Washington State Department of Transportation

Memorandum

November 7, 2013

TO: Rick Huey

FROM: Jim Laughlin
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SUBJECT: Orcas Island Ferry Terminal Zone of Influence Measurements for Removal of Timber and Installation of Steel Piles – Vibratory Pile Monitoring Technical Memorandum.

Underwater Noise Levels

This memo summarizes the measurements made while attempting to detect the outer boundary of the Zone of Influence (ZOI) for timber pile removal and steel pile installation using a vibratory hammer at the Orcas Island Ferry Terminal. Data was collected in real-time using the Underwater Sound Level Meter (USLM) at different ranges from the source during the months of October and November 2013 (Figures 1 and 2).

Two 12-inch diameter wooden piles were monitored on October 28th as they were removed as part of the dolphin replacement project using and APE 200-6 vibratory hammer. The same hammer was used to install one 24-inch steel pile on November 4th. No frequency weighting (*e.g.*, A-weighting or C-weighting) was applied to the underwater acoustic measurements presented in this report. Underwater sound levels quoted in this report are in decibels relative to the standard underwater acoustic reference pressure of 1 μPa. No noise attenuation devices were used during these vibratory measurements. Root Mean Square (RMS) noise levels corresponding to the functional hearing groups of Southall et al. (2007) are reported in terms of the 5-second average continuous sound level and have been computed from the Fourier transform of pressure waveforms in 5-second time intervals.

Measurements

- Underwater noise measurements for the timber pile removal were collected at a range of 364 meters (1,194 feet) and 572 meters (1,876 feet) from the piles.
  - Two piles were extracted with the vibratory hammer.
  - Table 1 summarizes the results of the measurements.
- Underwater noise measurements for the vibratory installation of one 24-inch steel pile were collected at ranges of 1,000 meters (3,281 feet), 1,559 meters (5,115 feet) and 2,040 meters (6,693 feet) from the pile.
  - One pile was installed with the vibratory hammer
  - Table 1 summarizes the results

