Kitty Hawk Wind

AVANGRID

Construction and Operations Plan

Chapter 4 - Physical Resources

September 30, 2022

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COP – Chapter 4: Physical Resources

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Table of Contents

Table of Contents		**1**
Table of Figures		**2**
Table of Tables		**2**
Abbreviations & Definitions		**3**
4	**PHYSICAL RESOURCES**	**6**
4.1	Physical and Oceanographic Conditions	6
4.1.1	Affected Environment	7
4.1.2	Impacts Analysis for Construction, Operations, and Decommissioning	16
4.2	Water Quality	20
4.2.1	Affected Environment	20
4.2.2	Impacts Analysis for Construction, Operations, and Decommissioning	26
4.3	Air Quality	32
4.3.1	Affected Environment	32
4.3.2	Impacts Analysis for Construction, Operations, and Decommissioning	35
4.4	In-Air Acoustic Environment	41
4.4.1	Affected Environment	42
4.4.2	Impacts Analysis for Construction, Operations, and Decommissioning	43
4.5	Underwater Acoustic Environment	52
4.5.1	Regulatory Context	52
4.5.2	Affected Environment	55
4.5.3	Impacts Analysis for Construction, Operations, and Decommissioning	57
4.6	References	60
4.6.1	Physical and Oceanographic Conditions	60
4.6.2	Water Quality	61
4.6.3	Air Quality	63
4.6.4	In-Air Acoustic Environment	64
4.6.5	Underwater Acoustic Environment	65

Table of Figures

Figure 4.1-1 NOAA National Buoy Data Center Stations 44006, 44014, and 44019 8
Figure 4.1-2 Monthly Wind Speeds 9
Figure 4.1-3 Monthly Significant Wave Height 9
Figure 4.1-4 Average Wave Direction within the Review Area 10
Figure 4.1-5 Model of Currents within the North Carolina and Atlantic East Coast Region 10
Figure 4.1-6 Monthly Mean Sea Water Temperature Profiles 12
Figure 4.2-1 Sediment Grab Sample Locations 23
Figure 4.2-2 Watershed Boundaries in Relation to Onshore Substation and Onshore Export Cables 25
Figure 4.4-1 NSA Locations Relative to the HDD Operations 46
Figure 4.5-1 Auditory Weighting Functions for Cetaceans (LF, MF, and HF Species) and Pinnipeds (PW Species) 54

Table of Tables

Table 4.1-1 Monthly Mean Water Temperatures at Sea Surface 11
Table 4.1-2 Monthly Mean Air Temperature at NOAA Data Buoy 44014 (°C) 13
Table 4.1-3 Mean Sea Levels Along the U.S. East Coast 14
Table 4.1-4 Delivery of Data to the Bureau of Ocean Energy Management (BOEM) for Completed 2020 Geophysical and Geotechnical Survey Campaigns 14
Table 4.3-1 National Ambient Air Quality Standards 33
Table 4.3-2 General Conformity Thresholds 34
Table 4.3-3 Construction Emissions for Calendar Year 2027 (tons) 37
Table 4.3-4 Construction Emissions for Calendar Year 2028 (tons) 37
Table 4.3-5 Construction Emissions for Calendar Year 2029 (tons) 37
Table 4.3-6 Operations and Maintenance Emissions for Calendar Year 2030 Onward (tons) 39
Table 4.3-7 PJM Marginal and System Average Emission Rates for 2019 40
Table 4.3-8 Potential Displaced Annual Emissions from Regional Fossil-Fueled Electric Generators 40
Table 4.4-1 HDD Equipment Sound Levels 44
Table 4.4-2 Sound Levels (dBA) during HDD Construction 44
Table 4.4-3 General Construction Noise Levels (dBA) 47
Table 4.4-4 Onshore Substation and Switching Station Predicted Nighttime Noise Levels at the Closest Noise Sensitive Areas 49
Table 4.5-1 Acoustic Threshold Levels for Marine Mammals 54
Table 4.5-2 Acoustic Threshold Levels for Fish and Sea Turtles, Injury and Behavior 55
Table 4.5-3 Acoustic Threshold Levels for Fish and Sea Turtles, Impulsive and Non-Impulsive 56
Table 4.5-4 Underwater Acoustic Modeling Scenarios 57
Table 4.6-1 Data Sources 60

Abbreviations & Definitions

Acronym	Definition
°C	degrees Celsius
AQCR	Air Quality Control Region
BOEM	Bureau of Ocean Energy Management
CFR	Code of Federal Regulations
cm	centimeter
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
COP	Construction and Operations Plan
dB	decibel
dB re 1 µPa	decibels referenced at one micropascal
dBA	A-weighted decibel
DIN	dissolved inorganic nitrogen
DIP	dissolved inorganic phosphorous
DNL	day-night average sound level
EPA	U.S. Environmental Protection Agency
ESP	electrical service platform
GHG	greenhouse gas
HAP	hazardous air pollutant
HDD	horizontal directional drilling
HF	high frequency
Hz	hertz
IMO	International Maritime Organization
kHz	kilohertz
km	kilometer
Lease Area	the designated Renewable Energy Lease Area OCS-A 0508
L_{eq}	energy-averaged sound level over a given measurement period
L_{dn}	ambient noise levels over a 24-hour period, including a 10 dB penalty during the nighttime period
LF	low frequency
L_{PK}	peak sound pressure level
m	meter

Acronym	Definition
m/s	meters per second
MF	mid-frequency
mg/L	milligram per liter
MLLW	Mean Lower Low Water
MMPA	Marine Mammal Protection Act
NAA	Nonattainment Area
NAAQS	National Ambient Air Quality Standards
NCDEQ	North Carolina Department of Environmental Quality
NDZ	No Discharge Zone
nm	nautical mile
NO	nitric oxide
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries	National Oceanic and Atmospheric Administration's National Marine Fisheries Service
NO_X	nitrogen oxides
NSA	Noise Sensitive Area
O&M	operations and maintenance
OCS	Outer Continental Shelf
PDE	Project Design Envelope
PJM	PJM Interconnection LLC
PM	particulate matter
PM_{10}	particulate matter less than 10 microns in diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
ppm	parts per million
Project	Kitty Hawk North Wind Project
PTS	permanent threshold shift
PW	Phocids underwater
SEL_{cum}	cumulative sound exposure level, expressed in dB re 1 μPa^2 s
SO_2	sulfur dioxide
SPL	sound pressure level
SPL RMS	root mean squared sound pressure level
SWPPP	Stormwater Pollution Prevention Plan
the Company	Kitty Hawk Wind, LLC

Acronym	Definition
TOC	total organic carbon
TTS	temporary threshold shift
U.S.	United States
USCG	United States Coast Guard
USGS	United States Geological Survey
VDEQ	Virginia Department of Environmental Quality
VOC	volatile organic compound
Wind Development Area	approximately 40 percent of the Lease Area in the northwest corner closest to shore (19,441 hectares)
WTG	wind turbine generator

4 PHYSICAL RESOURCES

4.1 Physical and Oceanographic Conditions

This section describes the oceanographic and meteorological environment, geological conditions, and possible natural and anthropogenic hazards within and surrounding the Project Area. Potential impacts to physical and oceanographic conditions resulting from construction, operations, and decommissioning of the Kitty Hawk North Wind Project (Project) are discussed, as well as potential impacts to the Project resulting from these conditions. Avoidance, minimization, and mitigation measures proposed by Kitty Hawk Wind, LLC (the Company) are also described in this section.

Other assessments detailed within this Construction and Operations Plan (COP) that are related to physical and oceanographic conditions include:

- Marine Archaeological and Cultural Resources (Section 6.1);
- Commercial and Recreational Fishing (Section 7.2);
- Offshore Renewable Energy, Mineral Exploration, and Infrastructure (Section 7.5);
- Health and Safety and Low Probability Events (Section 7.12);
- Foundation Structure Concept Screening (Appendix E);
- Sandbridge Export Cable Landfall Conceptual Design Study (Appendix H);
- Preliminary Cable Burial Risk Assessment (Appendix J);
- Marine Site Investigation Report (Appendix K);
- Climatic Conditions Report (Appendix L);
- Marine Archaeological Resources Assessment (Appendix X); and
- Desk Study for Potential UXO Contamination Kitty Hawk Wind Farm – Virginia Beach (Appendix HH).

For the purposes of this section, the review area includes the onshore and offshore Project components and the areas that have the potential to be directly affected by the construction, operations, and decommissioning of the Project. This section is prepared in accordance with 30 Code of Federal Regulations (CFR) § 585.627(a)(1).

Data used to complete the oceanographic and meteorological analysis comes from the following sources:

- The Global Reanalysis of Ocean Waves-Fine U.S. East Coast hindcast model operated by Oceanweather Inc. (2019);
- National Oceanic and Atmospheric Administration (NOAA) National Data Buoy Center assets (NOAA 2020);
- ERA5 data processing system (Hersbach et al. 2019);
- Climate Forecast System Reanalysis (Saha 2010);
- Oregon State University TPXO (Egbert and Erofeeva 2002); and
- Project-specific marine site investigation survey data (Appendix K).

In accordance with 30 CFR § 585.627(a)(1), a preliminary metocean analysis is included as Appendix L Climatic Conditions Report to support the design of the Project. Under the approved Site Assessment Plan, metocean equipment (one WindSentinel™ Buoy and one trawl-resistant bottom mount platform) was deployed in June 2020. However, data from the metocean equipment is not available to support the COP at this time of submittal. In accordance with 30 CFR § 585.701, a detailed metocean analysis will be submitted with the Facility Design Report prior to construction.

In addition, the Company has completed geophysical and geotechnical survey campaigns across approximately 40 percent of the designated Renewable Energy Lease Area OCS-A 0508 (Lease Area) in the northwest corner closest to shore (19,441 hectares; the Wind Development Area) and the offshore export cable corridor. The scope and schedule of these campaigns is shown in Table 4.1-4, below. Available data from completed campaigns has been incorporated into the preliminary ground model developed for the Project, which informs the Project Design Envelope (PDE). The Marine Site Investigation Report is included as Appendix K to this COP in accordance with 30 CFR § 585.626(a)(2)(4) and (6).[1]

4.1.1 Affected Environment

4.1.1.1 Oceanography and Meteorology

4.1.1.1.1 Wind

Based on wind data from Oceanweather Inc. and Climate Forecast System Reanalysis, wind speeds in the Wind Development Area averaged 7.56 meters per second (m/s) from 1979 to 2019 (Oceanweather Inc. 2019; Saha 2010). There are also several NOAA National Buoy Data Center stations near the review area, including NOAA buoys 44006, 44014, and 44019, with the locations depicted in Figure 4.1-1 (NOAA 2020). Data from the NOAA buoys near the review area was consistent with observations from the Oceanweather Inc. dataset. Figure 4.1-2 summarizes wind data from Oceanweather Inc. at 10 meters (m) above the water surface. Stronger winds typically occurred during the winter months, with averages ranging from 4 to 12 m/s at 10 m above the water surface (Oceanweather Inc. 2019). Storm events have the potential to cause extreme wind speed levels, and wind speed maximums identified using the Method of Independent Storms Extreme Wind Model resulted in a 50-year gust speed of 37.1 m/s using Oceanweather Inc. data and 43.6 m/s using NOAA Buoy 44014 data (Appendix L Climatic Conditions Report).

4.1.1.1.2 Waves

The wave data analyzed was obtained from Oceanweather Inc. (2019). Wave heights are typically greater during the winter months, averaging approximately 2 m in height, whereas wave heights during the summer months average less than 1.5 m in height (Figure 4.1-3). The exception to this trend is when extreme weather events occur, typically in late summer and early fall. Wave height maximums occurring during extreme weather events can exceed heights of 8 m. These extreme weather events include hurricanes and tropical storms.

Wave direction in the review area is primarily northeast to south (Figure 4.1-4). However, winter months experience an increase in north and northeast waves, and summer months experience an increase in south and south-east waves.

4.1.1.1.3 Currents

Offshore ocean currents in the review area are considered to be moderate and are driven by a complex system of ocean currents, depicted in Figure 4.1-5 below. The general trend of currents along this portion of the Mid-Atlantic Bight is a southward current. This southward trending current continues on until Diamond Shoals, off of Cape Hatteras, North Carolina (Skidaway Institute of Oceanography 2017).

Current data was analyzed using the Hybrid Coordinate Ocean Model (Bleck 1998; Halliwell et al. 1998). The current data at the sea surface indicated a flow direction to the south at a mean velocity of 0.2 m/s and a maximum velocity of 1.45 m/s. However, further down the water column, the current shifts slightly to the east, transitioning to a south to southeast flow direction. Additionally, current velocity decreases with depth along the water column, flowing at 0.11 m/s at a depth of 30 m below the water surface.

[1] This approach was discussed and agreed upon with the BOEM on 22 Jun 2020.

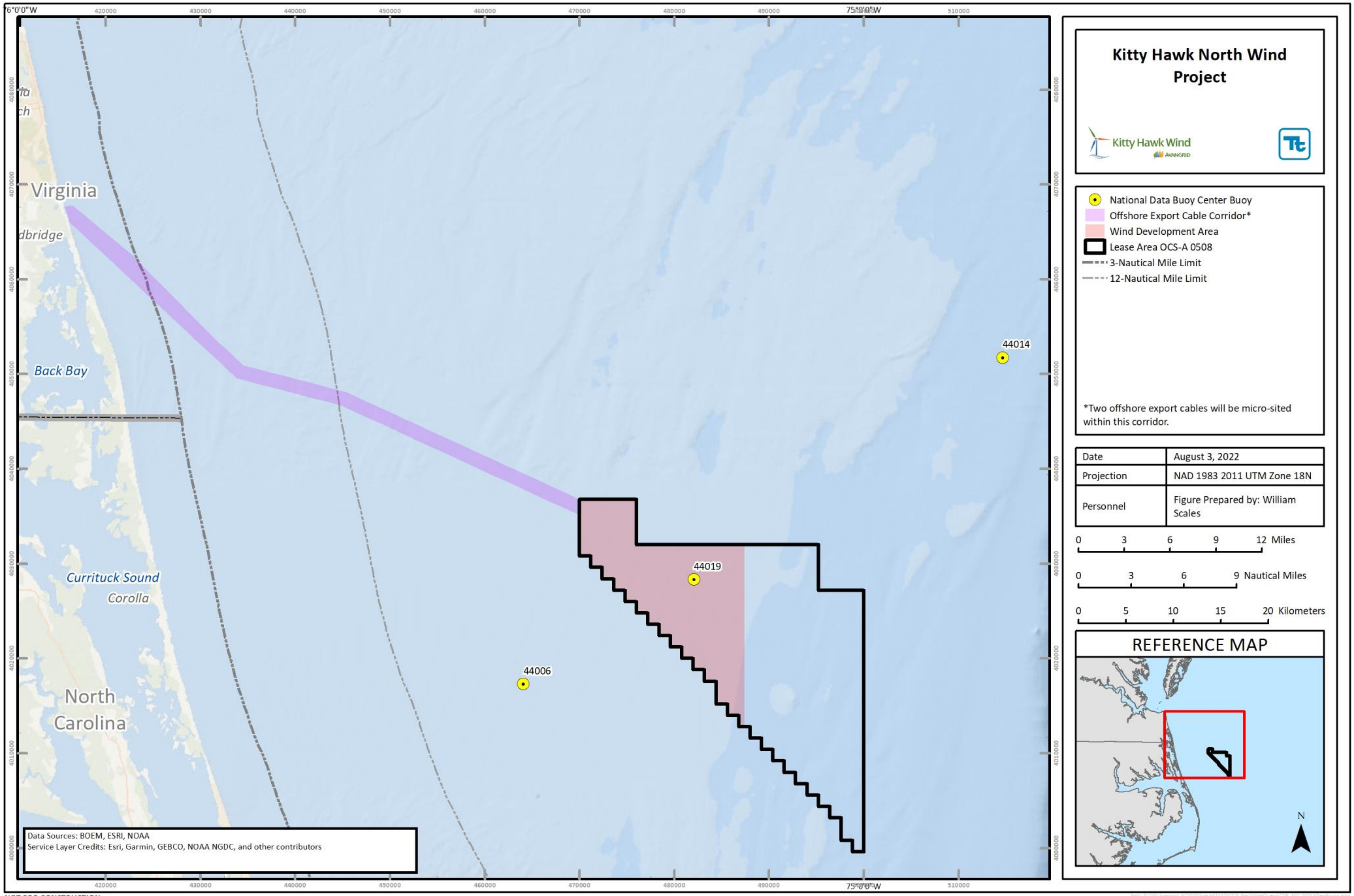
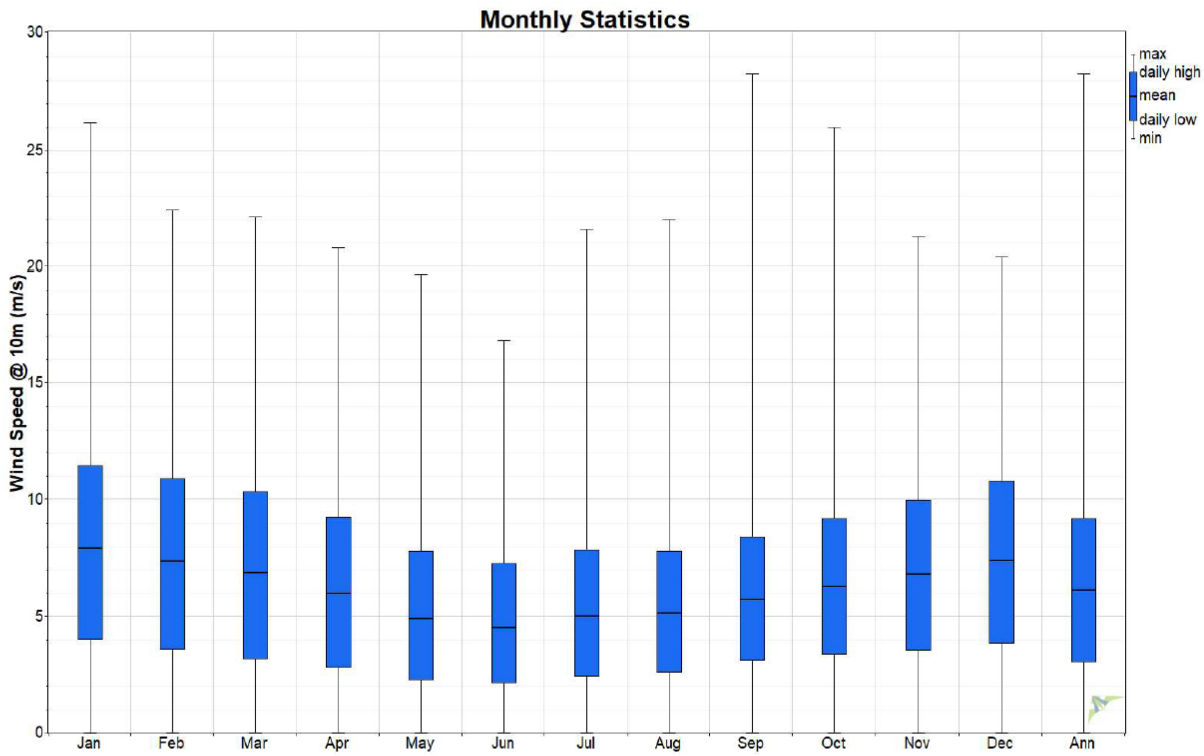
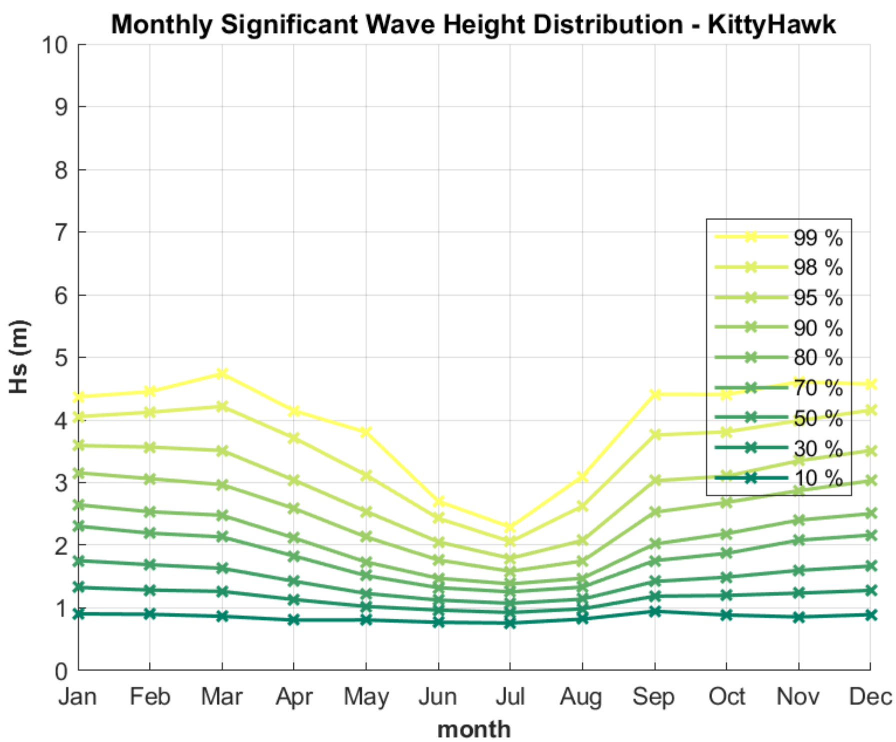


