Description of Underwater Noise Attenuation System
Design Unit 6

for the

New NY Bridge Project

Revision 2
June 4, 2014

Prepared by

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1.0 Introduction

The Pile Load Test (PLT) Program includes an underwater noise monitoring program for the installation of the test piles. The purpose of this noise monitoring program is to confirm that the underwater noise attenuation system (NAS) intended for use during production impact pile driving achieves its design goal of minimizing (to the maximum extent practicable) the effects of underwater noise during pile driving on fishes in the Hudson River. This program is being conducted pursuant to the following Tappan Zee Hudson River Crossing project requirements:

- New York State Thruway Authority (NYSTA) Tappan Zee Hudson River Crossing Project DB Contract Document Part 3 Project Requirements, Section 3 (P3PR3) Environmental Compliance, Conformed November 2012 and other applicable sections;
- New York State Department of Environmental Conservation (NYSDEC) DEC ID 3-9903-00043/00012-0014 (NYSDEC Permit); and
- National Marine Fisheries Service (NMFS) Biological Opinion (BO) April 10, 2013.

Underwater noise monitoring is conducted to verify that the NAS is deployed and operating in accordance with design specifications and determine compliance with underwater noise attenuation requirements.

Tappan Zee Constructors, LLC, (TZC) provided NYSTA and NYSDEC with a report titled *Description of Pile Load Test Program and Underwater Noise Attenuation System for the Tappan Zee Hudson River Crossing (PLT-NAS Description)* in July 2013. That report compared the NASs that were considered for possible adoption based upon the 2012 Pile Installation Demonstration Program (PIDP). The report also described the multi-tier bubble curtain which was selected for further testing. The *PLT-NAS Description* indicates the following criteria are being used to determine the effectiveness of the NAS:

1. Attenuation – System has achieved at least a 10 dB single strike sound exposure level (SELss) reduction during impact pile driving;
2. Ensonified Area – System has attenuated underwater noise to achieve the distances to the required NMFS and NYSDEC thresholds during pile driving that were established by the NMFS BO Term and Condition 9 and by NYSDEC Permit Condition 14; and
3. System Operation and Compatibility – System can be safely deployed and retrieved repeatedly during production pile driving without impact to pile driving requirements and project schedule.

The *PLT-NAS Description Report* demonstrated that the multi-tier bubble curtain can achieve at least a 10 dB SEL attenuation during impact pile driving and that the system could be safely deployed and retrieved repeatedly during production pile driving. As such, the multi-tier bubble curtain was selected for further testing during test pile installation. The report also provided a plan for testing the NAS to determine whether or not the required distances to the NMFS and NYSDEC thresholds are being achieved.

Test pile installation monitoring results provide guidance on operational specifications of the NAS monitoring, as well as the monitoring locations for production pile driving. The purpose of the present Report is to provide the results of the underwater noise monitoring during installation of test piles for the Design Unit 6 (see Attachment 1) and based on those results, provide the design plans and anticipated operational specifications for the NAS for Design Unit 6 in accordance with the following NYSDEC Permit Conditions 8 and 9:

> 8. The results of sound attenuation tests conducted during the 2012 Pile Installation Demonstration Program (PIDP); and any additional test results from underwater sound attenuation studies during the 2013 PIDP2 will be used to determine the most effective underwater sound attenuation system. An underwater sound attenuation system or

systems must be deployed during driving of steel piles [redacted] to minimize to the maximum extent practicable the effects of underwater sound upon fishes in the Hudson River.

9. At least 30 days before starting installation of permanent piles [redacted] within each specific in-river design unit (as identified in the March 21, 2013 letter) the Permittee must give the Department design plans and operational specifications for the underwater sound attenuation system for that design unit. Except for piles installed during the 2013 PIDP2, installation of piles [redacted] may begin when the Department has given written approval of the underwater sound attenuation system for each in-river design unit. Upon Department approval the final sound attenuation plan will be posted on the project website maintained by the Permittee.

2.0 Test Piles

The Pile Load Test Program uses test piles in each of the 10 design units plus the Main Span (11 total design units), with the primary purpose to confirm pile load capacities. Design Unit 6 consists of [redacted] piles in Piers 21 to 25. Test piles were installed with IHC S-280 and IHC S-800 impact hammers. A summary of the impact pile driving for test piles at Design Unit 6 is provided in Table 1.

Table 1. Summary of Impact Pile Driving for Test Piles at Design Unit 6

Test Pile	Pile Diameter	Impact Hammering Date
PLT-110	[redacted]	9/6/2013
PLT-109 (Day 1)*	[redacted]	10/4/2013
PLT-109 (Day 2)*	[redacted]	10/7/2013

***PLT-109 was installed over two separate days.**

3.0 Unconfined Multi-tier Bubble Curtain NAS Design

Based on the NAS effectiveness determination in the *PLT-NAS Description*, the unconfined multi-tier bubble curtain was selected for further testing during test-pile installation. Refer to Attachment 2 for engineering details on the system.

3.1 NAS Components

The unconfined multi-tier bubble curtain consists of aluminum bubbler rings suspended from the pile-driving template at four points, spaced a maximum of 10 feet vertically, and connected to the template using ½”-diameter wire rope. See Attachment 2 for bubbler ring dimensions and hole diameter, spacing, and orientation.

The aluminum ring is connected to a dedicated compressor (Figure 1). This compressor is connected to a reservoir tank to allow a continuous supply of air throughout pile driving (Figure 1). During the installation of test piles, a flow meter and air pressure gauge are used to measure air flow and pressure (Figure 2). The air compressor is capable of supplying an air pressure of up to 100 pounds per square inch (psi) at an air flow of 1600 cubic feet per meter (cfm) to each bubbler ring (Attachment 3). The reservoir tank allows the system to supply an air flow of up to 2000 cfm, to each bubbler ring, as was demonstrated during testing.

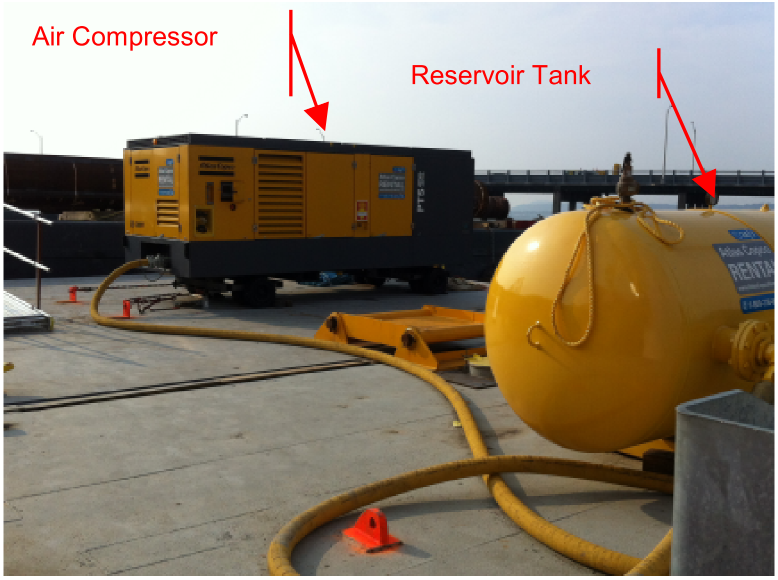

Figure 1. Air Compressor and Reservoir Tank

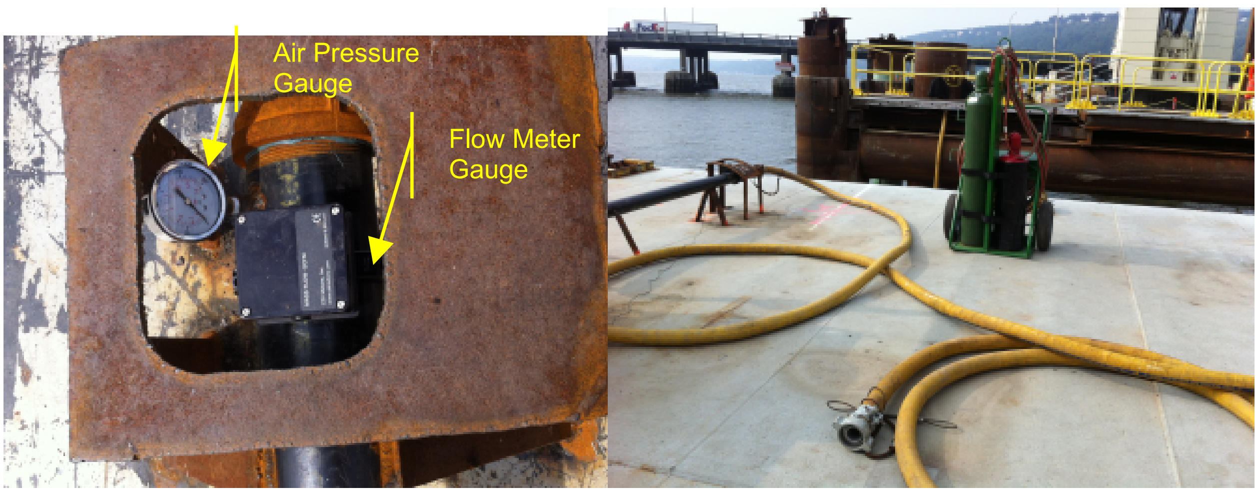

Figure 2. Flow Meter and Pressure Gauge on Outlets from the Reservoir Tank to the Bubbler Ring

3.2 NAS Deployment and Operation

The NAS deployment and operation proceeded as expected. After the piles were initially driven with the vibratory hammer, the bubble curtain ring was deployed with a crane and hung from the secondary template using wire rope slings and shackles (Figure 3). The air compressor/reservoir tank pumped air into the ring (Figure 4), the impact hammer was lofted, the piles were tapped (i.e., a series of minimal energy strikes), and then driven to the required depth.

Figure 3. Deployment of the Unconfined Multi-tier Bubble Curtain

Figure 4. Operation of the Multi-tier Bubble Curtain

4.0 Underwater Noise Monitoring During Test Pile Installation

4.1 Methods

Details of the equipment, the calibration of the equipment, the data collected, and the signal processing for underwater noise monitoring are included in the Underwater Noise Monitoring Plan. Details on the underwater noise monitoring during the installation of PLT 110, PLT 109 (Day 1), and PLT 109 (Day 2) are provided in the Daily Memoranda for each day of pile driving (Attachment 1).

Figure 5 illustrates a typical barge and hydrophone arrangement for [redacted] piles. As seen in Figure 5, a real time Autonomous Multichannel Acoustic Recorder (AMAR-RT) and two Autonomous Multichannel Acoustic Recorders (AMARs) were generally placed at the distances of the noise level thresholds predicted in the NMFS BO (although locations varied based on conditions, such as vessel traffic and currents). The AMAR-RT was continuously monitored through-out the pile driving process while data collected from the AMARs was downloaded following pile driving. The noise level thresholds predicted in the NMFS BO (April 2013) are as follows:

- peak SPL (sound pressure level) – located on the barge or survey vessel, approximately 33 feet from the pile, based on the distance that can be safely recorded (the distance to the 206 re 1 μPa peak SPL isopleth for [redacted] piles is 20 feet)
- cSEL (cumulative Sound Exposure Level) – located approximately 132 feet from the pile, based on the distance from the pile to the 187 dB re 1 μPa^2-s cSEL isopleth for [redacted] piles
- rms SPL (root mean square SPL) – located approximately 400 feet from the pile, based on the distance from the pile to the 150 dB re 1μPa rms SPL for [redacted] piles

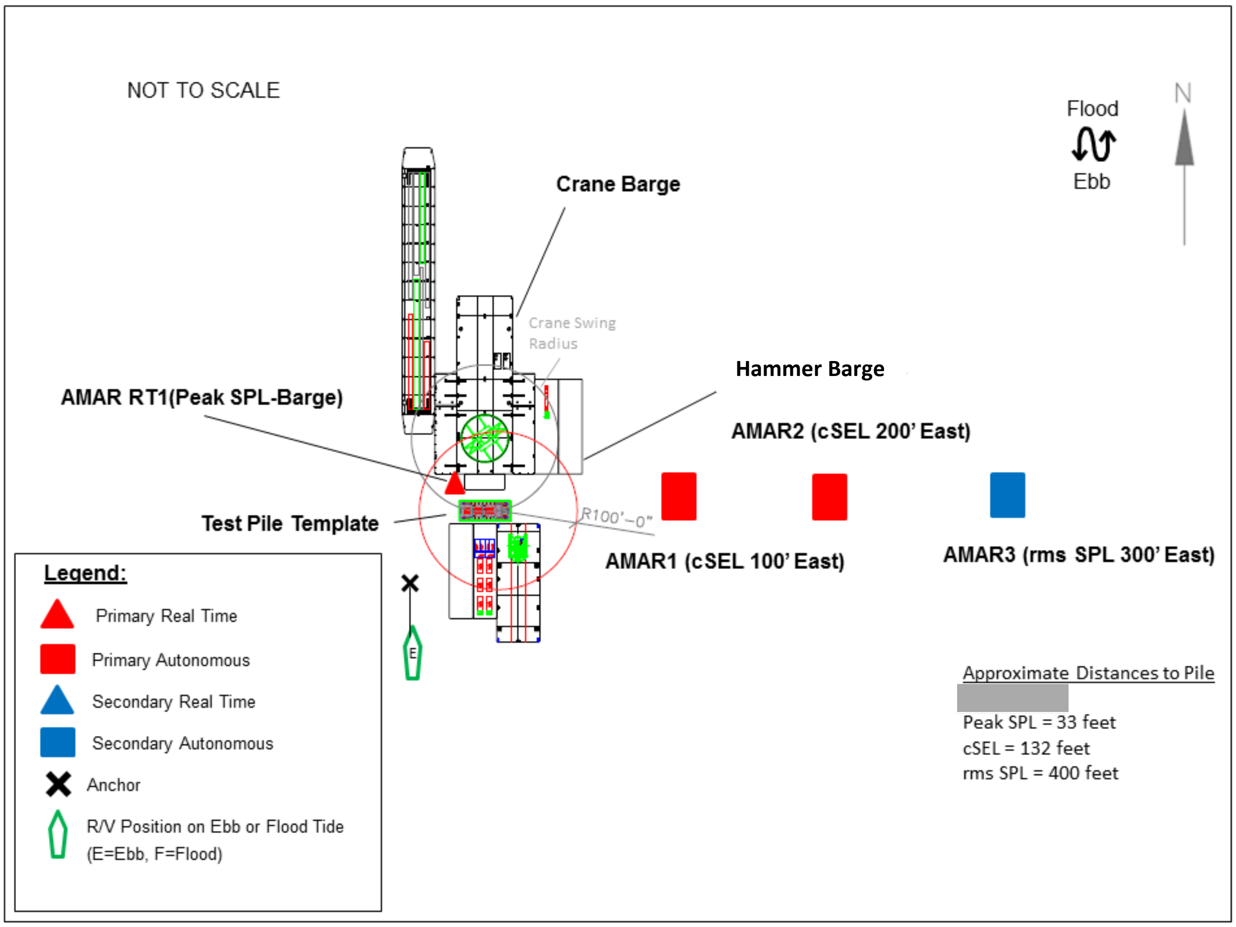

Figure 5. Plan View of a Typical Test Pile Barge Arrangement and Hydrophone Locations for [redacted] piles

Test pile installation for Design Unit 6 occurred during a variety of river current conditions (ebb flood, and slack currents). Hydrophones (AMARs) were strategically placed to capture data to analyze variation in the performance of the NAS correlated with variation in the river current and barge placement. During the installation of PLT 110 the NAS was tested up-current and cross-current in a 0. 6-knot ebb current. During the installation of PLT 109 (Day 1) the NAS was tested up-current in a 0.6-0.8-knot ebb current. During the installation of PLT 109 (Day 2) the NAS was tested down-current in a 0.6-0.8 knot flood current. Table 2 provides a summary of the underwater noise monitoring equipment deployment and position relative to the current for the driving of the two test piles.

Table 2. Equipment Deployment and Position Relative to Current for PLT 110, PLT 109 (Day 1), and PLT 109 (Day 2)

Date/Test Pile No.	Hydrophone ID	Location Relative to Pile*	Location Relative to Current	Current During Pile Driving	Distance to Pile (ft)	Water depth (ft)
9/6/2013 PLT 110	AMAR-RT 11	Peak SPL- Barge	Up-current	Ebb (0.5 – 1.6 knots)	33	18
	AMAR-175	cSEL 100' East	Cross-Current		132	18
	AMAR-221	cSEL 200' East	Cross-Current		221	18
	AMAR-228	rms SPL 300' East	Cross-Current		389	20
10/4/2013 PLT 109 (Day 1)	AMAR-RT 11	Peak SPL Barge	Up-current	Ebb (0.6 knots)	29	13
	AMAR-175	cSEL North	Up-current		263	13
	AMAR-228	rms SPL North	Up-current		707	11
10/7/2013 PLT 109 (Day 2)	AMAR-RT 11	Peak SPL Barge	Down-Current	Flood (0.6 – 0.8 knots)	33	13
	AMAR-175	cSEL North	Down-Current		264	13
	AMAR-228	rms SPL North	Down-Current		835	12

*Locations correspond to the hydrophone locations labeled in Figure 5 and are based on the following:

- peak SPL – located on the barge or survey vessel, approximately 40 feet from the pile, based on the distance from the pile to the 206 re 1 μPa peak SPL isopleth for piles
- cSEL- located approximately 132 feet from the pile, based on the distance from the pile to the 187 dB re 1 μPa^2-s cSEL isopleth for piles
- rms SPL – located approximately 400 feet from the pile, based on the distance from the pile to the 150 dB re 1μPa rms SPL for piles

The tests for this design unit were informed by the previous testing within the PLT program where air flow was varied throughout pile driving but never independently of other variables, such as impact hammer energies or tidal conditions. All tests were performed at a range of tidal conditions and hammer energies which could be expected during production pile driving. Table 3 provides the number of rings deployed and the NAS settings during the installation of the two test piles.

Table 3. Description of NAS During Installation of Test Piles for Design Unit 6

Date/ Test Pile No.	Water Depth (ft)	Number of Rings	Air Flow (cfm) per Bubbler Ring	Air Pressure (psi)
9/6/2013 PLT 110	18	2	1400-1750	60-66
10/4/2013 PLT 109 (Day 1)	13	2	1050-1100	40
10/7/2013 PLT 109 (Day 2)	13	2	1750-1800	65

4.2 Results

4.2.1 NMFS Physiological and Behavioral Thresholds

In accordance with the NMFS BO Term and Condition Number 6, the monitoring program estimated (i) the peak sound pressure level (peak SPL in dB re 1 µPa) at each recorder and the distance from the pile at which the peak SPL exceeds the 206 dB re 1 µPa peak, (ii) the cSEL at each recorder and the distance from the pile at which the cSEL exceeds 187 dB re 1 µPa^2·s at the end of pile driving[1], and (iii) the rms SPL at each recorder and the distance from the pile at which rms SPL exceeds 150 dB re 1 µPa.

Table 4 provides a summary of the underwater noise levels measured at each recorder during the test pile installation. Table 5 provides the diameter of the sound level isopleths that serve as the NMFS physiological and behavioral thresholds. **These results show that when the NAS was operational, the diameter of the 206 dB re 1 µPa peak SPL did not exceed NMFS requirement of 40 feet for at Design Unit 6.** The largest diameter of the 206 dB re 1 µPa peak SPL isopleth was 17-ft, which is similar to the 206 dB re 1 µPa peak SPL for the NASs tested during the 2012 PIDP. Specifically, during the 2012 PIDP the diameters of the 206 dB re 1 µPa peak SPL isopleth were 15 – 40 feet for [redacted] piles (JASCO 2012)[2]. Furthermore, the estimated diameter of the isopleth at the end of installation of test piles that corresponded to 187 dB re 1 µPa^2-s cSEL never exceeded 146-ft. The river width is approximately 15,000 ft; therefore a fish movement corridor of more than one mile [5,280 ft], which was continuous for more than 1,500 ft, was maintained throughout pile driving, in accordance with NYSDEC Permit Condition 14.

Table 4. Summary of the Measured Sound Levels at Each Recorder During the PLT 110, PLT 109 (Day 1), and PLT 109 (Day 2)

Date Test Pile No.	Location*	Max. peak SPL (dB re 1 µPa)	cSEL (dB re 1 µPa^{2-}s)**
9/6/2013 PLT 110	Peak SPL Barge	192	195
	cSEL 100’ East	177	180
	cSEL 200’ East	171	176
	rms SPL 300’ East	166	166
9/4/2013 PLT 109 (Day 1)	Peak SPL Barge	192	192
	cSEL North	163	162
	rms SPL North	159	152
9/7/2013 PLT 109 (Day 2)	Peak SPL Barge	188	197
	cSEL North	166	171
	rms SPL North	153	159

*Locations correspond to the hydrophone locations labeled in Figure 5 and are based on the following:

- peak SPL – located on the barge or survey vessel, approximately 33 feet from the pile, based on the distance from the pile to the 206 re 1 µPa peak SPL isopleth for [redacted] piles
- cSEL- located approximately 132 feet from the pile, based on the distance from the pile to the 187 dB re 1 µPa^2-s cSEL isopleth for [redacted] piles
- rms SPL – located approximately 400 feet from the pile, based on the distance from the pile to the 150 dB re 1µPa rms SPL for [redacted] piles

**At the completion of pile driving.

[1] cSEL increases as the number of strikes increases therefore; the diameter of the 187 dB isopleth also reaches a maximum at the end of piling.
[2] JASCO. 2012. Underwater Acoustic Monitoring of the Tappan Zee Bridge Pile Installation Demonstration Project.

Table 5. Diameters of Sound Level Isopleths that Represent NMFS Physiological and Behavioral Impact Threshold

Measurement		PLT 110	PLT 109 (Day 1)	PLT 109 (Day 2)
Pile Installation Duration (hh:mm)*		00:25	00:05	00:22
Approximate Diameter (ft) of Isopleth	206 dB re 1 µPa peak SPL	13	17	10
	187 dB re 1 µPa^2-s cSEL	140	84	146
	150 dB re 1 µPa rms SPL	572	478	476

* Net pile driving times are rounded to the nearest minute.

4.2.2 NAS Performance

The NAS was tested in ebb, flood, and slack currents with hydrophones located in up-current, down-current, and cross current positions (Table 2). Current speed ranged from 0.5 to 1.6 knots. Air flow settings ranged from air pressures of 40 to 66 psi and air flows of 1050 to 1800 cfm.

During the installation of the PLT 110 the NAS was tested in an ebb current, with speed ranging from 0.5 to 1.6 knots. Air pressure and air flow was relatively constant at 60-66 psi and 1400 to 1750 cfm, respectively, throughout the installation of PLT 110, except for a brief period where the NAS was inadvertently turned off. Hammer energy was increased independently of river current and NAS air flow. Hammer energies of 125-280 kip-ft were used. Sound levels measured at all hydrophones remained constant throughout the installation of PLT 110 while the NAS was in operation despite variation of the hammer energy. When the NAS was off, the maximum SELss recorded was approximately 180 dB re 1µPa^2•s versus approximately 165 dB re 1µPa^2•s recorded while the NAS was functional (Attachment 1: Daily Memorandum for Underwater Noise Monitoring for PLT 110). The thresholds required by the NMFS BO and NYSDEC permit were not exceeded when the NAS was operating during the installation of the PLT 110. The estimated diameter of the 206 dB re 1 µPa peak SPL isopleth using only the 15 strikes that occurred in the approximately 11 seconds when the NAS was turned off was 41 feet.

During the installation of PLT 109 (Day 1) the NAS was tested in an ebb current. Air pressure and air flow were 40 psi and 1050–1100 cfm, respectively, throughout the pile installation. The hammer energy remained constant at 160 ± 6 kip-ft. River currents were constant at approximately 0.6 knots during active pile driving. The measured sound levels at all measurement locations showed minimal variation at ± 2 dB (Attachment 1: Daily Memorandum for Underwater Noise Monitoring for PLT 109 [October 4, 2013]). The 206 dB re 1 µPa peak SPL limit as set forth by the NMFS BO was not exceeded during the installation of this test pile.