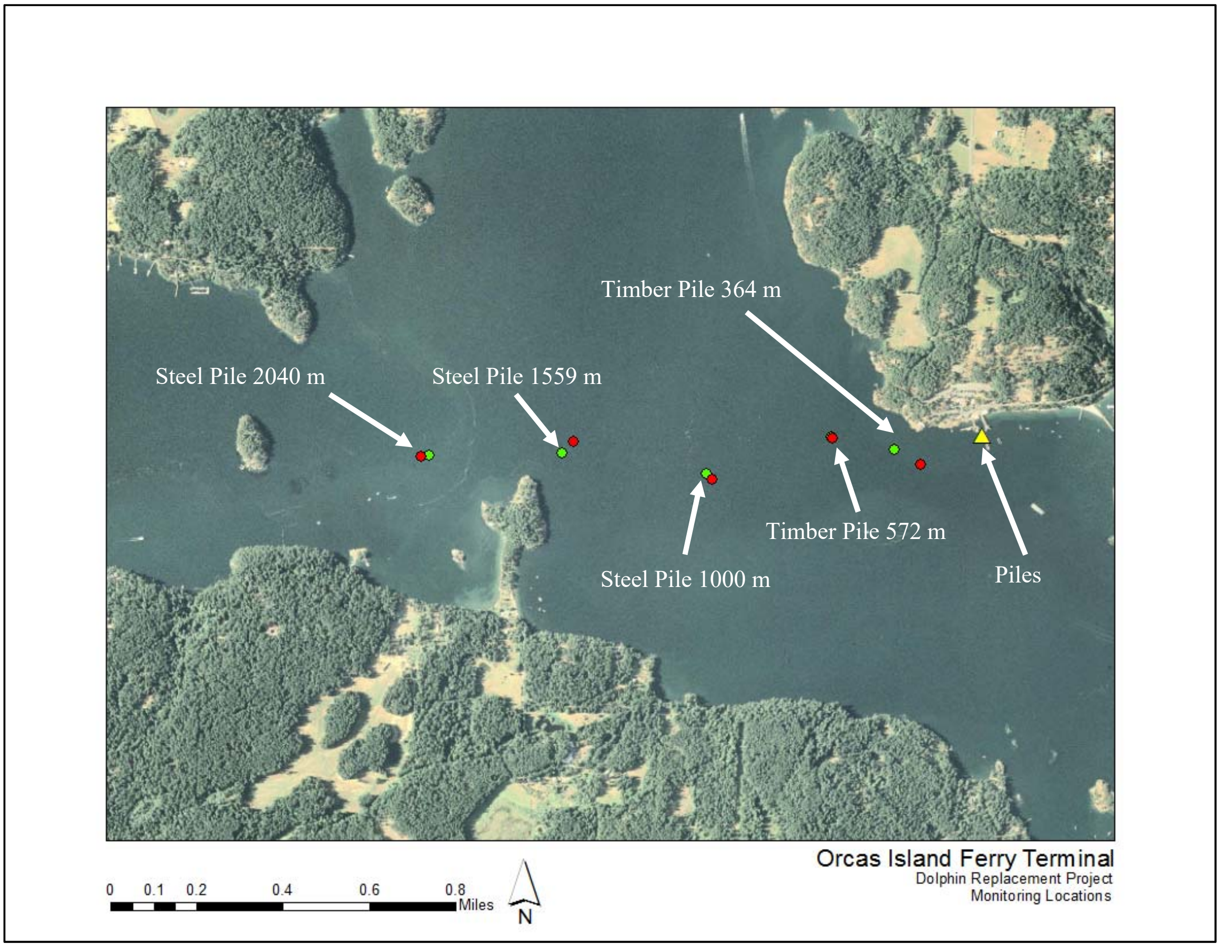

Figure 1: Locations of the noise monitoring and pile location at the Orcas Island Ferry Terminal. Green circle is location at start of measurement, red circle location at end of measurement.

Table 1: Summary Table of Underwater Monitoring Results for Timber Removal and Steel Pile Installation.

Pile Type	Pile #	Hydrophone Depth Below Surface (meters)	Distance To Pile (meters)	Functional Hearing Group Frequency Range	Maximum RMS (dB)	Average RMS Value (dB)
Timber	1	10	364	7 Hz to 20 kHz	131	127
				75 Hz to 20 kHz	128	125
				150 Hz to 20 kHz	127	123
				200 Hz to 20 kHz	126	122
Timber	2	10	572	7 Hz to 20 kHz	130	128
				75 Hz to 20 kHz	122	120
				150 Hz to 20 kHz	122	120
				200 Hz to 20 kHz	121	119

Pile Type	Pile #	Hydrophone Depth Below Surface (meters)	Distance To Pile (meters)	Functional Hearing Group Frequency Range	Maximum RMS (dB)	Average RMS Value (dB)
Steel	1	10	1000	7 Hz to 20 kHz	137	137
				75 Hz to 20 kHz	137	137
				150 Hz to 20 kHz	137	137
				200 Hz to 20 kHz	137	137
Steel	1	10	1559	7 Hz to 20 kHz	132	130
				75 Hz to 20 kHz	129	128
				150 Hz to 20 kHz	129	128
				200 Hz to 20 kHz	129	128
Steel	1	10	2040	7 Hz to 20 kHz	130	129
				75 Hz to 20 kHz	129	128
				150 Hz to 20 kHz	129	128
				200 Hz to 20 kHz	129	128

Timber Piles
The results of Table 1 shows for removal of timber pile 1 over approximately 5 minutes the average RMS value for the broadband measurement (7 Hz to 20 kHz is equivalent to broadband) was 127 dB at 364 meters. Using the practical spreading model the 120 dB RMS isopleth would be approximately an additional 1066 meters (3500 feet) from the measurement location or 1430 meters (4700 feet) from the source. Figure 2 shows the time series of RMS measurements at 364 meters and that there is a significant amount of energy in the 25 to 75 Hz range of frequencies that are typical of vibratory driving. When this low frequency energy is filtered out with a high pass filter at 150 Hz and 200 Hz there is not as much of a difference between the plots.

