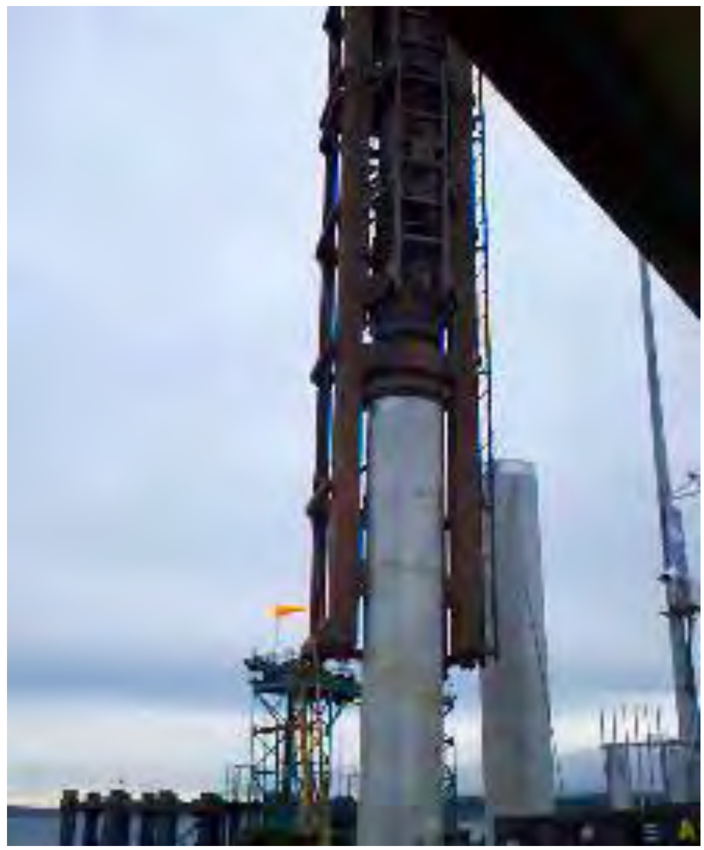
SR 20 PORT TOWNSEND FERRY TERMINAL

Slip 1 Transfer Span Piles Underwater Sound Levels:



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ACRONYMS AND ABBREVIATIONS

AMAR	Autonomous Multi-Channel Acoustic Recorder
CDF	Cumulative Distribution Function
dB	un-weighted decibel
dBA	A-weighted decibel
FHWA	Federal Highway Administration
HPU	hydraulic power unit
Hz	hertz
Leq	equivalent sound pressure level
Ldn	day – night sound level
μPa	micro-Pascal
NIST	National Institute of Standards and Technology
NMFS	National Marine Fisheries Service
Pa	Pascal
RMS	route mean squared
s.d.	standard deviation
SEL	Sound Exposure Level
SL	sound level, regardless of descriptor
SPL	sound pressure level
SR	State Route
USFWS	U.S. Fish and Wildlife Service
WSDOT	Washington State Department of Transportation
WSF	Washington State Ferries

EXECUTIVE SUMMARY

This technical report describes the data collected during impact driving and monitoring of underwater sound levels from driving the 24-inch and 30-inch steel piles for the Washington State Department of Transportation (WSDOT) and Washington State Ferries (WSF) Port Townsend Ferry Terminal Transfer Span project in January of 2013. Data was collected for three 24-inch piles and three 30-inch piles as outlined in the *Port Townsend Ferry Terminal Slip 1 Transfer Span Project Underwater Noise Monitoring Plan* prepared in October of 2012. Bubble curtains were deployed for all piles driven to mitigate potential noise effects.

To compare a previous standard 10 meter measurement distance with the newer preferred distance of 3 times the water depth at the pile, two simultaneous measurements were taken. The 10 M location at mid water depth and a second at a distance of 3H where H is the water depth at the pile and 80% of the water depth at the hydrophone location as described in the monitoring plan.

Background sound levels were measured with an Autonomous Multi-Channel Acoustic Recorder (AMAR) at approximately 914 meters (3000 feet) from the project area in April of 2010. The analysis of these measurements used high pass filters at 7 Hz, 75 Hz, 150 Hz and 200 Hz, corresponding to the marine mammal functional hearing groups outlined by Southall (2007) and includes a spectral analysis of the frequencies per NMFS (2012). Overall average background sound levels reported from the AMAR produced a 100 dB_{RMS} calculated and plotted as the 50^{th} percentile Cumulative Distribution Function (CDF) as reported in Dahl, et al. (2010).

None of the six piles monitored exceeded the 206 dBpeak interim threshold for fish at 33 feet. The peak sound levels measured ranged between 191 and 200 at 33 feet (10 meters) while monitoring the impact pile driving operation as shown in Table 1. The cumulative Sound Exposure Level (cSEL) for the six piles monitored exceeded the interim threshold of 187 dB_{SEL} when calculated using the actual measured SEL value for each impact strike at the 33 feet (10 meter) for two 24-inch piles and all three 30-inch piles and at 63feet (3H) only the 30-inch piles exceeded the threshold. At the 1312 feet location (400 meter) location the interim threshold was never exceeded for either the 24-inch piles or 30-inch piles.

Table 1: Summary of 24-inch and 30-inch Pile drives underwater sound levels.

Pile # & Size	Date	Total Number Of Strikes	Site	Maximum Peak (dB)	Average Peak (dB)	Average RMS (dB)	Single Strike SEL (dB)	Interim Cumulative SEL Criteria (dB)	Cumulative SEL (dB)
					24-inch Steel Piles				
24" #1	1/23/13	141	10M	200	195	185	171	187	191
			3H	187	184	171	163	187	180
			AMAR	165	163	151	140	187	161
24" #2	1/23/13	78	10M	196	186	172	170	187	180
			3H	186	185	171	162	187	180
			AMAR	163	160	150	140	187	170
24" #3	1/23/13	132	10M	191	187	173	164	187	199
			3H	189	187	172	164	187	183
			AMAR	171	167	155	144	187	168
					30-inch Steel Piles				
30" #2	1/25/13	230	10M	196	193	183	170	187	190
			3H	192	190	176	170	187	190
			AMAR	172	170	159	148	187	170
30" #3	1/25/13	259	10M	197	193	182	170	187	192
			3H	190	187	175	167	187	190
			AMAR	172	170	160	147	187	171
30" #4	1/25/13	467	10M	196	192	182	173	187	195
			3H	192	186	174	169	187	191
			AMAR	172	169	159	148	187	173

Measurements were collected of in air sound levels as they propagate from the pile. Continuous A-weighted and un-weighted (Z-) 5-minute Leq's were measured throughout the day, with and without pile driving. Table 2 below gives the 5 minute Leq (RMS) and the Lmax (Peak) for the time period that most closely matches the time when the 24-inch piles were driven. Only the 24-inch piles were measured in air but it is assumed that there would be little difference in sound levels for the larger 30-inch piles because the same hammer was used for both.

Table 2: Summary of 24-inch pile in airborne sound levels.

Pile # & Size	Date & Time	Acoustical Weighting	Measured Distance (feet)	Peak at 50 ft. (Lmax dB)	RMS at 50 ft. (Leq(5 min.) dB)	Distance to Criteria or Guidance Levels (feet)
24" #1	1/23/13	A	65	107	97	294[3]
	1:35 PM	Z		110	98	128[1], 41[2]
24" #2	1/23/13	A	58	108	95	315[3]
	2:10	Z		109	97	108[1], 34[2]
24" #3	1/23/13	A	50	108	96	308[3]
	2:20 & 2:40	Z		110	98	126[1], 40[2]

[1] Distance to the 100 dB RMS (Leq)

[2] Distance to the 90 dB RMS (Leq)

[3] Distance to the 92 dBA Lmax

INTRODUCTION

The Washington State Department of Transportation (WSDOT) / Washington State Ferries (WSF) Division proposes to replace the existing vehicle transfer span with a new hydraulic transfer span at Slip 1 of the Port Townsend Ferry Terminal. See vicinity map (Figure 1).

Figure 1: Vicinity Map of Port Townsend Slip 1 Transfer Span Project.

Project work includes removal of the existing transfer span, lift towers, tower foundations and a portion of the bridge seat and replacing them with a new transfer span, bridge seat and lift cylinder shafts. Five 30" steel piles support the new bridge seat which the contractor installed using a vibratory hammer, and diesel impact hammer to drive the last two feet (proof). The lift cylinder shafts consist of 2, 80-inch steel piles installed with a vibratory hammer (no proofing). A Hydraulic Power Unit (HPU) for the lift cylinders will be installed adjacent to the trestle. Due to space limitations on the trestle, the HPU unit will be supported by a platform mounted on up to 3, 24-inch steel piling, adjacent to the trestle. The 24-inch steel piles were installed with a vibratory hammer, and impact driven the last two feet (proofed).

PROJECT AREA

As shown in the Figure 1 vicinity map, the project area consists of the area surrounding Slip 1 of the Port Townsend FerryTerminal. The contractor drove the three 24-inch steel piles on January 23, 2013 and three 30-inch piles on the 25th of January. The 60 to 65 ft long piles were driven to refusal or to within 3 feet of the tip elevation with an APE Model 700 vibratory hammer. Water depth of approximately 20 feet varied 3 to 4 feet as a result of tidal changes. The geotechnical report for the site indicates that the substrate consists of 1.5 meters/5 feet of loose sand over very dense glacially consolidated soils (WSF 2010b).

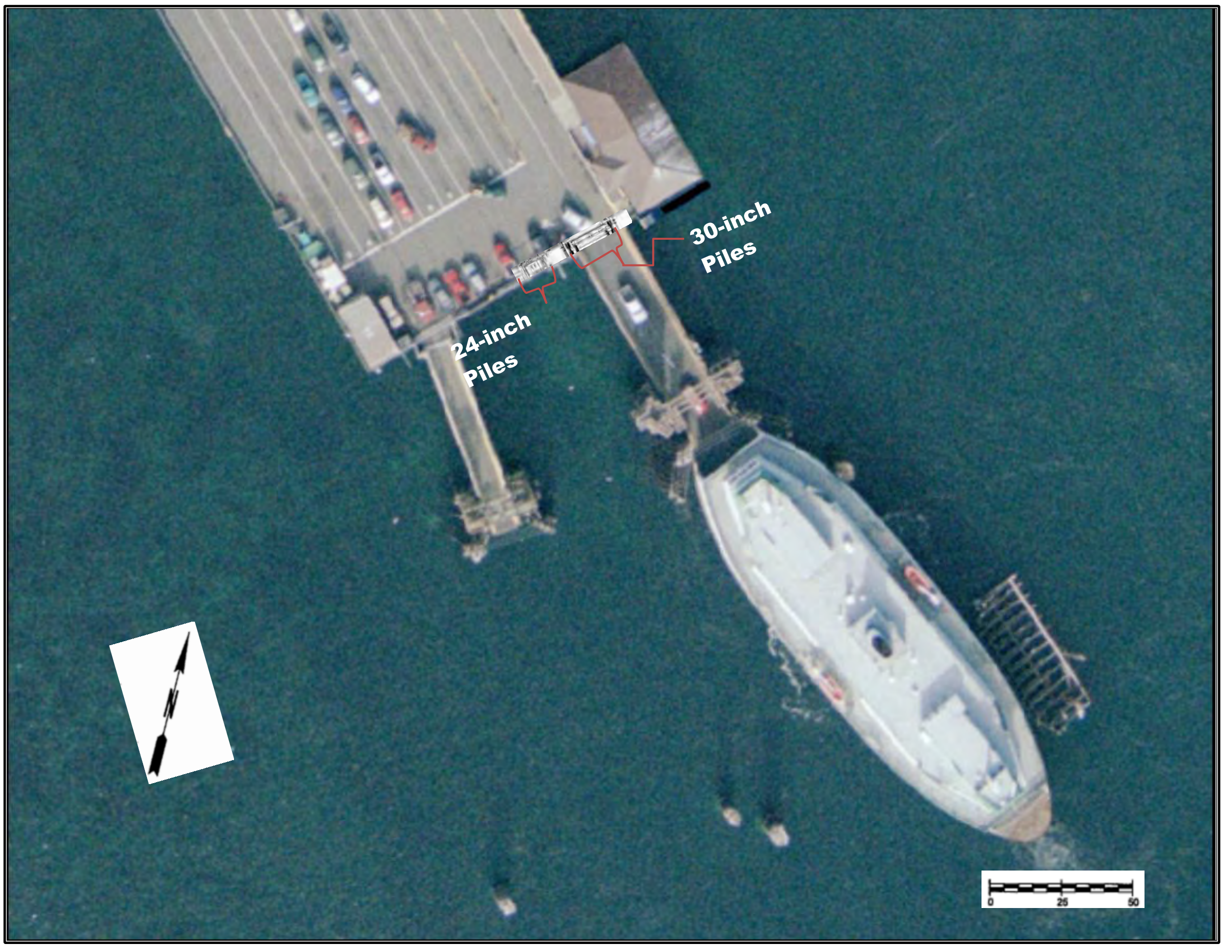

Figure 2: 24-inch and 30-inch Pile Locations.

UNDERWATER SOUND LEVELS

Characteristics of Underwater Sound

Several descriptors are used to describe underwater noise impacts. Two common descriptors are the instantaneous peak sound pressure level (SPL) and the Root Mean Square (RMS) pressure level during the impulse. The peak SPL is the maximum of the absolute value of the instantaneous pressure observed during each pulse and can be presented in Pascal (Pa) or decibels (dB) referenced to a pressure of 1 micropascal (μPa). A different sound level reference pressure is used for each. In water, the most commonly used reference pressure is 1 μPa whereas the reference pressure for air is 20 μPa. Except where otherwise noted, sound levels reported in this report are expressed in dB re: 1 μPa. The equation to calculate the sound pressure level is:

Sound Pressure Level (SPL) = 20 log (p/p_{ref}), where p_{ref} is the reference pressure (i.e., 1 μPa for water)

The RMS level is the square root of the mean value, taken over the duration of the pulse, of the square of the sound pressure presented in dB re: 1 μPa. The RMS level is determined by analyzing the waveform and computing the average of the squared pressures over the time that comprise that portion of the waveform containing 90 percent of the sound energy. This RMS term is described as $RMS_{90\%}$. It has been used by National Marine Fisheries Service (NMFS) in criteria for judging effects to marine mammals from underwater impulse-type sounds.

One-third octave band analysis offers a more convenient way to look at the composition of the sound and is an improvement over previous techniques. One-third octave bands are frequency bands whose upper limit in hertz is $2^{1/3}$ (1.26) times the lower limit. The width of a given band is 23% of its center frequency. For example, the 1/3-octave band centered at 100 Hz extends from 89 to 112 Hz, whereas the band centered at 1000 Hz extends from 890 to 1120 Hz. The 1/3-octave band level is calculated by integrating the spectral densities between the band frequency limits. Conversion to decibels is

dB = 10*LOG (sum of squared pressures in the band) (eq. 1)

Sound levels are often presented for 1/3-octave bands because the effective filter bandwidth of mammalian hearing systems is roughly proportional to frequency and often about 1/3-octave. In other words, a mammal's perception of a sound at a given frequency will be strongly affected by other sounds within a 1/3-octave band around that frequency. The overall level (acoustically summing the pressure level at all frequencies) of a broadband (20 Hz to 20 kHz) sound exceeds the level in any single 1/3-octave band.

Another measure of the pressure waveform that can be used to describe the pulse is the sound energy itself. The total sound energy in the pulse is referred to in many ways, such as the "total energy flux". The "total energy flux" is equivalent to the un-weighted sound exposure level (SEL) for a plane wave propagating in a free field, a common unit of sound energy used in airborne acoustics to describe short-duration events. The unit is dB re 1μPa^2-sec. The single strike SEL is for each pile strike using SEL = $RMS_{90\%}$ + 10LOG(t) where 't' is the time interval calculated for the $RMS_{90\%}$. This term is described as the $SEL_{90\%}$. These values are accumulated for all pile strikes to calculate the cumulative SEL (cSEL).

METHODOLOGY

Background underwater noise levels have been be measured for a minimum of three full 24-hour cycles (i.e., 6 am to 6 am) in the absence of construction activities to determine background sound levels (Dahl et al., 2010) for frequencies between 20 Hz and 20 kHz. Following NMFS guidance (NMFS, 2012), analysis was conducted using both data from the full range of frequencies recorded for fish and murrelets, using high pass filters at 7 Hz, 75 Hz, 150 Hz and 200 Hz, corresponding to the marine mammal functional hearing groups outlined by Southall (2007). Data was used to calculate 30-second Root Mean Square (RMS) values for each 30 seconds of the three 24-hour cycles measured. These data were used to calculate and plot a Cumulative Distribution Function (CDF) (NMFS, 2012). An overall 100 dB average background sound levels was reported as the 50% CDF and include a spectral analysis of the frequencies (NMFS, 2012) for a minimum of an hourly cycle.

Typical Equipment Deployment

The hydrophones were deployed from the Port Townsend Ferry terminal building passenger waiting area through the windows that surround this area. The monitoring equipment outlined below and shown in Figure 4 on page 8 was connected to shore power in the waiting area and deployed from the windows that could best accommodate the project monitoring plan specifications. The hydrophones were stationed and fixed with anchors at the predetermined distances of 10 meters and 3 H from the source, where H is the depth of water at the source as prescribed by the Port Townsend Ferry Terminal Slip 1 Transfer Span Project Underwater Noise Monitoring Plan, 2012. A Bubble Curtain was also deployed in accordance with monitoring plan and Contract Plan design and specifications.

All impact driven piles were monitored with the sound attenuation bubble curtain system on only. No un-attenuated pile strikes were measured for this project, per USFW requirements (Hamilton, pers. comm.)[1].

The Autonomous Multi-Channel Acoustic Recorder (AMAR) used to measure the background sound levels (Dahl et al, December, 2010) was also used to measure sound levels during this impact monitoring to determine far field underwater sound levels from this activity. The AMAR was located approximately 1,312 feet (400 meters) from the pile driving activities (See Figure 3)

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[1] Hamilton, Brooke. USFW. 2009 Personal communication. Email to Rick Huey, WSF. December 7, 2009. Note: There may be circumstances where the U.S. Fish and Wildlife Service determines that unattenuated pile driving (striking the pile with the bubble curtain turned off) would pose a significant risk of injury to marbled murrelets. In those situations, the Service may request that unattenuated pile driving does not occur and that hydroacoustic monitoring be conducted to determine the extent at which certain thresholds are met instead. This will need to be determined on a case by case basis for projects that may affect marbled murrelets.

Figure 3: AMAR Monitoring Location

Underwater sound levels were measured near the piles using two Reson TC 4013 hydrophones deployed on a weighted nylon cord from the ferry terminal waiting room at each pile. The two hydrophones were positioned, one at a distance of 10 meters from the pile at mid-water depth and one at 3H (where H is the depth of water at the pile) from the piles being monitored and at a depth of 15 to 17 feet (depending on tide) which represents 80% of the water depth. The measurement system includes a Brüel and Kjær Nexus type 2692 4-channel signal conditioner, which kept the high underwater sound levels within the dynamic range of the signal analyzer Figure 4. The output of the Nexus signal conditioner is received by a Brüel and Kjær Photon 4-channel signal spectrum analyzer that is attached to a Dell ATG laptop computer similar to the one shown in Figure 4.

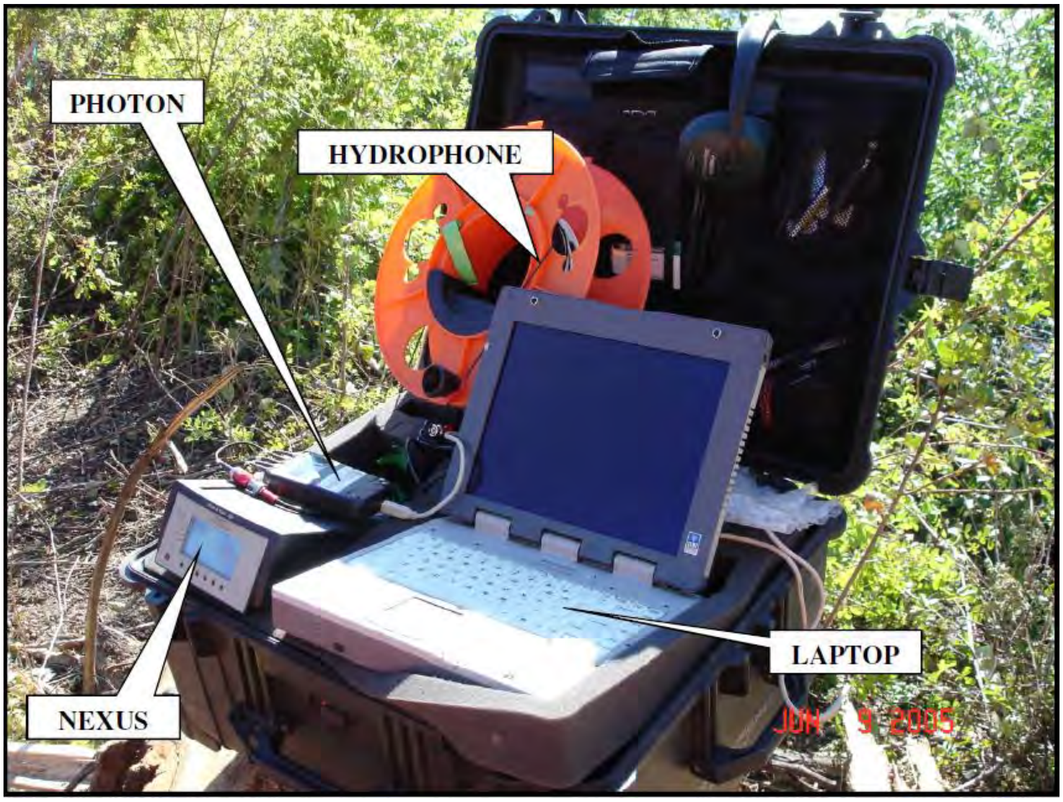

Figure 4: Near Field Acoustical Monitoring Equipment.

The equipment captures sound levels from the pile driving operation as a signal file for processing later. The WSDOT has this system and software calibration checked annually against NIST traceable standard.

Signal analysis software provided with the Photon was set at a sampling rate of one sample every 122.1 µs. This sampling rate provides sufficient resolution to catch the peaks and other relevant data; however, due to an error during setup the software did not record the full frequency range to 20 kHz. Because the dominant frequency for impact pile driving is approximately 800 Hz and the higher frequencies are 10 dB or more below the levels at the dominant frequencies we do not believe that the lack of data beyond 3,200 Hz significantly affected the results presented in this report. The anti-aliasing filter included in the Photon also allows the capture of the true peak.

Due to the variability between the absolute peaks for each pile impact strike, an average peak and RMS value is computed along with the standard deviation (s.d.) to give an indication of the amount of variation around the average for each pile.

Two type I Larson Davis model LXT meters were deployed to measure sound levels in air. One of the meters was set to capture the A-weighted sound level and frequency spectra and the other captured the un-weighted (Z-weighted) levels and spectra. Each meter measured continuous 5 minute L_{eq}'s (RMS) for the duration of the 24-inch impact pile drives. The L_{max} (peak) level was also captured for each of these 5 minute segments. The two Larson Davis meters were positioned in the temporarily closed pedestrian passageway for walk on ferry passengers. Distances were measured to each of the piles to determine the 50 foot reference sound level and the distance to the airborne noise thresholds.

Hydrophone and Microphone Location

As shown in Figure 5 the hydrophones were deployed along WSF terminal edge where distance measurements were easily acquired by tape measure. The analyst determined hydrophone and microphone locations by insuring a clear line of sight was maintained between the hydrophone / microphone and the pile driven. Due to the frequent prop wash from ferries landing at slip 2, moving the hydrophones into the piles that support the terminal, the hydrophone locations were moved after the first two 24-inch piles were driven. The hydrophones were then deployed at a more central location between the ferry terminal southeast edge and the work barge used in driving the pile. When distances from the pile to the hydrophone, due to its location further out from the ferry dock were difficult to determine using the tape measure, a distance measurement using a Bushnell Yardage Pro rangefinder was taken. The hydrophone was attached to a weighted nylon cord anchored with 5 pound weights. The cord and hydrophone cables were lowered at 10 meters to mid-water depth and at the 3H location, to a depth of 80% of the total water column depth as shown in **Error! Reference source not found.**.

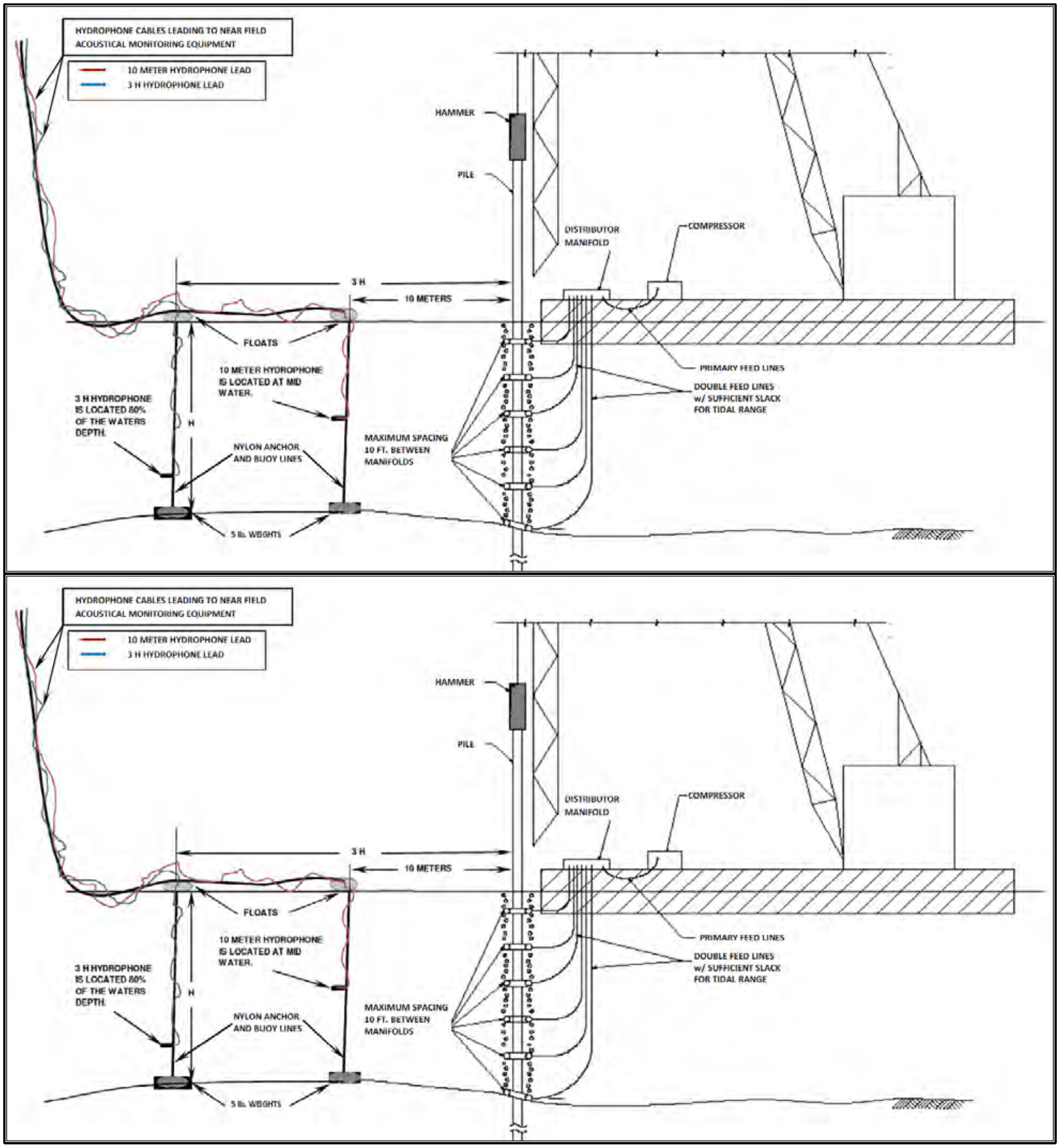

Figure 5: Hydrophone and Bubble Curtain Deployment.

Threshold Calculations

Initial negotiations with the National Marine Fisheries (NMFS) and U.S. Fish and Wildlife Service (USFWS) establishes interim threshold for potential effects from noise generated from impact pile driving construction projects both for in water and in air. The thresholds agreed to require post processing of the data acquired during monitoring.

The $RMS_{90\%}$ was calculated for each individual impact strike. The $SEL_{90\%}$ was calculated for each individual impact strike using the following equation:

$$SEL_{90\%} = RMS_{90\%} + 10\ LOG\ (\tau) \qquad \text{(eq. 2)}$$

Where τ is the 90% time interval over which the $RMS_{90\%}$ value is calculated for each impact strike.

The interim thresholds of 206 dB_{peak} and 187 dB_{SEL} for fish apply for this project. The thresholds for marine mammal disturbance from impact driving are 160 dB_{RMS} and for the injury threshold it is 180 dB_{RMS} for cetaceans and 190 dB_{RMS} for pinnipeds.

Both weighted and un-weighted airborne sound levels (SL) in air are back calculated to sound levels at 50 feet using the following equation:

$$SL_{\text{at 50 ft.}} = SL_{\text{measured}} - 20\ LOG\ (D/50) \qquad \text{(eq. 3)}$$

Where D is the measured distance between pile and the sound level meter.

The thresholds for airborne noise for Pinnipeds and other marine mammals are 90 dB_{RMS} and 100 dB_{RMS}, un-weighted. There are no haul-out areas for Pinnipeds within the project area. USFW Marbled Murrelet guidance for analysis level is 92 dBA L_{max}

RESULTS

Underwater Sound Levels

WSDOT monitored six attenuated steel piles, three 24-inch and three 30-inch steel piles, for underwater noise. Each pile is analyzed in the paragraphs below and summarized in Table 5 on page 27. The waveforms obtained from the piles show typical impact waveforms for attenuated strikes. The bubble curtain is shown deployed in Figure 6.

Figure 6: Impact Pile Drive with Bubble Curtain.

24-inch Pile 1

The 24-inch Pile 1 was furthest west of all the piles monitored. As with all the piles a bubble curtain was deployed and turned on before piles could be driven. This pile had the highest peak level of 200 dB reported of the 6 piles measured from the 33 feet (10 meter) measurement location. This is well below the 206 dB peak threshold at 33 feet. The results of broadband measurements for the 24-inch Pile 1 at both the 33 feet and 63 feet (3 H) locations and the AMAR at 1312 feet (400 meters) are outlined in the bulleted list below and compared with the other piles driven in Table 5 on page 27:

- The highest absolute peak from the hydrophone at 33 feet (10 meters) from the pile and mid-water depth (10 feet) is 200 dB_{peak} which did not exceed the 206 dB_{peak} interim threshold for fish at 33 feet. The hydrophone at 63 feet from the pile measured at 16 feet below the surface or 80% of the water depth was 187 dB_{peak}. By the time the sound reached the AMAR at 1,312 feet (400 meters) at 110 feet deep it was only 165 dB_{peak}.
- The $RMS_{90\%}$ at 33 feet and mid-water depth is 187 dB_{RMS} which exceeds both the 160 dB_{RMS} disturbance threshold and the 180 dB_{RMS} injury threshold for marine mammals at 33 feet. At 63 feet from the pile the $RMS_{90\%}$ was 173 dB_{RMS} which is below the injury thresholds at 63 feet. The sound level drops to well below these thresholds by the time it reaches the AMAR at 1,312 feet to 153 $dB_{RMS90\%}$. The distance to the 180 dB_{RMS} injury threshold from the 33feet location using the practical spreading model is 96 feet. The distance to the 160 dB_{RMS} disturbance threshold from the 63 feet location is 459 feet. Using the proposed transmission loss model proposed by Dahl et al., (2012) the distance to the 180 dB_{RMS} injury threshold is 98 feet and the distance to the 160 dB_{RMS} disturbance threshold from the 33 feet location is 1,772 feet.
- The highest single strike Sound Exposure Level (SEL) for the peak strike at 33 feet and mid-water depth is 171 $dB_{SEL,}$ at the 63 feet location at 16 feet below the surface is 163 dB_{SEL} and at the AMAR at 110 feet depth and 1,312 feet from the pile the sound drops to 140 dB_{SEL}.
- Based on the single strike SEL measured for each pile strike for 141 impact strikes that were measured at 33 feet, the drive had a cumulative SEL (cSEL) of 191 dB_{SEL} and measured at 3H to be 183 dB_{SEL} (Figure 7) which at 33 feet exceeded the 187 dB_{SEL} interim threshold for fish after 68 strikes. This did not exceed the auditory injury (202 dB_{SEL}) or the non-auditory injury (208 dB_{SEL}) but did exceed the non-injurious hearing threshold shift (183 dB_{SEL}) cumulative thresholds for marbled murrelets at 33 feet. The cSEL calculated at 1,312 feet is 161 dB_{SEL} which is below the interim threshold for fish and cumulative thresholds for marbled murrelets at 1,312 feet.

