2019 Annual Report

Pile Driving Noise Measurements for Chevron Long Wharf Maintenance and Efficiency Project

Submitted to:

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1. Introduction

This report presents the results of hydroacoustic monitoring conducted for the Chevron Long Wharf Maintenance and Efficiency Project (LWMEP) in Richmond, California during the 2019 calendar year. Monitoring was conducted on 24-inch concrete piles installed at Berth #2 and 20-inch and 36-inch steel piles installed at Berth #4.

Hydroacoustic data was collected and reported for the peak sound pressure level, root mean square (RMS) sound pressure level (SPL), sound equivalent level (SEL), and cumulative sound equivalent level (cSEL). The peak sound pressure level is presented in dB re 1 µPa as the maximum sound pressure level over the pulse duration. The RMS sound pressure level is presented in dB re 1 µPa and is averaged over 125 milliseconds for vibratory pile driving or the pulse duration for impact pile driving. The SEL sound pressure level is presented in dB re 1 μPa^2 and summarized where the SEL is greater than 150 dB to compute the cSEL. Generally, the majority of the acoustic energy of pile driving is confined to frequencies between 20 and 20,000 Hertz (Hz), and therefore sound levels were processed within this frequency range.

Each of these data are summarized as the maximum, mean, and median for each pile. If impact pile driving took place, recorded measurements were played through a Labview pulse detection program to identify the peak, RMS, pulse duration, and SEL for each pulse. These data were then used to estimate distances to exceedance thresholds for fish and marine mammals. Cumulative Distribution Function (CDF) plots of the RMS are shown for the driving of each pile as well as for background levels.

2. Monitoring Equipment and Methodology

2.1 Underwater System Equipment

Measurements were made by a live system and a stationary hydrophone recording system. For the live system, a Reson Model TC-4033 hydrophone was fed through an in-line charge amplifier into a Larson Davis Model 831 Precision Sound Level Meters (LDL 831 SLM) where measurements were observed in real-time. For the stationary hydrophone recording system, a Reson Model TC-4013 hydrophone was fed through a PCB Multi Gain Signal Conditioner (Model 480M122) and into a Roland Model R-05 Solid State Recorder. This unit was deployed via an anchor and buoy or off the construction barge. Following measurements, the recorded files from the stationary hydrophone unit's recorder were played through a calibrated LDL 831 SLM to analyze sound pressure levels.

All field notes were recorded in water-resistant field notebooks. Notebook entries include calibration notes, measurement positions (i.e., distance from source, depth of sensor), measurement conditions (e.g., currents, sea conditions, etc.), system gain settings, and the equipment used to make each measurement. Notebook entries were copied after each measurement day and filed for safekeeping. Digital recordings were also copied and stored for subsequent analysis, if needed.

2.2 Underwater System Acoustic Calibration

The measurement systems were calibrated prior to use in the field with a G.R.A.S. Type 42AA pistonphone and hydrophone coupler. The pistonphone, when used with the hydrophone coupler, produces a continuous 136.4 dB re 1 µPa tone for the TC-4033 hydrophones and 145.3 dB re 1 µPa tone for the TC-4013 hydrophones at 250 Hertz (Hz). The tone measured by the SLM was recorded at the beginning of the recordings. The system calibration status was checked at the beginning of each measurement day by measuring both the calibration tone and recording the tone on the solid-state digital data recorder. The pistonphones were certified at an independent facility.

2.3 Placement of Hydrophones

Measurements were made at three fixed positions on each day of monitoring in order to compute distances to fish and marine mammal thresholds. The first position was approximately 10 meters from the piles (or as close as possible given site conditions), the second measurement position was between 50 and 100 meters, and the third position was generally around 200 meters. Hydrophones at all positions were placed at approximately mid-depth in the water column. Water depth on the west side of the wharf, where hydrophones were positioned to measure piles driven at Berth #2, was relatively constant at approximately 14 to 15 meters at all hydrophone positions. Water depth on the east side of the wharf, where hydrophones were positioned to measure piles driven at Berth #4, was also relatively constant at approximately 6 meters at all hydrophone positions.

2.4 Background Sound Data

Current speeds were generally less than 1.0 meter/second but were influenced by tidal shifts. Background levels were measured prior to and following pile-driving events at each of the measurement locations. Cumulative Distribution Function (CDF) plots of background measurements are shown in Appendix A. Background levels were generally higher to the west of the wharf due to greater current speeds, larger waves, and closer proximity to the shipping channel and vessels docked at nearby berths. background sound pressure levels were generally between 110-125 RMS and at least 10 dB lower than pile driving sound pressure levels. On October 3rd, 2019, intermittent drilling occurred at the wharf near the hydrophone positioned at 50 meters. A vessel releasing water from the hull of the ship in Berth #3 also influenced background levels at the hydrophone positioned at 195 meters. These higher background levels affected impulse measurements but did not significantly influence pulse levels after measurements were processed through the Labview program.

3. Measurement Results and Analysis

Table 1 summarizes the monitoring results for the installation of 24-inch concrete piles at Berth #2 on June 5th, 2019 and October 3rd, 2019. A bubble curtain was used during the installation of all piles driven with a diesel impact hammer. On June 5th only, the hydrophone positioned at 66 meters did not capture the final 19 strikes of pile driving. Sound pressure levels were not detected above background noise at the hydrophone positioned at 150 meters due to a vessel docked at

Berth #1. Since the distances to the fish and marine mammal thresholds were measured to be between the hydrophone positions at 10 meters and 66 meters, the drop-off rate between these hydrophones was computed and used to estimate the distance to applicable thresholds. Data collected with the hydrophone at 150 meters was not analyzed further.

Table 2 summarizes the monitoring results for the installation of steel piles at Berth #4 on June 21st, 2019 and August 22nd, 2019. Piles installed on August 22nd, 2019 had a diameter of 36 inches and overall sound pressure levels were significantly higher compared to 20-inch piles installed on June 21st, 2019.

Table 3 summarizes the distances to exceedance thresholds for fish. Note that the injury thresholds were not exceeded at the nearest hydrophone position for all dates monitored. The calculation of the cSEL for fish criteria assumes that strikes below 150 dB SEL are effective quiet and are not included in the calculation. Table 4 summarizes the distances to exceedance thresholds for marine mammals based on drop-off rates calculated from sound pressure levels measured at all positions. Drop-off rates for vibratory pile driving were calculated using the median RMS impulse values and drop-off rates for impact pile driving were calculated using the median RMS pulse values. Permanent Threshold Shift (PTS) isopleth distances were calculated using the NOAA Marine Mammal Calculation Guide[1]. Distances to PTS thresholds for impact pile driving are reported as the largest isopleth distance of either the Peak or cSEL. If more than one pile was driven during the daily monitoring period, distances to PTS thresholds were calculated based on the measurements of all piles driven within that daily monitoring period. To compute daily PTS thresholds for impact driving, drop-off rates, the median single strike SEL, and measurement distances of the single strike SEL for each pile were averaged for all piles driven within a driving period. The cSEL and total number of strikes were summed over the driving period. To compute daily PTS thresholds for vibratory driving, drop-off rates, the median RMS, and measurement distances of the RMS for each pile were averaged for all piles driven within a driving period. The duration of sound production was summed over the driving period.

Samples of the median 1/3 octave band spectra for pile installation are included in Appendix B. For piles installed with a vibratory hammer, the one-second LZ_{eq} of each octave band was recorded, and for piles installed with a diesel impact hammer, the LZI of each octave band was recorded. The median value for each octave band was then calculated over a duration of one minute for piles driven with a vibratory hammer or eight strikes for piles driven with a diesel impact hammer. Cumulative Distribution Function plots of the RMS values and Time History plots of all piles are included in Appendices C and D, respectively. Note that time history plots shown for 24-inch concrete piles driven with a diesel impact hammer are based on impulse values since pulse detection is not linked with real time history.

[1] NMFS. 2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts (Version 2.0).

Table 1. Summary Statistics for the Installation of 24-inch Concrete Piles with a Diesel Impact Hammer at Berth #2

Date	Pile #	# of Strikes	Water Depth at Pile (m)	Msmt Distance from Pile (m)	Water Depth at Msmt (m)	Hydrophone Depth (m)	Peak (dB)			RMS – 90% pulse (dB)				SEL (dB)			cSEL
							Max	Mean	Median	Max	Mean	Median	Pulse Duration	Max	Mean	Median	
6/5	1	181	13	10	14	8	195	175	175	177	163	163	0.126	165	155	155	178
				66[a]	14	8	159	151	150	148	139	139	0.172	138	132	132	160
				150[b]	14	8	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
				Daily Cumulative SEL at 10 meters – 178 dB re:1µPa^2-sec													
10/3	1	439	13	7	13	6	185	177	177	172	166	166	0.067	161	155	155	184
				52	14	8	171	164	164	157	152	152	0.177	149	145	145	172
				195	14	6	164	157	156	154	144	143	0.225	144	137	137	165
	2	437	13	7	13	6	197	179	179	180	167	167	0.068	167	156	156	183
				50	13	8	171	168	167	158	155	155	0.158	150	147	147	174
				195	13	6	168	159	159	160	147	147	0.194	148	140	140	167
				Daily Cumulative SEL at 7 meters – 186 dB re:1µPa^2-sec													

[a] The hydrophone at this position missed the final 19 strikes.
[b] The hydrophone at this position only captured the final 19 strikes. This data is not representative of the driving event and is not reported.
[c] The cSEL is summed for all piles driven during the day.

Table 2. Summary Statistics for the Installation of Steel Piles with a Vibratory Hammer at Berth #4

Date	Pile #	Duration (seconds)	Water Depth at Pile (m)	Hydrophone Distance from Pile (m)	Water Depth at Hydrophone (m)	Hydrophone Depth (m)	Peak (dB)			RMS – 1 sec (dB)			SEL (dB)			cSEL
							Max	Mean	Median	Max	Mean	Median	Max	Mean	Median	
6/21	1^A	115	6	22	6	3	171	163	164	158	150	150	158	150	150	170
				75	6	3	165	151	152	146	134	135	146	134	135	157
				220	6	3	150	133	133	127	119	120	127	119	120	141
	2^A	185	6	18	6	3	174	159	154	154	147	146	154	147	146	172
				75	6	3	168	145	141	146	131	130	146	131	130	160
				220	6	3	155	136	130	136	121	117	136	121	117	150
				Daily Cumulative SEL normalized to 20 meters – 174 dB re:1μPa^2-sec												
8/22	1^B	684	6	10	7	3	196	172	169	176	158	155	176	158	155	196
				85	6	3	179	155	151	159	140	138	159	140	138	180
				228	6	3	168	144	142	149	129	126	149	129	126	167
	2^B	218	6	15	7	3	192	175	183	174	160	167	174	160	167	192
				79	6	3	180	157	168	161	149	151	161	149	151	177
				222	6	3	166	143	155	147	134	137	147	134	137	164
				Daily Cumulative SEL normalized to 10 meters – 199 dB re:1μPa^2-sec												

[A] 24-inch Steel Pile
[B] 36-inch Steel Pile

Table 3. Distances to Fish Criteria for Piles Driven with a Diesel Impact Hammer

Date	Pile #	206 dB Peak	150 dB RMS	187 dB cSEL[a]
5-Jun	1	< 10	28	< 10
3-Oct	1	< 10	73	< 10
	2	< 10	112	< 10

[a] The cSEL is summed over the driving period..

Table 4. Distances to Marine Mammal Criteria

Date	Pile #	PTS Threshold [a] (m)					Behavioral Harassment Threshold (m)		Calculated Drop-Off Rates	
		LF	MF	HF	PW	OW	120 dB RMS	160 dB RMS	Median RMS	Median SEL [c]
5-Jun	1	< 10	< 10	< 10	< 10	< 10	--	13	NR	NR
21-Jun	1	< 10	< 10	< 10	< 10	< 10	207	--	31.0	--
	2	< 10	< 10	< 10	< 10	< 10	170	--	27.1	--
	Daily	< 10	< 10	< 10	< 10	< 10	--	--	28.9[b]	--
22-Aug	1	< 10	< 10	< 10	< 10	< 10	491	--	20.8	--
	2	< 10	< 10	< 10	< 10	< 10	1,085	--	25.0	--
	Daily	< 10	< 10	< 10	< 10	< 10	--	--	22.9[b]	--
3-Oct	1	< 10	< 10	< 10	< 10	< 10	--	17	15.9	12.4
	2	< 10	< 10	< 10	< 10	< 10	--	21	13.9	11.0
	Daily	11	< 10	14	< 10	< 10	--	--	--	11.7[b]

[a] Calculated using the dual metric threshold where the largest isopleth of the peak or cSEL is reported.