Removal of timber pile 2 measured over approximately 3.5 minutes has an average RMS value for the broadband measurement of 128 dB at 572 meters (Table 1). Using the practical spreading model the distance to the 120 dB isopleth is approximately an additional 1950 meters (6400 feet) from this location or 2500 meters (8200 feet) from the source. The RMS level at this location was 1 dB higher than the measurement more than 200 meters closer to the source. This could be caused by the variability in the hammer energy between the two measurements.

Figure 3 shows the time series of RMS measurements at 572 meters and that there is a significant amount of energy in the frequencies below 75 Hz. Vibratory pile driving has a dominant frequency between 25 Hz and 60 Hz. When this low frequency energy is filtered out with a high pass filter at 75 Hz, 150 Hz and 200 Hz there is not as much of a difference between the plots and an approximate 8 dB difference between these plots and the broadband plot (7 Hz). This also implies that the marine mammals with a lower hearing threshold of 75 Hz or higher are experiencing sound levels 8 dB lower beyond about 600 meters from the timber piles.

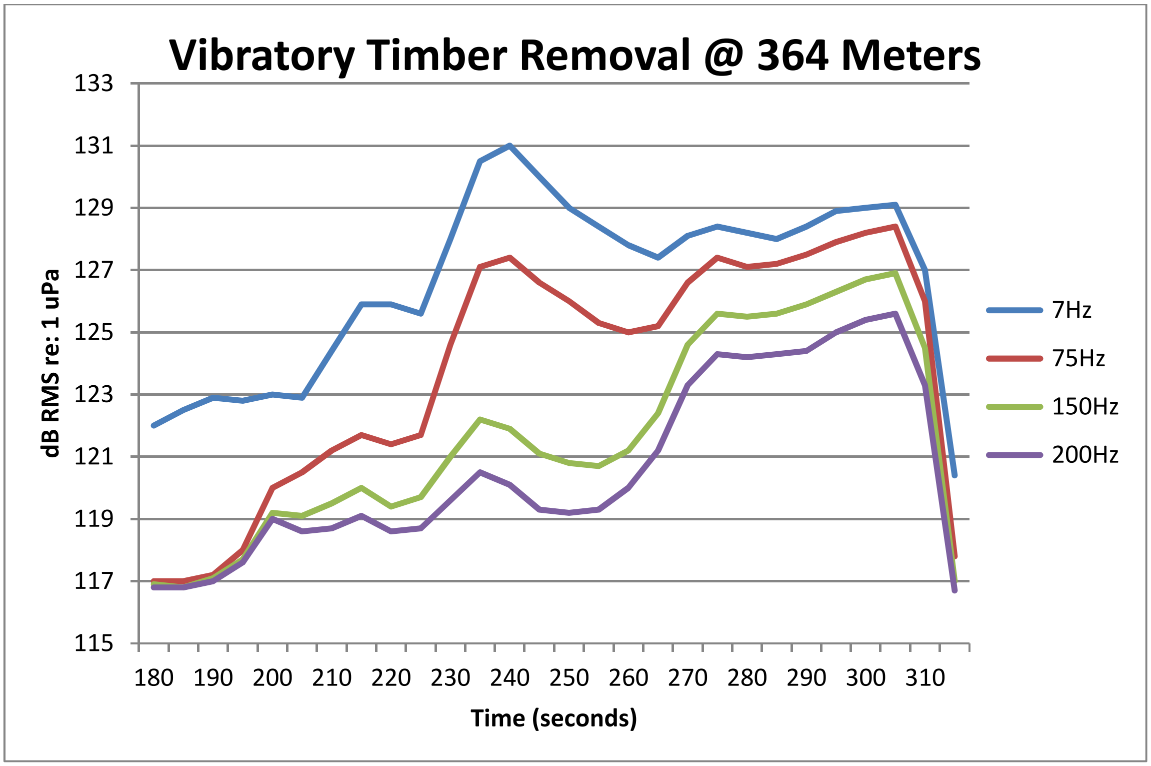

Figure 2: Time series of 5-second RMS values for timber pile 1 at a range of 364 meters.

