Appendix F: Ecology

F-5B Appendix to Underwater Ambient Sound Level in the Hudson River near the Tappan Zee Bridge: Short and Long Span Ambient Noise Modeling (Jasco, July 2011)

Tappan Zee Bridge Construction Hydroacoustic Noise Modeling

Appendices

Submitted to:
AECOM
One World Financial Center
200 Liberty St, 25th Floor
New York, NY 10281

Authors:
Alexander MacGillivray
Graham Warner
Roberto Racca
Caitlin O'Neill

JASCO Applied Sciences
Suite 2101, 4464 Markham St.
Victoria, BC, V8Z 7X8, Canada
Phone: +1.250.483.3300
Fax: +1.250.483.3301
www.jasco.com

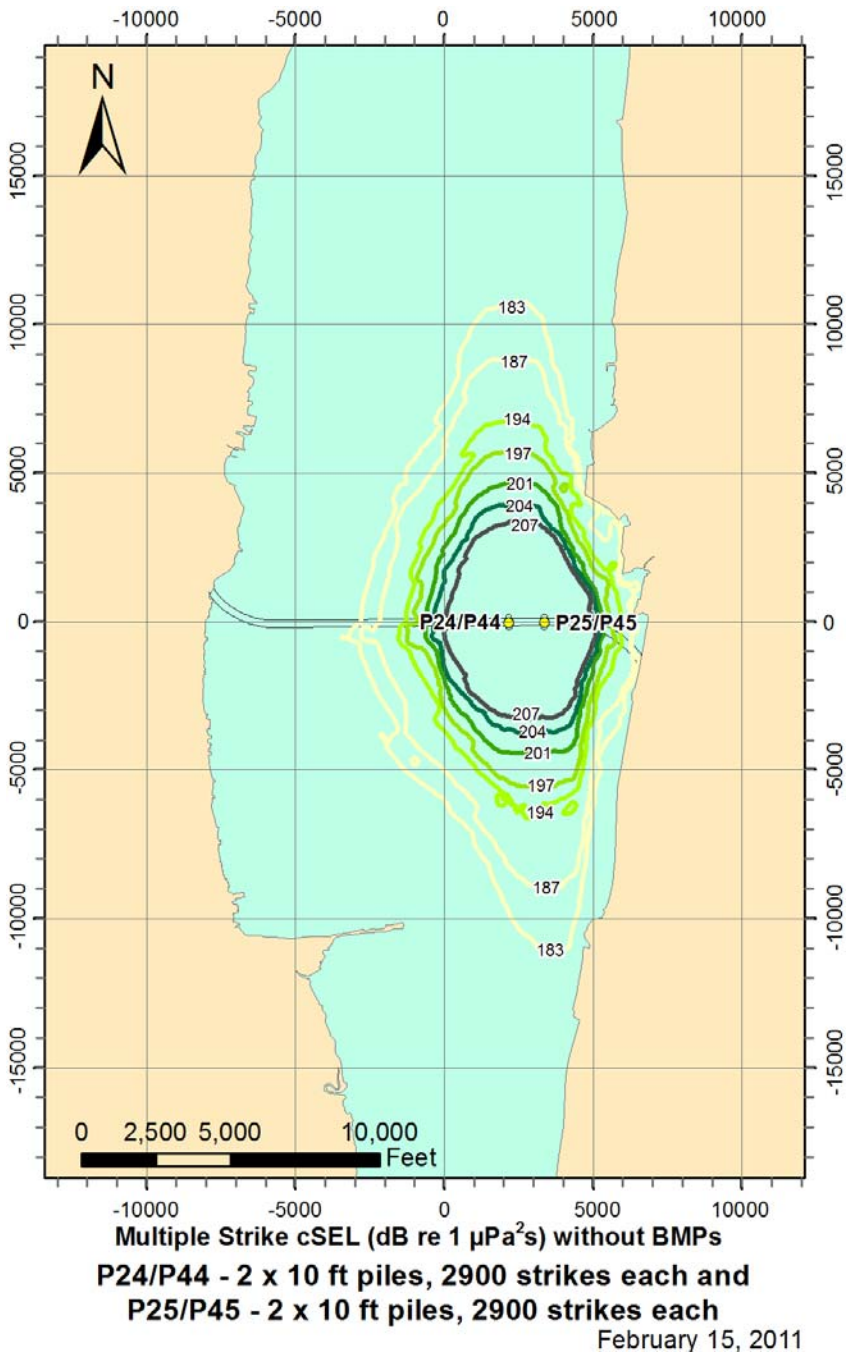
March 2011
P001116-001
Version 1.0

Contents

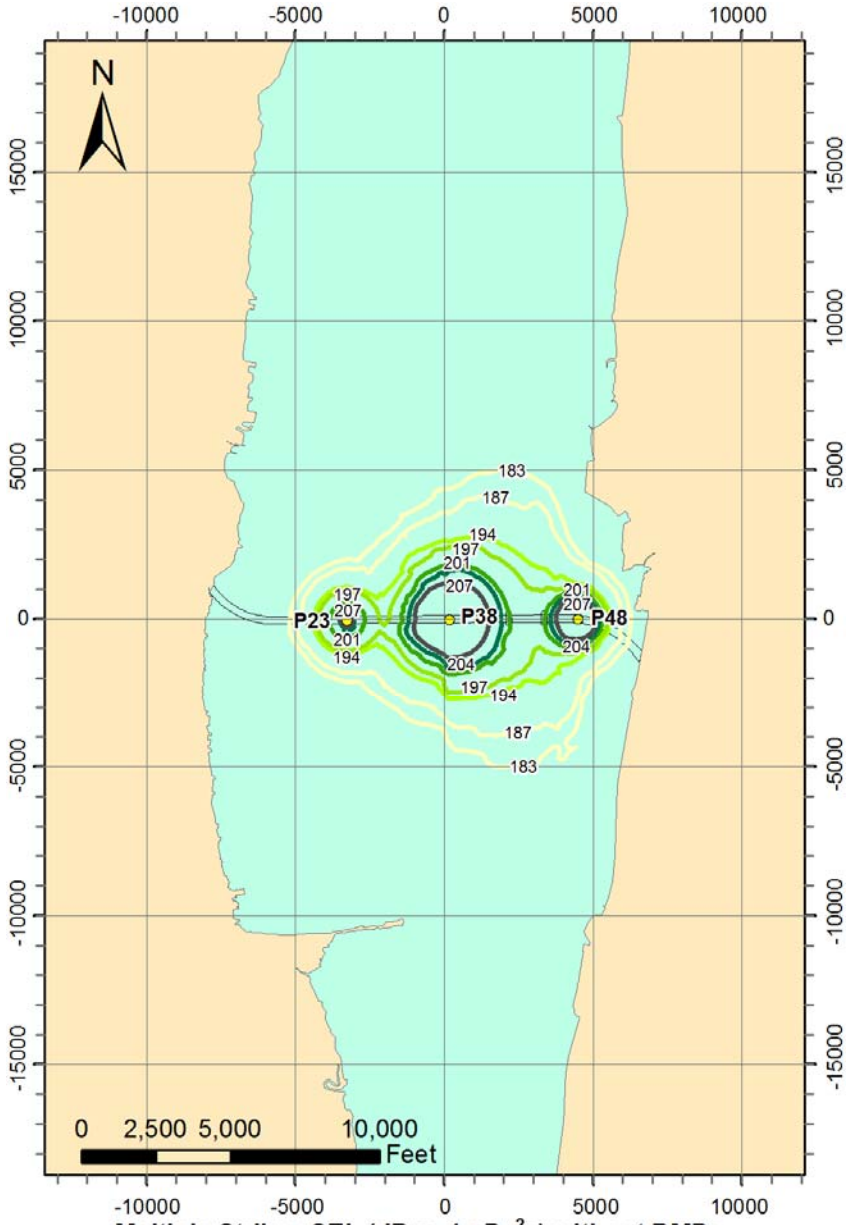
Appendix A. Cumulative cSEL Scenario Maps

A.1. Single Level Bridge: No BMPs Applied

A.1.1. Max Case 1 (also dual level bridge)



A.1.2. Max Case 2A

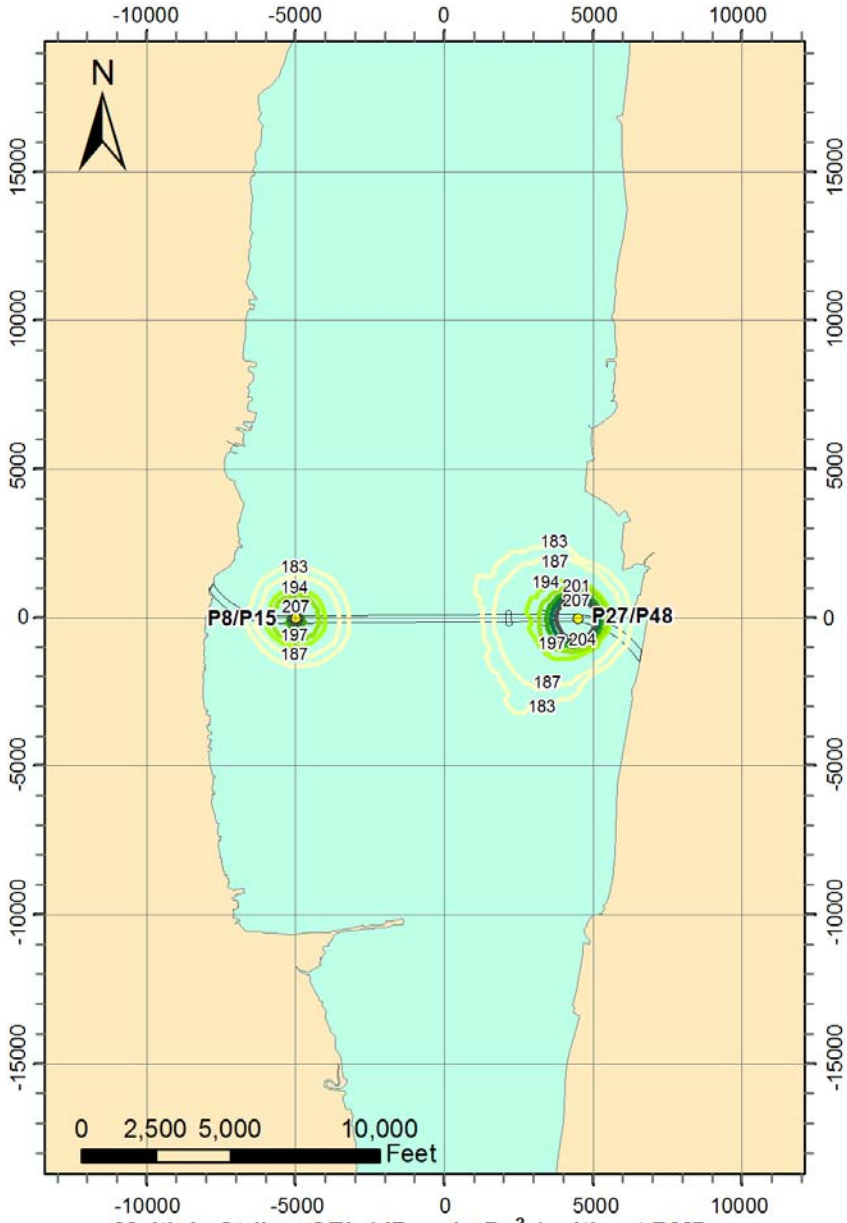


Multiple Strike cSEL (dB re 1 μPa^{2}s) without BMPs

P23 - 3 x 4 ft piles, 3800 strikes each,
P38 - 3 x 8 ft piles, 2100 strikes each, and
P48 - 4 x 6 ft piles, 1000 strikes each

January 27, 2011

A.1.3. Max Case 3 (also dual level bridge)

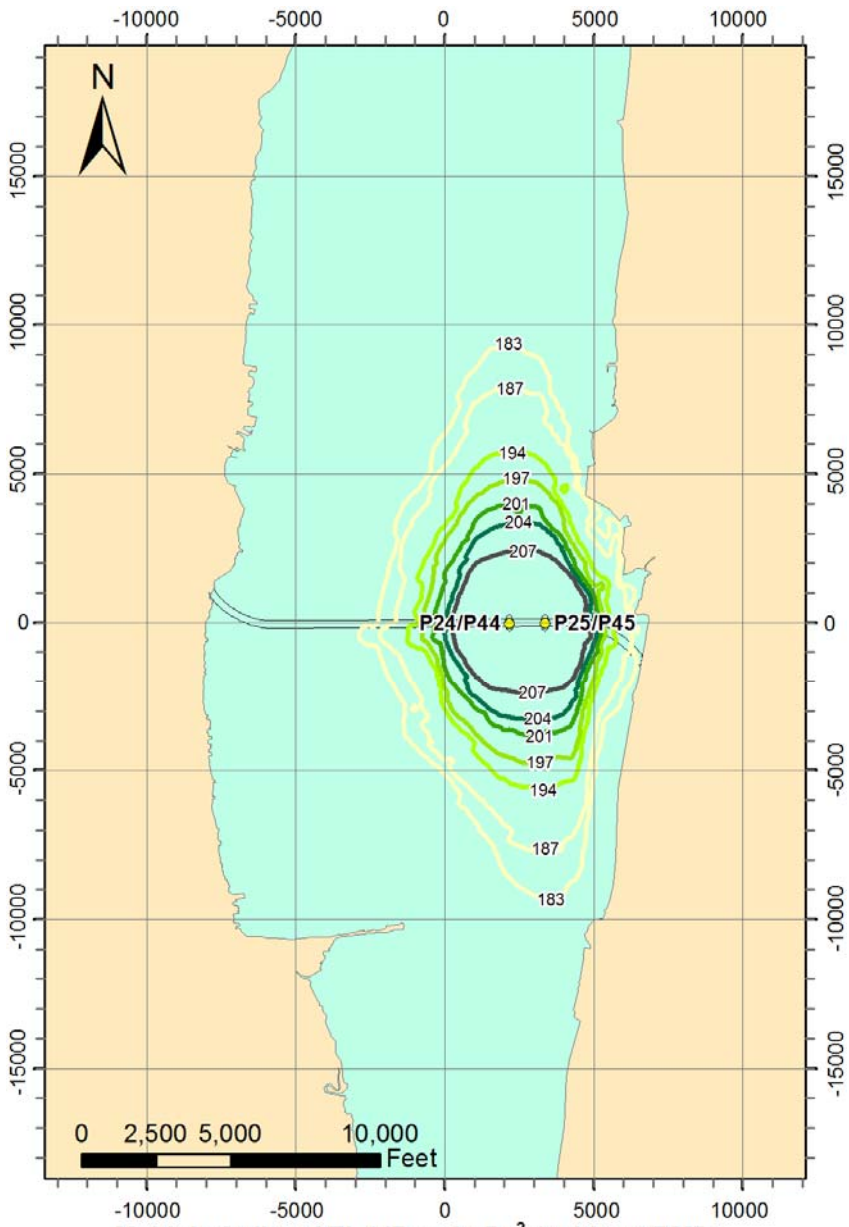


Multiple Strike cSEL (dB re 1 μPa^{2}s) without BMPs

P8/P15 - 3 x 4 ft piles, 3800 strikes each and
P27/P48 - 4 x 6 ft piles, 1000 strikes each

January 27, 2011

A.1.4. Typical Case 1 (also dual level bridge)

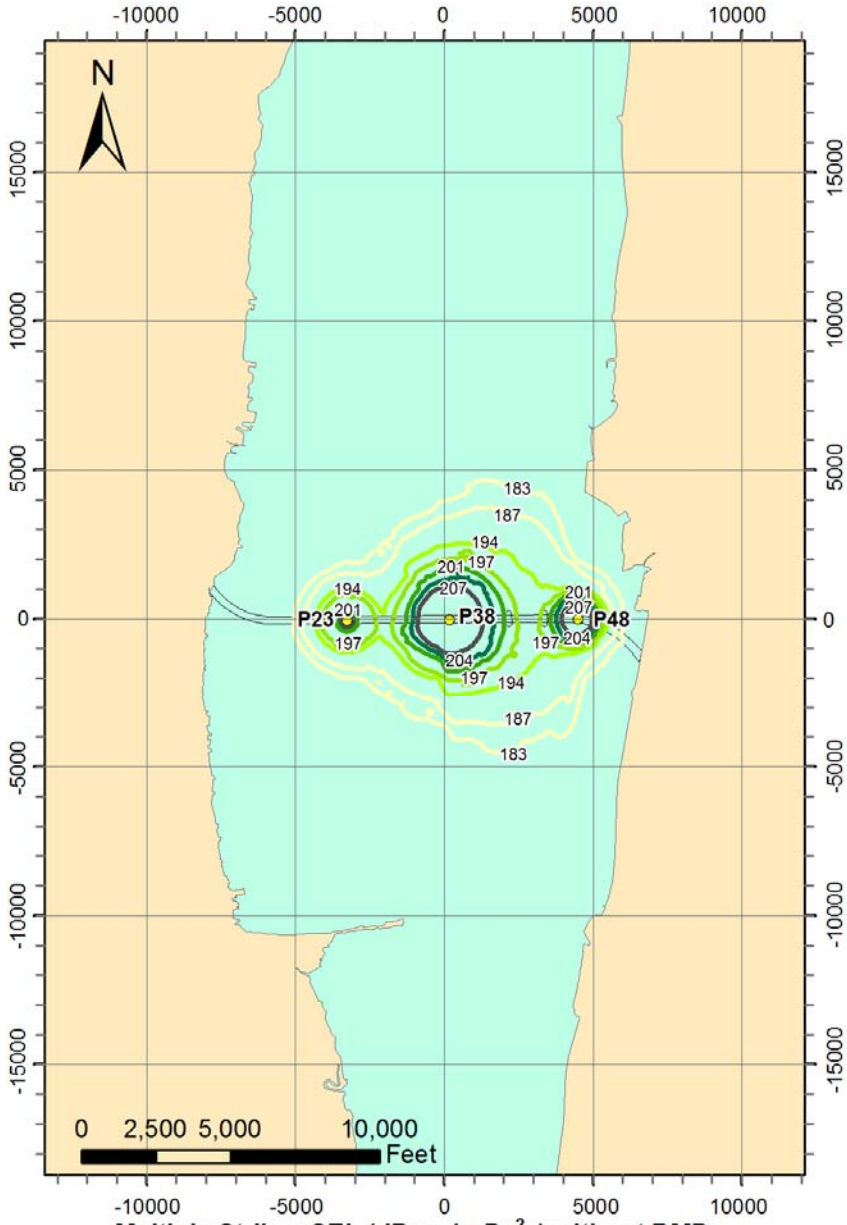


Multiple Strike cSEL (dB re 1 μPa^{2}s) without BMPs

P24/P44 - 1 x 10 ft pile, 2900 strikes each and
P25/P45 - 1 x 10 ft pile, 2900 strikes each

January 27, 2011

A.1.5. Typical Case 2A

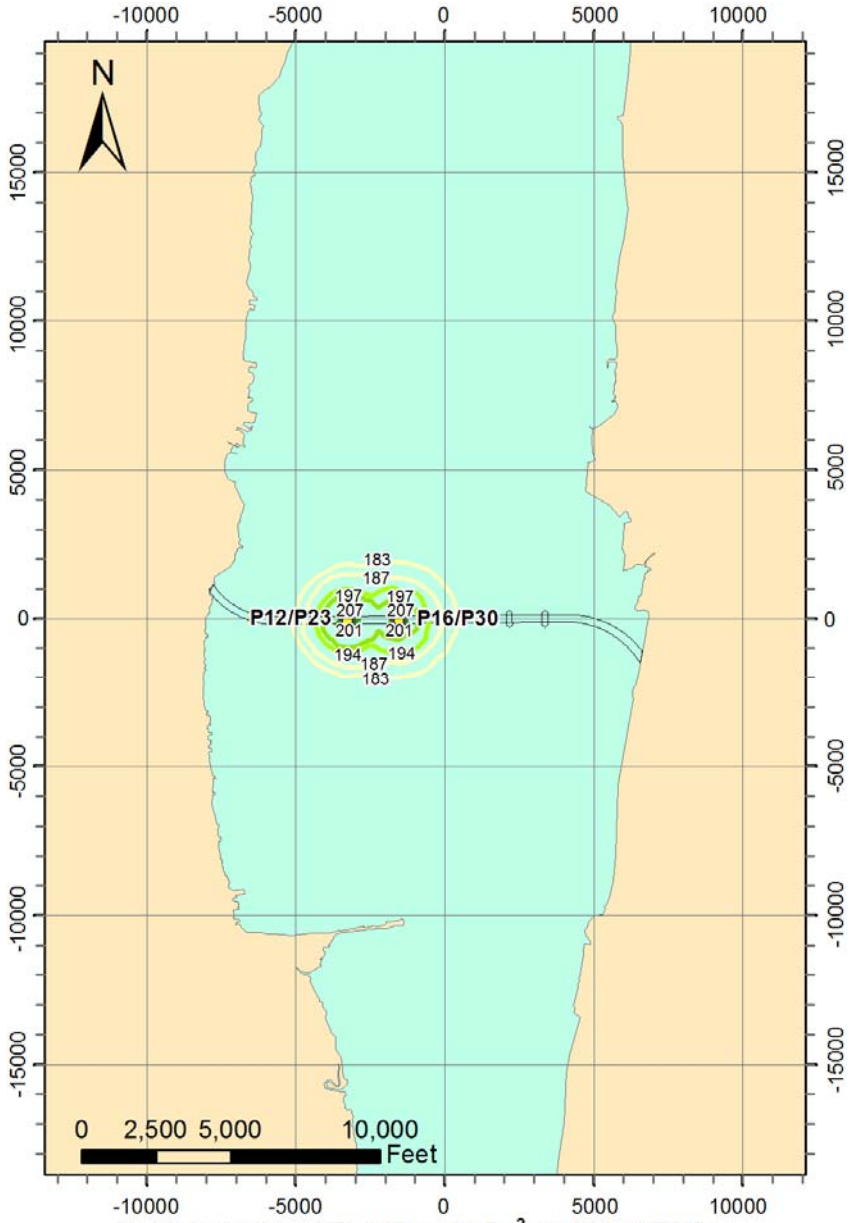


Multiple Strike cSEL (dB re 1 μPa^{2}s) without BMPs

P23 - 2 x 4 ft piles, 3800 strikes each,
P38 - 2 x 8 ft piles, 2100 strikes each, and
P48 - 2 x 6 ft piles, 1000 strikes each

January 27, 2011

A.1.6. Typical Case 3 (also dual level bridge)