During the installation of PLT 109 (Day 2) the NAS was tested in a flood current with ranging from 0.6 to 0.8 knots. Air pressure and air flow remained constant at 65 psi and 1750–1800 cfm, respectively, for the duration of pile driving. Three distinct hammer energies were used for the installation of the pile. For the first 1,117 strikes the hammer energy was 160 kip-ft; hammer energy was then increased to 250 kip-ft for 73 strikes and finally 380 kip-ft for 16 strikes. The distance to 206 dB re 1 µPa peak SPL isopleth as set forth by the NMFS BO was not exceeded during the installation of this test pile. (Attachment 1: Daily Memorandum for Underwater Noise Monitoring for PLT 109 [October 7, 2013], Table 5).

PLT-109 was driven with the S-280 hammer on 04 October and completed on 07 October using the S-800 hammer, with significantly different river currents and NAS settings (Table 6). Despite these differences, the size of the isopleths corresponding to the noise criteria were similar between days (Table 7). In both cases the values are well within the permit limits.

Table 6. Pile driving, NAS, and environmental conditions for the pile driving of PLT-109 on 04 and 07 October 2013.

Date	Pile driving hammer			NAS settings		Environmental conditions	
	Hammer	Mean hammer energy (± SD, kip-ft)	Strikes	Air pressure (psi)	Airflow rate (cfm)	Current	Speed (knots)
04 Oct	S-280	160 (6.0)	207	40	1050–1100	Ebb	0.6
07 Oct	S-800	160 (21.7)	1206	65	1750–1800	Flood	0.6 - 0.8

Table 7. Diameter (ft) of acoustic monitoring criteria isopleths from the pile driving of PLT-109 on 04 and 07 October 2013.

Date	206 dB re 1 µPa peak SPL	187 dB re 1 µPa^2·s cSEL*	150 dB re 1 µPa rms SPL†
04 Oct	17	84	478
07 Oct	10	146	476

* Assuming 1206 strikes for each hammer
† 1 s integration time

Overall there was very little variation in sound propagation was noted during the testing for each individual test pile under air pressure settings, current conditions, measurement locations and hammer energies; however, the distances to the NMFS and NYSDEC required thresholds were not exceeded during installation of test piles for Design Unit 6.

4.3 Conclusions

In accordance with NYSDEC Permit Condition 8, "an underwater noise attenuation system or systems must be deployed during the driving of steel piles [redacted] to minimize to the maximum extent practicable the effects of underwater sound upon fishes in the Hudson River." The *PLT-NAS Description* concludes that the most effective system is the one that will be capable of attenuating noise to achieve the distance thresholds required by NMFS in the BO and that can be safely deployed and retrieved repeatedly during production pile driving without affecting pile driving requirements and project schedule.

Results of test pile installation indicate that the unconfined multi-tier bubble curtain with bubble rings spaced a maximum of ten feet vertically, is effective in minimizing noise in order to meet the NMFS and NYSDEC requirements. Not only did the NAS meet the requirements in full ebb and flood currents and for various NAS settings, underwater noise isopleths were smaller than anticipated by the NMFS BO. Results indicate that the largest estimated width of the 206 dB re 1µPa peak SPL isopleth was measured at 17 ft as compared to the 40 ft predicted by the NMFS BO. These results indicate that the size of the 206 dB re 1 µPa isopleth measured for the [redacted] piles in 13-18 ft of water was smaller than the 206 dB re 1 µPa isopleths measured during the 2012 PIDP. Furthermore, the diameter of the 187 dB re 1 µPa^2-s cSEL isopleth at the end of installation of each pile was never estimated to be more than 146 ft. Therefore, the noise levels across the majority of the river at the construction site would be less than 187 dB cSEL, and would thus provide the required corridor for sturgeon migration through the site.

5.0 NAS Design Plan and Operational Specifications

The installation of the test piles also demonstrated that the unconfined multi-tier bubble curtain is readily and safely deployable and retrievable. Given these logistical attributes, combined with the proven effectiveness at obtaining required distances to NMFS and NYSDEC thresholds, the unconfined multi-tier bubble curtain is considered most effective to minimize harm to fish in the Hudson River, to the maximum extent practicable.

During production pile driving for Design Unit 6, the unconfined multi-tier bubble curtain will be deployed and retrieved in a similar manner to the PLT 110 and PLT 109 pile installations. Based on dredging and armoring, the river bottom at Design Unit 6 will be approximately -11 feet at mean lower low water (MLLW). Bubbler rings and compressors will be deployed for each pile, so that vertical spacing in the water column is a maximum of 10 feet or less at mean higher high water (MHHW). That is, the NAS will consist of two bubbler rings in Design Unit 6, unless water depth is 20 feet or greater, in which case, three rings will be deployed. The NAS will be deployed according the Construction Work Plan. Table 8 provides the range of water depths at each Design Unit 6 pier and the anticipated number of bubble curtain rings to be deployed for pile driving at that pier.

Table 8. Range of Water Depths at Each Design Unit 6 Pier and the Number of Bubble Curtain Rings to be Deployed

Pier Number	Approximate Water Depth (feet)	Number of Bubble Rings*
21	11-13	2
22	11-13	2
23	11-13	2
24	11-14	2
25	15-18	2

*The number of bubbler rings at specific piles within a pier is subject to change, based on field measurements of water depth during pile installation. Two rings will be deployed for pile driving at Design Unit 6, unless water depth is 20 feet or greater, in which case, three rings will be deployed.

The NAS system contains three valves at the:

1. air compressor outlet to the reservoir tank (Figure 6),
2. reservoir tank inlet (Figure 7),
3. reservoir tank outlet (Figure 8) to the bubbler ring.

Prior to impact pile driving, the compressor will be turned on and the valves will be open such that air will be supplied to the bubbler rings individually to visually confirm sufficient air to each ring. All valves will be opened during the operation of the bubble curtain. The bubble curtain will remain on during periods of active pile driving. The air pressure gauge will be used to monitor NAS operation during production pile driving. Air pressure at the outlet from the reservoir tank will be maintained at a target pressure of between 60 and 80 psi with a minimum pressure of 40 psi to each bubbler ring (Figure 9).

The following will be checked for each of the piles at each pier within Design Unit 6 (as outlined in the Construction Work Plan):

- Reservoir tank is pressurized prior to pile driving.
- The tank inlet and outlet valves are open immediately prior to starting the compressor.
- Air pressure at each reservoir tank outlet approximately 5 minutes after pile driving begins.
- Visual inspection of the water surface for sufficient air bubbles.

Figure 6. Valve at the Air Compressor Outlet to the Reservoir Tank

Figure 7. Valve at the Reservoir Tank Inlet

Figure 8. Valve at the Outlet from the Reservoir Tank to the Bubble Curtain

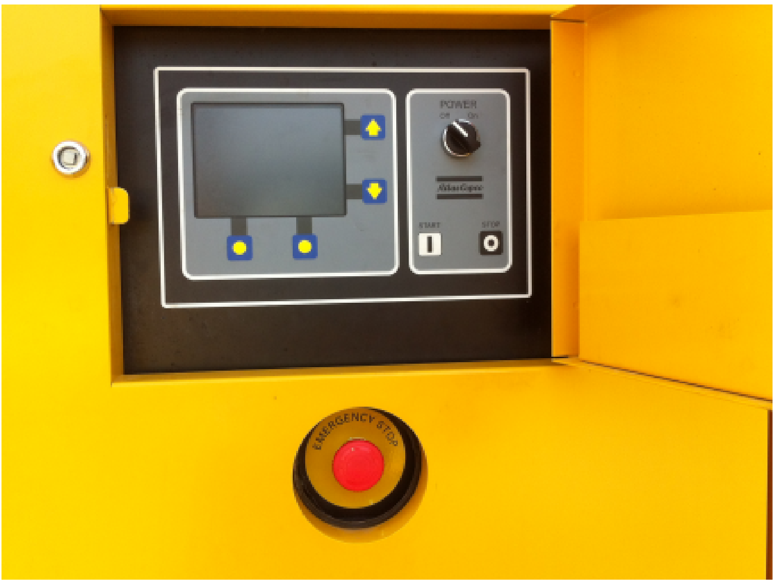

Figure 9. Air Compressor Controls

Attachment 1 – Daily Memoranda for Underwater Acoustic Monitoring of the Tappan Zee Bridge Test Pile Installation

Underwater Acoustic Monitoring of the Tappan Zee Bridge Test Pile 110 Installation

Daily Memorandum for 06 September 2013

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17 March 2014

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1. Summary

1.1. Pile Location and Monitoring Summary

Test Pile PLT-110 is a [redacted] pile driven at the construction site of the New NY Bridge on the west side of the navigation channel on 06 September 2013 (Table 1). One real-time acoustic monitoring system and three autonomous acoustic monitoring systems were deployed by JASCO (Section 4) on behalf of Tappan Zee Constructors, LLC (TZC) (Figure 1 and Table 2). Pile driving occurred between 16:19–17:34 Eastern Daylight Time (EDT), and full ebb current occurred at 17:09 EDT.

Table 2 provides the sound levels measured at each recorder. Plots of the measured values, frequency distributions of 1/3-octave-band single-strike sound exposure levels (SELss), and sound level statistics for the distribution of the measured data are presented in Appendix A.

Table 1. Summary of Test Pile PLT-110 activities, 06 September 2013.

Date:	06 September 2013
Pile-Driving Activity	
Test pile identifier:	PLT-110
Pile diameter:	[redacted]
Water depth:	18 ft
Hammer type:	Impact (IHC S-800)
Total hammer strikes:	[redacted]
Total penetration:	[redacted]
Net duration of pile driving (hh:mm:ss):	00:25:11
Maximum single strike energy:	283.3 thousand foot-pounds (kip-ft), (384 kJ)
Total energy transferred:	220,797 kip-ft (299 MJ)
Noise Attenuation System (NAS)	
Two-tier unconfined bubble curtain airflow rate:	1400–1750 cubic feet minute (cfm), 60–66 pounds per square inch (psi)
River conditions during pile driving:	Ebb tide, 0.5–1.6 knots (0.25–0.8 meters per second [m/s] depth dependent; Table 6 and Figure 7)

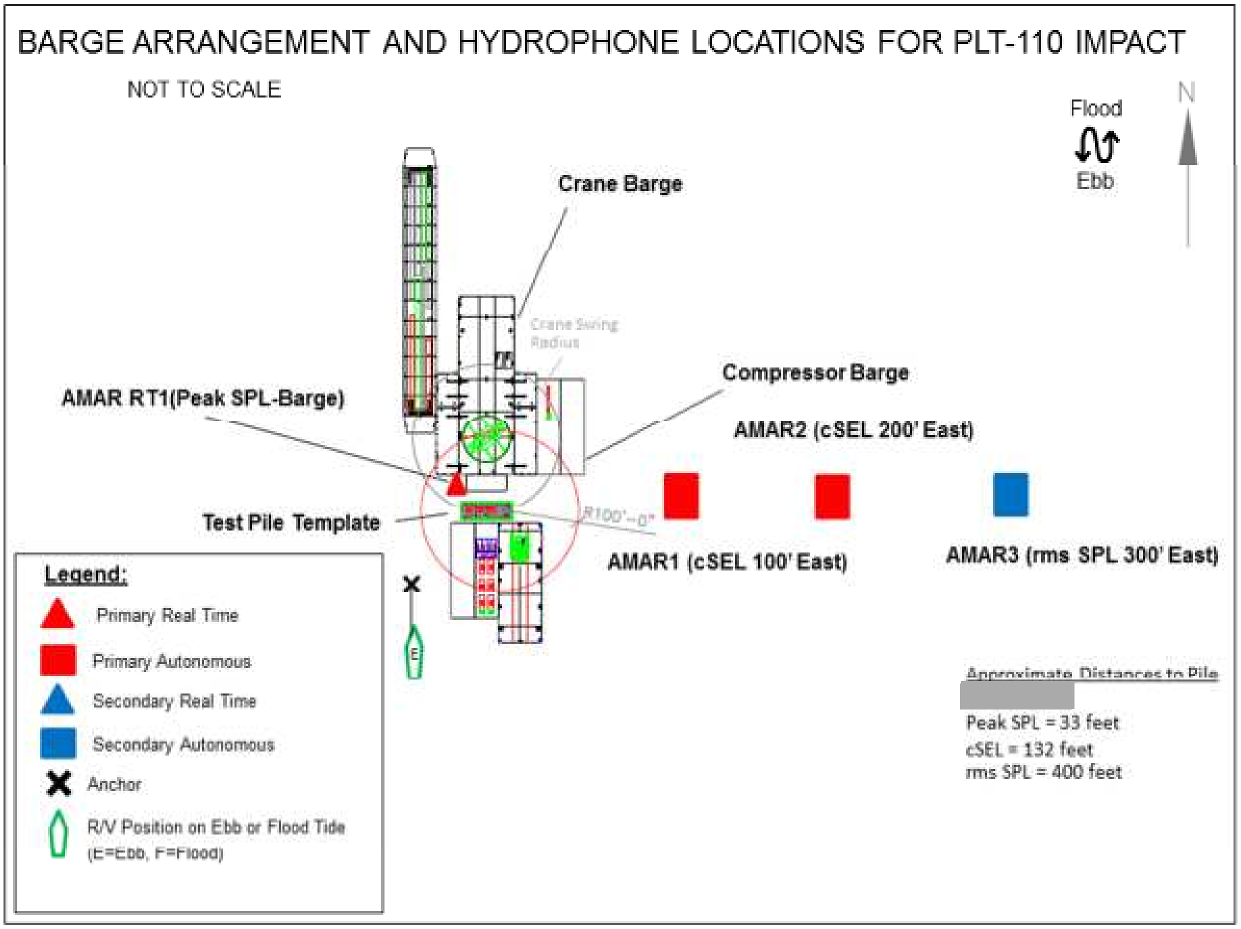

Figure 1. Plan view of pile and barge layout, 06 September 2013, PLT-110.

Table 2. Summary of Autonomous Multichannel Acoustic Recorders (AMAR) locations and measured sound levels. Detailed sound level plots are contained in Appendix A.

Location	Recorder ID	Distance to pile (ft)	Water depth (ft)	Max peak SPL (dB re 1 µPa)	cSEL (dB re 1 µPa^{2}s*)
Peak SPL Barge (up current)	AMAR-RT-11	33	18	192	195
cSEL 100' East (cross current)	AMAR-175	132	18	177	180
cSEL 200' East (cross current)	AMAR-221	221	18	171	176
rms SPL 300' East (cross current)	AMAR-228	389	20	166	166

* Estimated at each recorder by multiplying the mean of the per-strike SEL by the number of strikes reported by the pile driving contractor, for the final value at the recorder, representing the total energy at the end of pile driving.

1.2. NMFS Physiological and Behavioral Thresholds

The distances from pile driving to the noise levels that serve as the National Marine Fisheries Service (NMFS) physiological and behavioral thresholds were extrapolated using a logarithmic regression based on mean values of the peak sound pressure level (SPL), root-mean-square (rms) SPL, and SELss from each recorder (Table 3 and Figure 2).

The regression indicates that the estimated diameter of the 206 dB re 1 µPa peak SPL isopleth was approximately 13 ft, and did not exceed NMFS criteria of a diameter of 40 ft for [redacted] piles. The diameter of the 187 dB re 1 µPa^2·s cumulative sound exposure level (cSEL) isopleth was estimated to be 140 ft at the end of pile driving. Since cSEL increases as the number of strikes increases, the diameter of the 187 dB isopleth was smaller than 140 ft for most of the pile driving operation. No other pile driving occurred during this pile load test. The river width is approximately 15,000 ft; therefore, a fish-movement corridor of more than one mile, which was continuous for more than 1,500 ft, was maintained throughout pile driving in accordance with New York State Department of Environmental Conservation (NYSDEC) Permit Condition 14.

Table 3. Estimated isopleth diameters for the NMFS physiological and behavioral thresholds.

Criteria	Estimated diameter (ft)
206 dB re 1 µPa peak SPL	13
187 dB re 1 µPa^2·s cSEL*	140
150 dB re 1 µPa rms SPL (1 s integration time)	572

* At the end of pile driving

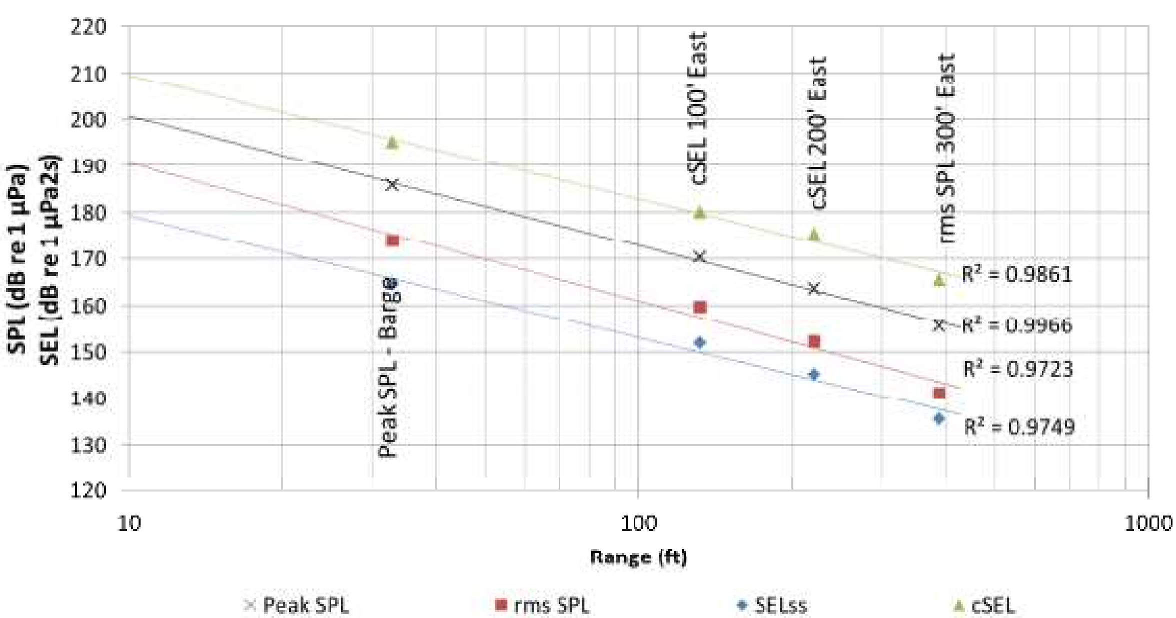

Figure 2. Regression based on mean values of the SELss, peak SPL, cSEL, and rms SPL from each recorder from pile driving of Test Pile PLT-110, 06 September 2013. SELss, peak SPL, and rms SPL are instantaneous values. The cSEL represents total sound energy measured during the pile driving.

1.3. Observations

The recorder at location cSEL 100’ East (AMAR-175) was dragged by a tug boat at 16:40 EDT. After that time its position was no longer certain, so data are not included for AMAR-175 after that point. There was a brief period (16:24:37–16:25:19) of pile driving that occurred without the NAS operating. During this period, peak SPL levels of 206 dB re 1 µPa were measured at location Peak SPL Barge (Figure 8) and SELss increased by 10–15 dB at each measurement location (Figure 3). The estimated diameter the 206 dB re 1 µPa peak SPL isopleth using only the 15 strikes that occurred without the NAS was 41 feet for approximately 12 seconds (Figure 4).

The hammer energy during pile driving at PLT-110 varied from 125–280 kip-ft (Figure 3, Figure 5). The NAS air pressure and airflow were nearly constant at 60–65 psi and 1400–1750 cfm (Figure 3, Table 5). Pile driving occurred during the ebb tide, with an approximate average current of 0.5 to 1.6 knots (Figure 3, Figure 7); however, the only observable effect on the measured sound occurred when the NAS was temporarily turned off (Figure 3).

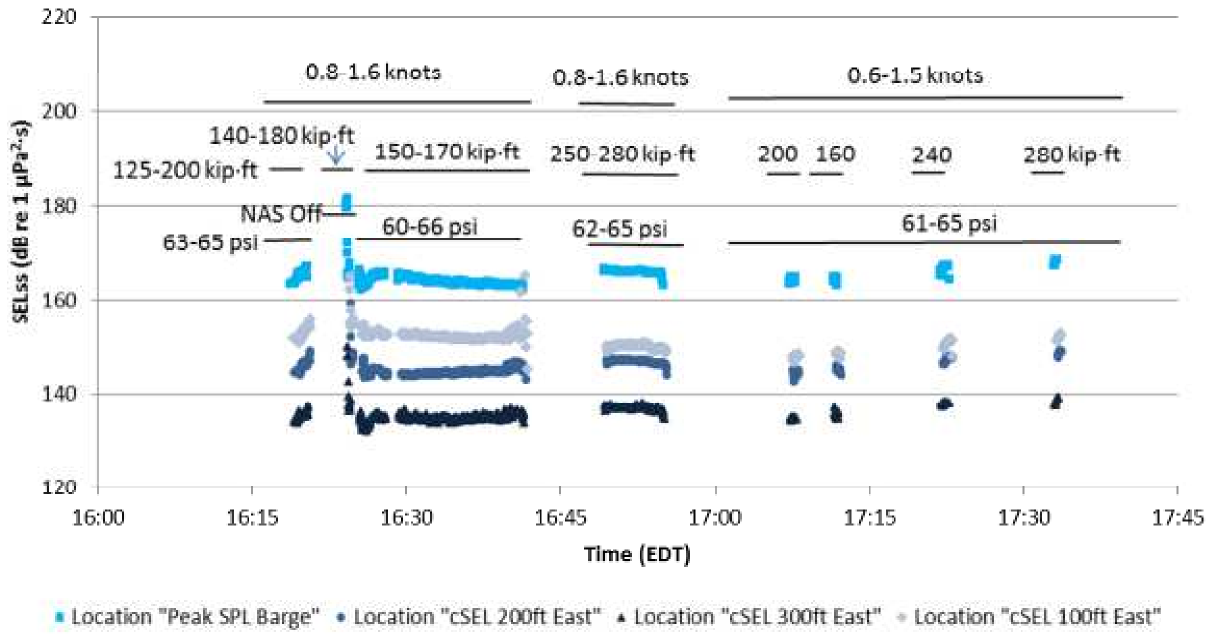

Figure 3. SELss at each location annotated with hammer energy (kip-ft), NAS air pressure (psi), and river current (knots).

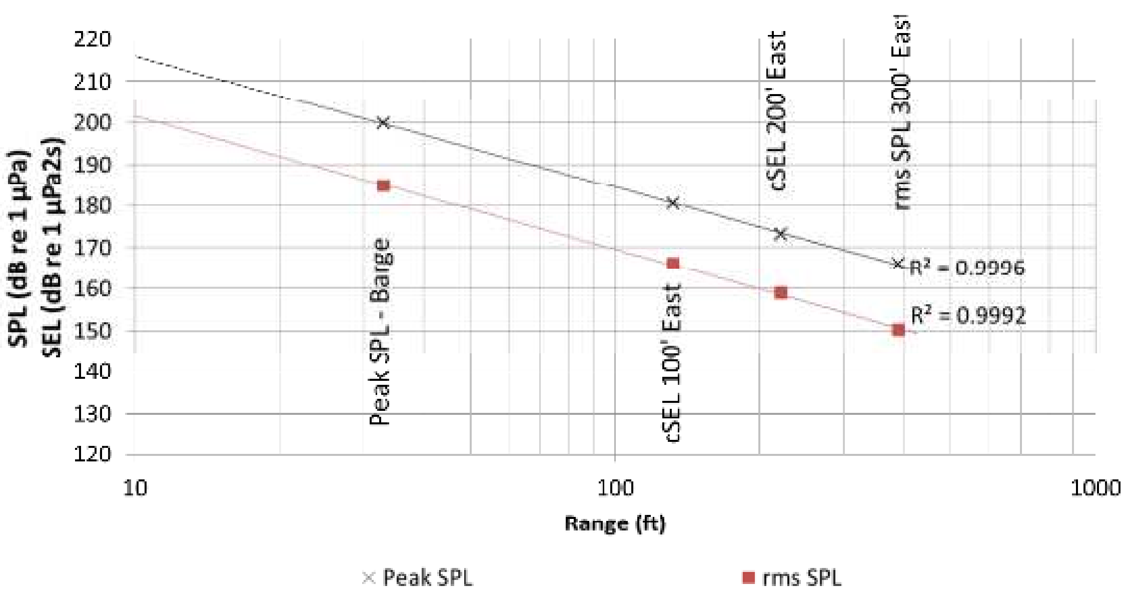

Figure 4. Regression based on mean values of the peak SPL and rms SPL from each recorder from pile driving of Test Pile PLT-110, 06 September 2013 for the 15 strikes (for approximately 12 seconds) when the NAS was disabled. peak SPL, and rms SPL are instantaneous values.

