OCS Study
BOEM 2019-028

Field Observations During Wind Turbine Operations at the Block Island Wind Farm, Rhode Island

US Department of the Interior
Bureau of Ocean Energy Management
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DISCLAIMER

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REPORT AVAILABILITY

To download a PDF file of this report, go to the U.S. Department of the Interior, Bureau of Ocean Energy Management Data and Information Systems webpage (http://www.boem.gov/Environmental-Studies-EnvData/), click on the link for the Environmental Studies Program Information System (ESPIS), and search on 2019-028. The report is also available at the National Technical Reports Library at https://ntrl.ntis.gov/NTRL/.

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ABOUT THE COVER

Cover photo: Block Island Wind Farm Facility Wind Turbine 3 Construction (left panel) Wind Turbines 1–5 operating (right panel). Courtesy of HDR RODEO Team. Used with permission.

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List of Abbreviations and Acronyms

BIWF	Block Island Wind Farm
BOEM	Bureau of Ocean Energy Management
CTD	conductivity, temperature, and depth
dB	decibel(s)
ft	foot/feet
HLA	horizontal line array
Hz	Hertz
kHz	kilohertz
km	kilometer(s)
m	meter(s)
mi	mile(s)
mm	millimeter(s)
m/s	meter(s)/second
NMFS	National Marine Fisheries Service
PTS	Permanent Threshold Shift
RMS	root mean square
rpm	revolutions per minute
RODEO	Real-Time Opportunity for Development Environmental Observations
SPL	sound pressure level
TTS	Temporary Threshold Shift
VLA	vertical arrays
WHOI	Woods Hole Oceanographic Institution
WTG	wind turbine generator

Editorial Note

To facilitate presentation, review, and perusal of the large quantity of observations and data generated under Task Order M16PD00025, the task order deliverable was divided into the following four standalone documents:

1. **Field Observations during Wind Turbine Installation at the Block Island Wind Farm, Rhode Island (BOEM 2019-027) –** reports on the methods, observations, data analyses, results, and conclusions from environmental monitoring conducted at the BIWF under BOEM's RODEO Program during the *assembly of the wind turbine generator components (turbine towers, nacelles, and blades*).

2. **Field Observations during Wind Turbine Operations at the Block Island Wind Farm, Rhode Island (BOEM 2019-028) –** reports on the methods, data analyses, results, observations, and conclusions from environmental monitoring conducted at the BIWF under BOEM's RODEO Program during *turbine operations*.

3. **Underwater Acoustic Monitoring Data Analyses for the Block Island Wind Farm, Rhode Island (BOEM 2019-029) –** reports on the methods, observations, results, and conclusions from additional analyses of underwater acoustic monitoring data collected under BOEM's RODEO Program during the *pile driving for securing the turbine foundations to the seabed*.

4. **Benthic Monitoring During Wind Turbine Installation and Operation at the Block Island Wind Farm, Rhode Island (BOEM 2018-047) –** Published in 2018, this report presented the methods, data analyses, results, observations, and conclusions from benthic monitoring conducted in 2017 and 2018 at the Block Island Wind Farm (BIWF) under BOEM's RODEO Program.

Executive Summary

This report presents methods, data analyses, and results from the Bureau of Ocean Energy Management's Real-Time Opportunity for Development Environmental Observations Program environmental monitoring conducted within the Block Island Wind Farm Project Area during wind turbine operations. Visual observations of the operating turbines, airborne noise monitoring, and underwater sound monitoring were conducted[1]. Key results and conclusions from these monitoring surveys are summarized below.

Visual Observations

The operating turbines were observed from various onshore and offshore locations during day-time, night-time, and various weather conditions. Key conclusions are as follows:

- During daytime and under clear weather conditions, the turbines are noticeably visible from the Southeast Lighthouse shoreline on Block Island, which is approximately 4.6 kilometers (km; 2.83 miles [mi]) away.
- During daytime and under foggy conditions, the turbines and its lights cannot be seen from approximately 4.6 km (2.83 mi) away.
- From the Point Judith shoreline, on a clear day, both Block Island and the turbines are visible with the naked eye during the day and at night.
- Neither the island nor the turbines are visible from Point Judith under foggy conditions.
- During daytime, Block Island is barely visible from Brenton State Park, which is located approximately 38.28 km (23.79 mi) from the turbines and the turbines cannot be seen with the naked eye.
- On a clear night, however, the turbine lights are visible from Brenton State Park.
- Offshore, at nighttime and under clear skies, the turbine lights are visible with the naked eye up to 43.05 km (26.75 mi). The lights cannot be seen even with binoculars on a clear night at an offshore distance of 44.3 km (27.5 mi).

Overall, visibility of the turbines from land and water during the day was strongly dependent upon weather conditions and distance. At night the turbine lights could be seen on a clear night from as far away as 43.05 km (26.75 mi).

Airborne Noise Monitoring

Continuous airborne noise monitoring was conducted at an onshore location on Block Island over a three-month (8 February to 28 May 2017) period to record noise levels emanating from the turbine operations. Measurements were also recorded from a survey vessel at selected offshore locations in the vicinity of the turbines. Results from the data analyses indicated that airborne noise from the turbine operations was not detected at the onshore monitoring station on Block Island at any time during the 14 weeks of monitoring, and airborne noise levels in the vicinity of the turbines were low. Noise levels were sampled 65 decibels (dB) Equivalent Continuous Sound Pressure Level (LAeq),1 m at 50 meters (m) from the turbine tower, and even this level of noise appears to be significantly influenced by natural ambient noise. In isolation, the airborne noise from turbine operations would be less than the 65 dB LAeq,1 m.

[1] During the Block Island Wind Farm operational phase, sediment samples from the seabed also were collected and analysed for changes in abundance and diversity of benthic organisms; results from the benthic assessment are reported in an accompanying document entitled: *Benthic Monitoring During Wind Turbine Installation and Operation at the Block Island Wind Farm, Rhode Island, OCS BOEM 2018-047* (HDR 2019d).

The lack of detected airborne noise from the operating turbines during high output periods also may be partially attributable to an increase in onshore background noise levels from rustling of vegetation caused by the high winds that are responsible for increased output from the turbines. **The overall conclusion from the operational phase airborne noise monitoring is that, as part of a risk mitigation plan, this type of monitoring could be bypassed for future facilities**.

Underwater Sound Monitoring

Underwater acoustic and seismic signals were measured and recorded during winter (20 December 2016 to 7 January 2017) and late summer (2 October to 3 November 2017) conditions. In addition, extended underwater acoustic monitoring also was conducted over 100 days during summer 2017 (15 July to 24 October 2017). Several different kinds of monitoring systems were deployed. Monitoring was conducted at different depths and ranges, for varying durations, and at different times of the year to gather data for evaluation of spatial, temporal, and seasonal differences. Recreational fishing activity was observed each time the site was visited.

The acoustic data were analyzed for level, frequency content, and temporal properties, including impulsiveness. Concurrent oceanographic and geologic conditions were also measured during monitoring and incorporated into the data analyses and conclusions. Unlike the construction phase monitoring during which sensors could only be placed outside the U.S. Coast Guard established 457.2 m (1,500 feet or 500 yards) safety zone around each foundation site, during the operational phase acoustic measurements were recorded at 50 to 100 m (164 to 328.1 feet) and beyond from selected turbine foundations.

Results from the winter 2016 and summer 2017 short-term monitoring indicated that sound levels emanating from the operating turbines were lower than expected and primarily consisted of one or more low-frequency, modulated tonals at or above 70 Hertz (Hz).

The short-term *winter* monitoring period was marked by stormy weather. During calm periods between storms, sound suspected to be from wind turbine generator (WTG) 5 was measured as a modulated sinusoidal signal at approximately 71 Hz. Lower level spectral lines were also recorded, but these lower measurements could not be conclusively attributed to turbine operations. The sound speed profile was almost constant throughout the water column during the measurement period. Surface wave heights peaked at approximately 5 m during the stormy winter measurement period mixing the water column and causing the sound speed profile to be isovelocity (constant sound speed). Other sources of sound measured included vocalizations from fin whales and humpback whales, and from shipping. Measured particle velocities were below the threshold of some of the fishes for which audiograms are available. Overall, sound pressure levels measured in winter during turbine operations were lower than those recorded during the construction phase.

Results from the short-term *late summer* monitoring indicated that underwater sound between approximately -70 Hz and 120 Hz was recorded in the water column on all four channels of a vertical line array placed 100 m away from WTG 1. Simultaneous air noise measurements also showed tonals near 71 Hz indicating that the source of the operational sound from the wind turbines may be due to aero-dynamical sources. Acoustic signals less than 40 Hz were also recorded; these are most likely attributable to mooring noise due to windy events and high currents. A large increase in sound was recorded after 23 October; this is most likely caused by storms. Similar to the winter measurements, the sound speed profile in summer was almost a constant throughout the water column, but the speed was higher because of warmer waters.

Data also indicated that numerous vessels transited the survey area during the monitoring period. Tonals were also measured on the bottom mounted hydrophones co-located with the geophones. Statistical analyses indicated that the mean sound levels were independent of wind turbine location except for larger variability near WTG 1 likely due to increased shipping near that turbine. Particle velocities measured in late summer were higher than measured during the winter 2016 measurements. The signals were still below the threshold of some of the fishes for which audiograms are available. Overall, sound pressure levels measured in late summer during turbine operations were lower than those recorded during the construction phase.

Extended underwater acoustic monitoring was also conducted during summer 2017 using a stationary hydrophone located 50 m (164 feet) south of WTG 5. Data were sampled continuously over 100 days between 15 July and 24 October. Over the 100-day monitoring period, sound levels were sampled for all typical turbine operating and weather conditions, from calm and still to wind speeds of up to 23 meters per second (m/s), in excess of the speed required to drive the turbine rotor at maximum speed (approximately 12 revolutions per minute [rpm]). Wind speeds over the monitoring period ranged from flat calm to 22 m/s and a maximum rotor speed of 11 rpm.

Operational data for the turbines (rotational speed for the turbines, wind speed, and wind direction) concurrent with the monitoring period were obtained from Deepwater Wind and used in the analyses. The operational data indicated that from the turbine cut-in to maximum speeds in rpm (approximately 3 to 12 rpm) and wind speed in m/s tracked closely under normal operation, such that at wind speeds of 5 m/s the rotation speed was 5 rpm, at 9 m/s the rotation was 9 rpm, etc.

Monitoring data analysis indicated that in general, underwater noise produced by the operating turbines linearly increased with the wind speed. Strong anthropogenic noise contributions were detected at approximately 12 Hz, and multiples thereof, and the noise from the operational turbine exceeded the ambient noise, caused by wind and sea state, at the monitoring location.

Substantial tonal sound was detected at the 10 kilohertz (kHz) and 20 kHz ⅓ octave center-frequency bands, which varied little throughout the monitoring period. The source of this sound is unknown, but the fluctuations in the levels (±1 dB) do not correlate with wind speed. This tonal sound was not detected in verification measurements using different equipment, so is most likely to be generated by the monitoring system itself.

The noise emissions produced by the BIWF turbines (which are not equipped with a gear box) did not have the tonal characteristics of wind turbines in Europe, which are generally associated with mechanical systems within the device that are typically source of noise, such as a gearbox. Strong tones at 10 kHz and 20 kHz were also identified during the monitoring; but the source of these higher frequency tones could not be determined. Follow on measurements with different equipment did not replicate these tones and it is hypothesized that these higher frequencies may be associated with electrical noise in the monitoring equipment. In the absence of these tones and most other underwater noise contamination (e.g. from passing vessels), the average underwater noise at 50 m from the turbine was 119 dB sound pressure level root mean square referenced to 1 micro Pascal over the survey duration.

Based on an analysis of data up to 8 kHz, it was concluded that under worst-case assumptions and using the 2018 NMFS and Popper et al. (2014) noise impact thresholds, no risk of temporary or permanent hearing damage (permanent threshold shift or temporary threshold shift) could be projected even if the receptor remained in the water at 50 m (164 ft) from the turbine for a full 24-hour period.

The overall conclusion from the operational phase underwater acoustic monitoring is that given the 1) low levels of sound recorded by the various sensors under differing environmental and weather conditions and 2) very low probability of these low levels causing potential harm to fish and marine mammals, operational phase underwater acoustic monitoring may not provide much additional value for future facilities. As part of a risk mitigation plan, this monitoring phase could be bypassed.

The data, results, and conclusions presented in this report were generated for the Bureau of Ocean Energy Management by the HDR Real-Time Opportunity for Development Environmental Observations Team under IDIQ Contract M15PC00002, Task Order M15PD00025.

1 Introduction

This report presents methods, data, observations, results, and conclusions from real-time environmental monitoring surveys conducted in and around the Block Island Wind Farm (BIWF) Project Area (**Figure 1**) during wind turbine operations. Visual observations of the operating turbines, airborne noise monitoring, and underwater sound monitoring were performed. The monitoring was conducted under the Bureau of Ocean Energy Management's (BOEM's) Real-Time Opportunity for Development Environmental Observations (RODEO) Program.

1.1 The RODEO Program

The purpose of the RODEO Program is to make direct, real-time measurements of the nature, intensity, and duration of potential stressors during the construction and initial operations of selected proposed offshore wind facilities. The purpose also includes recording direct observations during the testing of different types of equipment that may be used during future offshore development to measure or monitor activities and their impact-producing factors.

BOEM conducts environmental reviews, including National Environmental Policy Act analyses and compliance documents for each major stage of energy development planning which includes leasing, site assessment, construction, operations, and decommissioning. These analyses include: 1) identification of impact producing factors (stressors) and receptors such as marine mammals and seafloor (benthic) habitats, and 2) evaluation of potential environmental impacts from the proposed offshore wind development activities on human, coastal, and marine environments. The analyses require estimations of impact-producing factors such as noise and the effects from the stressor on the ecosystem or receptors. Describing the impact-producing factors requires knowledge or estimates of the duration, nature, and extent of the impact-generating activity. Because there have been no offshore facilities constructed in the United States prior to BIWF, model predictions will be used primarily to forecast likely impacts from future projects.

The RODEO Program data may be used by BOEM as inputs to analyses or models that evaluate the effects or impacts from future offshore wind turbine construction and operations, as well as facilitate operational planning that would reduce potential impacts to the greatest extent possible. The understanding and insights gained from the BIWF monitoring program data analyses will help BOEM to identify, reduce, and mitigate environmental risks in the future, and significantly increase the efficiency and efficacy of BOEM's regulatory review process for offshore wind development in the United States. Finally, data collected by the BIWF monitoring program will support prioritization of future monitoring efforts and risk retirement. For example, if the BIWF monitoring data indicate that likelihood of impacts from a particular project development phase is low or inconsequential, then such phases may not be monitored during future projects.

It is important to note that the RODEO Program is not intended to duplicate or substitute for any monitoring that may otherwise be required to be conducted by the developers of the proposed projects. Therefore, RODEO monitoring was limited to selected parameters only. Also, RODEO Program monitoring is coordinated with the industry and is not intended to interfere with or result in delay of industry activities.

The BIWF is the first facility to be monitored under the RODEO Program. All monitoring surveys were implemented in accordance with a pre-approved Field Sampling Plan, which included a project-specific Health and Safety Plan (**Appendix A**). **Table 1** identifies the types of field data collected under the RODEO Program during construction and/or initial operations of this facility.

Figure 1. BIWF Project Area.

Table 1. RODEO Program monitoring conducted at the BIWF.

Phase	Key Activities	Dates	Monitoring Surveys	Comment
Construction Phase 1	• Steel jacket foundations were installed on the seabed using two different types of hammers. Both derrick barges and a lift boat were used as construction platforms. Piles were installed with a 13.27° rake from the vertical.	26 July–26 October 2015.	• Visual observations and documentation of the construction activities. • Airborne noise monitoring associated with pile driving. • Underwater sound monitoring associated with pile driving. • Seabed sediment disturbance and recovery monitoring through bathymetry surveys conducted immediately after construction was completed and in approximately 3-month intervals for one year. • Turbine platform scour monitoring through installation of two scour monitoring devices on selected WTG foundations. • An Acoustic Wave and Current Profiler was also deployed within the project area.	Results, conclusions and recommendations from Construction Phase 1 monitoring were presented in the report entitled "*Field Observations during Wind Turbine Foundation Installation at the Block Island Wind Farm, Rhode Island. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, OCS Study BOEM 2018-029 (HDR 2018a)*."
Construction Phase 2	• WTGs were installed on the steel foundations.	3 August–18 August 2016.	• Airborne noise monitoring. • Visual observations and documentation of activities.	Results, findings, conclusions, and recommendations from the Phase 2 Construction Monitoring are presented in the report entitled: "*Field Observations During Wind Turbine Installation at the Block Island Wind Farm, Rhode Island, OCS Study BOEM 2019-027 (HDR 2019a)*."

Phase	Key Activities	Dates	Monitoring Surveys	Comment
	• Submarine transmission power cables connecting Block Island and mainland were laid using a jet plowing in the offshore portions and horizontal directional drilling in the near shore area.	3 June–26 June 2016.	• Visual observations and documentation of the cable laying activities and of turbine installation from both on shore and off shore locations. • Still photography and filming of portions of trenching operations for cable laying. • Seabed sediment disturbance monitoring. • Post-construction seabed recovery through bathymetry surveys.	For details see report entitled: "*Observing Cable Laying and Particle Settlement During the Construction of the Block Island Wind Farm. Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, OCS Study BOEM 2017-027 (Elliot et al. 2017).*
Operational Phase	• Testing of the newly installed turbines. • Testing of the submarine transmission power cables.	Operational testing conducted from 29 August–30 November 2016.	• Visual observations of the operational wind farm from on shore and off shore locations at varying distances.	Results, conclusions, and recommendations from monitoring conducted during turbine operations are presented in an accompanying report entitled: "*Field Observations during Wind Turbine Operations at the Block Island Wind Farm, Rhode Island, OCS Study BOEM 2019-028 (HDR 2019b).*"
	• Facility operations.	Wind farm operation began on 2 December 2016.	• Airborne noise monitoring. • Underwater sound monitoring. • Seabed sediment disturbance and recovery monitoring.	
			• Benthic monitoring.	Results, conclusions, and recommendations from this monitoring are presented in an accompanying report entitled: "*Benthic Monitoring During Wind Turbine Installation and Operation at the Block Island Wind Farm, Rhode Island, OCS Study, BOEM 2018-047 (HDR 2018b).*"

Phase	Key Activities	Dates	Monitoring Surveys	Comment
Follow-on Data Analyses	• Additional in-depth analyses were conducted using data collected during construction Phase 1.	28 July– 31 December 2019	• No field surveys. Only desk-top data analyses and preliminary 3-dimensional modeling with were conducted during this phase.	Results, finding, conclusions and recommendations from the additional data analyses are presented in an accompanying report entitled: "*Underwater Acoustic Monitoring Data Analyses for the Block Island Wind Farm, Rhode Island, OCS Study BOEM 2019-029 (HDR 2019c).*"

1.2 The Block Island Wind Farm

The BIWF is the first offshore wind farm in the United States, located 4.5 kilometers (km) (2.8 mi [mi]) from Block Island, Rhode Island. Water depth in the wind farm area is approximately 30 meters (m) (98.4 feet [ft]). The five-turbine, 30-megawatt facility is owned and operated by Deepwater Wind Block Island, LLC. Power from the turbines is transmitted to Block Island. A 32 km (19.9 mi) transmission submarine power cable transfers excess power from Block Island to the mainland. This cable is buried under the ocean floor and makes landfall on the mainland, north of Scarborough Beach at Narragansett.

BIWF construction began in July 2015, and was conducted in a phased manner through November 2016. During the first phase, five turbine foundations were installed on the seabed from 26 July to 26 October 2015. These turbines were designated as wind turbine generator (WTG) 1 to WTG 5. Unlike in Europe where the majority of the offshore wind turbines have monopile foundations, the BIWF turbine foundations consist of a four-legged jacket structure, which is tailored to accommodate the complex aerodynamic and hydrodynamic loading of deep waters. The four legs of the jacket structure are raked at an angle of 13.27° to the vertical.

Phase 2 construction was completed in two steps. In Step 1, which was initiated in January 2016, submarine power cables were laid on the seabed. In Step 2, which was conducted over a two-week period in August 2016, a turbine tower, a nacelle, and three blades were assembled on each of the five WTG transition decks. During this assembly, the first of three turbine tower sections was bolted in place on each transition deck and then the other two sections were sequentially placed on top of the first section. A nacelle was then connected to the top of the tower and three blades were installed on the nacelle.

Operational testing of the facility was conducted from August through November 2016, and the initial operations commenced on 2 December 2016.

1.3 BIWF Operational Phase Monitoring

Operational testing was conducted at the wind farm from August through November 2016, and the facility began commercial operations on 2 December 2016. The following types of monitoring were conducted under the RODEO Program during the BIWF operational phase:

1. onshore and offshore visual observations
2. onshore and offshore airborne noise monitoring
3. short- and long-term underwater sound monitoring
4. benthic and epifouling monitoring.[2]

Monitoring methods, data, results, and observations from the first three types of monitoring are presented in this document.

1.4 Report Organization

Key results, major observations, and conclusions from each type of environmental monitoring conducted during turbine operations are summarized in individual sections in this report. Where applicable, raw data and detailed discussions from the monitoring are contained in technical reports, which are provided as digital appendices to this summary report:

[2] The results from this monitoring are presented in an accompanying document entitled "*Benthic Monitoring During Wind Turbine Installation and Operation at the Block Island Wind Farm, Rhode Island*" *OCS Study BOEM 2018-047* (HDR 2019d).

- **Section 1** presents an overview of the BIWF Facility and the RODEO Program and includes a summary description of the BIWF operations.
- **Section 2** describes methods and key points from the onshore and offshore visual observations of the operating turbines.
- **Section 3** contains a description of the methods, data analyses, results, and observations from the onshore and offshore airborne noise monitoring.
- **Section 4** presents the methods, data analyses, results, and observations from the underwater acoustic monitoring.
- **Section 5** lists references cited in the report.

2 Visual Monitoring

The purpose of the operational phase visual monitoring was to document visibility of the operating turbines from selected onshore and offshore locations under varying conditions and at different times. All field activities were conducted in accordance with a BOEM-approved Field Sampling Plan, which included a project-specific Health and Safety Plan (**Appendix A**). Visual observations were recorded by a team of two observers over a five-day period (19 to 23 June 2017). On-site training was conducted by the Field Team Leader at the start of the field effort to ensure consistency in describing activities and recording observations by the observers.

The observations were recorded from the following three strategically selected onshore locations (**Figure 2**):

- The Southeast Lighthouse, which is located approximately 4.6 km (2.83 mi) from the turbines
- Point Judith, located approximately 26.32 km (16.35 mi) from the turbines
- Brenton Point State Park, which is located approximately 38.28 km (23.79 mi) away.

Data were recorded daily at early morning, mid-day, late afternoon, and at night (approximately 1 hour after sunset). The night-time shoreline observations were intended to record and characterize the turbine-associated lighting visible from shoreline. In addition to the post-sunset shoreline observations, one round of offshore observations also were conducted on a clear night from a locally chartered fishing vessel, the F/V *Hula Dog*, to determine how far from the turbines the lights were visible after sunset.

During daytime and nighttime, shoreline observations included taking a series of photographs from a fixed location, at the same angle, using a constant zoom setting with a tripod-mounted camera setup. In addition, a vessel was used to determine how far offshore the turbine lights could be seen at night. For this assessment, photographs of the turbines were taken from the survey vessel as it travelled away from the facility until the lights were no longer visible. Video recordings were made as necessary to document unusual sightings or infrequent occurrences. Visual monitoring field logs and meteorological conditions affecting the visibility of the turbines are shown in **Appendix B**.

During each recording event, a set of still photographs and high-resolution video of the operating turbines were recorded from the monitoring location using a Canon 5D Mark III camera with a 70- to 200-millimeter (mm) telephoto lens and Canon 7D with a 100 to 400 mm lens . The telephoto lens was wide enough to capture ambient lighting and environmental conditions and had the capability of zooming in for closer images. To ensure that photographs taken at different times could be compared side-by-side, the same camera angle and a constant zoom setting was used, and the camera was mounted on a tripod to maintain image consistency. The 5-day monitoring period was characterized by a range of meteorological conditions, from heavy fog to clear days.

Observations were recorded using a customized iPad application (app), which was specially created for this project using the database platform FileMaker Go. A screenshot of the iPad app input screen is shown in **Figure 3**. The app was field tested prior to field monitoring, and standardized data entry procedures were used for data entry to ensure consistency among field observers. Observers took a photograph and then recorded the photograph frame number along with notes of activity observed, time, and weather conditions. Meteorological data recorded included wind direction, sea state, cloud cover, and humidity. These data were verified, quality checked, edited if needed, and backed up on a dedicated hard drive at the end of each day.

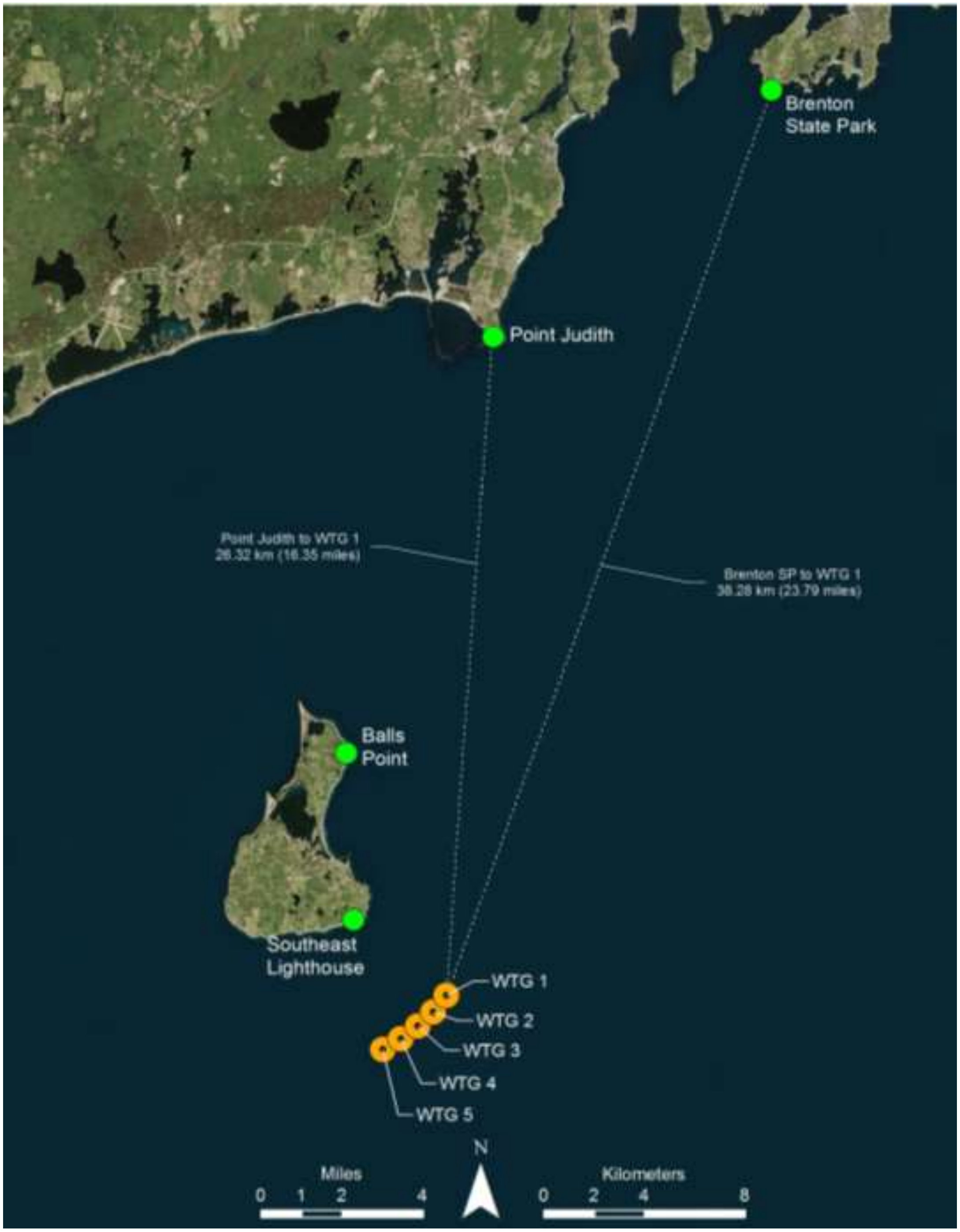

Figure 2. Visual Monitoring Locations.

Figure 3. Sample data log screen from the iPad App.

2.1 Observations

2.1.1 Southeast Lighthouse

The WTG coordinates and their distance from Southeast Lighthouse are listed in **Table 2**. The lighthouse is situated on top of Mohegan Bluff at the southeastern corner of the island at an elevation of approximately 75 m (246 ft) above mean sea level and approximately 4.6 km (2.83 mi) away from the wind farm. From the lighthouse grounds, the survey team had a clear unobstructed view of the turbines as they were assembled on the foundations. Access to the lighthouse grounds was coordinated with the Southeast Lighthouse Foundation.

Clear weather prevailed on 22 June 2017. There was some cloud cover with a high temperature of 75 degrees Fahrenheit, humidity at approximately 84 percent with a slight southwest wind. Photographs of the spinning turbines taken on this date are shown in **Figures 4** and **5**. **Figure 6** shows a photograph taken from Block Island's Old Harbor, which is located to the south of the ferry dock. **Figure 7** is a night-time photograph, which shows the navigational warning lights on WTG 3.

Table 2. WTG coordinates and distance from Block Island.

WTG	Latitude (Deepwater Wind 2016)	Longitude (Deepwater Wind 2016)	Distance from Block Island
1	41° 7.546' N	71° 30.451' W	4.55 km (2.83 mi)
2	41° 7.193' N	71° 30.837' W	4.69 km (2.91 mi)
3	41° 6.883' N	71° 31.270' W	4.81 km (2.99 mi)
4	41° 6.609' N	71° 31.744' W	4.97 km (3.09 mi)
5	41°6.380' N	71°32.258' W	5.17 km (3.21 mi)

Figure 4. WTG 3 as seen from the Southeast Lighthouse on a clear day (22 June 2017) (Photograph taken with lowest camera focal length setting of 100 mm).

Figure 5. WTGs 4 and 5 seen from the Southeast Lighthouse on a clear day (22 June 2017) (Photograph taken with lowest camera focal length setting of 100 mm).

Figure 6. View of the turbines from Old Harbor, Block Island (22 June 2017).

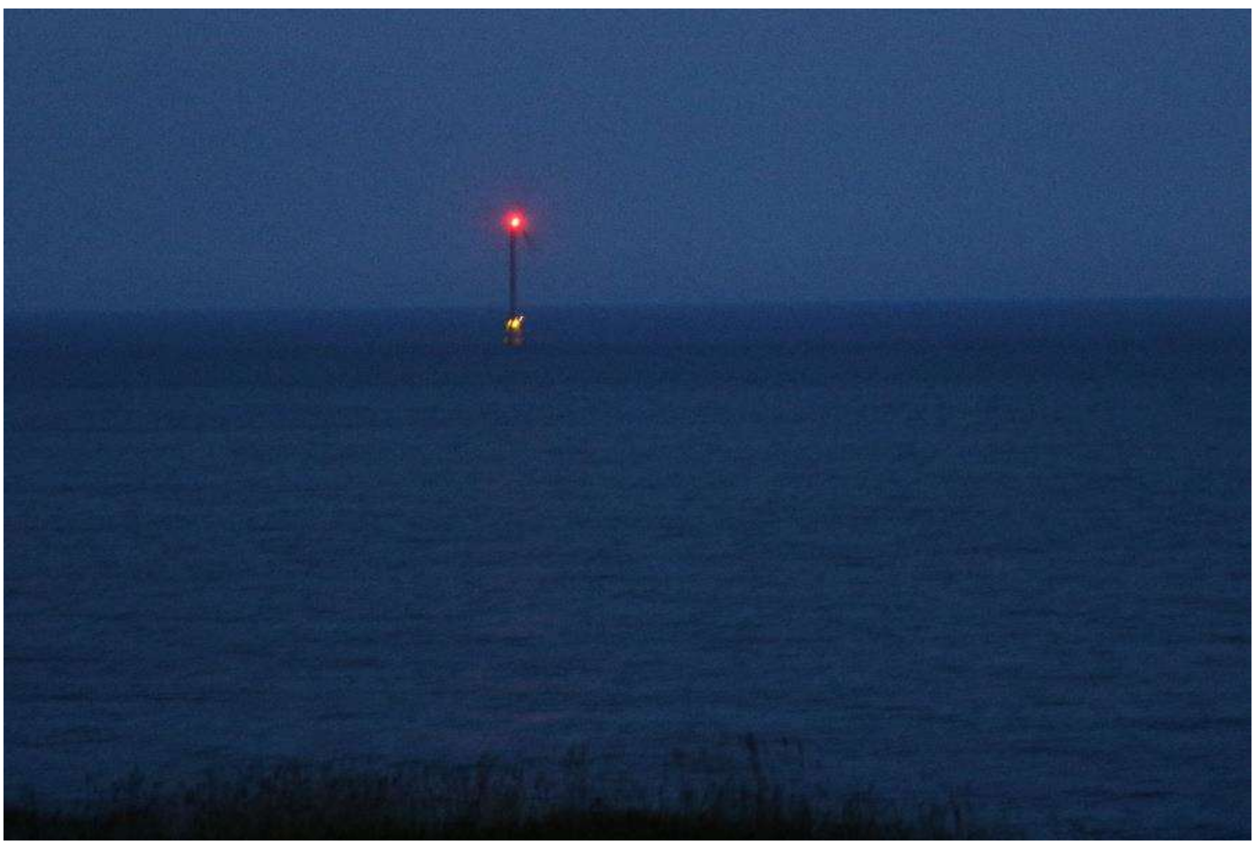

Figure 7. WTG 3 as seen from the Southeast Lighthouse at night (22 June 2017; 9:15 pm).

The area experienced heavy fog on 19 and 20 of June 2017 and under foggy conditions the turbines and its lights were not visible from approximately XX km (3 mi) away (**Figure 8**). **Figure 9** shows a photograph taken in the early morning of 22 June 2017 prior to the haze burning off from the water area. Conditions on Block Island were clear at this time.

Figure 8. WTGs are not visible from Block Island because of heavy fog on 20 June 2017.

Figure 9. WTG 5 barely visible from Block Island because of haze on 22 June 2017.

2.1.2 Point Judith

The WTG coordinates and their distance from Point Judith shoreline are shown in **Table 3**. Observations were recorded from the Camp Cronin Fishing Area, which is situated to the west of Point Judith Lighthouse, approximately 2.82 km (1.75 mi) from the Block Island ferry terminal. The turbines are located approximately 26.32 km (16.35 mi) offshore. Coordinates of the monitoring station were: 41°21'43.8"N 71°29'09.3"W. During the day, this area was not congested with visitors, and at night it was characterized by low ambient lighting.

Table 3. WTG coordinates and distance from Point Judith.

WTG	Latitude (Deepwater Wind 2016)	Longitude (Deepwater Wind 2016)	Distance from Pt. Judith
1	41o 7.546' N	71o 30.451' W	26.32 km (16.35 miles)
2	41o 7.193' N	71o 30.837' W	27.01 km (16.78 miles)
3	41o 6.883' N	71o 31.270' W	27.64 km (17.17 miles)
4	41o 6.609' N	71o 31.744' W	28.22 km (17.54 miles)
5	41o6.380' N	71o32.258' W	28.74 km (17.86 miles)

On a clear day, both Block Island and the turbines were visible from the monitoring station with the naked eye during the day and at night. **Figures 10** and **11** depict the turbines as seen from the Point Judith monitoring station on a clear day (22 June 2017).

Figure 12 shows a nighttime view from Point Judith on 21 June 2017; all five 5 WTGs are visible along with lights on Block Island. The turbines are not visible from Point Judith under foggy conditions as shown in **Figure 13**.

2.1.3 Brenton State Park

The WTG coordinates and their distance from Brenton State Park are listed in **Table 4**. The park is located near the southwestern tip of Aquidneck Island in the town of Newport, Rhode Island. It has an unobstructed view of Block Island, and the turbines are located approximately 38.28 km (23.79 mi) offshore. The coordinates of the monitoring station were: 41 27.014' N 71 21.200' W.

Table 4. WTG coordinates and distance from Brenton State Park.

WTG	Latitude (Deepwater Wind 2016)	Longitude (Deepwater Wind 2016)	Distance from Brenton State Park
1	41o 7.546' N	71o 30.451' W	38.28 km (23.79 miles)
2	41o 7.193' N	71o 30.837' W	39.08 km (24.28 miles)
3	41o 6.883' N	71o 31.270' W	39.83 km (24.75 miles)
4	41o 6.609' N	71o 31.744' W	40.54 km (25.19 miles)
5	41o6.380' N	71o32.258' W	41.20 km (25.60 miles)

During daytime, Block Island is barely visible from the park and the turbines cannot be seen with the naked eye (**Figure 14**). On a clear night, however, the WTG lights can be seen from the park (**Figure 15**).

Figure 10. Block Island and the turbines as seen from the Point Judith monitoring station under clear conditions on 22 June 2017.

Figure 11. The five turbines as seen from the Point Judith monitoring station under clear conditions on 22 June 2017.

Figure 12. Nighttime view from Point Judith on 21 June 2017; all five WTGs visible along with lights on Block Island.

Figure 13. Turbines not visible from Point Judith under foggy conditions on 20 June 2017.

Figure 14. Turbines not visible from Brenton State Park during the day even under clear conditions.

Figure 15. Lights on all five turbines are visible from Brenton State Park on a clear night.

2.1.4 Night-time Offshore Monitoring

Structures that protrude into the sky, depending on their height, can create safety hazards for aircraft that must navigate around them. Any structure that is taller than 61 m (200 ft) above ground level is subject to Federal Aviation Administration lighting requirements. The BIWF turbines are 180 m (600 ft) tall and are therefore equipped with lights on the top so they can be clearly seen from a distance during poor weather-related light conditions such as fog and mist and at night time. The purpose of the night-time offshore monitoring was to determine how far offshore the turbine lights were visible with the naked eye.

Offshore night-time observations were recorded using a local charted fishing vessel on the night of 22 October 2017. The vessel departed Block Island at 7 PM on a 210° heading under clear skies. Still photographs of the turbines were taken at periodic intervals as the vessel sailed away from the turbines using a Canon 5D EOS with a 100 to 400 mm lens. Observations were recorded until the vessel was approximately 44.3 km (27.5 mi) away at which point the turbine lights could not be seen under clear skies even with the use of binoculars. The furthest point from the turbines that the lights were visible with the naked eye was 43.1 km (26.8 mi).

Figure 16 is a photograph taken approximately 24.1 km (15 mi) from the turbines. The photograph in **Figure 17** was taken at approximately 42.8 km (26.6 mi) away just before the observer lost sight of the lights.

Figure 16. All five turbines lights are visible on a clear night from approximately 24.1 km (15 mi) offshore.

Figure 17. Turbine lights from 42.8 km (26.6 mi) away just before the observer lost sight of them.

2.2 Discussion and Conclusions

The operating turbines were observed from various onshore and offshore locations during day-time, night-time, and various weather conditions. Key conclusions are as follows:

- During daytime and under clear weather conditions, the turbines are noticeably visible from the Southeast Lighthouse shoreline on Block Island (approximately 4.6 km [2.83 mi] away).
- During daytime and under foggy conditions, the turbines and its lights cannot be seen from approximately 4.6 km (2.83 mi) away.
- From the Point Judith shoreline, on a clear day, both Block Island and the turbines are visible with the naked eye during the day and at night.
- Neither the island nor the turbines are visible from Point Judith under foggy conditions.
- During daytime, Block Island is barely visible from Brenton State Park, which is located approximately 38.28 km (23.79 mi) from the turbines and the turbines cannot be seen with the naked eye.
- On a clear night, however, the turbine lights are visible from Brenton State Park.
- Offshore, at nighttime and under clear skies, the turbine lights are visible with the naked eye up to 43.05 km (26.75 mi). The lights cannot be seen even with binoculars on a clear night at an offshore distance of 44.3 km (27.5 mi).

Overall, day-time visibility of the turbines from land and water is strongly dependent upon weather conditions and distance. At night, the turbine lights can be seen on a clear night from as far away as 42.8 km (26.6 mi).

3 Airborne Noise Monitoring

The construction and operation of an offshore wind farm will necessarily generate noise from sources such as transportation of construction equipment and materials, operation of construction equipment including pile driving, and operation of the assembled wind turbines. Because 1) the purpose of the RODEO Program is to make direct, real-time measurements of the nature, intensity, and duration of potential stressors during the construction and operations of offshore wind facilities and 2) both airborne noise and underwater sound could potentially be major stressors, an elaborate airborne noise and underwater sound monitoring program was undertaken during the construction and operational phases of the BIWF. The objective of the program was to collect real-time data that would be used to improve model predictions of likely impacts associated with future offshore wind facilities.

Methods, results, and conclusions from airborne noise monitoring conducted during the *construction phase* were previously reported (HDR 2018). Methods, results, and conclusions from airborne noise monitoring conducted during the installation of the tower sections on the WTG foundations are presented in an accompanying document[3]. Methods, results, and conclusions from airborne noise monitoring conducted during wind turbine *operations* are presented in this section.

Continuous airborne noise monitoring was conducted at an *onshore* location over a three-month period (8 February to 28 May 2017) to record noise levels emanating from the turbine operations. A Svantek 979 sound level meter, connected to an external power supply, was installed at the top of the Southeast Lighthouse, with the microphone extending 1 m (3.3 ft) from the side of a lighthouse window, with full view of the ocean to the south (**Figure 18**).

Figure 18. View of the Southeast Lighthouse with microphone protruding from the right of the lighthouse, above the roof line of the building behind the lighthouse. [Right] View of microphone from the lighthouse window.

[3] Field Observations During Wind Turbine Installation at the Block Island Wind Farm, Rhode Island, OCS BOEM 2019-027 (HDR 2019a).

In addition, *offshore* noise airborne level monitoring also was conducted during the operational phase using a Svantek 979 sound level meter installed on a survey vessel, the 36'R/V *Rooster*. The microphone was located approximately 2 m (6.6 ft) above sea level with the vessel drifting past the turbine with the wind, and with the engines shut down on the vessel. Measurements were taken continuously along the passing transect, with the closest point to the turbine between 50 and 100 m (164 and 328 ft) from the turbine tower, but were observed up to 750 m (2,460.6 ft) and beyond.

Results and key findings from the monitoring are summarized below. All noise measurements are reported as decibels (dB) relative to 20 micropascals[4] (μPa). Additional details are presented in **Appendix C**.

3.1 Onshore Airborne Noise Monitoring Results

Data from the 14-week survey indicated that airborne noise from turbine operations was inaudible at the monitoring location on Block Island. A representative dataset from the onshore monitoring is shown in **Figure 19**, which illustrates data from monitoring conducted in March and April 2017. Wind conditions are shown at the top of the figure for comparison. The horizontal red bar in the wind conditions chart identifies the southeast compass point. The red boxes show the times when the monitoring location was downwind of the BIWF, i.e., where the red dots coincide with the red bar.

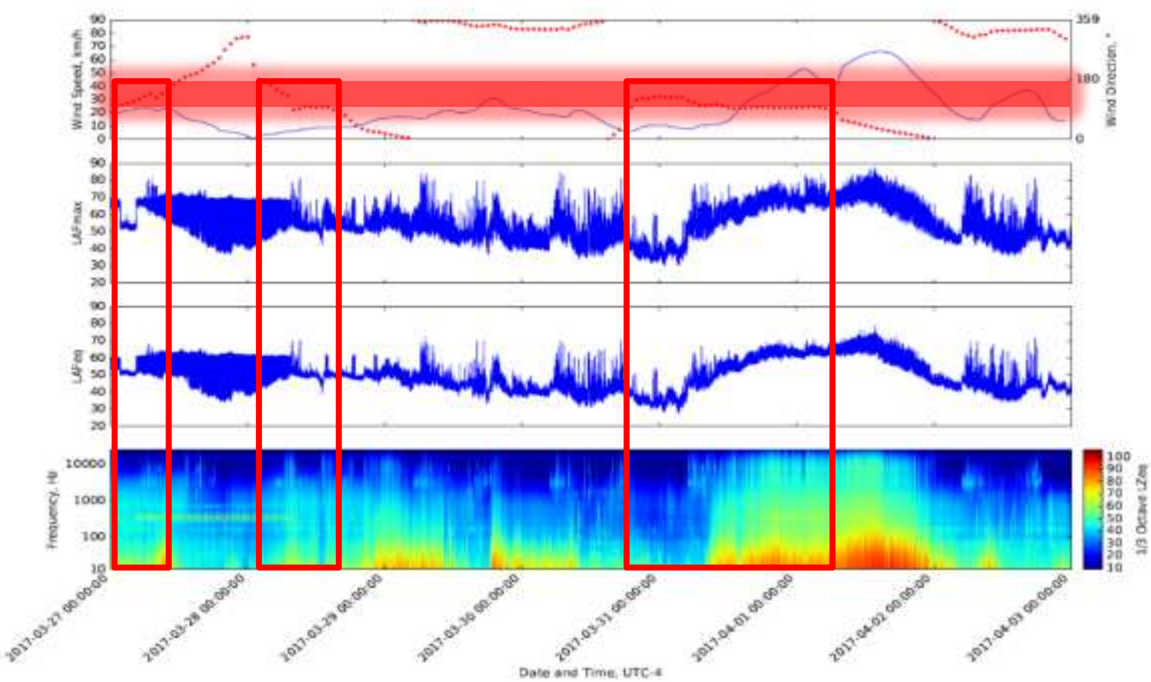

Figure 19. Noise measurement summary at the Southeast Lighthouse, 6 to 13, March 2017. Top chart: wind speed (blue line) and wind direction (red dots). Transparent red bar shows south-east orientation. 2nd chart: dB LAFmax[5] noise level time history. 3rd chart: dB LAFeq (10 minute average) noise level time history. Bottom chart: LAeq[6] spectrogram showing frequencies between 10 Hz and 10 kHz.

[4] Approximately the quietest sound a human can hear on land.

[5] LAFmax = A-weighted, fast response, maximum, sound level, note: maximum is not peak

[6] LAeq = A-weighted, equivalent sound level

In **Figure 19**, the continuous high noise levels observed on 27 March extending into 28 March are caused by the foghorn warning system near to the lighthouse. This also appears on the night of 1 April but is lost in the loud background noise, caused by high winds.

There are a number of low-level tonal noises visible across the spectrogram; these can be seen as faint horizontal lines primarily starting from just under 100 Hertz (Hz) to just under 1,000 Hz, which do not coincide with the foghorn. These tend to coincide with times when the wind is blowing towards the BIWF. These would need to be loud to propagate from the turbines against the wind, and thus there is neither evidence nor indication that the noise is related to the turbines in any way. It may be caused by wind 'whistling' around structures near the lighthouse.

The period of late-night 30 March through the middle of the day on 1 April provides the most useful data, as it shows an increasing wind speed with a continuous southeasterly direction. The low wind speed at the start of the period is reflected in the low noise levels. Increasing wind leads to increasing broadband noise levels as would be expected where produced by vegetation (e.g., wind in the trees and bushes). Any potential tonal noise or hum that could be indicative of the operational WTGs is masked by the ambient noise at the time.

There are some isolated and intermittent features that can be seen in the figure at 2 to 3 kilohertz (kHz), e.g., in the morning of 30 March, and in the morning and evening of 2 April. Although distinct, these generally occur at upwind times and so are unlikely to be linked to the turbines.

3.2 Offshore Airborne Noise Monitoring Results

The following two sets of measurements were taken from the survey vessel in the immediate vicinity of the turbines:

- 19 October 2017, 13:00-14:00. Wind NE approximately 8 to 9 meters/second (m/s), dry, blade speed approximately 11 revolutions per minute (rpm).
- 3 October 2018. 13:45-14:35. Wind SW approximately 3 to 4 m/s, dry, blade speed approximately 6 rpm.

The wind speed during measurements was strong enough to turn the blades at approximately 6 rpm. The wind was not high enough to cause significant wave breaking, although some contribution from background noise caused by waves against the side of the vessel could not be avoided. Initial analysis of the noise measurements proved challenging; although perceptible to a human observer, the noise was difficult to identify around the background noise using standard analysis of overall (A-weighted) or 1/3 octave band frequency analysis, even at distances less than 200 m (656 ft) from the tower.

The audible noise could be broken down into two components: continuous noise, or hum, from the WTG internal machinery, and the regular 'swish' from blades as they passed. There also appeared to be an indirect contribution from wind passing around the tower or blades.

High resolution (narrow-band frequency) analysis of measurements on both days provided more information and showed a low-level tonal contribution between 70 and 80 Hz on both sampling days in 2017 and 2018. Another band at 2 kHz was audible and visible in narrowband analysis on 3 October 2018 only.

On 19 October 2017, a noise level from 63 to 67 dB LAFeq was measured during blade swishes at approximately 50 m (164 ft), drifting downwind and away from the turbine tower WTG 5, equivalent to 65 dB LAeq,1m. Longer term sampling was not possible as the vessel was allowed to drift to minimize background noise. Although this was the cleanest measurement taken, with the minimum of contamination from 'self-noise' (primarily wave slap on the vessel, and waves breaking), this figure can only be an indicative guide and it is not recommended to be used in any formal assessment due to the many contributing factors, primarily the variable distance and significant contribution from natural sources.

An illustrative sample is shown in **Figure 20**. Fluctuating wind noise as it blows around the tower and blade structure causes increases between 3,000 and 4,000 Hz. Blade passes (swish) can be seen as mid-frequency vertical bars approximately every second; this may imply an airborne-water noise path contribution to the noise from the wind turbine. Any noise directly generated by the turbine machinery appears to be limited to frequencies below 50 Hz, with most noise produced by the movement of air.

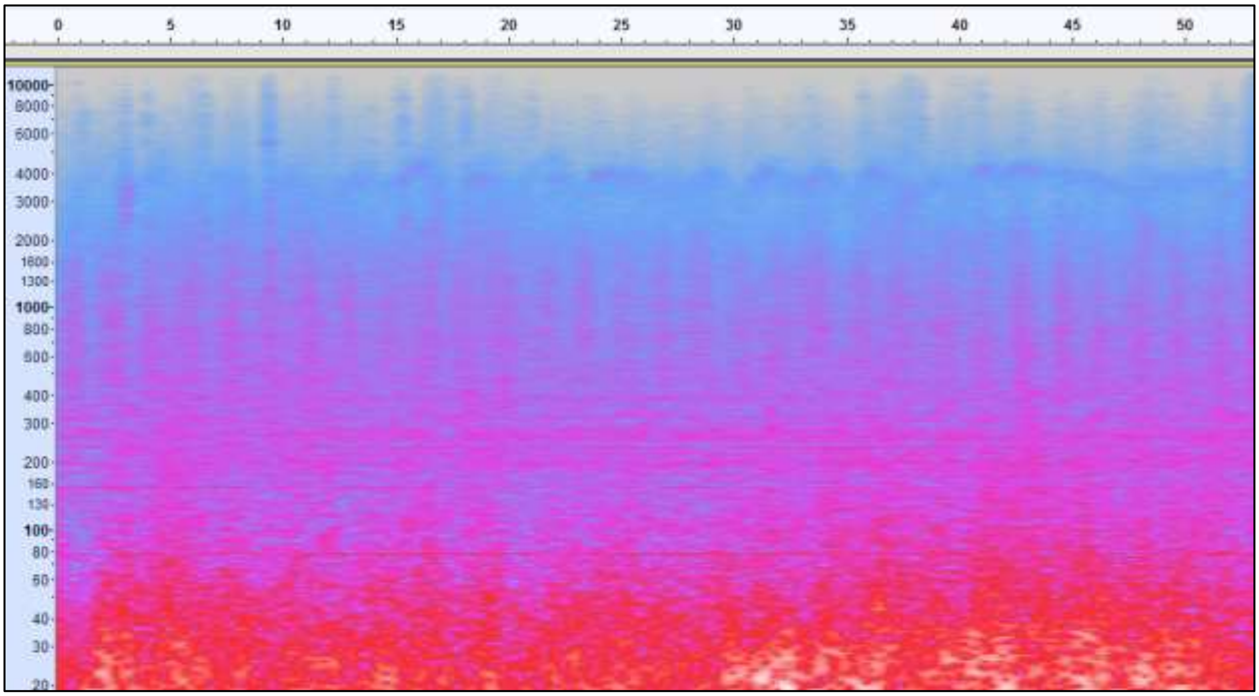

Figure 20. Spectrogram showing narrow-band analysis of offshore noise measurement, 19 October 2017, at approximately 50 m downwind of BIWF WTG 5 to show characteristics. Horizontal axis: Time (seconds); Vertical axis: Frequency (Hz).

3.3 Discussion and Conclusions

Airborne noise from turbine operations was not detected at the onshore monitoring station on Block Island at any time during the 14 weeks of monitoring, and noise levels in the vicinity of the turbines were low. Noise levels were sampled 65 dB LAeq,1m at 50 m (164 ft) from the turbine tower, and even this level of noise appeared to be significantly influenced by natural ambient noise. In isolation, the airborne noise from turbine operations would be less than the 65 dB LAeq,1m.

The lack of airborne noise detected may also be due in part to the fact that when the turbines are operating at high outputs, the background noise levels also increase onshore due to movement of vegetation. **The overall conclusion from the operational phase airborne noise monitoring is that as part of a risk mitigation plan this type of monitoring could be bypassed for future facilities.**

4 Underwater Sound Monitoring

Numerous studies have been conducted in Europe to investigate underwater sound associated with wind turbine operations (Westerberg 1994, Degn 2000, Lindell 2003, Nedwell et al. 2004, Thomsen et al. 2006, Nedwell et al. 2007, Nedwell et al. 2011a, b). In general, the sound associated with wind turbine operations has been described as continuous in nature, and characterized by one or more tonal components typically at frequencies below 1,000 Hz (Degn 2000, Betke et al. 2004, Madsen et al. 2006, Wahlberg and Westerberg 2005, Tougaard et al. 2009, Sigray and Andersson 2011).

The consensus is that the sound from the operating turbines originates from the rotation of the wind-powered components, which causes mechanical vibrations in the nacelle that are transmitted down to the turbine foundation and into the surrounding water column and seabed. The correlation of mechanical vibrations of the turbine tower with sound pressure and particle motion measurements in the water column has been reported by several studies including Lindell (2003) and Sigray and Andersson (2011) and has been corroborated through model simulations (Marmo et al. 2013).

The relationship between wind speed induced rotation of the turbine components and the radiated underwater noise characteristics during particular wind conditions has also been investigated by several researchers (Lindell, 2003; Betke, 2004; Tougaard et al., 2009; Sigray and Andersson, 2011).

Similar to all European offshore wind turbines, the BIWF turbine operations also were expected to produce some level of underwater sound that would radiate into the surrounding water column and adjacent seabed. Underwater sound monitoring was therefore conducted within the project area to gather data for characterizing sound levels, frequency content, and temporal properties. Data were also compared to the updated 2018 temporary and the permanent threshold (TTS and PTS) shift onset criteria recommended by the National Marine Fisheries Service Marine Mammal Guidance (2018).

Different types of acoustic sensors and recorders were deployed at strategic onshore, offshore, and underwater locations within the BIWF Project Area to record the intensity and duration of sounds produced during turbine construction and operations in real time. Methods, results, and conclusions from underwater sound monitoring conducted during the *construction phase* were previously reported (Elliott et al. 2016, HDR 2018). Methods, results, and conclusions from underwater sound monitoring conducted during wind turbine *operations* are presented in this section.

Monitoring was conducted at different depths and ranges, for varying durations, and at different times of the year to gather data for evaluation of spatial, temporal, and seasonal differences. Unlike the construction phase monitoring during which sensors could only be placed outside the U.S. Coast Guard established 457.2 meters (1,500 feet or 500 yards) safety zone around each foundation site, during the operational phase acoustic measurements were recorded 50 to 100 meters (164 to 328.1 feet) and beyond from selected turbine foundations. The acoustic data were analyzed for sound pressure level, frequency content, temporal properties, and where appropriate impulsiveness. Concurrent oceanographic and geologic conditions were also measured during the monitoring and incorporated into the data analyses and conclusions.

4.1 Survey Methods

Acoustic and seismic signals were measured and recorded during *winter* (20 December 2016 to 7 January 2017) and *late summer* (2 October to 3 November 2017) conditions. In addition, extended underwater acoustic monitoring was also conducted over 100 days during summer 2017 (15 July to 24 October 2017). The following types of monitoring systems were deployed:

- An eight-element hydrophone horizontal line array (HLA), and a four-element hydrophone vertical line array (VLA) for measurement of levels of sound generated by the wind turbines.

These stationary arrays were used to measure and record sound levels in the water column at specified distances from the turbines.

- A stationary geosled equipped with 1) four sound pressure hydrophone tetrahedral array arrangement for measurement of acoustic pressure and estimation of particle velocity near the seabed, and 2) a three-axis geophone with a low sensitivity sound pressure hydrophone for measurement of sediment motion and acoustic pressure on the seabed. The geosled configuration was configured to measure both the seabed and water column signals in close proximity. This data was used to assess and predict potential impacts of the measured sound levels on pelagic and demersal fish.
- A three-element omnidirectional microphone array with four recorders for simultaneous measurements of sound at the air/sea boundary to gather data to improve understanding of the air/sea acoustic interaction.
- A towed seven-element hydrophone array coupled with a Lubell sound source. This assembly was used to collect acoustic transmission data used to validate a three-dimensional sound propagation model established for the BIWF area. The results from the 3-dimensional modeling are presented in an accompanying document[7].
- A stationary hydrophone that was deployed on the sled placed on the seabed for extended underwater acoustic monitoring.

All moorings were deployed and recovered from the Woods Hole Oceanographic Institution (WHOI) vessel R/V *Tioga* (**Figure 21**). This vessel is equipped with an on-board GPS tracking system, sea surface sensors and a calibrated conductivity, temperature, and depth (CTD) sensor.

Figure 21. WHOI Research Vessel R/V *Tioga*.

Deployment dates, locations, and water depths for each recording system deployed during the monitoring are presented in **Table 5**. **Figure 22** is a schematic that shows the relative positions of the various sensors.

[7] Underwater Acoustic Monitoring Data Analyses for the Block Island Wind Farm, Rhode Island, OCS Study BOEM 2019-029 (HDR 2019c).

Table 5. BIWF Operational Phase Underwater Acoustic Monitoring Summary.

Deployment Season/ Dates	Systems Deployed	Principal Investigator	Deployment Locations	Latitude (N)/ Longitude (W)	Water Depth (m)	Remarks
Short-term Seasonal Monitoring						
Winter 2016 (20 December 2016 to 7 January 2017)	Vertical Line Array[8] (VLA)	WHOI	~7.5 Km (4.7 mi) from WTG 5	41 06.38118 71 24.30420	26	
	Horizontal Line Array (HLA)	WHOI	~15 Km (31.6mi) from WTG 5	41 00.7514 71 24.2037	40	
	Geosled	URI	~100 m (328 ft) from WTG 5	41 06.38298 71 32.27400	23	
Late Summer 2017 (2 October to 3 November 2017)	4-element VLA	WHOI	~100 m (328 ft) from WTG 1	41 07.5968 71 30.4749	28.6	
	8-element HLA	WHOI	~120 m (394 ft) from WTG 5	41 06.4454 71 32.2319	26	
	Geosled #917/910	URI	~100 m (328 ft) from WTG 5	41 06.3921 71 32.3147	23	
2 October 2017	3-element Omnidirectional microphone array with four recorders	WHOI	WTG 1	41 07.5438 71 30.4536	NA	Concurrent sampling in air and water to generate data for interpretation of air/sea interaction
Extended Summer Monitoring						
Summer 2017 (15 July to 24 October 2017	Single Hydrophone Monitoring System	Subacoustech	WTG 5	41 06.3515 71 32.1730	30	

[8] The VLA was accidentally dislodged from its mooring by a fishing vessel halfway the deployment period.

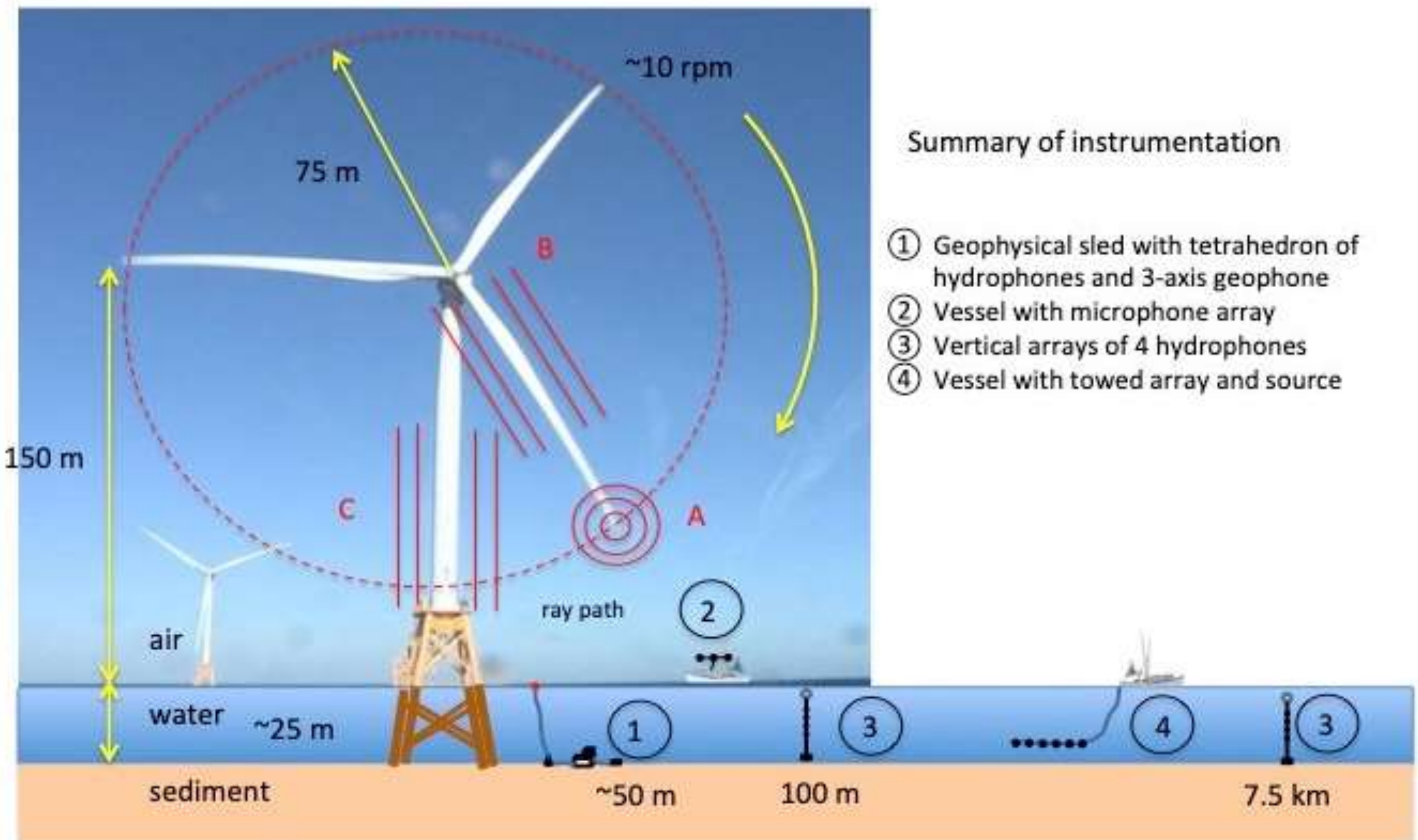

Figure 22. Schematic showing relative placement of the various monitoring sensors for measurement of acoustic and seismic signals during offshore WTG operations (nominal ranges).

4.2 Winter 2016 Monitoring Results

During 2016 winter, the BIWF Project Area was characterized by strong winds and multiple storms, which resulted in a well-mixed water column with constant temperatures near WTG 5 (**Figures 23** and **24**). Farther offshore (approximately 7.5 km [4.7 mi]), the water column was approximately 2 degrees warmer compared to WTG 5; this would influence the speed of sound in the water column (**Figure 25**). Wave height measurements obtained from the National Oceanic Atmospheric Administration National Data Buoy Center indicated an average wave height of approximately 2 m (6.5 ft) recorded by a buoy close to Block Island (**Figure 26**).

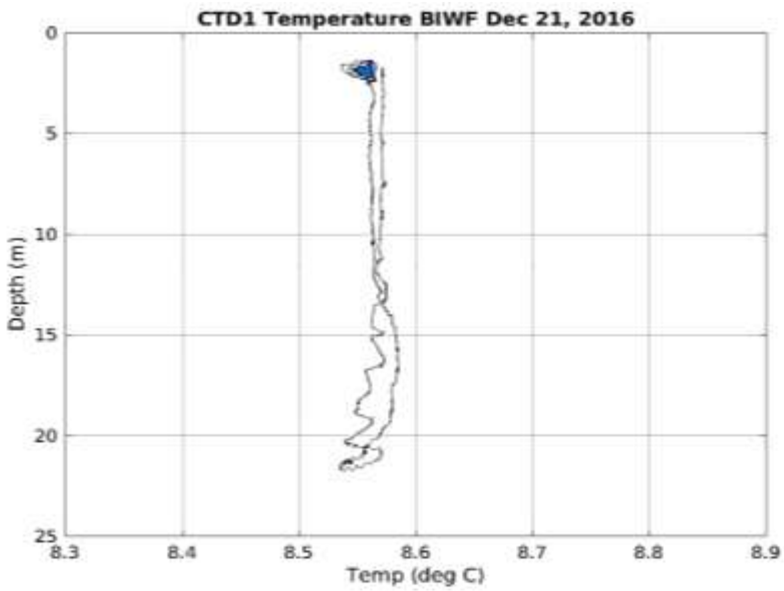

Figure 23. CTD temperature profile at WTG 5 showing a well-mixed water column.

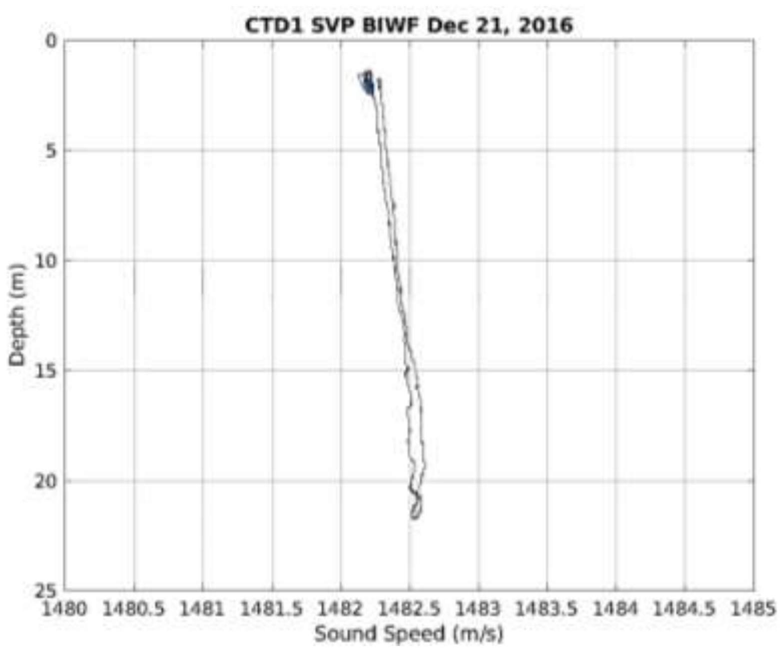

Figure 24. Sound speed from December 21 CTD cast showing an isovelocity profile at WTG 5.

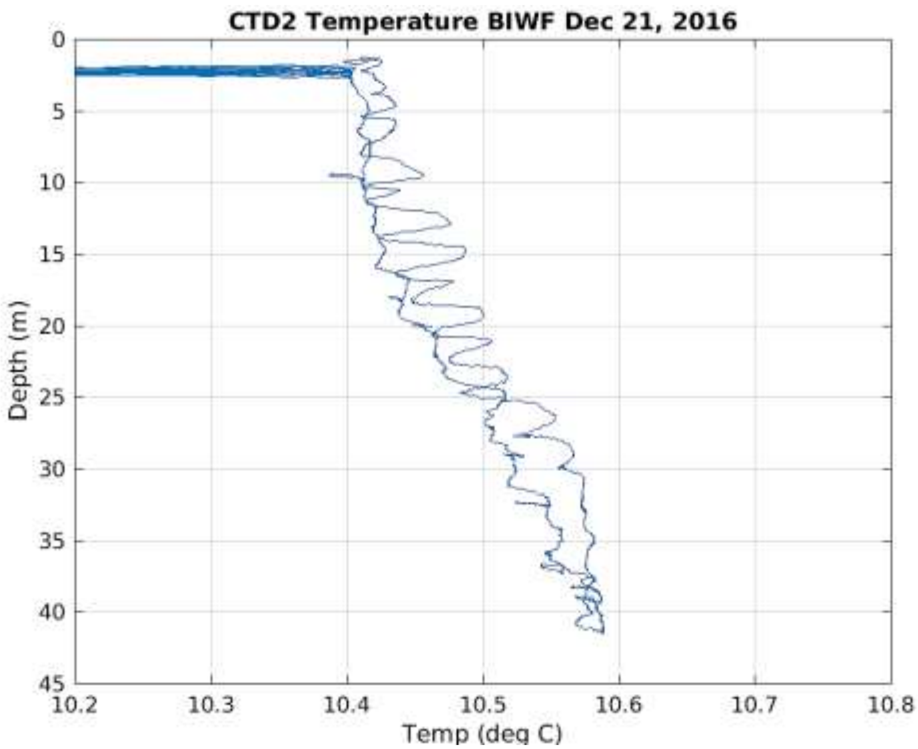

Figure 25. CTD Profile at 7.5 km offshore (2 degrees warmer than at WTG 5).

