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PGA # 582-16-60849-01
Task 3.1.1

Oil and Gas Emission Inventory,
Eagle Ford Shale
QUALITY ASSURANCE PROJECT PLAN (QAPP)

Level III: Secondary Data
Revision: 1

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Prepared by:

Alamo Area Council of Governments

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TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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The content, findings, opinions and conclusions are the work of the author(s) and do not necessarily represent the findings, opinions or conclusion of the TCEQ.

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APPROVAL SHEET

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1 PROJECT DESCRIPTION AND OBJECTIVES

AACOG has prepared this Level III Quality Assurance Project Plan (QAPP) for the Texas Commission on Environmental Quality (TCEQ) following EPA guidelines. The nature of the technical analysis and tasks to be conducted as part of this project are consistent with quality assurance (QA) Category III – National Risk Management Research Laboratory (NRMRL) QAPP requirements for secondary data projects. This QAPP is in effect for the duration of this project, November 30, 2015 through August 31, 2017. All calculations conducted for this project will be completed with new production data, new emission factors, new methodologies, and/or new survey results.

1.1 Purpose of Study

The Clean Air Act (CAA) is the comprehensive federal law that regulates airborne emissions across the United States.[1] This law authorizes the U.S. Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment. Of the many air pollutants commonly found throughout the country, EPA has recognized six "criteria" pollutants that can injure health, harm the environment, and/or cause property damage. Air quality monitors measure concentrations of these pollutants throughout the country.

Of the six criteria pollutants, the one that poses the greatest challenge to the San Antonio-New Braunfels metropolitan statistical area (MSA) is ground-level ozone. Ozone monitors in the MSA have recorded violations of the 70 ppb 2015 ozone standard. Ozone is produced when volatile organic compounds (VOC) and nitrogen oxides (NO_X) react in the presence of sunlight, especially during the summer time.[2] These ozone precursors can be generated by natural processes, but the majority of chemicals that form ground-level ozone originate from anthropogenic sources.

To conduct analyses that determine the emission reductions required to bring the area into compliance with the standards, local and state air quality planners need an accurate temporal and spatial account of emissions and their sources in the region. The compilation of the Eagle Ford emissions inventory (EI) requires extensive research and analysis. By understanding these varied sources that create ozone precursor pollutants, planners, political leaders, and citizens can work together to protect heath and the environment. This assessment provides key information on the impact of increased oil and gas production in the Eagle Ford Shale. The project will update the previous Eagle Ford emission inventory completed under PGA14-1, 582-14-40051, Amendment 2, Task 3, Deliverable 3.1.2 delivered to TCEQ on October 20, 2015.

1.2 Project Objectives

"The Eagle Ford Shale is a hydrocarbon producing formation of significant importance due to its capability of producing both gas and more oil than other traditional shale plays. It contains a much higher carbonate shale percentage, upwards to 70% in south Texas, and becomes shallower and the shale content increases as it moves to the northeast. The high percentage of

[1] EPA. November 17, 2015. "Summary of Clean Air Act." Available online: http://www2.epa.gov/laws-regulations/summary-clean-air-act. Accessed: 11/19/2015.
[2] EPA. September 23, 2011. "Ground-level Ozone." Available online: http://www3.epa.gov/airquality/ozonepollution/. Accessed: 11/19/2015.

carbonate makes it more brittle and 'fracable.'"[3] Hydraulic fracturing is a technological advancement which allows producers to recover natural gas and oil resources from shale formations. Today, significant amounts of natural gas and oil from deep shale formations across the United States are being produced through the use of horizontal drilling and hydraulic fracturing.[4]

Hydraulic fracturing is the process of creating fissures, or fractures, in underground formations to allow natural gas and oil to flow up the wellbore to a pipeline or tank battery. In the Eagle Ford Shale, product is extracted by pumping "water, sand and other additives under high pressure into the formation to create fractures. The fluid is approximately 99% water and sand, along with a small amount of special-purpose additives. The newly created fractures are 'propped' open by the sand, which allows the natural gas to flow into the wellbore and be collected at the surface."[5]

From exploration to production, the multiple phases of the oil and gas industry contribute to the inventory of chemicals that form ground-level ozone. Eagle Ford counties and the location of permitted wells are provided in Figure 1-1. Oil wells on schedule are marked in green, gas wells on schedule are marked in red, and permits are highlighted in blue. "American petroleum Institute's inverted scale for denoting the 'lightness' or 'heaviness' of crude oils and other liquid hydrocarbons. Calibrated in API degrees (or degrees API), it is used universally to expresses a crude's relative density in an inverse measure lighter the crude, higher the API gravity, and vice versa because lighter the crude higher its market value."[6]

- "Condensate: A low-density, high-API gravity liquid hydrocarbon phase that generally occurs in association with natural gas. Its presence as a liquid phase depends on temperature and pressure conditions in the reservoir allowing condensation of liquid from vapor. The API gravity of condensate is typically 50ºF to 120ºF."[7]
- "Crude Oil: Liquid petroleum as it comes from out of the ground as distinguished from refined oils manufactured out of it."[8] The API gravity of crude is typically is typical less than 50ºF.
- "Natural Gas: A naturally occurring mixture of hydrocarbon and non-hydrocarbon gases in porous formations beneath the earth's surface, often in association with petroleum. The principal constituent is methane."[9]

Most of the wells are concentrated in the core area. There are also a significant number of wells in the southwest section of the Eagle Ford, while there are very few wells in the northern counties of the Eagle Ford. The project objective is to develop an oil and gas emission inventory of hydraulic fracture activities and wells in the counties highlighted on the map.