Figure 4.1-1 NOAA National Buoy Data Center Stations 44006, 44014, and 44019



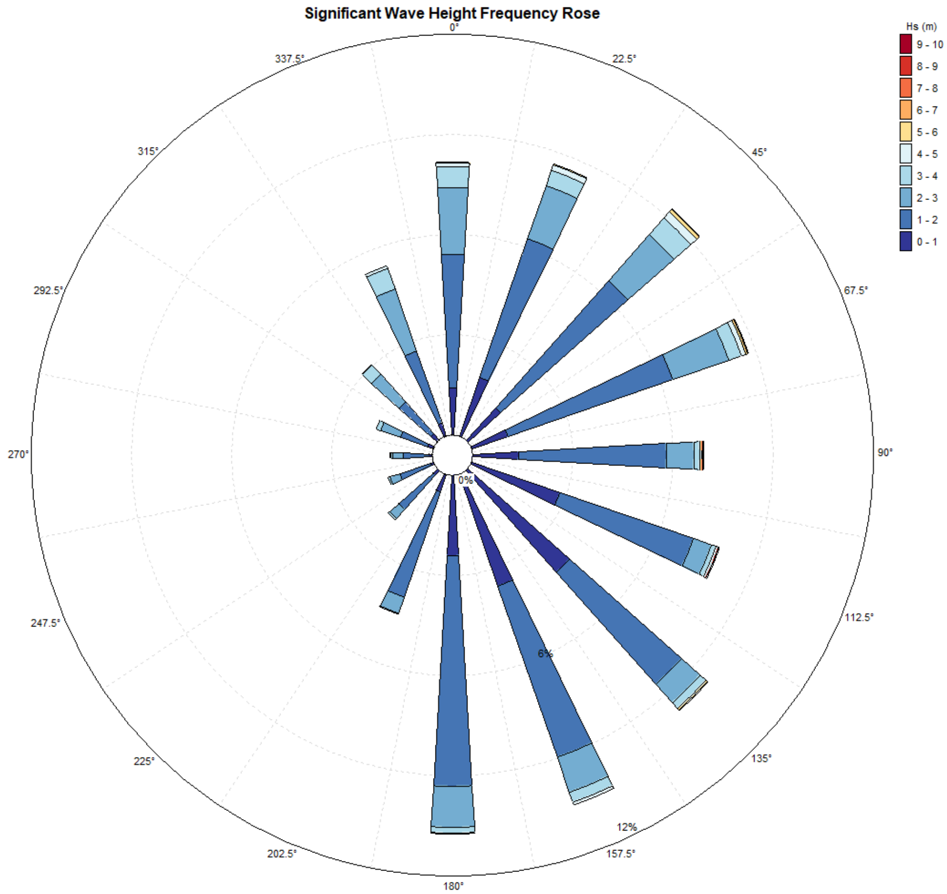
Source: Oceanweather Inc. 2019

Figure 4.1-2 Monthly Wind Speeds



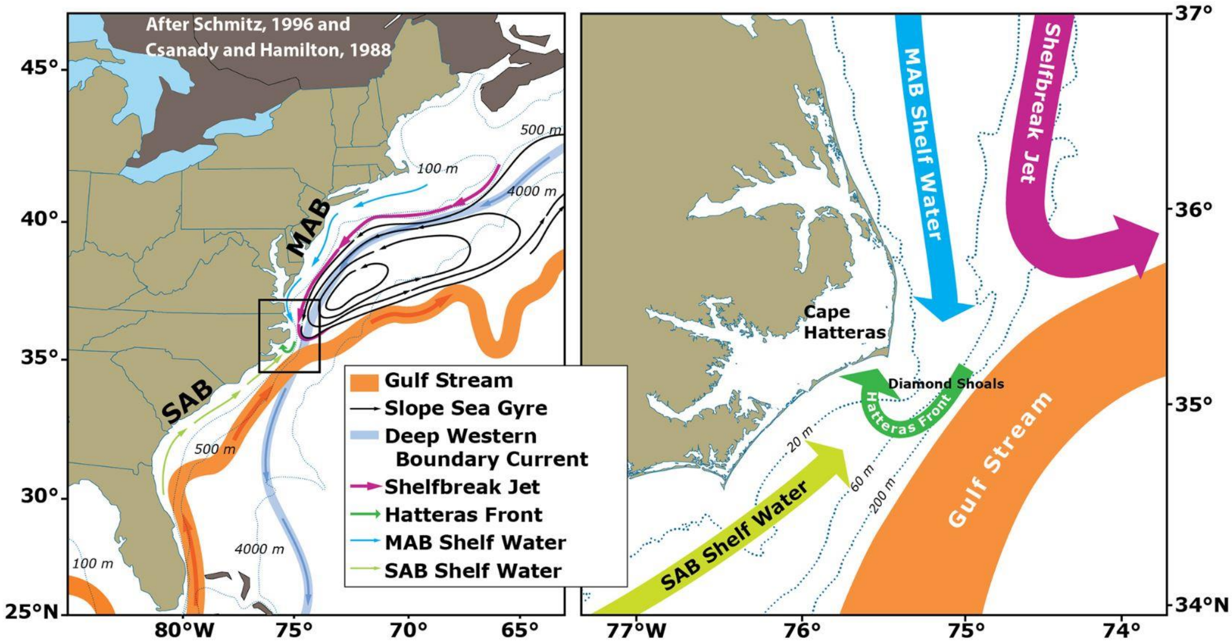
Source: Oceanweather Inc. 2019

Figure 4.1-3 Monthly Significant Wave Height



Source: Oceanweather Inc. 2019

Figure 4.1-4 Average Wave Direction within the Review Area



Source: Skidaway Institute of Oceanography 2017

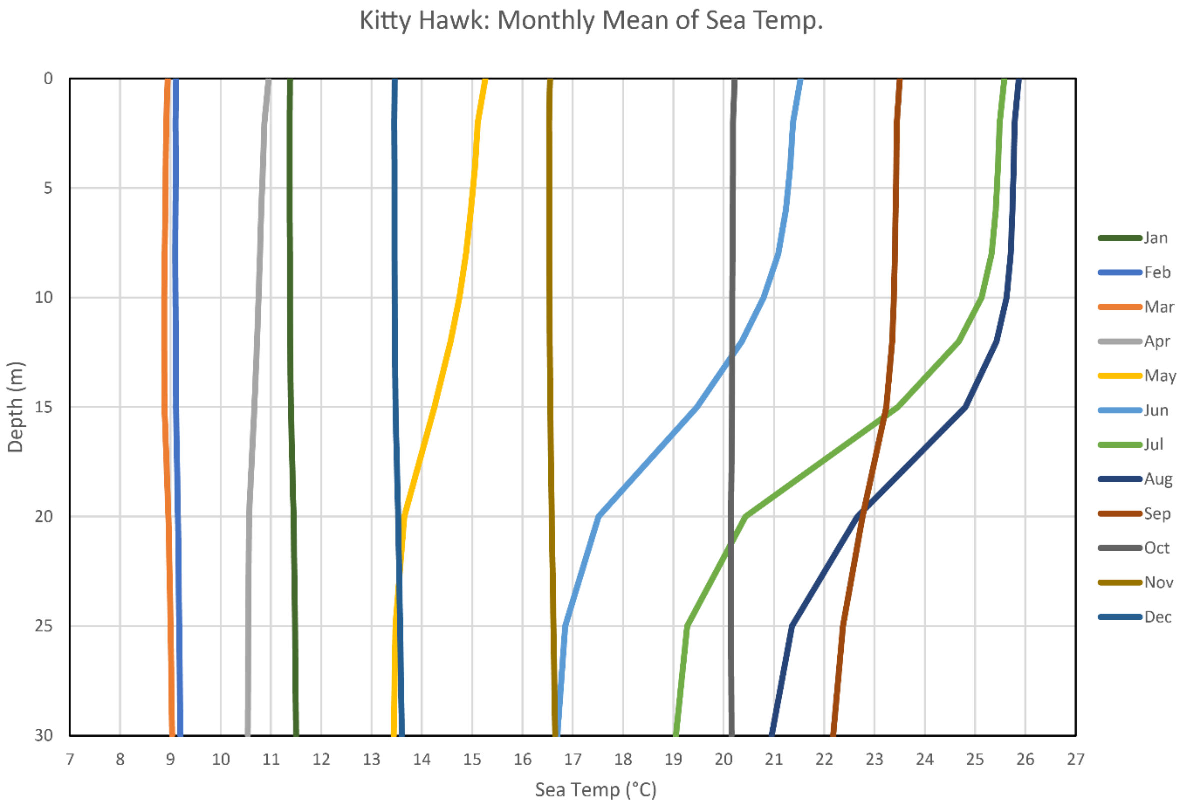
Figure 4.1-5 Model of Currents within the North Carolina and Atlantic East Coast Region

4.1.1.1.4 Water Temperature

Water temperature data analyzed for the Project was from ERA-5 (Hersbach et al. 2019). The temperatures analyzed were taken at the sea surface and averages ranged from 9 degrees Celsius (°C) to 26 °C annually. The warmest water temperatures occurred during the late summer (July, August, September), which ranged from 18.1 °C to 30.0 °C. The coldest water temperatures occurred during late winter and early spring (February, March, April) and ranged from 5.5 °C to 20.6 °C. Monthly mean water temperatures at sea surface are detailed in Table 4.1-1. Water temperatures were typically warmer and show a wider range of temperatures at the surface, with bottom waters remaining cooler and more consistent, depicted in Figure 4.1-6.

Table 4.1-1 Monthly Mean Water Temperatures at Sea Surface

Month	Average Temperature (°C)	Maximum Temperature (°C)	Minimum Temperature (°C)
Jan	11.7	21.1	6.6
Feb	10	20.6	5.5
Mar	9.3	19.8	5.8
Apr	10.5	20.4	5.5
May	14.7	24.5	7
Jun	20.7	28.7	10.2
Jul	25	29.8	18.1
Aug	25.7	29.9	18.1
Sep	23.4	30	18.1
Oct	20.3	28.1	14.4
Nov	16.3	24.7	10.7
Dec	13.8	21.6	8.6
Source: Hersbach et al. 2019			



Source: Hersbach et al. 2019

Figure 4.1-6 Monthly Mean Sea Water Temperature Profiles

4.1.1.1.5 Air Temperature

Air temperature in the review area was analyzed using data from both the Climate Forecast System Reanalysis and NOAA Data buoy 44014 (NOAA 2020; Saha 2010). Temperatures were analyzed from 1991 to 2019, with mean air temperatures ranging from 7.7 °C to 25.3 °C. Warmer air temperatures occurred during the summer months, and colder air temperatures occurred during the winter months (NOAA 2020). Table 4.1-2 below details the monthly mean air temperatures at NOAA Data buoy 44014 from 1991 to 2019.

4.1.1.1.6 Water Level

Water level data was analyzed using the Oregon State University global tidal model (Egbert and Erofeeva 2002). Tidal models along the United States (U.S.) East Coast are driven by a semidiurnal tide, with two highs and two lows each day. The heights of each tide throughout each day varies. Mean sea levels along the East Coast, using the Oregon State University model, are detailed in Table 4.1-3.

The southeastern coast of the U.S. is historically known for being subject to extreme weather events, such as tropical storms and hurricanes. The Atlantic hurricane season occurs from June to December annually, and the southeastern coast of the U.S. is typically hit by several events each season. Additionally, it is common for events to build offshore and not make landfall, which indicates that the review area may be subject to a higher number of extreme weather events than coastal North Carolina and Virginia.

Table 4.1-2 Monthly Mean Air Temperature at NOAA Data Buoy 44014 (°C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
1991	9	9.9	10.8	13.2	17.6	21.8	25.7	25.2	22.5	17.9	13	11.3	**16.5**
1992	8.3	7.7	7.8	9.9	11.6	17.9	23.9	23.7	22.7	16.1	13.2	9.4	**14.4**
1993	8.8	5.5	6.6	8.7	15.2	21	25.9	24.5	23.2	18.5	15.1	9	**15.2**
1994	10.9	6.9	7.9	13.3	15.2	22.8	25.7	24.1	21.5	17.4	17.1	13.1	**16.4**
1995	9.2	6.4	8.8	12.6	15	21.3	25.9	25.3	22.7	20.4	12.9	7.6	**15.7**
1996	6.9	5.9	6.6	9.9	14.3	20.8	23	23.9	22.4	16.6	10.3	9.5	**14.2**
1997	6.6	8	9.7	10.1	15.1	18.1	24.3	24.4	22.5	19.7	15.1	9.9	**15.3**
1998	10.3	7.8	9.8	9.5	14.2	21.4	25.1	24.9	23.4	18.7	13.9	11.2	**15.9**
1999	9.1	8	7.9	11.1	14	20.9	25.1	25.7	23.1	18.9	16	11	**15.9**
2000	7.5	9.4	9.6	12.5	16.1	19.7	23.8	23.7	22.1	17.3	12.1	7.4	**15.1**
2001	7.7	8.8	7.4	9.9	14.6	22	23.6	24.5	22.2	17.8	15.3	12.2	**15.5**
2002	10.8	9.4	11.1	13.8	16.5	21.2	25	25.3	23.3	19	12.8	9.1	**16.5**
2003	5	7.4	9.5	10.1	13.6	19.4	23.8	24.2	22.9	16.6	12.6	8.9	**14.5**
2004	4.9	6.7	7.7	10	18.3	21.8	25.5	24.8	22.4	17.3	13.5	10.1	**15.3**
2005	6.9	6	6.5	9.3	11.5	19.4	25.1	26.3	24.3	19.2	14	7.1	**14.7**
2006	9.7	6.6	8.3	12.4	16.8	21.2	25.3	26.3	21.7	18.3	15.2	12.4	**16.3**
2007	10	5.8	9.5	10.7	14.5	20.6	24.8	25.8	23.4	21.6	14.3	11.1	**16.1**
2008	7.7	8.9	10.6	13.4	15.7	22.9	25.5	25.4	23.4	17.9	12.5	11.1	**16.3**
2009	6.8	6.9	8.4	11.7	16.6	20.5	23.6	26	22.4	18.7	15	10.1	**15.6**
2010	5.7	5.3	8.2	12	16.8	23.4	25.8	26	23.4	18.5	13.3	5.7	**15.4**
2011	5.7	7.5	8.5	13	17.3	23.8	25.9	25.7	22.3	20.1	17.2	15	**16.9**
2012	14	11	9.3	12.3	15.8	22	27.7	27.8	24.2	19.5	12.1	11.8	**17.3**
2013	8.7	7.8	7.3	11.4	15.7	22	26.2	24.7	22.5	19.1	13.2	11.4	**15.9**
2014	7.2	8.3	8.8	11.5	16.7	21.9	24.6	24.8	23.6	19.7	13.2	10.8	**16**
2015	8	3.7	9.4	13.4	17.5	23.9	26	26	24.9	19.7	17	15.7	**17.2**
2016	8.7	8.2	11.4	12.1	15.1	21.4	26.1	27.1	24	19.6	14.2	10.9	**16.6**
2017	10.3	10.2	8.6	13.4	17.5	21.1	25.6	24.5	22	20.2	15.2	10	**16.6**
2018	7.4	9.8	7.2	10.6	17.7	22.1	25.3	26.5	25.4	19.4	13.6	10.5	**16.3**
2019	7.9	10	8.9	13.6	18.1	22.6	26.2	26.1	23.4	20.1	13.4	12	**16.9**
All	**8.3**	**7.7**	**8.7**	**11.6**	**15.7**	**21.3**	**25.2**	**25.3**	**23**	**18.8**	**14**	**10.6**	**15.9**

Source: NOAA 2020

Table 4.1-3 Mean Sea Levels Along the U.S. East Coast

Datum	Description	Tidal Levels		
		Meters Above LAT	Meters Above MSL	Meters Above HAT
HAT	Highest Astronomical Tide	1.47	0.81	0
MHHW	Mean Higher High Water	1.18	0.52	-0.29
MLHW	Mean Lower High Water	1.03	0.37	-0.44
MSL	Mean Sea Level	0.66	0	-0.81
MHLW	Mean Higher Low Water	0.29	-0.37	-1.18
MLLW	Mean Lower Low Water	0.15	-0.51	-1.32
LAT	Lowest Astronomical Tide	0	-0.66	-1.47
Source: Egbert and Erofeeva 2002				

4.1.1.2 Geological Conditions

4.1.1.2.1 Offshore Conditions

The Company contracted TerraSond Limited and Horizon Geosciences to conduct geophysical and geotechnical surveys, respectively (see Table 4.1-4), and Offshore Wind Consultants Limited to develop a three-dimensional ground model. The information provided in this section is an overview of the preliminary ground model, additional geophysical and geotechnical data can be found in Appendix K Marine Site Investigation Report..

Table 4.1-4 Delivery of Data to the Bureau of Ocean Energy Management (BOEM) for Completed 2020 Geophysical and Geotechnical Survey Campaigns

Approved Survey Plan	Scope of Survey Campaign	Survey Dates	Timeline for Anticipated Data Delivery to BOEM
High Resolution Geophysical Survey Plan	Reconnaissance-level high-resolution geophysical survey across the offshore Project Area	Q3 2019 – Q1 2020	31 Dec 2021 a/
Revised Geophysical Survey Plan	30-m line spacing high-resolution geophysical survey across the offshore Project Area	Q2 2020 – Q4 2020	31 Dec 2021
Geotechnical and Geophysical Survey Plan	Reconnaissance-level geotechnical survey across the offshore Project Area	Q3 2020	31 Dec 2021

Note:
a/ As discussed with BOEM on 22 Jun 2020, the Company submitted a preliminary Ground Model Report with this COP based on data collected under this campaign. The ground model is intended to support a Departure Request regarding geotechnical borings at each foundation location (30 CFR § 585.626(a)(4)(ii)).

The geologic setting along coastal North Carolina is comprised of the 'coastal plain' province, which consists of a flat low-lying landscape, including wetlands, sounds, and barrier islands (USGS 2020; NCDEQ 1985). Further offshore, the geology consists of thick, gently seaward dipping units of sediments, similarly found along much of the U.S. East Coast. These sediment units are the result of millions of years of depositions, and deposition presently continues. Additionally, various sea-level transgressions and regressions, due to sea level change and tectonic events, have occurred over the depositional time-frame of these units, which has resulted in an alternating and cross-cutting sequence of alluvial and marine sediments occurring across the continental shelf. The barrier islands along the southeast coast of the U.S. indicate the likelihood of a series of relict and submerged depositional settings offshore of the North Carolina coast. These depositional settings are expected to contain alluvial and shallow marine sediments, beneath more recent marine sediments that include Holocene sand bedforms.

The Wind Development Area and offshore export cable corridor are both at the southernmost part of the Baltimore Canyon Trough, a geological feature that extends along the Atlantic continental shelf from Cape Hatteras in the south up to Georges Bank in the north (Poag 1978). Off the coast of North Carolina, including in the Wind Development Area and offshore export cable corridor, the Quaternary sediments are expected to be predominantly Quaternary fluviatile sands and silts, perhaps generally decreasing in grain size with increasing distance from the shore.

In general, the shallowest sediments on the continental shelf are Holocene unconsolidated sediments. These unconsolidated sediments are expected to be tens of meters thick or less, sandy in composition, iron stained, and containing shells. There is also potential for them to be significantly thicker or absent in some locations. In general, the present-day continental shelf is starved of sediment due to sediment accumulation in coastal estuaries. Typically, seabed sands originating from the Appalachian Mountains have been transported by major rivers, deposited in coastal plains in the nearshore zone and subsequently reworked during the Holocene transgression (sea level rise).

Water depths in the Wind Development Area range from approximately 23 m mean lower low water (MLLW) in the northwest corner of the area, to approximately 41 m MLLW in the center of the area. Water depths across the majority of the Wind Development Area are 30 to 40 m MLLW, aside from several isolated banks at which depths shallower than 30 m MLLW are observed. Water depths along the offshore export cable corridor range from approximately 0 to 30 m MLLW, with seabed undulation along the offshore export cable corridor.

4.1.1.2.2 Onshore Conditions

The onshore Project components are located within the Coastal Plain geologic tectonic province of Virginia (William & Mary 2020). The Virginia Coastal Plain is characterized by a terraced landscape of topographic scarps having formed as ancient shorelines, which stair-steps eastward towards the Atlantic Ocean shoreline. The Coastal Plain was formed over the last few million years as a result of sea-level rising and falling. The onshore Project components are located in the younger, easternmost portion of the terrestrial Coastal Plain.

A sedimentary wedge underlies the Coastal Plain province of Virginia, with thickness of the wedge increasing with proximity to the eastern edge of the province (William & Mary 2020). The sediments are comprised primarily of Jurassic and Cretaceous clay, sand, and gravel, all having eroded from the Appalachian highlands. The most recent sediments of this layer are fossiliferous marine sands of the Tertiary age.

