Mukilteo Multimodal Terminal Project – Season 3
UNDERWATER NOISE MONITORING PLAN

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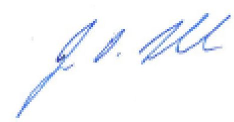

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INTRODUCTION

During Year 3 of the Mukilteo Multimodal Terminal project, the Washington State Ferries (WSF) proposes to continue construction of the new Mukilteo Multimodal ferry terminal.
For this Phase of the project, a vibratory hammer will be used on 78 and 120-inch diameter steel piles.

PROJECT AREA

The new Mukilteo Multimodal Terminal will be located east of the existing Mukilteo terminal. See vicinity maps shown in Figure 1 and Figure 2.

Figure 1. Vicinity map of Mukilteo Multimodal Terminal Project.

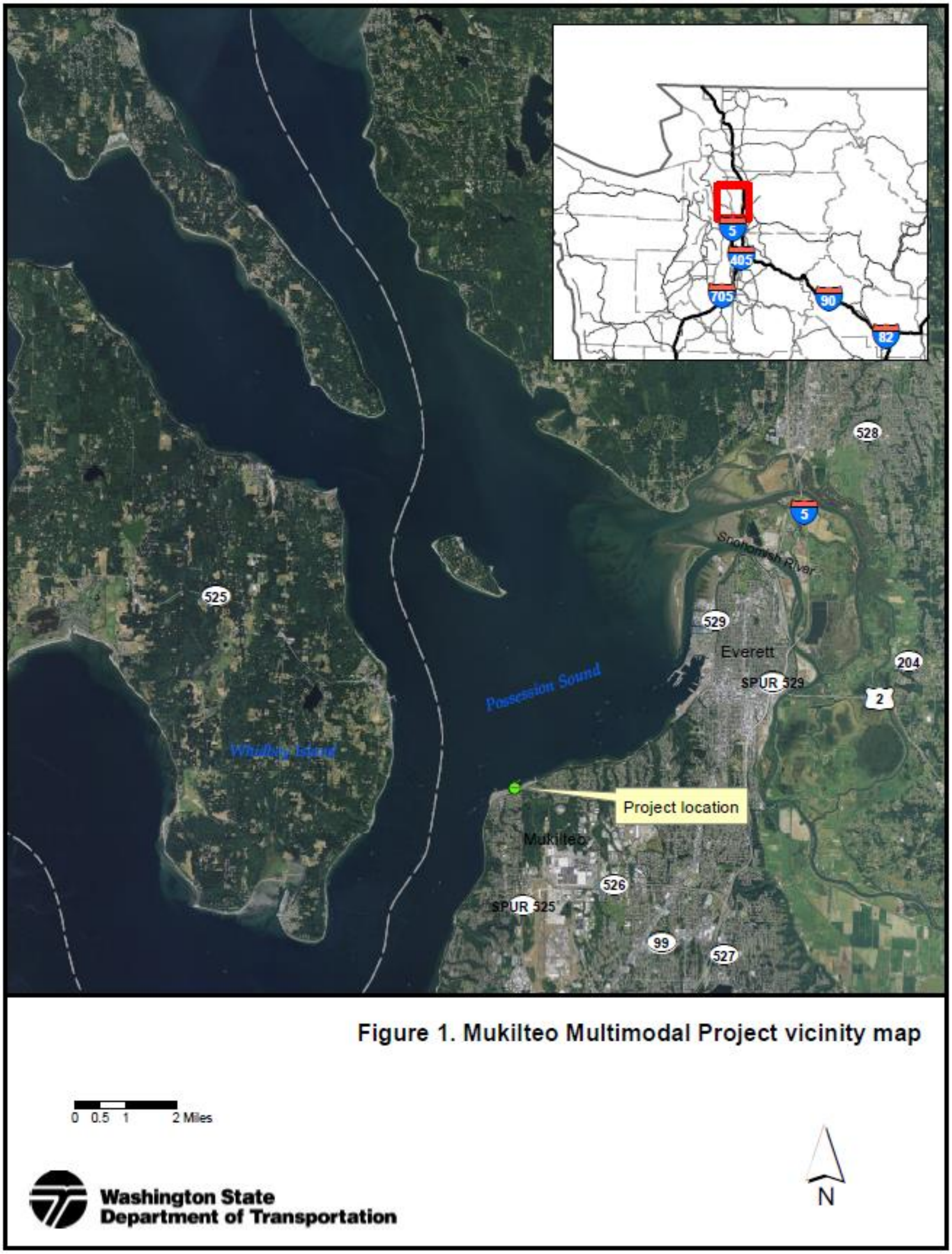
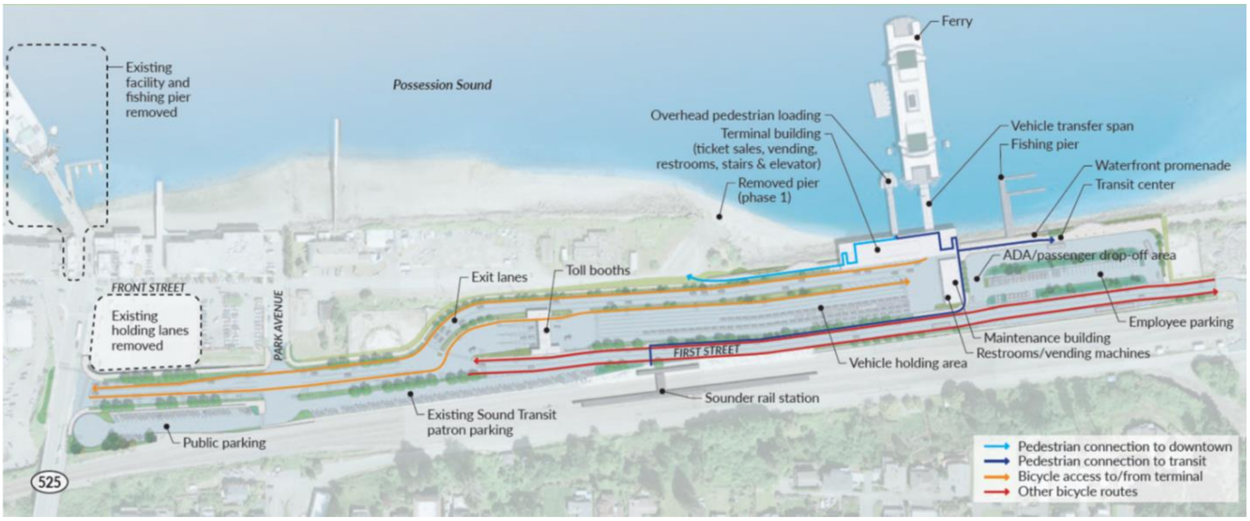


