From: Daly, Keith
To: document.control;
cc: Peppers, Nicki;
Subject: FW: Final Hydroacoustic Monitoring Plan for Test Pile Project
Date: Wednesday, February 02, 2011 3:01:07 PM
Attachments: Final Hydroacoustic Monitoring Plan.pdf

Please file under Contract 8078, Underwater Noise Monitoring Plan, Hydro Acoustic Monitoring Plan

Thanks,

Keith Daly
Assistant Business Manager

Columbia River Crossing Project | mailto:dalyk@columbiarivercrossing.org
700 Washington St. Suite 300, Vancouver, WA 98660
office: 360.816.8870 | Office: 503.256.2726 Ext. 8870
Fax: 360.737.0294

From: Daly, Keith
Sent: Wednesday, February 02, 2011 3:00 PM
To: 'Kevin Culbert (Kevinc@americanconstco.com)'; 'vernonu@americanconstco.com'
Cc: Green, Frank; Morrow, Steve
Subject: FW: Final Hydroacoustic Monitoring Plan for Test Pile Project

Kevin/Vernon,

Please make sure a copy of the attached Underwater Noise Monitoring Plan is kept on the jobsite with other permits and approvals. If you have any questions please let me know.

Thanks,

Keith Daly
Assistant Business Manager

Columbia River Crossing Project | mailto:dalyk@columbiarivercrossing.org
700 Washington St. Suite 300, Vancouver, WA 98660
office: 360.816.8870 | Office: 503.256.2726 Ext. 8870
Fax: 360.737.0294

From: Morrow, Steve
Sent: Wednesday, February 02, 2011 1:39 PM

To: Green, Frank; Daly, Keith
Cc: Peterson, Laura; RainsbS@wsdot.wa.gov; Degenhart, Mark
Subject: Final Hydroacoustic Monitoring Plan for Test Pile Project

Frank & Keith:

Can you make sure this plan is part of the contractor's binder (and inspector) for permits/approvals? Thanks!

Steve Morrow
Environmental Coordinator
Columbia River Crossing
700 Washington Street, Suite 300
Vancouver, WA 98660
(360) 816-8892
morrows@columbiarivercrossing.org

INTERSTATE 5

Columbia River Crossing Test Pile Project
UNDERWATER NOISE MONITORING PLAN

Prepared by:
Columbia River Crossing
700 Washington Street, Suite 300
Vancouver, WA 98660

And

Washington State Department of Transportation
Office of Air Quality, Noise and Energy
15700 Dayton Avenue North, P.O. Box 330310
Seattle, WA 98133-9710

January 2011

INTRODUCTION

The Columbia River Crossing Project proposes to drive test piles into the underwater substrate near two proposed pier locations for the new Interstate 5 (I-5) bridge (see vicinity map Figure 1). These locations were chosen to represent the range of substrate conditions and underwater noise expected from pile installation for temporary works required to support construction of the new bridge piers in the Columbia River.

Piles will be monitored and evaluated to determine noise levels during installation and tested for load capacity after installation. Driving methods will include vibratory and impact driving. Piles installed will be extracted by vibratory methods to determine noise levels and duration. If vibratory extraction is not possible then piles will be cut off 2 feet below the mud line.

Acoustic monitoring will include airborne and underwater noise levels. A confined and an unconfined bubble curtain will be tested and evaluated. Structural evaluation of the pile capacity will also be determined. The results of the test program will be summarized in a report.

Objective of the project include:

- Determine the potential underwater noise levels expected for vibratory installation of temporary piles in the predominant substrate type found at the project site.
- Determine the underwater noise levels expected for impact installation of temporary piles for the two substrate types found at typical mid-channel depths at the project site.
- Determine strike numbers necessary to place pile to reach load bearing capacity with an impact hammer.
- Determine effectiveness of two noise mitigation strategies during impact pile driving.
- Determine transmission loss of pile installation noise for both impact and vibratory installation.
- Determine extent of construction noise impacts in-air for impact pile driving.
- Verify production rates for pile installation.
- Determine the feasibility of vibratory installation methods in liquefiable substrate.

