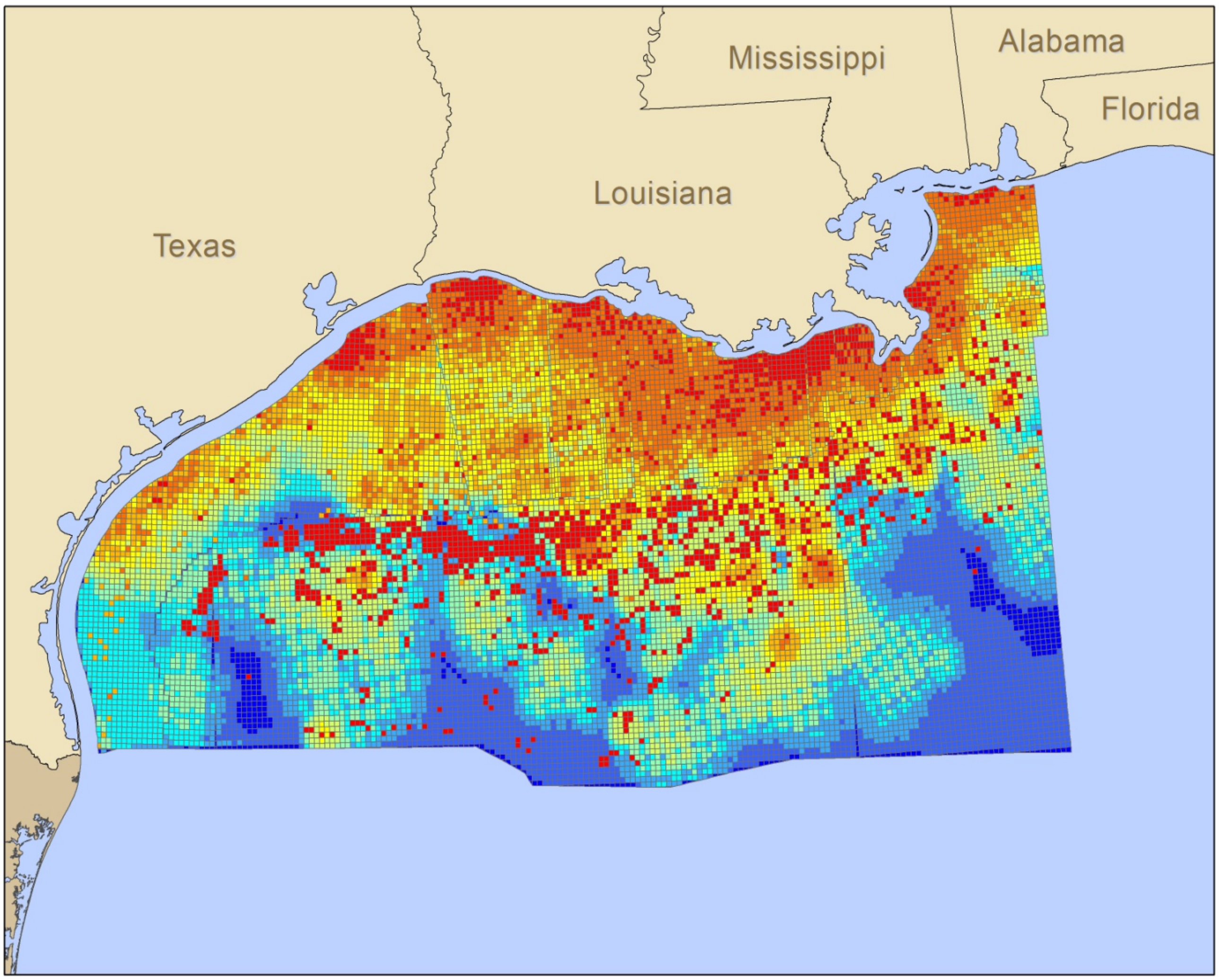
OCS Study
BOEM 2014-666

Year 2011 Gulfwide Emission Inventory Study



U.S. Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico OCS Region

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Authors

D. Wilson
R. Billings
R. Chang
H. Perez
J. Sellers

Prepared under BOEM Contract
M10PC00084
by
Eastern Research Group, Inc.
1600 Perimeter Park Drive
Morrisville, NC 27560

Published by

U.S. Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico OCS Region

New Orleans, LA
November 2014

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Study concept, oversight, and funding were provided by the US Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, DC, under Contract Number M10PC00084. This report has been technically reviewed by BOEM and it has been approved for publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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CITATION

Wilson, D., R. Billings, R. Chang, H. Perez, and J. Sellers. 2014. Year 2011 Gulfwide emissions inventory study. US Dept. of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEM 2014-666.

ACKNOWLEDGMENTS

This report would not have been possible without the contributions of the following staff at Eastern Research Group: Bebhinn Do, Stacie Enoch, Karla Faught, Steve Mendenhall, Regi Oommen, and Jody Tisano. Invaluable assistance was also provided by the staff of COMM Engineering: Brian Boyer, Stephanie Myers, and Rachelle Suir.

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EQUATION UNIT DEFINITIONS

Unit	Definition
avg	Average
bbl	Barrel
Btu	British thermal unit
CF	conversion factor
°F	degrees Fahrenheit
ft	Feet
ft^3	cubic feet
gal	Gallon
G	Gram
GOR	gas-to-oil ratio
hp	Horsepower
hr	Hour
kW	Kilowatt
kWh	kilowatt-hour
lb	Pound
LF	load factor
LTO	landing and takeoff
m^2	meter squared
MMBtu	million British thermal units
Mscf	thousand standard cubic feet
MMscf	million standard cubic feet
MMscfd	million standard cubic feet per day
ppm	parts per million
ppmv	parts per million volume
psig	pressure per square inch gauge
°R	degrees rankine
scf	standard cubic feet
sec	Second
tpy	tons per year
μmol	Micromole
wt	Weight

1. SUMMARY

The Bureau of Ocean Energy Management (BOEM) is responsible for assessing the potential impacts of air pollutant emissions from offshore oil and gas exploration, development, and production sources on the Outer Continental Shelf (OCS). This responsibility is driven by the OCS Lands Act (1134(a)(8)), which tasks BOEM to assure that emissions from these activities do not significantly affect onshore air quality. In particular, BOEM is responsible for determining if any OCS oil and gas exploration, development, and production sources influence the National Ambient Air Quality Standard (NAAQS) compliance status of onshore areas in Louisiana, Texas, Mississippi, Alabama, and Florida. This responsibility was mandated by the 1990 Clean Air Act (CAA) Amendments. In addition, the CAA requires BOEM to coordinate air pollution control activities with the State regulatory agencies. Thus, there will be a continuing need for emission inventories and modeling whenever the U.S. Environmental Protection Agency (USEPA) updates the NAAQS, such as the eight-hour ozone, one-hour nitrogen dioxide, and one-hour sulfur dioxide standards. To assess the emissions of offshore oil and gas platforms and their associated emissions, BOEM conducted limited emission inventories in the GOM OCS in the 1980s. In 1995, BOEM completed the *Gulf of Mexico Air Quality Study* (Systems Applications International et al. 1995); in 2004 BOEM completed the *Gulfwide Emission Inventory Study for the Regional Haze and Ozone Modeling Effort* (Wilson et al. 2004) and the *Data Quality Control and Emissions Inventories of OCS Oil and Gas Production Activities in the Breton Area of the Gulf of Mexico Study* (Billings and Wilson 2004); in 2007 the *Year 2005 Gulfwide Emission Inventory Study* (Wilson et al. 2007) was completed; and in 2010 the *Year 2008 Gulfwide Emission Inventory Study* (Wilson et al. 2010) was completed. Because the offshore sources are changing due to new technology and drilling in deep waters and because of new and updated NAAQS standards, BOEM continues to update the emissions inventories every three years to concide with the USEPA and State agency inventory process.

The BOEM Gulf of Mexico OCS Regional office sponsored this project, the *Year 2011 Gulfwide Emissions Inventory Study* (BOEM Contract No. M10PC00084), which builds on the previous studies and has the goal of developing a calendar year 2011 air pollution emissions inventory for all OCS oil and gas production-related sources in the GOM, including non-platform sources. Pollutants covered in this inventory are the criteria pollutants—carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter-10 (PM_{10}), $PM_{2.5}$, and volatile organic compounds (VOC); as well as major greenhouse gases—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The platform and non-platform emission inventory files are provided in Microsoft® Access® format. Documentation of the structure of these files is provided in the ReadMe Word files.

Similar to the previous air quality emission inventory studies, the 2011 Gulfwide Offshore Activities Data System (GOADS-2011) software was created to collect monthly activity data from platform sources. The activity data were combined with the most recent emission factors published by the USEPA, and Emission Inventory Improvement Program (EIIP) emission estimation methods to develop a comprehensive criteria pollutant and greenhouse gas emissions inventory. Non-platform emission estimates were developed for sources such as the Louisiana Offshore Oil Platform (LOOP), drilling rigs, marine vessels, and helicopters. Ultimately, State agencies and Regional Planning Organizations will use these offshore oil and gas platform and non-platform inventories to perform modeling for ozone and regional haze for use in their State Implementation Plans (SIPs), and BOEM will use the emission inventory for the cumulative impact analysis in National Environmental Policy Act (NEPA) Environmental Impact Statement (EIS) documents.

Somewhat similar to the results of the 2008 inventory, the 2011 inventory results indicate that OCS oil and gas production platform and non-platform sources emit the majority of criteria pollutants and greenhouse gases in the GOM on the OCS, with the exception of SO_2 (primarily emitted from commercial marine vessels), and N_2O (from biological sources). The OCS oil and gas production platform and non-platform sources account for 90% of the total CO emissions, 73% of NO_x emissions, 68% of PM_{10} emissions, 42% of SO_2 emissions, 63% of VOC emissions, and 85% of the greenhouse gas emissions. Similar to the 2008 inventory, natural gas engines on platforms represented the largest CO emission source, accounting for 47% of the total estimated CO emissions, and support vessels were the highest emitters of both NO_x and PM_{10}, accounting for 37% and 42% of the total estimated emissions. Oil and natural gas production platform vents account for the highest percentage (29%) of the VOC emissions. Support vessels (32% of total emissions), production platform natural gas, diesel, and dual-fuel turbines (18% of total emissions), and commercial marine vessels (11% of total emissions) emit the majority of the greenhouse gas emissions.

Though the emission estimation methods and emission factors for platform sources included in this study are very similar to those used in the *Year 2008 Gulfwide Emission Inventory Study* (Wilson et al. 2010), the emission factors used to estimate emissions for the non-platform mobile source categories differ, because emission factors specifically representative of 2011 were used in this study. The USEPA emission factors vary by year because the data take into account changes in the implementation of marine fuel and engine exhaust standards, and changes in the marine fleet due to the addition of new vessels and the retirement of older vessels. It should also be noted that commercial marine vessel (CMV) emission estimates for 2008 were provided by the USEPA using a top-down approach and only accounted larger Category 3 vessels. For 2011, CMV activity was developed from port entrance and clearance data for individual vessels (including Category 1, 2, and 3 vessels), such that the activity data used in 2011 is more complete and of higher quality than the top-down USEPA data provided in 2008.

Comparisons of pollutant-specific emission estimates for oil and natural gas production platform and non-platform sources show that the total CO emission estimates vary slightly from 2008 to 2011. A 12% increase is seen in the overall VOC emission estimate. Greater differences are seen, however, in the NO_x (25% increase), PM_{10} (33% increase), and SO_2 estimates (23% decrease). For greenhouse gases, the overall N_2O emission estimate varies slightly from 2008 to 2011. A significant increase is seen in the CO_2 estimates (37%), while a decrease (36%) is seen in the CH_4 estimates.

For oil and natural gas production platforms, the CO and VOC emission estimates show slight decreases in emissions from 2008 to 2011, and the NO_x and PM_{10} emission estimates show slight increases. The SO_2 emission estimate, however, shows greater than 200% increase. This increase is due primarily to the natural gas, diesel, and dual-fuel turbine emission estimates. The

2008 turbine emission estimate included only natural gas turbines. The 2011 natural gas engine estimates drive the overall decrease in estimated emissions for CO, indicating a decrease in reported activity levels. The decrease in the 2011 emission estimates for VOC is driven by the fugitives and pressure level controllers emission estimates. Similar to the SO_2 estimate, the increase seen in the NO_x and PM_{10} emission estimates is driven by natural gas, diesel, and dual-fuel turbines. Greenhouse gas emissions from oil and natural gas production platforms slightly increased from 2008 to 2011. Similar to the increase in the SO_2 emission estimate, the increase is driven in large part by the natural gas, diesel, and dual-fuel turbine estimates. The CH_4 emission estimates for flashing losses also contributed to the increase.

A comparison of the 2008 and 2011 emission estimates for non-platform sources indicates a significant increase in criteria pollutant emission estimates, with the exception of SO_2. The SO_2 reduction is due to a reduction in vessel activities, and application of the most recent USEPA emission factors. The USEPA factors have lower sulfur values for smaller vessels equipped with Category 1 and 2 propulsion engines, such as pipelaying vessels, crew and coast guard patrol boats, commercial fishing vessels, and support vessels generators, and pumps associated with the Louisiana Offshore Oil Port (LOOP). The increase in CO, NO_x, PM_{10}, and VOC emission estimates for non-platforms sources is primarily due to the use of updated USEPA emission factors. The application of the USEPA factors is compounded by increased activity in 2011 for support, survey, and commercial marine vessels. For other categories, such as commercial fishing, pipelaying drilling rigs, and the LOOP, reductions in activity in 2011 partially offset the effects of the USEPA factors. The updated emission factors and activity data yielded an overall increase in greenhouse gas emissions.

2. INTRODUCTION

2.1 BACKGROUND

The Bureau of Ocean Energy Management (BOEM) is responsible for determining if air pollutant emissions from Outer Continental Shelf (OCS) oil and natural gas platforms and other oil and natural gas sources in the Gulf of Mexico (GOM) influence the National Ambient Air Quality Standards (NAAQS) compliance of onshore areas. Texas and Louisiana have coastal areas that are designated as nonattainment for the eight-hour ozone standard. Ozone forms in the presence of sunlight from the reaction of volatile organic compounds (VOC) and oxides of nitrogen (NO_x).

The Clean Air Act Amendments of 1990 (CAAA Title VIII, Sec 801[b]) specifically mandate that BOEM conduct a research study to assess the potential for onshore impacts of certain types of air pollutant emissions from offshore oil and gas exploration, development, and production in regions of the GOM. This mandate grew out of concerns regarding the cumulative onshore impacts of air pollutant emissions from more than 3,000 offshore facilities in the central and western GOM. BOEM launched a series of studies, beginning in the 1980s, to assess the emissions of offshore oil and gas platforms and their associated emissions. In 1991 BOEM sponsored a regional ozone modeling effort conducted by the U.S. Environmental Protection Agency (USEPA) using the Regional Oxidant Model (ROM). The *Gulf of Mexico Air Quality Study* was initiated that same year, and activity data for a Gulfwide emissions inventory were collected for a one-year period in 1991–92 (Systems Applications International et al. 1995).

BOEM has sponsored four more recent air quality emission inventory projects. Through an Office of Management and Budget-approved Information Collection Request, BOEM required affected platform operators to collect activity data used in these studies. One study affected only platforms within 100 kilometers (km) of the Breton National Wilderness Area in the GOM, where visibility and regional haze concerns may apply. As part of its program to collect activity data, a Microsoft® Visual Basic® program was developed, known as the Breton Offshore Activities Data System (BOADS), for platform operators to submit activity data on a monthly basis. An Oracle® database management program (DBMS) was updated and used to develop the emissions estimates for calendar year 2000 (Billings and Wilson 2004).

The *Gulfwide Emission Inventory Study for Regional Haze and Ozone Modeling Effort* built upon the previous BOEM studies with the goal of developing criteria pollutant and greenhouse gas emission inventories for all oil and gas production-related sources in the entire GOM OCS for calendar year 2000. The Gulfwide Offshore Activities Data System (GOADS) was developed from the BOADS Microsoft® Visual Basic® program; it was modified to request activity data for additional emission sources. The emission estimation procedures in the Breton Oracle® DBMS were also expanded (Wilson et al. 2004). The *2005 and 2008 Gulfwide Emission Inventory Studies* covered the same sources, pollutants, and geographic area as the 2000 inventory (Wilson et al. 2007; 2010). Updates were made to the GOADS-2005 and GOADS-2008 programs as needed.

The BOEM Gulf of Mexico OCS Regional office sponsored this project, the "Year 2011 Gulfwide Emissions Inventory Study" (BOEM Contract No. M10PC00084), with the goal of developing a calendar year 2011 air pollution emissions inventory for all OCS oil and gas production-related sources on the GOM OCS. Pollutants covered in this inventory are the criteria pollutants—carbon monoxide (CO), NO_x, sulfur dioxide (SO_2), particulate matter-10 (PM_{10}), $PM_{2.5}$, and VOC; as well as major greenhouse gases—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

2.2 Scope and Purpose of This Project

BOEM is responsible for determining if GOM OCS oil and natural gas platforms and other oil and natural gas production sources in the central and western GOM (west of latitude 87.5^o) influence the NAAQS compliance of onshore areas. The BOEM also has responsibilities under the NEPA to assess the cumulative air quality impacts of oil and natural gas production on the GOM OCS. The goal of this project is to develop a calendar year 2011 air pollution emissions inventory for all OCS oil and gas production-related sources in the GOM, including non-platform sources.

Through an Office of Management and Budget-approved Information Collection Request, BOEM required affected platform operators to collect and submit the activity data needed to develop air pollutant emissions estimates from platform activities for calendar year 2011. The activity data were collected based on BOEM NTL No. 2010-G06, "2011 Gulfwide OCS Emissions Inventory (Western Gulf of Mexico)."

BOEM updated and distributed a Mircosoft® Visual Basic® program for platform operators to use to collect activity data on a monthly basis and submit to BOEM on an annual basis. The program, known as the GOADS-2011, was used by operators to submit activity data for a number of production platform emission sources. Operators used the GOADS software to collect activity data for amine units, boilers/heaters/burners, diesel engines, drilling equipment, fugitives, combustion flares, glycol dehydrators, losses from flashing, mud degassing, natural gas engines, natural gas/diesel/dual-fuel turbines, pneumatic pumps, pressure/level controllers, storage tanks, and cold vents.

These activity data were used to calculate CO, NO_x, SO_2, PM_{10}, $PM_{2.5}$, and VOC emissions estimates; as well as CO_2, CH_4, and N_2O. The Gulfwide Oracle® DBMS calculates and archives the activity data and the resulting emissions estimates. Database users can query by pollutant, month, equipment type, platform, etc.

Emission estimates for non-platform sources on the GOM OCS include both oil and natural gas production-related sources, as well as non-oil and natural gas production sources. Production sources consist of survey vessels, drilling rigs, pipelaying operations, and support vessels and helicopters. Non-oil and natural gas production sources include commercial marine vessels, the Louisiana Offshore Oil Platform (LOOP), and biogenic and geogenic sources.

2.3 STUDY OBJECTIVES

The objectives of this study are:

- To review, modify, and provide support services for GOADS-2011 and the 2011 Gulfwide Oracle® DBMS.
- To collect, describe, quality check, quality assure, and archive activity data from all platform and non-platform sources on the OCS that emit air pollutants over the course of one (1) calendar year (2011). Activity data from platform sources were collected using GOADS-2011.
- To calculate and archive a calendar year 2011 total emissions inventory using the most current emission factors and the 2011 Gulfwide DBMS for all specified platform and non-platform sources, and to compare the emissions inventory with previously collected emissions data.
- To provide the platform and non-platform emission inventory files in Microsoft® Access® format, along with documentation of the structure of the files in ReadMe Microsoft® Word files.

2.4 REPORT ORGANIZATION

Following this introduction, the *Year 2011 Gulfwide Emissions Inventory Study* report is organized as follows:

- Section 3 discusses how the platform activity data were collected and compiled.
- Section 4 summarizes the quality assurance/quality control (QA/QC) procedures that were implemented after receipt of the platform activity data files to prepare the data for use in developing emissions calculations. The approach used to fill in data gaps in the platform data is also discussed in Section 4.
- Section 5 presents calculation methods for each piece of platform equipment. These calculation routines are performed in the Oracle® DBMS.
- Section 6 presents the collection of activity data, QA/QC, and calculation methods for non-platform sources.
- Section 7 summarizes the resulting emission estimates by equipment type, source category, and pollutant. The limitations associated with the data and the emission estimates are also noted in Section 7, and the results are compared with the *Year 2008 Gulfwide Emission Inventory Study Report* (Wilson et al. 2010).
- Section 8 presents references cited throughout the report.

3. DATA COLLECTION FOR PLATFORM SOURCES

3.1 INTRODUCTION

To develop a calendar year 2011 inventory of criteria pollutant and greenhouse gas emissions for all OCS oil and gas production-related sources in the GOM, BOEM collected activity data from platform operators during the year 2011. On September 15, 2010, NTL 2010-G06 was published to introduce the "2011 Gulfwide OCS Emissions Inventory (Western Gulf of Mexico)" and inform operators about the mandatory data collection. Affected operators are lessees and operators of Federal oil, gas, and sulfur leases in the GOM OCS region west of latitude 87.5°. The USEPA jurisdiction has air quality jurisdiction east of latitude 87.5°.

This section of the report outlines the steps that BOEM took to collect the data, including modifying the data collection software, meeting with and training platform operators, and answering questions about data collection. Activity data were collected during one calendar year (2011) and were used to calculate and archive emissions data using the most current emission factors and calculation methods.

3.2 IMPROVEMENT OF THE GOADS DATA COLLECTION SOFTWARE

The GOADS data collection software that was used to collect calendar year 2000, 2005, and 2008 platform activity data was revised for this study to address several issues uncovered during its use for preparing previous inventories. The largest improvement to the new version, GOADS-2011, was the addition of diesel and dual-fuel turbines.

3.3 WORKING WITH USERS

A workshop was held in New Orleans on October 8, 2010, to discuss and explain the 2011 Gulfwide study information collection and reporting procedures. The *User's Guide for the 2011 Gulfwide Offshore Activities Data System (GOADS-2011)* (Wilson and Boyer 2011) was the primary source of information for operators. The guide was provided at the workshop, and made available to all users through the BOEM website, where it could be downloaded and printed. The guide contains instructions on installation, starting and exiting the GOADS program, creating and editing data, quality control, and saving and backing up files. For details on the GOADS-2011 program, refer to the User's Guide (Wilson and Boyer 2011).

3.4 GOADS QUALITY ASSURANCE/QUALITY CONTROL

BOEM programmed automatic QA procedures into the software in an effort to minimize the submittal of incomplete and erroneous activity data by the platform operators as detailed in Section 4. BOEM requested that operators submit a printout of their Quality Assurance Summary Form along with their monthly activity files. The QA Summary focuses on identification of critical data that the operators need to complete prior to submitting their data to BOEM.

The software also automatically runs a series of QC checks (discussed in Section 4) on the data when the operator saves it. If the operator leaves a field blank, provides data that are out of range, or enters a value that is not consistent on a month-to-month basis, an error message will appear. The operator may then correct the problem, override the QC check (and provide a comment), or ignore the message and save the changes. When operators entered data that appeared in the QC results or on the QA Summary Form, BOEM attempted to reconcile the missing, atypical, or suspect data by reviewing the comments, contacting the operators, or developing surrogate data as described in Section 4 of this report. Surrogate data were developed primarily for the stack parameters requested for the emission release point for each piece of equipment. These parameters are needed for air quality modeling efforts. The surrogates were developed based on industry averages and through discussions within BOEM.

4. QUALITY ASSURANCE/QUALITY CONTROL

4.1 INTRODUCTION

Platform operators submitted data files and QA Summary Forms generated by the GOADS-2011 software. Ninety six companies submitted data for 3,051 active or inactive platforms (combination of complex ID and structure ID) (about 85% of OCS platforms) including minor sources. 2,544 structures were active (at least one month). Of these, 1,366 were flagged as minor sources. Thus, approximately 330 platforms are unaccounted for in the year 2011 inventory.

This section summarizes the data received, the steps BOEM took to review the GOADS-2011 descriptive and monthly activity data for completeness and accuracy, and the types of errors encountered. Also discussed in this section are the procedures used to correct and gap-fill missing data, including stack parameter data provided by the operators. When operators failed to enter data or entered data that were atypical or suspect, BOEM attempted to reconcile the data by reviewing the comments, contacting the operators, or developing surrogate data.

4.2 CHECKING FILE INTEGRITY

BOEM received 101 unique data files for the 2,544 active platforms. All electronic data were in the prescribed Microsoft® Access® database that was created by the GOADS-2011 software. For comparison, 113 unique data files were submitted for the calendar year 2008 inventory for 3,026 active platforms. Similar to the calendar year 2008 inventory, BOEM required minor sources to report minimal data through GOADS-2011.

The ERG checked file integrity to verify that the file submitted could be opened, and that it matched its QA Summary Form (same user, structure, and complex IDs). The ERG was able to open and review all of the files provided.

4.3 EQUIPMENT SUMMARY CHECKS

Each GOADS-2011 submittal contained templates for up to 34 tables. The majority of these tables cover the descriptive and activity data for specific equipment types (amine units, boilers, etc.). The user-, structure-, and QC tables were appended along with the equipment tables into one composite database. Primary keys (user ID, month, year, complex ID, structure ID, and equipment ID) were retained in all tables to ensure that no duplicate data were added.

4.3.1 User-Level Summary

The first data entry page in GOADS is for user information. The user ID should be BOEM company number assigned by BOEM. The user IDs submitted were checked against the BOEM master lease and company lists.

BOEM used these master lists to check and correct the lease, company, and platform IDs. Additionally, BOEM checked and corrected the locational data (latitude/longitude pairs) for each platform. Corrections were only needed for one platform's structure ID.

4.3.2 Structure-Level Summary

For each survey, the user was required to enter platform-level data that includes location coordinates, sales gas composition, total monthly platform fuel usage, status (active or inactive for that month), and indicate if the platform was a minor source. A total of 36,784 records were submitted, and 29,887 were considered active (81%). For comparison, 35,952 active records were submitted for calendar year 2008.

4.3.3 Equipment-Level Summary

Equipment descriptive information and activity-level data for 15 different types of equipment can be populated for each platform. A list of all the platform equipment submitted per equipment type was compiled. This composite list includes a total of 259,700 equipment surveys, of which 152,957 were active (59%).

4.4 QA/QC CHECKS

A number of QA/QC steps were performed to identify missing and out-of-range data for each type of equipment. The first step of the QA/QC task consisted of reviewing the sales gas compositions for validity and completeness. The sum of compositions that deviated from 100% were evaluated and corrected. Questionable sales gas compositions were replaced with a default set of compositions. Less than 2% of the monthly equipment records required this correction.

Another part of the QA/QC task for the GOADS submittals was to identify incorrect and missing equipment descriptive and activity data, and to correct and populate the missing information with surrogates. Seven types of data analyses were performed: 1) pre-processing of the data; 2) equipment survey consistency; 3) data range checks; 4) stream analysis between certain equipment; 5) applying surrogate values; 6) post-processing of surrogates; and comparison and revision based on OGOR-reported vent and flare volumes.

4.4.1 Pre-Processing

Three pre-processing steps occurred before the rigorous data analysis could begin. First, the activity status of each survey was confirmed. Second, the reported number of operating hours for each piece of equipment was checked to make sure it did not exceed the maximum number of hours in the month. Third, the reported fuel usage at the equipment level was compared to the maximum capacity of the equipment and the reported fuel usage for the entire platform.

Operators had the opportunity to identify a platform or individual pieces of equipment as being inactive for each month by checking a “No Emissions to Report” checkbox. Otherwise, all platforms and equipment were treated as active. Inactive data are not considered for emissions calculations, so this step is extremely important. For equipment surveys that request hours of operation, platform surveys were labeled as active if any of the equipment the operating hours were greater than zero. Conversely, a platform survey was labeled as inactive if all of the equipment operating hours were zero.

Platform/equipment surveys were also considered active based on a review of the following equipment data if: 1) in the Fugitive equipment table, the component count provided was greater than zero and other active equipment records are reported; 2) in the Losses from Flashing equipment tables the throughput was greater than zero; or 3) in the Mud Degassing equipment table, the drilling days per month were greater than zero.

45% of the monthly activity data records were revised in these pre-processing QA/QC steps. It is important to note that this percentage is misleadingly high because it is almost exclusively changes where "No Emissions to Report" were assigned to a minor source, and because GOADS-2011 automatically flags a record as active when a monthly record is created, but its status is actually inactive when zero values are entered for throughput or fuel use.

For each month, operating hours were provided for most types of equipment. A typical error would be to exceed the maximum hours possible for a given month. Similarly, hours of operation may not have been populated. For both of these errors, data were corrected in the same manner by populating with the maximum number of hours possible. The maximum number of hours for months with 31 days (January, March, May, July, August, October, and December) is 744; for months with 30 days (April, June, September, and November), the maximum number of hours is 720. The maximum number of hours for February (with 28 days) is 672. Two exceptions are also noted due to the implementation of daylight savings: 1) the number of hours possible for March is 743 hours; and 2) the number of hours possible for November is 721 hours. Less than 5% of the monthly equipment records required corrections in this process.

The last pre-processing step focused on the reported fuel usage. Platform operators provided estimates of total fuel used for each month for the entire platform, and for each boiler/heater/burner, diesel engine, natural gas engine, natural gas turbine, and drilling rig operation. Additionally, operators were asked to provide fuel equipment parameters such as hours operated, fuel usage rate (average and maximum), operating horsepower (average and maximum), and heat input rate.

The average and theoretical maximum fuel usage values for each reported boiler/heater/burner, diesel engine, natural gas engine, and natural gas turbine were calculated by multiplying the hours operated by the average or maximum heat input or fuel usage rate and operating horsepower, and dividing by the fuel heating value. Less than 3% of the monthly equipment records required corrections in this process.

4.4.2 Equipment Survey Consistency

A platform may contain several pieces of equipment that operate year-round, but data parameters may not have been populated for every month. In this situation, the entire platform equipment dataset was examined. For example, 11 of the 12 monthly surveys may be populated for a boiler with the same fuel heating value, while one month, although marked active, may be null or provide a different fuel heating value. The missing or different value was populated to match the other platform equipment surveys if ERG believed a data entry error occurred. Less than 1% of the monthly equipment records required corrections in this process.

4.4.3 Data Range Checks

After the equipment surveys were checked for survey consistency, the parameters were checked to ensure that they were within an acceptable data range. For example, some operators mistakenly entered incorrect fuel heating values. Natural gas has a fuel heating value on average of 1,050 Btu/scf. However, some equipment surveys had entered 105 Btu/scf as their fuel heating value, or even 19,300, which is the average fuel heating value of diesel fuel (in units of Btu/lb, however). Only 1% of the monthly equipment records required corrections in this process.

The GOADS-2011 QC checks flag these incorrect data, as indicated by the limited number of corrections needed. Unfortunately, there was clear evidence that some databases were not populated with the GOADS software as they contained invalid equipment type codes, mismatching equipment type codes, and database relational integrity errors.

The ranges were checked for the fields listed in Table 4-1. These ranges are based on the relationship between the parameters noted in Table 4-1 (e.g., actual fuel usage rate cannot exceed the reported maximum fuel usage rate), and typical fuel and control device efficiency values.

4.4.4 Stream Analysis Between Certain Equipment

Certain pieces of equipment may not be vented locally, but rather piped downstream to a cold vent or combustion flare. It is important for the downstream exhaust vents to be correctly identified; otherwise the calculations may overestimate emissions. The Amine Unit, Glycol Dehydrator, Losses from Flashing, Pneumatic Pumps, and Storage Tanks equipment may exhaust gases locally or downstream. If the Cold Vent or Combustion Flare ID is populated in these tables, then a downstream analysis was performed on the Cold Vent or Combustion Flare equipment tables to verify their existence. For Cold Vent or Combustion Flare IDs that could not be traced to an existing active vent or flare, the survey was updated as to being vented/flared locally. Only 1% of the monthly equipment records required corrections during this process.

Table 4-1. Fields and range check values

Field	Range Check
API Specific Gravity	Minimum value: 9 degrees API
Flare Efficiency	Between 90 and 99%
Fuel Heating Value	Natural gas: 500 to 1500 Btu/scf Diesel: 18,000 to 22,000 Btu/lb
Fuel Usage Rate	Not to exceed maximum fuel usage rate
Fuel H_2S Content	0 to 5 ppmv
Fuel Sulfur Content	0 to 5%
Heat Input Rate	Not to exceed maximum heat input rate
Inner Diameter	Varies by equipment type
Operating Horsepower	Not to exceed maximum rated horsepower
Stack Angle	Between 0 and 180

4.4.5 Applying Surrogate Values

Surrogate values were used to populate missing stack parameters that are not used to calculate emissions, but are needed for air quality modeling. These parameters are listed in Table 4-2 by equipment type. As shown in Table 4-2, surrogate values could be calculated for exit velocity and exhaust volume flow rate from the submitted data. Other surrogate data were developed from industry averages, and through discussions with BOEM. Approximately 12% of the monthly equipment records required corrections in this process.

Table 4-2. Surrogate stack parameters used to supplement GOADS-2011 data

Unit	Field	Default Value
Amine Unit	Elevation (above sea level)	50 ft
Amine Unit– ventilation system for acid gas from reboiler	Exit velocity (ft/sec)	Calculated with AMINECalc[a]
Amine Unit– ventilation system for acid gas from reboiler	Exit temperature	110 ^oF
Amine Unit–ventilation system for acid gas from reboiler	Combustion temperature	1832 ^oF
Boiler/heater/burner	Elevation (above sea level)	50 ft
Boiler/heater/burner– exhaust System	Exit temperature	400 ^oF
Boiler/heater/burner– exhaust system	Outlet orientation	0 degrees
Boiler/heater/burner– exhaust system	Outlet diameter	12 inches
Boiler/heater/burner– exhaust system	Exit velocity	Calculated
Diesel Engine	Elevation (above sea level)	50 ft
Diesel Engine	Max rated fuel use	7000 Btu/hp-hr
Diesel Engine	Average fuel use	7000 Btu/hp-hr
Diesel Engine– exhaust system	Outlet height	7 ft above engine
Diesel Engine– exhaust system	Exit velocity	Calculated
Diesel Engine– exhaust system	Exit temperature	900 ^oF
Diesel Engine– exhaust system	Outlet orientation	0 degrees
Diesel Engine– exhaust system	Outlet diameter	12 inches
Combustion Flare	Combustion temperature (excluding upsets)	1832 ^oF
Combustion Flare	Stack orientation	0 degrees
Combustion Flare	Outlet diameter	12 inches
Combustion Flare	Pilot feed rate	2.28 Mscf/day
Combustion Flare	H_2S concentration	3.38 ppm

Unit	Field	Default Value
Glycol Dehydrator	Elevation (above sea level)	50 ft
Glycol Dehydrator– flash tank	Temperature	120 ^{o}F
Glycol Dehydrator– flash tank	Pressure	60 psig
Glycol Dehydrator– ventilation system	Exit temperature	GLYCalc™ default (usually 212 ^{o}F)[b]
Glycol Dehydrator– ventilation system	Outlet orientation	0 degrees
Glycol Dehydrator– ventilation system	Flare feed rate (scf/hr)	Calculated with GLYCalc™[b]
Glycol Dehydrator– ventilation system	Combustion temperature	1832 ^{o}F
Glycol Dehydrator– ventilation system	Condenser temperature	110 ^{o}F (or calculated with GLYCalc™)[b]
Glycol Dehydrator– ventilation system	Condenser pressure	14.8 psia
Losses from Flashing– ventilation system	Exhaust volume flow rate	Calculated
Losses from Flashing– ventilation system	Exit velocity	Calculated
Losses from Flashing– ventilation system	Exit temperature	70 ^{o}F
Losses from Flashing– ventilation system	Outlet diameter	Use tank vent outlet diameter
Natural Gas Engine	Max rated fuel usage	7500 Btu/hp-hr
Natural Gas Engine	Average fuel usage	7500 Btu/hp-hr
Natural Gas Engine– exhaust system	Exit velocity	Calculated
Natural Gas Engine– exhaust system	Exit temperature	4-cycle rich burn: 1100 ^{o}F
Natural Gas Engine– exhaust system	Exit temperature	2-cycle lean burn: 700 ^{o}F
Natural Gas Engine– exhaust system	Outlet diameter	12 inches
Natural Gas Turbine	Max rated fuel use	10,000 Btu/hp-hr
Natural Gas Turbine	Average fuel use	10,000 Btu/hp-hr
Natural Gas Turbine– exhaust system	Exit velocity	Calculated
Natural Gas Turbine– exhaust system	Outlet diameter	12 inches
Natural Gas Turbine– exhaust system	Exit temperature	1000 ^{o}F
Pneumatic Pumps	Elevation (above sea level)	50 ft

Unit	Field	Default Value
Pneumatic Pumps– ventilation system	Exit velocity	Calculated
Pneumatic Pumps– ventilation system	Exit temperature	70 ^{o}F
Pressure/level Controllers	Elevation (above sea level)	50 ft
Storage Tank– General Information	Roof Height above Shell (ft)	0.0625*(Tank Diameter ÷2), ft
Storage Tank– ventilation system	Exit velocity	Calculated
Storage Tank– ventilation system	Exit temperature	70 ^{o}F
Storage Tank– ventilation system	Outlet orientation	0 degrees
Storage Tank– ventilation system	Flare feed rate	Calculated (or use the calculated storage tank exhaust vol. flow rate)
Cold Vent	Outlet elevation (above sea level)	50 ft
Cold Vent	Outlet diameter	Calculated (average of submitted data)
Cold Vent	Exit temperature	70 ^{o}F
Cold Vent	Outlet orientation	0 degrees

[a] AMINECalc is released by the American Petroleum Institute (API 1999)
[b] GLYCalc™ is released by the Gas Technology Institute, formerly the Gas Research Institute (GRI) (GTI 2000)

4.4.6 Post-Processing of Surrogates

After all the missing data have been populated through quality assurance checks and surrogates, two calculations were performed to check the overall quality of the data. The first calculation was for exit velocity; the second was for total fuel usage. Both of these parameters were recalculated using a combination of corrected and originally-submitted activity and descriptive data to yield values consistent with the inter-related, quality assured data parameters.

4.4.7 Comparison to OGOR Reports

The last QA/QC check implemented was a comparison of the GOADS-2011 data submittals for volume vented and flared with the values reported to the Office of Natural Resources Revenue (ONRR) through Oil and Gas Operations Report (OGOR) forms (Form ONRR-4054-B). Operators must provide monthly OGOR forms of the volumes vented and flared for “all wells for a lease/agreement.” BOEM contacted 86 companies (with a total of 1,439 platforms), and received revised vent/flare estimates for 401 platforms. BOEM received confirmation for 305 platforms that the submitted GOADS-2011 vent/flare volumes were correct. No response was provided for 72 platforms. The remaining platforms reported only to OGOR, were exempt from GOADS reporting, or had no vent/flare volumes.

Based on the results of this comparison, it is clear that BOEM must continue to highlight the need for consistent reporting with the OGOR reports for future GOADS data collection and inventory efforts.

5. DEVELOPMENT OF THE PLATFORM EMISSION INVENTORY

5.1 INTRODUCTION

The goal of this study is to develop criteria pollutant and greenhouse gas emission inventories for all oil and gas production-related sources in the GOM OCS. To achieve this goal, BOEM revised the 2008 Gulfwide Oracle® DBMS to create the 2011 Gulfwide Oracle® DBMS. The 2011 Gulfwide DBMS imports the activity data provided by platform operators, and applies emission factors and emission estimation algorithms to calculate emissions from platform sources in the GOM. The database calculates emissions of CO, SO_2, NO_x, PM_{10}, $PM_{2.5}$, VOC, CO_2, CH_4, and N_2O, which contribute to regional haze, ozone, or greenhouse gas effects.

The BOEM provided surrogates for values such as fuel sulfur content, fuel heating value, fuel density, and control efficiency. These surrogate values are based on industry averages and/or BOEM recommended values. For example, the diesel fuel sulfur content is consistent with BOEM "Spreadsheet for Exploration Plans."

Natural gas hydrogen sulfide (H_2S) content	= 3.38 ppmv
Diesel fuel sulfur content	= 0.4 wt%
Natural gas heating value	= 1050 Btu/scf
Diesel fuel heating value	= 19,300 Btu/lb
Diesel fuel density	= 7.1 lb/gal
Gasoline fuel heating value	= 20,300 Btu/lb
Gasoline density	= 6.17 lb/gal
Flare efficiency for H_2S	= 95%
Vapor recovery/condensor (VR/C) efficiency for total hydrocarbons (THC) and VOCs	= 80%
Sulfur recovery (SR) + VR/C efficiency for THC and VOCs	= 80%
SR efficiency for THC and VOCs	= 0%

5.2 EMISSION ESTIMATION PROCEDURES

For the most part, the emission estimation procedures presented in this section are unchanged from those in the 2008 Gulfwide DBMS (Wilson et al. 2010), as the emission estimation methods for platform sources have not been revised by USEPA or other sources. The exceptions are losses from flashing and cold vents, where adjustments were made to the emission estimation equations. USEPA emission factors were updated for several equipment types. The following sections present the methods used to calculate criteria pollutant and greenhouse gas emissions from platform sources in the study.

5.2.1 Amine Units

Some platforms produce natural gas containing unacceptable amounts of hydrogen sulfide. While most platform operators pipe the sour gas onshore for sulfur removal, a few remove the sulfur on the platform using the amine process. Various amine solutions are used to absorb H_2S. After the H_2S has been separated out, it is vented, flared, incinerated, or used for feedstock in elemental sulfur production (Systems Applications International et al. 1995).

Activity data were submitted for five amine units. Operators were required to use the "Model Inputs" tab. CH_4 and VOC emissions are estimated externally using AMINECalc (API 1999), and loaded directly into the DBMS. Emissions are adjusted for any control devices that were reported, such as a combustion flare, a vapor recovery system/condenser, or a sulfur recovery unit, and other user-specified control devices. Controlled emissions of VOC are calculated as follows:

$$E_{c,control} = E_{c,unc} \times \sum \frac{100 - Eff_{c,d}}{100\%}$$

where:

$E_{c,control}$ = Controlled VOC emissions (pounds per month)
$E_{c,unc}$ = Uncontrolled VOC emissions (pounds per month)
$Eff_{c,d}$ = Control efficiency of control device d for VOCs (%)

Devices that are intended to control H_2S emissions, such as sulfur recovery units or combustion flares, will produce emissions of SO_2 as a by-product. If a combustion flare is present, SO_2 emissions are calculated as follows (EIIP 1999; Wilson et al. 2007).

$$E_{SO_2,control} = E_{H2S}\left(\frac{lb \cdot mol_{H_2S}}{34\,lb_{H_2S}}\right) \times \left(\frac{64\,lb_{SO_2}}{lb \cdot mol_{SO_2}}\right) \times \left(\frac{Eff_{SO_2}}{100}\right)$$

where:

$E_{SO_2, control}$ = Resulting SO_2 emissions (pounds per month)
E_{H_2S} = Uncontrolled emissions of H_2S (pounds per month)
Eff_{SO_2} = Flare efficiency (%)

If a sulfur recovery unit is present, SO_2 emissions are calculated as follows (EIIP 1999, Billings and Wilson 2004):

$$E_{SO_2,control} = E_{H_2S}\left(\frac{lb \cdot mol_{H_2S}}{34\,lb_{H_2S}}\right) \times \left(\frac{64\,lb_{SO_2}}{lb \cdot mol_{SO_2}}\right) \times \left(\frac{Eff_{SO_2}}{100}\right) \times \left(\frac{1\,lb \cdot mol_{SO_2}}{3\,lb \cdot mol_{S}}\right) \times \left(1 - \frac{\%\,RE}{100}\right)$$

where:

$E_{SO_2, control}$ = Resulting SO_2 emissions (pounds per month)
E_{H_2S} = Uncontrolled emissions of H_2S (pounds per month)
% RE = Recovery efficiency of the sulfur recovery unit (%)

5.2.2 Boilers/Heaters/Burners

Boilers, heaters, and burners provide process heat and steam for many processes such as electricity generation, glycol dehydrator reboilers, and amine reboiler units (EIIP 1999). Activity data were submitted for 583 boilers, heaters, or burners. To calculate uncontrolled emissions for liquid-fueled engines (waste oil or diesel) based on fuel use, $E_{fu,liq}$:

$$E_{fu,\,liq} = EF_{(lb/10^3\ gal)} \times 10^{-3} \times U_{liq} \div 7.1\,lb/gal$$

To calculate uncontrolled emissions for gas-fueled engines (natural gas, process gas, or waste gas) based on fuel use, $E_{fu,gas}$:

$$E_{fu,gas} = EF_{(lb/MMscf)} \times 10^{-3} \times U_{gas}$$

where:

E = Emissions in pounds per month
EF = Emission factor
U_{liq} = Fuel usage (pounds/month)
U_{gas} = Fuel usage (Mscf/month)

If fuel usage is not provided, it is calculated based on hours operated, max rated or average heat input, and fuel heating value. Fuel usage was calculated for 408 of the active units.

The following emission factors are used to estimate emissions (Tables 5-1 through 5-6). These factors come from *AP-42*, Sections 1.3 and 1.4 (USEPA 2010). All boilers are assumed to be wall-fired boilers (no tangential-fired boilers). Emission factors for No. 6 residual oil were used to estimate emissions from waste-oil-fueled units.

