SAN FRANCISCO–OAKLAND BAY BRIDGE
EAST SPAN SIESMIC SAFETY PROJECT

INCIDENTAL HARASSMENT AUTHORIZATION APPLICATION

For the Incidental Harassment of Marine Mammals Resulting from Activities Associated with the Dismantling of the Original East Span of the San Francisco–Oakland Bay Bridge

EA 04-013571
EFIS#: 0412000609
04-SF-80 KP 12.2/KP 14.3

04-ALA-80 KP 0.0/KP 2.1

March 2016

California Department of Transportation

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California Department of Transportation

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The environmental review, consultation, and any other action required in accordance with applicable Federal laws for this project is being, or has been, carried-out by the Department under its assumption of responsibility pursuant to 23 USC 327.

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List of Abbreviated Terms

µPa	micropascal(s)
ADD	Acoustic Deterrent Devices
BAS	Blast Attenuation System
Bay	San Francisco Bay
Department	California Department of Transportation
dB	decibel(s)
FESA	Federal Endangered Species Act
GI	gastrointestinal
Hz	Hertz
IHA	Incidental Harassment Authorization
kHz	kilohertz
MMC	Marine Mammal Center
MMEZ	marine mammal exclusion zone
MMO	marine mammal observer
MMPA	Marine Mammal Protection Act
msec	millisecond(s)
NMFS	National Marine Fisheries Service
OTD	Oakland Touchdown
psi	pounds per square inch
PTS	Permanent Threshold Shift
RMS	root-mean-square
SEL	sound exposure level
SFOBB	San Francisco–Oakland Bay Bridge
SFOBB Project	San Francisco–Oakland Bay Bridge East Span Seismic Safety Project
SPL	sound pressure level
TTS	Temporary Threshold Shift
YBI	Yerba Buena Island
ZOI	zone of influence

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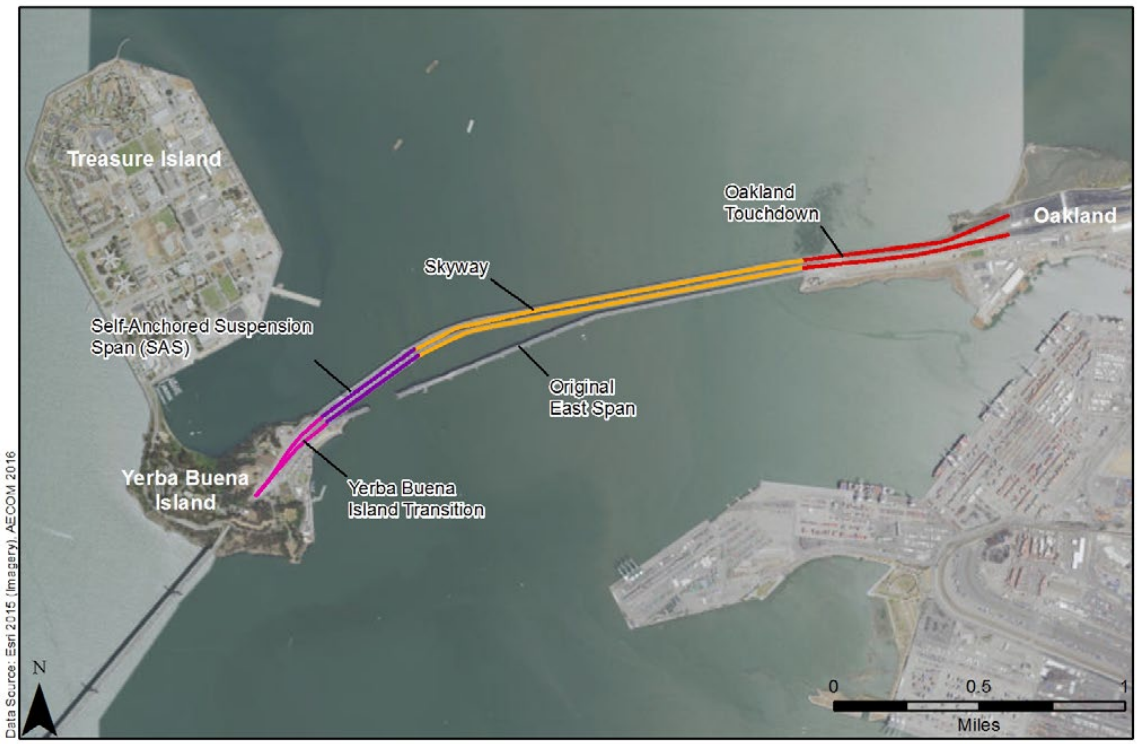
Chapter 1. Description of Specified Activity

The California Department of Transportation (Department), as part of the San Francisco–Oakland Bay Bridge (SFOBB) East Span Seismic Safety Project (SFOBB Project), has replaced the original east span of the SFOBB with a new bridge north of the former bridge (Figure 1). The SFOBB Project includes both constructing the new east span and dismantling the original east span. The Department is currently in the dismantling phase of the original east span. The Department is requesting regulatory authorization for the incidental harassment of marine mammals resulting from activities associated with dismantling the existing east span. These activities include vibratory pile driving, vibratory pile extraction/removal, attenuated impact pile driving, pile proofing, and the use of highly controlled charges to dismantle the Pier E4 and Pier E5 marine foundations.



Source: ESRI 2015 (imagery); compiled by AECOM in 2016

Figure 1. Sections of the SFOBB New East Span

1.1. Background and Project History

In 2001, in accordance with the Marine Mammal Protection Act (MMPA), the Department requested authorization from the National Marine Fisheries Service (NMFS) for possible harassment of small numbers of two pinniped species (California sea lions

and Pacific harbor seals) and one cetacean species (gray whales), incidental to conducting the SFOBB Project. On November 10, 2003, NMFS issued an Incidental Harassment Authorization (IHA) to the Department, authorizing the take of a small number of marine mammals incidental to the SFOBB Project. The Department has been issued nine subsequent IHAs for the SFOBB Project, in 2005, 2007, 2009, 2011, January 2013, December 2013, 2014, July 2015, and September 2015. Harbor porpoise was added to the Department's IHA authorization in 2007. The first five IHAs (2003, 2005, 2007, 2009, and 2011) addressed potential impacts on marine mammals and monitoring requirements associated with pile driving for constructing the new east span. The 2013, 2014, and July 2015 IHAs addressed activities associated with both constructing the new east span and dismantling the original east span—specifically vibratory pile driving, vibratory pile extraction/removal, attenuated impact pile driving, pile proof testing, and mechanical dismantling of temporary and permanent marine foundations. The September 2015 IHA specifically addressed a demonstration project that included use of highly controlled charges to dismantle the Pier E3 marine foundation (the Demonstration Project).

Hydroacoustic and marine mammal monitoring has been performed during all activities authorized under the Departments IHAs. Based on monitoring results, the Department and NMFS have determined that in-water mechanical dismantling of marine foundations via drilling, sawing, cutting, cracking, breaking, and pulverizing will not result in the incidental take of marine mammals as defined under the MMPA. Therefore, the Department is not requesting coverage under an IHA to conduct these in-water mechanical dismantling activities.

In accordance with the conditions of the September 2015 IHA, the Department successfully imploded Pier E3 with highly controlled charges. The successful implosion of the pier, as well as the results from hydroacoustic, biological, and water quality monitoring that were conducted during and following the implosion, demonstrated the use of highly controlled charges to be an effective and efficient method for removal of these types of marine foundations, with the least impact on the environment and biological resources. Hydroacoustic monitoring results from the implosion of Pier E3 will be used to inform predicted sound pressure levels and distances to marine mammal threshold criteria for the implosions of Piers E4 and E5.

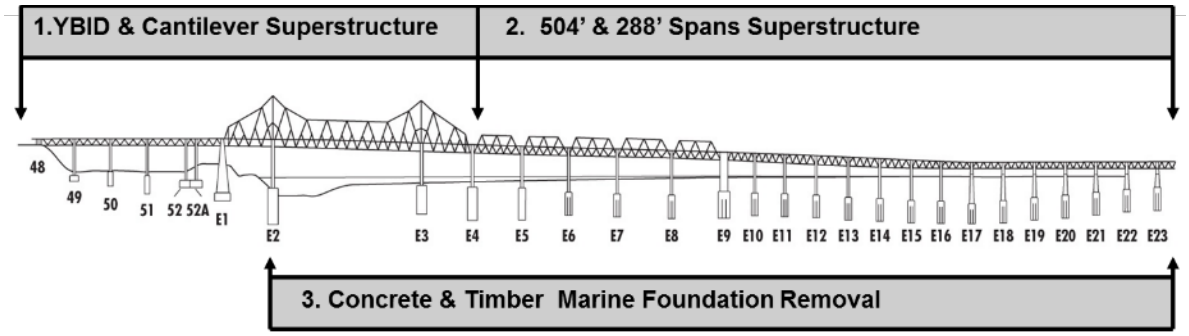
1.1.1. Project Area

The SFOBB project area is located in the central San Francisco Bay (the Bay), between Yerba Buena Island (YBI) and the city of Oakland. The western limit of the project area is the east portal of the YBI tunnel, located in the city of San Francisco. The eastern limit

of the project area is located approximately 1,312 feet (400 meters) west of the Bay Bridge toll plaza, where the new and former spans connect with land at the Oakland Touchdown (OTD) in the city of Oakland.

1.1.2. History of the Original East Span

Construction of the original east span connecting YBI and the Oakland shoreline was completed in 1936. The original east span was a double-deck structure, 12,127 feet (3,696 meters) in length and approximately 58 feet (18 meters) wide. It was constructed and opened with six traffic lanes on the upper deck; the lower deck had two rail lines, one lane for large trucks, and two lanes for traffic. From 1963 to the time of decommission, the original east span carried five traffic lanes on each of the upper and lower decks. The original east span was supported by 21 in-water bridge piers (Piers E2 to E22), as well as by land-based bridge piers and bents on YBI and in Oakland. Figure 2 shows the breakdown of the original east span, divided into three major sections.



Source: Department

Figure 2. Elevation View of the SFOBB Original East Span

The three major sections of the original east span can be described as follows:

CANTILEVER SUPERSTRUCTURE AND YBI DETOUR

Cantilever Superstructure: A cantilever bridge consisting of two 511-foot side spans and a 1,400-foot main span over the navigation channel immediately east of YBI. Removal of this structure was completed in 2015.

YBI Detour: To complete construction of the new SFOBB east span and tie into the YBI tunnel, a portion of the original east span between Pier E1 and the YBI tunnel was dismantled in 2009, and was replaced with the YBI Detour. The YBI Detour consisted of a double-decked bypass structure that connected to the original east span at Pier E1 on the east side of YBI.

504-FOOT AND 288-FOOT SPANS SUPERSTRUCTURE

The 504-foot and 288-foot spans superstructure (504/288) segment of the bridge is made up of five 504-foot-long (153.6 meters) steel truss spans and fourteen 288-foot-long (87.8 meters) steel truss spans. The vertical clearance beneath the spans gradually decreases, as the structure descends to the OTD. The superstructure includes trusses, road deck, and steel support towers.

CONCRETE AND TIMBER MARINE FOUNDATIONS

The marine foundations vary in structural type. Pier E2 at the eastern edge of YBI is a large, reinforced concrete, cellular structure, resting on an unreinforced concrete seal course with an average thickness of about 35 feet that bears on rock. Piers E3, E4, and E5 are founded on concrete caissons that were advanced over 130 feet into the soil beneath the waters of the Bay. The in-water portion of Pier E3 was removed in 2015, to demonstrate the efficacy of controlled, engineered blasting for demolition of marine piers. Piers E6 to E22 consist of lightly reinforced concrete foundations that are supported by timber piles driven into the Bay mud.