Figure 1. Mukilteo Multimodal Project vicinity map

Figure 2. Location of new Mukilteo Multimodal Terminal.



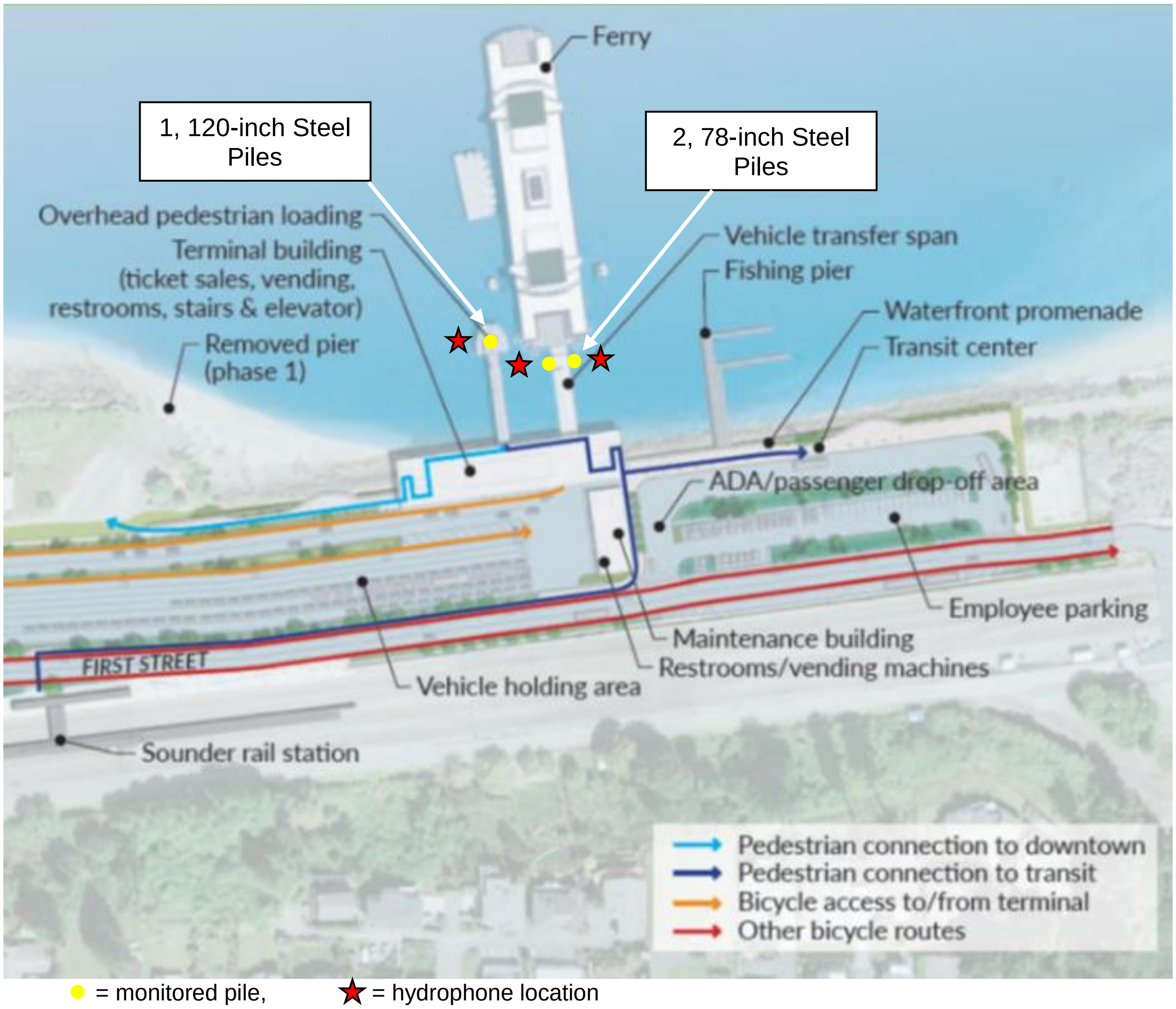
PERMIT/ESA CONDITIONS

Please refer to the USFWS and NMFS Biological Opinion for permit and ESA conditions for this project.

PILE INSTALLATION LOCATION

Figure 3 indicates the location of the one 120-inch and two 78-inch diameter steel pipe piles that will be monitored during vibratory driving.

Figure 3. Approximate location of steel pipe piles to be vibratory driven for the Mukilteo Multimodal Season 3 Project (yellow) and the approximate location of the hydrophones (stars).



PILE INSTALLATION

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Hydroacoustic monitoring of the piles during vibratory driving will include:

- Monitoring at 10 meters range.

Hydrophones will be located with a clear acoustic line-of-sight between the pile and the hydrophone.

Table 1 lists the equipment specifications that will be used during monitoring.

Table 1
Equipment for underwater sound monitoring (hydrophone, signal amplifier, and calibrator). All have current National Institute of Standards and Technology (NIST) traceable calibration.