Table 5-1. Emission factors for liquid-fueled units – diesel where max rated heat input ≥ 100 MMBtu/hr

	Emission Factors (lb/10³ gal)		
Pollutant	**Uncontrolled**	**Low NO_x Burner**	**Flue Gas Recirculation**
VOC	0.2	0.2	0.2
SO_2[a]	142 × S	142 × S	142 × S
NO_x	24	10	10
$PM_{2.5}$	0.25	0.25	0.25
PM_{10}	1	1	1
CO	5	5	5
N_2O	0.26	0.26	0.26

	Emission Factors ($lb/10^3$ gal)		
Pollutant	**Uncontrolled**	**Low NO_x Burner**	**Flue Gas Recirculation**
CH_4	0.052	0.052	0.052
CO_2	22,300	22,300	22,300

[a] S = Fuel sulfur content (wt%)

Table 5-2. Emission factors for liquid-fueled units – diesel where max rated heat input < 100 MMBtu/hr

	Emission Factors ($lb/10^3$ gal)		
Pollutant	**Uncontrolled**	**Low NO_x Burner**	**Flue Gas Recirculation**
VOC	0.2	0.2	0.2
SO_2[a]	142 × S	142 × S	142 × S
NO_x	20	20	20
$PM_{2.5}$	0.25	0.25	0.25
PM_{10}	2	2	2
CO	5	5	5
N_2O	0.26	0.26	0.26
CH_4	0.052	0.052	0.052
CO_2	22,300	22,300	22,300

[a] S = Fuel sulfur content (wt %)

Table 5-3. Emission factors for liquid-fueled units – waste oil where max rated heat input ≥ 100 MMBtu/hr

	Emission Factors ($lb/10^3$ gal)		
Pollutant	**Uncontrolled**	**Low NO_x Burner**	**Flue Gas Recirculation**
VOC	0.28	0.28	0.28
SO_2[a]	157 × S	157 × S	157 × S
NO_x	47	40	40
$PM_{2.5}$	5.23 × S + 1.73	5.23 × S + 1.73	5.23 × S + 1.73
PM_{10}	9.19 × S + 3.22	9.19 × S + 3.22	9.19 × S + 3.22
CO	5	5	5
N_2O	0.53	0.53	0.53
CH_4	1.00	1.00	1.00
CO_2	24,400	24,400	24,400

[a] S = Fuel sulfur content (wt%)

Table 5-4. Emission factors for liquid-fueled units – waste oil where max rated heat input < 100 MMBtu/hr

	Emission Factors (lb/10^3 gal)		
Pollutant	**Uncontrolled**	**Low NO_x Burner**	**Flue Gas Recirculation**
VOC	0.28	0.28	0.28
SO_2[a]	157 × S	157 × S	157 × S
NO_x	55	55	55
$PM_{2.5}$	5.23 × S + 1.73	5.23 × S + 1.73	5.23 × S + 1.73
PM_{10}	9.19 × S + 3.22	9.19 × S + 3.22	9.19 × S + 3.22
CO	5	5	5
N_2O	0.53	0.53	0.53
CH_4	1.00	1.00	1.00
CO_2	24,400	24,400	24,400

[a] S = Fuel sulfur content (wt%)

Table 5-5. Emission factors for gas-fueled units – natural gas or process gas where max rated heat input ≥ 100 MMBtu/hr

	Emission Factors (lb/MMscf)		
Pollutant	**Uncontrolled**	**Low NO_x Burner**	**Flue Gas Recirculation**
VOC	5.5	5.5	5.5
SO_2	0.6	0.6	0.6
NO_x	280	140	100
PM_{10}[a]	1.9	1.9	1.9
CO	84	84	84
N_2O	2.2	0.64	0.64
CH_4	2.3	2.3	2.3
CO_2	120,000	120,000	120,000

[a] Also represents $PM_{2.5}$

Table 5-6. Emission factors for gas-fueled units – natural gas or process gas where max rated heat input < 100 MMBtu/hr

Pollutant	Emission Factors (lb/MMscf) Uncontrolled	Low NO_x Burner	Flue Gas Recirculation
VOC	5.5	5.5	5.5
SO_2	0.6	0.6	0.6
NO_x	100	50	32
PM_{10}[a]	1.9	1.9	1.9
CO	84	84	84
N_2O	2.2	0.64	0.64
CH_4	2.3	2.3	2.3
CO_2	120,000	120,000	120,000

[a] Also represents $PM_{2.5}$

5.2.3 Diesel and Gasoline Engines

Diesel and gasoline engines are used to run generators, pumps, compressors, and well-drilling equipment. Most of the pollutants emitted from these engines are from the exhaust. Evaporative losses are insignificant in diesel engines due to the low volatility of diesel fuels (USEPA 2010). Activity data were submitted for 2,318 engines. A user-entered value for total fuel usage, or a calculated value for total fuel usage based on operator-supplied hours of operation, average fuel usage (or a surrogate fuel consumption rate of 7,000 Btu/hp-hr), fuel heating value, and operating horsepower, is used to estimate emissions. The surrogate fuel consumption rate was only needed for four units.

To calculate uncontrolled emissions based on fuel use, E_{fu}:

$$E_{fu} = EF_{(lb/MMBtu)} \times 10^{-6} \times U \times \frac{7.1\,lb}{gal} \times H$$

where:

E = Emissions in pounds per month
EF = Emission factor (units are shown in parentheses)
U = Fuel usage (gallons/month)
H = Fuel heating value (Btu/lb)

The following emission factors are used to estimate emissions (Tables 5-7 through 5-9). These factors come from *AP-42*, Sections 3.3 and 3.4 (USEPA 2010).

Table 5-7. Emission factors for gasoline engines

Pollutant	EF_{fu} (lb/MMBtu)	EF_{po} (g/hp-hr)
VOC	3.03	9.8
SO_2	0.084	0.268
NO_x	1.63	4.99
PM_{10}[a]	0.1	0.327
CO	0.99	3.157
CO_2	154.0	489.9

[a] Also represents $PM_{2.5}$

Table 5-8. Emission factors for diesel engines where max HP < 600

Pollutant	EF_{fu} (lb/MMBtu)	EF_{po} (g/hp-hr)
VOC	0.33	1.04
SO_2	0.29	0.93
NO_x	4.41	14.1
PM_{10}[a]	0.31	1
CO	0.95	3.03
CO_2	164.0	521.6

[a] Also represents $PM_{2.5}$

Table 5-9. Emission factors for diesel engines where max HP ≥ 600

Pollutant	EF_{fu} (lb/MMBtu)	EF_{po} (g/hp-hr)
VOC	0.08	0.29
SO_2[a]	$1.01 \times S$	$3.67 \times S$
NO_x	3.2	10.9
$PM_{2.5}$[b]	0.056	0.178
PM_{10}	0.057	0.182
CO	0.85	2.5
CH_4	0.008	0.03
CO_2	165.0	526.2

[a] S = Fuel sulfur content (wt%)
[b] <3 µm

If the corresponding field is null, a surrogate fuel consumption rate of is applied.

5.2.4 Drilling Equipment

Drilling activities associated with an existing facility or from a jack-up rig adjacent to a platform are included because of their emissions associated with gasoline, diesel, and natural gas fuel usage in engines. Total emissions equal the sum of emissions due to gasoline, diesel, and natural gas fuel usage. Activity data were submitted for 39 drilling units, all of which reported only diesel fuel usage.

For gasoline fuel use, calculate uncontrolled emissions, E_{gas}, as follows (Wilson et al. 2007):

$$E_{gas} = EF_{(lb/MMBtu)} \times 10^{-6} \times U \times \frac{6.17\ lb}{gal} \times \frac{20{,}300\ Btu}{lb}$$

where:

E = Emissions in pounds per month
EF = Emission factor (units shown in parentheses)
U = Fuel usage (gallons)

For diesel fuel use, calculate uncontrolled emissions, E_{die}, as follows (Wilson et. al. 2007):

$$E_{die} = EF_{(lb/MMBtu)} \times 10^{-6} \times U \times \frac{7.1\ lb}{gal} \times \frac{19{,}300\ Btu}{lb}$$

where:

E = Emissions in pounds per month
EF = Emission factor (units shown in parentheses)
U = Fuel usage (gallons)

For natural gas fuel use, calculate uncontrolled emissions, E_{ng}, as follows:

$$E_{ng} = EF_{(lb/MMscf)} \times 10^{-3} \times U$$

where:

E = Emissions in pounds per month
EF = Emission factor (units shown in parentheses)
U = Fuel usage (Mscf)

The following emission factors are used to estimate emissions (Tables 5-10 through 5-12). These factors come from *AP-42*, Sections 3.2, 3.3 and 3.4 (USEPA 2010). Diesel engines are assumed to be ≥ 600 hp. Natural gas engines are assumed to be four-cycle and evenly distributed between lean and rich burns (by averaging).

Table 5-10. Emission factors for gasoline fuel use

Pollutant	EF_{gas} (lb/MMBtu)
VOC	3.03
SO_2	0.084
NO_x	1.63
PM_{10} [a]	0.1
CO	0.99
CO_2	154

[a] Also represents $PM_{2.5}$

Table 5-11. Emission factors for diesel fuel use

Pollutant	EF_{die} (lb/MMBtu)
VOC	0.08
SO_2 [a]	$1.01 \times S$
NO_x	3.2
$PM_{2.5}$ [b]	0.056
PM_{10}	0.057
CH_4	0.008
CO	0.85
CO_2	165

[a] S = Fuel sulfur content (wt%)
[b] <3 µm

Table 5-12. Emission factors for natural gas fuel use

Pollutant	EF_{ng} (lb/MMscf)
VOC	75.3
SO_2	0.6
NO_x	2,467.5
PM_{10} [a]	4.9
CO	2,127.3
CH_4	755
CO_2	112,200

[a] Also represents $PM_{2.5}$

5.2.5 Combustion Flares

A flare is a burning stack used to dispose of hydrocarbon vapors. Flares can be used to control emissions from storage tanks, loading operations, glycol dehydration units, vent collection system, and amine units. Flares usually operate continuously; however, some are used only for process upsets (Systems Applications International et al. 1995). As noted in Section 4.4.7 for the 2011 effort, due to the U.S. Government Accountability Office (GAO) report 11-34, the GOADS volumes vented were verified against and corrected if necessary with the ONRR OGOR data. Activity data were submitted for 144 combustion flares.

Flare emissions for THC, VOC, NO_x, PM_{10}, and CO are estimated according to the following equation:

$$E_{flare} = V_{tot} \times H \times EF_{flare} \div 1000$$

where:

E_{flare} = Emissions in pounds per month
V_{tot} = Total volume of gas flared (Mscf, including upsets)
H = Flare gas heating value (Btu/scf)
EF_{flare} = Emission factor for flares (lb/MMBtu)

SO_2 emissions are estimated using the following equation:

$$E_{flare,SO_2} = \left(\frac{Eff_F\%}{100\%}\right) \times \frac{10^{-6}}{ppm} \times \frac{m_{SO_2}}{379.4 \text{ scf/lb} \cdot \text{mol}} \times 1000 \times \left(V' \times C_{H_2S}\right)$$

where:

$E_{flare,\ SO_2}$ = Emissions in pounds per month
$Eff_F\%$ = The combustion efficiency of the flare (%)
m_{SO_2} = Molecular weight of SO_2 = 64 lb/lb·mol
V' = Volume of gas flared (Mscf)
C_{H_2S} = Concentration of H_2S in the flare gas (ppm)

If the user indicates there is a continuous flare pilot, pilot light emissions are estimated as follows:

$$E_{pilot} = P \times D \times EF_{pilot} \div 1000$$

where:

E_{pilot} = Pilot emissions in pounds per month
P = Pilot feed rate (Mscf/day)
D = Number of days in month
EF_{pilot} = Emission factor for pilot (lb/MMscf)

The following emission factors are used to estimate emissions (Tables 5-13 and 5-14). The CO, NO_x, and THC emission factors come from *AP-42*, Sections 13.5 and 1.4 (USEPA 2010). The VOC and CH_4 emission factors are derived from the default sales gas composition shown in Table 5-25 of this report based on the weight fraction of the volatile components.

Table 5-13. Emission factors for combustion flares[a]

Pollutant	EF (lb/MMBtu)
VOC	0.006
NO_x	0.068
PM_{10}[b]	0; where flare smoke = none
	0.002; where flare smoke = light
	0.01; where flare smoke = medium
	0.02; where flare smoke = heavy
CO	0.37
N_2O	0.002
CH_4	0.126
CO_2	114.285

[a] Factors for N_2O and CO_2 were derived from pilot emission factors

[b] Also represents $PM_{2.5}$

Table 5-14. Emission factors for pilots

Pollutant	EF (lb/MMscf)
VOC	5.5
NO_x	100
PM_{10}[a]	1.9
SO_2	0.6
CO	84
N_2O	2.2
CH_4	2.3
CO_2	120,000

[a] Also represents $PM_{2.5}$

If the corresponding fields are null, the following surrogate values (based on industry defaults) are applied:

Flare $Smoke_{default}$ = None
Pilot Fuel Feed Rate = 2.28 Mscf/day

27 flares were assigned none as the surrogate for flare smoke, and 33 flares were assigned the surrogate pilot fuel feed rate. The emission factors shown in Table 5-13 are assumed to be based on flares operating under stable conditions, with a combustion efficiency of approximately 98%. Based on a comment by a Science Review Board member for the *Year 2005 Gulfwide Emission Inventory Study* (Wilson et al. 2007) that platforms may not all be operating under stable conditions, however, the BOEM reviewed the flare velocities to insure that all were less than 400 fps, reflective of stable conditions (TCEQ 2000). In 2011, five flares had reported exit gas velocities greater than 400 fps; thus the emission factors for VOC and CH_4 for these sources were adjusted to reflect unstable conditions and hence combustion efficiencies of 93% were applied (TCEQ 2006).

5.2.6 Fugitives

Fugitive emissions are leaks from sealed surfaces associated with process equipment. Specific fugitive source types include equipment components such as valves, flanges, and connectors (EIIP 1999). Operators were required to delineate the stream type (gas, heavy oil, light oil, or water/oil) and average VOC weight percent of fugitives, and provide an equipment inventory (number of components). Fugitive records were submitted for 92% of the active platforms.

Fugitive THC emissions are estimated according to the following equation:

$$E_{THC} = \sum_{comp}\left(EF_{comp,stream} \times N_{comp}\right) \times D$$

where:

E_{THC}	=	THC emissions in pounds per month
$EF_{comp,stream}$	=	Emission factor unique to the type of component and process stream (lb/component-day) (Table 5-15)
N_{comp}	=	Count of components of a given type present on the facility. (Note: Null values are treated as zero.)
D	=	Number of days in month

Fugitive VOC emissions are estimated according to the following equation:

$$E_{VOC} = E_{THC} \times WtFrVOC_{comp,\ stream}$$

where:

E_{VOC}	=	VOC emissions in pounds per month
E_{THC}	=	THC emissions in pounds per month
$WtFrVOC_{comp,stream}$	=	Weight fraction of VOC unique to the process stream

Fugitive CH_4 emissions are estimated according to the following equation:

$$E_{CH4} = E_{THC} \times WtFrCH_{4\,comp,\ stream}$$

where:

E_{CH4}	=	CH_4 emissions in pounds per month
E_{THC}	=	THC emissions in pounds per month
$WtFrCH_{4comp,stream}$	=	Weight fraction of CH_4 unique to the process stream

Table 5-15. THC emission factors for oil and gas production operations (lb/component-day)[a]

Component	Gas	Natural Gas Liquid	Heavy Oil (<20 API Gravity)	Light Oil (≥ 20 API Gravity)	Water/Oil	Oil/Water/ Gas[c]
Connector	1.1E-02	1.1E-02	4.0E-04	1.1E-02	5.8E-03	1.1E-02
Flange	2.1E-02	5.8E-03	2.1E-05	5.8E-03	1.5E-04	2.1E-02
Open-end	1.1E-01	7.4E-02	7.4E-02	7.4E-02	1.3E-02	1.1E-01
Other[b]	4.7E-01	4.0E-01	1.7E-03	4.0E-01	7.4E-01	7.4E-01
Pump	1.3E-01	6.9E-01	6.9E-01	6.9E-01	1.3E-03	1.3E-01
Valve	2.4E-01	1.3E-01	4.4E-04	1.3E-01	5.2E-03	2.4E-01

[a] Source: API 1996
[b] Includes compressor seals, diaphragms, drains, dump arms, hatches, instruments, meters, pressure relief valves, polished rods, and vents
[c] Assumed to be equal to either gas or water/oil, whichever is greater

If a component count is not provided, the following surrogate component counts are used (derived from API 1993, average number of offshore platform components, and percentage of total components by type):

Connectors: 9,194
Valves: 1,713
Open-Ends: 285
Others: 228

These surrogates were only applied to 27 platforms. If stream type is not provided, emissions are calculated assuming the stream type is light oil. The default values in Table 5-16 are assigned if the average VOC weight percent field is blank.

Table 5-16. Default speciation weight fractions for THC emissions by stream type[a]

THC Fraction	Gas	Natural Gas Liquid	Light Oil (≥ 20 API Gravity)	Heavy Oil (<20 API Gravity)	Water/Oil[b]	Oil/Water/ Gas
CH_4	0.8816	0.612	0.612	0.942	0.612	0.612
VOC	0.0396	0.296	0.296	0.030	0.296	0.296

[a] Source: API 1996 for all stream types except gas. Emission factors for gas streams derived from default sales gas composition.
[b] Water/oil refers to water streams in oil service with a water content greater than 50% from the point of origin to the point where the water content reaches 99%. For water streams with a water content greater than 99%, the emission rate is considered negligible.

5.2.7 Glycol Dehydrators

Glycol dehydrators remove excess water from natural gas streams to prevent the formation of hydrates and corrosion in the pipeline (EIIP 1999). Surrogate VOC glycol dehydrator still column vent emission estimates were calculated based on regression equations from GRI-GLYCalc™ Version 4.0 (GTI 2000) computer program runs for varying combinations of wet gas pressure and wet gas temperature. Surrogate glycol dehydrator flash tank vent emissions were also calculated based on regression equations from GRI-GLYCalc™ Version 4.0 computer program runs for varying combinations of flash tank pressure and flash tank temperature. Activity data were submitted for 256 glycol dehydrators. Table 5-17 presents the surrogate gas analysis (based on industry averages) used in the runs.

The VOC emission rate in pounds per hour is directly proportional to the volume of gas dehydrated if all other variables are held constant. Thus, emission factors from the GRI-GLYCalc™ runs were developed to express VOC emissions in pounds per hour per million standard cubic feet per day gas (lbs/hr-MMscfd) processed. For still column vents, VOC emission factors were developed for over 60 combinations of wet gas pressure and temperature. The emission factors range from 0.0126 lb VOC/hr-MMscfd at a pressure of 1200 psig and temperature of 50°F, to 0.3357 lb VOC/hr-MMscfd at a pressure of 600 psig and temperature of 130°F.

For glycol dehydrator flash tanks, VOC emission factors were developed for over 120 combinations of wet gas pressure and temperature, and flash tank pressure and temperature. The lowest emission factor is 0.03457 lb VOC/hr-MMscfd at a wet gas pressure of 1100 psig and temperature of 70°F, and flash tank pressure of 100 psig and temperature of 75°F. The highest emission factor is 0.09282 lb VOC/hr-MMscfd at a wet gas pressure of 800 psig and temperature of 90°F, and flash tank pressure of 50 psig and temperature of 125°F.

The following assumptions were used to estimate emissions:

- The wet gas is saturated;
- The volume of dry gas was constant at 10 MMscfd;
- The dry gas water content is 7 lbs water per MMscf gas;
- The triethylene glycol (TEG) circulation rate is 3 gallons/lb water removed;
- A gas injection pump is used to recirculate the TEG;
- If a flash tank is present, the flash tank is vented to the atmosphere; and
- No stripping gas used.

Table 5-17. Surrogate gas analysis for GLYCalc™ runs

Component	Mole Percent (%)
Hydrogen Sulfide	0.000
Nitrogen	0.100
Carbon Dioxide	0.800
Methane	94.500
Ethane	3.330
Propane	0.750
n-Butane	0.150
Iso-Butane	0.150
N-Pentane	0.050
Iso-Pentane	0.050
Iso-Hexanes	0.077
N-Hexane	0.018
Benzene	0.004
Toluene	0.003
Ethylbenzene	0.000
Xylenes	0.001
Trimethylpentane	0.003
Heptanes	0.008
Octanes	0.006
Nonanes	0.000
Decanes +	0.000

5.2.8 Losses from Flashing

Flash gas is a natural gas that is liberated when an oil stream undergoes a pressure drop. Flash gas is associated with high, intermediate, and low pressure separators, heater treaters, surge tanks, accumulators, and fixed roof atmospheric storage tanks. Flash gas emissions are only estimated for gas that is vented to the atmosphere or burned in a flare. No emissions are associated with flash gas that is routed back into the system (e.g., sales gas). Only 339 platforms provided activity data for losses from flashing.

If a pressure drop occurs between vessels, flash gas emissions are estimated using the Vasquez-Beggs correlation equations to estimate tank vapors in standard cubic feet per barrel of oil produced. Operators were asked to report the following parameters for each part of the process:

- API gravity of stored oil;
- Operating pressure (psig) of each vessel and immediately upstream (i.e., separator, heater treater, surge tank, storage tank);
- Operating temperature (°F) of each vessel and immediately upstream;
- Actual throughput of oil for each vessel;

- Disposition of flash gas from each vessel – routed to system (e.g., sales pipeline, gas-lift), vented to atmosphere, or burned in flare; and
- Scf of flash gas per barrel (bbl) of oil throughput (optional).

Flashing losses of THC, in pounds, are calculated according to the following equation:

$$L_f = (GOR_U - GOR_V) \times \text{Throughput} \times GD$$

where:

L_f	=	Emissions in pounds per month
GOR_U	=	Gas-to-oil ratio (scf/bbl) for upstream vessel
GOR_V	=	Gas-to-oil ratio (scf/bbl) for vessel
Throughput	=	Throughput volume for each vessel (bbl/month)
GD	=	Gas density (lb/scf)

Gas-to-oil ratio, GOR:

$$GOR = C_1 \times OP^{C_2} \times CSG \times e^{\left(\frac{C_3 \times \text{API gravity}}{\text{Vessel temp} + 460}\right)}$$

where:

GOR = Gas-to-oil ratio (scf/bbl)

C_1 = Vasquez-Beggs constant = $\begin{cases} 0.0178; \text{if API gravity} > 30 \\ 0.0362; \text{otherwise} \end{cases}$

OP = Vessel operating pressure (psia)

C_2 = Vasquez-Beggs constant = $\begin{cases} 1.187; \text{if API gravity} > 30 \\ 1.0937; \text{otherwise} \end{cases}$

CSG = Corrected specific gravity of gas (see below)

C_3 = Vasquez-Beggs constant = $\begin{cases} 23.931; \text{if API gravity} > 30 \\ 25.724; \text{otherwise} \end{cases}$

Emissions of VOC, CO_2, and CH_4 are estimated using the following gas densities based on the average sales gas weight percent for OCS platforms:

$$GD_{,VOC} = 0.0018 \text{ lb/scf}$$
$$GD_{,CO_2} = 0.000928 \text{ lb/scf}$$
$$GD_{,CH_4} = 0.04 \text{ lb/scf}$$

If the corresponding field is null, a default API gravity of 37 is applied. A default tank molecular gas weight of 24.994 lbs/lb·mole is also assumed as an industry average.

The following surrogate values are used for the corrected specific gravity of gas (CSG):

API Gravity	Gas Specific Gravity (at 100 psig)
>30	0.93
<30	1.08

5.2.9 Mud Degassing

Hydrocarbon emissions from mud degassing occur when gas that has seeped into the well bore and dissolved or become entrained in the drilling mud is separated from the mud and vented to the atmosphere (EIIP 1999). Activity data were reported for 22 active mud degassing operations. To estimate mud degassing emissions, operators were asked to provide:

- Number of days that drilling operations occurred; and
- Type of drilling mud used (water-based, synthetic, oil-based).

Emissions were calculated using the equation:

$$E_{THC} = EF_{THC} \times D_{drill}$$

where:

E_{THC} = THC emissions (pounds per month)
EF_{THC} = THC emission factor (lbs/day)
D_{drill} = Number of days in the month that drilling occurred

For water-based and oil-based muds, hydrocarbon emissions are estimated using emission factors provided in the USEPA report *Atmospheric Emissions from Offshore Oil and Gas Development and Production* (USEPA 1977)*:*

Water-based muds: 881.84 lbs THC/day
Oil-based muds: 198.41 lbs THC/day
Synthetic based muds: 198.41 lbs THC day

For synthetic-based muds, no information is available on air emission rates. Synthetic-based muds are used as substitutes for oil-based muds, and may occasionally be used to replace water-based muds. Synthetic muds perform like oil-based muds, but with lower environmental impact and faster biodegradability (USEPA 2000). No information was found, however, on a possible reduction in THC emissions. Because most emissions are associated with the release of entrained hydrocarbons, and USEPA estimates no change in the amount of waste cuttings between synthetic- and oil-based muds (USEPA 2000), the oil-based mud THC emission factor is used for synthetic-based muds as well.

THC emissions are speciated based on the average sales gas weight percent for OCS platforms as:

Component	Composition by Weight (%)
Methane	88.16
VOC	3.96

CO_2 emissions are assumed to be 0.3% of the gases emitted. If the type of mud used was specified but the number of days that drilling occurred is left blank, a surrogate for number of drilling days per month, developed from the activity data submitted for all platforms, was applied.

5.2.10 Natural Gas Engines

Like diesel and gasoline engines, natural gas engines are used to run generators, pumps, compressors, and well-drilling equipment. Most of the pollutants emitted from these engines are from the exhaust (USEPA 2010). Activity data were submitted for 1,590 natural gas engines.

A user-entered value for total fuel usage, or a calculated value for total fuel usage based on operator-supplied hours of operation, average fuel usage (or a surrogate fuel consumption rate of 7,500 Btu/hp-hr), fuel heating value, and operating horsepower, is used to estimate emissions. The surrogate fuel consumption rate was only needed for 3 units.

Emissions are calculated based on fuel use as:

$$E_{fu} = EF_{(lb/MMBtu)} \times H \times U \times 10^{-3}$$

where:

E = Emissions in pounds per month
EF = Emission factor (units are shown in parentheses)
H = Fuel heating value (Btu/scf)
U = Fuel usage (Mscf/month)

Tables 5-18 through 5-21 present the emission factors used to estimate natural gas engine emissions. These factors come from *AP-42*, Section 3.2 (USEPA 2010).

Table 5-18. Emission factors for natural gas engines where engine stroke cycle = 2-cycle and engine burn type = lean

Pollutant	EF_{fu} (lb/MMBtu)	EF_{po} (g/hp-hr)
VOC	0.12	0.41
SO_2	5.88×10^{-4}	2×10^{-3}
NO_x (<90% load)	1.94	6.6
PM_{10}[a]	3.84×10^{-2}	0.13
CO (<90% load)	0.353	1.2
CH_4	1.45	4.9
CO_2	110	374.2

[a] Also represents $PM_{2.5}$

Table 5-19. Emission factors for natural gas engines where engine stroke cycle = 4-cycle and engine burn type = lean

Pollutant	EF_{fu} (lb/MMBtu)[a]	EF_{po} (g/hp-hr)
VOC	0.12	0.41
SO_2	5.88×10^{-4}	2.00×10^{-3}
NO_x (<90% load)	0.85	2.89
PM_{10}[a]	7.71×10^{-5}	2.6×10^{-4}
CO (<90% load)	0.56	1.9
CH_4	1.25	4.25
CO_2	110	374.2

[a] Also represents $PM_{2.5}$

Table 5-20. Emission factors for natural gas engines where engine stroke cycle = 4-cycle and engine burn type = rich

Pollutant	EF_{fu} (lb/MMBtu)	EF_{po} (g/hp-hr)
VOC	0.03	0.1
SO_2	5.88×10^{-4}	2.00×10^{-3}
NO_x (<90% load	2.27	7.72
PM_{10}[a]	9.5×10^{-3}	0.03
CO (<90 % load)	3.51	11.94
CH_4	0.23	0.78
CO_2	110	374.22

[a] Also represents $PM_{2.5}$

Table 5-21. Emission factors for natural gas engines where engine burn type = clean

Pollutant	EF_{fu} (lb/MMBtu)	EF_{po} (g/hp-hr)
VOC	0.12	0.41
SO_2	5.88×10^{-4}	2.00×10^{-3}
NO_x	0.59	2.00
PM_{10}[a]	7.71×10^{-5}	2.6×10^{-4}
CO	0.88	3.00
CH_4	1.25	4.25
CO_2	110	374.22

[a] Also represents $PM_{2.5}$

5.2.11 Natural Gas, Diesel, and Dual-Fuel Turbines

A turbine is an internal combustion engine that operates with rotary rather than reciprocating motion. Turbines are primarily used to power compressors rather than generate electricity (Boyer and Brodnax 1996). A turbine's operating load has a considerable effect on the resulting emission levels. With reduced loads, there are lower thermal efficiencies and more incomplete combustion (USEPA 2010). Activity data were submitted for 383 turbines. Of these, 250 reported only natural gas use, 131 reported both natural gas and diesel fuel use, and 2 reported only diesel fuel use.

A user-entered value for total fuel usage, or a calculated value for total fuel usage based on operator-supplied hours of operation, average fuel usage (or a surrogate fuel consumption rate), fuel heating value, and operating horsepower, is used to estimate emissions. A surrogate natural gas fuel consumption rate of 10,000 Btu/hp-hr is applied as needed, and a diesel fuel consumption rate of 5,954 Btu/hp-hr is applied as needed. These surrogate values were assigned for 7 natural gas turbines and 122 diesel or dual-fuel turbines.

To calculate emissions based on fuel use:

$$E_{fu} = EF_{(lb/MMBtu)} \times 10^{-3} \times H \times U$$

where:

E = Emissions in pounds per month
EF = Emission factor (units are shown in parentheses)
H = Fuel heating value (Btu/scf)
U = Fuel usage (Mscf/month)

The following emission factors are used to estimate emissions for natural gas turbines (Table 5-22). These factors come from *AP-42* Section 3.1 (USEPA 2010).

Table 5-22. Emission factors for natural gas turbines

Pollutant	EF (lb/MMBtu)[a]
VOC	2.1×10^{-3}
SO_2[a]	$0.94 \times S$
NO_x	0.32
PM_{10}[b]	1.9×10^{-3}
CO	8.2×10^{-2}
N_2O	0.003
CH_4	8.6×10^{-3}
CO_2	110

[a] S= Fuel sulfur content (wt%). If not available, EF is 3.47×10^{-3} lb/MMBtu
[b] Also represents $PM_{2.5}$

The following emission factors are used to estimate emissions for diesel turbines (Table 5-23). These factors come from *AP-42* Section 3.1 (USEPA 2010).

Table 5-23. Emission factors for diesel turbines

Pollutant	EF (lb/MMBtu)
VOC	4.1×10^{-4}
SO_2[a]	$1.01 \times S$
NO_x	0.88
PM_{10}[b]	4.3×10^{-3}
CO	3.3×10^{-3}
CO_2	157

[a] S = Fuel sulfur content (wt%)
[b] Also represents $PM_{2.5}$

5.2.12 Pneumatic Pumps

A readily-available supply of compressed natural gas is used to power gas actuated pumps. There is no combustion of the gas because the energy is derived from the gas pressure. These pumps include reciprocating pumps such as diaphragm, plunger, and piston pumps. Most gas actuated pumps vent directly to the atmosphere (Boyer and Brodnax 1996). Activity data were submitted for 2,417 pneumatic pumps on 608 platforms.

Operators were asked to provide the following information for pumps that are in natural gas service:

- Manufacturer and model;
- Amount of natural gas consumed in scf/hr (optional);
- Hours of operation in the reporting period; and
- Whether it is vented to a manifold, a flare, or the atmosphere.

CO_2, CH_4, THC, and VOC emissions (in pounds) for pneumatic pumps are developed using Equation 10.4-3, from Chapter 10, "Preferred and Alternative Methods for Estimating Air Emissions from Oil and Gas Field Production and Processing Operations" (EIIP 1999):

$$E = t \times FU \times (\text{mole weight of gas, lbs/lb-mole}) \times (1 \text{ lb-mole}/379.4 \text{ scf})$$

where:

E = Emissions in pounds per month
t = Operating time (hr/month)
FU = Fuel usage rate (scf/hr)
Mole weight of gas = Mole percent of constituent/100 × mole weight of constituent/gas MW

To determine the mole percent of each constituent (CH_4, CO_2, THC, and VOC), operators were asked to provide the sales gas composition for their structure. Table 5-24 presents the default gas composition if not provided (applied for 25 units on 5 platforms). Table 5-24 also presents the mole weight for each gas constituent.

If the fuel usage rate is not provided, an average value for each make and model is assigned based on reported manufacturer data, or an average surrogate based on the manufacturer is applied. This surrogate was applied for 1,059 units on 359 platforms.

Table 5-24. Default sales gas composition

Component	Default Mol%	Mole Weight (lb/lb-mole)
CO_2	0.80	44.010
CH_4	94.50	16.043
C_2	3.33	30.070
C_3	0.75	44.097
i-C_4	0.15	58.124
n-C_4	0.15	58.124
i-C_5	0.05	72.150
n-C_5	0.05	72.150
C_6	0.099	86.177
C_7	0.011	100.272
C_8+	0.007	114.231

Source: Developed from average sales gas weight percents for OCS platforms.

5.2.13 Pressure/Level Controllers

Devices that control both pressure and liquid levels on vessels and flow lines are used extensively in production operations. The units are designed to open or close a valve when a preset pressure or liquid level is reached. The valves are automatically actuated by bleeding compressed gas from a diaphragm or piston. The gas is vented to the atmosphere in the process. Most production facilities use natural gas to actuate the controllers. The amount of gas vented is dependent on several factors, including the manufacturer and application (Boyer and Brodnax 1996). Activity data were submitted for 1,834 pressure/level controllers on 524 platforms.

Operators were asked to provide the following information for controllers that are in natural gas service:

- Service type (pressure control vs. level control);
- Manufacturer and model;
- Amount of natural gas consumed in scf/hr (optional); and
- Hours of operation in the reporting period.

Similar to pneumatic pumps, CO_2, CH_4, THC, and VOC emissions estimates (in pounds) for pressure and level controllers are developed using the following equation (EIIP 1999):

$$E = \text{No. of units} \times t \times FU \times (\text{mole weight of gas, lbs/lb-mole}) \times (1 \text{ lb-mole}/379.4 \text{ scf})$$

where:

E = Emissions in pounds per month
t = Operating time (hr/month)
FU = Fuel usage rate (scf/hr)
Mole weight of gas = mole percent of constituent/100 × mole weight of constituent/gas MW

To determine the mole percent of each constituent (CH_4, CO_2, and VOC), operators were asked to provide the sales gas composition for their structure. Table 5-24 presents the default gas composition if not provided (applied for 20 units on 10 platforms). Table 5-24 also presents the mole weight for each gas constituent.

If the fuel usage rate is not provided, an average value for each make and model is assigned based on reported manufacturer data, or an average surrogate based on the manufacturer and service type is applied. This surrogate was applied for 1,092 units on 314 platforms.

5.2.14 Storage Tanks

VOC and THC may be lost from storage tanks as a result of flashing, working, and standing losses. This discussion only addresses working and standing losses (L_w and L_s). Flashing losses are estimated separately. Activity data were submitted for 607 storage tanks.

Standing losses result from the expulsion of vapors due to vapor expansion and contraction resulting from temperature and barometric pressure changes. Working losses result from filling and emptying operations (Boyer and Brodnax 1996). These calculations assume that all tanks are fixed roof tanks.

Standing losses of THC in pounds are calculated according to the following equation:

$$L_{s,THC} = D \times V_V \times W_V \times K_E \times K_S$$

where:

L_s = Standing losses (lbs/month)
D = Number of days in the month
V_V = Tank vapor space volume (ft^3)
W_V = Stock vapor density (lb/ft^3)
K_E = Calculated vapor space expansion factor (unitless)
K_S = Calculated vented vapor saturation factor (unitless)

Vapor space volume for a horizontal, rectangular tank is calculated as:

$$V_V = \text{Tank Shell Length} \times \text{Tank Shell Width}_1 \times H_{VO}$$

where:

V_V = Vapor space volume (ft^3)
H_{VO} = Vapor space outage (ft) = Tank Shell Height – Tank Average Liquid Height

Vapor space volume for a vertical, rectangular tank is calculated as:

$$V_V = \text{Tank Shell Width}_1 \times \text{Tank Shell Width}_2 \times H_{VO}$$

where:

V_V = Vapor space volume (ft^3)
H_{VO} = Vapor space outage (ft) = Tank Shell Height – Tank Average Liquid Height

Vapor space for a horizontal, cylindrical tank is calculated as:

$$V_v = \frac{\pi \times \text{Tank Shell Diam} \times \text{Tank Shell Length} \times H_{VO}}{4 \times 0.785}$$

where:

V_V = Vapor space volume (ft^3)
H_{VO} = Vapor space outage (ft) = 0.5 × Tank Shell Diameter

Vapor space for a vertical, cylindrical tank is calculated as:

$$V_V = \frac{\pi}{4} \times \text{Tank Shell Diam}^2 \times H_{VO}$$

where:

V_V = Vapor space volume (ft^3)
H_{VO} = Vapor space outage (ft) =

$$\begin{cases} \text{Tank Shell Hgt-Tank Avg Liquid Hgt} + \tfrac{1}{3}\text{Tank Roof Hgt}; \text{if Tank Roof Type} = \text{"cone" or "peaked"} \\ \text{Tank Shell Hgt-Tank Avg Liquid Hgt} + \text{Tank Roof Hgt}\left[\tfrac{1}{2} + \tfrac{1}{6}\left(\dfrac{\text{Tank Roof Hgt}}{\text{Tank Shell Diam}}\right)^2\right]; \text{if Tank Roof Type} = \text{"dome"} \end{cases}$$

TankShell Hgt-TankAvgLiquidHgt; if Tank Roof Type = “Flat”

Stock vapor density is calculated as:

$$W_v = (\text{Tank VOC Molecular Weight} \times P_{VA}) \div (10.731 \times T_{LA})$$

where:

W_V = Stock vapor density (lb/ft^3)
P_{VA} = True vapor pressure (psia) = $\exp[A - (B/T_{LA})]$
A = Empirical constant = 12.82 – 0.9672 × ln(ReidVP)

B = Empirical constant = 7261 – 1216 × ln(ReidVP)
T_{LA} = Daily average liquid surface temperature (°R) = 0.44 × T_{aa} + (0.56 × T_b) + (0.0079 × a × I)
T_{aa} = Daily average ambient temperature (°R) (See Table 5-25)
a = Tank paint solar absorptance (See Table 5-26)
T_b = Liquid bulk temperature (°R)
I = Daily solar insulation factor (Btu/ft^2·day) = 1437 Btu/ft^2·day

The vapor space expansion factor is calculated as:

$$K_E = (T_v/T_{LA}) + (P_v - P_b)/(P_a - P_{va})$$

where:

K_E = Vapor space expansion factor
T_v = Daily vapor temperature range (°R) = 0.72 × T_a+ 0.028 × a × I
T_{LA}= Daily average liquid surface temperature (°R)
P_v = Daily pressure range (psia) = 0.50 × B × P_{va} × $T_v/T_{LA}{}^2$
P_b = Breather vent pressure setting range (psig) = Breather vent pressure – breather vent vacuum
P_a = Atmospheric pressure (psia)
P_{va} = Vapor pressure at daily average liquid surface temperature (psia)

The vented vapor saturation factor is calculated as:

$$K_S = 1/(1 + 0.053 \times P_{VA} \times H_{VO})$$

where:

K_S = Vented vapor saturation factor
P_{VA} = Vapor pressure at daily average liquid surface temperature (psia)
H_{VO} = Vapor space outage (ft)

Working losses of THC in pounds are calculated according to the following equation:

$$L_{w,THC} = 0.0010 \times \text{Tank VOC Mol Weight} \times P_{VA} \times \text{Throughput} \times K_P \times K_N$$

where:

L_w = Working losses
P_{VA} = Vapor pressure at daily average liquid surface temperature (psia)
K_P = Working loss product factor (unitless) = 0.75
K_N = Working loss turnover factor (unitless) = $\begin{cases} 1; \text{for } N \le 36 \\ \frac{180+N}{6N}; \text{for } N > 36 \end{cases}$

N = Number of turnovers per month = $5.614 \times \text{throughput}/V_{LX}$

V_{LX} = Tank maximum liquid volume (ft^3)

Tank maximum liquid volume for a horizontal, rectangular tank is calculated as:

$$V_{LX} = \text{Tank Shell Length} \times \text{Tank Shell Width}_1 \times \text{Tank Shell Height}$$

Tank maximum liquid volume for a vertical, rectangular tank is calculated as:

$$V_{LX} = \text{Tank Shell Width}_1 \times \text{Tank Shell Width}_2 \times \text{Tank Shell Height}$$

Tank maximum liquid volume for a horizontal, cylindrical tank is calculated as:

$$V_{LX} = \frac{\pi}{4} \times \text{Tank Shell Diam}^2 \times \text{Tank Shell Length}$$

Tank maximum liquid volume for a vertical, cylindrical tank is calculated as:

$$V_{LX} = \frac{\pi}{4} \times \text{Tank Shell Diam}^2 \times \text{Tank Shell Hgt}$$

where:

V_{LX} = Tank maximum liquid volume (ft^3)

Emissions of CH_4 and VOC are estimated using the following speciation profiles (USEPA 2008): 0.467 for VOC, and 0.463 for CH_4.

The following surrogates are assigned or estimated if the corresponding fields are null:

Product type = Crude Oil
Paint Color = Grey
Condition = Good
Roof type = Fixed
Roof Shape = Cone
API Gravity$_{default}$ = 37
Reid VP$_{default}$ = –1.699 + 0.179 × API Gravity (or 5, if no other information is available)
$T_{b,default} = T_{aa} + 6 \times a - 1$ (or 530º R, if no other information is available)
Breather Vent Pressure$_{default}$ = 0.03
Breather Vent Vacuum$_{default}$ = –0.03
Tank Bulk LiqT$_{default}$ = T_{aa}
Tank VOC Mol Weight$_{default}$ = 50
Mole Fraction$_{default}$ = 0.9
Tank Avg Liquid Hgt$_{default}$ = 0.5 × Tank Shell Hgt

Table 5-25. Daily average ambient temperature, T_{aa}

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
°F	53	55	66	73	76	83	83	86	80	72	65	58
°R	513	515	526	533	536	543	543	546	540	532	525	518

Source: USDOC, National Climatic Data Center 2011

Table 5-26. Tank paint solar absorptance, a

Paint Color	Solar Absorptance by Paint Color and Condition	
	Paint Condition	
	Good	Poor
Aluminum/Specular	0.39	0.49
Aluminum/Diffuse	0.6	0.68
Grey/Light	0.54	0.63
Grey/Medium	0.68	0.74
Red/Primer	0.89	0.91
White	0.17	0.34

5.2.15 Cold Vents

Production facilities often discharge natural gas to the atmosphere via vents. The discharges can be due to routine or emergency releases. Vents receive exhaust streams from miscellaneous sources, as well as manifold exhaust streams from other equipment on the same platform such as amine units, glycol dehydrators, loading operations, and storage tanks. Emissions from vents are calculated based on the volume of gas vented from miscellaneous equipment (less the volume from the manifold equipment, which are reported with the other equipment), including periods of upset venting in the total, and the chemical composition of the gas. As noted in Section 4.4.7, for the 2011 effort, due to the GAO report 11-34, the GOADS volumes vented were verified against and corrected if necessary with the ONRR OGOR data. Activity data were submitted for 1,169 cold vents.

Vent emissions of VOC are estimated using the following equation:

$$E_{\text{vent, VOC}} = C_{\text{VOC}} \times \frac{10^{-6}}{\text{ppm}} \times \frac{m_{\text{VOC}}}{379.4\ \text{scf/lb}\cdot\text{mol}} \times 1000 \times (V)$$

where:

$E_{\text{vent, VOC}}$ = VOC emissions in pounds per month
C_{VOC} = Concentration of VOC in the vent gas (default = 12,700 ppmv)
m_{VOC} = Molecular weight of VOC (lb/lb·mol)
V = Volume of gas vented from miscellaneous sources (Mscf)

Vent emissions of CH_4 are estimated using the following equation:

$$E_{vent, CH_4} = W_{CH4} \times \frac{\text{sales gas mole weight (lbs/lb} \cdot \text{mol)}}{379.4 \text{ scf/lb} \cdot \text{mol}} \times 1000 \times (V)$$

where:

E_{vent, CH_4} = CH_4 emissions in pounds
W_{CH_4} = Weight percent CH_4 (default = 88.165592)
V = Volume of gas vented from miscellaneous sources (Mscf)

Vent emissions of CO_2 are estimated using the following equation:

$$E_{vent, CO_2} = W_{CO2} \times \frac{\text{sales gas mole weight (lbs/lb} \cdot \text{mol)}}{379.4 \text{ scf/lb} \cdot \text{mol}} \times 1000 \times (V)$$

where:

E_{vent, CO_2} = CO_2 emissions in pounds
W_{CO_2} = Weight percent CO_2 (default = 2.04796139)
V = Volume of gas vented from miscellaneous sources (Mscf)

5.2.16 Minor Sources

To prepare a “complete” inventory of OCS oil and natural gas platforms and other sources in the GOM, BOEM requested that operators compiling the GOADS-2011 activity data files also identify minor sources, such as caissons, wellhead protectors, and living quarters, and provide information for the Structure and Complex ID, Area, Block, Lease No., and locational coordinates, so that BOEM can assign surrogate emission estimates for these sources. In this way, platform operators do not need to expend resources providing detailed information needed to develop emission estimates, yet with BOEM-supplied surrogates these sources can still be included in the inventory. GOADS-2011 records were submitted for 1,366 minor sources. For caissons and wellhead protectors, these estimates were developed based on average emissions from a single gas well plus average emissions from a single oil well. For minor sources that operators flagged as “Other,” the estimates are also based on the same surrogates as the caissons and wellhead protectors, as most were commented to be “fugitive sources only.” Emissions for living quarters were determined to be too minor to include in the inventory. If a platform was flagged as a minor source, and equipment records were not populated, the Technical Information Management System (TIMS) database was reviewed to confirm the platform type. If TIMS also identified the platform as a minor source, the surrogate emission estimates were used. Otherwise, emissions were calculated using the activity data provided. Emissions were estimated based on populated equipment records for 6 caissons, 1 wellhead protector, and 32 minor sources flagged as “Other.”