2. Activity Logs

2.1. Log of JASCO and Construction Activities

Table 4 provides activities for 06 September 2013.

Table 4. JASCO and construction activities for Test Pile PLT-110, 06 September 2013.

Time (EDT)	Activity
08:45	Arrive at Cornetta's, prep gear
09:30	Transit to job site
10:10	Begin deploying AMAR-221, AMAR-175, and AMAR-228
10:25	Transit to Hudson Harbor to standby
12:00	Transit to Cornetta's
13:15	Transit to Hudson Harbor to transfer to barge
13:30	Prepare AMAR-RT-11
14:00	Stand by
14:42	Deploy AMAR-RT-11; start crane picking hammer
16:19	Start pile driving
16:40	AMAR-175 dragged by a tugboat
17:34	Stop pile driving
17:45	Retrieve AMAR-RT-11
18:30	Retrieve AMAR-221, AMAR-175 and AMAR-228
18:45	All work complete

2.2. Pile Driving Logs

2.2.1. NAS

NAS used: Two-tier unconfined bubble curtain

NAS settings: 1400–1750 cfm, 60–66 psi

Table 5. NAS setting recorded during pile driving at Test Pile PLT-110, 06 September 2013.

Time (EDT)	Volume/min (cfm)	Pressure (psi)
16:19–16:21	1400–1650	63–65
16:24–16:28	1500–1700	60–65
16:29–16:41	1400–1750	60–66
16:49–16:55	1400–1650	62–65
17:07–17:09	1400–1650	62–65
17:12	1700–1650	62–65
17:22–17:23	1450–1700	61–65
17:33	1450–1700	61–65

2.2.2. Impact Hammering Log

Total energy: 220,797 kip-ft (299 MJ)

Total number of strikes: [redacted]

Maximum per-strike energy: 283.3 kip-ft (384 kJ)

Net pile driving duration (hh:mm:ss): 00:25:11

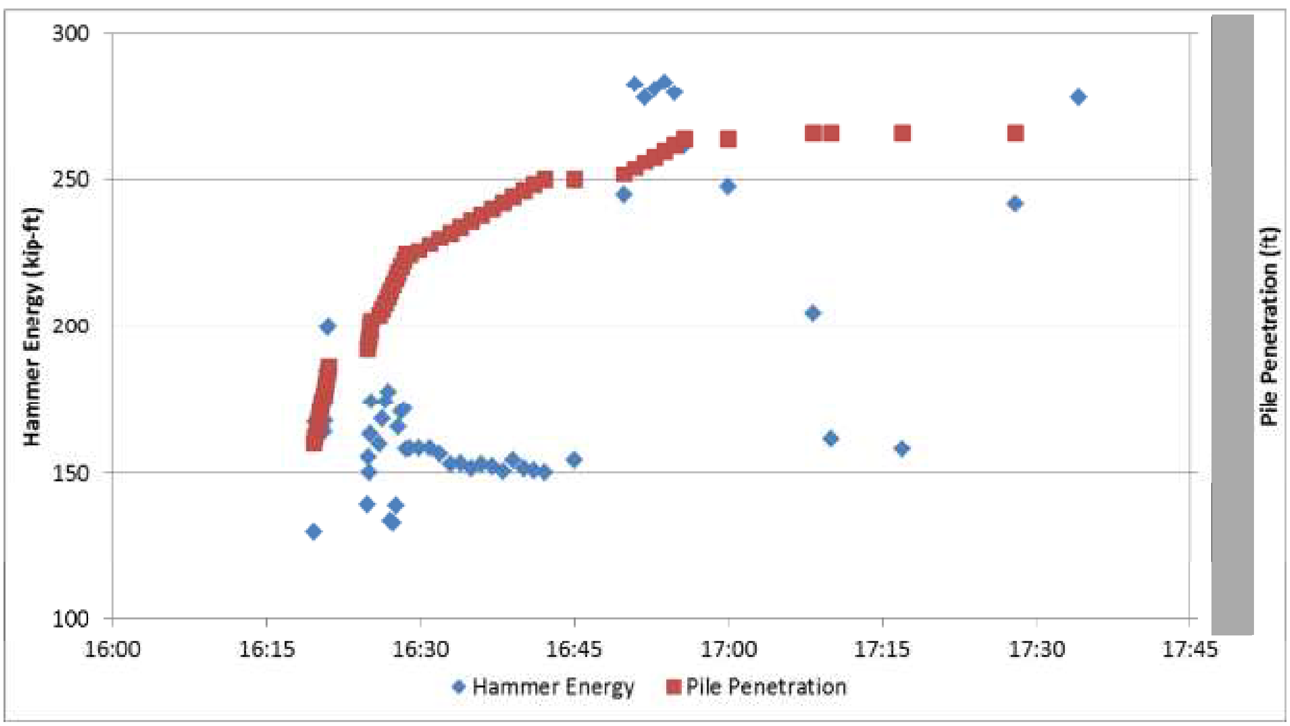

Figure 5. Hammer energy (kip-ft) and pile penetration (ft) for the impact pile driving of PLT-110 on 06 September 2013.

3. Weather and River Conditions

Table 6 provides the predicted currents at the project site for 06 September 2013. Figure 6 provides the measured speed of sound in water, based on a conductivity, temperature, depth (CTD) cast. Figure 6 provides the measured currents at the project site on 06 September 2013 using an Acoustic Doppler Current Profiler (ADCP).

Table 6. Weather conditions, and predicted local current times (EDT).

Weather conditions:	Sunny, ~ 3 knots northerly wind
Full ebb current:	17:13 (2.2 knots)
Slack current:	13:41, 20:06
Full flood current:	10:38 (1.2 knots)

Reference: http://tidesandcurrents.noaa.gov/get_predc.shtml?year=2013&stn=0611+George WashingtonBridge&secstn=Tappan+Zee+Bridge&sbfh=%2B1&sbfm=12&fldh=%2B0&fldm=55&sbeh=%2B0&sbem=52&ebbh=%2B1&ebbm=06&fldr=0.6&ebbr=0.8&fldavgd=356&ebbavgd=175&footnote=

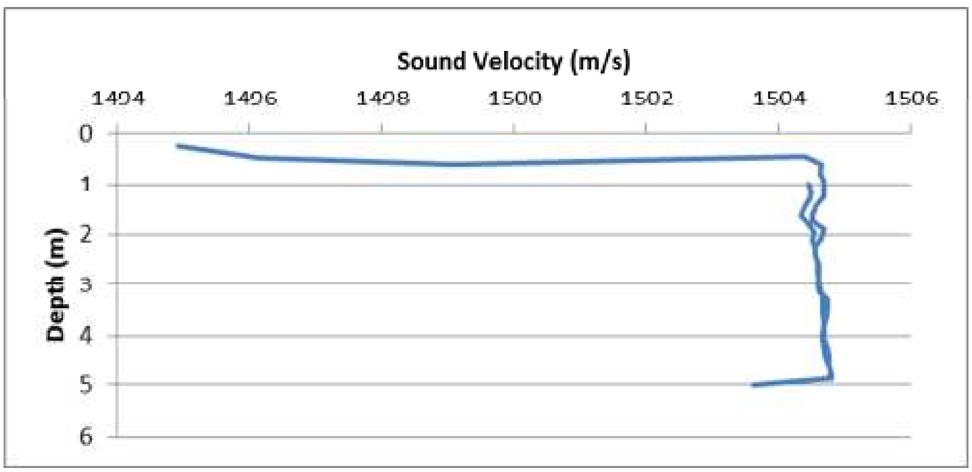

Figure 6. CTD cast performed at 14:22 (EDT) from the Alpine vessel, located 264 ft SE of the pile (41.07079 N, 73.8917 W).

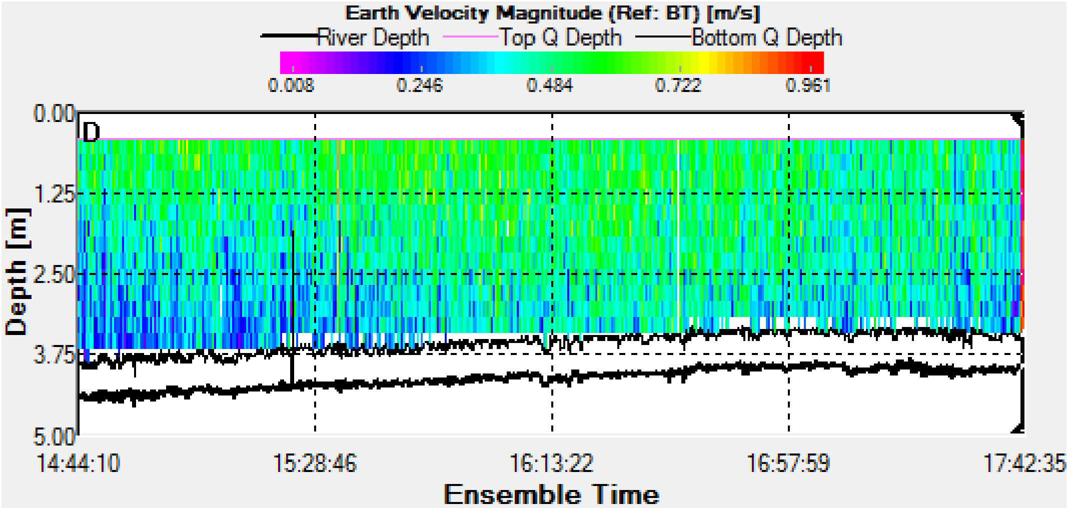

Figure 7. ADCP data from 06 September from the Alpine vessel, located 264 ft SE of the pile (41.07079 N, 73.8917 W), times are in EDT.

4. Monitoring Equipment

4.1. Real-time Monitoring Equipment

Table 7 provides information on the real-time monitoring equipment used on 06 September 2013.

Table 8 provides location information on the real-time recorders.

Table 7. Real-time monitoring equipment for Test Pile PLT-110, 06 September 2013.

Equipment used		Units deployed
Acoustic Data Logger		
Model:	AMAR RT (JASCO Applied Sciences)	1
SpectroPlotter version:	6.0.1	1
Hydrophone		
Model:	M8KC (GTI)	1
AMAR-RT-11 sensitivity:	−210.8 dB re 1 V/μPa	1
Other		
Hydrophone calibrator:	Pistonphone Type 42AC (G.R.A.S. Sound and Vibration)	1
CTD profiler:	Minos X (AML Oceanographic)	1
ADCP:	RDI Teledyne Workhorse Sentinel 1200 kHz	1

Table 8. Locations (WGS84) and deployment times (EDT) of the AMAR-RT monitoring stations, 06 September 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time (EDT)	Water depth (ft)	Distance to pile (ft)
Peak SPL Barge	AMAR-RT-11	41.07143	73.89115	14:42	18	33

4.2. Autonomous Monitoring Equipment

Table 9 provides information on the autonomous monitoring equipment used on 06 September 2013. Table 10 provides the locations of the autonomous recorders.

Table 9. Autonomous monitoring equipment for Test Pile PLT-110, 06 September 2013.

Equipment used		Units deployed
Acoustic Data Logger		
Model:	AMAR G3 (JASCO Applied Sciences)	3
SpectroPlotter version:	6.0.1	3
Hydrophone		
Model:	M8E-51-0dB (GTI)	3
AMAR-221 sensitivity:	−199.9 dB re 1 V/µPa	1
AMAR-228 sensitivity:	−200.1 dB re 1 V/µPa	1
AMAR-175 sensitivity:	−200.1 dB re 1 V/µPa	1

Table 10. Locations (WGS84) and deployment times (EDT) of the long-range monitoring AMAR stations on 06 September 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time (EDT)	Water depth (ft)	Distance to pile (ft)
cSEL 100’ East (cross current)	AMAR-175	41.07137	73.8906	10:10	18	132
cSEL 200’ East (cross current)	AMAR-221	41.07137	73.8903	10:14	18	221
rms SPL East (cross current)	AMAR-228	41.07135	73.8897	10:20	20	389

Appendix A. Pile Driving Plots

A.1. Impact Pile-Driving Sound Levels from Peak SPL Barge

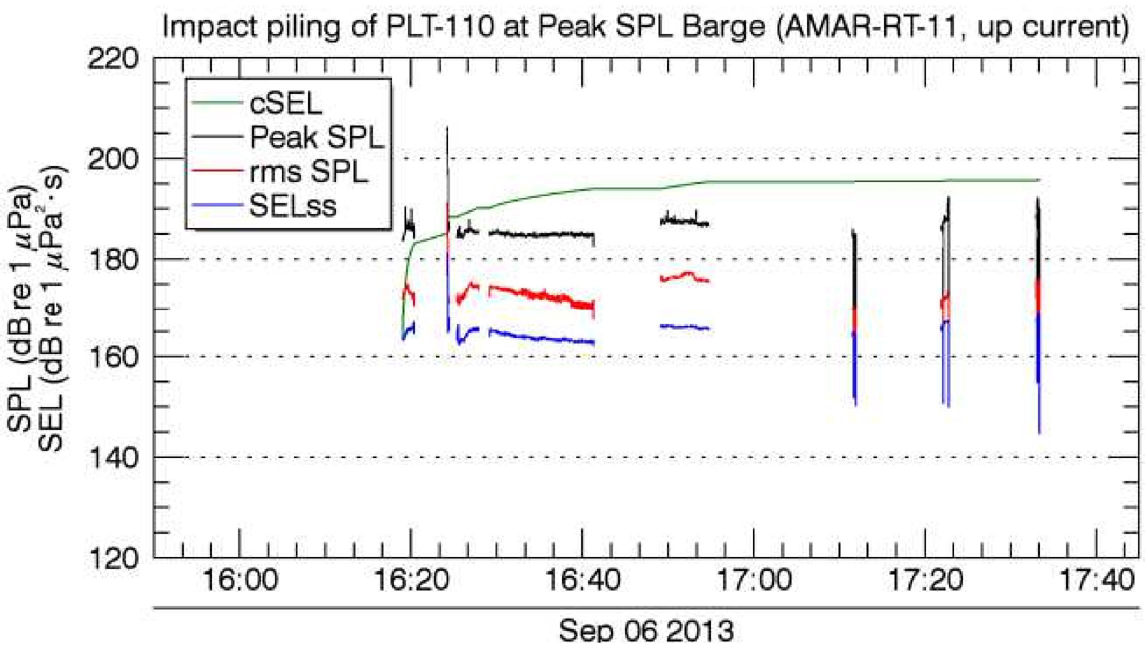

Figure 8. *Impact Pile Driving*: Peak SPL, rms SPL, SELss and cSEL versus time (EDT) for the pile driving of Test Pile PLT-110 measured 33 ft from the pile at location Peak SPL Barge using AMAR-RT-11. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

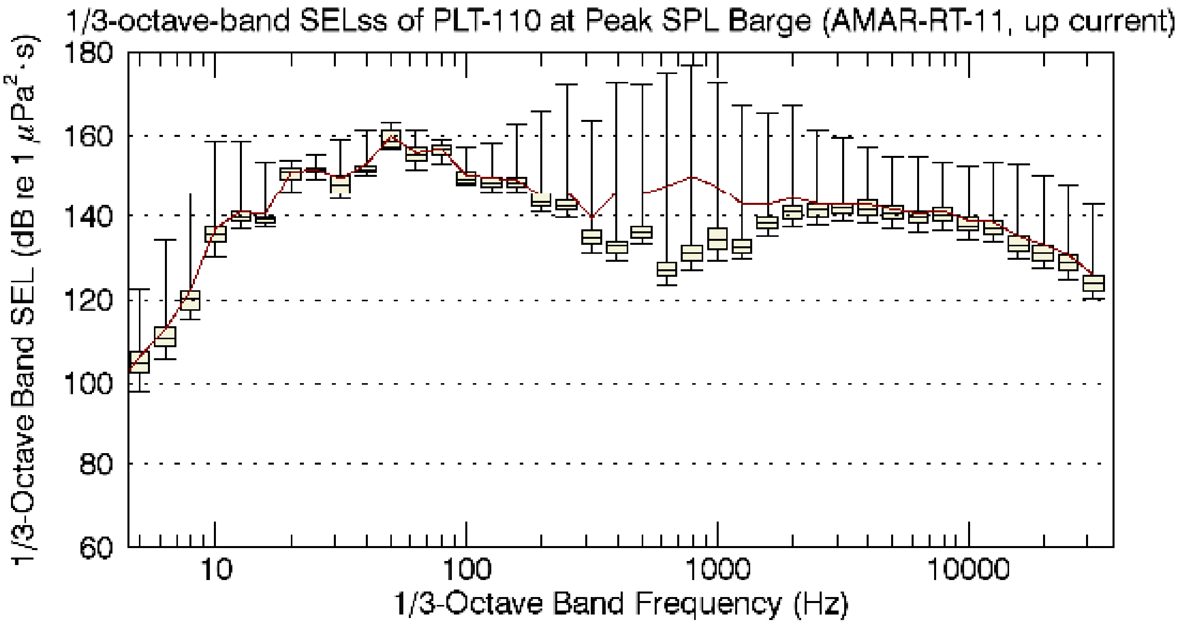

Figure 9. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-110 measured 33 ft from the pile at location Peak SPL Barge using AMAR-RT-11. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 11. Sound levels for the pile driving of Test Pile PLT-110 measured 33 ft from the pile at location Peak SPL Barge using AMAR-RT-11.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	192.4	177.3	168.4
L_5	187.8	176.7	166.1
L_{25}	186.7	174.6	165.6
L_{50}	185.1	173.3	164.2
L_{75}	184.7	172.0	163.3
L_{95}	184.4	170.1	162.9
L_{mean}	185.9	173.9	164.6

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

A.2. Impact Pile-Driving Sound Levels from cSEL 100' East

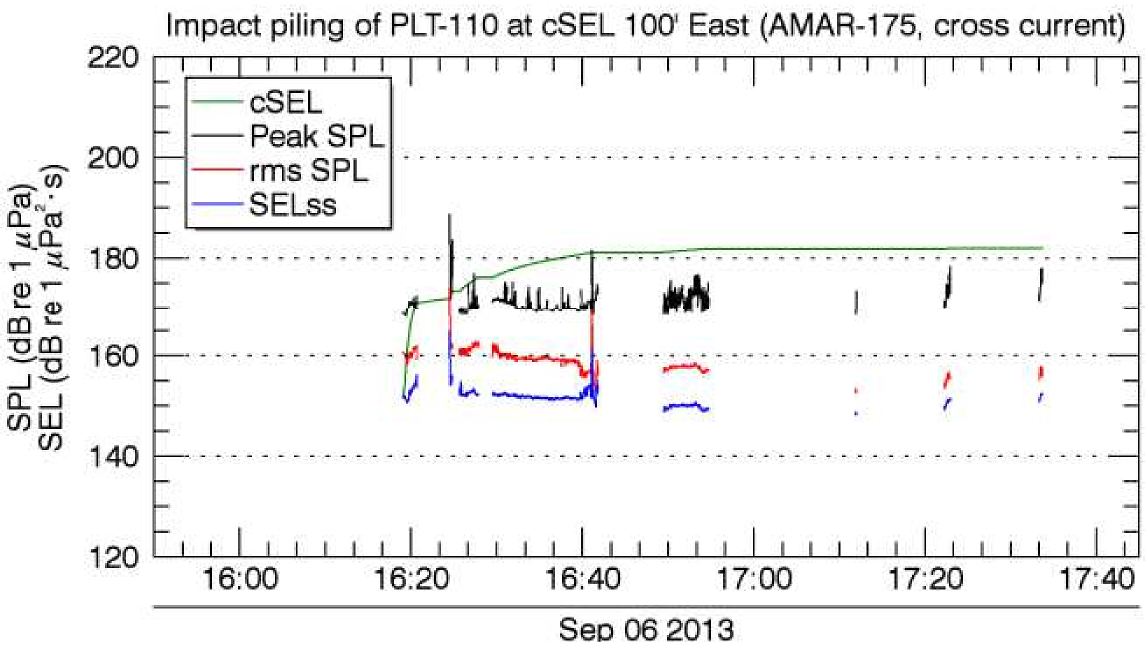

Figure 10. *Impact Pile Driving*: Peak SPL, rms SPL, SELss and cSEL versus time (EDT) for the pile driving of Test Pile PLT-110 measured 132 ft from the pile at location cSEL 100' East using AMAR-175. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time. The sound spike at 16:41 was caused by a tugboat dragging the recorder. Data after this time was not used in the regressions or 1/3-octave-band plots since the range to the recorder was uncertain.