Item	Specifications	Minimum Quantity	Usage
Hydrophone	Receiving Sensitivity- -211dB re 1V/µPa	1	Capture underwater sound pressures near the source and convert to voltages that can be recorded/analyzed by other equipment.
Signal Conditioning Amplifier	Amplifier Gain- 0.1 mV/pC to 10 V/pC Transducer Sensitivity Range- 10-12 to 103 C/MU	1	Adjust signals from hydrophone to levels compatible with recording equipment.
Calibrator (pistonphone-type)	Accuracy- IEC 942 (1988) Class 1	1	Calibration check of hydrophone in the field.
Digital Signal Analyzer	Sampling Rate- 48kHz or greater	1	Analyzes and transfers digital data to laptop hard drive.
Laptop computer or Digital Audio Recorder	Compatible with digital signal analyzer	1	Record digital data on hard drive or digital tape.
Real Time and Post-analysis software	-	1	Monitor real-time signal and post-analysis of sound signals.

To facilitate further analysis of data, the full bandwidth, time-series underwater signal shall be converted to a text file (.txt) or wave file (.wav) or similar format. Recorded data shall not use data compression algorithms or technologies (e.g. MP3, compressed .wav, etc.).

METHODOLOGY

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A weighted tape measure will be used to determine the depth of the water. The hydrophones will be attached to a nylon cord. The nylon cord will be attached to an anchor that will keep the line the appropriate distance from each pile. The nylon cord or chain will be attached to a float or tied to a static line at the surface. The distances will be measured by a tape measure, where possible, or a range-finder.

The hydrophone calibration will be checked at the beginning of each day of monitoring activity. The monitoring software (RTPro, v7.4) is used in combination with the Pistonphone calibrator to determine the correction factor for each hydrophone. The hydrophone correction factor must be less than 0.2 dB to be acceptable. Prior to the initiation of pile driving, the hydrophone will be placed at the appropriate distance and depth as described above.

The onsite inspector/contractor will inform the acoustics specialist when pile driving is about to start to ensure that the monitoring equipment is operational. Underwater sound levels will be continuously monitored during the entire duration of each pile being driven with a minimum one-third octave band frequency resolution. The broadband signal will be analyzed in 10-second increments and the Root Mean Square (RMS), absolute peak pressure and Sound Exposure Level (SEL) values of each 10-second duration will be calculated along with an estimate of the daily cumulative SEL. Peak and RMS pressures will be reported in dB (re:1 μPa). SEL will be reported in dB (re: 1 $\mu Pa^2 \cdot sec$).

Prior to, and during, the pile driving activity, environmental data will be gathered, such as water depth and tidal level, wave height, and other factors that could contribute to influencing the underwater sound levels (e.g. aircraft, boats, etc.). Start and stop time of each pile driving event will be logged.

The contractor will provide the following information, in writing, to the noise specialist conducting the hydroacoustic monitoring for inclusion in the final monitoring report:

- a description of the substrate composition,
- approximate depth of significant substrate layers,
- hammer model and size,
- pile cap or cushion type,
- depth pile driven,

SIGNAL PROCESSING

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Post-analysis of the underwater pile driving sounds will include:

- For each recorded pile, determine the following:
    - The peak pressure, defined as the maximum absolute value of the instantaneous pressure (overpressure or underpressure).
    - The root mean squared sound pressure (RMS).
    - Sound Exposure Level (SEL). Calculation methodology is provided in Appendix A.
    - Both broadband and marine mammal functional hearing group analysis.
- Maximum and L50.
- Maximum, L50 and SEL.
- Cumulative SEL (cSEL) across the entire pile drive. If SEL was calculated for each 10-second interval, cSEL is estimated as indicated in Appendix A.
- A frequency spectrum between a minimum of 20 and 20 kHz for up to eight successive 10-second intervals with similar sound levels.