The following surrogate emission estimates were assigned:

Caissons and wellhead protectors: VOC: 0.141 tons/yr, CH_4: 0.425 tons/yr

Other minor sources: VOC: 7.034 tons/yr, CH_4: 2.536 tons/yr

5.2.17 PM Augmentation

The PM emission factors presented in this section are specifically for PM_{10} filterable (PM_{10}-FIL) and $PM_{2.5}$ filterable ($PM_{2.5}$-FIL). In order to incorporate the data into the USEPA National Emissions Inventory (NEI), emission estimates for three additional PM species must be included: PM condensable (PM-CON), PM_{10} primary (PM_{10}-PRI), and $PM_{2.5}$ primary ($PM_{2.5}$-PRI). The relationships between these PM species are:

$$PM_{10}\text{-PRI} = PM_{10}\text{-FIL} + \text{PM-CON; and}$$

$$PM_{2.5}\text{-PRI} = PM_{2.5}\text{-FIL} + \text{PM-CON.}$$

Thus, PM_{10}-PRI is always greater than or equal to PM_{10}-FIL, and $PM_{2.5}$-PRI is always greater than or equal to $PM_{2.5}$-FIL. In addition, PM_{10}-PRI is always equal to or greater than $PM_{2.5}$-PRI.

Emission estimates for the additional PM species were generated using the USEPA PM-Calculator to apply ratios between PM_{10}-FIL and PM-CON (USEPA 2003). Adjustments were made to the PM-CON emission estimates for natural gas combustion. According to information published by the USEPA (2005), the AP-42 emission factors (used in PM-Calculator) for condensable emissions from natural gas combustion are too high.

The following example calculations illustrate how PM_{10}-PRI, PM-CON, and $PM_{2.5}$-PRI were estimated based on the PM_{10}-FIL estimate for a combustion source:

$$E_{\text{PM-CON}} = E_{PM_{10}\text{-FIL}} \times \text{adj factor}_{\text{PM-CON}}$$

$$E_{PM_{10}\text{-PRI}} = E_{\text{PM-CON}} + E_{PM_{10}\text{-FIL}}$$

$$E_{PM_{2.5}\text{-PRI}} = E_{\text{PM-CON}} + E_{PM_{2.5}\text{-FIL}}$$

where:

$E_{\text{PM-CON}}$	=	PM-condensable emissions (tons/yr)
$E_{PM_{10}\text{-FIL}}$	=	PM_{10}-filterable emissions (tons/yr)
adj $\text{factor}_{\text{PM-CON}}$	=	PM multiplier to calculate PM-CON from PM_{10}-filterable
$E_{PM_{10}\text{-PRI}}$	=	PM_{10}-primary emissions (tons/yr)
$E_{PM_{2.5}\text{-FIL}}$	=	$PM_{2.5}$-filterable emissions (tons/yr)
$E_{PM_{2.5}\text{-PRI}}$	=	$PM_{2.5}$-primary emissions (tons/yr)

For a given month, augmented PM emissions from a diesel engine are therefore calculated as:

$$
\begin{aligned}
E_{PM\text{-}CON} &= 2.468 \text{ tons } (PM_{10}\text{-FIL}) \times 0.0232 \text{ (adj factor}_{PM\text{-}CON}) \\
&= 0.057 \text{ tons} \\
E_{PM_{10}\text{-}PRI} &= 0.057 \text{ tons (PM-CON)} + 2.468 \text{ tons } (PM_{10}\text{-FIL}) \\
&= 2.525 \text{ tons} \\
E_{PM_{2.5}\text{-}PRI} &= 0.057 \text{ tons (PM-CON)} + 2.425 \text{ tons } (PM_{2.5}\text{-FIL}) \\
&= 2.482 \text{ tons}
\end{aligned}
$$

6. DEVELOPMENT OF THE NON-PLATFORM EMISSIONS INVENTORY

Emission estimates were developed for criteria air pollutants and greenhouse gases for non-platform OCS sources operating in federal waters of the central and western areas of the GOM (i.e., east of latitude 87.5°) for the 2011 calendar year. The non-platform sources included in this study are noted below.

Non-platform oil/gas production sources:

- Drilling rigs
- Pipelaying operations
- Support helicopters
- Support vessels
- Survey vessels

Non-platform non-oil/gas production sources:

- Biogenic and geogenic sources
- Commercial fishing vessels
- Commercial marine vessels (including lightering services)
- Louisiana Offshore Oil Platform (LOOP)
- Military vessels (Coast Guard/Navy)
- Recreational vessels

BOEM developed the Gulfwide non-platform emission estimates primarily based on work previously performed in the *Year 2008 Gulfwide Emission Inventory Study* (Wilson et al. 2010). The 2011 inventory is based on updated activity data to accurately represent operations in the GOM. Drilling rig data for 2011 were obtained from BOEM and matched to vessel characteristics data in RigZone. Propulsion operations for self-propelled drill ships and semisubmersibles were accurately estimated in the 2011 inventory for individual rigs based on the departure and arrival times reported by BOEM. Similarly, BOEM pipelaying data for 2011 were downloaded and used in this inventory. The National Oceanic & Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) provided new data sets of fishing activities.

Some source categories did not have activity data for 2011 such as biogenic and geogenic sources, the LOOP, and military vessels. A literature survey was implemented to identify new biogenic and geogenic emission source studies that could be used to enhance the 2011 estimates, but no recent or appropriate data were identified that would improve the accuracy of the emission estimates. BOEM did release a study of seabed anomalies in the central and western areas of the Gulf that provided insight into the locations of geogenic vents and seeps (USDOI, BOEM 2012). Though the data could not indicate when the seeps occurred it did note locations where seeps tended not to occur; this information was used to spatially apportion emissions away from blocks which did not show a history of emissions and consolidated geogenic emission estimates to locations where there is evidence that they occurred at one time.

The LOOP was contacted repeatedly for data on vessels that visit the offshore platform, but no data were provided that could improve the accuracy of previous estimates. A study was found that documented a decline of 30% in LOOP total crude imports from 2008, when the platform was operating at full capacity, to 2011 (Fielden 2012). Most of this decline is attributed to an increase in domestic production that has reduced the demand for imported oil. The 2008 LOOP activity and emissions data were reduced by 30% to more accurately represent 2011 emissions. A patrol vessel was added to the LOOP recently to address security concerns, but details concerning the patrol vessel were not publically available, therefore emissions from this vessel could not be included in the 2011 inventory.

The U.S. Coast Guard was contacted to determine if any new patrol boats or cutters had been added to their Gulf fleet or if any older vessels had been retired; there were no changes reported in their fleet composition for 2011. Similarly, military port closures were evaluated to determine if the Gulf U.S. naval fleet emission estimates should be updated to reflect changes in base operations. The Ingleside Naval base was officially closed in 2010; this base supported the Navy mine counter measures fleet. The original GOM fleet information provided by the Navy was adjusted to remove the anti-mine vessels (MCM and MSO) from the dataset.

The Federal Aviation Administration (FAA) was contacted several times to obtain updated 2011 helicopter data, but no new data were provided. Data from the Helicopter Safety Advisory Conference survey for 2011 were used in conjunction with more detailed emission factors that allowed for better differentiation between medium and heavy duty twin engine helicopters.

The biggest change to the 2011 Gulfwide inventory was the use of Automatic Identification System (AIS) data. AIS tracks vessel movements along shipping lanes within range of Very High Frequency (VHF) transmitting stations. The vessel transmitters send a signal every two seconds that documents: vessel identification codes, radio call signs, location, direction, speed, and final destination. Portvision was commissioned to compile these data for this inventory. These data were used to develop vessel traffic contours for each vessel type (e.g., tanker, containership, support vessel) that was used to spatially allocation emissions. The AIS data were compared with the U.S. Army Corps of Engineers Entrance and Clearance data for Gulf ports to assess the completeness of the commercial marine vessel fleet included in the AIS dataset. The two datasets were comparable, but the entrance and clearance data seems to be slight more complete as it included smaller vessel that didn’t trigger the AIS reporting requirements. The Entrance and Clearance data were used to quantify hours of operation by mapping the length of the route in federal waters between the ports the vessels visited, divided by their reported cruising speed. Hours of operation were applied to the vessels power rating to get kilowatt hours.

Recreational vessels involved in non-commercial fishing are a new source category for the 2011 Gulfwide inventory. Emissions for these boats was estimated by applying USEPA recreational marine emission factors to typical vessel power ratings and total hours of operation in Federal waters.

Emissions were calculated for all diesel powered vessels by applying kilowatt hours to the USEPA's latest commercial vessel emission factors for the year 2011 for all vessel propulsion engine categories (1, 2, and 3).

6.1 NON-PLATFORM OIL/GAS PRODUCTION RELATED SOURCES

Emission sources included in this group are preliminary drilling operations (exclusive of drilling associated with a platform); construction, removal or maintenance of pipelines; helicopters and vessels that provide supplies, equipment, and personnel for platforms; and survey vessels that are used to identify oil finds.

6.1.1 Marine Diesel Emission Factors

With the exception of recreational fishing and helicopters, the same set of emission factors were used for all marine diesel engines, whether they were for drilling rigs, pipeline construction, support or survey vessels, fishing boats, commercial marine vessels, or military vessels. These emission factors were obtained from the USEPA (USEPA 2010). The USEPA emission factors varied by year because the data took into account changes in the regulations, changes in the marine fuels, and changes in the marine fleet due to the addition of new vessels and the retirement of older vessels. Emission factors that were representative of 2011 were used in this study. It should be noted that the emission factors used in previous BOEM Gulfwide inventories used factors that were specific for the modes of operation. In general, most vessels in the Gulf operate in underway mode. At-sea maneuvering occurs when vessels are adjacent to the platforms; using the USEPA factors at-sea maneuvering was estimated by adjusting the load factor as noted in the equation below.

The USEPA emission factors varied depending upon the engine that the vessel uses for propulsion and fall into two groups Category 1 and 2 vessels and Category 3 vessels. These two groups have different emission standards that go into effect at different times. Most offshore oil and gas vessels are equipped with Category 1 and 2 engines which range in size from something equivalent to a bulldozer up to a locomotive. Commercial marine vessels tend to be equipped with large Category 3 engines that are similar to large utility diesel engines. For the purpose of this study it was assumed that marine distillate was used for the Category 1 and 2 vessels. The sulfur content for the Category 1 fuel was assumed to be 236 ppm and the 312 ppm for the Category 2 fuel. For Category 3 vessels, the USEPA data weighted their emission for ultra low sulfur distillate (100 ppm), low sulfur distillate (1000 ppm), and high sulfur residual (27,000 ppm). Commercial fishing vessels were assumed to all be Category 1. Vessels involved in lightering activities were assumed to be Category 3. LOOP tankers were also considered to be Category 3 vessels, while LOOP support vessels were Category 1 and LOOP generators and pumps were Category 2. Pipelying vessels, survey vessels, and tug boats were Category 2. Support vessels other than LOOP were a combination of Category 1 and Category 2. The Coast Guard buoy tenders and cutters were Category 3 and the patrol boats were Category 2.

Recreational fishing emission factors were pulled from the USEPA's nonroad model for diesel inboard and discussed in more detail in recreational fishing section. Helicopter emission factors were compiled from the Swiss Federal Office of Civil Aviation (FOCA) and are also discussed in more detail in the helicopter section.

Vessel-specific assumptions about mode of operation, fuel type, and engine speed are noted in each section. The USEPA emission factors used for this study are presented in Table 6-1. The table also shows the load factors used in this study.

Diesel marine engine emissions were calculated for all vessel categories using the following equation:

$$E = AH \times kW \times LF \times EF \times CF$$

where:

E	=	Emissions (tons)
AH	=	Annual hours per mode of operation (underway, maneuvering, hoteling) (hours)
kW	=	Average vessel kW (totaling individual propulsion engines) (kW)
LF	=	Engine load factor for specified mode of operation (%)
EF	=	Emission factor (g/kWH)
CF	=	Conversion factor (g = 1.10231 E-6 ton)

6.1.2 Drilling Rigs

Drilling vessels are used for exploratory drilling to supplement the geologic information provided by survey vessels. The drilling rig drills a hole in the ocean floor by turning a drill bit attached to lengths of tubular pipe. Several different types of drill rigs operate in the GOM, including barges, jack-ups, semisubmersibles, submersibles, and drill ships. Application of the appropriate drilling rig varies relative to the water depth where they operate. For example, barges tend to operate closer to shore and in inland waterways, jack-ups are able to work in water up to 375 feet deep, semisubmersibles and submersibles operate in water with depths of 300 to 2,000 feet, and drill ships operate in waters with depths greater than 2,000 feet.

Table 6-1. Marine vessel emission factors

Vessel Type	Mode	Load Factor	EF (g/kW-hr)									
			VOC	HC	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O
Commercial Fishing Vessels												
Longline, Reef, and Shrimp Fishing Vessels	At Sea	0.80	0.39	0.37	2.15	12.35	0.44	0.42	0.15	1044.40	0.006	0.031
	Maneuvering	0.10	0.39	0.37	2.15	12.35	0.44	0.42	0.15	1044.40	0.008	0.031
Recreational Fishing Vessels												
Recreational Fishing Vessels	At Sea	0.80	0.59	0.56	2.01	9.30	0.35	0.34	0.22	726.90	[a]	[a]
	Maneuvering	0.30	0.59	0.56	2.01	9.30	0.35	0.34	0.22	726.90	[a]	[a]
Vessel Lightering												
Oil Tankers	Maneuvering	0.10	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.012	0.031
Escort Vessels	Maneuvering	0.10	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.008	0.031
	At Sea	0.80	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.006	0.031
LOOP												
Tankers	At Sea	0.55	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.006	0.031
	Maneuvering	0.10	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.012	0.031
Support Vessels	Maneuvering	0.25	0.39	0.37	2.15	12.35	0.44	0.42	0.15	1044.40	0.008	0.031
LOOP Generator	At Sea	0.50	0.22	0.21	3.64	16.25	0.60	0.58	0.20	1044.83	0.006	0.031
LOOP Pumps	At Sea	0.10	0.22	0.21	3.64	16.25	0.60	0.58	0.20	1044.83	0.006	0.031
Pipelaying Operations												
Pipelaying Vessels	Maneuvering	0.75	0.22	0.21	3.64	16.25	0.60	0.58	0.20	1044.83	0.008	0.031
Drilling Rigs												
Drill Ship, Jack-up, Semisubmersible, Submersible, and Emergency Equipment[a]	At Sea	0.75	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.006	0.031
Drill Ship Propulsion (maintain position)	Maneuvering	0.15	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.006	0.031

Vessel Type	Mode	Load Factor	EF (g/kW-hr)									
			VOC	HC	CO	NO_x	PM_{10}	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O
Semisubmersible Propulsion (maintain position)	Maneuvering	0.15	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.006	0.031
Drilling Propulsion (relocation)	At Sea	0.75	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.006	0.031
Semisubmersible Propulsion (relocation)	At Sea	0.75	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.006	0.031
Survey Vessels												
Survey Vessels	At Sea	0.90	0.22	0.21	3.64	16.25	0.60	0.58	0.20	1044.83	0.006	0.031
Support Vessels												
Supply/crew, Lift, and Tugs/towing Vessels	At Sea	0.85	0.32	0.31	2.86	14.08	0.52	0.50	0.17	1043.11	0.006	0.031
	Maneuvering	0.10	0.32	0.31	2.86	14.08	0.52	0.50	0.17	1043.11	0.008	0.031
Coast Guard Vessels												
Buoy Tenders and Cutters	At Sea	0.85	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.006	0.031
Patrol Vessels	At Sea	0.85	0.22	0.21	3.64	16.25	0.60	0.58	0.20	1044.83	0.006	0.031
Commercial Marine Vessels												
All Except Tug Boats	At Sea	0.80	0.78	0.74	1.77	19.54	0.74	0.68	5.90	776.81	0.006	0.031
Tug Boats	At Sea	0.80	0.22	0.21	3.64	16.25	0.60	0.58	0.20	1044.83	0.006	0.031

[a] Emergency generators are assumed to operate 500 hours per year based on USEPA guidance.

The Operation and Analysis Branch of the Engineering and Operations Division of BOEM provided 2011 activity data for drilling rigs by block, which included activity for drill ships, jack-ups, platform rigs, semisubmersibles, and submersibles (Mathews 2012). The drilling rig activity data used in this study are based on the specific blocks where drilling activities took place, the drilling rig name, and the time drilling commenced and concluded. These data were extracted for the period from January 2011 through December 2011, as noted in Table 6-2.

Table 6-2. Drilling vessel activity data

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
PF	GB	426	AUGER	1/1/2011	1/13/2011	12
PF	GB	426	AUGER	4/20/2011	4/28/2011	8
PF	GB	426	AUGER	7/16/2011	8/9/2011	24
PF	GB	426	AUGER	12/4/2011	12/30/2011	26
PF	ST	316	BLAKE 1006	8/10/2011	9/27/2011	48
PF	ST	316	BLAKE 1006	9/27/2011	12/31/2011	95
PF	GC	608	BLAKE 1007	12/26/2011	12/31/2011	5
PF	EI	175	BLAKE 14	1/1/2011	1/29/2011	28
PF	EI	189	BLAKE 14	1/29/2011	3/20/2011	50
PF	EI	189	BLAKE 14	3/20/2011	4/9/2011	20
PF	MP	296	BLAKE 14	4/10/2011	4/16/2011	6
PF	MP	296	BLAKE 14	4/16/2011	4/21/2011	5
PF	SP	62	BLAKE 14	4/22/2011	5/12/2011	20
PF	SP	62	BLAKE 14	5/12/2011	6/8/2011	27
PF	SP	62	BLAKE 14	6/8/2011	6/17/2011	9
PF	SP	62	BLAKE 14	6/17/2011	7/16/2011	29
PF	SP	62	BLAKE 14	7/16/2011	8/13/2011	28
PF	SP	70	BLAKE 14	8/14/2011	8/21/2011	7
PF	SP	70	BLAKE 14	8/21/2011	8/31/2011	10
PF	SP	70	BLAKE 14	8/31/2011	9/16/2011	16
PF	WD	71	BLAKE 14	9/23/2011	10/30/2011	37
PF	VR	265	BLAKE 14	10/31/2011	12/10/2011	40
PF	EC	270	BLAKE 14	12/11/2011	12/31/2011	20
PF	MP	308	BLAKE 1505	9/29/2011	12/31/2011	93
PF	SS	216	BLAKE 210	1/1/2011	1/13/2011	12
PF	EC	278	BLAKE 210	5/10/2011	5/31/2011	21
PF	EC	278	BLAKE 210	5/31/2011	7/18/2011	48
PF	MP	153	BLAKE 210	7/20/2011	9/6/2011	48
PF	ST	206	BLAKE 210	9/14/2011	10/13/2011	29
PF	ST	295	BLAKE 210	10/13/2011	12/31/2011	79
SD	GC	178	CAL DIVE Q-4000	1/1/2011	1/9/2011	8
SD	EW	949	CAL DIVE Q-4000	1/9/2011	1/27/2011	18
SD	EW	977	CAL DIVE Q-4000	1/27/2011	2/13/2011	17
SD	GC	244	CAL DIVE Q-4000	2/13/2011	2/13/2011	0
SD	GC	244	CAL DIVE Q-4000	2/13/2011	3/16/2011	31
SD	GC	200	CAL DIVE Q-4000	3/16/2011	3/16/2011	0

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
SD	GC	200	CAL DIVE Q-4000	3/16/2011	3/25/2011	9
SD	GC	200	CAL DIVE Q-4000	3/25/2011	4/13/2011	19
SD	GC	200	CAL DIVE Q-4000	4/13/2011	4/19/2011	6
SD	GC	200	CAL DIVE Q-4000	4/19/2011	4/24/2011	5
SD	GB	516	CAL DIVE Q-4000	5/1/2011	5/16/2011	15
SD	GB	516	CAL DIVE Q-4000	5/16/2011	5/25/2011	9
SD	GB	516	CAL DIVE Q-4000	5/25/2011	5/27/2011	2
SD	GB	516	CAL DIVE Q-4000	5/27/2011	5/30/2011	3
SD	GB	516	CAL DIVE Q-4000	5/30/2011	6/1/2011	2
SD	GB	516	CAL DIVE Q-4000	6/1/2011	6/3/2011	2
SD	GB	385	CAL DIVE Q-4000	6/3/2011	6/12/2011	9
SD	MC	809	CAL DIVE Q-4000	6/13/2011	6/26/2011	13
SD	MC	810	CAL DIVE Q-4000	6/26/2011	7/7/2011	11
SD	GB	385	CAL DIVE Q-4000	7/9/2011	7/14/2011	5
SD	MC	66	CAL DIVE Q-4000	7/16/2011	8/3/2011	18
SD	EB	646	CAL DIVE Q-4000	8/5/2011	8/13/2011	8
SD	EB	646	CAL DIVE Q-4000	8/15/2011	9/8/2011	24
SD	EB	642	CAL DIVE Q-4000	9/9/2011	9/24/2011	15
SD	EB	558	CAL DIVE Q-4000	9/24/2011	10/16/2011	22
SD	GB	877	CAL DIVE Q-4000	10/17/2011	11/6/2011	20
SD	GC	379	CAL DIVE Q-4000	11/7/2011	11/11/2011	4
SD	GC	518	CAL DIVE Q-4000	11/11/2011	12/24/2011	43
SD	VK	826	CAL DIVE Q-4000	12/22/2011	12/30/2011	8
SD	MC	810	CAL DIVE Q-4000	12/26/2011	12/31/2011	5
SS	EI	339	CAL DIVE UNCLE JOHN	1/1/2011	1/10/2011	9
SS	EC	272	CAL DIVE UNCLE JOHN	3/24/2011	3/24/2011	0
SS	EI	339	CAL DIVE UNCLE JOHN	4/8/2011	4/19/2011	11
SS	EI	339	CAL DIVE UNCLE JOHN	4/20/2011	7/1/2011	72
SS	EC	272	CAL DIVE UNCLE JOHN	7/15/2011	9/6/2011	53
SS	EC	272	CAL DIVE UNCLE JOHN	9/26/2011	10/28/2011	32
BR	SM	212	COASTAL RIG 22	1/1/2011	1/14/2011	13
BR	SM	217	COASTAL RIG 22	1/16/2011	7/23/2011	188
SS	GC	299	DIAMOND OCEAN AMERICA	6/20/2011	6/20/2011	0
JU	EI	51	DIAMOND OCEAN COLUMBIA	9/30/2011	12/31/2011	92
SS	GB	515	DIAMOND OCEAN MONARCH	5/7/2011	9/1/2011	117
SS	MC	20	DIAMOND OCEAN SARATOGA	1/1/2011	1/24/2011	23
SS	MC	20	DIAMOND OCEAN SARATOGA	1/24/2011	1/25/2011	1
SS	MC	20	DIAMOND OCEAN SARATOGA	1/25/2011	3/24/2011	58
SS	VK	821	DIAMOND OCEAN SARATOGA	5/11/2011	6/2/2011	22
SS	GB	302	DIAMOND OCEAN SARATOGA	6/5/2011	6/26/2011	21

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
SS	GC	50	DIAMOND OCEAN SARATOGA	6/28/2011	7/31/2011	33
SS	VK	821	DIAMOND OCEAN SARATOGA	11/14/2011	12/31/2011	47
JU	SS	290	DIAMOND OCEAN TITAN	1/1/2011	1/11/2011	10
JU	SM	73	DIAMOND OCEAN TITAN	1/11/2011	2/13/2011	33
JU	SM	73	DIAMOND OCEAN TITAN	2/13/2011	3/19/2011	34
JU	SS	229	DIAMOND OCEAN TITAN	3/19/2011	4/23/2011	35
JU	SS	290	DIAMOND OCEAN TITAN	5/2/2011	6/15/2011	44
JU	ST	264	DIAMOND OCEAN TITAN	7/22/2011	9/1/2011	41
SS	EW	948	DIAMOND OCEAN VICTORY	3/5/2011	3/22/2011	17
SS	GC	282	DIAMOND OCEAN VICTORY	4/14/2011	5/24/2011	40
SS	MC	711	DIAMOND OCEAN VICTORY	5/26/2011	6/21/2011	26
SS	GC	299	DIAMOND OCEAN VICTORY	6/21/2011	12/19/2011	181
SS	EW	834	DIAMOND OCEAN VICTORY	12/19/2011	12/31/2011	12
BR	EC	281	DIVE SUPPORT VESSEL (DSV)	3/16/2011	3/31/2011	15
BR	WC	606	DIVE SUPPORT VESSEL (DSV)	9/12/2011	9/22/2011	10
JU	MP	298	ENSCO 68	1/1/2011	1/1/2011	0
JU	MP	298	ENSCO 68	1/1/2011	1/31/2011	30
JU	MP	298	ENSCO 68	1/31/2011	2/12/2011	12
JU	MP	298	ENSCO 68	2/12/2011	2/20/2011	8
JU	MP	313	ENSCO 68	2/20/2011	3/2/2011	10
JU	MP	313	ENSCO 68	3/2/2011	4/24/2011	53
JU	MP	313	ENSCO 68	4/24/2011	5/14/2011	20
JU	MP	313	ENSCO 68	5/14/2011	5/31/2011	17
JU	MP	313	ENSCO 68	5/31/2011	7/12/2011	42
JU	MP	313	ENSCO 68	7/12/2011	7/30/2011	18
JU	MP	144	ENSCO 68	7/30/2011	8/18/2011	19
JU	MP	144	ENSCO 68	9/11/2011	10/9/2011	28
JU	MP	144	ENSCO 68	10/9/2011	10/17/2011	8
JU	MP	144	ENSCO 68	10/17/2011	12/31/2011	75
JU	EI	330	ENSCO 75	1/1/2011	1/2/2011	1
JU	EI	330	ENSCO 75	1/2/2011	1/16/2011	14
JU	EI	330	ENSCO 75	1/16/2011	2/2/2011	17
JU	EI	330	ENSCO 75	2/2/2011	2/13/2011	11
JU	EI	330	ENSCO 75	2/15/2011	3/11/2011	24
JU	EI	330	ENSCO 75	3/11/2011	3/31/2011	20
JU	EI	330	ENSCO 75	3/31/2011	4/10/2011	10
JU	EI	330	ENSCO 75	4/10/2011	4/11/2011	1
JU	EI	330	ENSCO 75	4/11/2011	4/22/2011	11
JU	EI	330	ENSCO 75	4/22/2011	4/29/2011	7
JU	EI	330	ENSCO 75	4/29/2011	6/8/2011	40
JU	EI	330	ENSCO 75	7/1/2011	7/9/2011	8
JU	EI	330	ENSCO 75	7/14/2011	9/25/2011	73

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
JU	EI	330	ENSCO 75	9/25/2011	10/16/2011	21
JU	EI	330	ENSCO 75	10/16/2011	11/3/2011	18
JU	EI	330	ENSCO 75	11/3/2011	11/4/2011	1
JU	EI	330	ENSCO 75	11/4/2011	12/31/2011	57
JU	HI	A 547	ENSCO 81	3/2/2011	3/23/2011	21
JU	WD	106	ENSCO 81	3/28/2011	5/7/2011	40
JU	WD	106	ENSCO 81	5/7/2011	6/14/2011	38
JU	WD	106	ENSCO 81	6/14/2011	7/22/2011	38
JU	WD	106	ENSCO 81	7/22/2011	8/2/2011	11
JU	ST	265	ENSCO 81	9/14/2011	11/12/2011	59
JU	ST	265	ENSCO 81	11/21/2011	12/31/2011	40
JU	SM	99	ENSCO 82	1/1/2011	2/20/2011	50
JU	SM	99	ENSCO 82	2/20/2011	4/3/2011	42
JU	SM	90	ENSCO 82	4/3/2011	4/26/2011	23
JU	EI	276	ENSCO 82	4/27/2011	5/7/2011	10
JU	EI	276	ENSCO 82	5/7/2011	5/9/2011	2
JU	EI	276	ENSCO 82	5/10/2011	5/11/2011	1
JU	EI	276	ENSCO 82	5/12/2011	5/13/2011	1
JU	EI	276	ENSCO 82	5/14/2011	6/6/2011	23
JU	EI	276	ENSCO 82	6/6/2011	6/15/2011	9
JU	EI	276	ENSCO 82	6/15/2011	7/25/2011	40
JU	EI	276	ENSCO 82	7/25/2011	8/5/2011	11
JU	EI	276	ENSCO 82	8/5/2011	8/21/2011	16
JU	EI	276	ENSCO 82	8/21/2011	9/29/2011	39
JU	EI	276	ENSCO 82	10/3/2011	10/15/2011	12
JU	EI	276	ENSCO 82	10/15/2011	11/11/2011	27
JU	VR	214	ENSCO 82	11/12/2011	12/31/2011	49
SD	GC	518	ENSCO 8500	1/1/2011	1/14/2011	13
SD	GC	683	ENSCO 8500	1/15/2011	3/23/2011	67
SD	KC	875	ENSCO 8500	3/23/2011	6/3/2011	72
SD	DC	620	ENSCO 8500	6/6/2011	7/25/2011	49
SD	GC	517	ENSCO 8500	7/29/2011	8/12/2011	14
SD	EB	602	ENSCO 8500	8/19/2011	12/11/2011	114
SD	EB	602	ENSCO 8500	12/11/2011	12/31/2011	20
SD	MC	519	ENSCO 8501	3/29/2011	7/26/2011	119
SD	GC	723	ENSCO 8501	7/28/2011	11/24/2011	119
SD	MC	948	ENSCO 8501	11/26/2011	12/31/2011	35
SD	EB	579	ENSCO 8502	1/1/2011	1/26/2011	25
SD	GC	504	ENSCO 8502	6/22/2011	12/31/2011	192
SD	GC	814	ENSCO 8503	12/26/2011	12/31/2011	5
JU	MI	623	ENSCO 86	1/14/2011	3/18/2011	63
JU	MI	623	ENSCO 86	3/18/2011	5/17/2011	60
JU	MI	623	ENSCO 86	5/17/2011	6/10/2011	24
JU	WC	311	ENSCO 86	6/19/2011	7/2/2011	13

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
JU	SM	281	ENSCO 86	7/2/2011	10/19/2011	109
JU	SS	126	ENSCO 86	10/21/2011	11/13/2011	23
JU	MO	830	ENSCO 86	11/18/2011	12/31/2011	43
JU	WD	71	ENSCO 87	1/1/2011	2/19/2011	49
JU	WD	70	ENSCO 87	2/19/2011	3/7/2011	16
JU	WD	122	ENSCO 87	3/10/2011	4/23/2011	44
JU	MP	315	ENSCO 87	5/14/2011	7/11/2011	58
JU	SM	66	ENSCO 87	7/14/2011	10/11/2011	89
JU	SS	189	ENSCO 87	10/12/2011	12/31/2011	80
JU	SS	219	ENSCO 90	1/27/2011	2/13/2011	17
JU	VR	267	ENSCO 90	2/14/2011	2/22/2011	8
JU	VR	267	ENSCO 90	2/22/2011	3/30/2011	36
JU	EI	208	ENSCO 90	3/31/2011	4/29/2011	29
JU	EI	208	ENSCO 90	4/29/2011	5/16/2011	17
JU	PL	25	ENSCO 90	5/16/2011	7/9/2011	54
JU	MI	668	ENSCO 90	7/13/2011	9/15/2011	64
JU	MI	668	ENSCO 90	9/15/2011	10/1/2011	16
JU	MI	669	ENSCO 90	10/1/2011	12/31/2011	91
JU	SS	93	ENSCO 99	1/1/2011	1/31/2011	30
JU	GA	209	ENSCO 99	4/1/2011	4/29/2011	28
JU	GA	209	ENSCO 99	4/29/2011	5/15/2011	16
JU	WD	29	ENSCO 99	6/3/2011	6/24/2011	21
JU	WD	29	ENSCO 99	6/24/2011	7/13/2011	19
JU	WD	29	ENSCO 99	7/13/2011	7/22/2011	9
JU	WD	29	ENSCO 99	7/22/2011	8/8/2011	17
JU	GI	22	ENSCO 99	10/6/2011	11/26/2011	51
JU	GI	23	ENSCO 99	11/26/2011	12/18/2011	22
JU	GI	23	ENSCO 99	12/18/2011	12/22/2011	4
DS	GC	654	GSF C.R. LUIGS	1/1/2011	3/12/2011	70
DS	GC	653	GSF C.R. LUIGS	3/12/2011	5/26/2011	75
DS	GC	653	GSF C.R. LUIGS	6/1/2011	10/1/2011	122
DS	GC	654	GSF C.R. LUIGS	10/1/2011	12/31/2011	91
PF	SP	87	H&P 105	1/1/2011	3/14/2011	72
PF	SP	87	H&P 105	3/14/2011	5/11/2011	58
PF	SP	87	H&P 105	5/11/2011	5/29/2011	18
PF	GI	116	H&P 105	7/12/2011	12/31/2011	172
PF	SS	349	H&P 107	8/12/2011	11/13/2011	93
PF	SS	349	H&P 107	11/13/2011	12/31/2011	48
PF	MC	807	H&P 201	1/1/2011	10/10/2011	282
PF	MC	807	H&P 201	10/11/2011	12/2/2011	52
PF	MC	807	H&P 201	12/2/2011	12/31/2011	29
PF	GC	158	H&P 202	6/24/2011	10/5/2011	103
PF	GC	158	H&P 202	10/6/2011	10/31/2011	25
PF	GC	158	H&P 202	11/28/2011	12/31/2011	33

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
PF	GC	158	H&P 202	11/28/2011	12/31/2011	33
PF	MC	809	H&P 204	1/1/2011	2/13/2011	43
PF	MC	809	H&P 204	2/13/2011	7/6/2011	143
PF	AC	857	H&P 205	1/1/2011	2/20/2011	50
PF	AC	857	H&P 205	2/24/2011	4/15/2011	50
PF	AC	857	H&P 205	4/16/2011	8/27/2011	133
PF	AC	857	H&P 205	8/28/2011	9/10/2011	13
PF	AC	857	H&P 205	10/8/2011	12/31/2011	84
PF	MC	109	H&P 206	1/1/2011	2/24/2011	54
PF	MC	109	H&P 206	2/24/2011	5/1/2011	66
PF	MC	109	H&P 206	5/1/2011	7/20/2011	80
PF	MC	109	H&P 206	7/20/2011	11/22/2011	125
JU	ST	35	HERCULES 120	1/1/2011	1/9/2011	8
JU	ST	35	HERCULES 120	1/9/2011	2/11/2011	33
JU	ST	37	HERCULES 120	2/11/2011	2/24/2011	13
JU	ST	37	HERCULES 120	7/13/2011	9/15/2011	64
JU	MP	41	HERCULES 120	9/16/2011	11/30/2011	75
JU	MP	41	HERCULES 120	11/30/2011	12/31/2011	31
JU	VR	39	HERCULES 150	2/7/2011	4/13/2011	65
JU	EI	28	HERCULES 150	8/19/2011	9/11/2011	23
JU	BM	2	HERCULES 173	3/30/2011	4/20/2011	21
JU	GI	37	HERCULES 173	8/4/2011	9/26/2011	53
JU	ST	23	HERCULES 173	10/22/2011	11/15/2011	24
JU	BM	2	HERCULES 173	12/8/2011	12/31/2011	23
JU	BM	2	HERCULES 173	12/29/2011	12/29/2011	0
JU	HI	116	HERCULES 200	1/1/2011	1/22/2011	21
JU	EC	265	HERCULES 200	1/22/2011	2/17/2011	26
JU	SM	76	HERCULES 200	2/17/2011	4/12/2011	54
JU	HI	129	HERCULES 200	5/27/2011	6/3/2011	7
JU	WC	35	HERCULES 200	6/4/2011	7/4/2011	30
JU	WC	165	HERCULES 200	7/4/2011	7/29/2011	25
JU	HI	46	HERCULES 200	7/31/2011	9/24/2011	55
JU	HI	A 155	HERCULES 200	9/24/2011	10/13/2011	19
JU	WC	110	HERCULES 200	10/21/2011	12/30/2011	70
JU	EI	243	HERCULES 201	2/24/2011	3/11/2011	15
JU	BS	55	HERCULES 201	3/14/2011	4/28/2011	45
JU	MP	42	HERCULES 201	5/16/2011	6/4/2011	19
JU	ST	52	HERCULES 201	7/23/2011	8/23/2011	31
JU	ST	52	HERCULES 201	8/23/2011	9/1/2011	9
JU	ST	52	HERCULES 201	9/2/2011	9/9/2011	7
JU	ST	52	HERCULES 201	9/9/2011	10/5/2011	26
JU	MP	98	HERCULES 202	1/1/2011	3/20/2011	78
JU	MP	108	HERCULES 202	3/20/2011	5/13/2011	54
JU	MP	108	HERCULES 202	5/13/2011	7/21/2011	69

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
JU	MP	108	HERCULES 202	7/21/2011	9/25/2011	66
JU	SS	218	HERCULES 202	10/31/2011	11/25/2011	25
JU	SS	218	HERCULES 202	11/25/2011	12/31/2011	36
JU	WD	68	HERCULES 204	1/1/2011	1/12/2011	11
JU	EI	113B	HERCULES 204	3/29/2011	4/29/2011	31
JU	SS	151	HERCULES 204	5/4/2011	7/15/2011	72
JU	SS	227	HERCULES 204	7/15/2011	9/26/2011	73
JU	SS	119	HERCULES 204	9/26/2011	9/26/2011	0
JU	SS	209	HERCULES 204	12/1/2011	12/31/2011	30
JU	MU	831	HERCULES 205	1/1/2011	1/17/2011	16
JU	MI	526	HERCULES 205	3/21/2011	4/13/2011	23
JU	BA	375	HERCULES 205	4/14/2011	6/8/2011	55
JU	HI	37	HERCULES 205	6/9/2011	7/3/2011	24
JU	MP	60	HERCULES 205	7/7/2011	12/31/2011	177
JU	HI	205	HERCULES 212	9/14/2011	10/31/2011	47
JU	EC	160	HERCULES 212	11/24/2011	12/31/2011	37
JU	SS	189	HERCULES 213	5/9/2011	8/29/2011	112
JU	SS	225	HERCULES 213	10/20/2011	10/20/2011	0
JU	SS	225	HERCULES 213	10/20/2011	10/20/2011	0
JU	SS	72	HERCULES 213	10/20/2011	11/21/2011	32
JU	SS	72	HERCULES 213	11/21/2011	12/12/2011	21
JU	SS	72	HERCULES 213	12/12/2011	12/26/2011	14
JU	SS	72	HERCULES 213	12/26/2011	12/31/2011	5
JU	EI	224	HERCULES 214	5/3/2011	7/15/2011	73
JU	MP	59	HERCULES 214	9/19/2011	10/22/2011	33
JU	MP	59	HERCULES 214	10/22/2011	12/31/2011	70
JU	EI	304	HERCULES 251	1/1/2011	1/14/2011	13
JU	HI	A 544	HERCULES 251	1/22/2011	2/5/2011	14
JU	EI	266	HERCULES 251	2/21/2011	3/18/2011	25
JU	WC	132	HERCULES 251	5/3/2011	5/12/2011	9
JU	WC	132	HERCULES 251	5/6/2011	5/12/2011	6
JU	HI	A 171	HERCULES 251	11/4/2011	12/31/2011	57
JU	GA	241	HERCULES 253	1/1/2011	2/19/2011	49
JU	VR	170	HERCULES 253	2/22/2011	4/18/2011	55
JU	VR	342	HERCULES 253	5/6/2011	6/12/2011	37
JU	GA	A 133	HERCULES 253	6/12/2011	6/26/2011	14
JU	WC	171	HERCULES 253	7/15/2011	8/15/2011	31
JU	WD	89	HERCULES 253	10/21/2011	11/19/2011	29
JU	WD	89	HERCULES 253	11/19/2011	12/13/2011	24
JU	WD	89	HERCULES 253	12/13/2011	12/31/2011	18
JU	PL	15	HERCULES 263	6/13/2011	6/29/2011	16
JU	BA	A 133	HERCULES 263	8/9/2011	9/24/2011	46
JU	WD	39	HERCULES 263	9/29/2011	10/26/2011	27
JU	PL	13	HERCULES 263	10/27/2011	12/28/2011	62

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
JU	ST	204	HERCULES 263	12/28/2011	12/31/2011	3
JU	VR	245	HERCULES 264	1/31/2011	6/16/2011	136
JU	WC	18	HERCULES 264	6/16/2011	8/12/2011	57
JU	WC	18	HERCULES 264	8/12/2011	11/1/2011	81
JU	VR	245	HERCULES 264	11/1/2011	12/31/2011	60
JU	ST	161	HERCULES 265	5/30/2011	6/17/2011	18
JU	ST	172	HERCULES 265	6/17/2011	6/17/2011	0
JU	ST	172	HERCULES 265	6/17/2011	6/17/2011	0
JU	ST	172	HERCULES 265	6/17/2011	6/17/2011	0
JU	ST	172	HERCULES 265	6/17/2011	6/17/2011	0
JU	ST	172	HERCULES 265	6/17/2011	7/5/2011	18
JU	GI	82	HERCULES 265	7/7/2011	7/22/2011	15
JU	GI	82	HERCULES 265	7/22/2011	7/22/2011	0
JU	GI	82	HERCULES 265	7/22/2011	7/27/2011	5
JU	ST	41	HERCULES 265	9/10/2011	11/19/2011	70
JU	EC	111	HERCULES 265	11/19/2011	12/31/2011	42
JU	EC	328	HERCULES 300	5/6/2011	8/6/2011	92
JU	EC	328	HERCULES 300	8/6/2011	8/14/2011	8
JU	EC	328	HERCULES 300	8/14/2011	8/22/2011	8
JU	EC	328	HERCULES 300	8/22/2011	9/8/2011	17
JU	EC	328	HERCULES 300	9/8/2011	9/11/2011	3
JU	EC	328	HERCULES 300	9/11/2011	9/22/2011	11
JU	EC	328	HERCULES 300	9/22/2011	11/21/2011	60
JU	EC	328	HERCULES 300	11/21/2011	12/22/2011	31
JU	SM	79	HERCULES 300	12/28/2011	12/31/2011	3
JU	ST	131	HERCULES 350	1/1/2011	1/3/2011	2
JU	ST	128	HERCULES 350	1/3/2011	3/13/2011	69
JU	ST	188	HERCULES 350	7/31/2011	10/2/2011	63
JU	ST	188	HERCULES 350	10/2/2011	12/17/2011	76
JU	ST	134	HERCULES 350	12/17/2011	12/31/2011	14
SD	KC	919	MAERSK DEVELOPER	3/22/2011	8/22/2011	153
SD	AC	810	MAERSK DEVELOPER	8/22/2011	10/9/2011	48
SD	LL	400	MAERSK DEVELOPER	10/14/2011	12/30/2011	77
PF	WD	73	NABORS 17	12/21/2011	12/31/2011	10
PF	MC	941	NABORS 202	3/18/2011	8/22/2011	157
PF	MC	941	NABORS 202	8/22/2011	12/31/2011	131
PF	GC	205	NABORS 85 (MAYRONNE 162)	4/2/2011	5/28/2011	56
PF	VK	786	NABORS 87	1/1/2011	3/15/2011	73
PF	VK	786	NABORS 87	3/15/2011	4/2/2011	18
PF	VK	786	NABORS 87	4/2/2011	4/20/2011	18
PF	VK	786	NABORS 87	4/2/2011	8/20/2011	140
PF	VK	786	NABORS 87	8/20/2011	8/26/2011	6
PF	VK	786	NABORS 87	8/26/2011	9/11/2011	16
PF	VK	786	NABORS 87	9/11/2011	9/18/2011	7