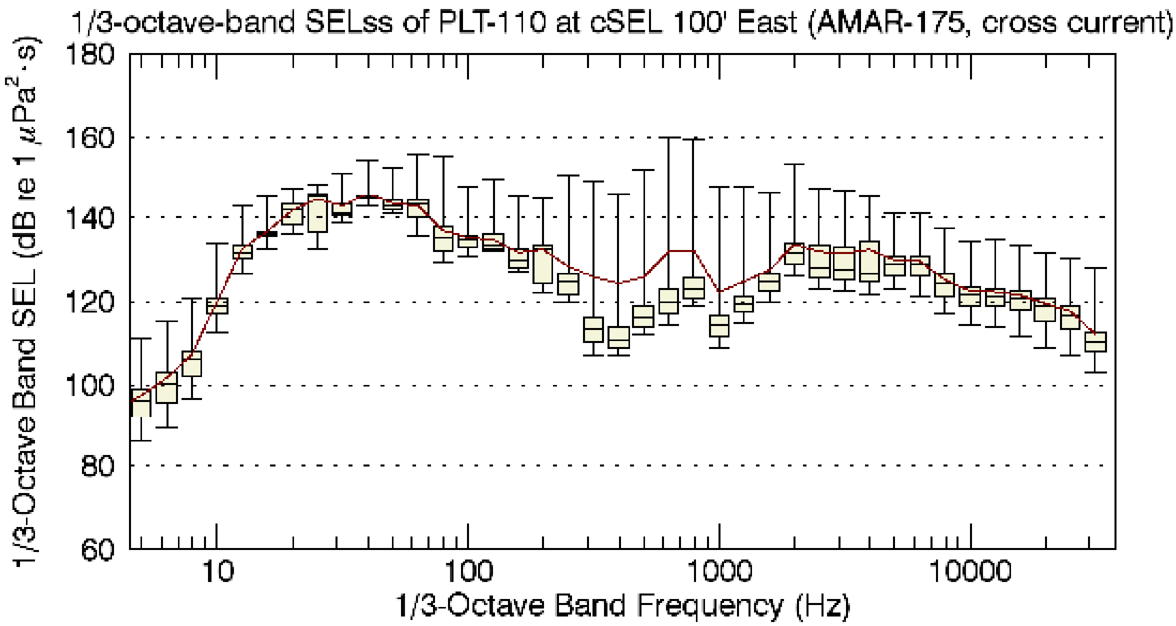

Figure 11. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-110 measured 132 ft from the pile at location cSEL 100' East using AMAR-175. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 12. Sound levels for the pile driving of Test Pile PLT-110 measured 132 ft from the pile at location cSEL 100' East using AMAR-175.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa²·s)
L_{max}	176.9	162.6	154.3
L_5	172.2	161.8	152.9
L_{25}	170.8	160.2	152.2
L_{50}	169.7	159.4	151.7
L_{75}	169.4	159.1	151.5
L_{95}	169.0	158.5	151.3
L_{mean}	170.3	159.8	151.9

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

A.3. Impact Pile-Driving Sound Levels from cSEL 200' East

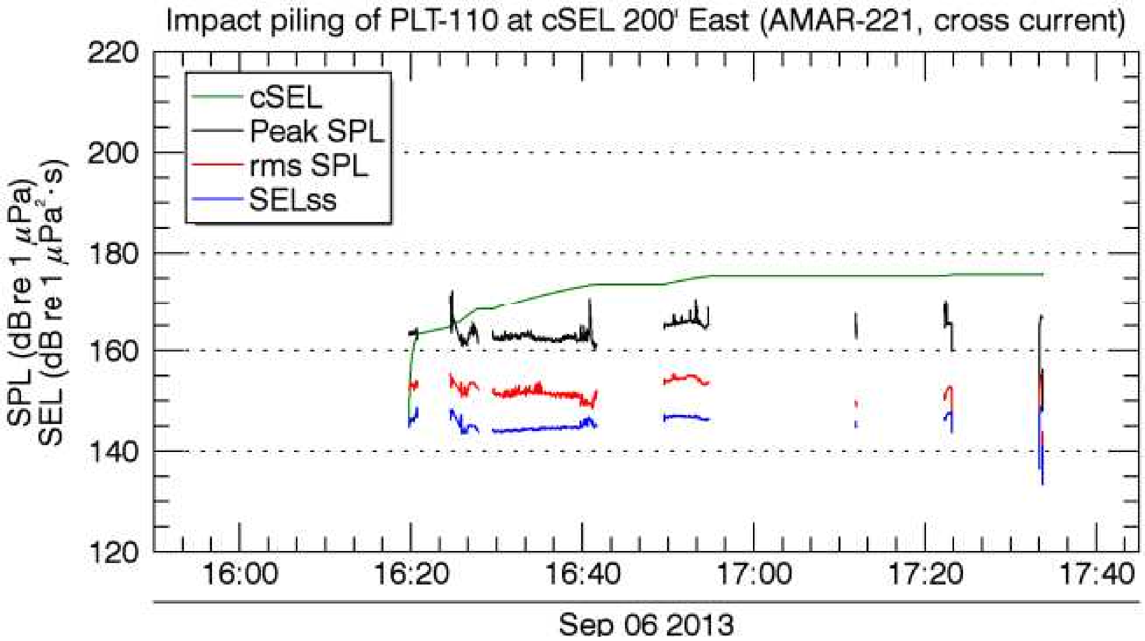

Figure 12. *Impact Pile Driving*: Peak SPL, rms SPL, SELss and cSEL versus time (EDT) for the pile driving of Test Pile PLT-100 measured 221 ft from the pile at location cSEL 200' East using AMAR-221. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

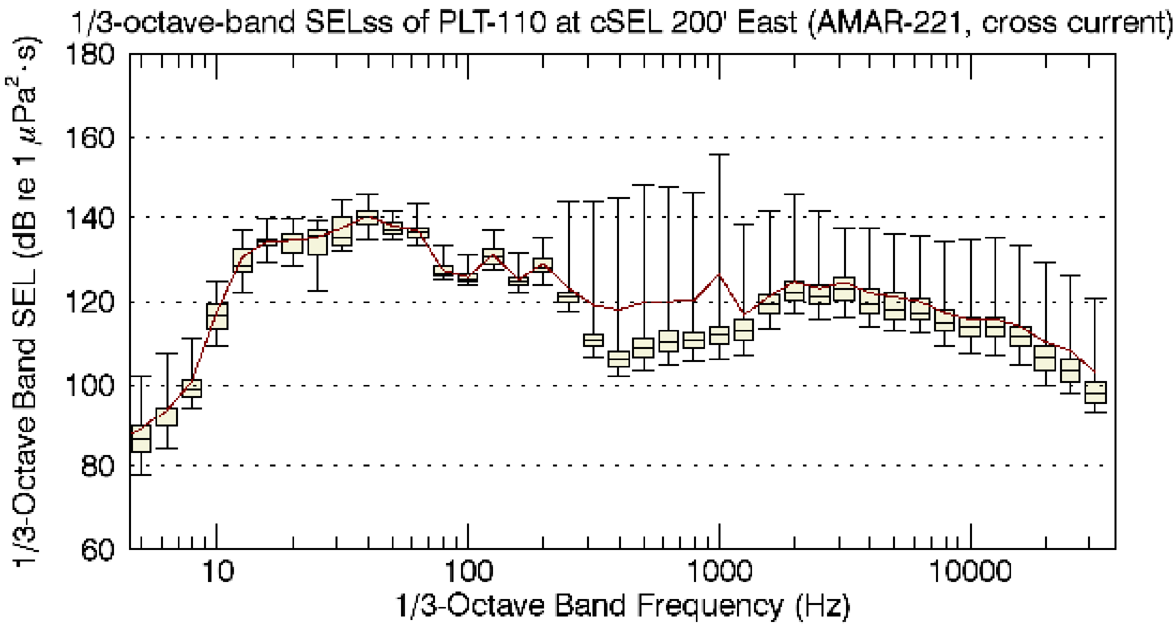

Figure 13. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-110 measured 221 ft from the pile at location cSEL 200’ East using AMAR-221. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 13. Sound levels for the pile driving of Test Pile PLT-110 measured 221 ft from the pile at location cSEL 200’ East using AMAR-221.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	170.9	155.7	148.9
L_5	166.0	154.9	147.0
L_{25}	164.8	153.4	146.3
L_{50}	162.8	151.6	144.7
L_{75}	162.2	151.1	144.3
L_{95}	161.3	149.5	143.8
L_{mean}	163.7	152.3	145.3

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

A.4. Impact Pile-Driving Sound Levels from rms SPL 300’ East

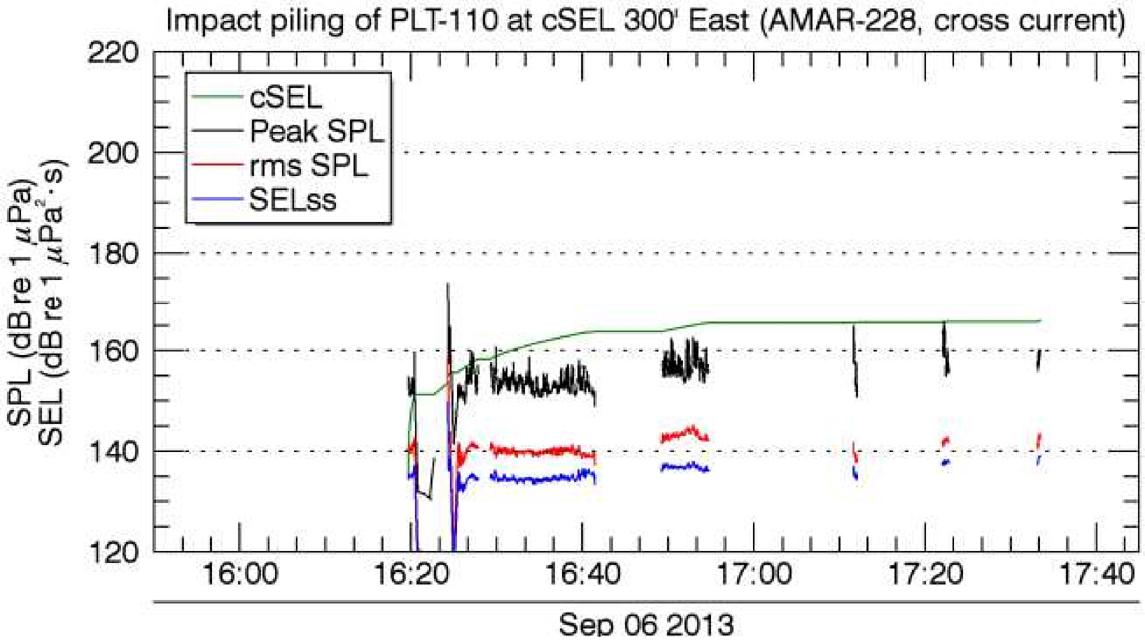

Figure 14. *Impact Pile Driving*: Peak SPL, rms SPL, SELss and cSEL versus time (EDT) for the pile driving of Test Pile PLT-110 measured 389 ft from the pile at location rms SPL 300’ East using AMAR-228. For periods during which there is no pile driving the cSEL is necessarily displayed as a constant value over time.

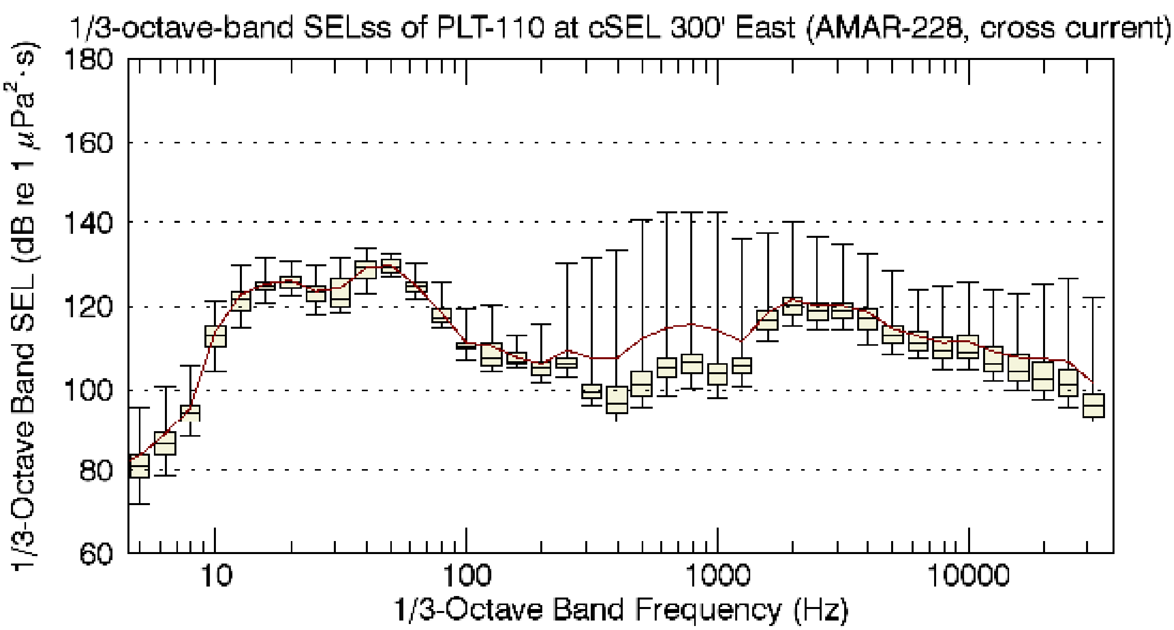

Figure 15. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-110 measured 389 ft from the pile at location rms SPL 300’ East using AMAR-228. Beige bars indicate the first, second, and

third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 14. Sound levels for the pile driving of Test Pile PLT-110 measured 389 ft from the pile at location rms SPL 300' East using AMAR-228.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	166.0	145.2	139.2
L_5	160.0	143.8	137.4
L_{25}	156.0	142.2	136.4
L_{50}	153.9	140.2	134.9
L_{75}	152.5	139.7	134.4
L_{95}	151.2	139.0	133.9
L_{mean}	155.6	141.1	135.5

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

JASCO APPLIED SCIENCES

Underwater Acoustic Monitoring of the Tappan Zee Bridge Test Pile 109 Installation

Daily Memorandum for 4 October 2013

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17 March 2014

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1. Summary

1.1. Pile Location and Monitoring Summary

Test Pile PLT-109 is a [redacted] pile driven at the site of the New NY Bridge on the west side of the navigation channel on 04 October 2013 (Table 1). One real-time acoustic monitoring system and two autonomous acoustic monitoring systems were deployed by JASCO (Section 4) on behalf of Tappan Zee Constructors, LLC (TZC) (Figure 1, Table 2). Pile driving occurred between 16:46–16:50 Eastern Daylight Time (EDT), and full ebb current occurred at 16:10 EDT.

Table 2 provides the sound levels measured at each recorder. Plots of the measured values, frequency distributions of 1/3-octave-band single-strike sound exposure levels (SELss), and sound level statistics for the distribution of the measured data are presented in Appendix A.

Table 1. Summary of Test Pile PLT-109 activities, 04 October 2013.

Date:	04 October 2013
Pile-Driving Activity	
Test pile identifier:	PLT-109
Pile diameter:	[redacted]
Water depth:	13 ft
Hammer type:	Impact (IHC S-280)
Total hammer strikes:	[redacted]
Total penetration:	[redacted]
Net duration of pile driving (hh:mm:ss):	00:04:30
Maximum single strike energy:	166 thousand foot-pounds (kip-ft), (225 kJ)
Total energy transferred:	33,275 kip-ft (45 MJ)
Noise Attenuation System (NAS)	
Two-tier unconfined bubble curtain airflow rate:	1050–1100 cubic feet per minute (cfm), 40 pounds per square inch (psi)
River conditions during pile driving:	Ebb current, 0.6 knots current (0.3 meters per second [m/s], depth dependent; Table 5 and Figure 6)

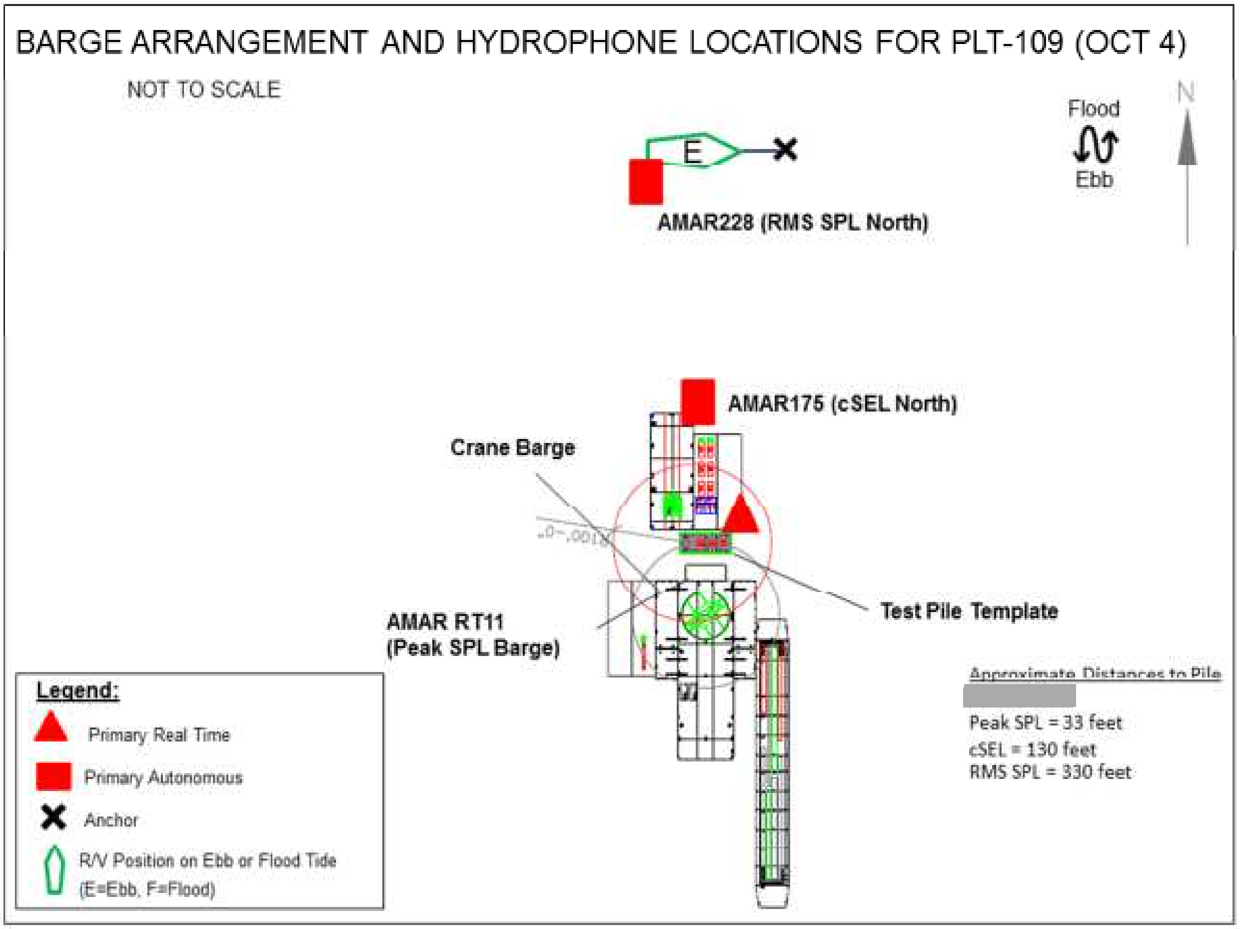

Figure 1. Plan view of pile and barge layout, 04 October 2013, Test Pile PLT-109.

Table 2. Summary of Autonomous Multichannel Acoustic Recorder (AMAR) locations and measured sound levels. Detailed sound level plots are contained in Appendix A.

Location	Recorder ID	Distance to pile (ft)	Water depth (ft)	Max peak SPL (dB re 1 µPa)	cSEL (dB re 1 µPa^{2}s)*
Peak SPL Barge (up current)	AMAR-RT-11	29	13	192	192
cSEL North (up current)	AMAR-175	263**	13	163	162
rms SPL North (up current)	AMAR-228	707	11	159	152

* Estimated at each recorder by multiplying the mean of the per-strike SEL by the number of strikes reported by the pile driving contractor, for the final value at the recorder, representing the total energy at the end of pile driving.
** Due to the barge layout this was as close to the pile as the recorder could be deployed along the north radial.

1.2. NMFS Physiological and Behavioral Thresholds

The distances from pile driving to the noise levels that serve as the National Marine Fisheries Service (NMFS) physiological and behavioral thresholds were extrapolated using a logarithmic regression based on mean values of the peak sound pressure level (SPL), root mean square (rms) SPL, and SELss from each recorder (Table 3 and Figure 2).

The regression indicates that the estimated diameter of the 206 dB re 1 µPa peak SPL isopleth was approximately 17 ft, and did not exceed NMFS criteria of a diameter of 40 ft for piles. The diameter of the 187 dB re 1 µPa^2·s cumulative sound exposure level (cSEL) isopleth was estimated to be 84 ft at the end of pile driving. Since cSEL increases as the number of strikes increases, the diameter of the 187 dB isopleth was smaller than 84 ft for most of the pile driving operation. No other pile driving occurred during this pile load test. The river width is approximately 15,000 ft; therefore, a fish-movement corridor of more than one mile, which was continuous for more than 1,500 ft, was maintained throughout pile driving in accordance with New York State Department of Environmental Conservation (NYSDEC) Permit Condition 14.

Table 3. Estimated isopleth diameters for the NMFS physiological and behavioral thresholds.

Criteria	Estimated mean diameter (ft)
206 dB re 1 µPa peak SPL	17
187 dB re 1 µPa^2·s cSEL*	84
150 dB re 1 µPa rms SPL (1 s integration time)	478

* At the end of pile driving

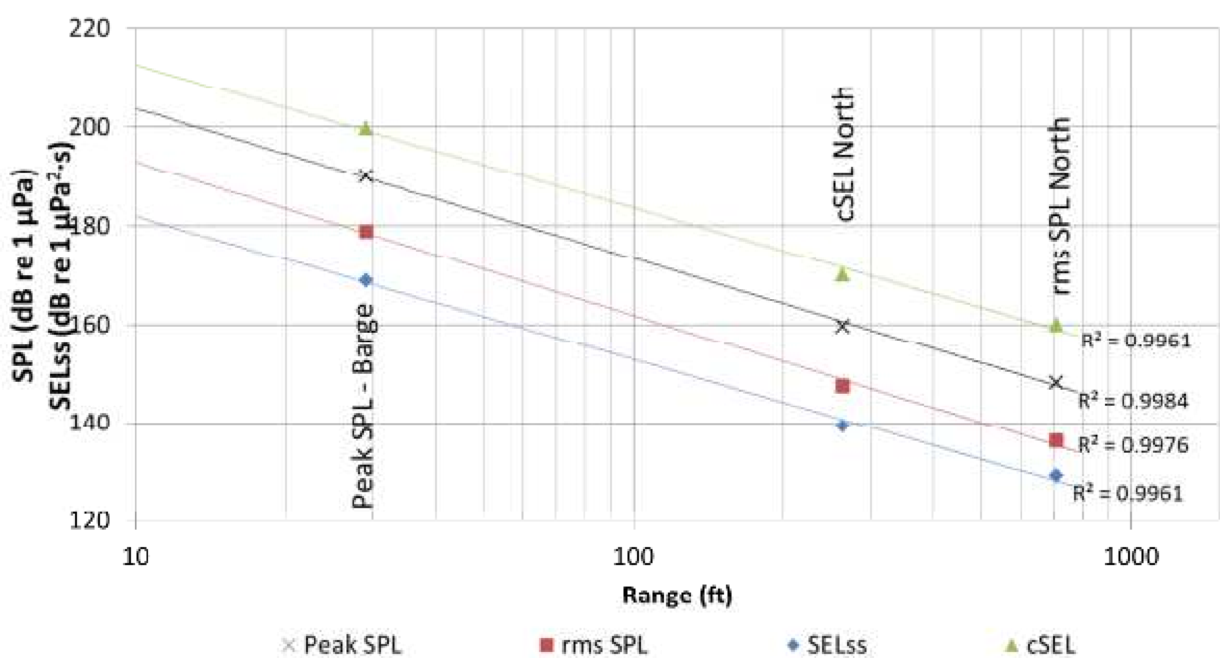

Figure 2. Regression based on mean values of the SELss, peak SPL, cSEL, and rms SPL from each recorder from pile driving of Test Pile PLT-109, 04 October 2013. SEL_{ss}, peak SPL, and rms SPL are instantaneous values. The cSEL represents the total sound energy measured during the pile driving.

1.3. Observations

PLT-109 was driven for 4 min on 04 October 2013 with a hammer energy of 160 ± 6 kip-ft (Figure 4). The NAS air pressure and airflow were constant (40 psi, 1050–1100 cfm) during the pile driving. River currents constant at ~ 0.6 knots. The measured sound levels at all measurement locations showed very small variations of ± 2dB (Figure 3, Figure 7, Figure 9, and Figure 11).

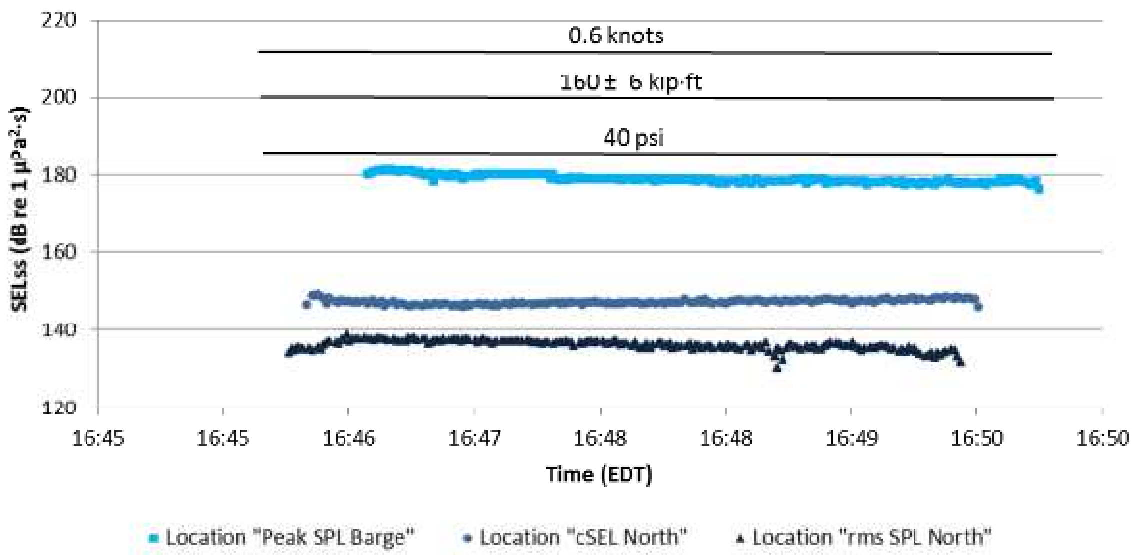

Figure 3. SELss at each location annotated with hammer energy (kip-ft), NAS air pressure (psi), and river current (knots). Note that the clocks on the three recorders were unsynchronized by ~15 seconds.

2. Activity Logs

2.1. Log of JASCO and Construction Activities

Table 4 provides activities for 04 October 2013.

