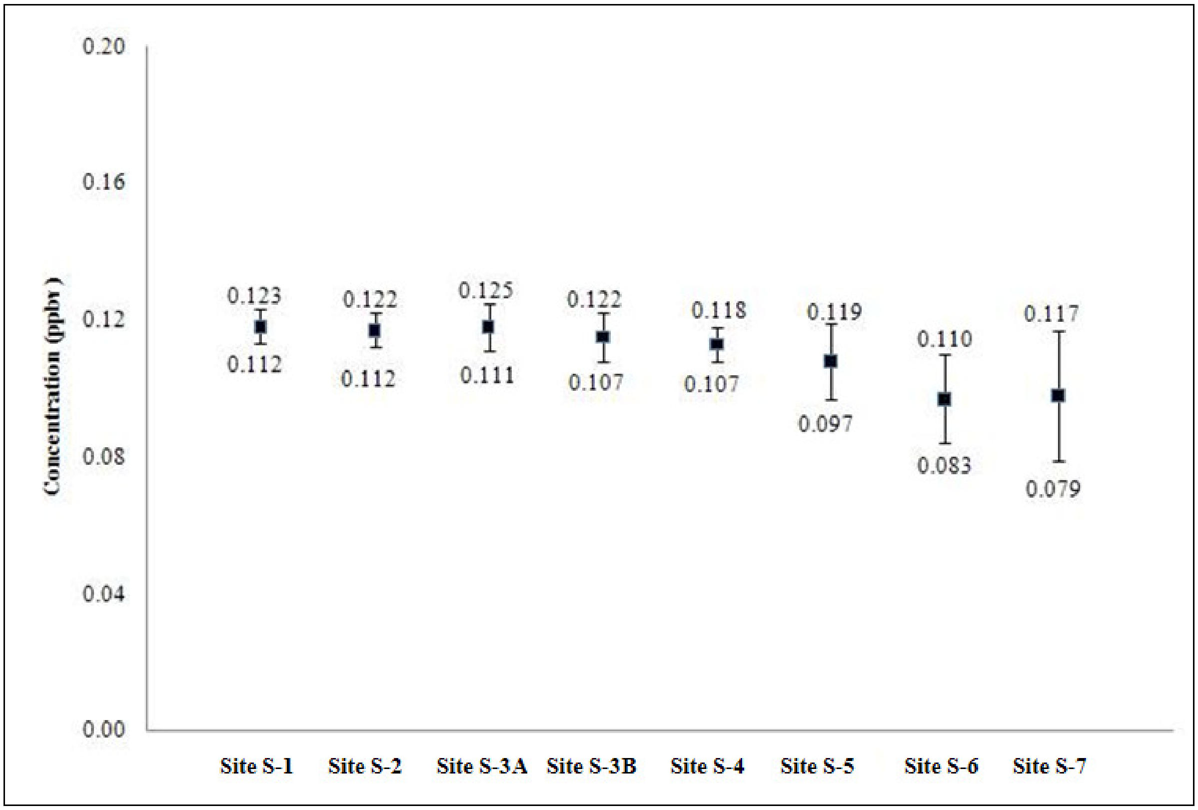


Figure 2.5-4. Carbon Tetrachloride Average Concentrations by Site

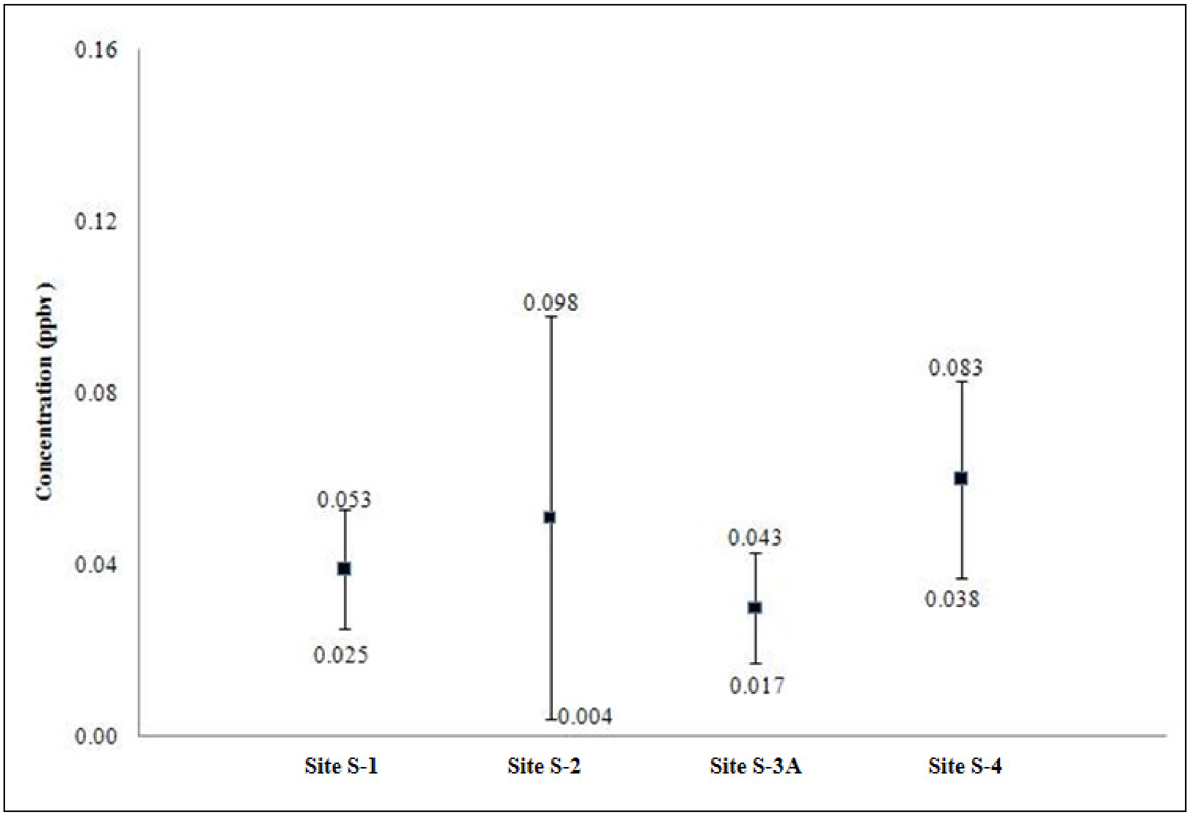


Figure 2.5-5. ***p*-Dichlorobenzene Average Concentrations by Site**

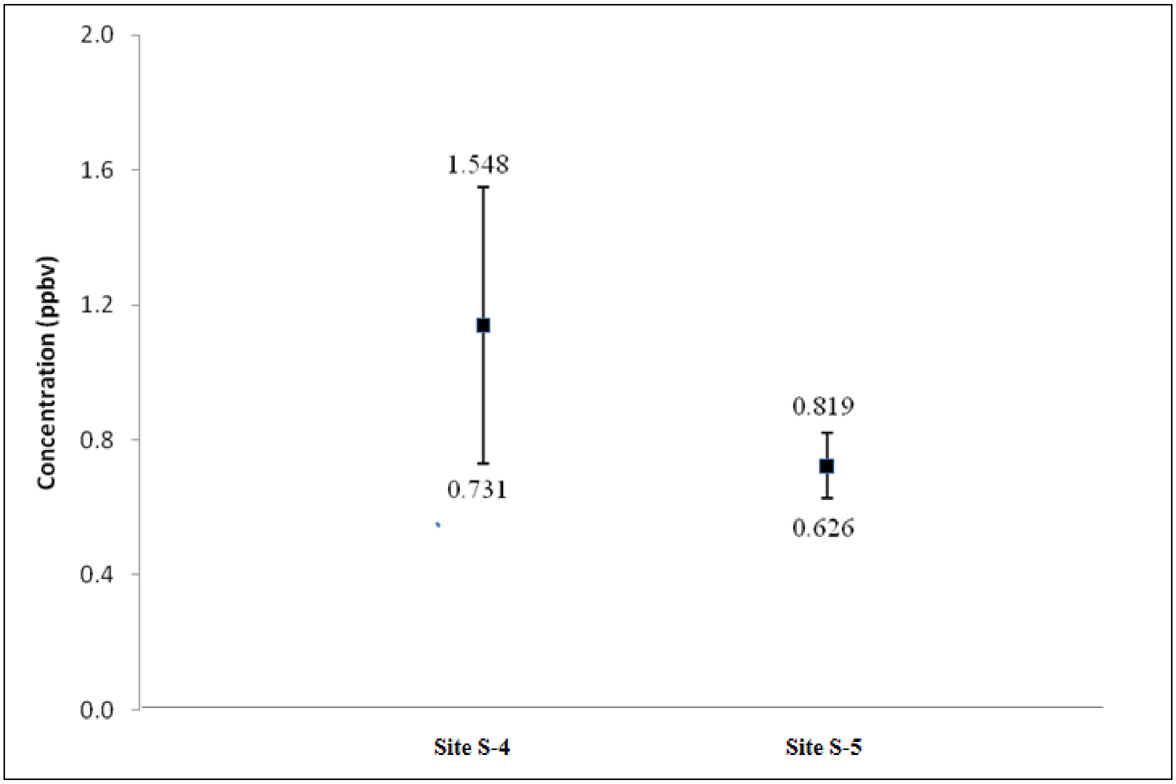


Figure 2.5-6. Formaldehyde Average Concentrations by Site

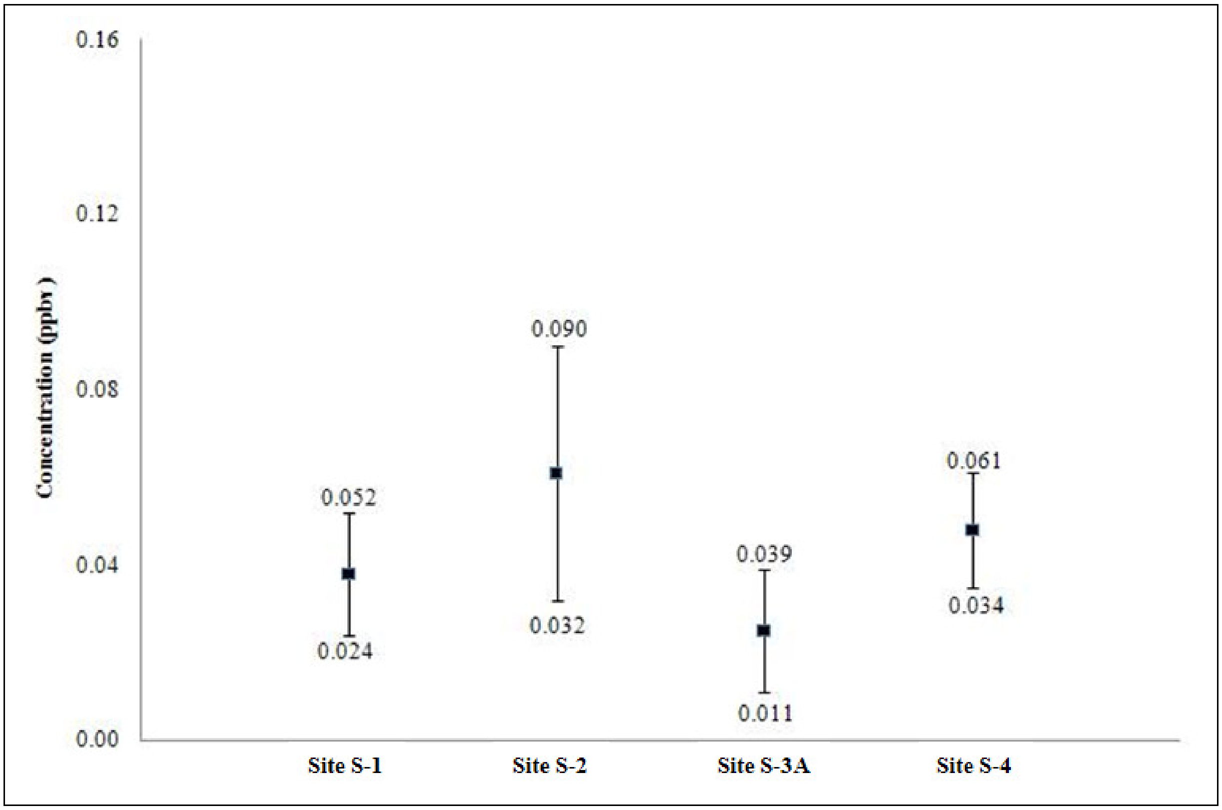


Figure 2.5-7. Tetrachloroethylene Average Concentrations by Site

Table 2.5-20. Meteorological Stations Used in This Study

Site	Closest Meteorological Station	Distance/ Orientation from Site	Type	Alternate Meteorological Station	Distance/ Orientation from Site	Type
S-1	Dallas–Ft. Worth International (03927)	5.29 miles/ north	National Weather Service	Oakwood Terrace Elementary School	2.75 miles/ west	Weatherbug
S-2	Nolan High School (NOLAN)	2.22 miles/ west	Weatherbug	Arlington Municipal Airport	10.30 miles/ southeast	National Weather Service
S-3A	Nolan High School (NOLAN)	0.50 miles/ southeast	Weatherbug	Arlington Municipal Airport	12.15 miles/ southeast	National Weather Service
S-3B	Ft. Worth Naval Air Station/Carswell Field (13911)	3.11 miles/ east	National Weather Service	Ft. Worth Northwest (48-439-1002)	8.23 miles/ east-northeast	TCEQ
S-4	Ft. Worth Meacham Airport (13961)	2.98 miles/ northwest	National Weather Service	Ft. Worth Northwest (48-439-1002)	2.21 miles/ northwest	TCEQ
S-5	Ft. Worth Alliance Airport (53909)	3.88 miles/ east	National Weather Service	Eagle Mountain Lake (48-439-0075)	5.40 miles/ west	TCEQ
S-6	Spinks Airport (03985)	0.69 miles/ north-northeast	National Weather Service	Wm. Stribling Elementary School	2.75 miles/ southeast	Weatherbug
S-7	Spinks Airport (03985)	0.40 miles/ southeast	National Weather Service	Wm. Stribling Elementary School	3.50 miles/ southeast	Weatherbug

Figure 2.5-8 presents an overview of the monitoring sites and their nearest meteorological stations.

Windrose Analysis

In this set of analyses, ERG compared wind patterns on sample days to patterns for the whole sampling period, as well as comparing the sampling period's wind patterns to historical wind patterns. The purpose of these analyses was to confirm that sampling occurred under typical conditions. Finally, the historical two-month patterns were compared to the long-term annual patterns that were generated at onset of this study.

Key Point: Windrose Analysis
Based on the windrose profiles associated with each monitoring site during the sampling period, the locations of the monitoring sites were accurately sited relative to wind direction.

Windroses were created for several time periods (historical, annual for 2009, sample days, and sample period) for each sampling site. The data for the windroses came from the NWS stations, EPA's Air Quality System (AQS), and the Fort Worth Weatherbug Network; the windroses were created using Lakes Environmental's WRPlot® View (version 6.5.1) software.

The following observations are made for each site:

- *Site S-1:* As presented in Table 2.5-20, the closest meteorological station is located at Dallas–Fort Worth International Airport, approximately 5 miles north of Site S-1. As shown in Figure 2.5-9, all five time-period windroses appear similar, with winds predominantly from the south-southeast and south.
- *Site S-2:* As presented in Table 2.5-20, the closest meteorological station is located at Nolan High School, which is approximately 2 miles west of Site S-2. For historical comparisons, ERG used the meteorological data from Arlington Municipal Airport, a station approximately 10 miles to the southeast. As shown in Figure 2.5-10, the sample day and sample period windroses at Nolan High School are from the south, south-southeast, and southeast, while the windroses at Arlington Municipal Airport are predominantly southerly.
- *Site S-3A:* Similar to Site S-2, the closest meteorological station is located at Nolan High School, which is approximately one-half mile southwest of Site S-3A. For historical comparisons, ERG used the meteorological data from Arlington Municipal Airport, a station approximately 12 miles to the southeast. As shown in Figure 2.5-11, the sample day and sample period windroses at Nolan High School are from the south, south-southeast, and southeast, while the windroses at Arlington Municipal Airport are predominantly southerly.
- *Site S-3B:* As presented in Table 2.5-20, the closest meteorological station is located at Fort Worth Naval Air Station/Carswell Field, approximately 3 miles east of Site S-3B. As shown in Figure 2.5-12, all five time-period windroses appear similar, with winds predominantly from the south-southeast and south.
- *Site S-4:* As presented in Table 2.5-20, the closest meteorological station is located at Fort Worth Meacham Airport, approximately 3 miles northeast of Site S-4. As shown

in Figure 2.5-13, all five time-period windroses appear similar, with winds predominantly from the south-southeast and south.

- *Site S-5:* As presented in Table 2.5-20, the closest meteorological station is located at Fort Worth Alliance Airport, approximately 4 miles east of Site S-5. As shown in Figure 2.5-14, all five time-period windroses appear similar, with winds predominantly from the south-southeast and south.
- *Site S-6:* As presented in Table 2.5-20, the closest meteorological station is located at Spinks Airport, less than 0.75 miles north-northeast of Site S-6. As shown in Figure 2.5-15, all five time-period windroses appear similar, with winds predominantly from the south-southeast and south.
- *Site S-7:* Similar to Site S-6, the closest meteorological station is located at Spinks Airport, less than half a mile southeast of Site S-7. As shown in Figure 2.5-16, all five time-period windroses appear similar, with winds predominantly from the south-southeast and south.

As described in the Ambient Air Monitoring Plan, the monitoring network was designed in part after understanding typical wind patterns in and around the City of Fort Worth through the use of historical windroses. Monitoring sites were placed to capture ambient air downwind of the target areas of interest. The general conclusion from the above windrose comparisons at each monitoring site during the study period is that wind patterns on sample days were generally typical of year-round and long-term historical wind patterns, indicating that the monitoring sites were able to collect samples from the target direction.

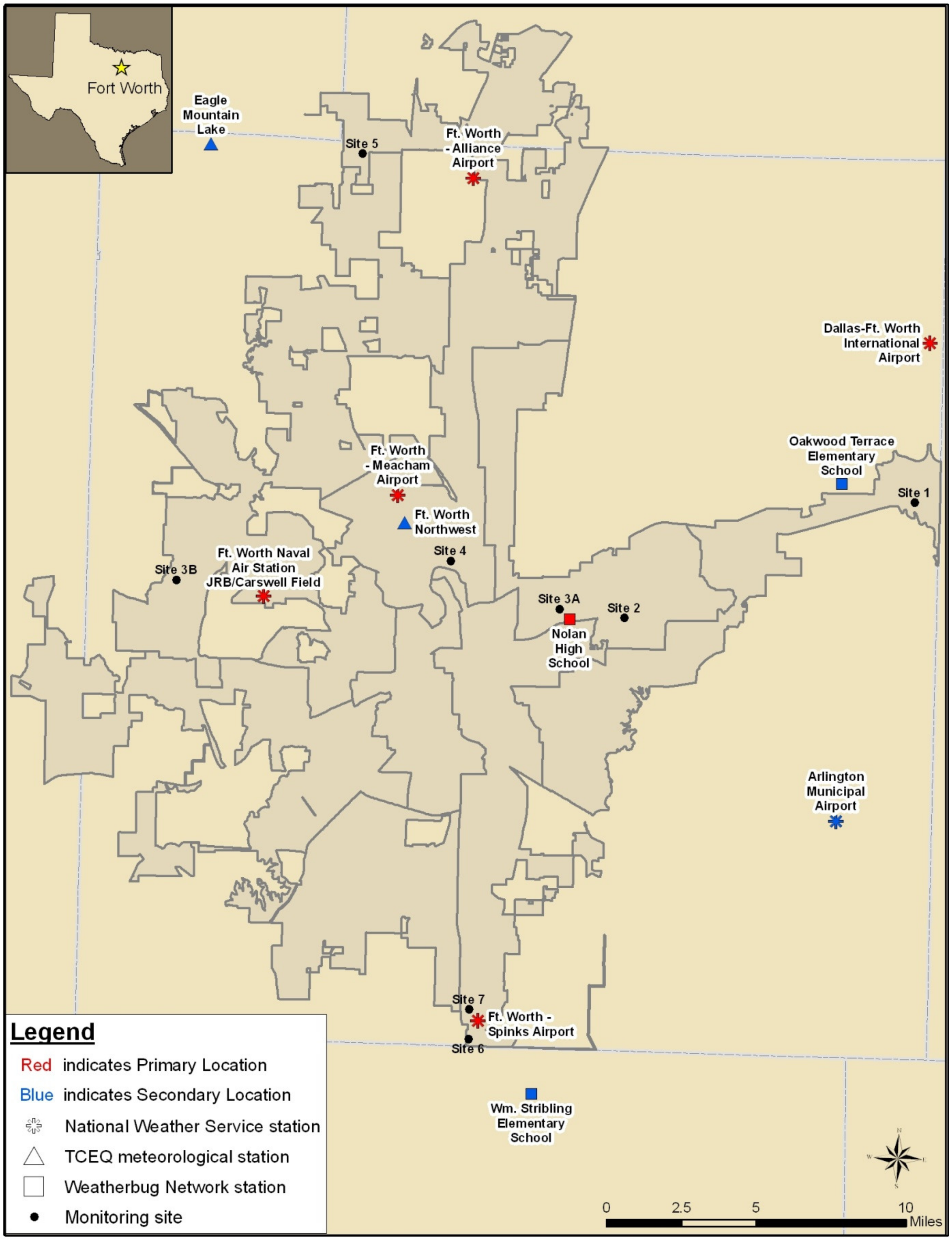
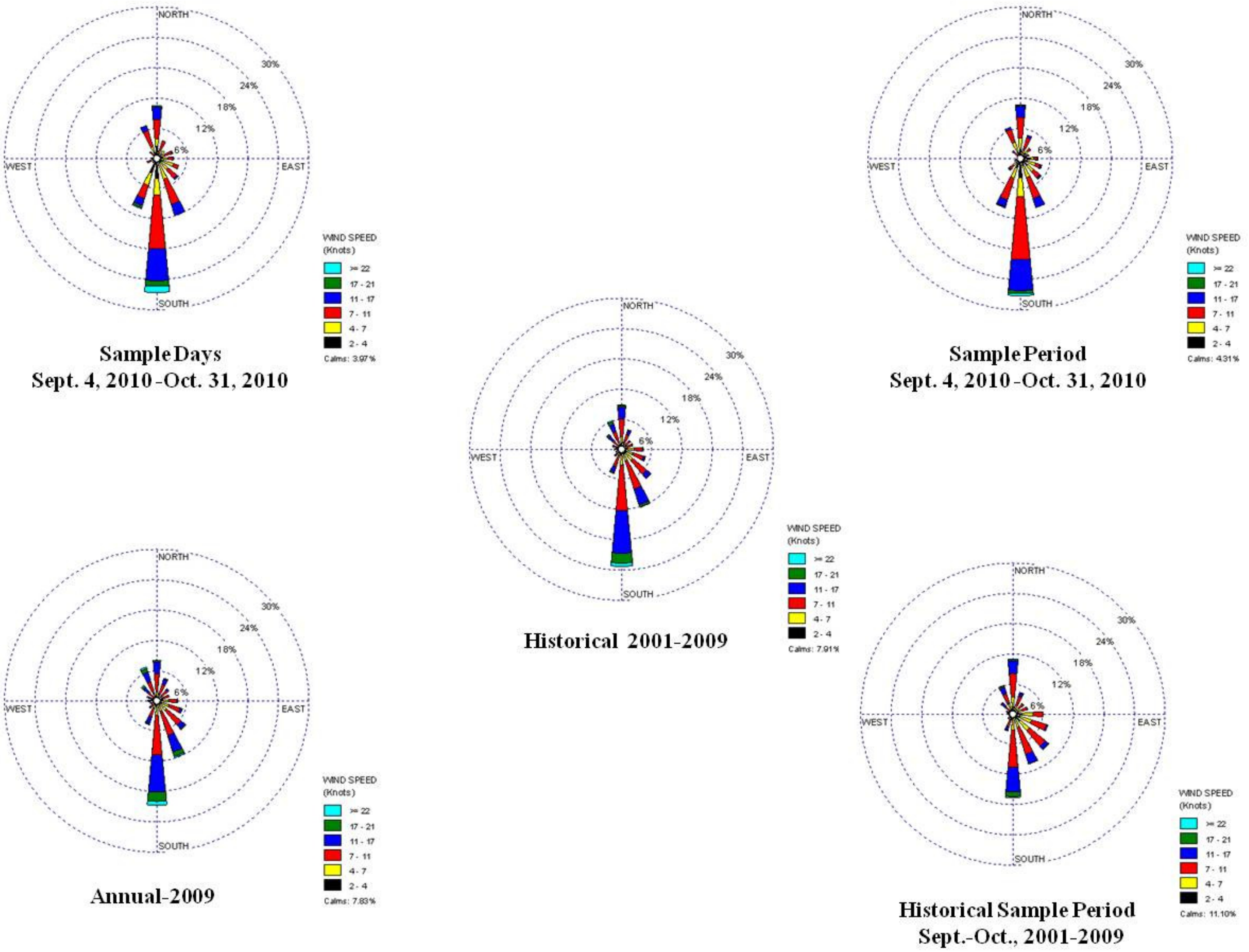


Figure 2.5-8. Meteorological Stations and Monitoring Site Locations

NWS WBAN 03927



Sample Days
Sept. 4, 2010 - Oct. 31, 2010

Sample Period
Sept. 4, 2010 - Oct. 31, 2010

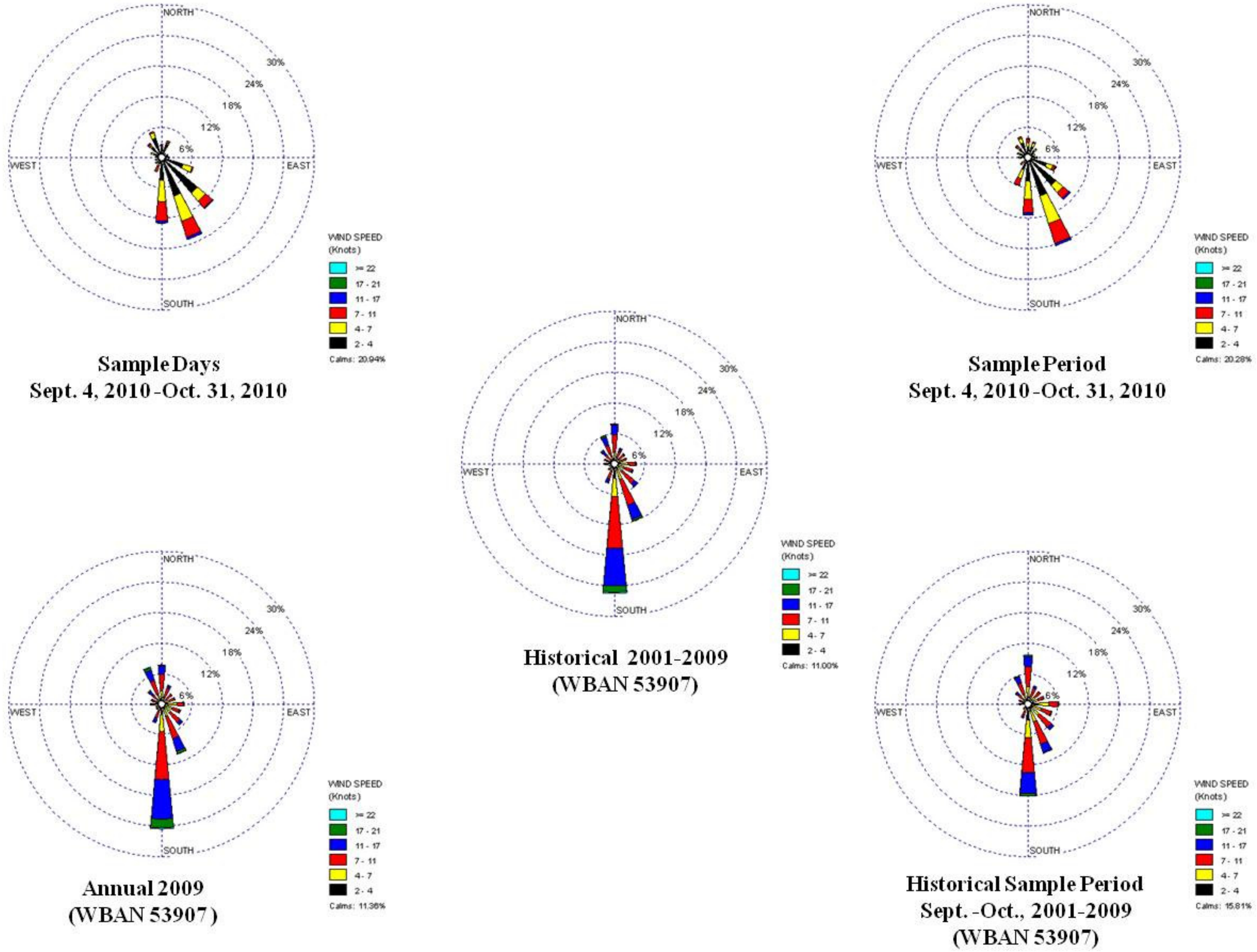
Historical 2001-2009

Annual-2009

Historical Sample Period
Sept.-Oct., 2001-2009

Figure 2.5-9. Site S-1 Windrose Comparisons

Nolan High School



Sample Days
Sept. 4, 2010 - Oct. 31, 2010

Sample Period
Sept. 4, 2010 - Oct. 31, 2010

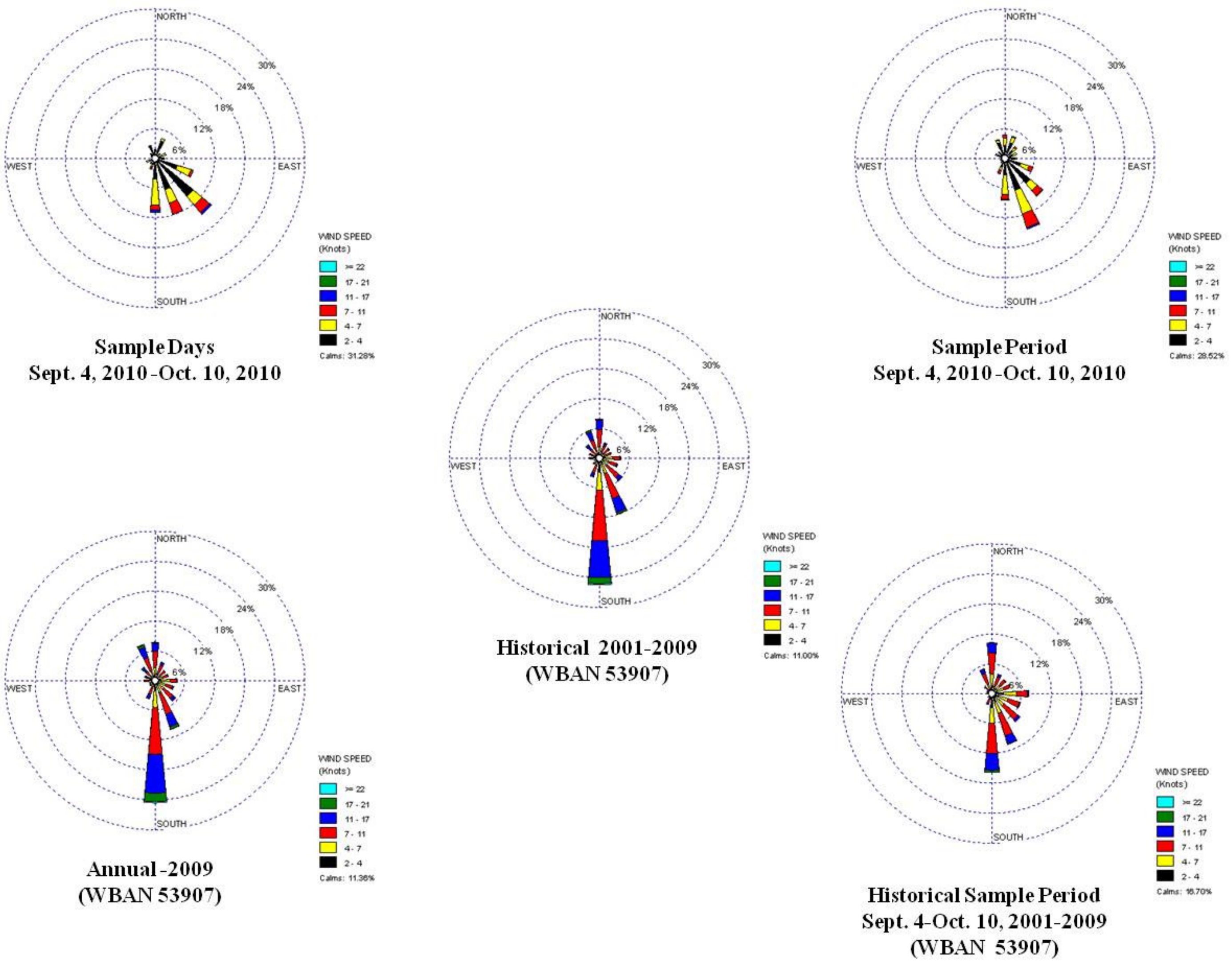
Historical 2001-2009
(WBAN 53907)

Annual 2009
(WBAN 53907)

Historical Sample Period
Sept. - Oct., 2001-2009
(WBAN 53907)

Figure 2.5-10. Site S-2 Windrose Comparisons

Nolan High School



Sample Days
Sept. 4, 2010 - Oct. 10, 2010

Sample Period
Sept. 4, 2010 - Oct. 10, 2010

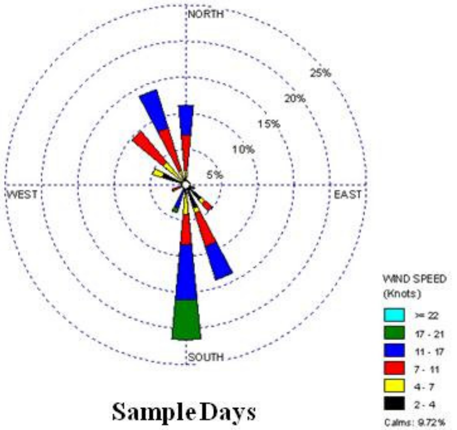
Historical 2001-2009
(WBAN 53907)

Annual - 2009
(WBAN 53907)

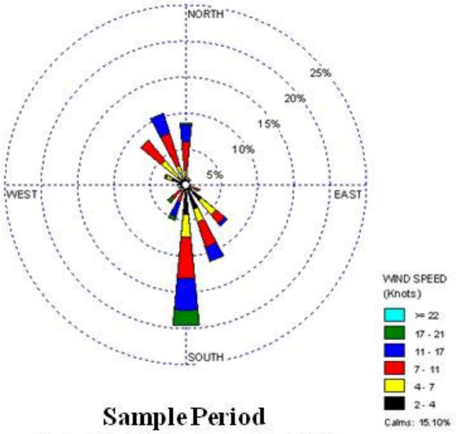
Historical Sample Period
Sept. 4-Oct. 10, 2001-2009
(WBAN 53907)

Figure 2.5-11. Site S-3A Windrose Comparisons

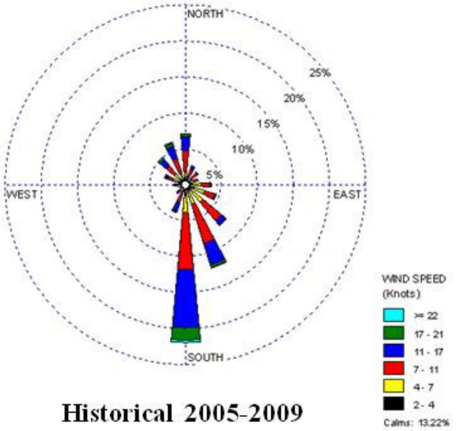
NWS WBAN 13911



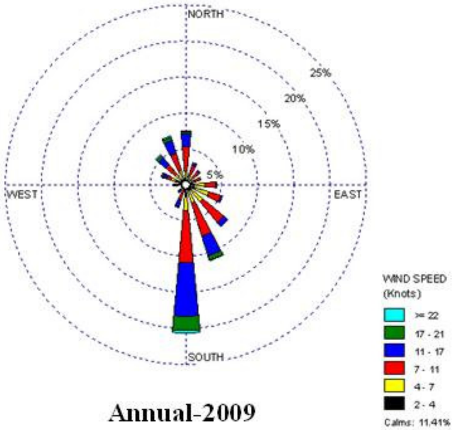
Sample Days
Oct. 13, 2010 - Oct. 31, 2010



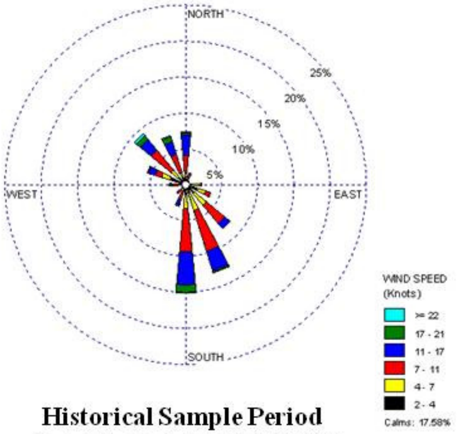
Sample Period
Oct. 13, 2010 - Oct. 31, 2010



Historical 2005-2009



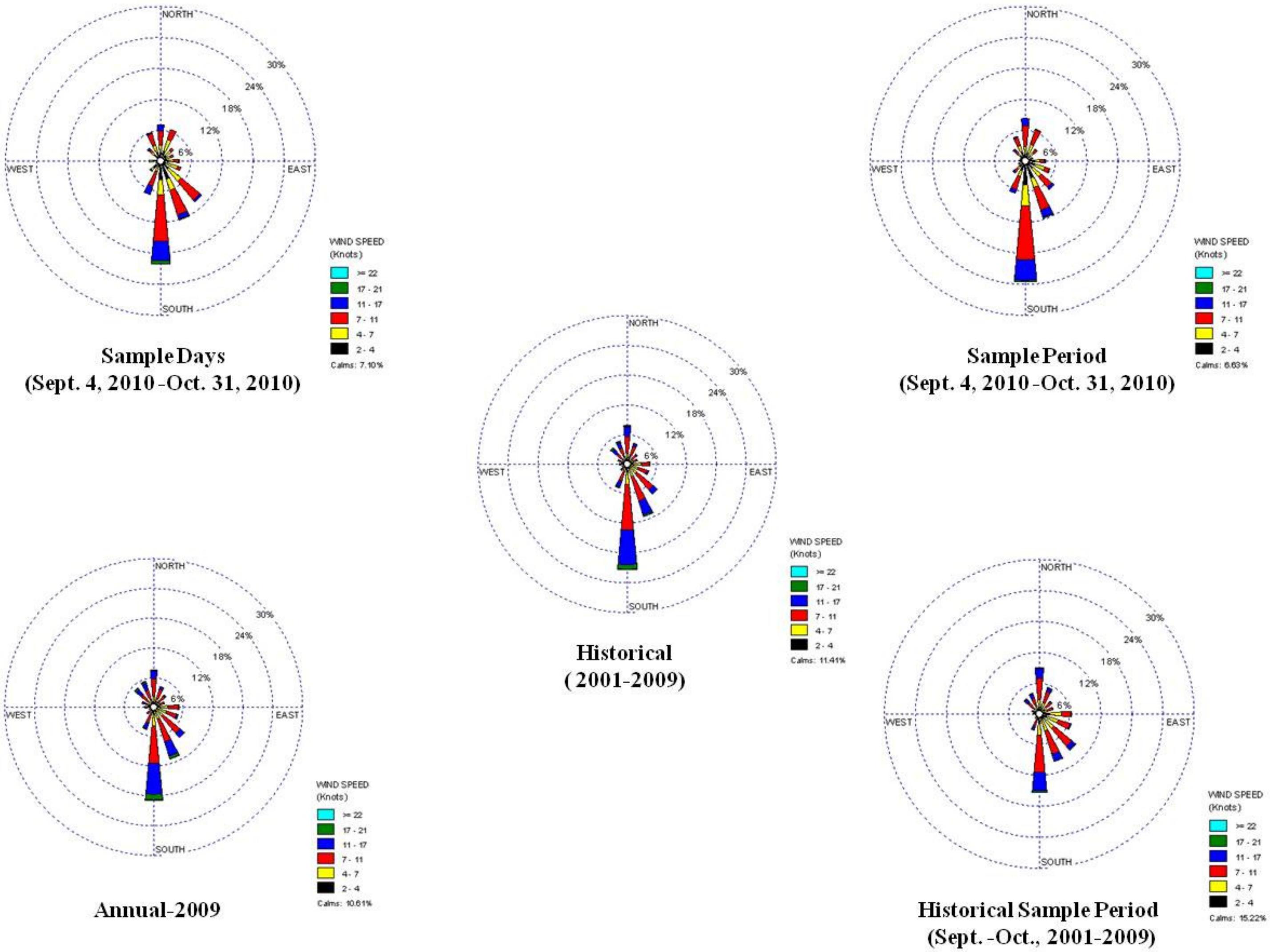
Annual-2009



Historical Sample Period
Oct. 13 - Oct. 31, 2005-2009

Figure 2.5-12. Site S-3B Windrose Comparisons

NWS WBAN 13961



Sample Days
(Sept. 4, 2010 -Oct. 31, 2010)

Sample Period
(Sept. 4, 2010 -Oct. 31, 2010)

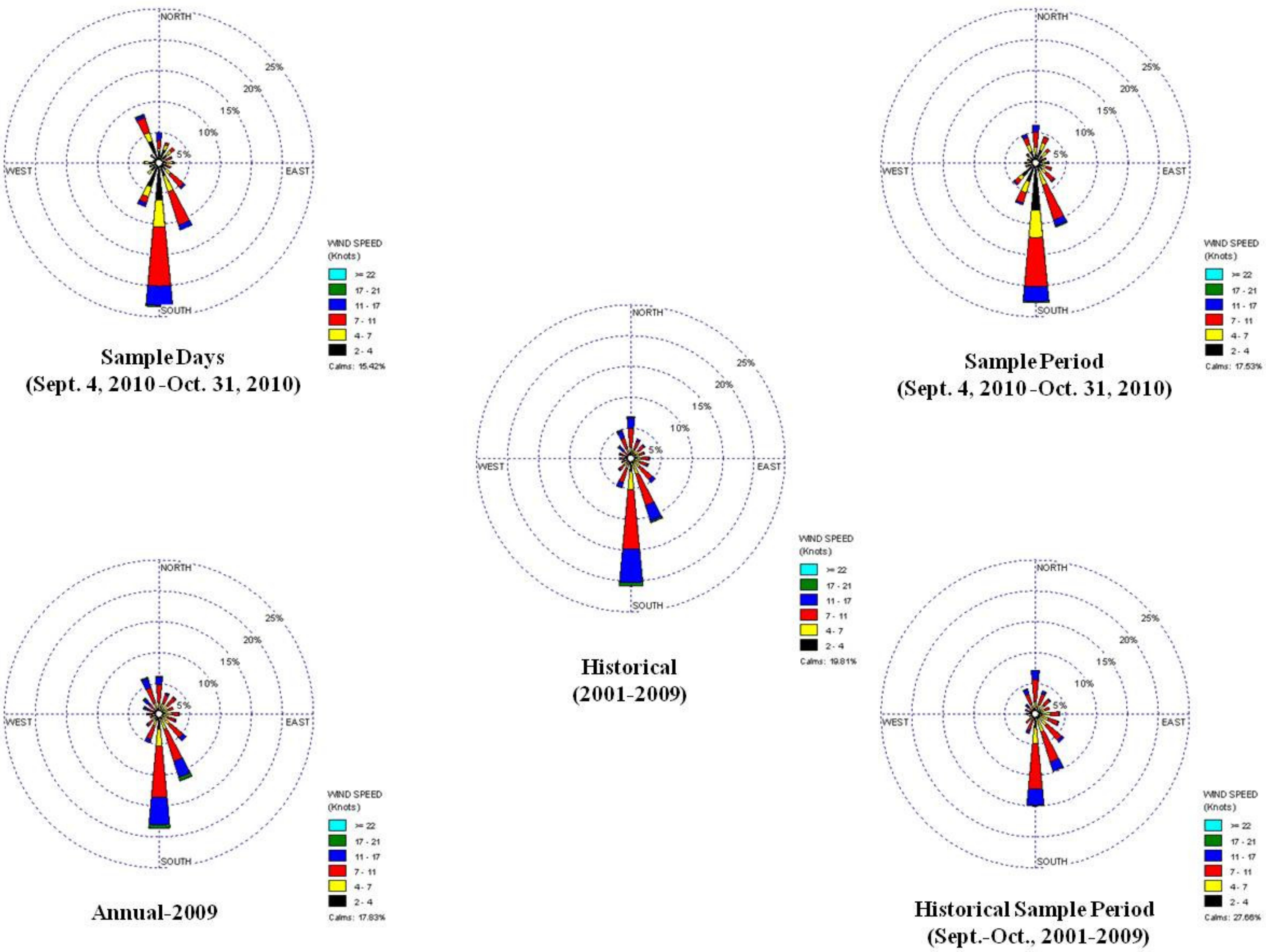
Historical
(2001-2009)

Annual-2009

Historical Sample Period
(Sept. -Oct., 2001-2009)

Figure 2.5-13. Site S-4 Windrose Comparisons

NWS WBAN 53909



Sample Days
(Sept. 4, 2010-Oct. 31, 2010)

Sample Period
(Sept. 4, 2010-Oct. 31, 2010)

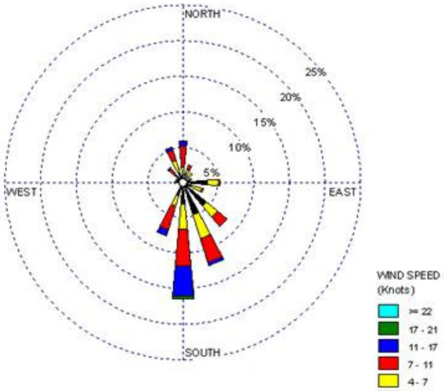
Historical
(2001-2009)

Annual-2009

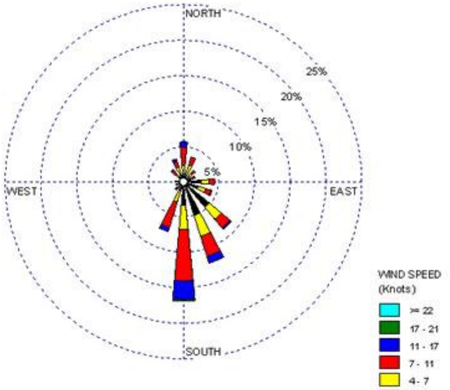
Historical Sample Period
(Sept.-Oct., 2001-2009)

Figure 2.5-14. Site S-5 Windrose Comparisons

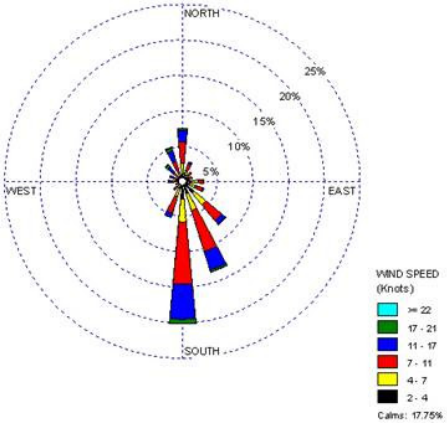
NWS WBAN 03985



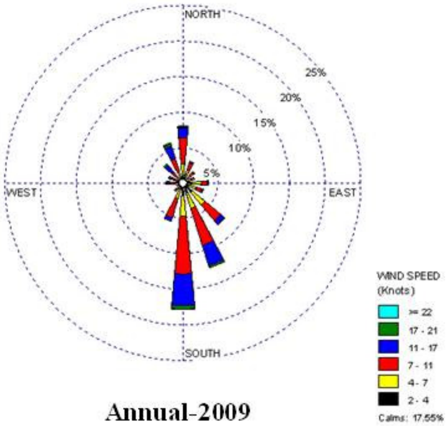
Sample Days
(Sept. 4, 2010 -Oct. 31, 2010)



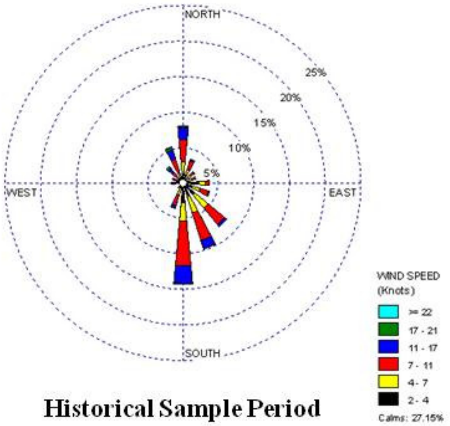
Sample Period
(Sept. 4, 2010 -Oct. 31, 2010)



Historical
(2006-2009)



Annual-2009



Historical Sample Period
(Sept.-Oct., 2006-2009)

Figure 2.5-15. Site S-6 Windrose Comparisons

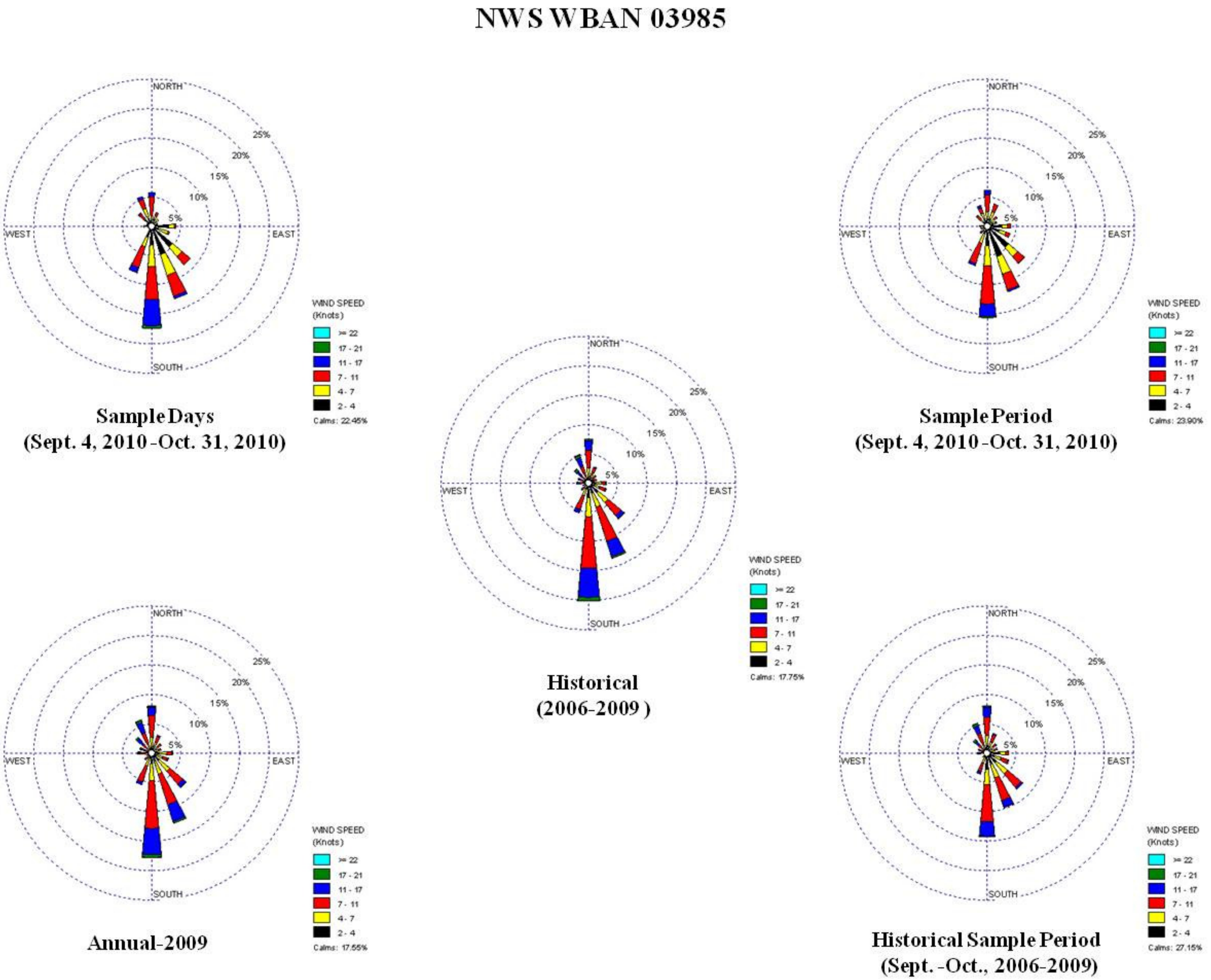


Figure 2.5-16. Site S-7 Windrose Comparisons

2.6 Ambient Air Monitoring Conclusions

Ambient air monitoring sampling at eight monitoring sites for nearly 140 pollutants yielded over 15,000 data points for this study. The ambient monitoring data presented in this report is based on air samples collected during a two-month timeframe at eight locations. The data should not be used to make inferences about air quality during times when, and locations where, samples were not collected. Insights from the dispersion modeling analysis have been used to help address this inherent limitation of the ambient air monitoring program, and a full discussion of the health implications of this study are presented in Section 5 of this report.

Key findings from the ambient monitoring study are as follows:

- 169 ambient air samples from 8 locations in Fort Worth were collected and analyzed, resulting in over 15,000 ambient air data points generated for this study.
- ERG found little variability across the sampling network for certain pollutants, such as carbon tetrachloride, chloroform, chloromethane, crotonaldehyde, dichlorodifluoromethane, dichlorotetrafluoroethane, ethylene, 1-hexene, isoprene, propylene, trichlorotrifluoromethane, and trichlorotrifluoroethane. The low variability across the entire network suggests that these pollutants are not affected by localized, anthropogenic sources, but rather exist as background pollutants.
- Benzene and carbon tetrachloride were identified as key VOCs at each site.
- Acetaldehyde and formaldehyde were identified as key carbonyls at Sites S-4 and S-5.
- No SNMOCs were identified as key pollutants.
- Concentrations measured at Site S-4 (located in a high-level activity area near compressor stations, well pads, and mobile sources) were generally higher than at other sites. For some of the key pollutants (acetaldehyde and benzene), concentrations at this site were considerably higher.
- Pollutant concentrations at Sites S-6 and S-7 (located in a medium-level activity area) were surprisingly low relative to other sites, especially given their close proximity to active well pad locations.
- Concentrations at Site S-1 (“background” site with no nearby natural gas well pads upwind) were generally similar to Site S-2 (“mobile sources” site). Concentrations at these two sites were slightly higher than Sites S-6 and S-7.
- Concentrations at the two “preproduction” sites did not display higher pollutant concentrations than the two monitoring stations designated as “background” and “mobile source” sites.
- Wind patterns observed during the sampling period were consistent with historical wind patterns, indicating proper placement of the ambient air monitors.

3.0 Point Source Testing

ERG subcontracted the point source testing task to Sage Environmental Consulting LP (Sage). This section discusses how the point source testing task was conducted and the results that were obtained.

This section has seven sub-sections:

- 3.1 Introduction – Provides a summary of the purpose of the point source study, the scope of work, and the project timeline.
- 3.2 Point Source Survey Sampling Equipment – This section describes the field instrumentation.
- 3.3 Point Source Survey and Sampling Procedures – This section discusses survey procedures, documentation of emission points, the collection of emission data, canister sampling, and data archival procedures.
- 3.4 Emissions Calculation Procedures – The development of canister-derived emissions, the application of correlation equations, the creation of surrogate tank and non-tank emissions profiles, the use of EPA default-zero emissions factors, the use of engine emissions tables, and the calculation of Screening Emissions Factors are discussed in this section.
- 3.5 Point Source Emissions Results – The results of the point source study are provided in the charts and tables of this section.
- 3.6 Quality Control (QC) Results – This section contains the results of the QC procedures specified in the Final Point Source Test Plan including instrument calibration checks, canister sample collection procedures, and laboratory analytical checks.
- 3.7 Point Source Testing Conclusions – This section presents conclusions of the point source testing task.
- Appendix 3-A: Emissions summary for each point source site surveyed.
- Appendix 3-B: Two DVD discs containing the emissions calculation workbook, “MASTER - Well Char Emission Data 2011-07-13_FINAL” together with the data collected for each point source site.
- Appendix 3-C: One DVD containing the canister sample logbooks and the canister analytical results, the laboratory quality control results and the canister chain-of custody documentation.

3.1 Introduction

The purpose of the point source emissions study was to characterize emissions from natural gas-related point sources located within the Fort Worth city limits. These sources are categorized in seven groups:

- Well Pads – Comprising the largest group of sites visited, natural gas well pads typically contained several active wells, produced water storage tanks, separators, and metering runs (piping). Approximately one-third (123) of the well pads also had lift compressors used to increase a well's gas production rate. Emission sources typically related with well pads include equipment leaks, produced water and condensate storage and loading, and lift compressors. The amount of condensate production and related emissions are usually dependant on whether the produced gas is wet or dry gas.

- Compressor Stations – Compressor stations contain one or more large (generally 250 horsepower (hp) or greater) line compressors which provide the necessary pressure to move the natural gas through many miles of transmission lines. The most significant emissions from compressors stations are usually from combustion at the compressor engines or turbines. Other emissions sources may include equipment leaks, storage tanks, glycol dehydrators, flares, and condensate and/or wastewater loading. None of the compressor stations visited included turbines.
- Processing Facilities – Processing facilities generally remove impurities from the natural gas, such as carbon dioxide, water, and hydrogen sulfide. These facilities may also be designed to remove ethane, propane, and butane fractions from the natural gas for downstream marketing. Processing facilities are usually the largest emitting natural gas-related point sources including multiple emission sources such as, but not limited to equipment leaks, storage tanks, separator vents, glycol dehydrators, flares, condensate and wastewater loading, compressors, amine treatment and sulfur recovery units. The Processing Plant visited included most of these sources except for sulfur recovery units.
- Saltwater Treatment Facility – The single saltwater treatment facility permitted for operation within the City's boundaries uses underground injection to dispose of well production liquids such as oilfield brine, drilling mud, fracture materials, and well treatment fluids. Emission sources typically related with salt water treatment facilities include equipment leaks, storage tanks, and generators.
- Drilling Operation – Drilling of a new well is typically a two to three week process from start to finish and involves several large diesel-fueled generators. Other emission sources related to drilling operations may include equipment leaks and waste storage.
- Fracking Operation – Fracking is the high pressure injection of water mixed with sand and a variety of chemical additives into the well to fracture the shale and stimulate natural gas production from the well. Fracking operations can last for several weeks and involve many large diesel-fueled generators. Other emission sources related to fracking operations may include equipment leaks and waste storage.
- Flowback – Flowback is a well completion activity that occurs following the conclusion of a fracking operation. Flowback thus entails the removal of fracking fluids from the well in preparation either for a subsequent phase of treatment or for cleanup and returning the well to production. Similar to fracking operations, other related emission sources may include equipment leaks and waste storage.

Key Point: Sites Surveyed
This study included surveying a total of 388 sites comprised of well pads, compressor stations, processing facilities, a salt water treatment facility, drilling operations, fracking operations, and completion operations.

The point source teams surveyed a total of 388 sites (including repeat visits at two sites). The sites are identified by owner and type in Table 3.1-1. Figure 3.1-1 locates each site on an overlay map of Fort Worth. Figure 3.1-2 indicates which well pads were considered to be wet gas, and which were considered to be dry gas. For purposes of this study, a site was considered to be a wet gas site if it produced more than 1 barrel of condensate/day as indicated by the Texas Railroad Commission records.

The point source emissions survey occurred in two phases. Phase I was completed in the fall of 2010 (August 30 – October 21, 2010). Phase II took place during the beginning months of 2011 (January 4 – February 16, 2011). There were no significant differences in methodology or scope between the two phases. Any slight differences between the methodologies are discussed below. During Phase I, 199 point source sites were surveyed and are identified using Point Source ID’s PS-001 through PS-201. An additional 189 sites were completed in Phase II and are identified as Point Source ID’s 6 through 487.

Quality Control results indicate that the field and the laboratory equipment were in a state of control during the point source survey and that project quality control checks were followed. Site-by-site emission summaries are provided in Appendix 3-A of this report. Appendix 3-B provides the field data and emission calculation workbook on two DVD discs. Appendix 3-C contains the canister analytical data on one DVD disc.

3.2 Point Source Emissions Survey Sampling Equipment

The point source surveys were carried out by two teams of two persons each. In Phase I each team was staffed by a Sage employee and an employee from Hicks & Co. Environmental (Hicks). This changed in Phase II to one team of two Sage employees while the other team remained a Sage and a Hicks employee. The point source teams were equipped with the following test equipment:

- FLIR™ Infrared (IR) Camera.
- Thermo Environmental ™ Toxic Vapor Analyzer.
- Bacharach™ Hi Flow Sampler.
- Summa Passivated Stainless Steel Canisters from TestAmerica™.
- Miscellaneous Support Equipment (Global Positioning System (GPS) Finder, Laser Distance Finder, Weather meter, Digital Camera).

Table 3.1-1. Point Source Sites by Owner and Type

Owners	Well Pad	Compressor Station	Processing Facility	Saltwater Treatment Facility	Drilling Operation	Fracking Operation	Completion Operation (Flowback)	Total
Burnett Oil Production	2							**2**
Chesapeake Operating Inc.	84 [a]	2		1				**87**
Crosstex			1					**1**
Crow Creek Operating Inc	3							**3**
Devon Energy Production Co	105							**105**
Eagle Oil And Gas	1							**1**
Encana Oil & Gas (USA) Inc	18 [b]							**18**
Finley	2							**2**
Frost Brothers	2							**2**
Grand Operating Inc	1							**1**
Lakota Energy LTD	1							**1**
Newark Energy	1							**1**
Proven Resources	3							**3**
Quicksilver Resources	28	1				1	1	**31**
Range Production Co	16	3						**19**
Vargus Energy LTD	1							**1**
Williams Production	5							**5**
XTO Energy Inc	102	2			1			**105**
Grand Total	**375**	**8**	**1**	**1**	**1**	**1**	**1**	**388**

[a] Includes repeat visits to the same site i.e., Site IDs: PS-192 and 294.

[b] Includes repeat visits to the same site i.e., Site IDs: PS-086 and 260.

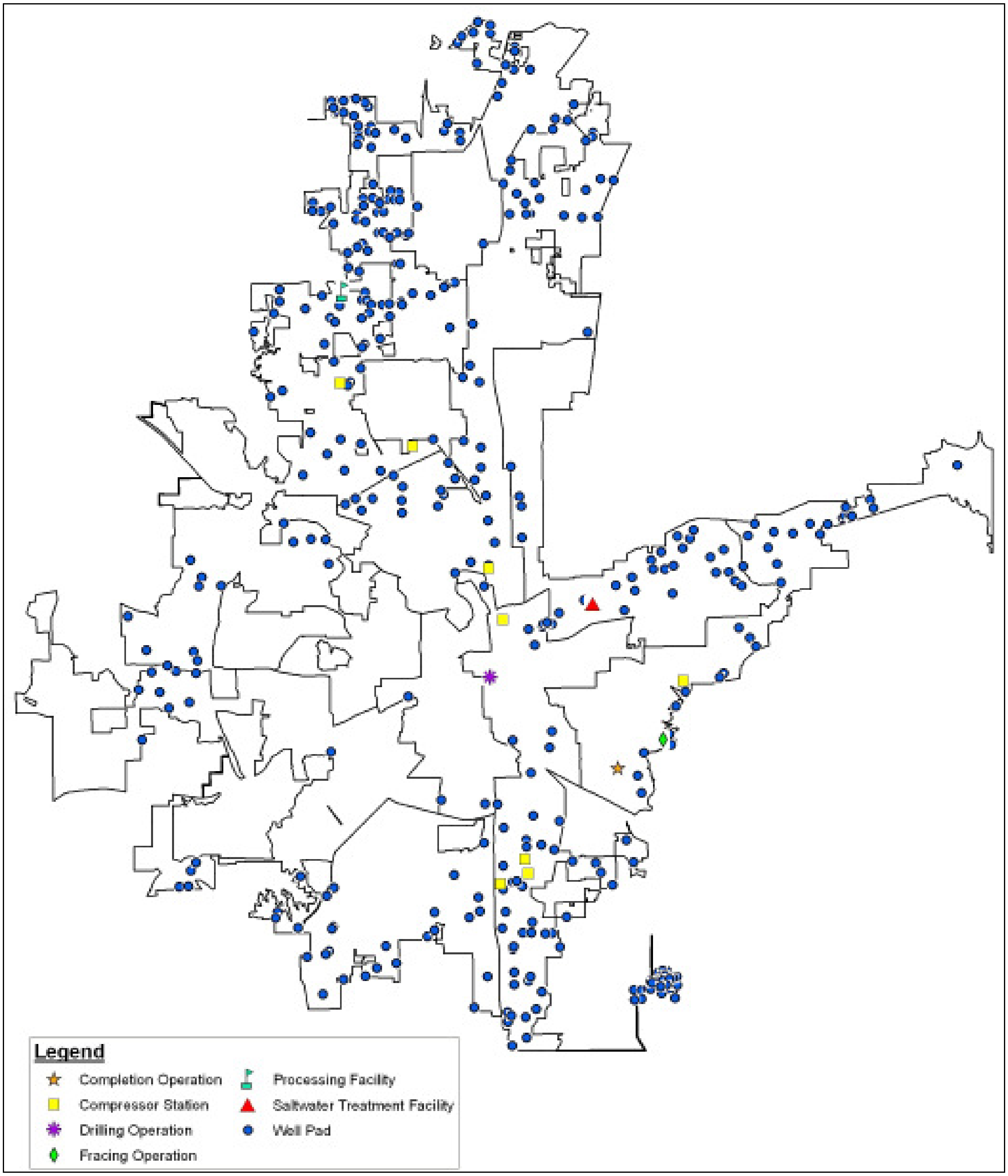


Figure 3.1-1. Point Source Survey Sites (August 2010 – February 2011)

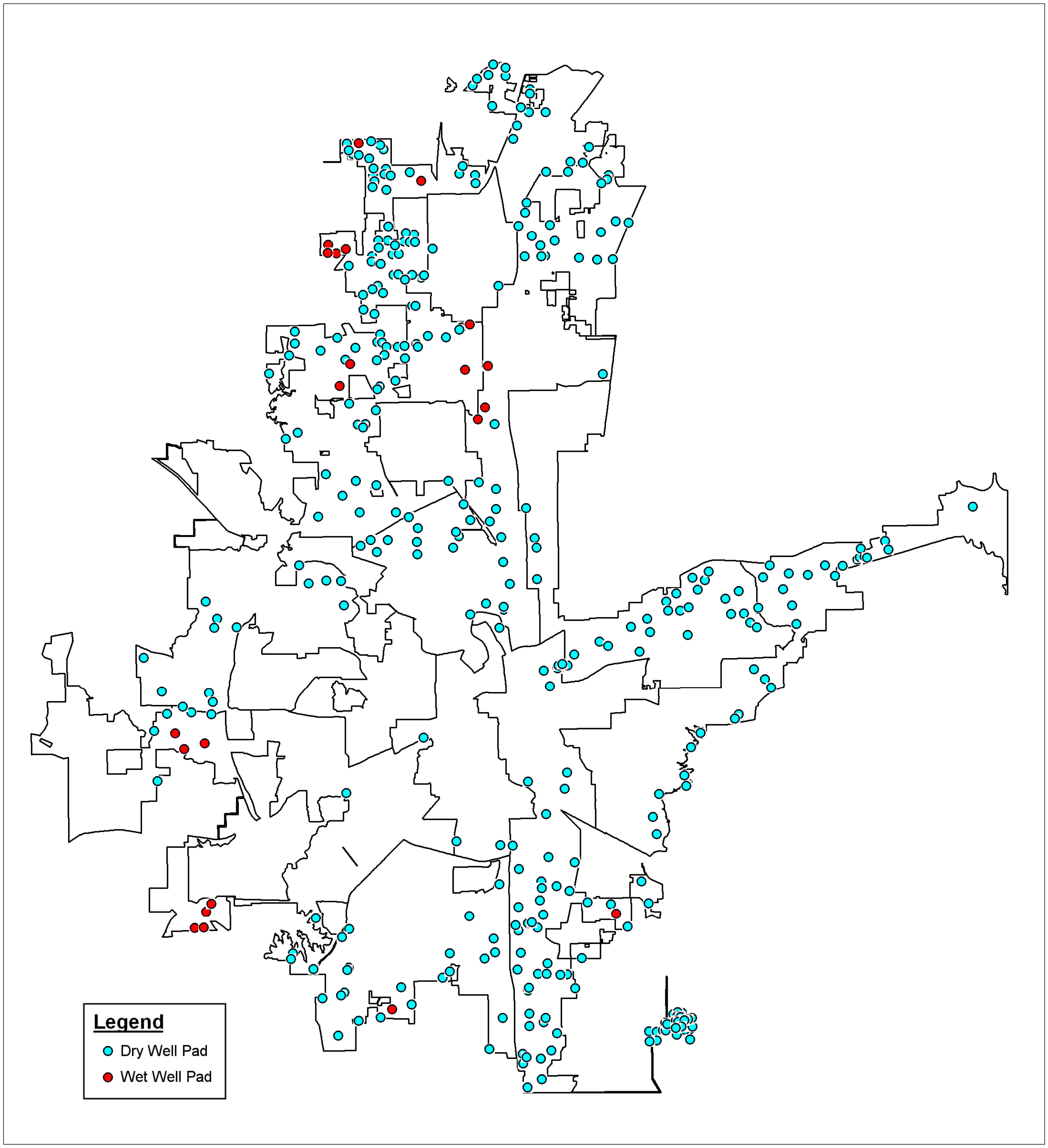


Figure 3.1-2. Wet Gas and Dry Gas Well Pads

3.2.1 The FLIR™ Infrared Camera

FLIR™ infrared cameras were used to survey all equipment in natural gas service at each point source site visited. The IR camera enables rapid detection of large emission sources (for instance, sources with concentrations > 10,000 parts per million by volume (ppmv). Moreover, the infrared camera is well suited to detecting methane emissions, the largest constituent of natural gas, as well as ethane, propane, and butane. Figure 3.2-1 illustrates the use of a FLIR™ infrared camera at a well site.

Figure 3.2-1. IR Camera Imaging at a Well Site

Two models of infrared camera were used on this project. One team used the GasFindIR™ camera equipped with a 50 mm lens and an external COWAN™ video recorder. The second team used the FLIR™ Model GF-320 infrared camera. While the two cameras share identical performance characteristics, the GF-320 has more user-friendly features (such as built-in video recorder and digital camera). All infrared camera imaging was performed by trained Level 1 or Level 2 Thermographers.

3.2.2 The Toxic Vapor Analyzer (TVA)

The TVA is a portable, battery-powered, intrinsically safe, hydrocarbon analyzer with a measurement range extending from 0.5 ppmv (parts per million by volume) to 50,000 ppmv hydrocarbon. This instrument was used to screen a random selection of site valves and connectors for leaks below the detection limit of the IR camera. It was also used to measure emissions detected with the camera, although in most cases these measurements resulted in a “flame-out” of the analyzer (that is, a reading greater than 50,000 ppmv). Figure 3.2-2 illustrates the use of a TVA at a well site.

Key Point: IR Camera and TVA Detection Limits
The Infrared camera is typically used to detect large emission sources at concentrations >10,000 ppmv whereas the TVA can detect emissions with concentrations as low as 0.5 ppmv.

Figure 3.2-2. Method 21 Screening with the TVA at a Well Site

Use of the TVA followed EPA Method 21 procedures (40 CFR 60 Appendix A), which prescribes how to screen various components for fugitive emissions. Each TVA was calibrated daily prior to use with methane-in-air calibration standards.

3.2.3 The Hi Flow Sampler

The Hi Flow Sampler is a portable, intrinsically safe instrument designed to measure the rate of gas leakage around various pipe fittings, valve packings and compressor seals found at natural gas facilities. Because of its high flow rate (8 to 10 standard cubid feet per minute (SCFM)) the Hi Flow Sampler is able to completely capture any gas emitting from a component. The rate of the gas leak is determined by accurately measuring the flow rate of the sampling stream and the natural gas concentration. Figure 3.2-3 illustrates the sampling of a tank vent with the Hi Flow sampler.

Figure 3.2-3. Sampling a Tank Vent with the Hi Flow Sampler

To make an emission measurement with the Hi Flow Sampler, an attachment is chosen that is suitable for capturing the entire leak. An assortment of attachments are available to enable testing of a wide variety of components. For instance, for thief hatchs or tank vents, a large nylon bag attachment was used. A plunger-style attachment was used to enclose small valves. Flanges were enclosed with a plastic strap and secured with Velcro™. For equipment that could not be enclosed with the standard Hi Flow Sampler attachments, plastic wrapping was used. With one end of the attachment enclosing the emission source and the other end attached to the instrument's main sampling hose, the Sampler was switched on and sampling initiated using the menu options available through the unit's controller. An entire Hi Flow Sampler test run lasted approximately 3 to 5 minutes.

For the point source surveys the Hi Flow Sampler was operated in its Automatic 2-Stage Mode, performing a leak rate measurement first at a high flow rate setting for one minute, and then automatically switching to a lower flow rate for a second minute of additional sampling. The unit calculated the degree of comparison between two measurements and displayed the total sample flow rate in cubic feet per minute (CFM) and the leak as percent methane and as the percent of the sample flow rate (% CFM).

3.2.4 Summa Canisters

Evacuated, six-liter, canisters provided by TestAmerica's™ Austin, Texas laboratory, were used to collect gas samples from selected emission points for VOC and HAP analysis by Gas chromatograph/Mass spectrometer (GC/MS) and for methane analysis by gas chromatography with a thermal conductivity detector (TCD). Canisters were shipped to the field office in a pre-cleaned, evacuated condition. Completed canisters were returned within several days of sample collection, together with chain-of-custody documentation, to TestAmerica™ for analysis. Unused canisters were kept securely stored in the project field office. Figure 3.2-4 illustrates how a canister sample was collected from the exhaust port of the Hi Flow Sampler.

Figure 3.2-4. Collecting a Canister Sample from the Exhaust Port of the Hi Flow Sampler

3.2.5 Miscellaneous Equipment

In addition to the equipment described above the point source teams also employed:

- A GPS receiver to document a site's North and West coordinates.
- A Kestrel Weathermeter™ to measure wind speed, temperature, relative humidity, and barometric pressure during a site visit.
- A laser distance finder to measure heights of emission points.
- An Archer™ field computer to record site data.
- A digital camera for site and equipment photos.

3.3 Point Source Survey and Sampling Procedures

This section discusses pre-test equipment preparation, site survey procedures, and data retrieval/archiving activities. The point source survey and sampling procedures followed were consistent with the Point Source Test Plan previously submitted and approved by the City of Fort Worth. Any deviations from this plan are discussed in the following sections as applicable.

3.3.1 Pre-Test Equipment Preparation

Equipment was prepared for use each morning prior to the first site visit. Preparations included:

- The IR Camera Daily Demo.
- A calibration check of the Hi Flow Sampler.
- A multipoint calibration of the TVA.

IR Camera Daily Demo Quality Assurance Check

The IR Camera Daily Demo provides a validation of the camera's operation by releasing a known mass emission rate of gas (100% propane) and measuring the distance from which the release can be reliably viewed. This validation was performed first thing each morning with both cameras at two mass emission rates: a low emission rate of 10 grams/hour propane and a higher emission rate of 31 grams/hour propane. The distance from which each emission rate could be detected (i.e. sighting distance) was recorded, together with wind direction, wind speed, temperature, relative humidity, barometric pressure, and percent cloud cover information. The equipment used to perform the daily demo included a steel compressed gas cylinder of 100% propane gas, a single stage gas regulator, a calibrated rotameter, flow control valves and tubing to position the emission flow at eye-level. The results of the daily demos are provided in Section 3.6 of this report and further documented in the field log notes included in Appendix 3-B.