PROJECT AREA

The project is located on the west side of the I-5 bridges crossing the mainstem Columbia River in Oregon and Washington (Figure 1).

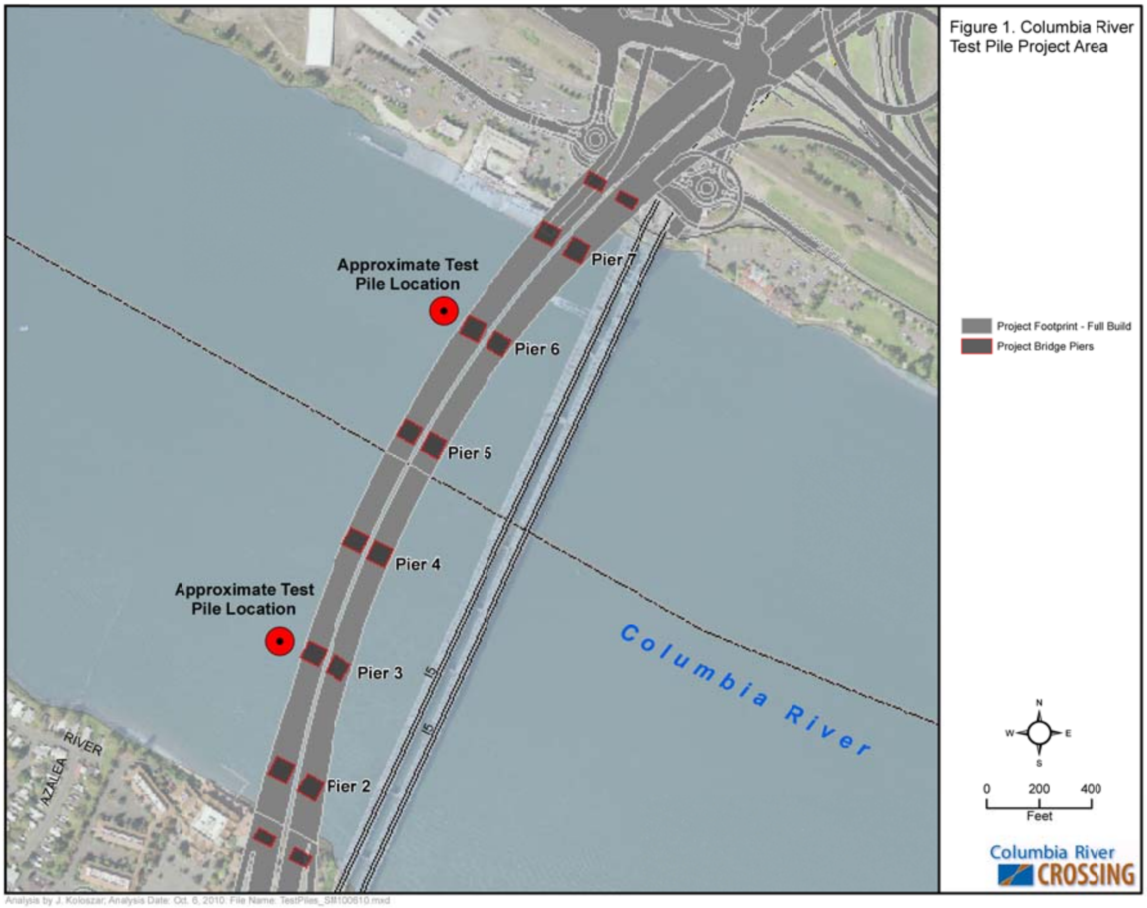
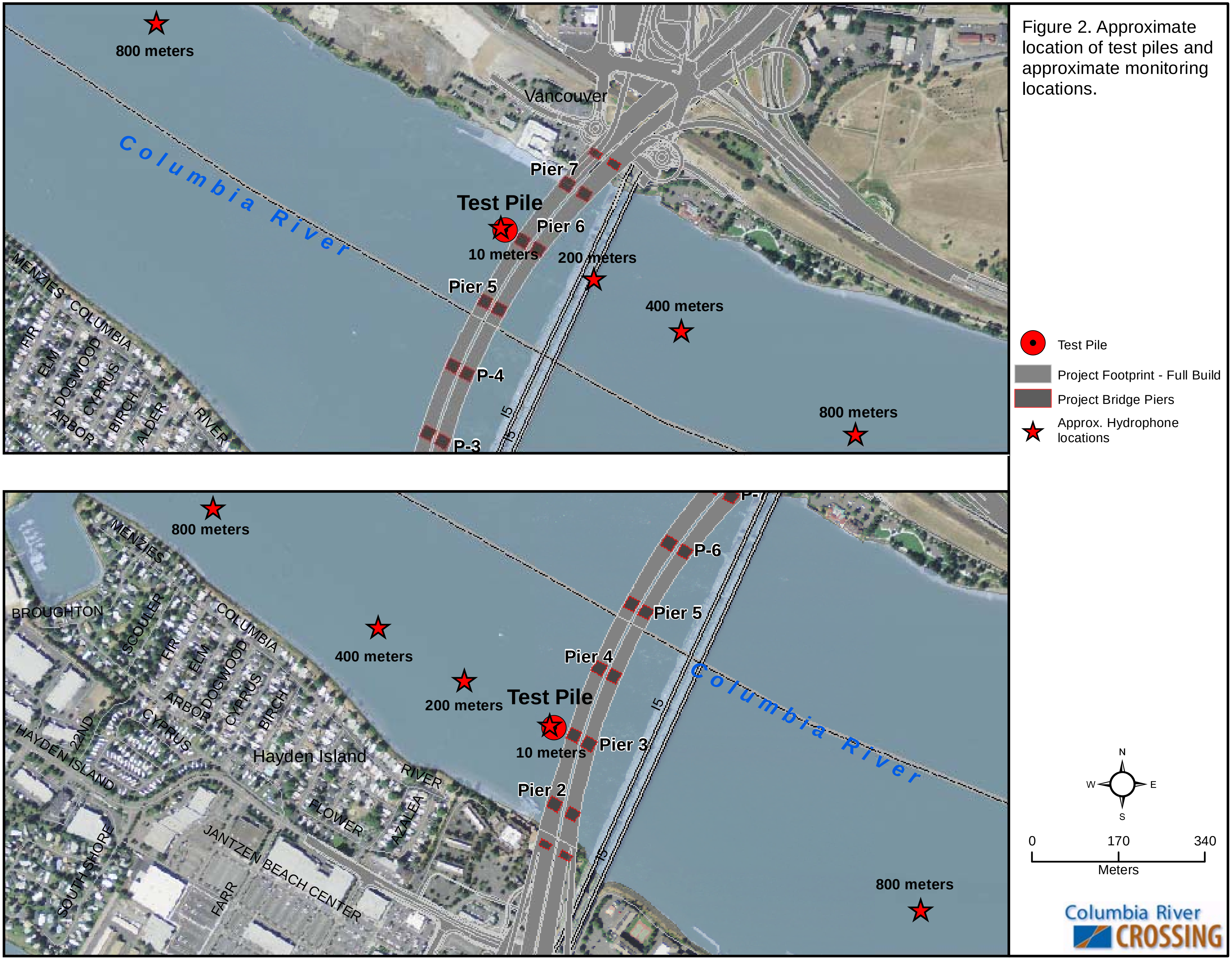