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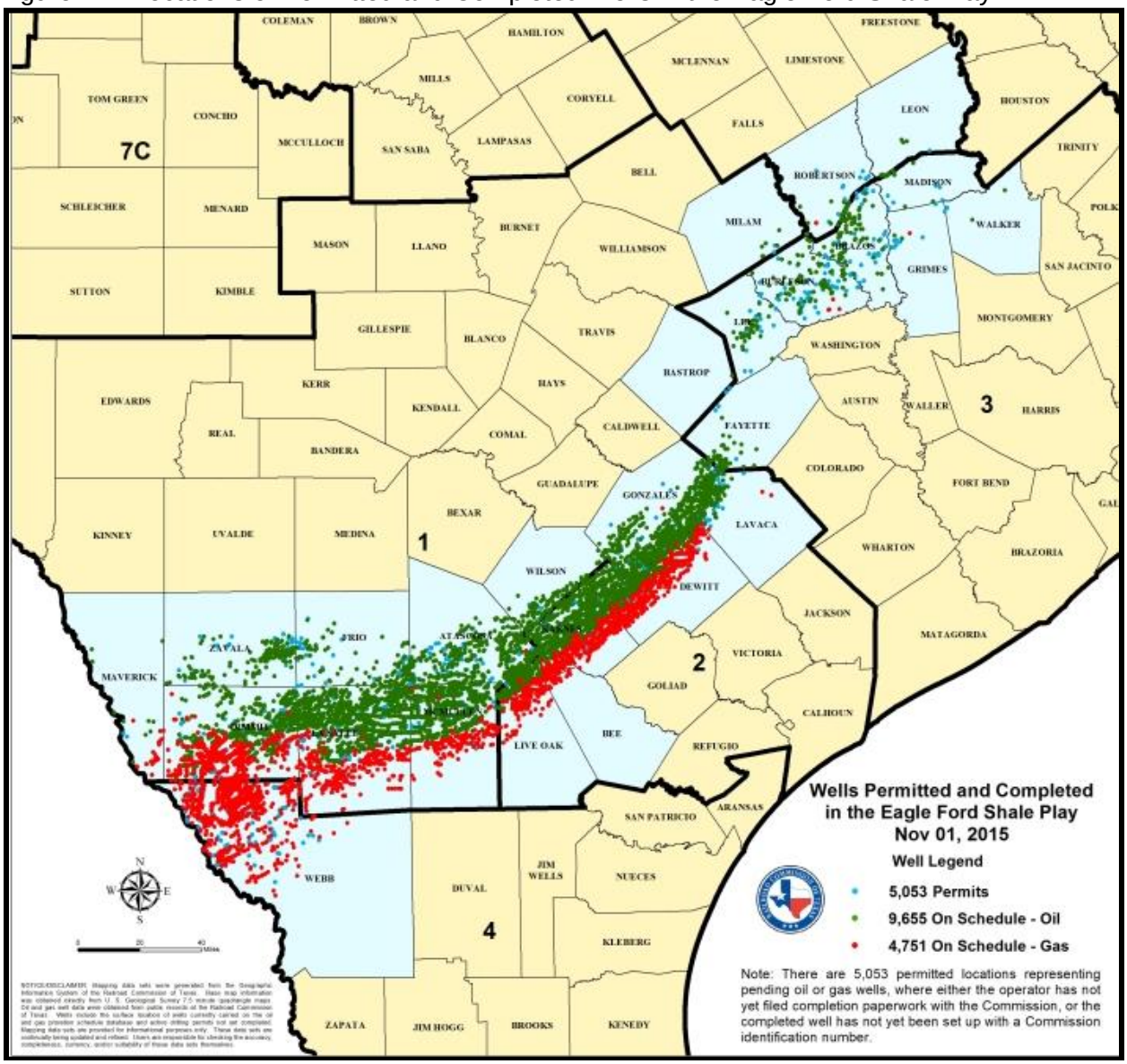
[3] Railroad Commission of Texas, November 18, 2015. "Eagle Ford Information." Available online: http://www.rrc.state.tx.us/oil-gas/major-oil-gas-formations/eagle-ford-shale/. Accessed 11/19/2015.
[4] Chesapeake Energy. January 2012. "Barnett Shale Hydraulic Fracturing." Available online: http://isites.harvard.edu/fs/docs/icb.topic1061062.files/Barnett_Hydraulic_Fracturing_Fact_Sheet.pdf. Accessed: 11/20/2015.
[5] *Ibid*.
[6] Business Dictionary, 2015. "API gravity". Available online: http://www.businessdictionary.com/definition/API-gravity.html. Accessed 12/10/2015.
[7] National Ocean Economics Program, Oct 2. 2012. "Oil & Gas Terms and Definitions". Available online: http://www.oceaneconomics.org/minerals/oil_gas_terms.asp. Accessed 12/10/2015.
[8] *Ibid*.
[9] *Ibid*.

Figure 1-1: Locations of Permitted and Completed Wells in the Eagle Ford Shale Play[10]



[10] Railroad Commission of Texas. November 1, 2015. "Wells Permitted and Completed in the Eagle Ford Shale Play." Available online: http://www.rrc.state.tx.us/media/31085/eaglefordshaleplay2015-11-lg.jpg. Accessed: 11/19/2015.

2 PROJECT ORGANIZATION AND RESPONSIBILITIES

2.1 Responsibilities of Project Participants

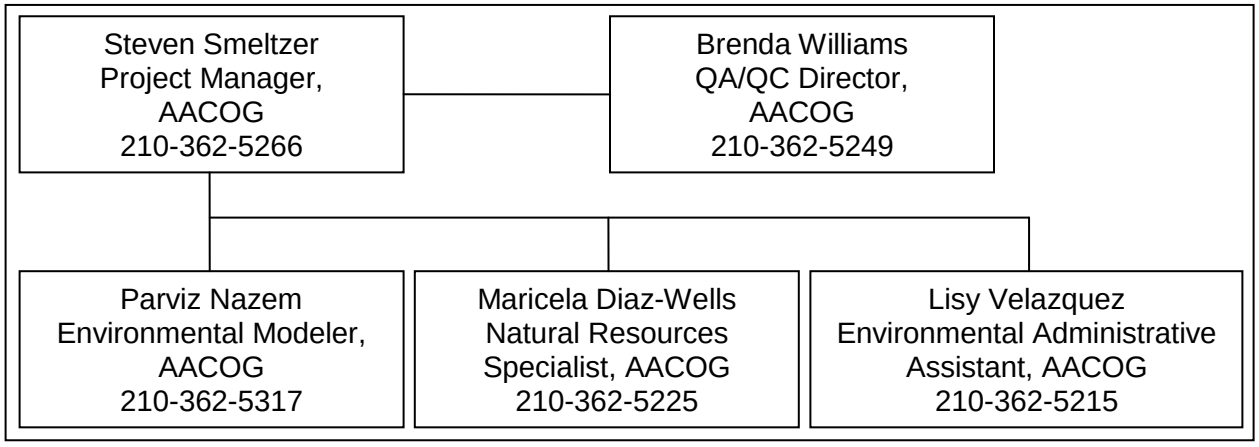
This study will be conducted by the Alamo Area Council of Governments (AACOG) under Contract (Grant) # 582-16-60180, PGA # 582-16-60849-01 and provided to the Texas Commission on Environmental Quality (TCEQ). Staff working on this project and their specific responsibilities are listed below. "The project manager is ultimately responsible for assessing whether the performance and acceptance criteria for the intended modeling use were met and works iteratively with the intended users of the results."[11]

Table 2-1: AACOG's Project Team Participants and Their Responsibilities

Participant	Project Responsibility
Steven Smeltzer	Project manager and expert on developing emission inventories including previous Eagle Ford emission inventories. He will ensure the project implementation follows all contract requirements and that project quality standards are met on all deliverables. He will assist in interactions with TCEQ as required.
Parviz Nazem	Expert on developing emission inventory and will be responsible for collecting and analyzing raw production data
Brenda Williams	Expert on emission inventory and will be responsible for implementing project review and quality assurance
Maricela Diaz-Wells	Expert on emission inventory calculations and will be responsible for data collection and performing emission inventory calculations
Lisy Velazquez	Expert on data management and data collection and will be responsible for data collection

In addition, TCEQ staff will participate in the review of the technical documentation generated during this project.

2.2 Project Organization Chart



[11] EPA. December 2002. "Guidance for Quality Assurance Project Plans for Modeling EPA QA/G-5M." EPA/240/R-02/007. Available online: http://www2.epa.gov/sites/production/files/2015-06/documents/g5m-final.pdf. Accessed 11/19/2015.

2.3 Project Schedule

Emission inventory development will be performed in four steps:

(1) Calculate a 2015 Eagle Ford emission inventory,
(2) Calculate a projected 2020 Eagle Ford emission inventory,
(3) Calculate a projected 2023 Eagle Ford emission inventory, and
(4) Create input files in EPS3 format for the 2015, 2020, and 2023 Eagle Ford emission inventories.