Table 4. JASCO and construction activities for Test Pile PLT-109, 04 October 2013.

Time (EDT)	Activity
05:40	Arrive at dock, prep recorders
06:30	Leave dock for job site
06:50	Stand by at Cornetta’s
11:00	Transfer to barge, deploy AMAR-175
11:11	Deploy AMAR-RT from barge
11:40	Deploy AMAR-228 from Alpine vessel
16:46	Start pile driving with S-280

16:50	Stop pile driving
17:00	Retrieve recorders
18:30	All work complete

2.2. Pile Driving Logs

2.2.1. NAS

NAS used: Two-tier unconfined bubble curtain

NAS settings: 1050–1100 cfm, 40 psi

2.2.2. Impact Hammering Log

Total Energy: 33,275 kip-ft (45 MJ)

Total number of strikes: [redacted]

Maximum per-strike energy: 166 kip-ft (225 kJ)

Net pile driving duration (hh:mm:ss): 00:04:30

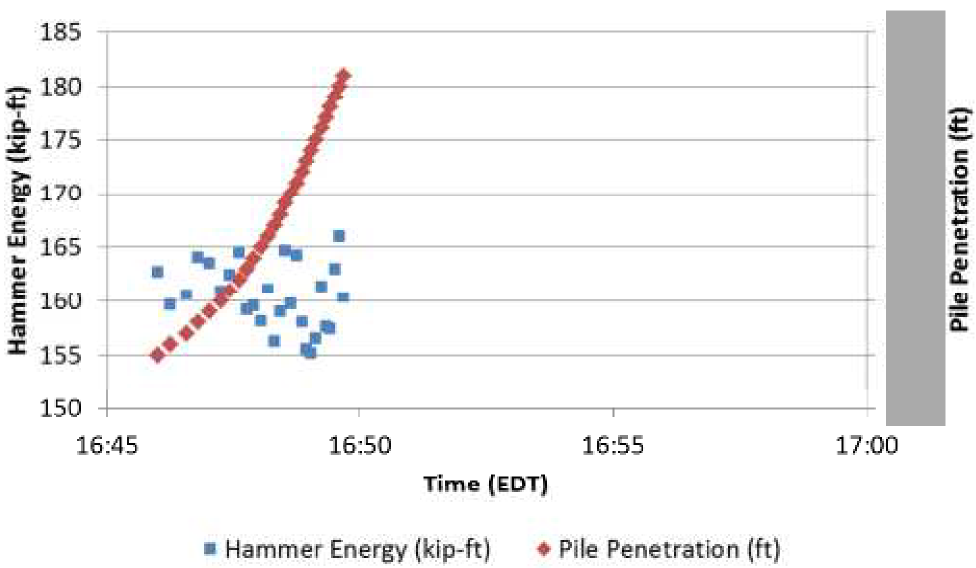

Figure 4. Hammer energy (kip-ft) and pile penetration (ft) during pile driving of PLT-109, 04 October 2013.

3. Weather and River Conditions

Table 5 provides the predicted currents at the project site on 04 October 2013. Figure 6 provides the measured currents collected using an Acoustic Doppler Current Profiler (ADCP) at the project site on 04 October 2013. Figure 5 provides the speed of sound in water, based on salinity and temperature, measured using the conductivity, temperature, depth (CTD) cast.

Table 5. Weather conditions and predicted local current times (EDT).

Weather conditions:	Sunny, light winds
Full ebb current:	16:10 (−2.3 knots)
Slack current:	12:28, 19:03
Full flood current:	09:29 (1.3 knots)

Reference: http://tidesandcurrents.noaa.gov/get_predc.shtml?year=2013&stn=0611+George Washington Bridge&secstn=Tappan+Zee+Bridge&sbfh=%2B1&sbfm=12&fldh=%2B0&fldm=55&sbeh=%2B0&sbem=52&ebbh=%2B1&ebbm=06&fldr=0.6&ebbr=0.8&fldavgd=356&ebbavgd=175&footnote=

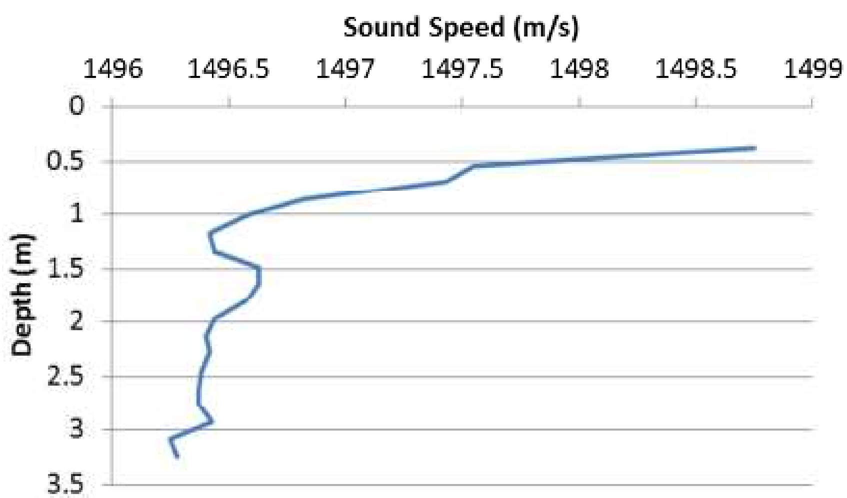

Figure 5. CTD cast performed at 16:32 EDT from the Alpine vessel, located 700 ft from the pile.

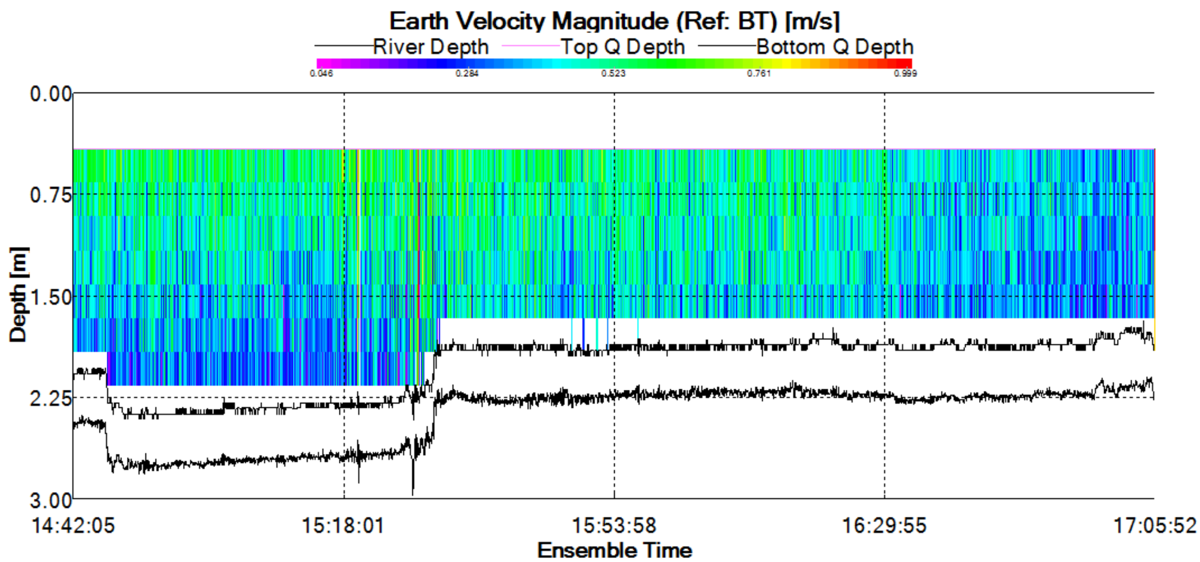

Figure 6. Current data from 04 October 2013 recorded at rms SPL North (Alpine Vessel) using an ADCP. Pile driving occurred from 16:46–16:50 EDT.

4. Monitoring Equipment

4.1. Real-time Monitoring Equipment

Table 6 provides information on the real-time monitoring equipment used on 04 October 2013.

Table 7 provides location information on the real-time recorders.

Table 6. Real-time monitoring equipment for Test Pile PTLT-109, 04 October 2013.

Equipment used		Units deployed
Acoustic data logger		
Model:	AMAR RT (JASCO Applied Sciences)	1
SpectroPlotter version:	6.0.1	1
Hydrophone		
Model:	M8KC (GTI)	1
AMAR-RT-11 sensitivity:	−210.9 dB re 1 V/µPa	1
Other		
Hydrophone calibrator:	Pistonphone Type 42AC (G.R.A.S. Sound and Vibration)	1
CTD profiler:	Minos X (AML Oceanographic)	1
ADCP:	RDI Teledyne Workhorse Sentinel 1200 kHz	1

Table 7. Locations (WGS84) and deployment times (EDT) of the AMAR-RT monitoring stations, 04 October 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time (EDT)	Water depth (ft)	Distance to pile (ft)
Peak SPL Barge (up current)	AMAR-RT-11	41.07135	73.89616	11:11	13	29

4.2. Autonomous Monitoring Equipment

Table 8 provides information about the autonomous monitoring equipment used on 04 October 2013.

Table 9 provides the locations of the autonomous recorders.

Table 8. Autonomous monitoring equipment Test Pile PTLT-109, 04 October 2013.

Equipment used		Units deployed
Acoustic data logger		
Model:	AMAR G3 (JASCO Applied Sciences)	2
SpectroPlotter version:	6.0.1	2
Hydrophone		
Model:	M8E-51-0dB (GTI)	2
AMAR-228 sensitivity:	−199.74 dB re 1 V/µPa	1
AMAR-175 sensitivity:	−199.84 dB re 1 V/µPa	1

Table 9. Locations (WGS84) and deployment times (EDT) of the long-range monitoring AMAR stations on 04 October 2013

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time (EDT)	Water depth (ft)	Distance to pile (ft)
cSEL North (up current)	AMAR-175	41.07198	−73.89646	11:11	13	263
rms SPL North (up current)	AMAR-228	41.07322	−73.89609	11:40	11	707

Appendix A. Pile Driving Plots

A.1. Impact Pile-Driving Sound Levels from Peak SPL Barge

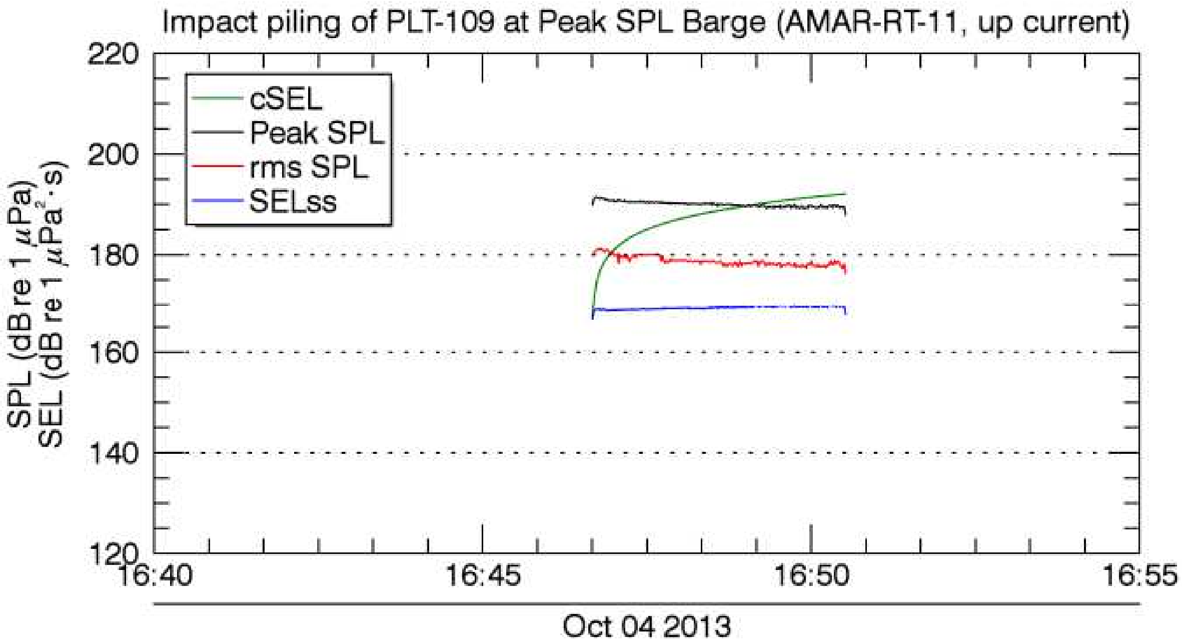

Figure 7. *Impact Pile Driving*: Peak SPL, rms SPL, SEL, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-109 measured 29 ft from the pile at location Peak SPL Barge using AMAR-RT-11.

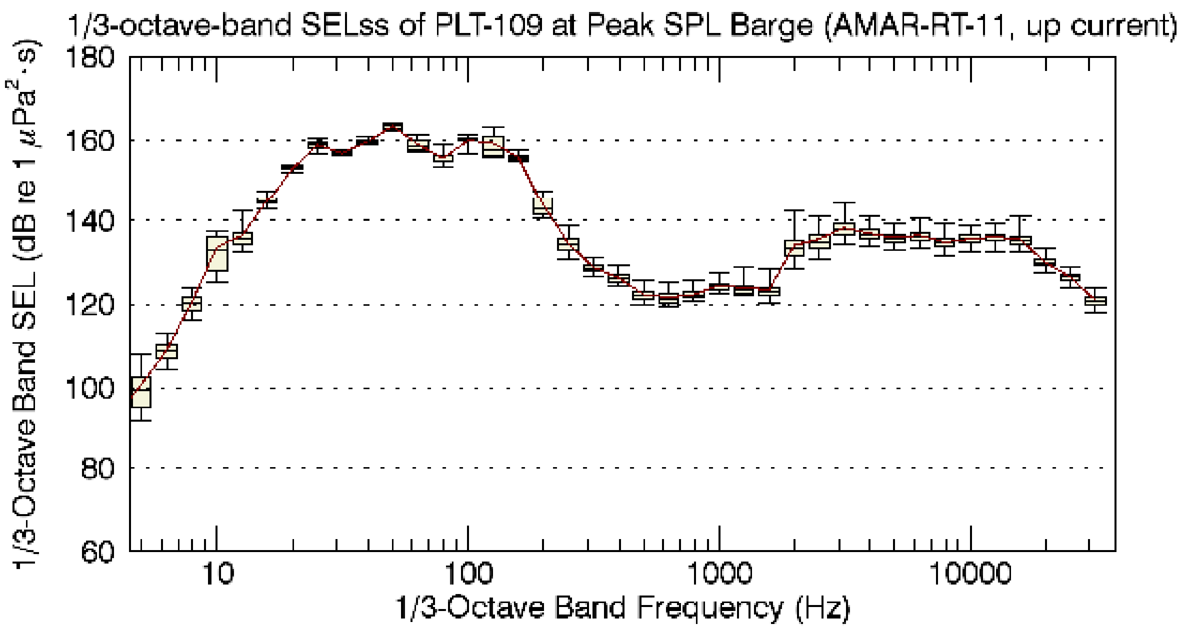

Figure 8. Distribution of 1/3-octave SELss for the pile driving of Test Pile PLT-109 measured 29 ft from the pile at location Peak SPL Barge using AMAR-RT-11. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 10. Sound levels for the pile driving of Test Pile PLT-109 measured 29 ft from the pile at location Peak SPL Barge using AMAR-RT-11.

Sound level statistic*	peak SPL (dB re 1 μPa)	rms SPL (dB re 1 μPa)	SELss (dB re 1 μPa^2·s)
L_{max}	191.5	181.3	169.7
L_5	190.9	180.6	169.4
L_{25}	190.3	179.4	169.1
L_{50}	189.9	178.6	168.9
L_{75}	189.6	178.1	168.6
L_{95}	189.3	177.6	168.4
L_{mean}	190.0	178.9	168.9

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

A.2. Impact Pile-Driving Sound Levels cSEL North

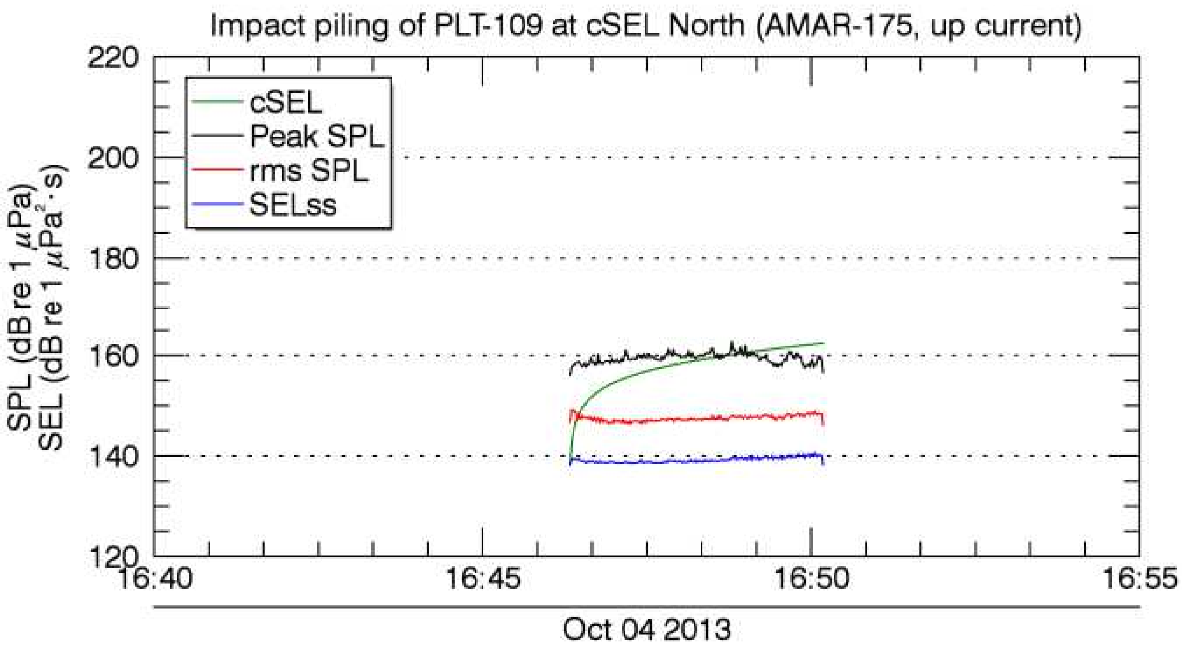

Figure 9. *Impact Pile Driving*: Peak SPL, rms SPL, SEL, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-109 measured 263 ft from the pile at location cSEL North using AMAR-175.

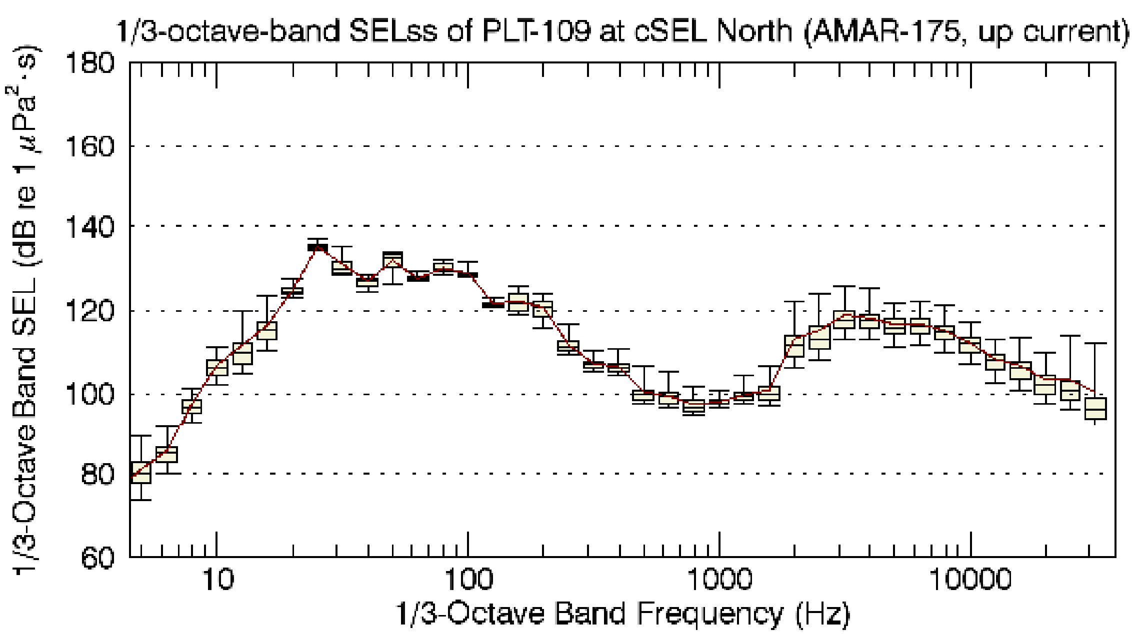

Figure 10. Distribution of 1/3-octave SELss for the pile driving of Test Pile PLT-109 measured 263 ft from the pile at location cSEL North using AMAR-175. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 11. Sound levels for the pile driving of Test Pile PLT-109 measured 263 ft from the pile at location cSEL North using AMAR-175.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	162.8	149.2	140.6
L_5	161.0	148.5	140.1
L_{25}	160.1	147.9	139.6
L_{50}	159.6	147.4	139.1
L_{75}	158.7	147.0	138.8
L_{95}	158.0	146.6	138.6
L_{mean}	159.6	147.5	139.2

*The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

A.3. Impact Pile-Driving Sound Levels rms SPL North

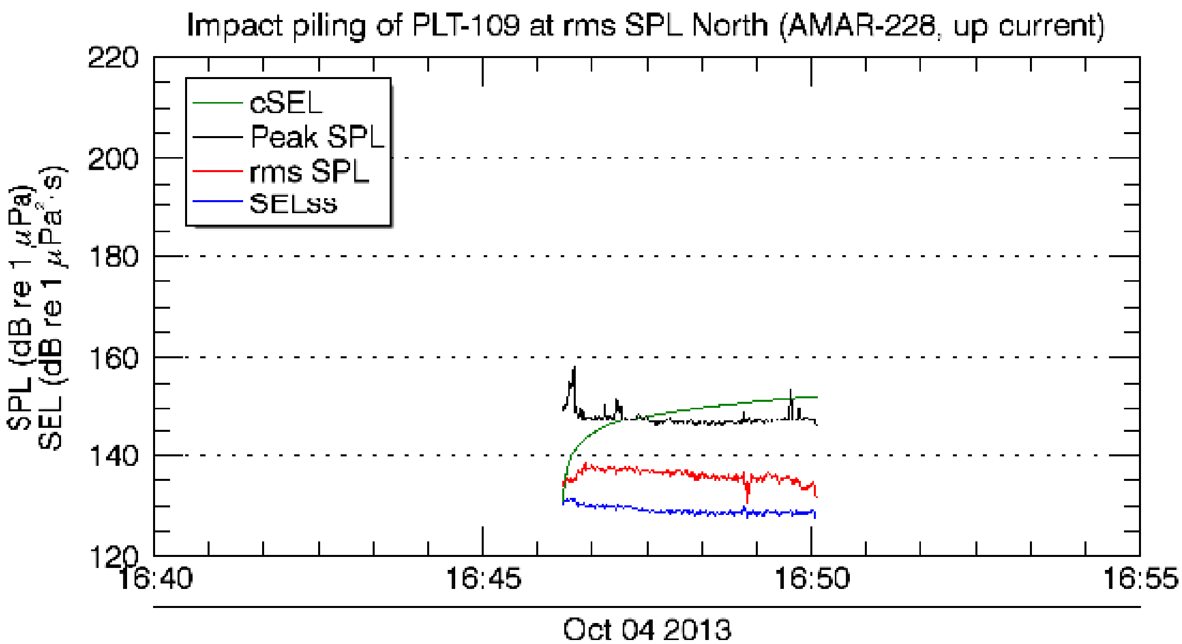

Figure 11. *Impact Pile Driving*: Peak SPL, rms SPL, SEL, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-109 measured 707 ft from the pile at location rms SPL North using AMAR-228.