4.1.1.3 Natural and Anthropogenic Hazards

As discussed in Section 4.1.1.2, the Company contracted TerraSond Limited and Horizon Geosciences to conduct geophysical and geotechnical surveys, respectively (see Table 4.1-4). The Marine Site Investigation Report is included as Appendix K to the COP.

Various existing natural and anthropogenic hazards were identified in the Wind Development Area and along the offshore export cable corridor during the geophysical and geotechnical survey campaigns. A detailed description of natural and anthropogenic hazards identified within the review area will be provided in Appendix K Marine Site Investigation Report. Further details on anthropogenic hazards with historical significance are discussed in Section 6.1 Marine Archaeological and Cultural Resources and in Appendix X Marine Archaeological Resources Assessment.

In addition to the natural and anthropogenic hazards identified in the forthcoming Marine Site Investigation Report (Appendix K) and the Marine Archaeological Resources Assessment (Appendix X), the Company also conducted a Preliminary Cable Burial Risk Assessment (Appendix J) in order to assess the level of risk that natural and anthropogenic hazards pose to the offshore export cables. Based on this understanding of hazards, the Preliminary Cable Burial Risk Assessment provided a recommendation for the target burial depth; however, the Company will revise the Preliminary Cable Burial Risk Assessment as additional site-specific information is available from completed high-resolution geophysical and geotechnical surveys. Potential hazards to the offshore export cables at landfall are assessed in Appendix H Sandbridge Export Cable Landfall Conceptual Design Study.

4.1.2 Impacts Analysis for Construction, Operations, and Decommissioning

The potential impact-producing factors resulting from the construction, operations, and decommissioning of the Project are based on the maximum design scenario from the PDE (see Chapter 3 Description of Proposed Activity). For this impact analysis, the maximum design scenario is the build-out of the Project onshore, which includes the onshore export cable installation and construction of the onshore substation, and offshore, which includes the offshore export cables, the wind turbine generators (WTGs), and the electrical service platform (ESP). This represents the maximum number of structures within the Wind Development Area.

The Project is not anticipated to impact physical and oceanographic conditions such as wind speed and direction, current, water level, and temperature. WTGs offshore cause localized atmospheric wakes, which are not known to cause any large-scale impacts. Construction, operations, and decommissioning of the Project are not anticipated to result in broad-scale impacts to the oceanographic or geological setting in the area. Safety plans for extreme weather conditions will be in effect for all construction, operations, and decommissioning activities. Crews will follow all operational limitations and weather-related activity restrictions as defined by equipment manufacturers. Construction will be stopped during any weather event that exceeds the operational limits of the Project, such as lightning storms or excessive wind or waves. Relevant personnel will be trained in implementing these response plans, should a non-routine event occur. Prevention and response measures for low probability events are further detailed in Section 7.12 Health and Safety and Low Probability Events and Appendix F Safety Management System. A detailed Project Execution Plan (or similar) will be developed by the construction contractor prior to the beginning of construction.

Physical and oceanographic conditions may result in impacts to Project components and/or activities, and/or must be accounted for in designing the Project, as discussed below. Potential impacts from natural and anthropogenic hazards are also discussed.

Preliminary Project siting and design is informed by and sited to avoid natural and anthropogenic hazards to the extent possible; further refinement of siting and design will be completed based on additional high-resolution geophysical and geotechnical investigations and other evaluations. Based on the current geophysical and geotechnical survey data of the Wind Development Area and offshore export cable corridor, the following primary natural and anthropogenic hazards have been identified and/or may be present, including, but not limited to:

- Identified unexploded ordnance, wrecks, and debris;

- Presence of soft soils, shallow gas, and potentially mobile seabed features;
- Scour and erosional features associated with mobile seabed; and
- Navigation channels and other federally authorized projects along the offshore export cable corridor.

Identified unexploded ordnance, wrecks, and debris. During construction of the Project, the identification of unexploded ordnance, wrecks, and debris may require avoidance buffers, and each case will be assessed individually. The Company conducted a desktop study and risk assessment for potential unexploded ordnance contamination within the Project area (see Appendix HH Desk Study for Potential UXO Contamination Kitty Hawk Wind Farm – Virginia Beach). Unexploded ordnance with the potential to impact the Project will be avoided or cleared prior to installation activities with industry best management practices and according to industry guidelines. As discussed in Section 6.1 Marine Archaeological and Cultural Resources, wrecks with the potential to impact or be impacted by the Project will be avoided, to the extent practicable, by a recommended avoidance buffer. Non-historically significant marine debris with the potential to impact or be impacted by the Project will be moved prior to installation activities following industry best management practices. There are no known cable assets currently anticipated to be crossed by the Project's export and inter-array cables.

Presence of soft soils, shallow gas, and potentially mobile seabed features. The presence of soft soils, shallow gas, and potentially mobile seabed features may increase the risk of unstable seabed. Soft soils, shallow gas, and potentially mobile seabed features will be avoided by the Project to the extent practicable in order to avoid any areas of challenging geology. Potentially mobile seabed features may be present along the offshore export cable corridor, in which case some dredging of the upper portions of these features may be required prior to cable laying in order to achieve sufficient burial depth.

Scour and erosional features associated with mobile seabed. The presence of scour and erosional features associated with mobile seabed may increase the likelihood that the buried offshore export cables may not maintain target burial depth. Mobile seabed will be avoided by the Project to the extent practicable in order to avoid this occurrence. This and other risks to cable burial are assessed in the Preliminary Cable Burial Risk Assessment (see Appendix J). The Company will periodically monitor burial depth as deemed necessary and note and address any concerns.

Navigation channels and other federally authorized projects along the offshore export cable corridor. Certain areas of the offshore export cable corridor may require deeper burial of the offshore export cables. However, federally authorized maintained navigation channels, ocean disposal sites, and active sand borrow areas have largely been avoided through siting of Project infrastructure. During discussions with the U.S. Army Corps of Engineers, one potential federally authorized project is present within the review area, the Sandbridge Beach Coastal Storm Damage Reduction Project. This project is located at Sandbridge Beach in the vicinity of the landfall. The Project will utilize horizontal directional drilling (HDD) technology to minimize impacts to this portion of the beach. The Company will continue to coordinate with the U.S. Army Corps of Engineers and other appropriate agencies as necessary to avoid impacts to federally authorized projects and navigation channels.

4.1.2.1 Construction

Project design and construction plans will be informed by site conditions, including meteorological and oceanographic conditions, site geology, and potential hazards. In relation to the Project, geologic resources include both subsurface and surficial materials, as well as broader scale features with the potential to exist in the review area such as stratigraphic formations, faults, and buried channels. While the installation and existence of Project infrastructure in and on the seabed will not have any impact on the overall geologic framework and sediment composition of the region, construction activities will have short-term localized impacts as sediments and seabed are displaced. Displaced sediments are likely to be re-positioned to a nearby location containing sediments made up of the same characteristics such as grainsize and composition.

During construction, the potential impacts to physical and oceanographic conditions may include the following:

- Short-term sediment suspension associated with installation of foundations and offshore export and inter-array cables;
- Short-term modification to seafloor morphology (seabed scar) associated with offshore export and inter-array cable installation; and
- Short-term disturbance to soil along the onshore export cable corridors and onshore substation site.

Short-term sediment suspension associated with installation of foundations and offshore export and inter-array cables. Short-term sediment suspension may occur as a result of cable pre-lay and installation activities, including HDD. Surface sediments will be slightly disturbed and displaced as a result of these activities, and sediments will remain temporarily suspended in the water column and have the potential to be transported a short distance before settling once again on the seabed, likely on top of sediments of the same type. For a detailed discussion on sediment suspension in the water column, see Section 4.2 Water Quality and Appendix M Sediment Transport Modeling Report.

Short-term modification to seafloor morphology (seabed scar) associated with offshore export and inter-array cable installation. Short-term modification to seabed morphology will occur as a direct result of offshore cable installation activities. This seabed morphology will be short-term, as during pre-lay installation sediments will be pushed away and will pile up onto the sides of the trench. Post-lay cable burial activities will then move this sediment on top of the offshore export or inter-array cable, and the seabed will be returned to a state similar to its condition prior to cable installation.

Short-term disturbance to soil along the onshore export cable corridors and onshore substation site. A geotechnical survey campaign will be conducted onshore to confirm the current understanding of conditions as discussed in this section. The decision of the locations for onshore Project components will consider the existing geologic conditions of the area and avoid areas for which the geologic conditions could pose a risk to the Project. Additionally, the Company will consider the geologic conditions when determining Project design and construction methods and account for any requirements specific to the geology of the area.

4.1.2.2 Operations and Maintenance

During operations, the potential impacts to physical and oceanographic conditions may include the following:

- Long-term modification of seabed resulting from scour around WTG and ESP foundations and offshore export and inter-array cables.

Long-term modification of seabed resulting from scour around WTGs and ESP foundations and offshore export and inter-array cables. Long-term modification of the seabed from the installation of scour around WTG and ESP foundations as well as the offshore export and inter-array cables may occur as a result of mobile sediments surrounding the Project infrastructure. As sediments shift, a natural process as a result of currents or weather events, there will be a naturally occurring tendency to either shift away from the Project infrastructure, or for sediments to pile up at the base of Project infrastructure. Scour protection will be utilized, as necessary, in order to protect both the Project infrastructure from becoming buried or unburied as a result of scour, and to protect the seabed and ensure it remains impacted to the least extent possible.

Project infrastructure will be designed to withstand normal and reasonably foreseeable physical and oceanographic conditions throughout the useful life of the Project, taking into consideration the possibility of extreme weather conditions within the Wind Development Area. Scour protection will be applied around WTG and ESP foundations as appropriate, which will mitigate impacts to and from ocean currents.

Anthropogenic hazards such as potential interactions with fishing gear and anchor drags, and natural hazards, including mobile seabed, scouring, and strong weather events, have the potential to pose a risk to the offshore export and inter-array cables. A Preliminary Cable Burial Risk Assessment was completed (Appendix J). Additional work is ongoing and will inform the Company regarding how deeply the offshore export and inter-array cables should be buried to mitigate potential risks from known sources of external aggression. Monitoring, including periodic geophysical surveys of the offshore export and inter-array cables will be conducted in order to assure that the cables remain properly buried throughout the useful life of the Project. In the event that an offshore export or inter-array cable has become unburied or damaged, industry standard methods will be implemented to bury or repair the cable. Distributed temperature sensing will be included in the offshore export cables to monitor temperature changes along the offshore export cables over the useful life of the Project. Distributed temperature sensing systems use fiber optic cable alongside the electrical conductor cores to monitor the temperature at each location along the length of the entire cable. The Company will be alerted in real time should the temperature change, which often is the result of cable exposure. If a change in temperature occurs, the Company will, as appropriate, inspect that location to determine if cables have become damaged, exposed, or over buried, and will conduct necessary repairs or maintenance.

4.1.2.3 Decommissioning

Impacts resulting from decommissioning of the Project are expected to be similar or less than those experienced during construction. Decommissioning techniques are further expected to advance during the useful life of the Project. A full decommissioning plan will be provided to the Bureau of Ocean Energy Management (BOEM) for approval prior to decommissioning activities, and potential impacts will be re-evaluated at that time.

4.2 Water Quality

This section describes the water quality within and surrounding the Project Area, which includes the Wind Development Area, export cable corridors, and onshore substation. Potential impacts to water quality resulting from construction, operations, and decommissioning of the Project are discussed. Avoidance, minimization, and mitigation measures proposed by the Company are also described in this section.

Other assessments detailed within this COP that are related to water quality include:

- Physical and Oceanographic Conditions (Section 4.1);
- Wetlands and Waterbodies (Section 5.1); and
- Sediment Transport Modeling Report (Appendix M).

For the purposes of this section, the review area includes the onshore and offshore Project components and the areas that have the potential to be directly affected by the construction, operations, and decommissioning of the Project.

In order to characterize the existing water quality in the review area, publicly available resources for the marine, groundwater, and surface waters were reviewed and assessed. To satisfy the requirements of 30 CFR § 585.627(a)(2), publicly available data and site-specific sediment characteristics were also used to develop a sediment transport model and analyze potential impacts during Project construction. Potential impacts include turbidity from the installation of the offshore export and inter-array cables, including associated landfall activities (Appendix M Sediment Transport Modeling Report). Data used to complete this analysis included meteorological information, simulated currents velocities, and seabed sediment characterization from the following sources:

- Recorded precipitation at Corolla 11.7 NNW (GHCND ID: US1NCCC000) located in Currituck County, North Carolina, approximately 77 kilometers (km) northwest of the Lease Area;
- Simulated flow directions and current velocities from the Experimental System for Predicting Shelf and Slope Optics hydrodynamic model; and
- Estimated sediment characteristics from seabed grab samples collected by the Company in the Project Area during 2019 and 2020.

The modeling approach for this sediment transport analysis, as well as the data used, was presented to BOEM and the U.S. Army Corps of Engineers on 21 Apr 2020 and 22 May 2020, respectively. Agency feedback was incorporated into the modeling approach and both agencies concurred with the data and methodology used.

4.2.1 Affected Environment

Water quality refers to the physical, chemical, and biological attributes of water. Water quality in the review area is assessed by the waterbodies' ability to sustain existing ecosystems and existing human uses. Pollutants from both natural and anthropogenic sources can contribute to changes in water quality, which may be detrimental to existing ecosystems. Natural sources of pollutants include influx of nutrients and sediments from undeveloped land uses and natural stream processes. Anthropogenic pollutant sources include those from direct discharges, accidental releases or spills, runoff from developed areas, and resuspended seabed sediment due to human actions.

In addition to nutrients and sediments, other water quality properties can be impacted by anthropogenic activities. While water temperature naturally changes seasonally, it is also altered when water is used for power plant or industrial cooling, or when mixing is forced across stratified layers within the water column. Dissolved oxygen levels fluctuate with water depth, seasonally, and with changes in the biological and chemical oxygen demand, which can reflect natural and anthropogenic changes in levels of organic matter in the water. Coastal and ocean water quality, marine sediment quality, surface water quality, and groundwater quality within the review area are discussed below. Available data is further summarized below.

4.2.1.1 Coastal and Ocean Water Quality

Marine environments in the review area are located in the Virginia state coastal waters and the Atlantic Outer Continental Shelf (OCS) offshore of Virginia and North Carolina, known as the Mid-Atlantic Bight subarea. The offshore export cables traverse the coastal waters of Virginia and the Mid-Atlantic Bight. The Wind Development Area is within the Mid-Atlantic Bight offshore of North Carolina.

4.2.1.1.1 Virginia State Coastal Waters

The U.S. Environmental Protection Agency (EPA) National Coastal Condition Report IV rated the coastal waters of the Northeast Coast Region as “fair” for water quality (EPA 2012). The Northeast Coast Region includes the Virginia state coastal waters and extends north along the coast of Maine. The state coastal waters of Virginia include coastal estuaries, intertidal zones, and coastal ocean waters. Site water quality indices are rated as “fair” for data points near the export cable landfall (EPA 2012). Water quality ratings were based on measurements of dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorous (DIP), chlorophyll *a*, water clarity, and dissolved oxygen.

An assessment of the National Aquatic Resource Surveys 2010 water quality data for 23 stations along Virginia coastal estuaries show that DIN concentrations averaged 0.05 milligrams per liter (mg/L), DIP concentrations averaged 0.02 mg/L, chlorophyll *a* concentrations averaged 13.4 micrograms per liter, and dissolved oxygen concentrations averaged 5.6 mg/L (EPA 2016). Light transmissivity was measured to assess water clarity and reported the percent of incident light transmitted through one meter of water. Light transmissivity ranged from 60.64 percent at 1 m depth to 3.52 percent at 1 m depth with an average of 32 percent (EPA 2016).

Virginia Department of Health conducts routine *Enterococcus* bacteria water quality sampling at a beach monitoring station very near the location of the export cable landfall (Station ID: 21VABCH-VA863269). Monitoring results are available for May through September beginning in 2006 through 2019 (NWQMC 2020). For transition and saltwater waterbodies, Virginia water quality standards state that *Enterococcus* bacteria shall not exceed a geometric mean of 35 counts per 100 milliliters and shall not have greater than a 10 percent excursion frequency of a statistical threshold value of 130 counts per 100 milliliters, both in an assessment period of up to 90 days. Samples at Station ID: 21VABCH-VA863269 (also referred to as Sandbridge North) did not exceed state water quality standards in 2019 (Virginia Department of Health 2020).

4.2.1.1.2 Mid-Atlantic Bight

The EPA National Coastal Condition Report IV assessed DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen for the Mid-Atlantic Bight ocean waters. The EPA did not report the water quality index rating for the Mid-Atlantic Bight as a whole because index rating cutpoints for ocean waters did not exist for DIN, DIP, chlorophyll *a*, total suspended solids, and dissolved oxygen as they do for coastal waters (EPA 2012). Index rating cutpoints are the values used to determine if a component is “good”, “fair”, or “poor”. For the Mid-Atlantic Bight, the EPA National Coast Condition Report IV reported average DIN concentrations in ocean surface waters of 0.04 mg/L and near-bottom DIN concentrations averaged 0.13 mg/L. Ocean concentrations of DIN were lower compared to the average of 0.28 mg/L measured in estuaries. Average DIP concentrations were reported as 0.04 mg/L, which are very similar to concentrations measured in nearby estuaries, which also averaged 0.04 mg/L. Chlorophyll *a* surface concentration averaged 0.23 micrograms per liter and near-bottom concentrations averaged 0.30 micrograms per liter. Near-bottom chlorophyll *a* levels were also low. Ocean water clarity was assessed using measurements of total suspended solids concentrations. Total suspended solids averaged 5.6 mg/L and near-bottom concentrations averaged 6.9 mg/L. Dissolved oxygen surface concentrations averaged 8.9 mg/L and near-bottom concentrations averaged 9.1 mg/L.

The warmest water temperatures occur during the late summer (July, August, September), ranging from 18.1 °C to 30.0 °C. The coldest water temperatures occur during late winter and early spring (February, March, April), ranging from 5.5 °C to 20.6 °C (Hersbach et al. 2019). Refer to Section 4.1 Physical and Oceanographic Conditions for additional information on water temperatures.

A persistent cross-shelf salinity gradient exists in the Mid-Atlantic Bight due to freshwater runoff from the Hudson Raritan Estuary System, Delaware Bay, and Chesapeake Bay (MAROA 2020; Castelao et.al. 2010). Following periods of high runoff, a strong vertical salinity gradient has been observed across much of the 100-km wide shelf (Wilkin and Hunter 2013). Stratification starts in early June and often lasts until October (Stevenson et al. 2004). The National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries) reports mean surface salinity in 1999 as 32.6 Practical Salinity Units and mean bottom salinity as 33.2 Practical Salinity Units (NOAA Fisheries 2020). Seasonal variations in salinity are smaller than variations in temperature. (Castelao et.al. 2010). At the shelf edge, strong horizontal gradients in salinity occur separating the shelf water from the warmer saltier sea water (Csanady and Hamilton 1988).

4.2.1.2 Marine Sediment Quality

The EPA National Coastal Condition Report IV rated the coastal waters of the Northeast Coast Region (including Virginia state coastal waters) as "fair" for sediment (EPA 2012). Sediment rating is based on toxicity, contaminants, and total organic carbon (TOC) component indicators. Sediment toxicity, contaminants, and TOC at monitoring stations in the vicinity of the Virginia Beach landfall are mostly rated as "good" or "fair".

Measurements of sediment contaminants and TOC were used to assess ocean sediment conditions in the Mid-Atlantic Bight. Index rating cutpoints were not available for ocean sediment condition; therefore, no index rating was reported. The indicators were compared to the estuarine cutpoints. The EPA (2012) reported sediment in the Mid-Atlantic Bight as relatively uncontaminated and ocean sediments had very low TOC concentrations. High TOC concentrations can indicate adverse conditions, because some chemical pollutants tend to bind to organic matter. Increasing proportions of fine-grained sediments, such as silts and clays, are often associated with high TOC concentration in ocean waters. The majority (92 percent) of the ocean area was composed of sand with 2 percent consisting of greater than 80 percent silt-clay (EPA 2012).

The site-specific grab samples collected by the Company concur with the EPA's assessment of sediment composition. In Q1 2020, the Company collected surface sediment grab samples in and around the Project Area at 49 locations within the offshore export cable corridor and Lease Area (TerraSond-Avangrid Renewables 2020). Of these locations, 20 were in or near the offshore export cable corridor, nine were within the Wind Development Area, and the other 20 were in the remaining portion of the Lease Area (Figure 4.2-1). The sampling event evaluated sediment grain size, moisture content, solids content, and organic content. The samples were not evaluated for toxicity, contaminants, and TOC. Sediment sample particle classification percentages were provided based on the sediment grain size. Percentages of silt and clay particles based on the sediment grain size were calculated based on United States Geological Survey (USGS) methodology (USGS 2005). Of the 49 samples, 48 samples consisted of less than 4 percent silt and clay particles, with one sample in the offshore export cable corridor measuring 12 percent silt and clay particles. A comprehensive benthic survey of the offshore Project Area was completed by RPS Ocean Science in Q4 2020 and will be submitted to BOEM as a supplemental filing to this COP. See Section 5.4 Benthic Resources and Finfish, Invertebrates, and Essential Fish Habitat for additional detail.

