

**UNITED STATES ENVIRONMENTAL PROTECTION
AGENCY
REGION 10
SEATTLE, WASHINGTON**

**TECHNICAL SUPPORT DOCUMENT
REVIEW OF SHELL'S
SUPPLEMENTAL AMBIENT AIR QUALITY IMPACT ANALYSIS
FOR THE DISCOVERER OCS PERMIT APPLICATIONS
IN THE BEAUFORT AND CHUKCHI SEAS**

June 24, 2011

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A. Introduction

This report provides the U.S. EPA Region 10's (Region 10) findings regarding several supplemental ambient air quality analyses submitted by Shell Offshore Incorporated and Shell Gulf of Mexico, Inc. (collectively, "Shell") to supplement their previous application materials requesting Clean Air Act (CAA) permits for exploratory drilling programs in the Beaufort Sea and the Chukchi Sea. For the reasons described below, Shell's analysis adequately shows that operating the Discoverer and Associated Fleet within the requested constraints will not cause or contribute to violations of the National Ambient Air Quality Standards (NAAQS).

On March 31, 2010, Region 10 issued an Outer Continental Shelf (OCS) Prevention of Significant Deterioration (PSD) Permit to Construct, Permit Number R10OCS/PSD-AK-09-01, to Shell for operations in the Chukchi Sea. On April 9, 2010, Region 10 issued another OCS PSD Permit to Construct, Permit Number R10OCS/PSD-AK-2010-01, to Shell to authorize operations in the Beaufort Sea. These permits (collectively, the "2010 Permits") authorized Shell to operate the Discoverer to conduct air pollutant emitting activities for the purpose of oil exploration on lease blocks in the Chukchi and Beaufort Seas off the North Slope of Alaska. Both 2010 Permits provided for the use of an associated fleet of support ships (Associated Fleet), such as icebreakers, oil spill response vessels, and a supply ship, in addition to the Discoverer.

Following petitions for review to the Environmental Appeals Board (EAB or Board), the Board remanded the 2010 Permits back to Region 10 for further consideration. This analysis is a supplement to the air quality impact analysis included in the Statement of Basis and other documents in the administrative record for the 2010 Permits. This analysis addresses several issues raised by the Board in its remand order including: new modeling of the 1-hour SO₂ and NO₂ standards using AERMOD to address standards that have come into effect since issuance of the 2010 Permits and to supplement the environmental justice analysis for the 2010 Permits; air monitoring data that has been collected since issuance of the 2010 Permits; and additional analysis of the secondary formation of PM_{2.5}. The analysis also addresses changes requested by Shell, including the addition of emergency equipment not addressed in the 2010 Permits and a new operating scenario for the Supply Ship. Together with other documents in the administrative record, it provides support for the revised permits (2011 Revised Draft Permits) to be proposed by Region 10 for public comment to address the Board's orders on remand and the additional changes requested by Shell.

B. Background

Shell is planning to use the Discoverer to conduct exploratory drilling within select lease blocks of the Beaufort and Chukchi Seas but under separate permits. The locations and Shell's plan of operation are fully described in EPA's Statement of Basis (SOB) for both locations. In summary, all of the lease blocks are in federal Outer Continental Shelf (OCS) waters. Drilling as an OCS source would occur for up to 120 days during each July through November drilling season. The drilling season will likely include both open water and broken ice conditions.

Shell's analysis for operations in both the Beaufort and Chukchi Seas uses the highest emitting sources (i.e. the associated support fleet) for an analysis in both Seas although the fleet of ships may vary between the two Seas. Using the highest emitting sources in both Seas allows for a similar modeling approach and

is conservative as the emissions represent a worst case scenario. This report reviews the technical analysis in both Seas and will support the separate permitting actions in the two locations.

C. Air Quality Standards

The ambient air quality analysis supporting the 2010 Permits considered the air quality standards in effect at the time of the original application. The original evaluated standards can be found in Table 5.2.4 in the Statement of Basis for the 2010 Beaufort Permit. Two additional NAAQS have come into effect since issuance of the 2010 Permits, standards for 1-hour NO₂ and SO₂, and are being reviewed in this impact analysis(see Table 1.)

Table 1. National Ambient Air Quality Standards in Effect since Issuance of 2010 Permits

Pollutant	Averaging Time	NAAQS (µg/m ³)
NO ₂	1-hour ¹	188 (100 ppb)
SO ₂	1-hour ²	196 (75 ppb)

¹ To attain this standard, the 3-year average of the 98th percentile of the daily maximum 1-hour average must not exceed 100 ppb

² To attain this standard, the 3-year average of the 99th percentile of the daily maximum 1-hour average must not exceed 75 ppb

D. Modeling Approach

D.1 Air Quality Model

A dispersion model is a computer simulation that uses mathematical equations to predict air pollution concentrations based on weather, topography, emissions data, and emissions source characteristics. AERMOD is the current model preferred by EPA for use in nearfield regulatory applications, per 40 CFR Part 51 Appendix W, Section 3.1.2, and Appendix A to Appendix W:

“AERMOD is a steady-state plume dispersion model for assessment of pollutant concentrations from a variety of sources. AERMOD simulates transport and dispersion from multiple sources based on an up-to-date characterization of the atmospheric boundary layer. AERMOD is appropriate for: point, volume, and area sources; surface, near-surface, and elevated releases; rural or urban areas; simple and complex terrain; transport distances over which steady-state assumptions are appropriate, up to 50 km; 1- hour to annual averaging times; and continuous toxic air emissions.”

For purposes of evaluating the impact of the project emissions Shell used AERMOD. For secondary formation of PM_{2.5}, an additional analysis of secondary formation potential based on the proposed precursor emissions was evaluated. This evaluation did not require additional modeling. Shell also used AERMOD to evaluate additional changes it has requested be made to the 2010 Permits with respect to the air quality analysis for other pollutants.

Note that the modeling supporting the 2010 Permits used a different modeling approach that relied upon a screening model, SCREEN3. The revised modeling in this analysis relies upon a refined dispersion

model, AERMOD, with representative meteorological data. The current analysis also relies upon a 500 meter ambient boundary while the modeling supporting the 2010 Permits had no ambient boundary.

D.2 Meteorological Data

Meteorological data representative of the open Beaufort and Chukchi Seas was not available prior to issuance of the 2010 Permits, so Shell used screening meteorology in conjunction with the screening model to predict worst-case ambient air impact concentrations from its exploratory drilling program. The use of screening meteorology typically results in a conservative analysis because it assumes a range of conditions conducive to high ambient pollution impacts, which may or may not be likely to occur frequently in the modeled domain. Shell now has access to representative meteorological data and is proposing to use this in conjunction with AERMOD for their impact analysis.

AERMOD requires hourly surface meteorological data to estimate plume dispersion. According to Appendix W, a minimum of one-year of site-specific data, or five years of representative National Weather Service (NWS) data should be used. When modeling with site-specific data, Appendix W states that additional years (up to five) should be used when available to account for year-to-year variation in meteorological conditions. AERMOD also requires a morning sounding from a representative upper air station.

Because the drilling season of July 1 to November 30 spans periods of both open water and ice, several different meteorological datasets are being used to prepare model ready input files. For the Beaufort Sea, Shell has collected tower data at Reindeer Island and will use Barrow soundings along with National Weather Service (NWS) data from Deadhorse. For the Chukchi Sea, Shell has collected tower data at Point Lay and obtained NWS data at Wainwright and will use Barrow soundings. In addition to the tower data, Shell deployed buoys in both Seas at varying times and also operated a profiler at Endeavor Island (Endicott) in the Beaufort Sea. This additional data is needed for the open water periods when AERMOD-COARE is used. Data was collected for the 2009 and 2010 drilling season for both locations.

Shell's approach to preparing meteorological data for AERMOD includes both AERMET processing of meteorological data during periods with ice cover and AERMOD-COARE processing for periods of open water. Shell defined the open water period as the time a buoy could be deployed. A complete description of the processing of meteorological data is found in Attachment C of Shell's March 18, 2011 submittal to Region 10 (Shell Offshore Inc. 2011c). Region 10 has reviewed this approach to preparing meteorological data and believes it is representative of conditions in the Beaufort and Chukchi Seas.

Since issuance of the 2010 Permits, AERMOD-COARE had been approved by EPA for use in open water conditions in the Beaufort and Chukchi Seas (USEPA. 2011b). This new technique uses an over-water meteorological preprocessor program that replaces the AERMET preprocessor program within the AERMOD modeling system. The standard version of AERMOD is then used for the dispersion modeling, to calculate concentrations. The replacement for AERMET is based on the results of the coupled atmosphere-ocean response experiment (*Fairall et al., 2003*). COARE provides most of the inputs required by AERMOD, typically supplied via output files from AERMET. Two parameters, the mixing height and vertical potential temperature gradient above the mixing layer, are not provided by COARE. Shell used data from a thermal profiler located on Endeavor Island (Endicott) to diagnose these needed parameters.

Region 10 reviewed the profiler data, the quality assurance audits, high-resolution radiosonde data, temperature and potential temperature profiles, and other calculated parameters associated with the COARE dataset. Diagnosed mixing heights using the Richardson number along with imposed restrictions on mixing heights were also reviewed by Region 10 and found to be representative for use in this case. A

full description of the AERMOD-COARE approach is found in Attachment D of Shell's March 18, 2011 Submittal (Shell Offshore Inc. 2011c).

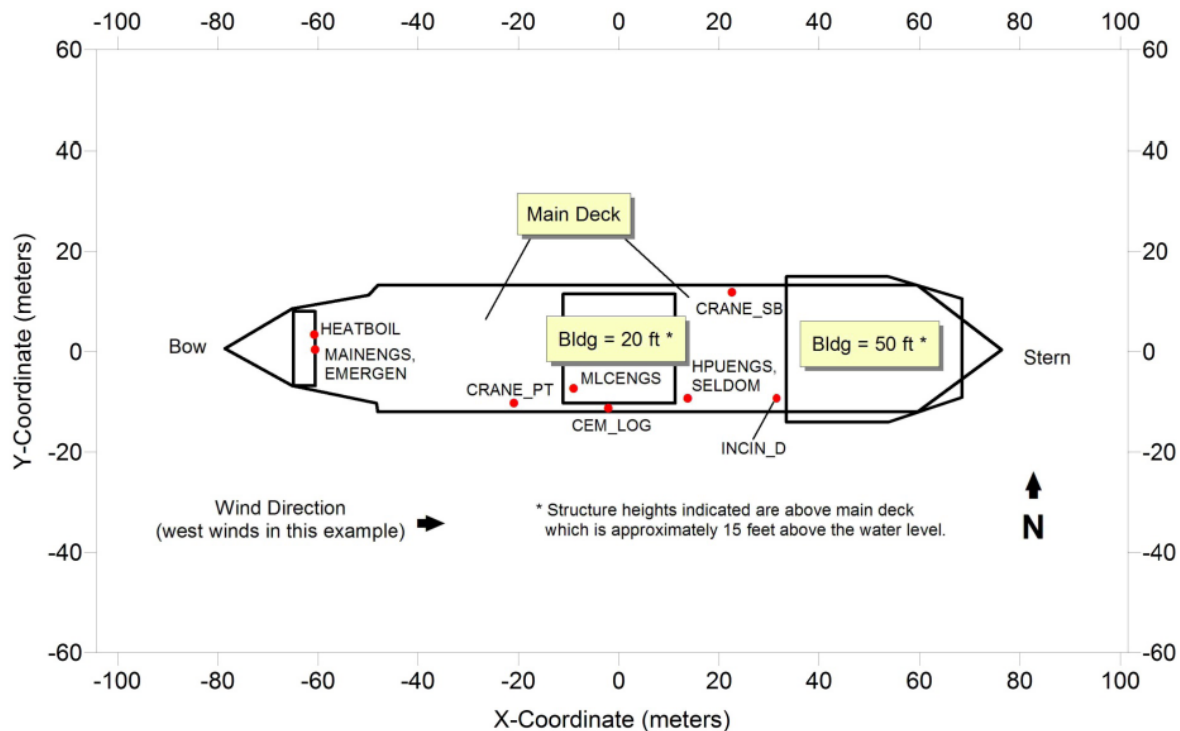
In the analysis of 1-hour NO₂, only one year of concurrent ozone and meteorological data is available, representing the 2009 drilling season (2010 ozone data was not available at the time of submittal). This 2009 dataset was used for the impact evaluation of 1-hour NO₂. For 1-hour SO₂ both the 2009 and 2010 meteorological data can be used. It is important to note that the probabilistic form of the new 1-hour standards is evaluated using three years of monitoring data, which would include three years of varying meteorological data. In this case, Shell is basing the 1-hour NO₂ impact assessment on only one year of meteorological data (a drilling season), which is likely more conservative as no averaging is performed over multiple years. In addition, movement of the drilling ship will decrease short-term impacts, especially in the near field, if averaging were performed over multiple years. The combination of a single year of met data and the assumption of a fixed drilling location produces a conservative analysis (i.e. the predicted modeled impacts are larger than will actually be realized with a moving ship in different meteorological conditions.)

