APPENDIX 5

CONDENSATE TANK OIL AND GAS ACTIVITIES

CONDENSATE TANK OIL AND GAS ACTIVITIES

FINAL REPORT

Prepared for:

Texas Commission on Environmental Quality

Air Quality Division

Prepared by:

Eastern Research Group, Inc.

October 10, 2012

ERG N0. 0292.01.011.001

Condensate Tank Oil and Gas Activities

FINAL REPORT

Prepared for:

Miles Whitten
Texas Commission on Environmental Quality
P. O. Box 13087
Austin, TX 78711-3087

Prepared by:

Mike Pring
Eastern Research Group, Inc.
1600 Perimeter Park Dr., Suite 200
Morrisville, NC 27560

October 10, 2012

Table of Contents

Executive Summary v

1.0 Introduction 1-1

2.0 VOC Emissions From Condensate Storage Tanks 2-1

2.1 Condensate Production 2-1

2.2 Literature Review 2-2

2.2.1 Emissions Data Derived from Testing 2-3

2.2.2 Comparisons of Emissions Data Derived from Testing with Emissions Estimates Derived from Models/Software Programs 2-5

2.2.3 Emissions Estimates Derived Solely from Models/Software Programs 2-10

2.2.4 Other Studies 2-12

2.3 Emission Factor Development Using the Barnett Shale Area Special Inventory, Phase II (2009) 2-13

2.4 Phone Survey of Area Sources 2-16

2.4.1 Analysis of Data Collected via Phone Survey 2-18

2.4.2 Use of Vapor Recovery and Controls to Reduce Emissions 2-20

2.4.3 Self-Selection Bias 2-21

2.4.4 Innovative Practices that Lower Area Emissions 2-21

2.5 Weighting the Data 2-22

2.5.1 Weighting Data based on Method 2-22

2.5.2 Weighting Data based on Production 2-23

2.6 Regional Emission Factors 2-24

2.7 Accounting for the Effect of Recovery and Control Devices 2-35

2.7.1 Barnett Shale 2-35

2.7.2 HGB, BPA, and Haynesville Shale 2-35

2.7.3 Calculation of Control Factor 2-36

2.7.4 ERG 2012 Survey 2-37

2.8 Summary of Findings and Recommended Emission Factors 2-39

3.0 Hazardous Air Pollutant Emissions from Condensate Storage Tanks 3-1

3.1 BTEX Emissions Data Derived from Testing 3-1

3.2 BTEX Emissions Data Derived from the Barnett Shale Area Special Inventory, Phase II (2009) 3-3

3.3 BTEX Emissions Data Derived from E&P TANK Reports Submitted in Response to the ERG Survey 3-4

3.4 Summary of Findings and Recommended Regional BTEX Emission Factors 3-8

4.0 Recommendations for Future Condensate Tank Investigations 4-1

5.0 Natural Gas Composition Data Collection and Analysis 5-1

Attachment A Survey Letter

Attachment B Survey Materials – Word Table and Excel Spreadsheet

Attachment C Condensate Tank Emissions Data (Condensate_Tank_Data.xlsx)

Attachment D County-Level Average Natural Gas Composition Profiles (NG_Composition_Profiles.xlsx)

List of Tables

Table E-1. County-Level VOC Emission Factors v
Table E-2. Basin-Level and State-Level Average Natural Gas Stream Composition Profiles xii
Table 2-1. Condensate Tank Emission Data from the HARC 2006 Study 2-5
Table 2-2. Operating Parameters, Production, and Measured Emissions 2-7
Table 2-3. Comparison of Estimated Emissions with Measured Emissions 2-8
Table 2-4. Ratio Between Estimated Emissions and Measured Emissions 2-9
Table 2-5. Condensate Tank Emission Factors from the TCEQ 2010 Study 2-11
Table 2-6. Producer-Supplied VOC Emission Estimates for Condensate Tank Batteries in Haynesville Shale Area 2-12
Table 2-7. Condensate Tank VOC Emission Factors by Method – Barnett Shale Inventory 2-14
Table 2-8. Condensate Tank VOC Emission Factors by County – Barnett Shale Inventory 2-15
Table 2-9. Target Survey Counties 2-16
Table 2-10. Survey Results Using all Valid Survey Data Estimated with Preferred Estimation Methods 2-19
Table 2-11. Weighting Factors by Emissions Estimation Method 2-23
Table 2-12. Average Regional VOC Emission Factors Derived from Testing Data. 2-25
Table 2-13. Average Regional VOC Emission Factors Derived from Estimation Methods 2-25
Table 2-14. Average Regional VOC Emission Factors from ERG Survey Data and Barnett Shale Inventory Data 2-26

List of Tables (Continued)

Table 2-15. Average Regional VOC Emission Factors 2-26
Table 2-16. County-Level VOC Emission Factors 2-29
Table 2-17. Percentage of Surveyed Production with Tank Emissions Controlled in the HGB, BPA, and Haynesville Shale Areas 2-38
Table 2-18. Surveyed Production, Total Production, Percent of Surveyed Production Controlled, and Control Factor, by Region 2-41
Table 3-1. VOC and BTEX Content in the Vent Gas 3-1
Table 3-2. VOC and BTEX Emission Factors 3-2
Table 3-3. Condensate Tank BTEX Emission Factor Estimates Using Data from the Barnett Shale Phase II 2009 Inventory 3-4
Table 3-4. Condensate Tank BTEX Emission Factor Estimates Using Data from E&P TANK Reports Submitted for ERG Survey 3-5
Table 3-5. Production-Weighted Average Regional BTEX Emission Factors, from Testing Data, Barnett Shale Inventory, and Survey Data 3-8
Table 3-6. Arithmetic Average Regional BTEX Emission Factors, from Testing Data, Barnett Shale Inventory, and Survey Data 3-8
Table 5-1. Counties Included in the Natural Gas Composition Analysis 5-2
Table 5-2. List of Counties Located in Marathon Thrust Belt Basin and Palo Duro Basin 5-3
Table 5-3. Basin-Level and State-Level Average Natural Gas Stream Composition Profiles 5-4
Table 5-4. Average Natural Gas Composition Profile Allocation Scheme 5-6

List of Figures

Figure 2-1. Condensate Producing Regions in Texas 2-1
Figure 2-2. Target Survey Counties 2-17
Figure 2-3. Relationship between Production and Emission Factor 2-24
Figure 2-4. Condensate Tank Emission Data Sources by County 2-27
Figure 2-5. Average Regional Emission Factors, Before Controls 2-28
Figure 5-1. Natural Gas Methane Composition Distribution across Texas Counties 5-11

List of Acronyms

Acronym	Definition
API	American Petroleum Institute
BBL	Barrel
BPA	Beaumont-Port Arthur
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CENRAP	Central Regional Air Planning Association
CO_2	Carbon Dioxide
EPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group
GOR	Gas/Oil Ratio
HAP	Hazardous Air Pollutants
HARC	Houston Advanced Research Center
HGB	Houston-Galveston-Brazoria
IPAMS	Independent Petroleum Association of Mountain States
lbs	Pounds
NSPS	New Source Performance Standard
psig	pounds per square inch gauge
QA	Quality Assurance
RRC	Texas Railroad Commission
TCEQ	Texas Commission on Environmental Quality
TERC	Texas Environmental Research Consortium
VOC	Volatile Organic Compound
VRU	Vapor Recovery Unit
WRAP	Western Regional Air Partnership

Executive Summary

This report is a deliverable for Texas Commission on Environmental Quality (TCEQ) Work Order No. 582-11-99776-FY12-11 to improve area source emission estimates for the oil and gas sector. Improvements will be gained through this effort by the development of refined emission factors for volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions from condensate storage tanks, as well as improved gas speciation profiles for different gas formations on a county-by-county basis.

Under this project, a review of available literature was conducted for data on emissions testing and emissions estimates for condensate tanks in Texas. In addition, data collected in the Barnett Shale Area Special Inventory conducted by TCEQ was evaluated, a phone survey of Texas condensate producers was conducted, and additional data on emissions estimates was obtained from several recent studies evaluating condensate storage tank emissions. ERG evaluated this data for its relevance and quality, and derived region-specific emission factors for eight geographic regions in the state. These emission factors are presented in Table E-1 below.

Table E-1. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Anderson	East Texas/Haynesville Shale	4.22	5.92
Andrews	Permian	7.07	5.90
Angelina	East Texas/Haynesville Shale	4.22	5.92
Aransas	Western Gulf	11.0	14.8
Archer	Fort Worth/Barnett Shale	9.76	16.0
Armstrong	Palo Duro	7.61	9.75
Atascosa	Eagle Ford Shale	10.5	10.0
Austin	Western Gulf	11.0	14.8
Bailey	Palo Duro	7.61	9.75
Bandera	Fort Worth/Barnett Shale	9.76	16.0
Bastrop	Western Gulf	11.0	14.8
Baylor	Fort Worth/Barnett Shale	9.76	16.0
Bee	Eagle Ford Shale	10.5	10.0
Bell	Western Gulf	11.0	14.8
Bexar	Western Gulf	11.0	14.8
Blanco	Fort Worth/Barnett Shale	9.76	16.0
Borden	Permian	7.07	5.90
Bosque	Fort Worth/Barnett Shale	9.76	16.0
Bowie	East Texas/Haynesville Shale	4.22	5.92
Brazoria	Western Gulf	11.0	14.8
Brazos	Eagle Ford Shale	10.5	10.0
Brewster	Marathon Thrust Belt	7.61	9.75

Table E-1. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Briscoe	Palo Duro	7.61	9.75
Brooks	Western Gulf	11.0	14.8
Brown	Fort Worth/Barnett Shale	9.76	16.0
Burleson	Eagle Ford Shale	10.5	10.0
Burnet	Fort Worth/Barnett Shale	9.76	16.0
Caldwell	Western Gulf	11.0	14.8
Calhoun	Western Gulf	11.0	14.8
Callahan	Fort Worth/Barnett Shale	9.76	16.0
Cameron	Western Gulf	11.0	14.8
Camp	East Texas/Haynesville Shale	4.22	5.92
Carson	Anadarko	3.15	5.87
Cass	East Texas/Haynesville Shale	4.22	5.92
Castro	Palo Duro	7.61	9.75
Chambers	Western Gulf	11.0	14.8
Cherokee	East Texas/Haynesville Shale	4.22	5.92
Childress	Palo Duro	7.61	9.75
Clay	Fort Worth/Barnett Shale	9.76	16.0
Cochran	Permian	7.07	5.90
Coke	Permian	7.07	5.90
Coleman	Fort Worth/Barnett Shale	9.76	16.0
Collin	Fort Worth/Barnett Shale	9.76	16.0
Collingsworth	Palo Duro	7.61	9.75
Colorado	Western Gulf	11.0	14.8
Comal	Western Gulf	11.0	14.8
Comanche	Fort Worth/Barnett Shale	9.76	16.0
Concho	Fort Worth/Barnett Shale	9.76	16.0
Cooke	Fort Worth/Barnett Shale	9.76	16.0
Coryell	Fort Worth/Barnett Shale	9.76	16.0
Cottle	Palo Duro	7.61	9.75
Crane	Permian	7.07	5.90
Crockett	Permian	7.07	5.90
Crosby	Permian	7.07	5.90
Culberson	Permian	7.07	5.90
Dallam	Palo Duro	7.61	9.75
Dallas	Fort Worth/Barnett Shale	9.76	16.0
Dawson	Permian	7.07	5.90
Deaf Smith	Palo Duro	7.61	9.75
Delta	East Texas/Haynesville Shale	4.22	5.92
Denton	Fort Worth/Barnett Shale	9.76	16.0
DeWitt	Eagle Ford Shale	10.5	10.0
Dickens	Permian	7.07	5.90
Dimmit	Eagle Ford Shale	10.5	10.0
Donley	Palo Duro	7.61	9.75
Duval	Western Gulf	11.0	14.8

Table E-1. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Eastland	Fort Worth/Barnett Shale	9.76	16.0
Ector	Permian	7.07	5.90
Edwards	Permian	7.07	5.90
El Paso	Permian	7.07	5.90
Ellis	Fort Worth/Barnett Shale	9.76	16.0
Erath	Fort Worth/Barnett Shale	9.76	16.0
Falls	East Texas/Haynesville Shale	4.22	5.92
Fannin	East Texas/Haynesville Shale	4.22	5.92
Fayette	Eagle Ford Shale	10.5	10.0
Fisher	Permian	7.07	5.90
Floyd	Palo Duro	7.61	9.75
Foard	Fort Worth/Barnett Shale	9.76	16.0
Fort Bend	Western Gulf	11.0	14.8
Franklin	East Texas/Haynesville Shale	4.22	5.92
Freestone	East Texas/Haynesville Shale	4.22	5.92
Frio	Eagle Ford Shale	10.5	10.0
Gaines	Permian	7.07	5.90
Galveston	Western Gulf	11.0	14.8
Garza	Permian	7.07	5.90
Gillespie	Fort Worth/Barnett Shale	9.76	16.0
Glasscock	Permian	7.07	5.90
Goliad	Western Gulf	11.0	14.8
Gonzales	Eagle Ford Shale	10.5	10.0
Gray	Anadarko	3.15	5.87
Grayson	Fort Worth/Barnett Shale	9.76	16.0
Gregg	East Texas/Haynesville Shale	4.22	5.92
Grimes	Eagle Ford Shale	10.5	10.0
Guadalupe	Western Gulf	11.0	14.8
Hale	Palo Duro	7.61	9.75
Hall	Palo Duro	7.61	9.75
Hamilton	Fort Worth/Barnett Shale	9.76	16.0
Hansford	Anadarko	3.15	5.87
Hardeman	Fort Worth/Barnett Shale	9.76	16.0
Hardin	Western Gulf	11.0	14.8
Harris	Western Gulf	11.0	14.8
Harrison	East Texas/Haynesville Shale	4.22	5.92
Hartley	Palo Duro	7.61	9.75
Haskell	Fort Worth/Barnett Shale	9.76	16.0
Hays	Western Gulf	11.0	14.8
Hemphill	Anadarko	3.15	5.87
Henderson	East Texas/Haynesville Shale	4.22	5.92
Hidalgo	Western Gulf	11.0	14.8
Hill	Fort Worth/Barnett Shale	9.76	16.0
Hockley	Permian	7.07	5.90

Table E-1. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Hood	Fort Worth/Barnett Shale	9.76	16.0
Hopkins	East Texas/Haynesville Shale	4.22	5.92
Houston	East Texas/Haynesville Shale	4.22	5.92
Howard	Permian	7.07	5.90
Hudspeth	Permian	7.07	5.90
Hunt	East Texas/Haynesville Shale	4.22	5.92
Hutchinson	Anadarko	3.15	5.87
Irion	Permian	7.07	5.90
Jack	Fort Worth/Barnett Shale	9.76	16.0
Jackson	Western Gulf	11.0	14.8
Jasper	Western Gulf	11.0	14.8
Jeff Davis	Permian	7.07	5.90
Jefferson	Western Gulf	11.0	14.8
Jim Hogg	Western Gulf	11.0	14.8
Jim Wells	Western Gulf	11.0	14.8
Johnson	Fort Worth/Barnett Shale	9.76	16.0
Jones	Fort Worth/Barnett Shale	9.76	16.0
Karnes	Eagle Ford Shale	10.5	10.0
Kaufman	East Texas/Haynesville Shale	4.22	5.92
Kendall	Fort Worth/Barnett Shale	9.76	16.0
Kenedy	Western Gulf	11.0	14.8
Kent	Permian	7.07	5.90
Kerr	Fort Worth/Barnett Shale	9.76	16.0
Kimble	Fort Worth/Barnett Shale	9.76	16.0
King	Permian	7.07	5.90
Kinney	Western Gulf	11.0	14.8
Kleberg	Western Gulf	11.0	14.8
Knox	Fort Worth/Barnett Shale	9.76	16.0
La Salle	Eagle Ford Shale	10.5	10.0
Lamar	East Texas/Haynesville Shale	4.22	5.92
Lamb	Palo Duro	7.61	9.75
Lampasas	Fort Worth/Barnett Shale	9.76	16.0
Lavaca	Eagle Ford Shale	10.5	10.0
Lee	Eagle Ford Shale	10.5	10.0
Leon	Eagle Ford Shale	10.5	10.0
Liberty	Western Gulf	11.0	14.8
Limestone	East Texas/Haynesville Shale	4.22	5.92
Lipscomb	Anadarko	3.15	5.87
Live Oak	Eagle Ford Shale	10.5	10.0
Llano	Fort Worth/Barnett Shale	9.76	16.0
Loving	Permian	7.07	5.90
Lubbock	Permian	7.07	5.90
Lynn	Permian	7.07	5.90
Madison	Western Gulf	11.0	14.8

Table E-1. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Marion	East Texas/Haynesville Shale	4.22	5.92
Martin	Permian	7.07	5.90
Mason	Fort Worth/Barnett Shale	9.76	16.0
Matagorda	Western Gulf	11.0	14.8
Maverick	Eagle Ford Shale	10.5	10.0
McCulloch	Fort Worth/Barnett Shale	9.76	16.0
McLennan	Fort Worth/Barnett Shale	9.76	16.0
McMullen	Eagle Ford Shale	10.5	10.0
Medina	Western Gulf	11.0	14.8
Menard	Fort Worth/Barnett Shale	9.76	16.0
Midland	Permian	7.07	5.90
Milam	Eagle Ford Shale	10.5	10.0
Mills	Fort Worth/Barnett Shale	9.76	16.0
Mitchell	Permian	7.07	5.90
Montague	Fort Worth/Barnett Shale	9.76	16.0
Montgomery	Western Gulf	11.0	14.8
Moore	Anadarko	3.15	5.87
Morris	East Texas/Haynesville Shale	4.22	5.92
Motley	Palo Duro	7.61	9.75
Nacogdoches	East Texas/Haynesville Shale	4.22	5.92
Navarro	East Texas/Haynesville Shale	4.22	5.92
Newton	Western Gulf	11.0	14.8
Nolan	Permian	7.07	5.90
Nueces	Western Gulf	11.0	14.8
Ochiltree	Anadarko	3.15	5.87
Oldham	Palo Duro	7.61	9.75
Orange	Western Gulf	11.0	14.8
Palo Pinto	Fort Worth/Barnett Shale	9.76	16.0
Panola	East Texas/Haynesville Shale	4.22	5.92
Parker	Fort Worth/Barnett Shale	9.76	16.0
Parmer	Palo Duro	7.61	9.75
Pecos	Permian	7.07	5.90
Polk	Western Gulf	11.0	14.8
Potter	Palo Duro	7.61	9.75
Presidio	Permian	7.07	5.90
Rains	East Texas/Haynesville Shale	4.22	5.92
Randall	Palo Duro	7.61	9.75
Reagan	Permian	7.07	5.90
Real	Fort Worth/Barnett Shale	9.76	16.0
Red River	East Texas/Haynesville Shale	4.22	5.92
Reeves	Permian	7.07	5.90
Refugio	Western Gulf	11.0	14.8
Roberts	Anadarko	3.15	5.87
Robertson	Eagle Ford Shale	10.5	10.0

Table E-1. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Rockwall	East Texas/Haynesville Shale	4.22	5.92
Runnels	Fort Worth/Barnett Shale	9.76	16.0
Rusk	East Texas/Haynesville Shale	4.22	5.92
Sabine	East Texas/Haynesville Shale	4.22	5.92
San Augustine	East Texas/Haynesville Shale	4.22	5.92
San Jacinto	Western Gulf	11.0	14.8
San Patricio	Western Gulf	11.0	14.8
San Saba	Fort Worth/Barnett Shale	9.76	16.0
Schleicher	Permian	7.07	5.90
Scurry	Permian	7.07	5.90
Shackelford	Fort Worth/Barnett Shale	9.76	16.0
Shelby	East Texas/Haynesville Shale	4.22	5.92
Sherman	Anadarko	3.15	5.87
Smith	East Texas/Haynesville Shale	4.22	5.92
Somervell	Fort Worth/Barnett Shale	9.76	16.0
Starr	Western Gulf	11.0	14.8
Stephens	Fort Worth/Barnett Shale	9.76	16.0
Sterling	Permian	7.07	5.90
Stonewall	Permian	7.07	5.90
Sutton	Permian	7.07	5.90
Swisher	Palo Duro	7.61	9.75
Tarrant	Fort Worth/Barnett Shale	9.76	16.0
Taylor	Fort Worth/Barnett Shale	9.76	16.0
Terrell	Marathon Thrust Belt	7.61	9.75
Terry	Permian	7.07	5.90
Throckmorton	Fort Worth/Barnett Shale	9.76	16.0
Titus	East Texas/Haynesville Shale	4.22	5.92
Tom Green	Permian	7.07	5.90
Travis	Western Gulf	11.0	14.8
Trinity	Western Gulf	11.0	14.8
Tyler	Western Gulf	11.0	14.8
Upshur	East Texas/Haynesville Shale	4.22	5.92
Upton	Permian	7.07	5.90
Uvalde	Western Gulf	11.0	14.8
Val Verde	Permian	7.07	5.90
Van Zandt	East Texas/Haynesville Shale	4.22	5.92
Victoria	Western Gulf	11.0	14.8
Walker	Western Gulf	11.0	14.8
Waller	Western Gulf	11.0	14.8
Ward	Permian	7.07	5.90
Washington	Western Gulf	11.0	14.8
Webb	Eagle Ford Shale	10.5	10.0
Wharton	Western Gulf	11.0	14.8
Wheeler	Anadarko	3.15	5.87

Table E-1. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Wichita	Fort Worth/Barnett Shale	9.76	16.0
Wilbarger	Fort Worth/Barnett Shale	9.76	16.0
Willacy	Western Gulf	11.0	14.8
Williamson	Western Gulf	11.0	14.8
Wilson	Eagle Ford Shale	10.5	10.0
Winkler	Permian	7.07	5.90
Wise	Fort Worth/Barnett Shale	9.76	16.0
Wood	East Texas/Haynesville Shale	4.22	5.92
Yoakum	Permian	7.07	5.90
Young	Fort Worth/Barnett Shale	9.76	16.0
Zapata	Western Gulf	11.0	14.8
Zavala	Eagle Ford Shale	10.5	10.0

Updated natural gas speciation profiles were developed through evaluation of GLYCalc emissions inventory reports submitted to TCEQ as part of the annual point source emissions inventory compilation. ERG reviewed TCEQ emissions inventory files and obtained GLYCalc data for 157 sites located in 64 counties across Texas. Using this information, average county natural gas composition profiles were developed. The 64 counties for which data were available were then grouped by basins (Anadarko, Bend Arch-Forth Worth, East Texas, Permian, and Western Gulf Basins), and basin-level average natural gas composition (wet and dry) profiles were calculated. Basin-level average natural gas composition profile and state-level average profiles were then allocated to counties with no data based on which basin the county was located in. For two basins, the Marathon Thrust Belt and Palo Duro, no data was available so a state-level average profile was developed. Table E-2 presents the basin-level and state-level average natural gas stream composition profiles for both wet and dry natural gas streams.

