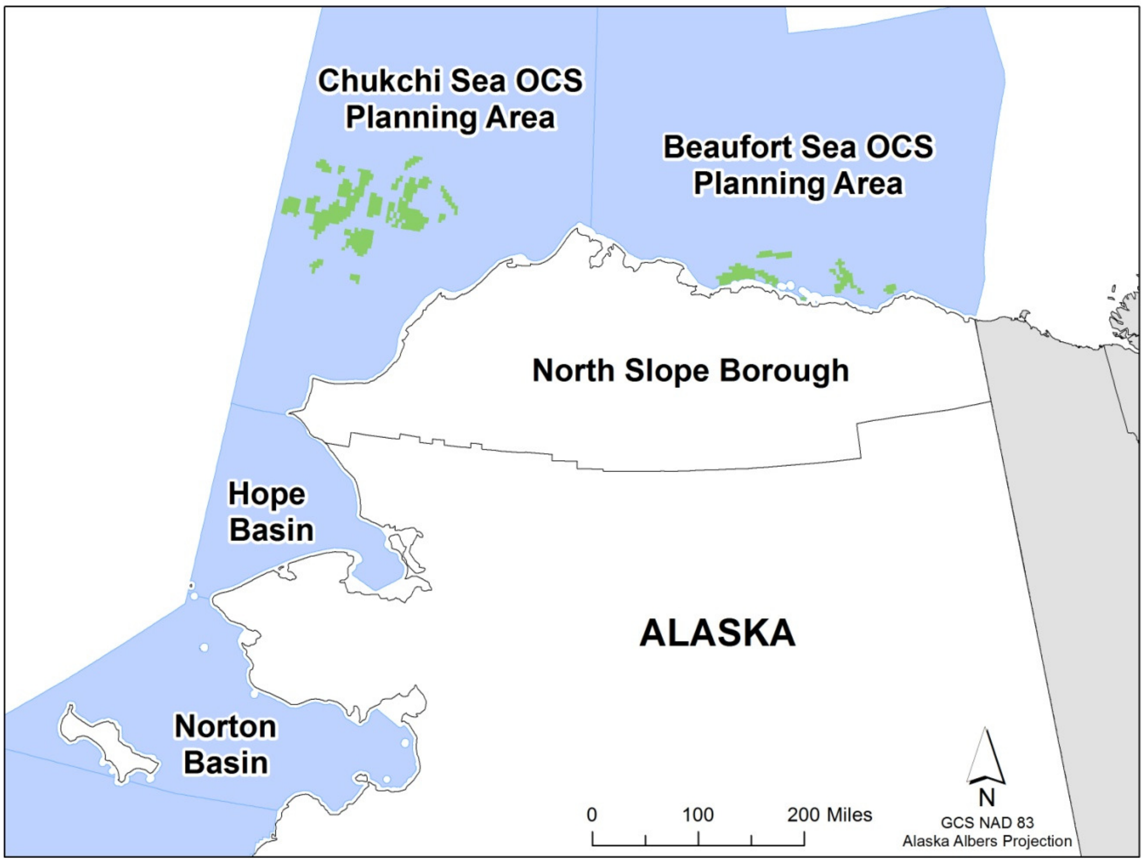
OCS Study
BOEM 2017-040

Arctic Air Quality Impact Assessment Modeling Study – Evaluation of the Emissions Exemption Thresholds



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Bureau of Ocean Energy Management
Alaska OCS Region

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Disclaimer

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This report discusses a conservative "full build-out scenario" that describes air emissions sources associated with potential future oil and gas exploration, development, and production activities on the Beaufort Sea and Chukchi Sea Outer Continental Shelf. The elements of this scenario are included for the purpose of analysis and do not necessarily represent expected activities.

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Abbreviations and Acronyms

ADM	atmospheric near-field dispersion modeling
AERMAP	AERMOD terrain preprocessor
AERMET	meteorological pre-processor for AERMOD
AERMOD	American Meteorological Society/United States Environmental Protection Agency regulatory model for dispersion
AERSCREEN	AERMOD screening model
AKOCSR	Alaska Outer Continental Shelf Regional Office
AQRP	Air Quality Regulatory Program
AQRV	air quality-related value
BOEM	Bureau of Ocean Energy Management
CAA	Clean Air Act
COARE	Coupled Ocean-Atmosphere Response Experiment
DOI	U.S. Department of the Interior
DPP	development and production plan
EET	emission exemption threshold
EP	exploration plan
USEPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group, Inc.
FPSO	floating production storage and offloading
MERP	model emissions rates for precursors
MMIF	Meso-scale Model Interface program
NAAQS	National Ambient Air Quality Standards
NSB	North Slope Borough
NSR	new source review
NWS	National Weather Service
OCD	Offshore Coastal Dispersion
OCS	Outer Continental Shelf
OCSLA	OCS Lands Act
ppb	parts per billion
PSD	prevention of significant deterioration
SER	significant emission rate
SIL	significant impact level
SIP	State Implementation Plan
USFWS	United States Fish and Wildlife Service
WRF	Weather Research and Forecasting model
$\mu g/m^3$	micrograms per cubic meter
U.S.	United States

Pollutants

CO	carbon monoxide
NH_3	ammonia
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen (NO and NO_2)
O_3	ozone
Pb	lead
$PM_{2.5}$	particulate matter with an aerodynamic diameter less than or equal to 2.5 micrometers
PM_{10}	particulate matter with an aerodynamic diameter less than or equal to 10 micrometers
TSP	total suspended particles
SO_2	sulfur dioxide

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1.0 INTRODUCTION

The Bureau of Ocean Energy Management (BOEM) Alaska Outer Continental Shelf Regional Office (AKOCSR) has the delegated authority to regulate stationary sources of emissions from oil and gas activities proposed within the Chukchi Sea and Beaufort Sea Outer Continental Shelf (OCS) Planning Areas adjacent to the North Slope Borough (NSB) of Alaska. Proposed operators on the Arctic OCS are required to comply with the Department of Interior (DOI)/BOEM Air Quality Regulatory Program (AQRP), established under 30 CFR Part 550, Subpart C, and BOEM has the obligation to implement the authority provided in OCS Lands Act (OCSLA) Section 5(a)(8). Figure 1 shows the Alaska OCS planning areas, where the overlaid box represents the study area (i.e., 4 km modeling domain) and the green shading represents select areas that are historically leased for oil and gas activity.

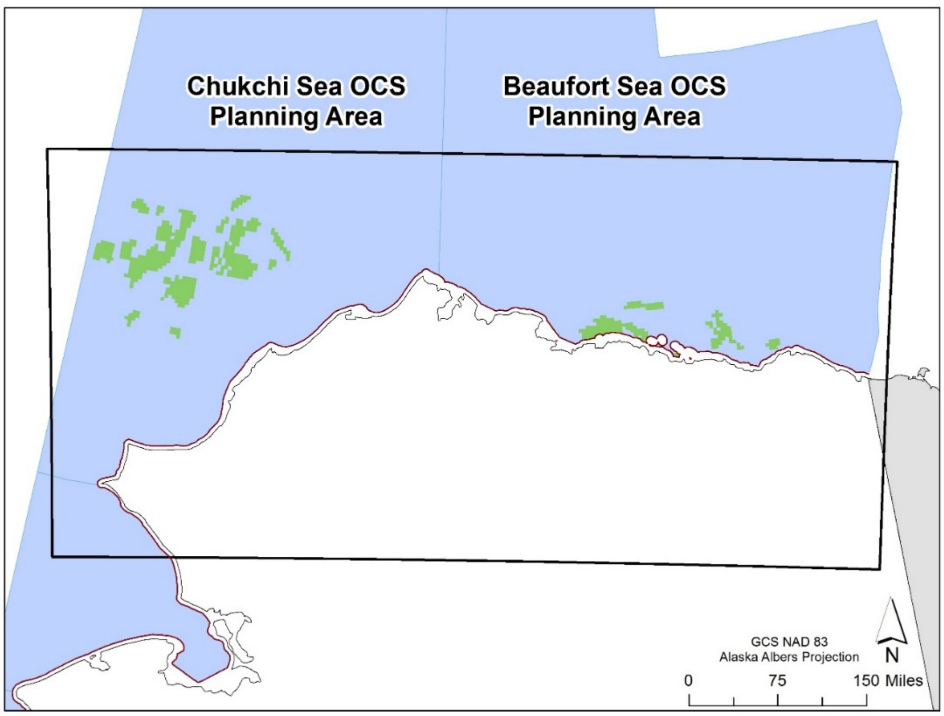

Figure 1. Regional Map Depicting the OCS Planning Areas and the Study Domain (Green areas represent select historical oil and gas lease areas.)

A key objective of the Arctic Air Quality Modeling Study is to evaluate the current regulatory equations at 30 CFR 550.303(d) that are used to estimate exemption thresholds for offshore source emission rates of selected pollutants for the study domain.

Task 6 builds on the modeling analyses conducted by the Eastern Research Group (ERG)/ Ramboll Environ (Ramboll Environ, 2017) in Tasks 4 and 5, and combines additional modeling to rigorously test and evaluate the existing emission exemption threshold (EET) formulas.

1.1 Background

This section provides regulatory context for the EET formulas by outlining the National Ambient Air Quality Standards (NAAQS) and permitting process.

1.1.1 National Ambient Air Quality Standards

The Clean Air Act (CAA) (42 USC 7401 *et seq.*) directs the USEPA to establish NAAQS for the following "criteria" pollutants that may reasonably be anticipated to endanger public health or welfare: ground-level ozone (O_3) (i.e., precursor volatile organic compounds [VOC]), sulfur oxides (SO_x), nitrogen dioxide (NO_2), carbon monoxide (CO), lead (Pb), and particulate matter (PM). The USEPA is required to review the NAAQS every five years and revise the NAAQS if justified by the scientific evidence collected during the review. Revisions can include changes to the level, indicator, and/or averaging time of the NAAQS.

The indicator of a NAAQS defines the chemical species or mixture that is to be measured in determining whether an area attains the standard. For example, the indicator for the first PM NAAQS was total suspended particles (TSP), which includes particles with an aerodynamic diameter of less than 100 micrometers. As the understanding of the health effects of PM improved, the indicator was revised to a concentration of PM with an aerodynamic diameter of less than or equal to 10 micrometers (PM_{10}) and for PM with an aerodynamic diameter of less than or equal to 2.5 micrometers ($PM_{2.5}$).

Averaging time is also an important component for determining attainment with the standard. The averaging time is the period over which the concentrations are averaged for the NAAQS. The averaging time is intended to represent the exposure time with significant health impacts as derived from controlled human exposure studies. NAAQS with averaging times of less than or equal to 24 hours are considered short-term standards, while averaging times of greater than 24 hours are considered long-term standards. Table 1 summarizes the current levels, averaging times, and indicators for the NAAQS, as well as the prevention of significant deterioration (PSD) increments, and significant impact levels (SILs).

After promulgation of a NAAQS, the USEPA designates nonattainment areas (NAAs), which are communities associated with a monitor showing emission levels that do not meet the NAAQS. NAAs also include areas that contribute to monitored NAAQS violations in a nearby area. States are required to submit State Implementation Plans (SIPs) to the USEPA that contain strategies to control emissions and demonstrate that the NAA will achieve the NAAQS by the required date. After an NAA attains the NAAQS, the area can be redesignated as a maintenance area and must continue to demonstrate compliance with the NAAQS.

There is currently only one designated NAA in Alaska—the Fairbanks North Star Borough, which exceeds the 2006 NAAQS for $PM_{2.5}$. This area is over 200 statute miles (321.9 km) from the NSB. Alaska also has three maintenance areas—Anchorage Municipality (CO and PM_{10}), Fairbanks North Star Borough (CO), and Juneau City and Borough (PM_{10}) —all of which are at least 200 statute miles (231.9 km) from the southern border of the NSB. Figure 2 shows the location of these nonattainment and maintenance areas with respect to the NSB. In addition, Figure 2 identifies the "mandatory" Class I areas, which are national parks and wilderness areas identified under the 1999 Regional Haze Rule (64 FR 35714).

Table 1. Current Forms of the NAAQS, PSD Increments, and SILs

Pollutant	Indicator	Averaging Time	NAAQS Level[a]		Class II SIL[b]	
			µg/m³	ppb	µg/m³	ppb
Carbon Monoxide	CO	1-hour	40,000	35,000	2,000	2,000
		8-hour	10,000	9,000	500	400
Lead	Pb in TSP (Pb-TSP)	Rolling 3-month avg	0.15	-	-	-
Nitrogen Oxides	Nitrogen Dioxide (NO_2)	1-hour	188	100	7.5	4
		Annual	100	53	1	1
Photochemical Oxidants/Ozone	O_3	8-hour	137	70	1.9	1.0
Particulate Matter	$PM_{2.5}$	24-hour	35	-	1.2	-
		Annual	12	-	0.2	-
	PM_{10}	24-hour	150	-	5	-
		Annual	-	-	1	-
Sulfur Oxides	Sulfur Dioxide (SO_2)	1-hour	196	75	7.9	3
		3-hour	1,300	500	25	10
		24-hour	365	140	5	2
		Annual	-	-	1	0.4

[a] Source: 40 CFR Part 50

[b] Source for CO, PM_{10}, NO_2 (annual), and SO_2 (annual, 24-hr and 3-hr): 40 CFR 51.165(b)(2).
Source 1-hr SO_2: USEPA's "Guidance Concerning the Implementation of the 1-hour SO_2 NAAQS for the Prevention of Significant Deterioration Program, August 23, 2010."
Source 1-hr NO_2: USEPA's "General Guidance for Implementation of the 1-hour NO_2 NAAQS in Prevention of Significant Deterioration Permits, Including an Interim 1-hour NO_2 Significant Impact Level, June 28, 2010."
Source for Ozone and $PM_{2.5}$: USEPA Draft Guidance Memo "Significant Impact Levels for Ozone and Fine Particle in the Prevention of Significant Deterioration Permitting Program, August 1, 2016"

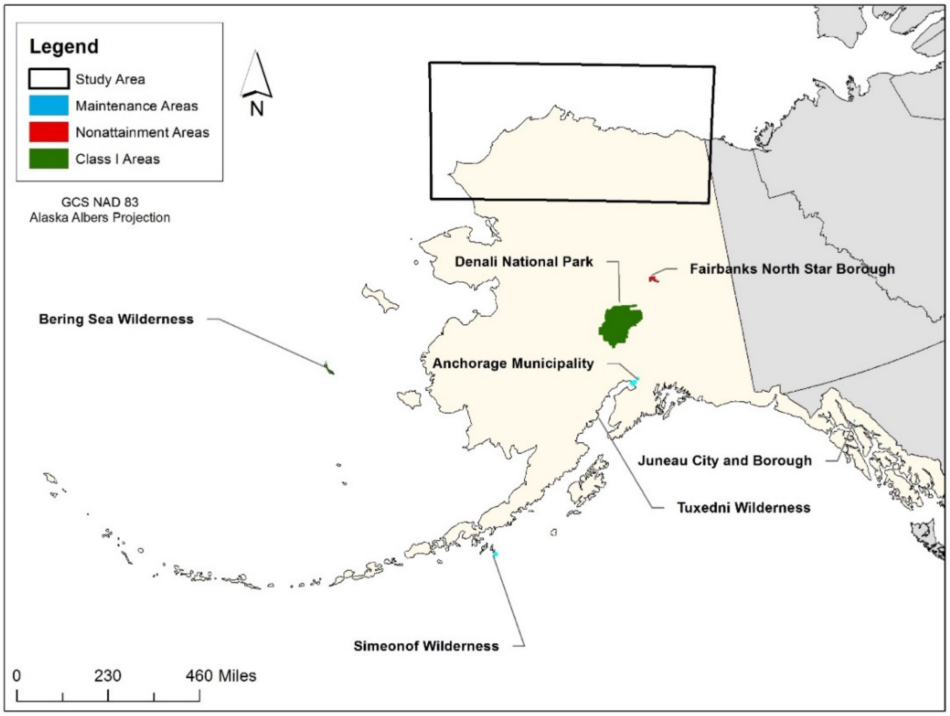

Figure 2. Alaska Maintenance, Nonattainment, and Mandatory Class I Areas

Although some temporary monitors exist in the NSB for permitting purposes, there are currently no permanent ambient ozone or $PM_{2.5}$ monitors operating in the NSB, resulting in an "unclassifiable" designation for these NAAQS in the NSB. The USEPA revised the ozone NAAQS on October 1, 2015. On December 22, 2017 the USEPA responded to state recommendations and indicted all areas in Alaska have anticipated area designations "Attainment/Unclassifiable". In February 2010, USEPA issued a new 1-hour NO_2 NAAQS with a threshold of 100 parts per billion (ppb) and in June 2010 promulgated a new 1-hour SO_2 NAAQS with a threshold of 75 ppb. The USEPA designated all of Alaska as "attainment/ unclassifiable" for the 1-hour NO_2 and for the 1-hour SO_2 NAAQS. That is all of Alaska is meeting the standard and not contributing to a violation of the standard, largely due to limited sources in the state.

In addition to nonattainment areas, the CAA designates 156 Class I areas nationwide. These areas consist of national parks and wilderness areas that warrant special protection for air quality and air quality related values (AQRVs). The CAA also defines Class II and Class III distinctions. The Class I areas have lower PSD increments and SILs than Class II areas, and are protected against excessive increases in several AQRVs, including visibility impairment, acid (sulfur and nitrogen) deposition, and nitrogen eutrophication.

The nearest Class I area to the NSB, Denali National Park, is located over 200 statute miles (321.9 km) to the south of the NSB border. The Alaska Department of Environmental Conservation (ADEC) permit modeling guidance (ADEC, 2015) notes facilities over 300 km are not subject to Class I impact analysis. Because the offshore sources modeled to evaluate the EET exceed this distance, Class I impact analyses do not need to be performed as part of this project.

1.2 Overview of Approach

As noted in Section 1, one of the objectives of this study is to evaluate the existing formulas used to exempt from modeling requirements proposed oil and gas activities, including offshore exploratory drilling and production platform drilling. As currently written, these formulas provide an emissions level based on the platform's distance to shore that it must fall below to be exempt from further analysis, including modeling.

To evaluate the existing EET formulas, ERG compared dispersion modeling results to the outcome from the EET formulas. For the dispersion modeling, ERG used a different approach to the emissions inventory than was used in the impacts analysis modeling under Tasks 4 and 5. Instead of using the future year projected emissions, ERG developed and modeled a series of "hypothetical" sources using an iterative approach.

To remain consistent with EPs, DPPs, and the current formulation of the EET formulas, the Task 6 modeling did not consider any changes to onshore emission sources that might occur with a new offshore source. However, the hypothetical sources considered all platform equipment emissions.

ERG modeled the hypothetical sources and compared the dispersion modeling results for all pollutants to the appropriate SILs to determine if the project is estimated to have a significant impact to onshore air quality. The same sources were subject to the existing EET formulas, and the results were compared to the outcomes of the modeling. This comparison determined which pollutants, if any, might benefit from a revision to the EET formulas to continue to be protective of onshore air quality. The photochemical modeling from Task 5 was used to assess ozone and secondary $PM_{2.5}$ formation to determine the potential ramifications to the existing EET formulas.

Section 2.0 summarizes the development of the hypothetical sources used in the models. Section 3 summarizes the model selected for the study and Section 4 summarizes the various inputs and modeling options. Section 5 summarizes the results of the dispersion modeling and Section 6 summarizes the evaluation of ozone and secondary $PM_{2.5}$ formation.

1.2.1 USEPA Air Quality Permitting Program

To protect NAAs and Class I Areas, major (and some minor) new source construction or major modification of sources in an NAA must go through nonattainment new source review (NSR) to ensure emission levels in the nonattainment area do not increase. After an area attains the NAAQS, the area can be re-designated as a maintenance area and must continue to demonstrate compliance with the NAAQS. Any proposed new source seeking a permit or existing source making modifications to permits in a maintenance, attainment, or unclassifiable area must show PSD (i.e., analysis must show that emissions from any new or modified facility do not increase pollutant concentrations from the baseline concentration over the maximum allowable amount). This maximum allowable amount, or PSD increment, varies for each criteria pollutant.

The USEPA allows PSD programs to use screening methods to streamline the permitting process if the proposed construction is not anticipated to have a significant impact on air quality. These screening level tools have included significant emission rates (SERs) and SILs to determine the level of air quality analysis needed to demonstrate that source emissions will not cause or contribute to a violation of an NAAQS or increment. SERs act an initial screening to determine if a source is required to provide additional analysis of the ambient air quality impacts (i.e., modeling). USEPA regulation requires that only sources emitting at a level greater than or equal to a pollutant's SER provide additional analysis (USEPA, 2014b). If the difference between the NAAQS and the background concentration for the source site is greater than or equal to the SIL, then next step is to compare the estimated impacts of a pollutant from source modeling to its SIL. If the impacts from this single source modeling analysis are less than the SIL, then air quality analysis for the NAAQS is satisfied. If the impacts of the individual source are found to be greater than the level of a SIL or the difference between the NAAQS and background is less than the SIL, then cumulative impact analysis is required (i.e., modeling that considers the combined impact of the proposed source and other sources in the affected area) to demonstrate that the proposed source will not cause or significantly contribute to a violation of the NAAQS (USEPA, 2014b). Table 1 summarizes the PSD increments and SILs for Class I and II areas along with the related NAAQS.

BOEM must ensure that any proposed offshore development does not significantly impact the air quality of any state, including significantly contributing to or causing a NAAQS violation. To help accomplish this, BOEM has developed a process consistent with the USEPA permitting program by which operators submit plans that ensure the protection of the offshore and onshore environment. These plans include air quality analysis for potential impact on the NAAQS. Similar to the tiered approach to the air quality analysis in the USEPA program, operators report the total complex emissions anticipated for modified or new offshore facilities. These emissions are then compared to the respective EET to determine if additional modeling is warranted to ensure no significant air quality impacts are anticipated onshore.

The next section discusses the BOEM process and EETs in detail.

1.2.2 BOEM EET Formulas

BOEM is required to comply with the NAAQS, described in Section 1.1.2, by ensuring that OCS offshore oil and gas exploration, development, and production sources do not significantly affect the air quality of any state. To assess the impact of development on the OCS, BOEM requires lessees to submit either exploration plans (EPs) or development and production plans (DPPs) for any new offshore activities. An EP describes all exploration activities planned by an operator for a specific lease and a DPP describes development and production activities proposed by an operator for a lease or group of leases. Both documents include the timing of the proposed activities, information concerning drilling unit or drillships, the location of each proposed well or production platform or other structure, and an analysis of both offshore and onshore impacts that may occur as a result of the project's implementation.

To determine whether a proposed source would have the potential to cause or contribute to a significant violation of the NAAQS, BOEM developed a screening method similar to the screening methods allowed by the USEPA for PSD program. This screening method—the EET formulas—identifies whether a facility described in an EP or DPP is exempt from further air quality regulatory review because the project's potential emissions would cause no significant, or *de minimis*, impacts on the air quality of any state.

In the existing equations in 30 CFR 550.303, the lessee compares the highest annual total amount of emissions from the facility for each air pollutant calculated in their EP or DPP to the emission exemption amount "E" for each air pollutant calculated using the following formulas:

For CO:

$$E = 3{,}400 \times (D)^{(2/3)}$$

For TSP, SO_2, NO_x, and VOC:

$$E = 33.3 \times D$$

Where:

E = Emission exemption amount expressed in tons per year

D = Distance of the proposed facility from the closest onshore area of a state expressed in statute miles

If projected emissions are less than or equal to the emission exemption amount E for the air pollutant, then the project is considered to not impact the NAAQS of onshore areas and is exempt from further air quality review.

If the projected emissions are more than the emission exemption amount, the facility must conduct modeling to estimate the highest onshore impact to compare to the SIL like the onshore permitting process described in Section 1.2.1. The facility would also need to start to review potential control strategies to reduce emissions. If the modeling shows an impact that exceeds the SIL, the facility would need to review potential control strategies to reduce emissions.

It is important to note that the emission exemption amounts produced by the EET formulas do not replace the SERs or SILs. These formulas act as an initial screening tool to simplify the review process for facilities with insignificant, or *de minimis*, impact from further effort. In this respect, the EET formulas are similar to the emission over distance (Q/d) screening method used by Federal Land Managers to screen sources for Class I area impact analysis.

The existing EET formulas were developed in the 1980s and were based on Offshore Coastal Dispersion (OCD) modeling results compared to the NAAQS established at that time. Since then, the NAAQS have undergone several revisions, including changes in indicator and averaging times. For example, the current EET formulas do not address ozone directly, and do not address any short-term NAAQS. The work under this Task 6 is aimed to evaluate the established EET formulas and assess whether they are still a viable approach as a screening tool to ascertain presumed compliance with the NAAQS.

In this analysis, ERG reviewed impacts along the shoreline and state seaward boundary, based on the current level of the SILs listed in Table 1. The state seaward boundary represents the end of the state jurisdiction and the start of federal jurisdiction in the OCS as defined under the OCS Lands Act (OCSLA; at 43 U.S. Code §1331 through §1356a).

2.0 HYPOTHETICAL SOURCES

For the EET evaluation, several “hypothetical” offshore sources were modeled in the Chukchi and Beaufort Seas. The reason for using hypothetical, but representative, sources is twofold:

- Using hypothetical sources avoids the perception that BOEM is calling into question previous exemption analysis for existing sources. It is not the intent of this study to review previous plans and test the validity of the analysis already conducted for current exploration or production operations.
- Modeling hypothetical sources allows the flexibility to pair various emission levels with various distances to shore to ensure the formula is tested with the full range of possible values. By capturing the full range of possibilities, the existing EET formulas will be thoroughly tested for any limitations, including combinations of emissions and distance to shore not currently leased.