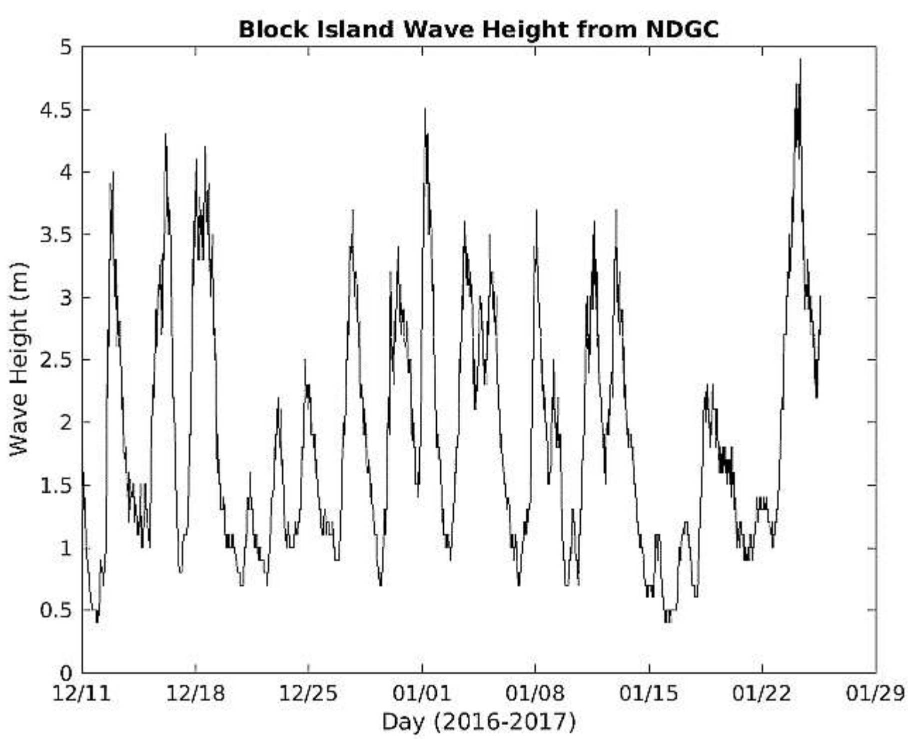

Figure 26. Wave height in meters from mean low tide from a National Data Buoy Center buoy near Block Island indicating a stormy 2016 winter season.

4.2.1 Vertical and Horizontal Line Array Monitoring Data

As expected, the VLA and HLA monitoring data indicated that the underwater soundscape during the turbine operations was dominated by winter weather conditions. **Figure 27** shows a calm sea period recorded from the HLA hydrophone. The low frequency signals from approximately 60 Hz to approximately 120 Hz seen in this spectrogram are representative of distant ship noise, and these signals were recorded throughout the 2016 winter monitoring dataset.

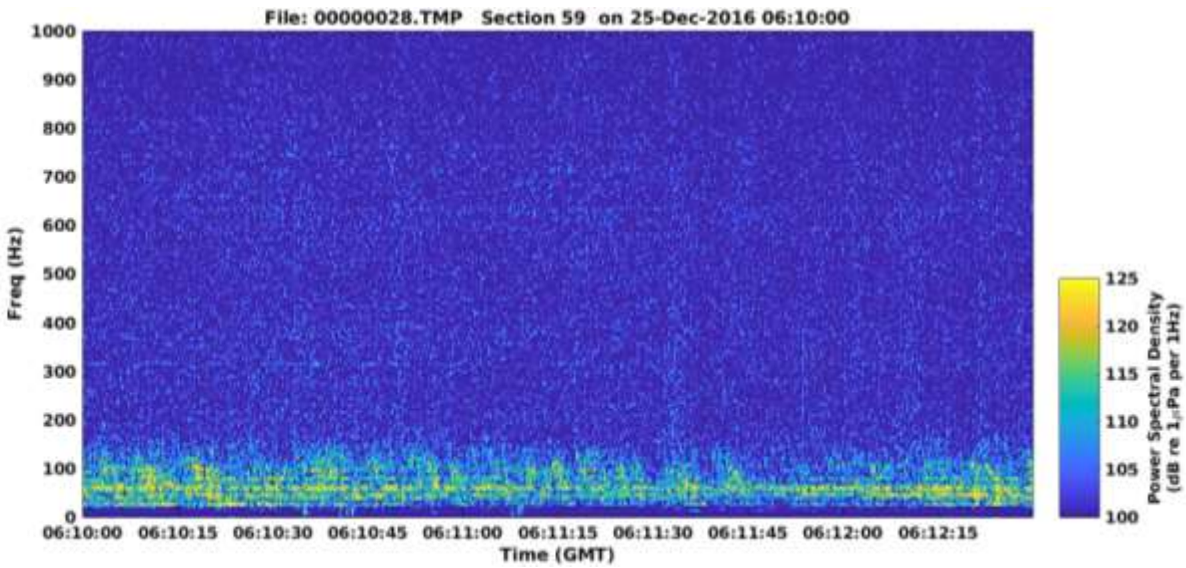

Figure 27. HLA hydrophone spectrogram from a calm sea winter day showing low frequency sounds from distant vessels.

Figure 28 shows a spectrogram with no obvious low frequency signature but an increase in marine mammal vocalizations. No sound from the operating turbines was recorded at the HLA location even under calm weather conditions, which would allow long range underwater sound propagation.

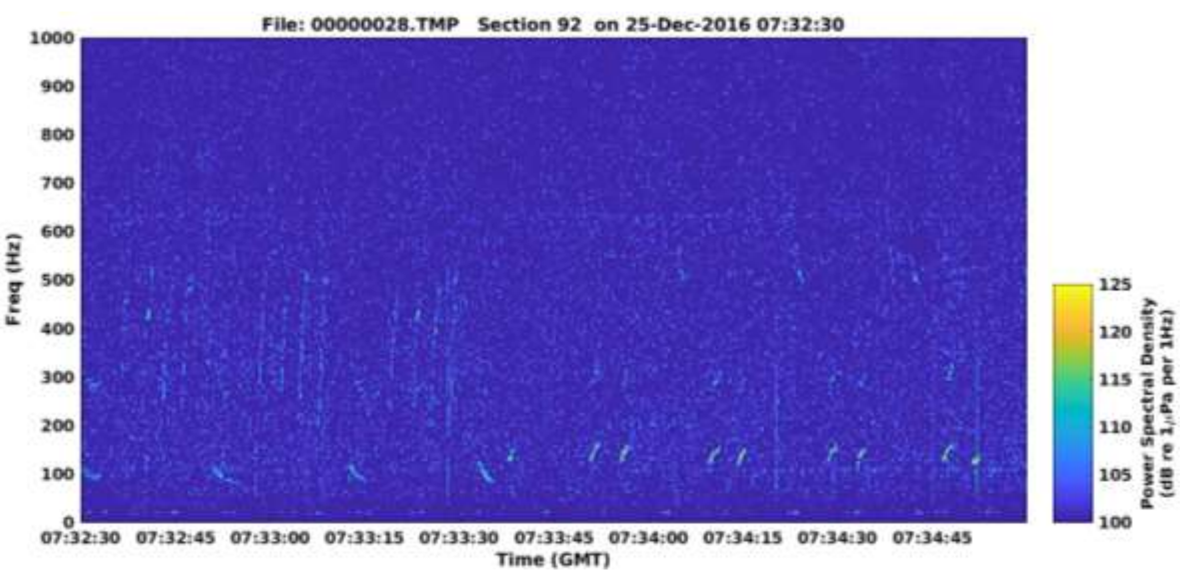

Figure 28. HLA hydrophone spectrogram when the turbines are apparently not operating and the appearance of marine mammal vocalizations.

4.2.2 Geosled Monitoring Data

Acoustic pressure gradient data collected by the hydrophones on the geosled was used to compute acoustic **particle accelerations** using the following equation:

$$-\nabla p = \rho \frac{\partial \vec{u}}{\partial t}$$

p acoustic pressure

$\vec{u}$ acoustic particle velocity

ρ density

The **particle velocity** was estimated from the above equation by numerically integrating the particle accelerations.

The spectrogram in **Figure 29** shows the acoustic sound measured at 100 m (328.1 ft) on one of the hydrophones in the tetrahedral array. Probable tonal sound from the turbine is seen at approximately 71 Hz. The acoustic level was measured at approximately 90 dB re 1 µPa (rms). The intense acoustic signature at 20 Hz is from a vocalizing fin whale. These fin whale received levels were measured at 125 dB re 1 µPa (peak).

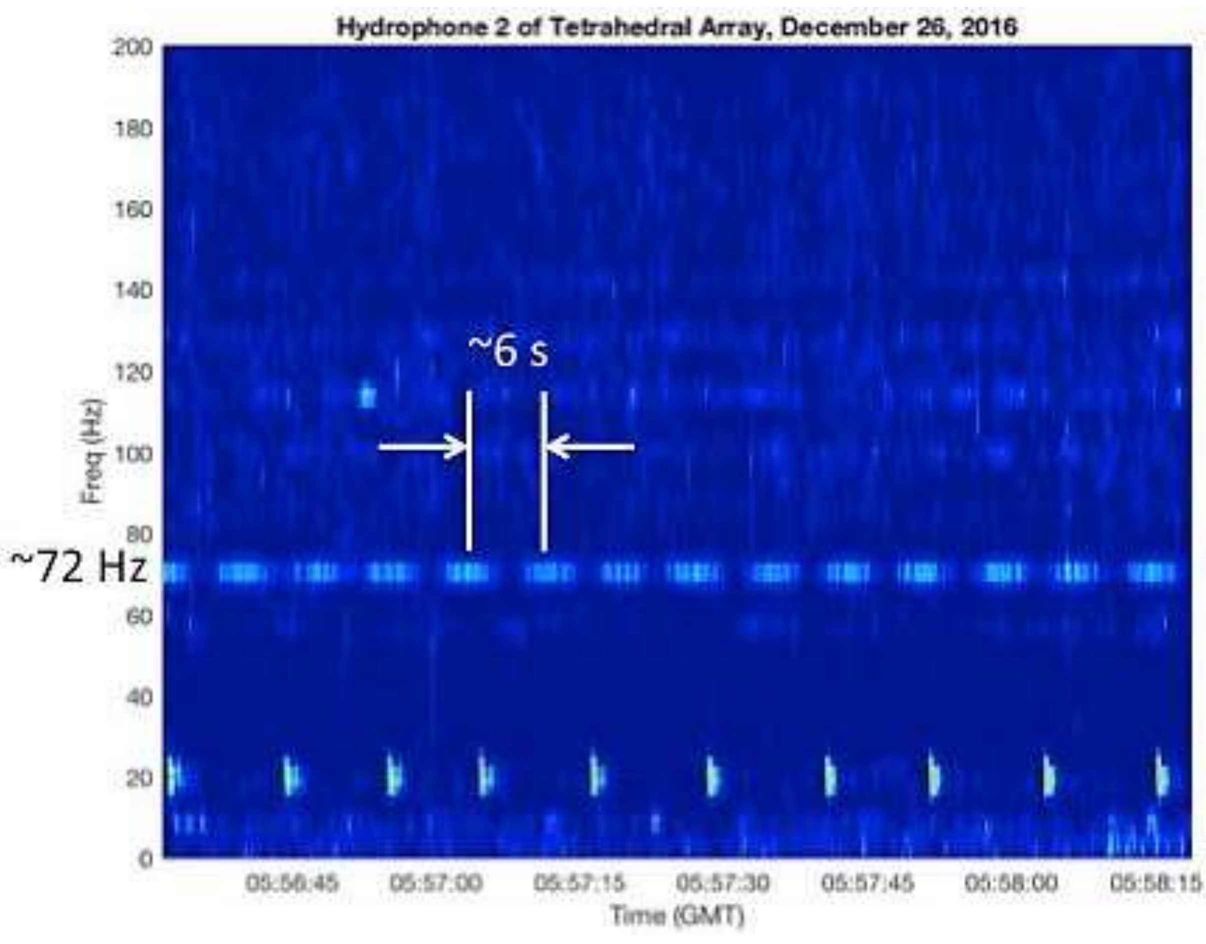

Figure 29. WTG operational sound spectrogram from the tetrahedral array hydrophone. Probable tonal sound from the turbine is seen at approximately 71 Hz. The intense acoustic signature at 20 Hz is from a vocalizing fin whale.

Figure 30 shows the spectrogram of sound measured on the tetrahedral array on 26 December 2016 at approximately 02:25 UTC showing an approaching vessel. The striation pattern is due to the waveguide propagation effects. The vessel was identified using the Automated Identification System.

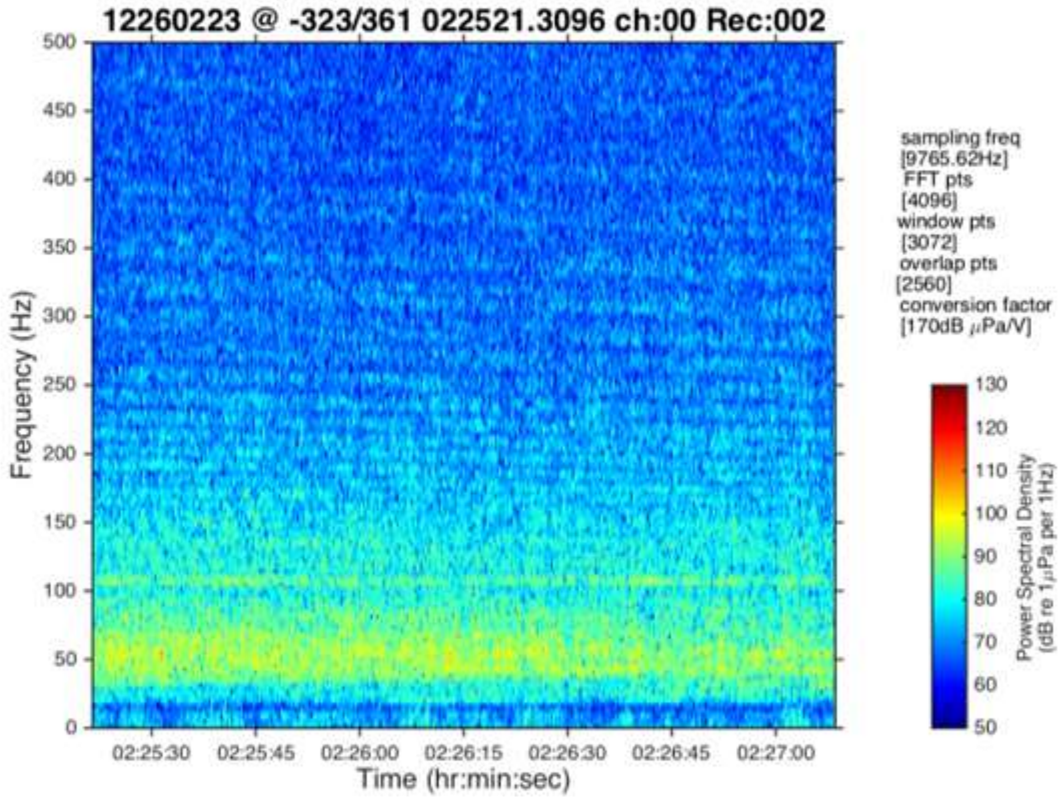

Figure 30. Spectrogram of sound measured on the tetrahedral array on 26 December 2016 at approximately 02:25 UTC showing an approaching vessel. The striation pattern is due to the waveguide propagation effects. The vessel was identified using the Automated Identification System.

Acoustic particle velocity measurements recorded during WTG operations are shown in **Figure 31**. The left panel shows the measurements from geophones on the seabed. The right panel shows the particle velocity calculated using the gradient of pressure measured on the tetrahedral array. The velocities are shown in dB re 1 nm/sec. The peak values are approximately 40 dB re 1 nm/sec, which is much less than the values measured during construction.

Particle accelerations calculated from the BIWF operational phase monitoring field measurements were compared with published behavioral audiograms for some of the fishes (**Figure 32**). The left panel shows the frequency distribution of particle acceleration calculated using the tetrahedral array data and the right panel shows the geophone data. Particle accelerations are shown in dB re 1 $\mu m/s^2$.

Acoustic pressure measurements recorded during the BIWF operational phase monitoring (red line in **Figure 33**) were also compared with data recorded during the BIWF construction Phase 1 monitoring (black line). Some variations in data may be attributable to the slightly different monitoring locations between the two phases: approximately 500 m (1,640 ft) away from the base of WTG 5 during construction[9] versus 100 m (328.1 ft) away from the same turbine.

[9] During the construction phase, a 500-yard safety zone was enforced and monitoring equipment could only be deployed outside this boundary.

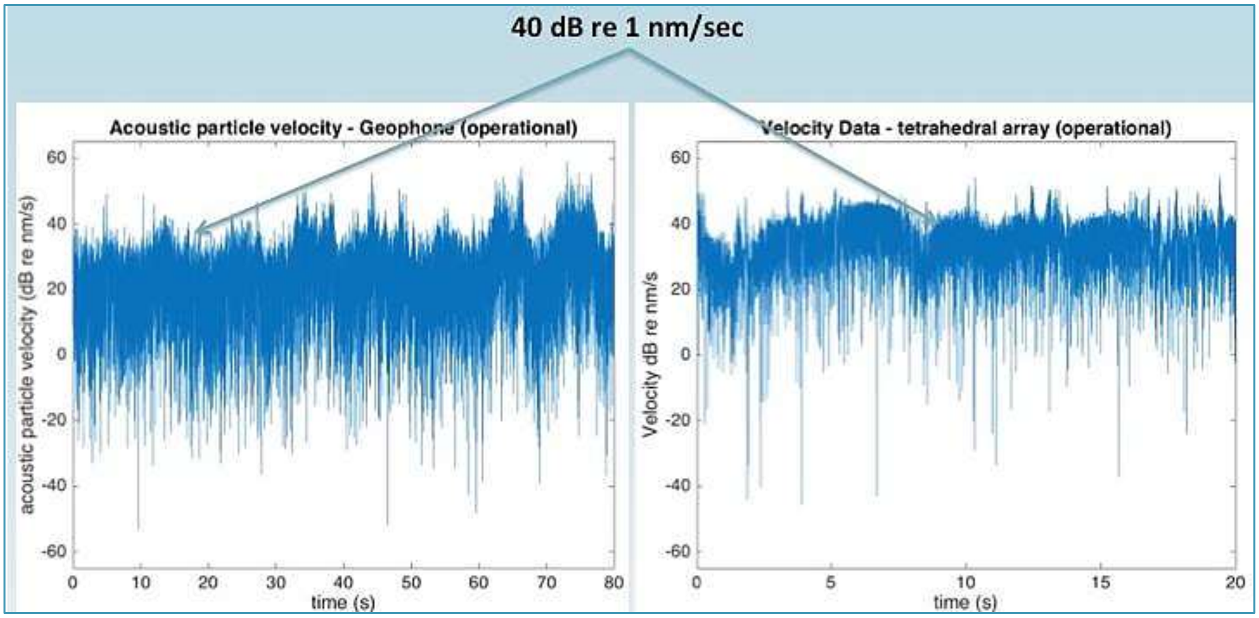

Figure 31. Acoustic particle velocity measurements during WTG operations.

Note: The left panel shows the measurements from geophones on the seabed. The right panel shows the particle velocity calculated using the gradient of pressure measured on the tetrahedral array. The velocities are shown in dB re 1 nm/sec.

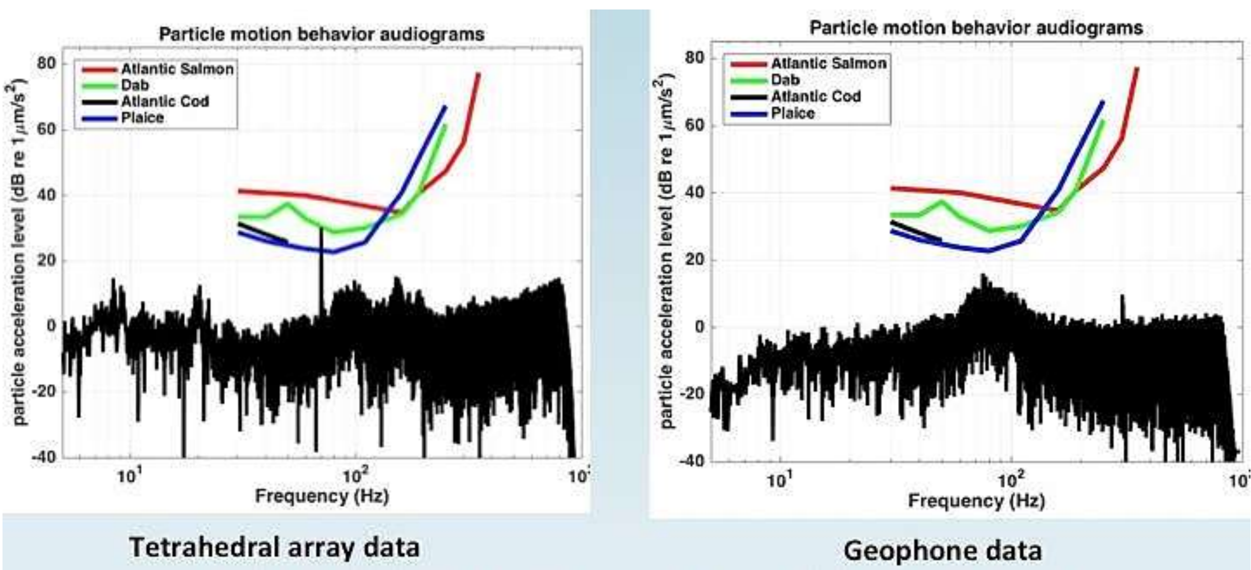

Figure 32. Particle acceleration data comparison between BIWF operational phase monitoring field measurements and published behavioral audiograms for selected fishes.

Note: Behavior audiograms: Atlantic salmon (*Salmo salar*) (Hawkins and Johnstone 1978), Plaice (*Pleuronectes platessa*) and Dab (*Limanda limanda*) (Chapman and Sand 1974), Atlantic cod (*Gadus morhua*) (Chapman and Hawkins 1973).

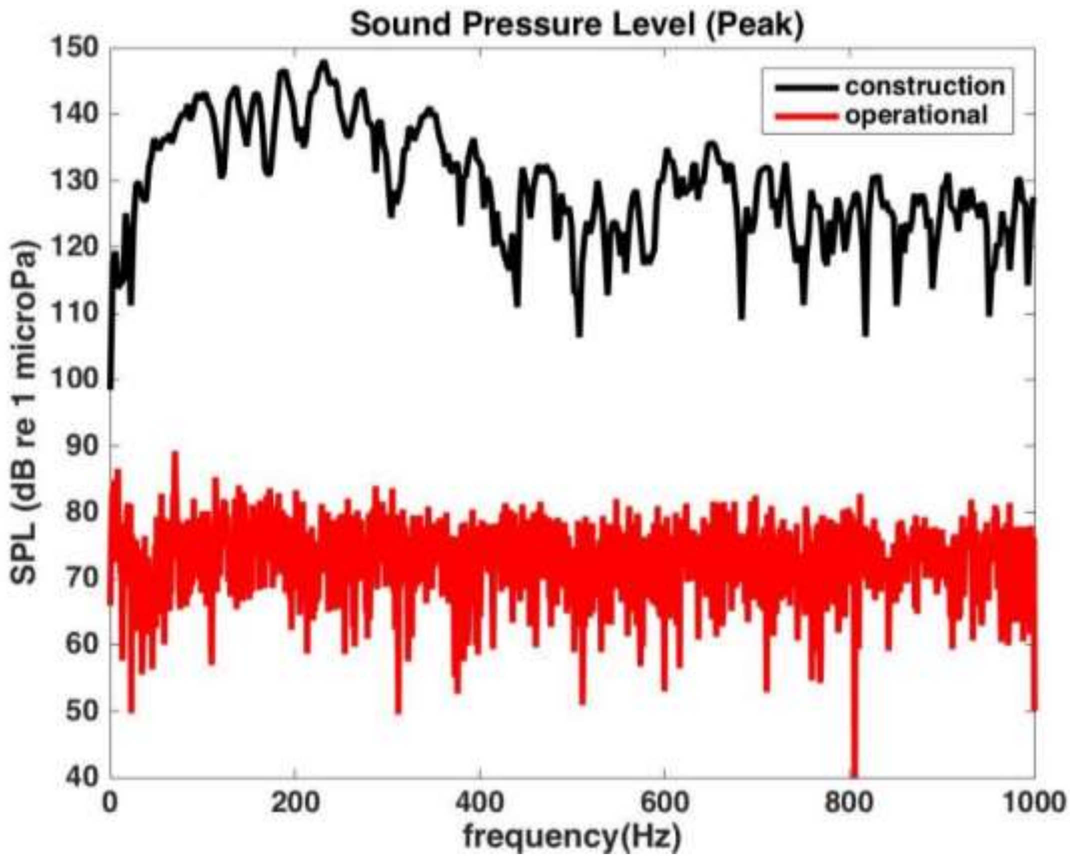

Figure 33. Acoustic pressure data comparison between BIWF operational phase and construction phase field measurements.

4.2.3 Conclusions from 2016 Winter Operational Phase Underwater Acoustic Monitoring

Key conclusions from the winter operational phase underwater acoustic monitoring are as follows:

1. The monitoring period was marked by stormy weather. During calm periods between the storms, sound suspected to be from WTG 5 was measured as a modulated sinusoidal signal at approximately 71 Hz.
2. Lower level spectral lines were also recorded, but these lower measurements could not be conclusively attributed to turbine operations.
3. The sound speed profile was almost constant throughout the water column during the measurement period.
4. Surface wave heights peaked at approximately 5 m (16.4 ft) during the stormy winter measurement period mixing the water column and causing the sound speed profile to be isovelocity (constant sound speed).
5. Other sources of sound measured included vocalizations from fin whales and humpback whales and shipping.
6. Particle velocities measured were below the threshold of some of the fishes for which audiograms are available.
7. Overall, sound pressure levels measured in winter during turbine operations were lower than those recorded during the construction phase.

4.3 Late Summer 2017 Monitoring Results

As expected, during summer the water temperatures (**Figure 34**) were almost twice as high as those recorded in winter.

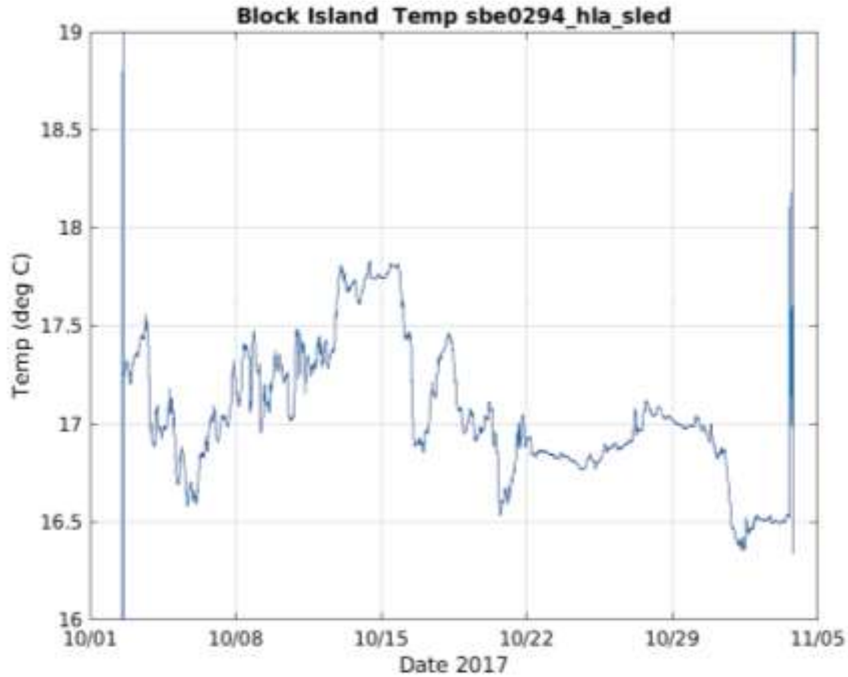

Figure 34. HLA SBE39 T/P temperature record at WTG 5. The temperatures recorded during this time were twice as high as those recorded during winter deployments.

Wave activity pressure records were compared to water column temperatures (**Figure 35**) and the profile clearly showed surface water warming from 8 to 12 October, which could create downward refracting sound conditions.

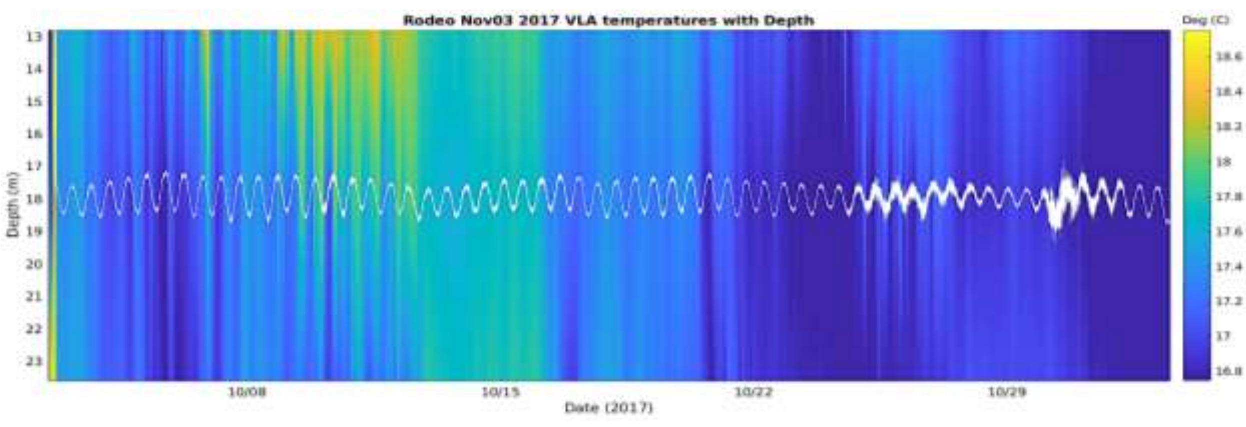

Figure 35. VLA temperature profiles from an array of sensors attached to the VLA with an overlay (white) with water depths at WTG1.

The summer monitoring period was marked by two storms (**Figure 36**), which resulted in a mixed water column. A CTD cast from the R/V *Tioga* during the same period (**Figure 37**) also shows a well-mixed water column profile and constant sound speeds (isovelocity).

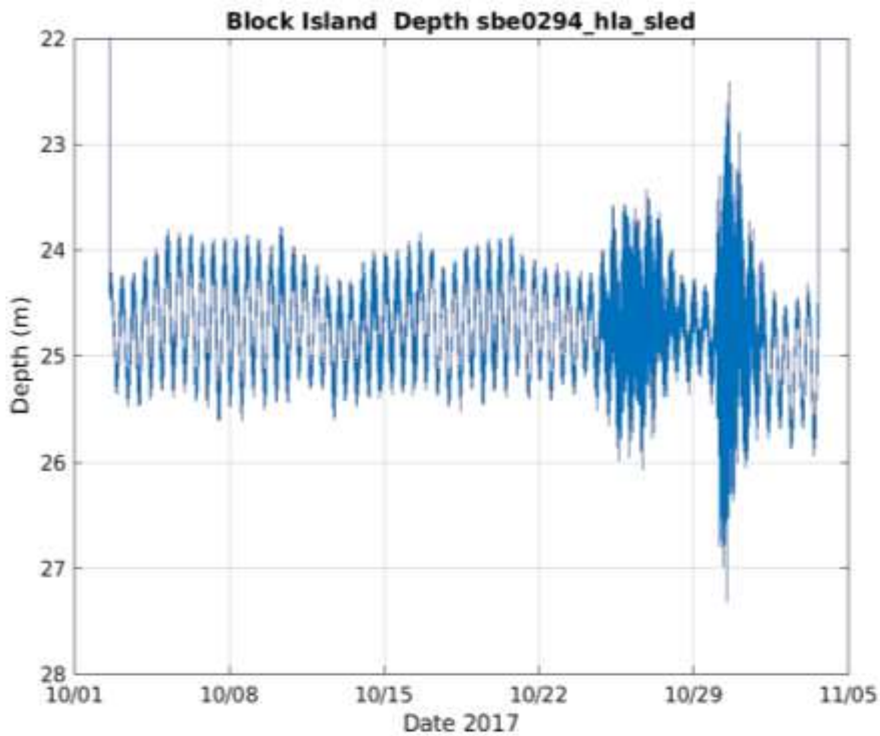

Figure 36. HLA SBE39 T/P sensor depths showing surface tides and surface wave activities due to two large storms on 26 and 31 October 2017.

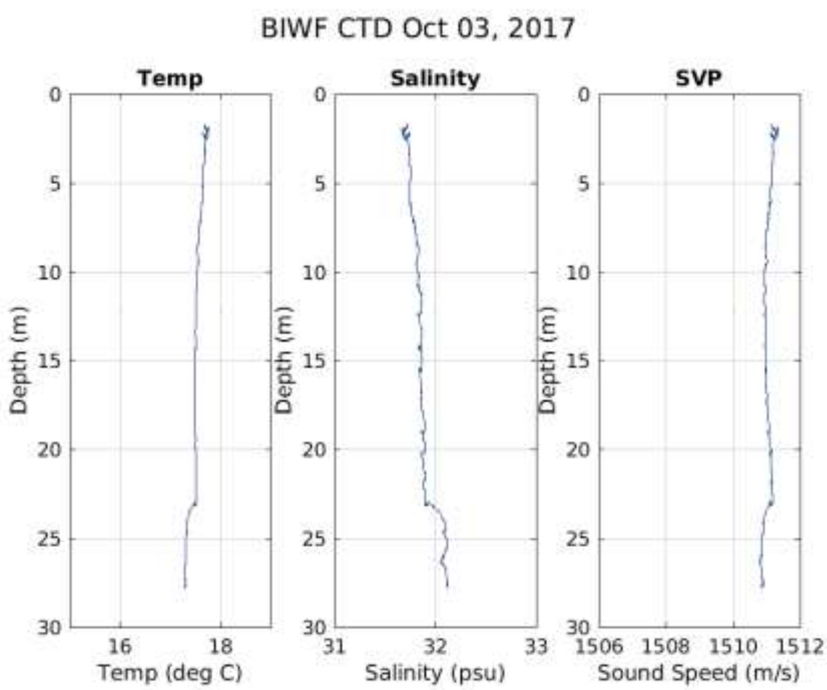

Figure 37. CTD cast from the R/V *Tioga* showing a well-mixed water column (2 October 2017 at 17:21 UTC at WTG5).

4.3.1 Vertical and Horizontal Line Array Monitoring Data

Spectrogram from all four channels of the VLA deployed at WTG 1 are shown in **Figure 38**. The signals under 40 Hz for all channels are mooring sounds due to windy events and currents. The vertical stripes seen in this figure are vessels that were in the vicinity. Recreational fishing activity was observed each time the site was visited. Long-term sound can be seen at approximately 70 and 120 Hz on all four channels. The large increase in sound after 23 October is most likely caused by storms.

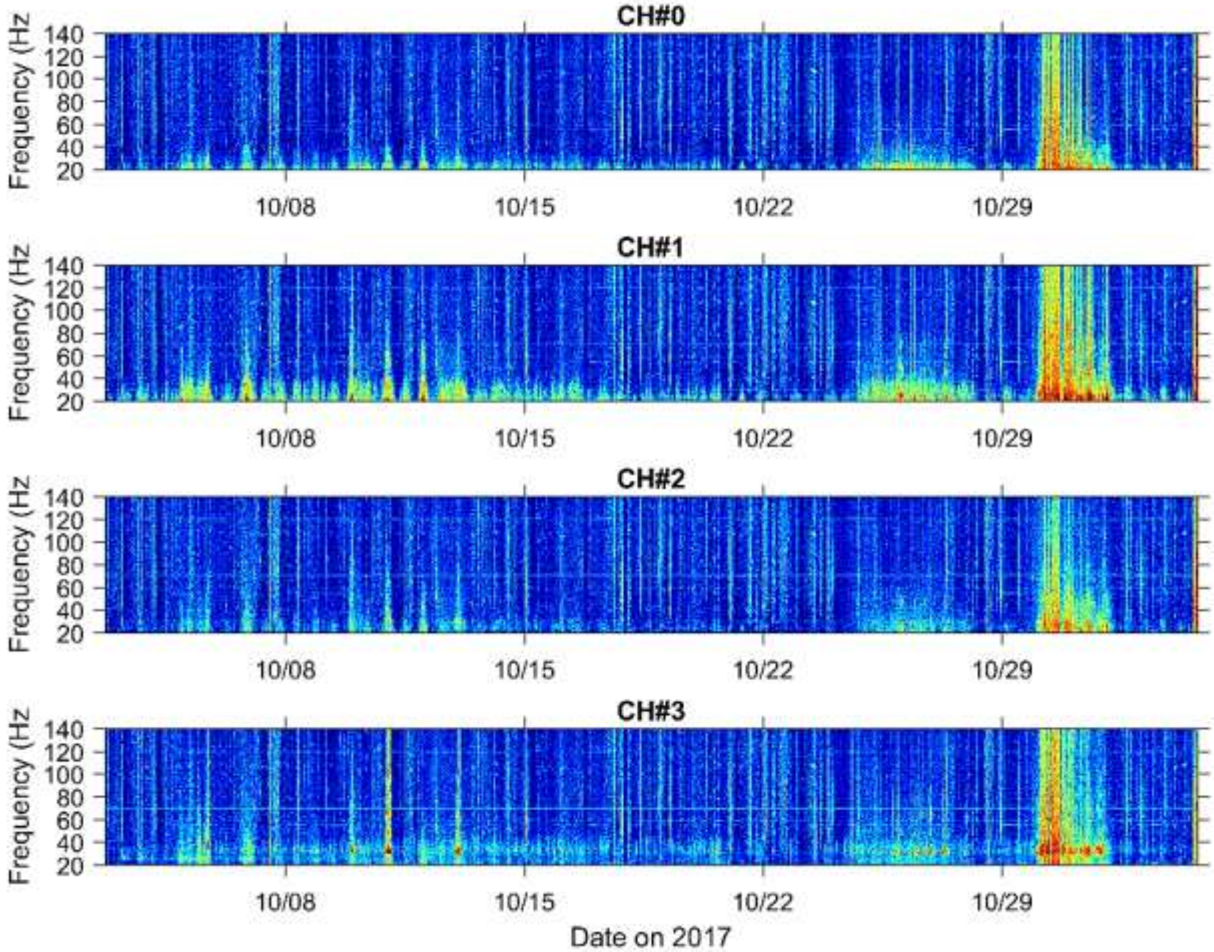

Figure 38. Spectrograms at 20 to 140 Hz from each VLA sensor at WTG1.

To evaluate frequency distribution, each channel's data were analyzed for frequency content by creating a power spectrum, which describes the distribution of a received signal into frequency components composing that signal (**Figure 39**). The significant contributors to the distribution are identified in the figure. The low frequencies are dominated by mooring sound and the higher frequencies are dominated by ambient sound. Acoustic signals show up as peaks at 30, 60, 70 and 120 Hz. The width of the distributions are caused by the presence of boat noise, which made longer delay times in the density estimates.

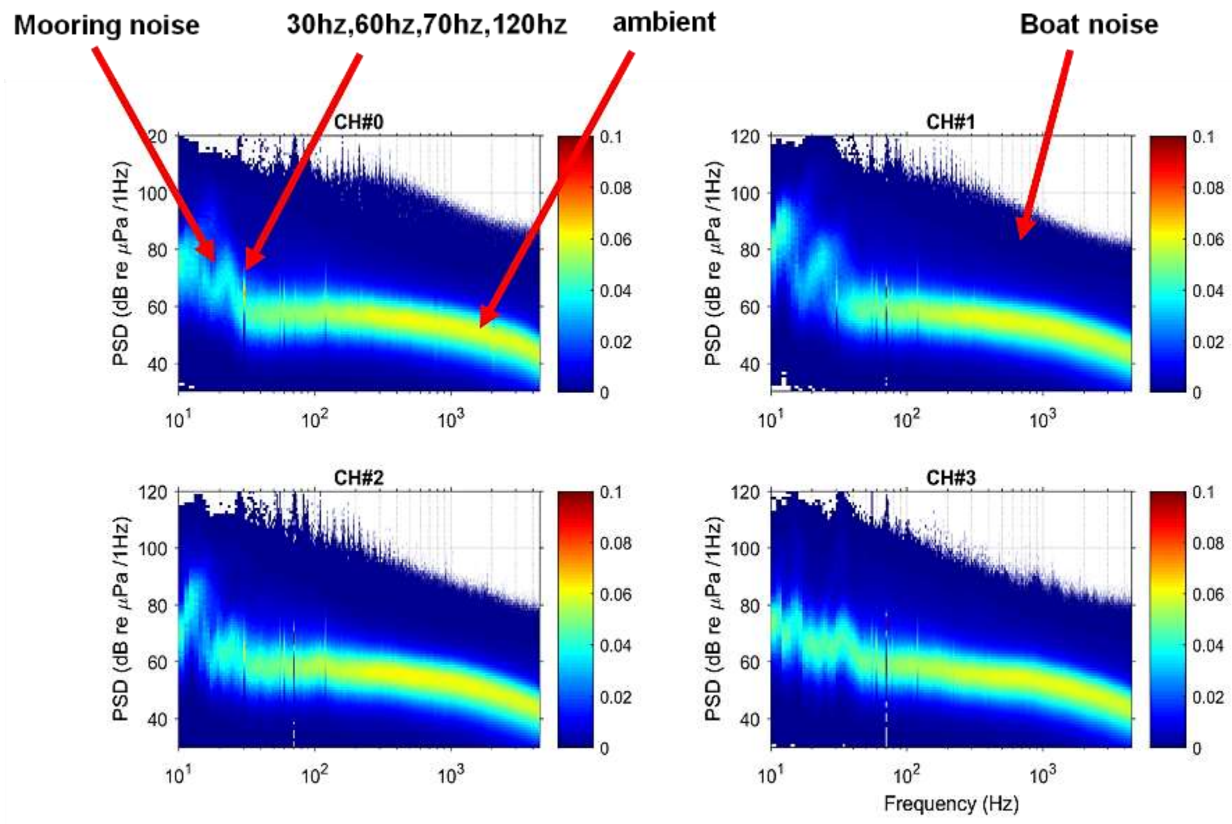

Figure 39. Frequency distributions from all four hydrophones on the VLA at WTG1.

Operational sound statistics in ⅓ octave bands from the late summer deployment are summarized in **Table 6**. The operational turbine sound mean and standard deviation from the VLA at WTG 1 are shown in **Tables 6** and **7**. Operational turbine sound mean and standard deviation from the HLA at WTG 5 are shown in **Tables 8** and **9**. The data indicate that the mean changes little from WTG 1 to WTG 5, but the standard deviation is larger at WTG 5, most likely due to increased boat activity in the area.

Table 6. Operational average power spectrum density level (PSD, dB re μPa /1Hz) in the first seven octave bands from SHRU VLA at WTG 1.

Band #	Frequency (center)	CH0	CH1	CH2	CH3
0	31.25	61.4	66.7	61.7	66.2
1	62.50	58.5	60.8	59.6	61.7
2	125.00	57.8	58.8	57.7	58.7
3	250.00	56.1	56.5	55.5	55.9
4	500.00	53.8	54.1	53.4	53.6
5	1000.00	51.0	51.3	50.8	51.1
6	2000.00	47.3	47.4	46.9	47.2

Table 7. Standard deviation power spectrum density level (PSD, dB re µPa /1Hz) in the first seven octave bands from SHRU VLA at WTG 1.

Band #	Frequency (center)	CH0	CH1	CH2	CH3
0	31.25	11.7	13.0	11.0	11.0
1	62.50	10.4	10.8	9.4	10.0
2	125.00	9.2	9.6	8.6	9.3
3	250.00	8.3	8.6	7.9	8.7
4	500.00	7.7	8.1	7.5	8.0
5	1000.00	7.7	7.9	7.5	7.8
6	2000.00	7.9	8.1	7.7	7.9

Table 8. Average power spectrum density level (PSD, dB re µPa /1Hz) in the first seven octave bands from the horizontal line array at WTG 5.

Band #	Frequency (center)	CH0	CH1	CH2	CH3
0	31.25	55.9	58.4	59.7	59.9
1	62.50	57.5	59.5	61.3	61.6
2	125.00	56.3	58.5	60.2	60.2
3	250.00	54.5	57.5	58.1	58.4
4	500.00	51.5	54.6	56.2	55.1
5	1000.00	48.1	50.1	50.9	50.7

Table 9. Standard deviation power spectrum density level (PSD, dB re µPa /1Hz) in the first seven octave bands from the horizontal line array WTG 5.

Band #	Frequency (center)	CH0	CH1	CH2	CH3
0	31.25	12.7	14.1	14.7	15.5
1	62.50	11.8	12.9	13.6	14.3
2	125.00	10.9	12.2	12.6	13.4
3	250.00	11.0	13.0	12.7	13.8
4	500.00	10.1	12.3	12.6	12.7
5	1000.00	8.3	9.2	9.9	9.8

4.3.2 Geosled Monitoring Data

To compare seasonal sound propagation conditions in the project area, a Geosled equipped with a geophone and tetrahedral array was deployed near WTG 5 (41 06.3921N; 71 32.3147W) in a water depth of 23 m (75 ft). The geosled was deployed on 2 October and recovered on 3 November 2017.

Figure 40 shows a sample of the data collected on 16 October 2017 (UTC 03:46). This spectrogram shows the acoustic data collected on the hydrophone in the geophone package (deployed on the seabed). The data are dominated by the intense sound below 30 Hz. In addition, multiple tonals also are seen in the spectrogram.

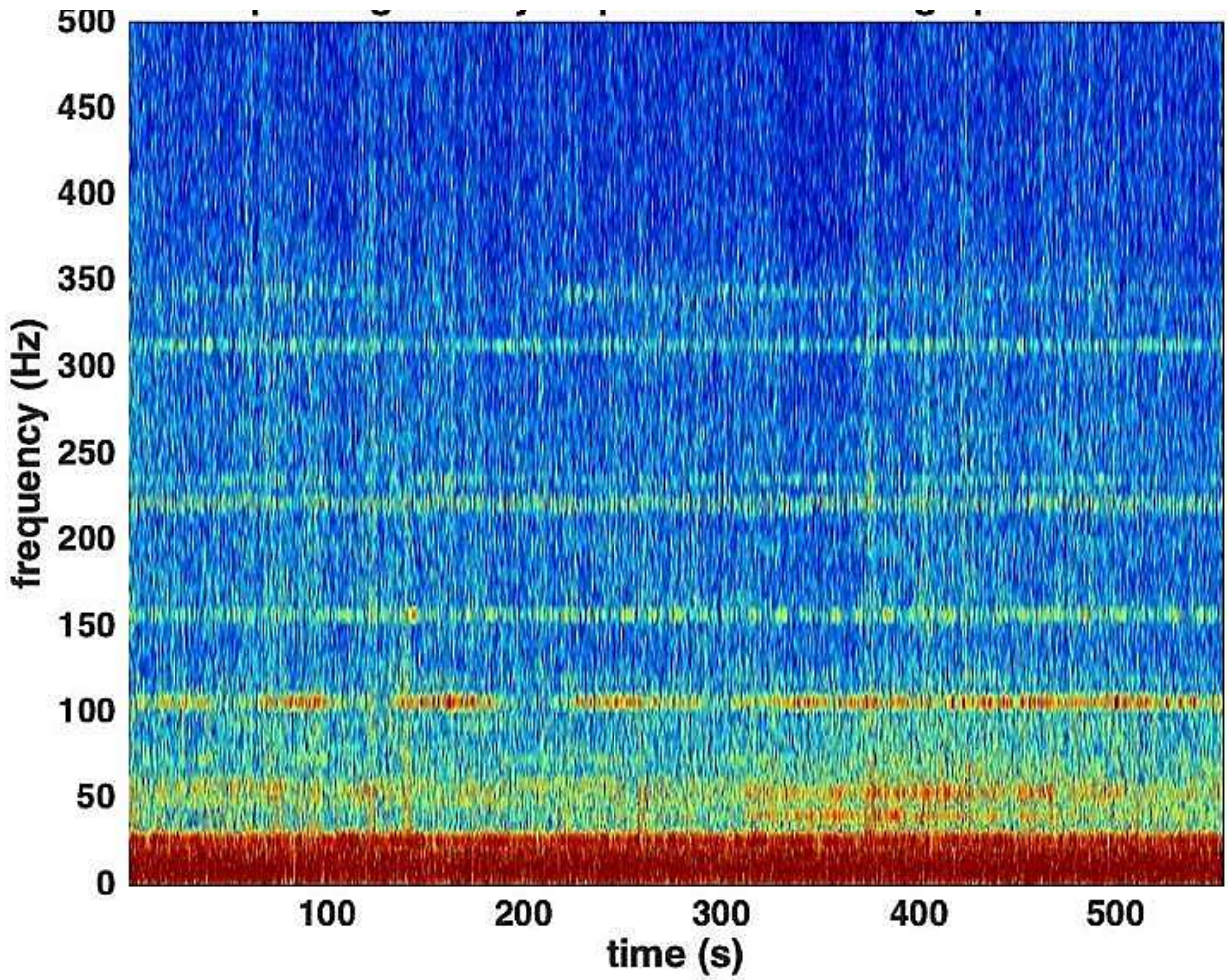

Figure 40. Spectrogram of the acoustic data collected during the operational phase of the turbine on 16 October 2017 at 03:46 UTC time. Note the intense sound below 25 Hz and tonals.

The frequency content in the signal is clearer in the power spectral density as shown in **Figure 41** (left panel). This figure also shows that frequencies below 25 Hz dominate the signal. In order to highlight the frequencies higher than 25 Hz, the hydrophone and geophone data were high pass filtered with a cutoff equal to 30 Hz and the result is shown the right panel of **Figure 41**. The spectrum of the high pass filtered data highlights the frequencies above 30 Hz. Geophone signals are dominated by frequencies below 100 Hz while the hydrophone signal shows multiple tonals.

Figure 42 shows the acoustic particle velocity measurements during operation. Data shown in **Figure 42** correspond to the measurements from geophones on the seabed. The velocities are shown in dB re 1 nm/sec. The peak values are approximately 85 to 90 dB re 1 nm/sec, which is much less than the values recorded during Phase 1 construction (HDR 2018). But the values measured in October, 2017 are much higher than those measured in winter (**Figure 32**). Much of the increase in the velocity levels can be attributed to contributions from frequencies lower than 25 Hz.

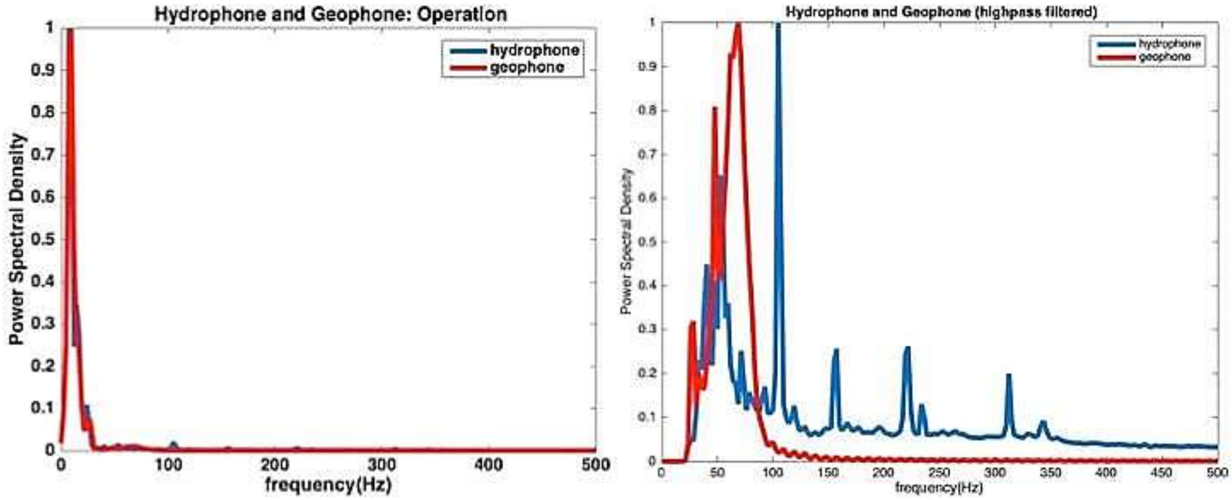

Figure 41. Power spectral density of the hydrophone and geophone signals deployed on the seabed (left panel).

Note: The right panel shows high pass filtered showing frequencies above 30 Hz; highlighting the power in the frequencies above 30 Hz. Geophone signals are dominated by frequencies below 100 Hz while the hydrophone signal shows multiple tonals.

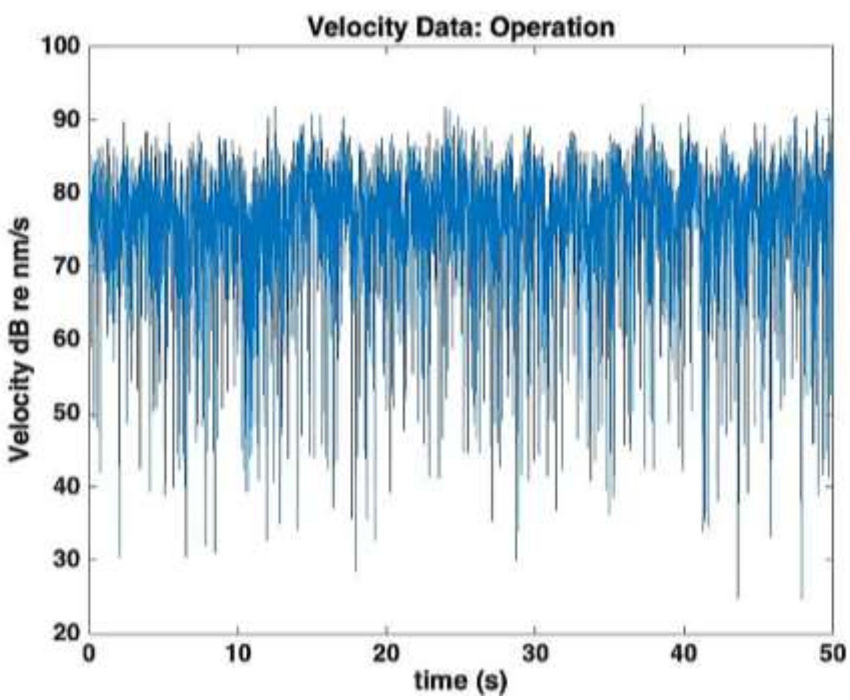

Figure 42. Acoustic particle velocity measurements during operation. Data shows the measurements from geophones on the seabed. The velocities are shown in dB re 1 nm/sec.

Figure 43 shows the comparison of the particle accelerations calculated from geophone measurements with published behavioral audiograms for some of the fishes (Hawkins and Johnstone 1978, Chapman and Sand 1974, and Chapman and Hawkins 1973). Particle accelerations are shown in dB re 1 $\mu m/s^2$. The particle acceleration near 70 Hz is approximately 25 to 30 dB re 1 $\mu m/s^2$, which is higher than that measured in the winter deployment. The peak levels near 70 Hz in **Figure 12** are less than 20 dB re 1 $\mu m/s^2$.

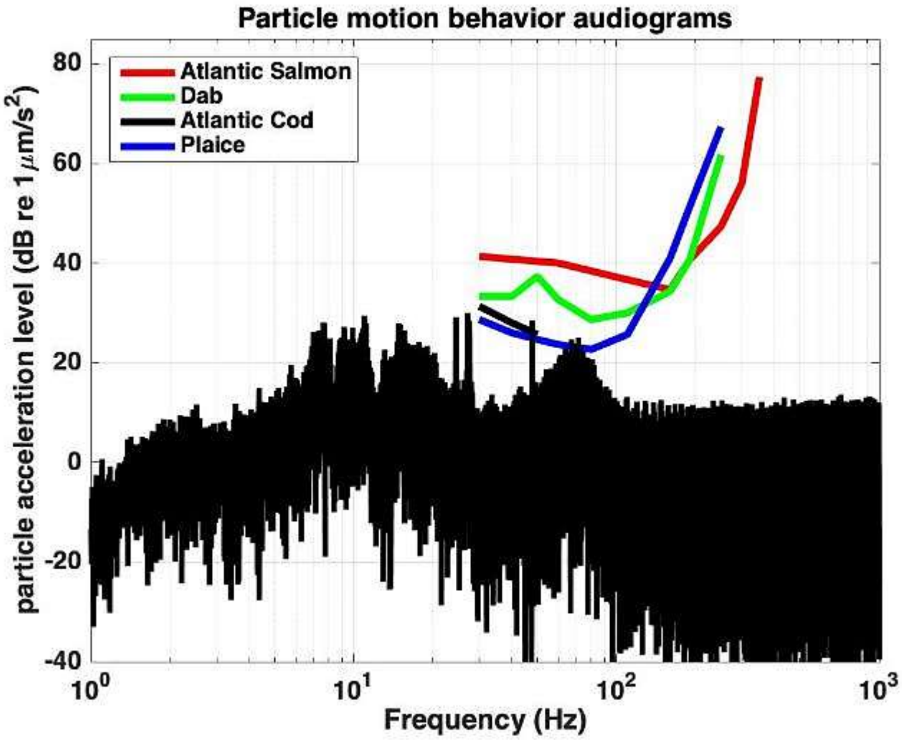

Figure 43. Particle acceleration calculated from geophone measurements for the October/November deployment compared with behavioral audiograms of Atlantic salmon (Hawkins and Johnstone 1978), Plaice and Dab (Chapman and Sand 1974), Atlantic cod (Chapman and Hawkins 1973). Particle accelerations are shown in dB re 1 μm/s2.

4.3.3 Air/Sea Acoustic Interaction Data

Concurrent air/water sound measurements were recorded near WTG 1 on 2 October 2017 using a customized three-element omni-directional microphone array (**Figure 44**). Each microphone was separated by 2.7 m (8.9 ft) and pointed directly at the wind turbine. A single hydrophone was concurrently lowered into the water column to 5 m (16 ft) depth. All four recorders were synchronized and recorded at 44.1 kHz. All vessel engines were shut off to reduce ambient sound.

A GoPro™ video camera was attached to the array to record blade speed rates. A single frame from the GoPro™ video recorder while drifting from WTG 1 during sea/air sound recording is shown in **Figure 46**. The video output was used to determine the blade rate for a complete cycle at WTG1 during the recording, which was measured at 14 seconds or 4.6 seconds per blade.

Spectrograms from each channel for the entire recording period are shown in **Figure 46**. The three omni-direction microphones are show in the top three panels, and the hydrophone signal is show in the bottom panel. All four channels were synced and the figure shows good comparison between the channels. The horizontal bars in the image separates the section that will be inspected closer. The same signal is also compared in **Figures 47** (higher frequencies) and **48** (lower frequencies). Only sound from the turbines was noticed in the lower frequencies.

Figure 49 is a comparison of the microphone signal and the hydrophone signal. The figure shows both mechanical sounds and wind, but the wind dominates the mechanical sounds, which were recorded at frequencies of 60, 70, and 85 Hz on the hydrophone located 750 m (2,477 ft) from the turbine. The sound propagation path needs further investigation.

Figure 44. Customized omni-directional microphone array used for concurrent recording of air/water sound measurements.

Note: The wind speeds on 2 October 2017 were too high for data processing; therefore, aerial sound monitoring data from a single hydrophone were compared to underwater sound monitoring data collected using a hydrophone that was lowered from the side of the vessel.

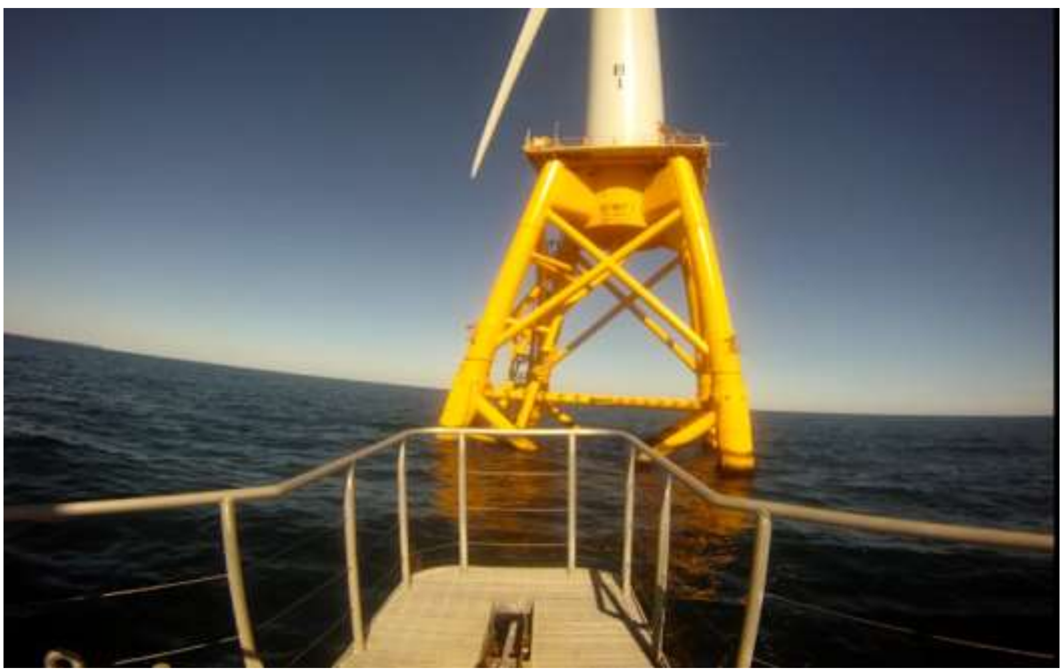

Figure 45. A single frame from the GoPro™ video recorder while drifting from WTG1 during sea/air sound recording.

Note: The GoPro™ compresses (normalizes) the recorded audio to its highest value, thus making the audio unusable due to wind and handling sound. At the closest range that recording started and listening on the deck, mechanical sound from the turbine generator was slightly noticeable.

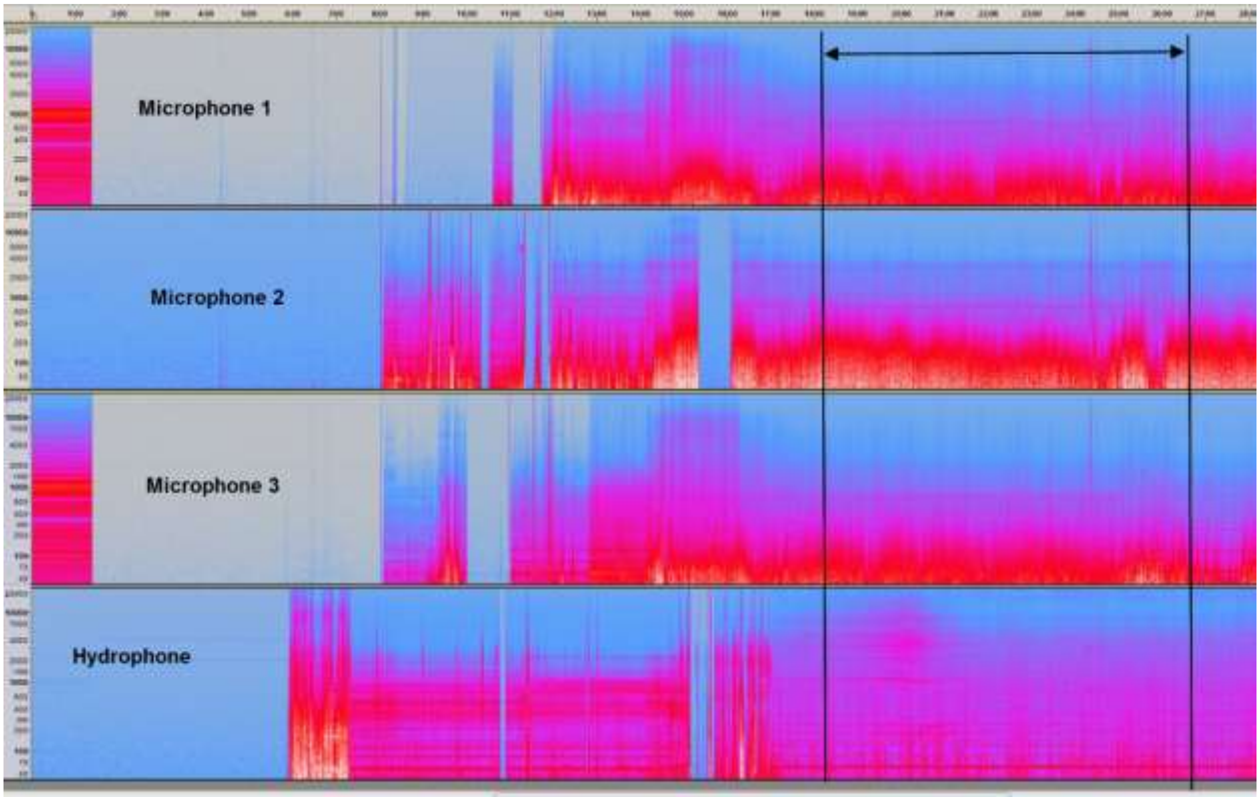

Figure 46. Spectrograms from three microphones and a hydrophone that were recording simultaneously.

Note: The black lines mark the section where the ship was drifting and the WTG 1 generator sound inspected. The frequency band seen here is from 50 Hz to 20 kHz.

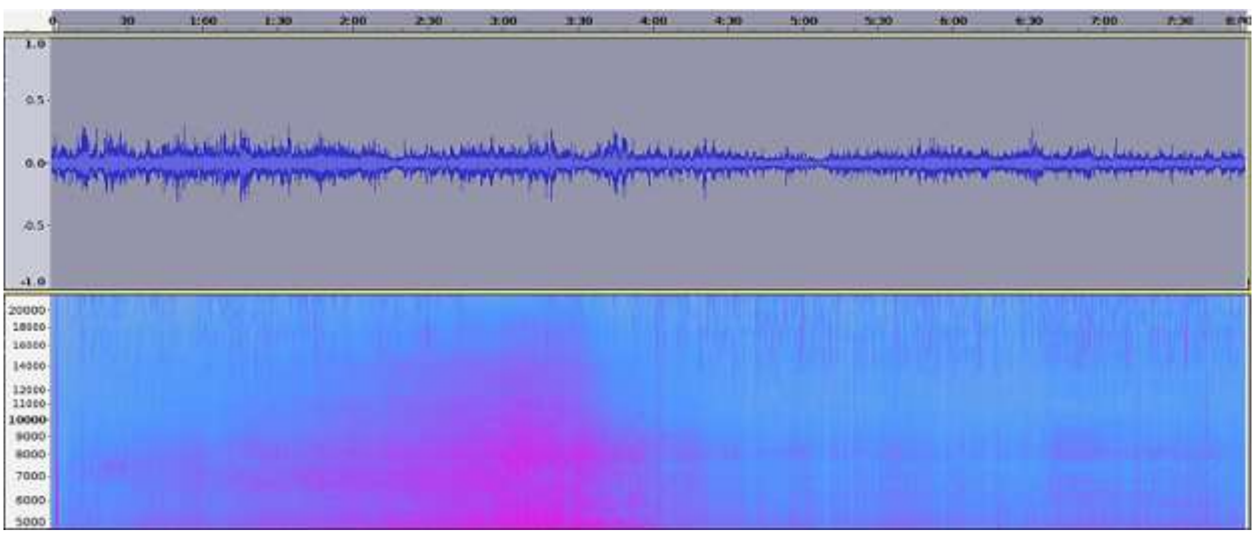

Figure 47. A look at the higher frequencies from the turbine sound from microphone #3. The top panel is the recorded signal and the bottom panel is a spectrogram from 5 to 20 kHz.

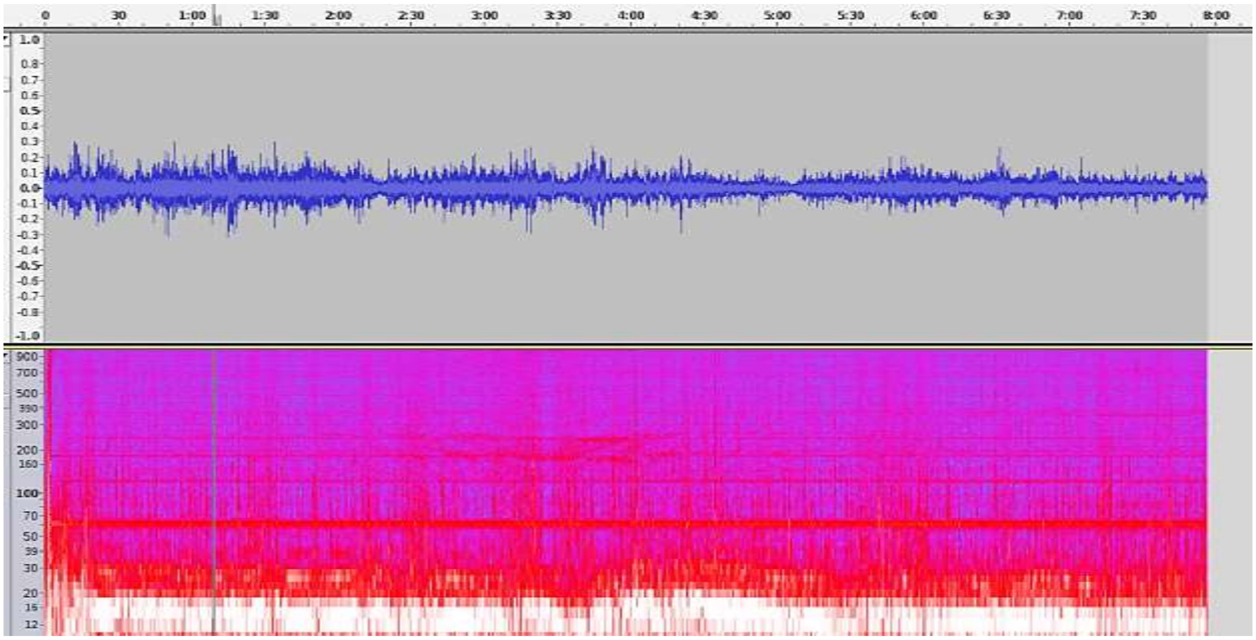

Figure 48. Zooms into the lower frequencies from the same signal as Figure 28 from microphone #3.