Table E-2. Basin-Level and State-Level Average Natural Gas Stream Composition Profiles

Composition in % Volume	Anadarko Basin		Bend Arch-Fort Worth Basin		East Texas Basin		Permian Basin		Western Gulf		State Profile	
	Dry Stream	Wet Stream	Dry Stream	Wet Stream	Dry Stream	Wet Stream	Dry Stream	Wet Stream	Dry Stream	Wet Stream	Dry Stream	Wet Stream
Water	0.04	0.13	0.01	0.12	0.01	0.12	0.01	0.15	0.01	0.12	0.01	0.12
Carbon Dioxide	0.64	0.65	1.74	1.74	1.72	1.71	0.95	0.90	1.13	1.14	1.43	1.44
Hydrogen Sulfide	0.03	0.03	0.001	0.001	0.0004	0.0004	0.11	0.11	0.0003	0.25	0.03	0.09
Nitrogen	1.35	1.34	1.74	1.73	0.88	0.87	2.14	2.18	0.51	0.49	1.20	1.19
Methane	90.76	90.68	87.91	87.59	91.73	91.49	80.43	78.53	90.07	89.94	88.67	88.36
Ethane	3.99	3.98	5.23	5.21	3.57	3.64	9.02	9.07	4.51	4.51	5.03	5.00
Propane	1.74	1.74	2.14	2.18	1.04	1.06	4.48	5.39	2.04	2.05	2.13	2.21
Isobutane	0.26	0.26	0.31	0.32	0.28	0.29	0.51	0.61	0.48	0.48	0.38	0.40
n-Butane	0.54	0.54	0.62	0.68	0.31	0.32	1.19	1.63	0.51	0.51	0.58	0.64
Isopentane	0.16	0.16	0.20	0.22	0.15	0.17	0.35	0.40	0.24	0.24	0.22	0.23
n-Pentane	0.17	0.17	0.27	0.29	0.11	0.12	0.32	0.44	0.17	0.17	0.20	0.22
Cyclopentane	0.01	0.01	0.03	0.04	0.04	0.04	0.01	0.02	0.03	0.02	0.02	0.03
n-Hexane	0.10	0.06	0.05	0.12	0.05	0.05	0.16	0.18	0.05	0.06	0.06	0.09
Cyclohexane	0.01	0.01	0.04	0.03	0.03	0.03	0.09	0.11	0.05	0.06	0.04	0.05
Other Hexanes	0.14	0.14	0.07	0.06	0.10	0.11	0.24	0.29	0.17	0.15	0.13	0.13
Heptanes	0.06	0.06	0.08	0.08	0.06	0.07	0.14	0.14	0.07	0.09	0.08	0.08
Methylcyclohexane	0.02	0.02	0.02	0.02	0.01	0.02	0.04	0.04	0.04	0.04	0.03	0.04
Benzene	0.01	0.01	0.01	0.01	0.02	0.03	0.07	0.08	0.01	0.02	0.02	0.02
Toluene	0.01	0.01	0.003	0.003	0.01	0.01	0.04	0.04	0.01	0.02	0.01	0.01
Ethylbenzene	0.001	0.001	0.0005	0.001	0.001	0.001	0.01	0.01	0.001	0.002	0.001	0.002
Xylenes	0.003	0.01	0.002	0.003	0.002	0.005	0.01	0.01	0.003	0.01	0.003	0.005
C8+ Heavies	0.04	0.04	0.03	0.03	0.03	0.04	0.07	0.07	0.11	0.11	0.06	0.06

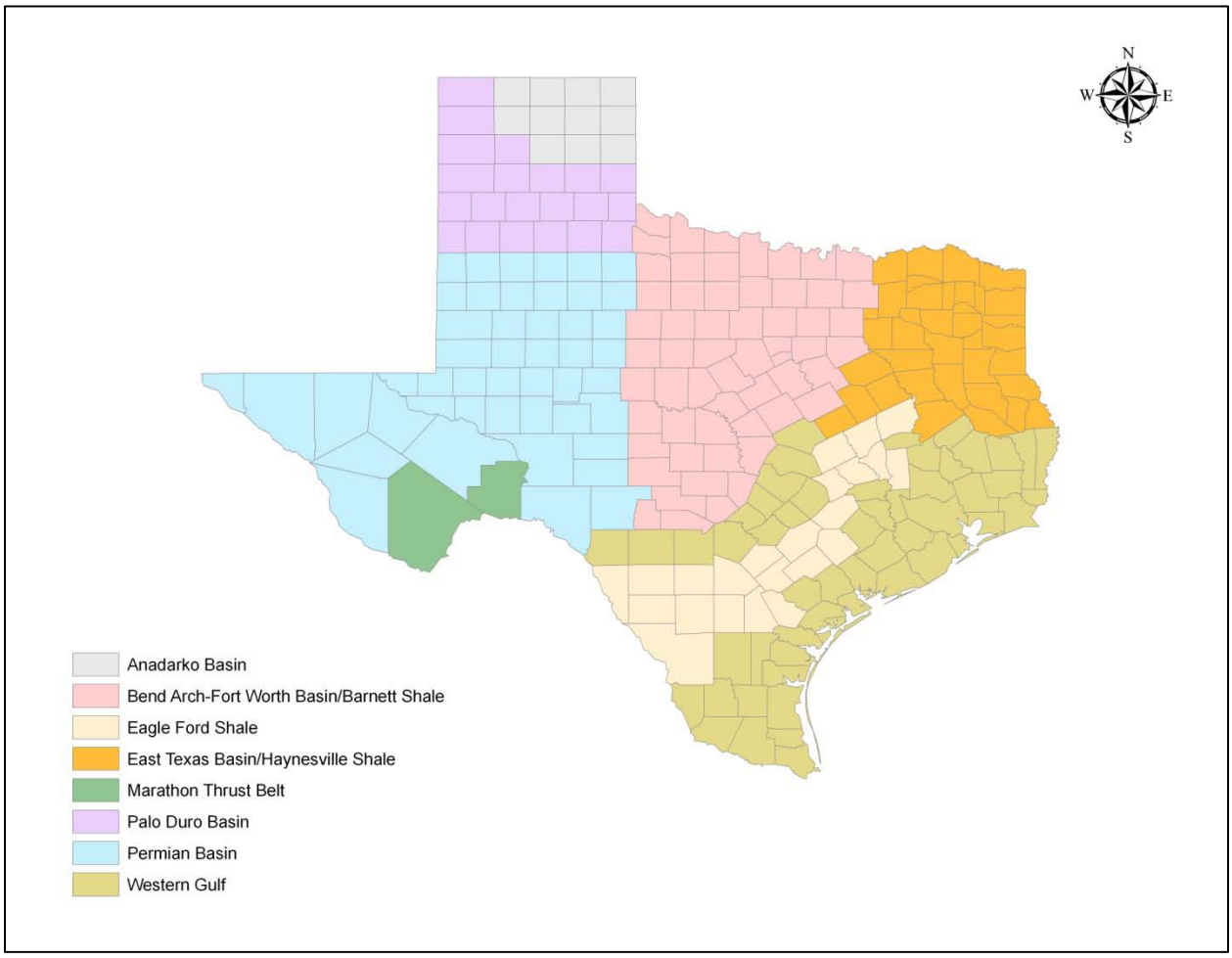
1.0 Introduction

Under contract with the Texas Commission on Environmental Quality (TCEQ), Eastern Research Group, Inc. (ERG) developed refined emission factors for volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions from condensate tanks, as well as improved gas speciation profiles for different gas formations on a county-by-county basis. This information will be used to improve area source emissions inventory estimates for the oil and gas sector. This report describes ERG's findings relative to an analysis of existing condensate tank emissions data, survey efforts to collect additional condensate tank emissions data, and development of natural gas speciation profiles in Texas.

2.0 VOC Emissions From Condensate Storage Tanks

A review of available literature was conducted for data on emissions testing and emissions estimates for condensate tanks in Texas. In addition, data collected in the Barnett Shale Area Special Inventory was evaluated, a phone survey of Texas condensate producers was conducted, and additional data on emissions estimates was obtained from TCEQ as available. ERG evaluated this data for its relevance and quality, and derived region-specific emission factors for eight geographic regions in the state. These eight regions are shown in Figure 2-1.

Figure 2-1. Condensate Producing Regions in Texas



2.1 Condensate Production

Condensate, for purposes of this survey, is defined as a hydrocarbon liquid produced at an oil or gas well and having an American Petroleum Institute (API) gravity greater than

40 degrees.[1] The API gravity of crude oil/condensate can vary from 20 to 70 degrees. In practice, most producers do not distinguish between oil and condensate, calling any petroleum liquid "oil". However, the API gravity of produced liquid is important, as a petroleum liquid with a higher API gravity will generally command a premium in the market.[2] API gravity is also important in determining what calculation method should be used to estimate the VOC emissions associated with the production of a hydrocarbon liquid. The Texas Railroad Commission (RRC) distinguishes between oil and condensate, with 'oil' being the liquid produced at oil wells and 'condensate' being the hydrocarbon liquid produced at gas wells.

TCEQ's area source emissions estimate is based upon county-level oil and condensate production as reported on the RRC website. When creating an area source emissions estimate, it is important to distinguish between the emissions from petroleum liquid storage tanks located at 'oil' wells, and the emissions from petroleum liquid storage tanks located at 'gas' wells because the VOC emission factor for tanks at oil wells (1.6 pounds (lbs) VOC/barrel (bbl)) is significantly lower than the emission factor historically used for tanks at gas wells (33.3 lbs VOC/bbl).[3] Given the difference in these estimates, it is important to distinguish between oil and condensate.

The RRC county level production data shows that the majority of petroleum-producing counties produce both 'oil' and 'condensate'. This is usually due to the fact that, within the geographic boundary of many counties, there may be two or more petroleum producing formations stacked atop one another at different depths below ground. One of the formations may produce oil, while the other may produce gas, while perhaps a third formation yields gas from shale. Therefore, the estimates of emissions from any particular county or region could reflect the emissions from wells tapping one, two, or more petroleum-producing formations underground.

2.2 Literature Review

ERG reviewed the current literature for existing studies and other sources that evaluated emissions from oil and condensate tanks in Texas. These studies included emissions measured via testing, emissions estimated through the use of software programs using

[1] The American Petroleum Institute (API) does not define condensate in terms of its API gravity. The State of Colorado defines condensate as a hydrocarbon liquid that has an API gravity greater than or equal to 40° API at 60°F. Colorado Department of Public Health and Environment, PS Memo 05-01, Oil and Gas Atmospheric Condensate Storage Tank Batteries, Regulatory Definitions and Permitting Guidance, October 1, 2009. http://www.cdphe.state.co.us/ap/down/ps05-01.pdf

[2] Well Servicing Magazine, "Crude Oil Testing", Andy Maslowski, September/October 2009, http://wellservicingmagazine.com/crude-oil-testing

[3] These emission factors were used for estimating emissions from upstream area sources in the oil and gas industry in the report "Characterization of Oil and Gas Production Equipment and Develop a Methodology to Estimate Statewide Emissions", TCEQ, 11/24/2010. The emission factors were first developed in the 2006 HARC study "VOC Emissions From Oil and Condensate Storage Tanks".

equations-of-state, and comparisons of measured emissions with estimated emissions. The data in these studies were analyzed for their validity and utility, and a refined emission factor for estimating emissions from condensate storage tanks was developed. A brief description follows of the available literature, the information they contain, and the information from the study used in developing updated emission factors.

2.2.1 Emissions Data Derived from Testing

This section examines studies where emissions data was generated via direct measurement (testing) of emissions from oil and condensate tanks.

"*VOC Emissions from Oil and Condensate Storage Tanks*" (Houston Advanced Research Center (HARC), 2006, and Texas Environmental Research Consortium (TERC), 2009).[4]

This study is widely referred to as the "HARC" or "HARC H051C" study. In this study, researchers examined 2 oil and 13 gas (condensate) sites in the Fort Worth basin, and 9 oil and 9 gas sites in the Western Gulf basin. This study measured oil and condensate tank emissions from each site and includes information such as API gravity and separator pressure. The HARC 2006 study noted that the emission estimates had a high uncertainty, due in part to the very low condensate production rates at well sites in Parker and Denton counties. The HARC 2006 study also noted that these measurements were taken during a period when recorded daytime high temperatures ranged from 98 to 107 degrees Fahrenheit at the nearby Dallas-Fort Worth Airport. The VOC emission factor of 33.3 lbs VOC/bbl condensate and the HAP emission factors used in TCEQ's 2008 upstream oil and gas area source inventory are derived from this report.

API provided comments[5] to the U.S. Environmental Protection Agency (EPA) on the derivation of this emission factor in their comments on EPA's proposed changes to the New Source Performance Standard (NSPS) for Oil and Gas Production (Subpart OOOO) on November 30, 2011.[6] API called into question the validity of two of the data points used in developing the emission factor. API also questioned the use of emissions data from several sites where the measured condensate production was minimal. API noted in their comments that the 24-hour production measurement methodology used in the HARC study (manual gauging of oil level in the tank) may be subject to error, as the onsite measurements for two barrels of production would require accurately

[4] Houston Advanced Research Center, VOC Emissions from Oil and Condensate Storage Tanks, October 31, 2006. http://files.harc.edu/Projects/AirQuality/Projects/H051C/H051CFinalReport.pdf

[5] The API comments relative to condensate storage tank emissions were made by Dr. Ed Ireland of the Barnett Shale Energy Education Council.

[6] American Petroleum Institute, API Comments on the Proposed Rulemaking – Oil and Gas Sector Regulations, November 30, 2011, http://www.api.org/Newsroom/testimony/upload/2011-11-30-API-Oil-and-Gas-Rule-Final-Comments-Text.pdf

determining a difference of 0.71 to 1.2 inches in oil level via manual gauging of these 300 bbl condensate tanks.[7] However, in the 2009 revisions to the original report, the study authors noted that daily average production rates during the sampling period were obtained from site operating logs, not manual measurement as first erroneously reported.

API also questioned the presumption that emissions are solely a function of throughput and presented evidence that the VOC emissions per barrel of condensate produced are a non-linear function, dependent primarily upon separator pressure, and, to a lesser extent, API gravity. The comments suggest that each well/tank combination has unique emissions, based on: the composition of the liquids and gas produced, the API gravity of the liquid, the types of separator equipment in use, and the operating parameters of the separator. In general, liquids with a higher API gravity tend to have higher flash emissions per barrel than liquids with a lower API gravity. Also, the larger the pressure drop at the last stage of liquid-gas separation prior to moving the liquid to the storage tank, the higher the flash emissions. Therefore, any emission factor that is dependent solely upon production and does not take these other factors into account may not accurately estimate emissions for a specific well/tank combination.

While such a multivariate approach is feasible for estimating point source emissions at any individual location, this approach would be impractical for estimating county-level, area source emissions where site-specific operating data is not readily available. The approach used by this study overcomes these limitations and provides a reasonably accurate means for estimating emissions from the condensate-producing regions of Texas by developing regional emission factors based on testing data and emissions estimates developed using TCEQ's published preferred methodologies.

ERG re-examined the data from all 33 oil and condensate sites examined in the HARC 2006 study. Although 27 sites produce liquids having an API gravity of 40 degrees or greater, only data from the 22 sites designated as producing condensate have been considered in this analysis. In this re-analysis, three additional data points were removed from the data set. Data for tank 17 was removed because the calculated flash emissions (145 pounds VOC per barrel condensate produced (lbs/bbl)) indicated that 55% of the condensate flashed when reduced in pressure from 200 pounds per square inch gauge (psig). Data for tank 25 was removed because the calculated flash emissions (215 lbs/bbl) indicated that 82% of the condensate flashed when reduced in pressure from 200 psig. According to API, neither of these flash emission values is possible at this separator pressure.[6] Data for tank 26 was also removed from the dataset, as the recorded emissions (1,217.6 lbs/bbl) seem to indicate an equipment failure (such as a

[7] Information in Appendix A of the study report indicates that, for the sites having production of two or less barrels of condensate per day, condensate was stored in a single 300 BBL capacity tank. 300 BBL oil tanks typically come in 12 foot and 15.5 foot diameters, and have capacities of 1.68 bbl/inch and 2.8 bbl/inch, respectively.

separator dump valve stuck in the open position) or a measurement error as a 42 gallon barrel of condensate weighs approximately 270 pounds. An emission factor for each of the remaining 19 sites was calculated. Table 2-1 shows the emissions measurement data from the HARC 2006 study.

Table 2-1. Condensate Tank Emission Data from the HARC 2006 Study

Tank Battery	County	Region	API Gravity	Separator Discharge Pressure (psi)	VOC (lbs/day)	Production (bbl/day)	VOC Emission Factor (lbs/bbl)
2	Montgomery	Western Gulf	42	41	383.2	105	3.65
3	Montgomery	Western Gulf	41	38	688.9	87	7.92
4	Montgomery	Western Gulf	40	34	93.7	120	0.78
5	Montgomery	Western Gulf	43	46	67.4	100	0.67
6	Montgomery	Western Gulf	39	33	384.7	130	2.96
13	Denton	Fort Worth	61	200	78.5	2	39.25
14	Denton	Fort Worth	59	200	118	4	29.50
15	Denton	Fort Worth	61	200	60	5	12.00
16	Denton	Fort Worth	61	200	121.2	2	60.60
18	Denton	Fort Worth	58	200	73.4	10	7.34
19	Denton	Fort Worth	58	200	26.3	2	13.15
20	Denton	Fort Worth	59	200	304.3	10	30.43
23	Parker	Fort Worth	48	39	150.2	27	5.56
24	Parker	Fort Worth	41	36	4.2	1	4.20
27	Denton	Fort Worth	59	200	28.8	2	14.40
28	Brazoria	Western Gulf	46	38	125.2	30	4.17
29	Brazoria	Western Gulf	42	41	2,055	61	33.69
30	Brazoria	Western Gulf	42	36	91.6	15	6.11
32	Galveston	Western Gulf	48	121	9,016	142	63.49

The production-weighted average emission factor for these 19 condensate tanks is 16.22 lbs/bbl, whereas the arithmetic average is 17.89 lbs/bbl. The production-weighted approach reduces the effect of measurement error (as noted in the API comments) on the emissions estimate, as the error attributable to measurement error from tanks with very low production has minimal 'weight' in the computation of the overall estimate.

2.2.2 Comparisons of Emissions Data Derived from Testing with Emissions Estimates Derived from Models/Software Programs

There is only a small amount of data from testing available at present. Emission estimates derived through use of emissions estimation software utilizing equations-of-state can provide useful information in developing regional emission factors. Therefore,

emissions data estimated with software and models were used to supplement the existing testing data.

This section examines two studies where researchers conducted emissions testing on tanks and then generated emission estimates for those same tanks using models or software programs.

"*Upstream Oil and Gas Storage Tank Project Flash Emissions Models Evaluation*" (TCEQ, 2009)

This 2009 study conducted by Hy-Bon Engineering for TCEQ compared actual measured emissions from 30 test sites to estimated emissions from those same sites. Emissions estimates were created using onsite data and several different emissions estimating models and software[8]. At each test site, extensive data was taken on tanks and equipment, operating parameters, environmental conditions, and liquids production. Liquid and gas samples were taken for lab analysis and direct measurements were taken of vapors vented. The measured emissions from the 30 test sites were then compared to the estimated emissions from those same sites.

This report concludes that the calculated emissions using the E&P Tank – AP 42 model typically overestimated measured emissions in 85.7% of the cases, while the E&P Tank - RVP model overestimated emissions for 82.1% of the cases. Calculated emissions using HYSYS Process Simulation software overestimated measured emissions in 64.3% of the cases. Therefore, it was assumed that emissions estimated using E&P Tank – AP 42, E&P Tank – RVP, or HYSYS may over-estimate emissions, and are conservative. This same study showed that the Gas/Oil Ratio (GOR) method in combination with Tanks 4.09 underestimated flashing, breathing and working emissions in 76.7% of the cases. Therefore, any information obtained that utilizes the GOR method to estimate emissions will be, on average, an underestimate of the actual emissions. TCEQ has issued guidance[9] stating that testing, the various process simulation software packages, E&P Tank, and GOR, in combination with site sampling and analysis, are the preferred methods for estimating flash emissions, in order of most preferred to least preferred.

There are eleven sites out of the thirty whose API gravity is less than 40 degrees, the lower bound for condensate in this study. Therefore, data from these eleven sites will

[8] The emissions estimation methods used in this study include: E&P TANK 2.0, AspenTech HYSYS 2006.5, GRI-HapCalc 3.0, the Environmental Consultant Research (EC/R) Algorithm, Vasquez-Beggs Correlation, Gas-Oil Ratio (GOR), and Valko-McCain Correlation. TANKS 4.09 was used to estimate breathing and working emissions for the GOR, Vasquez-Beggs, and Valko-McCain methods, which only calculate flash emissions.

[9] "Calculating Volatile Organic Compounds (VOC) Flash Emissions from Crude Oil and Condensate Tanks at Oil and Gas Production Sites", APDG 5942, May 2012, http://www.tceq.texas.gov/assets/public/permitting/air/Guidance/NewSourceReview/guidance_flashemission.pdf

not be considered. Emissions measurement data from the 19 remaining sites in this report are shown in Table 2-2.