For the hypothetical source emissions levels, ERG developed emission rates for the following emissions scenarios that represent:

- Drilling exploration plan (EP) with well testing
- Development and production plan (DPP)
- DPP with well testing
- Production-only DPP
- Floating Production Storage and Offloading (FPSO) vessels.

ERG developed all five scenarios for small-, medium-, and large-scale operations using calculation methods consistent with submitted EPs and DPPs. Appendix A contains profiles of the equipment modeled at hypothetical sources.

ERG reviewed publicly available EPs and DPPs from BOEM’s website (http://www.boem.gov/akplans/) for typical platform configurations and emissions levels submitted to BOEM for approval. ERG then used the platform configurations from the available plans to construct hypothetical sources for each of the five scenarios and each operational scale. Table 2 summarizes the scenarios and indicates equipment required under each scenario. For example, all production operations (Scenarios 2, 3, and 4) include at least one vent or flare (whose volumes include upsets).

After adding all the representative equipment for each scenario, ERG made additional modifications to operational hours and activity levels to ensure an adequate variation in the annual and hourly emission level to be modeled. Hourly emission rates are consistent with the supporting maximum hourly emission rate calculations in the EP and DPP air quality spreadsheets (i.e., the total hourly emission rate if all equipment was operated at the same time).

The annual emission values were rounded to the nearest hundred to flag that the modeled emissions are hypothetical sources (e.g., 15,897 would be rounded to 15,900). Table 3 presents the hour emission levels of PM_{10}, $PM_{2.5}$, SO_2, NO_x, ammonia (NH_3), VOC, and CO used in modeling.

Table 2. Summary of Mandatory Equipment Under Each Scenario

Scenario	Description	Includes (At Least One)
1	Drilling EP with well testing	Drillship/prime mover
2	Production and drilling DPP	Diesel engine, flare or vent, and fugitives (default of 11,420 components with light oil stream type)
3	Production and drilling DPP with well testing	Diesel engine, flare or vent, and fugitives (default of 11,420 components with light oil stream type)
4	Production only DPP	Diesel engine, flare or vent, and fugitives (default of 11,420 components with light oil stream type)
5	FPSOs	Diesel engine, flare or vent, and fugitives (default of 11,420 components with light oil stream type)

Table 3. Modeled Hourly Emission Levels for Hypothetical Sources

Scenario	Description	Size	Emissions (lb/hr)						
			PM_{10}	$PM_{2.5}$	SO_2	NO_x	NH_3	VOC	CO
1	Drilling EP with well testing	L	66	65	631	1,487	0.77	56	356
		M	42	41	459	948	0.63	34	224
		S	31	31	176	587	0.25	34	142
2	Production and drilling DPP	L	114	113	669	3,824	0.77	126	600
		M	41	40	460	1,076	1.10	138	263
		S	32	31	176	600	0.25	139	144
3	Production and drilling DPP well testing	L	77	77	506	2,780	0.63	88	346
		M	44	44	461	1,001	0.84	140	238
		S	32	31	176	600	0.25	139	144
4	Production only DPP	L	14	14	1.7	925	0.05	119	305
		M	2.7	2.7	1.7	289	0.05	105	161
		S	1.0	1.0	0.9	28	0.01	106	6.6
5	FPSOs	L	15	14	112	676	0.22	125	182
		M	17	17	115	671	0.14	135	178
		S	13	12	113	517	0.22	21	142

To determine locations for the hypothetical sources, ERG calculated the distance to shore for all the active lease blocks in the Arctic OCS and each emission scenario was modeled for the variety of distances to shore that are representative of the active lease blocks in the Chukchi Sea and Beaufort Sea. The distance to shore for active lease blocks was determined using the Active Lease Polygons shapefile published on the BOEM "Geographic Mapping Data in Digital Format" website (BOEM, 2015) and the ArcGIS proximity toolset to calculate the closest distance to shore for each active lease block. Because of coastal features, the minimum distance of 3 statute miles (4.8 km) determined by the analysis periodically fell outside the BOEM Planning Area boundary (i.e., within state waters). ERG adjusted the initial distances to fall within the BOEM Planning Area, or 1 mile (1.6 km) off of the state seaward boundary. All other distances were adjusted to be parallel to the state seaward boundary. Table 4 summarizes the final distances used for hypothetical source placement in modeling, both as distance from shore and distance from the state seaward boundary.

Table 4. Summary Statistics for Distance to Shore

Distance to Shore (statute miles (km))	Distance from Seaward Boundary (statute miles (km))	Represents
3 (4.8)	1 (1.6)	Minimum distance of all lease blocks
16 (25.7)	13 (20.9)	Average distance for Beaufort Sea
22 (35.4)	19 (30.6)	75th percentile distance for the Beaufort Sea
39 (62.8)	36 (57.9)	Maximum distance for the Beaufort Sea
60 (96.6)	57 (91.9)	25th percentile distance for all lease blocks
83 (133.6)	80 (128.7)	25th percentile Distance for Chukchi Sea
91 (146.5)	89 (143.2)	Median distance of all lease blocks
106 (170.6)	103 (165.8)	Average/median distance for Chukchi Sea
120 (193.1)	117 (188.3)	75th percentile distance for all lease blocks
163 (262.3)	160 (257.5)	Maximum distance for all lease blocks

ERG selected the proposed hypothetical source locations at random from the modeling grid cell that fell along the distance lines. All locations are within federal waters in the 2.5 statute mile (4 km) Weather Research and Forecasting (WRF) model domain and coincide with the center of a modeling grid cell. Figure 3 shows the proposed hypothetical source locations in the study area at the selected distances from shore.

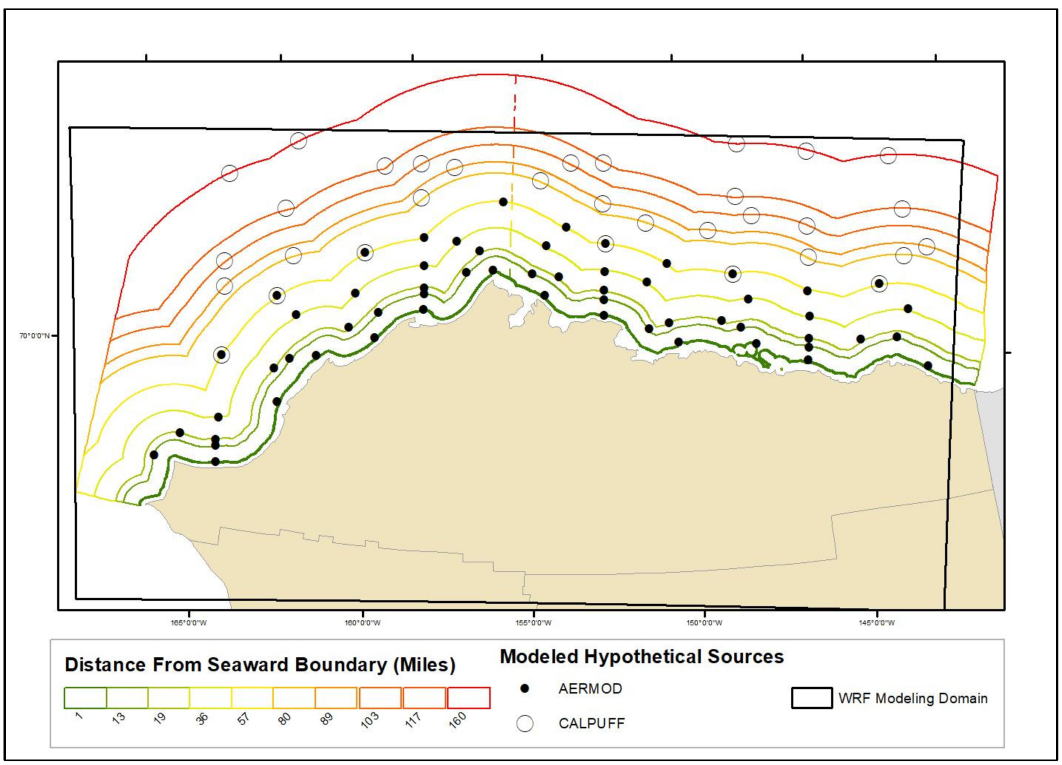

Figure 3. Hypothetical Source Placement

ERG modeled the hypothetical sources at 31 statute miles (50 km) or less from the state seaward boundary using American Meteorological Society/United States Environmental Protection Agency regulatory model for dispersion (AERMOD) following similar modeling procedures to the atmospheric near-field dispersion modeling (ADM) modeling in Task 4 (i.e., same modeling set and options) in multiple locations in the Chukchi and Beaufort Seas at multiple distances to shore. ERG modeled hypothetical sources at a distance greater than 50 km from the state seaward boundary using CALPUFF. Along the 57- statute-mile (92-kilometer) contour from the state seaward boundary, a subset of sources was modeled with both AERMOD and CALPUFF to determine the difference in impact predicted by both models.

Dispersion modeling requires that the emission source have defined stack characteristics (i.e., release height, exit temperature, exit velocity, and stack diameter). Because of the limited data on platform sources in the Arctic, the platform stack parameters for the theoretical sources were to be determined from the values provided from platforms further south in the Cook Inlet of Alaska, National Emission Inventory (NEI) defaults, and the stack parameters used in the full build-out scenario from the Task 3 emissions inventory (Fields Simms, et al, 2014). ERG reviewed the stack parameters per equipment type to determine typical values and identify the variability of these parameters across the sources. Table 5 lists the equipment-specific stack parameters to be used in the modeling. Not all equipment types are present under each scenario.

USEPA's "Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Revised" (USEPA-454/R-92-019, October 1992) allows sources that emit the same pollutant from several stacks with similar parameters that are within about 100 meters to be treated as if all of the emissions were coming from a single representative stack. Thus, based on the result of the stack parameter analysis, ERG combined equipment with similar stack parameters on the platform to simplify the modeling setup.

Table 5. Average Platform Equipment Stack Parameters

Equipment Type	Stack Parameter				
	Height (m)	Diameter (m)	Temperature (K)	Flow Rate (m^3/second)	Velocity (m/second)
Boiler/heater/burner (BOI)[a]	15.6	0.41	467	1.4	10.6
Diesel or gasoline engine (DIE)[a]	10.4	0.41	760	4.94	32.7
Drilling rig (DRI)[a]	15.4	0.31	813	3.09	12.3
Natural gas engine (NGE)[a]	28.75	0.44	832	6.5	42.7
Natural gas, diesel, and dual-fuel turbine (NGT)[a]	10.97	1.7	815	70	31.7
Combustion flare (FLA)[b]	22.51	0.74	837	4.34	10.13
Fugitives (FUG)[b]	12	0.001	295	0	0.0001
All Other Equipment Types [c]	12	0.73	399	4.4	10.5

[a] Based on BOEM EP/DPPs.
[b] NEI Defaults.
[c] Full build-out scenario inventory.

3.0 AIR QUALITY MODEL SELECTION

Offshore sources and associated activities have the potential to impact air quality, not just on a local scale (near-field, within approximately 31 statute miles (50 km) of the source), but also on a regional scale (far-field, greater than 31 statute miles (50 km) from the source). The USEPA's Guideline on Air Quality Models (40 CFR Part 51, Appendix W, November 2005, hereafter referred to as "USEPA's Guideline") and BOEM's Modeling Guidance (30 CFR 550.218 and 30 CFR 550.249) also recognize the different spatial scales of impacts and recommend different models to evaluate near-field and far-field effects.

The OCD model is the preferred dispersion model for overwater sources for short-range transport (source-to-receptor distances less than 50 km). The 2017 USEPA's Guideline does not currently list a preferred dispersion model for long-range (source-to-receptor distances greater than 50 km) transport over water, but the previous version (2005) listed CALPUFF as the preferred model for long-range transport over land. In general, AERMOD is the preferred dispersion model for over-land short-range modeling. The last substantial change to the OCD model was in 1997, almost two decades ago (though there was a small bug fix released in 2000). AERMOD, unlike OCD, has undergone continuous updates to both its scientific algorithms and its input and output formats.

As part of this study, the OCD model was rigorously compared to AERMOD and CALPUFF models for the overwater environment. Based on this comparison, the Weather Research and Forecasting-Meso-scale Model Interface-AERMOD (WRF-MMIF-AERMOD) system was selected for near-field overwater modeling and WRF-MMIF-CALPUFF was selected for far-field modeling. The model justification report (Ramboll Environ, 2017) provides the full analysis for the selection of these modeling platforms for overwater modeling.

For the ADM conducted for this study (Task 4), the latest version of AERMOD was used for the near-field modeling. AERMOD-specific modeling options are summarized in Section 4.3. CALPUFF was used for the far-field dispersion modeling for directly emitted pollutants. CALPUFF-specific modeling options are summarized in Section 6.4.

4.0 MODELING INPUTS AND CONFIGURATION

In addition to emissions data, dispersion modeling requires meteorological data and defined receptor fields. The models selected for this portion of the study also have additional options and data needs. The following sections provide a summary of these additional data and options used. More detail can be found in the modeling protocol (Do, 2015) for this task.

4.1 Meteorology

The USEPA's Guideline specifies that a minimum of one year of site-specific data, or five years of representative National Weather Service (NWS) data should be used. The USEPA's Guideline also states that up to five additional years should be used when available to account for year-to-year variation in meteorological conditions when modeling with site-specific data.

The meteorological dataset used for the Arctic Air Quality Modeling Study was developed under Task 2 of this study (Brashers, et al., 2015). Because of the harsh conditions, meteorological monitoring in the North Slope rarely results in complete annual records. ERG's efforts under Task 2 focused on using meteorological modeling to produce the necessary meteorological inputs for the study. The results of Task 2 are five years (2009-2013) of WRF Model simulations that can be used for the air quality modeling tasks. These hind-cast WRF runs provide a complete dataset for each year, including upper air values. ERG determined the model performance of each annual run and documented that performance under Task 2 (Brashers, et al., 2016).

ERG used the MMIF program to output the needed meteorological data from the WRF modeling output. MMIF was run in "direct" mode and resulted in a file in the proper format for running AERMOD and CALPUFF. This method is supported by the model justification report (Ramboll Environ, 2017).

4.2 Receptors

To estimate the impact of the emissions changes from baseline emissions to the full build-out scenario, ERG used separate receptor fields to individually examine each new source and sources projected to have increased/decreased emissions. Initial receptor placement consisted of receptors along the shoreline and along the state seaward boundary at 500-meter intervals for all sources. ERG constructed an initial receptor list with 500-meter spacing and used a subset of these locations for each modeling run.

The shoreline receptors follow a generalized coastline definition (1:20,000,000 resolution) (U.S. Census Bureau, 2014a), rather than a strict shoreline definition that would follow every coastal feature (1:500,000 resolution) (U.S. Census Bureau, 2014b). This simplifies the receptor placement by not strictly following large coastal features such as bays, lagoons, and mouths of rivers. Figure 4 provides an example of this generalization along the shoreline. The receptors, shown with 500-meter spacing receptors, cut across the mouth of a bay and take a straight-line path instead of strictly following the coast. Elevation for all receptors was set at sea level for the study area.

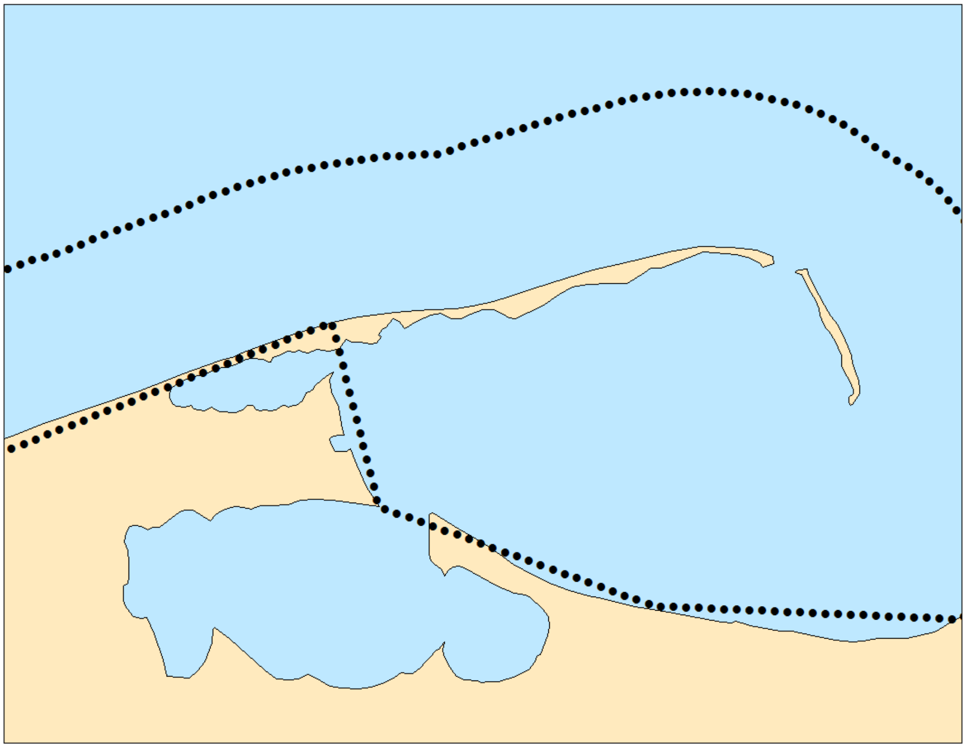

Figure 4. Example of Generalized Shoreline Receptors Along the North Slope

4.3 AERMOD Modeling Approach

ERG utilized the same model setup and meteorological data to determine the impacts from each pollutant.

When modeling NO_x, an additional option is specified to estimate the NO_2 values, because emissions from combustion sources are partly nitric oxide (NO) and partly NO_2 with additional NO_2 created due to atmospheric reactions after the gas leaves the stack. The NAAQS and increments were developed for NO_2; therefore, a methodology to estimate how much of the released NO is converted to NO_2 is needed in order to compare a modeled concentration to an NO_2 standard or increment.

The USEPA's Guideline discuses a tiered approach to modeling the annual average NO_2 impacts:

- Tier 1: Assumes total conversion of NO to NO_2
- Tier 2: Multiplies Tier 1 result by empirically-derived NO_2/NO_x ratio (e.g., national default ratio of 0.8 (1-hour) and 0.75 (annual))
- Tier 3: Detailed analysis on Case-by-Case Basis.

Tier 1 calculations represent the most conservatively high estimates of NO_2 and was used to for the study.

The study area is coastal and relatively flat. Therefore, ERG ran AERMOD using the flat terrain option. For modeling purposes, the rural/urban classification of an area is determined by either the dominance of a specific land use or by population data in the study area. Due to the clearly rural nature of the North Slope, the area was flagged as rural.

ERG included a unit emissions rate run to allow the scaling of impacts during post-processing for additional alternate emission scenarios.

4.4 CALPUFF Modeling Approach

ERG used the current regulatory versions of CALPUFF (CALPUFF version 5.8.5; CALPOST version 6.221) with regulatory defaults applied. For the CALPUFF modeling, ERG used the same Lambert Conformal projection parameters as the WRF modeling (70°N, 155°W with true latitude at 70°N, Polar Stereographic projection).

5.0 DIRECT EMISSION IMPACT EVALUATION

ERG applied the existing EET formulas to each of the modeled hypothetical sources to determine the level of impact at the receptors compared to the established SILs for each NAAQS. ERG compared the results of the exemption formulas to the over/under SILs conclusions from the modeling. This produced three outcomes with respect to the EET:

- "Pass" – A correct evaluation (formulas determined modeling was needed and it was needed, or formula determined modeling was not needed and it was not needed).
- "False positive" (Type I error) – Formula determined that modeling was necessary, when it was not (i.e., impact below the SIL).
- "Miss" (Type II error) – Formula determined that modeling not necessary, when it was (i.e., impact was over the SIL).

The results are summarized in the following section. Additional plots of the results are provided in Appendix B, with numerical results for each run provided in Appendix C.

5.1 Short-term Standards Evaluation

For the short-term standards (NAAQS with averaging times of less than or equal to 24 hours), the highest impacts occur at the modeling points closest to shore (i.e., D001, indicated by light blue dots) and the higher emission scenarios as illustrated in Figure 5 for the NO_2 1-hour NAAQS. The plumes from the hypothetical sources closest to shore have less time to disperse, so high values are anticipated at these locations. Also, higher impacts are expected for the higher emission scenarios.

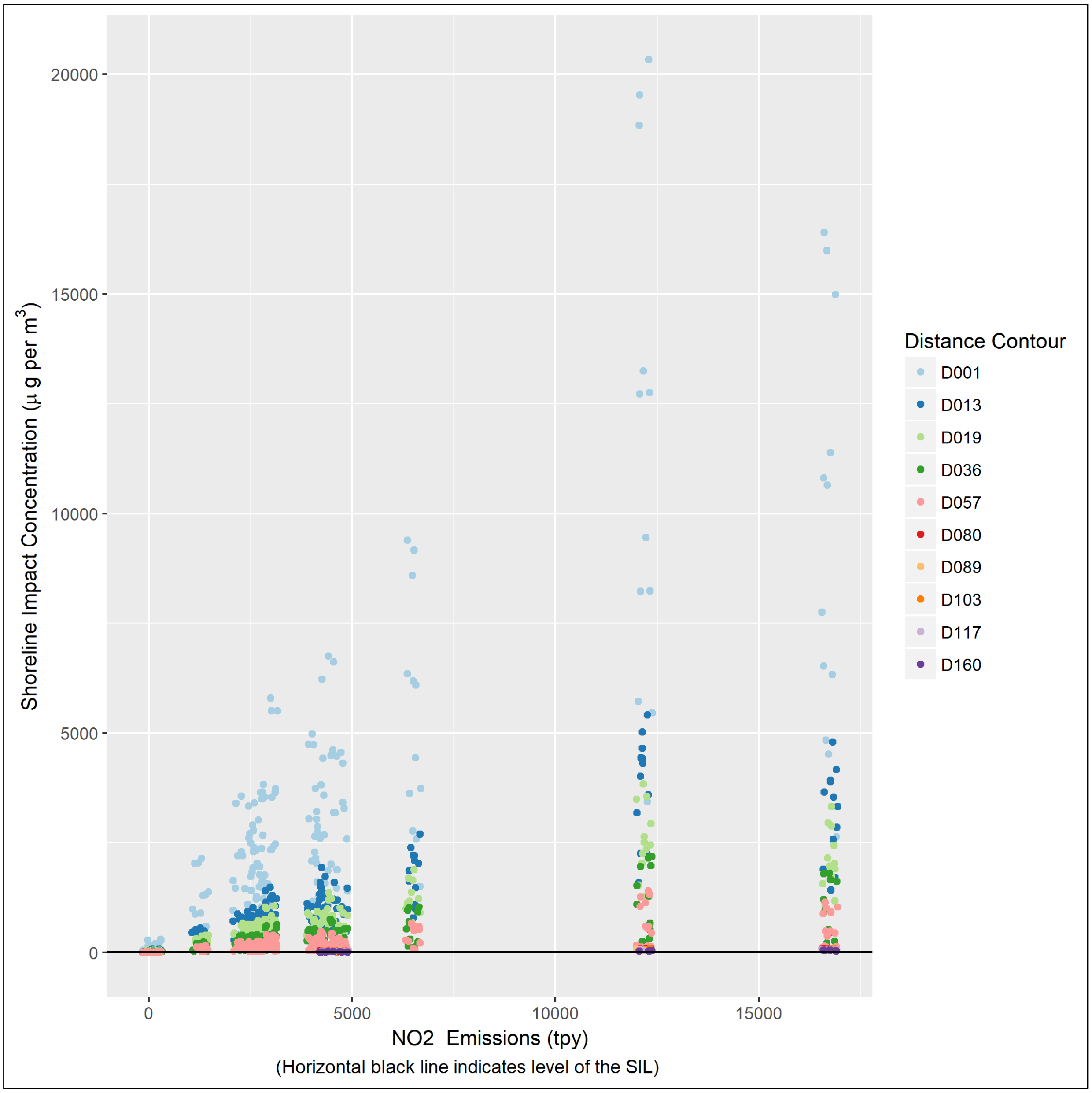

Figure 5. NO_2 1-hr Impact by Emission Rate at the Shoreline.

When impacts were compared to the existing EET formulas, there was a high level of agreement between the modeling and EET estimated significance (Table 6). For the NO_2 1-hour standard, there was 95% agreement between the model and EET formal outcome. The highest "miss" rate is associated with $PM_{2.5}$ and corresponds to the largest emission scenarios. The high miss rate for $PM_{2.5}$ may be due to conservatively high model estimates, as the runs did not consider dry or wet depletion of $PM_{2.5}$.

Table 6. Short-term NAAQS Outcomes at the Shoreline

Pollutant	Averaging Time	Number Of Modeling Runs	Evaluation Outcome (percentage of total) Pass	False Positive (Type I)	Miss (Type II)
CO	1-hour	890	88%	0%	12%
	8-hour	890	87%	0%	13%
NO_2	1-hour	1167	95%	0%	5%
$PM_{2.5}$	24-hour	812	42%	0%	58%
PM_{10}	24-hour	983	80%	0%	20%
SO_2	1-hour	989	81%	0%	19%
	3-hour	989	82%	7%	11%
	24-hour	989	86%	3%	12%

Overall, the EET formula generally has a low miss rate for the combinations of emissions and distances tested. That is, the existing EETs occasionally do not recommend modeling for some facilities that cause an impact larger than the SIL at the shoreline. Figure 6 shows where these errors occur with respect to the distance to shore and emission rate modeled. Figure 6 is a scatter plot of all distance and emission combinations modeled. These points are color coded based on the error type seen, with the black line indicating the current EET formula (33.3*D). The figure can be interpreted as non-red points falling below the line were below the emission threshold indicated by the current EET, that is the EET indicated modeling was not necessary. Points with a "Pass" error type below the line are where the modeling showed an impact that fell below the SIL. Under the line we see "Miss" errors, that is the EET indicated that the project was below the *de minimis* threshold and did not need further analysis; however, modeling showed that the project did have a shoreline impact greater than the SIL. Most of the Misses occur close to shore, which makes sense as the near shore location would not have a lot of time to disperse could have higher impact.