[b] Calculated as the average drop-off rate of all piles driven for the day

[c] Same as the RMS for vibratory driving

LF = Low-Frequency Cetaceans, MF = Mid-Frequency, HF = High-Frequency Cetaceans, PW = Phocid Pinnipeds in Water, and OW = Otariid Pinnipeds in water.

A

Background Sound Pressure Levels

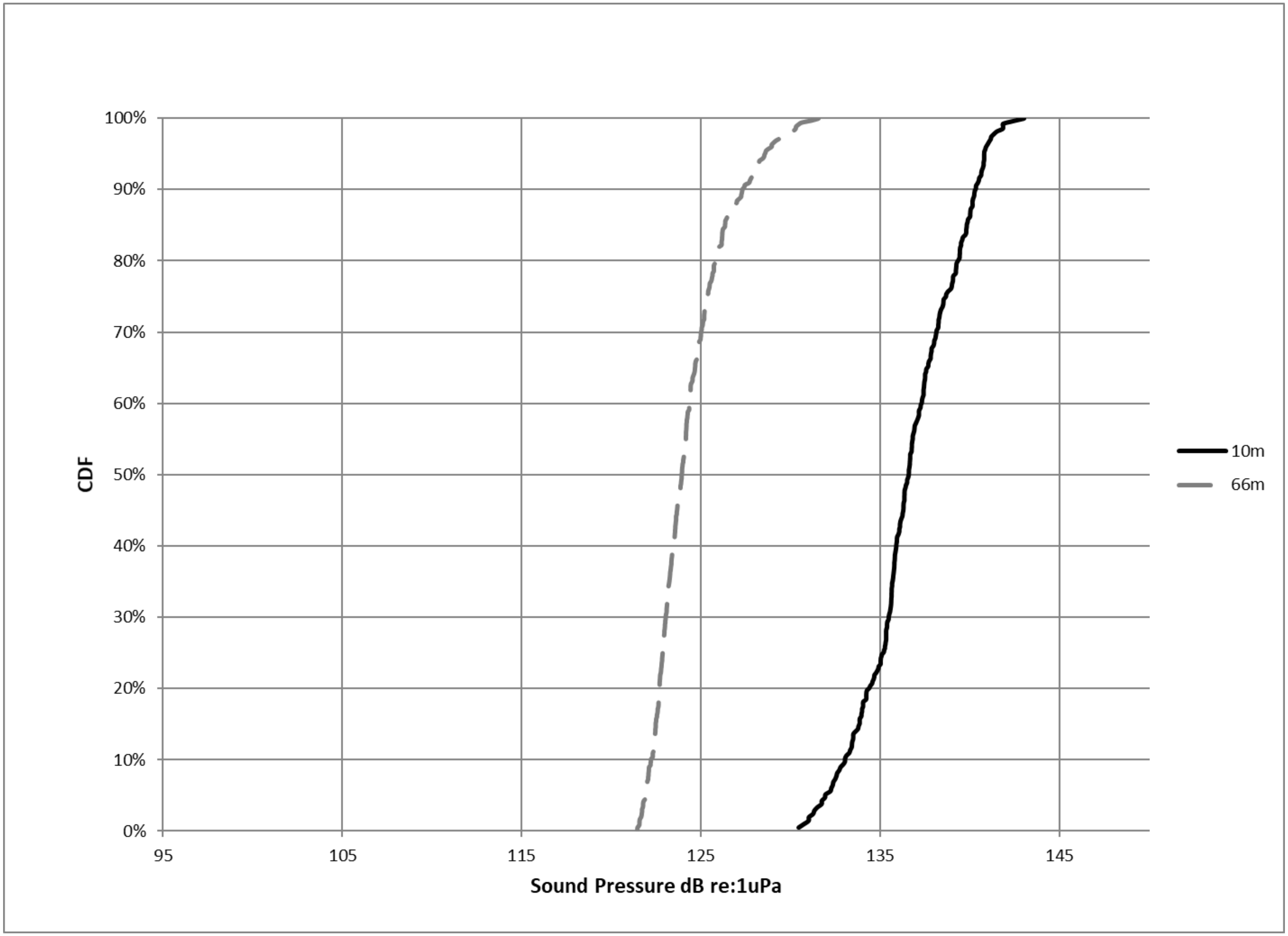

Figure A-1. CDF of Background RMS SPL at Hydrophone Positions on June 5th, 2019

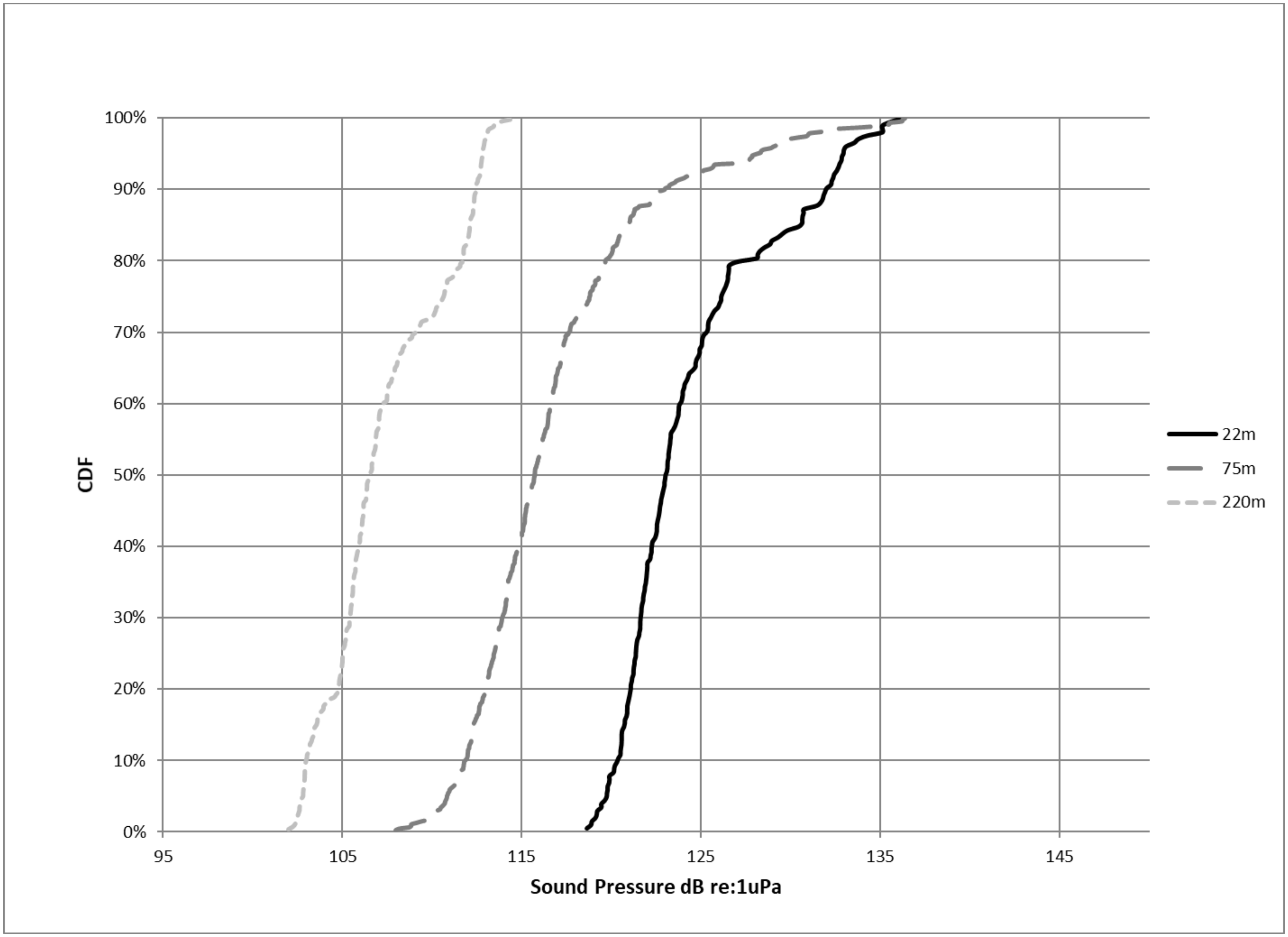

Figure A-2. CDF of Background RMS SPL at Hydrophone Positions on June 21st, 2019

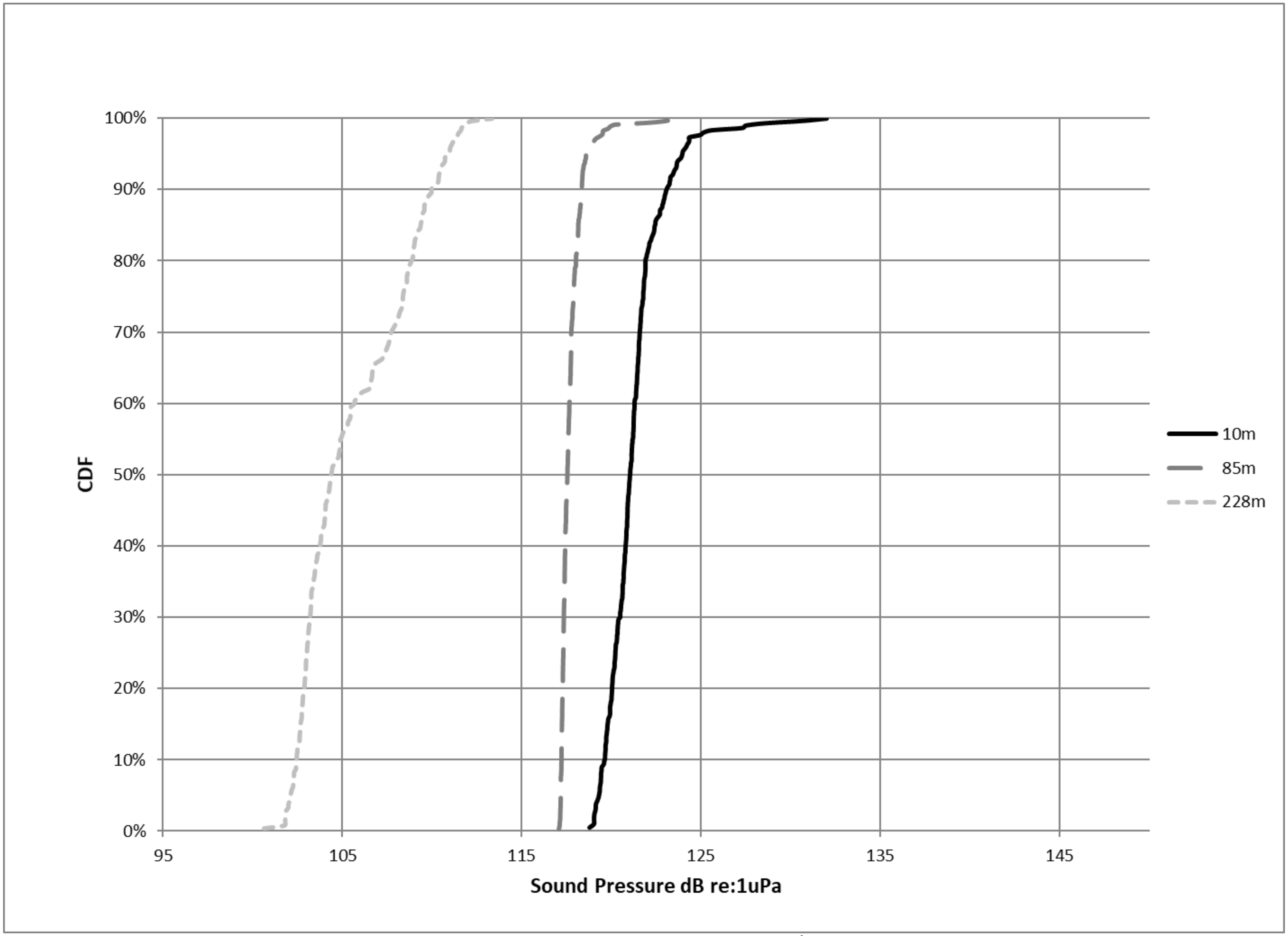

Figure A-3. CDF of Background RMS SPL at Hydrophone Positions on August 22nd, 2019