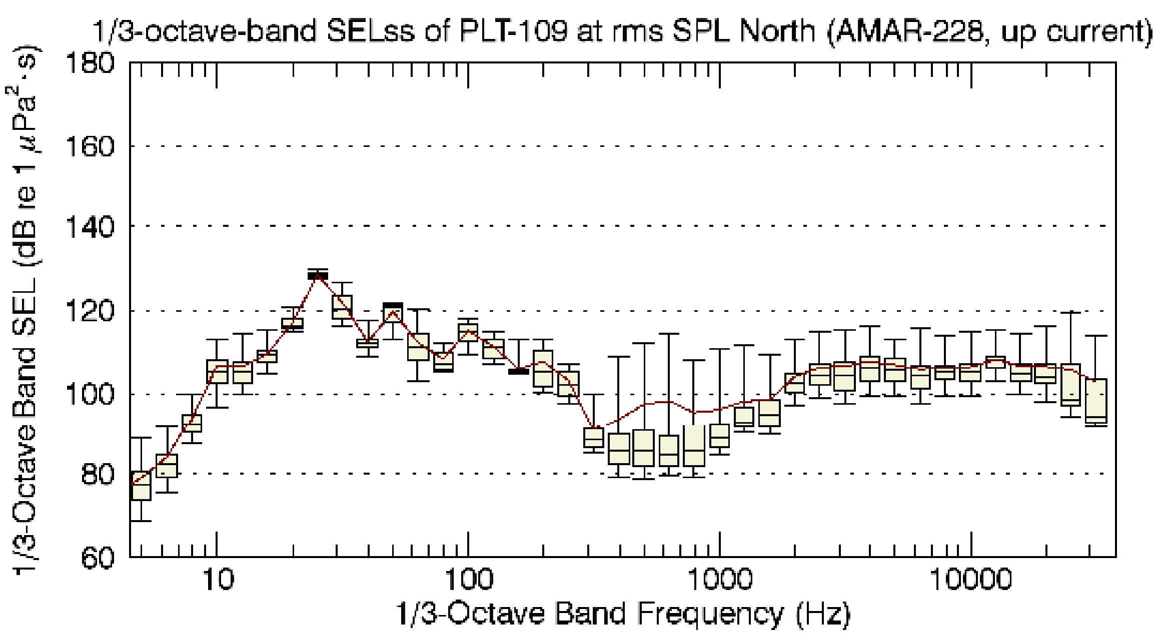

Figure 12. Distribution of 1/3-octave SELss for the pile driving of Test Pile PLT-109 measured 707 ft from the pile at location rms SPL North using AMAR-228. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 12. Sound levels for the pile driving of Test Pile PLT-109 measured 707 ft from the pile at location rms SPL North using AMAR-228.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	158.5	138.5	131.4
L_5	150.7	137.6	130.5
L_{25}	148.0	136.9	129.7
L_{50}	147.3	136.1	129.0
L_{75}	146.8	135.2	128.7
L_{95}	146.2	134.0	128.2
L_{mean}	148.2	136.2	129.2

*The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

Underwater Acoustic Monitoring of the Tappan Zee Bridge Test Pile 109 Installation

Daily Memorandum for 07 October 2013

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24 March 2014

P001206-001

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1. Summary

1.1. Pile Location and Monitoring Summary

Test Pile PLT-109 is a [redacted] pile driven at the site of the New NY Bridge on the east side of the navigation channel on 07 October 2013 (Table 1). One real-time acoustic monitoring system and two autonomous acoustic monitoring systems were deployed by JASCO (Section 4) on behalf of Tappan Zee Constructors, LLC (TZC) (Figure 1, Table 2). Pile driving occurred between 08:15–09:11 Eastern Daylight Time (EDT), and slack current occurred at 07:45 EDT. The pile was started on 04 October with the S-280 impact hammer and completed with an S-800 impact hammer on 07 October.

Table 2 provides the sound levels measured at each recorder. Plots of the measured values, frequency distributions of 1/3-octave-band single-strike sound exposure levels (SELss), and sound level statistics for the distribution of the measured data are presented in Appendix A.

Table 1. Summary of Test Pile PLT-109 activities, 07 October 2013.

Date:	07 October 2013
Pile-Driving Activity	
Test pile identifier:	PLT-109
Pile diameter:	[redacted]
Water depth:	13 ft
Hammer type:	Impact (IHC S-800)
Total hammer strikes:	[redacted]
Total penetration:	[redacted]
Net duration of pile driving (hh:mm:ss):	00:22:00
Maximum single strike energy:	382.4 thousand foot-pounds (kip-ft), (519 kJ)
Total energy transferred:	181,158 kip-ft (246 MJ)
Noise Attenuation System (NAS)	
Two-tier unconfined bubble curtain airflow rate:	1750–1800 cubic feet per minute (cfm), 65 pounds per square inch (psi)
River conditions during pile driving:	Slack to flood current, 0.6-0.8 knots current (0.3 – 0.4 meters per second [m/s], depth dependent; Table 7 and Figure 6)*

*The ADCP was not available after 08:32.

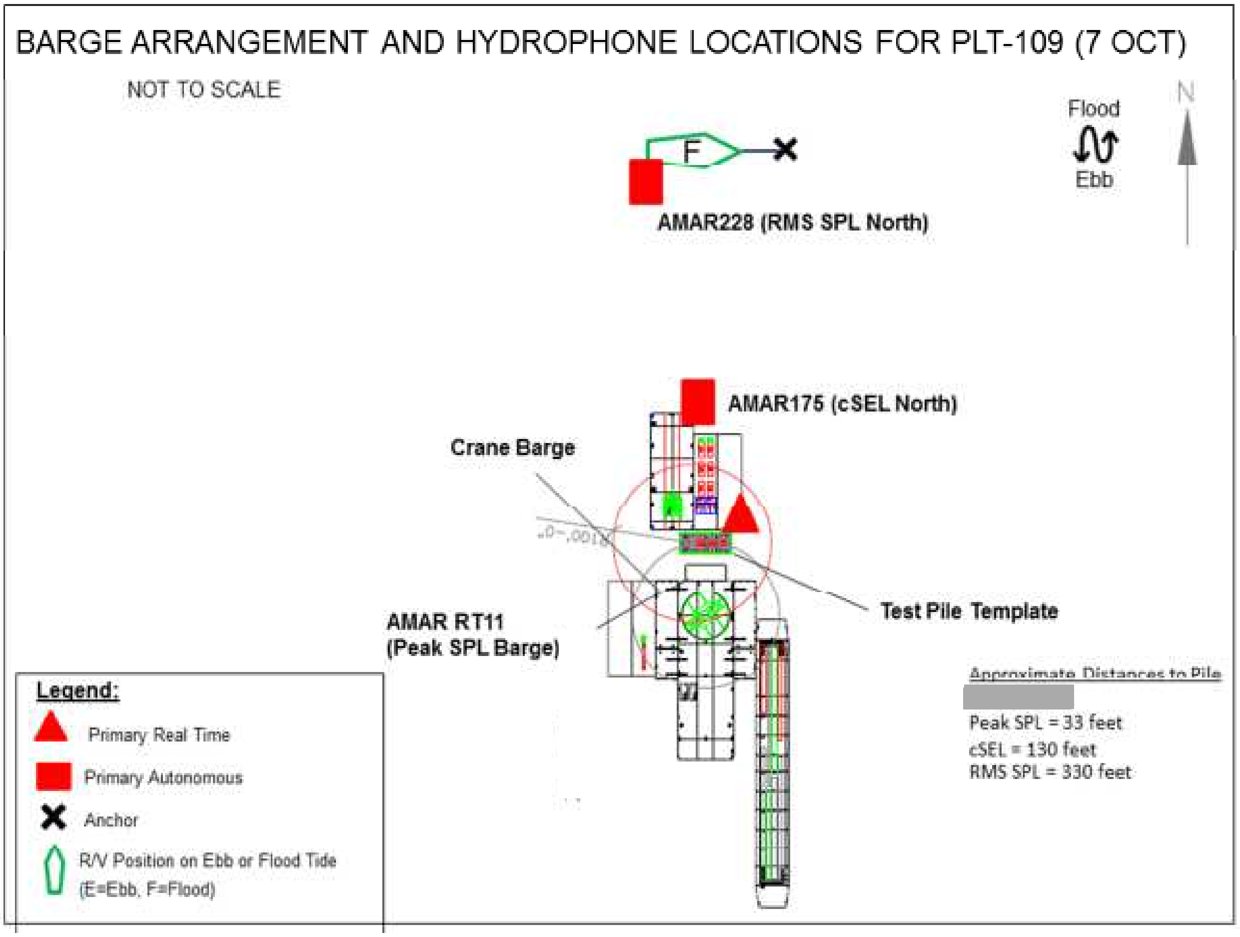


Figure 1. Plan view of pile and barge layout, 07 October 2013, Test Pile PLT-109.

Table 2. Summary of Autonomous Multichannel Acoustic Recorder (AMAR) locations and measured sound levels. Detailed sound level plots are contained in Appendix A.

Location	Recorder ID	Distance to pile (ft)	Water depth (ft)	Max peak SPL (dB re 1 µPa)	cSEL (dB re 1 µPa^{2}s)*
Peak SPL Barge (down current)	AMAR-RT-11	33	13	188	197
cSEL North (down current)	AMAR-175	264**	13	166	171
rms SPL North (down current)	AMAR-228	835	12	153	159

* Estimated at each recorder by multiplying the mean of the per-strike SEL by the number of strikes reported by the pile driving contractor, for the final value at the recorder, representing the total energy at the end of pile driving.
** Due to the barge layout this was as close to the pile as the recorder could be deployed along the north radial.

1.2. NMFS Physiological and Behavioral Thresholds

The distances from pile driving to the noise levels that serve as the National Marine Fisheries Service (NMFS) physiological and behavioral thresholds were extrapolated using a logarithmic regression based on mean values of the peak sound pressure level (SPL), root mean square (rms) SPL, and SELss from each recorder (Table 3 and Figure 2).

The regression indicates that the estimated diameter of the 206 dB re 1 µPa peak SPL isopleth was approximately 10 ft, and did not exceed NMFS criteria of a diameter of 40 ft for [redacted] piles. The diameter of the 187 dB re 1 µPa^2·s cumulative sound exposure level (cSEL) isopleth was estimated to be 146 ft at the end of pile driving. Since cSEL increases as the number of strikes increases, the diameter of the 187 dB isopleth was smaller than 146 ft for most of the pile driving operation. No other pile driving occurred during this pile load test. The river width is approximately 15,000 ft; therefore, a fish-movement corridor of more than one mile, which was continuous for more than 1,500 ft, was maintained throughout pile driving in accordance with New York State Department of Environmental Conservation (NYSDEC) Permit Condition 14.

Table 3. Estimated isopleth diameters for the NMFS physiological and behavioral thresholds.

Criteria	Estimated mean diameter (ft)
206 dB re 1 µPa peak SPL	10
187 dB re 1 µPa^2·s cSEL*	146
150 dB re 1 µPa rms SPL (1 s integration time)	476

* At the end of pile driving

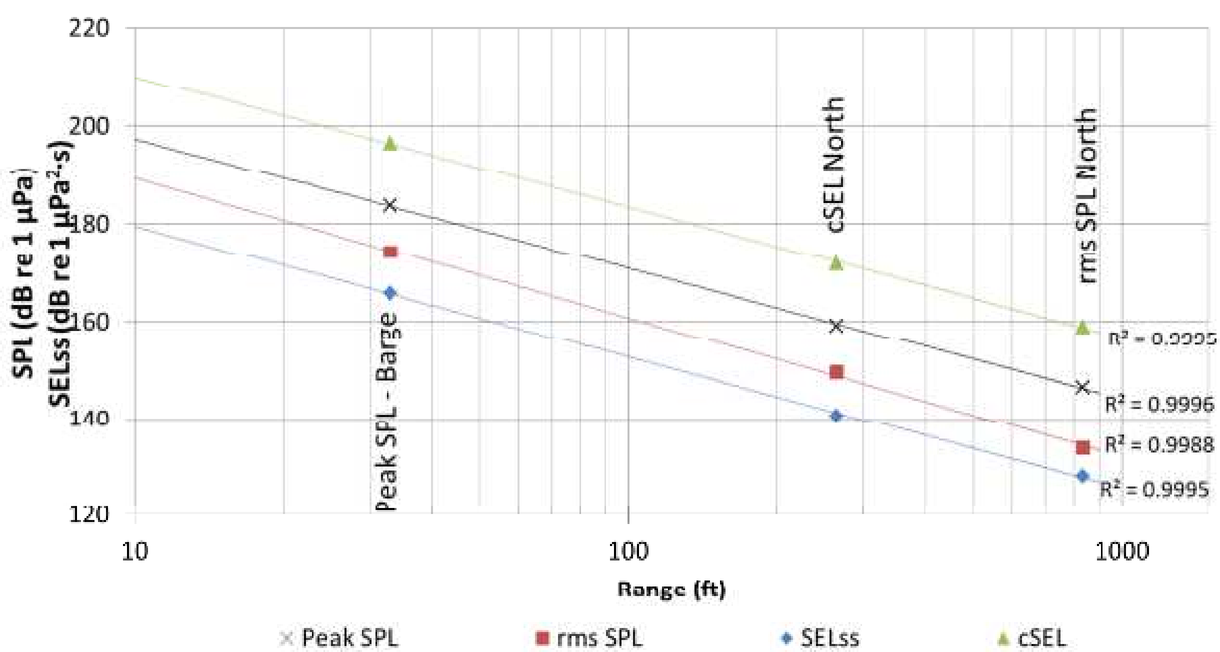


Figure 2. Regression based on mean values of the SELss, peak SPL, cSEL, and rms SPL from each recorder from pile driving of Test Pile PLT-109, 07 October 2013. SELss, peak SPL, and rms SPL are instantaneous values. The cSEL represents the total sound energy measured during the pile driving.

1.3. Observations

During the pile driving of PLT-109 on 07 October the hammer energy was increased twice within a 30 min period after the pile had hit refusal (Figure 3, Figure 4). The NAS and river current conditions were constant over this period allowing for an evaluation of the effect of hammer energy on noise levels to be performed. There were 1117 strikes at 160 kip-ft, 73 strikes at 250 kip-ft, and 16 strikes at 380 kip-ft. The peak SPL and SELss increased by 4–8 dB at all three recorders, while the rms SPL changed levels more erratically (Table 4, Figure 3, Figure 7, Figure 9, and Figure 11). The ranges to the acoustic monitoring criteria isopleths remained well within the NMFS and NYSDEC permitted levels (Table 5) at all hammer settings.

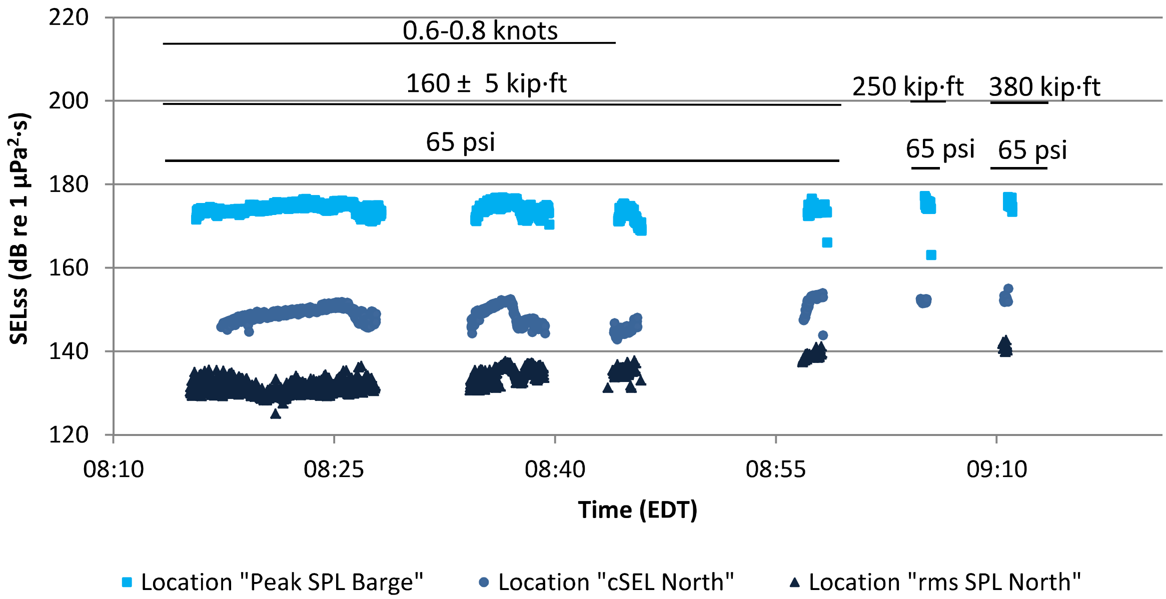


Figure 3. SELss at each location annotated with hammer energy (kip-ft), NAS air pressure (psi), and river current (knots). Note: ADCP read out not available after 8:32. Per Table 7, maximum flood current occurred at 10:54.

Table 4. Effect of hammer energy on median sound levels at PLT-109. There were 1117 strikes at 160 kip-ft, 73 at 250 kip-ft, and 16 at 380 kip-ft.

Location	Hammer energy (kip-ft)	Peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
Peak SPL Barge	160	183	174	165
	250	186	173	167
	380	188	175	169
cSEL North	160	158	149	140
	250	163	153	145
	380	166	153	147
rms SPL North	160	146	132	127
	250	151	139	134
	380	153	142	135

Table 5. Estimated isopleth diameters for the NMFS physiological and behavioral thresholds using the sound levels at each hammer energy.

Criteria	Estimated mean diameter, all data (ft)	Estimated mean diameter, 160 kip-ft (ft)	Estimated mean diameter, 250 kip-ft (ft)	Estimated mean diameter, 380 kip-ft (ft)
206 dB re 1 µPa peak SPL	10	10	10	14
187 dB re 1 µPa^2·s cSEL*	146	144	181	224
150 dB re 1 µPa rms SPL (1 s integration time)	476	458	624	716

* At the end of pile driving assuming 1206 strikes

2. Activity Logs

2.1. Log of JASCO and Construction Activities

Table 6 provides activities for 07 October 2013.

Table 6. JASCO and construction activities for Test Pile PLT-109, 07 October 2013.

Time (EDT)	Activity
06:25	Arrive at dock, prepare recorders
06:44	Leave dock for job site
07:15	Deploy AMAR-RT
07:30	Deploy AMAR-175 and AMAR-228
08:15	Start pile driving
09:11	Stop pile driving; begin retrieving AMAR
09:30	En route to barge
09:40	Standing by
14:00	Work stopped due to weather conditions
14:20	En route to dock
14:00	All work complete

2.2. Pile Driving Logs

2.2.1. NAS

NAS used: Two-tier unconfined bubble curtain

NAS settings: 1750–1800 cfm, 65 psi

2.2.2. Impact Hammering Log

Total Energy: 181,158 kip-ft (246 MJ)

Total number of strikes: [redacted]

Maximum per-strike energy: 382.4 kip-ft (518 kJ)

Net pile driving duration (hh:mm:ss): 00:22:00

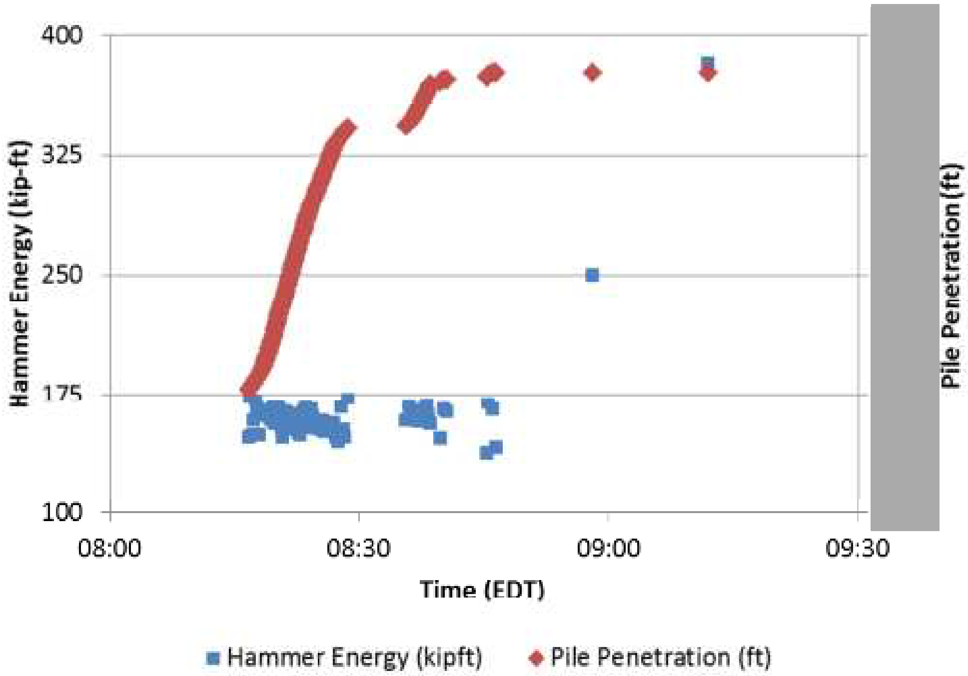


Figure 4. Hammer energy (kip-ft) and pile penetration (ft) during pile driving of PLT-109, 07 October 2013.

3. Weather and River Conditions

Table 7 provides the predicted currents at the project site on 07 October 2013. Figure 6 provides the currents measured with the Acoustic Doppler Current Profiler (ADCP) at the project site on 07 October 2013. The ADCP was not available past 08:32. Figure 5 provides the speed of sound in water, based on salinity and temperature, measured using the conductivity, temperature, depth (CTD) cast.

Table 7. Weather conditions and predicted local current times (EDT).

Weather conditions:	Sunny, light winds
Full ebb current:	05:36 (−2.3 knots)
Slack current:	08:33
Full flood current:	10:54 (1.6 knots)

Reference: http://tidesandcurrents.noaa.gov/get_predc.shtml?year=2013&stn=0611+George Washington Bridge&secstn=Tappan+Zee+Bridge&sbfh=%2B1&sbfm=12&fldh=%2B0&fldm=55&sbeh=%2B0&sbem=52&ebbh=%2B1&ebbm=06&fldr=0.6&ebbr=0.8&fldavgd=356&ebbavgd=175&footnote=

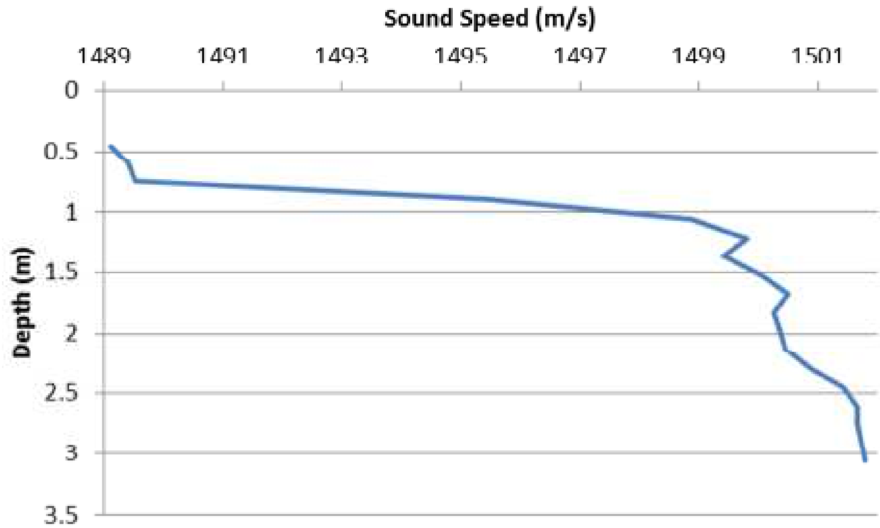


Figure 5. CTD cast performed at 11:57 EDT from the Alpine vessel, located 835 ft from the pile.