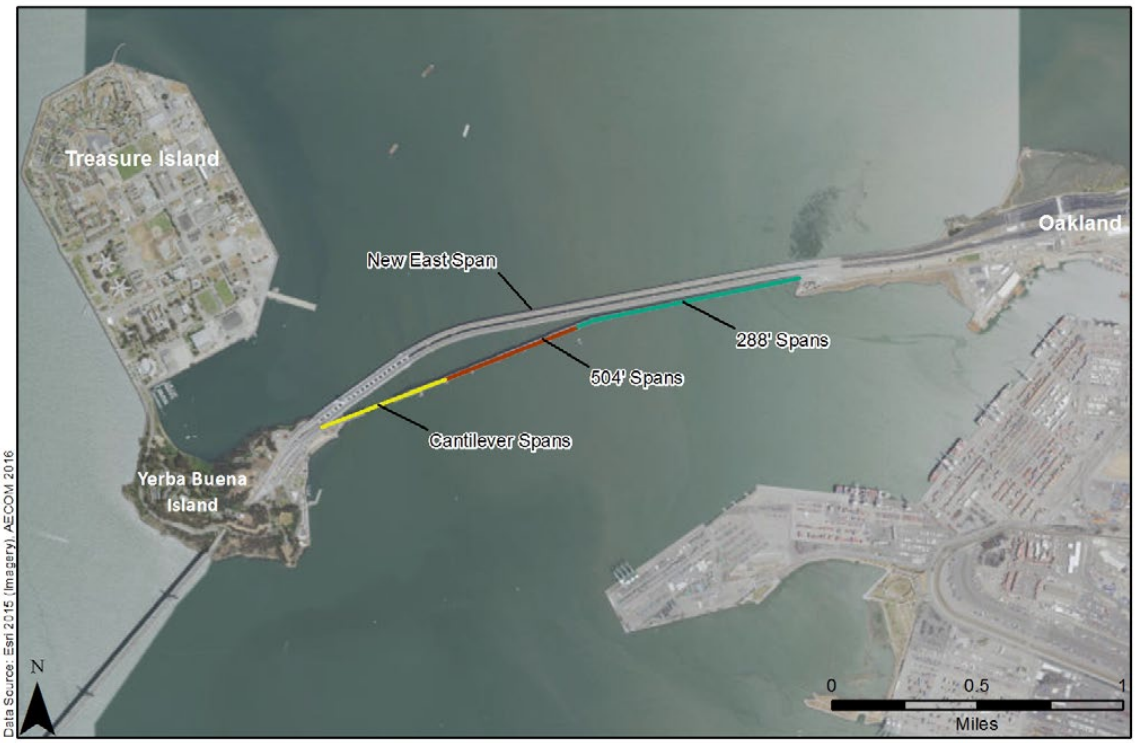
1.1.3. Dismantling the Original East Span

Dismantling the SFOBB original east span began in late 2013, after the new bridge was opened to traffic. The dismantling work was divided into multiple components, corresponding to the different sections of the original east span (Figure 2 and 3). These components include the following:

- Dismantling the cantilever superstructure and YBI Detour span, and the supporting steel tower legs;
- Dismantling the 504/288 segment's steel trusses and the supporting steel tower legs; and
- Removing the Marine Foundations

Dismantling the cantilever superstructure and YBI Detour span was completed in June 2015. Removing the 504-foot and 288-foot spans started in mid-2015 and is ongoing (Figure 3). Marine foundation removal began with the dismantling of Pier E3, initiated in April 2015. Pier E3 was the first marine foundation chosen for dismantling, and it was selected to demonstrate the effective use of controlled blasting to remove the marine foundations.

On November 14, 2015, as part of the Demonstration Project, Pier E3 of the original east span was successfully imploded with highly controlled charges. The pier was imploded into its open hollow cellular chambers below the mudline (i.e., the Bay floor). A Blast



Source: ESRI 2015 (imagery); compiled by AECOM in 2016

Figure 3. Sections of the SFOBB Original East Span

Attenuation System (BAS) and other avoidance and minimization measures were effective in minimizing potential impacts on biological resources in the Bay. Collected data indicate greater reduction and minimization of environmental impacts than originally modeled and proposed by the Department. Results from the Demonstration Project supported the finding that use of the controlled blasting reduced adverse effects on environmental resources compared to conventional dismantling methods (i.e., cofferdams, pile driving and mechanical dismantling). Controlled blasting removal greatly reduced in-water work periods for Pier E3, from approximately three to four years to a few weeks.

Based on the results of the Demonstration Project, the Department believes that using controlled charges to remove the remaining marine foundations will be the least environmentally damaging practicable alternative. The next phase of marine foundation will incorporate the experience from the Demonstration Project remove of Piers E4 and E5 using both mechanical and controlled blasting methods (Figures 2 and 4).

1.2. Dismantling Construction Activities with the Potential to Result in Incidental Take of Marine Mammals

Construction activities associated with dismantling the original east span potentially may result in incidental take of marine mammals. These activities include vibratory pile driving, vibratory pile extraction/removal, impact pile driving, and the use of highly controlled charges to dismantle the Pier E4 and Pier E5 marine foundations.

1.2.1. Vibratory and Impact Driving of Temporary Piles

The Department anticipates temporary access trestles, in-water falsework, and cofferdams may be required to dismantle the existing bridge. Temporary access trestles, supported by temporary marine piles, and cofferdams may be needed to provide construction access. Temporary falsework supports will be necessary to provide stability for the portions of the structure not yet removed. Marine pile-supported falsework is anticipated to be necessary to facilitate removal of the superstructure. These temporary structures will be contractor-designed; therefore, their exact nature (e.g., size, type, number of piles), location, and timing of installation are not known at this point. As discussed in detail in the April 13, 2013 IHA application, a maximum of 2,540 temporary piles may be installed to support all temporary structures required for bridge dismantling.

The Department conservatively estimates that a maximum of 200 temporary piles may be installed during the 1-year period of IHA coverage. Types of temporary piles to be installed may include sheet piles, 14-inch (0.34-meter) H-piles, and steel pipe piles, equal to or less than 36 inches (0.91 meters) in diameter.

All H-piles will be installed with an impact hammer, without the use of a marine pile driving energy attenuator. Impact driving (with the exception of pile proofing) will be restricted to June 1 through November 30, to avoid the peak migration period for salmonids and spawning adult green sturgeon. Vibratory driving and proofing of piles may be performed year-round.

All pipe piles will be installed with a vibratory hammer. The vibratory hammer will be used to drive the majority of the total pile lengths. The remaining piles may be impact-driven with the use of a marine pile-driving energy attenuator (i.e., air bubble curtain system), or other equally effective sound attenuation method (e.g., dewatered cofferdam). A maximum of 20 piles may be impact-driven per day.

In the event a pipe pile is installed entirely with a vibratory hammer, it still will be subject to final “proofing” with an impact hammer. “Proofing” will be accomplished by

using a limited number of blows with an impact hammer, intended to test integrity and seating of the pile. A maximum of 10 percent of the piles installed completely with a vibratory hammer may be proofed with an impact hammer, without the use of a marine pile-driving energy attenuator. Proofing of piles will be limited to a maximum of two piles per day, for less than 1 minute per pile, administering a maximum of 20 blows per pile.

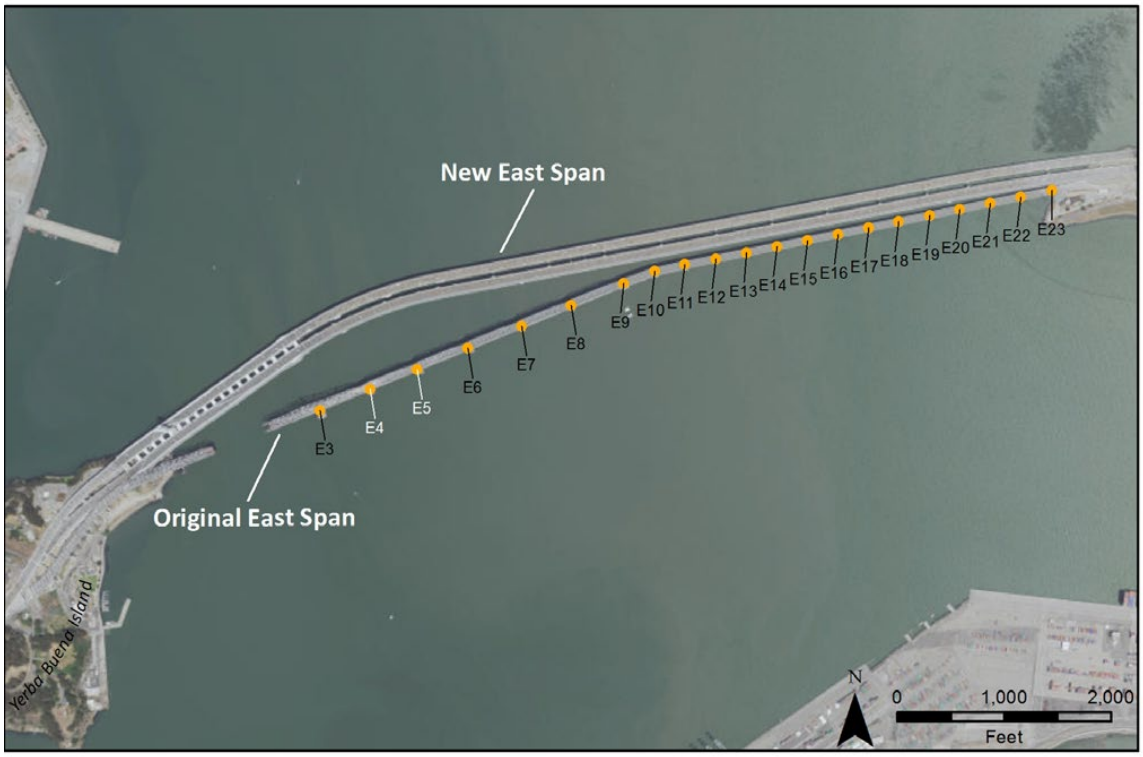
In addition to the temporary pipe piles and H-piles described above, sheet piles may be driven with a vibratory hammer to construct temporary cofferdams or other types of barriers. A cofferdam is a temporary enclosure, built within a body of water, usually composed of sheet piles welded together. The enclosures generally are watertight, allowing them to be fully or partially dewatered for construction access in the marine environment. Partially or un-dewatered cofferdams also may be used to isolate work areas; preventing water temporarily affected by construction activities from mixing with the surrounding waters of the Bay.

When no longer needed, all temporary piles will be retrieved or cut off 1.5 feet (0.46 meter) below the mudline, in compliance with United States Coast Guard requirements. A vibratory pile extractor will be used to retrieve piles.

1.2.2. Removal of Piers E4 and E5

The Department proposes the removal of Piers E4 and E5 of the original east span by use of controlled charges to implode each pier into its open cellular chambers below the mudline. A BAS will be used to minimize potential impacts on biological resources in the Bay. The Department believes that the results from the Pier E3 Demonstration Project support the use of controlled charges as a more expedient method of removal that will cause less environmental impact as compared to approved mechanical methods using a dry (fully dewatered) cofferdam.

Piers E4 and E5 of the original east span are located in the Bay, within the city and county of San Francisco. Both piers are located between the OTD area and YBI, and just south of the SFOBB new east span (Figure 4). These piers are concrete cellular structures that occupy areas deep below the mudline, within the water column, and above the water line of the Bay. The piers have been used to support the steel superstructure of the original east span. Each pier stands within a scoured pit that occurs because of the natural tidal action and currents of the Bay. Each pit is approximately 10 feet deeper than the surrounding mudline elevation. Detailed descriptions of each pier’s location and structure are provided next.



Source: ESRI 2015 (imagery); compiled by AECOM in 2016

Figure 4. SFOBB East Span, Location of Piers E4 and E5 Relative to Other Bridge Piers

the pile cap to the cutting edge (i.e., the deepest edge of the caisson) at the bottom of the caisson. The cutting edge of the structure is at an approximate elevation of -170 feet (National Geodetic Vertical Datum 1929 [NGVD29]). Approximately 68 feet (21 meters) is above the mudline, and approximately 132 feet (40.2 meters) of the structure's height remains

1.2.2.1. PIER E4 SITE LOCATION

Pier E4 is located on the original east span of the SFOBB, west of the OTD and approximately 2,000 feet (609 meters) east of YBI near the coordinates 37°48'58.53"N, 122°21'8.69"W (Figure 4). Pier E4 is located in an area that has a water depth of approximately 40 to 50 feet (12 to 15 meters) in the Bay.

1.2.2.2. PIER E5 SITE LOCATION

Pier E5 is located on the original east spans of the SFOBB, west of the OTD area and approximately 2,490 feet (759 meters) east of YBI near the coordinates 37°49'0.35"N, 122°21'2.84"W (Figure 4). Pier E5 is located in an area that has a water depth of approximately 40 to 50 feet (12 to 15 meters) in the Bay.

1.2.2.3. PIER E4 DESCRIPTION

The Pier E4 caisson is a cellular concrete structure, topped with a pier cap and concrete pedestals. It is approximately 200 feet (61 meters) in height, 90 feet (27.4 meters) long, and 60 feet (18.3 meters) wide. The pier is made up of 15 hollow cellular chambers (Figure 5). All of the chambers run vertically from below buried in the Bay mud. The hollow chambers of Pier E4 contain water. Weep holes in the foundation are located at an approximate elevation of -2 feet NGVD29. Through these weep holes, the water inside the caisson exchanges with the Bay water and varies in height with the tide.

Supported above the hollow cellular caisson portion of the structure are a pier cap and concrete pedestals. These elements are above water. This portion of the pier extends from the bottom of the pile cap, with an approximate elevation of +8 feet NGVD29 to the top of the pier at +30 feet NGVD29. The concrete pedestals are approximately 6 feet (1.8 meters) tall. The pier cap and pedestals extend above the water line to support the steel superstructure of the 504-foot section, and they are visible from the Bay. The 504-foot steel truss and supporting tower legs that are mounted on top of Pier E4's concrete pedestals will be removed before dismantling begins.