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
PF	VK	786	NABORS 87	9/18/2011	9/24/2011	6
PF	VK	786	NABORS 87	9/24/2011	12/31/2011	98
JU	WC	311	NABORS DOLPHIN 109	5/22/2011	6/23/2011	32
JU	WC	132	NABORS DOLPHIN 109	10/21/2011	11/16/2011	26
JU	SM	239	NABORS DOLPHIN 109	12/8/2011	12/26/2011	18
JU	SP	28	NABORS DT 110	4/5/2011	4/17/2011	12
JU	SP	28	NABORS DT 110	4/17/2011	4/23/2011	6
JU	SP	28	NABORS DT 110	4/23/2011	4/29/2011	6
JU	SP	28	NABORS DT 110	4/29/2011	6/3/2011	35
JU	SP	28	NABORS DT 110	6/3/2011	6/12/2011	9
JU	SS	72	NABORS DT 110	11/24/2011	12/13/2011	19
JU	SS	87	NABORS DT 110	12/13/2011	12/24/2011	11
PF	GC	338	NABORS MODS 200	4/7/2011	12/31/2011	268
PF	AC	25	NABORS MODS 201	12/15/2011	12/31/2011	16
PF	VK	826	NABORS P-10	1/4/2011	2/27/2011	54
PF	VK	826	NABORS P-10	2/27/2011	3/15/2011	16
PF	VK	826	NABORS P-10	3/15/2011	4/21/2011	37
PF	VK	826	NABORS P-10	4/21/2011	4/23/2011	2
PF	GI	102	NABORS P-10	6/13/2011	7/18/2011	35
PF	GI	102	NABORS P-10	7/18/2011	8/2/2011	15
PF	GI	102	NABORS P-10	8/2/2011	8/14/2011	12
PF	GI	102	NABORS P-10	8/14/2011	8/27/2011	13
PF	GI	102	NABORS P-10	8/27/2011	9/12/2011	16
PF	GI	102	NABORS P-10	9/12/2011	9/21/2011	9
PF	VR	408	NABORS S.D. IV	1/22/2011	3/15/2011	52
PF	VR	408	NABORS S.D. IV	3/15/2011	4/28/2011	44
PF	SM	130	NABORS S.D. IV	4/28/2011	7/18/2011	81
PF	SM	130	NABORS S.D. IV	7/18/2011	8/14/2011	27
PF	SM	130	NABORS S.D. IV	8/14/2011	8/31/2011	17
PF	SM	130	NABORS S.D. IV	8/31/2011	10/3/2011	33
PF	SM	107	NABORS S.D. IV	10/6/2011	11/18/2011	43
PF	SM	107	NABORS S.D. IV	11/19/2011	12/19/2011	30
PF	GB	260	NABORS S.D. XVI	12/29/2011	12/31/2011	2
SS	MC	503	NOBLE AMOS RUNNER	1/1/2011	1/5/2011	4
SS	MC	503	NOBLE AMOS RUNNER	1/5/2011	2/25/2011	51
SS	MC	199	NOBLE AMOS RUNNER	2/26/2011	3/21/2011	23
SS	MC	199	NOBLE AMOS RUNNER	3/21/2011	4/24/2011	34
SS	MC	199	NOBLE AMOS RUNNER	4/24/2011	5/28/2011	34
SS	MC	751	NOBLE AMOS RUNNER	5/29/2011	7/30/2011	62
SS	GB	462	NOBLE AMOS RUNNER	8/25/2011	10/29/2011	65
SS	ST	318	NOBLE AMOS RUNNER	11/2/2011	12/10/2011	38
SS	MC	431	NOBLE AMOS RUNNER	12/13/2011	12/25/2011	12
SS	MC	431	NOBLE AMOS RUNNER	12/25/2011	12/31/2011	6
SD	MC	764	NOBLE DANNY ADKINS	1/1/2011	2/27/2011	57

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
SD	AC	859	NOBLE DANNY ADKINS	5/10/2011	10/14/2011	157
SD	AC	857	NOBLE DANNY ADKINS	10/14/2011	12/31/2011	78
SS	MC	935	NOBLE DRILLER	8/3/2011	12/31/2011	150
JU	ST	295	NOBLE EDDIE PAUL	10/22/2011	10/22/2011	0
SD	MC	762	NOBLE JIM DAY	7/11/2011	8/1/2011	21
SD	MC	762	NOBLE JIM DAY	8/1/2011	8/14/2011	13
SD	MC	762	NOBLE JIM DAY	8/14/2011	8/25/2011	11
SD	MC	762	NOBLE JIM DAY	8/25/2011	9/13/2011	19
SD	MC	762	NOBLE JIM DAY	9/13/2011	9/21/2011	8
SD	MC	762	NOBLE JIM DAY	9/21/2011	12/31/2011	101
SS	GB	427	NOBLE JIM THOMPSON	4/7/2011	11/2/2011	209
SS	GC	116	NOBLE JIM THOMPSON	11/3/2011	12/31/2011	58
BR	EI	10	PARKER 72-B	5/9/2011	7/18/2011	70
DS	WR	206	PRIDE DEEP OCEAN MENDOCINO	8/24/2011	11/16/2011	84
DS	WR	206	PRIDE DEEP OCEAN MENDOCINO	11/30/2011	11/30/2011	0
DS	WR	206	PRIDE DEEP OCEAN MENDOCINO	12/2/2011	12/20/2011	18
JU	SS	72	PRIDE NORTH DAKOTA	11/17/2011	11/17/2011	0
JU	SS	259	ROWAN CECIL PROVINE	1/1/2011	2/20/2011	50
JU	WD	70	ROWAN CECIL PROVINE	2/20/2011	4/6/2011	45
JU	WD	70	ROWAN CECIL PROVINE	4/6/2011	5/11/2011	35
JU	WD	70	ROWAN CECIL PROVINE	5/11/2011	6/25/2011	45
JU	SS	258	ROWAN CECIL PROVINE	6/29/2011	10/7/2011	100
JU	SM	281	ROWAN CECIL PROVINE	10/13/2011	12/28/2011	76
JU	GI	48	ROWAN CECIL PROVINE	12/30/2011	12/31/2011	1
JU	BA	A 23	ROWAN EXL III	2/7/2011	6/25/2011	138
JU	GI	23	ROWAN EXL III	6/29/2011	7/14/2011	15
JU	GI	23	ROWAN EXL III	7/14/2011	8/4/2011	21
JU	GI	22	ROWAN EXL III	8/4/2011	8/28/2011	24
JU	GI	22	ROWAN EXL III	8/28/2011	9/25/2011	28
JU	GI	22	ROWAN EXL III	9/26/2011	10/10/2011	14
JU	MP	296	ROWAN EXL IV	11/3/2011	11/28/2011	25
JU	MP	296	ROWAN EXL IV	11/28/2011	12/26/2011	28
JU	MP	296	ROWAN EXL IV	12/26/2011	12/31/2011	5
JU	HI	A 376	ROWAN GORILLA II	1/2/2011	1/9/2011	7
JU	HI	A 376	ROWAN GORILLA II	1/9/2011	1/10/2011	1
JU	HI	A 376	ROWAN GORILLA II	1/10/2011	1/20/2011	10
JU	HI	A 376	ROWAN GORILLA II	1/20/2011	1/31/2011	11
JU	HI	A 376	ROWAN GORILLA II	1/31/2011	2/13/2011	13
JU	HI	A 376	ROWAN GORILLA II	2/13/2011	2/20/2011	7
JU	HI	A 376	ROWAN GORILLA II	2/20/2011	3/10/2011	18
JU	HI	A 376	ROWAN GORILLA II	3/10/2011	3/16/2011	6
JU	EI	302	ROWAN GORILLA II	4/2/2011	4/24/2011	22

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
JU	EI	391	ROWAN GORILLA II	4/28/2011	5/18/2011	20
JU	MP	72	ROWAN GORILLA III	3/20/2011	5/10/2011	51
JU	MP	72	ROWAN GORILLA III	5/10/2011	6/15/2011	36
JU	MP	72	ROWAN GORILLA III	6/15/2011	7/11/2011	26
JU	EI	26	ROWAN LOUISIANA	2/19/2011	11/19/2011	273
JU	SM	234	ROWAN MISSISSIPPI	1/1/2011	6/23/2011	173
JU	HI	A 1	SEAHAWK 2001	2/19/2011	4/14/2011	54
JU	SS	90	SEAHAWK 2004	1/1/2011	1/18/2011	17
JU	HI	176	SEAHAWK 2007	1/1/2011	2/14/2011	44
JU	HI	88	SEAHAWK 2007	2/14/2011	2/21/2011	7
JU	EI	224	SEAHAWK 2007	4/2/2011	5/1/2011	29
JU	SM	50	SEAHAWK 2600	1/1/2011	4/12/2011	101
JU	SM	111	SEAHAWK 2600	4/12/2011	5/4/2011	22
JU	VR	245	SEAHAWK 2601	1/1/2011	1/3/2011	2
JU	VR	245	SEAHAWK 2601	1/3/2011	1/18/2011	15
JU	VR	245	SEAHAWK 2601	1/18/2011	1/31/2011	13
JU	MP	122	SEAHAWK 2602	1/1/2011	1/3/2011	2
JU	MP	120	SEAHAWK 2602	1/3/2011	2/9/2011	37
JU	MP	120	SEAHAWK 2602	2/11/2011	3/7/2011	24
JU	ST	161	SEAHAWK 2602	3/11/2011	4/22/2011	42
JU	HI	A 309	SEAHAWK 3000	1/20/2011	2/7/2011	18
JU	HI	A 309	SEAHAWK 3000	2/7/2011	2/21/2011	14
JU	HI	A 309	SEAHAWK 3000	2/21/2011	3/2/2011	9
JU	EC	328	SEAHAWK 3000	3/15/2011	4/3/2011	19
JU	EC	328	SEAHAWK 3000	4/4/2011	4/17/2011	13
JU	EC	328	SEAHAWK 3000	4/17/2011	4/26/2011	9
JU	EC	328	SEAHAWK 3000	4/26/2011	5/6/2011	10
JU	EI	208	SPARTAN 208	3/26/2011	4/15/2011	20
JU	SM	107	SPARTAN 208	5/27/2011	6/7/2011	11
JU	HI	A 264	SPARTAN 208	6/24/2011	7/21/2011	27
JU	BA	502	SPARTAN 208	8/6/2011	8/19/2011	13
JU	GA	424	SPARTAN 208	11/1/2011	12/27/2011	56
JU	GA	A 133	SPARTAN 303	1/1/2011	1/6/2011	5
PF	SP	93	SUNDOWNER I	5/8/2011	6/5/2011	28
PF	SP	93	SUNDOWNER I	6/5/2011	6/24/2011	19
PF	SP	93	SUNDOWNER I	6/24/2011	7/10/2011	16
PF	SP	93	SUNDOWNER I	7/10/2011	7/26/2011	16
PF	SP	93	SUNDOWNER I	7/26/2011	8/12/2011	17
PF	SP	93	SUNDOWNER I	8/12/2011	8/21/2011	9
PF	SP	93	SUNDOWNER I	8/21/2011	8/26/2011	5
PF	SP	93	SUNDOWNER I	8/26/2011	9/22/2011	27
PF	GI	23	SUNDOWNER I	10/13/2011	11/17/2011	35
DS	WR	969	T. O. DISCOVERER AMERICAS	5/9/2011	10/22/2011	166
SS	EW	965	T.O. AMIRANTE	2/13/2011	3/28/2011	43

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
SS	MC	460	T.O. AMIRANTE	3/29/2011	6/16/2011	79
SS	MC	687	T.O. DEEPWATER NAUTILUS	5/19/2011	7/16/2011	58
SS	MC	348	T.O. DEEPWATER NAUTILUS	7/17/2011	12/31/2011	167
DS	MC	772	T.O. DEEPWATER PATHFINDER	3/2/2011	6/22/2011	112
DS	MC	728	T.O. DEEPWATER PATHFINDER	6/22/2011	9/19/2011	89
DS	MC	772	T.O. DEEPWATER PATHFINDER	9/19/2011	12/31/2011	103
SD	GC	654	T.O. DEVELOPMENT DRILLER I	1/1/2011	6/18/2011	168
SD	GC	738	T.O. DEVELOPMENT DRILLER I	6/19/2011	12/12/2011	176
SD	AT	617	T.O. DEVELOPMENT DRILLER I	12/12/2011	12/31/2011	19
SD	GC	743	T.O. DEVELOPMENT DRILLER II	9/6/2011	11/7/2011	62
SD	GC	743	T.O. DEVELOPMENT DRILLER II	12/2/2011	12/22/2011	20
SD	GC	743	T.O. DEVELOPMENT DRILLER II	12/30/2011	12/31/2011	1
SD	MC	252	T.O. DEVELOPMENT DRILLER III	1/23/2011	3/9/2011	45
SD	GC	743	T.O. DEVELOPMENT DRILLER III	7/15/2011	12/31/2011	169
DS	GC	903	T.O. DISCOVERER AMERICAS	10/23/2011	11/23/2011	31
DS	GC	903	T.O. DISCOVERER AMERICAS	11/23/2011	12/31/2011	38
DS	GC	640	T.O. DISCOVERER CLEAR LEADER	1/1/2011	3/3/2011	61
DS	GC	640	T.O. DISCOVERER CLEAR LEADER	3/3/2011	3/11/2011	8
DS	GC	640	T.O. DISCOVERER CLEAR LEADER	6/15/2011	8/24/2011	70
DS	GC	640	T.O. DISCOVERER CLEAR LEADER	8/24/2011	11/27/2011	95
DS	WR	758	T.O. DISCOVERER CLEAR LEADER	11/27/2011	12/31/2011	34
DS	KC	785	T.O. DISCOVERER DEEP SEAS	5/15/2011	10/8/2011	146
DS	GC	640	T.O. DISCOVERER DEEP SEAS	10/9/2011	12/31/2011	83
DS	VK	914	T.O. DISCOVERER ENTERPRISE	12/1/2011	12/31/2011	30
DS	WR	758	T.O. DISCOVERER INDIA	11/5/2011	11/22/2011	17
DS	WR	677	T.O. DISCOVERER INDIA	11/24/2011	11/24/2011	0
DS	WR	634	T.O. DISCOVERER INDIA	11/24/2011	11/24/2011	0
DS	WR	677	T.O. DISCOVERER INDIA	11/24/2011	12/6/2011	12
DS	WR	29	T.O. DISCOVERER INDIA	12/6/2011	12/8/2011	2
DS	WR	29	T.O. DISCOVERER INDIA	12/8/2011	12/31/2011	23
DS	WR	677	T.O. DISCOVERER INDIA	12/15/2011	12/15/2011	0

Rig Type	Surface Area Code	Surface Block Number	Rig Name	Rig Move on Date	Rig Move off Date	Days
DS	KC	736	T.O. DISCOVERER INSPIRATION	3/26/2011	10/4/2011	192
DS	WR	143	T.O. DISCOVERER INSPIRATION	10/4/2011	12/7/2011	64
DS	WR	634	T.O. DISCOVERER INSPIRATION	12/7/2011	12/16/2011	9
DS	WR	677	T.O. DISCOVERER INSPIRATION	12/16/2011	12/31/2011	15
DS	GC	726	T.O. DISCOVERER SPIRIT	1/1/2011	3/17/2011	75
DS	GC	726	T.O. DISCOVERER SPIRIT	3/17/2011	6/8/2011	83
PF	MC	778	THUNDER HORSE PDQ	12/23/2011	12/31/2011	8

The drilling rig names in the BOEM dataset were matched to vessel names in the RigZone database (RigZone Data Center 2012) and other online sources. RigZone is an oil and gas trade service that monitors drilling rigs, and their database includes details concerning the drilling rig propulsion engines, prime engines, mud pumps, draw works, and emergency power. By matching the BOEM drilling rig vessel names to vessel characteristics in the RigZone database, accurate engine and equipment data were used to estimate emissions. Where RigZone did not include a vessel noted in the BOEM dataset, the RigZone data were averaged by vessel type and used to gap-fill missing data. The average engine kW ratings used to gap-fill missing data are noted in Table 6-3.

Table 6-3. Equipment kW ratings by drilling rig type

Rig Type	Average Total Main Power (kW)	Average Total Emergency (kW)	Average Total Propulsion (kW)
Drillship	25,347	1,352	40,383
Inland Barge	3,807	42	[a]
Jackup	3,751	256	[a]
Platform Rig	4,066	[b]	[a]
Semisubmersible	13,426	495	3,913
Submersible	3,849	213	[a]

[a] Not self-propelled, relocated with support vessels (see Section 6.1.5).
[b] Unknown.

The kilowatt (kW) rating of each rig was applied to the hours that the rig spent at a block, or, if vessel specific data were not available, then the data in Table 6-3 were used to get the vessel kW-hours. These values were applied to the emission and load factors provided in Table 6-1. In selecting the emission factors (USEPA 2010), it was assumed that all rig engines were classified as high-speed diesel engines.

It should be noted that the few drilling rigs with propulsion engines tended to be semi-submersible rigs and drill ships, which use their thrusters to maintain the vessel's drilling position at the drill site; these engines tend to operate at relatively low loads to keep the vessel in place. It is assumed that propulsion engines operate at 15% load, as noted in Table 6-1, to maintain position.

Transit emissions for drill ships and semisubmersibles have been quantified by applying the kW rating of the propulsion engines to the hours that the rig spent between relocations. Some rigs leave the lease block where drilling activities occur and exit the GOM or return to port. For this reason, propulsion emissions are limited to 10 days between relocations. It is assumed that propulsion engines operate at 75% load while the rig is relocating.

Emissions associated with emergency power generation were quantified using USEPA guidance for land-based emergency generators assumes operations of 500 hours per year to account for maintenance checks, operator training, and power outages (USEPA 1995). This assumption was applied to drilling rigs.

Calendar year 2011 drilling rig annual emission estimates were developed using the approach discussed in Section 6.1.1. An example of how the equation in Section 6.1.1 was used for this vessel category is provided below.

Example Calculation:

$$E = AH \times kW \times LF \times EF \times CF$$

where:

E	=	Emissions (tons)
AH	=	Annual hours per mode of operation (underway, maneuvering, hoteling) (hours)
kW	=	Average vessel kW (totaling individual propulsion engines) (kW)
LF	=	Engine load factor for specified mode of operation (%)
EF	=	Emission factor (g/kWH)
CF	=	Conversion factor (g = 1.10231 E-6 ton)

In 2011, all drill ships operated 48,432 hours. Average weighted kW rating for drill ships is 29,742, load factor is 0.75, and the emission factor for NO_x is 19.54 g/kWh.

$$E = 48{,}432 \times 29{,}742 \times 0.75 \times 19.54 \times 1.10231 \times 10^{-6}$$

$$E = 23{,}679 \text{ tons of } NO_x$$

The variation in monthly drilling activities developed using the 2011 BOEM drill rig data, as presented in Table 6-4. This monthly profile was applied to the annual emission estimates to calculate the monthly emissions.

Table 6-4. Seasonal drilling activity 2011

Month	Total Drilling Days (%)
January	6.30
February	5.97
March	6.98
April	7.96
May	8.56
June	8.59
July	8.78
August	9.08
September	8.63
October	9.15
November	9.30
December	10.70

The drilling operation emissions were spatially allocated to the lease blocks where drilling occurred. Figure 6-1 maps the location of all 2011 drilling rig operations.

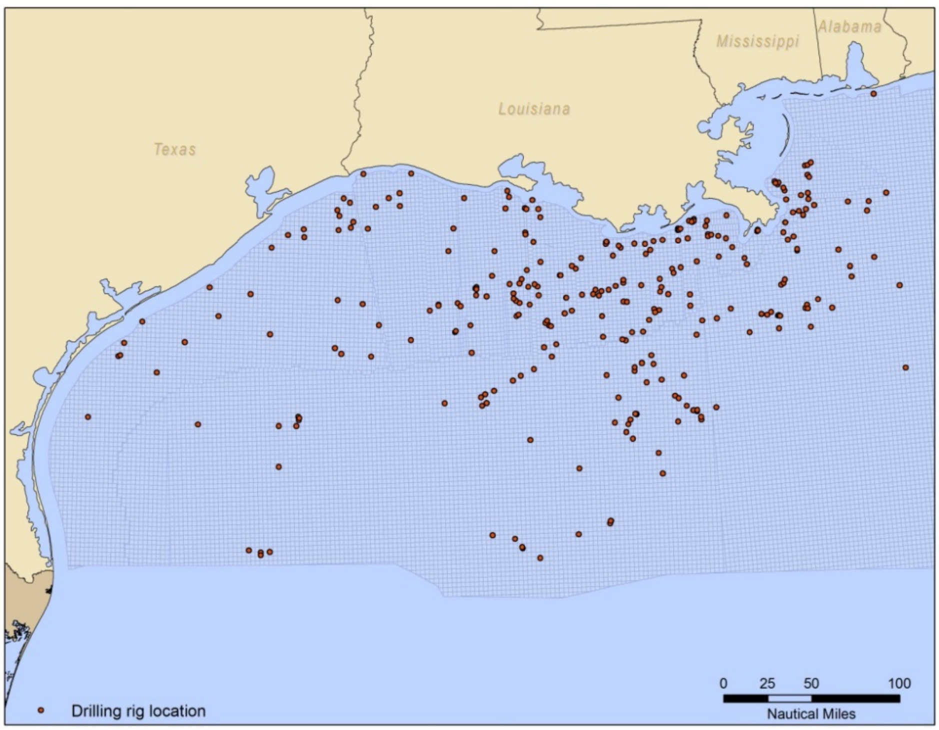

Figure 6-1. Location of drilling operations and BOEM lease blocks for 2011

6.1.3 Pipelaying Operations

Product from oil platforms is generally transported to shore through pipelines. New pipelines are constantly being laid, linking new well heads and platforms to shore or increasing the capacity of the existing pipeline network. Pipelines also require occasional maintenance and repair. To install, maintain, or replace sections of pipeline necessitates considerable vessel support. Using data from the 2009 Louisiana State University study entitled "Empirical Analysis of Offshore Service Vessel Utilization in the Gulf of Mexico," (Kaiser and Snyder 2009) the number of vessel hours needed to lay a foot of pipe was estimated to be 0.32 hours/ft. This operating hours factor was applied to BOEM data documenting the segments built or maintained in 2011. It should be noted that this estimate includes emissions from support vessels involved in pipelaying. In some cases, these support vessels may be included in the support vessel emission estimates described in Section 6.1.5 as well.

The BOEM data documents the length and location of individual sections constructed or maintained from January 2011 to December 2011 (USDOI, BOEM 2013a and 2013b). These new pipeline segments were mapped to individual lease blocks in the GOM using Geographic Information System (GIS) tools (USDOI, BOEM 2013c). The total length of pipeline constructed within a lease block was calculated for each lease block along with the total vessel hours included in these activities, based on the following equation:

$$T_{pi} = \Sigma (L_i \times 0.32 \text{ hrs/ft})$$

where:

T_{pi} = Total vessel time involved in pipelaying or maintenance for lease block i (hours)
L_i = Length of individual pipe segment within the boundaries of lease block i (feet)

The 2011 vessel hours associated with pipeline construction, including new pipelaying and pipeline repair, totaled 788,574 hours. Pipeline maintenance activities were identified as those segments in the BOEM master pipeline dataset with a pipeline construction date in the year 2011. New pipelines were identified from the BOEM master pipeline dataset as those that showed no construction date but had an initial hydrostatic test date in 2011. These two types of pipelaying activities are summarized in Table 6-5.

Table 6-5. Pipelaying activity

Activity	Hours of Activity in 2011
New Pipelaying	325,864
Repair	462,710

Emissions associated with pipelaying vessels are attributed to the operation of the primary diesel engine used for propulsion, and other smaller diesel engines that are used to run generators, air compressors, welding equipment, or small cranes and winches. For this inventory, it was assumed that the main propulsion engines are medium-speed diesel engines. Assumptions about average horsepower and load factors (Table 6-6) were obtained from the *Gulf of Mexico Air Quality Study* (Systems Applications International et al. 1995) and applied to the emission factors presented in Section 6.1.1. Accidental releases of gas or oil from pipelines during construction or maintenance were not considered in this study.

Table 6-6. Average pipelaying vessel characteristics

Average Vessel kW	Load Factor
894.84	0.75

Emission estimates were developed using the approach discussed in Section 6.1.1. An example of how the equation in Section 6.1.1 was used for this vessel category is provided below.

Example Calculation:

$$E = AH \times kW \times LF \times EF \times CF$$

where:

E = Emissions (tons)
AH = Annual hours per mode of operation (underway, maneuvering, hoteling) (hours)
kW = Average vessel kW (totaling individual propulsion engines) (kW)
LF = Engine load factor for specified mode of operation (%)
EF = Emission factor (g/kWH)
CF = Conversion factor (g = 1.10231 E-6 ton)

In 2011, total hours of pipeline repair activity were 462,710. Average vessel kW of pipelaying vessels is 894.84, load factor is 0.75, and the emission factor for NO_x is 16.25 g/kWh.

$E = 462{,}710 \times 894.84 \times 0.75 \times 16.25 \times 1.10231 \times 10^{-6}$
$E = 5{,}563$ tons of NO_x

The new pipelaying activity is summarized with both total pipe length constructed and total hours by BOEM lease block in Table 6-7. Repair activity is summarized by total pipe length and hours by BOEM lease block in Table 6-8. Total pipelaying activity data are broken down by month in Table 6-9; these monthly data were based on construction or hydrostatic test dates and used to represent seasonality of pipeline-related activities.

Pipeline construction and repair emissions were mapped to the lease blocks where the activity occurred using data provided by BOEM and are provided in Figure 6-2 (USDOI, BOEM 2013c).

Table 6-7. New pipelaying activity data

Pipeline Segment ID	Lease Block ID (AC_LAB)	Initial Hydrostatic Test Date	Length (Meters)	Hours of Operation (Hrs)
18270	EB602	20110805	17.31	18.18
18271	EB602	20110805	13.98	14.67
18175	EC24	20110422	967.76	1,016.02
18175	EC33	20110422	879.32	923.17
18175	EC34	20110422	2,689.55	2,823.68
18290	EI100	20111005	1,914.44	2,009.92
18290	EI105	20111005	1,670.16	1,753.45
18290	EI106	20111005	4,536.50	4,762.73
18272	EI302	20110806	3,373.29	3,541.51
18272	EI303	20110806	1,656.87	1,739.49
18216	GAA132	20110718	1,702.75	1,787.66
18216	GAA133	20110718	285.58	299.82
18216	GAA155	20110718	2,477.89	2,601.46
18083	GC139	20110520	5,244.19	5,505.71
18083	GC182	20110520	1,067.93	1,121.19
18083	GC183	20110520	4,055.80	4,258.06
18083	GC226	20110520	5,120.21	5,375.55
18083	GC270	20110520	5,014.96	5,265.06
18083	GC314	20110520	4,891.11	5,135.02
18083	GC358	20110520	4,929.12	5,174.93
18083	GC402	20110520	4,624.97	4,855.62
18083	GC403	20110520	1,561.01	1,638.86
18083	GC447	20110520	5,439.09	5,710.33
18083	GC448	20110520	1,312.65	1,378.12
18083	GC52	20110520	302.39	317.47
18083	GC52	20110520	2,032.85	2,134.22
17778	GC640	20111025	610.98	641.45
18219	GC640	20111123	28.91	30.35
18220	GC640	20111124	26.71	28.04
17778	GC641	20111025	2,427.38	2,548.43
18319	GC743	20111128	19.31	20.27
18320	GC743	20111128	19.03	19.98
18321	GC743	20111228	22.02	23.12
18322	GC743	20111228	23.09	24.24
18323	GC743	20111219	20.21	21.22
18324	GC743	20111216	20.16	21.17
18325	GC743	20111219	12.22	12.83
18326	GC743	20111216	12.75	13.39
18329	GC743	20111120	18.97	19.92
18330	GC743	20111113	19.70	20.68
18331	GC743	20111020	17.20	18.06
18332	GC743	20111020	16.66	17.49
18333	GC743	20111030	12.28	12.90
18334	GC743	20111107	12.47	13.10
18339	GC743	20111118	17.54	18.41

Pipeline Segment ID	Lease Block ID (AC_LAB)	Initial Hydrostatic Test Date	Length (Meters)	Hours of Operation (Hrs)
18341	GC743	20111018	28.76	30.19
18342	GC743	20110906	28.13	29.53
18345	GC743	20111128	20.58	21.60
18346	GC743	20111018	29.12	30.58
18348	GC743	20111128	15.54	16.31
18349	GC743	20111021	25.70	26.98
18351	GC743	20111212	15.06	15.81
18352	GC743	20111209	15.04	15.79
18353	GC743	20111209	15.11	15.86
18354	GC743	20111212	15.14	15.89
18355	GC743	20111208	19.35	20.32
18356	GC743	20111118	19.35	20.32
18357	GC743	20111208	19.37	20.34
18358	GC743	20111111	19.38	20.34
18083	GC95	20110520	2,748.27	2,885.33
18083	GC96	20110520	3,744.33	3,931.06
18164	MC109	20110624	3,088.51	3,242.53
18176	MC115	20110814	4,942.58	5,189.06
18177	MC115	20110814	4,943.47	5,190.00
18164	MC153	20110624	4,841.86	5,083.31
18176	MC159	20110814	4,977.71	5,225.95
18177	MC159	20110814	4,976.80	5,224.99
18164	MC197	20110624	4,842.09	5,083.56
18176	MC203	20110814	2,831.27	2,972.46
18177	MC203	20110814	2,905.30	3,050.18
18176	MC204	20110814	2,145.50	2,252.49
18177	MC204	20110814	2,072.14	2,175.48
18164	MC241	20110624	1,061.03	1,113.94
18166	MC241	20110609	11.28	11.84
18176	MC248	20110814	4,923.57	5,169.10
18177	MC248	20110814	4,922.32	5,167.79
18176	MC26	20110814	2,779.18	2,917.77
18177	MC26	20110814	2,843.58	2,985.39
18176	MC27	20110814	2,196.53	2,306.06
18177	MC27	20110814	2,132.07	2,238.40
18176	MC292	20110814	1,317.51	1,383.21
18177	MC292	20110814	1,330.58	1,396.93
18178	MC292	20110814	14.34	15.06
18179	MC292	20110814	15.72	16.50
18204	MC503	20111026	1,943.88	2,040.82
18205	MC503	20110918	2,175.66	2,284.15
18206	MC503	20110922	264.11	277.29
18210	MC503	20110309	17.75	18.63
18212	MC503	20110218	17.06	17.91
18217	MC503	20110216	18.46	19.38
18314	MC503	20110329	19.08	20.03

Pipeline Segment ID	Lease Block ID (AC_LAB)	Initial Hydrostatic Test Date	Length (Meters)	Hours of Operation (Hrs)
18315	MC503	20110325	18.94	19.89
18265	MC519	20111120	19.22	20.18
18266	MC519	20111123	19.08	20.04
18189	MC547	20111027	2,225.92	2,336.93
18204	MC547	20111026	3,184.20	3,342.99
18205	MC547	20110918	3,248.87	3,410.88
18206	MC547	20110922	4,081.16	4,284.68
18189	MC589	20111027	2,737.02	2,873.51
18189	MC590	20111027	5,278.11	5,541.32
18189	MC591	20111027	2,044.66	2,146.62
18189	MC632	20111027	4,278.02	4,491.36
18189	MC633	20111027	2,842.29	2,984.03
18189	MC675	20111027	5,478.48	5,751.69
18189	MC676	20111027	1,977.69	2,076.31
18176	MC71	20110814	4,970.87	5,218.76
18177	MC71	20110814	4,970.83	5,218.72
16324	MC711	20110213	875.40	919.06
16335	MC711	20110213	1,940.19	2,036.95
18189	MC718	20111027	1,456.17	1,528.79
18189	MC719	20111027	818.01	858.80
18234	MC728	20110925	18.26	19.17
18235	MC728	20110925	19.33	20.30
18236	MC728	20110925	22.78	23.91
16332	MC754	20110213	20.76	21.80
16333	MC754	20110213	909.08	954.42
16335	MC754	20110213	995.97	1,045.63
16324	MC755	20110213	923.96	970.04
16333	MC755	20110213	1,023.62	1,074.67
16334	MC755	20110213	20.36	21.38
16335	MC755	20110213	1,444.46	1,516.50
18275	MC772	20110908	19.68	20.66
18198	MI622	20110703	718.36	754.18
18198	MI623	20110703	1,553.64	1,631.12
18299	MP108	20111222	1,760.95	1,848.76
16342	MP112	20110303	2,472.51	2,595.81
16342	MP113	20110303	1,145.51	1,202.63
16342	MP117	20110303	4,911.79	5,156.74
16342	MP118	20110303	3,880.52	4,074.04
16342	MP126	20110303	122.09	128.18
16342	MP127	20110303	4,608.40	4,838.21
18159	MP308	20111028	1,347.19	1,414.37
18160	MP308	20111028	1,343.22	1,410.20
18159	MP309	20111028	4,432.56	4,653.60
18160	MP309	20111028	4,432.43	4,653.47
18159	MP310	20111028	1,951.08	2,048.37
18160	MP310	20111028	1,946.46	2,043.53

Pipeline Segment ID	Lease Block ID (AC_LAB)	Initial Hydrostatic Test Date	Length (Meters)	Hours of Operation (Hrs)
18267	MP40	20110917	3,670.03	3,853.05
18267	MP41	20110917	527.48	553.79
18267	MP59	20110917	1,446.90	1,519.06
18154	PL23	20110425	662.58	695.62
18155	PL23	20110424	662.92	695.98
18259	SS150	20111003	1,281.02	1,344.91
18186	SS153	20110708	65.02	68.26
18186	SS154	20110708	29.40	30.87
18486	SS189	20111215	569.45	597.85
18187	ST128	20110701	117.91	123.79
18187	ST134	20110701	1,135.67	1,192.30
18187	ST135	20110701	269.78	283.23
18176	VK900	20110814	3,026.41	3,177.34
18177	VK900	20110814	3,033.90	3,185.20
18176	VK944	20110814	4,975.35	5,223.46
18177	VK944	20110814	4,974.50	5,222.57
18176	VK988	20110814	4,975.19	5,223.30
18177	VK988	20110814	4,975.44	5,223.56
18286	VR170	20110806	2,270.06	2,383.27
18286	VR171	20110806	4,059.23	4,261.66
18481	WC110	20111027	885.42	929.58
18174	WC116	20110513	3,984.67	4,183.38
18174	WC117	20110513	4,108.21	4,313.08
18364	WC71	20111022	978.87	1,027.68
18129	WD106	20110821	5,073.59	5,326.61
18129	WD107	20110821	533.19	559.78
18245	WD30	20110721	824.64	865.76
18369	WD73	20111212	1,068.49	1,121.77
18196	WD89	20111229	149.56	157.02
18196	WD89	20111229	2,137.14	2,243.72
18369	WD92	20111212	1,935.79	2,032.32
18369	WD93	20111212	2,978.82	3,127.37

Table 6-8. Pipeline Repair Activity Data

Pipeline Segment ID	Lease Block ID (AC_LAB)	Initial Hydrostatic Test Date	Length (Meters)	Hours of Operation (Hrs)
6992	BM3	20110110	499.53	524.44
8031	BM3	20110813	480.15	504.09
13468	EB602	20111022	28.99	30.44
13469	EB602	20110817	9.95	10.45
13470	EB602	20111010	29.55	31.02
14869	EC265	20110308	1,591.24	1,670.59
14870	EC265	20110308	1,591.17	1,670.52
14869	EC278	20110308	93.70	98.37
14870	EC278	20110308	93.48	98.14
11056	EI107	20110510	4,132.03	4,338.09
4792	EI307	20110424	100.67	105.69
1707	EI32	20110731	764.12	802.23
7631	EI330	20110402	876.83	920.55
11228	EI331	20110618	2,820.33	2,960.97
11228	EI336	20110618	111.33	116.88
11228	EI337	20110618	5,044.51	5,296.08
12749	EI344	20110302	488.63	513.00
12749	EI345	20110302	5,711.21	5,996.02
12749	EI347	20110302	5,223.43	5,483.92
12749	EI348	20110302	1,251.18	1,313.57
11228	EI355	20110618	5,155.30	5,412.39
11228	EI357	20110618	2,278.99	2,392.64
11228	EI358	20110618	3,292.14	3,456.32
12749	EI364	20110302	228.12	239.50
12749	EI365	20110302	5,875.02	6,168.00
12749	EI370	20110302	4,202.55	4,412.13
12749	EI371	20110302	4,830.82	5,071.73
11228	EI378	20110618	4,437.51	4,658.80
11228	EI379	20110618	3,268.04	3,431.02
12749	EI386	20110302	713.36	748.94
12749	EI386	20110302	2,238.48	2,350.11
12749	EI387	20110302	2,305.29	2,420.25
12749	EI388	20110302	4,873.83	5,116.88
4705	EI57	20110120	104.11	109.31
4705	EI57	20110120	208.13	218.50
4709	EI57	20110119	917.94	963.72
18161	EW908	20110326	1,159.80	1,217.64
18163	EW908	20110326	1,161.39	1,219.30
18161	EW952	20110326	4,203.01	4,412.61
18163	EW952	20110326	4,341.44	4,557.94
18161	EW953	20110326	1,218.36	1,279.12
18163	EW953	20110326	1,061.08	1,113.99
12749	EW981	20110302	1,425.30	1,496.38
18161	EW997	20110326	5,439.03	5,710.27
18163	EW997	20110326	5,451.11	5,722.95

Pipeline Segment ID	Lease Block ID (AC_LAB)	Initial Hydrostatic Test Date	Length (Meters)	Hours of Operation (Hrs)
11228	GB128	20110618	1,483.66	1,557.64
11228	GB84	20110618	5,923.42	6,218.81
11228	GB85	20110618	421.62	442.65
12749	GC101	20110302	686.38	720.61
12749	GC101	20110302	2,472.07	2,595.35
12749	GC102	20110302	3,378.34	3,546.81
12749	GC11	20110302	1,675.95	1,759.53
18161	GC116	20110326	837.12	878.87
18163	GC116	20110326	975.94	1,024.61
12749	GC12	20110302	1,284.25	1,348.29
12749	GC12	20110302	3,435.26	3,606.57
12749	GC146	20110302	3,080.02	3,233.61
12749	GC147	20110302	4,033.33	4,234.47
12749	GC191	20110302	1,079.15	1,132.97
12749	GC191	20110302	1,610.41	1,690.72
12749	GC192	20110302	4,087.16	4,290.98
12749	GC236	20110302	2,244.67	2,356.61
12749	GC237	20110302	50.19	52.70
18161	GC27	20110326	3,588.71	3,767.67
18163	GC27	20110326	3,732.83	3,918.98
18161	GC28	20110326	1,836.86	1,928.46
18163	GC28	20110326	1,692.66	1,777.07
12749	GC56	20110302	2,409.72	2,529.89
12749	GC57	20110302	3,974.36	4,172.56
18161	GC72	20110326	5,354.11	5,621.11
18163	GC72	20110326	5,364.08	5,631.58
18016	GI47	20110723	906.98	952.21
18016	GI48	20110723	1,175.35	1,233.96
15653	MC919	20110620	2,947.95	3,094.96
15653	MC920	20110620	2,555.95	2,683.41
15653	MC961	20110620	3,252.42	3,414.62
15653	MC962	20110620	5,115.87	5,371.00
15653	MC963	20110620	2,227.69	2,338.78
8985	MP107	20110303	227.11	238.44
8985	MP108	20110303	3,681.64	3,865.24
8985	MP112	20110303	3,823.28	4,013.94
15811	MP117	20110314	2,669.64	2,802.77
15811	MP118	20110314	1,441.56	1,513.45
15811	MP126	20110314	1,908.06	2,003.21
15811	MP127	20110314	4,328.92	4,544.80
9149	MP64	20110119	831.35	872.81
9149	MP65	20110119	550.50	577.95
15495	SM108	20110926	3,188.95	3,347.98
15495	SM113	20110926	153.18	160.81
15495	SM114	20110926	5,934.39	6,230.34
15495	SM122	20110926	6,028.12	6,328.74
15495	SM123	20110926	459.68	482.60

Pipeline Segment ID	Lease Block ID (AC_LAB)	Initial Hydrostatic Test Date	Length (Meters)	Hours of Operation (Hrs)
15495	SM131	20110926	407.97	428.31
15495	SM132	20110926	5,245.81	5,507.41
15495	SM137	20110926	1,587.29	1,666.45
17433	SM149	20111206	3,022.92	3,173.67
11228	SM190	20110618	3,387.49	3,556.42
11228	SM191	20110618	1,046.34	1,098.52
11228	SM192	20110618	4,205.27	4,414.98
11228	SM204	20110618	2,993.12	3,142.38
11228	SM205	20110618	3,270.17	3,433.25
13514	SM239	20111217	1,738.03	1,824.70
7608	SM41	20110531	665.79	698.99
7608	SM41	20110531	3,336.41	3,502.80
6185	SP77	20110112	3,033.38	3,184.65
6185	SP78	20110112	3,605.00	3,784.78
8284	SS153	20110715	188.34	197.73
8284	SS154	20110715	4,189.68	4,398.61
1137	SS204	20110216	801.31	841.27
1137	SS205	20110216	4,591.65	4,820.64
12749	SS205	20110302	1,518.84	1,594.58
1137	SS206	20110216	4,591.29	4,820.25
10573	SS206	20110108	1,025.52	1,076.66
10574	SS206	20110108	1,025.52	1,076.66
12749	SS206	20110302	4,739.87	4,976.24
1137	SS207	20110216	1,678.46	1,762.16
1190	SS207	20110105	1,018.68	1,069.48
3907	SS207	20110105	1,165.71	1,223.84
4241	SS207	20110105	1,325.72	1,391.83
7002	SS207	20110104	939.94	986.81
10573	SS207	20110108	2,143.99	2,250.91
10574	SS207	20110108	2,143.99	2,250.91
12749	SS207	20110302	1,369.98	1,438.30
1833	SS209	20110611	550.92	578.40
3907	SS216	20110105	1,392.65	1,462.10
12749	SS218	20110302	4,714.85	4,949.98
12749	SS219	20110302	1,228.77	1,290.05
12749	SS228	20110302	4,890.66	5,134.55
12749	SS243	20110302	3,579.12	3,757.60
12749	SS244	20110302	1,650.92	1,733.24
5902	SS247	20110927	2,603.58	2,733.42
5902	SS248	20110927	360.11	378.07
12749	SS251	20110302	5,400.19	5,669.49
12749	SS268	20110302	161.13	169.17
12749	SS269	20110302	5,501.27	5,775.61
12749	SS273	20110302	3,194.24	3,353.53
12749	SS274	20110302	2,011.34	2,111.65
12749	SS294	20110302	4,248.07	4,459.92
12749	SS295	20110302	1,149.96	1,207.31

Pipeline Segment ID	Lease Block ID (AC_LAB)	Initial Hydrostatic Test Date	Length (Meters)	Hours of Operation (Hrs)
12749	SS296	20110302	1,200.78	1,260.67
12749	SS296	20110302	4,312.23	4,527.28
12749	SS319	20110302	501.17	526.16
6267	SS33	20110815	2,685.92	2,819.86
14471	SS58	20111013	2,237.13	2,348.70
7802	ST295	20110331	1,943.91	2,040.85
7802	ST296	20110331	4,756.46	4,993.66
7802	ST297	20110331	1,980.39	2,079.15
18161	ST300	20110326	2,414.52	2,534.93
18163	ST300	20110326	2,514.41	2,639.80
18161	ST301	20110326	1,429.40	1,500.68
18163	ST301	20110326	1,320.74	1,386.61
18161	ST314	20110326	5,018.41	5,268.68
18163	ST314	20110326	5,021.30	5,271.71
18161	ST317	20110326	2,054.81	2,157.28
18163	ST317	20110326	2,201.70	2,311.50
18161	ST318	20110326	2,694.15	2,828.50
18163	ST318	20110326	2,546.01	2,672.97
1240	VR264	20111120	3,265.73	3,428.59
1240	VR265	20111120	2,891.65	3,035.86
1240	VR279	20111120	2,041.72	2,143.54
11002	VR279	20111115	2,572.49	2,700.77
1240	VR280	20111120	5,266.78	5,529.42
1240	VR281	20111120	587.88	617.20
1240	VR282	20111120	5,062.66	5,315.13
17934	VR282	20110916	112.57	118.19
13218	VR369	20110211	1,856.96	1,949.57
13219	VR369	20110211	1,856.96	1,949.57
10146	VR39	20110301	1,427.92	1,499.13
11350	WC110	20110414	1,696.88	1,781.51
18228	WC128	20110720	1,158.09	1,215.84
18228	WC129	20110720	5,327.27	5,592.93
18228	WC130	20110720	1,324.99	1,391.07
18228	WC153	20110720	1,491.26	1,565.63
12743	WC170	20110608	921.76	967.73
12744	WC170	20110608	921.99	967.97
14175	WC47	20110505	6,057.34	6,359.41
14175	WC48	20110505	1,364.41	1,432.45
14175	WC54	20110505	0.08	0.09
14175	WC54	20110505	2,726.81	2,862.79
6185	WD109	20110112	1,507.32	1,582.48
6185	WD110	20110112	637.19	668.97
18022	WD70	20110717	1,555.11	1,632.66
18022	WD95	20110717	4,169.88	4,377.82
		Total	440,731.49	462,710.24

Table 6-9. Pipelaying monthly adjustment factors

Month	2011 Monthly Adjustment Factors (%)
January	3.21
February	3.14
March	33.23
April	1.14
May	10.45
June	10.85
July	4.18
August	14.42
September	5.54
October	8.85
November	2.92
December	2.07

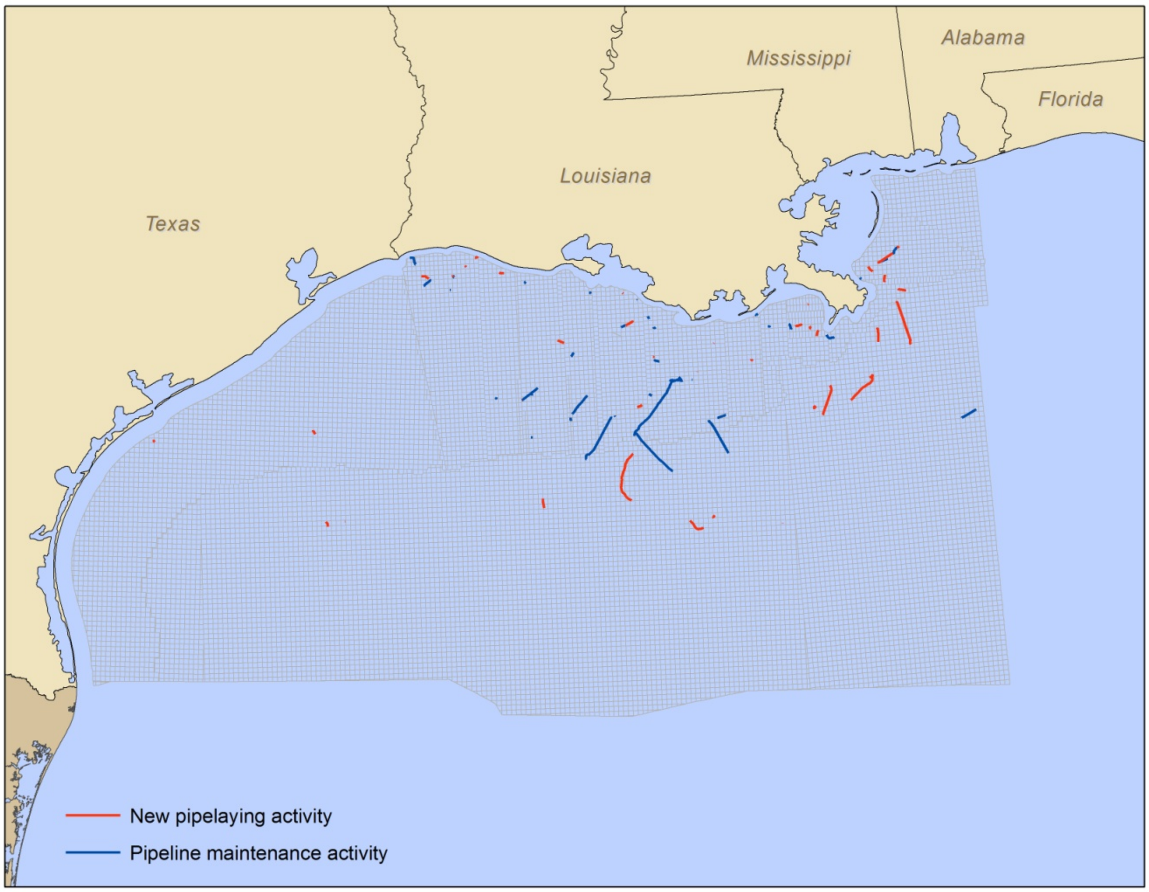

Figure 6-2. 2011 pipelaying activity locations and BOEM lease blocks

6.1.4 Support Helicopters

Helicopters are used extensively in the GOM to move light supplies and personnel to and from platforms. The best data source for all helicopter operations in the GOM is the Helicopter Safety Advisory Conference (HSAC*)* annual safety report, *Gulf of Mexico Offshore Helicopter Operations and Safety Review* (HSAC 2012). The report contains a snapshot of all helicopter operations in the GOM as reported by participating operators. However, the report underestimates operations, as activity data are voluntarily provided by a fraction of operators. Based on personal communications with the government liaison committee chairman for the HSAC (Raaz 2009), approximately 70% of the offshore support helicopters provide activity data to HSAC. Therefore the 2011 HSAC activity data were corrected by multiplying the landing and takeoff (LTO) data by 100/70 or 1.4286. The HSAC compiled activity data are disaggregated into single engine, light twin engine, medium twin engine, and heavy twin engine helicopters, as noted in Table 6-10.

