ADMIRALTY INLET PILOT TIDAL PROJECT
FERC PROJECT NO. 12690

ACOUSTIC MONITORING AND MITIGATION PLAN

Submitted by:

Public Utility District No. 1 of Snohomish County

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1.0 INTRODUCTION

The acoustic stressor from tidal turbine operation is not well-understood (Polagye et al., 2011). This uncertainty is a barrier to understanding acoustic effects of turbine noise on marine animals and, in doing so, to ensure proper resource protection.

This plan will investigate two hypotheses: (1) that the sound from tidal turbines will vary will power generation state and (2) that the sound from tidal turbines may change over time due to biofouling or component wear. Data to address these hypotheses will be collected by drifting hydrophones on the surface and cabled hydrophones on the turbine foundation, respectively. This information is essential to estimate the exposure of marine animals to turbine noise.

Through adaptive management, this information will provide for proper resource protection and suitability of marine mammal monitoring (Marine Mammal Monitoring and Mitigation Plan). Additional details regarding instrumentation on the turbines are presented in the Monitoring Plan Summary.

2.0 PROJECT DESCRIPTION

The demonstration project proposed by Snohomish County Public Utility District consists of two turbines manufactured by OpenHydro, an Irish turbine developer. Each of these turbines has a 6 m diameter outer shroud, as shown in Figure 1. These will be deployed on a gravity tri-frame, with tubular cans contacting the seabed at the vertices. Turbine hub height will be 10 m above the seabed. The OpenHydro turbines are fixed-pitch, high-solidity rotors with an open center. The rotor cassette is the single moving part and is supported by water-lubricated bearings. A permanent magnet generator is contained in the shroud surrounding the blades. Anti-fouling coatings are applied to the interior surface of the shroud, hub, and rotor blades, but the gravity frame (steel, ballasted by concrete and aggregate) is left bare. The turbine shown in Figure 1 represents the 6 m version of 4th Generation technology. The turbines deployed in Puget Sound will be 6 m variants of 7th Generation technology – the principle differences being fewer blades and more streamlined central hub.

The turbines will be deployed in northern Admiralty Inlet, Puget Sound, Washington. Admiralty Inlet is a constricted sill separating the deep Main Basin of Puget Sound from the Straits of Juan de Fuca and Straits of Georgia. At the narrowest point, between Admiralty Head and Point Wilson, the channel is approximately 5 km wide and 70 m deep. Excepting a small exchange through Deception Pass, the entire tidal prism of Puget Sound passes through this constriction, giving rise to tidal currents that routinely exceed 3 m/s (6 knots) at mid-water. The project site is approximately 1 km SE of Admiralty Head in 55 m of water (Figure 2). The project location was chosen on the basis of strong tidal currents (intensified by the proximity to the headland), negligible seabed slope (necessary to deploy the gravity foundation), separation from high vessel traffic areas (federal navigation lanes, ferry route), and ease of cable routing back to shore.

Each turbine will be connected to shore by a separate power cable. These cables will also provide power for monitoring instrumentation and fiber optic communication with the turbine and monitoring instrumentation. Turbine monitoring systems are grouped into two categories –

instruments that will be deployed for the duration of the demonstration project (fixed) and instruments that will be periodically recovered for maintenance (recoverable). This will be enabled by an Adaptable Monitoring Package (AMP) consisting of a self-aligning frame with instrumentation and a wet-mate power and fiber connector.