The production-weighted average emission factor from testing for all of these sites is 4.59 lbs/bbl of condensate, whereas the arithmetic average is 11.0 lbs/bbl. The emission measurement tests on these tanks were conducted during the months of July, August, and September.

Table 2-2. Operating Parameters, Production, and Measured Emissions

Site ID #	County	Region	API Gravity (deg.)	Separator Pressure (psia)	Liquid Production (bbl/day)	VOC Emissions (ton/yr)	VOC Emission Factor (lbs/bbl)
WTB# 1	Ector	Permian	43.7	83.82	976	1134.9	6.37
WTB# 4	Terrell	Permian	50	88.82	34	12.6	2.03
WTB# 5	Terrell	Permian	48.3	103.82	18	53	16.1
WTB# 11	Crane	Permian	42.8	33.82	250	72	1.58
WTB# 15	Martin	Permian	40.6	30.82	332	98.8	1.63
WTB# 17	Martin	Permian	41.4	35.82	166	13.1	0.43
WTB# 19	Ector	Permian	42.8	73.82	1979	1790	4.96
WTB# 23	Andrews	Permian	43.3	53.82	327	93.5	1.57
NTB# 1	Ochiltree	Anadarko	44.8	62.14	69	36.7	2.91
NTB# 2	Hansford	Anadarko	45.3	48.44	74	8.3	0.62
NTB# 3	Hansford	Anadarko	42.3	40.44	98	6.9	0.386
NTB# 5	Ochiltree	Anadarko	67.5	44.44	50	154.8	17.0
NTB# 6	Denton	Fort Worth	55.7	158.44	13	19.3	8.14
NTB# 7	Wise	Fort Worth	58.6	161.44	34	38.1	6.14
NTB# 8	Wise	Fort Worth	58.9	139.44	16	100.3	34.3
NTB# 9	Wise	Fort Worth	55.2	167.44	12	38.6	17.6
NTB# 11	Wise	Fort Worth	63.7	245.44	5	71.5	78.4
NTB# 12	Wise	Fort Worth	63.7	239.44	14	14.8	5.79
NTB# 13	Wise	Fort Worth	56.2	139.44	62	39.3	3.47

Table 2-3 shows the estimated emission factors for the 19 test sites using the methods preferred by TCEQ. The emissions factor based on measured emissions is also included for comparison purposes.

Table 2-3. Comparison of Estimated Emissions with Measured Emissions

Site ID #	County	Liquid Production (bbl/day)	VOC Emission Factors (lbs/bbl)				
			Testing	E&P TANK - AP 42 LPO	E&P TANK - RVP LPO	HYSYS	GOR + TANKS 4.09
WTB# 1	Ector	976	6.37	24.67	37.41	13.42	1.99
WTB# 4	Terrell	34	2.03	14.83	17.89	8.70	9.15
WTB# 5	Terrell	18	16.13	12.48	14.61	8.16	6.03
WTB# 11	Crane	250	1.58	8.90	19.66	8.97	0.48
WTB# 15	Martin	332	1.63	13.04	18.07	6.88	0.61
WTB# 17	Martin	166	0.43	20.76	35.35	15.72	0.86
WTB# 19	Ector	1979	4.96	30.52	55.26	22.69	4.51
WTB# 23	Andrews	327	1.57	46.60	55.48	42.44	1.79
NTB# 1	Ochiltree	69	2.91	9.69	26.13	11.91	1.23
NTB# 2	Hansford	74	0.62	9.70	17.92	7.26	0.32
NTB# 3	Hansford	98	0.39	12.52	26.50	4.98	1.59
NTB# 5	Ochiltree	50	16.96	53.81	59.84	4.71	13.63
NTB# 6	Denton	13	8.14	13.49	24.03	12.64	2.74
NTB# 7	Wise	34	6.14	8.22	17.57	1.77	1.43
NTB# 8	Wise	16	34.35	15.07	26.37	3.77	4.28
NTB# 9	Wise	12	17.63	37.44	72.60	4.57	27.03
NTB# 11	Wise	5	78.36	12.60	17.53	8.77	4.60
NTB# 12	Wise	14	5.79	18.79	24.27	2.74	9.00
NTB# 13	Wise	62	3.47	25.98	30.58	0.53	8.15

It is instructive to see how much the various emissions estimation methods over-estimate or under-estimate emissions when compared to measured emissions values. This can help place the estimates generated via emissions estimation methods in context with the measured emissions, and give a sense of their value in estimating actual emissions from condensate tanks. Table 2-4 shows the ratio that the various estimation models over- or under- estimated emissions. The ratio is presented as (estimated emission/measured emission). A ratio of 1 indicates the estimate is in perfect agreement with the measurement, whereas a ratio of 10 indicates the estimated emission rate is ten times higher than the measured emission rate. A ratio of 0.5 indicates the estimated emissions are half of the measured emissions, while a ratio of 0.1 indicates the estimated emissions are 1/10th of the measured emissions. For simplicity, some values have been rounded.

Table 2-4. Ratio Between Estimated Emissions and Measured Emissions

Site ID #	Emission Factor From Measurement (lbs/bbl)	Ratio of Over Estimate or Under Estimate			
		E&P TANK - AP 42 LPO	E&P TANK - RVP LPO	HYSYS	GOR + Tank 4.09
WTB# 1	6.37	4.0	6.0	2.0	0.3
WTB# 4	2.03	7.0	9.0	4.3	4.5
WTB# 5	16.13	0.8	0.9	0.5	0.4
WTB# 11	1.58	5.6	12.5	5.7	0.3
WTB# 15	1.63	8.0	11	4.0	0.4
WTB# 17	0.43	48	82	36	2.0
WTB# 19	4.96	6.0	11	4.6	0.9
WTB# 23	1.57	30	35	27	1.1
NTB# 1	2.91	3.3	9.0	4.0	0.4
NTB# 2	0.62	16	29	12	0.5
NTB# 3	0.39	32	69	13	4.0
NTB# 5	16.96	3.0	3.5	0.3	0.8
NTB# 6	8.14	1.7	3.0	1.6	0.3
NTB# 7	6.14	1.3	3.0	0.3	0.2
NTB# 8	34.35	0.4	0.8	0.1	0.1
NTB# 9	17.63	2.0	4.0	0.3	1.5
NTB# 11	78.36	0.2	0.2	0.1	0.1
NTB# 12	5.79	3.0	4.0	0.5	1.6
NTB# 13	3.47	7.5	9.0	0.2	2.3
	Average	9.5	15.9	6.1	1.1

As can be seen in the table, the discrepancy between the estimated emissions and measured emissions is quite high. Only 18% of these estimates are within the range of half to twice (0.5 to 2) of the actual measured value. In this comparison, the emissions estimation models are shown to be inconsistent.

"*Upstream Oil and Gas Tank Emission Measurements*" (TCEQ, 2010)

This 2010 study conducted by TCEQ examined 7 gas wells/condensate tank sites in the Barnett Shale. This study compared actual measured emissions to estimated emissions using an emissions estimations model (E&P TANK). The research team collected extensive information on the equipment, operating parameters, production, and vented emissions. Vented emissions were measured with both a thermal mass flow meter and an ultrasonic flow meter. Samples of vent gas were collected and analyzed at two different labs. Production of water and condensate were measured. VOC emission rates and emission factors were calculated using this data. Liquid samples were collected

from the pressurized separators and analyzed in a lab. The lab data on the pre-flash liquid composition and equipment operating parameter data were used as inputs to E&P TANK software, and emissions were estimated.

This study is notable for its duplication of all critical measurements and analyses. However, only three of the wells produced condensate during the study period. One of those wells produced only one barrel of condensate, and this production was measured with manual gauging of two tanks of unknown size operating in parallel. The accuracy of this measurement could be subject to the same questions about measurement precision noted by API in their comments on the 2006 HARC study.[10] The other four wells produced no condensate, but VOC emissions were measured from the associated produced water tanks at two of these sites. The study was conducted in July 2010, and the average ambient temperatures recorded on the sites ranged from 74.8 to 86.3 degrees Fahrenheit.

In Table 2-5, the VOC emissions are calculated for the three tanks having condensate production. This table shows the emissions measured using the production data from the thermal mass flow meter and the ultrasonic flow meter. The emissions estimated using E&P TANK are also shown.

If the emissions data from the three sites that produced condensate are averaged using a production-weighted average of the data from the two measurement methods, the average emission factor from both the measurement methods is 12.11 lbs VOC/bbl condensate, whereas the arithmetic average for these three sites from both the measurement methods is 17.52 lbs VOC/bbl condensate. In this study, the estimates of emissions produced with the E&P TANK model varied significantly from the values for actual measured emissions.

2.2.3 Emissions Estimates Derived Solely from Models/Software Programs

This section examines a study which provided a set of emission estimates that were generated using only models or software programs.

"Control of VOC Flash Emissions from Oil and Condensate Storage Tanks in East Texas" (TCEQ, 2010)

This 2010 study conducted by TCEQ assessed the impact of Title 30 Texas Administrative Code 115.112(d)(5) on the implementation of VOC control devices on oil and condensate tanks in the Houston-Galveston-Brazoria (HGB) ozone nonattainment area. In this study, producers in the target areas were surveyed to assess the number of

[10] American Petroleum Institute, API Comments on the Proposed Rulemaking – Oil and Gas Sector Regulations, November 30, 2011, http://www.api.org/Newsroom/testimony/upload/2011-11-30-API-Oil-and-Gas-Rule-Final-Comments-Text.pdf

Table 2-5. Condensate Tank Emission Factors from the TCEQ 2010 Study

Tank Battery	County	Region	API Gravity	Separator Pressure (psi)	Production (bbl/day)	Measured with Thermal Mass Flow Meter		Measured with Ultrasonic Mass Flow Meter		Estimated with E&P TANK
						VOC Emissions (lbs/day)	VOC Emission Factor (lbs/bbl)	VOC Emissions (lbs/day)	VOC Emission Factor (lbs/bbl)	VOC Emission Factor (lbs/bbl)
Gage Pitts	Wise	Fort Worth	61.2	171	58.5	717.9	12.3	639.9	10.9	11.5
Waggoner Crystelle	Wise	Fort Worth	61.2	119	3.34	12.7	3.8	105.3	31.5	7.6
First Baptist Church Slidell No.1	Wise	Fort Worth	51	NR	1	11.3	11.3	35.3	35.3	0.7

tanks that were controlled and the type of controls installed. Although this report does not include any new emissions measurements, it is valuable as it contains E&P TANK and HYSYS reports for 21 condensate batteries in the Haynesville Shale area. One company provided a summary of VOC emissions calculated using E&P TANK run with site-specific sampling inputs for 13 condensate tank batteries in the Haynesville Shale area.

Another company provided emissions estimated using the HYSYS Version 2006.5 process simulator for eight natural gas condensate tank batteries in the Haynesville Shale. These estimates are shown in Table 2-6. As no production figures were given, a production-weighted average cannot be calculated. The arithmetic average is 5.80 lbs VOC/ bbl condensate.

Table 2-6. Producer-Supplied VOC Emission Estimates for Condensate Tank Batteries in Haynesville Shale Area

Site Number	Region	Separator Pressure (psig)	Separator Temperature (°F)	API Gravity @ 60°F	Estimation Model	VOC Emissions (lbs/bbl)
1	Haynesville Shale	45	80	50.6	E&P TANK	2.67
2		40	80	49.6	E&P TANK	8.45
3		25	86	54.2	E&P TANK	5.38
4		95	89	55.4	E&P TANK	1.67
5		16	97	59.5	E&P TANK	1.09
6		30	70	55.3	E&P TANK	1.45
7		60	78	64.6	E&P TANK	8.91
8		120	89	55.0	E&P TANK	10.24
9		95	80	55.0	E&P TANK	11.97
10		60	75	52.4	E&P TANK	4.62
11		80	72	57.0	E&P TANK	3.98
12		120	85	55.0	E&P TANK	11.97
13		60	77	53.8	E&P TANK	3.49
14		40	85	N/A	HYSYS	1.16
15		108	98	N/A	HYSYS	0.31
16		752	82	N/A	HYSYS	15.84
17		76	90	N/A	HYSYS	0.32
18		110	80	N/A	HYSYS	0.85
19		690	70	N/A	HYSYS	14.79
20		560	98	N/A	HYSYS	0.73
21		230	90	N/A	HYSYS	11.83
				Average		5.80

2.2.4 Other Studies

The following study was evaluated for its utility in contributing estimates for the regional emission factors being developed in this study.

"*Recommendations for Improvements to the CENRAP State's Oils and Gas Emissions Inventories*" (Central Regional Air Planning Association (CENRAP), 2008)

This report contains emission factors for flashing, working, and breathing emissions for condensate tanks in the Anadarko basin. The CENRAP 2008 report states that this emission factor (13.86 lbs VOC/bbl) was obtained from the Independent Petroleum Association of Mountain States (IPAMS)/Western Regional Air Partnership (WRAP) Phase III work (Bar-Ilan, et al, 2008). The IPAMS/WRAP Phase III report states that the emission factors were derived from producer surveys conducted in 2008, but this information and the emission factor could not be verified. The CENRAP 2008 report also contains an emission factor for flashing, working, and breathing emissions from condensate tanks in the East Texas, Western Gulf, Fort Worth, and Permian basins. However, as this emission factor (33.3 lbs VOC/bbl) was taken from the HARC H051C study, it will not be used. Therefore, the emission factors from the CENRAP 2008 report will not be used.

2.3 Emission Factor Development Using the Barnett Shale Area Special Inventory, Phase II (2009)

TCEQ provided ERG with data from the "Barnett Shale Area Special Inventory, Phase II 2009" (Barnett Shale Inventory) information in spreadsheet format. The Barnett Shale Inventory data contains 2,268 records with reported condensate production rates and calculated VOC emissions. The VOC emissions were estimated using a variety of methods, including direct measurement of tank emissions, test data, and flash emission and working and breathing emissions models. ERG analyzed this data and developed emission factors for condensate tanks in the Bend-Arch-Fort Worth and Barnett Shale counties.

The original data from 4 separate spreadsheet pages was uploaded into an Access database so that data for individual facilities could be joined into one record. The data was then downloaded back into Excel for analysis. Records were sorted to remove: all records using non-preferred emission estimations methods (Vasquez-Beggs equation, derived emission factors, and HARC H051C emission factor), all records where condensate tank emissions were equal to zero, and all records where annual throughput of condensate was equal to zero. Individual records were examined for internal consistency, and were rejected if the recorded site values for annual throughput were not equal to condensate production. Emission factors were calculated using the values for emissions and throughput. All records with emission factors above 140 lbs/bbl were rejected, as it was deemed that emissions above 50% of the weight of produced condensate were indicative of equipment malfunction or an error in the data, estimating method, or record. The records were then sorted by estimation method. Records in which the estimation method was not noted were not analyzed, as these records lacked

critical information for determining their usefulness and accuracy. Both a production-weighted average and an arithmetic average emission factor, before controls, were calculated for each of the emission estimation methods. The percent of total production that is reported in the special inventory as controlled was also calculated. The results are presented in Table 2-7.

The production-weighted average of the emission factors developed using the estimation methods preferred by TCEQ is 6.77 lbs/bbl, before the effect of controls. The arithmetic average of the emission factors developed using the estimation methods preferred by TCEQ is 12.95 lbs/bbl, before the effect of controls. As discussed in the report "*Upstream Oil and Gas Storage Tank Project Flash Emissions Models Evaluation*", the E&P TANK and the Process Simulator models tended to produce higher emission estimates, while the GOR method produced lower estimates. This is reflected in the Barnett Shale Inventory data; the emission estimates generated with E&P TANK (6.58, 6.71, and 10.13 lbs/bbl) and process simulator models (7.51 lbs/bbl) are generally, but not always, higher than the emission estimates generated using the GOR method (3.96 and 8.12 lbs/bbl).

Table 2-7. Condensate Tank VOC Emission Factors by Method – Barnett Shale Inventory

Flash Emission Calculation Method	Working and Breathing Emission Calculation Method	Total Production (bbl)	Number of Sources (Count)	Production-Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)	% of Production Controlled
Process Simulator Models	EPA TANKS Program	62,112	32	7.51	10.8	0%
E&P TANK	Other:	112,651	142	6.58	23.3	7.7%
E&P TANK	EPA TANKS Program	94,544	29	6.71	13.5	15.2%
E&P TANK	E&P TANK	947,655	918	10.13	12.9	0.26%
GOR Method	EPA TANKS Program	74,652	36	8.12	9.60	6.71%
GOR Method	E&P TANK	1,175,194	407	3.96	9.87	25.8%
Direct Measurement of Emissions	Other:	12,601	11	7.82	13.3	0%
Preferred Methods	Totals	2,479,409	1,575	6.77	12.95	13.5%

One survey respondent indicated that they used direct measurement to estimate emissions, but, since no other details were given, these data points were treated as being calculated by a preferred method.

The Barnett Shale Inventory data was also sorted by county, and emission factors for condensate tanks were developed at the county level. The data analysis was similar to that done for the entire Barnett Shale region. Emission factors were created using the values for emissions and throughput. The records were then sorted by estimation method, and only records using the preferred estimation methods for flashing emissions (direct measurement, process simulator, E&P Tank, GOR) were analyzed. Records in which the estimation method was unknown were not analyzed. Records were then sorted by county. A production-weighted average emission factor, and an arithmetic average of the emission factors, before controls, was calculated for each of the counties. The results are presented in Table 2-8.

Table 2-8. Condensate Tank VOC Emission Factors by County – Barnett Shale Inventory

Emission Calculation Methods	County	Total Production (bbl)	Number of Sources (Count)	Production-Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)	% of Production Controlled
Flash Emissions: Process Simulator Models, E&P Tank, Direct Measurement, GOR Working and Breathing Emissions: E&P Tank, EPA TANKS Program, Other	Clay	6,404	3	3.83	7.10	0.0%
	Cooke	155,352	41	4.15	4.53	35.7%
	Denton	180,295	226	9.51	13.98	2.6%
	Erath	35,520	72	16.88	18.75	0.0%
	Hood	199,738	183	7.70	12.10	1.9%
	Jack	62,590	40	4.86	8.57	0.0%
	Johnson	62,207	71	9.77	16.74	3.5%
	Montague	588,385	135	3.55	5.39	42.1%
	Palo Pinto	333,620	53	2.25	5.14	0.2%
	Parker	164,973	231	10.70	13.58	5.6%
	Somervell	6,753	23	10.24	16.50	0.0%
	Stephens	4,156	4	3.96	3.96	0.0%
	Tarrant	42,517	81	11.09	12.39	6.0%
	Wise	636,347	411	9.75	15.58	0%

For certain counties, sufficient data may be available to develop a county-specific emission factor based only on the data available for that particular county. However, a careful examination of these county-specific emission factors (see Attachment C) shows that they vary widely within any one region. This may be indicative of the variation in properties of the condensate produced, or it may be due to an inadequate sample size. Due to the variation observed in the county-specific factors and the uncertainties associated with these factors, the regional emission factors presented in Table 2-15 (see

discussion below) are recommended for developing the state-wide area source inventory.

2.4 Phone Survey of Area Sources

ERG attempted to contact 54 producers operating in the six regions of interest and request condensate tank emissions data. The companies selected were identified by a search of the RRC website[11] as major producers of condensate in the six regions of interest for the survey. The six regions of interest were the Anadarko, East Texas, Permian, and Western Gulf basins and the Haynesville and Eagle Ford shales. Table 2-9 and Figure 2-2 show the counties within each of the regions that were targeted. These counties were chosen due to their high condensate production relative to all of the counties in that region.[12]

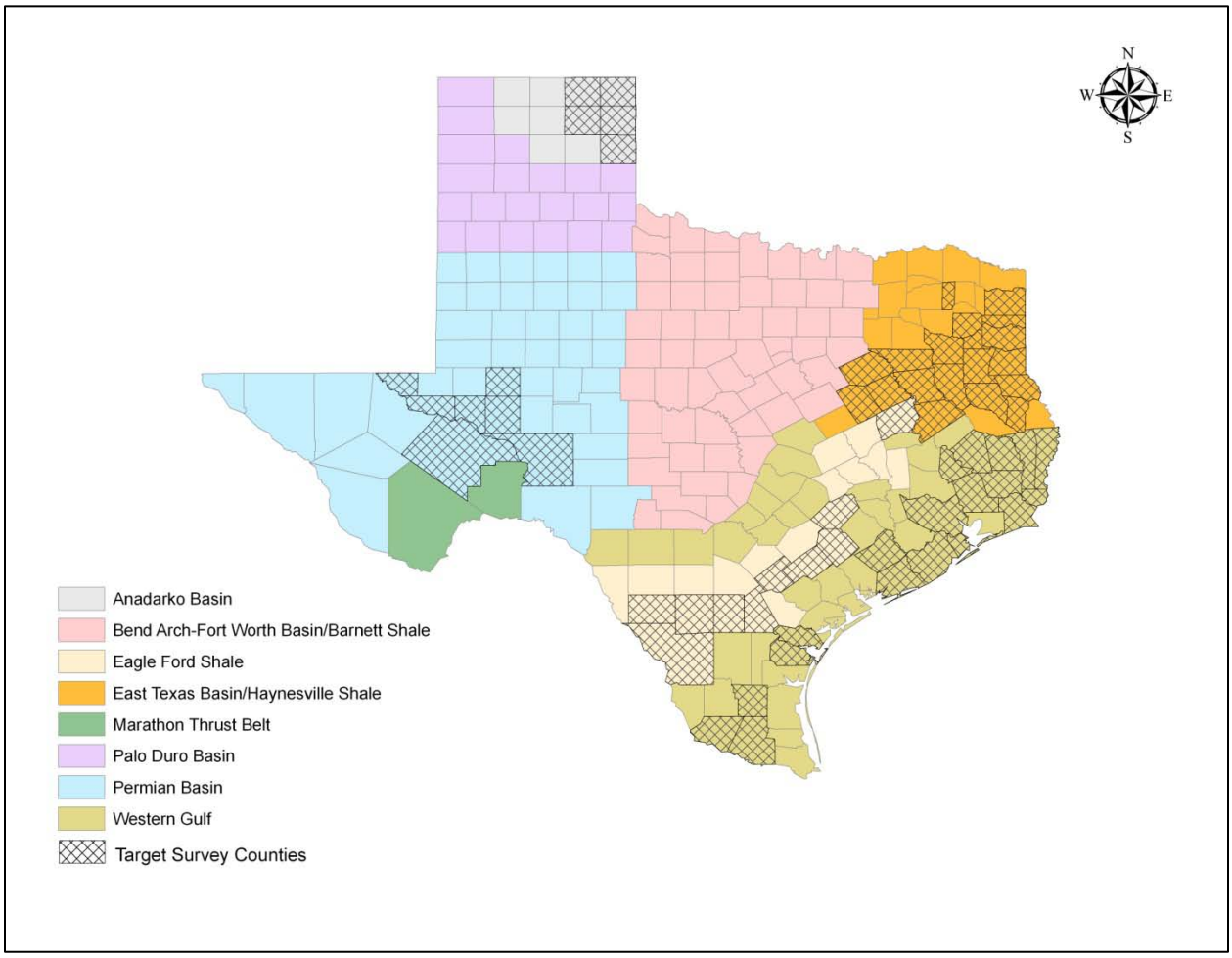
Table 2-9. Target Survey Counties

Anadarko	Permian	East Texas	Western Gulf	Eagle Ford Shale	Haynesville Shale
Hemphill, Lipscomb, Ochiltree, Roberts, and Wheeler	Crane, Crockett, Loving, Midland, Pecos, Upton, and Ward	Anderson, Cass, Cherokee, Franklin, Freestone, Henderson, Houston, Limestone, Navarro, Smith, and Upshur	Brazoria, Brooks, Galveston, Hardin, Harris, Hidalgo, Jasper, Jefferson, Liberty, Matagorda, Newton, Nueces, Orange, Polk, San Jacinto, San Patricio, Starr, Tyler, and Wharton	DeWitt, Dimmit, Fayette, Karnes, LaSalle, Lavaca, Leon, Live Oak, McMullen, and Webb	Gregg, Harrison, Marion, Nacogdoches, Panola, Rusk, San Augustine, and Shelby

[11] Railroad Commission of Texas, Statewide Production data Query System, http://www.rrc.state.tx.us/data/online/index.php

[12] Condensate production data at the county level was mapped in ARC GIS, and the top-producing counties in each region were identified. The RRC database was then queried for operators of gas wells in these top-producing counties in each region. Operator production data was compiled for each region and the top producers were identified. These companies were contacted.