Table 6-10. HSAC helicopter data

Helicopter Type	2011 LTO	Adjusted 2011 LTO[a]
Single	636,058	908,654
Twin Light	92,762	132,517
Twin Medium	131,368	187,669
Twin Heavy	30,984	44,263
Total	891,172	1,273,103

[a] Raw LTO data adjusted to account for survey bias based on personal communication with Dana Raaz, government liaison committee chairman for the HSAC on July 20, 2009.

The primary helicopter emission factors were obtained from Switzerland FOCA's Guidance on Determination of Helicopter Emissions. However, the LTO cycle used by FOCA was determined to be too short for typical trips taken in the GOM. The average trip length was relatively short (20 minutes) (HSAC 2009); therefore it was assumed that helicopters typically hop from platform to platform. In addition to the 20 minute flight time, it was assumed that the helicopters idle for an additional 15 minutes while on the platform. Therefore the time in modes from the FOCA were adjusted to reflect conditions in the GOM. Table 6-11 shows the original FOCA time in mode values and the new adjusted values for the GOM.

Table 6-11. Time-in-mode values

Source	Pretake-Off Idle (Min)	Take-Off Time (Min)	Approach Time (Min)	Post-Landing Idle (Min)	Total Idling (Min)	Total Flight (Min)
FOCA	4.0	3.0	5.5	1.0	5.0	8.5
GOM	12	7	13	3	15	20

The FOCA emission factors were recalculated based on the new time in mode values. Then the LTO-based emission factors for each helicopter type were averaged to yield the emission factors used in this study. Table 6-12 lists the FOCA emission factors by helicopter and helicopter type.

The VOC helicopter emission factors were developed by converting the hydrocarbon (HC). $PM_{2.5}$ factors were speciated from PM_{10} using USEPA aircraft speciation data. SO_2 emission factors were developed based on typical jet fuel sulfur concentration of 0.05% (UNEP 2012). CO_2, N_2O, and CH_4 emission factors were obtained from the U.S. Department of Transportation's Energy Information Administration Voluntary Reporting of GHG Program. The compiled emission factors are summarized in Table 6-13.

Table 6-12. FOCA average emission factors by helicopter type

Helicopter Type	Fuel/ LTO (kg)	Emission Factors (lbs/LTO)									
		NO_X[1]	HC[1]	VOC[2]	CO[1]	PM_{10}[1]	$PM_{2.5}$[3]	SO_2[4]	CO_2[5]	N_2O[5]	CH_4[5]
Single	57.31	0.68	1.93	1.87	2.48	0.02	0.02	0.12	176.69	0.01	0.01
Twin Light	94.31	0.95	5.28	5.13	6.93	0.03	0.03	0.20	290.78	0.02	0.02
Twin Medium	134.45	1.95	4.13	4.01	5.33	0.06	0.06	0.29	414.51	0.03	0.03
Twin Heavy	327.03	8.82	2.76	2.68	3.43	0.22	0.22	0.70	1008.27	0.07	0.06

1 FOCA 2009
2 HC to VOC = * 0.9708
3 $PM_{2.5}$ = 97.6% of PM_{10}
4 SO_2 (g/gal) = (fuel density) × (conversion factor) × (64 g SO_2/32 g S) × (S content of fuel)
5 EIA 2012

The emission factors developed from this project were applied to the activity data to estimate emissions using the following equation:

$$E_i = EF_i / 2000 \times LTO_i$$

where:

E_i = Helicopter emisions for helicopter type i (tons per year)
EF_i = Helicopter emission factor for helicopter type i (pounds/LTO)
LTO_i = Landing and take off cycle for helicopter type i (cycles per year)
i = Helicopter type (i.e., single, light, or medium)
2000 = Conversion factor pounds per ton

Example Calculation:

The emission factor of NO_x for single engine helicopter is 0.6846 pounds/LTO, and the LTOs for single engine helicopters in 2011 were 908,654.

$$E_{Single} = EF_{Single} / 2000 \times LTO_{Single}$$

$$E = 0.6846/2000 \times 908,654$$
$$E = 217.72 \text{ tons of } NO_x$$

Table 6-13. Helicopter emission factors by helicopter and helicopter type

Type	Code	Aircraft ICAO	Aircraft Name	Engine Name	LTO fuel (kg)	LTO NO_X (g)	LTO HC (g)	LTO CO (g)	LTO PM non volatile (g)
Single	H001	ALO2	ALOUETTE II	ARTOUSTE IIC5	45.6	184	1055	1372	7
Single	H001	ALO2	ALOUETTE II	ARTOUSTE IIC6	45.6	184	1055	1372	7
Single	H001	ALO3	SA316B ALOUETTE III	ARTOUSTE IIIB	53.6	264	859	1106	9
Single	H001	ALO3	SA316B ALOUETTE III	ASTAZOU XIVB	54.9	278	835	1073	9
Single	H001	AS35	AS 350 B3	ARRIEL 2B	68.6	433	684	869	13
Single	H001	AS35	AS 350 B3	ARRIEL 2B1	68.6	433	684	869	13
Single	H001	AS35	AS 350 ECUREUIL	ARRIEL 1B	58.7	312	806	1033	10
Single	H001	AS35	AS 350B ECUREUIL	ARRIEL 1D1	63.1	364	745	951	12
Single	H001	AS50	AS 550 FENNEC	ARRIEL 1D1	63.1	364	745	951	12
Single	H001	B06	BELL 206B	DDA250-C20	45.5	183	1058	1376	7
Single	H001	B06	BELL 206B	DDA250-C20B	46.5	192	1027	1333	7
Single	H001	B06	BELL 206B	DDA250-C20J	46.5	192	1027	1333	7
Single	H001	B06	BELL 206B	DDA250-C20R	48.0	207	984	1276	7
Single	H001	B06	BELL 206B	DDA250-C20R/4	48.0	207	984	1276	7
Single	H001	B06	BELL 206L	DDA250-C20R	48.0	207	984	1276	7
Single	H001	B06	BELL 206L	DDA250-C30	59.1	317	799	1024	10
Single	H001	B06	BELL 206L	DDA250-C30P	59.1	317	799	1024	10
Single	H001	B407	Bell 407	DDA250-C47B	59.1	317	799	1024	10
Single	H001	EC20	EC 120	ARRIUS 2F	47.1	198	1009	1309	7
Single	H001	EC30	EC 130 B4	ARRIEL 2B1	68.6	433	684	869	13
Single	H001	EN48	ENSTROM 480	DDA250-C20W	46.5	192	1027	1333	7
Single	H001	GAZL	SA341 GAZELLE	ASTAZOU IIIA	58.8	314	804	1030	10
Single	H001	GAZL	SA341 GAZELLE	ASTAZOU IIIN2	58.8	314	804	1030	10
Single	H001	GAZL	SA342 GAZELLE	ASTAZOU XIVG	54.9	278	835	1073	9
Single	H001	GAZL	SA342 GAZELLE	ASTAZOU XIVH	54.9	278	835	1073	9
Single	H001	H500	HUGHES 500	DDA250-C18	41.2	145	1223	1601	6

Type	Code	Aircraft ICAO	Aircraft Name	Engine Name	LTO fuel (kg)	LTO NO_X (g)	LTO HC (g)	LTO CO (g)	LTO PM non volatile (g)
Single	H001	H500	HUGHES 501	DDA250-C20B	46.5	192	1027	1333	7
Single	H001	H500	MD 500N	DDA250-C20R	48.0	207	984	1276	7
Single	H001	KMAX	K-1200	T53 17A-1	108.1	945	573	716	27
Single	H001	LAMA	SA315B LAMA	ARTOUSTE IIIB	53.6	264	859	1106	9
Single	H001	MD52	MD 520N	DDA250-C20	45.5	183	1058	1376	7
Single	H001	MD60	MD 600N	DDA250-C47M	59.1	317	799	1024	10
Single	H002	UH1	BELL UH-1H	T53 L13	104.1	873	597	747	25
Single	H013	A119	AGUSTA A119	PT6B-37	71.1	466	661	838	14
AVERAGE of Single					57.3	310.5	873.7	1125.6	10.2
Twin Light	H001	A109	AGUSTA A109	DDA250-C20R/1	83.6	333	2654	3500	13
Twin Light	H001	A109	AGUSTA A109	PW207C	102.9	508	2172	2834	17
Twin Light	H001	A109	AGUSTA A109 K2	ARRIEL1K1	109.8	586	2007	2608	19
Twin Light	H001	A109	AGUSTA A109 Power	ARRIUS 2K	104.4	525	2131	2778	18
Twin Light	H001	A109	AGUSTA A109A II	DDA250-C20B	81.1	310	2770	3661	12
Twin Light	H001	A109	AGUSTA A109C	DDA250-C20R	83.6	333	2654	3500	13
Twin Light	H001	AS55	AS 355	DDA250-C20F	81.1	310	2770	3661	12
Twin Light	H001	AS55	AS 355 N	ARRIUS 1A	86.1	356	2550	3357	13
Twin Light	H001	AS55	AS 555 FENNEC	ARRIEL 1D1	107.7	562	2052	2669	19
Twin Light	H001	B06T	Bell TWIN RANGER	DDA250-C20R	83.6	333	2654	3500	13
Twin Light	H001	B105	BO 105	DDA250-C20	79.5	295	2857	3781	12
Twin Light	H001	B105	BO 105	DDA250-C20B	81.1	310	2770	3661	12
Twin Light	H001	B222	BELL 222	DDA250-C40B	108.0	565	2047	2662	19
Twin Light	H001	B222	BELL 222	LTS101-750C.1	109.5	583	2012	2615	19
Twin Light	H001	EC35	EC 135	ARRIUS 2B1	101.5	493	2209	2884	17
Twin Light	H001	EC35	EC 135	ARRIUS 2B2	101.5	493	2209	2884	17
Twin Light	H019	EXPL	MD 900	PW206A	100.6	483	2236	2921	17
Twin Light	H021	A109	AGUSTA A109E	PW206C	91.8	411	2348	3079	15

Type	Code	Aircraft ICAO	Aircraft Name	Engine Name	LTO fuel (kg)	LTO NO_X (g)	LTO HC (g)	LTO CO (g)	LTO PM non volatile (g)
AVERAGE of Twin Light					94.3	432.7	2394.7	3142.1	15.2
Twin Medium	H001	AS65	AS 365 C1 DAUPHIN	ARRIEL 1A1	102.2	500	2192	2860	17
Twin Medium	H001	AS65	AS 365 C2 DAUPHIN	ARRIEL 1A2	102.2	500	2192	2860	17
Twin Medium	H001	AS65	AS 365 N DAUPHIN	ARRIEL 1C	103.6	517	2152	2805	18
Twin Medium	H001	AS65	AS 365 N1 DAUPHIN	ARRIEL 1C1	106.8	552	2074	2699	18
Twin Medium	H001	AS65	AS 365 N3 DAUPHIN	ARRIEL 2C	117.7	680	1858	2404	22
Twin Medium	H001	B430	Bell 430	DDA250-C40B	108.0	565	2047	2662	19
Twin Medium	H001	BK17	BK117	ARRIEL 1E2	109.8	586	2007	2608	19
Twin Medium	H001	BK17	BK117 C-2	ARRIEL 1E2	109.8	586	2007	2608	19
Twin Medium	H001	BK17	BK117B	LTS101-750B.1	108.9	576	2026	2634	19
Twin Medium	H001	EC55	EC 155 B	ARRIEL 2C1	117.7	680	1858	2404	22
Twin Medium	H001	EC55	EC 155 B1	ARRIEL 2C2	126.0	783	1733	2235	25
Twin Medium	H001	S76	SIKORSKY S76	DDA250-C30S	102.9	508	2172	2834	17
Twin Medium	H001	S76	SIKORSKY S-76 C+	ARRIEL 2S1	119.1	696	1836	2374	22
Twin Medium	H002	A139	AGUSTA A139	PT6C-67C	149.2	901	2098	2703	29
Twin Medium	H002	H60	SIKORSKY BLACK HAWK	T700-GE-700	179.9	1369	1613	2054	41
Twin Medium	H002	MI8	MIL MI-8	TV2-117	173.0	1256	1698	2167	38
Twin Medium	H002	S92	SIKORSKY S92A	GE CT7-8A	242.4	2542	1173	1469	69
Twin Medium	H011	S76	SIKORSKY S76	PT6B-36A	128.9	820	1695	2183	26
Twin Medium	H014	B412	Bell 412	PT6T-3	190.0	1539	1509	1915	45
Twin Medium	HF30	AS32	SUPER PUMA	MAKILA 1A1	191.1	1559	1499	1901	46
AVERAGE of Twin Medium					134.4	885.6	1871.9	2418.9	27.3
Twin Heavy	H001	KA27	KA-32A12	TV3-117VMA	212.4	1945	1334	1681	55
Twin Heavy	H002	H53	SIKORSKY CH-53G (S-65)	T 64-GE-7	307.5	4024	967	1197	99
Twin Heavy	H002	H53S	SIKORSKY SUPER STALLION	T 64-GE-7	461.2	6036	1450	1795	148
AVERAGE of Twin Heavy					327.0	4001.6	1250.4	1557.6	100.7

The emission factors developed from this project were applied to the activity data to estimate emissions using the following equation:

$$E_i = EF_i / 2000 \times LTO_i$$

where:

E_i	=	Helicopter emisions for helicopter type i (tons per year)
EF_i	=	Helicopter emission factor for helicopter type i (pounds/LTO)
LTO_i	=	Landing and take off cycle for helicopter type i (cycles per year)
i	=	Helicopter type (i.e., single, light, or medium)
2000	=	Conversion factor pounds per ton

Example Calculation:

The emission factor of NO_x for single engine helicopter is 0.6846 pounds/LTO, and the LTOs for single engine helicopters in 2011 were 908,654.

$$E_{Single} = EF_{Single} / 2000 \times LTO_{Single}$$

$$E = 0.6846/2000 \times 908{,}654$$
$$E = 217.72 \text{ tons of } NO_x$$

No monthly helicopter data were identified in this effort; therefore it was assumed that activity was consistent through out the year therefore the annual emission estimates were temporally apportioned to individual months equally (i.e., 8.33%).

Helicopter emissions were assigned to lease blocks (USDOI, BOEM 2013c) with active platforms that have heliports (Figure 6-3), as most of the emissions associated with support helicopters occurs while the craft is near or at the platform. Spatial allocation of helicopter emissions was made using the equation below:

$$E_{Hi} = E_H \times (P_{Hi}/P_{HT})$$

where:

E_{Hi}	=	Support helicopter emissions associated with lease block i (tons)
E_H	=	Total helicopter emissions (tons)
P_{Hi}	=	Number of platforms with heliports in lease block i
P_{HT}	=	Total number of platforms with heliports

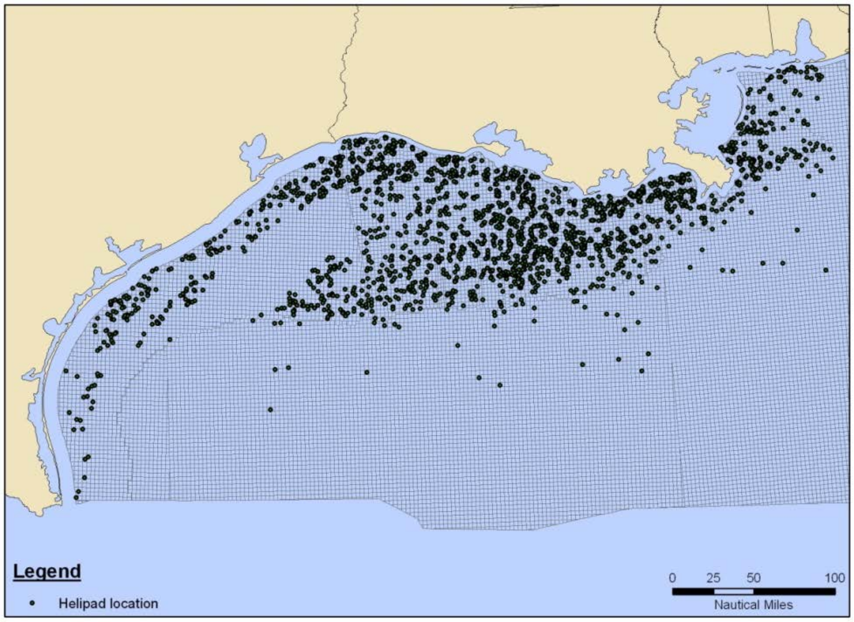

Figure 6-3. Location of active platforms with heliports

6.1.5 Support Vessels

Support vessels include crew boats that transport workers to and from work sites, supply vessels that carry supplies to offshore sites, and tug and tow boats that transport heavy equipment and supplies. Emissions associated with support vessels are attributed to the operation of the primary diesel engine used for propulsion and other smaller diesel engines that are used to run generators or small cranes and winches for loading and unloading the vessels.

Support vessel population data were derived from AIS data. The AIS data included 682 offshore oil and gas platform support vessels and associated vessel characteristics data including main engine power rating. Unfortunately, the time-stamped AIS data had data gaps and other issues that complicated accurate calculation of annual hours of operation. As a result, it was assumed that the support vessels operated in federal waters 70% of the time. For the remaining 30% of the time, these vessels are in state waters for refueling, loading supplies and equipment, unloading materials from the platforms, and for engine maintenance and repair activities. These operating assumptions result in 6,132 annual hours of operation in federal waters per vessel. Of these hours in federal waters, it was estimated that 85% of the time is spent at sea underway and 15% of the time is spent idling adjacent to the platform. Regulations require that support vessels cannot tie-up to platforms; instead, they idle nearby while offloading or loading cargo (McGill 2006).

Offshore support vessel load factors were provided by the U.S. Coast Guard National Offshore Safety Advisory Committee (McGill 2006). These load factors vary, with most of the time spent at 80% load while at-sea underway, and 10% load while idling adjacent to the platform.

The vessel population, engine kW rating, average hours of operation and typical load factor for the two modes (i.e., underway and at-sea idling) were used to calculate the total annual kW-hours associated with support vessels operate in federal waters (Table 6-14).

Table 6-14. Support vessel census, kW rating, and annual hours of operation

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
AARON S MCCALL	WDF5812	10,247	1,025	62,834,604
ABDON CALLAIS	WCY6640	1,175	745	7,205,100
ABIGAIL CLAIRE	WDC7550	2,942	745	18,040,344
ABIGAIL RICHE	WDE3336	1,492	300	9,148,944
ACCARDO	WDD6845	4,848	485	29,727,936
ACO ARTHUR A FORET	WDE4812	1,940	745	11,896,080
ACO DODIE LORRAINE	WDF9818	1,174	117	7,198,968
ACO ISAURE BIENVENU	WDD9103	1,174	117	7,198,968
ACO JESSICA MOORE	WDF7317	2,849	1,820	17,470,068
ACO KEITH DUGGAN	WDD5913	7,452	745	45,695,664
ACO LANDRY A GALIANO	WDF2329	2,237	117	13,717,284
ACO TOM-BIENVENU	WDD3253	1,940	745	11,896,080
ADA B CALLAIS	WDC9102	7,452	745	45,695,664
ADAMS CHALLENGE	2BQX7	10,400	139	63,772,800
ADAMS VISION	C6YG5	8,632	863	52,931,424
ADRIATIC	WDD7795	1,250	139	7,665,000
AEGEAN	WDD9236	1,268	139	7,775,376
AET DISCOVERY	WDE4530	1,653	139	10,136,196
AET HARRIS	WDE4530	1,653	165	10,136,196
AET INNOVATOR	WDF9351	2,087	204	12,797,484
AIDEN MITCHEL	WDB4507	1,029	103	6,309,828
AKIRA CHOUEST	WCV3741	8,049	1,500	49,356,468
ALEX CHOUEST	WCZ2532	11,186	1,119	68,592,552
ALEX G MCRAE	WDE9824	1,492	139	9,148,944
ALEX GROS II	WDD2670	1,250	73	7,665,000
ALIANCE IV	WDF7374	805	81	4,936,260
ALICE G MCCALL	WDE4782	6,715	73	41,176,380
ALICE G MCCALL	WDE4782	6,715	139	41,176,380
ALICIA SUE	WDC6370	820	82	5,028,240
AL-KAT	WDF7462	3,282	313	20,125,224
ALLIANCE III	WDF7376	805	81	4,936,260
ALLIANCE IV	WDF7374	805	81	4,936,260
ALLIE CHOUEST	KFHA	4,920	745	30,169,440
ALLIED ELEVATOR 2	WDD2679	447	45	2,741,004
ALLISON	WAS6653	2,648	745	16,237,536

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
ALYSSA CHOUEST	WDF9511	5,421	139	33,241,572
AM. CONSTITUTION	HP2029	5,884	139	36,080,688
AMBER	WDB5838	4,920	745	30,169,440
AMERICAN TRIUMPH	WDC7837	1,125	139	6,898,500
AMERICAN VICTORY	WDC7838	1,125	745	6,898,500
AMETHYST	WDA9537	1,386	139	8,498,952
AMPOL RECOVERY	WDC6338	492	49	3,016,944
AMPOL RESPONDER	WDC7028	634	63	3,887,688
ANDREA CHOUEST	WDE4574	4,920	139	30,169,440
ANGELLE CENAC	WDC2768	895	89	5,488,140
ANNA M	WDD3952	3,972	139	24,356,304
APOLLO TIDE	HQXJ5	1,653	165	10,136,196
ARCTIC	WDF2734	1,268	127	7,775,376
ASHTON T	WDIJ	1,141	114	6,996,612
BAILEY JANICE	WDC8399	52,457	5,246	3.22E+08
BASTIAN BAY	WDE3709	984	98	6,033,888
BAYOU BEE	WDE9861	2,982	900	18,285,624
BAYOU STATE	XCZ7836	4,848	485	29,727,936
BEE STING	WDF2238	2,982	900	18,285,624
BERTHA D	WDD2172	1,268	745	7,775,376
BETH E CHERAMIE	WDE6767	1,940	745	11,896,080
BETTY PFANKUCH	WDF7129	7,299	730	44,757,468
BEVERLY F	WCX2731	2,001	139	12,270,132
BJ DISCOVERY	WCY2843	2,515	139	15,421,980
BLANCHE CALLAIS	WDB8917	1,492	198	9,148,944
BLUE DOLPHIN	WDE9988	5,421	139	33,241,572
BLUE DOLPHIN	WDE9988	5,421	745	33,241,572
BLUE TARPON	WNSD	5,421	139	33,241,572
BLUE TARPON	WNSD	5,421	745	33,241,572
BOA SUB C	9HUC8	24,720	139	1.52E+08
BOTRUC 33	WDC3314	2,339	745	14,342,748
BOTRUC 39	WDB9134	2,386	139	14,630,952
BOTRUC 39	WDB9134	2,386	745	14630952
BOTRUC 41	WNSG	2,982	328	18,285,624
BOTRUC19	WDC3295	1,368	73	8,388,576
BRAWLER	WDC7608	2,248	139	13,784,736
BRAXTON PERRY	WDC6474	507	51	3,108,924
BRAZOS EXPRESS	WRB4886	1,368	139	8,388,576
BRODY PAUL	WDD2761	679	68	4,163,628

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
BROOK DANOS	WDC8122	477	48	2,924,964
BRUTUS	WBS4624	895	89	5,488,140
BULL SHARK	WDC8201	746	75	4,574,472
BUMBLE BEE	WRAJ	2,982	745	18,285,624
BUNNY BORDELON	WDA5139	1,103	139	6,763,596
BUSY BEE	WDE9328	3,432	900	21,045,024
BYWATER LUDLOW	WDD7098	1,030	103	6,315,960
C ACCLAIM	XCKH7	1,884	73	11,552,688
C CHALLENGER	WCX7953	2,515	745	15,421,980
C CONTENDER	WCY2600	2,515	745	15,421,980
C FIGHTER	WDE3604	4,920	139	30,169,440
C LEADER	WDB2505	4,920	745	30,169,440
C LEADER	WDB2505	4,920	139	30,169,440
C LEGEND	WDB3410	4,920	139	30,169,440
C LIBERTY	WDB7959	5,296	745	32,475,072
C MICHAEL CALLAIS	WCY6639	1,175	745	7,205,100
C TRUC 7	WDA5890	2,354	354	14,434,728
C TRUC NO 5	WDA5888	3,297	258	20,217,204
C TRUC NO 8	WDB7934	2,354	264	14,434,728
C_TRUCNO4	WDA5887	2,868	258	17,586,576
CADE CANDIES	WKBG	9,400	269	57,640,800
C-ADMIRAL	YJRL3	1,884	188	11,552,688
C-AGGRESSOR	YJRK3	1,884	188	11,552,688
CAITLYN A CALLAIS	WDD4558	1,940	745	11,896,080
CAL DIVER I	WYT8527	2,574	139	15,783,768
CAL DIVER II	WTS2811	1,368	139	8,388,576
CAL DIVER IV	WDB6118	1,061	139	6,506,052
CALLAIS EXPLORER	WDE6977	1,492	745	9,148,944
CALLAIS PROVIDER	WDF3277	1,268	350	7,775,376
CALLAIS SEARCHER	WDF5618	1,289	350	7,904,148
CALVIN BAYNE	WCX9824	2,796	745	17,145,072
CANDY BARREL	WDD4859	1,386	139	8,498,952
CANDY COUNTER	WDD8297	1,386	139	8,498,952
CANDY FACTORY	WDE2194	3,972	100	24,356,304
CANDY LAND	WDE5133	3,972	100	24,356,304
CAPE KALA KANE	WDE9703	2,207	745	13,533,324
CAPT JOHN E GRAHAM	WDC2329	7,452	745	45,695,664
CAPT LEVERT	WDA7416	3,972	745	24,356,304
CAPT.GLENN	WDA7528	3,972	139	24,356,304

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
CAPT.J.RIMES	WDC6696	507	51	3,108,924
CAPTAIN TIDE	WDB3662	1,368	224	8,388,576
CAPTAIN WHITEY GROS	WDE8889	3,748	745	22,982,736
CARL F. THORNE	WDB3673	9,032	73	55,384,224
CARLENE MCCALL	WDF4273	6,711	870	41,151,852
CAROL CHOUEST	WDD5159	4,920	745	30,169,440
CAROLINE G	WDC3113	1,324	139	8,118,768
CAROLINE MORRISON	WDC8384	1,368	139	8,388,576
CAROLYN CHOUEST	WCP5628	8,386	139	51,422,952
CASPIAN	WDF4690	1,268	127	7,775,376
C-CAPTAIN	WCW9590	2,515	139	15,421,980
C-CARRIER	WCY2601	2,515	745	15,421,980
C-CHALLENGER	WCX7953	2,515	745	15,421,980
C-CHARIOT	WCX7952	2,515	139	15,421,980
CCLIPPER	WCX6887	2,515	745	15,421,980
C-COMMANDER	WCX6345	1,118	139	6,855,576
CECELIA	WDF8451	2,501	139	15,336,132
CELENA CHOUEST	WDD9072	4,920	139	30,169,440
C-EXPRESS	WCZ2530	2,515	254	15,421,980
C-FIGHTER	WDE3604	4,920	139	30,169,440
C-FREEDOM	WDE2596	4,920	745	30,169,440
CGBM 101	Missing	1,653	0	10,136,196
CGBM 101	Missing	2,515	0	15,421,980
CGBM 102	Missing	1,653	0	10,136,196
CGBM 102	Missing	1,884	0	11,552,688
CGBM 102	Missing	4,631	198	28,397,292
CGBM 104	Missing	1,268	0	7,775,376
CGBM 104	Missing	1,653	0	10,136,196
CGBM 104	Missing	2,501	0	15,336,132
CHANTISE G	WDA3676	52,478	5,248	3.22E+08
CHARGER	WDF7227	1,214	745	7,444,248
CHARGER	WDD4671	1,214	121	7,444,248
CHARLES M CALLAIS II	WDE9170	1,940	745	11,896,080
CHARLIE BYCHURCH	WDE8486	1,250	745	7,665,000
CHARTRES	WDD3652	4,559	745	27,955,788
CHASE	WDF7418	3,533	139	21,664,356
CHERAMIE BOTRUC 34	WDC3315	2,339	745	14,342,748
CHERAMIE BOTRUC 40	WNAO	2,982	139	18,285,624
CHERAMIE BOTRUC22	WDC3313	1,368	745	8,388,576

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
C-HERO	WDA9706	3,800	745	23,301,600
CHLOE CANDIES	WXXP	4,969	139	30,469,908
CHRIS R	WDD9632	895	89	5,488,140
CHRISTIAN CHOUEST	WDC7173	4,920	492	30,169,440
CHRISTOPHER CALLAIS	WDA6993	1,940	198	11,896,080
CINDY BROWN TIDE	KCBE	5,050	139	30,966,600
CLAIRE CANDIES	WDE4319	7,140	232	43,782,480
CLAIRE M CALLAIS	WDB8162	2,351	510	14,416,332
CLARA_B	WBR6261	1,434	73	8,793,288
CLAY ELLA	WDB7446	1,767	745	10,835,244
C-LEGACY	WDB6654	4,920	745	30,169,440
C-LIBERTY	WDB7959	5,296	139	32,475,072
CLIPPER	WDF7572	883	745	5,414,556
COASTAL MARINER	WDF4037	843	84	5,169,276
COLIN B MCCALL	WDB5803	3,972	139	24,356,304
CONTENDER	WDD2409	895	89	5,488,140
CORCOVADO	WDE6916	5,421	139	33,241,572
COREY CAL LAIS	WCY6638	1,193	119	7,315,476
C-PERFORMER	WCZ6248	2,530	139	15,513,960
C-PROMOTER	WCZ5472	2,530	254	15,513,960
CRAIG MICHAEL	WDF7392	507	51	3,108,924
CROSBY SUN	WDA3843	730	73	4,476,360
C-ROVER	WCZ4365	2,515	745	15,421,980
C-ROVER	WCZ4365	2,515	745	15,421,980
C-TRUC 6	WDA5889	2,354	354	14,434,728
D-32 STEVEN	WAA9413	52,619	5,262	3.23E+08
DAKOTAH BILL	WDD2009	2,207	139	13,533,324
DAMON B. BANKSTON	WHDB	7,505	745	46,020,660
DANCER	WDC7846	2,412	139	14,790,384
DANIELLE CALLAIS	WDE2794	2,315	745	14,195,580
DANTE	KUGY	4,920	246	30,169,440
DAVID ADAMS	WDC7610	870	87	5,334,840
DAVID B	WDE7890	895	89	5,488,140
DEEP BLUE RESPONDER	WBO8585	1,881	139	11,534,292
DEEP SEA CHAMPION	WDA9673	1,368	139	8,388,576
DEEPSTIM BRASIL I	WDSQ	5,421	500	33,241,572
DELTA RUNNER	WDA6057	4,119	403	25,257,708
DIAMOND BACK	WDE6773	298	30	1,827,336
DICTATOR	WDF7930	4,851	150	29,746,332

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
DIONNE CHOUEST	WDC5617	4,920	139	30,169,440
DIP	WDF2482	477	48	2,924,964
DISCOVERY	WDF8208	1,837	745	11,264,484
DMO PAPPY	WDF8105	2,485	745	15,238,020
DRAKE	WDC4654	883	139	5,414,556
DRONE BEE	WDBE	2,982	900	18,285,624
DRY TORTUGAS	Error	1,837	184	11,264,484
DUSTIN_DANOS	WDE9077	1,342	134	8,229,144
DUTCHMAN	WDE9761	5,372	403	32,941,104
DWIGHT S. RAMSAY	WDF6858	7,299	139	44,757,468
DYLAN JOHN	WCX2736	2,574	139	15,783,768
EDIE LAB	WDF9375	2,574	139	15,783,768
ELIZABETH A. MCCALL	WDB7558	4,028	139	24,699,696
ELIZABETH A. MCALL	WDB7558	4,028	139	24,699,696
ELLA G	WDE9523	5,421	139	33,241,572
ELSA LEIGH	WDB3416	2,207	745	13,533,324
EMILY ANN	WDF8996	1,368	161	8,388,576
EMILY BORDELON	WDE5150	716	72	4,390,512
EMILY CANDIES	WDC5786	4,784	227	29,335,488
EMILY G	WDB3034	1,250	745	7,665,000
ENTERPRISE 1	WDE2858	1,368	139	8,388,576
EPIC EXPLORER	WDD4415	1,653	139	10,136,196
EPIC SEAHORSE	WCZ9485	1,653	139	10,136,196
ESPLANADE	WDD3650	4,559	321	27,955,788
FAST BANDIT	WDA5724	1,386	139	8,498,952
FAST BULLET	WDA8488	1,386	139	8,498,952
FAST CAJUN	WDD5116	4,854	139	29,764,728
FAST GIANT	WDF6212	5,999	540	36,785,868
FAST GOLIATH	WDF7625	5,999	540	36,785,868
FAST MAMMOTH	WDF9442	5,999	540	36,785,868
FAST SAILOR	WCX7184	4,854	492	29,764,728
FAST SCOUT	WDE3301	4854	5,246	29,764,728
FAST SKIPPER	WDE6367	4,854	139	29,764,728
FAST TEAM	WDE6231	5,999	139	36,785,868
FAST TRACK	WDE4610	4,996	139	30,635,472
FAST VIKING	WDE9537	5,399	139	33,106,668
FATHERJOHNKELLER	WDD3254	1,268	127	7,775,376
FOX	WDC7535	1,618	119	9,921,576
GALAXIE	V7VR6	2,868	300	17,586,576

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
GARY CHIASSON	WDF2244	403	40	2,471,196
GARY CHOUEST	WCY7287	2,868	139	17,586,576
GAVEA	WDE5320	5,421	139	33,241,572
GAVEA	WDE5320	5,421	139	33,241,572
GAYLA GRAHAM	WDD9662	5,369	73	32,922,708
GENIE LAB	WPAG	3,842	1,275	23,559,144
GERTIE C	WDE8134	1,653	745	10,136,196
GIS BLAKLEY	WDF9706	2,001	139	12,270,132
GIS-VAYDA	WDF9376	1,175	73	7,205,100
GIS-VAYDA	WDF9376	1,175	139	7,205,100
GLOBAL ORION	YJVL7	9,499	139	58,247,868
GLOBAL PIONEER	WCW9255	2,939	139	18,021,948
GLOMAR PRIDE	HP8229	1,386	139	8,498,952
GLORIA B CALLAIS	WDB5625	2,315	510	14,195,580
GLORIA B CALLAIS	WDB5625	2,386	239	14,630,952
GRAND SLAM	WDD9838	921	92	5,647,572
GRANT	WDE2204	2,248	139	13,784,736
GRANT CANDIES	WDE5747	7,899	139	48,436,668
GRANVILLE C MCCALL	WDB5848	6,619	139	40,587,708
GREATER SCOTT	WDE2875	3,580	139	21,952,560
GREEN PROVIDER	WDD3558	1,809	745	11,092,788
GREG DANOS	WDA6017	1,331	73	8,161,692
GULF GRACE	WDA8201	1,386	139	8,498,952
GULF HERO	WDE7093	3,033	139	18,598,356
GULF HONOR	WDC3481	4,028	139	24,699,696
GULF INFLUENCE	WDE9705	1,653	745	10,136,196
GULF MAJESTY	WDC7277	3,819	73	23,418,108
GULF PRINCESS	WDE7880	5,369	170	32,922,708
GULF PROTECTOR	WDD4853	5,369	139	32,922,708
GULF QUEST	WDE6227	1,492	157	9,148,944
GULF SPIRIT	WDB4859	3,972	139	24,356,304
GULF TIGER	WNSE	5,050	505	30,966,600
GULF VICTORY	WDA9647	730	73	4,476,360
GULF WIND	WDB5836	1,368	139	8,388,576
GUY C.	WDD6387	1,029	103	6,309,828
HANNAH CHOUEST	WDD4129	4,920	139	30,169,440
HANNAH RAY	WDE4972	4,119	139	25,257,708
HARLAN S MCCALL	WDD7531	5,034	139	30,868,488
HARRY JOSEPH	WDB7449	994	745	6,095,208

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
HARVEY EXPLORER	WDB4217	3,372	745	20,677,104
HARVEY PROVIDER	WDB2506	3,324	745	20,382,768
HARVEY CARRIER	KRTQ	3,650	850	22,381,800
HARVEY DISCOVERY	WDC9728	3,494	139	21,425,208
HARVEY SPIRIT	WDD4830	4,516	139	27,692,112
HARVEY SUPPLIER	WDAW	4,579	745	28,078,428
HARVEY SUPPORTER	WDF9689	7,299	500	44,757,468
HERCULES	WDC5161	57,833	5,783	3.55E+08
HILDA LAB	WKDT	3,839	1,275	23,540,748
HOLLIE MARIE	WDC2042	1,044	104	6,401,808
HOLLIE MARIE	WDC2042	1,044	104	6,401,808
HOMERUN	WDE2977	1,386	139	8,498,952
HONDO RIVER	WCZ2334	4,231	745	25,944,492
HORIZON RUNNER	WDE4930	4,701	160	28,826,532
HOS ACHIEVER	YJVG4	11,880	139	72,848,160
HOS BEAUFORT	WDD9064	3,091	298	18,954,012
HOS BRIMSTONE	WDA8419	3,722	73	22,823,304
HOS BYRD	WDD9065	3,091	745	18,954,012
HOS CENTERLINE	KYBZ	8,399	1,275	51,502,668
HOS CORAL	WDE6625	5,050	1,420	30,966,600
HOS CORNERSTONE	WCZ5505	2,942	745	18,040,344
HOS DAKOTA	WCY8949	2,942	294	18,040,344
HOS DAKOTA	XCRF7	2,942	294	18,040,344
HOS DAVIS	WDD9066	3,091	745	18,954,012
HOS DOMINATOR	WDA6788	3,310	745	20,296,920
HOS EXPLORER	WDB4530	7,452	745	45,695,664
HOS EXPRESS	WDB4532	2,868	745	17,586,576
HOS INNOVATOR	WDA4032	3,372	745	20,677,104
HOS IRON HORSE	YJQR3	11,536	139	70,738,752
HOS LODE STAR	WDE7090	2,485	73	15,238,020
HOS MYSTIQUE	WDE3118	4,700	139	28,820,400
HOS NORTH STAR	WDE3119	2,982	1,020	18,285,624
HOS PINNACLE	WDF2604	4,700	139	28,820,400
HOS PIONEER	WDB4533	3,432	298	21,045,024
HOS POLESTAR	WDE3121	2,985	1,020	18,304,020
HOS RIDGEWIND	WDA6136	4,988	139	30,586,416
HOS SANDSTORM	WDA8997	6,780	506	41,574,960
HOS SHOOTING STAR	WDE3120	2,985	745	18,304,020
HOS SILVER ARROW	WDE8275	5,050	298	30,966,600

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
HOS SILVERSTAR	WDB5655	3,310	745	20,296,920
HOS STORMRIDGE	WDA8996	4,987	745	30,580,284
HOS SUPER H	WCY8159	2,942	745	18,040,344
HOS SWEET WATER	WDE8276	2,942	1,050	18,040,344
HOS THUNDERFOOT	WCY8948	2,942	745	18,040,344
HOS WILDWING	WDF2606	4,700	447	28,820,400
HOS WINDANCER	WDF2605	4,700	745	28,820,400
IBERVILLE	WDD3651	4,559	139	27,955,788
IMILOA	WDC7061	1,653	745	10,136,196
INDEPENDENCE	WDA6136	4,988	139	30,586,416
INEZ EYMARD	WDF3099	447	45	2,741,004
INFANT JESUS PRAGUE	WDF2951	2,237	117	13,717,284
INGRID	WDF2598	4,920	139	30,169,440
INSPIRATION	WCX7141	2,515	745	15,421,980
INT L DIAMOND	WDD8333	895	89	5,488,140
INT.__TITAN	WDD6675	895	89	5,488,140
INTL ANGEL	WDF6119	4,848	485	29,727,936
INT'L BRAVE	WDF5644	1,454	145	8,915,928
INT'L FALCON	WDD7424	895	89	5,488,140
INT'L FORCE	WDF3679	447	45	2,741,004
INTL GENERAL	WDD9533	925	92	5,672,100
INT'L HUNTER	WDD9571	895	89	5,488,140
INT'L QUEEN	WDF5514	4,848	485	29,727,936
INT'L RAIDER	WDE9276	702	139	4,304,664
INTL SEARCHER	WDD4667	895	89	5,488,140
INTL THUNDER	WDD6674	1,386	139	8,498,952
INT'L TRADITION	WDD6853	895	89	5,488,140
INT'L TROOPER	WDD8509	895	89	5,488,140
INTL VOYAGER	WDD6746	1,386	139	8,498,952
IPANEMA	WDE7991	5,999	139	36,785,868
IRENE B.	WDC8280	1,268	745	7,775,376
ISAAC J CALLAIS	WDA8444	1,940	198	11,896,080
ISLAND ENFORCER	YJRG2	20,123	2,012	1.23E+08
ISLAND PIONEER	LDJN	10,441	1,044	64,024,212
J.F.JETT	WDB9235	2,868	499	1,7586,576
JA/SON	WDE2622	883	139	5,414,556
JAMBON SUPPLIER	WDC9502	1,703	153	10,442,796
JAMIE G	WSA6608	1,368	745	8,388,576
JANSON R GRAHAM	WDF4127	5,700	570	34,952,400