Similarly, all the points above the line indicate runs where the EET indicated a project above the *de minimis* threshold that required additional modeling. Point shaded to indicate a "Pass" showed an impact above the SIL at the shoreline. The False Positives, sources that would have been required to model under the current process but did not have a modeled impact above the SIL, would be seen above the EET line. Plots like Figure 6 for the other pollutant and averaging times can be found in the Appendix B.

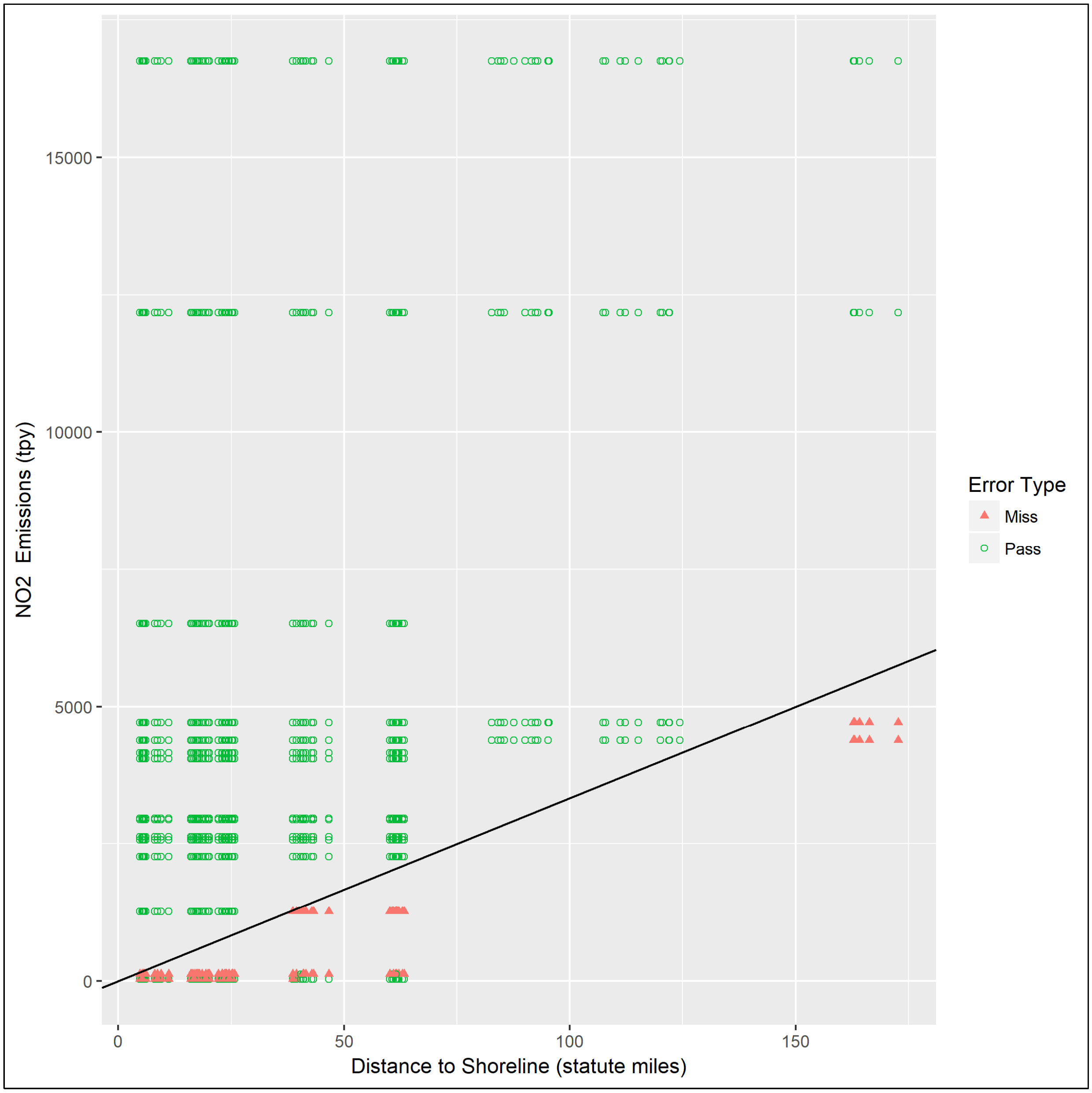

Figure 6. Scatter Plot of NO_2 1-hour Modeling Results at the Shoreline. Black Line Indicates the EET

ERG also reviewed the results at the seaward boundary. Overall, impacts from the modeling were similar, with slightly higher impacts modeled at the seaward boundary. The highest impacts were seen at the same locations (Figure 7); that is, at those locations closest to the receptors. For the EET comparisons, the intent of the distance in the EET formulas is to represent the distance to the point of impact. As such, ERG adjusted the EET calculations for the state seaward boundary to use the distance to the seaward boundary as opposed to the distance to shore. With this adjustment, there was a high level of agreement between the modeling and EET estimated significance (Table 7).

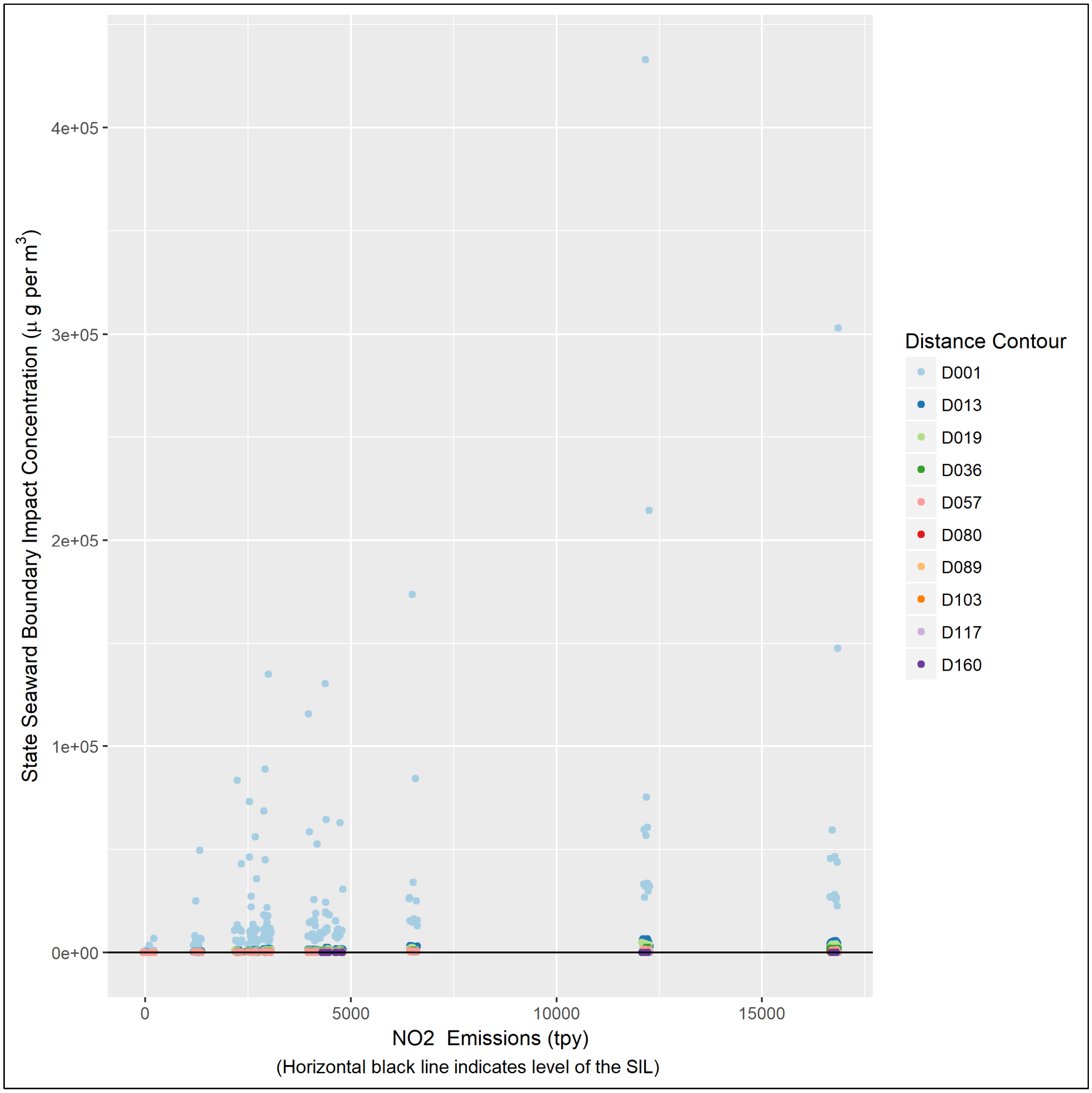

Figure 7. Scatter Plot of NO_2 1-hour Impact at the Seaward Boundary

There is a slight increase in the miss rate for some of the averaging times with the move to the state seaward boundary. This typically occurs within the first 40 statute miles (64 km), as seen in Figure 8. It appears the closer impact point created more agreement between the modeling and EET—that is, the EET formulas suggested more sources were above the *de minimis*, and modeling showed an impact larger than the SIL. Overall, the existing EET formulas perform similarly at the seaward boundary and at the shoreline boundary.

Table 7. Short-term NAAQS Outcomes at the Seaward Boundary

Pollutant	Averaging Time	Number Of Modeling Runs	Evaluation Outcome (percentage of total)		
			Pass	False Positive (Type I)	Miss (Type II)
CO	1-hour	708	80%	0%	20%
	8-hour	719	81%	0%	19%
NO_2	1-hour	1094	94%	0%	6%
$PM_{2.5}$	24-hour	637	48%	0%	52%
PM_{10}	24-hour	470	81%	0%	18%
SO_2	1-hour	843	85%	0%	15%
	3-hour	841	85%	6%	9%
	24-hour	865	87%	3%	10%

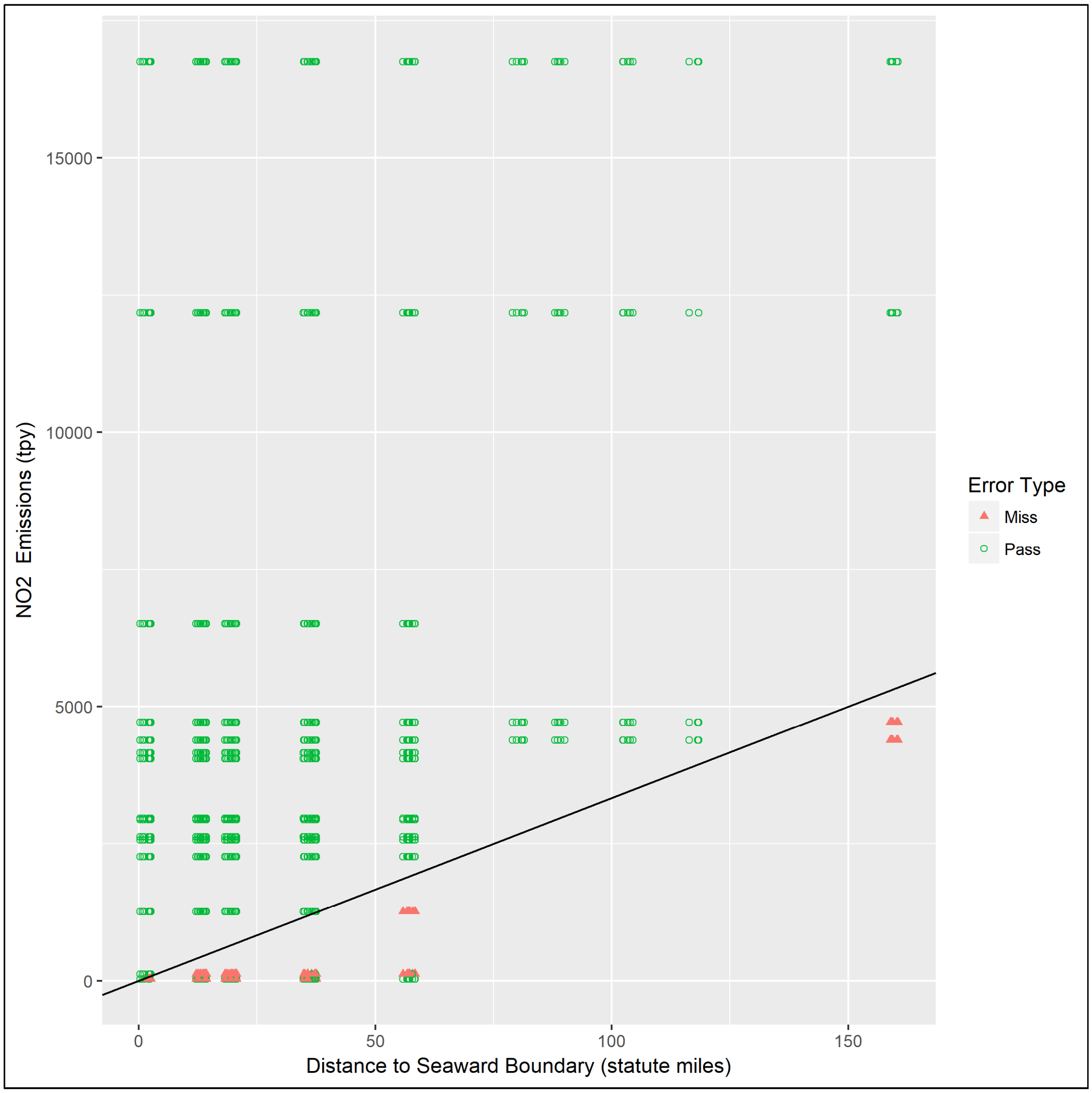

Figure 8. Scatter Plot of NO_2 1-hour Modeling Results at the Seaward Boundary. Black Line Indicates the EET

5.2 Long-term Standards Evaluation

For the long-term standards (NAAQS with annual averaging times), the highest impact occurs at the closest distance and highest emissions rate (Figure 9). For the long-term standards (annual NAAQS), the existing EET formulas showed more false positives (Type I errors). That is, the existing EET formulas called for modeling when an impact larger than the SIL was not seen (Table 8). False positives were especially common at distance greater than 50 statute miles (80 km) (Figure 10). This modeling was conducted with CALPUFF, which was run iteratively. That is, modeling started with the highest emissions rate, and moved to next lowest emission scenario until the results showed no significant impact onshore.

ERG modeled at a conservatively high emission rate, using the calculated *maximum* hourly emission rate for all averaging times, consistent with USEPA regulatory modeling guidance (i.e., 40 CFR Part 51, Appendix W). Modeling an *annualized* hourly emission rate (i.e., total annual emission divided by hours operating) would produce a lower emission rate and therefore would result in a lower impact in the modeling. Modeling at the *maximum* hourly emission rate suggests the current EET formulas for the annual NAAQS is especially conservative, thus requiring more modeling than potentially necessary and indicating the EET formulas are overly protective of public health. This outcome is less of a concern than a high miss rate, which could indicate the EET formulas may be less protective of public health.

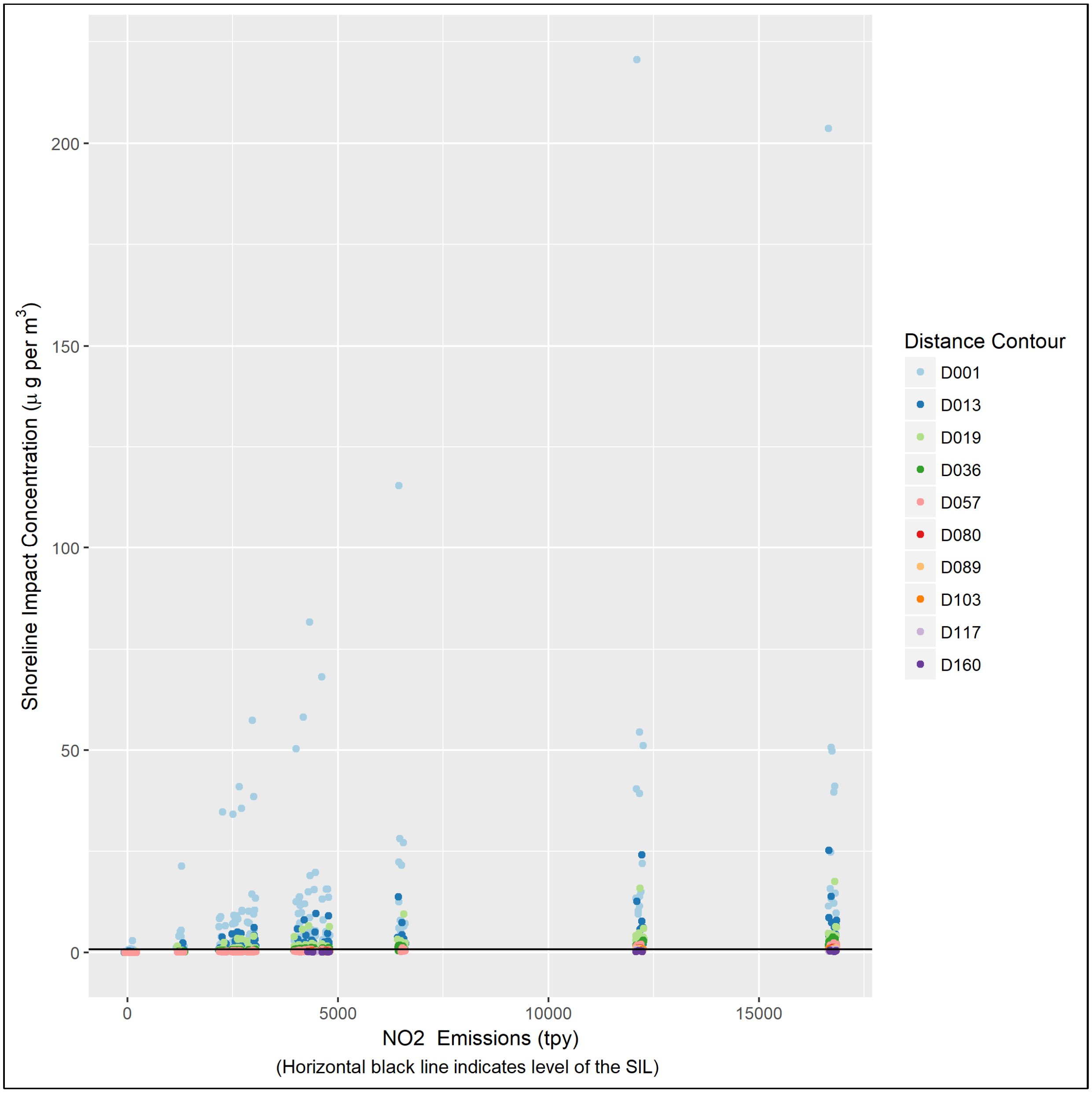

Figure 9. Scatter Plot of NO_2 Annual Results at the Shoreline

Table 8. Long-term NAAQS Outcomes at the Shoreline

Pollutant	Evaluation Outcome (percentage of total)			
	Number Of Modeling Runs	**Pass**	**False Positive (Type I)**	**Miss (Type II)**
NO_2	1,167	86%	14%	0%
$PM_{2.5}$	890	90%	4%	6%
PM_{10}	782	86%	14%	1%
SO_2	928	56%	44%	0%

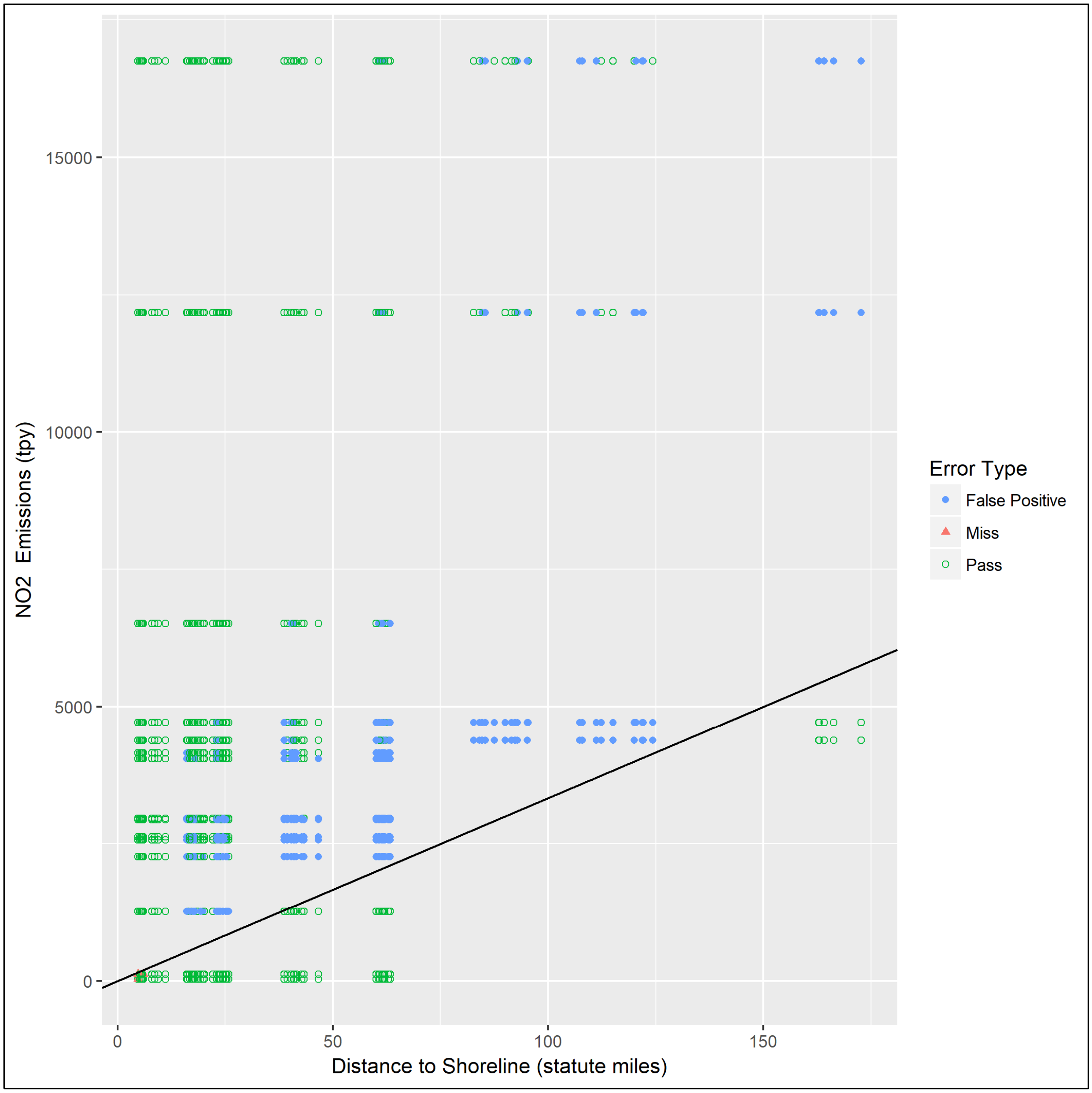

Figure 10. Scatter Plot of NO_2 Annual Results at the Shoreline
Black line indicates the EET

The results at the seaward boundary were similar to the results at the shoreline. The highest impacts were seen at the same locations (closest distance and highest emissions rate) (Figure 11). The outcomes of the comparison were similar (Table 9), with most pollutants showing a high pass rate and false positive rate. The false positives were typically seen at the farthest distances (Figure 12). Overall, the existing EET formulas perform similarly at the seaward boundary as at the shoreline.