Calibration Check of the Hi Flow Samplers

The Hi Flow Sampler contains two sensors – a background sensor and a leak sensor. Both sensors were calibrated at the start of Phase I and at the start of Phase II using certified standards of 2.5% methane-in-air and 100% methane. On a daily basis, prior to testing, the background and leak sensors of each Sampler were calibration-checked with the 2.5% methane standard. If an error greater than 10% resulted, the instrument was re-calibrated. Each Monday, the background and leak sensors of both instruments were calibration-checked with both the 2.5% and the 100% methane standards. Again, errors above 10% required re-calibration of the instrument.

The results of the Hi Flow Sampler daily calibration checks are provided in Section 3.6 of this report and further documented in the field log notes included in Appendix 3-B.

Multipoint Calibration of the TVAs

A multipoint calibration of each TVA was performed daily prior to testing with the following gases:

- Zero gas (<0.1 ppmv total hydrocarbon).
- Low Level Span gas (nominally 500 ppmv methane-in-air).
- Mid Level Span gas (nominally 1,000 ppmv methane-in-air).
- High Level Span gas (nominally 10,000 ppmv methane-in-air).

Following the calibration, each TVA would be re-checked with the same gases. The instrument was considered to be in a state of control if its response to each gas was accurate to within +/- 10%. Failure to meet this criterion required recalibration, repair, or replacement of the instrument.

3.3.2 Final Preparations

KeyPoint: Random Site Selection
To reduce bias in the survey relative to owner, operator, location, or any other variable, sites were selected for surveying on a random basis.

Following the instrument performance checks, data from the previous day would be reviewed for completeness and accuracy, the City Chief Gas Inspector would be called with the addresses of the first sites to be visited, and the vans would be loaded with the instrumentation and canisters. There would be a brief group safety discussion, the field office would then be locked, and the each team would depart to the first of their assigned sites for the day.

Sites were selected for surveying on a random basis. During the day, City Gas Inspectors were only told of the next scheduled site upon departure. These procedures were followed to avoid the possibility of site owners learning of the survey schedule in advance.

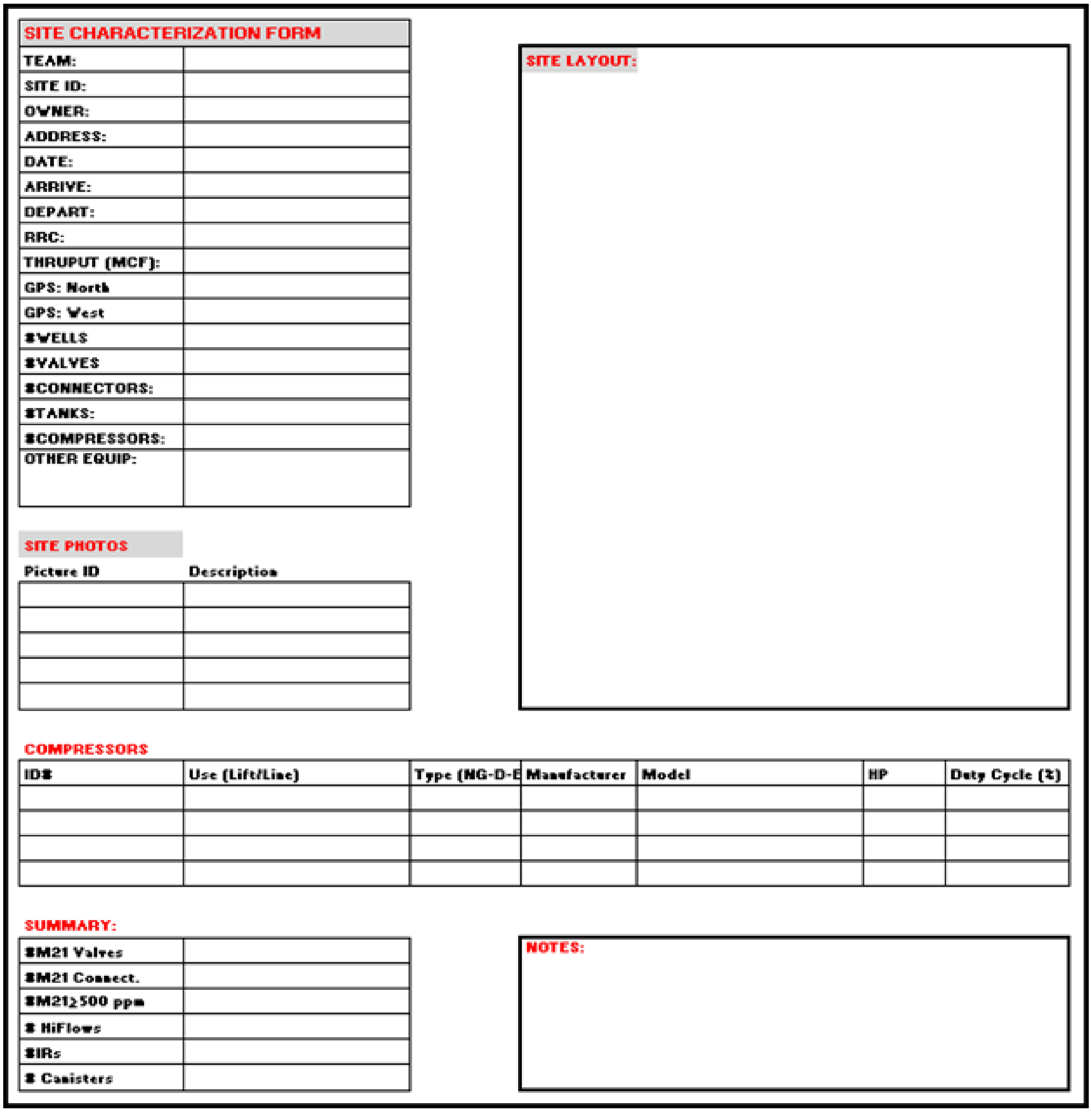
3.3.3 Site Arrival

Upon arrival at the designated point source site, the survey team met with the City Gas Inspector who unlocked the site gate to allow entrance to the site. On no occasion did the team enter a site without the City Gas Inspector also being present. Customarily at this time, a picture was taken of the front gate signage as part of the site documentation (Figure 3.3-1 shows an example of front gate signage).

Figure 3.3-1. Front Gate Signage

Immediately after arrival, a brief safety screening of the site would be conducted with the TVA to avoid entering an area of potentially dangerous pollutant concentrations.

One objective of each point source site visit was to document important site parameters such as the number of wells, storage tanks, and compressors, the site's GPS coordinates, the site's Railroad Commission (RRC) postings, and site throughput. Much of this information would be collected on preformatted data forms at the start of the survey. The use of pre-formatted forms helped to ensure a consistent data collection effort between the two teams as well as between sites. Figure 3.3-2 illustrates the site characterization form on which much of this information was recorded. In the "SITE LAYOUT" section of the form a sketch illustrating the positions of all major pieces of equipment would be drawn. All forms completed during the site surveys are included in Appendix 3-B.



SITE CHARACTERIZATION FORM

TEAM:	
SITE ID:	
OWNER:	
ADDRESS:	
DATE:	
ARRIVE:	
DEPART:	
RRC:	
THRUPUT (MCF):	
GPS: North	
GPS: West	
#WELLS	
#VALVES	
#CONNECTORS:	
#TANKS:	
#COMPRESSORS:	
OTHER EQUIP:	

SITE LAYOUT:

SITE PHOTOS

Picture ID	Description

COMPRESSORS

ID#	Use (Lift/Line)	Type (NG-D-E	Manufacturer	Model	HP	Duty Cycle (%)

SUMMARY:

#M21 Valves	
#M21 Connect.	
#M21≥500 ppm	
# HiFlows	
#IRs	
# Canisters	

NOTES:

Figure 3.3-2. Point Source Site Characterization Form

3.3.4 IR Camera Survey

The IR camera survey of a site began with the thermographer starting at one end of the site and working his way in logical fashion to the opposite end so that all equipment was surveyed. In a typical route, for instance, the thermographer would begin at the well pads, carefully surveying all of the valves and connectors associated with each well. From the well pads he would proceed to the compressor if one was present. Next, he might image the metering run and from there proceed to the piping and separators inside the tank battery. Finally he would finish the survey with a careful imaging of each storage tank, climbing up the stairs to the tank walkway in order to view each thief hatch and pressure relief valve (PRV) vent line. Depending on circumstances, such as the size and amount of equipment on the site and the number of detected emission points, an IR camera site survey of a typical well pad might last from one to several hours.

When an emission was detected with the IR camera, a video recording of the IR imaging would be made, a photograph of the emission source would be taken and the following data documented:

- Date and time.
- Equipment description and size.
- Emission point height above ground (feet).
- GPS coordinates of emission point (Phase II only).
- Sighting distance (feet).
- TVA reading of emission (ppmv).
- Tank height and radius if tank emission (feet).
- Video file name.
- Maximum sighting distance (feet) – The maximum sighting distance is the distance from which the emission can be reliably detected with the IR camera and provides a measure of the emission's magnitude (i.e. large emissions can be detected from further away).
- Weather conditions (Wind Direction, Wind Speed, Temperature, Relative Humidity, Barometric Pressure, and Cloud Cover).

As standard practice, the thermographer would image equipment from different angles. This is necessary since environmental conditions such as sunlight, wind, and background (i.e. air, piping, concrete or heat profiles) can cause an emission stream to be difficult to see from one angle, but easily detected from another.

With the GasFindIR™ camera integration settings would be switched to enable viewing of very hot surfaces (typically found at compressors), manual mode would be used on occasion to verify the absence or presence of a subtle emission, and "nuking" would be employed as required to eliminate optical background noise. Nuking adjusts the GasFindIR's background so that a more uniform pixel response is obtained.

With the GF-320 camera the thermographer would frequently shift to High Sensitivity mode to confirm or detect a more subtle emission that was hard to see. All field data forms, digital photographs and videos are provided in electronic form in Appendix 3-B.

3.3.5 Method 21 Site Survey with the Toxic Vapor Analyzer

While one team member conducted the IR camera site survey, the second member calculated the total number of site valves and connectors. This was done by first determining the valve count and then applying a multiplying factor to arrive at the number of connectors. For this project, a connector multiplier of 7 was conservatively used, based upon detailed connector counts performed at the beginning of both Phase I and Phase II. Thus if it was determined that a site contained 245 valves, then a connector count of 1,715 (7 x 245) was assumed. The 7:1 connector to valve ratio held true for all equipment except at compressor skids where a higher ratio was often noted. Consequently the number of connectors at compressor skids was estimated separately by multiplying the number of compressor valves by factors ranging from 10 to 15, depending on the size and complexity of the compressor.

Key Point: Method 21 Screening
To estimate low level emissions from fugitive equipment leaks, at least 10% of the valve and connector population at each site surveyed was screened.

These component counts were necessary since one objective of the point source testing was to estimate low level emissions (i.e. emissions below the detection limits of the IR camera) from fugitive equipment leaks. This objective was accomplished by screening at least ten percent of the valve and connector population at each point source site with the TVA. Thus while the IR camera survey was in progress, Method 21 screening of the site's valves and connectors was performed with the TVA on one of every ten valves and one of every ten connectors until ten percent of the total valve and connector counts was reached. This procedure ensured that the required number of components was screened and that the screening population was evenly distributed across all areas of the site. This screening was conducted independent of the IR camera survey. Once it was completed, the TVA was then used to screen any emission points identified by the IR camera.

Following Method 21 procedures, valves were screened at their three primary leak areas: the stem, the packing, and the bonnet flange. Method 21 screening entails placing the TVA's probe at the various leak interfaces and sampling the complete circumference. Flanges were screened by placing the TVA probe at the edge of the flange-gasket interface. Connectors were screened by sampling the circumference of the threaded sections. All other components were monitored through a peripheral traverse of the seal interface. Whenever an elevated reading was obtained the sample probe was left at this elevated point for at least twice the instrument's response time (i.e. at least for 8 seconds) to ensure that the maximum concentration was measured.

When an emission at or above 500 ppmv was detected with the TVA the following data would be recorded:

- Date and time.
- Screening concentration (ppmv).
- Equipment Description.
- Equipment Location (GPS coordinates in Phase II only).

3.3.6 Hi Flow Sampler Emissions Testing

The Hi Flow Sampler, as discussed previously, provides a quick and effective means of quantifying emissions by sampling at a high enough flow rate to capture all the emissions escaping from a component. By accurately measuring the flow rate of the sample stream and the natural gas concentration within the stream, the instrument is able to determine the gas leak rate expressed both as percent methane and percent CFM. When this data is combined with canister analytical data, mass emission rates for individual compounds can be calculated as explained in Section 3.4.

Hi Flow Sampler testing was conducted at all emission points identified with the IR Camera (high level emissions) as well as at each emission point identified through Method 21 screening with a concentration ≥500 ppmv (low level emissions). A number of low level emissions in Phase I were below the detection capability of the Hi Flow Sampler. Emissions from these points have had to be subsequently estimated. In Phase II this was remedied by sampling the exhaust stream of the Hi Flow Sampler with the TVA and using the resulting TVA concentration to calculate the low level emission rate.

The following data was documented for each Hi Flow Sampler test:

- Date and time.
- The percent difference in leak rate between the sample flow rates.
- Total sample flow (CFM).
- Background concentration (%).
- Leak rate as % methane (% CH_4).
- Leak rate as % of total sample flow (% CFM).

3.3.7 Canister Sampling

As documented in the Point Source Test Plan, it was originally intended that a canister sample be collected at each emission point identified by the IR camera. However, as Phase I testing commenced, it became apparent that the sampling teams were observing an unexpectedly high frequency of camera-detected emission points. Therefore, an alternative canister sampling strategy was needed; neither the project budget nor laboratory resources would be able to keep up with the canister demand otherwise. A revised canister sampling plan was developed and subsequently approved by the City of Fort Worth. The revised canister sampling plan was based upon three criteria.

Key Point: Canister Sampling
164 canister samples were collected throughout Fort Worth during the study. Data obtained from the 164 canister samples were used to develop surrogate canister emission profiles and correlation equations to characterize emissions from those points not directly sampled.

A canister sample would be collected from an emission point only if:

1. The % CFM reading obtained with the Hi Flow Sampler from that point exceeded the daily rolling average % CFM for all Hi Flow Sampler tests conducted thus far. In other words, the emission rate had to equal or exceed the average emission rate. The average emission rate was originally expressed as the rolling average of the third quartile % CFM; this was later changed to the rolling average % CFM.

2. Less than three canister samples have been collected from a similar component at other sites.

3. Less than three canister samples had been collected in the general geographical region. Geographical regions will be defined as the north, east, south, and west quadrants of the City of Fort Worth as well as any particular region in which the characteristics of the natural gas are substantially different from other regions (for instance, regions with wet gas and regions with dry gas).

If all of these conditions were not met, a canister sample was not collected. This approach succeeded in reducing the canister demand to a manageable level and was followed through the remainder of Phase I and through all of Phase II (a total of 164 canister samples were collected, not including 8 duplicate canister samples). Data obtained from these 164 canister samples were then used to develop surrogate canister emission profiles and correlation equations to characterize points for which no canister sample was taken.

Figure 3.3-3 provides a map of Fort Worth indicating the locations where canister samples were collected, as well as those locations where no samples were taken. As indicated in the map, the locations where canister samples were collected provide a well distributed characterization of canister samples. In other words, there were no large geographic locations in which there were no canister samples taken.

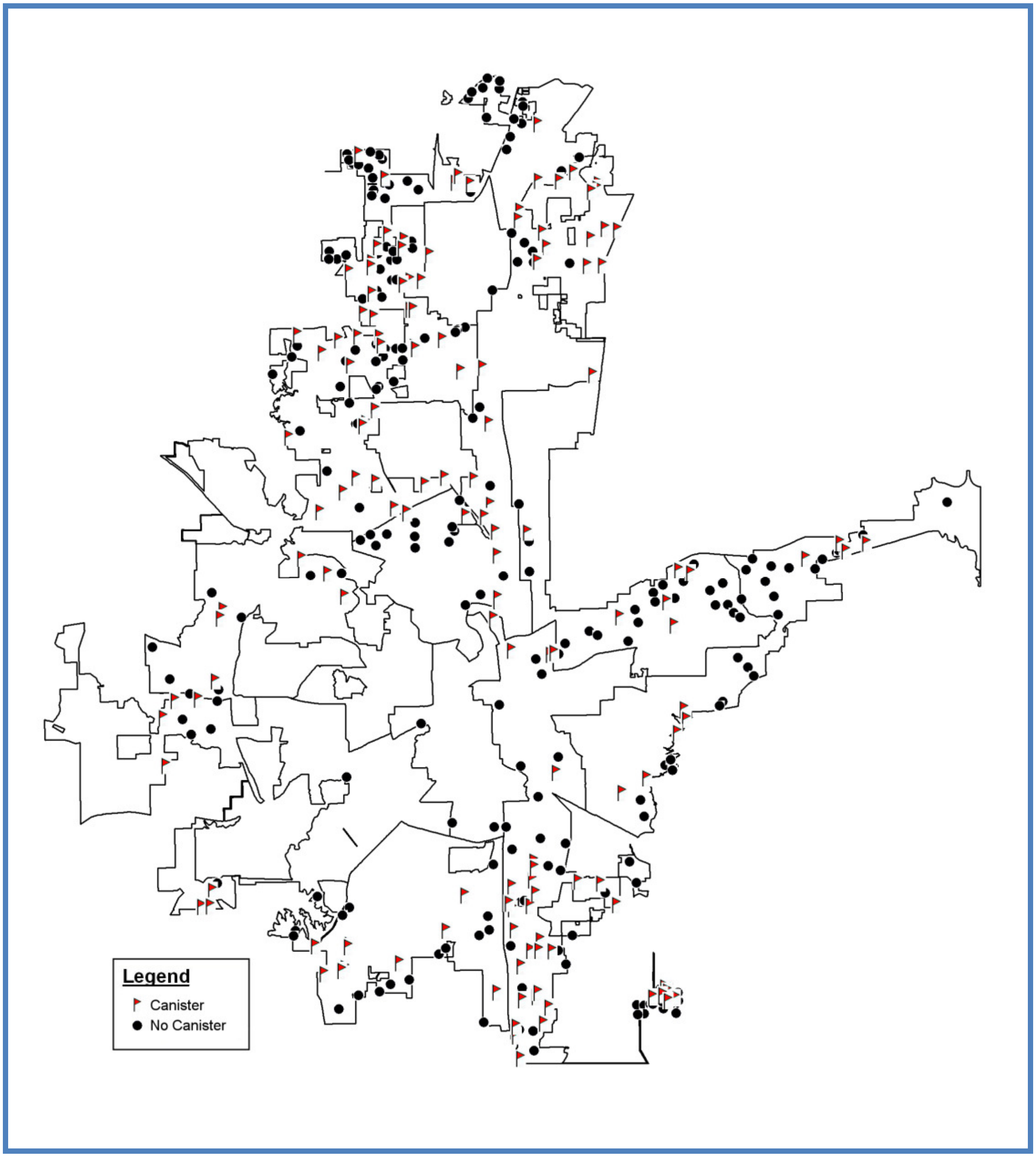


Figure 3.3-3. Canister Sample Locations

Whenever a canister sample was to be collected, the collection process followed specific protocols. A canister sampling manifold (Figure 3.3-4) consisting of a flow control valve and vacuum gauge was connected to the canister inlet port, and the canister's initial vacuum was checked. If less than 25-inches Hg vacuum was measured the canister was not used for sampling and was returned to the laboratory (this occurred only once).

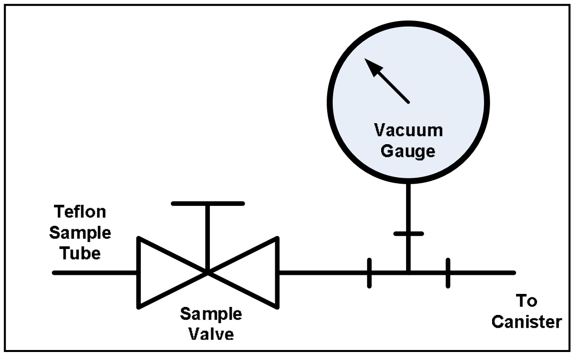


Figure 3.3-4. Canister Sampling Manifold

To collect a sample, the canister's sample probe was directed into the exhaust port of the Hi Flow Sampler. Since it was possible, if the canister was opened very quickly, for the canister inlet flow to exceed the exhaust flow of the Hi Flow and thereby dilute the sample with ambient air, the sampling flow was carefully controlled. This was accomplished by adjusting the sample valve located upstream of the vacuum gauge (Figure 3.3-4) to ensure a slow but steady decrease in the canister vacuum. In practice, canister fill times were never less than 20 seconds and more typically, were between 30 seconds and 1 minute, far longer than the less than 2 second fill rate required to overcome the Hi Flow's exhaust rate.

A canister was never filled completely but rather enough sample was collected to bring the canister vacuum up between 10 to 5 inches Hg. Following the collection of a canister sample the following data was documented both in a canister collection logbook and in the site's data form:

- Sample ID Number.
- Site Address.
- Date and Time.
- Initial Vacuum (inches Hg).

Similar information was also recorded on the canister's tag. Copies of the canister collection logbook entries are provided in Appendix 3-C.

3.3.8 Completion of the Site Survey

Following completion of the IR camera survey, the Method 21 screening, the Hi Flow Sampler testing of low level and high level emission points, and the canister sampling, the major equipment-containing areas of the site were documented both in photographs and with a site layout sketch. Figures 3.3-5, 3.3-6, and 3.3-7 provide typical examples of site photographs. Figure 3.3-8 illustrates a completed site layout sketch. Copies of all field data including site photos and site videos are provided in Appendix 3-B.

Figure 3.3-5. Site Documentation – Wells

Figure 3.3-6. Site Documentation – Tanks and Separators

Figure 3.3-7. Site Documentation – Lift Compressor

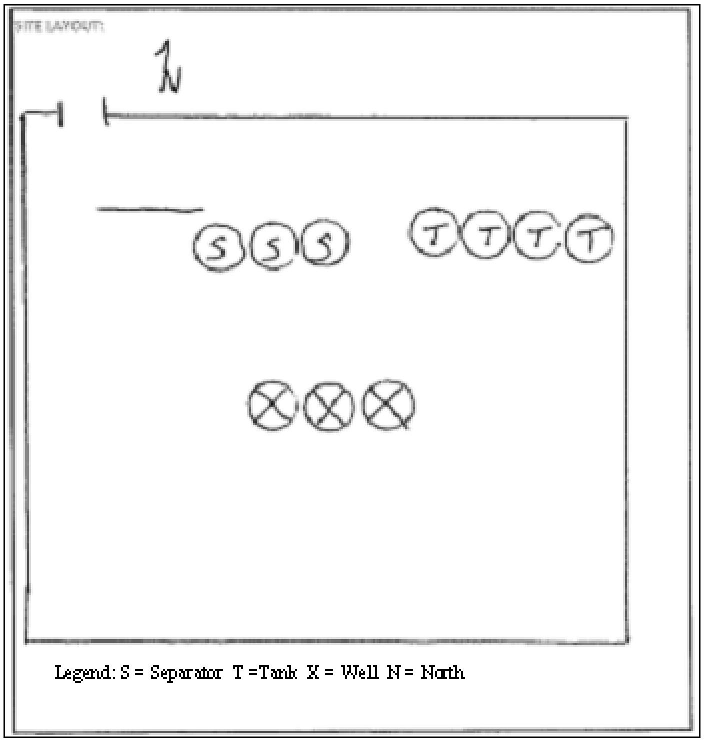


Figure 3.3-8. Example Site Sketch

Following this, the point source team prepared to depart from the site. The site data forms were checked for completeness and accuracy, any temporary flagging was removed the site's equipment, all well and tank battery gates were closed and secured, and the departure time was documented. The gas inspector was then told the address of the next site to visit, and the facility's main gate was locked behind the departing vehicles.

At the end of the day both teams returned to the field office where the equipment was off loaded from the project vans. Any canister samples taken that day were securely stored. The collected field data for that day was downloaded to a computer, printed out, and backed up.

Data archiving consisted of setting up separate computer site folders for the site's visited that day. Each folder was populated with the completed data forms, the site IR videos, and the site photos. Each team stored their data on the team computer and backed it up on dedicated hard drives. In addition, hardcopy printouts of the completed data forms were kept in large loose-leaf binders organized in chronological order. While one team member handled the data archiving, the other team member unloaded the van and prepared for the next work day. IR Camera, Hi Flow Sampler, TVA, digital camera and Archer data logger batteries were set up for overnight charging and facility field sketches were copied onto the printed out data forms. The completed data forms were quality control reviewed on a regular basis, either at the end of the day, the first thing the next day, or on the following weekend.

3.4 Emissions Calculation Procedures

This section describes the emissions calculation procedures used to derive a total emissions profile for each point source site. It is important to understand that for this study, not all of the site's emissions were calculated and/or characterized. For purposes of this study, in most cases, the emissions were calculated from only those sources in which emissions were detected and/or could be measured following the procedures described in the previous section. Hence, emissions were only estimated from piping and instrumentation equipment leaks, storage tanks, and compressors, which contribute the majority of emissions from natural gas-related facilities. Other sources of emissions, including but not limited to, storage tank breathing and standing losses, glycol dehydrator reboiler vents, wastewater and/or condensate loading, and flaring were not calculated. Non-routine emissions such as those generated during upsets or from maintenance, startup, and shutdown activities were also not measured or calculated as part of this study unless they were observed at the time of the site visit.

Annual emission estimates for each site were derived based on data obtained during the site visit and by assuming that conditions during the visit were representative of site conditions throughout the year. While it is important to note that emissions at any individual site can fluctuate depending on day-to-day operating and equipment conditions, the variation in emissions over the entire population were captured as a whole and are encompassed in this study as a result of breadth and depth of the point source testing and the use of surrogate emission profiles.

3.4.1 Well Pad, Compressor Station, Gas Plant, and Salt Water Disposal Facility Emissions

Total speciated emissions were calculated for each well pad, compressor station, gas plant and salt water disposal facility visited by the point source teams. These calculations fall into two categories: 1) Direct and 2) Indirect. Direct emission calculations were based upon the analytical results of the canister samples. Indirect emission measurements were derived from several sources including the emission results from the canister sampling, correlation equations, calculated surrogate emission rates, EPA emission factors, and engine emission data for both natural gas and diesel powered engines. Each site's total emissions were calculated as a combination of direct and indirect emissions results. Figure 3.4-1 illustrates the overall approach followed in calculating total site emissions.

3.4.2 Direct Emission Calculations

Direct calculation of speciated emissions from a canister result was accomplished in 3 steps:

- Step 1: Convert the ppmv canister result to mg/m3 using Equation 5-1:

$$C = \frac{ppmv * MW}{24.45}$$

Where:

C = Concentration in mg/m^3
ppmv = Parts per million by volume
MW = Molecular Weight of analyte in gram/mols
24.45 = Molar Volume @ 25^{o}C and 1 atmosphere in L/mols.

- Step 2: Convert the actual Hi Flow Sampler gas flow to standard gas flow using Equation 5-2:

$$CFMstd = (CFMact)\left(\frac{Tstd}{Tact}\right)\left(\frac{Pact}{Pstd}\right)$$

Where:

CFM_{std} = Flow rate corrected for standard conditions (ft^3/min)
CFM_{act} = Flow rate at actual conditions (ft^3/min)
T_{std} = Absolute gas temperature at standard conditions (^{o}R)
T_{act} = Absolute gas temperature at actual conditions (^{o}R)
P_a = Absolute gas pressure at actual conditions (psia)
P_{std} = Absolute gas pressure at standard conditions (psia).

- Step 3: Calculate the emission rate using Equation 5-3:

$$ER = C * CFMstd * CF * 8760$$

Where:

ER = Emission Rate (lb/yr)
C = Analyte Concentration (mg/m^3)
CFM_{std} = Flow rate (ft^3/min) corrected to standard conditions
CF = Units Conversion Factor = 3.75E-06 (1 m^3/35.32147 ft^3) x 60 minutes/hour x (1 pound/453592.37 mg)
8760 = Hours per year

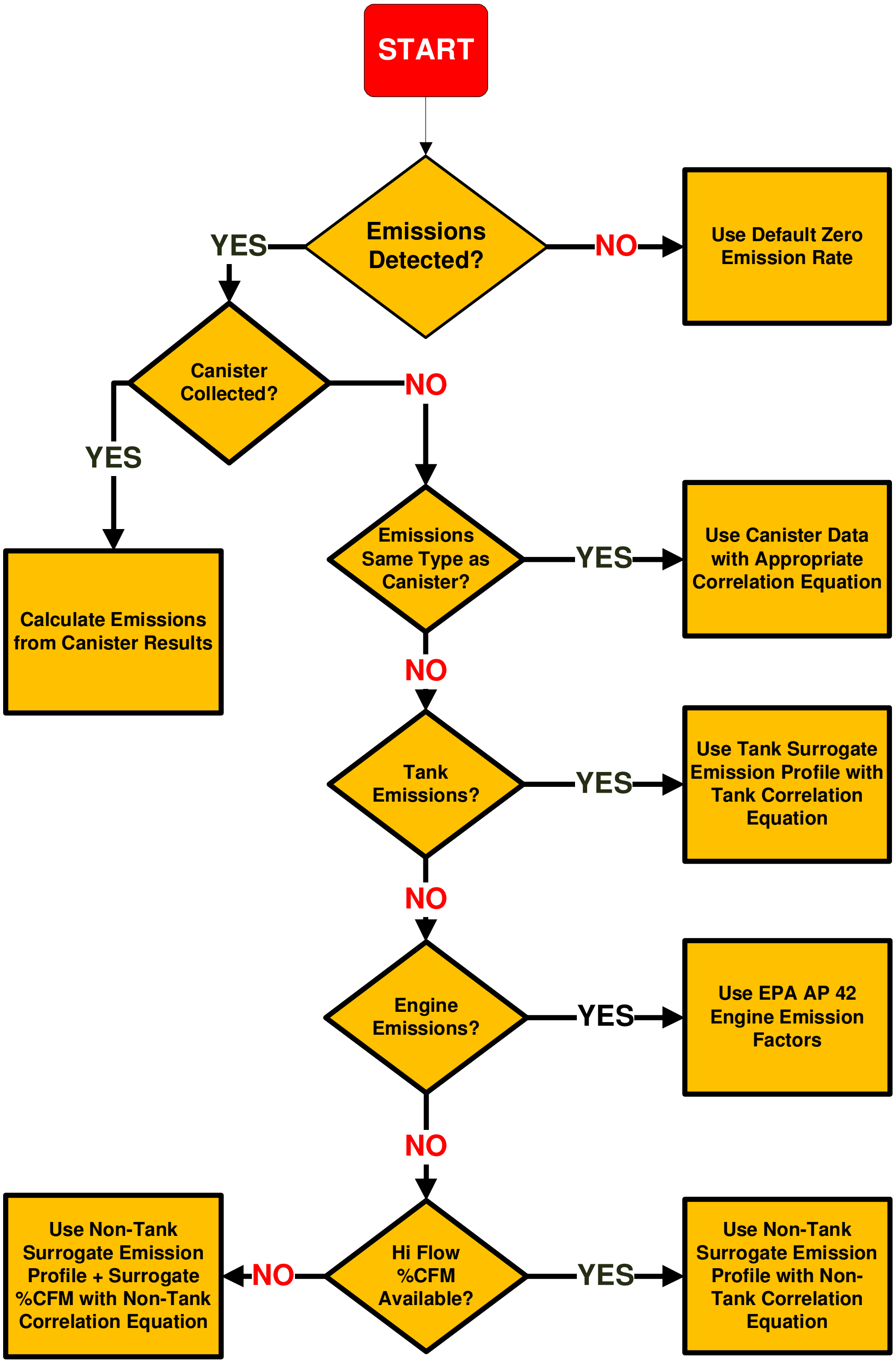


Figure 3.4-1. Emissions Calculation Flowchart

3.4.3 Indirect Emission Calculations -- Correlation Equation Development

The results of the canister samples were used to estimate emissions from those emission points that did not have a canister sample through the use of correlation equations. Two correlation equations, one for tank emissions and one for non-tank emissions, were developed based upon guidance from Section 2 and Appendix B of EPA's 1995 *Protocol for Equipment Leak Emission Estimates*.[7]

> ***KeyPoint: Normality Correction***
> To estimate emissions from those sources not directly sampled with a canister, a correlation equation was developed between the calculated TOC (lb/yr) and the corresponding measured % CFM from those sources that were sampled. Since the data used to develop the correlation was not normally distributed, it was necessary to normalize the data by taking the natural logarithm of the data. A scale bias correction factor was then used to convert back to the arithmetic space.

The first step in the development of the tank and non-tank correlation equations was the calculation of the natural logarithm of each canister's mass emission of total organic compounds (TOC) (lbs/yr) and its corresponding % CFM value.

The second step performed a linear regression in log space with the TOC values as the dependent variable (Y) and the % CFM values as the independent variable (X). The resulting regression line took the following form:

$$\text{Emission Rate} = \beta_0 + \beta_1(\%\ \text{CFM})$$

Where:

Emission Rate = Natural log of the leak rate determined by the canister results;

% CFM_i = Natural log of the % CFM_i;
β_0 = Intercept of regression line, and
β_1 = Slope of regression line.

The Mean Square Error (MSE) was then calculated by:

$$\text{MSE} = \frac{1}{n-2}\sum_{i=1}^{n} r_i^{2}$$

Where:
$r_i = Y_i - \beta_O - \beta_1 x_i.$

In the final step, the slope and intercept and a scale bias correction factor (SBCF) were used to transform the regression equations from log space to arithmetic space resulting in the tank and non-tank correlation equations:

$$\text{Leak Rate} = \text{SBCF} \times e^{\beta_0} \times \%\ \text{CFM}^{\beta_1}$$

Where:

Leak Rate = Emission rate of TOC's from the individual source (lb/yr)

SBCF = Scale Bias Correction Factor
β_0, β_1 = Regression constants, and
% CFM = Cubic feet per minute measured by the Hi Flow Sampler.

The SBCF corrects for the variability of the log space data. It was calculated by summing 15 significant numbers of the terms from the infinite series:

$$SBCF = 1 + \frac{(m-1)*T}{m} + \frac{(m-1)^3 * T^2}{m^2 * 2!*(m+1)} + \frac{(m-1)^5 * T^3}{m^3 * 3!*(m+1)*(m+3)} + ...$$

Where:
T = MSE/2.
MSE = mean square error from the regression.
m = number of data pairs.

3.4.4 Applying Canister Results to Non-Canister Emission Points

Canister-derived emission profiles were used to characterize non-canister emission points if 1) the non canister emission point was from the same site as the canister sample and 2) if the emission source types were the same (i.e. tank or non-tank).

For instance, if non-canister emissions were detected from a tank source, and if a canister had been collected at that site from another tank source, then that canister's data would be used to characterize the non-canister emission point. If the reverse was true, if the emissions were from a non-tank component, then a surrogate non-tank canister profile was used.

The distinction between tank and non-tank emission sources was made due to the differences in emissions characteristics observed between these two emission types. Tank emissions develop from the volatilization of heavier hydrocarbons entrained in the liquids produced by the facility separators, whereas non-tank emissions (i.e., particularly fugitive equipment leaks) are generally lighter gas emissions. Consequently, the chemical profile of each is somewhat different. For example, Table 3.4-1 provides a comparison of the average TOC, VOC, and HAP emissions resulting from a tank and non-tank canister sample collected during the study.

Table 3.4-1. Comparison of Emissions Between Tank and Non-Tank Emission Sources

Source Type (Canister Site ID)	TOC (tons/yr)	VOC (tons/yr)	HAP (tons/yr)
Non-Tank (PS-126)	6.65	0.01	0.00
Tank (295)	18.18	0.21	0.19

As indicated by the above comparison, tank emissions commonly exceed fugitive gas emissions.

Pairing a canister sample with a non-canister emission point provides the latter with a chemical composition. To calculate its emission rate, the Hi Flow Sampler results were used as follows:

1. The % CFM for the sample was entered into the correlation equation developed for the emission type (tank or non-tank) to determine the TOC mass emission rate.
2. The constituent contribution for each compound was determined from the weight percentages of the canister sample result.

This was done for each constituent so that the resulting products represented the speciated emission profile for the non-canister component.

For example, in Table 3.4-2 a canister sample (#A002) was collected from a leaking ¼-inch tubing connector – a non-tank sample type. Two other non-tank emission sources were detected at this site – a tee union connector and a pneumatically actuated valve. Since canister samples were not collected from these two sources, their emission profiles were be derived as follows:

1. The non-canister total organic compound emission rate was calculated by the non-tank correlation equation. For the tee union with a % CFM of 0.39 the TOC emission rate was 11,644.25 lb/yr calculated as:

   $$LR = 2.3759 * e^{9.674501743} * 0.39^{1.250318323} = 11{,}644.25 lbs / year .$$

   Where:
   LR = TOC Leak Rate.
   2.3759 = SBCF
   9.674502= non-tank correlation equation intercept.
   1.250318 = non-tank correlation equation slope.

2. Similarly, for the pneumatic valve which had a % CFM of 0.05 the TOC emission rate was 892.71 lb/yr calculated as:

   $$LR = 2.3443 * e^{9.674501743} * 0.05^{1.2502318323} = 892.71 lbs / year .$$

3. The non-canister emissions were assumed to have the same composition as the canister sample since they are both from the same site and from non-tank sources.

4. The speciated emissions of the non-canister were generated by multiplying the canister's speciated results by product of the ratio of each canister compound's emission to the canister TOC emission and the correlation equation TOC emission. The Tee union's methane emission rate, for instance, was 11,643.77 lbs/yr calculated as:

   $$\frac{13{,}993.20}{13{,}993.78} * 11{,}644.25 = 11{,}643.77 \text{ lbs/yr methane.}$$

Where:
13,993.20 = Canister CH_4 lbs/yr.
13,993.78 = Canister TOC lbs/yr.
11,644.25 = Correlation Equation TOC lbs/yr.

Table 3.4-2. Non-Canister Methane Emissions Calculation Example

Emission Pt.	HF % CFM	Canister ID	Methane (lbs/yr)	Methane (tons/yr)
¼-inch tubing	1.01	A002	13,993	6.99
Tee Union	0.39	--	11,644	5.82
Pneumatic Valve	0.05	--	893	0.45

3.4.5 Surrogate Canister Profiles

For emission points which could not be directly tied to a canister profile, either because a canister was not collected at the site or because the canister sample from the site was from a non-matching source (i.e. tank vs. non-tank), then a surrogate canister profile was used in the emissions calculations. Two canister surrogate emission profiles with the units of pounds/yr were developed: 1) a non-tank surrogate emission profile and 2) a tank surrogate emission profile (Table 3.4-3). The non-tank surrogate emission profile was used for components associated with valves, connectors, and other piping and instrumentation equipment located at well heads, metering runs, separator pads and compressor skids. The tank surrogate emission profile was used to characterize emissions primarily from tank thief hatches and tank relief vents.

Table 3.4-3. Surrogate Tank and Non-Tank Emission Profiles

Category	Type	TOC (pounds/yr)	Non-VOC (pounds/yr)	VOC (pounds/yr)	HAP (pounds/yr)
Wet/Dry Gas	Non-Tank	13,256	13,252	4.12	0.78
Wet/Dry Gas	Tank	27,786	27,768	17.20	4.12

An attempt was made to further distinguish between emissions from sites in wet gas service versus sites in dry gas service for both tank and non-tank sources, but the number of emission sources in wet gas service turned out to be too small to draw statistically reliable inferences. At wet gas sites, emissions were detected from only 3 tank component types and 6 non-tank component types. At least 30 data points are needed to form reliable statistical conclusions.

The two surrogate emission profiles were developed using standard statistical procedures referenced in EPA's 1995 *Protocol for Equipment Leak Emission Estimates*:

1. The canister data for each emission type was checked for normality using probability plots to evaluate the correlation between the data and a normal distribution.
2. Since, in both cases, the data turned out to be non-normal, a natural logarithmic transformation of both sets of canister data was performed.
3. The normality of the transformed data was again checked using probability plots and found to be sufficiently linear.
4. The surrogate compositions were determined as the anti-logarithmic mean of the transformed data.

For summary purposes, Table 3.4-2 indicates the surrogate emission profiles only for categories of compounds (i.e. TOC, VOC, etc.). It is important to note that each surrogate profile also contains the emission rates for all of the individual compounds found in the aggregate canister samples used to generate the surrogate emission profiles.

Once the use of a surrogate canister profile was applied to an emission point, the emission calculation was performed according to the procedures described above in Section 3.4.3.

In Phase I there were several instances in which a low level emission fell below the detection limit of the Hi Flow Sampler (this limitation was overcome in Phase II by measuring the hydrocarbon concentration of the Hi Flow Sampler's exhaust stream with the TVA). For these occasions a surrogate % CFM was derived as the anti-log mean value of the normalized % CFM readings recorded in Phase II with the TVA.

3.4.6 Calculation of Non-Sampled Low Level Emission Points

While all site piping and instrumentation equipment was surveyed with the IR camera for high level emissions, only ten percent of the components at a site were sampled for low level emissions using a TVA following Method 21 screening procedures. Two separate emission calculations were used to arrive at emission rate estimates for the ninety percent not screened with the TVA:

1. The percent of components found leaking in the Method 21 screening was applied to the total non-sampled population of valves and connectors at the site and the non-tank correlation equation was used to estimate their emissions.

2. The remaining components were assumed to be non-leaking and their emissions were calculated using the Synthetic Organic Chemical Manufacturing Industry (SOCMI) default zero values listed in EPA's 1995 *Protocol for Equipment Leak Emission Estimates* (Figure 3.4-2). Studies by EPA have demonstrated that non-leaking equipment actually have low level emissions. These emission values are termed "default zeros" and are routinely used across the petroleum industry in the calculation of emission inventories.

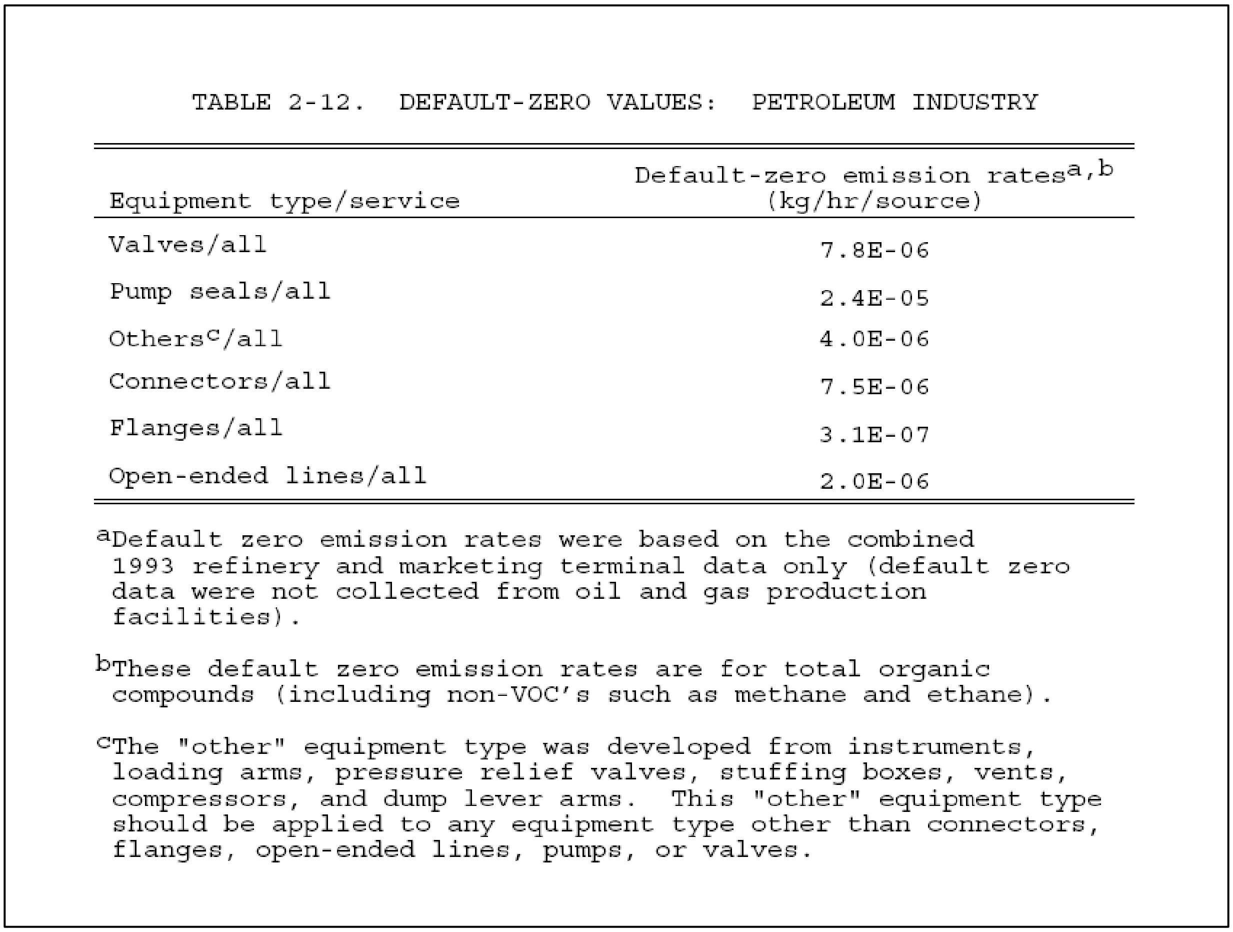


TABLE 2-12. DEFAULT-ZERO VALUES: PETROLEUM INDUSTRY

Equipment type/service	Default-zero emission rates[a,b] (kg/hr/source)
Valves/all	7.8E-06
Pump seals/all	2.4E-05
Others[c]/all	4.0E-06
Connectors/all	7.5E-06
Flanges/all	3.1E-07
Open-ended lines/all	2.0E-06

[a] Default zero emission rates were based on the combined 1993 refinery and marketing terminal data only (default zero data were not collected from oil and gas production facilities).

[b] These default zero emission rates are for total organic compounds (including non-VOC's such as methane and ethane).

[c] The "other" equipment type was developed from instruments, loading arms, pressure relief valves, stuffing boxes, vents, compressors, and dump lever arms. This "other" equipment type should be applied to any equipment type other than connectors, flanges, open-ended lines, pumps, or valves.

Figure 3.4-2. Default-Zero Values

As an example, a site component count indicates a site contains 150 valves and 1,050 connectors. Method 21 screening is therefore performed on 15 of the valves and 105 connectors (i.e. 10%). Emissions at or above 500 ppmv are detected on 3 of the valves (20%) and 2 of the connectors (1.9%). The remaining 135 valves and 945 connectors that were not monitored are assumed to have the same leak percentages. Accordingly an additional 27 valves (20% of 135) and 18 connectors (1.9% of 945) would be assumed to be leaking at this site. The emission rates of these components would be determined as follows:

1. For valves, the valve minor emission % CFM would be multiplied by 27. For connectors a multiplier of 18 would be used.
2. The resulting % CFMs would be entered into the non-tank correlation equation to calculate a single TOC emission for the additional 27 valves and a single TOC emission for the additional 18 connectors presumed leaking.
3. The calculated weight percentages from the non-tank surrogate profile would be applied to derive speciated emissions for each result.

The remaining 108 valves (135-27) and 927 connectors (945-18) would have the valve and connector default zero emission rates applied to them. This would be done by converting the default zero kg/hr emission rates to % CFM as methane. The resulting value would be then entered into the non-tank correlation equation to calculate TOC emissions. Speciated results would be obtained using the calculated weight percentages from the non-tank surrogate profile.

3.4.7 Compressor Engine Emissions

A total of 186 natural gas compressor engines were encountered during the site surveys. Of these, 150 were located at 123 well pad sites, 12 were located at the gas processing facility, 1 was located at the salt water treatment facility, and 23 were located at the eight line compressor stations. The majority of the compressor engines located on well pads functioned as lift compressors.

Emissions from compressor engines were derived from field data collected during the site surveys, vendor specification sheets and published emission factors. In calculating emissions for compressor engines, a 100% compressor duty cycle was conservatively assumed (i.e. 24 hours/day/ for 365 days/year). In addition, it was conservatively assumed that these engines were uncontrolled. Multiple XTO facilities were noted as having catalyst controls on their engines, but as stack testing of the exhaust from compressor engines was not included in the scope of this study, the control efficiency of these engines is unknown.

Key Point: Compressor Engine Controls
Emissions from compressor engines were estimated using the best available data collected during the point source testing. Where data was limited, conservative assumptions were used including but not limited to, the use of uncontrolled emission factors where controls where known to be present but no control efficiency data was readily available.

3.4.8 Well Drilling and Fracking Engine Emissions

Criteria pollutant, VOC and HAP emissions from natural gas and diesel engines used in well drilling and fracking operations were conservatively estimated based upon vendor specifications and published emission factors. Engine emissions from well drilling assume 504 hours of continuous operation (3 weeks, 7 days/week, 24 hours/day). Engine emissions associated with a fracking operation are based upon 120 hours of non-continuous operation (3 weeks, 5 days/week, 8 hours/day).

3.4.9 Calculation of Method 21 TOC Screening Emission Factors

Method 21 screening results were used to calculate VOC emission factors for non-tank equipment in natural gas service so that emissions due to future build out can be predicted based upon Method 21 monitoring results. Emission factors were calculated for the following equipment /screening categories:

- Valves: 500 ppmv to 999 ppmv and 1,000 ppmv to 10,000 ppmv.
- Connectors: 500 ppmv to 999 ppmv and 1,000 ppmv to 10,000 ppmv

- Other (sump pumps, pneumatic valve controllers, regulators, flow meters, knock-out pots, vents, etc.): 500 ppmv to 999 ppmv and 1,000 ppmv to 10,000 ppmv.

The emission factors were derived in a five step procedure:

1. Step 1: Filter for Phase II data since this data contained a larger data set of Hi Flow Sampler emission measurements for low level emissions.
2. Step 2: Sequentially filter the result of Step 1 by component type (valve, connector or other).
3. Step 3: Sequentially filter the result of Step 2 by the desired range of screening values (500 – 999 ppmv or 1000 – 10,000 ppmv).
4. Step 4: Sum the individual TOC emissions for the filtered results to produce total TOC emissions (lbs/hr) for each.
5. Calculate the emission factor for the selected component type and screening value range as the median of the Step 5 results and convert from pounds per hour to kilograms per hour.

3.5 Point Source Emissions Results

A total of 388 point source emissions sites were surveyed, including two repeated sites, for natural gas emissions in the point source study. Of these, 375 well pads and 8 compressor stations were visited, which comprised approximately 75% of the population. This section provides the point source survey results as TOC, VOC, HAP and Criteria Pollutant emissions in tons/yr. TOC are the sum of non-VOCs and VOCs. VOCs are the sum of non-HAP VOCs and HAPs. Criteria pollutants are VOCs, particulate matter (PM), Oxides of Nitrogen (NO_x), Carbon Monoxide (CO), and sulfur dioxide (SO_2).

Table 3.5-1 lists the average and maximum emission rates by site type. Emissions are extrapolated over a one year period (i.e. tons per year) for different site types. The average and maximum values are the same for processing and saltwater treatment facilities because only one of each was surveyed.

Table 3.5-1. Average and Maximum Point Source Emission Rates by Site Type[a]

Site Type	TOC (tons/yr)		VOC (tons/yr)		HAP (tons/yr)	
	Average	Max	Average	Max	Average	Max
Well Pad	16	445	0.07	8.6	0.02	2
Well Pad with Compressor(s)	68	4433	2	22	0.9	8.8
Compressor Station	99	276	17	43	10	25
Processing Facility	1,293	1,293	80	80	47	47
Saltwater Treatment Facility	1.5	1.5	0.65	0.65	0.4	0.4

[a] For values reported as <0.01 see Appendix 3-A for actual emissions expressed in scientific notation.

Table 3.5-2 summarizes the average emission volumes for each site type as measured by the Hi Flow Sampler. Note that engine emission volumes are not included in this table.

Table 3.5-2. Average Point Source Emission Volumes by Site Type

Site Type	TOC (cubic feet/yr)
Well Pad	148,552
Well Pad with Compressor(s)	218,035
Compressor Station	188,236
Processing Facility	372,019
Saltwater Treatment Facility	526

Table 3.5-1 shows the contribution compressor engines make to total site-wide emissions. In addition to increasing TOC, VOC and HAP emissions, the exhaust from a compressor engine contains the criteria pollutants (PM, SO_2, CO and NO_x). By way of illustration, Figure 3.5-1 compares the average annual emissions from a well pad without a compressor to one with a compressor. Clearly, compressor engines are a significant contributor of emissions at natural gas-related facilities.

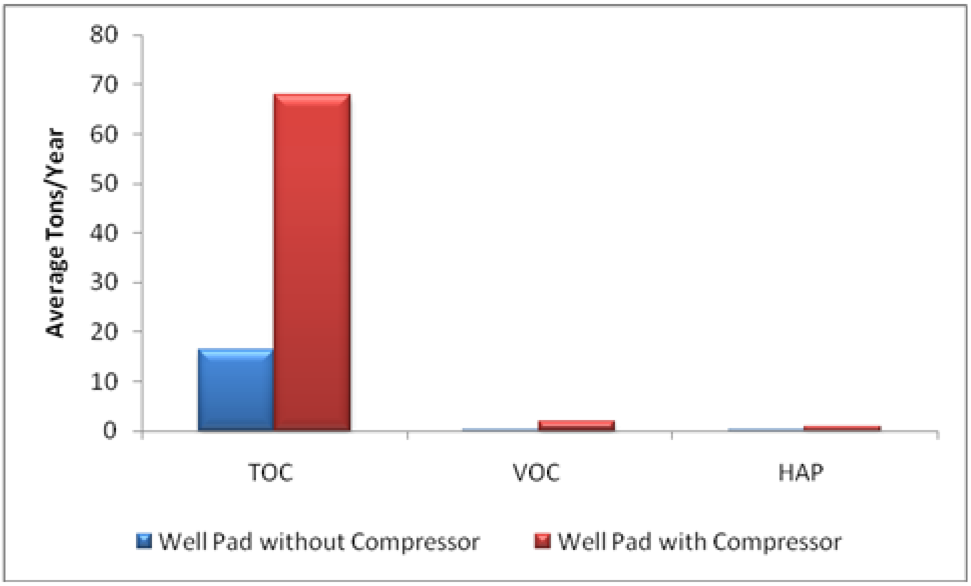


Figure 3.5-1. The Effect of Compressors on Site Emissions

Table 3.5-3 summarizes the emissions rates for all criteria pollutants and HAPs per each site surveyed during the point source testing. For each site, the summary provides the number of emission sources by type (e.g., compressor engines, storage tanks, fugitive leaks) and their contribution to total site-wide VOCs. Furthermore, the table provides for each site surveyed, the number of leaks detected by the IR camera and the number of leaks detected above 500 ppm using Method 21 screening.

Table 3.5-3. Point Source Emissions Summary by Site [a]

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-001	16791 WOODSIDE DR	WELL PAD	2	89	384	2	0	6	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-002	2098 BRENNAN; F6	WELL PAD	3	347	2040	10	1	7	4	0.05	0.70	18.85	<0.01	0.68	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-003	16616 FORD OAKS LN; F1	WELL PAD	1	65	320	2	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-004	2033 J CHESHEIR RD; F1	WELL PAD	1	73	286	1	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-005	SAM REYNOLDS; F1	WELL PAD	1	76	710	2	0	4	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-006	1101 HWY 114; F1	WELL PAD	1	59	590	2	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-007	1850 BLK HWY 114; F1	WELL PAD	1	22	220	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-008	2690 HWY 114 (BEECH) (C-PAD); F1	WELL PAD	3	214	2140	3	0	1	2	-0-	-0-	-0-	-0-	0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-009	2690 HWY 114 (BEECH) (B-PAD); F1	WELL PAD	2	198	1386	2	0	5	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-010	2598 HWY 114 (BEECH) (A-PAD); F1	WELL PAD	2	109	388	1	0	4	3	-0-	-0-	-0-	-0-	0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-011	15096 AMERICAN WAY (A-COMMERCE) (B-PAD); F1	WELL PAD	2	128	984	6	0	4	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-012	12601 KATY RD; G1	WELL PAD	1	207	1149	2	1	0	3	0.01	3.18	5.21	<0.01	0.17	0.17	<0.01	<0.01	0.10	0.07	<0.01
PS-013	CAYLOR RD; G3	WELL PAD	1	65	390	1	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-014	12497 OLD DENTON RD POWELL 1; G3	WELL PAD	1	8	48	0	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-015	12497 OLD DENTON RD POWELL 2; G3	WELL PAD	2	113	791	3	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-016	12698 OLD DENTON RD; G3	WELL PAD	1	9	56	0	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-017	12498 ALTA VISTA ; G3	WELL PAD	1	105	735	1	1	1	4	0.04	0.57	11.17	<0.01	0.58	0.58	<0.01	<0.01	0.34	0.23	<0.01
PS-018	3897 LITSEY RD; G1	WELL PAD	3	234	1190	6	1	4	0	0.05	0.70	18.85	<0.01	0.68	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-019	15695 NORTH FWY (BEECH) (E-PAD); G3	WELL PAD	5	298	1888	5	0	3	4	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-020	2660 PETTY PLACE; G1	WELL PAD	1	77	548	2	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-021	16280 3 WILD DRIVE; G1	WELL PAD	3	172	1204	3	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-022	2898 HWY 114; G1	WELL PAD	2	87	609	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-023	2297 SILVER CREEK RD; C6	WELL PAD	1	53	371	2	0	1	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-024	2297 SILVER CREEK RD (PAD 2); C6	WELL PAD	2	82	574	3	0	0	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-025	3193 JIMISONS LN (XTO) (SURBER CA/CWS); J6	WELL PAD	3	209	1254	4	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-026	11494 MOSIER VALLEY RD (XTO) (REGAN); J6	WELL PAD	1	77	440	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-027	11468 MOSIER VALLEY RD (XTO) (KNAPP); J6	WELL PAD	1	84	500	1	0	0	3	-0-	-0-	-0-	-0-	0.01	<0.01	0.01	<0.01	<0.01	-0-	<0.01
PS-028	11693 MOSIER VALLEY RD (XTO) (EULESS A); J6	WELL PAD	4	273	1530	4	0	3	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-028.1	14193 JOHN DAY RD (H-PAD); E1	WELL PAD	2	96	672	2	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-029	14193 JOHN DAY RD (G-PAD); E1	WELL PAD	4	209	1449	4	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-030	14193 JOHN DAY RD (F-PAD); E1	WELL PAD	3	136	952	3	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-031	14193 JOHN DAY RD (D-PAD); E1	WELL PAD	1	48	336	1	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-032	11591 TRINITY BLVD (XTO) (EULESS C); J6	WELL PAD	1	78	468	1	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-033	11696 MOSIER VALLEY RD (XTO) (JW ARLINGTON); J6	WELL PAD	4	255	1300	4	0	2	3	-0-	-0-	-0-	-0-	0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-034	12196 TRINITY BLVD (XTO) (EULESS B); J6	WELL PAD	5	214	1284	5	0	0	2	-0-	-0-	-0-	-0-	0.01	<0.01	0.01	<0.01	<0.01	-0-	<0.01
PS-035	141931 JOHN DAY RD (C-PAD); E1	WELL PAD	1	50	350	1	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-036	14193 JOHN DAY RD (A-PAD); E1	WELL PAD	2	117	819	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-037	14193 JOHN DAY RD (E-PAD); E1	WELL PAD	2	105	735	2	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-038	14193 JOHN DAY RD (B-PAD); E1	WELL PAD	1	65	455	1	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-039	493 AVONDALE HASLET RD (DEVON) (GARNETT-LAPRELLE); E2	WELL PAD	2	194	1620	2	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-040	493 AVONDALE HASLET RD (XTO) (HUFFMAN); E2	WELL PAD	2	137	1218	3	0	2	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-041	1701 AVONDALE HASLET RD (DEVON) (MOSS) (A-PAD); E2	WELL PAD	2	140	840	1	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-042	1701 AVONDALE HASLET RD (DEVON) (MOSS) (B-PAD); E2	WELL PAD	2	150	1244	2	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-043	1502 AVONDALE HASLET RD (DEVON) (MORRIS HARMONSON) (F-PAD); E2	WELL PAD	2	131	917	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-044	1400 AVONDALE HASLET RD (DEVON) (MORRIS HARMONSON) (C-PAD); E2	WELL PAD	1	57	342	2	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS[b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-045	4594 HWY 360 SOUTH PAD; K5	WELL PAD	1	160	1120	3	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-046	10896 TRINITY BLVD; J6	WELL PAD	2	255	1785	3	0	1	4	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-047	1480 AVONDALE HASLET RD (DEVON) (MORRIS HARMONSON) (E-PAD); E2	WELL PAD	3	203	1421	3	0	0	4	-0-	-0-	-0-	-0-	0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-048	13800 SENDERA RANCH BLVD (DEVON) (MORRIS HARMONSON) (A-PAD); E2	WELL PAD	3	178	1176	3	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-049	694 AVONDALE HASLET (DEVON) (LBJ) (B-PAD); E2	WELL PAD	1	60	420	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-050	694 AVONDALE HASLET RD (XTO) (SONNY NANCE) (A-PAD); E2	WELL PAD	2	68	340	0	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-051	694 AVONDALE HASLET RD (XTO) (SONNY NANCE) (B-PAD); E2	WELL PAD	1	22	154	0	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-052	694 AVONDALE HASLET (DEVON) (LBJ) (K-PAD); E2	WELL PAD	2	127	889	2	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-053	694 AVONDALE HASLET RD (XTO) (SONNY NANCE) (C-PAD); E2	WELL PAD	1	86	516	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-054	694 AVONDALE HASLET (BOAZ) (N-PAD); E2	WELL PAD	3	196	1332	3	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-055	12494 HWY 287 (DEVON) (PHASE 3) (A-PAD); E2	WELL PAD	1	63	441	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-056	290 BLUE MOUND RD (DEVON) (GARNETT-LAPRELLE) (B-PAD); E2	WELL PAD	2	137	822	2	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-057	4950 PAINT HORSE DR; G6	WELL PAD	6	291	2037	3	0	7	8	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-058	2796 PREMIER ST; G6	WELL PAD	1	197	1429	4	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-059	694 AVONDALE HASLET (DEVON) (LBJ) (A-PAD); E2	WELL PAD	1	62	434	1	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-060	694 AVONDALE HASLET (DEVON) (LBJ) (D-PAD); E2	WELL PAD	2	137	959	4	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-061	694 AVONDALE HASLET (DEVON) (LBJ) (E-PAD); E2	WELL PAD	1	69	414	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-062	1400 AVONDALE HASLET RD (DEVON) (MORRIS HARMONSON) (D-PAD); E2	WELL PAD	1	63	441	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-064	694 AVONDALE HASLET (DEVON) (LBJ) (F-PAD); E2	WELL PAD	2	120	840	4	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-065	694 AVONDALE HASLET (DEVON) (LBJ) (J-PAD); E2	WELL PAD	2	126	882	4	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-066	3399 E LONG AVE; G6	WELL PAD	5	472	5345	3	3	11	18	0.32	4.71	47.67	0.02	4.74	4.71	0.01	0.01	2.80	1.89	0.07

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-067	694 AVONDALE HASLET (DEVON) (LBJ) (G-PAD); E2	WELL PAD	2	118	708	3	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-068	694 AVONDALE HASLET (DEVON) (LBJ) (H-PAD); E2	WELL PAD	1	62	372	1	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-069	694 AVONDALE HASLET (DEVON) (LBJ) (I-PAD); E2	WELL PAD	1	47	329	1	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-070	694 AVONDALE HASLET (DEVON) (LBJ) (M-PAD); E2	WELL PAD	3	200	1230	3	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-071	694 AVONDALE HASLET (DEVON) (LBJ) (L-PAD); E2	WELL PAD	1	62	434	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-072	2292 N TARRANT PKWY; F4	WELL PAD	4	438	3456	8	1	14	9	0.10	1.50	17.21	<0.01	1.39	1.38	0.01	<0.01	0.82	0.55	0.02
PS-073	693 AVONDALE HASLET (DEVON) (LBJ) (O-PAD); E2	WELL PAD	1	59	416	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-074	693 AVONDALE HASLET (DEVON) (LBJ) (N-PAD); E2	WELL PAD	1	65	390	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-075	693 AVONDALE HASLET (DEVON) (LBJ) (Q-PAD); E2	WELL PAD	2	126	882	4	0	2	1	-0-	-0-	-0-	-0-	3.57	<0.01	<0.01	3.57	0.72	-0-	<0.01
PS-076	693 AVONDALE HASLET (DEVON) (LBJ) (R-PAD); E2	WELL PAD	1	85	425	2	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-077	693 AVONDALE HASLET (DEVON) (LBJ) (S-PAD); E2	WELL PAD	2	147	735	3	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-078	1300 BLUFF SPRINGS RD (DEVON) (BOAZ) (B-PAD); E2	WELL PAD	1	54	324	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-079	1301 BLUFF SPRINGS RD (DEVON) (BOAZ) (C-PAD); E2	WELL PAD	1	60	360	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-080	1101 DURANGO SPRINGS DR (DEVON) (BOAZ) (A-PAD); E2	WELL PAD	1	61	376	1	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-081	1417 WHISPER WILLOWS (DEVON) (BOAZ) (D-PAD); E2	WELL PAD	1	50	315	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-082	8191 HORSEMAN RD; F4	WELL PAD	4	508	3646	6	1	8	3	0.15	2.00	6.38	<0.01	2.18	2.18	<0.01	<0.01	1.29	0.87	0.03
PS-083	9191 BLUE MOUND RD; F4	WELL PAD	1	152	1064	3	1	4	4	0.04	0.57	11.17	<0.01	0.59	0.58	<0.01	<0.01	0.35	0.23	<0.01
PS-084	7598 BLUE MOUND RD; F4	WELL PAD	1	109	763	2	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-085	2591 BASSWOOD BLVD; F4	WELL PAD	4	368	2100	5	1	4	5	0.10	1.57	5.02	<0.01	1.38	1.38	<0.01	<0.01	0.82	0.55	0.02
PS-086	11398 WEST FWY; B8	WELL PAD	3	217	1519	6	0	4	8	-0-	-0-	-0-	-0-	8.65	<0.01	8.65	<0.01	1.99	-0-	0.02
PS-087	4496 LOST CREEK BLVD; B8	WELL PAD	1	83	581	4	0	4	2	-0-	-0-	-0-	-0-	0.20	<0.01	0.20	<0.01	0.02	-0-	<0.01
PS-088	10293 OLD WEATHERFORD RD; C7	WELL PAD	2	130	910	4	0	2	4	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-090	14193 JOHN DAY RD (DEVON) (I-POOL PAD); E2	WELL PAD	2	101	707	2	0	3	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-091	14193 JOHN DAY RD (DEVON) (L-POOL PAD); E2	WELL PAD	1	62	372	1	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-092	14193 JOHN DAY RD (J-POOL PAD); E2	WELL PAD	1	68	476	1	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-093	14193 JOHN DAY RD (K-BLAKLEY PAD); E2	WELL PAD	4	198	1336	3	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-094	14193 JOHN DAY RD (M-BLAKLEY PAD); E2	WELL PAD	2	122	732	2	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-095	14193 JOHN DAY RD (N-BLAKLEY PAD); E2	WELL PAD	5	216	1512	3	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-096	14193 JOHN DAY RD (W-BLAKLEY PAD); E2	WELL PAD	4	283	1698	4	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-097	14193 JOHN DAY RD (O-POOL PAD); E2	WELL PAD	2	134	1164	2	0	1	9	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-098	14193 JOHN DAY RD (P-BLAKLEY PAD); E2	WELL PAD	5	225	1870	3	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-099	14293 SNAFFLE BIT TRL (Q-BLAKLEY PAD); E2	WELL PAD	4	258	2020	4	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-100	14193 JOHN DAY RD (U-BLAKLEY PAD); E2	WELL PAD	7	480	4016	7	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-101	14193 JOHN DAY RD (V-BLAKLEY PAD); E2	WELL PAD	5	131	1870	3	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-102	9767 VERNA TRAIL N; C7	WELL PAD	4	288	1816	4	0	5	4	-0-	-0-	-0-	-0-	0.53	<0.01	0.53	<0.01	0.07	-0-	0.02
PS-103	1299 W LOOP 820; C7	WELL PAD	1	65	455	2	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-104	9798 WESTPOINT DR; C7	WELL PAD	2	203	1550	2	1	0	8	0.07	1.04	2.91	<0.01	1.01	1.01	<0.01	<0.01	0.60	0.40	0.01
PS-105	9596 OLD WEATHERFORD; C7	WELL PAD	1	103	721	2	0	0	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-106	10590 OLD WEATHERFORD; B7	WELL PAD	2	142	994	4	0	2	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Connectors	No. Tanks	No. Compressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formaldehyde	Benzene
PS-107	5291 EVERMAN KENNEDALE BURLESON RD (CFW SOUTH); H10	WELL PAD	4	286	2002	4	1	0	3	0.07	0.98	32.48	<0.01	1.22	0.99	0.23	<0.01	0.64	0.40	0.03
PS-108	7196 WICHITA (GARRETT); G9	WELL PAD	2	105	805	2	0	0	1	-0-	-0-	-0-	-0-	0.02	<0.01	<0.01	0.02	<0.01	-0-	<0.01
PS-109	5691 CA ROBERSON BLVD (FWISD); G9	WELL PAD	8	547	3329	10	2	3	1	0.09	1.40	37.69	<0.01	1.40	1.36	<0.01	0.04	0.81	0.55	0.02
PS-110	2400 BLK CAMPUS ST (SMP); G9	WELL PAD	1	68	476	2	1	2	1	0.05	0.70	18.85	<0.01	0.68	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-111	11495 WHITE SETTLEMENT RD (B-PAD); B7	WELL PAD	3	224	1568	4	0	3	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-112	10595 WEST CLEBURNE RD; E11	WELL PAD	6	549	4480	8	1	9	8	0.05	0.70	18.85	<0.01	0.69	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-113	10495 W CLEBURNE; E11	WELL PAD	3	236	2744	3	2	5	7	0.09	1.40	37.69	<0.01	1.38	1.36	<0.01	0.01	0.81	0.55	0.02
PS-114	6599 OAK GROVE RD (CARTER TRUST); G9	WELL PAD	3	316	2212	3	2	6	10	0.82	13.33	69.56	0.05	11.99	11.93	0.02	0.03	7.10	4.79	0.17
PS-115	10296 OLD CLEBURNE CROWLEY RD; E11	WELL PAD	1	146	1399	2	1	5	7	0.05	0.70	18.85	<0.01	0.69	0.68	<0.01	<0.01	0.41	0.27	0.01
PS-116	10699 OLD GRANDBURY RD; D11	WELL PAD	6	632	5022	8	1	9	12	0.05	0.70	18.85	<0.01	0.69	0.68	<0.01	<0.01	0.41	0.27	<0.01
PS-117	3595 ANGLE RD	WELL PAD	7	31	207	6	1	0	4	0.05	0.70	18.85	<0.01	0.70	0.68	<0.01	0.02	0.41	0.27	0.01
PS-118	590 NW LOOP 820; KS	COMPRESSOR STATION	0	1414	9888	3	6	2	7	0.02	51.42	269.95	0.18	42.69	42.59	<0.01	0.11	25.31	17.08	0.60
PS-119	6900 E ROSEDALE; I8; KS	COMPRESSOR STATION	0	985	6895	8	7	5	9	0.02	45.77	240.30	0.16	37.80	37.79	<0.01	0.01	22.46	15.16	0.53
PS-120	2298 E 4TH ST; F7; KS	COMPRESSOR STATION	0	325	2548	1	1	2	11	0.05	0.70	18.85	<0.01	0.72	0.68	<0.01	0.03	0.41	0.27	0.01
PS-121	7091 OAK GROVE; G10; KS	COMPRESSOR STATION	0	208	1456	0	1	0	3	<0.01	5.07	11.76	0.02	4.88	4.87	<0.01	<0.01	2.90	1.95	0.07