Figure 1. Location of Test Pile Sites at Proposed Piers #3 and #6.

PILE INSTALLATION LOCATION

There will be a total of six piles driven near the two proposed pier locations The locations for driving test piles were identified to represent the two substrate types present (coarse sand at Pier 3 and Troutdale formation at Pier 6) and a typical or mid-channel depths at the proposed pier locations. Figure 2 indicates the approximate location of the piles to be monitored and the approximate hydrophone locations. One hydrophone will be located at 10 meters from each pile. For piles installed near Pier 3, three additional hydrophones (with a clear line-of-sight between the hydrophone and the piles) will be placed at approximately 200 meters, 400 meters, and 800 meters downriver and one additional hydrophone 800 meters upriver from each pile. For piles installed near Pier 6, three additional hydrophones will be placed at approximately 200 meters, 400 meters and 800 meters upriver and one additional hydrophone will be placed 800 meters downriver.

Figure 2. Approximate location of test piles and approximate monitoring locations.



Analysis by J. Koloszar; Analysis Date:Jan. 21, 2011: File Name: TestPiles2_SM100610.mxd

PILE INSTALLATION

Two steel pile sizes will be used for the test pile project; 24-inch and 48-inch. Because of the uncertainty of what pile size a contractor will use on the work trestles/platforms, the sizes were chosen to represent the range of sizes potentially used on the project. Table 1 lists the water depth, and the number and size of piles that will be installed.

Table 1
Piles to be Installed for the Columbia River Crossing Test Pile Program

Structure	Approximate Water Depth (from OHWM)	Diameter of Hollow Steel Piles
Pier 3	41-46 feet	2 24-inch 2 48-inch
Pier 6	41-46 feet	1 24-inch 1 48-inch

Two test piles at Pier 3 will be installed to test production rates using a vibratory hammer first with load bearing capacity determined by an impact hammer. During the time the impact hammer is used, both an unconfined and confined bubble curtain will be in place. Two test piles at Pier 3 will be installed using an impact hammer to test the effectiveness of both an unconfined and confined bubble curtain. Two test piles at Pier 6 will be installed using only a confined bubble curtain to test its effectiveness. Bubble curtains will not be used during vibratory driving. Table 2 lists the method of installation for each pile at each of the two locations. All piles will be subsequently removed with a vibratory hammer, if possible. If piles cannot be extracted, they will be cut off approximately 2 feet below the mud line. The hammer apparatus will be stationed on a work barge anchored in position with spuds.

Table 2
Method of Steel Pipe Pile Installation for the Columbia River Crossing Test Pile Project

Pier #3 24-inch	Pier #3 24-inch	Pier #3 48-inch	Pier #3 48-inch	Pier #6 24-inch	Pier #6 48-inch
Impact	Vibe & Impact	Impact	Vibe & Impact	Impact	Impact
Unconfined bubble curtain	Confined bubble curtain	Unconfined Bubble curtain	Confined bubble curtain	Confined bubble curtain	Confined bubble curtain

Hydroacoustic monitoring will be conducted during installation of all six piles, which are driven in water depths that are representative of mid-channel or typical water depths at the project location where piles will be driven. Hydroacoustic monitoring equipment will be strategically located in near-field and far-field locations. Near-field monitoring points will be 10 meters from the pile installation. T Far-field monitoring locations of the test piles near Pier 3 will be downriver, approximately 200, 400, and 800 meters, and downriver and approximately 800 meters upriver. Far-field monitoring locations of the test piles near Pier 6 will be downriver, approximately 800 meters, and upriver, approximately 200, 400, and 800 meters.

Hydroacoustic monitoring of steel pile driving will include:

- Measuring underwater background levels,
- Monitoring of 6 steel piles,
- Testing sound attenuation system effectiveness.

METHODOLOGY

Background underwater noise levels will be measured for a minimum of three full 24-hour cycles in the absence of construction activities to determine background sound levels. Background sound levels will be reported as the 50% Cumulative Distribution Function (CDF) based on 30-second Root Mean Square (RMS) values and include a spectral analysis of the frequencies.

A total of three 24-inch and three 48-inch diameter steel piles will be monitored for underwater noise levels. If piles require splicing of one pile to another to create a longer pile, then monitoring will be conducted for the entire length of the pile to be driven. All piles monitored will be tested with the sound attenuation system, on and off (presence and absence) to test its effectiveness. To account for varying resistance as the pile is driven; the sound attenuation device will be turned off for 30 second periods during the beginning, the middle third, and near the end of the drive. Pile driving should resume for a minimum of two minutes after each 30 second period the attenuation device is off.
Details the equipment that will be used to monitor underwater sound pressure levels are provided in the Appendix.

Monitoring equipment will be set to a minimum frequency range of 20 Hz to 10 kHz and a minimum sampling rate of 24,000 Hz. Sampling rates higher than 24 kHz are preferred. Frequency ranges above 10 kHz are preferable. To facilitate possible further analysis of data the underwater signal will be recorded as a text file (.txt) or wave file (.wav).