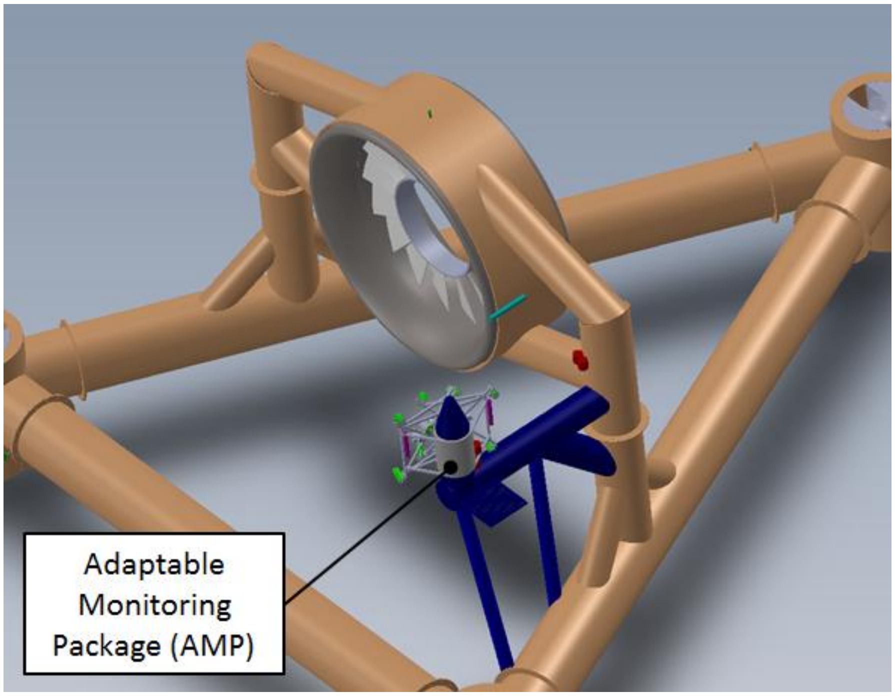
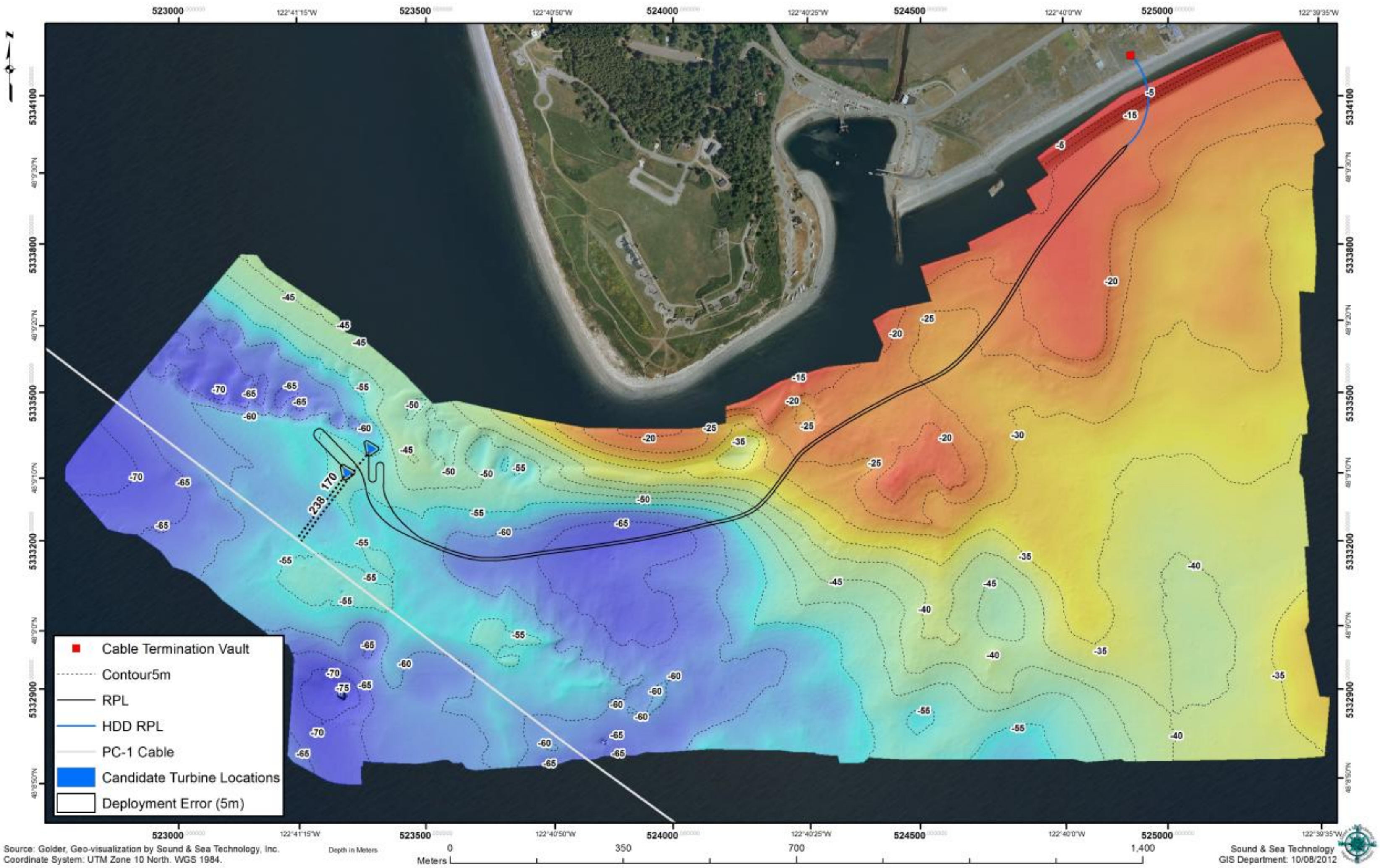


Figure 1 -- Conceptual instrumentation layout (fixed and recoverable). Instrumentation shown on a 4th Generation turbine (higher rotor solidity than 7th Generation turbine). The general dimensions of the subsea based and support structure are approximately constant between technology generations for the same rotor size.



Source: Golder, Geo-visualization by Sound & Sea Technology, Inc.
Coordinate System: UTM Zone 10 North. WGS 1984.

Figure 2 -- Turbine deployment location in northern Admiralty Inlet. Blue triangles denote turbines, each of which is connected back to shore via a separate power cable. Dashed red polygon to the east of Keystone Harbor is a marine protected area.

3.0 BACKGROUND INFORMATION

A brief summary of information about turbine sound, site-specific ambient noise, and the likely sound generated by turbines in the context of ambient for the proposed project is presented in this section. Further details are presented in Polagye et al. (*submitted*), which is appended to this plan.

3.1 Overview

There is limited information in the public domain about the sound produced by tidal turbines. Figure 3 shows one-third octave source levels estimates from measurement of a 6 m OpenHydro turbine undergoing testing at the European Marine Energy Centre (EMEC). Each blue-shaded spectrum corresponds to consecutive 8 second windows and the red spectrum is the mean of all eight measurements. The sound profile of the turbine shows considerable variability over these time scales, but tonal clusters are apparent around 40, 160, 500, and 1600 Hz. Measurements were obtained from a free-drifting surface package with a hydrophone suspended to a depth of 5 m.

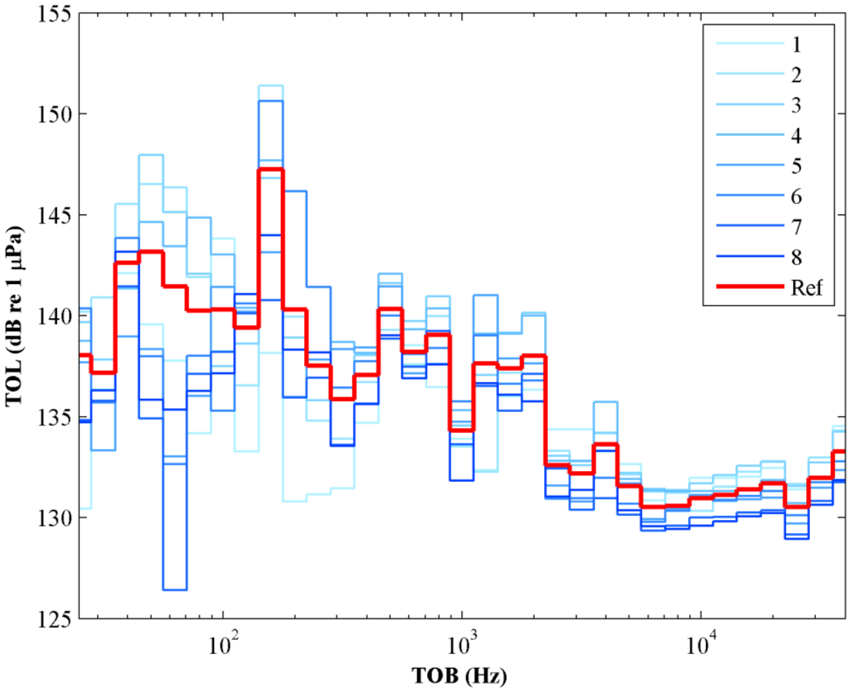


Figure 3 -- One-third octave source levels from measurements of an OpenHydro turbine at EMEC, red line indicates the mean of the 8 measurements (acoustic harassment device removed by linear interpolation). (excerpted from Polagye et al., *submitted*)

The measurements shown in Figure 3 correspond to a single operating state (inflow current velocity of 1.8 m/s). To date, no measurement campaigns have been undertaken to characterize how turbine would be expected to vary with operating state (combination of current velocity and turbine generator load).