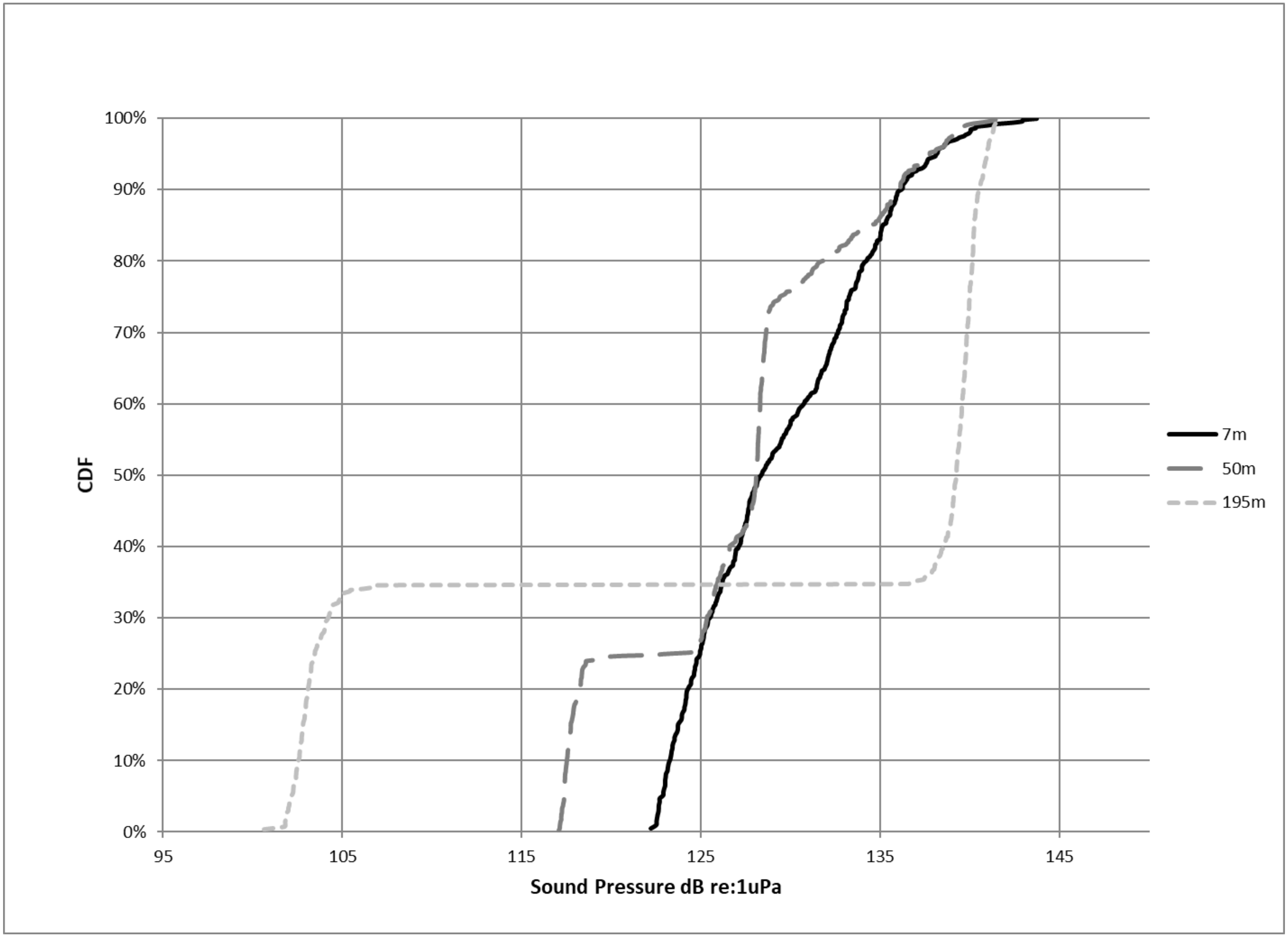

Figure A-4. CDF of Background RMS SPL at Hydrophone Positions on October 3rd, 2019

B

1/3 Octave Band Spectrum Plots

Figure B-1. 1/3 Octave Band Plot of Median LZI over Eight Pile Strikes During the Installation of a 24-inch Concrete Pile with a Diesel Impact Hammer on June 5th, 2019

Figure B-2. 1/3 Octave Band Plot of Median LZeq over One Minute During the Installation of 20-inch Steel Pile #1 with a Vibratory Hammer on June 21st, 2019

Figure B-3. 1/3 Octave Band Plot of Median LZeq over One Minute During the Installation of 20-inch Steel Pile #2 with a Vibratory Hammer on June 21st, 2019

Figure B-4. 1/3 Octave Band Plot of Median LZeq over One Minute During the Installation of 36-inch Steel Pile #1 with a Vibratory Hammer on August 22nd, 2019

Figure B-5. 1/3 Octave Band Plot of Median LZeq over One Minute During the Installation of 36-inch Steel Pile #2 with a Vibratory Hammer on August 22nd, 2019

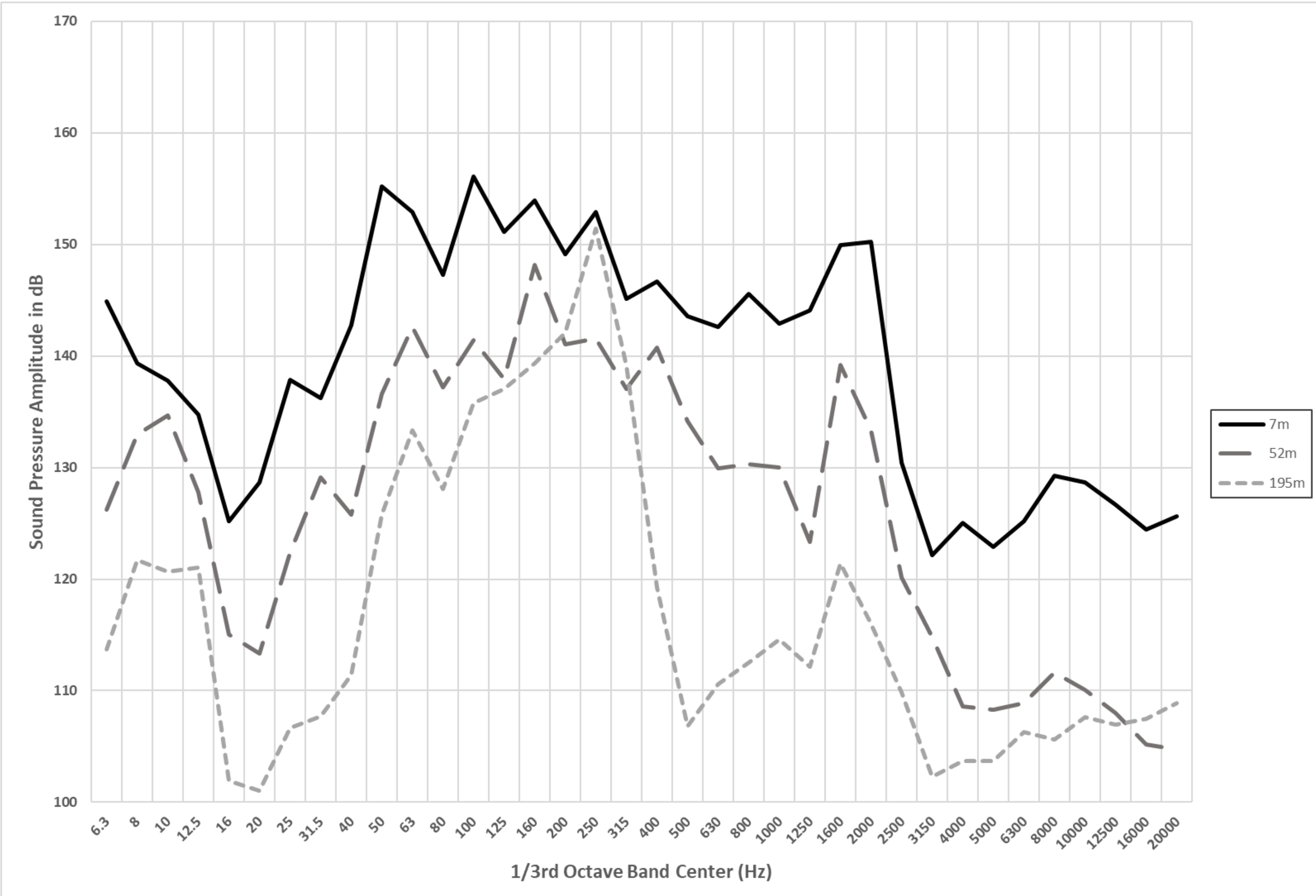

Figure B-6. 1/3 Octave Band Plot of Median LZI over Eight Pile Strikes During the Installation of 20-inch Concrete Pile #1 with a Diesel Impact Hammer on October 3rd, 2019

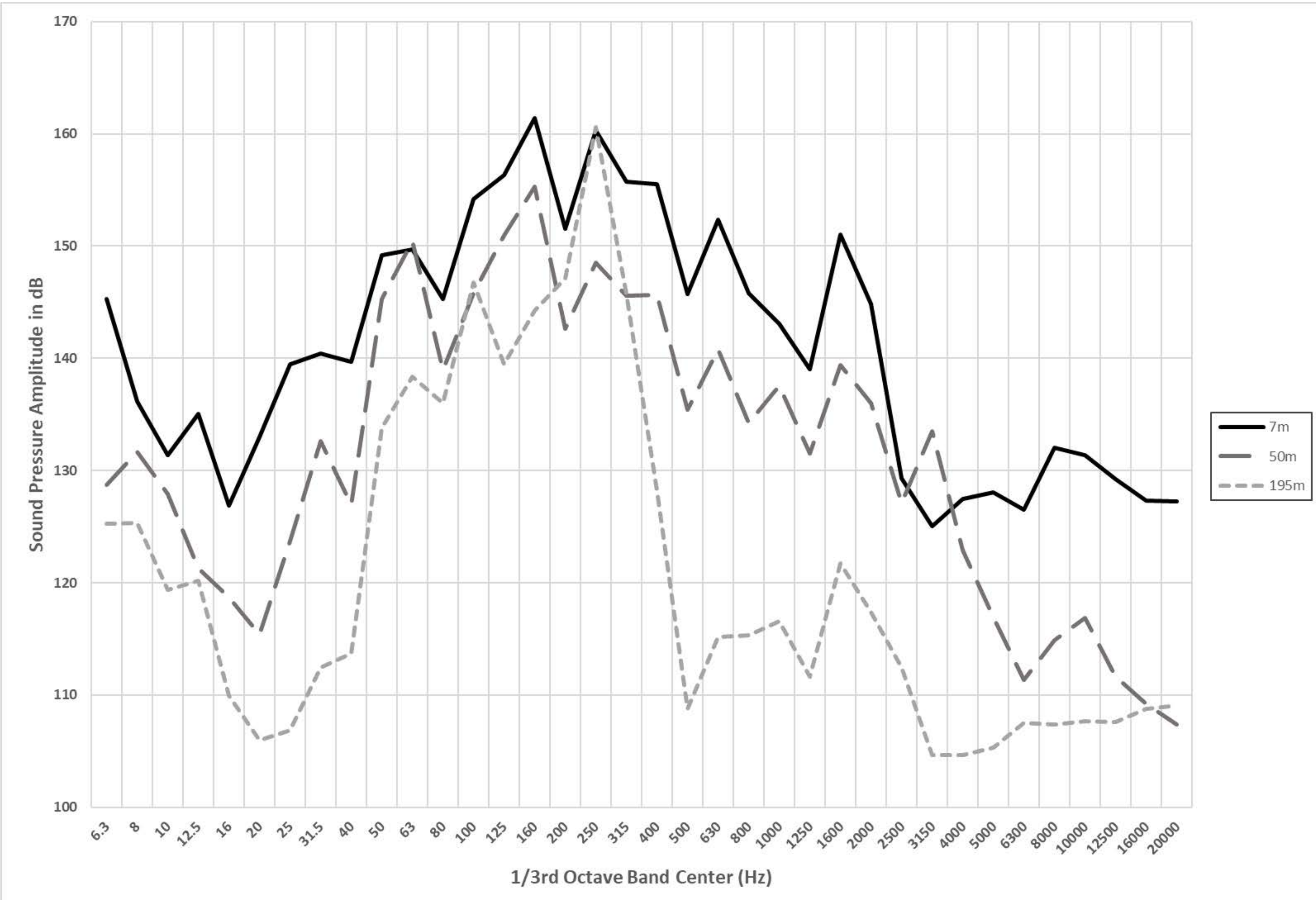

Figure B-7. 1/3 Octave Band Plot of Median LZI over Eight Pile Strikes During the Installation of 20-inch Concrete Pile #2 with a Diesel Impact Hammer on October 3rd, 2019