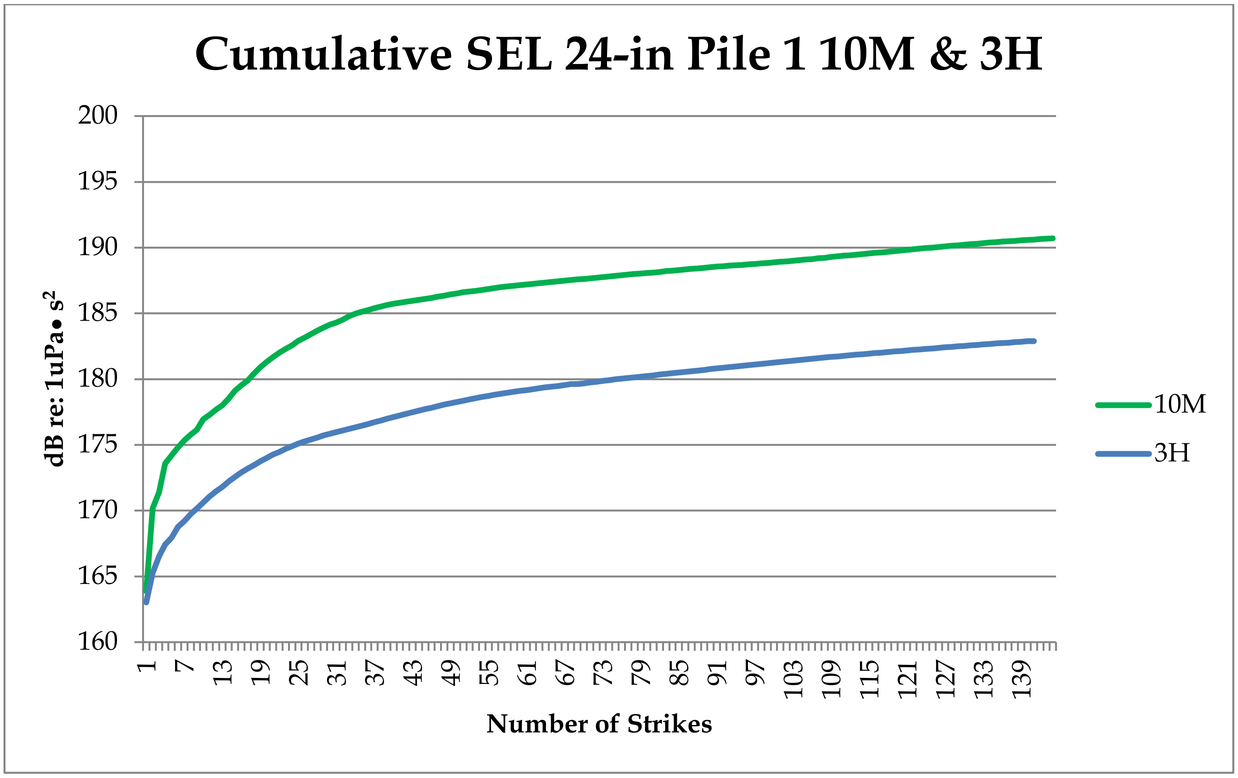

Figure 7: Cumulative SEL plot for 24-inch Pile 1 at 10 meters (Green) versus the SEL plot at 3 H (Blue)

The average un-weighted frequency distribution calculated over three pile strikes nearest the absolute peak strike for the 24-inch Pile 1 measured at 33 feet indicates a dominant frequency at 130 Hz with lesser contributions from other frequencies to 3 kHz (Figure 8).

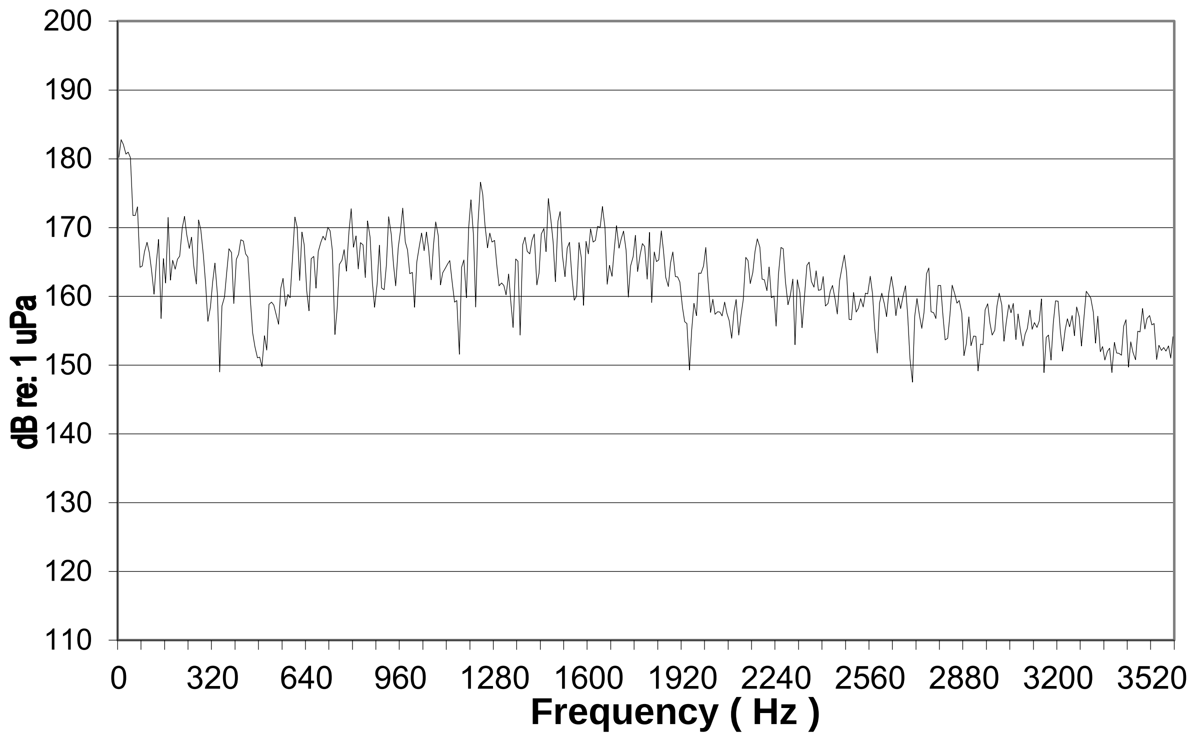

Figure 8: 24-inch Pile 1 Frequency Distribution.

24-inch Pile 2

The 24-inch Pile 2 was the in the middle of the three 24-inch piles driven. This pile had a peak level of 196 dB_{peak} measured from the 33 feet measurement location. This again is well below the 206 dB_{peak} threshold at 33 feet. The results of broadband measurements for the 24-inch Pile 2 at the 33 feet, 63 feet, and at the AMAR, 1,312 feet locations are outlined in the bulleted list below and compared with the other piles driven in Table 5 on page 27.

- The highest absolute peak from the hydrophone at 33 feet from the pile and mid-water depth (10 feet) is 196 dB_{peak} which did not exceed the 206 dB_{peak} interim threshold for fish at 33 feet. The hydrophone at 63 feet from the pile measured 16 feet below the surface or 80% of the water depth was 186 dB_{peak}. The sound level at the AMAR at 1,312 feet and 110 feet deep is only 163 dB_{peak}.
- The $RMS_{90\%}$ at 33 feet and mid-water depth is 184 dB_{RMS} which exceeds the 160 dB_{RMS} disturbance threshold and the 180 dB_{RMS} injury threshold for marine mammals at 33 feet. At 63 feet from the pile the $RMS_{90\%}$ was 171 dB_{RMS} which exceeds the disturbance threshold for marine mammals at 63 feet. The sound level drops to well below these thresholds by the time it reaches the AMAR at 1,312 feet to $154_{RMS90\%}$. The distances to the 180 dB_{RMS} injury threshold from the 33 feet location using the practical spreading model is 61 feet. The distance to the 160 dB_{RMS} disturbance threshold from the 63 feet location is 337 feet. Using the proposed transmission loss model proposed by Dahl et al., (2012) the distance to the 180 dB_{RMS} injury threshold is 82 feet and the distance to the 160 dB_{RMS} disturbance threshold from the 33 feet location is 1,213 feet.

- The highest single strike Sound Exposure Level (SEL) for the peak strike at 33 feet and mid-water depth is 170 dB_{SEL}, at the 3H location at 16 feet below the surface it is 162 dB_{SEL} and at the AMAR at 110 feet depth and 1,312 feet from the pile the sound drops to 140 dB_{SEL}.
- Based on the single strike SEL measured for each pile strike for 78 impact strikes that were measured at 33 feet the drive had a cSEL of 179 dB_{SEL} and measured at 63 feet to be 180 dB_{SEL} (Figure 9) which did not exceed the 187 dB_{SEL} interim threshold for fish or the non-injurious hearing threshold shift (183 dB_{SEL}), the auditory injury (202 dB_{SEL}), non-auditory injury (208 dB_{SEL}) cumulative thresholds for marbled murrelets at 63 feet. The cSEL calculated at 1,312 feet is 170 dB_{SEL} which does not exceed the 187 dB_{SEL} threshold for fish and the non-injurious hearing threshold shift for marbled murrelets at 1,312 feet.

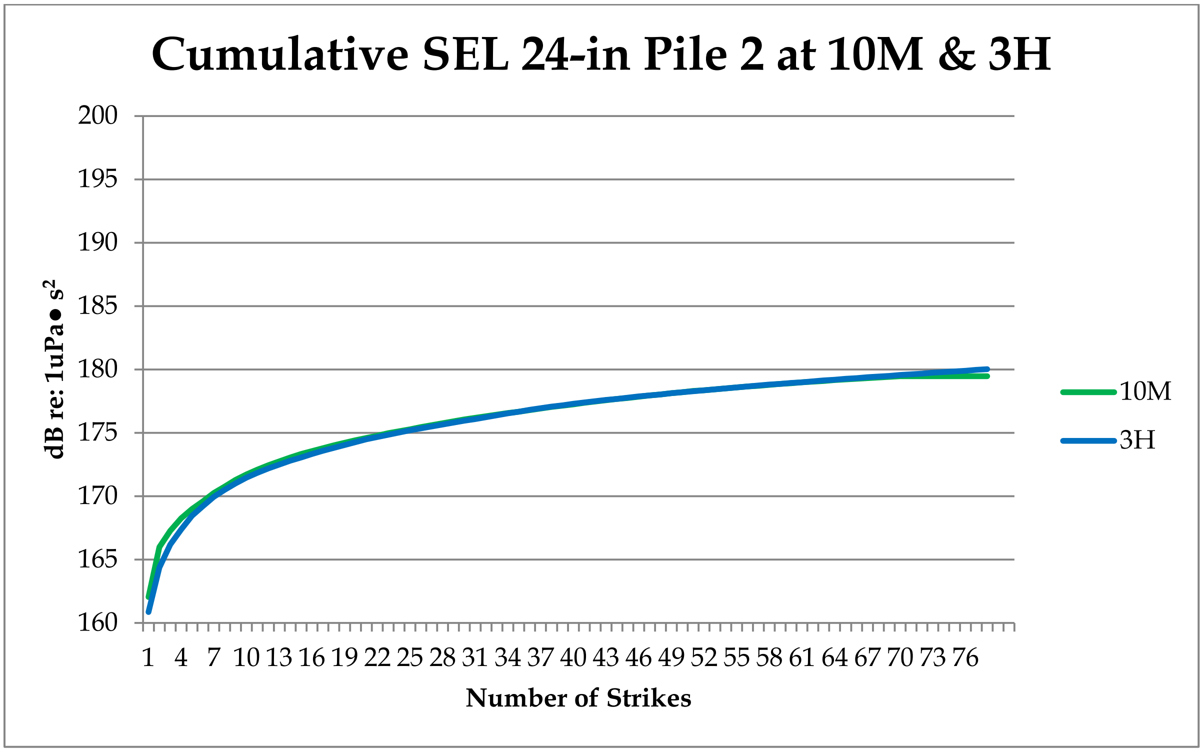

Figure 9: Cumulative SEL plot for 24-inch Pile 2 at 10 meters (Green) versus the SEL plot at 3 H (Blue)

The average un-weighted frequency distribution calculated over three pile strikes nearest the absolute peak strike for the 24-inch Pile 2 measured at 33 feet indicates a dominant frequency at 250 Hz with lesser contributions from other frequencies to about 2500 Hz (Figure 10).

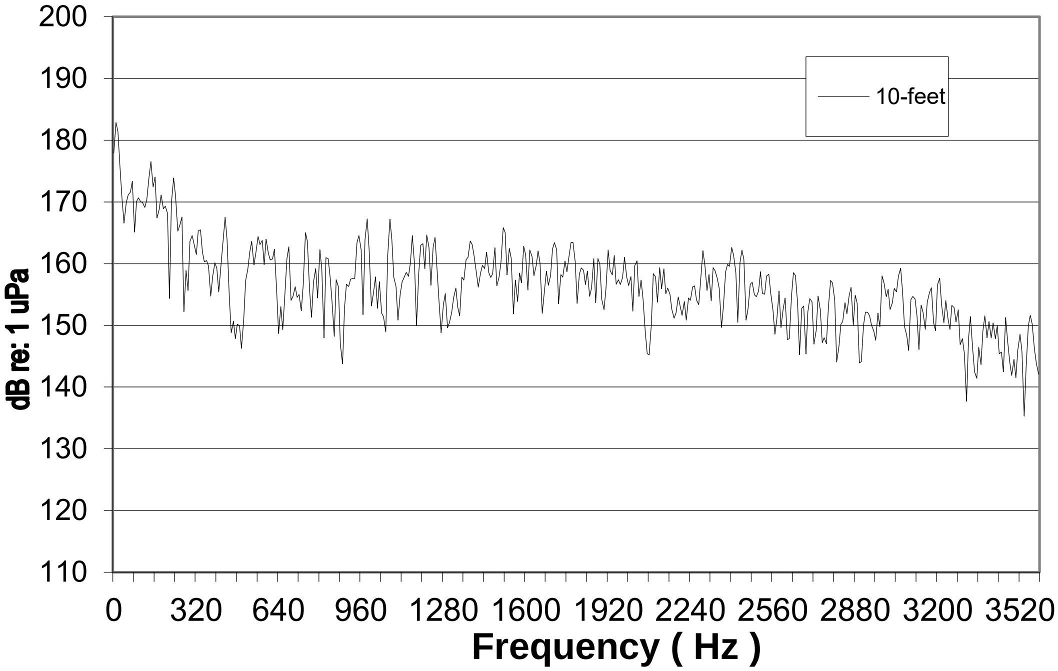

Figure 10: 24-inch Pile 2 Frequency Distribution.

24-inch Pile 3

The final 24-inch Pile 3 had to be measured in two parts completed at 2:44 PM on 1/23/13. This pile had the lowest peak, 191 dB_{peak}, level of the six piles measured from the 33 feet location. This again is well below the 206 dB peak interim threshold for fish at 33 feet. The results of broadband monitoring for the 24-inch Pile 3 at both the 33 feet and 63 feet, and the AMAR at 1312 feet are outlined in the bulleted list below and compared with the other piles driven in Table 5 on page 27.

- The highest absolute peak from the hydrophone at 33 feet from the pile and mid-water depth (10 feet) is 191 dB_{peak} which did not exceed the 206 dB_{peak} interim threshold for fish at 33 feet. The hydrophone at 63 feet from the pile and 16 feet deep or 80% of the water depth was 189 dB_{peak}. When the sound reached the AMAR at 1,312 feet and 110 feet deep it was only 171 dB_{peak}.
- The $RMS_{90\%}$ at 33 feet and mid-water depth is 175 dB_{RMS} which exceeds the 160 dB_{RMS} disturbance threshold for marine mammals but below the injury thresholds at 33 feet. At the 63 feet location the $RMS_{90\%}$ was 174 dB_{RMS} which also exceeds the 160 dB_{RMS} disturbance threshold but below the injury thresholds at 63 feet. The RMS sound level drops to below this threshold when it reaches the AMAR at 1,312 feet to 158 dB_{RMS}. The distance to the 160 dB_{RMS} disturbance threshold from the 33 feet location using the practical spreading model is 328 feet. The distance to the 160 dB_{RMS} disturbance threshold from the 63 feet location is 535 feet. Using the proposed transmission loss model (Dahl et al., 2012) the distance to the 160 dB_{RMS} disturbance threshold from the 33 feet location is 524 feet.

- The highest single strike Sound Exposure Level (SEL) for both the peak strike at 33 feet and mid-water depth and at the 63 feet location at 16 feet below the surface is 164 dB_{SEL} and at the AMAR at 1,312 feet the sound level drops to 144 dB_{SEL}.
- Based on the single strike SEL measured for each pile strike for 132 impact strikes that were measured for both the total pile drive at 33 feet the cSEL is 199 dB_{SEL} and measured at 63 feet to be lower at 183 dB_{SEL} (Figure 11) which does not exceed the 187 dB threshold for fish, the non-injurious hearing threshold shift (183 dB), the auditory injury (202 dB_{SEL}) or the non-auditory injury (208 dB_{SEL}) cumulative thresholds for marbled murrelets at 63 feet. The cSEL calculated at 1,312 feet is 168 dB_{SEL} which is below the 187 dB_{SEL} interim threshold for fish and the non-injurious hearing threshold shift for marbled murrelets at 1,312 feet.

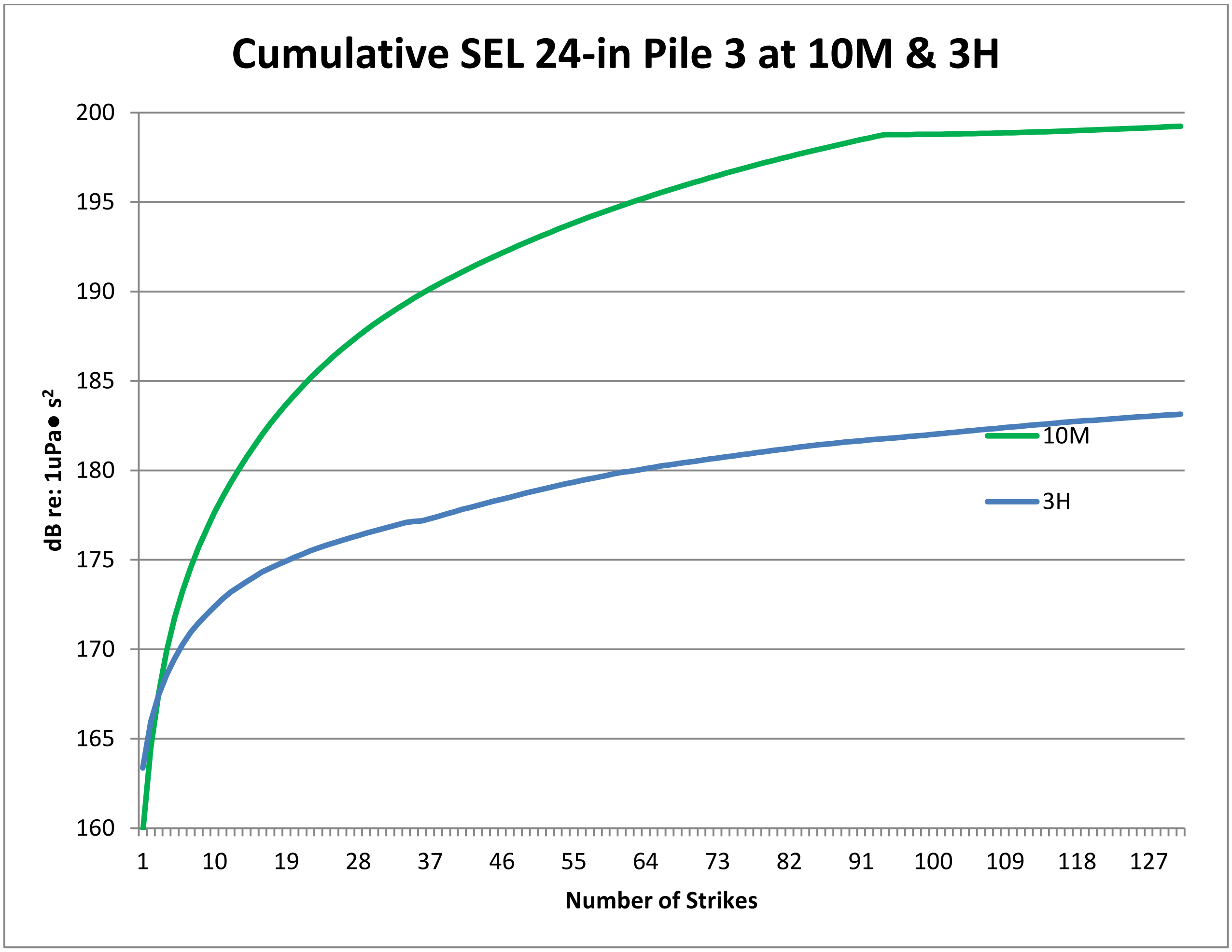

Figure 11: Cumulative SEL plot for 24-inch Pile 3 at 10 meters (Green) versus the SEL plot at 3 H (Blue)

The average un-weighted frequency distribution calculated over three pile strikes nearest the absolute peak strike for the 24-inch Pile 3 measured at 33 feet indicates a dominant frequency at 200 Hz and lesser contributions from other frequencies to about 2 kHz (Figure 12).

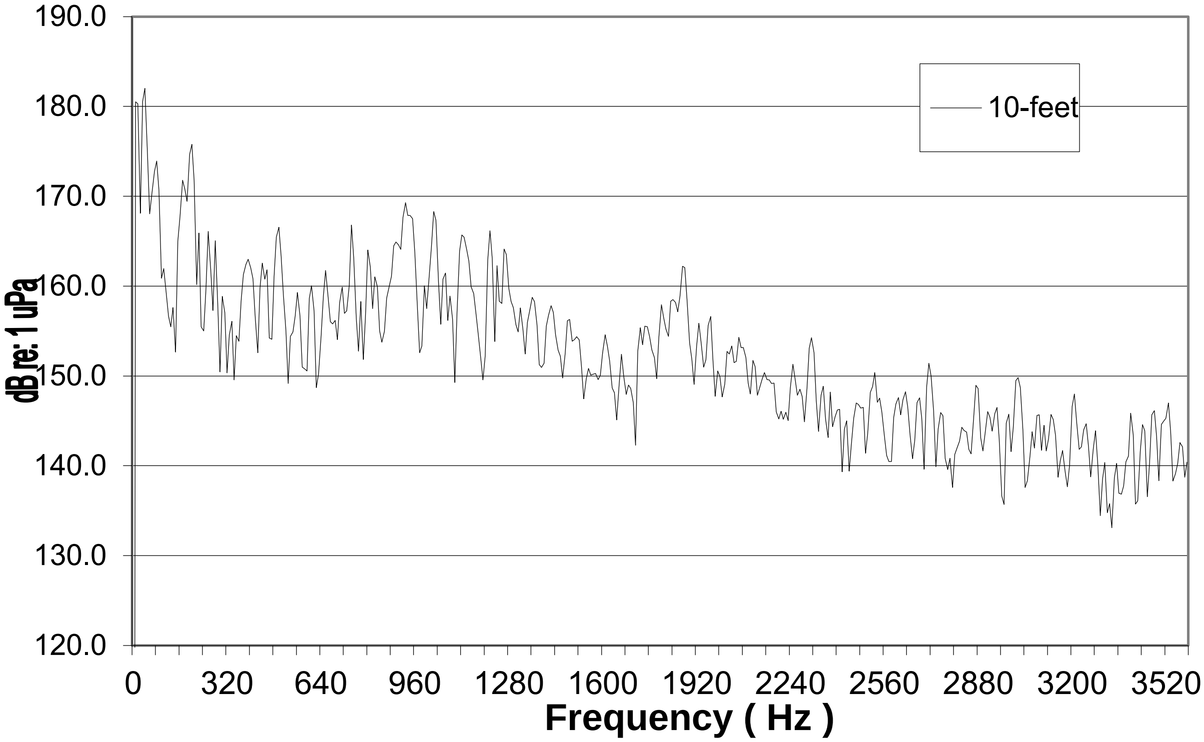

Figure 12: 24-inch Pile 3 Frequency Distribution.

30-inch Pile 1

On 1/24/13 the analyst attempted to monitor the first 30-inch pile, but an apparent subsurface obstruction prevented it from properly seating into position. These results were determined to not be representative of a typical pile drive and the data is not analyzed for this report.

30-inch Pile 2

This 30-inch Pile 2 was measured at a peak level of 196 dB_{peak} at the 10 meter measurement location. This is well below the 206 dB peak interim threshold for fish at 33 feet. The results of broadband monitoring for the 30-inch Pile 2 at both the 33 feet and at 63 feet are outlined in the bulleted list below and compared with the other piles driven in Table 5:

- The highest absolute peak measure with the hydrophone at 33 feet from the pile and mid-water depth was 196 dB_{peak} which did not exceed the 206 dB_{peak} interim thresholds for fish at 33 feet. The hydrophone at 63 feet from the pile and 16 feet from the surface or 80% of the water depth was 192 dB_{peak} and at 1,312 feet was 172 dB_{peak}.
- The $RMS_{90\%}$ at 33 feet and mid-water depth was 184 dB_{RMS} which exceeds both the 160 dB_{RMS} disturbance threshold for marine mammals and 180 dB_{RMS} injury threshold for cetaceans at 33 feet. At the 63 feet location the $RMS_{90\%}$ was 180 dB_{RMS} which exceeds the 160 dB_{RMS} disturbance threshold for marine mammals at 63 feet. The sound level drops to 162 dB_{RMS} at the 1,312 foot distance to the AMAR. The distances to the disturbance and injury thresholds from the 33 feet location using the practical spreading model are 1,306 feet to the 160 dB_{RMS} disturbance threshold and 61 feet to the 180 dB_{RMS} injury threshold for cetaceans. The distance to the 160 dB_{RMS} disturbance threshold from the 63 feet location is 1,343 feet. Using the proposed transmission loss model proposed

by Dahl et al., (2012) the distance to the 180 dB_{RMS} injury threshold is 66 feet and to the 160 dB_{RMS} disturbance threshold is 1,411 feet from the 33 feet location. At 1,312 feet the RMS90% level exceeds the 160 dB_{RMS} disturbance threshold and the distance to the disturbance threshold from this point is 1,784 feet.

- The highest single strike Sound Exposure Level (SEL) for both the peak strike at 33 feet and mid-water depth and at the 63 feet location at 16 feet below the surface is 170 dB_{SEL}. At the AMAR location at 110 feet depth and 1,312 feet from the pile is 148 dB_{SEL}.
- Based on the single strike SEL measured for each pile strike for 230 impact strikes that were measured for the pile drive at 33 feet calculated to a cSEL of 192 dB_{SEL} and calculated at 63 feet to be slightly lower at 190 dB_{SEL} (Figure 13) both of which exceeded the 187 dB_{SEL} interim threshold for fish and the non-injurious hearing threshold shift (183 dB_{SEL}) for marbled murrelets after about 64 to 108 strikes but not the auditory injury (202 dB_{SEL}), non-auditory injury (208 dB_{SEL}) cumulative thresholds for marbled murrelets at 33 feet and 63 feet. The cSEL calculated at 1,312 feet is 171 dB_{SEL} which does not exceed the interim threshold for fish and the non-injurious hearing threshold shift for marbled murrelets at 1,312 feet.

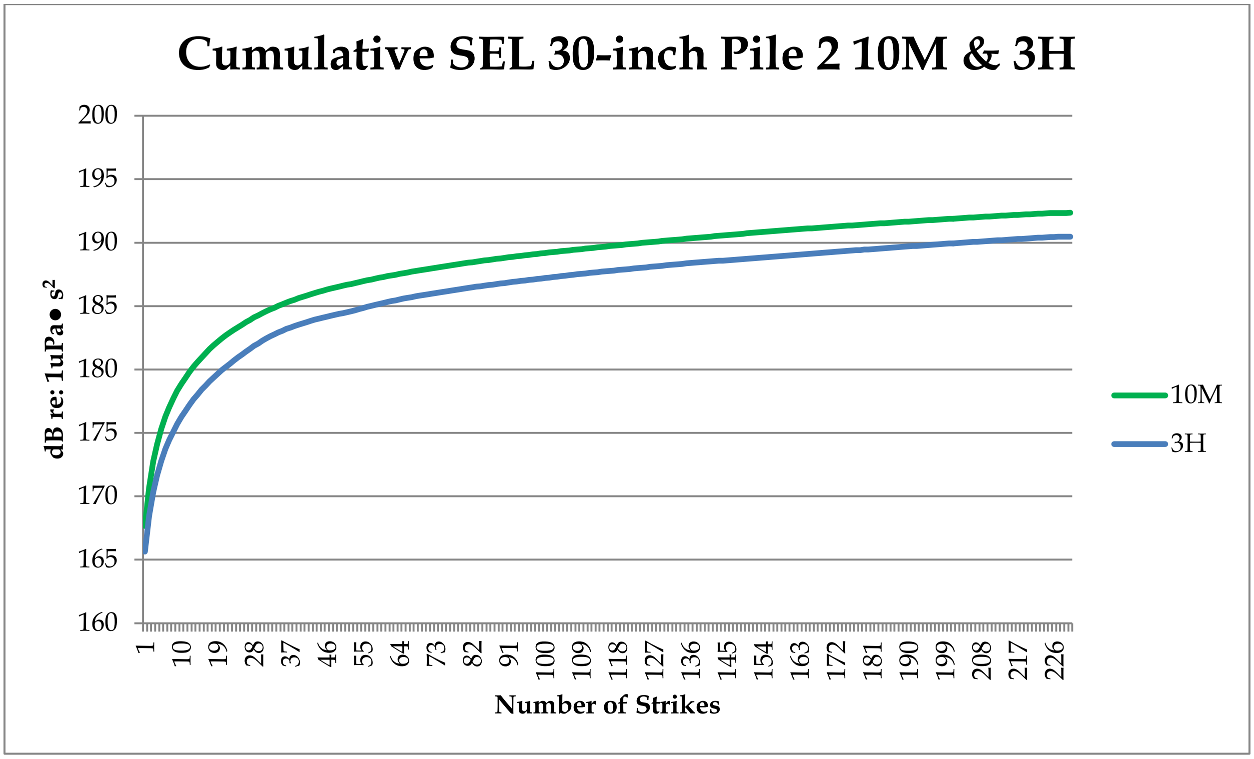

Figure 13: Cumulative SEL plot for 30-inch Pile 2 at 10 meters (Green) versus the SEL plot at 3 H (Blue)

The average un-weighted frequency distribution calculated over three pile strikes nearest the absolute peak strike for the 30-inch Pile 2 measured at 33 feet indicates a dominant frequency at 250 Hz and lower with contributions from other frequencies to about 2.5 kHz (Figure 14).

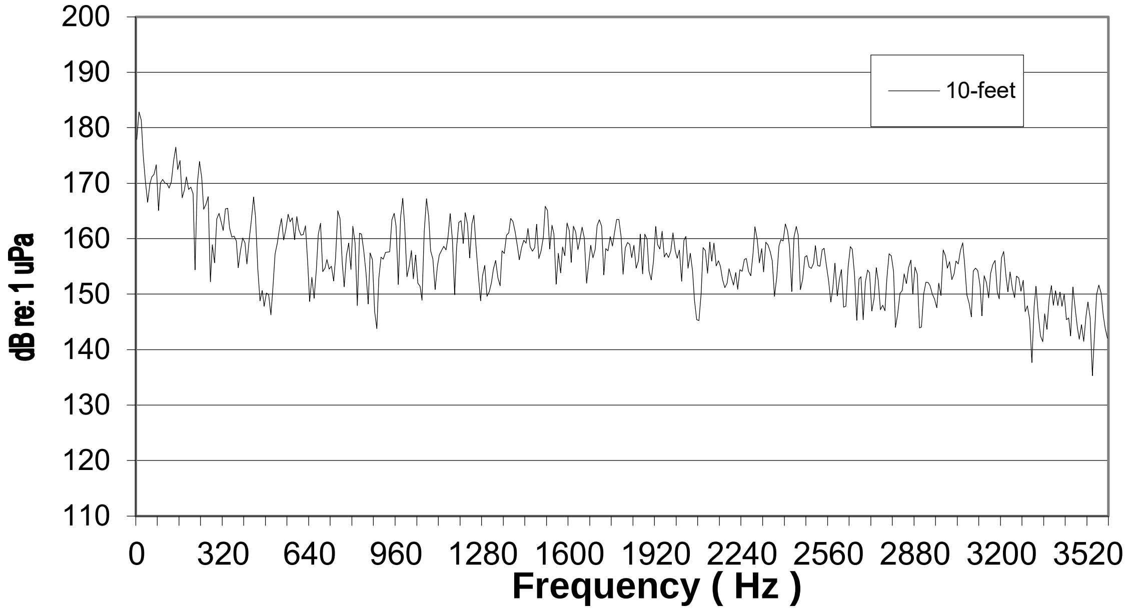

Figure 14: 30-inch Pile 2 Frequency Distribution.