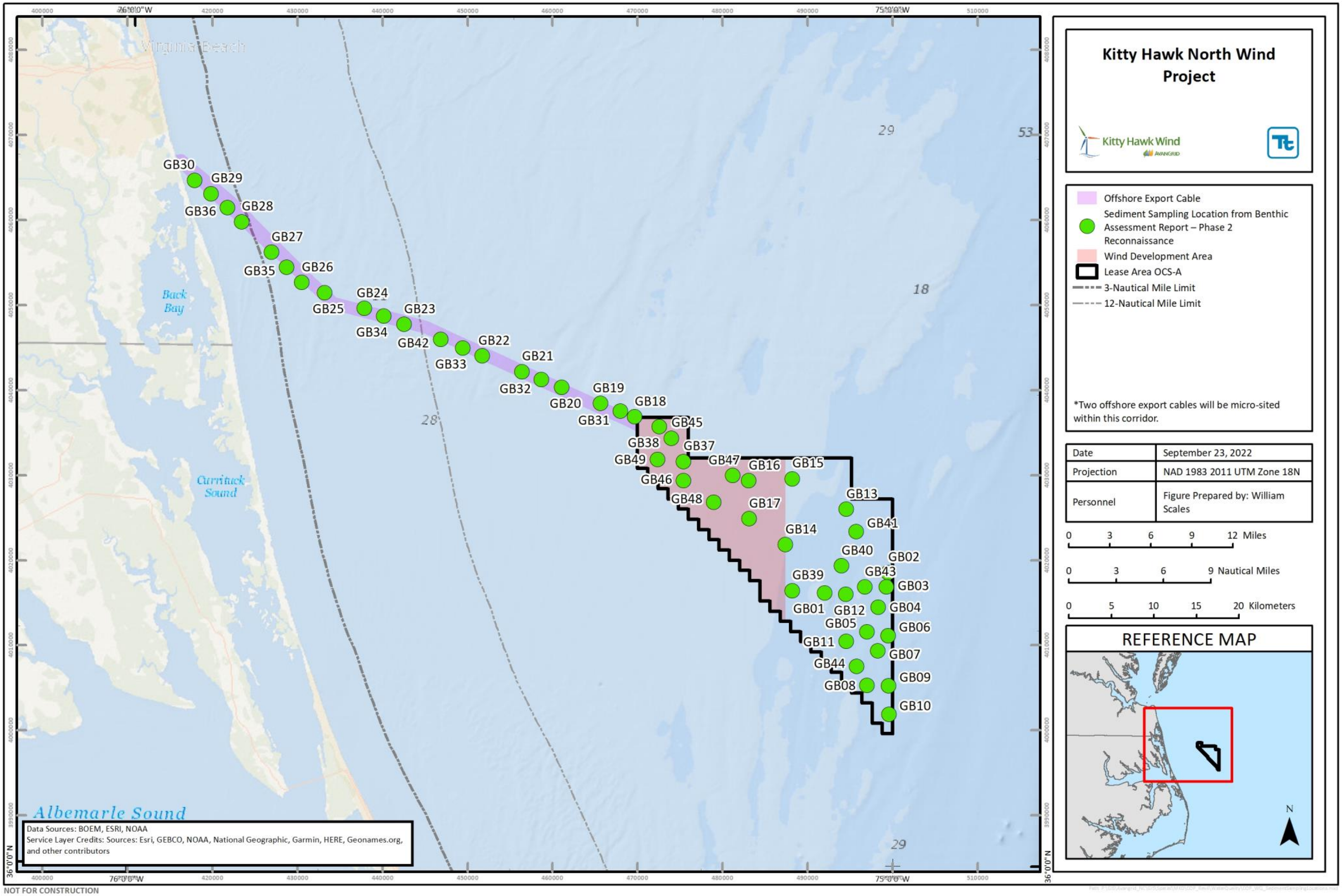


Figure 4.2-1 Sediment Grab Sample Locations

4.2.1.3 Onshore Groundwater Quality

The onshore Project Area is underlain by the Northern Atlantic Coastal Plain aquifer system. Groundwater elevations were measured at the USGS monitoring well near Lake Tecumseh (station USGS 364613075583201) beginning in March 1981 to April 2019 (125 measurements). The Lake Tecumseh USGS station is approximately 2 km northeast of the Sandbridge route and western route option onshore export cable corridors as they parallel Nimmo Parkway. This data shows depths to water levels typically within 1.2 to 2.4 m of the ground surface (USGS 2020).

In 1999, the USGS, in conjunction with the Virginia Beach Public Utilities Department, completed a shallow aquifer study for Virginia Beach (Johnson 1999). The study found that high salt content is prevalent in all but the upper 30 to 60 m of the shallower aquifer in the Project Area. High concentrations of dissolved iron and sulfur were also found throughout the aquifer.

The residences and businesses in the vicinity of the export cable landfall receive their drinking water from Lake Gaston, via the Gaston pipeline, and use ground water for car washing, yard irrigation, and other small-scale domestic uses (Johnson 1999). Rural south Virginia Beach uses approximately 380,000 gallons per day of groundwater mostly for domestic supply (Johnson 1999). Some groundwater is used for irrigation throughout the state.

4.2.1.4 Onshore Surface Water Quality

As shown in Figure 4.2-2, the onshore substation is located within two watersheds: the Currituck Sound watershed and the North Landing Creek watershed (City of Virginia Beach 2019). The onshore export cable corridors are primarily located within the Currituck Sound watershed. Stormwater runoff from the currently undeveloped northwest portion of the onshore substation parcel drains to the existing Corporate Landing Lake #5 and ultimately to the Currituck Sound (City of Virginia Beach 2020). Virginia Beach includes Corporate Landing Lake #5 in its stormwater infrastructure GIS database as a stormwater best management practice. The lake is designed to prevent or reduce the pollution of surface waters and groundwater systems from the impacts of land-disturbing activities (City of Virginia Beach 2020, 2014). Corporate Landing Lake #5 has an existing permanent pool that is likely to also provide water quality benefits. However, details on water quality features or water quality monitoring for the lake are not readily available.

The remaining southeast portion of the parcel within the North Landing Creek watershed is also undeveloped. Runoff from this portion of the onshore substation parcel flows west to West Neck Creek. West Neck Creek is on the 2018 EPA 303-D List of Impaired Waters for fecal coliform, dissolved oxygen, and polychlorinated biphenyl in fish tissue impairments (VDEQ 2019a). West Neck Creek generally flows south to the North Landing River and eventually to Currituck Sound. The nearest water quality monitoring stations are maintained by the Virginia Department of Environmental Quality (VDEQ) and are located along West Neck Creek at Route 149 bridge (Station ID: 21VASWCB-5BWNC006.64), which is 6.6 km to the southwest of the onshore substation parcel.

The total maximum daily load decision rationale describes the causes for fecal coliform impairment, including both wet weather and directly deposited nonpoint sources (EPA 2005). An implementation plan for the bacteria total maximum daily load was developed in 2009 (VDEQ 2009). MapTech, Inc. (2010) completed a dissolved oxygen assessment for Virginia Beach, and concluded that anthropogenic sources were exacerbating the naturally low dissolved oxygen in West Neck Creek. A total maximum daily load for polychlorinated biphenyl has not been developed.

The wetlands in the onshore Project Area and potential impacts are provided in Section 5.1 Wetlands and Waterbodies.

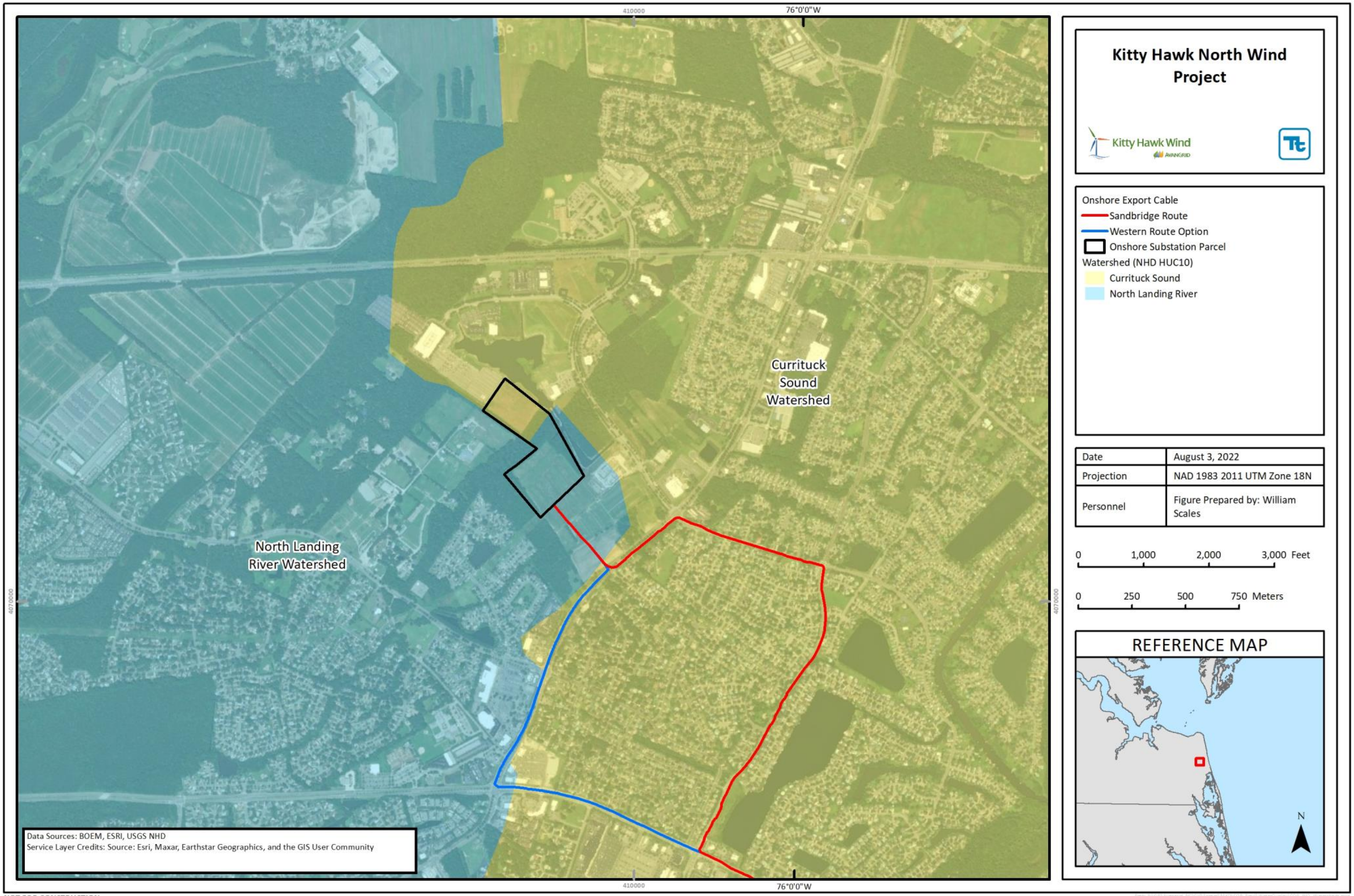


Figure 4.2-2 Watershed Boundaries in Relation to Onshore Substation and Onshore Export Cables

4.2.2 Impacts Analysis for Construction, Operations, and Decommissioning

The potential impact-producing factors resulting from the construction, operations, and decommissioning of the Project are based on the maximum design scenario from the PDE (see Chapter 3 Description of Proposed Activity). For offshore water quality, the maximum design scenario is represented by 67 monopile foundations and three 4-legged suction caisson jacket foundations with maximum scour protection, as this scenario represents the greatest area of seafloor impacted during construction. In addition, the maximum design scenario includes the maximum length of offshore export cables and inter-array cables, installed via jet plow/jet trencher,[2] the installation method that would result in the maximum amount of seabed sediment disturbance and potential turbidity.

For onshore water quality, the maximum design scenario is represented by the greatest area of land disturbed during construction of the onshore cables and onshore substation. This scenario represents the greatest potential for rainfall to erode exposed soil and be transported into streams, lakes, or wetlands. The maximum design scenario is represented by the full build out of the onshore Project features, including onshore export cables, onshore substation, and export cable landfall. A Summary of Applicant-Proposed Avoidance, Minimization, and Mitigation Measures is provided in Appendix FF.

4.2.2.1 Construction

The potential short-term impacts to water quality may include the following:

- Short-term disturbance of seabed sediment due to seabed preparation, foundation installation, and offshore export and inter-array cable installation;
- Short-term potential to impact wetlands (addressed in Section 5.1 Wetlands and Waterbodies);
- Short-term increase in erosion and runoff;
- Short-term impacts due to dewatering trenches and excavations;
- Short-term potential for inadvertent return of drilling fluids during HDD;
- Short-term potential for accidental releases from onshore construction vehicles or equipment; and
- Short-term impacts due to accidental spills and/or releases offshore.

Short-term disturbance of seabed sediment due to seabed preparation, foundation installation, and offshore export and inter-array cable installation. Suspension of sediments in the water column may occur as a result of installation of the offshore WTG and ESP foundations and offshore export and inter-array cables. To evaluate the impacts of offshore export and inter-array cable installation, a conservative analytical sediment transport model was developed to evaluate the potential suspended sediment transport and deposition associated with cable installation along the offshore export cable corridor and within the Wind Development Area (see Appendix M Sediment Transport Modeling Report).

The model assumed the following design scenario:

- The proposed offshore export cable corridor with landfall at Sandbridge Beach, Virginia;
- A maximum target burial depth for offshore export and inter-array cables of 2.5 m;
- The use of a trailing suction hopper dredge with hopper overflow and dredge material disposal from the vessel bottom (6.1 m [20 ft] below the surface) to smooth mobile seabed features during the pre-cable installation activities;

[2] As a base case, a towed jet plow is anticipated to be used for the offshore export cable installation and a remote-operated jet trencher will be used for the inter-array cable installation. Both tools use the same methodology to fluidize the sediment and bury the cable. Therefore, impacts to sediment suspension and dispersal from both tools are expected to be the same.

- The use of a jet plow/jet trencher,[3] since this is anticipated to be the cable installation method used for the majority of the offshore export and inter-array cable installation; and
- The use of HDD for cable landfall.

The analytical sediment transport model yielded the following general conclusions:

For pre-cable installation:

- The maximum suspended sediment concentration at 25 m ranged between 1,700 mg/L and 2,200 mg/L during pre-cable installation dredging. The maximum deposition thickness was less than 2 cm during ebb tides.
- For dredge material disposal, maximum flood concentrations range from 2.4 x 104 mg/L to 4.2 x 104 mg/L at a distance of 50 m from the disposal location. Estimated maximum deposition depth of 206 cm occurring during ebb conditions at distances less than 0.5 m from the point of disposal. By 100 m from the disposal location, deposition is less than 2 cm for all locations for flood and ebb conditions

For jet-plow cable installation:

- The suspended sediment concentration, deposition depth, and area of influence is dependent upon flood and ebb current velocities, burial depth, and the percentage of fine sediments at the location of cable installation.
- The very fine sediment particles (silt and clay) remain in suspension for about 4 hours after being mobilized in the water column. Slightly larger sediment particles (fine sand) settle at a faster rate, about 1 minute after being mobilized.
- The initial maximum concentration at the release point is dependent on the percentage of fine particles (defined as fine sand and smaller). At stations that are 90 percent fine particles, maximum concentrations at the trench line are approximately 3.1×10^6 mg/L for a maximum trench depth of 2.5 m. This instantaneous concentration is conservatively high and assumes that all particles finer than fine sand are instantly mobilized in the water column and remain in suspension until they settle.
- The suspended sediment concentrations diminish rapidly away from the release point, and at most stations over 80 percent of the suspended particles deposit within 10 m of the trench centerline. The typical concentration at 100 m is about 300 mg/L above background concentration for flood tides and about 50 mg/L above background concentration for ebb tides.
- The suspended sediment concentrations drop rapidly with time. At most locations, the concentration drops by 75 percent within two minutes of jetting activity. The maximum concentration at two minutes is 0.7×10^5 mg/L for flood tide and 4.7×10^5 mg/L for ebb tide. Average concentration at two minutes is 3.3×10^4 mg/L for flood tide and 1.6×10^5 mg/L for ebb tide.
- The deposition thicknesses are predicted to be greatest closest to the centerline trench. The maximum expected sediment deposition thickness under simulated conditions is 158.6 centimeters (cm) at 0 m from the trench centerline. On average, deposition thicknesses were approximately 12.6 cm at 0 m from the trench centerline for flood tides and 55.5 cm at 0 m from the trench centerline for ebb tides.

[3] To install the cable, the jet plow or jet trencher's water nozzle temporarily loosens the soil, creating a narrow trench. The cable is fed into this trench as the tool moves along the ocean floor. Marine sediment resettles upon the cable, closing the trench with minimal impact to the sea floor. However, some marine sediments may stay suspended in the water column, temporarily increasing total suspended solids, and dispersion of the sediments may cause material to deposit outside the area of disturbance.

- Deposition thicknesses are predicted to decrease rapidly away from the trench. Average deposition thicknesses were less than 4 cm within 25 m of the trench centerline. On an average, the deposition thickness dropped to 0.05 cm after 50 m from the trench centerline.
- The maximum suspended sediment concentration was 3.23 x10^6 mg/L in the HDD exit pit area with concentrations dropping below 1,000 mg/L at a distance of 100 m from the trench centerline. The maximum deposition thickness was 110.66 cm during ebb tides and dropped to below 0.1 cm within 50 m of the trench centerline.

Construction activities associated with installation of foundations in the Wind Development Area, including site preparation and the installation of scour protection, may increase water column suspended sediment concentrations in proximity to a foundation. Furthermore, the seabed and near-bottom water column in the nearshore review area are highly dynamic environments, with suspension and redeposition of sediment occurring continuously due to storms and tidal currents. Offshore, anthropogenic processes such as trawling and dredging regularly create water quality impacts that are similar to or larger than impacts associated with cable installation, and these activities have not been shown to inhibit fish migration or transit (Johnson 2018).

Short-term increase in erosion and/or stormwater runoff. Clearing, excavation, soil stockpile, and grading associated with construction of the onshore substation, onshore export cables, and supporting infrastructure may have the potential to temporarily impact the water quality and quantity of the stormwater runoff from the work areas.

Clearing and grading for construction of the onshore substation will expose soil to wind and rain erosion until the site is fully stabilized after construction is completed. If picked up by stormwater flow, sediment may be transported to downstream surface waters. Land disturbance activities disturbing 232.3 square meters (2,500 square feet) or more of land must obtain a Land Disturbing Permit in accordance with the provisions of the City of Virginia Beach Erosion and Sediment Control Ordinance (Chapter 30). Construction activities disturbing 4,047 square meters (1 acre) or more are covered by the VDEQ construction general permit, which requires the operator to develop and implement a Stormwater Pollution Prevention Plan (SWPPP) (VDEQ 2019b). The Company will develop a SWPPP that will conform with the VDEQ Stormwater Management Program regulations, the construction general permit, and the City of Virginia Beach Erosion and Sediment Control Ordinance. The SWPPP will include steps the Company will take to comply with the permit, including water quality requirements.

Short-term impacts due to dewatering trenches and excavations. Disturbance of soils during construction of the onshore export cables and the onshore substation may have the potential to temporarily impact the water quality of groundwater resources. Final engineering design will determine if groundwater will need to be managed during construction activities that require digging of pits or trenches for the Project's onshore facilities. As design for the onshore export cable corridor and the associated onshore substation develops, the Company will determine through site test pits whether groundwater is expected to be encountered during excavation. If groundwater is expected and dewatering is required, the Company will develop a site-specific dewatering plan to protect groundwater and nearby surface water resources in accordance with an agency-approved, Project-specific SWPPP.

Short-term potential for inadvertent return of drilling fluids during HDD. The HDD drilling process involves pumping a drilling fluid, usually water mixed with bentonite, into the borehole to maintain borehole stability, remove cuttings, and cool the drilling tools. The bentonite mixture is inert, non-toxic clays, and rock particles consisting predominantly of clay with quartz, feldspars, and accessory material such as calcite and gypsum. An inadvertent return/release can occur if the drilling fluids migrate to the land or seabed surface through fractures, fissures, or other conduits in the underlying rock or unconsolidated sediments that may not be detected in the geotechnical investigations. An inadvertent return/release could potentially increase turbidity in marine, groundwater, and/or surface water. Should an inadvertent return/release occur, it would likely only result in short-term and localized impacts to water quality in the shallow marine environment associated with the export cable landfall and/or the portion of the onshore export cables that cross wetlands or streams. The Company will develop and implement an HDD Inadvertent Release Plan, if applicable. Local pollution prevention and spill response procedures will be included in the SWPPP submitted to state agencies for the portions of the land-disturbing activity covered by the Virginia Pollutant Discharge Elimination System permit.