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
JASON K MCCALL	WDA4730	4,965	139	30,445,380
JEAN GILBERT	WDB7444	1,767	745	10,835,244
JEAN PIERRE LAB	WDE9670	3,788	1,275	23,228,016
JEFFREY D	WDD3237	1,368	745	8,388,576
JENNY MCCALL	WDC3101	5,372	139	32,941,104
JESSICA LYNSIE	WDC4480	895	89	5,488,140
JOANNE MORRISON	WDE6218	2,207	139	13,533,324
JOE GRIFFIN	WDF3170	5,421	745	33,241,572
JOEL PAUL	WDC 286	1,940	745	11,896,080
JOHN B MARTIN MCCALL	WCY7082	5,958	139	36,534,456
JOHN G MCCALL	WDD4719	6,619	580	40,587,708
JOHN P LAB	WCY9737	2,942	340	18,040,344
JONATHAN KING BOYD	WDF7273	4,848	485	29,727,936
JOSEPH G	WDF9637	5,369	537	32,922,708
JOSEPHINE K MILLER	WDE9978	883	745	5,414,556
JOSHUA CANDIES	WJCD	1,386	269	8,498,952
JUDY FRANCES	WDF2927	2,207	745	13,533,324
JUSTIN CALLAIS	WCZ5803	1,767	198	10,835,244
K MARINE 22	WDD5117	2,315	139	14,195,580
K MARINE 7	WDA6850	2,574	745	15,783,768
KARLA F	WDE3008	1,268	139	7,775,376
KATRINA FAGAN	WDA8008	3,542	745	21,719,544
KELLY MORRISON	WDC7532	1,678	139	10,289,496
KERRY GROS	WDE8301	1,368	745	8,388,576
KESTREL	YJUW5	7,054	705	43,255,128
KIM B	WDD8579	870	87	5,334,840
KINGFISHER	YJVA3	3,198	73	19,610,136
KLINE DANOS	WDC4083	2,207	745	13,533,324
K-MARINE VI	WDC8531	2,574	73	15,783,768
KNOCKOUT	WDE2978	7,452	745	45,695,664
KOBE CHOUEST	WDB9562	4,920	139	30,169,440
KOLBY D	WDD3077	1,030	139	6,315,960
KRISTIN FAGAN	WCY2612	2,796	745	17,145,072
KRISTIN FAYE	WDD2885	343	34	2,103,276
KURT DAVID	WDA3186	1,368	139	8,388,576
KYLIE D	WDD3078	1,491	149	9,142,812
KYLIE WILLIAMS	WDD5998	2,460	745	15,084,720
L\B MR. ALAN	WDC2932	1,119	112	6,861,708
LA LOUSIANA	WDC8128	1,653	745	10,136,196

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
LACHNEY TIDE	WDF4527	1,368	745	8,388,576
LADY MADI	WDB6145	2,059	206	12,625,788
LADY OF LA SALETTE	WDF5883	2,852	188	17,488,464
LAUREN LACOSTE	WDD9102	1,250	198	7,665,000
LEADER	WDD2064	895	89	5,488,140
LEE ADAMS	WDC7434	679	68	4,163,628
LEEZA RENED'	WDE3011	2,207	745	13,533,324
LINDA	WDB7799	941	745	5,770,212
LOOP LIFTER	WYQ7524	1,653	139	10,136,196
LOOP SECURITY	WCX3304	883	139	5,414,556
LOUISIANA RESPONDER	WBO8576	2,237	224	13,717,284
LOUISIANA RESPONDER	WBO8576	2,237	139	13,717,284
LUCAS JOHN	WDB6767	1,368	139	8,388,576
LUKE THOMAS	WDE7707	969	426	5,941,908
LYMAN MARTIN	WNSA	4,920	139	30,169,440
MACY LYN	WDD9845	343	34	2,103,276
MADISON	WDC6635	895	89	5,488,140
MAHI MAHI	WDC6569	597	60	3,660,804
MAKO	WDD7791	761	100	4,666,452
MAKO	WDE3476	5,372	139	32,941,104
MALOY.G	WYB7318	52,464	5,246	3.22E+08
MANRESA	WDD5766	1,492	300	9,148,944
MARC C	WDC9503	895	89	5,488,140
MARCELLE BORDELON	WDC7864	1,103	139	6,763,596
MARIE ELISE	WSAC	5,050	850	30,966,600
MARY DIANE MCCALL	WDC8407	671	67	4,114,572
MASCO 6	WSF6561	895	89	5,488,140
MASCO ENDEAVOR	WDC2519	730	73	4,476,360
MASON BEE	WMBY	3,432	900	21,045,024
MATT	WCW8997	895	89	5,488,140
MATTHEW D MCRAE	WDF5979	1,268	127	7,775,376
MEG L SKANSI	WDDL	1,250	139	7,665,000
MELINDA B. ADAMS	WCZ2666	1,125	745	6,898,500
MIA	WDD2870	4,920	139	30,169,440
MIA MALOY	WDC7436	895	89	5,488,140
MIDNIGHT STAR	YJXM9	5,296	139	32,475,072
MIKE HOOKS	WDE9086	4,848	485	29,727,936
MISS AMANDA	WCV5696	2,059	139	12,625,788
MISS ANGIE	WDF4652	1,386	139	8,498,952

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
MISS BET	WDB7803	1,500	139	9,198,000
MISS DARLENE	WCY6597	2,574	139	15,783,768
MISS EMMA JO	WDD3627	1,492	139	9,148,944
MISS FAYE	WDB7810	1,500	150	9,198,000
MISS FLO	WDB7986	1,061	139	6,506,052
MISS GINGER	WDC9604	1,653	139	10,136,196
MISS LILLY	WDC4352	1,324	745	8,118,768
MISS LINDA LEE	WDE5415	4,119	139	25,257,708
MISS MEGAN	WDC7706	1,434	198	8,793,288
MISS PAM	YYT4728	1,500	150	9,198,000
MISS PEARL	WCV5666	2,324	73	14,250,768
MISS PEGGY ANN	WCV5664	1,500	139	9,198,000
MISS SAIDY	WDB7056	1,912	499	11,724,384
MISS WYNTER	WDD9362	1,500	139	9,198,000
MISSISSIPPI RESPONDE	WBO8584	2,237	139	13,717,284
MONICA ANN	WDE7047	5,050	139	30,966,600
MONICA W CALLAIS	WDF5042	1,883	1,820	11,546,556
MOTHER TERESA	WDC6424	1,250	745	7,665,000
MOTHER TERESA	WDC6424	1,250	745	7,665,000
MR ALEX	WDE3593	537	54	3,292,884
MR DINO	WDF4396	870	87	5,334,840
MR JOE	WDE8716	686	69	4,206,552
MR LANNIE	WDB3903	7,452	745	45,695,664
MR LIONEL	WDE4348	1,492	300	9,148,944
MR LLOYD	WDB9843	4,413	139	27,060,516
MR SEAMAN	WCZ3468	3,972	139	24,356,304
MR VICK	WDB5123	7,452	745	45,695,664
MR. ANDRE	WDC8896	597	60	3,660,804
MR. COLBY	WDE2343	1,103	745	6,763,596
MR. J.O.	WDC5062	4,475	73	27,440,700
MR. JESSIE	WCX6476	2,515	139	15,421,980
MR. MURVIN	WDE2316	2,248	139	13,784,736
MR. SIDNEY	WKAH	4,920	139	30,169,440
MR. SIDNEY	WKAH	4,920	745	30,169,440
MR.HENRY	WDB2323	1,386	139	8,498,952
MR.JAKE	WDF4254	2,427	139	14,882,364
MS ADRIENNE	WDC2869	2,427	139	14,882,364
MS ALISSA	WDC8737	895	89	5,488,140
MS JESSICA	WDE8982	3,972	139	24,356,304

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
MS JILL	WDE9603	5,369	537	32,922,708
MS JOY	WCY2036	3,972	139	24,356,304
MS JOYCE	WDF4282	1,066	150	6,536,712
MS MADISON	WDA5301	917	92	5,623,044
MS MARY	WDF5767	1,386	139	8,498,952
MS MEGGIE	WDF9903	1,250	745	7,665,000
MS MELISSA	WDF5504	1,175	198	7,205,100
MS PEARL	WDB6990	730	73	4,476,360
MS RAMONA	WDB4731	1,386	139	8,498,952
MS RUBY	WCZ9439	3,972	139	24,356,304
MS TAMI	WDD5843	1,193	119	7,315,476
MS TAYLOR	WDC9501	2,051	205	12,576,732
MS VIRGIE	WDE6282	4,920	139	30,169,440
MS YVONNE	WDF6477	5,999	470	36,785,868
MS. LAUREN	WDE7317	5,296	745	32,475,072
MS. MARY	WCX2042	1,066	73	6,536,712
MS. MARY	WCX2042	1,066	745	6,536,712
MS. MEGAN	WDE3441	1,044	104	6,401,808
MS. JANE	WAS5900	52,466	5,247	3.22E+08
MS. JOLIE	WDB3176	2,942	73	18,040,344
MS. KRISTIE	WDE5516	5,969	139	36,601,908
MS. LISA	WDD3043	52,464	5,246	3.22E+08
MS. MAGGIE	WCZ7255	1,653	745	10,136,196
MS. MIA	WDD7039	4,848	485	29,727,936
MS. MONICA	WDC2757	1,846	185	11,319,672
MS. NANCY	WDB6287	4,413	139	27,060,516
MSROBIN	WCT9171	1,703	73	10,442,796
MYSTIC VIKING	C6HC5	3,972	73	24,356,304
MYSTIC VIKING	C6HC5	3,972	139	24,356,304
NICHOLAS C	WDE8986	1,175	745	7,205,100
NICHOLAS P CALLAIS	WDF3930	1,883	188	11,546,556
NICK L SKANSI	WOEA	1,250	745	7,665,000
NICKI CANDIES	WDE5761	7,140	232	43,782,480
NOAH J CALLAIS	WDB5266	1,193	119	7,315,476
NOAH J CALLAIS	WDB5266	1,193	119	7,315,476
NOAH J CALLAIS	WDB5266	3,530	745	21,645,960
NOONIE G	WDC9901	1,029	103	6,309,828
NORBERT BOUZIGA	WDF2074	4,922	139	30,181,704
NORMAND COMMANDER	LNPW3	7,499	139	45,983,868

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
NORMAND FORTRESS	LIKW3	7,499	745	45,983,868
NORMAND PACIFIC	2EKX3	15,999	1,600	98,105,868
NRC ADMIRAL	WCC8506	883	139	5,414,556
NRC ENERGY	WDB5151	883	139	5,414,556
NRC QUEST	WDF7619	1,250	127	7,665,000
OCEAN CARRIER	YJRH8	5,999	139	36,785,868
OCEAN INSPECTOR	WDB7674	1,250	127	7,665,000
OCEAN INTERVENTION	WCY4505	4,709	139	28,875,588
OCEAN INTERVENTION 2	WCZ7505	2,985	139	18,304,020
OCEAN INTERVENTION 3	LMWK	11,408	139	69,953,856
OCEAN PATRIOT	WBAH	5,440	139	33,358,080
OCEAN PROJECT	WDF6447	3,530	1,700	21,645,960
OCEAN QUEST	WDB2700	1,175	280	7,205,100
ODYSSEA CHAMPION	WDE6600	3,432	745	21,045,024
ODYSSEA DARWIN	WDE2876	1,940	745	11,896,080
ODYSSEA DEFENDER	WDE7022	3,432	745	21,045,024
ODYSSEA DILIGENT	WDE6273	1,250	300	7,665,000
ODYSSEA EXPLORER	WDD4728	1,103	745	6,763,596
ODYSSEA FORCE	WDF8169	1,492	745	9,148,944
ODYSSEA GOLD	WDE8097	2,849	1,500	17,470,068
ODYSSEA RANGER	WDD5847	1,175	745	7,205,100
ODYSSEA TITAN	WDF8168	2,663	745	16,329,516
ODYSSEA TREK	WDD6220	806	745	4,942,392
ODYSSEA*DIAMOND*	WDE4687	2,999	745	18,389,868
OLIVIA RAE	WDD2252	2,460	139	15,084,720
OLYMPIC CHALLENGER	LAEY7	15,150	139	92,899,800
OLYMPIC INTERVENTION	LAFQ3	10,000	139	61,320,000
OLYMPIC TRITON	LADM3	10,020	1,002	61,442,640
OP CALLAIS	WDB6392	1,492	745	9,148,944
ORLEANS	WDD3648	4,559	745	27,955,788
OSV GLORIA MARIA	WDE6549	1,119	112	6,861,708
PAO DE ACUCAR	WDE8602	4,920	745	30,169,440
PAT TAYLOR	WDD3152	3,372	745	20,677,104
PAUL CALLAIS	WCY6856	1,175	139	7,205,100
PAULA MCCALL	WDE8306	6,715	320	41,176,380
PAULINE T	WCS2857	1,044	104	6,401,808
PENNY F	WDE3007	1,268	745	7,775,376
PENNY F	WDE3007	1,268	139	7,775,376
PETER CALLAIS	WCY7925	1,193	119	7,315,476

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
PEYTON CANDIES	WTAF	7,452	269	45,695,664
PHILIP ALAN MCCALL	WDB7424	5,958	139	36,534,456
PIPER	WDE6779	1,007	101	6,174,924
POPE BENEDICT XVI	WDE6443	1,940	745	11,896,080
POPE JOHN PAUL II	WDC7969	1,250	198	7,665,000
PORT EADS	WDD9878	1,268	745	7,775,376
PREDATOR	WDF6591	5,034	150	30,868,488
PRESIDENT TIDE	WDF4522	1,728	745	10,596,096
Q4000	WDA6676	21,121	139	1.3E+08
QB	WAM2522	895	89	5,488,140
QUEEN BEE	WKIR	3,432	900	21,045,024
R J COCO MCCALL	WDF6648	11,521	1,024	70,646,772
R.E.B. BORDELON	WDC9776	477	48	2,924,964
R/V GEOEXPLORER	WDA6456	1,379	139	8,456,028
R/V PERSISTENCE	WDD3089	574	73	3,519,768
R\V RACHEL CARSON	WDF9370	1,386	139	8,498,952
RACHEL CALLAIS	WCZ7017	1,767	198	10,835,244
RACHEL CALLAIS	WCZ7017	52,466	5,247	3.22E+08
RAM CHALLENGER	WCX5838	2,560	745	15,697,920
RAM 7	WBN3003	507	51	3,108,924
RANA MILLER	WDE7064	1,103	745	6,763,596
RANDALL B MCCALL	WDB4219	5,369	139	32,922,708
RAYMOND M	WDC4224	5,296	73	32,475,072
RED LAB	WCY7791	2,942	340	18,040,344
REM FORZA	LASA	6,957	745	42,660,324
REM POSEIDON	C6YF2	9,698	139	59,468,136
REMORA	WDC6572	671	67	4,114,572
RENE	WDF4268	1,795	745	11,006,940
RESOLVE PIONEER	WDD8846	4,289	139	26,300,148
RESPONSE RUNNER	WDC4923	4,701	160	28,826,532
RMS CITATION	WDD5362	1,767	139	10,835,244
RMS CITATION	WDD5362	1,767	745	10,835,244
ROMANDA SUE	WDB9492	671	67	4,114,572
ROSEANNA	WDB3630	1,703	139	10,442,796
ROSITE G	WDF8455	956	139	5,862,192
ROSS CANDIES	WDF2225	9,400	269	57,640,800
ROSS CHOUEST	WCW7550	8,093	139	49,626,276
ROXANNE B MCCALL	WDB6977	3,972	139	24,356,304
ROYAL	WDD3653	4,559	745	27,955,788

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
RUSTY EYMARD	WDB4289	2,985	745	18,304,020
RW ARMSTRONG	WDE3706	984	98	6,033,888
RYAN CHOUEST	WDC6796	2,515	745	15,421,980
SAILFISH	WDD6170	5,296	139	32,475,072
SALLY B	WDC6964	895	89	5,488,140
SANTEE	WDF6486	3,001	139	18,402,132
SARAH BORDELON	WDC7198	1,103	745	6,763,596
SEA ANGEL	WDE5879	3,580	139	21,952,560
SEA BROOKE	WDC3114	1,703	745	10,442,796
SEA CECILE	WDC6244	1,703	745	10,442,796
SEA HORSE VI	WDB7467	1,103	745	6,763,596
SEA LEGEND	J8AA5	1,030	745	6,315,960
SEA SERVICE 1	WDF9972	1,491	149	9,142,812
SEA TROUT	WDC6577	671	67	4,114,572
SEABULK NEBRASKA	WDF9501	3,091	745	18,954,012
SEABULK WISCONSIN	WCY6329	3,091	745	18,954,012
SEABULK ACADIA	WCV2233	2,427	139	14,882,364
SEABULK CARMEN	WDC3918	1,940	745	11,896,080
SEABULK KANSAS	WDE4694	3,091	745	18,954,012
SEABULK ST CHARLES	YYT4727	2,651	265	16,255,932
SEACOR CONQUEST	WDA9650	3,091	745	18,954,012
SEACOR MADISON	WDD5977	3,544	740	21,731,808
SEACOR PRIDE	WDB7465	2,982	745	18,285,624
SEACOR QUEST	WDB7813	1,250	125	7,665,000
SEACOR RELENTLESS	WCZ6034	5,346	745	32,781,672
SEACOR RELIANT	WCZ2533	5,346	745	32,781,672
SEACOR RIGOROUS	WCZ9586	5,344	537	32,769,408
SEACOR SPIRIT	WCY3195	2,868	139	17,586,576
SEACOR WASHINGTON	WDD5978	3,542	740	21,719,544
SECRETARIAT	WDA4396	1,472	745	9,026,304
SETH MCCALL	WDB769	5,296	139	32,475,072
SIEM SWORDFISH	LAKN3	8,632	139	52,931,424
SIMON JR	WDC8941	662	139	4,059,384
SISTER CLAIRE	WDE7329	2,237	745	13,717,284
SISTER MARY ROLAND	WDC4512	7,452	745	45,695,664
SKANDI ACHIEVER	C6WC7	9,879	139	60,578,028
SKANDI NEPTUNE	LASG5	10,260	139	62,914,320
SKIPPIN SUE	WDC6842	1,029	103	6,309,828
SKYE FALGOUT	WDF3199	1,656	745	10,154,592

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
SLAM DUNK	WDE2559	452	745	45,695,664
SLAP SHOT	WDE2976	7,452	745	45,695,664
SOUTHER STAR	WDF3098	5,372	537	32,941,104
SOUTHERN BELLE	WDE7492	5,372	537	32,941,104
SOUTHERN COMET	WDD5209	4,919	139	30,163,308
SOUTHERN CROSS	KRTF	5,050	850	30,966,600
SOUTHERN QUEST	WCZ5544	2,868	340	17,586,576
SOUTHERN SEAHORSE	WCX6191	1,250	150	7,665,000
SOUTHERN SPIRIT	WDC4087	4,631	139	28,397,292
SPENCER PHILIP	WDE7248	1,193	119	7,315,476
SPT DEFENDER	WDC6636	1,653	139	10,136,196
SPT PROTECTOR	WDC6637	1,653	73	10,136,196
SPT VICTORY	WDE2255	1,653	139	10,136,196
ST IGNATIUS LOYOLA	WDD7860	1,492	198	9,148,944
ST JOSEPH THE WORKER	WDF8656	2,237	224	13,717,284
ST LOUIS	WDD3646	4,559	745	27,955,788
ST MARTIN DE PORRES	WDD6206	1,250	300	7,665,000
STARFLEET PATRIOT	WDA7014	2,795	139	17,138,940
STARFLEET VIKING	WDE8934	4,475	418	27,440,700
STEPHANIE MORRISON	WDB5472	1,986	139	12,178,152
STIM STAR 3	WDA7484	3,753	139	23,013,396
STORM	WDF8260	5,669	402	34,762,308
STRIKER	WDE7237	3,825	139	23,454,900
SUE LEON LAB	WDE6715	4,201	73	25,760,532
SUN RIVER	WDE6902	1,809	139	11,092,788
SUPERIOR FORTITUDE	WDA5229	529	53	3,243,828
SUPERIOR LEGACY	WDA5243	671	67	4,114,572
SURF CHALLENGER	WDF5385	7,299	745	44,757,468
SUSAN	WBC4105	671	67	4,114,572
SWORDFISH	WDE3480	5,296	139	32,475,072
TAMPA SEAHORSE	WDC5373	1,250	745	7,665,000
TEMAN	WDD4228	883	139	5,414,556
TERRY BORDELON	WDA5140	1,103	745	6,763,596
TEXAS RESPONDER	WBO8579	2,237	139	13,717,284
THUNDER AMERICA	WDD5310	1,521	152	9,326,772
TIFFANY LOUISA	WDD6944	746	75	4,574,472
TIGER	WDE3248	4,848	485	29,727,936
TIGER	WDE3479	5,296	139	32,475,072
TIM MCCALL	WDB5746	2,501	139	15,336,132

Vessel Name[a]	Call Sign	Main kW	Aux kW	kW-HR
TODD G	WDF8454	1,118	139	6,855,576
TOUCHDOWN	WDE2561	3,365	745	20,634,180
TOULOUSE	WDC5354	4,559	745	27,955,788
TRADEWIND	WDE6438	1,723	139	10,565,436
TRANSPORTER	WDD3838	895	89	5,488,140
TRINITY I	WDF3138	1,007	101	6,174,924
TRISTAN JANICE	WDC3975	895	89	5,488,140
TRITON CRUSADER	WCE3923	2,207	139	13,533,324
TRITON FREEDOM	WDF2983	1,434	139	8,793,288
TRITON LIBERTY	WDF4755	679	68	4,163,628
TRITON PATRIOT	WDF4756	1,631	139	10,001,292
TYLER STEPHEN	WDE8720	3,130	850	19,193,160
UNIVERSAL SURVEYOR	WBB8829	1,386	139	8,498,952
US CUSTOMS M759	Missing	579	58	3,550,428
USAV BRANDY STATION	AADU	1250	139	7,665,000
VIKING POSEIDON	LFKP	15,300	139	93,819,600
WARREN THOMAS	WDD7841	1,268	139	7,775,376
WES BORDELON	WDA5141	1,103	745	6,763,596

[a] Vessel information is provided by ship operators and may contain errors.

To estimate the emissions for each support vessel, the annual kilowatt hours of operation were applied to the USEPA emission factors provided in Table 6-1. An example of how the equation in Section 6.1.1 was used for this vessel category is provided below.

Example Calculation:

$$E = AH \times kW \times LF \times EF \times CF$$

where:

E	=	Emissions (tons)
AH	=	Annual hours per mode of operation (underway, maneuvering, hoteling) (hours)
kW	=	Average vessel kW (totaling individual propulsion engines) (kW)
LF	=	Engine load factor for specified mode of operation (%)
EF	=	Emission factor (g/kWH)
CF	=	Conversion factor (g = 1.10231 E-6 ton)

In 2011, a support vessel spent 5,212.2 hours operating underway at sea in the GOM. Its main engine has a kW rating of 3,034 kW, the load factor is 0.8, and the emission factor for NO_x is 14.08 g/kWh.

$$E = 5{,}212.2 \times 3{,}034 \times 0.80 \times 14.08 \times 1.10231 \times 10^{-6}$$
$$E = 196.35 \text{ tons of } NO_x$$

Support vessel monthly emissions were estimated by applying a monthly adjustment factor (Table 6-13) to the annual emission estimates. Monthly AIS vessel traffic data were reviewed for these vessels and activity levels seem to be consistent throughout the year, therefore, annual emission estimates were temporally apportioned to individual months equally (i.e., 8.33%).

AIS support vessel locations were mapped in a GIS, and a density grid was calculated to develop an overall activity grid from a series of point locations. The BOEM lease blocks were overlaid on top of the density grid to obtain the proportion of activity that occurred within each block. Support vessel emissions were then spatially apportioned to lease blocks based on the density of activity within each block.

$$E_{SVi} = E_{SV} \times (S_{li}/S_{lt})$$

where:

E_{SVi} = Support vessel emissions associated with lease block i (tons)
E_{SV} = Total underway emissions associated with support vessels (tons)
S_{li} = Density of support vessel activity within the boundaries of the lease block i
S_{lt} = Total sum of all support vessel activity densities in GOM federal waters

Figure 6-4 shows the support vessel density derived from AIS data. As anticipated, activity is highest near the coast where vessels are approaching port areas and also in regions where active platforms are located.

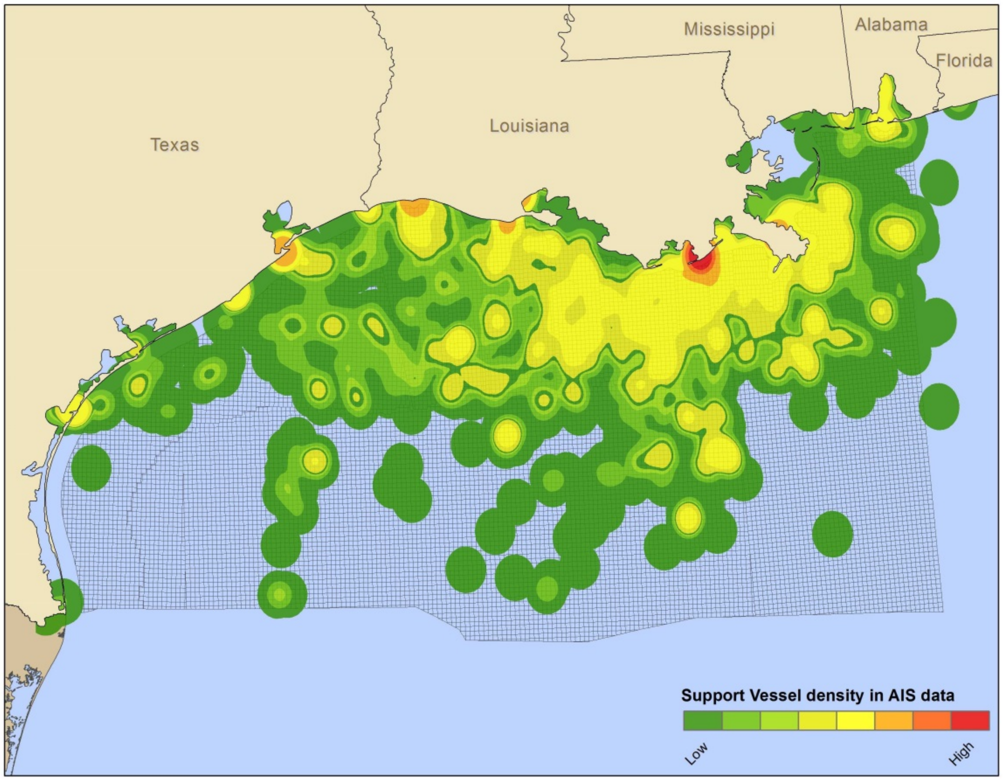

Figure 6-4. Support vessel activity in the GOM

6.1.6 Survey Vessels

Survey vessels are used in the GOM to map geologic formations and seismic properties. These survey mapping activities are needed to evaluate potential oil reserves. The most common survey technique uses blasts from underwater air guns. The sound waves from the air gun blasts are deflected by underground geologic strata and detected by sound wave receptors trailed behind the survey vessel (Figure 6-5). There are two types of surveys that can be performed: two dimensional (2-D) and three dimensional (3-D). 3-D surveys are the dominant and preferred exploration technique in the GOM. Most modern survey vessels tow multiple streamers (sound wave reception devices), such that for every linear mile traveled, they acquire data for a square mile of subsurface area (Brinkman 2002).

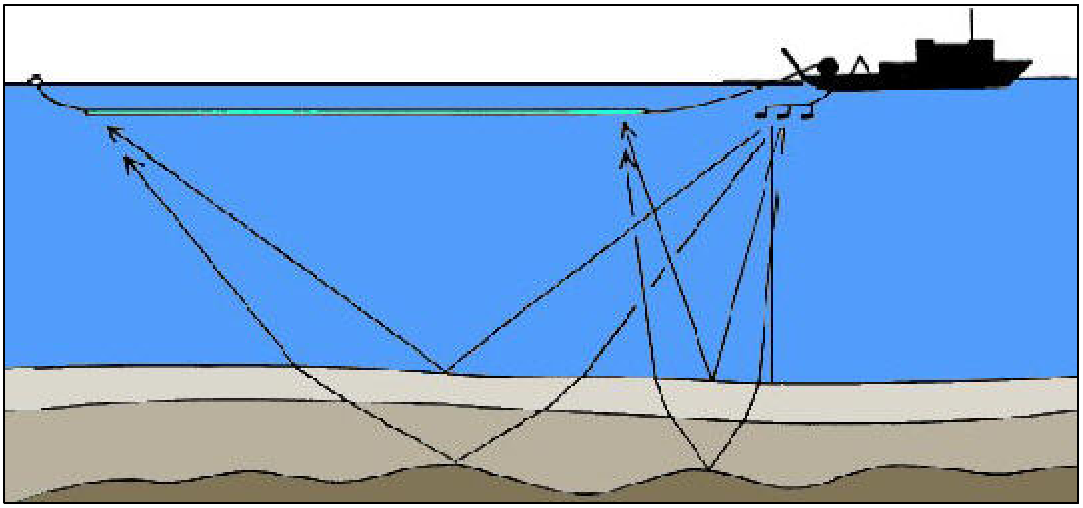

Figure 6-5. Typical geophysical survey vessel operations

Attempts were made to obtain survey vessel data from the vessel operators. For the *Year 2005 Gulfwide Emission Inventory Study* (Wilson et al. 2007), the operators provided data for only 6 of the 16 survey vessels. Therefore, survey vessel data were developed by using average characteristics of the 6 vessels and applying them to the remaining 10 vessels. For the 2008 inventory effort, one operator provided additional data about their fleet. The data also indicated that survey vessels remain at sea for longer periods of time than previously estimated, in fact, vessels remaining at sea for all but a few days of the year. Supply and crew changes occur by helicopters or supply boats. Accounting for the longer period of time that vessels remain at sea increased the estimated hours of operation associated with these vessels. For this 2011 inventory effort, 16 additional survey vessels were identified that were located primarily in the GOM (Penn Well 2012).

The survey vessel information included the number of continuous days the vessel could operate before heading back to port. The average number of continuous days was 62. It was assumed the vessel would need a week at port to be re-supplied and maintained. Therefore, it was estimated that in one year survey a vessel typically was at sea for approximately 328 days and in port for approximately 37 days. With 31 survey vessels, it was assumed that collectively all survey vessels operated at sea for 238,821 hours. Of the 31 survey vessels, the power ratings were known for 19 of the survey vessels. The average power rating for survey vessels was 2,039 kW. These engines are assumed to be medium-speed diesel engines, and the load factor was assumed to be 90%, which was obtained from the *Gulf of Mexico Air Quality Study* (Systems Applications International et al. 1995).

Emissions associated with survey vessels are primarily from marine diesel engines used for propulsion and to provide electricity and compressed air to operate the survey equipment. Emissions were estimated by applying the activity hours and load factors to the marine engine emission factors provided in Table 6-1.

Emission estimates were developed using the approach discussed in Section 6.1.1. An example of how the equation in Section 6.1.1 was used for this vessel category is provided below.

***Example Calculation*:**

$$E = AH \times kW \times LF \times EF \times CF$$

where:

E	=	Emissions (tons)
AH	=	Annual hours per mode of operation (underway, maneuvering, hoteling) (hours)
kW	=	Average vessel kW (totaling individual propulsion engines) (kW)
LF	=	Engine load factor for specified mode of operation (%)
EF	=	Emission factor (g/kWH)
CF	=	Conversion factor (g = 1.10231 E-6 ton)

Total hours of operation of all survey vessels were 238,821. The average kW is 2,039, load factor is 0.90, and the emission factor for NO_x is 16.25 g/kWh.

$$E = 238{,}821 \times 2{,}039 \times 0.90 \times 16.25 \times 1.10231 \times 10^{-6}$$
$$E = 7{,}851.5 \text{ tons of } NO_x$$

No monthly survey data were identified in this effort; it was assumed that activity was consistent throughout the year, therefore, annual emission estimates were temporally apportioned to individual months equally (i.e., 8.33%).

Because survey data are considered proprietary, emissions were allocated to each lease block based on the surface area of the lease block, as noted in the following equation:

$$E_{Si} = E_S \times (S_{ii}/S_{ti})$$

where:

E_{Si}	=	Survey vessel emissions associated with lease block i (tons)
E_S	=	Total survey vessel emissions (tons)
S_{ii}	=	Surface area of lease block i (square miles)
S_{ti}	=	Total surface area of all inactive lease blocks (square miles)

6.2 OTHER NON-PLATFORM SOURCES

6.2.1 Biogenic and Geogenic Emissions

The primary biogenic and geogenic sources of air pollution that were evaluated for this study are: subsurface seeps of crude oil, subsurface seeps of natural gas (including methane hydrates), and emissions from bacterial processes and ocean processes. In the previous inventory effort, credible emission estimates could only be developed for VOC subsurface seeps of oil and N_2O from bacterial processes. Published studies were reviewed to determine if any new data sources were available to improve the 2008 emission estimates for these source categories. No additional references were uncovered that provided new data specific for the Central and Western areas of the GOM, nor were any references identified that could be used to enhance the 2008 biogenic/geogenic emission estimates. Given the nature of these emission sources, the 2008 estimates were used to represent 2011 emissions.

Subsurface Seeps of Crude Oil

Subsurface seeps, more commonly referred to as oil seeps, occur when crude oil deposits beneath the ocean floor escape into the ocean waters because of cracks and vents in the sea bed. These cracks and vents open and close as the result of geological activities. The volume of oil seeping into the ocean can be relatively significant. The total quantity of oil that is released into the ocean does not, however, find its way to the surface and end up as air emissions. Some ocean-dwelling biota develop communities surrounding oil seeps that use the hydrocarbons as a source of nutrients. Other free floating organisms in the water column consume portions of the escaping oil as the material rises to the surface. Although these processes do mitigate the amount of oil that reaches the surface for possible volatilization, there is significant uncertainty and variability on the amounts of hydrocarbons consumed. After the seepage is on the surface, air pollutants, including VOC, CH_4, CO_2, and organic air toxics can be emitted through evaporation. Based on the data found in the literature, only VOC emissions can be estimated at this time.

BOEM and other researchers have conducted a significant amount of work to study the extent of oil seepage in the GOM and off the coast of California. Much of this investigation has focused on the occurrence of communities of chemosynthetic organisms and oil slicks. Estimates have been made of the total quantity of oil seeping into various ocean waters based on studies of oil slicks both at the ocean level and from satellite and space shuttle photography. These data have been input to models capable of estimating overall oil seepage rates. Crucial variables in the models include wind speed, oil layer thickness, and the oil degradation half-life. Over the last 10 years, several different and sometimes highly variable estimates of total oil seepage into the GOM have been prepared. With improvements in remote sensing technology, better estimates are being made possible. Some of the work places oil seepage in the northern Gulf at $2.5–6.9 \times 10^5$ barrels/yr (Mitchell et al. 1999). Converting to tons, the average estimate of seepage in the northern Gulf is 73,000 tons/yr.

Using this figure, emissions can be estimated using either the oil seepage emission factor (105 lbs of VOC/barrel oil released) developed by the California Air Resources Board (CARB 1993) or the average mass volatilization from oil slicks predicted by the BOEM open ocean weathering model (USDOI, MMS 1998). One model prediction showed that after 10 days time, 34% of the oil mass from a slick would have evaporated. The application of these methods results in similar mass emission estimates as shown below.

1) 73,000 tpy × 294 gal/ton × 1 bbl/42 gal × 105 lbs/bbl = ~26,827 tons/yr VOC

2) 73,000 tpy × 0.34 = 24,820 tons/yr VOC

For the purposes of this BOEM non-platform inventory an average of the two estimates was used (25,823.5 tons/yr). It should also be noted that none of the studies provided accurate definitions of the Northern Gulf, such that it was not possible to map the study area to BOEM lease blocks. In which case, it is assumed that these emission estimates are for the whole Northern Gulf area. When adjusted to represent only the Central and Western Gulf, the VOC emissions were 13,561 tpy.

Bacterial Processes

Bacterial process sources include plankton producing dimethylsulfide (DMS) and sediment bacteria producing methane. DMS released from protozoa and zooplankton has been linked to the formation of tropospheric aerosols and cloud condensation nuclei, which can result in negative influences on global warming (Gabric et al. 1993). Estimates of DMS flux from the GOM range from 9.2 μmol/m^2/day (in January) to 13.8 μmol/m^2/day (in July). Note, DMS is not one of the pollutants included in this study. As described previously, sediment bacteria methane generation and potential atmospheric release is not well characterized and cannot be estimated for the purposes of this inventory.

N_2O, a potent greenhouse gas, is produced in hypoxic coastal zones by deep-water bacteria, and is transferred to the atmosphere through upwelling and air-sea transfer mechanisms (Nevison et al. 1995). The large nitrogen inputs and deoxygenation typical of these hypoxic systems create the potential for large N_2O emissions (Walker et al. 2010). Bouwman et al. (1995) compared several earlier inventories of ocean N_2O to create a gridded annual N_2O inventory available as part of the Global Emission Inventory Activity (GEIA) data set. Based on this information, total annual emissions for the GOM study area have been estimated to be 3,710 tons N_2O as nitrogen (N) /Year. When adjusted to represent only the Western and Central Gulf, the N_2O estimate is 1,948 tons per year.

Mud Volcanoes

Mud volcanoes are submarine formations that emit gases or liquids. The gases they release often contain CH_4, CO_2, and VOCs. Four mud volcanoes have been identified in the GOM (Kohl and Roberts 1994). As information about the pollutant release rates for each volcano were not readily available, data concerning typical volumetric emission release rates for mud volcanoes were obtained from a study performed by Dimitrov (2003). The Dimitrov study also provided speciation values to allow for estimation of the CH_4, CO_2, and VOC releases. The volume of CH_4, CO_2, and VOC were converted to mass emissions using the chemical density of each pollutant. Most VOC emitted from mud volcanoes are higher carbon compounds such as isobutane, so the isobutane density was used as a surrogate for the VOC mass emission estimate. Adjustments were made to the methane estimate to account for the observation that 80% of the

CH_4 emitted by mud volcanoes is consumed by biologic organisms as reported by Zhang and Noakes (2006). The emission estimates and locations of the mud volcanoes are noted Table 6-15.

Table 6-15. Mud volcano locations and emission characteristics

Location	Typical Emission Rate (M^3/yr)	CH_4 Fraction (%)	CO_2 Fraction (%)	VOC Fraction (%)
Garden Banks Block 382	3.60E+06	90	8	2
Green Canyon Block 143	3.60E+06	90	8	2
Green Canyon Block 272	3.60E+06	90	8	2
Mississippi Canyon Block 929	3.60E+06	90	8	2

It was assumed that all biogenic/geogenic emissions are consistent throughout the year, therefore, annual emission estimates were temporally apportioned to individual months equally (i.e., 8.33%).

Previously, biogenic/geogenic emissions were applied to all lease blocks based on the surface area of each lease block; the exception being the mud volcanoes, their emissions were assigned to the lease block where the volcano was located. For this 2011 inventory effort, biogenic/geogenic emissions were allocated based on surface area of lease blocks containing evidence of seepage or leakage activity using the equation below:

$$E_{bgi} = E_{bg} \times (S_i/S_{TNG})$$

where:

E_{bgi} = Biogenic/geogenic emissions associated with lease block i (tons)
E_{bg} = Total biogenic/geogenic emissions for GOM (tons)
S_i = Surface area of lease block i (square miles)
S_{TG} = Surface area of total Gulf lease blocks (square miles)

BOEM's 2011 Seismic Water Bottom Anomalies dataset was used to identify areas that containing evidence of activity (US DOI BOEM 2012). This study provided information about anomalies in the seabed that would indicate seepage or underwater explosions related to the release of hydrocarbons. These anomalies were mapped in GIS and joined to the lease block grid in order to specify which lease blocks contained activity (Figure 6-6). It was assumed that if a lease block does not contain an anomalies than there is no evidence of biogenic/geogenic activity in that lease block and emission were not be mapped to these lease blocks. Note this approach does not quantify the magnitude or the temporal period of the release, but it does identify locations where there is no evidence of activity providing an improvement over the previous methodology.

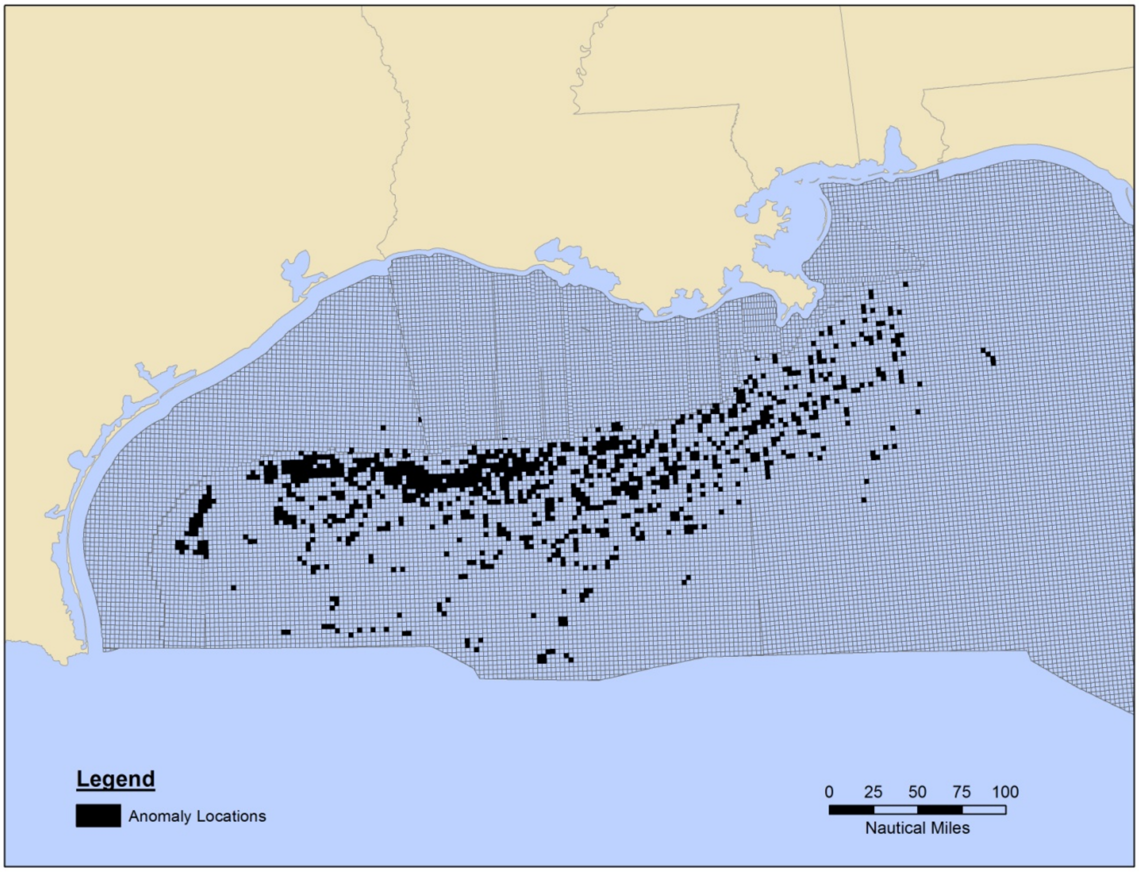

Figure 6-6. Locations of negative anomalies and pockmarks

6.2.2 Commercial Fishing Vessels

The GOM is an active commercial fishing area, providing a wide range of fish and seafood products. Detailed commercial fishing data were obtained from the NOAA NMFS. Separate activity data were provided for the three types of offshore fishing activities that occur in the GOM: pelagic long line, reef, and shrimp operations (Maiello 2012; Farmer 2012; Nance 2012).

The activity data for these different fishing operations were provided as latitude and longitude for pelagic long line fishing operations, and in terms of NMFS statistical zones for reef and shrimp fishing operations. The activity data for shrimp and reef fish operations are presented in Table 6.16 and Table 6.17, respectively. (The line fishing activity data includes over 3,000 records, and cannot be provided in a hardcopy format.)

Table 6-16. Shrimp vessel activity data

NMFS Zones	2011 Shrimp Fishing Vessel Hours
10 - 12	137,747
13 - 17	808,432
18 - 21	516,779
Total	1,462,957

Table 6-17. Reef fishing vessel activity data

NMFS Zones	2011 Reef Fishing Vessel Hours
11 - 21	3,944

Emissions associated with commercial fishing vessels are attributed to the operation of diesel engines used for propulsion and other smaller diesel engines that are used to run generators or small cranes and winches to lift nets and lines onto the vessel. To estimate emissions from operating these diesel engines, the emission factors provided in Table 6-1 were used.

Assumptions about typical fishing vessel horsepower (300 HP) for pelagic long line fishing vessels were obtained from the *Gulf of Mexico Air Quality Study* (Systems Applications International et al. 1995). Average fishing vessel horsepower for reef (382 HP) and shrimp vessels (558 HP) were obtained by taking the average horsepower of the 2008 permitted shrimp vessels and reef fish vessels (Dudley 2012). These typical horsepower ratings were converted to kilowatts to match the units of the USEPA emission factors. The typical operating loads were assumed to be 80% for underway operations, and 10% for maneuvering while setting the nets (Systems Applications International et al. 1995). These load factors were applied to the rated kW of the typical vessel engines and the total annual hours operation presented in Table 6-16 and 6-17 to get kilowatt hours which was used to calculate emissions for this source category using the approach discussed in Section 6.1.1. An example of how the equation in Section 6.1.1 was used for this vessel category is provided below.