30-inch Pile 3

The 30-inch Pile 3 was measured at a peak level of 197 dB_{peak} at the 10 meter measurement location. This again is well below the 206 dB peak interim threshold for fish at 33 feet. The results of broadband monitoring for the 30-inch Pile 3 at both the 33 feet and at 63 feet are outlined in the bulleted list below and compared with the other piles driven in Table 5.

- The highest absolute peak measure with the hydrophone at 33 feet from the pile and mid-water depth (10 feet) was 197 dB_{peak} which did not exceed the 206 dB_{peak} interim threshold for fish at 33 feet. The hydrophone at 63 feet and 16 feet depth or 80% of the water depth was 190 dB_{peak} and at 1,312 feet was 172 dB_{peak}.
- The $RMS_{90\%}$ at 33 feet and mid-water depth was 183 dB_{RMS} which exceeds both the 160 dB_{RMS} disturbance threshold for marine mammals and the 180 dB_{RMS} injury thresholds for cetaceans at 33 feet. At 63 feet from the pile the $RMS_{90\%}$ was 177 dB_{RMS} which exceeds the 160 dB_{RMS} disturbance threshold but not the injury thresholds for marine mammals at 63 feet. The $RMS_{90\%}$ sound level at the AMAR location 1,312 feet from the pile dropped to 161 dB_{RMS}. The distances to the disturbance threshold from the 33 feet location using the practical spreading model are 1,120 feet. The distance to the disturbance threshold from the 63 feet location is 847 feet. The distance to the disturbance threshold from the 1,312 location is 1,530 feet. Using the proposed transmission loss model by Dahl et al., (2012) the distance to the 180 dB_{RMS} injury threshold is 66 feet and to the 160 dB_{RMS} disturbance threshold is 1,050 feet from the 33 feet location.
- The highest single strike Sound Exposure Level (SEL) for the peak strike at 33 feet and mid-water depth was170 dB_{SEL}, at the 63 feet location 16 feet below the surface was 167 dB_{SEL} and at the AMAR location 1,312 feet from the pile the sound drops to 147 dB_{SEL}
- Based on the single strike SEL measured for each pile strike for 259 impact strikes that were measured for the pile drive at 33 feet a calculation of the cSEL is 192 dB_{SEL} and at

63 feet is 190 dB_{SEL} (Figure 15) both of which exceeded the 187 dB_{SEL} interim threshold for fish after about 97 strikes and the non-injurious hearing threshold shift (183 dB_{SEL}) for murrelets but not the auditory injury (202 dB_{SEL}) or non-auditory injury (208 dB_{SEL}) cumulative thresholds for marbled murrelets at both 33 feet and 63 feet. The cSEL calculated at 1,312 feet is 171 dB_{SEL} which does not exceed the interim threshold for fish and the non-injurious hearing threshold shift for marbled murrelets at 1,312 feet.

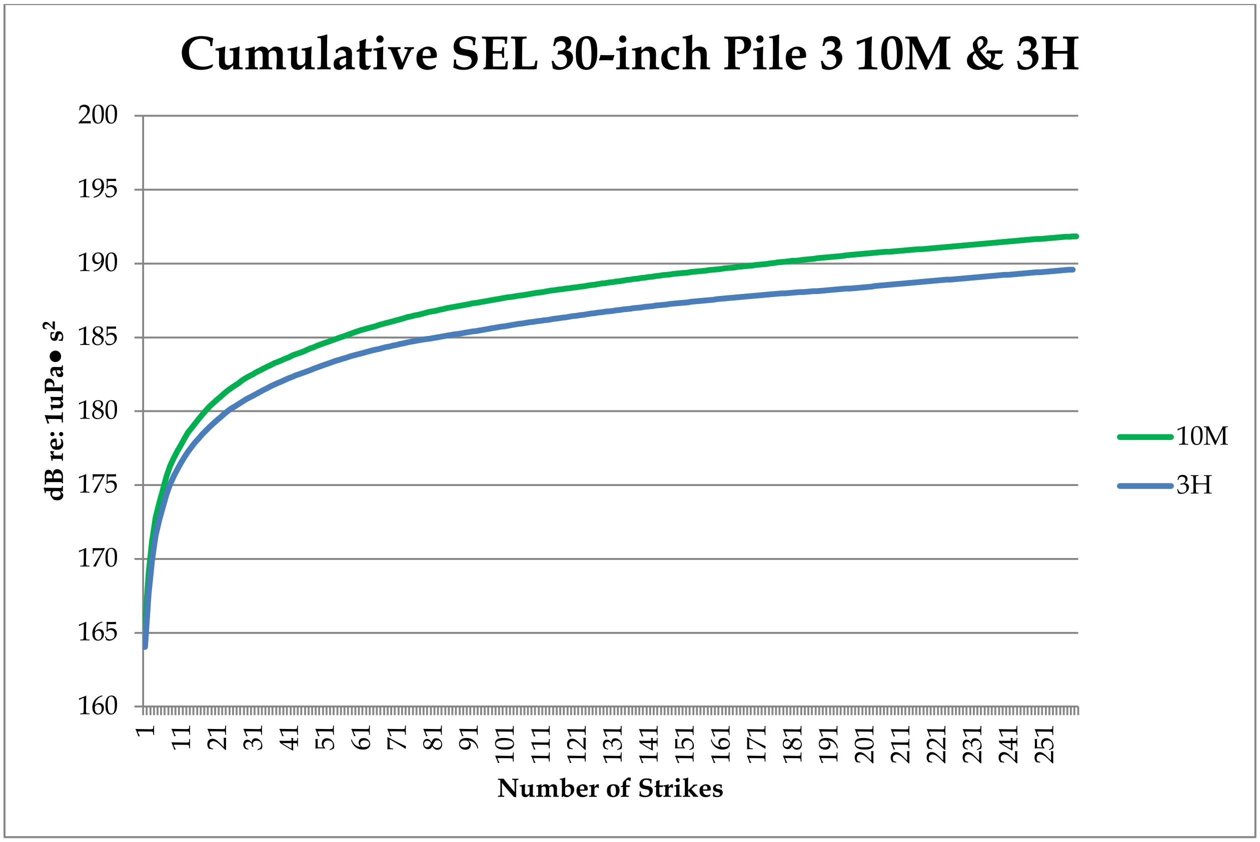

Figure 15: Cumulative SEL plot for 30-inch Pile 3 at 10 meters (Green) versus the SEL plot at 3 H (Blue)

The average un-weighted frequency distribution calculated over three pile strikes nearest the absolute peak strike for the 30-inch Pile 3 measured at 33 feet indicates a dominant frequency at 1,250 Hz and lesser contributions from other frequencies to about 3 kHz (Figure 16).

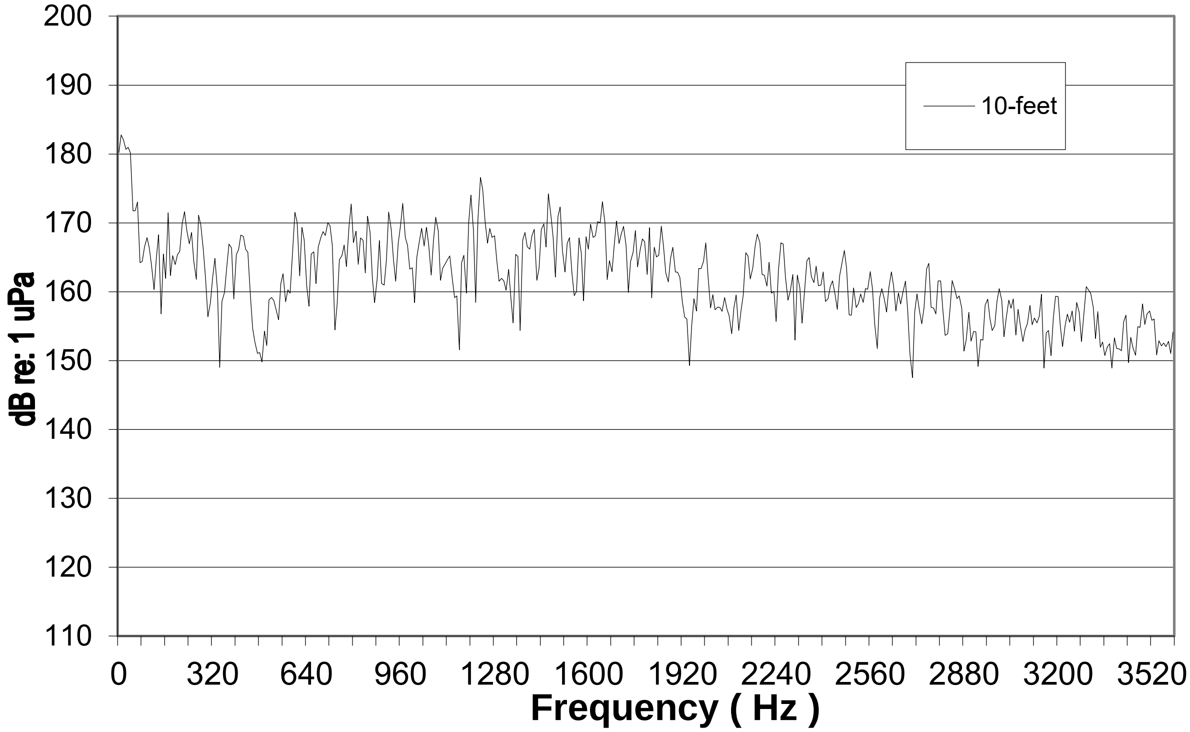

Figure 16: 30-inch Pile 3 Frequency Distribution.

30-inch Pile 4

The 30-inch Pile 4 monitored was measured at a peak level of 196 dB_{peak} at the 33 feet measurement location. This is well below the 206 dB peak interim threshold for fish at 33 feet. The results of broadband wave form monitoring for the 30-inch Pile 4 at both the 33 feet (10 meter) and at 63 feet (3 H) are outlined in the bulleted list below and compared with the other piles driven in Table 5.

- The highest absolute peak measure with the hydrophone at 33 feet from the pile and mid-water depth (10 feet) was 196 dB_{peak} which did not exceed the 206 dB_{peak} interim thresholds for fish at 33 feet. The hydrophone at 63 feet from the pile and 16 feet from the surface or 80% of the water depth was 192 dB_{peak} and 172 dB_{peak} at the 1,312 foot location.
- The $RMS_{90\%}$ at 33 feet and mid-water depth was 183 dB_{RMS} which exceeds both the 160 dB_{RMS} disturbance threshold for marine mammals and the 180 dB_{RMS} injury threshold for cetaceans at 33 feet. At the 63 feet location the $RMS_{90\%}$ was 179 dB_{RMS}. The sound level drops to well below these thresholds at the AMAR location 1,312 feet from the pile where the RMS90% is 161 dB. The distances to the 160 dB_{RMS} disturbance threshold and 180 dB_{RMS} injury threshold from the 33 feet location using the practical spreading model are 1,120 feet and 52 feet respectively. The distance to the 160 dB_{RMS} disturbance threshold from the 63 feet location is 2,128 feet. The distance to the 160 dB_{RMS} disturbance threshold from the 1,312 feet location is 1,530 feet. Using the proposed transmission loss model proposed by Dahl et al., (2012) the distance to the distance to the 180 dB_{RMS} injury

threshold is 52 feet and the distance to the 160 dB_{RMS} disturbance threshold from the 33 feet location is 902 feet.

- The highest single strike Sound Exposure Level (SEL) for the peak strike at 33 feet and mid-water depth was173 dB_{SEL}, at the 63 feet location at 16 feet below the surface was 169 dB_{SEL} and at the AMAR location 1,312 feet from the pile was 148 dB_{SEL}.
- Based on the single strike SEL measured for each pile strike for 467 impact strikes that were measured for the pile drive at 33 feet the cSEL is 195 dB_{SEL} and at 63 feet is 191 dB_{SEL} both of which exceeded the 187 dB_{SEL} interim threshold for fish after about 189 strikes and the non-injurious hearing threshold shift (183 dB_{SEL}) for murrelets but not the auditory injury (202 dB_{SEL}) or non-auditory injury (208 dB_{SEL}) cumulative thresholds for marbled murrelets (Figure 17). The cSEL calculated at 1,312 feet is 173 dB_{SEL} which does not exceed the non-injurious hearing threshold for marbled murrelets at 1,312 feet.

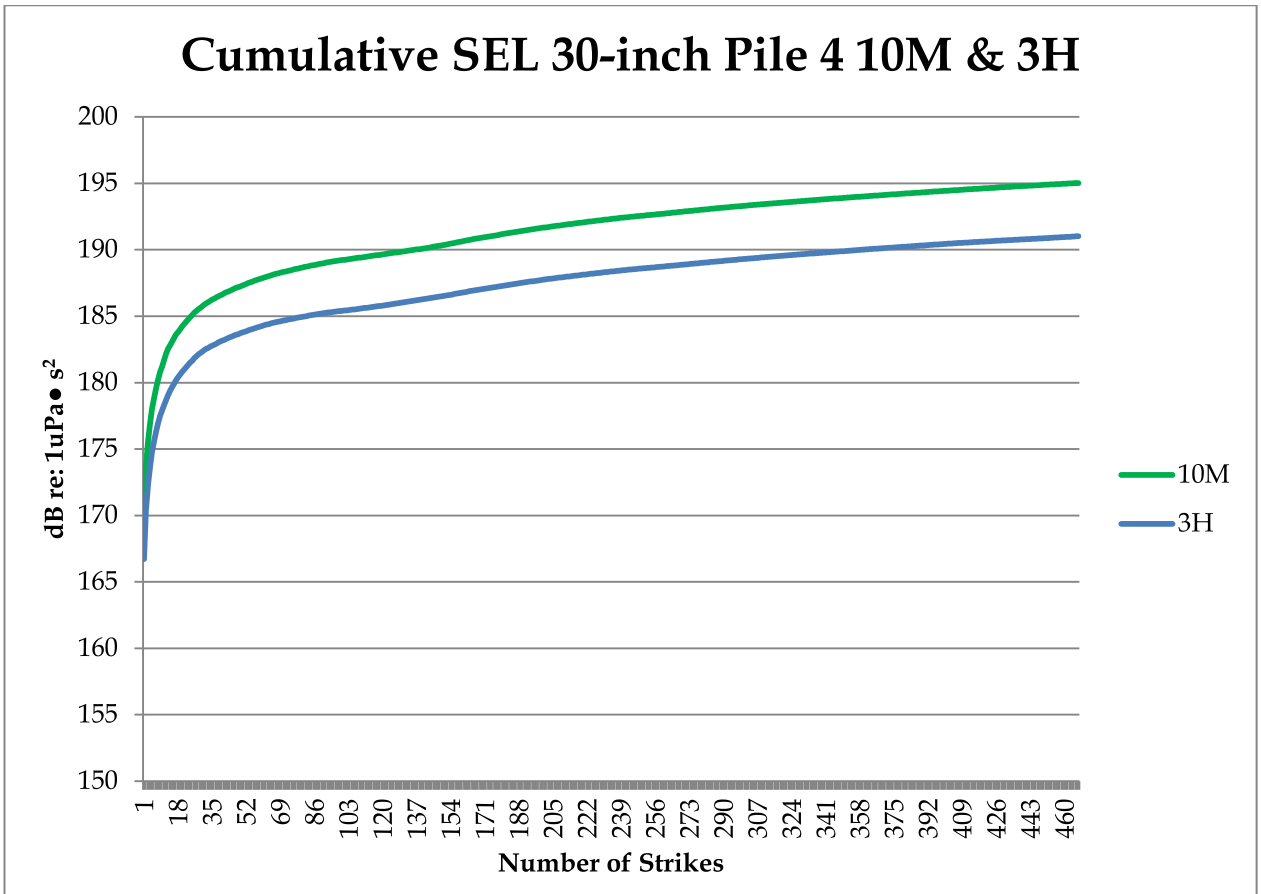

Figure 17: Cumulative SEL plot for 30-inch Pile 4 at 10 meters (Green) versus the SEL plot at 3 H (Blue).

The average un-weighted frequency distribution calculated over three pile strikes nearest the absolute peak strike for the 30-inch Pile 4 measured at 33 feet indicates a dominant frequency at 125 Hz and lesser contributions from other frequencies to about 550 Hz (Figure 18).

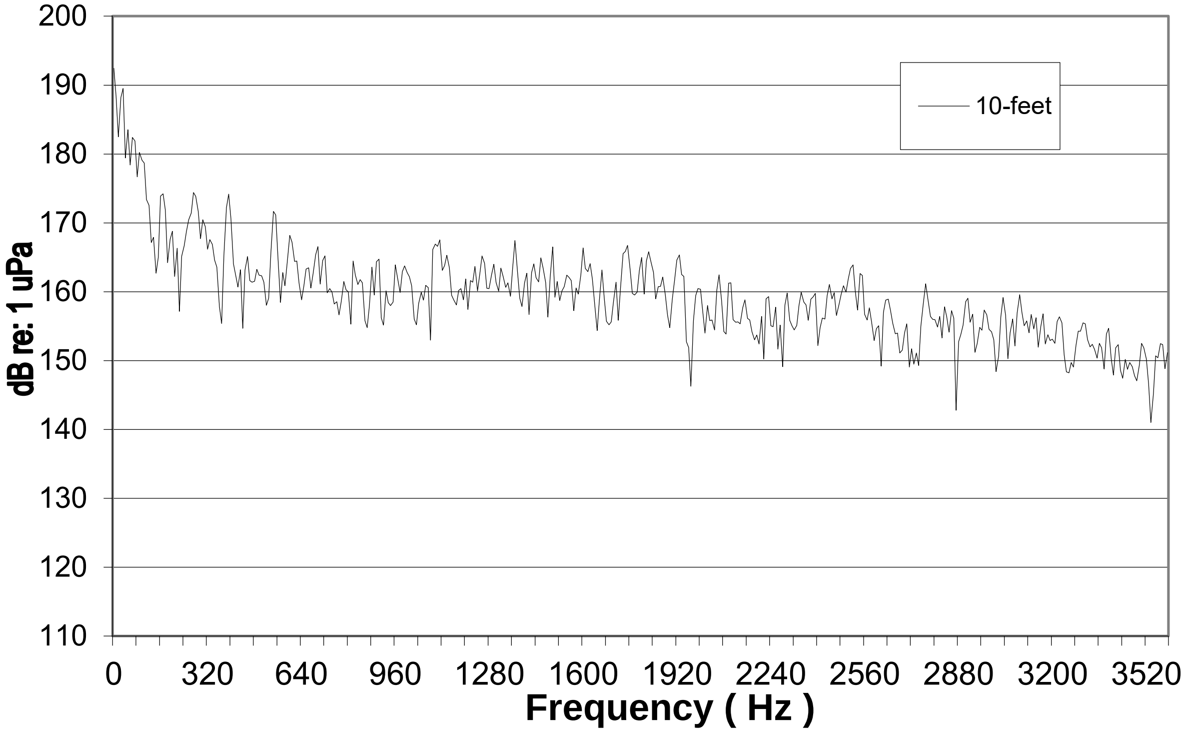

Figure 18: 30-inch Pile 4 Frequency Distribution.

Daily Cumulative SEL

Daily cumulative SEL's (cSEL's) were calculated based on the single strike SEL calculated for each individual pile strike for each day. On January 23, when the 24-inch piles were monitored, the total cSEL at 33 feet calculated to a cSEL of 216 dB_{SEL}. For the 30-inch piles on January the 25[th] the cSEL at 33 feet calculated to 226 dB_{SEL}.

Since all three 24-inch piles were impact driven on the same day we considered the cSEL for all the piles driven within a 12-hour period. The measured single strike SEL was combined for all three piles and accumulated individually for the 33 feet and 63 feet locations. The results indicate that the cSEL for the day is 216 dB_{SEL} at the 33 feet location and 213 dB_{SEL} at the 63 feet location which exceeded the 187 dB_{SEL} interim threshold for fish and the non-injurious hearing threshold shift (183 dB_{SEL}) for murrelets at the 33 feet location but not the auditory injury (202 dB_{SEL}), non-auditory injury (208 dB_{SEL}) cumulative thresholds for marbled murrelets.

For all three 30-inch piles impact driven on January 25 we considered the cSEL for all the piles driven within a 12-hour period. The measured single strike SEL was combined for all three piles and accumulated individually for the 33 feet and 63 feet locations. The results indicate that the cSEL for the day is 226 dB_{SEL} at the 33 feet location and 225 dB_{SEL} at the 63 feet location. Both exceeded the 187 dB_{SEL} interim threshold for fish and the non-injurious hearing threshold shift (183 dB_{SEL}) for murrelets but not the auditory injury (202 dB_{SEL}) or non-auditory injury (208 dB_{SEL}) cumulative thresholds for marbled murrelets.

Measurement Comparison at 3 H and at 10 Meters

The measurements at 63 feet (3H) were generally lower than at the 33 feet (10M) location (Table 3). They differed by 2 to 13 dB for peak levels, 1 to 14 dB for RMS90% levels and 0 to 16 dB for the cSEL levels. As with the RMS and peak levels cSEL for the 63 feet (3H) location was generally lower than the cSEL at 33 feet. The differences also varied from 0 to 7 dB, but varied less for the 30-inch piles than the 24-inch piles. Also cSEL's varied less when compared based on pile size than either the RMS or peak levels (Table 3).

There was generally more of a difference for the 24-inch piles than for the 30-inch piles. However, we feel that these differences may be somewhat due to some shielding of the 3H hydrophone by existing piles under the terminal due to the tight configuration of the hydrophone deployment on site that may have caused additional attenuation and added to the variability. More data needs to be collected to evaluate these measurement ranges.

Table 3: Summary of 10 Meter and 3H Broadband Measurements.

Pile	Date & Time	Hydrophone Range (feet)	Highest Absolute Peak (dB)	Delta	$RMS_{90\%}$ (dB)	Delta	Cumulative SEL (dB)	Delta
24 inch Piles								
Pile 1	1/23/2013 1:41 PM	33	200	13	187	14	191	11
		63	187		173		180	
Pile 2	1/23/2013 2:14 PM	33	196	10	184	13	180	0
		63	186		171		180	
Pile 3	1/23/2013 2:44 PM	33	191	2	175	1	199	16
		63	189		174		183	
30 inch Piles								
Pile 2	1/25/2013 12:20 PM	33	196	4	184	4	190	2
		63	192		180		192	
Pile 3	1/25/2013 1:31 PM	33	197	7	183	6	192	2
		63	190		177		190	
Pile 4	1/25/2013 2:03 PM	33	196	4	183	4	195	4
		63	192		179		191	

Airborne Sound Levels

WSDOT monitored the three 24-inch pile drives for airborne noise level and calculated standardized distances. No abatement techniques are currently available for airborne noise from impact pile driving. Each pile is analyzed in the paragraphs below and summarized in Table 4 on page 26.

24-inch Pile #1

The meter located 65 feet from the pile measured the A weighted L_{max} at the first 24-inch pile to be 105 dBA. The un-weighted level measured 108 dB. Background peaks at that same location when pile driving activities were not occurring measured at between 82 and 90 dBA L_{max}. The un-weighted L_{eq}, used to determine effects to Pinnipeds and other marine mammals, was measured to be 96 dB at the 65 foot location. That equates to 98 dB at 50 feet. Background levels during that hour when pile driving activities were not occurring were between 80 and 86 dB.

- The distance to the USFW 92 dBA L_{max} guidance level for Marbled Murrelet is calculated to be 294 feet.

- Un-weighted airborne sound levels for would drop to the 90 dB Leq in 128 feet and to the 100 dB Leq level in 41 feet.

24-inch Pile #2

The Larson Davis in the same location was located 58 feet from the pile 2 measuring an A weighted L_{max} of 107 dBA 108 at 50 feet. The un-weighted level also measured 107 dB but calculated to 109 dB at 50 feet due to rounding. Background peaks at that same location when during the 2:00 pm to 3:00 pm hour when pile driving activities were not occurring L_{max} measurements were between 84 and 94 dBA L_{max}. The un-weighted L_{eq}'s used to determine effects to Pinnipeds and other marine mammal was measured to be 95 dB at this 58 foot location or 97 dB at 50 feet. Background levels during that hour when pile driving activities were not occurring were between 81 and 85 dB. These same A-weighted and un-weighted background levels apply to both the 24 inch pile #2 and pile #3 as they both fell within the same 2 pm to 3 pm hour.

- The distance to the USFW 92 dBA L_{max} interim guidance level for Marbled Murrelet is calculated to be 315 feet.
- Un-weighted airborne sound levels for would drop to the 90 dB Leq in 108 feet and to the 100 dB Leq level in 34 feet.

24-inch Pile #3

The Larson Davis LXT meter was located 50 feet from the pile for this airborne measurement. The A weighted L_{max} at this 24 inch pile measured 108 dBA. The un-weighted level measured 110 dB. Background was the same as reported for 24 inch pile #2. This pile was driven in two short sessions rather than 1 as the previous piles. The un-weighted L_{eq}'s used to determine effects to Pinnipeds and other marine mammal was measured to be 98 dB at this 50 foot location.

- The distance to the USFW 92 dBA L_{max} interim guidance level for Marbled Murrelet is calculated to be 294 feet.
- Un-weighted airborne sound levels for would drop to the 90 dB Leq in 217 feet and to the 100 dB Leq level in 69 feet.

Table 4: Summary of Airborne Sound Levels for the SR 20 Port Townsend Ferry Terminal Transfer Span Project

Pile # & Size	Date & Time	Acoustical Weighting	Measured Distance (feet)	Peak (Lmax dB)	Peak at 50 ft. (Lmax dB)	RMS (Leq 5 min.) (dB)	RMS at 50 ft. (Leq 5 min.) (dB)	Distance to Criteria or Guidance Levels (feet)
24" #1	1/23/13	A	65	105	107	94	97	294[3]
	1:35 PM	Un-weighted		108	110	96	98	128[1], 41[2]
24" #2	1/23/13	A	58	107	108	94	95	315[3]
	2:10	Un-weighted		107	109	95	97	108[1], 34[2]
24" #3	1/23/13	A	50	108	108	96	96	308[3]
	2:20 & 2:40	Un-weighted		110	110	98	98	126[1], 40[2]

[1] Distance to the 100 dB RMS (Leq) [2] Distance to the 90 dB RMS (Leq) [3] Distance to the 92 dBA Lmax

Table 5: Summary of Underwater Broadband Sound Levels for the SR 20 Port Townsend Ferry Terminal Transfer Span Project

Pile	Date & Time	Hydrophone Range (feet)	Depth (feet)	Total Number Of Strikes	Highest Absolute Peak (dB)	Interim Peak Threshold (dB)	$RMS_{90\%}$ (dB)	$SEL_{90\%}$ (dB)	Avg. Peak ± s.d. (Pascal)	Avg. RMS ± s.d. (Pascal)	Interim Cumulative SEL Threshold For Fish (dB)	Cumulative SEL (dB)
						24 inch Piles						
Pile 1	1/23/2013 1:41 PM	33	10	141	200	206	187	171	5676±1592	1733±464	187	191
		63	16		187		173	163	1634±195	359±37		180
		1312	110		165		153	140	137±26	37±6		161
Pile 2	1/23/2013 2:14 PM	33	10	78	196	206	184	170	1896±241	405 ±67	187	180
		63	16		186		171	162	1706±82	346±25		180
		1312	110		163		154	140	102±38	31±12		170
Pile 3	1/23/2013 2:44 PM	33	10	132	191	206	175	164	2190±467	432 ±86	187	199
		63	16		189		174	164	2163±292	393±31		183
		1312	110		171		158	144	219±58	57±12		168
Total	**1/23/2013**			**351**								**216**
						30 inch Piles						
Pile 2	1/25/2013 12:20 PM	33	10	230	196	206	184	170	4559±500	1366±172	187	192
		63	16		192		180	170	2990±423	662±110		190
		1312			172		162	148	303±50	90±16		170
Pile 3	1/25/2013 1:31 PM	33	10	259	197	206	183	170	4440±986	1311±116	187	192
		63	16		190		177	167	2284±245	563±48		190
		1312			172		161	147	301±49	100±15		171
Pile 4	1/25/2013 2:03 PM	33	10	467	196	206	183	173	4074±562	1219±203	187	195
		63	16		192		179	169	2108 ±424	489±80		191
		1312			172		161	148	291±58	85±18		173
Total	**1/25/2013**			**956**								**226**

Table 6: Summary of Underwater Sound Levels by Functional Hearing Group for the SR 20 Port Townsend Ferry Terminal Transfer Span Project

Pile	Date & Time	Hydrophone Range (feet)	Functional Hearing Group (Hz)	Highest Absolute Peak (dB)	$RMS_{90\%}$ (dB)	$SEL_{90\%}$ (dB)
Pile 1 24-inch	1/23/2013 1:41 PM	33	7	200	187	170
			75	200	187	170
			150	200	186	170
			200	200	189	171
		63	7	186	173	162
			75	187	176	162
			150	184	172	158
			200	182	173	158
		1312	7	165	153	140
			75	165	154	140
			150	162	152	138
			200	160	150	136
Pile 2 24-inch	1/23/2013 2:14 PM	33	7	186	173	162
			75	188	175	160
			150	187	174	160
			200	185	175	159
		63	7	185	172	162
			75	186	175	161
			150	183	173	159
			200	181	173	158
		1312	7	163	154	140
			75	162	154	140
			150	162	151	138
			200	160	148	135
Pile 3 24-inch	1/23/2013 2:44 PM	33	7	191	176	164
			75	192	177	163
			150	191	176	162
			200	191	174	161
		63	7	189	174	164
			75	187	176	162
			150	186	173	160
			200	186	173	160
		1312	7	171	158	144
			75	170	158	144
			150	169	157	143
			200	167	155	141
Pile 2 30-inch	1/25/2013 12:20 PM	33	7	196	184	170
			75	195	185	169
			150	195	180	167
			200	193	177	164
		63	7	189	174	164
			75	191	182	168
			150	189	180	166
			200	188	178	164
		1312	7	172	162	148
			75	172	162	148
			150	172	161	147
			200	169	157	143
Pile 3 30-inch	1/25/2013 1:31 PM	33	7	197	184	170
			75	197	183	169
			150	197	183	169

Pile	Date & Time	Hydrophone Range (feet)	Functional Hearing Group (Hz)	Highest Absolute Peak (dB)	$RMS_{90\%}$ (dB)	$SEL_{90\%}$ (dB)
			200	196	183	168
		63	7	190	177	167
			75	189	176	163
			150	188	175	162
			200	187	175	162
		1312	7	172	161	147
			75	172	161	147
			150	173	159	146
			200	169	155	142
Pile 4 30-inch	1/25/2013 2:03 PM	33	7	196	187	171
			75	193	179	166
			150	192	178	164
			200	192	178	164
		63	7	192	179	169
			75	190	180	166
			150	186	175	161
			200	186	175	161
		1312	7	172	161	148
			75	172	162	147
			150	173	160	146
			200	170	154	141

CONCLUSIONS

A total of six steel piles were monitored for the construction of the Port Townsend Ferry Terminal Slip 1 Hydraulic Transfer span. The underwater sound levels analyzed, produced the following results.

- Peak underwater sound levels at 33 feet varied in a range between 200 dB_{Peak} and 191 dB_{Peak}.
- The $RMS_{90\%}$ levels of these 33 feet measurements ranged between 187 dB_{RMS} and 175 dB_{RMS}.
- Cumulative Sound Exposure Levels (cSEL), calculated from SEL's for individual pile strikes were in a range between 180 dB_{SEL} and 199 dB_{SEL} at the 33 feet hydrophones. At the 3H hydrophone that range was 180 dB_{SEL} to 191dB_{SEL}.
- Cumulative Sound Exposure Levels (cSEL) for all piles for each days pile drive were calculated for both the 33 and 63 feet hydrophones. They all exceeded the 187 dB_{SEL} threshold. The cSEL measured for the three 24-inch piles on January 23, was 192 dB_{SEL} at 33 feet and 187 dB_{SEL} at 63 feet. The three 30-inch piles measured on January 25 had a cSEL of 198 dB_{SEL} at 33 feet and 195 dB_{SEL} at 63 feet.
- The 24-inch Pile 1 produced highest peak sound level 200 dB_{peak}.
- The 10 meter measurements were consistently higher than those at 63 feet (3H) and no clear relationship between 33 feet and 63 feet measurements were discernible.

The three 24-inch piles were also monitored for airborne sound levels. The impact pile driving produced the following results.

- Un-weighted peak sound levels were measured to between 109 and 110 dB_{Max}, the A-weighted peak levels were between 107 and 108 dBA_{Max} at 50 feet.
- The un-weighted RMS levels ranged between 97 and 98 dBL_{eq} at 50 feet. The A-weighted L_{eq}'s were between 95 and 97 dBA L_{eq} at 50 feet.