The table below shows the overall schedule for completion of this project.

Table 2-2: Summary of Project Schedule and Milestones

Work Element	Deliverable Date
Deliverable 3.1.1: QAPP	
Drafts submitted to TCEQ for review and approval	November 30, 2015
Deliverable 3.1.2: Final Report	
Draft Report	August 15, 2017
Final Report and EPS3 emission files	September 15, 2017

3 SCIENTIFIC APPROACH

3.1 Data Needed

The data needed for this study includes activity and emission factors from emission sources related to oil and gas activities in the Eagle Ford region. Emission sources include non-road equipment, generators, drill rigs, on-road vehicles, compressor engines, fugitive emissions, and flares. Emission sources vary according to phases of oil and gas activities, so this study will be developed based on the emission sources for five main phases of oil and gas activities. The phases are described in the paragraphs that follow, and the emission sources are provided by phase in more detail in Table 3-1: Emission Sources by Activity Phase and by their associated SCC in Table 3-2.

Exploration and Pad Construction
During exploration, vibrator trucks produce sound waves beneath the surface to help determine subsurface geologic features. Construction of the drill pad requires clearing, grubbing, and grading, followed by placement of a base material by construction equipment and trucks. Reserve pits are also usually required at each well pad because the drilling and hydraulic fracturing process uses a large volume of fluid that is circulated through the well and back to the surface.[12]

Drilling Operation
"Drilling of a new well is typically a two to three week process from start to finish and involves several large diesel-fueled generators."[13] Other emission sources related to drilling operations include construction equipment and trucks to haul supplies, equipment, fluids, and employees.

Hydraulic Fracturing and Well Completion
Hydraulic fracturing "is the high pressure injection of water mixed with sand and a variety of chemical additives into the well to fracture the shale and stimulate natural gas production from the well. Fracking operations can last for several weeks and involve many large diesel-fueled generators."[14] "Once drilling and other well construction activities are finished, a well must be completed in order to begin producing. The completion process requires venting of the well for a sustained period of time to remove mud and other solid debris in the well, to remove any inert gas used to stimulate the well (such as CO_2 and/or N_2) and to bring the gas composition to pipeline grade."[15] In the Eagle Ford, gas vented during the completion process is usually flared.

Production

[12] University of Arkansas and Argonne National Laboratory. n.d. "Fayetteville Shale Natural Gas: Reducing Environmental Impacts: Site Preparation." Available online: http://lingo.cast.uark.edu/LINGOPUBLIC/natgas/siteprep/index.htm. Accessed: 11/19/2015.
[13] Eastern Research Group Inc. July 13, 2011. "Fort Worth Natural Gas Air Quality Study Final Report". Prepared for: City of Fort Worth, Texas. p. 3-2. Available online: http://fortworthtexas.gov/uploadedFiles/Gas_Wells/ERG/ERGReport_section3.pdf. Accessed: 11/20/2015.
[14] ibid.
[15] Amnon Bar-Ilan, Rajashi Parikh, John Grant, Tejas Shah, Alison K. Pollack, ENVIRON International Corporation. November 13, 2008. "Recommendations for Improvements to the CENRAP States' Oil and Gas Emissions Inventories." p. 48. Available online: http://www.wrapair.org/forums/ogwg/documents/2008-11_CENRAP_O&G_Report_11-13.pdf. Accessed: 11/20/2015.

Once the product is collected from the well, emissions might be released at well sites from compressor engines, flares, heaters, and pneumatic devices. There can also be significant emissions from equipment leaks, storage tanks, and loading operations. Tanker trucks are often used to transport product to processing facilities and refineries.

Midstream Sources: Midstream sources in the Eagle Ford consist mostly of compressor stations and processing facilities, but other facilities can include cryogenic plants, saltwater disposal facilities, and tank batteries. "The most significant emissions from compressors stations are usually from combustion at the compressor engines or turbines. Other emissions sources may include equipment leaks, storage tanks, glycol dehydrators, flares, and condensate and/or wastewater loading. Processing facilities generally remove impurities from the natural gas, such as carbon dioxide, water, and hydrogen sulfide. These facilities may also be designed to remove ethane, propane, and butane fractions from the natural gas for downstream marketing. Processing facilities are usually the largest emitting natural gas-related point sources including multiple emission sources such as, but not limited to equipment leaks, storage tanks, separator vents, glycol dehydrators, flares, condensate and wastewater loading, compressors, amine treatment and sulfur recovery units."[16]

There are some emission sources that will be excluded from this study. AACOG's Eagle Ford emissions inventory will omit some infrequent, ancillary, and indirect sources. Except for blowdowns from gas wells, non-routine emissions, such as those generated during upsets or from maintenance, startup, and shutdown activities will be excluded from the emission inventory. The emission inventory will not include construction of midstream facilities, building offices, quarrying of fracturing sands, pipeline construction, etc. Generators and other equipment at camp houses and offices used by oil field workers will be excluded. Emission sources outside of the Eagle Ford shale region that are directly or indirectly affected by the shale development are also excluded. The emission inventory excludes trucks that bring supplies to midstream sources, worker camps, and other facilities not located at the wellhead. Emissions from the production of cement, steel pipes, and other non-recycled material are not included in the emission inventory. Finally, the emission inventory will exclude emissions from railroad activity related to Eagle Ford development, such as hauling fracturing sands, pipelines, petroleum products, equipment, building materials, and other supplies to production sites in the Eagle Ford.

[16] Eastern Research Group Inc. July 13, 2011. "Fort Worth Natural Gas Air Quality Study Final Report". Prepared for: City of Fort Worth, Texas. p. 3-2. Available online: http://fortworthtexas.gov/uploadedFiles/Gas_Wells/ERG/ERGReport_section3.pdf. Accessed: 11/20/2015.

Table 3-1: Emission Sources by Activity Phase

Phase	Emission Sources
Exploration and Pad Construction	• Seismic Trucks • Non-Road Equipment used for Pad Construction • Heavy-Duty Trucks • Light-Duty Trucks
Drilling Operation	• Electric Drill Rigs • Mechanical Drill Rigs • Other Non-Road Equipment used during drilling • Heavy-Duty Trucks • Light-Duty Trucks
Hydraulic Fracturing and Completion Operation	• Pump Trucks • Other Non-Road Equipment used during Hydraulic Fracturing • Heavy-Duty Trucks • Light-Duty Trucks • Completion Venting • Completion Flares
Production	• Wellhead Compressors • Heaters • Flares • Dehydrators Flash Vessels and Regenerator Vents • Storage Tanks • Fugitives (Leaks) • Loading Operations • Well Blowdowns • Pneumatic Devices • Heavy-Duty Trucks • Light-Duty Trucks
Midstream Sources	• Compressor Stations • Production Facilities • Other Midstream Sources