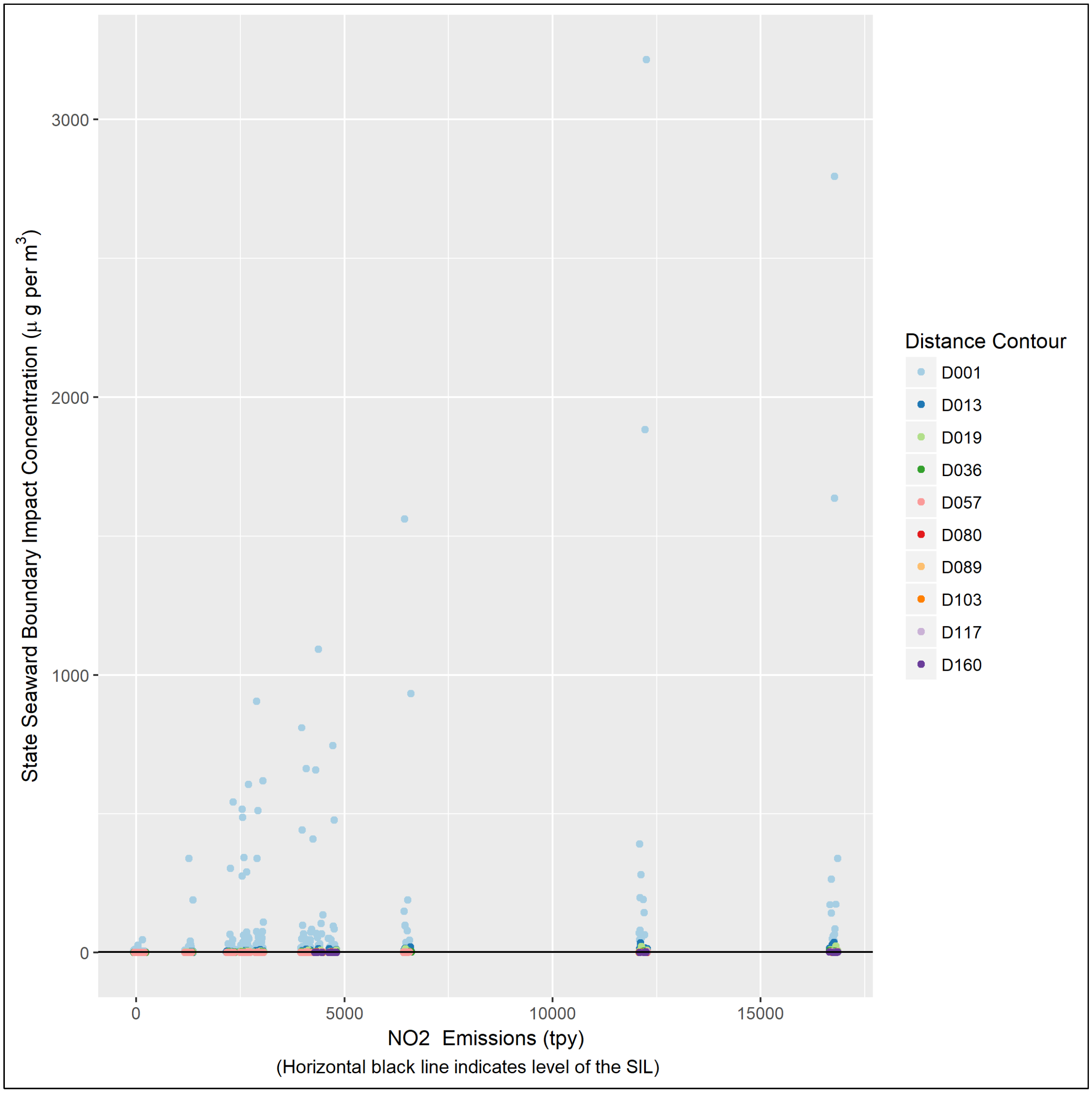

Figure 11. Scatter Plot of NO_2 Annual Impact at the State Seaward Boundary

Table 9. Long-term NAAQS Outcomes at the Seaward Boundary

Pollutant	Evaluation Outcome (percentage of total)			
	Number Of Modeling Runs	**Pass**	**False Positive (Type I)**	**Miss (Type II)**
NO_2	1,167	87%	12%	1%
$PM_{2.5}$	890	93%	3%	4%
PM_{10}	782	86%	13%	0%
SO_2	928	60%	40%	0%

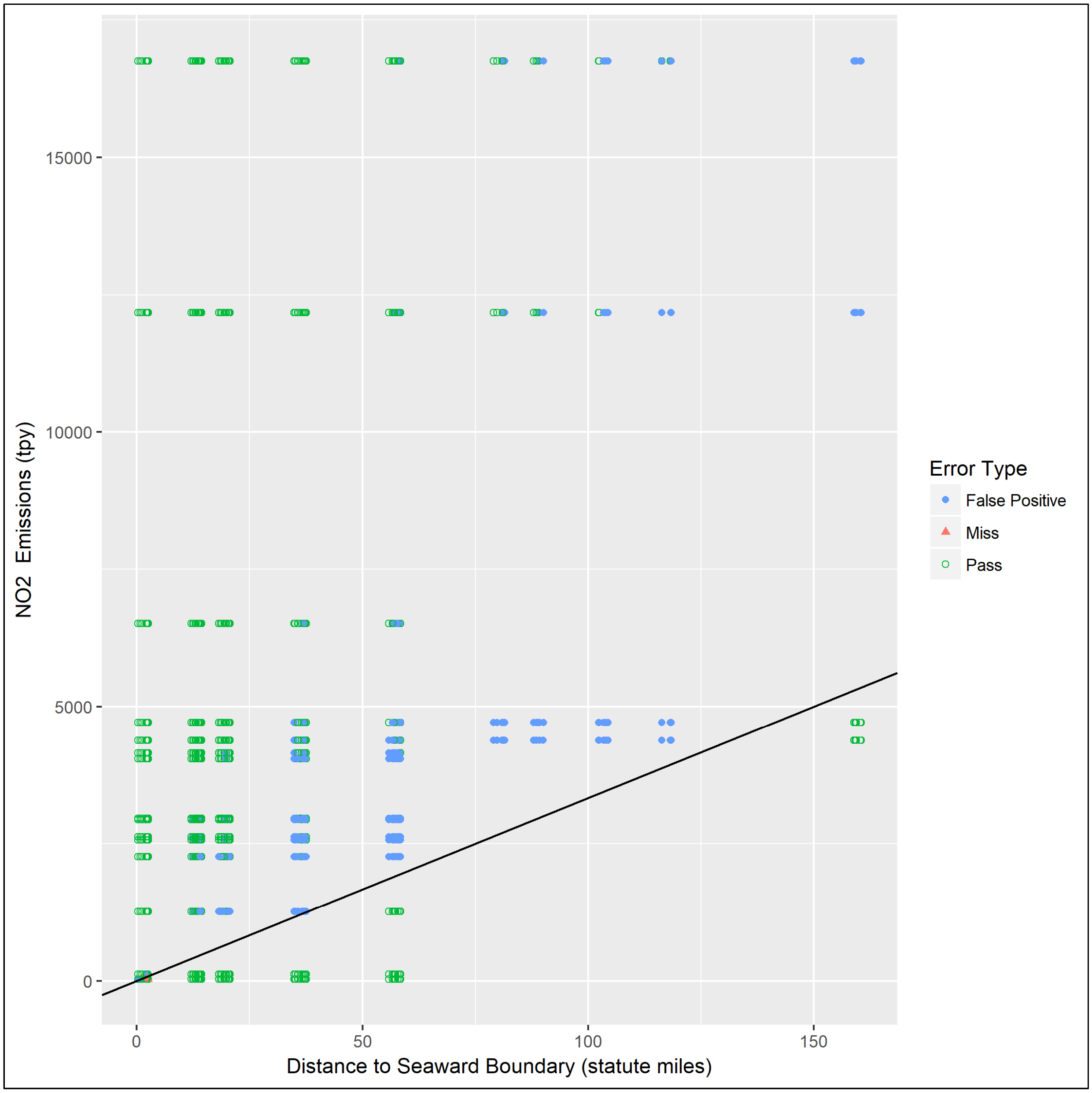

Figure 12. Scatter Plot of NO_2 Annual Results at the State Seaward Boundary (Black line indicates the EET)

6.0 SECONDARY FORMATION IMPACT EVALUATION

Modeling of single-source impacts on secondarily formed pollutants, $PM_{2.5}$ and O_3, is an evolving modeling area. The recently proposed changes to the USEPA's Guideline include new memoranda and guidance (USEPA 2015a, 2015b, 2015c) and expanded guidance (USEPA 2016a, 2016b, 2016c) on secondary formation that represent a slight shift in the modeling approach described in USEPA's Guidance for $PM_{2.5}$ Modeling (USEPA, 2014b).

The latest USEPA guidance documents (i.e., those from 2015 and 2016) includes a two-tiered demonstration approach for secondary formation. The first tier involves use of pre-established technically credible relationships between precursor emissions and a source's impacts to assess impacts. The second tier involves application of more sophisticated case-specific photochemical grid models conducted consistent with new USEPA single-source modeling guidance (USEPA. 2015c).

As part of the first tier, USEPA permit applicants can use a new demonstration tool for ozone and $PM_{2.5}$ precursors referred to as model emissions rates for precursors (MERP). The MERPs offer a screening method that would represent a level of emissions of precursors that is not expected to contribute significantly to concentrations of secondarily formed $PM_{2.5}$ or O_3.

To derive a MERP value, the model-predicted relationship between precursor emissions from hypothetical sources and their downwind maximum impacts can be combined with a critical air quality threshold using the following equation:

$$MERP = SIL * \left(\frac{Modeled\ emission\ rate\ from\ hypothetical\ source}{Modeled\ air\ quality\ impact\ from\ hypothetical\ source}\right)$$

Where the SIL, or other critical air quality thresholds, would be expressed as a concentration for $PM_{2.5}$ ($\mu g/m^3$) or O_3 (ppb or ppm), modeled emission rate is expressed in tons per year, and modeled air quality impact expressed in units of $\mu g/m^3$ (ppb) for $PM_{2.5}$ (and ozone). The modeled impacts would reflect the maximum downwind impacts for $PM_{2.5}$ and O_3. The final MERP is expressed as an annual emissions rate in tons per year. Thus, the calculated MERP act similar to an EET, in that a project with emissions less than the MERP is anticipated to cause no significant, or *de minimis*, impacts on the air quality from secondary formation.

As part of its 2016 guidance on MERPs (2016b), the USEPA calculates MERP values for each of the precursors of $PM_{2.5}$ and ozone for several hypothetical sources around the country based on source apportionment modeling. The hypothetical sources modeled had emissions rates of either 500, 1000, or 3,000 tons per year. These modeling results were used to develop a "most conservative" MERP value for each region, which is summarized in Table 10. The conservative MERPs are only for regions in the continental U.S. because the analysis did not include Alaska.

Table 10. Regional Most Conservative MERPs (tons per year)

Precursor	Area	8-hr O3	Daily $PM_{2.5}$	Annual $PM_{2.5}$
NO_x	Central U.S.	126	1,820	7,427
NO_x	Eastern U.S.	107	2,467	10,037
NO_x	Western U.S.	184	1,155	3,184
SO_2	Central U.S.	-	256	1,795
SO_2	Eastern U.S.	-	675	4,013
SO_2	Western U.S.	-	225	2,289
VOC	Central U.S.	948	-	-
VOC	Eastern U.S.	814	-	-
VOC	Western U.S.	1,049	-	-

The development of this Arctic Air Quality Impact Assessment Modeling study occurred prior to the release of the draft MERPs guidance, and as such, the photochemical grid modeling portion of this study (Task 5) does not include source apportionment modeling that could be used to calculate MERPs for the study area. However, photochemical modeling was conducted that included three hypothetical platform sources, shown in Figure 13. ERG compared the impact on $PM_{2.5}$ and ozone from the addition of these sources.

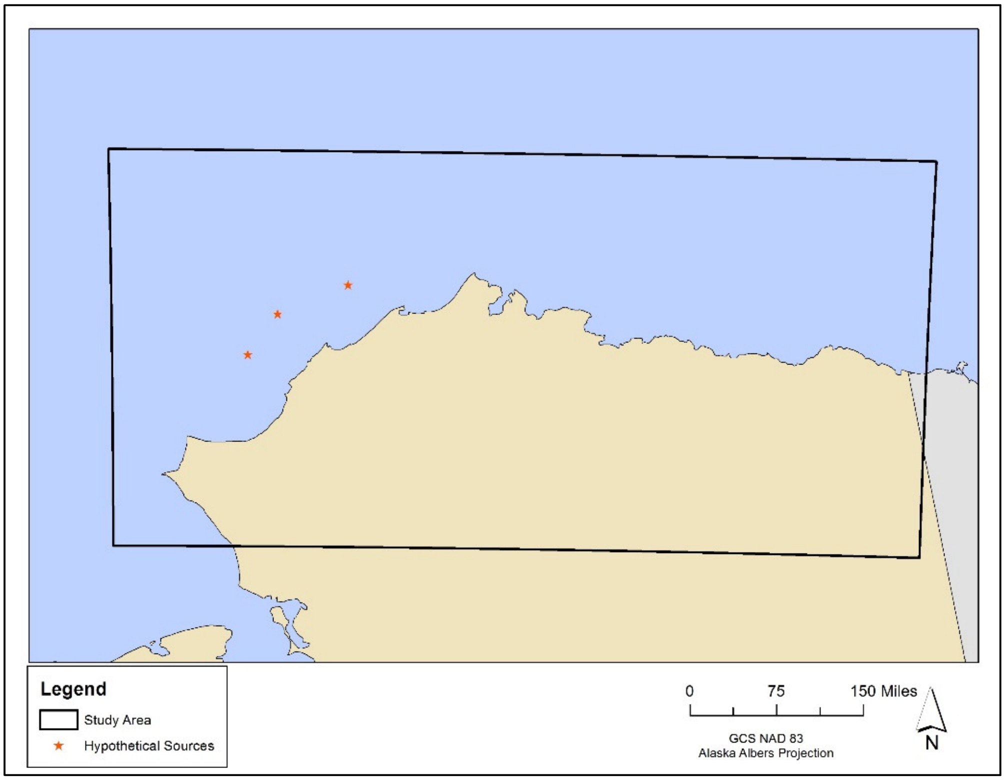

Figure 13. Hypothetical Platforms Included in Modeling

Each of the three hypothetical sources released were designed with emission rates of 100 tons per year for NO_x, SO_2, and VOC. Because the emission rate for each pollutant was released at the same rate, a generic MERP was calculated for ozone and each averaging time of the $PM_{2.5}$ NAAQS that assumed that the entire impact was attributable to each of the precursors (Table 11). This generates a conservatively low estimate because the impact is not separated for SO_2, NO_x, and primary $PM_{2.5}$ contribution. This estimate essentially represents a minimum estimate of a MERP for this region. This is seen in the estimates for the $PM_{2.5}$ MERP, which are lower than what is seen in the continental U.S., especially for the annual NAAQS. The emission levels of the hypothetical sources considered here are much lower than those used by the USEPA in their analysis. ERG suggests that any future EET analysis use higher emitting sources more comparable to the USEPA analysis in order to confirm these estimates before utilizing such a restrictive MERP level for analysis.

Table 11. Cursory MERPs Based on Hypothetical Sources

NAAQS	SIL (μgm^{-3})	Emission Rate (tpy)	Estimated Impact (μgm^{-3})	MERP (tpy)
Daily $PM_{2.5}$	1.2	100	1.18	102
Annual $PM_{2.5}$	0.2	100	0.22	91
8-hr O_3	1.0	100	0.04	2,500

Alaska's unique environment is generally prohibitive to ozone development, which led to a very large MERP compared to the continental U.S. values. Given the modeling data available from this study, and the emission thresholds from the existing EET formulas for NO_2 are significantly lower than the MERP produced here, the existing formulas are likely protective of the ozone NAAQS in the Arctic. Again, the emission levels of the hypothetical sources considered here are much lower than those used by the USEPA in their analysis (2016c). ERG suggests that any future EET analysis use higher emitting sources more comparable to the USEPA analysis to confirm this assertion.

Because the MERPs and the USEPA approach for evaluating secondary formation is evolving, ERG suggests BOEM continue to coordinate with the USEPA on the best methods for estimating source contributions to secondary formation, and possibly collaborate on modeling for Alaska. BOEM should also consider coordinating with ADEC on MERP analysis, because ADEC will need to perform analysis considering Alaska's omission from the initial analysis.

7.0 OVERALL SUMMARY OF RESULTS

The existing EET formulas are overly conservative for most annual standards. Specifically, the existing formulas suggest modeling is needed more often than is necessary. In addition, for the short-term standards, the formulas have a higher "miss" rate. However, the miss rate generally does not exceed 15% for most of the NAAQS. The 1-hour SO_2 and 24-hour NAAQS $PM_{2.5}$ and PM_{10} have a miss rate higher than 15%.

Although the EETs generally show they are still protective, BOEM may want to consider alternative approaches to reduce the error rate for short-term standards and false positive rate for annual standards. Reducing the false positive rate would reduce some of the burden on the operator. An alternative approach to the EET formulas would be to utilize the modeling information from this task to estimate impacts based on comparable modeled sources. For example, an operator could identify a hypothetical source modeling run at a comparable emission rate and distance to shore as the proposed source to evaluate the likelihood of a significant impact. If the comparable hypothetical source impacts are below SIL values, the proposed source should be as well. Because not all possible iterations of emissions levels and distances to shore were modeled, there would have to be concessions in matching to ensure a protective estimate (i.e., conservatively high estimate of impact). For example, a comparable source should select a hypothetical source with higher emission rates in the absence of an exact match. The results from any modeling submitted to BOEM could also be added to the database to provide additional sources for comparison. Additionally, the hypothetical source database does include a unit emission rate source (i.e., 1 gs^{-1}) impact run for three source types: 1) elevated hot stack, 2) short cold stack, and 3) vessel characterized as a volume (used in this study for sensitivity purposes). These results could be scaled and combined to estimate a more comparable emissions rate.

For secondary formation, ERG attempted to develop conservatively low MERPs. Because the MERPs and the approach for evaluating secondary formation is evolving, BOEM may want to continue to coordinate with the USEPA on the best methods for estimating source contributions to secondary formation. Also, BOEM could coordinate with the ADEC on any modeling efforts to support MERP development specific to Alaska.

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APPENDIX A: HYPOTHETICAL SOURCE EQUIPMENT PROFILES

01. INTRODUCTION

This document presents the equipment for each hypothetical source by scenario. Each table present the equipment type, count, activity level, and total hours of operation.

02. SCENARIO 1

Table A-1: Equipment included in Scenario 1 (Small)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Drilling	Auxiliary Equipment	Diesel Reciprocating Engine (< 600 hp.)	45	hp	2208	1
			77	hp	368	1
			190	hp	4416	2
			240	hp	2208	1
			315	hp	368	1
			320	hp	368	1
			380	hp	4416	2
			500	hp	368	1
			530	hp	2208	1
			560	hp	2208	1
			960	hp	2208	1
		Diesel Reciprocating Engine (> 600 hp.)	543	hp	368	1
			1180	hp	13248	6
			1340	hp	2208	1
			1950	hp	368	1
		Gasoline Reciprocating Engine (< 600 hp.)	380	hp	2208	1
	Drilling	Diesel Reciprocating Engine (> 600 hp.)	5184	kW	2208	1
	Heaters, Boilers, & Burners (H/B/B)	Diesel H/B/B (<100 MMBtu/hr)	30000	gal/yr	2208	1
			200000	gal/yr	6624	3
		Solid Waste Incinerator	150	lb/hr	6624	3
			220	lb/hr	2208	1

Table A-2: Equipment included in Scenario 1 (Medium)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Drilling	Auxiliary Equipment	Diesel Recip. Engine (< 600 hp.)	46	hp	2280	1
			77	hp	9120	4
			113	hp	2280	1
			200	hp	4560	2
			240	hp	2280	1
			308	hp	2280	1
			322	hp	480	1
			395	hp	480	1
			498	hp	2880	1
			543	hp	2280	1
		Diesel Recip. Engine (> 600 hp.)	568	hp	2880	1
			639	hp	8640	3
			1201	hp	2280	1
			1951	hp	480	1
			2948	hp	11400	5
			7290	hp	2880	1
	Drilling	Diesel Reciprocating Engine (> 600 hp.)	5184	kW	2880	1
	Heater, Boilers, & Burners (H/B/B)	Diesel H/B/B (<100 MMBtu/hr)	109773	gal/yr	2880	1
			197591	gal/yr	2880	1
			570819	gal/yr	2280	1
			1163592	gal/yr	2880	1
		Solid Waste Incinerator	154	lb/hr	2880	1
			188	lb/hr	2880	1
			220	lb/hr	2880	1
			276	lb/hr	2880	1

Table A-3: Equipment included in Scenario 1 (Large)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Drilling	Auxiliary Equipment	Diesel Reciprocating Engine (< 600 hp.)	46	hp	5760	2
			77	hp	11520	4
			94	hp	2880	1
			113	hp	2880	1
			182	hp	480	1
			194	hp	5760	2
			200	hp	5760	2
			240	hp	5760	2
			308	hp	2880	1
			322	hp	960	2
			395	hp	480	1
			498	hp	2880	1
			536	hp	2880	1
			840	hp	2880	1
			965	hp	2880	1
		Diesel Reciprocating Engine (> 600 hp.)	543	hp	2880	1
			568	hp	5760	2
			639	hp	8640	3
			1181	hp	17280	6
			1201	hp	2880	1
			1340	hp	2880	1
			1951	hp	480	1
			2948	hp	14400	5
			7290	hp	2880	1
	Drilling	Diesel Reciprocating Engine (> 600 hp.)	5184	kW	2880	1
			6480	kW	2880	1
	Heaters, Boilers, & Burners (H/B/B)	Diesel H/B/B (<100 MMBtu/hr)	30078	gal/yr	2880	1
			109773	gal/yr	2880	1
			197591	gal/yr	5760	2
			351273	gal/yr	2880	1
			570819	gal/yr	2880	1
			1163592	gal/yr	2880	1
		Solid Waste Incinerator	154	lb/hr	5760	2
			188	lb/hr	2880	1
			220	lb/hr	2880	1
			276	lb/hr	5760	2

03. SCENARIO 2

Table A-4: Equipment included in Scenario 2 (Small)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Drilling	Auxiliary Equip	Diesel Reciprocating Engine (< 600 hp.)	45	hp	2208	1
			77	hp	368	1
			190	hp	4416	2
			240	hp	2208	1
			315	hp	368	1
			320	hp	368	1
			380	hp	4416	2
			500	hp	368	1
			530	hp	2208	1
			560	hp	2208	1
			960	hp	2208	1
		Diesel Reciprocating Engine (> 600 hp.)	543	hp	368	1
			1180	hp	13248	6
			1340	hp	2208	1
			1950	hp	368	1
		Gasoline Reciprocating Engine (< 600 hp.).	380	hp	2208	1
	Drilling	Diesel Reciprocating Engine (> 600 hp.)	5184	kW	2208	1
	Heaters, Boilers, & Burners (H/B/B)	Diesel H/B/B (<100 MMBtu/hr)	30000	gal/yr	2208	1
			200000	gal/yr	6624	3
		Solid Waste Incinerator	150	lb/hr	6624	3
			220	lb/hr	2208	1
Production	Flare	Pilot	560	SCF/HR	1248	1
		Upset	4000000	SCF/HR	48	1
	Fugitives	Oil/Water/Gas	11420	Count	1248	1
	Recip. Engines	Diesel Reciprocating Engine (< 600 hp.)	83	hp	2496	2

Table A-5: Equipment included in Scenario 2 (Medium)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Drilling	Auxiliary Equipment	Diesel Reciprocating Engine (< 600 hp.)	46	hp	2160	1
			77	hp	336	4
			113	hp	2160	1
			200	hp	4320	2
			240	hp	2160	1
			308	hp	84	1
			322	hp	84	1
			395	hp	360	1
			498	hp	2160	1
			543	hp	2160	1
		Diesel Reciprocating Engine (> 600 hp.)	568	hp	2160	1
			639	hp	6480	3
			1201	hp	84	1
			1951	hp	84	1
			2948	hp	10800	5
			7290	hp	2160	1
	Drilling	Diesel Reciprocating Engine (> 600 hp.)	5184	kW	2160	1
	Heaters, Boilers, & Burners (H/B/B)	Diesel H/B/B (<100 MMBtu/hr)	109773	gal/yr	2160	1
			197591	gal/yr	2160	1
			570819	gal/yr	2160	1
			1163592	gal/yr	2160	1
		Solid Waste Incinerator	154	lb/hr	2160	1
			188	lb/hr	2160	1
			220	lb/hr	2160	1
			276	lb/hr	2160	1
Production	Flare	Flare - Pilot	1000	scf/hr	5880	1
		Flare - Upset	8000000	scf/hr	48	1
	Fugitives	Oil/Water/Gas	11420	Count	2880	1
	Heaters, Boilers, & Burners (H/B/B)	NG H/B/B (<100 MMBtu/hr)	35	MMBtu/hr	7032	3
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp.)	500	hp	5880	2
			1065	hp	104	2
		Diesel Reciprocating Engine (> 600 hp.)	1435	hp	52	1
	Turbine	NG Turbines	4300	hp	29712	11
			16172	hp	11760	2

Table A-6: Equipment included in Scenario 2 (Large)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Drilling	Auxiliary Equipment	Diesel Reciprocating Engine (< 600 hp.)	46	hp	5760	2
			77	hp	11520	4
			94	hp	2880	1
			113	hp	2880	1
			182	hp	480	1
			194	hp	5760	2
			200	hp	5760	2
			240	hp	5760	2
			308	hp	2880	1
			322	hp	960	2
			395	hp	480	1
			498	hp	2880	1
			536	hp	2880	1
			840	hp	2880	1
			965	hp	2880	1
		Diesel Reciprocating Engine (> 600 hp.)	543	hp	2880	1
			568	hp	5760	2
			639	hp	8640	3
			1181	hp	17280	6
			1201	hp	2880	1
			1340	hp	2880	1
			1951	hp	480	1
			2948	hp	14400	5
			7290	hp	2880	1
	Drilling	Diesel Reciprocating Engine (> 600 hp.)	5184	kW	2880	1
			6480	kW	2880	1
	Heaters, Boilers, & Burners (H/B/B)	Diesel H/B/B (<100 MMBtu/hr)	30078	gal/yr	2880	1
			109773	gal/yr	2880	1
			197591	gal/yr	5760	2
			351273	gal/yr	2880	1
			570819	gal/yr	2880	1
			1163592	gal/yr	2880	1
		Solid Waste Incinerator	154	lb/hr	5760	2
			188	lb/hr	2880	1
			220	lb/hr	2880	1
			276	lb/hr	5760	2
Production	Flare	Pilot	560	scf/hr	8760	1
		Upset	9375000	scf/hr	168	1
	Fugitives	Oil/Water/Gas	2500	Count	2880	1
	Glycol Dehydrator Vent	Glycol Dehydrator Vent	1	Count	8760	1
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp.)	284	hp	21	1
			311	hp	3	1
			382	hp	240	1
			1050	hp	2920	1

Table A-6: Equipment included in Scenario 2 (Large)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
			1500	hp	4272	1
			2736	hp	24	1
			2816	hp	192	1
			14376	hp	3000	1
	Turbine	Diesel Turbines	29745	hp	2400	5
		NG Turbines	29745	hp	33600	5