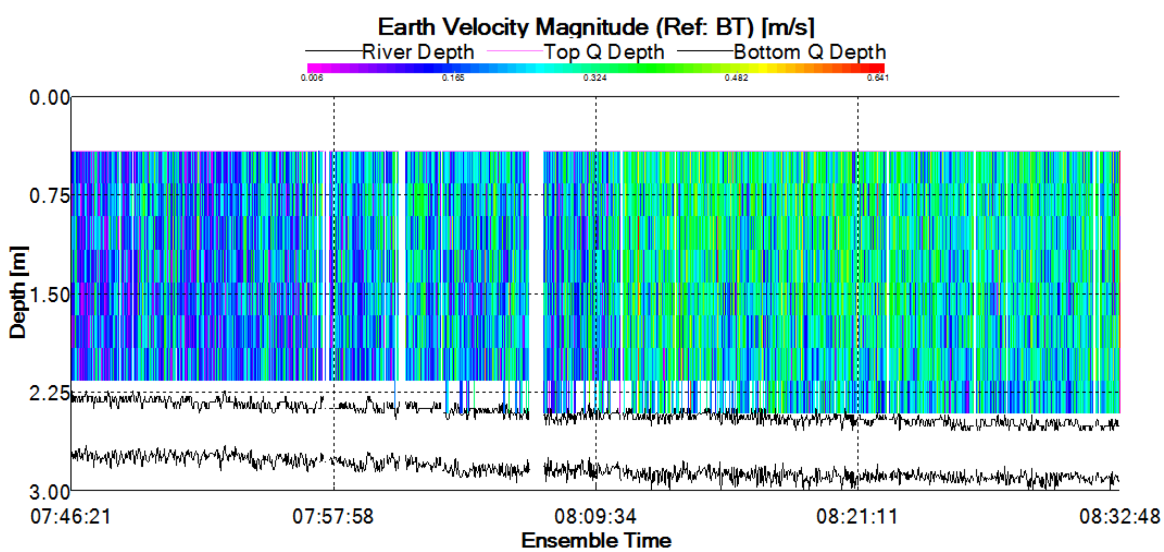


Figure 6. ADCP current data from 07 October 2013 recorded at rms SPL North (Alpine Vessel).

4. Monitoring Equipment

4.1. Real-time Monitoring Equipment

Table 8 provides information on the real-time monitoring equipment used on 07 October 2013. Table 9 provides location information on the real-time recorders.

Table 8 Real-time monitoring equipment for Test Pile PLT-109, 07 October 2013.

Equipment used		Units deployed
Acoustic data logger		
Model:	AMAR-RT (JASCO Applied Sciences)	1
SpectroPlotter version:	6.0.1	1
Hydrophone		
Model:	M8KC (GTI)	1
AMAR-RT-11 sensitivity:	−210.9 dB re 1 V/µPa	1
Other		
Hydrophone calibrator:	Pistonphone Type 42AC (G.R.A.S. Sound and Vibration)	1
CTD profiler:	Minos X (AML Oceanographic)	1
ADCP:	RDI Teledyne Workhorse Sentinel 1200 kHz	1

Table 9. Locations (WGS84) and deployment times (EDT) of the AMAR-RT monitoring stations, 07 October 2013.

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time (EDT)	Water depth (ft)	Distance to pile (ft)
Peak SPL Barge (down current)	AMAR-RT-11	41.07137	73.89616	07:15	13	33

4.2. Autonomous Monitoring Equipment

Table 10 provides information about the autonomous monitoring equipment used on 07 October 2013. Table 11 provides the locations of the autonomous recorders.

Table 10. Autonomous monitoring equipment for Test Pile PLT-109, 07 October 2013.

Equipment used		Units deployed
Acoustic data logger		
Model:	AMAR G3 (JASCO Applied Sciences)	2
SpectroPlotter version:	6.0.1	2
Hydrophone		
Model:	M8E-51-0dB (GTI)	2
AMAR-228 sensitivity:	−199.74 dB re 1 V/µPa	1
AMAR-175 sensitivity:	−199.84 dB re 1 V/µPa	1

Table 11. Locations (WGS84) and deployment times (EDT) of the long-range monitoring AMAR stations on 07 October 2013

Station	Recorder ID	Latitude (°N)	Longitude (°W)	Deployment time (EDT)	Water depth (ft)	Distance to pile (ft)
cSEL North (down current)	AMAR-175	41.07197	−73.89651	07:30	13	264
rms SPL North (down current)	AMAR-228	41.07355	−73.89651	07:30	12	835

Appendix A. Pile Driving Plots

A.1. Impact Pile-Driving Sound Levels from Peak SPL Barge

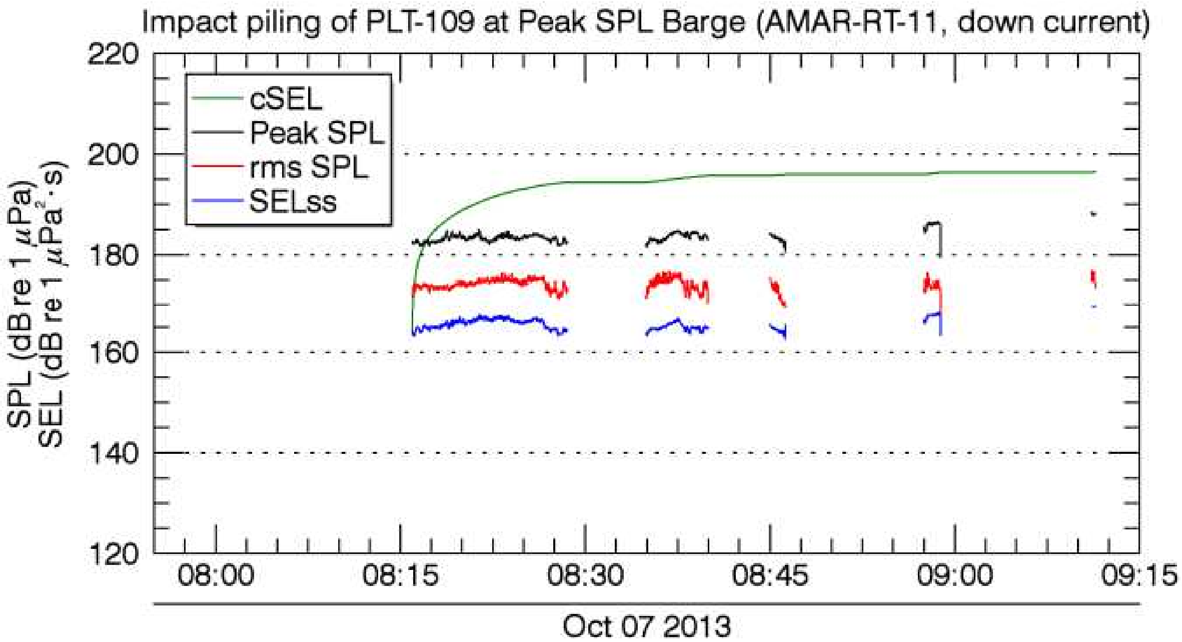


Figure 7. *Impact Pile Driving*: Peak SPL, rms SPL, SEL, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-109 measured 33 ft from the pile at location Peak SPL Barge (down current) using AMAR-RT-11.

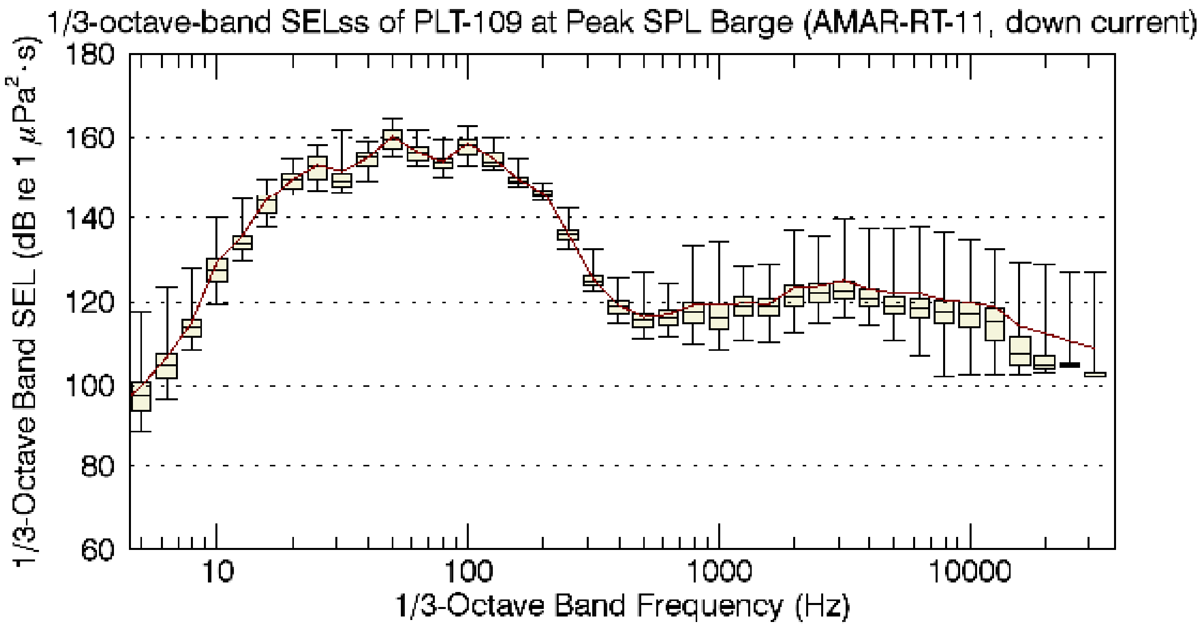


Figure 8. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-109 measured 33 ft from the pile at location Peak SPL Barge using AMAR-RT-11. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error-bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 12. Sound levels for the pile driving of Test Pile PLT-109 measured 33 ft from the pile at location Peak SPL Barge using AMAR-RT-11.

Sound level statistic*	peak SPL (dB re 1 μPa)	rms SPL (dB re 1 μPa)	SELss (dB re 1 μPa²·s)
L_{max}	188.4	176.9	169.5
L_5	186.1	175.8	167.4
L_{25}	183.9	174.9	166.3
L_{50}	183.4	174.1	165.5
L_{75}	182.9	173.3	164.7
L_{95}	182.2	171.8	163.8
L_{mean}	183.7	174.2	165.7

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

A.2. Impact Pile-Driving Sound Levels cSEL North

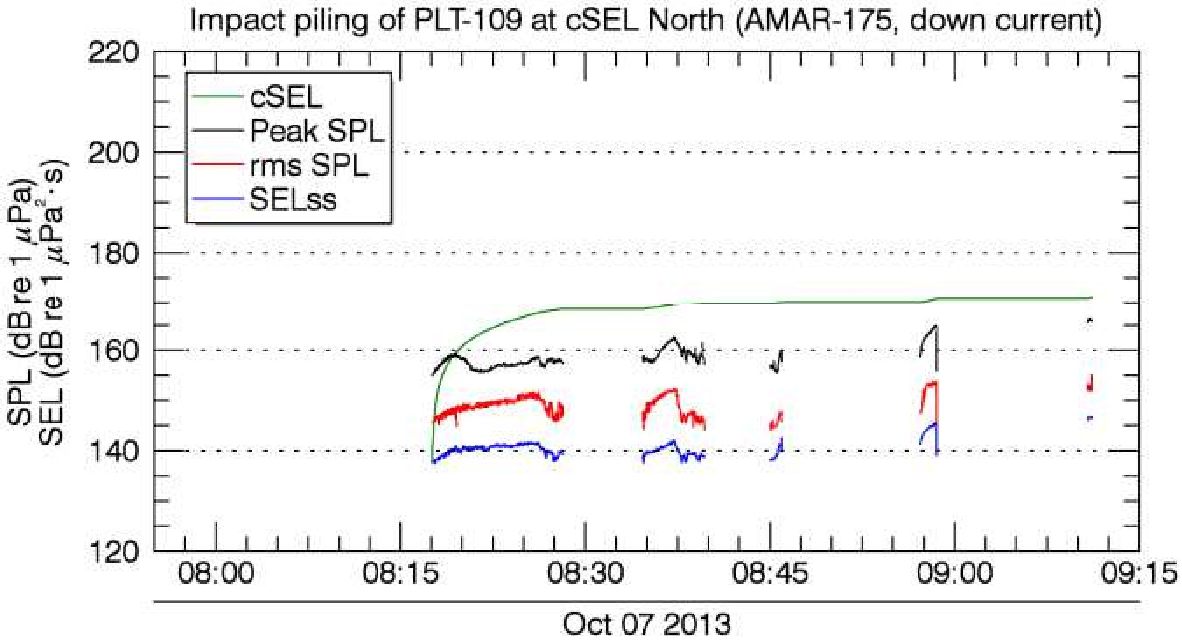


Figure 9. *Impact Pile Driving*: Peak SPL, rms SPL, SEL, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-109 measured 264 ft from the pile at location cSEL North using AMAR-175.

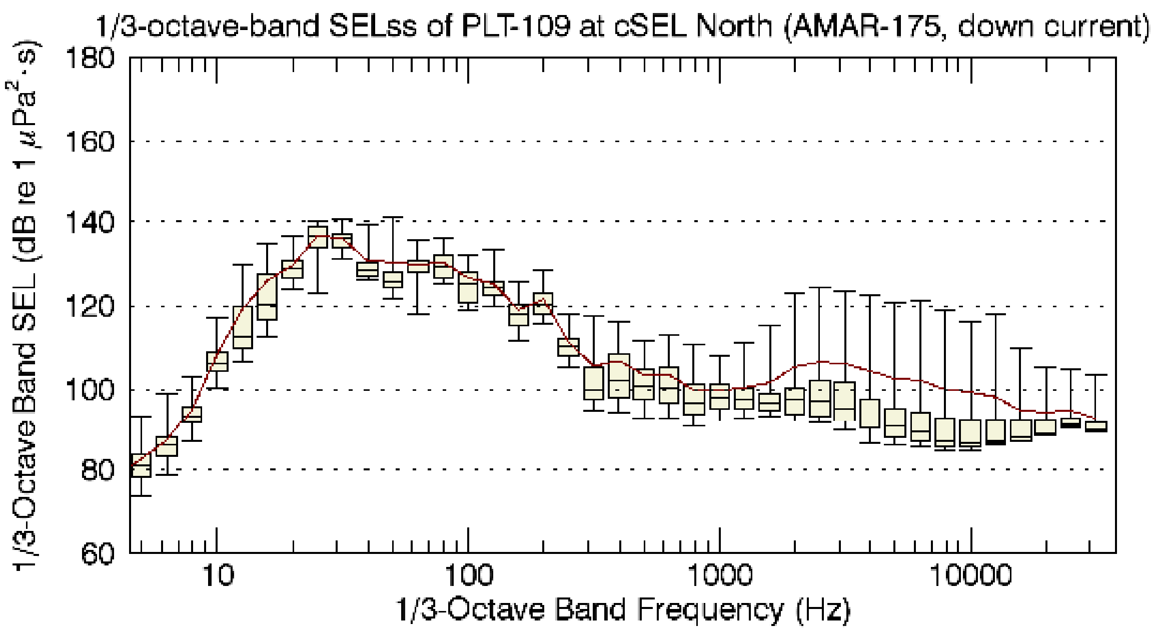


Figure 10. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-109 measured 264 ft from the pile at location cSEL North using AMAR-175. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 13. Sound levels for the pile driving of Test Pile PLT-109 measured 264 ft from the pile at location cSEL North using AMAR-175.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	166.4	155	146.8
L_5	163.1	152.5	144.4
L_{25}	159.2	150.4	141.1
L_{50}	158.0	149.1	140.4
L_{75}	157.0	147.3	139.4
L_{95}	155.8	145.7	138.2
L_{mean}	159.1	149.5	140.8

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

A.3. Impact Pile-Driving Sound Levels rms SPL North

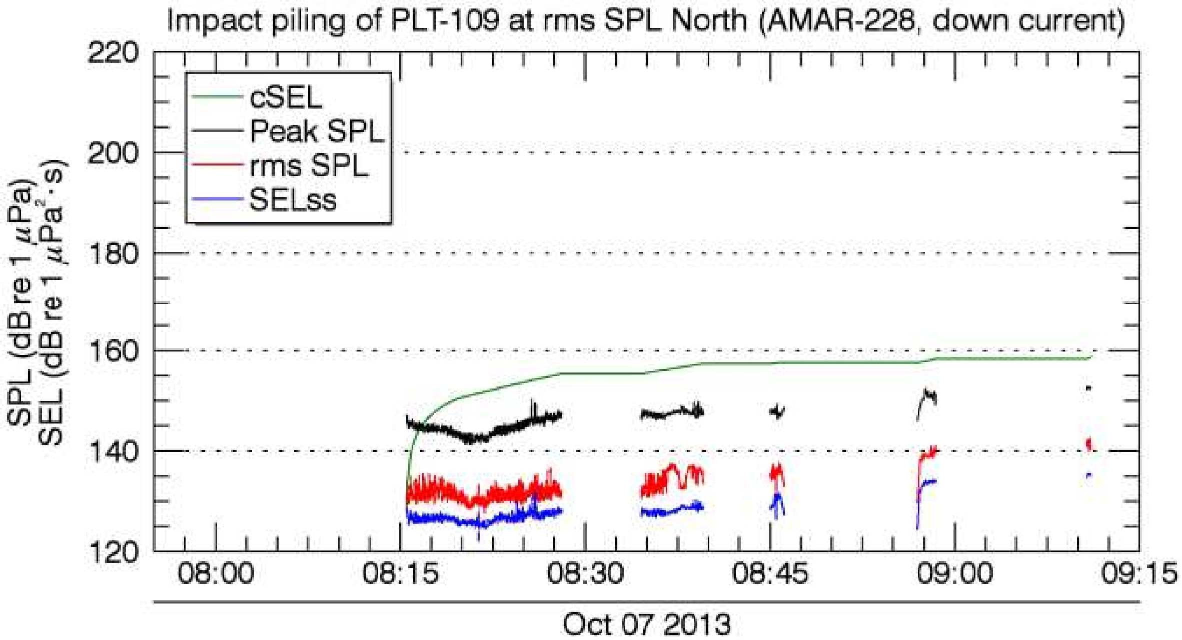


Figure 11. *Impact Pile Driving*: Peak SPL, rms SPL, SEL, and cSEL versus time (EDT) for the pile driving of Test Pile PLT-109 measured 835 ft from the pile at location rms SPL North using AMAR-228.

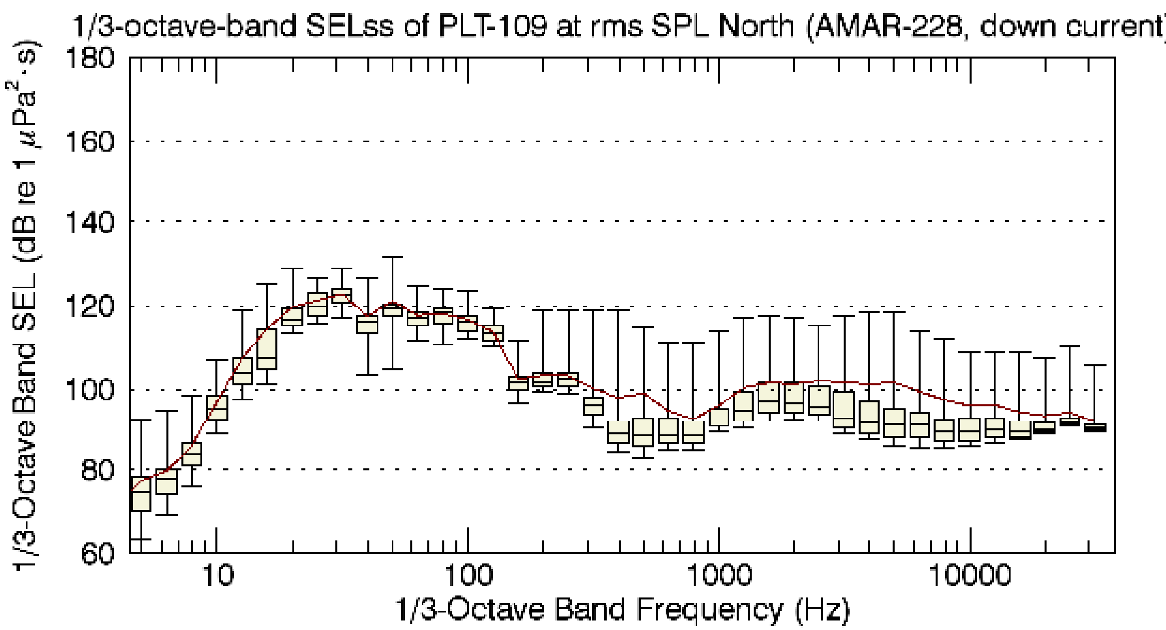


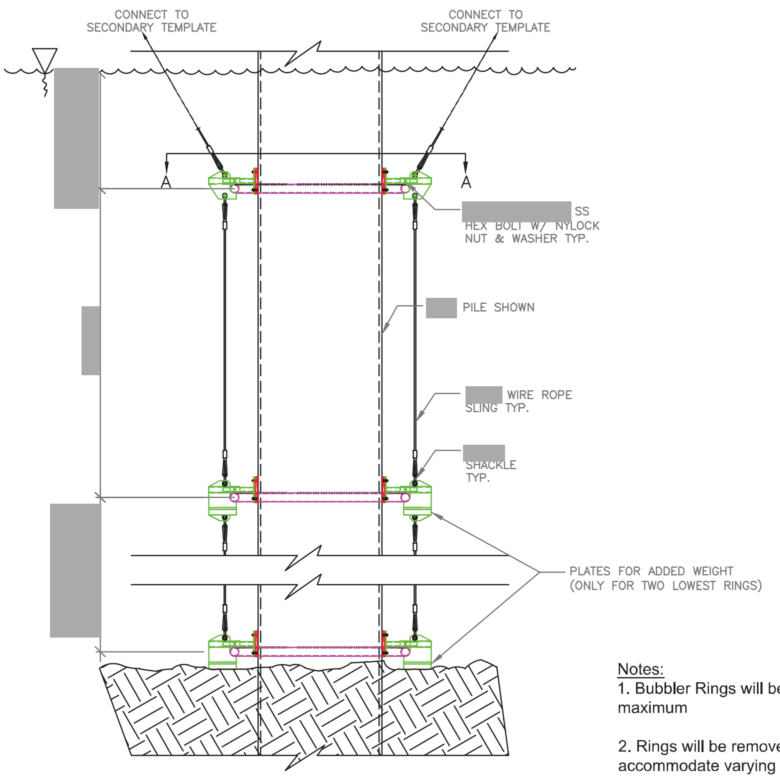
Figure 12. Distribution of 1/3-octave-band SELss for the pile driving of Test Pile PLT-109 measured 835 ft from the pile at location rms SPL North using AMAR-228. Beige bars indicate the first, second, and third quartiles (L_{25}, L_{50}, and L_{75}). Upper error bars indicate the maximum levels (L_{max}). Lower error bars indicate the 95% exceedance percentiles (L_{95}). The maroon line indicates the arithmetic mean (L_{mean}).

Table 14. Sound levels for the pile driving of Test Pile PLT-109 measured 835 ft from the pile at location rms SPL North using AMAR-228.

Sound level statistic*	peak SPL (dB re 1 µPa)	rms SPL (dB re 1 µPa)	SELss (dB re 1 µPa^2·s)
L_{max}	153.0	142.7	135.5
L_5	149.9	138.1	132.6
L_{25}	147.4	134.5	128.2
L_{50}	145.8	132.2	127.3
L_{75}	144.1	130.9	126.4
L_{95}	142.4	129.6	125.5
L_{mean}	146.5	133.9	128.2

* The sound level statistics quantify the observed distribution of recorded sound levels. Following standard acoustical practice, the *n*th percentile level (L_n) is the SPL or SEL exceeded by *n*% of the data. L_{max} is the maximum recorded sound level. L_{mean} is the linear arithmetic mean of the sound power, which can be significantly different from the median sound level (L_{50}).