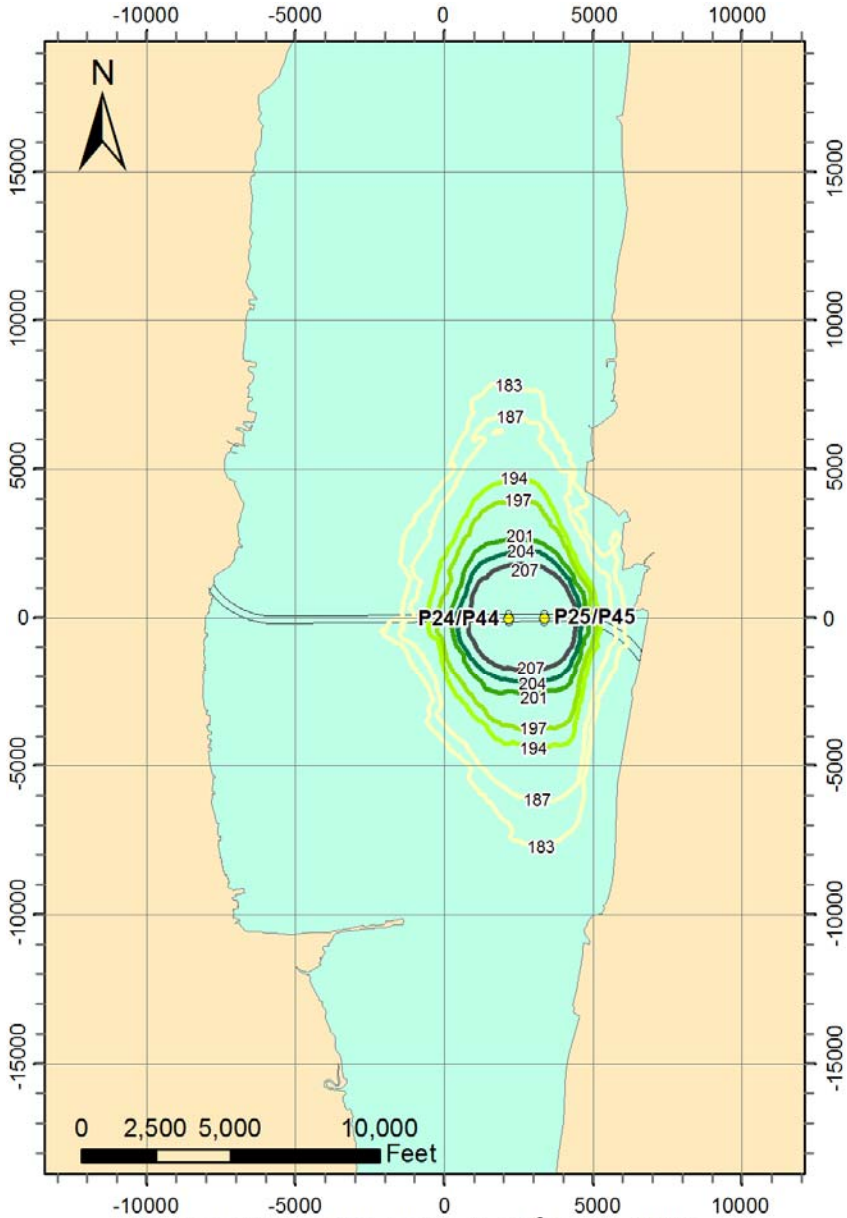
Multiple Strike cSEL (dB re 1 μPa²s) without BMPs

P12/P23 - 2 x 4 ft piles, 3800 strikes each and
P16/P30 - 2 x 4 ft piles, 3800 strikes each

January 27, 2011

A.2. Single Level Bridge: BMPs Applied

A.2.1. Max Case 1 (also dual level bridge)

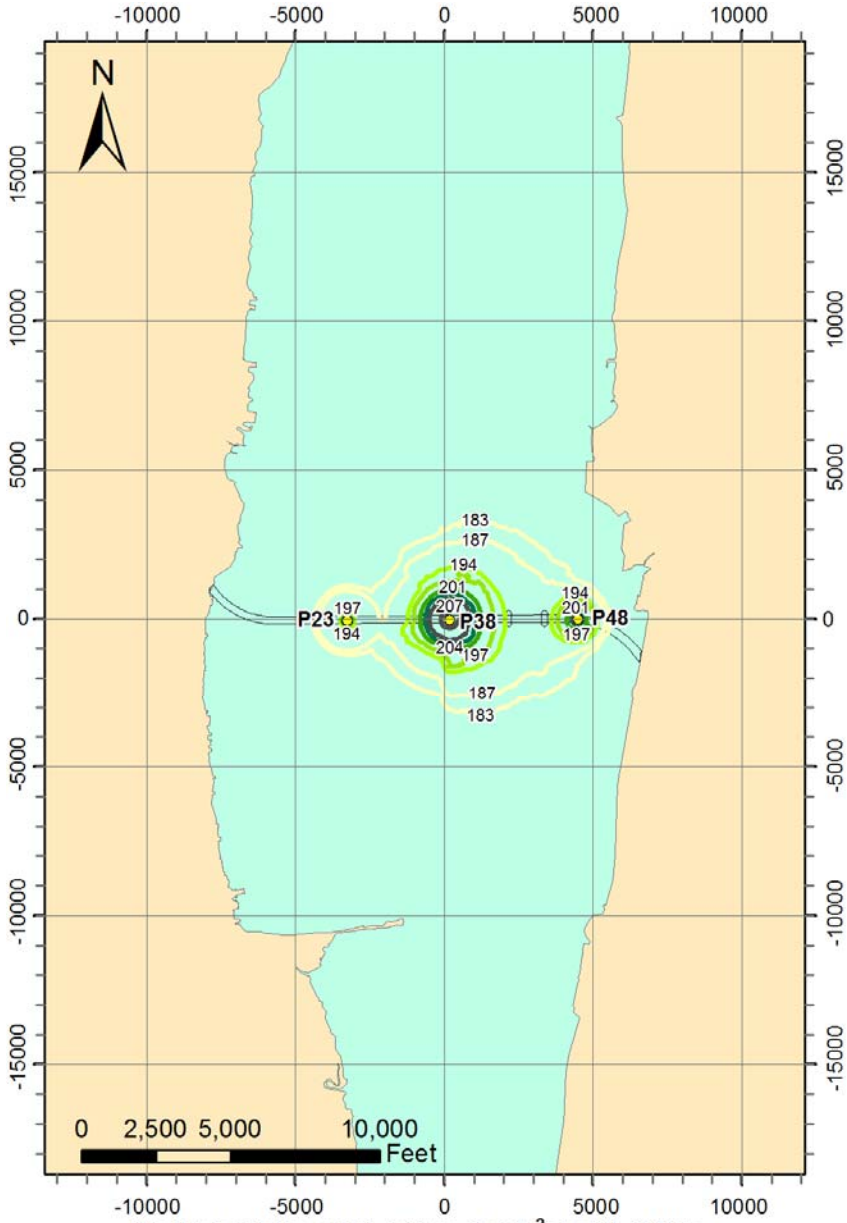


Multiple Strike cSEL (dB re 1 μPa^{2}s) with BMPs

P24/P44 - 2 x 10 ft piles, 2900 strikes each and
P25/P45 - 2 x 10 ft piles, 2900 strikes each

January 27, 2011

A.2.2. Max Case 2A

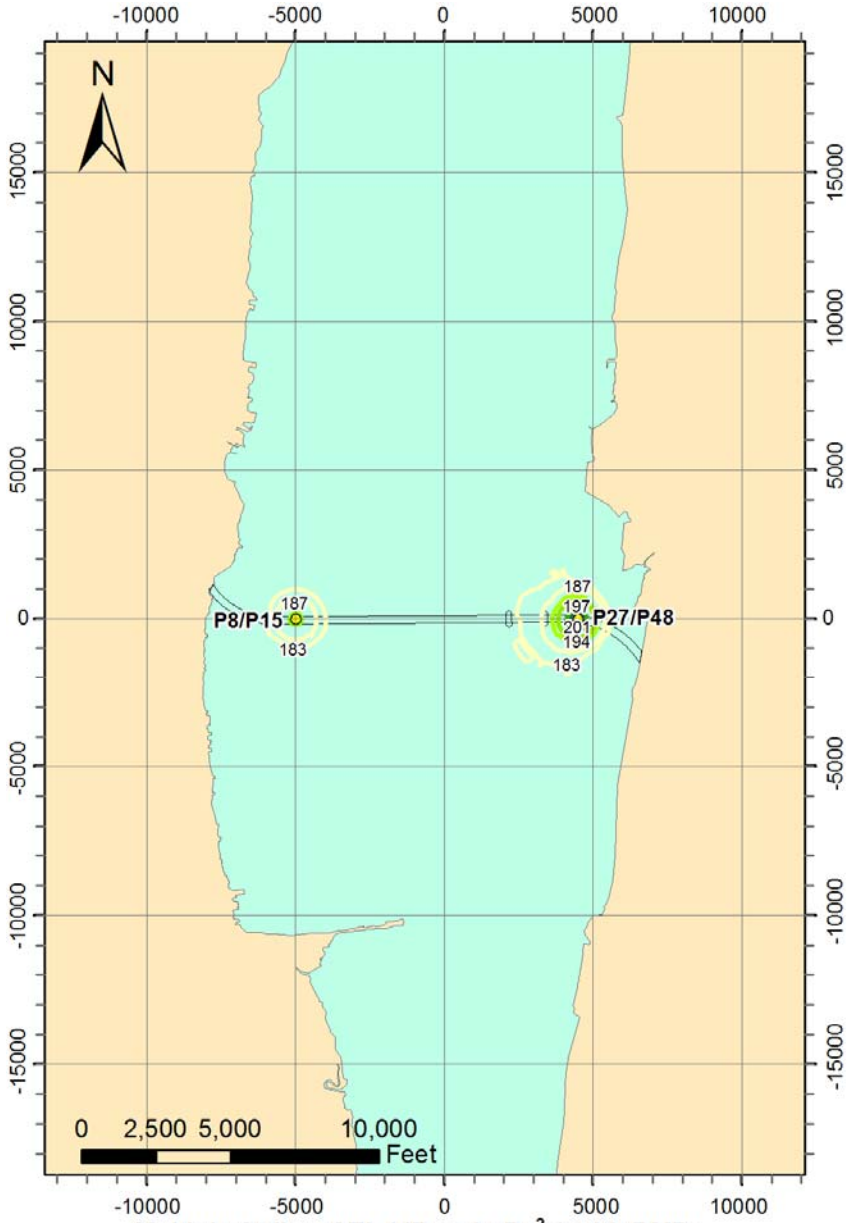


Multiple Strike cSEL (dB re 1 μPa^{2}s) with BMPs

P23 - 3 x 4 ft piles, 3800 strikes each,
P38 - 3 x 8 ft piles, 2100 strikes each, and
P48 - 4 x 6 ft piles, 1000 strikes each

January 27, 2011

A.2.3. Max Case 3 (also dual level bridge)

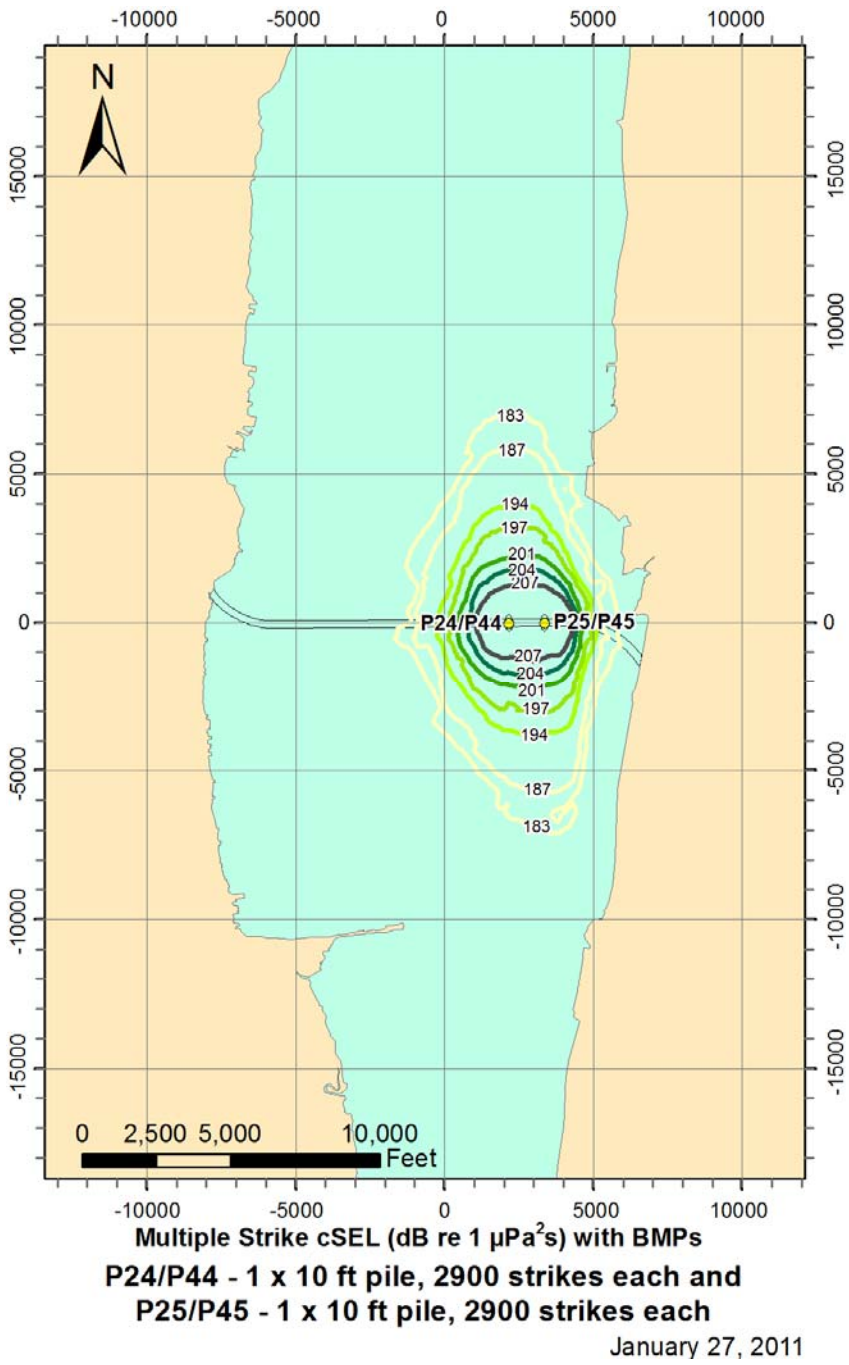


Multiple Strike cSEL (dB re 1 μPa^{2}s) with BMPs

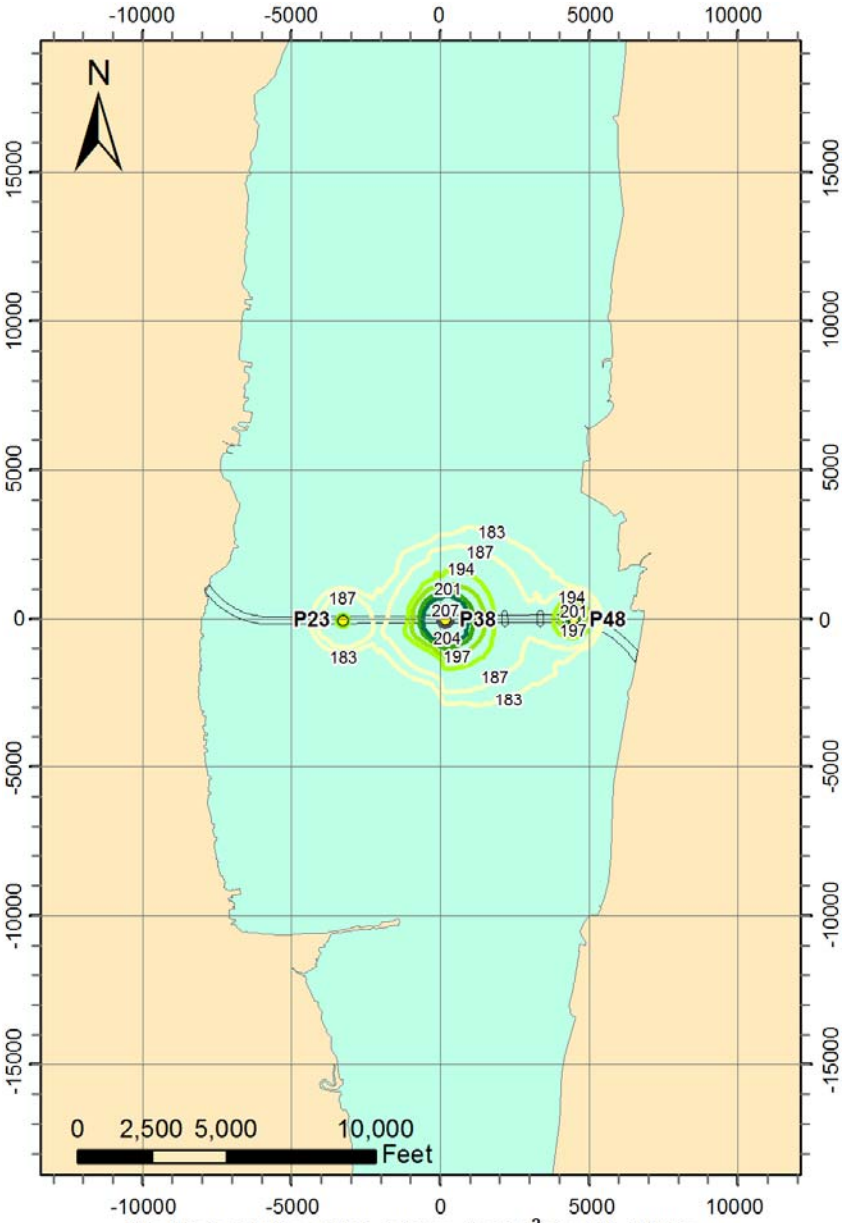
P8/P15 - 3 x 4 ft piles, 3800 strikes each and
P27/P48 - 4 x 6 ft piles, 1000 strikes each

January 27, 2011

A.2.4. Typical Case 1 (also dual level bridge)



A.2.5. Typical Case 2A

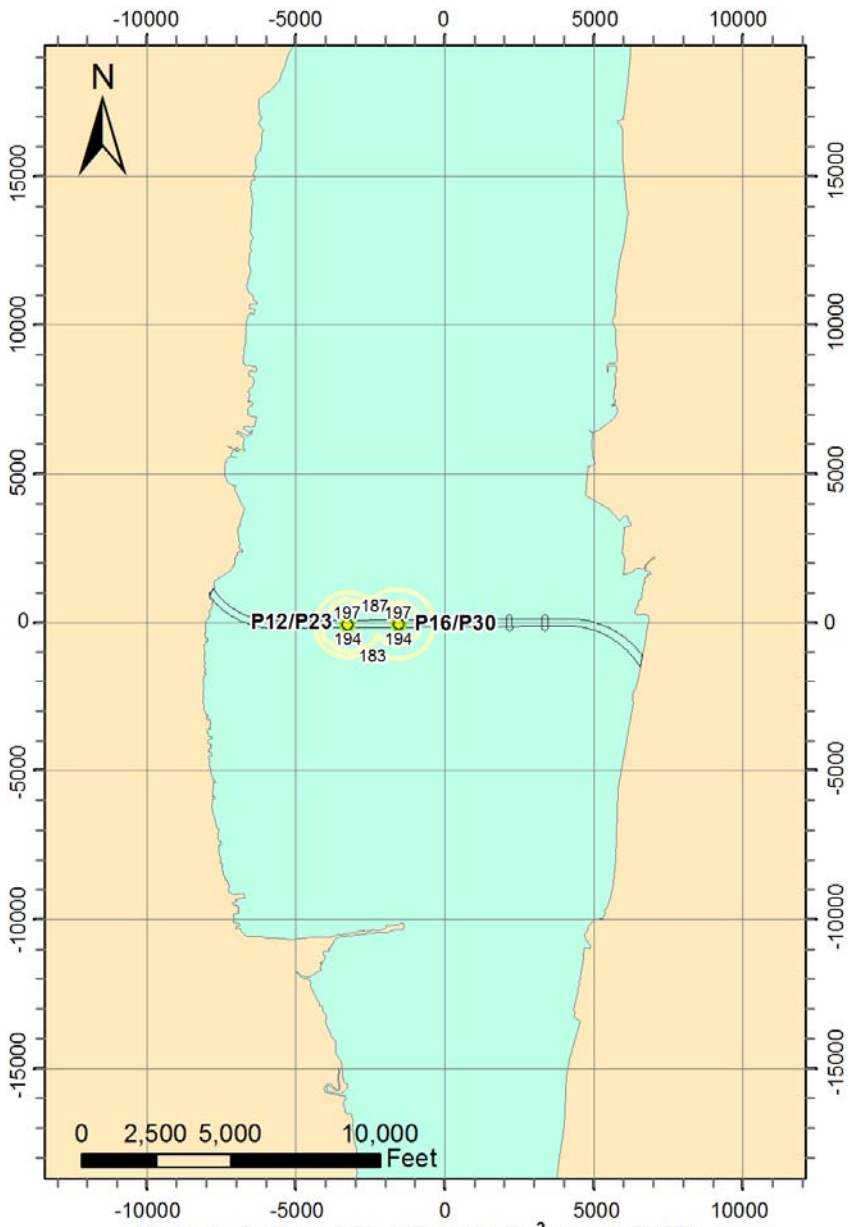


Multiple Strike cSEL (dB re 1 μPa^{2}s) with BMPs

P23 - 2 x 4 ft piles, 3800 strikes each,
P38 - 2 x 8 ft piles, 2100 strikes each, and
P48 - 2 x 6 ft piles, 1000 strikes each

January 27, 2011

A.2.6. Typical Case 3 (also dual level bridge)



Multiple Strike cSEL (dB re 1 μPa²s) with BMPs

P12/P23 - 2 x 4 ft piles, 3800 strikes each and
P16/P30 - 2 x 4 ft piles, 3800 strikes each

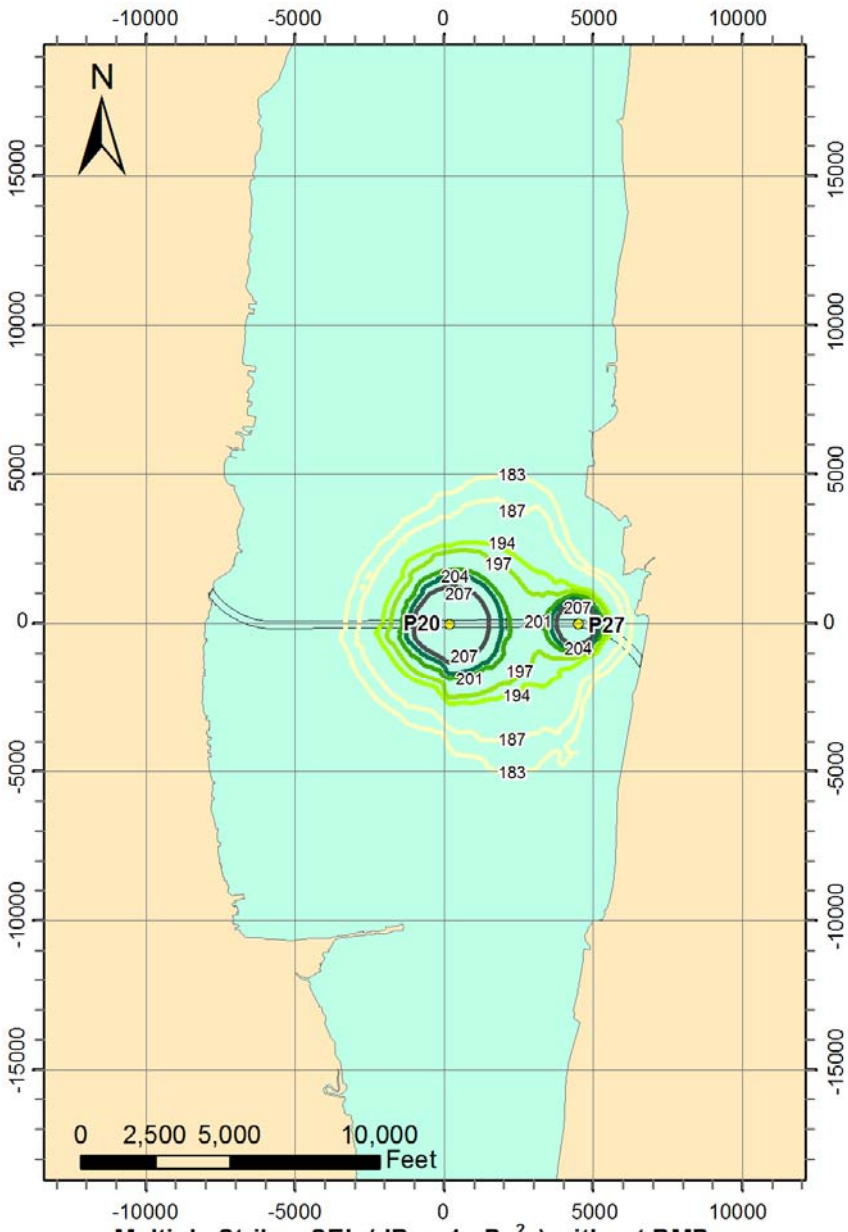
January 27, 2011

A.3. Dual Level Bridge: No BMPs Applied

A.3.1. Max Case 1

Sound level contours are identical to those of the single level bridge in section A.1.1. Max Case 1 (also dual level bridge).