The fender system of Pier E4 is supported in two ways. On the longer east and west faces, the steel and timber fender system is attached and hung directly to the pier with anchor bolts. On the shorter north and south faces, a steel and timber fender system attaches directly to the concrete, extending approximately 33 feet (10 meters) away from the structure and supported on each side by 19 steel H-piles configured in a triangular pattern that were driven into Bay mud, for a total of 38 piles.

The mudline elevation around Pier E4 is approximately -45 feet NGVD29 outside the scoured area.

1.2.2.4. PIER E5 DESCRIPTION

The Pier E5 caisson is a hollow cellular concrete structure, topped with a pier cap and concrete pedestals. It is approximately 200 feet (61 meters) tall and containing 15 hollow chambers (Figure 6); approximately 130 feet (40 meters) is buried below the mudline. Like the former Pier E3, and unlike Pier E4, the Pier E5 structure's lower portion is wider than its upper potion. The shape of its bottom segment is wider from the approximate point where it meets the mudline (i.e., at its height of 130 feet [39.6 meters]) to its cutting edge, than it is in its upper segment. Pier E5 is described here in two segments: 1) the upper portion that occurs in and above the water column; and the 2) lower portion that occurs mostly below the mudline.

The upper portion of the structure that occurs predominantly above the mudline is supported on its longer east and west sides by 12 angled buttress walls that are approximately 18 feet (5.5 meters) tall and completely submerged at all times. All buttress walls are perpendicular to the structure. The upper portion of the structure is approximately 70 feet (21 meters) in height, 90 feet (27.4 meters) long, and 22 feet (6.7 meters) wide. The height of the structure includes two 6-foot-tall (1.8 meters) concrete pedestals on its top. The upper segment includes five hollow chambers in a single row through the center of the structure. These five caisson cells continue into the lower segment of the structure, all the way to the bottom of the structure. The top of Pier E5 is covered by a concrete pier cap and concrete pedestals that are always above the water line. The hollow chambers in this portion of the structure contain water. Weep holes in foundation are located at an approximate elevation of -1 feet NGVD29. Through these weep holes, the water line inside the caisson exchanges with the Bay water and varies with the tide.

The lower portion of Pier E5 is described here from its approximate height at the mudline down to the cutting edge. This lower segment is approximately 130 feet (39.6 meters) in height, 90 feet (27.4 meters) long, and 60 feet (18.3 meters) wide, and includes all 15 caisson cells. In addition to the central row of five chambers, two single rows of five chambers occur west and east of the central structure and run from approximately the scoured mudline to the cutting edge. The outer chambers in the lower segment are filled with water and are covered with pre-cast concrete slabs. The Pier E5 caisson does not reach bedrock.

Supported by the upper portion of the hollow cellular caissons are a concrete pile cap and concrete pedestals. This portion of the pier extends from an approximate elevation of +20 feet to +30 feet NGVD29. The concrete pedestals are approximately 6 feet (1.8 meters) tall. The pier cap and pedestals extend above the water line to support the steel superstructure of the 504-foot section and are visible from the Bay. The 504-foot steel truss and supporting tower legs mounted on top of Pier E4 will be removed before dismantling begins.

The fender system of Pier E5 is supported in two ways. The steel and timber fender system hangs and is attached directly to the pier with anchor bolts on the longer east and west faces. On the shorter north and south faces, a steel and timber fender system attaches directly to the concrete, extending approximately 20 feet (6 meters) away from the structure and supported at each side by 13 steel H-piles configured in a triangular pattern that were driven into the Bay, for a total of 26 piles.

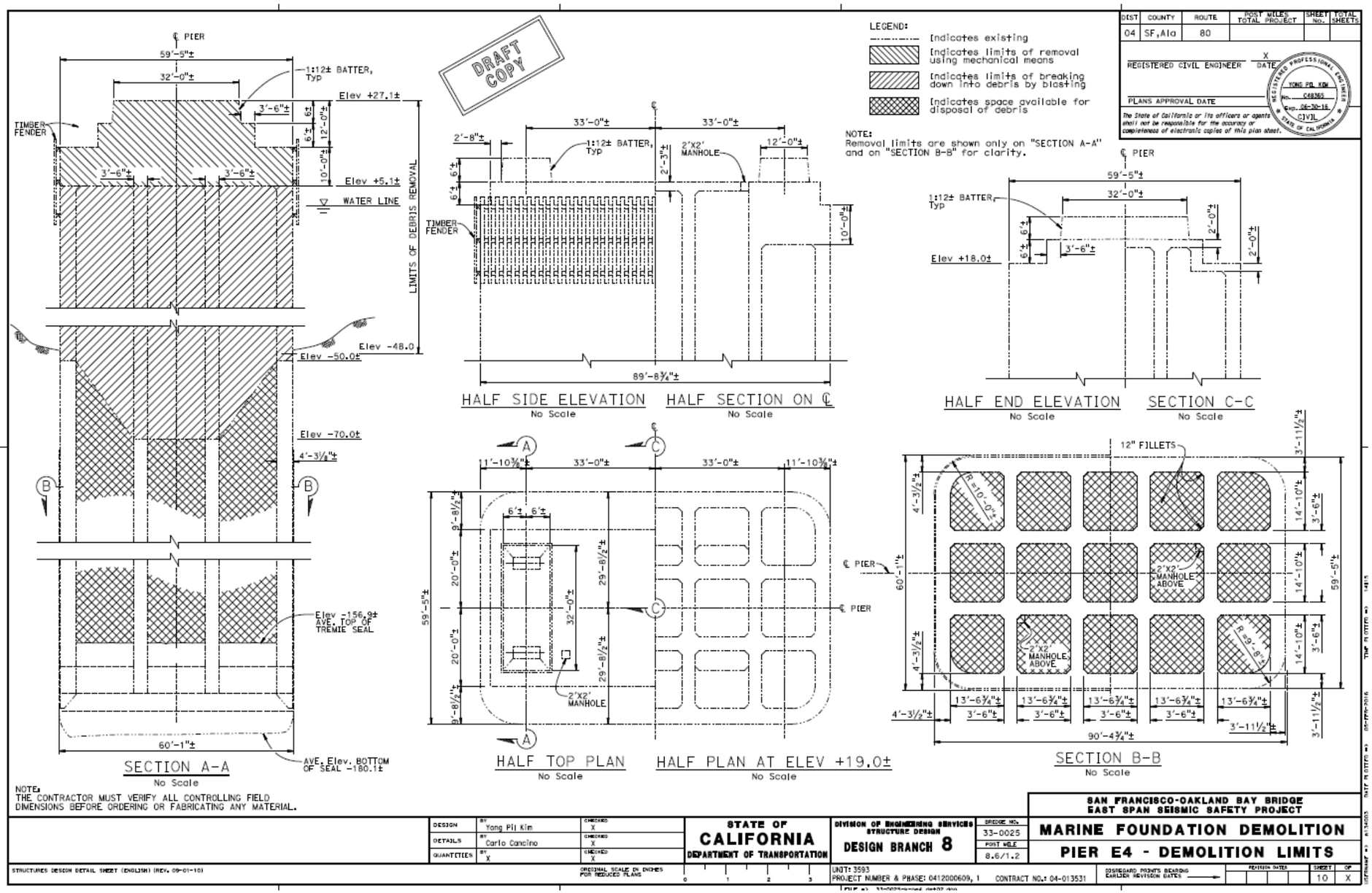


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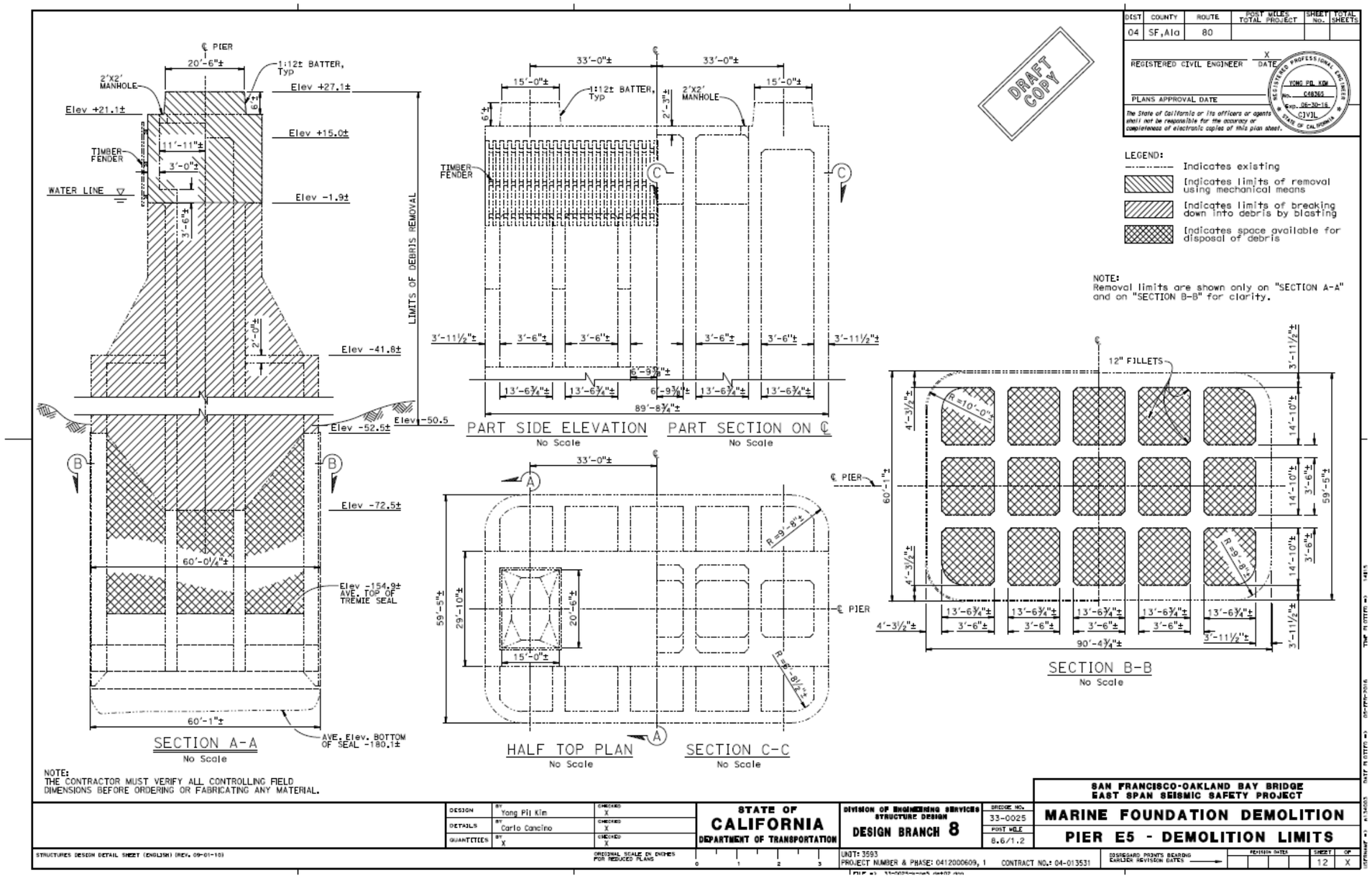
Figure 5. Removal Plan Sheet of Pier E4 Caisson



Source: Department

Figure 6. Removal Plan Sheet of Pier E5 Caisson

The mudline elevation around Pier E5 is approximately -47.5 feet NGVD29 outside the scoured area.

1.2.2.5. DISMANTLING OF PIERS E4 AND E5

The Department proposes removal of Piers E4 and E5 by use of controlled charges to implode the piers into their open cellular chambers below mudline. A BAS will be used to minimize impacts on biological resources in the Bay.

The successful implosion of Pier E3 in 2015 demonstrated the use of highly controlled charges to be an effective and efficient method for removal of these types of marine foundations, with low impact on environment and biological resources. The use of controlled charges greatly reduces in-water work periods and shortens the overall duration of marine foundation removal compared with mechanical removal.

Because of the similar structures for both Piers E4 and E5, each will be removed following the same five steps:

- Dismantling the fender system and removing the pier cap and concrete pedestals;
- Drilling bore holes into the marine foundation;
- Installing and testing the BAS;
- Installing charges, activating the BAS, and imploding the pier; and
- Managing and removing remaining dismantling debris.

Mechanical dismantling of Piers E4 and E5 is expected to start in June 2016, following removal of the overhead 504-foot truss sections and steel support towers that are part of the 504/288 dismantling work. The removal of Piers E4 and E5 will be similar to the successful Pier E3 Demonstration Project. Steps to remove the marine foundations will include mechanically removing the timber, steel, and pile-supported fender system that surrounds Piers E4 and E5, dismantling the concrete pedestals and concrete pier cap by mechanical means (including use of torches and excavators mounted with hoe rams, drills, and cutting tools) to an approximate elevation of +9 feet NGVD29, and drilling vertical boreholes where charges will be loaded for the controlled blasting. The charges will be loaded into the drilled boreholes. Controlled blasting removal will be accomplished using hundreds of small charges, with delays between individual charges. The maximum charge weight per delay will be 35 pounds (16 kilograms). The entire detonation sequence for each pier is expected to last approximately 3 to 5 seconds. The controlled blast removals have been designed to remove each pier to a minimum 3 feet below the average mudline elevation that occurs outside each pier’s scoured pit. To minimize impacts on aquatic biological resources in the Bay, a BAS will be installed

around the base of the pier. The BAS is specifically designed to minimize noise and pressure effects that are generated by a controlled implosion.