D.3 Building Downwash/Wake Effects

The Building Profile Input Program for PRIME (BPIPFRM) (EPA 4/21/04 User's Guide) calculates direction-specific building dimensions for input into AERMOD. These dimensions are used by the model to account for building downwash and wake effect which result from the effects of airflow around large structures near emission points.

The relative location of the Discoverer exhaust stacks and structures is shown in Figure 1. Shell input the stack location and height for each of the exhaust stacks above the water surface, along with the corner locations and structure height above the water surface of the Discoverer's main deck, the helicopter pad, the pipe deck and the derrick, and the Supply Ship's structures into BPIPFRM. Shell used the current version of BPIPFRM – version 04274. Shell included the resulting direction-specific building dimensions in its AERMOD modeling analysis. Note in the case of the Discoverer, the bow is always modeled facing into the wind based on the ships turret-moored design (i.e. the hull pivots around the drill rig to enable the bow to face into the prevailing wind or current.) The Associated Fleet also repositions with the wind or current and is modeled in a fixed position relative to the Discoverer on an hourly basis. Placing the Associated Fleet in-line with the Discoverer on an hourly basis produces conservative modeling impacts as the emissions are always aligned with the prevailing wind, resulting in overlapping impacts. The overlapping impacts represent the orientation of the Discoverer and Associated Fleet that result in maximum modeled concentrations.

Figure 1 – Layout of Exhaust Stacks and Structures on the Discoverer



Region 10 reviewed Shell’s characterization of the exhaust stacks and structure locations/heights used in the modeling demonstration and determined they were representative of the equipment and as described in Shell’s permit application.

D.4 Shell Operating Scenarios - New Permit Conditions and Equipment

The impact evaluation in Shell’s March 18, 2011 Submittal (Shell Offshore Inc. 2011c) included new proposed permit conditions and equipment not included in the 2010 Permits. The proposed changes include an emergency engine that was upgraded since issuance of the 2010 Permits, seldom used emergency equipment on the Discoverer drillship and Associated Fleet that was not identified in the applications for the 2010 Permits, a reduced restriction on the number of days the Discoverer can be an OCS source, new restrictions on the number of hours the MLC and HPU equipment can be utilized, installation of post combustion controls for particulate matter (PM) and NO_x on Ice Management Vessel #1, and a new operating mode for the Supply Ship.

One important difference in this latest application is the new operating mode of the Supply Ship. Shell is proposing that up to 8 resupply trips be made during the drilling season when the Discoverer is an OCS source. During the periods of resupply, the resupply ship will operate in dynamic positioning (DP) mode. Duration of DP mode operations can be up to 24 hours per resupply trip. Shell has modeled these emissions associated with resupply using the highest emitting candidate resupply ship with a fixed emission point near one of the Discoverer’s two cranes. Shell has also modeled the transit emissions within 2km of the ship occurring the hour before and after DP mode operations. This new resupply scenario represents an increase in emissions from the 2010 Permits.

One of the ice management vessels will also be used as an anchor handler and for crew transport to and from the Discoverer. Anchor handling and crew transport will occur during open water conditions. In the

March 18, 2011 submittal (Shell Offshore Inc. 2011c) the ice management vessel use was only modeled during ice conditions. Shell has provided an additional modeling analysis (Shell Offshore Inc. 2011f) for anchor handler use in open water conditions. Again, this a change from the operating scenario described in the March 18 submittal.

Overall, these changes in permit restrictions have substantially decreased the overall emissions for all criteria pollutants both on an annual basis and hourly basis under 2011 Revised Draft Permits when compared to the 2010 Permits. A summary of the annual emissions changes resulting from the new operating restrictions and other operational changes, on an annual basis for the Beaufort and Chukchi, are summarized in Tables 2 and 3 below.

Table 2. Annual Comparison of Criteria Pollutants and Ammonia from the 2010 permit to the current submittal for the Beaufort¹

Application	NO _x (ton/yr)	PM _{2.5} (ton/yr)	PM ₁₀ (ton/yr)	CO (ton/yr)	VOC (ton/yr)	SO ₂ (ton/yr)	NH ₃ (ton/yr)
Original	1,371	57	65	464	96	2	0.34
Updated ³	336	21	22	154	43	1.3	0.52
Percent Change	-75%	-63%	-66%	-67%	-55%	-35%	53%

Table 3. Annual Comparison of Criteria Pollutants and Ammonia from the 2010 permit to the current submittal for the Chukchi²

Application	NO _x (ton/yr)	PM _{2.5} (ton/yr)	PM ₁₀ (ton/yr)	CO (ton/yr)	VOC (ton/yr)	SO ₂ (ton/yr)	NH ₃ (ton/yr)
Original	1,188	52	58	449	87	2	0.34
Updated ³	336	21	22	154	43	1.3	0.52
Percent Change	-72%	-60%	-62%	-66%	-51%	-35%	53%

Note that there will be a slight increase (0.18 tons/year) in NH₃ emissions associated with the installation of SCR control equipment on Icebreaker #1. This does not change the prior analysis supporting the Beaufort 2010 Permit for the Alaska State Ambient Air Quality Standard for NH₃ that applies under the COA regulations when the source is operating in the OCS because the increase in emissions is so small. There will also be a slight increase in H₂SO₄ from Icebreaker #1, but the requirement to use only ULSD fuel in both the Discoverer and Associated Fleet still ensures that the PTE for H₂SO₄ will remain well below the Significant Emission Rate or SER.

In the Statement of Basis for the 2010 Permits, an impact analysis was performed for all criteria pollutants and averaging times in effect at the time the 2010 Permits were issued. This analysis was based on a SCREEN3 modeling effort, which is a screening model and not a refined model. In addition, the impact analysis performed to support the 2010 Permits assumed an ambient air boundary at the hull of the

¹ Original permit levels from the 2010 statement of basis (USEPA Region 10. 2010d)

² Original permit levels from the 2010 statement of basis (USEPA Region 10. 2010e)

³ Updated values from Shell's May 19th Submittal (Shell Offshore Inc., 2011e)

Discoverer and the Associated Fleet. In the modeling submitted by Shell to support the 2011 Revised Draft Permits, Shell has assumed an ambient air boundary of 500 meters from the center of the Discoverer. Because Shell has identified additional equipment not included in the original permits (mainly the Supply Ship operating in dynamic positioning mode), Shell submitted an additional demonstration on May 19th, 2011 that included all other averaging times and pollutants (Shell Offshore Inc., 2011e).

This refined analysis also included updated background monitoring data for some pollutants because additional data was available and the latest guidance issued by EPA on how to use background data in an air impact analysis for the PM_{2.5} standard (USEPA, 2010b) was also used.

D.4.1 Scenario Management

Because Shell is reducing the number of days the Discoverer can be an OCS source from the 2010 Permits, they incorporated the 120-day OCS limit in their modeling of NO₂, SO₂, PM₁₀ and PM_{2.5} impacts. To ensure the modeled results were not underestimated by their selection of when the 120-day period would occur, Shell modeled two 120-day periods during the drilling season: an “early season” period (July 1 through October 28th); and a “late-season” (August 3rd through November 30th). Shell then took the higher of the two impacts for comparison to the air quality standards.

Shell also incorporated the various levels of operation during a 30-day drilling sequence in their NO₂, SO₂, PM₁₀ and PM_{2.5} analysis. They did this by creating an AERMOD input file for each day and hour of the 120-day period (2,880 files) for each pollutant. They then ran AERMOD for each file and post-processed the results.

Shell used the full five month (153-day) meteorological period when modeling their CO and NH₃ impacts. They also used the worst-case emissions for each unit and assumed all units are operating concurrently. This is a conservative and therefore, acceptable, approach.

Shell prorated the period averages in order to estimate the annual average impacts. For example, to estimate the annual average NO₂, PM_{2.5} or SO₂ impacts, Shell multiplied the 120-day average impact by 0.329 (120 drilling days out of 365 days in a year). Shell’s approach for estimating the annual average impact is reasonable since there are no impacts during non-drilling periods.

D.5 Receptor Grid

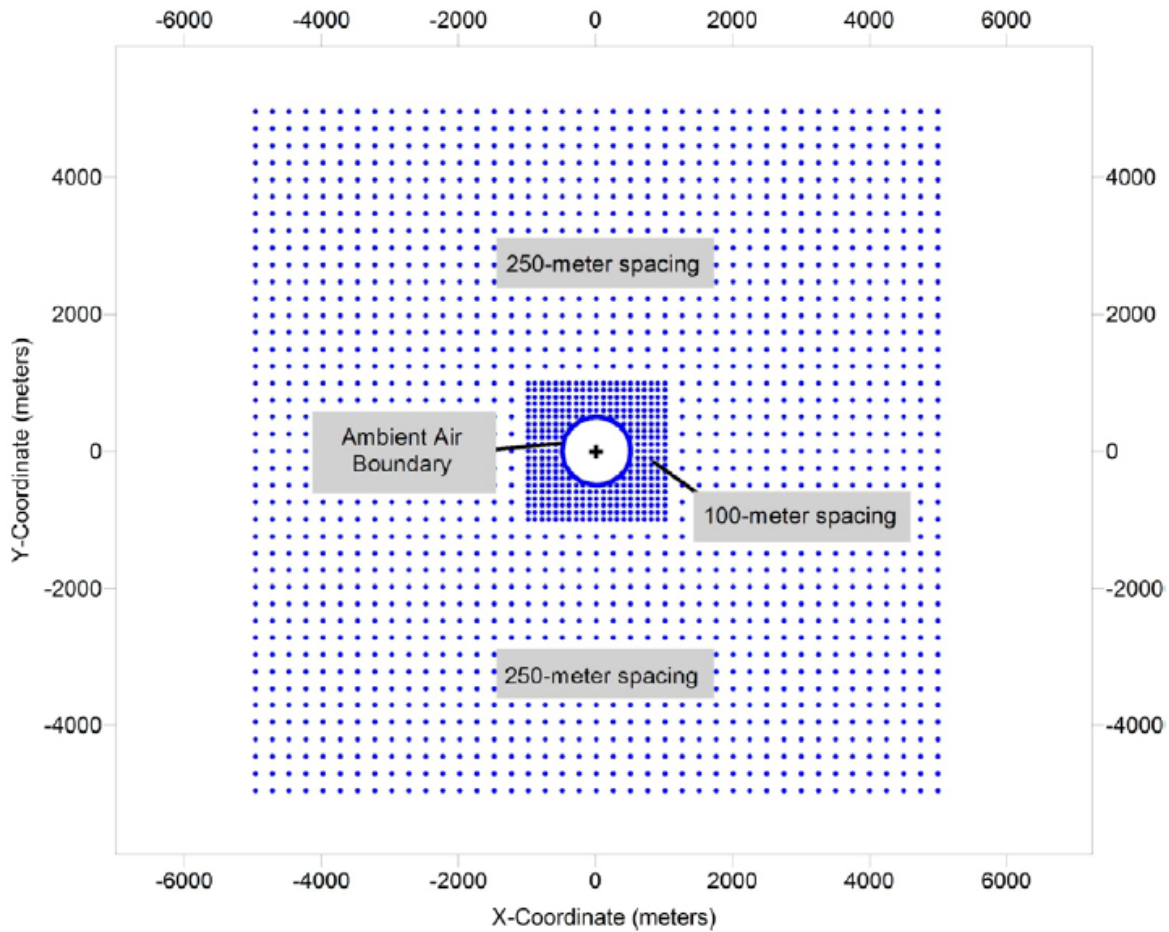
A local Cartesian coordinate system was used by Shell to define its primary modeling domain and cover all its overwater drilling and support operations. Shell has used an ambient air boundary of 500 meters from the center point of the Discoverer. Surface elevations were set to 0.0 meters reflecting the lack of terrain in an overwater setting. The grid does not have a defined origin because drilling will occur in multiple locations within the specified permitted lease blocks. Having a local coordinate system allows emissions impacts to be placed at various lease block locations to analyze modeled impacts without having to redo modeling runs for each potential location. As discussed above, the prior screening modeling analysis assumed the ambient air boundary was at the hull of the Discoverer, while the refined analysis assumes a 500 meter boundary.

