APPENDIX 7-A: NOISE ATTENUATION MODELLING RESULTS

This appendix describes the method and results of modelling undertaken to understand the distance in which noise generated from construction and operation of the proposed project would attenuate to underwater background levels (i.e., distances from which the proposed project noise becomes indistinguishable from background noise).

7.A.1 BACKGROUND

This section provides background information useful to understand the methodology and results of noise modelling. This includes a description of the types of underwater noise metrics used, the grouping of wildlife species into 'functional hearing groups' and introduces the concept of impulsive and non-impulsive noise sources.

7.A.1.1 Underwater Noise Metrics Area

Underwater sound amplitude is measured in decibels (dB) relative to a fixed reference pressure (p0 = 1 micro Pascal [μPa]) or reference energy level (1 μPa^2●s)[1], and are grouped by the following common descriptors:

- Peak Sound Pressure Level, dB_{peak} ($_{peak}$ SPL, measured in dB re: 1 μPa)
- Root mean square SPL, dBrms ($_{RMS}$ SPL, measured in dB re: 1 μPa)
- Sound exposure level, dB_{SEL} $_{(SEL}$, measured in dB re: 1 μPa^2●s)[2]

The peak SPL metric is the maximum instantaneous SPL in a stated frequency band attained by an acoustic event. The peak metric is commonly quoted for impulsive sounds, but does not account for the duration or bandwidth of the sound. At higher intensities, the peak SPL can be a valid criterion for assessing whether a sound is potentially injurious or may cause behavioral implications to a marine receptor.

The RMS SPL is a measure of the average pressure or the effective pressure over the duration of an acoustic event, such as the emission of one acoustic pulse from a seismic source. This level is the root mean square pressure level of the pulse.

The SEL is a measure of the total acoustic energy contained in one or more acoustic events and is often used as an indication of the energy dose over a specific event or time. The SEL metric measures the sound energy to which an organism at that location would be exposed.

Sound loudness is a subjective term describing the strength of the ear's perception of a sound. It is a complex interaction between the sound pressure level and the hearing ability of an individual receptor for that sound (how well the sound can be detected). Because the loudness of impulsive sound is not generally proportional to the instantaneous acoustic pressure, the peak SPL is a poor indicator of perceived loudness. As such, several other sound level metrics such as RMS SPL

[1] 1 microPascal squared normalized to 1 second
[2] Decibels at a reference pressure of 1 microPascal squared normalized to 1 second

and SEL are commonly used to evaluate the loudness of impulsive sound and its impact on marine life.

7.A.1.2 Functional Hearing Groups

Not all marine wildlife species hear and use sound in the same manner. For this reason, species are grouped into different 'functional hearing groups', i.e. groups of species that hear and use sound in similar ways. These groups are (NOAA2016):

- Low-frequency cetaceans, which have a hearing range of 7 Hz to 35 kHz, and include large, baleen whale species
- Mid-frequency cetaceans, which have a hearing range of 150 Hz to 160 kHz, and include dolphins, toothed whales, beaked whales, and bottlenose whales
- High-frequency cetaceans, which have a hearing range of 275 Hz to 160 kHz, and include porpoise species
- Otariid pinnipeds, which have a hearing range of 60 Hz to 39 kHz, and include eared seals such as sea lions
- Phocid pinnipeds, which have a hearing range of 50 Hz to 86 kHz, and include true/earless seals, such as harbor seals
- Fish, which have a hearing range of 1 Hz-20 kHz.

7.A.1.3 Impulsive and Non-Impulsive Noise

Sources of sound are organized into two primary signal types, impulsive sources (air-guns and sonar) and non-impulsive or continuous sources (frequency-modulated (low-frequency and other sonars) (NRC 2005). Impulsive sources such as impact pile drivers and vertical seismic profilers are typically brief and intermittent. Noise from these sources rapidly becomes loud, and rapidly fades away. In contrast, non-impulsive sources such as marine vessels' main propulsion systems and internal machinery (e.g., generators, cranes) can be brief or prolonged, and continuous or intermittent. However, non-impulsive sources do not have the high peak pressure and rapid rise time that impulsive sounds do. The proposed project would generate only non-impulsive noise sources.