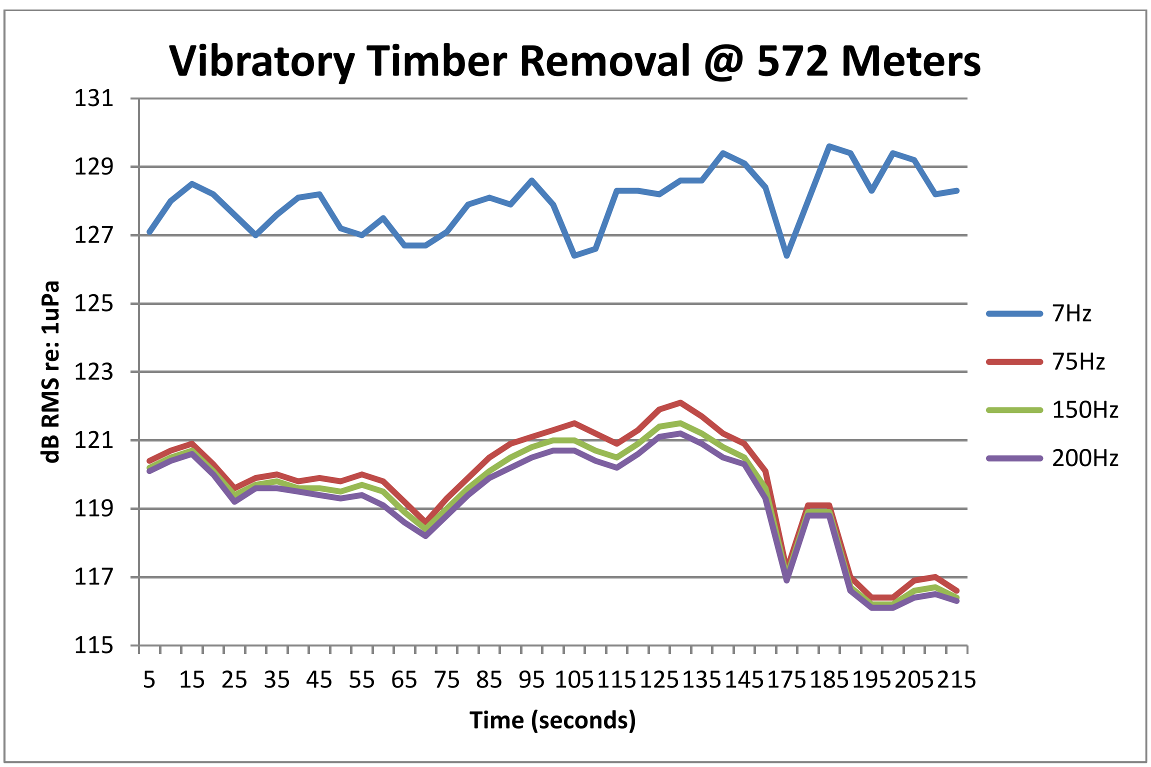

Figure 3: Time series of 5-second RMS values for timber pile 2 at range of 572 meters.

Figure 4 indicates where the measured 120 dB isopleth for timber piles would be located.