Figure 2-2. Target Survey Counties



The Bend Arch-Fort Worth basin and Barnett Shale were not surveyed, as adequate data on condensate tank emissions had already been gathered during the Barnett Shale Area Special Inventory.[13] As the survey progressed, it became apparent that much of the condensate produced in the counties designated as Haynesville Shale was actually being produced from another petroleum formation (Cotton Valley Group) located in the same counties as the Haynesville Shale. Therefore, for purposes of calculating emissions, the East Texas and Haynesville Shale regions were merged into one region.

Letters were sent to a total of 61 regional offices at 54 separate companies. Letters were sent to 116 contacts at these companies explaining the survey and requesting cooperation in gathering data. The letter requested data on county, separator pressure, API gravity, 2011 condensate production, 2011 VOC emissions, emissions estimation method, control technology, and control efficiency. This letter is shown in

[13] Texas Commission on Environmental Quality (TCEQ), Barnett Shale Area Special Inventory, Phase Two, http://www.tceq.texas.gov/airquality/point-source-ei/psei.html#barnett2

Attachment A. The initial contact list was obtained from RigData© as it provided the names of people involved in the production (drilling) operation for the respective companies. In most cases, each contact was called 3 or 4 times in order to get a referral to someone in the environmental department of the company. Once phone contact was made with a person in a position to provide the requested information, ERG explained the purpose of the survey and requested participation. ERG obtained email addresses and sent survey materials via email directly to the contact person. The survey materials explained the background and purpose of the survey in greater detail, asked for the voluntary participation of the company, and stated that information would be held confidential. Since many of the companies surveyed only had production in one or two regions, the survey materials were tailored for each company to provide a specific and detailed listing of the region(s) and counties of interest. These materials included a Word document with a table for reporting the data, and an Excel spreadsheet with individual tabs for reporting data from each of the regions. The intent with providing these user-friendly survey materials was to make response as easy as possible and also to gather the data in a format that could be easily copied into spreadsheets for data analysis. These survey materials are shown in Attachment B. Once survey materials had been sent, a follow-up phone call was made a week later to ask if there were any questions and to determine if the company was willing to participate in the survey.

Active survey outreach efforts spanned a six-week period, and included sending the initial contact letters, calling sources to establish contact, sending follow-up letters to the proper contact as needed, making follow-up phone calls, sending emails with survey materials, and making phone calls/sending emails to determine if companies would be willing to participate. Fifteen companies participated in the survey, providing information on more than 251 separate wells/tanks.

2.4.1 Analysis of Data Collected via Phone Survey

Fifteen companies responded to the survey, and provided data from more than 251 separate wells/tank batteries. One company sent data for nine representative wells that represented production from 140 separate wells. Other companies sent data for a few sites that were representative of their other wells in that region.

Certain data received in the survey were not used in the analysis. One company provided data for ten wells but no estimates of VOC emissions, and several companies sent data for wells with API gravity less than 40 degrees. Several companies also provided data for wells with a final separator pressure less than 5 psig; this data was not used in the calculations as these low separator pressures are more indicative of wells producing oil and were not consistent with the separator pressures observed in the survey results for the primary condensate producing regions in Texas. Finally, the emissions data generated using non-preferred methods was not included in the analysis.

The raw data collected in the ERG survey, along with notes on which data was excluded from the analysis, is provided in Attachment C.

Data was collected from a sufficient number of tank batteries in each target region. ERG developed a region-wide emission factor for each of the five gas-producing regions targeted in the phone survey. This data was sorted by region. Emission factors were calculated for each of the regions. The survey also requested information on any recovery or control methods used at each well. A very high percentage of respondents indicated that they used recovery or control methods on their wells/tanks. For purposes of comparing the survey results with the test results and emission estimates from earlier studies, emission factors for the emissions before the effect of any controls were calculated.

The producers who responded to this survey used a variety of calculation models (testing, E&P Tank, ProMax, WinSim, VMGSim, HYSYS, GOR, and Vasquez Beggs) for estimating flash emissions. ERG examined these results in light of the evaluation of the accuracy of these models presented in "Upstream Oil and Gas Storage Tank Project Flash Emissions Models Evaluation" (TCEQ, 2009)[14] and TCEQ's guidance on calculating flash emissions[15]. ERG used only records where the flash emissions calculation method was one of the methods preferred by TCEQ. One producer sent test results for three tanks. Since only the results and no underlying data or test reports were submitted, these three data points were treated as being calculated by a preferred method.

Table 2-10 summarizes the findings from the survey. The data show a clear difference in the emission factors by region.

Table 2-10. Survey Results Using all Valid Survey Data Estimated with Preferred Estimation Methods

Region	Total Production Represented in Survey (bbl)	Data Points	Production-Weighted VOC Emission Factor (lbs/bbl)	Arithmetic Average VOC Emission Factor (lbs/bbl)	Percent of Surveyed Production Controlled
Anadarko	533,419	18	1.63	7.47	99.4%
Eagle Ford	10,538,273	41	11.3	9.41	92.2%

[14] Texas Commission on Environmental Quality, Upstream Oil and Gas Storage Tank Project Flash Emissions Models Evaluation, 2009, http://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/ei/20090716-ergi-UpstreamOilGasTankEIModels.pdf

[15] "Calculating Volatile Organic Compounds (VOC) Flash Emissions from Crude Oil and Condensate Tanks at Oil and Gas Production Sites", APDG 5942, May 2012, http://www.tceq.texas.gov/assets/public/permitting/air/Guidance/NewSourceReview/guidance_flashemission.pdf

Table 2-10. Survey Results Using all Valid Survey Data Estimated with Preferred Estimation Methods

Region	Total Production Represented in Survey (bbl)	Data Points	Production-Weighted VOC Emission Factor (lbs/bbl)	Arithmetic Average VOC Emission Factor (lbs/bbl)	Percent of Surveyed Production Controlled
East Texas	518,691	83	5.91	5.75	82.1%
Permian	245,545	5	10.75	8.13	79.5%
Western Gulf	182,349	28	1.84	5.32	46.5%

2.4.2 Use of Vapor Recovery and Controls to Reduce Emissions

The ERG survey data indicates that companies are installing vapor recovery units (VRU) or control devices (flares or combustors) on their highest producing wells. VRUs may be installed for economic reasons as any vapor recovery equipment installed on a high-producing well will deliver a higher return of saleable product per dollar invested in equipment. Similarly, for companies using flares or combustors to control emissions, these control devices are being used on the highest-producing wells.

Survey data indicated that surveyed companies have installed vapor recovery or control devices on 34% of their wells/tanks, representing 91.1% of their total production. The data indicate that the emissions before controls for nearly all of the wells/tanks that had recovery devices or controls installed is greater than 25 tons per year of VOC. Producers reported that emissions from 5.7% of surveyed production were recovered with VRUs, and emissions from 85.4% of surveyed production were controlled with flares or combustors, and the average percent reduction was 97.6%.

This level of control is much higher than the results reported in the 2010 TCEQ study "Control of VOC Flash Emissions from Oil and Condensate Storage Tanks in East Texas", in which survey respondents reported that 72% of surveyed production in the Beaumont-Port Arthur (BPA) counties were controlled, 25% of surveyed production in the HGB area were controlled, and 9% of surveyed production in the Haynesville Shale counties were controlled. The survey data also shows a much higher percentage of control than was observed in the Barnett Shale Area Special Inventory, where 13.2% of total surveyed production was reported as recovered or controlled.[16] This may be due to the differences in production in the Barnett Shale and Haynesville Shale versus the other regions of Texas. The Barnett Shale and Haynesville Shale both produce a 'dry' gas, with limited condensate production. Therefore, it may not have been economically

[16] These data are shown in Table 17 of this report.

feasible or necessary from a regulatory standpoint at the time this survey was taken to control the emissions from the condensate tanks in the Barnett and Haynesville Shale.

The higher level of control observed in the ERG survey may also be due to the increasing awareness and implementation of recovery and control technologies over time, and the effect of new regulations. The Barnett Shale Inventory and the TCEQ surveys were conducted in 2009, whereas the ERG survey was conducted in 2012 and covers production and emissions in 2011. Title 30 Texas Administrative Code 106.352, Permit by Rule for Oil and Gas Handling and Production Facilities[17], became effective on February 2, 2012, which may account for the higher control percentages observed during this survey.

2.4.3 Self-Selection Bias

For any survey, the researchers need to consider if the respondents have given them data that is representative of all of their operations. ERG specifically requested in the survey materials and phone conversations that companies submit a random, representative sampling of their wells. ERG has no direct knowledge that any of the companies who responded to this survey biased the data that they submitted. However, the percent of surveyed production with emissions being recovered or controlled (91.1%) is very high when compared to the results obtained from the Barnett Shale Area Special Inventory and other studies. In reviewing the differences in the percentage of production that was reported as recovered or controlled in the ERG survey, versus the amount that was reported as controlled in the Barnett Shale Area Special Inventory, it must be noted that the results of the ERG survey were obtained voluntarily, whereas the Barnett Shale Area Special Inventory was a mandatory survey of all producers operating in that region. ERG collected survey data from 15 large and medium sized companies. A significant portion of the larger companies operate the highest producing wells in many regions. Also, larger companies may have the capital to purchase and install control devices, and may also have more resources to respond to surveys.

2.4.4 Innovative Practices that Lower Area Emissions

Two innovative practices in use that have the effect of lowering emissions were identified as part of the survey. During initial phone conversations, two companies declared that they had no tank emissions at upstream sites (well pads) because they no longer routinely used tanks in the field for their day to day operations. While these companies would install a portable liquids tank during the initial phase of well completion, the tank would soon be replaced with piping that collected all gas and condensate from multiple wells in an area and route them to a single gathering station. All gas and liquids would be processed at that station, which utilized vapor recovery and

[17] Texas Commission on Environmental Quality, Rules, http://www.tceq.state.tx.us/rules/indxpdf.html

control equipment such that condensate tank emissions were negligible. This company replaced the traditional tank at the well site with piping and a centralized processing facility.

Another company submitted data with very low emission factors, despite the fact that tank emissions were uncontrolled. When questioned, the company official stated that the emissions factors were low as a result of their operating practices. This company captures as much flash gas as possible and has designed their facilities such that when liquids reach the tanks the pressure has been released to 2 psi [above ambient] allowing flash gas in the liquids to be released prior to the tank, captured by a vapor recovery system, and sent to the gas pipeline. This company also routes the vapors from their storage tanks to a flare. Finally, the emissions from the trucks loading liquids from the field tanks is sent back to the storage tank with vapor balance piping and routed to the flare.

Both of these practices lower the emissions from storage tanks substantially, as they recover or control nearly 100% of the VOC that would normally be emitted in an uncontrolled operation. Ultimately, these potential survey participants did not provide data as part of this survey as they had no upstream tanks and no tank emissions.

2.5 Weighting the Data

2.5.1 Weighting Data based on Method

This study compiled emissions data produced by both testing and emissions estimation methods, with the data coming from four published studies, one TCEQ inventory, and the survey associated with this report. All of this data was evaluated for its accuracy and relative merit in compiling regional and county-specific emission factors. TCEQ's guidance "Calculating Volatile Organic Compounds (VOC) Flash Emissions from Crude Oil and Condensate Tanks at Oil and Gas Production Sites"[18] was used as the basis for weighting the data obtained from testing and the various emissions estimation methods. Data obtained from testing is considered the most accurate source of emissions data, and is weighted the highest. Emissions estimates produced through use of process simulation models, E&P TANK, and the Gas-Oil-Ratio method are weighted in decreasing order of preference, consistent with the TCEQ guidance.

Table 2-11 shows the weighting factors applied to each estimation method.

[18] "Calculating Volatile Organic Compounds (VOC) Flash Emissions from Crude Oil and Condensate Tanks at Oil and Gas Production Sites", APDG 5942, May 2012, http://www.tceq.texas.gov/assets/public/permitting/air/Guidance/NewSourceReview/guidance_flashemission.pdf

Table 2-11. Weighting Factors by Emissions Estimation Method

Emissions Estimation Method	Weight
Testing	4
Process Simulator (HYSIM, HYSIS, VMG, PROMAX)	2
E&P TANK	1.5
Gas-Oil-Ratio	1

The equation used to derive the regional emission factors is shown below:

$$\text{Regional Emission Factor (lbs/bbl)}_{\text{Region i}} = [(EF_{\text{Region i TESTING}} \times 4) + (EF_{\text{Region i PROCESS SIMULATOR}} \times 2) + (EF_{\text{Region i E\&P TANK}} \times 1.5) + (EF_{\text{Region i GAS-OIL-RATIO}} \times 1)]/(4+2+1.5+1) \quad \text{(Eq. 2-1)}$$

Where:

$EF_{\text{Region i TESTING}}$ = emission factor for the region based on testing (lbs/bbl)

$EF_{\text{Region i PROCESS SIMULATOR}}$ = emission factor for the region based on process simulator (lbs/bbl)

$EF_{\text{Region i E\&P TANK}}$ = emission factor for the region based on E&P Tank (lbs/bbl)

$EF_{\text{Region i GAS-OIL-RATIO}}$ = emission factor for the region based on the GOR method (lbs/bbl)

2.5.2 Weighting Data based on Production

In addition to the method weighting discussed above, a production weighted average was used to assess the average emission rate for the wells/tanks in each particular county or region. This approach more accurately reflects the overall total emissions in a region containing a mix of high and low production sites and is appropriate for area source emissions estimation.

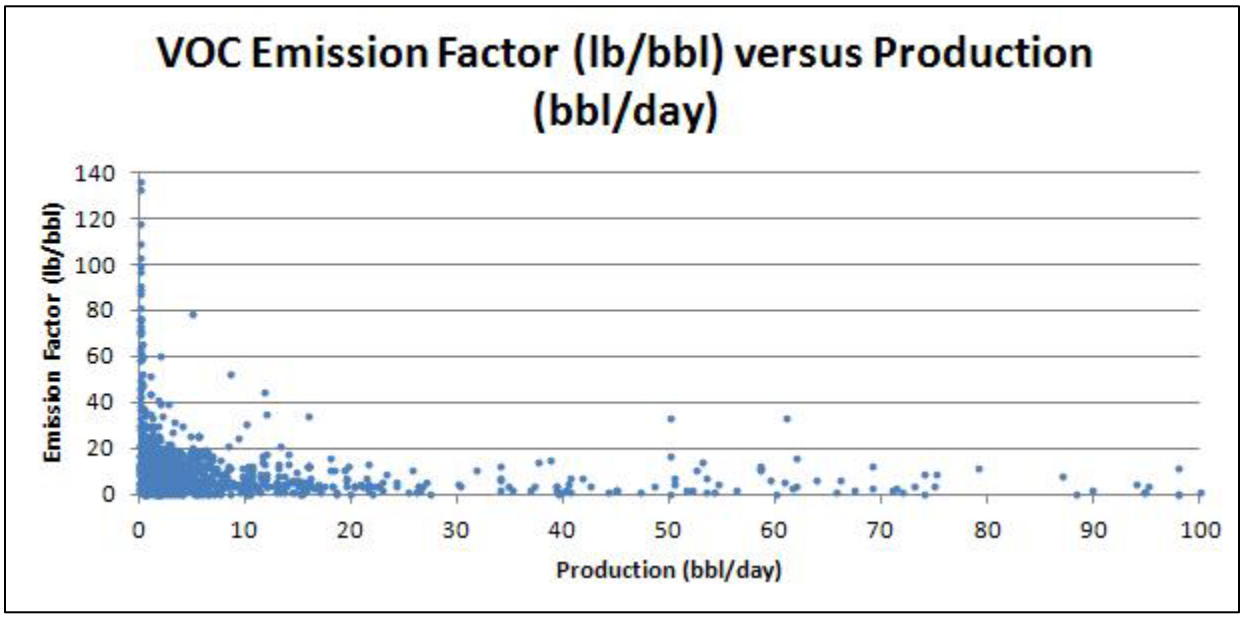
For example, if a region contains ten well sites, and there are 5 sites each producing 2 barrels of condensate per day and having measured emissions of 40 lbs/ bbl, and there are another 5 sites each producing 130 barrels per day and having measured emissions of 4 lbs/bbl, by using a production-weighted approach, the average emissions from these 10 wells/tanks is:

$$(5 \times 2 \times 40 + 5 \times 130 \times 4)/(5 \times 2 + 5 \times 130) = 4.55 \text{ lbs VOC/bbl}$$

The straight arithmetic average for these sites is 22 lbs/bbl. The actual total VOC emissions from the ten sites in this region are 3,000 pounds per day, and the total production from the ten sites in the region is 660 barrels. On a region-wide basis, the actual emissions are 3,000/660 = 4.55 lbs/bbl.

A scatter plot of the data points compiled in this report provides a useful visual depiction of the relationship between emissions on a per barrel basis and production at a given well. Figure 2-3 shows the production for each tank on the x-axis and the VOC emission factor for each tank on the y-axis. The data show a clear relationship between low production and high per-barrel emission factors, yet most of the production in any region comes from the wells with high production, which typically have lower per barrel emission factors.

Figure 2-3. Relationship between Production and Emission Factor



2.6 Regional Emission Factors

A two-step process was used in compiling the emissions data into regional emission factors for VOC and HAP. First, data was separated into subgroups by region. Subsequently, data records from each regional subgroup were separated into categories by the estimation method used (testing, process simulator, E&P Tank, GOR). A production weighted average emission factor was calculated for each subgroup for each region. The production-weighted average emission factors for each region were then combined into a single regional emission factor using the weighting factors shown in Table 2-11 as described above.

The compiled results of the testing data and estimates from the studies and surveys are shown in the Tables 2-12 through 2-16. Table 2-12 shows the compiled average of emission factors derived from testing. The test results are grouped by region, and a production-weighted average and arithmetic average is calculated for each region. These emission factors show the emissions before the effect of any controls.

Table 2-12. Average Regional VOC Emission Factors Derived from Testing Data

Studies	Region	Count of Data Points	Production-Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Flash[a]	Anadarko	4	3.89	5.22
HARC 51C, Flash[a], Upstream[b]	Fort Worth	23	12.26	20.67
Flash[a]	Permian	8	4.39	4.34
HARC 51C	Western Gulf	9	16.34	13.72

[a] Upstream Oil & Gas Storage Tank Project Flash Emissions Models Evaluation (2009).
[b] Upstream Oil & Gas Tank Emissions Measurement (2010).

Table 2-13 shows the compiled emission factors derived from the three studies referenced in this report. These emission factors (all based on E&P TANK, process simulation models, or GOR data) are grouped by region, and a production-weighted average and arithmetic average is calculated for each region. The averages for each region were developed using the weighting factors in Table 2-11. These emission factors show the emissions before the effect of any controls.

Table 2-13. Average Regional VOC Emission Factors Derived from Estimation Methods

Studies	Region	Count of Data Points	Production-Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Flash[a]	Anadarko	4	14.65	16.36
Control of VOC Flash Emissions[b]	East Texas	21	5.78	5.78
Upstream[c], Flash[a]	Fort Worth	10	13.69	12.89
Flash[a]	Permian	8	23.51	18.06

[a] Upstream Oil & Gas Storage Tank Project Flash Emissions Models Evaluation (2009).
[b] Control of VOC Flash Emissions from Oil and Condensate Storage Tanks in East Texas (2010).
[c] Upstream Oil & Gas Tank Emissions Measurement (2010).

Table 2-14 shows the compiled average emission factors derived from the ERG 2012 survey responses and the 2009 Barnett Shale Special Area Inventory. In these surveys, producers used direct measurement and estimation methods (E&P TANK, process simulation models, GOR) to estimate emissions from their condensate tanks. However,

for the testing data, only the test results and no underlying data or test reports were submitted. Therefore, the testing data were treated as being calculated by a preferred method and given a weight of 1.5 instead of 4.