3.2 Present Knowledge of Ambient Noise in Admiralty Inlet

Several factors contribute to ambient noise in Admiralty Inlet, including anthropogenic sound from vessel traffic, bedload transport associated with strong tidal currents, rain, biological vocalizations. At frequencies below 1 kHz, ambient noise levels are dominated by anthropogenic sound associated with commercial vessel traffic (Bassett et al., 2012). Consequently, the temporal patterns in ambient noise levels at those frequencies mirror those in commercial vessel traffic. Percentile ambient noise levels in the 25 Hz – 1000 Hz frequency range are shown in Figure 4. These data are derived from measurements of ambient noise in Admiralty Inlet described in Bassett et al. (2012) using autonomous recording hydrophones on seabed moorings. This accepted copy of the manuscript is appended to this plan.

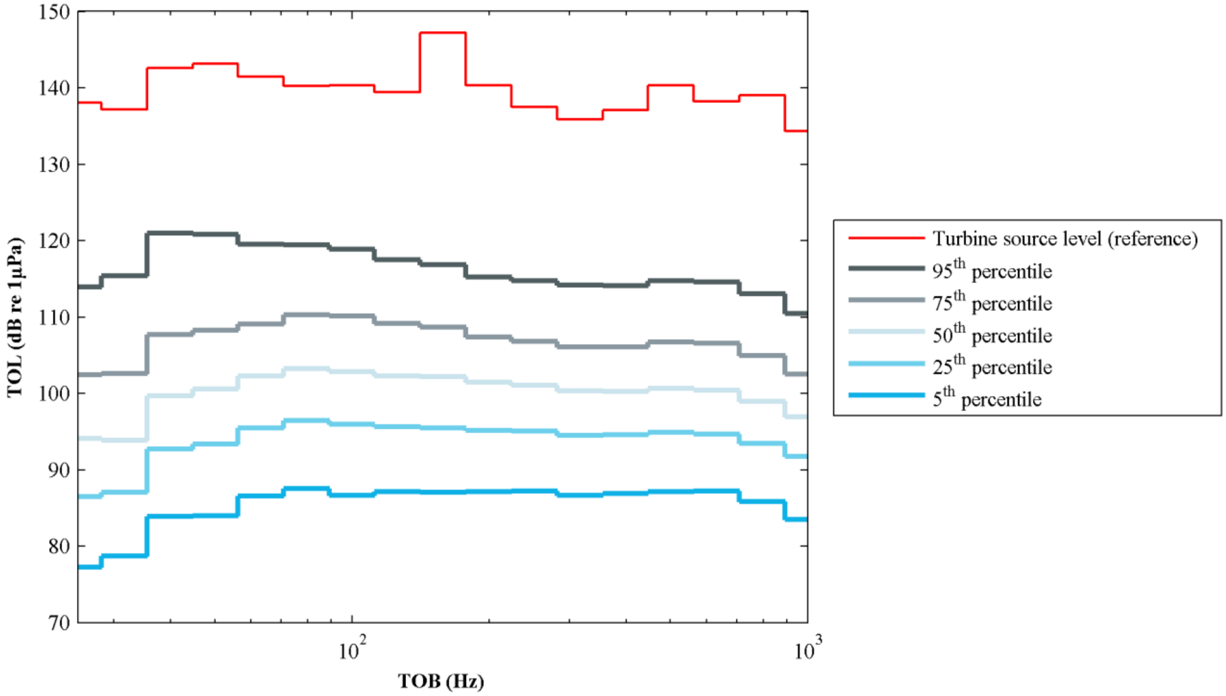


Figure 4 -- Percentile TOLs for ambient noise (25 – 1000 Hz) (excerpted from Polagye et al., *in prep*)

At frequencies above 1 kHz, bedload transport (mobilization of gravel and shell hash) is a significant sound source during periods of strong currents (Bassett et al., *in revision*). Consequently, the temporal patterns in ambient noise at those frequencies are correlated with current magnitude. Figure 5 shows median one-third octave levels (TOLs) as a function of tidal current magnitude.