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APPENDIX A

Waveform Analysis Figures

Figure 19: Waveform analysis of 24-inch Pile 1 10M and 3H Broadband

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 10M

Figure a. Waveform

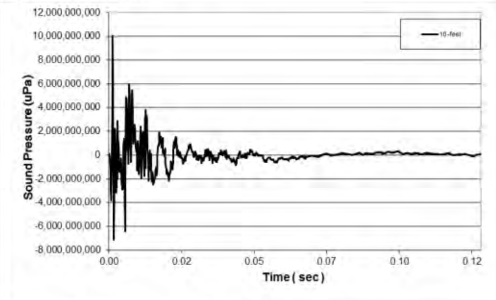

Figure b. Narrow Band Frequency Spectra

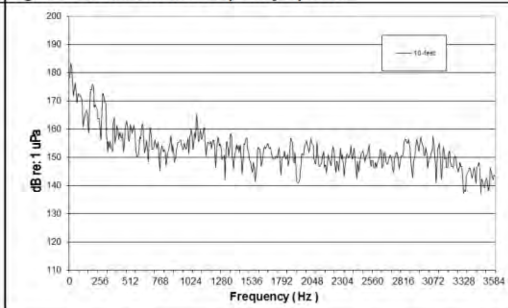

Figure c. Accumulation of Sound Energy

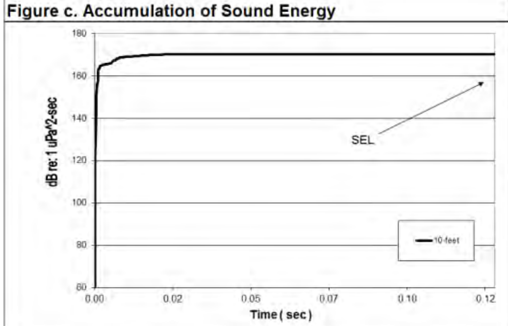

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	200	187	171

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 3H

Figure a. Waveform

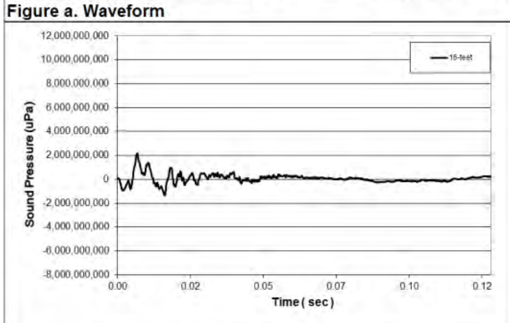

Figure b. Narrow Band Frequency Spectra

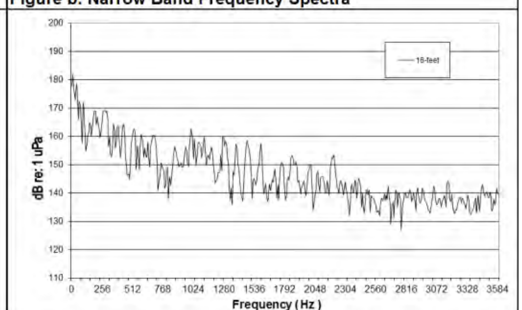

Figure c. Accumulation of Sound Energy

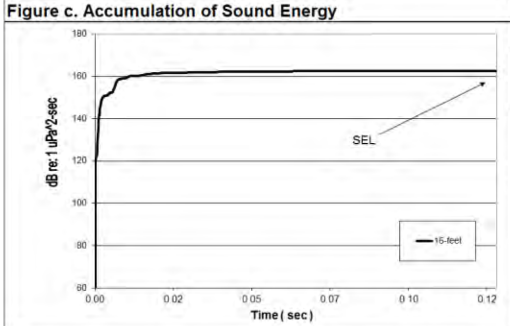

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	187	173	163

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

Figure 20: Waveform analysis of 24-inch Pile 1 10M and 3H 7Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 10M 7Hz

Figure a. Waveform

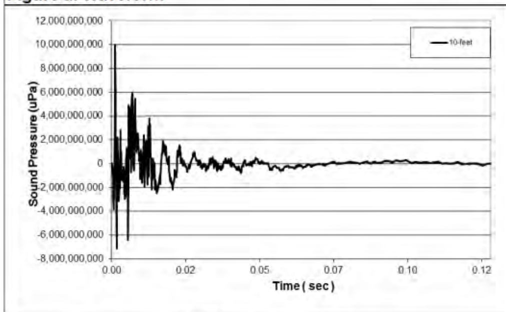

Figure b. Narrow Band Frequency Spectra

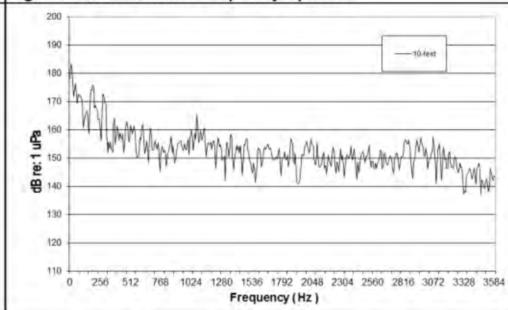

Figure c. Accumulation of Sound Energy

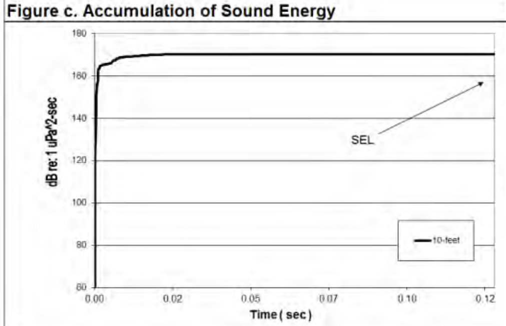

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	200	187	170

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 3H 7Hz

Figure a. Waveform

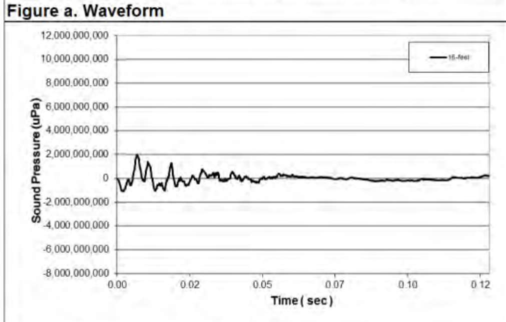

Figure b. Narrow Band Frequency Spectra

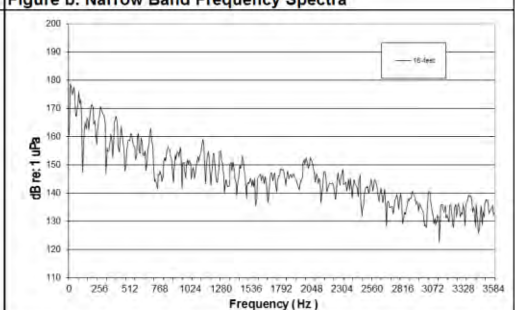

Figure c. Accumulation of Sound Energy

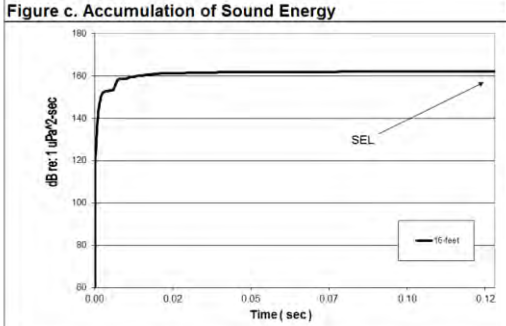

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	186	173	162

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

Figure 21: Waveform analysis of 24-inch Pile 1 10M and 3H 75Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 10M 75Hz

Figure a. Waveform

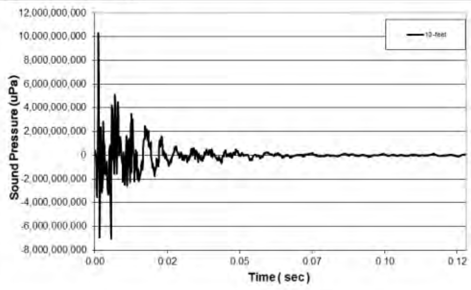

Figure b. Narrow Band Frequency Spectra

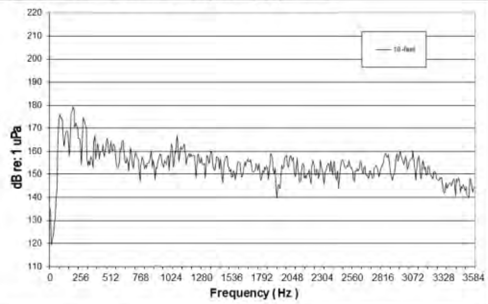

Figure c. Accumulation of Sound Energy

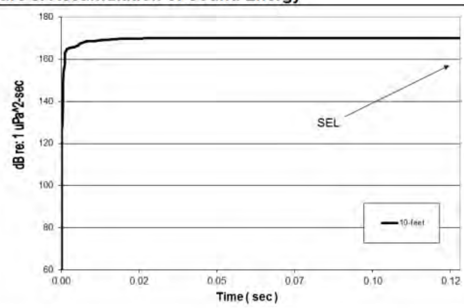

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	200	187	170

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 3H 75Hz

Figure a. Waveform

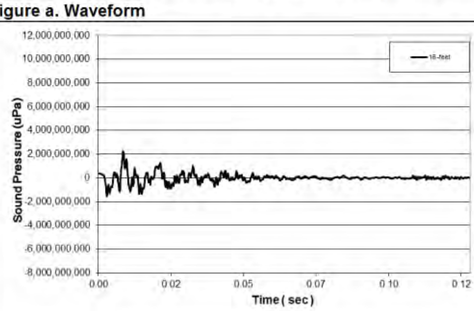

Figure b. Narrow Band Frequency Spectra

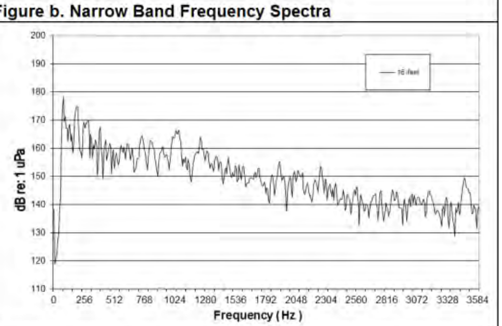

Figure c. Accumulation of Sound Energy

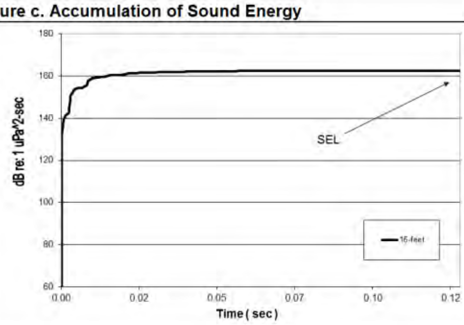

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	187	176	162

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

Figure 22: Waveform analysis of 24-inch Pile 1 10M and 3H 150Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 10M 150Hz

Figure a. Waveform

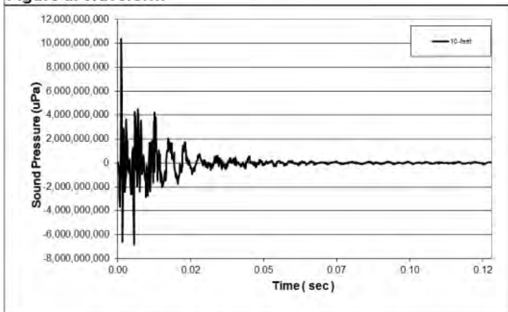

Figure b. Narrow Band Frequency Spectra

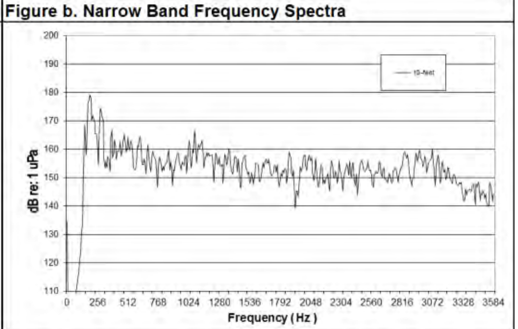

Figure c. Accumulation of Sound Energy

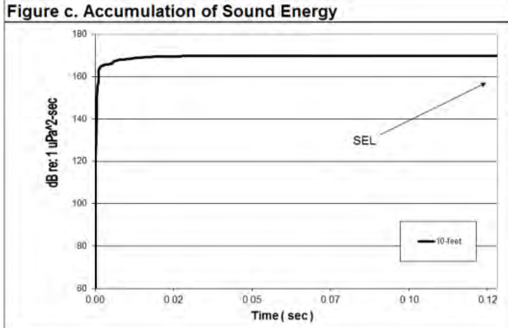

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	200	186	170

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 3H 150Hz

Figure a. Waveform

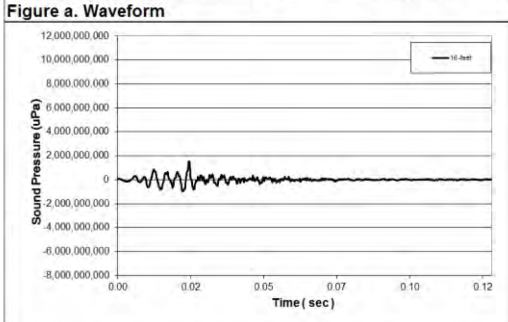

Figure b. Narrow Band Frequency Spectra

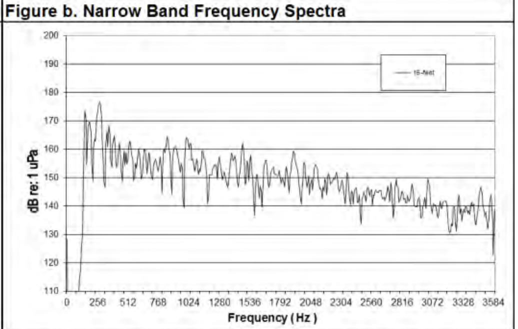

Figure c. Accumulation of Sound Energy

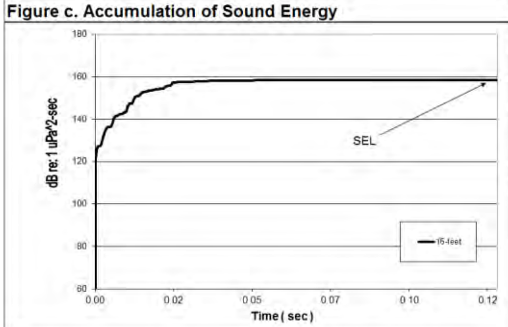

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	184	172	158

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

Figure 23: Waveform analysis of 24-inch Pile 1 10M and 3H 200Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 10M 200Hz

Figure a. Waveform

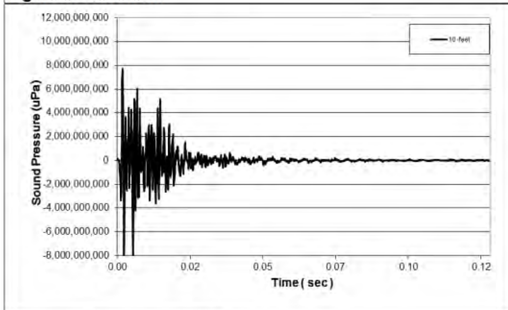

Figure b. Narrow Band Frequency Spectra

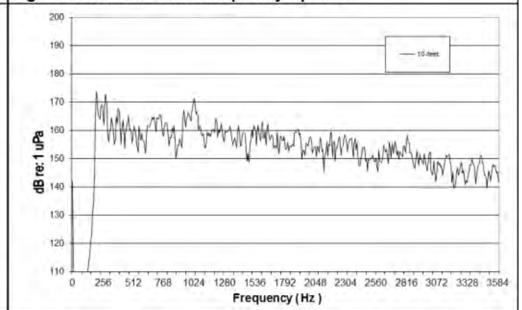

Figure c. Accumulation of Sound Energy

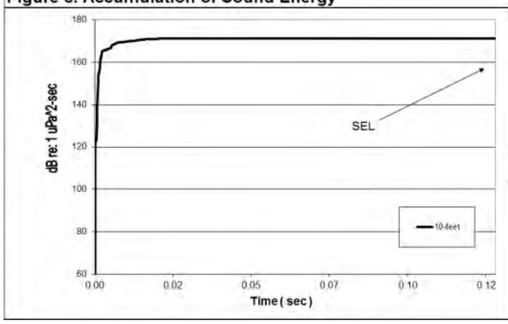

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	200	189	171

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 1 at 3H 200Hz

Figure a. Waveform

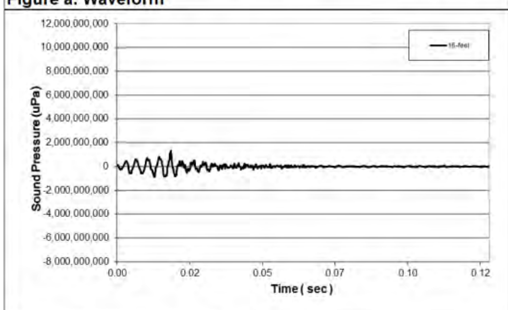

Figure b. Narrow Band Frequency Spectra

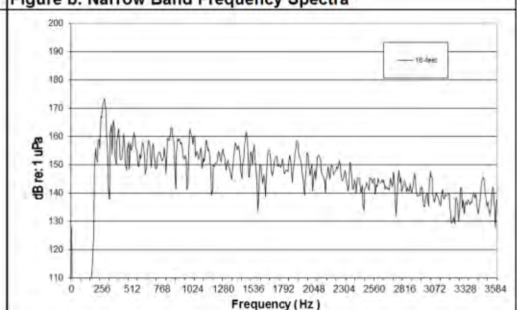

Figure c. Accumulation of Sound Energy

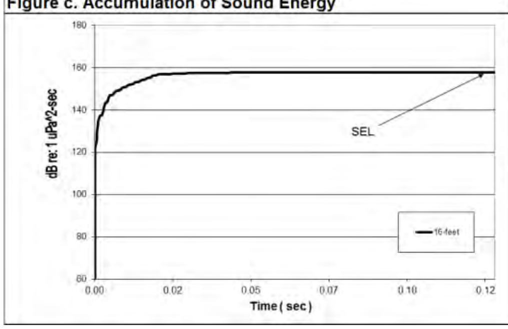

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	182	173	158

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

Figure 24: Waveform analysis of 24-inch Pile 2 10M and 3H Broadband

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 10M Broadband

Figure a. Waveform

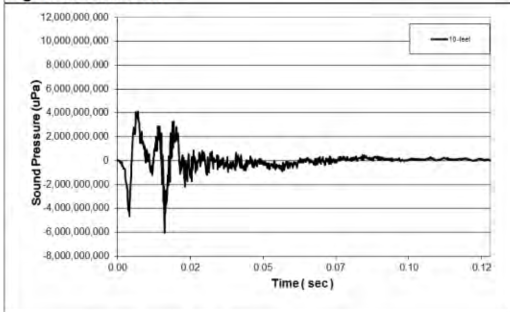

Figure b. Narrow Band Frequency Spectra

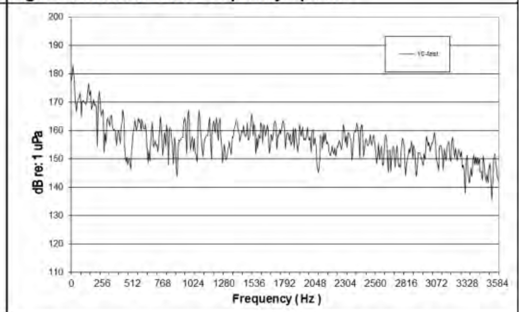

Figure c. Accumulation of Sound Energy

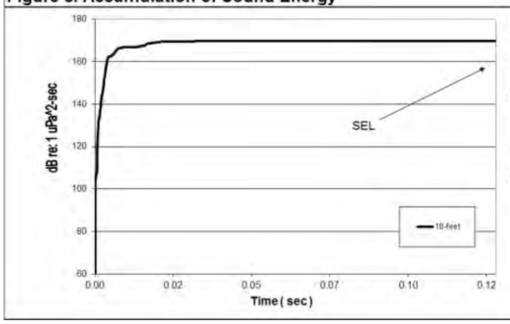

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	196	184	170

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 3H Broadband

Figure a. Waveform

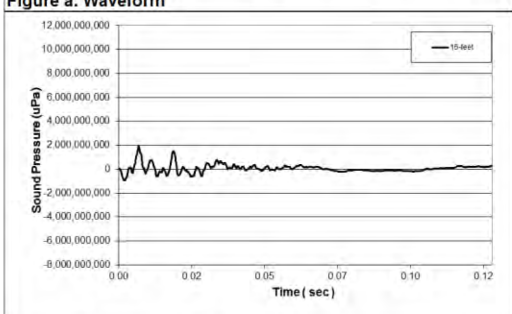

Figure b. Narrow Band Frequency Spectra

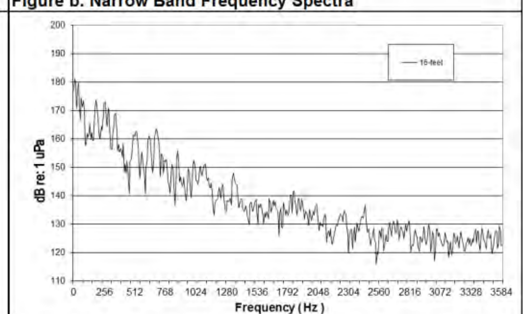

Figure c. Accumulation of Sound Energy

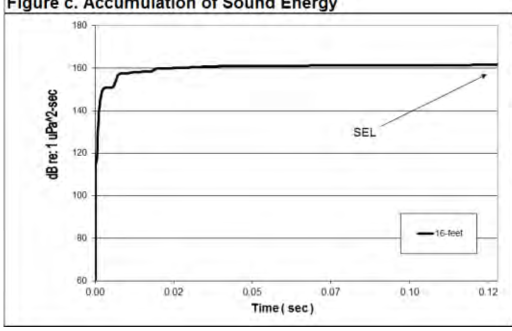

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	186	171	162

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

Figure 25: Waveform analysis of 24-inch Pile 2 10M and 3H 7Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 10M 7Hz

Figure a. Waveform

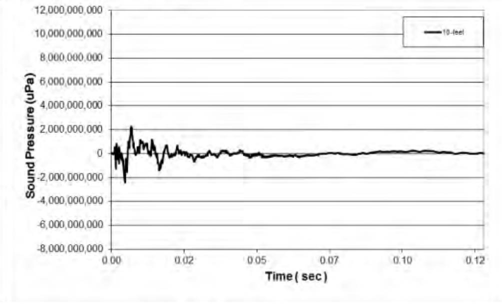

Figure b. Narrow Band Frequency Spectra

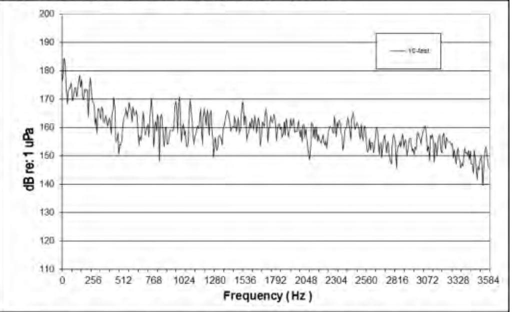

Figure c. Accumulation of Sound Energy

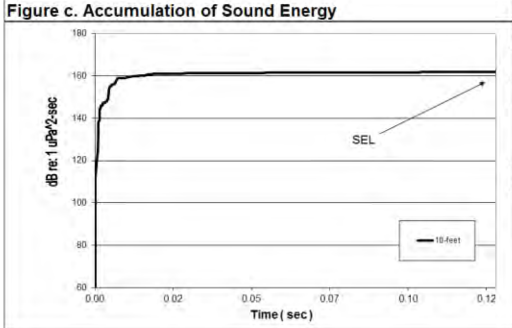

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	188	173	162

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 3H 7Hz

Figure a. Waveform

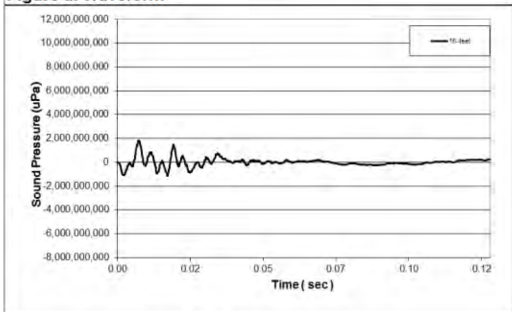

Figure b. Narrow Band Frequency Spectra

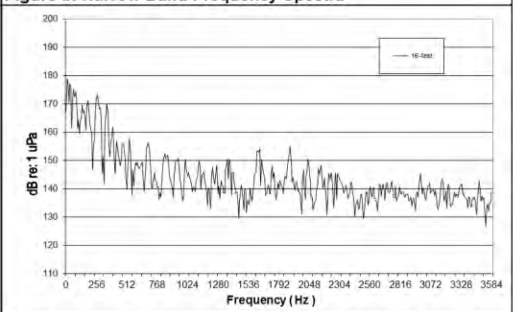

Figure c. Accumulation of Sound Energy

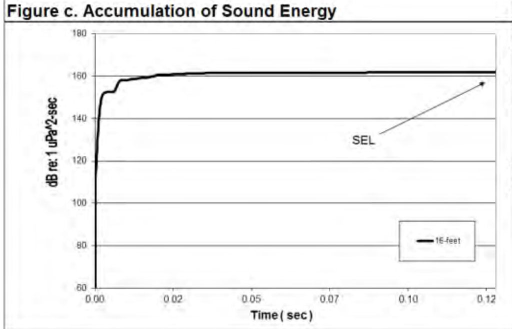

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	185	172	162

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

Figure 26: Waveform analysis of 24-inch Pile 2 10M and 3H 75Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 10M 75Hz

Figure a. Waveform

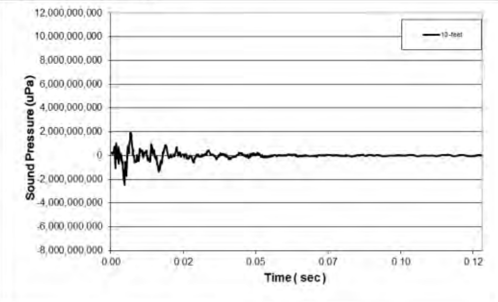

Figure b. Narrow Band Frequency Spectra

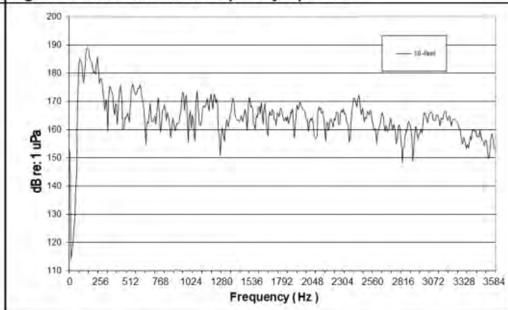

Figure c. Accumulation of Sound Energy

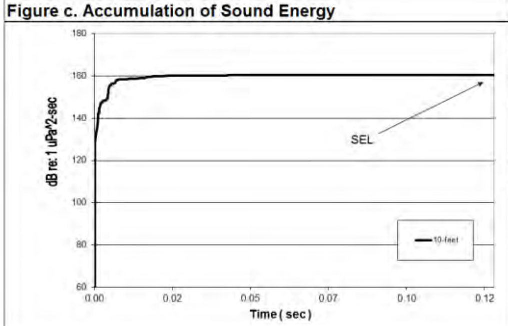

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	188	175	160

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 3H 75Hz

Figure a. Waveform

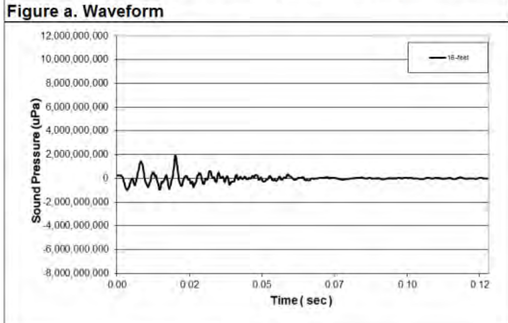

Figure b. Narrow Band Frequency Spectra

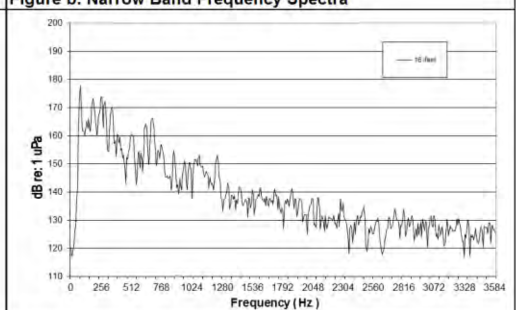

Figure c. Accumulation of Sound Energy

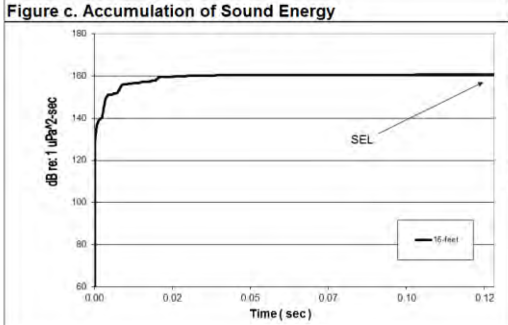

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	186	175	161

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

Figure 27: Waveform analysis of 24-inch Pile 2 10M and 3H 150Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 10M 150Hz

Figure a. Waveform

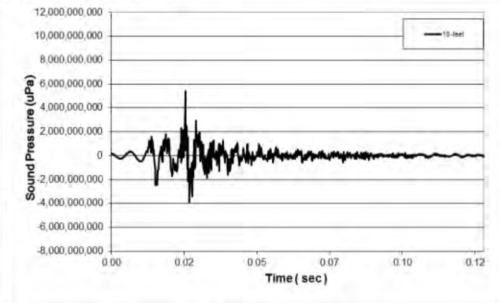

Figure b. Narrow Band Frequency Spectra

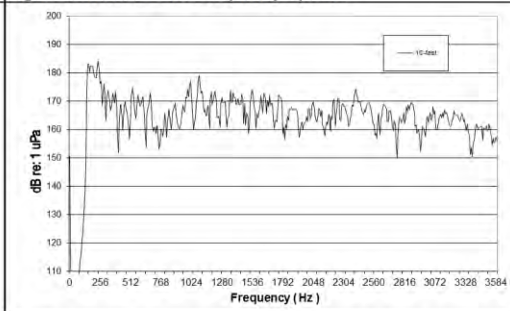

Figure c. Accumulation of Sound Energy

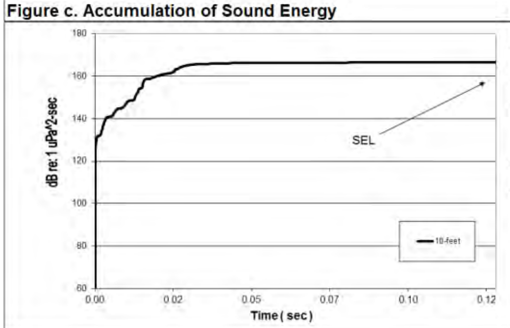

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	195	180	167

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 3H 150Hz

Figure a. Waveform

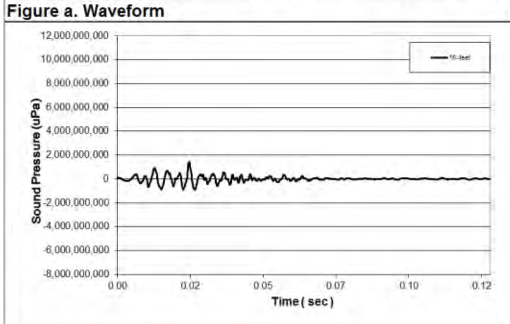

Figure b. Narrow Band Frequency Spectra

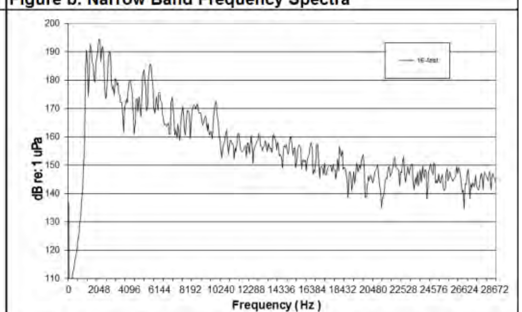

Figure c. Accumulation of Sound Energy

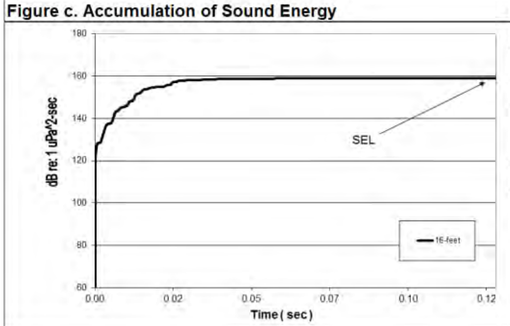

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	183	173	159

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

Figure 28: Waveform analysis of 24-inch Pile 2 10M and 3H 200Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 10M 200Hz