C

RMS Cumulative Distribution Function Plots

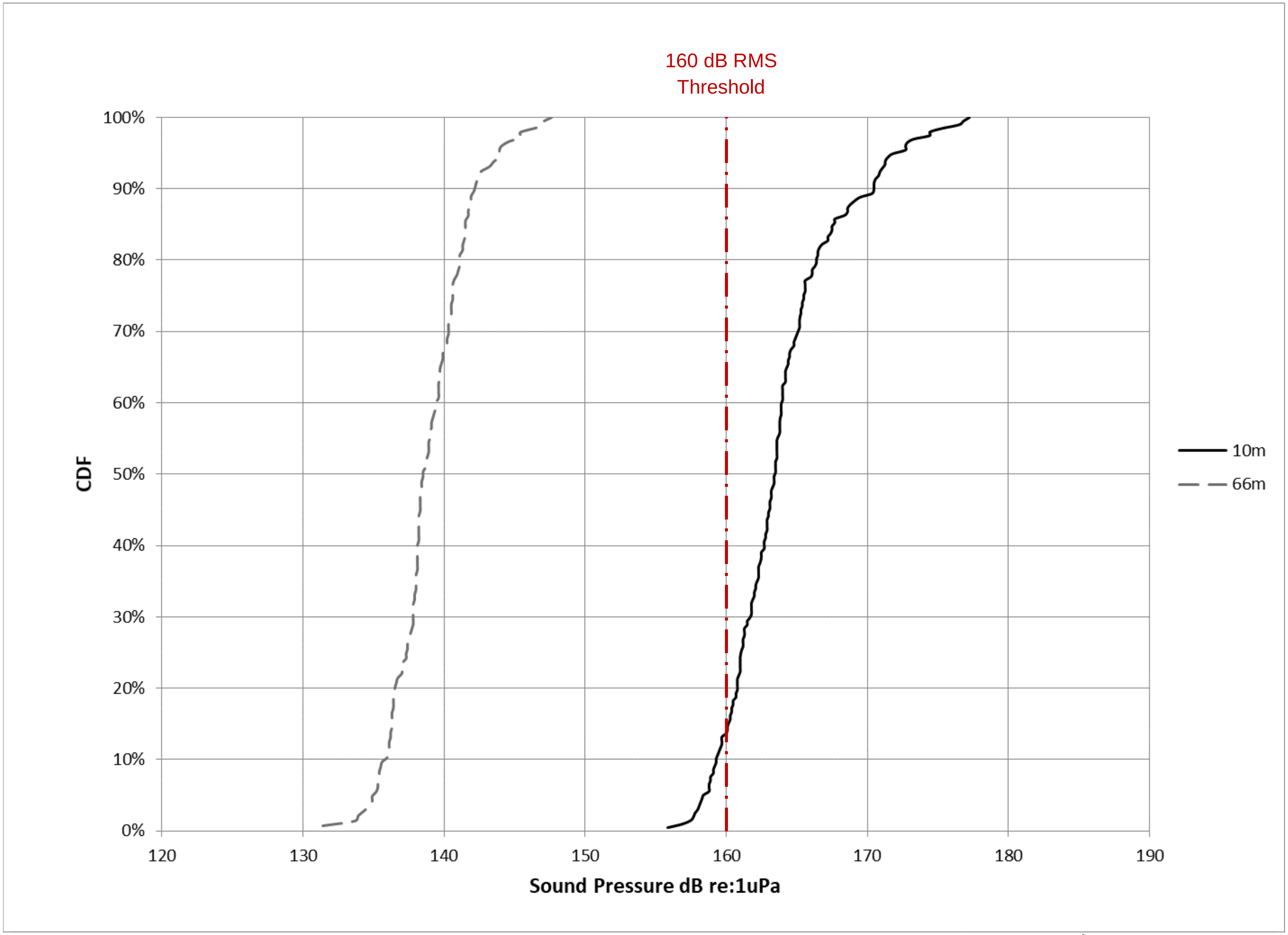

Figure C-1. CDF (RMS values) of the Installation of a 24-inch Concrete Pile with a Diesel Impact Hammer on June 5th, 2019

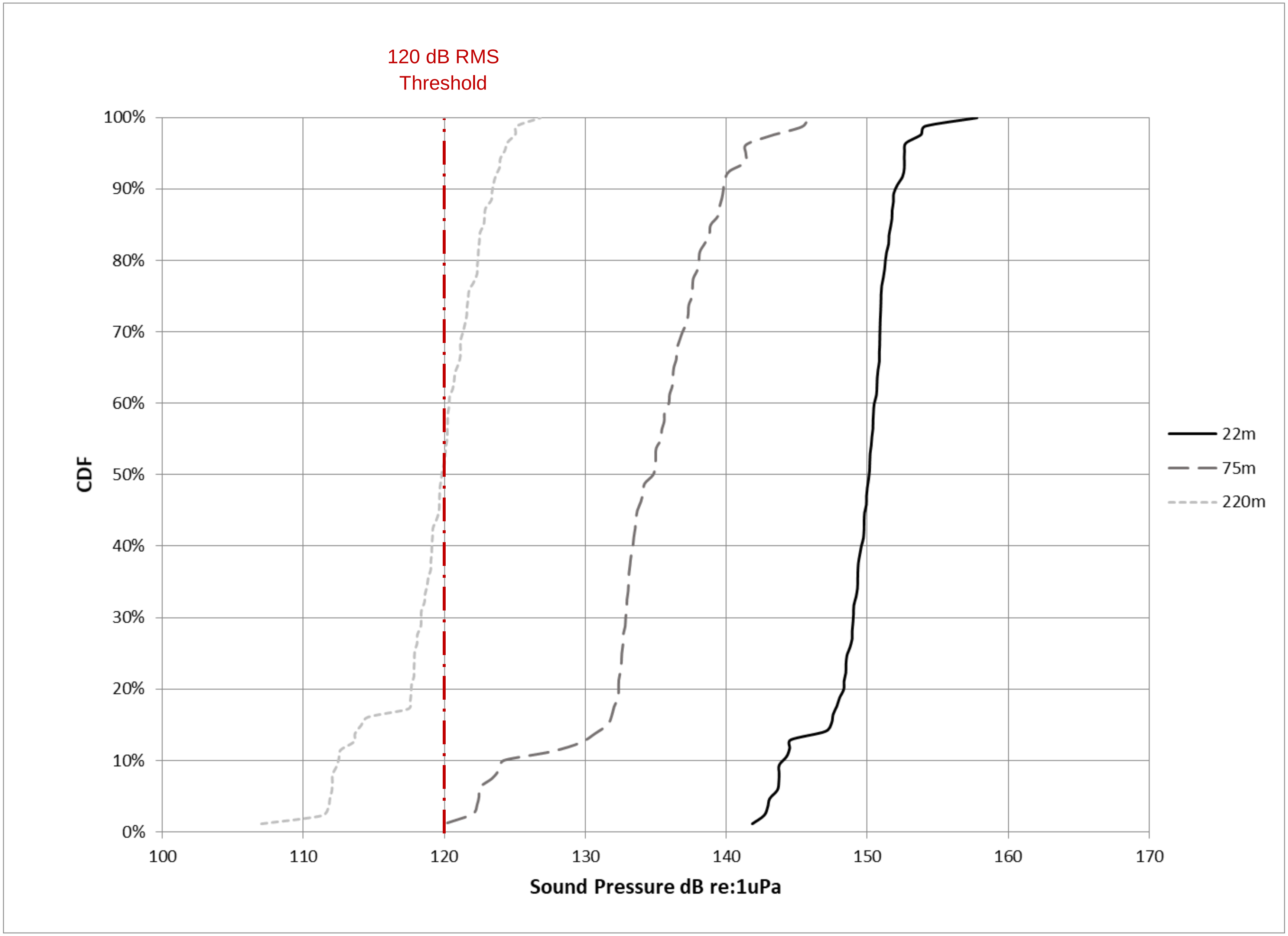

Figure C-2. CDF (RMS values) of the Installation of 20-inch Steel Pile #1 with a Vibratory Hammer on June 21st, 2019

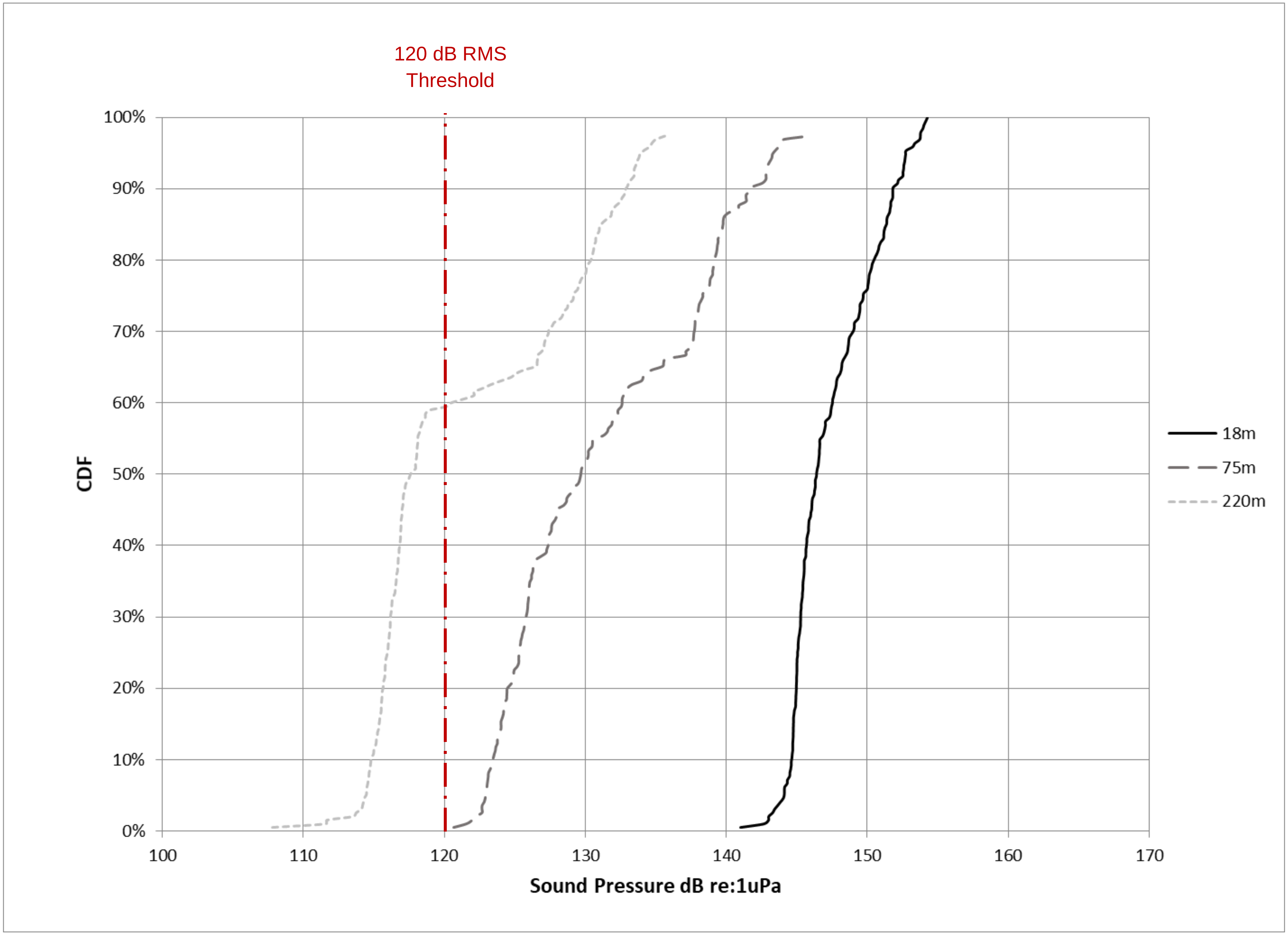

Figure C-3. CDF (RMS values) of the Installation of 20-inch Steel Pile #2 with a Vibratory Hammer on June 21st, 2019