One hydrophone will be placed at between 1 and 3 meters above the bottom at a distance of 10 meters from each pile being monitored. Hydrophones placed upriver and downriver (at the 200-, 400- and 800-meter distances) will be placed at a depth greater than 5 m below the water surface or placed 1-3 meters above the bottom. A weighted tape measure will be used to determine the depth of the water. Each hydrophone will be attached to a nylon cord or a steel chain if the current is swift enough to cause strumming of the line. The nylon cord or chain 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 buoy or raft at the surface and checked regularly to maintain the tightness of the line. The distances will be measured by a tape measure, where possible, or a range-finder for those hydrophones that are distant from the pile. There will be a direct line of sight between the pile and the hydrophone in all cases. GPS coordinates will be recorded for each hydrophone location.

When the river velocity is greater than 1 meter/second, a flow shield around each hydrophone will be used to provide a barrier between the irregular, turbulent flow and the hydrophone. River velocity will be measured concurrent to sound measurements. If velocity is greater than 1 meter/second, a correlation between sound levels and current speed will be made to determine whether the data is valid and should be included in the analysis.

Hydrophone calibrations will be checked at the beginning of each day of monitoring activity. Prior to the initiation of pile driving, the hydrophones will be placed at the appropriate distances and depth as described above.

It will be necessary to have the inspector/contractor coordinate with and 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. Peak levels of each strike will be monitored in real time. Sound pressure will be measured in Pascals which are easily converted to decibel (dB) units (e.g. 1000 Pascals = 180 dB).

Prior to and during the pile driving activity environmental data will be gathered such as wind speed and direction, air temperature, humidity, surface water temperature, water depth, wave height, weather conditions, 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 and the time at which the bubble curtain or functional equivalent is turned on and off will be recorded.

The chief construction inspector will supply the acoustics specialist with a description of the substrate composition, hammer model and size, hammer energy settings and any changes to those settings during the piles being monitored, depth pile driven, blows per foot for the piles monitored, and total number of strikes to drive each pile that is monitored.

SIGNAL PROCESSING

Post-analysis of the sound level signals will include determination of the maximum absolute value of the instantaneous pressure within each strike recorded for each pile, Root Mean Square (RMS) values for both vibratory and impact strikes for each absolute peak pile strike, impact rise time, number of strikes per pile and per day, number of individual strikes exceeding 206 dB_{peak}, number or percent of strikes exceeding 183 dB Sound Exposure Level (SEL) and 187 dB SEL, SEL of the pile strike with the absolute peak sound pressure, mean SEL, and cumulative SEL (cumulative SEL = single strike SEL + 10*log (# hammer strikes) and a frequency spectrum both with and without mitigation, between a minimum of 20 and 10,000 Hz for up to eight successive strikes with similar sound levels. RMS value for vibratory pile driving will be calculated as 30-

second RMS values for each 30-seconds of the vibratory driving event on each pile. The 30-second RMS values for each pile will be averaged.

Background sound levels will include calculating 30-second RMS and plotting these values on a CDF. The average background sound level will be estimated using the 50% CDF.

ANALYSIS

Analysis of the data from the San Francisco-Oakland Bay Bridge Pile Driving Demonstration project (PIDP) indicated that 90 percent of the acoustic energy for most impact pile driving impulses occurred over a 50 to 100 milliseconds period with most of the energy concentrated in the first 30 to 50 milliseconds. The impact RMS values computed for this project will be computed over the duration between where 5% and 95% of the energy of the pulse occurs. The single strike Sound Exposure Levels (SEL) will be calculated from the impact data between 5% and 95% of the energy of the individual pulse. The SEL energy plot will assist in interpretation of the single strike waveform. The single strike SEL of the absolute peak pile strike along with the total number of strikes per pile and per day will be used to calculate the cumulative SEL for each pile and each 24-hour period

In addition a waveform analysis of the individual absolute peak pile strikes will be performed to determine any changes to the waveform with the bubble curtain operating. A comparison of the frequency content with and without noise attenuation as well as between monitoring locations will be conducted.

Units of underwater sound pressure levels will be dB re: 1 micropascal and units of SEL will be dB re: 1 mircropascal^2 sec.