Figure a. Waveform

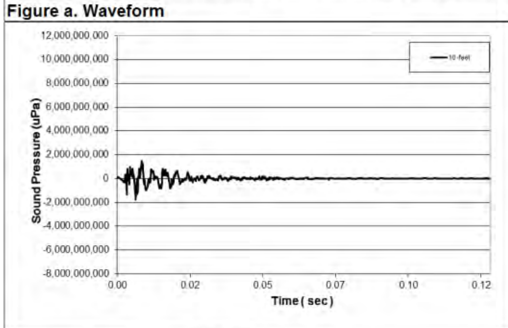

Figure b. Narrow Band Frequency Spectra

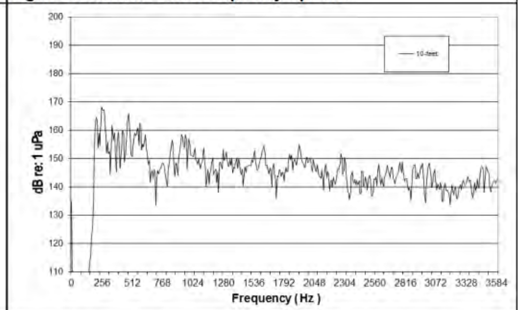

Figure c. Accumulation of Sound Energy

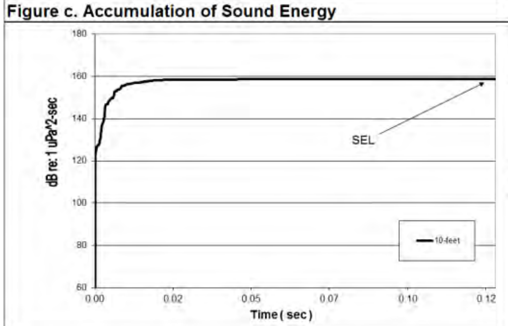

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	185	175	159

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 2 at 3H 200Hz

Figure a. Waveform

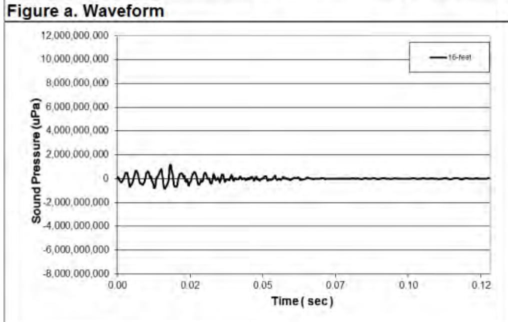

Figure b. Narrow Band Frequency Spectra

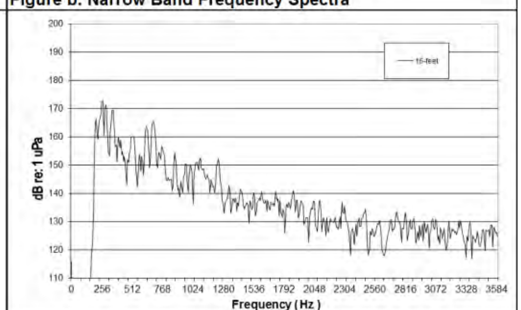

Figure c. Accumulation of Sound Energy

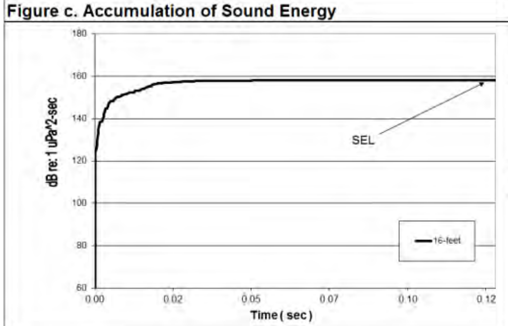

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	181	173	158

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

Figure 29: Waveform analysis of 24-inch Pile 3 10M and 3H Broadband

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 10M Broadband

Figure a. Waveform

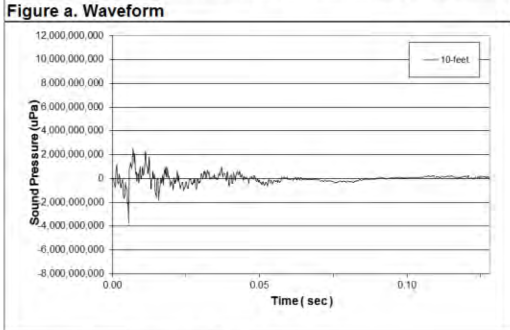

Figure b. Narrow Band Frequency Spectra

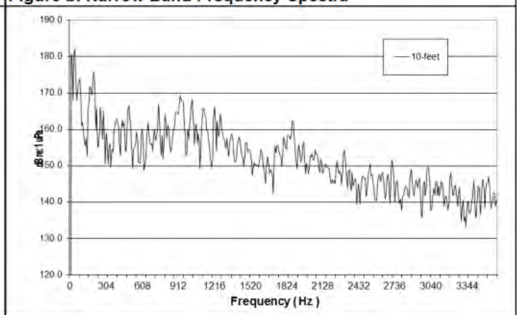

Figure c. Accumulation of Sound Energy

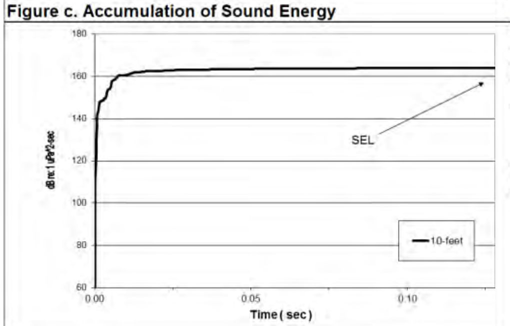

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

neters from pile - 00:00	Peak	RMS90%*	SEL
10-feet	191	175	164

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 3H Broadband

Figure a. Waveform

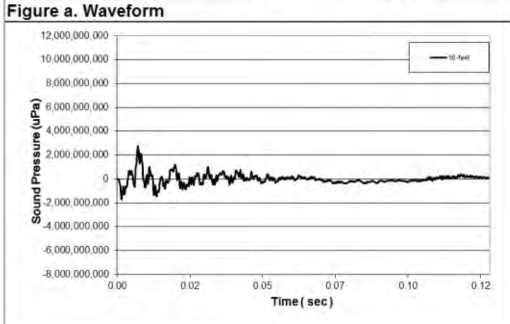

Figure b. Narrow Band Frequency Spectra

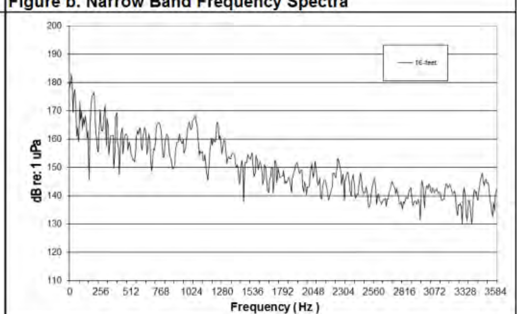

Figure c. Accumulation of Sound Energy

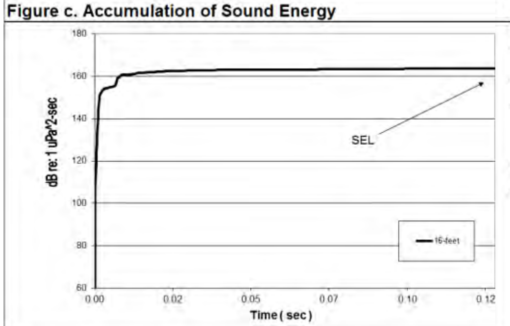

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	189	174	164

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

Figure 30: Waveform analysis of 24-inch Pile 3 10M and 3H 7Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 10M 7Hz

Figure a. Waveform

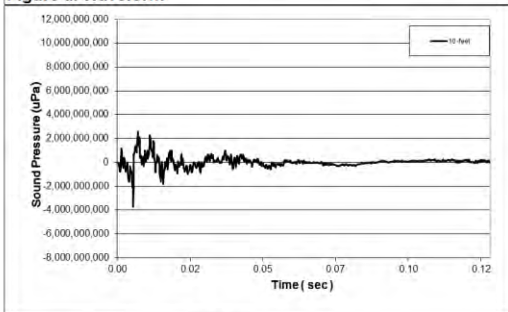

Figure b. Narrow Band Frequency Spectra

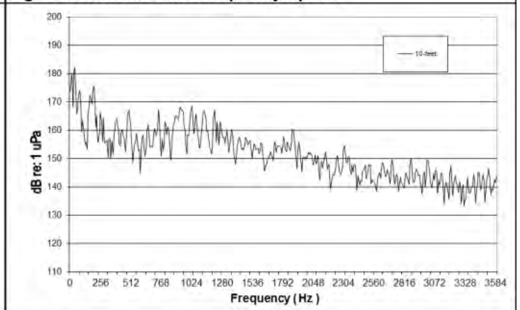

Figure c. Accumulation of Sound Energy

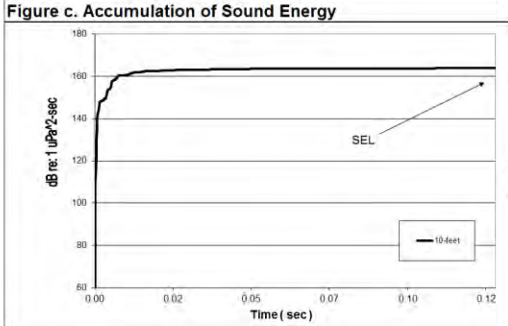

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	191	176	164

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 3H 7Hz

Figure a. Waveform

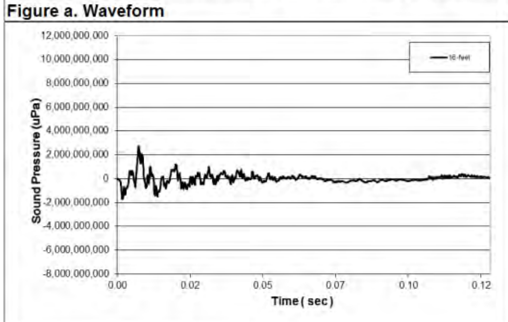

Figure b. Narrow Band Frequency Spectra

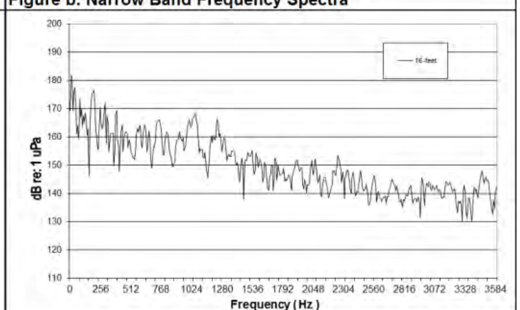

Figure c. Accumulation of Sound Energy

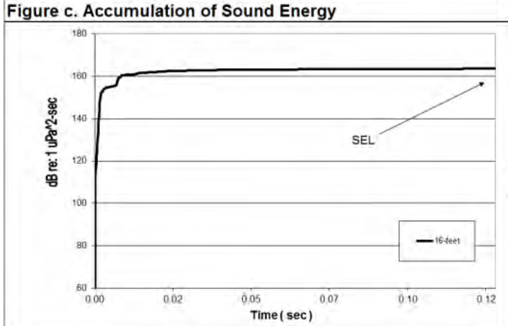

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	189	174	164

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

Figure 31: Waveform analysis of 24-inch Pile 3 10M and 3H 75 Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 10M 75Hz

Figure a. Waveform

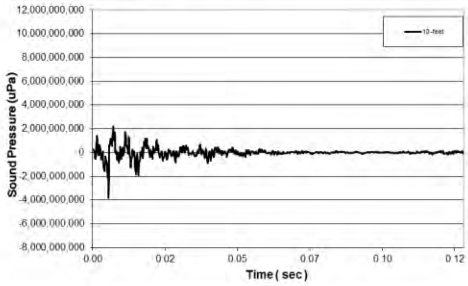

Figure b. Narrow Band Frequency Spectra

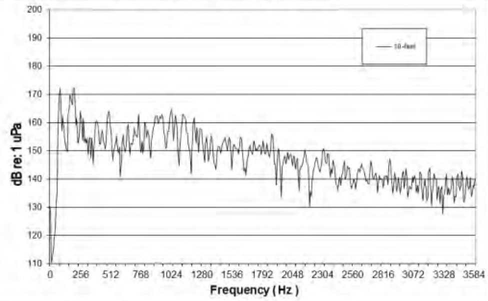

Figure c. Accumulation of Sound Energy

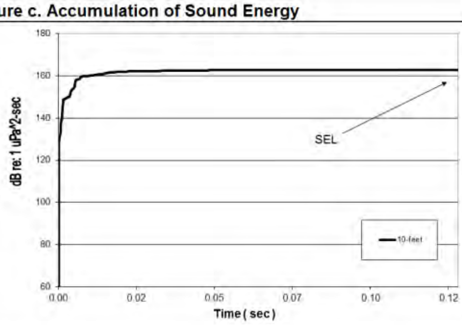

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	192	177	163

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 3H 75Hz

Figure a. Waveform

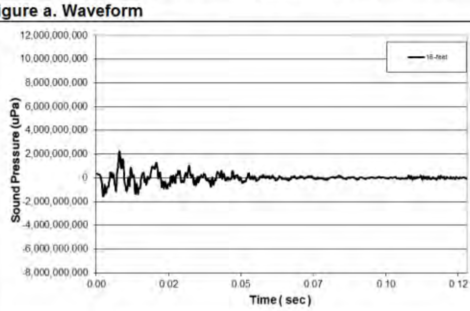

Figure b. Narrow Band Frequency Spectra

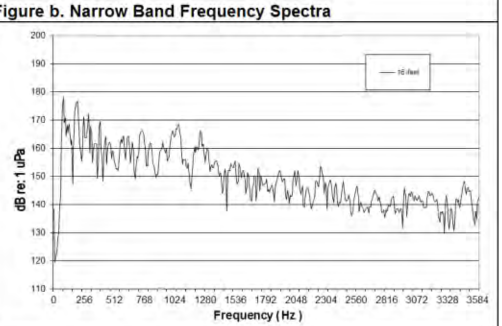

Figure c. Accumulation of Sound Energy

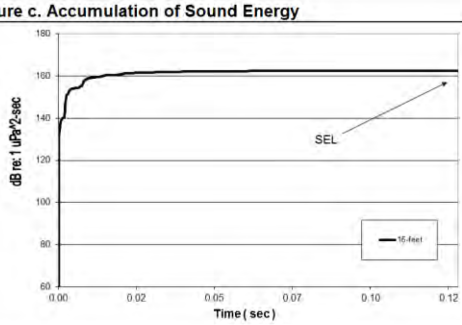

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	187	176	162

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

Figure 32: Waveform analysis of 24-inch Pile 3 10M and 3H 150 Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 10M 150Hz

Figure a. Waveform

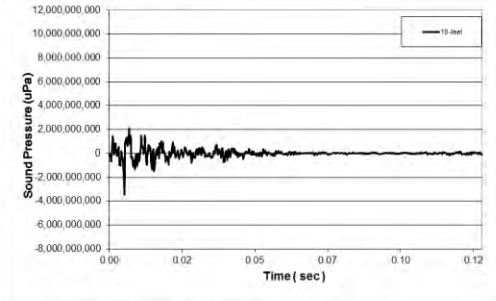

Figure b. Narrow Band Frequency Spectra

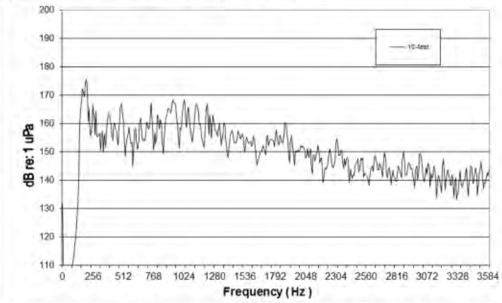

Figure c. Accumulation of Sound Energy

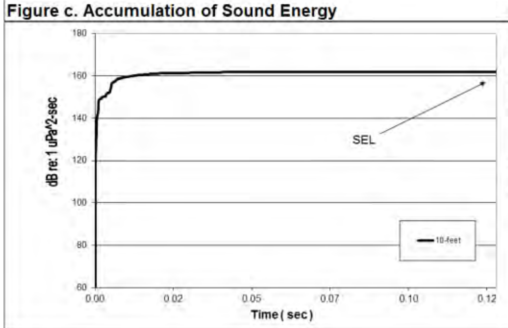

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	191	176	162

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 3H 150Hz

Figure a. Waveform

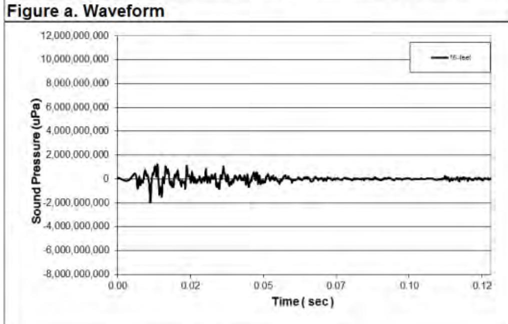

Figure b. Narrow Band Frequency Spectra

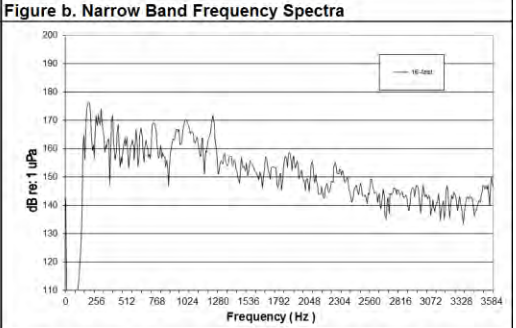

Figure c. Accumulation of Sound Energy

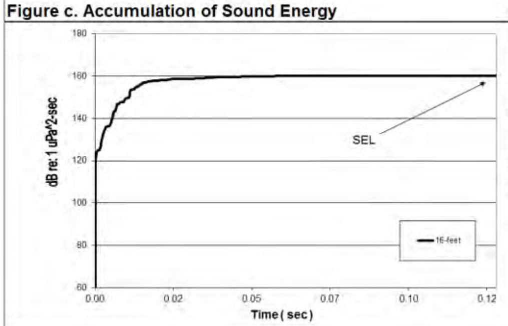

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	186	173	160

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

Figure 33: Waveform analysis of 24-inch Pile 3 10M and 3H 200 Hz

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 10M 200Hz

Figure a. Waveform

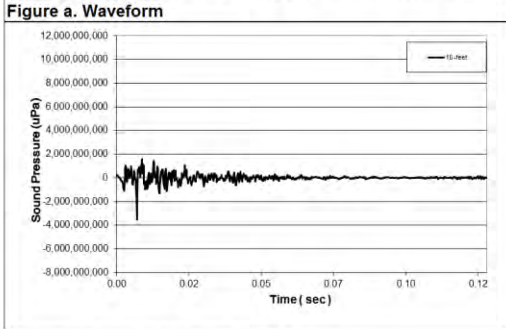

Figure b. Narrow Band Frequency Spectra

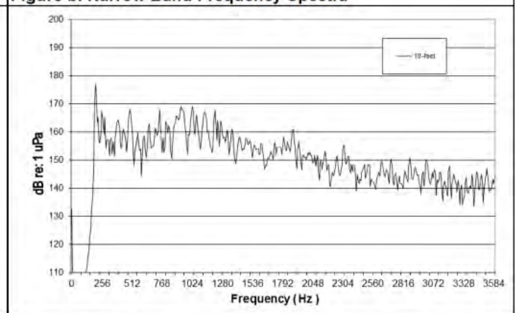

Figure c. Accumulation of Sound Energy

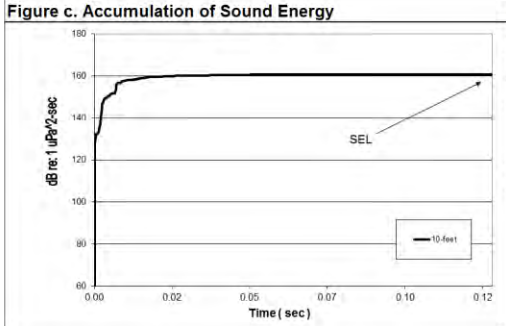

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	191	174	161

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 3H 200Hz

Figure a. Waveform

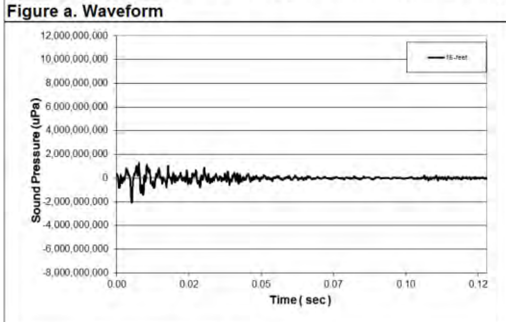

Figure b. Narrow Band Frequency Spectra

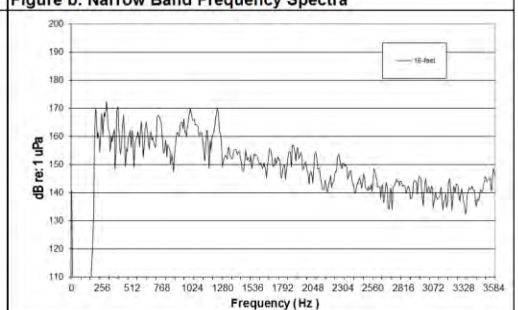

Figure c. Accumulation of Sound Energy

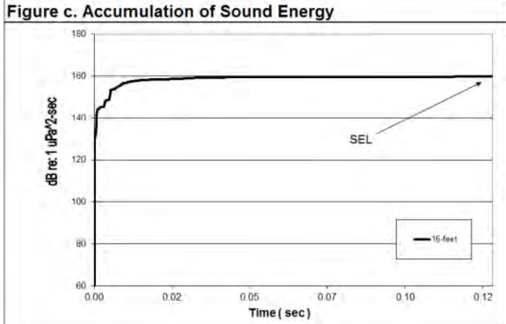

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	186	173	160

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

Figure 34: Waveform analysis of 30-inch Pile 2 10M and 3H Broadband

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 2 at 10M Broadband

Figure a. Waveform

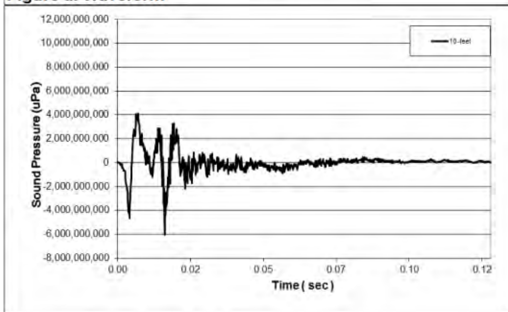

Figure b. Narrow Band Frequency Spectra

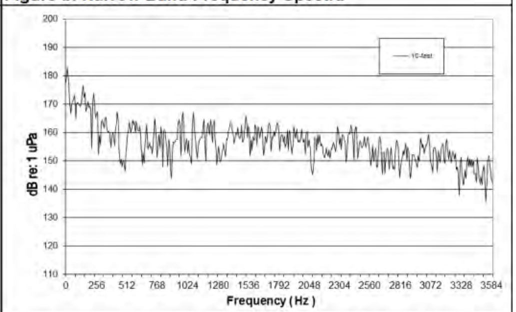

Figure c. Accumulation of Sound Energy

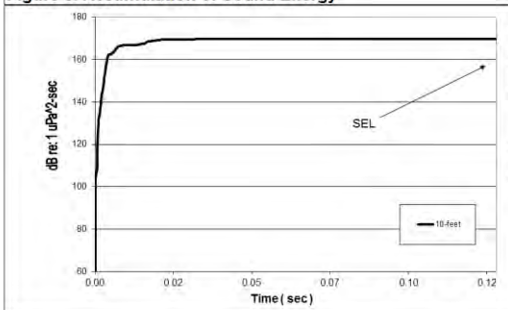

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	196	184	170

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

Port Townsend 30-inch Pile 2 3H Broadband

Figure a. Waveform

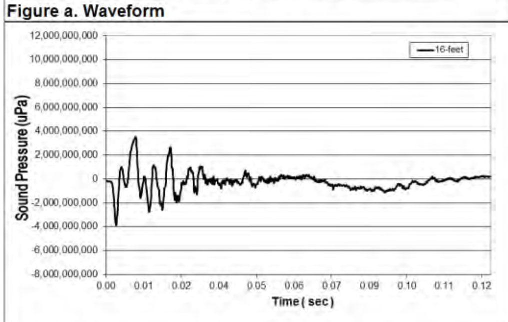

Figure b. Narrow Band Frequency Spectra

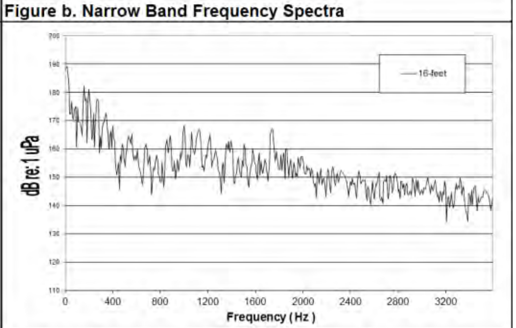

Figure c. Accumulation of Sound Energy

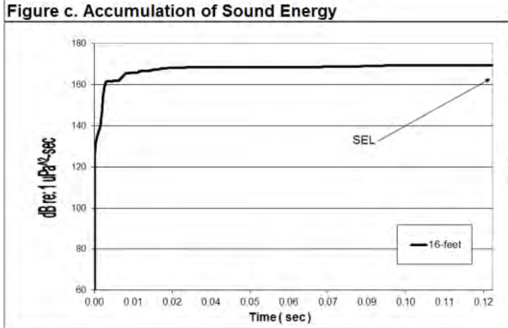

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

63 feet from pile	Peak	RMS90%*	SEL
16-feet	192	180	170

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

Figure 35: Waveform analysis of 30-inch Pile 2 10M and 3H 7Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 2 at 10M 7Hz

Figure a. Waveform

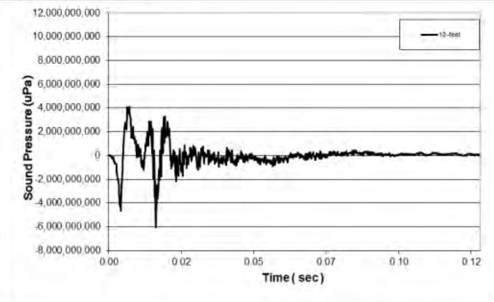

Figure b. Narrow Band Frequency Spectra

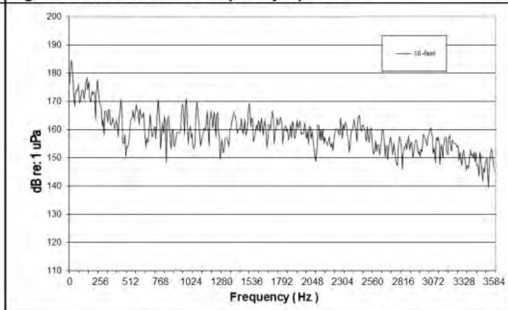

Figure c. Accumulation of Sound Energy

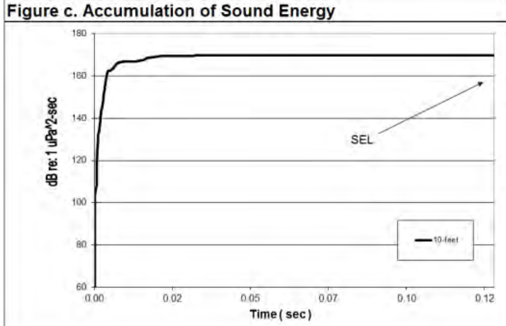

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	196	184	170

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

SR 20 Port Townsend Ferry Transfer Span 24 in. Pile 3 at 3H 7Hz

Figure a. Waveform

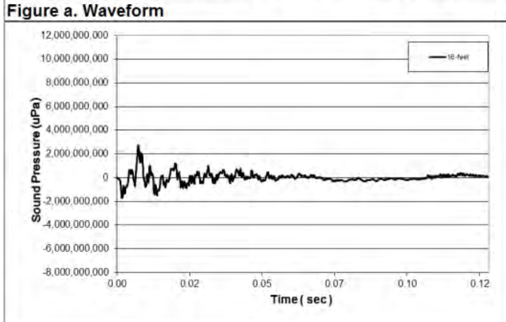

Figure b. Narrow Band Frequency Spectra

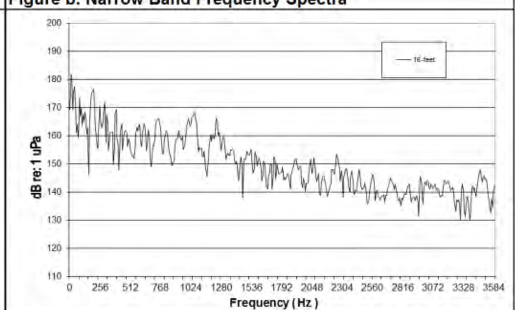

Figure c. Accumulation of Sound Energy

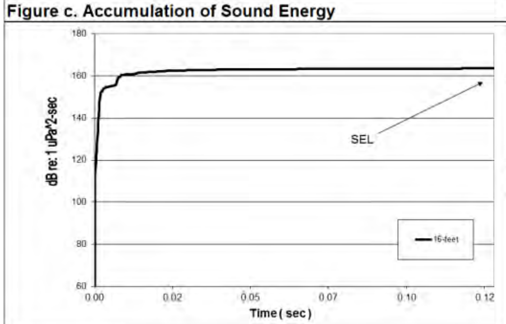

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	189	174	164

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

Figure 36: Waveform analysis of 30-inch Pile 2 10M and 3H 75Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 2 at 10M 75Hz

Figure a. Waveform

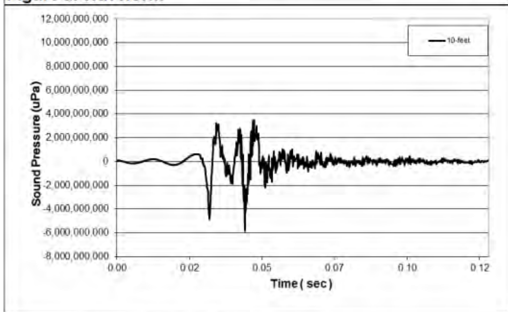

Figure b. Narrow Band Frequency Spectra

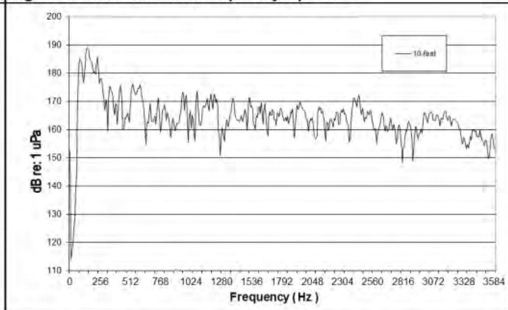

Figure c. Accumulation of Sound Energy

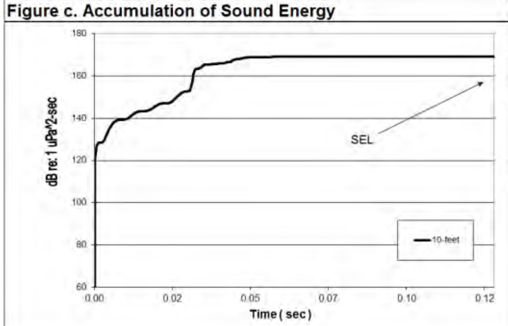

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	195	185	169

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 2 at 3H 75Hz

Figure a. Waveform

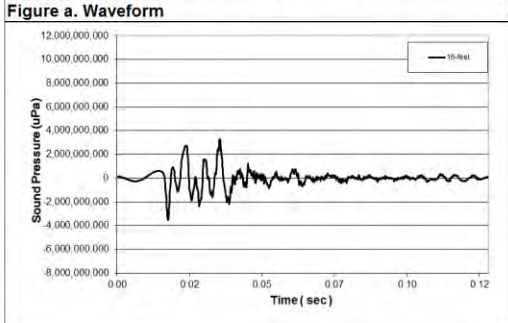

Figure b. Narrow Band Frequency Spectra

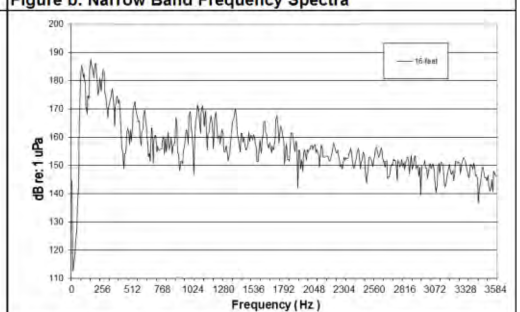

Figure c. Accumulation of Sound Energy

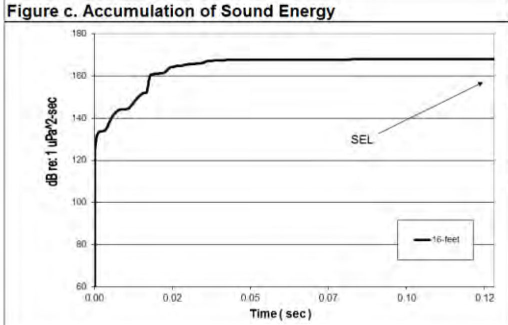

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	191	182	168

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

Figure 37: Waveform analysis of 30-inch Pile 2 10M and 3H 150Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 2 at 10M 150Hz