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-122	7091 OAK GROVE; G10	WELL PAD	4	208	1456	4	0	3	5	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-123	7695 OAK GROVE; G10	WELL PAD	5	204	1408	6	0	5	6	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-124	7695 OAK GROVE; G10; KS	COMPRESSOR STATION	5	242	1694	6	2	1	5	<0.01	10.14	23.52	0.04	9.76	9.75	<0.01	0.01	5.79	3.91	0.14
PS-125	7997 SOUTH FWY; G10; KS	COMPRESSOR STATION	2	357	4020	4	1	7	13	0.41	6.66	34.78	0.03	6.42	5.97	<0.01	0.45	3.56	2.39	0.09
PS-126	7997 SOUTH FWY; G10	WELL PAD	2	128	896	4	0	1	4	-0-	-0-	-0-	-0-	0.02	<0.01	0.01	<0.01	<0.01	-0-	<0.01
PS-127	5296 BAILEY BOSWELL; E4; KS	COMPRESSOR STATION	0	414	2898	4	3	6	11	1.61	24.33	545.08	0.10	23.70	23.56	0.11	0.04	14.02	9.45	0.34
PS-128	580 E ROSEDALE	DRILLING OPERATION	0	0	0	0	0	0	0	0.37	11.74	6.42	4.51	0.04	0.04	<0.01	<0.01	0.01	<0.01	<0.01
PS-129	10091 OLD GRANBURY RD; D11	WELL PAD	3	212	1913	4	1	2	9	0.05	0.70	18.85	<0.01	0.92	0.68	0.21	0.03	0.42	0.27	0.02
PS-130	6597 OAK GROVE (CARTER ALCON); G9	WELL PAD	5	517	3619	5	0	1	7	-0-	-0-	-0-	-0-	0.29	<0.01	0.25	0.04	0.06	-0-	0.03
PS-131	6799 OAK GROVE (CARTER TRUST); G9	WELL PAD	3	244	2458	3	1	1	3	0.07	0.98	32.48	<0.01	0.99	0.99	<0.01	<0.01	0.59	0.40	0.01
PS-132	2795 QUAIL RD (EXELON); H8	WELL PAD	4	338	2296	4	0	3	3	-0-	-0-	-0-	-0-	0.02	<0.01	<0.01	0.02	<0.01	-0-	<0.01
PS-133	6099 WILBARGER (OLCOTT SOUTH); H8	WELL PAD	8	613	4291	6	0	6	5	-0-	-0-	-0-	-0-	0.27	<0.01	0.27	<0.01	0.07	-0-	0.02
PS-134	5199 VILLAGE CREEK RD; H9	COMPLETION OPERATION	4	0	0	0	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-135	6293 HATCHERY RD; D6	WELL PAD	5	279	1953	5	1	1	17	0.05	0.70	18.85	<0.01	1.42	0.68	0.04	0.70	0.44	0.27	0.02
PS-136	6497 SHADY OAKS MANOR RD; D6	WELL PAD	3	232	2027	3	1	3	12	0.05	0.70	23.20	<0.01	1.06	0.71	0.05	0.31	0.45	0.28	0.02
PS-137	6791 NW LOOP 820; D6	WELL PAD	3	161	1127	3	0	1	6	-0-	-0-	-0-	-0-	0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-138	4993 FREEMAN DR (KATES); H9	WELL PAD	1	84	588	1	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-139	7797 E LANCASTER AVE (GREEN OAKS); I8	WELL PAD	6	603	4219	6	2	6	6	0.09	1.40	37.69	<0.01	1.37	1.36	<0.01	0.01	0.81	0.55	0.02
PS-140	6896 NW LOOP 820; D6	WELL PAD	4	227	1589	4	0	2	5	-0-	-0-	-0-	-0-	0.05	<0.01	0.01	0.04	<0.01	-0-	<0.01
PS-141	2693 ROBERTS CUT-OFF RD; D6	WELL PAD	2	123	861	2	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-142	3291 NW LOOP 820; E6	WELL PAD	2	158	1706	2	1	0	11	0.05	0.70	23.20	<0.01	0.76	0.71	0.04	0.01	0.43	0.28	0.01
PS-143	3091 NW LOOP 820; E6	WELL PAD	3	116	813	3	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-144	2399 DOTTIE LYNN (SOWELL N); I7	WELL PAD	4	419	2933	4	2	9	5	0.11	1.74	21.75	<0.01	1.70	1.69	<0.01	0.01	1.01	0.68	0.02
PS-145	6093 WILBARGER (OLCOTT NORTH); H8	WELL PAD	12	366	2562	0	0	7	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-146	5693 E LOOP 820 S (DUKE); H9	WELL PAD	2	199	1393	2	0	4	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-147	5195 E LOOP 820 S (820 MARTIN); H9	WELL PAD	8	536	3752	4	1	9	8	0.05	0.70	18.85	<0.01	0.83	0.68	0.14	0.02	0.44	0.27	0.02
PS-148	3093 NW LOOP 820; E6	WELL PAD	2	202	1817	2	1	2	13	0.07	0.98	32.48	<0.01	1.14	0.99	0.12	0.03	0.62	0.40	0.02
PS-149	7500 RANDOL MILL RD (BLAKEMAN); I7	WELL PAD	1	129	903	1	1	0	2	0.07	0.98	32.48	<0.01	1.01	0.99	0.02	<0.01	0.59	0.40	0.02
PS-150	7891 RANDOL MILL RD (MORRIS); I7	WELL PAD	1	121	847	1	1	1	0	0.05	0.70	23.20	<0.01	0.71	0.71	<0.01	<0.01	0.42	0.28	<0.01
PS-151	8096 RANDOL MILL RD (DOREX); I7	WELL PAD	1	121	847	2	1	0	2	0.05	0.70	18.85	<0.01	0.68	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-152	8390 RANDOL MILL RD (BUZZYS); I7	WELL PAD	2	143	1001	2	1	1	4	0.01	3.18	5.21	<0.01	0.18	0.17	<0.01	<0.01	0.10	0.07	<0.01
PS-153	2298 PRECINCT LINE (DUCK LAKE) (D-PAD); I7	WELL PAD	2	151	1057	3	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-153.1	2298 PRECINCT LINE (DUCK LAKE) (B-PAD); I6	WELL PAD	4	0	0	3	1	0	0	0.05	0.70	18.85	<0.01	0.68	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-154	8091 BRENTWOOD STAIR RD (CLANECO); I7	WELL PAD	1	154	1078	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-155	3598 ANGLE AVE; E6	WELL PAD	2	108	756	1	0	2	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-156	2095 NW LOOP 820; E6	WELL PAD	4	234	1638	4	0	3	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-157	4592 ANGLE AVE (LS); E6	WELL PAD	4	198	1386	2	0	2	6	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-158	3491 LINCOLN AVE (A-PAD); E6	WELL PAD	2	107	749	2	0	1	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-159	10488 HICKS FIELD RD (CROSSTEX AMINE TREATMENT CENTER)	PROCESSING FACILITY	0	1800	12590	10	12	10	67	1.00	87.74	1038.90	0.34	79.93	79.58	<0.01	0.34	47.32	31.93	1.14
PS-160	7595 E LANCASTER AVE (BOSWELL); I8	WELL PAD	7	429	3007	0	0	4	6	-0-	-0-	-0-	-0-	0.02	<0.01	<0.01	0.02	<0.01	-0-	<0.01
PS-161	7397 RANDOL MILL RD (DUCKHEAD); I6	WELL PAD	3	256	2176	0	1	4	4	0.07	1.04	2.91	<0.01	1.01	1.01	<0.01	<0.01	0.60	0.40	0.01
PS-162	1999 PRECINCT RD (RIVERBEND); I6	WELL PAD	2	226	1869	6	1	1	2	0.05	0.70	18.85	<0.01	0.69	0.68	<0.01	<0.01	0.41	0.27	<0.01
PS-163	490 E RENDON CROWLEY RD (N SPINKS); G11	WELL PAD	3	212	1484	4	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-164	14091 STONE RD (S SPINKS); G11	WELL PAD	4	260	1820	4	2	5	6	0.09	1.40	37.69	<0.01	1.36	1.36	<0.01	<0.01	0.81	0.55	0.02
PS-165	7996 TRAMMEL DAVIS RD (DUCK LAKE) (A-PAD); I6	WELL PAD	6	356	2492	2	1	1	4	0.05	0.70	18.85	<0.01	0.68	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-166	9799 TRAMMEL DAVIS RD (TXI A); I6	WELL PAD	1	140	973	2	1	0	3	0.05	0.70	18.85	<0.01	0.68	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-167	3198 S NORWOOD DR (TXI); I6	WELL PAD	1	144	1008	2	1	1	5	0.05	0.70	18.85	<0.01	0.78	0.68	0.10	<0.01	0.43	0.27	0.02

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-168	9992 TRINITY BLVD (BELL) (B-PAD); I6	WELL PAD	3	264	1848	6	1	2	3	0.05	0.70	18.85	<0.01	0.68	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-169	10190 TRINITY BLVD (BELL) (A-PAD); I6	WELL PAD	3	264	1848	4	1	1	2	0.05	0.70	18.85	<0.01	0.68	0.68	<0.01	<0.01	0.40	0.27	<0.01
PS-170	4697 ENON RD (KARANGES); G10	WELL PAD	3	273	1911	3	1	0	6	0.07	0.98	32.48	<0.01	1.09	0.99	<0.01	0.09	0.61	0.40	0.02
PS-171	3892 LON STEVENSON RD (WALLS COLEMAN); G10	WELL PAD	4	433	3031	4	2	3	6	0.14	1.96	64.96	<0.01	2.02	1.98	0.04	<0.01	1.19	0.79	0.03
PS-172	8290 ANGLIN CR (MOORE); G10	WELL PAD	3	161	1127	3	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-173	2999 LANA LN (HOSLER); G10	WELL PAD	3	183	1281	5	0	3	1	-0-	-0-	-0-	-0-	0.03	<0.01	<0.01	0.03	<0.01	-0-	<0.01
PS-174	5591 E 1ST ST (CARTER STATE) (SALT WATER DISPOSAL SITE); G7	SALTWATER TREATMENT FACILITY	3	211	1477	8	1	3	0	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
PS-176	1375 OAK GROVE SHELBY RD (SHULTZ); G10	WELL PAD	1	54	378	1	0	2	2	-0-	-0-	-0-	-0-	0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-177	9499 SOUTH RACE ST (HARRISON); G10	WELL PAD	1	88	616	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-178	10198 FOREST HILL EVERMAN RD (MISSION) (A-PAD); G10	WELL PAD	2	183	1775	2	1	1	2	0.07	0.98	32.48	<0.01	1.01	0.99	0.02	<0.01	0.59	0.40	0.01
PS-179	3691 MOPAC (PEARSON); E8	WELL PAD	4	30	210	0	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-180	695 E NORTHSIDE DR (STOCKYARDS); F7	WELL PAD	3	70	490	4	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-181	3298 VAN HORN AVE (CRAIN); G7	WELL PAD	1	75	525	3	0	1	2	-0-	-0-	-0-	-0-	0.02	<0.01	0.02	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-182	691 BEACH ST (FROST); G7	WELL PAD	3	115	705	4	0	2	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-184	10590 CHAPIN RD (CHAPEL CREEK); E9	WELL PAD	1	144	2408	2	1	0	12	0.30	4.01	12.76	0.02	22.32	4.36	<0.01	17.95	4.09	1.75	0.16
PS-185	10199 OAK GROVE RD (BEAN) (A-PAD); G10	WELL PAD	3	143	1001	3	0	0	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-186	394 EVERMAN PKWY (MARITZ); F10	WELL PAD	4	207	1449	4	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-187	9198 FORUM WAY (UNION PACIFIC); F10	WELL PAD	3	166	1162	3	0	3	4	-0-	-0-	-0-	-0-	0.01	<0.01	0.01	<0.01	<0.01	-0-	<0.01
PS-188	1298 W RISINGER RD (HOLT HICKMAN); F10	WELL PAD	2	117	819	2	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-189	2990 BRASWELL DR (RP STEPHENS); F6	WELL PAD	1	83	797	1	1	0	0	0.01	3.18	5.21	<0.01	0.17	0.17	<0.01	<0.01	0.10	0.07	<0.01
PS-190	796 MEACHAM BLVD (PRIME RAIL); F6	WELL PAD	3	146	1022	3	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-191	3592 DEEN RD; F6	WELL PAD	3	173	1211	3	0	3	4	-0-	-0-	-0-	-0-	0.05	<0.01	0.04	<0.01	<0.01	-0-	<0.01
PS-192	2299 MERCADO DRIVE; F6	WELL PAD	10	616	4312	13	2	6	12	0.13	2.08	5.81	<0.01	2.20	2.01	0.15	0.03	1.26	0.81	0.06
PS-193	5900 WILLBARGER (FRACKING JOB)	FRACKING OPERATION	3	0	0	0	0	0	0	0.51	16.37	8.26	5.82	0.05	0.05	<0.01	<0.01	0.02	<0.01	<0.01
PS-194	10395 CAMP BOWIE W (JOHNSON HUBBELL); E9	WELL PAD	1	93	652	2	0	0	4	-0-	-0-	-0-	-0-	0.02	<0.01	0.02	<0.01	<0.01	-0-	<0.01
PS-195	3497 LONGVUE (HAVENER); E9	WELL PAD	2	134	938	4	0	2	9	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-196	792 DE COSTA (EASTSIDES); G7	WELL PAD	4	215	1405	3	2	0	8	0.16	4.83	16.69	0.02	4.98	4.85	0.09	0.03	2.94	1.95	0.09

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS ^{b} (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
PS-197	692 BEACH ST (FROST); G7	WELL PAD	1	228	1596	3	1	2	7	0.07	1.04	2.91	<0.01	1.10	1.01	0.09	0.01	0.63	0.40	0.03
PS-198	5699 RANDOL MILL RD (GOODMAN); H7	WELL PAD	3	260	1824	4	1	4	2	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
PS-199	7094 JACK NEWELL BLVD S (TRIMBLE); H7	WELL PAD	2	118	826	4	0	2	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-200	7092 ENTERPRISE AVE (PARROT) (B-PAD); H7	WELL PAD	2	41	294	0	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
PS-201	5895 MARINE CREEK PKWY (MARINE CREEK) (A-PAD); E5	WELL PAD	2	183	1645	3	1	2	6	-0-	-0-	-0-	-0-	1.11	0.99	0.11	0.01	0.60	0.40	0.02
6	HWY 114	WELL PAD	1	62	134	1	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
20	4190 LITSEY RD	WELL PAD	2	103	960	8	0	5	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
23	4192 LITSEY RD	WELL PAD	6	448	3584	0	1	2	6	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
24	3596 ELIZABETHTOWN CEMETERY RD	WELL PAD	6	434	2738	6	1	3	2	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
25	14797 ELIZABETHTOWN CEMETERY RD	WELL PAD	5	206	1650	4	1	4	6	0.05	0.70	1.96	<0.01	0.67	0.65	<0.01	0.01	0.39	0.26	<0.01
26	14798 ELIZABETHTOWN CEMETERY RD	WELL PAD	6	463	4270	6	1	3	9	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
27	4791 HENRIETTA CREEK RD	WELL PAD	1	99	996	2	1	3	4	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
28	4794 HENRIETTA CREEK RD	WELL PAD	1	76	768	2	1	3	5	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
29	14404 CHAPARRAL	WELL PAD	2	154	1482	4	1	2	3	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
32	13794 NORTH FWY	WELL PAD	8	506	3542	8	1	1	8	0.05	0.70	1.96	<0.01	0.67	0.65	0.01	<0.01	0.39	0.26	0.01
33	13593 NORTH FWY	WELL PAD	8	539	4672	6	2	6	8	0.09	1.40	3.92	<0.01	1.34	1.31	0.03	<0.01	0.78	0.52	0.02
35	2890 WESTPORT PKWY	WELL PAD	1	68	476	2	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
36	3397 ALLIANCE GATEWAY	WELL PAD	8	549	4747	1	1	4	15	0.07	1.04	2.91	<0.01	1.04	1.01	<0.01	0.03	0.60	0.40	0.02
37	5198 WESTPORT PKWY	WELL PAD	2	128	1256	4	1	0	1	0.07	0.98	2.76	<0.01	1.00	1.00	<0.01	<0.01	0.59	0.40	0.01
38	5290 WESTPORT PKWY	WELL PAD	1	74	662	2	1	2	4	0.03	0.48	12.87	<0.01	0.45	0.45	<0.01	<0.01	0.26	0.18	<0.01
39	13195 PARK VISTA BLVD	WELL PAD	3	166	1282	3	1	4	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
41	3398 ALLIANCE GATEWAY	WELL PAD	12	801	7041	1	1	4	25	0.05	0.70	1.96	<0.01	0.67	0.65	<0.01	<0.01	0.39	0.26	0.01
44	12695 OLD DENTON	WELL PAD	1	193	1331	2	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
50	11498 HARMON RD	WELL PAD	2	218	1526	3	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
55	5696 N TARRANT PKWY	WELL PAD	2	275	2181	3	1	2	3	0.05	0.70	1.96	<0.01	0.67	0.65	<0.01	0.01	0.39	0.26	0.01
57	1098 BLK EAST BONDS RANCH RD S SIDE	WELL PAD	2	164	1099	1	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
59	1392 BLK E BONDS RANCH RD S-SIDE	WELL PAD	1	24	175	0	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
62	1098 E BONDS RANCH RD	WELL PAD	1	6	42	0	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
63	1096 EAST BONDS RANCH RD	WELL PAD	1	59	413	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
98	13393 SENDERA RANCH BLVD	WELL PAD	2	102	816	2	0	0	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
110	12595 WILLOW SPRINGS	WELL PAD	1	60	420	1	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
111	12591 BLK WILLOW SPRINGS RD W-SIDE	WELL PAD	1	74	518	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
125	12690 WILLOW SPRINGS RD	WELL PAD	1	53	371	1	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
126	693 AVONDALE HASLET RD	WELL PAD	3	220	1540	3	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
130	290 BLUE MOUND RD WEST	WELL PAD	2	133	931	3	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
132	12294 NW HWY 287 CFW	WELL PAD	2	151	1057	2	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
134	12290 NW HWY 287	WELL PAD	2	75	525	1	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
136	998 BLUE MOUND RD WEST	WELL PAD	7	421	2947	3	0	6	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
138	1096 BLK W BLUE MOUND AT HWY-287 N-SIDE	WELL PAD	3	245	1855	3	0	2	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
139	1099 BLUE MOUND RD W	WELL PAD	2	160	1120	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
141	692 BLUE MOUND RD	WELL PAD	1	60	420	2	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
142	392 BLUE MOUND RD WEST	WELL PAD	3	191	1337	3	0	3	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
143	893 BLUE MOUND RD W	WELL PAD	2	167	1169	3	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
147	12890 BLK SAGINAW BLVD	WELL PAD	2	162	1079	3	1	2	0	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
147A	12700 BLK HWY 287 & 81 S-SIDE	WELL PAD	1	60	420	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
149	12700 SAGINAW RD	WELL PAD	1	38	266	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
150	12700 SAGINAW RD	WELL PAD	1	42	294	1	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
153	2492 BLUE MOUND RD W	WELL PAD	2	128	896	3	0	5	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
154	11996 WILLOW SPRINGS RD	WELL PAD	1	87	609	1	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
155	11693 WILLOW SPRINGS RD	WELL PAD	4	315	2205	4	0	1	4	-0-	-0-	-0-	-0-	0.02	<0.01	0.02	<0.01	<0.01	-0-	<0.01
156	11498 WILLOW SPRINGS RD	WELL PAD	3	217	1519	3	0	0	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
159	LPA BONDS RANCH RD	WELL PAD	4	314	2198	3	0	5	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
160	1892 W BONDS RANCH RD	WELL PAD	5	377	2639	4	0	1	7	-0-	-0-	-0-	-0-	0.26	<0.01	0.26	<0.01	0.06	-0-	0.02

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
161	10999 WILLOW SPRINGS RD	WELL PAD	4	330	2310	4	0	2	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
164	11300 BLK HWY 287 & 81	WELL PAD	4	309	2163	3	0	3	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
165	452 WEST BONDS RANCH RD	WELL PAD	5	328	2672	2	1	5	1	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
167	4099 W BONDS RANCH RD	WELL PAD	2	76	725	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
168	3091 W BONDS RANCH RD	WELL PAD	4	245	1715	4	0	2	5	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
171	11593 SAGINAW BLVD	WELL PAD	7	286	2288	4	0	3	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
172	4099 W BONDS RANCH RD	WELL PAD	4	264	3248	8	0	5	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
174	9698 BOAT CLUB ROAD	WELL PAD	1	70	490	1	1	1	2	0.02	3.74	6.13	<0.01	0.20	0.20	<0.01	<0.01	0.12	0.08	<0.01
176	11593 SAGINAW BLVD	WELL PAD	5	371	2597	3	1	2	2	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
178	11601 BLK SAGINAW BLVD	WELL PAD	5	374	2597	3	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
182	1898 W BONDS RANCH RD	WELL PAD	3	189	1323	1	0	3	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
187	10398 HICKS FIELD RD	WELL PAD	5	200	1400	5	0	2	2	-0-	-0-	-0-	-0-	0.02	<0.01	0.02	<0.01	<0.01	-0-	<0.01
188	10398 HICKS FIELD RD	WELL PAD	1	53	371	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
189	10398 HICKS FIELD RD	WELL PAD	2	119	833	2	0	0	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
191	10094 HICKS FIELD RD	WELL PAD	2	130	910	3	0	2	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
192	LPA WAGLEY ROBERTSON RD	WELL PAD	1	167	1170	4	0	0	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
193	10197 WAGLEY ROBERTSON RD	WELL PAD	3	66	462	0	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
194	LPA WAGLEY ROBERTSON RD	WELL PAD	1	92	930	1	1	0	5	0.05	0.79	21.19	<0.01	0.76	0.76	<0.01	<0.01	0.45	0.31	0.01
195	10094 HICKS FIELD RD	WELL PAD	1	55	385	2	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
196	10000 BLK HICKS FIELD RD	WELL PAD	1	52	364	2	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
197	10200 BLK WAGLEY ROBERTSON RD	WELL PAD	3	170	1190	3	0	3	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
198	10196 EVENING VIEW DR	WELL PAD	4	162	1134	1	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
199	293 W BONDS RANCH RD	WELL PAD	3	184	1288	2	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
201	10191 NW HIGHWAY 287	WELL PAD	2	124	868	1	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
207	8799 WAGLEY ROBERTSON RD	WELL PAD	1	101	716	2	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
208	7999 WAGLEY ROBERTSON RD	WELL PAD	1	78	555	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
209	9491 SAGINAW BLVD	WELL PAD	2	187	1790	2	1	4	4	0.01	3.58	5.87	<0.01	0.19	0.19	<0.01	<0.01	0.11	0.08	<0.01
213	10999 SAGINAW RD	WELL PAD	1	80	560	2	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
214	9500 BLK PARK DR	WELL PAD	1	173	1211	2	1	4	1	0.03	0.46	12.35	<0.01	0.43	0.43	<0.01	<0.01	0.26	0.17	<0.01
216	9098 PARK DR	WELL PAD	1	51	357	1	0	0	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
217	8793 OLD DECATUR RD	WELL PAD	4	247	2262	3	1	4	11	0.05	0.70	1.96	<0.01	0.68	0.65	0.01	0.01	0.39	0.26	0.01
222	5299 W BAILEY BOSWELL RD	WELL PAD	2	73	511	3	0	3	4	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
223	5293 W BAILEY BOSWELL RD	WELL PAD	3	134	938	3	0	1	5	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
225	5696 W J BOAZ RD	WELL PAD	2	69	490	2	0	1	2	-0-	-0-	-0-	-0-	0.18	<0.01	0.18	<0.01	<0.01	-0-	<0.01
227	6325 CROMWELL MARINE CREEK RD	WELL PAD	1	82	572	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
228	5693 CROMWELL MARINE CREEK RD	WELL PAD	1	108	920	2	1	0	4	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Connectors	No. Tanks	No. Compressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formaldehyde	Benzene
230	5996 BOWMAN ROBERTS RD	WELL PAD	2	163	1615	2	1	3	4	0.07	0.98	2.74	<0.01	1.01	0.99	<0.01	0.02	0.59	0.40	0.01
234	5492 TEN MILE BRIDGE RD	WELL PAD	1	48	320	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
235	6493 TEN MILE BRIDGE RD	WELL PAD	1	71	491	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
238	798 INDUSTRIAL ROAD	WELL PAD	2	691	5185	4	2	4	10	0.53	15.71	219.33	0.06	14.24	14.12	0.11	<0.01	8.42	5.67	0.21
240	1392 CANELL SAMPSON RD	WELL PAD	2	298	2586	2	1	0	5	0.05	0.70	1.96	<0.01	0.67	0.65	0.02	<0.01	0.39	0.26	0.01
241	1895 NORTHEAST LOOP 820	WELL PAD	2	218	1676	2	1	2	1	0.07	0.99	2.77	<0.01	1.00	1.00	<0.01	<0.01	0.59	0.40	0.01
247	1290 SILVER CREEK RD	WELL PAD	4	478	4646	4	0	2	4	-0-	-0-	-0-	-0-	0.97	<0.01	0.97	<0.01	0.11	-0-	0.02
257	10999 OLD WEATHERFORD RD	WELL PAD	3	253	2863	4	2	5	16	0.07	1.06	11.58	<0.01	20.93	1.01	19.91	<0.01	4.93	0.41	0.11
258	9595 OLD WEATHERFORD RD	WELL PAD	3	145	1015	2	0	0	5	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
260	11398 WEST FWY	WELL PAD	3	217	1519	6	0	4	8	-0-	-0-	-0-	-0-	0.02	<0.01	0.01	<0.01	<0.01	-0-	<0.01
261	10499 CHAPIN RD	WELL PAD	2	147	1029	4	0	1	6	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
266	11392 TIGER TRL	WELL PAD	5	310	1740	10	1	7	6	0.05	0.70	1.96	<0.01	1.43	0.65	0.01	0.77	0.46	0.26	0.01
267	11392 TIGER TRL	WELL PAD	5	445	3115	20	1	6	26	0.14	1.98	24.21	<0.01	19.87	2.00	17.85	0.02	3.02	0.80	0.16
268	11395 TIGER TRL	WELL PAD	5	311	3732	0	1	1	7	0.14	1.98	24.21	<0.01	4.30	2.00	<0.01	2.30	1.34	0.80	0.04
269	11392 TIGER TRL	WELL PAD	8	657	4599	0	0	1	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
282	4490 OLD DECATUR RD	WELL PAD	6	378	2485	6	1	3	13	0.05	0.70	1.96	<0.01	0.70	0.65	0.03	0.02	0.40	0.26	0.01
284	998 RAILHEAD RD	WELL PAD	2	138	966	2	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
285	4890 BLUE MOUND RD	WELL PAD	1	84	588	1	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
287	4201 BLUE MOUND RD	WELL PAD	1	151	357	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
288	291 NE 38TH ST	WELL PAD	4	175	1225	5	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
289	4999 MARK IV PKWY	WELL PAD	2	233	1781	2	1	3	3	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
290	1990 GREAT SOUTHWEST PKWY	WELL PAD	2	152	1064	2	0	0	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
291	2591 DOWNING DR	WELL PAD	4	181	1267	4	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
294K	2299 MERCADO DR	COMPRESSOR STATION	0	436	3310	0	2	4	6	0.80	12.94	67.54	0.05	11.59	11.59	<0.01	<0.01	6.89	4.65	0.16
294	2299 MERCADO DR	WELL PAD	10	616	4312	13	2	5	22	0.13	2.08	5.81	<0.01	2.16	2.01	0.13	0.02	1.21	0.81	0.03
295	1099 NIXON ST	WELL PAD	9	1010	7262	11	1	2	7	0.40	6.47	33.77	0.02	6.02	5.79	0.21	0.01	3.63	2.32	0.13
302	2099 MARTIN LYDON AVE	WELL PAD	2	150	1376	4	1	0	4	0.05	0.70	1.96	<0.01	0.67	0.65	0.02	<0.01	0.39	0.26	0.01
303	5092 SOUTH FWY	WELL PAD	4	437	3649	5	1	0	1	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
308	5990 COLUMBUS TRAIL	WELL PAD	4	368	2576	4	1	4	0	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
309	6091 COLUMBUS TRAIL	WELL PAD	1	75	525	2	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
310	9290 GRANBURY RD	WELL PAD	4	257	1799	4	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
311	9292 GRANBURY RD	WELL PAD	2	173	1211	2	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
312	9198 GRANBURY RD	WELL PAD	2	192	1344	2	0	2	1	-0-	-0-	-0-	-0-	1.50	<0.01	1.50	<0.01	1.08	-0-	0.23
315	5701 W RISINGER RD	WELL PAD	1	184	1288	2	1	3	1	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
316	8699 BREWER BLVD	WELL PAD	9	743	5201	12	0	5	6	-0-	-0-	-0-	-0-	0.05	<0.01	<0.01	0.05	<0.01	-0-	<0.01
317	9991 STEWART FELTZ RD	WELL PAD	5	223	1631	6	0	2	7	-0-	-0-	-0-	-0-	0.02	<0.01	<0.01	0.02	<0.01	-0-	<0.01
318	5892 STEWART FELTZ RD	WELL PAD	8	516	4128	12	0	4	7	-0-	-0-	-0-	-0-	0.07	<0.01	<0.01	0.07	<0.01	-0-	<0.01
324	10193 OLD CROWLEY CLEBURNE RD	WELL PAD	3	300	2100	4	1	1	1	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
325	9599 WEST CLEBURNE	WELL PAD	1	67	469	1	0	0	1	-0-	-0-	-0-	-0-	0.02	<0.01	0.02	<0.01	<0.01	-0-	<0.01
327	2998 N CROWLEY CLEBURNE RD	WELL PAD	3	226	2193	4	1	3	4	0.07	1.04	2.91	<0.01	1.01	1.01	<0.01	<0.01	0.60	0.40	0.01
328	2592 NORTH CROWLEY CLEBURNE RD	WELL PAD	2	176	924	4	1	1	3	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
329	2195 CUNNINGHAM	WELL PAD	1	110	866	1	1	0	4	0.05	0.70	1.96	<0.01	0.67	0.65	0.02	<0.01	0.39	0.26	0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
332	9590 TECHNOLOGY RD	WELL PAD	2	95	665	2	0	2	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
335	7393 CROWLEY RD	WELL PAD	1	95	897	1	1	1	4	0.05	0.70	1.96	<0.01	0.69	0.65	0.03	<0.01	0.39	0.26	0.01
336	293 ALTAMESA BLVD	WELL PAD	4	416	2912	4	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
338	11790 SOUTH FWY	WELL PAD	3	733	5805	4	2	8	7	<0.01	17.85	93.74	0.06	14.86	14.74	0.11	0.01	8.83	5.91	0.24
339	599 W RENDON CROWLEY RD	WELL PAD	6	492	3444	7	0	10	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
341	13790 WILDCAT WAY SOUTH	WELL PAD	3	263	1641	4	0	3	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
342	296 PACE ALSBURY COURT	WELL PAD	1	80	560	1	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
344	12795 SOUTH FWY	WELL PAD	1	223	1561	4	0	1	3	-0-	-0-	-0-	-0-	0.01	<0.01	0.01	<0.01	<0.01	-0-	<0.01
346	13790 WILDCAT WAY SOUTH	WELL PAD	3	198	1386	4	0	4	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
348	12298 OAK GROVE ROAD SOUTH	WELL PAD	8	553	5301	10	3	5	15	0.12	1.86	16.27	<0.01	1.77	1.74	0.02	<0.01	1.04	0.70	0.03
349	1297 E RENDON CROWLEY	WELL PAD	5	272	1904	4	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
350	495 OLD HWY 1187	WELL PAD	5	410	2870	5	0	6	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
351	1099 E RENDON CROWLEY RD	WELL PAD	4	268	1966	4	1	2	8	0.05	0.70	1.96	<0.01	0.67	0.65	<0.01	<0.01	0.39	0.26	0.01
352	1099 E RENDON CROWLEY RD	WELL PAD	4	230	1610	5	0	0	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
353	11799 SOUTH FWY	WELL PAD	2	130	910	2	0	5	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
354	492 GARDEN ACRES DR	WELL PAD	3	432	4064	3	1	2	1	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
355	10598 OAK GROVE RD	WELL PAD	2	224	1568	4	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
356	9798 OLD BURLESON RD	WELL PAD	3	276	2308	4	1	4	3	0.07	1.04	2.91	<0.01	1.01	1.01	<0.01	<0.01	0.60	0.40	0.01
357	10199 OAK GROVE RD	WELL PAD	3	208	1728	3	1	1	6	0.05	0.70	1.96	<0.01	0.67	0.65	<0.01	0.01	0.39	0.26	<0.01
360	10596 FOREST HILL-EVERMAN RD	WELL PAD	4	288	2016	5	0	2	4	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS ^{b} (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
362	10196 FOREST HILL EVERMAN RD	WELL PAD	2	84	588	2	0	2	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
368	8598 WILL ROGERS BLVD	WELL PAD	1	53	371	1	0	1	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
369	8490 OAK GROVE RD	WELL PAD	5	236	1652	5	0	2	11	-0-	-0-	-0-	-0-	0.04	<0.01	<0.01	0.04	<0.01	-0-	<0.01
371	7893 WILL ROGERS RD	WELL PAD	2	115	805	3	1	1	1	0.08	1.23	3.45	<0.01	1.13	1.13	<0.01	<0.01	0.67	0.45	0.02
373	1290 JOHN BURGESS DR	WELL PAD	4	84	588	0	0	0	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
374	6994 WILL ROGERS BLVD	WELL PAD	2	273	2295	2	1	4	15	0.08	1.23	3.45	<0.01	1.24	1.13	0.01	0.10	0.69	0.45	0.02
381	1191 INTERMODEL PKWY	WELL PAD	12	759	6072	12	0	8	19	-0-	-0-	-0-	-0-	0.13	<0.01	0.13	<0.01	0.03	-0-	0.01
382	6197 SOUTH FWY	WELL PAD	1	119	833	1	0	0	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
392	5091 SOUTH FREEWAY	WELL PAD	1	69	483	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
396	2295 E SEMINARY DR	WELL PAD	10	858	6144	10	1	8	10	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
397	1294 E BERRY ST	WELL PAD	2	588	4494	5	3	2	2	0.85	13.64	69.50	0.05	12.24	12.24	<0.01	<0.01	7.27	4.91	0.17
399	4296 MITCHELL BLVD	WELL PAD	5	374	2986	6	1	6	3	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
400	3997 MITCHELL BLVD	WELL PAD	6	379	2989	8	1	3	7	0.07	1.04	2.91	<0.01	1.01	1.01	<0.01	<0.01	0.60	0.40	0.01
403	1999 BOMAR AVE	WELL PAD	4	467	3395	4	1	0	0	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
405	892 BEACH ST	WELL PAD	5	362	3619	0	1	1	2	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
409	4298 EAST FIRST ST	WELL PAD	3	278	1946	4	0	0	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
411	5391 EAST FIRST ST	WELL PAD	9	1143	8136	9	1	3	6	0.07	1.04	2.91	<0.01	1.01	1.01	<0.01	<0.01	0.60	0.40	0.01
415	7092 ENTERPRISE AVE	WELL PAD	1	76	670	1	1	2	2	0.03	0.46	12.35	<0.01	0.44	0.43	<0.01	<0.01	0.26	0.17	<0.01
416	5290 BOCA RATON BLVD	WELL PAD	3	238	1666	4	0	3	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
419	7090 ENTERPRISE AVE	WELL PAD	9	389	4049	12	2	3	19	0.13	2.08	5.81	<0.01	2.02	2.01	<0.01	0.01	1.20	0.81	0.03
420	7094 JACK NEWELL BLVD S	WELL PAD	2	159	1750	4	1	3	3	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01

Table 3.5-3. Point Source Emissions Summary by Site (Continued)

Site ID	Address	Site Type	No. Wells	No. Valves	No. Conn-ectors	No. Tanks	No. Comp-ressors	No. M21 >500 ppm	No. IRs	PM (tons/yr)	NOx (tons/yr)	CO (tons/yr)	SO2 (tons/yr)	VOCs (tons/yr)				HAPS [b] (tons/yr)		
														VOC Total	Engine VOC	Tank VOC	Fugitive VOC	HAP Total	Formal dehyde	Benzene
421	2392 AUSTIN RD	WELL PAD	2	146	1581	2	1	5	6	0.05	0.70	1.96	<0.01	0.66	0.65	<0.01	<0.01	0.39	0.26	<0.01
422	7213 ATCO DR	WELL PAD	3	137	959	3	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
423	7603 TRINITY BLVD	WELL PAD	3	273	2730	4	0	1	4	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
424	7498 MOSIER VIEW CT	WELL PAD	4	434	4510	4	4	4	11	0.19	2.80	7.84	0.01	2.63	2.61	0.01	<0.01	1.55	1.05	0.04
426	692 BRIDGEWOOD DR	WELL PAD	5	735	5427	5	2	1	11	0.09	1.40	3.92	<0.01	1.31	1.31	<0.01	<0.01	0.78	0.52	0.02
427	7990 TRINITY BLVD	WELL PAD	6	144	1008	0	0	0	6	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
428	7990 TRINITY BLVD	WELL PAD	5	780	6015	12	3	6	10	0.18	2.78	7.77	0.01	2.67	2.67	<0.01	<0.01	1.58	1.07	0.04
429	8097 TRINITY BLVD	WELL PAD	1	143	1337	2	1	2	4	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
438	9290 KEMP ST	WELL PAD	3	301	2786	5	1	0	2	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
447	2598 GREENBELT RD	WELL PAD	2	200	1400	2	1	2	5	0.05	0.70	1.96	<0.01	0.65	0.65	<0.01	<0.01	0.39	0.26	<0.01
457	1992 EAST CHASE PKWY	WELL PAD	1	119	786	2	0	1	1	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
462	6796 ROSEDALE ST	WELL PAD	13	600	4200	0	0	5	6	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
468	1593 INTERMODEL PKWY	WELL PAD	12	743	5201	0	0	2	3	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
469	7098 ROBERTSON RD	WELL PAD	11	260	1820	3	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
470	7294 ROBERTSON RD	WELL PAD	2	167	1570	6	1	1	4	0.01	3.58	5.87	<0.01	0.21	0.19	<0.01	<0.01	0.12	0.08	<0.01
471	1597 INTERMODEL PKWY	WELL PAD	6	383	2481	0	0	0	7	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
472	1791 INTERMODEL PKWY	WELL PAD	7	482	3374	0	0	5	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
474	6593 DIRKS RD	WELL PAD	1	80	560	1	0	3	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
480	5096 N SYLVANIA AVE	WELL PAD	3	357	2499	3	0	1	0	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01
483	4898 MARINE CREEK PKWY	WELL PAD	1	70	1095	1	1	0	7	0.05	0.70	1.96	<0.01	0.67	0.65	<0.01	0.02	0.39	0.26	<0.01
485	4691 E LOOP 820 S	WELL PAD	9	447	3465	6	2	2	19	0.09	1.40	3.92	<0.01	1.36	1.31	0.01	0.04	0.79	0.52	0.02
487	3490 BRYANT IRVIN RD	WELL PAD	2	97	679	2	0	0	2	-0-	-0-	-0-	-0-	<0.01	<0.01	<0.01	<0.01	<0.01	-0-	<0.01

[a] For values reported as <0.01, see Appendix 3-A for actual emissions expressed in scientific notation.

[b] The HAP Total emissions listed include all HAP emissions that were measured and calculated as part of this study. For a complete list of estimated HAPs emissions, see Appendix 3-A.

Figure 3.5-2 shows the average TOC emissions for the three basic component categories found at the natural gas facilities which were surveyed by the point source team: Valves, Connectors, and Other. Valves include manual valves, automatic actuation valves, and pressure relief valves. Connectors include flanges, threaded unions, tees, plugs, caps and open-ended lines where the plug or cap was missing. The category "Other" consists of all remaining components such as tank thief hatches, pneumatic valve controllers, instrumentation, regulators, gauges, vents, etc.

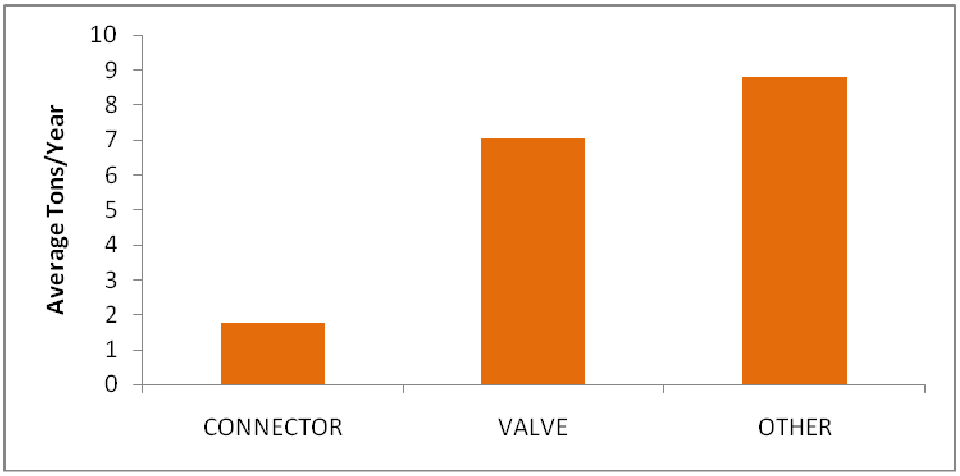


Figure 3.5-2. Average TOC Emissions by Component Category

As indicated in Figure 3.5-2, average TOC emissions from components in the "Other" category exceeded emissions from valves and connectors. Figure 3.5-3 identifies individual equipment types in the "Other" category with the highest average TOC emissions. Among these, tank thief hatches have the largest average TOC emission contribution, followed by miscellaneous equipment, tank vents, pneumatic valve controllers, and gas regulators. Miscellaneous equipment included a variety of emission sources such as holes and cracks in tank roofs, various types of instrumentation and meters, sumps, compressor shafts, orifice plates, sight glasses, and underground piping.

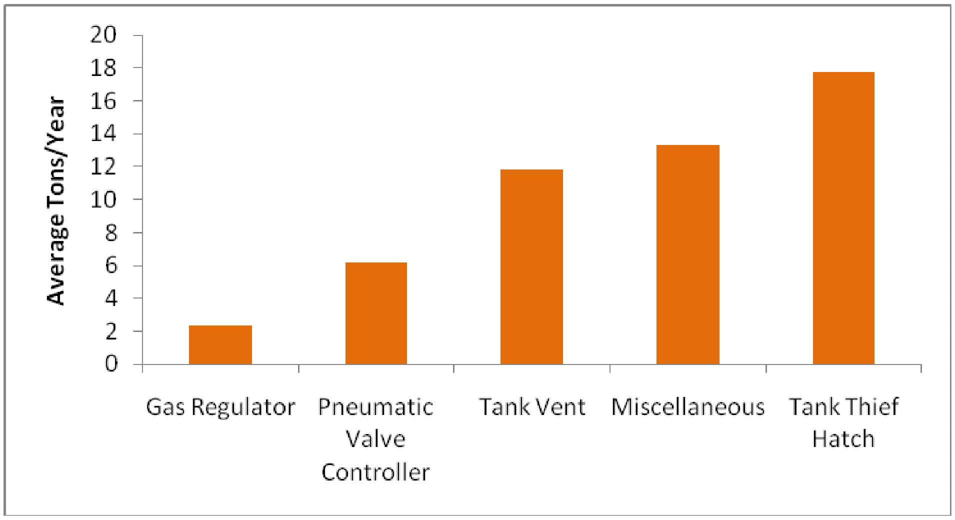


Figure 3.5-3. Average TOC Emissions in Category "Other"

Figure 3.5-4 summarizes the average annual TOC, VOC, HAP, and Criteria Pollutant emissions from compressor engines alone. Criteria pollutant emission data is based upon vendor-provided and published engine emission factors and pertains to those compressors encountered at well pad sites.

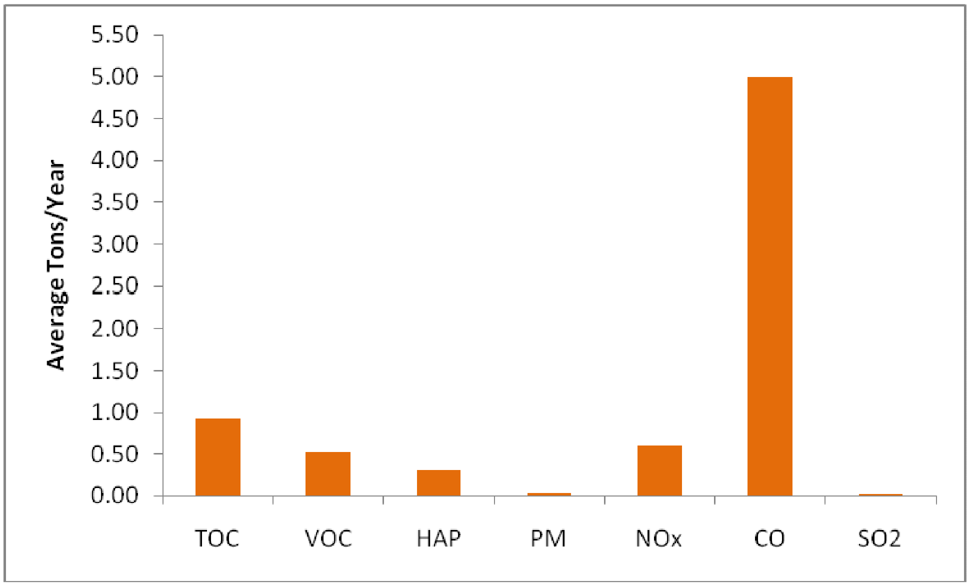


Figure 3.5-4. Average Annual Emissions from Well Pad Compressor Engines

Figure 3.5-5 compares VOC and HAP average annual emissions from Non-Tank and Tank sources.

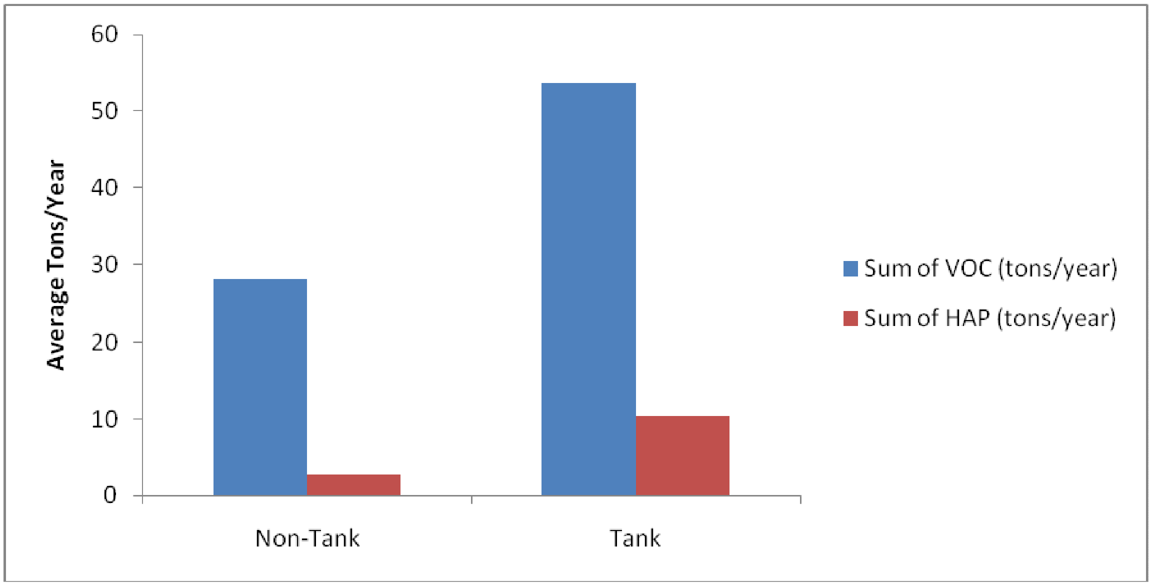


Figure 3.5-5. Non-Tank vs. Tank: Average VOC and HAP Emissions

Figures 3.5-6 and 3.5-7 compare TOC, VOC, and HAP average emissions from dry gas and wet gas sites. For purposes of this study, a site was considered to be a wet gas site if it produced more than 1 barrel of condensate/day as indicated by the Texas Railroad Commission.

Figure 3.5-6 indicates that average TOC emissions from wet gas well pad sites were higher than those from dry gas well pad sites. Also, indicated in Figure 3.5-7, wet gas well pad sites were found to have higher average VOC and HAP emissions.

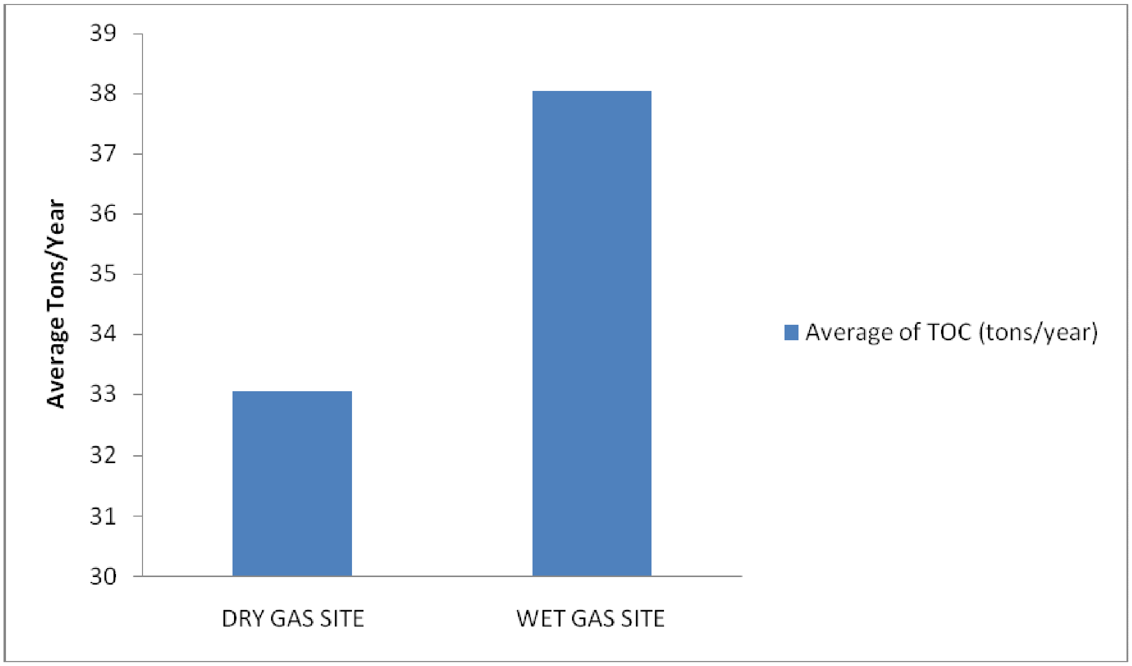


Figure 3.5-6. Average Wet Gas vs. Dry Gas TOC Emissions

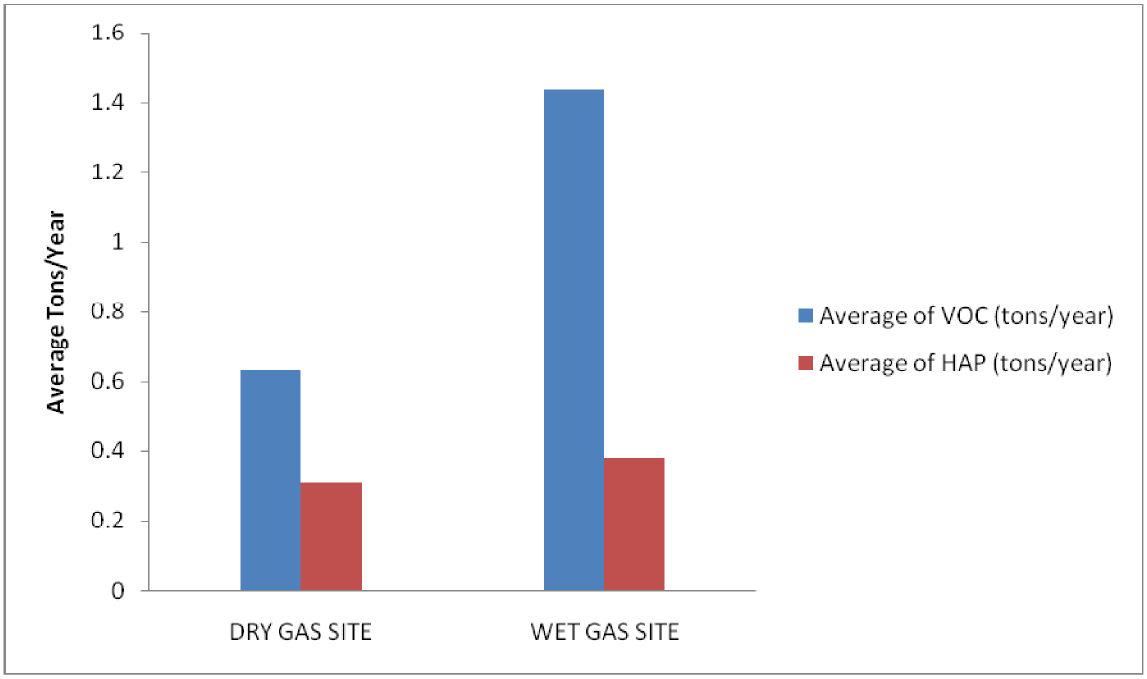


Figure 3.5-7. Average Wet Gas vs. Dry Gas VOC and HAP Emissions

At the City's request, the point source team re-visited two sites in Phase II that had been previously surveyed in Phase I. The Chesapeake site at 2299 Mercado Drive was surveyed on October 20, 2010 (Point Source ID PS -192) and again on February 15, 2011 (Point Source ID 294). The ENCANA site at 11398 West Freeway was surveyed in Phase I on September 21, 2010 (Point Source ID PS -086) and again, in Phase II on February 16, 2011 (Point Source ID 260). Table 3.5-4 summarizes the results of each survey.

Table 3.5-4. Summary of Repeat Surveys[a]

Site/Date	Temp °F[b]	# IR Detects[c]	# M21 Detects[d]	TOC (tons/yr)	VOC (tons/yr)	HAP (tons/yr)
Chesapeake - 2299 Mercado Drive (Site IDs: PS-192 and 294)						
20-Oct-10	88	12	6	188	2.2	1.3
15-Feb-11	64	22	5	181	2.15	1.2
ENCANA - 11398 West Fwy (Site IDs: PS-086 and 260)[e]						
21-Sep-10	87	8	4	25.7	8.7	1.9
16-Feb-11	65	8	4	35.7	<0.1	<0.1

[a] For values reported as <0.01 see Appendix 3-A for actual emissions expressed in scientific notation.
[b] Ambient site temperature in degrees Fahrenheit
[c] Number of emission points detected with the IR camera
[d] Number of emission points detected by Method 21 screening procedures.
[e] During the first site visit, one canister sample was collected from a tank emission point and the results used to estimate the site's emissions accordingly, During the second site visit, no canister was collected. Therefore, consistent with the point source test plan, a surrogate emission rate was used to estimate the site's emissions during the second visit.

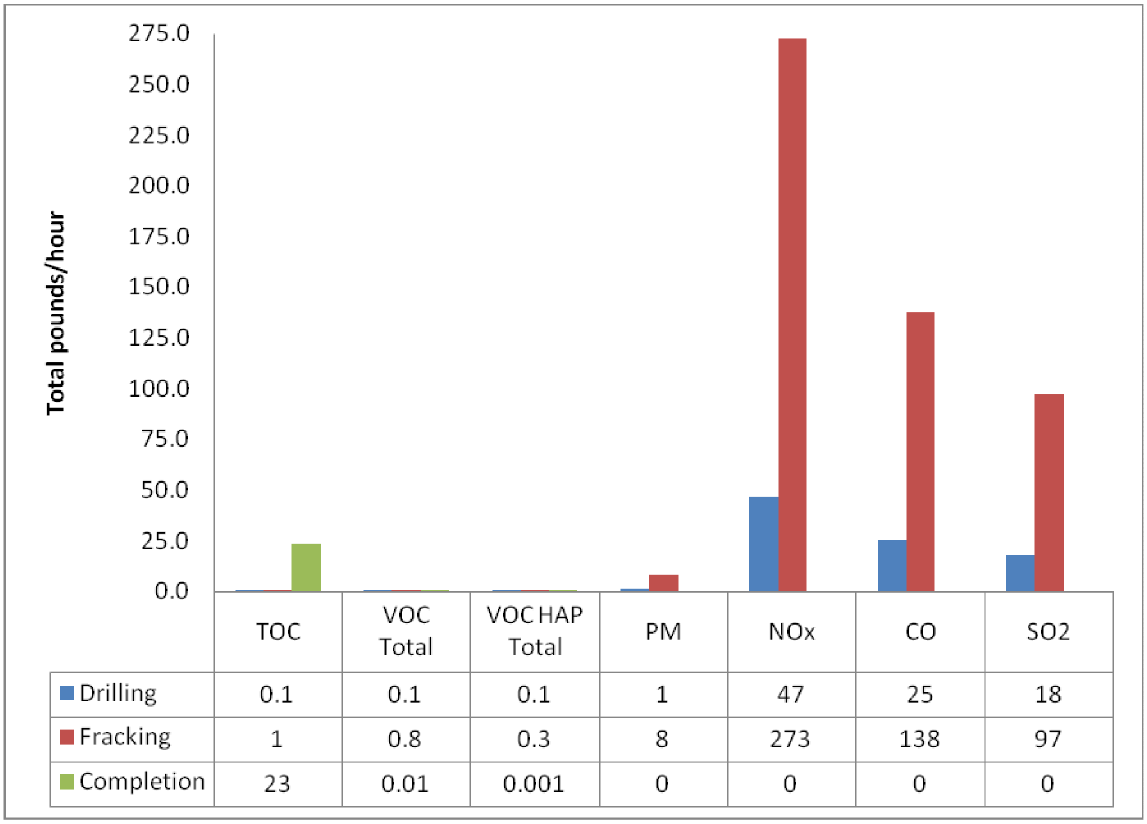
Detailed site-by-site emission results are provided in Appendix 3-A.

3.5.1 Well Activity Emissions

In addition to well pads, compressor stations, a natural gas processing facility and a salt water treatment facility, three types of exploration and stimulation activities were surveyed for emissions:

- Well Drilling.
- Fracking.
- Completion.

Figure 3.5-8 summarizes the hourly emissions from these operations. Since each lasts approximately three weeks or less, emissions are presented on a pounds/hour basis rather than annual basis.



	TOC	VOC Total	VOC HAP Total	PM	NOx	CO	SO2
🟦 Drilling	0.1	0.1	0.1	1	47	25	18
🟥 Fracking	1	0.8	0.3	8	273	138	97
🟩 Completion	23	0.01	0.001	0	0	0	0

Figure 3.5-8. Well Activity Emissions (lbs/hr)

Well Drilling

A drilling site located at 580 East Rosedale and operated by XTO (Point Source ID PS-128) was surveyed on October 1, 2010. During the time of the site visit, the drilling operation was in process and operating under normal conditions. An IR camera scan was performed on all aspects of the drilling operation. No emissions from leaking components or drilling mud were detected by the camera during this survey. Estimated combustion emissions from the drilling rig engines are based on engine data obtained during the site survey. Detailed combustion emissions are provide in Appendix 3-A.

Fracking

A large fracking operation was surveyed on October 20, 2010 at 5900 Wilbarger (Point Source ID PS-193). During the time of the site visit, the fracking operation was in process and operating under normal conditions. The operation included the following equipment: 8 sand trucks, 11 diesel engine pump trucks, 8 mobile water trucks, 3 sand hoppers, 1 chemical injection flatbed trailer, and 1 chemical injection truck. Two complete IR camera scans were performed on all equipment. No emissions from leaking components or fluids handling were detected by the camera. Combustion emissions from the pump engines have been estimated and are based on engine data obtained during the site survey. Detailed combustion emissions are provide in Appendix 3-A.

Well Completion

A flowback operation was surveyed by the point source team on October 5, 2010 at 5199 Village Creek Road (Point Source ID PS-134). One emission point was detected with the IR camera and five low level emission points were identified with the TVA during Method 21 screening while the flowback operation was in progress. Detailed emissions are provide in Appendix 3-A.

3.5.2 Method 21 TOC Screening Emission Factors

Emission factors for the Method 21 screening ranges 500-999 ppmv and 1,000 to 10,000 ppmv were calculated for the equipment categories valves, connectors, and others according to the procedures explained in Section 3.4.2. Unfortunately, an insufficient number of valves and other equipment were found with emissions in the 500 – 999 ppmv category (two and four respectively) to derive reliable emission factors for this screening range. The remaining categories however were sufficiently populated to enable the derivation of the emission factors provided in Table 3.5-5 below.

Table 3.5-5. TOC Screening Emission Factors

Concentration Range	Valves	Connectors	Other
500 – 999 ppmv	—	2.17E-04 kg/hr 4.78E-04 lbs/hr	—
1000 – 10,000 ppmv	1.10E-03 kg/hr 2.43E-03 lbs/hr	4.70 E-04 kg/hr 1.04E-03 lbs/hr	1.60E-02 kg/hr 3.52E-02 lbs/hr

3.6 Quality Control Results

Point Source project Quality Assurance/Quality Control (QA\QC) was ensured through both field and analytical quality control procedures. Field QC procedures included:

- IR Camera Daily Demo.
- Hi Flow Sampler Daily Calibration Verification.
- TVA Daily Calibration and Drift Checks.
- Regular review of completed field data forms.
- Canister sampling protocols.
- Duplicate canister sample collection.

Analytical QC procedures included:

- Method Blanks.
- Surrogate Recoveries.
- Laboratory Control Samples and Control Sample Duplicates.
- Continuing Calibration Verification.

The results of the field QC checks are provided in the tables following. The results of the analytical QC are provided with the TestAmerica™ laboratory reports in the Appendix 3-C.

3.6.1 IR Camera Daily Demo Results

Three IR cameras were used during this project. IR cameras "GasFindIR" and "GF-320 were used continuously throughout the project. IR camera "Dexter" was used only for one day as a temporary replacement. The sensitivity of each IR camera was evaluated daily prior to testing (i.e. Daily Demo). The Daily Demo was performed at two flow rates: ~10 grams/hour propane and ~30 grams/hour propane. The maximum distance from which the two flow rates could be observed with the cameras was recorded together with current weather data. The results of the IR camera daily demos are provided in Tables 3.6-1 through 3.6-5.

3.6.2 Hi Flow Sampler Calibration Verification

Three Hi Flow Samplers were used during the project. Hi Flow Samplers #QS1002 was used in both Phase I and II. Hi Flow Sampler #QS 1005 was used in Phase I and was replaced in Phase II with Hi Flow Sampler #QX 1007. Each Hi Flow Sampler was calibrated at the start of Phase I and Phase II testing using certified gas cylinders of 2.5% and 99% methane. A calibration verification check of both background and sample sensors was performed daily prior to testing with the 2.5% methane standard. Once each week the calibration verification check of both sensors was performed with the 2.5% and the 99% methane gas standards with an acceptance criterion of +/- 10% agreement. The results of Hi Flow Sampler daily calibration verification checks are summarized in Tables 3.6-6 through 3.6-9.

Table 3.6-1. IR Camera ID: GasFindIR Daily Demo September – October, 2010

Timestamp	Low Flow[a]		Hi Flow[b]		WD[c] (from)	WS[d] (mile/hr)	Temp[e] (°F)	RH[f] (%)	BP[g] (kPa)	Cloud (%)
	Sighting Distance (feet)	Video File	Sighting Distance (feet)	Video File						
9/1/10 9:26	27.00	100831_002	68.01	100831_003	N	6.5	84.5	73.4	99.4	35
9/2/10 10:15	24.16	100901_006	40.50	100901_007	S	1.5	76.7	89.1	98.7	95
9/3/10 7:39	27.72	100902_001	39.11	100902_002	W	5.5	72.1	61.0	99.9	100
9/7/10 7:25	50.10	100906_001	163.70	100906_002	CALM	CALM	84.2	72.0	99.6	100
9/8/10 8:33	53.25	100907_002	72.90	100907_001	CALM	CALM	80.0	82.8	99.2	0
9/9/10 8:20	28.32	100908_001	53.04	100908_002	N	2.6	91.3	86.5	99.17	100
9/10/10 8:30	39.04	100909_001	65.21	100909_002	SE	1.1	85.0	88.7	99.01	85
9/16/10 7:30	22.20	100915_001	36.90	100915_003	W	1.8	81.2	75.4	99.4	4
9/17/10 7:00	26.54	100916_001	31.16	100916_002	CALM	CALM	80.2	61.5	99.5	10
9/20/10 7:20	29.90	100919_001	39.65	100919_002	CALM	1.0	80.3	67.2	99.7	1
9/21/10 7:30	31.90	100920_001	52.24	100920_002	S	2.8	78.8	81.2	99.3	15
9/22/10 7:28	25.20	100921_002	42.92	100921_003	SE	2.3	75.7	83.8	99.5	0
9/23/10 7:20	27.10	100922_001	43.47	100922_002	E	3.4	78.0	81.1	99.4	97
9/24/10 7:25	32.68	100923_001	59.69	100923_002	SE	1.4	79.9	81.0	99.8	80
9/27/10 7:28	27.07	100926_001	38.12	100926_002	SW	1.5	57.5	65.8	99.8	0
9/28/10 7:26	26.61	100927_002	37.54	100927_003	SW	1.4	59.3	78.7	99.5	0
9/29/10 7:20	25.07	100928_001	35.94	100928_002	NW	4.0	63.8	71.0	99.1	0
9/30/10 7:45	30.92	100929_001	48.38	100929_002	CALM	CALM	64.3	72.1	99.5	0
9/31/10 7:45	26.70	100930_001	41.50	100930_002	CALM	CALM	64.3	71.9	101.2	0
10/4/10 7:44	14.60	101003_001	35.15	101003_002	CALM	CALM	61.4	68.1	100.7	5
10/5/10 7:45	16.50	101004_002	33.60	101004_003	CALM	CALM	51.6	69.4	100.7	0
10/6/10 7:50	15.90	101005_001	32.30	101005_002	CALM	CALM	59.2	67.5	100.7	0
10/7/10 7:37	26.53	101006_001	45.91	101006_001	CALM	CALM	57.8	72.5	100.4	0
10/8/10 7:45	22.73	101007_001	32.14	101007_002	CALM	CALM	58.9	66.9	100.1	0
10/11/10 7:36	27.54	101010_001	45.25	101010_002	CALM	CALM	72.1	70.8	99.2	100

Table 3.6-1. GasFindIR Daily Demo (Continued)

Timestamp	Low Flow[a]		Hi Flow[b]		WD[c] (from)	WS[d] (mile/hr)	Temp[e] (°F)	RH[f] (%)	BP[g] (kPa)	Cloud (%)
	Sighting Distance (feet)	Video File	Sighting Distance (feet)	Video File						
10/12/10 7:30	18.28	101011_001	36.51	101011_002	W	1.9	62.5	77.5	99.6	4
10/13/10 7:40	23.50	101012_001	35.28	101012_002	W	1.2	64.7	69.7	100.3	0
10/14/10 7:45	18.00	101013_001	29.80	101013_002	CALM	CALM	57.8	54.1	100.8	0
10/15/10 7:50	22.10	101014_001	33.80	101014_002	CALM	CALM	60.1	69.1	100.1	0
10/18/10 7:40	17.50	101017_001	27.45	101017_002	CALM	CALM	69.5	78.4	99.5	0
10/19/10 7:40	22.16	101018_001	35.21	101018_002	CALM	CALM	70.5	71.3	99.4	0
10/20/10 7:35	21.78	101019_001	30.03	101019_002	N	2.5	67.3	65.5	99.8	60
10/21/10 7:53	16.89	101020_001	31.38	101020_002	CALM	CALM	68.5	82.7	99.7	67

[a] 10 grams/hour propane.
[b] 31.4 grams/hour propane.
[c] WD – Wind Direction
[d] WS – Wind Speed (mile/hour)
[e] TEMP – Temperature (°F)
[f] RH – Relative Humidity (%)
[g] BP – Barometric Pressure (kPa)

Table 3.6-2. IR Camera ID: GF-320 Daily Demo
September – October, 2010

Timestamp	Low Flow[a]		Hi Flow[b]		WD[c] (from)	WS[d] (mile/hr)	Temp[e] (°F)	RH[f] (%)	BP[g] (kPa)	Cloud (%)
	Sighting Distance (feet)	Video File	Sighting Distance (feet)	Video File						
9/7/10 8:30	38.83	0025	70.85	0026	CALM	CALM	84.2	72.0	99.6	100
9/8/10 8:30	53.25	0034	71.57	0033	CALM	CALM	80.0	82.8	99.21	0
9/9/10 8:08	9.00	0041	22.00	0042	S	2.3	80.0	90.3	99.9	100
9/10/10 7:45	18.50	0054	27.00	0055	SE	1.1	82.9	84.7	99.01	85
9/13/10 8:45	48.69	0058	77.18	0059	E	1.9	80.5	82.7	99.85	80
9/14/10 7:20	18.93	0069	228.36	0020	CALM	CALM	81.1	77.8	99.63	0
9/15/10 7:17	20.17	0079	25.30	0080	N	1.5	76.5	76.8	99.5	0
9/16/10 7:10	19.00	0086	23.00	0087	W	1.8	81.2	75.4	99.4	4
9/17/10 0:00	9.40	0109	18.80	0110	CALM	CALM	80.2	61.5	99.5	10
9/20/10 7:45	8.60	0121	23.50	0122	CALM	CALM	80.3	67.2	99.7	1
9/21/10 7:30	13.60	0135	31.30	0136	S	2.8	78.8	81.2	99.3	15
9/22/10 7:24	7.80	0151	24.70	0152	SE	2.3	75.7	83.8	99.5	1
9/23/10 7:40	6.50	0175	28.30	0176	E	3.4	78.0	81.1	99.4	97
9/24/10 7:28	16.80	0199	34.90	0200	SE	1.8	79.9	81.0	99.8	80
9/27/10 7:35	13.10	0221	21.30	0222	SW	1.5	57.5	65.8	99.8	0
9/28/10 7:26	14.60	0234	26.00	0235	SW	1.4	59.3	78.7	99.5	0
9/29/10 7:15	16.40	0247	23.30	0248	CALM	CALM	63.8	71.0	99.1	0
9/30/10 7:45	10.30	0268	24.50	0269	CALM	CALM	64.3	72.1	99.5	0
9/31/10 7:35	14.86	0299	20.70	0300	CALM	CALM	64.3	71.9	100	0

[a] 10 grams/hour propane.
[b] 31.4 grams/hour propane.
[c] WD – Wind Direction
[d] WS – Wind Speed (mile/hour)
[e] TEMP – Temperature (°F)
[f] RH – Relative Humidity (%)
[g] BP – Barometric Pressure (kPa)

Table 3.6-2. GF-320 Daily Demo (Continued)

Timestamp	Low Flow[a]		Hi Flow[b]		WD[c] (from)	WS[d] (mile/hr)	Temp[e] (°F)	RH[f] (%)	BP[g] (kPa)	Cloud (%)
	Sighting Distance (feet)	Video File	Sighting Distance (feet)	Video File						
10/4/10 7:35	17.57	0313	30.80	0314	CALM	CALM	61.4	68.1	100.7	5
10/5/10 7:35	13.42	0325	24.80	0326	CALM	CALM	51.6	69.4	100.7	0
10/6/10 7:58	12.44	0345	21.00	0346	CALM	CALM	59.2	67.5	100.7	0
10/7/10 7:32	29.78	0368	36.25	0372	CALM	CALM	57.8	72.5	100.8	0
10/12/10 7:36	18.20	0423	24.20	0424	W	1.9	62.5	77.5	99.6	4
10/13/10 7:40	23.00	0436	31.00	0437	W	1.2	64.7	69.7	100.3	0
10/14/10 7:50	18.10	0460	26.60	0461	CALM	CALM	57.4	54.0	100.8	0
10/15/10 7:50	17.00	0504	25.80	0505	CALM	CALM	60.4	69.0	100.1	0
10/18/10 7:50	7.80	0506	14.60	0507	CALM	CALM	69.5	78.4	99.5	0
10/18/10 7:55	12.02	0511	19.17	0512	CALM	CALM	70.5	94.0	99.4	0
10/20/10 7:49	12.30	0529	24.60	0530	N	2.5	67.3	65.5	99.8	60
10/21/10 7:55	13.7	0549	23.9	0550	CALM	CALM	68.5	82.7	99.7	67

Table 3.6-3. IR Camera ID: Dexter Daily Demo
September – October, 2010

Timestamp	Low Flow[a]		Hi Flow[b]		WD[c] (from)	WS[d] (mile/hr)	Temp[e] (°F)	RH[f] (%)	BP[g] (kPa)	Cloud (%)
	Sighting Distance (feet)	Video File	Sighting Distance (feet)	Video File						
9/15/10 7:45	3.00	VID0016	4.00	VID0015	N	1.5	76.5	76.8	99.5	0

[a] 10 grams/hour propane.
[b] 31.4 grams/hour propane.
[c] WD – Wind Direction
[d] WS – Wind Speed (mile/hour)
[e] TEMP – Temperature (°F)
[f] RH – Relative Humidity (%)
[g] BP – Barometric Pressure (kPa)

Table 3.6-4. IR Camera ID: GasFindIR Daily Demo
January – February, 2011

Timestamp	Low Flow[a]		Hi Flow[b]		WD[c] (from)	WS[d] (mile/hr)	Temp[e] (°F)	RH[f] (%)	BP[g] (kPa)	Cloud (%)
	Sighting Distance (feet)	Video File	Sighting Distance (feet)	Video File						
1/4/11 7:50	34.1	110103_001	84.7	110103_002	E	1.4	64.2	58.5	99.9	0
1/5/11 7:21	23.94	110104_001	54.6	110104_002	CALM	CALM	46.2	64.9	99.5	0
1/6/11 7:28	30.81	110105_001	51.46	110105_002	E	1.8	51.3	36.7	99.38	5
1/7/11 7:35	32.81	110106_001	57.17	110106_002	N	1	51.1	42.9	99.1	10
1/8/11 7:32	21.66	110107_001	38.87	110107_002	CALM	CALM	48.5	45.4	99.5	0
1/10/11 7:36	10.178	110109_001	31.96	110109_002	N	2.1	38.4	59.3	99.8	100
1/13/11 7:26	21.86	110112_001	52.41	110112_002	E	1.4	34.7	65.3	101.6	100
1/14/11 7:23	14.45	110113_001	30.49	110113_002	CALM	CALM	41.2	35.2	100.5	100
1/15/11 8:05	17.51	110114_001	50.4	110114_002	SE	3.2	38.2	69.2	100.4	100
1/18/11 7:20	8.38	110117_001	17.36	110117_002	2.7	W	44.9	78.1	99.1	100
1/19/11 7:30	12.74	110118_001	24.86	110118_002	CALM	CALM	38.9	45.6	99.7	5
1/20/11 7:31	14.36	110119_001	22.79	110119_002	N	4.8	38.6	72.3	99.8	100
1/21/11 7:27	16.9	110120_001	30.78	110120_002	CALM	CALM	33	39.5	100.1	50
1/22/11 7:08	18.2	110121_001	31.8	110121_002	CALM	CALM	39.1	50.0	99.7	0
1/24/11 7:23	21	110123_001	29.6	110123_002	CALM	CALM	36.3	55.7	99.9	0
1/25/11 7:18	11.4	110124_001	11.4	110124_002	NW	3.8	42.1	46.3	100.5	100
1/26/11 7:15	13.7	110125_001	30.7	110125_002	CALM	CALM	38.8	46.6	100.1	0
1/27/11 7:15	12.6	110126_001	20.1	110126_002	CALM	CALM	33.6	75.3	100.2	0
1/28/11 6:50	24.6	110127_001	47.5	110127_002	CALM	CALM	37.3	73.6	99.8	0

[a] 10 grams/hour propane.
[b] 31.4 grams/hour propane.
[c] WD – Wind Direction
[d] WS – Wind Speed (mile/hour)
[e] TEMP – Temperature (°F)
[f] RH – Relative Humidity (%)
[g] BP – Barometric Pressure (kPa)

Table 3.6-4. GasFindIR Daily Demo (Continued)

Timestamp	Low Flow[a]		Hi Flow[b]		WD[c] (from)	WS[d] (mile/hr)	Temp[e] (°F)	RH[f] (%)	BP[g] (kPa)	Cloud (%)
	Sighting Distance (feet)	Video File	Sighting Distance (feet)	Video File						
1/31/11 7:25	39.7	110130_002	62.4	110130_003	NW	2.4	44.5	62.9	99.6	100
2/3/11 10:35	20.9	110202_001	44.1	110202_002	NW	5.2	20.5	50.1	101.5	100
2/5/11 11:15	41.3	110204_001	78.4	110204_002	W	2.4	51.5	38.7	99.1	0
2/6/11 8:14	26.5	110105_001	79.4	110205_002	CALM	CALM	44.1	61.1	98.9	10
2/7/11 8:41	8	110206_001	21.3	110206_002	W	7.1	40.1	62.8	100.6	0
2/8/11 7:28	20.8	110207_001	35	110207_002	E	4.2	37.3	57.4	100.1	0
2/10/11 10:05	30.1	110209_001	52.7	110209_002	N	4.1	26.1	38.1	101	0
2/11/11 7:10	11.6	110210_001	20.6	110210_002	CALM	CALM	30.6	64.8	100.6	0
2/14/11 7:17	51.3	110213_001	79.4	110213_002	CALM	CALM	49.4	76.8	100	30
2/15/11 7:25	60	110214_001	130.9	110214_002	SE	2.3	59.8	86.0	99.86	90
2/16/11 7:28	41.1	110215_001	109.9	110215_002	S	6.8	64.3	77.9	99.53	95

Table 3.6-5. IR Camera ID: GF-320 Daily Demo
January – February, 2011

Timestamp	Low Flow[a]		Hi Flow[b]		WD[c] (from)	WS[d] (mile/hr)	Temp[e] (°F)	RH[f] (%)	BP[g] (kPa)	Cloud (%)
	Sighting Distance (feet)	Video File	Sighting Distance (feet)	Video File						
1/4/11 8:15	17.4	827	53.4	828	E	1.4	64.2	58.5	99.9	0
1/5/11 7:31	11.1	840	17.04	841	W	5	46.2	64.9	99.5	0
1/6/11 7:48	16.41	859	37.63	860	E	1.8	51.3	36.7	99.38	5
1/7/11 7:13	15.7	879	37.58	880	N	1	51.1	42.9	99.1	10
1/8/11 7:17	10.21	916	15.52	917	N	3.0	48.5	45.4	99.5	0
1/10/11 7:46	9.14	934	20.35	935	N	2.1	38.4	59.3	99.8	100
1/11/11 7:35	7.08	963	21.51	964	NW	3.2	24.7	38.8	101.6	0
1/12/11 7:26	11.25	986	38.72	987	NW	2.7	29.1	37.9	102.1	95
1/13/11 7:17	21.24	1004	41.82	1005	E	1.4	44.7	65.3	101.6	100
1/14/11 7:13	12.22	1020	18.48	1021	CALM	CALM	41.2	35.2	100.5	100
1/15/11 7:15	13	1046	18.81	1047	SE	3.2	38.2	69.2	100.4	100
1/18/11 7:20	4.50	1062	15.24	1063	2.7	W	44.9	78.1	99.1	100
1/19/11 7:15	10.37	1081	25.86	1082	CALM	CALM	48.9	45.6	99.7	5
1/20/11 7:14	6.87	1113	15.1	1114	N	4.8	38.6	72.3	99.8	100
1/21/11 6:58	15.88	1123	28.45	1124	CALM	CALM	33	39.5	100.1	50
1/22/11 6:45	8.6	1132	17.8	1133	CALM	CALM	39.1	50.0	99.7	0
1/24/11 7:06	11.8	1141	18.9	1142	CALM	CALM	36.3	55.7	99.9	0
1/25/11 7:00	6.9	1157	10.5	1158	NW	3.8	42.1	46.3	100.5	100
1/26/11 7:03	10.7	1191	26.5	1192	CALM	CALM	38.8	46.6	100.1	0

[a] 10 grams/hour propane.