REPORTING

An analysis of the change in the waveform and sound levels with and without the bubble curtain rings operating or functional equivalent will be conducted. Background sound levels will be reported as the 50 percent CDF on both a daily and overall basis.

A 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 impact and 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. A detailed description of the bubble curtain(s), including design specifications.
3. The impact hammer energy rating used to drive the piles, make and model of the hammer(s), and description of the vibratory hammer.

4. A description of the sound monitoring equipment.
5. The distance between hydrophones and depth of water at the hydrophone locations.
6. The depth of the hydrophones.
7. The distance from the pile to the water's edge.
8. The depth of water in which the pile was driven.
9. The depth into the substrate that the pile was driven.
10. The physical characteristics of the bottom substrate into which the piles were driven.
11. The total number of strikes to drive each pile and for all piles driven during a 24-hr period.
12. The background sound pressure level reported as the 50% CDF.
13. The results of the hydroacoustic monitoring, including the frequency spectrum, ranges and means including the standard deviation/error for the peak and RMS SPL's, single-strike and cumulative SEL with and without the attenuation system, an estimation of the number of strikes that exceeded the cumulative SEL threshold and an estimation of the distance at which peak and cumulative SEL values reach respective thresholds and the distance at which RMS values reach the relevant marine mammal thresholds and background sound levels. Vibratory driving results will include the maximum and overall average RMS calculated from 30-second RMS values during the drive of the pile.
14. A description of any observable fish, pinniped, or bird behavior in the immediate area and, if possible, correlation to underwater sound levels occurring at that time.

APPENDIX

Equipment for Underwater Sound Monitoring

DAVID EVANS AND ASSOCIATES INC.
MARINE SERVICES

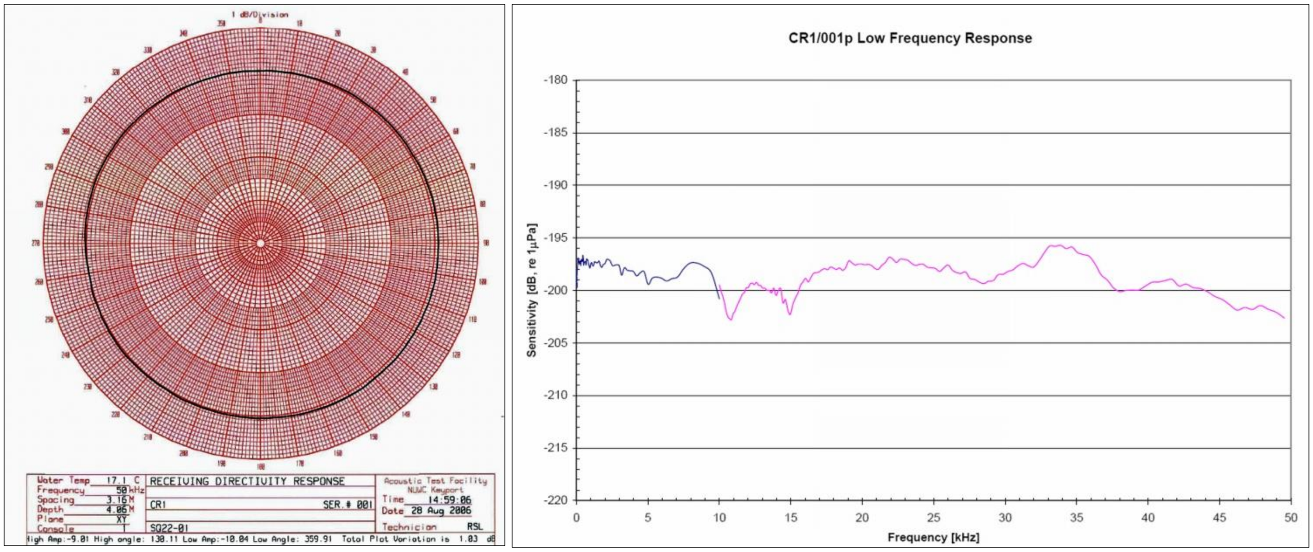
HYDROACOUSTIC MONITORING EQUIPMENT FOR PILE DRIVING
DEA equipment relative to Table 3 from CRC monitoring Plan