These emission estimates are grouped by region, and a production-weighted average and arithmetic average is calculated for each region. The averages for each region were weighted according to the weighting factors in Table 2-11. These emission factors show the emissions before the effect of any controls.

Table 2-14. Average Regional VOC Emission Factors from ERG Survey Data and Barnett Shale Inventory Data

Survey	Region	Count of Data Points	Production-Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
ERG 2012 survey	Anadarko	18	2.49	6.45
ERG 2012 survey	Eagle Ford	41	10.5	10.0
ERG 2012 survey	East Texas	83	3.51	6.22
ERG 2012 survey	Permian	5	6.25	6.08
ERG 2012 survey	Western Gulf	28	4.95	16.1
Barnett Shale Inventory	Fort Worth	1,575	7.54	12.2

Table 2-15 shows the compiled average emission factors when the data from the testing results (Table 2-12), studies (Table 2-13), and the ERG 2012 and Barnett Shale surveys (Table 2-14) is combined. The testing and emission estimate data is grouped by region, and a production-weighted average and an arithmetic average is determined for each region. The production-weighted average and arithmetic average for each region were weighted according to the weighting factors in Table 2-11. As there are no data available for the Palo Duro Basin and the Marathon Thrust Belt, a statewide average is used for these two regions. These emission factors show the emissions before the effect of any controls.

Table 2-15. Average Regional VOC Emission Factors

Region	Count of Data Points	Production-Weighted Emission Factor (lb/bbl)	Arithmetic Average Emission Factor (lb/bbl)
Anadarko	26	3.15	5.87
Eagle Ford Shale	41	10.5	10.0
East Texas/Haynesville Shale	104	4.22	5.92
Fort Worth/Barnett Shale	1,604	9.76	16.0
Permian	21	7.07	5.90

Table 2-15. Average Regional VOC Emission Factors

Region	Count of Data Points	Production-Weighted Emission Factor (lb/bbl)	Arithmetic Average Emission Factor (lb/bbl)
Western Gulf	37	11.0	14.8
Palo Duro[a]	N/A	7.61	9.75
Marathon Thrust Belt[a]	N/A	7.61	9.75

[a] Statewide average.

Figure 2-4 provides the geographical distribution of the data sources used to compile the regional emission factors in Table 2-15 on a county-basis.

Figure 2-4. Condensate Tank Emission Data Sources by County

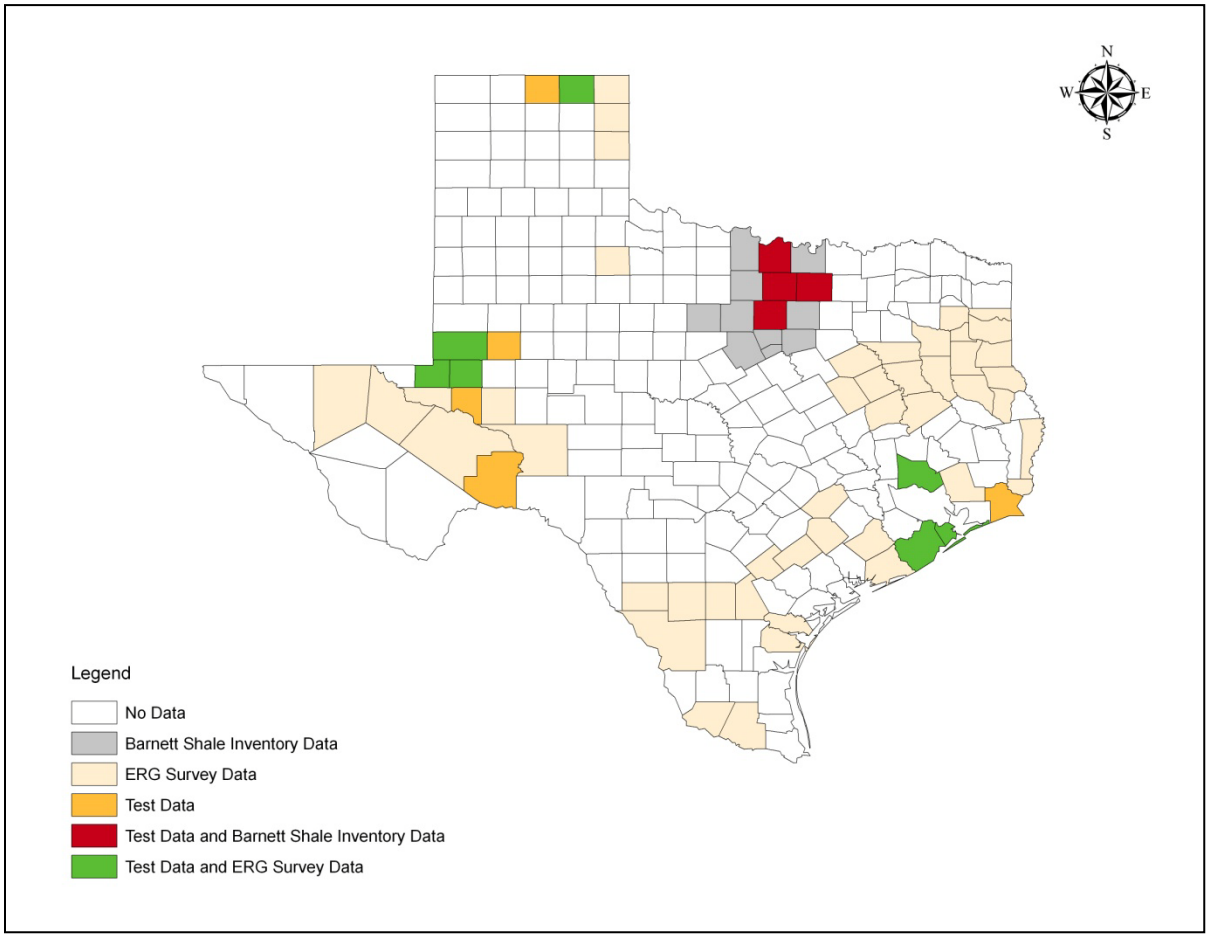
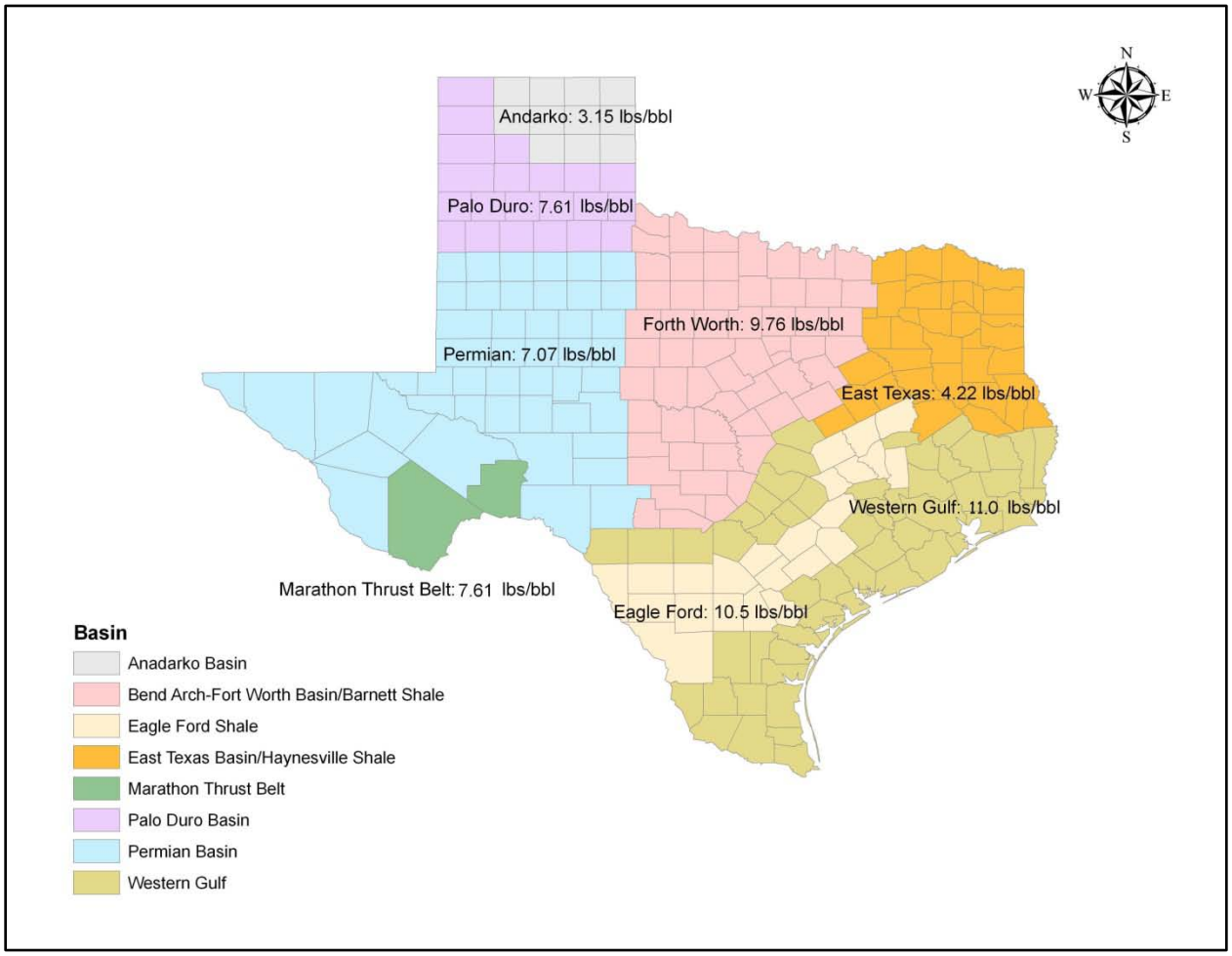


Figure 2-5 shows the results from Table 2-15 geographically. Determination of which counties are included in each region is from the United States Geological Survey.[19] Counties in the Eagle Ford Shale were identified by the RRC.[20] For certain counties, there was sufficient data available to develop a county-specific emission factor based only on the data available for that particular county. However, a careful examination of these county-specific emission factors (see Attachment C) shows that they vary widely within any one region. This may be indicative of the variation in properties of the condensate produced, or it may be due to an inadequate sample size. Due to the variation observed in the county-specific factors and the uncertainties associated with these factors, the regional emission factors presented in Table 2-15 are recommended for developing the state-wide area source inventory.

Figure 2-5. Average Regional Emission Factors, Before Controls



[19] United States Geological Survey, National Oil and Gas Assessment, http://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment.aspx
[20] Texas Railroad Commission, Eagle Ford Information, http://www.rrc.state.tx.us/eagleford/

The region-specific condensate tank emission factors can then be assigned on a county basis by allocating each county in the state to one of the regions identified in Table 2-15. The county-level VOC emission factor (both production weighted and arithmetic average) for each county in Texas is shown in Table 2-16.

Table 2-16. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Anderson	East Texas/Haynesville Shale	4.22	5.92
Andrews	Permian	7.07	5.90
Angelina	East Texas/Haynesville Shale	4.22	5.92
Aransas	Western Gulf	11.0	14.8
Archer	Fort Worth/Barnett Shale	9.76	16.0
Armstrong	Palo Duro	7.61	9.75
Atascosa	Eagle Ford Shale	10.5	10.0
Austin	Western Gulf	11.0	14.8
Bailey	Palo Duro	7.61	9.75
Bandera	Fort Worth/Barnett Shale	9.76	16.0
Bastrop	Western Gulf	11.0	14.8
Baylor	Fort Worth/Barnett Shale	9.76	16.0
Bee	Eagle Ford Shale	10.5	10.0
Bell	Western Gulf	11.0	14.8
Bexar	Western Gulf	11.0	14.8
Blanco	Fort Worth/Barnett Shale	9.76	16.0
Borden	Permian	7.07	5.90
Bosque	Fort Worth/Barnett Shale	9.76	16.0
Bowie	East Texas/Haynesville Shale	4.22	5.92
Brazoria	Western Gulf	11.0	14.8
Brazos	Eagle Ford Shale	10.5	10.0
Brewster	Marathon Thrust Belt	7.61	9.75
Briscoe	Palo Duro	7.61	9.75
Brooks	Western Gulf	11.0	14.8
Brown	Fort Worth/Barnett Shale	9.76	16.0
Burleson	Eagle Ford Shale	10.5	10.0
Burnet	Fort Worth/Barnett Shale	9.76	16.0
Caldwell	Western Gulf	11.0	14.8
Calhoun	Western Gulf	11.0	14.8
Callahan	Fort Worth/Barnett Shale	9.76	16.0
Cameron	Western Gulf	11.0	14.8
Camp	East Texas/Haynesville Shale	4.22	5.92
Carson	Anadarko	3.15	5.87
Cass	East Texas/Haynesville Shale	4.22	5.92
Castro	Palo Duro	7.61	9.75
Chambers	Western Gulf	11.0	14.8
Cherokee	East Texas/Haynesville Shale	4.22	5.92
Childress	Palo Duro	7.61	9.75
Clay	Fort Worth/Barnett Shale	9.76	16.0

Table 2-16. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Cochran	Permian	7.07	5.90
Coke	Permian	7.07	5.90
Coleman	Fort Worth/Barnett Shale	9.76	16.0
Collin	Fort Worth/Barnett Shale	9.76	16.0
Collingsworth	Palo Duro	7.61	9.75
Colorado	Western Gulf	11.0	14.8
Comal	Western Gulf	11.0	14.8
Comanche	Fort Worth/Barnett Shale	9.76	16.0
Concho	Fort Worth/Barnett Shale	9.76	16.0
Cooke	Fort Worth/Barnett Shale	9.76	16.0
Coryell	Fort Worth/Barnett Shale	9.76	16.0
Cottle	Palo Duro	7.61	9.75
Crane	Permian	7.07	5.90
Crockett	Permian	7.07	5.90
Crosby	Permian	7.07	5.90
Culberson	Permian	7.07	5.90
Dallam	Palo Duro	7.61	9.75
Dallas	Fort Worth/Barnett Shale	9.76	16.0
Dawson	Permian	7.07	5.90
Deaf Smith	Palo Duro	7.61	9.75
Delta	East Texas/Haynesville Shale	4.22	5.92
Denton	Fort Worth/Barnett Shale	9.76	16.0
DeWitt	Eagle Ford Shale	10.5	10.0
Dickens	Permian	7.07	5.90
Dimmit	Eagle Ford Shale	10.5	10.0
Donley	Palo Duro	7.61	9.75
Duval	Western Gulf	11.0	14.8
Eastland	Fort Worth/Barnett Shale	9.76	16.0
Ector	Permian	7.07	5.90
Edwards	Permian	7.07	5.90
El Paso	Permian	7.07	5.90
Ellis	Fort Worth/Barnett Shale	9.76	16.0
Erath	Fort Worth/Barnett Shale	9.76	16.0
Falls	East Texas/Haynesville Shale	4.22	5.92
Fannin	East Texas/Haynesville Shale	4.22	5.92
Fayette	Eagle Ford Shale	10.5	10.0
Fisher	Permian	7.07	5.90
Floyd	Palo Duro	7.61	9.75
Foard	Fort Worth/Barnett Shale	9.76	16.0
Fort Bend	Western Gulf	11.0	14.8
Franklin	East Texas/Haynesville Shale	4.22	5.92
Freestone	East Texas/Haynesville Shale	4.22	5.92
Frio	Eagle Ford Shale	10.5	10.0
Gaines	Permian	7.07	5.90

Table 2-16. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Galveston	Western Gulf	11.0	14.8
Garza	Permian	7.07	5.90
Gillespie	Fort Worth/Barnett Shale	9.76	16.0
Glasscock	Permian	7.07	5.90
Goliad	Western Gulf	11.0	14.8
Gonzales	Eagle Ford Shale	10.5	10.0
Gray	Anadarko	3.15	5.87
Grayson	Fort Worth/Barnett Shale	9.76	16.0
Gregg	East Texas/Haynesville Shale	4.22	5.92
Grimes	Eagle Ford Shale	10.5	10.0
Guadalupe	Western Gulf	11.0	14.8
Hale	Palo Duro	7.61	9.75
Hall	Palo Duro	7.61	9.75
Hamilton	Fort Worth/Barnett Shale	9.76	16.0
Hansford	Anadarko	3.15	5.87
Hardeman	Fort Worth/Barnett Shale	9.76	16.0
Hardin	Western Gulf	11.0	14.8
Harris	Western Gulf	11.0	14.8
Harrison	East Texas/Haynesville Shale	4.22	5.92
Hartley	Palo Duro	7.61	9.75
Haskell	Fort Worth/Barnett Shale	9.76	16.0
Hays	Western Gulf	11.0	14.8
Hemphill	Anadarko	3.15	5.87
Henderson	East Texas/Haynesville Shale	4.22	5.92
Hidalgo	Western Gulf	11.0	14.8
Hill	Fort Worth/Barnett Shale	9.76	16.0
Hockley	Permian	7.07	5.90
Hood	Fort Worth/Barnett Shale	9.76	16.0
Hopkins	East Texas/Haynesville Shale	4.22	5.92
Houston	East Texas/Haynesville Shale	4.22	5.92
Howard	Permian	7.07	5.90
Hudspeth	Permian	7.07	5.90
Hunt	East Texas/Haynesville Shale	4.22	5.92
Hutchinson	Anadarko	3.15	5.87
Irion	Permian	7.07	5.90
Jack	Fort Worth/Barnett Shale	9.76	16.0
Jackson	Western Gulf	11.0	14.8
Jasper	Western Gulf	11.0	14.8
Jeff Davis	Permian	7.07	5.90
Jefferson	Western Gulf	11.0	14.8
Jim Hogg	Western Gulf	11.0	14.8
Jim Wells	Western Gulf	11.0	14.8
Johnson	Fort Worth/Barnett Shale	9.76	16.0
Jones	Fort Worth/Barnett Shale	9.76	16.0

Table 2-16. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Karnes	Eagle Ford Shale	10.5	10.0
Kaufman	East Texas/Haynesville Shale	4.22	5.92
Kendall	Fort Worth/Barnett Shale	9.76	16.0
Kenedy	Western Gulf	11.0	14.8
Kent	Permian	7.07	5.90
Kerr	Fort Worth/Barnett Shale	9.76	16.0
Kimble	Fort Worth/Barnett Shale	9.76	16.0
King	Permian	7.07	5.90
Kinney	Western Gulf	11.0	14.8
Kleberg	Western Gulf	11.0	14.8
Knox	Fort Worth/Barnett Shale	9.76	16.0
La Salle	Eagle Ford Shale	10.5	10.0
Lamar	East Texas/Haynesville Shale	4.22	5.92
Lamb	Palo Duro	7.61	9.75
Lampasas	Fort Worth/Barnett Shale	9.76	16.0
Lavaca	Eagle Ford Shale	10.5	10.0
Lee	Eagle Ford Shale	10.5	10.0
Leon	Eagle Ford Shale	10.5	10.0
Liberty	Western Gulf	11.0	14.8
Limestone	East Texas/Haynesville Shale	4.22	5.92
Lipscomb	Anadarko	3.15	5.87
Live Oak	Eagle Ford Shale	10.5	10.0
Llano	Fort Worth/Barnett Shale	9.76	16.0
Loving	Permian	7.07	5.90
Lubbock	Permian	7.07	5.90
Lynn	Permian	7.07	5.90
Madison	Western Gulf	11.0	14.8
Marion	East Texas/Haynesville Shale	4.22	5.92
Martin	Permian	7.07	5.90
Mason	Fort Worth/Barnett Shale	9.76	16.0
Matagorda	Western Gulf	11.0	14.8
Maverick	Eagle Ford Shale	10.5	10.0
McCulloch	Fort Worth/Barnett Shale	9.76	16.0
McLennan	Fort Worth/Barnett Shale	9.76	16.0
McMullen	Eagle Ford Shale	10.5	10.0
Medina	Western Gulf	11.0	14.8
Menard	Fort Worth/Barnett Shale	9.76	16.0
Midland	Permian	7.07	5.90
Milam	Eagle Ford Shale	10.5	10.0
Mills	Fort Worth/Barnett Shale	9.76	16.0
Mitchell	Permian	7.07	5.90
Montague	Fort Worth/Barnett Shale	9.76	16.0
Montgomery	Western Gulf	11.0	14.8
Moore	Anadarko	3.15	5.87

Table 2-16. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Morris	East Texas/Haynesville Shale	4.22	5.92
Motley	Palo Duro	7.61	9.75
Nacogdoches	East Texas/Haynesville Shale	4.22	5.92
Navarro	East Texas/Haynesville Shale	4.22	5.92
Newton	Western Gulf	11.0	14.8
Nolan	Permian	7.07	5.90
Nueces	Western Gulf	11.0	14.8
Ochiltree	Anadarko	3.15	5.87
Oldham	Palo Duro	7.61	9.75
Orange	Western Gulf	11.0	14.8
Palo Pinto	Fort Worth/Barnett Shale	9.76	16.0
Panola	East Texas/Haynesville Shale	4.22	5.92
Parker	Fort Worth/Barnett Shale	9.76	16.0
Parmer	Palo Duro	7.61	9.75
Pecos	Permian	7.07	5.90
Polk	Western Gulf	11.0	14.8
Potter	Palo Duro	7.61	9.75
Presidio	Permian	7.07	5.90
Rains	East Texas/Haynesville Shale	4.22	5.92
Randall	Palo Duro	7.61	9.75
Reagan	Permian	7.07	5.90
Real	Fort Worth/Barnett Shale	9.76	16.0
Red River	East Texas/Haynesville Shale	4.22	5.92
Reeves	Permian	7.07	5.90
Refugio	Western Gulf	11.0	14.8
Roberts	Anadarko	3.15	5.87
Robertson	Eagle Ford Shale	10.5	10.0
Rockwall	East Texas/Haynesville Shale	4.22	5.92
Runnels	Fort Worth/Barnett Shale	9.76	16.0
Rusk	East Texas/Haynesville Shale	4.22	5.92
Sabine	East Texas/Haynesville Shale	4.22	5.92
San Augustine	East Texas/Haynesville Shale	4.22	5.92
San Jacinto	Western Gulf	11.0	14.8
San Patricio	Western Gulf	11.0	14.8
San Saba	Fort Worth/Barnett Shale	9.76	16.0
Schleicher	Permian	7.07	5.90
Scurry	Permian	7.07	5.90
Shackelford	Fort Worth/Barnett Shale	9.76	16.0
Shelby	East Texas/Haynesville Shale	4.22	5.92
Sherman	Anadarko	3.15	5.87
Smith	East Texas/Haynesville Shale	4.22	5.92
Somervell	Fort Worth/Barnett Shale	9.76	16.0
Starr	Western Gulf	11.0	14.8
Stephens	Fort Worth/Barnett Shale	9.76	16.0

Table 2-16. County-Level VOC Emission Factors

County	Region	Production Weighted Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Sterling	Permian	7.07	5.90
Stonewall	Permian	7.07	5.90
Sutton	Permian	7.07	5.90
Swisher	Palo Duro	7.61	9.75
Tarrant	Fort Worth/Barnett Shale	9.76	16.0
Taylor	Fort Worth/Barnett Shale	9.76	16.0
Terrell	Marathon Thrust Belt	7.61	9.75
Terry	Permian	7.07	5.90
Throckmorton	Fort Worth/Barnett Shale	9.76	16.0
Titus	East Texas/Haynesville Shale	4.22	5.92
Tom Green	Permian	7.07	5.90
Travis	Western Gulf	11.0	14.8
Trinity	Western Gulf	11.0	14.8
Tyler	Western Gulf	11.0	14.8
Upshur	East Texas/Haynesville Shale	4.22	5.92
Upton	Permian	7.07	5.90
Uvalde	Western Gulf	11.0	14.8
Val Verde	Permian	7.07	5.90
Van Zandt	East Texas/Haynesville Shale	4.22	5.92
Victoria	Western Gulf	11.0	14.8
Walker	Western Gulf	11.0	14.8
Waller	Western Gulf	11.0	14.8
Ward	Permian	7.07	5.90
Washington	Western Gulf	11.0	14.8
Webb	Eagle Ford Shale	10.5	10.0
Wharton	Western Gulf	11.0	14.8
Wheeler	Anadarko	3.15	5.87
Wichita	Fort Worth/Barnett Shale	9.76	16.0
Wilbarger	Fort Worth/Barnett Shale	9.76	16.0
Willacy	Western Gulf	11.0	14.8
Williamson	Western Gulf	11.0	14.8
Wilson	Eagle Ford Shale	10.5	10.0
Winkler	Permian	7.07	5.90
Wise	Fort Worth/Barnett Shale	9.76	16.0
Wood	East Texas/Haynesville Shale	4.22	5.92
Yoakum	Permian	7.07	5.90
Young	Fort Worth/Barnett Shale	9.76	16.0
Zapata	Western Gulf	11.0	14.8
Zavala	Eagle Ford Shale	10.5	10.0

2.7 Accounting for the Effect of Recovery and Control Devices

The effect of existing vapor recovery and control devices should be accounted for in determining emissions from area sources. However, there is limited information on the use of control devices in the condensate producing regions of Texas, and the quantity of the information varies.