Figure 2 shows the receptor layout used in the modeling. The receptor grid extends out to 5 km, to characterize the pattern and location of maximum hourly impacts from the Discoverer and Associated Fleet. Shell used a 25 meter (m) spacing at the ambient air boundary. Shell constructed the rest of the grid as follows:

- 100-m spacing out to 1 km from the center of the Discoverer;
- 250-m spacing from 1 km to 5 km from the center of the Discoverer.

Additional receptors were placed at communities or at 50km from the Discoverer in the direction of a community. Fifty kilometers is the maximum distance where AERMOD is recommended for use. For this analysis, the communities with additional receptors include Kaktovik and Deadhorse in the Beaufort Sea and Pt. Lay and Wainwright in the Chukchi. Note that the prior analysis also included impacts at Nuiqsut. Because Nuiqsut is in the same direction as Deadhorse from the permitted lease blocks but Nuiqsut is further away, the modeled concentration results from Shell's activities at Deadhorse can also be considered as conservatively representative of modeled concentrations from Shell's activities at Nuiqsut.

Figure 2. Receptor Layout (Discoverer is Origin)



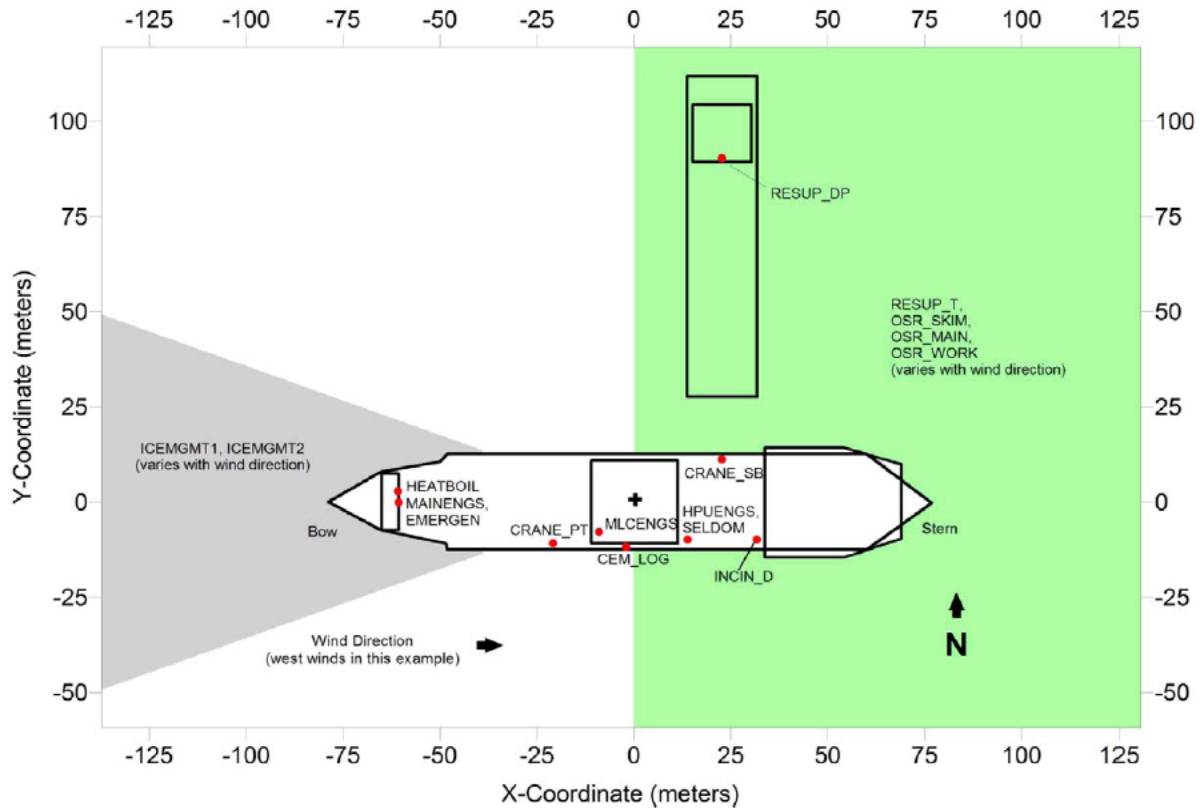
Region 10 has reviewed Shell’s grid and determined that it has sufficient density and coverage for characterizing the maximum impacts from drilling operations. In addition, Region 10 verified that receptors placed at onshore locations or at 50km in the direction of a sensitive onshore location were correctly located.

D.6 Source Locations and Source Parameters

D.6.1 Source Locations

Modeled locations for the drillship and Associated Fleet during drilling are specified on a local coordinate system within the model. This was done so modeled concentrations can be placed at various locations throughout the permitted lease blocks in the impact analysis without re-doing modeling runs. Because the Discoverer is a turret moored ship and rotates with the wind, the orientation of the Discoverer and location of the Associated Fleet varies with wind direction. In the modeling analysis this varying orientation and Associated Fleet location was accounted for by orienting the ship into the wind on an hourly basis, and by moving the Associated Fleet to also line up with the wind in their respective locations, either in front or behind the Discoverer. Varying the orientation of the drillship and moving the Associated Fleet with the prevailing wind direction will provide the most conservative impact analysis as all the emissions are aligned such that the highest cumulative impacts from all equipment will occur. This also best reflects how the actual drilling operations are performed. Figure 3 provides the modeled locations of the drillship and Associated Fleet for a given wind direction.

Figure 3. Drillship Orientation and Associated Fleet Location by Wind Direction



To orient the ship with the wind in the modeling, Shell used hourly wind directions to create a corresponding hourly input file with varying source locations. So for each hour, emissions from the Discoverer and the Associated Fleet will be in different locations but aligned with the prevailing wind direction for that hour. In addition to the hourly source location changes, each hourly input file also accounted for varying emission release characteristics for the portion of the Associated Fleet that is modeled with as an area polygon (areapoly). The hourly input file was needed in order to account for both plume rise and the vertical dispersion coefficient that vary with meteorological conditions. To do these calculations, Shell performed a preliminary model run with a line of receptors along the centerline of the areapoly used for the ice management vessels and determined the worst case concentration at each receptor. Shell then took the corresponding plume heights and vertical dispersion coefficients for the receptor with the highest modeled concentrations. These plume heights and vertical dispersion coefficients then became the final modeled inputs for the ice management vessels in the full impact analysis. A similar approach was used to characterize the remaining areapoly sources (i.e. resupply transit and oil spill response fleet). The end result of this approach allows Shell to place emissions for the moving Associated Fleet in the area they generally work while providing a conservative impact analysis by using worst case dispersion characteristics for the portion of the Associated Fleet that is modeled as an areapoly. Region 10 reviewed this approach and believes it provides a conservative estimate of modeled impacts while adequately characterizing a moving fleet of vessels.

D.6.2 Source Emissions Parameters

Shell provided emissions rates for each piece of equipment for each operating scenario. Table 4 contains the worst case emission rates for each piece of equipment regardless of operating scenario. Note that not

all equipment will operate at the same time and some equipment only operates for restricted periods of time. For example the ice management vessels will generally not be operating in open water conditions; or the cementing and logging activities will not occur during MLC drilling. A full list of emissions under various operating scenarios can be found in Tables 2-2, 2-3 and 2-4 in Shell's March 18, 2011 Submittal (Shell Offshore Inc., 2011c).

Table 4. Maximum Daily Emissions Rates (lb/day)

	NO _x (lb/day)	PM _{2.5} (lb/day)	PM ₁₀ (lb/day)	CO (lb/day)	SO ₂ (lb/day)
Discoverer					
Generation	111.4	28.3	28.3	39.9	1.5E+00
MLC	170.6	4.3	4.3	79.3	2.9E-01
HPU	79.0	0.6	0.6	13.8	1.3E-01
Cranes	59.5	0.4	0.4	1.3	3.9E-02
Cementing/Logging	157.3	3.9	3.9	8.8	6.8E-02
Heaters	76.5	9.0	9.0	29.5	6.1E-01
Seldom-used	12.6	0.9	0.9	2.7	4.5E-03
Emergency	39.5	2.8	2.8	8.5	1.4E-02
Incinerator	3.3	4.6	5.3	20.2	1.6E+00
Primary Ice Management					
Propulsion	1576.9	246.4	246.4	712.9	6.7E+00
Heaters	36.1	6.0	6.0	9.0	3.8E-01
Seldom-used	8.4	0.6	0.6	1.8	3.0E-03
Incinerator	9.2	16.8	24.6	554.4	4.6E+00
Secondary Ice Management / Anchor Handler					
Propulsion	1625.4	254.0	254.0	734.8	6.9E+00
Heaters	14.4	2.4	2.4	3.6	1.5E-01
Seldom-used	8.4	0.6	0.6	1.8	3.0E-03
Incinerator	9.2	16.8	24.6	554.4	4.6E+00
Resupply Ship - transit mode					
Propulsion	704.4	18.8	18.8	151.7	2.5E-01
Resupply Ship - DP mode					
Propulsion	2817.4	75.1	75.1	606.9	1.0E+00
Offshore Management / Skimmer vessel					
Propulsion	1192.6	21.4	21.4	316.8	5.9E-01
Seldom-used	8.4	0.6	0.6	1.8	3.0E-03
Incinerator	7.5	13.7	20.0	450.0	3.8E+00
OSR vessel					
Propulsion	1618.6	3.0	3.0	8.7	8.1E-01
Seldom-used	8.4	0.6	0.6	1.8	3.0E-03
Incinerator	7.5	13.7	20.0	450.0	3.8E+00
OSR work boats					
Work	317.7	22.3	22.3	68.4	1.2E-01

D.6.3 Emission Unit Characterization

In addition to providing the model with an emission rate, the release characteristics must be provided in order for the model to estimate how the release disperses over time. The release parameters needed for modeling point sources include stack height, stack gas exit temperature, stack gas exit velocity and inside stack diameter. Modeling polynomial area sources with buoyant exhaust characteristics requires a description of the polynomial (i.e, the corner coordinates), the release height and the initial vertical spread of the exhaust plume (sigma-z). Table 5 provides the modeled point sources parameters. The area

polygon sources (i.e. the associated support fleet) vary their position hourly based on wind direction, as described in section D.7.1, and are not included in Table 5 because there are 2880 different configurations. Region 10 reviewed all release characteristics and found them to be representative of the proposed equipment.