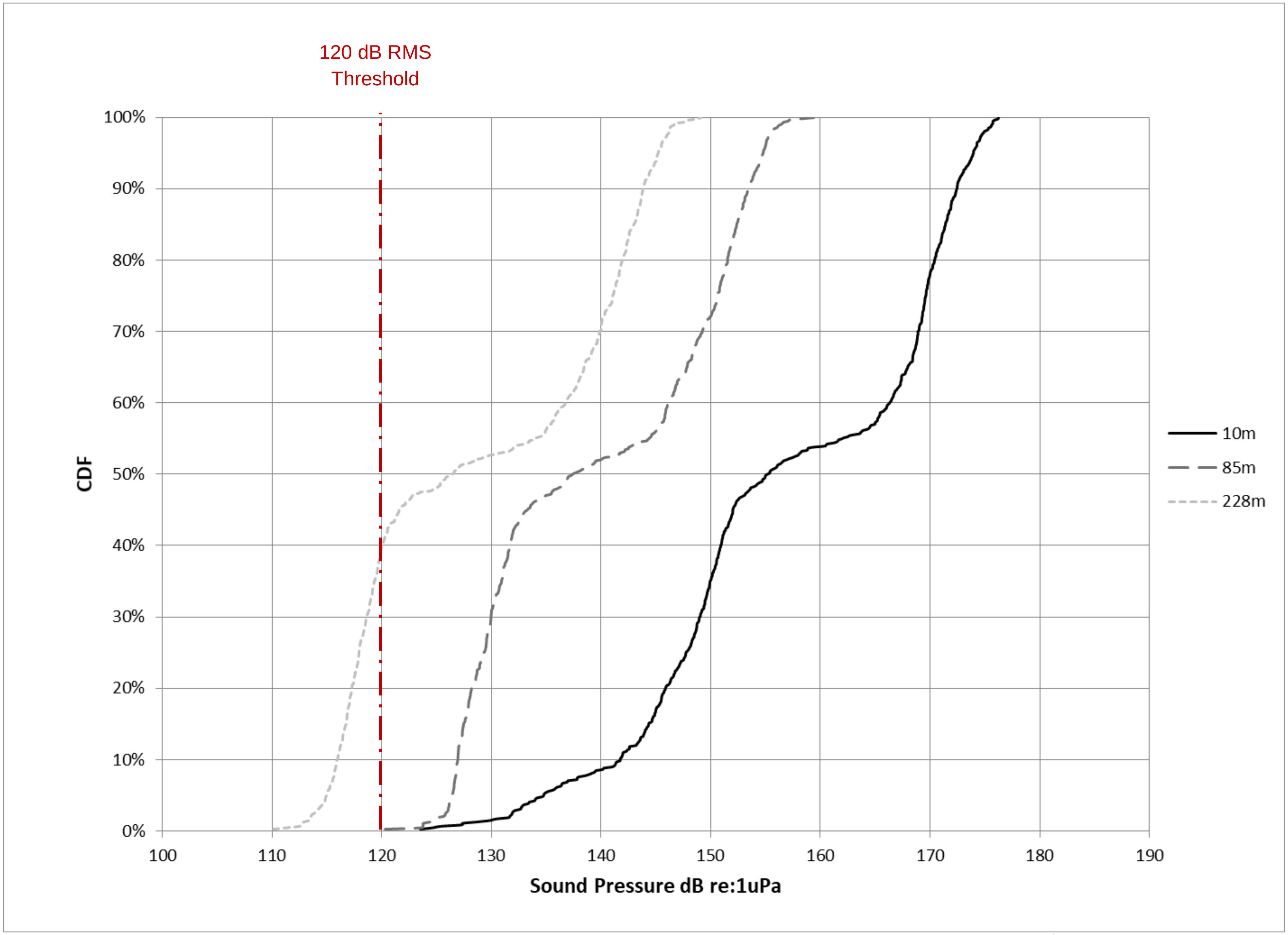

Figure C-4. CDF (RMS values) of the Installation of 36-inch Steel Pile #1 with a Vibratory Hammer on August 22nd, 2019

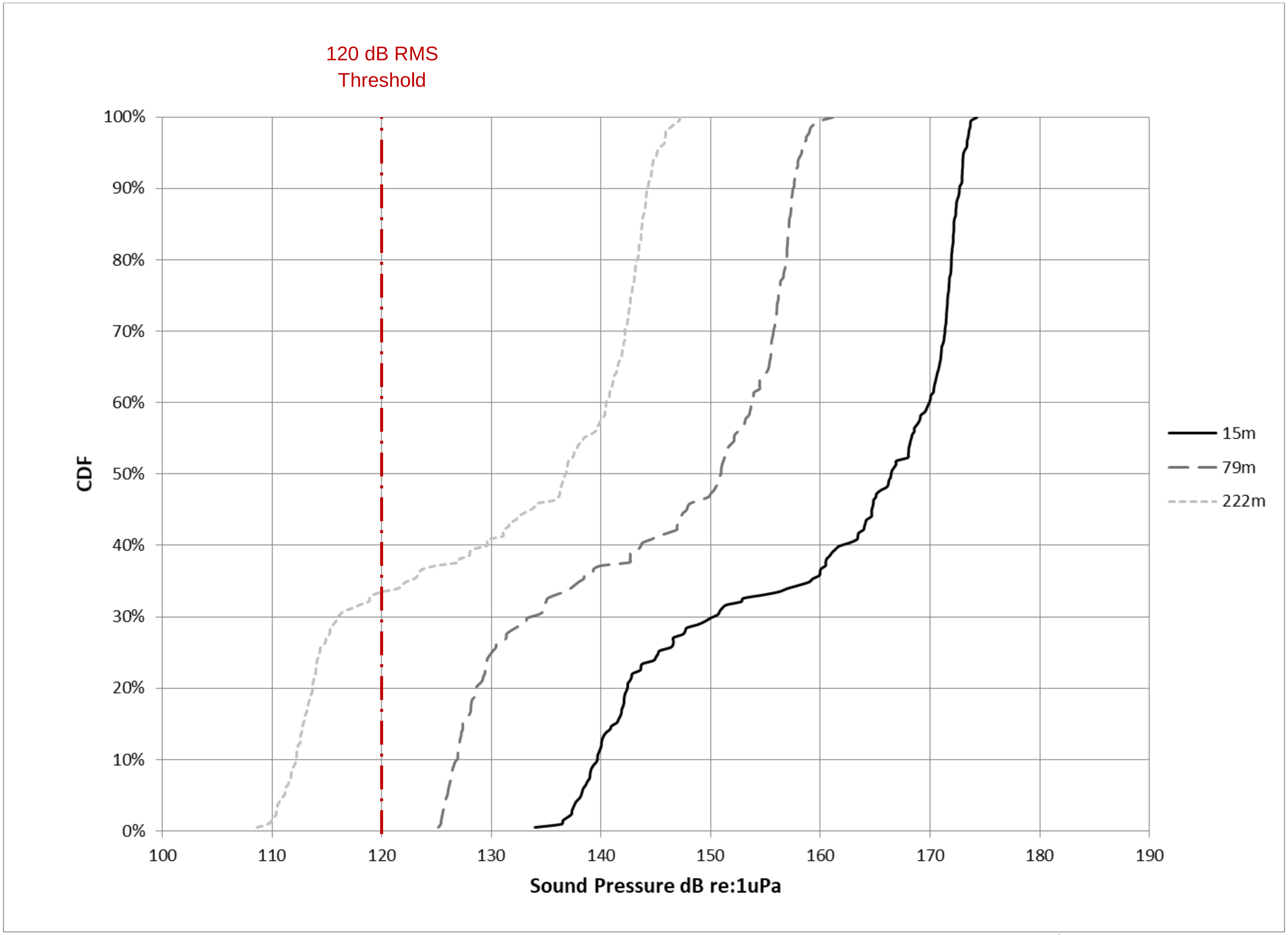

Figure C-5. CDF (RMS values) of the Installation of 36-inch Steel Pile #2 with a Vibratory Hammer on August 22nd, 2019

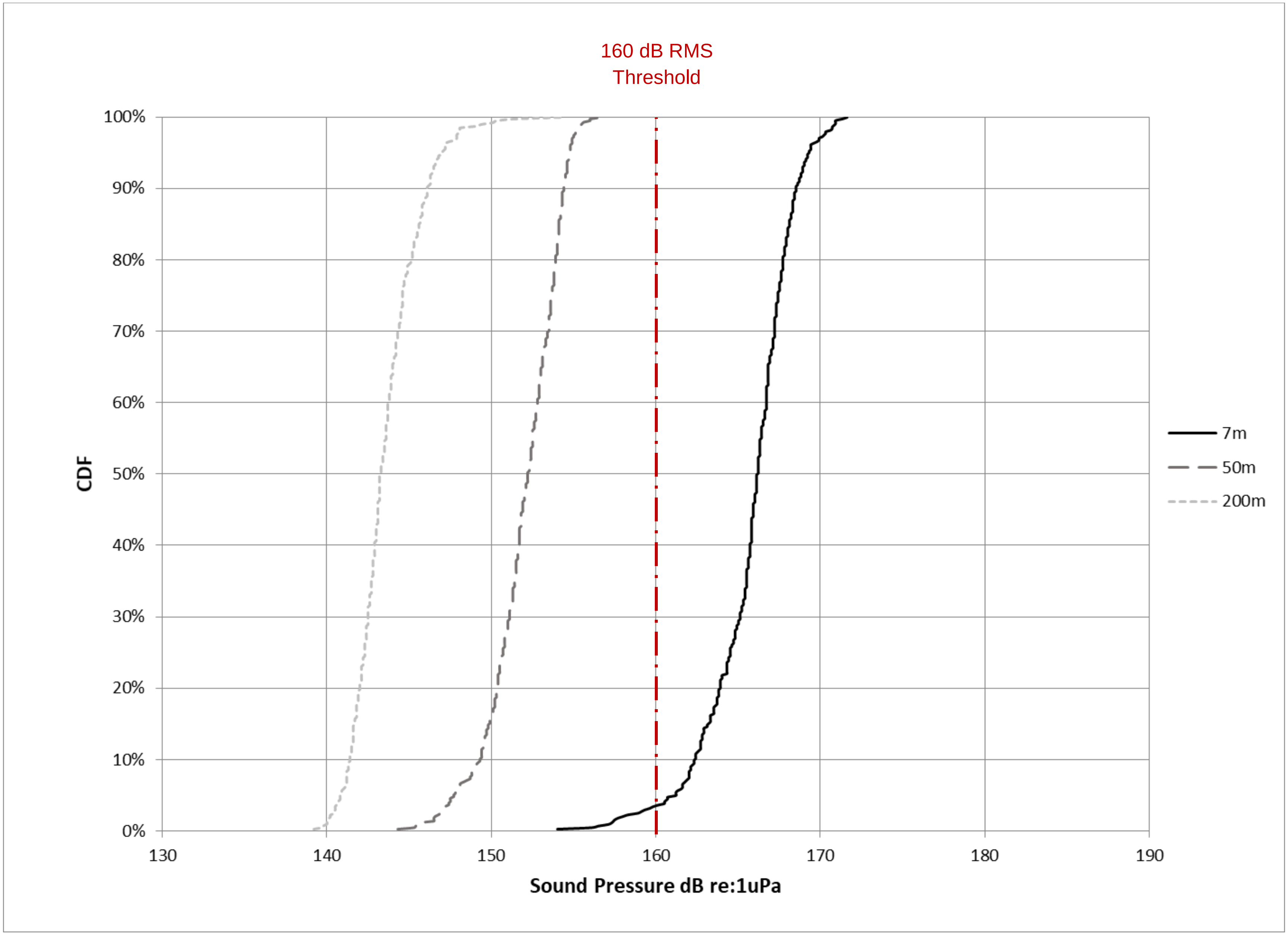

Figure C-6. CDF (RMS values) of the Installation of 20-inch Concrete Pile #1 with a Diesel Impact Hammer on October 3rd, 2019