Note: The upper panel is the turbine signal. The lower panel is a spectrogram from 10 to 900 Hz. Notice frequency bands in the lower frequencies.

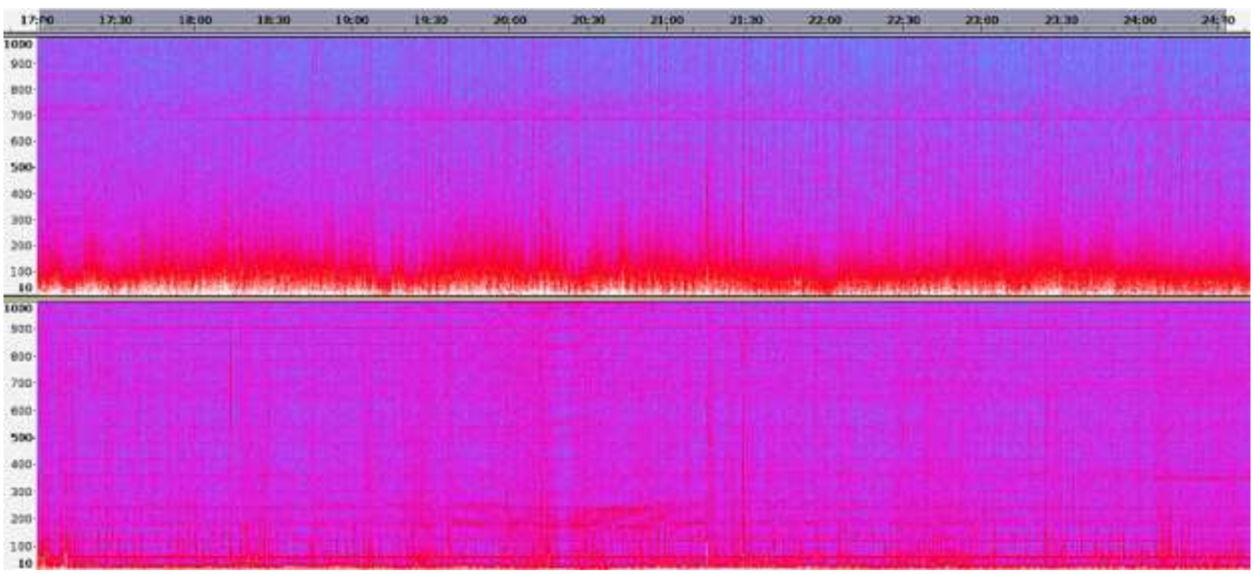

Figure 49. Comparison of low frequency signals from microphone #3 and hydrophone at 5 m (16.4 ft) under water.

Note: The top panel is the spectrogram from microphone #3. The lower panel shows the spectrogram from the underwater hydrophone. The frequencies show here range from 40 to 1,000 Hz. Periodic saturated sound from wind and waves is evident but frequency bands in the same levels are noticed in both air and water.

4.3.4 Conclusions from 2017 Late Summer Operational Phase Underwater Acoustic Monitoring

Key conclusions from the late summer operational phase underwater acoustic monitoring are as follows:

1. Underwater sound between approximately 70 and 120 Hz was recorded in the water column on all four channels of the VLA placed 100 m (328.1 ft) away from WTG 1.
2. Air noise measurements also showed tonals near 71 Hz, indicating that the source of the operational sound from the wind turbines may be due to aero-dynamical sources.
3. Acoustic signals less than 40 Hz were also recorded; these are most likely attributable to mooring sound due to windy events and high currents.
4. A large increase in sound was recorded after 23 October; this is most likely caused by storms.
5. Similar to the winter measurements, the sound speed profile in late summer (October) was also almost a constant throughout the water column, but the speed was higher due to warmer waters.
6. Data also indicated that numerous vessels transited the survey area during the monitoring period.
7. Tonals were also measured on the bottom mounted hydrophones collocated with the geophones.
8. Statistical analyses indicated that the mean sound levels were independent of wind turbine location except for larger variability near WTG 1 likely due to increased shipping near that turbine.
9. Particle velocities measured in late summer were higher than measured during the winter 2016 measurements. The signals were still below the threshold of some of the fishes for which audiograms are available.
10. Overall, sound pressure levels measured in late summer during turbine operations were lower than those recorded during the construction phase.

4.4 Extended Summer 2017 Monitoring Results

Underwater sound produced during wind turbine operations was measured at approximately 50 m (164 ft) from the base of WTG 5 over 100 days (approximately 14 weeks) from 15 July to 24 October 2017 using a sled-mounted, stationary Brüel & Kjær type 8106 hydrophone (Serial No. #2575949). Results and key findings from this monitoring are summarized below. Additional details are presented in **Appendix D**.

4.4.1 Survey Methods

The sled was deployed at 41 06.3515 N and 71 32.1730 W at a water depth of 30 m (98.4 ft). It consisted of a specially built frame and pressure vessels for custom-built amplification and audio data acquisition electronics, with two additional pressure vessels containing alkaline batteries. The hydrophone was suspended above the frame using a pellet buoy, with the sensor located approximately 2 m (6.6 ft) above the seabed.

The monitor sampled sound pressure levels continuously, processing and storing them as 10 second ⅓ octave-band center frequency data between 10 and 20,000 Hz. Discrete 15-second audio .wav files were recorded in parallel at 48 kHz sample rate every 15 minutes for the duration of the survey, until the batteries were exhausted.

Sound measurements were sampled as both duty cycled .wav files at a rate of 15 seconds every 15 minutes at a sample rate of 48 kHz, and as continuous ⅓ octave .csv data from 10 Hz to 20 kHz octave band center frequencies averaged every 10 seconds. Wind speeds over this period ranged from flat calm to 22 m/s and a maximum rotor speed of 11 rpm. Operational data for the turbines (rotational speed for the turbines, wind speed, and wind direction) concurrent with the monitoring period were obtained from Deepwater Wind and used in the analyses.

4.4.2 Results

Monitoring data indicated that the underwater sound levels recorded over the 100-day period ranged from 101.2 (10-minute sample time) to 141.7 dB re 1 µPa sound pressure level (SPL) RMS. It is possible that the outliers in the recorded range are not necessarily correlated to turbine operations; underwater sound from turbine operations most likely fluctuated between 110 and 125 dB re 1 µPa SPL RMS.

Overall, recorded underwater sound levels showed consistent correlation with prevailing wind speeds (**Figures 50** to **54**). Data from one week of monitoring conducted in July 2017 are shown in **Figure 50**. This figure shows the correlation in general, but also shows features where sound levels did not track as expected, such as the reduction in sound on 27 July despite increasing wind speed.

Figure 51 presents wind speeds and underwater sound 10-minute resolution time history for August 2017. It is worth noting that two sound level traces have been included on the chart with different upper frequency limits: the top trace excludes all frequencies above 8 kHz. This is because of a significant and continuous signal that was found to affect sound at 10 kHz, which was apparently independent of turbine operation or environmental conditions. Further verification noise samples using different measurement equipment did not replicate this signal. There is a clear lower limit to the broadband sound level of approximately 125 dB caused by data at these higher frequencies and a 'whistle' at 10 kHz is clearly audible on the audio recordings. Therefore for detailed analysis a high frequency cut-off at 8 kHz was selected, as these lower frequencies relate to the environmental conditions. The low frequency cut-off was set to 10 Hz.

The correlation between underwater sound and prevailing wind speeds was also observed in data recorded during September 2017; measured sound level increased and decreased with changing wind speeds (**Figure 52**). A number of extended zero wind speed periods can be seen, particularly around 4 and 20–24 September. These represent periods where auxiliary data were not available. In October 2017, data were recorded over the first 24 days, and the trend between underwater sound levels and prevailing wind speeds is shown in **Figure 53**.

4.4.2.1 Analysis of effects of wind speeds on sound levels

Approximately 900,000 sound data samples, averaged every 10 seconds, were captured during the survey. The recorded data were reduced to 10-minute averages and plotted against wind speeds to determine the effect of wind on the sampled sound levels. The analysis only included the 10 Hz to 8 kHz frequency bandwidth.

Figure 54 shows the complete data set of underwater sound levels sampled by the monitor over the entire survey duration (15 July to 24 October 2017) against wind speed. No attempt has been made here to filter out specific events. There is considerable scatter although the overall sound levels largely tend to remain within a 20 dB band across all wind speeds. The averaging line shows a clear increase in sound with wind speed. It is worth noting that there is no clear effect on the sound level at the wind speed where the rotor should cut-in (3 m/s) or the wind speed at which the turbine will reach maximum rotational speed (11 to 12 m/s). This may indicate that the overall underwater sound is influenced directly by wind sound; that is, natural environmentally generated sound.

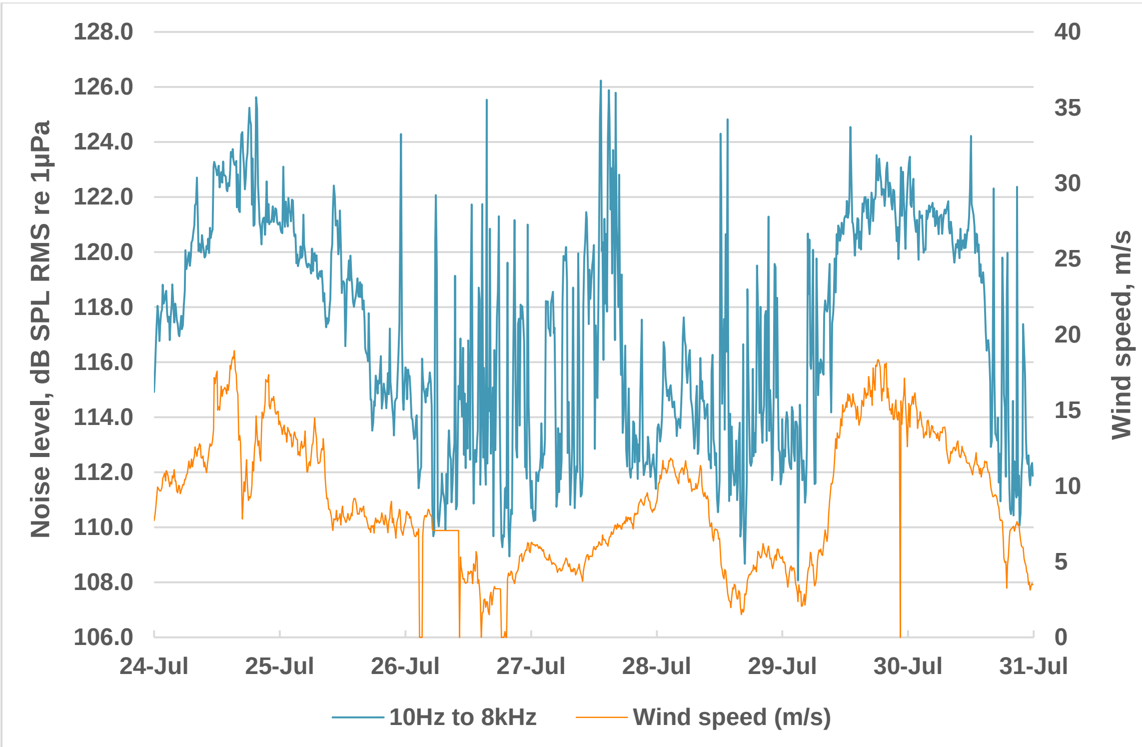

Figure 50. Prevailing wind speeds and underwater sound levels recorded in July 2017 (with an 8 kHz upper frequency limit).

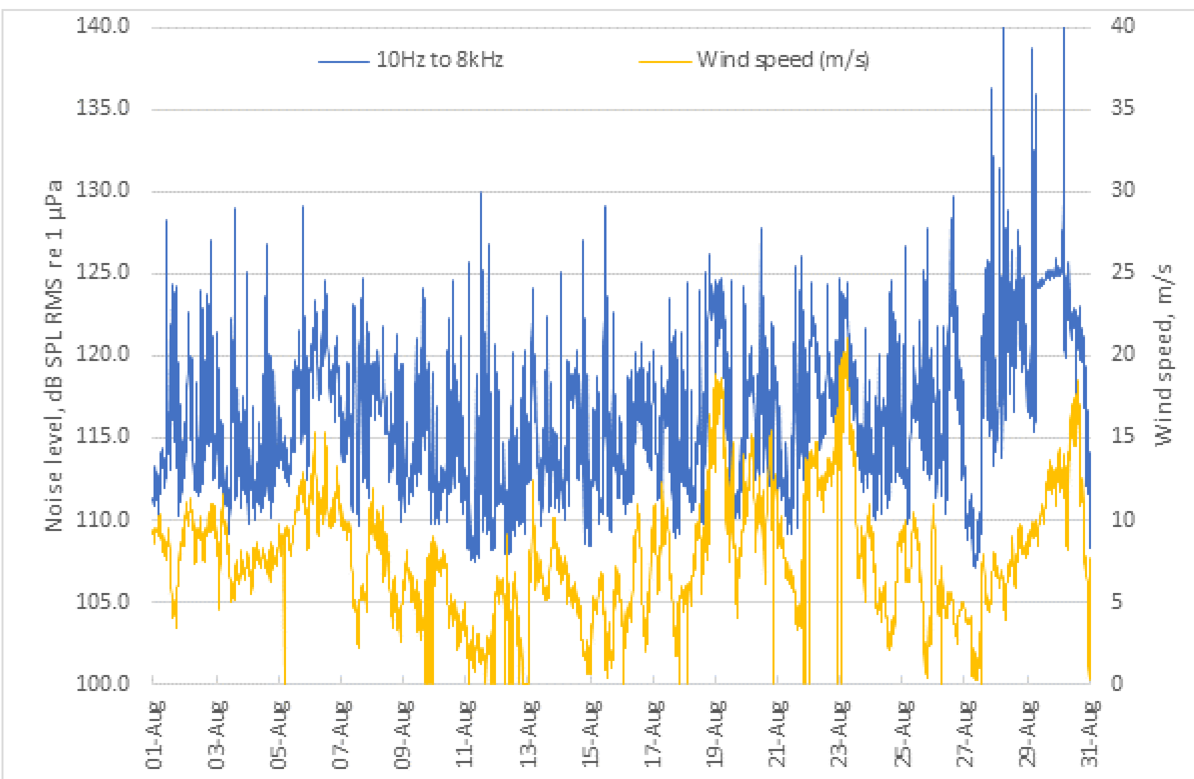

Figure 51. Prevailing wind speeds and underwater sound levels recorded in August 2017 (with an 8 kHz upper frequency limit).

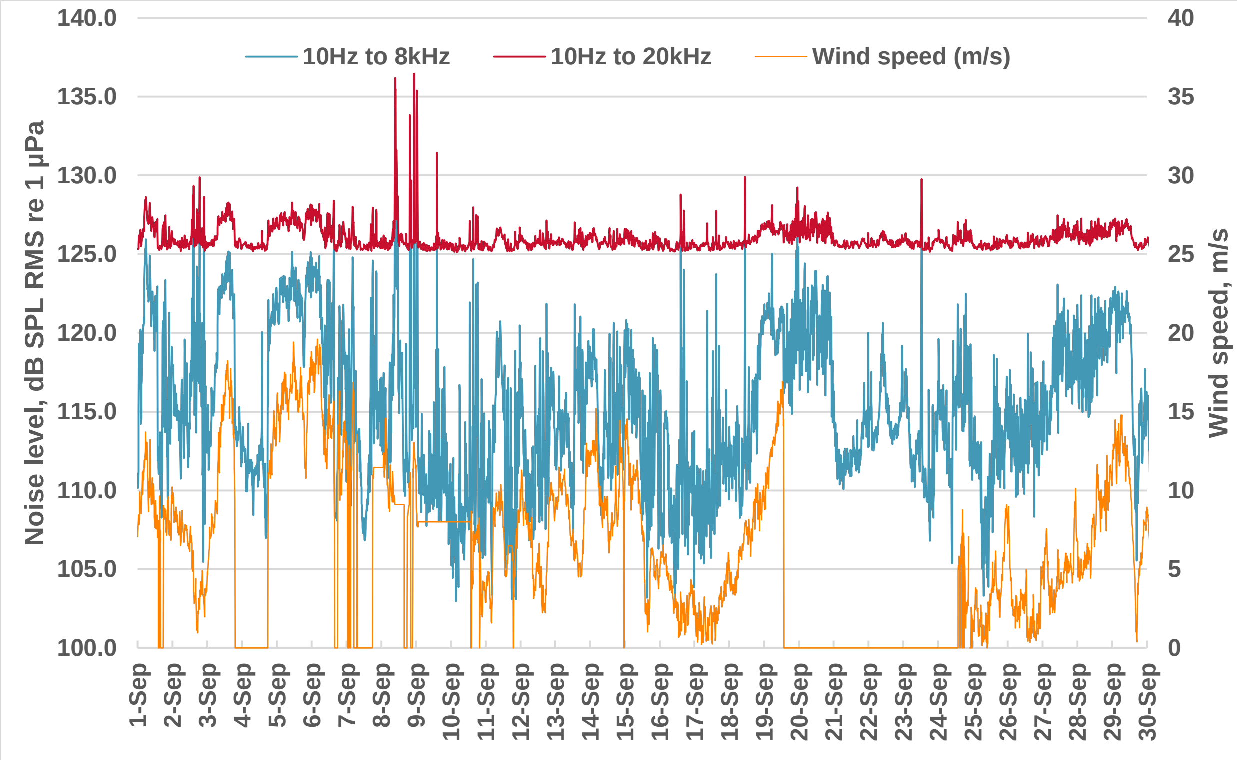

Figure 52. Prevailing wind speeds and underwater sound levels recorded in September 2017 (with both an 8 kHz and 20 kHz upper frequency limit).

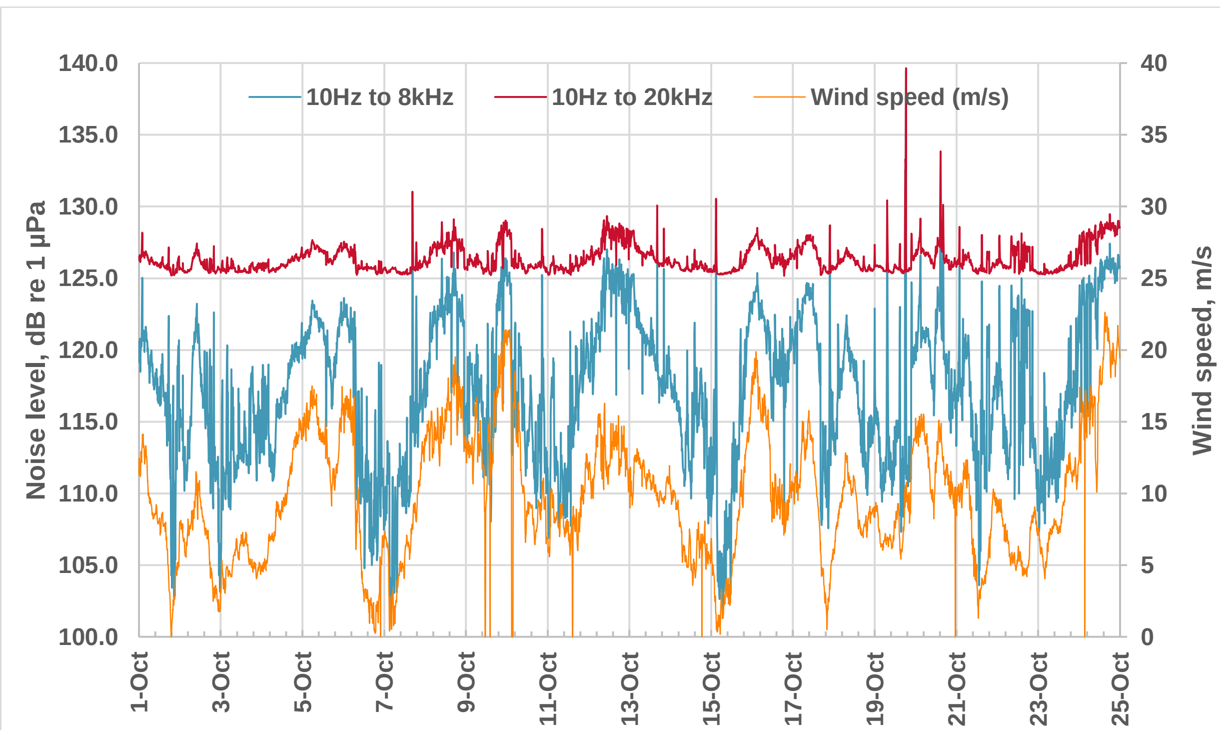

Figure 53. Prevailing wind speeds and underwater sound levels recorded in October 2017 (with both an 8 kHz and 20 kHz upper frequency limit).

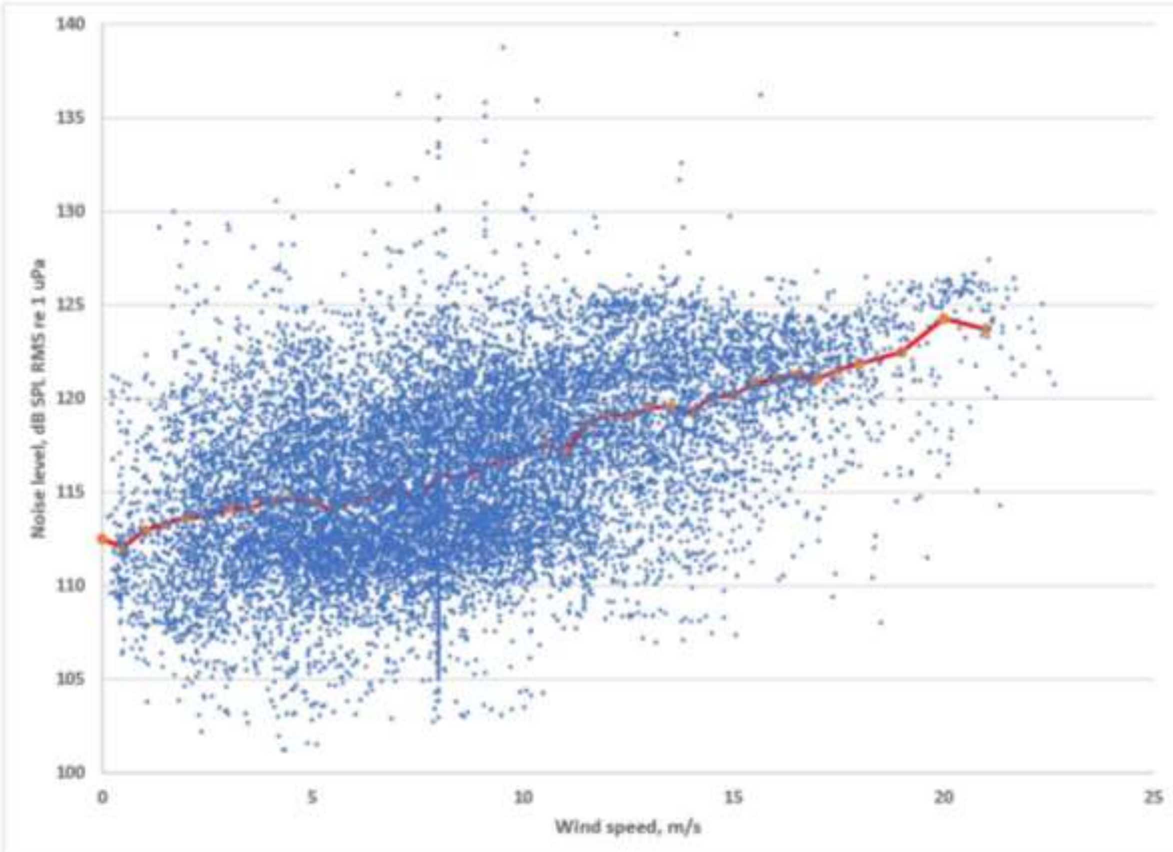

Figure 54. Sampled sound levels (10 Hz to 8 kHz) for July to October 2017 survey period against wind speed with 0.5 m/s interval average.

Overall, measured sound levels were shown to be affected by sounds from local vessel traffic especially during daylight hours. Vessel sound was clearly visible in the charts and increased the sound primarily in the hundreds and low thousands of Hz. It was also observed that the majority of vessel traffic on any given day occurred between 10 AM and 10 PM. Therefore, to reduce risk of contamination from vessel sound and improve resolution of the analysis of underwater sounds directly associated with turbine operations, all data points sampled between 10 AM and 10 PM were eliminated from further analyses. Data between 10 Hz and 8 kHz (⅓ octave bands inclusive) were used for the analysis.

Figure 55 shows all sound samples between 10 PM and 10 AM. Possible effects on the sound level around the wind speeds relevant to the maximum speed of the rotor can be seen in a hump around this speed. However, the difference in dB of the trend is small compared to the approximately 20 dB natural fluctuations of sampled sound levels. This is not thought to be influenced by any airborne noise from the blades or their orientation, or any other non-water-based noise source as the noise levels in air were so low compared to the existing ambient airborne noise (see **Section 3.2**)

The scatter analysis depicted in **Figure 56** shows little overall variation between August and September 2017; although outliers did tend to be higher in August and lower in September. The trend lines showed that the average sound level in August tends to be higher at the same wind speeds, although the difference is marginal. Thus the effect of the event on the overall sound levels appears to be small. A 'blip' occurred at 8 m/s; this appears to be a default figure applied in the supplied wind speed data and is likely to be spurious.

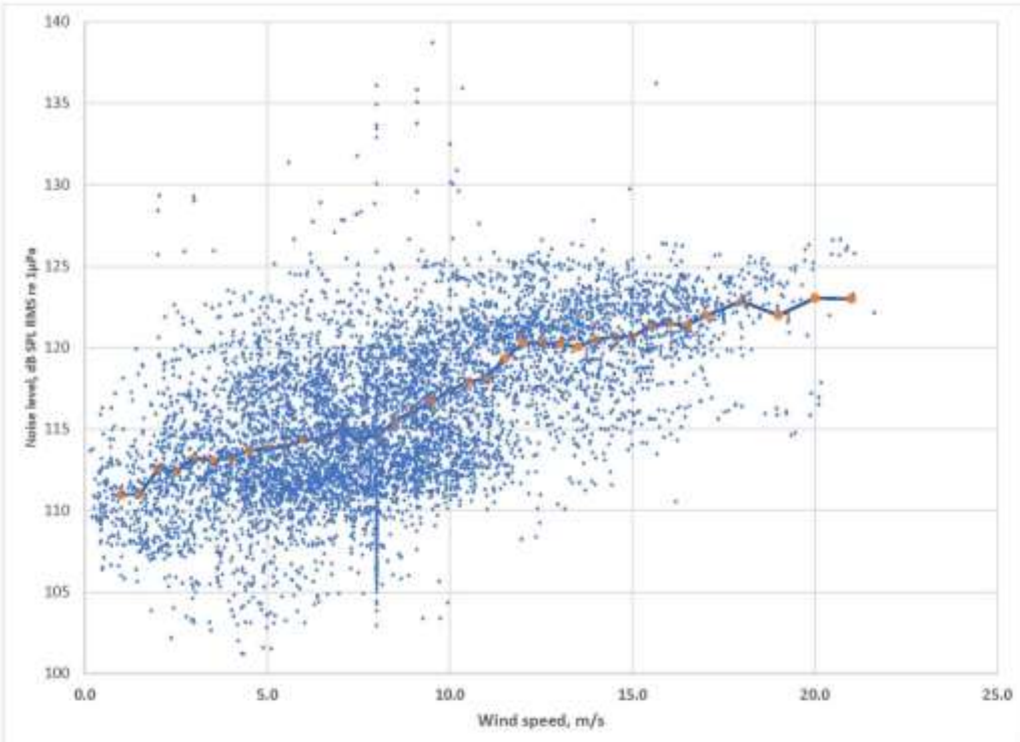

Figure 55. Sampled sound levels (10 Hz to 8 kHz) for July to October 2017 against wind speed with 0.5 m/s interval average. Data sampled between 10 PM and 10 AM only.

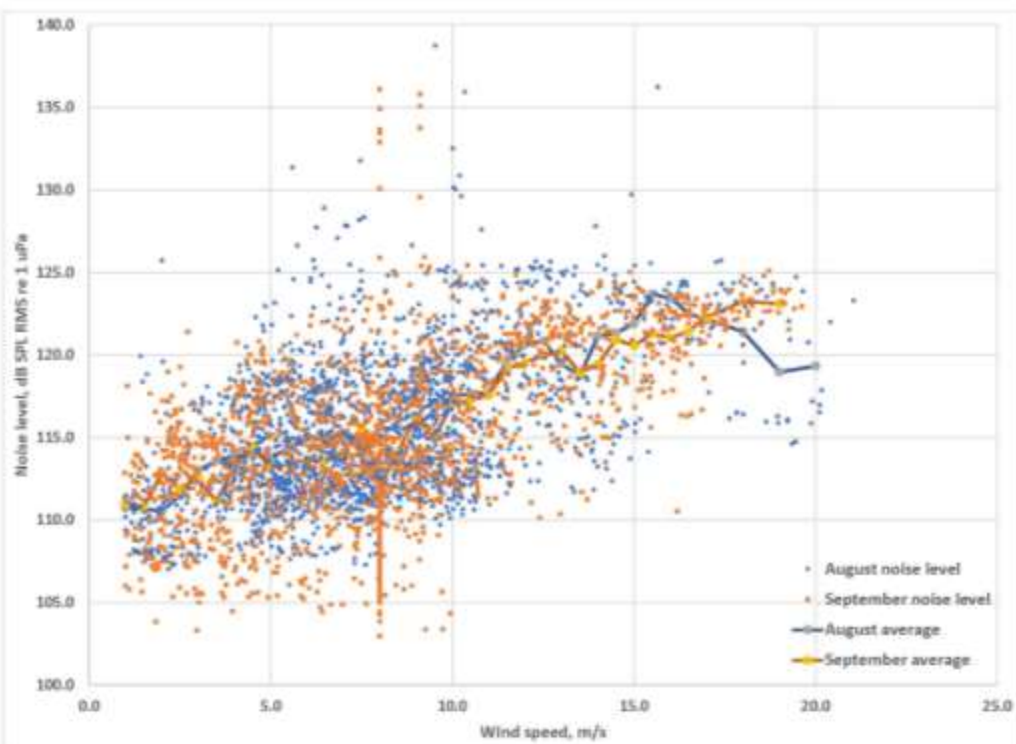

Figure 56. Sampled sound levels (10 Hz to 8 kHz) against wind speed with 0.5 m/s interval average trend-lines for August and September 2017. Data sampled between 10 PM and 10 AM only.

A comparative scatter plot for data collected over 15 days in July and 24 days in October (10 PM to 10 AM data only) is shown in **Figure 57**. The results show a similar scatter, although the October data has more points at higher wind speed and show a larger collection of points above 20 m/s with respective increased sound levels. Similarly, there is a large collection of data points in October at lower levels than occurred in July, and they occur at a range of wind speeds up to 9 m/s. These lower levels are also seen to a lesser extent in sampled overall sound levels (10 Hz to 8 kHz) against wind speed with 50 pt. moving average trend-lines for August and September 2017. Data sampled between 10 PM and 10 AM only.

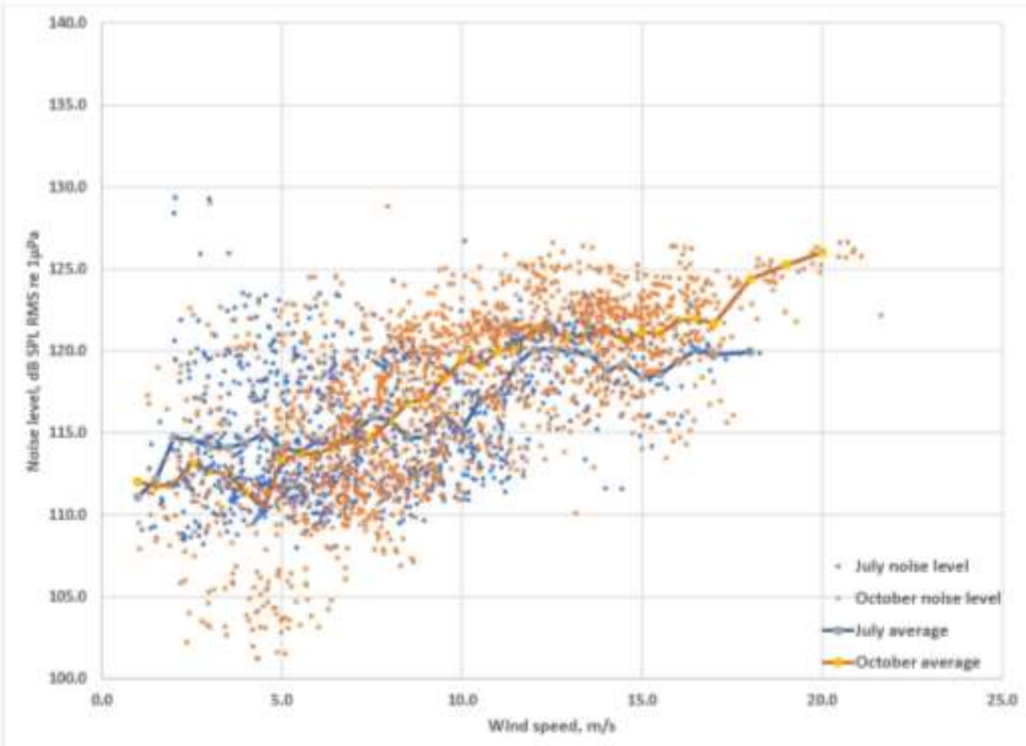

Figure 57. Sampled overall sound levels (10 Hz to 8 kHz) against wind speed with 0.5 m/s interval average trend-lines for July and October. Data sampled between 10 PM and 10 AM only.

Many of these data points occur in the period of September 7 to 10, when for most of a four day period there is no rotation of the turbine despite good winds. It is suspected that the turbine had been shut down for maintenance or other operational reason. The low-noise level data in October all occur in the early morning of October 7, when the rotor was not moving. Winds in this time were also low.

Table 10 shows the arithmetic average of overall sound levels recorded between 10 PM and 10 AM from each month's data points, in wind speed blocks. Each band includes all data from the labelled wind speed ±1 m/s; for example the 2 m/s band includes data from 1 m/s to 2.9 m/s. The month-to-month variation in overall average sound level is no greater than ±1.8 dB for each wind speed band.

Table 10. Average underwater sound level 50 m from WTG 5.

Wind speed	July, dB	#	August, dB	#	September, dB	#	October, dB	#	Average, dB	#
2 m/s	113.9	14	110.8	20	111.7	32	112.3	10	112.2	76
4 m/s	114.6	35	113.8	43	112.8	35	111.3	21	113.1	135
6 m/s	114.2	43	114.5	87	113.5	33	113.8	47	114.0	210
8 m/s	115.3	31	115.1	75	114.6	40	115.4	52	115.1	198

Wind speed	July, dB	#	August, dB	#	September, dB	#	October, dB	#	Average, dB	#
10 m/s	115.6	27	116.7	72	116.3	38	118.3	44	116.7	180
12 m/s	118.8	22	119.3	25	119.1	19	120.6	34	119.5	99
13+ m/s	119.5	19	120.8	33	120.9	43	121.4	76	120.6	170

Note: SPL dB re 1 μPa, at wind speed bands. # indicates number of hours over which each average was calculated.

The numerical effect of increasing wind speed are shown in **Table 11** along with the average sound levels across the entire measured dataset (10 PM to 10 AM).

Table 11. Effect of wind speed increases on underwater sound level, SPL RMS dB re 1 μPa, at 50 m from the turbine.

Wind speed	Overall average sound level, dB	Increase from previous wind speed band, dB	Increase in sound level for doubling of wind speed, dB
2 m/s	112.2	-	-
4 m/s	113.1	0.9	0.9 (2 to 4 m/s)
6 m/s	114.0	0.9	1.9 (3 to 6 m/s)
8 m/s	115.1	1.1	1.9 (4 to 8 m/s)
10 m/s	116.7	1.7	3.2 (5 to 10 m/s)
12 m/s	119.5	2.7	5.5 (6 to 12 m/s)
13+ m/s	120.6	1.2	5.6 (8 to ~15 m/s)
TOTAL	* ARI 115.9; LOG 119.0	1.5 per 2 m/s increase	

* Indicates the ARIthmetic and LOGarithmic average of sound levels at all wind speeds. Data collected from 10:00 PM to 10:00 AM.

A more direct analysis of the turbine's underwater sound output was conducted by comparing turbine rotor speed with recorded sound levels. Two separate analyses were conducted, one with the complete data set (**Figure 58**) and the other with data sampled between 10 PM and 10 AM only (**Figure 59**). For both analyses, data points at rotor speed 0 were excluded.

Results indicated that there are two distinct rotor operational modes, the first with rotational speed between 3.8 and 5.1 rpm, and a second at 6.4 to 11.5 rpm. There appears to be an artificial restriction of the blade rotational speed at these limits, leading to a clustering of data points. The two modes did not have any clear impact on the average sound level, which was observed to increase fairly smoothly. There was an increase in the average sound level that occurred at the final cluster of data points at the highest rotor speed of 3 to 4 dB; this is not unexpected and is most likely caused due to the effect of increasing wind speed beyond the rotational speed limit.

The exclusion of sound levels sampled between 10 AM and 10 PM had little effect on the average except at low rotor speeds, when the conditions were calm and more vessel movements could be expected, even outside of 10 AM to 10 PM.

The results from these analyses do not necessarily show a clear influence of sound caused by turbine machinery over and above the direct effect of wind speed (and therefore sea condition) on local underwater sound levels, when using the overall broadband sound levels as the data point.

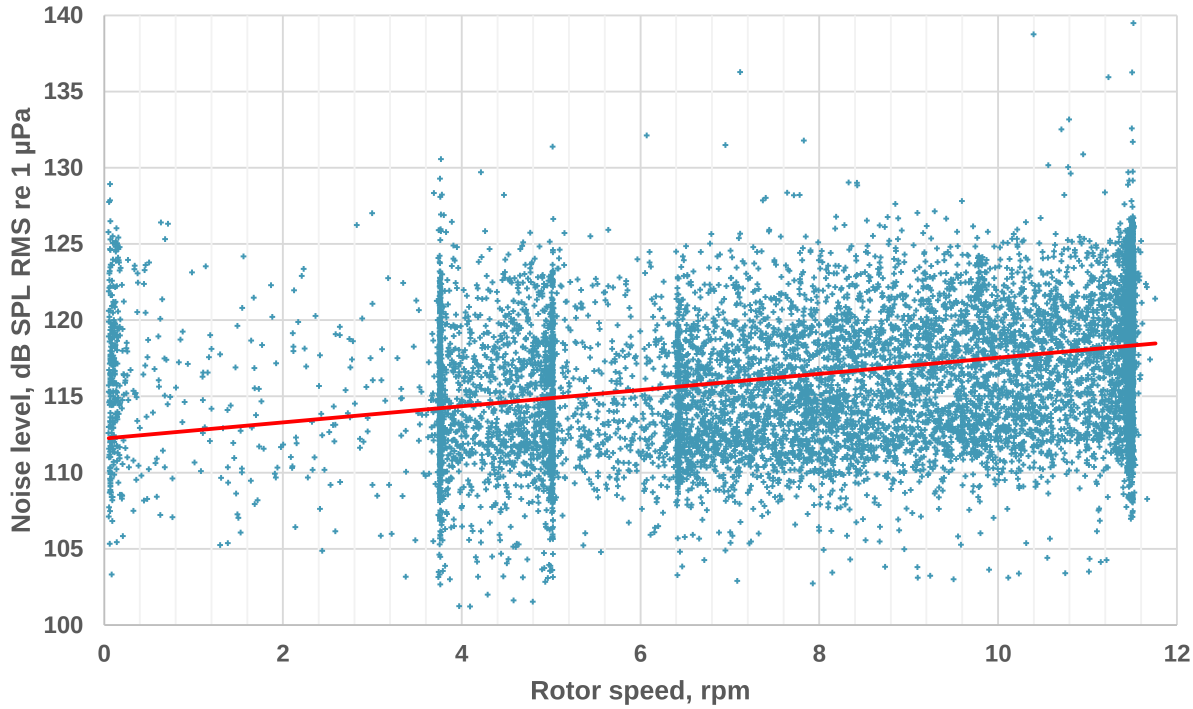

Figure 58. Sampled overall sound levels (10 Hz to 8 kHz) against blade rotation speed with linear average. Full dataset.

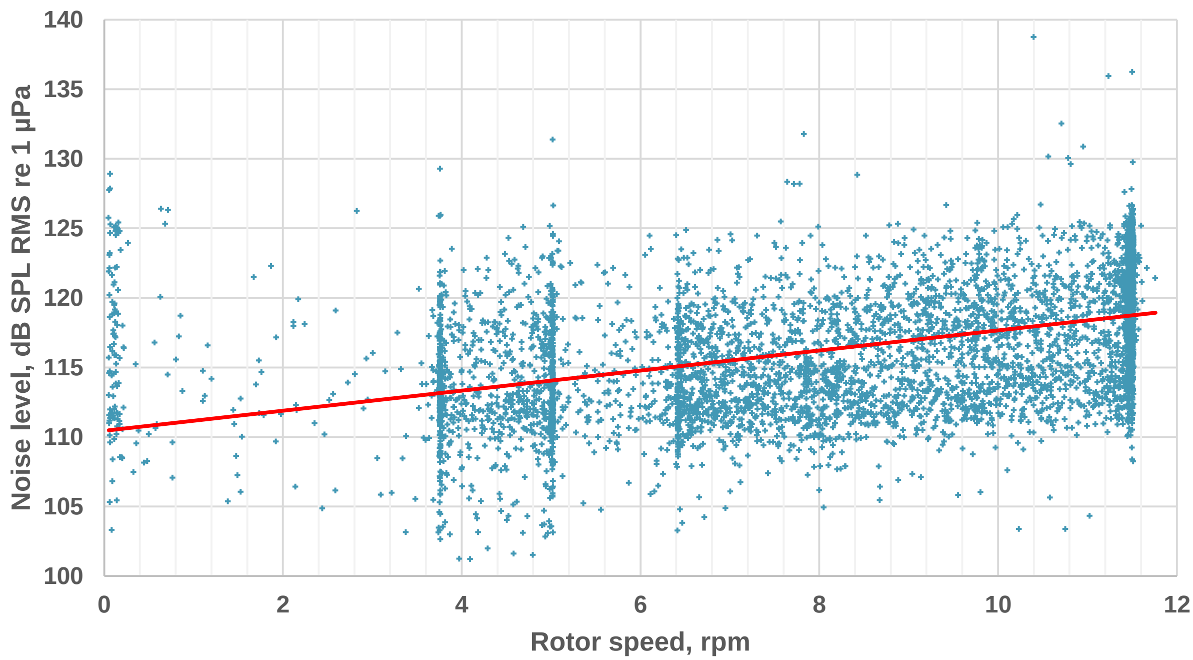

Figure 59. Sampled overall sound levels (10 Hz to 8 kHz) against blade rotation speed with linear average; data sampled between 10 PM and 10 AM only.

4.4.2.2 Frequency Analysis

Both the turbine machinery and natural weather conditions (wind and sea state, for example) are likely to generate low frequency sounds. Therefore a frequency analysis was conducted to evaluate the composition of the recorded underwater sound levels.

Figure 60 shows a sample of the composition of the sound, as ⅓ octave band sound level spectra, of samples within a 24-hour period on a day showing the extremes of the turbine operation and key features of the captured sound levels. The red, purple and blue spectra in **Figure 60** were taken from 10-minute average sound levels before, during and after a temporary rotor shut-down. The wind speed remained at the upper end of speeds that the turbine could tolerate. The reason for the shut-down was unknown but it provided an opportunity for analysis of effects of blade rotation on underwater sound levels while the wind conditions remained approximately constant.

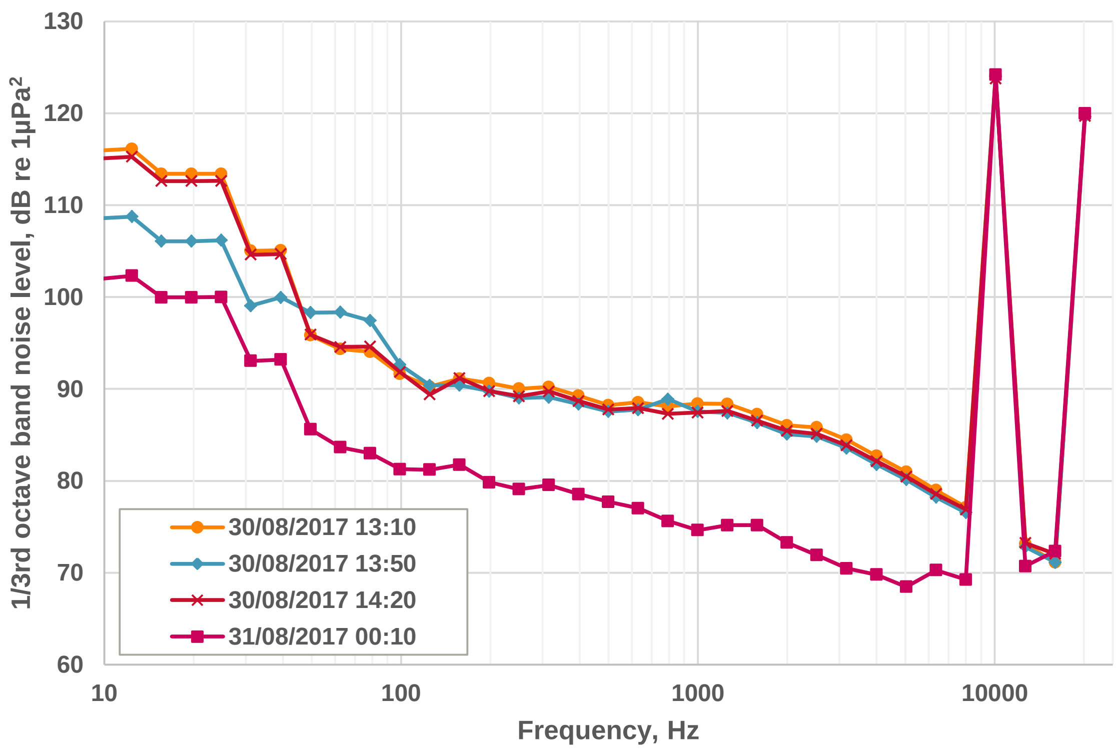

Figure 60. 1/3rd octave band center frequency spectra for [RED and ORANGE] turbine active, maximum rotor speed, approximately 18 m/s wind speed, [BLUE] shut-down, no rotation, approximately 15 m/s wind speed; [PINK] no rotation, calm wind. No vessel traffic.

Results indicated that while the blades were turning at maximum speed (12 rpm), the sound in ⅓ octave bands below 100 Hz increased by 3 to 10 dB, with the effect greatest at the lowest frequencies (**Figure 61**). Above 100 Hz, the turbine appeared to have no effect on sound levels. There was a small increase in sound levels between 50 and 100 Hz when there was high wind and no rotation and further analysis of the data over the long term shows this only occurred around the shut-down period at other times. It is speculated that this may be due to with the braking mechanism or because of wind movement over the blades under a forced stop, producing vibrations that are transmitted through the tower to the foundations and then into the water column.

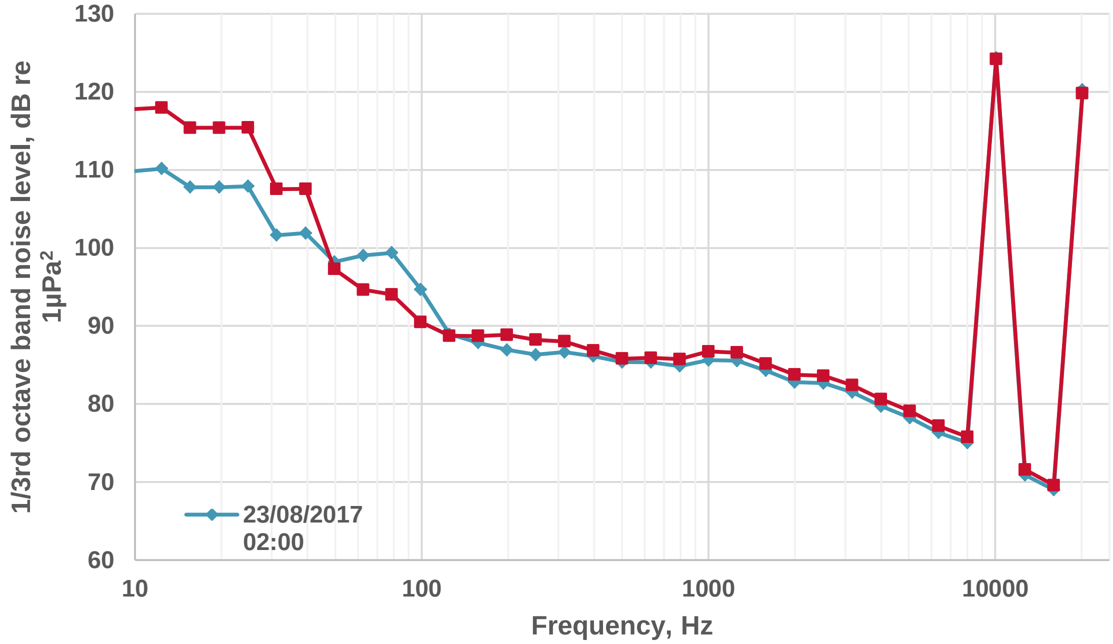

Figure 61. Verification of data shown Figure 60. 1/3rd octave band center frequency spectra for [RED] turbine active, maximum rotor speed, approximately 20 m/s wind speed, [BLUE] shut-down, no rotation, approximately 15 m/s wind speed. No vessel traffic.

A notable feature in **Figure 61** are the significant tonal peaks at approximately 10 and 20 kHz. These tones were continuous over the total survey period and audible as a high whistle on accompanying audio files. They were not present while the equipment was on the vessel and began only when the hydrophone entered the water. Narrow band analysis showed that there were small variations in these tones both in level and frequency, varying between approximately 9.5 and 11 kHz. The source of these sounds could not be identified. Follow on monitoring was conducted with different sensors, but these tones could not be identified on any other measurement system either. It is possible that they are generated by the monitoring systems itself.

As the sound level at these specific frequency bands is greater than that at any other frequency, the calculation of any broadband sound level would be totally controlled by these tones. Therefore for broadband analysis (i.e., the calculation of overall sound levels across the spectrum), investigating the variation in the sound levels with any external factor such as wind speed, has been limited to frequencies up to 8 kHz. The tones were treated as spurious and not included in the data analysis.

Figure 62 shows a chart of a comparative situation to that in **Figure 61**, with rotors at maximum speed and also shut-down despite the presence of high winds. Exactly the same sound reduction is seen on the rotor active/inactive condition under 50 Hz, and then the small increase between 50 and 100 Hz, which is only seen in the spectrogram during shut-down. The sound levels in **Figure 61** are within approximately 2 dB of those in **Figure 62**, although they are a week apart. The low frequency sound is greatest between 10 and 100 Hz and so the overall broadband sound level is controlled by sound at low frequency. The overall sound levels were calculated by summation of the ⅓ octave bands between 10 Hz and 8 kHz inclusive.

A comparative measurement was sampled approximately 10 hours later (31 August 2017 12:10 AM), when the wind speed had dropped to below where it could be registered (<1 m/s) and the blades had consequently stopped rotating. The sound levels between high wind and no wind scenarios, with no rotor movement at either, drop by at least 6 dB at all frequencies (except the 10 and 20 kHz tones). This suggests the underwater sound across the whole measured spectrum (below 10 kHz) is affected by increased wind speed.

The curves in **Figures 61** and **62** show a clear difference in low frequency sound between the "with turning" and "without turning" scenarios. There is greater energy below 50 Hz with the rotor turning as compared to the 50 to 100 Hz band when the rotor is not turning.

Figure 63 shows narrow band analysis of the periods shown in **Figure 62**, with the turbine blades turning and not turning, but with the wind speed remaining high in both. Tonal bands are visible approximately every 12 Hz and continue to be just visible throughout the analyzed spectrum, which are lost in the coarser ⅓ octave band spectra shown in **Figure 60**. These tonal bands are the primary contributors to the low frequency sound and this feature is unlikely to be produced directly by wind effects on the sea surface.

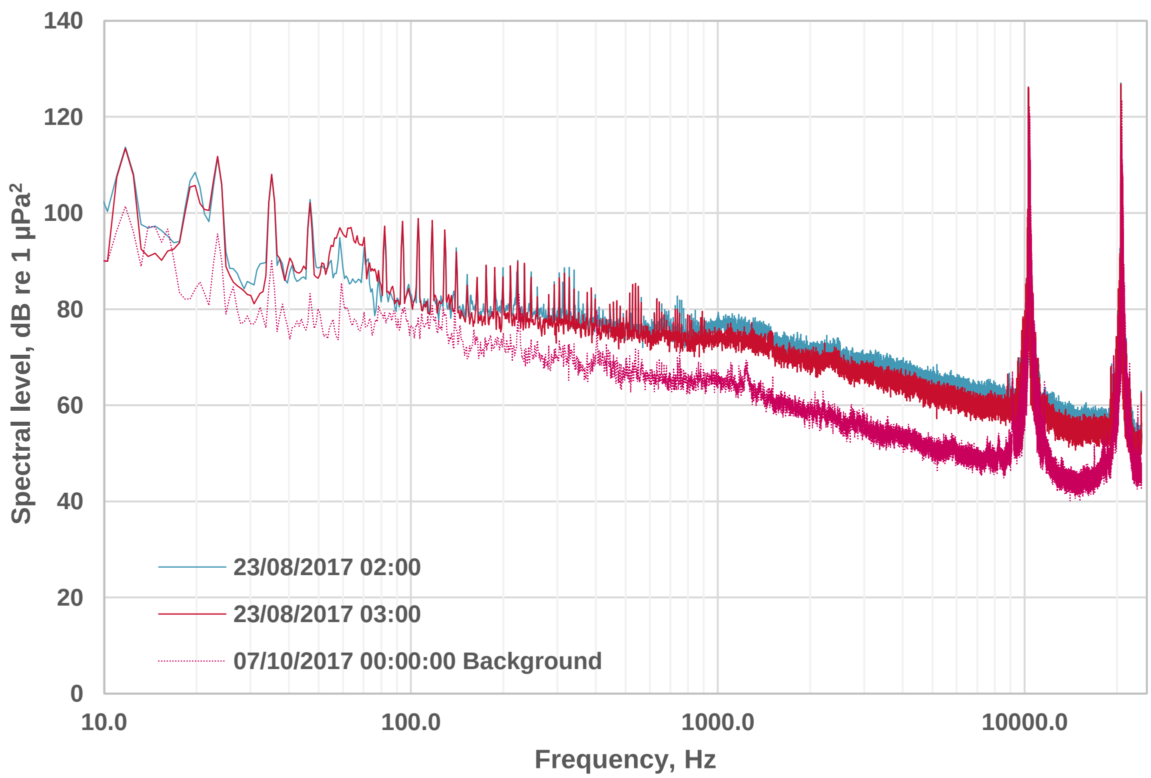

Figure 62. Narrow band analysis of 15-second audio data, wind speed 15-20 m/s. [BLUE] with rotor turning; [RED] without rotor turning.

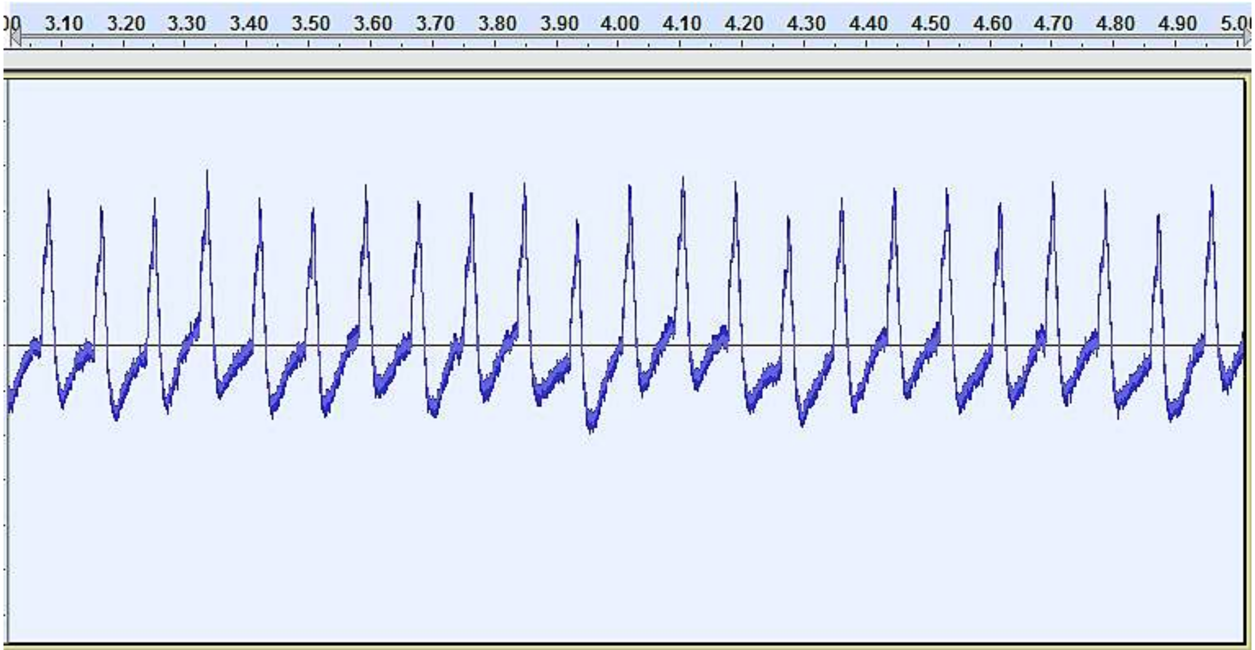

Figure 63. Waveform at 4 PM 29 August 2017, 2-second sample, showing clear 12 Hz periodic characteristics.

To investigate this effect further, a day was chosen that had clear, continuous wind and blade rotation (**Figure 63**). Narrow-band analysis was undertaken on data from 29 August 2017 at 4 AM, which had continuous wind speeds of 10 to 12 m/s and blade rotation speed at or near the maximum throughout the day. This showed almost identical signature to **Figure 62** and thus this is not repeated. A waveform of this file is shown below. This shows the clear periodic characteristics at 12 Hz.

4.4.3 Key Observations

A number of events were detected over the survey period, which contributed to the sampled sound levels. A few noteworthy ones are discussed below.

4.4.3.1 30 August 2017

A significant event was observed on 30 August, which followed from a day of strong winds and continuous, maximum blade turning speeds recorded on 29 August. The continuous wind and sound prevailed throughout the day on 29 August and continued into the next day. A sharp change in the spectral pattern was observed at approximately 4 AM on August 30 (**Figure 64**). This change coincided with the blades continuing to rotate with no apparent variation and continuous wind speeds at approximately 12 to 13 m/s. The audio of the sample collected at 4 AM was characterized by a crackling sound and it ended abruptly implying that it was not associated with a vessel or the impact on the monitoring station due to the build-up in sound over a few minutes.

A narrow band analysis of the 30-minute monitoring period from 3:45 AM to 04:15 AM on 30 August is shown in **Figure 65**. The 12 Hz characteristic seen in the spectra shown in **Figure 65** has been identified from almost the start of the monitoring period. After the 30 August 4 AM event, the characteristics only appear to recur with the lower intensity for the remainder of the duration of the survey, even at high wind and rotation speeds. This 12 Hz characteristic is visible in all 2017 spectra (**Figure** 6**5**), and it continued to influence the sound levels at both low and high frequencies. This feature distinguished the contemporary measurements from the background spectrum sampled within the survey area in September 2015.

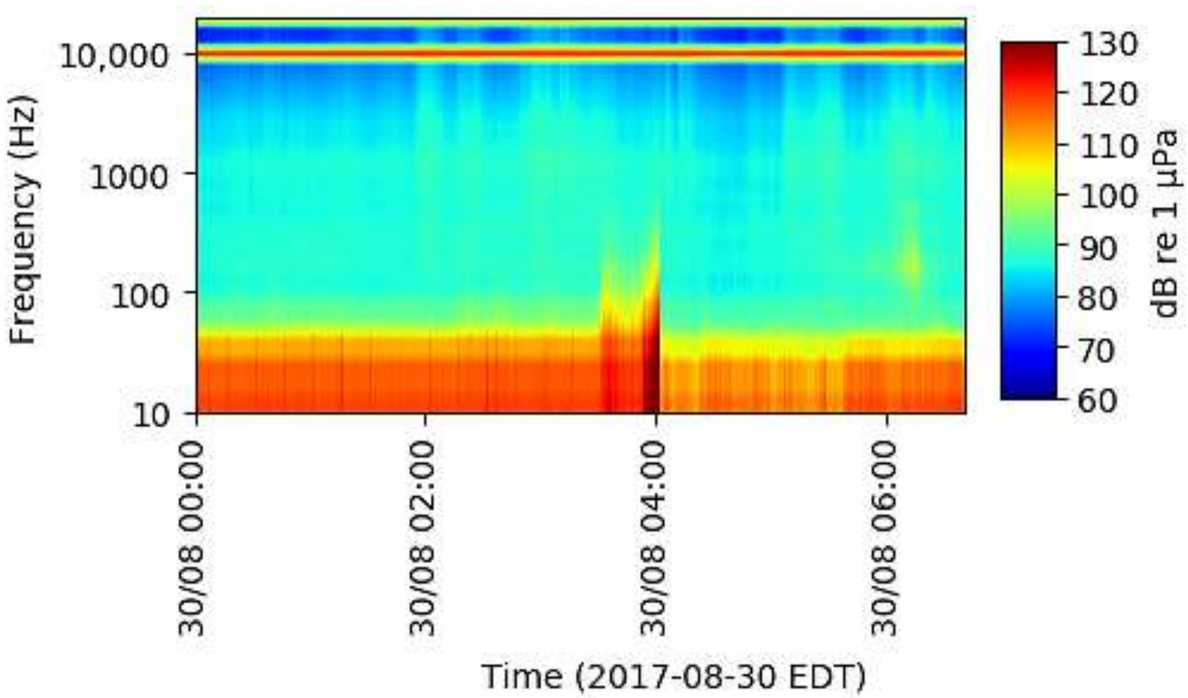

Figure 64. Spectrogram highlighting the 4 AM event on 30 August 2017.

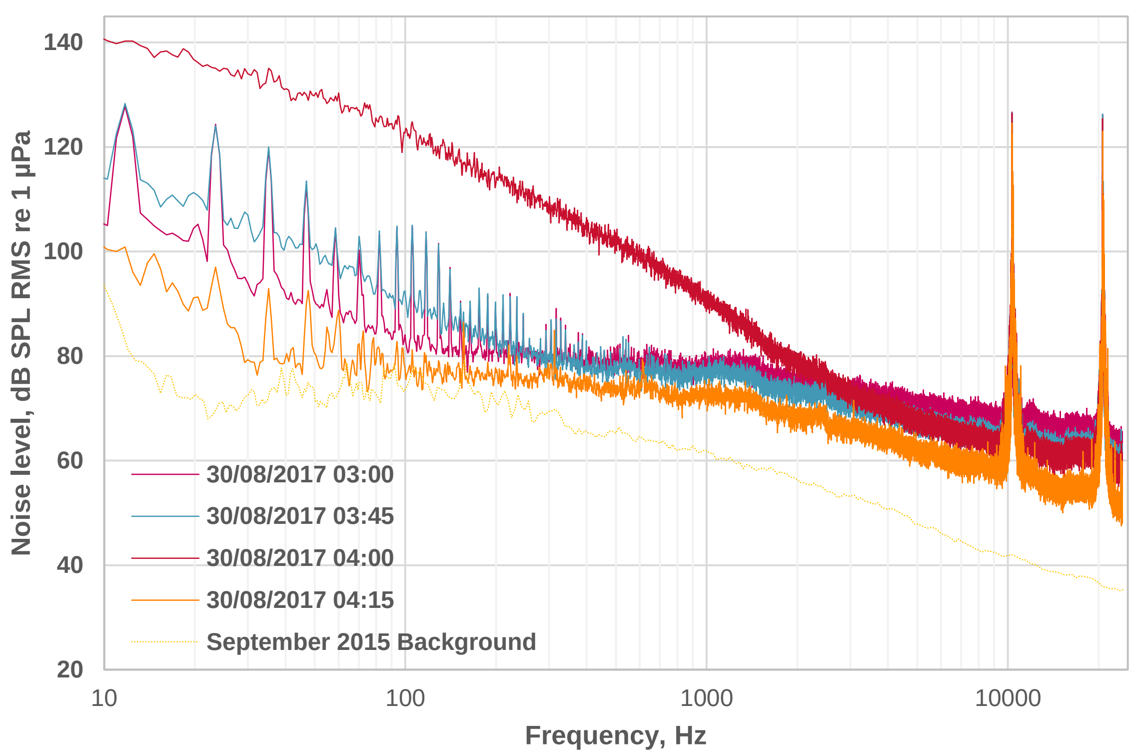

Figure 65. Narrow band analysis of 15-second samples 15 minutes before and after the 4 AM event on 30 August 2017. September 2015 background sound samples are shown for comparison purposes.

4.4.3.2 Correlation of 10 kHz and 20 kHz tones with wind speed

The sound versus wind speed time history over eight days in September to October 2017 is shown in **Figure 66**. The recorded sound levels linearly tracked the wind speeds (**Figure 66**). When the wind speed increased the sound level (up to 8 kHz) also increased. The rate at which the sound level increased with increase in wind speeds were correlated but not always consistent. For example, the two variables related closely after 29 September, but before this date, after a rapid increase on 25 September, the increase to maximum sound levels between 26 and 29 September was much slower.

A closer, zoomed-in look at the primary Y-axis (sound levels) from **Figure 66,** including the high frequency tones in the overall sound level, is shown in **Figure 67**. This figure also shows that high frequency tones track the wind speeds. It was hypothesized that the overall sound level is simply influenced by the lower frequency bands rather than the higher tones at 10 and 20 kHz.

The relationship between wind speed and the 10 kHz ⅓ octave band in isolation is shown in **Figure 68**. Data indicate that the sound level at this particular frequency did not show any consistent correlation with wind speeds. However, the sound levels in the 10 kHz ⅓ octave band do appear to vary within an upper and lower limit. The reason for this behavior is unclear. Also, the source of the 10 kHz tone is unknown.

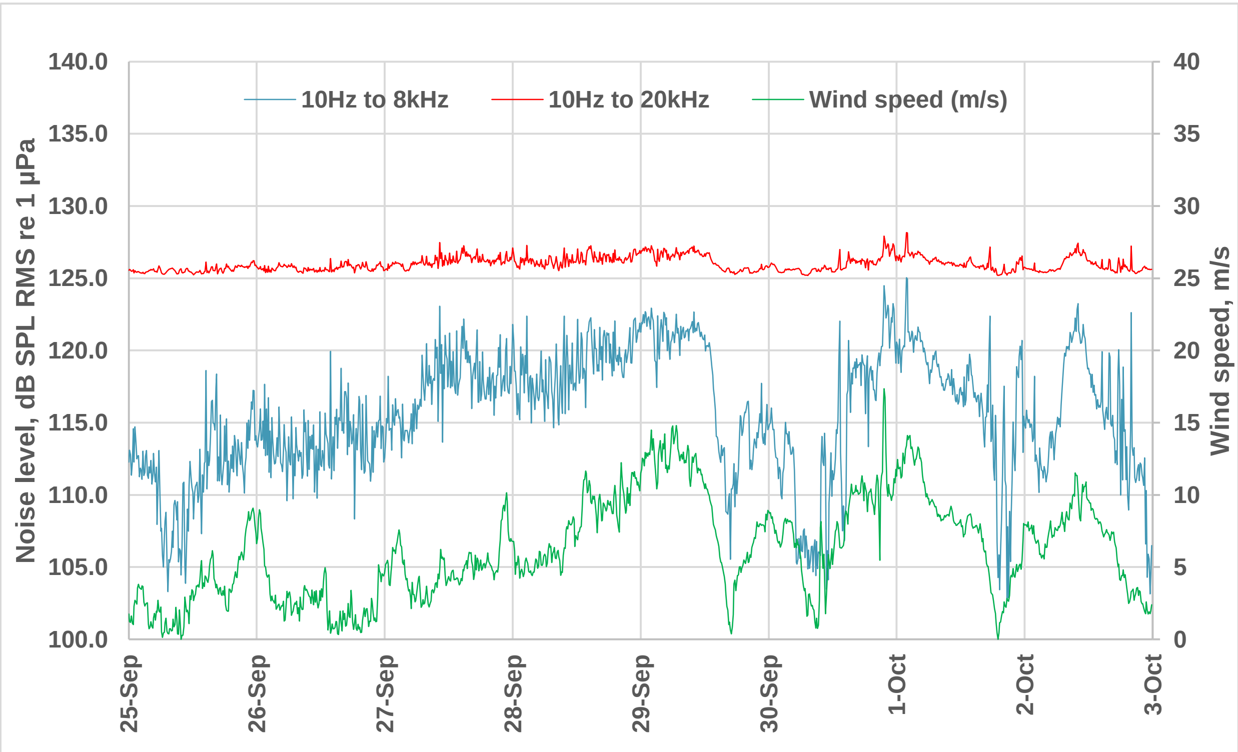

Figure 66. Sample underwater sound levels variation with time, against wind speed. Overall levels calculated using ⅓ octave bands from 10 Hz to 8 kHz and from 10 Hz to 20 kHz.