Table 5. Modeled point source parameters.

Point Source Description	Model ID	X (m)	Y (m)	Source Type	Release Height Above Main Deck (m)	Release Height Above Water (m)	Exit Temperature (K)	Exit Velocity (m/s)	Stack Diameter (m)
Generation	MAINENGS	-61.1	0.2	POINT	12.83	17.4	710	32.9	0.32
Emergency Generator	EMERGEN	61.1	0.2	POINT	12.83	17.4	710	32.9	0.32
MLC compressors	MLCENGS	9	8	POINT	8.53	13.11	700	40	0.21
HPU engines	HPUENGS	14	10	POINT	6.1	10.67	700	40	0.18
Crane (Port)	CRANE_PT	21	11	POINT	13.72	18.29	672	20.1	0.25
Crane (starbord)	CRANE_SB	22.9	11.3	POINT	13.72	18.29	672	20.1	0.25
Cementing and Logging	CEM_LOG	2	12	POINT	6.1	10.67	800	46.6	0.18
Heaters and Boilers	HEATBOIL	61.3	2.8	POINT	12.83	17.4	478	7.3	0.46
Seldom used Units	SELDOM	14	10	POINT	6.1	10.67	700	40	0.18
Incinerator	INCIN_D	32	10	POINT	2.44	7.01	623	10	0.46
Resupply DP mode	RESUP_DP	22.9	91.5	POINT	NA	18.29	650	14.6	0.6

Source: Shell Offshore Inc., 2011c

D.7 Urban/Rural Area Determination

Shell did not utilize the AERMOD option to incorporate the effects of increased surface heating from an urban area. Shell's approach is appropriate since there are no urban areas in the Beaufort or Chukchi Seas.

D.8 Background Monitoring Data

In order to ensure the NAAQS are protected, modeled concentrations are combined with existing monitored background data and then evaluated against the air quality standards to ensure compliance. The monitored data should represent impacts from sources not specifically modeled, such as natural, area-wide, long-range transport, and distant stationary sources.

As discussed in the Statements of Basis supporting the 2010 Permits, because there are no islands, platforms, or infrastructure in the Beaufort or Chukchi Seas in the vicinity of Shell's offshore operations on which to install, operate, and maintain ambient air quality monitoring equipment, it is appropriate to use onshore preconstruction monitoring data as a conservative representation of background concentrations in the vicinity of Shell's operations. The onshore data is expected to be conservative because these onshore monitoring stations will be somewhat influenced by local sources that are not present in the vicinity of Shell's offshore operations.

The 2010 Permits were supported by background monitoring data collected at the Wainwright Near-Term site for the 2010 Chukchi Permit and, for the 2010 Beaufort Permit, at Badami and at a number of other monitoring stations in the Prudhoe Bay area. The Deadhorse monitoring site was predicted to have the highest PM_{2.5} concentrations in the network and was therefore selected as the location for installation of collocated PM_{2.5} monitors for the monitoring network, including the monitoring sites in Wainwright.

Several of the monitoring stations Shell relied on for issuance of the 2010 Permits continued to collect background monitoring data. The Wainwright Permanent site became operational in late 2009 and replaced the Wainwright Near-Term site. In addition, a monitoring station has been established in the Village of Point Lay, located on the Chukchi Sea, and has been collecting data since June 2010. Region 10 has reviewed the quarterly reports, including instrument operating parameters, and analyzed the measured air pollutant data collected for the periods from March 6, 2009 to December 31, 2010 for the Wainwright, Point Lay, Badami, and Deadhorse monitoring stations and has concluded that the data were collected in accordance with the applicable Quality Assurance Project Plans (QAPP) for the monitors and met applicable quality control and quality assurance requirements. See June 23 Memorandum from Christopher Hall Region 10, Titled "EPA Region 10 Determination of Appropriate Background Values for the Chukchi Sea and Beaufort Sea OCS Permits." The Alaska Department of Environmental Conservation (ADEC) has reviewed the quarterly reports, including instrument operating parameters, and analyzed the measured air pollutant data collected for the CCP, Pad A, and Endicott SDI monitoring stations and has concluded that the data was collected in accordance with the applicable QAPPs for the monitors and met applicable quality control and quality assurance requirements. Table 6 and Table 7 summarize the monitoring sites, pollutants, and years of record that Region 10 is relying upon for the air quality analyses for the 2011 Revised Draft Permits.

Table 6. Ambient Air Monitoring Sites, Pollutants, and Years of Record for Chukchi Sea Operations

	Wainwright Near-term	Wainwright Permanent	Point Lay
PM _{2.5}	3/6/09 - 12/7/09 ^a	12/10/09 - current ^b	6/1/10 - current
PM ₁₀	11/8/08 - 12/7/09 ^a	10/7/09 - current ^b	6/1/10 - current
NO ₂	11/8/08 - 12/7/09	9/14/09 - current	6/1/10 - current
O ₃	11/8/08 - 12/7/09	9/14/09 - current	6/1/10 - current
SO ₂	11/8/08 - 12/7/09	9/14/09 - current	6/1/10 - current
CO	11/8/08 - 12/7/09	9/14/09 - current	6/1/10 - current

^a Data include impacts from local fugitive dust events

^b Data include impacts from two wildfire events in 2010

Table 7. Ambient Air Monitoring Sites, Pollutants, and Years of Record for Beaufort Sea Operations

	Badami	Deadhorse	A Pad ^a	CCP ^b	Endicott SDI ^c
PM _{2.5}	8/20/09 - 12/31/10	10/23/09 - current	NA	NA	NA
PM ₁₀	NA	NA	NA	1/2/06 - 12/30/09	NA
NO ₂	8/15/09 - 12/31/10	NA	1/1/06 - 12/31/09 ^d	1/1/06 - 12/31/09	2/1/07 - 1/31/08
O ₃	NA	NA	1/1/06 - 12/31/09	1/1/06 - 12/31/09	NA
SO ₂	NA	NA	1/1/06 - 12/31/09	1/1/06 - 12/31/09	2/1/07 - 1/31/08
CO	NA	NA	NA	NA	2/1/07 - 1/31/08

NA – Monitoring for this pollutant not conducted

^a. The site labeled A Pad here was listed in the previous Statement of Basis for the Beaufort permit as BPXA Prudhoe Bay

^b. The site labeled CCP here was listed in the previous Statement of Basis for the Beaufort permit as BPXA Prudhoe Bay

^c. The site labeled Endicott SDI here was listed in the previous Statement of Basis for the Beaufort permit as BPXA Liberty

^d. 2008 data did not meet PSD criteria as the 3rd quarter data did not meet the 80% completeness requirement.

Region 10 has evaluated the available monitoring data from these onshore sites and has determined which are most representative of background values for use in the air quality analyses for offshore locations near the Shell lease blocks in both seas as well as at onshore communities where the air quality impact of the Discover and Associated Fleet is being evaluated. Table 8 summarizes the monitoring sites and the background values that Region 10 believes best represent offshore locations in the Beaufort and Chukchi Seas.

Table 8. Background Values for Use with Modeled Impacts at Offshore Locations Near Shell Lease Blocks for the 2011 Revised Draft Permits

Pollutant	Averaging Period	Beaufort Sea		Chukchi Sea	
		Concentration ($\mu\text{g}/\text{m}^3$)	Data Source	Concentration ($\mu\text{g}/\text{m}^3$)	Data Source
NO ₂	1-hour	varies by hour	Badami	varies by hour	Wainwright
	Annual	1	Badami	2	Wainwright
PM _{2.5}	24-hour	6	Badami	11	Wainwright ^a
	Annual	3	Badami	2	Wainwright ^a
PM ₁₀	24-hour	53	CCP	79	Wainwright ^a
SO ₂	1-hour	13	SDI	23	Wainwright
	3-hour	11	SDI	14	Wainwright
	24-hour	4	SDI	5	Wainwright
	Annual	2	SDI	0.4	Wainwright
CO	1-hour	1742	SDI	959	Wainwright
	8-hour	1094	SDI	945	Wainwright

^a. Only uses 2010 data from the Wainwright Permanent Site

Region 10 believes that the two monitoring sites to the east of Prudhoe Bay (Badami and SDI) are the most representative of background concentrations at the Shell lease blocks covered by the 2011 Revised Draft Permit for Shell's operations in the Beaufort Sea. However, since the CCP site is the only monitoring site in the Beaufort Sea area that has collected PM₁₀ data, it has been used as the PM₁₀ value for the Beaufort offshore locations. Region 10 believes that the Wainwright monitoring sites are the most representative of background at the Chukchi Sea lease blocks because they (1) are closer to the Shell lease blocks than the Point Lay site, (2) have a more robust data set with 2 years of available data for most pollutants, and (3) they generally have lower values, which are more representative of the expected offshore concentrations.

Table 9 summarizes the monitoring sites and background values that Region 10 believes are appropriate for evaluating impacts in the identified onshore communities. The Point Lay and Wainwright monitoring sites along the Chukchi Sea have been used to determine background values in each of those villages. In the case of Nuiqsut and Kaktovik, because there are no quality assured monitoring data being collected in either of these villages, Region 10 has generally used data from the monitoring sites closest to each of those villages. Specifically, where available, Region 10 has used data from sites to the west of Prudhoe Bay for Nuiqsut and sites to the east of Prudhoe Bay for Kaktovik, with a preference for more recent data if more than one site has data for the same pollutant. As discussed above, the only monitoring site along the Beaufort Sea that has collected PM₁₀ data was the CCP site and so it has been used for both Nuiqsut and Kaktovik. In addition, the only site that has collected CO data in the Beaufort Sea area was SDI so it also has been used for both Nuiqsut and Kaktovik. From the available data, Region 10 calculated background values following the provisions of the applicable appendices to 40 CFR Part 50 and EPA modeling guidance.

Table 9. Background Values for Use with Modeled Impacts at Onshore Locations

Pollutant	Averaging Period	Point Lay		Wainwright		Nuiqsut		Kaktovik	
		Concentration ($\mu\text{g}/\text{m}^3$)	Data Source	Concentration ($\mu\text{g}/\text{m}^3$)	Data Source	Concentration ($\mu\text{g}/\text{m}^3$)	Data Source	Concentration ($\mu\text{g}/\text{m}^3$)	Data Source
NO ₂	1-hour	41	Point Lay	38	Wainwright	94	A Pad	21	Badami
	Annual	2	Wainwright	2	Wainwright	11	A Pad	1	Badami
PM _{2.5}	24-hour	7	Point Lay	13	Wainwright	17	Deadhorse	6	Badami
	Annual	2	Point Lay	2	Wainwright	4	Deadhorse	3	Badami
PM ₁₀	24-hour	65	Point Lay	114	Wainwright	53	CCP	53	CCP
SO ₂	1-hour	14	Point Lay	12	Wainwright	14	A Pad	10	SDI
	3-hour	14	Point Lay	14	Wainwright	180	A Pad	11	SDI
	24-hour	14	Point Lay	5	Wainwright	15	A Pad	4	SDI
	Annual	0.4	Wainwright	0.4	Wainwright	4	A Pad	2	SDI
CO	1-hour	1029	Point Lay	959	Wainwright	1742	SDI	1742	SDI
	8-hour	1029	Point Lay	945	Wainwright	1094	SDI	1094	SDI

Note that, the Wainwright Permanent site began operation in September 2009 and has now replaced the Wainwright Near-Term site, which ceased operation in December 2009. As discussed in the Statement of Basis for the 2010 Chukchi Permit, because the Wainwright Near-Term site was determined to be unduly impacted by local fugitive dust sources, days with high dust impacts were excluded from the determination of the offshore PM_{2.5} and PM₁₀ background values supporting issuance of the 2010 Chukchi Permit, although such days were still included for the onshore background values. See 2010 Chukchi Statement of Basis at 106-107. Now that there is one year of data for the Wainwright Permanent site that includes the drilling season, Region 10 believes it is appropriate to consider only the PM_{2.5} and PM₁₀ data from the Wainwright Permanent site for determining the appropriate offshore PM_{2.5} and PM₁₀ concentrations in the Chukchi Sea. Data from the Wainwright Near-Term site has still been considered for purposes of determining the appropriate onshore PM_{2.5} and PM₁₀ concentrations onshore in Wainwright and has also been considered for all other pollutants.