Item	Specifications	Usage	DEA Equipment
Hydrophone with 200 feet of cable	Receiving Sensitivity- 211dB ±3dB re 1V/µPa	Capture underwater sound pressures and convert to voltages that can be recorded / analyzed by other equipment.	CR1 Hydrophones with 30 meter and 60 meter cables. **Specifications attached.**
Signal Conditioning Amplifier (4-channel)	Amplifier Gain- 0.1 mV/pC to 10 V/pC Transducer Sensitivity Range- 10^{-12} to 10^{3} C/MU	Adjust signals from hydrophone to levels compatible with recording equipment.	4 Channel ST1400ENV has integral **voltage** preamplifiers with precision gain steps. Additional monitoring sites will use dual channel ST191's. **Specifications attached.**
Calibrator (pistonphone-type)	Accuracy- IEC 942 (1988) Class 1	Calibration check of hydrophone in the field.	DEA will perform a free-field calibration with calibrated projector to confirm proper system levels and operation.
Portable Dynamic Signal Analyzer (4-channel)	Sampling Rate- 24K Hz or greater	Analyzes and transfers digital data to laptop hard drive.	ST1400ENV mobile date recorder and sound level monitor. **Specifications attached.**
Microphone (free field type)	Range- 30 – 120 dBA Sensitivity- -29 dB ± 3 dB (0 dB = 1 V/Pa)	Monitoring airborne sounds from pile driving activities (if not raining).	Larson Davis Type 1 precision integrating sound level meters
Laptop computer	Compatible with digital analyzer	Record digital data on hard drive and signal analysis.	ST1400ENV mobile date recorder and sound level monitor. **Specifications attached.**
Real Time and Post-analysis software	-	Monitor real-time signal and post-analysis of sound signals.	SpectraLAB software by Sound Technologies. Required for post processing of data using spectrogram and narrow band spectrum features. Also includes expanded time series views and other advanced processing tools.

UNDERWATER SOUND MONITORING - HYDROPHONE SPECIFICATIONS

Model and Serial No.	CR-1, 10181-01	CR-1, 10246-03	CR-1, 10247-01	CR-1, 10247-02
Cable length	30 m , 98 ft	30 m , 98 ft	61 m , 200 ft	61 m , 200 ft
Linear Freq Range (+/- 3dB)	20 Hz – 50 kHz†	20 Hz – 50 kHz†	20 Hz – 50 kHz†	20 Hz – 50 kHz†
Useable Frequency Range (+3/-20dB)	0.2 Hz – 110 kHz†	0.2 Hz – 110 kHz†	0.2 Hz – 110 kHz†	0.2 Hz – 110 kHz†
Sensitivity [dB, re 1V/μPa]	-202.3‡	-199.29‡	-199.86‡	-200.16‡
Date of last Calibration	18-May-2010	16-Sept-2010	16-Sept-2010	16-Sept-2010
Capacitance [nF]	12.13	11.62	13.28	13.81
Dissipation (%)	1.60	1.474	1.415	1.340
Directionality (below 10 kHz)	Omnidirectional	Omnidirectional	Omnidirectional	Omnidirectional
Dimensions [mm]	73 L x 32 Dia.	73 L x 32 Dia.	73 L x 32 Dia.	73 L x 32 Dia.
Operating Temperature Range (°C)	-25 to 60‡	-25 to 60‡	-25 to 60‡	-25 to 60‡

† Based on integration with ST191 with 1MΩ input impedance. If used with the ST1400 with 10MΩ input impedance, then the low frequency -3dB point will be decreased by a factor of 10 (e.g. 2Hz instead of 20Hz).
‡ Hydrophone is spot calibrated at the factory; calibration is guaranteed between -5C and 30C.



Typical CR1 hydrophone directivity and frequency response graphs.

DAVID EVANS AND ASSOCIATES INC.

