Columbia River CROSSING

# Memorandum

1 August 2011

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| **FROM:** | James Coleman, David Evans and Associates, Inc. |
| **SUBJECT:** | **Columbia River Crossing Test Pile Project Vibratory Extraction Sound Levels** |
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## Vibratory Extraction Analysis

This memorandum summarizes the results of hydroacoustic monitoring on the vibratory extraction of piles during the Columbia River Crossing Test Pile Project. A detailed discussion of monitoring procedures and the data processing methodology used in this analysis can be found in the *Columbia River Crossing Test Pile Project Hydroacoustic Monitoring Final Report.* The final report also includes the definitions of the derived qualities referred to in this memorandum. Two 24-inch and four 48-inch piles were extracted using an APE King Kong model 400 vibratory hammer between 14 and 21 February 2011. No noise mitigation measures were used during pile extraction. Hydroacoustic measurements were taken at ranges of approximately 10 meters, 200 meters, 400 meters, 800 meters, and also 800 meters in the opposite direction from the pile being extracted.

A RMS pressure level and Cumulative SEL level was calculated for each vibratory extraction. No frequency weightings were used during calculations. RMS pressure levels were calculated for each 30-second block of vibration and averaged together to represent the RMS pressure level of the entire vibratory extraction. Cumulative SEL was calculating by directly integrating the square of the sound pressure over the duration of the vibratory extraction. Both Cumulative SEL values and RMS sound pressure levels are presented as decibels (re: 1μPa).

## Observed Sound Levels for Vibratory Extraction

A typical time series of the RMS sound pressure level for vibratory extraction is shown in figure-1. A summary of the average RMS pressure level, measured Cumulative SEL, and approximate time for the extraction are shown in table-1. The average RMS pressure level for extraction was 173 dB, and did not appear to vary with pile size. The 173 dB observed for extraction was slightly less than the 176 dB average observed during installation as found in the *Columbia River Crossing Test Pile Project Hydroacoustic Monitoring Final Report*. The variance of the pressure levels was also less, with extraction values ranging 167-176 dB while installation values ranged 157-181 dB.

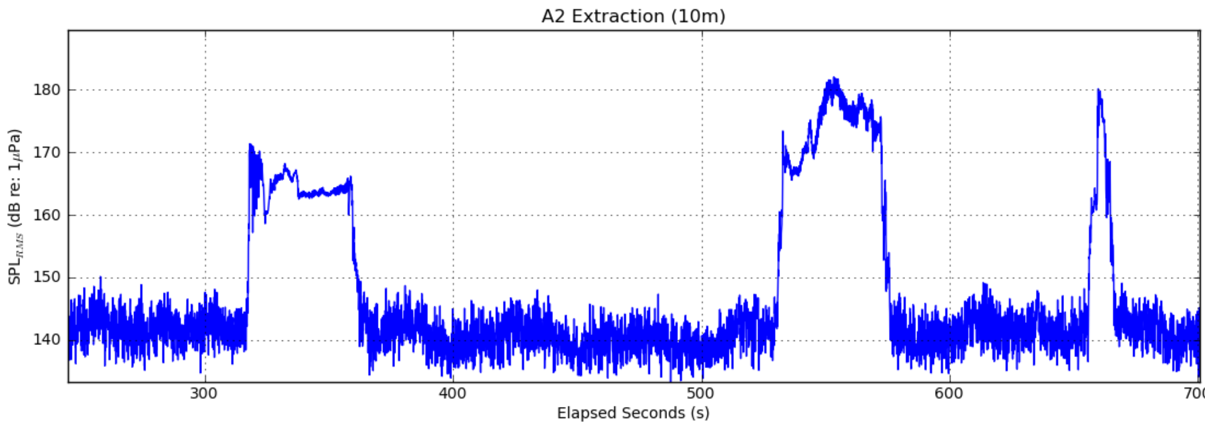


**FIGURE TIME SERIES OF RMS SOUND PRESSURE LEVELS AT 10-METERS FOR VIBRATORY EXTRACTION OF PILE B-2. THREE SEPARATE VIBRATION EVENTS OCCUR DURING THE EXTRACTION.**

Time required for vibratory extraction varied widely, from 1 minute to over 110 minutes. Unlike the RMS pressure level, the extraction time varied with pile size. Extraction time was shorter for 24-inch piles (1, 2, and 3 minutes) than 48-inch piles (9,10,110 minutes). The extraction of pile A-3, totaled approximately 110 minutes, which is significantly longer than the next longest extraction of 10 minutes for pile B-2. Extraction began for pile A-3 on 15 February, however after over 65 minutes of active vibration the pile had not moved. Extraction for the same pile was attempted again on 18 February. After over 15 minutes of vibration the pile still had not moved. The pile was then impact driven another foot in an attempt to loosen the pile and extraction was attempted again. Extraction was complete after approximately 30 minutes of vibration following the impact driving. The average time for vibratory extraction, approximately 20 minutes, was much longer than the average time of 3 minutes used to drive the pile with vibration, due primarily to the significant time required to extract pile A3. If pile A3 is considered an outlier and not included, the average extraction time, 5 minutes, is only slightly longer than the time for the vibratory drive used to set the pile.