[b] 31.4 grams/hour propane.

[c] WD – Wind Direction

[d] WS – Wind Speed (mile/hour)

[e] TEMP – Temperature (°F)

[f] RH – Relative Humidity (%)

[g] BP – Barometric Pressure (kPa)

Table 3.6-5. GF-320 Daily Demo (Continued)

Timestamp	Low Flow[a]		Hi Flow[b]		WD[c] (from)	WS[d] (mile/hr)	Temp[e] (°F)	RH[f] (%)	BP[g] (kPa)	Cloud (%)
	Sighting Distance (feet)	Video File	Sighting Distance (feet)	Video File						
1/27/11 7:07	8.8	1209	16	1210	CALM	CALM	33.6	75.3	100.2	0
1/28/11 6:50	11.1	1223	22.4	1224	W	4.0	37.3	73.6	99.8	0
1/31/11 7:15	22.9	1247	53.6	1248	NW	2.4	44.5	62.9	99.6	100
2/3/11 10:17	14.4	1270	50.7	1271	NW	5.2	20.5	50.1	101.5	100
2/5/11 11:05	16.5	1283	35.9	1284	W	2.4	51.5	38.7	99.1	0
2/6/11 8:24	16.5	1287	32.4	1288	CALM	CALM	44.1	61.1	98.9	10
2/7/11 8:30	5	1300	16.6	1301	W	7.1	40.1	62.8	100.6	0
2/8/11 7:15	12	1316	17.6	1317	E	4.2	37.3	57.4	100.1	0
2/10/11 9:57	10.5	1333	39.5	1334	N	4.1	26.1	38.1	101	0
2/11/11 7:00	12.7	1354	18.1	1355	CALM	CALM	30.6	64.8	100.6	0
2/14/11 7:05	15.1	1370	51.2	1371	CALM	CALM	49.4	76.8	100	30
2/15/11 7:08	10	1398	19.2	1399	SE	2.3	59.8	86.0	99.86	90
2/16/11 7:15	10.4	1413	19.3	1414	S	6.8	64.3	77.9	99.53	95

Table 3.6-6. Hi Flow ID: QS1002 Verification
September – October 2010

Timestamp	Input: 2.5% CH_4		Input: 99% CH_4	
	Background Sensor % Difference[a]	Leak Sensor % Difference[b]	Background Sensor % Difference	Leak Sensor % Difference
9/8/10 8:46	-0.8	0.4	-5.5	0.3
9/9/10 18:13	-1.2	-2.8	--	--
9/10/10 7:43	-0.8	-0.8	--	--
9/13/10 7:12	-1.2	-0.8	-2.8	-0.9
9/14/10 7:12	0.0	-0.8	--	--
9/15/10 7:15	-1.2	0.8	--	--
9/16/10 7:21	-1.2	-1.2	--	--
9/18/10 6:48	-2.0	0.4	--	--
9/20/10 7:34	5.6	0.8	--	--
9/21/10 7:28	-3.2	0.0	--	--
9/22/10 7:08	-2.8	0.4	--	--
9/23/10 7:17	-3.2	0.4	--	--
9/24/10 7:27	-0.8	-0.4	--	--
9/27/10 9:40	1.6	0.0	-0.1	-0.1
9/28/10 7:13	0.4	-0.4	--	--
9/29/10 7:12	-1.2	-0.8	--	--
9/30/10 7:55	-1.6	-0.4	--	--
10/1/10 7:33	0.0	-1.6	--	--
10/4/10 7:53	-0.4	-0.8	--	--
10/5/10 7:23	-0.8	-1.2	--	--
10/6/10 7:15	0.8	-3.2	--	--
10/7/10 7:14	0.4	-2.0	--	--
10/8/10 7:25	0.0	-3.2	--	--
10/11/10 7:15	-0.4	-4.8	--	--
10/12/10 7:22	-0.8	-4.4	--	--
10/13/10 7:26	-0.4	-3.6	--	--
10/14/10 7:21	-1.2	-3.2	--	--
10/15/10 7:26	-0.8	-2.4	--	--
10/18/10 7:23	-2.4	-3.6	--	--
10/19/10 7:19	-2.8	-3.6	--	--
10/20/10 7:25	-15.2	-4.8	--	--

[a] Background Sensor Percent Difference = ((Output-Input)/Input) x 100

[b] Leak Sensor Percent Difference = ((Output-Input)/Input) x 100

Table 3.6-7. Hi Flow ID: QS1005 Verification
September – October 2010

Timestamp	Input: 2.5% CH_4		Input: 99% CH_4	
	Background Sensor % Difference[a]	Leak Sensor % Difference[b]	Background Sensor % Difference	Leak Sensor % Difference
9/8/10 8:27	-0.4	-0.8	-1.01	-3.84
9/9/10 6:51	1.2	0.4	--	--
9/10/10 7:31	8.0	-1.2	--	--
9/13/10 8:26	-7.6	0.4	--	--
9/14/10 7:45	-0.4	0.4	--	--
9/15/10 7:35	-4.8	1.2	--	--
9/16/10 7:15	-2.0	-2.0	--	--
9/17/10 6:32	0.0	1.2	--	--
9/20/10 7:40	1.2	-0.8	--	--
9/21/10 7:20	-2.0	-0.4	-1.11	-1.72
9/22/10 7:31	4.8	-1.2	--	--
9/23/10 7:14	1.6	-1.2	--	--
9/24/10 7:27	6.0	-0.4	--	--
10/4/10 8:12	-4.4	0.0	--	--
10/5/10 7:55	-2.0	-1.6	-1.92	1.11
10/6/10 7:10	-3.2	0.0	--	--
10/7/10 7:16	0.8	7.6	--	--
10/8/10 7:22	-0.4	10.4	--	--
10/11/10 7:13	-2.8	13.2	--	--
10/12/10 7:15	1.2	0.4	--	--
10/13/10 7:20	1.6	0.0	--	--
10/14/10 7:17	2.8	-1.6	--	--
10/15/10 7:30	2.4	3.2	--	--
10/18/10 7:40	1.2	3.2	--	--
10/19/10 7:23	2.8	4.8	--	--
10/20/10 7:30	3.2	4.0	--	--
10/21/10 7:34	2.8	5.2	--	--

[a] Background Sensor Percent Difference = ((Output-Input)/Input) x 100

[b] Leak Sensor Percent Difference = ((Output-Input)/Input) x 100

Table 3.6-8. Hi Flow ID: QS1002 Verification
January – February, 2011

Timestamp	Input: 2.5% CH_4		Input: 100% CH_4	
	Background Sensor % Difference[a]	Leak Sensor % Difference[b]	Background Sensor % Difference	Leak Sensor % Difference
1/4/11 8:20	-1.2	2.0	--	--
1/5/11 7:26	-0.4	3.2	--	--
1/6/11 7:25	-0.4	3.6	--	--
1/7/11 7:41	-1.2	2.8	--	--
1/8/11 7:36	-0.8	3.2	--	--
1/10/11 7:50	-1.2	3.6	-1.9	0.0
1/11/11 7:30	0.4	4.0	--	--
1/12/11 7:36	0.4	4.0	--	--
1/13/11 7:26	-3.2	4.0	--	--
1/14/11 7:14	2.4	3.6	--	--
1/15/11 7:35	19.2	2.8	--	--
1/18/11 7:15	-30	0.8	-7.0	0.0
1/19/11 7:01	0	2.0	--	--
1/20/11 7:05	2.8	0.0	--	--
1/21/11 6:58	3.6	2.4	--	--
1/22/11 7:01	0.8	2.0	--	--
1/24/11 7:09	0	0.8	-2.2	0.0
1/25/11 6:51	25.2	2.0	-2.5	0.0
1/26/11 7:13	0	-0.8	0.0	0.0
1/27/11 6:45	-1.6	-0.8	--	--
1/28/11 6:40	-11.2	-0.8	--	--
1/31/11 7:40	0	1.2	0.0	-2.5
2/3/11 10:26	-8	-1.2	--	--
2/5/11 11:07	0	-1.6	--	--
2/6/11 8:07	0	-1.2	--	--
2/7/11 8:34	0	-1.2	-1.3	-0.1
2/8/11 7:05	0	-0.4	--	--
2/10/11 9:48	-0.4	0.8	--	--
2/11/11 7:04	-0.8	-1.2	--	--
2/14/11 6:55	0	-1.6	-0.7	-2.0
2/15/11 7:25	0	-0.4	--	--
2/16/11 7:06	0	-1.2	--	--

[a] Background Sensor Percent Difference = ((Output-Input)/Input) x 100
[b] Leak Sensor Percent Difference = ((Output-Input)/Input) x 100

Table 3.6-9. Hi Flow ID: QX1007 Verification
January – February, 2011

Date/Time	Input: 2.5% CH_4		Input: 100% CH_4	
	Background Sensor % Difference[a]	Leak Sensor % Difference[b]	Background Sensor %	Leak Sensor % Difference
1/4/11 8:35	2.0	0.8	--	--
1/5/11 7:25	2.0	2.0	--	--
1/6/11 7:29	1.2	2.0	--	--
1/7/11 7:50	2.0	1.6	--	--
1/8/11 7:33	2.8	2.4	--	--
1/10/11 7:48	3.2	1.6	-0.5	-2.0
1/13/11 7:36	1.6	1.2	--	--
1/14/11 7:12	3.2	1.2	--	--
1/15/11 7:58	2.0	0.8	--	--
1/18/11 7:30	1.6	0.8	-2.0	0.0
1/19/11 6:55	2.8	0.4	--	--
1/20/11 6:59	2.4	0.4	--	--
1/21/11 6:50	4.0	1.6	--	--
1/22/11 6:58	3.2	1.6	--	--
1/24/11 6:58	2.8	0.0	0.0	0.0
1/25/11 6:35	4.0	0.8	-0.7	-3.5
1/26/11 6:55	3.2	0.4	--	--
1/27/11 6:40	2.8	0.8	--	--
1/28/11 6:35	2.0	0.0	--	--
1/31/11 7:45	2.8	-0.4	-4.0	-5.0
2/3/11 10:22	3.2	0.4	--	--
2/5/11 11:03	2.8	0.0	--	--
2/6/11 8:20	-0.4	-0.4	--	--
2/7/11 8:27	0.0	0.0	0.0	0.0
2/8/11 7:08	0.0	0.0	--	--
2/10/11 9:45	0.4	0.0	--	--
2/11/11 6:58	0.4	0.0	--	--
2/14/11 7:15	0.0	0.4	0.0	0.0
2/15/11 7:00	1.2	1.2	--	--
2/16/11 6:56	2.0	0.8	--	--

[a] Background Sensor Percent Difference = ((Output-Input)/Input) x 100

[b] Leak Sensor Percent Difference = ((Output-Input)/Input) x 100

3.6.3 TVA Calibration Procedures

Several TVAs were used during the point source field surveys. Each TVA was calibrated daily before testing with four certified gas standards:

- Zero Air (<0.1 total hydrocarbon content).
- Low Level Span (approximately 500 ppmv methane-in-air).
- Mid Level Span (approximately 2000 ppmv methane-in-air).
- High Level Span (approximately 10,000 ppmv methane-in-air).

Drift checks were performed during the test day using the Low Level calibration standard. Tables 3.6-10 through 3.6-15 summarize the calibration and drift check results for the project TVAs.

Table 3.6-10. TVA Serial Number (S/N): 5362 Calibration and Drift Check Results September – October 2010

Timestamp	Zero (ppmv)	Low Span[a] % Difference[b]	Mid Span[c] % Difference	High Span[d] % Difference
8/30/10 10:00	-0.5	-1.22	-3.57	-9.83
9/1/10 8:05	0.4	-0.20	0.26	-0.23
9/1/10 14:50	--	-21.63	--	--
9/1/10 14:53	0.78	5.71	2.81	-0.59
9/1/10 17:25	--	25.10	--	--
9/2/10 9:03	0.61	4.90	2.24	4.06
9/2/10 17:33	--	13.27	--	--
9/3/10 9:10	0.2	0.61	0.36	-0.01
9/3/10 12:36	--	20.41	--	--
9/7/10 8:10	-0.98	-1.84	0.46	-0.46
9/8/10 8:02	-0.7	1.02	0.92	0.56
9/9/10 8:25	0.18	-3.88	-5.05	-7.20
9/9/10 16:28	--	5.31	--	--
9/10/10 8:02	-0.43	-0.20	-0.77	0.15
9/10/10 14:35	--	0.20	--	--
9/13/10 8:14	-0.37	0.20	0.10	-1.61
9/13/10 13:30	--	-0.41	--	--
9/14/10 7:13	-0.22	1.22	1.38	0.38
9/14/10 15:25	--	5.10	--	--
9/15/10 7:25	-0.17	-4.08	1.02	1.32
9/16/10 7:13	-0.27	0.41	0.66	0.03
9/17/10 7:35	-0.35	-3.06	-0.46	1.01
9/17/10 13:15	--	5.10	--	--

[a] Low Span = 490 ppm CH_4.
[b] % Difference = ((Output-Input)/Input) x 100
[c] Mid Span = 1960 ppm CH_4.
[d] High Span = 9860 ppm CH_4.

Table 3.6-10. TVA S/N: 5362 (Continued)

Timestamp	Zero (ppmv)	Low Span[a] % Difference [b]	Mid Span[c] % Difference	High Span[d] % Difference
9/20/10 7:43	-0.75	0.61	0.56	0.20
9/20/10 16:04	--	3.06	--	--
9/21/10 7:49	-0.15	0.20	1.28	0.81
9/21/10 15:20	--	2.04	--	--
9/22/10 7:41	0.24	2.04	-2.81	3.45
9/22/10 16:15	--	0.82	--	--
9/23/10 7:34	-0.08	1.63	1.79	0.66
9/23/10 15:42	--	4.49	--	--
9/24/10 7:45	0.53	-2.24	-1.53	0.11
9/24/10 13:45	--	-6.73	--	--
9/27/10 7:50	0.32	0.41	0.92	2.43
9/28/10 7:53	0.07	0.82	0.56	1.42
9/29/10 7:51	0.17	0.20	0.20	-0.12
9/30/10 3:10	-0.27	3.67	1.58	0.15
9/30/10 17:15	--	-1.63	--	--
10/4/10 7:38	-0.15	1.63	0.77	0.95
10/4/10 15:57	--	-3.27	--	--
10/5/10 7:42	0.39	-2.45	1.68	0.58
10/5/10 16:48	--	8.57	--	--
10/6/10 7:35	1.62	-4.08	-1.53	-1.52
10/6/10 16:20	--	5.10	--	--
10/7/10 7:30	0.98	-4.49	2.55	-1.12
10/7/10 16:28	--	9.80	--	--
10/8/10 7:30	1.31	2.04	0.66	-0.10
10/8/10 12:42	--	1.22	--	--
10/11/10 7:32	1.24	-2.86	-1.84	-2.13
10/11/10 16:04	--	4.49	--	--
10/12/10 7:23	-0.39	3.47	3.62	0.16
10/12/10 16:41	--	13.27	--	--
10/13/10 7:21	1.07	0.00	-25.20	-1.12
10/14/10 7:35	-0.08	0.61	0.36	6.49
10/14/10 16:59	--	-2.45	--	--
10/15/10 7:36	-0.73	1.02	0.92	-0.19
10/15/10 12:24	--	-2.45	--	--
10/18/10 7:32	0.71	1.02	1.79	0.06
10/19/10 7:28	-0.25	1.63	1.17	1.42
10/19/10 15:29	--	-2.45	--	--
10/20/10 7:34	1.51	4.49	-3.06	5.48
10/20/10 17:00	--	10.61	--	--

Table 3.6-11. TVA S/N: K10419 Calibration and Drift Check Results September – October 2010

Timestamp	Zero (ppmv)	Low Span[a] % Difference[b]	Mid Span[c] % Difference	High Span[d] % Difference
9/1/10 8:10	0.85	0.0	-0.3	-0.9
9/2/10 8:59	1.8	-0.6	-1.3	2.4
9/3/10 9:10	-0.46	1.8	1.1	1.4
9/3/10 12:36	--	-6.5	--	--
9/7/10 8:10	-0.63	-0.2	0.3	0.1
9/8/10 7:54	-0.26	0.8	-0.6	-0.2
9/9/10 7:34	1.9	0.6	0.2	0.3
9/10/10 8:10	1.13	1.0	1.0	0.4
9/13/10 7:23	0.47	-0.4	0.3	--
9/13/10 7:23	-1.33	-0.6	-0.3	1.0
9/14/10 7:25	-0.19	-1.0	1.2	0.2

[a] Low Span = 490 ppm CH_4.

[b] % Difference = ((Output-Input)/Input) x 100

[c] Mid Span = 1960 ppm CH_4.

[d] High Span = 9860 ppm CH_4.

Table 3.6-11. TVA S/N: K10419 (Continued)

Timestamp	Zero (ppmv)	Low Span[a] % Difference [b]	Mid Span[c] % Difference	High Span[d] % Difference
9/15/10 6:42	0.82	1.0	-1.3	0.0
9/16/10 7:20	0.62	0.8	1.6	1.0
9/20/10 7:43	0.73	-1.6	-0.7	-2.8
9/21/10 7:14	0.13	-0.2	0.2	0.0
9/22/10 7:28	0.42	-0.6	-0.4	1.0
9/23/10 9:29	2.7	0.2	-0.2	1.0
9/24/10 7:35	7.6	3.9	2.3	2.0
9/27/10 7:52	0.8	0.2	1.0	1.0
9/28/10 7:50	0.2	1.0	0.1	1.0
9/29/10 7:39	0.93	-1.0	-1.4	-1.5
9/30/10 8:19	0.39	-3.9	-0.6	0.0
9/30/10 17:16	--	-0.6	--	--
10/1/10 8:07	-0.35	2.4	0.6	1.0
10/4/10 8:00	1.29	1.2	2.5	1.0
10/4/10 0:00	--	3.9	--	--
10/5/10 7:45	0.49	4.5	2.1	1.0
10/6/10 7:52	0.21	0.8	0.1	0.2
10/6/10 10:23	--	-8.8	--	--
10/7/10 7:26	0.01	-2.0	0.9	1.0
10/7/10 15:26	--	7.3	--	--
10/11/10 7:29	0.45	-3.7	-1.3	-0.6
10/12/10 7:42	1.8	3.9	2.4	1.0
10/13/10 7:45	-0.25	5.1	0.4	1.0
10/13/10 17:30	--	1.2	--	--
10/14/10 7:40	1.12	0.0	-0.4	0.4
10/14/10 17:05	--	5.1	--	--
10/15/10 7:25	0.2	1.0	0.6	2.0
10/15/10 12:20	--	0.4	--	--
10/18/10 7:30	0.35	6.1	3.6	1.0
10/18/10 17:30	--	-0.6	--	--
10/19/10 7:50	1.15	-0.8	-6.6	-5.5
10/19/10 16:05	--	9.4	--	--
10/20/10 7:40	1.35	-2.0	-0.6	-1.4
10/20/10 16:40	--	-3.7	--	--
10/21/10 8:05	1.45	0.8	1.5	-0.4
10/21/10 15:40	--	-0.6	--	--

[a] Low Span = 490 ppm CH_4.

[b] % Difference = ((Output-Input)/Input) x 100

[c] Mid Span = 1960 ppm CH_4.

[d] High Span = 9860 ppm CH_4.

Table 3.6-12. TVA S/N: 5362 Calibration and Drift Check Results
January – February 2011

Timestamp	Zero (ppmv)	Low Span[a] % Difference [b]	Mid Span[c] % Difference	High Span[d] % Difference
1/5/11 7:48	2.21	-1.6	-0.1	-1.2
1/6/11 7:07	-0.97	1.8	1.2	0.6
1/6/11 16:38	--	-6.7	--	--
1/7/11 15:42	--	4.1	--	--
1/8/11 7:09	-0.42	1.8	0.7	0.5
1/8/11 14:41		-3.9	--	--
1/10/11 7:35	-0.29	-2.2	2.4	1.0
1/11/11 7:18	0.39	0.0	0.6	-0.5
1/11/11 16:27		-3.1	--	--
1/12/11 7:45	-1.07	0.0	0.2	0.1
1/12/11 13:36	--	-1.6	--	--
1/12/11 16:48	--	-1.2	--	--
1/13/11 7:30	0.19	0.6	-0.1	0.0
1/13/11 14:50	--	3.3	--	--
1/13/11 17:25	--	-6.5	--	--
1/14/11 7:07	0.22	-1.6	0.8	0.0
1/14/11 17:47	--	25.9	--	--
1/15/11 7:30	1.21	0.0	-0.4	0.3
1/15/11 15:22	--	6.5	--	--
1/18/11 7:07	0.19	0.4	0.5	0.5
1/18/11 17:41	--	-6.1	--	--
1/19/11 7:22	0.51	0.8	-0.1	0.4
1/19/11 14:13	--	5.1	--	--
1/19/11 17:22	--	8.4	--	--
1/20/11 7:45	0.72	-1.0	2.3	1.0
1/20/11 18:09	--	5.9	--	--
1/21/11 7:12	1.07	0.2	0.1	0.7
1/21/11 16:11	--	0.0	--	--
1/21/11 17:00	--	2.9	--	--
1/22/11 7:19	1.2	0.4	-1.0	-0.4
1/22/11 13:45	--	-0.4	--	--
1/22/11 15:23	--	-1.0	--	--
1/24/11 7:30	0	-0.6	-0.2	-0.4
1/24/11 17:27	--	5.7	--	--
1/25/2011 6:40	0.61	-2.4	-1.6	-1.2
1/26/2011 6:55	0.13	-1.4	-0.9	-1.0
1/26/11 14:26	0.55	-3.7	-5.9	-3.8
1/26/11 17:30	--	0.4	--	--

[a] Low Span = 490 ppm CH_4.
[b] % Difference = ((Output-Input)/Input) x 100
[c] Mid Span = 1960 ppm CH_4.
[d] High Span = 9860 ppm CH_4.

Table 3.6-12. TVA S/N: 5362 (Continued)

Timestamp	Zero (ppmv)	Low Span[a] % Difference [b]	Mid Span[c] % Difference	High Span[d] % Difference
1/27/11 7:00	0.07	3.9	2.0	1.0
1/27/11 17:30	--	21.4	--	--
1/28/11 6:50	0.01	-0.4	-1.0	-0.3
1/28/11 18:10	--	-8.2	--	--
1/31/11 9:00	0.51	3.1	3.6	2.0
1/31/11 14:33	--	-3.1	--	--
1/31/11 17:22	--	2.4	--	--
2/3/11 10:45	0	0.4	0.1	0.1
2/3/11 17:52	--	3.7	--	--
2/5/11 11:33	0.56	1.2	1.0	-0.5
2/5/11 16:17	--	-2.4	--	--
2/6/11 8:26	0.55	0.0	-0.2	0.1
2/7/11 8:51	0	-4.1	0.2	0.0
2/7/11 15:36	--	1.2	--	--
2/7/11 17:05	--	-1.0	--	--
2/8/11 7:28	1.43	-0.2	0.4	0.7
2/8/11 16:45	--	3.3	--	--
2/10/11 11:12	0.59	0.4	2.0	0.0
2/10/11 16:45	--	5.7	--	--
2/11/11 7:25	0	0.8	0.8	-1.3
2/14/11 7:40	-1.71	-0.2	4.2	1.0
2/14/11 17:17	--	6.1	--	--
2/15/11 7:40	0.49	-0.6	-0.5	-1.1
2/15/11 16:55	--	-2.9	--	--
2/16/11 7:21	0.25	0.2	-0.1	0.8

Table 3.6-13. TVA S/N: 0528413543 Calibration and Drift Check Results January – February 2011

Timestamp	Zero (ppmv)	Low Span[a] % Difference [b]	Mid Span[c] % Difference	High Span[d] % Difference
1/4/11 8:10	0.55	-0.4	1.0	0.5
1/4/11 14:17	--	-2.7	--	--
1/5/11 7:36	1.15	-0.4	-0.3	-0.1
1/5/11 13:33	0.8	1.0	0.2	-12.5
1/5/11 14:42	--	-0.4	--	--
1/6/11 7:14	1.35	0.0	0.2	-0.5
1/6/11 12:35	--	-4.1	--	--
1/6/11 13:06	--	-2.7	--	--
1/6/11 15:18	--	-4.3	--	--
1/6/11 16:32	--	-3.3	--	--
1/7/11 7:43	N/A	-2.4	2.8	8.1
1/7/11 11:53	--	-1.8	--	--
1/7/11 15:04	--	-4.7	--	--
1/8/11 7:25	-2.14	-1.6	-1.5	-0.2
1/10/11 7:28	-8.88	-0.4	-1.5	-0.5
1/10/11 12:52	--	4.5	--	--
1/10/11 15:30	--	10.2	--	--
1/13/11 7:21	2.7	0.2	-0.2	0.0
1/13/11 14:47	--	7.3	--	--
1/13/11 16:32	--	-6.1	--	--
1/14/11 7:17	-9	0.4	0.2	-0.1

[a] Low Span = 490 ppm CH_4.
[b] % Difference = ((Output-Input)/Input) x 100
[c] Mid Span = 1960 ppm CH_4.
[d] High Span = 9860 ppm CH_4.

Table 3.6-14. TVA S/N: R6488 Calibration and Drift Check Results January – February 2011

Timestamp	Zero (ppmv)	Low Span[a] % Difference [b]	Mid Span[c] % Difference	High Span[d] % Difference
1/15/11 9:58	0	1.0	-1.5	1.0
1/15/11 17:20	--	-2.0	--	--
1/18/11 7:00	0.23	0.2	-1.5	-0.3
1/18/11 13:43	--	7.1	--	--
1/18/11 17:26	--	6.9	--	--
1/19/11 7:18	0.98	1.6	0.5	0.5
1/19/11 13:30	--	6.7	--	--
1/19/11 17:00	--	2.7	--	--
1/20/11 7:32	0.65	-3.3	0.3	0.5
1/20/11 13:50	--	7.1	--	--
1/21/11 7:05	0.89	-1.4	0.6	0.6
1/21/11 14:21	--	3.5	--	--
1/21/11 16:52	--	--	--	--
1/22/11 7:12	0.79	-2.2	-1.5	1.0
1/22/11 14:20	--	3.9	--	--
1/24/11 7:20	0	-0.4	-0.5	0.0
1/24/11 12:00	--	1.4	--	--
1/24/11 16:45	--	-17.1	--	--
1/25/11 7:00	0.01	-0.4	-0.4	-0.3
1/25/11 12:05	--	2.4	--	--
1/25/11 17:40	--	1.6	--	--
1/26/11 7:00	0.01	0.4	0.6	-0.6
1/26/11 11:45	--	1.2	--	--
1/26/11 14:55	--	1.8	--	--
1/27/11 6:50	0.03	0.2	-0.1	1.0
1/27/11 11:45	--	2.4	--	--
1/27/11 17:05	--	1.6	--	--
1/28/11 6:55	0.06	-1.6	-2.0	-0.7
1/28/11 11:45	--	2.4	--	--
1/28/11 16:20	--	1.8	--	--
1/31/11 7:39	0.5	-0.2	-2.0	-0.9
1/31/11 13:43	--	-5.3	-8.7	-7.5
1/31/11 17:55	--	-5.9	--	--
2/3/11 10:36	0	0.8	-2.0	0.0
2/3/11 15:16	--	-6.5	--	--

[a] Low Span = 490 ppm CH_4.
[b] % Difference = ((Output-Input)/Input) x 100
[c] Mid Span = 1960 ppm CH_4.
[d] High Span = 9860 ppm CH_4.

Table 3.6-14. TVA S/N: R6488 (Continued)

Timestamp	Zero (ppmv)	Low Span[a] % Difference [b]	Mid Span[c] % Difference	High Span[d] % Difference
2/5/11 11:25	1.03	-1.6	-1.1	0.3
2/5/11 14:56	--	-3.7	--	--
2/5/11 16:30	--	-6.5	--	--
2/6/11 8:20	0.12	2.4	-1.1	0.3
2/6/11 11:45	--	-0.8	--	--
2/7/11 8:39	0	0.0	0.4	0.7

Table 3.6-15. TVA S/N: R1376 Calibration and Drift Check Results January – February 2011

Timestamp	Zero (ppmv)	Low Span[a] % Difference [b]	Mid Span[c] % Difference	High Span[d] % Difference
2/8/11 10:18	0.61	-0.8	-0.2	0.2
2/8/11 13:51	--	-1.4	--	--
2/8/11 16:47	--	-2.7	--	--
2/10/11 10:59	0.23	-0.6	-0.7	-0.1
2/10/11 14:05	--	-0.8	--	--
2/11/11 7:15	0	0.4	0.6	1.0
2/11/11 16:35	--	-3.9	--	--
2/11/11 16:35	--	3.7	--	--
2/14/11 7:43	0.12	0.6	1.5	0.0
2/14/11 16:52	--	3.1	--	--
2/15/11 7:32	0.93	-0.6	-0.8	0.1
2/15/11 15:07	--	8.2	--	--
2/16/11 7:15	0.5	-0.8	-0.3	0.2
2/16/11 13:00	--	1.0	--	--
2/16/11 17:03	--	-1.0	--	--

[a] Low Span = 490 ppm CH_4.

[b] % Difference = ((Output-Input)/Input) x 100

[c] Mid Span = 1960 ppm CH_4.

[d] High Span = 9860 ppm CH_4.

3.6.4 Field Data Review

Field data was reviewed each week in Phase I by the acting QA|QC Officer. In Phase II, this role was divided between the two field team leaders. Each team leader checked the other team's field data for completeness and accuracy on a daily basis. The team leaders also checked periodically for consistency in sampling procedures and data recording between the two teams.

3.6.5 Canister Sample Collection QC

A strict canister sampling protocol was followed to ensure quality sampling results:

1. All canisters were vacuum checked prior to sampling. Canisters with vacuums less than 25 inches Hg were rejected.
2. Residual vacuums of 2 to 10 inches Hg were left in canisters following sample collection.
3. Canister collection data was recorded on data forms as well as in canister logbooks (one per team).
4. Standard canister Chain-of-Custody procedures were observed.
5. Between use and prior to shipping, canisters were kept securely in the project field office.
6. Five percent of the canister samples were collected in duplicate to provide a measure of total sampling and analytical variability.

Eight duplicate canister samples were collected. Comparisons of the analytical results for each duplicate pair are provided in Table 3.6-16 as the relative percent differences (% RPD) between analytes. Since each canister sample was analyzed by EPA Method TO-15 for VOCs and by ASTM D1946 for methane, Table 3.6-16 includes the results for both analytical techniques. The average percent relative differences for the duplicate canisters range between 11 to 61 percent. This is considered an acceptable result for field samples.

Table 3.6-16. Duplicate Canister Results

Site ID:	PS-134
Site Address:	5199 Village Creek Rd
Owner/Operator:	Quicksilver Resources
Date:	10/5/2010
Time:	10:00-11:30
Canister Numbers:	103 and HL 0887

Compounds	**Sample #A020**	**Sample #A021**	**RPD**[a]
Methane	255000	480000	61.2
Butane	16.1	32.9	68.6
Isopentane	2.30	2.51	8.7
Acetone	0.034	ND[b]	--
n-Pentane	1.53	1.08	34.5
Methylene chloride	0.0084	0.01120	28.6
Hexane	0.128	0.304	81.5
Benzene	1.87	3.01	46.7
Cyclohexane	1.10	1.32	18.2
Heptane	ND	0.0299	--
Toluene	0.852	1.93	77.5
n-Octane	ND	0.00876	--
Ethylbenzene	0.00531	0.0112	71.4
m-Xylene & p-Xylene	0.0466	0.0956	68.9
o-Xylene	0.0162	0.0316	64.4
Isopropylbenzene	0.00748	0.0134	56.7
n-Propylbenzene	0.0304	0.0574	61.5
4-Ethyltoluene	0.105	0.143	30.7
1,3,5-Trimethylbenzene	0.0599	0.12	66.8
1,2,4-Trimethylbenzene	0.145	0.381	89.7
n-Decane	ND	0.00681	--
sec-Butylbenzene	ND	0.00535	--
n-Undecane	ND	0.0187	--
n-Dodecane	0.128	1.49	168.4
		Average RPD:	61.8
		Maximum RPD:	168.4
		Minimum RPD:	8.7

[a] RPD = Relative Percent Difference = 100* Absolute Value(X1-X2)/ ((X1+X2)/2)

[b] ND = None Detected

Table 3.6-16. (Continued)

Site ID:	PS-171
Site Address:	3892 Lou Stevenson (Walls Coleman)
Owner/Operator:	Chesapeake Operating Inc.
Date:	10/14/2010
Time:	13:38-16:15
Canister Numbers:	5440 and RA 2402

Compounds	**Sample #B034**	**Sample #B035**	**RPD**
Methane	357000	334000	6.7
Chloromethane	0.00837	ND	--
Butane	8.18	7.86	4.0
Isopentane	0.486	0.494	1.6
Acetone	0.0196	0.0133	38.3
n-Pentane	0.490	0.539	9.5
Methylene chloride	0.01340	0.01450	7.9
Hexane	0.0165	0.0481	97.8
Benzene	0.188	0.370	65.2
Cyclohexane	0.183	0.249	30.6
Toluene	ND	0.0975	--
1,2,4-Trichlorobenzene	0.0199	ND	--
Naphthalene	0.0230	ND	--
n-Dodecane	0.0154	ND	--
1,2,3-Trichlorobenzene	0.0293	ND	--
Hexachlorobutadiene	0.00863	ND	--
		Average RPD:	29.1
		Maximum RPD:	97.8
		Minimum RPD:	1.6

Table 3.6-16. (Continued)

Site ID:	176
Site Address:	11593 Saginaw Blvd
Owner/Operator:	Devon Energy Production Co
Date:	1/7/2011
Time:	11:55-14:45
Canister Numbers:	HL 0979 and 240

Compounds	**Sample #A036**	**Sample #A037**	**RPD**
Methane	65800	63800	3.1
Butane	1.20	1.14	5.1
Isopentane	0.0830	0.0833	0.4
n-Pentane	0.0525	0.0525	0.0
Methylene chloride	0.01260	0.01290	2.4
Benzene	0.117	0.115	1.7
Cyclohexane	0.0321	0.0255	22.9
Toluene	0.0906	0.0755	18.2
m-Xylene & p-Xylene	0.0289	0.0182	45.4
		Average RPD:	11.0
		Maximum RPD:	45.4
		Minimum RPD:	0.0

Table 3.6-16. (Continued)

Site ID:	161
Site Address:	10999 Willow Springs Rd
Owner/Operator:	Devon Energy Production Co
Date:	1/15/2011
Time:	11:00-13:15
Canister Numbers:	RA 2247 and 221

Compounds	**Sample #A042**	**Sample #A043**	**RPD**
Methane	63800	35400	57.3
Butane	1.52	1.01	40.3
Isopentane	0.210	0.138	41.4
n-Pentane	0.103	0.0545	61.6
Methylene chloride	0.01080	0.0110	1.8
Hexane	0.0231	0.00570	120.8
Benzene	0.0803	0.0499	46.7
Cyclohexane	0.0250	0.0160	43.9
Toluene	0.0574	0.0299	63.0
m-Xylene & p-Xylene	0.0265	ND	--
1,2,4-Trimethylbenzene	0.00752	ND	--
		Average RPD:	52.9
		Maximum RPD:	120.8
		Minimum RPD:	1.8

Table 3.6-16. (Continued)

Site ID:	153
Site Address:	2492 Blue Mound Rd W
Owner/Operator:	Devon Energy Production Co
Date:	1/19/2011
Time:	14:30-17:10
Canister Numbers:	203 and 5424

Compounds	**Sample #A047**	**Sample #A048**	**RPD**
Methane	118000	76200	43.1
Butane	2.28	1.57	36.9
Isopentane	0.139	0.0903	42.5
n-Pentane	0.0850	0.0533	45.8
Methylene chloride	0.010	0.01320	27.6
Benzene	0.189	0.144	27.0
Cyclohexane	0.0431	0.0295	37.5
Toluene	0.0475	0.0483	1.7
		Average RPD:	32.8
		Maximum RPD:	45.8
		Minimum RPD:	1.7

Table 3.6-16. (Continued)

Site ID:	240
Site Address:	1392 Conell Sampson Rd
Owner/Operator:	XTO Energy Inc
Date:	1/27/2011
Time:	10:25-12:48
Canister Numbers:	KA 2315 and HL 0930

Compounds	**Sample #A059**	**Sample #A060**	**RPD**
Methane	21300	39400	59.6
Butane	1.01	1.99	65.3
Isopentane	0.0823	0.164	66.3
n-Pentane	0.0377	0.0648	52.9
Methylene chloride	0.01390	0.02050	38.4
Benzene	0.0820	0.143	54.2
Cyclohexane	0.0213	0.0362	51.8
Toluene	0.0440	0.0855	64.1
		Average RPD:	56.6
		Maximum RPD:	66.3
		Minimum RPD:	38.4

Table 3.6-16. (Continued)

Site ID:	238
Site Address:	798 Industrial Rd
Owner/Operator:	XTO Energy Inc
Date:	1/31/2011
Time:	10:55-16:25
Canister Numbers:	279 and 217

Compounds	**Sample #A065**	**Sample #A066**	**RPD**
Methane	549000	528000	3.9
Butane	132	106	21.9
Isopentane	21.0	19.8	5.9
Acetone	0.0968	0.0898	7.5
n-Pentane	6.69	5.84	13.6
Methylene chloride	0.02310	0.01680	31.6
Hexane	2.90	2.65	9.0
Benzene	17.2	16.6	3.6
Cyclohexane	4.37	4.57	4.5
Heptane	0.269	0.259	3.8
Toluene	14.2	12.6	11.9
n-Octane	0.0285	0.0242	16.3
Ethylbenzene	0.139	0.126	9.8
m-Xylene & p-Xylene	3.67	3.04	18.8
o-Xylene	0.442	0.368	18.3
n-Nonane	0.0106	ND	--
Isopropylbenzene	0.0162	0.0129	22.7
n-Propylbenzene	0.0209	0.0176	17.1
4-Ethyltoluene	0.0312	0.0242	25.3
1,3,5-Trimethylbenzene	0.214	0.144	39.1
1,2,4-Trimethylbenzene	0.178	0.101	55.2
n-Decane	0.0126	0.00762	49.3
Naphthalene	0.0232	ND	--
1,2,3-Trichlorobenzene	0.0219	ND	--
Hexachlorobutadiene	0.00995	ND	--
		Average RPD:	18.5
		Maximum RPD:	55.2
		Minimum RPD:	3.6

Table 3.6-16. (Continued)

Site ID:	426
Site Address:	692 Bridgewood Dr
Owner/Operator:	Chesapeake Operating Inc.
Date:	2/11/2011
Time:	9:50-12:25
Canister Numbers:	RA 2173 and RA 2150

Compounds	Sample #B095	Sample #B096	RPD
Methane	76600	93800	20.2
Butane	1.98	2.46	21.6
Isopentane	0.135	0.162	18.2
n-Pentane	0.0664	0.0694	4.4
Methylene chloride	0.01180	0.01200	1.7
Benzene	0.135	0.173	24.7
Cyclohexane	0.0177	0.0101	54.7
Toluene	0.0383	0.0522	30.7
		Average RPD:	22.1
		Maximum RPD:	54.7
		Minimum RPD:	1.7

3.6.6 Analytical QC Results

To ensure high quality analytical results, TestAmerica™ performed several quality control checks during the analysis of each batch of canister samples received by them from the point source team. The most significant of these were: Method Blanks, Surrogate Recoveries, Laboratory Control Samples and Control Sample Duplicates, and Continuing Calibration Verification checks.

Method Blanks

Analytical method blanks were analyzed by TestAmerica™ either daily or after a certain number samples (i.e. after each batch of 20 samples). The method blank is treated like any other sample except that a clean material, free from any of the sample targets, is used. The results of the method blank indicate if any contaminants are present in the analytical system. The only compound that routinely appeared in the analytical method blanks associated with this project's canister samples was small amounts of methylene chloride, a common laboratory solvent. In calculating the canister emission factors the amount of methylene chloride detected in the method blank was subtracted from the reported methylene chloride result. Method blank results are provided for each canister sample result in the TestAmerica™ analytical reports provided in Appendix 3-C.

Surrogate Recoveries

A surrogate standard is a non-target analyte having a chemical structure similar to the target analytes that is added to a sample prior to extraction. Six surrogate standards were added to each point source canister sample prior to extraction and their percent recoveries were evaluated following analysis of the canister's contents. The surrogates monitor the efficiency of the extraction, the cleanup, and evaporation of the solvent if any has been used on the sample. Surrogate percent recoveries for each canister result together with acceptable recovery limits are provided with each of TestAmerica's™ analytical reports contained in Appendix 3-C.

Laboratory Control Samples and Control Sample Duplicates

The Laboratory Control Sample (LCS) is a clean matrix that is fortified with the target analytes and analyzed in the same manner as a batch of samples is analyzed. Since in this case the concentration of each analyte is known, the resulting values provide a measure of the accuracy of the system for each analyte. As a further measure of quality control, the LCS is analyzed in duplicate and the relative percent difference between the two results is calculated and evaluated against the laboratory's acceptance criteria. Both LCS and LCS duplicate results are provided towards the conclusion of each TestAmerica™ report.

Continuing Calibration Verification

Continuing Calibration Verification (CCV) checks are performed over specific time periods during sample analysis to confirm the instrument's calibration and performance. A CCV check was performed by TestAmerica™ with each batch of sample analyses. The results are evaluated as the percent recoveries of the known analyte concentrations making up the CCV spike. The results of each CCV check are reported under the heading "Calibration Check" in the TestAmerica™ documentation located in Appendix 3-C.

3.7 Point Source Testing Conclusions

Point source testing was conducted to determine how much air pollution is being released by natural gas exploration in Fort Worth, and if natural gas extraction and processing sites comply with environmental regulations. The point source testing program occurred in two phases, with Phase I occurring from August through October of 2010, and Phase II occurring in January and February of 2011. Under the point source testing program, field personnel determined the amount of air pollution released at individual well pads, compressor stations, and other natural gas processing facilities by visiting 388 sites, includes two repeat visits, and testing the equipment at each site for emissions using infrared cameras, toxic vapor analyzers (TVAs), Hi Flow Samplers, and evacuated canisters to collect emission samples for laboratory analysis.

TOC, VOC, and HAP emissions were calculated on an annual basis for each site as the sum of 1) direct canister sample results; 2) adjusted canister results using correlation equations; 3) tank and non-tank surrogate emission profiles; 4) engine emission data; and 5) default zero emission factors. Emissions associated with tank unloading, tank flashing, well snubbing, glycol reboilers, flares or any type of maintenance/repair activities were not included in the calculated site emissions profiles.

Key findings from the point source testing program are as follows:

- A total of 2,126 emission points were identified in the four month field study: 192 of the emission points were Valves, 644 were Connectors and 1,290 were classified as Other Equipment. 1,330 emission points were detected with the IR camera (i.e. high level emissions) and 796 emission points were detected by Method 21 screening (i.e. low level emissions).
- At 96 sites, no emissions were detected by the IR camera. At 46 sites, no emissions were detected by either the IR camera or the TVA. Of these 46 sites, 38 had less than three wells and subsequently lower auxiliary equipment counts such as tanks, separators, valves, and connectors.
- Emissions from lift compressors have a significant impact on well pad emissions. Most lift compressors are mobile and are moved from site to site as needed. The addition of a lift compressor to a well pad site has the effect of raising TOC emissions four-fold while emitting an average 16 tons/yr of criteria pollutants.
- The largest source of fugitive emissions detected with the IR camera was leaking tank thief hatches. Emissions were detected at 252 tank thief hatches resulting in a combined TOC emission rate of 4,483 tons/yr. Some of these emissions were due to the operators simply leaving the hatches unsecured as shown in Figure 3.7-1 below. Many others, however, appeared to be due to lack of proper maintenance.

Figure 3.7-1. Thief Hatch Left Open

- Pneumatic Valve Controllers were the most frequent emission sources encountered at well pads and compressor stations. These controllers use pressurized natural gas to actuate separator unloading valves. Under normal operation a pneumatic valve controller is designed to release a small amount of natural gas to the atmosphere during each unloading event. Due to contaminants in the natural gas stream, however, these controllers eventually fail (often within six months of installation) and begin leaking natural gas continually. The emissions from the 489 failed pneumatic valve controllers detected by the point source team result in a combined TOC emission rate of 3,003 tons per year.

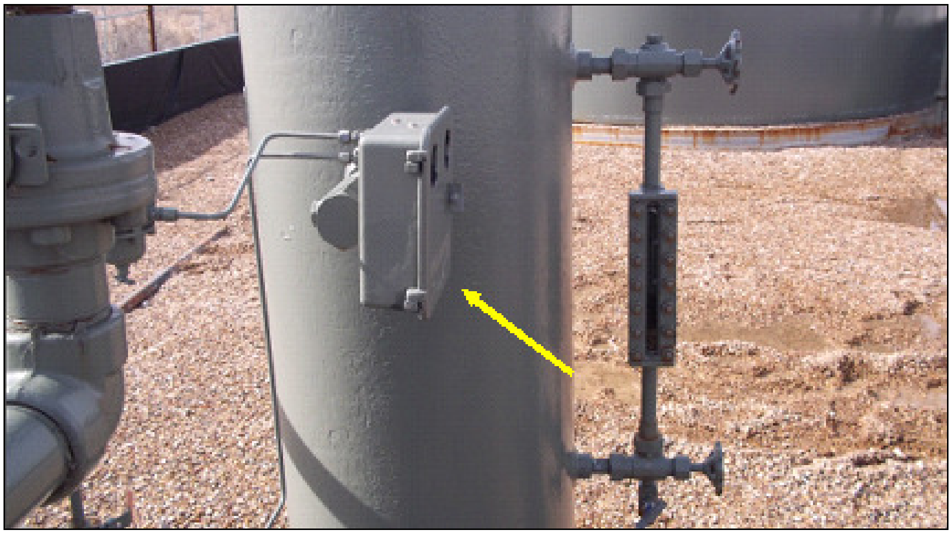


Figure 3.7-2. Pneumatic Valve Controller on Separator

- Emissions from 175 storage tank vents were detected by the IR camera accounting for a combined total of 2,076 tons of TOC per year. In numerous instances several tanks would be manifolded to one vent controlled by a pressure relief valve. In these cases, vent emissions detected with the IR camera indicated a failure of the pressure relief valve.

Figure 3.7-3. Storage Tank Vent

- Emissions from 257 leaking natural gas pressure regulators accounted for a combined TOC total of 614 tons/yr.

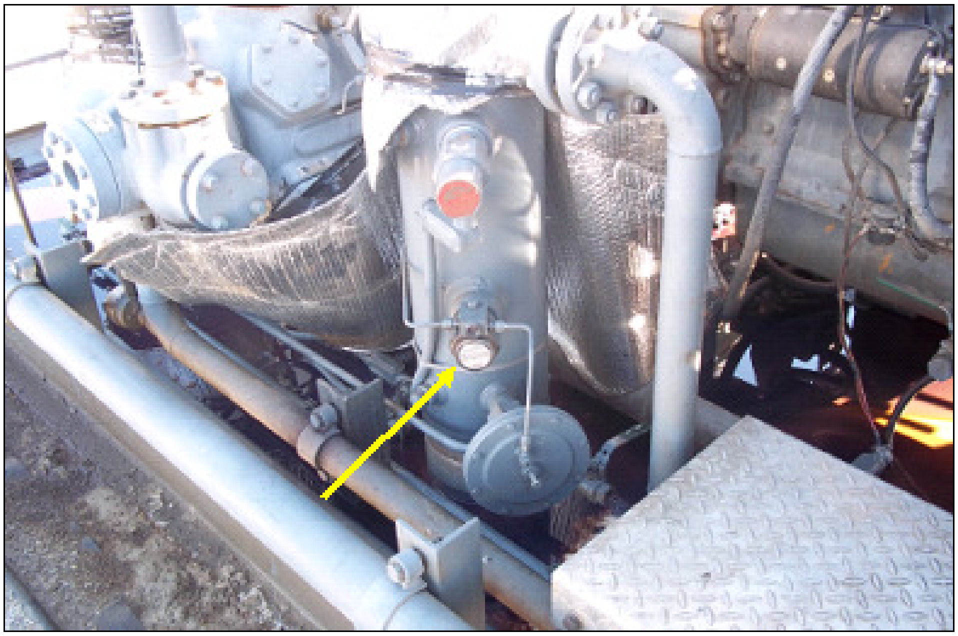


Figure 3.7-4. Natural Gas Pressure Regulator

- Fifty-five (55) instances of emissions from miscellaneous equipment were detected, accounting for a combined TOC emission rate of 731 tons/yr. Miscellaneous equipment includes pinholes, compressor shafts, sumps, knock-out pots, underground piping, glycol contactor controllers, pressure indicators, and quite frequently, holes or breaks in the tank roofs (Figure 3.7-5).

Figure 3.7-5. Hole in Tank Roof - Miscellaneous Emission Source

- No natural gas emissions associated with drilling and fracking activities were detected by the IR camera. Engine emissions associated with these activities were estimated based upon vendor data and published emission factors.
- Emissions were detected from a well completion activity with the IR camera. However, no measurements were taken using the TVA and Method 21 screening procedures and/or the highflow sampler due to safety considerations.
- Emissions were also detected at the Salt Water Treatment facility using the TVA. No emissions were detected using the IR camera. The emissions that were detected with the TVA resulted from minor fugitive emission components only. The Evaporative Unit was not able to be tested since it was out of service during the point source survey.
- Although there was little difference in average TOC emissions between dry and wet gas sites, average VOC and HAP emissions from wet gas sites proved to be considerably higher than dry gas sites as would be expected due to the additional storage and loading of condensate at wet gas sites.
- An Encana Oil & Gas Well Pad (Site ID PS-184) located at 10590 Chapin Road had the highest VOC emissions among well pads (22 tons/yr). This site had only a single well, with two tanks. However, it also had one large line compressor (Caterpillar G-399). Twelve (12) emission points were detected at this site with the IR camera: Four in the area of the separators, three on the tanks, and five at the compressor.

4.0 Air Dispersion Modeling

Existing well pads and compressor stations in the city of Fort Worth emit air pollutants that affect off-site air quality. Under Task 4, a modeling analysis was conducted to quantify downwind impacts from natural gas activities at facility property lines and beyond using the latest EPA-approved models and methodologies. Modeling was conducted for 91 pollutants for which emission rates were measured and/or estimated under the Point Source Testing task (Task 3). See Section 3 of this report for details on how the point source emission estimates were derived. The modeling did not include criteria pollutant emissions from natural gas combustion in the compressor engines, and only considered emissions data from the well pads. Emissions from other source types, such as onroad emissions, were not considered for this task.

The modeling results can also be used to assess the adequacy of existing setback distances; as well, they were also used in the public health evaluation performed under Task 7 of this project. The findings of the public health evaluation, including a detailed analysis of the modeling results and their implications relative to the city's required setback distances, can be found in Section 5 of this report.

This section has five sub-sections:

- 4.1 Modeling Scenarios and Source Parameters – A description of how how the modeling scenarios were established is provided in this section.
- 4.2 Modeling Inputs and Options – This section provides the specific modeling inputs and options used to conduct the dispersion modeling.
- 4.3 Model Output – Summary tables showing the maximum 1-hour, 24-hour, and annual modeled impacts are provided in this section.
- 4.4 Electronic Modeling Files – This section provides electronic versions of the modeling input and output files.
- 4.5 Air Dispersion Modeling Conclusions – This section presents the conclusions of the air dispersion modeling task.

4.1 Modeling Scenarios and Source Parameters

There are over 500 individual well pads and compressor stations within the city of Fort Worth. While many of these sites are similar with respect to source types and emissions profiles, there is a wide variety of configurations of the emission sources at each site. For this analysis, as described in the Work Plan, four different scenarios were modeled that represent both average and potential worst-case estimates of modeled impacts based on actual emissions from source testing, source position relative to the property line, source alignments relative to one another, and associated downwash structure effects.

All emission sources observed during the point source testing were considered, and have been categorized and modeled as storage tanks, fugitive emission points, and compressor engines. A summary of these three source categories follows.

Storage tanks were modeled as pseudo-point sources, using an exit velocity of 0.001 meters per second and a stack diameter of 0.001 meters, along with ambient exhaust temperature. These stack parameters were chosen to produce conservative estimates of impacts from the tanks; such parameters effectively negate any airflow from the source, thereby eliminating the effect of vertical displacement on the plume. This approach is widely used in many states throughout the U.S., and is considered standard modeling practice for sources of this type. A hypothetical tank layout for each site, including tank diameters and heights, was used to determine the potential for downwash effects using AERMOD's included Plume Rise Model Enhancements (PRIME) algorithms. Based on ERG's understanding of the emission sources at each site, the tanks are the only sources that would significantly impede the free flow of air, so direction-specific source dimensions were only calculated for storage tanks. Figure 4.1-1 shows a battery of six storage tanks at a well pad (emissions associated with the horizontal separators shown on the right side of this image are accounted for with the fugitive emission points as discussed below).

Figure 4.1-1. Storage Tanks

All *fugitive emission points* were modeled as a single elevated area source. This source category includes estimated emissions from piping, valves, and connectors associated with emission sources such as wellheads, separators, or pneumatic liquid level controllers. A release height of 6 feet was assumed, representing the average height of all the piping and associated equipment. This source category included every emission type not modeled under the storage tank or compressor engine source category. Figure 4.1-2 shows a close-up view of equipment at a well pad or compressor station that may emit fugitive emissions.

Figure 4.1-2. Fugitive Emission Points

For *compressor engines,* emissions from the combustion of natural gas were modeled as standard point sources, using representative exhaust flow and temperature. Fugitive emissions of natural gas from piping associated with the gas compression process are included with the fugitive emission points discussed above. Figure 4.1-3 shows a compressor engine located at a compressor station.

Figure 4.1-3. Natural Gas Compression Engine

Table 4.1-1, below, summarizes the different types of source categories at well pads and compressor stations in Fort Worth, along with the modeling classification of each source.

Table 4.1-1. Source Types Modeled

Source Category	Number of Modeled Sources per Well Pad or Compressor Station	Modeling Classification
Storage tanks	5 to 10	Pseudo-point source with downwash
Fugitive emission points	1	Elevated area source
Compressor engines	0 to 6	Point source

The four modeling scenarios are described in more detail below.

4.1.1 Scenario 1 (Typical Well Pad)

This scenario represents a typical well pad without compression and includes storage tanks and fugitive emission points. Emission rates are based on point source testing conducted under Task 3. Typical well pad emission sources include storage tanks, wellheads, separators, and pneumatic devices. All identified emission sources at a well pad without compression have been included in this scenario. Specifically, this scenario includes the following:

Key Point: Scenario 1
Emission rates modeled under Scenario 1 represent the average emission rates from storage tanks and fugitive emission points from all well pads tested under this study.

- Five storage tanks, each 10 feet tall and 15 feet in diameter, modeled as pseudo-point sources.
- Storage tank emission rates based on the average, pollutant-specific storage tank emission rate observed at all well pad sites.
- Emission rates from fugitive emission points (wellheads, separators, pneumatic devices, piping, etc.) based on the average, pollutant-specific well pad emission rate observed during point source testing, modeled as a single elevated area source.
- Well pad measuring 200 feet by 200 feet.

Table 4.1-2 shows the emission rates used in the modeling demonstration for Scenario 1.

Table 4.1-2. Scenario 1 (Typical Well Pad) Model Input Emission Rates

Pollutant	Storage Tanks (lb/hr)[a]	Fugitive Emission Points (lb/hr)
Acetone	2.18E-05	5.67E-04
Benzene	1.16E-03	1.07E-04
Bromomethane	NA	1.14E-06
Butadiene, 1,3-	NA	4.85E-06
Butane	2.16E-02	8.96E-03
Butanone, 2- (Methyl Ethyl Ketone)	8.24E-06	3.36E-06
Butylbenzene, *sec-*	1.98E-05	6.63E-06
Carbon disulfide	2.77E-06	NA
Carbon tetrachloride	NA	1.12E-06
Chlorodifluoromethane	NA	4.41E-07
Chloroethane	NA	1.16E-06
Chloromethane	8.41E-07	6.07E-07
Chlorotoluene, 2-	NA	1.52E-06
Cyclohexane	1.38E-03	2.17E-04
Decane, *n-*	2.64E-04	4.83E-05
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	NA	1.05E-06
Dichlorodifluoromethane	NA	8.77E-07
Dodecane, *n-*	2.11E-05	8.96E-06
Ethylbenzene	8.68E-05	1.65E-05
Ethyltoluene, 4-	8.11E-05	2.42E-05
Heptane	5.66E-03	4.32E-04
Hexachlorobutadiene	7.48E-06	6.61E-06
Hexane	5.22E-03	5.03E-04

Table 4.1-2. Scenario 1 (Typical Well Pad) Model Input Emission Rates (Continued)

Pollutant	Storage Tanks (lb/hr)	Fugitive Emission Points (lb/hr)
Isopentane	8.83E-03	2.53E-03
Isopropylbenzene	3.33E-05	6.29E-06
Isopropyltoluene, 4-	1.94E-05	1.77E-05
Methane	8.36E+00	3.60E+00
Methyl-2-pentanone, 4- (Methyl Isobutyl Ketone)	2.46E-06	1.17E-05
Methylene chloride	3.40E-06	4.43E-04
Naphthalene	1.02E-05	5.39E-06
Nonane, *n-*	4.78E-03	1.18E-04
Octane, *n-*	6.14E-03	2.17E-04
Pentane, *n-*	6.78E-03	1.67E-03
Propylbenzene, *n-*	4.11E-05	1.38E-05
Propylene	1.66E-06	2.51E-06
Styrene	2.68E-06	NA
Tetrachloroethene	7.04E-05	NA
Toluene	4.40E-03	2.80E-04
Trichlorobenzene, 1,2,3-	1.02E-05	1.14E-05
Trichlorobenzene, 1,2,4-	9.95E-06	7.46E-06
Trichlorofluoromethane	NA	1.29E-06
Trimethylbenzene, 1,2,4-	2.11E-04	3.73E-05
Trimethylbenzene, 1,3,5-	1.64E-04	4.36E-05
Trimethylpentane, 2,2,4-	1.31E-05	3.60E-06
Undecane, *n-*	4.23E-05	1.91E-05
Vinyl acetate	1.30E-05	NA
Vinyl bromide	NA	1.38E-06
Vinyl chloride	NA	6.67E-07
Xylene, *o-*	1.85E-04	4.06E-05
Xylenes, *m-,p-*	2.44E-03	2.14E-04

[a] Emission estimates are shown in this table using scientific notation. In scientific notation, the format “2.18E-05” is used to display a value of “0.0000218” by shifting the decimal place 5 places to the left using “E-“ prefix. Likewise, the format “2.18E+05” would be used to display a value of “218,000” by shifting the decimal place 5 places to the right using “E+“ prefix.

NA = not applicable

Figure 4.1-4 shows the layout of the typical well pad modeled under Scenario 1.

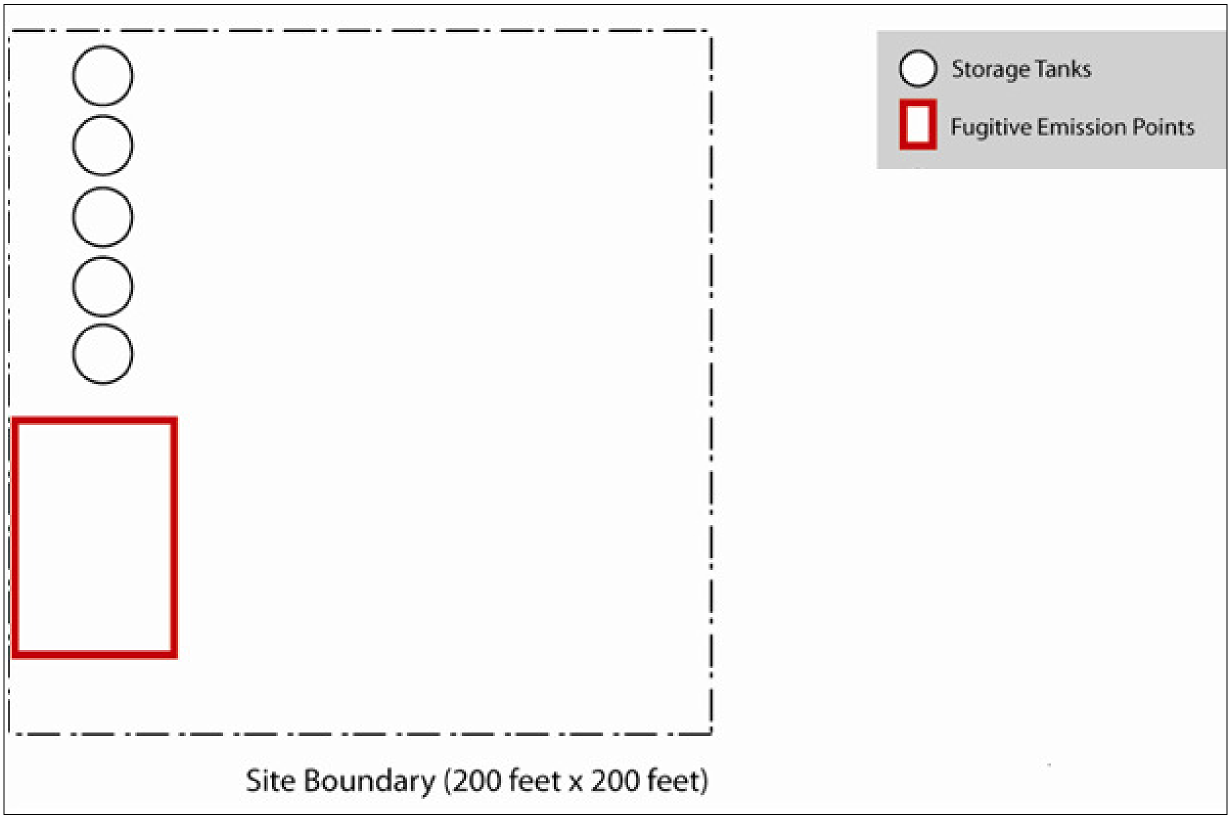


Figure 4.1-4. Scenario 1 Layout (Typical Well Pad)

4.1.2 Scenario 2 (Worst-Case Well Pad)

This scenario represents a worst-case well pad with storage tanks, fugitive emission points, and two compression engines (250 hp each). Emissions from combustion of natural gas in the compression engines are based on published emission factors, while emissions from storage tanks and fugitive emission points are based on point source testing. Specifically, this scenario includes the following:

Key Point: Scenario 2
Emission rates modeled under Scenario 2 represent the maximum emission rates from storage tanks and fugitive emission points from all well pads tested under this study.

- Ten storage tanks, each 10 feet tall and 15 feet in diameter, modeled as pseudo-point sources.
- Storage tank emission rates based on the maximum, pollutant-specific storage tank emission rate observed at all well pad sites.
- Two 250-hp compressor engines, uncontrolled, modeled as point sources.
- Emission rates from fugitive emission points (wellheads, separators, pneumatic devices, piping, etc.) based on the maximum, pollutant-specific well pad emission rate observed during point source testing, modeled as a single elevated area source.
- Well pad measuring 250 feet by 250 feet.

Table 4.1-3 shows the emission rates used in the modeling demonstration for Scenario 2.

Table 4.1-3. Scenario 2 (Worst-Case Well Pad) Model Input Emission Rates

Pollutant	Storage Tanks (lb/hr)	Fugitive Emission Points (lb/hr)	Compressor Engines (lb/hr)
Acenaphthene	NA	NA	5.17E-06
Acenaphthylene	NA	NA	2.15E-05
Acetaldehyde	NA	NA	3.25E-02
Acetone	8.98E-04	2.09E-01	NA
Acrolein	NA	NA	3.02E-02
Anthracene	NA	NA	2.79E-06
Benzene	5.26E-02	2.24E-02	7.54E-03
Benzo (a) anthracene	NA	NA	1.31E-06
Benzo (a) pyrene	NA	NA	2.21E-08
Benzo (b) fluoranthene	NA	NA	6.45E-07
Benzo (e) pyrene	NA	NA	1.61E-06
Benzo (g,h,i) perylene	NA	NA	1.61E-06
Benzo (k) fluoranthene	NA	NA	1.66E-08
Biphenyl	NA	NA	8.24E-04
Bromomethane	NA	3.82E-05	NA
Butadiene, 1,3-	NA	1.61E-04	3.19E-03
Butane	2.14E+00	2.16E+00	NA
Butane, *n*-	NA	NA	1.85E-02
Butanone, 2- (Methyl Ethyl Ketone)	1.88E-04	1.13E-04	NA
Butylbenzene, *sec*-	9.55E-04	2.22E-04	NA
Carbon disulfide	5.90E-05	NA	NA
Carbon tetrachloride	NA	3.74E-05	2.36E-04
Chlorobenzene	NA	NA	1.73E-04
Chlorodifluoromethane	NA	1.48E-05	NA
Chloroethane	NA	3.91E-05	7.27E-06
Chloroform	NA	NA	1.83E-04
Chloromethane	1.77E-05	1.99E-05	NA
Chlorotoluene, 2-	NA	5.10E-05	NA
Chrysene	NA	NA	2.69E-06
Cyclohexane	9.01E-02	6.52E-02	1.20E-03
Cyclopentane	NA	NA	8.82E-04
Decane, *n*-	2.17E-02	1.28E-02	NA
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	NA	3.50E-05	NA
Dichlorodifluoromethane	NA	2.94E-05	NA
Dichloroethane, 1,1-	NA	NA	1.52E-04
Dichloropropene, 1,3-	NA	NA	1.70E-04
Dodecane, *n*-	5.89E-04	1.45E-03	NA
Ethane	NA	NA	4.08E-01
Ethylbenzene	3.62E-03	4.20E-03	4.20E-04
Ethylene dibromide	NA	NA	2.85E-04
Ethylene dichloride	NA	NA	1.64E-04
Ethyltoluene, 4-	5.99E-03	1.72E-03	NA
Fluoranthene	NA	NA	4.32E-06

Table 4.1-3. Scenario 2 (Worst-Case Well Pad) Model Input Emission Rates (Continued)

Pollutant	Storage Tanks (lb/hr)	Fugitive Emission Points (lb/hr)	Compressor Engines (lb/hr)
Fluorene	NA	NA	2.20E-05
Formaldehyde	NA	NA	2.15E-01
Heptane	5.79E-01	1.32E-01	NA
Hexachlorobutadiene	1.68E-04	2.21E-04	NA
Hexane	6.00E-01	1.48E-01	4.32E-03
Indeno (1,2,3-cd) pyrene	NA	NA	3.86E-08
Isobutane	NA	NA	1.46E-02
Isobutyraldehyde	NA	NA	1.70E-03
Isopentane	7.25E-01	7.46E-01	NA
Isopropylbenzene	1.11E-03	7.92E-04	NA
Isopropyltoluene, 4-	4.94E-04	5.91E-04	NA
Methane	9.93E+01	7.27E+01	NA
Methyl alcohol	NA	NA	1.19E-02
Methyl Naphthalene, 2-	NA	NA	1.29E-04
Methyl-2-pentanone, 4- (Methyl Isobutyl Ketone)	5.59E-05	3.94E-04	NA
Methylcyclohexane	NA	NA	4.78E-03
Methylene chloride	7.08E-05	1.64E-01	5.71E-04
Naphthalene	2.00E-04	1.80E-04	3.77E-04
Nonane, *n*-	5.38E-01	3.45E-02	4.28E-04
Octane, *n*-	5.54E-01	7.13E-02	1.36E-03
Pentane, *n*-	6.05E-01	5.13E-01	1.01E-02
Perylene	NA	NA	1.93E-08
Phenanthrene	NA	NA	4.04E-05
Phenol	NA	NA	1.64E-04
Polycyclic Aromatic Hydrocarbons (PAH)	NA	NA	5.48E-04
Propane	NA	NA	1.63E-01
Propylbenzene, *n*-	2.00E-03	9.24E-04	NA
Propylene	3.46E-05	1.10E-04	NA
Propylene dichloride	NA	NA	1.73E-04
Pyrene	NA	NA	5.29E-06
Styrene	6.07E-05	NA	2.13E-04
Tetrachloroethane, 1,1,2,2-	NA	NA	2.58E-04
Tetrachloroethene	1.49E-03	NA	NA
Toluene	2.82E-01	8.39E-02	3.74E-03
Trichlorobenzene, 1,2,3-	2.28E-04	3.83E-04	NA
Trichlorobenzene, 1,2,4-	2.26E-04	2.49E-04	NA
Trichloroethane, 1,1,2,2-	NA	NA	2.05E-04
Trichlorofluoromethane	NA	4.32E-05	NA
Trimethylbenzene, 1,2,3-	NA	NA	1.38E-04
Trimethylbenzene, 1,2,4-	1.90E-02	7.75E-03	4.32E-04
Trimethylbenzene, 1,3,5-	7.87E-03	9.14E-03	1.31E-04
Trimethylpentane, 2,2,4-	4.18E-04	1.17E-04	3.29E-03
Undecane, *n*-	2.32E-03	5.32E-03	NA
Vinyl acetate	2.97E-04	NA	NA

Table 4.1-3. Scenario 2 (Worst-Case Well Pad) Model Input Emission Rates (Continued)

Pollutant	Storage Tanks (lb/hr)	Fugitive Emission Points (lb/hr)	Compressor Engines (lb/hr)
Vinyl bromide	NA	4.63E-05	NA
Vinyl chloride	NA	2.24E-05	9.60E-05
Xylene, *o-*	9.64E-03	1.17E-02	1.04E-03
Xylenes, *m-,p-*	2.25E-01	7.10E-02	1.04E-03

NA = not applicable

Figure 4.1-5 shows the layout of the worst-case well pad modeled under Scenario 2.

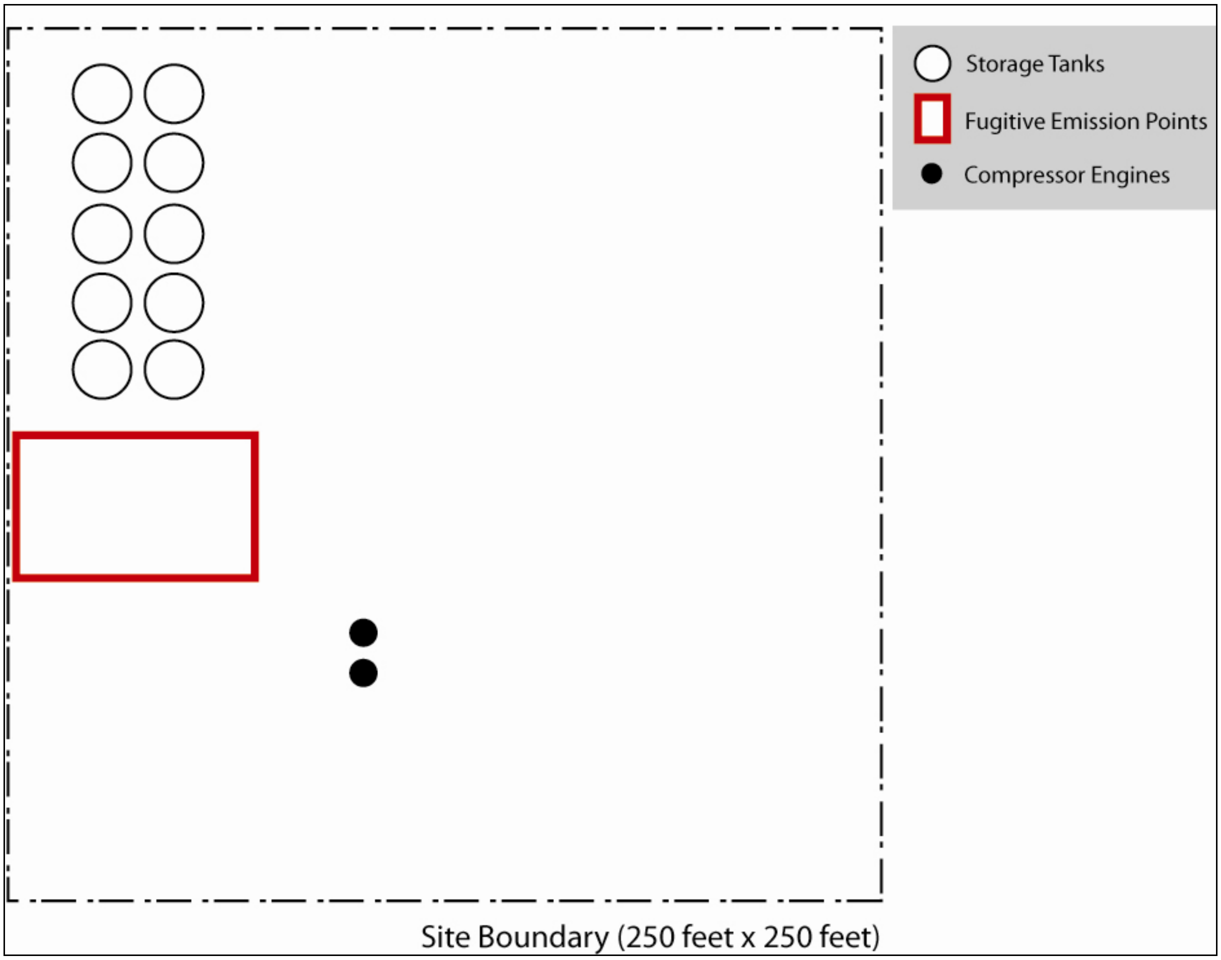


Figure 4.1-5. Scenario 2 Layout (Worst-Case Well Pad)

4.1.3 Scenario 3 (Worst-Case Compressor Station)

This scenario represents a worst-case compressor station with six compression engines (1,775 hp each). Emissions from combustion of natural gas in the compression engines are based on published emission factors, while emissions from storage tanks and fugitive emission points are based on point source testing. Specifically, this scenario includes the following:

Key Point: Scenario 3
Emission rates modeled under Scenario 3 represent the maximum emission rates from storage tanks and fugitive emission points from all compressor stations tested under this study.