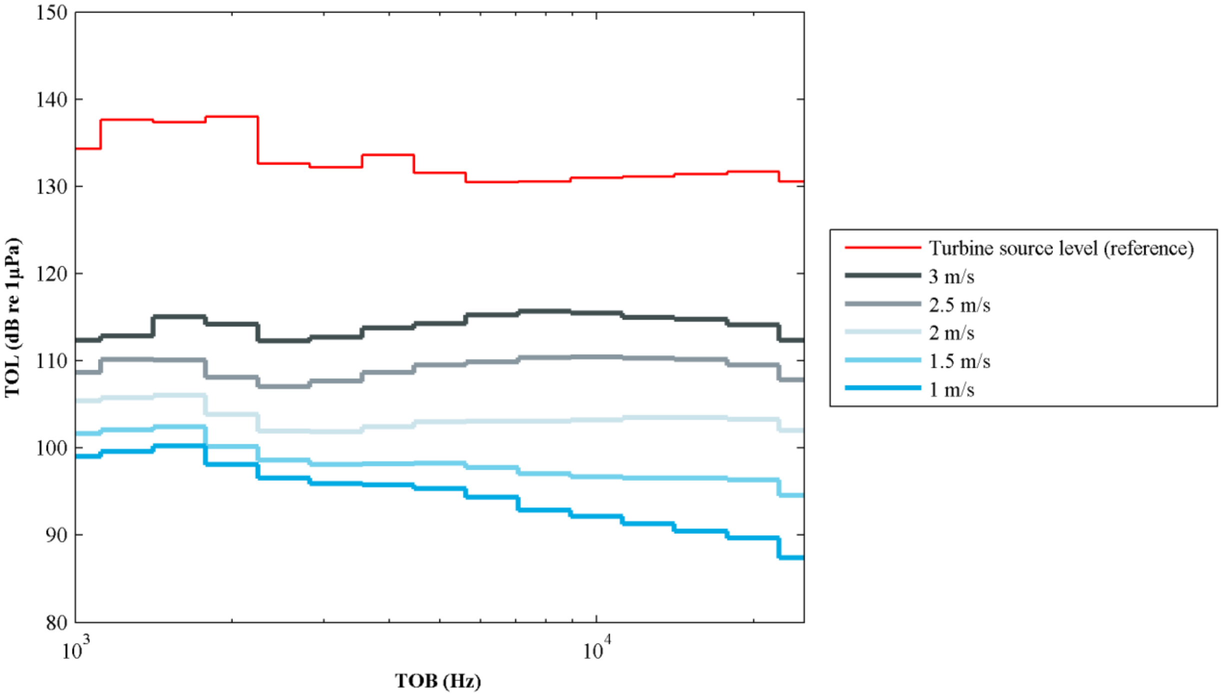


Figure 5 -- Median TOLs for ambient noise as a function of velocity (1000 – 25 000 Hz)

While rain and biological activity also are sound sources, they do not significantly influence overall sound budgets.

3.3 Pre-Installation Acoustic Effects Estimate

Polagye et al. (*submitted*) describes a framework for estimating the acoustic effects of tidal turbines in the context of ambient noise. This framework is largely structured around the concept of "signal excess" which is defined as the excess of a sound source relative to ambient noise levels in a particular frequency band (in this case, one-third octave bands). This model, described in NRC (2003), is modified to account for hearing thresholds of particularly functional hearing groups (e.g., mid-frequency cetaceans). The analysis presumes a correlation between sound intensity and the power generated by a tidal turbine, an analogue to the correlation between sound intensity and power input for underwater mechanical processes described by Hazelwood and Connelly (2005). Estimates for turbine source levels are combined with a simple, frequency-dependent propagation model to predict received levels as a function of distance to the turbines, as shown in Figure 6.

Maximum turbine source levels (radiated noise levels) are estimated to be 172 dB re 1 µPa at 1 m, corresponding to an extreme inflow condition of 3.6 m/s. The expected temporal variability in turbine sound levels is shown in Figure 7, based upon the measured distributions of current velocity at the project site (Polagye and Thomson, *in press*).

Figure 8 shows the fraction of one-third octave bands of turbine sound that are likely to be detected relative to ambient noise, given the variations in turbine sound and ambient noise for four different inflow velocity conditions. This is for a hydrophone with an assumed uniform sensitivity over all frequencies of interest (marine animal detection of turbine sound will have a frequency dependence due to auditory thresholds). Deep reds denote conditions under which the majority of sound from a turbine would likely be identified during a characterization study. Cool colors denote conditions under which only a few one-third octave bands might be distinguishable from ambient noise. For example, at an inflow velocity of 1.5 m/s, the full spectrum of turbine sound would not likely be identifiable at any range from the turbine, whereas, at 2.5 m/s, turbine sound would likely be identifiable in a majority of one-third octave bands to a range up to a few hundred meters. This information serves to structure the approach for post-installation characterization of turbine sound described in this plan.