A.3.2. Max Case 2B



Multiple Strike cSEL (dB re 1 μPa²s) without BMPs

P20 - 3 x 8 ft piles, 2100 strikes each and
P27 - 4 x 6 ft piles, 1000 strikes each

January 21, 2011

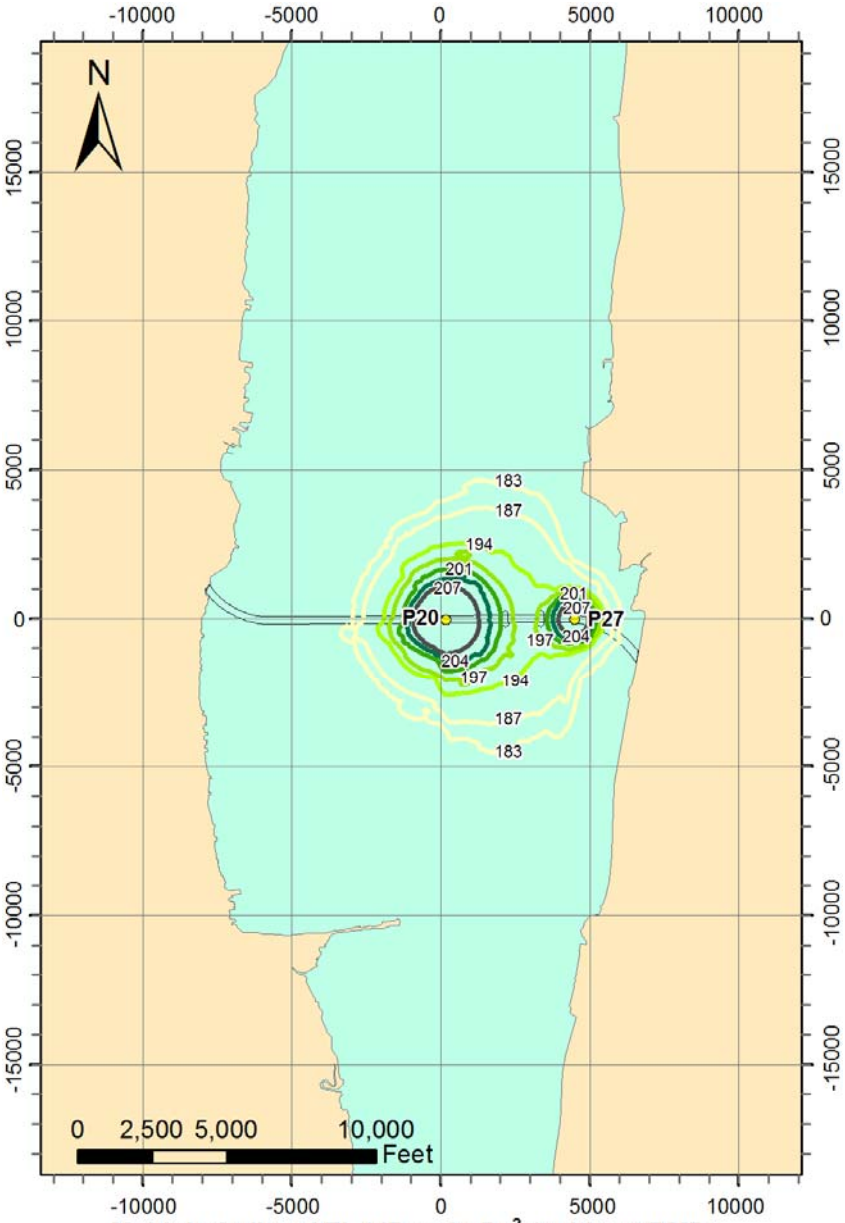
A.3.3. Max Case 3

Sound level contours are identical to those of the single level bridge in section A.1.3. Max Case 3 (also dual level bridge).

A.3.4. Typical Case 1

Sound level contours are identical to those in of the single level bridge section A.1.4. Typical Case 1 (also dual level bridge).

A.3.5. Typical Case 2B



Multiple Strike cSEL (dB re 1 μPa^{2}s) without BMPs

P20 - 2 x 8 ft piles, 2100 strikes each and
P27 - 2 x 6 ft piles, 1000 strikes each

January 27, 2011

A.3.6. Typical Case 3

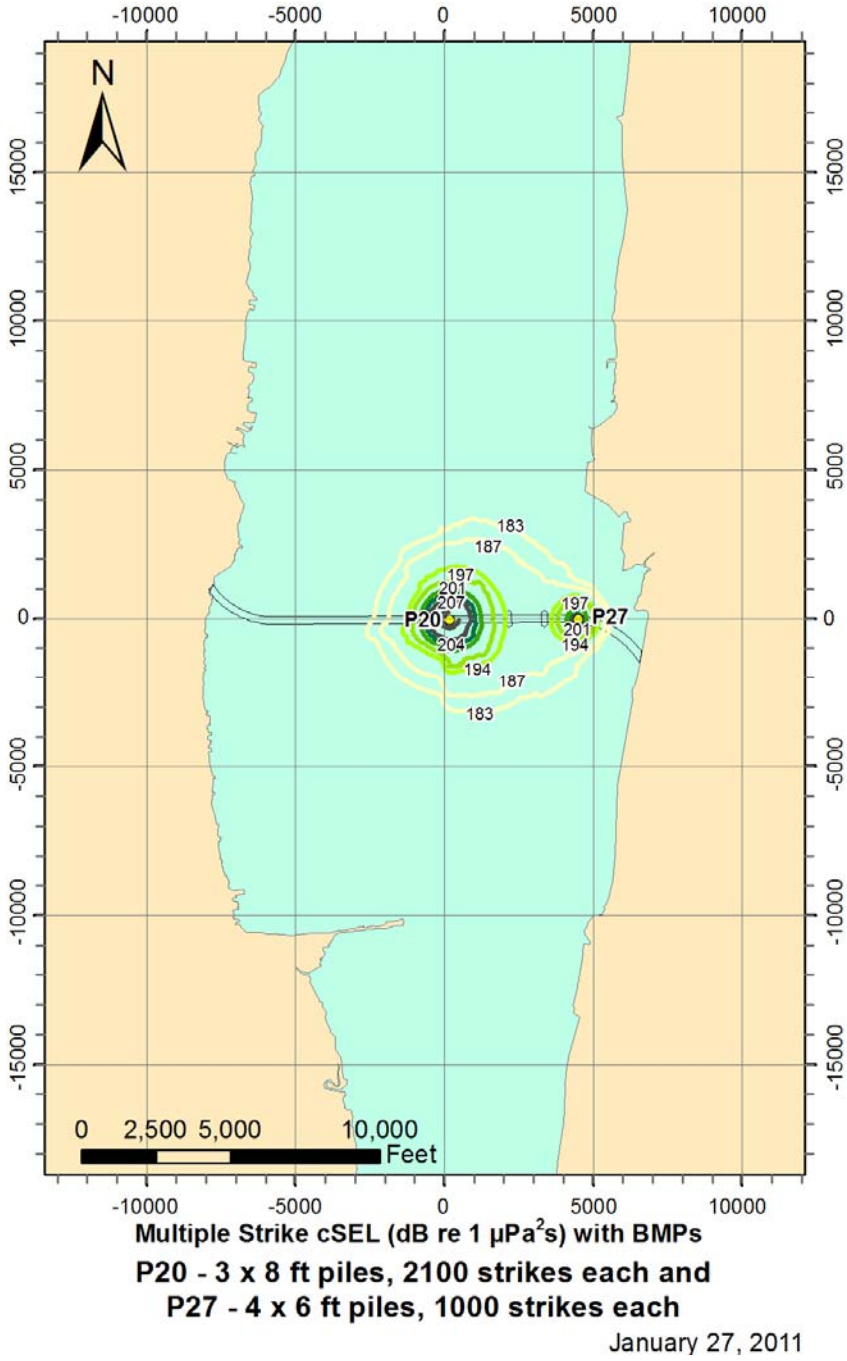
Sound level contours are identical to those of the single level bridge in section A.1.6. Typical Case 3 (also dual level bridge).

A.4. Dual Level Bridge: BMPs Applied

A.4.1. Max Case 1

Sound level contours are identical to those of the single level bridge in section A.2.1. Max Case 1 (also dual level bridge).

A.4.2. Max Case 2B



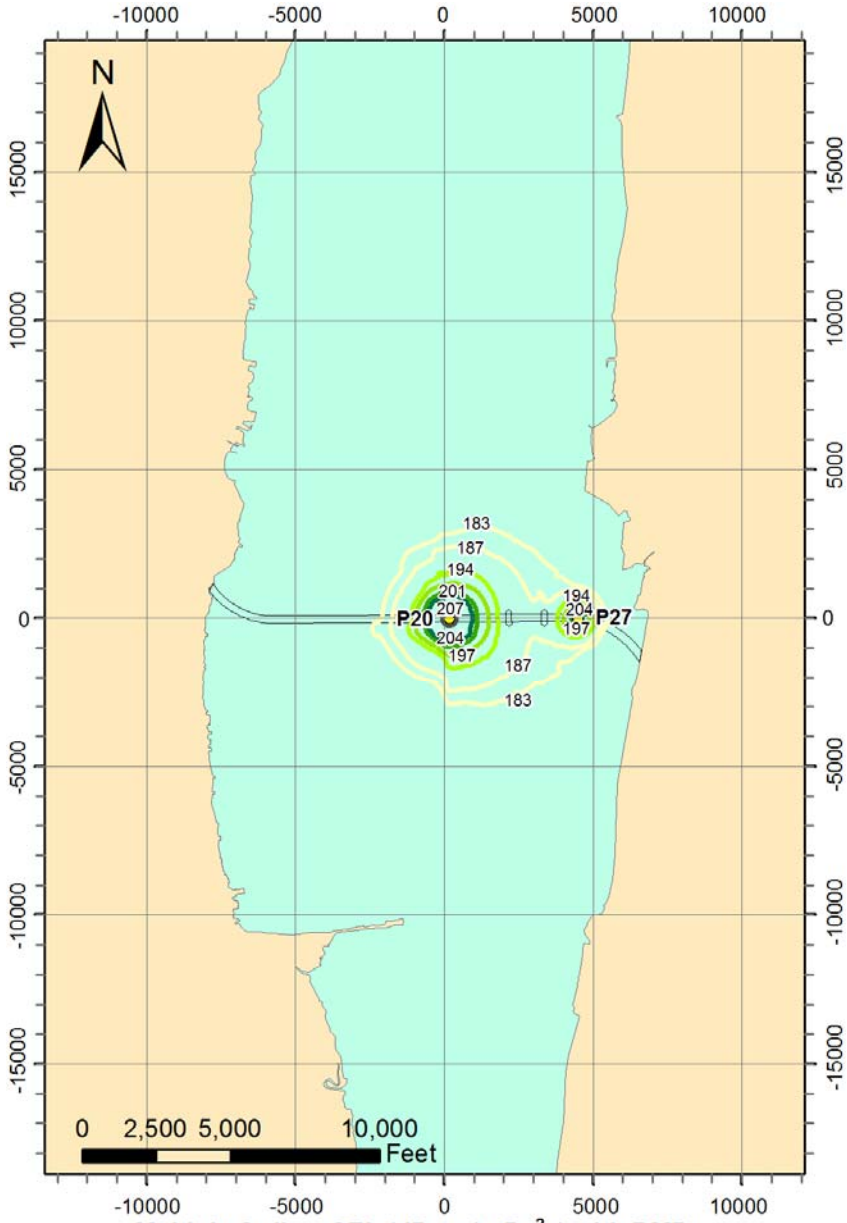
A.4.3. Max Case 3

Sound level contours are identical to those of the single level bridge in section A.2.3. Max Case 3 (also dual level bridge).

A.4.4. Typical Case 1

Sound level contours are identical to those of the single level bridge in section A.2.4. Typical Case 1 (also dual level bridge).

A.4.5. Typical Case 2B



Multiple Strike cSEL (dB re 1 μPa²s) with BMPs

P20 - 2 x 8 ft piles, 2100 strikes each and
P27 - 2 x 6 ft piles, 1000 strikes each

January 27, 2011

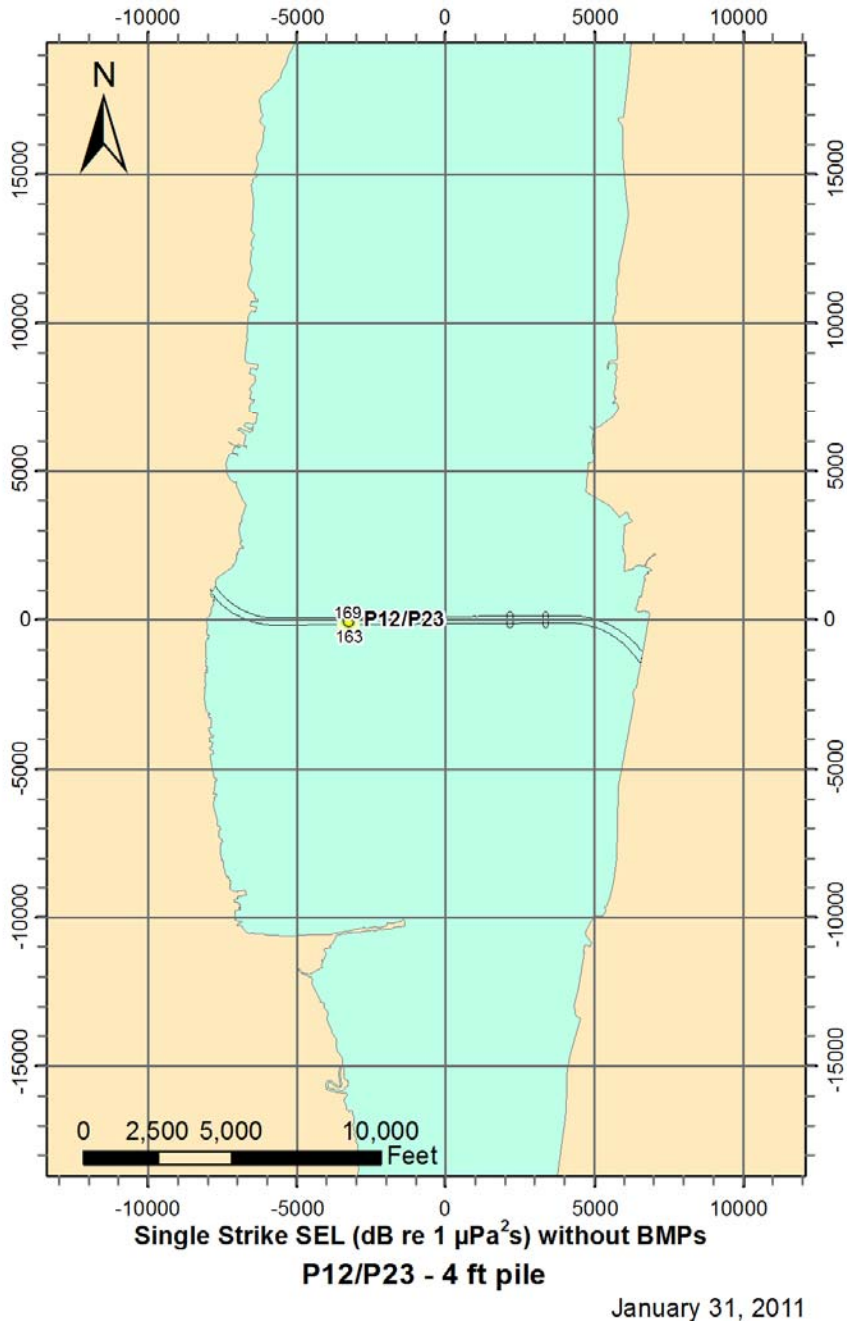
A.4.6. Typical Case 3

Sound level contours are identical to those of the single level bridge in section A.2.6. Typical Case 3 (also dual level bridge).

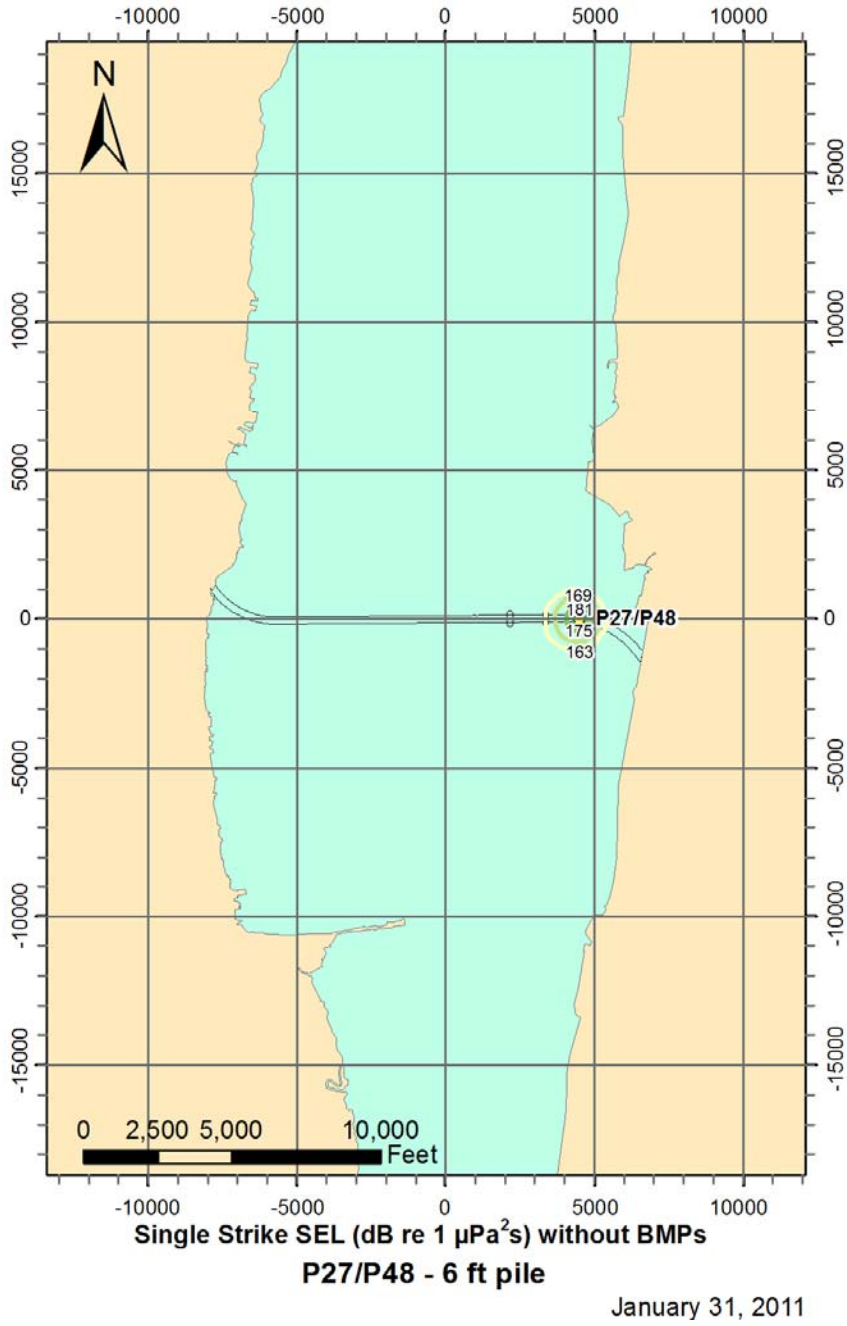
Appendix B. Single Strike SEL Scenario Maps