- Storage tank emission rates based on the maximum, pollutant-specific storage tank emission rate observed at all compressor station sites.
- Eight tanks, each 10 feet tall and 15 feet in diameter, modeled as pseudo-point sources.
- Six 1,775-hp compressor engines, uncontrolled, modeled as point sources.
- Emission rates from all other sources (wellheads, separators, pneumatic devices, dehydrators, piping, etc.) based on the maximum, pollutant-specific compressor station emission rate observed during point source testing, modeled as a single elevated area source.
- Compressor station measuring 600 feet by 400 feet.

Table 4.1-4 shows the emission rates used in the modeling demonstration for Scenario 3.

Table 4.1-4. Scenario 3 (Worst-Case Compressor Station) Model Input Emission Rates

Pollutant	Storage Tanks (lb/hr)	Fugitive Emission Points (lb/hr)	Compressor Engines (lb/hr)
Acenaphthene	NA	NA	9.40E-05
Acenaphthylene	NA	NA	3.91E-04
Acetaldehyde	NA	NA	5.91E-01
Acetone	5.27E-04	1.06E-03	NA
Acrolein	NA	NA	5.50E-01
Anthracene	NA	NA	5.07E-05
Benzene	1.53E-02	1.31E-03	1.37E-01
Benzo (a) anthracene	NA	NA	2.37E-05
Benzo (a) pyrene	NA	NA	4.01E-07
Benzo (b) fluoranthene	NA	NA	1.17E-05
Benzo (e) pyrene	NA	NA	2.93E-05
Benzo (g,h,i) perylene	NA	NA	2.93E-05
Benzo (k) fluoranthene	NA	NA	3.01E-07
Biphenyl	NA	NA	1.50E-02
Bromomethane	NA	1.38E-05	NA
Butadiene, 1,3-	NA	5.83E-05	5.79E-02
Butane	1.13E-01	1.45E-02	NA

Table 4.1-4. Scenario 3 (Worst-Case Compressor Station) Model Input Emission Rates (Continued)

Pollutant	Storage Tanks (lb/hr)	Fugitive Emission Points (lb/hr)	Compressor Engines (lb/hr)
Butane, *n-*	NA	NA	3.36E-01
Butanone, 2- (Methyl Ethyl Ketone)	1.79E-05	4.09E-05	NA
Butylbenzene, *sec-*	2.64E-05	5.58E-04	NA
Carbon disulfide	5.62E-06	NA	NA
Carbon tetrachloride	NA	1.36E-05	4.29E-03
Chlorobenzene	NA	NA	3.14E-03
Chlorodifluoromethane	NA	5.36E-06	NA
Chloroethane	NA	1.41E-05	1.32E-04
Chloroform	NA	NA	3.33E-03
Chloromethane	1.69E-06	7.19E-06	NA
Chlorotoluene, 2-	NA	1.85E-05	NA
Chrysene	NA	NA	4.90E-05
Cyclohexane	5.26E-03	4.36E-04	2.18E-02
Cyclopentane	NA	NA	1.60E-02
Decane, *n-*	3.86E-05	1.46E-04	NA
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	NA	1.27E-05	NA
Dichlorodifluoromethane	NA	1.07E-05	NA
Dichloroethane, 1,1-	NA	NA	2.76E-03
Dichloropropene, 1,3-	NA	NA	3.10E-03
Dodecane, *n-*	3.04E-05	4.80E-05	NA
Ethane	NA	NA	7.42E+00
Ethylbenzene	2.69E-04	5.21E-05	7.63E-03
Ethylene dibromide	NA	NA	5.19E-03
Ethylene dichloride	NA	NA	2.98E-03
Ethyltoluene, 4-	5.71E-05	1.35E-02	NA
Fluoranthene	NA	NA	7.84E-05
Fluorene	NA	NA	4.01E-04
Formaldehyde	NA	NA	3.90E+00
Heptane	3.66E-04	1.98E-04	NA
Hexachlorobutadiene	1.60E-05	8.00E-05	NA
Hexane	3.53E-03	4.68E-04	7.84E-02
Indeno (1,2,3-cd) pyrene	NA	NA	7.02E-07
Isobutane	NA	NA	2.65E-01
Isobutyraldehyde	NA	NA	3.09E-02
Isopentane	3.47E-02	5.52E-03	NA
Isopropylbenzene	3.95E-05	1.67E-04	NA
Isopropyltoluene, 4-	3.09E-05	2.90E-04	NA
Methane	2.17E+02	2.63E+01	NA
Methyl alcohol	NA	NA	2.16E-01
Methyl naphthalene, 2-	NA	NA	2.35E-03
Methyl-2-pentanone, 4- (Methyl Isobutyl Ketone)	5.32E-06	1.43E-04	NA

Table 4.1-4. Scenario 3 (Worst-Case Compressor Station) Model Input Emission Rates (Continued)

Pollutant	Storage Tanks (lb/hr)	Fugitive Emission Points (lb/hr)	Compressor Engines (lb/hr)
Methylcyclohexane	NA	NA	8.69E-02
Methylene chloride	2.42E-05	1.82E-05	1.04E-02
Naphthalene	1.91E-05	6.53E-05	6.86E-03
Nonane, *n*-	8.99E-05	2.71E-04	7.77E-03
Octane, *n*-	9.89E-05	1.54E-04	2.48E-02
o-Xylene, *o*-	2.66E-04	1.87E-04	1.89E-02
Pentane, *n*-	1.33E-02	2.32E-03	1.84E-01
Perylene	NA	NA	3.51E-07
Phenanthrene	NA	NA	7.35E-04
Phenol	NA	NA	2.97E-03
Polycyclic aromatic hydrocarbons (PAH)	NA	NA	9.96E-03
Propane	NA	NA	2.96E+00
Propylbenzene, *n*-	4.42E-05	5.03E-03	NA
Propylene	3.29E-06	2.68E-05	NA
Propylene dichloride	NA	NA	3.15E-03
Pyrene	NA	NA	9.61E-05
Styrene	5.77E-06	NA	3.87E-03
Tetrachloroethane, 1,1,2,2-	NA	NA	4.68E-03
Tetrachloroethene	1.42E-04	NA	NA
Toluene	1.23E-02	6.97E-04	6.80E-02
Trichlorobenzene, 1,2,3-	2.17E-05	1.39E-04	NA
Trichlorobenzene, 1,2,4-	2.15E-05	9.03E-05	NA
Trichloroethane, 1,1,2-	NA	NA	3.72E-03
Trichlorofluoromethane	NA	1.57E-05	NA
Trimethylbenzene, 1,2,3-	NA	NA	2.50E-03
Trimethylbenzene, 1,2,4-	7.07E-05	5.98E-02	7.84E-03
Trimethylbenzene, 1,3,5-	7.79E-05	1.49E-02	2.39E-03
Trimethylpentane, 2,2,4-	1.84E-05	4.23E-05	5.98E-02
Undecane, *n*-	5.26E-05	5.68E-05	NA
Vinyl acetate	2.82E-05	NA	NA
Vinyl bromide	NA	1.68E-05	NA
Vinyl chloride	NA	8.11E-06	1.75E-03
Xylenes, *m-,p-*	1.67E-03	1.72E-04	1.89E-02

NA = not applicable

Figure 4.1-6 shows the layout of the worst-case compressor station modeled under Scenario 3.

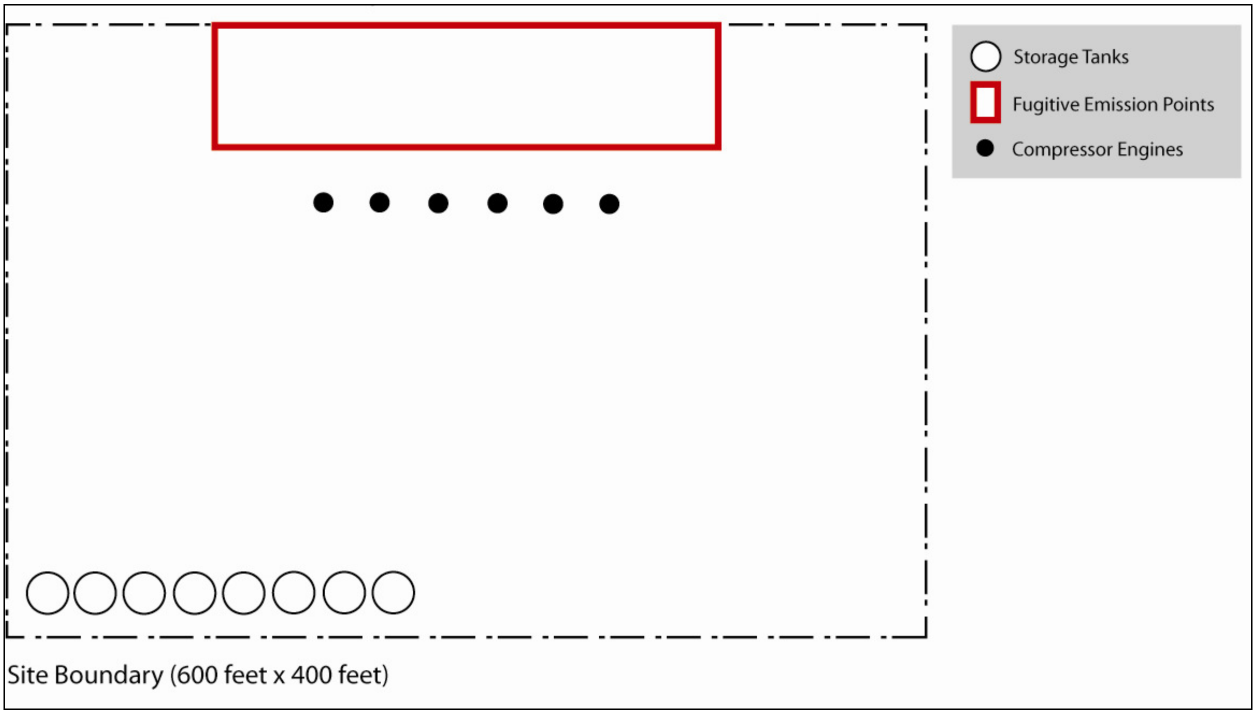


Figure 4.1-6. Scenario 3 Layout (Worst-Case Compressor Station)

4.1.4 Scenario 4 (Co-located Worst-Case Well Pad and Worst-Case Compressor Station)

This modeling scenario quantifies the combined impacts of the worst-case well pad in Scenario 2 and the worst-case compressor station in Scenario 3. This scenario assumes co-location of a well pad and a compressor station. The emission rates used in Scenario 4 are the same as used in Scenario 2 for the well pad and Scenario 3 for the compressor station.

Figure 4.1-7 shows the layout of the co-located well pad and compressor station modeled under Scenario 4.

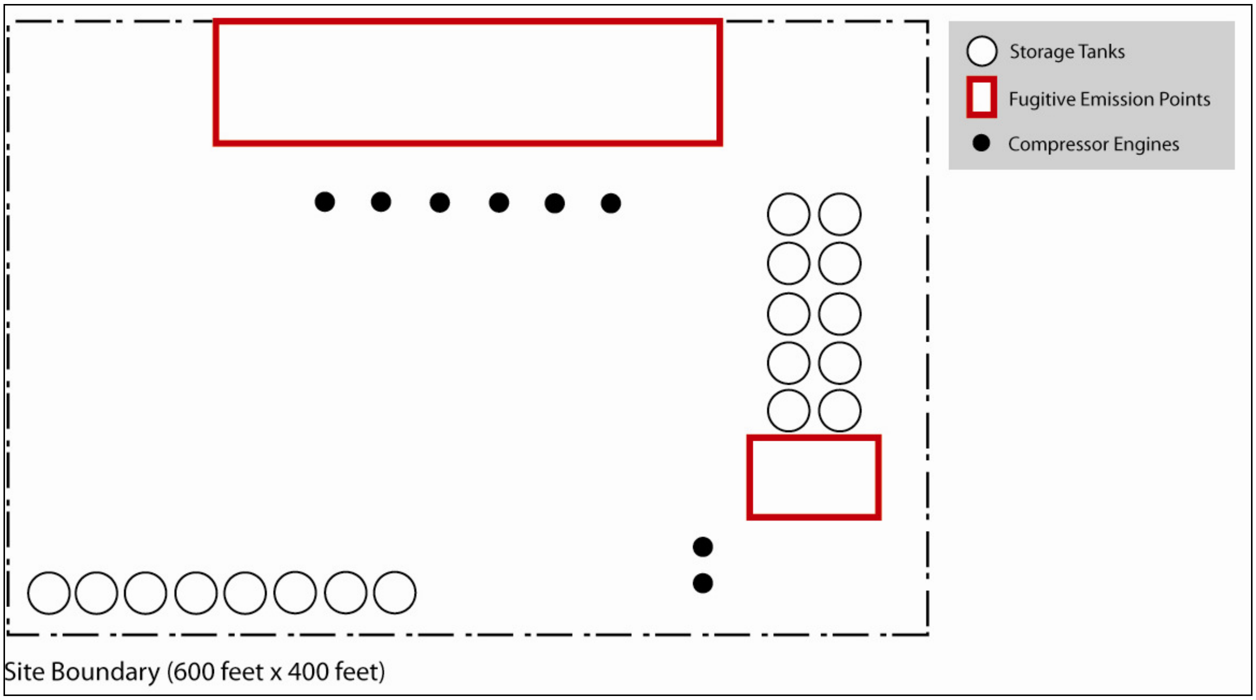


Figure 4.1-7. Scenario 4 Layout (Co-located Well Pad and Compressor Station)

4.2 Model Setup and Options

ERG used the latest version of the AMS/EPA Regulatory MODel (AERMOD), Version 11103, to estimate pollutant impacts for four different well pad and compressor station layouts. The modeling predicts, by scenario, 1-hour average, 24-hour average, and annual average concentrations for the pollutants listed in Section 4.1 above. Building downwash effects were simulated using the PRIME algorithm, which is included with AERMOD and is "designed to incorporate the two fundamental features associated with building downwash: enhanced plume dispersion coefficients due to the turbulent wake, and reduced plume rise caused by a combination of the descending streamlines in the lee of the building and the increased entrainment in the wake." [8] All model runs were constructed and executed using BEEST for Windows 9.90, a commercial dispersion modeling software package that combines AERMOD and its supporting programs into a single interface for use in model pre- and post-processing.

4.2.1 Receptor Grids

The modeling estimated air quality impacts at locations outside the property line of the well pads and compressor stations. Predictions were made from the property line out to a distance 2 kilometers away. Receptor grids of different resolutions were used to predict the maximum ambient concentrations around each site. ERG used 10-meter spacing along each site's property fence line out to 40 meters; 25-meter spacing from 50 to 150 meters; 100-meter spacing from 200 meters to 1 kilometer; and 200-meter spacing between 1 and 2 kilometers. Because the terrain in the Fort Worth area is primarily flat, terrain heights of zero meters were assumed.

4.2.2 Meteorological Data and Surface Parameters

The meteorological data used in this analysis was obtained from TCEQ. It has been preprocessed to ensure data quality, and is approved for use in AERMOD for state and federal modeling analyses. It consists of a single year of surface data from Dallas–Fort Worth International Airport (about 10 miles east-northeast of the Fort Worth) and upper air observations from Stephenville, Texas (about 60 miles southwest of Fort Worth) for 1988. The associated albedo for this dataset is 0.150, while the Bowen ratio is 0.600; both of these were input to the model. A "medium" surface roughness of 0.5 meters, corresponding to rural/suburban areas, was selected; this choice is representative of a large portion of Tarrant County, where natural gas well pads are primarily situated.

4.3 Model Output

A summary of maximum impacts for each scenario, pollutant, and averaging period of interest are presented in Tables 4.3-1 through 4.3-4 below. In most cases, these outputs represent impacts at the fence line defined in each scenario. Figure 4.3-1 presents a graphical illustration of formaldehyde impacts for each of the four scenarios. Please see section 5 for a detailed analysis of the public health implication of the modeling findings, as well as additional modeling graphics.

Impacts for all receptors are contained within the modeling output files, which are described in further detail in Section 4.4. All modeled concentrations are presented in ppbv (with the exception of PAH as noted below).

Table 4.3-1. Modeled Impacts—Scenario 1 (Typical Well Pad)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Acetone	7.20E+00	1.44E+00	4.07E-01
Benzene	1.74E+00	4.72E-01	1.10E-01
Bromomethane	1.12E-03	2.21E-04	6.18E-05
Butadiene, 1,3-	8.33E-03	1.66E-03	4.70E-04
Butane	4.35E+01	1.22E+01	3.06E+00
Butanone, 2- (Methyl Ethyl Ketone)	1.23E-02	3.46E-03	8.67E-04
Butylbenzene, *sec-*	1.72E-02	4.76E-03	1.18E-03
Carbon disulfide	4.26E-03	1.16E-03	2.60E-04
Carbon tetrachloride	6.74E-04	1.34E-04	3.81E-05
Chlorodifluoromethane	4.75E-04	9.33E-05	2.54E-05
Chloroethane	1.68E-03	3.34E-04	9.48E-05
Chloromethane	2.11E-03	5.76E-04	1.60E-04
Chlorotoluene, 2-	1.11E-03	2.22E-04	6.18E-05
Cyclohexane	1.91E+00	5.20E-01	1.24E-01
Decane, *n-*	2.17E-01	5.92E-02	1.42E-02
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	5.69E-04	1.13E-04	3.15E-05
Dichlorodifluoromethane	6.73E-04	1.33E-04	3.84E-05
Dodecane, *n-*	1.46E-02	4.08E-03	1.03E-03

Table 4.3-1. Modeled Impacts—Scenario 1 (Typical Well Pad) (Continued)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Ethylbenzene	8.74E-02	2.38E-02	5.71E-03
Ethyltoluene, 4-	7.89E-02	2.17E-02	5.35E-03
Heptane	6.61E+00	1.80E+00	4.15E-01
Hexachlorobutadiene	3.78E-03	1.02E-03	2.98E-04
Hexane, *n-*	7.08E+00	1.93E+00	4.48E-01
Isopentane	1.43E+01	3.92E+00	9.67E-01
Isopropylbenzene	3.24E-02	8.82E-03	2.12E-03
Isopropyltoluene, 4-	1.92E-02	5.16E-03	1.52E-03
Methane	6.12E+04	1.71E+04	4.32E+03
Methyl-2-pentanone, 4- (Methyl Isobutyl Ketone)	1.09E-02	2.26E-03	7.52E-04
Methylene chloride	4.85E-01	9.69E-02	2.75E-02
Naphthalene	9.58E-03	2.66E-03	6.79E-04
Nonane, *n-*	4.36E+00	1.18E+00	2.68E-01
Octane, *n-*	6.29E+00	1.71E+00	3.89E-01
Pentane, *n-*	1.10E+01	2.99E+00	7.32E-01
Propylbenzene, *n-*	4.00E-02	1.11E-02	2.75E-03
Propylene	6.40E-03	1.55E-03	5.40E-04
Styrene	3.01E-03	8.17E-04	1.83E-04
Tetrachloroethene	4.97E-02	1.35E-02	3.03E-03
Toluene	5.59E+00	1.52E+00	3.49E-01
Trichlorobenzene, 1,2,3-	7.81E-03	2.07E-03	6.54E-04
Trichlorobenzene, 1,2,4-	7.00E-03	1.91E-03	5.32E-04
Trichlorofluoromethane	8.70E-04	1.74E-04	4.98E-05
Trimethylbenzene, 1,2,4-	2.06E-01	5.60E-02	1.34E-02
Trimethylbenzene, 1,3,5-	1.60E-01	4.35E-02	1.07E-02
Trimethylpentane, 2,2,4-	1.34E-02	3.66E-03	9.03E-04
Undecane, *n-*	3.20E-02	8.93E-03	2.26E-03
Vinyl acetate	1.77E-02	4.80E-03	1.08E-03
Vinyl bromide	1.20E-03	2.40E-04	6.86E-05
Vinyl chloride	9.90E-04	2.00E-04	5.48E-05
Xylene, *o-*	2.04E-01	5.56E-02	1.35E-02
Xylenes, *m-, p-*	2.69E+00	7.31E-01	1.69E-01

Table 4.3-2. Modeled Impacts—Scenario 2 (Worst-Case Scenario Well Pad)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Acenaphthene	1.08E-04	7.13E-05	1.43E-05
Acenaphthylene	4.53E-04	2.97E-04	6.27E-05
Acetaldehyde	2.37E+00	1.56E+00	3.27E-01
Acetone	2.71E+02	5.07E+01	1.55E+01
Acrolein	1.74E+00	1.14E+00	2.39E-01
Anthracene	5.08E-05	3.29E-05	6.86E-06
Benzene	5.95E+01	1.34E+01	3.99E+00
Benzo (a) anthracene	1.82E-05	1.18E-05	2.14E-06
Benzo (a) pyrene	0.00E+00	0.00E+00	0.00E+00
Benzo (b) fluoranthene	8.72E-06	5.81E-06	9.69E-07
Benzo (e) pyrene	2.04E-05	1.36E-05	2.91E-06
Benzo (g,h,i) perylene	1.86E-05	1.24E-05	2.65E-06
Benzo (k) fluoranthene	0.00E+00	0.00E+00	0.00E+00
Biphenyl	1.72E-02	1.13E-02	2.38E-03
Bromomethane	3.02E-02	5.66E-03	1.73E-03
Butadiene, 1,3-	2.24E-01	1.29E-01	3.40E-02
Butane	4.00E+03	8.60E+02	2.38E+02
Butane, *n-*	1.02E+00	6.73E-01	1.41E-01
Butanone , 2- (Methyl Ethyl Ketone)	2.27E-01	5.03E-02	1.46E-02
Butylbenzene, *sec-*	5.80E-01	1.33E-01	4.07E-02
Carbon disulfide	5.70E-02	1.36E-02	4.27E-03
Carbon tetrachloride	1.83E-02	4.74E-03	1.60E-03
Chlorobenzene	4.94E-03	3.25E-03	6.82E-04
Chlorodifluoromethane	1.29E-02	2.41E-03	7.35E-04
Chloroethane	4.55E-02	8.55E-03	2.64E-03
Chloroform	4.95E-03	3.25E-03	6.82E-04
Chloromethane	3.95E-02	8.45E-03	2.44E-03
Chlorotoluene, 2-	3.03E-02	5.67E-03	1.73E-03
Chrysene	3.86E-05	2.46E-05	5.36E-06
Cyclohexane	1.06E+02	2.32E+01	6.60E+00
Cyclopentane	4.05E-02	2.66E-02	5.59E-03
Decane, *n-*	1.44E+01	3.18E+00	9.22E-01
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	1.54E-02	2.88E-03	8.81E-04
Dichlorodifluoromethane	1.83E-02	3.42E-03	1.05E-03
Dichloroethane, 1,1-	4.95E-03	3.25E-03	6.82E-04
Dichloropropene, 1,3-	4.94E-03	3.25E-03	6.81E-04
Dodecane, *n-*	7.04E-01	1.33E-01	4.40E-02
Ethane	4.37E+01	2.87E+01	6.03E+00
Ethylbenzene	3.55E+00	7.58E-01	2.23E-01
Ethylene dibromide	4.91E-03	3.23E-03	6.77E-04
Ethylene dichloride	5.34E-03	3.51E-03	7.36E-04
Ethyltoluene, 4-	4.16E+00	9.46E-01	2.87E-01
Fluoranthene	6.89E-05	4.47E-05	9.67E-06
Fluorene	4.27E-04	2.81E-04	5.88E-05

Table 4.3-2. Modeled Impacts—Scenario 2 (Worst-Case Scenario Well Pad) (Continued)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Formaldehyde	2.30E+01	1.51E+01	3.17E+00
Heptane	4.70E+02	1.08E+02	3.30E+01
Hexachlorobutadiene	7.92E-02	1.63E-02	5.01E-03
Hexane, *n*-	5.71E+02	1.31E+02	3.99E+01
Indeno (1,2,3-cd) pyrene	8.85E-07	0.00E+00	0.00E+00
Isobutane	8.09E-01	5.31E-01	1.12E-01
Isobutyraldehyde	7.59E-02	4.99E-02	1.05E-02
Isopentane	1.10E+03	2.36E+02	6.58E+01
Isopropylbenzene	9.10E-01	2.00E-01	5.69E-02
Isopropyltoluene, 4-	4.26E-01	9.02E-02	2.68E-02
Methane	6.13E+05	1.34E+05	3.82E+04
Methyl alcohol	1.20E+00	7.87E-01	1.65E-01
Methyl Naphthalene, 2-	2.92E-03	1.92E-03	4.04E-04
Methyl-2-pentanone, 4- (Methyl Isobutyl Ketone)	3.05E-01	5.64E-02	1.81E-02
Methylcyclohexane	1.57E-01	1.03E-01	2.16E-02
Methylene chloride	1.45E+02	2.71E+01	8.28E+00
Naphthalene	1.64E-01	3.64E-02	1.07E-02
Nonane, *n*-	3.18E+02	7.45E+01	2.33E+01
Octane, *n*-	3.78E+02	8.75E+01	2.73E+01
Pentane, *n*-	8.64E+02	1.88E+02	5.26E+01
Perylene	0.00E+00	0.00E+00	0.00E+00
Phenanthrene	7.31E-04	4.80E-04	1.00E-04
Phenol	5.60E-03	3.68E-03	7.72E-04
Polycyclic Aromatic Hydrocarbons (PAH)[a]	7.23E-02	4.75E-02	9.96E-03
Propane	1.19E+01	7.82E+00	1.64E+00
Propylbenzene, *n*-	1.49E+00	3.33E-01	9.85E-02
Propylene	2.12E-01	3.96E-02	1.30E-02
Propylene dichloride	4.95E-03	3.25E-03	6.82E-04
Pyrene	8.46E-05	5.56E-05	1.21E-05
Styrene	4.28E-02	1.12E-02	3.75E-03
Tetrachloroethane, 1,1,2,2-	4.96E-03	3.26E-03	6.83E-04
Tetrachloroethene	6.59E-01	1.57E-01	4.94E-02
Toluene	2.57E+02	5.84E+01	1.77E+01
Trichlorobenzene, 1,2,3-	1.82E-01	3.48E-02	1.17E-02
Trichlorobenzene, 1,2,4-	1.39E-01	2.98E-02	8.56E-03
Trichloroethane, 1,1,2-	4.93E-03	3.24E-03	6.80E-04
Trichlorofluoromethane	2.37E-02	4.43E-03	1.35E-03
Trimethylbenzene, 1,2,3-	3.69E-03	2.42E-03	5.09E-04
Trimethylbenzene, 1,2,4-	1.39E+01	3.12E+00	9.31E-01
Trimethylbenzene, 1,3,5-	7.46E+00	1.59E+00	4.67E-01
Trimethylpentane, 2,2,4-	3.05E-01	8.17E-02	2.87E-02
Undecane, *n*-	2.83E+00	5.35E-01	1.78E-01
Vinyl acetate	2.53E-01	6.04E-02	1.90E-02
Vinyl bromide	3.25E-02	6.08E-03	1.86E-03

Table 4.3-2. Modeled Impacts—Scenario 2 (Worst-Case Scenario Well Pad) (Continued)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Vinyl chloride	2.69E-02	6.16E-03	2.09E-03
Xylene, *o*-	1.06E+01	2.24E+00	6.69E-01
Xylenes, *m*-,*p*-	1.79E+02	4.07E+01	1.23E+01

[a] Concentration in (µg/m^3).

Table 4.3-3. Modeled Impacts—Scenario 3 (Worst-Case Compressor Station)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Acenaphthene	1.62E-04	8.88E-05	2.06E-05
Acenaphthylene	6.80E-04	3.71E-04	8.68E-05
Acetaldehyde	3.55E+00	1.94E+00	4.52E-01
Acetone	7.95E-01	1.71E-01	4.20E-02
Acrolein	2.59E+00	1.42E+00	3.30E-01
Anthracene	7.55E-05	4.12E-05	9.60E-06
Benzene	1.50E+01	3.64E+00	9.05E-01
Benzo (a) anthracene	2.78E-05	1.50E-05	3.21E-06
Benzo (a) pyrene	0.00E+00	0.00E+00	0.00E+00
Benzo (b) fluoranthene	1.26E-05	6.78E-06	1.94E-06
Benzo (e) pyrene	3.10E-05	1.65E-05	3.88E-06
Benzo (g,h,i) perylene	2.83E-05	1.50E-05	3.54E-06
Benzo (k) fluoranthene	0.00E+00	0.00E+00	0.00E+00
Biphenyl	2.57E-02	1.40E-02	3.28E-03
Bromomethane	2.68E-03	4.61E-04	1.47E-04
Butadiene, 1,3-	2.84E-01	1.55E-01	3.65E-02
Butane	1.49E+02	3.59E+01	8.80E+00
Butane, *n*-	1.53E+00	8.33E-01	1.94E-01
Butanone, 2- (Methyl Ethyl Ketone)	2.04E-02	4.34E-03	1.06E-03
Butylbenzene, *sec*-	7.67E-02	1.31E-02	4.17E-03
Carbon disulfide	5.59E-03	1.36E-03	3.34E-04
Carbon tetrachloride	7.41E-03	4.05E-03	9.68E-04
Chlorobenzene	7.38E-03	4.03E-03	9.41E-04
Chlorodifluoromethane	1.14E-03	1.95E-04	6.22E-05
Chloroethane	4.03E-03	7.31E-04	2.50E-04
Chloroform	7.38E-03	4.03E-03	9.40E-04
Chloromethane	3.38E-03	6.59E-04	1.60E-04
Chlorotoluene, 2-	2.68E-03	4.62E-04	1.47E-04
Chrysene	5.68E-05	3.11E-05	7.50E-06
Cyclohexane	4.77E+00	1.16E+00	2.85E-01
Cyclopentane	6.04E-02	3.30E-02	7.70E-03
Decane, *n*-	2.66E-02	5.29E-03	1.28E-03
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	1.36E-03	2.35E-04	7.44E-05
Dichlorodifluoromethane	1.62E-03	2.79E-04	8.90E-05
Dichloroethane, 1,1-	7.38E-03	4.03E-03	9.39E-04
Dichloropropene, 1,3-	7.38E-03	4.03E-03	9.41E-04
Dodecane, *n*-	1.52E-02	3.35E-03	8.22E-04
Ethane	6.55E+01	3.57E+01	8.34E+00
Ethylbenzene	1.78E-01	4.34E-02	1.11E-02
Ethylene dibromide	7.30E-03	3.99E-03	9.31E-04
Ethylene dichloride	7.97E-03	4.35E-03	1.02E-03
Ethyltoluene, 4-	2.07E+00	3.56E-01	1.13E-01
Fluoranthene	1.03E-04	5.56E-05	1.33E-05
Fluorene	6.38E-04	3.49E-04	8.09E-05

Table 4.3-3. Modeled Impacts—Scenario 3 (Worst-Case Compressor Station) (Continued)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Formaldehyde	3.44E+01	1.88E+01	4.38E+00
Heptane	2.88E-01	6.75E-02	1.66E-02
Hexachlorobutadiene	6.46E-03	1.22E-03	3.11E-04
Hexane, *n*-	3.14E+00	7.65E-01	1.95E-01
Indeno (1,2,3-cd) pyrene	8.85E-07	0.00E+00	0.00E+00
Isobutane	1.21E+00	6.59E-01	1.54E-01
Isobutyraldehyde	1.13E-01	6.19E-02	1.44E-02
Isopentane	3.69E+01	8.88E+00	2.18E+00
Isopropylbenzene	3.31E-02	6.47E-03	1.56E-03
Isopropyltoluene, 4-	4.01E-02	6.84E-03	2.18E-03
Methane	1.03E+06	2.49E+05	6.10E+04
Methyl alcohol	1.78E+00	9.74E-01	2.27E-01
Methyl Naphthalene, 2-	4.37E-03	2.38E-03	5.55E-04
Methyl-2-pentanone, 4- (Methyl Isobutyl Ketone)	2.62E-02	4.50E-03	1.43E-03
Methylcyclohexane	2.34E-01	1.28E-01	2.99E-02
Methylene chloride	3.24E-02	1.77E-02	4.20E-03
Naphthalene	1.43E-02	7.96E-03	1.97E-03
Nonane, *n*-	6.56E-02	1.42E-02	3.90E-03
Octane, *n*-	7.36E-02	3.44E-02	7.78E-03
Pentane, *n*-	1.41E+01	3.42E+00	8.59E-01
Perylene	0.00E+00	0.00E+00	0.00E+00
Phenanthrene	1.09E-03	5.93E-04	1.39E-04
Phenol	8.37E-03	4.57E-03	1.07E-03
Polycyclic Aromatic Hydrocarbons (PAH) [a]	1.08E-01	5.88E-02	1.37E-02
Propane	1.78E+01	9.69E+00	2.26E+00
Propylbenzene, *n*-	7.69E-01	1.32E-01	4.19E-02
Propylene	1.19E-02	2.02E-03	6.45E-04
Propylene dichloride	7.38E-03	4.03E-03	9.39E-04
Pyrene	1.26E-04	6.89E-05	1.57E-05
Styrene	9.83E-03	5.37E-03	1.26E-03
Tetrachloroethane, 1,1,2,2-	7.39E-03	4.03E-03	9.41E-04
Tetrachloroethene	6.47E-02	1.57E-02	3.85E-03
Toluene	1.01E+01	2.46E+00	6.08E-01
Trichlorobenzene, 1,2,3-	1.43E-02	2.45E-03	7.73E-04
Trichlorobenzene, 1,2,4-	1.19E-02	2.33E-03	5.63E-04
Trichloroethane, 1,1,2-	7.39E-03	4.03E-03	9.42E-04
Trichlorofluoromethane	2.09E-03	3.60E-04	1.14E-04
Trimethylbenzene, 1,2,3-	5.51E-03	3.01E-03	7.02E-04
Trimethylbenzene, 1,2,4-	9.13E+00	1.57E+00	4.99E-01
Trimethylbenzene, 1,3,5-	2.28E+00	3.92E-01	1.25E-01
Trimethylpentane, 2,2,4-	1.39E-01	7.56E-02	1.78E-02
Undecane, *n*-	2.76E-02	6.25E-03	1.54E-03
Vinyl acetate	2.48E-02	6.04E-03	1.48E-03

Table 4.3-3. Modeled Impacts—Scenario 3 (Worst-Case Compressor Station) (Continued)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Vinyl bromide	2.88E-03	4.96E-04	1.58E-04
Vinyl Chloride	7.43E-03	4.08E-03	9.82E-04
Xylene, *o-*	2.00E-01	4.81E-02	1.32E-02
Xylenes, *m-,p-*	1.20E+00	2.92E-01	7.29E-02

[a] Concentration in (µg/m^3).

Table 4.3-4. Modeled Impacts—Scenario 4 (Co-located Well Pad and Compressor Station)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Acenaphthene	1.63E-04	8.88E-05	2.06E-05
Acenaphthylene	6.84E-04	3.74E-04	8.68E-05
Acetaldehyde	3.58E+00	1.96E+00	4.54E-01
Acetone	2.25E+02	4.18E+01	9.09E+00
Acrolein	2.62E+00	1.43E+00	3.32E-01
Anthracene	7.55E-05	4.12E-05	9.60E-06
Benzene	5.84E+01	6.36E+00	1.90E+00
Benzo (a) anthracene	2.78E-05	1.50E-05	3.21E-06
Benzo (a) pyrene	0.00E+00	0.00E+00	0.00E+00
Benzo (b) fluoranthene	1.26E-05	6.78E-06	1.94E-06
Benzo (e) pyrene	3.10E-05	1.65E-05	3.88E-06
Benzo (g,h,i) perylene	2.83E-05	1.50E-05	3.54E-06
Benzo (k) fluoranthene	0.00E+00	0.00E+00	0.00E+00
Biphenyl	2.60E-02	1.42E-02	3.29E-03
Bromomethane	2.39E-02	4.44E-03	9.73E-04
Butadiene, 1,3-	2.87E-01	1.57E-01	3.68E-02
Butane	3.55E+03	5.67E+02	1.50E+02
Butane, *n*-	1.54E+00	8.41E-01	1.95E-01
Butanone, 2- (Methyl Ethtyl Ketone)	1.88E-01	2.01E-02	4.47E-03
Butylbenzene, *sec*-	5.75E-01	6.31E-02	1.59E-02
Carbon disulfide	6.06E-02	6.46E-03	1.44E-03
Carbon tetrachloride	1.45E-02	4.98E-03	9.87E-04
Chlorobenzene	7.44E-03	4.06E-03	9.45E-04
Chlorodifluoromethane	1.02E-02	1.89E-03	4.13E-04
Chloroethane	3.60E-02	6.69E-03	1.48E-03
Chloroform	7.44E-03	4.07E-03	9.44E-04
Chloromethane	3.43E-02	5.70E-03	1.49E-03
Chlorotoluene, 2-	2.40E-02	4.45E-03	9.75E-04
Chrysene	5.68E-05	3.11E-05	7.50E-06
Cyclohexane	9.77E+01	1.30E+01	3.70E+00
Cyclopentane	6.10E-02	3.33E-02	7.74E-03
Decane, *n*-	1.35E+01	1.63E+00	4.82E-01
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	1.22E-02	2.26E-03	4.95E-04
Dichlorodifluoromethane	1.45E-02	2.69E-03	5.88E-04
Dichloroethane, 1,1-	7.44E-03	4.07E-03	9.44E-04
Dichloropropene, 1,3-	7.45E-03	4.07E-03	9.45E-04
Dodecane, *n*-	5.49E-01	1.11E-01	2.60E-02
Ethane	6.60E+01	3.61E+01	8.38E+00
Ethylbenzene	3.09E+00	5.34E-01	1.38E-01
Ethylene dibromide	7.37E-03	4.02E-03	9.34E-04
Ethylene dichloride	8.04E-03	4.39E-03	1.02E-03
Ethyltoluene, 4-	4.14E+00	4.81E-01	1.30E-01
Fluoranthene	1.04E-04	5.68E-05	1.33E-05
Fluorene	6.44E-04	3.52E-04	8.24E-05

Table 4.3-4. Modeled Impacts—Scenario 4 (Co-located Well Pad and Compressor Station) (Continued)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-hour Average (ppbv)	Max Annual Average (ppbv)
Formaldehyde	3.47E+01	1.89E+01	4.40E+00
Heptane, *n*-	4.74E+02	5.12E+01	1.36E+01
Hexachlorobutadiene	6.51E-02	1.18E-02	3.00E-03
Hexane	5.73E+02	6.20E+01	1.67E+01
Indeno (1,2,3-cd) pyrene	8.85E-07	0.00E+00	0.00E+00
Isobutane	1.22E+00	6.65E-01	1.55E-01
Isobutyraldehyde	1.14E-01	6.25E-02	1.45E-02
Isopentane	9.72E+02	1.57E+02	4.15E+01
Isopropylbenzene	8.42E-01	1.12E-01	3.18E-02
Isopropyltoluene, 4-	3.64E-01	6.30E-02	1.62E-02
Methane	1.03E+06	2.49E+05	6.14E+04
Methyl alcohol	1.80E+00	9.83E-01	2.28E-01
Methyl Naphthalene, 2-	4.40E-03	2.41E-03	5.59E-04
Methyl-2-pentanone, 4- (Methyl Isobutyl Ketone)	2.37E-01	4.54E-02	1.02E-02
Methylcyclohexane	2.37E-01	1.29E-01	3.00E-02
Methylene chloride	1.20E+02	2.23E+01	4.85E+00
Naphthalene	1.47E-01	2.18E-02	6.28E-03
Nonane, *n*-	3.31E+02	3.55E+01	8.35E+00
Octane, *n*-	3.89E+02	4.18E+01	1.04E+01
Pentane, *n*-	7.83E+02	1.14E+02	3.13E+01
Perylene	0.00E+00	0.00E+00	0.00E+00
Phenanthrene	1.10E-03	5.99E-04	1.39E-04
Phenol	8.44E-03	4.61E-03	1.07E-03
Polycyclic Aromatic Hydrocarbons (PAH) [a]	1.09E-01	5.94E-02	1.38E-02
Propane	1.79E+01	9.78E+00	2.27E+00
Propylbenzene, *n*-	1.44E+00	1.69E-01	5.01E-02
Propylene	1.70E-01	3.37E-02	7.78E-03
Propylene dichloride	7.44E-03	4.06E-03	9.43E-04
Pyrene	1.27E-04	6.89E-05	1.57E-05
Styrene	4.55E-02	7.43E-03	1.35E-03
Tetrachloroethane, 1,1,2,2-	7.45E-03	4.07E-03	9.45E-04
Tetrachloroethene	7.01E-01	7.48E-02	1.66E-02
Toluene	2.56E+02	2.77E+01	7.69E+00
Trichlorobenzene, 1,2,3-	1.37E-01	2.81E-02	6.83E-03
Trichlorobenzene, 1,2,4-	1.21E-01	2.00E-02	5.24E-03
Trichloroethane, 1,1,2-	7.46E-03	4.07E-03	9.46E-04

Table 4.3-4. Modeled Impacts—Scenario 4 (Co-located Well Pad and Compressor Station) (Continued)

Pollutant	Max 1-Hour Average (ppbv)	Max 24-Hour Average (ppbv)	Max Annual Average (ppbv)
Trichlorofluoromethane	1.87E-02	3.48E-03	7.62E-04
Trimethylbenzene, 1,2,3-	5.56E-03	3.04E-03	7.06E-04
Trimethylbenzene, 1,2,4-	1.35E+01	1.64E+00	5.14E-01
Trimethylbenzene, 1,3,5-	6.49E+00	1.16E+00	2.97E-01
Trimethylpentane, 2,2,4-	3.03E-01	8.17E-02	1.82E-02
Undecane, *n*-	2.19E+00	4.47E-01	1.05E-01
Vinyl acetate	2.69E-01	2.87E-02	6.37E-03
Vinyl bromide	2.57E-02	4.78E-03	1.05E-03
Vinyl chloride	7.46E-03	4.07E-03	9.47E-04
Xylene, *o*-	9.08E+00	1.61E+00	4.13E-01
Xylenes, *m*-,*p*-	1.78E+02	1.93E+01	5.41E+00

[a] Concentration in (µg/m^3).

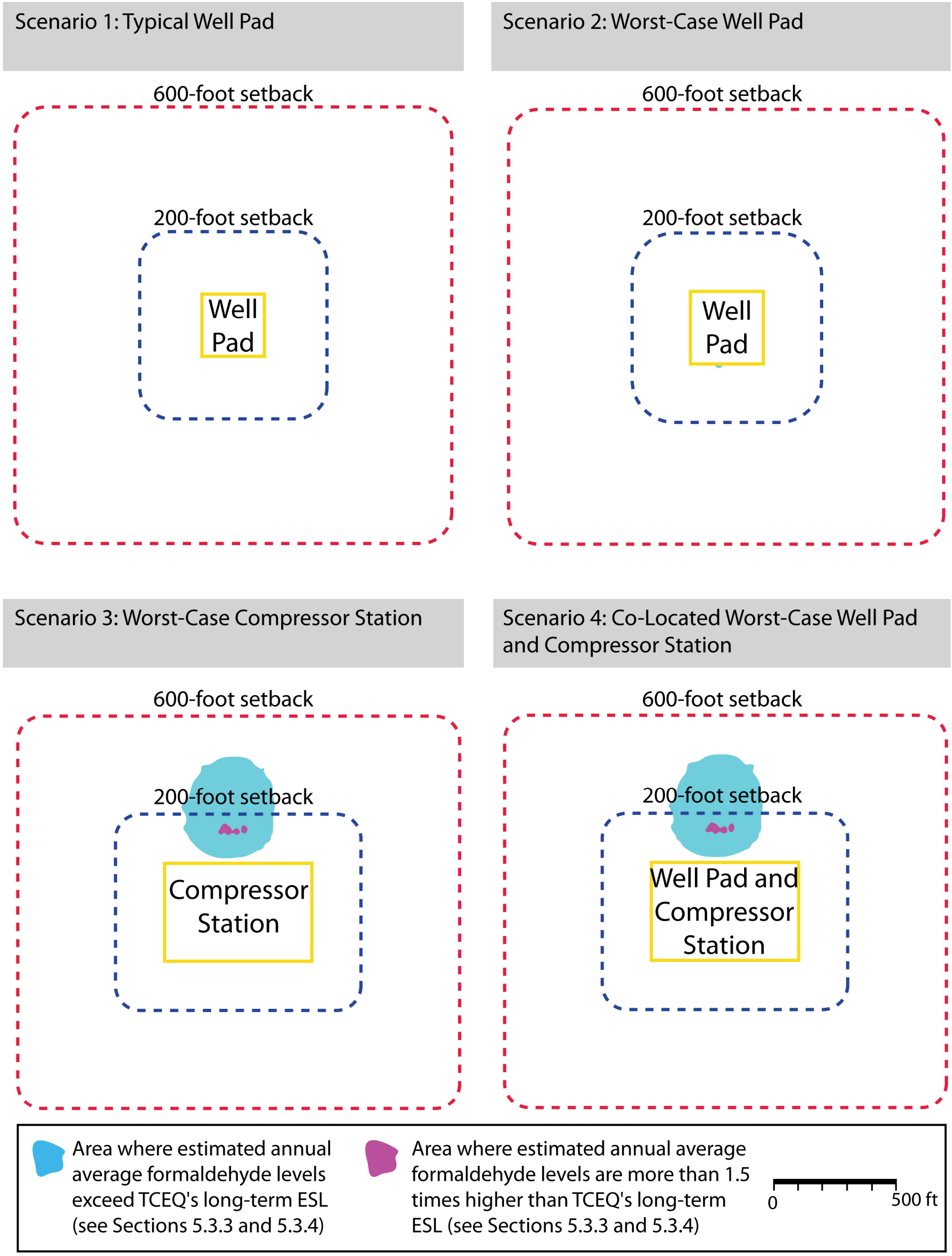


Figure 4.3-1. Formaldehyde Modeling Results for Scenarios 1 - 4

4.4 Electronic Modeling Files

Modeling input and output files are provided electronically in Appendix 4-A. This includes files associated with AERMOD as well as its downwash processing program, BPIP-PRIME, along with meteorological files. AERMOD inputs and outputs follow a specific naming convention: "Scen*XX*_1988_*Pollutant.ext,*" where *XX* is the scenario of interest (01 through 04), *Pollutant* is an abbreviation for the compound modeled, and *ext* is the extension denoting the file type. BPIP-PRIME files follow a similar convention, "Scen*XX*-Prime.*ext*." The various types of files included in Appendix 4-A are described below. Table 4.4-1 contains a crosswalk table which associates the compound abbreviations used in the BEEST modeling package with their proper chemical names.

Model Input Extensions

- **DTA**—AERMOD runstream files
- **PIP**—BPIP-PRIME inputs files
- **SFC**—Surface meteorological data
- **PFL**—Upper Air meteorological data

Model Output Extensions

- **GRF**—AERMOD detailed plot files
- **LST**—AERMOD detailed list files
- **SUM**—AERMOD summary files
- **TAB**—BPIP-PRIME detailed results
- **SO**—BPIP-PRIME block outputs for use in the model runstream

Table 4.4-1. BEEST Pollutant Abbreviation Crosswalk

Pollutant Abbreviation	Pollutant Name
1122TCE	Tetrachloroethane, 1,1,2,2-
112TCE	Trichloroethane, 1,1,2-
11DCE	Dichloroethane, 1,1-
123TCB	Trichlorobenzene, 1,2,3-
123TMB	Trimethylbenzene, 1,2,3-
124TCB	Trichlorobenzene, 1,2,4-
124TMB	Trimethylbenzene, 1,2,4-
12D1122T	Dichloro-1,1,2,2-tetrafluoroethane, 1,2-
135TMB	Trimethylbenzene, 1,3,5-
13BUTAD	Butadiene, 1,3-
13DICHL	Dichloropropene, 1,3-
224TMP	Trimethylpentane, 2,2,4-
2BN	Butanone, 2- (Methyl Ethyl Ketone)
2CT	Chlorotoluene, 2-
2MN	Methyl Naphthalene, 2-
3CLFMETH	Trichlorofluoromethane
4ET	Ethyltoluene, 4-
4IPT	Isopropyltoluene, 4-
4M2P	Methyl-2-pentanone, 4- (Methyl Isobutyl Ketone)
ACENAP1	Acenaphthene
ACENAP2	Acenaphthylene
ACETALDE	Acetaldehyde
ACETONE	Acetone
ACROLEIN	Acrolein
ANTHRACE	Anthracene
BAA	Benzo (a) anthracene
BAP	Benzo (a) pyrene
BBFA	Benzo (b) fluoranthene
BENZENE	Benzene
BEP	Benzo (e) pyrene
BGHIP	Benzo (g,h,i) perylene
BIPHENYL	Biphenyl
BKF	Benzo(k)fluoranthene
BRMETH	Bromomethane
BUTANE	Butane
CCL4	Carbon tetrachloride
CHRYSENE	Chrysene

Table 4.4-1. BEEST Pollutant Abbreviation Crosswalk (Continued)

Pollutant Abbreviation	Pollutant Name
CL2F2MET	Dichlorodifluoromethane
CL4ETHEN	Tetrachloroethene
CL6BUTA	Hexachlorobutadiene
CLBENZ	Chlorobenzene
CLDFM	Chlorodifluoromethane
CLETH	Chloroethane
CLFORM	Chloroform
CLMETH	Chloromethane
CS2	Carbon disulfide
CYCLOHEX	Cyclohexane
CYCLOPEN	Cyclopentane
ETHANE	Ethane
ETHYLBEN	Ethylbenzene
ETHYLBR2	Ethylene dibromide
ETHYLCL	Ethyl chloride
FLANTH	Fluoranthene
FLUORENE	Fluorene
FORMALDE	Formaldehyde
HEPTANE	Heptane
HEXANE	Hexane, *n-*
IND123PY	Indeno (1,2,3-cd) pyrene
ISOBUTAN	Isobutane
ISOBUTYR	Isobutyraldehyde
ISOPENT	Isopentane
ISOPRBEN	Isopropylbenzene
METHALC	Methyl alcohol
METHANE	Methane
METHCL	Methylene chloride
METHCYHX	Methylcyclohexane
MPXYL	Xylenes, *m-,p-*
NAPTH	Naphthalene
NBUT	Butane, *n-*
NDEC	Decane, *n-*
NDODEC	Dodecane, *n-*
NNON	Nonane, *n-*
NOCT	Octane, *n-*
NPENT	Pentane, *n-*
NPROPBEN	Propylbenzene, *n-*

Table 4.4-1. BEEST Pollutant Abbreviation Crosswalk (Continued)

Pollutant Abbreviation	Pollutant Name
NUNDEC	Undecane, *n*-
OXYL	Xylene, *o*-
PAH	Polycyclic Aromatic Hydrocarbons (PAH)
PERYLENE	Perylene
PHENAN	Phenanthrene
PHENOL	Phenol
PROPANE	Propane
PROPYCL2	Propylene dichloride
PROPYL	Propylene
PYRENE	Pyrene
SECBUTYL	Butylbenzene, sec-
STYRENE	Styrene
TOLUENE	Toluene
VINLYBRO	Vinyl bromide
VINYLACE	Vinyl acetate
VINYLCL	Vinyl chloride

4.5 Air Dispersion Modeling Conclusions

Air dispersion modeling was conducted using the emission estimates developed under Task 3 (Point Source Testing) to estimate how releases from natural gas sites affect off-site air pollution levels. The estimated off-site air pollution impacts are fully analyzed in Section 5 of this report to determine if the city's required setbacks (as published in City Ordinance No. 18449-02-2009) for natural gas exploration and production sites are adequate to protect public health.

5.0 Public Health Evaluation

This section evaluates the ambient air monitoring data and the dispersion modeling results from a public health perspective. The evaluation compares measured and modeled air pollution levels to TCEQ's health-based screening levels. Additional context and more detailed evaluations are presented for the pollutants with estimated or measured air concentrations greater than these screening levels. The monitoring and modeling results are also used to assess the adequacy of the city of Fort Worth's setback distances for sites with natural gas exploration and production activity. Text boxes throughout this section highlight important findings for specific topics. This section has five sub-sections:

- 5.1 Methodology – Describes the approach used to evaluate the air data.
- 5.2 Interpretation of Ambient Air Monitoring Data – Includes a health screening analysis for the measured air pollution levels.
- 5.3 Interpretation of Dispersion Modeling Data – Includes a health screening analysis for the modeled air pollution levels.
- 5.4 Additional Context for Selected Pollutants – Provides further perspective for pollutants selected for further evaluation.
- 5.5 Public Health Evaluation Conclusions – Concisely summarizes the public health evaluation.

5.1 Methodology

The point source testing identified numerous pollutants that natural gas exploration and production activities in Fort Worth release to the air. Once emitted, these pollutants move through the air to downwind locations where residents can be exposed. Air pollution levels at a given time and location in Fort Worth are ultimately influenced by emissions from a wide range of sources, not just releases from natural gas exploration and production activity. Examples of other sources that affect Fort Worth's outdoor air quality include industrial facilities, motor vehicles, and gasoline stations.

Key Point: Screening Methodology
This study presents measured and modeled air pollution levels for more than 150 different pollutants. Health-based screening levels are used to identify which pollutants are most important from a health perspective.

Several factors must be considered when evaluating the public health implications of outdoor air pollution levels. Which pollutants are found in the air and at what concentrations? Over what duration are people exposed? Are the exposed populations uniquely susceptible to the effects of air pollution? Environmental and health agencies use different approaches when evaluating the public health implications of exposure to outdoor air pollution. In cases with thousands of measurements and estimates of outdoor air quality for numerous pollutants, a commonly applied methodology is to use health-based screening levels to determine which subsets of pollutants are of potential health concern.

Health-based screening levels are developed from scientific studies that have examined links between air pollution and health effects. To ensure that screening levels are protective of public health, the agencies that derive these values set them at levels considerably lower than concentrations found to have been associated with adverse health effects. This means that residents are generally not expected to experience health effects when exposed to air pollution levels that are lower than health-based screening levels—but also that the levels are not thresholds for toxicity. Measured or modeled air pollution levels above a health-based screening level are not necessarily harmful, but they do require a more detailed evaluation to assess public health implications. Broadly speaking, this document uses the health-based screening levels to identify the subset of pollutants that require more thorough health evaluations.

This report primarily relies on screening levels published by TCEQ for evaluating the implications of inhalation exposure to outdoor air pollution, considering both measured and estimated air pollution levels. TCEQ has published two sets of screening levels for use in evaluating outdoor air quality issues:

- *Effects Screening Levels (ESLs).* For many years, TCEQ has published and updated its ESLs. These values are primarily used in the permitting process, particularly when reviewing dispersion modeling data. TCEQ has developed separate ESLs for short-term and long-term exposure durations, where short-term values are typically used for assessing 1-hour average concentrations and long-term values are typically used for assessing annual average concentrations. Most of TCEQ's ESLs were developed based on health effects, but some were developed to protect vegetation or based on odor detection. The ESLs are not regulatory standards, but are used to interpret potential exposures to air pollution, primarily pollution levels predicted by models.

  TCEQ advises that estimated air quality impacts and ESLs should be interpreted as follows: "If predicted airborne levels of a constituent do not exceed the screening level, adverse health or welfare effects are not expected. If predicted ambient levels of constituents in air exceed the screening levels, it does not necessarily indicate a problem but rather triggers a review in more depth." The complete set of ESLs is available at http://www.tceq.texas.gov/toxicology/esl.

- *Air Monitoring Comparison Values (AMCVs).* In addition to ESLs, TCEQ has more recently developed AMCVs, which are pollutant-specific ambient air concentrations that the agency has established to protect human health and welfare. In contrast to ESLs, which are primarily used when evaluating air pollution levels predicted by models, AMCVs are used when conducting health screening evaluations of air monitoring data. The complete set of AMCVs is also available online at http://www.tceq.texas.gov/toxicology/AirToxics.html#amcv.

In this section, the modeled and measured air pollution levels are presented alongside the corresponding health-based ESLs and AMCVs. For pollutants with air concentrations above the TCEQ screening levels, additional context is provided in Section 5.4 by presenting screening levels published by ATSDR and EPA. All screening values used in this report were accessed from agency publications in March 2011.

5.2 Interpretation of Ambient Air Monitoring Data

This section presents a health screening analysis for this program's ambient air monitoring data—the air pollution levels that were measured at eight locations in Fort Worth in September and October, 2010. Ambient air monitoring data are particularly useful for health evaluations, because they represent direct measurements of the air pollution levels that residents actually breathe, without introducing the uncertainty of models. These measurements reflect contributions from many different local emission sources. While many pollutants found in the air samples are emitted from natural gas exploration and production activity, not every pollutant is associated with this source. The dispersion modeling analysis (Section 5.3) comments further on incremental air quality impacts attributable specifically to the well pads and compressor stations.

The section first evaluates the sensitivity of the monitoring methods (Section 5.2.1) and then compares the measured concentrations for nearly 150 pollutants to health-based screening levels, for both short-term (Section 5.2.2) and long-term (Section 5.2.3) exposure durations. The purpose of the health screening analysis is to identify the subset of pollutants requiring further evaluation. The section concludes by acknowledging limitations and uncertainties inherent in the screening of the ambient air monitoring data (Section 5.2.4).

5.2.1 Sensitivity of Monitoring Methods

An important consideration when evaluating ambient air monitoring data is whether the measurement methods are capable of detecting air pollution at levels of interest. As Section 2 of this report describes, all ambient air monitoring for this study was conducted with methods developed by EPA and widely used in air toxics monitoring programs nationwide. To assess whether the methods were adequately sensitive to support a health evaluation, this section compares the detection limits achieved in this monitoring program to the pollutants' lowest health-based screening levels published by TCEQ, considering both short-term and long-term values.

Key Point: Measurement Sensitivity
The ambient air monitoring program used highly sensitive measurement methods. For all but two pollutants, the methods were capable of detecting air concentrations at levels below TCEQ's most protective health-based screening values. Therefore, the air pollution measurements were sensitive enough to support health evaluations.

Table 5.2-1 compares the ranges of pollutant detection limits for the two laboratories that analyzed samples to the lowest health-based screening levels published by TCEQ, whether for short-term or long-term exposure durations. The ERG laboratory analyzed all samples collected from Sites S-1 through S-5, and the TestAmerica™ laboratory analyzed all samples collected from Sites S-6 and S-7. When planning this program, ERG's goal was to achieve detection limits lower than health-based screening values for as many pollutants as possible, but particularly for pollutants that had previously been identified as potential concerns for these operations (e.g., benzene, formaldehyde). Shading is used in the table to identify pollutants whose ranges of detection limits were not lower than TCEQ screening levels.

As Table 5.2-1 shows, the ERG laboratory's detection limits were below the TCEQ health-based screening values for every pollutant considered, including for benzene and formaldehyde. With just two exceptions, TestAmerica's™ detection limits were also below the screening values. For just two pollutants (1,2-dibromoethane and hexachloro-1,3-butadiene), TestAmerica's™ detection limits were higher than the most protective health-based TCEQ screening values, but only by small margins. This is not a significant limitation for the study, because both pollutants are primarily synthetic chemicals that are not typically associated with natural gas reserves. The modeling results presented in Section 5.3 confirm that these pollutants are not found at levels of health concern near natural gas sites in Fort Worth. Overall, the comparisons in Table 5.2-1 demonstrate that the measurement methods used in the ambient air monitoring program achieved adequate sensitivity for comparing measured concentrations to TCEQ's health-based screening levels.

Table 5.2-1. Ranges of Detection Limits, by Laboratory

Pollutant	Lowest TCEQ Short- or Long-Term Health-Based Screening Level (ppbv)		Range of Detection Limits (ppbv) [a,b]	
	Value	Type	ERG Laboratory	TestAmerica™
Acetaldehyde	25	AMCV/ESL	0.006–0.009	NM
Acetone	250	AMCV/ESL	0.007–0.011	0.05–0.07
Acetylene	2,500	AMCV/ESL	0.025–0.025	NM
Acrylonitrile	2	ESL	0.027–0.027	NM
Allyl chloride	1	ESL	NM	0.06–0.16
Amyl methyl ether, *tert-*	65	ESL	0.013–0.013	NM
Benzaldehyde	2	ESL	0.002–0.003	NM
Benzene	1.4	AMCV/ESL	0.019–0.019	0.05–0.08
Bromochloromethane	200	ESL	0.018–0.018	NM
Bromodichloromethane	10	ESL	0.021–0.021	0.06–0.08
Bromoform	0.5	ESL	0.011–0.011	0.06–0.13
Bromomethane	3	AMCV/ESL	0.013–0.013	0.06–0.11
Butadiene, 1,3-	4.5	ESL	0.01–0.01	0.04–0.07
Butane, *n-*	800	AMCV	0.043–0.043	0.05–0.07
Butanol, *n-*	20	ESL	NM	0.11–0.18
Butene, *cis*-2-	15,000	AMCV	0.045–0.045	0.06–0.11
Butene, *trans*-2-	15,000	AMCV	0.035–0.035	0.06–0.12
Butyraldehyde/isobutyraldehyde	25	ESL	0.002–0.003	NM
Carbon disulfide	1	ESL	0.011–0.011	NM
Carbon tetrachloride	2	AMCV/ESL	0.024–0.024	0.06–0.08
Chlorobenzene	10	AMCV/ESL	0.014–0.014	0.06–0.08
Chloroethane	19	ESL	0.012–0.012	0.04–0.14
Chloroform	2	AMCV/ESL	0.017–0.017	0.06–0.14
Chloromethane	50	AMCV/ESL	0.016–0.016	0.05–0.12
Chloromethylbenzene	1	ESL	0.017–0.017	NM

Table 5.2-1. Ranges of Detection Limits, by Laboratory (Continued)

Pollutant	Lowest TCEQ Short- or Long-Term Health-Based Screening Level (ppbv)		Range of Detection Limits (ppbv) [a,b]	
	Value	Type	ERG Laboratory	TestAmerica™
Chloroprene	1	ESL	0.014–0.014	NM
Crotonaldehyde	0.3	AMCV/ESL	0.002–0.004	NM
Cyclohexane	100	AMCV/ESL	0.032–0.032	0.05–0.08
Cyclopentane	120	AMCV/ESL	0.024–0.024	NM
Cyclopentene	290	AMCV/ESL	0.048–0.048	NM
Decane, *n*-	175	AMCV/ESL	0.023–0.023	0.06–0.10
Decene, 1-	20	ESL	0.024–0.024	NM
Dibromochloromethane	0.2	ESL	0.011–0.011	0.06–0.08
Dibromoethane, 1,2-	0.05	AMCV/ESL	0.012–0.012	**0.06–0.12**
Dichlorobenzene, *m*-	5.4	ESL	0.01–0.01	0.06–0.08
Dichlorobenzene, *o*-	5.4	ESL	0.012–0.012	0.06–0.12
Dichlorobenzene, *p*-	5.4	ESL	0.01–0.01	0.06–0.13
Dichlorodifluoromethane	1,000	AMCV/ESL	0.012–0.012	0.06–0.08
Dichloroethane, 1,1-	100	AMCV/ESL	0.017–0.017	0.06–0.13
Dichloroethane, 1,2-	1	AMCV/ESL	0.015–0.015	0.06–0.11
Dichloroethylene, 1,1-	26	ESL	0.013–0.013	0.07–0.10
Dichloroethylene, *cis*-1,2-	200	ESL	0.036–0.036	0.06–0.08
Dichloroethylene, *trans*-1,2-	200	ESL	0.014–0.014	0.12–0.15
Dichloropropane, 1,2-	10	AMCV/ESL	0.025–0.025	0.05–0.08
Dichloropropylene, *cis*-1,3-	1	AMCV/ESL	0.016–0.016	0.05–0.08
Dichloropropylene, *trans*-1,3-	1	AMCV/ESL	0.015–0.015	0.04–0.08
Dichlorotetrafluoroethane	1,000	ESL	0.012–0.012	0.06–0.10
Diethylbenzene, *m*-	46	AMCV/ESL	0.024–0.024	NM
Diethylbenzene, *p*-	46	AMCV/ESL	0.014–0.014	NM
Dimethylbenzaldehyde, 2,5-	2	ESL	0.001–0.002	NM
Dimethylbutane, 2,2-	100	AMCV/ESL	0.033–0.033	NM
Dimethylbutane, 2,3-	99	AMCV	0.033–0.033	NM
Dimethylpentane, 2,3-	85	AMCV/ESL	0.053–0.053	NM
Dimethylpentane, 2,4-	85	AMCV/ESL	0.033–0.033	NM
Dioxane, 1,4-	25	ESL	NM	0.09–0.19
Dodecane, *n*-	50	ESL	0.024–0.024	NM
Dodecene, 1-	10	ESL	0.029–0.029	NM
Ethane	1,000,000 [c]	AMCV/ESL	0.06–0.06	0.06–0.84
Ethyl acrylate	4	ESL	0.011–0.011	NM
Ethyl *tert*-butyl ether	5	ESL	0.009–0.009	NM

Table 5.2-1. Ranges of Detection Limits, by Laboratory (Continued)

Pollutant	Lowest TCEQ Short- or Long-Term Health-Based Screening Level (ppbv)		Range of Detection Limits (ppbv) [a,b]	
	Value	Type	ERG Laboratory	TestAmerica™
Ethyl-1-butene, 2-	No screening level		0.06–0.06	NM
Ethylbenzene	135	ESL	0.012–0.012	0.06–0.12
Ethylene	30	ESL	0.19–0.19	0.08–0.16
Ethyltoluene, *m*-	25	AMCV/ESL	0.017–0.017	NM
Ethyltoluene, *o*-	25	AMCV/ESL	0.02–0.02	NM
Ethyltoluene, *p*-	25	AMCV/ESL	0.027–0.027	0.05–0.08
Formaldehyde	2.7	ESL	0.004–0.006	NM
Heptane, *n*-	85	AMCV/ESL	0.026–0.026	0.04–0.08
Heptene, 1-	350	ESL	0.053–0.053	NM
Hexachloro-1,3-butadiene	0.02	ESL	0.012–0.012	**0.06–0.37**
Hexanaldehyde	200	AMCV/ESL	0.001–0.002	NM
Hexane, *n*-	57	ESL	0.04–0.04	0.06–0.13
Hexene, 1-	50	AMCV/ESL	0.06–0.06	NM
Hexene, *cis*-2-	50	AMCV/ESL	0.06–0.06	NM
Hexene, *trans*-2-	50	AMCV/ESL	0.06–0.06	NM
Isobutane	800	AMCV/ESL	0.0325–0.0325	0.06–0.12
Isobutene/1-butene	800	ESL	0.0375–0.0375	0.04–0.08
Isopentane	120	AMCV/ESL	0.038–0.038	NM
Isoprene	2	AMCV/ESL	0.048–0.048	NM
Isopropylbenzene	50	AMCV/ESL	0.023–0.023	0.11–0.15
Isovaleraldehyde	50	AMCV/ESL	0.002–0.003	NM
Methane	No screening level		NM	280–399
Methanol	200	ESL	NM	0.22–0.28
Methyl ethyl ketone	200	AMCV	0.026–0.026	0.08–0.15
Methyl isobutyl ketone	20	ESL	0.01–0.01	0.05–0.15
Methyl methacrylate	120	ESL	0.02–0.02	NM
Methyl *tert*-butyl ether	50	AMCV/ESL	0.009–0.009	0.11–0.14
Methyl-1-butene, 2-	No screening level		0.048–0.048	NM
Methyl-1-butene, 3-	800	AMCV/ESL	0.048–0.048	NM
Methyl-1-pentene, 2-	30	ESL	0.06–0.06	NM
Methyl-1-pentene, 4-	30	ESL	0.06–0.06	NM
Methyl-2-butene, 2-	50	AMCV	0.048–0.048	NM
Methylcyclohexane	400	AMCV/ESL	0.027–0.027	NM
Methylcyclopentane	75	AMCV	0.016–0.016	NM
Methylene chloride	7.5	ESL	0.023–0.023	0.06–0.08

Table 5.2-1. Ranges of Detection Limits, by Laboratory (Continued)

Pollutant	Lowest TCEQ Short- or Long-Term Health-Based Screening Level (ppbv)		Range of Detection Limits (ppbv) [a,b]	
	Value	Type	ERG Laboratory	TestAmerica™
Methylheptane, 2-	75	AMCV/ESL	0.021–0.021	NM
Methylheptane, 3-	75	AMCV/ESL	0.014–0.014	NM
Methylhexane, 2-	75	AMCV/ESL	0.016–0.016	NM
Methylhexane, 3-	75	AMCV/ESL	0.021–0.021	NM
Methylpentane, 2-	100	AMCV/ESL	0.023–0.023	NM
Methylpentane, 3-	100	AMCV/ESL	0.033–0.033	NM
Nonane, *n-*	200	AMCV/ESL	0.02–0.02	0.06–0.11
Nonene, 1-	100	ESL	0.027–0.027	NM
Octane, *n-*	75	AMCV/ESL	0.012–0.012	0.06–0.10
Octene, 1-	75	ESL	0.035–0.035	NM
Pentane, *n-*	120	AMCV/ESL	0.018–0.018	0.06–0.12
Pentene, 1-	2,600	AMCV	0.024–0.024	NM
Pentene, *cis*-2-	2,600	AMCV/ESL	0.038–0.038	NM
Pentene, *trans*-2-	2,600	AMCV/ESL	0.028–0.028	NM
Pinene, *alpha-*	1	ESL	0.024–0.024	NM
Pinene, *beta-*	1	ESL	0.024–0.024	NM
Propane	1,000,000 [c]	AMCV/ESL	0.067–0.067	0.06–0.11
Propionaldehyde	20	AMCV/ESL	0.002–0.004	NM
Propylbenzene, *n-*	25	AMCV/ESL	0.022–0.022	0.06–0.16
Propylene	1,000,000 [c]	AMCV/ESL	0.028–0.028	0.05–0.08
Propyne	1,000	ESL	0.067–0.067	NM
Styrene	33	ESL	0.01–0.01	0.06–0.15
Tetrachloroethane, 1,1,2,2-	1	AMCV/ESL	0.011–0.011	0.06–0.11
Tetrachloroethylene	3.8	AMCV/ESL	0.011–0.011	0.04–0.08
Tolualdehydes	2	ESL	0.003–0.004	NM
Toluene	330	ESL	0.013–0.013	0.06–0.08
Trichlorobenzene, 1,2,4-	5	ESL	0.018–0.018	0.06–0.46
Trichloroethane, 1,1,1-	200	ESL	0.02–0.02	0.06–0.13
Trichloroethane, 1,1,2-	10	AMCV/ESL	0.018–0.018	0.06–0.08
Trichloroethylene	10	AMCV/ESL	0.017–0.017	0.05–0.08
Trichlorofluoromethane	500	ESL	0.012–0.012	0.06–0.08
Trichlorotrifluoroethane	500	ESL	0.014–0.014	0.06–0.09
Tridecane, *n-*	50	ESL	0.022–0.022	NM
Tridecene, 1-	10	ESL	0.022–0.022	NM
Trimethylbenzene, 1,2,3-	25	AMCV/ESL	0.02–0.02	NM

Table 5.2-1. Ranges of Detection Limits, by Laboratory (Continued)

Pollutant	Lowest TCEQ Short- or Long-Term Health-Based Screening Level (ppbv)		Range of Detection Limits (ppbv) [a,b]	
	Value	Type	ERG Laboratory	TestAmerica™
Trimethylbenzene, 1,2,4-	25	AMCV/ESL	0.011–0.027	0.05–0.08
Trimethylbenzene, 1,3,5-	25	AMCV/ESL	0.01–0.019	0.06–0.18
Trimethylpentane, 2,2,3-	No screening level		0.035–0.035	NM
Trimethylpentane, 2,2,4-	75	AMCV/ESL	0.021–0.021	0.06–0.08
Trimethylpentane, 2,3,4-	75	AMCV	0.018–0.018	NM
Undecane, *n*-	50	ESL	0.02–0.02	NM
Undecene, 1-	20	ESL	0.02–0.02	NM
Valeraldehyde	50	AMCV/ESL	0.003–0.004	NM
Vinyl acetate	4	ESL	NM	0.10–0.33
Vinyl chloride	0.45	AMCV/ESL	0.013–0.013	0.06–0.12
Xylene, *m-,p-*	42	ESL	0.014–0.014	0.13–0.22
Xylene, *o-*	42	ESL	0.01–0.01	0.06–0.10

NM = not monitored.

No screening level = For these pollutants, TCEQ has not published an ESL or an AMCV.

[a] The two laboratories that analyzed ambient air samples—ERG and TestAmerica™—measured different pollutants. The ERG laboratory measured a greater number of pollutants, primarily because ERG had sole responsibility for measuring the carbonyl and SNMOC samples. For VOCs, TestAmerica's™ measurements considered the following pollutants that were not measured by ERG: allyl chloride, n-butanol, 1,4-dioxane, methanol, and vinyl acetate.

[b] In the final two columns, bold font is used to indicate pollutants for which the range of detection limits was not lower than the lowest health-based screening value. Refer to Appendix 5-A for further information on how health-based screening values were selected for this program.

[c] For ethane, propane, and propylene, TCEQ has not published specific values for AMCVs or ESLs, but has instead labeled these pollutants as "simple asphyxiants." The principal concern for asphyxiants at sufficiently high concentrations is that they displace oxygen in the air. A concentration of 0.1% (by volume) is used in this table as a very conservative estimated screening level for these pollutants.

5.2.2 Health Evaluation for Measured 24-Hour Average Concentrations

As described previously, ambient air monitoring occurred for two months at eight locations throughout the city of Fort Worth, and concentrations were measured for nearly 150 pollutants. All measurements were based on 24-hour average samples, and more than 15,000 observations were recorded over the course of the program.

Key Point: Short-Term Air Pollution Measurements
The ambient air monitoring data provide no evidence of 24-hour average concentrations reaching levels of health concern. Out of more than 15,000 air pollution measurements, only one exceeded a TCEQ health-based screening level for short-term exposures; but that one measurement was of questionable quality and was for a pollutant not typically associated with natural gas activity.

When evaluating the monitoring data, ERG first considered whether the highest measured 24-hour average concentrations exceeded TCEQ's *short-term* health-based screening levels. Throughout the monitoring program in 2010, ERG made these comparisons in order to promptly identify any indications of imminent health hazards, but none occurred. Comparing 24-hour average measurements to *long-term* health-based screening values is scientifically inappropriate and is not done in this report. For every pollutant considered in the ambient monitoring program, Table 5.2-2 lists the highest 24-hour average concentration detected during the program, the location where this value was detected, and the lowest short-term, health-based screening level published by TCEQ. For this evaluation, the hierarchy for selecting screening levels follows: First, if a pollutant has a short-term *health-based* AMCV, that value was used in Table 5.2-1, even if a different ESL is available. The preference for AMCVs over ESLs was applied here because this is an evaluation of ambient air monitoring data, not modeling data. Next, if a pollutant does not have a *health-based* AMCV, the table displays the pollutant's short-term *health-based* ESL. If neither value is available for the pollutant, short-term *odor-based* ESLs are used, if available. The table also indicates which pollutants have no TCEQ screening values. Shading is used in the table to identify pollutants that had at least one measured 24-hour average concentration higher than the TCEQ short-term screening level.