Table 3-2: SCC by Emission Source

Phase	Emission Source	SCC
Exploration and Pad Construction	Diesel Seismic Trucks	2270002051
	Diesel Dozer	2270002069
	Diesel Excavator	2270002018
	Diesel Scraper	2270002036
	Diesel Grader	2270002048
	Diesel Tractors	2270002066
	Diesel Loader	2270002060
	Diesel Roller	2270002015
	Heavy-Duty Trucks Exhaust	MVDSCS21RX
	Heavy-Duty Trucks Idling	MVDSCSOFIX
	Light-Duty Trucks Exhaust	MVDSLC21RX
	Light-Duty Trucks Idling	MVDSLCOFIX
Drilling Operation	Diesel Mechanical Drill Rigs	2270002033
	Diesel Electric Drill Rigs	2270006005
	Diesel Cranes	2270002045
	Diesel Pumps	2270006010
	Diesel Excavators	2270002036
	Heavy-Duty Trucks Exhaust	MVDSCS21RX
	Heavy-Duty Trucks Idling	MVDSCSOFIX
	Light-Duty Trucks Exhaust	MVDSLC21RX
	Light-Duty Trucks Idling	MVDSLCOFIX
Hydraulic Fracturing and Completion Operation	Diesel Pump Engines	2270006005
	Diesel Cranes	2270002045
	Diesel Backhoe	2270002066
	Diesel Bulldozer	2270002069
	Diesel Forklift	2270003020
	Diesel Generator Sets	2270006005
	Diesel Water Pumps	2270006010
	Diesel Blender Truck	2270010010
	Diesel Sand Kings	2270010010
	Diesel Blow Out Control Systems	2270010010
	Heavy-Duty Trucks Exhaust	MVDSCS21RX
	Heavy-Duty Trucks Idling	MVDSCSOFIX
	Light-Duty Trucks Exhaust	MVDSLC21RX
	Light-Duty Trucks Idling	MVDSLCOFIX
	Completion Flares – Oil Wells	2310021600
	Completion Flares – Natural Gas Wells	2310010700

Phase	Emission Source	SCC
Production	Natural Gas, Lean - 2 Cycle Compressors	20200252
	Natural Gas, Lean - 4 Cycle Compressors	20200251
	Natural Gas, Rich - 2 Cycle Compressors	20200251
	Natural Gas, Rich - 4 Cycle Compressors	20200253
	Diesel Compressors	2265006015
	Wellhead Heaters	2310011100
	Flares - Natural Gas Wells	31000204
	Flares - Oil Wells	31000160
	Wellhead Dehydrators - Natural Gas Wells	2310021400
	Wellhead Dehydrators - Oil Wells	2310021400
	Condensate Tanks	2310011010
	Oil Tanks	2310011020
	Fugitives - Natural Gas Wells	2310021501
	Fugitives - Oil Wells	2310011501
	Loading Loss - Condensate	2310011201
	Loading Loss - Oil	2310011202
	Blowdowns - Gas Wells	2310021600
	Blowdowns - Oil Wells	2310010700
	Pneumatic Devices – Gas Wells	2310020800
	Pneumatic Devices – Oil Wells	2310023800
	Heavy-Duty Trucks Exhaust	MVDSCS21RX
	Heavy-Duty Trucks Idling	MVDSCSOFIX
	Light-Duty Trucks Exhaust	MVDSLC21RX
	Light-Duty Trucks Idling	MVDSLCOFIX
Midstream	Heater/ Boiler	2310010100
	Glycol Dehydration	31000301
	Amine Unit	31000305
	Compressor Engine	20200253
	Pumps	2310023000
	Fugitives	2310020700
	Gas Cooler Engine	2310003100
	Crude Storage Tanks	2310011020
	Condensate Tanks	2310011010
	Produced Water Storage Tanks	2310011020
	Oil Loading Facility	2310011202
	Condensate Loading	2310011201
	Produced Water Loading Facility	2310011202
	Flare/ Combustor	31000204
	Other	2310001000

3.2 Sources of Data to be Used

A variety of data sources have been identified to estimate emissions from Eagle Ford oil and gas production. They include scientifically significant surveys, reports, and databases (Table 3-3). The data and methods used in developing the emissions inventory should be peer-reviewed and should be consistent with best current scientific practices. Any industry data will be well documented including the results from any surveys; however, whenever possible, local data will be used to calculate emissions and project future production.

With the exception of midstream phase sources, area and non-road emission sources will be based on the Barnett Shale Area Special Inventory. The inventory was conducted by TCEQ "to determine the location, number and type of emissions sources located at upstream and midstream oil and gas operations associated with the Barnet Shale formation." Well characteristics and production amounts will be collected from Schlumberger and the Railroad Commission of Texas. Non-road equipment emissions will be calculated using local industry data, emission factors from ERG's statewide "Drilling Rig Emission Inventory for the State of Texas",[17] the latest version of the TexN model available on Dec. 31, 2016 (current version is 1.7.1), equipment manufacturers, and TCEQ. Compressor engine emissions factors will be updated with the latest production data from the Railroad Commission of Texas and any updates from the final Barnett Special Inventory.

All emissions source calculations will include updated production data. Calculations will also incorporate any updated activity data including horsepower, fuel usage, and fugitive emissions from relevant surveys. Spatial allocation factors will be updated with new well data locations from the Railroad Commission of Texas. Production emission calculations will be based on data produced from TCEQ's Barnett Shale Area Special Inventory. Other sources for production emissions may include local industry data, ERG's Texas emission inventory, ENVIRON's CENRAP emission inventory, Railroad Commission of Texas, and AP42 emission factors for flares. On-road data sources are from NCTCOG's study in the Barnett Shale, TxDOT's Barnett Shale study, and a report ENVIRON developed for operations in Colorado. Emission factors for heavy-duty and light-duty trucks will be produced by the MOVES model and from EPA.

[17] Eastern Research Group, Inc. July 15, 2009 (revised August 20, 2014). "Drilling Rig Emission Inventory for the State of Texas". TCEQ Contract No. 582-11-99776. Available online: http://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/ei/5821199776FY1105-20110815-ergi-drilling_rig_ei.pdf. Accessed: 12/10/2015.

Table 3-3: Data Sources by Phase and Source Category

Phase	Source Category	Activity Data Source	Emission Factor Data Source
Exploration and Pad Construction	Seismic Trucks	• Number of Trucks: Marathon Oil Corporation • Horsepower: Equipment Manufacturers • Activity Rate: Marathon Oil Corporation • Load Factor: TexN Model	TexN Model
	Construction Equipment	• Equipment Population: Aerial Imagery • Horsepower: San Juan Inventory (Colorado) • Activity Rate: San Juan Inventory (Colorado) • Load Factor: TexN Model • Number of wells per well pad: RRC of Texas	TexN Model
	Heavy-Duty Vehicles On-Road Vehicles	• Vehicle Type: TxDOT Traffic Counts • Number of Vehicles: TxDOT (Barnett) • Distance Traveled: NCTCOG (Barnett) • Diurnal Profiles: TxDOT Traffic Counts • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Heavy-Duty Vehicles Idling Vehicles	• Vehicle Type: TxDOT Traffic Counts • Number of Vehicles: TxDOT (Barnett) • Hours Idling: ENVIRON Colorado Report • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Light-Duty Vehicles On-Road Vehicles	• Number of Vehicles: ENVIRON Colorado Report • Distance Traveled: Railroad Commission of Texas • Diurnal Profiles: TxDOT Traffic Counts • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Light-Duty Vehicles Idling Vehicles	• Number of Vehicles: ENVIRON Colorado Report • Hours Idling: ENVIRON Colorado Report • Number of wells per well pad: RRC of Texas	MOVES2014 Model
Drilling	Mechanical Drill Rigs	• Total Depth Drilled: Schlumberger Limited, • % of time Drill rigs are mobilized: Oil and Gas Financial Journal • Length of Laterals: RRC of Texas • Number of Laterals per well: RRC of Texas • Number of Drill rigs: Baker Hughes • Percentage of Electric Drill Rigs: Eagle Ford Emission Inventory Survey	ERG Drill Rig EI