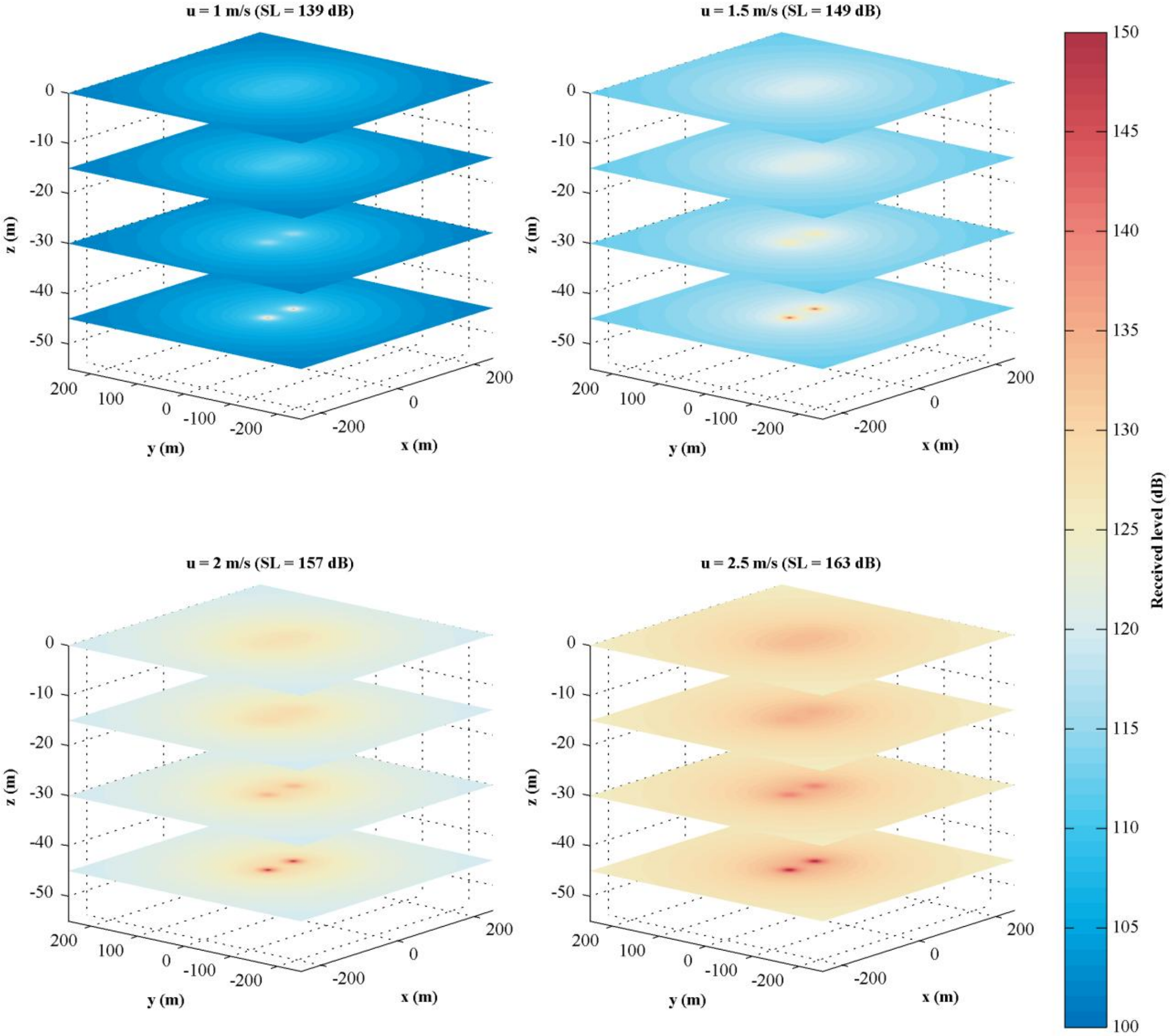


Figure 6 -- Horizontal slices of broadband turbine sound field at different inflow velocity conditions, based on analysis from Polagye et al. (*submitted*). The sound patterns associated with the pair of sources are only distinct at close range (i.e., within 100 m).

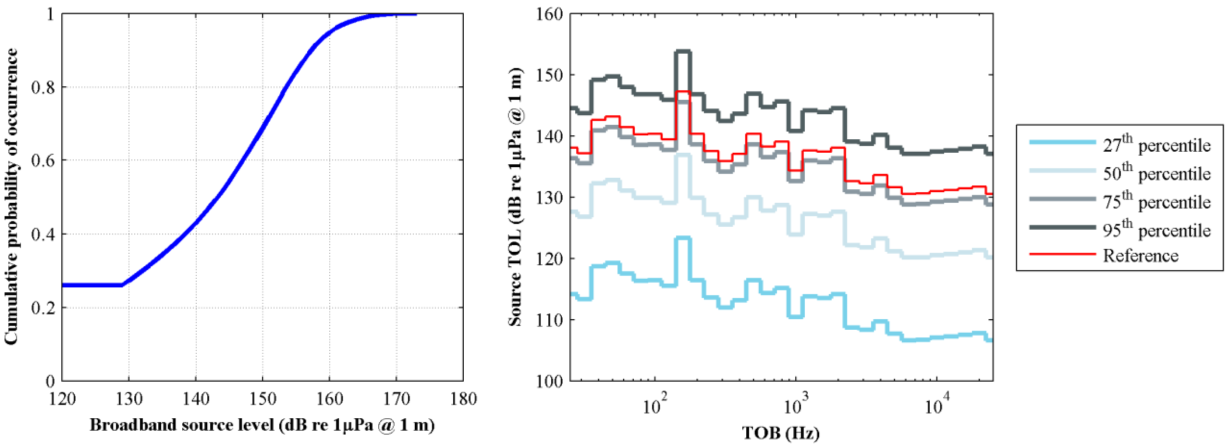


Figure 7 -- Probability distribution of turbine source levels. (left) Broadband (25 – 25 000 Hz). (right) One-third octave source levels for select percentiles. Turbine operation begins at the 27th percentile currents. (excerpted from Polagye et al., *submitted*)

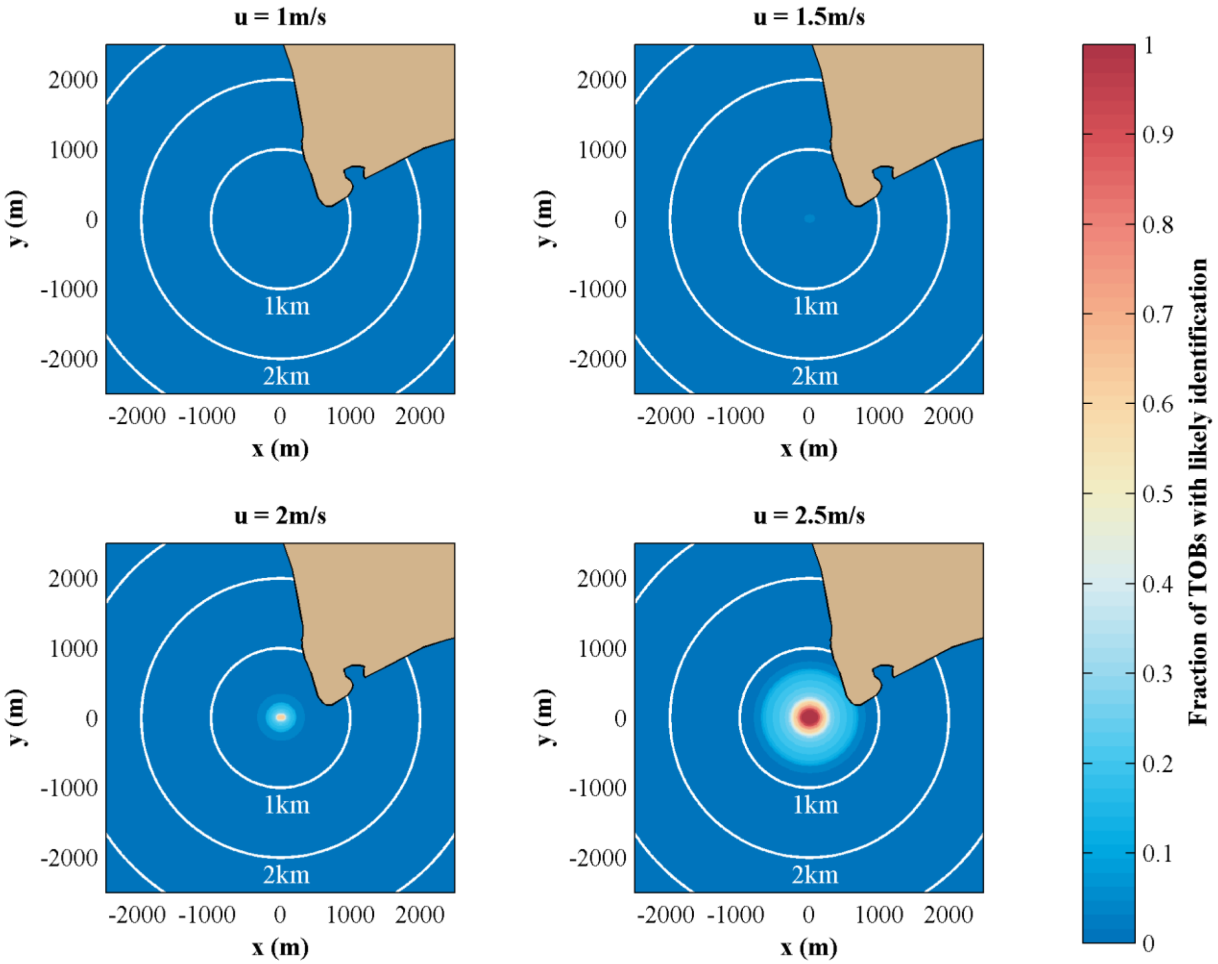


Figure 8 -- Fraction of one-third octave bands likely to be identified relative to ambient noise (at least 75% probability, 25 – 25 000 Hz) at four inflow velocities (5 m depth relative to surface). (excerpted from Polagye et al., *submitted*)