Short-term potential for accidental releases from onshore construction vehicles or equipment. Construction vehicles and equipment may be accessing regulated areas during construction activities and will be refueled and potentially serviced. The Company proposes to implement the following measures to avoid, minimize, and mitigate impacts:

- Accidental spills or releases of oils or other hazardous wastes will be managed through the Oil Spill Response Plan, as detailed in Appendix I;
- During construction, access will be restricted to existing paved roads and approved access roads at wetland and stream crossings, where possible;
- Access through wetlands and waterbodies will be restricted to identified construction sites, access roads, and work zones; and
- Onshore refueling and/or maintenance of construction equipment and vehicles will be conducted outside sensitive resource areas to the extent practicable.

Short-term impacts due to accidental spills and/or releases offshore. During construction, water quality has the potential to be impacted through the introduction of pollutants, including oil and fuel spills and releases; for example, from grout used to seal the monopile to the transition piece. Project-related construction vessels also have the potential to release oil and fuels.

Project-related vessels will be subject to U.S. Coast Guard (USCG) wastewater and discharge regulations and will operate in compliance with oil spill prevention and response plans that meet USCG requirements. Specifically, all Project vessels will comply with USCG standards in U.S. territorial waters to legally discharge uncontaminated ballast and bilge water, and standards regarding ballast water management. While outside of the 5.6 km (3 nautical mile [nm]) state-border/No-Discharge Zone (NDZ), vessels will deploy a USCG-certified marine sanitation device with certifications displayed. While inside of the 5.6 km state-border/NDZ, vessels will take normal vessel procedures to close off marine sanitation device-effluence discharge piping and redirect it to onboard 'Zero-Discharge Tanks' for the appropriate disposal either at dock or outside of an NDZ. Additionally, all vessels less than 24.1 m (79 ft) will comply with the Small Vessel General Permit issued by EPA on 10 Sep 2014 for compliance with National Pollutant Discharge Elimination System permitting. Prevention and response measures for accidental spills and releases are further described in Appendix I Oil Spill Response Plan.

4.2.2.2 Operations and Maintenance

During operations, the potential impacts to water quality may include the following:

- Long-term effects due to offshore foundations and associated scour protection;
- Short-term change in water quality due to oil spills or accidental release of fluids from vessels required during operations; and
- Long-term effects due to stormwater runoff.

Long-term effects due to offshore foundations and associated scour protection. During operations, scour around WTG and ESP foundations may cause potential impacts to water quality through the formation of suspended sediment plumes. The relatively low current velocities in the Wind Development Area, combined with scour mitigation, will limit scour potential around foundations. Furthermore, scour is not expected to occur around the offshore export and inter-array cables where the cable burial target depth is achieved.

Scour around foundations is dependent on water currents, wave action, and water depths, and scour depth can range from 0.3 times the pile diameter to 2.0 times the pile diameter or greater. Water currents are typically the largest indicator of the amount of expected scour (van der Tempel et al. 2004). In general, studies have shown the maximum scour depth around most piles is 1.3 times the diameter of the pile (DNV GL 2016; Whitehouse et al. 2011). The Project's foundations will be in deeper water with typical current speeds of 0.2 meters per second (Appendix M Sediment Transport Modeling Report), and piles located in these conditions have minimal scour (Epsilon Associates, Inc. 2018; Nielsen et al. 2014; Whitehouse et al. 2011).

Several studies have shown that most scour tends to occur within the first month of installation (Harris et al. 2011; van der Tempel et al. 2004). However, scouring is a continuous process that can change over a period of years (Harris et al. 2011; Whitehouse et al. 2011). In addition, large storms with strong currents can temporarily increase the scour rate (Harris et al. 2011; Whitehouse et al. 2011; van der Tempel et al. 2004). For some piles, backfilling occurs in the scour hole around the pile when there are changes in current conditions (Peterson 2014).

As necessary, the Company will install scour protection around foundations to further minimize effects of local sediment transport. Proper scour protection, which usually consists of a layer of small-sized rock and gravel topped with a layer of larger rocks placed immediately after installation, can reduce scour (Peterson 2014; Whitehouse et al. 2011). Edge scour is related to the size of the rock and the depth and tapering of the protection, with smaller rock and shallower protections with more tapering resulting in less edge scour (Peterson 2014). Edge scour has been shown to be approximately 0.12 times the diameter of the pile (Whitehouse et al. 2011), and depending on the scour protection and currents, it could be half of that value (Peterson 2014; van der Tempel et al. 2004). In some areas, specifically in deep areas and those with small waves, scour is minimal and scour protection can be foregone (Whitehouse et al. 2011).

Short-term change in water quality due to oil spills or accidental release of fluids from vessels required during operations. During operations, water quality has the potential to be impacted through the introduction of pollutants from vessels performing operations and maintenance (O&M) work, including oil and fuel spills and releases. Project-related vessels will be subject to USCG wastewater and discharge regulations and will operate in compliance with oil spill prevention and response plans that meet USCG requirements. Specifically, all Project vessels will comply with USCG standards in U.S. territorial waters to legally discharge uncontaminated ballast and bilge water, and standards regarding ballast water management. While outside of the 5.6 km state-border/NDZ, vessels will deploy a USCG-certified marine sanitation device with certifications displayed. While inside of the 5.6 km state-border/NDZ, vessels will take normal vessel procedures to close off marine sanitation device-effluence discharge piping and redirect it to onboard 'Zero-Discharge Tanks' for the appropriate disposal either at dock or outside of an NDZ. Additionally, all vessels less than 24.1 m (79 ft) will comply with the Small Vessel General Permit issued by EPA on 10 Sep 2014 for compliance with National Pollutant Discharge Elimination System permitting.

Prevention and response measures for accidental spills and releases are further described in Appendix I Oil Spill Response Plan.

Long-term effects due to increased stormwater runoff. The presence of a new onshore substation may increase the stormwater runoff volume and peak flow due to changes of the land cover from an undeveloped vegetated site to a more compacted surface with less vegetation. Changes in land use may increase the pollutant load over existing conditions and impact water quality. If not properly managed, increased peak flows may cause increased channel erosion or flooding downstream of the onshore substation. The onshore substation will be required to meet stormwater requirements for the state and Virginia Beach, which will control stormwater runoff based on state and local requirements. On-site stormwater control features may be required, and if so will be inspected and cleaned to remove debris or excess vegetation that may impede the designed functionality. The inspection schedule will be detailed in the SWPPP or appropriate Operations Plan.

4.2.2.3 Decommissioning

Impacts resulting from decommissioning of the Project are expected to be similar or less than those experienced during construction. Decommissioning techniques are further expected to advance during the useful life of the Project. A full decommissioning plan will be provided to BOEM for approval prior to decommissioning activities, and potential impacts will be re-evaluated at that time.

4.3 Air Quality

This section describes the air environment within and surrounding the Project Area, which includes the Wind Development Area, export cable corridors, and the onshore substation site. Potential impacts to air quality resulting from construction, operations, and decommissioning of the Project are discussed. Avoidance, minimization, and mitigation measures proposed by the Company are also described in this section.

Other assessments detailed within this COP that are related to air quality include:

- Air Emissions Calculations and Methodology (Appendix N).

The Project's WTGs, once operational, will not generate air emissions. Rather, electricity generated by the WTGs may displace electricity generated by higher-polluting fossil fuel-powered plants and reduce emissions from the PJM Interconnection LLC (PJM) power grid over the useful life of the Project.

For the purposes of this section, the review area for OCS air quality includes a 46.3-km (25-nm) buffer around the Wind Development Area within federal waters (e.g., stops at the 5.6 km [3 nm] state waters boundary), while the review area for Conformity Determination air quality includes the counties in which Project activities will occur, including construction and staging areas, O&M facilities, and onshore components.

4.3.1 Affected Environment

Emissions associated with construction, operations, and decommissioning of Project components will be subject to EPA regulations governing air quality, established under the Clean Air Act. These include the National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO), lead, nitrogen dioxide (NO_2), ozone, particulate matter (PM), and sulfur dioxide (SO_2; collectively known as "criteria pollutants"). The NAAQS for criteria pollutants are presented in Table 4.3-1. For certain criteria pollutants, the EPA sets primary standards to protect public health, as well as secondary standards to protect the environment and guard against other adverse effects of pollution, such as damage to crops and decreased visibility (EPA 2016).

Certain criteria pollutants are emitted directly into the atmosphere, while others are formed by chemical reactions. For example, ozone is formed in the atmosphere by reactions between volatile organic compounds (VOCs) and nitrogen oxides (NO_X), which includes nitric oxide (NO), NO_2, and other NO_X. In this context, VOCs and NO_X, referred to as ozone precursors, are regulated by the EPA to achieve ambient ozone reductions. Similarly, particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) can be formed by chemical reactions between SO_2, NO_X, VOCs, and ammonia; these precursors are also regulated by the EPA. Particulate matter less than 10 microns in diameter (PM_{10}) is also regulated under its own standard.

The EPA monitors compliance with the NAAQS through a network of air pollution monitoring stations. If monitored ambient concentrations do not exceed the NAAQS, the area is designated an "attainment area" and no further action is required. If ambient concentrations exceed the NAAQS for a given pollutant, the area is designated a "nonattainment area" for that pollutant. States are required to develop implementation plans to bring each nonattainment area into compliance with the NAAQS. Once a nonattainment area demonstrates compliance with the NAAQS standard, the EPA will designate the area as attainment and classify it as a "maintenance area" (EPA 2020a).

The EPA also regulates pollutants not covered by the NAAQS, including hazardous air pollutants (HAPs) and greenhouse gases (GHGs). HAPs are pollutants known or suspected to cause adverse health and environmental effects (EPA 2017). GHGs are gases that create a "greenhouse effect" by trapping heat in the atmosphere. Common GHGs include carbon dioxide (CO_2), methane, and nitrous oxide (EPA 2020b). In the U.S., CO_2 accounted for 81 percent of all GHG emissions in 2018 (EPA 2020c). The EPA has not established ambient air quality standards for HAPs or GHGs. However, emissions of these pollutants are regulated at the national and state level through emissions standards and permit requirements.

Table 4.3-1 National Ambient Air Quality Standards

Pollutant	Average Time	Standard
$PM_{2.5}$	24 hours 1 year 1 year	98th percentile concentration averaged over 3 years ≤ 35 μg/m^3 Annual mean, averaged over 3 years ≤ 12.0 μg/m^3 (primary) Annual mean averaged over 3 years ≤ 15.0 μg/m^3 (secondary)
PM_{10}	24 hours	150 μg/m^3, not to be exceeded more than once per year on average over 3 years
Ozone	8 hours	4th highest daily maximum value, averaged over 3 years ≤ 0.070 ppm
NO_2	1 hour 1 year	98th percentile daily maximum, averaged over 3 years ≤ 0.100 ppm Not to exceed 0.053 ppm
SO_2	1 hour 3 hours	99th percentile daily maximum, averaged over 3 years ≤ 0.075 ppm 0.5 ppm, not to be exceeded more than once per year
CO	1 hour 8 hours	35 ppm, not to be exceeded more than once per year 9 ppm, not to be exceeded more than once per year
Lead	Rolling 3-month average	Not to exceed 0.15 μg/m^3
Source: 40 CFR Part 50 Notes: μg/m^3 = micrograms per (standard) cubic meter ppm = parts per million (by volume)		

4.3.1.1 Outer Continental Shelf Air Regulations

For emission sources and activities on the OCS, the EPA regulates air quality through the regulations established under 40 CFR Part 55. An "OCS source," as defined by Section 328 of the Clean Air Act (at 42 United States Code § 7627(a)(4)(c)), includes the following: (i) any equipment, activity, or facility that emits, or has the potential to emit, any air pollutant; (ii) is regulated or authorized under the OCS Lands Act (43 United States Code § 1331); and (iii) is located on the OCS or in or on waters above the OCS. This includes vessels that are permanently or temporarily attached to the seabed (40 CFR § 55.2).

In addition to the federal OCS air regulations, the OCS sources operating within 46.3 km (25 nm) of the seaward boundary of a state are subject to the requirements applicable to the attainment designation of the Corresponding Onshore Area, as determined by the EPA. North Carolina is likely to be the Corresponding Onshore Area for the Project, since the nearest point of land to the Wind Development Area is located in Currituck County, North Carolina. The Commonwealth of Virginia may also submit a petition to the EPA, requesting to be designated as the Corresponding Onshore Area. If Virginia were designated as the Corresponding Onshore Area, the Project would instead be subject to Virginia's applicable air quality requirements.

4.3.1.2 General Conformity Determination and National Environmental Policy Act Review

Under the EPA's General Conformity rule, federal agencies must demonstrate that proposed actions comply with the NAAQS. None of the jurisdictions where emissions are currently anticipated to occur during construction or operations are designated as nonattainment or maintenance areas with respect to any current NAAQS standard. In nonattainment or maintenance areas, the proposed actions must conform to the applicable state implementation plan, and in attainment areas, proposed actions must not cause new violations of the NAAQS or increase the frequency or severity of previous violations (EPA 2020a). In accordance with 40 CFR Part 51 Subpart W and 40 CFR Part 93 Subpart B, BOEM must issue a General Conformity Determination stating if construction and operations of the Project will conform with applicable state and/or federal implementation plans. The General Conformity thresholds are presented in Table 4.3-2 and only apply to nonattainment areas or maintenance areas.

Table 4.3-2 General Conformity Thresholds

Pollutant	Designation	Tons per year
Nonattainment Area (NAA) Thresholds		
Ozone (VOCs or NO_X precursors)	Extreme NAA	10
	Severe NAA	25
	Serious NAA	50
	Other ozone NAA outside an ozone transport region	100
	Other ozone NAAs inside an ozone transport region	50 (VOCs)
		100 (NO_X)
CO	All NAAs	100
SO_2	All NAAs	100
NO_2	All NAAs	100
PM_{10}	Moderate NAA	100
	Serious NAA	70
$PM_{2.5}$ (direct emissions, SO_2, NO_X, VOCs, and ammonia)	Moderate NAA	100
	Serous NAA	70
Lead	All NAAs	25
Maintenance Area Thresholds		
Ozone (VOCs or NO_X precursors)	All maintenance areas	100 (NO_X)
	Maintenance areas outside an ozone transport region	100 (VOCs)
	Maintenance areas inside an ozone transport region	50 (VOCs)
CO	All maintenance areas	100
SO_2	All maintenance areas	100
NO_2	All maintenance areas	100
PM_{10}	All maintenance areas	100
$PM_{2.5}$ (direct emissions, SO_2, NO_X, VOCs, and ammonia)	All maintenance areas	100
Lead	All maintenance areas	25
Source: 40 CFR § 93.153(b)		

A portion of the emissions during construction and operations of the Project are anticipated to occur in the Norfolk-Virginia Beach-Newport News (Hampton Roads) Air Quality Control Region (AQCR), which is a maintenance area for the 1997 8-hour ozone standard. VDEQ is currently in the process of updating its State Implementation Plan, which includes a maintenance plan for the Hampton Roads AQCR, and has invited the Company to submit estimated emissions for inclusion in the State Implementation Plan. Accordingly, the Company has provided VDEQ with estimated annual and ozone season emissions of NO_X and VOC that would occur inside the boundaries of the Hampton Roads AQCR during construction and operations of the Project.

The nearest onshore area to the Wind Development Area is located in Currituck County, North Carolina, which is not designated as a nonattainment or maintenance area for any current NAAQS standard. The majority of Project-related emissions will occur in the Wind Development Area.

4.3.1.3 North Carolina

The North Carolina Department of Environmental Quality (NCDEQ), Division of Air Quality, is responsible for protecting and improving air quality in the State of North Carolina, and for administering state and federal air permitting programs. The Division of Air Quality operates 57 ambient air quality monitoring stations across the state, including six monitoring stations in the NCDEQ's Washington Region of the state in which Currituck County is located. These monitoring stations measure ambient concentrations of criteria pollutants, as well as VOCs and a selection of hazardous air pollutants. The NCDEQ has published historical data summaries showing that the 2017 through 2019 design values for ozone, SO_2, NO_x, PM_{10}, and $PM_{2.5}$ are all less than the NAAQS values (NCDEQ 2020).

In January 2019, the NCDEQ published a GHG inventory of actual emissions from 1990 through 2017, with projected future emissions through 2030. North Carolina had net GHG emissions of 116 million metric tons of CO_2 equivalents (CO_2e), representing a 24 percent reduction from the peak year of 2005. Net GHG emissions are also projected to decrease slightly over the next decade (NCDEQ 2019).

4.3.1.4 Virginia

In Virginia, the VDEQ Air Pollution Control Board is responsible for ensuring clean air and managing the state and federal air pollution control programs. A division of the Air Pollution Control Board, the Office of Air Quality Monitoring, collects ambient air quality data for criteria pollutants, VOCs, and hazardous air pollutants from a total of 38 ambient air quality monitoring stations in the state (VDEQ 2019). Five of these stations are within the Hampton Roads AQCR where construction and operations for the Project are anticipated to occur. Ambient monitoring data for the most recent three-year period studied (2016 through 2018) indicate that concentrations for all pollutants have either decreased or remained unchanged (VDEQ 2019).

The VDEQ has not published a GHG inventory for Virginia, but a new CO_2 budget trading regulation was finalized in 2019 to reduce CO_2 emissions from fossil fuel fired electric generating facilities. The VDEQ Air and Renewable Energy Division is also developing a framework to limit leakage of methane from natural gas infrastructure and landfills (VDEQ 2020).

4.3.2 Impacts Analysis for Construction, Operations, and Decommissioning

The potential impact-producing factors resulting from the construction, operations, and decommissioning of the Project are based on the maximum design scenario from the PDE (see Chapter 3 Description of Proposed Activity). For air quality, the maximum design is represented by the monopile foundation option with a total of 70 positions, as this would represent the greatest number of installation days and vessel transits. A Summary of Applicant-Proposed Avoidance, Minimization, and Mitigation Measures is provided in Appendix FF.

4.3.2.1 Construction

During construction, the potential impacts to air quality may include the following:

- Direct, short-term increase in Project-related air emissions.

Direct, short-term increase in Project-related air emissions. Short-term impacts to air quality may occur during construction of the Project. The primary emission sources during construction include marine vessels, with the majority of emissions occurring within the Wind Development Area and along the offshore export cable corridor. A smaller amount of emissions resulting from marine vessel transits are anticipated to occur in Virginia state waters, with Norfolk, Virginia assumed to be the local port location for crew changes and onshore staging of materials. Onshore construction activities will occur in Virginia Beach, Virginia with emissions from low-sulfur diesel-powered construction equipment used during construction of the onshore substation, switching station, onshore export cables, and landfall. Emissions of fugitive dust may also result from onshore construction activities.

An inventory of anticipated construction emissions is provided in Appendix N Air Emissions Calculations and Methodology and includes detailed assumptions for engine ratings, operating hours, number of trips, and the emission factors that underlie the estimated emissions. The emission inventory assumes the use of low-sulfur fuels and the use of vessels that meet the applicable marine and/or stationary source emission standards. A detailed summary of the avoidance, minimization, and mitigation measures that will be employed is provided below.

Table 4.3-3 through Table 4.3-5 present the potential construction emissions as calendar year totals, broken down by geographic area for the purpose of evaluating applicability for OCS air permitting and General Conformity. The emission totals in each geographic area include total emissions from both onshore and offshore construction, including vessel transits. OCS air permit emissions (indicated as “Inside OCS radius”) include activities that meet the definition of an OCS source under 40 CFR § 55.2, as well as emissions from marine vessels while traveling to and from the Project when within 46.3 km (25 nm) of the Wind Development Area boundary. General Conformity air emissions include onshore construction activities, as well as vessel emissions that occur within the state seaward boundary, which extends outward to 5.6 km (3 nm) from shore. A portion of vessel transit emissions are both beyond the state seaward boundary and beyond 46.3 km (25 nm) from the Wind Development Area, and these emissions are indicated as occurring in “federal waters outside the OCS radius.” These emissions are not subject to either OCS air permitting or General Conformity and are presented for National Environmental Policy Act purposes only.

The following tasks were assumed to occur in each year of construction activity:

- Year 1 (2027): Onshore substation, switching station, onshore export cables, and landfall; and offshore installation of WTG foundations and transition pieces, ESP foundation and topside, and offshore export and inter-array cables.
- Year 2 (2028): Completion of onshore construction, including onshore substation, switching station, onshore export cables, and landfall; offshore construction, including installation of WTG foundations and transition pieces, inter-array cables, ESP topside commissioning, and WTG installation and commissioning.
- Year 3 (2029): Completion of offshore construction, including WTG commissioning, and partial O&M activity (conservatively assumed to be equal to the maximum full-year potential O&M emissions).