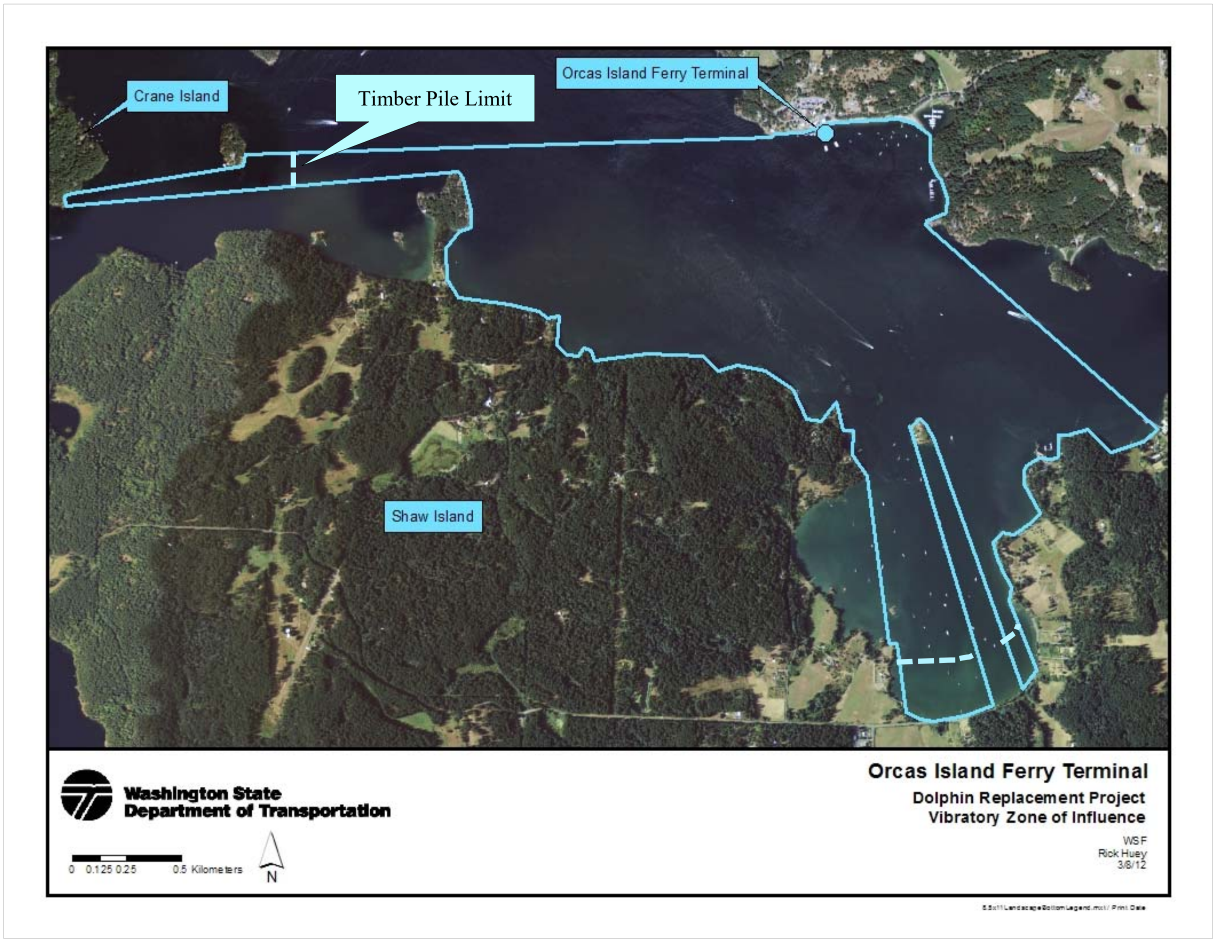

Figure 4: Location of the measured 120 dB isopleth (dashed line).

Steel Piles

The results for the steel pile in Table 1 shows the average RMS value for the broadband measurement (7 Hz to 20 kHz is equivalent to broadband) was 137 dB at 1000 meters. Figures 5, 6 and 7 show the time series and spectral density plots of the peak value for the steel pile. At 1559 meter range the average RMS value for the broadband measurement is 130 dB (Table 1).

Figure 7 shows the time series of RMS measurements at 2040 meters and that there is a significant amount of energy in the frequencies below 75 Hz. Vibratory pile driving has a dominant frequency between 25 Hz and 60 Hz. When this low frequency energy is filtered out with a high pass filter at 75 Hz, 150 Hz and 200 Hz there is not as much of a difference between the time series plots and an approximate 4 dB difference between these plots and the broadband plot (7 Hz). This also implies that the marine mammals with lower hearing frequencies from 75 hz and higher are experiencing sound levels 4 dB lower beyond about 1,500 meters from the piles. Using the practical spreading model to calculate the distance from 2,000m to the 120 dB threshold it would be another 8,000m for a total of 10,000m to the isopleth, however, it would reach land before it would reach that distance.

Figures 5, 6 and 7 show the time series and spectral density plot of the peak value for the steel pile at range 1000 meters.