B.1. Single and Dual Level Bridge: No BMPs Applied

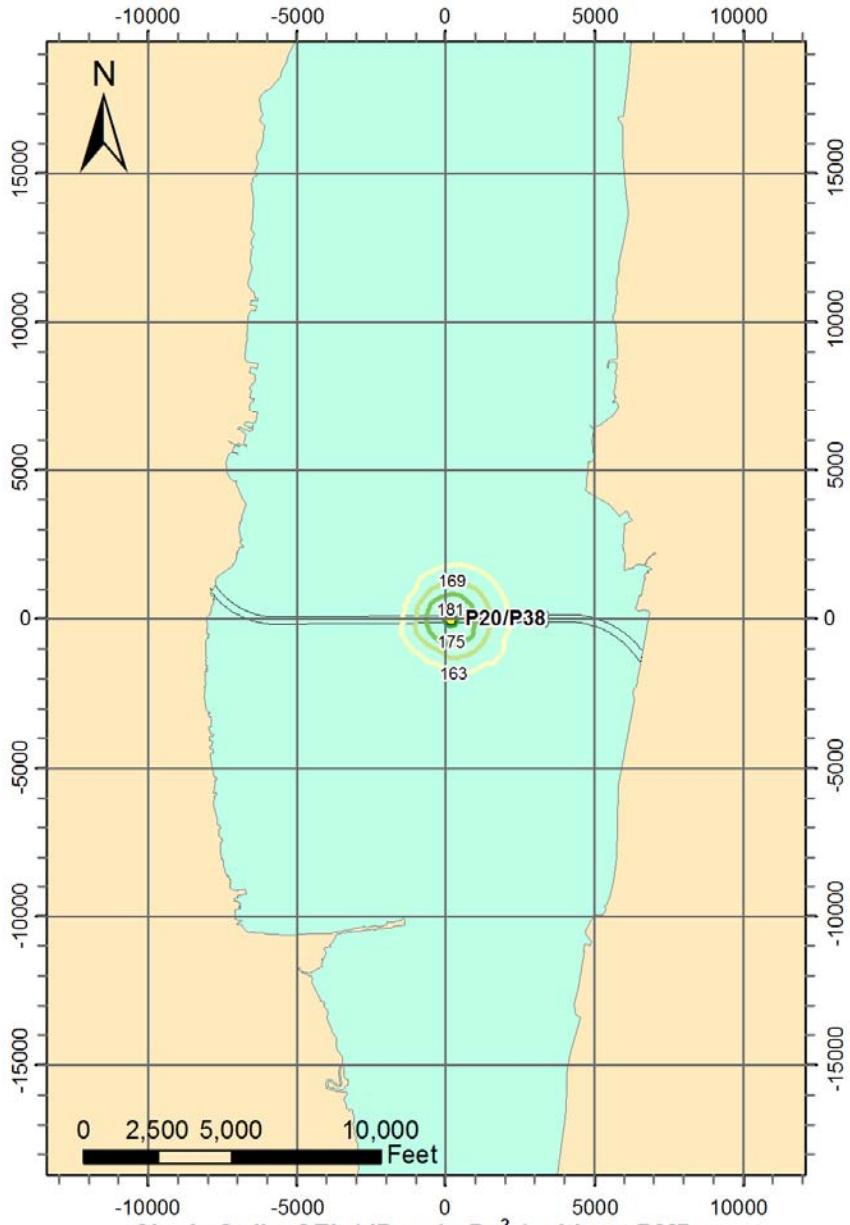
B.1.1. 4' pile size



B.1.2. 6' pile size



B.1.3. 8' pile size

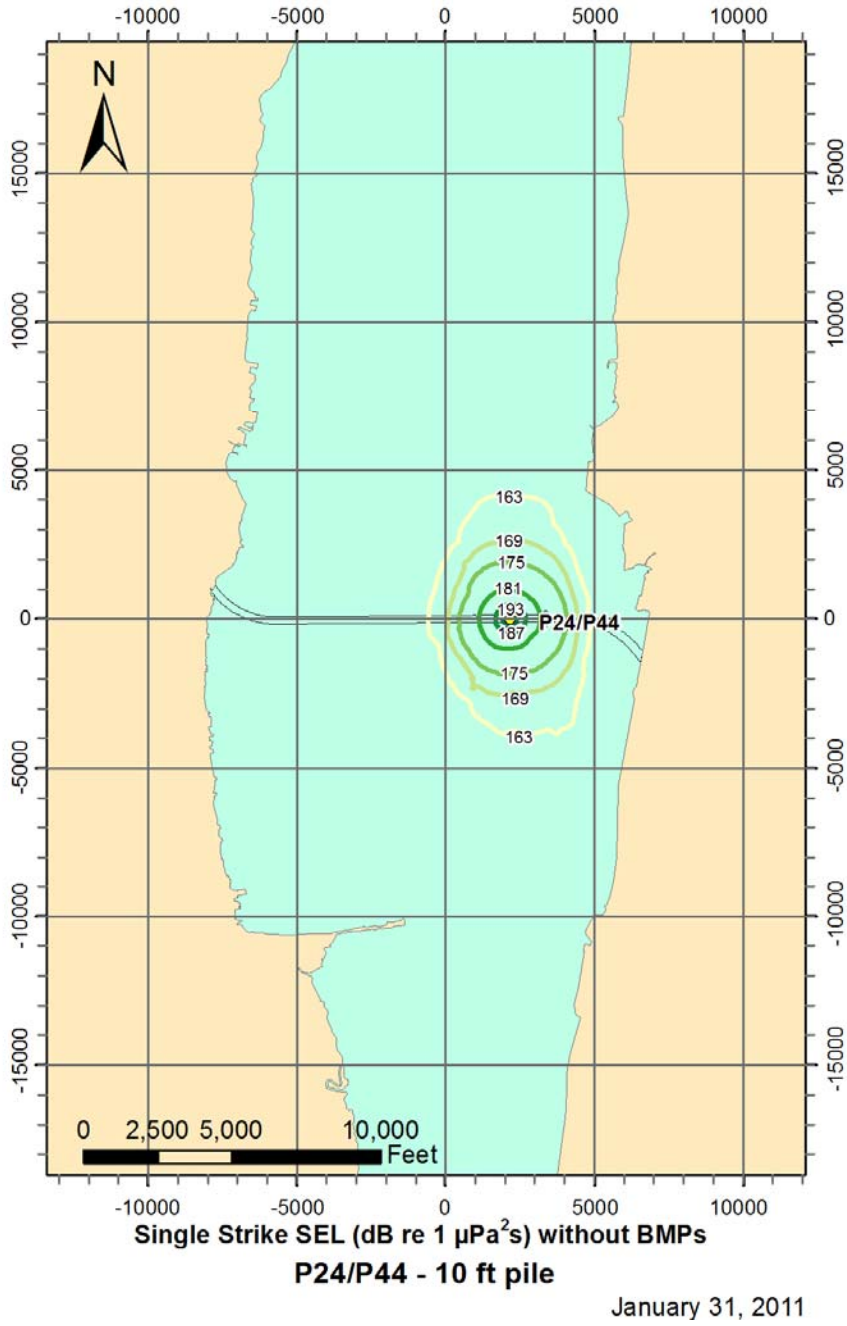


Single Strike SEL (dB re 1 μPa^{2}s) without BMPs

P20/P38 - 8 ft pile

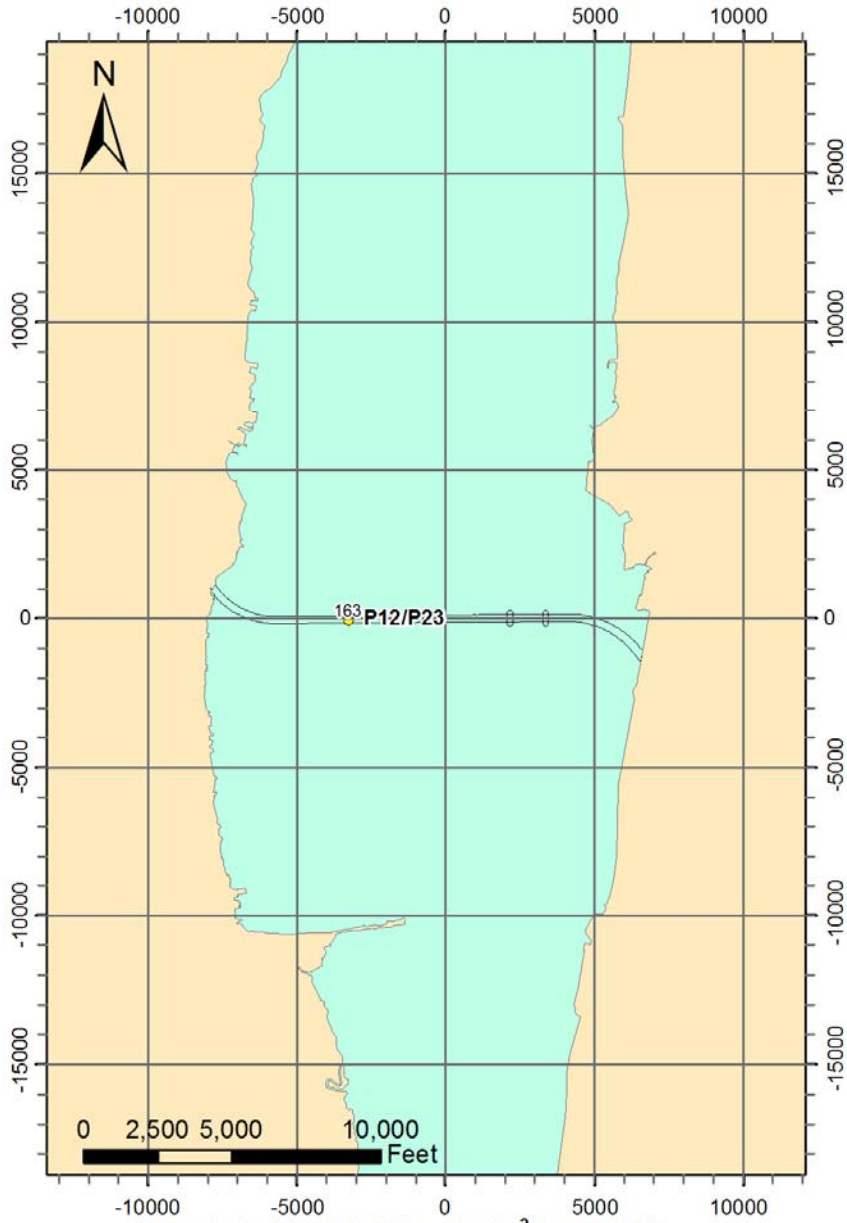
January 31, 2011

B.1.4. 10' pile size



B.2. Single and Dual Level Bridge: BMPs Applied

B.2.1. 4' pile size

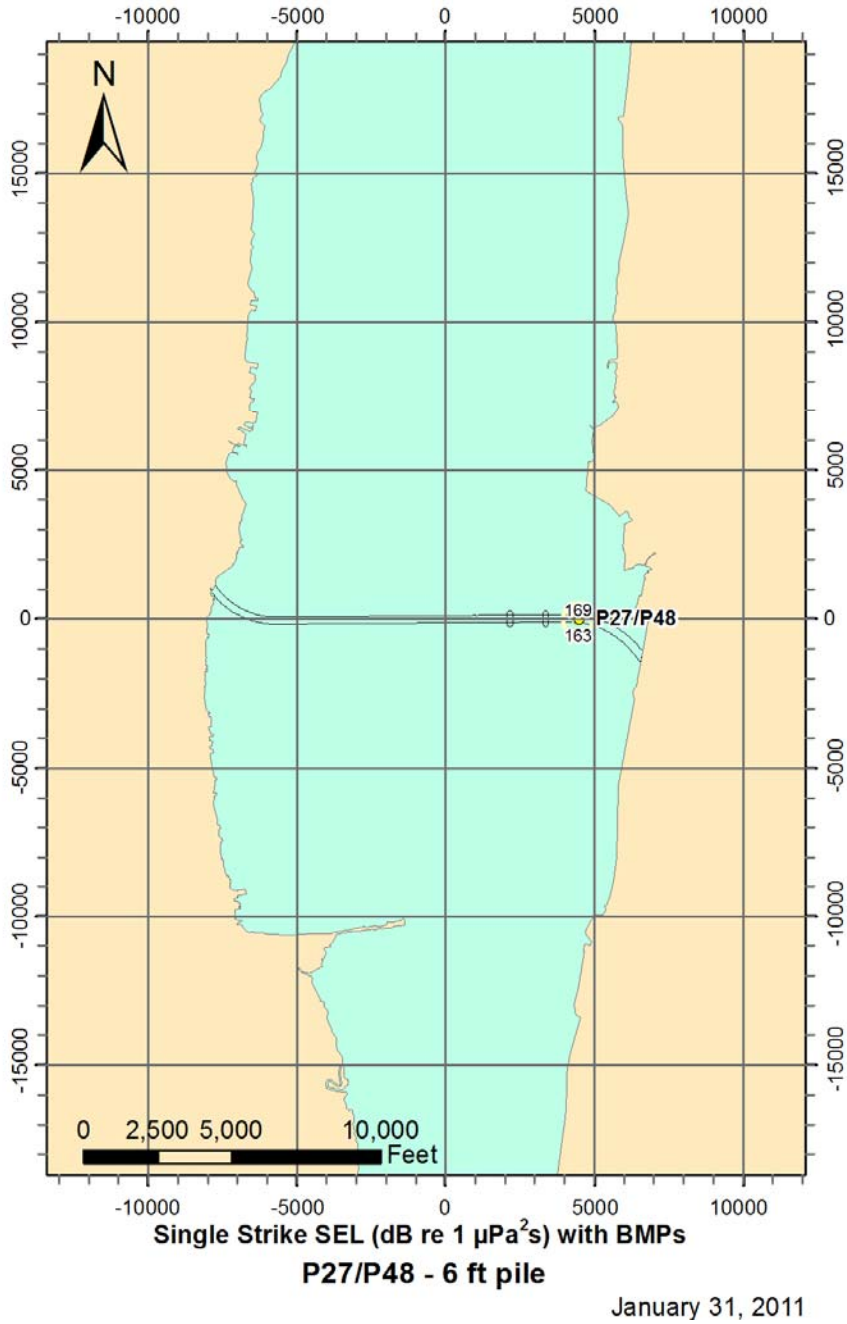


Single Strike SEL (dB re 1 μPa^{2}s) with BMPs

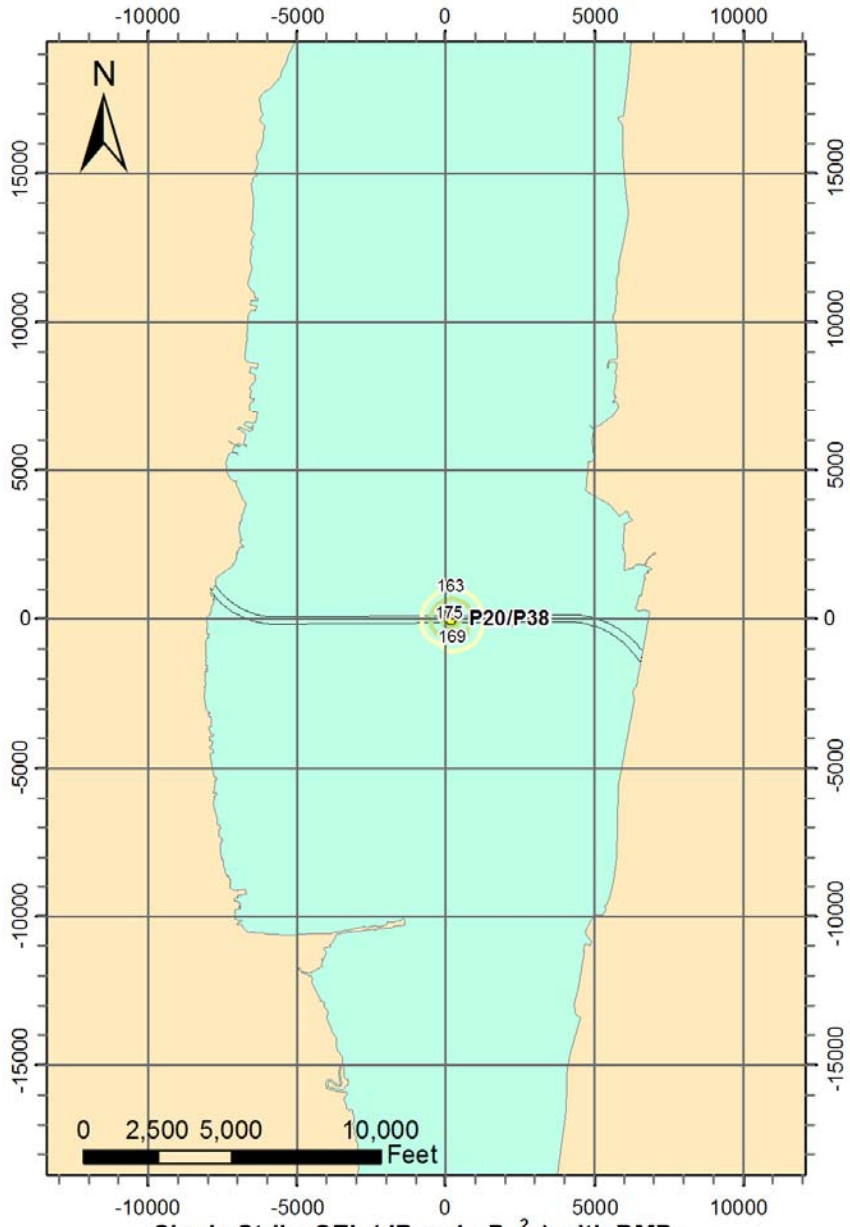
P12/P23 - 4 ft pile

January 31, 2011

B.2.2. 6' pile size



B.2.3. 8' pile size

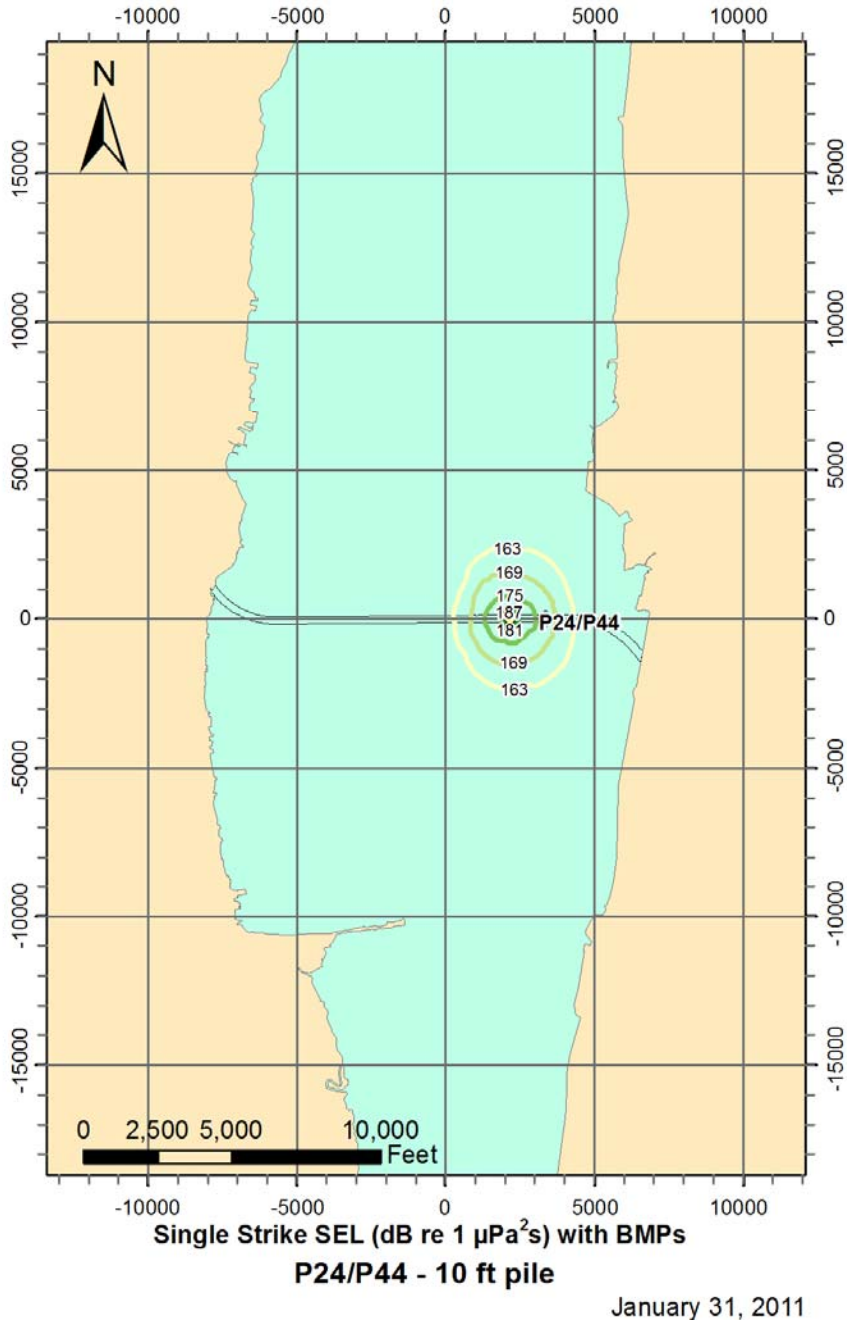


Single Strike SEL (dB re 1 μPa^{2}s) with BMPs

P20/P38 - 8 ft pile

January 31, 2011

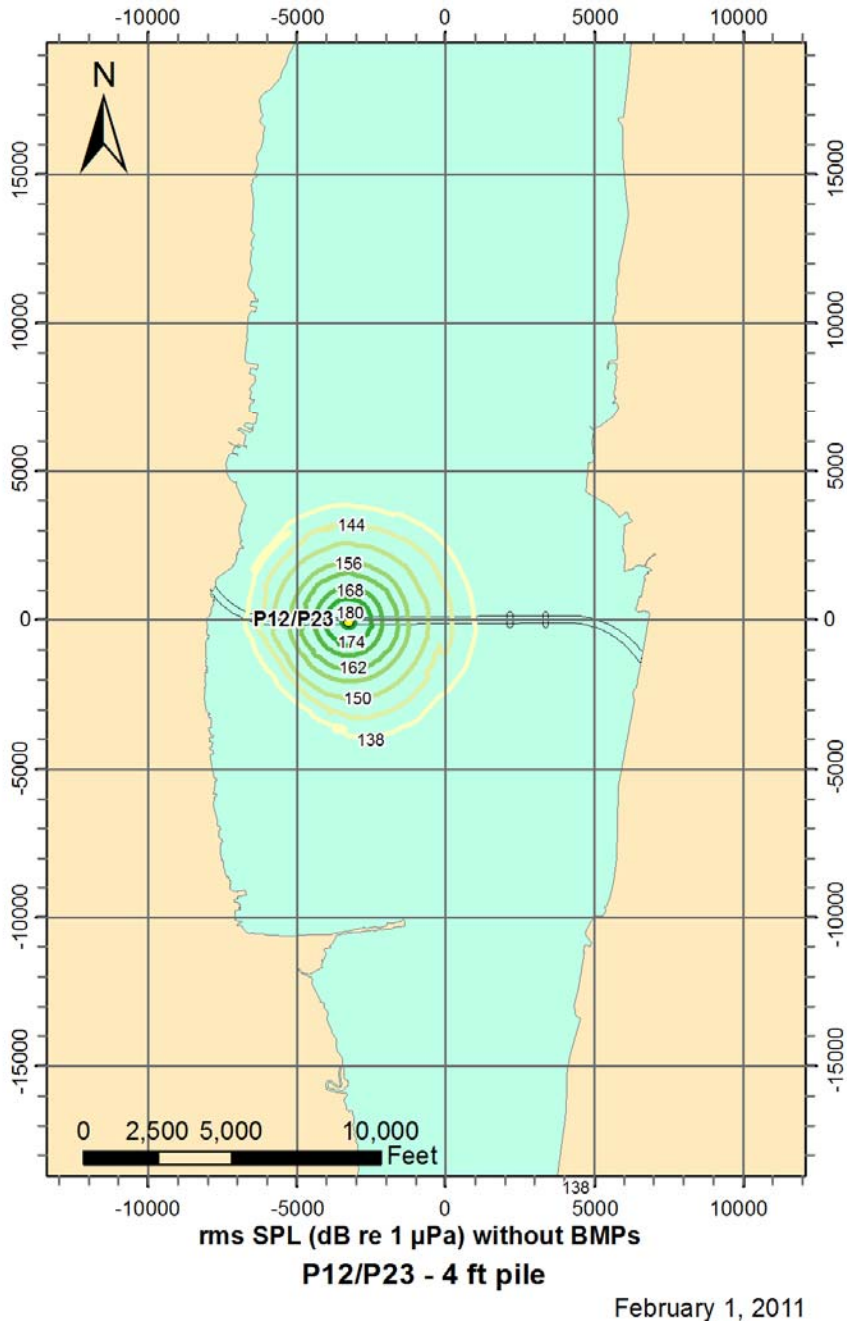
B.2.4. 10' pile size



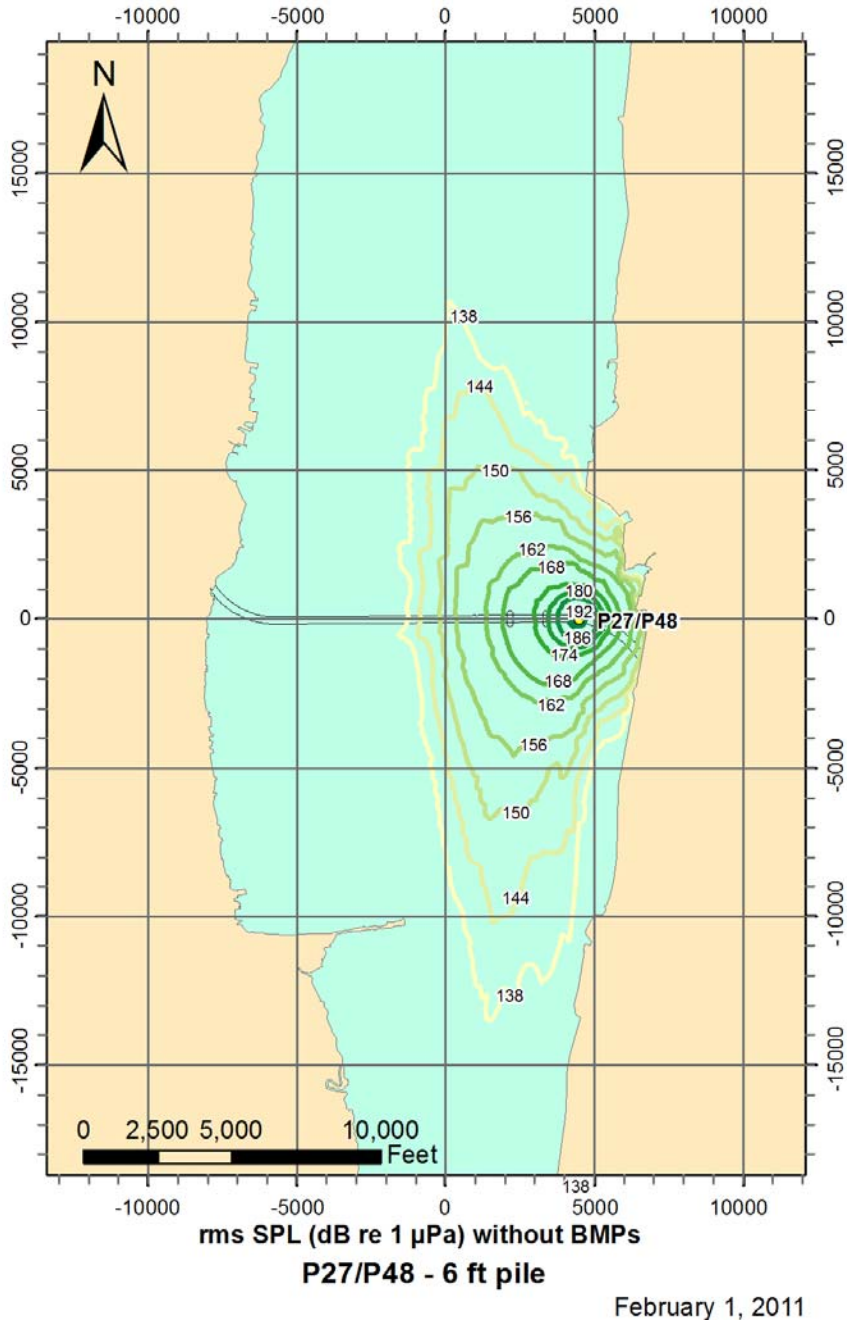
Appendix C. *rms* SPL Scenario Maps

C.1. Single and Dual Level Bridge: No BMPs Applied

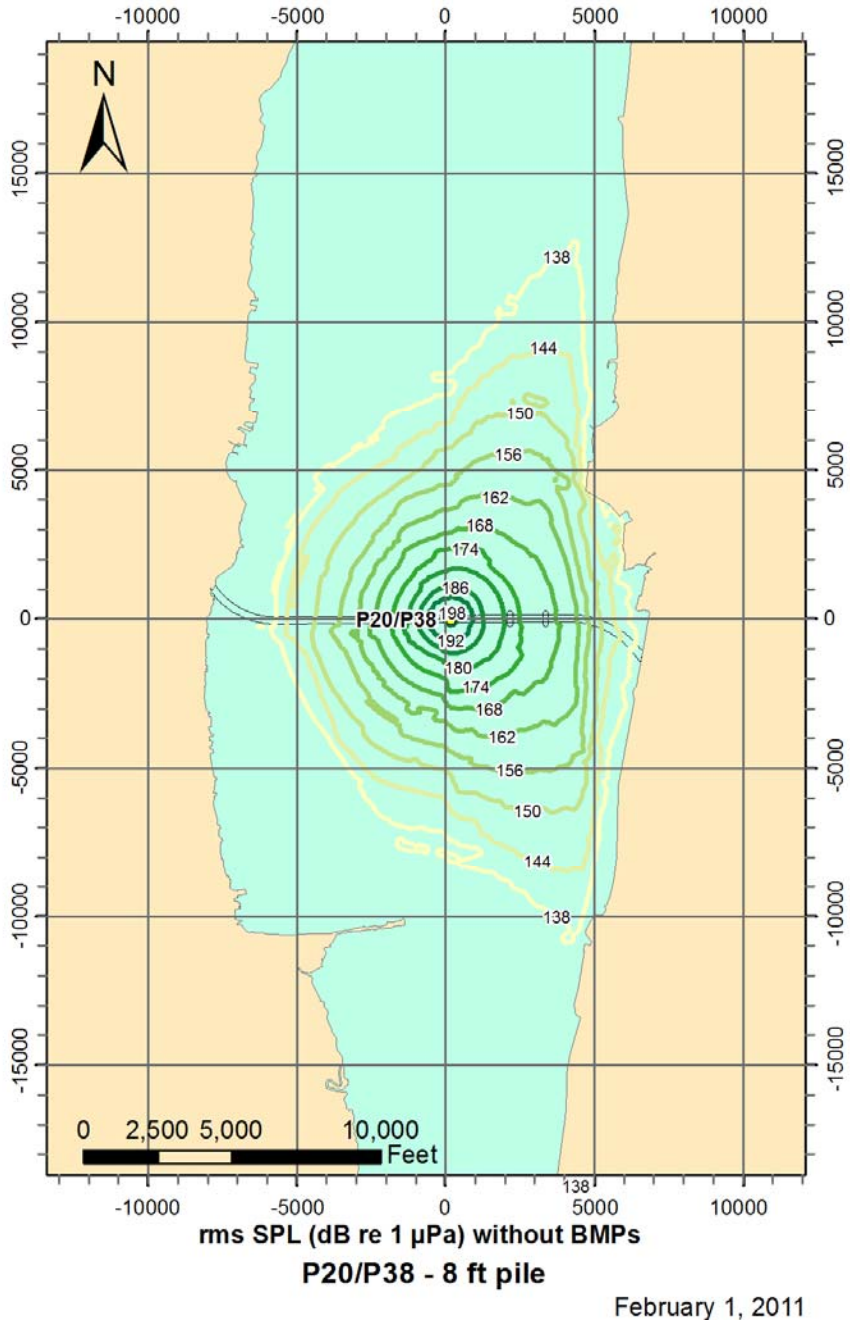
C.1.1. 4' pile size



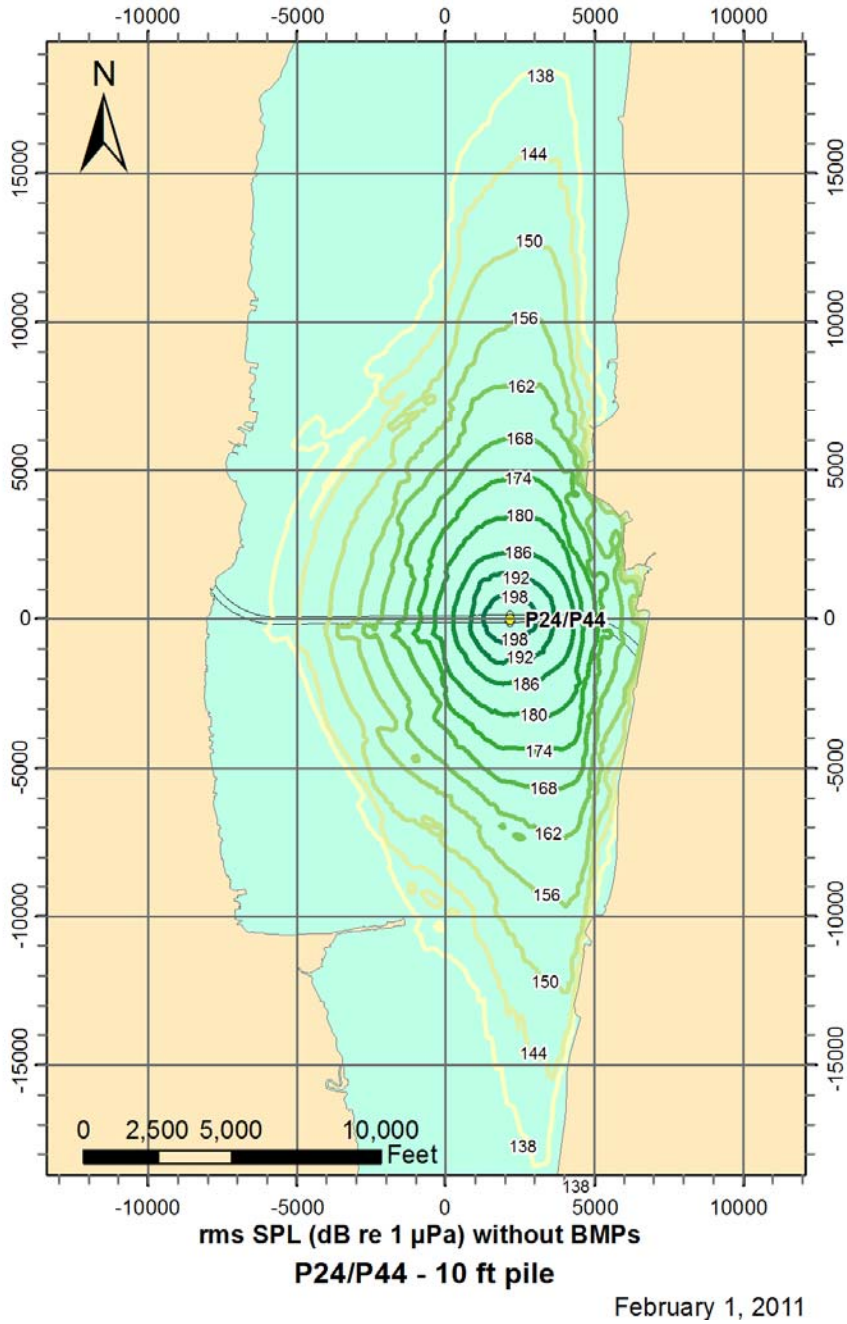
C.1.2. 6' pile size



C.1.3. 8' pile size

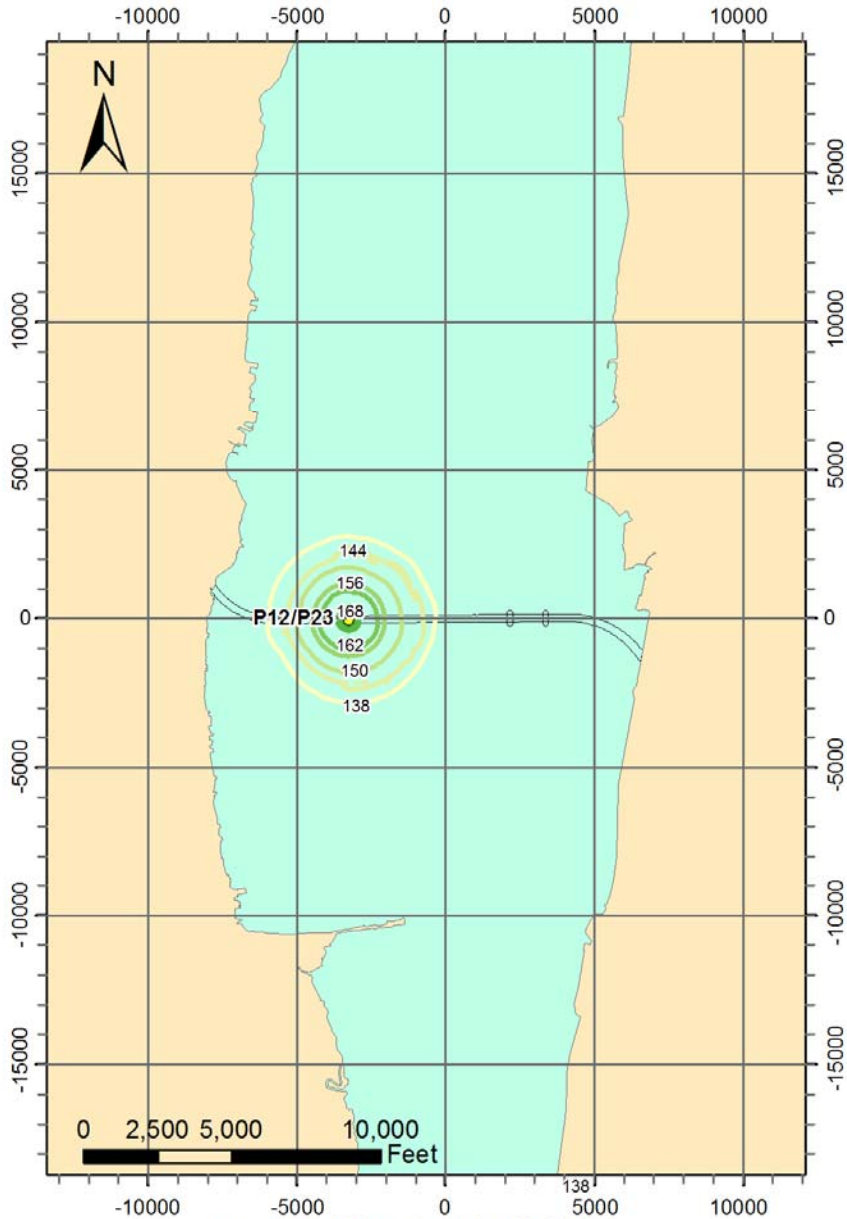


C.1.4. 10' pile size



C.2. Single and Dual Level Bridge: BMPs Applied

C.2.1. 4' pile size

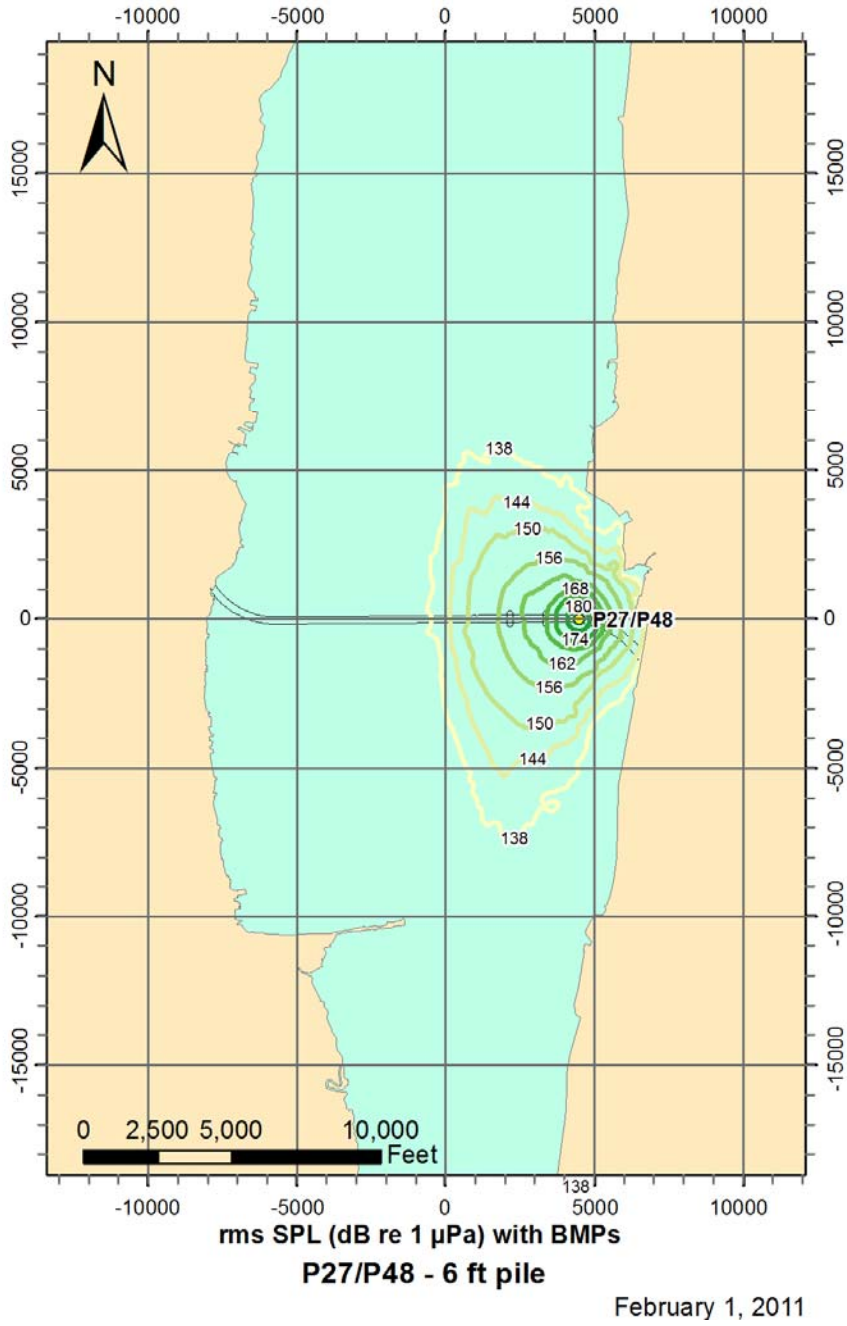


rms SPL (dB re 1 µPa) with BMPs

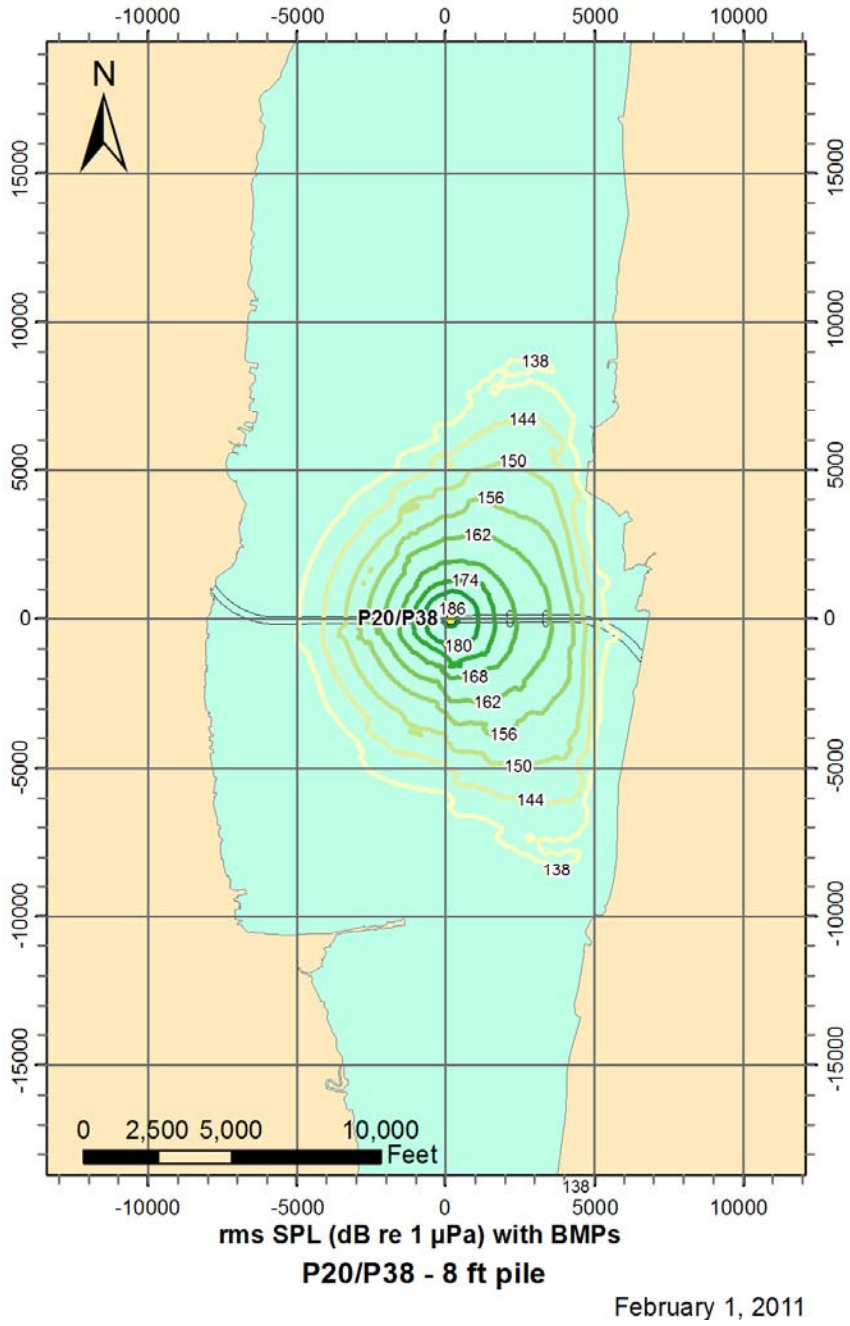
P12/P23 - 4 ft pile

February 1, 2011

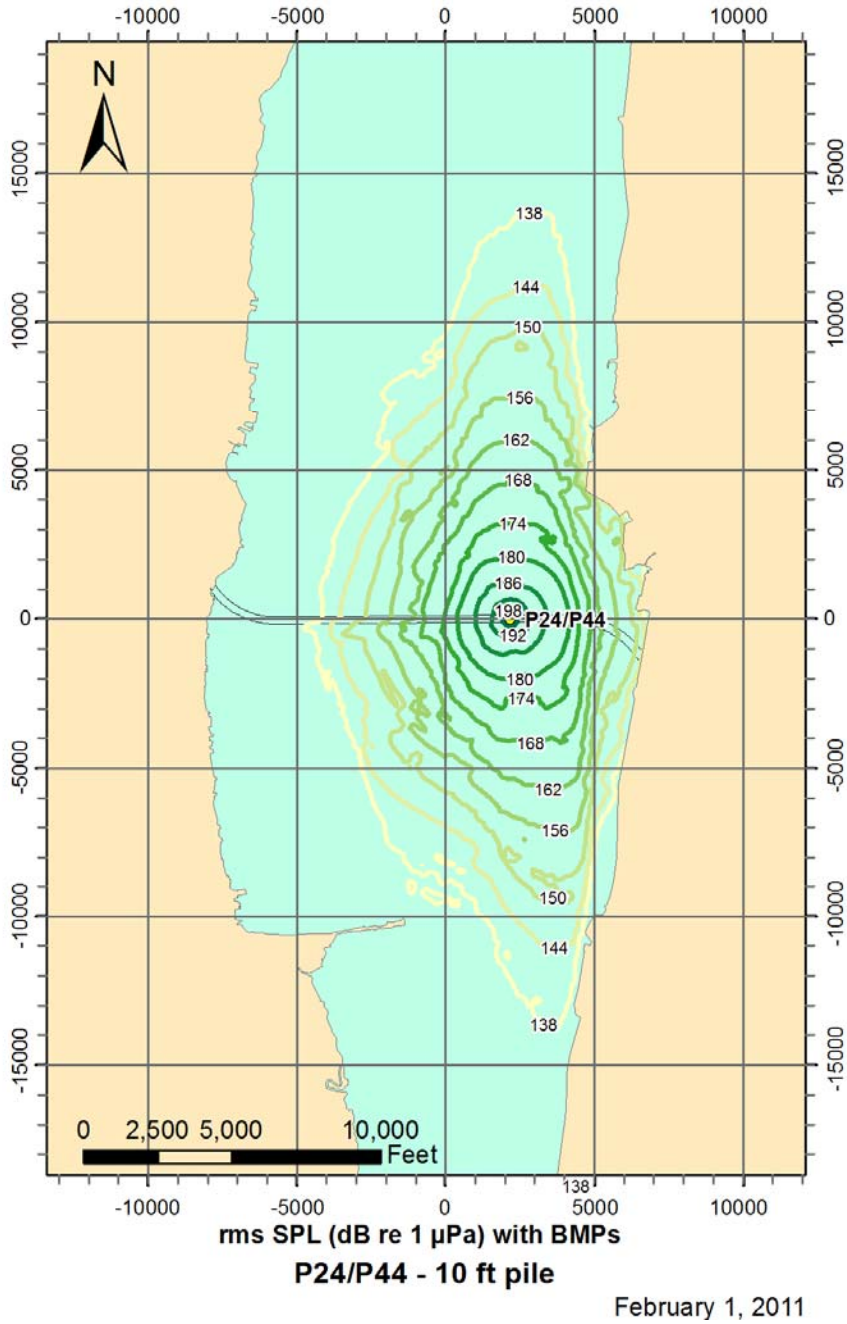