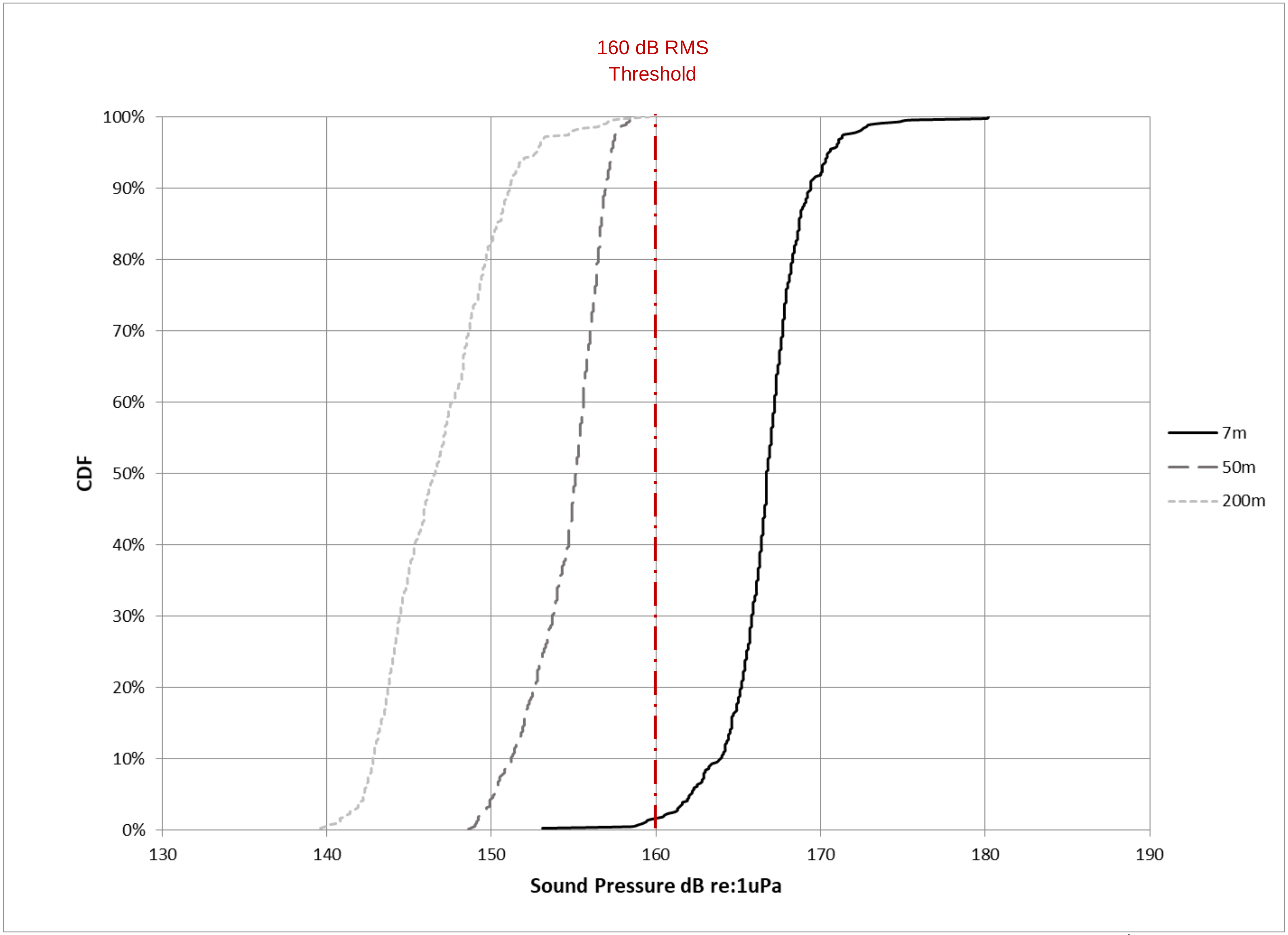

Figure C-7. CDF (RMS values) of the Installation of 20-inch Concrete Pile #2 with a Diesel Impact Hammer on October 3rd, 2019

D

Time History Plots

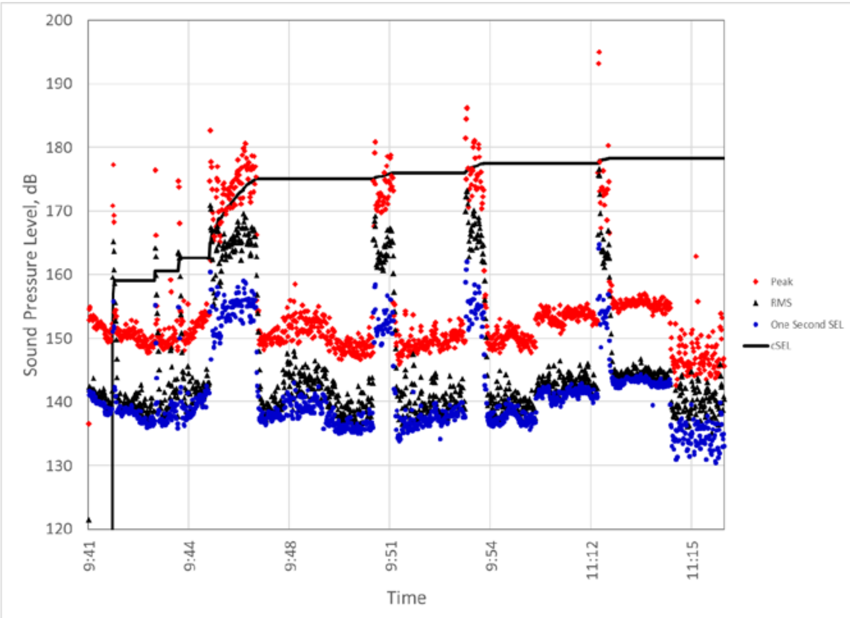

Figure D-1. Time History Plot of the Installation of a 24-inch Concrete Pile with a Diesel Impact Hammer on June 5th, 2019 at 10 meters

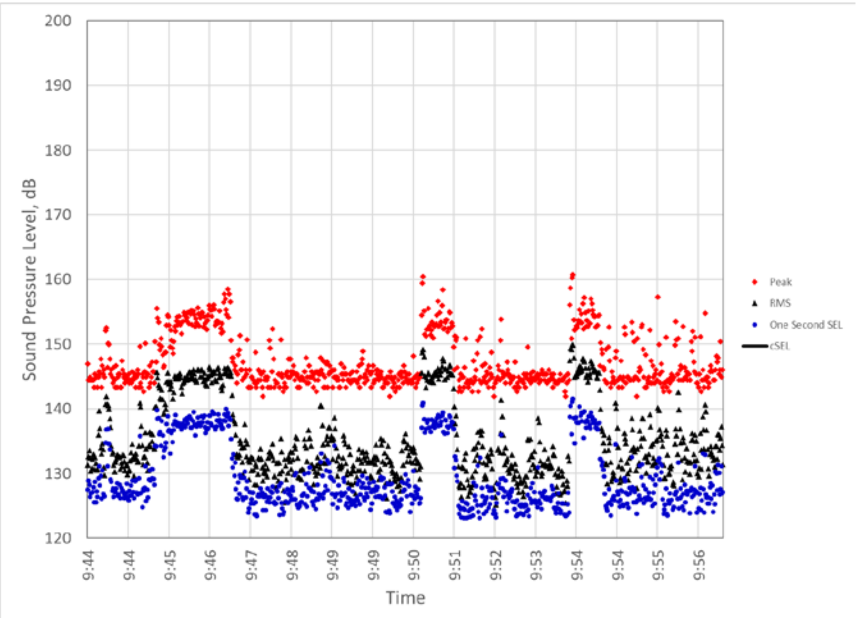

Figure D-2. Time History Plot of the Installation of a 24-inch Concrete Pile with a Diesel Impact Hammer on June 5th, 2019 at 66 meters

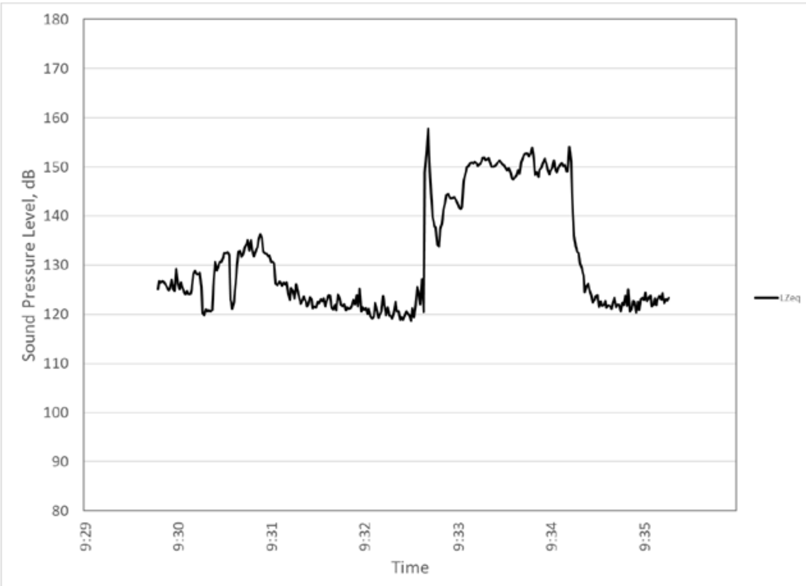

Figure D-3. Time History Plot of the Installation of 20-inch Steel Pile #1 with a Vibratory Hammer on June 21st, 2019 at 22 meters

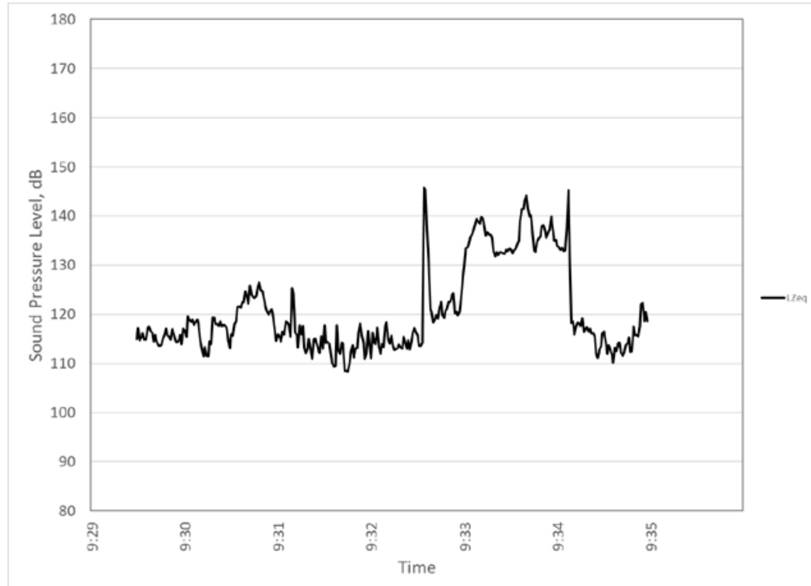

Figure D-4. Time History Plot of the Installation of 20-inch Steel Pile #1 with a Vibratory Hammer on June 21st, 2019 at 75 meters