**TABLE 1. OBSERVED SOUND LEVELS FOR VIBRATORY EXTRACTION.**

| Pile | Date | Size (inches) | $SPL_{RMS}$ (dB) (10m) | Approximate Time (minutes) | Cumulative SEL (dB) |
|---|---|---|---|---|---|
| A1 | 14-Feb | 24 | 167 | 3 | 190 |
| A2 | 17-Feb | 24 | 176 | 2 | 193 |
| A3 | 15-Feb | 48 | 173 | 65 | 210 |
| A3 | 18-Feb | 48 | 170 | 45 | 206 |
| A4 | 18-Feb | 48 | 174 | 9 | 203 |
| B1 | 21-Feb | 24 | 171 | 1 | 188 |
| B2 | 21-Feb | 48 | 172 | 10 | 199 |

The measured Cumulative SEL values shown in table-1 deviate in some instances by up to a couple decibels from the Cumulative SEL that would be expected given the average RMS pressure level and drive duration. These differences are attributable to the different approach used in calculating each quantity; RMS values were calculated using 30-second averages to be consistent with previous studies, while Cumulative SEL was derived from direct integration.

## Observed Transmission Loss for Vibratory Extraction

The coefficient of transmission loss for vibratory extraction was calculated using the transmission loss equation and actual observed ranges as outlined in the *Columbia River Crossing Test Pile Project Hydroacoustic Monitoring Final Report*. Transmission loss calculated from both RMS pressure and Cumulative SEL were similar to one another, as expected, and in line with the practical spreading model at all ranges except 200 meters. High levels of ambient noise were observed at the 200 meter station during five of the seven vibratory extractions. The high noise levels affected the calculation of RMS pressure and Cumulative SEL, resulting in higher overall sound levels and a lower than anticipated transmission loss at 200 meters. The cause of the high ambient noise is unknown.

**TABLE 2. TRANSMISSION LOSS FOR VIBRATORY EXTRACTION.**

| Coefficient of Transmission Loss | | | | |
|---|---|---|---|---|
| | RMS Pressure | | Cumulative SEL | |
| Range (m) | Average | 1σ | Average | 1σ |
| 200.0 | 12.9 | 1.2 | 13.1 | 2.9 |
| 400.0 | 15.3 | 2.0 | 15.8 | 1.7 |
| 800.0 | 14.7 | 1.5 | 14.9 | 1.4 |
| -800.0 | 14.8 | 0.9 | 15.8 | 1.3 |

## Spectral Density of Vibratory Extraction

Power spectral densities were calculated for each vibratory extraction at each monitored range. Vibratory extraction produced broadband energy. The majority of the energy occurred in frequencies below 1,000 Hz, with energy levels gradually falling off at higher frequencies. Transmission loss was expected to be spectrally flat, however was consistently observed to be greatest between 100 and 1,000 Hz, and flat above 1,000 Hz. The cause of the increased propagation loss at frequencies between 100 and 1,000Hz is unknown.

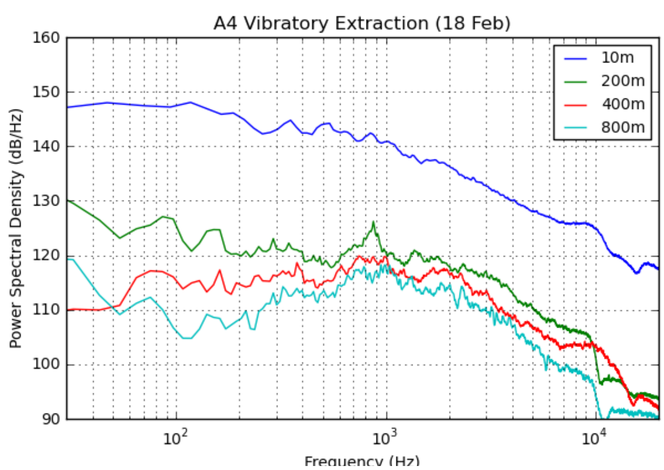


**FIGURE 1. SPECTRAL DENSITY OF VIBRATORY EXTRACTION WITH RANGE.**