C.2.2. 6' pile size



C.2.3. 8' pile size



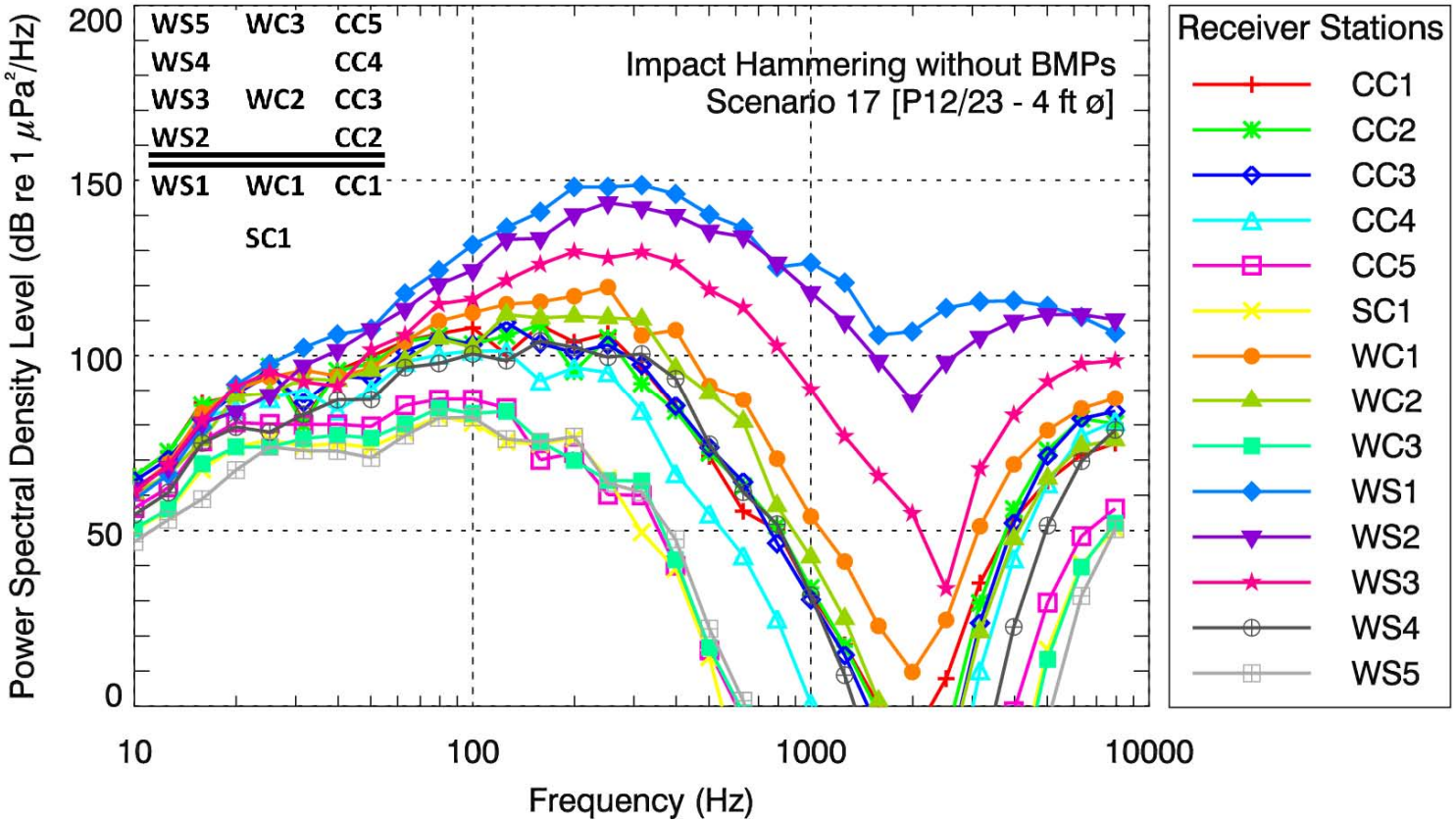
C.2.4. 10' pile size



Appendix D. Power Spectral Density Levels in 1/3-Octave Bands

D.1. Single and Dual Level Bridge: No BMPs Applied

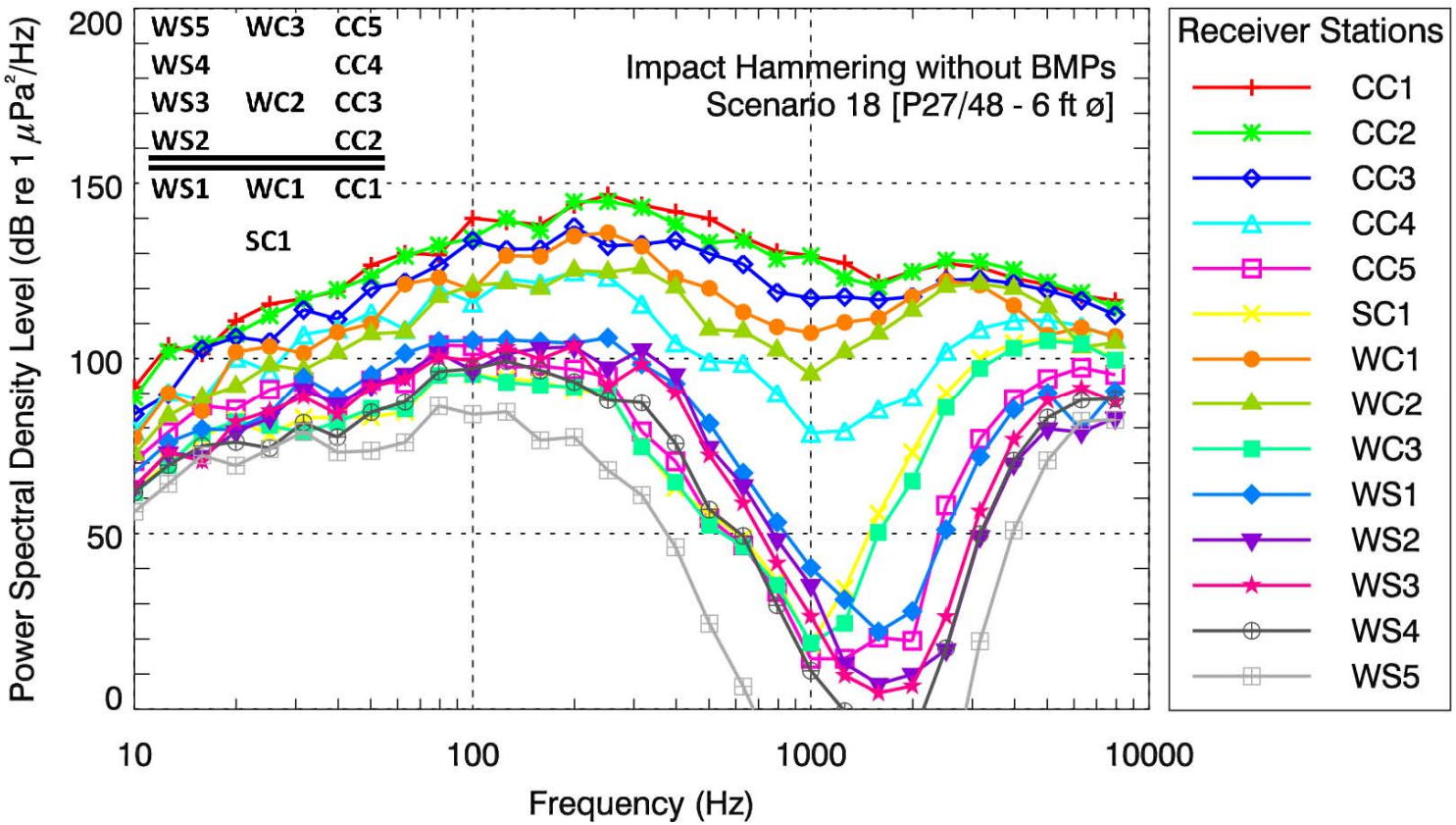
D.1.1. 4' pile size



Power spectral density levels (dB re 1 µPa2/Hz) for Scenario 17: Impact hammering a 4 ft diameter pile at Pier 12/23 without BMPs.

	Receiver Station											
Frequency (Hz)	*CC1*	*CC2*	*CC3*	*CC4*	*CC5*	*SC1*	*WC1*	*WC2*	*WC3*	*WS1*	*WS2*	*WS3*
10	69.1	68.9	67.7	64.8	60.0	53.7	65.3	64.2	54.1	62.4	65.7	64.5
13	76.8	77.0	74.9	73.1	66.8	60.2	73.6	70.4	60.7	70.5	72.6	73.2
16	91.9	91.2	87.2	87.7	80.9	72.9	89.0	81.3	74.6	84.9	86.2	86.9
20	94.9	95.3	95.7	91.2	87.3	80.4	96.8	95.0	80.4	98.3	90.4	97.7
25	104.6	104.5	102.2	95.2	87.9	83.3	101.4	96.7	81.3	105.2	96.2	102.9
32	89.7	88.8	95.1	98.7	88.7	82.6	104.5	102.1	84.7	110.9	105.7	101.1
40	105.3	105.3	103.8	93.7	89.8	84.3	103.8	102.5	86.7	115.7	111.1	100.8
50	110.4	108.4	104.1	101.0	90.2	84.2	106.9	106.4	86.9	118.3	118.1	112.3
63	115.7	115.6	112.8	109.8	97.2	89.7	115.6	110.2	91.9	129.4	124.9	117.5
79	118.9	118.3	117.5	112.9	100.0	95.1	122.5	117.5	97.4	137.0	132.9	127.4
100	121.6	116.9	116.8	115.0	101.0	94.2	125.9	116.0	96.9	145.3	138.0	129.8
126	114.9	120.3	124.1	115.9	99.4	89.8	129.3	126.4	98.5	151.2	147.8	136.1
159	124.3	124.5	119.1	108.4	85.7	90.2	131.0	126.4	90.9	156.7	149.1	141.7