2.7.1 Barnett Shale

The TCEQ Barnett Shale Special Inventory data indicates whether condensate tank emissions are recovered or controlled at each site. This dataset contains 1,575 records covering the 14 counties listed in Table 2-8 above. The Barnett Shale Inventory data indicate that 13.2% of total surveyed production in these 14 counties was controlled, and the average percent reduction was 97.2%. The 2009 RRC condensate production data for these 14 counties is 2,680,019 bbl. The surveyed production (2,479,409 bbl from Table 2-8) represents 92.5% of total 2009 condensate production in these counties. Because the Barnett Shale Inventory was a mandatory survey of all producers in these counties, and had a very high response rate, we can assume that 12.2% (92.5% x 13.2%) of total production in that region should be considered to be controlled by 97.2%, for an overall reduction of 11.8%.

2.7.2 HGB, BPA, and Haynesville Shale

The 2010 study conducted by ENVIRON for TCEQ titled "*Control of VOC Flash Emissions from Oil and Condensate Storage Tanks in East Texas*" reported on control of emissions from oil and condensate storage tanks in three geographic regions of Texas. This study investigated the effect on VOC emissions reductions in the HGB nonattainment area due to the implementation of requirements in Title 30 Texas Administrative Code 115.112(d)(5). The report investigated the possible effects should this same rule be implemented in the BPA area and the Haynesville Shale area. This report also considered the effect of the Texas Permit by Rule (Title 30 TAC 106.352) requirements, which allow a well/tank site with emissions less than 25 tons of VOC per year to qualify for a more streamlined permit. [21]

This report included results from surveys of the HGB area, the BPA area, the Haynesville Shale, and a TCEQ Region 12 survey for the HGB area. 82 producers responded to these two surveys and submitted control information for 1,940 sites.[22]

[21] The Permit By Rule for Oil and Gas sites (Title 30 TAC 106.352) allows new or modified facilities that meet certain conditions and that emit less than 25 tons per year of VOC to be obtain authorization per rule requirements. It has the effect of encouraging larger oil and gas sources to install control devices on their oil and condensate tanks so as to limit emissions.

[22] There is a small overlap in data collected for the HGB area (Table ES-3 of the report). It does not affect the results, as the overlap has been accounted for in analyzing the data.

The data collected for this report[23] indicated that 25% of the surveyed production in the HGB area was controlled, 9% of the surveyed production in the Haynesville Shale area was controlled, and 72% of the surveyed production in the BPA area was controlled. The high surveyed percentage of controlled production in the BPA area can be attributed to a group of large condensate producing sites (accounting for more than 1000 bbl/day) equipped with a suite of control devices. These sites accounted for approximately half of the surveyed BPA area production and significantly contribute to the high percentage of surveyed controlled production.

This study also requested information from producers about tank emissions controls. When this information is combined with production information, it gives an estimate of the percent of total surveyed production in each of the surveyed areas that is controlled.

2.7.3 Calculation of Control Factor

Each region-specific or county-specific control factor should reflect the percentage of production in that region/county that was reported as controlled per the survey. For the percentage of production that was not reported in these surveys, instead of assuming this production is uncontrolled, a default control percentage is applied. The assumed default control factor for the production not reported in these surveys was developed from the TCEQ Barnett Shale Special Inventory data. The large sample size of this special inventory data combined with the characteristics of the Barnett Shale formation represents a conservative control estimate.

To calculate an overall control factor, a multi-step calculation was developed that accounts for reported versus unreported survey condensate production. This calculation is outlined for the HGB area in detail below; the same calculation was employed with area-specific data for the other areas. The calculation methodology was as follows:

1. 68 % of HGB condensate production was reported in the survey.
    a. 25% of reported production is controlled at a 95% level
    b. 75% of reported production is not controlled
2. 32 % of HGB production data was not reported in the survey
3. To account for the different categories of data, each category will be treated separately and the results summed to produce the control factor.
    a. For the controlled category, category 1a, the basic formula is:
        i. Portion of control factor = (percent of production represented by category) * (percent of controlled production) * (control efficiency)
        ii. For category 1a, this equals: (0.680*0.25*0.95) = 0.161 or 16.1%
    b. For the category where production was not reported, category 2, default data is assumed and the basic formula is:

[23] TCEQ provided ERG with three spreadsheets containing the survey data obtained from the ENVIRON surveys.

i. Portion of control factor = (percent of production represented by category) * (percent of controlled production, default from Barnett Shale special inventory) * (control efficiency, default from Barnett Shale special inventory)
ii. For category 2, this equals: (0.320*0.122*0.972) = 0.0379 or 3.8%

c. Total control for 100% of production in the HGB area is therefore the sum of portion of controls from categories 1a and 2, or (16.1+3.8) % or 19.9%.

Table 2-17 below presents the findings of this analysis and includes a recommended control factor for each region.

2.7.4 ERG 2012 Survey

The ERG 2012 survey collected data from 15 companies for 251 sites in 50 counties. Data from 175 of these sites was used in calculating results. The survey data show that emissions from 91.1% of all surveyed production was either recovered with a VRU or controlled with a flare or combustor, and the average percent reduction was 97.6%. These are exceptionally high percentages when compared with the amount of production reported as controlled in the Barnett Shale Inventory and the TCEQ 2010 study above. The ERG 2012 survey data was voluntary, and may not be representative of all producers or other counties in the regions surveyed. This difference may also be due to the characteristics of the Barnett Shale and Haynesville Shale formations versus the other regions of Texas. The Barnett Shale and Haynesville Shale both produce a 'dry' gas, with little condensate production. Therefore, it may not have been economical or necessary from a regulatory standpoint at the time this survey was taken to control the emissions from the condensate tanks in the Barnett and Haynesville Shale.

The higher level of control observed in the ERG survey may also be due to the increasing implementation of recovery and control technologies over time, and the effect of new regulations limiting air pollutant emissions in specific areas. The Barnett Shale Inventory and the TCEQ surveys were conducted in 2009, whereas the ERG survey was conducted in 2012 and covers production and emissions in 2011. Title 30 Texas Administrative Code 106.352, Permit by Rule for Oil and Gas Handling and Production Facilities[24], became effective on February 2, 2012, which may account for the higher control percentages observed during this survey.

[24] Texas Commission on Environmental Quality, Rules, http://www.tceq.state.tx.us/rules/indxpdf.html

Table 2-17. Percentage of Surveyed Production with Tank Emissions Controlled in the HGB, BPA, and Haynesville Shale Areas

Region (counties)	2009 Total Production Reported to RRC [a] (bbl)	Number of Sites/Tank Batteries Surveyed [b]	Total Surveyed Production [c]	Total Controlled Production Reported in Survey [d] (bbl)	Percent of Reported Production That is Controlled [d] (%)	Percent of Production Not Reported in the Survey [e] (%)	Control Efficiency (%)	Control Factor (%)
Houston-Galveston-Brazoria (Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller)	3,436,859	180	2,335,837	583,462	25.0	32.0	95	19.9
Beaumont - Port Arthur (Hardin, Jefferson, Orange)	5,456,431	26	1,196,723	863,250	72.1	78.1	90	23.5
Haynesville Shale (Gregg, Harrison, Marion, Nacogdoches, Panola, Rusk, San Augustine, Smith, Shelby, Upshur)	5,445,378	523	2,018,527	182,525	9.04	62.9	90	10.5
Barnett Shale (Clay, Cooke, Denton, Erath, Hood, Jack, Johnson, Montague, Palo Pinto, Parker, Somervell, Stephens, Tarrant, Wise) [f]	2,680,019	1,575	2,478,858	326,545	13.2	7.5	97.2	11.8

[a] Data for 2009 condensate production from these counties is from a production data query at the Railroad Commission of Texas website.
[b] Data for the number of sites/tank batteries surveyed in the HGB, BPA, and Haynesville Shale areas comes from Tables 14a and 14b of the "*Control of VOC Flash Emissions from Oil and Condensate Storage Tanks in East Texas*" (TCEQ, 2010) report.
[c] Data for the total surveyed production for the HGB, BPA, and Haynesville Shale areas comes from Table 8 of the "*Control of VOC Flash Emissions from Oil and Condensate Storage Tanks in East Texas"* report.
[d] Data for the total controlled production for the HGB, BPA, and Haynesville Shale areas comes from spreadsheets provided to ERG by TCEQ.
[e] This percentage is derived from the 2009 total production reported to RRC (column 2) and the total surveyed production (column 4).
[f] The data for the Barnett Shale counties comes from the TCEQ Barnett Shale Special Inventory (Table 2-8 and Attachment C of this report).

In assessing whether the surveyed data is representative of all basin operations, ERG has no direct knowledge that any of the companies who responded to this survey biased the data that they submitted. However, as noted above, the percent of surveyed production with emissions being recovered or controlled (91.1%) is very high when compared to the results obtained from the Barnett Shale Area Special Inventory and other studies. ERG collected survey data from 15 large and medium sized companies. A significant portion of the larger companies operate the highest producing wells in many regions. Also, larger companies may have the capital to purchase and install control devices, and may also have more resources to respond to surveys.

The figures for surveyed production as a percentage of total production reported by the RRC also indicate that the survey counts as 'condensate' a significant percentage of liquids production that the RRC considers to be oil. Although ERG requested data for condensate production, data was also requested for wells producing liquids with an API gravity greater than 40 degrees. Since the RRC condensate production values are ultimately used for TCEQ area source emissions inventory development, survey data was reviewed and outlier data suspected of representing oil production (e.g., extremely low separator pressure) was not used for emissions and control factor development. The majority of outlier data appeared in the Permian Basin region, where oil production is at least 100 times greater than condensate production.[25] Survey responses for certain basins in the state captured a limited amount of basin production. With the varying amount of data available for analysis, uncertainties exist about applying the control factor from the surveyed data to the remainder of condensate production in those counties and areas.

Table 2-18 shows the control information developed from the ERG survey data.

2.8 Summary of Findings and Recommended Emission Factors

Analysis of data from four studies and two surveys indicates that there exists a distinct regional variation in emissions from condensate storage tanks across the oil and gas producing regions of Texas. Emission estimates from testing and software models were considered and each of these data sources has limitations.

Survey data indicate that producers are installing recovery and control devices on an increasing percentage of their condensate wells. The Barnett Shale Inventory data indicates that emissions from 12.2% of total surveyed production were controlled, and data from the 15 producers participating in the ERG 2012 survey indicated that emissions from 91.0% of their total production was recovered or controlled. Other innovative techniques, such as piping all production directly to a centralized processing facility, or using multi-stage separators with ultra-low final stage pressure drop, also

[25] Railroad Commission of Texas, http://www.rrc.state.tx.us/permianbasin/index.php

reduce emissions from condensate production at area sources. An accurate assessment of area source emissions will need to account for the effect of these techniques, and for any increase in their implementation over time.

ERG recommends use of the uncontrolled, production-weighted VOC emission factors in Table 2-16 when calculating the emissions from area source condensate production. Application of the control factors to the percentage of surveyed, controlled condensate production presented in Table 2-17 is recommended for the HGB, BPA, Haynesville Shale, and Barnett Shale counties listed. Despite the availability of ERG 2012 survey data for other regions as shown in Table 2-18, the 11.8% control factor derived from the comprehensive Barnett Shale Inventory is recommended for the remainder of condensate production in these regions and throughout the state until additional data for a large number of producers in the other regions can be obtained. These emission reduction factors will capture the effect of emission recovery and control devices that producers have installed on their production equipment in the counties listed, while conservatively estimating emissions for the remainder of condensate production.

Alternatively, the control factors presented in both Tables 2-17 and 2-18 can be applied to the percentage of surveyed, controlled condensate production for the counties in each region. For the remainder of production, application of the 11.8% control factor derived from the Barnett Shale Inventory is recommended.

Table 2-18. Surveyed Production, Total Production, Percent of Surveyed Production Controlled, and Control Factor, by Region

Region	Total Production Represented in Survey (bbl)	Total Annual Production[a] (bbl)	Percent of 2011 Production Represented by the Survey	Total Controlled Production Reported in Survey (bbl)	Percent of Surveyed Production Controlled	Control Efficiency (%)	Control Factor (%)[b]	Alternate Control Factor (%)[c]
Anadarko	533,419	8,609,960	6.2	530,324	99.4	97.9	6.03	17.1
Eagle Ford	10,538,273	24,343,253	43.3	9,716,987	92.2	98.5	39.3	46.0
East Texas	518,691	4,681,732	11.1	425,644	82.1	98.1	8.92	19.4
Permian	245,545	2,036,996	12.1	195,275	79.5	94.7	9.08	19.5
Western Gulf	182,349	18,241,171	1.0	84,785	46.5	98.0	0.46	12.2

[a] Data for 2009 condensate production from the Barnett Shale area and 2011 condensate production for the other five regions is from the RRC.
[b] Control factor assumes that only the surveyed production is controlled.
[c] Control factor assumes that surveyed production is controlled at the surveyed control rate, and that the unsurveyed production is controlled at a default rate of 11.8 percent.

3.0 Hazardous Air Pollutant Emissions from Condensate Storage Tanks

As part of the study to refine the condensate tank VOC emission factor used in the TCEQ area source inventory, ERG accumulated a significant amount of data on emissions of benzene, toluene, ethylbenzene, and xylene (BTEX) from condensate storage tanks. This data was obtained from the 2006 HARC study, the Barnett Shale Area Special Inventory Phase II survey of producers, and E&P TANK report data submitted by producers in response to the ERG 2012 survey. ERG determined that the amount and quality of this data was sufficient to allow development of region-specific emission factors for BTEX emissions from storage tanks for four geographic regions in the state. These four regions are: Eagle Ford Shale, East Texas/Haynesville Shale, Bend Arch-Fort Worth/Barnett Shale, and Western Gulf. These regions are shown in Figure 2-1 above.

3.1 BTEX Emissions Data Derived from Testing

The researchers who conducted the study "*VOC Emissions from Oil and Condensate Storage Tanks*" (Houston Advanced Research Center, 2006, and Texas Environmental Research Consortium, 2009)[26] also made measurements of BTEX content of the emissions from each of the oil and condensate storage tanks. The report provided data for the weight percent of benzene, toluene, ethylbenzene, and xylene in the tank vent gas; data on the weight percent of VOC in the tank vent gas; the liquid production in barrels per day; and the VOC emissions in pounds per day and pounds per barrel. ERG re-examined the data from the sites examined in the HARC 2006 study. Although 27 sites produce liquids having an API gravity of 40 degrees or greater, only data from the 22 sites designated as being condensate is considered. In this analysis, three data points were removed from the data set as was done for the VOC emission factor development process as described above. An emission factor for each of the remaining 19 sites was calculated. Table 2-1 (above) and Table 3-1 (below) show the measurement data from the HARC 2006 study for these 19 condensate tanks.

Table 3-1. VOC and BTEX Content in the Vent Gas

Tank Battery	Weight % VOC	Weight % Benzene	Weight % Toluene	Weight % Ethylbenzene	Weight % Xylene
2	47	0.34	0.53	0.04	0.21
3	62	0.63	1.10	0.06	0.46
4	57	0.57	1.02	0.06	0.41
5	70	0.75	1.32	0.07	0.55
6	65	0.49	0.56	0.03	0.14
13	81	0.19	0.40	0.01	0.14
14	53	0.13	0.33	0.02	0.16

[26] Houston Advanced Research Center, VOC Emissions from Oil and Condensate Storage Tanks, October 31, 2006. http://files.harc.edu/Projects/AirQuality/Projects/H051C/H051CFinalReport.pdf

Table 3-1. VOC and BTEX Content in the Vent Gas

Tank Battery	Weight % VOC	Weight % Benzene	Weight % Toluene	Weight % Ethylbenzene	Weight % Xylene
15	82	0.18	0.25	0.01	0.09
16	85	0.20	0.41	0.02	0.19
18	70	0.23	0.65	0.03	0.38
19	77	0.25	0.58	0.02	0.25
20	89	0.17	0.35	0.01	0.18
23	81	0.39	1.08	0.03	0.48
24	70	0.19	0.67	0.22	0.36
27	86	0.27	0.83	0.02	0.33
28	55	1.07	0.68	0.07	0.28
29	83	0.28	0.10	0.02	0.03
30	62	1.35	0.67	0.03	0.16
32	87	0.44	0.48	0.03	0.19

Emission factors in terms of lbs/bbl can be calculated with the following formula:

$$\text{HAP Pollutant}_i\ (\text{lbs/bbl}) = (\text{weight \% HAP Pollutant}_i/\text{weight \% VOC}_i) \times \text{VOC Emissions}_i\ (\text{lbs/bbl}) \qquad \text{(Eq. 3-1)}$$

Table 3-2 shows the VOC and BTEX emission factors for these 19 sites. As all data was obtained through testing, preferential weighting is not used to calculate the average emission factors.

Table 3-2. VOC and BTEX Emission Factors

Tank Battery Site #	Region	VOC Emission Factor (lbs/bbl)	Benzene Emission Factor (lbs/bbl)	Toluene Emission Factor (lbs/bbl)	Ethylbenzene Emission Factor (lbs/bbl)	Xylene Emission Factor (lbs/bbl)
2	Western Gulf	3.65	0.0264	0.0412	0.0031	0.0163
3	Western Gulf	7.92	0.0805	0.1405	0.0077	0.0588
4	Western Gulf	0.78	0.0078	0.0140	0.0008	0.0056
5	Western Gulf	0.67	0.0072	0.0126	0.0007	0.0053
6	Western Gulf	2.96	0.0223	0.0255	0.0014	0.0064
13	Fort Worth	39.23	0.0920	0.1937	0.0048	0.0678
14	Fort Worth	29.51	0.0724	0.1837	0.0111	0.0891
15	Fort Worth	11.99	0.0263	0.0366	0.0015	0.0132
16	Fort Worth	60.58	0.1425	0.2922	0.0143	0.1354
18	Fort Worth	7.34	0.0241	0.0682	0.0031	0.0398
19	Fort Worth	13.16	0.0427	0.0991	0.0034	0.0427
20	Fort Worth	30.43	0.0581	0.1197	0.0034	0.0615
23	Fort Worth	5.56	0.0268	0.0741	0.0021	0.0329

Table 3-2. VOC and BTEX Emission Factors

Tank Battery Site #	Region	VOC Emission Factor (lbs/bbl)	Benzene Emission Factor (lbs/bbl)	Toluene Emission Factor (lbs/bbl)	Ethylbenzene Emission Factor (lbs/bbl)	Xylene Emission Factor (lbs/bbl)
24	Fort Worth	4.22	0.0115	0.0404	0.0133	0.0217
27	Fort Worth	14.39	0.0452	0.1389	0.0033	0.0552
28	Western Gulf	4.17	0.0811	0.0516	0.0053	0.0212
29	Western Gulf	33.68	0.1136	0.0406	0.0081	0.0122
30	Western Gulf	6.11	0.1330	0.0660	0.0030	0.0158
32	Western Gulf	63.49	0.3211	0.3503	0.0219	0.1387
Production-Weighted Average Emission Factor (lbs/bbl)			0.0864	0.0981	0.0063	0.0387
Arithmetic Average Emission Factor (lbs/bbl)			0.0702	0.1047	0.0059	0.0442

3.2 BTEX Emissions Data Derived from the Barnett Shale Area Special Inventory, Phase II (2009)

TCEQ provided ERG with data from the "Barnett Shale Area Special Inventory, Phase II 2009" (Barnett Shale Inventory) information in spreadsheet format. The Barnett Shale Inventory data contains records of condensate tanks with reported condensate production rates and calculated BTEX emissions. ERG analyzed the BTEX emissions data and developed emission factors for condensate tanks in the Bend-Arch-Fort Worth and Barnett Shale counties. The data analysis was similar to that done for VOC for the entire Barnett Shale region. All records with emission factors above 140 lbs/bbl were rejected. Only records using the preferred estimation methods for flashing emissions (direct measurement, process simulator, E&P TANK, GOR) were analyzed. A production-weighted average of the emission factors, before controls, was calculated for each HAP pollutant as shown in Table 3-3. The data is grouped by estimation method, and a production-weighted average and an arithmetic average is used in determining an emission factor for each estimation method. The production-weighted average and arithmetic average for each estimation method were weighted according to the weighting factors in Table 2-11.