ANALYSIS

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The peak, RMS and SEL values computed for this project will be computed for each 10-second interval. Units of underwater sound pressure levels will be dB (re:1 μPa) and units of SEL will be re:1 $\mu Pa^2 \bullet sec$. In addition to a full broadband analysis the data will be analyzed for each marine mammal functional hearing group (Southall et al., 2007, NMFS 2016). Data will be represented using a Power Spectral Density (PSD) plots and Spectrogram plots.

REPORTING

Preliminary results for the daily monitoring activities, if required, will be submitted/reported to the primary point of contact[1] at each of the Services within 24 hours after monitoring concludes for the day. In addition, a final draft report including data collected and summarized from all monitoring locations will be submitted to the Services within 90 days of the completion of hydroacoustic monitoring. The results will be summarized in graphical form and include summary statistics and time histories of vibratory sound values for each pile. A final report will be prepared and submitted to the Services within 30 days following receipt of comments on the draft report from the Services. The report shall include:

1. Size and type of piles.
2. The vibratory hammer energy rating used to drive the piles, make and model of the hammer.
3. A description of the sound monitoring equipment.
4. The distance between hydrophones and piles.
5. The depth of the hydrophones and depth of water at hydrophone locations.
6. The distance from the pile to the water's edge.
7. The depth of water in which the pile was driven.
8. The physical characteristics of the bottom substrate into which the piles were driven.
9. The total number of seconds/minutes to drive each pile and for all piles driven during a 24-hour period.
10. The results of the hydroacoustic monitoring, as described under Signal Processing including an analysis of the marine mammal functional hearing groups. An example table is provided in Appendix C for reporting the results of the monitoring.
11. Source levels of 78-inch and 120-inch pile diameters and distance measured.
12. The distance at which peak, cSEL, and RMS values exceed the respective threshold values.
13. A description of any observable fish, marine mammal, or bird behavior in the immediate area will and, if possible, correlate to underwater sound levels occurring at that time.

[1] The primary point of contact is the biologist that conducted the MMPA IHA analysis the NMFS.

REFERENCES

Illingworth and Rodkin, Inc. 2001. Noise and Vibration Measurements Associated with the Pile Installation Demonstration Project for the San Francisco-Oakland Bay Bridge East Span, Final Data Report, Task Order 2, Contract No. 43A0063.

NMFS, 2016. Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing. Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. NMFS-OPR-55.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals 33(4): 411-521.

APPENDIX A

Calculation of Cumulative SEL

An estimation of individual SEL values can be calculated for each 10-second interval by calculating the following integral, where T is the 10-second interval (eq. 1).

$$SEL = 10\log\left(\int_0^T \frac{p^2(t)}{{p_0}^2} dt \right) \quad dB \qquad \text{(eq. 1)}$$

Calculating a cumulative SEL from individual SEL values cannot be accomplished simply by adding each SEL decibel level arithmetically. Because these values are logarithms they must first be converted to antilogs and then accumulated. Note, first, that if each 10-second interval SEL is very close to a constant value (within 1 dB), then cumulative SEL = SEL + 10 times log base 10 of the RMS duration t, i.e, $10Log_{10}(t)$. However if the 10-second interval SEL varies over the sequence of intervals, then a linear sum of the energies for each 10-second interval needs to be computed. This is done as follows: divide each SEL decibel level by 10 and then take the antilog. This will convert the decibels to linear units (or $uPa^2 \bullet s$). Next, compute the sum of the linear units and convert this sum back into dB by taking $10Log_{10}$ of the value. This will be the cumulative SEL for the entire vibratory pile drive.

APPENDIX B

Table 1. Example table for required information for reporting the results of hydroacoustic monitoring of pile driving.

Date and Time	Pile ID	Hammer Impact or Vibratory	# Strikes or Vibratory Seconds	Distance to Pile from Hydrophone (m)	Water Depth (m)		Peak (dB)			SEL (dB)				RMS (dB)			Notes
					At Pile	At H-phone	Max	Min	L50	Max	Min	L50	cSEL	Max	Min	L50	