For the annual NO₂ and SO₂ standards, the background value is the highest calendar year average from the relevant monitoring site. For the 24-hour PM₁₀, 3-hour and 24-hour SO₂, and 1-hour and 8-hour CO standards, Region 10 is using the highest value for either of the possible 5-month drill seasons at the appropriate monitoring sites.

For the 24-hour PM_{2.5} standard, Region 10 calculated the 98th percentiles for each available 5-month drill season and averaged those values over the available drill seasons at each monitoring site. See Memorandum from Tyler Fox, OAQPS, re: “Model Clearinghouse Review of Modeling Procedures for Demonstrating Compliance with PM_{2.5} NAAQS,” dated February 26, 2010. For the annual PM_{2.5} standard, Region 10 calculated the annual average for each calendar year of data available for the four PM_{2.5} monitoring sites and averaged them over available years.

Note that the Wainwright Permanent and Point Lay PM_{2.5} sites were potentially impacted by wildfires on six days during the 2010 drilling season. Region 10 has not excluded any of those potentially impacted days from the determination of PM_{2.5} background values and has included them in the 98th percentile calculations, although it is possible they could be excluded from consideration with appropriate documentation. Excluding these wildfire days from consideration would result in a background concentration of only 5 $\mu\text{g}/\text{m}^3$.

For the 1-hour SO₂ standard, Region 10 selected the highest 1-hour value from any available 5-month drilling season (USEPA. 2010d and USEPA. 2010e). Region 10 has not calculated a single 1-hour NO₂ background value for the modeling of maximum offshore impacts. This is because, consistent with EPA guidance for modeling conducted in connection with the 1-hour NO₂ standard, Shell has used paired modeled and monitored concentrations based on hour-of-day in its modeling analysis for the 1-hour NO₂ NAAQS (USEPA. 2011a.)

E. Modeling Results

E.1 New 1-Hour NAAQS for NO₂

On January 22, 2010, EPA announced a new 1-hour NO₂ NAAQS standard that is attained when the 3-year average of the 98th- percentile of the annual distribution of daily maximum 1-hour concentrations does not exceed 100 ppb (188 µg/m³) at each monitor within an area. The final rule was published on February 9, 2010 (75 FR 6474-6537) and the standard became effective on April 12, 2010. Two memorandums were issued providing guidance for modeling NO₂ impacts in accordance with the PSD permits requirements to demonstrate compliance with the new 1-hour NO₂ standard (USEPA. 2010c and USEPA. 2011).

With the form of the new standard being probabilistic, a much stricter averaging period, and the more complex analysis procedures associated with the form of the new standard, EPA issued this additional guidance to clarify the applicability of current guidance in 40 CFR Part 51, Appendix W with respect to procedures for demonstrating compliance with the new 1-hour NO₂ NAAQS.. In the case of the Discoverer permits, Shell is proposing to use the AERMOD dispersion model (09292) using an AERMET-by-pass approach for the meteorological data and Plume Volume Molar Ratio Method (PVMRM) (Hanrahan 1999), which is considered a Tier 3 application under Section 5.2.4 of Appendix W. This PVMRM method is considered a non-regulatory-default option within AERMOD and requires approval by the Regional Office on a case-by-case basis, pursuant to Sections 3.1.2.c, 3.2.2.a, and A.1.a(2) of Appendix W. The AERMET-by-pass approach, in this case AERMOD-COARE, also requires Regional Office approval. OAQPS approved the use of AERMOD-COARE on May 6, 2011(USEPA. 2011b). Region 10 gave Shell conditional approval to use AERMOD-COARE in its air quality analysis for the 2011 Revised Draft Permits on May 8, 2011 (USEPA Region 10. 2011a) pursuant to 3.2.2.a of Appendix W. Note that the use of AERMOD-COARE and PVMRM will also be subject to public notice and comment with the 2011 Revised Draft Permits and Region 10 will be requesting public comments on the models, their inputs, and all applicable associated documents that will be included in the public record. Regional office review and approval of PVMRM and the underlying key modeling inputs for PVMRM are discussed below.

The NO_x emissions created during combustion are partly nitric oxide (NO) and partly NO₂. After the combustion gas exits the stack, additional NO₂ can be created due to atmospheric reactions. The modeling of ambient NO₂ concentrations therefore requires ambient data or assumptions regarding the atmospheric conversion of NO to NO₂. Section 5.2.4 of the Appendix describes several approaches that may be considered in modeling annual average NO₂ impacts. These approaches are also generally applicable in modeling 1-hour NO₂ impacts (USEPA. 2010c).

As discussed above, Shell used the PVMRM to estimate their 1-hour and annual average NO₂ impacts. PVMRM assumes NO will convert to NO₂ in the presence of O₃, based on the following basic chemical mechanism, known as titration:



PVMRM also assumes that the NO₂ already present in the exhaust plume remains as NO₂ in the atmosphere. A user of this technique must therefore know or assume the amount of NO₂ present in the exhaust gas (NO₂/NO_x in-stack ratios), and the amount of O₃ present in the atmosphere.

In the case of the Discoverer when operating in the Beaufort Sea, Shell used the maximum ozone concentrations from either the Barrow or Prudhoe Bay A Pad ozone monitors. Region 10 reviewed both of these datasets and found they were representative of likely ozone levels in the Beaufort Sea. Using the maximum of the two sites allows for missing hours at either site, and results in the use of a higher hourly ozone reading, which will lead to increased conversion of NO to NO₂; thus, using the higher ozone reading is most conservative. In general the ozone readings at both sites were similar, varying only a few ppb on an hourly basis. Hourly readings at Barrow were slightly higher on average than those at A Pad. For the Chukchi Sea, Shell used the Wainwright ozone dataset, filling missing hours with Barrow monitoring data when there were missing hours at the Wainwright site. The Wainwright site averages slightly lower ozone readings than the Barrow site but should be more representative of the Chukchi Sea due to its closer proximity to the lease blocks.

For NO₂/NO_x in-stack ratios, Shell conducted specific stack testing on equipment being used on the Discoverer and the Associated Fleet. In all, Shell provided 90 stack tests of equipment being used in the project at different loads and control scenarios. One of the issues identified during the Region 10 review was varying NO₂/NO_x in-stack ratios at different loads and for different control equipment. Because of the ranges of NO₂ ratios, Shell chose to use generic ratios for the equipment based on the type of controls on the equipment. In order to ensure the use of generic ratios were protective of the NAAQS, Region 10 requested and Shell provided several AERMOD runs with varying ratios based on actual testing of the permitted equipment. Shell submitted additional modeling runs with alternative in-stack ratios on April 29, 2011 (Shell Offshore Inc., 2011d.) Region 10 also performed independent modeling of these ratios to ensure 1-hour NO₂ NAAQS were being protected should the ratios vary. It was determined that the ratios do make a difference in the modeled concentrations, but in all cases reviewed, the NAAQS were protected.

As described above, for the background NO₂ values, Shell used the Badami monitoring data for the Beaufort Sea, and Wainwright data for the Chukchi Sea. Shell initially used hour-by-hour pairing of modeled concentrations with background NO₂ data. Region 10 determined hour-by-hour pairing of monitored data may not to be representative of the entire modeling domain or of background sources. Thus, Region 10 requested that Shell use a diurnal profile of monitoring data for the drilling season based on the 98th percentile values by hour-of-day, to be combined with modeled concentrations by hour-of-day. Shell's April 29, 2011 Submittal included the pairing of modeling results with the 98th percentile diurnal profiles by hour-of-day based on the monitoring data in both the Beaufort and Chukchi Seas. This difference in pairing methodology did change overall cumulative modeled concentrations but in all cases the 1-hour NO₂ NAAQS are protected.

Results of the modeling indicate the maximum 98th percentile total impacts (including background values) of 81.6 µg/m³ in the Beaufort Sea and 174.0 µg/m³ in the Chukchi Sea³. These 98th percentile impacts at the location of maximum impact are below the NAAQS and, given the conservative modeling approach, demonstrate compliance with the NAAQS will be met. The large differences in modeling concentrations between the two seas are due to varying meteorological conditions.. Note that the maximum modeled

³ Note that these maximums are derived from several modeling scenarios that Region 10 requested Shell perform based on varying in-stack NO₂/NO_x ratios. Values are taken from Shell's May 19th 2011 submittal (Shell Offshore Inc., 2011e)

impacts occur near the ambient air boundary, a typical finding for sources with short stacks and plumes subject to downwash. Modeled impacts generally decrease as the distance from this 500 meter ambient air boundary increases, and in general there is a rapid decrease in concentrations as the distance from the Discoverer increases in both locations.

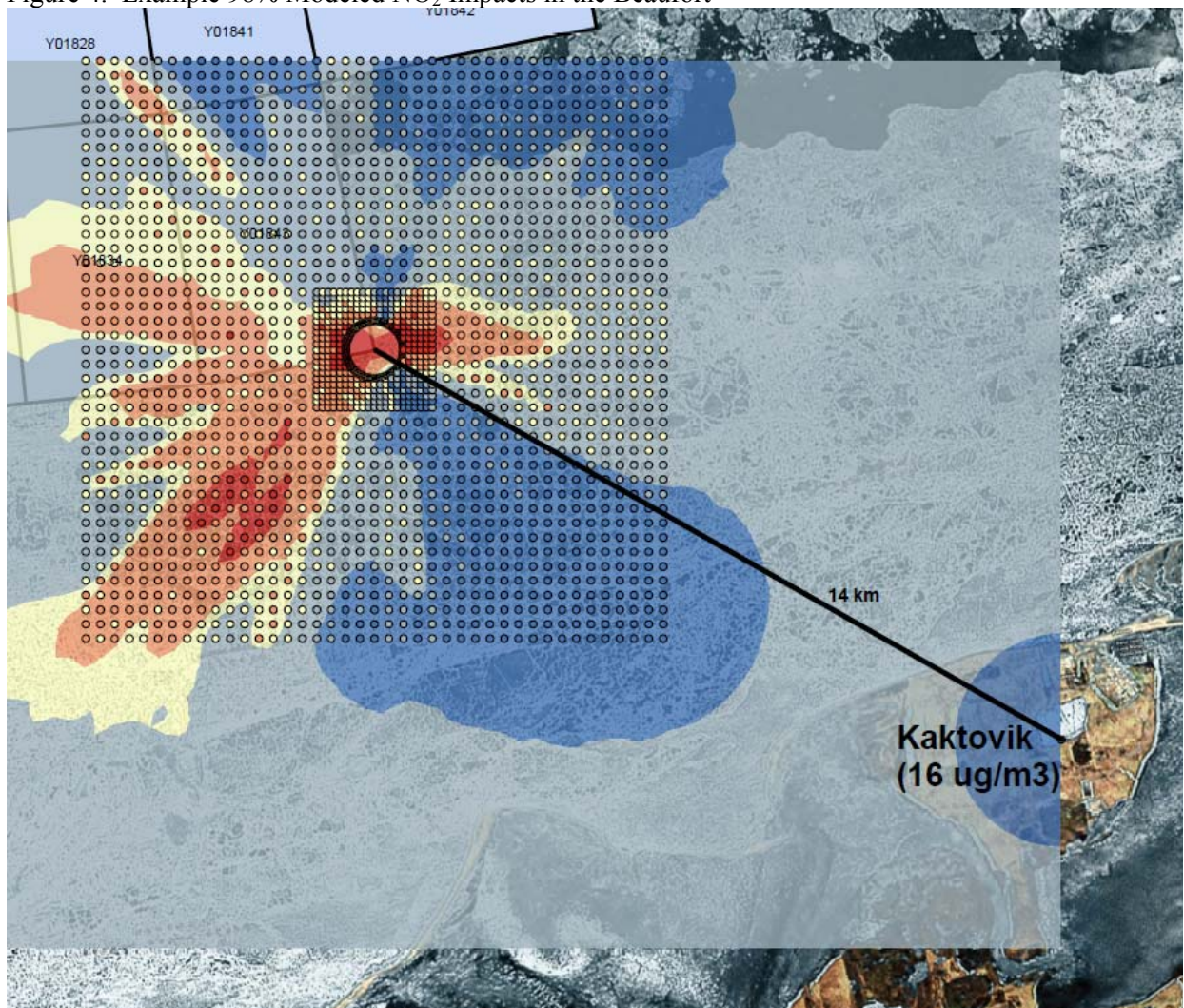
Modeled impacts at communities⁴ along the Beaufort Sea also indicate that emissions authorized under the 2011 Revised Draft Permit for the Beaufort Sea will be well below the 1-hour NO₂ NAAQS at all locations. At Kaktovik, the maximum modeled 98th percentile impact was 37.0 µg/m³, while the impact at Deadhorse and Nuiqsut was 98.9 µg/m³ (represented by 50 km impact in the direction of Deadhorse and Nuiqsut). It is important to note that these impacts include monitored background concentrations, which in both cases are a significant portion of the total impact.

