September 21, 2006

Mr. Ross Widener
Widener & Associates
10108 32nd Ave W, Suite D
Everett, WA 98204

Re: SR 411, Lexington Bridge Underwater Noise Monitoring Results

Dear Mr. Widener,

This memo summarizes the preliminary results from the pile driving monitoring activities associated with the construction of the Lexington Bridge on SR 411. These measurements were obtained side-by-side with your biologist monitoring the affected environment.

This technical memorandum describes the data collected during pile driving efforts at the construction site for the new Lexington Bridge on SR411 during the months of July and August 2006. Ambient underwater sound levels in the river were measured with and without the nearby train traffic on the nearby Burlington Northern Railroad tracks. The ambient sound level results were an RMS of 160 dB with peaks between 170 and 175 dB (see Attachment 1).

Eight 24-inch diameter steel piles were monitored at various water depths. Piles were driven with an ICE Model 60 diesel Pile Hammer (see Attachment 2). The pile hammer energy to drive a pile can be estimated by the stroke length used to drive the pile. Most piles for this structure were driven using 5 to 7 foot hammer strokes with an occasional 9 foot stroke. This equates to 35 to 49 K foot pounds with an occasional drive in excess of 60K ft-lbs. Table 1 summarizes the results for each pile monitored.

Table 1: Summary Table of Monitoring Results.

<table>
<thead>
<tr>
<th>Pile #</th>
<th>Midwater Hydrophone Depth</th>
<th>Bubble Curtain</th>
<th>Absolute Peak (dB)</th>
<th>Rise Time (Sec.)</th>
<th>Number of Pile Strikes</th>
<th>Average Peak for all Pile Strikes (Pa)</th>
<th>+/- Standard Deviation</th>
<th>RMS Average for all Pile Strikes (Pa)</th>
<th>+/- Standard Deviation</th>
<th>Average Decibel Reduction (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4 feet</td>
<td>YES</td>
<td>188</td>
<td>.0011</td>
<td>3</td>
<td>2157</td>
<td>418</td>
<td>370</td>
<td>12</td>
<td>*8</td>
</tr>
<tr>
<td>2</td>
<td>4 feet</td>
<td>NO</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>1.5 feet</td>
<td>YES</td>
<td>194</td>
<td>.0066</td>
<td>12</td>
<td>2063</td>
<td>1315</td>
<td>258</td>
<td>150</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>1.5 feet</td>
<td>NO</td>
<td>202</td>
<td>.0074</td>
<td>180</td>
<td>4864</td>
<td>1702</td>
<td>576</td>
<td>166</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>2 feet</td>
<td>YES</td>
<td>188</td>
<td>.0083</td>
<td>82</td>
<td>2015</td>
<td>234</td>
<td>339</td>
<td>43</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>2 feet</td>
<td>NO</td>
<td>198</td>
<td>.0049</td>
<td>17</td>
<td>5428</td>
<td>1369</td>
<td>533</td>
<td>70</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>1.5 feet</td>
<td>YES</td>
<td>187</td>
<td>.0010</td>
<td>64</td>
<td>1918</td>
<td>107</td>
<td>200</td>
<td>19</td>
<td>4</td>
</tr>
</tbody>
</table>

*Pile 2 required only one strike to seat pile and the monitoring equipment failed to record the data. Pile 8 was used for comparison purposes.

A bubble curtain was tested on alternate piles. The bubble curtain was used to minimize effects of underwater sound for piles 1, 3, 5 and 6. Peak underwater sound levels ranged from 187 to
202 dB peak during the pile driving activity with an effective average reduction of 4 to 9 dB from the use of bubble curtains. The average sound reduction achieved with the bubble curtain on pile 6 was 4 dB, which was approximately half of the reduction seen with the other piles. This could possibly be because the bubble curtain sitting on a small rock and was not seated properly on the bottom of the river allowing sound to escape through the opening.

Other notes and observations made during the monitoring of the pile driving activity include; piles 1 through 3 and the last pile, pile 8, required few strikes before attaining the bearing required for this temporary work structure. Small fish appeared to be feeding along the west bank of the Cowlitz River. No harm to fish was apparent during the pile driving operation from observations made near the piles. Post analysis of the unweighted frequency distribution of the peak pile strikes in the underwater environment can be seen in Figures 1 through 5 below. Figure 1 is the ambient level frequency distribution in the river before driving piles, and it likely includes sound from the project propagating through the piles already in the river as well as sound propagating from the project itself. It does provide a base line for comparing the effect the pile driving activity has on the existing river sound environment. It does not, however, take into consideration the sensitivity organisms may have to any particular range of frequencies by any form of weighting that is likely important in considering its effect on the species effected.