Table 3-3. Condensate Tank BTEX Emission Factor Estimates Using Data from the Barnett Shale Phase II 2009 Inventory

Emission Calculation Methods	Pollutant	Total Emissions (lbs)	Total Production (bbl)	Production-Weighted Average Emission Factor (lbs/bbl)	Arithmetic Average Emission Factor (lbs/bbl)
Flash Emissions: Process Simulator Models, E&P TANK, Direct Measurement, GOR Working and Breathing Emissions: E&P TANK, EPA TANKS Program, Other	Benzene	17,393	723,298	0.019	0.084
	Toluene	28,926	734,626	0.042	0.13
	Ethylbenzene	2,057	310,139	0.011	0.036
	Xylene	20,047	730,722	0.067	0.20

3.3 BTEX Emissions Data Derived from E&P TANK Reports Submitted in Response to the ERG Survey

One respondent to the ERG Survey provided paper copies of the E&P Tank V 2.0 Calculation Reports for 85 well/tank sites. The E&P TANK reports contain detailed information on a tank, its equipment, and its emissions, including: API gravity, separator pressure, separator temperature, and annual liquids production; and annual emissions of methane, non-methane volatile organic compounds, benzene, toluene, ethylbenzene, and xylene. As E&P TANK is one of the methods preferred by TCEQ for calculating flashing, working, and breathing emissions, this data was used in evaluating BTEX emissions in the three regions (Eagle Ford Shale, East Texas/Haynesville Shale, and Western Gulf) in which the tanks are located. Eight sites produced liquids having an API gravity of less than 40 degrees, so these sites were removed from the dataset. Data from the remaining 77 records is shown in Table 3-4.

Table 3-4. Condensate Tank BTEX Emission Factor Estimates Using Data from E&P TANK Reports Submitted for ERG Survey

Region	County	API Gravity (deg.)	Separator Pressure (psig)	Condensate Production (bbl)	Emission Factors (lbs/bbl)				
					VOC	Benzene	Toluene	Ethylbenzene	Xylene
Eagle Ford	Fayette	49.2	25.4	2,555	0.53	0.0039	0.0078	0.0008	0.0047
Eagle Ford	Fayette	49.2	25.2	2,811	0.52	0.0043	0.0078	0.0007	0.0050
Eagle Ford	Fayette	49.2	28.5	2,190	0.58	0.0046	0.0091	0.0009	0.0055
Eagle Ford	Lavaca	40.8	35	949	0.27	0.6322	0.0358	0.0243	0.0084
Eagle Ford	Leon	45.2	14	1,460	0.92	0.0288	0.0055	0.0014	0.0055
Eagle Ford	Leon	45.2	52.9	219	1.28	0.0822	0.0183	0.0091	0.0183
Eagle Ford	Leon	45.2	108.9	256	1.33	0.0783	0.0157	0.0078	0.0235
Eagle Ford	Leon	45.2	64.1	146	1.51	0.1096	0.0274	0.0137	0.0274
Eagle Ford	McMullen	54.7	48	14,856	1.51	0.0059	0.0125	0.0003	0.0040
Eagle Ford	McMullen	54.7	48	8,322	1.80	0.0077	0.0166	0.0002	0.0053
Eagle Ford	McMullen	59.3	38	220,570	3.91	0.0226	0.0336	0.0007	0.0156
Eagle Ford	McMullen	59.3	38	86,943	3.94	0.0228	0.0340	0.0008	0.0157
Eagle Ford	Webb	64.5	65	149,139	3.42	0.0139	0.0172	0.0003	0.0077
Eagle Ford	Webb	64.5	200	276,816	3.47	0.0142	0.0176	0.0003	0.0079
East Texas	Anderson	42	58.8	37	1.64	0.1644	0.1644	0.0205	0.1096
East Texas	Cherokee	45.2	142.4	146	1.64	0.1096	0.0274	0.0137	0.0274
East Texas	Cherokee	45.2	76.9	256	1.33	0.0783	0.0157	0.0078	0.0235
East Texas	Cherokee	45.2	84.9	110	1.46	0.1096	0.0365	0.0183	0.0365
East Texas	Freestone	60	205	4,271	12.96	0.1892	0.1321	0.0037	0.0239
East Texas	Freestone	60	75.4	329	16.32	0.3592	0.2740	0.0061	0.0548
East Texas	Freestone	60	69.3	1,679	14.71	0.2418	0.1739	0.0048	0.0322
East Texas	Freestone	60	81.2	730	15.21	0.2767	0.2055	0.0055	0.0384
East Texas	Freestone	60	77.6	1,971	14.50	0.2334	0.1674	0.0051	0.0315
East Texas	Harrison	53.5	100	1,095	0.20	0.0091	0.0018	0.0004	0.0018
East Texas	Henderson	50.4	40	219	0.46	0.0457	0.0183	0.0057	0.0091
East Texas	Henderson	50.4	267.3	475	0.46	0.0253	0.0084	0.0032	0.0042
East Texas	Henderson	50.4	78.1	3,650	0.36	0.0077	0.0027	0.0010	0.0011
East Texas	Henderson	50.4	45.8	621	0.42	0.0193	0.0064	0.0024	0.0032
East Texas	Henderson	50.4	34	730	0.44	0.0192	0.0082	0.0024	0.0027
East Texas	Henderson	50.4	36	803	0.42	0.0174	0.0075	0.0022	0.0025

Table 3-4. Condensate Tank BTEX Emission Factor Estimates Using Data from E&P TANK Reports Submitted for ERG Survey

Region	County	API Gravity (deg.)	Separator Pressure (psig)	Condensate Production (bbl)	Emission Factors (lbs/bbl)				
					VOC	Benzene	Toluene	Ethylbenzene	Xylene
East Texas	Houston	50.6	40	219	0.18	0.0183	0.0091	0.0018	0.0051
East Texas	Houston	50.6	146.5	256	0.23	0.0157	0.0078	0.0016	0.0043
East Texas	Houston	50.6	54.5	183	0.22	0.0219	0.0110	0.0022	0.0061
East Texas	Houston	50.6	59.2	621	0.19	0.0064	0.0032	0.0006	0.0018
East Texas	Limestone	42	40	183	0.55	0.0767	0.0438	0.0015	0.0219
East Texas	Limestone	42	69.8	73	1.10	0.1370	0.1096	0.0027	0.0548
East Texas	Limestone	42	77.3	37	1.64	0.1644	0.1644	0.0033	0.1096
East Texas	Limestone	42	66.2	110	0.91	0.1096	0.0731	0.0022	0.0365
East Texas	Limestone	42	64.3	183	0.55	0.0767	0.0438	0.0015	0.0329
East Texas	Marion	45.2	20	876	0.98	0.0365	0.0068	0.0023	0.0091
East Texas	Marion	45.2	50	1,424	0.91	0.0281	0.0056	0.0014	0.0056
East Texas	Marion	45.2	40	840	1.02	0.0381	0.0071	0.0024	0.0095
East Texas	Marion	45.2	40	219	1.37	0.0822	0.0183	0.0091	0.0183
East Texas	Nacogdoches	58.8	807	110	1.28	0.0548	0.0731	0.0183	0.0913
East Texas	Navarro	46.3	38	6,023	3.22	0.0306	0.0186	0.0007	0.0040
East Texas	Panola	45.2	76	1,497	0.88	0.0281	0.0053	0.0013	0.0053
East Texas	Panola	45.2	102	4,709	0.76	0.0174	0.0030	0.0008	0.0038
East Texas	Panola	45.2	99.5	1,314	0.91	0.0304	0.0061	0.0015	0.0061
East Texas	Panola	45.2	90	2,044	0.88	0.0245	0.0039	0.0010	0.0049
East Texas	Panola	45.2	40.2	1,825	0.91	0.0252	0.0044	0.0011	0.0055
East Texas	Rusk	55.5	105	21,681	6.46	0.0540	0.0564	0.0017	0.0167
East Texas	Rusk	55.5	40	183	6.36	0.0548	0.0548	0.0034	0.0219
East Texas	San Augustine	58.8	168	146	1.10	0.0411	0.0548	0.0137	0.0685
East Texas	Shelby	58.8	40	1,460	0.33	0.0082	0.0082	0.0014	0.0096
East Texas	Upshur	55.6	230	1,095	20.31	0.2466	0.0731	0.0037	0.0511
East Texas	Upshur	55.6	112.4	4,818	21.02	0.2665	0.0797	0.0037	0.0556
East Texas	Upshur	55.6	233.2	730	19.78	0.2411	0.0712	0.0027	0.0493
East Texas	Upshur	55.6	222.7	1,095	21.39	0.2612	0.0767	0.0037	0.0530
East Texas	Upshur	55.6	215	3,030	20.73	0.2535	0.0753	0.0040	0.0522
Western Gulf	Liberty	49.9	50	511	1.06	0.0352	0.0783	0.0039	0.0391

Table 3-4. Condensate Tank BTEX Emission Factor Estimates Using Data from E&P TANK Reports Submitted for ERG Survey

Region	County	API Gravity (deg.)	Separator Pressure (psig)	Condensate Production (bbl)	Emission Factors (lbs/bbl)				
					VOC	Benzene	Toluene	Ethylbenzene	Xylene
Western Gulf	Liberty	53.9	25	475	1.35	0.0126	0.0421	0.0042	0.0337
Western Gulf	Newton	59.8	70	6,607	3.55	0.0061	0.0127	0.0009	0.0070
Western Gulf	Newton	59.8	70	2,373	3.57	0.0059	0.0126	0.0008	0.0067
Western Gulf	Nueces	49.2	20	6,789	0.36	0.0024	0.0044	0.0003	0.0027
Western Gulf	Nueces	49.2	20	1,935	0.60	0.0052	0.0093	0.0010	0.0062
Western Gulf	Nueces	51.9	35	3,723	0.59	0.0038	0.0064	0.0005	0.0043
Western Gulf	Orange	40.9	40	35,770	0.18	0.0003	0.0008	0.0001	0.0004
Western Gulf	Orange	40.9	40	1,351	0.47	0.0015	0.0044	0.0005	0.0030
Western Gulf	San Patricio	58.1	20	61,466	58.03	0.4031	0.3360	0.0257	0.1990
Western Gulf	Starr	49.2	213.8	438	1.05	0.0137	0.0320	0.0046	0.0183
Western Gulf	Starr	49.2	213.8	1,095	0.69	0.0073	0.0146	0.0018	0.0091
Western Gulf	Starr	49.2	215.7	949	0.74	0.0084	0.0148	0.0021	0.0105
Western Gulf	Wharton	47.2	30	10,001	0.60	0.0052	0.0126	0.0004	0.0060
Western Gulf	Wharton	47.2	32	2,519	0.85	0.0095	0.0222	0.0008	0.0111
Western Gulf	Wharton	47.2	31	767	1.12	0.0183	0.0470	0.0026	0.0235
Western Gulf	Wharton	47.2	27	3,650	0.75	0.0077	0.0181	0.0005	0.0088
Western Gulf	Wharton	47.2	25	1,570	0.89	0.0115	0.0280	0.0013	0.0140
Arithmetic Average Emission Factor (lbs/bbl)						0.0772	0.0438	0.0040	0.0230
Production-Weighted Average Emission Factor (lbs/bbl)						0.0465	0.0441	0.0022	0.0227

3.4 Summary of Findings and Recommended Regional BTEX Emission Factors

ERG compiled emission factor data for each region for which data was available using the data from the testing results (Table 3-2), Barnett Shale Area Special Inventory (Table 3-3), and the E&P TANK reports from the ERG survey (Table 3-4). Table 3-5 shows the production-weighted average emission factors for each region, before the effect of any controls. Table 3-6 shows the arithmetic average emission factors for each region, before the effect of any controls. A statewide average emission factor can be used in estimating BTEX emissions from condensate tanks in the other regions of the state (Anadarko, Palo Duro, Permian, and Marathon Thrust Belt).

Table 3-5. Production-Weighted Average Regional BTEX Emission Factors, from Testing Data, Barnett Shale Inventory, and Survey Data

Region	Number of Data Points	Production-Weighted Average Emission Factors (lbs/bbl)			
		Benzene	Toluene	Ethylbenzene	Xylene
Eagle Ford	14	0.0181	0.0238	0.0005	0.0108
East Texas	45	0.0914	0.0512	0.0023	0.0190
Fort Worth	537	0.0164	0.0351	0.0068	0.0433
Western Gulf	30	0.0866	0.0829	0.0063	0.0429
All Other Counties	-	0.0385	0.0494	0.0063	0.0466

Table 3-6. Arithmetic Average Regional BTEX Emission Factors, from Testing Data, Barnett Shale Inventory, and Survey Data

Region	Number of Data Points	Arithmetic Average Emission Factors (lbs/bbl)			
		Benzene	Toluene	Ethylbenzene	Xylene
Eagle Ford	14	0.0736	0.0185	0.0044	0.0110
East Texas	45	0.0968	0.0537	0.0044	0.0270
Fort Worth	537	0.0956	0.1574	0.0222	0.1571
Western Gulf	30	0.0562	0.0552	0.0041	0.0244
All Other Counties	-	0.0998	0.1389	0.0161	0.1491

4.0 Recommendations for Future Condensate Tank Investigations

ERG makes the following recommendations with respect to future investigations.

- The timing of this survey coincided with the requirement for many producers to file information with EPA in compliance with Subpart W of the Greenhouse Gas rules. Based upon discussions with survey recipients, this had a negative impact on survey participation by producers.

- If high participation rates are required, ERG recommends that the TCEQ consider collecting information from oil and gas producers through mandatory information collection requests. If mandatory surveys are not feasible, then any voluntary survey should be initiated with a list of the environmental contacts at each of the companies to be surveyed.

- A consistent definition of condensate based on API gravity should be developed by TCEQ in combination with the RRC so that the most appropriate emission factors are applied to tank liquids, including those tanks that store what operators consider to be a combination of oil and condensate.

5.0 Natural Gas Composition Data Collection and Analysis

In June of 2012, ERG staff visited TCEQ's office in Austin to review annual point source emissions inventory reports submitted by facilities throughout Texas identified as having dehydrators on site. The purpose of this visit was to obtain copies of GLYCalc reports to obtain natural gas composition data. GLYCalc is a software tool used to estimate emissions from dehydrators. Required GLYCalc inputs include natural gas composition data, temperature, and pressure.

TCEQ originally identified a possible 368 facilities across the state with dehydrators. ERG reviewed these files and obtained approximately 240 inventory reports related to dehydrator emissions, including many GLYCalc reports. These reports were reviewed and all incomplete reports were flagged and set aside. These incomplete reports did not contain natural gas stream composition data, or contained data in a format inconsistent with the GLYCalc reporting or output forms and were not evaluated further.

Ultimately, ERG was able to compile complete GLYCalc data for 157 sites located in 64 counties. Based on TCEQ's initial identification of 368 facilities, there are 101 counties in Texas that contain sites with dehydrators that submit an annual point source emissions inventory.

The following constituents were available in the GLYCalc natural gas stream composition data (% volume):

- Water,
- Carbon Dioxide (CO_2),
- Hydrogen Sulfide,
- Nitrogen,
- Methane,
- Ethane,
- Propane,
- Isobutane,
- n-Butane,
- Isopentane,
- n-Pentane,
- Cyclopentane,
- n-Hexane,
- Cyclohexane,
- Other Hexanes,
- Heptanes,
- Methylcyclohexane,
- Benzene,
- Toluene,

- Ethylbenzene,
- Xylenes, and
- C8+ Heavies

The natural gas stream composition data, both for dry stream and wet stream, were then transcribed into Microsoft Excel spreadsheets. This spreadsheet file consisted of composition data for 314 natural gas streams (wet and dry) in 64 counties. Once the data transcription was complete, these data were quality assured for accuracy and completeness. During the Quality Assurance (QA) steps, ERG staff identified a few data points that seemed indicative of a CO_2 well instead of a natural gas well. The CO_2 concentration for these streams was above 85% (by volume). These data points were present in Kent, Pecos, and Terrell counties. These data were excluded from further analysis. Also, the excluded data for Kent and Terrell counties were the only data points available for these two counties. Table 5-1, below, lists the number of GLYCalc reports used in the analysis by natural gas stream type and County.

Table 5-1. Counties Included in the Natural Gas Composition Analysis

County	Dry Gas Stream	Wet Gas Stream	County	Dry Gas Stream	Wet Gas Stream
Anderson	2	2	Jack	1	1
Atascosa	1	1	Jefferson	1	1
Bastrop	1	1	Johnson	17	17
Brazoria	11	11	Kenedy	1	1
Brooks	3	3	Kent [a]	1	1
Caldwell	1	1	Liberty	7	7
Callahan	1	1	Martin	1	1
Camp	1	1	Matagorda	2	2
Carson	1	1	Montague	1	1
Cass	1	1	Nacogdoches	2	2
Chambers	1	1	Nueces	1	1
Clay	2	2	Orange	2	2
Coke	1	1	Palo Pinto	1	1
Crockett	4	4	Panola	2	2
De Witt	1	1	Parker	5	5
Denton	2	2	Pecos [a]	4	4
Eastland	2	2	Refugio	2	2
Erath	1	1	Robertson	1	1
Fort Bend	1	1	Rusk	2	2
Freestone	5	5	San Patricio	2	2
Gaines	1	1	Smith	3	3
Galveston	3	3	Sterling	2	2
Gray	1	1	Tarrant	12	12
Gregg	4	4	Terrell [a]	1	1
Hansford	1	1	Upshur	1	2
Hardin	2	2	Upton	1	0
Harris	6	6	Ward	1	1

Table 5-1. Counties Included in the Natural Gas Composition Analysis

County	Dry Gas Stream	Wet Gas Stream	County	Dry Gas Stream	Wet Gas Stream
Harrison	3	3	Webb	1	1
Hemphill	1	1	Wheeler	1	1
Henderson	2	2	Wilbarger	1	1
Hood	1	1	Winkler	1	1
Houston	1	1	Wise	5	5
Irion	1	1	Young	1	1
			Total	**157**	**157**

[a] As described above, the data for Kent and Terrell counties was not used and only 3 of the 4 records for Pecos county were used.

After all the QA checks were completed, average county profiles were developed for the counties for which natural gas composition data were available (listed in Table 5-1 above). Both wet and dry natural gas composition averages were calculated. The 64 counties for which data were available were then grouped by basins (Anadarko, Bend Arch-Forth Worth, East Texas, Permian, and Western Gulf Basins). Basin-level average natural gas composition (wet and dry) profiles were calculated for all the basins where data was available at county level. No data were available for counties in Marathon Thrust Belt Basin and Palo Duro Basin. Table 5-2 lists the counties in Marathon Thrust Belt Basin and Palo Duro Basin.

Table 5-2. List of Counties Located in Marathon Thrust Belt Basin and Palo Duro Basin

Basin	Counties	
Marathon Thrust Belt	Brewster	Terrell
Palo Duro Basin	Armstrong	Hale
	Bailey	Hall
	Briscoe	Hartley
	Castro	Lamb
	Childress	Motley
	Collingsworth	Oldham
	Cottle	Parmer
	Dallam	Potter
	Deaf Smith	Randall
	Donley	Swisher
	Floyd	

Basin-level average natural gas composition profile and state-level average profile were then allocated to counties with no data based on which basin the county was located in. Except for the counties listed in Table 5-2, basin-level average profiles were allocated to all counties with no GLYCalc reports available. For the counties in Marathon Thrust Belt and Palo Duro basin, state-level average profile was allocated. Table 5-3 below

Table 5-3. Basin-Level and State-Level Average Natural Gas Stream Composition Profiles

Composition in % Volume	Anadarko Basin		Bend Arch-Fort Worth Basin		East Texas Basin		Permian Basin		Western Gulf		State Profile	
	Dry Stream	Wet Stream	Dry Stream	Wet Stream	Dry Stream	Wet Stream	Dry Stream	Wet Stream	Dry Stream	Wet Stream	Dry Stream	Wet Stream
Water	0.04	0.13	0.01	0.12	0.01	0.12	0.01	0.15	0.01	0.12	0.01	0.12
Carbon Dioxide	0.64	0.65	1.74	1.74	1.72	1.71	0.95	0.90	1.13	1.14	1.43	1.44
Hydrogen Sulfide	0.03	0.03	0.001	0.001	0.0004	0.0004	0.11	0.11	0.0003	0.25	0.03	0.09
Nitrogen	1.35	1.34	1.74	1.73	0.88	0.87	2.14	2.18	0.51	0.49	1.20	1.19
Methane	90.76	90.68	87.91	87.59	91.73	91.49	80.43	78.53	90.07	89.94	88.67	88.36
Ethane	3.99	3.98	5.23	5.21	3.57	3.64	9.02	9.07	4.51	4.51	5.03	5.00
Propane	1.74	1.74	2.14	2.18	1.04	1.06	4.48	5.39	2.04	2.05	2.13	2.21
Isobutane	0.26	0.26	0.31	0.32	0.28	0.29	0.51	0.61	0.48	0.48	0.38	0.40
n-Butane	0.54	0.54	0.62	0.68	0.31	0.32	1.19	1.63	0.51	0.51	0.58	0.64
Isopentane	0.16	0.16	0.20	0.22	0.15	0.17	0.35	0.40	0.24	0.24	0.22	0.23
n-Pentane	0.17	0.17	0.27	0.29	0.11	0.12	0.32	0.44	0.17	0.17	0.20	0.22
Cyclopentane	0.01	0.01	0.03	0.04	0.04	0.04	0.01	0.02	0.03	0.02	0.02	0.03
n-Hexane	0.10	0.06	0.05	0.12	0.05	0.05	0.16	0.18	0.05	0.06	0.06	0.09
Cyclohexane	0.01	0.01	0.04	0.03	0.03	0.03	0.09	0.11	0.05	0.06	0.04	0.05
Other Hexanes	0.14	0.14	0.07	0.06	0.10	0.11	0.24	0.29	0.17	0.15	0.13	0.13
Heptanes	0.06	0.06	0.08	0.08	0.06	0.07	0.14	0.14	0.07	0.09	0.08	0.08
Methylcyclohexane	0.02	0.02	0.02	0.02	0.01	0.02	0.04	0.04	0.04	0.04	0.03	0.04
Benzene	0.01	0.01	0.01	0.01	0.02	0.03	0.07	0.08	0.01	0.02	0.02	0.02
Toluene	0.01	0.01	0.003	0.003	0.01	0.01	0.04	0.04	0.01	0.02	0.01	0.01
Ethylbenzene	0.001	0.001	0.0005	0.001	0.001	0.001	0.01	0.01	0.001	0.002	0.001	0.002
Xylenes	0.003	0.01	0.002	0.003	0.002	0.005	0.01	0.01	0.003	0.01	0.003	0.005
C8+ Heavies	0.04	0.04	0.03	0.03	0.03	0.04	0.07	0.07	0.11	0.11	0.06	0.06

presents the basin-level and state-level average natural gas stream composition profiles for both wet and dry natural gas streams.