4.0 PLAN OBJECTIVES AND GOALS

As a means to assure that the License provides proper resource protection, the goal of this Acoustic Monitoring and Mitigation Plan is to measure and describe the sound profile of the Project and to modify the Project or monitoring plan, or both, based on results of monitoring. To accomplish this, the District will evaluate two hypotheses:

- *Hypothesis 1:* Turbine sound will vary with power generation state
- *Hypothesis 2:* Turbine sound may demonstrate a long-term variation due to wear on bearings or biofouling of the rotor and shroud.

The District will confer with the Marine Aquatic Resource Committee (MARC) to consider modification of the Project and/or this Plan in response to the results of acoustic monitoring efforts. NMFS will use the results of the Acoustic Monitoring and Mitigation Plan to evaluate the assumptions contained in the analyses under the Marine Mammal Protection Act and the Endangered Species Act; and based on the results FERC may need to reinitiate consultation.

5.0 POST-INSTALLATION MONITORING AND MITIGATION PLAN

5.1 Relation between Turbine Noise and Power Generation

5.1.1 Objective

Turbine sound is likely to vary with power generation state (i.e., higher intensity sound will be produced when the turbines are closer to their rated capacity than around cut-in speed). However, no studies to date have rigorously assessed this relation. Pre-installation estimates (Sec. 3.3) indicate that if sound from turbines does vary with power generation state, the extent of marine mammal detection of this sound will also be a strong function of power generation state. Understanding time-varying nature of turbine sound is central to evaluating the acoustic effects for large arrays and informing engineering design decisions that could enable quieter turbines.

5.1.2 Data Collection

Equipment Description

Acoustic data will be collected using surface drifters – specifically, the SWIFT (Surface Wave Instrumentation Float with Tracking) float described in Thomson (2012). This is a buoyant spar buoy equipped, for this application, with a radio frequency transmitter, GPS logger, and hydrophone. The hydrophone will be a Loggerhead DSG (www.loggerheadinstruments.com). This is an autonomous recorder connected to a Hi-Tech hydrophone (HTI-96-MIN). The hydrophone, when accounting for the internal preamplifier, had an effective sensitivity of -165.9 dB µPa V^{-1}. The frequency response of the hydrophone and data acquisition system is linear (±3 dB) from 20 Hz to 80 kHz. The Loggerhead hydrophones will be configured to sample continuously at 80 kHz (pre-installation measurements suggest the noise floor will be around 30 kHz). The hydrophone response will be compared to a calibration standard before and after testing to ensure accurate comparisons between multiple drifters, as discussed later in this plan.

When attached to the SWIFT, the hydrophone will be 1 m below surface. Received levels will vary with depth, particularly at relatively close range to the turbines (i.e., with 100 m). Depending on consultation with the MARC, following initial surveys, further surveys with cabled hydrophones may help to characterize this depth variation. However, the autonomous drifters at a fixed depth will be most effective to resolve the relation between turbine noise and power generation state.

The sound velocity profile will be measured periodically during surveys using a “time of flight” profiler. Water quality information collected during pre-installation studies indicate that the water column is generally well-mixed over the Admiralty sill on account of the vigorous tidal exchange, but a complete description of the acoustic medium is a best practice for studies of underwater noise.

An Automatic Identification System (AIS) receiver deployed on Admiralty Head in cooperation with Washington State Parks will be used to monitor vessel traffic and confirm that noise from commercial vessels is not masking turbine sound.

Doppler profilers mounted to the turbine foundations will monitor tidal currents throughout the acoustic survey in post-installation surveys. These will collect velocity data at a sampling rate of 1 Hz. The turbine Supervisory Control and Data Acquisition (SCADA) will monitor the power output from the turbine, also at a sampling rate of at least 1 Hz. In combination, acoustic, velocity, and power data will be used to understand if short-term fluctuations in turbine sound are correlated to short-term fluctuations in power generated. In pre-installation surveys, current velocity will be monitored by a vessel-mounted Doppler profiler.

Survey Procedure

Surveys will be conducted for nominal inflow velocity conditions of 1.0, 1.5, 2.0, and 2.5 m/s. The pre-installation sound estimates described in Polagye et al. (*submitted*) indicate that turbine sound will not likely be detected for inflow velocity of 1.0 m/s, only be detectable at close range (i.e., < 100 m distance) for inflow velocity of 1.5 m/s, detectable over a few hundred meters at 2.0 m/s, and detectable of several hundred meters at 2.5 m/s.

These surveys will be conducted during ebb or flood tides, as there is no known mechanism for a different turbine sound profile between ebb and flood at equivalent inflow velocities. Survey timing will be based on a prediction of sustained current magnitude (i.e., 10 minute average) greater than 2.5 m/s at hub height during the peak of the particular tidal cycle. Surveys at the inflow conditions listed above will be initiated based on real-time information from the Doppler profiler on Turbine 1 for post-installation measurements (velocities are likely to be similar between the two turbines) and a vessel-mounted Doppler profiler for pre-installation measurements.

During surveys, vessel traffic will be monitored using the AIS receiver on Admiralty Head and surveys will not be initiated if vessel noise is likely to mask turbine sound. Masking is likely to occur if large commercial vessels are within 10 km of the study area. Pre-installation studies of ambient noise (Bassett et al., 2012) show a “lull” in vessel traffic from 0200 – 0500 local time. Surveys will be conducted within this window to improve the probability of vessels not being present during the study, which will maximize the signal to noise ratio for measurements of turbine sound.