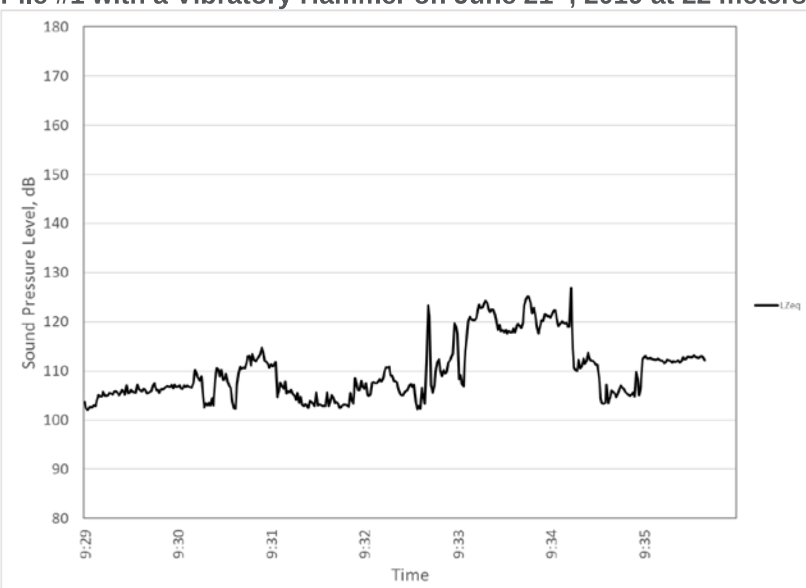

Figure D-5. Time History Plot of the Installation of 20-inch Steel Pile #1 with a Vibratory Hammer on June 21st, 2019 at 220 meters

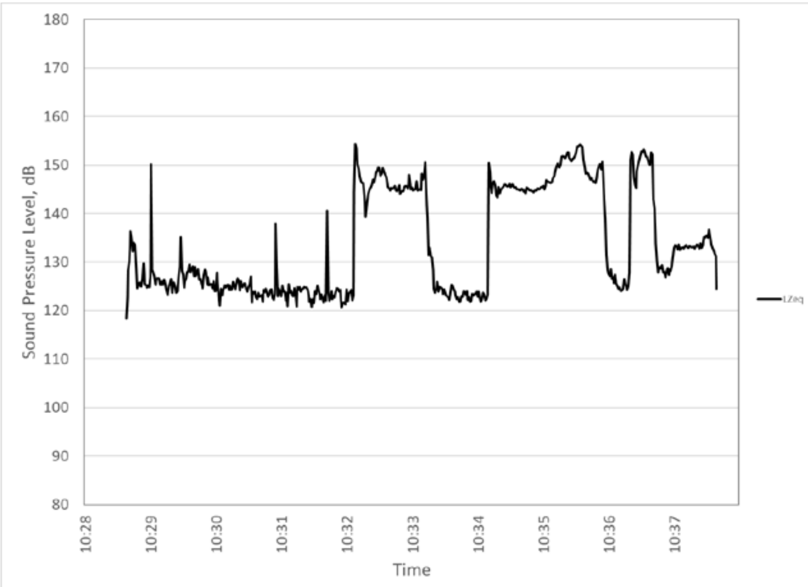

Figure D-6. Time History Plot of the Installation of 20-inch Steel Pile #2 with a Vibratory Hammer on June 21st, 2019 at 18 meters

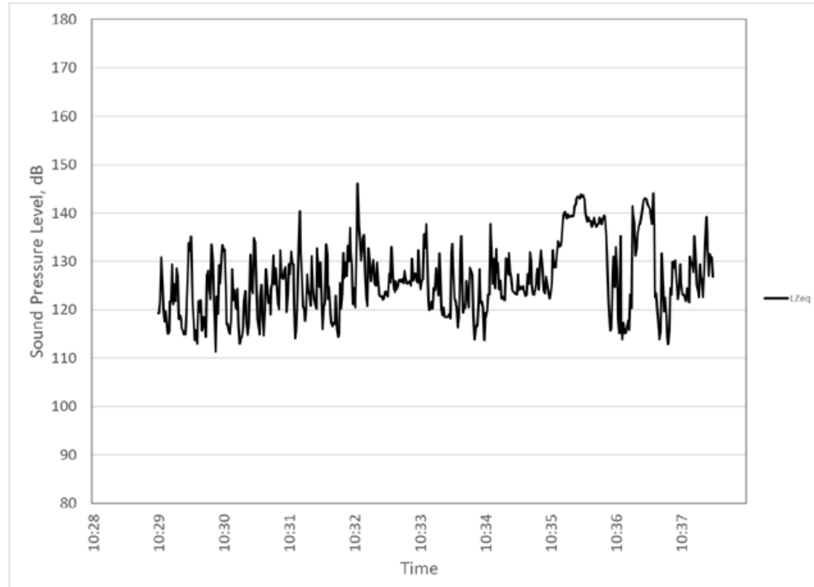

Figure D-7. Time History Plot of the Installation of 20-inch Steel Pile #2 with a Vibratory Hammer on June 21st, 2019 at 75 meters

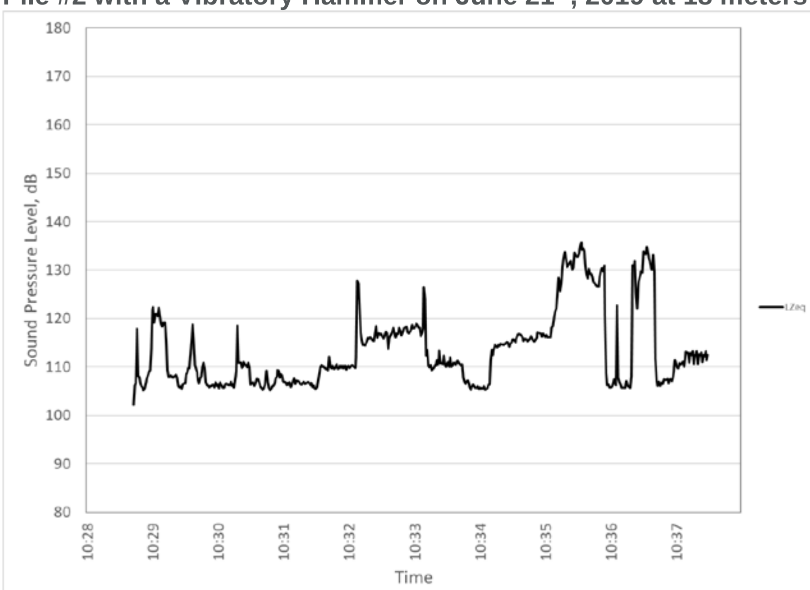

Figure D-8. Time History Plot of the Installation of 20-inch Steel Pile #2 with a Vibratory Hammer on June 21st, 2019 at 220 meters

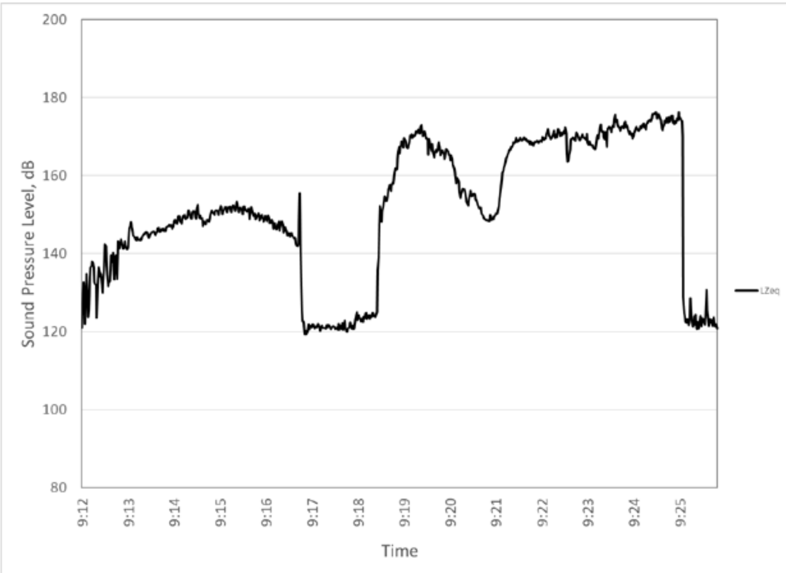

Figure D-9. Time History Plot of the Installation of 36-inch Steel Pile #1 with a Vibratory Hammer on August 22nd, 2019 at 10 meters

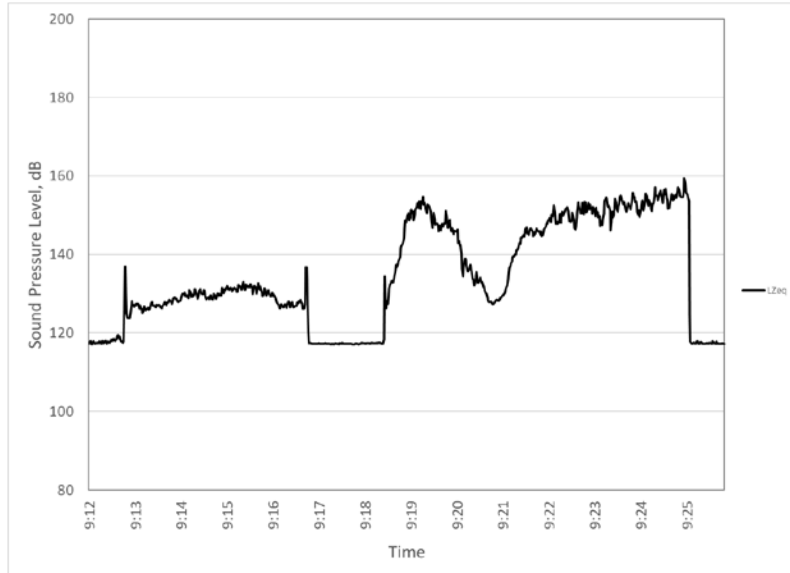

Figure D-10. Time History Plot of the Installation of 36-inch Steel Pile #1 with a Vibratory Hammer on August 22nd, 2019 at 85 meters

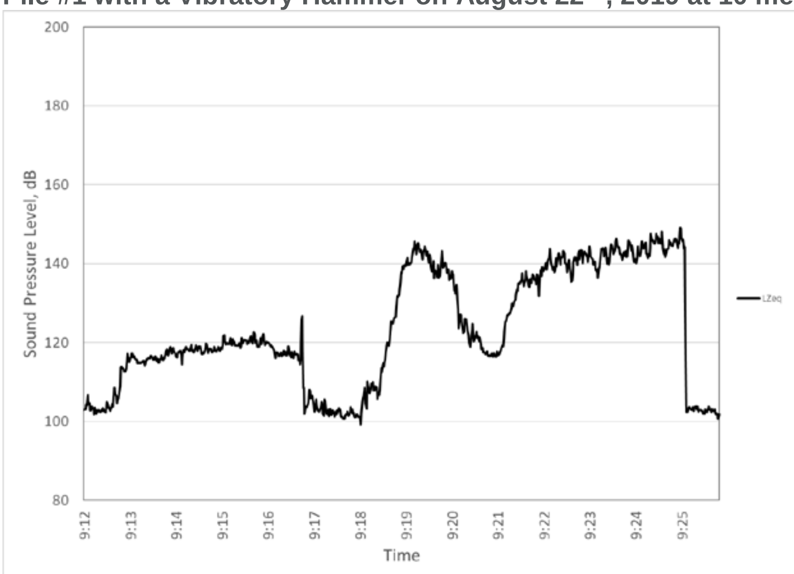

Figure D-11. Time History Plot of the Installation of 36-inch Steel Pile #1 with a Vibratory Hammer on August 22nd, 2019 at 228 meters