**Figure 1: Unweighted Ambient Underwater Sound**

![Graph of Unweighted Ambient Underwater Sound](image)

In Figure 2 it was not possible to analyze the sound level from pile driving and compare it with the sound level mitigated by the use of a bubble curtain. Pile 2 was not measured because of equipment malfunction during the single pile strike to set pile 2 so only the pile with the bubble curtain on it was measured and analyzed. I have left the ambient sound levels frequency distribution recorded in Figure 1 to show a relationship to the current ambient level.

Figures 3 through 5 demonstrate the effect on the frequency distribution of sound from the peak pile strike on the underwater environment with and without the use of a bubble curtain.
This information may be useful in the future when it is determined at what frequencies beings living in that environment are sensitive to sound.

Figure 2: Pile 1 Unweighted Frequency Distribution Compared with Ambient

Figure 3: Pile 3 & 4 Unweighted Frequency Distribution
Figure 4: Pile 8 & 5 Unweighted Frequency Distribution Compared with Ambient

Figure 5: Pile 6 & 7 Unweighted Frequency Distribution Compared with Ambient

Appended to this technical memorandum are the post processed data sheets for the peak pile strike for each of the piles monitored. This is the form we typically use to report the data that is acquire in our pile monitoring programs. We still have the raw data on file and may be able to further process this into useable information. If you would like to do something different or would like to get the raw data please contact me, Larry Magnoni at (206) 440-4544 or Jim Laughlin at (206) 440-4643.
Sincerely,

Larry J. Magnoni  
Acoustical, Air Quality and Energy Engineer  
LM/ljm  
Attachments  
  • Ambient Sound Level Analysis Sheet  
  • Pile Driver Data Sheet  
  • Unweighted Peak Sound Waveform Analysis Sheets for each Pile  
cc: Jim Laughlin  MS NB82-138  
    John C. Heinley  MS 47390  
    day file  
    file
Ambient Sound Level Analysis Sheet

**Ambient With & Without Train**

**Figure a. Waveform**
![Waveform Graph]

**Figure b. Narrow Band Frequency Spectra**
![Frequency Spectra Graph]

**Figure c. Accumulation of Sound Energy**
![Accumulation Graph]

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
<th>Peak</th>
<th>RMS90%*</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-feet - 00:00:00 With Train</td>
<td>170</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>2-feet - 00:00:00 Without Train</td>
<td>175</td>
<td>160</td>
<td>160</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*
Model 605
Fuel-Injected Diesel Pile Hammers

Clean • Efficient • Reliable

Designed and engineered for lightweight driven pile applications.
- High-pressure fuel injection provides easy start, even in extreme weather & soil conditions.
- Dual injectors dual-size fuel atomization and delivery for clean, efficient operation.
- Remote variable fuel pump.
- Operates on vegetable-based fuel & lubricants without modification, contributing to a clean and toxic-free job site.
- Hydraulically-operated remote throttle permits precise control of stroke to match hammer energy to any job or pile condition.
- Upper & lower polymers: ram bearings minimize wear and maximize energy transfer.
- Lower cylinder and other critical components are chemically-treated for superior surface hardness and fatigue resistance.
- Ferr-chromium alloy forged ram & axles exceed strength of cast ram & axles for durability and long life.
- Weighs less than competitive hammers to move more easily from pile to pile.
- Swiveling, fixed and sliding head set-ups available in 16 and 3 ft. sections.
- Four models of light- to- heavy- duty headers for precise pile positioning.