Dismantling of Pier E4 and Pier E5 Fender Systems and Concrete Caps

Dismantling of the Piers E4 and E5 fender systems and pier caps is expected to start in June 2016. The fender systems include timber, metal framing, and concrete aprons, which will be removed and disposed offsite. The steel piles that support the fender system will be removed and recycled off-site. The support piles either will be vibrated out and removed whole or will be cut off a minimum of 1.5 feet (0.46 meter) below the mudline and removed off-site.

Support barges will be used to move hydraulic excavators equipped with hoe rams, shearing attachments, drills, and other equipment, including cutting lances and torches that will be used during the mechanical dismantling. A barge-mounted crane will be used to move equipment onto and off each pier.

The concrete pedestals and pier cap will be removed by mechanical means, using tools including those listed above to break the concrete structure into pieces. Support platforms will be installed to provide a working surface for the excavators to dismantle the upper portion of the piers. A debris catchment system, accepted by the San Francisco RWQCB, will be in place to contain concrete debris from discharging into the Bay during dismantling operations. All concrete rubble from the mechanical dismantling will be placed into exposed cells of the caisson and will fall below the mudline for disposal.

During mechanical dismantling, the Department will monitor nesting birds and water quality, as required, and will employ best management practices to prevent inadvertent discharges into the Bay.

Pier E5 Lower-Chamber Pre-Cast Slab Removal

The lower caisson cells of Pier E5 on the east and west face of the lower segment of the pier are covered with pre-cast concrete slabs. To assure that the lower caisson chambers will be open to receive rubble during the controlled implosion of Pier E5, these slabs will be removed mechanically by breaking them with a modified steel pile that will be attached to and controlled by a barge-mounted crane. The controlled drop will bring the pile down on each slab. The weight of the modified pile will cause each concrete slab to shatter and fall into the caisson cells, to be entombed below the mudline.

Drill Boreholes

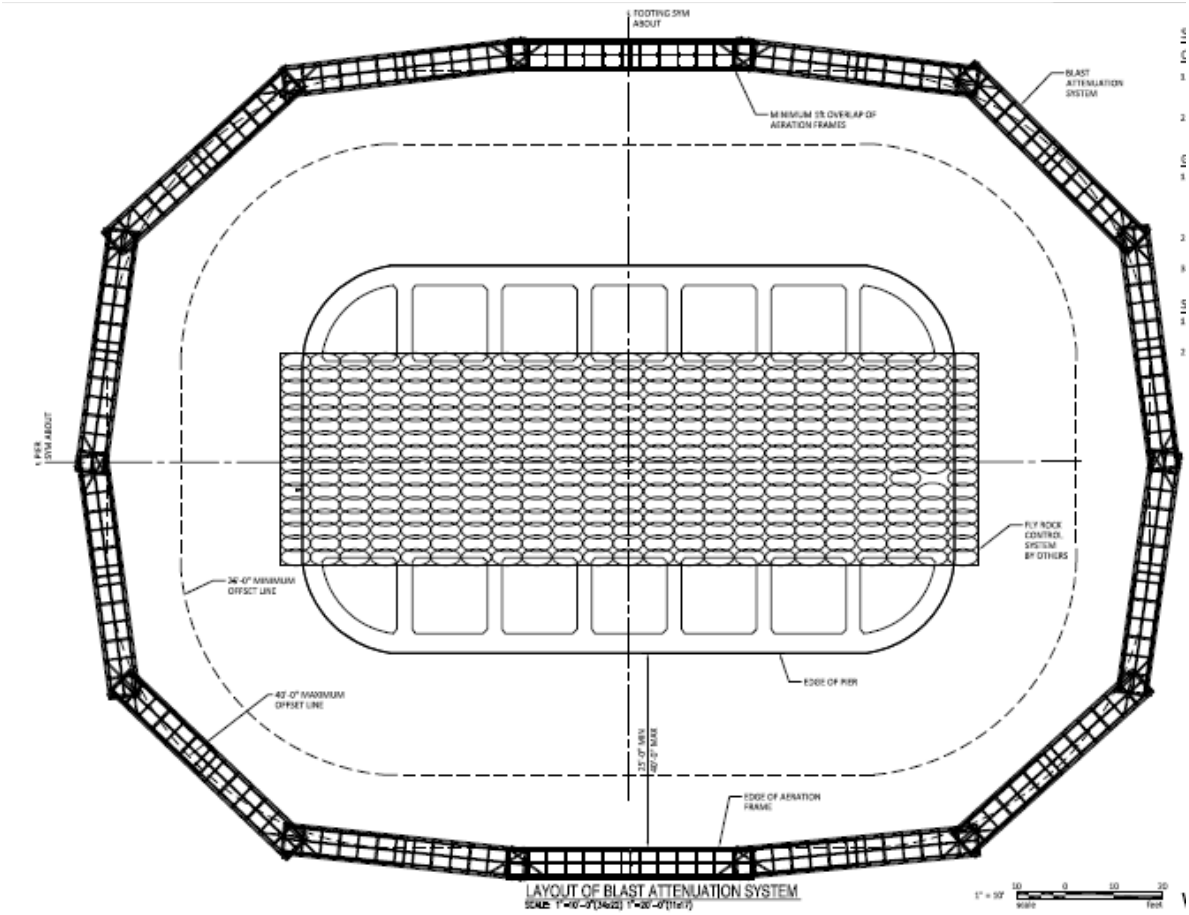
After the mechanical dismantling operations are complete, access platforms will be installed on top of each pier to support the drilling equipment. The exposed interior cell walls, buttress walls, and outside walls will be drilled from the top down, to remove concrete and create boreholes to just below the controlled blasting removal limit for each pier. Boreholes that are drilled in areas that are inundated with water (i.e., to the buttress walls and concrete slabs) will be done using a drill bit working within a tubular casing for guidance and to provide containment during in-water work. Monitoring will be performed to minimize and avoid impacts on water quality during this activity.

For Pier E5, an overhanging template system will be installed to guide the drill below the waterline. For Pier E5, divers will be required to cut notches into the buttress walls to guide the drilling of underwater boreholes. Pier E4 does not have buttress walls; therefore, it will not require in-water notching, and all borehole drilling will occur out of the water.

Blast Attenuation System Installation and Deployment

The BAS that will be used at Piers E4 and E5 is the same system that was successfully used for the Pier E3 Demonstration Project. The BAS is a modular system of pipe manifold frames, placed around each pier and fed by air compressors to create a curtain of air. The BAS will be activated before and during implosion. As shown during the Demonstration Project, the BAS will help minimize noise and pressure waves generated during each controlled blast, to minimize potentially adverse effects on biological resources that may be nearby. Each BAS frame is approximately 50.5 feet (15.4 meters) long by 6 feet (1.8 meters) wide. The BAS to be used at Piers E4 and E5 will be same system that was used at Pier E3 and will meet the same specifications. The BAS design details and specifications used for the implosion of Pier E3 are provided in Appendix A.

The complete BAS will be installed and tested during the weeks leading up to each controlled blast. Before installing the BAS, the Department will move any existing debris on the Bay floor that may interrupt proper installation of the BAS. Existing debris identified as a risk to proper installation of the BAS will be moved outside the path of the BAS layout. Each BAS frame will be lowered to the bottom of the Bay by a barge-mounted crane and positioned into place. Divers will be used to assist frame placement, and to connect air hoses to the frames. The BAS layout used during the implosion of Pier E3 is shown in Figure 7. A similar BAS layout will be used during the implosion of Piers E4 and E5. Based on location around the pier, the BAS frame elements will be situated from approximately 25 feet (7.6 meters) to 40 feet (12 meters) from the outside edge of



Source: Kiewit

Figure 7. BAS Layout Used during the Implosion of Pier E3 in November 2015

the pier. Frames will be situated to contiguously surround the pier. Each frame will be weighted to negative buoyancy for activation. Compressors will provide enough pressure to achieve a minimal air volume fraction of 3 to 4 percent, consistent with the successful use of BAS systems in past controlled blasting activities, including Pier E3. System performance is anticipated to provide approximately 80 percent sound and pressure attenuation, based on the results from the Demonstration Project and other marine structures removal projects that used a similar system.

Test Blasts

Before each pier implosion, test blasts may be conducted within the completely installed and operating BAS so that the hydroacoustic monitoring equipment will be properly triggered and functional before each pier implosion event. A key requirement of the implosion involves accurately capturing hydroacoustic information from the controlled blast. To accomplish this, a smaller test charge will be used to trigger recording

instrumentation. Multiple test blast events may be required to verify proper instrument operation and calibrate the equipment for the implosion event. These same instruments and others of the same type will use high-speed recording devices to capture hydroacoustic data at both near-field and far-field monitoring locations during the implosion.

The BAS will be in operation during all tests. Tests will use a charge weight of approximately 18 grains (0.0025 pound) or less. The test charge will be placed along one of the longer faces of the pier and inside the BAS while it is operating. Results from test blasts that occurred during the Pier E3 Demonstration Project indicate that these test blasts will have minimal impacts on fish and marine mammals (see Appendix B).

Controlled Implosion of Piers E4 and E5

Before pier removal via controlled blasting, the bore holes in the pier will be loaded with controlled charges. Individual cartridge charges, using electronic blasting caps versus pumpable liquid blasting agents, have been selected to provide greater control and accuracy in determining the individual and total charge weights. Use of individual cartridges will allow a refined blast plan that efficiently breaks concrete while minimizing the amount of charges needed.

Boreholes will vary in diameter and depth, and have been designed to provide optimal efficiency in transferring the energy created by the controlled charges to dismantle the pier. Individual charge weights will vary from 20 to 35 pounds (9 to 16 kilograms), and the total charge weight for each controlled blast event will be approximately 11,000 to 12,000 pounds (5,000 to 5,500 kilograms). Charges are arranged in different levels (decks) and will be separated in the boreholes by stemming. Stemming is the insertion of inert materials (e.g., sand or gravel) to insulate and retain charges in an enclosed space. Stemming will allow more efficient transfer of energy into the structural concrete for fracture, and further reduce the release of potential energy into the surrounding water column. The blast events for Piers E4 and E5 will each consist of approximately 400 individual delays of varying charge weight. The entire detonation sequence, consisting of approximately 400 detonations, will last approximately 3 to 4 seconds for each pier; with a minimum delay time of 9 milliseconds (msec) between detonations.

Through analysis and agency consultation, the Department determined that to minimize impacts on biological resources, the two controlled implosion events (one for each pier) should be conducted at slack tides on separate days, at least 24 hours apart, between October and December 2016.

Debris Removal and Site Restoration

Following the controlled implosion event and confirmation that the area is safe to work in, construction crews will begin to remove all associated equipment, including barges, compressors, the BAS, and blast mats. The Department expects that a small portion of rubble from each pier will fall outside its respective footprint and/or mound within the footprint of each pier, and will need to be managed after each controlled implosion. Concrete rubble resulting from the controlled implosions of Piers E4 and E5 that does not fall into the hollow caisson cells will be placed in the remaining caisson cells to be entombed below the mudline. The portions of each pier that do not break apart during controlled blasting and remain above the removal limits will be demolished by mechanical means. This may require the use of underwater mechanical equipment, including hydraulic crushing or grinding machinery or diver-operated jackhammers.