Table 5.2-2. Highest Measured Concentrations and TCEQ Short-Term Screening Levels

Pollutant	Highest Measured 24-Hour Average Concentration [a]		Lowest TCEQ *Short-Term* Health-Based Screening Level [b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Acetaldehyde	9.06	S-4	250	AMCV
Acetone	8.20	S-7	2,500	AMCV
Acetylene	3.57	S-4	25,000	AMCV
Acrylonitrile	Never detected		20	ESL
Allyl chloride	Never detected		10	ESL
Amyl methyl ether, *tert*-	0.065	S-2	130 [c]	ESL
Benzaldehyde	0.11	S-4	21	AMCV
Benzene	1.83	S-4	180	AMCV
Bromochloromethane	Never detected		2,000	ESL
Bromodichloromethane	0.075	S-5	100	ESL
Bromoform	Never detected		5	ESL
Bromomethane	0.03	S-4	30	AMCV
Butadiene, 1,3-	0.30	S-4	1,700	AMCV
Butane, *n*-	35.75	S-4	8,000	AMCV
Butanol, *n*-	Never detected		200	ESL
Butene, *cis*-2-	3.43	S-3B	15,000	AMCV
Butene, *trans*-2-	1.24	S-4	15,000	AMCV
Butyraldehyde	0.66	S-4	2,700	AMCV
Carbon disulfide	1.64	S-5	10	ESL
Carbon tetrachloride	0.14	S-4	20	AMCV
Chlorobenzene	0.026	S-5	100	AMCV
Chloroethane	0.24	S-7	190	ESL
Chloroform	0.11	S-1	20	AMCV
Chloromethane	0.95	S-4	500	AMCV
Chloromethylbenzene	0.30	S-5	10	ESL
Chloroprene	Never detected		10	ESL
Crotonaldehyde	0.19	S-4	3	AMCV
Cyclohexane	0.71	S-4	1,000	AMCV
Cyclopentane	1.20	S-4	1,200	AMCV
Cyclopentene	0.049	S-4	2,900	AMCV
Decane, *n*-	1.44	S-2	1,750	AMCV
Decene, 1-	0.031	S-1	20 [c]	ESL
Dibromochloromethane	0.017	S-1	2	ESL

Table 5.2-2. Highest Measured Concentrations and TCEQ Short-Term Screening Levels (Continued)

Pollutant	Highest Measured 24-Hour Average Concentration [a]		Lowest TCEQ *Short-Term* Health-Based Screening Level [b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Dibromoethane, 1,2-	0.28	S-5	0.5	AMCV
Dichlorobenzene, *m*-	0.55	S-5	120	ESL
Dichlorobenzene, *o*-	0.48	S-5	120	ESL
Dichlorobenzene, *p*-	0.71	S-5	120	ESL
Dichlorodifluoromethane	0.67	S-2	10,000	AMCV
Dichloroethane, 1,1-	0.009	S-5	1,000	AMCV
Dichloroethane, 1,2-	Never detected		40	AMCV
Dichloroethylene, 1,1-	0.007	S-5	180	AMCV
Dichloroethylene, *cis*-1,2-	Never detected		2,000	ESL
Dichloroethylene, *trans*-1,2-	Never detected		2,000	ESL
Dichloropropane, 1,2-	Never detected		100	AMCV
Dichloropropylene, *cis*-1,3-	0.045	S-5	10	AMCV
Dichloropropylene, *trans*-1,3-	0.046	S-5	10	AMCV
Dichlorotetrafluoroethane	0.026	S-5	10,000	ESL
Diethylbenzene, *m*-	0.082	S-4	460	AMCV
Diethylbenzene, *p*-	0.10	S-4	460	AMCV
Dimethylbenzaldehyde, 2,5-	Never detected		21	AMCV
Dimethylbutane, 2,2-	0.81	S-4	1,000	AMCV
Dimethylbutane, 2,3-	2.52	S-4	990	AMCV
Dimethylpentane, 2,3-	0.73	S-4	850	AMCV
Dimethylpentane, 2,4-	0.82	S-4	850	AMCV
Dioxane, 1,4-	Never detected		250	ESL
Dodecane, *n*-	0.33	S-5	500	ESL
Dodecene, 1-	0.225	S-4	10 [c]	ESL
Ethane	93.2	S-7	1,000,000 [d]	AMCV
Ethyl acrylate	Never detected		1.3 [c]	ESL
Ethyl *tert*-butyl ether	0.006	S-5	50	ESL
Ethyl-1-butene, 2-	0.87	S-2	No screening level	
Ethylbenzene	0.94	S-2	20,000	AMCV
Ethylene	5.40	S-4	500,000	AMCV
Ethyltoluene, *m*-	0.30	S-2	250	AMCV
Ethyltoluene, *o*-	0.39	S-2	250	AMCV
Ethyltoluene, *p*-	0.34	S-2	250	AMCV

Table 5.2-2. Highest Measured Concentrations and TCEQ Short-Term Screening Levels (Continued)

Pollutant	Highest Measured 24-Hour Average Concentration [a]		Lowest TCEQ *Short-Term* Health-Based Screening Level [b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Formaldehyde	4.45	S-4	41	AMCV
Heptane, *n*-	0.86	S-4	850	AMCV
Heptene, 1-	0.77	S-2	4 [c]	ESL
Hexachloro-1,3-butadiene [e]	0.37	S-6	0.2	ESL
Hexanaldehyde	0.55	S-4	2,000	AMCV
Hexane, *n*-	3.48	S-4	1,800	AMCV
Hexene, 1-	0.15	S-4	500	AMCV
Hexene, *cis*-2-	0.26	S-4	500	AMCV
Hexene, *trans*-2-	0.35	S-4	500	AMCV
Isobutane	9.48	S-4	8,000	AMCV
Isobutene/1-butene	2.29	S-4	50,000	AMCV
Isopentane	36.4	S-4	1,200	AMCV
Isoprene	0.50	S-1	20	AMCV
Isopropylbenzene	0.05	S-4	500	AMCV
Isovaleraldehyde	Never detected		500	AMCV
Methane	9,890	S-7	No screening level	
Methanol	19.4	S-6	2,000	ESL
Methyl ethyl ketone	8.85	S-4	2,000	AMCV
Methyl isobutyl ketone	0.60	S-2	500	AMCV
Methyl methacrylate	0.45	S-1	80 [c]	ESL
Methyl *tert*-butyl ether	Never detected		500	AMCV
Methyl-1-butene, 2-	1.66	S-4	No screening level	
Methyl-1-butene, 3-	0.046	S-4	8,000	AMCV
Methyl-1-pentene, 2-	0.26	S-4	500	AMCV
Methyl-1-pentene, 4-	0.13	S-4	500	AMCV
Methyl-2-butene, 2-	2.82	S-4	500	AMCV
Methylcyclohexane	0.82	S-4	4,000	AMCV
Methylcyclopentane	1.39	S-4	750	AMCV
Methylene chloride	2.21	S-2	3,500	AMCV
Methylheptane, 2-	0.30	S-4	750	AMCV
Methylheptane, 3-	0.24	S-4	750	AMCV
Methylhexane, 2-	1.79	S-4	750	AMCV
Methylhexane, 3-	1.24	S-4	750	AMCV

Table 5.2-2. Highest Measured Concentrations and TCEQ Short-Term Screening Levels (Continued)

Pollutant	Highest Measured 24-Hour Average Concentration [a]		Lowest TCEQ *Short-Term* Health-Based Screening Level [b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Methylpentane, 2-	6.45	S-4	1,000	AMCV
Methylpentane, 3-	3.77	S-4	1,000	AMCV
Nonane, *n*-	1.28	S-2	2,000	AMCV
Nonene, 1-	0.25	S-2	6 [c]	ESL
Octane, *n*-	0.84	S-2	750	AMCV
Octene, 1-	0.055	S-5	4.4 [c]	ESL
Pentane, *n*-	15.68	S-4	1,200	AMCV
Pentene, 1-	0.88	S-4	2,600	AMCV
Pentene, *cis*-2-	1.07	S-4	2,600	AMCV
Pentene, *trans*-2-	2.10	S-4	2,600	AMCV
Pinene, *alpha*-	0.42	S-3A	628	AMCV
Pinene, *beta*-	0.21	S-2	200	AMCV
Propane	34.67	S-4	1,000,000 [d]	AMCV
Propionaldehyde	0.38	S-4	200	AMCV
Propylbenzene, *n*-	0.22	S-2	250	AMCV
Propylene	2.38	S-4	1,000,000 [d]	AMCV
Propyne	0.025	S-2	10,000	ESL
Styrene	0.76	S-1	5,100	AMCV
Tetrachloroethane, 1,1,2,2-	Never detected		10	AMCV
Tetrachloroethylene	0.22	S-2	1,000	AMCV
Tolualdehydes	0.053	S-4	21	AMCV
Toluene	12.6	S-2	4,000	AMCV
Trichlorobenzene, 1,2,4-	0.84	S-5	50	ESL
Trichloroethane, 1,1,1-	0.46	S-2	1,700	AMCV
Trichloroethane, 1,1,2-	0.12	S-5	100	AMCV
Trichloroethylene	0.093	S-5	100	AMCV
Trichlorofluoromethane	0.33	S-1	10,000	AMCV
Trichlorotrifluoroethane	0.11	S-5	5,000	ESL
Tridecane, *n*-	0.056	S-4	500	ESL
Tridecene, 1-	0.068	S-4	100	ESL
Trimethylbenzene, 1,2,3-	0.28	S-2	250	AMCV
Trimethylbenzene, 1,2,4-	0.73	S-2	250	AMCV
Trimethylbenzene, 1,3,5-	0.58	S-2	250	AMCV

Table 5.2-2. Highest Measured Concentrations and TCEQ Short-Term Screening Levels (Continued)

Pollutant	Highest Measured 24-Hour Average Concentration [a]		Lowest TCEQ *Short-Term* Health-Based Screening Level [b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Trimethylpentane, 2,2,3-	0.56	S-4	No screening level	
Trimethylpentane, 2,2,4-	3.10	S-4	750	AMCV
Trimethylpentane, 2,3,4-	0.79	S-4	750	AMCV
Undecane, *n*-	0.69	S-5	550	AMCV
Undecene, 1-	0.25	S-4	20 [c]	ESL
Valeraldehyde	0.14	S-4	500	AMCV
Vinyl acetate	0.36	S-7	40	ESL
Vinyl chloride	0.052	S-5	26,000	AMCV
Xylene, *m-,p-*	3.12	S-2	1,700	AMCV
Xylene, *o-*	0.94	S-2	1,700	AMCV

[a] In the column for highest concentrations, pollutant concentrations less than 1 ppb are rounded to two significant figures, and "never detected" indicates that the pollutant was not detected in any of the samples collected during the ambient air monitoring program.

[b] Refer to Section 5.2.2 for a description of the hierarchy used in this table for selecting short-term health-based screening values.

[c] For these pollutants, TCEQ has not published short-term *health-based* screening values; the values shown in the table are short-term *odor-based* screening values.

[d] For ethane, propane, and propylene, TCEQ has not published specific values for AMCVs or ESLs, but has instead labeled these pollutants as "simple asphyxiants." The principal concern for asphyxiants at sufficiently high concentrations is that they displace oxygen in the air. A concentration of 0.1% (by volume) is used in this table as a very conservative estimated screening level for these pollutants.

[e] Hexachloro-1,3-butadiene is shaded because its highest concentration was higher than TCEQ's short-term ESL. However, as Section 5.2.2 describes, this particular measurement is of questionable quality.

With one exception, every measurement made during the program was lower than TCEQ's short-term health-based screening levels, suggesting that the pollution levels would not cause adverse health effects among exposed populations. As the exception, a single detection of hexachloro-1,3-butadiene exceeded TCEQ's short-term health-based ESL. For the air sample collected at Site S-6 on October 7, 2010, TestAmerica™ reported a hexachloro-1,3-butadiene concentration of 0.369 ppbv, and TCEQ's ESL is 0.2 ppbv. For further context on this issue, ERG plotted the results of all 129 ambient air monitoring measurements for this pollutant (Figure 5.2-1). The following important observations are made about these measurements:

- The highest detected concentration (0.369 ppbv) exceeded the short-term ESL (0.2 ppbv) by a relatively small margin. This was the only sample with a measured concentration higher than the ESL.

- The highest measurement is of questionable quality. When originally reporting this sample result, TestAmerica™ noted two data quality issues. First, the analytical report indicates that the measured concentration (0.369 ppb) is higher than the method detection limit, but lower than the laboratory's reporting limit. The report further indicated that "…the user of this data should be aware that this data is of limited reliability." Second, the testing laboratory reported that the sample was analyzed after the recommended holding time for this particular monitoring method had passed, which introduces additional uncertainty into the result.

- The 128 other measurements (see Figure 5.2-1), including every measurement at the two monitoring stations near the highest natural gas production activity, were all lower than the ESL; and 125 of these measurements were non-detects.

- For further context, ERG also considered the outputs from the dispersion modeling analysis, including those based on well pads found to have the highest emission rates throughout Fort Worth. The comparison (see Section 5.3.1) showed that the highest outputs predicted by the model were considerably lower than the average concentrations of hexachloro-1,3-butadiene observed during the ambient air monitoring data.

The most logical and consistent explanation for the above observations is that the single hexachloro-1,3-butadiene concentration above TCEQ's ESL is not a reliable measurement.

In summary, for every pollutant considered in this program, ERG concludes that the ambient air monitoring data provide no evidence of 24-hour average concentrations reaching levels of health concern for acute exposures. Few pollutants shown in Table 5.2-2 do not have published short-term health-based screening levels. However, with the exception of methane, these pollutants were detected at relatively low quantities. The measured methane concentrations ranked the highest of all pollutants considered, which was not a surprising result considering that measurements occurred in close proximity to active well pads. Though elevated, these methane concentrations did not approach values that would present a physical hazard (such as the lower explosive limit of 5%, or 50,000,000 ppbv) or an asphyxiation hazard, which are the two safety and health endpoints most frequently evaluated for this pollutant. A recent literature review

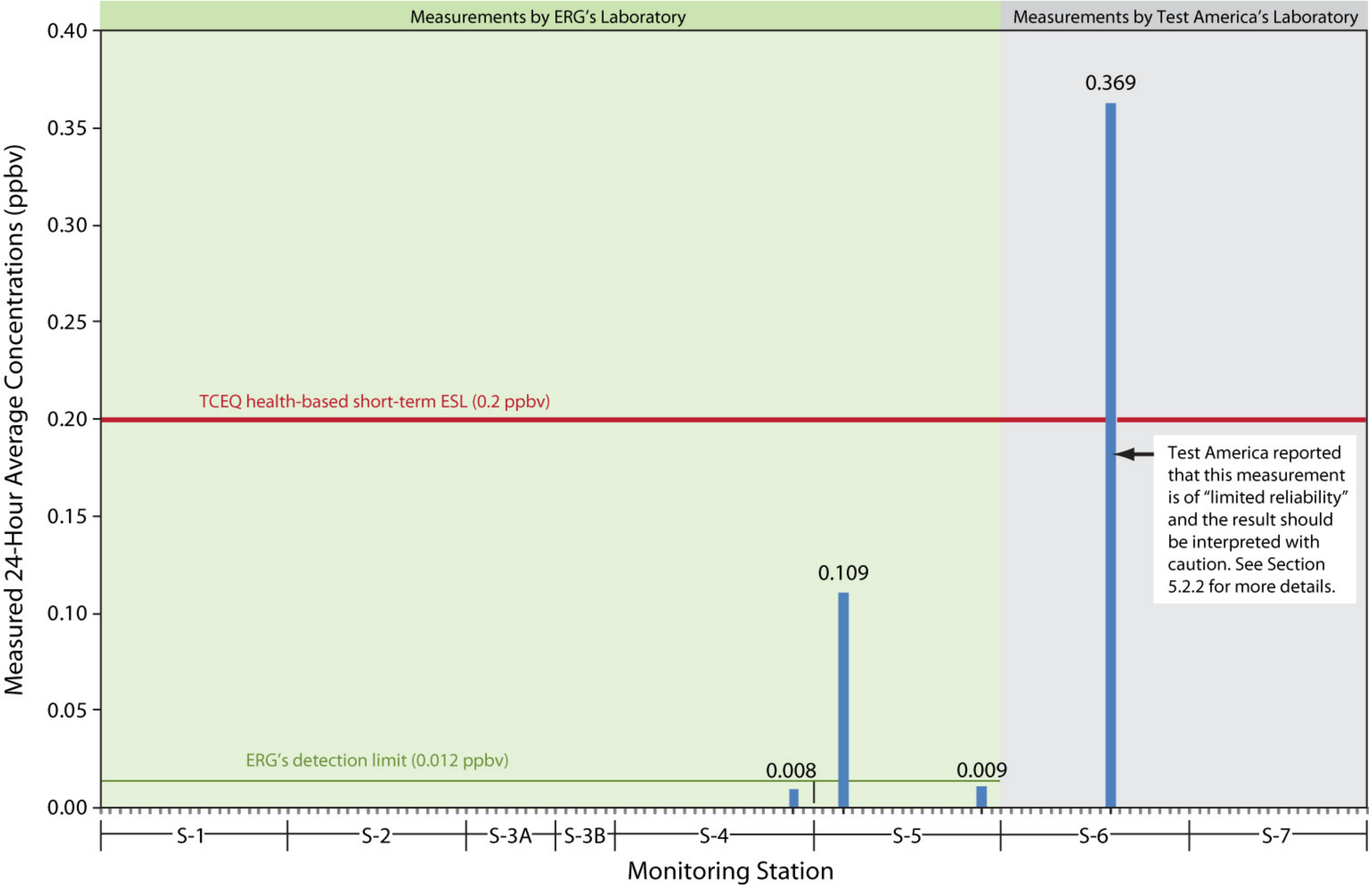


Figure 5.2-1. All Measurements of Hexachloro-1,3-Butadiene during the Ambient Air Monitoring Program

A tick mark is placed along the x-axis for every air sample that was analyzed for hexachloro-1,3-butadiene. The vertical columns display the measurement results for the four samples in which the pollutant was detected; the remaining 125 samples were non-detects. Detection limits are not displayed for the samples analyzed by TestAmerica™, because these values varied from one sample to the next.

documented in conference proceedings concluded that methane exhibits “no systemic toxicity” and supported the approach of assessing methane exposures by focusing on asphyxiation hazards.[9] Similarly, the Canadian Centre for Occupational Health and Safety has concluded that “harmful effects are not expected following long-term exposure” to methane, though this same finding acknowledges a lack of information about underlying human studies.[10] ERG conducted a supplemental literature search, but found no studies documenting advrse health effects in humans following long-term inhalation exposures to airborne methane.

5.2.3 Health Evaluation for Program-Average Concentrations

During this study, ambient air samples were collected every three days for two months. To assess the implications of longer-term exposures to the measured air pollution levels, ERG calculated average (i.e., arithmetic mean) concentrations for the individual pollutants at the eight different sites. These average concentrations represent two months of potential exposures, and were compared to longer-term health-based screening levels. The following paragraphs discuss this analysis.

When calculating average concentrations from individual sampling results, a decision must be made about how to handle non-detect observations, which are valid observations suggesting that a pollutant’s actual concentration in a sample had a value between zero and the detection limit. An approach commonly used when conducting health screening evaluations is to replace non-detects with a surrogate concentration of one-half the detection limit, and that approach is applied here. In cases where pollutants were detected in a large fraction of a site’s valid air samples, the approach used for replacing non-detects has little bearing on the magnitude of the calculated average concentrations, and the program-averages for the frequently detected pollutants are known to a high degree of confidence. On the other hand, for pollutants rarely detected in the air samples, there is considerable uncertainty associated with calculating the actual average concentrations—an observation revisited later in this section. Nonetheless, for sake of completeness, this analysis presents average concentrations for all pollutants detected in at least one sample.

Key Point: Program-Average Air Pollution Measurements
At the eight monitoring stations considered in this study, program-average concentrations for all but one pollutant were below levels of health concern. As the one exception, the program-average concentration of hexachloro-1,3-butadiene was higher than the TCEQ long-term effects screening level. However, this result is driven by a single unreliable measurement and is therefore of limited significance.

For every pollutant detected in the ambient air monitoring program, ERG compared the highest program-average concentrations to TCEQ’s corresponding long-term health-based screening levels. Table 5.2-3 lists the highest program-average concentration for each pollutant, the location where this value was observed, and the TCEQ screening level. For this evaluation, the hierarchy for selecting screening levels follows: If a pollutant has a long-term health-based AMCV, that value is used in Table 5.2-3 even if a different ESL is available; this preference again reflects the fact that TCEQ specifically derived AMCVs for evaluating ambient air monitoring data. Next, for pollutants that do not have AMCVs, the table displays the long-term health-based ESLs; and when no AMCV or ESL has been published for the pollutant, then “no screening level” appears in the table. Shading is used in the table to identify pollutants that had program-average concentrations higher than the TCEQ long-term screening level.

With one exception, every program-average concentration calculated for the pollutants listed in Table 5.2-3 is lower than the TCEQ long-term health-based screening values. This suggests that longer term exposure to the calculated program-average concentrations would not be expected to cause adverse health effects among exposed populations. The exception is again for hexachloro-1,3-butadiene. The calculated annual average concentration at monitoring site S-6 was 0.13 ppbv, which is higher than TCEQ's long-term ESL (0.02 ppbv). However, this calculated annual average concentration is highly uncertain, because it is driven entirely by a single measurement of questionable quality (see Section 5.2.2 and Figure 5.2-1) with the rest of the measurements at site S-6 being non-detects. ERG does not advise further evaluation of hexachloro-1,3-butadiene, given the extremely limited evidence of it being found in Fort Worth's air. ERG has no expectation of the chemical being found in underground shale formations, given that hexachloro-1,3-butadiene is a synthetic chemical that does not naturally occur in the environment.[11]

Table 5.2-3. Program-Average Concentrations and TCEQ Long-Term Screening Levels

Pollutant	Highest Program-Average Concentration [a]		Lowest TCEQ *Long-Term* Health-Based Screening Level [b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Acetaldehyde	3.80	S-4	25	AMCV
Acetone	4.30	S-7	250	AMCV
Acetylene	1.02	S-4	2,500	AMCV
Acrylonitrile	Never detected		2	ESL
Allyl chloride	Never detected		1	ESL
Amyl methyl ether, *tert*-	0.0098 [c]	S-2	65	ESL
Benzaldehyde	0.025	S-4	2.1	AMCV
Benzene	0.69	S-4	1.4	AMCV
Bromochloromethane	Never detected		200	ESL
Bromodichloromethane	0.037 [c]	S-6	10	ESL
Bromoform	Never detected		0.5	ESL
Bromomethane	0.045 [c]	S-6	3	AMCV
Butadiene, 1,3-	0.092	S-4	9.1	AMCV
Butane, *n*-	11.0	S-4	800	AMCV
Butanol, *n*-	Never detected		20	ESL
Butene, *cis*-2-	0.60	S-3B	No screening level	
Butene, *trans*-2-	0.38	S-4	No screening level	
Butyraldehyde	0.17	S-4	270	AMCV
Carbon disulfide	0.94	S-5	1	ESL
Carbon tetrachloride	0.12	S-1	2	AMCV
Chlorobenzene	0.036 [c]	S-6	10	AMCV
Chloroethane	0.056	S-7	19	ESL

Table 5.2-3. Program-Average Concentrations and TCEQ Long-Term Screening Levels (Continued)

Pollutant	Highest Program-Average Concentration[a]		Lowest TCEQ *Long-Term* Health-Based Screening Level[b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Chloroform	0.041	S-1	2	AMCV
Chloromethane	0.69	S-4	50	AMCV
Chloromethylbenzene	0.024[c]	S-5	1	ESL
Chloroprene	Never detected		1	ESL
Crotonaldehyde	0.072	S-4	0.3	AMCV
Cyclohexane	0.29	S-4	100	AMCV
Cyclopentane	0.45	S-4	120	AMCV
Cyclopentene	0.056[c]	S-2	290	AMCV
Decane, *n*-	0.26	S-2	175	AMCV
Decene, 1-	0.079[c]	S-2	20	ESL
Dibromochloromethane	0.0062[c]	S-5	0.2	ESL
Dibromoethane, 1,2-	0.046[c]	S-6	0.05	AMCV
Dichlorobenzene, *m*-	0.037	S-6	5.4	ESL
Dichlorobenzene, *o*-	0.045[c]	S-6	5.4	ESL
Dichlorobenzene, *p*-	0.061	S-4	5.4	ESL
Dichlorodifluoromethane	0.60	S-3B	1,000	AMCV
Dichloroethane, 1,1-	0.050[c]	S-6	100	AMCV
Dichloroethane, 1,2-	Never detected		1	AMCV
Dichloroethylene, 1,1-	0.045[c]	S-6	86	AMCV
Dichloroethylene, *cis*-1,2-	Never detected		200	ESL
Dichloroethylene, *trans*-1,2-	Never detected		200	ESL
Dichloropropane, 1,2-	Never detected		10	AMCV
Dichloropropylene, *cis*-1,3-	0.030[c]	S-7	1	AMCV
Dichloropropylene, *trans*-1,3-	0.033[c]	S-7	1	AMCV
Dichlorotetrafluoroethane	0.041[c]	S-6	1,000	ESL
Diethylbenzene, *m*-	0.080[c]	S-2	46	AMCV
Diethylbenzene, *p*-	0.061	S-2	46	AMCV
Dimethylbenzaldehyde, 2,5-	Never detected		2.1	AMCV
Dimethylbutane, 2,2-	0.30	S-4	100	AMCV
Dimethylbutane, 2,3-	0.95	S-4	99	AMCV
Dimethylpentane, 2,3-	0.34	S-4	85	AMCV
Dimethylpentane, 2,4-	0.33	S-4	85	AMCV
Dioxane, 1,4-	Never detected		25	ESL
Dodecane, *n*-	0.048	S-4	50	ESL

Table 5.2-3. Program-Average Concentrations and TCEQ Long-Term Screening Levels (Continued)

Pollutant	Highest Program-Average Concentration [a]		Lowest TCEQ *Long-Term* Health-Based Screening Level [b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Dodecene, 1-	0.030	S-4	10	ESL
Ethane	24.0	S-7	No screening level	
Ethyl acrylate	Never detected		4	ESL
Ethyl *tert*-butyl ether	0.0046 [c]	S-5	5	ESL
Ethyl-1-butene, 2-	0.14 [c]	S-2	No screening level	
Ethylbenzene	0.24	S-2	450	AMCV
Ethylene	1.77	S-4	5,300	AMCV
Ethyltoluene, *m*-	0.085	S-4	25	AMCV
Ethyltoluene, *o*-	0.083	S-2	25	AMCV
Ethyltoluene, *p*-	0.069	S-2	25	AMCV
Formaldehyde	1.14	S-4	8.9	AMCV
Heptane, *n*-	0.30	S-4	85	AMCV
Heptene, 1-	0.14 [c]	S-2	350	ESL
Hexachloro-1,3-butadiene	0.13 [c,d]	S-6	0.02	ESL
Hexanaldehyde	0.11	S-4	200	AMCV
Hexane, *n*-	1.31	S-4	190	AMCV
Hexene, 1-	0.073	S-4	50	AMCV
Hexene, *cis*-2-	0.089 [c]	S-2	50	AMCV
Hexene, *trans*-2-	0.13	S-4	50	AMCV
Isobutane	2.87	S-4	800	AMCV
Isobutene/1-butene	0.67	S-4	800	ESL
Isopentane	13.0	S-4	120	AMCV
Isoprene	0.27	S-1	2	AMCV
Isopropylbenzene	0.067	S-2	50	AMCV
Isovaleraldehyde	Never detected		50	AMCV
Methane	5,687	S-7	No screening level	
Methanol	6.740	S-7	200	ESL
Methyl ethyl ketone	1.55	S-4	200	AMCV
Methyl isobutyl ketone	0.12	S-2	50	AMCV
Methyl methacrylate	0.046 [c]	S-1	120	ESL
Methyl *tert*-butyl ether	Never detected		50	AMCV
Methyl-1-butene, 2-	0.51	S-4	No screening level	
Methyl-1-butene, 3-	0.056 [c]	S-2	800	AMCV
Methyl-1-pentene, 2-	0.090	S-4	50	AMCV

Table 5.2-3. Program-Average Concentrations and TCEQ Long-Term Screening Levels (Continued)

Pollutant	Highest Program-Average Concentration[a]		Lowest TCEQ *Long-Term* Health-Based Screening Level[b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Methyl-1-pentene, 4-	0.055	S-4	50	AMCV
Methyl-2-butene, 2-	1.00	S-4	50	AMCV
Methylcyclohexane	0.31	S-4	400	AMCV
Methylcyclopentane	0.57	S-4	75	AMCV
Methylene chloride	0.37	S-2	100	AMCV
Methylheptane, 2-	0.11	S-4	75	AMCV
Methylheptane, 3-	0.088	S-4	75	AMCV
Methylhexane, 2-	0.50	S-4	75	AMCV
Methylhexane, 3-	0.55	S-4	75	AMCV
Methylpentane, 2-	2.55	S-4	100	AMCV
Methylpentane, 3-	1.43	S-4	100	AMCV
Nonane, *n*-	0.21	S-2	200	AMCV
Nonene, 1-	0.045	S-2	100	ESL
Octane, *n*-	0.19	S-2	75	AMCV
Octene, 1-	0.076[c]	S-1	75	ESL
Pentane, *n*-	5.50	S-4	120	AMCV
Pentene, 1-	0.33	S-4	No screening level	
Pentene, *cis*-2-	0.39	S-4	No screening level	
Pentene, *trans*-2-	0.77	S-4	No screening level	
Pinene, *alpha*-	0.11	S-3A	63	AMCV
Pinene, *beta*-	0.097[c]	S-2	20	AMCV
Propane	10.7	S-4	No screening level	
Propionaldehyde	0.13	S-4	20	AMCV
Propylbenzene, *n*-	0.056[c]	S-6	25	AMCV
Propylene	0.81	S-4	No screening level	
Propyne	0.048[c]	S-2	1,000	ESL
Styrene	0.17	S-1	110	AMCV
Tetrachloroethane, 1,1,2,2-	Never detected		1	AMCV
Tetrachloroethylene	0.061	S-3B	3.8	AMCV
Tolualdehydes	0.0078[c]	S-4	2.1	AMCV
Toluene	2.31	S-2	1,100	AMCV
Trichlorobenzene, 1,2,4-	0.14	S-6	5	ESL
Trichloroethane, 1,1,1-	0.052	S-2	940	AMCV
Trichloroethane, 1,1,2-	0.035[c]	S-6	10	AMCV

Table 5.2-3. Program-Average Concentrations and TCEQ Long-Term Screening Levels (Continued)

Pollutant	Highest Program-Average Concentration [a]		Lowest TCEQ *Long-Term* Health-Based Screening Level [b]	
	Value (ppbv)	Monitoring Site Where Highest Value Occurred	Value (ppbv)	Type of Screening Level
Trichloroethylene	0.033 [c]	S-7	10	AMCV
Trichlorofluoromethane	0.28	S-1	1,000	AMCV
Trichlorotrifluoroethane	0.053	S-7	500	ESL
Tridecane, *n*-	0.12 [c]	S-2	50	ESL
Tridecene, 1-	0.12 [c]	S-2	10	ESL
Trimethylbenzene, 1,2,3-	0.052	S-4	25	AMCV
Trimethylbenzene, 1,2,4-	0.15	S-2	25	AMCV
Trimethylbenzene, 1,3,5-	0.11	S-2	25	AMCV
Trimethylpentane, 2,2,3-	0.18	S-4	No screening level	
Trimethylpentane, 2,2,4-	1.14	S-4	75	AMCV
Trimethylpentane, 2,3,4-	0.28	S-4	75	AMCV
Undecane, *n*-	0.12	S-2	55	AMCV
Undecene, 1-	0.080 [c]	S-2	20	ESL
Valeraldehyde	0.039	S-4	50	AMCV
Vinyl acetate	Never detected		4	ESL
Vinyl chloride	0.046 [c]	S-6	0.45	AMCV
Xylene, *m-,p-*	0.76	S-4	140	AMCV
Xylene, *o*-	0.25	S-4	140	AMCV

[a] In the column for highest program-average concentrations, pollutant concentrations less than 1 ppb are rounded to two significant figures, and "never detected" indicates that the pollutant was not detected in any of the samples collected during the ambient air monitoring program.

[b] Refer to Section 5.2.3 for a description of the hierarchy used in this table for selecting long-term health-based screening values. Several pollutants do not have any long-term screening values.

[c] These program-average concentrations are highly uncertain, because the pollutant was detected in fewer than half of the samples at the site with the highest average. The values shown are heavily influenced by the use of surrogate values (one-half the detection limit) for the non-detects.

[d] Hexachloro-1,3-butadiene is shaded because its highest concentration was higher than TCEQ's short-term ESL. However, as Section 5.2.2 describes, this particular measurement is of questionable quality.

5.2.4 Measured Concentrations: Main Findings, Limitations, and Uncertainties

The ambient air monitoring program was designed to provide insights into the nature and magnitude of air pollution levels at eight locations in Fort Worth. The more than 15,000 individual measurements of outdoor air pollution levels allowed for a health evaluation that considered both peak and average air pollution levels. The program found no evidence of air pollution reaching levels of health concern at these eight monitoring locations. However, the ambient air monitoring program has some inherent limitations that should be acknowledged:

Key Point: Air Monitoring Data
Overall, the short-term and long-term air pollution levels measured during the monitoring program did not reach levels of public health concern. However, this finding pertains only to the pollutants considered in this study and the locations where measurements were made.

- The analyses throughout Section 5.2 are based strictly on the air samples that ERG collected at eight locations in Fort Worth over a two-month time frame. The data should not be used to make inferences about air quality during times when, and at locations where, samples were not collected. This does not mean that this study failed to meet its stated goals, because a dispersion modeling analysis was conducted to help characterize potential air pollution levels at locations that were not sampled. Thus, the interpretations of the modeling data (see Section 5.3) help address this inherent limitation of the monitoring program.

- The ambient air monitoring program considered nearly 150 air pollutants, including dozens that were also detected during point source testing. The coverage of the monitoring data is therefore very extensive, but not necessarily comprehensive. This program did not consider the complete range of air pollutants that might be emitted from natural gas sites. For example, the monitoring program did not measure acrolein, which the modeling (see Section 5.3) identified as a pollutant of potential concern for certain sites. Therefore, this study’s findings apply only to the pollutants considered in the ambient air monitoring program and point source testing program, and should not be assumed to apply to a broader range of pollutants.

5.3 Interpretation of Dispersion Modeling Data

The dispersion modeling analysis conducted by ERG is an important complement to the ambient air monitoring data presented in Section 5.2. While the ambient air monitoring data has the advantage of directly measuring air pollution levels that residents might breathe, those data do not quantify how much different emission sources contribute to the measured concentrations. Further, the monitoring data do not characterize air quality for the entire range of well pad configurations. Dispersion modeling analysis was used to help fill these gaps. These models have the advantage of quantifying the incremental air quality impacts that can be attributed to natural gas exploration and production activity, based on the measured emission rates from the point source testing program. Section 4 of this report describes in detail the scope of the dispersion modeling analysis, and the inputs and assumptions used; this section comments on the health implications of the modeling results.

5.3.1 Comparison of Modeled and Measured Air Pollution Levels

Before evaluating health implications, ERG first compared the air concentrations predicted by the model to the air concentrations measured during the monitoring program. This comparison was performed for a subset of pollutants that were considered for both the ambient air monitoring and point source testing programs. Table 5.3-1 presents these results.

Table 5.3-1. Monitor-to-Model Comparisons for Selected Pollutants

Pollutant	Highest Program-Average Concentration Observed During the Monitoring Program (ppbv)	Highest Offsite Annual Average Concentration Predicted by the Dispersion Model (ppbv) [b]
Acetaldehyde	3.80	0.45
Benzene	0.69	3.99
Butadiene, 1,3-	0.092	0.037
Carbon tetrachloride	0.12	0.0016
Chloroform	0.050	0.00094
Dibromoethane, 1,2-	0.026 [a]	0.00093
Ethylbenzene	0.24	0.22
Formaldehyde	1.14	4.40
Hexachloro-1,3-butadiene	0.13 [a]	0.0050
Tetrachloroethylene	0.061	0.049
Trichloroethane, 1,1,2-	0.035 [a]	0.00095
Vinyl chloride	0.046 [a]	0.0021

[a] These program-average concentrations are highly uncertain, because the pollutants were detected in fewer than half of the samples at the sites with the highest average concentrations. The values shown are heavily influenced by the surrogate values (one-half the detection limit) used for the non-detects.

[b] For purposes of this table, "offsite" refers to any location at or beyond the facility fence lines for the modeling scenarios described in Section 4.

For many pollutants in the table, the highest program-average concentration observed during the monitoring program was considerably higher than the highest offsite annual average concentration predicted by the dispersion model—a trend that was particularly evident for the halogenated hydrocarbons. For purposes of this analysis, "offsite" refers to any location at or beyond the facility fence lines. Considering that the specific modeling results shown in Table 5.3-1 were based on the highest emission rates measured during the point source testing program, the substantially lower modeling results suggest that well pad and compressor stations emissions are not major contributors to the measured concentrations found during the ambient air monitoring program. In other words, even the highest emissions from well pads and compressor stations would not be expected to account for the levels measured in the ambient air for this subset of pollutants. ERG also considered the possibility that the modeling results might be biased low and therefore underestimating air quality impacts; however, this explanation does not appear to be likely, considering the fact that the modeling is based on the highest emission rates observed across all well pads that were tested. For the reasons stated above, ERG concludes that trace levels of halogenated hydrocarbons detected during the ambient air monitoring program cannot be attributed primarily to emissions from the natural gas exploration and production activity.

Conversely, for other pollutants listed in Table 5.3-1, the highest annual average concentration predicted by the modeling analysis was considerably higher than the highest program-average concentration calculated from the air sampling results. For benzene, the modeled concentration was nearly 6 times greater than the highest measured value; for formaldehyde, the measured and modeled values differed by nearly a factor of 4. For these two pollutants, the differences between the measured and modeled results most likely reflect the different scenarios portrayed by these data points. Specifically, the modeled values are estimates of the highest offsite annual average concentrations at the well pad or compressor station with the highest emissions—or the highest concentrations at or beyond the facility fence lines. On the other hand, the measured concentrations were intended to reflect some of the highest site-related air quality impacts; however, the monitoring generally did not occur at fence line locations, and the point source testing revealed that the ambient air monitoring stations were not close to some of the highest-emitting well pads. This discrepancy most likely explains why, for these two pollutants, the modeled concentrations were considerably higher than the measured ones.

5.3.2 Health Evaluation for Modeled 1-Hour Average Concentrations

As Section 4 describes, the dispersion modeling analysis was conducted for four different hypothetical scenarios, including some anticipated to represent the worst-case conditions for offsite air quality impacts. As noted previously, "offsite" in this section refers to any receptor location at or beyond the facility fence lines for the four modeling scenarios. Modeling was conducted for nearly 90 pollutants, depending on the scenario. Potential short-term air quality impacts are assessed here using the highest 1-hour average

Key Point: Short-Term Modeling
A model estimated how emissions from certain well pad and compressor station configurations affect local air quality. Of all pollutants considered, only acrolein, benzene, and formaldehyde had estimated 1-hour average concentrations greater than TCEQ's short-term ESLs. The model output suggested that estimated methylene chloride concentrations might also exceed health-based screening levels, but this was based on a suspect measurement and is not a robust finding.

concentrations output by the dispersion model for any location at or beyond the fence lines of the modeled well pads and compressor stations. Fence line concentrations were considered for the short-term evaluation, because access restrictions do not prevent residents from walking alongside the production operations at these sites. The modeling estimates are based on the highest emission rates observed during the point source testing, combined with the meteorological conditions anticipated to lead to the least dispersion.

For every pollutant considered in the modeling analysis, Table 5.3-2 compares the highest estimated 1-hour average concentrations to TCEQ's health-based short-term screening levels. For this evaluation, the hierarchy for selecting screening levels follows: First, if a pollutant has a short-term *health-based* ESL, that value was used in Table 5.2-1, even if a different AMCV is available. The preference for ESLs over AMCVs was applied here because this is an evaluation of dispersion modeling data, not ambient air monitoring data. Next, if a pollutant does not have a *health-based* ESL, the table displays the pollutant's short-term *health-based* AMCV. If neither value is available for the pollutant, short-term *odor-based* ESLs are used, if available. The table also indicates which pollutants have no TCEQ screening values. Shading is used in the table to identify pollutants that had at least one estimated 24-hour average concentration higher than the TCEQ short-term screening level.

Table 5.3-2. Modeled 1-Hour Average Concentrations and TCEQ Short-Term Screening Levels

Pollutant [a]	Highest Estimated 1-Hour Average Concentration Beyond Well Pad Fence Lines (ppbv)	Lowest TCEQ *Short-Term* Health-Based Screening Level [b]	
		Value (ppbv)	Type of Screening Level
Acenaphthene	0.00016	0.2	ESL
Acenaphthylene	0.00068	0.2	ESL
Acetaldehyde	3.58	250	AMCV
Acetone	271	2,500	ESL
Acrolein	2.62	1.6	ESL
Anthracene	0.000075	0.07	ESL
Benzene	59.5	54	ESL
Benzo (a) anthracene	0.000028	0.05	ESL
Benzo (b) fluoranthene	0.000013	0.05	ESL
Benzo (e) pyrene	0.000031	0.05	ESL
Benzo (g,h,i) perylene	0.000028	0.04	ESL
Biphenyl	0.026	0.4 [c]	ESL
Bromomethane	0.030	30	ESL
Butadiene, 1,3-	0.29	1,700	AMCV
Butane, *n-*	3,990	10,000	ESL
Butylbenzene, *sec-*	0.58	500	ESL
Carbon disulfide	0.061	10	ESL

Table 5.3-2. Modeled 1-Hour Average Concentrations and TCEQ Short-Term Screening Levels (Continued)

Pollutant [a]	Highest Estimated 1-Hour Average Concentration Beyond Well Pad Fence Lines (ppbv)	Lowest TCEQ *Short-Term* Health-Based Screening Level [b]	
		Value (ppbv)	Type of Screening Level
Carbon tetrachloride	0.018	20	ESL
Chlorobenzene	0.0074	100	ESL
Chlorodifluoromethane	0.013	5,000	ESL
Chloroethane	0.045	190	ESL
Chloroform	0.0074	20	ESL
Chloromethane	0.040	500	ESL
Chlorotoluene, 2-	0.030	45 [c]	ESL
Chrysene	0.000057	0.05	ESL
Cyclohexane	106	1,000	ESL
Cyclopentane	0.061	1,200	ESL
Decane, *n*-	14.4	1,750	ESL
Dibromoethane, 1,2-	0.0074	0.5	ESL
Dichlorodifluoromethane	0.018	10,000	ESL
Dichloroethane, 1,1-	0.0074	1,000	ESL
Dichloroethane, 1,2-	0.0080	40	ESL
Dichloropropane, 1,2-	0.0074	100	ESL
Dichloropropylene, 1,3-	0.0074	10	ESL
Dichlorotetrafluoroethane	0.015	10,000	ESL
Dodecane, *n*-	0.70	500	ESL
Ethane	66.0	1,000,000 [d]	ESL
Ethylbenzene	3.55	20,000	AMCV
Ethyltoluene, 4-	4.16	250	ESL
Fluoranthene	0.00010	0.06	ESL
Fluorene	0.00064	1	ESL
Formaldehyde	34.7	12	ESL
Heptane, *n*-	474	850	ESL
Hexachloro-1,3-butadiene	0.079	0.2	ESL
Hexane, *n*-	573	1,500	ESL
Indeno(1,2,3-cd)pyrene	0.00000088	0.04	ESL
Isobutane	1.22	8,000	AMCV
Isobutyraldehyde	0.11	2,700	AMCV
Isopentane	1,099	1,200	ESL
Isopropylbenzene	0.91	500	AMCV
Isopropyltoluene, 4-	0.43	500	ESL

Table 5.3-2. Modeled 1-Hour Average Concentrations and TCEQ Short-Term Screening Levels (Continued)

Pollutant [a]	Highest Estimated 1-Hour Average Concentration Beyond Well Pad Fence Lines (ppbv)	Lowest TCEQ *Short-Term* Health-Based Screening Level [b]	
		Value (ppbv)	Type of Screening Level
Methane	1,033,000	No screening level	
Methanol	1.80	2,000	ESL
Methyl ethyl ketone	0.23	2,000	AMCV
Methyl napththalene, 2-	0.0044	5	ESL
Methyl-2-pentanone, 4-	0.31	200	ESL
Methylcyclohexane	0.24	4,000	AMCV
Methylene chloride	145	75	ESL
Naphthalene	0.16	500,000	AMCV
Nonane, *n*-	331	2,000	ESL
Octane, *n*-	389	750	ESL
Pentane, *n*-	864	1,200	ESL
Phenanthrene	0.0011	0.07	ESL
Phenol	0.0084	40 [c]	ESL
Propane	17.9	1,000,000 [d]	ESL
Propylbenzene, *n*-	1.49	250	ESL
Propylene	0.21	1,000,000 [d]	ESL
Pyrene	0.00013	0.06	ESL
Styrene	0.046	5,100	AMCV
Tetrachloroethane, 1,1,2,2-	0.0075	10	ESL
Tetrachloroethylene	0.70	300	ESL
Toluene	257	4,000	AMCV
Trichlorobenzene, 1,2,3-	0.18	50	ESL
Trichlorobenzene, 1,2,4-	0.14	50	ESL
Trichloroethane, 1,1,2-	0.0075	100	ESL
Trichlorofluoromethane	0.024	5,000	ESL
Trimethylbenzene, 1,2,3-	0.0056	250	ESL
Trimethylbenzene, 1,2,4-	13.9	250	ESL
Trimethylbenzene, 1,3,5-	7.46	250	ESL
Trimethylpentane, 2,2,4-	0.30	750	ESL
Undecane, *n*-	2.83	500	ESL
Vinyl acetate	0.27	40	ESL
Vinyl bromide	0.033	50	ESL

Table 5.3-2. Modeled 1-Hour Average Concentrations and TCEQ Short-Term Screening Levels (Continued)

Pollutant [a]	Highest Estimated 1-Hour Average Concentration Beyond Well Pad Fence Lines (ppbv)	Lowest TCEQ *Short-Term* Health-Based Screening Level [b]	
		Value (ppbv)	Type of Screening Level
Vinyl chloride	0.027	7,800	ESL
Xylene, *m,p-*	179	1,700	AMCV
Xylene, *o-*	10.6	1,700	AMCV

[a] Acrolein, benzene, formaldehyde, and methylene chloride are shaded because their highest estimated 1-hour average concentrations were higher than TCEQ's short-term ESL. Refer to Section 5.3.2 for further information on these pollutants. Data are presented for all individual pollutants considered in the modeling analysis. As the exception, estimated concentrations are not presented for benzo(a)pyrene, benzo(k)fluoranthene, and perylene. For these pollutants, the estimated concentrations were so low that the model rounded the values to zero.

[b] Refer to Section 5.3.2 for a description of the hierarchy used in this table for selecting short-term health-based screening values. AMCVs are used for those pollutants that do not have health-based ESLs.

[c] For these pollutants, TCEQ has not published short-term *health-based* screening values; the values shown in the table are short-term *odor-based* screening values.

[d] For ethane, propane, and propylene, TCEQ has not published specific values for AMCVs or ESLs, but has instead labeled these pollutants as "simple asphyxiants." The principal concern for asphyxiants at sufficiently high concentrations is that they displace oxygen in the air. A concentration of 0.1% (by volume) is used in this table as a very conservative estimated screening level for these pollutants.

The highest offsite air quality impacts were found for Scenarios 2, 3, and 4 in the modeling analysis. For pollutants emitted primarily by tanks, modeling Scenario 2 yielded the highest offsite 1-hour average concentration, primarily because this scenario had tanks placed along the northern fence line and southerly winds (i.e., winds blowing from south to north) prevail in Fort Worth. On the other hand, for pollutants released largely by engines, Scenarios 3 and 4 predicted the highest offsite air quality impacts, because these scenarios considered the largest engines.

As Table 5.3-2 shows, four pollutants considered in the modeling analysis had at least one estimated 1-hour average concentrations greater than lowest short-term health-based TCEQ screening levels. When reviewing these results, it is important to remember that the model estimates are based on the least favorable meteorological conditions for dispersion and for the highest-emitting well pads and compressor stations. Modeling Scenario 1, which was based on typical well pad emissions, had considerably lower estimated air quality impacts—and no 1-hour average concentrations greater than short-term screening levels.

ERG further examined the underlying modeling outputs and screening levels, and notes the following important observations:

- *Benzene.* ERG modeled air quality impacts of benzene at hundreds of offsite locations, commonly referred to as receptors. In Scenarios 1 and 3, every estimated 1-hour average concentration at every receptor was below TCEQ's short-term ESL. In Scenarios 2 and 4, only a single receptor—out of the hundreds modeled—had at least one estimated 1-hour average concentration greater than the ESL, and this occurred at just one receptor located at the fence line within a few feet of the tanks themselves. Receptors just 30 feet downwind showed no concentrations above the ESL. Further, at this one receptor, estimated 1-hour average benzene concentrations above the ESL occurred no more than 6 hours per year, and these values (54–59.5 ppbv) were only marginally above the health-protective ESL (54 ppbv). Recalling that these estimates are based on the highest emission rates measured in the point source testing program, the available modeling data suggest that only the single well pad found to have the highest benzene emissions would likely lead to offsite concentrations above the short-term ESL, and this would occur infrequently and only within a few feet of the highest-emitting tanks. ERG's main recommendation for benzene (see Section 5.5) is that city officials periodically review TCEQ's "auto-GC" sampling data for sites throughout the Barnett Shale formation, and evaluate whether any benzene concentrations ever exceed short-term screening levels. Should this occur, city officials should confer with TCEQ about proper interpretation of the monitoring data and the health implications for the particular monitoring site and for unmonitored locations.

- *Acrolein and formaldehyde.* These two pollutants are combustion by-products emitted by engines at the well pads and compressor stations. The magnitude of emissions—and offsite air quality impacts—depends on the type of engines used. Modeling Scenario 2 considered the smaller "lift engines," which typically fall between 150 and

250 hp. For this scenario, highest 1-hour average concentrations of acrolein and formaldehyde exceeded TCEQ's short-term ESL, but this only occurred at fence line locations for acrolein and at receptors within 100 feet of fence lines for formaldehyde. On the other hand, Scenarios 3 and 4 considered the larger "line engines," which operate at roughly 1,500 hp. For these scenarios, 1-hour average concentrations of acrolein greater than TCEQ's short-term ESL extended approximately 400 feet from the fence lines, and 1-hour average concentrations of formaldehyde greater than TCEQ's ESL were estimated to occur up to 750 feet beyond the fence lines. In the case of formaldehyde, the highest offsite 1-hour average concentration was estimated to be nearly 3 times higher than TCEQ's short-term ESL. Section 5.4 presents further information on the health implications of the estimated concentrations for these pollutants.

- *Methylene chloride.* As Table 5.3-2 shows, the highest estimated 1-hour average concentration of methylene chloride (145 ppbv) is higher than TCEQ's short-term ESL (75 ppbv). However, the modeling output for methylene chloride is based on an emissions measurement of suspect quality. Specifically, the emission rate used in the modeling analysis is based on a sample (#B015) collected on September 20, 2010, at a well pad (Site #PS-075). However, the analytical report for this sample includes two qualifiers. First, the laboratory reported a "B" qualifier, which indicates that methylene chloride was also detected in the method blank, raising questions about contamination of the sampling equipment. Second, the laboratory reported a "J" qualifier, which means the measured concentration was higher than the MDL but lower than the laboratory's reporting limit; the analytical report further states that "…the user of [J-qualified] data should be aware that this data is of limited reliability." For these reasons, ERG concludes that the highest estimated methylene chloride concentration shown in Table 5.3-2 is of questionable quality. If this one sample were omitted from the emissions estimation analysis, the next highest 1-hour average concentrations of methylene chloride predicted by the model would be substantially lower than TCEQ's short-term ESL. Accordingly, ERG does not recommend further evaluation of this pollutant.

Overall, the highest estimated 1-hour average concentrations predicted by the dispersion model are below TCEQ's health-based short-term screening levels for nearly every pollutant considered. For reasons stated above, ERG concludes that further evaluation is warranted for the air quality impacts of acrolein and formaldehyde, which had 1-hour concentrations above screening levels beyond the fence line of any site with operating lift engines or line engines. Section 5.4 provides further insights on these two pollutants.

5.3.3 Health Evaluation for Modeled Annual Average Concentrations

Key Point: Long-Term Modeling
A model was used to estimate annual average air quality impacts caused by emissions from well pads and compressor stations. Of all pollutants considered, only acrolein and formaldehyde had estimated annual average concentrations at locations at least 200 feet from fence lines greater than TCEQ screening levels. These air quality impacts are greatest for well pads and compressor stations with large line engines.

ERG assessed potential long-term exposures to site-related pollutants by evaluating the highest annual average concentrations output by the dispersion model. This comparison considered all locations more than 200 feet from fence lines of well pads and compressor stations. This downwind distance was selected because, although most gas well must be at least 600 feet from residences, city variances allow setback distances as low as 200 feet. The comparisons presented here represent a worst-case scenario: a full-time resident living just 200 feet from the highest-emitting well pads and compressor stations.

For every pollutant considered in the modeling analysis, Table 5.3-3 compares the highest estimated annual average concentrations to TCEQ’s health-based, long-term screening levels. For this evaluation, the hierarchy for selecting screening levels follows: If a pollutant has a long-term health-based ESL, that value is used in Table 5.3-3, even if a different AMCV is available for the pollutant. This preference again reflects the fact that TCEQ specifically derived ESLs for evaluating dispersion modeling data, whereas AMCVs are the screening levels of choice when assessing ambient air monitoring data. The few pollutants that do not have long-term ESLs do not have any TCEQ health-based screening values, as indicated in the table. Shading is used in the table to identify pollutants that had at least one estimated annual average concentration at distances more than 200 feet from the fence lines higher than the TCEQ long-term screening level.

As Table 5.3-3 shows, only two pollutants considered in the modeling analysis—acrolein and formaldehyde—had estimated annual average concentrations greater than TCEQ’s health-based, long-term ESLs. Across all pollutants, the highest annual average concentrations reported in the table were all observed for modeling Scenarios 2, 3, or 4. In contrast, Scenario 1, which was based on typical well pad emissions, had considerably lower estimated air quality impacts—and no annual average concentrations greater than long-term screening levels at any locations beyond the fence lines. Further information follows for the two pollutants with estimated annual average concentrations greater than screening levels:

- *Acrolein.* The highest annual average concentration of acrolein at locations at least 200 feet from fence lines predicted by the model (0.33 ppbv) was higher than TCEQ’s health-based, long-term ESL (0.066 ppbv). However, considering receptors at least 200 feet from fence lines, only Scenarios 3 and 4 had at least one estimated annual average concentration of acrolein greater than TCEQ’s ESL. This suggests that emissions from the larger line engines account for the only instances where estimated acrolein levels exceeded TCEQ’s long-term ESL.

Table 5.3-3. Modeled Annual Average Concentrations and TCEQ Long-Term Screening Levels

Pollutant [a]	Highest Estimated Annual Average Concentration at Locations 200 Feet Beyond Fence Lines (ppbv)	Lowest TCEQ *Long-Term* Health-Based Screening Level [b]	
		Value (ppbv)	Type of Screening Level
Acenaphthene	0.000021	0.02	ESL
Acenaphthylene	0.000085	0.02	ESL
Acetaldehyde	0.45	25	ESL
Acetone	0.75	250	ESL
Acrolein	0.33	0.066	ESL
Anthracene	0.0000096	0.007	ESL
Benzene	0.24	1.4	ESL
Benzo (a) anthracene	0.0000032	0.005	ESL
Benzo (b) fluoranthene	0.0000019	0.005	ESL
Benzo (e) pyrene	0.0000039	0.005	ESL
Benzo (g,h,i) perylene	0.0000035	0.004	ESL
Biphenyl	0.0033	0.2	ESL
Bromomethane	0.000082	3	ESL
Butadiene, 1,3-	0.036	4.5	ESL
Butane, *n*-	16.2	1,000	ESL
Butylbenzene, sec-	0.0022	50	ESL
Carbon disulfide	0.00021	1	ESL
Carbon tetrachloride	0.00096	2	ESL
Chlorobenzene	0.00093	10	ESL
Chlorodifluoromethane	0.000037	500	ESL
Chloroethane	0.00014	19	ESL
Chloroform	0.00093	2	ESL
Chloromethane	0.00016	50	ESL
Chlorotoluene, 2-	0.000083	60	ESL
Chrysene	0.0000075	0.005	ESL
Cyclohexane	0.42	100	ESL
Cyclopentane	0.0076	120	ESL
Decane, *n*-	0.057	175	ESL
Dibromoethane, 1,2-	0.00092	0.05	ESL
Dichlorodifluoromethane	0.000051	1,000	ESL
Dichloroethane, 1,1-	0.00093	100	ESL
Dichloroethane, 1,2-	0.0010	1	ESL
Dichloropropane, 1,2-	0.00093	10	ESL

Table 5.3-3. Modeled Annual Average Concentrations and TCEQ Long-Term Screening Levels (Continued)

Pollutant [a]	Highest Estimated Annual Average Concentration at Locations 200 Feet Beyond Fence Lines (ppbv)	Lowest TCEQ *Long-Term* Health-Based Screening Level [b]	
		Value (ppbv)	Type of Screening Level
Dichloropropylene, 1,3-	0.00093	1	ESL
Dichlorotetrafluoroethane	0.000043	1,000	ESL
Dodecane, *n*-	0.0025	50	ESL
Ethane	8.28	No screening level	
Ethylbenzene	0.015	135	ESL
Ethyltoluene, 4-	0.027	25	ESL
Fluoranthene	0.000013	0.006	ESL
Fluorene	0.000081	0.1	ESL
Formaldehyde	4.34	2.7	ESL
Heptane, *n*-	1.79	85	ESL
Hexachloro-1,3-butadiene	0.00032	0.02	ESL
Hexane, *n*-	2.19	57	ESL
Isobutane	0.15	800	ESL
Isobutyraldehyde	0.014	25	ESL
Isopentane	4.47	120	ESL
Isopropylbenzene	0.0036	50	ESL
Isopropyltoluene, 4-	0.0017	50	ESL
Methane	3,660	No screening level	
Methanol	0.23	200	ESL
Methyl ethyl ketone	0.00090	900	ESL
Methyl naphthalene, 2-	0.00055	0.5	ESL
Methyl-2-pentanone, 4-	0.00094	20	ESL
Methylcyclohexane	0.030	400	ESL
Methylene chloride	0.40	7.5	ESL
Naphthalene	0.0021	10	ESL
Nonane, *n*-	1.19	200	ESL
Octane, *n*-	1.43	75	ESL
Pentane, *n*-	3.48	120	ESL
Phenanthrene	0.00014	0.007	ESL
Phenol	0.0011	5	ESL
Propane	2.24	No screening level	
Propylbenzene, *n*-	0.0099	25	ESL
Propylene	0.00073	No screening level	
Pyrene	0.000016	0.006	ESL

Table 5.3-3. Modeled Annual Average Concentrations and TCEQ Long-Term Screening Levels (Continued)

Pollutant [a]	**Highest Estimated Annual Average Concentration at Locations 200 Feet Beyond Fence Lines (ppbv)**	**Lowest TCEQ *Long-Term* Health-Based Screening Level** [b]	
		Value (ppbv)	**Type of Screening Level**
Styrene	0.0013	33	ESL
Tetrachloroethane, 1,1,2,2-	0.00093	1	ESL
Tetrachloroethylene	0.0024	3.8	ESL
Toluene	0.99	330	ESL
Trichlorobenzene, 1,2,3-	0.00072	5	ESL
Trichlorobenzene, 1,2,4-	0.00057	5	ESL
Trichloroethane, 1,1,2-	0.00093	10	ESL
Trichlorofluoromethane	0.000066	500	ESL
Trimethylbenzene, 1,2,3-	0.00070	25	ESL
Trimethylbenzene, 1,2,4-	0.12	25	ESL
Trimethylbenzene, 1,3,5-	0.034	25	ESL
Trimethylpentane, 2,2,4-	0.018	75	ESL
Undecane, *n*-	0.010	50	ESL
Vinyl acetate	0.00094	4	ESL
Vinyl bromide	0.000089	5	ESL
Vinyl chloride	0.00095	0.45	ESL
Xylene, *m,p*-	0.69	42	ESL
Xylene, *o*-	0.044	42	ESL

[a] Acrolein and formaldehyde are shaded because their highest estimated annual average concentrations were higher than TCEQ's long-term ESL. Refer to Sections 5.2.3 and 5.2.4 for further information on these pollutants. Data are presented for all individual pollutants considered in the modeling analysis. As the exception, estimated concentrations are not presented for benzo(a)pyrene, benzo(k)fluoranthene, and perylene. For these pollutants, the estimated concentrations were so low that the model rounded the values to zero.

[b] Refer to Section 5.2.3 for a description of the hierarchy used in this table for selecting long-term health-based screening values. Several pollutants do not have any long-term screening values.

- *Formaldehyde.* The highest annual average concentration of formaldehyde predicted by the modeling analysis beyond 200 feet from a fence line was 4.34 ppbv—higher than TCEQ's health-based, long-term ESL (2.7 ppbv). Estimated annual average concentrations greater than the long-term ESL were observed for Scenarios 3 and 4, but not at distances more than 600 feet from the fence lines.

In summary, for receptors at least 200 feet from fence lines, the highest estimated annual average concentrations predicted by the dispersion model are below TCEQ's health-based long-term ESL for every pollutant and modeling scenario considered, except for acrolein and formaldehyde in Scenarios 3 and 4. This indicated that air emissions from line engines account for the highest estimated air quality impacts. Because this study relied upon estimated emission rates for these engines, consideration should be given to gathering additional information (e.g., measured emission rates from compressor engines, ambient air monitoring data downwind from the highest-emitting sites) to gain greater confidence in the conclusions for these pollutants. Sections 5.4 and 5.5 provide further insights on this issue.

5.3.4 Adequacy of Setback Limits

Key Point: Setback Distances
For nearly every pollutant considered, the 600-foot setback distance appears to be adequately protective of public health, even for the highest-emitting sites. However, for sites with large line engines: (1) estimated annual average concentrations of acrolein are higher than TCEQ's long-term ESLs at distances more than 600 feet from the fence line, and (2) for formaldehyde, estimated 1-hour average concentrations are higher than TCEQ's short-term ESLs at some locations beyond the setback distance. Section 5.4 provides further context on these two pollutants.

Taken together, monitoring and modeling data provide a basis for assessing the adequacy of the city of Fort Worth's setback distances. The minimum setback distance required is 600 feet, though variances can lead to setbacks as low as 200 feet. The critical issue in evaluating setback distances is the extent to which air quality impacts decrease with distance from the facilities.

For some emission sources at well pads, particularly the tanks and fugitive emissions, estimated offsite air quality impacts peak at the fence line and decrease considerably with downwind distance. For instance, in Scenario 2, the highest annual average concentration of benzene at the fence line was 3.99 ppbv; the highest value at distances 200 feet from the fence line was 0.24 ppbv, falling to 0.04 ppbv at the 600-foot setback distance. Therefore, for this scenario, the annual average concentration decreased by 99% from the fence line to the setback distance. For pollutants emitted primarily or entirely by line engines and lift engines, the concentration gradient was notably less pronounced. In the case of acrolein for Scenario 4, for example, the maximum annual average concentration at the 600-foot setback distance was only 55% lower than the maximum offsite value.

To assess the setback distances, ERG focused on estimated air quality impacts at receptors 600 feet from fence lines, and additional insight is provided on distances as short as 200 feet, given the variances that can apply. A given well pad or compressor station's air quality impacts depend on the nature and extent of the site's emissions sources—the number and placement of tanks; the number, type, and size of engines; and so on. ERG's assessment of the setback distances is framed around the modeling results for the four scenarios defined in Section 4. For every scenario considered, Figures 5.3-1 through 5.3-3 illustrate how estimated annual average concentrations varied with location for acrolein, benzene, and formaldehyde. These pollutants were selected for the displays because they are the only site-related pollutants that had at least one offsite modeling result greater than a screening value.

ERG's assessment of the adequacy of the setback distances follows:

- *Well pads with tanks and fugitive emissions, but no engines.* The modeling results indicate that the setback distances are adequate for well pads equipped with tanks and fugitive emission sources, but no engines. Even in modeling analyses framed around the highest-emitting tanks and fugitive emissions, the setback distances were adequate for all pollutants considered (e.g., see Figure 5.3-1). Every estimated 1-hour average concentration at all offsite receptors was less than TCEQ's short-term ESLs, and every estimated annual average concentration at locations more than 200 feet from fence lines was less than TCEQ's long-term ESLs.

- *Well pads with tanks and lift engines.* Scenario 2 in the modeling analysis considered a well pad with two 250-hp lift engines. It also considered the highest measured emission rates for tanks and fugitive emissions. For this configuration, estimated annual average concentrations of all pollutants were lower than TCEQ's long-term ESL for receptor locations at least 200 feet from site fence lines. Further, estimated 1-hour average concentrations of all pollutants were lower than TCEQ's short-term ESL for receptor locations at least 600 feet from sites. While not an issue for the setback distances, some estimated 1-hour average concentrations of acrolein and formaldehyde exceeded TCEQ's short-term ESL, but this was limited to distances within 100 feet of the fence lines.

- *Well pads and compressor stations with line engines.* The primary issues for sites with line engines are emissions of acrolein and formaldehyde. For acrolein, estimated annual average concentrations exceed TCEQ's long-term ESL for several hundred feet beyond the 600-foot setback (see Figure 5.3-2). For formaldehyde, estimated annual average concentrations were below TCEQ's long-term ESL at all locations beyond the setback (see Figure 5.3-3), but some estimated 1-hour average concentrations were higher than the short-term ESL at a small number of receptors beyond the setback. While the estimated concentrations for these pollutants were higher than health-protective screening values, the modeled air quality impacts are lower than levels that have been actually associated with adverse health effects (see Section 5.4).

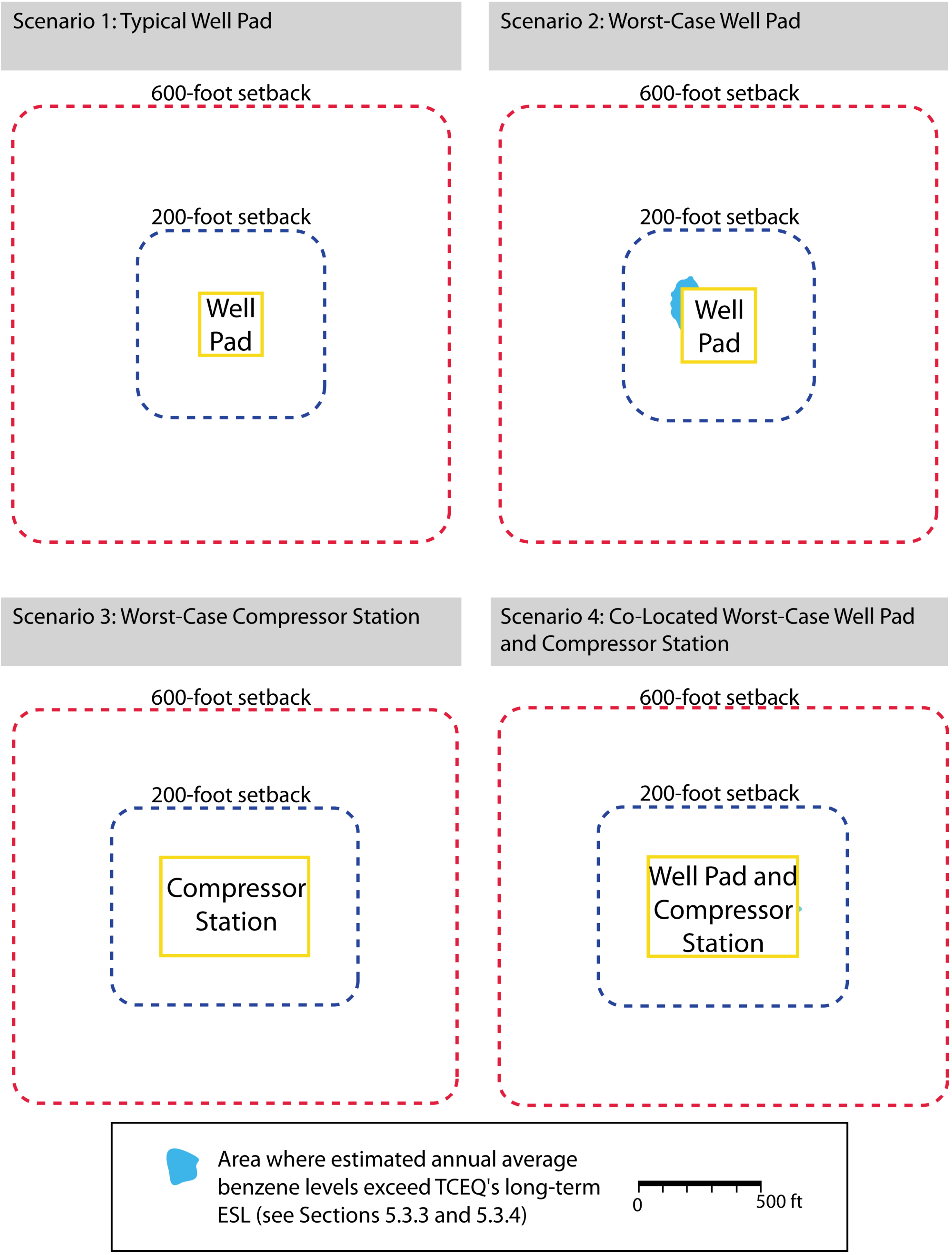


Figure 5.3-1. Locations of Estimated Annual Average Benzene Concentrations Greater Than TCEQ's Long-Term ESL, by Modeling Scenario

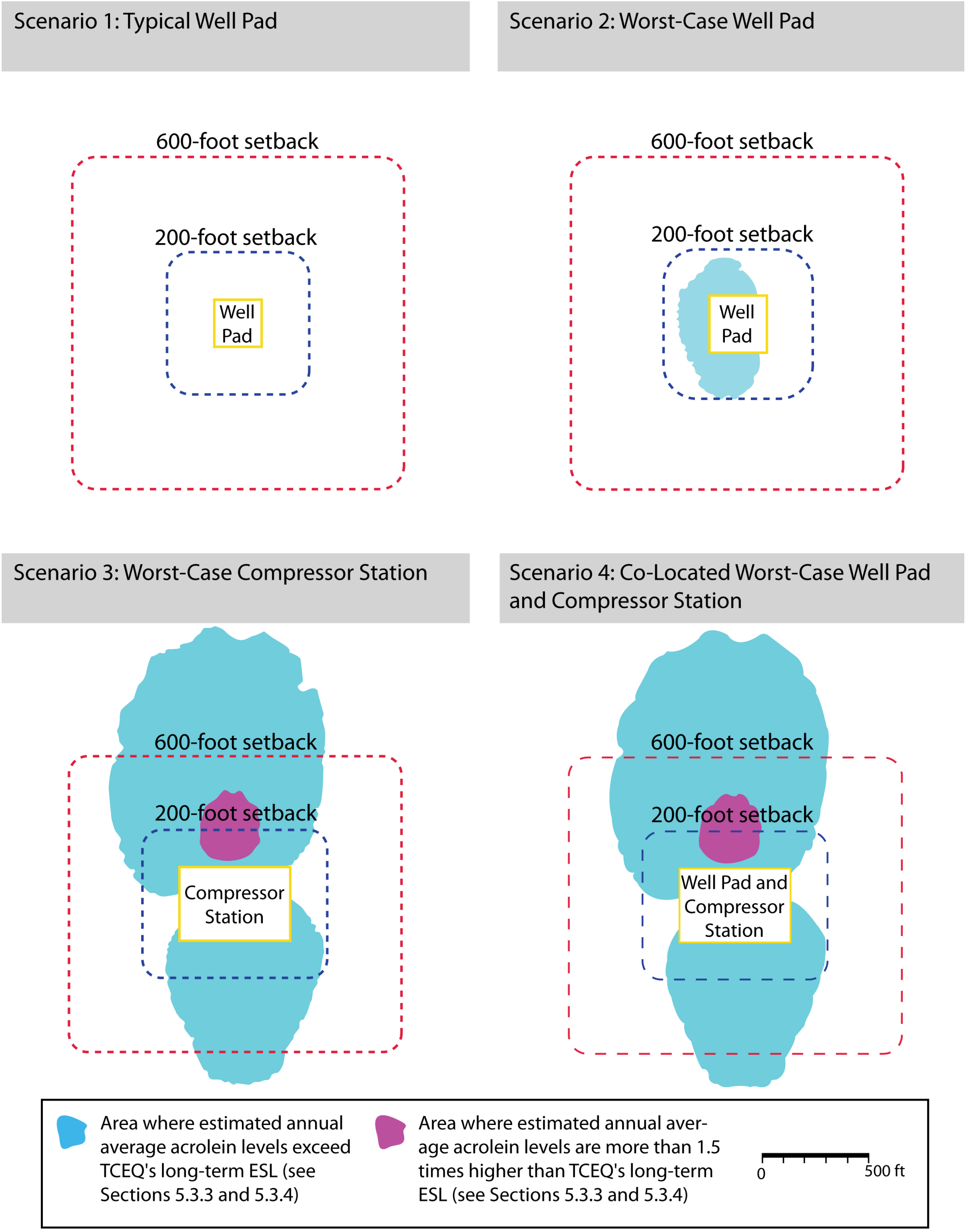


Figure 5.3-2. Locations of Estimated Annual Average Acrolein Concentrations Greater Than TCEQ's Long-Term ESL, by Modeling Scenario

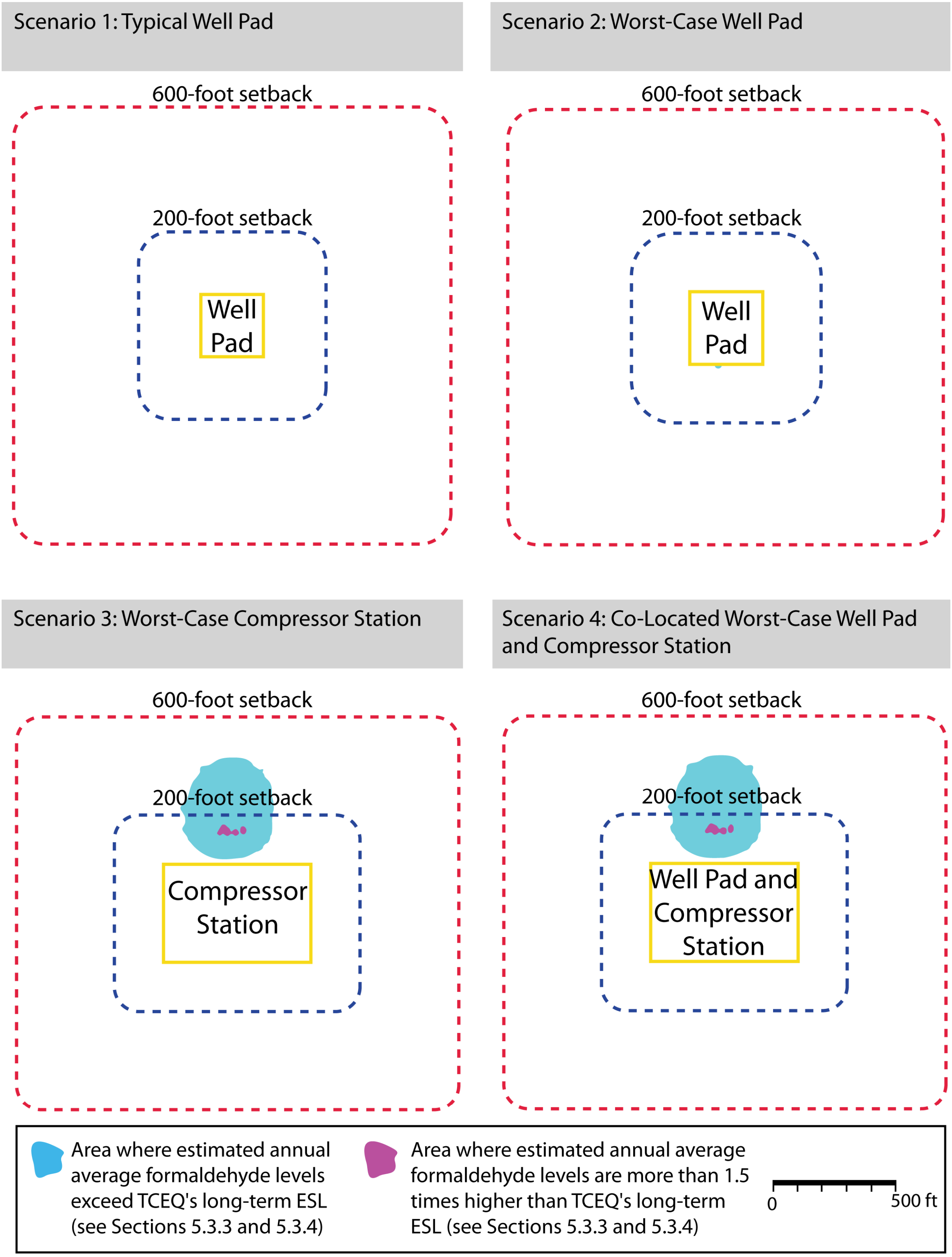


Figure 5.3-3. Locations of Estimated Annual Average Formaldehyde Concentrations Greater Than TCEQ's Long-Term ESL, by Modeling Scenario

In summary, for the overwhelming majority of sites considered in this study, the modeling analysis indicates that Fort Worth's 600-foot setback distance is adequate. For the relatively few sites with multiple, large line engines, the modeling analysis found some areas beyond the setbacks to have estimated acrolein and formaldehyde concentrations greater than TCEQ's ESLs. For both pollutants, ERG's modeling is based entirely on estimated emission rates, and not measured values. This underscores the value of obtaining more detailed acrolein and formaldehyde emissions data for line engines and focused ambient air monitoring to validate these findings. Such studies would provide greater confidence in the adequacy and protectiveness of the city's setbacks.