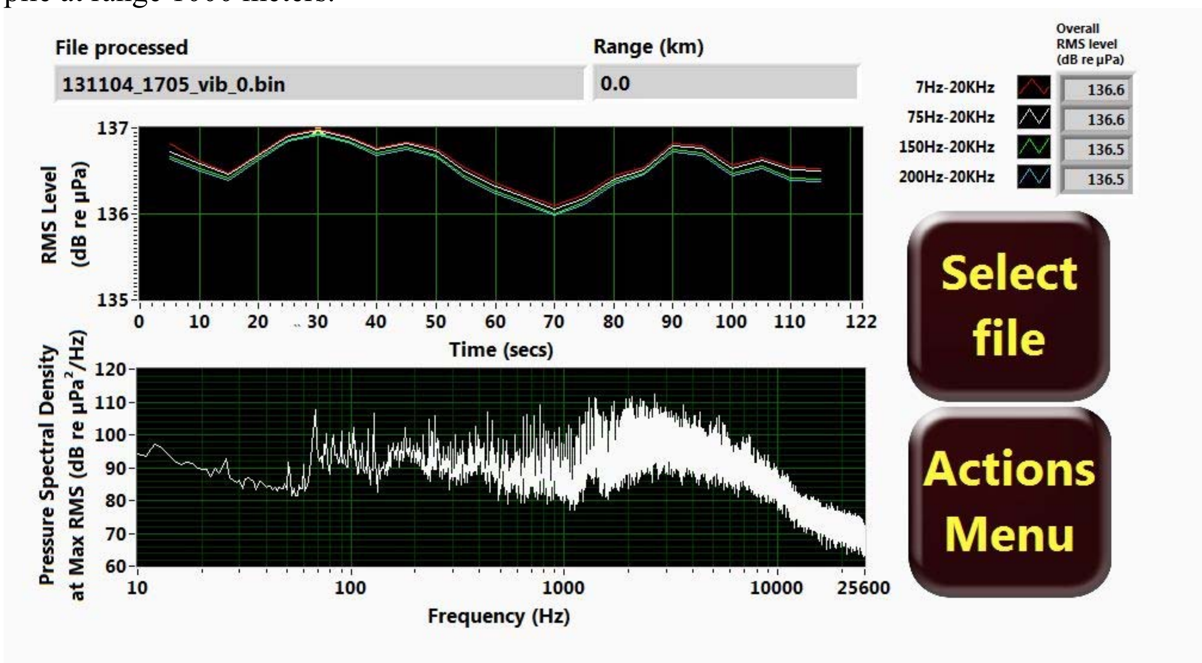

Figure 5: Time series and spectral density plot for 24-inch steel pile at range 1000 m.