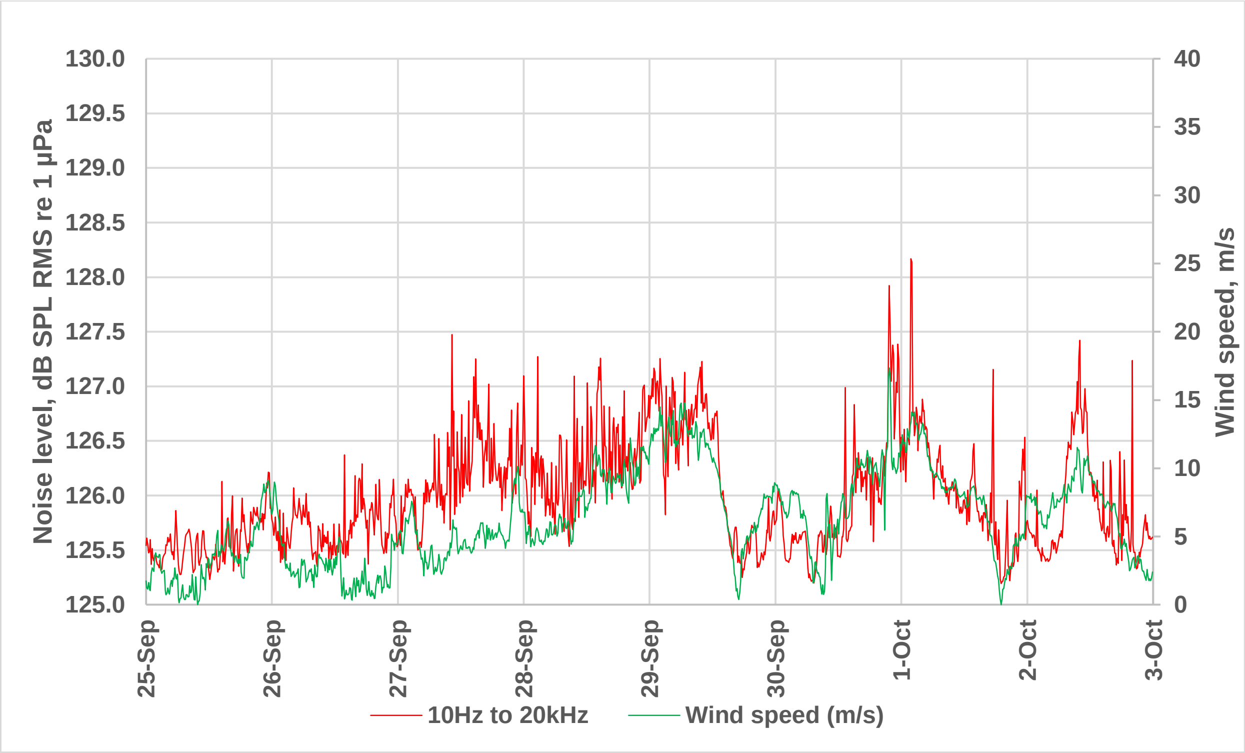

Figure 67. Sample underwater sound level variation with time, against wind speed. Overall levels calculated using ⅓ octave bands from 10 Hz to 20 kHz.

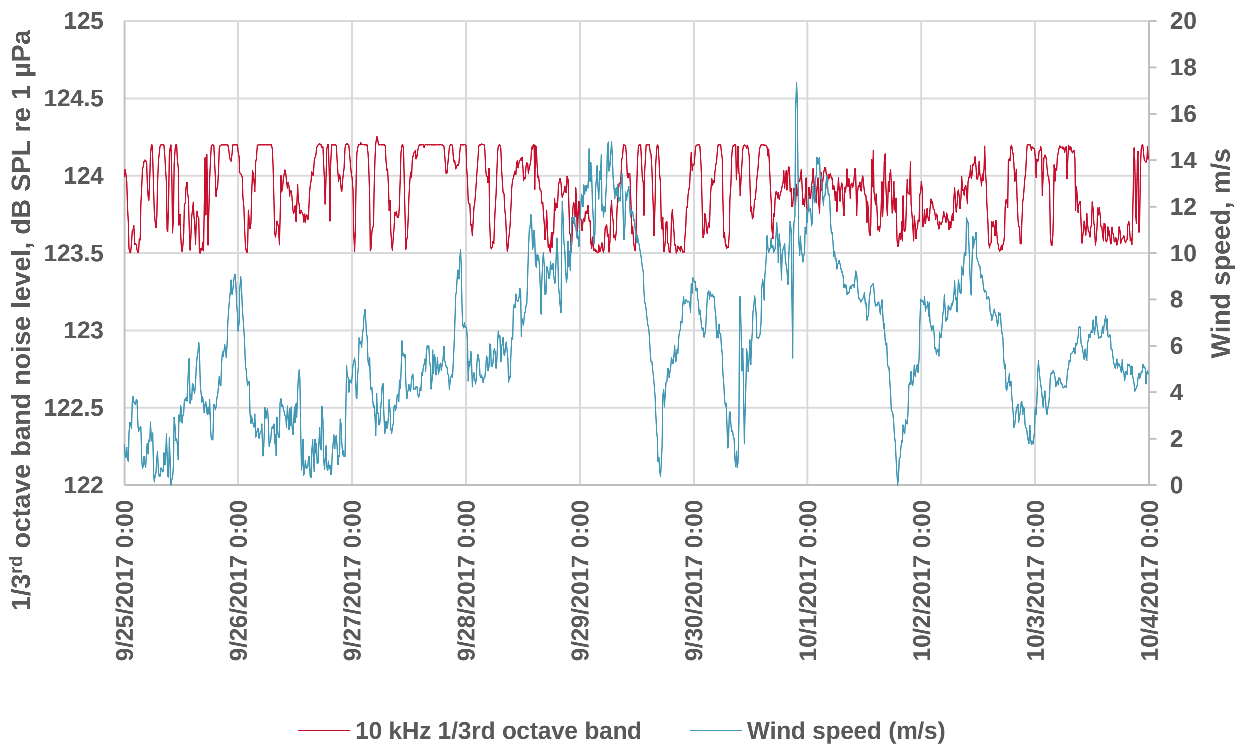

Figure 68. Sample underwater sound level variation at 10 kHz ⅓ octave band with time, against wind speed.

4.4.4 Discussion

Overall, the unweighted underwater sound levels sampled during the turbine operations were strongly influenced by anthropogenic sound, as demonstrated by the low-frequency pulsed sound shown in the narrow-band analysis and by listening to the recorded audio. This characteristic was not visible on the ⅓ octave-band frequency spectrum, which had insufficient resolution but it was clearly apparent on the calibrated audio files. It is important to note sound level increases at low frequency may plausibly be mistaken for natural sound sources such as waves, wind and current flow and therefore discounted when only considering ⅓ octave-bands.

The broadband, overall sound level is often the reference metric used in environmental underwater sound reporting. It is also frequently, but erroneously reported, without identifying the low-frequency cut-off—i.e., a lower limit on the frequency range analyzed—if one exists. This is a critical omission, and one which is rarely repeated in, for example, airborne sound, where broadband sound levels are invariably reported with a weighting (e.g., the A-weighting) that filters out the lowest frequencies.

The National Physical Laboratory (NPL) Good Practice Guide No. 133 for Underwater Noise Measurement (National Physical Laboratory 2014) notes that filters of 10 Hz can be used to remove non-acoustic parasitic signals and 10 Hz can be used as a reasonable cut-off. All of the frequency spectra presented above show increasingly high levels at low frequency, and the choice of low-frequency cut-off will determine the overall sound level calculated. In the case of the BIWF operational phase monitoring data, 10 Hz seemed appropriate because the pulsed sound at 12 Hz is clearly present, is significant and likely associated with turbine operations, although it is not a continuous 12 Hz acoustic tone.

The overall sound values reported were strongly influenced by the lower frequency limit used in the analysis. Where there is significant natural low frequency sound (for example where currents or wave movements are strong) then to help to isolate the effect of anthropogenic sound this lower limit can be increased. Using data from offshore wind turbine operational underwater sound monitoring, Pangerc et al. (2016) identified significant low frequency sound thought to be generated by tidal flow induced vibrations in their recorder’s housing or mounting and therefore they set their lower limit to 40 Hz. This was acceptable in the Pangerc et al. (2016) analysis as the turbine they studied produced significant sound emissions at higher frequencies; a feature at 160 Hz dominated the overall sound level, and the lowest frequencies were not so critical. The 40 Hz limit would not be appropriate for the BIWF analysis as the measured low frequency sounds appear to be associated with the operating turbines.

Figure 69 was adapted from Pangerc et al. (2016). It shows underwater sound measured at the Sheringham Shoal offshore wind farm in UK. Low frequency was limited to 40 Hz in this analysis. The tonal characteristics observed in this data set are not found in the sound measured at BIWF. The turbine studied by Pangerc et al. (2016) was a Siemens 3.6-megawatt turbine, and the paper suggested that it was likely that these tones originated from the gearbox. The General Electric Haliade 150 turbines at BIWF do not have a gearbox, and the lack of any dominant tones is thought to be due to the absence of this component.

In the absence of this tone, the turbine appears quiet in comparison with other operational wind turbines reported, although it is clearly above the background sound levels at the measurement location of 50 m (164 ft) from the machinery. It is anticipated that within 1 km (0.6 mi), the measured sound under quiet conditions and at any frequency will be below background levels (based on the snapshot measurement taken at 30 km [18.6 mi] to the east in calm conditions two years previously).

The National Oceanic Atmospheric Administration Fisheries Level B harassment thresholds are set at 120 dB SPL RMS for continuous underwater sound and the sound levels measured at BIWF during turbine operations were below this threshold except at wind speeds in excess of 13 m/s.

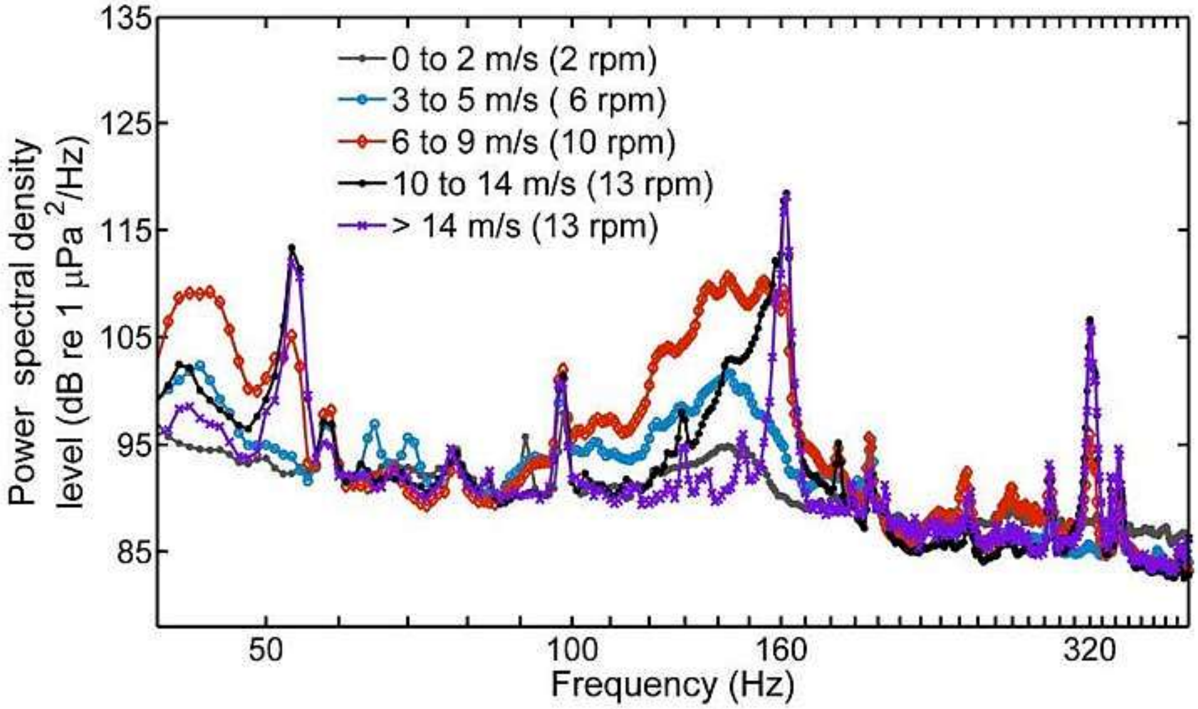

Figure 69. Image from Pangerc et al. (2016) showing underwater sound measured at the Sheringham Shoal offshore wind farm in the United Kingdom. Low frequency limited to 40 Hz.

The recorded sound levels were also far below the temporary and permanent threshold shift (TTS and PTS) onset criteria recommended by the National Marine Fisheries Service (NMFS) Marine Mammal Guidance (NMFS 2018). For reference, these are included below in **Table 12** for key species groups, based on a recording at a 15 m/s wind speed (29 September, 6:40 AM). Also included in this table is the cumulative SEL sound level, assuming that a receptor remained at the monitoring position for 24 hours. It is recognized that this comparison and conclusion is somewhat arbitrary, but it provides a guide to the potential level of impact or lack thereof.

Table 12. Weighted underwater sound levels at 50 m (164 ft) from the turbine, using NMFS (2018) guidance.

Species group	SEL (1-second) re 1 µPa2s 10 Hz to 8 kHz	SEL (1-second) re 1 µPa2s 10 Hz to 20 kHz	24 hour SELcum re 1 µPa2s 10 Hz to 8 kHz	24 hour SELcum re 1 µPa2s 10 Hz to 20 kHz
Unweighted	121.2 dB	127.1 dB	170.6 dB	176.5 dB
Low-frequency cetacean	103.0 dB	122.5 dB	152.4 dB	171.9 dB
Mid- frequency cetacean	79.0 dB	123.3 dB	128.4 dB	172.7 dB
High frequency cetacean	74.2 dB	121.4 dB	123.6 dB	170.8 dB
Phocid pinnipeds	92.3 dB	124.5 dB	141.7 dB	173.8 dB
Otariid pinnipeds	92.2 dB	123.9 dB	141.6 dB	173.3 dB

Assuming that a receptor remains at 50 m (164 ft) from the turbine without moving for a full day, all of the reported results are below both the TTS and PTS onset criteria defined by NMFS (2018) for all species. This indicates that there is little risk to the hearing of marine mammals in the area from the wind turbine operational sounds even under extreme conditions. As can be seen in comparison with the data in **Table 12**, the sound level used for this analysis is unusually high. However, if there are higher sound levels at frequencies in excess of the measured 20 kHz, then potential for sound exposure may rise.

Popper et al. (2014) represents the current best practice for assessment of noise impacts on fish. The thresholds defined in this document do not include any weighting and so would be considered precautionary in respect of fish hearing sensitivity. The noise levels identified in the vicinity of the turbine are far below any numerical criteria for adverse effects on fish.

Table 13 summarizes sound levels sampled over the full survey duration. These averages used data sampled between 10 PM and 10 AM each day to reduce the risk of sound contamination from passing vessels.

Table 13. Summary of SPL RMS average sound levels (10 Hz to 8 kHz) measured at 50 m (164 ft) from WTG 5.

Wind speed	Overall average sound level, dB re 1 µPa
2 m/s	112.2
4 m/s	113.1
6 m/s	114.0
8 m/s	115.1
10 m/s	116.7
12 m/s	119.5
13+ m/s	**120.6**
Average over survey duration	119.0
Background sound levels in calm conditions	107.4 [30 km from turbine] 110.2 [50 m from turbine]

Substantial tonal noise was detected at the 10 kHz and 20 kHz ⅓ octave center-frequency bands, which varied little throughout the monitoring period. The source of this is unknown, but the fluctuations in the noise level (±1 dB) do not correlate with the wind speed. It was also not present on any other recordings taken by other monitoring systems used in the RODEO project and is therefore not expected to be directly caused by the turbine itself.

Based on an analysis of data up to 8 kHz, it was concluded that under worst-case assumptions and using the 2018 NMFS and Popper et al. (2014) noise impact thresholds, no risk of temporary or permanent hearing damage (PTS or TTS) could be projected even if the receptor remained in the water at 50 m (164 ft) from the turbine for a full 24-hour period.

The overall conclusion from the operational phase underwater acoustic monitoring is that given the 1) low levels of sound recorded by the various sensors under differing environmental and weather conditions and 2) very low probability of these low levels causing potential harm to fish and marine mammals, operational phase underwater acoustic monitoring may not provide much additional value for future facilities. As part of a risk mitigation plan, this monitoring phase could be bypassed.

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Appendix A: Field Sampling Plan

Real-Time Opportunity for Development Environmental Observation (RODEO)

Final Field Plan for Monitoring Phase II Construction Activities at the Block Island Wind Farm

Contract No. M15PC00002,
Task Order No. M16PD00006

May 6, 2016

Prepared for:

BOEM
Bureau of Ocean Energy Management

Bureau of Ocean Energy Management
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Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler
BITS	Block Island Transmission System
BIWF	Block Island Wind Farm
BLM	Blue Land Media
COR	Contracting Officer Representative
dB	decibel(s)
dB re 1 µPa RMS	decibels referenced to 1 micro Pascal root mean square
DWW	Deepwater Wind
DMON	Digital acoustic monitoring
FAA	Federal Aviation Administration
HASP	Health and Safety Plan
HDD	horizontal directional drilling
Hz	Hertz
MAI	Marine Acoustic, Inc.
MBES	Multibeam Echosounder
NUWC	Naval Undersea Warfare Center
RODEO	Real-time Opportunity for Development Environmental Observations
SHRU	Several Hydrophone Receive Units
SSS	Side Scan Sonar
TO	Task Order
URI	University of Rhode Island
WTG	Wind Turbine Generator
WHOI	Woods Hole Oceanographic Institution

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1 Introduction and Background

Task Order (TO) M16PD00006 was issued to HDR on February 4, 2016, following BOEM BSEE award of an IDIQ Contract for Real-time Opportunity for Development Environmental Observations (RODEO). This Firm-Fixed-Price TO requires HDR to develop a Field Plan (Plan) to observe Phase II construction and initial operational activities associated with the Block Island Wind Farm (BIWF). The Plan is required to address the following key areas:

- Evaluation of visual activities during and after construction
- Evaluation of sediment disturbance and recovery
- Effects of mitigating measures or abatement measures
- Evaluate monitoring technologies or techniques
- Assessment of sound environment during construction.

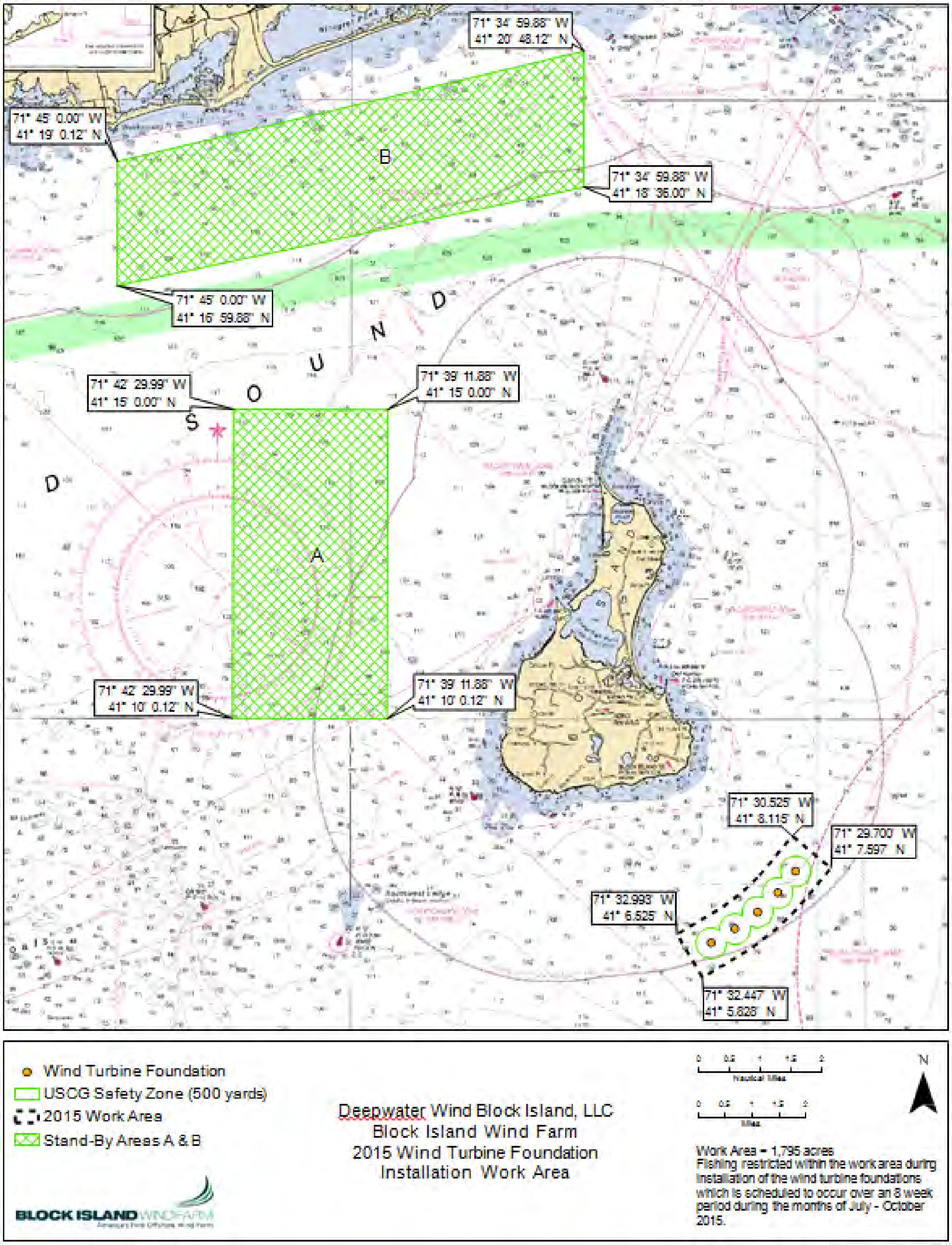
In addition, HDR is also required to provide in the Plan a process for coordinating monitoring and resulting data with other ongoing activities and a process for coordination of monitoring efforts with the industry.

1.1 Background, Purpose and Scope

The BIWF is America's first offshore wind farm, and it is being constructed by Deepwater Wind (DWW) Block Island, LLC approximately 3 miles off the coast of Block Island, which is located approximately 16 miles south of the Rhode Island mainland (**Figure 1**). BIWF consists of five, 6-MW Alstom Haliade 150 wind turbine generators (WTGs), a submarine cable interconnecting the WTGs (hereafter referred to as Inter-Array Cable), and a 34.5-kilovolt (kV) transmission cable from the northernmost WTG to an interconnection point on Block Island (hereafter referred to as Export Cable). Once completed, the five turbines will produce 30-megawatts for Block Island residents, and the mainland will receive the additional power.

BIWF construction began in July 2015, is occurring in a phased manner, and will be completed towards the end of 2016. During the recently completed Phase I construction, five steel jacket foundations were installed over 18 weeks from July 26 to October 26, 2015. The HDR Team developed and implemented a Phase I construction activity monitoring plan. Under this plan, the team maintained a visual record of the activities that occurred during Phase I construction including the types and numbers of vessels deployed, the chronology and duration of activities, and other relevant information for use in evaluating impact-producing factors. The Team also measured underwater sound and airborne noise generated during construction, both at onshore and offshore locations.

The HDR Team learned many lessons during Phase I construction. The primary hurdle was constantly changing construction schedule. Construction delays began when a barge damaged the first jacket after installation. Additionally, the original crane barges were unable to provide a steady platform for pile driving activities.



Source: Deepwater Wind Block Island LLC

Figure 1. BIWF Work Area

DWW's construction contractor, Crowley Marine, was able to eventually drive piles successfully from the surface crane barge but ultimately, a large "jack-up" vessel, the L/V Robert, arrived and proved a more successful and efficient platform for piling. The HDR team maintained communications with DWW during delays and ultimately developed a trusting partnership that greatly enhanced critical monitoring coordination.

Phase II construction will occur in 2016 and will include installing power transmission cables and the WTGs on the foundations that were installed during Phase I. National Grid will build and operate the infrastructure needed to connect the electric grid. Following the completion of Phase II construction, operational testing is scheduled towards the end of 2016.

1.1.1 Purpose of the Field Plan

This Field Plan describes for BOEM's consideration a suite of acoustic (underwater and/or airborne), sediment-related, and visual monitoring options that may be undertaken to identify and quantify the stressors or impact-producing factors that may be associated with the Phase II construction process (i.e., the characteristics of the proposed project that may cause an impact). The actual parameters monitored in the field during Phase II construction will be determined in consultation with the BOEM Project Manager. Phase II will include the following major construction activities:

1. **Sea2shore Cable Installation** – which is scheduled to start in June 2016, by National Grid, and will include construction/installation of the following components
    a. **Inter-array Cable**: Submarine cable connecting the WTGs.
    b. **Export Cable**: Cable connecting northern most WTG to Block Island.
    c. **Block Island Substation**: This will be located in New Shoreham on Block Island, and it will include approximately 0.8 mile of underground cable from the beach to the new substation.
    d. **Block Island Transmission System** (BITS): This includes a bi-directional approximately 20-mile submarine cable from Block Island to Scarborough State Beach in Narragansett and 3.5 miles of underground cable from Scarborough State Beach to the Dillon's Corner substation. The BITS will deliver power both to and from the Rhode Island mainland to Block Island.
2. **Turbine Installation** – This includes installation of turbine towers, blades, nacelles on the foundations that were constructed during Phase I, and it is scheduled to occur over 4 weeks in the summer of 2016. Each WTG consists of three sections. GE is currently manufacturing the lower sections at the Port of Providence facility. Final assembly of the turbine units will be completed at Quonset Point.
3. **Turbine Operational Testing** – WTG operational testing will be conducted during the fourth quarter of 2016.

Per guidance from BOEM, monitoring proposed in this Field Plan:

1. Does not duplicate or substitute for compliance monitoring that is required to be performed by the construction contractors,
2. Is compatible with scheduled construction
3. Is designed for providing additional information necessary for BOEM analysts to fully analyze the scope and extent of environmental impacts that may result from the construction activities and provide data to improve the accuracy of models and analysis criteria used to establish current monitoring controls and mitigations.

1.2 Monitoring Objectives

The objectives of the monitoring proposed to be conducted under this Plan include the following:

- Evaluation of visual activities during and after construction
- Evaluation of sediment disturbance and recovery during and after construction
- Evaluation of mitigating measures or abatement measures
- Assessment of sound environment during construction.

This Plan also includes mechanisms for the following:

- Ensuring that a process is in place for coordinating with other ongoing activities
- Providing a process for coordination of the team's efforts with the industry
- Providing sufficient safety procedures to protect personnel during monitoring activities.

1.3 Tasks and Subtasks

The scope of work for TO M16PD00006 consists of the following two tasks:

1.3.1 Task 2.4.1 – Provide Overall Project Management

HDR has assembled a qualified team expert of experts to assist in preparing this Field Plan. Key personnel and their areas of expertise are listed below:

1. HDR, Anwar Khan (Program Manager)
2. HDR, Jamey Elliott (Project Manager)
3. HDR, Randy Gallien, Craig Johnson (Technical Advisors)
4. HDR, Michael Richlen, (Marine Acoustician)
5. FUGRO, Kevin Smith, (Lead Sediment Engineer)
6. Subacoustech Environmental Ltd Tim Mason, (Acoustic Specialist)
7. University of Rhode Island (URI), Dr. Jim Miller, (Marine Acoustician)
8. Marine Acoustic, Inc. (MAI), Dr. Kathleen Vigness-Raposa (Acoustic Specialist)
9. Marine Acoustic, Inc. (MAI), Dr. Adam Frankel, (Acoustic Specialist)
10. Marine Acoustic, Inc. (MAI), Jennifer Giard, (Acoustic Specialist)
11. Woods Hole Oceanographic Institution's (WHOI's) Ocean Acoustics & Signal Lab, Art Newhall, (Acoustic Specialist)
12. Woods Hole Oceanographic Institution's (WHOI's) Ocean Acoustics & Signal Lab, YT Lin, (Acoustic Specialist)
13. Woods Hole Oceanographic Institution's (WHOI's) Ocean Acoustics & Signal Lab, Dr. Mark Baumgartner, (Acoustic Specialist)

14. University of Maryland, Arthur Popper, (Technical Advisor)
15. Blue Land Media (BLM), Walter Rissmeyer, (Producer)

1.3.2 Task 2.4.2 – Prepare a Field Plan for Data Collection

The Draft Field Plan presented in this document represents the first of two deliverables for Task 2.4.2. This Plan will be finalized by addressing comments and input received from BOEM. Field Plan implementation will be covered under a separate task order. To facilitate and manage implementation, Task 2.4.2 is divided into the following subtasks:

- 2.4.2.1 – Monitoring Associated with Sea2Shore Cable Installation
- 2.4.2.2 – Monitoring Associated with Turbine Installation
- 2.4.2.3 – Monitoring Associated with Turbine Operational Testing
- 2.4.2.4 –Acoustic Analysis of Existing Phase 1 Data
- 2.4.2.5 – Demonstration of Whale Detection and Feasibility of Marine Mammal Tracking
- 2.4.2.6 – Video Production
- 2.4.2.7 – Publications, Presentations and Outreach
- 2.4.2.8 – Technical Approaches for Environmental Review for Offshore Wind Energy Facilities

Specific activities that will be conducted under each subtask are described in detail in **Section 2**.

1.4 Schedule

The schedule of activities and deliverables for the Field Plan are listed in **Table 1**.

Table 1. Tentative Schedule for Implementing BIWF Phase II Construction Field Plan

Task	Action	Due Date
2.4.2.1 Sea2Shore Cable Installation	Monitoring	June 2016
2.4.2.1 Sea2Shore Cable Installation	Draft Underwater Sound Monitoring Report	TBD
2.4.2.1 Sea2Shore Cable Installation	Final Airborne Noise Monitoring Report	TBD
2.4.2.2 Turbine Installation	Monitoring	June 2016
2.4.2.2 Turbine Installation	Draft Turbine Installation Report	TBD
2.4.2.2 Turbine Installation	Final Turbine Installation Report	TBD
2.4.2.3 Turbine Operational Testing	Monitoring	TBD
2.4.2.3 Turbine Operational Testing	Draft Turbine Operational Testing Report	TBD
2.4.2.3 Turbine Operational Testing	Final Turbine Operational Testing	TBD

Task	Action	Due Date
2.4.2.4 Acoustic Analysis of Existing Phase I Data	Draft Phase 1 Acoustic Analysis Report	NLT 6 months after award
2.4.2.4 Acoustic Analysis of Existing Phase I Data	Final Phase 1 Acoustic Analysis Report	NLT 30 days after comments
2.4.2.5 DMON	Draft DMON Report	TBD
2.4.2.5 DMON	Final DMON Report	TBD
2.4.2.6 Video Production	Draft Vignette	TBD
2.4.2.6 Video Production	Final Vignette	TBD
2.4.2.7 Presentation	Present Effects of Noise on Aquatic Life	10-16 July 2016
2.4.2.8 Industry Coordination	Coordination	Upon award

1.5 Industry Coordination

During Phase II monitoring, close coordination will be required with National Grid, DWW and TetraTech. The HDR project manager will be responsible for ensuring this coordination. Prior to commencing any fieldwork, efforts will be coordinated with the BOEM Contracting Officer Representative COR, DWW and/or National Grid. The project manager will check in every morning with either DWW or the National Grid Manager to get an update on the activities planned for the day and their nature and duration. The project manager will share this information with all members of the HDR Team monitoring personnel to ensure that data collection is conducted in real-time when the construction activities are actually in progress.

1.6 Government-Furnished Information:

The following government-furnished information will facilitate finalization of the Draft Plan and subsequent implementation:

- Full details of construction methodology, especially:
  - installation methodology (equipment, procedures and predicted duration)
  - other activities (e.g., horizontal drilling)
- Timescales and program for each site
- Any planned mitigation or abatement
- Any specific requirements from BOEM acoustic modelers for data they wish to have for model verification
- Details of compliance monitoring required and proposed to be conducted by the construction contractors
- National Grid boring data along cable transect.
- Jasco's hydroacoustic data collected as part of the DWW mitigation plan.

2 BIWF Phase II Construction Monitoring Field Plan

This section contains a description of the monitoring activities that will be conducted under each of the eight subtasks.

2.1 Subtask 2.4.2.1 – Monitoring Associated with Sea2Shore Cable Installation

The HDR Team will monitor the submarine cable installation from Block Island Town Beach to Scarborough State Beach. The submarine cable will cover a distance of approximately 20 miles once complete. It estimated that laying the submarine cable would take approximately 27 days commencing in June 2016. The construction schedule is shown in **Figure 2**, and the cable route is shown in **Figure 3**.

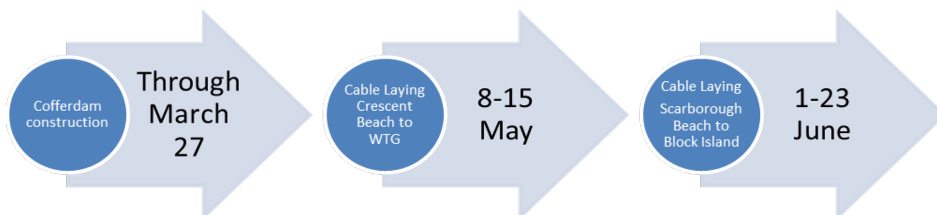
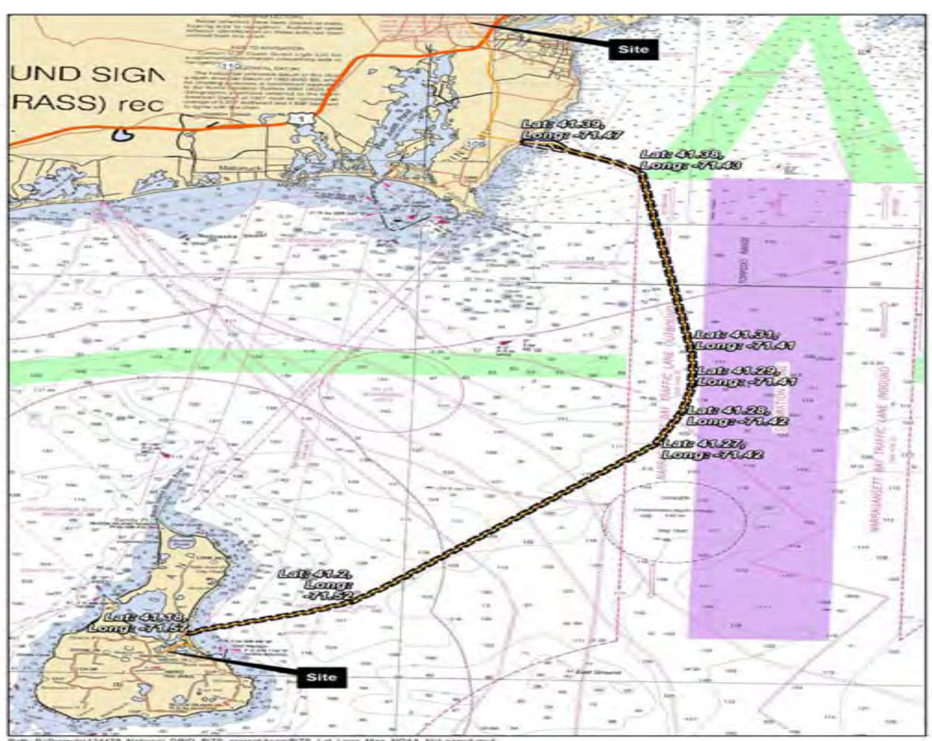


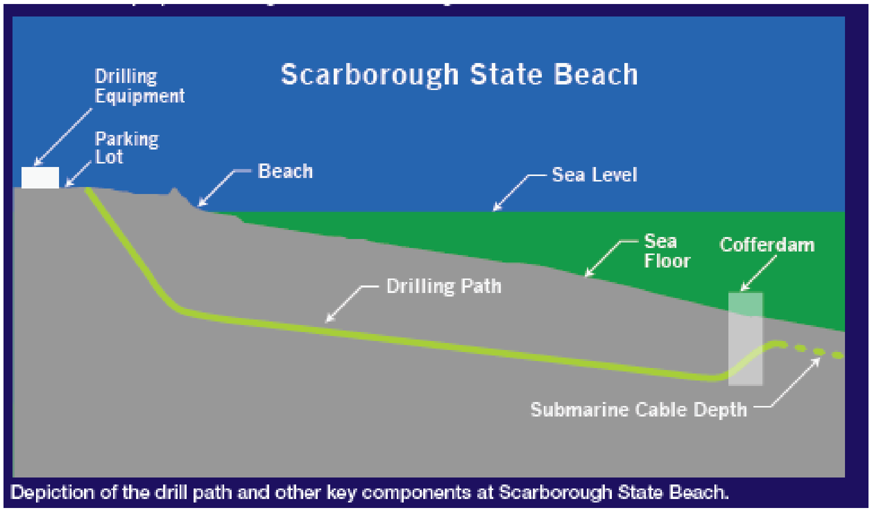
Figure 2. Tentative Schedule for Sea2Shore Cable Installation



Source: National Grid

Figure 3. Cable Route from Mainland

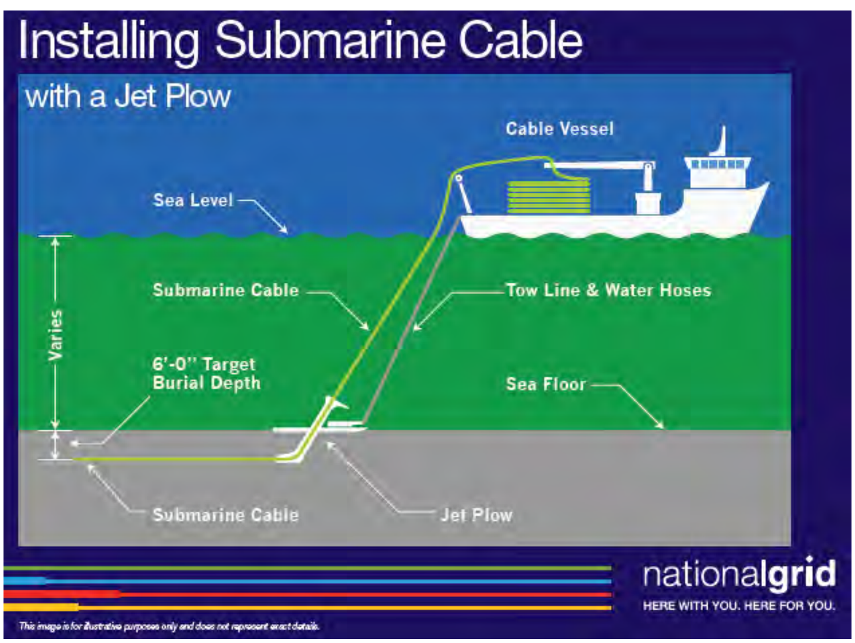
The inner-array and export cable will be installed using a jet plowing method in the offshore area and horizontal directional drilling (HDD) technique in the shoreline nearshore area. Temporary cofferdams will be constructed at Scarborough State Beach and Block Island to allow HDD to connect the submarine cable to shore (**Figure 4**).



Source: National Grid

Figure 4. Drill Path at Scarborough State Beach.

The submarine cable will be fed through a jet plow once in the water. The plow liquefies the soil using water jets. The plow is hollow and the cable passes through it and will be buried approximately 6ft below the seabed (**Figure 5**). The disturbed area is expected to fill back as the sediment settles naturally. A cable vessel will pull the jet plow to connect the mainland at Scarborough State Beach to Town Beach at Block Island. The proposed cable route covers a distance of approximately 20 miles.



Source: National Grid

Figure 5. Installing Submarine Cable with a Jet Plow.

Four types of monitoring are recommended under Subtask 2.4.2.1:

1. Acoustic
2. Sediment recovery and disturbance
3. Benthic
4. Visual.

Specific activities related to these four monitoring areas are discussed below.

2.1.1 Sediment Disturbance and Recovery Monitoring

Installation of all three sets of cables will disturb the seafloor sediment. HDR Team member FUGRO will monitor 1) sediment disturbances associated with these construction activities and 2) post-construction sediment recovery.

The inter-array and export cable will be installed using a jet plowing method in the offshore area and HDD technique in the shoreline nearshore area. In order to mitigate seafloor disturbance, a jet plowing technique will be utilized and will be supported by a dynamically positioned vessel to avoid anchoring and spud-can seafloor disturbance. Plans are to install the cable to a depth of 2 meters below the seafloor except at two cable crossings. Concrete blankets will be used to provide separation and cable protection at the two cable crossings.

Jet plowing utilizes high-pressure water streams to fluidize seabed sediments and excavate a trench. During fluidization of the seabed sediments, sediments are temporarily introduced into the water column until they settle out. Therefore, jet plowing can impact the environment by temporarily increasing turbidity levels in the water column, inducing sedimentation of excavated sediments outside the trench that cover the nearby seafloor, and disturb the seafloor in the trench zone. Those processes and effects are further described in a BOEM funded research report “Seabed Scour Considerations for Offshore Wind Development on the Atlantic OCS, Technology Assessment and Research Study No. 656.”

From FUGRO experiences, seabed scars and berms corresponding to the route of the installation tool and the placement of anchors of vessels used in the construction are usually visible using multibeam techniques but disappear relatively rapidly depending on the levels of natural seabed disturbances/weathering, rates of infilling by transient bedload and frequency of high wind/wave events. Trenches in more cohesive substrates such as chalk or clay, may of course be longer lived or permanent. Fine sediments ejected from the trench during the installation may be transported within the tidal currents and deposited over adjacent seabed areas to form a temporary thin fine sediment veneer, which may be visible in Side Scan Sonar (SSS) data as temporary areas of lower reflectivity or observed in multibeam backscatter data. This veneer will add to the volume of the natural bedload already in flux through the area. Subsequent tidal movements continuously re-mobilize and disperse and dilute this additional fine bedload sediment to background levels over time.

HDD technique will be used to install the cable at the shore crossings. HDD activities are only anticipated to affect the seafloor where the cable exits onto the seafloor and transitions into the trenching installation.

The HDR Team noted that DWW is required to conduct a post-cable lay survey within 14 days of completion and that DWW plans to conduct a multibeam echosounder (MBES) and sub-bottom profiler Compressed High-intensity Radar Pules survey after the cable is installed to document post-lay trench conditions, confirm back-filling of the trench, and determine depth of burial for the cable. The HDR Team will evaluate their proposed survey methods and equipment, and if warranted, recommend a survey program that will be capable of monitoring seafloor disturbance, spoil piles, etc.

If not already collected by DWW, the Team will consider collection of pre-construction MBES and SSS to allow comparison and assessment of post construction effects. This is important to differentiate the effects of natural transient fine sediment deposition from deposition by construction related sediment plume. We have assumed that the post-cable lay multibeam survey conducted by DWW will be of sufficient resolution to identify the trench and associated features. If the DWW survey data are deemed to be too low of resolution (i.e., binned at a large size) to define the trench, then we would request that our first survey be moved forward and conducted to document post-construction conditions.

The HDR Team will:

1. Record the extent of disturbance during cable laying, and the influence of bottom type on sediment disturbance and recovery rates using video imagery from cable lay and burial operations performed by the contractor or monitor.
2. Assess the variability of sediment disturbance with water depth for the distance from interfield turbine installations and landward to nearshore HDD using MBES and SSS.
3. Monitor seabed conditions periodically to evaluate changes in burial depth and scour, and periods of anomalously high seabed mobility associated with storm events using MBES and SSS.
4. Assess the reduction or elimination of sediment disturbance and mobility in areas of mitigation such as seabed protection.

Sediment disturbance monitoring and assessment will include the following steps:

1. Literature study comparing European standards for monitoring with United States Offshore Wind sites for applicability and repeatability.
2. Monitoring conducted using periodic marine surveys. Marine surveys will collect MBES bathymetry, MBES backscatter, and SSS data. The surveys will be conducted nominally at three -month intervals during fair-weather periods (summer and early fall) and then before/after winter. Initiation of this survey sequence will depend on when the cable installation is completed. Sediment grab sampling will be conducted along the cable route and used to constrain analysis of backscatter and SSS data.

   The Team will evaluate novel uses of backscatter acquisition and processing, such as angular response analysis, to pioneer new comparative and quantitative techniques using multibeam backscatter metrics as proxies for seabed physical condition. This represents an opportunity to evaluate a new means and methods for best practices in monitoring seafloor disturbance/recovery from wind farm cable trenching and for supporting technical NEPA disciplines.

Surveys will be conducted from cable reception pits at the HDD exit points to cable reception point location. We note those locations are within state waters; however, those locations represent complex areas where scour/erosion protection needs are not well understood.

After each survey, a report will be prepared that describes our assessment of the seafloor recovery from trenching activities, changes in seafloor conditions at the cable crossing locations that have implemented scour protection, and observed changes in extent of trench plume sediment deposition.

3. Preparation of an interpretative and assessment report. A report will be prepared that summarizes our assessment of the comparison between backscatter and SSS data for use in seafloor condition monitoring. Both technologies have advantages and limitations. For example, SSS data are widely used in practice to map seafloor conditions but the data and results are difficult to quantify in a repeatable manner. However, multibeam backscatter data offer a quantifiable method for interpreting seafloor bottom conditions. We will assess the two types of data and provide an assessment of their application for use in monitoring seafloor disturbance and recovery. The report will summarize our assessment of seafloor recovery rates and how they vary along the alignment with respect to water depths, seafloor sediment type, and in areas where migrating bedforms are observed. The report will also describe if the cables are observed to become exposed and describe our observations of seafloor recovery or changes where scour protection has been placed and at the cable crossing locations.
4. Evaluating potential “best practices” for differing monitoring technologies and monitor methods.
5. Field testing of various market available equipment for monitoring quality and maintenance.
6. Determination of the optimal frequency of monitoring both on recurrent intervals and before/after major storm events.
7. Demonstration of the potential re-use of the data acquired to inform other technical NEPA disciplines such as marine archaeology and ecology (i.e. distribution of fish critical habitat or sensitive or protected reefs / seagrass habitat).
8. Sediment plume turbidity monitoring and sedimentation.

During jetting, water is released through a series of nozzles at a high pressure on the lead face of the jet-plough device. The high-pressure water fluidizes the seabed sediments and causes the sediments to transition into a state of suspension in the water column, thus temporarily excavating a trench-like depression. The cable falls into the excavated trench as the jet-plow moves along the cable route on the seabed. The sediments excavated and placed into a temporary state of suspension by the high-pressure jets, eventually settle out of the water column and infill the trench, thus burying the cable. Not all of the sediments will settle out back into the trench.

In order to understand the dispersion of a sediment plume from seabed disturbance resulting from jet-plowing (or dredging) multiple factors need to be assessed:

- The extent of the plume
- The concentration of particulate material within the plume
- The particle size distribution of the material to understand settlement rates
- Distribution of settled material on the seabed

In addition, the following complexities will be considered during monitoring to ascertain the impact of the sediment plume: (1) the injection point of the sediment plume is constantly moving; (2) current patterns mean that pattern of dispersion will vary over the tidal cycle and throughout the lunar cycle; and (3) wave conditions may cause significant re-suspension of the bed material potentially masking any single from the anthropogenic activity.

Recommended Monitoring Method – Swath Bathymetry/ADCP/OBS-WS

From previous experience of similar projects, FUGRO has developed an approach that uses a mobile monitoring vessel with the following equipment suite. This preferred monitoring method is Swath Bathymetry/ADCP/OBS-WS:

- **Swath Bathymetry system**: using the water column backscatter data the structure of the plume can be discerned and its extent.
- **Acoustic Doppler Current Profile (ADCP)**: provides both flow information in 0.5 – 1.0 m bins throughout the water column and acoustic return data within the plume (from each beam separately) allowing estimates of concentration within the plume to be made.
- **Optical Backscatter Sensor / Water Sampler (OBS-WS)**: vertical profiles through the plume can be collected using an Optical Backscatter sensor combined with pressure (depth) data is used to ascertain the sediment concentration within the plume and its vertical structure, water samples are collected alongside in order to assist in the calibration of both the optical and acoustic backscatter data and to obtain data on the particle size distribution of the sediment plume.

The above approach can provide robust data about the sediment plume and its distribution, however seabed deposition levels are not directly obtained, the accuracy of measures of seabed level is such that a potential change of up to 1 cm will not be discernible form background fluctuations. However, this will be estimated based on the suspended sediment data and particle size distributions ascertained above, combined with the current flow information form the acoustic profiler.

This mobile method will allow the monitoring vessel to maneuver into a position down current from the trenching activity and monitor during peak tidal flow and slack-tide conditions. Sediment plumes are expected to extend further from the jet-plow during peak tidal flow conditions than during slack tide. Capturing those conditions with a seafloor mounted system will be difficult due to the challenge of predicting when the jet-plow would pass a forecasted position precisely at a peak tidal flow condition (when sediment plume would extend furthest from the plow).

The aim of this approach is to design a survey pattern that will allow the plume to be mapped spatially and temporally, FUGRO will gain an understanding of the time/distance the plume travels in suspension prior to settling.

2.1.2 Visual Monitoring

Visual monitoring of Phase II construction activities will be conducted from selected onshore and offshore locations.

Onshore Visual Monitoring

During cable installation, a dedicated onshore observer will record the following from the points to be determined on Block Island and Scarborough Beach:

- Visibility of construction activities from shoreline while cable laying vessel is within range
- The types of lighting used at the construction site and what can be seen from the shoreline
- Meteorological conditions that affect visibility from shore including humidity.

Data will be recorded daily at sunrise, mid-day, sunset, and during significant changes in meteorological conditions (e.g., rain, fog, etc.) during each day that construction takes place. The observations will include a set of photos taken from a fixed point, at the same angle, and using a constant zoom setting on the camera. Video recordings will be made as necessary to document unusual sightings or infrequent occurrences. HDR will use iPads with custom database application to standardize data entry. This database was developed for Phase I construction and utilizes Filemakergo ®.

Offshore Visual Monitoring

A second dedicated observer will be located offshore on a boat adjacent to the cable laying vessel during cable installation and record the following:

- Number, size, and type of construction vessels
- Size and location of deployed anchors
- Number and nature of lighting used at the site
- Type of construction activities being conducted and duration of each activity.

Where possible, the observer will also record relevant information including incidental observations on the occurrence of marine species and other activities (e.g., fishing vessels, recreational vessels). Offshore observation location will occur such that the survey vessel will remain outside the exclusionary zone (to be determined) and not interfere with the construction activities or with transit of the construction vessels. Construction activity observations will be recorded using a field data log sheet and a photo log will be maintained.

2.2 Subtask 2.4.2.2 – Monitoring Associated with Turbine Installation

The following types of monitoring will be conducted in association with the turbine installation:

1. Airborne Noise
2. Sediment
3. Benthic
4. Visual.

Specifics activities related to these four monitoring areas are discussed below.

2.2.1 Airborne Noise Monitoring

Acoustic monitoring will include measuring and recording changes in airborne noise levels. A sound level meter will be positioned at the Southeast Lighthouse. This location will provide a direct line of sight to the WTGs. Sound readings will be acquired in conjunction with visual surveys.

Data on background noise levels was acquired in the winter in the absence of either operational turbines or construction machinery. Wind speeds were high at this time, which, while representing a realistic condition (and appropriate for wind turbine operation), should be supplemented by an opportunity out-of-season at low wind speeds. Additional acquisition of background noise levels at the Southeast Lighthouse will be attempted under these conditions in April 2016 during cable installation acoustic monitoring once the activities exceed the range of detection.

2.2.2 Sediment Disturbance and Recovery Monitoring

Construction equipment used to install the turbines (e.g., tower, blades, and nacelle) is anticipated to utilize a lift boat. It is unclear at this time what other specific support construction equipment will be used. It is anticipated that support barges using anchoring systems may be used. Spud-can penetration and anchoring will disturb the seafloor.

Seafloor disturbance and recovery monitoring due to spud-can and anchoring during turbine installation are anticipated to be included in Task Order 3 monitoring. Task Order 3 monitoring includes conducting multibeam surveys to map the seafloor in the wind turbine area.

2.2.3 Benthic Monitoring

Benthic habitats likely to be affected by turbine installation will most likely be limited to the depressions on the seabed that are created due placement of the feet of the jack-ups causing displacement, compaction, and abrasion effects on benthic fauna and flora. Subsequent infilling of the depressions via slumping of the sidewalls and/or natural bedload transport processes will occur allowing faunal and floral communities to recover over time.

The HDR Team will collect geophysical data to determine the extents of the physical effects (depressions) on the seabed. These data will then be ground-truthed by seabed video to provide a visual record of the extents of the seabed physical impacts and associated effects on epifaunal communities. Subsequent surveys will record the infilling and erosion of these physical impacts and the recovery of affected epifaunal assemblages.

The geophysical and camera surveys can be performed in tandem from the same vessel platform to rationalize survey effort. Fugro and HDR will consider the program of routine engineering monitoring, such as cable burial or scour monitoring, performed by DWW with a view to further rationalize the overall field monitoring effort.

2.2.4 Visual Monitoring

The Visual Impact Assessment prepared by DWW evaluated the visual character of the individual turbines from a 30-mile radius. Several mitigation measures were implemented during the planning phase including: reduced number of turbines, turbines that will be of uniform design and without any logos; turbines that are white to blend in with sky and eliminates need for Federal Aviation Administration (FAA) daytime warning lights; FAA warning lights will have the longest off-cycle permitted. The Assessment concluded that no further mitigations were required once operational.

Onshore Visual Monitoring

Visual observations of construction activities from the shoreline will be logged during the turbine assembly and operational phase. The real-time data collected through the implementation of the approved field plan will provide additional information necessary for BOEM's evaluation of environmental effects of future facilities and generate data to improve the accuracy of models and analysis criteria employed to establish monitoring controls and mitigations.

During the operational testing, a dedicated onshore observer will record the following from the Southeast Lighthouse:

- Visibility of construction activities from shoreline
- The types of lighting used at the construction site and what can be seen from the shoreline
- Meteorological conditions that affect visibility from shore including humidity.

Data will be recorded daily at sunrise, mid-day, sunset, and during significant changes in meteorological conditions (rain, fog, etc.) during each day that construction takes place. The observations will include a set of photos taken from a fixed point, at the same angle, and using a constant zoom setting on the camera. Video recordings will be made as necessary to document unusual sightings or infrequent occurrences.

After observations are documented from the SE Lighthouse, the observer will transition to a to be determined location, and record activities occurring in Stand-by Area A. This area is located approximately 2 nautical miles to the west of Block Island and it will serve as a staging area for vessels or used during work stoppage due to weather or sea states.

In addition, visual monitoring will include night time surveys be conducted 2 hours after sunset to record and characterize types of lighting visible from shore for up to two nights. A Canon 7D camera setup on a tripod to accommodate the required slow shutter speed that is necessary to capture images will be utilized to photograph operational activities.

The last scheduled ferry departs Block Island at 7:30PM, therefore this monitoring will require 2 days lodging on Block Island. Furthermore, four nighttime observations will be recorded from the mainland to determine if the FAA Warning Lights installed on the turbines are visible. Ideally, these observations will occur under a variety of meteorological conditions (cloudy, clear, rain, fog, etc.).

Offshore Visual Monitoring

A second dedicated observer will be located offshore on a boat adjacent to jackets during the turbine assembly, and operation testing:

- Number, size, and type of construction vessels
- Size and location of deployed anchors
- Number and nature of lighting used at the site
- Type of construction activities being conducted and duration of each activity.

Where possible, the observer will also record relevant information including incidental observations on the occurrence of marine species and other activities (fishing vessels, recreational vessels, etc.). The offshore observation location will be selected such that the monitoring vessel will not interfere with the construction activities or with transit of the construction vessels. Observations will also be made at least once per survey day of the Stand by Area A. Construction activity observations will be recorded using an iPad with pre-formatted field logs.

2.3 Subtask 2.4.2.3 – Monitoring Associated with Turbine Operations

The following types of monitoring will be conducted in association with the turbine operational testing:

1. Acoustic,
2. Sediment disturbance and recovery monitoring
3. Benthic, and
4. Visual.

Specifics activities related to these four monitoring areas are discussed below.

2.3.1 Acoustic Monitoring

Acoustic monitoring will include measuring and recording changes in underwater sound and airborne noise levels.

Underwater Sound Monitoring

Detailed monitoring observations of the underwater sound and vibration emissions of the operational WTGs will be undertaken, using the same basic procedure are during construction. It is expected that the survey vessel will be able to approach the turbines at much closer range than during construction. This will be necessary, as the operational sound and vibration levels are expected to be significantly lower than during construction.

Medium to long-term samples of underwater sound will be taken as a baseline in the absence of underwater sound-producing machinery associated with the wind farm development. This is important to gauge the impact of the underwater sound during construction, and is critical for the comparative investigation of the sound output and propagation during the operational phase of the wind farm, as operational sound tends to be much closer to the ambient noise levels than construction.

A single underwater long-term acoustic monitor will be located in the vicinity of one of the WTG jackets. A distance of 750 meters is proposed towards the outside of the turbine array to avoid contamination from multiple turbines. The monitor will remain in situ for a period of 2 months, after which it will be recovered, downloaded, batteries recharged or replaced, redeployed for another 2 months, and then approximately for a final 2 months.

During installation, maintenance and removal operations for the long-term underwater noise monitor, transect measurements will be undertaken in the same manner as during earlier construction processes. These attended vessel-based measurements will sample over different periods of the year, ideally under similar wind and sea conditions. This will capture variations in noise and seabed vibration propagation under natural seasonal conditions, whereas the long-term monitor will capture variations caused by changes in wind and sea states. The transects will begin as close as permissible to the operational turbines and will continue until the turbines are no longer detectable. It is not expected to be possible to acquire attended noise measurements safely on the vessel at high wind conditions, and the wave noise under these conditions around the vessel would cause artificially high noise levels.

It should be noted that a 750-m distance from the operational turbine for the fixed monitor was selected to be equivalent to the distance measured during previous construction periods. However, where attended measurements show that the operational turbine noise levels are not significantly above the background noise, the fixed underwater noise monitor will be relocated closer to the turbine.

In addition, the HDR Team would deploy a Several Hydrophone Receive Unit (SHRU) mooring with four hydrophones similar to that deployed in the 2015 construction phase. The SHRU mooring would allow measurement of seabed vibration and particle motion contributing to essential data for analyses of future wind farms.

Airborne Noise Monitoring

In common with the previous construction monitoring programs, airborne noise will be sampled simultaneously with the underwater noise from a sound level meter situated on the survey vessel and at the Southeast Light. Special consideration will be given to amplitude modulation of the noise emissions from the turbine and how this and low frequency noise varies with distance, a key concern currently being investigated in its effects on people living near onshore wind turbines. More uniform conditions available in the offshore environment offer a unique opportunity to study this without the natural interruptions that exist on land.

Transects will be selected to study, as well as possible with the wind conditions and wind farm layout, the noise from a single turbine and from the entire array. Measurements will be taken in different wind directions but concentrating on downwind conditions. Opportunities to sample offshore under high wind conditions are unlikely to be possible for safety reasons but where an opportunity exists, will be sampled at the Southeast Lighthouse

2.3.2 Sediment Disturbance and Recovery Monitoring

TBD - with receipt of more description of initial operational testing activities

2.3.3 Benthic Monitoring

BOEM has guidelines for habitat monitoring surveys pursuant to 30 CFR § 585. Proposed methodologies for benthic monitoring will therefore have consideration to these guidelines. Recommendations for future iterations of the BOEM guidance and comparison with that used in Europe will be provided.

Post construction monitoring (recovery assessment) will utilize the same sampling stations that were sampled during the pre-construction survey and should be conducted at the same time of year to avoid effects of seasonal variation. Sampling and lab testing methods need to be comparable between pre and post survey occasions also.

The scale over which the monitoring will take place needs careful consideration and will be proportional to the questions being asked and level of concern raised. Medium- and large-scale monitoring campaigns have so far not been able to detect significant change in benthic conditions attributable to the construction and operation of offshore wind farms in Europe. However, local effects of offshore wind farms on benthos have generally not been studied and remain poorly understood, although there is some evidence emerging of benthic modifications relating to increased sediment enrichment over time as a result of the fall and accumulation of biomass from fouling organisms (such as mussels) from the turbine and foundations. Whilst the area of effect around each turbine might be quite small, say up to 50 or 100 m, the cumulative effect of benthic modification around 100 or 200 turbines on any one habitat may be considerable.

HDR team member FUGRO propose a series of monitoring studies to study potential near field benthic modification as a result of the fall of biomass from the turbines and foundation and associated sediment enrichment. The data derived from this monitoring will determine the extent and timescales for benthic modification through sediment enrichment and will allow BOEM to extrapolate the potential consequences of future larger developments on the US continental shelf on benthic ecology.

We will select two turbines, representing different habitat types, at Block Island for study. At each turbine seabed video and quantitative grab samples will be collected at 20-, 50- and 100-meter distances from the base of the turbine foundation, subject to the presence and spread of scour protection material at the base of the foundation and in collaboration with DWW. Sample stations will be orientated in line with the dominant tidal current flow and perpendicular to the current. The hypothesis tested in this instance will relate to the presence of a gradient of enrichment effects along the axis of the dominant tidal flow with minimal or no effects occurring on the seabed perpendicular to the direction of current flow. **Figure** 6 illustrates the proposed near field benthic sampling arrangement around each turbine.

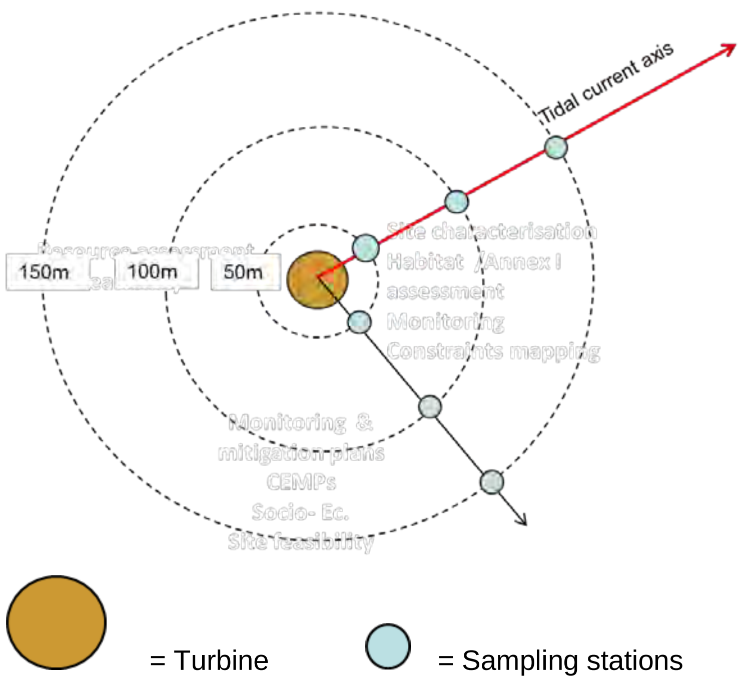


Figure 6. Indicative near field benthic ecology sampling station arrangement

Current meters from the benthic vessel prior to the initial sampling to establish the axis of the principal tidal current flow. However, it is recommended to use the data collected during the site assessment and impact assessment as well as any contemporaneous AWACS (or similar) deployment to predict the principal flow directions.

In addition to the turbine sample stations, two reference areas, located outside of the predicted influences of the offshore wind farm and in comparable substrate and depth conditions, will be selected and surveyed. Three stations shall be positioned within each reference area and sampled using the same methods. Data from the reference areas will allow assessment of benthic change attributable to the operation of the wind farm against the natural variation

Samples will be collected in triplicate to increase statistical rigor. The total number of samples will be 18 per turbine location (total 36 samples for 2 turbines) and 9 per reference area (18 samples for 2 reference areas) (total 54 samples).

Analyses will include macrofaunal species identification and enumeration, particle size distribution analysis and organic content. Species diversity and biomass metrics together with suitable enrichment indicators will be calculated for assessment of change over time. Video surveillance of sediment habitat conditions and associated epibenthos will also be collected at each sampling station for assessment of effects on these community components.

It is expected that any sediment enrichment and benthic modification will develop over a comparatively long time (years) and only once mature fouling communities have developed on the turbines and foundations. Following a preliminary survey soon after the installation of the turbines to collect baseline information, subsequent surveys may be undertaken relatively infrequently to allow for the accumulation of fallen biomass and development of associated enrichment and benthic modification. HDR and Fugro will consider aligning this monitoring program with the long term engineering monitoring or maintenance visits undertaken by DWW to rationalize the survey effort.

Re-locating sample stations with a high degree of accuracy will be important so that repeat samples are collected at the same point along the gradient of change for comparison between monitoring occasions. Differential GPS (dGPS) with navigational layback with accuracy of 1 – 3 m will be used for position fixing and finding during the proposed monitoring. As a further aid to position finding during repeat monitoring, the skipper of the survey vessel will have a heads up display. This will show each sampling station with a 5 – 10 m buffer and the vessel's relative position to each station. Once the vessel is within the required buffer area, the sampler is deployed and the seabed sample will be collected. From experience, it is known that proficient skippers in shallow waters achieve 10 m or less horizontal accuracy and frequently achieve < 5 m accuracy.

Fugro's own analysis of positioning accuracy during a recent project in 60 m depths in the eastern English Channel showed horizontal accuracy of < 5 m was commonly achieved. Application of an USBL fitted to the grab and the use of a dynamic positioning vessel can further improve positioning accuracy but can prove prohibitively expensive. Positioning options will be discussed with BOEM and will need to consider DWW's compliance monitoring methods.

2.3.4 Visual Monitoring

The Visual Impact Assessment prepared by DWW evaluated the visual character of the individual turbines from a 30-mile radius. Several mitigation measures were implemented during the planning phase including: reduced number of turbines, turbines that will be of uniform design and without any logos; turbines that are white to blend in with sky and eliminates need for FAA daytime warning lights; FAA warning lights will have the longest off-cycle permitted. The Assessment concluded that no further mitigations were required once operational.

Onshore Visual Monitoring

Visual observations of operational activities from the shoreline will be logged during the turbine operational phase. The real-time data collected through the implementation of the approved field plan will provide additional information necessary for BOEM's evaluation of environmental effects of future facilities and generate data to improve the accuracy of models and analysis criteria employed to establish monitoring controls and mitigations.

During the operational testing, a dedicated onshore observer will record the following from Southeast Lighthouse:

- Visibility of operational activities from shoreline in the vicinity of the turbines.
- The types of lighting used at the operational site and what can be seen from the shoreline during night time monitoring.
- Meteorological conditions that affect visibility from shore including humidity.

Data will be recorded daily at sunrise, mid-day, sunset, and during significant changes in meteorological conditions (e.g., rain, fog) during each day that operations takes place. The observations will include a set of photos taken from a fixed point, at the same angle, and using a constant zoom setting on the camera. Video recordings will be made as necessary to document unusual sightings or infrequent occurrences.

After observations are documented from the SE Lighthouse, the observer will transition to a to be determined location, and record activities occurring in Stand-by Area A located approximately 2 nautical miles to the west of Block Island. Stand-by Area A is a staging area for vessels or used during work stoppage due to weather or sea states.

In addition, monitoring will include nighttime surveys be conducted 2 hours after sunset to record and characterize types of lighting visible from shore for up to two nights. A Canon 7D-camera setup with a tripod to accommodate the required slow shutter speed necessary to capture images will be utilized to photograph operational activities. The last scheduled ferry departs Block Island at 7:30PM, therefore this monitoring will require 2 days lodging on Block Island. Furthermore, four nighttime observations will be recorded from the mainland to determine if the FAA Warning Lights installed on the turbines are visible. Ideally, these observations will occur in a variety of meteorological conditions (cloudy, clear, rain, fog, etc.).

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A second dedicated observer will be located offshore on a boat adjacent to jackets during the turbine assembly, and operation testing:

- Number, size, and type of construction vessels
- Size and location of deployed anchors
- Number and nature of lighting used at the site
- Type of operational activities being conducted and duration of each activity.

Where possible, the observer will also record relevant information including incidental observations on the occurrence of marine species and other activities (e.g., fishing vessels, recreational vessels). The offshore observation location will be selected such that the vessel will not interfere with the operational activities or with transit of the construction vessels. Observations will be recorded using an iPad with pre-developed field logs.

2.4 Subtask 2.4.2.4 – Acoustic Analysis of Existing Phase I Data

As part of the BIWF Phase I construction-monitoring efforts, HDR Team members from the University URI, MAI, and WHOI designed and deployed acoustic and seismic monitoring systems during pile driving for the construction of the Block Island Wind Farm. This construction involved driving 20 piles 60 m into the seabed and the HDR Team was able to successfully measure the underwater signals generated by the pile driving both in the water column and in the sediment. The systems included two vertical hydrophone array moorings with SHRUs for data collections and storage.

Also, a seabed vibration monitoring system consisting of a three-axis geophone and tetrahedral hydrophone array were deployed. Lastly, a towed array of hydrophones was deployed from a research vessel that collected acoustic signals during pile driving at various ranges on two different days. An initial review of the data is underway and preliminary results indicate a fully successful data collection effort.