Figure a. Waveform

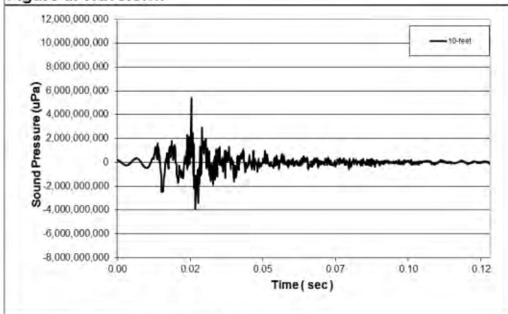

Figure b. Narrow Band Frequency Spectra

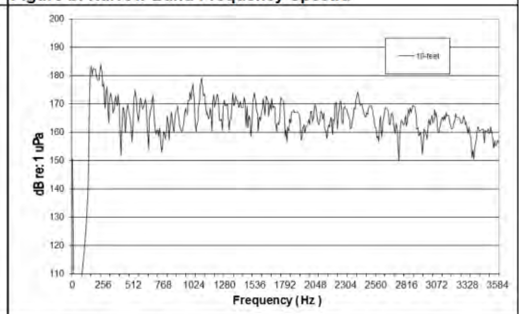

Figure c. Accumulation of Sound Energy

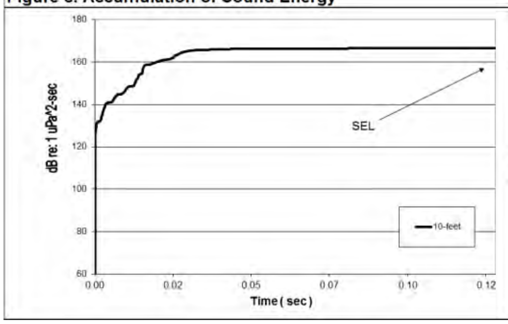

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	195	180	167

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 2 at 3H 150Hz

Figure a. Waveform

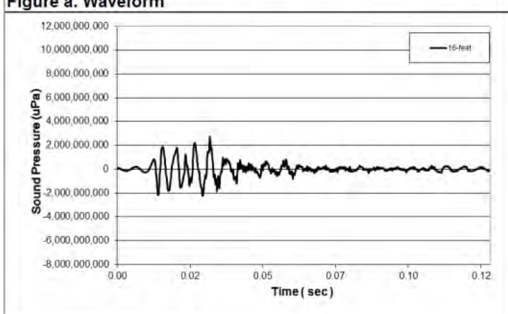

Figure b. Narrow Band Frequency Spectra

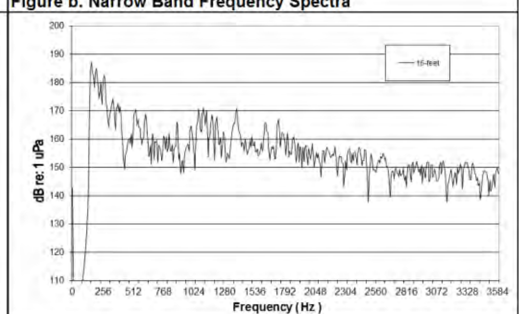

Figure c. Accumulation of Sound Energy

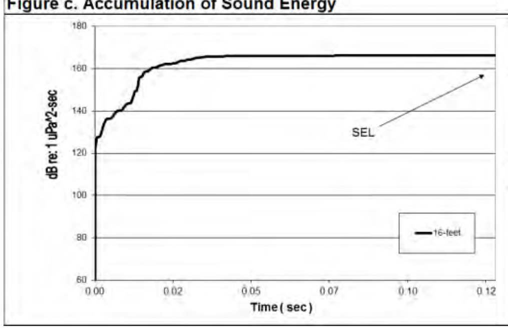

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	189	180	166

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

Figure 38: Waveform analysis of 30-inch Pile 2 10M and 3H 200 Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 2 at 10M 200Hz

Figure a. Waveform

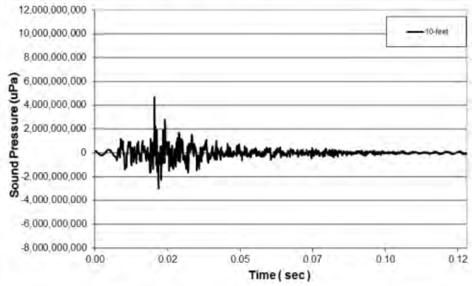

Figure b. Narrow Band Frequency Spectra

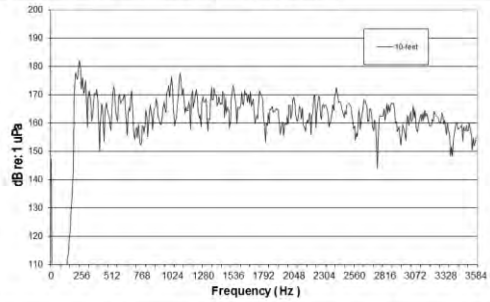

Figure c. Accumulation of Sound Energy

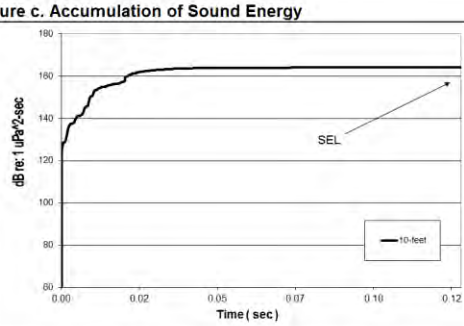

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	193	177	164

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 2 at 3H 200Hz

Figure a. Waveform

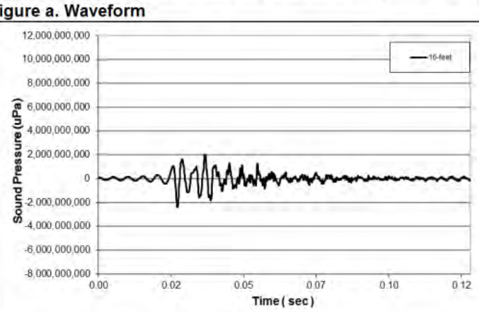

Figure b. Narrow Band Frequency Spectra

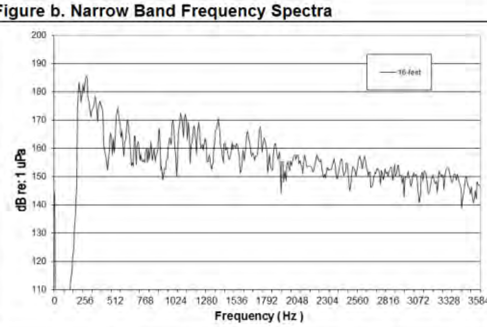

Figure c. Accumulation of Sound Energy

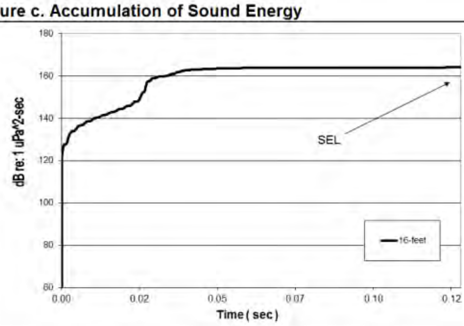

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	188	178	164

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

Figure 39: Waveform analysis of 30-inch Pile 3 10M and 3H Broadband

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 10M Broadband

Figure a. Waveform

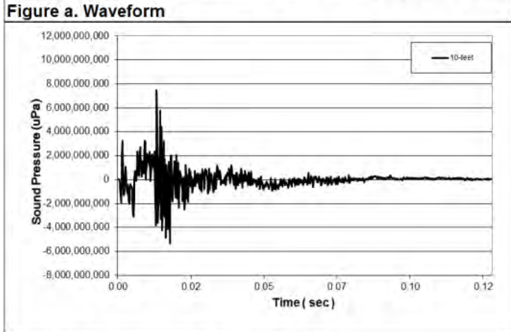

Figure b. Narrow Band Frequency Spectra

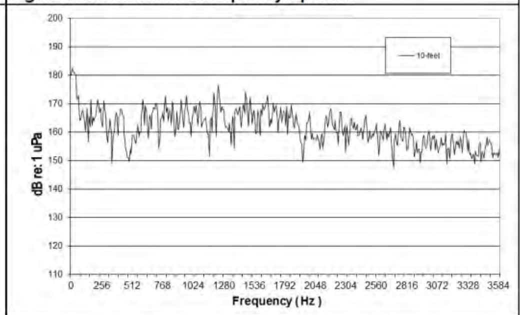

Figure c. Accumulation of Sound Energy

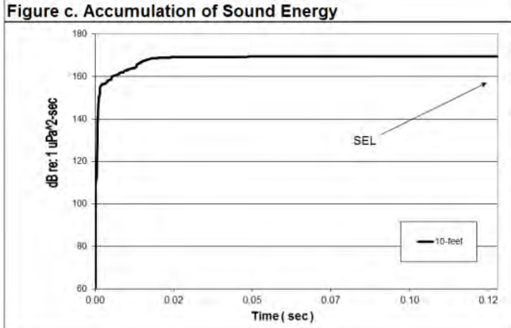

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	197	183	170

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 3H Broadband

Figure a. Waveform

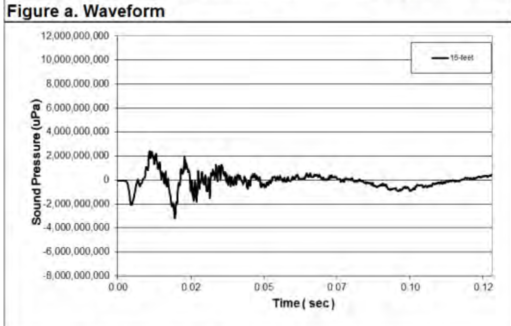

Figure b. Narrow Band Frequency Spectra

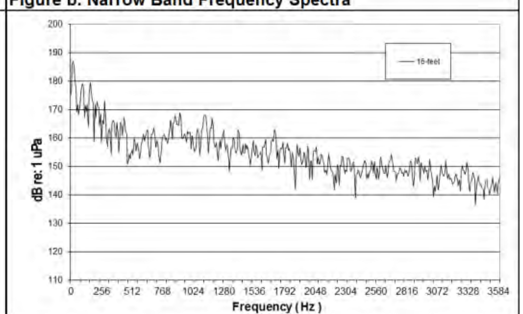

Figure c. Accumulation of Sound Energy

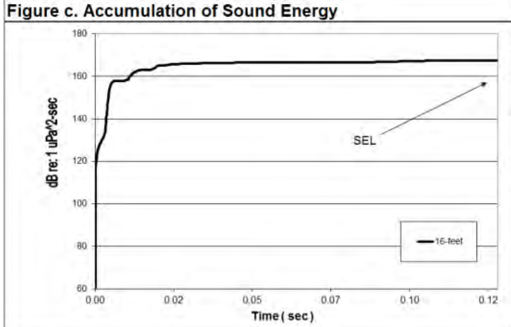

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	190	177	167

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

Figure 40: Waveform analysis of 30-inch Pile 3 10M and 3H 7 Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 10M 7Hz

Figure a. Waveform

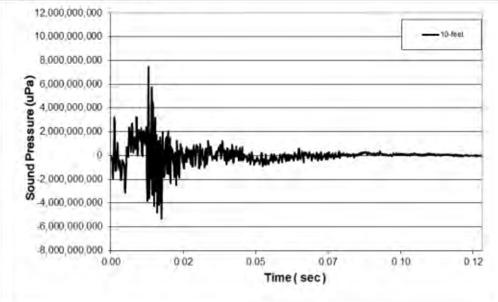

Figure b. Narrow Band Frequency Spectra

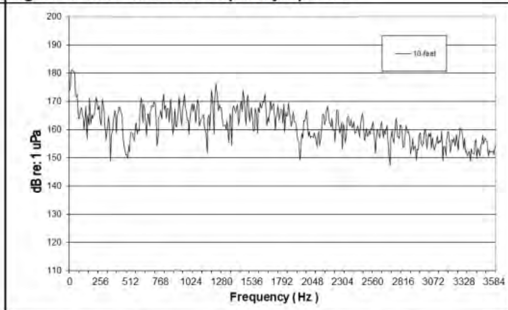

Figure c. Accumulation of Sound Energy

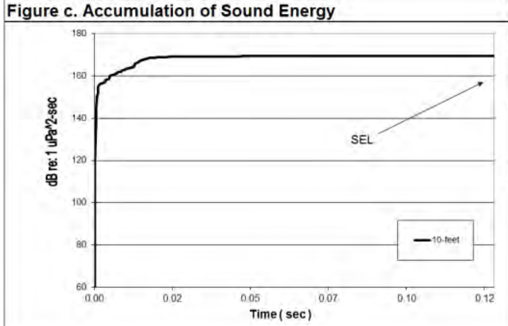

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	$RMS_{90\%}$*	SEL
10-feet	197	184	170

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 3H 7Hz

Figure a. Waveform

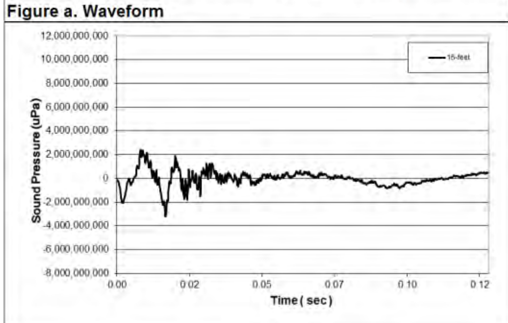

Figure b. Narrow Band Frequency Spectra

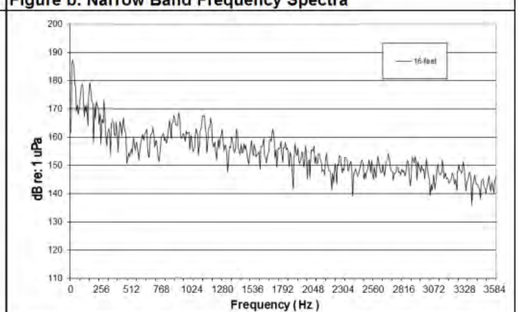

Figure c. Accumulation of Sound Energy

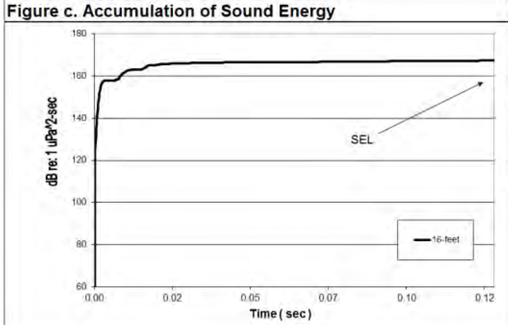

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	$RMS_{90\%}$*	SEL
16-feet	190	177	167

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

Figure 41: Waveform analysis of 30-inch Pile 3 10M and 3H 75 Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 10M 75Hz

Figure a. Waveform

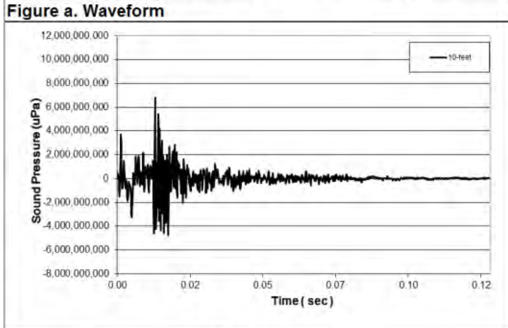

Figure b. Narrow Band Frequency Spectra

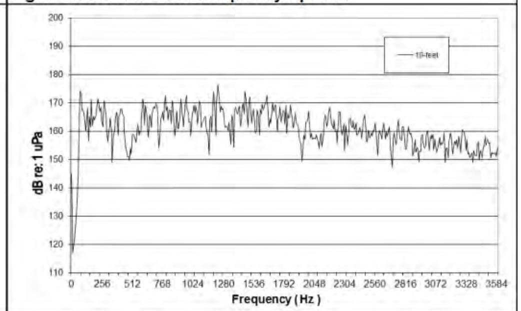

Figure c. Accumulation of Sound Energy

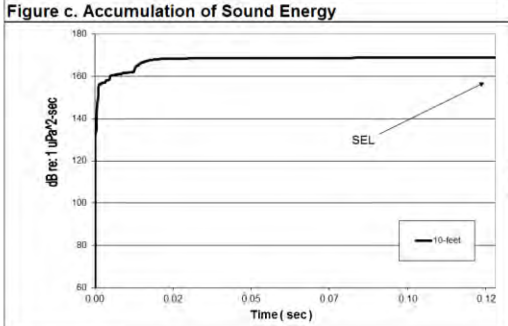

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	197	183	169

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 3H 75Hz

Figure a. Waveform

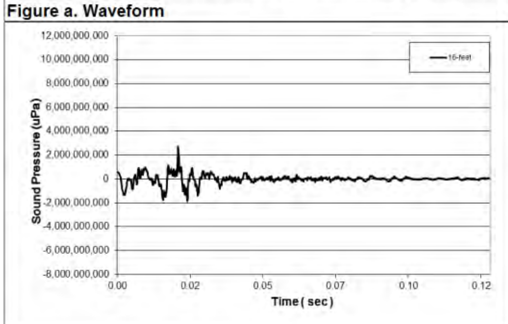

Figure b. Narrow Band Frequency Spectra

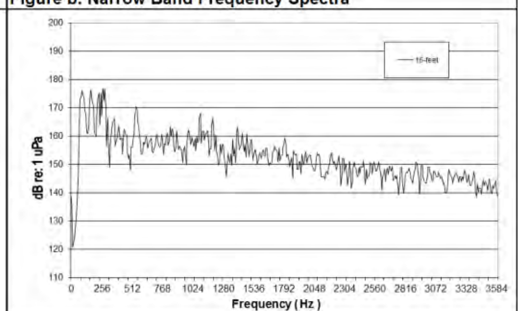

Figure c. Accumulation of Sound Energy

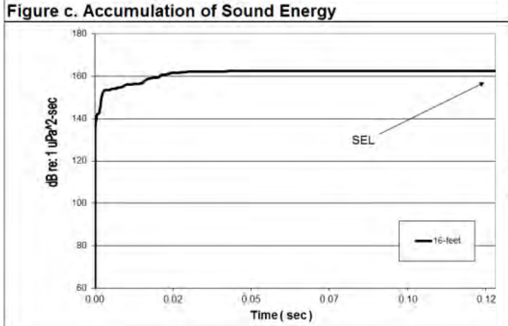

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	189	176	163

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

Figure 42: Waveform analysis of 30-inch Pile 3 10M and 3H 150Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 10M 150Hz

Figure a. Waveform

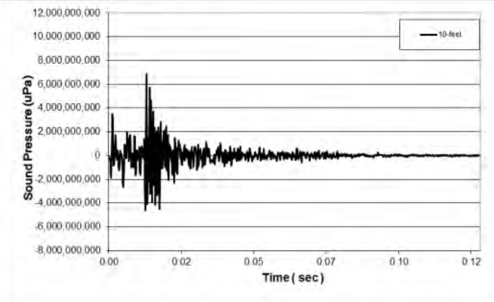

Figure b. Narrow Band Frequency Spectra

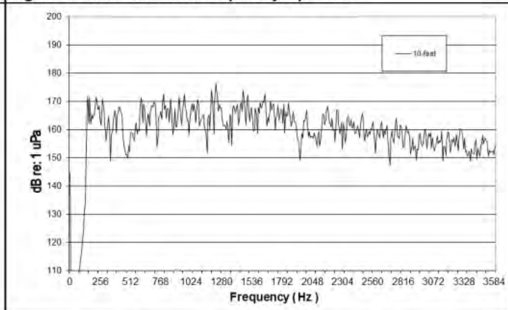

Figure c. Accumulation of Sound Energy

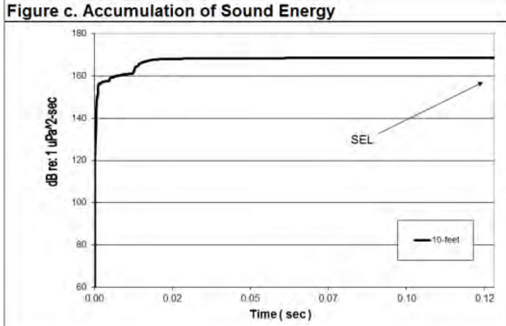

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	197	183	169

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 3H 150Hz

Figure a. Waveform

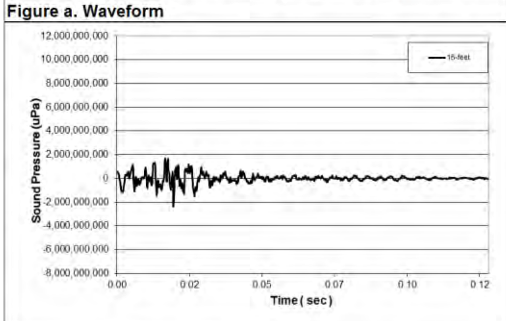

Figure b. Narrow Band Frequency Spectra

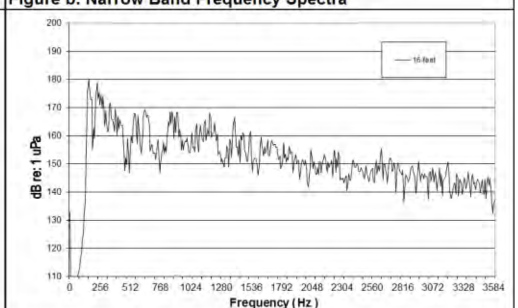

Figure c. Accumulation of Sound Energy

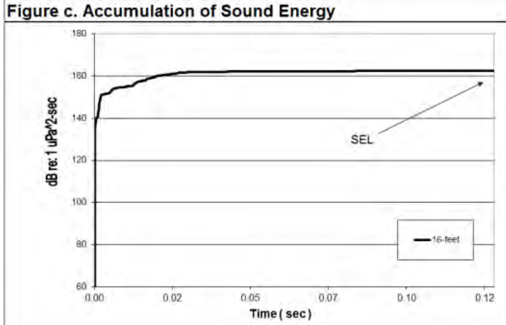

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	188	175	162

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

Figure 43: Waveform analysis of 30-inch Pile 3 10M and 3H 200 Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 10M 200Hz

Figure a. Waveform

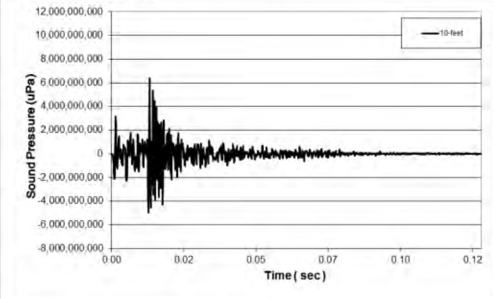

Figure b. Narrow Band Frequency Spectra

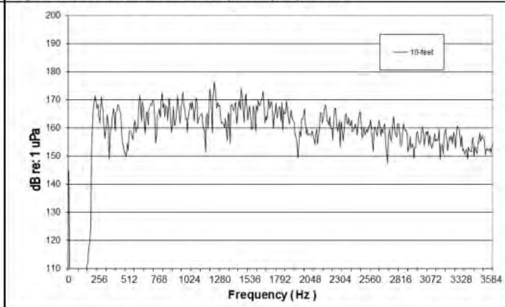

Figure c. Accumulation of Sound Energy

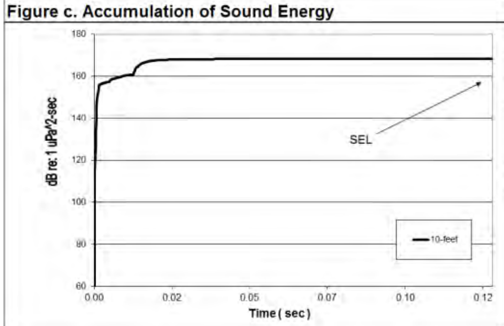

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	196	183	168

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 3 at 3H 200Hz

Figure a. Waveform

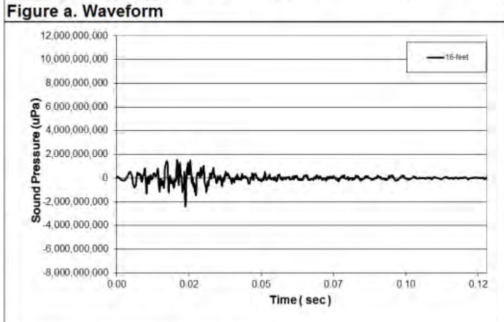

Figure b. Narrow Band Frequency Spectra

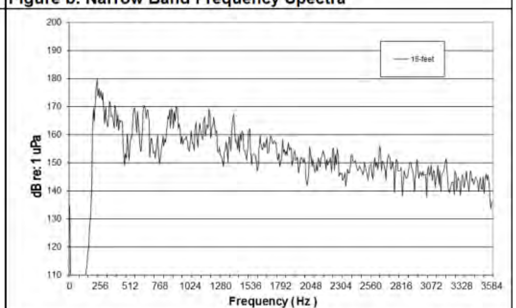

Figure c. Accumulation of Sound Energy

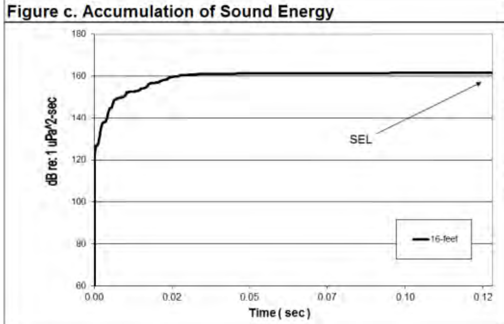

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	187	175	162

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

Figure 44: Waveform analysis of 30-inch Pile 4 10M and 3H Broadband

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 10M Broadband

Figure a. Waveform

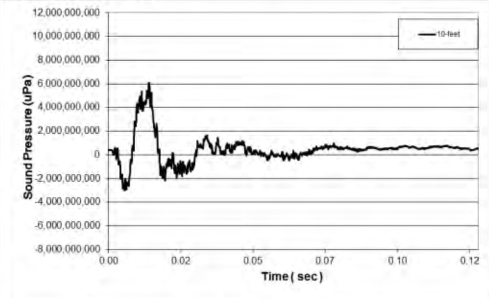

Figure b. Narrow Band Frequency Spectra

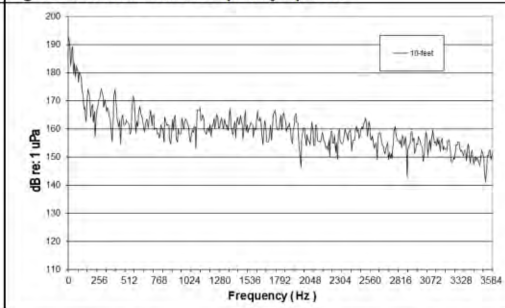

Figure c. Accumulation of Sound Energy

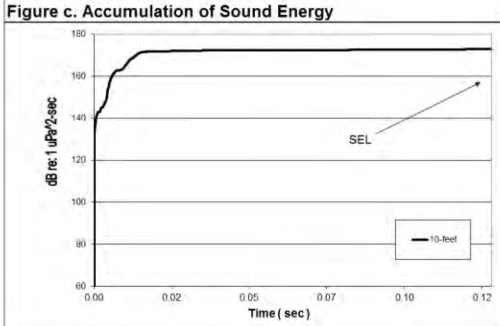

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	196	183	173

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 3H Broadband

Figure a. Waveform

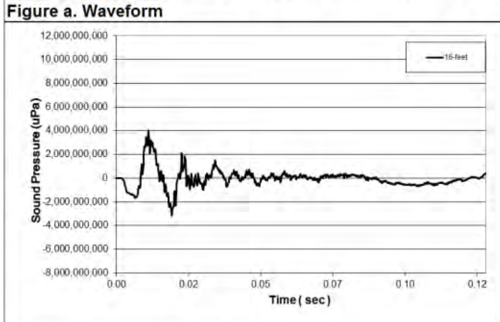

Figure b. Narrow Band Frequency Spectra

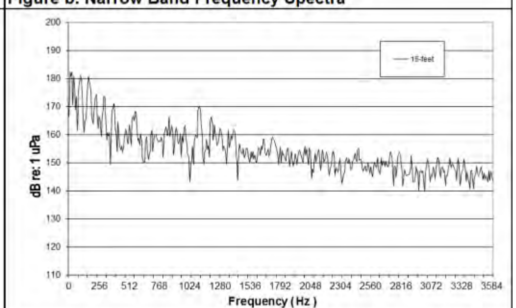

Figure c. Accumulation of Sound Energy

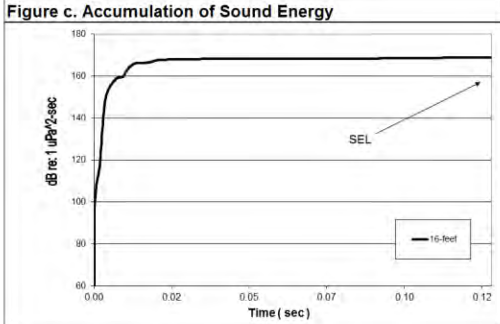

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	192	179	169

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

Figure 45: Waveform analysis of 30-inch Pile 4 10M and 3H 7Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 10M 7Hz

Figure a. Waveform

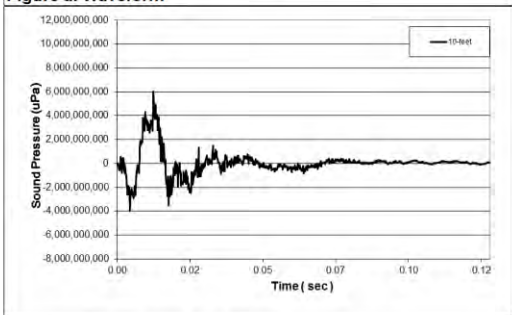

Figure b. Narrow Band Frequency Spectra

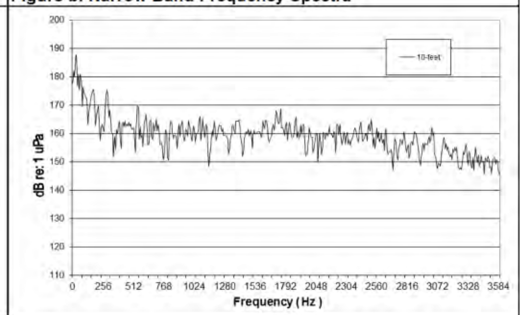

Figure c. Accumulation of Sound Energy

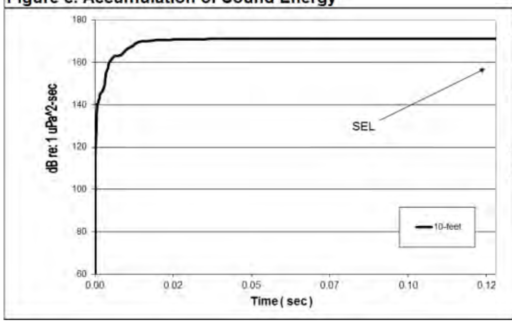

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	196	187	171

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 3H 7Hz

Figure a. Waveform

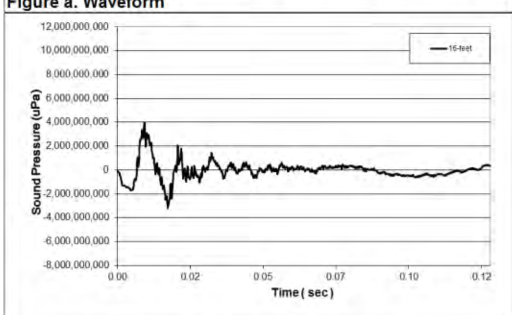

Figure b. Narrow Band Frequency Spectra

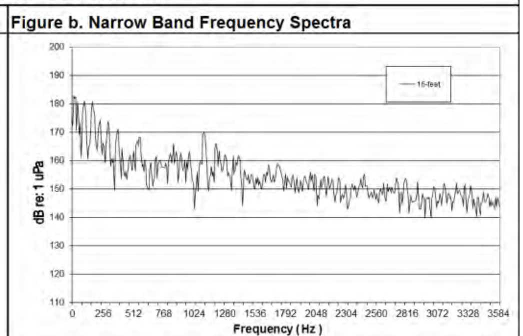

Figure c. Accumulation of Sound Energy

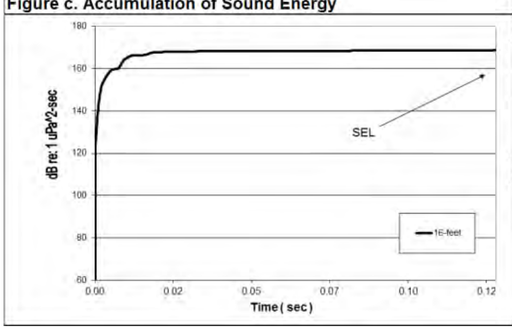

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	192	179	169

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

Figure 46: Waveform analysis of 30-inch Pile 4 10M and 3H 75Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 10M 75Hz