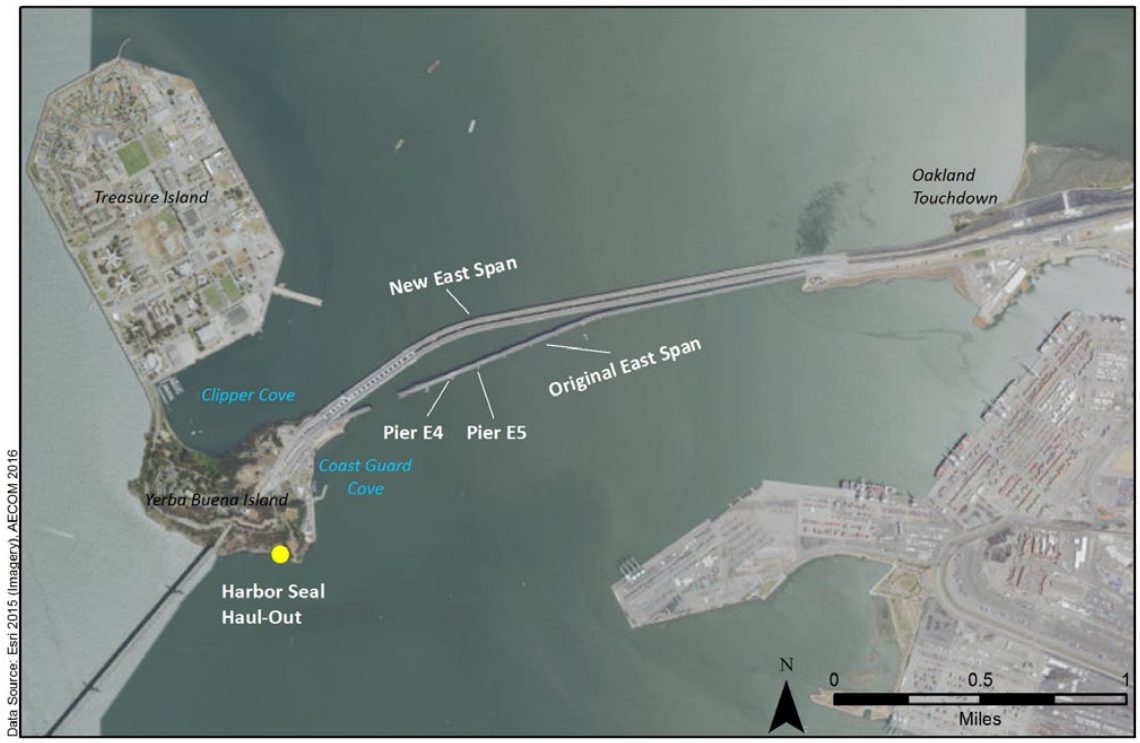
Rubble from the controlled implosion that does not fall into the hollow caisson cells will be picked up and disposed inside the remaining caisson cells, to be entombed below the mudline. Management of extraneous rubble will be done by a barge-mounted crane with a clam-shell bucket. Buckets used during this debris management phase will be equipped with a Global Position System unit, to accurately guide the location of the bucket in the water. The in-water site management operation is expected to take a few weeks following each implosion event and is anticipated to be completed by the end of December 2016.

Chapter 2. The Dates, Duration and Specified Geographical Region

Construction activities for replacement of the SFOBB original east span started in 2002. The new east span opened to traffic in September 2013. Construction activities for dismantling the original east span started in 2013 and currently are ongoing. Dismantling the original east span may take up to 4 more years to complete. The previous IHA issued for the implosion of Pier E3 was valid from October 1 through December 30, 2015. The current IHA issued on July 17, 2015, covering incidental take of marine mammals from pile driving and pile removal activities, will expire on July 16, 2016.

The demolition of Piers E4 and E5 through controlled implosion are planned to occur in October, November, or December 2016, and pile driving and pile removal activities may occur at any time of the year. The Department is requesting issuance of an IHA for a period of 1 year. To avoid a gap in IHA coverage, the Department is requesting issuance of a new IHA no later than July 17, 2016.

All dismantling activities with the potential to affect marine mammals will occur in the Bay, in the area around the original east span between YBI and the OTD area (Figure 8). Pile driving and pile removal activities may take place throughout this project area. The two controlled implosion events schedule for 2016 will take place at Piers E4 and E5.



Source: ESRI 2015 (imagery); compiled by AECOM in 2016

Figure 8. Bridge Spans and Piers E4 and E5 Relative to Marine Mammal Feeding Areas and Haul-Out Site

Chapter 3. Species and Numbers of Marine Mammals

Six species of marine mammals regularly inhabit or seasonally enter the San Francisco Bay (Table 1). The two most common species observed are the Pacific Harbor seal (*Phoca vitulina richardii*) and the California sea lion (*Zalophus californianus*). Juvenile northern elephant seals (*Mirounga angustirostris*) seasonally enter the Bay (spring and fall), while harbor porpoises (*Phocoena phocoena*) may enter the western side of the Bay throughout the year, but rarely occur near the SFOBB east span. Gray whales (*Eschrichtius robustus*) may enter the Bay during their northward migration in the late winter and spring, and bottlenose dolphins (*Tursiops truncatus*) may enter the western side of the Bay and are unlikely to occur near the SFOBB during November. None of these species are listed as endangered or threatened under the Federal Endangered Species Act (FESA), or as depleted or a strategic stock under the MMPA. In addition to the six common or regularly occurring species, nine species of marine mammals are considered extralimital (rare sightings or strandings in the Bay) and are unlikely to occur in the Bay (Table 1).

Information on the seasonal occurrence and estimated densities of harbor seals, sea lions, and harbor porpoises in the vicinity of the original east span were estimated from marine mammal monitoring conducted intermittently from 2000 to 2015, during the pile installation demonstration project, pile driving of permanent and temporary piles for new bridge construction, demolition of temporary tower foundations, blasting on YBI for Towers W2E and W2W, and the mechanical and the controlled implosion of Pier E3. The amount of monitoring performed per year varied depending on the frequency and duration of construction activities with the potential to affect marine mammals. During 237 days of monitoring (including 15 days of baseline monitoring in 2003), 822 harbor seals, 77 California sea lions, and 9 harbor porpoises were observed in the vicinity of the SFOBB east span (Department 2001, 2004b, 2009, 2013b, 2013c, 2014, 2015b). During this time, only two individuals showed responses to pile driving noise. In 2000, a sea lion was swimming slowly at the surface, approximately 3,281 feet (1,000 meters) west of a pile driving site. This individual then rapidly swam north at the start of pile driving (Thorson and Wagner 2001). In 2004, a harbor seal swam toward the pile driving barge during pile driving for the eastbound Skyway, and at approximately 180 feet (55 meters) from the piles, it abruptly turned around and dove (Department 2004b). Otherwise, most seals or sea lions were observed at least 328 feet (100 meters) beyond the pile driving activities. If an animal transited through the area, it typically would look toward the piles but not change swimming speed or direction (Thorson and Wagner 2001; Department 2004b).

Table 1. Summary of Marine Mammals in San Francisco Bay

Species	Stock	Status (FESA and MMPA)	Population	Population Trend
Species with Regular or Seasonally Occurrence in the San Francisco Bay				
Phocids				
Pacific Harbor Seal *Phoca vitulina richardii*	California	Not Listed	30,968 (CV=0.157)	Decreasing
Northern Elephant Seal *Mirounga angustirostris*	California Breeding	Not Listed	179,000	Increasing
Otarids				
California Sea Lion *Zalophus californianus*	United States	Not Listed	296,750	Increasing
Odontocetes				
Harbor Porpoise *Phocoena phocoena*	San Francisco-Russian River	Not Listed	9,886 (CV=0.51)	Stable
Mysticetes				
Gray Whale *Eschrichtius robustus*	Eastern North Pacific	Not Listed	20,990 (CV=0.05)	Stable
Species that are Extralimital to the San Francisco Bay				
Sea Otter *Enhydra lutris*	Southern (California population)	Threatened (ESA) Strategic (MMPA) Depleted (MMPA)	2,826	Stable
Northern Fur Seal *Callorhinus ursinus*	California	Not Listed	12,844	Increasing
Steller Sea Lion *Eumetopias jubatus*	Eastern (California Haul-out Sites)	Threatened (ESA) Strategic (MMPA) Depleted (MMPA)	2,781	Increasing (Stable in California)
Common Bottlenose Dolphin *Tursiops truncatus*	California Coastal	Not Listed	323 (CV=0.13)	Stable
Short-Beaked Common Dolphin *Delphinus delphis delphis*	California/Oregon/Washington	Not Listed	411,211 (CV= 0.21)	Increasing
Fin Whale *Balaenoptera physalus physalus*	California/Oregon/Washington	Endangered (ESA) Strategic (MMPA) Depleted (MMPA)	3,051 (CV=0.18)	Stable
Humpback Whale *Megaptera novaeangliae*	California/Oregon/Washington	Endangered (ESA) Strategic (MMPA) Depleted (MMPA)	1,918 (CV=0.03)	Increasing
Minke Whale *Balaenoptera acutorostrata scammoni*	California/Oregon/Washington	Not Listed	478 (CV=1.36)	Unknown
Sperm Whale *Physeter macrocephalus*	California/Oregon/Washington	Endangered (ESA) Strategic (MMPA) Depleted (MMPA)	971 (CV=0.31)	Unknown

Note:
CV = Coefficients of Variation; FESA = Federal Endangered Species Act; MMPA = Marine Mammal Protection Act
Sources: NMFS Stock Assessment Reports; Carretta et al. 2015; Allen and Angliss 2014

During past monitoring, the number of harbor seals observed increased as construction or demolition activities moved closer to YBI. Coast Guard Cove and Clipper Cove (between YBI and Treasure Island), and a small trench area 984 feet (300 meters) southeast of YBI are frequently used by harbor seals to forage. In 2015, weaned harbor seal pups or yearlings began foraging around the E2 piers of the new Bay Bridge. It is likely that algae and invertebrate growth on the piers has attracted fish, which the young seals can easily catch. YBI also is the site of one of the main harbor seal haul-outs in the San Francisco Bay (Department 2004b).

Chapter 4. Affected Species Status and Distribution

Six species may be affected by the SFOBB Project. The following discussion outlines their distribution and current population status. A summary of the information in this section is shown in Table 2.

4.1. Pacific Harbor Seal (California Stock)

Status: The harbor seal is protected under the MMPA, but is not listed as a strategic or depleted species under the MMPA (Carretta et al. 2013), or listed as endangered or threatened under the FESA. The California stock of harbor seals increased from 1972 through 2004, but showed a decline from 2009 through 2012 (Carretta et al 2015). The population size for the California stock during the last count in 2012 was estimated at 30,968 seals (CV=0.157; Carretta et al. 2015).

Distribution: Harbor seals are found from Baja California to the eastern Aleutian Islands of Alaska. They primarily haul out on remote mainland and island beaches and reefs, and estuary areas. Harbor seals tend to forage locally within 53 miles (85 kilometers) of haul-out sites (Harvey and Goley 2011). Harbor seals are the most common marine mammal species observed in the Bay and also commonly are seen near the SFOBB east span (Department 2013b, 2013c). Tagging studies have shown that most seals tagged in the Bay remain in the Bay (Harvey and Goley 2011; Manugian 2013). Foraging often occurs in the Bay, as noted by observations of seals exhibiting foraging behavior (short dives less than 5 minutes, moving back and forth in an area, and sometimes tearing up prey at the surface).

The molt occurs from May through June. During both pupping and molt seasons, the number of seals and the length of time hauled out per day increases, with about 60.5 percent of the population hauled out during this time versus less than 20 percent in the fall (Yochem et al. 1987; Huber et al. 2001; Harvey and Goley 2011). Mother-pup pairs spend more time on shore; therefore, the percentage of seals on shore at haul-out sites increases during the pupping season (Stewart and Yochem 1994). Peak numbers of harbor seals hauling out in central California occurs during late May to early June, which coincides with the peak of their molt. Seals haul out more often and spend more time on shore to molt. Yochem et al. (1987) found that harbor seals at San Miguel Island only hauled out 11 to 19 percent of the time in the autumn, from late October through early December.

Table 2. Summary of Marine Mammals with Potential to Occur near Piers E4 and E5

Species	Population in SF Bay	Distribution in SF Bay	Seasons Present In SF Bay	Pupping/ Calving Season	Dive Duration	Audiogram (Maximum Sensitivity)	Group Or Pod Size	Haul-Out Sites (Distance to Pier E4)
Pacific Harbor Seal	Up to 2,000	Throughout Bay	All Seasons	March-June (In SF Bay)	3 to 10 minutes (max of 30 min)	1-60 kHz (32 kHz)	1	YBI (4,593 feet; 1,400 meters)
California Sea Lion	Up to 2,000	Throughout Bay	All Seasons More In Summer - Winter	May-July (not SF Bay)	3-7 minutes (max of 10 min)	1-40 kHz (2-16 kHz)	1	Pier 39 (3.3 miles; 5.7 kilometers)
Northern Elephant Seal	Up to 100 (stranded juveniles)	Throughout Bay	Spring to Fall	December-March	10-15 minutes (max of 45 min)	3.2-55 kHz (3.2-45 kHz)	1	Mostly stranded, some haul out on YBI and TI
Harbor Porpoise	Up to 200	Western and Northern Bay	All Seasons	Spring (not SF Bay)	Short Dives up to 5 minutes	8–140 kHz (16-140 kHz)	Up to 6	N/A
Gray Whale	Up to 6 per year	Throughout Bay	Late Winter to Spring	Winter (not in SF Bay	Short Dives	100 Hz-4 kHz	1-2	N/A
Source: See species description sections 4.1-4.5								

Harbor seals tend to forage at night and haul out during the day. Harbor seals predominately haul out from 10:00 through 19:00, with a peak in the afternoon between 13:00 and 16:00 (Yochem et al. 1987; Stewart and Yochem 1994, Grigg et al. 2002; London et al. 2012). Harbor seals in the Bay typically haul out in groups ranging from a few individuals to several hundred seals. One known haul-out site is on the south side of YBI, approximately 4,593 feet (1,400 meters) from Piers E4 and E5. The YBI haul-out site had a range of zero to 109 harbor seals hauled out during November, with the highest numbers hauled out during afternoon low tides (Department 2004b). Pile driving for the SFOBB was not audible to the monitors just above the haul-out site and no response to pile driving was observed.