Table 4.3-3 Construction Emissions for Calendar Year 2027 (tons)

Geographic Area	VOC	NO_X	CO	PM/ PM_{10}	$PM_{2.5}$	SO_2	HAP	GHG (CO_2e)
Onshore (Virginia Beach)	**VOC**	**NO_X**	**CO**	**PM_{10}**	**$PM_{2.5}$**	**SO_2**	**HAPs**	8,911
State waters (Hampton Roads AQCR)	1.40	22.74	6.59	0.85	0.83	0.06	0.30	6,836
Federal waters outside OCS radius	4.62	104.26	41.48	4.71	4.57	0.88	0.47	3,357
Inside OCS radius	2.27	49.92	21.53	2.45	2.38	0.30	0.23	362,288
Total, All Areas	**269.40**	**6,683.28**	**1,158.79**	**159.52**	**154.73**	**159.45**	**25.02**	**381,392**

Table 4.3-4 Construction Emissions for Calendar Year 2028 (tons)

Geographic Area	VOC	NO_X	CO	PM/ PM_{10}	$PM_{2.5}$	SO_2	HAP	GHG (CO_2e)
Onshore (Virginia Beach)	0.56	8.62	2.44	0.37	0.36	0.03	0.12	3,866
State waters (Hampton Roads AQCR)	1.19	28.22	11.28	1.19	1.15	0.23	0.12	1,853
Federal waters outside OCS radius	0.72	16.93	6.77	0.71	0.69	0.14	0.07	1,112
Inside OCS radius	61.71	1,523.18	278.34	37.42	36.29	35.44	5.73	83,306
Total, All Areas	**64.18**	**1,576.95**	**298.83**	**39.68**	**38.49**	**35.84**	**6.05**	**90,136**

Table 4.3-5 Construction Emissions for Calendar Year 2029 (tons)

Geographic Area	VOC	NO_X	CO	PM/ PM_{10}	$PM_{2.5}$	SO_2	HAP	GHG (CO_2e)
Onshore (Virginia Beach)	0.06	4.41	7.28	0.07	0.07	4.14E-03	0.23	2,236
State waters (Hampton Roads AQCR)	3.59	72.33	30.02	2.89	2.80	1.06	0.33	5,595
Federal waters outside OCS radius	0.98	20.48	10.99	0.96	0.93	0.17	0.10	1,731
Inside OCS radius	13.19	208.11	106.35	11.73	11.38	3.00	1.22	18,797
Total, All Areas	**17.82**	**305.33**	**154.64**	**15.64**	**15.18**	**4.24**	**1.88**	**28,358**

During construction, the following avoidance, minimization, and mitigation measures will be implemented to mitigate the impacts described above. Vessels constructed on or after 01 Jan 2016 will meet Tier III NO_X requirements when operating within the North American Emission Control Area (extending 370.4 km [200 nm] from shore) established by the International Maritime Organization (IMO). Project-related diesel-powered equipment will use ultra-low-sulfur diesel fuel, as required under 40 CFR § 80.510(b). Project-related vessels will use low-sulfur diesel fuel where possible and will meet or be less than the maximum fuel sulfur content requirement of 1,000 parts per million (ppm) by weight established under 40 CFR § 80.510(k). Project-related vessels will comply with applicable EPA, or equivalent, emission standards. The Project will collect information necessary to determine actual emissions from Project-related vessels, in accordance with the requirements set forth in the Record of Decision and/or the issued OCS air permit. Such information may include the horsepower ratings of all propulsion and auxiliary engines, duration of time operating in state waters and/or inside the OCS permit radius, load factors, and fuel consumption for Project-related vessels. Project-related vehicles, stationary diesel engines, and/or nonroad diesel engines at the staging site will comply with applicable state regulations regarding idling. In Virginia, 9VAC5-40-5670(C) limits the idling of diesel-powered motor vehicles to 10 minutes unless the operation of heat or air conditioning is needed.

4.3.2.2 Operations and Maintenance

During operations, the potential impacts to air quality may include the following:

- Direct, long-term increase in Project-related air emissions;
- Long-term displacement of emissions produced by the PJM electric grid.

Direct, long-term increase in Project-related air emissions. Long-term impacts to air quality may occur during O&M of the Project. The primary emission sources during operations include marine vessels and helicopters used to service the offshore Project components, with the majority of emissions occurring within the Wind Development Area and along the offshore export cable corridor. A smaller amount of emissions resulting from marine vessel and helicopter transits are anticipated to occur in Virginia state waters, with Norfolk, Virginia assumed to be the local port location for crew changes and onshore staging of materials, and Virginia Beach Airport assumed to be the departure and arrival point for helicopter flights. Stationary source emissions will also result from the operation of emergency and non-emergency generator engines located on the ESP, from the operation of emergency generator engines at the onshore substation and onshore switching station, and from gas-insulated switchgear, which are located on the ESP, on the WTG towers, at the onshore substation, and at the switching station, and which release small amounts of the GHG sulfur hexafluoride.

As detailed in Appendix N Air Emissions Calculations and Methodology, a number of vessels are anticipated to be used for O&M activities, including a service operations vessel, crew transfer vessels, and environmental monitoring vessels. For certain maintenance and repair activities, several heavy lift vessels, cable survey vessels, and scour protection repair vessels may be used on an infrequent basis.

Table 4.3-6 presents the potential annual O&M emissions, broken down by geographic area for the purpose of evaluating applicability for OCS air permitting and General Conformity. Although partial O&M activities are expected to occur during the final year of construction activity in 2029, full-year O&M activities will commence in 2030, and therefore, this year represents the maximum potential emissions for ongoing O&M. The emission totals in each geographic area include total emissions from both onshore and offshore activities, including vessel transits. OCS air permit emissions (indicated as “Inside OCS radius”) include activities that meet the definition of an OCS source under 40 CFR § 55.2, as well as emissions from marine vessels while traveling to and from the Project when within 46.3 km (25 nm) of the Wind Development Area boundary. General Conformity air emissions include vessel emissions that occur within the state seaward boundary, which extends outward to 5.6 km (3 nm) from shore. A portion of vessel transit emissions are both beyond the state seaward boundary and beyond 46.3 km (25 nm) from the Wind Development Area, and these emissions are indicated as occurring in “federal waters outside the OCS radius.” These emissions are not subject to either OCS air permitting or General Conformity and are presented for National Environmental Policy Act purposes only.

Table 4.3-6 Operations and Maintenance Emissions for Calendar Year 2030 Onward (tons)

Geographic Area	VOC	NO_X	CO	PM/ PM_{10}	$PM_{2.5}$	SO_2	HAP	GHG (CO_2e)
Onshore (Virginia Beach)	0.06	4.41	7.28	0.07	0.07	4.14E-03	0.23	2,236
State waters (Hampton Roads AQCR)	3.51	70.25	28.96	2.80	2.72	1.06	0.32	5,446
Federal waters outside OCS radius	0.94	19.23	10.35	0.91	0.88	0.17	0.09	1,642
Inside OCS radius	12.37	193.35	101.95	10.84	10.52	3.00	1.15	18,885
Total, All Areas	**16.88**	**287.24**	**148.53**	**14.62**	**14.18**	**4.23**	**1.80**	**28,209**

During operations, the following avoidance, minimization, and mitigation measures will be implemented to mitigate the impacts described above. Vessels constructed on or after 01 Jan 2016 will meet Tier III NO_X requirements when operating within the North American Emission Control Area (extending 370.4 km [200 nm] from shore) established by the IMO. Project-related diesel-powered equipment will use ultra-low-sulfur diesel fuel, as required under 40 CFR § 80.510(b). Project-related vessels will use low-sulfur diesel fuel where possible and will meet or be less than the maximum fuel sulfur content requirement of 1,000 ppm by weight established under 40 CFR § 80.510(k). Project-related vessels will comply with applicable EPA, or equivalent, emission standards. The Project will collect all information necessary to determine actual emissions from Project-related vessels, in accordance with the requirements set forth in the Record of Decision and/or the issued OCS air permit. Such information may include the horsepower ratings of all propulsion and auxiliary engines, duration of time operating in state waters and/or inside the OCS permit radius, load factors, and fuel consumption for Project-related vessels.

Long-term displacement of emissions produced the PJM electric grid. The Project could result in lower emissions from fossil-fuel electric generation facilities in the region. In addition, the Project would decrease the regional reliance on fossil fuels and enhance the reliability and diversity of the energy mix in Virginia.

To support this assessment, a representative project of approximately 800 megawatts, with a projected average annual net capacity factor of 44.44 percent, was evaluated. This results in a projected net energy production of 3,125,810 megawatt-hours per year during the useful life. This renewable electric generation has the potential to displace emissions that would otherwise be produced by conventional fossil-fuel electric generation facilities in the area.

PJM is the regional transmission organization that regulates distribution of wholesale electric power for virtually the entire Commonwealth of Virginia, as well as for a large surrounding area including the entirety of Delaware, Maryland, New Jersey, Pennsylvania, Ohio, and West Virginia, along with portions of Illinois, Indiana, Kentucky, and Michigan. PJM has published system-wide emission rates of CO_2, SO_2, and NO_x for the five most recent years (through 2019) for marginal generating units during both on-peak and off-peak hours, as well as average emission rates for the entire PJM system (PJM 2020). “Marginal” generating units are those units that are dispatched on a short-term basis to meet rapid changes in local or system-wide demand, and are typically the last units to start up and first units to shut down, since they have higher production costs than base-load units, which operate continuously. In addition, marginal generating units often have higher emission rates than base-load units.

Table 4.3-7 presents the PJM marginal and system-wide average annual emission rates for CO_2, SO_2, and NO_x. For the purpose of estimating potential displaced emissions as a result of a representative 800-megawatt project, it is more appropriate to look at PJM system average rates rather than marginal rates, since the power output will vary from hour to hour based on prevailing wind speeds, and will not necessarily align with either peak or off-peak hours.

Table 4.3-7 PJM Marginal and System Average Emission Rates for 2019

Operating Scenario	CO_2 (lb/MWh)	SO_2 (lb/MWh)	NO_x (lb/MWh)
Marginal on-peak (annual)	1,268	0.65	0.72
Marginal off-peak (annual)	1,171	0.57	0.47
PJM system average (annual)	851	0.55	0.45
Note: lb/MWh = pounds per megawatt-hour			

As shown in Table 4.3-8, a representative 800-megawatt project has the potential to displace significant quantities of CO_2, SO_2, and NO_x emissions from existing fossil-fuel generating units each year during its operational useful life. These displaced emissions would be much greater than the new emissions produced by marine vessels used to support O&M, and would also contribute significantly to reducing overall GHG emissions in the entire PJM service area.

Table 4.3-8 Potential Displaced Annual Emissions from Regional Fossil-Fueled Electric Generators

Pollutant	CO_2	SO_2	NO_x
Displaced emissions (tons per year)	1,330,032	860	703

4.3.2.3 Decommissioning

Impacts resulting from decommissioning of the Project are expected to be similar to or less than those experienced during construction. Decommissioning techniques are further expected to advance during the useful life of the Project. A full decommissioning plan will be provided to BOEM for approval prior to decommissioning activities, and potential impacts will be re-evaluated at that time.

4.4 In-Air Acoustic Environment

This section describes the regulatory framework for in-air sound, as applicable to the Project, and the affected in-air sound environment. Potential impacts to the in-air sound environment resulting from construction, operations, and decommissioning of the Project are discussed. Avoidance, minimization, and mitigation measures proposed by the Company are also described in this section. It is the Company's objective to successfully demonstrate compliance with all applicable noise regulations and requirements. However, exceptions and/or variances may be sought, if needed, for construction-related activities.

Other resources and assessments detailed within this COP that are related to sound include:

- Underwater Acoustic Environment (Section 4.5);
- In-Air Acoustic Assessment (Appendix O); and
- Underwater Acoustic Assessment (Appendix P).

There are no federal or state noise regulations directly applicable to assessing the sound impacts resulting from the Project at offsite receptors. However, construction and operational worker's exposure to Project-related sound impacts is regulated through the Occupational Health and Safety Act of 1970.

The onshore substation site (housing the onshore substation, interconnection lines, and switching station), and landfall will be located in Virginia Beach, Virginia. There are local noise ordinances for the proposed onshore substation site and landfall (see below). The Company will comply with these ordinances unless work outside of these timeframes is authorized by the City of Virginia Beach.

The acoustic modeling for the Project was conducted with the Cadna-A® sound model from DataKustik GmbH (version 2020 MR1; DataKustik GmbH 2020). The outdoor sound propagation model is based on the International Organization for Standardization 9613 standard (ISO 1993, 1996). It is used by acoustic engineers to accurately describe sound emission and propagation from complex facilities (i.e., more than one sound source) and in most cases yields conservative results of operational sound levels in the surrounding community. These model predictions are accurate to within 1 decibel (dB) of calculations based on the ISO 9613 standard.

Virginia Beach, Virginia, Municipal Code 23 art. II (City of Virginia Beach 2020) includes provisions regulating sounds considered to be a hazard to public health, welfare, peace and safety, and quality of life, which are applicable to the Project. Virginia Beach, Virginia, Municipal Code 23-69 provides absolute noise limits for both the nighttime and daytime periods, and also states that construction activities are exempt from daytime provisions:

- *Nighttime.* No person shall permit, operate or cause any source of sound to create a sound level that can be heard in another person's residential dwelling during the hours between 10:00 p.m. and 7:00 a.m. in excess of 55 A-weighted decibels (dBA) when measured inside the residence at least four (4) feet from the wall nearest the source, with doors and windows to the receiving area closed.
- *Daytime.* No person shall permit, operate or cause any source of sound to create a sound level in another person's residential dwelling during the hours between 7:00 a.m. and 10:00 p.m. in excess of 65 dBA when measured inside the residence at least four (4) feet from the wall nearest the source, with doors and windows to the receiving area closed.
    - *Exemptions.* The following activities or sources of noise shall be exempt from the daytime prohibition set forth in subsection (b) of this section:
        - Activities related to the construction, repair, maintenance, remodeling or demolition, grading or other improvement of real property.

Additionally, Virginia Beach, Virginia, Municipal Code 23-71 cites limits to noise activities within proximity to defined noise-sensitive areas (NSAs) and limits construction activities to occur between 7:00 a.m. and 9:00 p.m., as follows:

- *Noise-sensitive areas.* The making of any unreasonably loud and raucous noise within two hundred (200) feet of any school, place of worship, court, hospital, nursing home, or assisted-living facility while the same is being used as such, that substantially interferes with the workings of the institution.
- *Construction equipment.* The operation of any bulldozer, crane, backhoe, front loader, pile driver, jackhammer, pneumatic drill, or other construction equipment between the hours of 9:00 p.m. and 7:00 a.m. except as provided in section 23-67 above, or as specifically deemed necessary and authorized by a written document issued by the city manager or his designee.

4.4.1 Affected Environment

The affected environment, as described below, is defined as the coastal and onshore areas that have the potential to be directly and/or indirectly affected by the construction, operations, and decommissioning of the Project. This includes the onshore export cables, onshore substation site and export cable landfall. Offshore Project facilities were considered, but the significant separation distance between those facilities and onshore NSAs precludes the possibility of material noise impacts.

Ambient sound levels are characterized by different sound levels. To account for these sound fluctuations, environmental sound is commonly described in terms of energy-averaged sound level over a given measurement period (L_{eq}). Another common metric used to describe ambient noise levels over a 24-hour period, including a 10 dB penalty during the nighttime period, is L_{dn}. The L_{eq} and L_{dn} metrics are expressed in dBA.

The ambient acoustic environment within the onshore review area, which encompasses the immediate surroundings of the onshore substation site, onshore export cables, and landfall location, is largely influenced by flyover noise from jets and vehicular traffic. Noise from jets associated with Naval Air Station Oceana, Naval Auxiliary Landing Field Fentress, and Norfolk International Airport, approximately 4 km, 13.4 km, and 26.7 km from the onshore substation site boundary respectively, are also present through the daytime and nighttime at the onshore substation site location.

Since Virginia Beach is home to those naval facilities, it is part of the Department of Defense's Air Installations Compatible Use Zones Program, which is a program used to balance the need for aircraft operations and community concerns. The goal of the Air Installations Compatible Use Zones Program is to protect the health, safety, and welfare of those living near a military airport while preserving its defense-flying mission. Air Installations Compatible Use Zones guidelines define zones of high noise and accident potential and recommend uses compatible within these zones. The Department of Defense measures noise exposure using the day-night average sound levels (DNL). The DNL noise metric averages noise events that occur over a 24-hour period. Aircraft operations conducted at night (10:00 p.m. to 7:00 a.m.) are weighted because people are more sensitive to noise during normal sleeping hours when ambient noise levels are lower. The DNL contours on the Air Installations Compatible Use Zones maps reflect the noise exposure in the surrounding communities and the fact that noise impacts diminish with distance from the airfield. DNL contours do not reflect the noise of individual aircraft events. DNL contours are used to assess average long-term noise exposure rather than the impact of a single event. As of 2005, around the Naval Air Station Oceana, almost 4,856 hectares are of residential use within noise contours above the 65 dBA DNL and approximately 1,214 hectares are in the highest noise zone above 75 dBA DNL. Around the Naval Auxiliary Landing Field Fentress, almost 1,214 hectares are of residential use within noise contours above the 65 dBA DNL and approximately 809 hectares are in the highest noise zone above 75 dBA DNL (Edaw Inc. 2005).

HMMH (2018) provides ambient noise levels within 0.8 km of the onshore substation site. The study shows a 24-hour L_{dn} level of 66 dBA at this location, which would be equivalent to a 59.6 dBA L_{eq}. However, the study removes airplane noise from this ambient level; and as such, the actual ambient level is expected to be higher.

HMMH (2018) did not include ambient measurements in proximity to the landfall. To estimate the ambient levels at this location, the population density method used by the Federal Transit Administration (FTA 2018) was used. According to the U.S. Census Bureau (2010), the City of Virginia Beach has an average of 1,759 people per square mile. The Federal Transit Administration methodology for estimating existing sound levels shows that a population density of this size results in sound levels of approximately 54 dBA L_{dn}, which is equivalent to 47.6 dBA L_{eq}.

4.4.2 Impacts Analysis for Construction, Operations, and Decommissioning

The potential impact-producing factors resulting from the construction, operations, and decommissioning of the Project are based on the maximum design scenario from the PDE (see Chapter 3 Project Description). For in-air sound, the onshore maximum design scenario is represented by the construction and installation of the onshore export cables, onshore substation, switching station, and landfall activities. Offshore, the maximum design scenario is determined by the maximum number of monopile foundations. A Summary of Applicant-Proposed Avoidance, Minimization, and Mitigation Measures is provided in Appendix FF.

4.4.2.1 Construction

During construction, the potential impacts to the in-air sound environment may include the following:

- Short-term elevated in-air noise levels associated with HDD at the export cable landfall;
- Short-term elevated in-air noise levels associated with construction of the onshore substation, switching station, and onshore export cables;
- Short-term elevated in-air noise levels associated with impact pile driving of WTG and ESP foundations; and
- Short-term elevated in-air noise levels associated with offshore support vessels.

Short-term elevated in-air noise levels associated with HDD at the export cable landfall. Landfall of the export cables at the landing site will be completed using HDD techniques. The Company may install one or more scenarios to limit the impact on both the community and the environment. HDD construction was evaluated for up to three scenarios with two HDD sites per scenario. The sequence of activity is yet to be determined. HDD construction would be exempt from the City of Virginia Beach noise regulations during daytime operations (7 a.m. to 9 p.m.). Where practicable, the Company will look to avoid nighttime operations (9 p.m. to 7 a.m.); however, under some circumstances, they may be deemed necessary due to program, safety, or engineering needs. Should it be deemed necessary, the appropriate regulatory will be notified to seek a waiver from any restriction.

Horizontal directional drilling construction equipment consists of HDD drill rigs and auxiliary support equipment, including electric mud pumps, portable generators, mud mixing and cleaning equipment, forklifts, loaders, cranes, trucks, and portable light plants. Table 4.4-1 lists the HDD components analyzed. Once the HDD and pull-back is completed, noise from the landfall area will be limited to typical construction activities associated with equipment such as tracked graders, backhoes, and pickup trucks. Nighttime work may be required for cable landfall activities.

Table 4.4-1 HDD Equipment Sound Levels

HDD Equipment Component	Sound Level without Acoustical Treatment (dBA)
HDD drill rig and power unit	102
Drilling mud mixer/recycling unit	90
Mud pumping unit	102
Generator set, 100 kilowatts	100
Generator set, 200 kilowatts	102
Vertical sump pump	75

Horizontal directional drilling construction activities, at the landfall, will occur during the daytime period unless a situation arises that would require operations to continue into the night or deemed acceptable from the appropriate regulatory authority. The HDD construction activities will require a 24-hour operational period phase, in which case during nighttime operations, only the HDD drill rig, power unit, light banks, and associated equipment needed for their safe operation will be used. Where additional equipment is needed, approval from the appropriate regulatory authority will be sought.

The predicted sound levels at the closest NSAs for each HDD scenario are summarized in Table 4.4-2. Distances are shown for each NSA relative to the closest operating HDD per scenario.

Table 4.4-2 Sound Levels (dBA) during HDD Construction

NSA	HDD 1 and HDD 2		HDD 3 and HDD 4		HDD 5 and HDD 6	
	Distance to NSA (m)	Received Sound Level at NSA (dBA)	Distance to NSA (m)	Received Sound Level at NSA (dBA)	Distance to NSA (m)	Received Sound Level at NSA (dBA)
NSA L-1	160	60	188	59	204	57
NSA L-2	127	61	157	60	189	58
NSA L-3	78	67	113	64	151	62
NSA L-4	196	57	231	55	267	52
NSA L-5	128	61	102	63	73	64
NSA L-6	146	61	114	62	79	64
NSA L-7	118	63	83	65	33	69
NSA L-8	116	63	82	65	31	70
NSA L-9	114	63	84	65	50	67
NSA L-10	142	61	110	63	68	65

The NSA locations, relative to the HDD operations, are presented in Figure 4.4-1. If necessary near NSAs, subject to regulatory requirements and stakeholder engagement, the Company will install moveable temporary noise barriers as close to the sound sources as possible, which have been shown to effectively reduce sound levels by 5 to 15 dBA.