MARINE SERVICES

UNDERWATER SOUND MONITORING – ST191
ACQUISITION SYSTEM SPECIFICATIONS

CONFIGURATION	FEATURE DESCRIPTION
Digital PC Link:	High Speed 24-bit USB (universal serial bus)
Digital Engine:	Integrated DSP w/Programmable EPROM
Data Buffers:	Proprietary High-Density (Virtual Zero Latency)
Size:	4.5”W x 3.0”D x 1.25”H (high-impact portable enclosure)
ANALOG INPUTS	
Channel:	Dual (Independent)
Type:	Single-Ended_SE
Connector:	Instrumentation BNC
Coupling:	AC (<1Hz)
Linear Signal Level:	20mV to 10Vrms; >28Vp-p
Max Signal Level:	18Vrms/50Vp-p (14Vdc)
Calibration:	NIST certified
Impedance:	18K Ohm
ANALOG OUTPUTS	
Channels:	Dual (Independent)
Type:	Single-Ended_SE
Impedance:	150 Ohms
GENERAL SYSTEM	
Power Source:	Self powered via fully regulated USB supply
Operational Mode:	High Speed 32-bit USB I/O
Amplitude Accuracy:	Typ: 0.1dB
SNR/THD/IMD/CS:	Typ: >100dB; <0.01%; <0.01%; >90dB
Phase Response:	Typ: <0.2_degrees @ 20Hz; <2_degrees @ 20kHz
Frequency Range:	2.5Hz - 22kHz; -3dB @ 2.5Hz
System Response:	Typical PassBand: <+/- 0.2dB_5Hz - 20kHz
Digital Engine:	24-bit internal audio stream
Sample Rate:	4kHz - 48kHz w/ auto SR detection
Converter System:	Proprietary high-resolution system w/precision aliasing
Duplex Operation:	Full Stereo (simultaneous Record_Capture/Play)

ST191, manufactured by Sound Technology, is a self-powered USB-based instrumentation I/O which provides direct-to-PC connections for record, playback, analyze and monitor high-quality audio, dynamic signals, or live acoustic sources (e.g. ambient or environmental sound). The ST191 is a precision device which is a combination PC sound system/instrument quality interface. The I/O circuitry is comprised of field proven advanced signal conditioning technology featuring an unprecedented linearized multi-stage input capable of handling up to 18Vrms (50Vp-p). High voltage overload protection is provided via the isolated dual channel analog BNC industrial connectors. The robust voltage input circuitry and extended low-frequency range was specifically optimized to easily handle a wide range of dynamic signal sources, transducers and sensors for mission critical PC-based Sound-DAQ applications.

The hot swappable/self-powered USB design utilizes a proprietary isolated, preconditioned, and regulated power supply scheme - optimized to maintain the highest signal integrity and performance regardless of environment. A buffered stereo output is provided to interface to the user system.

True instrument quality and performance is achieved through the use of proprietary designs, careful engineering, and the highest quality components.

I/O designed and optimized for the real world of data acquisition, dynamic signal analysis & processing.

DAVID EVANS AND ASSOCIATES INC.
MARINE SERVICES

UNDERWATER SOUND MONITORING – ST1400ENV SPECIFICATIONS
REAL TIME DYNAMIC SIGNAL ACQUISITION SYSTEM

Independent Acquisition Channels	4
Sampling / channel	24-bit @ 96kHz
Input Level Meter	Volts, dBV, dBu, RMS/Peak with Peak Frequency
Sound Level Meter	SPL, Pascals
Sound Profiles/SLM (air ref 20µPa; water ref 1 µPa)	Level, SPL, SEL, LEQ (slow, fast or impulse)
Digital Meter panel	Level, Peak Hz, Cal Ref, Units – NTFS File System
Input Voltage Range	<100µV to 70 Vrms (+/- 100 Vpeak)
Input Modes	Voltage, Hydrophone, ICP/IEPE, SE
Noise Floor (TYP)	120 dB
Spectral Dynamic Range	>100 dB (unweighted)
Frequency Response	<1 Hz to >40 kHz
Variable Gain	20 dB sliders
Selectable Precision Gain	X0.1, x1, x10, x100
Preset User Configurations	Text Based Log Files
System Calibration	NIST certified

ST1400ENV with 61 meter CR-1 hydrophone.