Tide level also can affect haul-out behavior, by exposing and submerging preferred haul out sites. Tides likely affect the maximum number of seals hauled out, but time of day and the season have the greatest influence on haul-out behavior (Stewart and Yochem 1994; Patterson and Acevedo-Gutiérrez 2008).

SFOBB Area: During 237 days of SFOBB monitoring, 822 harbor seals were observed in the vicinity of the SFOBB east span. Harbor seals make up 90 percent of the marine mammals observed during monitoring for the SFOBB Project. Foraging near the SFOBB is common, particularly in the coves adjacent to the YBI U.S. Coast Guard Station and in Clipper Cove between YBI and Treasure Islands. Foraging also occurs in a shallow trench area southeast of YBI (Department 2013a, 2013b). These sites are approximately 2,297 to 4,593 feet (700 to 1,400 meters) west of Piers E4 and E5.

Reproduction and Breeding: Pupping begins in late March in central California and pups start weaning in May. All pups are weaned by mid-June. Breeding occurs between late March and early May.

Diving and Foraging: Harbor seals generally are shallow divers, with about 90 percent of dives lasting less than 7 minutes (Gjertz et al. 1991; Eguchi and Harvey 2005), and with a maximum recorded dive time of 32 minutes (Eguchi and Harvey 2005).

Acoustics: Adult males produce low-frequency vocalizations underwater during the breeding season (Hanggi and Schusterman 1994; Van Parijs et al. 2003). Male harbor seals produce sounds in the frequency range of 100 to 1,000 Hertz (Hz) (Richardson et al. 1995). Generally, harbor seals do not vocalize while traveling or feeding; therefore, attempts to acoustically detect them before underwater implosions would not be useful. Harbor seals hear at frequencies from 1 to 180 kilohertz (kHz) (Møhl 1968); however, the species' hearing is most acute below 60 kHz, with peak hearing sensitivity at 32 kHz in

water and 12 kHz in air (Terhune 1968; Terhune and Turnball 1995; Kastak and Schusterman 1998; Wolski et al. 2003).

4.2. California Sea Lion (United States Stock)

Status: The California sea lion is protected under the MMPA but is not listed as a strategic or depleted species under the MMPA (Carretta et al. 2012), or listed as endangered or threatened under the FESA. The United States stock increased from 1975 through 2008, with an estimated population of 296,750 sea lions (Carretta et al. 2014).

Distribution: California sea lions breed on the offshore islands of California from May through July (Heath and Perrin 2008). During the non-breeding season, adult and sub-adult males and juveniles migrate northward along the coast, to central and northern California, Oregon, Washington, and Vancouver Island (Jefferson et al. 1993). They return south the following spring (Lowry and Forney 2005; Heath and Perrin 2008). Females and some juveniles tend to remain closer to rookeries (Antonelis et al. 1990; Melin et al. 2008).

California sea lions have been observed occupying docks near Pier 39 in San Francisco, about 3.2 miles (5.2 kilometers) from Piers E4 and E5, since 1987. A reported high of 1,105 sea lions at Pier 39 occurred in 2001 (Marine Mammal Center 2002). Occurrence of sea lions here typically is lowest in June (breeding season) and highest in August. Approximately 85 percent of the animals that haul out at this site are males, and no pupping has been observed here or at any other site in the Bay (Lander, pers. comm., 1999). Pier 39 is the only regularly used haul-out site around the SFOBB, but sea lions occasionally haul out on human-made structures, such as bridge piers, jetties, or navigation buoys (Riedman 1990).

SFOBB Area: During monitoring for the SFOBB Project, 77 California sea lions were observed from 2000 through 2015. Sea lions appear to be transiting through the SFOBB area rather than feeding, with the exception of a single observation. In 2004, several sea lions were observed following a school of Pacific herring that moved through the SFOBB construction area.

Reproduction and Breeding: Breeding and pupping occur from mid to late May until late July. After the mating season, adult males migrate northward to feeding areas as far away as the Gulf of Alaska (Lowry et al. 1992), and they remain away until spring (March–May), when they migrate back to the breeding colonies. Adult females remain

near the rookeries throughout the year and alternate between foraging and nursing their pups on shore until the next pupping/breeding season.

Diving and Foraging: Over one-third of the foraging dives by lactating females are 1–2 minutes in duration and 75 percent of dives are less than 3 minutes, with the longest recorded dive being 9.9 minutes (Feldkamp et al. 1989). More recent studies of adult lactating females have reported a range of mean dive durations from 1.6 to 8.1 minutes (Melin et al. 2008). Most sea lions in the Bay are juveniles or sub-adult males, and are similar in size to adult lactating female sea lions; therefore, these dive data should approximate the diving abilities of Bay sea lions.

Acoustics: California sea lions produce two types of underwater sounds: clicks (or short-duration sound pulses) and barks (Schusterman et al. 1966; Schusterman 1969). All underwater sounds have most of their energy below 4 kHz (Schusterman et al. 1967). The range of maximal sensitivity underwater for sea lions is between 1 and 28 kHz (Schusterman et al. 1972). Functional underwater high frequency hearing limits are between 35 and 40 kHz, with peak sensitivities from 15 to 30 kHz (Schusterman et al. 1972). The California sea lion shows relatively poor hearing at frequencies below 1,000 Hz (Kastak and Schusterman 1998). The best range of sound detection is from 2 to 16 kHz (Schusterman 1974). Kastak and Schusterman (2002) determined that the species' hearing sensitivity generally worsens with depth—hearing thresholds were lower in shallow water, except at the highest frequency tested (35 kHz), where this trend was reversed. Octave band noise levels of 65 to 70 decibels (dB) above the animal's threshold produced an average Temporary Threshold Shift (TTS) of 4.9 dB in the California sea lion (Kastak et al. 1999). Center frequencies were 1,000 Hz for corresponding threshold testing at 1,000 Hz and 2,000 Hz for threshold testing at 2,000 Hz; the duration of exposure was 20 minutes.

4.3. Northern Elephant Seal (California Breeding Stock)

Status: The northern elephant seal is protected under the MMPA, but is not listed as a strategic or depleted species under the MMPA (Carretta et al. 2013), or listed as endangered or threatened under the FESA. The population size for the California breeding stock is estimated at 179,000 seals and is increasing (Lowry et al. 2010, 2014; Carretta et al. 2015).

Distribution: Northern elephant seals are common on California coastal mainland and island sites where they pup, breed, rest, and molt. The largest rookeries are on San Nicolas and San Miguel islands in the northern Channel Islands. Near the Bay, elephant

seals breed, molt, and haul out at Año Nuevo Island, the Farallon Islands, and Point Reyes National Seashore.

Northern elephant seals haul out to give birth and breed from December through March. Pups remain onshore or in adjacent shallow water through May. Both sexes make two foraging migrations each year: one after breeding and the second after molting (Stewart 1989; Stewart and DeLong 1995). Pup mortality is high when they make the first trip to sea in May, and this period correlates with the time of most strandings. Pups of the year return in the late summer and fall to haul out at rookery sites but may occasionally make brief stops in the Bay.

SFOBB Area: Generally, only juvenile elephant seals enter the Bay and do not remain long. The most recent sighting was in 2012, on the beach at Clipper Cove on Treasure Island when a healthy yearling elephant seal hauled out for approximately 1 day. Approximately 100 juvenile northern elephant seals strand in the Bay each year, including individual strandings at YBI and Treasure Island (less than 10 strandings per year).

Diving and Foraging: Northern elephant seals have the highest diving capacity of any pinniped. Elephant seal juveniles regularly dive for 10 to 15 minutes, with a maximum reported time of 45.5 minutes (Thorson and Le Boeuf 1994; Le Boeuf et al. 1996).

Acoustics: The audiogram of the northern elephant seal indicates that the highest sensitivity range is between 3.2 and 45 kHz, with greatest sensitivity at 6.4 kHz and an upper frequency cutoff of approximately 55 kHz (Kastak and Schusterman 1998).

4.4. Harbor Porpoise (San Francisco-Russian River Stock)

Status: The harbor porpoise is protected under the MMPA but is not listed as a strategic or depleted species under the MMPA (Carretta et al. 2013), or listed as endangered or threatened under the FESA. The population size for the San Francisco–Russian River stock is estimated at 9,886 porpoises (CV= 0.51) and is increasing (Carretta et al. 2014; Forney et al. 2013).

Distribution: This species is seldom found in waters warmer than 17 degrees Celsius (Read 1990) or south of Point Conception, and occurs as far north as the Bering Sea (Barlow and Hanan 1995; Carretta et al. 2009; Carretta et al. 2012; Allen and Angliss 2013). The San Francisco–Russian River stock is found from Pescadero, 18 miles (30 kilometers) south of San Francisco Bay) to 99 miles (160 kilometers) north of the Bay to

Point Arena (Carretta et al. 2012). In most areas, harbor porpoises occur in small groups consisting of just a few individuals.

SFOBB Area: Harbor porpoises are frequently seen outside the Bay; they began to re-enter the Bay in 2008. Keener et al. (2012) reports sightings of harbor porpoises from just inside the Bay northeast to Tiburon and south to the SFOBB west span. Harbor porpoises have been observed only on three occasions (all single animals), swimming near the SFOBB east span. Those observations were made during spring and summer, and occurred near YBI (May to August; Department 2013c, 2014). The rare occurrence of harbor porpoises near the SFOBB east span makes it unlikely that they will be exposed to implosion activities.

Acoustics: Harbor porpoise vocalizations include clicks and pulses (Ketten 1998), as well as whistle-like signals and echolocation clicks (Verboom and Kastelein 1995). The dominant frequency range is 110 to 150 kHz (Ketten 1998), and a behavioral audiogram indicated the range of best sensitivity is 8 to 32 kHz at levels between 45 and 50 decibels re 1 micropascal-meter (dB re 1 μPa-m) (Andersen 1970) and 16 to 140 kHz (Kastelein et al. 2002). The TTS criteria were estimated at approximately 163 dB sound exposure level (SEL) from a 4 kHz airgun blast (Lucke et al. 2009).

4.5. Gray Whale (Eastern North Pacific)

Status: The gray whale is protected under the MMPA but is not listed as a strategic or depleted species under the MMPA (Carretta et al. 2015), or listed as endangered or threatened under the FESA. The population size for the eastern north Pacific stock is estimated at 20,990 (CV=0.71; Durban et al. 2013) and has been stable since the 1990s (Carretta et al. 2015).

Distribution: The eastern North Pacific population of gray whales ranges from the south tip of Baja California to the Chukchi and Beaufort Seas (Jefferson et al. 1993). The gray whale makes a well-defined seasonal north-south migration. Most of the population summers in the shallow waters of the northern Bering Sea, the Chukchi Sea, and the western Beaufort Sea (Rice and Wolman 1971). However, some individuals also summer along the Pacific coast, from Vancouver Island to central California (Rice and Wolman 1971; Darling 1984; Nerini 1984). In October and November, gray whales begin to migrate south and follow the shoreline south to breeding grounds along the west coast of Baja California and the southeastern Gulf of California (Braham 1984). Gray whales begin heading north in the late winter and early spring (Rice and Wolman 1971). The average gray whale migrates 4,660 to 6,213 miles (7,500 to 10,000 kilometers) at a rate

of 91 miles/day (147 kilometers/day; Jones and Swartz 2002). Gray whales generally calve and breed during the winter in lagoons in Baja California (Jones and Swartz 2002), although some calves are born along the coast of California during the migration south.

SFOBB Area: Reports from the Marine Mammal Center (MMC), the Sea Training Institute, the Oceanic Society, Richmond Bridge Seal monitors, and local news reports indicate that since 1999, gray whale sightings in the Bay have become more common, with at least two to six whales entering the Bay annually. Most gray whale sightings have occurred during the spring migration north. Although none have been sighted near the SFOBB east span, whales at the north have been reported at the end of Treasure Island during March, and one sighting about 1,000 yards (0.6 mile) south of YBI in December (P. Thorson, GANDA, February 2014).

Diving and foraging: Gray whales typically dive from 164 to 197 feet (50 to 60 meters) for 5 to 8 minutes. In breeding lagoons, the dives usually are less than 6 minutes (Jones and Swartz 2002), although dives as long as 26 minutes have been recorded (Harvey and Mate 1984). When migrating, gray whales may remain submerged near the surface for 7 to 10 minutes, and they travel 1,640 feet (500 meters) or more before resurfacing to breathe. Migrating gray whales sometimes exhibit a unique “snorkeling” behavior in which they surface cautiously, exposing only the area around the blow hole, exhale quietly without a visible blow, and sink silently beneath the surface (Jones and Swartz 2002).