200	120.5	112.1	117.5	113.2	88.6	92.8	133.6	127.9	86.5	164.8	156.9	146.3
251	123.9	122.7	120.7	112.8	77.8	82.3	137.2	128.4	81.8	165.8	161.3	145.5
316	115.4	110.6	116.0	102.8	78.6	68.1	124.4	129.0	82.7	167.3	160.9	148.2
398	104.5	103.6	105.1	85.9	59.6	58.7	126.9	116.0	61.3	165.8	159.7	146.2
501	91.7	92.7	94.2	75.4	36.5	34.6	111.9	109.7	37.3	160.9	156.2	139.4
631	77.1	84.2	85.4	64.5	18.1	-1.2	108.9	102.6	19.8	158.1	155.6	135.4
794	72.8	74.0	69.0	47.5	-11.3	-32.2	93.0	79.6	-14.5	147.9	149.1	125.4
1000	55.7	57.3	54.0	24.5	-45.2	-66.6	77.6	66.0	-56.6	150.1	141.7	113.9
1259	42.1	41.8	39.2	10.1	-63.7	-104.4	65.8	49.5	-93.0	145.5	134.3	101.4
1585	25.9	23.8	19.0	-7.5	-90.2	-153.7	48.5	27.1	-140.7	131.5	124.1	91.1
1995	17.5	13.2	7.0	-16.0	-103.0	-168.2	36.4	14.5	-163.0	133.5	113.5	81.5
2512	35.5	18.6	9.4	-10.2	-83.6	-142.6	52.2	9.4	-144.3	141.2	125.8	61.1
3162	63.7	58.0	52.3	38.9	-19.6	-56.8	79.8	49.8	-62.4	144.1	133.9	96.2
3981	82.8	85.7	81.7	71.7	28.2	5.2	98.4	77.2	0.8	145.3	139.5	112.5
5012	94.7	103.4	101.9	94.0	60.1	46.8	109.1	95.4	44.0	144.8	142.4	123.2
6310	103.1	113.4	113.4	108.4	80.0	72.1	116.3	105.6	71.2	142.7	143.4	129.3
7943	107.4	113.0	116.5	113.7	88.8	83.1	120.3	108.3	84.7	139.1	142.9	131.2

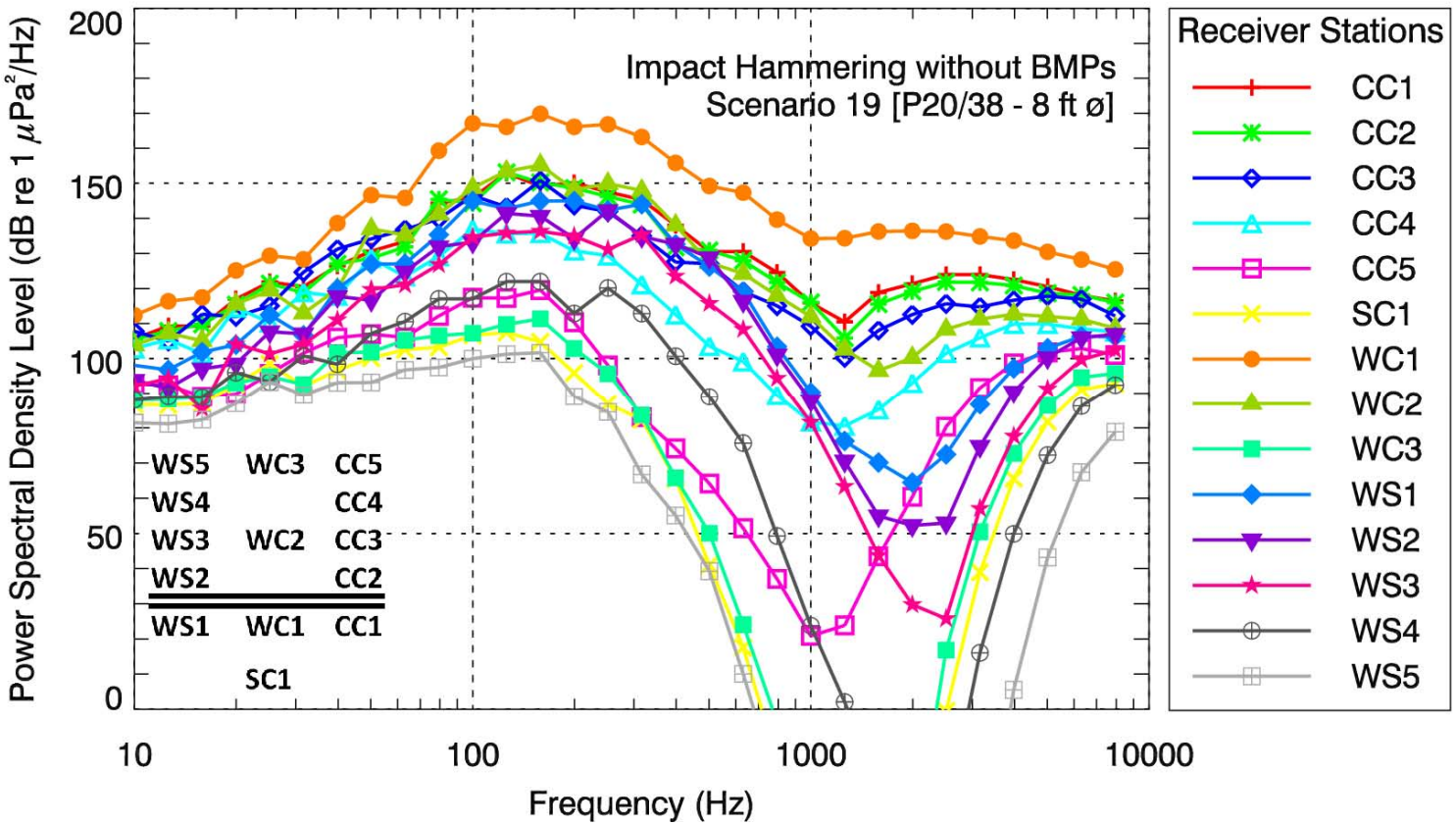
D.1.2. 6' pile size



Power spectral density levels (dB re 1 µPa^2/Hz) for Scenario 18: Impact hammering a 6 ft diameter pile at Pier 27/48 without BMPs.