Based on the basin and state level average natural gas composition profiles, the methane composition varies from 78% to 91%. However, individual GLYCalc reports indicated as high as 97.8% methane. Table 5-4 indicates the average natural gas composition profile allocation scheme that was adopted for counties where GLYCalc reports were not available. Figure 5-1 presents a distribution of methane concentrations across all Texas counties. Detailed county-level natural gas composition profile data are presented in Attachment D.

Table 5-4. Average Natural Gas Composition Profile Allocation Scheme

County	Profile Allocation	Basin	County	Profile Allocation	Basin
Anderson	Average County		Karnes	Average Basin	Western Gulf
Andrews	Average Basin	Permian Basin	Kaufman	Average Basin	East Texas Basin
Angelina	Average Basin	East Texas Basin	Kendall	Average Basin	Bend Arch-Fort Worth Basin
Aransas	Average Basin	Western Gulf	Kenedy	Average County	
Archer	Average Basin	Bend Arch-Fort Worth Basin	Kent[1]	Average Basin	Permian Basin
Armstrong	Average State	Palo Duro Basin	Kerr	Average Basin	Bend Arch-Fort Worth Basin
Atascosa	Average County		Kimble	Average Basin	Bend Arch-Fort Worth Basin
Austin	Average Basin	Western Gulf	King	Average Basin	Permian Basin
Bailey	Average State	Palo Duro Basin	Kinney	Average Basin	Western Gulf
Bandera	Average Basin	Bend Arch-Fort Worth Basin	Kleberg	Average Basin	Western Gulf
Bastrop	Average County		Knox	Average Basin	Bend Arch-Fort Worth Basin
Baylor	Average Basin	Bend Arch-Fort Worth Basin	La Salle	Average Basin	Western Gulf
Bee	Average Basin	Western Gulf	Lamar	Average Basin	East Texas Basin
Bell	Average Basin	Western Gulf	Lamb	Average State	Palo Duro Basin
Bexar	Average Basin	Western Gulf	Lampasas	Average Basin	Bend Arch-Fort Worth Basin
Blanco	Average Basin	Bend Arch-Fort Worth Basin	Lavaca	Average Basin	Western Gulf
Borden	Average Basin	Permian Basin	Lee	Average Basin	Western Gulf
Bosque	Average Basin	Bend Arch-Fort Worth Basin	Leon	Average Basin	East Texas Basin
Bowie	Average Basin	East Texas Basin	Liberty	Average County	
Brazoria	Average County		Limestone	Average Basin	East Texas Basin
Brazos	Average Basin	Western Gulf	Lipscomb	Average Basin	Anadarko Basin
Brewster	Average State	Marathon Thrust Belt	Live Oak	Average Basin	Western Gulf
Briscoe	Average State	Palo Duro Basin	Llano	Average Basin	Bend Arch-Fort Worth Basin
Brooks	Average County		Loving	Average Basin	Permian Basin
Brown	Average Basin	Bend Arch-Fort Worth Basin	Lubbock	Average Basin	Permian Basin
Burleson	Average Basin	Western Gulf	Lynn	Average Basin	Permian Basin
Burnet	Average Basin	Bend Arch-Fort Worth Basin	Madison	Average Basin	Western Gulf

Table 5-4. Average Natural Gas Composition Profile Allocation Scheme

County	Profile Allocation	Basin	County	Profile Allocation	Basin
Caldwell	Average County		Marion	Average Basin	East Texas Basin
Calhoun	Average Basin	Western Gulf	Martin	Average County	
Callahan	Average County		Mason	Average Basin	Bend Arch-Fort Worth Basin
Cameron	Average Basin	Western Gulf	Matagorda	Average County	
Camp	Average County		Maverick	Average Basin	Western Gulf
Carson	Average County		McCulloch	Average Basin	Bend Arch-Fort Worth Basin
Cass	Average County		McLennan	Average Basin	Bend Arch-Fort Worth Basin
Castro	Average State	Palo Duro Basin	McMullen	Average Basin	Western Gulf
Chambers	Average County		Medina	Average Basin	Western Gulf
Cherokee	Average Basin	East Texas Basin	Menard	Average Basin	Bend Arch-Fort Worth Basin
Childress	Average State	Palo Duro Basin	Midland	Average Basin	Permian Basin
Clay	Average County		Milam	Average Basin	Western Gulf
Cochran	Average Basin	Permian Basin	Mills	Average Basin	Bend Arch-Fort Worth Basin
Coke	Average County		Mitchell	Average Basin	Permian Basin
Coleman	Average Basin	Bend Arch-Fort Worth Basin	Montague	Average County	
Collin	Average Basin	Bend Arch-Fort Worth Basin	Montgomery	Average Basin	Western Gulf
Collingsworth	Average State	Palo Duro Basin	Moore	Average Basin	Anadarko Basin
Colorado	Average Basin	Western Gulf	Morris	Average Basin	East Texas Basin
Comal	Average Basin	Western Gulf	Motley	Average State	Palo Duro Basin
Comanche	Average Basin	Bend Arch-Fort Worth Basin	Nacogdoches	Average County	
Concho	Average Basin	Bend Arch-Fort Worth Basin	Navarro	Average Basin	East Texas Basin
Cooke	Average Basin	Bend Arch-Fort Worth Basin	Newton	Average Basin	Western Gulf
Coryell	Average Basin	Bend Arch-Fort Worth Basin	Nolan	Average Basin	Permian Basin
Cottle	Average State	Palo Duro Basin	Nueces	Average County	
Crane	Average Basin	Permian Basin	Ochiltree	Average Basin	Anadarko Basin
Crockett	Average County		Oldham	Average State	Palo Duro Basin
Crosby	Average Basin	Permian Basin	Orange	Average County	
Culberson	Average Basin	Permian Basin	Palo Pinto	Average County	

Table 5-4. Average Natural Gas Composition Profile Allocation Scheme

County	Profile Allocation	Basin	County	Profile Allocation	Basin
Dallam	Average State	Palo Duro Basin	Panola	Average County	
Dallas	Average Basin	Bend Arch-Fort Worth Basin	Parker	Average County	
Dawson	Average Basin	Permian Basin	Parmer	Average State	Palo Duro Basin
De Witt	Average County		Pecos[1]	Average County	
Deaf Smith	Average State	Palo Duro Basin	Polk	Average Basin	Western Gulf
Delta	Average Basin	East Texas Basin	Potter	Average State	Palo Duro Basin
Denton	Average County		Presidio	Average Basin	Permian Basin
Dickens	Average Basin	Permian Basin	Rains	Average Basin	East Texas Basin
Dimmit	Average Basin	Western Gulf	Randall	Average State	Palo Duro Basin
Donley	Average State	Palo Duro Basin	Reagan	Average Basin	Permian Basin
Duval	Average Basin	Western Gulf	Real	Average Basin	Bend Arch-Fort Worth Basin
Eastland	Average County		Red River	Average Basin	East Texas Basin
Ector	Average Basin	Permian Basin	Reeves	Average Basin	Permian Basin
Edwards	Average Basin	Permian Basin	Refugio	Average County	
El Paso	Average Basin	Permian Basin	Roberts	Average Basin	Anadarko Basin
Ellis	Average Basin	Bend Arch-Fort Worth Basin	Robertson	Average County	
Erath	Average County		Rockwall	Average Basin	East Texas Basin
Falls	Average Basin	East Texas Basin	Runnels	Average Basin	Bend Arch-Fort Worth Basin
Fannin	Average Basin	East Texas Basin	Rusk	Average County	
Fayette	Average Basin	Western Gulf	Sabine	Average Basin	East Texas Basin
Fisher	Average Basin	Permian Basin	San Augustine	Average Basin	East Texas Basin
Floyd	Average State	Palo Duro Basin	San Jacinto	Average Basin	Western Gulf
Foard	Average Basin	Bend Arch-Fort Worth Basin	San Patricio	Average County	
Fort Bend	Average County		San Saba	Average Basin	Bend Arch-Fort Worth Basin
Franklin	Average Basin	East Texas Basin	Schleicher	Average Basin	Permian Basin
Freestone	Average County		Scurry	Average Basin	Permian Basin
Frio	Average Basin	Western Gulf	Shackelford	Average Basin	Bend Arch-Fort Worth Basin
Gaines	Average County		Shelby	Average Basin	East Texas Basin
Galveston	Average County		Sherman	Average Basin	Anadarko Basin

Table 5-4. Average Natural Gas Composition Profile Allocation Scheme

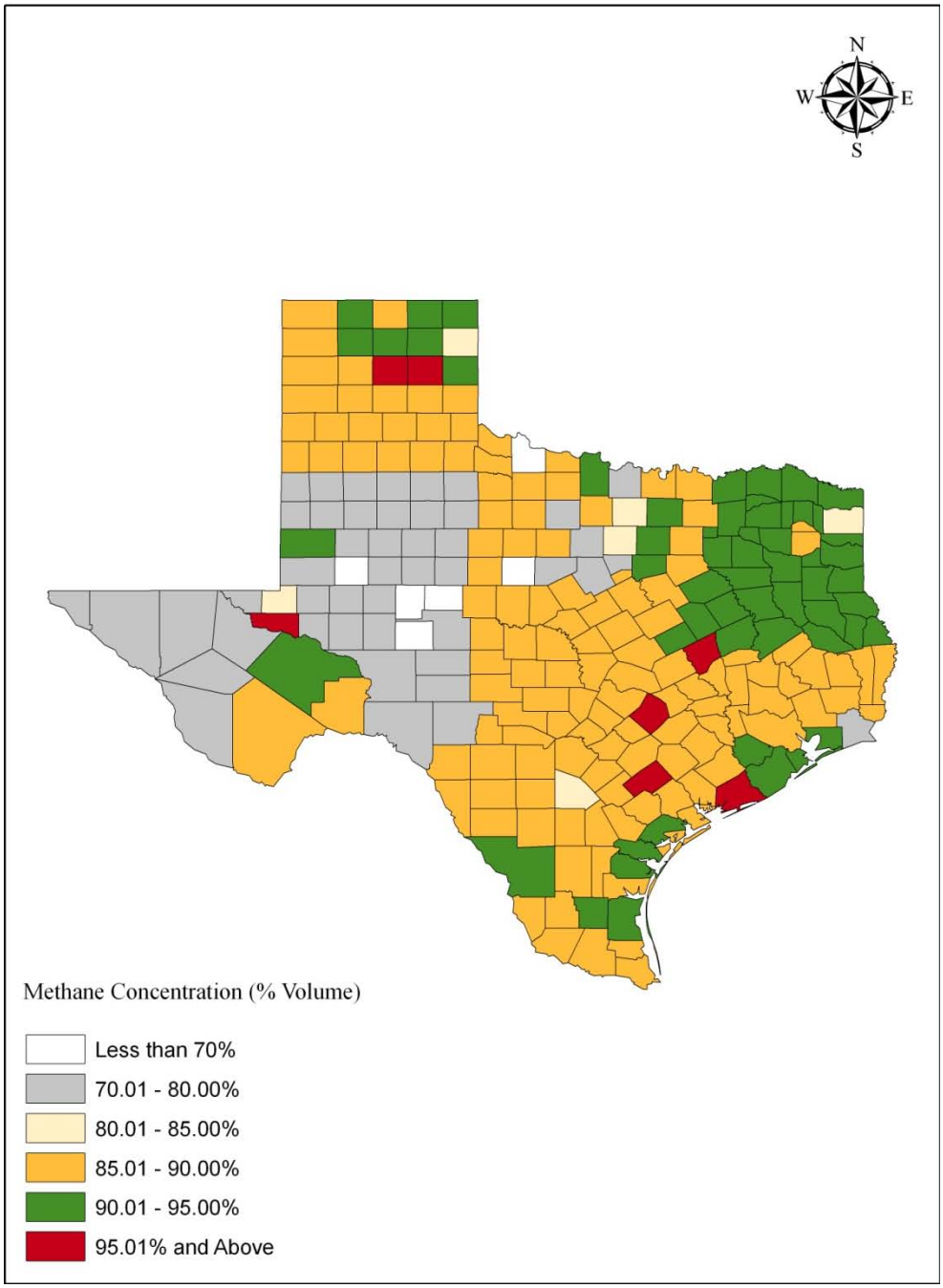
County	Profile Allocation	Basin	County	Profile Allocation	Basin
Garza	Average Basin	Permian Basin	Smith	Average County	
Gillespie	Average Basin	Bend Arch-Fort Worth Basin	Somervell	Average Basin	Bend Arch-Fort Worth Basin
Glasscock	Average Basin	Permian Basin	Starr	Average Basin	Western Gulf
Goliad	Average Basin	Western Gulf	Stephens	Average Basin	Bend Arch-Fort Worth Basin
Gonzales	Average Basin	Western Gulf	Sterling	Average County	
Gray	Average County		Stonewall	Average Basin	Permian Basin
Grayson	Average Basin	Bend Arch-Fort Worth Basin	Sutton	Average Basin	Permian Basin
Gregg	Average County		Swisher	Average State	Palo Duro Basin
Grimes	Average Basin	Western Gulf	Tarrant	Average County	
Guadalupe	Average Basin	Western Gulf	Taylor	Average Basin	Bend Arch-Fort Worth Basin
Hale	Average State	Palo Duro Basin	Terrell[1]	Average State	Marathon Thrust Belt
Hall	Average State	Palo Duro Basin	Terry	Average Basin	Permian Basin
Hamilton	Average Basin	Bend Arch-Fort Worth Basin	Throckmorton	Average Basin	Bend Arch-Fort Worth Basin
Hansford	Average County		Titus	Average Basin	East Texas Basin
Hardeman	Average Basin	Bend Arch-Fort Worth Basin	Tom Green	Average Basin	Permian Basin
Hardin	Average County		Travis	Average Basin	Western Gulf
Harris	Average County		Trinity	Average Basin	Western Gulf
Harrison	Average County		Tyler	Average Basin	Western Gulf
Hartley	Average State	Palo Duro Basin	Upshur	Average County	
Haskell	Average Basin	Bend Arch-Fort Worth Basin	Upton[2]	Average County/Average Basin	Permian Basin
Hays	Average Basin	Western Gulf	Uvalde	Average Basin	Western Gulf
Hemphill	Average County		Val Verde	Average Basin	Permian Basin
Henderson	Average County		Van Zandt	Average Basin	East Texas Basin
Hidalgo	Average Basin	Western Gulf	Victoria	Average Basin	Western Gulf
Hill	Average Basin	Bend Arch-Fort Worth Basin	Walker	Average Basin	Western Gulf
Hockley	Average Basin	Permian Basin	Waller	Average Basin	Western Gulf
Hood	Average County		Ward	Average County	
Hopkins	Average Basin	East Texas Basin	Washington	Average Basin	Western Gulf
Houston	Average County		Webb	Average County	

Table 5-4. Average Natural Gas Composition Profile Allocation Scheme

County	Profile Allocation	Basin	County	Profile Allocation	Basin
Howard	Average Basin	Permian Basin	Wharton	Average Basin	Western Gulf
Hudspeth	Average Basin	Permian Basin	Wheeler	Average County	
Hunt	Average Basin	East Texas Basin	Wichita	Average Basin	Bend Arch-Fort Worth Basin
Hutchinson	Average Basin	Anadarko Basin	Wilbarger	Average County	
Irion	Average County		Willacy	Average Basin	Western Gulf
Jack	Average County		Williamson	Average Basin	Western Gulf
Jackson	Average Basin	Western Gulf	Wilson	Average Basin	Western Gulf
Jasper	Average Basin	Western Gulf	Winkler	Average County	
Jeff Davis	Average Basin	Permian Basin	Wise	Average County	
Jefferson	Average County		Wood	Average Basin	East Texas Basin
Jim Hogg	Average Basin	Western Gulf	Yoakum	Average Basin	Permian Basin
Jim Wells	Average Basin	Western Gulf	Young	Average County	
Johnson	Average County		Zapata	Average Basin	Western Gulf
Jones	Average Basin	Bend Arch-Fort Worth Basin	Zavala	Average Basin	Western Gulf

[1]These counties had GLYCalc reports that were flagged as potential CO_2 wells and excluded from further analysis.
[2]Upton county had 1 GLYCalc report and that report did not include wet gas stream composition data.

Figure 5-1. Natural Gas Methane Composition Distribution across Texas Counties



Attachment A
Survey Letter

Dear [Owner/Operator Contact Name]: [Date]

Eastern Research Group (ERG), an independent research organization, is conducting a study on condensate storage tank emissions for the Texas Commission on Environmental Quality (TCEQ). The purpose of this study is to develop updated county- and region-specific emission factors for estimating condensate storage tank emissions for each of the regions in Texas. The study results will assist the TCEQ in refining the emission factors used to develop the Texas area source oil and gas air emissions inventory.

Condensate tank flashing, working, and breathing emissions of volatile organic compounds (VOC) are currently estimated using an emission factor from a 2006 Texas Environmental Research Consortium study entitled: "VOC Emissions from Oil and Condensate Storage Tanks". TCEQ uses this emission factor to develop county-level area source VOC emissions estimates from condensate tanks at upstream oil and gas operations. To further increase the accuracy of the area source inventory, the TCEQ is seeking information from operators to assist in development of a refined county-specific condensate tank emission factor.

We are asking for your ***voluntary participation*** in this study of emissions from condensate tanks at gas wells in Texas that were in production during 2011. The study will involve sharing information regarding condensate production and measured or estimated emissions from condensate tank(s). ***Individual wells and tanks do not need to be identified.*** The information your company provides will be used for statistical purposes only in order to develop county-level and basin-level estimates and will not be republished or disseminated for other purposes.

ERG will contact your company via phone to discuss this effort and collect any information you are willing to share. We are seeking basin-specific condensate tank emissions information for gas wells in the [Insert Basin_Specific_Text]. The specific information we are requesting for each condensate tank battery includes:

- County
- 2011 VOC emissions
- 2011 condensate production
- Emissions estimation method
- Control technology
- Control efficiency
- API gravity
- Separator pressure

A table on the reverse side of this letter shows the type of data we wish to collect.

We appreciate your assistance in this important study. Questions concerning the scope of this study or ERG's relationship with TCEQ may be directed to the TCEQ Project Manager, Miles Whitten, at (512) 239-5479, or via email at miles.whitten@tceq.texas.gov. If you have any questions on the technical aspects of the study, please feel free to contact me at (919) 468-7902, or via email at stephen.treimel@erg.com.

Sincerely,

Stephen Treimel
Environmental Scientist
Eastern Research Group, Inc.

Attachment B
Survey Materials – Word Table and Excel Spreadsheet

Operator Name: [Insert Operator_Name]

Basin : [Insert Basin_Name_and_Counties]

County	Condensate API Gravity (degrees)	Separator Pressure (psig)	2011 Condensate Production (bbl)	2011 VOC Emissions (tons)	Emissions Estimation Method (Testing, E&P Tank, Process Simulation model, GOR, HARC 051C, etc.)	Are Emissions vented, controlled, or recovered?	If controlled or recovered, what technology is used?	If controlled or recovered, what is the control or recovery efficiency?

Texas Commission on Environmental Quality - Condensate Tank Emissions Survey
Instructions: Provide the data listed below for up to ten separate condensate tank batteries located in the counties listed below. To avoid biasing the survey results, we ask that you please select the tanks at random from all of your producing wells in this region.

Operator Name:
Basin (Counties) : Anadarko basin (Hemphill, Lipscomb, Ochiltree, Roberts, and Wheeler counties).

County	Condensate API Gravity (degrees)	Separator Pressure (psig)	2011 Condensate Production (bbl)	2011 VOC Emissions (tons) (flashing, working, & breathing)	Emissions Estimation Method (Testing, E&P Tank, Process Simulation model, GOR, HARC 051C, TANKS 4.0, etc)	Are Emissions vented, controlled, or recovered?	If controlled or recovered, what technology is used?	If controlled or recovered, what is the control or recovery efficiency?

Completed surveys can be emailed to me at stephen.treimel@erg.com or printed and mailed to: Eastern Research Group, 1600 Perimeter Park Drive, Morrisville, NC 27560.

Attachment C
Condensate Tank Emissions Data
(Condensate_Tank_Data.xlsx)

Attachment D
County-Level Average Natural Gas Composition Profiles
(NG_Composition_Profiles.xlsx)