Short-term elevated in-air noise levels associated with construction of the onshore substation, switching station, and onshore export cables. The construction of the onshore substation, switching station, and the onshore export cables will result in a temporary increase in sound levels near active construction resulting from the use of construction equipment. The noise levels resulting from construction activities will vary greatly depending on factors such as the type of equipment and the operations being performed, and could be periodically audible from off-site locations at certain times.

The EPA has published data on the L_{eq} sound levels for typical construction phases (EPA 1971). Following the EPA method, sound levels were projected at four different distances that would encompass the neighborhoods surrounding the onshore substation, switching station, and export cables locations. This calculation conservatively assumes all equipment operating concurrently onsite for the specified construction phase and no sound attenuation for ground absorption or onsite shielding by the existing buildings or structures. The results of these calculations are presented in Table 4.4-3 and show estimated construction sound levels will vary depending on construction phase and distance, with the highest levels expected in proximity to the closest neighborhoods during the site grading and compaction phase.

During the equipment installation phase, a helicopter may be used for transmission line installation activities. The primary sources of wideband acoustic energy from helicopters are the main and tail rotor. Helicopters generally fly at low altitudes; therefore, potential temporary increases to ambient sound levels would occur in the area where helicopters are operating as well as along their flight path. Helicopter operations will only occur in the daytime.

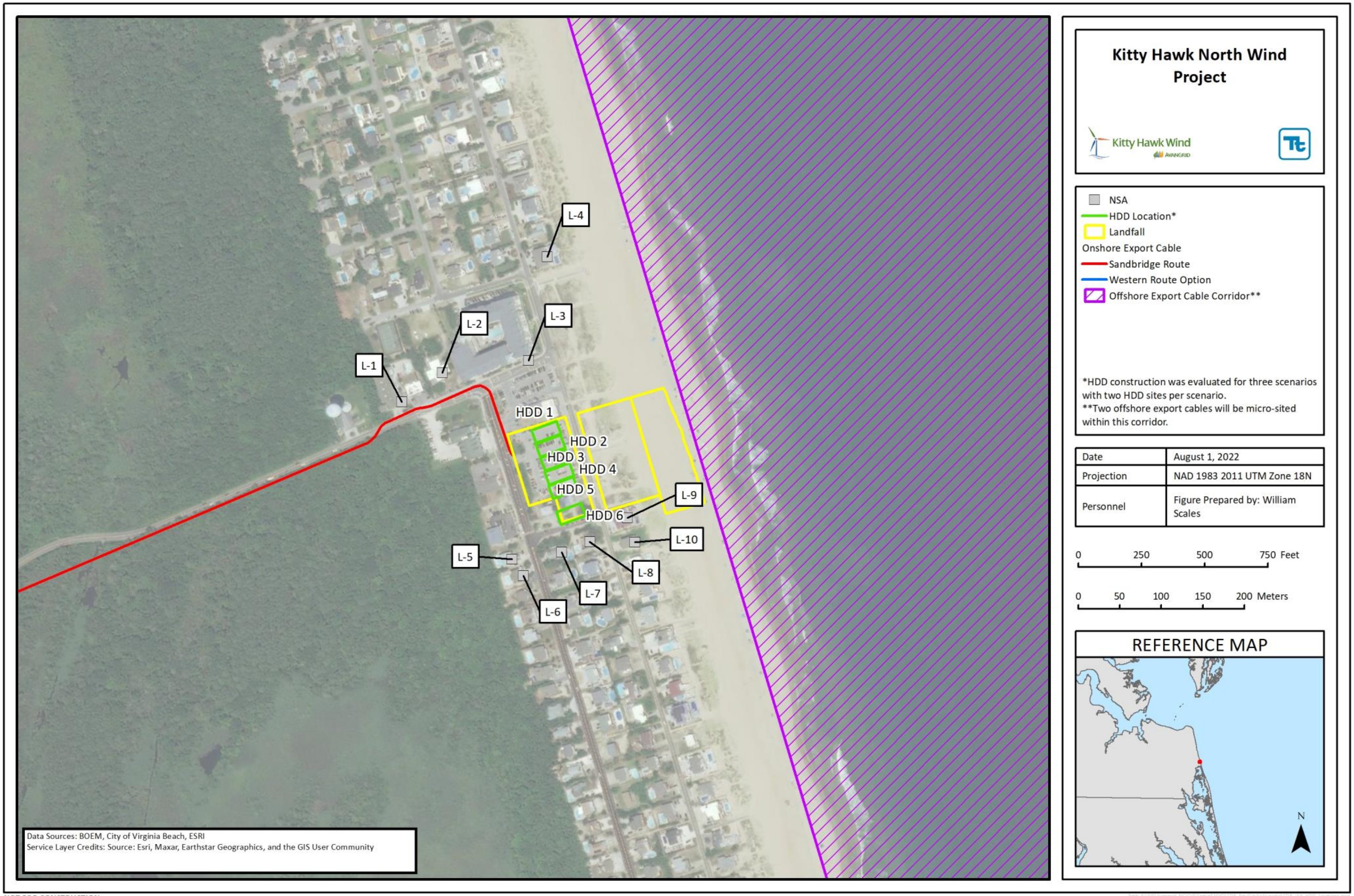


Figure 4.4-1 NSA Locations Relative to the HDD Operations

Table 4.4-3 General Construction Noise Levels (dBA)

Phase No.	Construction Phase	Example Construction Equipment	Equipment Noise Level at 15 meters, dBA	Operational Usage Factor (%)	Composite Noise Level, dBA			
					At 15 meters	At 76 meters	At 152 meters	At 305 meters
1	Site clearing	Tracked dozer	88	40	85	71	50	65
		Wheeled tractor	80	40				
		Wheeled loader	80	40				
		Water truck	80	40				
2	Site grading and compaction	Scraper	85	40	88	73	68	62
		Tracked dozer	88	40				
		Grader	82	40				
		Roller-compactor	75	20				
		Wheeled loader	80	40				
		Backhoe-loader	80	40				
		Water truck	80	40				
3	Trenching and foundations	Excavator	80	40	87	73	67	61
		Backhoe-loader	80	40				
		Skid-steer loader	70	40				
		Wheeled loader	80	40				
		Auger rig	85	20				
		Tracked dozer	88	40				
		Cement mixer truck	80	40				
		Water truck	80	40				
4	Equipment pads	Wheeled loader	80	40	83	70	64	58
		Mobile crane	82	16				
		Forklift	80	40				
		Flatbed truck	75	40				
		Dump truck	80	40				
		Cement mixer truck	80	40				
		Water truck	80	40				
5	Equipment installation	Compressor	81	40	84	70	64	58
		Mobile crane	82	16				
		Forklift	80	40				
		Wheeled loader	80	40				
		Dump truck	80	40				
		Specialty truck	75	40				
		Water truck	80	40				

In addition to the above-listed construction equipment, pile driving may be needed to install the foundation for the onshore substation and switching station. The pile driving technique, vibratory or impact, has not been selected at this stage of Project design. In the event that vibratory pile driving is selected, noise levels would be expected to be consistent with those reported during the excavation phase of construction. If impact pile driving is required, higher noise levels may be produced for temporary short-term periods.

Due to the character of the impulsive sound they produce, impact pile drivers are not typically analyzed in combination with non-impulsive construction sound sources such heavy-duty vehicles. Noise is generated from pile drivers from both the ram striking the pile as well as the operating steam, air, or diesel exhaust as it is exhausted from the cylinder (this is not present with hydraulic impact hammers). Assuming an approximate impact rate of 1,400 blows per minute, a sound pressure level of 111 dBA at 6 m is estimated. Assuming a load or usage factor of 20 percent, it is expected that sound from pile driving would attenuate to 70 dBA at a distance of approximately 305 m and would attenuate to below 60 dBA within 1.6 linear km of this construction activity, depending on meteorological and topographical effects.

As these levels are similar to existing daytime sound levels shown in HMMH (2018), construction-related sounds are not expected to create a noise nuisance condition within the onshore review area. The Company will limit onshore construction activities to daytime periods, to the extent practicable, unless a situation arises that would require operations to continue into the night. Where use of equipment is needed, approval from the appropriate regulatory authority will be sought. While construction is exempt from the City of Virginia Beach noise regulations during the day, the Company proposes to implement the following measures to avoid, minimize, and mitigate impacts:

- Construction will be limited to daytime period, to the extent practicable;
- Construction equipment will be well-maintained, and vehicles using internal combustion engines equipped with mufflers will be regularly checked to ensure they are in good working order;
- Quieter-type adjustable backup alarms will be used for vehicles as feasible;
- Construction equipment will be located within the confines of a temporary construction easement;
- If noise issues are identified, the Company will install moveable temporary noise barriers as close to the sound sources as possible, which have been shown to effectively reduce sound levels by 5 to 15 dBA; and
- A Project hotline will be made available to help actively address Project-related issues in a timely manner.

Short-term elevated in-air noise levels associated with impact pile driving of WTG and ESP foundations. During construction, pile driving of the WTG and ESP foundations will generate noise (see Section 4.5 Underwater Acoustic Environment and Appendix P Underwater Acoustic Assessment for details on the level of impact anticipated underwater). Acoustic modeling was conducted for noise produced from impact pile driving monopile foundations at the closest and furthest representative foundation locations relative to the shoreline, as this is anticipated to represent the average impact scenario for this activity. Pile driving activities are modeled to produce sound power levels of 87 dBA in air at a distance of 122 m with a corresponding sound power level at the source of 137 dBA (USDOT 2012).

The highest predicted received sound level at any onshore location during pile driving is less than 30 dBA, which is well below all applicable noise regulations. Given the extended distances between the Project and coastal shorelines (approximately 44 and 60 km for the two locations modeled), no negative impacts are expected. Offshore, marine users may be potentially disturbed due to the sound levels generated from pile driving. However, these installation activities are anticipated to be short-term. Furthermore, for safety reason, marine users are not expected to be in the immediate area during installation.

Short-term elevated in-air noise levels associated with offshore support vessels. During construction, Project-related vessels will be utilized to transport personnel and materials and to install offshore Project components. The IMO (1981, 1975) has established vessel noise limits of received noise levels to 70 dBA at designated listening stations at the navigation bridge and windows during normal sail and operational conditions. In addition, the IMO further limits noise to 75 dBA at external areas and rescue stations with recommended limits 5 dBA lower. The vessels used for nearshore work and vessels transiting between Project ports and the Wind Development Area will comply with these IMO noise standards, as applicable.

Nearshore, offshore export cable installation activities will move along the cable laterally. Therefore, no shoreline NSAs will be exposed to significant noise levels for an extended period of time. Due to the relatively short duration, it is not anticipated that construction activities associated with offshore export cable installation will cause any significant impact in the communities located along the shoreline.

4.4.2.2 Operations and Maintenance

During operations, the potential impacts to the in-air sound environment may include the following:

- Long-term elevated in-air sound levels associated with onshore substation and switching station operations;
- Short-term elevated in-air sound levels associated with O&M activities; and
- Long-term elevated in-air sound levels associated with the WTGs and ESP operations and, as necessary, use of sound signals.

Long-term elevated in-air sound levels associated with the onshore substation and switching station operations. During operations, the onshore substation and switching station equipment is anticipated to generate operational sound. Sound modeling of onshore substation and switching station components can be found in Appendix O In-Air Acoustic Assessment. The onshore substation and switching station were modeled as a conceptual layout, as the final layout is not available at this time. Therefore, it is possible that the final warranty sound specifications could vary slightly. As shown in Table 4.4-4, compliance is demonstrated with the most conservative applicable regulatory limit, the City of Virginia Beach nighttime noise limit of 55 dBA L_{eq}. However, please note that modeling results represent predicted sound levels at the outside of the NSAs, and the City of Virginia Beach 55 dBA nighttime limit is actually applicable as measured inside the residence. Due to sound attenuation provided by the residential structure, received sound levels inside the NSA residences would be even lower than the modeled results given in Table 4.4-4.

Table 4.4-4 Onshore Substation and Switching Station Predicted Nighttime Noise Levels at the Closest Noise Sensitive Areas

Location	Distance (m)	Regulatory Limit (dBA L_{eq})	Modeling Result (dBA L_{eq})
NSA-S-1	75	55	53
NSA-S-2	168	55	50
NSA-S-3	290	55	47
NSA-S-4	259	55	45
NSA-S-5	152	55	46
NSA-S-6	152	55	46
NSA-S-7	152	55	46
NSA-S-8	152	55	46
NSA-S-9	152	55	45
NSA-S-10	152	55	45
NSA-S-11	152	55	45

Location	Distance (m)	Regulatory Limit (dBA L_{eq})	Modeling Result (dBA L_{eq})
NSA-S-12	152	55	45
NSA-S-13	152	55	45
NSA-S-14	152	55	44
NSA-S-15	152	55	44
NSA-S-16	152	55	44
NSA-S-17	152	55	44
NSA-S-18	183	55	43
NSA-S-19	457	55	38
NSA-S-20	427	55	39
NSA-S-21	351	55	39
NSA-S-22	457	55	39
NSA-S-23	488	55	39
NSA-S-24	549	55	41

Note:
Modeling results represent predicted sound levels at the outside of the NSAs, and the City of Virginia Beach 55 dBA nighttime limit is actually applicable as measured inside the residence. Due to sound attenuation provided by the residential structure, received sound levels inside the NSA residences would be even lower than the modeled results given in Table 4.4 4.

During operations, the Project will be in compliance with relevant Virginia Beach noise requirements. Therefore, no mitigation is currently proposed.

Short-term elevated in-air sound levels associated with O&M activities. Project inspections and maintenance will occur regularly during the useful life of the Project but are not expected to result in significant noise generation. General maintenance would include on-site component safety inspections, including possible repair or replacement of equipment. Vehicular traffic noise generated during onshore Project maintenance and inspection will be of short duration and is not expected to result in adverse noise impacts. Project-related vessels and/or helicopters will be utilized to transport personnel to offshore Project components for maintenance activities but are not expected to result in significant noise generation. As with construction, these vessels transiting between Project ports and the Wind Development Area will comply with IMO noise standards, as applicable.

Long-term elevated in-air sound levels associated with WTGs and ESP operations and, as necessary, use of sound signals. During operations, an increase in in-air sound levels resulting from the WTGs and ESP is expected; however, it will be below audibility thresholds at all coastal areas due to the distance from shore as well as the masking effect (i.e., sound of waves and wind will mask the sound generated by the WTG rotation and ESP equipment). Offshore, marine users may be impacted due to the higher sound levels resulting from WTGs and ESP operation, depending on their distance relative to the structures, but this effect will be well below relevant Occupational Safety and Health Act health and safety requirements, even in immediate proximity of the WTGs and ESP. As necessary, sound signals specified by the USCG may be used during the operations of the WTGs and ESP.

4.4.2.3 Decommissioning

Impacts resulting from decommissioning of the Project are expected to be similar or less than those experienced during construction. Decommissioning techniques are further expected to advance during the useful life of the Project. A full decommissioning plan will be provided to BOEM for approval prior to any decommissioning activities, and potential impacts will be re-evaluated at that time.

4.5 Underwater Acoustic Environment

This section describes the regulatory framework for underwater sound, as applicable to the Project, and the affected underwater acoustic environment. Potential impacts to the underwater sound environment resulting from construction, operations, and decommissioning of the Project are discussed. Avoidance and minimization measures proposed by the Company are also described in this section.

Other resources and assessments detailed within this COP that are related to sound include:

- In-Air Acoustic Environment (Section 4.4);
- Benthic Resources and Finfish, Invertebrates, and Essential Fish Habitat (Section 5.4);
- Marine Mammals (Section 5.5);
- Sea Turtles (Section 5.6);
- In-Air Acoustic Assessment (Appendix O); and
- Underwater Acoustic Assessment (Appendix P).[4]

4.5.1 Regulatory Context

The Marine Mammal Protection Act (MMPA) of 1972 provides for the protection of all marine mammals. The MMPA prohibits, with certain exceptions, the "take" of marine mammals (NOAA Fisheries 2005). NOAA Fisheries has jurisdiction for overseeing the MMPA regulations as they pertain to most marine mammals. However, for the purposes of this Project Area, the U.S. Fish and Wildlife Service has jurisdiction over a select group of marine mammals, including manatees and otters.

Generally, NOAA Fisheries is responsible for issuing take permits under the MMPA, upon a request, for authorization of incidental but not intentional "taking" of small numbers of marine mammals by U.S. citizens or agencies who engage in a specified activity (other than commercial fishing) within a specified geographical region. The U.S. Fish and Wildlife Service would issue a take permit for manatees, but the criteria for evaluating the potential acoustic impacts to manatees has not yet been developed by the agency. The term *'take'*, as defined pursuant to the MMPA (16 United States Code 1362(13)), means *"to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal."* The term *'harass'* was then further defined in the 1994 amendments to the MMPA, with the designation of two levels of harassment: Level A and Level B.

By definition, Level A harassment is "*any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock*", while Level B harassment defined as "*any act of pursuit, torment, or annoyance which has the potential to disturb (but not injure) a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering*." In reference to the underwater acoustic environment, NOAA Fisheries defines the threshold level for Level B harassment at 160 decibels referenced at 1 micropascal (dB re 1 μPa) sound pressure level (SPL) for impulsive sound, averaged over the duration of the signal, and at 120 dB re 1 μPa for non-impulsive sound, with no relevant acceptable distance specified.

NOAA Fisheries provided guidance for assessing the impacts of anthropogenic sound on marine mammals under their regulatory jurisdiction, including whales, dolphins, seals, and sea lions. The updated 2018 guidance (NOAA Fisheries 2018) specifically defines marine mammal hearing groups, develops auditory weighting functions, and identifies the received levels, or acoustic threshold levels, above which individual marine mammals are predicted to experience changes in their hearing sensitivity (permanent threshold shift [PTS] or temporary threshold shift [TTS]) for acute, incidental exposure to underwater sound.

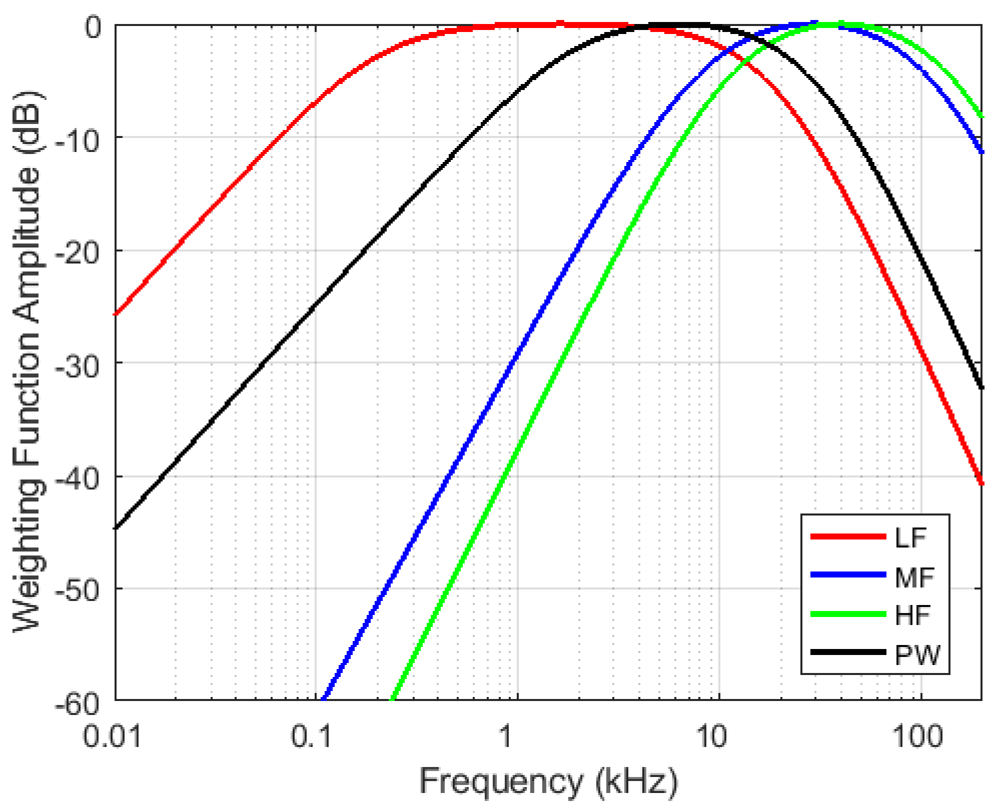
[4] The Company is updating Appendix P Underwater Acoustic Assessment, and it will be provided to BOEM in 2023.