Figure a. Waveform

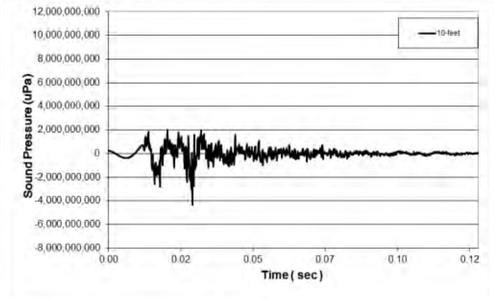

Figure b. Narrow Band Frequency Spectra

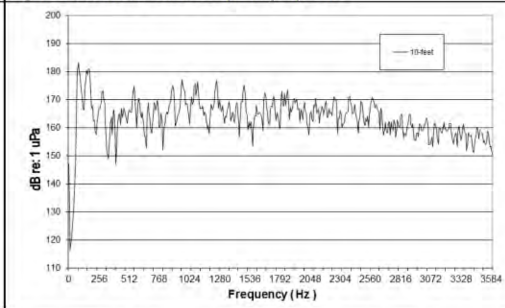

Figure c. Accumulation of Sound Energy

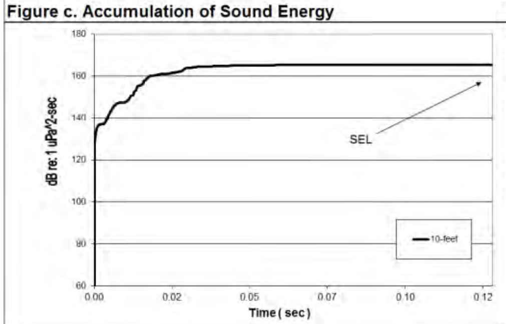

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	193	179	166

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 3H 75Hz

Figure a. Waveform

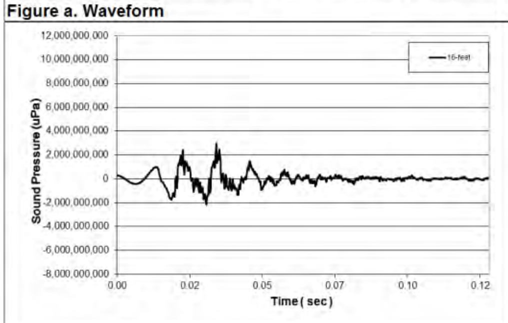

Figure b. Narrow Band Frequency Spectra

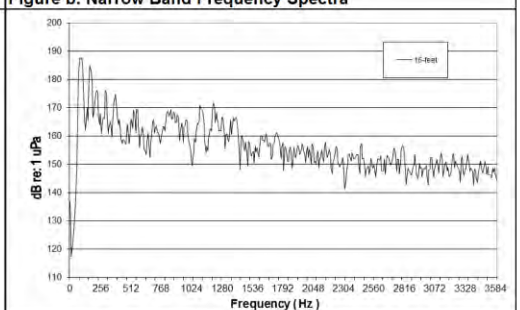

Figure c. Accumulation of Sound Energy

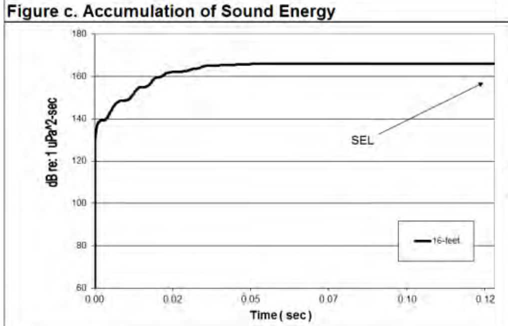

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	190	180	166

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

Figure 47: Waveform analysis of 30-inch Pile 4 10M and 3H 150Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 10M 150Hz