Modeled impacts at communities along the Chukchi Sea also indicate emissions authorized under the 2011 Revised Draft Permits will be well below 1-hour NO₂ NAAQS at all locations. At Point Lay the maximum modeled 98th percentile impact was 52.8 µg/m³ while at Wainwright the maximum 98th percentile modeled impact was 42.9 µg/m³. Both of these estimated impacts are based on modeled concentrations at 50 km in the direction of the communities because AERMOD is used to predict impacts at distances of 50km or less. Actual impacts will be lower than those reported above as the communities are further away than 50km as additional dispersion will further lower concentrations. Again, these estimates include background concentrations which are a significant portion of the total impact.

Examples of modeled 98% NO₂ concentrations from drilling activities are shown in Figures 4 and 5 for the Beaufort and Chukchi Seas respectively. Both of these examples represent the 98% NO₂ impacts that occur in the 2nd 120 day modeled period (8/3-11/31) in each sea. As was stated above, the meteorological data has an impact on modeled concentrations between the two seas. In the Chukchi Sea the frequency of wind directions and dispersion conditions are such that the resulting concentrations are higher than in the Beaufort. Also note that in the case of the Chukchi, the higher impacts are seen occurring northwest of the proposed drilling activities which is away from North Slope communities of Point Lay and Wainwright. Figure 5 also illustrates the 50 km receptor placement in the direction of a community. The 50 km receptors are used to represent concentrations in the community as AERMOD is only recommended out to a distance of 50km.

⁴ Note that in the Statement of Basis for the 2010 Beaufort Permits, ambient impacts at Nuiqsut were evaluated. Because Nuiqsut is beyond 50km, where AERMOD is recommended, and Deadhorse is in the same general direction in relation to the lease blocks but closer than Nuiqsut, Region 10 has determined that impacts at Deadhorse are representative (same order of magnitude) of what they would be at Nuiqsut. Although a Nuiqsut receptor is not specifically included in the modeling, Region 10 has determined NAAQS at this location is also protected.

Figure 4. Example 98% Modeled NO₂ Impacts in the Beaufort⁵



⁵ Note the Shell only Kaktovik impact was 16 $\mu\text{g}/\text{m}^3$ as labeled in Figure 4. Total impact at Kaktovik is 26 $\mu\text{g}/\text{m}^3$ with background included.

Figure 5. Example 98% Modeled NO₂ Impacts in the Chukchi

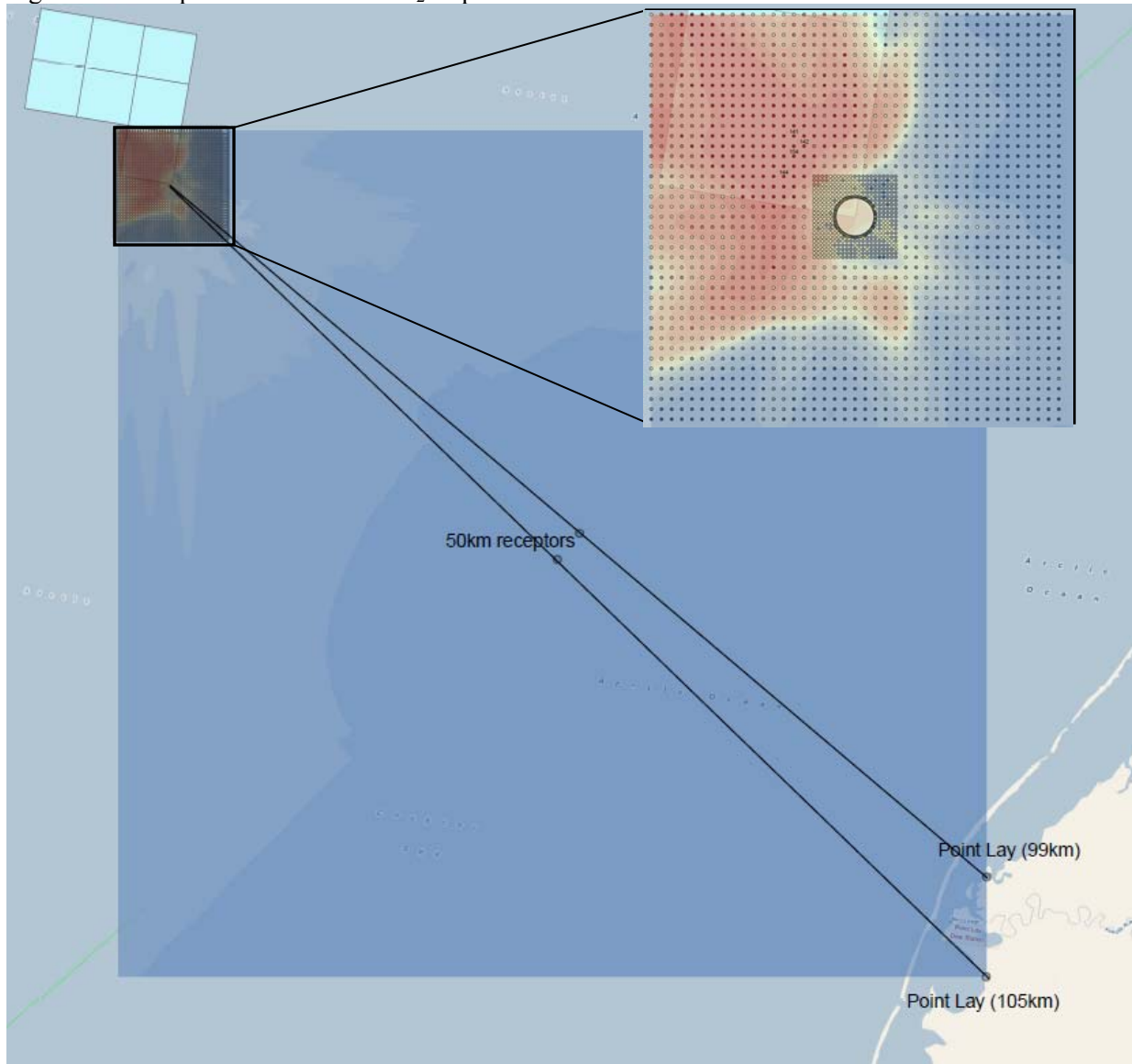


Table 10 provides the maximum modeled NO₂ impacts from Shell's Alternate Scenario's #1 and #2 which includes the tested in-stack NO₂/NO_x ratios and generic in-stack ratios.

Region 10 also performed several additional combinations of sensitivity runs using varying in-stack NO_x ratios for the drilling equipment. In all the cases Region 10 modeled, the NAAQS were protected at all locations accessible to the public. Region 10 believes the two modeling scenarios provided by Shell are representative of likely actual operating conditions while drilling. The scenarios are conservative as they assume a single drilling location for the entire drilling season. Results indicate compliance with the NAAQS with a significant factor of safety at all on-shore areas. Given the form of the 1-hour standard, which uses averages over three years, Region 10 concludes the actual 1-hour NO₂ impacts, if calculated by averaging over three years at different locations, would be even lower than has been modeled in this analysis. In summary, the modeled impacts demonstrate compliance with the 1-hour NO₂ NAAQS using conservative assumptions at all locations, including on-shore communities.

E.2 New 1-Hour NAAQS for SO₂

On June 2, 2010, EPA announced a new 1-hour SO₂ NAAQS which is attained when the 3 year average of the 99th-percentile of the annual distribution of daily maximum 1-hour concentration does not exceed 75 ppb (196 µg/m³). The final rule for the new 1-hour NAAQS was published in the Federal Register on June 22, 2010 (75 FR 35520-35603), and became effective on August 23, 2010. Two memorandums were issued providing guidance for modeling SO₂ impacts in accordance with the PSD permits requirements to demonstrate compliance with the new 1-hour SO₂ standard. These memorandums were issued concurrently on August 23, 2010 (USEPA 2010d and USEPA 2010e).

Because Shell is proposing to use ultra low sulfur diesel (ULSD), 1-hour SO₂ impacts are minimal when compared with the NAAQS. Shell used a very conservative approach to demonstrate compliance with the 1-hour SO₂ NAAQS. This conservative approach assumed a single wind direction for the entire drilling season, all equipment operating concurrently, plume heights and vertical dispersion coefficients for Associated Fleet sources were fixed to worst case predictions for the entire period, and the highest hourly SO₂ concentrations were used for background values. These are all very conservative assumptions.

Even with the conservative assumptions used, the modeled impacts were minimal. In the Beaufort Sea the worst case modeled SO₂ impact for the Discoverer was 35.0 µg/m³, while the impacts at Kaktovik were 12.9 µg/m³ and at Nuiqsut 15.4 µg/m³. For the Chukchi Sea, worst case modeled impacts were 40.3 µg/m³, while at Point Lay the impact was 16.2 µg/m³ and at Wainwright the impact was 14.2 µg/m³. Again, the modeled impacts include the worst case monitored background concentration for the areas. In both the Beaufort and Chukchi Seas the background value is a significant portion of the modeled concentrations for all areas. Table 11 provides the breakdown of the impacts at each of the locations.

In summary, for the 1-hour SO₂ NAAQS, Shell used a very conservative approach to model the impacts of drilling operations. The conservative analysis indicates the SO₂ NAAQS is protected in both the Beaufort and Chukchi Seas at all locations that represent ambient air, and at all locations on shore.