Under this guidance, any occurrence of PTS constitutes a Level A, or injury, *'take'*. The sound emitted by man-made sources may induce TTS or PTS in an animal in two ways: (1) peak sound pressure levels (L_{PK}) expressed in dB re 1 µPa may cause damage to the inner ear, and (2) the accumulated sound energy that the animal is exposed to (cumulative sound exposure levels [SEL_{cum}], expressed in dB re 1 $\mu Pa^2 \cdot s$) over the entire duration of a discrete or repeated noise exposure has the potential to induce auditory damage if it exceeds the relevant threshold levels.

Research has demonstrated that the frequency content of the sound plays a role in causing damage. In other words, sounds that are outside of the hearing range of the animal would unlikely affect its hearing, while the sound energy within the hearing range could be harmful. Under the NOAA Fisheries 2018 guidance, recognizing that marine mammal species do not have equal hearing capabilities, five hearing groups of marine mammals are defined as follows:

- ***Low-frequency (LF) Cetaceans*** - Consists of the baleen whales (mysticetes) with a collective generalized hearing range of 7 hertz (Hz) to 35 kilohertz (kHz).
- ***Mid-frequency (MF) Cetaceans*** - Includes most of the dolphins, all toothed whales except for *Kogia* spp., and all the beaked whales with a generalized hearing range of approximately 150 Hz to 160 kHz. (Renamed high-frequency cetaceans by Southall et al. [2019] because their best hearing sensitivity occurs at frequencies of several tens of kHz or higher).
- ***High-frequency (HF) Cetaceans*** - Incorporates all the true porpoises, plus *Kogia* spp. and two species of *Lagenorhynchus* (Peale's and hourglass dolphins) with a generalized hearing range estimated from 275 Hz to 160 kHz. (Renamed very high-frequency cetaceans by Southall et al. [2019] since some species have best sensitivity at frequencies exceeding 100 kHz).
- ***Phocids Underwater (PW)*** - Consists of true seals with a generalized underwater hearing range from 50 Hz to 86 kHz. (Renamed phocids carnivores in water by Southall et al. [2019]).

Within these generalized hearing ranges, the ability to hear sounds varies with frequency, as demonstrated by examining audiograms of hearing sensitivity (Southall et al. 2019; NOAA Fisheries 2018). To reflect higher noise sensitivities at particular frequencies, auditory weighting functions that reflected the best available data on hearing ability (composite audiograms), susceptibility to noise-induced hearing loss, impacts of noise on hearing, and data on equal latency were developed for each functional hearing group (NOAA Fisheries 2018). These weighting functions are applied to individual sound received levels to reflect the susceptibility of each hearing group to noise-induced threshold shifts, which is not the same as the range of best hearing (Figure 4.5-1).



Source: NOAA Fisheries 2018

Figure 4.5-1 Auditory Weighting Functions for Cetaceans (LF, MF, and HF Species) and Pinnipeds (PW Species)

NOAA Fisheries (2018) defined acoustic threshold levels at which PTS and TTS are predicted to occur for each hearing group for impulsive and non-impulsive signals (Table 4.5-1). These are presented in terms of dual metrics; SEL_{cum} and L_{PK}. The Level B harassment thresholds are also provided in Table 4.5-1. The TTS threshold is defined as 20 dB less than the PTS threshold for non-impulsive criteria.

Table 4.5-1 Acoustic Threshold Levels for Marine Mammals

Hearing Group	Impulsive Sounds			Non-Impulsive Sounds		
	PTS Onset	TTS Onset	Behavior	PTS Onset	TTS Onset	Behavior
LF cetaceans	219 dB (L_{PK}) 183 dB SEL_{cum}	213 dB (L_{PK}) 168 dB SEL_{cum}	160 dB SPL RMS	199 dB SEL_{cum}	179 dB SEL_{cum}	120 dB SPL RMS
MF cetaceans	230 dB (L_{PK}) 185 dB SEL_{cum}	224 dB (L_{PK}) 170 dB SEL_{cum}		198 dB SEL_{cum}	178 dB SEL_{cum}	
HF cetaceans	202 dB (L_{PK}) 155 dB SEL_{cum}	196 dB (L_{PK}) 140 dB SEL_{cum}		173 dB SEL_{cum}	153 dB SEL_{cum}	
PW	218 dB (L_{PK}) 185 dB SEL_{cum}	212 dB (L_{PK}) 170 dB SEL_{cum}		201 dB SEL_{cum}	181 dB SEL_{cum}	

Sources: Southall et al. 2019; NOAA Fisheries 2018

For sea turtles, NOAA Fisheries has considered injury onset beginning at a root mean squared sound pressure level (SPL RMS) of 180 dB re 1 μPa to prevent mortalities, injuries, and most auditory impacts, as well as behavioral responses from impulsive sources, such as impact pile driving at 166 dB re 1 μPa SPL RMS, which has elicited avoidance behavior of sea turtles (Table 4.5-2; Blackstock et al. 2017) in the past. There is currently limited information available on the effects of noise on sea turtles and the hearing capabilities of sea turtles are still poorly understood. However, the NOAA Fisheries Greater Atlantic Regional Fisheries Office recently updated the prescribed behavioral response threshold for sea turtles to 175 dB re 1 μPa SPL RMS (NOAA Fisheries 2020).

Table 4.5-2 Acoustic Threshold Levels for Fish and Sea Turtles, Injury and Behavior

Hearing Group	Injury	Behavior
Fish	206 dB (L_{PK}) 187 dB SEL_{cum} (Fish mass ≥ 2g) 183 dB SEL_{cum} (Fish mass < 2g)	150 dB SPL RMS
Sea turtles	180 dB SPL RMS	166 dB SPL RMS 175 dB SPL RMS
Sources: NOAA Fisheries 2020; Blackstock et al. 2017; Department of the Navy 2017; Stadler and Woodbury 2009		

In a cooperative effort between federal and state agencies, interim criteria were developed to assess the potential for injury to fish and sea turtles exposed to pile driving sounds. Noise thresholds have been established by the Fisheries Hydroacoustic Working Group, assembled by NOAA Fisheries. These thresholds have subsequently been adopted by NOAA Fisheries.

Recently, NOAA Fisheries applied these standards when updating its assessment of the potential effects of Endangered Species Act-listed fish species and sea turtles exposed to elevated levels of underwater sound produced during pile driving (NOAA Fisheries 2020). These noise thresholds are based on sound levels that have the potential to produce injury or illicit a behavioral response from fish (Table 4.5-2).

A Working Group organized under the American National Standards Institute also developed sound exposure guidelines for fish and sea turtles (Table 4.5-3 below; Popper et al. 2014). They identified three types of fish according to how they could potentially be affected by underwater sound. These categories include fish with no swim bladder or other gas chamber (e.g., dab and other flatfish), fish with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g., salmonids), and fish with a swim bladder that is involved in hearing (e.g., channel catfish).

4.5.2 Affected Environment

The affected environment, as described below, is defined as the offshore underwater acoustic environment that has the potential to be directly and/or indirectly affected by the construction, operations, and decommissioning of the Project. This includes the Wind Development Area and the offshore export cable corridor.

4.5.2.1 Existing Ambient Conditions

Noise in the ocean associated with natural sources is generated by physical and biological processes as well as anthropogenic sources such as shipping. Examples of physical noise sources are tectonic seismic activity, wind, and waves; examples of biological noise sources are the vocalizations of marine mammals and fish. There can be a strong minute-to-minute, hour-to-hour, or seasonal variability in sounds from biological sources. The ambient noise for frequencies above one kHz is due largely to waves, wind, and heavy precipitation (Simmonds et al. 2004). Surface wave interaction and breaking waves with spray have been identified as significant sources of noise. Wind induced bubble oscillations and cavitation are also near-surface noise sources. At areas within distances of 8 to 10 km of the shoreline, surf noise will be prominent in the frequencies ranging up to a few hundred Hz (Richardson et al. 2013).

Table 4.5-3 Acoustic Threshold Levels for Fish and Sea Turtles, Impulsive and Non-Impulsive

Hearing Group	Impulsive Sounds			Non-Impulsive Sounds	
	Mortality and Potential Mortal Injury	Recoverable Injury	TTS	Recoverable Injury	TTS
Fish without swim bladders	> 213 dB (L_{PK}) > 219 dB SEL_{cum}	> 213 dB (L_{PK}) > 216 dB SEL_{cum}	>> 186 dB SEL_{cum}	--	--
Fish with swim bladder not involved in hearing	> 207 dB (L_{PK}) 210 dB SEL_{cum}	> 207 dB (L_{PK}) 203 dB SEL_{cum}	>> 186 dB SEL_{cum}	--	--
Fish with swim bladder involved in hearing	> 207 dB (L_{PK}) 207 dB SEL_{cum}	207 dB (L_{PK}) 203 dB SEL_{cum}	186 dB SEL_{cum}	170 dB SPL RMS	158 dB SPL RMS
Sea turtles	> 207 dB (L_{PK}) 210 dB SEL_{cum} 232 dB (L_{PK}) PTS 204 dB SEL_{cum} PTS	(N) High (I) Low (F) Low	226 dB (L_{PK}) 189 dB SEL_{cum}	220 dB SEL_{cum}	200 dB SEL_{cum}
Eggs and larvae	> 207 dB (L_{PK}) > 210 dB SEL_{cum}	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	--	--

Sources: NOAA Fisheries 2020; Department of the Navy 2017; Popper et al. 2014.
Notes:
N = near (tens of meters)
I = intermediate (hundreds of meters)
F = far (thousands of meters)
-- = not applicable

A considerable amount of background noise may also be caused by biological activities. Aquatic animals generate sounds for communication, echolocation, prey manipulation, and as by-products of other activities such as feeding and breeding. Biological sound production usually follows seasonal and diurnal patterns, dictated by variations in the activities and abundance of the vocal animals. The frequency content of underwater biological sounds ranges from less than 10 Hz to beyond 150 kHz. Source levels show a great variation, ranging from below 50 dB to more than 230 dB SPL RMS re 1 µPa at 1 m. Likewise, there is a significant variation in other source characteristics such as the duration, temporal amplitude, frequency patterns, and the rate at which sounds are repeated (Wahlberg 2012). Typical underwater noise levels show a frequency dependency in relation to different noise sources; the classic curves are given in Wenz (1962).

Anthropogenic noise sources can consist of contributions related to industrial development, offshore oil industry activities, naval or other military operations, and marine research. A predominant contributing anthropogenic noise source is generated by commercial ships and recreational watercraft. Noise from these vessels dominates coastal waters and emanates from the ships' propellers and other dynamic positioning propulsion devices such as thrusters. The sound generated from main engines, gearboxes, and generators transmitted through the hull of the vessel into the water column is considered a secondary sound source to that of vessel propulsion systems, as is the use of sonar and depth sounders, which occur at generally high frequencies and attenuate rapidly. Typically, shipping vessels produce frequencies below one kHz, although smaller vessels such as fishing, recreational, and leisure craft may generate sound at somewhat higher frequencies (Simmonds et al. 2004).

There is limited publicly available site-specific ambient sound information collected within the offshore Project Area. NOAA's SoundMap, which is a mapping tool that provides maps of the temporal, spatial, and frequency characteristics of man-made underwater noise resulting from various activities, was consulted. Pressure fields associated with different contributors of underwater sound (i.e., shipping and passenger vessels) were summed and the sound pressure level values at frequencies ranging from 50 to 800 Hz were presented for various water column depths. Within the lower 50 Hz frequency range, underwater sound pressure levels were greatest, varying between approximately 80 to 100 dB depending on water depth and proximity to the coastline. The sound contribution and magnitude decreases with increasing frequency, indicating that the noise from shipping and passenger vessels is largely focused within the low frequency range.

4.5.3 Impacts Analysis for Construction, Operations, and Decommissioning

The potential impact-producing factors resulting from the construction, operations, and decommissioning of the Project are based on the maximum design scenario from the PDE (see Chapter 3 Description of Proposed Activity). For the underwater acoustic environment, the maximum design is represented by the installation of the 13.5-m diameter monopile. Underwater acoustic modeling is being completed using dBSea, and site-specific parameters were incorporated to reflect the Project Area including bathymetry, geoacoustic sediment properties, and seasonal sound speed profiles. The representative acoustic modeling scenarios will be derived from descriptions of the expected construction activities and operational conditions developed by the Project design and engineering teams. More detailed information regarding the underwater acoustic model and modeling inputs will be presented in the Underwater Acoustic Assessment (Appendix P). A pile drivability assessment was completed to inform the required hammer energy and number of strikes based on additional sediment data and a refined understanding of ground conditions in the Wind Development Area. A Summary of Applicant-Proposed Avoidance, Minimization, and Mitigation Measures is provided in Appendix FF.

Table 4.5-4 Underwater Acoustic Modeling Scenarios

Scenario	Description	Location (UTM Coordinates)	Hammer Energy (kilojoules)	Total Hammer Blows	Apparent Source Level a/
The representative acoustic modeling scenarios will be derived from descriptions of the expected construction activities and operational conditions developed by the Project design and engineering teams.					

4.5.3.1 Construction

During construction, the potential impacts to the underwater noise environment may include the following:

- Short-term increase in underwater noise levels associated with monopile and/or jacketed impact pile driving and/or vibratory activities required for the installation of WTG and ESP foundations;
- Short-term increase in underwater noise levels associated with drilling for installation of WTG and ESP foundations, if required;
- Short-term increase in underwater noise levels associated with offshore export and inter-array cable laying activities; and
- Short-term increase in underwater noise levels associated with Project-related vessels.

Short-term increase in underwater noise levels associated with monopile and/or jacketed impact pile driving activities required for the installation of WTG and ESP foundations. Three foundation options (monopile, piled jacket, and suction caisson jacket) are included in the PDE (see Section 3.2.3 WTG and ESP Foundations). As the maximum design scenario for underwater noise is generated by pile driving, only installation of the two piled foundation types will be considered in the underwater acoustic analysis. One monopile with a diameter of 13.5 m will be analyzed and one pin pile with a diameter of 4 m will be analyzed. A soft start and pile progression will also be incorporated into the model. Results will be provided in Appendix P.

Short-term increase in underwater noise levels associated with drilling for installation of WTG and ESP foundations, if required. If pile driving for the entire piling installation is not possible due to the presence of rock or hard soil in some lower part of the substrate, the drive and drill method may be used. If the pile meets refusal, the pile may be drilled out below the pile tip (a couple of meters). Then the piling will be re-established again and piled to its final depth. If refusal appears again, the drilling/driving will continue until the pile has reached its final position. If drilling is required, the maximum duration is expected to be 72 hours with drilling occurring almost continuously. Drilling may produce low-frequency noise that may contribute slightly to the overall ambient noise, with an estimated source level of 180 dB SEL. These estimated source levels are based on data captured from the underwater acoustic assessment completed in support of permitting the Virginia Offshore Wind Technology Advancement Project (Tetra Tech 2013). Potential sound impacts will be evaluated for drilling at the two representative foundation locations. Remaining consistent with the previous noise mitigation assumptions, an attenuation factor of 6 dB was applied to represent the expected effects of a bubble curtain or similar technology application. Results will be presented in Appendix P.

Short-term increase in underwater noise levels associated with offshore export and inter-array cable laying activities. Cable laying activities, including any pre-lay grapnel run or installation of cable protection, may result in a short-term increase in underwater noise levels. The underwater noise produced by subsea trenching operations depends on the equipment used and the nature of the seabed sediments, but will be predominantly generated by vessel thruster use (discussed below). In addition, there is the possibility that unexploded ordnance would need to be disposed of, including potential detonation. However, due to the uncertainty concerning both the potential for unexploded ordnance detonation and the variation in potential impacts depending on the size and type of ordnance, those impacts will be addressed, if necessary, through the NOAA Fisheries' Incidental Harassment Authorization process. As activities proceed in a linear fashion along the cable corridor, impacts will be limited to a certain portion of the corridor over the course of the installation campaign.

Short-term increase in underwater noise levels associated with Project-related vessels. During construction, vessels specifically designed for laying and burying cables on the seabed will be used offshore export and inter-array cable installation, which is proposed to be completed through the use of jet plow or trencher, mechanical plow or trencher, or free-lay and post-lay burial. Throughout the cable lay process, a dynamic positioning-enabled cable lay vessel will maintain its position (fixed location or predetermined track) by means of its propellers and thrusters using a Global Positioning System, which controls the ship's position by sending positioning information to an onboard computer that controls the thrusters. Thruster sound source levels may vary in part due to technologies employed and are not necessarily dependent on either vessel size, propulsion power, or the activity engaged. Dynamic positioning thruster noise is non-impulsive and continuous in nature, and is not expected to result in harassment. NOAA Fisheries has also previously indicated that they do not expect the use of directional thrusters to impact marine species in any material way as sound produced by this equipment is similar to that generated by transiting vessel, and no longer require that those activities be included in requests for an Incidental Harassment Authorization (communications cited in CSA Ocean Sciences 2018a, b, Tetra Tech 2018).

While dynamic positioning enabled cable lay vessels are expected to generate the highest level of vessel-related noise, there are other vessels used during construction that may also contribute to increases in sound level relative to the ambient underwater acoustic environment. These other vessels include those that are anchored such as jack-up barges, those in transit such as medium service vessels, and smaller vessels like tugboats and crew transfer/workboats. In comparison to dynamic positioning thruster noise, underwater noise emitted from other anchored and transiting vessels is expected to be relatively minimal.

In addition, the increase in Project vessel activity will not be a combined increase occurring all at once, but rather will be sporadic throughout the construction period (both in the 24-hour work period, and the season). It is unlikely that the noise impact of anchored vessels and vessel traffic associated with Project construction will result in a significant increase to the underwater acoustic environment.

4.5.3.2 Operations and Maintenance

During operations, the potential impacts to the underwater noise environment may include the following:

- Increase in underwater noise levels associated with WTG and ESP operations; and
- Increased intermittent underwater noise levels associated with Project O&M and Project-related vessels.

Increase in underwater noise levels associated with WTG and ESP operations. When the WTGs are operational, noise and vibration is transmitted into the sea by the structure of the tower itself, and manifests as low-frequency noise. Other sound transmission pathways are via the tower and the seabed, or through the air and air/water interface (Nedwell et al. 2004). A review of other published studies indicates that source levels from operating offshore wind turbines with monopile foundations show peak frequencies occurring predominantly below 500 Hz, and the apparent source level range from 140 to 153 dB re 1µPa at 1 m (Nedwell et al. 2004). Similar measurements by Nedwell et al. indicate the steady state background in an offshore oceanic environment also occurs within this frequency range, which implies masking effects. The available field data showed that although the absolute level of wind turbine noise increases with increasing wind speed, the noise level relative to background noise (i.e., from wave action, entrained bubbles) remained relatively constant. Furthermore, studies have shown the main impacts of noise and vibrations occur during the construction phases. Therefore, impacts to underwater sound levels due to Project operations are not expected to be significant.

Increase in intermittent underwater noise levels associated with Project O&M and Project-related vessels. During operations, underwater noise from Project-related operations and support vessel traffic is not anticipated to be greater than the ambient noise levels in the review area. Vessel traffic is expected to have an insignificant increase above the existing baseline conditions as a result of the Project. Vessel traffic will increase during operations mainly on account of the transportation of supplies and maintenance crews (See Section 7.3 Marine Transportation and Navigation). Given the amount of existing vessel traffic in the review area, the noise associated with supply vessels transiting to the offshore facilities will have a negligible contribution to the total ambient underwater sound levels. Similarly, nearshore vessel activity will be generally concentrated in established shipping channels and near industrial port areas, and will be consistent with the existing noise environment in those areas. Therefore, impacts from underwater sound due to Project-related vessel activity are not expected to be significantly greater than the existent ambient conditions.

As described in Section 3.3, infrequent maintenance may be required of major Project components. Impacts associated with these activities, and the associated vessels, is expected to similar or less than that described in Section 4.5.3.1.

4.5.3.3 Decommissioning

Impacts resulting from decommissioning of the Project are expected to be similar to or less than those experienced during construction. Decommissioning techniques are further expected to advance during the useful life of the Project. A full decommissioning plan will be provided to BOEM for approval prior to decommissioning activities, and potential impacts will be re-evaluated at that time.

4.6 References

See Table 4.6-1 for data sources used in the preparation of this chapter.

Table 4.6-1 Data Sources

Source	Includes	Available at	Metadata Link
BOEM	Lease Area	https://www.boem.gov/BOEM-Renewable-Energy-Geodatabase.zip	N/A
BOEM	State Territorial Waters Boundary	https://www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/ATL_SLA(3).aspx	http://metadata.boem.gov/geospatial/OCS_SubmergedLandsActBoundary_Atlantic_NAD83.xml
National Hydrography Dataset	Watershed (HUC10)	https://www.usgs.gov/core-science-systems/ngp/national-hydrography/access-national-hydrography-products	https://www.usgs.gov/core-science-systems/ngp/national-hydrography/watershed-boundary-dataset?qt-science_support_page_related_con=4#qt-science_support_page_related_con
NOAA	Territorial Sea (12-nautical mile limit)	http://maritimeboundaries.noaa.gov/downloads/USMaritimeLimitsAndBoundariesSHP.zip	https://inport.nmfs.noaa.gov/inport-metadata/NOAA/NOS/OCS/inport/xml/39963.xml
NOAA	National Data Buoy Center Buoy	https://www.ndbc.noaa.gov/stations.shtml	N/A

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