Only one foraging study has been done on a single animal from off the west coast of Vancouver Island (Malcolm and Duffus 2000; Malcolm et al. 1995/96). The majority of time was spent near the surface on interventilation dives and near the bottom, ranging from a 46 to 72-foot depth (14 to 22 meters). Very little time was spent in the water column between the surface and bottom. The whale spent half the time at the surface and on shallow interventilation dives, and half the time diving from 13 to 59 feet (4 to 18 meters).

Acoustics: Gray whales produce broadband signals ranging from 100 Hz to 4 kHz (and up to 12 kHz) (Dahlheim et al. 1984; Jones and Swartz 2002). The most common sounds on the breeding and feeding grounds are knocks (Jones and Swartz 2002), which are broadband pulses from about 100 Hz to 2 kHz, with most produced from 327 to 825 Hz (Richardson et al. 1995). During migration, individuals most often produce low-frequency moans (Crane and Lashkari 1996).

The structure of the gray whale ear has evolved for low-frequency hearing (Ketten 1992). The ability of gray whales to hear frequencies below 2 kHz has been demonstrated in playback studies (Cummings and Thompson 1971; Dahlheim and Ljungblad 1990; Moore and Clarke 2002). Gray whales also are responsive to underwater noise associated with oil and gas activities (Malme et al. 1986; Moore and Clarke 2002). Gray whale responses to noise include changes in swimming speed and direction, to move away from the sound source; abrupt behavioral changes from feeding to avoidance, with a resumption of feeding after exposure; changes in calling rates and call structure; and surface behavior changes from traveling to milling (e.g., Moore and Clarke 2002).

4.6. Extralimital or Rare Species

The following extralimital species currently do not regularly enter the Bay, but may occur sporadically in the Bay or strand in the Bay, and some species may only occur seasonally. These species are mentioned because they infrequently enter the Bay and, although very unlikely, could be near Piers E4 and E5 during implosion activities.

4.6.1. Common Bottlenose Dolphin (California Coastal Stock)

The common bottlenose dolphin is protected under the MMPA but is not listed as a strategic or depleted species under the MMPA (Carretta et al. 2013), or listed as endangered or threatened under the FESA. The population size for the California coastal stock is estimated at 323 dolphins and is stable (CV = 0.13; Carretta et al. 2012). Bottlenose dolphins only recently have begun to enter the Bay. Movements primarily have been just east of the Golden Gate Bridge and along the west coastline of the Bay, south to Redwood City (Stern, pers. comm., 2014). Bottlenose dolphins have not been observed in the SFOBB Project vicinity, however, bottlenose dolphins are known to frequent bay and estuary areas. As their population becomes more established in northern California, they may venture into other areas of the Bay.

4.6.2. Southern Sea Otter (California Population)

The southern sea otter (*Enhydra lutris*) is protected under the MMPA and is listed as threatened under the FESA (Carretta et al. 2012). The estimated population size is 3,054 sea otters (Tinker and Hatfield 2015). Sea otters are common in the near-shore waters from Point Conception to Half Moon Bay, but juvenile sea otters occasionally wander well beyond the observed range limits. Sea otters are not regular visitors to the Bay, but several animals have been observed in the Bay in the last decade (De Rango, pers. comm., 2013).

4.6.3. Northern Fur Seal (California Stock)

The northern fur seal (*Callorhinus ursinus*) is protected under the MMPA and is not listed as a depleted or strategic stock under the MMPA (Carretta et al. 2012). Northern fur seals are not listed as threatened or endangered under the FESA. The estimated Eastern Pacific stock is 648,534 fur seals (Allen and Angliss 2015) and 12,844 fur seals for the California Stock of San Miguel and the Farallon Islands (Carretta et al. 2015). It is likely that only sick or injured northern fur seals would enter the Bay. Northern fur seals are not regular visitors, but several animals have stranded in the Bay since the 1980s (De Rango, pers. comm., 2013).

4.6.4. Humpback Whale (California/Oregon/Washington Stock)

The humpback whale (*Megaptera novaeangliae*) is protected under the MMPA and is listed as a depleted and strategic stock under the MMPA (Carretta et al. 2012). Humpback whales are listed as endangered under the FESA. The current best estimate for the California, Oregon, and Washington stock is 1,729 whales (CV = 0.03; Carretta et al. 2015). Several reports have been made of humpback whales entering the Bay and heading up the Delta waterway. The most recent occurrence was in 2007, when an injured mother and calf entered the Bay for 7 days (Gulland et al. 2008).

4.6.5. Minke Whale (California/Oregon/Washington Stock)

The minke whale (*Balaenoptera acutorostrata scammoni*) is protected under the MMPA and is not listed as a depleted or strategic stock under the MMPA (Carretta et al. 2012). Minke whales are not listed as threatened or endangered under the FESA. The current best estimate for the California, Oregon, and Washington stock is 478 whales (CV = 1.36; Carretta et al. 2012). Minke whales are not regular visitors to the Bay but have been observed several times since the 1980s (De Rango, pers. comm., 2013).

4.6.6. Sperm Whale (California/Oregon/Washington Stock)

The sperm whale (*Physeter macrocephalus*) is protected under the MMPA and is listed as a depleted and strategic stock under the MMPA (Carretta et al. 2012). Sperm whales are listed as endangered under the FESA. The current best estimate for the California, Oregon, and Washington stock is 2,106 whales (CV = 0.58; Carretta et al. 2015). Sperm whales are not regular visitors to the Bay, having been observed only once since the 1980s (De Rango, pers. comm., 2013).

4.6.7. Fin Whale (California/Oregon/Washington Stock)

The fin whale (*Balaenoptera physalus physalus*) is protected under the MMPA and is listed as a depleted and strategic stock under the MMPA (Carretta et al. 2012). Fin

whales are listed as endangered under the FESA. The current best estimate for the California, Oregon, and Washington stock is 3,051 whales (CV = 0.18; Carretta et al. 2014). Fin whales are not regular visitors to the Bay, having been observed only once since the 1980s (De Rango, pers. comm., 2013).

4.6.8. Steller Sea Lion (Eastern Stock, California Population)

The Steller sea lion (*Eumetopias jubatus*) is protected under the MMPA and is not listed as a depleted and strategic stock under the MMPA (Allen and Angliss 2014). The eastern stock of Steller sea lions is no longer listed as threatened under the FESA (NOAA 2013). The current best estimate for the Eastern stock is 60,131 to 74,448 sea lions, with most of the population in southeast Alaska and British Columbia (Allen and Angliss 2015). From 1982 to 2009, the population of Steller sea lions using central California (Año Nuevo and the Farallon Islands) has been relatively stable or slowly decreasing, to approximately 2,781 in 2011 (Allen and Angliss 2013). Steller sea lions are not regular visitors to the Bay, but several animals have stranded in the Bay since the 1980s (De Rango, pers. comm., 2013).

4.6.9. Short-Beaked Common Dolphin (California/Oregon/Washington Stock)

The short-beaked common dolphin (*Delphinus delphis delphis*) is protected under the MMPA and is not listed as a depleted or strategic stock under the MMPA (Carretta et al. 2012). Common dolphins are not listed as threatened or endangered under the FESA. The short-beaked common dolphin is the most abundant cetacean in California waters, although they tend to be found further offshore. The current best estimate for the California, Oregon, and Washington stock is 411,211 dolphins (CV =0.21; Carretta et al. 2012). Only one report has been made of a short-beaked common dolphin stranding in the Bay since the 1980s (De Rango, pers. comm., 2013).

Chapter 5. Type of Incidental Taking Authorization Requested

The Department requests an Incidental Harassment Authorization (IHA) pursuant to Section 101 (a)(5)(A) of the MMPA, for the harassment of marine mammals incidental to dismantling activities for the removal of the original east span of the SFOBB. Sound and pressure levels from pile installation and removal activities and use of controlled charges to implode bridge piers have the potential to result in take of marine mammals.

Under the MMPA "take" is defined as "harass, hurt, capture, kill or collect, or attempt to harass, hurt, capture, kill or collect." Under the 1994 Amendment to the MMPA, harassment is statutorily defined as "any act of pursuit, torment, or annoyance which has the potential to injure or disturb a marine mammal or marine mammal stock in the wild." Harassment which has the potential to injure a marine mammal is further defined as Level A harassment. Harassment which has the potential to disturb a marine mammal by causing disturbance of behavioral patterns, including migration, breathing, nursing, breeding, feeding, or sheltering, but which does not have the potential to injure a marine mammal, is further defined as Level B harassment.

5.1. Pile Driving and Pile Removal

Vibratory pile driving and vibratory pile removal produces continuous sounds that can cause behavioral disturbance (Level B harassment) to marine mammals, but would not cause injury.

Impact pile driving produces impulse sounds that can cause behavioral disturbance to marine mammals (Level B harassment) and slight injury, from Permanent Threshold Shifts (PTS) in an animal's hearing (Level A harassment).

NMFS has established interim sound threshold criteria for behavioral disturbance (Level B harassment) and PTS (Level A harassment) to marine mammals from pile driving and other similar activities (Table 3). These sound threshold criteria do not apply to explosives. The underwater sound pressure threshold for behavioral disturbance (Level B harassment) is 120 dB root-mean-squared (RMS) for continuous sound (e.g., vibratory pile driving) and 160 dB RMS for impulse sound (e.g., impact pile driving) for both cetaceans and pinnipeds. The underwater sound pressure threshold for slight injury, PTS (Level A harassment) is 180 dB RMS for cetaceans (i.e., whale, dolphins, and porpoises) and 190 dB RMS for pinnipeds (i.e., seals and sea lions).

Table 3. Interim Underwater Sound Threshold Criteria for Pile Driving

Marine Mammal Taxa	Level B Harassment Behavioral *continuous sound*	Level B Harassment Behavioral *impulse sound*	Level A Harassment Slight Injury (PTS)
Cetaceans	120 dB RMS	160 dB RMS	180 dB RMS
Pinnipeds	120 dB RMS	160 dB RMS	190 dB RMS
Note: All decibels referenced to 1 micro Pascal (re: 1μPa). Source: NMFS 2010			

The Department is requesting authorization for the incidental take of marine mammals caused by behavioral disturbance (Level B harassment) during vibratory pile driving, vibratory pile removal, and impact pile driving. With implementation of the avoidance and minimization measures outlined in Section 11, no injury (Level A harassment) or mortality to marine mammals is anticipated from pile driving and pile removal activities.

5.2. Implosion of Piers E4 and E5

Underwater blasting can cause behavioral disturbance (Level B harassment), slight injury (Level A harassment), and mortality to marine mammals. NMFS has established interim sound threshold criteria for take of marine mammals from underwater blasting (Table 4). TTS in an animal's hearing for underwater blasting is a specific type of behavioral disturbance (Level B harassment). PTS in an animal's hearing is a specific type of slight injury (Level A harassment). Level A harassment criteria also have been established for slight injury to an animal's gastrointestinal tract and lungs from blasting. The specific acoustic thresholds depend on group and species of marine mammal. The metrics for these are criteria defined as:

<u>Peak pressure level</u>

$$L_{pk} = 20\ Log_{10}\left(P_{pk}/P_{ref}\right) \qquad (1)$$

where L_{pk} is the peak level in dB and p_{ref} is the reference pressure of 1μPa;

<u>SEL</u>

$$SEL = 10\ Log_{10}\left(\int_0^T \frac{P^2(t)\,dt}{P_{ref}^2 \cdot T_{ref}}\right) \qquad (2)$$

where T is the duration of the event, $P^2(t)$ is the instantaneous pressure squared and T_{ref} is the reference time of 1 second;

Impulse

$$I = \int_0^T \left(P(t)dt \Big/ P_{ref} \right) \qquad (3)$$

where T is the duration of the initial positive portion of p(t). To calculate these quantities, p(t) for the blast event is needed as a function of distance from the blast, or alternatively, empirical relationship can be used for L_{pk} and I. As shown in Table 4, different designations for the SEL criteria exist for each group/species. These refer to group/species-specific filter shapes that are to be applied to the pressure signal. For L_{pk} and I, no filters are specified.

The Department is requesting authorization for incidental take of marine mammals caused by behavioral disturbance and TTS (Level B harassment) during use of controlled charges to implode Piers E4 and E5. Based on previously measured sound pressure levels, discussed in Section 6, and the implementation of avoidance and minimization measures outlined in Section 11, no injury (Level A harassment) or mortality to marine mammals is anticipated from implosion of Pier E4 and E5.

5.3. Levels and Types of Marine Mammal Take

The following discussion provides additional information and background on the levels and types of marine mammal take for which NMFS has established threshold criteria.