***Example Calculation*:**

$$E = AH \times kW \times LF \times EF \times CF$$

where:

E	=	Emissions (tons)
AH	=	Annual hours per mode of operation (underway, maneuvering, hoteling) (hours)
kW	=	Average vessel kW (totaling individual propulsion engines) (kW)
LF	=	Engine load factor for specified mode of operation (%)
EF	=	Emission factor (g/kWH)
CF	=	Conversion factor (g = 1.10231 E-6 ton)

Shrimp fishing vessels spent 1,462,957 hours at sea in 2011. The average kW is 416.268, load factor is 0.80, and the emission factor for NO_x is 12.35 g/kWh.

$E = 1,462,957 \times 416.268 \times 0.80 \times 12.35 \times 1.10231 \times 10^{-6}$
$E = 6,629.67$ tons of NO_x

Commercial fishing activities vary monthly depending on fishing season. In order to quantify temporal variations, monthly adjustment factors were calculated based on NOAA monthly fisheries landing data for 2011. The monthly adjustment factors were applied to the annual emission estimates to calculate the monthly emissions. The monthly adjustment factors are presented in Table 6-18.

Table 6-18. Commercial fishing monthly adjustment factors

Month	2011 Monthly Adjustment Factors (%)
January	3
February	2
March	2
April	3
May	10
June	13
July	17
August	17
September	13
October	11
November	5
December	3

Commercial fishing locations were also provided by the NMFS. Reef and shrimp fishing operations are delineated by NMFS statistical zones (Figure 6-7). For line fishing operations, operating hours were estimated based on the assumption that it takes approximately 24 hours to tend each set. The Southeast Fisheries Science Center (SFSC) (Maiello 2012) provided latitude and longitude coordinates for line fishing operations. Emissions were spatially allocated for these three activities by overlaying a GIS plot of BOEM lease blocks onto a map of NMFS and SFSC location data. Commercial fishing emission estimates for reef and shrimp fishing operations were spatially allocated using the following formula:

$$E_{CFi} = E_{CFz} \times (S_i/S_{CFz})$$

where:

E_{CFi} = Commercial fishing emissions for lease block i (tons)
E_{CFz} = Commercial fishing emissions for NMFS area z (tons)
S_i = Surface area of lease block i (square miles)
S_{CFz} = Total surface area of NMFS area z (square miles)

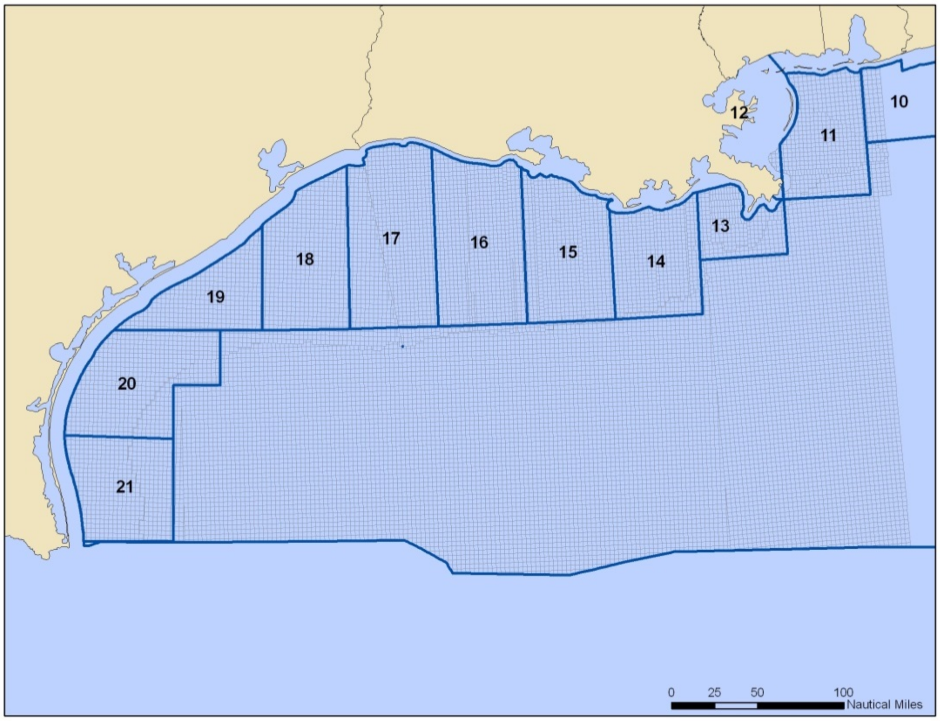

Figure 6-7. NMFS fishing zones with lease blocks

Where a lease block was included in two NMFS areas, the assignment was made proportional to the area of the NMFS zone that the lease block occupied. For example, lease block AB is split between NMFS zones 12 and 13. 75% of lease block AB is included in zone 12 and 25% of lease block AB is in zone 13. In this example, emissions associated with NMFS zones 12 and 13 would be split in lease block AB, proportional to the area with which each zone is associated. Line fishing emissions were assigned to individual lease blocks based on the latitude and longitude coordinates provided by SFSC and the estimated hours of operation.

6.2.3 Commercial Marine Vessels

Commercial marine vessels (CMV) are involved in transporting a wide range of agricultural, manufacturing, and chemical products through the GOM. The majority of CMVs tend to be powered by diesel engines that combust marine diesel fuel or a blend of distillate and residual oils. For vessels operating in the Gulf in 2011, AIS data were evaluated to determine whether the data could be used to estimate emissions from vessels that transit the central and western areas of the GOM. AIS tracks vessel movements in federal and state waters within range of VHF transmitting stations. The vessel transmitters send a signal every two seconds that documents vessel identification codes, radio call signs, location, direction, and speed. PortVision was commissioned to compile simplified data sets for this inventory effort. The first data set included all “event” data: instances where a vessel was first detected by each transmitter as the vessel transited the area of interest. The intent was to connect the events for each vessel and map individual transits to calculate vessel speed and hours of operation for a bottom-up activity estimate. However, the event data contained too many inconsistencies and irresolvable errors, such as repeat events and missing data points, to be useful in this effort.

The AIS data were compared with the U.S. Army Corps of Engineers Entrance and Clearance data for Gulf ports to assess the completeness of the commercial marine vessel fleet included in the AIS dataset. The two datasets were comparable, but the entrance and clearance data seems to be slightly more complete as it included smaller freight movement vessels that didn't trigger the AIS reporting requirements. The Entrance and Clearance data were used to quantify hours of operation by mapping the length of the routes in federal waters between the ports the vessels visited, divided by their reported cruising speed; adjustments were made for time spent transiting state waters. Hours of operation were applied to the vessels power rating to get kilowatt-hours. For block-level activity, the kilowatt-hours from all transits within the lease block were summed.

Emission estimates were developed using the approach discussed in Section 6.1.1. An example of how the equation in Section 6.1.1 was used for this vessel category is provided below.

Example Calculation:

$$E = \text{kW-hr} \times LF \times EF \times CF$$

where:

E	=	Emissions (tons)
kW-hr	=	Summed activity for the lease block (kW-hr)
LF	=	Engine load factor for specified mode of operation (%)
EF	=	Emission factor (g/kWH)
CF	=	Conversion factor (g = 1.10231 E-6 ton)

Category 3 CMV activity in BOEM lease block AC1002 was summed to be 633,363 kW-hrs. The load factor for Category 3 underway is 80% and the emission factor for NO_x is 19.54 g/kW-hr.

$$E = 633{,}363 \times 0.8 \times 19.54 \times 1.10231 \times 10^{-6}$$
$$E = 10.93 \text{ tons of } NO_x$$

The second data set obtained from PortVision (AIRSIS 2012) consisted of "snapshot" files of vessel name, Maritime Mobile Service Identity (MMSI), number call sign, vessel type, and position of all vessels within the Gulf at a single point in time for each month of the year. Vessel type was corrected and gap-filled using several datasets including those from Lloyd's of London and the Coast Guard vessel logs. These "snapshot" files were examined for seasonality in vessel activity throughout the year. No seasonal trends were detected either overall or by vessel type.

The snapshot files were then compiled to develop vessel traffic contours for each vessel type (e.g., tanker, containership, support vessel) that were used to spatially allocate emissions. This was accomplished by using GIS to develop density grids of the vessel point locations from the compiled snapshot files for each major vessel type. This approach was useful in demonstrating the different traffic profiles by vessel type; these density grids are shown in Figures 6-8 to 6-14.

However, because some vessel types had few vessels on which the density grid was created, there were gaps in coverage in the study area. To ensure a more robust spatial allocation, the AIS data were reprocessed to provide three activity density grids: one for Category 3 commercial marine vessels, which included different tankers, cargo ship, bulkers and containerships, etc.; one for Category 1 and 2 vessels developed from tug data; and one for support vessel.

6.2.4 LOOP

The LOOP is a platform located 45 miles from shore (Figure 6-16). This offshore port allows large oil tankers to unload product without having to enter and maneuver inside urban ports. The LOOP consists of several emission sources, one 1,000 kW generator, four 7,500 hp pumps, support vessels, as well as the oil tankers that use the facility. The engine characteristics for combustion sources located on the LOOP platform, including kW rating, load factors, and hours of operation are summarized in Table 6-19.

Table 6-19. LOOP hours of operation, kW rating, and load factors

Vessel/Equipment Type	Hours of Activity	Average kW	Load Factor
Generator	8,566	1,000	0.50
Pumps	3,300	22,371	1.00

The tankers and support vessels associated with the LOOP were included in the AIS data sets and were not calculated separately. However, vessels also emit VOCs through evaporative losses from tanker ballasting operations. Ballasting consists of pumping water into a vessel after the product has been removed, providing increased stability for the tanker. Because evaporative emissions from ballasting were not accounted for in the AIS-based data but were calculated in this effort. 2011 data were not available, 2008 data were adjusted to represent 2011 activity levels.

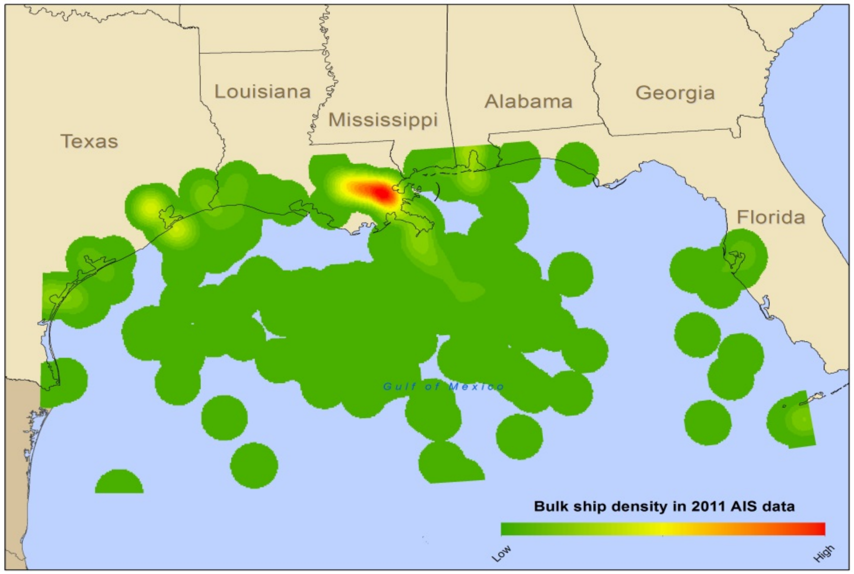

Figure 6-8. Vessel traffic density in bulkers

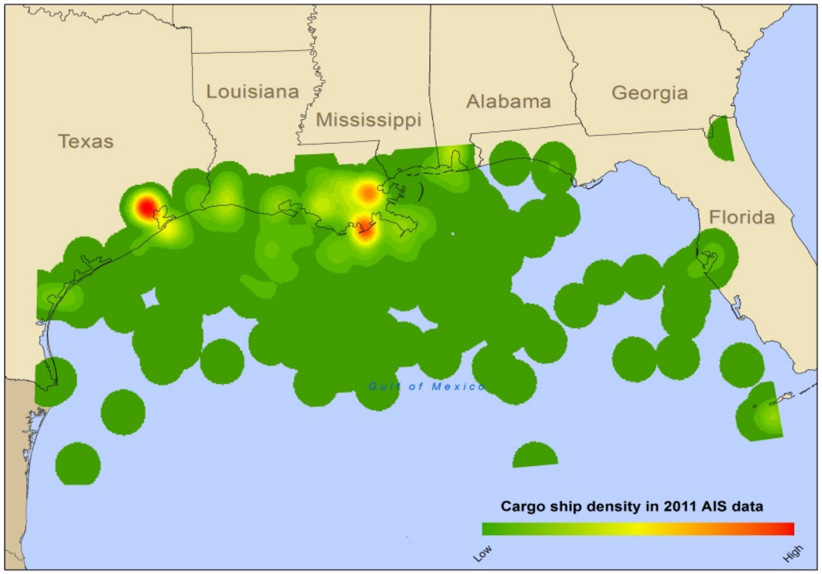

Figure 6-9. Vessel traffic density in cargo ships

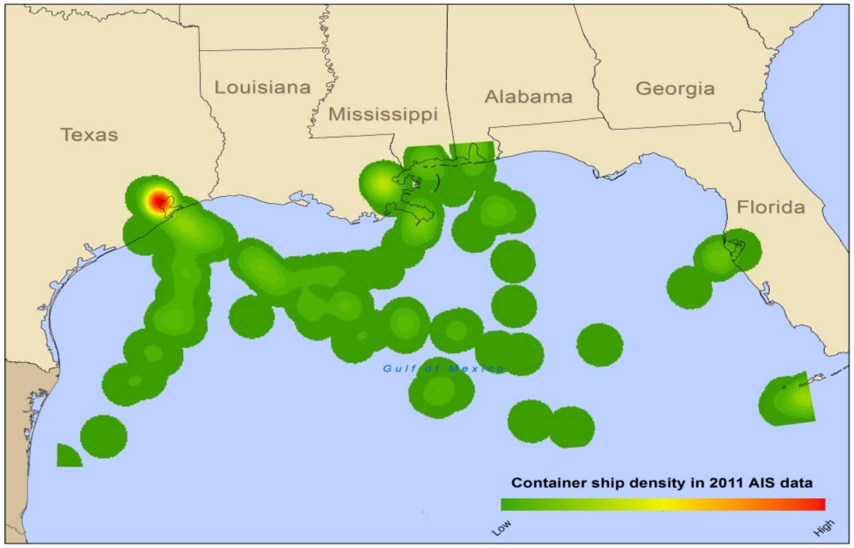

Figure 6-10. Vessel traffic density in container ships

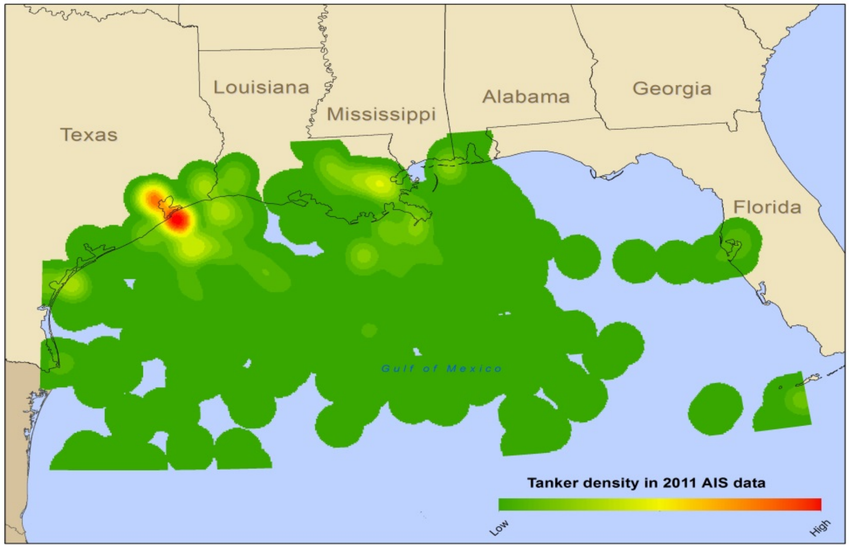

Figure 6-11. Vessel traffic density in tankers

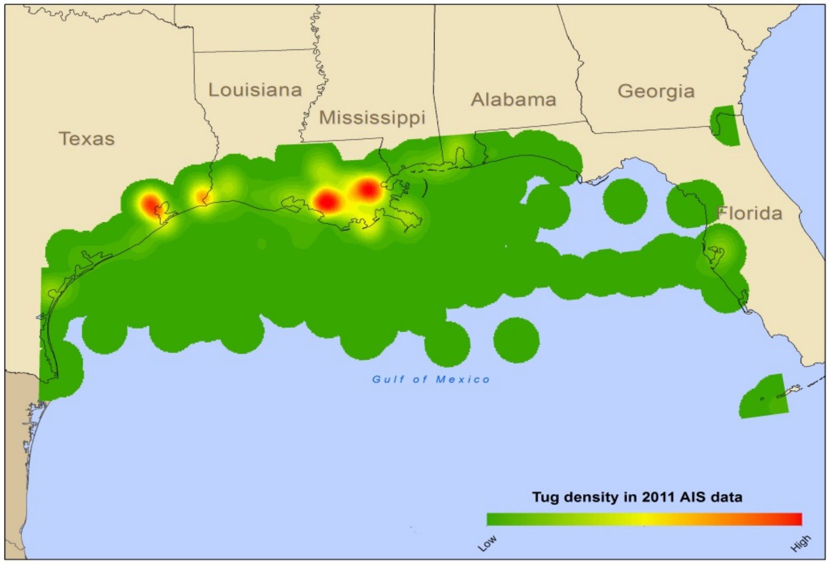

Figure 6-12. Vessel traffic density in tugs

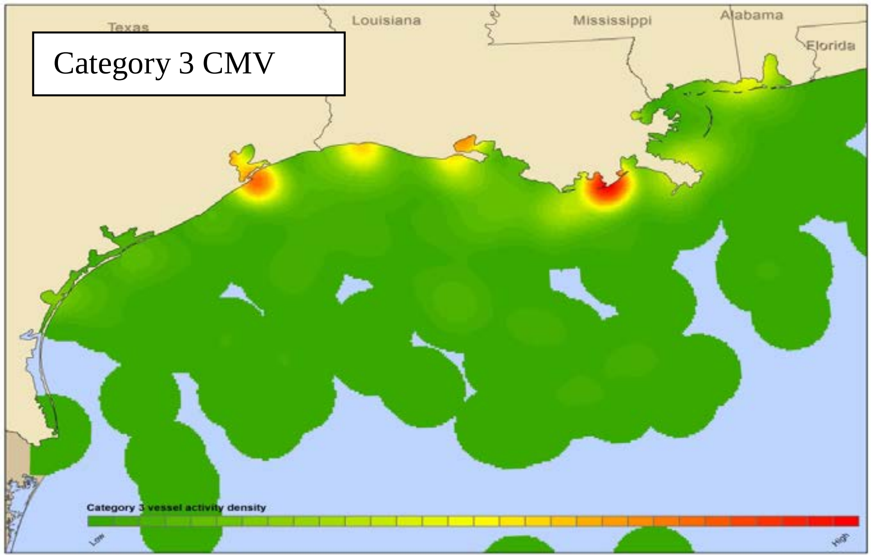

Figure 6-13. Vessel traffic density in Category 3 CMVs

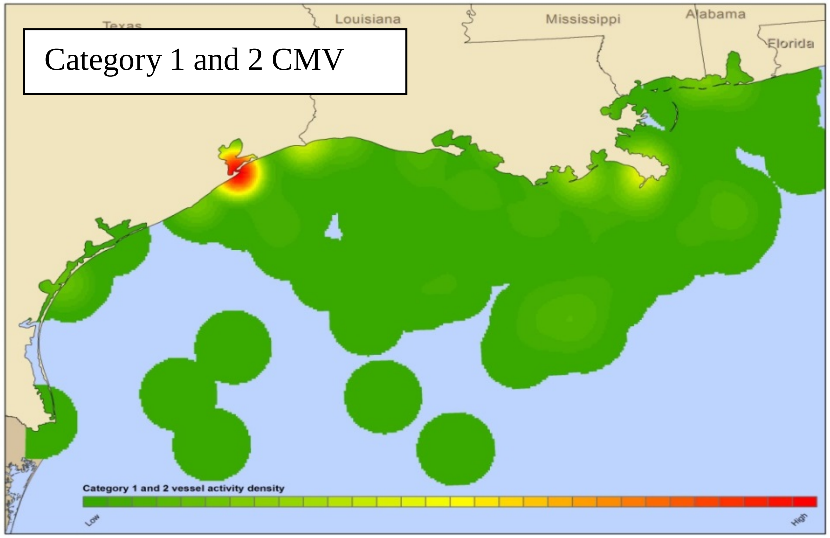

Figure 6-14. Vessel traffic density in Category 1 and 2 CMVs

The 2008 BOEM report estimated just over five calls per week, which corresponded to approximately 269 calls in 2008. According to the U.S. Energy Information Administration, crude oil imported to the LOOP declined 30% between 2008 and 2011 (EIA 2013). This decreased number of calls was used to calculate the appropriate hours of activity for the emission sources associated with the LOOP. It is assumed that for each call, 2.13 tons of VOC are emitted.

No monthly LOOP data were compiled in this effort; it was assumed that activity was consistent throughout the year; therefore, annual emission estimates were apportioned to each months equally (i.e., 8.33%). LOOP platform and evaporative emissions were all assigned to the latitude and longitude coordinates of the LOOP.

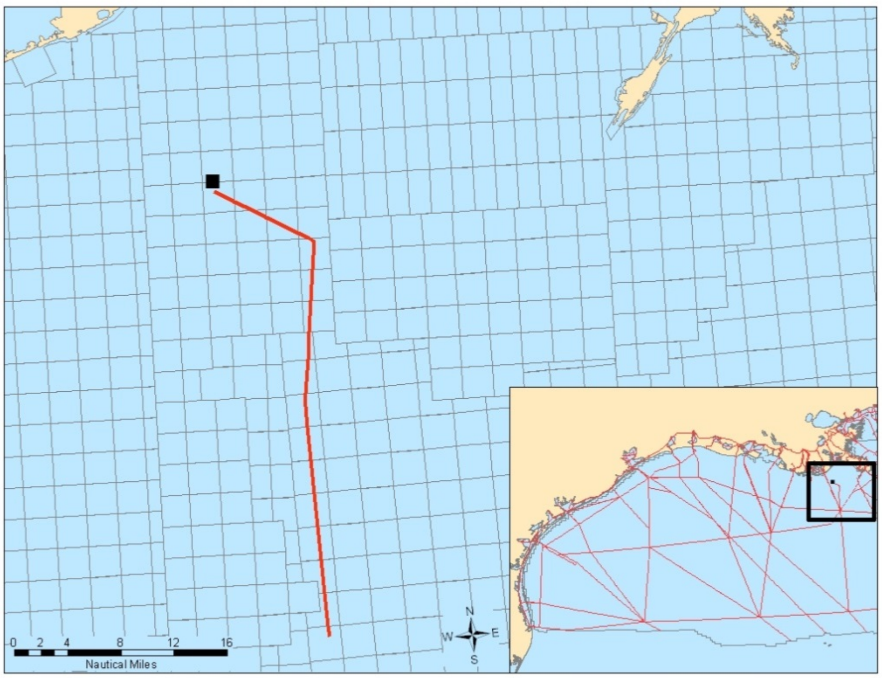

Figure 6-15. Shipping lane approach and location of LOOP

6.2.5 Military Vessels

The U.S. Navy and US Coast Guard patrol the coast and have maneuvers in the GOM. The U.S. military vessel fleet consists of vessels powered by a variety of engines, including older residual-fueled steam turbines, marine diesel engines, and high speed diesel turbines.

Contacts were made with the Navy to obtain activity data necessary to estimate vessel emissions. Unfortunately, no data were provided; therefore, the emission estimates developed for the Navy for the *Gulf of Mexico Air Quality Study* were used in this inventory (Systems Applications International et. al. 1995). Naval base closings announced in 2005 do include facilities located on the GOM. Two of the largest bases initially listed for closure are the Naval Support Activity Center New Orleans which has since been realigned and removed from the list of closures and the Naval Station Ingleside which completed the process of closing by 2011 moving the operation to San Diego. The Ingleside base supported minesweeping activities; such that eight minesweeping vessels were removed from the 2011 Gulfwide inventory. Note that these vessels accounted for 4% of naval vessel activity in the GOM.

All remaining base closings in the Gulf region involved small reserve centers that employ 10 to 30 people, many of which are located inland. No information on vessel activities was found for those small reserve centers. Given the difficulty of obtaining detailed activity data pertaining to naval vessels, the use AIS data was being considered as a possible source for military vessel tracking data. Unfortunately, military vessels rarely send signals that would identify their location on the public AIS. For the 2011 inventory, the naval activity data reported in the *Gulf of Mexico Air Quality Study* was applied to emission factors included in Section 6.1.1. In order to implement this approach, kW-hours were calculated for each naval vessel as noted in Table 6-20.

Table 6-20. Naval vessel kW hours

Vessel	Engine Type	No. Engines	Average kW Rating	Total Engine Hours	kW-hrs	Operating Load	Load Adjusted kW-hrs
PHM	Diesel	2	596.56	17,520	10,451,731	0.80	8,361,385
TAG	Diesel	2	1,043.98	17,520	18,290,530	0.80	14,632,424
TAG(50)	Diesel	1	1,043.98	17,520	18,290,530	0.80	14,632,424
TAGS(50)	Diesel	1	1,864.25	8,760	16,330,830	0.80	13,064,664
LSD	Diesel	4	7,643.43	35,040	267,825,787	0.80	214,260,630
TAGS(40)	Diesel	2	8,948.40	17,520	156,775,968	0.80	125,420,774
TAK(II)	Diesel	2	10,066.95	17,520	176,372,964	0.80	141,098,371
Total		14		131,400	664,338,340		531,470,672

The GOM naval fleet also includes diesel turbine and steam ships; the diesel turbine factors used in this study were obtained from the Swedish emissions data (SEPA 2004) while the steamship factors were obtained from USEPA guidance (Table 6-21) (USEPA 1992).

Table 6-21. Naval diesel turbine and steamship fuel consumption data and emission factors

Engine Type	Fuel Usage (liters/year)	Emission factors (lbs/1000 liters)					
		NO_X	CO	CO_2	SO_2	VOC	PM
Diesel Turbine	594,230	32.19	0.12	5742.9	14.78	0.01	0.44
Steamship	8,918,610	14.38	0.977	6872.3	85.9	0.33	6.816

The Coast Guard provided data for the *Year 2008 Gulfwide Emission Inventory Study* that included the number of vessels with a homeport in the GOM, the type of vessel, and the total number of operating days for some of the vessels. This dataset was updated with the Coast Guard fleet data provided by each district as reported on their Coast Guard websites. Although the Coast Guard has commissioned several new vessels for use in the GOM, they are not yet in service, nor were any vessels retired from service in 2011.

From the 2008 data set, the average number of operating hours was calculated for each type of ship. Engine horsepower was obtained for some but not all of the vessels through the vessel's homepage. Where vessel horsepower data were not readily available, averages for vessel types were developed using available data for sister ships. The average hours of operation and horsepower ratings are summarized in Table 6-22.

Table 6-22. Average horsepower and operating hours by coast guard vessel type

Boat Class	Type	Horsepower Rating	Hours of Operation	Vessel Count
WLB 225	Buoy Tenders	6,200	2,152.8	1
WMEC 210	Cutters	5,000	3,840.0	2
WPB 87	Patrol	3,050	1,518.5	14

To estimate emissions from the Navy and Coast Guard marine diesel engines, the emission factors noted in Section 6.1.1 were applied to the hours of operation and the vessel kW rating. It was assumed that the Coast Guard vessels typically operate at a load factor of 85% while in federal waters.

Emission estimates were developed using the approach discussed in Section 6.1.1. An example of how the equation in Section 6.1.1 was used for this vessel category is provided below.

Example Calculation:

$$E = AH \times kW \times LF \times EF \times CF$$

where:

E = Emissions (tons)
kW-hr = Summed activity for the lease block (kW-hr)
LF = Engine load factor for specified mode of operation (%)
EF = Emission factor (g/kWH)
CF = Conversion factor (g = 1.10231 E-6 ton)

Buoy tenders spent 89.7 days at sea. It is assumed that they operate 24 hours a day. Therefore, total hours of operation were 2,152.8. The average kW is 4,623, load factor is 0.85 while cruising, and the emission factor for NO_x is 19.54 g/kWh.

$$E = 2{,}152.8 \times 4{,}623 \times 0.85 \times 19.54 \times 1.10231 \times 10^{-6}$$
$$E = 182.21 \text{ tons of } NO_x$$

No monthly Navy or Coast Guard data were identified in this effort; it was assumed that activity was consistent throughout the year; therefore, annual emission estimates were temporally apportioned to individual months equally (i.e., 8.33%).

Because it was not possible to identify where Navy vessels operate, the emissions were allocated to individual lease blocks throughout the Central and Western areas of the GOM. All Coast Guard vessel emissions were allocated relative to each vessel’s home port and the area where the vessels patrol (Figure 6-17). The allocations were made based on the surface area of the lease blocks using the equation below:

$$E_{MVi} = E_{MV} \times (S_i/S_{TNG})$$

where:

E_{MVi} = Military vessel emissions associated with lease block i (tons)
E_{MV} = Total military vessel emissions for the GOM (tons)
S_i = Surface area of lease block i (square miles)
S_{TG} = Surface area of total Gulf lease blocks (square miles)

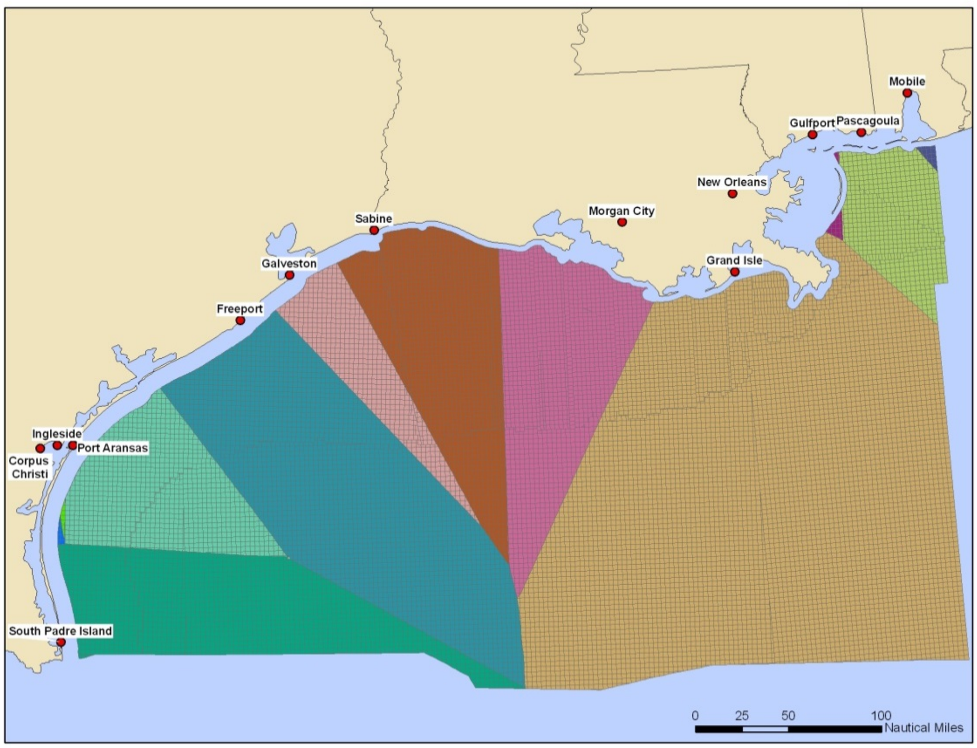

Figure 6-16. Coast Guard districts used to allocate emissions

6.2.6 Vessel Lightering

Lightering is the transfer of cargo to smaller ships that bring the product into port. Lightering occurs offshore in three designated areas. Emissions associated with lightering are attributed to primary propulsion engines of the vessels involved in lightering, secondary engines (e.g., pumps and winches), and evaporative emissions associated with ballasting.

Combustion emissions from the propulsion engines in large tankers and shuttle tankers involved in the lightering process are included in the AIS CMV data and were not calculated separately for 2011. As lightering occurs, the ships pump water into their holds to enhance the stability of the vessel, referred to as ballasting. As water enters the hold during ballasting, organic vapors are displaced into the atmosphere. Activity data were collected to quantify ballasting and estimate evaporative emissions as described below.

Skaugen Petrotrans (SPT), OSG Lightering (OSGL), and American Eagle Tankers (AET) are the three major lightering companies that account for a majority of ship-to-shore transfers of crude oil in the Gulf of Mexico. In 2008, SPT was contacted directly to obtain the annual number of barrels of crude and petroleum products lightered (Tonstad 2009). Additionally, SPT provided their market share estimates for SPT, OSGL, and AET. In order to obtain the 2011 annual number of barrels of crude and petroleum products lightered in the Gulf of Mexico, SPT, OSGL, and AET were contacted. The number of barrels of product lightered was provided by SPT (Lenz 2013) and OSGL (Wrenn 2013) (Table 6-23). The number of barrels of product lightered for AET in 2008 was adjusted to represent the number of barrels transferred in 2011, based on their 2008 market share and accounting for an average decline in activity for SPT and OSGL of 39% (Table 6-23).

Table 6-23. Full service lightering barrel data for 2008 and 2011

	SPT[a]		OSGL		AET	
	2008 Totals	**2011 Totals**	**2008 Totals**	**2011 Totals**	**2008 Totals**	**2011 Totals**
Annual barrels	200,600,000	105,000,000	250,043,662	170,000,000	527,634,507	321,982,759

[a] Note, at the time the 2008 Gulfwide Inventory was developed, data were only available for SPT, Inc.

The evaporative VOC emissions were calculated using the following equations. The total number of barrels per year transferred noted in Table 6-23 was used to quantify ballasting and estimate evaporative emissions using the equations listed below:

Evaporative Lightering:

$$E_v = PT \times \text{BBL/GAL conversion factor} \times TOC_c \times \text{VOC/TOC conversion factor}$$

where:

E_v = Evaporative emissions (tons)
PT = Annual amount of product transferred (barrels)

BBL/GAL = Barrels to gallons conversion factor (42 gallons/barrel)
TOC_c = Emission factor for total organic compounds emitted from thousand gallons of crude oil transfered (0.86 lb of TOC/10^3 gal of crude oil)
VOC/TOC = TOC to VOC conversion factor (0.85)

Evaporative Ballasting:

$$E_b = Wat \times TOC_c \times VOC/TOC$$

where:

E_b = Ballasting emissions (tons)
Wat = Ratio of Density of Crude Oil to Water Equivalent Adjustment
TOC_c = Emission factor for total organic compounds emitted from thousand gallons of crude oil transfered (0.9 lb of TOC/10^3 gal of crude oil)
VOC/TOC = TOC to VOC conversion factor (0.85)

Evaporative emissions were assigned to the center of the lightering zones (Figure 6-18). No monthly vessel lightering data were identified in this effort; it was assumed that activity was consistent throughout the year; therefore, annual emissions estimates were temporality apportioned to each month equally (i.e., 8.33%).

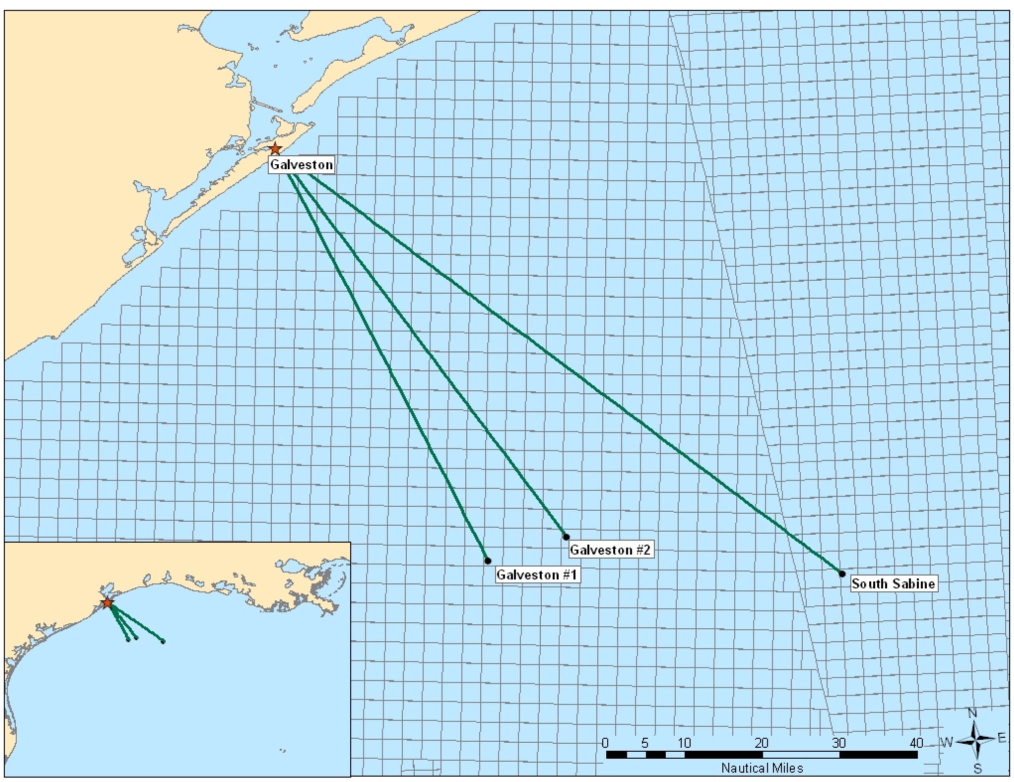

Figure 6-17. Centroid of the vessel lightering zone and shipping lane to Galveston

6.2.7 Recreational Fishing

The GOM is also an active recreational fishing area, providing a wide range of opportunities to recreational anglers. Oil platforms in the GOM act as artificial reefs that fish gather at, which make the platforms prime destinations for anglers (Gordon 1993). Detailed recreational fishing data were obtained from the NOAA Marine Recreational Information Program (MRIP) (NOAA 2012). Aside from Texas, the data were disaggregated into fishing areas (inland, ocean ≤ 3 miles, and ocean > 3 miles). Data for Texas are not disaggregated because Texas, not NOAA, administers the survey. Texas reports their data to NOAA in an aggregated form. To estimate the number of trips into federal waters, the average percent trips were calculated for the other states and then applied to Texas. Table 6-24 summarizes the number of recreational fishing trips to federal waters. It is assumed that four hours per trip (two hours there and two hours back) are underway at 80% load, and six hours per trip are maneuvering at 30% load. Table 6-25 estimates the underway hours and maneuvering hours based on the trips.

Table 6-24. Number of trips near platforms

State	Fishing Area*	Trips	Percent	Notes
Alabama	Not platform	2,245,855	90%	Known
Alabama	Platform	237,610	10%	Known
Alabama	Total	2,483,465	100%	Known
Louisiana	Not platform	4,479,553	98%	Known
Louisiana	Platform	96,694	2%	Known
Louisiana	Total	4,576,247	100%	Known
Mississippi	Not platform	1,602,195	99%	Known
Mississippi	Platform	13,195	1%	Known
Mississippi	Total	1,615,390	100%	Known
Texas	Not platform		96%	Calculated
Texas	Platform	46,882	4%	Calculated
Texas	Total	1,125,401	100%	Known

* It is assumed that all ocean fishing > 3 miles (deep ocean) are near the platforms.

Table 6-25. Activity hours based on number of trips

State	Fishing Area	Trips	Underway Hours	Maneuvering Hours
Alabama	Platform	237,610	950,440	1,425,660
Louisiana	Platform	96,694	386,776	580,164
Mississippi	Platform	13,195	52,780	79,170
Texas	Platform	46,882	187,529	281,293

The average weighted HP was estimated for diesel inboard engines from the USEPA's NONROAD (US EPA 2012) model's average hp per bin dataset and population distribution dataset noted in Table 6-26.

Table 6-26. USEPA nonroad recreational marine vessel power profile

HP Min	HP Max	HP Avg	Population	HP * Population
6	11	9.736	9,199	89,561.464
11	16	14.92	4,514	67,348.88
16	25	21.41	9,987	213,821.67
25	40	31.2	5,464	170,476.8
40	50	42.4	1,010	42,824
50	75	56.19	8,854	497,506.26
75	100	94.22	7,456	702,504.32
100	175	144.9	61,116	8,855,708.4
175	300	223.1	100,498	22,421,103.8
300	600	387.1	4,132	1,599,497.2
600	750	677	2,925	1,980,225
750	1000	876.5	5,546	4,861,069
1000	1200	1,154	452	521,608
1200	2000	1,369	1,586	2,171,234
2000	3000	2,294	971	2,227,474
			Avg Weighted HP	207.5095561

The emission factors used to calculate the emissions were obtained from the NONROAD model for SCCs 2282020000 and 2282020005. The emission factors are listed in Table 6-1. The annual emission for underway emissions, maneuvering emissions, and total emissions are summarized in Tables 6-27 to 6-29.

Table 6-27. Annual underway emissions for recreational fishing (tons)

State	CO	NO_x	PM_{10}	$PM_{2.5}$	VOC	SO_2	CO_2
Alabama	260.23	1,205.67	45.40	44.04	75.87	28.89	94,274.64
Louisiana	105.90	490.64	18.47	17.92	30.88	11.76	38,364.52
Mississippi	14.45	66.95	2.52	2.45	4.21	1.60	5,235.28
Texas	51.35	237.89	8.96	8.69	14.97	5.70	18,601.08
Total	431.93	2,001.15	75.35	73.09	125.93	47.95	156,475.52

Table 6-28. Annual maneuvering emissions for recreational fishing (tons)

State	CO	NO_x	PM_{10}	$PM_{2.5}$	VOC	SO_2	CO_2
Alabama	146.38	678.19	25.54	24.77	42.68	16.25	53,029.49
Louisiana	59.57	275.98	10.39	10.08	17.37	6.61	21,580.04
Mississippi	8.13	37.66	1.42	1.38	2.37	0.90	2,944.84
Texas	28.88	133.81	5.04	4.89	8.42	3.21	10,463.11
Total	242.96	1,125.65	42.39	41.11	70.84	26.97	88,017.48

Table 6-29. Annual total emissions for recreational fishing (tons)

State	CO	NO_x	PM_{10}	$PM_{2.5}$	VOC	SO_2	CO_2
Alabama	406.62	1,883.86	70.94	68.81	118.55	45.14	147,304.13
Louisiana	165.47	766.62	28.87	28.00	48.24	18.37	59,944.56
Mississippi	22.58	104.61	3.94	3.82	6.58	2.51	8,180.12
Texas	80.23	371.70	14.00	13.58	23.39	8.91	29,064.19
Total	674.90	3,126.80	117.74	114.21	196.77	74.92	244,493.00

Example Calculation:

$$E = AH \times HP \times LF \times EF \times CF$$

where:

E	=	Emissions (tons)
AH	=	Annual hours per mode of operation (underway, maneuvering, hoteling) hours
HP	=	Horse power
LF	=	Engine load factor for specified mode of operation (%)
EF	=	Emission factor (g/kWH)
CF	=	Conversion factor (g = 1.10231 E-6 ton)

Recreational fishing vessels in Alabama spent 950,440 underway hours at sea in 2011. The average HP is 207.5, load factor is 0.80, and the emission factor for CO_2 is 2.01 g/kW-hr.

$$E = 950{,}440 \times 207.5 \times 0.80 \times 2.01 \times 1.10231 \times 10^{-6}$$
$$E = 94{,}274.64 \text{ tons of } CO_2$$

7. RESULTS

7.1 SUMMARY OF STUDY APPROACH

This BOEM *Year 2011 Gulfwide Emissions Inventory Study* includes all major oil and gas production platforms and non-platform sources in the Central and Western GOM on the OCS. Pollutants covered in the inventory are the criteria pollutants—CO, NO_x, PM_{10}, $PM_{2.5}$, SO_2, and VOC; as well as major greenhouse gases—CO_2, CH_4, and N_2O.

BOEM attempted to collect activity data from each active major offshore oil and gas production platform in the GOM on the OCS. Operators were provided with the GOADS-2011 Visual Basic® activity data collection software for compiling monthly data for calendar year 2011. A total of 2,544 oil and gas production platforms submitted active monthly equipment activity data files. The platform equipment surveyed includes:

- Amine units
- Boilers/heaters/burners
- Diesel engines
- Drilling equipment
- Combustion flares
- Fugitive sources
- Glycol dehydrators
- Losses from flashing
- Minor sources
- Mud degassing
- Natural gas engines
- Natural gas, diesel, and dual-fuel turbines
- Pneumatic pumps
- Pressure/level controllers
- Storage tanks
- Cold vents

Rigorous QA/QC was performed on the activity data collected from platform operators. Tasks were implemented to correct the number of operating hours provided for a given month, fill in missing monthly operating data (if the equipment was operational), verify and correct activity values such as fuel heating value, make sure that the equipment shown to be vented included a vent ID and activity record, fill in missing stack parameters with surrogates, and double-check exit velocity and fuel usage totals by recalculating the parameters. The monthly activity data collected from the platform operators were then combined with emission factors and algorithms to develop the platform production equipment emission estimates. Inventory data files were compiled with the oil and gas production platform data suitable for use in air quality modeling applications. In addition to monthly emission estimates by pollutant and individual piece of equipment, the files include the company, structure and complex ID, lease number, block and area number, and latitude/longitude. For each piece of equipment, stack parameter information such as outlet height, exit velocity, and exhaust gas temperature is also presented.

Emission estimates were also developed for criteria air pollutants and greenhouse gases for non-platform sources operating in the GOM on the OCS for the 2011 calendar year. The non-platform sources included in this study are noted below.