5.3.5 Modeled Concentrations: Main Findings, Limitations, and Uncertainties

The information presented throughout Section 5.3 is based entirely on the dispersion modeling analysis. Unlike ambient air monitoring data, which are direct measurements of air pollution levels, models provide estimates of ambient air concentrations. The accuracy of the modeling outputs depends on many factors, but especially on the representativeness of the emissions data input to the model. Emission rates for this study were based on measured and estimated data: emissions from tanks and fugitive sources were directly measured during the point source testing program, and emissions from lift engines and line engines were estimated using standard computational algorithms and EPA-published emission factors. For some pollutants, most notably acrolein and formaldehyde, the estimated offsite ambient air concentrations from the model are based entirely on the estimated emissions from lift engines and line engines. While these estimates were generated using the best information available to ERG, the methodologies may not adequately represent the types of engines typically used at well pads and compressor stations in Fort Worth. Because acrolein and formaldehyde are two pollutants of concern for this study, consideration should be given to reducing uncertainties associated with the estimated concentrations. This could be achieved by either additional point source testing at sites with line engines or air monitoring for these compounds downwind from a line engine site known to burn the largest quantities of natural gas.

Additionally, the modeling conducted for this study only evaluated dispersion, or the movement of the pollutants through the air from their sources to offsite receptors. Many of the pollutants emitted at the well pads and compressor stations are known to react in the air and form other pollutants, and this was not considered in the modeling analysis. Supplemental analyses using photochemical models might be warranted to more fully investigate the full range of air quality impacts on local air quality (e.g., consideration of contributions to ozone formation and other processes).

5.4 Additional Context for Selected Pollutants

The earlier analyses in this section identified acrolein and formaldehyde as the pollutants that are most likely to have site-related air quality impacts greater than TCEQ health-based screening levels at locations beyond the 600-foot setbacks. Additionally, estimated ambient air concentrations of benzene were found to exceed short-term screening levels in the immediate vicinity of the highest-emitting tanks. This section presents additional context for these pollutants, which includes comparisons to air pollution levels measured elsewhere in Texas and further insights into toxicity. Finally, this section presents information on two pollutants that had estimated 1-hour average concentrations greater than *odor-based* short-term screening levels.

- *Benzene.* For additional perspective on benzene, ERG compared program-average concentrations calculated for all eight monitoring stations to 2010 annual average levels measured by TCEQ at 45 other locations statewide (see Figure 5.4-1). For the other statewide monitoring stations, 2010 statistical data summaries were downloaded from TCEQ's Texas Air Monitoring Information System.[12] ERG only considered sites that employed 24-hour average canister sampling technology—the same sampling approach used in the ambient air monitoring program. Further, ERG excluded any sites that had fewer than 40 valid 24-hour air samples over the calendar year, due to the large number of missing or invalid measurements for these sites. In the few cases where more than one monitor was placed at a given site, data from the monitor with the higher number of valid samples were used in this analysis.

  Figure 5.4-1 shows how program-average concentrations of benzene from this study compared to annual average concentrations measured elsewhere in Texas. The figure lists the names of the cities where the other monitoring occurred. While some comparison stations are located near large petrochemical refineries and industrial complexes, several other comparison stations were located in residential and commercial settings away from such larger sources.

  For seven out of eight monitoring stations in this study, the program-average benzene concentrations ranked relatively low when compared to 2010 annual averages for other monitors in Texas. However, program-average benzene levels at site S-4 ranked 11th out of the 53 sites shown in the figure. The relatively high ranking for this site likely reflects contributions from a nearby compressor station and well pad, and mobile source activity near the monitor. Overall, Figure 5.4-1 provides no evidence that benzene levels measured during this study were unusually elevated when compared to other monitoring stations in Texas. More importantly, the program-average concentrations for the Fort Worth monitoring stations are all lower than TCEQ's long-term health-based AMCV.

- *Acrolein.* As noted previously, acrolein was not a target analyte for the ambient air monitoring program. Even though many parties have previously measured airborne levels of acrolein at other locations in Texas and nationwide, recent studies have identified important data quality concerns associated with the ambient air monitoring methods that had been widely used for this pollutant. In December 2010, EPA summarized these concerns and began flagging past air measurements of acrolein as "unverified" if certain canister cleaning practices, calibration standards, and timely analysis were not applied.[13]

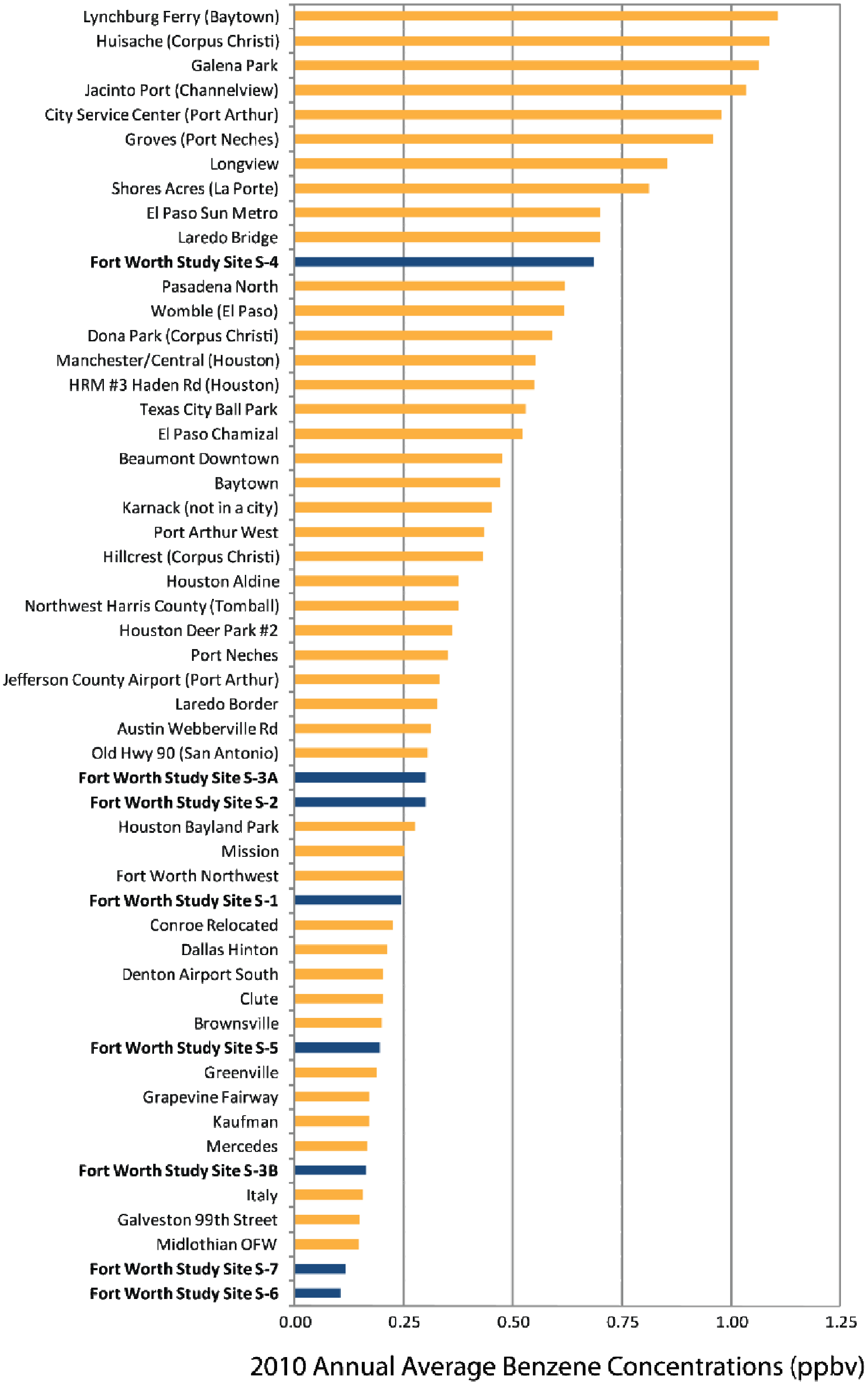


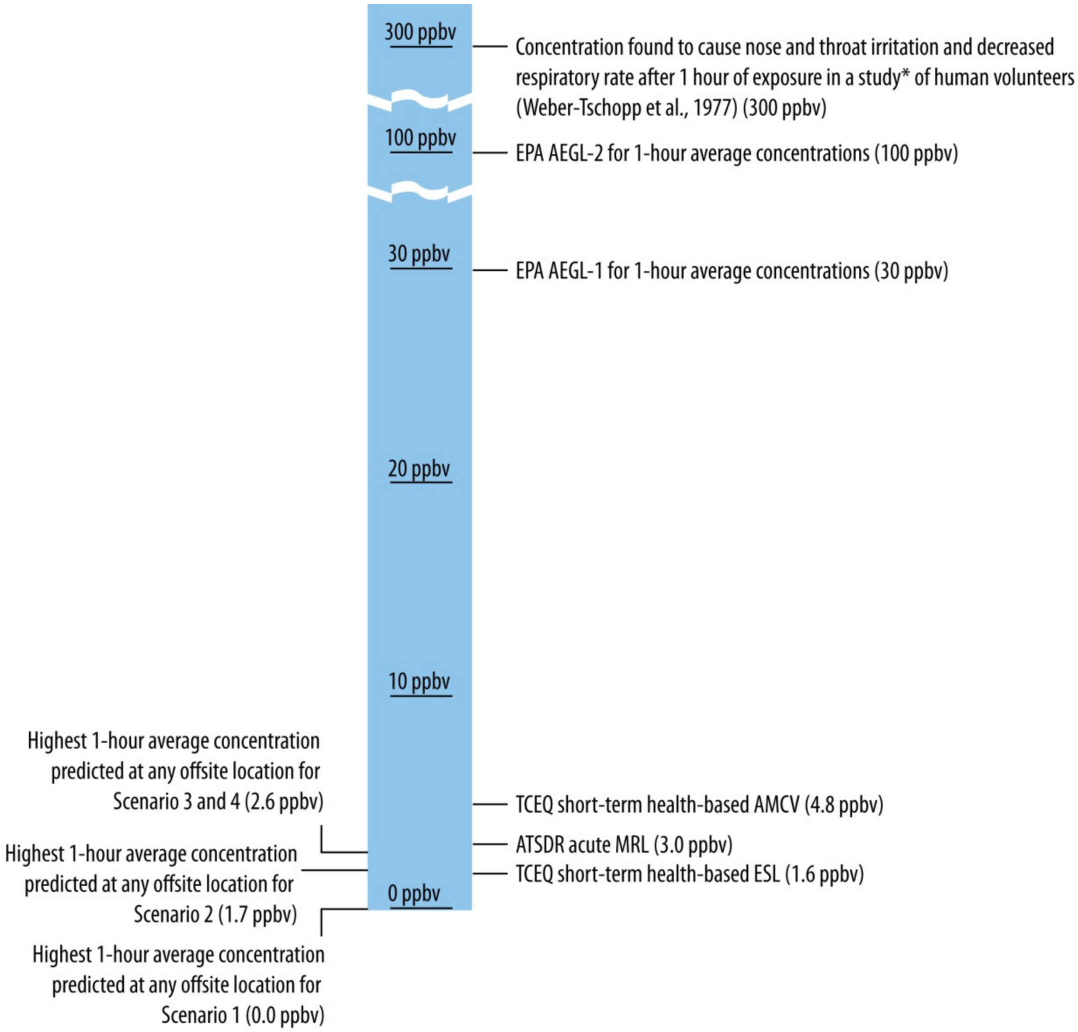
Figure 5.4-1. Comparison of Program-Average Benzene Concentrations in Fort Worth to 2010 Annual Average Benzene Concentrations Statewide (see Section 5.4)

Due to these and other data quality concerns that have been expressed for past measurements, the focus of this section is on acrolein toxicity. Extensive information is available on various non-cancer respiratory effects that have resulted from inhalation exposures to acrolein[14,15], and the following paragraphs assess whether the estimated acrolein air quality impacts are expected to result in adverse health effects, both for acute and chronic exposure durations. According to ATSDR, only limited, weak evidence is available suggesting that acrolein is carcinogenic[12], and no agencies have developed quantitative approaches for evaluating cancer risks for this pollutant. Potential cancer effects associated with acrolein exposures are therefore not evaluated here.

The assessment of acute, non-cancer effects is based on an earlier finding in this section indicating that lift engines and line engines are expected to contribute up to 2.6 ppbv to the highest offsite 1-hour average concentrations of acrolein. Figure 5.4-2[16] compares this estimated air quality impact to screening levels published by multiple agencies. Most notably, the estimated 1-hour average air quality impact of 2.6 ppbv is lower than ATSDR's acute Minimal Risk Level (3.0 ppbv), which is defined as an exposure concentration that is likely to be without appreciable risk of non-cancer health effects. Further, the highest modeling result is more than 100 times below the lowest exposure concentration that has been documented to cause health effects in humans. It is therefore unlikely that even the highest 1-hour average concentration would be expected to cause adverse health effects among the general population.

Figure 5.4-3[17] presents similar information on acrolein toxicity, but considering longer-term (e.g., annual) exposure scenarios. The highest annual average concentration estimated by the dispersion model varied considerably across model scenarios. For well pads with tanks and small lift engines, the highest annual average concentration predicted for receptors beyond the 600-foot setback distance was 0.012 ppbv—lower than health-based screening values published both by ATSDR and TCEQ. For sites having multiple, large line engines, which are represented by Scenarios 3 and 4, the highest annual average acrolein concentration beyond the 600-foot setback distance was 0.15 ppbv. While greater than certain screening values published by ATSDR, EPA, and TCEQ, this annual average concentration is still considerably lower than the lowest exposure concentration found to cause adverse health effects in laboratory studies.

Of all pollutants considered, acrolein was one of only two found to have estimated air quality impacts greater than highly protective screening levels at locations beyond the setback distances. The many layers of health-protective assumptions suggest that the estimated air concentrations would not lead to adverse health effects among residents who live beyond the setbacks. However, additional air sampling of acrolein is recommended to confirm these findings.



Definitions:

ATSDR Minimal Risk Level (MRL): "An estimate of daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse non-cancer health effects."

EPA Acute Exposure Guideline Level (AEGL)-1: "The airborne concentration. . . of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure."

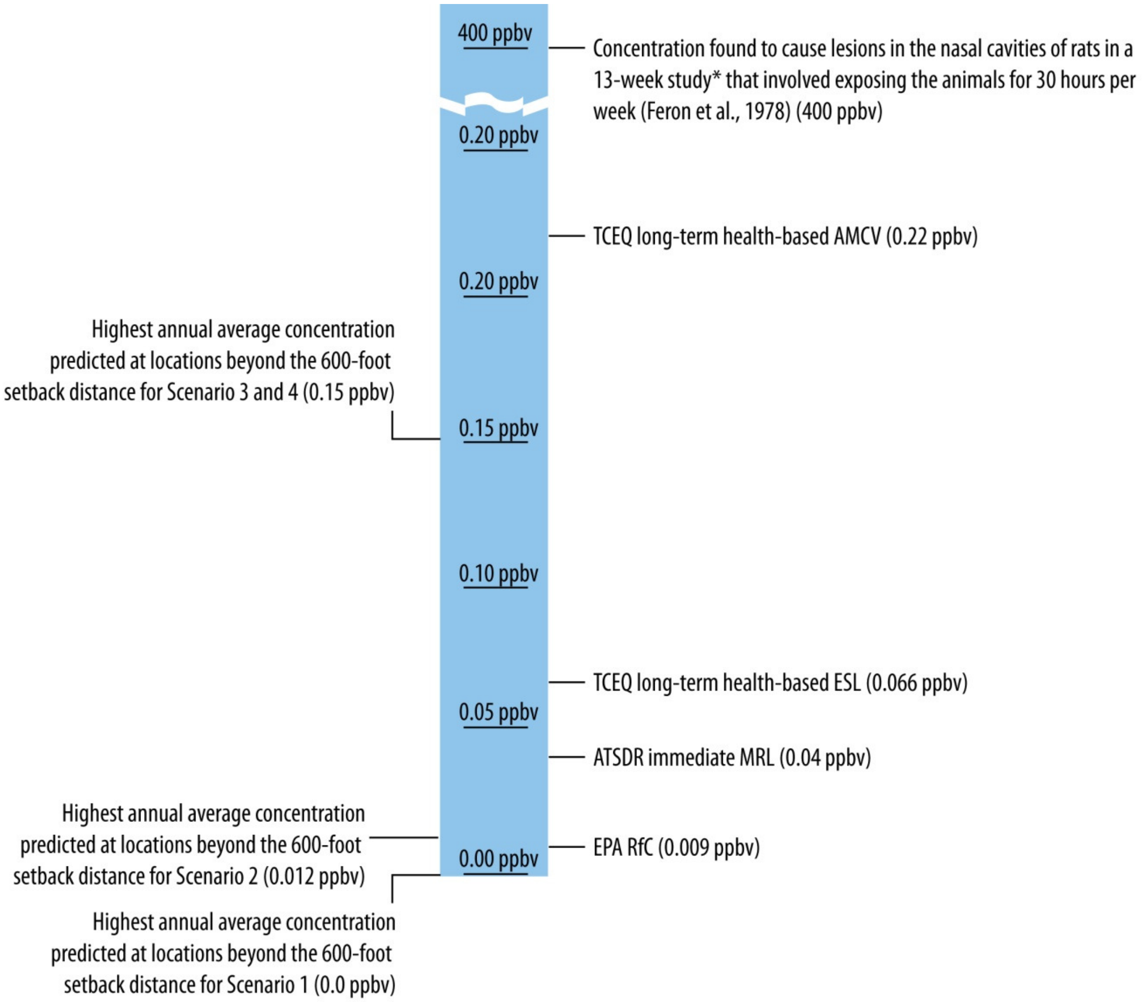
EPA Acute Exposure Guideline Level (AEGL)-2: "The airborne concentration. . . of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects."

TCEQ ESL: "Used in TCEQ's air permitting process to evaluate air dispersion modeling's predicted impacts. . . If predicted airborne levels of a constituent do not exceed the screening level, adverse health or welfare effects are not expected. If predicted ambient levels of constituents in air exceed the screening levels, it does not necessarily indicate a problem but rather triggers a review in more depth."

TCEQ AMCV: "Chemical-specific air concentrations set to protect human health and welfare. Exposure to an air concentration at or below the AMCVs is not likely to cause adverse health effects in the general public, including sensitive subgroups such as children, the elderly, pregnant women, and people with pre-existing health conditions."

* The study described at the top of this figure was used to derive some of the screening levels shown.

Figure 5.4-2. Toxicity of Acrolein: Short-Term Exposures



Definitions:

ATSDR Minimal Risk Level (MRL): "An estimate of daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse non-cancer health effects."

EPA Reference Concentration (RfC): "An estimate. . . of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime."

TCEQ ESL: "Used in TCEQ's air permitting process to evaluate air dispersion modeling's predicted impacts. . . If predicted airborne levels of a constituent do not exceed the screening level, adverse health or welfare effects are not expected. If predicted ambient levels of constituents in air exceed the s creening levels, it does not necessarily indicate a problem but rather triggers a review in more depth."

TCEQ AMCV: "Chemical-specific air concentrations set to protect human health and welfare. Exposure to an air concentration at or below the AMCVs is not likely to cause adverse health effects in the general public, including sensitive subgroups such as children, the elderly, pregnant women, and people with pre-existing health conditions."

* The study described at the top of this figure was used to derive some of the screening levels shown.

Figure 5.4-3. Toxicity of Acrolein: Long-Term Exposures

- *Formaldehyde.* For additional context on measured and estimated formaldehyde levels, ERG compared program-average concentrations calculated for the two monitoring stations with available sampling data to 2010 annual average levels measured by TCEQ at six other locations statewide (see Figure 5.4-4). Data for the other monitoring stations were accessed from TCEQ's Texas Air Monitoring Information System[12] and processed following the same methodology that is documented for the benzene analysis. As Figure 5.4-4 shows, formaldehyde is routinely monitored at far fewer stations in comparison to benzene. However, at every other TCEQ station that met the site selection criteria, annual average concentrations of formaldehyde in 2010 were higher than the program-average concentrations calculated for monitoring sites S-4 and S-5. This suggests that the formaldehyde levels measured during the Fort Worth Natural Gas Air Quality Study were not elevated in comparison to other monitoring locations in Texas.

  ERG also considered the health implications of the measured and modeled air quality impacts. This was done for both non-cancer health effects (for acute and chronic exposure durations) and for potential cancer effects (chronic exposures only). Figure 5.4-5[18] provides additional context on the health implications of short-term inhalation exposures to formaldehyde. All measured 24-hour average concentrations during the ambient air monitoring program were considerably lower than the most health-protective screening levels. Further, the highest 1-hour average concentration predicted by the model for the highest-emitting site (34 ppbv) was not only lower than ATSDR's Minimal Risk Level, but substantially below the lowest concentration that has been shown to cause adverse acute health effects in humans. Accordingly, the peak formaldehyde air quality impacts identified in this study are not expected to cause acute health effects among city residents.

  For chronic exposure durations, the highest program-average formaldehyde concentration calculated from the monitoring data and the highest annual average formaldehyde concentration estimated by the dispersion model were both lower than every applicable non-cancer screening level published by ATSDR and TCEQ. Therefore, even when considering the highest-emitting sites, the long-term air quality impacts of formaldehyde are not expected to cause adverse non-cancer effects. Figure 5.4-6[19] provided additional context on the health implications of long term inhalation exposures to formaldehyde. ERG also considered cancer endpoints, given that formaldehyde has been classified as a human carcinogen. According to risk levels currently published on EPA's Integrated Risk Information System (IRIS),[1] formaldehyde concentrations between 0.06 ppbv and 6 ppbv are expected to have theoretical lifetime cancer risks between 1 in 1,000,000 and 1 in 10,000. This risk range is common for urban settings, and the theoretical cancer risks for Fort Worth are lower than those for every other monitoring site shown in Figure 5.4-4.

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[1] New scientific information is continually becoming available on the links between certain air pollutants and adverse health effects. This is particularly true for formaldehyde, for which EPA, the National Academy of Sciences, and other entities have very recently published updates and reviews of the chemical's toxicity and carcinogenicity. However, EPA's final formaldehyde inhalation assessment was not available at the time this report was completed.

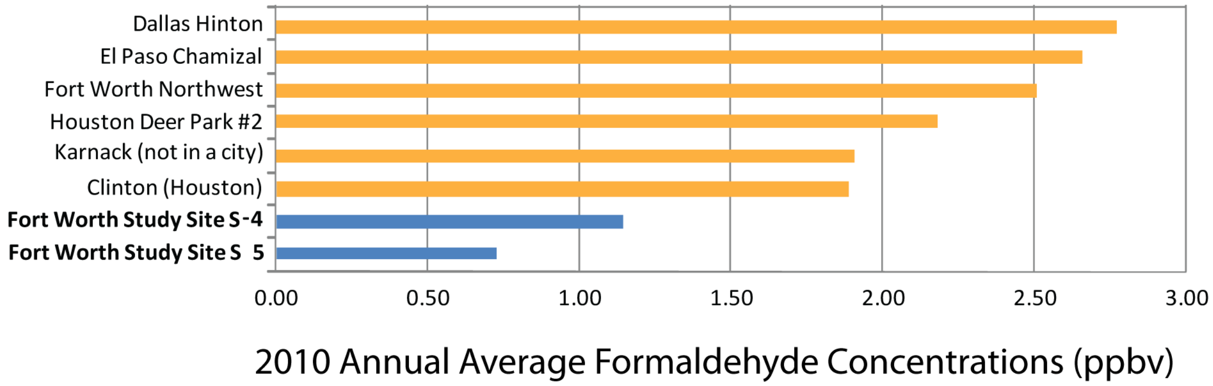
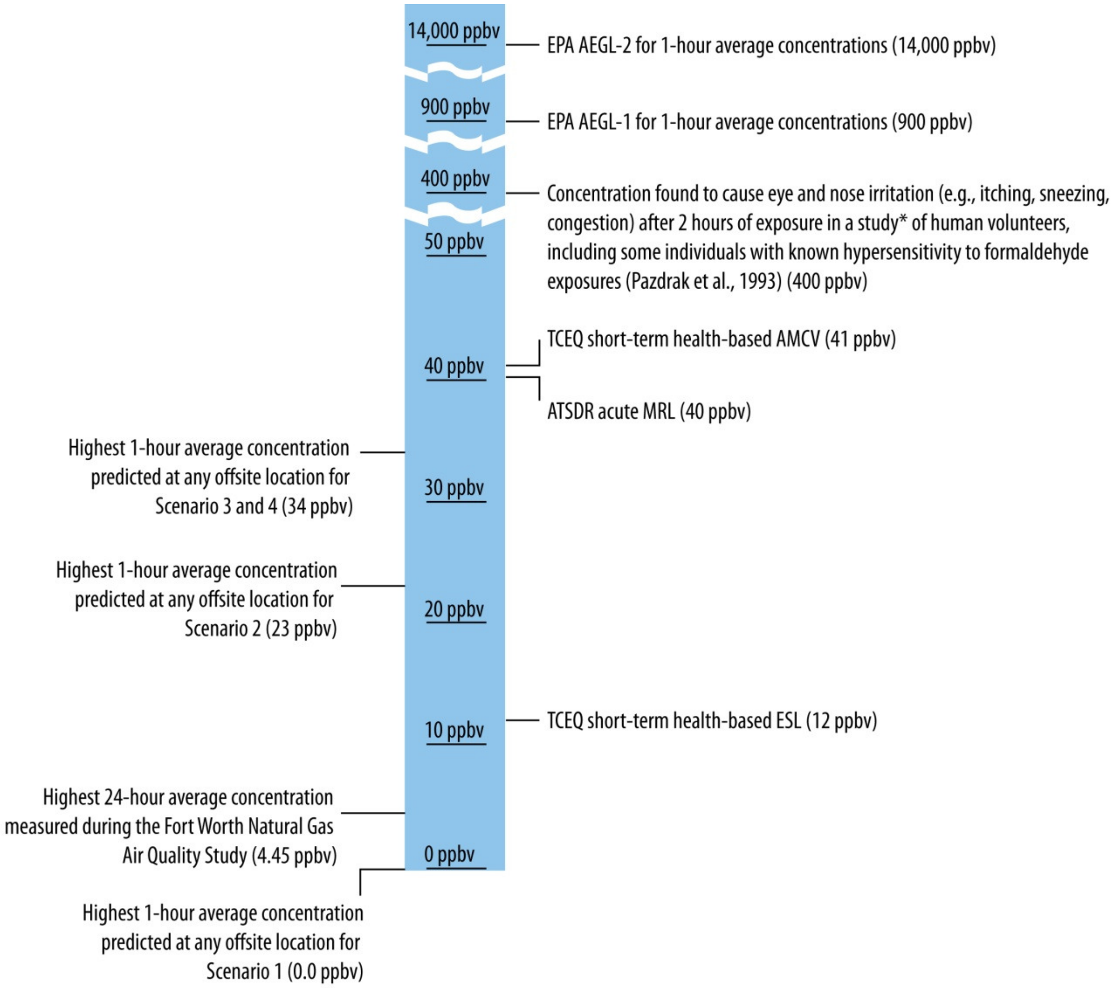


Figure 5.4-4. Comparison of Program-Average Formaldehyde Concentrations in Fort Worth to 2010 Annual Average Formaldehyde Concentrations Statewide (see Section 5.4)

- *Pollutants above odor-based screening levels.* Throughout this section, health-based screening levels were used to interpret the ambient air monitoring data and dispersion modeling results, but many pollutants emitted from well pads and compressor stations also have odor-based screening levels. Though not documented in the previous summary tables, ERG compared every measured and modeled ambient air concentration to pollutant-specific odor-based screening levels, where available. Every 24-hour average concentration measured during the monitoring program was lower than TCEQ's short-term odor-based ESLs. However, two pollutants—toluene and *m,p*-xylene—had estimated 1-hour average concentrations in certain modeling scenarios that exceeded the odor-based ESLs. This effect was highly localized to tanks at the highest-emitting sites and was predicted to occur just a few hours per year. While the peak levels of toluene and *m,p*-xylene would be expected to result in odorous conditions, neither pollutant had estimated short-term concentrations above health-based screening levels.



Definitions:

ATSDR Minimal Risk Level (MRL): "An estimate of daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse non-cancer health effects."

EPA Acute Exposure Guideline Level (AEGL)-1: "The airborne concentration. . . of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure."

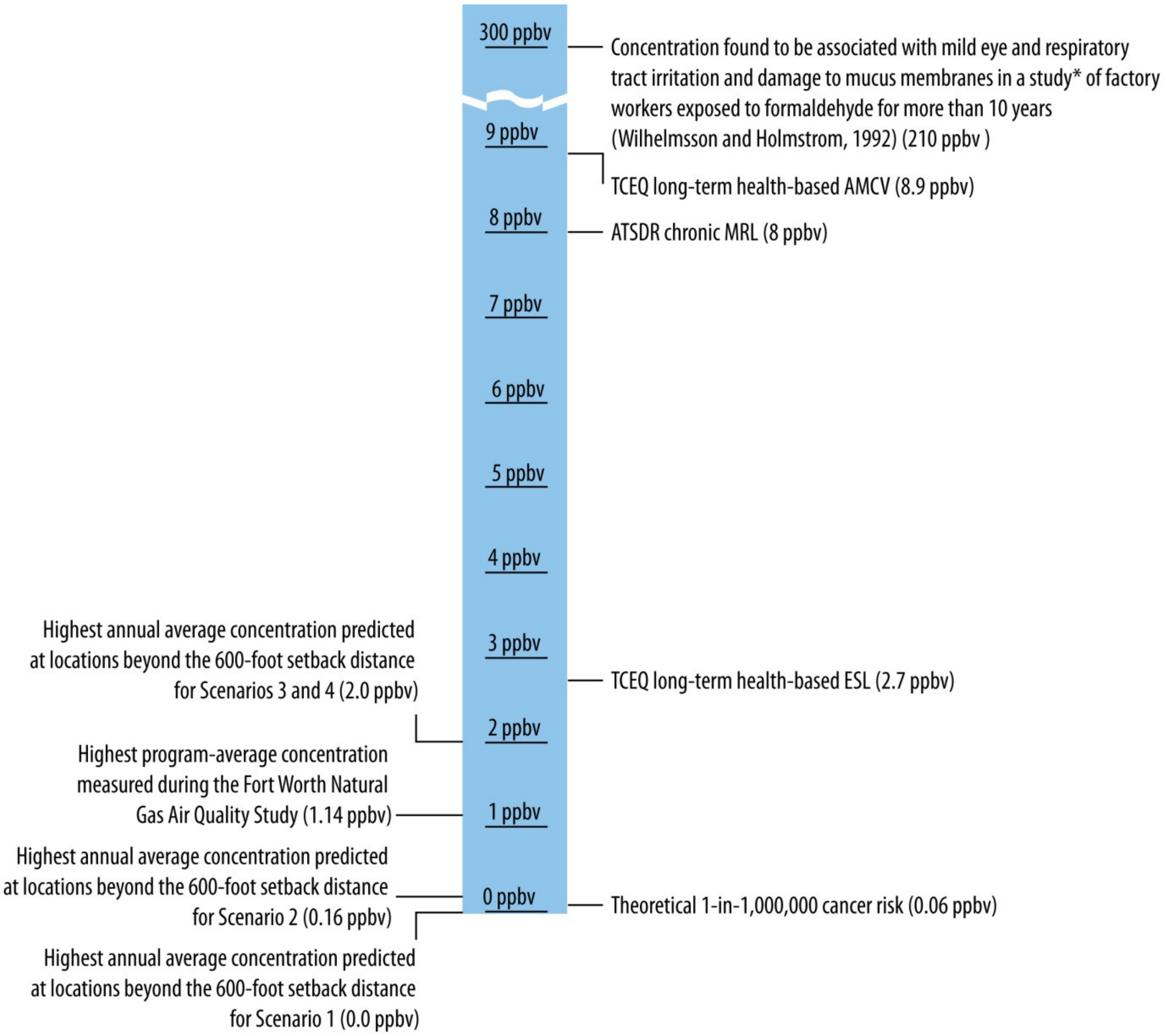
EPA Acute Exposure Guideline Level (AEGL)-2: "The airborne concentration. . . of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects."

TCEQ ESL: "Used in TCEQ's air permitting process to evaluate air dispersion modeling's predicted impacts. . . If predicted airborne levels of a constituent do not exceed the screening level, adverse health or welfare effects are not expected. If predicted ambient levels of constituents in air exceed the screening levels, it does not necessarily indicate a problem but rather triggers a review in more depth."

TCEQ AMCV: "Chemical-specific air concentrations set to protect human health and welfare. Exposure to an air concentration at or below the AMCVs is not likely to cause adverse health effects in the general public, including sensitive subgroups such as children, the elderly, pregnant women, and people with pre-existing health conditions."

* The study with the 400 ppbv observed effects level was used to derive some of the screening levels shown.

Figure 5.4-5. Toxicity of Formaldehyde: Short-Term Exposures



Definitions:

ATSDR Minimal Risk Level (MRL): "An estimate of daily human exposure to a hazardous substance that is likely to be without an appreciable risk of adverse non-cancer health effects."

TCEQ ESL: "Used in TCEQ's air permitting process to evaluate air dispersion modeling's predicted impacts… If predicted airborne levels of a constituent do not exceed the screening level, adverse health or welfare effects are not expected. If predicted ambient levels of constituents in air exceed the screening levels, it does not necessarily indicate a problem but rather triggers a review in more depth."

TCEQ AMCV: "Chemical-specific air concentrations set to protect human health and welfare. Exposure to an air concentration at or below the AMCVs is not likely to cause adverse health effects in the general public, including sensitive subgroups such as children, the elderly, pregnant women, and people with pre-existing health conditions."

* The study described at the top of this figure was used to derive some of the screening levels shown.

Figure 5.4-6. Toxicity of Formaldehyde: Long-Term Exposures

5.5 Public Health Evaluation Conclusions

The ambient air monitoring conducted in Fort Worth found dozens of air pollutants above detection limits. However, this is not uncommon for urban air quality, due to the complex mixture of emissions sources found in our country's metropolitan areas. The presence of a pollutant in Fort Worth's air likely reflects contributions from many different sources. Quantifying the extent to which natural gas exploration and production activity contributes to air quality is a complicated task, due to the confounding effect of other emission sources, such as motor vehicles, gasoline stations, and industrial sources. It is for this reason that the Fort Worth Natural Gas Air Quality Study considered two different approaches to evaluate air quality impacts from natural gas exploration and production activity.

First, ERG considered findings from the ambient air monitoring program, which directly measured air pollution levels at eight locations throughout Fort Worth. The ambient air monitoring data did not reveal any evidence of pollutants associated with natural gas exploration and production activity reaching concentrations above applicable screening levels: The highest 24-hour average concentrations of all site-related pollutants were lower than TCEQ's health-based short-term screening levels, and the program-average concentrations of all site-related pollutants were lower than TCEQ's health-based long-term screening levels. Even though the ambient air monitoring data provided useful insights into local air quality, review of modeling data was needed to consider potential air quality impacts at locations where and times when monitoring did not occur.

Next, ERG conducted a dispersion modeling analysis, which estimated air quality impacts that can be attributed specifically to emissions from well pads and compressor stations. These estimates were derived from measured emissions for tanks and fugitive sources and estimated emissions from compressor engines. The model was run for four different equipment configurations at well pads and compressor stations, and some modeling scenarios were based on the highest emission rates measured during the point source testing program. Most notably, the worst-case scenario assumed that the highest measured emission rates of all pollutants occurred at a single hypothetical site. The modeling analysis confirmed that benzene emissions from tanks could lead to air pollution levels slightly higher than TCEQ's short-term ESL, but this occurred infrequently and only in very close proximity to the highest-emitting tanks. The modeling also indicated that sites containing multiple, large line engines can emit acrolein and formaldehyde at levels that would cause offsite ambient air concentrations to exceed TCEQ's short-term and long-term screening levels over various distances. For all remaining pollutants considered, the modeling found no evidence of short-term or long-term air quality impacts at levels of health concern.

ERG considered both the modeling and monitoring results when assessing the adequacy of Fort Worth's setback limits. The details of this analysis depend on multiple factors, including the pollutant, exposure duration, and well pad equipment configuration. Table 5.5-1 documents ERG's main findings for different combinations of these factors. Overall, ERG concluded that the 600-foot setback distances are adequately protective of public health. Greater confidence in this finding can be gained through further study of acrolein and formaldehyde air quality impacts near sites with multiple, large line engines, especially when variances to the 600-foot setbacks are being considered for these higher-emitting facilities. TCEQ has recently completed an ambient air monitoring study that considered acrolein and formaldehyde levels in Fort Worth.[20] The week-long monitoring effort found no evidence of acrolein and formaldehyde exceeding short-term health-based screening levels, but that study was limited in scope and duration. Routine monitoring over a longer duration near a site with multiple, large lift engines is encouraged.

Table 5.5-1. Key Findings for Health Evaluation

Pollutant	Exposure Duration [a]	Key Findings from Screening Evaluation, by Equipment Configuration	Additional Context	Recommendations
Benzene	Short-term	*For sites with the highest-emitting tanks:* Receptors less than 30 feet from the highest emitting tanks had maximum 1-hour concentrations marginally above the short-term ESL.	These results are generally consistent with the findings of the ambient air monitoring program. Additionally, long-term average benzene levels in Fort Worth ranked relatively low when compared to those measured at other locations statewide.	Compare any future sampling results (e.g., from TCEQ's "auto-GC" monitors) to screening levels.
		For all remaining sites: Estimated offsite 1-hour average benzene levels were lower than TCEQ's short-term ESL for the overwhelming majority of well pad and compressor station configurations.		
	Long-term	*For every equipment configuration:* For all receptors at least 200 feet from fence lines, annual average concentrations were found to be lower than TCEQ's screening values, even for the highest-emitting sites (see Figure 5.3-1).		
Acrolein	Short-term	*For sites with no engines:* Acrolein emissions were not measured, but are not expected due to the lack of combustion.	The modeling results are based on the best available information, but no long-term ambient air monitoring data are available to verify or validate the modeling results. TCEQ conducted a week-long carbonyl monitoring program in December 2010, which found no acrolein levels above ESLs, but that program was limited in scope and duration.	Acrolein is one of only two pollutants that had estimated air quality impacts above ESLs beyond the setback distances. This occurred only for sites with multiple, large line engines. Routine monitoring downwind from one of the larger facilities would provide greater confidence in the adequacy of the city's setback limits.
		For sites with lift or line engines: All modeling simulations involving engines found some offsite 1-hour average concentrations greater than TCEQ's short-term ESL. The spatial extent and frequency of these elevated concentrations increased with the number and size of engines at a given site. For sites with multiple, large line engines, estimated 1-hour average concentrations above the ESL occurred up to 400 feet beyond the fence lines.		
	Long-term	*For sites with multiple, large line engines:* Estimated annual average concentrations exceeded the long-term ESL at locations several hundred feet beyond the 600-foot setback. Though greater than highly protective screening levels, the estimated air quality impacts did not reach concentrations that have been shown to cause adverse health effects.		
		For all other sites: For all receptors at least 200 feet from fence lines, annual average concentrations were found to be lower than TCEQ's screening values, even for the highest-emitting sites (see Figure 5.3-2).		

Table 5.5-1. Key Findings for Health Evaluation (Continued)

Pollutant	Exposure Duration [a]	Key Findings from Screening Evaluation, by Equipment Configuration	Additional Context	Recommendations
Formaldehyde	Short-term	*For sites with no engines:* Formaldehyde emissions were not measured, but are not expected due to the lack of combustion.	The findings for long-term exposures are consistent with the program-average formaldehyde levels from the monitoring program. Further, when compared to other active monitoring sites in Texas, the program-average concentrations measured in this study ranked the lowest. TCEQ conducted a week-long carbonyl monitoring program in December 2010, which found formaldehyde levels below ESLs, but that program was limited in scope and duration.	Formaldehyde is one of only two pollutants that had estimated air quality impacts above ESLs beyond the setback distances. This occurred only for sites with multiple, large line engines. Routine monitoring downwind from one of the larger facilities would provide greater confidence in the adequacy of the city's setback limits.
		For sites with lift or line engines: All modeling simulations involving engines found some offsite 1-hour average concentrations greater than TCEQ's short-term ESL. The spatial extent and frequency of these elevated concentrations increased with the number and size of engines. For sites with multiple, large line engines, estimated 1-hour average concentrations above the ESL occurred up to 750 feet beyond the fence lines, and the peak values were nearly 3 times higher than TCEQ's short-term ESL. However, even the highest estimated air quality impacts did not reach concentrations that have been shown to cause adverse health effects.		
	Long-term	*For every equipment configuration:* For all receptors at least 600 feet from fence lines, annual average concentrations were found to be lower than TCEQ's screening values, even for the highest-emitting sites (see Figure 5.3-3).		
All other pollutants considered in this study	Short- and long-term	*For every equipment configuration considered:* Estimated 1-hour average and annual average concentrations were lower than TCEQ's health-protective screening values at every offsite location, even for the highest-emitting sites.	This result is supported by the ambient air monitoring data, which found no site-related pollutants above screening levels.	Compare any future sampling results (e.g., from TCEQ's "auto-GC" monitors) to screening levels.

[a] For purposes of this table, "short-term" exposures are evaluated based on the highest estimated 1-hour average concentrations; and "long-term" exposures are evaluated based on program-average concentrations calculated from the monitoring data and annual average concentrations estimated by the dispersion model.

6.0 Regulatory Assessment

Under this task, facility-level emission estimates developed under Task 3 (point source testing) for well pads, compressor stations, and natural gas processing and treatment plants were evaluated against various federal and state air quality regulatory thresholds and standards applicable to these types of facilities. Regulatory standards considered include EPA's operating and construction permit rules, National Emissions Standard for Hazardous Air Pollutants (NESHAPs), and New Source Performance Standards (NSPS); TCEQ's permit-by-rule, standard permit, and other regulations applicable to upstream oil and gas facilities; and the city of Fort Worth's Gas Well Drilling Ordinance.

This section has four sub-sections:

- 6.1 Federal Air Quality Rules – A description of potentially applicable U.S. EPA air quality rules are provided here.
- 6.2 Texas Commission on Environmental Quality Air Quality Rules – This section provides a discussion of potentially applicable TCEQ air quality rules.
- 6.3 City of Fort Worth Air Quality Rules – The city of Fort Worth's Gas Well Drilling Ordinance (Ordinance No. 18449-02-2009) is discussed in this section.
- 6.4 Regulatory Assessment Conclusions – Provides a summary of the results of the regulatory assessment.

6.1 Federal Air Quality Rules

EPA regulates air emissions from stationary sources such as well pads and compressor stations through a variety of regulatory mechanisms. In brief, these are:

- Operating permit rules
- Construction permit rules
- NSPS
- NESHAPs
- The Greenhouse Gas Reporting Program

These air quality regulations are discussed individually in Sections 6.1.1 through 6.1.5.

6.1.1 Operating Permits

Operating permits are legally enforceable documents that permitting authorities issue to air pollution sources *after* the sources begin to operate. Depending on the magnitude of emissions from a facility, there are different types of operating permits available, with the largest sources (typically those emitting over 100 tons per year (tpy) of a regulated pollutant such as VOCs) required to obtain a Title V Operating permit. In Texas, these permits are issued by TCEQ as discussed below in Section 6.2.

6.1.2 Construction Permits

Construction permits are legally enforceable documents that permitting authorities issue to air pollution sources *before* construction. EPA regulations applicable to all new sources are included under the New Source Review (NSR) provisions, which are broken down into regulations for attainment areas and regulations for nonattainment areas. Tarrant County is considered a nonattainment area for ozone, which requires more stringent control of VOC and NO_x emissions.

The state of Texas implements the federal NSR rules through its construction permit program. Under Title 30 of the Texas Administrative Code (TAC), Chapter 116, Subchapter B, oil and gas exploration and production facilities may be authorized to construct through TCEQ's Permit-by-Rule (PBR), Standard Permit, or NSR permitting process. These types of permits are discussed in more detail below in Section 6.2.

6.1.3 New Source Performance Standards

NSPS regulations apply to new, modified, or reconstructed emission sources categorized by source type. For the oil and gas industry, the potentially applicable NSPS include the following:

- Subpart A—General Requirements (including flares)
- Subparts K and Ka—Storage Vessels for Petroleum Liquids
- Subpart Kb—Volatile Organic Liquid Storage Vessels (including Liquid Storage)
- Subpart GG—Stationary Gas Turbines
- Subpart KKK—Equipment Leaks of VOC from Onshore Natural Gas Processing Plants
- Subpart LLL—Onshore Natural Gas Processing: SO_2 Emissions
- Subpart IIII—Stationary Compression Ignition Internal Combustion Engines
- Subpart JJJJ—Stationary Spark Ignition Internal Combustion Engines
- Subpart KKKK—Stationary Combustion Engines

A brief discussion of each of these regulations follows. Where possible, a preliminary determination of compliance and applicability status with respect to the sites visited under the point source task has been made. However, a formal and comprehensive compliance and applicability assessment is not possible for each facility without a complete record of construction, monitoring, and recordkeeping activities.

Subparts K and Ka—Storage Vessels for Petroleum Liquids. These regulations apply to storage vessels for volatile organic liquids (including petroleum) built or modified after June 11, 1973 (Subpart K), or after May 18, 1978 (Subpart Ka). These rules apply to storage tanks with a design capacity greater than 40,000 gallons. None of the tanks visited under Task 3 have capacities greater than 40,000 gallons, so it appears that none of the visited tanks are subject to these rules.

Subpart Kb—Volatile Organic Liquid Storage Vessels (Including Liquid Storage). This regulation applies to storage vessels for volatile organic liquids (including petroleum) built or modified after July 23, 1984 (Subpart Kb) and with a capacity greater than 19,800 gallons. Six tanks that were visited under Task 3 appear to have capacities greater than 19,800 gallons. However, the rule does not apply to "Vessels with a design capacity less than or equal to 1,589.874 m^3 (~420,000 gallons) used for petroleum or condensate stored, processed, or treated prior to custody transfer." Therefore, this rule does not appear to apply to any storage tanks visited under Task 3.

Subpart GG—Stationary Gas Turbines. This regulation applies to stationary gas turbines with a heat input at peak load greater than 10 million British thermal units (Btu) per hour. This rule limits NO_x and SO_2 emissions from subject facilities. ERG did not identify any gas turbines under Task 3.

Subpart KKK—Equipment Leaks of VOC from Onshore Natural Gas Processing Plants. This regulation applies to onshore natural gas processing plants as defined as "any processing site engaged in the extraction of natural gas liquids from field gas, fractionation of mixed natural gas liquids to natural gas products, or both." This rule requires VOC leak detection and repair at facilities that remove natural gas liquids from field gas. Site PS-159 (the Crosstex Amine Treatment Center) could be subject to this rule. However, status of compliance with the monitoring requirements under this rule cannot be determined using the data obtained at the time of the survey.

Subpart LLL—Onshore Natural Gas Processing: SO_2 Emissions. This regulation applies to sweetening units (process devices that remove hydrogen sulfide (H_2S) and CO_2 contents from sour natural gas) and sulfur recovery units at facilities that process natural gas. Sour natural gas is natural gas with an H_2S concentration greater than 0.25 grains per 100 standard cubic feet. The natural gas in the Barnett Shale is not considered to be sour natural gas, so this rule does not appear to apply to any facilities in Fort Worth.

Subpart IIII—Stationary Compression Ignition Internal Combustion Engines. This regulation applies to compression ignition internal combustion engines of various sizes, dependent upon date of construction. Much of this regulation is applicable to engine manufacturers themselves, not the engine users. This rule limits combustion emissions (hydrocarbons, NO_x, CO, and PM) from subject engines, which were not tested as part of this project. While this rule may apply to engines used at natural gas well pads and compressor stations in Fort Worth, no applicability or compliance determination can be made at this time.

Subpart JJJJ—Stationary Spark Ignition Internal Combustion Engines. This regulation, similar to Subpart IIII, applies to stationary spark ignition internal combustion engines of various sizes, dependent upon date of construction. Much of this regulation is applicable to engine manufacturers themselves, not the engine users. This rule limits combustion emissions (VOC, NO_x, and CO) from subject engines, which were not tested as part of this project. While this rule may apply to engines used at natural gas well pads and compressor stations in Fort Worth, no applicability or compliance determination can be made at this time.

Subpart KKKK—Stationary Combustion Turbines. This regulation applies to stationary combustion turbines constructed, modified, or reconstructed after February 18, 2005. This rule limits NO_x and SO_2 emissions from subject facilities. ERG did not identify any gas turbines under Task 3.

6.1.4 National Emission Standards for Hazardous Air Pollutants

NESHAPs regulate HAPs from new and existing stationary sources. For the oil and gas industry, the potentially applicable NESHAPs include the following:

- Subpart H—Organic Hazardous Air Pollutants for Equipment Leaks
- Subpart V—Equipment Leaks (Fugitive Emission Sources)
- Subpart HH—Oil and Natural Gas Production Facilities
- Subpart VV—Oil-Water Separators and Organic-Water Separators
- Subpart HHH—Natural Gas Transmission and Storage Facilities
- Subpart YYYY—Stationary Combustion Turbines
- Subpart ZZZZ—Stationary Reciprocating Internal Combustion Engines

A brief discussion of each of these rules follows. Where possible, a preliminary determination of compliance and applicability status with respect to the sites visited under the point source task has been made. However, a formal and comprehensive compliance and applicability assessment is not possible for each facility without a complete record of construction, monitoring, and recordkeeping activities.

Many of the NESHAP regulations apply only to major HAP sources, those defined as emitting greater than 10 tpy of any single HAP, or 25 tpy of all HAPs combined. As a result of the point source testing task, three potential major HAP sources were identified, including two compressor stations (Site IDs PS-118 and PS-119) and the gas processing plant (Site ID PS-159). All of these facilities were determined to be major HAP sources due to formaldehyde emissions from their compressor engines. Due to the conservative nature of the emissions estimation approach used for these engines (24-hour-per-day, 365-day-per-year operation of all the engines at the facility without controls), a full compliance evaluation would need to be made to definitively conclude whether or not these facilities are major sources of HAP.

Subpart H—Organic Hazardous Air Pollutants for Equipment Leaks. This regulation applies to sources subject to other NESHAP rules under 40 CFR Part 63 that specifically point back to this rule. As such, any applicability under Subpart H would be referenced in the rules discussed below.

Subpart V—Equipment Leaks (Fugitive Emission Sources). This regulation applies to pumps, compressors, pressure relief devices, sampling connection systems, open-ended valves or lines, valves, connectors, surge control vessels, bottoms receivers, and control devices or systems that are intended to operate in volatile HAP service. However, this rule is only triggered when the fluid or gas flowing through the equipment contains at least 10% by weight of a volatile HAP. No sources visited under Task 3 have volatile HAP concentrations of 10% or greater.

Subpart HH—Oil and Natural Gas Production Facilities. This regulation applies to oil and gas production facilities. There are different requirements for major and minor HAP sources, based on the magnitude of emissions. Requirements for major HAP sources include controlling HAP from tanks with flash emissions, controlling equipment leaks, and controlling glycol dehydrators. As discussed above, there are three potential major HAP sources that were visited that may be subject to the major source provisions of this regulation.

For minor HAP sources, there are limited requirements under this rule for triethylene glycol dehydration units, and those requirements are dependent upon the throughput or benzene emissions. For sources with benzene emissions less than 1 tpy, the only requirement is to maintain records verifying the benzene emission rate. There was one source visited under Task 3 that was estimated to emit over one tpy of benzene, the gas processing plant (PS-159). The remainder of the sites emitted less than one tpy of benzene. The only requirement applicable to these sources would be to keep records (as defined under the rule) of benzene emissions.

Subpart VV—Oil-Water Separators and Organic-Water Separators. This regulation applies to facilities that control air emissions from oil-water and organic-water separators. However, it only applies when another NESHAP subpart references it. No such facilities have been identified under this project.

Subpart HHH—Natural Gas Transmission and Storage Facilities. This regulation applies to owners and operators of natural gas transmission and storage facilities that transport or store natural gas before it enters the pipeline to a local distribution company or a final end user, and that are major sources of HAPs. A compressor station that transports natural gas prior to the point of custody transfer or to a natural gas processing plant (if present) is not considered a part of the natural gas transmission and storage source category. If applicable, this rule would require control of emissions from any glycol dehydration unit that emits more than 1 tpy of benzene. As mentioned above, the gas processing plant (PS-159) was the only facility estimated to emit over one tpy of benzene, with estimated benzene emissions at 1.2 tpy.

Subpart YYYY—Stationary Combustion Turbines. This regulation applies to stationary combustion turbines located at major sources of HAPs. ERG did not identify any stationary combustion turbines under Task 3.

Subpart ZZZZ—Stationary Reciprocating Internal Combustion Engines. This regulation applies to stationary reciprocating internal combustion engines located at major and area sources of HAPs. The applicability of this rule depends on both the construction date and the size of the engine. For many of the engines subject to this rule in Fort Worth, the only requirements are to comply with 40 CFR part 60 subpart IIII for compression ignition engines, or 40 CFR part 60 subpart JJJJ for spark ignition engines, as discussed in Section 6.1.3. Certain engines may also be required to specifically control formaldehyde emissions.

6.1.5 Greenhouse Gas Reporting Program

On November 8, 2010, EPA signed a rule that finalizes reporting requirements for the petroleum and natural gas industry under 40 CFR Part 98, the regulatory framework for the Greenhouse Gas Reporting Program. In short, Subpart W of Part 98 requires petroleum and natural gas facilities that emit 25,000 metric tons or more of CO_2 equivalent per year to report annual methane and CO_2 emissions from equipment leaks and venting, and emissions of CO_2, methane, and nitrous oxide from gas flaring and from onshore petroleum and natural gas production stationary and portable combustion emissions and combustion emissions from stationary equipment involved in natural gas distribution. However, this rule does not require facilities to report their emissions until March 31, 2012, at which time emissions for the 2011 calendar year will need to be reported for subject facilities.

Based on the results of the point source testing, there are several facilities with methane emissions from equipment leaks and venting that emit over 8,000 metric tons of CO_2 equivalents per year. In addition, emissions from compressor engine exhausts are likely to account for a significant amount of CO_2 (a single 2,000 hp engine may emit over 7,000 metric tons of CO_2 equivalents per year), which would result in many of the larger compressor stations exceeding the annual threshold of 25,000 metric tons of CO_2 equivalent emissions. As such, it appears that several facilities in the city of Fort Worth will be required to report their greenhouse gas emissions to EPA under this rule beginning in 2012.

However, it should be noted that there is some uncertainty as to the applicability of this rule, and EPA is currently actively providing guidance and rule interpretation to the oil and gas industry as they prepare to begin reporting emissions next year.

6.2 Texas Commission on Environmental Quality Air Quality Rules

Like EPA, TCEQ regulates air emissions from stationary sources related to upstream oil and gas facilities through a variety of regulatory mechanisms:

- PBRs
- Standard permits
- NSR permits
- Control of Air Pollution from Visible Emissions and Particulate Matter
- Control of Air Pollution from Sulfur Compounds
- Standards of Performance for Hazardous Air Pollutants and for Designated Facilities and Pollutants
- Control of Air Pollution from Volatile Organic Compounds
- Control of Air Pollution from Nitrogen Compounds
- Federal operating permits

These air quality regulations are discussed individually in Sections 6.2.1 through 6.2.9. Where possible, a preliminary determination of compliance and applicability status with respect to the sites visited under the point source task has been made. However, a formal and comprehensive compliance and applicability assessment is not possible for each facility without a complete record of construction, monitoring, and recordkeeping activities.

6.2.1 Permit-by-Rules

Key Point: Permit-By Rule
TCEQ's PBR for Oil and Gas Handling and Production Facilities is the primary regulatory mechanism applicable to natural gas well pads and compressor stations in Fort Worth.

PBRs are an abbreviated permitting mechanism provided by TCEQ to authorize emissions from new construction or modifications to existing facilities. PBR requirements are grouped by source types (e.g., stationary turbines and engines) and codified under Title 30 of the Texas Administrative Code (TAC), Chapter 106 (30 TAC 106). The most common PBR used to authorize new construction or modifications involving oil and gas exploration and production facilities is found under 30 TAC 106, Subchapter O, Section 106.352, "Oil and Gas Handling and Production Facilities." TCEQ updated this PBR in February 2011, significantly expanding the requirements for oil and gas handling and production facilities located in the Barnett Shale, including Tarrant County. Per the rule, these new requirements took effect in April 2011 and apply only to new or modified emissions sources.

The new requirements include more stringent control requirements and emission limits. In addition to more stringent site-wide emission limits, the revised PBR requires a health effects demonstration using calculated emission limits based on ESLs for certain toxins and source specific characteristics. The maximum emission rates allowed by the new PBR for Level 2 Requirements are summarized in Table 6.2-1.

Table 6.2-1. New PBR Emission Rates

Pollutant	Steady-state lb/hr	< 30 psig periodic lb/hr up to 300 hr/yr	≥ 30 psig periodic lb/hr up to 300 hr/yr	Total tpy
Total VOC				25
Total crude oil or condensate VOC	100	145	318	
Total natural gas VOC	356	750	1,500	
Benzene	3.35	7	15.4	4.8
Hydrogen sulfide	6	6	9.8	25
Sulfur dioxide	63	93.2		25
Nitrogen oxides	54.4			250
Carbon monoxide	57			250
$PM_{2.5}$	12.7			10
PM_{10}	12.7			15

The ESL based emission limits are site and source specific based on the source characteristics and the distance of the source relative to the nearest off-site receptor.

Based on the emission estimates developed under Task 3, most of the facilities surveyed would likely meet the new site-wide emissions limits if they were applicable, except for two compressor stations (Site IDs PS-118 and PS-127) and the gas processing facility (Site ID PS-159). The emissions estimates for CO from these three sites are above the CO lb/hr emission limits. A complete comparison to the new ESL based emission limits cannot be determined using the data collected during the point source testing.

As the new PBR rule was not in effect at the time of the point source testing, it is likely that most of the emissions sources located at the sites tested in Task 3 were previously authorized and were operating under the old PBR requirements outlined in 30 TAC Section 106.352(l). Under the old PBR requirements, total emissions could not exceed 25 tpy each of SO_2, all other sulfur compounds combined, or all VOCs combined or 250 tpy each of NO_x and CO. Total emissions of sulfur compounds, excluding sulfur oxides, from all vents could not exceed 4.0 pounds per hour. Through the point source testing task, three potential sources were identified, including two compressor stations (Site IDs PS-118 and PS-119) and the gas processing plant (Site ID PS-159), with site-wide emissions exceeding the 25 tpy VOC limit. Additionally, estimated CO emissions from two compressor stations (Site IDs PS-118 and PS-127) and the gas processing plant (Site ID PS-159) exceed the 250 tpy threshold. For each of these facilities, it appears that emissions from the natural gas compressor engines cause them to exceed PBR thresholds.

30 TAC Section 106.352(l) also requires compressors and flares to meet the requirements of §106.492 and §106.512 of 30 TAC (relating to flares and stationary engines and turbines, respectively). 30 TAC §106.512 limits NO_x emissions, depending on engine type (rich-burn or lean-burn), fuel type (gas-fired, dual fuel-fired, liquid fuel-fired) and manufacturing date.

Compliance with the emission specification requirements under the PBR rules cannot be determined using the data obtained at the time of the survey. Records of manufacturing dates and the dates in which existing sources were last modified would be required to complete a full compliance assessment for any individual facility.

6.2.2 Standard Permit

Similar to PBRs, standard permits are an abbreviated permitting mechanism provided by TCEQ to authorize emissions from new construction or modifications. However, standard permits generally require more stringent emission controls meeting what is considered the best available control technology (BACT). New construction or modifications involving oil and gas exploration and production facilities permitted by standard permit must meet the requirements provided under 30 TAC Chapter 116, Subchapter F, Section 116.620, "Installation and/or Modification of Oil and Gas Facilities." The standard permit issued by TCEQ often includes site-specific requirements including, but not limited to, site-wide and/or source-specific emission limits. While some of the facilities visited in Task 3 may have been authorized under a standard permit, no information on these was available during this review.

6.2.3 New Source Review Permits

New construction or projects involving modifications to existing facilities that cannot meet the requirements of an applicable PBR or standard permit must be authorized prior to start of construction under 30 TAC Chapter 116, Subchapter B, “New Source Review Permits.” This permitting mechanism requires installation of either BACT or lowest achievable emission reductions, depending on whether the source is located in an attainment or a non-attainment area. Tarrant County is located in a non-attainment area for ozone, so the latter would be required for project sources emitting VOCs and NO_x; BACT would be required for all other project-related criteria pollutants. NSR permits also require two public notice periods and a health impacts review to evaluate to potential health impacts from certain toxins associated with the project-related emissions. The NSR permit issued by TCEQ often includes site-specific requirements including, but not limited to, site-wide and/or source-specific emission limits. NSR permits issued for the sites visited under Task 3 were considered outside the scope of this study, and were therefore not reviewed.

6.2.4 Control of Air Pollution from Visible Emissions and Particulate Matter

This rule regulates the amount of visible emissions and particulate matter that are permissible from any source operated in Texas. Visible emissions from stationary vents are not allowed to exceed opacities greater than 30% averaged over a six-minute period, 20% averaged over a six-minute period for any source on which construction was begun after January 31, 1972, or 15% averaged over a six-minute period for any source having a total flowrate greater than or equal to 100,000 actual cubic feet per minute, unless an optical instrument capable of measuring the opacity of emissions is installed in the vent. No visible emissions were observed from stationary vents located at the sites visited under Task 3. Visible emissions from a process gas flare used in routine or scheduled facility operations are not allowed for more than five minutes in any two-hour period. Two sites visited during Task 3 operated flares; however, compliance status with the requirements under this rule cannot be determined using the data obtained at the time of the survey. Compliance status with this requirement cannot be determined for the vents visited using the data obtained at the time of the survey. However, considering the nature of material (i.e., natural gas) being managed at the sites studied, the particulate matter emission rate limits specified are not expected to be exceeded.

6.2.5 Control of Air Pollution from Sulfur Compounds

This rule regulates the amount of sulfur compound emissions, particularly SO_2, H_2S, sulfuric acid, and total reduced sulfur, that are permissible from certain sources operated in Texas. Those sulfur compounds applicable to the operation of oil and gas facilities are SO_2 and H_2S. SO_2 emissions from a source or sources operated on a property or multiple sources operated on contiguous properties cannot cause an exceedance of a net ground level concentration of 0.4 parts per million by volume (ppmv) averaged over any 30-minute period. H_2S from a source or sources operated on a property or multiple sources operated on contiguous properties are also limited; the specific limit depends on the affected downwind sources.

Compliance with the ground-level concentration requirements under this rule cannot be determined using the data obtained at the time of the survey. As mentioned previously, the natural gas in the Barnett Shale is not considered to be sour natural gas, so this rule does not appear to apply to any facilities in Fort Worth.

6.2.6 Standards of Performance for Hazardous Air Pollutants and for Designated Facilities and Pollutants

This rule simply incorporates, by reference, all of the federal NESHAPs that regulate HAPs from new and existing stationary sources. Section 6.1.4 lists and briefly describes the potentially applicable NESHAPs for the oil and gas industry.

6.2.7 Control of Air Pollution from Volatile Organic Compounds

This rule regulates the amount of VOCs that are permissible from sources operated in Texas. The rule requirements are organized by source type under 30 TAC Chapter 115 and only apply to sources located in non-attainment areas specified in the rule. Those parts of the rule that are potentially subject to upstream oil and gas facilities are Subchapter B, Division 1, “Storage of VOCs”; Subchapter C, Division 1, “Loading and Unloading of VOCs”; and Subchapter D, Division 3, “Fugitive Emission Control in Petroleum Refining, Natural Gas/Gasoline Processing, and Petrochemical Processes in Ozone Non-attainment Areas.” Storage tanks containing VOCs including, but not limited to, crude or condensate must control emissions using control technologies specified in the rule. Control options vary depending on the size of the tank and its configuration. Loading of certain VOC materials must be controlled by a vapor control system that maintains a control efficiency of at least 90%, a vapor balance system, or pressurized loading. This rule also requires VOC leak detection and repair at natural gas/gasoline processing operations. Site PS-159 (the Crosstex Amine Treatment Center) could be subject to this rule.

Compliance status with the control and monitoring requirements under this rule cannot be determined using the data obtained at the time of the survey.

6.2.8 Control of Air Pollution from Nitrogen Compounds

This rule regulates the amount of nitrogen compounds that are permissible from sources operated in Texas. Similar to 30 TAC Chapter 115, the rule requirements for this chapter are organized by source type under 30 TAC Chapter 117 and only apply to sources located in non-attainment areas specified in the rule. Those parts of the rule that are most commonly subject to upstream oil and gas facilities are found under Subchapter D, “Combustion Control at Minor Sources in Ozone Non-attainment Areas.” For the Dallas–Fort Worth area, including Tarrant County, NO_x emissions from stationary internal combustion engines at any minor stationary source of NO_x (a source that emits less than 250 tpy) are limited, depending on engine type and construction date. Most engines at sites visited under Task 3 would be subject to a limit of 0.50 grams of NO_x per hp per hour.

Compliance with the emission specification requirements under this rule cannot be determined using the data obtained at the time of the survey. Records of manufacturing dates and the dates in which existing sources were last modified would be required to complete a full compliance assessment for any individual engine.

6.2.9 Federal Operating Permits

The Title V Federal Operating Permit Program is regulated under 30 TAC Chapter 122. Title V operating permits are required for any site that is a major source. A major source is a site which that emits, or has the potential to emit, 100 tpy or more of any air pollutant. A site is also considered a major source if it emits or has the potential to emit, in the aggregate, 10 tpy or more of any single hazardous air pollutant listed under the federal Clean Air Act or 25 tpy or more of any combination of hazardous air pollutants listed under the Act. One of the primary objectives of the Title V operating program is to assimilate in one document all of the requirements to which a facility is subject. The Title V permit serves as the key verification and documentation of a facility's compliance with all applicable requirements of the Texas and federal Clean Air Acts. Permit holders must annually certify compliance with the permit terms and conditions and submit semi-annual deviation reports in which they self-disclose known non-compliance activities during the reporting period.

Five potential major sources were identified, including three compressor stations (Site IDs PS-118, PS-119, PS-127), the gas processing plant (Site ID PS-159), and one well pad (Site ID 238). All of these facilities were determined to be major sources due to formaldehyde and/or CO emissions from their compressor engines. However, due to the conservative nature of the emissions estimation approach used for these engines (24-hour-per-day, 365-day-per-year operation of all the engines at the facility without controls), a full compliance evaluation would need to be made to definitively conclude whether or not these facilities are major sources and subject to the Title V Federal Operating Program.

6.3 City of Fort Worth Air Quality Rules

The city of Fort Worth's Gas Well Drilling Ordinance (Ordinance No. 18449-02-2009) has one provision that requires air emissions control. Under Section 15-42 of this ordinance, tank batteries with a rolling annual aggregate emissions rate of 25 tpy or more of VOC must use vapor recovery equipment with a 95% recovery efficiency. Based on the results of the point source testing under Task 3, two compressor stations (Site IDs PS-118 and PS-119) and the gas processing plant (Site ID PS-159) have facility-wide VOC emissions greater than 25 tpy. However, the majority of the VOC emissions at these sites come from non-tank emission points and the natural-gas-fired compression engines, and none of these facilities have VOC emissions from their storage tank batteries exceeding 25 tpy. Therefore, based on the results of Task 3, this rule does not appear to apply to any of the tested facilities.

6.4 Regulatory Assessment Conclusions

A regulatory assessment was conducted based on the results of the point source testing to determine if any facilities exceeded regulatory thresholds. For many of the rules potentially applicable to oil and gas sources in Fort Worth, we were unable to make a definitive determination on whether the source was subject to the rule, and/or whether the source was in compliance with the rule. A full compliance evaluation for any individual site is an involved process that requires research into historical construction, operating, and production records and was beyond the scope of this study. However, based on the emission estimates developed under Task 3, the sources listed in Table 6.4-1 may exceed the regulatory thresholds discussed above.

Table 6.4-1. Sources Above Regulatory Thresholds

Site ID	Site Type	VOC (tons/yr)	CO (tons/yr)	Total HAP (tons/yr)	Formaldehyde (tons/yr)
PS-159	Processing Facility	80[a]	1,039[b, c]	47[d]	32[e]
PS-118	Compressor Station	43[a]	270[b, c]	25[d]	17[e]
PS-119	Compressor Station	38[a]	240[c]	22	15[e]
PS-127	Compressor Station	24	545[b, c]	14	9
238	Well Pad	14	219[c]	8	6

[a] This site potentially exceeds the 25 tpy VOC threshold under 30 TAC 106, Subchapter O, Section 106.352.

[b] This site potentially exceeds the 250 tpy CO threshold under 30 TAC 106, Subchapter O, Section 106.352.

[c] This site potentially exceeds the 100 tpy CO threshold under the federal Title V Operating Permit Program.

[d] This site potentially exceeds the 25 tpy total HAP threshold under the federal Title V Operating Permit Program.

[e] This site potentially exceeds the 10 tpy single HAP threshold under the federal Title V Operating Permit Program.

7.0 Full Build-Out Estimates

Key Point: Full Build-Out Estimates
ERG projects that emissions from natural gas production operations in Fort Worth will peak in 2012 and 2013 before beginning to decline.

Over the last five years, there has been a dramatic increase in natural gas production in the Barnett Shale, and in the city of Fort Worth itself. The expansion of the natural gas industry within the city is expected to continue into the future, and emissions from these activities are also expected to increase. ERG has developed estimates of total emissions from natural gas production from 2010 to 2018, based on the results of the point source testing task. As described below, ERG projects that emissions from natural gas production will peak in 2012 and 2013, and will slowly decline over time as the known natural gas reserves in the Barnett Shale are depleted. In this context, "full build-out" means the point at which natural production will result in the maximum annual emissions. For purposes of this evaluation, total emissions from natural gas production activity are assumed to correlate to total natural gas production levels.

This evaluation includes emissions from production activities (all emission sources found at producing well pads, compressor stations, and the gas processing plant), but does not include emissions from pre-production activities such as site construction, exploration (drilling), stimulation (fracking), or well completion.

One drilling operation, one fracking operation, and one well completion operation were visited under the point source testing task, and emissions estimates were developed for each of these operations. However, this information was insufficient to extrapolate to all drilling, fracking, and completion operations occuring in 2010 due to the variability in how these operations are conducted from well to well, and from operator to operator. Additionally, the single saltwater treatment facility located in Fort Worth was also visited. However, emissions at the time of the visit were determined to be very small (less than half a pound of VOC per year).

This section has five sub-sections:

- 7.1 Factors Affecting Natural Gas Production – This section describes the various factors that must be considered when predicting future natural gas production.
- 7.2 Methodology for Forecasting Natural Gas Production – A description of the methodology used to estimate future natural gas production is provided in this section.
- 7.3 2010 Base Year Emissions Inventory – Describes how the current (2010) emissions inventory was compiled.
- 7.4 2010 through 2018 Projected Emissions Inventories – This section describes how the emissions estimates for 2011 – 2018 were calculated.
- 7.5 Full Build-Out Estimates Conclusions – This section presents the conclusions of the full build-out component of this study.

7.1 Factors Affecting Natural Gas Production

Key Point: Drilling and Permit Activity
By 2010, the number of active drill rigs and the number of well pad permits issued by the City of Fort Worth were down nearly 60% from their 2008 highs.

Estimating the future production of natural gas depends upon several factors. The primary factors include the amount of recoverable natural gas in the Barnett Shale formation, the ability of operators to access the gas with available drilling and fracturing methods (amounts technically recoverable), and the economics of the extraction process (amounts economically recoverable). Other operational factors include the number of existing producing wells, the depletion rate of existing wells, the number of new wells drilled, and the initial production from new wells, all of which contribute to the amounts of gas technically recoverable. These operational factors depend on the wellhead price of natural gas (price received by producers) and the costs of extracting the gas.

While the amount of recoverable gas in the Barnett Shale is finite, there will still be technically recoverable natural gas decades from now. However, the rate at which this gas is extracted will depend on the price received and the costs of drilling wells, installing production infrastructure such as pipelines and compressor stations, and the costs of operating these facilities.

The amount of recoverable gas in the Barnett Shale area is unknown. Current estimates of gas reserves in the Barnett Shale vary from 25 to 30 trillion cubic feet. This is not an absolute figure, as estimates of proven reserves and recoverable reserves change year by year. Reserve estimates increase as new data is obtained from exploration and drilling activities, while gas reserves are depleted as gas is extracted from existing wells. The Barnett Shale is unique in that it is the first domestic shale gas play to be extensively drilled and developed. Therefore, there is a wealth of information available about the size of the resource. In 2007, the Perryman Group estimated economically recoverable reserves of gas in the Barnett Shale at 2 trillion cubic feet and technically recoverable reserves at 30 trillion cubic feet.[21] The U.S. Energy Information Administration's most recent estimate of shale gas reserves for the three Texas Districts (Districts 5, 7B, and 9) that include Barnett Shale acreage is 26.47 trillion cubic feet.[22]

Figure 7.1-1 shows natural gas production in the entire Barnett Shale and in Tarrant County since 1993.[23] Notice that, over time, production of shale gas in Tarrant County has mirrored the larger trend in the entire Barnett Shale region. Due to the availability of county-level data from the Railroad Commission of Texas, this analysis uses current and projected production data for Tarrant County as a surrogate to reflect current and projected production data for the city of Fort Worth.