04. SCENARIO 3

Table A-7: Equipment included in Scenario 3 (Small)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Drilling	Auxiliary Equipment	Diesel Reciprocating Engine (< 600 hp.)	45	hp	2208	1
			77	hp	368	1
			190	hp	4416	2
			240	hp	2208	1
			315	hp	368	1
			320	hp	368	1
			380	hp	4416	2
			500	hp	368	1
			530	hp	2208	1
			560	hp	2208	1
			960	hp	2208	1
		Diesel Reciprocating Engine (> 600 hp.)	543	hp	368	1
			1180	hp	13248	6
			1340	hp	2208	1
			1950	hp	368	1
		Gasoline Reciprocating Engine (< 600 hp.)	380	hp	2208	1
	Drilling	Diesel Reciprocating Engine (> 600 hp.)	5184	kW	2208	1
	Heaters, Boilers, & Burners (H/B/B)	Diesel H/B/B (<100 MMBtu/hr)	30000	gal/yr	2208	1
			200000	gal/yr	6624	3
		Solid Waste Incinerator	150	lb/hr	6624	3
			220	lb/hr	2208	1
Production	Flare	Pilot	560	scf/hr	2400	1
		Upset	4000000	scf/hr	48	1
	Fugitives	Oil/Water/Gas	11420	Count	2400	1
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp.)	83	hp	4800	2
Well Test	Gas Flare	--	958	scf/hr	48	1

Table A-8: Equipment included in Scenario 3 (Medium)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Drilling	Auxiliary Equipment	Diesel Reciprocating Engine (< 600 hp.)	46	hp	2280	1
			77	hp	9120	4
			113	hp	2280	1
			200	hp	4560	2
			240	hp	2280	1
			308	hp	2280	1
			322	hp	480	1
			395	hp	480	1
			498	hp	2880	1
			543	hp	2280	1
		Diesel Reciprocating Engine (> 600 hp.)	568	hp	2880	1
			639	hp	8640	3
			1201	hp	2280	1
			1951	hp	480	1
			2948	hp	11400	5
			7290	HP	2880	1
	Drilling	Diesel Reciprocating Engine (> 600 hp.)	5184	kW	2880	1
	Heaters, Boilers, & Burners (H/B/B)	Diesel H/B/B (<100 MMBtu/hr)	109773	gal/yr	2880	1
			197591	gal/yr	2880	1
			570819	gal/yr	2280	1
			1163592	gal/yr	2880	1
		Solid Waste Incinerator	154	lb/hr	2880	1
			188	lb/hr	2880	1
			220	lb/hr	2880	1
			276	lb/hr	2880	1
Production	Flare	Flare - Pilot	860	scf/hr	5880	1
		Flare - Upset	8000000	scf/hr	48	1
	Fugitives	Oil/Water/Gas	11420	Count	2880	1

Table A-9: Equipment included in Scenario 3 (Large)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Drilling	Auxiliary Equipment	Diesel Reciprocating Engine (< 600 hp.)	77	hp	11520	4
			182	hp	480	1
			308	hp	2880	1
			322	hp	960	2
			395	hp	480	1
			498	hp	2880	1
			840	hp	2880	1
		Diesel Reciprocating Engine (> 600 hp.)	568	hp	5760	2
			639	hp	8640	3
			1340	hp	2880	1
			1951	hp	480	1
			7290	hp	2880	1
	Heaters, Boilers, & Burners (H/B/B)	Diesel H/B/B (<100 MMBtu/hr)	30078	gal/yr	2880	1
			109773	gal/yr	2880	1
			197591	gal/yr	5760	2
			570819	gal/yr	2880	1
			1163592	gal/yr	2880	1
		Solid Waste Incinerator	154	lb/hr	5760	2
			188	lb/hr	2880	1
			220	lb/hr	2880	1
			276	lb/hr	2880	1
Production	Flare	Pilot	560	scf/hr	8760	1
		Upset	9375000	scf/hr	168	1
	Fugitives	Oil/Water/Gas	2500	Count	2880	1
	Glycol Dehydrator Vent	Glycol Dehydrator Vent	1	Count	8760	1
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp.)	284	hp	21	1
			311	hp	3	1
			382	hp	240	1
			1050	hp	2920	1
			1500	hp	4272	1
			2736	hp	24	1
			2816	hp	192	1
			14376	hp	3000	1
	Turbine	Diesel Turbines	29745	hp	2400	5
		NG Turbines	29745	hp	33600	5
Well Test	Gas Flare	--	958	scf/hr	48	1

05. SCENARIO 4

Table A-10: Equipment included in Scenario 4 (Small)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Production	Flare	Flare - Pilot	860	scf/hr	2880	1
		Flare - Upset	11100	scf/hr	48	1
	Fugitives	Light Oil (>20 API Gravity)	11420	Count	2880	1
	NG Reciprocating Engines	NG 4-cycle Lean Engine	265	hp	2880	1
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp.)	350	hp	2880	1
		Gasoline Reciprocating Engine (< 600 hp.)	100	hp	104	1
			350	hp	2880	1

Table A-11: Equipment included in Scenario 4 (Medium)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Production	Flare	Flare - Pilot	860	scf/hr	8760	1
		Flare - Upset	110000	scf/hr	48	1
	Fugitives	Light Oil (>20 API Gravity)	11420	Count	8760	1
	Heaters, Boilers, & Burners (H/B/B)	NG H/B/B (<100 MMBtu/hr)	17	MMBtu/hr	8760	1
	NG Reciprocating Engines	NG 4-cycle Lean Engine	3300	hp	8760	1
		NG 4-cycle Rich Engine	3300	hp	8760	1
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp.)	39	hp	104	2
			212	hp	52	1
			275	hp	4380	1
			500	hp	4380	1
		Diesel Reciprocating Engine (> 600 hp.)	620	hp	468	2
	Turbine	NG Turbines	5600	hp	17520	2

Table A-12: Equipment included in Scenario 4 (Large)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
Production	Fugitives	Light Oil (>20 API gravity)	11420	Count	8760	1
	Heaters, Boilers, & Burners (H/B/B)	NG H/B/B (<100 MMBtu/hr)	15	MMBtu/hr	12410	1
	NG Reciprocating Engines	NG 4-cycle Rich Engine	818	hp	26280	3
	Process Vent	Gas Venting	1	Count	8760	1
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp.)	310	hp	4380	1
		Diesel Reciprocating Engine (> 600 hp.)	980	hp	52	1
			6036	hp	1825	1
			8902	hp	1825	1
	Turbine	NG Turbines	7000	hp	17520	2
			142110	hp	8760	1

06. SCENARIO 5

Table A-13: Equipment included in Scenario 5 (Small)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
FPSO	NG Flares	Flare - Pilot	860	scf/hr	2880	1
		Flare - Upset	11000	scf/hr	48	1
	FPSO/FSO propulsion	Vessel-FPSO	14701	kW	2880	1
	Heaters, Boilers. & Burners (H/B/B)	NG (H/B/B) (<100 MMBtu/hr)	22	MMBtu/hr	2880	1
			32	MMBtu/hr	1248	1
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp)	572	gal/yr	52	1
	Turbine	NG Turbines	5500	hp	4080	1

Table A-14: Equipment included in Scenario 5 (Medium)

Operations	Equipment Category	Equipment Type	Activity	Activity Units	hrs/yr	Count
FPSO	NG Flares	Flare - Pilot	1000	scf/hr	8760	1
		Flare - Upset	410000	scf/hr	120	1
	FPSO/FSO propulsion	Diesel Reciprocating Engine (> 600 hp.)	14701	kW	8760	1
	Fugitives	Light Oil (>20 API Gravity)	11420	Count	8760	1
	Glycol Dehydrator Vent	Glycol Dehydrator Vent	1	Count	8592	1
	Heaters, Boilers, & Burners (H/B/B)	NG H/B/B (<100 MMBtu/hr)	26	MMBtu/hr	8760	1
	Process Vent	Gas Venting	1	Count	8760	1
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp.)	110	hp	365	1
			572	hp	5579	5
		Diesel Reciprocating Engine (> 600 hp.)	670	hp	104	2
	Tank	Tank Vapors	1	Count	8760	1
	Turbine	NG Turbines	5500	hp	30660	4
			14500	hp	8760	1

Table A-15: Equipment included in Scenario 5 (Large)

Operations	Equipment Category	Equipment/ Type	Activity	Activity Units	hrs/yr	Count
FPSO	Flare	NG Flares	860	scf/hr	8760	1
			11000	scf/hr	120	1
	FPSO/FSO	Diesel Reciprocating Engine (> 600 hp.)	14701	kW	8760	1
	Fugitives	Light Oil (>20 API Gravity)	11420	Count	8760	1
	Glycol Dehydrator Vent	Glycol Dehydrator Vent	1	Count	8760	1
	Heaters, Boilers, & Burners (H/B/B)	NG H/B/B (<100 MMBtu/hr)	22	MMBtu/hr	2880	1
			32	MMBtu/hr	1248	1
	Reciprocating Engines	Diesel Reciprocating Engine (< 600 hp.)	572	hp	1877	2
		Diesel Reciprocating Engine (> 600 hp.)	572	hp	52	1
	Tank	Tank Vapors	1	Count	8760	1
	Turbine	NG Turbines	5500	hp	4380	1
			22167	hp	17520	2

APPENDIX B: IMPACT PLOTS

01. NOx

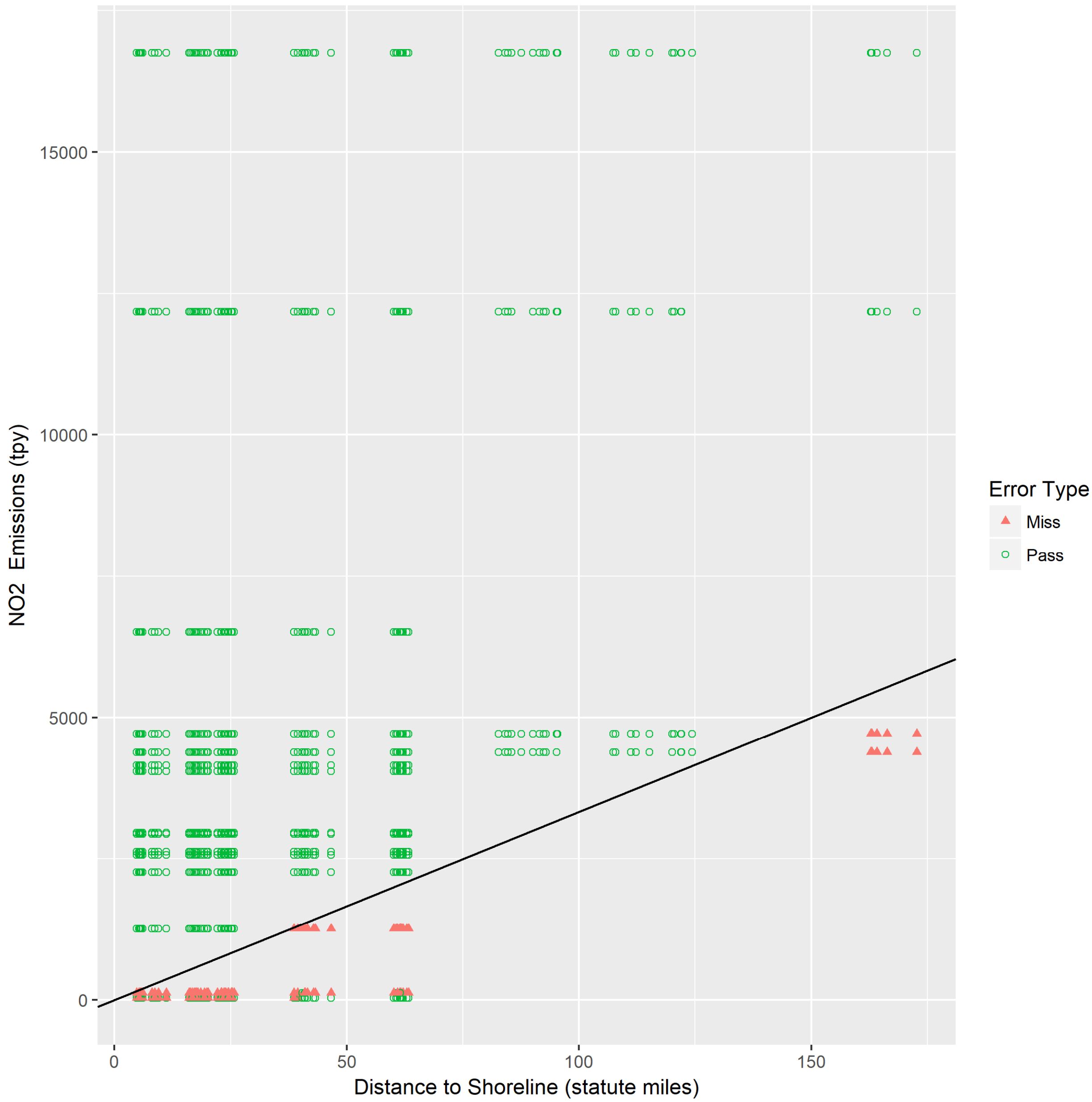

Figure B-1. Scatter Plot of NO_2 1-hour Modeling Results at the Shoreline. Black Line Indicates the EET.

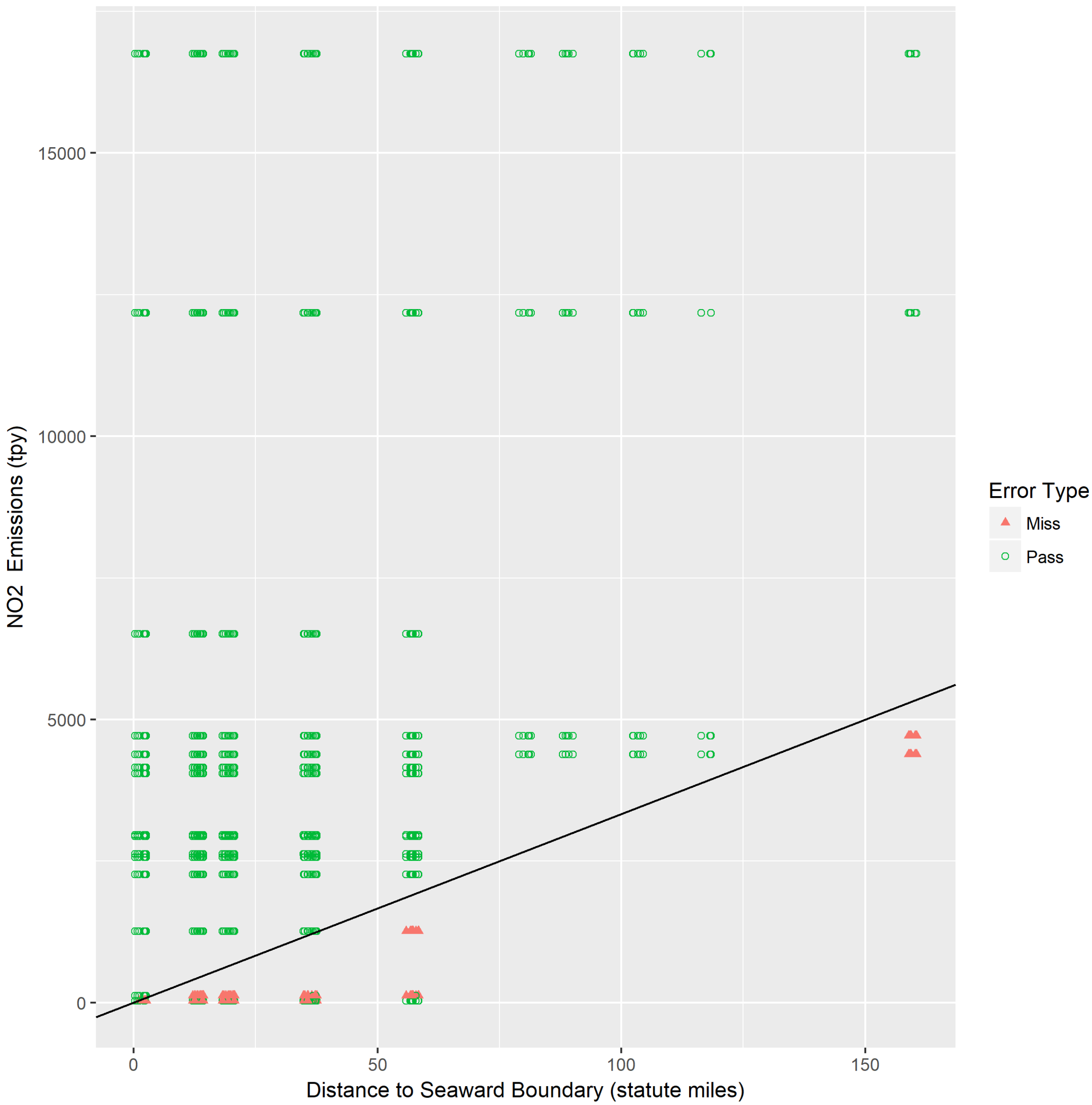

Figure B-2. Scatter Plot of NO_2 1-hour Modeling Results at the State Seaward Boundary. Black Line Indicates the EET.

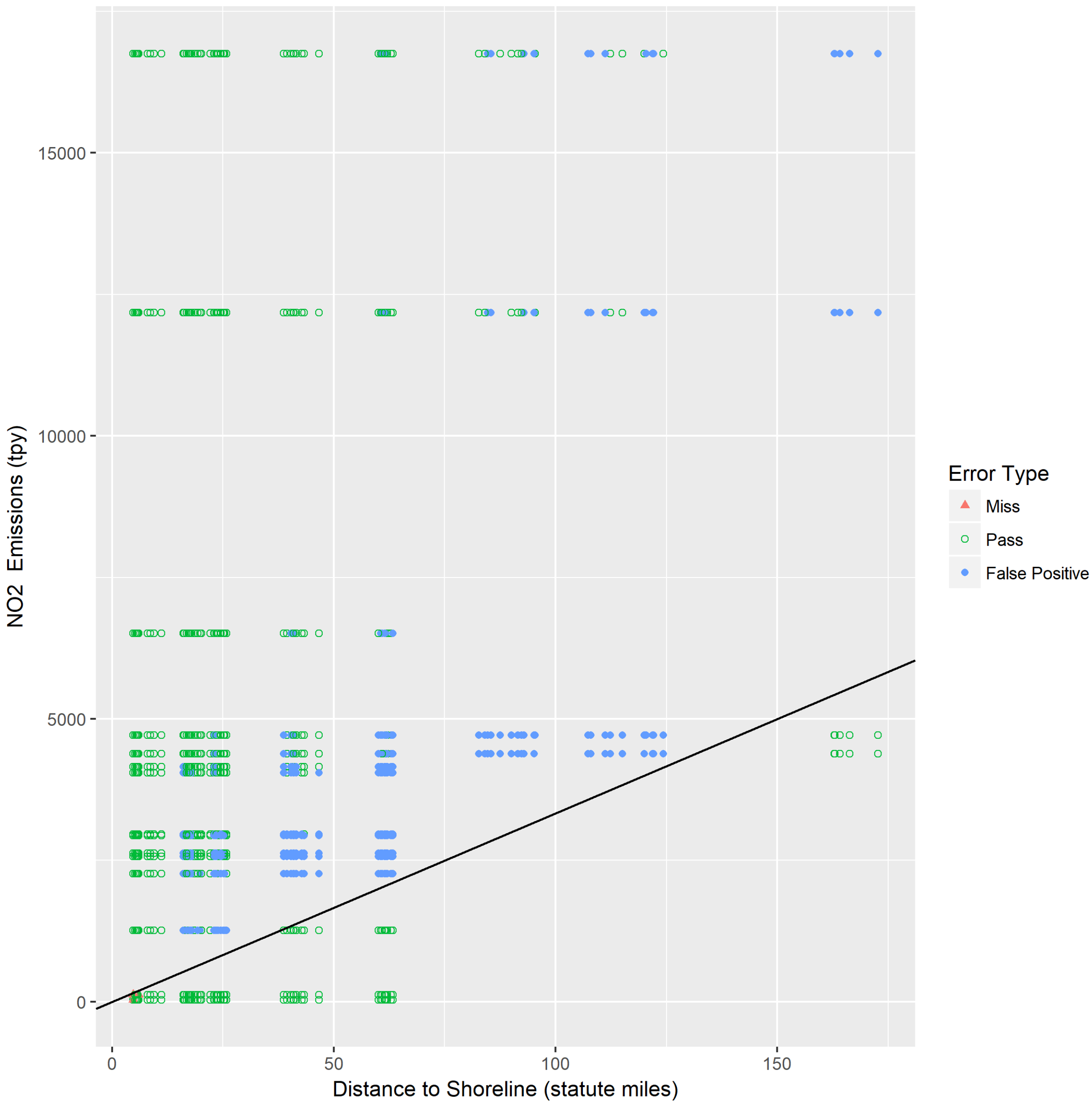

Figure B-3. Scatter Plot of NO_2 Annual Modeling Results at the Shoreline. Black Line Indicates the EET.

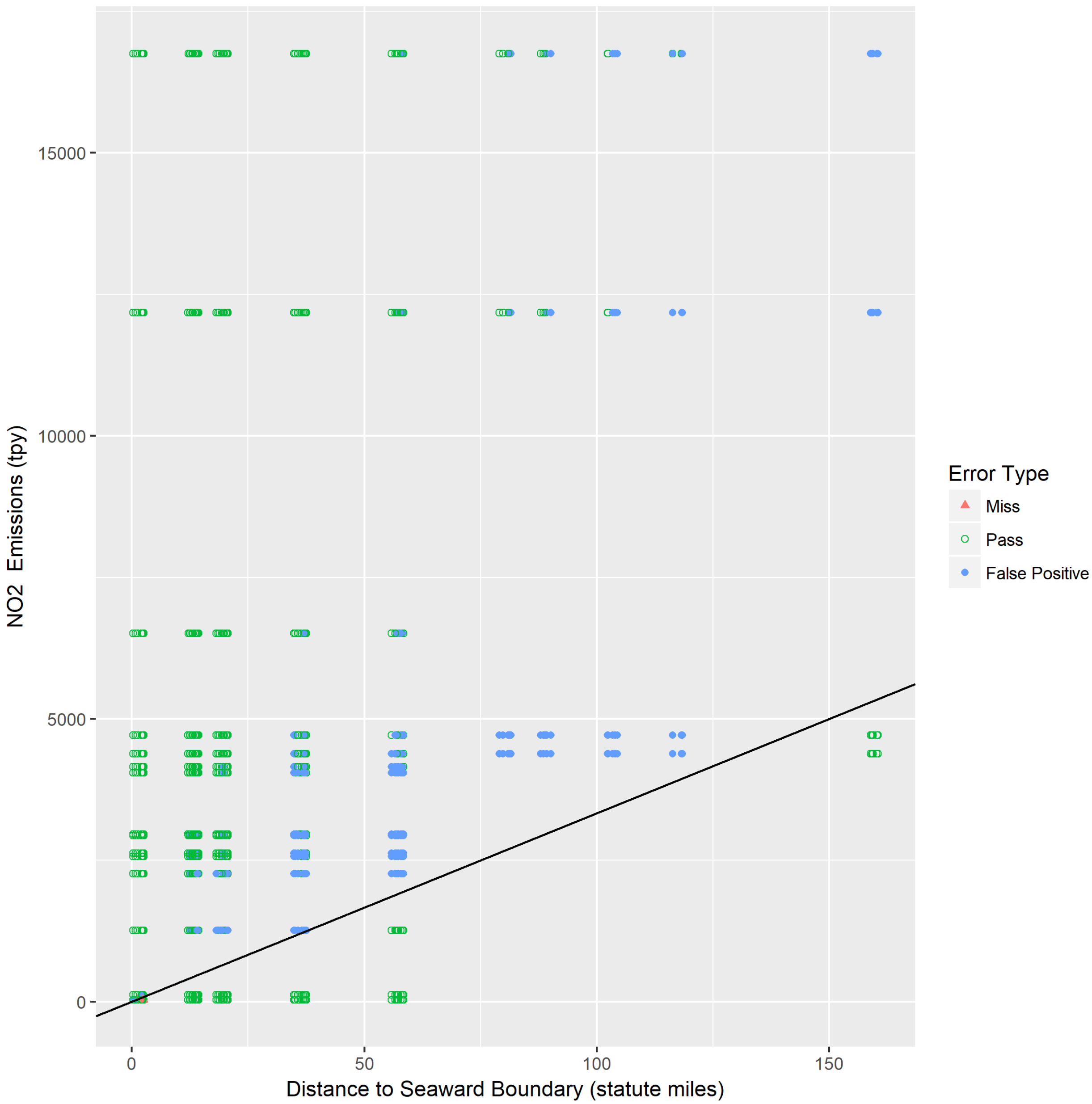

Figure B-4. Scatter Plot of NO_2 Annual Modeling Results at the State Seaward Boundary. Black Line Indicates the EET.