HDR team member URI proposes to analyze the data collected during the pile driving activities by DWW at the Block Island Wind Farm in 2015. The hydrophone and geophone calibrations will be incorporated into the calculation of acoustic field and particle velocity at all sensors. Based on the construction log, the received acoustic signatures will be correlated with the appropriate pile and the hammer strike.

The main focus of the URI efforts will be on the data from the geophysical sled consisting of the three-axis geophone and the tetrahedral hydrophone array. URI will lead the effort to estimate the particle velocities on the seafloor (from the three-axis geophone data) and in water (approximately 1 m from the seafloor using the data from the tetrahedral array). In addition, URI will also coordinate the modeling and data analysis efforts of WHOI and MAI and contribute towards interpreting the spatial variation of the levels measured by different systems (URI, MAI and WHOI). URI will also lead the effort in collecting and consolidating the available environmental information to facilitate the modeling efforts. These data include sound speed profiles from CTD data, bathymetry and geoacoustic information.

URI will also consider and include acoustic data gathered by DWW subcontractor Tetratech, Inc. Tetratech collected acoustic data during complete construction of wind turbine #3 using both real-time and static techniques. Tetratech is also conducting long term monitoring via static recorders. Data will be included in URI's analysis assuming release of information in a timely manner by DWW.

In summary, the major tasks URI will focus on are:

1. **Pile schedule, check pile rake, construct log of pile number and leg number vs. time**: Analyze the acoustic and particle velocity data and correlate it with the pile driving schedule and appropriate hammer impact on individual piles. We will tabulate the pile rake associated with the acoustic signatures addressing the potential cause of sound pressure level variation with rake.
2. **Incorporate the exact calibration of acoustic and particle velocity sensors**: Extract the correct absolute levels. Based on the hammer type, investigate the difference in the levels of sound radiated from hammer impacts. Characterize the

background sound and compare this with the data collected during the SAMP studies. Then, calculate the Kurtosis of the data to investigate the changes this metric as a function of range and pile rake. Subacoustech will also reanalyze their data acquired in respect of Kurtosis.

3. **Environmental data coordination**: Collect and consolidating the available environmental information to facilitate the three-dimensional modeling of the acoustic field. These data include sound speed profiles from CTD data, bathymetry and geoacoustic information. The Team will gather available environmental data from sources such as Ocean Special Area Management Plan, other surveys and coring from the location, site characterization by construction contractors, etc.
4. **Coordinate the three-dimensional modeling efforts**: URI will coordinate with WHOI, MAI and potentially Sandia National Laboratory. The pile rake information from task 1 and the environmental data from task 3 will be inputs to the three-dimensional models. WHOI will assemble all of the data collected during the pile driving activities; we will start to create a three dimensional sound propagation numerical model that incorporates oceanographic conditions, bathymetric variation and seabed properties. After WHOI completes the data assembling, we will use the experimental data to fine-tune the numerical model. The goal is to use the numerical model to fill the measurement gaps and construct the 3D soundscape, especially to calculate the Kurtosis of sound pressure distributions. We realize this modeling work will be a group effort, and WHOI will be collaborating with URI and MAI. URI will assist in creating the underwater soundscape by assimilating the data and model results. Investigate the effect of water depth, bathymetry, temperature, sea state, and sediment type on the sound propagation using the model. Estimate the sound levels at 750 m and compare this with BIWF measurements taken by Tim Mason at Subacoustech and with European measurements from comparable water depths, pile diameters and hammer energies. We have been contact with personnel from Sandia and they have shown interest in this collaboration. Sandia has computational capability along with both commercial and in- house modeling tools applicable to this problem. Details of this collaboration will be part of this task.
5. **Particle velocity on the seabed and in water**: URI will examine particle velocity calculation using the data from a three-axis geophone and acoustic data from the tetrahedral array. This will be done in coordination with Steve Crocker at the Naval Undersea Warfare Center.
6. **Pile driving data analyses**: In addition**,** BOEM will task Naval Undersea Warfare Center **(**NUWC) (Dr. Steve Crocker) to analyze the data collected on the tetrahedral array during the pile driving activities by DWW at the Block Island Wind Farm in 2015. NUWC tasking should include a requirement for coordination with URI in the analysis of tetrahedral array data for estimating the particle velocity. Preliminary analysis indicates that the data are of high quality for this estimation of particle velocity.
7. **Actual sound pattern**: Determine the actual sound pattern at the various locations comparing the background sound 30 minutes before the impulsive pile driving signals, followed by an hour of background sound level measurements. The analysis will include the energy measured at the piles by DWW to understand the effect of pile energy to received levels. This will be repeated for all available pile driving events.

2.5 Subtask 2.4.2.5 – Demonstration of Whale Detection and Feasibility of Marine Mammal Tracking

Passive acoustic monitoring has become a standard methodology for assessing the occurrence and distribution of marine mammals; however, surprisingly little research has been conducted on the detection range of different species' vocalizations, and how that detection range varies with environmental conditions (e.g., ocean conditions, water depth, sediment type), signal type, passive acoustic monitoring system, and platform (e.g., moored buoy, autonomous underwater vehicle). To effectively use passive acoustics to monitor marine mammals, an understanding of the area over which the monitoring system can detect each species of interest is absolutely critical.

WHOI engineers and scientists have built a system based on the digital acoustic monitoring (DMON) instrument to record, detect, classify, and remotely report in near real time the calls of marine mammals from moored buoys. The system concept has been demonstrated in several recent pilot projects, and ready to integrate the technology into Regional Ocean observing systems. To encourage and facilitate this integration, we must evaluate the efficacy of the near real-time acoustic detections (work underway now) and characterize the detection range for species of interest.

A WHOI buoy equipped with a DMON reporting system is presently operating near Nomans Land Island, Massachusetts and detecting various species of whale. (See http://dcs.whoi.edu) WHOI propose to deploy a second DMON system near the Block Island Wind Farm site. WHOI will use playbacks to verify our estimates of species-specific detection ranges in coordination with the URI and Marine Acoustics, Inc. There is a substantial need in the marine mammal research and conservation community for rigorous acoustic propagation studies that will be enable by this second system. **Figure 7** shows the configuration of the DMON system.

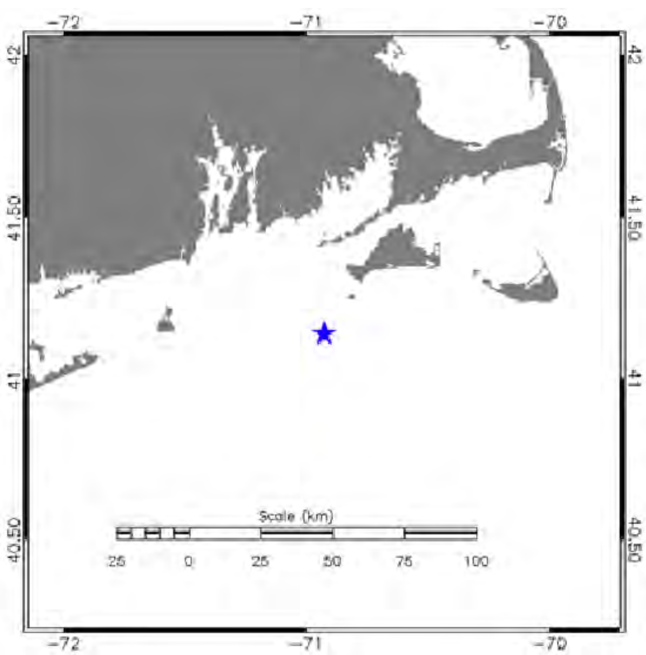

Figure 7. Location of the presently operating DMON system is shown by the star off Nomans Land Island Massachusetts.

The URI contribution to this task will be to coordinate the playback experiments, organize the boat deployment, and assist in the system design and in data analysis.

A fin whale was detected on the 15 km SHRU mooring on November 4, 2015, as shown in **Figure 8**. The data shown at http://dcs.whoi.edu/nomans0315/nomans0315.shtml for the Nomans Land Island DMON also detected fin whales call during the same period, showing the potential of joint detection and hence the possibility for localization.

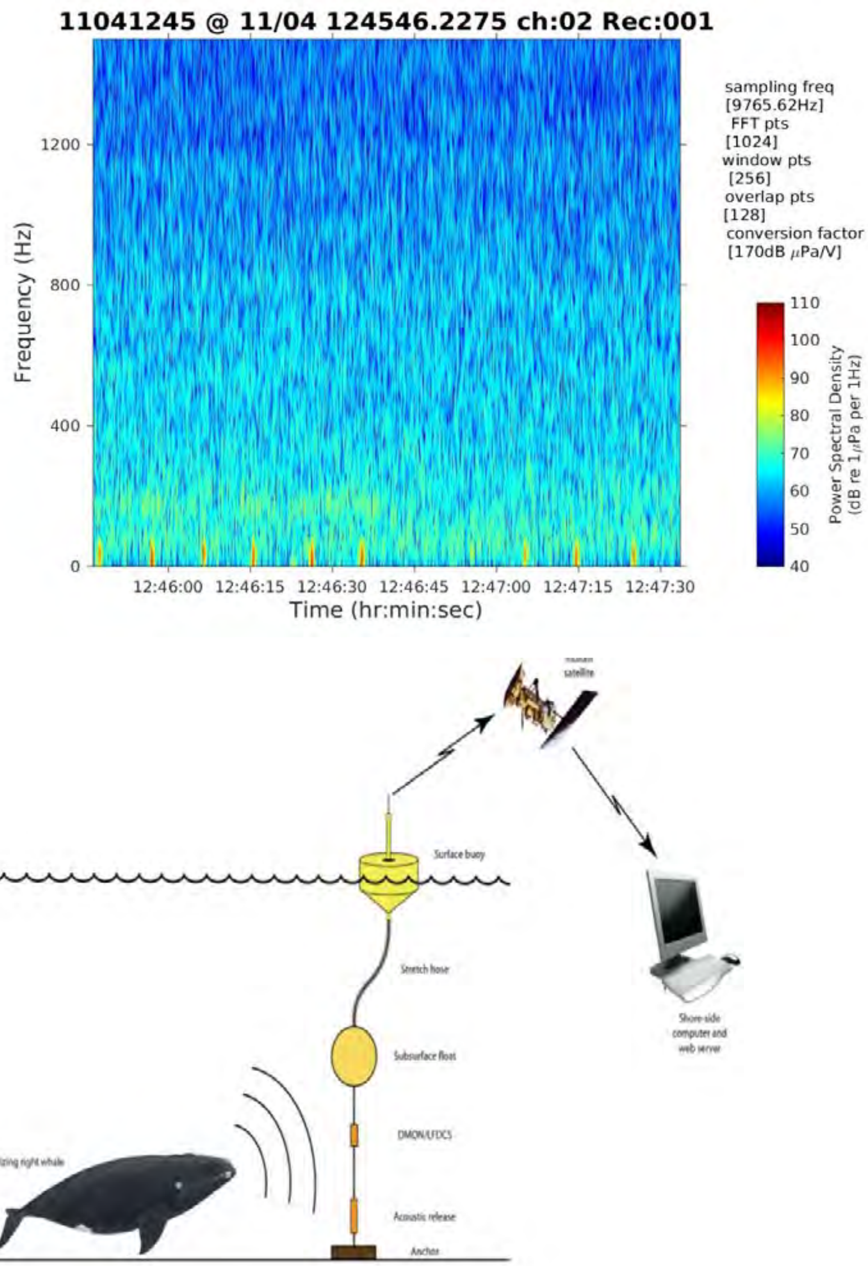

Figure 8. Spectrogram of the acoustic data recorded on the 15-km vertical array mooring on November 4, 2015 showing fin whale calls centered at 20 Hz.

Note: Fin whale calls (indicated by the vertical red lines about every 10 seconds) were also detected on the same day by the WHOI DMON system near Nomans Land Island, Massachusetts shown at **http://dcs.whoi.edu/nomans0315/nomans0315.shtml**.

2.6 Subtask 2.4.2.6 – Video Production

HDR proposes high definition b-roll footage of BOEM funded work be captured during the installation and testing of the turbines, as well as of the monitoring activities designed to assess the impact of the project to learn about offshore wind. Having professional video to document construction and the monitoring of the acoustic and visual impacts would be an asset during public meetings regarding future wind farms construction, for public outreach and are ideal for inclusion on various related websites. A potential future task order could include the production of a short vignette on the wind farm construction process.

HDR potential team member, BLM is uniquely positioned to execute this subtask of the task order. BLM is a full-service video and multimedia content producer focusing on documentary, arts, educational, and nonfiction entertainment programming for broadcast and cable television and informational communications for corporate and government clients. BLM offers complete production services and operates standard-definition and high-definition production and postproduction facilities and offers 4K production capabilities using the RED ONE Digital Cinema Camera. BLM has direct, ongoing experience in creating videos for Navy training and outreach purposes. BLM has previously completed Marine Species Awareness Training Video, Environmental Stewardship Outreach Video, and Environmental Compliance and Stewardship Vignettes for the Navy. If Government is receptive to this subtask, HDR will immediately initiate the process of adding BLM to the RODEO Team.

We recommend three filming trips of approximately 5 days of filming each (total 15 days filming). The first trip would be to document the cable installation, the second trip would be to cover the mounting of the turbines and the third trip would be to cover the installation of the blades and initial testing. During each trip, the production team would spend time documenting the construction as well as related monitoring activities. Beyond collecting footage of construction and fieldwork, the team would also conduct interviews of key team members to gather their insight into the process and results. This would provide a broad overall perspective of the process and outcomes.

After completing the filming, the team would isolate selected footage to create a media library for BOEM’s use that would be sorted by month, activity and participants. This will provide easy access to the material for creating short sequences or sharing selected imagery with media or other parties.

In addition to the video captured during these trips, it is recommended that the video production team also develop a series of short animations that illustrate specific elements of the project. For instance, a short animation might illustrate how the cable is installed, showing the ship at the surface feeding the cable to the sled at seafloor burying the cable. Another animation could show how the electricity is collected from the turbines, through the cable array, through the various connecting cables and substations and ultimately flowing through the grid to power homes and industry. Additional animations would demonstrate the acoustic monitoring and show how the team is able to precisely measure sound levels and determine possible impacts. The animations, used alone as part of presentations at public meetings and other outreach, will help make complex systems that cover large geographic areas easy to understand and share with the public. In addition, the animations can be used as part of short vignettes and documentary projects that help tell the broader story of the projects activities.

There is a lot of interest in this project and by documenting it carefully through high definition video and informative animations and graphics, we are creating the building blocks necessary to make sure the story can be told clearly and with full information. Misinformation can quickly take hold in the absence of a full understanding of how the project is implemented and the careful monitoring in place. Collecting strong visual imagery that tells the story helps make sure the tools are available to provide easily understood depictions of the construction process, testing and monitoring.

2.7 Subtask 2.4.2.7 – Publications, Presentations, and Outreach

HDR team member URI will organize the effort to document the results in the form of conference presentations, and journal articles. Special attention will be devoted to the generation of information in the form of graphics and associated reports for communication to the non-governmental organizations, other federal and state agencies, and the public as required.

URI proposes that Dr. Miller present a paper concerning the measurement of the sound during pile driving at the Block Island Wind Farm at the Effects of Noise on Aquatic Life meeting, which will take place July 10-16, 2016 in Dublin, Ireland.

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3 Field Plan Implementation

3.1 Construction Schedule

The tentative schedule for BIWF Phase II construction is as follows:

1. **Sea2Shore Cable Installation** – scheduled to start in June 2016 and projected to be completed over 27 days.
2. **Turbine Installation** – scheduled to occur over four weeks in the summer of 2016.
3. **Turbine Operational Testing** – WTG operational testing will be conducted during the fourth quarter of 2016.

3.2 Coordination with the DWW and Construction Contractors

Prior to start of the monitoring activities, the HDR Team will coordinate through BOEM with DWW and National Grid to identify limitations that the monitoring team will be working under. These limitations could include areas that are off-limit for surveying due to Health and Safety considerations.

After the start of monitoring, periodic discussions will be held with the on-site construction contractors to ensure that both teams are fully aware of each other's activities and that vessel traffic is appropriately coordinated.

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4 Healthy and Safety Plan

All field activities will be conducted in accordance with the guidance contained in the HASP (**Attachment A**). The objective of the HASP is to define the requirements and designate protocols to be followed during the field data collection. Applicability extends to HDR RODEO Team personnel and visitors, inclusive of client personnel and representatives. Work performed by the HDR Rodeo Team and subcontractors will comply with applicable Occupational Safety and Health Administration laws and regulations. Through careful planning and implementation of corporate and site-specific health and safety protocols, HDR will strive for zero accidents and incidents on the project.

The HDR Team Program Management Staff is committed to the health and safety of each employee that participates in the field data collection effort. It is essential that all Task Managers and Field Supervisors insist on the maximum safety performance and awareness of all employees under their direction, by enthusiastically and consistently administering all health and safety rules and regulations.

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5 Permitting

Any additional permitting requirements for monitoring will be investigated and pursued by the HDR Team. HDR will provide BOEM notification of the permit requirements and the scope associated with acquisition and a request for a modification to the scope of work to address the necessary resources.

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6 Literature Cited

Hitchcock, D.R. and S. Bell. 2004. Physical impacts of marine aggregate dredging on seabed resources in coastal deposits. Journal of Coastal Research 20(1): 101-114.

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A

Draft Health and Safety Plan

Health and Safety Plan

Real Time Opportunity for Development of Environmental Observations (RODEO)

Monitoring Phase II Construction Activities at the Block Island Wind Farm

Block Island, RI

M15C00002 –
Task Order M16PD00006

Prepared by:

HDR

Athens AL Project Office
300 North Madison Street, Athens AL 35613

May
2016

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SIGNATURE PAGE

Monitoring Phase II Construction Activities at the Block Island Wind Farm

Contract M15C00002
Task Order M16PD00006

HEALTH AND SAFETY PLAN

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Preparation Date:	May 2016	
Expiration Date:	May 2017	

APPROVALS

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Table of Contents

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Acronyms and Abbreviations

℃	Degrees Celsius
℉	Degrees Fahrenheit
AHA	Activity Hazard Analysis
BPM	Beats per minute
COR	Contracting Officer's Representative
EPIRB	Emergency Position-Indicating Radio Beacon
ESPD	Environmental Sciences & Planning Director
GPS	Global Positioning System
HASP	Health and Safety Plan
HP	Horse Power
MMO	Marine Mammal Observer
MOB	Man Overboard
NASBLA	National Association of Boating Law Administrators
OSHA	Occupational Safety and Health Administration
PIC	Principle-In-Charge
PFD	Personal Flotation Device
PjM	Project Manager
PM	Program Manager
PPE	Personal Protective Equipment
HSM	Safety Director
SOP	Standard Operating Procedure
SOW	Statement of Work
SPF	Sun Protection Factor
SSHO	Site Safety and Health Officer
QA/QC	Quality Assurance Quality Control
USCG	U.S. Coast Guard
UV	Ultraviolet
UVA	Ultraviolet A
UVB	Ultraviolet B

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Table 1. Emergency Contact List

Department	Telephone Numbers
United States Coast Guard First District Coast Guard	Main Phone: 617-223-8515 Emergency phone: 617-223-8555 Radio Channel VHF # 16
Marine Forecast - Norfolk:	Block Island Weather http://forecast.weather.gov/shmrn.php?mz=anz237&syn=anz200 NOAA weather marine VHF: channel 1marine VHF: channel 21
24-Hr Emergency Department:	Dial 911
WorkCare Incident Intervention:	888-449-7787
Hospitals:	Block Island Medical Center 6 Payne Road New Shoreham, RI 02807 Ph: 401-466-2974 Kent Hospital General Hospital 227 Centerville Rd Warwick, RI 02886 Ph: 401-737-7000
Emergency Responders	Police Department…………911 Fire Department……………911 Ambulance………….....…….911
In Event of Emergency, call for help as soon as possible	Give the following information: 1) **Where you are**. Address, cross streets, or landmarks 2) **Phone Number** you are calling from 3) **What happened** – type of injury, accident 4) **How many persons** need help 5) **What is being done** for the victim(s) 6) **You hang up last**. Let whomever you called hang up first.
HDR Project Manager:	Jamey Elliott 256-777-2766 James.B.Elliott@hdrinc.com)
Project Coordinator:	Michael Richlen 808-388-7312 Michael.Richlen@hdrinc.com
HDR Program Manager:	Anwar Khan 954-494-2084 Anwar.Khan@hdrinc.com)
HDR Principle-In-Charge:	Randy Gallien 256-998-2441 Dennis.Gallien@hdrinc.com
HDR Environmental Sciences & Planning Director	Brian Hoppy 484-612-1131 Brian.Hoppy@hdrinc.com
HDR EOC Safety Manager	Daniel Sciarro 303-643-6724 Daniel.Sciarro@hdrinc.com
See vessel details for boats (**Appendix C**)	Lead Captains: *HDR Vessel* – Michael Richlen (cell): 808-388-7312 Other vessel contacts
Poison Control Center:	800-222-1222
Chemical Transportation Emergency Center:	800-424-9300
Emergency Centers:	National Response Center 800-424-8802
	CHEMTREC 800-424-9300

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1. Introduction

HDR has prepared this Health and Safety Plan (HASP) to cover field and vessel observations during cable installation and wind turbine generator (WTG) construction and operational testing. HDR will maintain and update the plan as necessary during the course of the work, based on direction received from the Contracting Officer (CO) or authorized representative. This plan will be a "living" document and will be administrated by HDR project management team. This document is applicable to activities and services performed and/or provided by HDR during Phase II construction activities associated with Block Island Wind Farm.

1.1 Plan Objective

The objective of this plan is to define the HDR safety and health requirements and designate project safety responsibility for protocols to be followed for all field staff during onshore on offshore vessel observations during the installation of wind turbine generator (WTG) foundations. Applicability extends to HDR personnel and visitors inclusive of client personnel and representatives. Work performed under this contract will comply with applicable Federal and State Occupational Safety and Health (OSHA) laws and regulations. Through careful planning and implementation of corporate and site-specific health and safety protocols, HDR will strive for zero accidents and incidents on the project.

1.2 Health and Safety Policy Statement

HDR's management is committed to the health and safety of each and every employee. There is no place at HDR for an employee who will not work safely or who will endanger the health and safety of his fellow workers. It is essential that all Managers and Supervisors insist on the maximum safety performance and awareness of all employees under their direction, by enthusiastically and consistently administering all health and safety rules and regulations. It is HDR's policy to take the necessary actions, in engineering, planning, designing, assigning and supervising work operations, to create a safe work-site. HDR will:

- Maintain safe and healthful working conditions
- Provide and assure the use of all necessary personnel protection equipment to ensure the safety and health of site employees
- Require that site work be planned to provide a range of protection based on the degree of hazards encountered under actual working conditions
- Provide site workers with the information and training required to make them fully aware of known and suspected hazards that may be encountered and of the appropriate methods for protecting themselves, their co-workers and the public at large.

1.3 Project Health and Safety Expectations

The health and safety of workers, clients and the public and the protection of the environment are a fundamental responsibility assumed by HDR under this contract. HDR will:

- Promote project health and safety with an objective of zero lost-time accidents
- Manage activities in a proactive way that effectively increases the protection of HDR site workers, the public and the environment
- Reduce health and safety risk by identifying and eliminating hazards from site activities
- Carry out site activities in a manner that complies with all applicable safety, health and environmental laws and regulations.

The success of our health and safety program is ensured by our ability to seamlessly integrate our health and safety procedures into a site-specific document that establishes safe and healthy work conditions for on-site operations.

1.4 Project Health and Safety Compliance Program

Compliance with the requirements of applicable Federal and state laws will be accomplished through a combination of written programs, employee training, workplace monitoring, and system enforcement. HDR and regular inspections by supervisors and health and safety personnel as well as the culture of ownership and total involvement in the health and safety program will produce an atmosphere of voluntary compliance. However, disciplinary action for violations of project requirements will be taken, when necessary.

The safe and efficient work practices of this company require a spirit of teamwork and cooperation from all employees. Also required are uniform standards of expected behavior. Employees who refuse or fail to follow the standard set forth by this plan, the HDR Corporate Health and Safety Program, and/or Regulatory standards will subject themselves to disciplinary action up to, and including discharge. In cases not specifically mentioned, employees are expected to use good judgment and refer any questions to their supervisors.

1.5 Safety and Health Plan Revisions

The development and preparation of this HASP has been based on site-specific information provided to HDR. Should any unforeseen hazard become evident during the performance of the work, the Project Manager (PjM) shall notify the Health and Safety HSM Manger (HSM) both verbally and in writing for resolution as soon as possible. In the interim, HDR project staff will take necessary actions to maintain safe working conditions in order to safeguard on-site personnel, visitors, the public, and the environment.

No changes to the HASP will be allowed until the hazard has been reviewed and changes approved by the HDR HSM and PjM. Changes to the HASP will be documented and submitted to the Contracting Officer Representative (COR). The final approval will be accompanied by a formal addendum to the HASP.

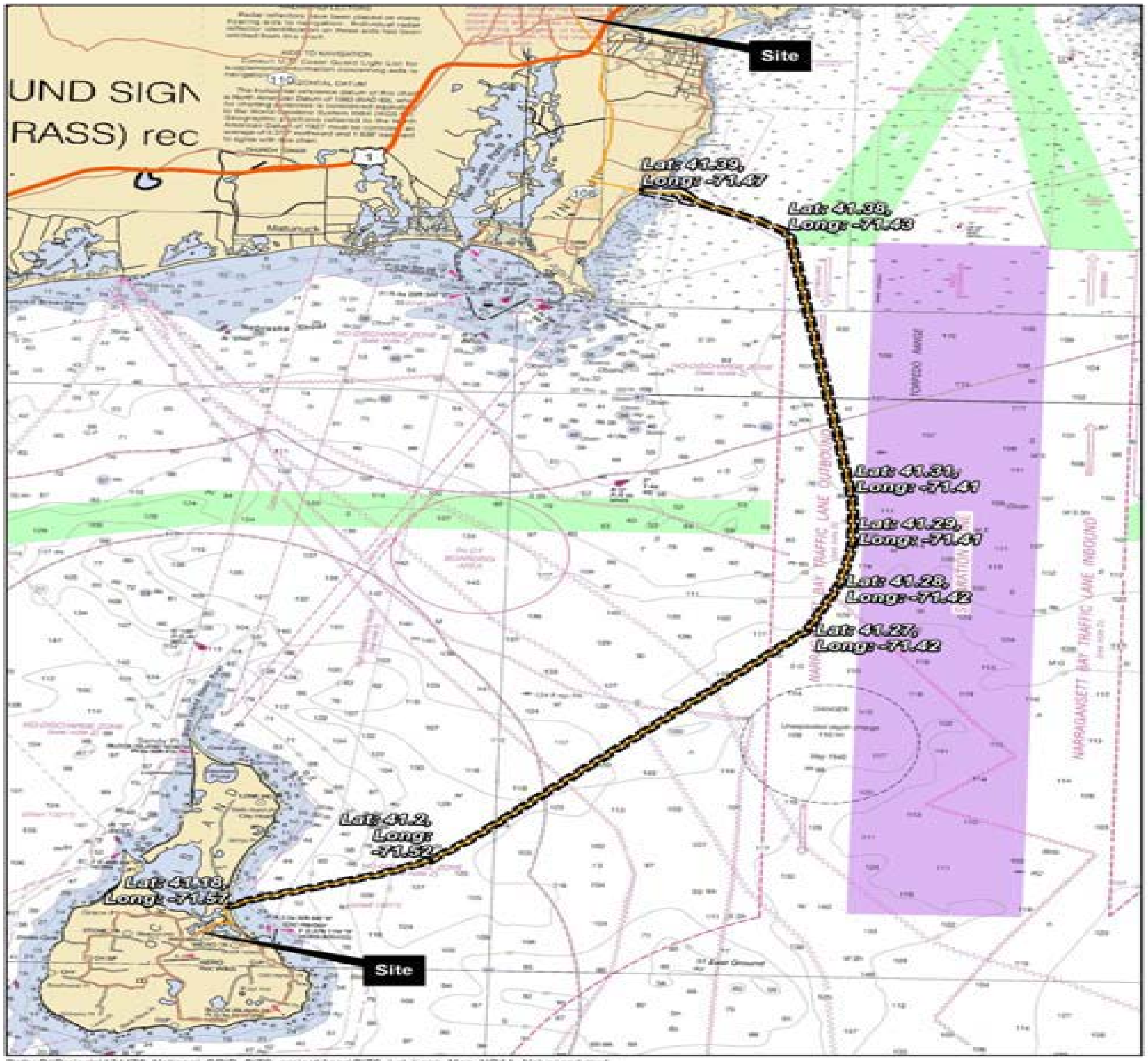


Figure 1. Overview of work area.

2. Organization and Responsibilities

All personnel are responsible for continuous adherence to this HASP during the performance of their work. The project personnel identified in the sections below have been designated as competent persons and will assume the authority and responsibility of their assignments herein. While the HDR Safety and Health Department directs and supervises the overall Safety, Health and Environmental Program, the responsibility for safety and health extends throughout our organization from top management to every employee. For this reason, it is each person's duty to notify project management personnel if a hazardous condition is identified and to make a "stop work" call if the condition represents an immediate danger to life or health., The Chief Scientist can make a further determination in consultation with the PM and/or PIC. The following are the HDR project personnel positions and responsibilities for this project:

- *Environmental Sciences & Planning Director* — Brian Hoppy
- *Program Manager*: — Anwar Khan
- *Project Manager:* — Jamey Elliott
- *Health and Safety Manager* — Daniel Sciarro
- *Project Coordinator:* — Michael Richlen
- *Observers*: — Michael Richlen
Jamey Elliott
URI Grad Student
URI Grad Student
URI Grad Student
- *Vessel Skippers*: — Michael Richlen
Mark Deakos
TBD Charter

2.1 Project Manager

The PjM reports directly to the PM and directs and manages the survey team in execution of the project activities in compliance with all contract and technical requirements. Technical direction will be given to the PjM by the Chief Scientist and changes to survey methodology will be approved by the Chief Scientist prior to PjM implementing. The PjM responsibilities include direction of data gathering and serving as the first line manager responsible for team safety. The PjM will ensure that survey personnel are briefed on QA/QC requirements, survey design, and ship safety requirements prior to embarking on each survey day. The PjM will support the Chief

Scientist and ensure any safety concern is brought to the attention of the Chief Scientist and will support the Chief Scientist in assessment of the situation and in implementing any required mitigation actions. The PjM will conduct daily tailgate safety meetings and necessary oversight of operations to ensure that health and safety requirements are continuously observed and implemented. The PM directs and manages all aspects of the project in compliance with all contract and technical requirements. The PM's responsibilities include serving as the primary liaison with the Contracting Officer Representative. The PM implements health and safety policy. He may request assistance from corporate resources at any time. He is specifically responsible for:

- Ensuring that appropriate health and safety training is provided on any equipment received
- Immediately reporting to the Chief Scientist/Site Safety and Health Officer (SSHO) and SD any incident that results in injury or death
- Ensuring regular updates of the Activity Hazard Analysis (AHAs)
- Implementing specific checklists and timelines to ensure full implementation of this HASP
- Ensuring self-audits are conducted at the start of the project
- Monitoring proper use and maintenance of specified personal protective equipment and communication equipment
- Maintaining a high level of health and safety awareness among team members and communicate pertinent matters to them promptly.
- Implementing health and safety training requirements at the Site.
- Ensuring that appropriate health and safety training is provided on any equipment received.
- Immediately reporting to the HSM, any incident that results in serious injury or damage to equipment.

2.2 Monitoring Coordinator

The Monitoring Coordinator/ SSHO reports directly to the PjM and directs and manages technical aspects of the survey in compliance with all contract task order procedural and technical requirements. The Monitoring Coordinator responsibilities include direct communication with the PjM as necessary during monitoring survey activities. The Monitoring Coordinator may assist with preparing all draft correspondence, submittals, and other documentation required for the project and submits to the PjM for approval and transmittal to the COR. The Monitoring Coordinator may help with the preparations of reports and documentation and provides technical and safety direction to the PjM and inspection personnel during execution of the survey. The Monitoring Coordinator serves as the SSHO and will make on-the-spot decisions concerning safety concerns and has the authority to terminate the survey as necessary to ensure safety of the crew and team. The Monitoring Coordinator will prepare immediate and follow-on incident reports and will coordinate with the PjM and/or PIC as soon as practicable to obtain decisions on ultimate safety incident resolution as well as follow all the responsibilities outlined below.

2.3 Site Safety and Health Officer

Have the authority to ensure site compliance with specified health and safety requirements, Federal OSHA regulations and all aspects of the HASP. This includes, but is not limited to: AHA, air monitoring; use of Personal Protective Equipment (PPE), decontamination site control; standard operating procedures (SOP) used to minimize hazards; safe use of engineering controls; the emergency response plan; confined space entry procedures; spill containment program; and preparation of records. This will be accomplished by performing a daily safety and health inspection and documenting results on the Site Safety Inspection Form, located in Appendix A.

- Stop work activities if unacceptable health or safety conditions exist, and take necessary action to re-establish and maintain safe working conditions.
- Consult and coordinate any modifications to the HASP with the PjM and/or the PIC.
- Conduct accident investigations and prepare accident reports.
- Review results of daily inspections and document health and safety findings in the Daily Safety Inspection Log.
- Consult with the PjM and/or the PIC at the earliest opportunity to safely do so, concerning safety incidents.
- Coordinate health and safety activities with the boat captains and any other subcontractor(s) to ensure that the planned work objectives reflect adequate health and safety considerations.
- Perform site-specific training and briefing sessions for employees prior to the start of field activities at the site and a briefing session each day before starting work.
- Promote proper use and maintenance of specified personal protective equipment and communication equipment.

2.4 Health and Safety Manager

The Health and Safety Manager (HSM) will:

- Assist the development and oversight of the HASP.
- Be available for consultation during project emergencies.
- Ensure accident reporting and investigations are completed.

- Provide consultation as needed to ensure that this HASP is fully implemented.
- Coordinate any modifications to the HASP with the PM as needed.
- Provide HDR personnel with support for upgrading/downgrading of the level of personal protection.
- Assist in evaluating and recommending changes to engineering controls, work practices, and PPE.
- Approve the HASP by signature

2.5 Program Manager

The PM reports directly to the PIC and will:

- Be responsible for the development and oversight of the HASP
- Be available for consultation during emergencies
- Provide consultation as needed to ensure that the HASP is fully implemented and fully supported
- Provide first tier approval of any modifications to the HASP coordinate those changes with the PIC for final approval prior to implementation and HSM approval
- Ensure necessary resources are available to provide adequate personal protection and training to all survey team members
- Augment the PIC during his absence or unavailability.

2.6 Principle-In-Charge

The PIC and ESPD have final approval of the HASP. The PIC will coordinate with the HSM as necessary and will make recommendations relative to needed project safety requirements.

The PIC will:

- Evaluate all safety incidents to ensure appropriate actions are taken in a timely manner
- Provide guidance for recommended changes to the Marine Species Monitoring HASP
- Provide guidance to the HSM, PM, and Chief Scientist as necessary as to any needed changes, revisions, or modifications necessary to this HASP.

2.7 Environmental Sciences & Planning Director

The ESPD will coordinate with the PIC as necessary and will assist in decisions relative to safety requirements and programmatic safety measures necessary to ensure protection of all survey personnel. The ESPD will:

- Evaluate all safety incidences to ensure appropriate actions are taken in a timely manner
- Provide approval for all programmatic changes to the Marine Species Monitoring HASP
- Provide guidance to the PM and Chief Scientist as necessary.

3. Boating Safety

HDR employees must recognize the inherent hazards associated with working in and around water, whether directly exposed through wading/swimming, or potentially exposed while performing services on surface watercraft or near water bodies. This HASP presents information and guidelines on the safe performance of work on or near water, where the possibility of drowning exists and conforms to the requirements of 29 CFR 1926.106 – Working Over or Near Water, 29 CFR 1926.802 – Cofferdams, and 29 CFR 1926.605 – Marine Operations and Equipment [Barges].

NOTE: *Activities in many states are regulated by state OSHA plans, which may have certain requirements that differ, and are more stringent than the Federal requirements presented here. When performing services in these state plan areas, HDR will comply with the state promulgated OSHA regulations. It is not anticipated these will differ significantly from the Federal-based regulations presented herein.*

In addition to this HASP (Reference the HDR Corporate H&S Program, Boating Water Safety Procedure #18 for further guidance on boating and water safety).This HASP applies to all HDR personnel at HDR client sites and at HDR facilities. All employees that perform surface services on or around water, where the potential for drowning exists, will be impacted by this plan. Section 13 of the HDR Procedure #18 addresses certain boating & water operations associated with the use of large open water craft. The PjM shall determine if any project task under this HASP will subject HDR personnel to water hazards, and incorporate appropriate preplanning into the project design. Preplanning includes the identification and acquisition of necessary equipment (PFDs, skiffs, etc.) and the verification that exposed personnel have the knowledge and training to correctly use the equipment.

3.1 Definitions

Personal Flotation Device (PFD) – Equipment designed to prevent drowning. The United States Coast Guard (USCG) is the approving agency and divides all PFDs into 5 current classifications. Three classes are approved for HDR use – Class III, IV and V. Types III and V are designed to be worn as apparel around the body during all times of exposure, and are commonly referred to as "life vests, life preservers, float coats, or float suits." Type IV are circular life rings designed to be thrown to personnel who are in the water, as a rescue measure. All vessel personnel are required to wear an automatically inflated PFD at all times while on the boat. Any personnel who are required to board the vessel for short periods of time and do not have automatically inflated PFD will be provided a Class III or V PFD by the vessel's captain.

Ring Buoy – Type IV life ring, with a retrieval rope attached.

NOTE: For cold weather work on boats, or on floating docks where the risk of falling into the water is present, if the water plus air temperature is less than 43.3 degrees Celsius (℃) a float coat or a float suit must be worn in lieu of a vest-type PFD.

Simply stated: Water temperature + air temperature < 43.3 ℃ = float coat or suit required. If this is contradictory to the heat stress brought on by wearing float coats or suits, then float coats or suits will not be worn. However, lifejackets will continue to be worn at all times.

Emergency Position Indicating Radio Beacon (EPIRB) – ACR GlobalFix™ iPro GPS EPIRB offers the latest in marine electronic life-saving technology. The iPro allows you to interface your onboard GPS to ensure that your latitude/longitude (LAT/LON) are stored inside so the coordinates are transmitted in the first data burst. iPro's internal GPS is optimized for cold starts and will pinpoint your exact location faster than standard GPS enable EPIRBs.

3.2 Marine Radio

Marine radios transmit along VHF/FM frequencies and are much more reliable than Citizen's Band (CB) radios. In addition to this more advanced technology, Marine Radios have designated channels that are monitored 24/7. Channel 16 is the international channel for all distress calls.

3.3 Medical Support

Emergency contingency information including on-site emergency contacts and offsite medical arrangements are summarized on the Emergency Contacts page of this HASP. If an injured individual is ambulatory, they should be transported to the nearest marina where medical services can obtain access.

3.4 Emergency Radio Calls/ Distress

3.4.1 How to Call for Help:

- Makes sure you radio is transmitting on Channel 16.

3.4.2 If you are in distress:

- Call "MAYDAY, MAYDAY, MAYDAY".

3.4.3 If you are not in distress:

- Call "Coast Guard".

3.4.4 What to tell the USCG:

- Your location or position
- Exact nature of the problem or emergency

- Number of people on board
- Your boat's name, registration, description, and safety equipment on board.

3.4.5 When to Call Back:

- A medical emergency develops
- A storm approaches
- Your boat begins to take on water
- Your last reported position changes.

3.4.6 Emergency VHF/FM CHANNELS

The following are some useful Channels to know, the most important of which is:

CHANNEL 16 VHF/FM 2182 kHz HF/SSB for international distress, safety and calling.

Table 2. Radio Calls

Channel Number MHz	Ship Transmit	Ship Receive MHz	Use
16	156.800	156.800	International Distress, Safety and Calling. Ships required to carry radio, USCG, and most coast stations maintain a listening watch on this channel.
21A	157.050	157.050	USCG only
22A	157.100	157.100	USCG Liaison and Maritime Safety Information Broadcasts. Broadcasts announced on channel 16.
13	156.650	156.650	Ships >20m length maintain a listening watch on this channel in US waters.

3.5 Over-Water Safety Requirements

Whenever work is conducted from the barge or monitoring vessels, there is an inherent risk of falling off and being immersed in water, with a risk of drowning or hypothermia. To minimize the risk of drowning hazards, the following will be performed:

- All HDR personnel on a boat, barge, or on the pier will be required to wear a Personal Flotation Device (Type III or V)
- The pier and boats will have tools and equipment organized in a manner to minimize trip/fall hazards.

3.6 Sinking/Flooding

In the unlikely event a hull is compromised, personnel will immediately evacuate the barge or boat and go to shore. All personnel are required to wear personal flotation devices when on the boat. Under no circumstances will personnel endanger one's own life to attempt to save another.

3.7 Man Overboard

All personnel are required to wear personal flotation devices when on the boat. In the unlikely event a person falls overboard, personnel will immediately assist using the following directions. Under no circumstances will personnel endanger one's own life to attempt to save another.

- Immediately throw a lifebuoy and attachment overboard. Immediately throw any other items that float over to assist in marking the spot.
- Raise the alarm by shouting: "MAN OVERBOARD" (Even if you are the only one left aboard, shouting "man overboard" may provide reassurance to the person in the water). If there are others on board, instruct a crew member to watch the person in the water and point continuously.
- Start your recovery maneuver. If possible note your position – most GPS units have a MOB function - it may prove vital if contact is lost with the person in the water.

REMEMBER the MOB function records where the person fell overboard - he/she will drift away with the tide.

- If you are the only person remaining on board, do not leave the deck as you may become disorientated and lose sight of the person in the water.

4. Heat Disorders

All crew will be familiar with the signs of dehydration, heat stress, heat stroke, and sunburn. Crew will need to take their own ample water supply on the survey vessel at all times and the SSHO will encourage everyone to drink plenty of liquids. In the event of someone demonstrating signs of heat disorders, they will be placed in a cool environment and allowed to cool down following the first aid treatment provided below, as needed and appropriate. Sun exposure is also a serious concern. All team members will be required to have sunglasses and sunscreen (SPF 15 or greater) readily available to avoid sun blindness and sunburn.

4.1 Heat-Related Illnesses

There are four typical types of heat-related illnesses (result of heat strain) resulting from prolonged exposure to high thermal environments (stressor which causes the strain). These are described in the sections below.

4.1.1 Heat Rash (Prickly Heat)

Heat rash is a painful temporary condition caused by clogged sweat pores. Heat rash is caused by the plugging of sweat ducts due to the swelling of the moist keratin layer of the skin which leads to inflammation of the sweat glands. Heat rash appears as tiny red bumps on the skin and can impair sweating, resulting in diminished heat tolerance. Signs and symptoms include:

- Tiny raised blustered red blisters or small pimples
- Pricking sensations, or itching during heat exposure
  - Most likely to occur on the neck and upper chest, in the groin, under the breasts, and in elbow creases.

Heat rash is usually a mild, temporary condition, although it decreases the body's ability to tolerate heat, as well as being a nuisance.

Treatment: Heat rash can usually be cured by providing cool areas; body powder may also help absorb moisture.

4.1.2 Heat Cramps

Heat cramps are characterized by painful intermittent spasms of the voluntary muscles following hard physical work in a hot environment. Heat cramps usually occur after heavy sweating, and often begin at the end of the workday. The cramps are caused by a loss of electrolytes, principally salt. This results in fluids leaving the blood and collecting in muscle tissue, resulting in painful spasms. Symptoms include muscle pain or spasms in the abdomen, arms, or legs.

Heat syncope is a condition caused by pooling of the blood in the extremities, usually related to activities where the person stands without moving for a period of time or sudden rising from a sitting or lying position. Factors that may contribute to heat syncope include dehydration and lack of acclimatization. The reduced blood volume to the head can cause fainting, which may in turn cause injuries. Symptoms include:

- Light-headedness
- Dizziness
    - Fainting.

4.1.3 Treatment:

Increase water ingestion. Eat normally throughout the day to replace electrolytes.

4.1.4 Heat Exhaustion

Heat exhaustion occurs when the body's regulatory system is not functioning efficiently. Symptoms of heat exhaustion include:

- Heavy sweating
- Extreme weakness or fatigue
- Low blood pressure
- Rapid pulse
- Dizziness, confusion
- Nausea
- Clammy, moist skin
- Pale or flushed complexion
- Muscle cramps
- Normal or slightly depressed body temperature
    - Fast and shallow breathing.

This is the most common form of serious heat illness encountered during employment activities. Any worker who is a victim of heat exhaustion may not be exposed to a hot working environment for an absolute minimum of 24 hours and, if fainting has occurred, the victim should not return to work until authorized by a physician.

Treatment: Move victim to a cool area, loosen clothing, and place in a head-low (shock prevention) position, and provide rest and plenty of fluids. Do not give coffee, tea or alcoholic beverages.

4.1.5 Heat Stroke

This is the most serious heat disorder and is life-threatening. Heat stroke is a true medical emergency. This results when the body's heat-dissipating system is overwhelmed and shuts down (thermoregulatory failure). Heat stroke results in a continual rise in the victim's deep core body temperature, which is fatal if not checked. Symptoms may include:

- Hot, dry skin; no perspiration
- Hallucinations
- Chills
- Throbbing headache
- High body temperature
- Confusion and/or dizziness
- Slurred speech
  - Unconsciousness may occur.

4.1.6 Treatment:

Call 911. First aid consists of immediately moving victim to a cool area; cool the body slowly by immersion in tepid (slightly warm) water or sponging the body with tepid water; treat for shock and obtain immediate medical assistance. Treatment response time is critical when assisting a victim of heat stroke! Do not give coffee, tea or alcoholic beverages.

4.2 General Heat Stress First Aid

First aid for heat stress conditions consists of proper evaluation of their condition, cooling the victim down, and rehydration. Specific actions which should be taken include:

- First-aid trained persons should be summoned to assist in evaluation of the victim’s condition
- If heat stroke is suspected, outside medical responders should be immediately contacted, as this condition should be considered immediately life-threatening. **Call 911** immediately
- Impermeable clothing should be removed as soon as possible following the required decontamination steps, unless the delay could compromise the victim’s health
- The victim’s clothing should be loosened to aid air circulation
- The victim should be moved to a shaded, cooler location, preferably air-conditioned
- The victim should sit, or lie down if they are dizzy or at risk of losing consciousness

- The victim should be encouraged to drink cool water if they are not nauseous or losing consciousness
- The victim may be cooled down further by:
  - Moistening the head, neck, torso and clothing with tepid water
  - Spraying, sponging, or showering them with tepid water
  - Fanning their body, gently
- To minimize the risk of shock, do not drench them with cold water, use tepid water, unless advised to do so by medical personnel.

4.3 Prevention of Heat Disorders

It is interesting to note that if a person works continually, for about a week, in a hot environment, he/she tolerates much hotter conditions than initially. This process of adjustment is termed "acclimatization". Acclimatization is essential if work is to be frequently performed in hot environments. Essentially, in acclimatized workers, their core body temperatures and heart rates are slower than non-acclimatized workers, and they sweat more but with less salt loss. Acclimatization to heat can, however, be lost almost as rapidly as it is acquired, if the worker is removed from the hot environment for a few days.

In order to prevent the onset of heat-related disorders, HDR employees should rely on the physiological monitoring methods described above, and practice the following good health measures.

4.3.1 Provision of Water (or other drinking fluids)

Fluids are a key preventative measure to minimize the risk of heat related illnesses. Each employee should have at least one quart per employee per hour for the entire shift. Each vehicle will carry at least 5 gallons of drinking water. This must be replenished at the beginning of each day. In addition, each employee is responsible for having a container (such as a Camelback or other means) so they can carry water with them throughout the day.

Coffee, tea and other warm and caffeinated beverages must be avoided. In addition, sport drinks and electrolyte replacement drinks are to be consumed in very limited quantities (one per day) as these contain sugar, which utilizes the bodies' water reserves to digest, thus dehydrating the individual.

Employees are encouraged to maximize water intake and realize that thirst is not an adequate indicator of sweat loss. Water should be consumed at a target rate of one cup every 20 minutes at a minimum.

If water containers are being shared by employees disposable/single use drinking cups need to be provided, or employees may use their own cup. In addition, a supervisor or designated employee shall be assigned to monitor the quantity and condition of the water. When water levels within a container drop below 50%, the water needs to be replenished.

4.3.2 Access to Shade (Rest Area)

Access to rest and shade or other cooling measures are important preventative steps to minimize the risk of heat related illnesses. Employees suffering from (or exhibiting symptoms of) heat illness or believing a preventative recovery period is needed, will be provided access to an area with shade that is either open to the air or provided with ventilation or cooling for a period of no less than five minutes. Such access to shade shall be permitted at all times.

The rest area should be shaded from the sun. Air-conditioned construction offices, trailers and work vehicles make good rest areas. When possible, rest areas should be readily accessible and near supplies of drinking fluids.

4.3.3 Additional Health Measures

To help prevent the onset of heat-related disorders, HDR employees should practice additional good health measures, such as:

- The workers should be as physically fit as possible. This is especially important concerning hot work. Obesity predisposes individuals to heat disorders.
- Older workers are at a disadvantage in hot work because the aging process results in a sluggish response of sweat glands, resulting in a less effective control of body temperature.
- A victim of a heat-related disorder is permanently predisposed to suffering a recurrence.
- Every worker is unique in his/her ability to handle heat. Work/rest periods should be based on the individual’s capacity to safely handle the heat, not on a predetermined or inflexible time length.
- Alcohol has been commonly associated with the occurrence of heat-related disorders. Alcohol reduces heat tolerance.
  - Inform female workers of the possible adverse consequences of hot work while pregnant, due to elevated core body temperatures.

4.4 Emergency Assistance Procedure

Employees are directed to immediately report to their SSHO, symptoms or signs of heat illness in themselves, or in co-workers. Employees should not delay in reporting these observations.

To help ensure proper medical care is provided with minimal delay, SSHO shall take the following steps:

- Providing First Aid: Should an HDR employee exhibit signs of possible heat illness, the treatment procedures described above should be implemented.

Contacting EMS: If emergency medical service (EMS) is required, the HDR field supervisor (or a designee) shall contact EMS using the procedures presented in Table 1. Once contact is established, stay on the phone with EMS to provide clear and precise directions to the work site.

4.5 Sunburn Prevention

Ultraviolet (UV) rays are a part of sunlight that is an invisible form of radiation. UV rays can penetrate and change the structure of skin cells. There are three types of UV rays: ultraviolet A (UVA), ultraviolet B (UVB), and ultraviolet C (UVC). UVA is the most abundant source of solar radiation at the earth's surface and penetrates beyond the top layer of human skin. Scientists believe that UVA radiation can cause damage to connective tissue and increase a person's risk for developing skin cancer. UVB rays penetrate less deeply into skin, but can still cause some forms of skin cancer. Natural UVC rays do not pose a risk to workers because they are absorbed by the Earth's atmosphere.

Light-colored sand reflects UV light and increases the risk of sunburn. At work sites with these conditions, UV rays may reach workers' exposed skin from both above and below. Workers are at risk of UV radiation even on cloudy days. Many drugs increase sensitivity to sunlight and the risk of getting sunburn. Some common ones include thiazides, diuretics, tetracycline, doxycycline, sulfa antibiotics, and nonsteroidal anti-inflammatory drugs, such as ibuprofen. Creosote, often found on or in wood used for piers and railroad ties, can increase sensitivity to sunlight.

Sunburn is an often painful sign of skin damage from spending too much time outdoors without wearing a protective sunscreen. Years of overexposure to the sun lead to premature wrinkling, aging of the skin, age spots, and an increased risk of skin cancer. In addition to the skin, eyes can get burned from sun exposure. Sunburned eyes become red, dry, and painful, and feel gritty. Chronic exposure of eyes to sunlight may cause pterygium (tissue growth that leads to blindness), cataracts, and perhaps macular degeneration, a leading cause of blindness.

4.5.1 Symptoms:

Symptoms may include:

- Red, warm, and tender skin
- Swollen skin
- Blistering
- Headache

- Fever
- Nausea
    - Fatigue.

4.5.2 First Aid:

There is no quick cure for minor sunburn, but symptoms can be treated with the following:

- Aspirin, acetaminophen, or ibuprofen to relieve pain and headache and reduce fever
- Drinking plenty of water helps to replace fluid losses
- Cool baths or the gentle application of cool wet clothes on the burned area may also provide some comfort
- Workers with sunburns should avoid further exposure until the burn has resolved
- Additional symptomatic relief may be achieved through the application of a topical moisturizing cream, aloe, or 1 percent hydrocortisone cream
    - A low-dose (0.5 percent-1 percent) hydrocortisone cream, which is sold over the counter, may be helpful in reducing the burning sensation and swelling and speeding up healing.

4.5.3 If blistering occurs:

- Lightly bandage or cover the area with gauze to prevent infection
- The blisters should not be broken, as this will slow the healing process and increase the risk of infection
- When the blisters break and the skin peels, dried fragments may be removed and an antiseptic ointment or hydrocortisone cream may be applied
- Seek medical attention if any of the following occur
- Severe sunburns covering more than 15 percent of the body
- Dehydration
- High fever (>101℉)
    - Extreme pain that persists for longer than 48 hours.

4.5.4 Prevention:

Take the following steps to protect yourself from exposure to UV radiation:

- Provide shaded or indoor break areas.
- Wear sunscreen with a minimum Sun Protection Factor (SPF) of SPF 15.

- SPF refers to the amount of time that persons will be protected from a burn. The SPF rating applies to skin reddening and protection against UVB exposure.
- SPF does not refer to protection against UVA. Products containing Mexoryl, Parsol 1789, titanium dioxide, zinc oxide, or avobenzone block UVA rays.
- Sunscreen performance is affected by wind, humidity, perspiration, and proper application.
- Old sunscreens should be thrown away because they lose their potency after 1-2 years.
- Sunscreens should be liberally applied (a minimum of 1 ounce) at least 20 minutes before sun exposure. Special attention should be given to covering the ears, scalp, lips, neck, tops of feet, and backs of hands.
- Sunscreens should be reapplied at least every 2 hours and each time a person gets out of the water or perspires heavily. Some sunscreens may also lose efficacy when applied with insect repellents, necessitating more frequent application when the two products are used together.
- Follow the application directions on the sunscreen bottle.
- Another effective way to prevent sunburn is by wearing appropriate clothing.
- Dark clothing with a tight weave is more protective than light-colored, loosely woven clothing.
  - High-SPF clothing has been developed to provide more protection for those with photosensitive skin or a history of skin cancer.

Workers should also wear wide-brimmed hats and sunglasses with almost 100 percent UV protection and with side panels to prevent excessive sun exposure to the eyes.

5. Hypothermia Prevention & First Aid

This project has the potential to be ongoing in the cooler months of October through May. The information provided reviews the different cold related illness, prevention and first aid requirements.

5.1 Hypothermia

When exposed to cold temperatures, your body begins to lose heat faster than it can be produced. Prolonged exposure to cold will eventually use up your body's stored energy. The result is hypothermia, or abnormally low body temperature. A body temperature that is too low affects the brain, making the victim unable to think clearly or move well. This makes hypothermia particularly dangerous because a person may not know it is happening and will not be able to do anything about it.

5.1.1 Symptoms

Symptoms of hypothermia can vary depending on how long you have been exposed to the cold temperatures.

5.1.2 Early Symptoms

- Shivering
- Fatigue
- Loss of coordination
  - Confusion and disorientation.

5.1.3 Late Symptoms

- No shivering
- Blue skin
- Dilated pupils
- Slowed pulse and breathing
  - Loss of consciousness.

5.1.4 First Aid

Take the following steps to treat a worker with hypothermia:

- Alert the Field Team Leader and request medical assistance.
- Move the victim into a warm room or shelter.
- Remove their wet clothing.
- Warm the center of their body first-chest, neck, head, and groin-using a blanket

or other available items; or use skin-to-skin contact under loose, dry layers of blankets, clothing, towels, or sheets.

- Warm beverages may help increase the body temperature, but do not give alcoholic beverages. Do not try to give beverages to an unconscious person.
- After their body temperature has increased, keep the victim dry and wrapped in a warm blanket, including the head and neck.
  - If victim has no pulse, begin CPR.

5.2 Cold Water Immersion

Cold water immersion creates a specific condition known as immersion hypothermia. It develops much more quickly than standard hypothermia because water conducts heat away from the body 25 times faster than air. Typically people in temperate climates don't consider themselves at risk from hypothermia in the water, but hypothermia can occur in any water temperature below 70 degrees Fahrenheit (℉). Survival times can be lengthened by wearing proper clothing (wool and synthetics and not cotton), using a personal flotation device (life vest, immersion suit, dry suit), and having a means of both signaling rescuers (strobe lights, personal locator beacon, whistles, flares, waterproof radio) and having a means of being retrieved from the water..

5.3 Frostbite

Frostbite is an injury to the body that is caused by freezing. Frostbite causes a loss of feeling and color in the affected areas. It most often affects the nose, ears, cheeks, chin, fingers, or toes. Frostbite can permanently damage body tissues, and severe cases can lead to amputation. In extremely cold temperatures, the risk of frostbite is increased in workers with reduced blood circulation and among workers who are not dressed properly.

5.3.1 Symptoms

Symptoms of frostbite include:

- Reduced blood flow to hands and feet (fingers or toes can freeze)
- Numbness
- Tingling or stinging
- Aching
  - Bluish or pail, waxy skin.

5.3.2 First Aid

Workers suffering from frostbite should:

- Get into a warm area as soon as possible.

- Unless absolutely necessary, do not walk on frostbitten feet or toes-this increases the damage.
- Immerse the affected area in warm-not hot-water (the temperature should be comfortable to the touch for unaffected parts of the body).
- Warm the affected area using body heat; for example, the heat of an armpit can be used to warm frostbitten fingers.
- Do not rub or massage the frostbitten area; doing so may cause more damage.
  - Do not use a heating pad, heat lamp, or the heat of a stove, fireplace, or radiator for warming. Affected areas are numb and can be easily burned.

5.4 Trench Foot

Trench foot, also known as immersion foot, is an injury of the feet resulting from prolonged exposure to wet and cold conditions. Trench foot can occur at temperatures as high as 60 ºF if the feet are constantly wet. Injury occurs because wet feet lose heat 25-times faster than dry feet. Therefore, to prevent heat loss, the body constricts blood vessels to shut down circulation in the feet. Skin tissue begins to die because of lack of oxygen and nutrients and due to the buildup of toxic products.

5.4.1 Symptoms

Symptoms of trench foot include:

- Reddening of the skin
- Numbness
- Leg cramps
- Swelling
- Tingling pain
- Blisters or ulcers
- Bleeding under the skin
  - Gangrene (the foot may turn dark purple, blue, or gray).

5.4.2 First Aid

Workers suffering from trench foot should:

- Remove shoes/boots and wet socks
- Dry their feet
- Place gauze or other cloth between the toes

- Avoid walking on feet, as this may cause tissue damage.

5.5 Chilblains

Chilblains are caused by the repeated exposure of skin to temperatures just above freezing to as high as 60 ºF. The cold exposure causes damage to the capillary beds (groups of small blood vessels) in the skin. This damage is permanent and the redness and itching will return with additional exposure. The redness and itching typically occurs on cheeks, ears, fingers, and toes.

5.5.1 Symptoms

Symptoms of chilblains include:

- Redness
- Itching
- Possible blistering
- Inflammation
  - Possible ulceration in severe cases.

5.5.2 First Aid

Workers suffering from chilblains should:

- Avoid scratching
- Slowly warm the skin
- Use corticosteroid creams to relieve itching and swelling
  - Keep blisters and ulcers clean and covered.

5.6 Equivalent Chill Temperature

Equivalent Chill Temperature – The Equivalent chill temperature is the temperature that it feels like outside to people and animals. Equivalent chill temperature is based on the rate of heat loss from exposed skin caused by combined effects of wind and cold. As the wind increases, heat is carried away from the body at an accelerated rate, driving down the both the skin temperature and eventually the internal body temperature. Therefore, the wind makes it feel much colder. If the temperature is 0°F and the wind is blowing at 15 miles per hour (mph), the wind chill is -19°F. At this equivalent chill temperature, exposed skin can freeze in 30 minutes.

The Equivalent Temperature Table, presented in **Table 5**, should be reviewed along with local temperature and wind speed data prior to extended work in the cold, and preventative work restrictions and preventions, presented herein, should be followed.

Table 5. Cooling Power of Wind on Exposed Flesh Expressed as Equivalent Temperature (under calm conditions)

Estimated Wind Speed (in mph)	Actual Temperature Reading (°F)											
	50	**40**	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**-60**
	Equivalent Chill Temperature (ºF)											
Calm	50	40	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**-60**
5	48	**37**	**27**	**16**	**6**	**-5**	**-15**	**-26**	**-36**	**-47**	**-57**	**-68**
10	40	**28**	**16**	**4**	**-9**	**-24**	**-33**	**-46**	**-58**	**-70**	**-83**	**-95**
15	**36**	**22**	**9**	**-5**	**-18**	**-32**	**-45**	**-58**	**-72**	**-85**	**-99**	**-112**
20	**32**	**18**	**4**	**-10**	**-25**	**-39**	**-53**	**-67**	**-82**	**-96**	**-110**	**-121**
25	**30**	**16**	**0**	**-15**	**-29**	**-44**	**-59**	**-74**	**-88**	**-104**	**-118**	**-133**
30	**28**	**13**	**-2**	**-18**	**-33**	**-48**	**-63**	**-79**	**-94**	**-109**	**-125**	**-140**
35	**27**	**11**	**-4**	**-20**	**-35**	**-51**	**-67**	**-82**	**-98**	**-113**	**-129**	**-145**
40	**26**	**10**	**-6**	**-21**	**-37**	**-53**	**-69**	**-85**	**-100**	**-116**	**-132**	**-148**
Wind speeds greater than 40 mph have little additional effect.	LITTLE DANGER In < hr with dry skin. Maximum danger of false sense of security.				INCREASING DANGER Danger from freezing of exposed flesh within one minute.			GREAT DANGER Flesh may freeze within 30 seconds.				
	Trench foot and immersion foot may occur at any point on this chart											

[shaded box] Equivalent chill temperature requiring dry clothing to maintain core body temperature above 36 Celsius (℃; 98.6 ºF) per cold stress threshold limit value (TLV).

* Developed by the U.S. Army Research Institute of Environmental Medicine, Natick, MA.

6. Other Physical Hazards

6.1 Vehicle Safety

Seat belts will be worn at all times when driving and rules of the road will be obeyed while engaged in company business. Drivers must be legally licensed to drive. Personnel will not ride on boats hauled by trailers nor ride in the bed of a pickup truck.

Staff members are required to comply with all Federal, state, and local regulations regarding the use of cellular devices while driving. If a cellular device must be used during vehicle operation, a hands-free device must be used. Under no circumstances is text messaging or any use of a keyboard allowed while operating a vehicle.

6.2 Slips/Trips/Falls

As with all fieldwork sites, caution will be exercised to prevent slips on rain-slick surfaces, stepping on sharp objects, etc. Slip/trip/hit/fall injuries are the most frequent of all injuries to workers. The boat deck will likely be wet so caution must be taken when moving.

All injuries can be prevented by the following prudent practices:

- Spot-check the work area to identify hazards
- Establish and utilize a pathway, which is most free of slip and trip hazards
- Beware of trip hazards such as uneven surfaces or terrain, wet surfaces, slopes
- Carry only loads that you can see over and around
- Communicate hazards to on-site personnel
    - Report and/or remove hazards.

6.3 Housekeeping

Responsibility for good housekeeping rests with each employee and shall be enforced by the SSHO. Keep all work areas clear (including all inside and outside areas). Supplies and material to be used, salvaged, or scrapped shall be stacked out of the way. Clean up all spills immediately to prevent slipping.

When using hoses, cables, or electrical extension cords, which must extend across decks, walkways, or stairs, position them in such a manner as to offer the least interference to people passing. Provide protection such as barricades or an inverted “V” device to prevent damage to the hose, cable, or electrical extension cord.

Clean up the area after each job (task) and at the end of the day. Remove tools and equipment to their proper places. No job is complete until this has been done.

6.4 Sanitation

The majority of vessels shall have a head (toilet) onboard. However, the 730 LE does not. The boat will be brought into shore for those needing to use restroom facilities. In addition, soap and water and/or sanitizer will be available for hand washing prior to eating and drinking on the boat.

6.5 Noise

Noise exposure may have a potential to occur during site observation and monitoring activities, especially when working around vessels and or heavy equipment. Noise has been defined as unwanted sound. The OSHA standard allows 90 decibels [dBA] for a full 8 hours and for a lesser time when the levels exceed 90 dBA. It is usually safe to assume that if you need to shout to be heard at arm's length, the noise level is at 90 dBA or above. Based on the nature of activities to be performed on site, the use of heavy equipment, power tools and other noise producing devices, personnel may be exposed to noise levels in excess of the allowable limits. Therefore, hearing protection will be utilized by personnel operating or working in areas near equipment emitting noise levels at or above 85 dBA. Employees exposed to 85 dBA or a noise dose of 50 percent must participate in the Hearing Conservation program including initial and annual (as required) audiograms. Hearing protection will be maintained in a clean and reliable condition, inspected prior to use and after any occurrence to identify any deterioration or damage, and damaged or deteriorated hearing protection repaired or discarded. In work areas where actual or potential high noise levels are present at any time, hearing protection must be worn by employees working or walking through the area. Areas where tasks requiring hearing protection are taking place may become hearing protection required areas as long as that specific task is taking place. High noise areas requiring hearing protection should be posted or employees must be informed of the requirements in an equivalent manner. When hearing protection must be worn, either ear plugs or ear muffs with an NRR30 will provide adequate protection.

6.6 Electrical Equipment Hazards

Field staff should assume electrical equipment may be live with current and caution should be taken to avoid any contact with potentially "live" electrical equipment. Electrical dangers can include short-circuit arcing faults, shock, or electrocution. Only "Qualified Persons" shall identify "live" electrical equipment. Qualified Person in accordance with OSHA's electrical worker term, describes a person "familiar with the construction and operation of the electrical equipment and the hazards involved." OSHA mandates that workers working on exposed energized electrical components, of 50 volts or more, be trained as a "qualified person"

If employees are "exposed", then the procedures presented in the HDR LOTO Energy Control Plan will be implemented. This is called the Lockout Tagout Program and as part of the program employees will need to be trained if this danger exsist due to

Servicing, Maintenance or Repair (unplanned servicing activities not integral to normal production.) .If these activities expose any part of an employee's body to a hazard caused by the sudden release of stored, potential or residual energy, it is covered by the HDR ECP.

It is important that safe work practices be employed to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts when work is performed near equipment or circuits which are or may be energized and that may affect the safety of HDR employees.

6.7 Energy Control Plan

There are four common types of energy present in energized equipment, which if released unexpectedly, could result in employee injury. These four types of energy are electrical, hydraulic, pneumatic, and mechanical compression. These are discussed below:

Electrical – This is the most common and familiar type of energy source present in many machines, especially fixed industrial equipment. The presence of electrical energy requires that the energized equipment be connected to an outside electrical source, either externally generated (A.C. line current), or internally generated from a stored electrical source (i.e., D.C. Battery). Electricity may also be supplied from outside the system, but stored within it in capacitors and high-capacitance elements that must be discharged or short-circuited and grounded to safely release this energy.

Hydraulic – Hydraulic energy is generated by the compression of fluid, whose resultant pressure generates the equipment movement. Prior to servicing, the stored pressure (potential energy) in hydraulic lines leading to movable equipment parts must be bled off, so as to release the fluid pressure, thus converting the potential energy into safely controlled kinetic energy.

Pneumatic – Pneumatic energy is generated by pressurized or compressed air (or other gas). This high-pressure air, fed to the equipment through a small diameter hose, powers various equipment components. Like hydraulic energy, during machine shutdown, this potential energy remains in the hoses and may be released suddenly, causing injury. Prior to equipment servicing, air pressure in these hose lines must be released to expend the stored energy present in the compressed air. If the line gas is something other than air, the uncontrolled release could pose environmental problems. The release of bulk pure oxygen is prohibited, as static electricity or friction could result in a fire.

Mechanical Compression – A mechanical compression system employs a spring or other type of object, which stores energy by being forcibly compressed during the machines operating cycle, and suddenly releases this energy through the expansion of the spring. This sudden and forcible release of mechanical energy can cause severe injury. This hazard is prevented by the placement of a blocking device against the spring, holding it in place to prevent expansion. The same blocking principle is used to prevent the gravity-caused fall of heavy machine components, when the authorized employee has to place any body part underneath a pneumatic or hydraulically powered component.

6.7.1 Definitions

Affected Employee – An employee who is working in the immediate area of an ongoing lockout event. All affected employees need to be informed of a lockout event prior to initiation, to prevent them from inadvertently attempting to operate the equipment or controls while the authorized employee is performing the lockout. Affected employees are never allowed or authorized to place, alter, or remove any lock out or tag out device.

Authorized Employee – A person who implements a LOTO Procedure on machines or equipment to perform the servicing or maintenance on that machine or equipment. The only person who may remove a lock or tag, under this program, is the authorized employee who originally affixed the lock/tag (For unusual situations, where the lock-affixing authorized employee is physically absent due to personnel change, sudden sickness, etc., Transference of LOTO Responsibility).

Energy Isolating Device – A mechanical switch that physically prevents the transmission of energy. Examples include circuit breaker, disconnect switch, line valve, or positive line block. Some machines may have multiple switches. An energy isolating device must be capable of being locked “out”, to prevent accidental energizing. Thus, pushbutton switches, selector switches, and other control circuit type devices are not energy isolating devices.