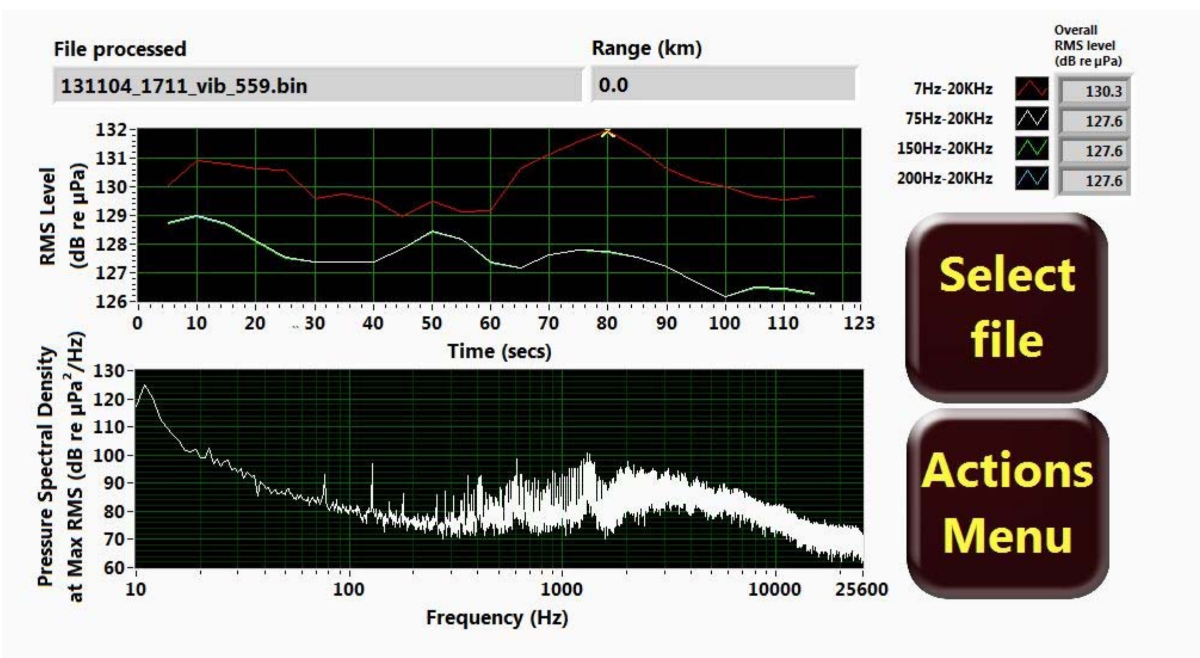

Figure 6: Time series and spectral density plot for 24-inch steel pile at range of 1559 m.

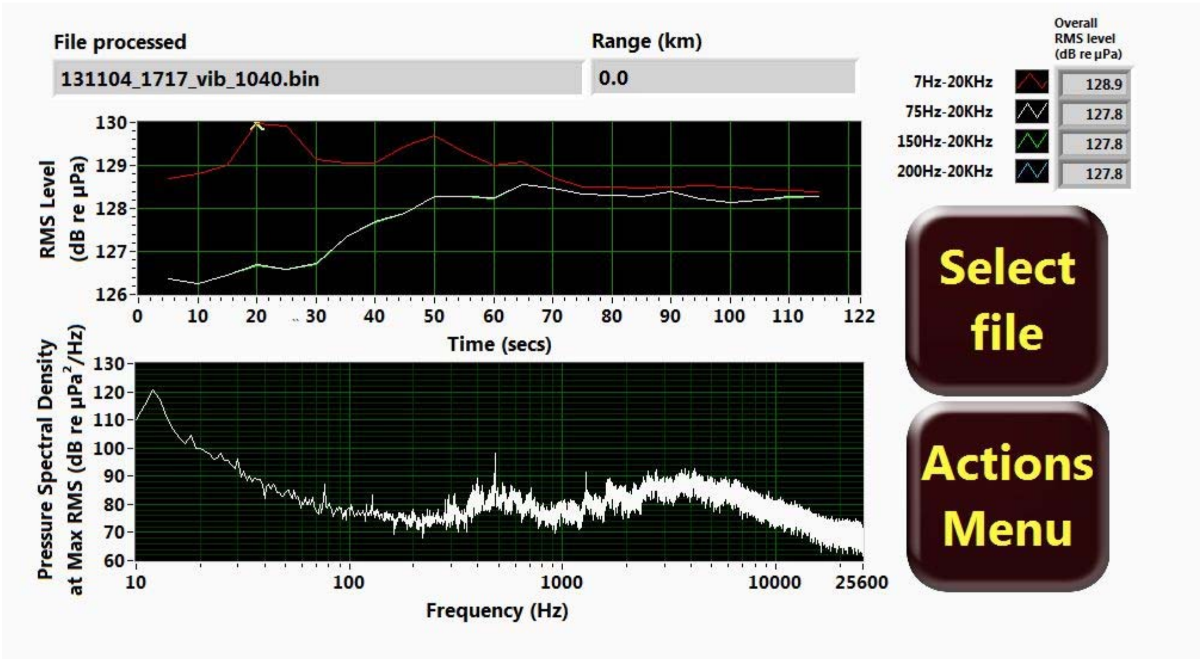

Figure 7: Time series and spectral density plot for 24-inch steel pile at range of 2040 m.

Conclusions

A hydrophone was deployed between 360 and 2000 meters from timber and steel piles during vibratory driving to attempt to detect in real time where the sound levels drop off to background or 120 dB.

It was found that the ZOI could be reduced slightly for timber piles. But would reach land before it would reach the maximum distance for steel piles.

If you have any questions please call me at (206) 440-4643.

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Attachments
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Literature Cited

Southall, Brandon L., Ann E. Bowles, William T. Ellison, James J. Finneran, Roger L. Gentry, Charles R. Greene Jr., David Kastak, Darlene R. Ketten, James H. Miller, Paul E. Nachtigal, W. John Richardson, Jeanette A. Thomas, and Peter L. Tyak. 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals, Volume 33(4).