02. SO_2

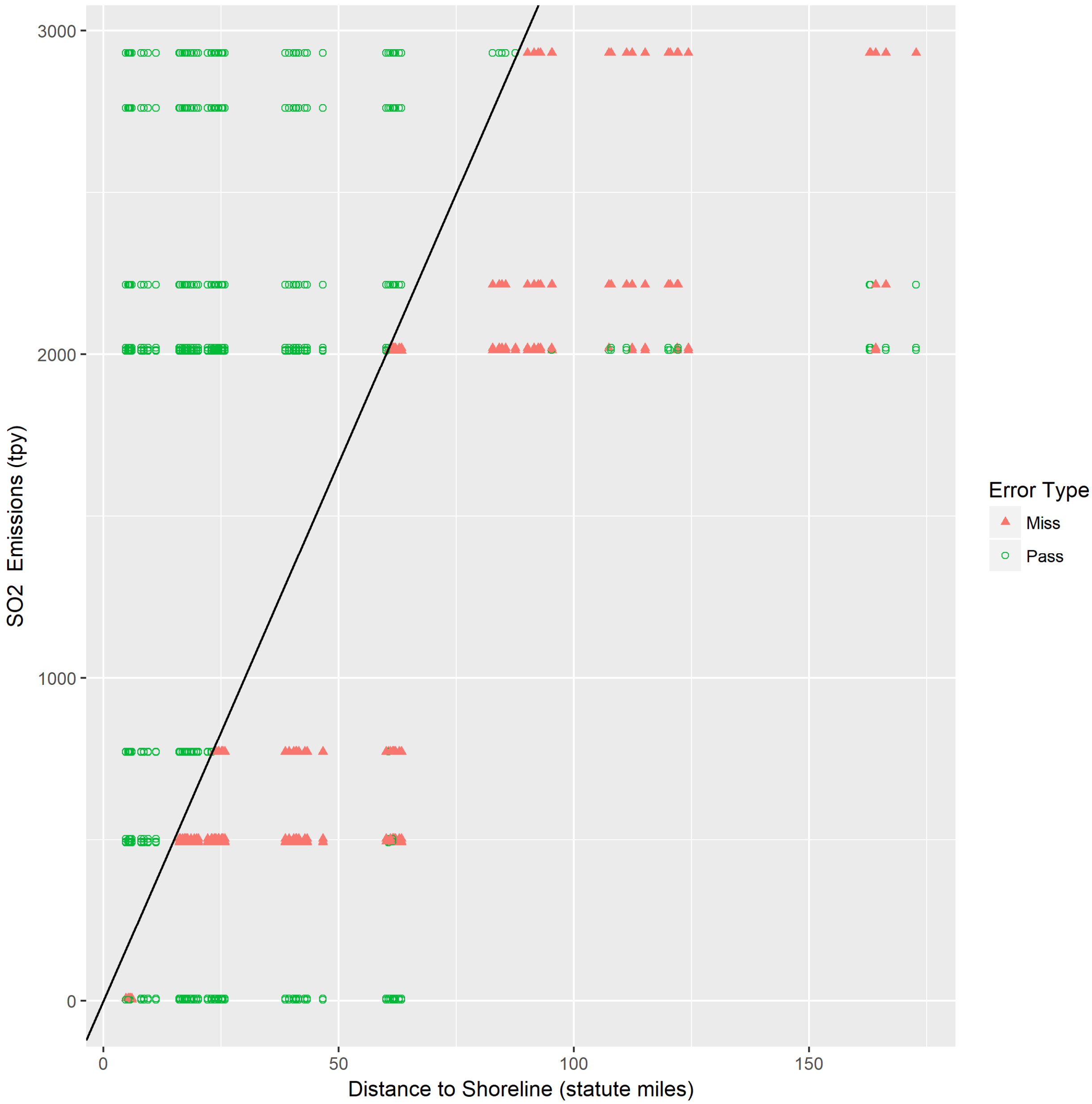

Figure B-5. Scatter Plot of SO_2 1-hour Modeling Results at the Shoreline. Black Line Indicates the EET.

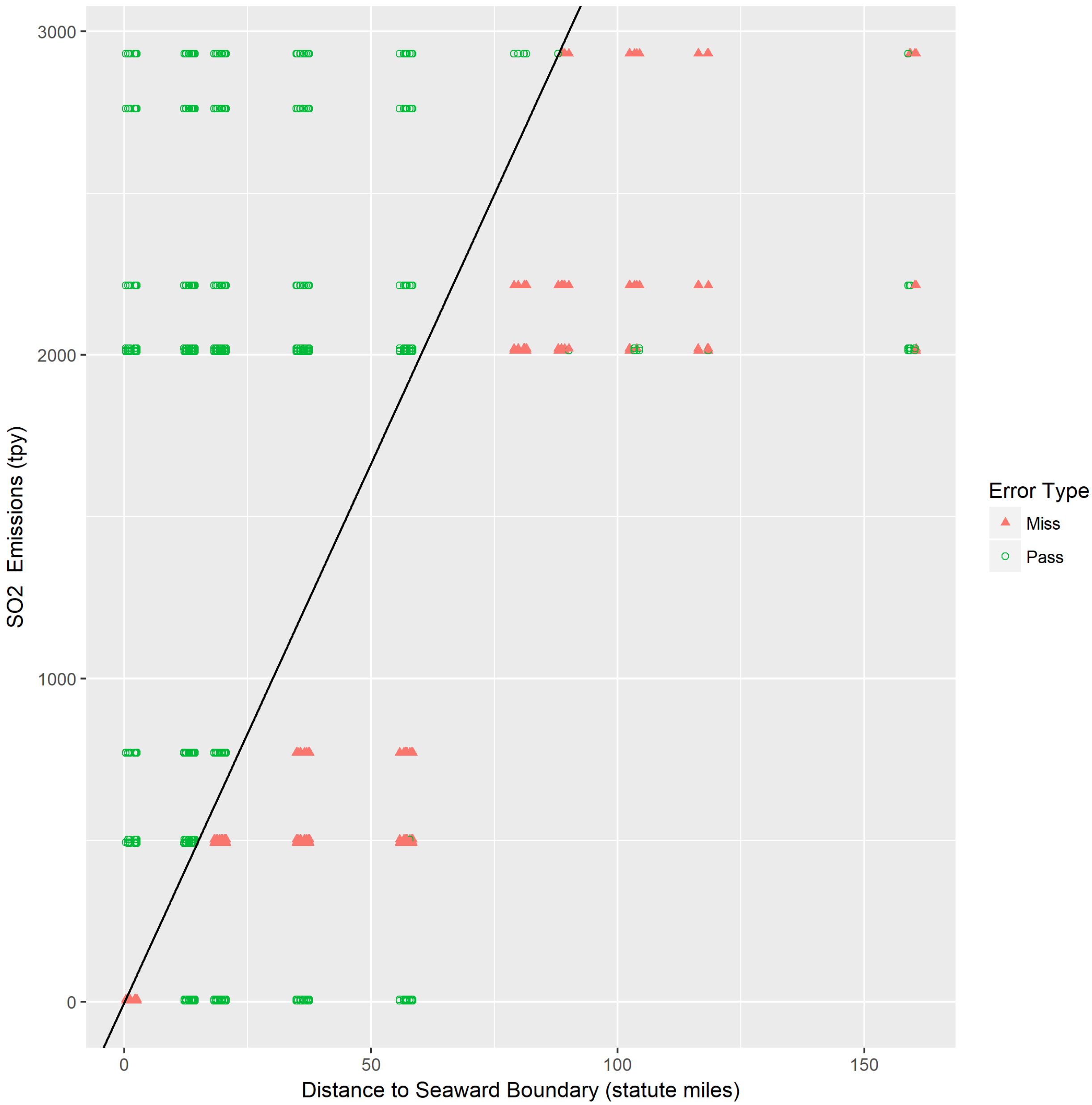

Figure B-6. Scatter Plot of SO_2 1-hour Modeling Results at the State Seaward Boundary. Black Line Indicates the EET.

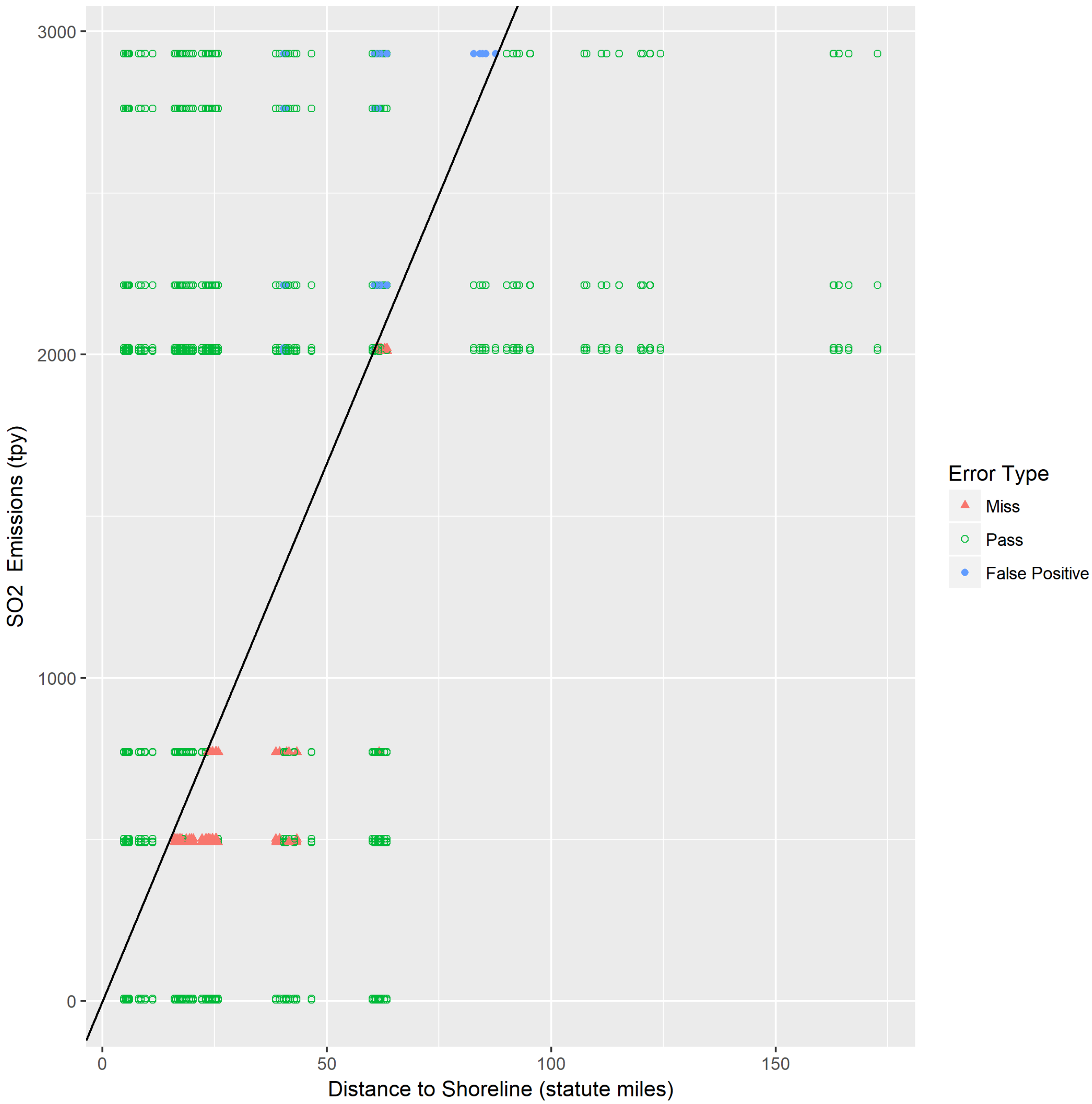

Figure B-7. Scatter Plot of SO_2 3-hour Modeling Results at the Shoreline. Black Line Indicates the EET.

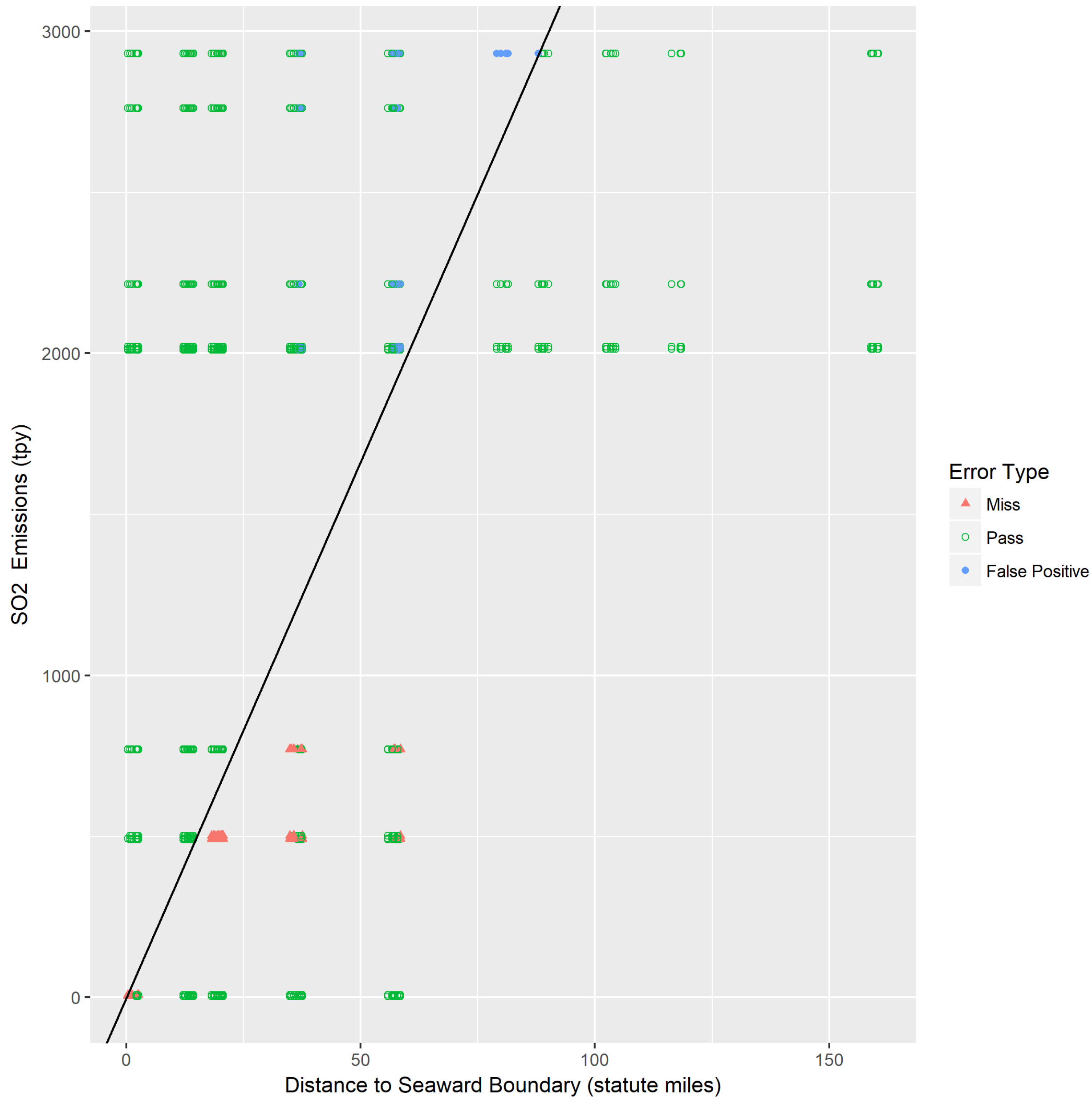

Figure B-8. Scatter Plot of SO_2 3-hour Modeling Results at the State Seaward Boundary. Black Line Indicates the EET.

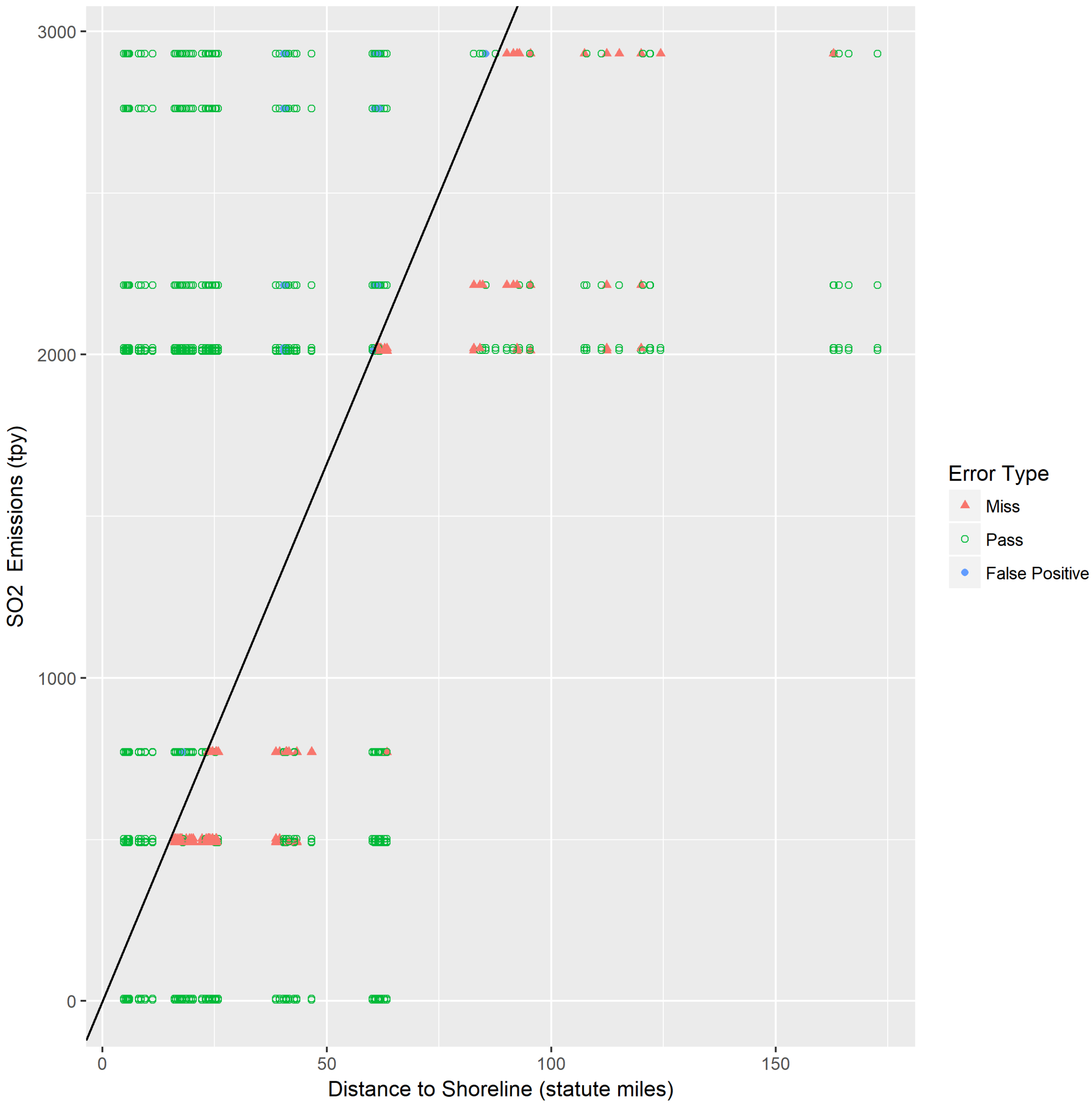

Figure B-9. Scatter Plot of SO_2 24-hour Modeling Results at the Shoreline. Black Line Indicates the EET.

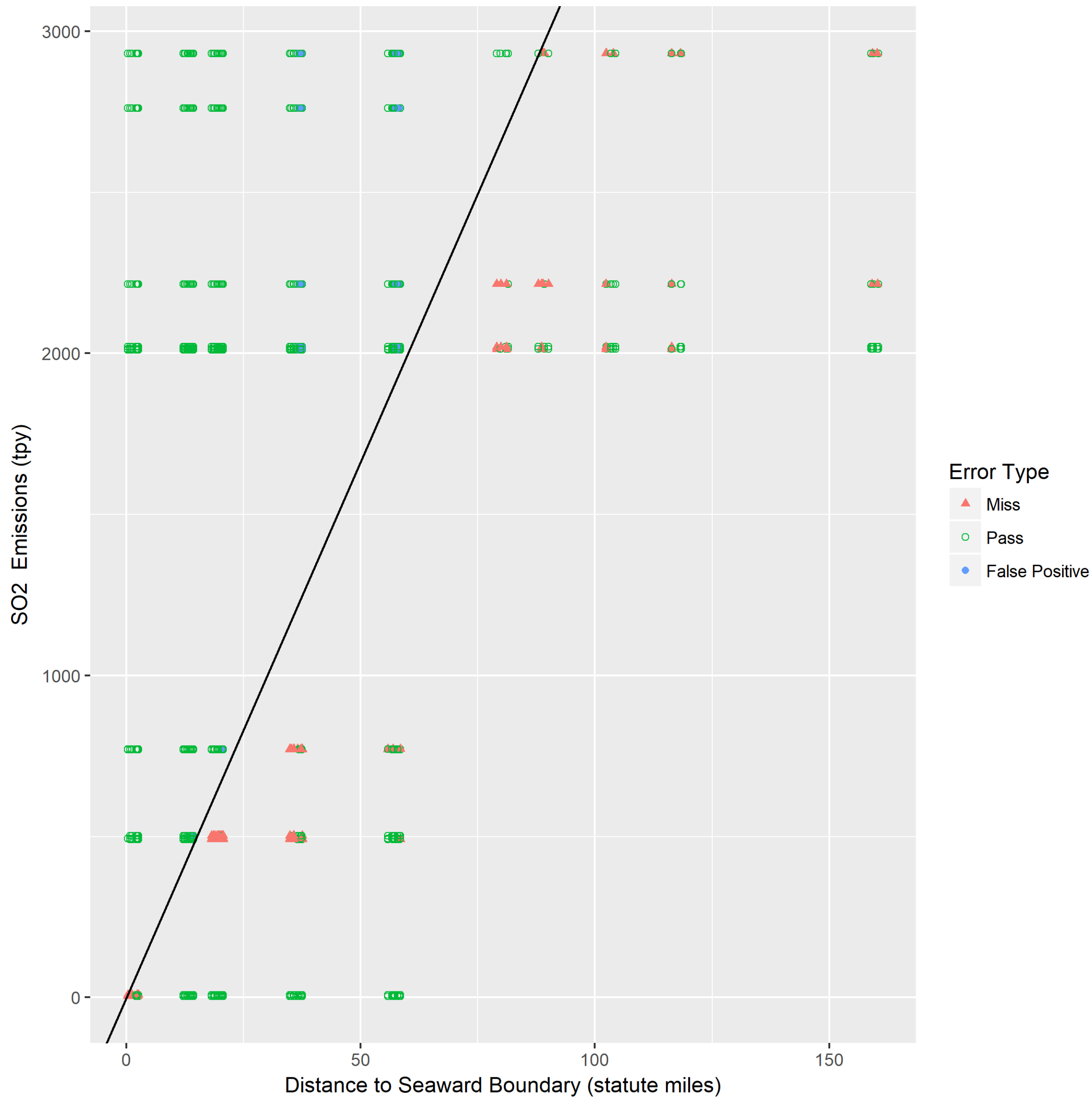

Figure B-10. Scatter Plot of SO_2 24-hour Modeling Results at the State Seaward Boundary. Black Line Indicates the EET.

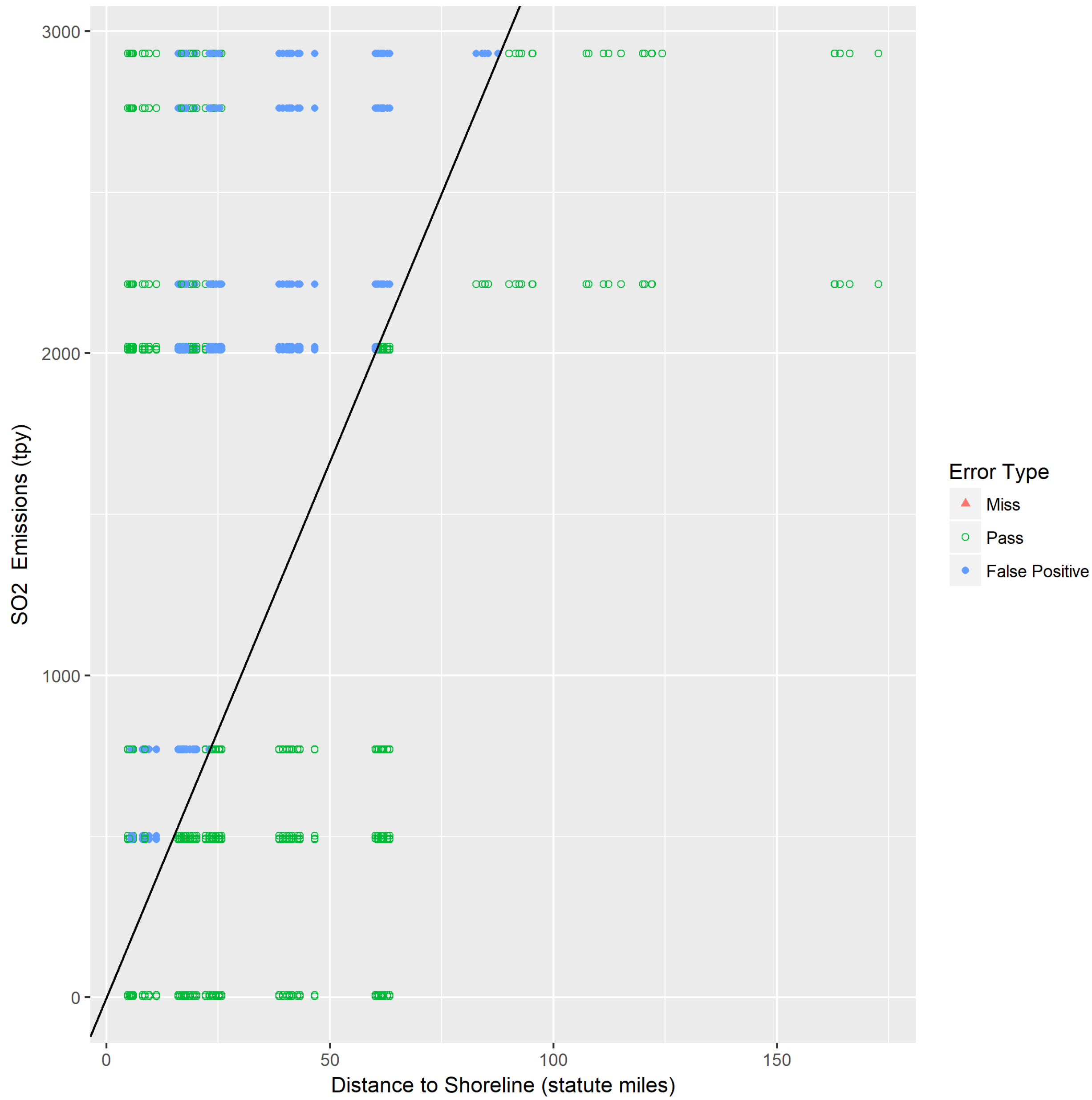

Figure B-11. Scatter Plot of SO_2 Annual Modeling Results at the Shoreline. Black Line Indicates the EET.