Lockout – The placement of a padlock on an energy isolating device, in accordance with this procedure, that maintains the device in the “off” position. This ensures that the energy isolating device and the equipment being controlled cannot be operated until the lock is removed. The lock may be either keyed or combination. If multiple authorized employees must perform simultaneous servicing, each authorized employee must place his/her own lock on a group lockout device, attached to the energy-isolating device.

Lockout Device – Refers to a lock, also called padlock. May be keyed or combination. Keyed locks are preferable. If keyed locks are used, one key is issued to the authorized employee “owning” the lock, and a second is maintained by the employer. All locks used for LOTO purposes must be identifiable as such – they must be identical in either color, size or shape. It is recommended that colored locks be used since other non-LOTO locks of the same size or shape may be present on project sites. Locks designated for this program may never be used for any other purpose (They cannot be used to lock project lockers, for personal security, etc. This defeats the purpose of “instant awareness” afforded by using identically shaped, sized or colored locks in this program.). Lockout devices must indicate the identity of the employee applying the device(s).

Normal Production Operations – The utilization of a machine or equipment as it was intended. Minor repairs or adjustments, made while the machine is operating, that are normal for the operation, and do not require removal of a machine guard, and do not present a hazard, are exempt from this Plan.

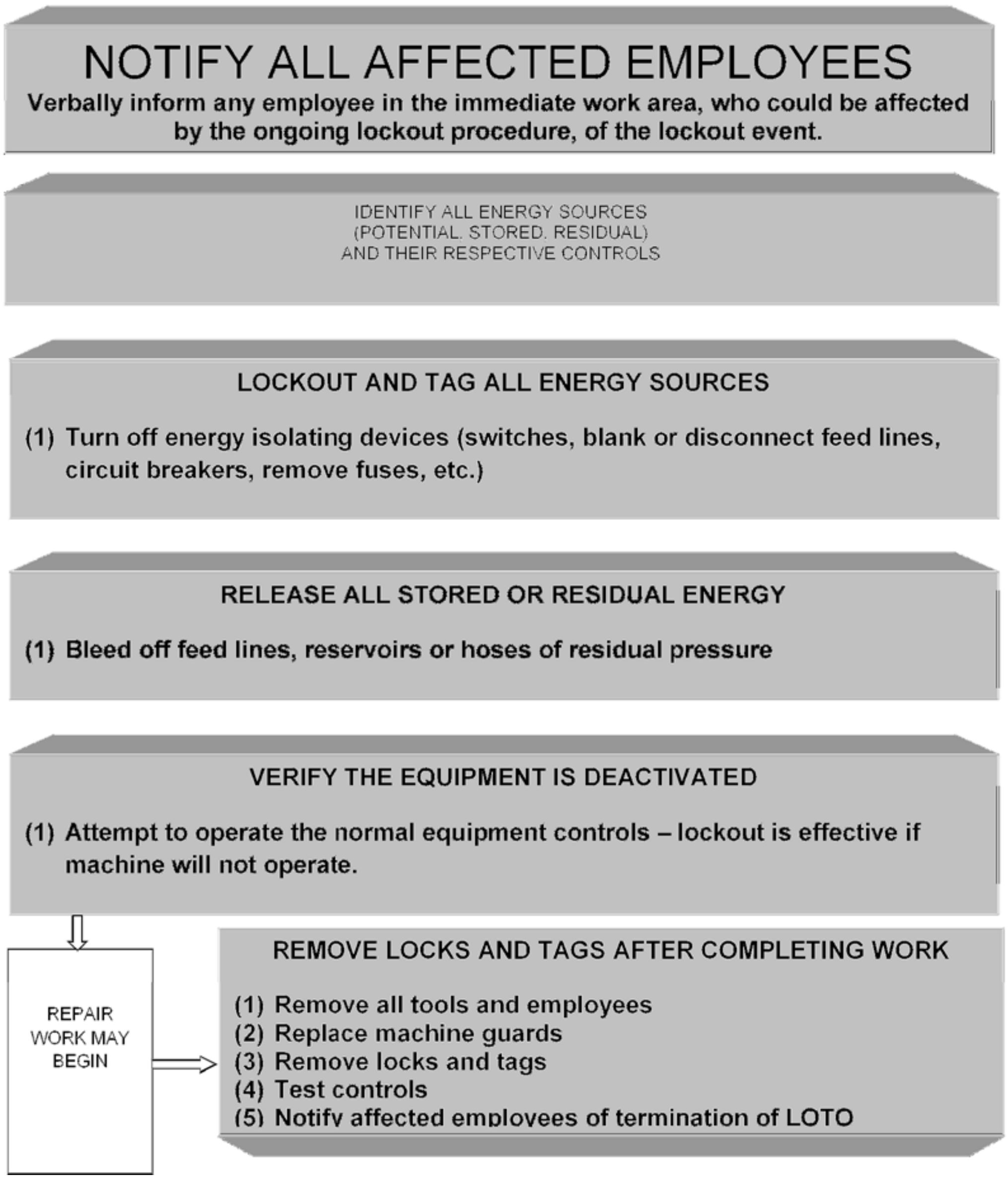
Qualified Person – OSHA electrical worker term, describing a person "familiar with the construction and operation of the [electrical] equipment and the hazards involved." OSHA mandates that workers working on exposed energized electrical components, of 50 volts or more, be trained as a "qualified person" (If the electrical component is not exposed, then the procedures presented in this energy control plan will serve to adequately lock out the energy source, and the designation of "qualified" does not apply.). This training may be accomplished by classroom training, on-the-job experience, or a combination of both.

Servicing, Maintenance or Repair – Unplanned servicing activities not integral to normal production. If these activities expose any part of an employee's body to a hazard caused by the sudden release of stored, potential or residual energy, it is covered by this Plan.

Tagout – The placement of a tagout device (tag) on an energy-isolating device, in accordance with this procedure, to indicate that the energy-isolating device and the equipment being controlled may not be operated until the tag is removed by the authorized person who originally placed the tag in position. Used to identify the authorized employee performing the lockout.

Tagout Device – A visually conspicuous standardized warning tag, with a strong attachment mechanism, that contains printed words, such as "DANGER - DO NOT OPERATE and EQUIPMENT LOCKED OUT BY…" and also contains information provided by the authorized employee identifying that employee, the date and time of LOTO initiation. The provided information shall be legibly printed, by a method (pen/pencil) that will not become illegible due to environmental conditions, for the anticipated duration of the LOTO activity. All tags utilized by HDR on a project site will be identical in size, color, etc., to assist employees in immediate recognition. Tags are considered non-reusable. The tag shall be affixed by a non-reusable, self-locking and non-releasable attachment that can withstand at least 50 lb of pressure without breaking. Tagout devices must indicate the identity of the employee applying the device(s).

6.7.2 Energy Control Procedures



6.7.3 Cord and Plug Exceptions to Lockout/Tagout

There is no requirement to perform LOTO on electrical cord and plug equipment, when electricity is the sole source of energy, and where the unexpected energization of the equipment can be controlled by unplugging the cord from the energy source. The unplugged cord must remain within sight, and under the exclusive control of the person performing the repair or maintenance. If visual observation of the cord/plug is not possible, the authorized employee shall affix a lockout device to the plug.

6.7.4 Training

Initial training will be provided to all HDR impacted employees to ensure that the purpose and function of the energy control program are understood and that the knowledge and skills required for the safe application, usage, and removal of the energy controls are acquired by employees. All training and retraining must be documented, signed, and certified. Documentation will be maintained by Corporate Safety. The training shall include the following areas:

- Authorized Employee: Each authorized employee shall receive training in the recognition of applicable energy sources, the type and magnitude of the energy available in the workplace, and the methods and means necessary for energy isolation.
- Affected Employee: Each affected employee shall be instructed in the purpose and use of the energy control procedure.
- Other Employees: All other employees whose work operations are or may be in an area where energy control procedures may be utilized, shall be instructed about the procedure, and about the prohibition relating to attempts to restart or re-energize machines or equipment which are locked out. This provision may apply to outside long-term contracted personnel working in HDR offices.
- Refresher Training: Refresher training shall be conducted whenever a new or revised control method and procedure is introduced, or whenever a deficiency in procedures is noted. HSM

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7. Biological Hazards

The section presents the potential biological hazards that exist at various sites throughout this project. Photographs of the species associated with biological hazards along with prevention and treatment methods are provided.

7.1 Bees, Wasps, and Hornets

Noxious insects are ubiquitous and can be encountered during field activities.

7.1.1 Background:

- Bees build hives in rock crevices and holes in trees.
- Wasps and hornets build nests in man-made structures and other areas where they are protected from the elements.

7.1.2 Prevention:

The following preventative measures should always be taken to minimize the chances of experiencing an insect bite or sting:

- Do not wear perfumes or colognes when performing field activities as they often attract stinging insects.
- Use an insect repellent.
- Wear protective clothing (long sleeves, long pants, and gloves).

7.1.3 Treatment:

The two greatest risks from most insect stings are allergic reaction (which can be fatal) and infection. General guidelines to follow if you experience an insect sting are as follows:

- If you are allergic, carry an Epi Pen and ensure your co-workers are informed of your allergy and the location of the Epi Pen.
- Do not drink a lot of liquid as this can cause vomiting.
- Remove the stinger by gently scraping it out with a blunt-edged object, such as a credit card or dull knife. Do not try to pull it out; this can release more venom into your body.
- For all types of stings, wash the area carefully with soap and water. Do this two to three times a day until the skin is healed.
- Apply a cold pack, an ice pack wrapped in a cloth.
- Apply a paste of baking soda and water for 15 to 20 minutes.
- Over-the-counter acetaminophen products can reduce pain.

- Some over-the-counter antihistamines advertise that they alleviate pain/swelling.
- Any employee who receives multiple stings should seek immediate medical attention.
- Any employee who knows that they are allergic to insect stings/bites should consult their own physician concerning the prudence of carrying self- administered anti-toxin injectable medicine.
- If any sting victim is complaining of a rapid heartbeat or tightness in the chest, keep the individual calm and in the shade. Seek medical attention immediately.

A sting in the mouth or nose warrants immediate medical attention, because swelling can block airways. You should also seek emergency care if you experience any of the following symptoms, which could indicate an allergic reaction:

- Large area of swelling
- Abnormal breathing
- Tightness in throat or chest
- Dizziness
- Hives
- Fainting
- Nausea or vomiting
  - Persistent pain or swelling (over 72 hours).

7.2 Centipedes and Scorpions

Centipedes and scorpions occur throughout the islands.

7.2.1 Treatment:

If you are stung by one of these invertebrates, do the following:

- If the victim is having a severe reaction, notify 911 or other Emergency Medical Services (EMS) assistance.
- Clean the affected area with soap and water.
- Apply cold compress to reduce the pain and swelling and to slow the spread of venom.
- Remove any rings or constricting items, since the bitten area may swell.

- Take steps to slow the rate at which the venom spreads in the victim's body. Have the victim stay still. Place the injured site below the level of the victim's heart and immobilize the injured site in a comfortable position.
- Watch for signs of shock.
- Raise the affected part, if possible.
- Seek medical attention by calling the Incident Intervention Care Team or transporting the victim to the nearest clinic.
- DO NOT apply a tourniquet.
- DO NOT raise the site of the bite above the level of the victim's heart.
- DO NOT give the victim aspirin, stimulants, or pain medication unless directed by a physician.
- DO NOT allow the victim to exercise.

7.3 Venomous Spiders

7.3.1 Treatment of Spider Bites:

Spider bites can be harmful and potentially deadly to humans. If you are bitten, do the following:

- If the victim is having a severe reaction, notify 911 or other EMS assistance.
- Clean the affected area with soap and water.
- Apply a cold compress to reduce the pain and swelling and to slow the spread of venom.
- Remove any rings or constricting items, since the bitten area may swell.
- Take steps to slow the rate at which the venom spreads in the victim's body. Have the victim stay still. Place the injured site below the level of the victim's heart and immobilize the injured site in a comfortable position.
- Watch for signs of shock.
- Raise the affected part, if possible.
- Seek medical attention by calling the Incident Intervention Care Team or transporting to the nearest clinic.
- DO NOT apply a tourniquet.
- DO NOT raise the site of the bite above the level of the victim's heart.
- DO NOT give the victim aspirin, stimulants, or pain medication unless directed by a physician.
- DO NOT allow the victim to exercise.

8. Personal Protective Equipment

Everyone on the survey vessels will have their own PFDs in case of emergency.

Selection of the appropriate PPE is a complex process, which takes into consideration a variety of factors. Key factors involved in this process are identification of the hazards, or suspected hazards, routes of potential exposure to employees (inhalation, skin absorption, ingestion, and eye or skin contact); and the performance of the PPE materials (and clothing seams) in providing a barrier to these hazards. The amount of protection provided by PPE is material-hazard specific. That is, protective equipment materials will protect well against some hazardous substances and poorly, or not at all, against others.

Other factors in this selection process to be considered are matching the PPE to the employee's work requirements and task-specific conditions. The durability of PPE materials, such as tear strength and seam strength, is considered in relation to the employee's tasks. The effects of PPE in relation to heat stress and task duration are a factor in selecting and using PPE.

The standard personal protective equipment for this project is:

- Multiple layers of long pants, including a thermal layer
- Multiple layers of long-sleeved shirts, including a thermal layer
- Mustang survival suit or comparable waterproof outer jacket and shell layer
- Sunglasses, as needed
- Facial mask to prevent wind burn, if needed.

8.1.1 Maintenance of PPE

All PPE will be inspected when received from the distributor, prior to use, and whenever questions arise as to the proper functioning of the equipment. PPE will be inspected for:

- General cleanliness
- Material degradation
- Proper functioning of adjustable, moving, or mechanical parts.

Protective equipment must be stored properly to prevent damage or malfunction due to exposure to moisture, sunlight, damaging chemicals, extreme temperatures, and impact. Many equipment failures can be directly attributed to improper storage.

All PPE must be cleaned by employees prior to storage, according to the manufacturer’s recommendations. PPE will not be stored in a wet condition. PPE hung up to dry will be located in an area free from contamination.

Improperly functioning equipment must be immediately taken out of service, “red-tagged”, and stored in a secured location to prevent use by uninformed individuals. Maintenance on PPE will be performed only by authorized service representatives for the specific equipment, or by individuals within the company who are trained and authorized to perform the repairs. Records of inspections and repairs will be kept with the Health and Safety records. These records will be reviewed according to the records review schedule to note any recurring problems.

9. Emergency Response

After first taking necessary precautions for personnel safety, the FPM/SSHO will assess the situation, If it is serious, the affected personnel will be sent or taken to the nearest safe zone or hospital identified at the beginning of this HASP. If the accident is serious enough to endanger life or limb, the HDR FPM/SSHO is to contact emergency personnel at 911 and immediately begin life- saving measures. A response vehicle will be available at all times in the event that immediate transportation to a hospital or emergency care center is necessary for injured person(s).

First aid will be administered to the extent possible while waiting for emergency responders. During the emergency, HDR personnel will take reasonable measures to ensure that no further accidents or injury occurs, including the following:

1 stopping all operations,
2 isolating the area where hazard exists, and
3 keeping a fire extinguisher close at hand for preventive purposes.

Injured persons will be treated at the place they suffered the injury whenever possible. Where it becomes necessary to move a victim, care must be taken not to cause further harm. Victims will be instructed to remain calm until more advanced treatment arrives at their location. While awaiting advanced medical treatment the worker will be monitored and treated for shock symptoms. A first- aid kit located in a company vehicle will be available during all field operations at all times to treat minor cuts, scrapes, and other minor injuries. **Table 14** outlines basic guidelines for employee response to specific emergencies.

If the injury is not life-threatening, the employee will call the Incident Intervention Care Team at:

(888) 449-7787

The Care Team will triage the injury and recommend first aid measures. If needed, the Care Team will locate a clinic and recommend the employee be seen at the local clinic for the injury.

HDR employees with any injury (other than life-threatening) are required to call the medical hotline.

- An occupational nurse or occupational physician provides treatment advice via phone. This could be any of the following:
- If the employee is to be seen by a physician, WorkCare will call ahead to the local clinic or hospital and discuss the case with the treating physician.
- If first aid is the recommended treatment, WorkCare continues to follow up with the employee until they have healed. Continued follow up could be

anywhere from 1-45 days, depending upon the injury.

- WorkCare will notify HDR immediately concerning the injured person. If additional treatment beyond first aid is required, the injured personnel will be transported to the nearest medical center designated in this HASP or a location designated by the WorkCare occupational physician.

- Any injury or illness (whether on or off the job) may require work restrictions after the employee returns to work. If the injury or illness required a visit with a physician, the attending physician must complete an appropriate return to work form and it must be provided to HDR and the onsite SSHO prior to the employee returning to work. The return to work form must be documented in the employee's file on-site.

Emergency	**Response**
Medical Emergency	• Always leave the area immediately if it is unsafe • Call the emergency number for assistance • Secure the area and the mechanism of injury (shut down equipment, secure unstable structures) • Render first aid to extent of your training, experience and equipment • Arrange for transport of victim to the nearest medical facility according to the appropriate medical transport guidelines. If the victim's condition is life-threatening, or has the possibility of change during transport, 911 must be called and transport made by ambulance For contact with chemicals, immediately take victim to eyewash or emergency shower, and have person wash area until outside responders arrive, or a minimum of 15 minutes • For inhalation exposures, remove to fresh air • Identify the type and amount of hazardous material released if possible • Contact emergency responders and give necessary information • Prepare victim for transport to medical facility by decontamination, as necessary • Do not allow any person to eat or smoke until decontamination has taken place • Do not allow any person to re-enter an area affected by hazardous material
Fire	• Notify co-workers, and commence evacuation as necessary • Assure that the emergency number has been called • Attempt to extinguish fire **if**: • The fire can be put out with one extinguisher, and • You can fight the fire with your back to an escape route or exit, and • The correct extinguisher is available, and • You possess the necessary training.
Severe Storm	• Secure your area • Move to a safe location • Tune radio to weather station for local conditions • Be prepared to evacuate

10. Fuel or Hazardous Material Spills

Upon a release of a fuel or hazardous material, personnel should take precautions for personal safety, and if possible contain the spill with onsite equipment, to the extent that the responder's training capability allows. If necessary, the SSHO will evacuate all non- response personnel and visitors to the refuge area. Fuels or hazardous materials must be properly containerized, labeled, and handled. Clean-up materials will be disposed of at an approved disposal facility. The HDR PM will notify the client if the spill is greater than the reportable quantity.

11. Communication/Remote Site Safety

The following actions will be taken by all survey staff while the vessel is away from shore:

- Inform the shore based observer by phone that you are departing and your vessel's planned activities for the day – which boat you will be on and which area you will be monitoring.
- Ensure VHF radios are available and in working order.
- Notify the shore based observer by phone once the vessel has returned to shore.
- If the shore based observer follower does not hear from you within thirty minutes of the agreed upon return to shore time, shore based observer will attempt to contact the vessel via VHF radio. If unable to make contact, the remaining vessels will be dispatched to search for the vessel in the pre-determined area of operation. If the search for the vessel is unsuccessful, the shore based observer shall notify the local Coast Guard (see contacts page) and request that they contact the vessel on VHF channel 16 to check on their safety and status before beginning an all-out search for the missing vessel. At this point, the shore based observer should notify the PjM and keep them informed as to the status of the missing vessel.

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12. Prevention of Alcohol and Drug Abuse

Plan for prevention of alcohol and drug abuse (Defense Federal Acquisition Regulation Supplement (DFARS) Subpart 252.223-7004)

HDR believes that alcohol or drug abuse is an illness requiring medical treatment. If you feel you may have an alcohol or drug-related problem, we encourage you to seek advice and help from your private physician or an agency with special licensing to provide treatment for chemical dependencies. Information related to substance abuse and treatment is available through the Human Resources Department.

Individuals, who use, possess, dispense, or distribute drugs at any HDR workplace may be subject to disciplinary action, up to and including discharge. The inappropriate use of prescription drugs is also prohibited. "Workplace" includes, but is not limited to, HDR offices, the physical work site, training sessions, business travel, conferences, work related social gatherings, etc. Any drugs confiscated will be turned over to law enforcement officials.

Individuals working under client contracts specifically calling for drug screening will, as a condition of working on those projects, be subject to baseline, periodic and perhaps random drug testing. HDR reserves the right to require a drug test as part of an accident investigation.

All individuals employed at HDR are required to abide by the terms of this policy statement. *Any employee who violates this prohibition shall be subject to disciplinary action. Such disciplinary action shall include any number of the following:*

- Discharge from his or her duties under the Federal contract
- Requiring participation in a substance abuse assistance or rehabilitation program
- Placement on "probation" of employment with HDR
- Termination of employment with HDR
- Any other action HDR deems necessary.

As a condition of employment, all employees must abide by the terms of the above statement and must notify the Human Resources Office of HDR of any criminal drug statue conviction arising from conduct in this workplace no later than five days after such conviction.

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13. Training and Records Retention

Prior to initiating site activities, the HDR SSHO will conduct a safety and health "Kick-off" or "Tail-gate" meeting. At this time, pertinent HDR procedures and this HASP will be discussed in detail with special attention being given to site physical hazards, PPE, emergency procedures, etc. Upon completion of this meeting and briefing, all routine field personnel in all areas, including subcontractors, will be required to read and sign the acceptance sheet of this HASP. Applicable field forms/documents can be found in Attachment A.

The HDR PjM and SSHO will maintain on site a copy of the certifications certifying that all HDR personnel have satisfied the minimum training requirements. Supporting documentation and certificates will remain on file with the HDR FPM/SSHO. Field work will not be allowed to take place in the absence of adequate documentation.

Additional site-specific training covering new site hazards, procedures, and contents left out of the approved HASP will be modified and added by the HDR HSM/PjM/SSHO for all on-site employees, prior to the commencement of any work not outline in this HASP, and also for visitors new to the project. The HDR SSHO will be responsible for maintaining a list on-site of training records and expiration dates of applicable training for all project personnel. The following will be completed by the onsite HDR SSHO before project starts:

- HSM Boating and Water Safety, to be discussed onsite by the SSHO
- A complete review of this HASP.
- Review of staffs safety training

A pre-job safety meeting will be held before the vessel departs on its initial survey on the first day of the fieldwork to review:

- Use of PFD
- A review of vessel safety features
- Site specific construction danger areas and protocols associated with working in or transiting through those areas.

An HDR Float Plan (see **Appendix A**) will be filed with the Monitoring Coordinator/ SSHO or a designated Point of Contact for each day's operations, and an Inspection Check List For Chartering Class III-IV (see **Appendix B**) shall be completed and submitted by HDR's Vessel Safety Ops Manager Michael Richlen to the PjM at the beginning of the project.

Records of all training will be maintained in the project files and in the HDR Connects system.

14. Accidents, Reports, and Recordkeeping

14.1 When to Report an Accident

If an accident occurs at any project location where an HDR employee is present (office, work site, hotel or vessel);

The first obligation of co-workers is to assist the victim and obtain medical assistance.

If the victim is an HDR employee, following the release of the victim to the medical authorities, the HDR employee(s) knowledgeable about the accident (this may be the injured employee, if able to do so) must notify the following HDR contacts immediately:

If a non-life threatening injury occurs at any project location where an HDR employee is present immediately call: INCIDENT INTERVENTION @ 1 (888) 449-7787

14.2 Incident Intervention

In the event of an accident or incident the HDR PM will be notified immediately. It will be the responsibility of the HDR PM/SSHO to investigate any accident and complete the HDR Accident form (see Attachment A), as appropriate. The HDR PM/SSHO will assist in these duties as appropriate.

All accidents, no matter how big or small and including near misses are to be reported to the HDR HSM within 24 hours.

The reporting procedure will be as follows:

- Following an injury accident involving any employee or subcontractor at the jobsite, the HDR PM will be notified immediately.
- The HDR FPM/SSHO will then complete an HDR Accident and Incident Report Form (Attachment A). The form will be forwarded to the client within 7 days of the incident. The form will also be provided to HDR Project HSM.

14.3 Accident and Incident Report Form

A current Accident and Incident Report Form and Accident Reporting Instructions, can be accessed at http://hdronline/ec/healthandsafety/Pages/AccidentNearMissReporting.aspx This form also includes the "Return to Work Form".

If you are not able to complete the information online, you may access the form in the Appendix. The form should be completed and submitted as quickly as possible **and** e-mailed to:

Daniel Sciarro, HDR HSM
daniel.sciarro@hdrinc.com

14.4 Accident Investigation

Following notification that an accident or injury has occurred, The HSM will initiate a formal accident investigation. Those onsite, including witnesses will be interviewed and may be asked to assist in the investigation. A formal accident report will be provided to the PM upon completion of the investigation.

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A

Health and Safety Forms

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DAILY SAFETY MEETING

Date:______________________________ Time: ______________________________

SUMMARY OF WORK CONDUCTED AND PLANNED:

SPECIFIC HEALTH AND SAFETY ISSUES DISCUSSED:

ATTENDEES:

Name (print)	Signature

Name (print)	Signature

MEETING CONDUCTED BY:

______________________________ ______________________________

Name (printed) **Signature**

______________________________ ______________________________

Name (printed) **Signature**

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Employee Self-Audit-#7 Part 1

(Field Visit Checklist)

Project Manager, please fill out this form during project start-up and provide a copy to each employee on the H&S Field Staff (page 2). Rerum original pages 1&2 to your section's Admin for filing.

Project Manager's Name & Office ——————————————————— ____________________

Project Name & Number ——————————————————————— ____________________

GENERAL- *before field visit*

O Review the HDR Project Safety Forrn!Guide for this project (PM will provide copy).
O Know what Personal Protective Equipment (PPE) is required and acquire them. (H&S Pro #21) (Hard Hats, Safety Glasses, Traffic Vests, Steel Toe Boots, etc.)
O Acquire any special equipment if necessary. (Respiratory Protection (H&S Pro #9) and/or Air Monitoring (H&S Pro #25))
O Check to see if a first aid kit is in the vehicle, if not, check one out from the front desk.
O Check the location of the nearest medical facility from the project location.
O Will work include overnight travel? (HDR Safety Memo: Travel Safety Guidelines and someone receives copy of itinerary)

MISCELLANEOUS- *during or afterfield visit*

- All accidents require the completion of an AccidenUlncident Report. (See your OSC)
- Complete a Potential Unsafe Conditions Report for all potentially (serious) unsafe conditions. (See your OSC)

DOES YOUR PROJECT ASSIGNMENT INCLUDE THE FOLLOWING?

PROJECT SPECIFIC TASKS	YES	NO	Not sure? Resear ch
Electrical -*I.ockout/Tagout* (H&S Pro #4 & #7)	D	D	D
Demolition (H&S Pro #22)	D	D	D
Drill Rigs (H&S Pro #37)	D	D	D
Excavation (H&S Pro #5)	D	D	D
Work in Elevated Areas (H&S Pro #12)	D	D	D
Noise (Hearing Conservation) (H&S Pro #26)	D	D	D
Permit-Required Confined Spaces (H&S Pro #1)	D	D	D
Portable Ladders (H&S Pro #2)	D	D	D
Work at a Remote Site (H&S Pro #38)	D	D	D
Work on or around a Drill Rig (H&S Pro #37)	D	D	D
Work on Aerial Lifts (H&S Pro #36)	D	D	D
Bridge Inspection (H&S Pro #15)	D	D	D
Work on or around a Railroad (H&S Pro #14)	D	D	D
Work in or around Traffic (H&S Pro #17)	D	D	D
OTHER??	D	D	D

COULD EMPLOYEES BE EXPOSED TO THE FOLLOWING ON YOUR PROJECT?

ENVIRONMENTAL HAZARDS	YES	NO	Not sure? Research
Biological Hazards (H&S Pro #34) (snakes, spiders, mites, insects, noxious plants, bacteria, fungi, etc)	D	D	D
Cold Temperab.lres (H&S Pro #29)	D	D	D
High Temperab.lres/Humidity (H&S Pro #28)	D	D	D
CHEMICAL HAZARDS			
Asbestos (H&S Pro #10)	D	D	D
Bloodbome Pathogens (H&S Pro #8)	D	D	D
Hazardous Waste (H&S Pro #20)	D	D	D
Lead/Lead-Based Paint (H&S Pro #11)	D	D	D
OTHER??	D	D	D

Any questions concerning Health & Safety on your project, please feel free to contact:

- Office Safety Coordinators (OSC): Kevin Ashby at 602.522.7726 or Kurt Watzek at 602.522.4327
- Regional Health & Safety Coordinator: Brad Kruger at 402.399.1267

Employee Self-Audit-#7 Part 1

(Field Visit Employee Lit't)

Project Manager ,please provide each employee a copy of the completed self-audit on page 1 of this document and a completed copy of the Project Safety Form/Guide. Return original pages 1&2 to your section's Admin for filing.

Project Manager's Name & Number ______________ ____________

Project Name & Number __________________ ____________

Employees expected to complete field work on project:

	Name	Home Office **if** Different from this one
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		

All listed staff were provided a completed copy of page 1of this document (Field Visit Checklist) and a completed copy of the Project Safety Form!Guide.

Project Manager Signature Date

HDR FLOAT PLAN

Date:___/___/___ Submitted By: ______________________

Vessel Name: __________________ Engine type/manufacturer: __________________

Fuel capacity (hours): ____

Vessel Description:

Hull Material: ________________________________ Color: ____________________

Manufacturer ____

Registration #: __________________________ Length: _________________________

Width: ________________________________ Draft: _________________________

Vessel Operator:

Name/Phone : __________________________ Experience Level: _______________

Health ____

Tow Vehicle:

Make ________________ Model ______________________ Color ____________

Plate # ________________ Location Parked: ___________________________________

Itinerary:

Depart From:	Time:	Arrive at destination:	Time:	Arrival:

Destination/route:*	Purpose for trip:*	Weather condition by shore:	How Far out are you going?

Upon Return, vessel operator will check in with:

Float Plan Follower (via phone call or text message)

***Persons Aboard*:**

Name	Age	Swim	Medical Conditions	Emergency Contact #

Equipment Checklist:

# PFDs:		**Medical Kit:**		**Flashlight:**		**Emergency contact List:**	
# Flares:		**Fire Extinguisher:**		**Anchor:**		**Paddles or oars:**	

Cell Phone # ______________________
Proper scale charts corrected, reviewed & aboard? _______
Radio Type: VHF/CB/other

*Attach complete description of work to be accomplished waypoints w/ estimated times of arrival and departure and a coms. Schedule and contact w/ shore based personnel. Refer to HDR Small Boat Operations Manual for Coms. Procedures.

INCIDENT REPORT

Fill this form out hardcopy only if you do not have access to HDR's online reporting system.

1 –

Employee Name

Location

(Select General Location of Incident)

- Active Mine Site
- Client Office
- Field or Construction Site
- HDR Office
- Parking Lot or Roadway
- Other ______

Circle one of the choices on the right and complete applicable questions

MINE

Enter MSHA Mine ID Number *(If Applicable)*

CLIENT OFFICE

Enter Name of Client *(If Applicable)*

FIELD/CONST SITE

Enter Name of Project *(If Applicable)*

Enter Project Number

Enter Name of Project Manager

Enter Name of Client *(If Applicable)*

OTHER

Enter Location details

ro;; ;

Indicate state or province where incident occurred

Date & Time

Date & Time (include A.M. or P.M.)

!:J!m!e *Office*

Home office of employee involved in incident

Operating Company

Circle One

- Architecture
- Canada
- CCC
- Constructors
- Corporate
- Engineering
- EOC
- HydroPower (DTA)
- United Kinl!!dom

Ine dent Type

Circle One

- YES, illness or impairment occurred
  - Complete *Attachments 1 & 2*
- NO injury, illness or impairment, but potential for such existed
  - Complete *Attachment 2*

INCIDENT REPORT

Attachment 1	
Witnesses *(HDR employees)*	
Witnesses *(non-HDR employees)*	
Did the incident occur within working hours? *(Circle One)*	YES NO (Occurred during break; before or after shift)
Work Impact *(Circle One)*	No Missed Time or Restricted Duties One or More Full Work Days Missed One or More Partial Work Days Missed Restricted Duties
If one or more full/partial work days are missed, or you have restricted duties, please specify the dates (do not include the day of the incident, but <u>do</u> count holidays and weekends)	Dates Missed ______ Restricted Dates ______
Medical Treatment needed *(Circle One)*	No Medical Treatment Needed *(Go to Attachment 2)* First Aid Given at Work Site *(Go to Attachment 2)* Medical Treatment Away From Work Site *£Go to Next guestionl*
Medical Treatment Away From Work Site:	Provider Name: Facility Name: Facility Address:
Treatment Type (Circle all that Apply)	Emergency Room Visit Overnight Hospitalization Physical Therapy MRI/X-Ray/CT Scan Stitches/Glue Hard Splint/Brace Soft Splint/Brace Other
Splint or Brace Details *(Circle all that Apply)*	Ankle Knee Wrist Other
Prognosis *(Describe Doctor's orders)*	
Medical Follow-Up Dates *(If Any)*	
Medication *(Circle One)*	No Medication Needed Over the Counter Medication (OTC) at OTC Strength Prescription for OTC Medicine at Prescription Strength Prescription for Prescription Strength Prescription Written But Not Filled
Have you filed a Workers' Compensation Claim with your HR Representative? *(Circle One)*	YES NO

HDR

INCIDENT REPORT

Attachment 2

Describe Incident

Enter detailed description of incident and where it happened *If more room is needed, attach additional documents to this Report* ***when returning***	

Hand Laceration

Was incident related to hand laceration?	**YES** **NO**
If **YES,** were Cut-Resistant Gloves Worn?	**YES** **NO**

Causative Factors

What circumstances contributed to the incident? *If more room is needed, attach additional documents to this Report* ***when returning***	

Suggestions for Prevention

What changes may prevent the circumstances from reoccurring? *If more room is needed, attach additional documents to this Report when returning*	

When you are finished with this report, enter it into HDR's online reporting system or give it to our local OSC for entry.

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PROJECT KICK-OFF HEALTH AND SAFETY MEETING DOCUMENTATION FORM

Project Name/Number: ____________________________________ Task:____________________________

______________________ Date: ____ Work Area/location: ______________________

REVIEW TOPICS (CHECK OFF LIST AS COMPLETED):

- D Review Job Hazard Analysis (JHA) forms for the day's work
- D Discuss relevant safety protocols
- D Discuss emergency procedures and equipment (satellite phone, whistles, horns, etc.)
- D Identify/bring specific safety gear
- D Identify necessary medications and individual crew member's medical situations/precautions (if staff is willing to share with crew)
- D Is everyone comfortable with daily plan of action, safety, and any other issues/concerns?

TEAM MEMBER SIGNATURES:

By signing below I certify that I have read and understand the contents of the project-specific health and safety plan.

____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________
____________________	____________________	____________________

FIELD CREW LEADER'S SIGNATURE:

Signature:_________________________________ Date: ________________

NOTES/COMMENTS:

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WORKER/VISITOR REVIEW AND ACKNOWLEDGEMENT OF THE SITE HEALTH AND SAFETY PLAN

Project Name: ______________________________

Job No.: ______________________________

Project Location: ______________________________

Client/Contract No.: ______________________________

I have been briefed on and understand the requirements of the Site Health and Safety Plan for the above site. By signing below, I acknowledge and agree to follow the Site Health and Safety Plan for this project.

Date	Name (Printed)	Company	Signature

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B

Inspection Checklist for Chartering Class III SRV Vessels

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INSPECTION CHECK LIST
FOR CHARTERING CLASS III-SRV VESSELS

Vessel Name: ______________________________

Owner: ______________________________

Address and Contact Information: ______________________________

Operator: ______________________________

Address and Contact Information: ______________________________

Licenses held: ______________________________

Vessel Type and General Description: ______________________________

Length Overall: ______________________________

Displacement: ______________________________

Tonnage [GT/GRT/NT] : ______________________________

Draft: ______________________________

Radio Call Sign: ______________________________

Number of Passengers/Scientists that can be carried: ______________________________

Dates of planned charter: ______________________________

Area of operations: ______________________________

Type of operations or activities planned: ______________________________

Number in planned science party: ______________________________

Bridge and Navigation Equipment:

Communications Equipment:

Documentation:

Life Saving Equipment:

Exterior Decks and Equipment:

Fire Fighting Equipment:

Engineering:

Structural:

Miscellaneous:

C

Vessel Description

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Willard Marine *Whale Research.* The Willard Marine Sea Force 730 LE is a 23 foot hybrid foam/air collar vessel with twin outboard Mercury 200HP engines. The research vessel has an open deck and covered console as well as an onboard navigation system, depth sounder, EPIRB, and additional USCG approve safety equipment.

R/V McMaster Sportcraft –URI owned, length 30’ R/V McMaster is a 30' Sportcraft owned by URI It has an A-frame and a windlass that can be used for various sampling and deployment and retrieval of instruments. URI always uses ~600-700 lbs as our safe working weight for the A-frame. It was repowered with an inboard Mercruiser engine 5 years ago and has all required electronic equipment

Hula Dog. The Hula Dog is a 27' long center console vessel manufactured by "Shamrock". The vessel is equipped with start of the art radar, global positioning, sonar, and communications systems.

Shanna Rose. Shanna Rose is a 42' with a 14.6' wide beam equipped with Lugger/Northern Light Turbo-Charged engine. It is equipped with state of the art electronics, VHF radios, EPIRB, and safety equipment for Coastal Navigation

D

Activity Hazard Analysis

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ACTIVITY HAZARD ANALYSIS

ACTIVITY HAZARD ANALYSIS Vessel based monitoring	Name of Task: Real-Time Opportunity for Development of Environmental Observations (RODEO)	AHA No.: 01	Date: July 29, 2015

Job Steps Areas of Operation ***Field Exploration Onshore***	Potential Hazards	Health and Safety Controls
• Drive to the marina • Crew to load gear and board small vessel at dock • Transit from marina WTG construction site offshore • Observe environmental conditions and record construction activities • Perform acoustic measurements • deteriorate, crew will transit boat back to marina	1. Vehicle Safety 2. Trips/Falls 3. Electrical Equipment Hazards 4. Over-water work 5. Pinching and Crushing 6. Rigging 7. Hypothermia 8. Heat Disorders 9. High Winds and Rain and/or Storms 10. Grounding (Bottoming out)	1. Seat belts will be worn at all times when driving and rules of the road will be obeyed while engaged in company business. 2. Caution will be exercised to prevent slips on rain-slick surfaces, stepping on sharp objects, etc. Work will not be performed on elevated platforms without fall protection PPE. Check soles of boots and shoes for wear. Footwear should have soles that provide good traction. 3. Personnel should assume all electrical equipment is live with current and caution should be taken to avoid any contact with electrical equipment. Electrical dangers can include short-circuit arcing faults and shock or electrocution. 4. All personnel on a boat, barge, and on the docks will be required to wear a Personal Flotation Device (Type V minimum). 5. Care will be taken by field employees when working with boats coming in and out of wharves to prevent pinching or crushing of body parts during operation. 6. Personnel will dress appropriately and regulate body temperature to avoid cold stress. 7. Heat Disorder precautions are discussed above. Personnel will dress appropriately. 8. In the case of extreme weather, vessel operations may cease or be delayed. 9. Follow protocols in the HASP

HDR

Equipment to be Used	Training Requirements	PPE Requirements
• GPS and navigator • Depth sounder / fish finder • Marine and VHF radio • Satellite telephone • EPIRB • Camera equipment with laser mount • Laser range finders • iPad for focal follows • Pool net to collect samples from water • Life jackets • Personal gear – hats, gloves, sunglasses, etc. • Water and food for the day	• HDR General Safety Awareness • HDR Safe Driving • HDR Disaster Communication • HDR Heat Stress • HDR Cold Stress	• All required PPE is listed in the HASP

ACTIVITY HAZARD ANALYSIS **Onshore based monitoring**	**Name of Task:** **Real-Time Opportunity for Development of Environmental Observations (RODEO)**	**AHA No.:** 01	**Date:** **July 29, 2015**

Job Steps **Areas of Operation** ***Field Exploration Onshore***	**Potential Hazards**	**Health and Safety Controls**
• Drive to the observation site • Crew to unload gear • Observe environmental conditions and record construction activities • Perform acoustic measurements • If weather deteriorates, crew will transit boat back to marina	1. Vehicle Safety 2. Trips/Falls 3. Electrical Equipment Hazards 4. Pinching and Crushing 5. Hypothermia 6. Heat Disorders 7. High Winds and Rain and/or Storms	8. Seat belts will be worn at all times when driving and rules of the road will be obeyed while engaged in company business. 9. Caution will be exercised to prevent slips on rain-slick surfaces, stepping on sharp objects, etc. Work will not be performed on elevated platforms without fall protection PPE. Check soles of boots and shoes for wear. Footwear should have soles that provide good traction. 10. Personnel will dress appropriately and regulate body temperature to avoid cold stress. 11. Heat Disorder precautions are discussed above. Personnel will dress appropriately. 12. In the case of extreme weather, crew operations may cease or be delayed. 13. Follow protocols in the HASP
Equipment to be Used	**Training Requirements**	**PPE Requirements**
• GPS • Camera equipment with laser mount • Personal gear – hats, gloves, sunglasses, etc. • Water and food for the day	• HDR General Safety Awareness • HDR Safe Driving • HDR Disaster Communication • HDR Heat Stress • HDR Cold Stress	• All required PPE is listed in the HASP

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Appendix B: Visual Monitoring Data

During visual monitoring over 1,400 photographs were taken from the onshore and offshore monitoring stations. These photographs illustrate the observations made during the operational phase. They were provided to BOEM on a DVD and are available upon request. **Tables B-1** and **B-2** provide a key to the photo logs. **Table B-3** summarizes meteorological data recorded during the monitoring.

Table B-1. Southeast Lighthouse Photo Log Key and Field Observation Summary

Date / Time	Location	Notes	Photo Frame #
06/20/2017 08:43:23	SE Lighthouse	Fog. WTG or lights not visible.	4217-4218
06/20/2017 08:43:57	SE Lighthouse	Flag at lighthouse to give perspective on fog.	4219
06/20/2017 11:36:28	SE Lighthouse	Fog, WTG not visible.	4220-4221
06/20/2017 11:37:21	SE Lighthouse	Lighthouse in dense fog.	4222
06/20/2017 15:20:49	SE Lighthouse	Sun is out, still a little hazy offshore. WTG 5 100mm.	4223
06/20/2017 15:22:49	SE Lighthouse	WTG 5 400mm	4224
06/20/2017 15:23:18	SE Lighthouse	WTG 4 100mm	4225
06/20/2017 15:24:07	SE Lighthouse	WTG 4 400mm	4226
06/20/2017 15:24:43	SE Lighthouse	WTG 3 100mm	4227
06/20/2017 15:25:08	SE Lighthouse	WTG 3 400mm	4228
06/20/2017 15:25:39	SE Lighthouse	WTG 2 100mm	4229
06/20/2017 15:25:57	SE Lighthouse	WTG 2 400mm	4230
06/20/2017 15:26:25	SE Lighthouse	WTG1 100mm	4231
06/20/2017 15:26:50	SE Lighthouse	WTG1 400mm	4232
06/20/2017 21:53:44	SE Lighthouse	Night observation. Lights flash on and off. Red light at top of nacelle and yellow light on deck. WTG5	4234
06/20/2017 21:56:57	SE Lighthouse	WTG4	4235
06/20/2017 21:57:30	SE Lighthouse	WTG3	4236
06/20/2017 21:57:59	SE Lighthouse	WTG4	4237
06/20/2017 21:58:13	SE Lighthouse	WTG5	4238
06/21/2017 08:42:05	SE Lighthouse	Hazy around WTG, No fog at light house. WTG5 100mm	4239
06/21/2017 08:43:42	SE Lighthouse	WTG 5 400mm	4240
06/21/2017 08:44:12	SE Lighthouse	WTG4 100mm	4241
06/21/2017 08:44:34	SE Lighthouse	WTG4 400mm	4242
06/21/2017 08:44:59	SE Lighthouse	WTG 3 100mm	4243
06/21/2017 08:45:24	SE Lighthouse	WTG 3 400mm	4244
06/21/2017 08:45:45	SE Lighthouse	WTG 2 100mm	4245
06/21/2017 08:46:11	SE Lighthouse	WTG 2 400mm	4246
06/21/2017 08:46:32	SE Lighthouse	WTG 1 100mm	4247
06/21/2017 08:46:54	SE Lighthouse	WTG 1 400mm	4248
06/21/2017 08:47:30	SE Lighthouse		
06/21/2017 11:28:41	SE Lighthouse	Very hazy, unable to see WTG 1 and 2. WTG5 100mm.	4250

Date / Time	Location	Notes	Photo Frame #
06/21/2017 11:29:45	SE Lighthouse	WTG 4 100mm	4251
06/21/2017 11:30:19	SE Lighthouse	WTG 3 100mm	4252
06/21/2017 11:33:01		Camera will not focus due to haze on WTG 1-2.	
06/21/2017 11:33:16	SE Lighthouse	WTG 5 400mm	4253
06/21/2017 11:33:51	SE Lighthouse	WTG 4 400mm	4254
06/21/2017 17:21:44	SE Lighthouse	Walking up to lighthouse, very foggy.	4256
06/21/2017 17:22:13	SE Lighthouse	WTG 5, had to use 200mm before camera could capture	4257
06/21/2017 17:22:52	SE Lighthouse	WTG 4 200mm	4258
06/21/2017 17:23:10	SE Lighthouse	WTG 3 200mm	4259
06/21/2017 17:23:32	SE Lighthouse	WTG 2 200mm	4260
06/21/2017 17:24:19	SE Lighthouse	WTG 1 200mm	4260
06/21/2017 17:24:49	SE Lighthouse	WTG 1 400mm	4261
06/21/2017 17:25:08	SE Lighthouse	WTG 2 400mm	4262
06/21/2017 17:25:30	SE Lighthouse	WTG 3 400mm	4263
06/21/2017 17:25:43	SE Lighthouse	WTG 4 400mm	4264
06/21/2017 17:26:00	SE Lighthouse	WTG 5 400mm	4265
06/21/2017 17:26:47			
06/21/2017 17:37:22	SE Lighthouse	Video WTG 1 , fog	4267
06/21/2017 17:40:27	SE Lighthouse	Video WTG 5 , fog	4268
06/21/2017 17:46:59	SE Lighthouse	WTG 5 400mm fog improving	4270
06/21/2017 17:47:50	SE Lighthouse	WTG 4 400mm	4271
06/21/2017 17:48:29	SE Lighthouse	WTG 3 400mm	4272
06/21/2017 17:49:08	SE Lighthouse	WTG 2 crew tender, 400	4273
06/21/2017 17:50:01	SE Lighthouse	WTG 1	4272
06/21/2017 21:20:54	SE Lighthouse	Night observation. Haze from afternoon cleared off. WTG 1 100mm	4275
06/21/2017 21:21:32	SE Lighthouse	WTG 2 100mm	4276
06/21/2017 21:21:53	SE Lighthouse	WTG 3 100mm	4277
06/21/2017 21:22:33	SE Lighthouse	WTG 4	4278-4279
06/21/2017 21:22:57	SE Lighthouse	WTG 5	4280-4282
06/21/2017 21:28:13		WTG 4 Manual Focus 300mm	4284
06/21/2017 21:30:25	SE Lighthouse	WTG 3 notice green and red light are both visible must have to do with blade orientation.	4285
06/22/2017 09:07:39	SE Lighthouse	First clear day of survey, waited till later in morning hoping haze would burn off.	
06/22/2017 09:09:35	SE Lighthouse	WTG1 100mm	4286
06/22/2017 09:09:51	SE Lighthouse	WTG 2 100mm	4287
06/22/2017 09:10:13	SE Lighthouse	WTG 3 100mm	4288
06/22/2017 09:10:28	SE Lighthouse	WTG 4 100mm	4289
06/22/2017 09:10:45	SE Lighthouse	WTG 5 100mm	4290
06/22/2017 09:15:48	SE Lighthouse	Video WTG 5	4291
06/22/2017 09:16:03	SE Lighthouse	Video WTG 5	4292

Date / Time	Location	Notes	Photo Frame #
06/22/2017 09:20:09	SE Lighthouse	WTG 1 400mm	4293
06/22/2017 09:20:31	SE Lighthouse	WTG 2 400mm	4294
06/22/2017 09:20:42	SE Lighthouse	WTG 3 400mm	4295
06/22/2017 09:20:58	SE Lighthouse	WTG 4 400mm	4296
06/22/2017 09:21:18	SE Lighthouse	WTG 400mm	4297
06/22/2017 09:33:33	SE Lighthouse	Different perspective from lighthouse, provides scale.	4298-4303
06/22/2017 09:41:35		Spring St, front of Spring House Hotel, blades visible.	4304-4305
06/22/2017 09:54:09		Entrance to old harbor, south side by Ballards. Looking south.	4306-4308
06/22/2017 13:34:48	SE Lighthouse	WTG 1 100mm	4309
06/22/2017 13:35:05	SE Lighthouse	WTG 2 100mm	4310
06/22/2017 13:35:28	SE Lighthouse	WTG 3 100mm	4311
06/22/2017 13:35:40	SE Lighthouse	WTG 4 100mm	4312
06/22/2017 13:35:57	SE Lighthouse	WTG 5 100mm	4313
06/22/2017 13:39:51	SE Lighthouse	WTG 5 400mm	4314
06/22/2017 13:40:25	SE Lighthouse	WTG 4 400mm red light visible in day	4315-4317
06/22/2017 13:41:21	SE Lighthouse	WTG 3 400mm	4318
06/22/2017 13:42:28	SE Lighthouse	WTG 2 400mm	4319-4320
06/22/2017 13:50:16	SE Lighthouse	WTG 1 400	4321
06/22/2017 13:53:25	SE Lighthouse	Video WTG2	4322
06/22/2017 18:15:04	SE Lighthouse	WTG 1 100mm	4323
06/22/2017 18:15:35	SE Lighthouse	WTG 2 100mm	4324
06/22/2017 18:15:51	SE Lighthouse	WTG 3 100mm	4325
06/22/2017 18:16:11	SE Lighthouse	WTG 4 100mm	4326
06/22/2017 18:16:24	SE Lighthouse	WTG 5 100mm	4327
06/22/2017 18:22:42	SE Lighthouse	WTG 5 400mm	4328
06/22/2017 18:22:57	SE Lighthouse	WTG 4 400mm	4229
06/22/2017 18:23:21	SE Lighthouse	WTG 3 400mm	4230
06/22/2017 18:23:40	SE Lighthouse	WTG 2 400mm	4231
06/22/2017 18:24:05	SE Lighthouse	WTG 1 400mm	4232
06/22/2017 18:24:23	SE Lighthouse	WTG 1 video	4233
06/22/2017 21:14:38	SE Lighthouse	WTG 1 100mm	4334
06/22/2017 21:14:58	SE Lighthouse	WTG 1 400mm	4335
06/22/2017 21:15:17	SE Lighthouse	WTG 2 100mm	4336
06/22/2017 21:15:44	SE Lighthouse	WTG 2 400mm	4337
06/22/2017 21:16:27	SE Lighthouse	WTG 3 100mm	4338
06/22/2017 21:16:54	SE Lighthouse	WTG 3 400mm	4339
06/22/2017 21:17:24	SE Lighthouse	WTG 4 100mm	4340
06/22/2017 21:18:21	SE Lighthouse	WTG 4 400mm	4341
06/22/2017 21:18:54	SE Lighthouse	WTG 5 100mm	4342
06/22/2017 21:19:29	SE Lighthouse	WTG 5 400mm	4343
06/23/2017 09:08:33	SE Lighthouse	Sunny on land , haze around WTGs.	

Date / Time	Location	Notes	Photo Frame #
06/23/2017 09:09:03	SE Lighthouse	WTG 1, manual focus.	4344
06/23/2017 09:09:26	SE Lighthouse	WTG 2, MF	4345
06/23/2017 09:09:46	SE Lighthouse	WTG 3 MF	4346
06/23/2017 09:10:01	SE Lighthouse	WTG 4 MF	4347
06/23/2017 09:10:31	SE Lighthouse	WTG 5 MF	4348
06/23/2017 09:10:50	SE Lighthouse	WTGs barely visible due to haze, camera had difficulty focusing	
06/23/2017 12:17:41	SE Lighthouse	WTG 1 100 mm barely visible, haze	4349
06/23/2017 12:18:08	SE Lighthouse	WTG 2 100mm	4350
06/23/2017 12:18:23	SE Lighthouse	WTG 3 100mm	4351
06/23/2017 12:18:37	SE Lighthouse	WTG 4	4352
06/23/2017 12:19:23	SE Lighthouse	WTG 5	4353
06/23/2017 18:09:51	SE Lighthouse	Cloudy with haze around turbines	
06/23/2017 18:10:19	SE Lighthouse	WTG 1 100mm	4355
06/23/2017 18:10:34	SE Lighthouse	WTG 1 400mm	4356
06/23/2017 18:10:55	SE Lighthouse	WTG 2 100mm	4357
06/23/2017 18:11:16	SE Lighthouse	WTG 2 400mm	4358
06/23/2017 18:11:34	SE Lighthouse	WTG 3 100mm	4359
06/23/2017 18:11:49	SE Lighthouse	WTG 3 400mm	4360
06/23/2017 18:12:12	SE Lighthouse	WTG 4 100mm	4361
06/23/2017 18:12:27	SE Lighthouse	WTG 4 400mm	4362
06/23/2017 18:12:45	SE Lighthouse	WTG 5 100mm	4363
06/23/2017 18:13:02	SE Lighthouse	WTG 5 400mm	4364
06/23/2017 18:13:33	SE Lighthouse	WTG 4 video	4365
06/23/2017 22:28:52	SE Lighthouse	Attempted to take night pictures, too windy and foggy.	

Table B-2. Point Judith and Brenton State Park Photo Log Key and Field Observations Summary

Date / Time	Location	Notes	Photo Frame #
06/19/2017 11:25:15	Pt. Judith	Foggy. Visibility no more than 100 yds. (41 21.730N 71 29.155W)	1547-1548
06/19/2017 12:32:28	Brenton Point State Park	Foggy. (41 27.014N 71 21.200W)	1550
06/19/2017 15:55:09	Brenton Point State Park	Fog still heavy. (41 27.014N 71 21.200W)	1551
06/19/2017 17:00:53	Pt. Judith	Fog has started to go away. Visibility up to 1/4 mile. Turbines are not visible. (41 21.730N 71 29.158W)	1552-1554
06/19/2017 20:47:50	Pt. Judith	41 21.730N 71 29.158W	1555-1557
06/19/2017 21:40:40	Brenton Point State Park	Fog still heavy. Cannot see wind farm lights. (41 27.014N 71 21.200W)	1558-1559
06/20/2017 08:32:25	Pt. Judith	Another foggy day. Still cannot see lights from wind farm. (41 21.729N 71 29.159W)	1560-1562
06/20/2017 09:33:09	Brenton Point State Park	Foggy. Visibility limited to 100yds. (41 27.021N 71 21.175W)	1563-1565
06/20/2017 11:55:55	Brenton Point State Park	Not able to see the wind farm	1566-1567
06/20/2017 13:00:10	Pt. Judith	Sun is starting to burn off the fog. Visibility up to 1/2 mile. (41 21.729N 71 29.166W)	1568-1570
06/20/2017 15:10:29	Pt. Judith	Can see Block Island on the horizon with the naked eye. Still cannot see the wind farm	
06/20/2017 15:51:59	Pt. Judith	Still can see Block Island but not the wind farm. (41 21.729N 71 29.166W)	1571-1573
06/20/2017 16:40:36	Brenton Point State Park	Unable to see the Block Island with the naked eye. (41 27.032N 71 21.139W)	1574-1579
06/20/2017 20:46:39	Brenton Point State Park	Cannot see lights on turbines	1580-1582
06/20/2017 21:37:51	Pt. Judith	Lights are visible on the turbines. (41 21.729N 71 29.166W)	1583-1589
06/21/2017 08:30:51	Pt. Judith	Block Island is not visible. Slight haze on the horizon. (41 21.730N 71 29.151W)	1590-1593
06/21/2017 09:33:18	Brenton Point State Park	Block Island is not visible. (41 27.009N 71 21.224W)	1594-1599
06/21/2017 11:55:00	Brenton Point State Park	Still can't see the island. (41 27.009N 71 21.224W)	1600-1604
06/21/2017 12:54:17	Pt. Judith	Can somewhat see the island. Wind farm is still not visible. (41 22.59N 71 30.32W)	1605-1608
06/21/2017 16:22:25	Pt. Judith	Still can't see Block Island or Wind farm due to some fog moving in on the horizon.	1608-1612

Date / Time	Location	Notes	Photo Frame #
06/21/2017 17:17:56	Brenton Point State Park	Fog has moved in. Visibility is 1/2 mile. Cannot see the island (41 27.012N 71 21.215W)	1613-1616
06/21/2017 20:59:06	Brenton Point State Park	Can't see lights on turbines. Lights from ship and buoy are all that can be seen	1617-1619
06/21/2017 21:51:25	Pt. Judith	Lights on turbines can be seen along with lights on the island. (41 21.730N 71 29.151W)	1620-1623
06/22/2017 08:26:26	Pt. Judith	All 5 turbines can be seen with the naked eye. Turbines are in motion. (41 22.59N 71 30.32W)	1624-1628
06/22/2017 09:53:22	Brenton Point State Park	Block Island is visible with naked eye. Turbines can be seen when zooming in with the camera. (41 28.6N 71 18.48W)	1629-1635
06/22/2017 10:10:21	Brenton Point State Park	Video of island and wind farm. Turbines are behind the red buoy, but it is very hard to see them in the video	1636
06/22/2017 12:05:13	Brenton Point State Park	Turbines and island still in view. 1642 is short video.	1636-1642
06/22/2017 13:06:10	Pt. Judith	1646 is short video. Island and turbines can be seen. Turbines are seen moving. (41 22.59N 71 30.32)	1643-1648
06/22/2017 15:46:16	Pt. Judith	Turbines still visible. They are moving.	1649-1653
06/22/2017 16:45:45	Brenton Point State Park	Haze has moved in. Can barely see turbines. Island is no longer visible. (41 28.6N 71 18.48W)	1654-1657
06/22/2017 21:06:49	Brenton Point State Park	Lights on turbines can be seen at night. The sixth red light is a buoy just off of Brenton point.	1658-1662
06/22/2017 21:58:04	Pt. Judith	Lights can be seen on top of the turbines	1663-1667
06/23/2017 08:23:00	Pt. Judith	Fog limiting visibility to about 1 mile. Can't see island or Wind farm. (41 22.59N 71 30.32W)	1668-1672
06/23/2017 09:21:02	Brenton Point State Park	Fog limiting visibility to about 1 mile. Can't see the turbines or island. (41 28.50N 71 18.50W)	1673-1677

Table B-3. Meteorological Data Recorded during Visual Monitoring

Timestamp	General Weather	Wind Direction	Beaufort Sea State	% Cloud Cover	Temperature Fahrenheit	Humidity	Notes	Wind Speed (mph)
06/19/2017 11:29:47	Hazy/Foggy	W	4	100	67	96	Fog limits visibility to less than 100yds. location: Pt Judith	3
06/19/2017 12:32:46	Hazy/Foggy	SSW	4	100	68	98	Visibility still less than 100yds. location: Brenton point	2
06/19/2017 15:55:34	Hazy/Foggy	S	4	100	67	98	fog is still heavy at Brenton point	7
06/19/2017 17:03:56	Hazy/Foggy	W	5	100	67	95	Fog has started to lift. Visibility up to 1/4 miles.	9
06/19/2017 20:45:47	Hazy/Foggy	NNW	4	100	66	99	Fog moved back in. visibility less than 100yds. cannot see lights from wind farm	9
06/19/2017 21:41:16	Hazy/Foggy	S	4	100	67	99	heavy fog at Brenton point prevent lights from being seen	4
06/19/2017 21:41:16	Hazy/Foggy	S	4	100	67	99	heavy fog at Brenton point prevent lights from being seen	4
06/20/2017 08:32:55	Hazy/Foggy	NW	4	100	64	99	Visibility is roughly 100yds.	8
06/20/2017 09:34:01	Hazy/Foggy	WNW	4	100	66	99		7
06/20/2017 11:54:48	Hazy/Foggy	SW	4	100	65	98	Remains very foggy. Sun is try to break through.	4
06/20/2017 13:00:48	Hazy/Foggy	WNW	4	75	70	87	fog is starting to lift a little	9
06/20/2017 15:50:54	Sunny	W	5	50	73	75		12
06/20/2017 16:40:47	Sunny	S	5	40	71	83	fog has lifted	6
06/20/2017 20:42:08	sun down	S	4	25	66	88	cannot see the island or lights on turbines from Brenton point	7
06/20/2017 21:39:11	sun down	WNW	4	25	67	87		8
06/20/2017 21:39:11	sun down	WNW	4	25	67	87		8
06/21/2017 08:32:53	Sunny	NNW	2	25	68	88	Clear calm day. island and wind farm are not visible	6

Timestamp	General Weather	Wind Direction	Beaufort Sea State	% Cloud Cover	Temperature Fahrenheit	Humidity	Notes	Wind Speed (mph)
06/21/2017 09:36:09	Sunny	SW	3	25	72	73	Clear day. a little haze on the horizon here at Brenton point	6
06/21/2017 11:55:48	Sunny	SE	3	25	73	83	no changes in weather	6
06/21/2017 12:57:54	Sunny	NW	3	40	76	69		7
06/21/2017 16:18:35	Sunny	NW	3	10	72	80	Some fog has moved in on the horizon.	7
06/21/2017 17:19:33	Sunny	SSW	3	25	67	93	Fog has moved in off the coast.	6
06/21/2017 20:54:34	Cloudy	S	2	25	64	95	Fog has lifted. can't see island	3
06/21/2017 21:52:37	Cloudy	WNW	2	100	67	89	Even with clouds overhead, there is clear visibility to the island. no haziness at all	6
06/22/2017 08:27:03	Sunny	NE	2	10	74	62	Very clear day. Now haze on the horizon.	2
06/22/2017 09:54:42	Sunny	SSW	2	5	72	69	Very clear at Brenton too. no haze or fog	2
06/22/2017 12:05:40	Sunny	SSW	2	0	72	68		2
06/22/2017 13:07:46	Sunny	WNW	2	5	76	61	No real change in the weather other than the wind picking up.	11
06/22/2017 15:46:53	Sunny	W	3	10	73	68		9
06/22/2017 16:46:47	Sunny	SSE	3	20	71	73	Haze has moved in at Brenton point limiting visibility	6
06/22/2017 21:07:29	Cloudy	S	2	75	66	83		5
06/22/2017 21:58:34	Cloudy	NW	2	100	66	87		5
06/22/2017 21:58:34	Cloudy	NW	2	100	66	87		5
06/23/2017 08:24:42	Cloudy	WNW	1	90	68	90	Fog has moved back in today	6
06/23/2017 09:22:42	Sunny	W	2	25	70	80	Fog has moved in here too.	8

Appendix C: Airborne Noise Monitoring Report

Project title	Monitoring of Airborne Noise at the Block Island Wind Farm during the Operational Phase
Project number	E494
Author(s)	Tim Mason
Company	Subacoustech Environmental Ltd.
Report number	E494R0502
Date of issue	19 May 2019

1 Background and rationale for monitoring location

As part of the monitoring of the environmental observations around the Block Island Wind Farm's (BIWF) construction and operation, a program of airborne noise measurement was undertaken during the turbine operation and power production phase. No construction or other machinery was present on or offshore, and so the noise monitored was entirely that produced by the wind turbine generators (WTGs) during normal operation, plus any natural ambient noise.

Airborne noise monitoring was originally planned to be undertaken at a series of the nearest sensitive receptor (i.e. human habitation) locations, representing a range of distances. During the turbine construction phase, airborne noise was sampled on land at:

- Southeast Light, Mohegan Bluffs, at the south of Block Island (five kilometers from the nearest WTG)
- Balls Point North, northeast Block Island (11 kilometers north of BIWF)
- Near Point Judith Lighthouse, Point Judith, Rhode Island mainland (27 kilometers north of BIWF)

Noise monitoring was undertaken during piling for foundation installation in the construction phase, which was the loudest potential source of noise during any phase of the BIWF's construction or operation. During this time, under favorable winds, the piling noise was clearly audible at the Southeast Light, but only intermittently at Balls Point North. Piling was never audible on the mainland; background noise levels here were relatively high due to constant waves and movement of rocks on the beach, as well as distance being a significant factor. As the noise during turbine operation was expected to be substantially quieter than piling, measurements of noise were only obtained at the Southeast Light. The likelihood of any noise detection at any other location was considered to be extremely low.

2 Monitoring methodology

A Svantek 979 sound level meter (SLM) connected to an external power supply was installed at the top of the Southeast Light lighthouse, with the microphone extending one meter from the side of a lighthouse window, with full view of the ocean to the south. The position of the microphone can be seen from the photographs in Figure 2-1. This location was chosen using a combination of safety of access inside the old lighthouse and security from disturbance by members of the public outside the lighthouse.

The SLM was set to monitor ambient noise levels continuously over a three-month (14 week) period between February 8 and May 28, 2017, including 1/3rd octave band center-frequency data. The SLM was fitted with a mobile data SIM card so all monitoring could be undertaken remotely. Meteorological conditions were recorded hourly from a monitoring station on Block Island.

Figure 2-1. [Left] View of Southeast Light with microphone protruding from the right of the lighthouse, above the roof line of the building behind the lighthouse. [Right] View of microphone from the lighthouse window.

Noise levels were also sampled using a Svantek 979 SLM installed on a survey vessel, the 36' Rooster. These noise measurements were primarily intended to identify the characteristics of the operational noise emissions near to the WTGs to aid identification in the long-term monitoring data from the fixed Block Island station. In the absence of a fixed platform offshore from which to sample the noise, only short-term samples were possible from the survey vessel.

The microphone was situated approximately two meters above sea level with the vessel drifting past the turbine with the wind, with the engines shut down on the vessel. The SLM was calibrated before and after measurements with a field calibrator.

Measurements were taken continuously along the passing transect, with the closest point to the turbine between 50 and 100 m from the turbine tower, and were observed up to 750 m.

3 Results

3.1 Offshore short-term noise

Two sets of measurements were taken in the immediate vicinity of the WTGs from the survey vessel as follows:

- October 19, 2017, 13:00-14:00. Wind NE ~8-9 m/s, dry, blade speed ~11 rpm.
- October 3, 2018. 13:45-14:35. Wind SW ~3-4 m/s, dry, blade speed ~6 rpm.

The wind speed during measurements in 2018 was strong enough to turn the blades at approximately 6 rpm. The wind was not high enough to cause significant wave breaking, although some contribution from background noise caused by waves against the side of the vessel could not be avoided. Initial analysis of the noise measurements proved challenging; although perceptible to a human observer, the noise was very difficult to identify around the background noise using standard analysis of overall (A-weighted) or 1/3 octave band frequency analysis, even at distances less than 200 m from the tower.

The audible noise could be broken down into two components: continuous noise, or hum, from the WTG internal machinery and the regular ‘swish’ from blades as they passed. There also appeared to be an indirect contribution from wind passing around the tower or blades.

High resolution (narrow-band frequency) analysis of measurements on both days provided more information, showing a low-level tonal contribution between 70 and 80 Hz on both sampling days in 2017 and 2018. Another band at 2 kHz was audible and visible in narrowband analysis on October 3, 2018 only.

On October 19, 2017, a noise level from 63 to 67 dB L_{AFeq} was measured during blade swishes at approximately 50 m, drifting downwind and away from the turbine tower (WTG #5 at the BIWF), equivalent to 65 dB $L_{Aeq,1min}$. Longer term sampling was not possible as the vessel was allowed to drift to minimize background noise. Although this was the measurement taken with the minimum of contamination from ‘self-noise’ (primarily wave slap on the vessel, and waves breaking), this figure can only be an indicative guide and it is not recommended to be used in any formal assessment due to the many contributing factors, primarily the variable distance and significant contribution from natural noise sources.

This sample is shown in Figure 3-1. Fluctuating wind noise as it blows around the tower and blade structure causes increases between 3000 and 4000 Hz. Blade passes (swish) can be seen as mid-frequency vertical bars approximately four times every five seconds. Any noise directly generated by the WTG machinery appears to be limited to frequencies below 100 Hz, with most noise produced by the movement of air. This figure is for illustrative use only and has not been annotated.