Non-platform oil/gas production sources:

- Drilling rigs
- Pipelaying operations
- Support helicopters
- Support vessels
- Survey vessels

Non-platform non-oil/gas production sources:

- Biogenic and geogenic sources
- Commercial fishing vessels
- Commercial marine vessels
- LOOP
- Military vessels (Coast Guard/Navy)
- Vessel lightering
- Recreational vessels

After intensive research and data gathering of activity data specific to each source category, the compiled activity data underwent detailed QA/QC. For most marine vessel source categories, the emission factors were developed by the USEPA (USEPA 2010b) specifically to represent 2011 emission and fuel standards as well as vessel turn over. The resulting non-platform emission estimates were then disaggregated into BOEM lease blocks, suitable for use in air quality modeling applications. If diurnal emission curves are needed for air quality modeling, please refer to the *Year 2008 Gulfwide Emissions Inventory Study* (Wilson et al. 2010).

7.2 PRESENTATION OF ANNUAL EMISSION ESTIMATES

The platform and non-platform emission estimates developed for criteria pollutants and greenhouse gases are presented in Tables 7-1 through 7-15. For an overview of the results, Table 7-1 summarizes the total platform criteria pollutant emission estimates, Table 7-2 summarizes the total non-platform criteria pollutant emission estimates, and Table 7-3 presents the combined platform and non-platform criteria pollutant estimates. To facilitate more detailed review, Tables 7-4 through 7-8 present platform and non-platform emission estimates by pollutant.

The greenhouse emission estimates are provided in Tables 7-9 through 7-15. The CO_2 equivalent (CO_2e) emission estimates shown in these tables represent the number of tons of CO_2 emissions with the same global warming potential as one ton of another greenhouse gas as shown in the following equation:

$$CO_2e = \sum GHG_i \times GWP_i$$

where:

CO_2e = Carbon dioxide equivalent, tons/year
GHG_i = Mass emissions of each greenhouse gas, tons/year
GWP_i = Global warming potential for each greenhouse gas in the inventory

The global warming potentials used are those required under the USEPA Final Mandatory Reporting of Greenhouse Gases Rule (*Federal Register* 2009), with a global warming potential of 21 for CH_4, and a global warming potential of 310 for N_2O. The global warming potentials will be updated in future BOEM inventories, as the USEPA has adopted the values of the Intergovernmental Panel for Climate Change, Fourth Assessment Report.

Table 7-1. Total platform emission estimates for criteria pollutants

Equipment	CO Emissions (tpy)	NO_x Emissions (tpy)	PM_{10} Emissions (tpy)	$PM_{2.5}$ Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Amine Units	0	0	0	0	4	0.2
Boilers/heaters/ Burners	621	1,156	14	14	5	41
Diesel Engines	2,187	8,927	349	348	827	406
Drilling Equipment	396	1,493	17	17	24	37
Combustion Flares	1,252	425	5	5	3	30
Fugitives	0	0	0	0	0	16,403
Glycol Dehydrators	0	0	0	0	0	1,158
Losses From Flashing	0	0	0	0	0	640
Minor Sources	0	0	0	0	0	157
Mud Degassing	0	0	0	0	0	23

Equipment	CO Emissions (tpy)	NO_x Emissions (tpy)	PM_{10} Emissions (tpy)	$PM_{2.5}$ Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Natural Gas Engines	62,024	44,863	224	224	14	1,310
Natural Gas, Diesel, and Dual-fuel Turbines	3,859	27,264	149	149	2,320	103
Pneumatic Pumps	0	0	0	0	0	2,182
Pressure/level Controllers	0	0	0	0	0	2,064
Storage Tanks	0	0	0	0	0	928
Cold Vents	0	0	0	0	0	29,243
Total Emissions (tpy)[a]	70,339	84,128	759	756	3,197	54,724

[a] Totals may not sum due to rounding.

Table 7-2. Total non-platform emission estimates for criteria pollutants

Source Category	CO Emissions (tpy)	NO_x Emissions (tpy)	PM_{10} Emissions (tpy)	$PM_{2.5}$ Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Drilling Rigs	6,248	69,135	2,634	2,407	20,863	2,750
Pipelaying Operations	2,124	9,480	350	338	117	128
Support Helicopters	2,163	753	23	22	112	1,624
Support Vessels	35,686	175,558	6,435	6,242	2,157	4,016
Survey Vessels	1,760	7,851	290	281	97	105
Total OCS Oil/Gas Production Sources (tpy)	47,981	262,777	9,732	9,290	23,346	8,623
Biogenic and Geogenic Sources	0	0	0	0	0	14,357
Commercial Fishing Vessels	1,206	6,917	245	238	85	218
Commercial Marine Vessels	9,779	108,203	4,122	3,768	32,651	4,303
LOOP	313	1,399	52	50	17	420
Military Vessels	1,035	11,448	436	399	3,455	455
Vessel Lightering[a]	0	0	0	0	0	17,113

Source Category	CO Emissions (tpy)	NO_x Emissions (tpy)	PM_{10} Emissions (tpy)	$PM_{2.5}$ Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Recreational Vessels	675	3,127	118	114	75	197
Total Non-OCS Oil/Gas Production Sources (tpy)	13,008	131,094	4,973	4,569	36,283	37,063
Total Non-Platform Emissions (tpy)[b]	60,989	393,871	14,705	13,859	59,629	45,686

[a] Vessel estimates are reflected in commercial marine vessels.

[b] Totals may not sum due to rounding.

Table 7-3. Total platform and non-platform emission estimates for criteria pollutants

Equipment/ Source Category	CO Emissions (tpy)	NO_x Emissions (tpy)	PM_{10} Emissions (tpy)	$PM_{2.5}$ Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Total Platform Emissions	70,753	84,415	760	759	3,197	54,724
Drilling Rigs	6,248	69,135	2,634	2,407	20,863	2,750
Pipelaying Operations	2,124	9,480	350	338	117	128
Support Helicopters	2,163	753	23	22	112	1,624
Support Vessels	35,686	175,558	6,435	6,242	2,157	4,016
Survey Vessels	1,760	7,851	290	281	97	105
Total OCS Oil/Gas Production Source Emissions	118,734	347,192	10,492	10,049	26,543	63,347
Total Non-OCS Oil/Gas Production Source Emissions	13,008	131,094	4,973	4,569	36,283	37,063
Total Emissions (tpy)[a]	131,742	478,287	15,465	14,618	62,827	100,410

[a] Totals may not sum due to rounding.

Table 7-4. Annual CO emission estimates for all sources

Equipment/Source Category	CO Emissions (tpy)
Natural Gas Engines	62,024
Support Vessels	35,686
Commercial Marine Vessels	9,779
Drilling Rigs	6,248
Natural Gas, Diesel, and Dual-fuel Turbines	3,859
Diesel Engines	2,187
Support Helicopters	2,163
Pipelaying Operations	2,124
Survey Vessels	1,760
Combustion Flares	1,252
Commercial Fishing Vessels	1,206
Military Vessels	1,035
Recreational Vessels	675
Boilers/heaters/burners	621
Drilling Equipment	396
LOOP	313
Total Emissions (tpy)[a]	131,328

[a] Totals may not sum due to rounding.

Table 7-5. Annual NO_x emission estimates for all sources

Equipment/Source Category	NO_x Emissions (tpy)
Support Vessels	175,558
Commercial Marine Vessels	108,203
Drilling Rigs	69,135
Natural Gas Engines	44,863
Natural Gas, Diesel, and Dual-fuel Turbines	27,264
Military Vessels	11,448
Pipelaying Operations	9,480
Diesel Engines	8,927
Survey Vessels	7,851
Commercial Fishing Vessels	6,917
Recreational Vessels	3,127
Drilling Equipment	1,493
LOOP	1,399
Boilers/heaters/burners	1,156
Support Helicopters	753
Combustion Flares	425
Total Emissions (tpy)[a]	478,286

[a] Totals may not sum due to rounding.

Table 7-6. Annual PM_{10} emission estimates for all sources[a]

Equipment/Source Category	PM_{10} Emissions (tpy)
Support Vessels	6,435
Commercial Marine Vessels	4,122
Drilling Rigs	2,634
Military Vessels	436
Pipelaying Operations	350
Diesel Engines	349
Survey Vessels	290
Commercial Fishing Vessels	245
Natural Gas Engines	224
Natural Gas, Diesel, and Dual-fuel Turbines	149
Recreational Vessels	118
LOOP	52
Support Helicopters	23
Drilling Equipment	17
Boilers/heaters/burners	14
Combustion Flares	5
Total Emissions (tpy)[b]	15,463

[a] Annual $PM_{2.5}$ emission estimates follow a similar pattern.
[b] Totals may not sum due to rounding.

Table 7-7. Annual SO_2 emission estimates for all sources

Equipment/Source Category	SO_2 Emissions (tpy)
Commercial Marine Vessels	32,651
Drilling Rigs	20,863
Military Vessels	3,455
Support Vessels	2,157
Natural Gas, Diesel, and Dual-fuel Turbines	2,320
Diesel Engines	827
Pipelaying Operations	117
Support Helicopters	112
Survey Vessels	97
Commercial Fishing Vessels	85
Recreational Vessels	75
Drilling Equipment	24
LOOP	17
Natural Gas Engines	14
Boilers/heaters/burners	5
Amine Units	4
Combustion Flares	3
Total Emissions (tpy)[a]	62,827

[a] Totals may not sum due to rounding.

Table 7-8. Annual VOC emission estimates for all sources

Equipment/Source Category	VOC Emissions (tpy)
Cold Vents	29,243
Vessel Lightering	17,113
Fugitives	16,403
Biogenic and Geogenic Sources	14,357
Commercial Marine Vessels	4,303
Support Vessels	4,016
Drilling Rigs	2,750
Losses From Flashing	640
Pneumatic Pumps	2,182
Pressure/level Controllers	2,064
Support Helicopters	1,624
Natural Gas Engines	1,310
Glycol Dehydrators	1,158
Storage Tanks	928
Military Vessels	455
LOOP	420
Diesel Engines	406
Commercial Fishing Vessels	218
Recreational Vessels	197
Minor Sources	157
Pipelaying Operations	128
Survey Vessels	105
Natural Gas, Diesel, and Dual-fuel Turbines	103
Mud Degassing	23
Boilers/heaters/burners	41
Drilling Equipment	37
Combustion Flares	30
Amine Units	0.2
Total Emissions (tpy)[a]	100,421

[a] Totals may not sum due to rounding.

Table 7-9. Total greenhouse gas emission estimates for platform sources

Equipment Types	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[a]
Amine Units	0	2	0	45
Boilers/heaters/burners	891,652	17	16	896,992
Diesel Engines	407,575	13	N/A[b]	407,851
Drilling Equipment	76,961	1.5	N/A	76,993
Combustion Flares	604,002	366	11	615,029
Fugitive Sources	0	61,232	0	1,285,862
Glycol Dehydrators	N/A	7,859	N/A	165,048
Losses From Flashing	330	14,231	0	299,175
Minor Sources	0	476	0	9,987
Mud Degassing	2	505	0	10,615
Natural Gas Engines	2,567,943	12,619	N/A	2,832,942
Natural Gas, Diesel, and Dual-fuel Turbines	7,329,476	400	140	7,381,165
Pneumatic Pumps	401	21,155	0	444,666
Pressure/level Controllers	871	16,739	0	352,384
Storage Tanks	0	877	0	18,414
Cold Vents	2,815	134,863	0	2,834,938
Total Emissions (tpy)[c]	11,882,029	271,355	167	17,632,106

[a] CO_2e = 21 for CH_4 and 310 for N_2O.
[b] N/A = not available
[c] Totals may not sum due to rounding.

Table 7-10. Total greenhouse gas emissions for non-platform sources

Source Category	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[a]
Drilling Rigs	2,748,279	21	110	2,782,820
Pipelaying Operations	609,535	5	18	615,220
Support Helicopters	160,752	10	11	164,373
Support Vessels	13,002,103	75	386	13,123,338
Survey Vessels	504,714	3	15	509,427
Total OCS Oil/Gas Production Sources (tpy)	17,025,383	114	540	17,195,178
Biogenic and Geogenic Sources	2,284	1,876	1,948	645,560
Commercial Fishing	585,204	2	17	590,516
Commercial Marine Vessels	4,301,312	33	172	4,355,325
LOOP	89,958	0.5	3	90,888
Military Vessels	455,071	4	18	460,735
Vessel Lightering[c]	0	N/A[b]	0	0
Recreational Vessels	244,483	N/A	N/A	244,483
Total Emissions (tpy)[d]	22,703,695	2,029	2,698	23,582,684

[a] CO_2e = 21 for CH_4 and 310 for N_2O.
[b] N/A = Not available
[c] Vessel estimates are reflected in commercial marine vessels.
[d] Totals may not sum due to rounding.

Table 7-11. Total platform and non-platform emission estimates for greenhouse gases

Equipment/ Source Category	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[a]
Total Platform Emissions	11,882,029	271,355	167	17,632,106
Drilling Rigs	2,748,279	21	110	2,782,820
Pipelaying Operations	609,535	5	18	615,220
Support Helicopters	160,752	10	11	164,373
Support Vessels	13,002,103	75	386	13,123,338
Survey Vessels	504,714	3	15	509,427
Total OCS Oil/Gas Production Source Emissions	28,907,412	271,469	707	34,827,284
Total Non-OCS Oil/Gas Production Source Emissions	5,678,312	1,915	2,158	6,387,507
Total Emissions (tpy)[b]	34,585,724	273,384	2,865	41,214,791

[a] CO_2e = 21 for CH_4 and 310 for N_2O.
[b] Totals may not sum due to rounding.

Table 7-12. Annual CO_2 emission estimates for all sources

Equipment/Source Category	CO_2 Emissions (tpy)
Support Vessels	13,002,103
Natural Gas, Diesel, and Dual-fuel Turbines	7,329,476
Commercial Marine Vessels	4,301,312
Drilling Rigs	2,748,279
Natural Gas Engines	2,567,943
Boilers/heaters/burners	891,652
Pipelaying Operations	609,535
Combustion Flares	604,002
Commercial Fishing Vessels	585,204
Survey Vessels	504,714
Military Vessels	455,071
Diesel Engines	407,575
Recreational Vessels	244,483
Support Helicopters	160,752
LOOP	89,958
Drilling Equipment	76,961
Cold Vents	2,815
Biogenic and Geogenic Sources	2,284
Losses From Flashing	330
Pressure/level Controllers	871
Pneumatic Pumps	401
Mud Degassing	2
Total Emissions (tpy)[a]	34,585,724

[a] Totals may not sum due to rounding.

Table 7-13. Annual CH_4 emission estimates for all sources

Equipment/Source Category	CH_4 Emissions (tpy)
Cold Vents	134,863
Fugitives	61,232
Losses From Flashing	14,231
Pneumatic Pumps	21,155
Pressure/level Controllers	16,739
Natural Gas Engines	12,619
Glycol Dehydrators	7,859
Biogenic and Geogenic Sources	1,876
Storage Tanks	877
Mud Degassing	505
Minor Sources	476
Natural Gas, Diesel, and Dual-fuel Turbines	400
Combustion Flares	366
Support Vessels	75
Drilling Rigs	21
Commercial Marine Vessels	33
Boilers/heaters/burners	17
Diesel Engines	13
Support Helicopters	10
Pipelaying Operations	5
Military Vessels	4
Survey Vessels	3
Amine Units	2
Commercial Fishing Vessels	2
Drilling Equipment	1.5
LOOP	0.5
Total Emissions (tpy)[a]	273,384

[a] Totals may not sum due to rounding.

Table 7-14. Annual N_2O emission estimates for all sources

Equipment/Source Category	N_2O Emissions (tpy)
Biogenic and Geogenic Sources	1,948
Support Vessels	386
Commercial Marine Vessels	172
Natural Gas, Diesel, and Dual-fuel Turbines	140
Drilling Rigs	110
Military Vessels	18
Pipelaying Operations	18
Commercial Fishing Vessels	17
Boilers/heaters/burners	16
Survey Vessels	15
Combustion Flares	11
Support Helicopters	11
LOOP	3
Total Emissions (tpy)[a]	2,865

[a] Totals may not sum due to rounding.

Table 7-15. Annual CO_2e emission estimates for all sources

Equipment/Source Category	CO_2e Emissions (tpy)[a]
Support Vessels	13,123,338
Natural Gas, Diesel, and Dual-fuel Turbines	7,381,165
Commercial Marine Vessels	4,355,325
Cold Vents	2,834,938
Natural Gas Engines	2,832,942
Drilling Rigs	2,782,820
Fugitives	1,285,862
Losses From Flashing	299,175
Boilers/heaters/burners	896,992
Biogenic and Geogenic Sources	645,560
Combustion Flares	615,029
Pipelaying Operations	615,220
Commercial Fishing Vessels	590,516
Survey Vessels	509,427
Military Vessels	460,735
Pneumatic Pumps	444,666
Diesel Engines	407,851
Pressure/level Controllers	352,384
Recreational Vessels	244,483
Glycol Dehydrators	165,048
Support Helicopters	164,373
LOOP	90,888
Drilling Equipment	76,993
Storage Tanks	18,414
Mud Degassing	10,615
Minor Sources	9,987
Amine Units	45
Vessel Lightering[b]	0
Total Emissions (tpy)[c]	41,214,791

[a] $CO_2e = 21$ for CH_4 and 310 for N_2O.

[b] Vessel estimates are reflected in commercial marine vessels.

[c] Totals may not sum due to rounding.

7.3 LIMITATIONS

As with previous BOEM Gulfwide emission inventory studies, the key limitation of the 2011 OCS platform emission estimates is associated primarily with the lack of direct source test data. BOEM requires that platform operators provide only activity data for sources such as fugitives, amine units, glycol dehydrators, losses from flashing, and cold vents. BOEM then applies emission factors to the activity data to yield emission estimates. In compiling the GOADS-2011 activity datasets, BOEM often must interpret inconstitently-reported data. For example, operators may flag a platform as inactive for a given month, yet populate fuel usage and other data fields. Though these inconsistencies are handled in the same manner for all platforms, it still limits the confidence of the resulting emission estimates. For the reported volumes vented and flared, BOEM conducted extensive research in order to reconcile the GOADS-2011 reported volumes with those reported to through the OGOR forms (Form ONRR-4054-B). Though BOEM worked directly with the platform operators in this effort, limitations likely still exist due to the way the reported data were interpreted. The requirement that platform operators submit source test data, calculated emission estimates based on source specific- emission factors, or calculated emission estimates based on industry-developed software would reduce the uncertainty in the emissions estimates. For fugitive sources, the current estimation method is based on out-of-date estimation methods and surrogate component counts. For glycol dehydrators and amine units, emission estimates would be improved if operators provided estimates and documentation from the GTI AIRCalc Software Program.

Limitations exist for some of the non-platform emission estimates based on the availability of activity data, as well as the quality of the emission factors. As discussed in Section 6, emission estimates for all marine diesel engines were developed using USEPA emission factors that specifically represent 2011, accounting for replacement of older vessels with new vessels that comply with appropriate Category 1, 2, and 3 engine regulations. To use these emission factors, assumptions were made about the engine category associated with each vessel type included in the GOM inventory. More detailed information about the different category engines used by each vessel type would improve the emission estimates by better matching of engines to emission factors.

AIS data were used to spatially allocate activity and emissions for commercial marine vessels (bulk, cargo, tankers, containerships, tugs), LOOP tanker traffic, lightering traffic, and support vessels. The AIS data are limited to locations where there are transmitters. As more transmitters are installed on offshore platforms, the resolution of the spatial traffic data will improve. Initially, attempts were made to use the AIS data to quantify activity in the GOM, but it was difficult to distill the data into a useful format. Instead, vessel activities were based on U.S. Army Corps of Engineer’s Entrance and Clearance data that documented a vessel’s previous and next port of call. These routes were assigned distances for transiting the central and western federal waters of the GOM along major shipping lanes. These distances were divided by the vessel’s speed to estimate hours of operation. An alternative approach using AIS time stamp data that documents when a vessel enters and leaves federal waters will provide more accurate estimate of hours of operation.

Support vessels represent one of the larger non-platform emissions sources. For the 2011 inventory, vessel-specific data were compiled for all identified support vessels. These data quantified the number and engines used on these vessels. To estimate emissions from these vessels, assumptions needed to be made regarding utilization rates, hours of operation in port and at sea, time spend cruising and maneuverings adjacent to platform during loading and unloading operations, and typical engine loads for cruising and maneuvering. More detailed data related to these assumptions will help improve the support vessel emission estimates.

For the LOOP, activity data that were previously available to the public are no longer available due to security issues, such that detailed matching of vessels and their operations was not possible. Instead, 2008 estimates were adjusted to reflect the recent decline in crude oil importation. A significant improvement was made in the 2011 inventory to lightering by including two other lightering services, one company provided data on the volume of crude transferred. The volume of crude handled by the second company was estimated based on their market share of lightering traffic. Actual data from all three companies would improve the accuracy of the lightering emission estimates. The unavailability of up-to-date vessel data for the U.S. Navy, especially where Naval and possibly some Coast Guard vessels have been moved away from the GOM to support actions in foreign countries, makes it difficult to accurately assess emissions from these vessels. It is likely that current estimates of Naval emissions over-estimate actual emissions.

BOEM updated the compilation of helicopter emission factors using Swiss helicopter data that allowed for differentiation between medium and heavy duty twin engine helicopters. It should be noted, however, that the compiled emission factors still represent available data and not the complete universe of helicopters that operate in the GOM. The updated helicopter factors are grouped relative to size and engine configuration, but there is large variance in the emission factor values within each helicopter group. As more helicopter emission factor data is published and included in the GOM helicopter database, it will be possible to more accurately match helicopters and their emission factors, providing more accurate emission estimates. Another limitation to the helicopter data concerns the activity data; for 2011 and earlier inventories, the primary data source for helicopter activity is HSAC data, which is voluntarily provided by the helicopter service companies. These data are adjusted to include helicopter activity from companies that do not provide data, but more accurate helicopter fleet and activity data would significantly improve emission estimates for this source category. Currently, the FAA is developing similar datasets to that used by the AIS for marine vessels. BOEM is evaluating the possibility of using the FAA data to better quantify helicopter activity.

One other limitation to note is as with the previous inventories, this inventory provides emission estimates for directly-emitted pollutants; it does not take into account changes of the emissions due to in-plume chemistry. These changes are based on the reactivity of the individual pollutant species, and transformation rates to secondary pollutants. For example, the inventory does not quantify how the NO_x and VOC emissions affect the chemical composition of the marine boundary layer, particularly in the formation of ozone and hydroxyl radicals. The transformation of pollutants needs to be modeled in order to account for all factors that impact the transformation rate.

7.4 COMPARISON WITH OTHER STUDIES

Now that BOEM has completed four Gulfwide emission inventory studies, the inventory results between the studies can be compared. The comparisons provided here focus on the *Year 2008 Gulfwide Emission Inventory Study* (Wilson et al. 2010). In the *Year 2008 Gulfwide Emission Inventory Study* (Wilson et al. 2007), the calendar year 2008 emission estimates were directly compared with those of the *Year 2005 Gulfwide Emission Inventory Study* (Wilson et al. 2007). In the report for the *Year 2005 Gulfwide Emission Inventory Study* (Wilson et al. 2007), the calendar year 2005 emission estimates were directly compared with those of the 2000 *Gulfwide Emission Inventory for Regional Haze and Ozone Modeling* (Wilson et al. 2004), and the 2000 *Gulfwide Emission Inventory for Regional Haze and Ozone Modeling* report (Wilson et al. 2004) provided a detailed comparison of the 2000 inventory with the *Gulf of Mexico Air Quality Study* (Systems Applications International et al. 1995); those comparisons are not reproduced here. The following discussion compares the emission estimates developed for calendar year 2008 and the 2011 emission estimates by equipment type, source category, and pollutant. Similarities and differences between the two inventories are discussed.

Overall comparisons of pollutant-specific emission estimates for platform and non-platform sources are presented in Table 7-16 (for criteria pollutants) and Table 7-17 (for greenhouse gases). For criteria pollutants, the overall CO emission estimate varies slightly from 2008 to 2011. A 12% increase is seen in the overall VOC emission estimate. Larger differences are seen, however, in the NO_x (25% increase), PM_{10} (33% increase), and SO_2 estimates (23% decrease). For greenhouse gases, the overall N_2O emission estimate varies slightly from 2008 to 2011. A significant increase is seen in the CO_2 estimates (37%), and a decrease is seen in the CH_4 estimates (36%). The following sections examine these differences for the platform and non-platform emission estimates.

Table 7-16. Comparison of total platform and non-platform criteria pollutant for years 2008 and 2011 emission estimates

Calendar Year	CO Emissions (tpy)	NO_X Emissions (tpy)	PM_{10} Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
2008	124,764	382,015	11,640	81,304	89,696
2011	131,328	478,286	15,463	62,827	100,421
Percent Difference	5%	25%	33%	-23%	12%

Table 7-17. Comparison of total platform and non-platform greenhouse gas emission estimates for Years 2008 and 2011

Calendar Year	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[a]
2008	25,257,583	424,664	2,661	35,000,497
2011	34,585,724	273,384	2,865	41,214,791
Percent Difference	37%	-36%	8%	18%

[a] CO_2e = 21 for CH_4 and 310 for N_2O.

7.4.1 OCS Oil and Gas Production Platforms

As noted previously, the emission estimation methods for platform sources are relatively unchanged between the 2008 and 2011 inventories. Any changes in emission levels, then, are due to the number of platforms included in the inventory, increases or decreases in activity levels, fuel type (for combustion sources), and how well the operators interpreted and completed the requested fields in the GOADS activity data collection software. In 2008, 113 companies submitted data for 3,026 active platforms; 1,538 were flagged as minor sources. In 2011, 96 companies submitted data for 2,544 active platforms; 1,366 were flagged as minor sources.

As shown in Table 7-18, for platform sources, the CO and VOC emission estimates show slight decreases in emissions from 2008 to 2011 (14% and 10%, respectively), while the NO_x and PM_{10} emission estimates show slight increases (13% and 11%, respectively). The SO_2 emission estimate, however, shows greater than 200% increase. This increase is primarily due to the natural gas, diesel, and dual-fuel turbine emission estimates. The 2008 turbine emission estimate included only natural gas turbines.

The 2011 natural gas engine estimates drive the overall decrease in estimated emissions for CO, indicating a decrease in reported activity levels. The decrease is counter-balanced somewhat, however, by an increase in reported activities (and emission estimates) for boilers/heaters/burners, diesel engines, and natural gas, diesel, and dual-fuel turbines.

The decrease in the 2011 emission estimates for VOC is driven by the fugitives and pressure level controllers emission estimates, although losses from flashing emissions increased significantly. Similar to the SO_2 estimate, the increase seen in the NO_x and PM_{10} emission estimates is driven by turbines.

Table 7-19 presents a comparison of emission estimates for greenhouse gases between the 2008 inventory and the 2011 inventory. Overall, the CO_2e emission estimate shows a 2% increase, as the CO_2 emission estimate increased 41%. Similar to the increase in the SO_2 emission estimate, the overall increase in greenhouse gas emissions is driven in large part by the CO_2 and CH_4 natural gas, diesel, and dual-fuel turbine estimates. The CH_4 emission estimates for flashing losses also contributed to the increase.

Table 7-18. Comparison of Years 2008 and 2011 OCS platform criteria pollutant emission estimates

	2008					2011				
Source Category	CO Emissions (tpy)	NO_X Emissions (tpy)	PM_{10} Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)	CO Emissions (tpy)	NO_x Emissions (tpy)	PM_{10} Emissions (tpy)	SO_2 Emissions (tpy)	VOC Emissions (tpy)
Amine Units	0	0	0	3	1	0	0	0	4	0.2
Boilers/heaters/ Burners	542	910	22	8	35	621	1,156	14	5	41
Diesel Engines	1,808	7,427	306	711	351	2,187	8,927	349	827	406
Drilling Equipment	545	2,060	37	260	51	396	1,493	17	24	37
Combustion Flares	1,304	254	2	2	22	1,252	425	5	3	30
Fugitives	0	0	0	0	21,476	0	0	0	0	16,403
Glycol Dehydrators	0	0	0	0	2,573	0	0	0	0	1,158
Losses From Flashing	0	0	0	0	950	0	0	0	0	640
Minor Sources	0	0	0	0	213	0	0	0	0	157
Mud Degassing	0	0	0	0	25	0	0	0	0	23
Natural Gas Engines	75,103	52,538	250	15	1,310	62,024	44,863	224	14	1,310
Natural Gas, Diesel, and Dual-fuel Turbines	2,844	11,096	66	21	73	3,859	27,264	149	2,320	103
Pneumatic Pumps	0	0	0	0	1,893	0	0	0	0	2,182
Pressure/level Controllers	0	0	0	0	3,939	0	0	0	0	2,064
Storage Tanks	0	0	0	0	909	0	0	0	0	928
Cold Vents	0	0	0	0	27,003	0	0	0	0	29,244
Total Emissions (tpy)[a]	82,146	74,286	682	1,021	60,824	70,339	84,128	759	3,197	54,724

[a] Totals may not sum due to rounding.

Table 7-19. Comparison of Years 2008 and 2011 OCS platform greenhouse gas emission estimates

	2008				2011			
Source Category	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)	CO_2 Emissions (tpy)	CH_4 Emissions (tpy)	N_2O Emissions (tpy)	CO_2e Emissions (tpy)[a]
Amine Units	0	8	0	171	0	2	0	45
Boilers/Heaters/ Burners	850,228	14	14	854,806	891,652	17	16	896,992
Diesel Engines	335,392	10	N/A[b]	335,608	407,575	13	N/A	407,851
Drilling Equipment	106,250	N/A	N/A	106,250	76,961	1.5	N/A	76,993
Combustion Flares	419,083	442	7	430,640	604,002	366	11	615,029
Fugitives	0	91,468	0	1,920,838	0	61,232	0	1,285,862
Glycol Dehydrators	N/A	19,505	N/A	409,615	N/A	7,859	N/A	165,048
Losses From Flashing	475	20,890	0	439,169	330	14,231	0	299,175
Minor Sources	0	646	0	13,561	0	476	0	9,987
Mud Degassing	1	194	0	4,076	2	505	0	10,615
Natural Gas Engines	2,886,612	12,244	N/A	3,143,735	2,567,943	12,619	N/A	2,832,942
Natural Gas, Diesel, and Dual-fuel Turbines	3,814,880	298	104	3,853,392	7,329,476	400	140	7,381,165
Pneumatic Pumps	414	20,426	0	429,355	401	21,155	0	444,666
Pressure/level Controllers	580	31,448	0	660,988	871	16,739	0	352,384
Storage Tanks	0	901	0	18,919	0	877	0	18,414
Cold Vents	3,251	224,211	0	4,711,689	2,815	134,863	0	2,834,938
Total Emissions (tpy)[c]	8,417,165	422,707	125	17,332,814	11,882,029	271,355	167	17,632,106

[a] CO_2e = 21 for CH_4 and 310 for N_2O.

[b] N/A = Not available

[c] Totals may not sum due to rounding.

7.4.2 Non-Platform Sources

As shown in Table 7-20, when comparing 2008 and 2011 emission estimates for non-platform sources, there is a significant increase in criteria pollutant emission estimates, with the exception of SO_2. The SO_2 emission estimate shows a 26% decrease from 2008 to 2011, due to reduction in vessel activities and application of the most recent USEPA emission factors. These USEPA factors have lower sulfur values for smaller vessels equipped with Category 1 and 2 propulsion engines, such as commercial fishing, pipelaying, crew and coast guard patrol boats and support vessels, generators, and pumps associated with the LOOP.

Table 7-20. Comparison of Years 2008 and 2011 OCS non-platform criteria pollutant emission estimates

	2008					2011				
Source Category	**CO Emissions (tpy)**	**NO_X Emissions (tpy)**	**PM_{10} Emissions (tpy)**	**SO_2 Emissions (tpy)**	**VOC Emissions (tpy)**	**CO Emissions (tpy)**	**NO_x Emissions (tpy)**	**PM_{10} Emissions (tpy)**	**SO_2 Emissions (tpy)**	**VOC Emissions (tpy)**
Drilling Rigs	5,343	58,288	971	7,772	971	6,248	69,135	2,634	20,863	2,750
Pipelaying Operations	2,186	10,535	398	1,789	398	2,124	9,480	350	117	128
Support Helicopters	13,636	1,114	217	275	2,693	2,163	753	23	112	1,624
Support Vessels	12,880	135,222	2,342	18,221	2,342	35,686	175,558	6,435	2,157	4,016
Survey Vessels	141	1,690	26	204	26	1,760	7,851	290	97	105
Total OCS Oil/Gas Production Sources (tpy)	34,186	206,849	3,954	28,261	6,430	47,981	262,777	9,732	23,346	8,623
Biogenic and Geogenic Sources	0	0	0	0	14,358	0	0	0	0	14,357
Commercial Fishing Vessels	681	8,120	124	988	124	1,206	6,917	245	85	218
Commercial Marine Vessels	6,593	79,329	6,603	49,009	2,794	9,779	108,203	4,122	32,651	4,303
LOOP	136	1,832	33	219	613	313	1,399	52	17	420
Military Vessels	702	8,539	158	1,409	130	1,035	11,448	436	3,455	455
Vessel Lightering[a]	320	3,060	86	397	4,423	0	0	0	0	17,113
Recreational Vessels	N/A	N/A	N/A	N/A	N/A	675	3,127	118	75	197
Total Non-OCS Oil/Gas Production Sources (tpy)	8,432	100,880	7,004	52,022	22,442	13,008	131,094	4,973	36,283	37,063
Total Non-Platform Emissions (tpy)[b]	42,618	307,729	10,958	80,283	28,872	60,989	393,871	14,705	59,629	45,686

[a] Vessel estimates for 2011 are reflected in commercial marine vessels.

[b] Totals may not sum due to rounding.

The increased CO, NO_x, PM, and VOC estimates, 43%, 28%, 34%, and 58% respectively, are primarily due to the use of updated USEPA emission factors. The application of the USEPA factors is compounded by increased activity in 2011 for support, survey, and commercial marine vessels. For other categories such as commercial fishing, pipelaying drilling rigs and the LOOP, reductions in activity in 2011 partially offset the effects of the USEPA factors.

The updated USEPA emission factors and activity data yielded an overall increase in greenhouse gas emissions of 33% as noted in Table 7-21. Note that this increase is roughly similar for OCS oil and gas production sources and non-oil and gas sources. The increase in GHG emissions is primarily driven by source categories that had an increase in activity relative to 2008; these include support, survey, and commercial marine vessels.

As with all source categories in the 2011 inventory, 2011 activity data and emissions estimates were compared to the 2008 inventory as a quality check. The drilling rig activity data were obtained from BOEM for both 2008 and 2011. In 2008 there was a total of 39,805 days of drilling in the GOM. In 2011 there was a total of 19,863 days of drilling in the GOM. The drilling rig emission factors were also revised for the 2011 inventory. The combination of reduced activity and application of the latest USEPA emission factors yielded larger emission estimates between 2008 and 2011. In 2011, pipeline repair activities were in line with 2008 levels, but new pipeline construction was approximately 50% of the 2008 level.

Compared to 2008, the 2011 inventory provides much better coverage of support vessel activity due to the use of AIS data. The AIS data identified 682 unique vessels that operators classified as offshore support vessels. These vessels were matched to vessel characteristics data, providing detailed kW ratings for each vessels propulsion engine. As a result, support vessels form a much larger contribution of activity and emissions in the 2011 inventory than identified in previous inventories. The combination of a more complete inventory of support vessels and use of the latest USEPA emission factors has yielded higher emission estimates for 2011 than 2008. There was an increase in the total estimated survey vessel activity due to the identification of 16 additional survey vessels.

The activity data for the 2011 commercial reef fishing vessels (3,944 hours) is considerably less than the 2008 reef fishing vessels activity data (888,120 hours). This is due to a correction made by NFMS to the 2011 code that compiled the data provided to BOEM. Despite the overall reduction in commercial fishing activity, some pollutants have higher emissions in 2011 due to the use of the latest USEPA emission factors.

Table 7-21. Comparison of Years 2008 and 2011 OCS non-platform greenhouse gas emission estimates

	2008				2011			
Source Category	**CO_2 Emissions (tpy)**	**CH_4 Emissions (tpy)**	**N_2O Emissions (tpy)**	**CO_2e Emissions (tpy)[a]**	**CO_2 Emissions (tpy)**	**CH_4 Emissions (tpy)**	**N_2O Emissions (tpy)**	**CO_2e Emissions (tpy)[a]**
Drilling Rigs	3,166,971	19	151	3,214,188	2,748,279	21	110	2,782,820
Pipelaying Vessels	712,570	8	31	722,348	609,535	5	18	615,220
Support Helicopters	1,373,574	N/A[b]	N/A	1,373,574	160,752	10	11	164,373
Support Vessels	7,418,855	47	352	7,528,962	13,002,103	75	386	13,123,338
Survey Vessels	83,500	1	4	84,761	504,714	3	15	509,427
Total OCS Oil/Gas Production Sources (tpy)	12,755,470	75	538	12,923,833	17,025,383	114	540	17,195,178
Biogenic and Geogenic Sources	2,284	1,874	1,948	645,518	2,284	1,876	1,948	645,560
Commercial Fishing Vessels	411,326	3	19	408,369	585,204	2	17	590,516
Commercial Marine Vessels	3,013,948	N/A	N/A	3,013,948	4,301,312	33	172	4,355,325
LOOP	88,564	1	4	89,825	89,958	0.5	3	90,888
Military Vessels	417,677	3	20	423,940	455,071	4	18	460,735
Vessel Lightering[c]	160,038	2	7	162,250	0	N/A	0	0
Recreational Vessels	N/A	N/A	N/A	N/A	244,483	N/A	N/A	244,483
Total Non-OCS Oil/Gas Production Sources (tpy)	4,093,837	1,883	1,998	4,743,850	5,678,312	1,915	2,158	6,387,507
Total Non-Platform Emissions (tpy)[d]	16,849,307	1,958	2,536	17,667,683	22,703,695	2,029	2,698	23,582,684

[a] CO_2e = 21 for CH_4 and 310 for N_2O.

[b] N/A = Not available

[c] 2011 vessel estimates are reflected in commercial marine vessels.

[d] Totals may not sum due to rounding.

Compared to the 2008, CMV emissions appear substantially higher in 2011, due to the use of improved vessel activity data. The 2008 CMV emission estimates were obtained from USEPA to ensure that the emissions developed for BOEM were consistent with emission estimates developed for recent rulemaking and the National Emission Inventory. The 2008 CMV emissions data provided by USEPA were derived from recent regulatory programs related to vessels equipped with Category 3 propulsion engines. The CMV component of the 2011 inventory was developed using vessel specific entrance and clearance data from the U.S. Army Corps of Engineers in conjunction with AIS traffic density data. The 2011 detailed data is of better quality than the top-down 2008 estimates as it accountings for smaller vessels not included in the USEPA's Category 3 vessel inventory. It should also be noted that the 2011 CMV category includes tankers involved in lightering and the LOOP. Emissions associated with the LOOP are accounted for in the CMV estimates derived from AIS data, thus, the 2011 LOOP emissions are limited to the support vessels, platform equipment and evaporative emissions. The 2011 LOOP activity and emissions reflect a 30% decrease in crude imports which partially offsets the effect that the USEPA emission factors have on the emission estimates. Similarly, the vessel activity and emissions associated with lightering are already accounted for in the CMV estimates, the 2011 lightering emissions are limited to evaporative emissions resulting from transferring crude to the smaller shuttle tankers and ballasting activities. The 2011 lightering emissions, are larger than the 2008 estimates as a more complete inventory of lightering service providers was developed; in 2008 one company (Skaugen Petrotrans) was included in the inventory while in 2011 two additional companies (Overseas Shipholding Group Lightering and AET Lightering) were added that have higher activity levels than the Skaugen Petrotans.

7.5 RECOMMENDATIONS

As discussed in Section 7.3, a key limitation for the 2011 OCS platform emissions inventory is that emissions are not estimated using direct source test data. In lieu of requiring that platform operators submit source test data or prepare and submit emission estimates, BOEM should continue to make use of the most recent emission factors and research results in developing the emission estimates for platform equipment. For example, there are a number of ongoing USEPA studies examining the regulatory requirements and flare destruction and removal efficiencies, as well as enforcement activities targeting flare operations. In addition, OCS platforms under BOEM jurisdiction that are estimated to emit more than 25,000 metric tons of CO_2e are subject to the USEPA Mandatory Reporting of Greenhouse Gases Rule (*Federal Register* 2009). USEPA summary data indicate that 106 offshore production platforms reported under the rule. BOEM should evaluate the data provided by these platforms to identify potential areas for improvement in the emission estimation methods and emission factors, especially for fugitive sources and flare operations. For glycol dehydrators, BOEM could require that operators submit emission estimates and supporting documentation from the GTI AIRCalc™ Software Program (BOEM's contractor runs the program for amine units, using detailed data collected from the operators). For losses from flashing, the BOEM collects information from the platform operators and calculates emissions using the Vasquez-Beggs correlation equations. BOEM could instead require that operators collect pressurized oil samples from separators or heater treaters and perform laboratory flash analyses to the obtain GOR and chemical composition, or use a process simulator such as Hysim® or Prosim® and provide documentation.

As discussed in Section 4.4.7, in addition to GOADS reporting requirements, BOEM also collects monthly volume vented and flared data from production operators through OGOR forms. 30 CFR Part 250, Oil and Gas and Sulphur Operations in the Outer Continental Shelf-Oil and Gas Production Requirements, now includes requirements that operators meter flared and vented gas volumes on facilities that process more than 2,000 barrels of oil per day, and to report flared gas separately from vented gas on the OGOR forms (*Federal Register* 2010). Future inventory development efforts should again rely on the use of these reported data.

Other recommendations for future inventory efforts for OCS oil and gas production platforms include validating or updating the range check values, surrogate stack parameters, and surrogate fugitive component counts, given changes in offshore platform operations (e.g., deepwater platforms are more now common). In addition, an evaluation of the surrogate fuel usage rates used to estimate emissions for pneumatic pumps and pressure level controllers is needed, based on recent studies by the British Columbia Ministry of Environment and the Canadian Association of Petroleum Producers, and the University of Texas Center for Energy and Environmental Resources. There is also ongoing research specific to tank emission factors. Recent evidence suggests that emissions from tanks may increase due to temporary increases in tank pressure as liquids are dumped to tanks from separators operating at pressures greater than one atmosphere.

For non-platform sources, the main recommendation for future inventory efforts is to develop a technique that better uses the AIS vessel tracking data to time-stamp when vessels enter and leave federal waters of the Central and Western areas of the GOM to accurately estimate hours of operation in the region. These vessel-specific data can be matched up with vessel characteristics using sources such as the IHS's Registry of Ships. This will provide more accurate estimates of activity and emissions. Detailed AIS information about the vessels that discharge product through the LOOP would also be helpful in assessing the carrying capacity of the vessels that visit the LOOP, allowing for more accurate estimate of evaporative emissions from ballasting.

Survey vessel estimates can also be improved by compiling impact assessments for survey activities if publicly available. Aternatively, survey of local seismic survey companies may provide useful data about the GOM fleet its characterictics and operations.

An alternative approach to estimating helicopter activities and emissions is the use of the FAA NextGen tracking data. These data are similar to the AIS data used to track ship movements. Flight paths of individual helicopters can be mapped to BOEM lease blocks and hours of operation calculated. This approach would require purchase of helicopter flight data from a vendor who would distill the data into a useful format, but would provide a more accurate assessment of helicopters, their flight paths, and an indication of monthly activity variance.

Given the limited data currently available for Navy vessel operations, it is recommended that a special study be developed to better quantify Naval vessel characteristics and activity in the GOM. To facilitate the exchange of data from the Navy, it may be necessary for senior Department of Interior staff to coordinate the data request with the U.S. Navy Atlantic Fleet command.

Additional research is also needed to confirm the reasonableness of the variance noted in the monthly drilling rig, pipelaying, support vessels, and commercial fishing temporal adjustment factors. Future non-platform inventory efforts should also evaluate how new pipelaying construction activities differ from maintenance operations with regard to required vessel support and hours of operation.

Another recommendation is to continue to research the availability of emission factors for black carbon, particularly for diesel engines and marine vessels. Black carbon is of concern because of health concerns and potential climate impacts. Black carbon is emitted directly into the atmosphere as $PM_{2.5}$ and influences climate by directly absorbing light, reducing the reflectivity ("albedo") of snow and ice through deposition, and interacting with clouds. A 2012 black carbon Report to Congress and a study currently underway by the Commission for Environmental Cooperation should yield results that can be incorporated into future BOEM inventories.

Last, at the completion of the 2014 inventory development effort, BOEM will have emission estimates for six consecutive inventory studies that span 2000 through2014. Detailed and comprehensive expanded comparisons and deviations (trends analyses) will benefit the BOEM in a number of ways, including preparation of NEPA documents and predicting future emission trends in spatial terms. In addition, it would be beneficial to perform a top-down assessment of the 2011 emission estimates, similar to assessments that are performed with on-shore emissions inventories. In this type of assessment, the bottom-up emissions inventory is evaluated by performing air quality modeling using the inventory, and the predictions are coupled with ambient observations in a top-down performance evaluation. Sources of measured ambient data include satellite measurements of total column masses of pollutants, and measurements made by aircraft overflights. This type of assessment could determine whether the inventory correctly predicts that specific areas are experiencing increases or decreases in emissions.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management Mission

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.