For each survey (i.e., measurement at a particular current velocity), 5 hydrophone-equipped SWIFT buoys will be deployed from a surface vessel. Prior to buoy deployment, a sound velocity profile will be collected to within 5 m of the seabed. Buoy position will be referenced to the "acoustic center" of the turbine array – the mid-point of a line connecting the center of mass of the two turbines.

At the start of each survey, buoys will be deployed upstream of the turbines on the principal current axis at distances of:

- **Buoy 1**: 125% of expected acoustic extent from pre-installation studies at survey inflow velocity (verify extent of turbine noise)
- **Buoy 2**: 800 m from acoustic center (evaluate received levels)
- **Buoy 3**: 400 m from acoustic center (evaluate received levels)
- **Buoy 4**: 200 m from acoustic center (evaluate received levels)
- **Buoy 5**: 100 m from acoustic center (evaluate received levels)

Buoys will drift and record sound until the buoy initially deployed furthest from the turbine deployment site passes its closest point of approach to the turbine deployment site.

Surveys will be conducted prior to turbine installation, following the installation of the first turbine, and following the installation of the second turbine. Each condition (e.g., ambient baseline, single turbine, two turbines) will be measured over three tidal cycles meeting the criteria for maximum sustained current velocity at the turbine deployment site (2.5 m/s).

The total data set will consist of these drifting measurements, from five buoys, during sixty-four surveys (four velocity states measured on the rising and falling tide nine times in total). This corresponds to 320 time series, each several minutes in duration, that will be post-processed.

Doppler profilers on the turbines will monitor hub-height current velocity throughout the acoustic survey for post-installation measurements. The turbine SCADA will monitor power generation state during the acoustic survey. Hub-height current velocity will be monitored by a vessel-based Doppler profiler for pre-installation measurements.

In summary, the time series that will be analyzed will include: acoustic pressure (measured by the hydrophone), hydrophone position (measured by the GPS logger), commercial vessel position (measured by the AIS), turbine inflow velocity (measured by a Doppler profiler), and turbine power generation (measured by the SCADA, for post-installation monitoring).

5.1.3 Data Analysis

Analysis of acoustic data will utilized the same Fourier transform method as Polagye et al. (*submitted*), with *post hoc* selection of analysis windows that provide the best interpretation of acoustic data. Analysis of sound intensity will be by one-third octave bands from 15 Hz to 25 kHz (i.e., one-third octave levels, TOLs). It is desirable to understand how the turbine "source level" varies with power generation state. For sound sources as large as a tidal turbine where sound will be produced at many points around the rotor and foundation, "source levels" at a range of 1 m are an abstraction. For this reason, it has been proposed to describe such extrapolations as "radiated noise levels" at a 1 m reference (discussion at BOEM workshop on underwater noise, March, 2012). Here, we use "source level" synonymously with "radiated noise levels".

Turbine acoustic signature: Using data from a single buoy, ambient noise spectra (pre-installation measurements) will be compared to spectra recorded during the operation of a single turbine (first round of post-installation measurements) under equivalent tidal current and vessel traffic conditions. One-third octave bands with statistically higher sound intensities will correspond to turbine sound (i.e., distinguish turbine sound from ambient noise).

Relation to between received levels and power generation state: Using data from a single buoy, received levels associated with turbine sound will be compared for equivalent distances and inflow velocities (i.e., 1.0, 1.5, 2.0 and 2.5 m/s). Trends in received levels will be quantified for one-third octave bands.

Increase in noise for multiple turbines: Using data from a single buoy, the sound from single-turbine operation (first round of post-installation measurements) will be compared to two-turbine operation (second round of post-installation measurements) at equivalent distances, power generation states, and vessel traffic conditions. The expectation is that turbines will act as incoherent sound sources, with broadband sound pressure levels increasing by no more than 3 dB with two turbines operating in comparison to one turbine operating.

Source level: Using data from all buoys during a single survey with only one turbine in operation, the source level will be estimated by fitting a transmission loss coefficient to each one-third octave band (i.e., *N*log). This analysis will be repeated for all surveys. In combination with results of other analyses, this information will be used to quantify the trend in source level with power generation state. In addition to one-third octave levels, source levels will also be estimated for root mean square (rms) sound pressure levels corresponding to four functional hearing groups established by NMFS (2012). The low frequency limit for each group is shown in Table 1. The high-frequency limit will be determined, in consultation with the MARC, based on the maximum frequency of sound produced by operating turbines, as determined by this study. Note that these limits correspond to a "box car" filter and, therefore, do not roll off in the same manner as the M-weightings described in Southall et al. (2007).

Table 1 -- Low-frequency hearing limits for functional groups established by NMFS (2012)

Functional Group	**Low Frequency Limit**
Low-frequency cetaceans	7 Hz
Mid-frequency cetaceans	150 Hz
High-frequency cetaceans	200 Hz
Pinnipeds	75 Hz

5.1.4 Reporting and Adaptive Management

An oral report will be made to the MARC within 60 days of survey completion describing the survey and presenting preliminary results. Final written and oral reports will be made to the MARC within 120 days of survey completion.

Based on the final results, the MARC may recommend additional surveys be undertaken to further decrease uncertainty and ensure resource protection.

5.2 Long-term Variation in Turbine Noise

5.2.1 Objective

If, over the time, the bearings on the turbine experience wear or the rotor and shroud are fouled (in spite of anti-fouling coatings), the sound profile of the turbine may vary. Information about long-term trends in noise is needed to evaluate acoustic effects over the operating life for a commercial project (nominally 25 years). While this pilot project will be substantially shorter in duration at five years, this time frame does correspond to expected maintenance intervals and information about trends in the acoustic signature of a device will be instructive.

5.2.2 Data Collection

Equipment Description

Acoustic data will be collected by a hydrophone with a flow shield that is integrated into the adaptable monitoring package (AMP). A flow shield is necessary because the frequencies of turbine sound overlap with the frequencies of turbulence-induced pseudo-noise for an unshielded hydrophone. The hydrophone will be cabled to shore and recovered/serviced/redeployed every 3-6 months in order to maintain the flow shield. The low-frequency version of the icListen “smart” hydrophone (www.instrumentconcepts.com) is compatible with the overall post-installation monitoring system and is one possible option for long-term monitoring. Each turbine will be equipped with a cabled hydrophone of this type.