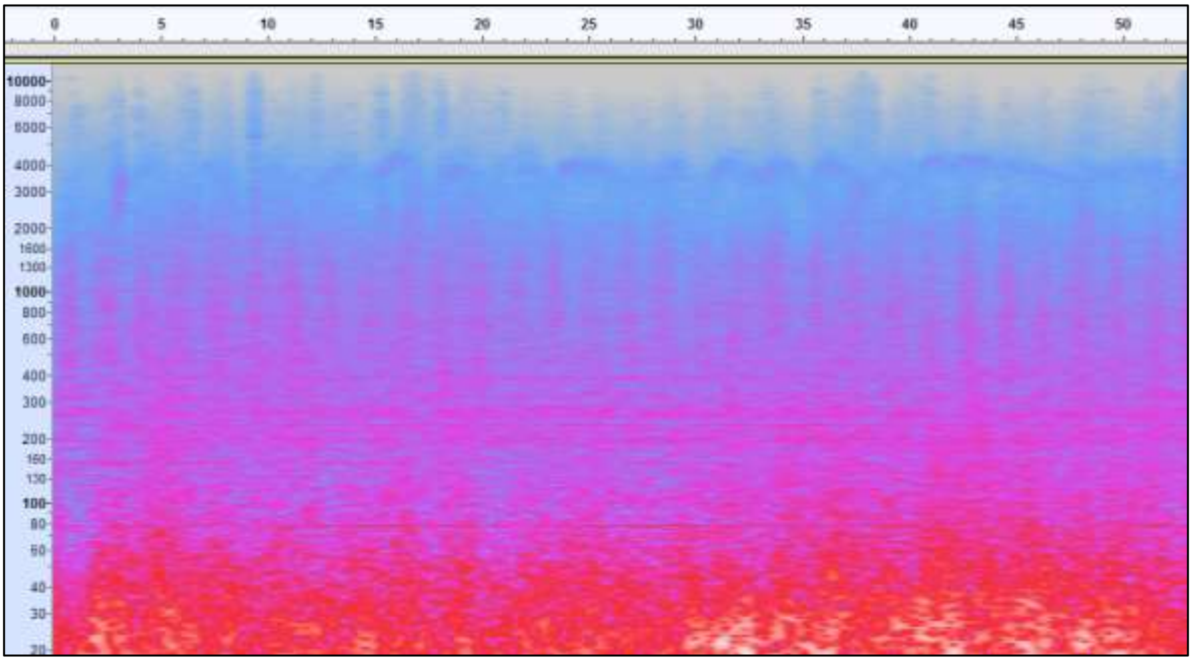

Figure 3-1. Spectrogram showing narrow-band analysis of offshore noise measurement, Oct 19, 2017, at approximately 50 m downwind of BIWF WTG #5 to show characteristics. Horizontal axis: Time (seconds) Vertical axis: Frequency (Hz)

Relatively high levels of noise below 50 Hz is typical of a normal environmental ambient soundscape. Provided the noise from a specific source is non-tonal (as in Figure 3-1) and unless it is significantly above the normal background noise at this frequency, it would not be disturbing, and would be unlikely to contribute to the overall A-weighted noise level.

3.2 Onshore long-term measurements

Observations during surveys offshore demonstrated that any noise from the WTGs was inaudible within a few hundred meters upwind. Therefore to give the best chance of identifying any contribution to the ambient noise from the BIWF at the fixed monitoring station at the lighthouse the focus from acquired noise data was for noise measurements sampled during downwind (i.e. south or south-easterly) conditions.

Figure 3-2 shows an example noise dataset for a week in March 2017, with wind conditions presented at the top for direct comparison. The horizontal red bar in the wind conditions chart identifies the south-east compass point for wind direction. The red boxes show the times when the monitoring location was downwind of the BIWF, i.e. where the red dots coincide with the red bar.

A few features should be identified from Figure 3-2. The continuous high noise levels on March 27, extending into March 28 (identified by a 'flat top' on chart 2 LAFmax and chart 3 LAFeq), are caused by the fog horn warning system near to the lighthouse. This also appears in the night of April 1st but is lost somewhat in the high background noise, caused by high winds.

There are a number of low-level tonal noises visible across the spectrogram: these can be seen as faint horizontal lines primarily starting from just under 100 Hz to just under 1000 Hz, which do not coincide with the fog horn. These tend to coincide with times when the wind is blowing towards the BIWF. These would need to be loud to propagate from the WTGs against the wind, and thus there is no evidence nor indication that the noise is related to the WTGs in any way. This may be caused by wind 'whistling' around structures nearby the lighthouse.

The period of late-night March 30 through to the middle of the day on April 1 provides the most useful data, as it shows an increasing wind speed with a continuous south-easterly direction. The low wind speed at the start of the period is reflected in the low noise levels. Increasing wind leads to increasing broadband noise levels as would be expected where produced by vegetation (e.g. wind in the trees and bushes). Any potential tonal noise or hum that could be indicative of the operational WTGs is masked by the ambient noise at the time.

There are some isolated and intermittent features that can be seen at 2-3 kHz, e.g. in the morning of March 30, and in the morning and evening of April 2. Although distinct, these generally occur at upwind times and so are unlikely to be linked to the WTGs.

A large amount of data was acquired in the onshore noise survey, and only a sample has been presented in detail in this summary report. This sample is representative however, in that no contribution to the ambient noise from the BIWF could be identified at any time in the 14-week survey period at the monitoring location on Block Island.

Plots of the full results for complete weeks are presented in Appendix A.

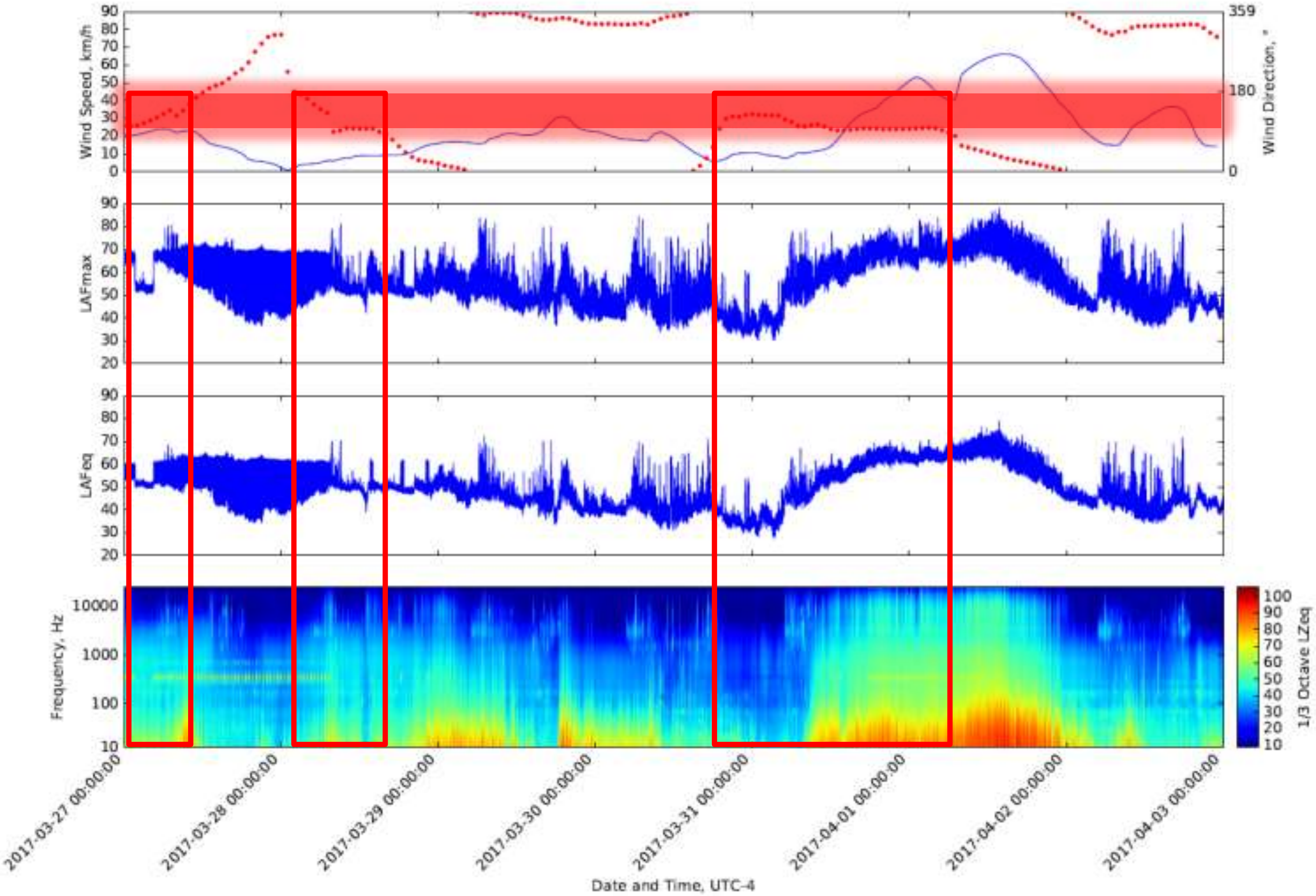

Figure 3-2. Noise measurement summary at the Southeast Light, March 27 to April 3, 2017 with annotations. Top chart: wind speed (blue line) and wind direction (red dots). Transparent red bar shows south-east compass point, with red boxes identifying time when monitor was downwind. 2nd: dB L_{AFmax} noise level time history. 3rd: dB L_{AFeq} (10 minute average) noise level time history. Bottom chart: L_{eq} spectrogram showing frequencies between 10 Hz and 10 kHz.

4 Conclusions

Noise monitoring was undertaken at the Southeast Light for more than 14 continuous weeks while the Block Island Wind Farm was fully operational. The monitoring was undertaken using a fixed position, unattended sound level meter, supplemented by meteorological data.

Attended investigation on a vessel between 50 m and 750 m of the WTGs offshore during operation confirmed that noise was usually difficult to identify over the ambient noise unless close to and directly downwind of the WTG.

The data from the fixed SLM was analyzed to focus on the measurements taken with south-easterly winds, giving the best chance of detecting noise from the turbines.

Any noise from the turbines could not be detected in the measurements onshore at any time. This is partly because when the turbine is operating at high outputs, the background noise also increases onshore due to movement of vegetation, but mostly because the measurements offshore confirm that the noise levels in the vicinity of the turbines are low. Noise levels were sampled 65 dB $L_{Aeq,1min}$ at 50 m from the turbine tower, although this value is significantly influenced by natural ambient noise. In isolation, the noise from the WTG would be lower than this.

Appendix A Analyzed data

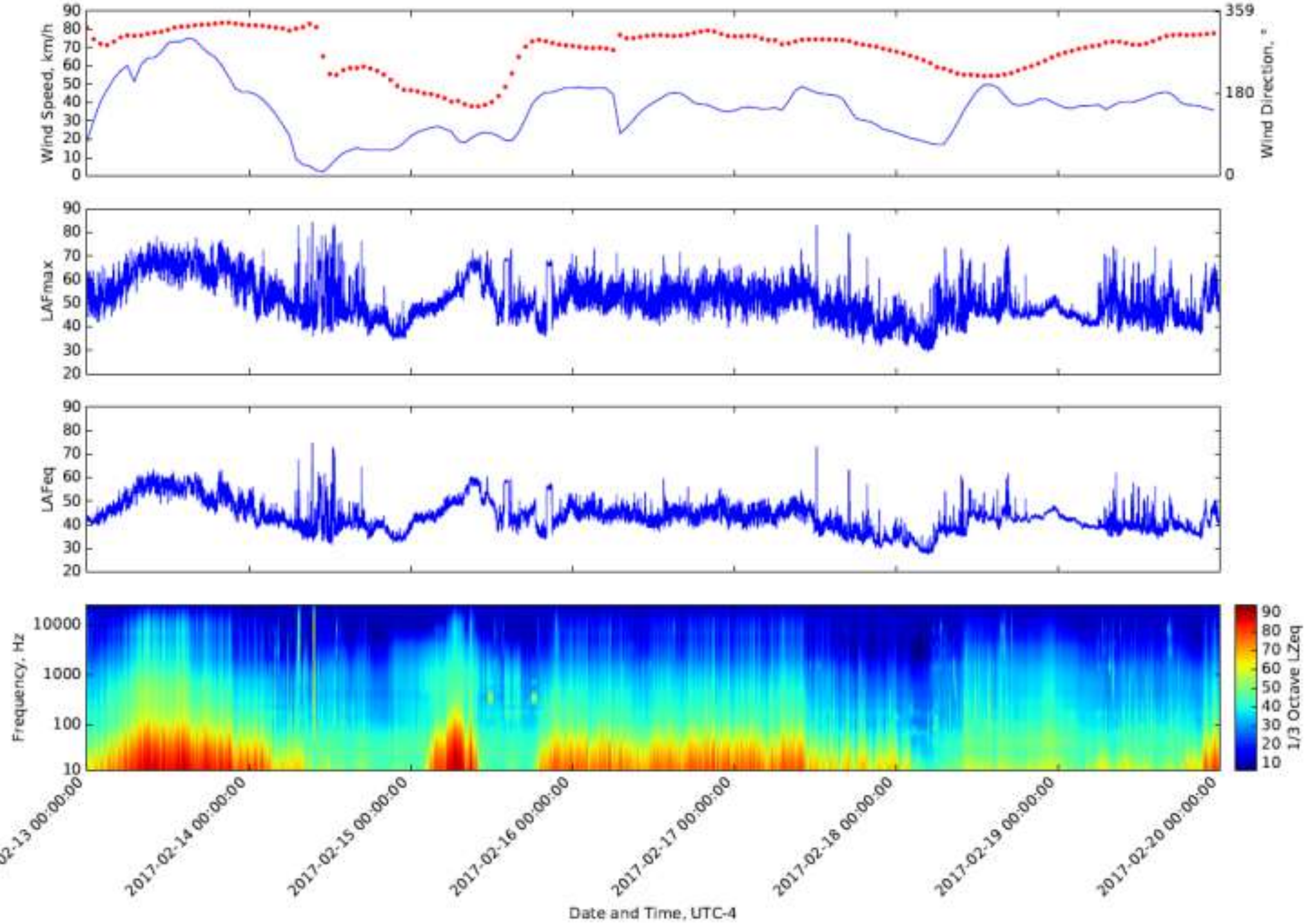

Figure A-1. Detailed data breakdown from February 13 to February 20, 2017

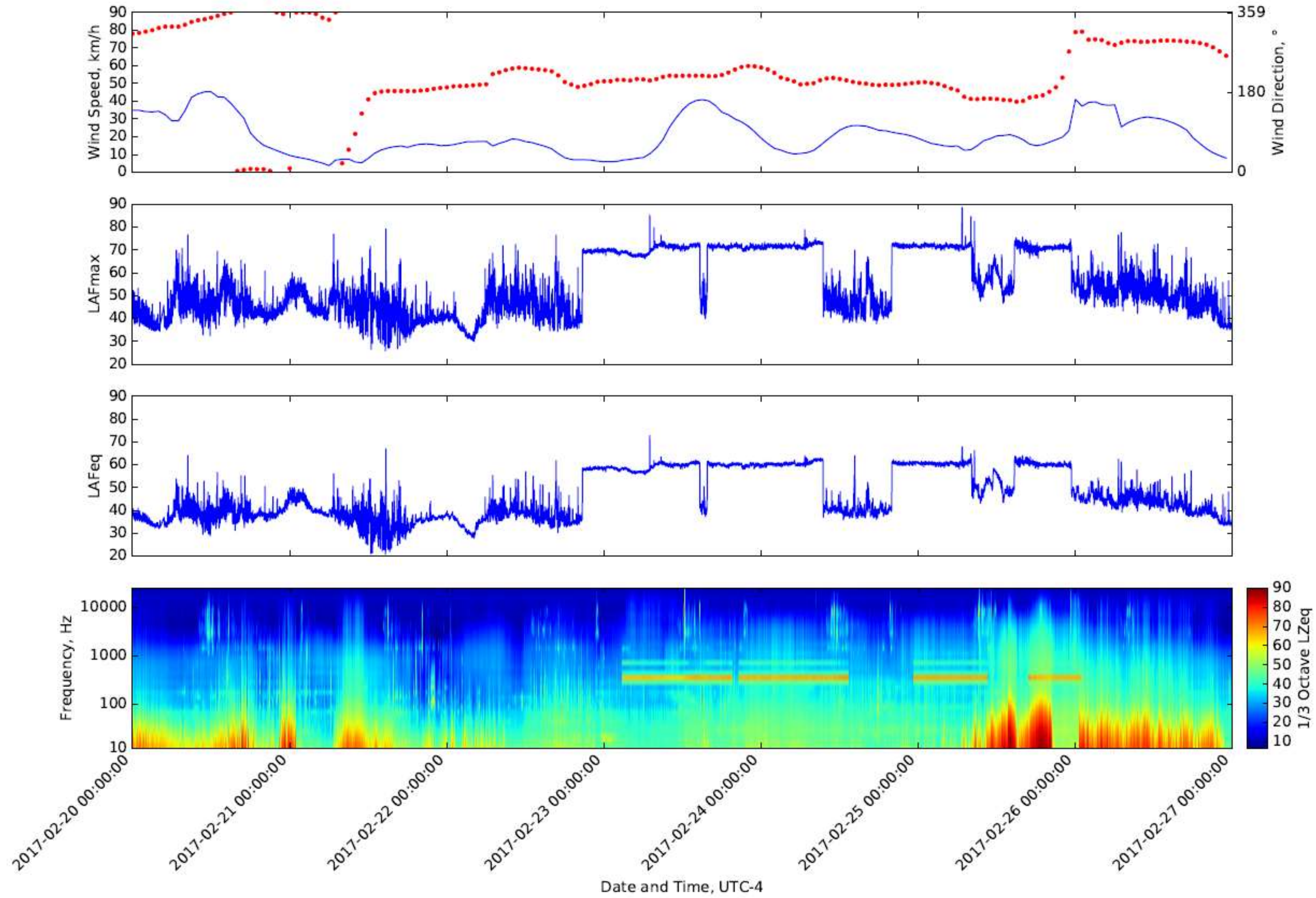

Figure A-2. Detailed data breakdown from February 20 to February 27, 2017

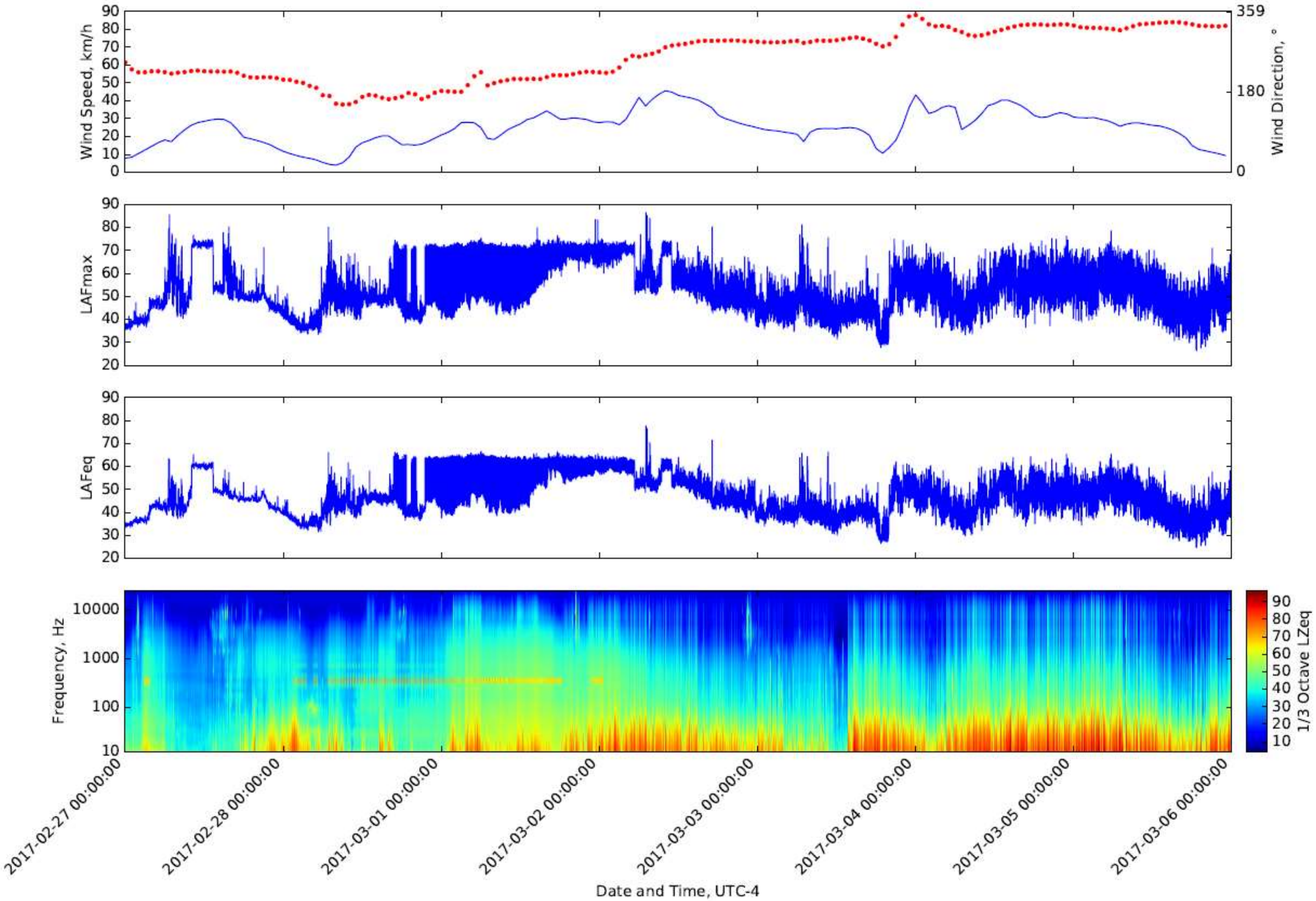

Figure A-3. Detailed data breakdown from February 27 to March 6, 2017

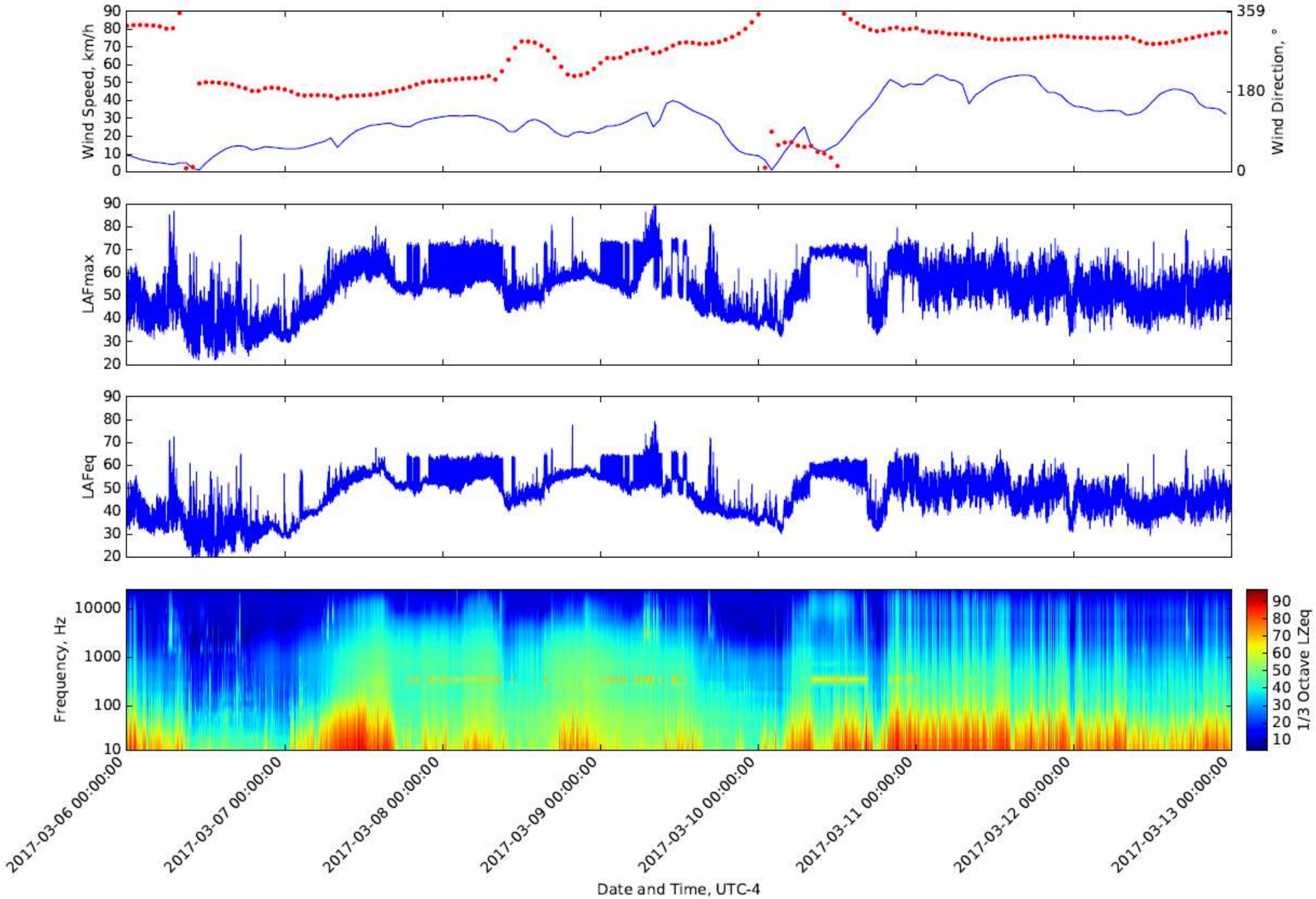

Figure A-4. Detailed data breakdown from March 6 to March 13, 2017

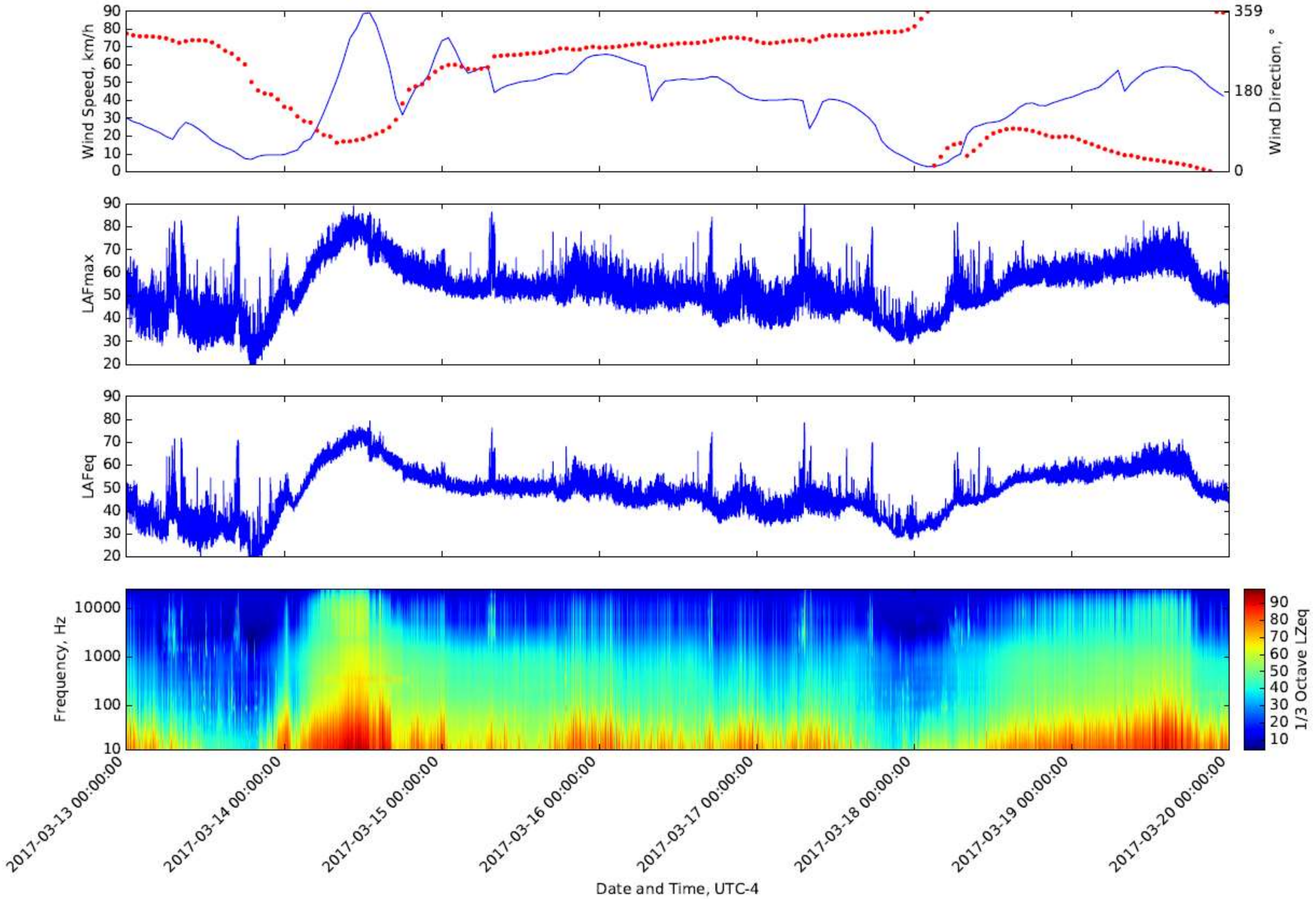

Figure A-5. Detailed data breakdown from March 13 to March 20, 2017

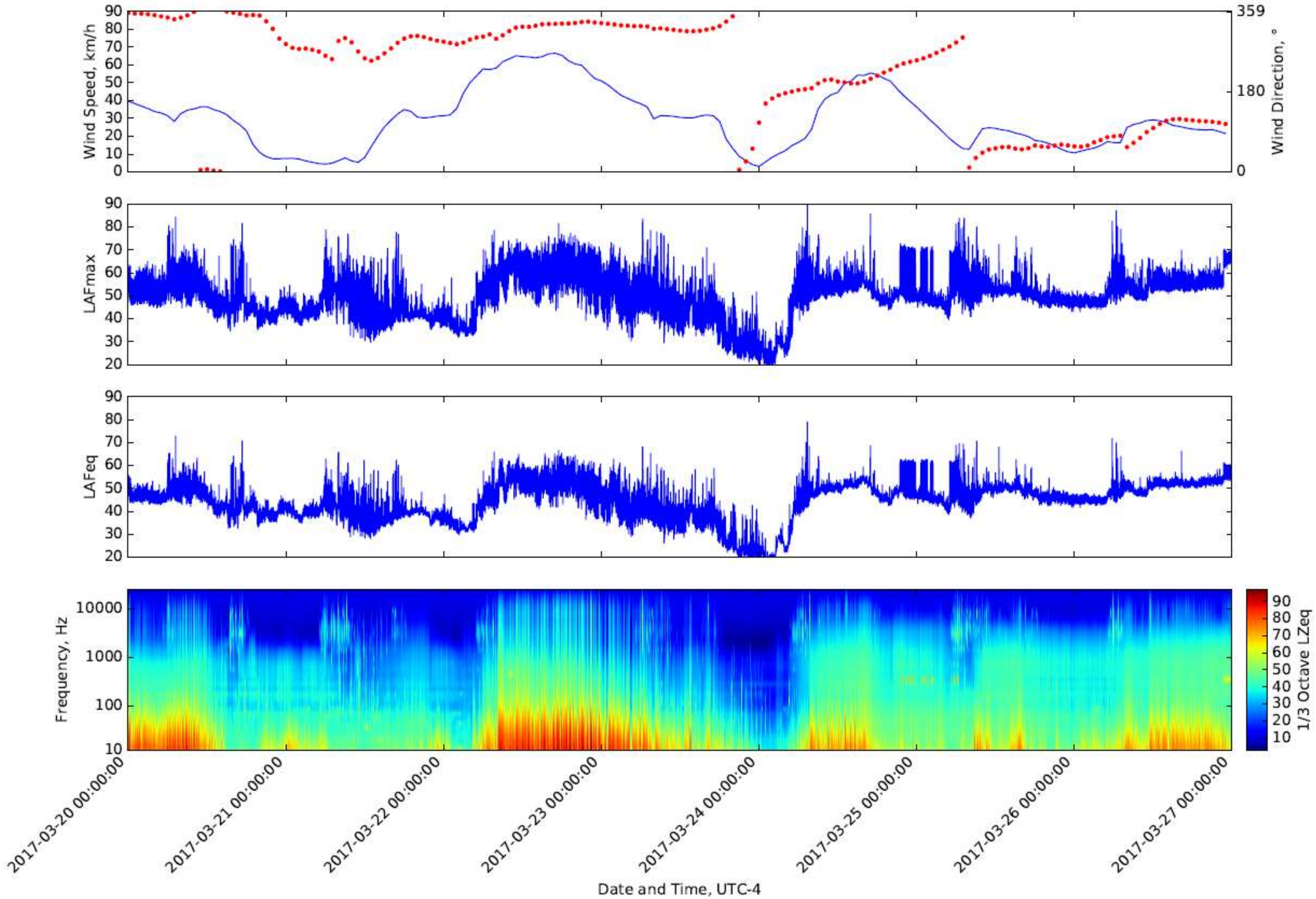

Figure A-6. Detailed data breakdown from March 20 to March 27, 2017

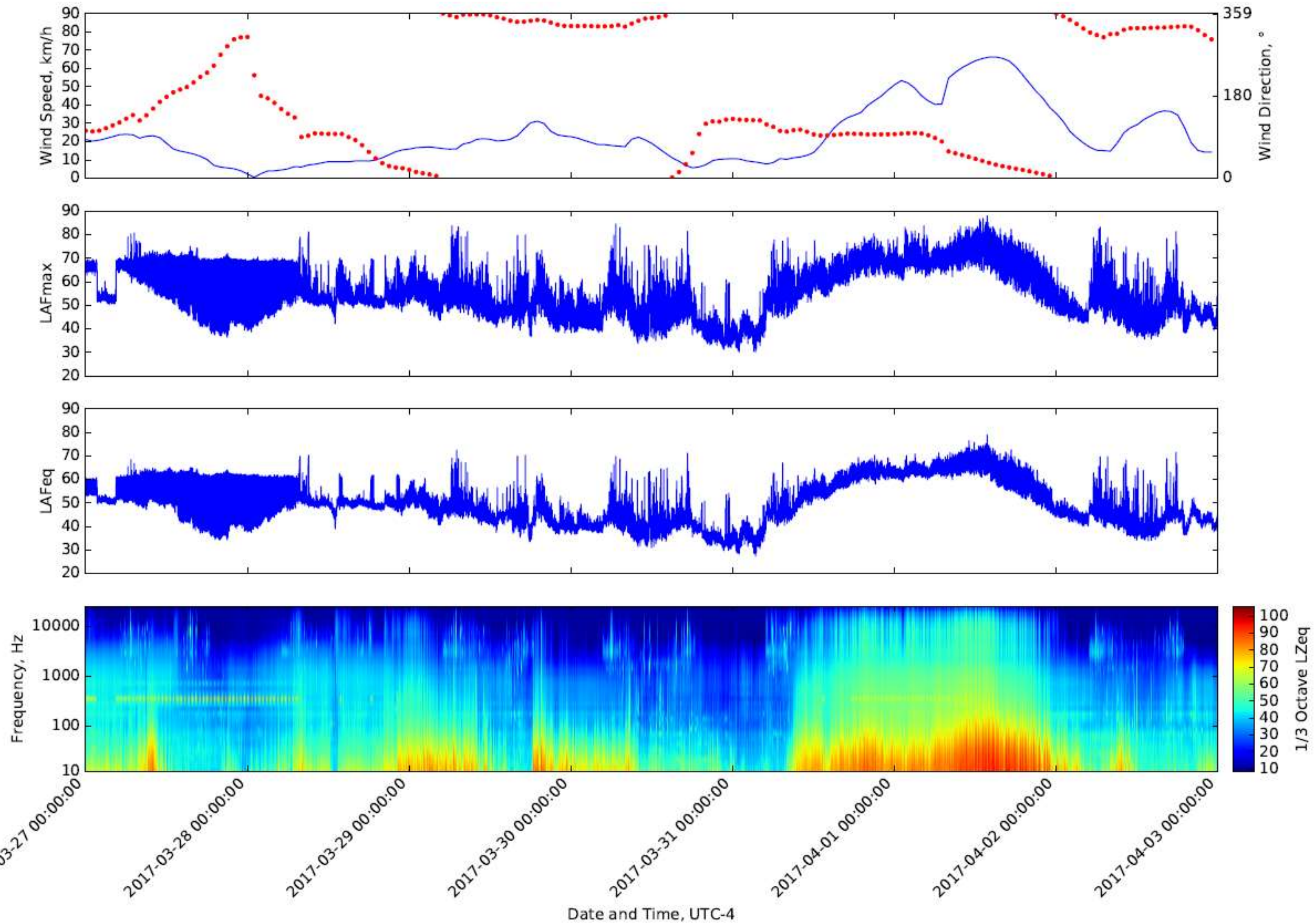

Figure A-7. Detailed data breakdown from March 27 to April 3, 2017

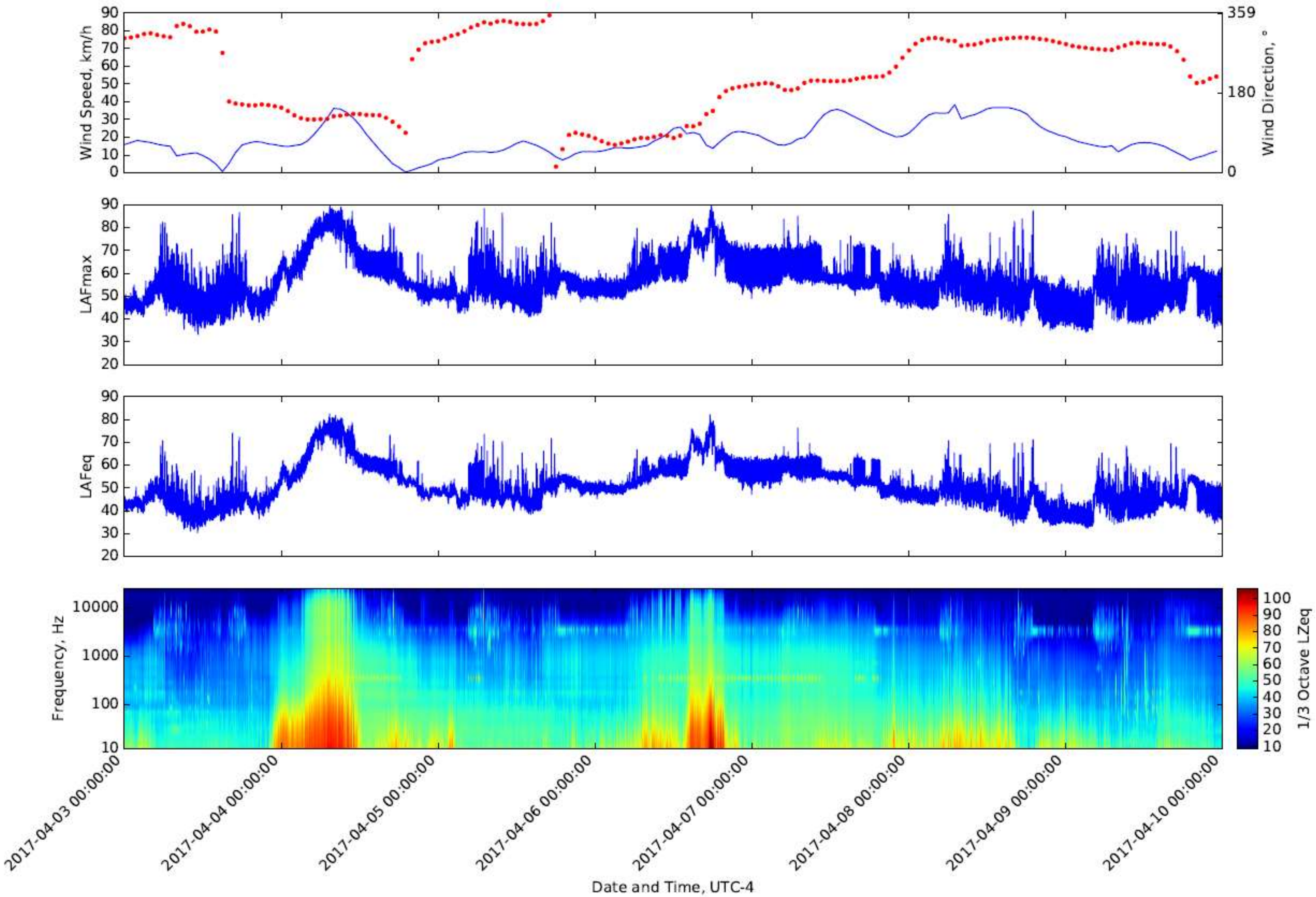

Figure A-8. Detailed data breakdown from April 3 to April 10, 2017

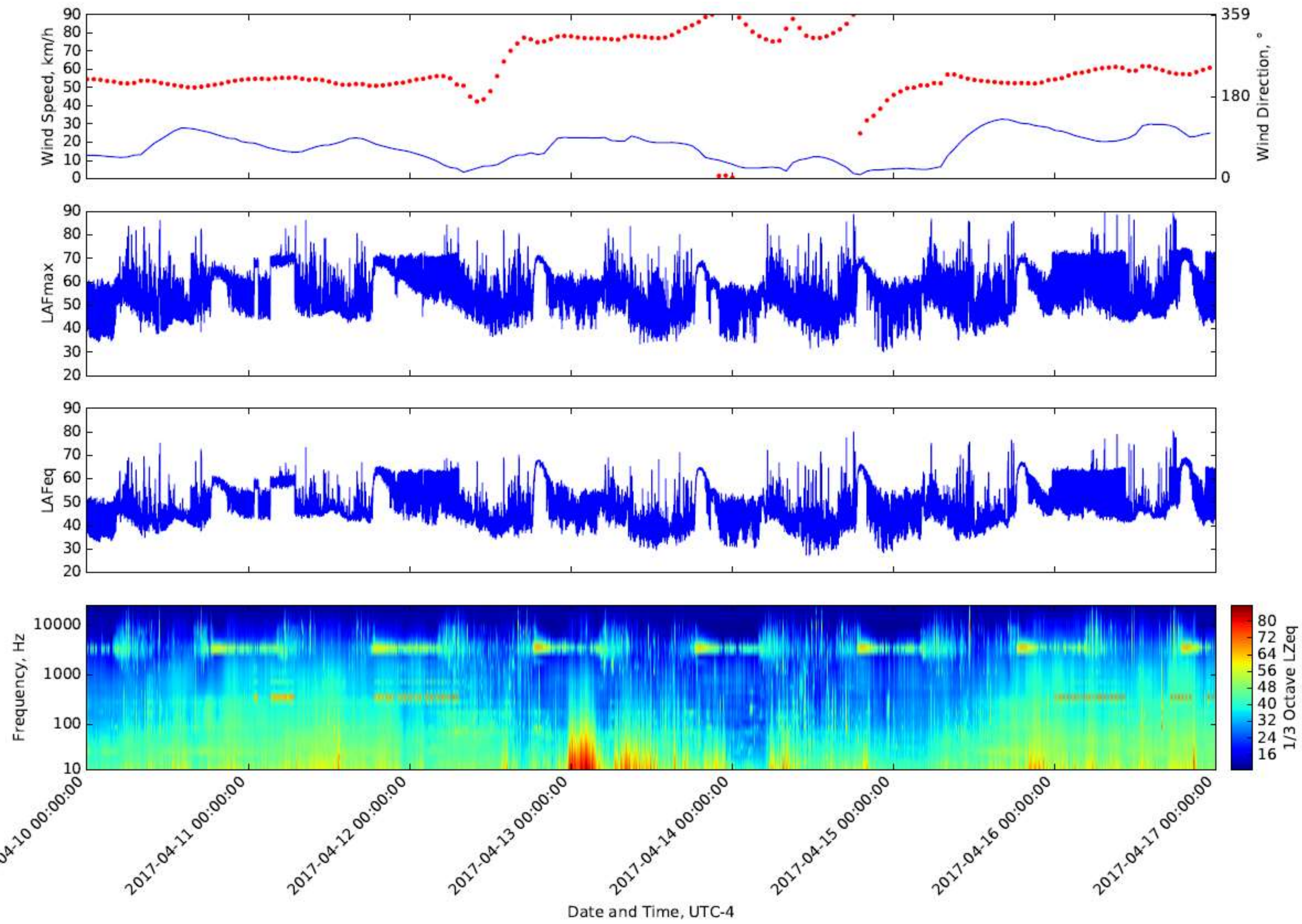

Figure A-9. Detailed data breakdown from April 10 to April 17, 2017

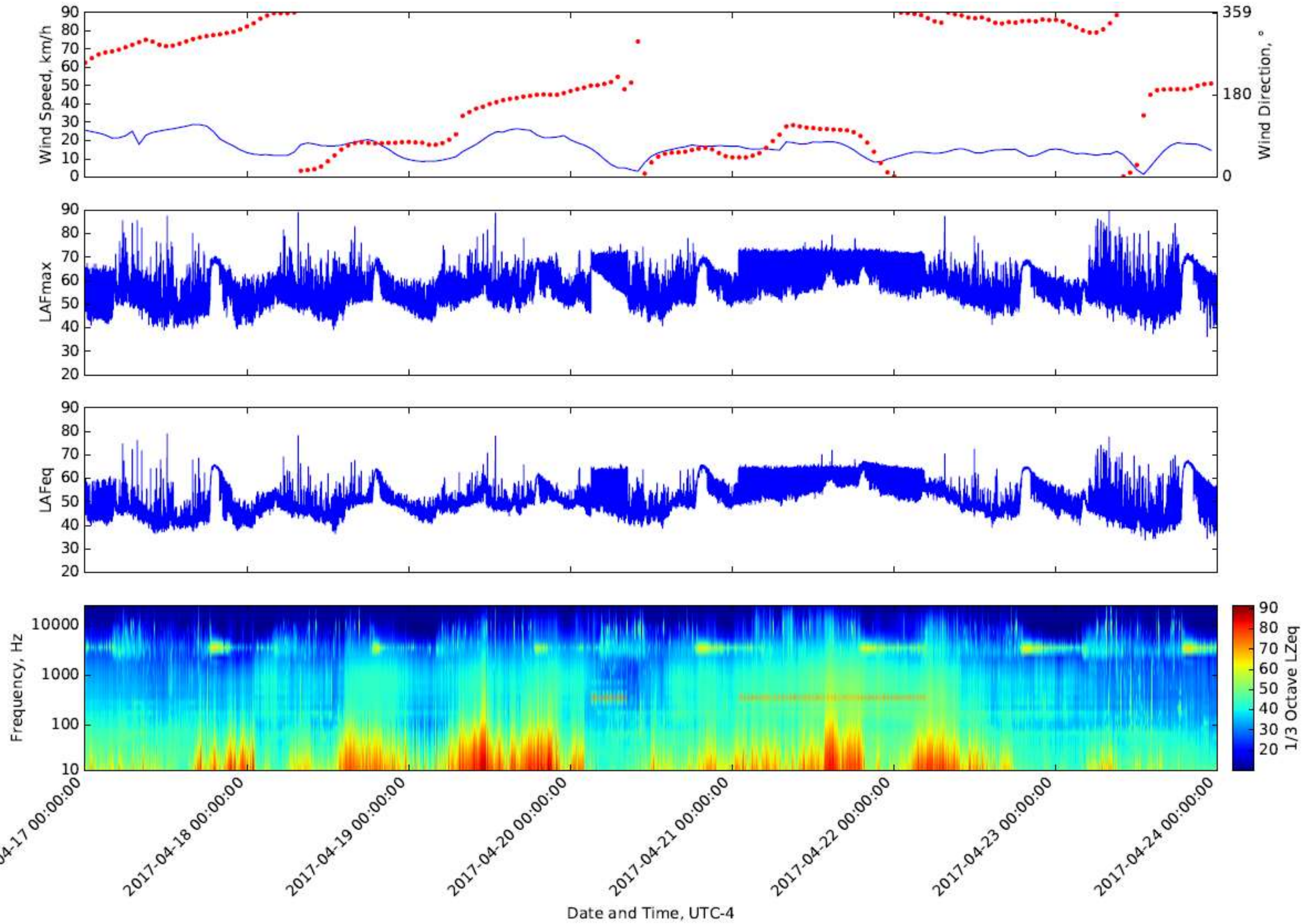

Figure A-10. Detailed data breakdown from April 17 to April 24, 2017

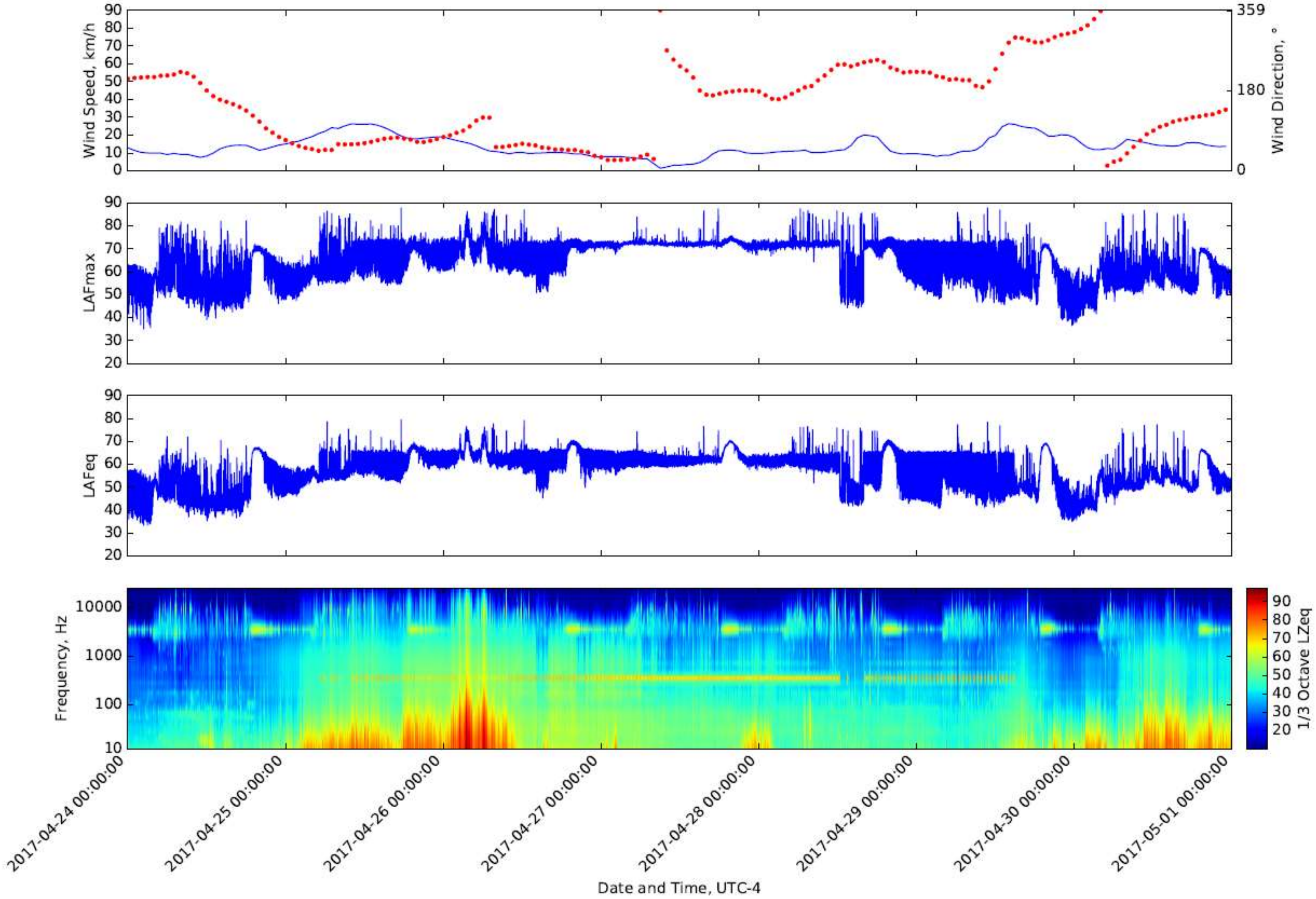

Figure A-11. Detailed data breakdown from April 24 to May 1, 2017

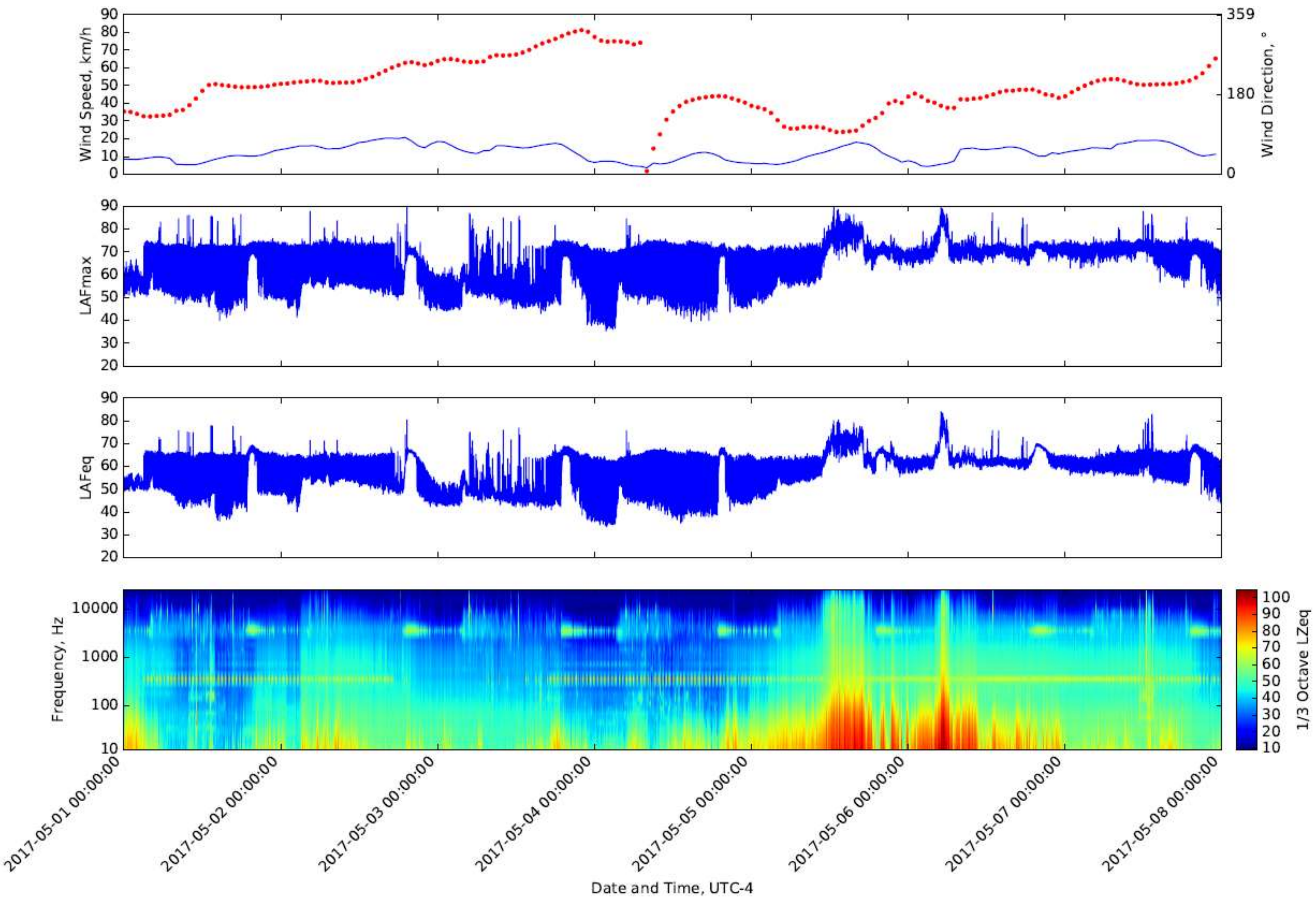

Figure A-12. Detailed data breakdown from May 1 to May 8, 2017

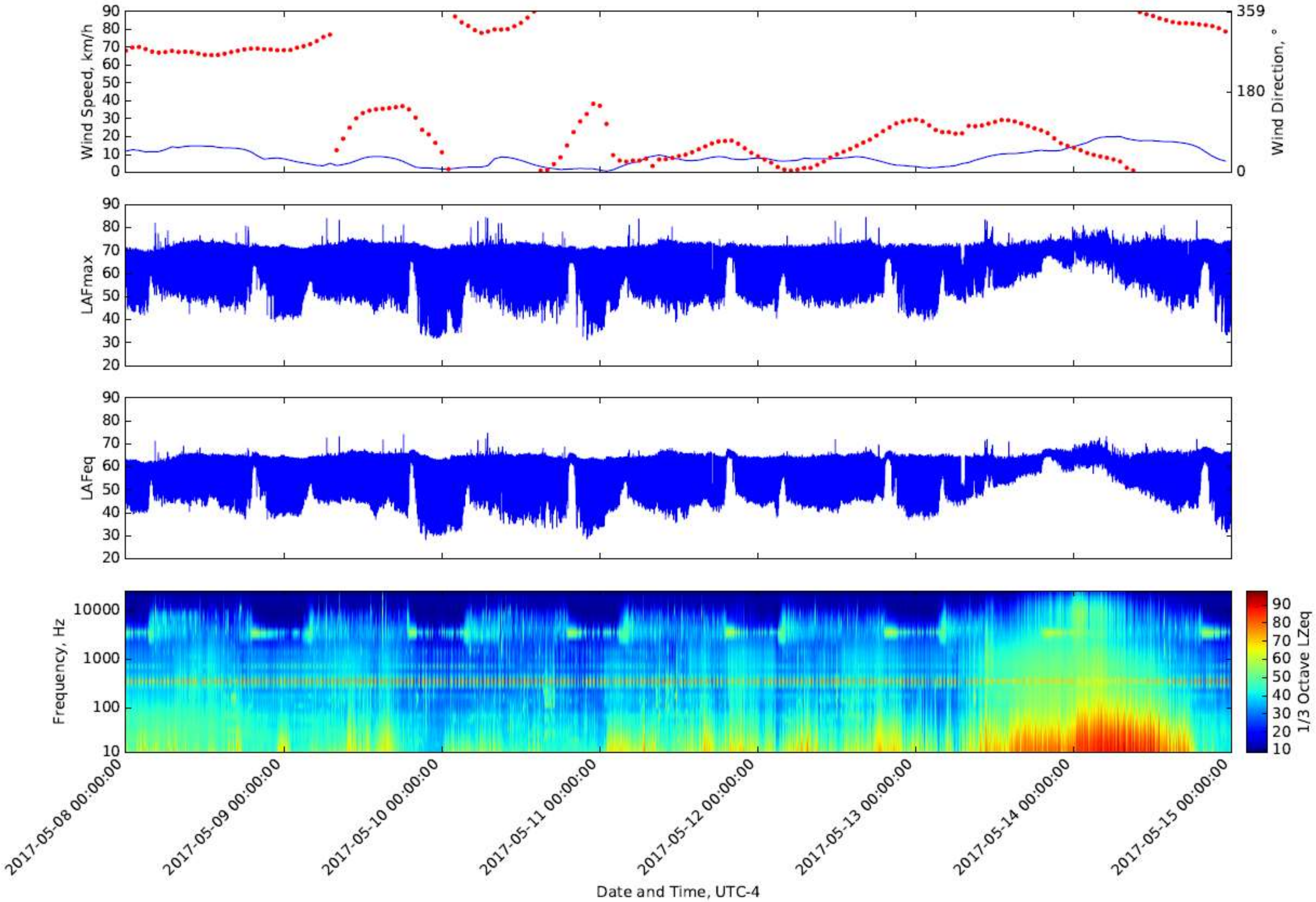

Figure A-13. Detailed data breakdown from May 8 to May 15, 2017

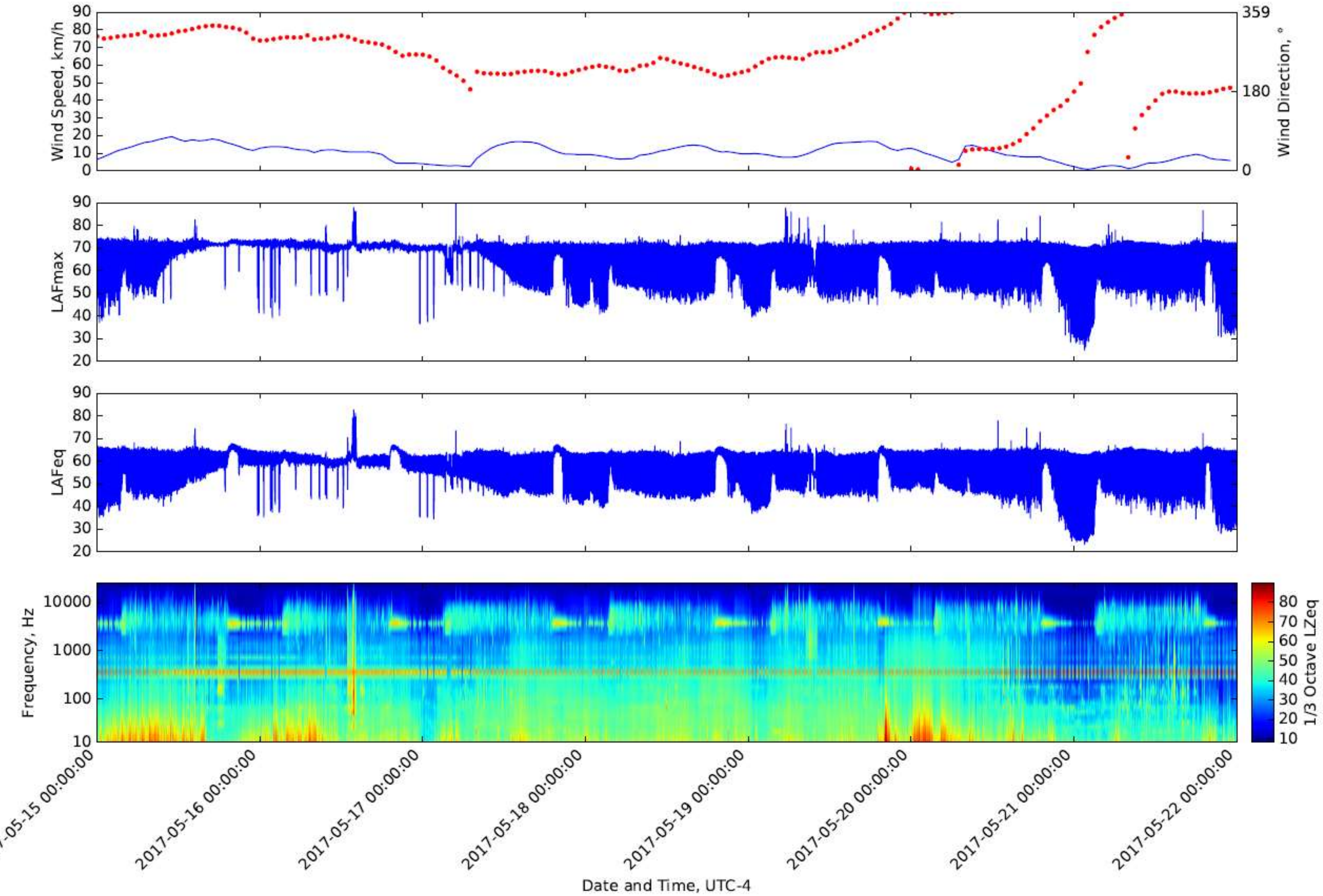

Figure A-14. Detailed data breakdown from May 15 to May 22, 2017

Appendix D: Late Summer 2017 Underwater Sound Monitoring Data Report

Observations from the Block Island Operational Wind Turbine Monitoring in 2016-2017
Data Report

Arthur Newhall, Ying-Tsong Lin, James H. Miller, Gopu Potty and Kathleen J. Vigness-Raposa

After construction at Block Island, Rhode Island of five wind turbine platforms and installation of the wind turbine generators in 2015, two field efforts mobilized to monitor the noise generated directly from the turbine operation. The two fieldwork efforts were scheduled during different seasons to investigate seasonal variability. Underwater noise and ambient noise measurements were taken during periods Dec 20, 2016 to Jan 7, 2017 and again from Oct 2, 2017 to Nov 3 2017. Concurrent airborne/underwater noise measurements conducted within 50 meters of a wind turbine generator (WTG) were also conducted during the later monitoring period.

All mooring deployment and recovery was performed from the Woods Hole Oceanographic Institution (WHOI) vessel R/V Tioga (Figure 1) which contained on-board GPS tracking, sea surface sensors and a calibrated Conductivity, Temperature, and Depth (CTD) sensor to probe the water environment.

Figure 1: WHOI research vessel R/V Tioga.

I. Wind turbine operation monitoring during winter conditions

Winter conditions were addressed during the December to January deployments. Strong winds and multiple storms were common during this time which created a well-mixed water column with constant temperature (Figure 6) and a nearly isovelocity profile (Figure 7).

A vertical Line Array (VLA), a Horizontal Line Array (HLA), laying on the ocean bottom, and a Geosled with a 4 element tetrahedral array and a bottom mounted 3-axis geophone were deployed. The HLA and Geosled were deployed 500 meters from WTG5 (Figure 5) and the VLA was deployed ~7.5 km from WTG5. The VLA was fished up halfway during this period but was returned at a later date by the fisherman who caught it in his bottom trawler. All of the other mooring components and sensors attached to that mooring were not recovered.

The surface noise from the winter weather conditions at this time dominated the recording signals from the turbines. Figure 2 does show a 'quieter' time period recorded at WTG5 from tan HLA hydrophone. The low frequency signals from ~60Hz to ~120 Hz shown here are seen throughout the most of the records. Figure 3 shows a spectrogram with no obvious turbine signature but an increase in marine mammal vocalizations. The absence of wind turbine noise at this time suggests much nicer weather that lowers the sound attenuation from a rough surface, thus allows reception of longer range signals.

Weather conditions can be plainly seen in the wave height (Figure 9) from the NOAA National Data Buoy Center (NDBC). A buoy nearby to Block Island recorded the wave height during this season. The average wave height seen here is ~2 meters. Strong winds and large waves mix the water producing a near constant water temperature profile and an isovelocity sound speed profile (Figure 7). These isovelocity conditions support well-known propagation in the water column meaning any sound reflecting from a rough surface will be greatly attenuated.

Also at this time, a towed array and playback experiment was conducted (Figures 4,5). A towed Lubell sound projector was towed from WTG5 towards the offshore VLA in conjunction with the towed array to validate a 3-dimensional (3D) acoustic propagation model. This experiment is described in more detail in the modeling section.

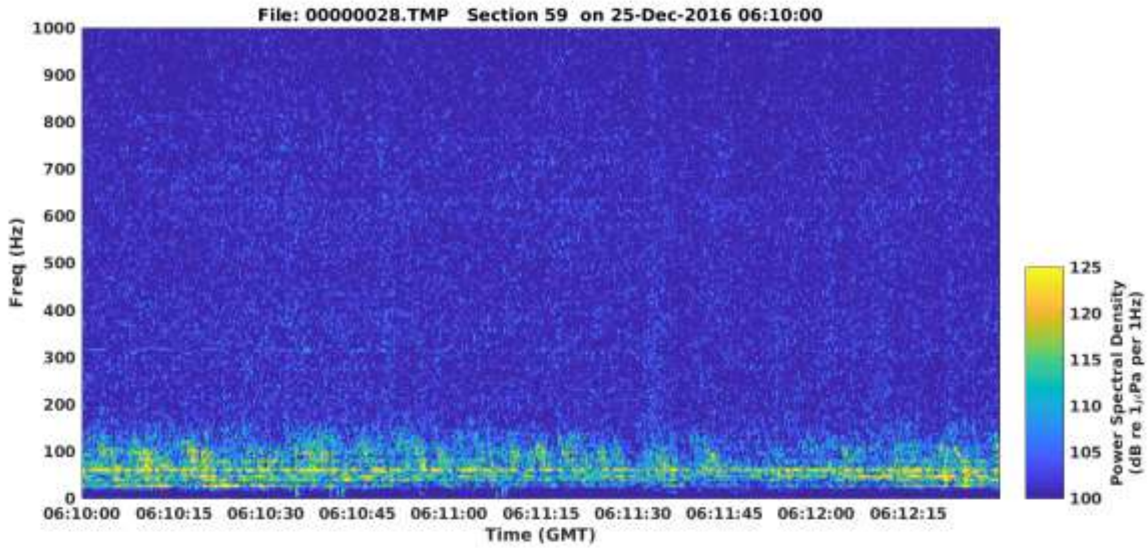

Figure 2: Spectrogram from a hydrophone on the horizontal line array at WTG5 during a good winter weather day showing low frequency noise from the wind turbine.

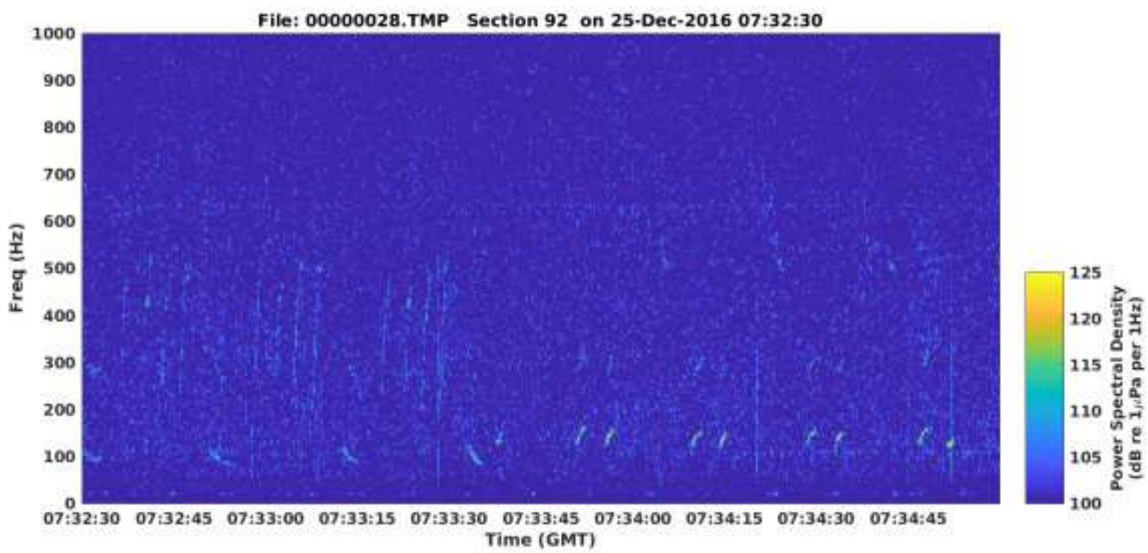

Figure 3: Spectrogram from the HLA at WTG5 when the turbines do not seem to be in operation and the appearance of marine mammal vocalizations.