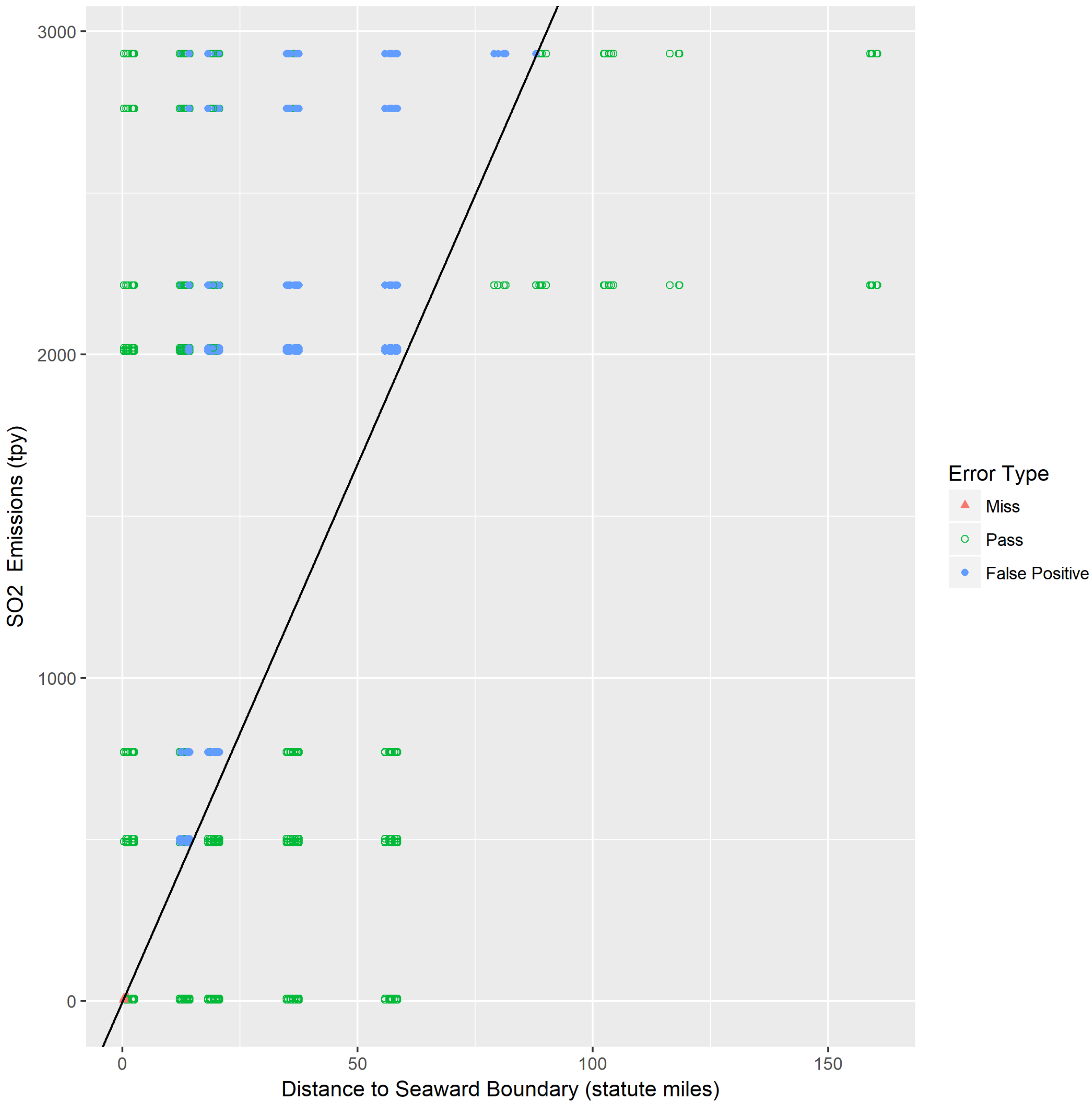

Figure B-12. Scatter Plot of SO_2 Annual Modeling Results at the State Seaward Boundary. Black Line Indicates the EET.

03. PM_{10}

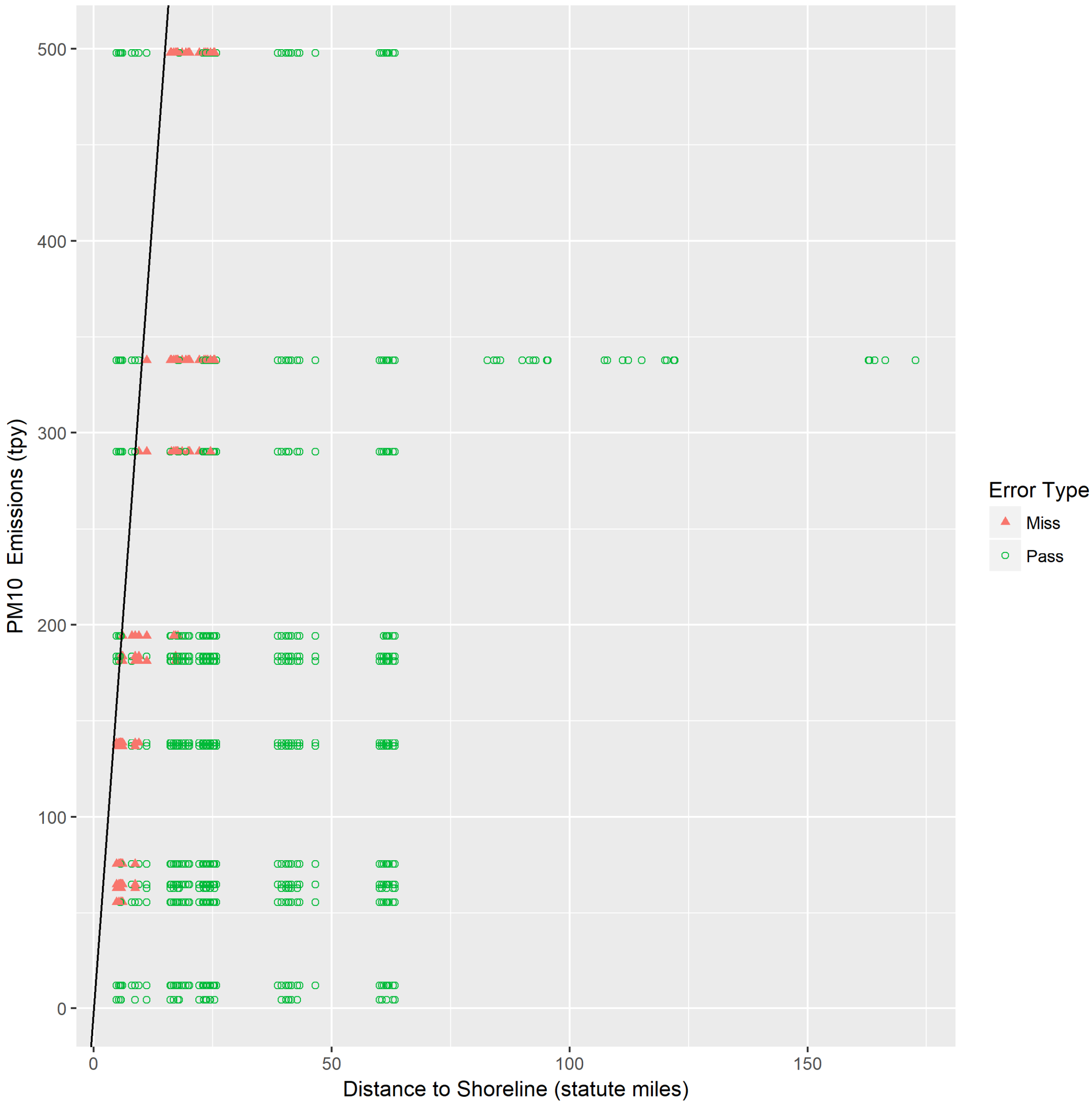

Figure B-13. Scatter Plot of PM_{10} 24-hour Modeling Results at the Shoreline. Black Line Indicates the EET.

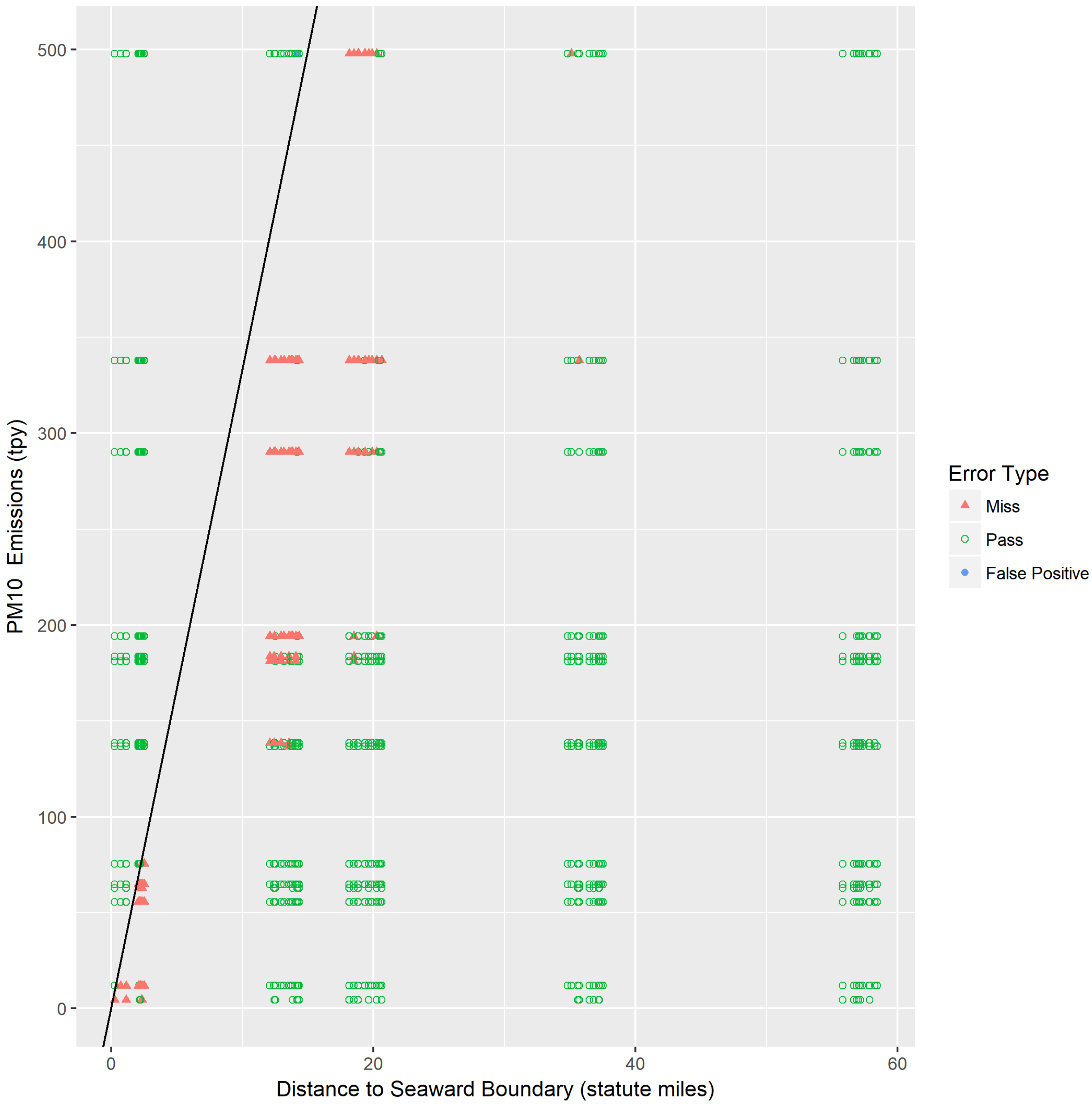

Figure B-14. Scatter Plot of PM_{10} 24-hour Modeling Results at the State Seaward Boundary.
Black Line Indicates the EET.

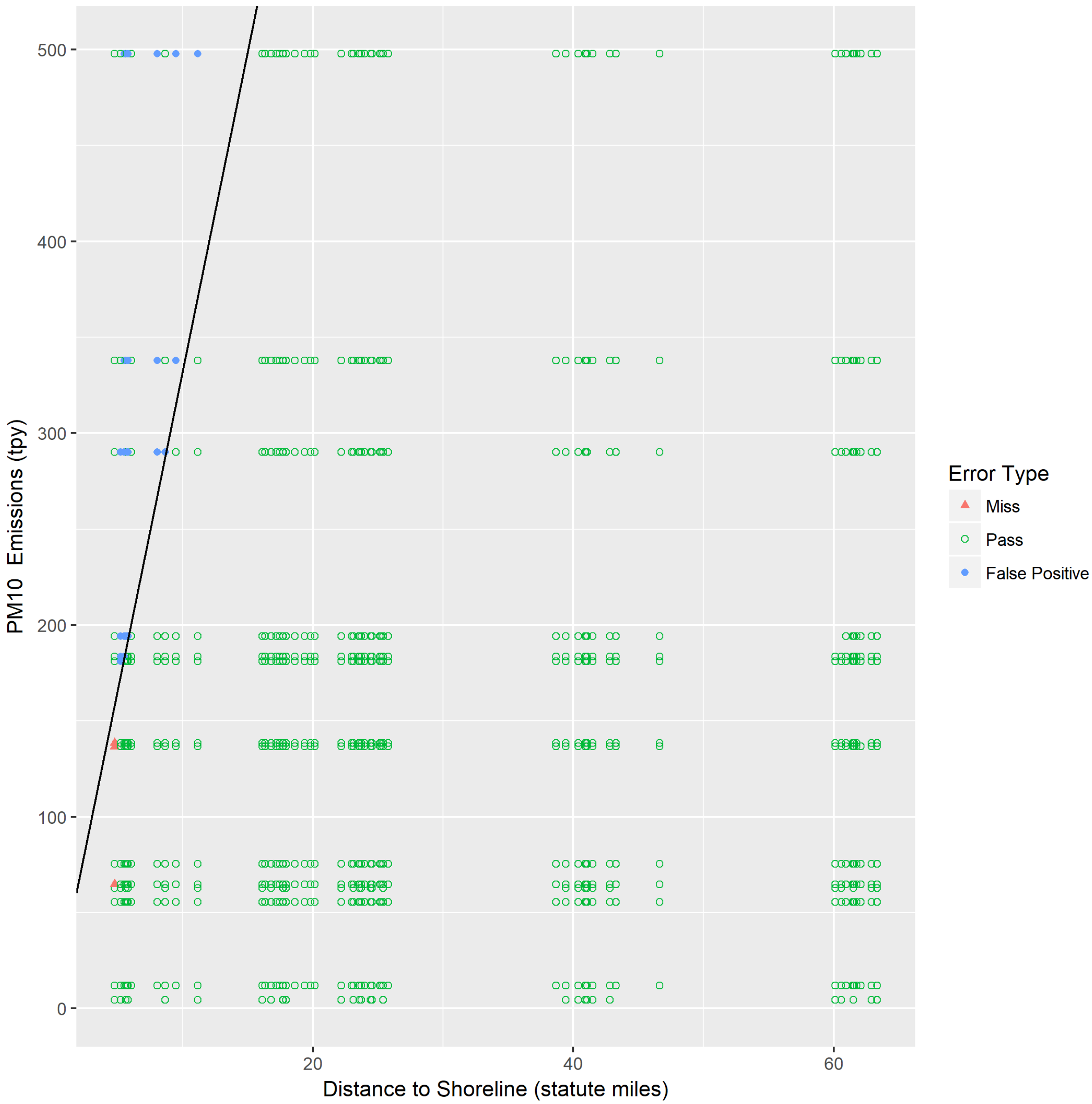

Figure B-15. Scatter Plot of PM_{10} Annual Modeling Results at the Shoreline. Black Line Indicates the EET.

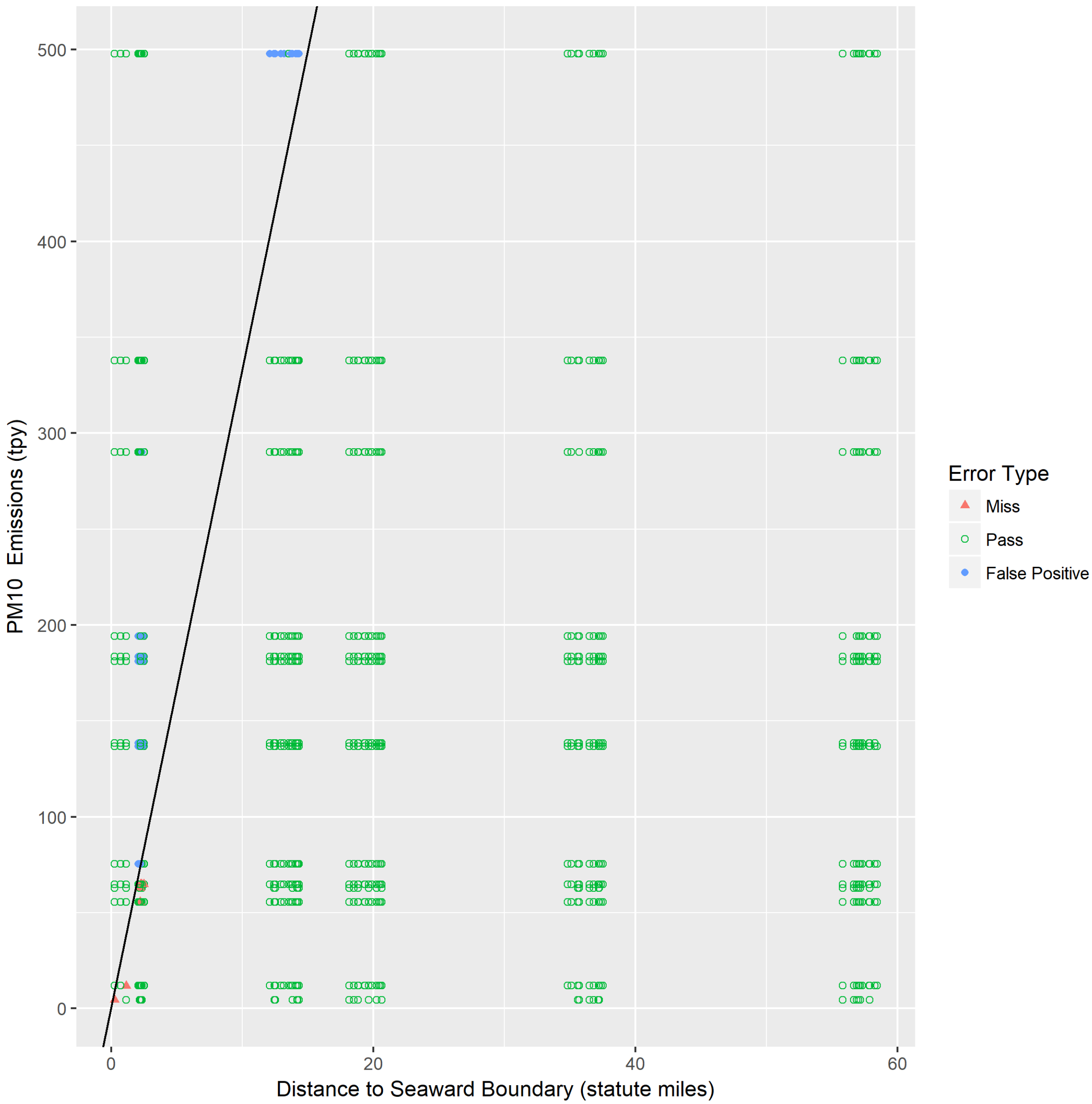

Figure B-16. Scatter Plot of PM_{10} Annual Modeling Results at the State Seaward Boundary.
Black Line Indicates the EET.

04. $PM_{2.5}$

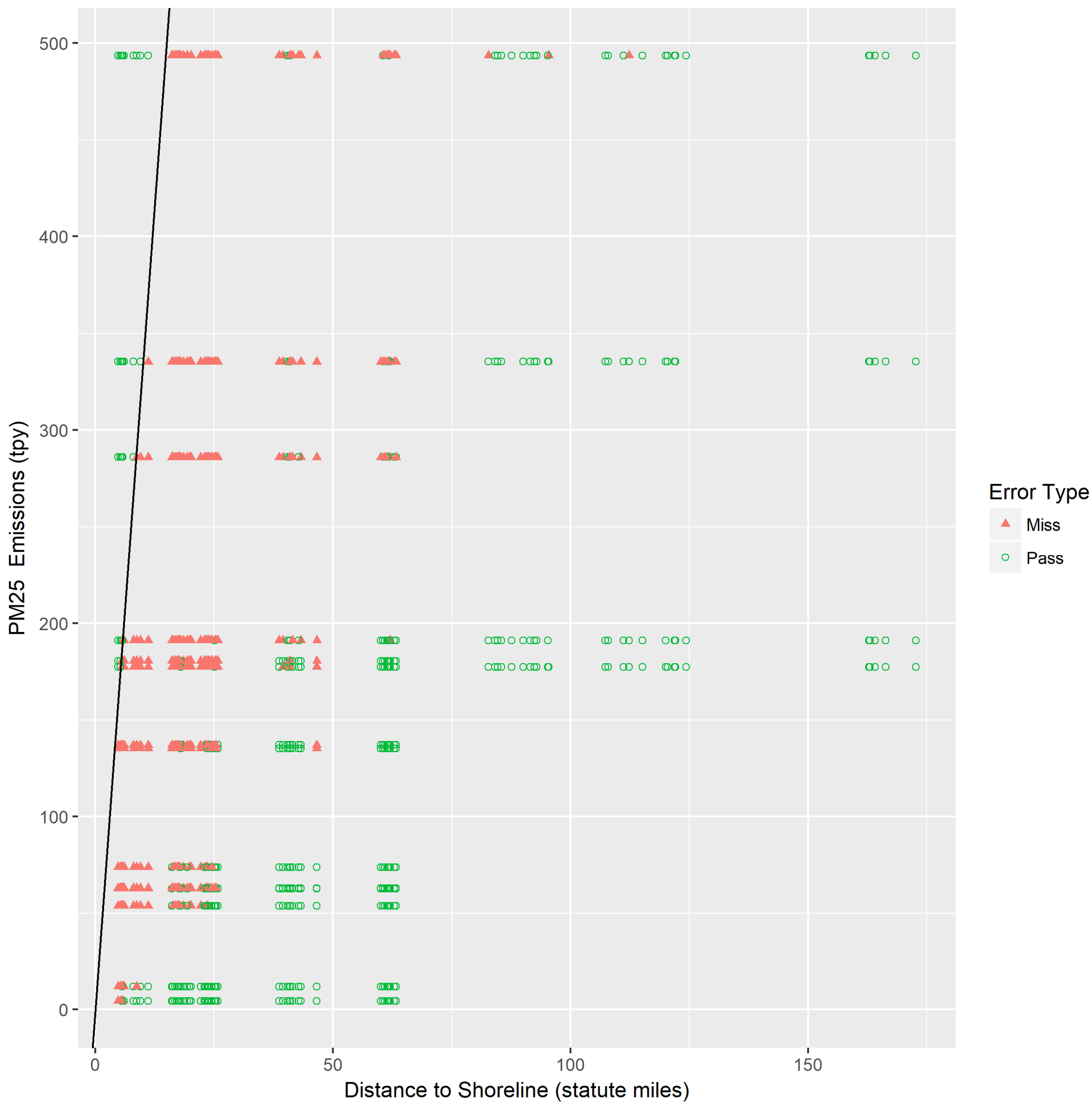

Figure B-17. Scatter Plot of $PM_{2.5}$ 24-hour Modeling Results at the Shoreline. Black Line Indicates the EET.