Phase	Source Category	Activity Data Source	Emission Factor Data Source
Drilling	Electric Drill Rigs	• Total Depth Drilled: Schlumberger Limited, • Percentage of time Drill rigs are mobilized: Oil and Gas Financial Journal • Length of Laterals: RRC of Texas • Number of Laterals per well: RRC of Texas • Drill rig Population: Baker Hughes • Percentage of Electric Drill Rigs: Eagle Ford Emission Inventory Survey • Number of Engines per Drill Rig: Eagle Ford Survey and other local industry data • Horsepower: Eagle Ford Survey and other local industry data • Load Factor: TexN Model • Tier profile for Drill rigs: Eagle Ford Survey	TCEQ TERP program, TexN Model, EPA, Caterpillar
	Non-Road Equipment Used During Drilling	• Number of Equipment: Eagle Ford survey and other local data • Horsepower for cement pumps: Local data • Horsepower for cranes, loaders, and forklifts: TexN model • Total Depth Drilled: Schlumberger Limited • Percentage of time each equipment operates: Eagle Ford survey • % of time Drill rigs are mobilized: Oil and Gas Financial Journal • Length of Laterals: RRC of Texas • Number of Laterals per well: RRC of Texas • Load Factor: TexN Model	TexN Model
	Heavy-Duty Vehicles On-Road Vehicles	• Vehicle Type: TxDOT Traffic Counts • Number of Vehicles: NCTCOG (Barnett) • Distance Traveled: NCTCOG (Barnett) • Diurnal Profiles: TxDOT Traffic Counts • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Heavy-Duty Vehicles Idling Vehicles	• Vehicle Type: TxDOT Traffic Counts • Number of Vehicles: NCTCOG (Barnett) • Hours Idling: ENVIRON Colorado Report • Number of wells per well pad: RRC of Texas	MOVES2014 Model

Phase	Source Category	Activity Data Source	Emission Factor Data Source
Drilling	Light-Duty Vehicles On-Road Vehicles	• Number of Vehicles: ENVIRON Colorado Report • Distance Traveled: Railroad Commission of Texas • Diurnal Profiles: TxDOT Traffic Counts • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Light-Duty Vehicles Idling Vehicles	• Number of Vehicles: ENVIRON Colorado Report • Hours Idling: ENVIRON Colorado Report • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Pump Trucks	• Number of Generators: Local aerial imagery • Horsepower: Eagle Ford Survey • Activity Rate: ENVIRON (Haynesville) • Load Factor: Local industry data • Tier profile for generators: Eagle Ford Survey	TCEQ TERP program, TexN Model, EPA, and Caterpillar
Hydraulic Fracturing and Completion	Other Non-Road Equipment Used During Fracturing	• Eagle Ford Emission Inventory Survey • Equipment Population: TCAT Survey • Horsepower: TCAT Survey • Activity Rate: ENVIRON (Haynesville) • % of time equipment operates: Eagle Ford survey • Load Factor: TexN Model	TexN Model
	Heavy-Duty Vehicles On-Road Vehicles	• Vehicle Type: TxDOT Traffic Counts • Number of Vehicles: TxDOT (Barnett) • Distance Traveled: NCTCOG (Barnett) • Diurnal Profiles: TxDOT Traffic Counts • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Heavy-Duty Vehicles Idling Vehicles	• Vehicle Type: TxDOT Traffic Counts • Number of Vehicles: NCTCOG (Barnett) • Hours Idling: ENVIRON Colorado Report • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Light-Duty Vehicles On-Road Vehicles	• Number of Vehicles: ENVIRON Colorado Report • Distance Traveled: RRC of Texas • Diurnal Profiles: TxDOT Traffic Counts • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Light-Duty Vehicles Idling Vehicles	• Number of Vehicles: ENVIRON Colorado Report • Hours Idling: ENVIRON Colorado Report • Number of wells per well pad: RRC of Texas	MOVES2014 Model

Phase	Source Category	Activity Data Source	Emission Factor Data Source
Hydraulic Fracturing and Completion	Completion Flares	• Volume of Gas: ENVIRON Western Gulf Basin • Heat Content: ENVIRON Western Gulf Basin • Percentage of Wells Controlled by Flares: Local data	AP42
Production	Wellhead Compressors	• Percentage of Wells Serviced by a Compressor: Final Results from Barnett Shale Special Inventory (Attainment Counties) • Engine Type: Final Results from Barnett Shale Special Inventory • Horsepower: Final Results from Barnett Shale Special Inventory • Activity Rate: Final Results from Barnett Shale Special Inventory	Final Results from Barnett Shale Special Inventory, ENVIRON CENRAP EI (Western Gulf), TexN Model
	Heaters	• Percentage of Wells with Heaters: ERG Texas EI • Heater Rating: ERG Texas EI • Activity Rate: ERG Texas EI • Natural Gas Heating Value: ERG Texas EI	California Air Resources Board, ENVIRON's CENRAP emission inventory in the Western Gulf Basin
	Wellhead Flares	• Volume of Gas Flared: RRC of Texas • Heating Value: ENVIRON Western Gulf Basin	TCEQ, Original AP42
	Dehydrators	• ERG Texas EI	ERG Texas EI
	Storage Tanks	• Percentage of Tanks with Controls: ERG's condensate tank study • Control Efficiency: ERG's condensate tank study	ERG Texas EI and ERG's condensate tank study
	Fugitives from Natural Gas Wells	• Final Results from Barnett Shale Special Inventory	Final Results from Barnett Shale Special Inventory
	Fugitives from Oil Wells	• ERG Texas EI	ERG Texas EI
	Loading Loss	• Temperature Data: NOAA • TCEQ's report on loading loss to be released in late 2015	TCEQ's report on loading loss to be released in late 2015
	Blowdowns	• Volume of Gas Vented: ENVIRON's CENRAP emission inventory • Molecular Weight: ENVIRON CENRAP EI (Western Gulf) • Number of Blowdowns per Well: ENVIRON's CENRAP emission inventory • Fraction of Blowdowns Controlled by Flares: ENVIRON's CENRAP emission inventory • Control Efficiency of Flaring during Blowdowns: ENVIRON's CENRAP emission inventory • Fraction of Blowdowns Controlled by Green Techniques: ENVIRON's CENRAP emission inventory	ERG's Texas emission inventory