Table 10. 1-Hour NO₂ Modeled Impacts at Various Locations

Location	Distance from Drilling Location (km)	Shell Only Impact ² (µg/m ³)	Background Concentration ³ (µg/m ³)	Total Impacts (including background) (µg/m ³)	NAAQS (µg/m ³)	% of NAAQS
<i>Beaufort Sea</i>						
Maximum Modeled Impact	0.5	72.3	9.3	81.6	188	43%
Kaktovik	14	16	21.0	37.0	188	20%
Deadhorse (84 km from nearest lease block) ¹	50	4.9	94.0	98.9	188	53%
Nuiqsut (182 km from nearest lease block) ¹	50	4.9	94.0	98.9	188	53%
<i>Chukchi Sea</i>						
Maximum Modeled Impact	2	160.8	13.2	174.0	188	93%
Point Lay (99 km from nearest lease block) ¹	50	11.8	41.0	52.8	188	28%
Wainwright (105 km from nearest lease block) ¹	50	4.9	38.0	42.9	188	23%

¹ Modeling concentrations 50 km away in the direction of village (50 km recommended AERMOD distance limit)

² NO₂ concentrations are highest impact from Table 5 or Table 6 in ALTERNATE APPROACHES TO EVALUATING 1-HOUR NO₂ IMPACTS FOR THE SHELL DISCOVERER DRILLSHIP – NO₂ PAIRING AND NO₂/NOX RATIOS

³ Background Concentrations at villages from June 23 memo from Chris Hall titled "EPA's Determination of Appropriate Background Values for the Chukchi Sea and Beaufort Sea OCS Permits"

Table 11. 1-Hour SO₂ Modeled Impacts at Various Locations

Location	Distance from Drilling Location (km)	Shell Only Impact ² (µg/m ³)	Background Concentration ³ (µg/m ³)	Total Impacts (including background) (µg/m ³)	NAAQS (µg/m ³)	% of NAAQS
<i>Beaufort Sea</i>						
Maximum Modeled Impact	0.5	22	13.0	35.0	196	18%
Kaktovik	14	2.9	10.0	12.9	196	7%
Deadhorse (84 km from nearest lease block) ¹	50	1.4	14.0	15.4	196	8%
Nuiqsut (182 km from nearest lease block) ¹	50	1.4	14.0	15.4	196	8%
<i>Chukchi Sea</i>						
Maximum Modeled Impact	2	17.3	23.0	40.3	196	21%
Point Lay (99 km from nearest lease block) ¹	50	2.2	14.0	16.2	196	8%
Wainwright (105 km from nearest lease block) ¹	50	2.2	12.0	14.2	196	7%

¹ Modeling concentrations 50 km away in the direction of village (50 km recommended AERMOD distance limit)

² SO₂ concentrations are from Tables 3-9 and 3-10 in Discoverer Drillsip Impact Evaluation for SO₂ and NO₂ Using AERMOD Chukchi and Beaufort Seas, Shell Alaska Exploratory Drilling Program

³ Background Concentrations at villages from June 23 memo from Chris Hall titled "EPA's Determination of Appropriate Background Values for the Chukchi Sea and Beaufort Sea OCS Permits"

E.3 Secondary PM_{2.5} for the Discoverer

PM_{2.5} is either directly emitted from a source (primary emissions) or through chemical reactions with pollutants already in the atmosphere (secondary formation). EPA promulgated AERMOD as an acceptable model for performing near-field analyses of primary pollutants (Appendix A to Appendix W of 40 CFR 51—Summaries of Preferred Air Quality Models, Part A-1). EPA has not developed and recommended, however, a near-field model that includes the necessary chemistry algorithms to estimate secondary impacts in an ambient air analysis.

To address this issue, EPA issued modeling guidance in 2010 to give further direction on how to conduct an ambient impact analyses for PM_{2.5} (USEPA 2010a and USEPA 2010b.) This guidance provides that, with appropriate selection of representative background monitoring data, much of the PM_{2.5} secondary formation from background sources should be adequately accounted for in most cases, but that in the case of a source that emits significant quantities of PM_{2.5} precursor emissions, some assessment of their potential contribution to cumulative impacts as secondary PM_{2.5} may be necessary. This assessment could include using other models for the secondary component, such as a photochemical model.

Shell used PM_{2.5} ambient monitoring data from onshore locations (Badami and Wainwright, the closest monitoring locations to the permitted lease blocks in the two seas) that include the impacts of secondary PM_{2.5} from existing onshore sources. These onshore monitors are expected to have accounted for much of the secondary formation that will occur in the two regions (i.e. the monitors are exposed to secondary formation from existing regional emissions sources). Shell took the resulting 24-hour monitored background values and added the two-year average of the maximum 24-hour modeled concentration (unpaired in time) to determine the total 24-hour PM_{2.5} impact. This approach is consistent with the “First Tier” approach described in the March 23, 2010 PM_{2.5} Guidance Memo and is considered conservative.

Results of this approach indicate a maximum PM_{2.5} concentration in the Beaufort of 18.2 µg/m³ and 23.4 µg/m³ in the Chukchi at the ambient air boundary (500 meters from the Discoverer) and lower levels as the distance from the Discoverer increases. In other words, the modeling indicates that primary PM_{2.5} impacts at the expected locations of maximum impact, including background (which is expected to include secondary PM_{2.5} impacts from existing sources), are less than 67% of the PM_{2.5} NAAQS of 35 µg/m³. Based on these results, the contribution from secondary PM_{2.5} emissions from the Discoverer and Associated Fleet could be as high as 11.6 µg/m³ at the locations of maximum impact before the NAAQS would be threatened.

It is important to note that secondary formation of PM_{2.5} will generally be low near the emission release point (here, the Discoverer), where modeled concentrations are highest, because there has not been enough time for the secondary chemical reactions to occur. Instead, secondary PM_{2.5} impacts will generally occur farther from the emission source. It is therefore unlikely that maximum primary PM_{2.5} impacts and maximum secondary PM_{2.5} impacts from the Discoverer and the Associated Fleet will occur at the same time (paired in time) or location (paired in space), providing further assurance that emissions from secondary formation of PM_{2.5} will not threaten compliance with the NAAQS. The fact that the PM_{2.5} modeling assumed that the Discoverer would be operating in a single drilling location for 3 years, when that scenario is unlikely to occur, further mitigate against the possibility that emissions to be authorized under the permits would cause or contribute to a violation of the NAAQS based on the contribution of PM_{2.5} precursor emissions.

Moreover, secondary PM_{2.5} formation is a complex photochemical reaction that requires a mix of precursor atmospheric pollutants in sufficient quantities for significant secondary formation to occur. Available PM_{2.5} monitoring data from the onshore communities along the Beaufort and Chukchi Seas, and

in potential transport areas where monitoring is performed, show low levels of PM_{2.5}, generally in the range of 2 µg/m³. The higher PM_{2.5} values recorded on monitors in the North Slope generally occur on days where windblown dust or fires are believed to be contributing factors. Thus, there is no indication that secondary formation of PM_{2.5} from existing sources in the North Slope is currently causing or contributing to a violation of the PM_{2.5} NAAQS in the onshore communities.

Emissions of the PM_{2.5} precursor SO₂ from the Discoverer and the Associated Fleet are less than 2 tons per year, less than the PM_{2.5} Significant Emission Rate (SER) for that precursor. See 40 CFR §§ 52.21(b)(23)(i). Emissions of the PM_{2.5} precursor NO_x from the Discoverer and the Associated Fleet are considerably higher, at 336 tons per year.⁶ As a point of comparison, however, actual emissions of NO_x from point sources in the North Slope oil and gas fields near Deadhorse are approximately 65,000, yet the total (not just the secondary) PM_{2.5} concentrations in Deadhorse are quite low. Given the amount of NO_x emissions to be authorized under these permits in comparison to NO_x emissions in the North Slope area in general, it is unlikely that NO_x emissions from the Discoverer and the Associated Fleet would be expected to cause or contribute to a violation of the PM_{2.5} NAAQS given the generally low levels of PM_{2.5} NAAQS recorded at monitoring stations in the area.

In summary, the updated modeling uses background PM_{2.5} monitoring results that are expected to include secondary PM_{2.5} formed from other existing sources, and PM_{2.5} monitoring data throughout the North Slope is generally low except on days where windblown dust or fires are a contributing factor. The refined PM_{2.5} modeling submitted by Shell indicates that a significant margin of safety exists before the PM_{2.5} NAAQS would be threatened and there is conservatism built into the current modeling assumptions due to the fact that maximum primary and secondary PM_{2.5} emissions are unlikely to occur at the same location or at the same time and the fact that the Discoverer is unlikely to remain at the same location for 3 years. Region 10 believes that the PM_{2.5} NAAQS will be protected at all locations when accounting for secondary precursors from the Discoverer and the Associated Fleet and that it is not appropriate or necessary to use a photochemical model to further evaluate secondary PM_{2.5} formation in this permitting action.

Additionally, the 2011 Revised Draft Permits continue to include a post-construction requirement to install and operate a Federal Reference Method (FRM) sampler in addition to a Federal Equivalent Method (FEM) continuous sampler. An FRM is a manual sampler that pulls air through a filter for 24 hours (midnight to midnight). The filter is then weighed in a lab and a PM_{2.5} concentration is calculated based on the mass increase of the filter and the volume of air drawn through it. Use of a manual sampler will allow the filter to be analyzed for the chemical speciation of PM_{2.5} constituents such as sulfates, nitrates, organics, sea salt and metals. With this data, Region 10, Shell and the public will be better able to evaluate the significance of secondary formation of PM_{2.5} in the North Slope region.

E.4 Other pollutants and averaging periods

Because Shell modified certain operations from the prior 2010 Permits to address the 1-hour NO₂ NAAQS and requested to make other operational changes, an additional analysis of other averaging periods was warranted. As discussed above, many of the additional operational limits and restrictions have lowered emissions from the 2010 Permits, especially on an annual basis. The one large difference

⁶ Region 10 has not made a determination of whether PM_{2.5} precursor emissions from the project are significant, but has instead accounted for the possibility of the formation of secondary PM_{2.5} through this non-modeling assessment as provided in the March 23, 2010 PM_{2.5} Guidance Memo. Note that EPA's final regulations for the "Implementation of the New Source Review (NSR) Program for Particulate Matter Less than 2.5 Micrometers (PM_{2.5})" (73 FR 28321, May 16, 2008), indicate that VOC and NH₃ emissions are presumed not to contribute to secondary formation of PM_{2.5}.

(increase in emissions) from the 2010 Permits is Shell's request to have the option of using dynamic positioning for the Supply Ship, where motive power is required to keep the Supply Ship in position next to the Discoverer, in addition to the previously permitted option of attaching the Supply Ship to the Discoverer during resupply activities.

To address the Supply Ship emissions, Region 10 requested that Shell provide an additional demonstration that these new Supply Ship emissions in the DP mode, in conjunction with the existing emissions sources, would not violate any NAAQS standard. On May 19, 2011, Shell submitted an AERMOD analysis that included the remaining pollutants and averaging periods. The analysis followed similar procedures for source characterizations, ambient air boundary, etc. as was applied in the 1-hour analysis for NO₂ and SO₂ as described above.

Region 10 has reviewed this additional analysis and finds that it satisfies the modeling requirements of Appendix W and the demonstration shows no NAAQS will be violated with the additional operational scenario. Region 10 believes this analysis is much more representative of potential impacts from Shell's operations than the prior screening analysis using SCREEN3 that was relied on in the 2010 Permits, because representative meteorological data and realistic emissions scenarios are now being used. Tables 12 and 13 provide a summary of the modeled impacts for all the various pollutants and averaging times in the Beaufort and Chukchi Seas, respectively. In addition to the modeled NAAQS impacts from AERMOD, Region 10 reviewed the emissions and background monitoring data for ozone (note ozone was needed for NO₂ with PVMRM) and believes no further evaluation is needed for the ozone standard as the background ozone reading in both the Beaufort and Chukchi are low and precursor emissions (NO_x and VOC) have decreased from the prior permit limits.