Collection Procedure

The AMP will be located within the acoustic near-field of the turbine. This precludes direct monitoring of source levels (i.e., radiated noise levels at 1 m), but will be suitable to compare relative changes in the acoustic signature of the turbine over time. Acoustic data will be streamed to shore via the instrumentation cable and archived on a 5% duty cycle spread out evenly over the quarter with each sample being 10 seconds in duration. Sample duration is in alignment with recent guidance on ambient noise characterization (NMFS, 2012). This duty cycle and sample duration will produce approximately 40,000 samples per quarter and is sufficient to achieve robust statistics without an unnecessary burden on the archiving and analysis of data.

Vessel traffic patterns will be monitored continuously using the AIS receiver on Admiralty Head.

Doppler profilers mounted to the turbine foundations will monitor tidal currents at a sampling rate of 1 Hz. The turbine Supervisory Control and Data Acquisition (SCADA) will monitor the power output from the turbine, also at a sampling rate of at least 1 Hz.

In summary, the time series that will be analyzed will include: acoustic pressure (measured by the cabled hydrophone), commercial vessel position (measured by the AIS), turbine inflow velocity (measured by the Doppler profiler), and turbine power generation (measured by the SCADA).

5.2.3 Data Analysis

Observations will be stratified by inflow velocity and retained for conditions corresponding to the characterization survey (i.e., 1.5, 2.0, and 2.5 ± 0.2 m/s). Periods in which vessel traffic is within 10 km of the turbine will be excluded.

On a quarterly basis, time series analysis will follow the same procedure applied to the turbine sound characterization study. One-third octave levels (TOLs) and broadband sound pressure levels for these three power generation states will be evaluated. In addition, root mean square (rms) sound pressure levels will be calculated for the four functional hearing groups described in § 5.1.3.

5.2.4 Reporting and Adaptive Management

If the mean, broadband sound pressure level increases by more than 5 dB relative to the mean broadband sound pressure level during the first quarter of operation and there are no obvious contributions from local anthropogenic sources (i.e., construction activities), the increase in noise will be ascribed to a change in the acoustic properties of the turbine and the MARC will be convened. Biofouling/colonization information from the Benthic Habitat Monitoring and Mitigation Plan will inform discussions with the MARC.

Cumulative probability distributions by one-third octave band, broadband sound pressure level, and the four functional hearing groups will be made available to the MARC within 30 days of the end of each quarter.

If post-installation noise characterization (§ 5.1) suggests that turbine sound is not dependent on power generation state or a weak function of power generation state, the MARC will determine if the stratification of results by velocity is unnecessary.

6.0 APPROACH TO ADAPTIVE MANAGEMENT AND MITIGATION

In implementing this Acoustic Monitoring and Mitigation Plan, the District will confer with the MARC as appropriate on the technical issues described above and data interpretation associated with the monitoring. This will include consideration of results from monitoring efforts and subsequent adjustments to monitoring, project operation, and removal methods.

The District will follow the procedures described in the Adaptive Management Framework when conferring with the MARC on implementation of the Acoustic Monitoring and Mitigation Plan and considering how to address the results of the monitoring.

Adaptive Management and Mitigation Trigger 1: If acoustic monitoring (drifting surveys or long-term monitoring) indicate received levels at any distance from the operating turbines has the potential to injure marine mammals, the District will modify Project operations to ensure that received levels are below this threshold. The District will develop modifications in consultation with the MARC, and will obtain NMFS' approval for any specific mitigation measures. Until the modifications are implemented, the District will engage the brake on the turbines or take other actions to reduce received levels to below the thresholds cited above. The District may also need to modify its monitoring plan if the information shows this is necessary for proper resource protection purposes.

Adaptive Management and Mitigation Trigger 2: If post-installation characterization surveys identify a larger area than the pre-installation estimate within which received levels exceed thresholds for Level B Harassment (MMPA Level B harassment is currently considered to occur for all exposures above 120 dB_{rms} SPL), the District will coordinate with the MARC to determine if modifications to Project operations are necessary to reduce the ensonified area to be consistent with the MMPA Authorization. The District will develop modifications to the Project and/or monitoring plan in consultation with the MARC, will obtain NMFS' approval for any specific mitigation measures.

Adaptive Management and Mitigation Trigger 3: Within 120 days of completion of the surveys to characterize the turbines' sound profile, a final report will be presented to the MARC by the District. The MARC will review this information and determine whether acoustic information is sufficient for decision making purposes or whether additional data collection is required to ensure proper resource protection. If the MARC determines that additional data is needed, the District will collect the additional information.

Adaptive Management and Mitigation Trigger 4: Following the first quarter of turbine operation, turbine sound statistics will be reviewed by the MARC to establish triggers for further adaptive management (i.e., determine the level of increase recorded by long-term monitoring that triggers further analysis for shifts in the underlying ambient noise).

Adaptive Management and Mitigation Trigger 5: Based on the results of the turbine noise characterization described in § 5.1, the MARC will establish a high-frequency limit for reporting rms sound pressure levels for the four functional groups of marine mammals.

By June 30 of each year of the license, the District will develop and file with the Commission an annual report fully describing its implementation of the Acoustic Monitoring and Mitigation Plan during the previous calendar year, the results of the monitoring, and a list of the proposed activities during the current calendar year. The District will develop the report in consultation with the MARC. The Annual report will provide the following:

- A summary of actions implementing the Plan, including any modifications to the Project, and the results of monitoring pursuant to this Plan.
- A summary of any issues or concerns identified by the District or other members of the MARC during the year regarding implementation of the Acoustic Monitoring and Mitigation Plan and results of the monitoring.

- A list of any changes to the Acoustic Monitoring and Mitigation Plan proposed by the MARC and how the District will address those proposed changes.
- A list of Acoustic Monitoring and Mitigation Plan activities planned for the current and next year.

As provided in the Adaptive Management Framework, the MARC will have at least 30 days to review and comment on a draft of the report prior to the District filing with the Commission. Modifications to the Acoustic Monitoring and Mitigation Plan will be implemented upon the Commission's approval. The District will provide copies of the final annual report to the members of the MARC. The District will also file MARC comments with the report itself.

7.0 REFERENCES

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Attachment 1

Submitted version of "A framework for detection of tidal turbine sound: A pre-installation case study for Admiralty Inlet, Puget Sound, Washington (USA)"