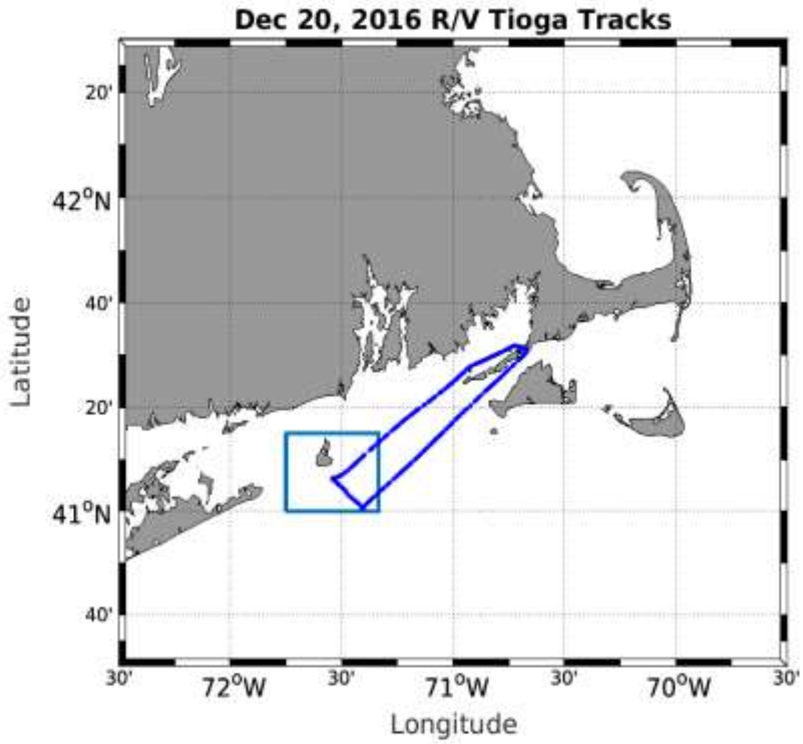

Figure 4: Vessel tracks from Woods Hole, MA to Block Island, RI for the R/V Tioga on Dec. 20, 2016.

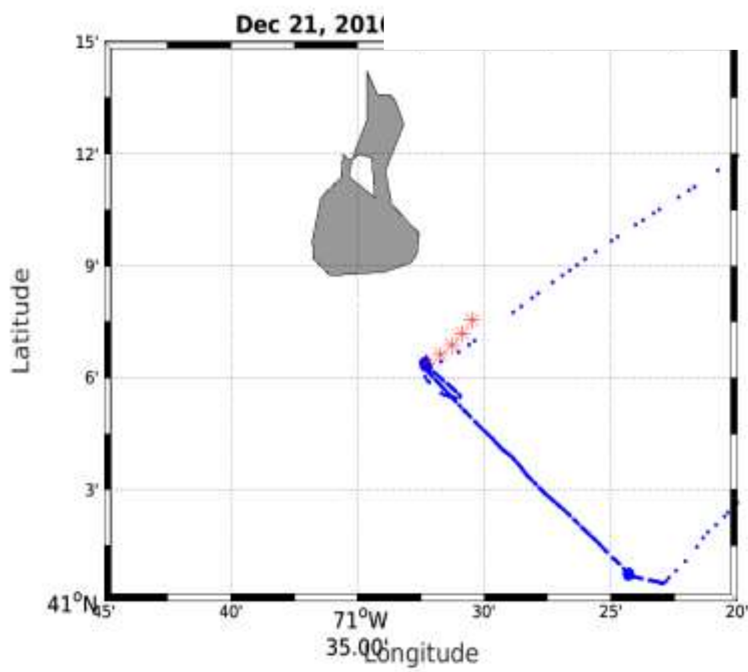

Figure 5: Playback track to the southeast from mooring at WTG5 on Dec 20 2016. The HLA and Geosled were collocated at WTG5. The VLA was deployed 7.5km to the southeast.

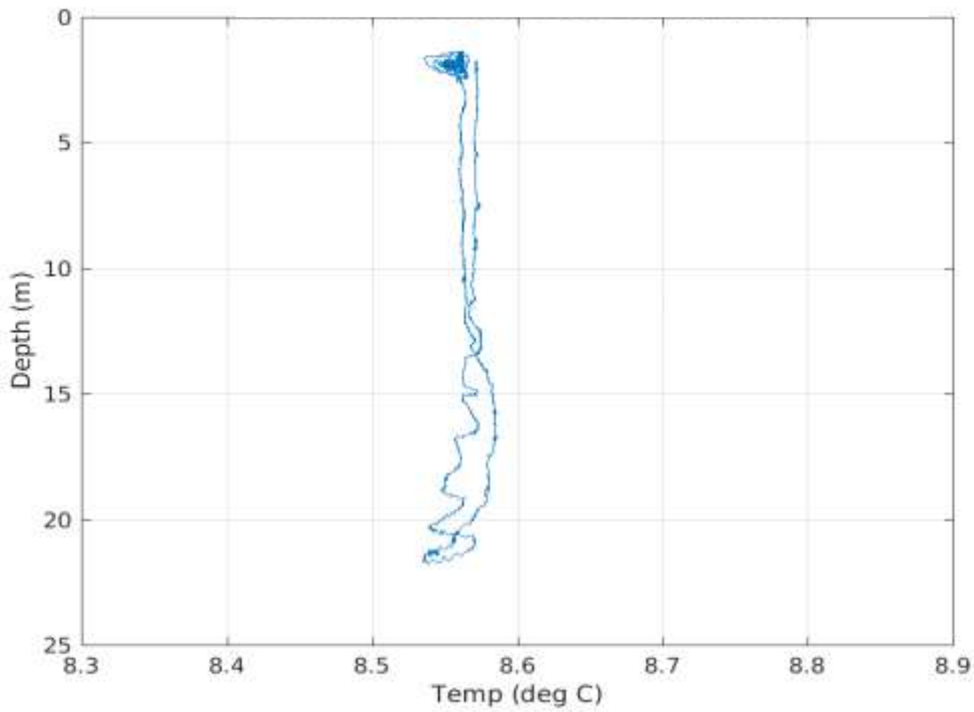

Figure 6: R/V Tioga CTD temperature profile at WTG5. The water was well mixed due to winter storms.

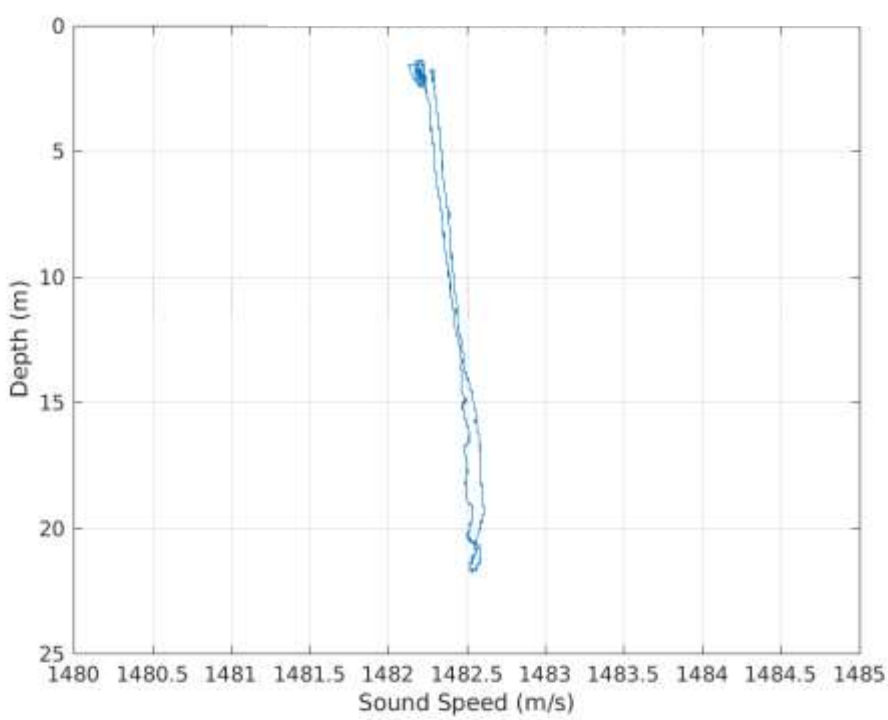

Figure 7: Sound speed from CTD cast showing an isovelocity profile at WTG5 on Dec 20.

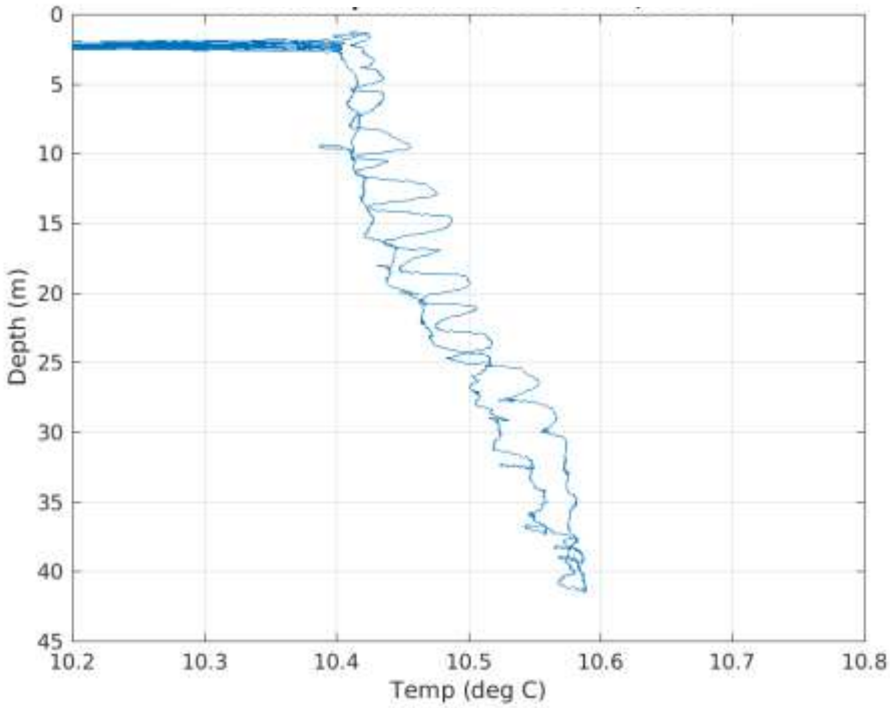

Figure 8: CTD temperature 7.5km offshore which is 2 Degrees warmer than at WTG5, thus speeding up the sound speed in the water column.

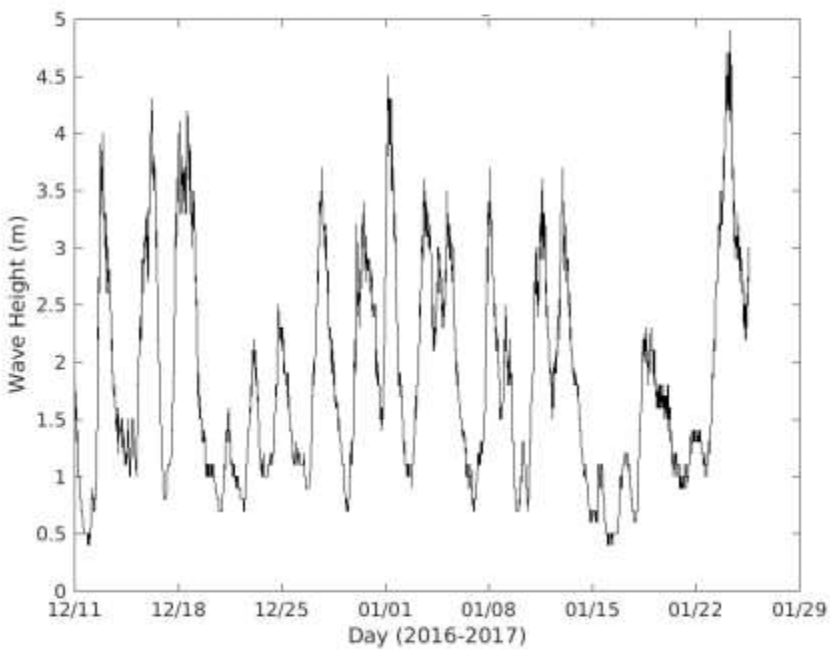

Figure 9: Wave height in meters from mean low tide from a nearby NDBC buoy showing very stormy winter season.

2. Late summer conditions Oct 2 – Nov 3, 2017

To compare seasonal sound propagation conditions at the wind turbine area, the URI Geosled with a geophone and tetrahedral array and a WHOI 8-element hydrophone horizontal line array (HLA) were deployed at WTG5. To compare noise between wind turbines, a WHOI four-element vertical line array (VLA) was deployed at WTG1. The site at WTG1 was slightly deeper than WTG5 as seen in Table 5. Figure 10 shows the locations of the moorings and turbines at Block Island and Figure 11 shows the locations with respect to the turbines.

Table 1: Mooring deployments for October 2. The Geophone sled and VLA were deployed at WTG5. The VLA was deployed at WTG1.

Mooring	Position	Deployment date/time (GMT)	Recovery date/time (GMT)	Depth (m)	Turbine
Geo/tetrahedral sled #917/910	41 06.3921 71 32.3147	10/02/2017 13:52:21	11/03/2017 11/12/30	23	5
SHRU 4 element Vertical Line Array (VLA)	41 07.5968 71 30.4749	10/02/2017 17:05:44	11/03/2017 10:23:00	28.6	1
Webb 8 element Horizontal Line Array (HLA)	41 06.4454 71 32.2319	10/02/2017 14:20:08	11/03/2017 11:27:18	23	5

The depth record from a stationary temperature/depth sensor attached to the HLA shows two extreme storms from during a period from October 24, 2017 to November 2, 2017 (Figure 12). These storms once again well-mixed the water column (Figure 14). When comparing the temperature (Figure 13) at WTG5 to the winter profile (Figure 6) at the same location, the temperature at the ocean bottom during late summer was twice that from the winter.

The pressure record showing wave activity was compared to the water column temperatures in figure 14. The profiles shown here display surface water warming from October 8-12 thus creating a downward refracting sound condition. But the storms later from October 23 on show the water column being well-mixed (temperature remained same from surface to bottom). A CTD cast from the R/V Tioga at this time (Figure 15) shows the well-mixed water column profile and isovelocity sound speed.

Another interesting item to note here adds to the comparison between the two turbines separated by ~3.5km. After recovering the three moorings, the HLA and Geophone sled at WTG5 were fouled with barnacles. The VLA at WTG1 was also fouled, but did not contain any barnacles, only fine, hairy seaweed. We should also note that most of the recreational fishing activity was noticed around WTG5, and none at WTG1, whenever we were at the site.

Figure 10: Image of Block Island wind turbine area. The wind turbine generators are indicated in white, the horizontal line array placement in cyan at WTG5, and the vertical line array in gray at WTG1.

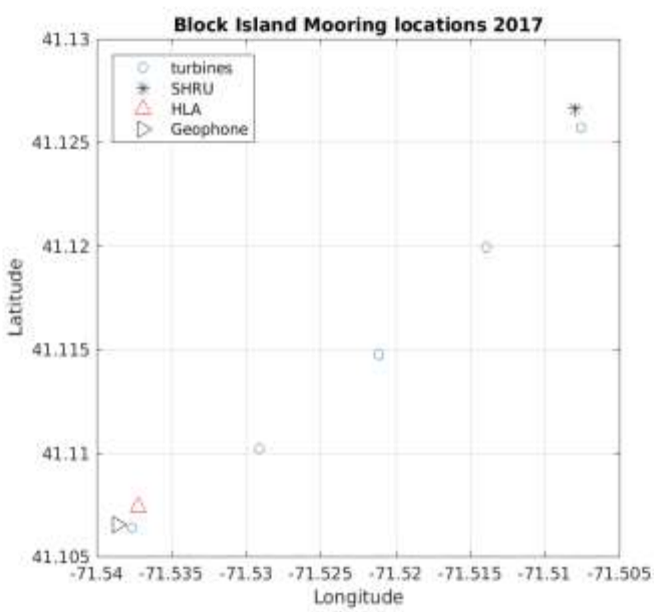

Figure 11: Locations of acoustic monitoring moorings in relation to the wind turbines.

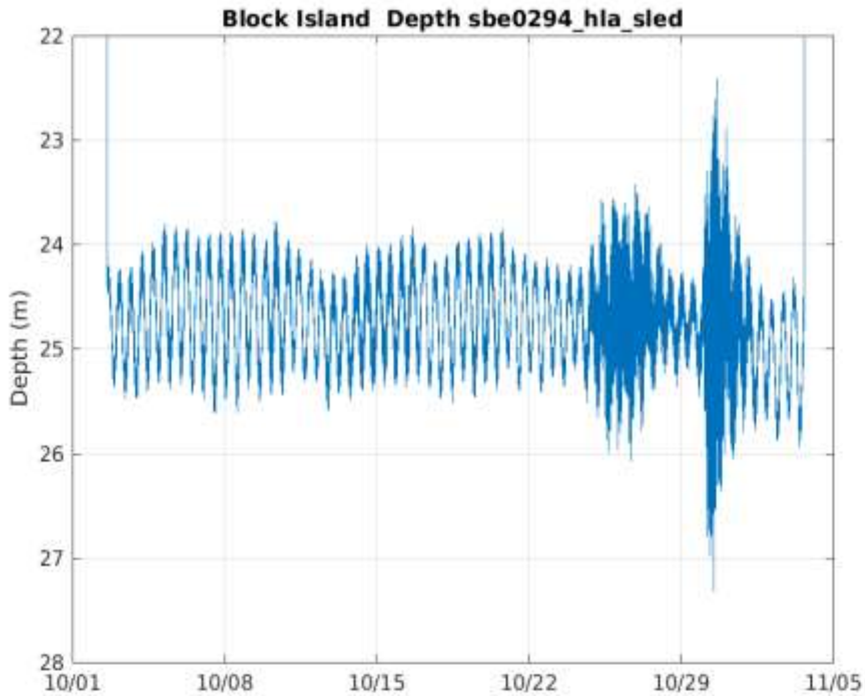

Figure 12: HLA SBE39 T/P sensor depths showing surface tides and two large storms.

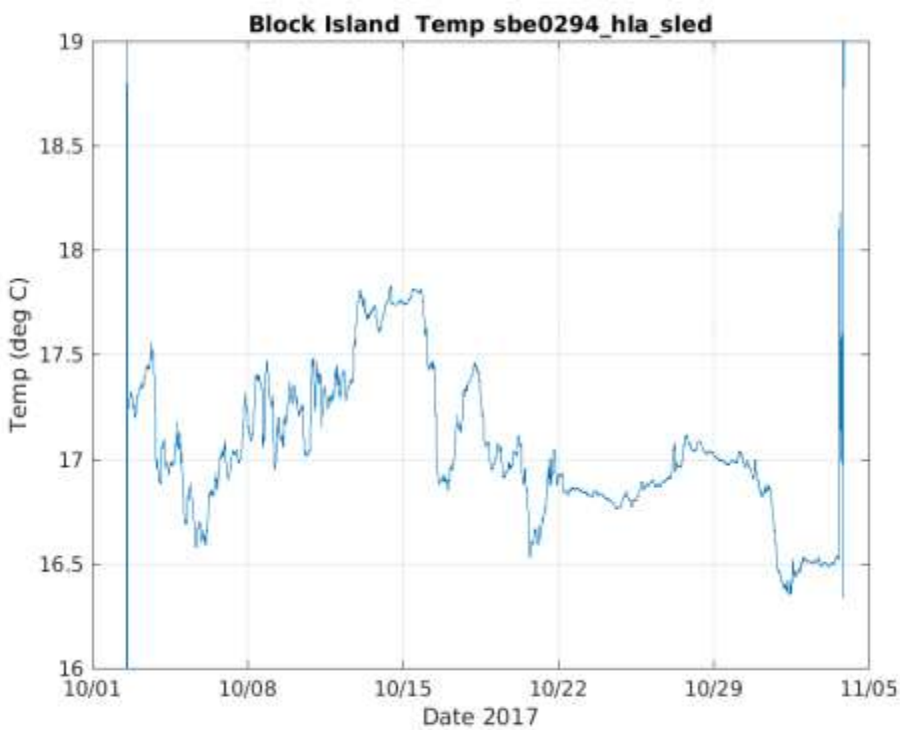

Figure 13: HLA SBE39 T/P temperature record at WTG5. The temperatures recorded during this time were twice that were found during the previous winter deployments.

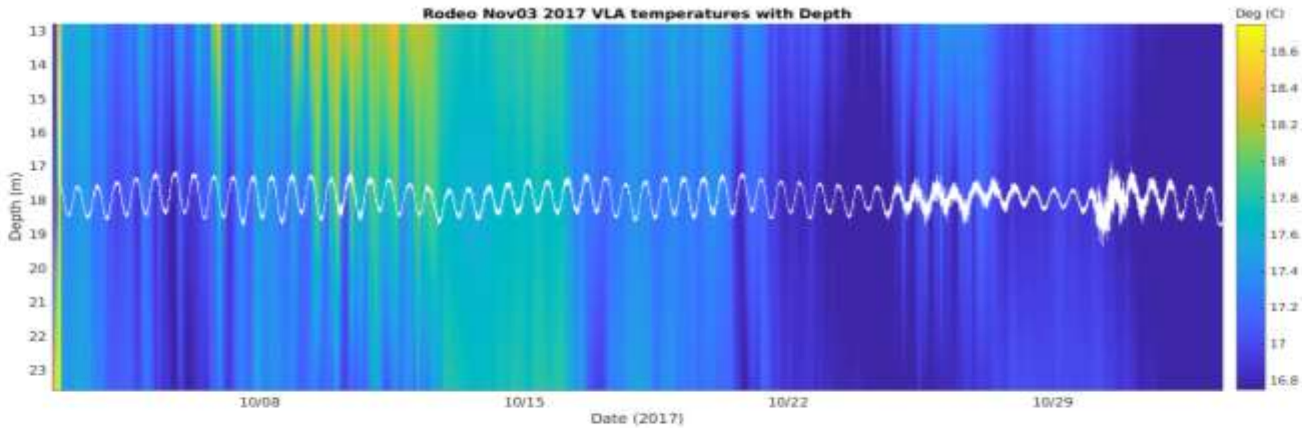

Figure 14: VLA temperature profiles from an array of sensors attached to the VLA with an overlay (white) with water depths at WTG1.

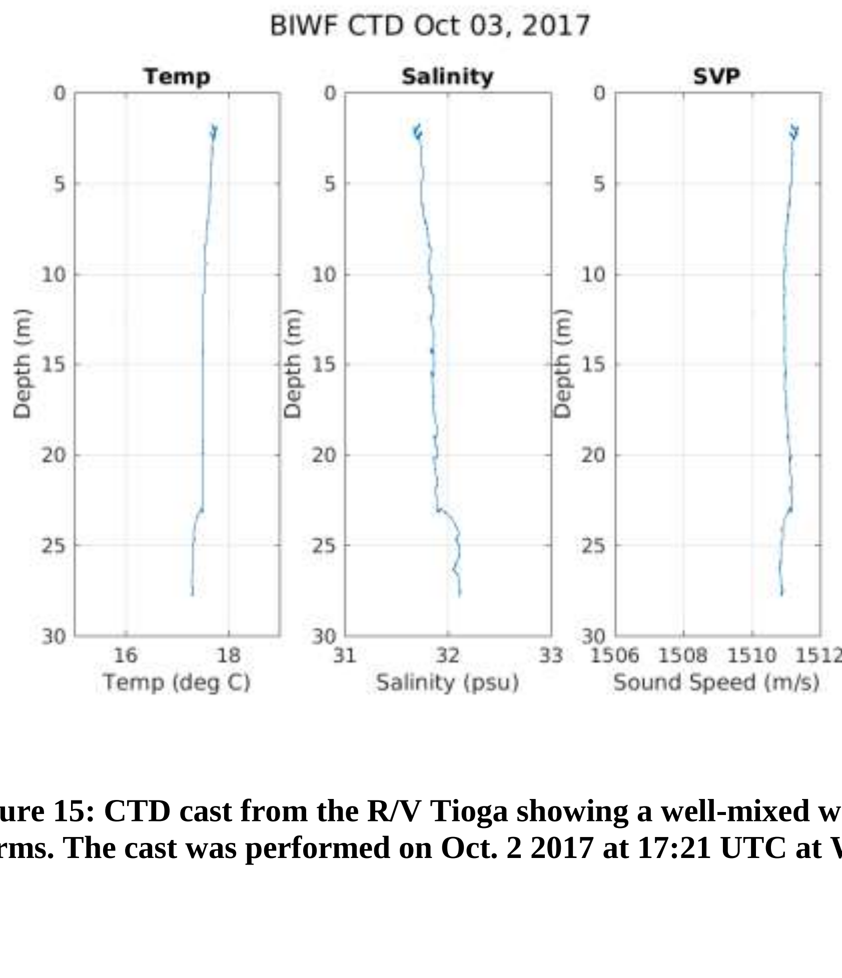

Figure 15: CTD cast from the R/V Tioga showing a well-mixed water column due to winter storms. The cast was performed on Oct. 2 2017 at 17:21 UTC at WTG5

Figure 16 shows the spectrogram for all 4 channels of the VLA deployed at WTG1. The signals under 40 hz for all channels is mooring noise due to windy events and currents. The vertical stripes seen here are vessels that were in the vicinity. Recreational fishing activity was seen each time the site was visited. Long term noise can be seen at ~70Hz and 120Hz on all four channels. And the large increase in noise after October 23 is caused by storms.

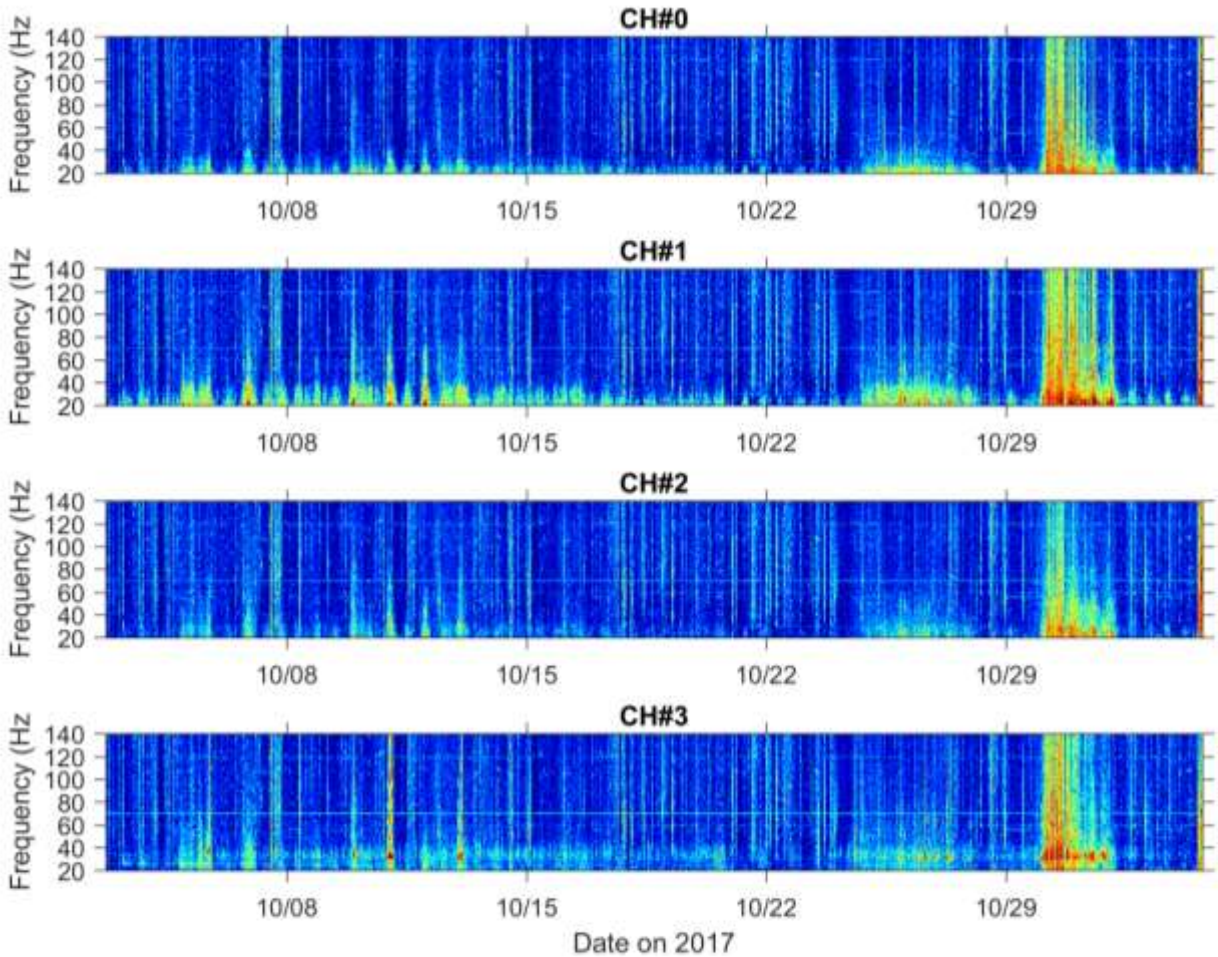

Figure 16: Spectrograms at 20 Hz to 140 Hz from each VLA sensor. Note higher level of noise during storms after 10/23.

The power spectrum describes the distribution (PSD) of a received signal into frequency components composing that signal. To gain insight in the frequency distribution, each channel was analyzed for frequency content. Results of the frequency content are seen in Figure 17 and the larger contributors to the distribution are labeled. The low frequencies are dominated by mooring noise and the higher frequencies are mainly ambient noise. Signals seen in the spectrograms show up as peaks at 30Hz, 60Hz, 70Hz and 120 hz. The width of the distributions are caused by the presence of boat noise.

Tables 2-5 give the operational noise statistics in 1/3 octave bands for the Oct-Nov late summer deployment. The operational turbine noise mean and standard deviation from the VLA at WTG1 are shown in Table 2 and 3. Operational turbine noise mean and standard deviation from the horizontal line array (HLA) at WTG5 are shown in Table 4 and 5. The mean changes little from WTG1 to WTG5, but the standard deviation is larger at WTG5 mostly due to increased boat activity there.

Table 2: Operational noise mean (dB) from SHRU913 VLA at WTG1

Band #	Frequency (center)	CH0	CH1	CH2	CH3
0	31.25	61.4	66.7	61.7	66.2
1	62.50	58.5	60.8	59.6	61.7
2	125.00	57.8	58.8	57.7	58.7
3	250.00	56.1	56.5	55.5	55.9
4	500.00	53.8	54.1	53.4	53.6
5	1000.00	51.0	51.3	50.8	51.1
6	2000.00	47.3	47.4	46.9	47.2

Table 3: Operational noise standard deviation (dB) from SHRU913 at WTG1

Band #	Frequency (center)	CH0	CH1	CH2	CH3
0	31.25	11.7	13.0	11.0	11.0
1	62.50	10.4	10.8	9.4	10.0
2	125.00	9.2	9.6	8.6	9.3
3	250.00	8.3	8.6	7.9	8.7
4	500.00	7.7	8.1	7.5	8.0
5	1000.00	7.7	7.9	7.5	7.8
6	2000.00	7.9	8.1	7.7	7.9

Table 4: Operational noise mean (dB) from horizontal line array at WTG5

Band #	Frequency (center)	CH0	CH1	CH2	CH3
0	31.25	55.9	58.4	59.7	59.9
1	62.50	57.5	59.5	61.3	61.6
2	125.00	56.3	58.5	60.2	60.2
3	250.00	54.5	57.5	58.1	58.4
4	500.00	51.5	54.6	56.2	55.1
5	1000.00	48.1	50.1	50.9	50.7

Table 5: Operational noise standard deviation (dB) from horizontal line array at WTG5

Band #	Frequency (center)	CH0	CH1	CH2	CH3
0	31.25	12.7	14.1	14.7	15.5
1	62.50	11.8	12.9	13.6	14.3
2	125.00	10.9	12.2	12.6	13.4
3	250.00	11.0	13.0	12.7	13.8
4	500.00	10.1	12.3	12.6	12.7
5	1000.00	8.3	9.2	9.9	9.8

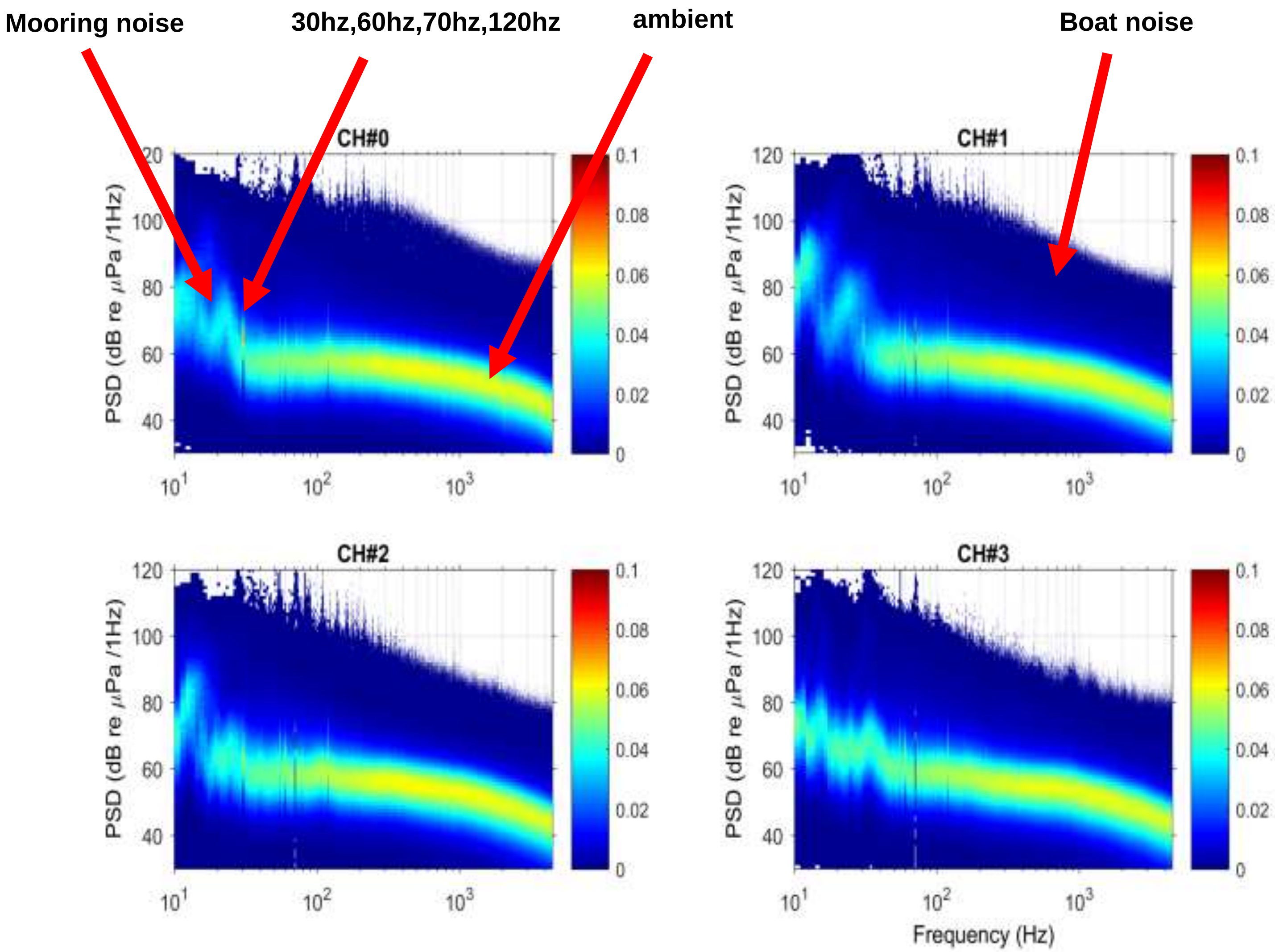

Figure 17: Frequency distributions from all four hydrophones on the VLA at WTG1. The low frequencies are dominated by mooring noise and the higher frequencies show the levels of ambient noise. Signals at 30,60,70 and 120Hz was recorded throughout the entire record. Boat noise made longer delay times in the density estimate.

3. Source tow operations – Oct 20, 2017

Sound can propagate through the bottom and reflect off sub-bottom features. A source towed in conjunction with a hydrophone array can interpret signal arrival times to determine these layers.

On October 20, the R/V Tioga towed a 7 element hydrophone array and a Lubell sound source. A cartoon of the tow configuration can be seen in figure 21 and the array configuration in distance from the secured point on the vessel is shown in Table 7. The tow path from WTG1 to the northeast was chosen since the bathymetry showed some interesting features (Figure 18), such as a small change in depth intersecting the path about halfway. Figure 19 shows the path, the VLA, and the five turbine locations. To check on array hydrophone tow depths and temperatures for calculating sound speed, a number of temperature and pressure sensors were attached to the array (Table 6) close to each hydrophone that was designated for recording (Table 7). Temperature along the path (Figure 20) and depth of the sensors (Figure 22) were then used to understand the signal receptions on the multiple hydrophones. Tables 8 and 9 show the signal characteristics and source path locations used to penetrate the bottom.

One of the study objectives of the towed source operations is to resolve the sub-bottom layering structure in the acoustic reflections off the seafloor. The source frequency band was designed to be 700 Hz to 2 kHz (see Table 9) and suitable to penetrate deep into the sediment layers. A pulse compression technique was carried out to improve the resolution of the reflected pulses so that the sub-bottom layering structure is revealed. As shown in Figure 23, a distinct sediment layer is observed beneath the seafloor, and the layer thickness has a strong range-dependency. This reflection image suggests that the towed source track was across an ancient river channel, which is now buried by marine sediment.

Figure 18: This figure shows the Block Island area. The five turbines are marked in white, and the vertical line array is marked in gray at turbine #1. The red line is the track of the R/V Tioga towing a sound source for playback operations.

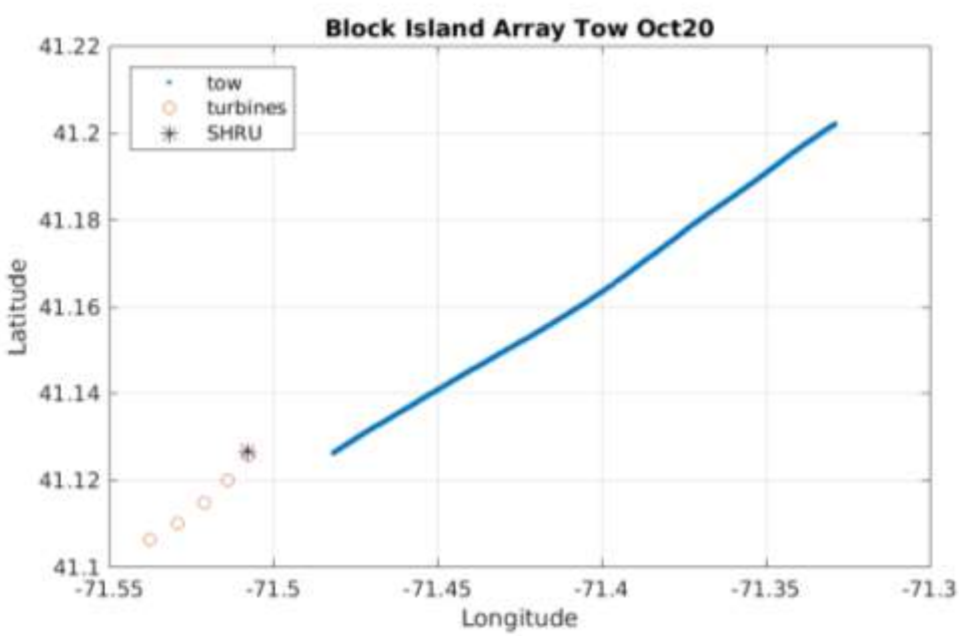

Figure 19: Locations of acoustic monitoring moorings in relation to the wind turbines

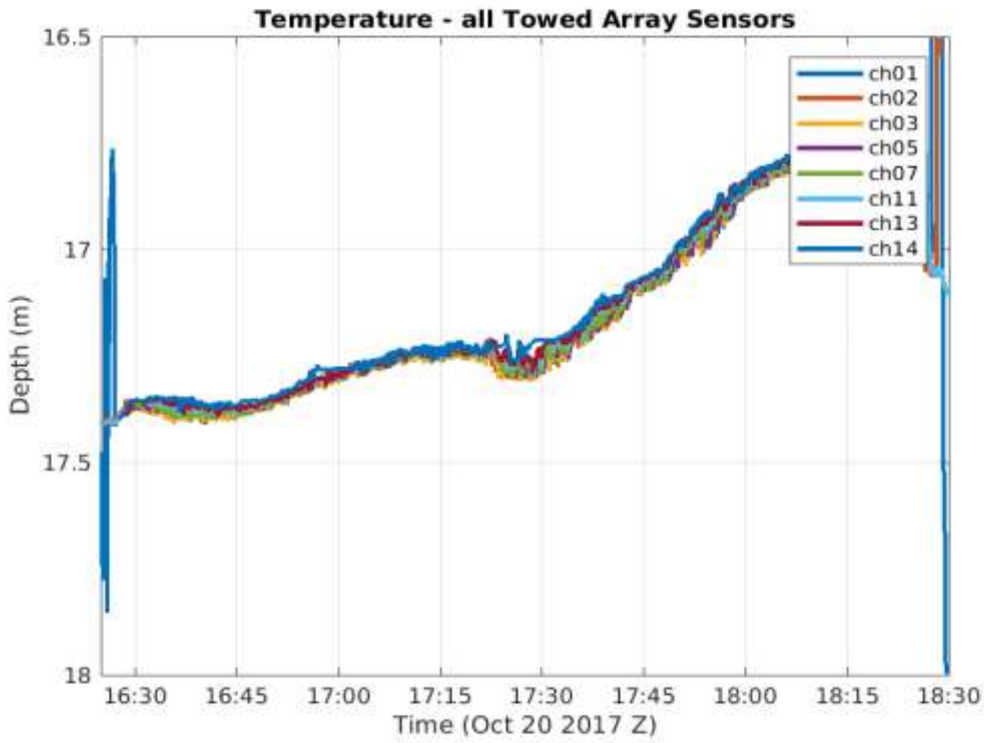

Figure 20: Temperature profile from 8 temperature sensors attached to the towed array during playback operations.

Figure 21: Locations of SBE39 t/P sensors on towed array and on the playback

Table 6: SBE39 temperature and pressure sensor locations on the towed array.

Towed Array Sensor Number	Mean Depth (Z)	SBE39 Sensor Number
1	10.1	0242
2	10.2	0291
3	9.9	0321
5	11.0	3270
7	11.2	0324
11	12.8	3126
13	13.8	0322
14	14.7	3120

Table 7: Towed array element locations along array.

Element (*recording)	Distance relative to element 1 (m)	Channel recorded/gain (Ch 7/1x - Irig-b)
1 *	0	0 / 200x
2 *	12.21	1 / 200x
3	18.86	
4 *	23.07	2 / 500x
5	33.17	
6 *	40.11	3 / 500x
7	45.37	
8	52.06	
9	56.24	
10 *	67.04	4 / 500x
11	73.28	
12 *	78.36	5 / 500x
13 *	86.83	6 / 500x
14	100.21	
15	111.53	
16	120	

Table 8: Playback transducer Lubell LL916H specifications.

Type	Piezoelectric Pistonic Acoustic Transducer
Frequency Response	200Hz – 23kHz
Maximum Output Level	180dB/uPa/m @ 1kHz
Maximum Cable Voltage/Current	20 Vrms / 3A
Recommended Amplifier Power	78 watts @ 8 ohms (25 Vrms) max
Maximum Operating Depth Range	18 meters

Table 9: Playback transmitted signals.

Frequencies transmitted	700-2000 Hz
duration	
Output Level	170 dB
Amp output voltage	21.6 / 23.8 Vrms
Function generator output	.750 Vpp / 1.05 Vpp during recovery
Depth	7 meters
Time/Location started (GPS)	15:29:15 / 41 06.6580 071 30.8682
Time/Location ended (GPS)	18:44:11 / 41 12.4607 071 18.9798
Vessel Speed (knots)	~1.8

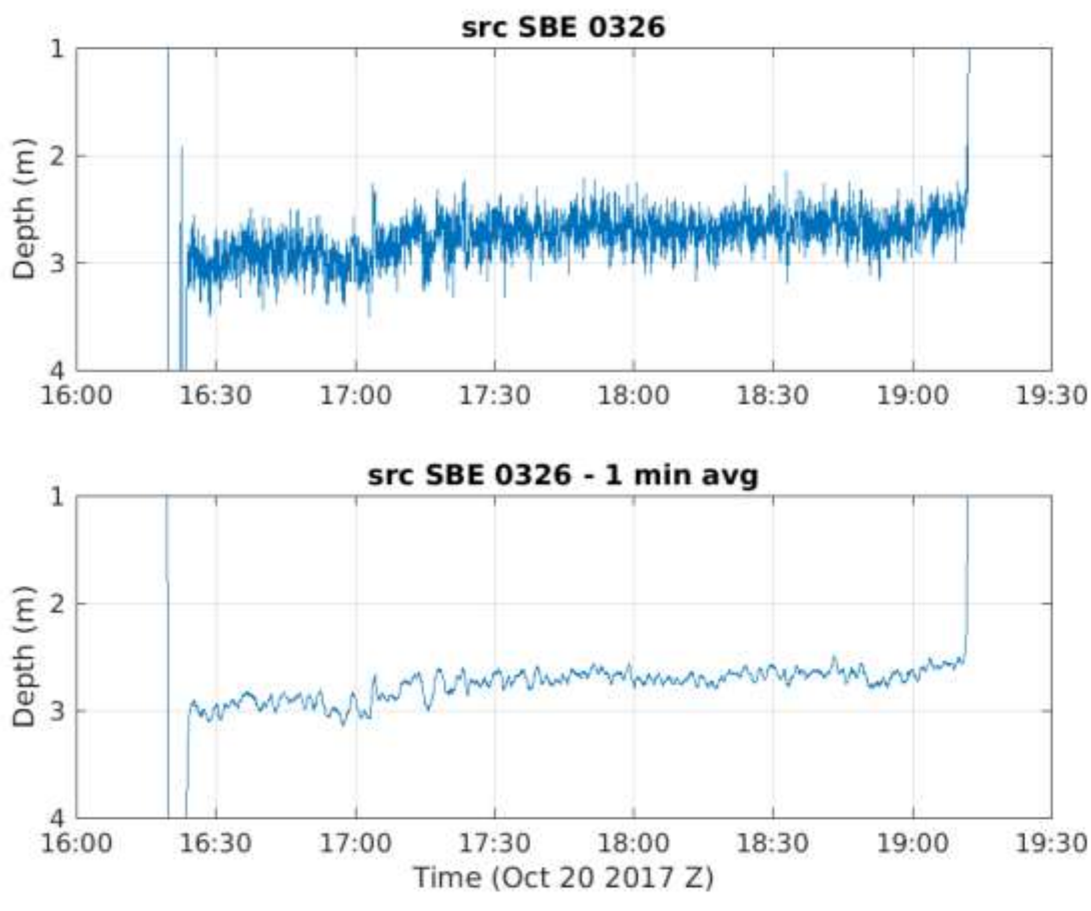

Figure 22: Depth of playback transducer

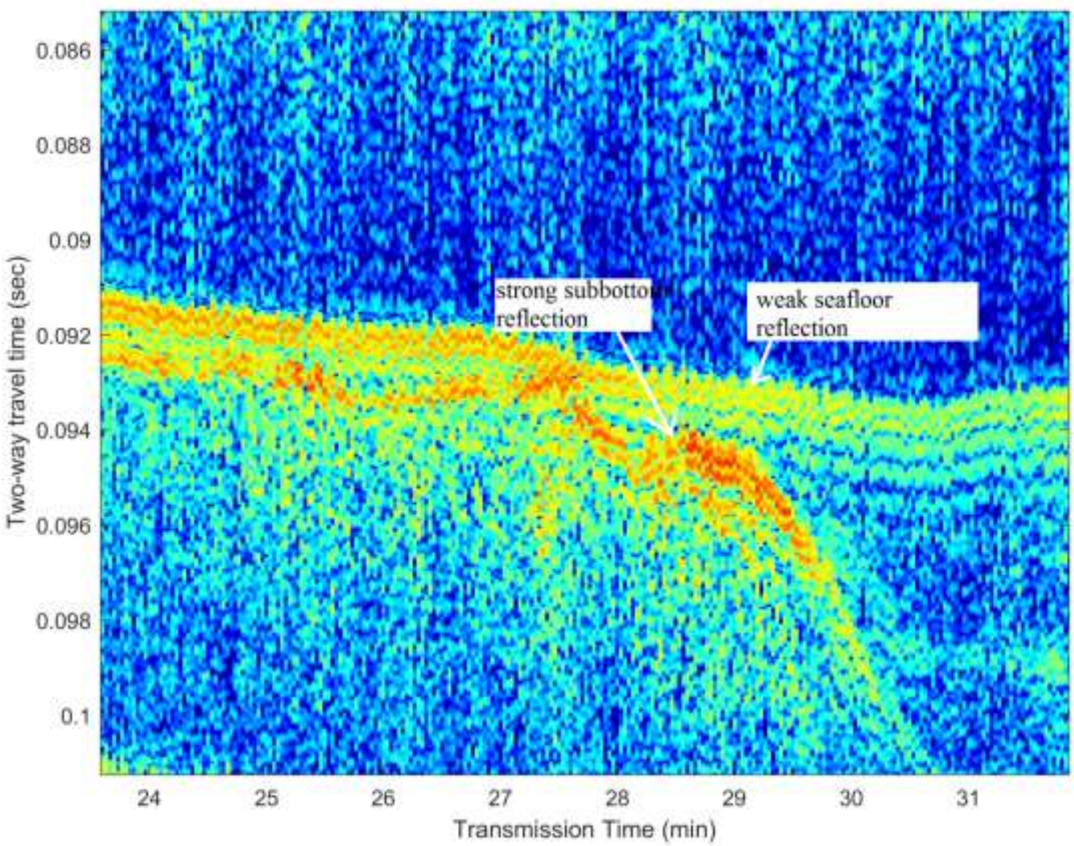

Figure 23: Bottom reflection layers resolved after pulse compression.

4. Concurrent sampling of a wind turbine in Air and water - Air/sea acoustic interaction

On Oct 2, 2017, we built a system to take concurrent air/water measurements of sound at one of the turbines at Block Island. A 3-element microphone array (Figure 29) was constructed to take advantage of array processing techniques to reduce wind and boat noise. However, the wind speeds were still too high for processing, so a single hydrophone was use to compare with the hydrophone that we lowered into the water from the side of the vessel.

The 3-element omni-directional microphone array was attached to a PVC structure. Each microphone was separated by 2.7 meters and pointed directly at the wind turbine. A single hydrophone was lowered at the same time to 5 meters depth. All four recorders were synchronized and recorded at 44.1kHz. All vessel engines were shut off to help quiet the environment.

A GoPro video camera was also attached to the array for blade speed rates. From GoPro video, the blade rate for a complete cycle at WTG1 during the recording was measured t 14 seconds or 4.6 seconds per blade. The GoPro compresses (normalizes) the audio recorded to its highest value, thus making the audio unusable due to wind and handling noise. At the closest range that recording started and listening on the deck, mechanical noise from the turbine generator was lightly noticeable.

Figure 24: Holding the omni-directional microphone array at WTG1.

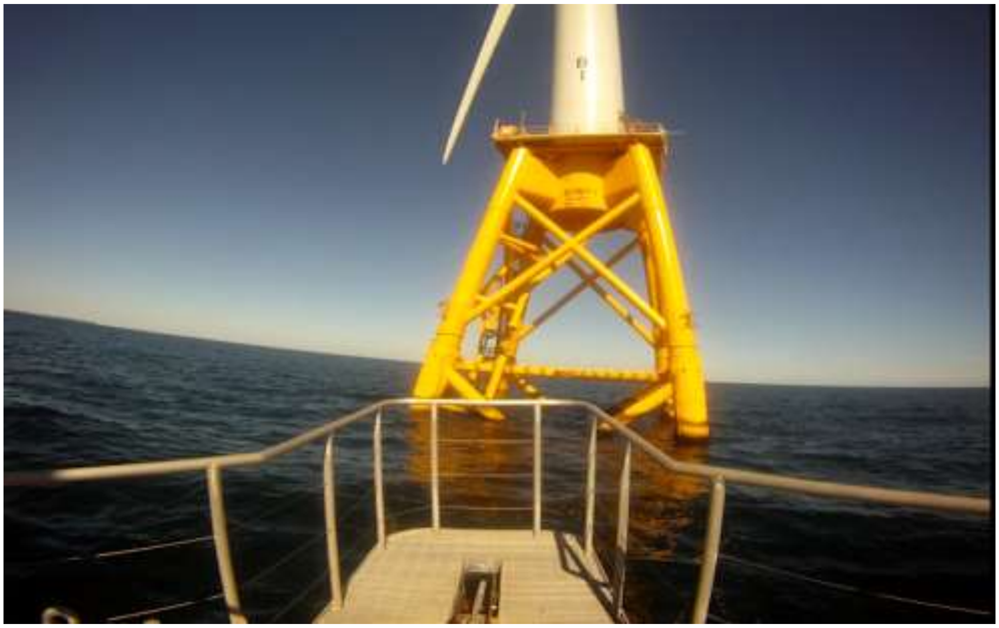

Figure 25: A single frame from the GoPro video recorder while drifting from WTG1 during sea/air sound recording.

Figure 26 shows spectrograms from each channel for the entire recording period. The three omni-direction microphones are show in the top 3 top panels and the hydrophone signal is show in the bottom panel. All four channels were synced so there is good comparison. The horizontal bars in the image separates the section that will be inspected closer.

The same signal is compared in Figures 25 and 26, looking at the higher frequency part of the signal in Figure 27 and the lower part of the signal in Figure 28. Only noise from the turbines was noticed in the lower frequencies.

Figure 29 is a comparison of the microphone signal and the hydrophone signal. It shows that the wind dominates the noise at the wind turbine, and the mechanical noise can be seen in the spectrograms. However, the wind generates much more noise than the mechanical noise. Mechanical noise at frequencies 60Hz, 70Hz and 85Hz penetrate the water surface and are received on the hydrophone up to 750m from the turbine.

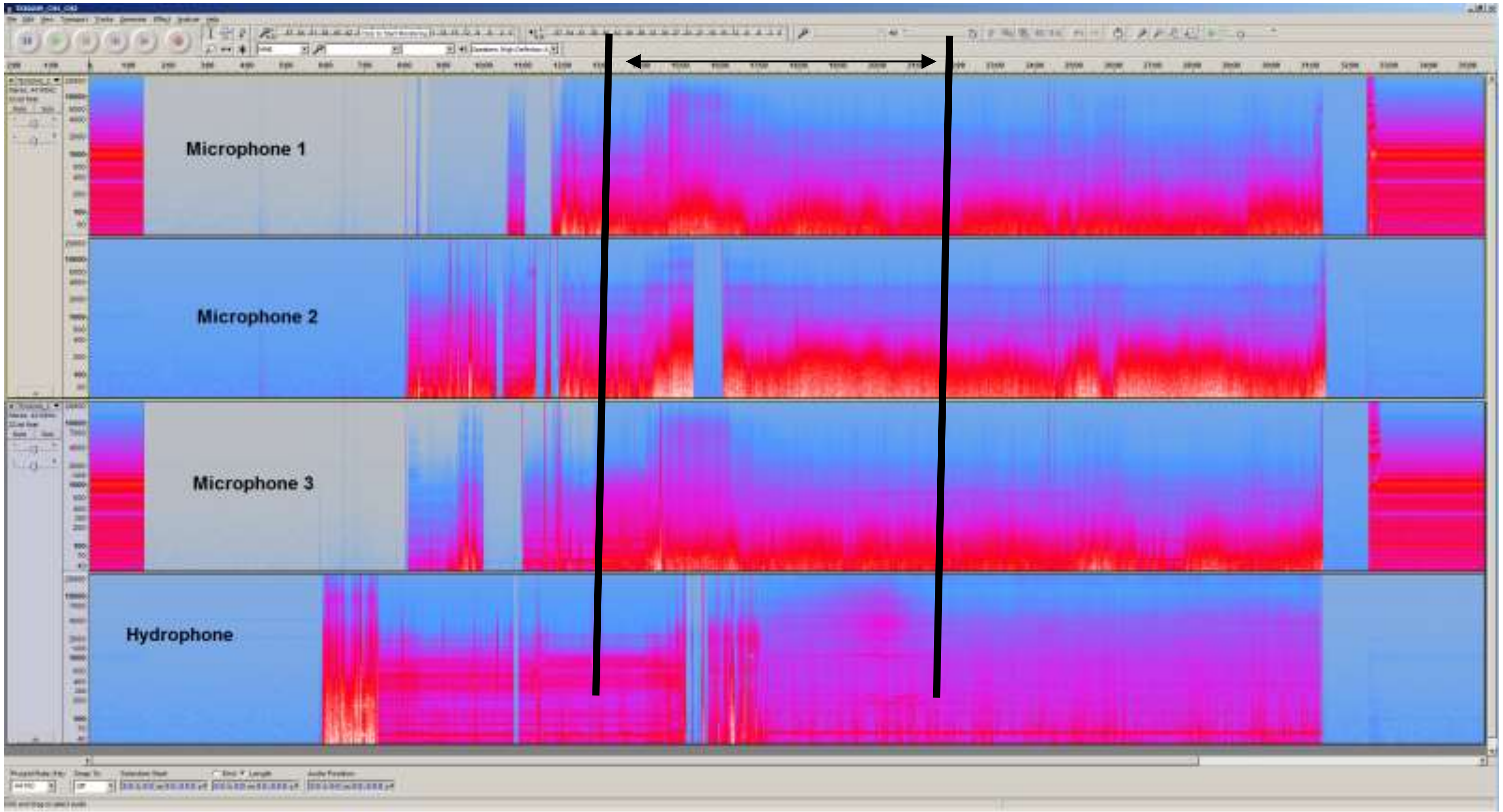

Figure 26: Spectrograms from three microphones and a hydrophone that were recording simultaneously. The black lines mark the section where the ship was drifting and the WTG1 generator noise inspected. The frequency band seen here is from 75Hz to 20kHz.

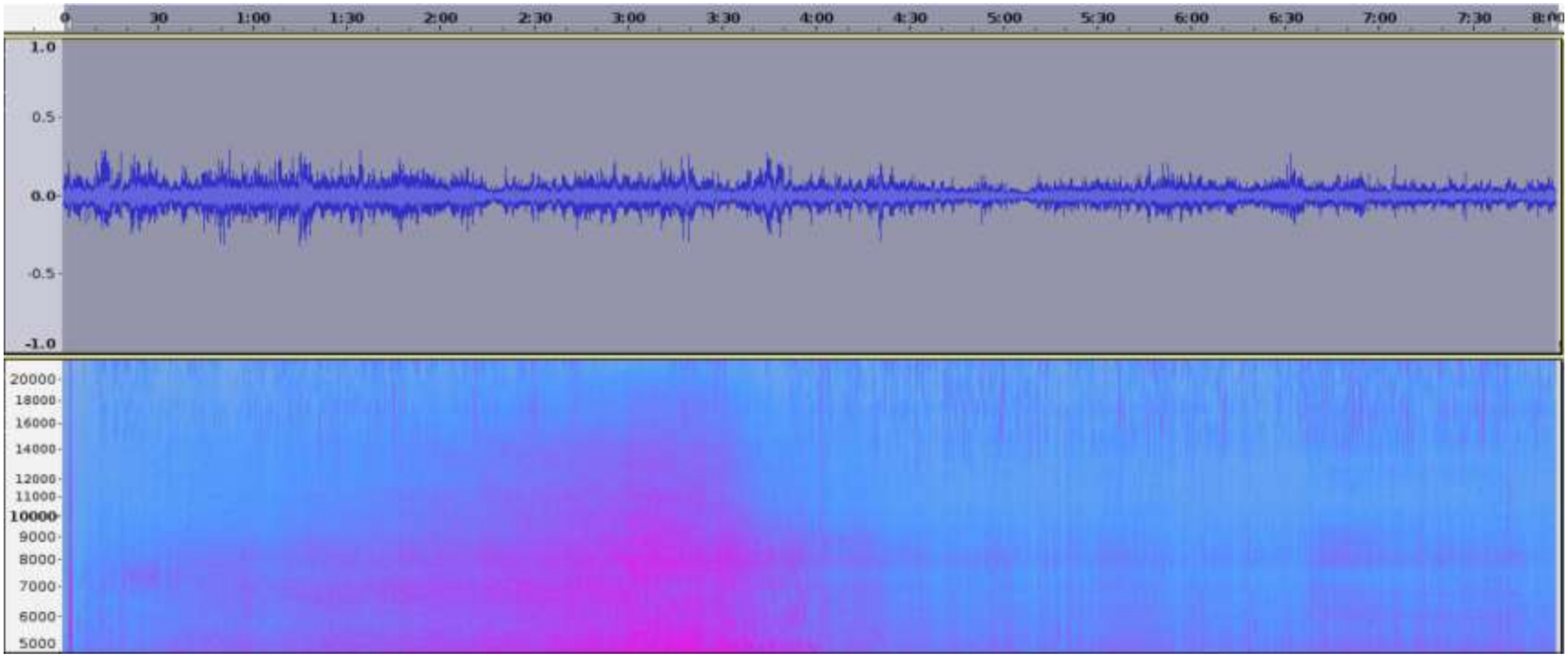

Figure 27: This figure is a look at the higher frequencies from the turbine noise from microphone #3. The top panel is the recorded signal; the bottom panel is a spectrogram from 5 kHz to 20 kHz.

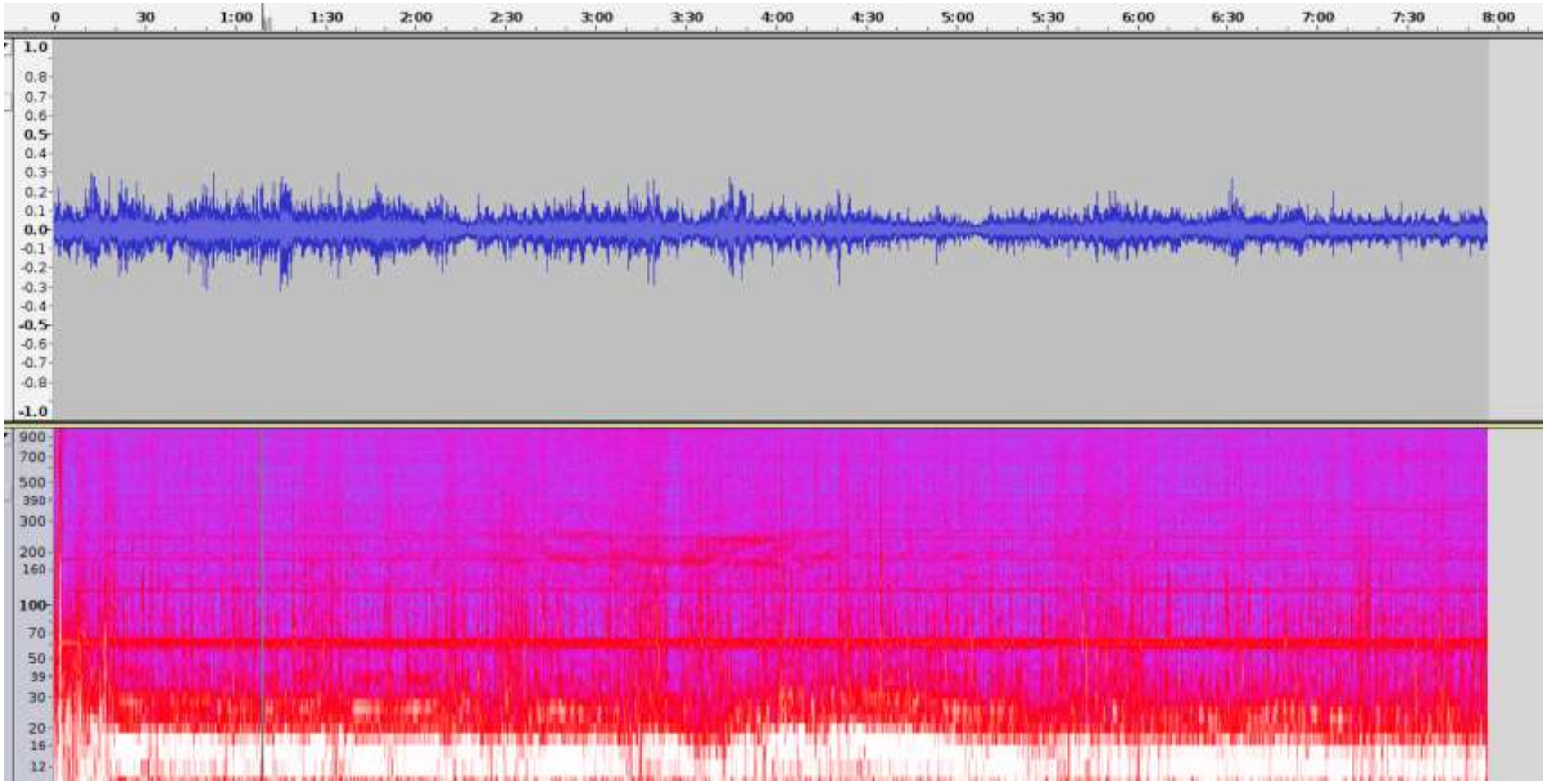

Figure 28: This figure zooms into the lower frequencies from the same signal as Figure 32 from microphone #3. It shows the low frequency noise from the turbine operation. The upper panel is the turbine signal. The lower panel is a spectrogram from 10Hz to 900Hz. Notice frequency bands in the lower frequencies.

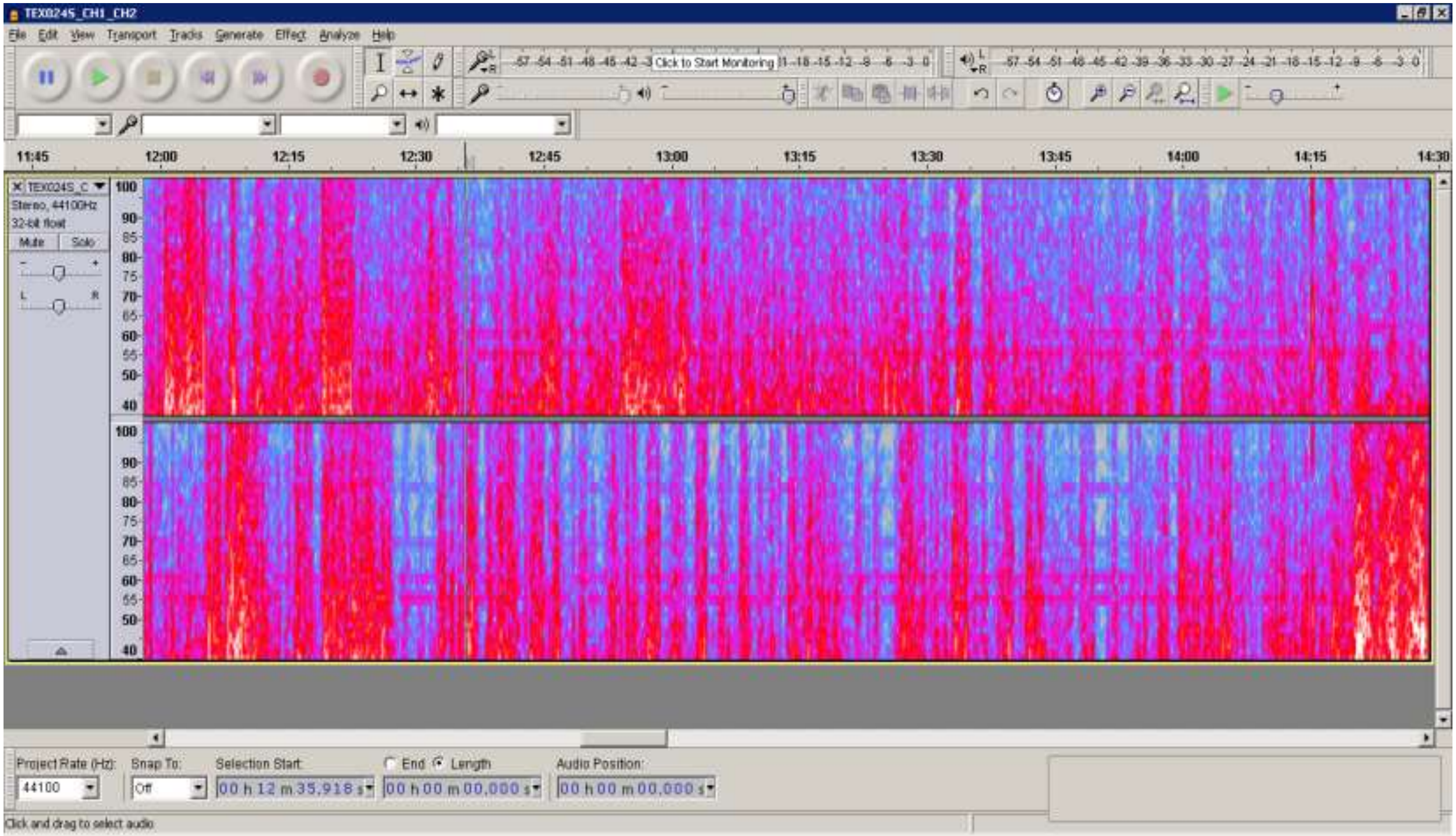

Figure 29: Comparison of low frequency signals from microphone #3 and the hydrophone 5 meters under water. The top panel is the spectrogram from microphone #3. The lower panel shows the spectrogram from the underwater hydrophone. The frequencies show here range from 40Hz to 100Hz. Periodic saturated noise from wind and waves is evident but frequency bands in the same levels are noticed in both air and water.

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