Attachment 2 – Design Plans for the Multi-Tier Bubble Curtain (Drawings 1UBCR through 10UBCR)

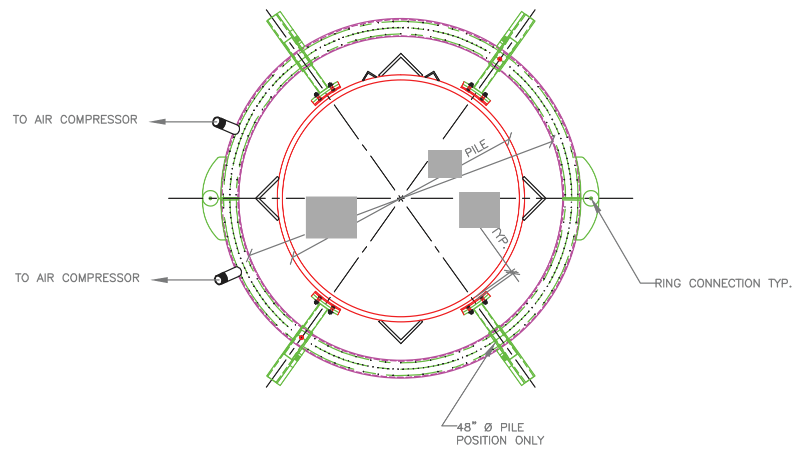


ELEVATION - BUBBLER RINGS [redacted] PILES
SCALE: NTS

Notes:
1. Bubbler Rings will be spaced at [redacted] centers maximum

2. Rings will be removed and added as needed to accommodate varying depths

3. These Bubbler Rings can be used on [redacted] diameter piles only



A - PLAN - BUBBLER RINGS
SCALE: NTS

REVISIONS			
DATE	DESCRIPTION	BY	SYM.

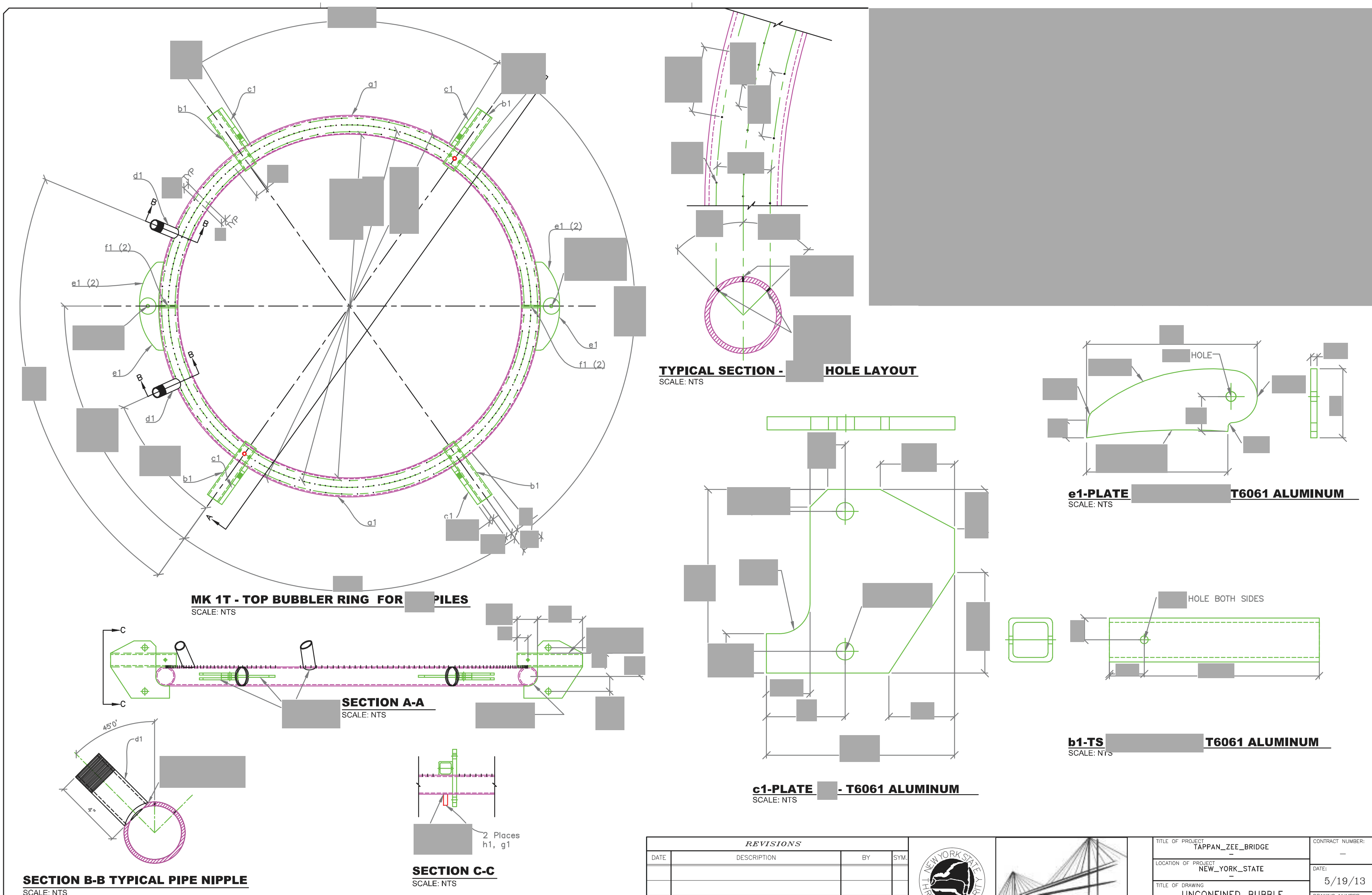
NEW YORK STATE THRUWAY AUTHORITY

TAPPAN ZEE CONSTRUCTORS, LLC

TITLE OF PROJECT: TAPPAN_ZEE_BRIDGE
LOCATION OF PROJECT: NEW_YORK_STATE
TITLE OF DRAWING: UNCONFINED_BUBBLE CURTAIN RINGS [redacted]
CONTRACT NUMBER: –
DATE: 5/19/13
DRAWING NUMBER: 2UBCR

DESIGN SUPERVISOR:
DESIGNED BY:
CHECKED BY:
DRAFTED BY: MARTIR_ORTEZ
CHECKED BY:

DOCUMENT TRACKING CODE: -



DESIGN SUPERVISOR:

DESIGNED BY:

CHECKED BY:

DRAFTED BY: MARTIR_ORTEZ

CHECKED BY:

DOCUMENT TRACKING CODE: -

REVISIONS			
DATE	DESCRIPTION	BY	SYM.

NEW YORK STATE THRUWAY AUTHORITY

TAPPAN ZEE CONSTRUCTORS, LLC

TITLE OF PROJECT: TAPPAN_ZEE_BRIDGE

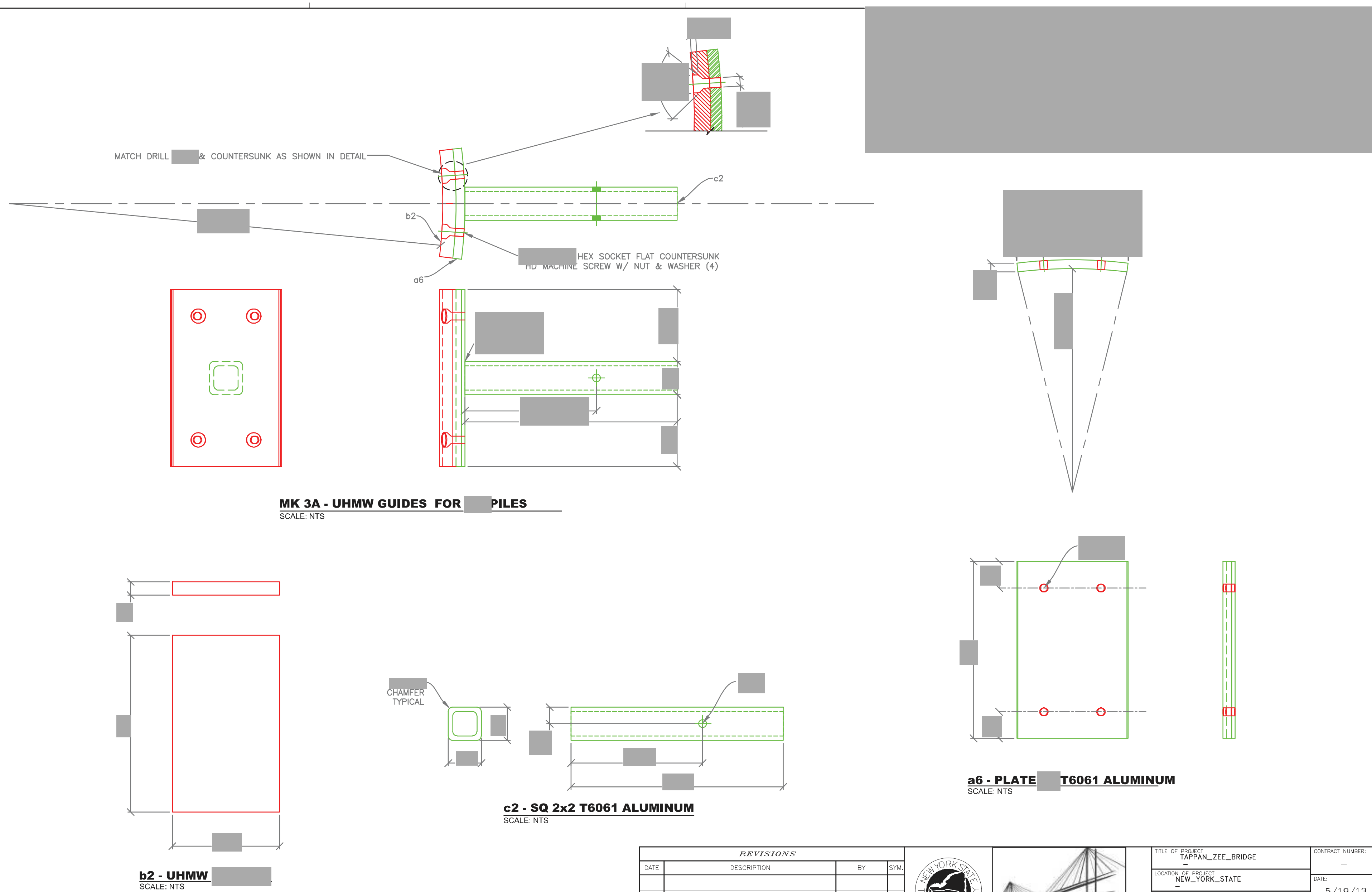
LOCATION OF PROJECT: NEW_YORK_STATE

TITLE OF DRAWING: UNCONFINED_BUBBLE CURTAIN_RINGS [redacted]

CONTRACT NUMBER: –

DATE: 5/19/13

DRAWING NUMBER: 3UBCR



DESIGN SUPERVISOR: | DESIGNED BY: | CHECKED BY: | DRAFTED BY: MARTIR_ORTEZ | CHECKED BY:

REVISIONS			
DATE	DESCRIPTION	BY	SYM.

NEW YORK STATE THRUWAY AUTHORITY

TAPPAN ZEE CONSTRUCTORS, LLC

TITLE OF PROJECT: TAPPAN_ZEE_BRIDGE

LOCATION OF PROJECT: NEW_YORK_STATE

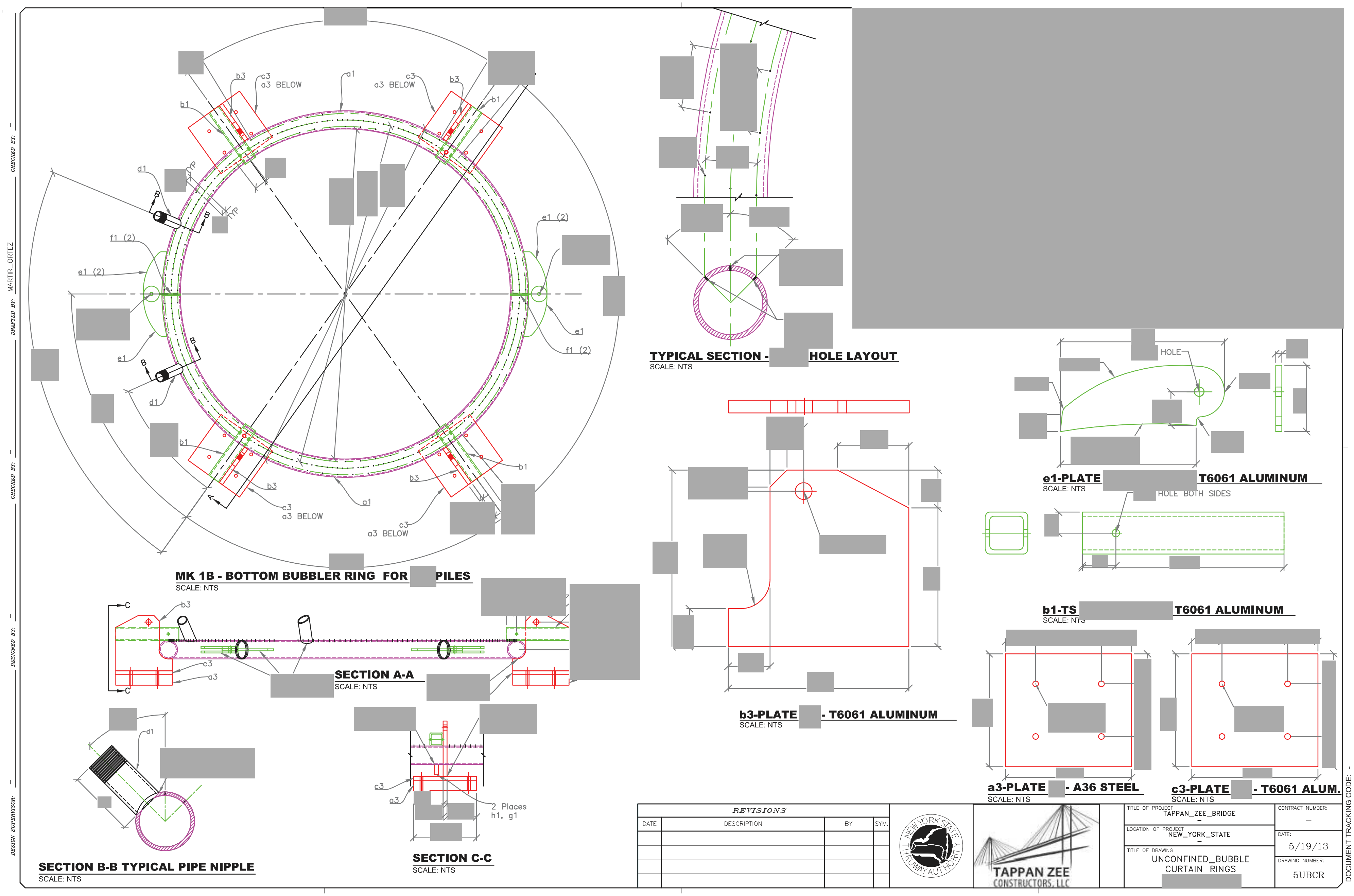
TITLE OF DRAWING: UNCONFINED_BUBBLE CURTAIN RINGS [redacted]

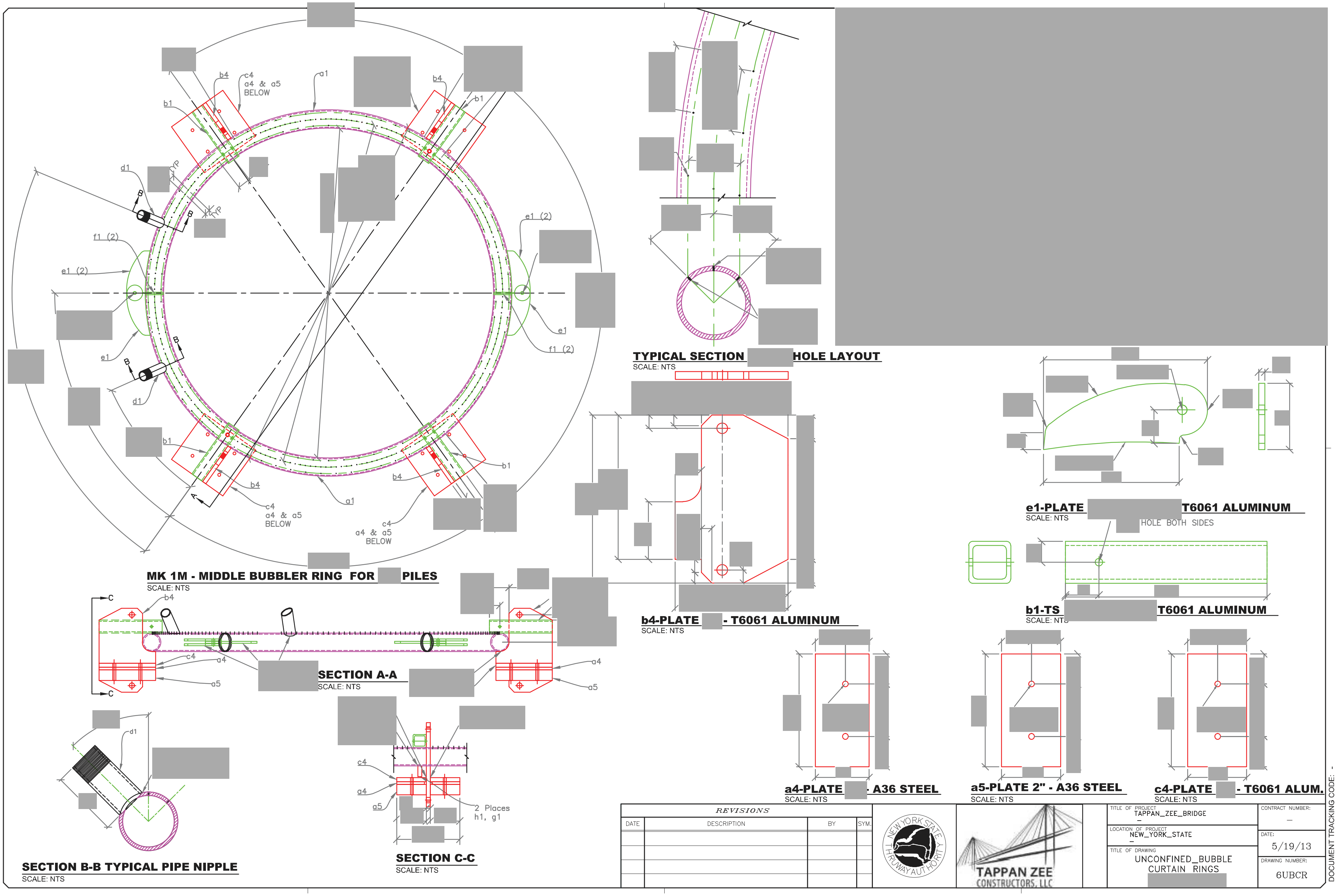
CONTRACT NUMBER: –

DATE: 5/19/13

DRAWING NUMBER: 4UBCR

DOCUMENT TRACKING CODE: -


MK 1B - BOTTOM BUBBLER RING FOR [redacted] PILES
SCALE: NTS
b1
b3
c3
a3 BELOW
a1
d1
TYP
B
f1 (2)
e1 (2)
e1
A
TYPICAL SECTION - [redacted] HOLE LAYOUT
SCALE: NTS
SECTION A-A
SCALE: NTS
C
SECTION B-B TYPICAL PIPE NIPPLE
SCALE: NTS
SECTION C-C
SCALE: NTS
2 Places
h1, g1
b3-PLATE [redacted] - T6061 ALUMINUM
SCALE: NTS
e1-PLATE [redacted] T6061 ALUMINUM
SCALE: NTS
HOLE
HOLE BOTH SIDES
b1-TS [redacted] T6061 ALUMINUM
SCALE: NTS
a3-PLATE [redacted] - A36 STEEL
SCALE: NTS
c3-PLATE [redacted] - T6061 ALUM.
SCALE: NTS
REVISIONS
DATE
DESCRIPTION
BY
SYM.
NEW YORK STATE THRUWAY AUTHORITY
TAPPAN ZEE CONSTRUCTORS, LLC
TITLE OF PROJECT
TAPPAN_ZEE_BRIDGE
LOCATION OF PROJECT
NEW_YORK_STATE
TITLE OF DRAWING
UNCONFINED_BUBBLE CURTAIN RINGS
CONTRACT NUMBER:
DATE:
5/19/13
DRAWING NUMBER:
5UBCR
DESIGN SUPERVISOR:
DESIGNED BY:
CHECKED BY:
DRAFTED BY:
MARTIR_ORTEZ
DOCUMENT TRACKING CODE: -



MK 1M - MIDDLE BUBBLER RING FOR [redacted] PILES
SCALE: NTS
TYPICAL SECTION [redacted] HOLE LAYOUT
SCALE: NTS
e1-PLATE [redacted] T6061 ALUMINUM
SCALE: NTS
HOLE BOTH SIDES
b4-PLATE [redacted] - T6061 ALUMINUM
SCALE: NTS
b1-TS [redacted] T6061 ALUMINUM
SCALE: NTS
SECTION A-A
SCALE: NTS
SECTION B-B TYPICAL PIPE NIPPLE
SCALE: NTS
SECTION C-C
SCALE: NTS
2 Places
h1, g1
a4-PLATE [redacted] - A36 STEEL
SCALE: NTS
a5-PLATE 2" - A36 STEEL
SCALE: NTS
c4-PLATE [redacted] - T6061 ALUM.
SCALE: NTS
c4
a4 & a5
BELOW
b1
b4
d1
e1 (2)
f1 (2)
e1
f1 (2)
g1
a4
a5
DRAFTED BY: MARTIR_ORTEZ
CHECKED BY:
DESIGNED BY:
DESIGN SUPERVISOR:
REVISIONS
DATE
DESCRIPTION
BY
SYM.
NEW YORK STATE THRUWAY AUTHORITY
TAPPAN ZEE CONSTRUCTORS, LLC
TITLE OF PROJECT TAPPAN_ZEE_BRIDGE
LOCATION OF PROJECT NEW_YORK_STATE
TITLE OF DRAWING UNCONFINED_BUBBLE CURTAIN RINGS
CONTRACT NUMBER: –
DATE: 5/19/13
DRAWING NUMBER: 6UBCR
DOCUMENT TRACKING CODE: -

Attachment 3 – Air Compressor Specifications

Atlas Copco Rental

PTS 916

100% Oil-free Air Compressor - Diesel driven - TIER III compliant

Atlas Copco Rental is the leader in 100% oil-free air compressor rentals and maintains a strong commitment to customer service and availability, with locations across North America. A highly specialized service team is readily accessible 24/7 when you work with the Atlas Copco Rental team.

Sustainable Productivity

Atlas Copco

PTS 916 100% Oil-free Air Compressor

General

Dimensions LxWxH	17'8" x 7'3" x 7'9"
Shipping weight (wet)	18,600 lbs / 8,437 kg
Fuel tank capacity	237 gal / 900 l
Sound pressure level LPA	74 dB (A)
Sound power level LWA	102 dB (A)

Engine

Engine make	Caterpillar
Type	C18 Acert
Output	575 HP / 429 kW
Fuel consumed (Gal/Hr)	22

Compressor

Number of stages	2
Maximum capacity FAD l/s	762
Maximum capacity FAD m³/min	45.7
Maximum capacity FAD cfm	1,600

Performance

Working Pressure		Free Air Delivery		
bar(e)	*psig*	*m³/min*	*m³/H*	*cfm*
6.9	10-150	45.7	2,742	1,300-1,600
9.3	135	43.1	2,586	1,522
10.3	150	37.4	2,244	1,321

Other Features

- Integrated aftercooler (15°F + A)
- Spillage free frame
- Weatherproof canopy
- Spark arrestor
- Overspeed shut down system
- Cold weather package
- Auxillary tank hook-ups w/ switching valves
- Operator safety devices:
  - Emergency stop buttons
  - Warning light
  - Alarm horn

Never use compressed air as breathing air without prior purifcation in accordance with local legislation and standards.

The TÜV found no traces of oil in the output air stream. Atlas Copco has thereby become the first compressor manufacturer to receive certification for a new industry standard of air purity: **ISO 8573-1 CLASS 0.** More information can be found on: **www.classzero.com**

All Routine Service Included

We provide routine maintenance at no charge.
No hidden costs!

Additional Rental Product Solutions

- Boosters
- Dryers
- Fuel Tanks (double wall)
- Hoses
- Manifolds
- Nitrogen Generation Equipment
- Particulate Discharge Scrubbers
- Trailers

Triple certification, Triple benefit

24/7 Rental Service all across USA and Canada
1-800-736-8267
www.AtlasCopcoRental.com