7.A.2 Underwater Noise Prediction Methodology

A screening-level assessment was performed using conservative assumptions to evaluate potential underwater noise impacts. The screening-level underwater noise levels were calculated on the basis of data and methods described in WSDOT 2016. This screening analysis used the Practical Spreading Loss Model developed by WSDOT.

The model requires an input of baseline underwater noise. Baseline underwater noise data have not been collected specifically for the proposed project. The Washington State Department of Transportation (WSDOT) analyzed broadband background underwater sound (20 Hz to 20 kHz) over three consecutive 24-hour periods at marine areas adjacent to the Anacortes Ferry Terminal.

Based on WSDOT's recent research, the broadband sound level at Anacortes Ferry Terminal ranges from 123 to 133 dB, depending on the hearing frequency group for marine mammals and fish (Table 7-A-1, WSDOT 2016). The decibels reported at this location represent 50 percent of the cumulative distribution functions of these three periods for daytime sound levels. These broadband background sound levels (dBrms) for each hearing group at Anacortes Ferry Terminal were used to represent baseline underwater noise data for the proposed project.

Table 0-A-1: Underwater Background Noise Levels for Daytime at Anacortes Ferry Terminal

Frequency Range	Functional Hearing Group	Anacortes Ferry Terminal (dB re: 1 µPa)[a]
7 Hz-20 kHz	Low frequency cetaceans	133
75 Hz-20 kHz	Phocid pinnipeds	125
100 Hz-20 kHz	Otarrid pinnipeds	No data
150 Hz-20 kHz	Mid frequency cetaceans	124
200 Hz-20 kHz	High frequency cetaceans	123
1 Hz-20 kHz	Broadband background (fish, murrelets)	133

Source: WSDOT 2016

[a] Measured in March 2011

[c] WSDOT 2016. The Practical Spreading Loss Model is based on the following formula for geometric spreading:

$$TL = 15 * Log (R1/R2) + \alpha R$$

Where:

αR = linear absorption and scattering loss
R1 = distance in meters to point 1
R2 = distance in meters to point 2
TL = the change in noise level between R1 and R2 (WSDOT refers to this as transmission loss)

Transmission loss (TL) is the accumulated decrease in acoustic intensity as an acoustic pressure wave propagates outwards from a source. The intensity of the source is reduced with increasing distance due to spreading. The linear absorption and scattering loss (αR) starts to influence transmission loss 1,000 meters beyond the source. However, there is no agreement on alpha's value and WSDOT recommends that it not be used. If the linear absorption is not included, the above formula results in a 4.5 dB reduction for each doubling of distance. This is acknowledged to be a simplified model that results in conservative (unrealistically high) estimates of noise levels at large distances. The range of realistic distances has not been identified by WSDOT; rather, it is noted that the underwater sound propagation has a large amount of uncertainty and the model overestimates noise levels at large distances. Temperature gradients, bottom topography, and currents are noted to cause sound levels to attenuate more rapidly than geometric spreading.

The extent of underwater project-related noise is determined by considering the underwater area through which noise would travel until it reaches background levels (WSDOT 2016). Distances to background noise levels for peak and root mean squared (rms or RMS) sound levels are calculated as follows:

Distances to peak or RMS background level =10*10((sound level-background level)/15)

The above data and formulas were used to evaluate distances to underwater background noise levels as various functional hearing groups for marine mammal and fish. In other words, the equation helps to determine at what point the project noise becomes indistinguishable from background sound assuming a 4.5 dB decrease with each doubling of distance. To use the Practical Spreading Loss Model, the underwater sound metrics must be converted to either peak or RMS sound pressure levels. Non-impulsive sources generally do not generate peak sound pressure levels; therefore, only the RMS sound pressure levels (abbreviated as “dBrms”) was used for the screening-level assessment. More information on the description of the Practical Spreading Loss Model can be found in WSDOT 2016.