Phase	Source Category	Activity Data Source	Emission Factor Data Source
Production	Pneumatic Devices	• TCEQ Pneumatic Survey	TCEQ Pneumatic Survey
	Heavy-Duty Vehicles On-Road Vehicles	• Vehicle Type: TxDOT Traffic Counts • Number of Vehicles: NCTCOG (Barnett) • Distance Traveled: NCTCOG (Barnett) • Diurnal Profiles: TxDOT Traffic Counts • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Heavy-Duty Vehicles Idling Vehicles	• Vehicle Type: TxDOT Traffic Counts • Number of Vehicles: NCTCOG (Barnett) • Hours Idling: ENVIRON Colorado Report • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Light-Duty Vehicles On-Road Vehicles	• Number of Vehicles: ENVIRON Colorado Report • Distance Traveled: RRC of Texas • Diurnal Profiles: TxDOT Traffic Counts • Number of wells per well pad: RRC of Texas	MOVES2014 Model
	Light-Duty Vehicles Idling Vehicles	• Number of Vehicles: ENVIRON Colorado Report • Hours Idling: ENVIRON Colorado Report • Number of wells per well pad: RRC of Texas	MOVES2014 Model
Midstream	Compressor Stations, Production Facilities, etc.	• Equipment Counts: TCEQ Standard Permit Database	Final Results from Barnett Shale Special Inventory, TCEQ Standard Permit Database

NO_X emission estimates for all diesel equipment will be adjusted to account for Texas Low Emission Diesel (TxLED) supplied in the following 19 counties of the Eagle Ford.[18]

- Atascosa
- Bee
- Brazos
- Burleson
- De Witt
- Fayette
- Goliad
- Gonzales
- Grimes
- Houston
- Karnes
- Lavaca
- Lee
- Leon
- Live Oak
- Madison
- Milam
- Washington
- Wilson

When the Eagle Ford emission inventory is completed, a number of updates will be incorporated that were not included in the previous Eagle Ford emission inventory. All calculations conducted for this project will be completed with new production data, new emission factors, new methodologies, and/or new survey results. The paragraphs that follow identify new sources of data that will be incorporated into the updated Eagle Ford emissions inventory.

Projection of Midstream Sources

The projections of midstream sources for 2020 and 2023 will be revised with updated equipment counts from TCEQ's permit database.[19] The previous Eagle Ford emission inventory projections were based on all permitted midstream sources between 2008 and April 2014. Midstream sources may still be expanding in the Eagle Ford and may represent a larger emission source then what was reported in the previous emission inventory.

TCEQ's Loading Loss Report

TCEQ is schedule to release a report on loading loss from oil and gas wellheads and production facilities in late 2015. The emission factor and activity data in this report will be included in the updated Eagle Ford Emission Inventory.

Compressor Engine Survey

The South Texas Energy & Economic Roundtable (STEER) approached AACOG in June 2015 about the value of conducting additional surveys on oil and gas operations in the Eagle Ford. STEER is interested in AACOG conducting surveys on compressor engines and other production emission sources.

AACOG will work with STEER and other industry stakeholders to determine the feasibility of additional surveys. Other emission source surveys may include storage tanks and flares in the Eagle Ford.

Updated Spatial Allocation of Emissions

In the previous Eagle Ford emission inventory, pad construction, drilling operations, and hydraulic fracturing emissions were geo-coded to the location of all permitted Eagle Ford wells. Emissions from natural gas production were geo-coded to the location of natural gas wells in the Eagle Ford, while emissions from oil production and casinghead gas were geo-coded to the location of oil wells. Emissions from condensate production were geo-coded to natural gas

[18] Eastern Research Group, Inc. July 15, 2009. "Drilling Rig Emission Inventory for the State of Texas." Prepared for: Texas Commission on Environmental Quality. p. 6-18. Available online: http://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/ei/5820783985FY0901-20090715-ergi-Drilling_Rig_EI.pdf. Accessed: 11/20/2015.

[19] TCEQ. January 2012. "Detailed Data from the Point Source Emissions Inventory." Available online: http://www.tceq.texas.gov/airquality/point-source-ei/psei.html. Accessed 11/20/2015.

wells located in the condensate window.[20] The spatial allocation of wells will be updated to include new wells that were permitted by the Railroad Commission of Texas since the previous inventory was developed. The spatial surrogates used for geo-coding all emission sources will be based on well locations by county.

3.3 Industry Involvement

Beginning in May 2012, AACOG convened a group of technical experts representing many of the major oil and natural gas producers in the Eagle Ford shale play in order to improve the Eagle Ford emissions inventory. These experts can assist with acquisition of improved activity data and/or an improved equipment inventory.

In the case that industry data provided to AACOG is judged as being valuable for use in updating data proposed for this deliverable, AACOG's Project Manager will contact TCEQ staff for advisements on including this data in the final deliverable report. If included, the data source will be clearly identified for the corresponding data in a manner that is consistent with all protocols contained in this QAPP.

3.4 Growth Factors

Projection data will be reviewed for completeness before using the data to develop 2020 and 2023 emission projections. Three different scenarios will be used to estimate future drill rig counts:

(1) Low Development
(2) Moderate Development
(3) Aggressive Development

Projected emission factors for electric drill rigs and hydraulic pumps' Tier 2 generators will be based on emission factors for engines ≥ 750 from TCEQ's Texas Emissions Reduction Plan (TERP).[21] NO_X emission factors for Tier 4 Interim and Tier 4 engines >900 bkW will be based on EPA's emission limit requirements,[22] while VOC and CO emission factors for these engines will be based on certified engine data from Caterpillar.[23]

The estimated activity rates, horsepower, load factors, and equipment populations of other non-road equipment used for pad construction, drilling, and hydraulic fracturing will be kept the same for each projection year. Emission factors for other non-road equipment will be projected using the latest version of the TexN model. To calculate on-road emissions, many parameters, such as number of on-road trips, vehicle speeds, vehicle types, distances travelled, and idling hours per trip during pad construction, and drilling, and hydraulic fracturing, are kept the same for each projection year. The number of vehicles, however, will be determined by multiplying future projections of wells drilled and emission factors developed from the MOVES model.

[20] Railroad Commission of Texas, 2012. "Digital Map Information". Austin, Texas.
[21] TCEQ, April 24, 2010. "Texas Emissions Reduction Plan (TERP): Emissions Reduction Incentive Grants Program Technical Supplement No. 2, Non-Road Equipment". Austin, Texas. p. 5.
[22] California Environmental Protection Agency Air Resources Board, March 30, 2011. "New Off-Road Compression-Ignition Engines: Caterpillar Inc.".
[23] Caterpillar, 2011. "TIER 4 Interim EPA Emissions Requirements for Diesel Generator Sets".