Working Specifications

Ram:
- Maximum energy
  Ratemax 7,000 lb (3175 kg)
- Ratemax continuous energy
  72,900 ft-lbs (98.9 kJm)
- Ratemax minimum energy
  60,000 ft-lbs (81.4 kJm)
- Speed (strokes per minute)
  26,000 ft-lbs (35.2 kJm)
  44±5

Weights:
- Bare hammer
  3,900 lb (1765 kg)
- Typical weight (with pile cap in 26” leads)
  5,900 lb (2680 kg)

Capacities (adequate for average day of operation):
- Diesel fuel tank
  18 gal (70 l)
- Lube oil tank
  8 gal (30 l)

Dimensions of Hammer:
- Width (side to side)
  26” (660 mm)
- Depth
  37.5” (950 mm)
- Centline to front
  17” (430 mm)
- Centline to rear
  20.5” (520 mm)
- Length (hammer only)
  17-3” (508 mm)
- Operating length (top of ram to toe of pile)
  26-9” (8550 mm)
# Model 60S Fuel-Injected Diesel Pile Hammers

## ICE 60S Diesel Pile Hammer Bearing Chart

<table>
<thead>
<tr>
<th>x</th>
<th>s</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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</tr>
</tbody>
</table>

**CAUTION:** Driving at high speeds can result in severe damage. Driving in excess of the lower limit for more than 1 hour can result in severe damage. Driving in excess of 1 hour can result in severe damage. Driving in excess of 1 hour can result in severe damage.

## Leads/Spotters

ICE manufactures leads with 20", 26", 32", and 36" guide rails for all ICE and other pile hammers. Standard components are available in 8 instruments for swinging, fixed, and sliding lead setups. Two designs are available to provide the most effective configuration for every job. Four models of spotters and three spotter power unit sizes are available.

## Drive Caps

ICE offers a drive cap bushing system for all ICE lead sizes as well as for pile leads. Drive cap bushings are available for practically any pile type and size. The ICE drive cap system maintains pile top position under the hammer, protects the hammer from peak stresses, maximizes pile top deformation, and transmits maximum force to pile.

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**Corporate office:**
307 Warehouse Drive, Matthews, NC 28104
Phone: 704-827-0300, 800 ICE (430-8100)
Fax: 704-827-8200
Figure a. Waveform

Figure b. Narrow Band Frequency Spectra

Figure c. Accumulation of Sound Energy

Figure d. Sound Pressure and Sound Energy Levels

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-feet - 11:15:16</td>
</tr>
<tr>
<td>4-feet</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

Pile 3 w BC

**Figure a. Waveform**

**Figure b. Narrow Band Frequency Spectra**

**Figure c. Accumulation of Sound Energy**

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
<th>Peak</th>
<th>RMS90%*</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-feet - 11:01:07</td>
<td>194</td>
<td>181</td>
<td>165</td>
</tr>
<tr>
<td>1.5-feet</td>
<td>194</td>
<td>181</td>
<td>165</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

**Pile 4 w/o BC**

**Figure a. Waveform**

**Figure b. Narrow Band Frequency Spectra**

**Figure c. Accumulation of Sound Energy**

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>37-feet - 11:52:15</td>
</tr>
<tr>
<td>1.5-feet</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

**Pile 5 w/ BC**

**Figure a. Waveform**

**Figure b. Narrow Band Frequency Spectra**

**Figure c. Accumulation of Sound Energy**

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
<th>Peak</th>
<th>RMSse%*</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.8-feet - 15:34:04</td>
<td>188</td>
<td>174</td>
<td>162</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

**Pile 6 w BC**

**Figure a. Waveform**

**Figure b. Narrow Band Frequency Spectra**

**Figure c. Accumulation of Sound Energy**

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>33-feet - 16:03:35</th>
<th>Peak</th>
<th>RMSs90%*</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5-feet</td>
<td>187</td>
<td>173</td>
<td>157</td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

**Pile 7 w/o BC**

**Figure a. Waveform**

**Figure b. Narrow Band Frequency Spectra**

**Figure c. Accumulation of Sound Energy**

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
<th>Peak</th>
<th>RMS50%*</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.8-feet - 16:18:52</td>
<td>193</td>
<td>181</td>
<td>164</td>
</tr>
<tr>
<td>1.5-feet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%).*
Unweighted Peak Sound Waveform Analysis Sheets for each Pile

**Pile 8 w/o BC**

**Figure a. Waveform**

**Figure b. Narrow Band Frequency Spectra**

**Figure c. Accumulation of Sound Energy**

**Figure d. Sound Pressure and Sound Energy Levels**

<table>
<thead>
<tr>
<th>Signal Analysis Sound Pressure / Energy Levels</th>
<th>32.8-feet - 16:35:43</th>
<th>Peak</th>
<th>RMS90%*</th>
<th>SEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-feet</td>
<td>198</td>
<td>184</td>
<td>166</td>
<td></td>
</tr>
</tbody>
</table>

*Impulse averaged over 90% of accumulated energy (5% to 95%)*