Figure a. Waveform

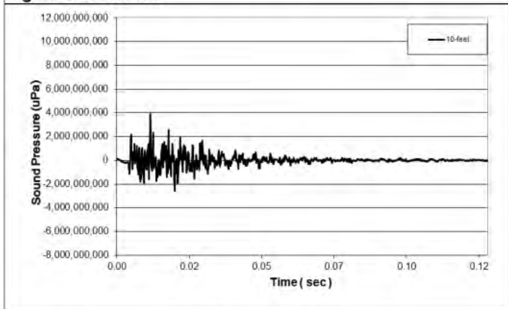

Figure b. Narrow Band Frequency Spectra

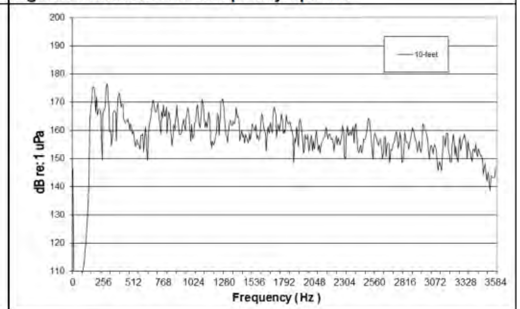

Figure c. Accumulation of Sound Energy

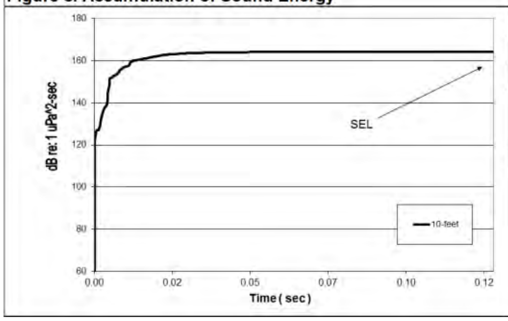

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	192	178	164

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 3H 150Hz

Figure a. Waveform

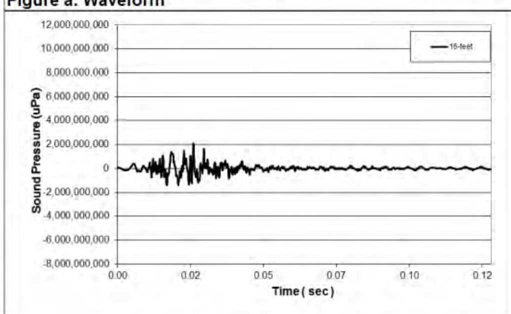

Figure b. Narrow Band Frequency Spectra

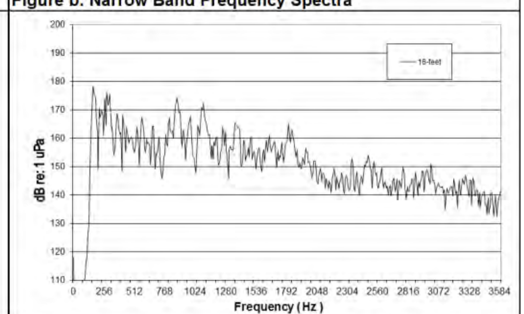

Figure c. Accumulation of Sound Energy

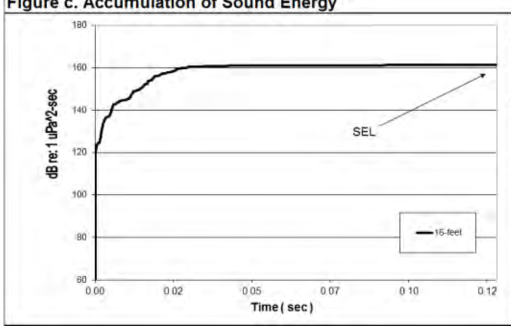

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	186	175	161

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

Figure 48: Waveform analysis of 30-inch Pile 4 10M and 3H 200Hz

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 10M 200Hz

Figure a. Waveform

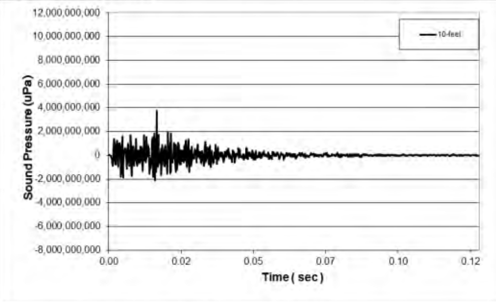

Figure b. Narrow Band Frequency Spectra

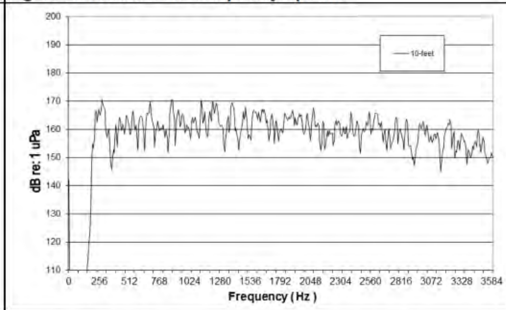

Figure c. Accumulation of Sound Energy

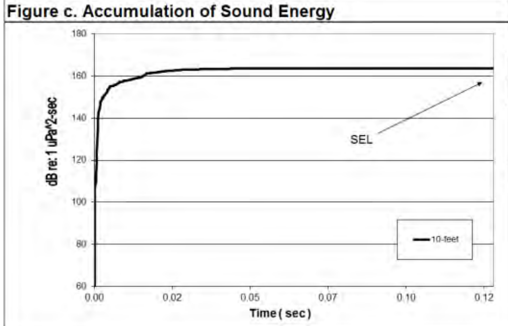

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
10-feet	192	178	164

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

SR 20 Port Townsend Ferry Transfer Span 30 in. Pile 4 at 3H 200Hz

Figure a. Waveform

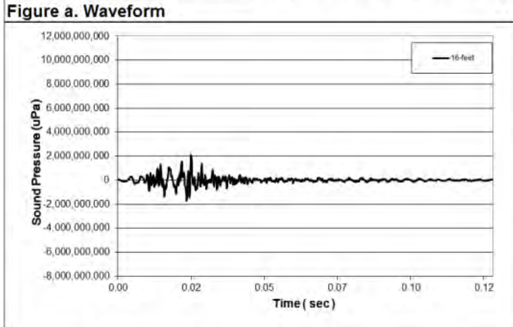

Figure b. Narrow Band Frequency Spectra

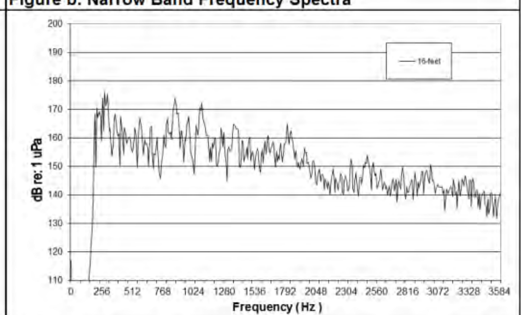

Figure c. Accumulation of Sound Energy

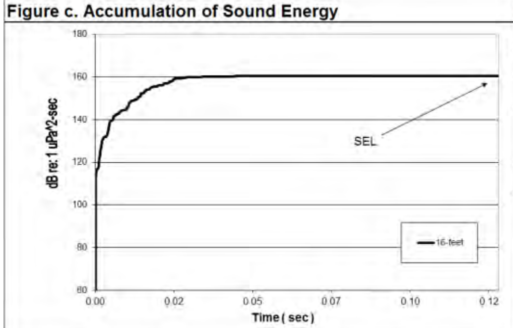

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

Sensor Depth	Peak	RMS90%*	SEL
16-feet	186	175	161

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

Figure 49: Waveform analysis of 24-inch Pile 1 400M Broadband

Port Townsend Pile 1-24 inch Broadband

Figure a. Waveform

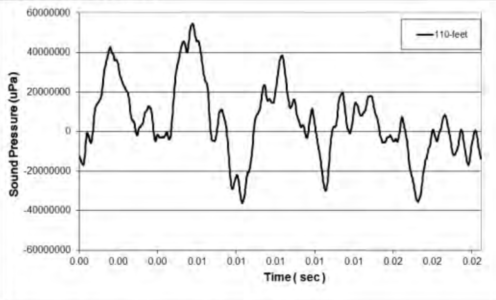

Figure b. Narrow Band Frequency Spectra

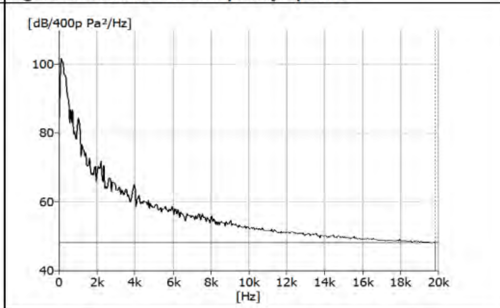

Figure c. Accumulation of Sound Energy

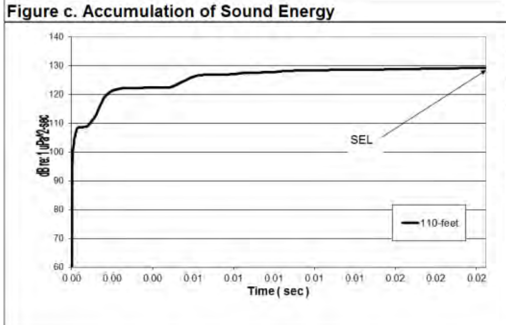

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	155	147	129

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

Figure 50: Waveform analysis of 24-inch Pile 1 400M 7Hz

Port Townsend Pile 1 24 inch 7hz

Figure a. Waveform

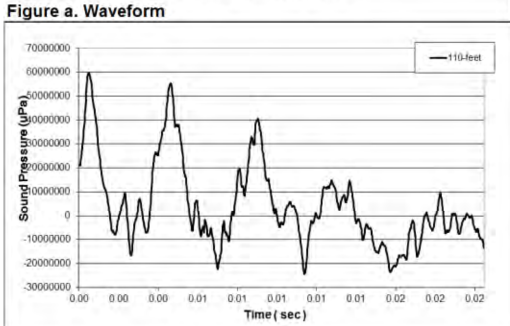

Figure b. Narrow Band Frequency Spectra

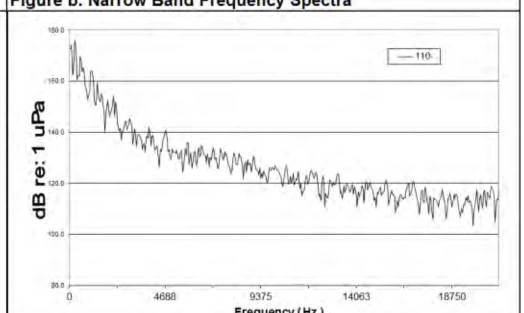

Figure c. Accumulation of Sound Energy

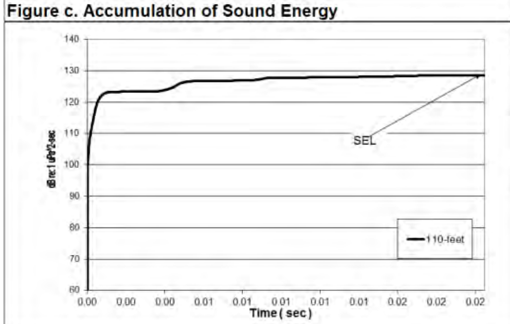

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	156	146	128

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

Figure 51: Waveform analysis of 24-inch Pile 1 400M 75Hz

Port Townsand Pile 1- 24 inch 75hz

Figure a. Waveform

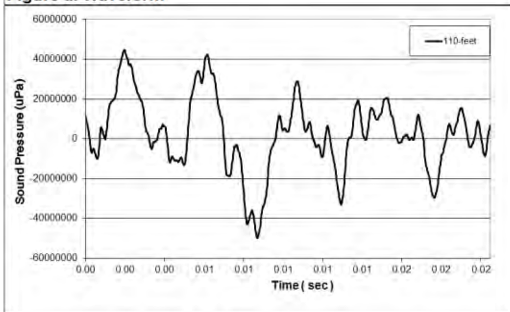

Figure b. Narrow Band Frequency Spectra

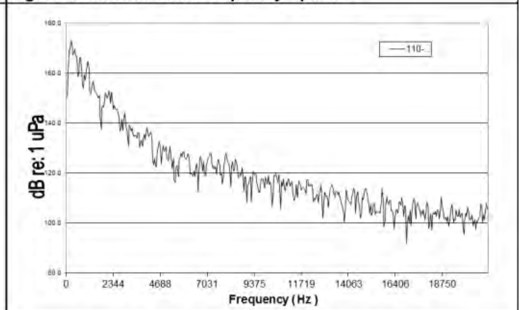

Figure c. Accumulation of Sound Energy

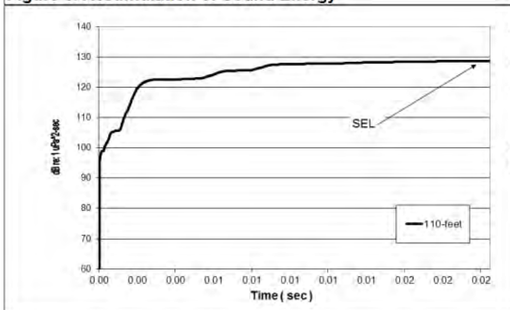

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	154	146	129

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

Figure 52: Waveform analysis of 24-inch Pile 1 400M 150Hz

Port Townsand Pile 1- 24 inch 150hz

Figure a. Waveform

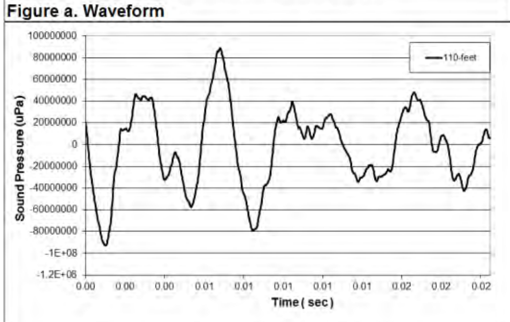

Figure b. Narrow Band Frequency Spectra

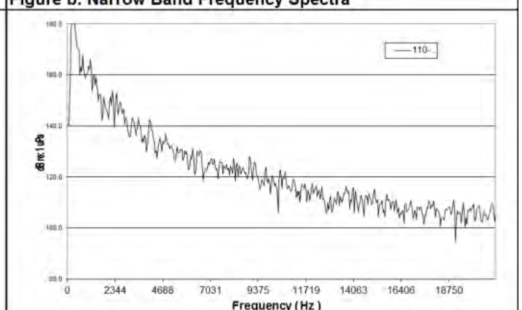

Figure c. Accumulation of Sound Energy

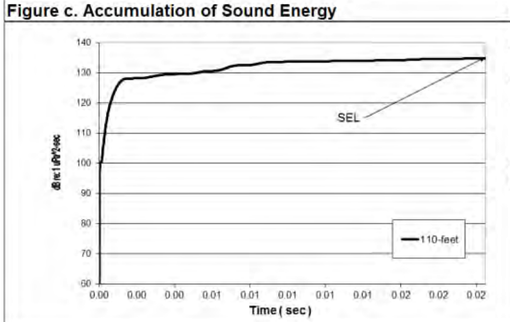

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	159	152	135

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

Figure 53: Waveform analysis of 24-inch Pile 1 400M 200Hz

Port Townsand Pile 1-24 inch 200hz

Figure a. Waveform

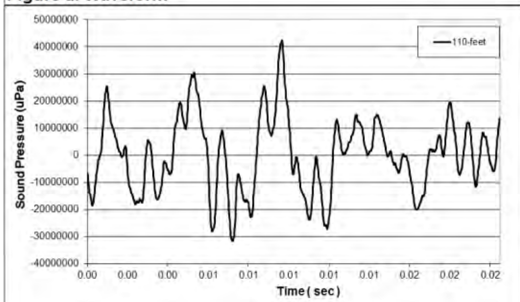

Figure b. Narrow Band Frequency Spectra

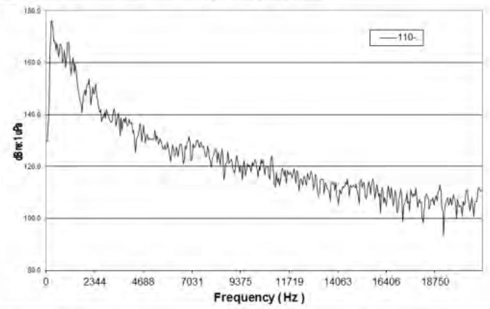

Figure c. Accumulation of Sound Energy

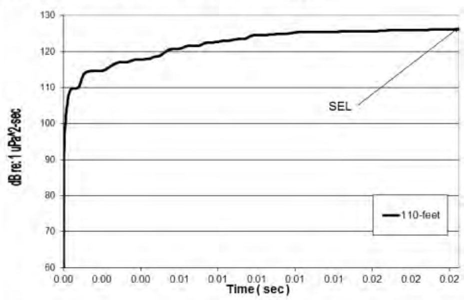

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	153	143	126

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

Figure 54: Waveform analysis of 24-inch Pile 2 400M Broadband

Port Townsand Pile 2 24inch Broadband

Figure a. Waveform

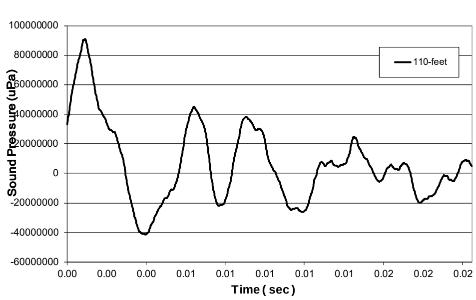

Figure b. Narrow Band Frequency Spectra

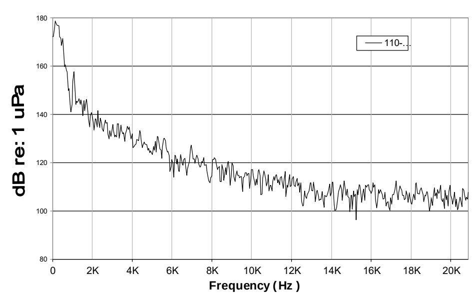

Figure c. Accumulation of Sound Energy

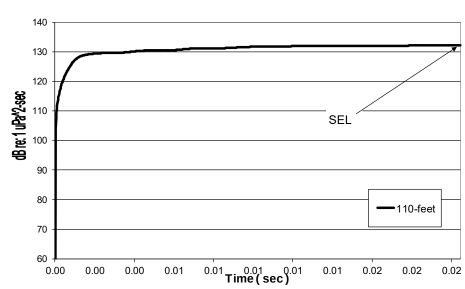

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	159	151	132

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

Figure 55: Waveform analysis of 24-inch Pile 2 400M 7Hz

Port Townsand Pile 2 24inch 7 Hz

Figure a. Waveform

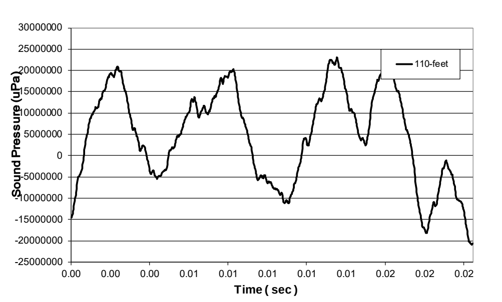

Figure b. Narrow Band Frequency Spectra

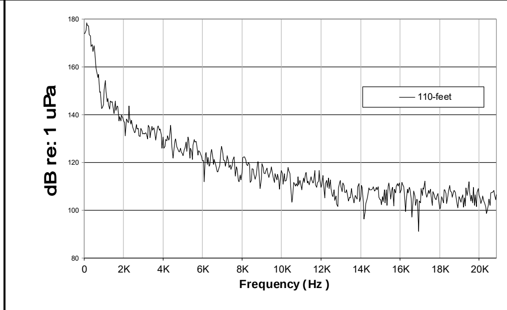

Figure c. Accumulation of Sound Energy

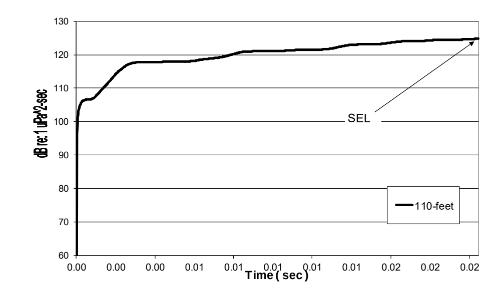

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	147	142	125

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

Figure 56: Waveform analysis of 24-inch Pile 2 400M 75Hz

Port Townsand Pile 2 24inch 75 Hz

Figure a. Waveform

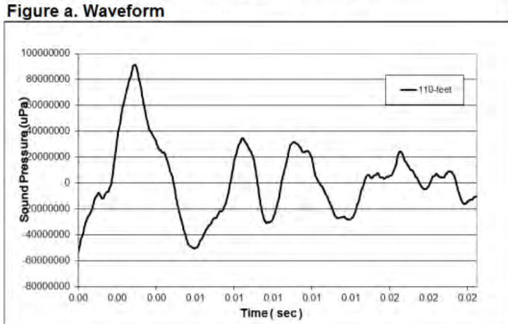

Figure b. Narrow Band Frequency Spectra

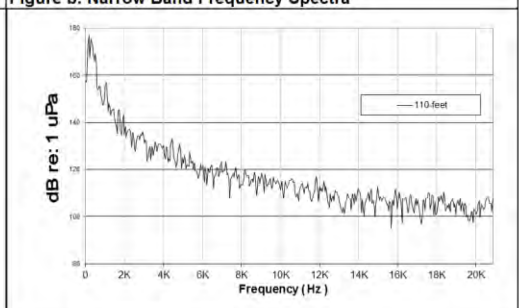

Figure c. Accumulation of Sound Energy

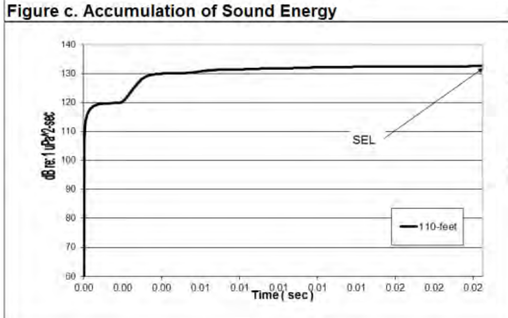

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	159	151	133

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

Figure 57: Waveform analysis of 24-inch Pile 2 400M 150Hz

Port Townsand Pile 2 24inch 150 Hz

Figure a. Waveform

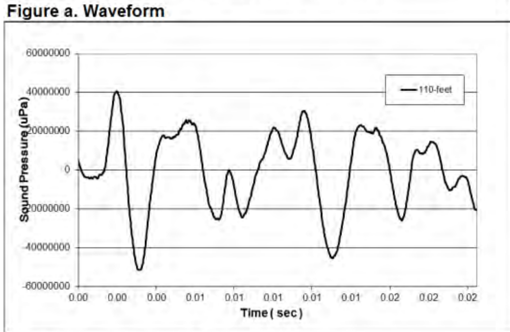

Figure b. Narrow Band Frequency Spectra

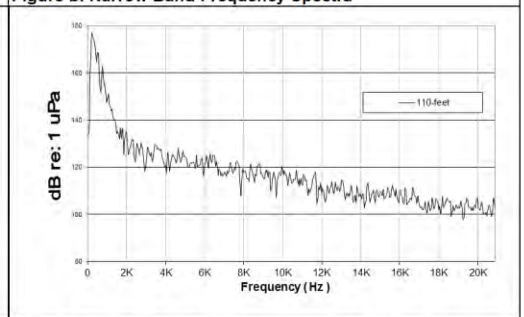

Figure c. Accumulation of Sound Energy

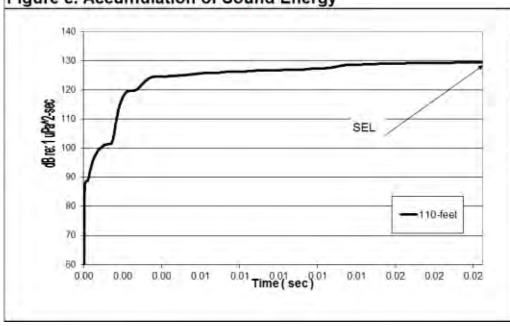

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	154	147	129

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

Figure 58: Waveform analysis of 24-inch Pile 2 400M 200Hz

Port Townsand Pile 2 24inch 200Hz

Figure a. Waveform

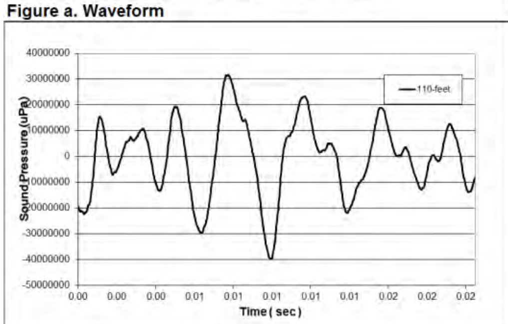

Figure b. Narrow Band Frequency Spectra

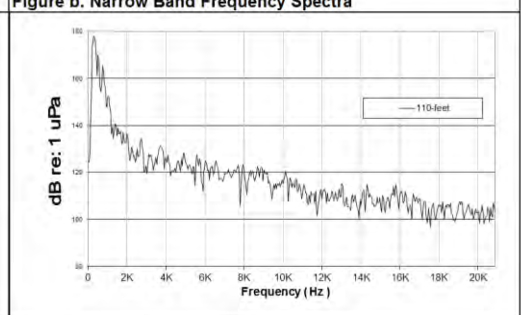

Figure c. Accumulation of Sound Energy

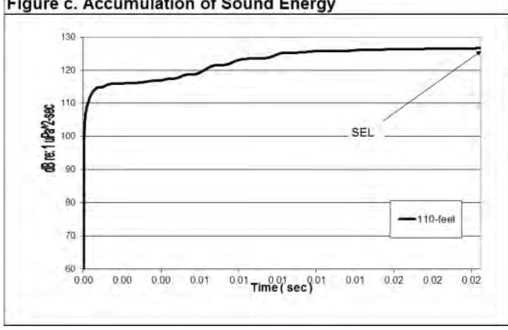

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	152	144	127

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

Figure 59: Waveform analysis of 24-inch Pile 3 400M Broadband

Port Townsand Pile 3 24-inch Broadband

Figure a. Waveform

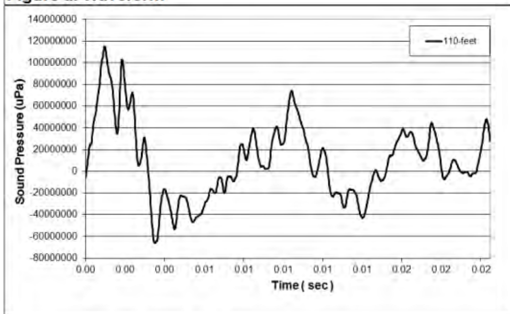

Figure b. Narrow Band Frequency Spectra

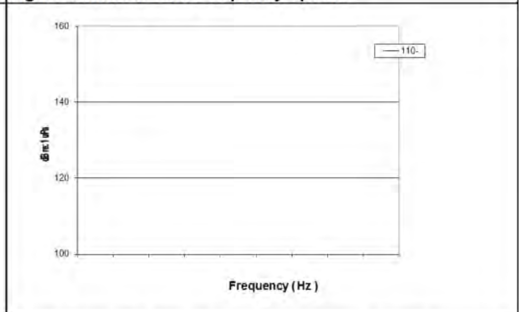

Figure c. Accumulation of Sound Energy

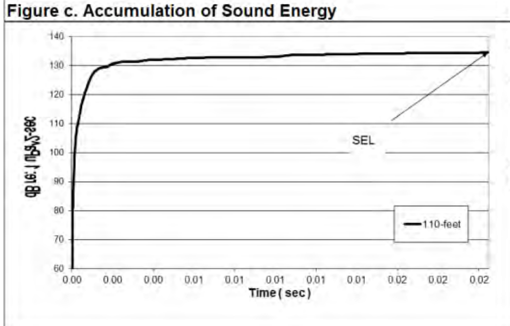

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	161	152	135

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

Figure 60: Waveform analysis of 24-inch Pile 3 400M 7Hz

Port Townsand Pile 3 24inch 7 Hz

Figure a. Waveform

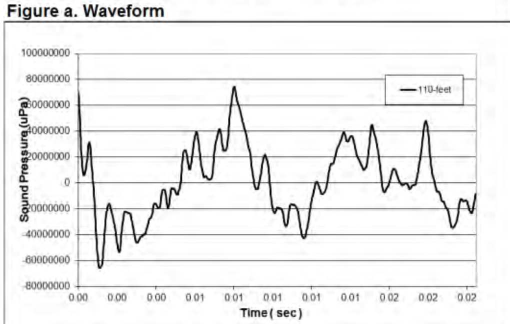

Figure b. Narrow Band Frequency Spectra

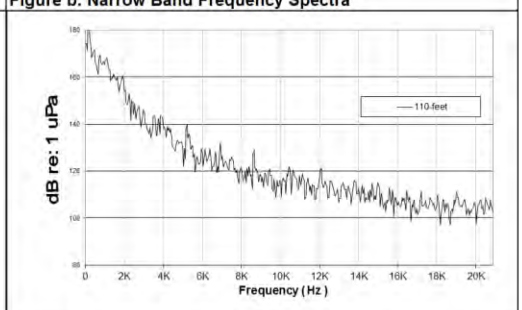

Figure c. Accumulation of Sound Energy

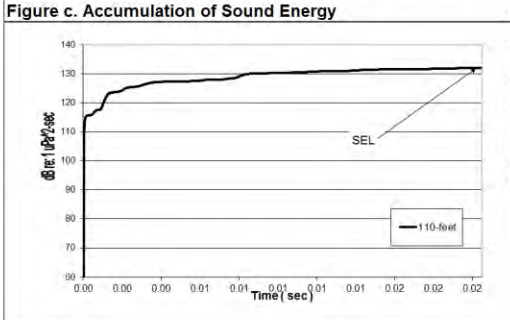

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	157	149	132

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

Figure 61: Waveform analysis of 24-inch Pile 3 400M 75Hz

Port Townsand Pile 3 24inch 75 Hz

Figure a. Waveform

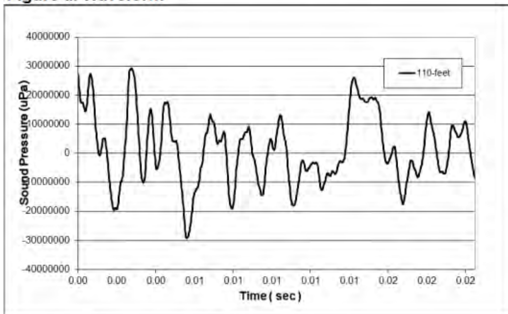

Figure b. Narrow Band Frequency Spectra

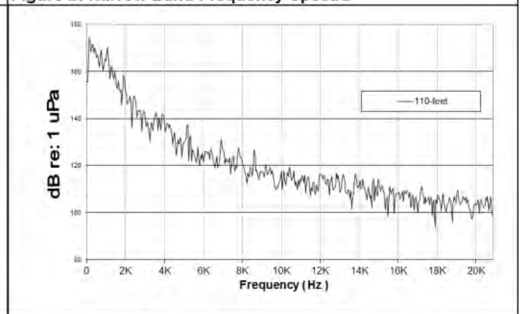

Figure c. Accumulation of Sound Energy

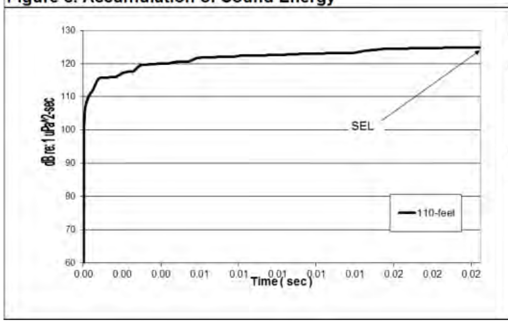

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	149	142	125

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

Figure 62: Waveform analysis of 24-inch Pile 3 400M 150Hz

Port Townsand Pile 3 24inch 150Hz

Figure a. Waveform

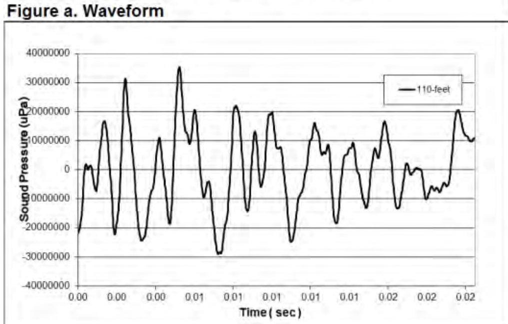

Figure b. Narrow Band Frequency Spectra

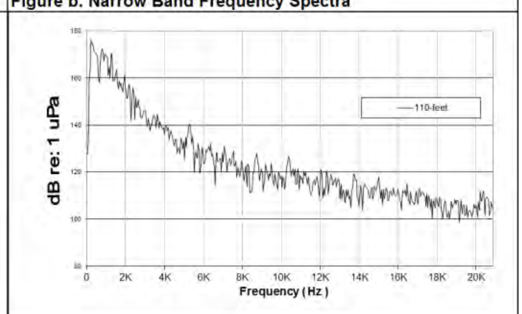

Figure c. Accumulation of Sound Energy

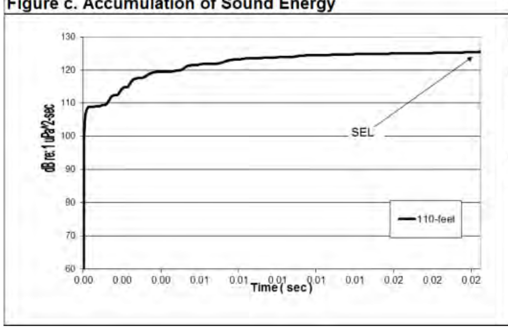

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	151	142	126

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

Figure 63: Waveform analysis of 24-inch Pile 3 400M 200Hz

Port Townsand Pile 3 24inch 200 hz

Figure a. Waveform

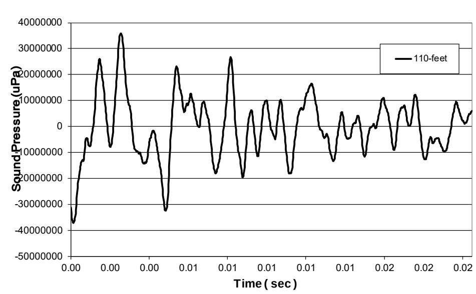

Figure b. Narrow Band Frequency Spectra

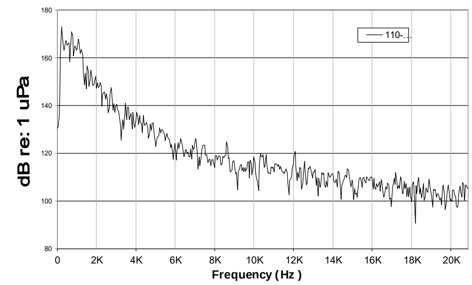

Figure c. Accumulation of Sound Energy

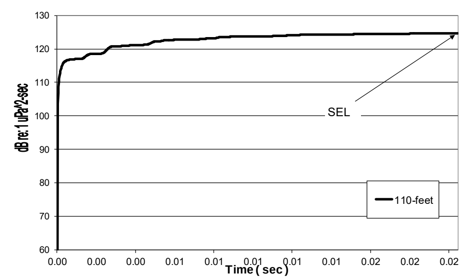

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	151	142	125

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

Figure 64: Waveform analysis of 30-inch Pile 2 400M Broadband

Port Townsand Pile 2 30 inch Broadband

Figure a. Waveform

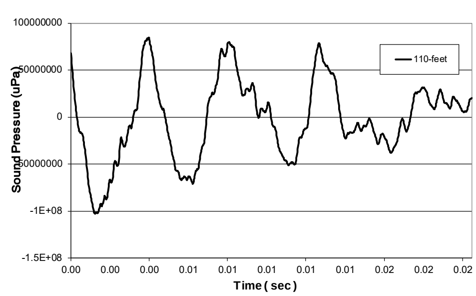

Figure b. Narrow Band Frequency Spectra

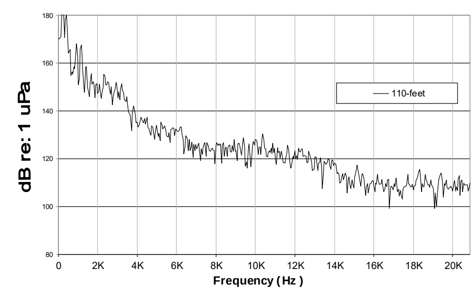

Figure c. Accumulation of Sound Energy

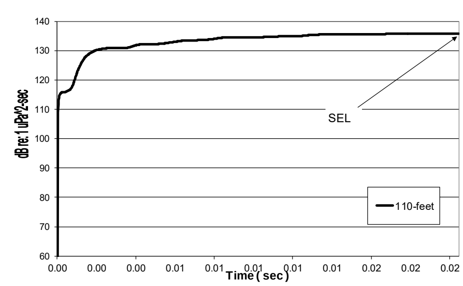

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	160	153	136

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

Figure 65: Waveform analysis of 30-inch Pile 2 400M 7Hz

Port Townsand Pile 2 30 inch 7 hz

Figure a. Waveform

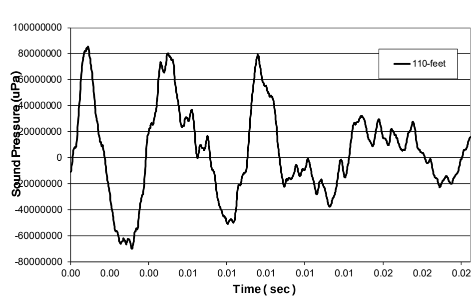

Figure b. Narrow Band Frequency Spectra

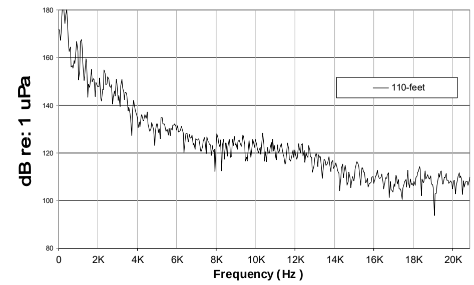

Figure c. Accumulation of Sound Energy

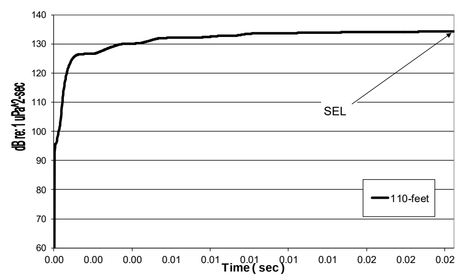

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	$RMS_{90\%}$*	SEL
110-feet	159	152	134

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

Figure 66: Waveform analysis of 30-inch Pile 2 400M 75Hz

Port Townsand Pile 2 30 inch 75 hz

Figure a. Waveform

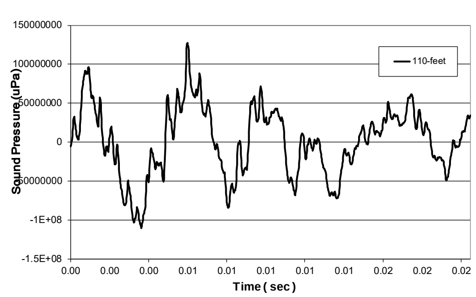

Figure b. Narrow Band Frequency Spectra

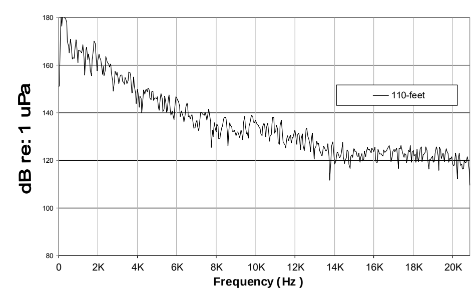

Figure c. Accumulation of Sound Energy

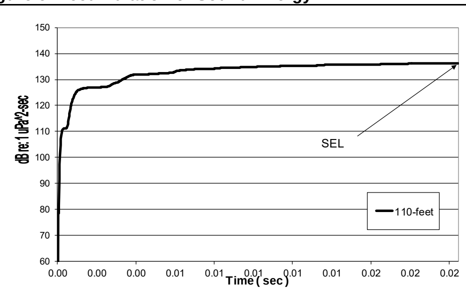

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	$RMS_{90\%}$*	SEL
110-feet	162	153	136

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

Figure 67: Waveform analysis of 30-inch Pile 2 400M 150Hz

Port Townsand Pile 2 30 inch 150hz

Figure a. Waveform

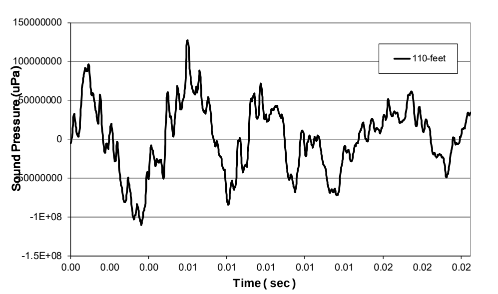

Figure b. Narrow Band Frequency Spectra

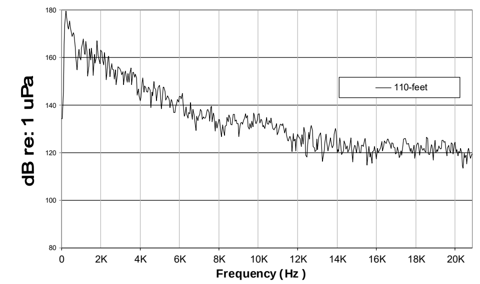

Figure c. Accumulation of Sound Energy

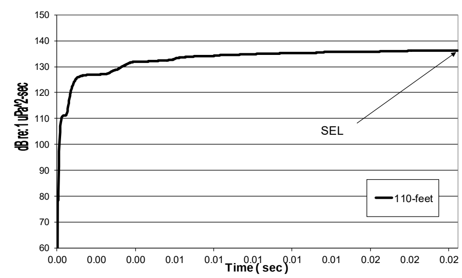

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	162	153	136

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

Figure 68: Waveform analysis of 30-inch Pile 2 400M 200Hz

Port Townsand Pile 2 30 inch 200hz

Figure a. Waveform

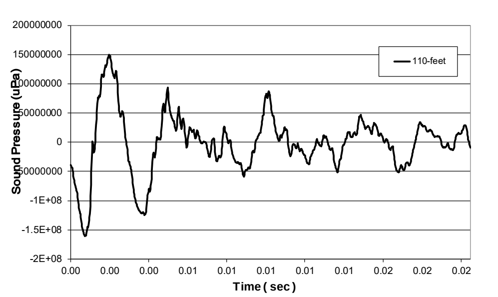

Figure b. Narrow Band Frequency Spectra

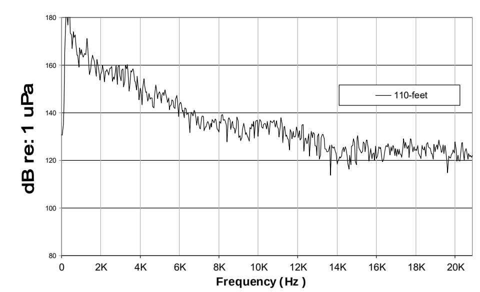

Figure c. Accumulation of Sound Energy

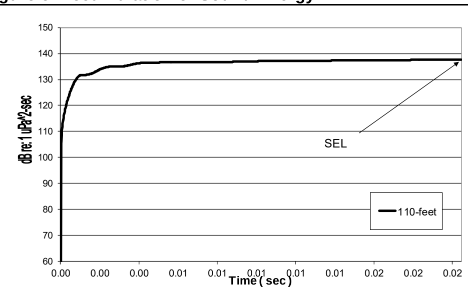

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	164	155	138

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

Figure 69: Waveform analysis of 30-inch Pile 3 400M Broadband

Port Townsand Pile 3 30 inch Broadband

Figure a. Waveform

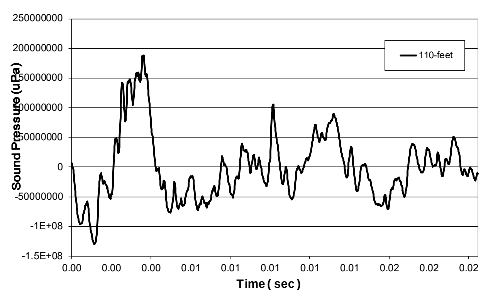

Figure b. Narrow Band Frequency Spectra

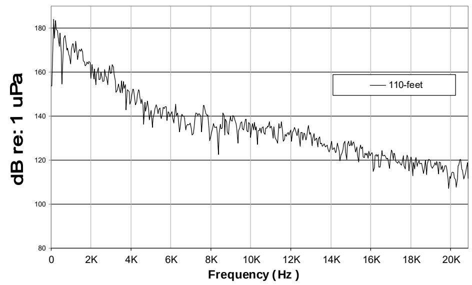

Figure c. Accumulation of Sound Energy

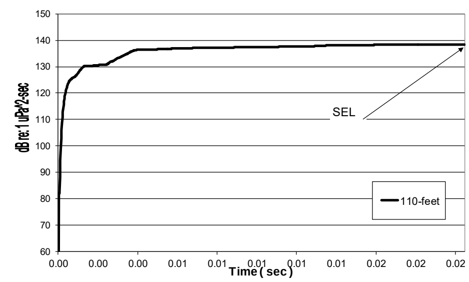

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	165	156	138

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

Figure 70: Waveform analysis of 30-inch Pile 3 400M 7Hz

Port Townsand Pile 3 30 inch 7 hz

Figure a. Waveform

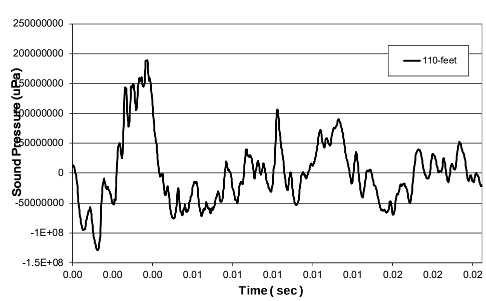

Figure b. Narrow Band Frequency Spectra

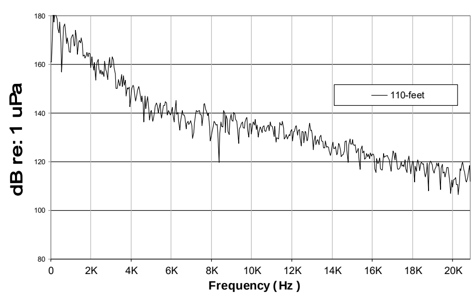

Figure c. Accumulation of Sound Energy

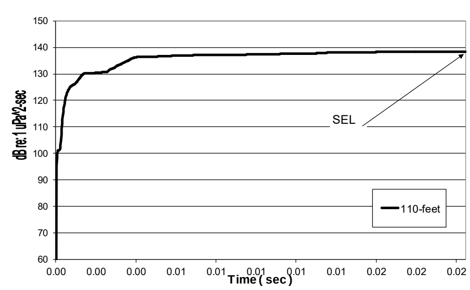

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	166	156	138

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

Figure 71: Waveform analysis of 30-inch Pile 3 400M 75Hz

Port Townsand Pile3 30 inch 75 hz

Figure a. Waveform

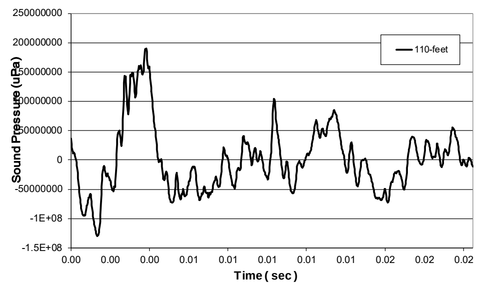

Figure b. Narrow Band Frequency Spectra

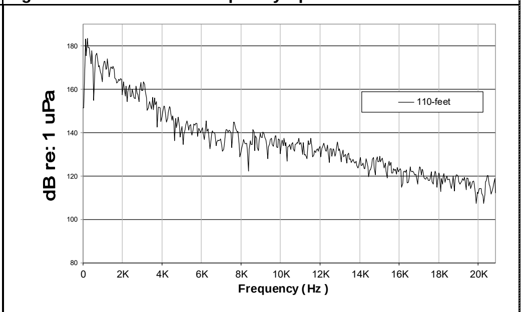

Figure c. Accumulation of Sound Energy

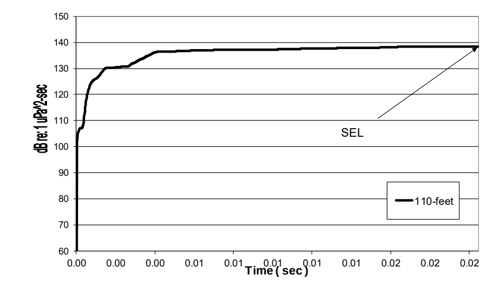

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	166	156	138

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

Figure 72: Waveform analysis of 30-inch Pile 3 400M 150Hz

Port Townsand Pile 3 30 inch 150hz

Figure a. Waveform

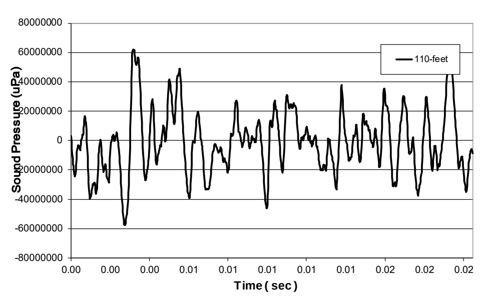

Figure b. Narrow Band Frequency Spectra

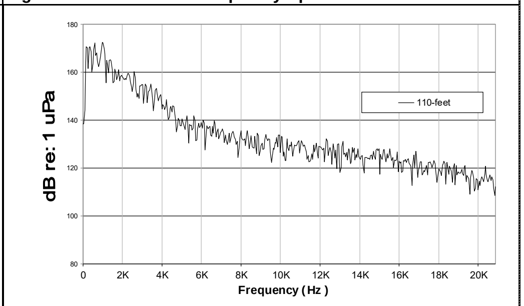

Figure c. Accumulation of Sound Energy

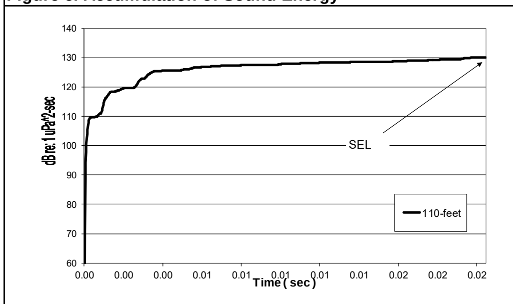

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	156	147	130

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

Figure 73: Waveform analysis of 30-inch Pile 3 400M 200Hz

Port Townsand Pile3 30 inch 200hz

Figure a. Waveform

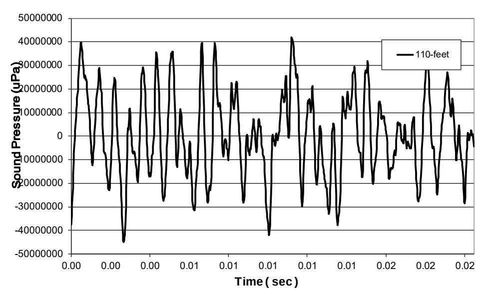

Figure b. Narrow Band Frequency Spectra

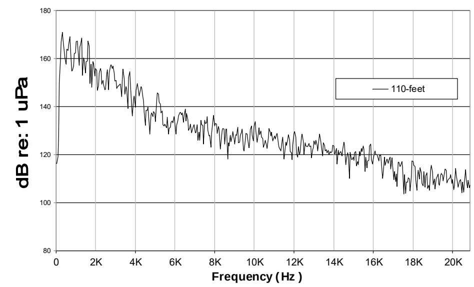

Figure c. Accumulation of Sound Energy

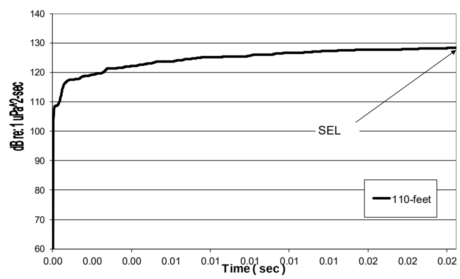

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	$RMS_{90\%}$*	SEL
110-feet	153	145	128

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

Figure 74: Waveform analysis of 30-inch Pile 4 400M Broadband

Port Townsand Pile 4 30 inch Broadband

Figure a. Waveform

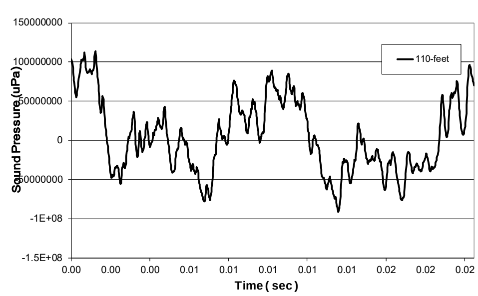

Figure b. Narrow Band Frequency Spectra

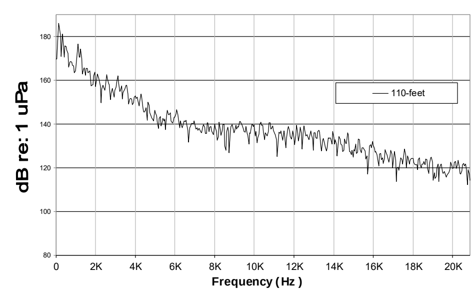

Figure c. Accumulation of Sound Energy

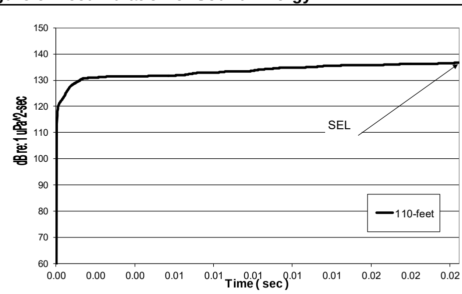

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	$RMS_{90\%}$*	SEL
110-feet	161	153	137

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

Figure 75: Waveform analysis of 30-inch Pile 4 400M 7Hz

Port Townsand Pile 4 30 inch 7 hz

Figure a. Waveform

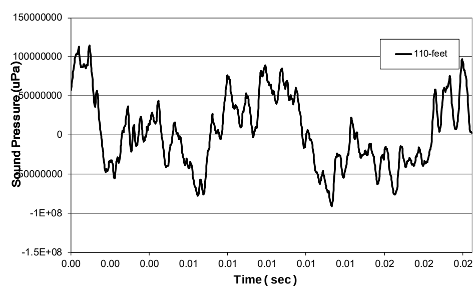

Figure b. Narrow Band Frequency Spectra

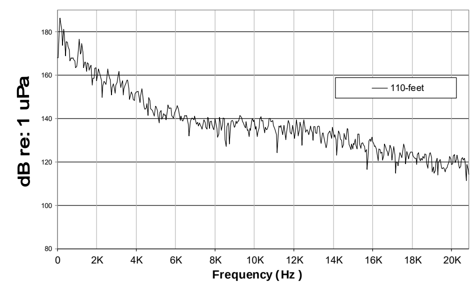

Figure c. Accumulation of Sound Energy

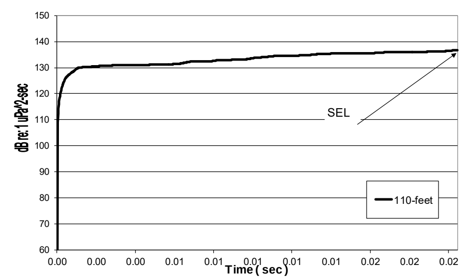

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	161	153	137

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

Figure 76: Waveform analysis of 30-inch Pile 4 400M 75Hz

Port Townsand Pile 4 30 inch 75 hz

Figure a. Waveform

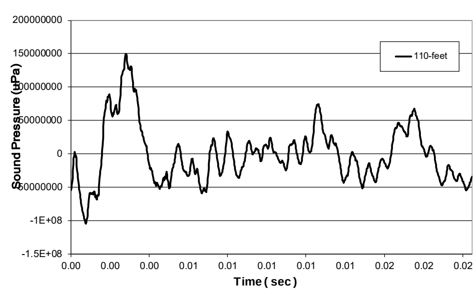

Figure b. Narrow Band Frequency Spectra

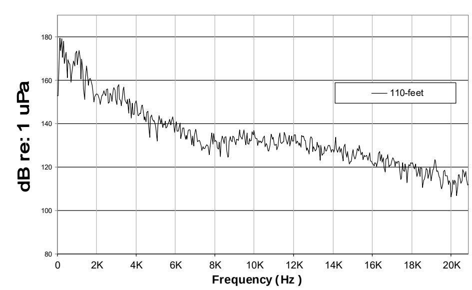

Figure c. Accumulation of Sound Energy

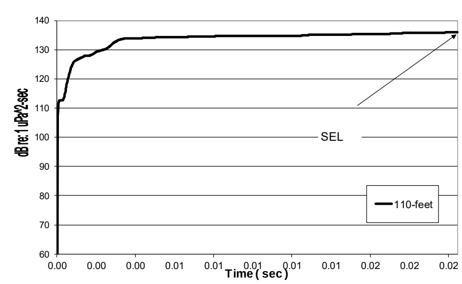

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	164	153	136

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

Figure 77: Waveform analysis of 30-inch Pile 4 400M 150Hz

Port Townsend Pile 4 30 inch 150hz

Figure a. Waveform

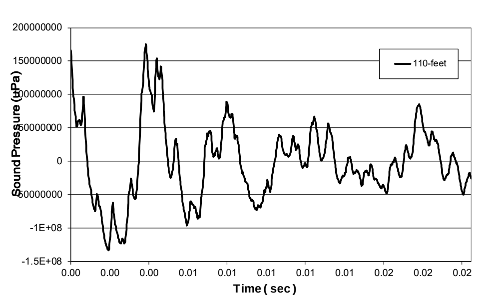

Figure b. Narrow Band Frequency Spectra

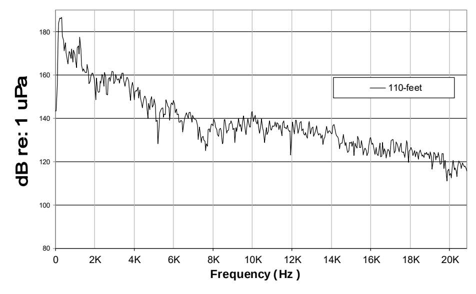

Figure c. Accumulation of Sound Energy

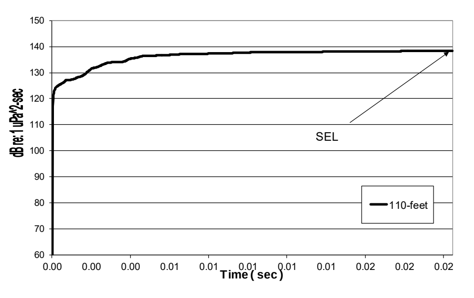

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	165	155	138

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

Figure 78: Waveform analysis of 30-inch Pile 4 400M 200Hz

Port Townsend Pile 4 30 inch 200hz

Figure a. Waveform

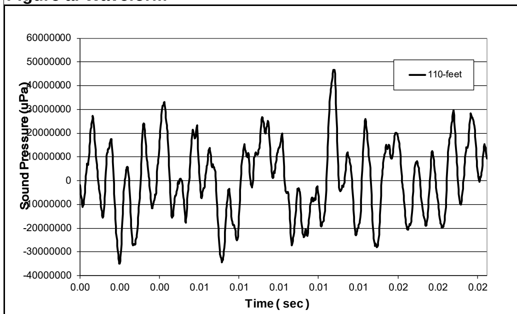

Figure b. Narrow Band Frequency Spectra

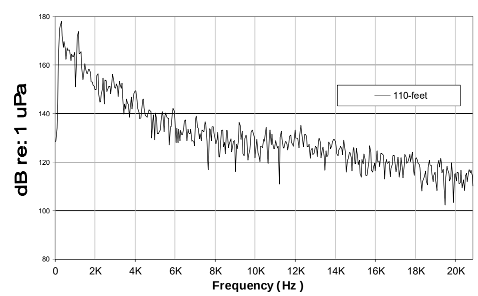

Figure c. Accumulation of Sound Energy

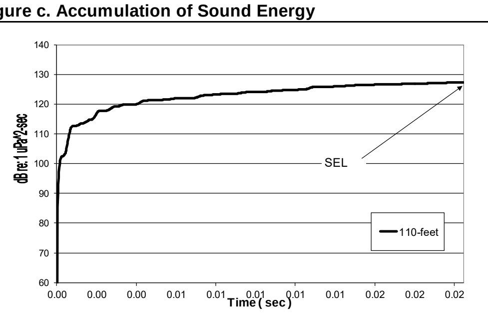

Figure d. Sound Pressure and Sound Energy Levels

Signal Analysis Sound Pressure / Energy Levels

400 meters from pile	Peak	RMS90%*	SEL
110-feet	153	144	127

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