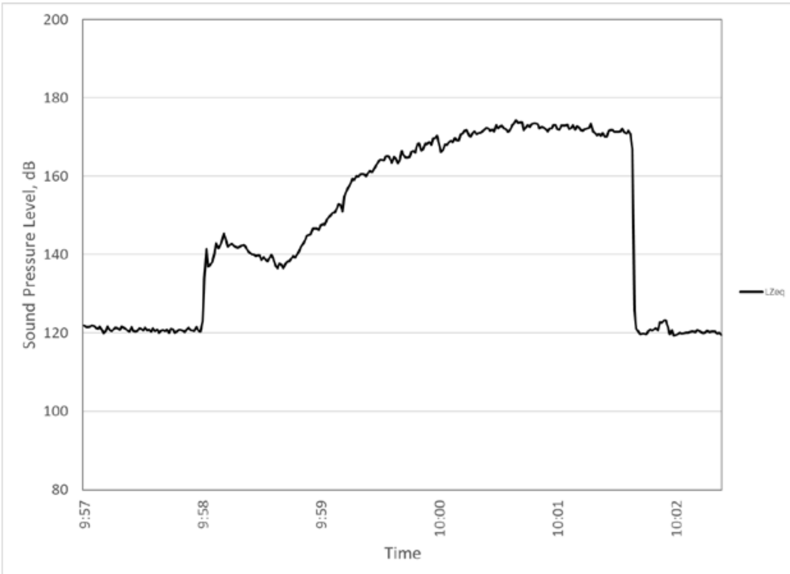

Figure D-12. Time History Plot of the Installation of 36-inch Steel Pile #2 with a Vibratory Hammer on August 22nd, 2019 at 15 meters

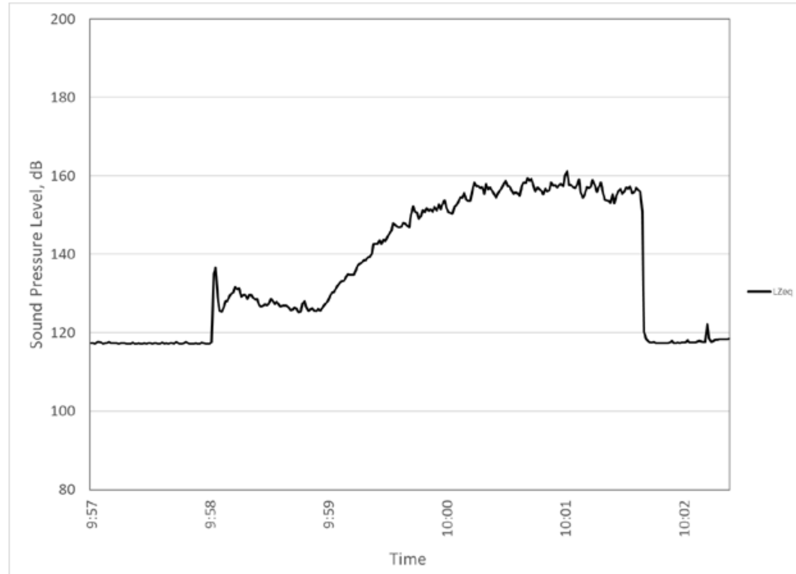

Figure D-13. Time History Plot of the Installation of 36-inch Steel Pile #2 with a Vibratory Hammer on August 22nd, 2019 at 79 meters

Figure D-14. Time History Plot of the Installation of 36-inch Steel Pile #2 with a Vibratory Hammer on August 22nd, 2019 at 222 meters

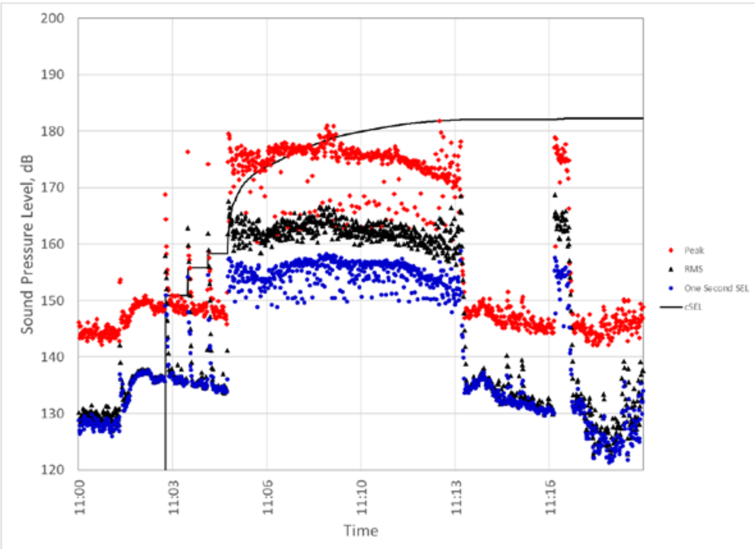

Figure D-15. Time History Plot of the Installation of 24-inch Concrete Pile #1 with a Diesel Impact Hammer on October 3rd, 2019 at 7 meters

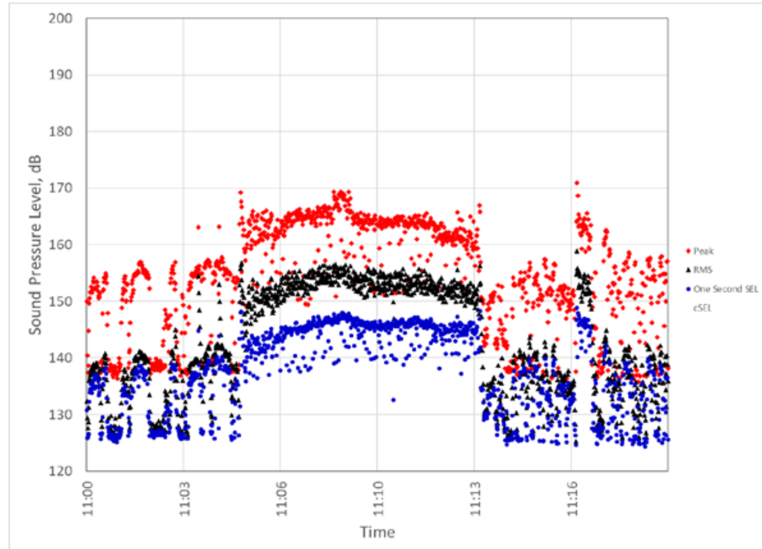

Figure D-16. Time History Plot of the Installation of 24-inch Concrete Pile #1 with a Diesel Impact Hammer on October 3rd, 2019 at 52 meters

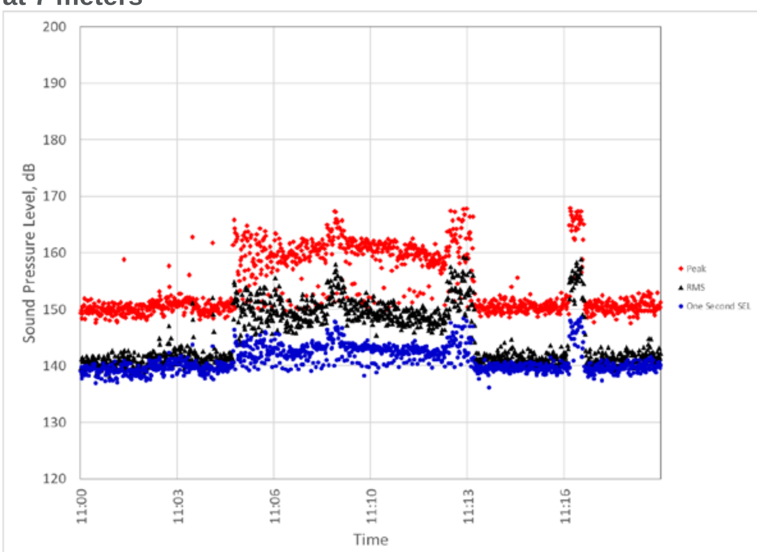

Figure D-17. Time History Plot of the Installation of 24-inch Concrete Pile #1 with a Diesel Impact Hammer on October 3rd, 2019 at 195 meters

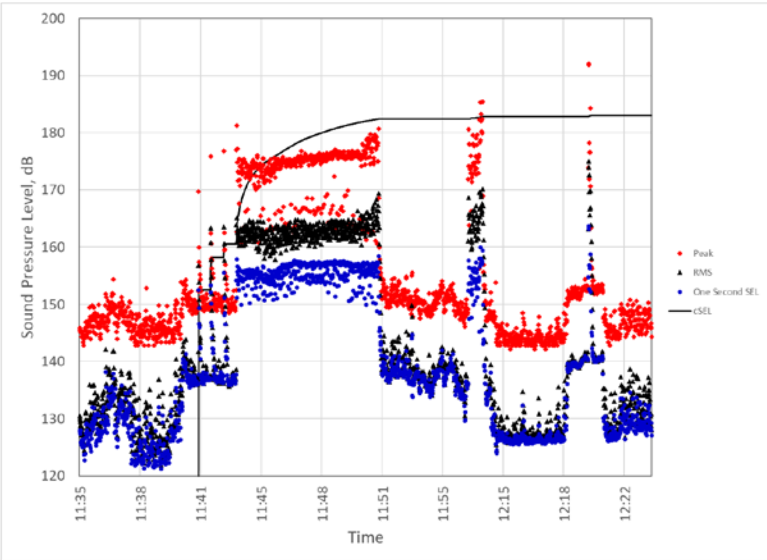

Figure D-18. Time History Plot of the Installation of 24-inch Concrete Pile #2 with a Diesel Impact Hammer on October 3rd, 2019 at 7 meters

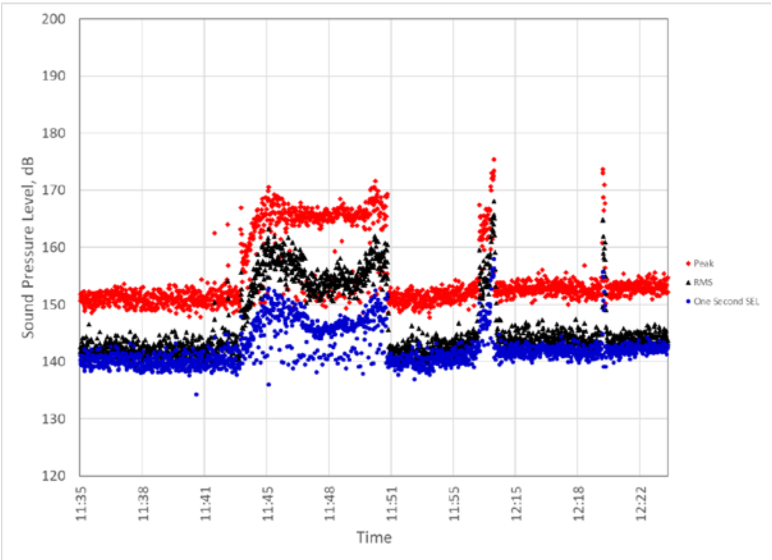

Figure D-19. Time History Plot of the Installation of 24-inch Concrete Pile #2 with a Diesel Impact Hammer on October 3rd, 2019 at 50 meters

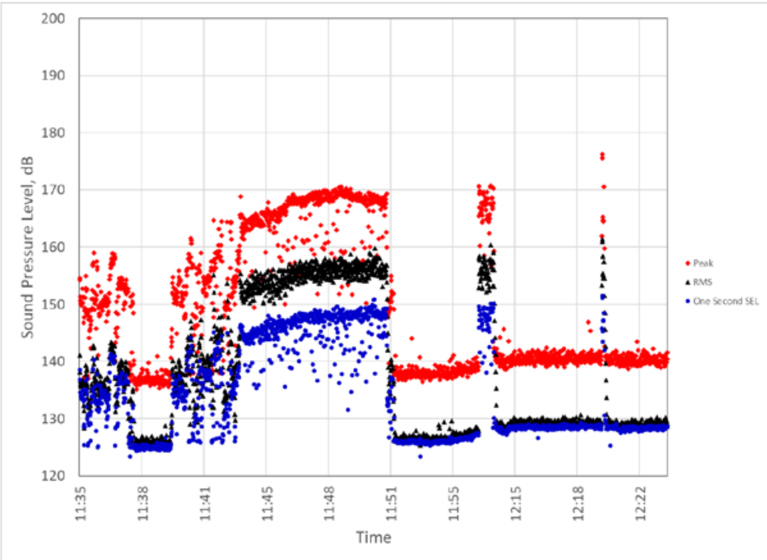

Figure D-20. Time History Plot of the Installation of 24-inch Concrete Pile #2 with a Diesel Impact Hammer on October 3rd, 2019 at 195 meters