Table 12. Modeled impacts in the Beaufort Sea at the Location of Maximum Impact

Air Pollutant	Averaging Period	Shell Only Impacts ¹ (without background) (µg/m ³)	Background Concentration ² (µg/m ³)	Total Impact Including Background (µg/m ³)	NAAQS (µg/m ³)	Total impact as a % of NAAQS
NO ₂	1-hour	72.3	9.3	81.6	188	43%
	Annual	2.9	1.0	3.9	100	4%
PM _{2.5}	24-hour	12.2	6.0	18.2	35	52%
	Annual	0.5	3.0	3.5	15	23%
PM ₁₀	24-hour	10.7	53.0	63.7	150	42%
SO ₂	1-hour	22	13.0	35.0	196	18%
	3-hour	13.4	11.0	24.4	1300	2%
	24-hour	5.9	4.0	9.9	365	3%
	Annual	1.2	2.0	3.2	80	4%
CO	1-hour	493.9	1742.0	2235.9	40000	6%
	8-hour	352.8	1094.0	1446.8	10000	14%

¹ Modeled Impacts from Tables 3 and 4 in Shell Technical Memorandum "AERMOD AIR QUALITY IMPACT ANALYSIS OF NO₂, SO₂, PM_{2.5}, PM₁₀, CO, AND NH₃ – DISCOVERER DRILLSHIP." May 19,2011

² Background concentrations from June 17 memo from Chris Hall titled "EPA's Determination of Appropriate Background Values for the Chukchi Sea and Beaufort Sea OCS Permits"

Table 13. Modeled impacts in the Chukchi Sea at the Location of Maximum Impact

Air Pollutant	Averaging Period	Shell Only Impacts ¹ (without background) (µg/m ³)	Background Concentration ² (µg/m ³)	Total Impact Including Background (µg/m ³)	NAAQS (µg/m ³)	Total impact as a % of NAAQS
NO ₂	1-hour	160.8	13.2	174.0	188	93%
	Annual	3.3	2.0	5.3	100	5%
PM _{2.5}	24-hour	12.4	11.0	23.4	35	67%
	Annual	0.4	2.0	2.4	15	16%
PM ₁₀	24-hour	11.5	79.0	90.5	150	60%
SO ₂	1-hour	17.3	23.0	40.3	196	21%
	3-hour	13.6	14.0	27.6	1300	2%
	24-hour	8.1	5.0	13.1	365	4%
	Annual	1.4	0.4	1.8	80	2%
CO	1-hour	561.9	959.0	1520.9	40000	4%
	8-hour	328.7	945.0	1273.7	10000	13%

¹ Modeled Impacts from Tables 3 and 4 in Shell Technical Memorandum "AERMOD AIR QUALITY IMPACT ANALYSIS OF NO₂, SO₂, PM_{2.5}, PM₁₀, CO, AND NH₃ – DISCOVERER DRILLSHIP." May 19,2011

² Background concentrations from June 17 memo from Chris Hall titled "EPA's Determination of Appropriate Background Values for the Chukchi Sea and Beaufort Sea OCS Permits"

E.5 Offsite Impacts

The impact from neighboring (off-site) sources must be accounted for in a cumulative impact assessment. Per Section 8.2.3 of Appendix W, “all sources expected to cause a significant concentration gradient in the vicinity of the [applicant’s source] should be explicitly modeled.” The impact from other sources can be accounted for through ambient monitoring data.

A common long-term practice for selecting the “nearby” sources for explicit modeling was to follow a very prescriptive procedure in EPA’s draft New Source Review Workshop Manual (Manual) (USEPA 1990). Under this approach, an off-site source located within the applicant’s “significant impact area” (SIA) would need to be explicitly modeled. Sources located beyond the applicant’s SIA, but with impacts inside of the SIA, would also be candidates for modeling.

EPA recently clarified that “following such procedures in a literal and uncritical manner may in many cases result in cumulative impact assessments that are overly conservative” (USEPA 2011a). Appendix W instead is consistent with this approach, stating that professional judgment is required for ascertaining which sources should be explicitly modeled and which sources can be represented through ambient monitoring data.

The BP Badami facility is the only regional source located within 50 kilometers of the remote Shell permitted lease blocks in either the Beaufort or Chukchi Seas. The BP Badami facility is located 37 km from the nearest permitted OCS lease blocks in the Beaufort. The NO₂ and PM₁₀ standards were the only pollutant where the SIA extended to this distance. Because the distance to the BP source is so far, it is not expected that the BP Badami source would cause a significant concentration gradient in the vicinity of Shell’s lease blocks. In addition, for NO₂, Badami monitoring data is being used as background monitoring data in the modeling analysis and should reflect the impacts of this source. For PM₁₀, the Prudhoe Bay area monitoring data was used. Prudhoe Bay has significantly more PM₁₀ sources than any other area within 50km of the permitted lease blocks so this monitor should represent a background value higher than any current neighboring source would cause. Based on this analysis Region 10 has determined the one distant BP source is represented in the ambient monitoring data for NO₂ and PM₁₀, would not cause a significant concentration gradient, and does not need to be explicitly included in the modeling runs.

Although there are currently no other permitted exploratory drilling operations in the OCS north of Alaska, Region 10 is aware of additional permit applications for operations that could potentially be in the Beaufort or Chukchi Seas. Region 10 intends to require all permitted operations to notify region 10 regarding their anticipated drilling locations far in advance of each drilling season (6 months) so that Region 10 can evaluate whether there is a need for additional ambient analyses.

F. Conclusion

Region 10 has reviewed and determined that the materials, air quality data, meteorological measurements, and model input and output files submitted by Shell satisfy the requirements in Appendix W to make an adequate demonstration of compliance with the NAAQS. The AERMOD and AERMOD-COARE modeling predicted concentrations with representative background concentrations do not show a violation of any NAAQS. The revised analysis also demonstrates that the proposed Discoverer drilling program complies with the Alaska Ambient Air Quality Standards (AAAQS) and Prevention of Significant Deterioration (PSD) increments as was demonstrated in issuance of the 2010 Permits. This analysis is

applicable to both Beaufort and Chukchi Seas as Shell has used the worst case emissions in both Seas and has used worst case vessel emissions when more than one candidate vessel is available.

In the Chukchi, modeled NO₂ impacts at the location of maximum expected impact are very close to the applicable NAAQS. These impacts are partially due to the conservative nature used by Shell in their modeling analysis. For example, in reality, the 1-hour NO₂ standards are evaluated using three years of ambient monitoring data, which would include three years of varying meteorological data. In Shell's case, Shell estimated their NO₂ impacts using only on one year of meteorological data. This approach likely provides a more conservative estimate than if the impacts could be averaged over additional year(s) with additional varying meteorological data.

In addition, movement of the drilling ship will decrease short-term impacts of all pollutants, especially in the near field where high modeled concentrations occur, if averaging were performed over multiple years. The combination of only one year (two years for PM_{2.5}) of meteorological data and the assumption of a fixed drilling location for the entire 120 day OCS period produces a conservative analysis (i.e., the predicted modeled impacts are larger than what would likely be realized with a moving ship with averaging over a longer period of time).

Finally, modeled impacts generally decrease as the distance from the 500 meter ambient air boundary increases, and on average there is a rapid decrease in concentrations as the distance from the Discoverer increases. Modeled impacts at all on-shore locations in both seas are well below the NAAQS.

G. References

Fairall, C.W. and E.F. Bradley. 2003. The TOGA-COARE Bulk Air-Sea Flux Algorithm. NOAA/ERL/ETL, 325 Broadway, Boulder, CO. September 2.

Hanrahan 1999. The Plume Volume Molar Ratio Method for Determining NO₂/NO_x Ratios in Modeling – Part I: Methodology. J. Air & Waste Manage. Assoc., 49, 1324-1331.

Shell Offshore Inc. 2011a, Updated Baseline PM_{2.5} and PM₁₀ Data Collected at Wainwright and Badami – Shell Discoverer Air Permits. Prepared by Air Sciences Inc. March 8, 2011.

Shell Offshore Inc., 2011b, Letter regarding Shell Chukchi Sea and Beaufort Sea PSD Permits Remand Shell Gulf of Mexico Inc. Permit R10OCS/PSD-AK-09-01 Shell Offshore, Inc. Permit R10OXCS/PSD-AK-2010-01. March 9, 2011.

Shell Offshore Inc., 2011c, Discoverer Drillship Impact Evaluation for SO₂ and NO₂ Using AERMOD Chukchi and Beaufort Seas, Shell Alaska Exploratory Drilling Program. March 18, 2011.

Shell Offshore Inc., 2011d, ALTERNATE APPROACHES TO EVALUATING 1-HOUR NO₂ IMPACTS FOR THE SHELL DISCOVERER DRILLSHIP – NO₂ PAIRING AND NO₂/NO_x RATIOS. April 29, 2011.

Shell Offshore Inc., 2011e, AERMOD AIR QUALITY IMPACT ANALYSIS OF NO₂, SO₂, PM_{2.5}, PM₁₀, CO, AND NH₃ – DISCOVERER DRILLSHIP; SUPPLEMENT TO MARCH 18 AND APRIL 29, 2011, AERMOD IMPACT REPORTS, May 19, 2011.

Shell Offshore Inc., 2011f, Email from Pauline Ruddy, Shell, to Doug Hardesty titled “BACT and modeling questions. June 10, 2011.

USEPA 1990 Draft NSR Manual. Draft New Source Review Workshop Manual, Prevention of Significant Deterioration and Nonattainment Area Permitting. October 1990.

USEPA. 2005. Appendix W of 40 CFR 51 Federal Register / Vol. 70, No. 216 / Wednesday, November 9, 2005.

USEPA 2010a. Memorandum, from Tyler Fox titled, “Model Clearinghouse Review of Modeling Procedures for Demonstrating Compliance with PM_{2.5} NAAQS”, Office of Air Quality Planning and Standards, February 26, 2010.

USEPA. 2010b. Memorandum from Steve D. Page titled “Additional Procedures for Demonstrating Compliance with PM_{2.5} NAAQS. Office of Air Quality Planning and Standards, Research Triangle Park, NC.” March 23, 2010.

USEPA. 2010c Memorandum from Stephen Page titled “Guidance Concerning the Implementation of the 1-hour NO₂ NAAQS for the Prevention of Significant Deterioration Program.” June 29, 2010.

USEPA. 2010d Memorandum from Stephen Page titled “Guidance Concerning the Implementation of the 1-hour SO₂ NAAQS for the Prevention of Significant Deterioration Program.” August 23, 2010.

USEPA. 2010e Memorandum from Tyler Fox titled “Applicability of Appendix W Modeling Guidance for the 1-hour SO₂ National Ambient Air Quality Standard.” August 23, 2010.

USEPA. 2011a. Memorandum from Tyler Fox titled “Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO₂ National Ambient Air Quality Standard.” Office of Air Quality Planning and Standards March 01, 2011.

USEPA. 2011b. Memorandum from George Bridgers titled “Model Clearinghouse Review of AERMOD-COARE as an Alternative Model Application in an Arctic Marine Ice Free Environment.” Office of Air Quality Planning and Standards, Research Triangle Park, NC. March 01, 2011.

USEPA Region 10. 2010a. OUTER CONTINENTAL SHELF PREVENTION OF SIGNIFICANT DETERIORATION PERMIT TO CONSTRUCT Permit Number: R10OCS/PSD-AK-2010-01. April 9

USEPA Region 10. 2010b. RESPONSE TO COMMENTS FOR OUTER CONTINENTAL SHELF PREVENTION OF SIGNIFICANT DETERIORATION PERMIT NO. R10OCS/PSD-AK-2010-01

USEPA Region 10. 2010c. Memorandum from Christopher Hall on Badami Air Monitoring Data Review – August 15 through December 15, 2009. April 7, 2010.

USEPA Region 10. 2010d. STATEMENT OF BASIS FOR PROPOSED OUTER CONTINENTAL SHELF PREVENTION OF SIGNIFICANT DETERIORATION PERMIT NO. R10OCS/PSD-AK-2010-01. February 17, 2010.

USEPA Region 10. 2010e. STATEMENT OF BASIS FOR PROPOSED OUTER CONTINENTAL SHELF PREVENTION OF SIGNIFICANT DETERIORATION PERMIT NO. R10OCS/PSD-AK-09-01. January 6, 2010.

USEPA Region 10. 2011a. E-mail from Herman Wong, Region 10 Modeling Contact to Andy Hawkins dated May 8, 2011 titled, "Re: Approval request for non-guideline modeling – Shell Disco and Kulluk dispersion modeling." May 8

USEPA Region 10. 2011b. Memorandum from Christopher Hall titled "EPA's Determination of Appropriate Background Values for the Chukchi Sea and Beaufort Sea OCS Permits." June 23.