To estimate emissions from production sources, future projections of oil, condensate, and natural gas will be calculated. Projections of liquid and gas production in the Eagle Ford will be based on three factors:

(1) Number of new production wells drilled each year,
(2) Estimated ultimate recovery (EUR) for each well, and
(3) Decline curve for each well

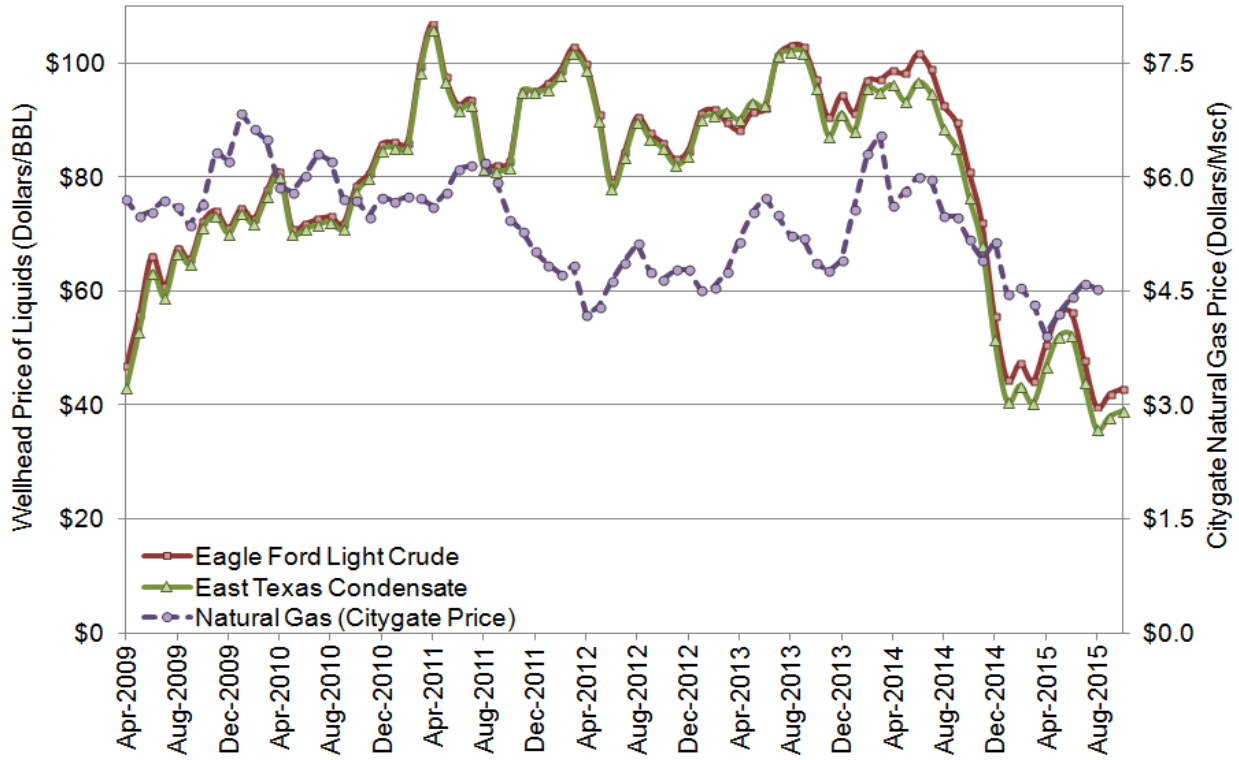
Future projections of wells will be based on the number of drill rigs operating in the Eagle Ford. The number of new production wells will be based on the average number of days between spud to spud for each drill rig.

All state or federal mandated controls will be included in each projection scenario. Future projections will take into account EPA's amendments to air regulations for the oil and natural gas industry. "On April 17, 2012, the U.S. Environmental Protection Agency (EPA) issued cost-effective regulations to reduce harmful air pollution from the oil and natural gas industry while allowing continued, responsible growth in U.S. oil and natural gas production. The final rules include the first federal air standards for natural gas wells that are hydraulically fractured, along with requirements for several other sources of pollution in the oil and gas industry that currently are not regulated at the federal level."[24]

Future projections will take into account recent drops in oil prices and reduced drilling activity in the Eagle Ford. Since 2014, the price of oil has significantly decreased from $99.0 per barrel in July 2014 to $42.90 per barrel in October 2015[25] (Figure 3-1). The price of U.S. citygate[26] natural gas also decreased from $5.8 per Mscf to $4.5 per Mscf in August 2015[27]. Since 2014, the number of drill rigs operating in the Eagle Ford has decreased more than 60%, from 196 drill rigs in August 2014 to 73 drill rigs in November 2015.[28]

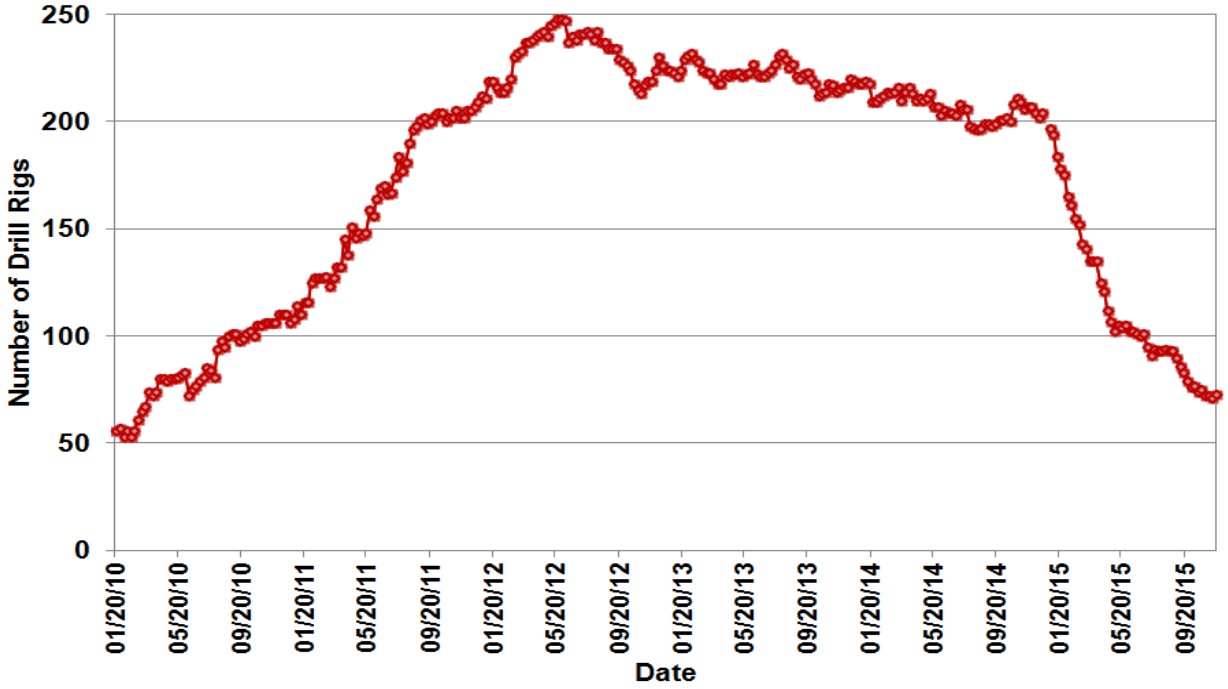
[24] EPA, April 17th, 2012. "Overview of Final Amendments to Air Regulations for the Oil and Natural Gas Industry". Available online: http://www.epa.gov/airquality/oilandgas/pdfs/20120417fs.pdf. Accessed 10/21/2013.
[25] Plains Marketing, November 2015. "L.P. Crude Oil Price Bulletin - Recap". Houston, Texas. Available online: https://www.plainsallamerican.com/customer-center/crude-oil-bulletins/historical/plains-marketing,-l-p. Accessed: 11/19/2015.
[26] Citygate price is "a point or measuring station at which a distributing gas utility receives gas from a natural gas pipeline company or transmission system." U.S. Energy Information Administration. "Natural Gas: Definitions, Sources and Explanatory Notes". Available online: http://www.eia.gov/dnav/ng/tbldefs/ng_pri_sum_tbldef2.asp. Accessed 08/18/2014.
[27] U.S. Energy Information Administration, September 30, 2013. "U.S. Natural Gas CityGate Price". Available online: http://www.eia.gov/dnav/ng/hist/n3050us3m.htm. Accessed 08/28/2015.
[28] Baker Hughes Investor Relations. November 2015. "Interactive Rig Counts". Available online: http://gis.bakerhughesdirect.com/Reports/RigCountsReport.aspx. Accessed: 11/19/2015.