	Receiver Station											
Frequency (Hz)	*CC1*	*CC2*	*CC3*	*CC4*	*CC5*	*SC1*	*WC1*	*WC2*	*WC3*	*WS1*	*WS2*	*WS3*
10	95.4	92.4	87.6	82.8	74.2	65.5	80.9	76.1	65.2	70.9	67.0	66.7
13	108.4	106.6	94.3	95.0	83.4	75.0	94.6	88.1	73.9	80.5	77.5	77.7
16	107.0	109.8	108.4	93.7	92.0	82.9	90.5	94.4	84.2	85.3	77.5	76.2
20	117.4	113.8	112.8	106.9	91.9	88.9	108.5	98.6	88.4	86.1	85.5	88.4
25	123.2	119.9	112.5	103.8	98.7	85.7	111.1	105.8	88.3	91.8	90.4	92.5
32	125.8	125.6	122.6	115.5	101.9	91.5	110.2	105.4	87.3	103.2	99.7	97.6
40	128.9	129.3	120.9	118.2	94.9	92.7	117.2	111.3	91.3	98.7	96.5	93.6
50	137.3	134.0	130.7	123.8	104.3	93.7	120.6	117.7	96.2	105.9	102.9	102.6
63	141.7	140.9	133.5	120.0	104.5	96.2	132.9	119.2	97.1	113.1	107.2	105.8
79	142.3	145.0	139.3	132.6	116.5	107.8	135.7	130.3	107.8	117.6	114.3	113.1
100	153.7	148.0	147.4	129.6	117.2	109.0	133.2	134.6	109.1	118.8	110.2	113.0
126	153.7	154.6	145.8	137.3	112.2	108.9	144.0	136.2	107.8	120.0	116.0	117.8
159	153.9	152.2	147.0	137.3	113.5	109.1	144.8	135.6	108.0	120.5	118.6	115.5
200	160.4	161.4	154.3	141.5	113.5	107.6	151.6	141.8	108.4	121.0	120.0	120.3
251	164.4	162.5	149.8	141.0	112.4	107.8	153.6	142.3	108.1	123.6	115.0	109.6
316	162.5	161.8	151.3	134.3	97.6	93.4	150.7	144.5	93.2	117.0	121.2	117.0
398	161.5	158.0	153.4	124.2	90.1	82.6	142.7	140.0	84.2	112.4	115.1	109.7
501	160.6	153.8	150.6	119.9	74.9	76.0	140.7	129.0	72.9	101.9	95.1	92.9
631	156.3	155.4	148.6	120.4	68.2	70.4	134.9	129.4	67.9	88.8	85.2	80.3
794	153.2	151.1	141.6	112.7	56.0	59.2	131.7	125.0	57.9	75.8	70.9	64.2
1000	153.0	152.9	140.9	102.2	38.0	42.1	131.0	119.1	42.5	63.9	58.9	50.1
1259	151.9	147.6	142.3	103.8	39.0	59.0	135.0	126.5	49.1	55.8	37.7	34.3
1585	147.4	146.2	142.4	111.1	46.0	81.2	137.2	132.8	75.9	47.7	32.8	30.3
1995	151.5	151.4	144.3	115.6	46.1	99.7	144.3	140.4	91.5	54.5	36.6	33.3
2512	154.8	155.7	150.0	129.8	85.6	117.8	149.8	148.2	113.5	78.7	44.6	54.0
3162	154.7	156.3	151.3	137.1	105.5	128.6	149.6	150.0	125.8	100.5	77.8	85.0
3981	152.6	155.0	151.1	140.5	118.0	134.1	144.8	149.6	132.6	114.9	99.4	106.4
5012	151.7	152.4	150.1	141.6	124.8	136.3	137.3	145.4	135.7	120.7	110.4	118.5
6310	149.6	150.4	148.3	141.0	129.0	136.6	140.5	134.9	135.9	111.0	110.4	123.1
7943	149.2	147.0	145.1	138.5	128.0	132.3	139.0	137.2	132.2	123.3	115.5	120.2

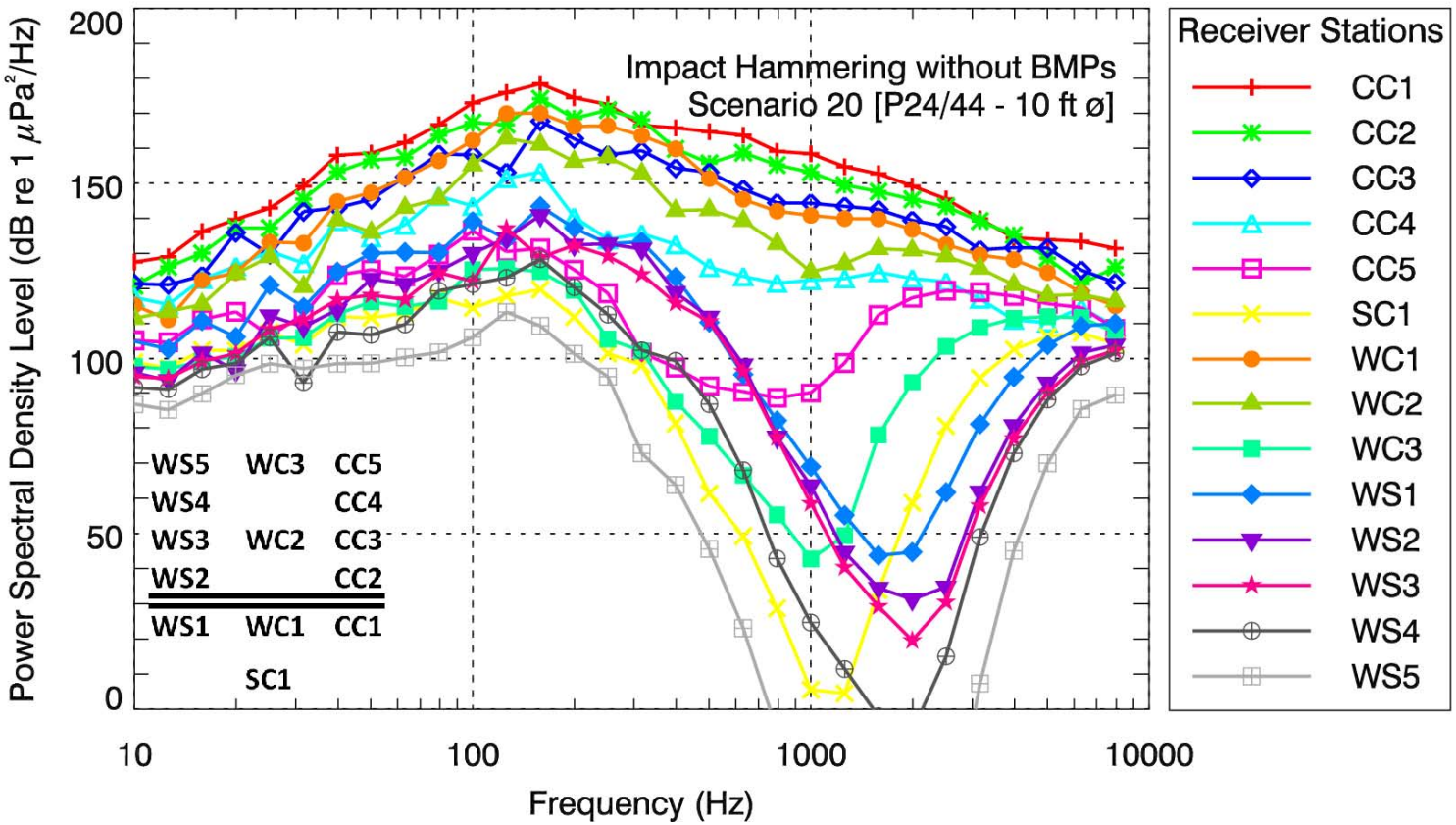
D.1.3. 8' pile size



Power spectral density levels (dB re 1 µPa^2/Hz) for Scenario 19: Impact hammering an 8 ft diameter pile at Pier 20/38 without BMPs.

	Receiver Station											
Frequency (Hz)	*CC1*	*CC2*	*CC3*	*CC4*	*CC5*	*SC1*	*WC1*	*WC2*	*WC3*	*WS1*	*WS2*	*WS3*
10	109.3	109.1	111.4	106.5	96.3	90.4	116.0	107.5	91.6	101.7	97.4	95.8
13	113.9	112.5	109.6	110.1	97.0	91.2	121.0	111.9	92.9	101.4	96.1	98.9
16	114.9	115.4	118.3	107.0	94.7	92.7	123.1	110.7	94.5	107.5	102.7	91.2
20	123.6	122.0	118.6	121.2	96.4	99.2	131.8	122.2	99.6	110.6	105.1	110.8
25	129.5	129.0	122.7	117.9	103.3	106.1	137.0	127.1	102.5	120.1	115.3	109.0
32	129.2	127.5	133.3	127.5	110.2	100.6	137.0	121.6	101.2	115.3	115.7	112.7
40	136.1	136.7	140.9	127.5	115.6	106.3	148.3	129.5	111.3	129.6	127.4	120.7
50	141.3	139.3	144.8	139.3	117.6	110.8	157.3	147.7	112.5	137.6	127.3	130.4
63	145.1	143.5	148.5	135.1	117.7	114.2	157.5	146.9	116.9	138.7	136.4	132.7
79	157.0	158.1	152.5	141.8	124.8	115.9	172.0	153.9	119.2	148.0	144.6	139.5
100	159.6	158.0	160.2	150.6	131.0	120.3	180.8	162.4	120.9	158.6	146.9	148.3
126	167.6	167.8	157.9	150.3	131.9	122.1	180.8	168.1	124.4	157.4	156.1	150.5
159	164.9	165.9	166.5	151.4	135.2	120.4	185.5	170.9	127.0	160.6	156.3	152.0
200	166.8	165.3	160.4	147.4	127.0	112.5	182.8	164.8	119.5	161.6	150.9	151.6
251	165.2	163.9	159.6	147.0	115.7	104.6	184.5	167.6	113.3	160.0	159.9	148.8
316	164.0	162.6	153.7	139.8	101.7	101.0	181.9	166.6	102.3	162.7	153.5	154.0
398	157.7	151.4	147.2	132.2	93.8	85.1	175.5	157.7	85.4	152.3	152.3	143.2
501	151.2	151.5	147.7	124.2	84.8	61.7	169.9	148.0	70.7	146.9	149.5	136.4
631	152.2	149.6	140.8	120.8	73.1	39.2	169.0	145.9	45.7	140.7	138.0	130.0
794	147.2	144.4	137.7	112.0	59.7	8.1	162.3	140.6	19.0	126.0	123.7	117.0
1000	139.5	139.7	132.9	105.4	44.5	-21.0	157.9	135.6	-5.5	113.9	111.5	105.3
1259	135.1	130.5	124.9	105.2	48.5	-43.8	159.0	127.3	-26.1	100.9	95.2	88.0
1585	144.5	141.2	133.7	110.9	69.1	-57.9	161.9	122.2	-34.5	95.8	80.6	69.4
1995	148.0	145.8	139.2	119.6	87.0	-44.9	163.1	126.9	-15.7	91.1	78.9	56.4
2512	151.6	149.5	143.3	129.2	108.0	27.1	163.9	136.0	44.5	100.1	80.6	53.4
3162	152.6	150.4	143.4	134.6	120.2	67.6	163.5	139.9	79.1	115.4	103.4	85.7
3981	152.2	150.5	146.3	139.5	128.3	95.2	163.3	142.3	102.4	126.8	120.0	107.3
5012	151.2	149.3	148.5	140.5	132.4	112.4	161.1	142.7	117.1	133.6	130.9	121.9
6310	149.7	149.8	148.6	140.1	134.5	122.7	159.9	142.9	126.2	138.0	137.6	131.3
7943	149.1	148.6	144.8	140.3	133.7	125.4	158.1	141.3	128.4	138.9	139.6	135.1

D.1.4. 10' pile size

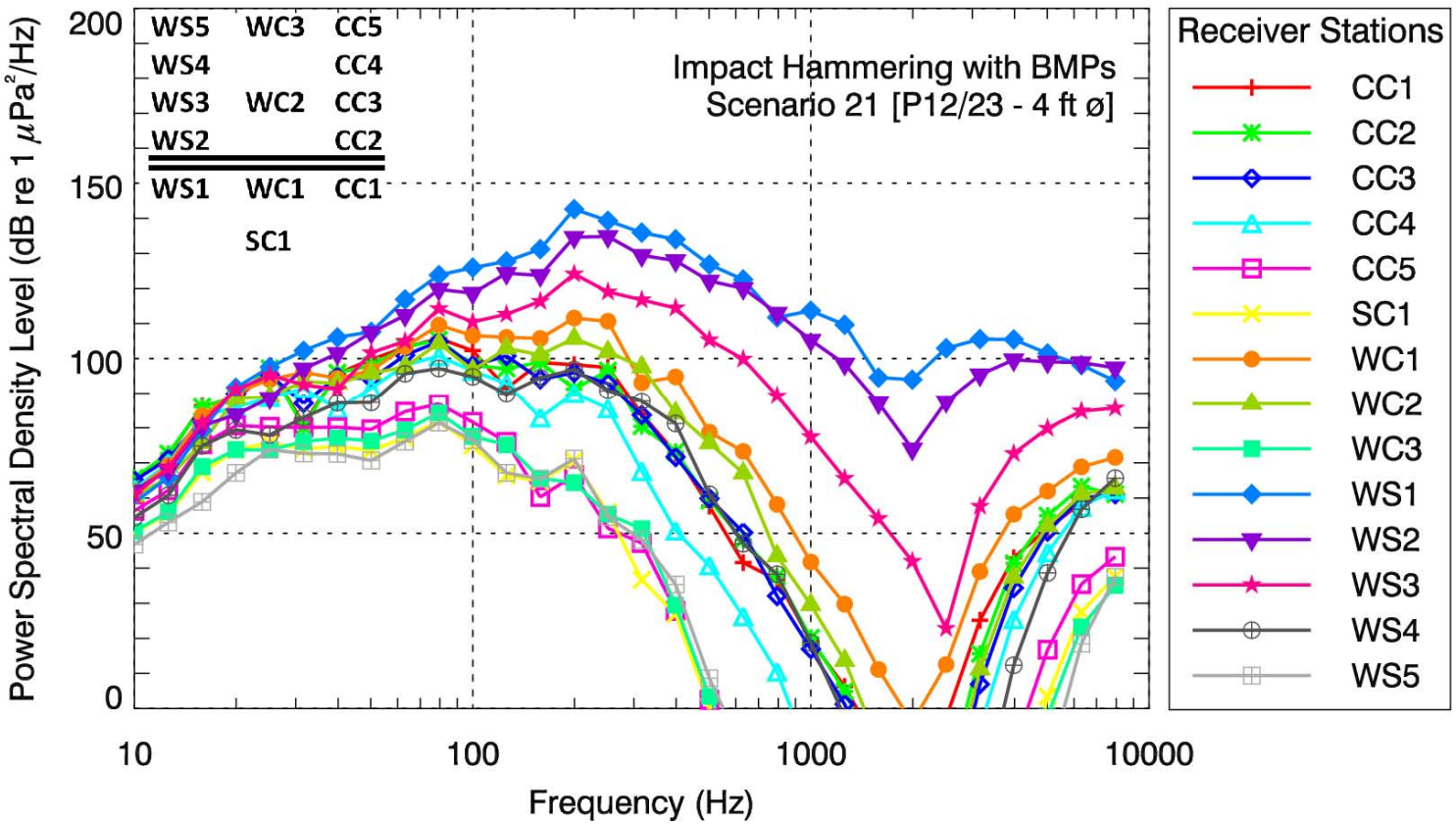


Power spectral density levels (dB re 1 µPa^2/Hz) for Scenario 20: impact hammering a 10 ft diameter pile at Pier 24/44 without BMPs.

	Receiver Station											
Frequency (Hz)	*CC1*	*CC2*	*CC3*	*CC4*	*CC5*	*SC1*	*WC1*	*WC2*	*WC3*	*WS1*	*WS2*	*WS3*
10	131.2	124.4	125.0	121.1	108.8	102.6	118.9	115.1	101.4	108.6	99.6	98.5
13	133.7	130.8	125.7	120.1	109.3	101.9	115.7	118.1	101.6	107.4	98.4	99.0
16	141.9	135.7	129.3	128.3	116.8	108.0	128.0	121.1	105.0	116.4	107.3	104.8
20	146.4	143.9	142.6	133.0	120.0	109.0	131.2	130.9	107.2	112.8	103.2	108.1
25	150.6	144.9	137.4	138.3	114.1	115.2	140.9	136.7	113.5	128.6	119.9	116.0
32	157.9	154.2	150.6	135.9	121.3	112.6	141.6	129.1	114.6	123.3	117.7	119.7
40	167.7	162.9	152.7	148.9	133.4	121.6	154.5	149.2	122.4	134.4	123.6	126.5
50	169.3	167.3	156.1	145.2	136.0	122.3	158.0	146.7	126.8	140.7	133.4	128.8
63	173.3	169.0	163.5	149.8	135.1	124.6	163.3	154.7	126.5	142.0	132.9	128.5
79	179.4	176.4	171.0	159.0	142.3	130.0	169.1	158.3	129.0	142.9	137.6	137.2
100	186.6	181.0	171.8	157.2	150.1	128.1	175.9	168.9	139.0	152.8	143.7	135.7
126	190.6	181.4	167.8	166.1	145.2	132.5	184.6	177.5	140.4	148.7	149.0	151.8
159	194.1	189.8	183.4	168.9	147.1	135.4	185.7	176.8	140.5	159.1	156.5	144.5
200	191.1	185.2	179.4	157.1	142.0	128.5	182.9	172.9	136.1	153.9	149.1	149.0
251	190.2	188.6	175.8	151.7	136.3	119.1	184.1	175.1	123.2	150.4	150.4	146.9
316	185.2	186.8	178.0	154.3	120.3	116.8	182.3	171.5	120.8	152.0	149.9	142.7
398	185.5	179.5	174.0	152.2	117.1	100.9	179.5	161.9	107.2	142.9	138.5	135.5
501	185.4	176.4	173.8	146.7	112.7	82.0	172.0	163.1	98.2	131.0	132.5	131.2
631	185.4	180.4	170.0	145.1	112.0	70.8	167.1	161.0	88.1	117.1	119.9	118.0
794	181.8	177.9	167.1	144.2	111.2	51.3	164.7	155.4	77.9	104.7	100.0	99.9
1000	182.1	176.8	168.0	146.0	113.7	29.2	164.5	148.4	66.4	92.6	87.2	82.2
1259	179.4	174.2	168.1	147.5	123.4	29.2	164.6	151.7	74.0	79.8	69.3	65.0
1585	178.4	173.3	168.2	150.3	138.1	59.5	165.5	157.0	103.6	69.4	60.1	54.9
1995	175.9	172.1	166.1	149.5	144.0	85.3	163.5	157.6	119.8	71.3	57.9	46.2
2512	173.2	171.0	165.3	149.6	147.0	108.2	160.2	156.9	131.1	89.3	62.4	58.1
3162	168.5	167.9	159.7	145.7	147.6	123.1	158.2	154.4	137.5	109.7	90.4	86.5
3981	164.1	164.9	161.3	140.7	147.5	132.3	157.9	150.7	141.1	124.4	110.3	106.6
5012	164.6	159.3	162.2	140.9	146.3	136.9	155.2	148.6	142.6	134.5	123.7	120.9
6310	165.1	153.0	156.9	146.2	146.2	139.0	150.3	150.0	143.3	140.9	133.3	130.9
7943	164.1	158.7	154.3	141.8	141.1	136.8	147.7	149.0	140.1	142.7	136.5	135.0

D.2. Single and Dual Level Bridge: BMPs Applied

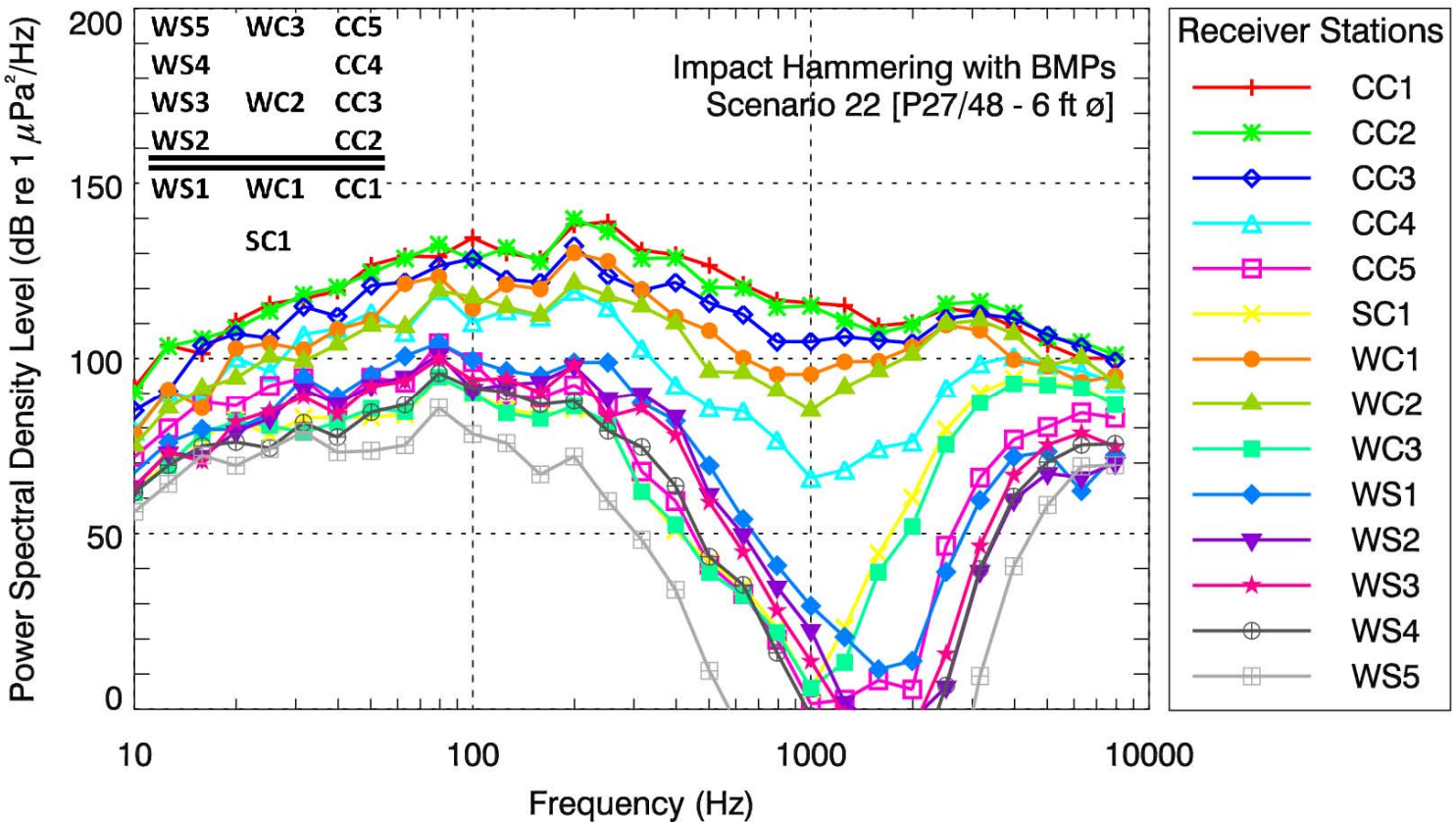
D.2.1. 4' pile size



Power spectral density levels (dB re 1 µPa^2/Hz) for Scenario 21: Impact hammering a 4 ft diameter pile at Pier 12/23 with BMPs.