7.A.3 RESULTS

Using the Practical Loss Spreading Model and unattenuated reference source level for non-impulsive or continuous sources (root mean squared decibel [dBrms] referenced to 1 micro Pascal at 1 meter [dBrms re: 1µPa at 1 m]), the limiting distances (i.e., distances from source at which underwater background noise levels are achieved) to underwater background noise levels at various functional hearing groups are shown in Table 7-A-1.

According to the Practical Spreading Loss Model, in open water and without mitigation, non-impulsive noise (rms) from construction activities (tugboat operation, safety vessel operation and spud deployment) would attenuate to the underwater background levels of LF cetaceans, MF cetaceans, HF cetaceans, phocid pinnipeds, and otarrid pinnipeds at maximum distances of 123, 488, 569, 419, 419, and 123 meters, respectively. Non-impulsive noise (rms) from marine vessel movements during operation would extend over a large area before attenuating to baseline noise levels. The geographic extent ranged from 1,585 m for LF cetaceans and fish, to 7,356 m for HF cetaceans (see Table 7-A-2).

Table 0-A-2: Distance to Underwater Background Noise Levels at Various Functional Hearing Groups during Construction

Underwater Non-impulsive Noise Source	Unattenuated Reference Source Level, SL (dBrms, re: 1µPa at 1 m)[a]	Distance to Underwater Background Noise Levels at Various Functional Hearing Groups[bc] (meters)					
		LF Cetaceans	MF Cetaceans	HF Cetaceans	Phocid Pinnipeds	Otarrid Pinnipeds[d]	Fish
Construction							
Tug boat	163.8	113	450	525	386	386	113
Safety vessel	162.0	86	341	398	293	293	86
Spud barge deployment into seabed	164.3	123	488	569	419	419	123

Operation							
Large commercial vessel	181.0	1,585	6,310	7,356	5,412	5,412	1,585

dBrms = root mean square decibel levels; HF = high frequency; Hz = Hertz; kHz = kilohertz; LF = low frequency; MF = mid frequency; µPa at 1m = micro Pascal at one meter; SL = source level

[a] root mean square source level data at 1 meter for the tug boat and safety vessel were based on measured data from a tug pushing gravel barge and a small work boat at full speed, respectively (Wyatt 2008); root mean square source level data for the deployment of spuds (vertical shafts) from the spud barge into the seabed was based on a maximum sound level of 136.2 dBrms, re: 1µPa at 75 m (Kevin Reine et al. 2012). This maximum sound level at 75 m was converted to a reference source level of 164.3 dB re: 1 µPa at 1 m using the Practical Spreading Loss Model described in WSDOT 2016. Root mean square source level data at 1 meter for the large commercial vessel was based on measured data from a loaded container vessel (Wyatt 2008).

[b] Extent of project-related underwater noise in meters were calculated using the Practical Spreading Loss Model described in the WSDOT Advanced Training Manual, Biological Assessment Preparation for Transportation Projects, Chapter 7 (WSDOT 2016).

[c] Baseline data used for modelling for each functional hearing group is presented in Table 2-A.1 0f WSDOT 2016.

[d] Underwater background noise levels for Otarrid pinnipeds were not available, background noise data for Phocid pinnipeds was assumed.

7.A.4 References

National Oceanic and Atmospheric Administration (NOAA). 2016. *Technical Acoustic Guidance FAQs*. Accessed: February 2017. Retrieved from: http://www.nmfs.noaa.gov/pr/acoustics/faq.htm.

WSDOT (Washington State Department of Transportation). 2016. *WSDOT's Advanced Training Manual, Biological Assessment Preparation for Transportation Projects, Chapter 7, Version 9-2016*. Accessed: December 2016. Retrieved from: https://www.wsdot.wa.gov/NR/rdonlyres/8314F097-11DA-4642-A7A5-CE8D2FDE6BF4/0/BA_Manual_CH7.pdf.