Figure 3-1: Monthly Price for Eagle Ford Crude Oil and Condensate from Plains Marketing and Natural Gas from EIA, April 2009-September 2015



Note: Before September 2010, North Texas Sweet price was used for Eagle Ford crude and East Texas condensate price was used for Eagle Ford condensate after February 2013

Figure 3-2: Horizontal Trajectory Rig Counts by Week in the Eagle Ford, 2010-November, 2015



4 QUALITY METRICS

In this section, the quality requirements for the data used in this study and the procedures for determining the quality of the data are described. Note that 10% of the data used in this study will be audited. After each section is completed, the QA/QC manager will check the data inputs into the formulas and will check all documentation on methodologies. All formulas will be recalculated by the QA/QC manager to make sure the results can be replicated and are accurate. The QA/QC manager will work closely with the project manager to update the calculations, emission estimates, and documentation. The results of the audit process will be provided in the draft and final emission inventory submitted to TCEQ.

4.1 Data

The data used in calculating emissions from Eagle Ford oil and gas activities must be statistically significant. The data must be reasonably consistent with other studies and be sufficiently complete to be expected to adequately represent emissions. In addition, collected data will be assessed for missing information and outliers through communications with industry contacts, oil and gas sector experts, and trade group officials.

4.2 Quality Control

Quality control (QC) is a system of routine technical activities implemented by inventory development personnel to measure and control the quality of the inventory as it is being developed. The QC system is designed to:

- "Provide routine and consistent checks and documentation points in the inventory development process to verify data integrity, correctness, and completeness;
- Identify and reduce errors and omissions;
- Maximize consistency within the inventory preparation and documentation process; and
- Facilitate internal and external inventory review processes.

QC activities include technical reviews, accuracy checks, and the use of approved standardized procedures for emission calculations. These activities should be included in inventory development planning, data collection and analysis, emission calculations, and reporting."[29]

Equations, data sources, and methodology will be checked throughout the development of the emission inventory. "Simple QA procedures, such as checking calculations and data input, can and should be implemented early and often in the process. More comprehensive procedures should target:

- Critical points in the process;
- Critical components of the inventory; and
- Areas or activities where problems are anticipated"[30]

Special emphases will be put on critical components, such as drill rigs and hydraulic fracturing pumps, for quality checks. Eagle Ford data developed through the emission inventory process

[29] Eastern Research Group, Inc, Jan. 1997. "Introduction: The Value of QA/QC'. Quality Assurance Committee Emission Inventory Improvement Program, U.S. Environmental Protection Agency. p. 1.2-1. Available online: http://www.epa.gov/ttn/chief/eiip/techreport/volume06/vi01.pdf. Accessed 06/04/2012.
30 *Ibid*., p. 1.2-2.

will be compared to previous data sets from other shale oil and gas emission inventories. The data sets from other oil and gas emission inventories will include emission factors and activity data. These reports can include ERG's Texas EI, Barnett Shale Special Inventory, ENVIRON CENRAP EI (Western Gulf), and TCEQ's Pneumatic Survey.

Ten percent of calculations will be independently replicated to ensure accuracy. The project manager will ensure that all of the QA checks performed are compiled, and maintained in the project archives.

When errors and omissions are identified, they will be corrected and all documentation will be updated with the corrections. All emission inventory calculation methodologies will be documented and described in detail so external officials and other interested parties can replicate the results. For every emission inventory source, documentation will be consistent and contain data sources, methodology, formulas, and results.

Pertinent information and supporting statistics used for developing the Eagle Ford emission inventory will be analyzed to ensure that the information and statistics are reasonable (i.e., avoiding extremely low or high values that are indicative of errors). Data that are found to be questionable will be examined in greater detail to determine what errors might be present and what adjustments might be needed. If data are revised, the procedures and assumptions used will be thoroughly documented. The Project Manager will review and approve all data adjustments.

AACOG will use a senior peer reviewer not directly involved in conducting the project to review all methods and results of the work. The senior peer reviewer will be involved in the initial planning stages of this project to ensure the planned approaches are technically sound, and will also provide quality checks and review on all final products prior to submittal to TCEQ to ensure the project procedures were properly implemented. When the emission inventory is completed, documentation and spreadsheets will be sent to TCEQ and other interested parties for review.

5 DATA ANALYSIS, INTERPRETATION AND MANAGEMENT

5.1 Data Reporting Requirements

Primary data on emissions from oil and gas activity in the Eagle Ford that are assembled for this study will be reported electronically and documented in the project final report. Any data that are assembled for this study, such as well counts and production data, will also be delivered electronically and documented in the final report. Data that are documented elsewhere, such as data on emission factors or data used to calculate emissions, will be documented in the final report by reference to the original data source. Records will be maintained that include sufficient information to reconstruct each emission inventory calculation.

5.2 Data Management Procedures

Hard copy data received during the course of the project will be cataloged into the file index and made available for copying or checkout. Electronic data files will be stored in a specific project directory on AACOG's fileserver network drives. Original data files will be kept in a separate folder and will not be altered or changed. Project staff will make copies of any data files needed and perform their work with the copy. All project staff will have access to these files, and all files on the network drive undergo automatic backup each night, such that any information can be easily retrieved as necessary. After the final product is completed and approved by TCEQ, all project data will be archived on CD-ROM for storage.

6 DATA REPORTING

6.1 Project Deliverables

The project final delivery will include a report documenting the Eagle Ford oil and gas emissions inventory improvement project and the information necessary to update TCEQ modeling files. All relevant QA/QC findings will be included in the final report. The report will describe the steps taken and any background that is relevant to the project. The report shall be provided in Microsoft Office Word and Adobe Acrobat Reader (*.pdf) formats. The final report will include the following components:

(1) An executive summary and abstract,
(2) An introduction that discusses background and objectives, including relationships to other studies if applicable,
(3) A discussion of the pertinent accomplishments, shortfalls, and limitations of the work completed, and
(4) Recommendations, if any, for what should be considered in future studies.

The final report will provide a comprehensive overview of activities undertaken and data collected and analyzed during the study. The final report will highlight major activities and key findings, provide pertinent analysis, describe encountered problems and associated corrective actions, and detail relevant statistics including data, parameter, or model completeness, accuracy and precision.

Modeling files will be in EPS3 format based on the grid system consistent with EPA's Regional Planning Organizations (RPO) Lambert Conformal Conic map projection with the following parameters:

- First True Latitude (Alpha): 33°N
- Second True Latitude (Beta): 45°N
- Central Longitude (Gamma): 97°W
- Projection Origin: 97°W, 40°N
- Spheroid: Perfect Sphere, Radius: 6,370 km

All future TCEQ photochemical model emissions processing work, including the Eagle Ford emission inventory, will be based on the grid system listed above.