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.