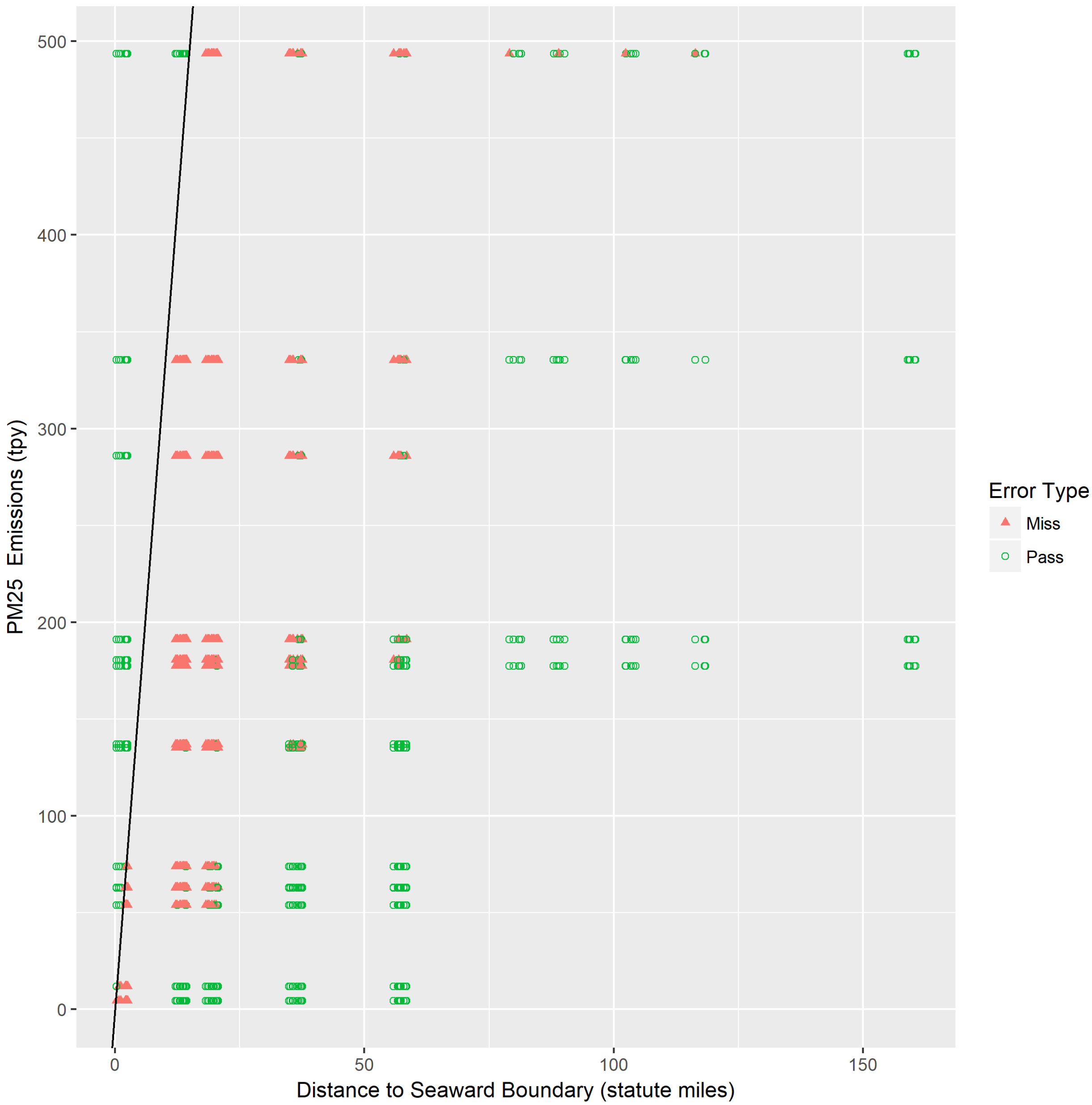

Figure B-18. Scatter Plot of $PM_{2.5}$ 24-hour Modeling Results at the State Seaward Boundary.
Black Line Indicates the EET.

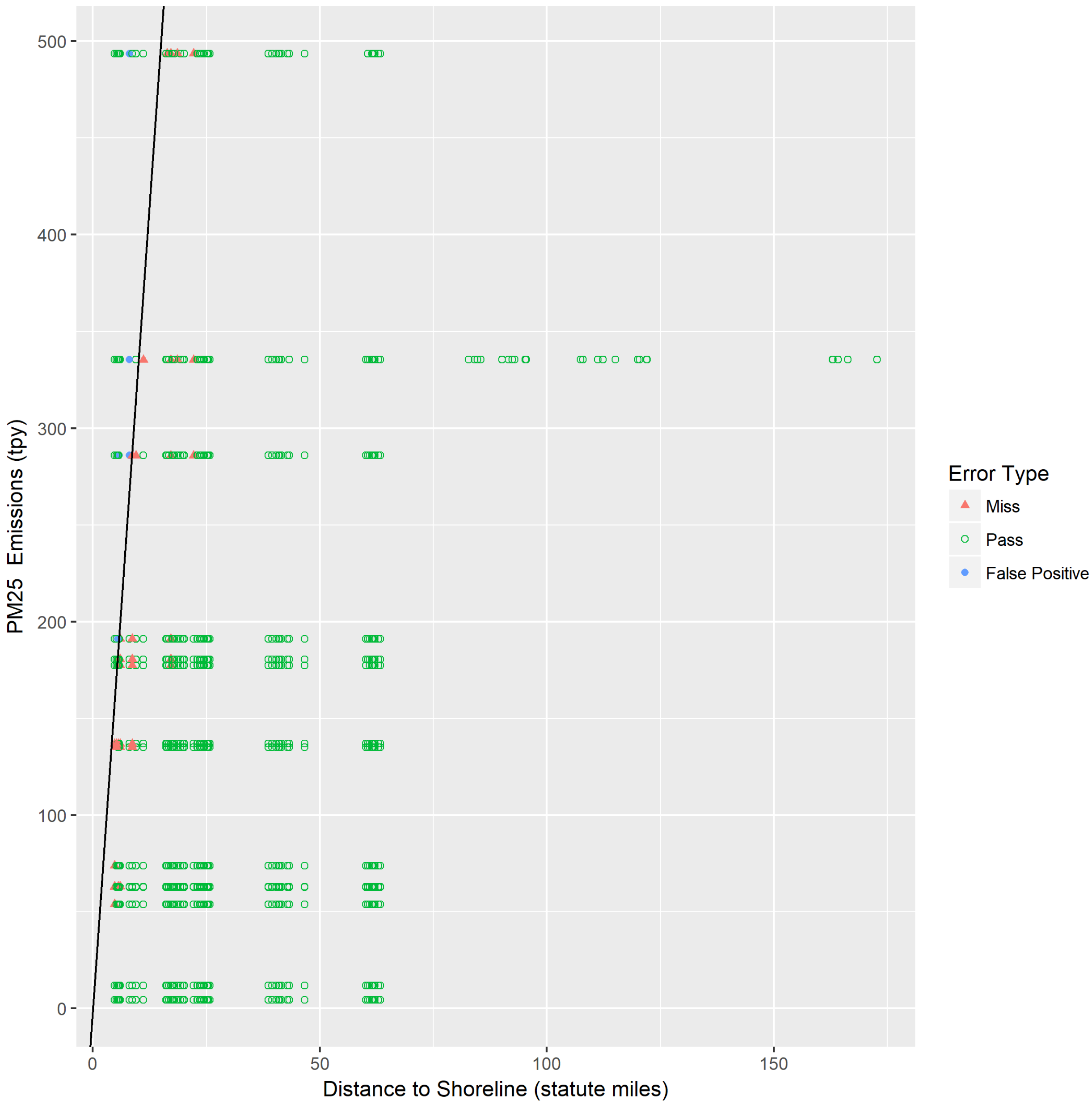

Figure B-19. Scatter Plot of $PM_{2.5}$ Annual Modeling Results at the Shoreline. Black Line Indicates the EET.

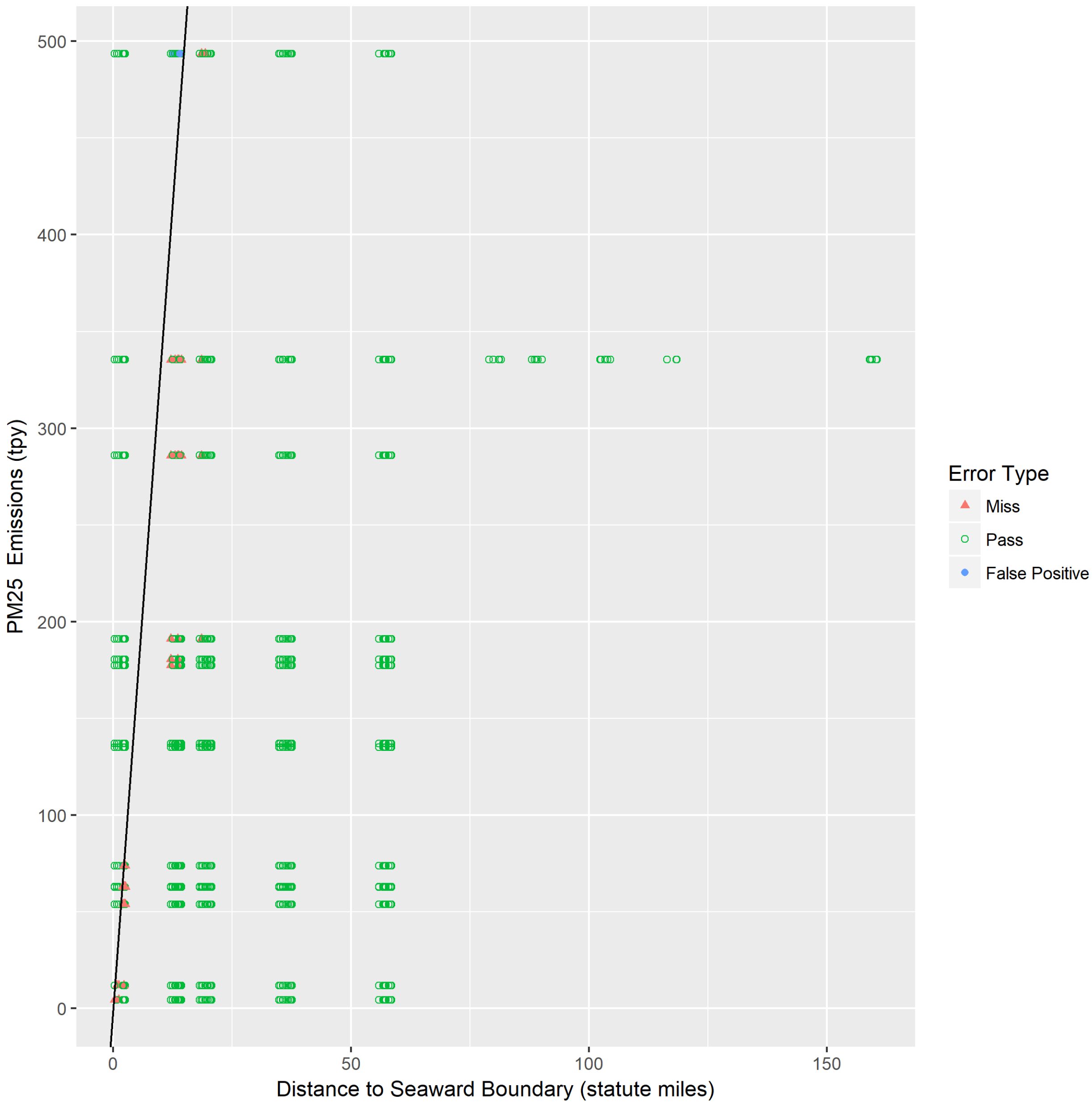

Figure B-20. Scatter Plot of $PM_{2.5}$ Annual Modeling Results at the State Seaward Boundary.
Black Line Indicates the EET.

05. CO

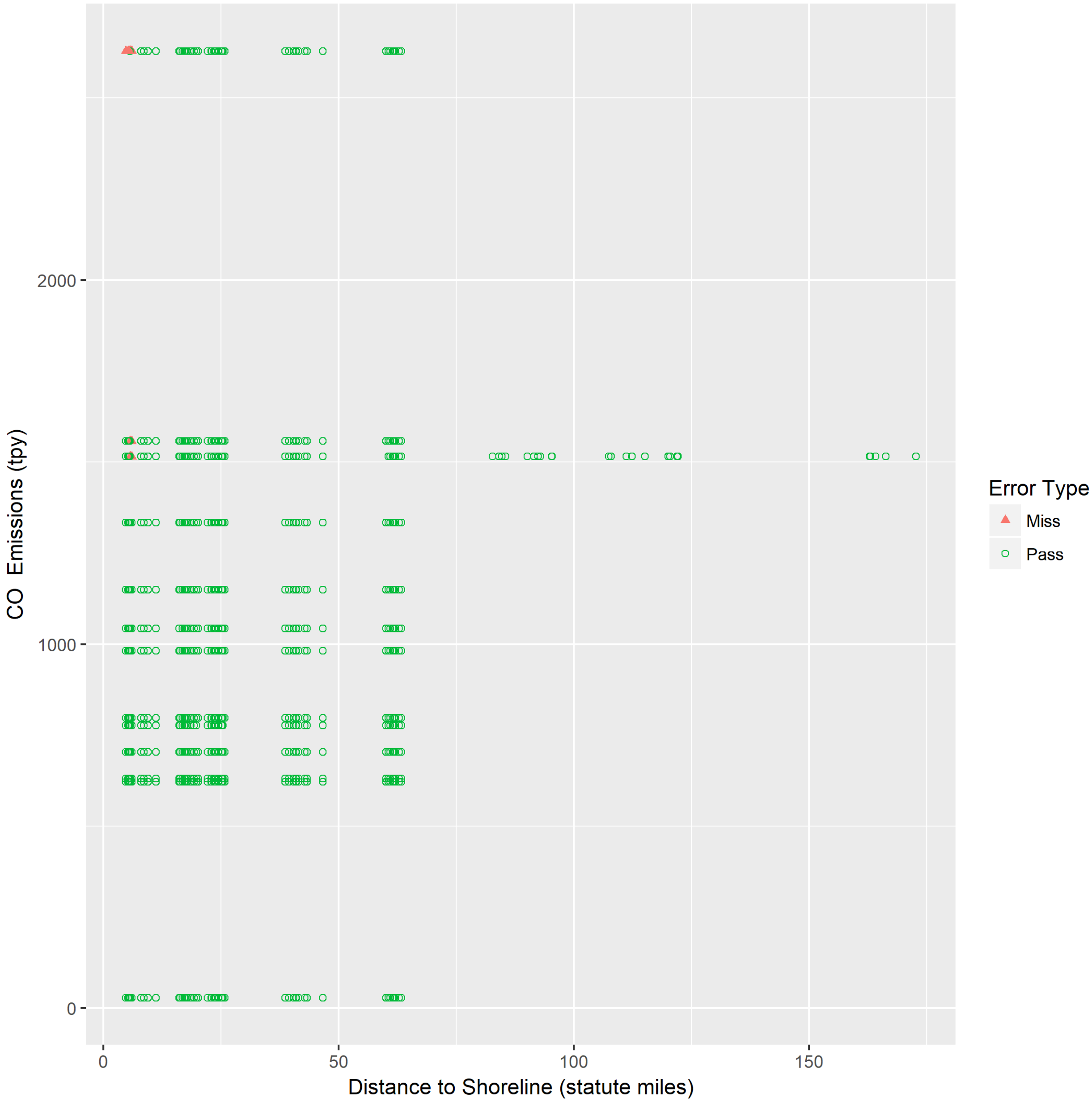

Figure B-21. Scatter Plot of CO 1-hour Modeling Results at the Shoreline. Black Line Indicates the EET.

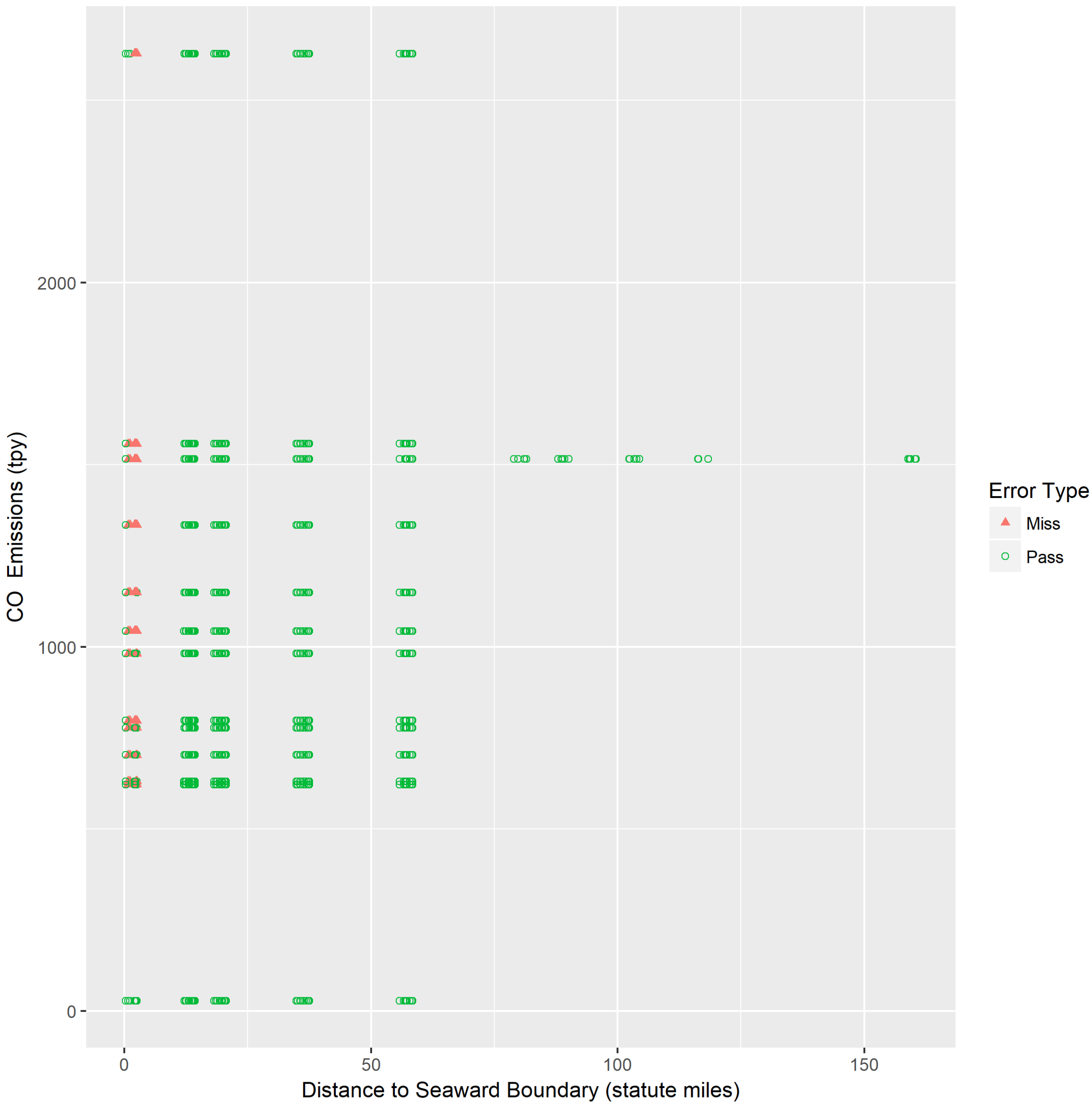

Figure B-22. Scatter Plot of CO 1-hour Modeling Results at the State Seaward Boundary. Black Line Indicates the EET.

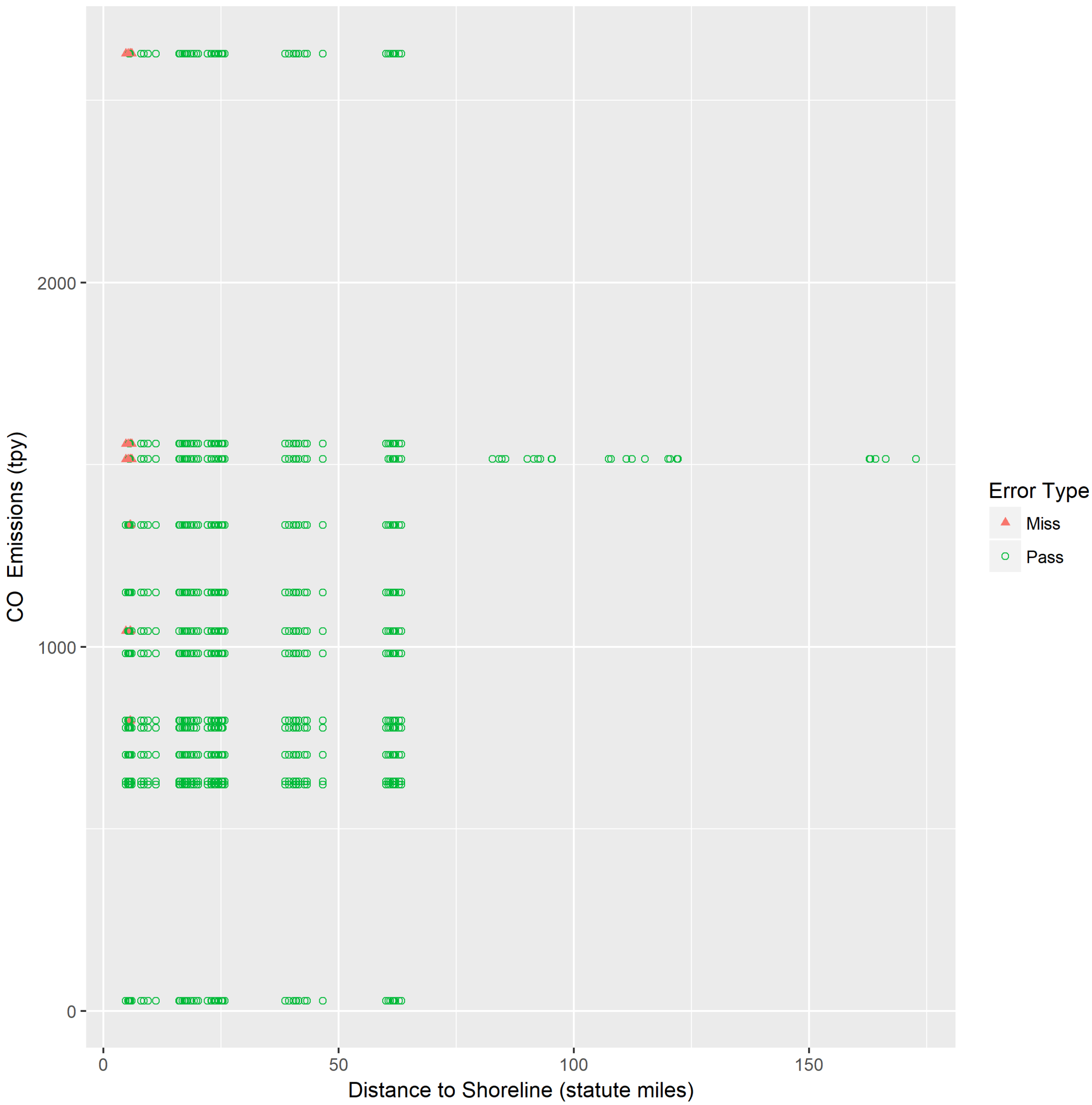

Figure B-23. Scatter Plot of CO 8-hour Modeling Results at the Shoreline. Black Line Indicates the EET.

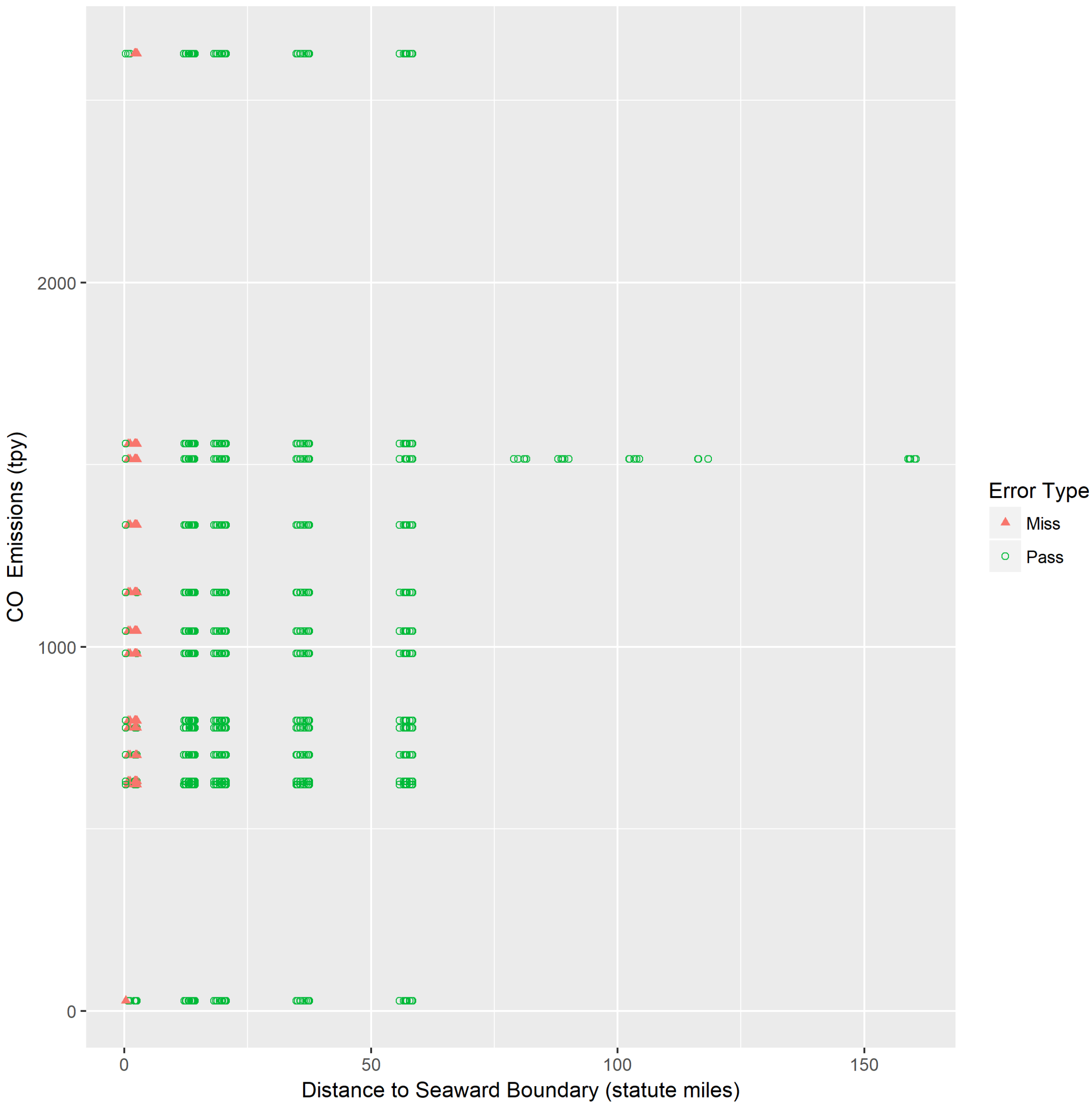

Figure B-24. Scatter Plot of CO 8-hour Modeling Results at the State Seaward Boundary. Black Line Indicates the EET.

APPENDIX C: MODELING RESULTS

Please see the included database (Appendix C - Modeling results-final.accdb)