	Receiver Station											
Frequency (Hz)	*CC1*	*CC2*	*CC3*	*CC4*	*CC5*	*SC1*	*WC1*	*WC2*	*WC3*	*WS1*	*WS2*	*WS3*
10	69.1	69.3	68.6	66.2	60.0	53.7	65.5	64.2	54.1	62.4	65.7	64.5
13	76.8	77.3	75.8	74.5	66.8	60.2	73.9	70.4	60.7	70.5	72.6	73.2
16	91.9	91.6	88.0	89.0	80.9	72.9	89.1	81.3	74.6	84.9	86.2	86.9
20	94.9	95.6	96.5	92.5	87.3	80.4	96.9	95.0	80.4	98.3	90.4	97.7
25	104.6	104.8	103.0	96.4	87.9	83.3	101.6	96.7	81.3	105.2	96.2	102.9
32	89.7	88.9	95.7	100.0	88.7	82.6	104.7	102.1	84.7	110.9	105.7	101.1
40	105.3	105.6	104.5	95.0	89.8	84.3	104.0	102.5	86.7	115.7	111.1	100.8
50	110.4	108.6	104.8	102.1	90.2	84.2	107.2	106.4	86.9	118.3	118.1	112.3
63	114.8	114.9	112.6	109.8	96.3	88.8	115.0	109.3	91.0	128.5	124.0	116.6
79	118.4	118.0	117.5	113.3	99.5	94.6	122.2	117.0	96.9	136.5	132.4	126.9
100	115.9	111.6	111.7	110.1	95.3	88.5	120.2	110.3	91.2	139.6	132.3	124.1
126	106.1	111.8	115.4	107.5	90.6	81.0	120.7	117.6	89.8	142.4	139.0	127.3
159	114.5	114.6	109.7	98.6	75.9	80.4	121.4	116.7	81.2	146.9	139.4	132.0
200	114.9	107.9	112.6	106.6	83.1	87.2	128.2	122.4	81.0	159.3	151.3	140.8
251	115.1	114.2	110.5	103.2	69.0	73.5	128.3	119.6	73.0	157.0	152.5	136.7
316	102.6	99.1	102.3	86.3	65.8	55.3	111.7	116.2	69.9	154.6	148.1	135.4
398	92.4	92.8	91.3	70.3	47.5	46.6	114.4	103.9	49.1	153.7	147.6	134.1
501	78.3	79.9	80.5	61.4	23.1	21.2	99.4	96.3	24.1	147.5	142.8	126.0
631	63.2	69.7	71.8	47.9	4.2	-15.1	94.9	88.7	5.7	144.2	141.7	121.5
794	59.3	60.3	54.7	33.1	-24.8	-45.7	80.8	66.1	-27.9	134.4	135.6	111.9
1000	42.9	43.8	40.6	9.0	-58.0	-79.4	65.4	53.2	-69.0	137.3	128.9	101.1
1259	30.9	29.6	25.9	-3.6	-74.9	-115.6	54.4	38.3	-105.2	134.3	123.1	90.2
1585	14.6	10.8	4.4	-22.5	-101.5	-165.0	36.8	15.8	-152.7	120.2	112.8	79.8
1995	4.6	-2.2	-10.4	-33.4	-115.9	-181.1	22.6	1.6	-176.3	120.6	100.6	68.6
2512	24.9	4.7	-6.8	-26.1	-94.2	-153.2	40.2	-1.2	-156.0	130.6	115.2	50.5
3162	53.8	44.3	35.6	23.1	-29.5	-66.7	67.7	39.9	-73.9	134.2	124.0	86.3
3981	72.6	71.0	64.0	55.1	18.0	-5.0	85.0	67.0	-11.6	135.1	129.3	102.3
5012	82.0	85.6	81.1	75.1	47.4	34.1	92.6	82.7	28.4	132.1	129.7	110.5
6310	90.2	94.9	91.6	89.1	67.1	59.2	100.5	92.7	54.9	129.8	130.5	116.4
7943	94.5	93.7	93.7	95.0	75.9	70.2	104.2	95.4	67.7	126.2	130.0	118.3

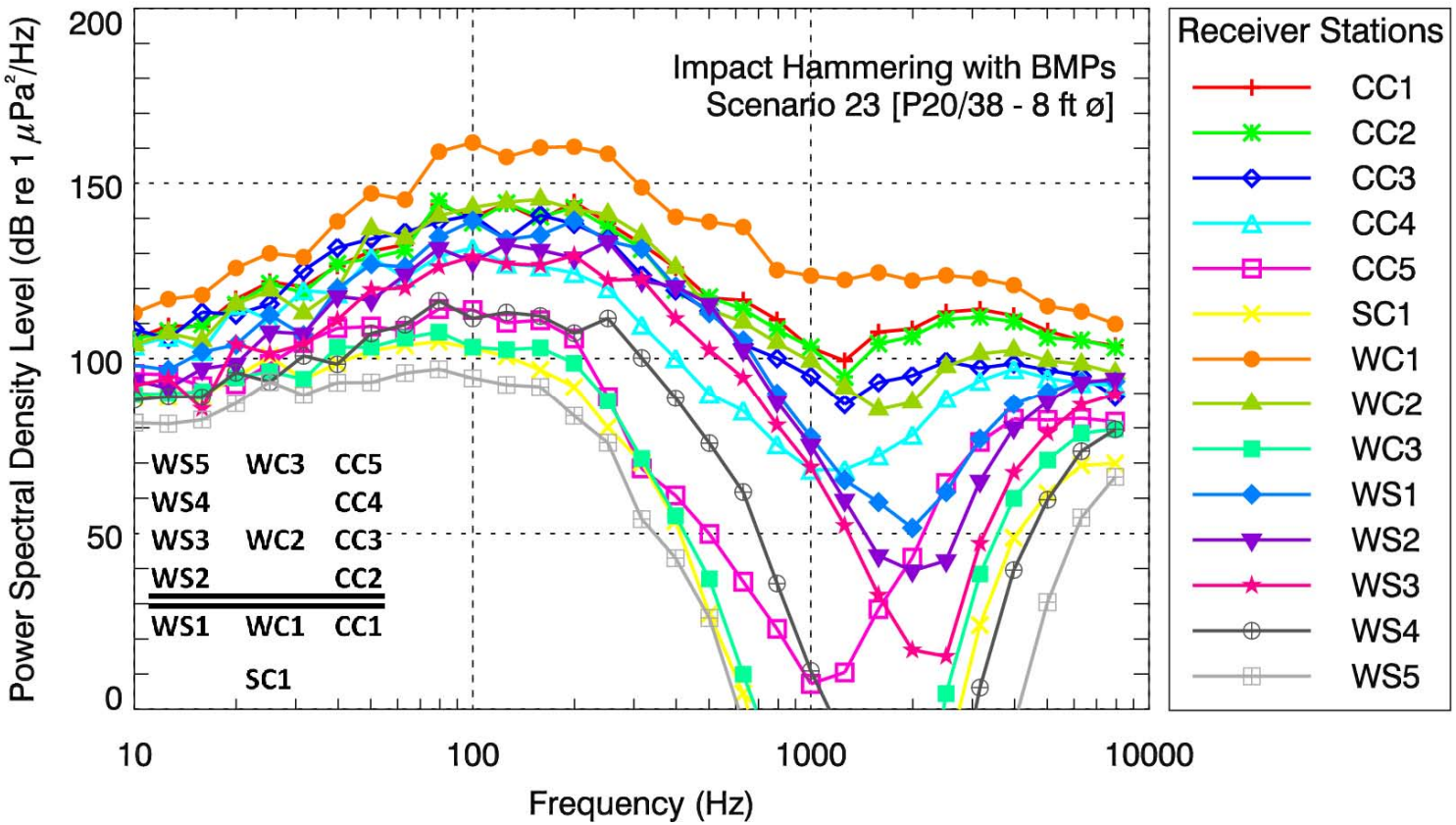
D.2.2. 6' pile size



Power spectral density levels (dB re 1 µPa^2/Hz) for Scenario 22: Impact hammering a 6 ft diameter pile at Pier 27/48 with BMPs.

	Receiver Station											
Frequency (Hz)	*CC1*	*CC2*	*CC3*	*CC4*	*CC5*	*SC1*	*WC1*	*WC2*	*WC3*	*WS1*	*WS2*	*WS3*
10	95.4	93.9	88.6	82.8	75.4	65.5	81.9	78.6	65.2	70.9	67.0	66.7
13	108.4	108.1	95.3	95.0	84.5	75.0	95.6	90.5	73.9	80.5	77.5	77.7
16	107.0	111.3	109.4	93.7	93.2	82.9	91.4	97.0	84.2	85.3	77.5	76.2
20	117.4	115.1	113.7	106.9	93.0	88.9	109.5	101.0	88.4	86.1	85.5	88.4
25	123.2	121.2	113.5	103.8	99.8	85.7	112.0	108.2	88.3	91.8	90.4	92.5
32	125.8	126.9	123.5	115.5	103.0	91.5	111.1	107.8	87.3	103.2	99.7	97.6
40	128.9	130.0	121.7	118.2	95.8	92.7	118.0	113.7	91.3	98.7	96.5	93.6
50	137.3	135.1	131.5	123.8	105.2	93.7	121.6	120.1	96.2	105.9	102.9	102.6
63	140.9	140.2	133.5	119.2	104.7	95.4	133.0	120.7	96.3	112.3	106.4	105.1
79	141.7	145.2	139.1	132.1	117.0	107.3	136.0	132.0	107.3	117.1	113.8	112.6
100	148.1	141.8	142.2	124.0	112.6	103.4	127.9	131.2	103.5	113.2	104.6	107.4
126	144.8	146.2	137.3	128.4	104.0	100.0	135.8	129.4	98.9	111.1	107.1	108.9
159	144.1	143.3	137.4	127.6	104.3	99.3	135.5	128.0	98.3	110.7	108.8	105.8
200	154.8	156.5	148.8	135.9	109.0	102.0	146.8	138.1	102.9	115.5	114.5	114.8
251	156.6	153.9	141.3	132.3	104.4	99.0	145.4	135.6	99.3	116.5	106.2	100.8
316	149.6	147.2	138.1	121.6	86.2	80.7	138.3	133.6	80.5	105.9	108.5	104.4
398	149.3	148.4	141.4	112.1	78.8	70.5	131.5	129.7	72.1	101.7	103.0	97.6
501	147.2	141.0	136.5	106.5	61.7	62.6	128.6	116.9	59.5	89.9	81.7	79.5
631	142.8	141.8	134.2	106.5	54.4	56.5	121.8	117.6	54.0	75.7	71.3	66.4
794	139.3	137.3	127.5	99.2	42.4	45.7	118.1	113.3	44.4	63.5	57.4	50.7
1000	139.5	138.7	128.5	89.4	25.2	29.3	119.1	108.6	29.7	53.0	46.1	37.3
1259	139.8	135.4	130.9	92.7	27.4	47.9	123.7	116.3	38.0	45.2	26.6	23.2
1585	135.0	132.8	130.9	99.8	33.9	69.9	124.9	122.1	64.6	37.0	21.5	19.0
1995	136.9	136.3	131.1	102.7	32.3	86.8	129.9	127.8	78.6	40.4	23.7	20.4
2512	141.9	143.2	139.1	119.2	74.1	107.2	137.2	137.6	102.9	66.7	34.0	43.4
3162	141.8	144.9	141.4	127.2	94.5	118.7	136.7	139.6	115.9	88.1	67.9	75.1
3981	138.7	142.6	141.1	130.3	106.3	123.9	129.3	136.7	122.4	101.4	89.2	96.2
5012	134.7	136.6	137.4	128.9	110.9	123.6	128.5	128.7	123.0	103.9	97.7	105.8
6310	131.7	136.4	135.1	128.1	116.0	123.7	124.9	131.8	123.0	93.7	97.5	110.2
7943	132.8	133.7	132.0	125.6	115.5	119.4	127.7	125.8	119.3	104.9	102.6	107.3

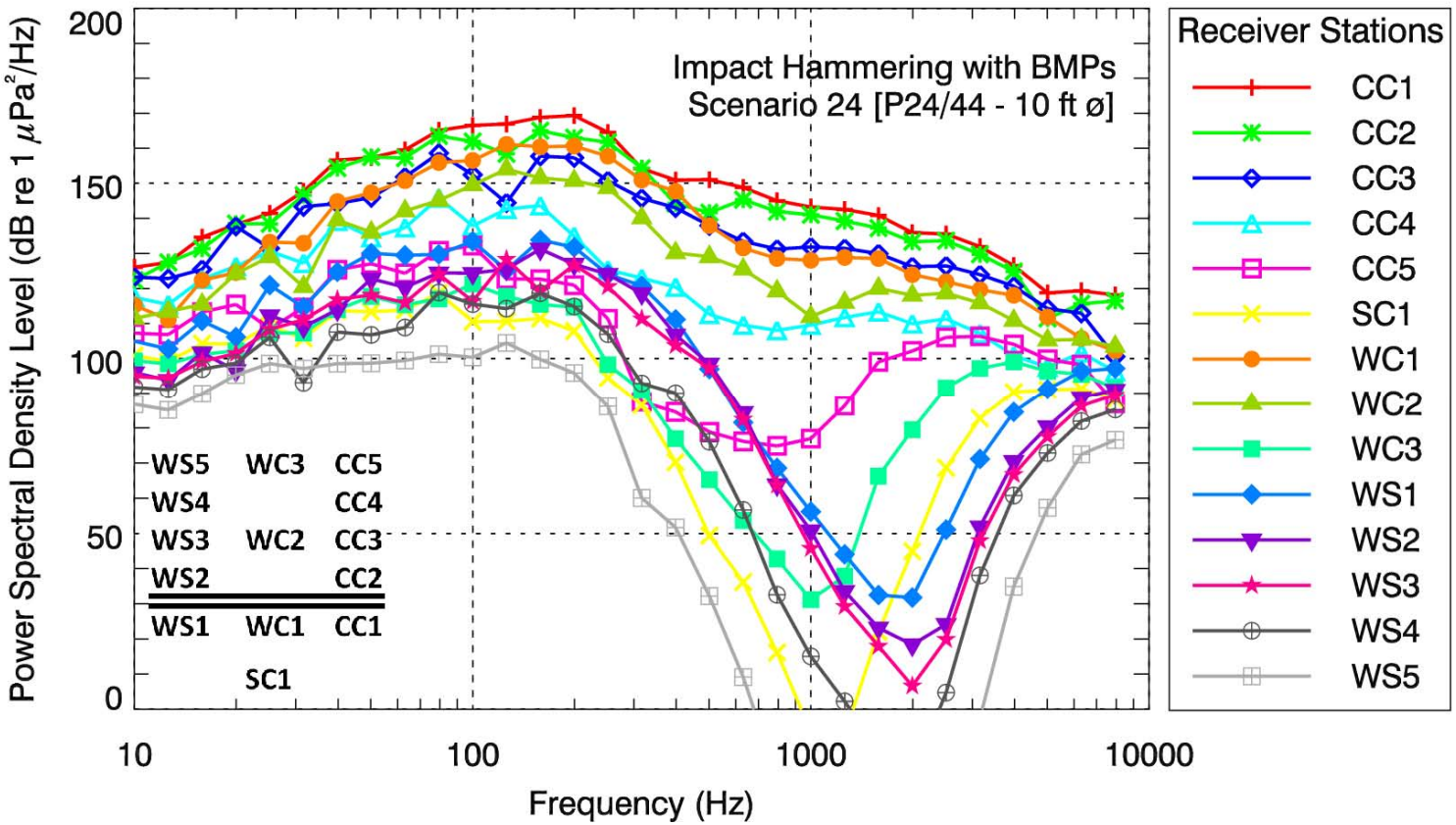
D.2.3. 8' pile size



Power spectral density levels (dB re 1 µPa^2/Hz) for Scenario 23: Impact hammering an 8 ft diameter pile at Pier 20/38 with BMPs.

	Receiver Station											
Frequency (Hz)	*CC1*	*CC2*	*CC3*	*CC4*	*CC5*	*SC1*	*WC1*	*WC2*	*WC3*	*WS1*	*WS2*	*WS3*
10	109.3	109.1	112.0	107.3	99.3	92.5	116.7	107.5	93.2	101.7	97.4	95.8
13	113.9	112.5	110.3	110.8	100.0	93.4	121.6	111.9	94.5	101.4	96.1	98.9
16	114.9	115.4	118.9	107.8	97.7	94.8	123.8	110.7	96.1	107.5	102.7	91.2
20	123.6	122.0	119.2	121.9	99.3	101.3	132.5	122.2	101.1	110.6	105.1	110.8
25	129.5	129.0	123.2	118.6	106.1	108.2	137.7	127.1	103.9	120.1	115.3	109.0
32	129.2	127.5	133.8	128.1	113.1	102.6	137.6	121.6	102.7	115.3	115.7	112.7
40	136.1	136.7	141.3	128.2	118.3	108.3	148.8	129.5	112.9	129.6	127.4	120.7
50	141.3	139.3	144.8	139.6	119.8	112.9	157.8	147.7	113.9	137.6	127.3	130.4
63	144.2	142.6	147.7	134.7	119.6	115.4	157.0	146.0	117.5	137.8	135.5	131.8
79	156.5	157.6	151.7	141.8	126.8	117.5	171.7	153.4	120.2	147.4	144.1	138.9
100	154.0	152.4	154.6	145.2	127.5	116.6	175.3	156.8	116.9	153.0	141.3	142.7
126	158.8	159.0	148.6	141.7	124.9	115.3	172.2	159.3	117.2	148.6	147.2	141.7
159	155.2	156.1	156.6	141.9	126.6	112.4	175.9	161.1	118.7	150.9	146.6	142.3
200	161.3	159.7	155.1	141.1	122.4	108.5	177.1	159.2	115.3	156.0	145.4	146.1
251	156.4	155.1	151.8	137.7	106.6	97.8	176.1	158.8	105.4	151.2	151.1	140.0
316	151.3	149.9	142.5	128.2	87.1	88.8	167.5	153.9	89.9	150.0	140.8	141.3
398	145.6	139.3	139.1	119.7	80.4	73.1	160.1	145.6	74.6	140.2	140.2	131.1
501	137.9	138.2	134.2	110.4	70.5	47.8	159.7	134.7	57.7	133.6	136.2	123.1
631	138.3	135.7	125.7	106.6	57.9	26.1	159.2	132.0	31.6	126.8	124.1	116.1
794	133.7	130.9	122.7	97.9	45.5	-4.5	147.9	127.1	6.6	112.5	110.2	103.5
1000	126.7	126.9	118.5	91.7	30.9	-36.0	147.3	122.8	-18.5	101.1	98.7	92.5
1259	124.0	119.4	111.4	92.8	35.1	-57.0	147.1	116.2	-37.8	89.8	84.1	76.9
1585	133.2	129.9	118.8	97.8	54.1	-70.9	150.2	110.9	-46.4	84.5	69.3	58.1
1995	135.1	132.9	121.7	104.6	69.7	-60.2	148.9	114.0	-29.6	78.2	66.0	43.5
2512	140.9	138.8	126.8	116.2	91.9	12.6	151.4	125.3	32.1	89.4	69.9	42.7
3162	142.7	140.5	125.9	122.2	104.6	52.6	151.5	130.0	67.1	105.5	93.5	75.8
3981	141.9	140.2	128.2	126.6	112.2	78.4	150.6	132.0	89.6	116.5	109.7	97.0
5012	138.5	136.6	127.3	125.0	112.9	92.0	145.6	130.0	101.5	120.9	118.2	109.2
6310	136.8	136.9	126.7	124.5	114.4	101.0	145.1	130.0	110.1	125.1	124.7	118.4
7943	136.3	135.8	121.6	125.0	114.4	102.5	142.5	128.5	112.3	126.1	126.8	122.3

D.2.4. 10' pile size



Power spectral density levels (dB re 1 µPa^2/Hz) for Scenario 24: Impact hammering a 10 ft diameter pile at Pier 24/44 with BMPs.

	Receiver Station											
Frequency (Hz)	*CC1*	*CC2*	*CC3*	*CC4*	*CC5*	*SC1*	*WC1*	*WC2*	*WC3*	*WS1*	*WS2*	*WS3*
10	129.7	126.0	126.9	121.1	110.9	104.5	118.9	115.1	103.0	108.6	99.6	98.5
13	132.1	132.1	127.5	120.1	111.5	103.8	115.7	118.1	103.1	107.4	98.4	99.0
16	140.3	137.0	131.1	128.3	118.9	109.9	128.0	121.1	106.8	116.4	107.3	104.8
20	144.9	145.2	144.4	133.0	122.1	110.8	131.2	130.9	108.9	112.8	103.2	108.1
25	149.1	146.1	139.1	138.3	116.1	117.0	140.9	136.7	115.0	128.6	119.9	116.0
32	156.4	155.3	152.0	135.9	123.2	114.4	141.6	129.1	115.9	123.3	117.7	119.7
40	166.3	164.0	153.9	148.9	135.0	123.3	154.5	149.2	123.6	134.4	123.6	126.5
50	168.0	168.2	156.6	145.2	137.7	124.0	158.0	146.7	128.4	140.7	133.4	128.8
63	171.2	168.9	163.5	149.0	136.0	125.5	162.4	153.8	127.0	141.1	132.0	127.6
79	177.8	176.2	171.3	158.5	143.4	131.3	168.6	157.8	129.7	142.4	137.1	136.7
100	180.2	175.6	166.1	151.5	145.9	124.2	170.2	163.2	134.9	147.1	138.0	130.0
126	181.6	173.1	159.1	157.3	137.4	125.3	175.8	168.7	132.4	139.9	140.2	143.0
159	184.5	180.7	173.4	159.3	138.3	127.1	176.1	167.2	131.1	149.5	146.9	134.9
200	186.0	179.7	174.0	151.6	137.6	124.5	177.3	167.4	131.3	148.4	143.6	143.4
251	182.2	179.4	168.4	143.0	129.0	112.1	175.4	166.4	115.9	141.7	141.7	138.2
316	172.9	173.0	164.4	141.6	106.1	105.2	169.6	158.8	109.4	139.4	137.2	130.0
398	170.6	163.9	162.7	140.1	104.2	89.9	167.4	149.8	96.6	130.8	126.4	123.4
501	171.7	162.3	158.6	133.3	99.5	70.0	158.6	149.7	85.9	117.6	119.1	117.8
631	170.5	167.0	155.1	131.2	97.8	57.8	153.2	147.1	75.3	103.2	106.0	104.1
794	167.7	164.6	153.9	130.7	97.5	38.8	151.2	141.9	65.4	91.2	86.5	86.4
1000	166.9	164.7	155.5	133.2	100.6	17.4	151.7	135.6	54.8	79.8	74.4	69.4
1259	167.2	163.9	156.1	136.4	111.0	17.5	153.5	140.6	62.5	68.7	58.2	53.9
1585	166.5	162.9	155.6	139.0	124.7	47.7	154.2	145.7	91.9	58.1	48.8	43.6
1995	162.6	160.0	152.9	136.6	128.8	71.6	150.6	144.7	106.1	58.4	45.0	33.3
2512	163.2	161.3	154.1	139.0	133.7	96.3	149.6	146.3	119.2	78.7	51.8	47.5
3162	160.6	158.4	152.6	135.8	135.0	111.4	148.3	144.5	125.8	99.8	80.5	76.6
3981	156.2	154.5	150.3	130.5	133.7	120.0	147.7	140.5	128.7	114.2	100.1	96.4
5012	149.4	142.1	144.9	128.2	130.4	121.6	142.5	135.9	127.0	121.8	111.0	108.2
6310	151.0	147.3	144.6	133.3	129.9	122.9	137.4	137.1	127.1	128.0	120.4	118.0
7943	150.8	149.1	133.2	128.9	119.6	120.9	134.8	136.1	124.1	129.8	123.6	122.1