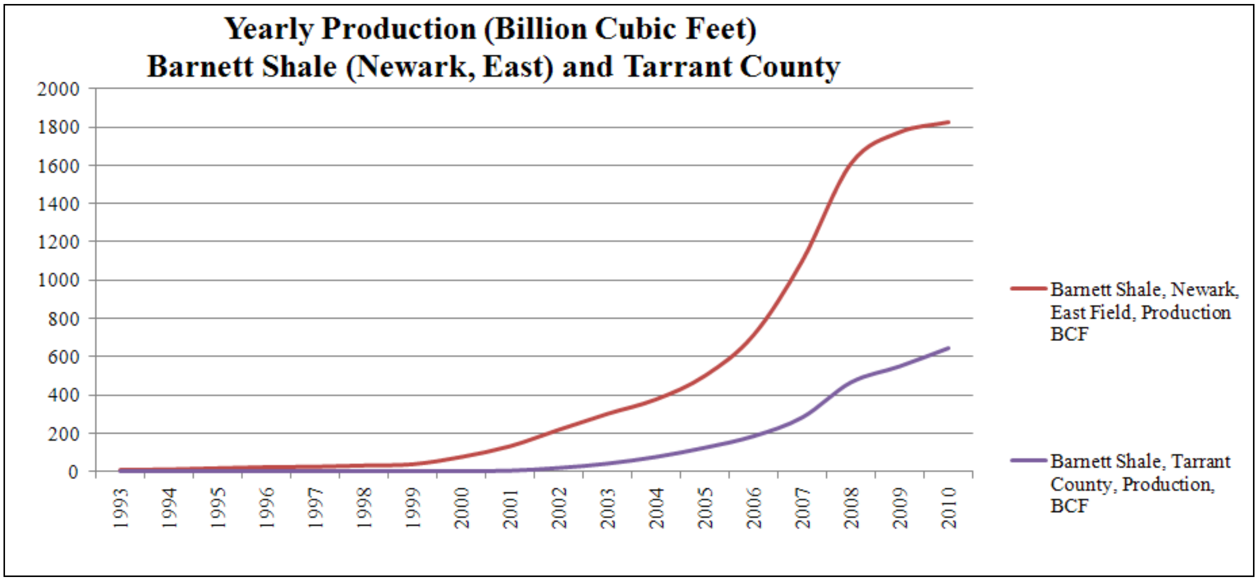
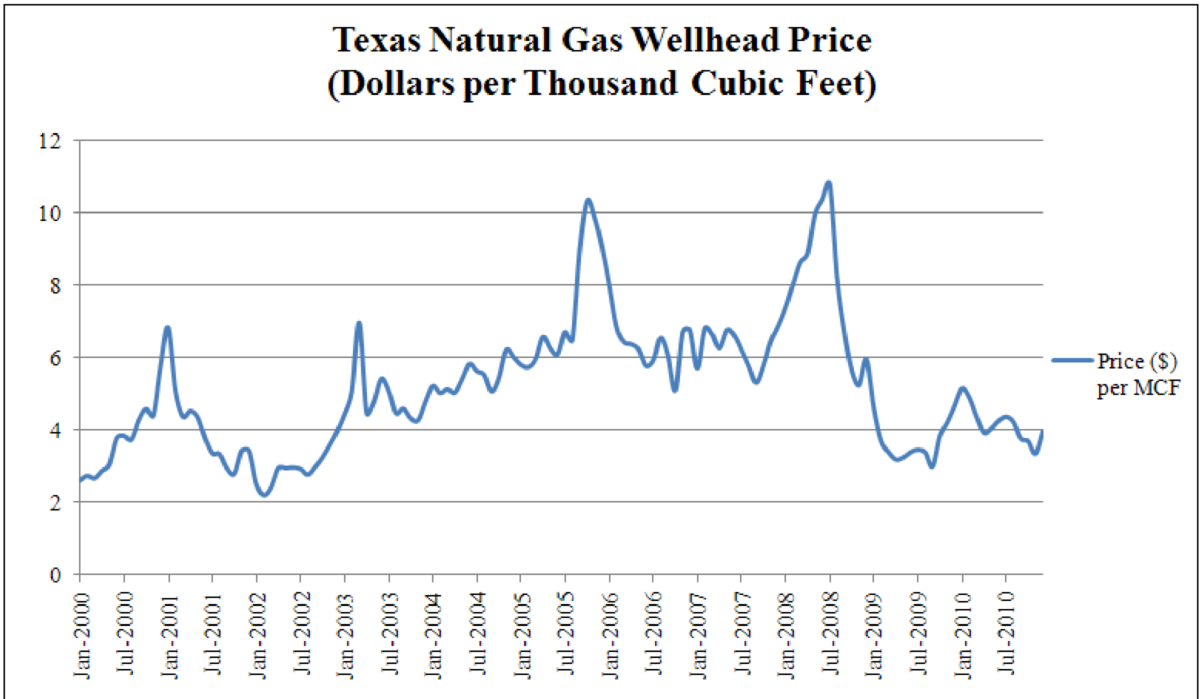


Figure 7.1-1. Natural Gas Production in the Barnett Shale and Tarrant County (1993–2010)

The price received for natural gas (the wellhead price) has a significant effect on the extent of exploration and the amount of gas produced. Higher wellhead prices stimulate increased exploration, drilling, and production. Figure 7.1-2 shows the monthly wellhead price of natural gas during the previous decade in which the shale gas underneath Tarrant and neighboring counties began to be extracted in significant amounts.[24] As can be seen in the figure, wellhead prices have fluctuated significantly over this time and peaked in 2008 before falling by more than 50% to current levels.

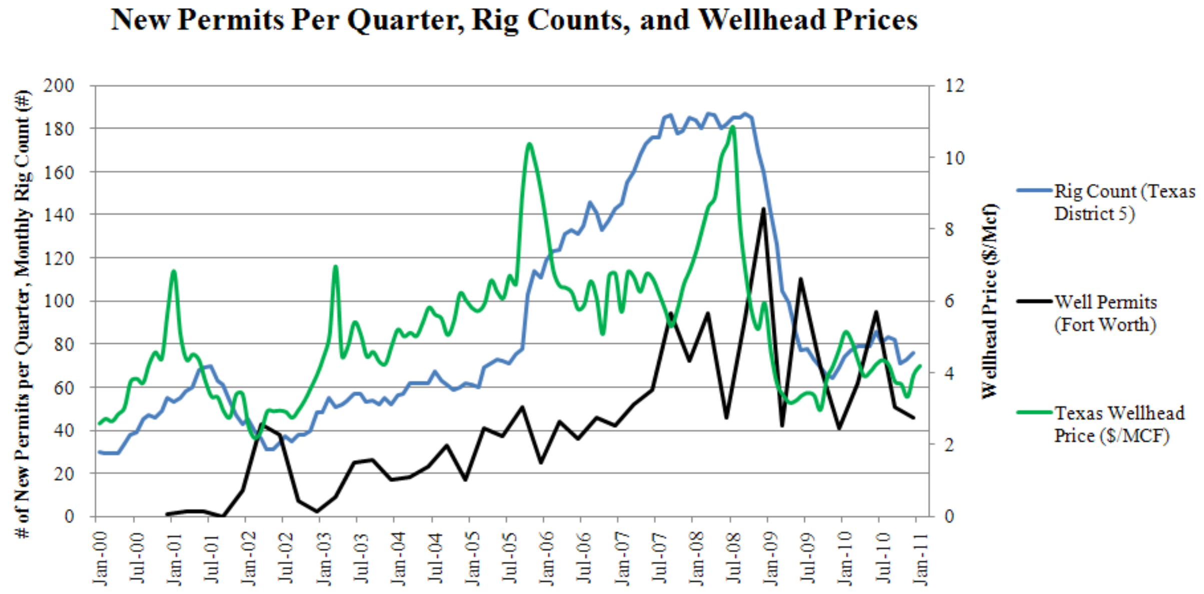


Source: U.S. Energy Information Administration, http://www.eia.doe.gov/dnav/ng/hist/na1140_stx_3a.htm

Figure 7.1-2. Texas Natural Gas Wellhead Price (2000–2010)

The U.S. Energy Information Administration, in its *Annual Energy Outlook Overview 2011,*[25] has forecast natural gas prices for the next 25 years. The Administration predicts that the average wellhead price for natural gas will increase by an average of 2.1% per year, to $5.00 per million Btu in 2024 and to $6.26 per million Btu in 2035 (2009 dollars). It should be noted that these estimates fall below the average wellhead natural gas prices between 2005 and 2008, indicating a less desirable economic climate for producers to invest in new drilling and production compared to the prices during the peak in these activities as discussed below.

Due to the depletion of existing wells, new wells must be drilled on a continuing basis to ensure a constant supply of natural gas. However, with current gas prices remaining relatively low, it may not make economic sense for producers to continue to invest in new production. Figure 7.1-3 shows the relationship between wellhead prices and drilling and permit activity over the last 10 years.



Quarterly permit data for Tarrant County from City of Fort Worth and Railroad Commission of Texas, 3/2011 .
Monthly rotary rig count data for Texas District 5 from Baker-Hughes http://investor.shareholder.com/bhi/rig_counts/rc_index.cfm
Monthly Texas natural gas wellhead price data from U.S. Energy Information Administration, http://www.eia.doe.gov/dnav/ng/hist/na1140_stx_3a.htm

Figure 7.1-3. Permits, Rig Counts, and Wellhead Gas Prices in Tarrant County (2000–2010)

As shown in the figure, the number of active drilling rigs in District 5 (which includes Tarrant County) decreased dramatically in response to the drop in natural gas wellhead price beginning in August 2008.[26] Likewise, the number of well pad permits processed by the city of Fort Worth peaked shortly after the peak in natural gas wellhead price in 2008 and have trended downward since then. Prices dropped below $7 per thousand cubic feet in September 2008, below $6 per thousand cubic feet in October 2008. By 2010, both District 5 rig counts and the number of well pad permits issued by the city of Fort Worth were down nearly 60% from their highs in 2008.

7.2 Methodology for Forecasting Natural Gas Production

To estimate future emissions, an estimate of future natural gas production for the target years of 2010 through 2018 must be developed. In 2008, Tristone Capital estimated future production of shale gas in nine shale gas basins in the U.S. and Canada, including the Barnett Shale, for a 10-year period from 2008 to 2018.[27] Figure 7.2-1 shows Tristone's estimates of future production for these eight shale gas plays.

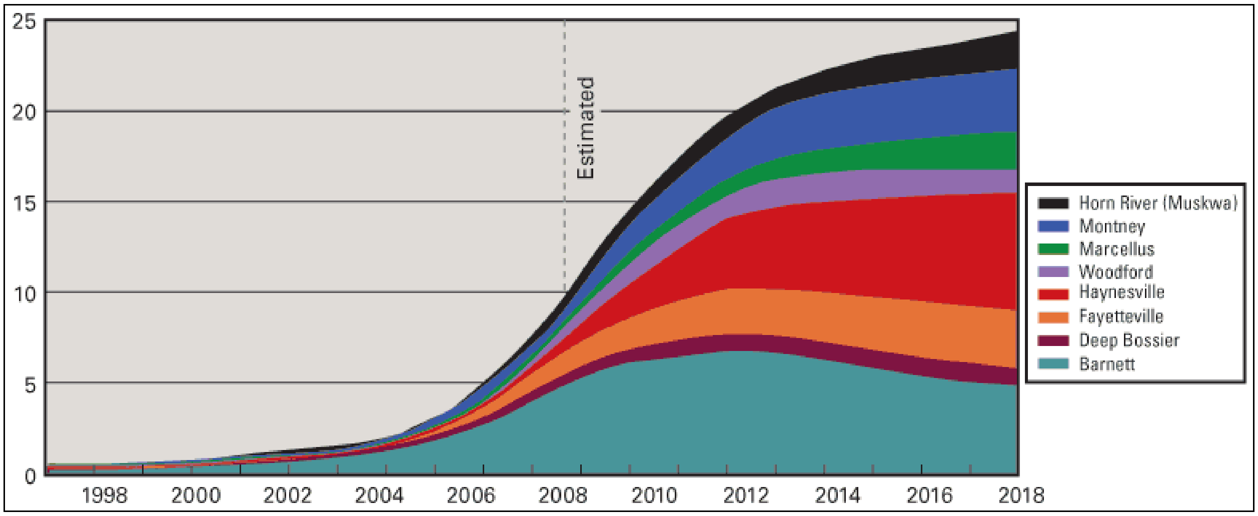
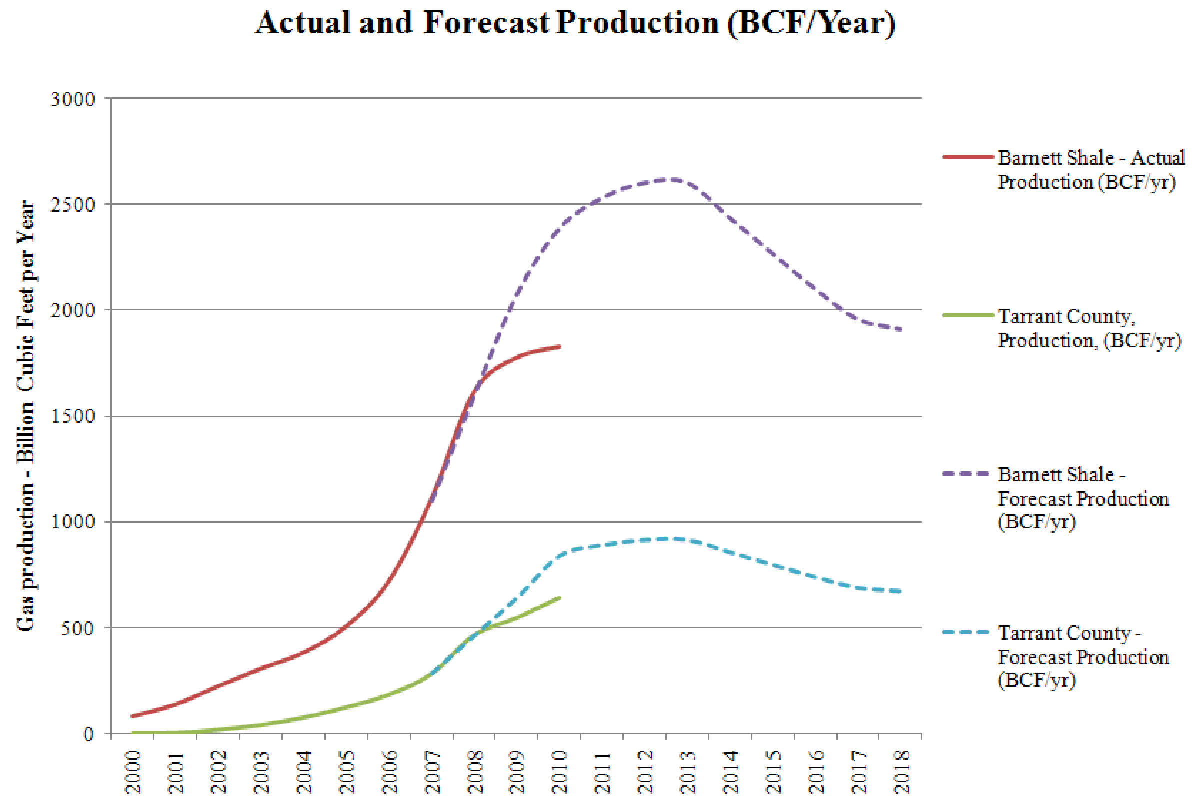


Figure 7.2-1. Projected Production in Eight Shale Plays (BCF) (1998–2018)

Tristone's estimate of future production from the Barnett Shale is reproduced in Figure 7.2-2 as the purple dashed line in the graph. This data is compared with actual production data for the Barnett Shale as taken from the Railroad Commission of Texas (the solid red line). Actual production data for Tarrant County is also presented in the graph (the solid green line), as is projected production data for Tarrant County (the dashed turquoise line). To develop the projected production data for Tarrant County, it was assumed that the percentage growth in production in Tarrant County would increase (or decrease) at the same rate as the Barnett Shale as a whole.



Forecast Production: Source: Oil & Gas Journal, Volume 106, Issue 42, "Study Analyzes Nine US, Canada Gas Plays" 11/08. Data by Tristone Capital, Inc.
Actual Production: Source: RailRoad Commission of Texas, Barnett Shale Gas Well Production, http://www.rrc.state.tx.us/barnettshale/index.php

Figure 7.2-2. Barnett Shale and Tarrant County Actual and Projected Natural Gas Production (2000–2018)

As can be seen in the graph, Tristone's estimates closely align with actual production through 2009, then appear to overestimate production. This may be attributed to the dramatic decrease in natural gas prices between 2008 and 2009, resulting in a decrease in drilling activity. Note that this decrease occurred after Tristone had published its projected trends in natural gas production activity. Therefore, ERG believes Tristone's projections provide a conservative estimate of the peak natural gas production in the city of Fort Worth and has based the full build-out emissions inventory on this data, as described below.

7.3 2010 Base Year Emissions Inventory

Under Task 2 of the Fort Worth Natural Gas Air Quality Study, point source testing was conducted at 388 sites, including 375 well pads, eight compressor stations, and the gas processing plant. These data were used to calculate average emission rates for well pads and compressor stations. ERG used these average emission rates to develop a complete 2010 base year emissions inventory from natural gas production in the city of Fort Worth by multiplying the average emissions per well pad (and compressor station) by the total number of well pads (and compressor stations) operating in 2010. As documented in the Final Point Source Test Plan (October 4, 2010) there were 489 active well pads in the city of Fort Worth at the commencement of this study. While data from the city of Fort Worth indicated there were 13 active compressor stations in Fort Worth at the start of this study, there were a total of 30 compressor stations either permitted, under construction, or already in service in 2010. Therefore, for purposes of developing the 2010 base year emissions inventory, it was assumed that there were 30 active compressor stations in Fort Worth in 2010.

Table 7.3-1 shows the average emissions for an individual well pad as determined from the point source testing, as well as the projected total 2010 base year emissions across all 489 well pads in the city of Fort Worth.

Table 7.3-1. 2010 Base Year Well Pad Emissions Inventory

Pollutant	2010 Base Year Average Well Pad Emissions (tons/yr)	2010 Base Year Total Well Pad Emissions (tons/yr)
TOC	33.34	16,302.29
VOCs	0.68	332.71
Total HAPs	0.31	152.36
Methane	32.30	15,795.98
PM	0.03	13.57
NO_x	0.55	266.76
CO	4.77	2,330.62
SO_2	0.002	0.97
Acenaphthene	4.50E-06	2.20E-03
Acenaphthylene	1.87E-05	9.14E-03
Acetaldehyde	2.83E-02	1.38E+01
Acetone	2.52E-03	1.23E+00
Acrolein	2.63E-02	1.29E+01
Anthracene	2.43E-06	1.19E-03
Benzene	9.45E-03	4.62E+00
Benzo (a) anthracene	1.14E-06	5.56E-04
Benzo (a) pyrene	1.92E-08	9.39E-06
Benzo (b) fluoranthene	5.61E-07	2.74E-04
Benzo (e) pyrene	1.40E-06	6.86E-04
Benzo (g,h,i) perylene	1.40E-06	6.84E-04
Benzo (k) fluoranthene	1.44E-08	7.04E-06
Biphenyl	7.17E-04	3.51E-01
Bromomethane	4.98E-06	2.43E-03
Butadiene, 1,3-	2.79E-03	1.37E+00
Butane	8.33E-02	4.07E+01
Butane, n-	1.61E-02	7.85E+00

Table 7.3-1. 2010 Base Year Well Pad Emissions Inventory (Continued)

Pollutant	2010 Base Year Average Well Pad Emissions (tons/yr)	2010 Base Year Total Well Pad Emissions (tons/yr)
Butanone (MEK), 2-	3.08E-05	1.51E-02
Carbon disulfide	5.36E-06	2.62E-03
Carbon tetrachloride	2.10E-04	1.03E-01
Chlorobenzene	1.50E-04	7.34E-02
Chlorodifluoromethane	1.93E-06	9.43E-04
Chloroethane	1.14E-05	5.58E-03
Chloroform	1.59E-04	7.79E-02
Chloromethane	4.29E-06	2.10E-03
Chlorotoluene, 2-	6.64E-06	3.25E-03
Chrysene	2.34E-06	1.15E-03
Cyclohexane	4.81E-03	2.35E+00
Cyclopentane	7.67E-04	3.75E-01
Decane, n-	7.50E-04	3.67E-01
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	4.57E-06	2.24E-03
Dichlorodifluoromethane	3.83E-06	1.87E-03
Dichloroethane, 1,1-	1.32E-04	6.46E-02
Dichloropropene, 1,3-	1.48E-04	7.24E-02
Dodecane, n-	8.18E-05	4.00E-02
Ethane	3.55E-01	1.74E+02
Ethylbenzene	6.14E-04	3.00E-01
Ethylene dibromide	2.48E-04	1.21E-01
Ethylene dichloride	1.43E-04	6.98E-02
Ethyltoluene, 4-	2.69E-04	1.31E-01
Fluoranthene	3.75E-06	1.84E-03
Fluorene	1.92E-05	9.37E-03
Formaldehyde	1.87E-01	9.13E+01
Heptane	1.35E-02	6.58E+00
Hexachlorobutadiene	4.33E-05	2.12E-02
Hexane	1.66E-02	8.12E+00
Indeno(1,2,3-cd) pyrene	3.36E-08	1.64E-05
Isobutane	1.27E-02	6.20E+00
Isobutyraldehyde	1.48E-03	7.23E-01
Isopentane	2.91E-02	1.42E+01
Isopropylbenzene	9.36E-05	4.58E-02
Isopropyltoluene, 4-	1.15E-04	5.63E-02
Methyl alcohol	1.03E-02	5.06E+00
Methyl Naphthalene, 2-	1.12E-04	5.49E-02
Methyl-2-pentanone, 4- (MIBK)	5.59E-05	2.73E-02
Methylcyclohexane	4.16E-03	2.03E+00
Methylene chloride	2.44E-03	1.19E+00
Naphthalene	3.72E-04	1.82E-01
Nonane, n-	1.07E-02	5.21E+00

Table 7.3-1. 2010 Base Year Well Pad Emissions Inventory (Continued)

Pollutant	2010 Base Year Average Well Pad Emissions (tons/yr)	2010 Base Year Total Well Pad Emissions (tons/yr)
Octane, n-	1.47E-02	7.18E+00
Pentane, n-	2.99E-02	1.46E+01
Perylene	1.68E-08	8.22E-06
Phenanthrene	3.52E-05	1.72E-02
Phenol	1.42E-04	6.96E-02
Polycyclic Aromatic Hydrocarbons (PAH)	4.77E-04	2.33E-01
Propane	1.42E-01	6.93E+01
Propylbenzene, n-	1.42E-04	6.94E-02
Propylene	1.42E-05	6.94E-03
Propylene dichloride	1.51E-04	7.37E-02
Pyrene	4.60E-06	2.25E-03
sec-Butylbenzene	6.80E-05	3.32E-02
Styrene	1.90E-04	9.31E-02
Tetrachloroethane, 1,1,2,2-	2.24E-04	1.10E-01
Tetrachloroethene	1.37E-04	6.69E-02
Toluene	1.35E-02	6.62E+00
Trichlorobenzene, 1,2,3-	6.96E-05	3.41E-02
Trichlorobenzene, 1,2,4-	5.18E-05	2.53E-02
Trichloroethane, 1,1,2-	1.78E-04	8.71E-02
Trichlorofluoromethane	5.63E-06	2.75E-03
Trimethylbenzene, 1,2,3-	1.20E-04	5.85E-02
Trimethylbenzene, 1,2,4-	9.67E-04	4.73E-01
Trimethylbenzene, 1,3,5-	6.37E-04	3.12E-01
Trimethylpentane, 2,2,4-	2.90E-03	1.42E+00
Undecane, n-	1.68E-04	8.20E-02
Vinyl acetate	2.51E-05	1.23E-02
Vinyl bromide	6.03E-06	2.95E-03
Vinyl chloride	8.64E-05	4.23E-02
Xylene, o	5.58E-04	2.73E-01
Xylenes (isomers)	9.06E-04	4.43E-01
Xylenes, m-, p-	5.92E-03	2.90E+00

Table 7.3-2 shows the average emissions for an individual compressor station as determined from the point source testing, as well as the projected total 2010 base year emissions across all 30 compressor stations in the city of Fort Worth.

Table 7.3-2. 2010 Base Year Compressor Station Emissions Inventory

Pollutant	2010 Base Year Average Compressor Station Emissions (tons/yr)	2010 Base Year Total Compressor Station Emissions (tons/yr)
TOC	99.61	2,988.29
VOCs	17.20	515.86
Total HAPs	10.17	304.95
Methane	69.37	2,080.99
PM	0.36	10.94
NO_x	19.63	588.88
CO	151.47	4,544.19
SO_2	0.07	2.17
Acenaphthene	1.65E-04	4.96E-03
Acenaphthylene	6.87E-04	2.06E-02
Acetaldehyde	1.04E+00	3.12E+01
Acetone	6.63E-04	1.99E-02
Acrolein	9.67E-01	2.90E+01
Anthracene	8.92E-05	2.68E-03
Benzene	2.44E-01	7.31E+00
Benzo (a) anthracene	4.18E-05	1.25E-03
Benzo (a) pyrene	7.06E-07	2.12E-05
Benzo (b) fluoranthene	2.06E-05	6.19E-04
Benzo (e) pyrene	5.16E-05	1.55E-03
Benzo (g,h,i) perylene	5.14E-05	1.54E-03
Benzo (k) fluoranthene	5.29E-07	1.59E-05
Biphenyl	2.63E-02	7.90E-01
Bromomethane	7.78E-06	2.33E-04
Butadiene, 1,3-	1.02E-01	3.06E+00
Butane	2.65E-02	7.94E-01
Butane, n-	5.90E-01	1.77E+01
Butanone (MEK), 2-	2.76E-05	8.28E-04
Carbon disulfide	1.44E-06	4.32E-05
Carbon tetrachloride	7.55E-03	2.27E-01
Chlorobenzene	5.52E-03	1.66E-01
Chlorodifluoromethane	3.02E-06	9.05E-05
Chloroethane	2.40E-04	7.21E-03
Chloroform	5.85E-03	1.76E-01
Chloromethane	4.48E-06	1.34E-04
Chlorotoluene, 2-	1.04E-05	3.12E-04
Chrysene	8.61E-05	2.58E-03
Cyclohexane	3.94E-02	1.18E+00
Cyclopentane	2.82E-02	8.46E-01
Decane, n-	9.74E-05	2.92E-03
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	7.14E-06	2.14E-04
Dichlorodifluoromethane	5.99E-06	1.80E-04
Dichloroethane, 1,1-	4.86E-03	1.46E-01
Dichloropropene, 1,3-	5.44E-03	1.63E-01

Table 7.3-2. 2010 Base Year Compressor Station Emissions Inventory (Continued)

Pollutant	2010 Base Year Average Compressor Station Emissions (tons/yr)	2010 Base Year Total Compressor Station Emissions (tons/yr)
Dodecane, n-	4.57E-05	1.37E-03
Ethane	1.30E+01	3.91E+02
Ethylbenzene	1.35E-02	4.05E-01
Ethylene dibromide	9.12E-03	2.74E-01
Ethylene dichloride	5.24E-03	1.57E-01
Ethyltoluene, 4-	7.55E-03	2.27E-01
Fluoranthene	1.38E-04	4.14E-03
Fluorene	7.05E-04	2.11E-02
Formaldehyde	6.86E+00	2.06E+02
Heptane	2.76E-04	8.27E-03
Hexachlorobutadiene	4.91E-05	1.47E-03
Hexane	1.39E-01	4.16E+00
Indeno(1,2,3-cd) pyrene	1.23E-06	3.70E-05
Isobutane	4.66E-01	1.40E+01
Isobutyraldehyde	5.43E-02	1.63E+00
Isopentane	6.77E-03	2.03E-01
Isopropylbenzene	1.29E-04	3.86E-03
Isopropyltoluene, 4-	2.86E-04	8.59E-03
Methyl alcohol	3.80E-01	1.14E+01
Methyl Naphthalene, 2-	4.13E-03	1.24E-01
Methyl-2-pentanone, 4- (MIBK)	1.33E-04	3.98E-03
Methylcyclohexane	1.53E-01	4.59E+00
Methylene chloride	1.83E-02	5.49E-01
Naphthalene	1.21E-02	3.64E-01
Nonane, n-	1.38E-02	4.15E-01
Octane, n-	4.37E-02	1.31E+00
Pentane, n-	3.26E-01	9.78E+00
Perylene	6.18E-07	1.85E-05
Phenanthrene	1.29E-03	3.88E-02
Phenol	5.23E-03	1.57E-01
Polycyclic Aromatic Hydrocarbons (PAH)	1.75E-02	5.26E-01
Propane	5.21E+00	1.56E+02
Propylbenzene, n-	2.84E-03	8.51E-02
Propylene	1.59E-05	4.78E-04
Propylene dichloride	5.54E-03	1.66E-01
Pyrene	1.69E-04	5.07E-03
sec-Butylbenzene	3.57E-04	1.07E-02
Styrene	6.81E-03	2.04E-01
Tetrachloroethane, 1,1,2,2-	8.24E-03	2.47E-01
Tetrachloroethene	3.62E-05	1.09E-03
Toluene	1.21E-01	3.64E+00
Trichlorobenzene, 1,2,3-	8.35E-05	2.51E-03

Table 7.3-2. 2010 Base Year Compressor Station Emissions Inventory (Continued)

Pollutant	2010 Base Year Average Compressor Station Emissions (tons/yr)	2010 Base Year Total Compressor Station Emissions (tons/yr)
Trichlorobenzene, 1,2,4-	5.63E-05	1.69E-03
Trichloroethane, 1,1,2-	6.55E-03	1.96E-01
Trichlorofluoromethane	8.81E-06	2.64E-04
Trimethylbenzene, 1,2,3-	4.40E-03	1.32E-01
Trimethylbenzene, 1,2,4-	4.66E-02	1.40E+00
Trimethylbenzene, 1,3,5-	1.25E-02	3.75E-01
Trimethylpentane, 2,2,4-	1.05E-01	3.15E+00
Undecane, n-	4.54E-05	1.36E-03
Vinyl acetate	7.23E-06	2.17E-04
Vinyl bromide	9.43E-06	2.83E-04
Vinyl chloride	3.07E-03	9.22E-02
Xylene, o	1.89E-04	5.68E-03
Xylenes (isomers)	3.33E-02	9.99E-01
Xylenes, m-, p-	3.30E-04	9.89E-03

Table 7.3-3 shows the cumulative 2010 base year emissions from all compressor stations, well pads, and the gas processing plant in the city of Fort Worth, combined.

Table 7.3-3. 2010 Base Year Cumulative Emissions Inventory

Pollutant	2010 Compressor Station Emissions (tons/yr)	2010 Well Pad Emissions (tons/yr)	2010 Processing Plant Emissions (tons/yr)	2010 Total Emissions (tons/yr)
TOC	2,988.29	16,302.29	1,293.26	20,583.84
VOCs	515.86	332.71	79.93	928.51
Total HAPs	304.95	152.36	47.32	504.63
Methane	2,080.99	15,795.98	1,152.60	19,029.56
PM	10.94	13.57	1.00	25.51
NO_x	588.88	266.76	87.74	943.38
CO	4,544.19	2,330.62	1,038.90	7,913.71
SO_2	2.17	0.97	0.34	3.48
Acenaphthene	4.96E-03	2.20E-03	7.69E-04	7.93E-03
Acenaphthylene	2.06E-02	9.14E-03	3.20E-03	3.30E-02
Acetaldehyde	3.12E+01	1.38E+01	4.84E+00	4.98E+01
Acetone	1.99E-02	1.23E+00	2.35E-04	1.25E+00
Acrolein	2.90E+01	1.29E+01	4.50E+00	4.64E+01
Anthracene	2.68E-03	1.19E-03	4.15E-04	4.28E-03
Benzene	7.31E+00	4.62E+00	1.14E+00	1.31E+01
Benzo (a) anthracene	1.25E-03	5.56E-04	1.94E-04	2.00E-03
Benzo (a) pyrene	2.12E-05	9.39E-06	3.29E-06	3.39E-05
Benzo (b) fluoranthene	6.19E-04	2.74E-04	9.60E-05	9.89E-04
Benzo (e) pyrene	1.55E-03	6.86E-04	2.40E-04	2.47E-03
Benzo (g,h,i) perylene	1.54E-03	6.84E-04	2.39E-04	2.47E-03
Benzo (k) fluoranthene	1.59E-05	7.04E-06	2.46E-06	2.54E-05
Biphenyl	7.90E-01	3.51E-01	1.23E-01	1.26E+00
Bromomethane	2.33E-04	2.43E-03	9.34E-07	2.67E-03
Butadiene, 1,3-	3.06E+00	1.37E+00	4.74E-01	4.90E+00
Butane	7.94E-01	4.07E+01	2.15E-01	4.17E+01
Butane, n-	1.77E+01	7.85E+00	2.75E+00	2.83E+01
Butanone (MEK), 2-	8.28E-04	1.51E-02	2.58E-05	1.59E-02
Carbon disulfide	4.32E-05	2.62E-03	7.25E-06	2.67E-03
Carbon tetrachloride	2.27E-01	1.03E-01	3.51E-02	3.64E-01
Chlorobenzene	1.66E-01	7.34E-02	2.57E-02	2.65E-01
Chlorodifluoromethane	9.05E-05	9.43E-04	3.62E-07	1.03E-03
Chloroethane	7.21E-03	5.58E-03	1.08E-03	1.39E-02
Chloroform	1.76E-01	7.79E-02	2.72E-02	2.81E-01
Chloromethane	1.34E-04	2.10E-03	1.07E-04	2.34E-03

Table 7.3-3. 2010 Base Year Cumulative Emissions Inventory (Continued)

Pollutant	2010 Compressor Station Emissions (tons/yr)	2010 Well Pad Emissions (tons/yr)	2010 Processing Plant Emissions (tons/yr)	2010 Total Emissions (tons/yr)
Chlorotoluene, 2-	3.12E-04	3.25E-03	1.25E-06	3.56E-03
Chrysene	2.58E-03	1.15E-03	4.01E-04	4.13E-03
Cyclohexane	1.18E+00	2.35E+00	1.91E-01	3.72E+00
Cyclopentane	8.46E-01	3.75E-01	1.31E-01	1.35E+00
Decane, n-	2.92E-03	3.67E-01	5.97E-05	3.70E-01
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	2.14E-04	2.24E-03	8.57E-07	2.45E-03
Dichlorodifluoromethane	1.80E-04	1.87E-03	7.19E-07	2.05E-03
Dichloroethane, 1,1-	1.46E-01	6.46E-02	2.26E-02	2.33E-01
Dichloropropene, 1,3-	1.63E-01	7.24E-02	2.53E-02	2.61E-01
Dodecane, n-	1.37E-03	4.00E-02	4.25E-05	4.14E-02
Ethane	3.91E+02	1.74E+02	6.07E+01	6.26E+02
Ethylbenzene	4.05E-01	3.00E-01	6.27E-02	7.68E-01
Ethylene dibromide	2.74E-01	1.21E-01	4.25E-02	4.37E-01
Ethylene dichloride	1.57E-01	6.98E-02	2.44E-02	2.51E-01
Ethyltoluene, 4-	2.27E-01	1.31E-01	8.90E-05	3.58E-01
Fluoranthene	4.14E-03	1.84E-03	6.42E-04	6.62E-03
Fluorene	2.11E-02	9.37E-03	3.28E-03	3.38E-02
Formaldehyde	2.06E+02	9.13E+01	3.19E+01	3.29E+02
Heptane	8.27E-03	6.58E+00	2.75E-03	6.59E+00
Hexachlorobutadiene	1.47E-03	2.12E-02	2.60E-05	2.27E-02
Hexane	4.16E+00	8.12E+00	6.52E-01	1.29E+01
Indeno(1,2,3-cd) pyrene	3.70E-05	1.64E-05	5.74E-06	5.92E-05
Isobutane	1.40E+01	6.20E+00	2.17E+00	2.23E+01
Isobutyraldehyde	1.63E+00	7.23E-01	2.53E-01	2.60E+00
Isopentane	2.03E-01	1.42E+01	4.54E-02	1.45E+01
Isopropylbenzene	3.86E-03	4.58E-02	5.43E-05	4.97E-02
Isopropyltoluene, 4-	8.59E-03	5.63E-02	5.43E-05	6.50E-02
Methyl alcohol	1.14E+01	5.06E+00	1.77E+00	1.82E+01
Methyl Naphthalene, 2-	1.24E-01	5.49E-02	1.92E-02	1.98E-01
Methyl-2-pentanone, 4- (MIBK)	3.98E-03	2.73E-02	1.65E-05	3.13E-02
Methylcyclohexane	4.59E+00	2.03E+00	7.11E-01	7.33E+00
Methylene chloride	5.49E-01	1.19E+00	8.53E-02	1.83E+00
Naphthalene	3.64E-01	1.82E-01	5.62E-02	6.02E-01
Nonane, n-	4.15E-01	5.21E+00	6.41E-02	5.69E+00
Octane, n-	1.31E+00	7.18E+00	2.04E-01	8.69E+00
Pentane, n-	9.78E+00	1.46E+01	1.54E+00	2.60E+01
Perylene	1.85E-05	8.22E-06	2.87E-06	2.96E-05
Phenanthrene	3.88E-02	1.72E-02	6.01E-03	6.20E-02
Phenol	1.57E-01	6.96E-02	2.43E-02	2.51E-01

Table 7.3-3. 2010 Base Year Cumulative Emissions Inventory (Continued)

Pollutant	2010 Compressor Station Emissions (tons/yr)	2010 Well Pad Emissions (tons/yr)	2010 Processing Plant Emissions (tons/yr)	2010 Total Emissions (tons/yr)
Polycyclic Aromatic Hydrocarbons (PAH)	5.26E-01	2.33E-01	8.15E-02	8.40E-01
Propane	1.56E+02	6.93E+01	2.42E+01	2.50E+02
Propylbenzene, n-	8.51E-02	6.94E-02	6.59E-05	1.55E-01
Propylene	4.78E-04	6.94E-03	6.06E-06	7.43E-03
Propylene dichloride	1.66E-01	7.37E-02	2.58E-02	2.66E-01
Pyrene	5.07E-03	2.25E-03	7.87E-04	8.11E-03
sec-Butylbenzene	1.07E-02	3.32E-02	3.95E-05	4.40E-02
Styrene	2.04E-01	9.31E-02	3.17E-02	3.29E-01
Tetrachloroethane, 1,1,2,2-	2.47E-01	1.10E-01	3.83E-02	3.95E-01
Tetrachloroethene	1.09E-03	6.69E-02	1.83E-04	6.81E-02
Toluene	3.64E+00	6.62E+00	5.63E-01	1.08E+01
Trichlorobenzene, 1,2,3-	2.51E-03	3.41E-02	3.74E-05	3.66E-02
Trichlorobenzene, 1,2,4-	1.69E-03	2.53E-02	3.39E-05	2.70E-02
Trichloroethane, 1,1,2-	1.96E-01	8.71E-02	3.05E-02	3.14E-01
Trichlorofluoromethane	2.64E-04	2.75E-03	1.06E-06	3.02E-03
Trimethylbenzene, 1,2,3-	1.32E-01	5.85E-02	2.05E-02	2.11E-01
Trimethylbenzene, 1,2,4-	1.40E+00	4.73E-01	6.43E-02	1.94E+00
Trimethylbenzene, 1,3,5-	3.75E-01	3.12E-01	1.97E-02	7.07E-01
Trimethylpentane, 2,2,4-	3.15E+00	1.42E+00	4.89E-01	5.06E+00
Undecane, n-	1.36E-03	8.20E-02	7.17E-05	8.34E-02
Vinyl acetate	2.17E-04	1.23E-02	3.64E-05	1.25E-02
Vinyl bromide	2.83E-04	2.95E-03	1.13E-06	3.23E-03
Vinyl chloride	9.22E-02	4.23E-02	1.43E-02	1.49E-01
Xylene, o	5.68E-03	2.73E-01	2.87E-04	2.79E-01
Xylenes (isomers)	9.99E-01	4.43E-01	1.55E-01	1.60E+00
Xylenes, m-, p-	9.89E-03	2.90E+00	1.01E-03	2.91E+00

7.4 2010 through 2018 Projected Emissions Inventories

Using the projected production data shown in Figure 7.2-2, growth factors (relative to the 2010 base year) were developed for years 2010 through 2018. Table 7.4-1 shows these factors, and indicates that projected peak production will occur in 2012 and 2013.

Table 7.4-1. Growth Factors for Years 2010–2018

Year	Growth Factor
2010	1.00
2011	1.06
2012	1.09
2013	1.09
2014	1.02
2015	0.95
2016	0.88
2017	0.82
2018	0.80

The growth factors shown in Table 7.4-1 were then used to project the 2010 base year emissions inventory to the years 2011 through 2018. Table 7.4-2 shows the resultant emissions inventory for each pollutant for each year.

Table 7.4-2. Projected Emissions for Years 2010–2018

Pollutant	2010 (tons/yr)	2011 (tons/yr)	2012 (tons/yr)	2013 (tons/yr)	2014 (tons/yr)	2015 (tons/yr)	2016 (tons/yr)	2017 (tons/yr)	2018 (tons/yr)
TOC	20,583.84	21,818.87	22,436.38	22,436.38	20,995.51	19,554.65	18,113.78	16,878.75	16,467.07
VOCs	928.51	984.22	1,012.07	1,012.07	947.08	882.08	817.09	761.38	742.80
Total HAPs	504.63	534.91	550.04	550.04	514.72	479.40	444.07	413.79	403.70
Methane	19,029.56	20,171.33	20,742.22	20,742.22	19,410.15	18,078.08	16,746.01	15,604.24	15,223.65
PM	25.51	27.04	27.81	27.81	26.02	24.24	22.45	20.92	20.41
NO_x	943.38	999.99	1,028.29	1,028.29	962.25	896.21	830.18	773.57	754.71
CO	7,913.71	8,388.53	8,625.94	8,625.94	8,071.98	7,518.02	6,964.06	6,489.24	6,330.97
SO_2	3.48	3.68	3.79	3.79	3.55	3.30	3.06	2.85	2.78
Acenaphthene	7.93E-03	8.40E-03	8.64E-03	8.64E-03	8.08E-03	7.53E-03	6.98E-03	6.50E-03	6.34E-03
Acenaphthylene	3.30E-02	3.49E-02	3.59E-02	3.59E-02	3.36E-02	3.13E-02	2.90E-02	2.70E-02	2.64E-02
Acetaldehyde	4.98E+01	5.28E+01	5.43E+01	5.43E+01	5.08E+01	4.73E+01	4.38E+01	4.09E+01	3.99E+01
Acetone	1.25E+00	1.33E+00	1.37E+00	1.37E+00	1.28E+00	1.19E+00	1.10E+00	1.03E+00	1.00E+00
Acrolein	4.64E+01	4.91E+01	5.05E+01	5.05E+01	4.73E+01	4.40E+01	4.08E+01	3.80E+01	3.71E+01
Anthracene	4.28E-03	4.54E-03	4.66E-03	4.66E-03	4.36E-03	4.07E-03	3.77E-03	3.51E-03	3.42E-03
Benzene	1.31E+01	1.38E+01	1.42E+01	1.42E+01	1.33E+01	1.24E+01	1.15E+01	1.07E+01	1.05E+01
Benzo (a) anthracene	2.00E-03	2.12E-03	2.18E-03	2.18E-03	2.04E-03	1.90E-03	1.76E-03	1.64E-03	1.60E-03
Benzo (a) pyrene	3.39E-05	3.59E-05	3.69E-05	3.69E-05	3.45E-05	3.22E-05	2.98E-05	2.78E-05	2.71E-05
Benzo (b) fluoranthene	9.89E-04	1.05E-03	1.08E-03	1.08E-03	1.01E-03	9.40E-04	8.71E-04	8.11E-04	7.91E-04
Benzo (e) pyrene	2.47E-03	2.62E-03	2.70E-03	2.70E-03	2.52E-03	2.35E-03	2.18E-03	2.03E-03	1.98E-03
Benzo (g,h,i) perylene	2.47E-03	2.62E-03	2.69E-03	2.69E-03	2.52E-03	2.34E-03	2.17E-03	2.02E-03	1.97E-03
Benzo (k) fluoranthene	2.54E-05	2.69E-05	2.77E-05	2.77E-05	2.59E-05	2.41E-05	2.23E-05	2.08E-05	2.03E-05
Biphenyl	1.26E+00	1.34E+00	1.38E+00	1.38E+00	1.29E+00	1.20E+00	1.11E+00	1.04E+00	1.01E+00
Bromomethane	2.67E-03	2.83E-03	2.91E-03	2.91E-03	2.72E-03	2.53E-03	2.35E-03	2.19E-03	2.13E-03
Butadiene, 1,3-	4.90E+00	5.19E+00	5.34E+00	5.34E+00	5.00E+00	4.65E+00	4.31E+00	4.02E+00	3.92E+00
Butane	4.17E+01	4.42E+01	4.55E+01	4.55E+01	4.26E+01	3.97E+01	3.67E+01	3.42E+01	3.34E+01

Table 7.4-2. Projected Emissions for Years 2010–2018 (Continued)

Pollutant	2010 (tons/yr)	2011 (tons/yr)	2012 (tons/yr)	2013 (tons/yr)	2014 (tons/yr)	2015 (tons/yr)	2016 (tons/yr)	2017 (tons/yr)	2018 (tons/yr)
Butane, n-	2.83E+01	3.00E+01	3.09E+01	3.09E+01	2.89E+01	2.69E+01	2.49E+01	2.32E+01	2.26E+01
Butanone (Methyl Ethyl Ketone), 2-	1.59E-02	1.69E-02	1.74E-02	1.74E-02	1.63E-02	1.51E-02	1.40E-02	1.31E-02	1.27E-02
Carbon disulfide	2.67E-03	2.83E-03	2.91E-03	2.91E-03	2.73E-03	2.54E-03	2.35E-03	2.19E-03	2.14E-03
Carbon tetrachloride	3.64E-01	3.86E-01	3.97E-01	3.97E-01	3.72E-01	3.46E-01	3.21E-01	2.99E-01	2.91E-01
Chlorobenzene	2.65E-01	2.80E-01	2.88E-01	2.88E-01	2.70E-01	2.51E-01	2.33E-01	2.17E-01	2.12E-01
Chlorodifluoromethane	1.03E-03	1.10E-03	1.13E-03	1.13E-03	1.05E-03	9.82E-04	9.10E-04	8.48E-04	8.27E-04
Chloroethane	1.39E-02	1.47E-02	1.51E-02	1.51E-02	1.41E-02	1.32E-02	1.22E-02	1.14E-02	1.11E-02
Chloroform	2.81E-01	2.98E-01	3.06E-01	3.06E-01	2.86E-01	2.67E-01	2.47E-01	2.30E-01	2.25E-01
Chloromethane	2.34E-03	2.48E-03	2.55E-03	2.55E-03	2.39E-03	2.22E-03	2.06E-03	1.92E-03	1.87E-03
Chlorotoluene, 2-	3.56E-03	3.77E-03	3.88E-03	3.88E-03	3.63E-03	3.38E-03	3.13E-03	2.92E-03	2.85E-03
Chrysene	4.13E-03	4.38E-03	4.50E-03	4.50E-03	4.21E-03	3.92E-03	3.63E-03	3.39E-03	3.30E-03
Cyclohexane	3.72E+00	3.95E+00	4.06E+00	4.06E+00	3.80E+00	3.54E+00	3.28E+00	3.05E+00	2.98E+00
Cyclopentane	1.35E+00	1.43E+00	1.47E+00	1.47E+00	1.38E+00	1.29E+00	1.19E+00	1.11E+00	1.08E+00
Decane, n-	3.70E-01	3.92E-01	4.03E-01	4.03E-01	3.77E-01	3.51E-01	3.25E-01	3.03E-01	2.96E-01
Dichloro-1,1,2,2-tetrafluoroethane, 1,2-	2.45E-03	2.60E-03	2.67E-03	2.67E-03	2.50E-03	2.33E-03	2.16E-03	2.01E-03	1.96E-03
Dichlorodifluoromethane	2.05E-03	2.18E-03	2.24E-03	2.24E-03	2.09E-03	1.95E-03	1.81E-03	1.68E-03	1.64E-03
Dichloroethane, 1,1-	2.33E-01	2.47E-01	2.54E-01	2.54E-01	2.38E-01	2.21E-01	2.05E-01	1.91E-01	1.86E-01
Dichloropropene, 1,3-	2.61E-01	2.77E-01	2.85E-01	2.85E-01	2.66E-01	2.48E-01	2.30E-01	2.14E-01	2.09E-01
Dodecane, n-	4.14E-02	4.39E-02	4.52E-02	4.52E-02	4.23E-02	3.94E-02	3.65E-02	3.40E-02	3.31E-02
Ethane	6.26E+02	6.63E+02	6.82E+02	6.82E+02	6.38E+02	5.94E+02	5.51E+02	5.13E+02	5.01E+02
Ethylbenzene	7.68E-01	8.14E-01	8.37E-01	8.37E-01	7.83E-01	7.29E-01	6.75E-01	6.29E-01	6.14E-01
Ethylene dibromide	4.37E-01	4.64E-01	4.77E-01	4.77E-01	4.46E-01	4.16E-01	3.85E-01	3.59E-01	3.50E-01
Ethylene dichloride	2.51E-01	2.67E-01	2.74E-01	2.74E-01	2.57E-01	2.39E-01	2.21E-01	2.06E-01	2.01E-01
Ethyltoluene, 4-	3.58E-01	3.80E-01	3.90E-01	3.90E-01	3.65E-01	3.40E-01	3.15E-01	2.94E-01	2.86E-01

Table 7.4-2. Projected Emissions for Years 2010–2018 (Continued)

Pollutant	2010 (tons/yr)	2011 (tons/yr)	2012 (tons/yr)	2013 (tons/yr)	2014 (tons/yr)	2015 (tons/yr)	2016 (tons/yr)	2017 (tons/yr)	2018 (tons/yr)
Fluoranthene	6.62E-03	7.01E-03	7.21E-03	7.21E-03	6.75E-03	6.28E-03	5.82E-03	5.42E-03	5.29E-03
Fluorene	3.38E-02	3.58E-02	3.68E-02	3.68E-02	3.45E-02	3.21E-02	2.97E-02	2.77E-02	2.70E-02
Formaldehyde	3.29E+02	3.49E+02	3.59E+02	3.59E+02	3.36E+02	3.13E+02	2.89E+02	2.70E+02	2.63E+02
Heptane	6.59E+00	6.99E+00	7.18E+00	7.18E+00	6.72E+00	6.26E+00	5.80E+00	5.41E+00	5.27E+00
Hexachlorobutadiene	2.27E-02	2.41E-02	2.47E-02	2.47E-02	2.31E-02	2.16E-02	2.00E-02	1.86E-02	1.82E-02
Hexane	1.29E+01	1.37E+01	1.41E+01	1.41E+01	1.32E+01	1.23E+01	1.14E+01	1.06E+01	1.03E+01
Indeno(1,2,3-cd) pyrene	5.92E-05	6.27E-05	6.45E-05	6.45E-05	6.04E-05	5.62E-05	5.21E-05	4.85E-05	4.73E-05
Isobutane	2.23E+01	2.37E+01	2.44E+01	2.44E+01	2.28E+01	2.12E+01	1.97E+01	1.83E+01	1.79E+01
Isobutyraldehyde	2.60E+00	2.76E+00	2.84E+00	2.84E+00	2.66E+00	2.47E+00	2.29E+00	2.14E+00	2.08E+00
Isopentane	1.45E+01	1.54E+01	1.58E+01	1.58E+01	1.48E+01	1.38E+01	1.28E+01	1.19E+01	1.16E+01
Isopropylbenzene	4.97E-02	5.26E-02	5.41E-02	5.41E-02	5.07E-02	4.72E-02	4.37E-02	4.07E-02	3.97E-02
Isopropyltoluene, 4-	6.50E-02	6.89E-02	7.08E-02	7.08E-02	6.63E-02	6.17E-02	5.72E-02	5.33E-02	5.20E-02
Methyl alcohol	1.82E+01	1.93E+01	1.99E+01	1.99E+01	1.86E+01	1.73E+01	1.60E+01	1.50E+01	1.46E+01
Methyl Naphthalene, 2-	1.98E-01	2.10E-01	2.16E-01	2.16E-01	2.02E-01	1.88E-01	1.74E-01	1.62E-01	1.58E-01
Methyl-2-pentanone, 4- (Methyl Isobutyl Ketone)	3.13E-02	3.32E-02	3.41E-02	3.41E-02	3.19E-02	2.97E-02	2.76E-02	2.57E-02	2.51E-02
Methylcyclohexane	7.33E+00	7.77E+00	7.99E+00	7.99E+00	7.48E+00	6.96E+00	6.45E+00	6.01E+00	5.86E+00
Methylene chloride	1.83E+00	1.94E+00	1.99E+00	1.99E+00	1.86E+00	1.74E+00	1.61E+00	1.50E+00	1.46E+00
Naphthalene	6.02E-01	6.38E-01	6.56E-01	6.56E-01	6.14E-01	5.72E-01	5.30E-01	4.94E-01	4.82E-01
Nonane, n-	5.69E+00	6.03E+00	6.20E+00	6.20E+00	5.80E+00	5.40E+00	5.01E+00	4.66E+00	4.55E+00
Octane, n-	8.69E+00	9.22E+00	9.48E+00	9.48E+00	8.87E+00	8.26E+00	7.65E+00	7.13E+00	6.96E+00
Pentane, n-	2.60E+01	2.75E+01	2.83E+01	2.83E+01	2.65E+01	2.47E+01	2.28E+01	2.13E+01	2.08E+01
Perylene	2.96E-05	3.14E-05	3.23E-05	3.23E-05	3.02E-05	2.81E-05	2.61E-05	2.43E-05	2.37E-05
Phenanthrene	6.20E-02	6.57E-02	6.76E-02	6.76E-02	6.32E-02	5.89E-02	5.45E-02	5.08E-02	4.96E-02
Phenol	2.51E-01	2.66E-01	2.73E-01	2.73E-01	2.56E-01	2.38E-01	2.21E-01	2.06E-01	2.01E-01

Table 7.4-2. Projected Emissions for Years 2010–2018 (Continued)

Pollutant	2010 (tons/yr)	2011 (tons/yr)	2012 (tons/yr)	2013 (tons/yr)	2014 (tons/yr)	2015 (tons/yr)	2016 (tons/yr)	2017 (tons/yr)	2018 (tons/yr)
Polycyclic Aromatic Hydrocarbons (PAH)	8.40E-01	8.91E-01	9.16E-01	9.16E-01	8.57E-01	7.98E-01	7.39E-01	6.89E-01	6.72E-01
Propane	2.50E+02	2.65E+02	2.72E+02	2.72E+02	2.55E+02	2.37E+02	2.20E+02	2.05E+02	2.00E+02
Propylbenzene, n-	1.55E-01	1.64E-01	1.68E-01	1.68E-01	1.58E-01	1.47E-01	1.36E-01	1.27E-01	1.24E-01
Propylene	7.43E-03	7.87E-03	8.09E-03	8.09E-03	7.57E-03	7.05E-03	6.53E-03	6.09E-03	5.94E-03
Propylene dichloride	2.66E-01	2.82E-01	2.90E-01	2.90E-01	2.71E-01	2.53E-01	2.34E-01	2.18E-01	2.13E-01
Pyrene	8.11E-03	8.59E-03	8.83E-03	8.83E-03	8.27E-03	7.70E-03	7.13E-03	6.65E-03	6.48E-03
sec-Butylbenzene	4.40E-02	4.66E-02	4.80E-02	4.80E-02	4.49E-02	4.18E-02	3.87E-02	3.61E-02	3.52E-02
Styrene	3.29E-01	3.49E-01	3.59E-01	3.59E-01	3.36E-01	3.13E-01	2.90E-01	2.70E-01	2.63E-01
Tetrachloroethane, 1,1,2,2-	3.95E-01	4.19E-01	4.31E-01	4.31E-01	4.03E-01	3.75E-01	3.48E-01	3.24E-01	3.16E-01
Tetrachloroethene	6.81E-02	7.22E-02	7.43E-02	7.43E-02	6.95E-02	6.47E-02	6.00E-02	5.59E-02	5.45E-02
Toluene	1.08E+01	1.15E+01	1.18E+01	1.18E+01	1.10E+01	1.03E+01	9.52E+00	8.87E+00	8.66E+00
Trichlorobenzene, 1,2,3-	3.66E-02	3.88E-02	3.99E-02	3.99E-02	3.73E-02	3.48E-02	3.22E-02	3.00E-02	2.93E-02
Trichlorobenzene, 1,2,4-	2.70E-02	2.87E-02	2.95E-02	2.95E-02	2.76E-02	2.57E-02	2.38E-02	2.22E-02	2.16E-02
Trichloroethane, 1,1,2-	3.14E-01	3.33E-01	3.42E-01	3.42E-01	3.20E-01	2.98E-01	2.76E-01	2.58E-01	2.51E-01
Trichlorofluoromethane	3.02E-03	3.20E-03	3.29E-03	3.29E-03	3.08E-03	2.87E-03	2.65E-03	2.47E-03	2.41E-03
Trimethylbenzene, 1,2,3-	2.11E-01	2.24E-01	2.30E-01	2.30E-01	2.15E-01	2.00E-01	1.86E-01	1.73E-01	1.69E-01
Trimethylbenzene, 1,2,4-	1.94E+00	2.05E+00	2.11E+00	2.11E+00	1.98E+00	1.84E+00	1.70E+00	1.59E+00	1.55E+00
Trimethylbenzene, 1,3,5-	7.07E-01	7.49E-01	7.70E-01	7.70E-01	7.21E-01	6.71E-01	6.22E-01	5.79E-01	5.65E-01
Trimethylpentane, 2,2,4-	5.06E+00	5.37E+00	5.52E+00	5.52E+00	5.16E+00	4.81E+00	4.46E+00	4.15E+00	4.05E+00
Undecane, n-	8.34E-02	8.85E-02	9.10E-02	9.10E-02	8.51E-02	7.93E-02	7.34E-02	6.84E-02	6.68E-02
Vinyl acetate	1.25E-02	1.33E-02	1.37E-02	1.37E-02	1.28E-02	1.19E-02	1.10E-02	1.03E-02	1.00E-02
Vinyl bromide	3.23E-03	3.43E-03	3.52E-03	3.52E-03	3.30E-03	3.07E-03	2.84E-03	2.65E-03	2.59E-03
Vinyl chloride	1.49E-01	1.58E-01	1.62E-01	1.62E-01	1.52E-01	1.41E-01	1.31E-01	1.22E-01	1.19E-01
Xylene, o	2.79E-01	2.95E-01	3.04E-01	3.04E-01	2.84E-01	2.65E-01	2.45E-01	2.28E-01	2.23E-01
Xylenes (isomers)	1.60E+00	1.69E+00	1.74E+00	1.74E+00	1.63E+00	1.52E+00	1.41E+00	1.31E+00	1.28E+00
Xylenes, m-, p-	2.91E+00	3.08E+00	3.17E+00	3.17E+00	2.97E+00	2.76E+00	2.56E+00	2.38E+00	2.33E+00

7.5 Full Build-Out Estimates Conclusions

Emissions from the production of natural gas in the city of Fort Worth are projected to peak in 2012 and 2013, and in 2015 are projected to decrease to below 2010 levels. The projected peak emission levels occurring in 2012 and 2013 are expected to be 9% higher than emissions during the 2010 baseline year.

As discussed above, natural gas production is primarily dependent on the price that producers will receive. This concept is reflected in the demonstrated relationship between drilling rig and permit activity and natural gas prices. If the wellhead price for natural gas remains relatively low, as it is now, producers do not have economic incentive to invest in new exploration and drilling. Under this scenario, it is expected that total production from currently producing wells and leased wells not yet in production (but currently in development) will increase in the short term, followed by a slow decline.

Should wellhead prices for natural gas unexpectedly increase in future years, natural gas production and associated air emissions may be greater than projected. However, it is important to note that the longer natural gas prices remain flat, the lower the peak production rate will be, even with a spike in the price of natural gas. This is because the overall size of the resource, or the reserves, is finite, and the reserve decreases in size as each year passes. The data used in this analysis shows that, based on a reserve estimate of 30 trillion cubic feet of natural gas in the Barnett Shale, approximately one-third has already been depleted, and over 75% will have been recovered by the end of 2018.

Key Point: Barnett Shale
Based on a reserve estimate of 30 trillion cubic feet of natural gas, over 75% of the available natural gas in the Barnett Shale is projected to be recovered by the end of 2018.

8.0 Conclusions and Recommendations

Commencing with planning activities in July 2010 and field activities in August 2010, the Fort Worth Natural Gas Air Quality Study was a multi-phase project aimed at characterizing the air quality impacts of natural gas exploration and production, determining any potential health risks associated with those impacts, quantifying the total amount of pollutants being emitted, and determining if natural gas sites were in compliance with air quality regulations.

Two primary raw data collection activities were used: 1) an ambient air monitoring network, and 2) a systematic point source testing program. Point source testing data were then used to perform air dispersion modeling, and measured and modeled air concentrations were used in the public health evaluation. Each of these tasks was designed to help city officials answer the following questions:

- How much air pollution is being released by natural gas exploration in Fort Worth?
- Do sites comply with environmental regulation?
- How do releases from these sites affect off-site air pollution levels?
- Are the city's required setbacks for these sites adequate to protect public health?

Section 8.1 provides a summary of the conclusions for each task of this study, Section 8.2 includes answers to the four primary study questions, and Section 8.3 provides specific recommendations for ensuring that emissions from natural gas sites do not cause unhealthy air pollution levels.

8.1 Task Level Conclusions

As discussed previously, the Fort Worth Natural Gas Air Quality Study was multi-faceted and included Ambient Air Monitoring, Point Source Testing, Air Dispersion Modeling, a Public Health Evaluation, a Regulatory Assessment, and Full Build-Out Estimates. The key findings for each of these tasks are provided below.

Key findings of the Ambient Air Monitoring task include:

- 169 ambient air samples from 8 locations in Fort Worth were collected and analyzed, resulting in over 15,000 ambient air data points generated for this study.
- Methane, ethane, propane, and butane were the pollutants found at highest concentrations. However, more toxic pollutants (e.g., benzene) were also found, but generally at much lower levels.
- Concentrations measured at Site S-4 (located in a high-level activity area near compressor stations, well pads, and mobile sources) were generally higher than at the other sites.
- Concentrations measured at Sites S-6 and S-7 (both located within 350 of active well pads) were surprisingly low relative to the other sites.

- Wind patterns observed during the sampling period were consistent with historical wind patterns, indicating proper placement of the ambient air monitors.

Key findings of the Point Source Testing task include:

- At 96 sites, no emissions were detected by the IR camera. Most of these sites contained 3 wells or less.
- The largest source of fugitive emissions detected with the IR camera was leaking tank thief hatches.
- Pneumatic Valve Controllers were the most frequent emission sources encountered at well pads and compressor stations.
- Compressor engines have a significant impact on emissions, especially the large line compressors found at compressor stations.
- There was little difference in average TOC emissions between dry and wet gas sites, but average VOC and HAP emissions from wet gas sites proved to be considerably higher.

Key findings of the Public Health Evaluation task (including analysis of the emissions concentrations predicted under the Air Dispersion Modeling task) include:

- Benzene emissions from tanks could lead to air pollution levels slightly higher than TCEQ's short-term ESL, but only in very close proximity to the highest-emitting tanks.
- Large line engines can emit acrolein and formaldehyde at levels that would cause offsite ambient air concentrations to exceed TCEQ's short-term and long-term screening levels over various distances. This finding is based entirely on estimated emission rates.
- Trace levels of halogenated hydrocarbons detected during the ambient air monitoring program are not likely to be attributable to emissions from natural gas exploration and production activity.

Key findings of the Regulatory Assessment task include:

- Five sites had cumulative VOC emissions greater than the PBR trigger level of 25 tons/yr and/or CO emissions greater than the major source threshold of 100 tons/yr.

Key findings of the Full Build-Out Estimates task include:

- Emissions from the production of natural gas in the city of Fort Worth are projected to peak in 2012 and 2013 at 9% above 2010 levels.

- Total VOC emissions from the production of natural gas in the city of Fort Worth are estimated to peak at approximately 1,012 tons per year in 2012.
- Total HAP emissions from the production of natural gas in the city of Fort Worth are estimated to peak at approximately 550 tons per year in 2012.
- Total methane emissions from the production of natural gas in the city of Fort Worth are estimated to peak at approximately 20,742 tons per year in 2012.

8.2 Study Question Answers

How much air pollution is being released by natural gas exploration in Fort Worth?

During the point source testing, field personnel determined the amount of air pollution released at individual well pads, compressor stations, and other natural gas processing facilities by visiting 388sites and testing the equipment at each site for emissions. Table 8.2-1 shows the average emissions of TOC, VOCs, and HAPs for each site type that was visited. In the table, the emissions of HAPs are a subset of emissions of VOCs, and the emissions of VOCs are a subset of the TOC emissions. The primary air pollutant emitted at all sites was methane, which is not considered a VOC but constitutes over 94% of the TOC estimate for all sites combined.

Table 8.2-1. Average Emissions by Site Type

Site Type	Average TOC (tons/yr)	Average VOC (tons/yr)	Average HAP (tons/yr)
Well Pad	16	0.07	0.02
Well Pad with Compressor(s)	68	2	0.9
Compressor Station	99	17	10
Processing Facility	1,293	80	47
Saltwater Treatment Facility	1.5	0.65	0.4

Under Task 7 (full build-out estimates), the results of the point source testing task were used to estimate total emissions from the gas processing plant and all well pads and compressor stations in the city of Fort Worth. Table 8.2-2 summarizes city-wide emissions from these operations.

Table 8.2-2. Total City-Wide Emissions from Natural Gas Production Activity, by Pollutant Category

Pollutant	Total Compressor Station Emissions (tons/yr)	Total Well Pad Emissions (tons/yr)	Total Gas Processing Plant Emissions (tons/yr)	Total Emissions (tons/yr)
TOC	2,988	16,302	1,293	20,584
VOCs	516	333	80	929
Total HAPs	305	152	47	505

Table 8.2-2. Total City-Wide Emissions from Natural Gas Production Activity, by Pollutant Category (Continued)

Pollutant	Total Compressor Station Emissions (tons/yr)	Total Well Pad Emissions (tons/yr)	Total Gas Processing Plant Emissions (tons/yr)	Total Emissions (tons/yr)
Methane	2,081	15,796	1,152.60	19,030
PM	10.94	13.57	1.00	25.51
NO_x	588.88	266.76	87.74	943.38
CO	4,544.19	2,330.62	1,038.90	7,913.71
SO_2	2.17	0.97	0.34	3.48

Do sites comply with environmental regulations?

A number of federal and state air quality regulations could apply to well pads and compressor stations. Each of the potentially applicable rules is discussed in Section 6. While a comprehensive, site-specific regulatory analysis was not possible for each site visited, some broad observations have been made based on the results of the point source testing.

In particular, the primary environmental regulation that would be applicable to the facilities visited under Task 3 is TCEQ's permit-by-rule for oil and gas handling and production facilities. This regulation allows certain sources a streamlined permitting process if they have emissions below 25 tpy of VOCs and 250 tpy of CO. Sites with emissions of CO greater than 100 tpy, of any single HAP greater than 10 tpy, or any combination of HAPs greater than 25 tpy would also be required to operate under a Title V operating permit.

As a result of the point source testing task, five potential sources were identified with site-wide emissions estimates exceeding these thresholds. These larger emitting sites generally had more compressor engine capacity, resulting in higher VOC and CO emissions when compared to sites with fewer, or smaller, engines. Table 8.2-3 lists the sites with estimated emissions exceeding regulatory thresholds.

Table 8.2-3. Sources Above Regulatory Thresholds

Site ID	Site Type	VOC (tons/yr)	CO (tons/yr)	Total HAP (tons/yr)	Formaldehyde (tons/yr)
PS-159	Processing Facility	80[a]	1,039[b, c]	47[d]	32[e]
PS-118	Compressor Station	43[a]	270[b, c]	25[d]	17[e]
PS-119	Compressor Station	38[a]	240[c]	22	15[e]
PS-127	Compressor Station	24	545[b, c]	14	9
238	Well Pad	14	219[c]	8	6

[a] This site potentially exceeds the 25 tpy VOC threshold under 30 TAC 106, Subchapter O, Section 106.352.
[b] This site potentially exceeds the 250 tpy CO threshold under 30 TAC 106, Subchapter O, Section 106.352.
[c] This site potentially exceeds the 100 tpy CO threshold under the federal Title V Operating Permit Program.
[d] This site potentially exceeds the 25 tpy total HAP threshold under the federal Title V Operating Permit Program.
[e] This site potentially exceeds the 10 tpy single HAP threshold under the federal Title V Operating Permit Program.

How do releases from these sites affect off-site air pollution levels?

Under Task 2 of this project, ambient air monitoring was conducted to measure concentrations of selected air toxics present in the air outside the property boundaries of air emissions sources such as a natural gas well pads and compressor stations. Over 160 air samples were collected in September and October of 2010, resulting in over 15,000 data points being generated for this study. Table 8.2-4 provides a summary of these measured off-site air pollution levels for selected pollutants.

Table 8.2-4. Off-Site Air Pollution Levels for Selected Pollutants as Determined Through the Ambient Air Monitoring Network

Pollutant	Number of Detects	Number of Samples	Average of Detects (ppbv)[a]	Minimum Detected Value (ppbv)	Maximum Detected Value (ppbv)
Acetaldehyde	40	40	2.813	0.83	9.06
Benzene	121	129	0.291	0.0635	1.83
Butadiene, 1,3-	86	129	0.057	0.01	0.304
Carbon disulfide	92	92	0.243	0.008	1.64
Carbon tetrachloride	126	129	0.112	0.053	0.142
Formaldehyde	40	40	0.931	0.41	4.45
Tetrachloroethylene	81	129	0.043	0.01	0.218

[a] These averages only include the average of the detected values for each pollutant.

Under Task 4 of this project, a dispersion modeling was used to predict the downwind concentrations of pollutants emitted from well pads and compressor stations. The modeling provided valuable insights into air quality at locations where, and at times when, ambient air samples were not collected. The modeling was conducted for typical and "worst-case" emissions scenarios. Table 8.2-5 summarizes predicted off-site air concentrations for selected pollutants.

Table 8.2-5. Off-Site Air Pollution Levels for Selected Pollutants as Determined Through Air Dispersion Modeling

Pollutant	Highest Estimated 1-Hour Average Concentration Beyond Well Pad Fence Lines (ppbv)	Highest Estimated 24-Hour Average Concentration Beyond Well Pad Fence Lines (ppbv)	Highest Estimated Annual Average Concentration at Locations 200 Feet Beyond Fence Lines (ppbv)
Acrolein	2.62	1.43	0.33
Benzene	59.5	13.4	0.24
Butadiene, 1,3	0.29	0.16	0.036
Formaldehyde	34.7	18.9	4.34

Are the city's required setbacks for these sites adequate to protect public health?

ERG conducted a health screening evaluation to evaluate the health implications of air emissions from natural gas exploration and production activity. This evaluation was based on protective health-based screening values, primarily those published by TCEQ, though consideration was also given to EPA and ATSDR values for the pollutants of greatest concern. The ambient air monitoring data revealed no site-related pollutants with 24-hour average concentrations or program-average concentrations above TCEQ's health-based screening levels. The modeling analysis identified three pollutants—acrolein, benzene, and formaldehyde—with estimated 1-hour average or annual average concentrations above screening levels at some offsite locations. This was most prevalent for sites with multiple, large line compressor engines. However, due to the highly protective nature of the health-based screening values, none of the estimated concentrations reached levels expected to be associated with adverse health effects.

The modeling analysis served as the basis for evaluating the adequacy of setback distances. For the overwhelming majority of sites considered in this study, the modeling results indicate that Fort Worth's 600-foot setback distance is adequate. More specifically, for sites with no engines and for sites with smaller lift engines, no pollutants were found to have estimated 1-hour maximum or annual average concentrations above TCEQ's applicable health-based screening levels beyond the setback distances. For the relatively few sites with multiple, large line engines, the modeling analysis found some areas beyond the setbacks to have estimated acrolein and formaldehyde concentrations greater than TCEQ's ESLs, though not reaching concentrations expected to cause adverse health effects. For both pollutants, ERG's modeling is based entirely on estimated emission rates, and not measured values. This underscores the value of obtaining more detailed acrolein and formaldehyde emissions data for line engines and focused ambient air monitoring to validate these findings. Such studies would provide greater confidence in the adequacy and protectiveness of the city's setbacks.

8.3 Recommendations

Although this study did not reveal any significant health threats beyond setback distances, it is important to remember that the sources of concern for this project—natural gas exploration and production activity—are located in residential settings throughout a metropolitan area. Though the most toxic pollutants these sources emit are released in relatively low quantities, all reasonable precautions to reduce emissions from the well pads and compressor stations should be made. This is particularly important for tanks and line compressor engines, because these two sources accounted for the greatest portion of the risks observed for the pollutants selected for further evaluation. Such precautions would include the installation and operation of the following air pollution control equipment:

Vapor Recovery Units on storage tanks – storage tanks are the highest source of benzene emissions, and vapor recovery units could reduce these emissions by 90% or more. This would be most beneficial at wet gas sites with higher condensate production.

3-way catalysts and/or catalytic oxidizers on compressor station compressor engines – the large compressor engines located at compressor stations are the main source of acrolein and formaldehyde, the two pollutants of greatest concern from a public health perspective. 3-way catalysts are primarily NO_x control technologies, but have a co-benefit of reducing CO and VOC emissions. Catalytic oxidizers are used to control CO and VOC emissions.

Electric compressor engines – As many of the compressor stations in Fort Worth are located in an urban setting, easy access to the electric grid also provides an opportunity to eliminate emissions from compressor engines completely through the use of electric motors.

Low bleed or no bleed pneumatic valve controllers – Pneumatic valve controllers were the most frequent fugitive emission source found during the point source testing task. Under EPA's voluntary Natural Gas STAR Program, the use of low bleed valve controllers and electric valve controllers is encouraged and has proven effective in reducing VOC (and methane) emissions from natural gas operations.

In addition to these air pollution control equipment recommendations, enhanced inspection and maintenance of equipment at natural gas sites can help ensure that preventable emissions are greatly reduced or eliminated. At a small subset of sites, the point source testing team noted signs of malfunctioning equipment that likely caused increased emissions. For example, some hatches atop tanks were ajar and not closed, and corrosion had apparently caused a hole to form on the roof of at least one tank.

The emission estimates used in this study for acrolein and formaldehyde are based on the best emissions information currently available for compressor engines – emission factors from U.S. EPA's Compilation of Air Pollutant Emission Factors (AP-42).[28] As control of acrolein and formaldehyde emissions from compressor engines is not explicitly required under any current regulation, no control efficiency was assumed in our estimates. Options available to confirm our assumptions and findings with regards to these pollutants include:

- Contact compressor station owners and operators to establish the frequency at which their engines have installed controls, and to obtain any existing stack testing results
- Analyze the findings of TCEQ's Phase II Barnett Shale Area Special Inventory efforts to establish the frequency at which compressor engines have installed controls
- Conduct point source stack testing at the exhaust of compressor engines to characterize acrolein and formaldehdye emissions
- Conduct focused ambient air monitoring of acrolein and formaldehdye emissions in close proximity to the larger compressor stations

Finally, ERG fully supports continued ambient air monitoring in and around the city of Fort Worth in order to confirm the key findings of this report. In particular, the results of TCEQ's ongoing monitoring efforts in the Barnett Shale should be monitored for any changes in air quality in Fort Worth as worsening air quality may require additional response such as additional controls or site maintenance requirements.

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