Behavioral Responses

Generally, a louder source of sound results in a more intense behavioral response. However, other factors, such as the proximity of a sound source, type, and frequency of the sound, and the animal's experience, motivation, and conditioning also are critical factors influencing the response (reviewed by Southall et al. 2007). The distance from the sound source and whether it is perceived as approaching or moving away also can affect the type and the intensity of the animal's response to a sound (Richardson et al. 1995, Wartzok et al. 2003, Nowacek et al. 2007; Southall et al. 2007). Behavioral responses can vary, from a minor response (i.e., orientation to the sound or head movement) to a strong response (i.e., rapidly swimming away from the sound, abandonment of the area).

Most low-frequency cetaceans (i.e., mysticete whales) usually avoided sound sources at levels of 160 dB re 1 μPa (Richardson et al. 1995). Gray whales migrating along the U.S. West Coast and in the Bering Sea showed avoidance responses to seismic vessels by

Table 4. Underwater Sound Pressure Threshold Criteria for Underwater Blasting

Group	Species	Behavior		Slight Injury			Mortality
		Behavioral (for ≥2 pulses/24 hours)	TTS	PTS	Gastro-Intestinal Tract	Lung	
Low-frequency Cetaceans	Mysticetes	167 dB SEL (LF_{II})	172 dB SEL (LF_{II}) or 224 dB peak SPL	187 dB SEL (LF_{II}) or 230 dB peak SPL	237 dB SPL or 104 psi	39.1 $M^{1/3}$ $(1+[D_{Rm}/10.081])^{1/2}$ Pa-sec Where: M = mass of the animals in kg D_{Rm}= depth of the receiver (animal) in meters	91.4 $M^{1/3}$ $(1+[D_{Rm}/10.081])^{1/2}$ Pa-sec Where: M = mass of the animals in kg D_{Rm}= depth of the receiver (animal) in meters
Mid-frequency Cetaceans	Most delphinids, medium and large toothed whales	167 dB SEL (LF_{II})	172 dB SEL (LF_{II}) or 224 dB peak SPL	187 dB SEL (LF_{II}) or 230 dB peak SPL			
High-frequency Cetaceans	Porpoises and *Kogia* spp.	141 dB SEL (HF_{II})	146 dB SEL (HF_{II}) or 195 dB peak SPL	161 dB SEL (HF_{II}) or 201 dB peak SPL			
Phocidae	Hawaiian monk, elephant, and harbor seal	172 dB SEL (P_{WI})	177 dB SEL (P_{WI}) or 212 dB peak SPL	192 dB SEL (P_{WI}) or 218 dB peak SPL			
Otariidae	Sea lions and fur seals	195 dB SEL (O_{WI})	200 dB SEL (O_{WI}) or 212 dB peak SPL	215 dB SEL (O_{WI}) or 218 dB peak SPL			

Source: Finneran and Jenkins 2012 and NMFS 2013

10 percent of animals at 164 dB re 1 μPa, and by 90 percent of animals at 190 dB re 1 μPa (Malme et al. 1986, 1988). In contrast, impact noise from seismic surveys was not found to affect feeding behavior or exhalation rates from resting or diving western gray whales off the coast of Russia (Gailey et al. 2007; Yazvenko et al. 2007). The behavior of baleen whales to loud sounds included avoidance of the sound (Malme et al, 1986, 1988), a decrease in surface intervals and breathing (Richardson et al. 1995), and changes in vocalizations rates or source level (Gordon and Moscrop 1996; Miller et al. 2000; Croll et al. 2002; Gordon et al. 2003, Southall et al. 2007). Seismic pulses caused blue whales to increase call production (Di Iorio and Clark 2010), although a blue whale stopped

vocalizing and changed its travel direction within 6 miles (10 kilometer) of a seismic survey ship using airguns (McDonald et al. 1995).

Mid-frequency cetaceans, including sperm whales and bottlenose dolphins, may show no clear tendency in response to sound sources. Captive United States Navy bottlenose dolphins sometimes vocalized after an exposure to impulsive sound from a seismic watergun (Finneran et al. 2002). Sperm whales in the Gulf of Mexico did not show any movement away from a seismic survey ship that was located approximately 2 to 7 nautical miles (3.7 to 13.0 kilometers) away (Madsen et al. 2006 and Miller et al. 2009).

High-frequency cetaceans (e.g., harbor porpoises) exhibited changes in respiration and avoidance behavior when exposed to sounds between 90 and 140 dB re 1 μPa. During pile driving, a sound pressure level (SPL) of 136 dB re 1 mPa caused an increase in the respiratory rate of a captive harbor porpoise, and at 154 dB re 1 mPa, the porpoise jumped out of the water more often (Kastelein et al. 2013).

Phocid seals showed avoidance reactions at or below 190 dB re 1 μPa (Richardson et al. 1995). Blackwell et al. (2004) observed that ringed seals exhibited little or no reaction to pile driving noise with mean underwater levels of 157 dB re 1 μPa and suggested that the seals had habituated to the noise. In contrast, captive California sea lions avoided sounds from an impulsive source at levels of 165 to 170 dB re 1 μPa (Finneran et al. 2003). Although noise was not necessarily a factor, harbor seals abandoned a haul-out site after it was repeatedly disturbed by small boats (Allen et al. 1984).

5.3.1. Hearing Threshold Shifts (TTS and PTS)

The magnitude of TTS or PTS is dependent on the level of sound, frequency, and duration of the sound (Parvin et al. 2007). Recovery from TTS usually occurs within minutes to hours, depending on the severity of the TTS exposure (Nachtigall et al. 2004; Finneran et al. 2005; Mooney et al. 2009). PTS has not been measured in marine mammals because of ethical concerns, but it has been measured in terrestrial animals. For marine mammals, PTS has been assumed to occur at a level about 6 dB above the level that causes TTS.

5.3.2. Injury and Mortality

Injury from impulse sounds, including underwater implosions, usually involve air-filled cavities, such as the lungs, gastro-intestinal tract, and nasal sinuses, as well as the auditory system (Yelverton et al. 1973; Goertner 1982; Craig and Hearn 1998). Damage to the tissues of the brain also may occur (Knudsen and Øen 2003). Impulse injuries to the respiratory system may consist of lung contusions, collapsed lungs, air in the chest

cavity between the lungs, traumatic lung cysts, or interstitial or subcutaneous emphysema (Phillips and Richmond 1990). The reinforced trachea, flexible thoracic cavity, and ability to deflate and re-inflate the lungs during diving (Kooyman et al. 1970; Ridgway and Howard 1979) may decrease the risk of lung injury in marine mammals when exposed to loud sounds or pressures. In addition, the gastrointestinal (GI) tract is more robust than lung tissues that require higher pressures for tissue damage to occur.

Mortality to fur seals occurred within 75.5 feet (23 meters) of a 24.25 pound (11 kilogram) submerged dynamite charge (peak pressure of 530 pounds per square inch (psi) [252 dB re 1μPa; reported in Parvin et al. 2007]). Sea otters were injured when exposed to peak pressures of 100 psi (236 dB re 1μPa), and mortality occurred at peak pressures of 300 psi (246 dB re 1μPa) (reported in Parvin et al. 2007). Many marine mammals must quickly breathe when surfacing and undergo lung collapse during deep diving, and thus lung injuries can be particularly debilitating or fatal. Mortalities to bottlenose dolphins also have occurred from underwater implosions associated with oil rig removal in the Gulf of Mexico (Klima et al. 1988) and to long-beaked common dolphins during Navy training in southern California (Danil and St. Ledger 2011).

Chapter 6. Take Estimates for Marine Mammals

The distance to marine mammal threshold criteria for pile driving, blasting activities, and corresponding zones of influence (ZOI) have been determined based on underwater sound and pressure measurements collected during pervious activities in the SFOBB Project area. The numbers of marine mammals by species that may be taken by each type of take were calculated based on distance to the marine mammal threshold criteria, duration of the activity, and the estimated density of each species in the ZOI.

6.1. Estimates of Species Densities of Marine Mammals

No systematic line transect surveys of marine mammals have been performed in the San Francisco Bay. Therefore, the in-water densities of harbor seals, California sea lions, and harbor porpoises were calculated based on 15 years of observations during monitoring for the SFOBB construction and demolition. The amount of monitoring performed per year varied depending on the frequency and duration of construction activities with the potential to affect marine mammals. During the 237 days of monitoring from 2000 through 2015 (including 15 days of baseline monitoring in 2003), 822 harbor seals, 77 California sea lions, and 9 harbor porpoises were observed within the waters of the SFOBB east span. Density estimates for other species were made from stranding data, provided by the MMC (for Northern elephant seal).

6.1.1. Pacific Harbor Seal Density Estimates

Most data on harbor seal populations are collected while the seals are hauled out because they are much easier to count when they are out of the water. In-water density estimates rely on haul-out counts, the percentage of seals not on shore based on radio telemetry studies, and the size of the foraging range of the population. Harbor seal density in the water can vary greatly, depending on weather conditions or the availability of prey. For example, during Pacific herring runs further north in the Bay (near Richardson Bay, outside the Piers E4 and E5 hydroacoustic zone) in February 2014, very few harbor seals were observed foraging near YBI or transiting through the SFOBB Project area for approximately 2 weeks. Sightings went from a high of 27 harbor seal individuals foraging or in transit in one day to no seals per day in transit or foraging through the SFOBB Project area (Department 2014). Calculated harbor seal density (Table 5) is a per day estimate of harbor seals in a 1 square kilometer area during the fall/winter or spring/summer season.

Table 5. Estimated In-Water Density of Marine Mammals in the SFOBB Project Area

Species	Main Season of Occurrence	Density West of Piers E4 and E5 within 1,500 meters of SFOBB (animals/square kilometer)	Density East of Piers E4 and E5 and/or beyond 1,500 meters of SFOBB (animals/square kilometer)
Pacific Harbor Seal	Spring–Summer (pupping/molt seasons)	0.32	0.17
Pacific Harbor Seal	Fall–Winter	0.83	0.17
California Sea Lion	Late Summer–Fall (post breeding season)	0.09	0.09
California Sea Lion	Late Spring–Early Summer (breeding season)	0.04	0.04
Northern Elephant Seal	Late Spring–Early Winter (pups after first trip to sea)	0.03	0.03
Harbor Porpoise	All Year	0.021	0.021
Gray Whale	Late Winter and Spring	0.00004	0.00004

Note:
Densities for Pacific harbor seals, California sea lions and harbor porpoises are based on monitoring for the east span of the SFOBB from 2000 to 2013. Gray whale and elephant seal densities are estimated from sighting and stranding data from the MMC.

Harbor seal density was calculated from all observations during SFOBB Project monitoring from 2000 to 2015. These observations included data from baseline, pre-, during and post-pile driving, mechanical dismantling, onshore blasting, and offshore implosion activities. During this time, the population of harbor seals in the Bay remained stable (Manugian 2013). Therefore, substantial differences in numbers or behaviors of seals hauling out, foraging, or in their movements are not anticipated. All harbor seal observations within a 1-square kilometer area were used in the estimate. Distances were recorded using a laser range finder (Bushnell Yardage Pro Elite 1500; ± 1.0 yard accuracy). Care was taken to eliminate multiple observations of the same animal, although this was difficult when more than three seals were foraging in the same area.

Density of harbor seals was highest near YBI and Treasure Island, probably because of the haul-out site and nearby foraging areas in Coast Guard and Clipper coves (Figure 8). Therefore, density estimates were calculated for a higher density area within 4,921 feet (1,500 meters) west of Piers E4 and E5, which included the two foraging coves. A lower density estimate was calculated from the areas east of Piers E4 and E5, and beyond 4,921 feet (1,500 meters) north and south of the bridge. The calculated Pacific harbor seal density was a per day estimate of harbor seals in a 1 square kilometer area during the fall/winter or spring/summer seasons (Table 5).

6.1.2. California Sea Lion Density Estimates

Most data on California sea lion populations are collected while the seals are hauled out because they are much easier to count when they are out of the water. In-water density estimates rely on haul-out counts, the percentage of sea lions not on shore based on radio telemetry studies, and the size of the foraging range of the population. Sea lion density, like harbor seal densities, in the water can vary greatly, depending on weather conditions, the availability of prey, and the season. For example, sea lion density increases during the summer and fall, after the end of the breeding season at the southern California rookeries.

Within the SFOBB Project area, California sea lion density was calculated from all observations during SFOBB Project monitoring from 2000 to 2015. These observations included data from baseline, pre, during, and post-pile driving, mechanical dismantling, onshore blasting, and offshore implosion activities. During this time, the population of sea lions in the Bay remained stable as did the numbers observed near the SFOBB (Manugian 2013). Therefore, substantial differences in the number of sea lions or their movements are not anticipated. All sea lion observations within a 1-square kilometer area were used in the estimate. Distances were recorded using a laser range finder (Bushnell Yardage Pro Elite 1500; ± 1.0 yard accuracy). Care was taken to eliminate multiple observations of the same animal, although most sea lion observations involve a single animal.

Density of California sea lions was highest near YBI and Treasure Island, probably because of the foraging areas in Coast Guard and Clipper coves (Figure 8). Therefore, density estimates were calculated for a higher density area within 4,921 feet (1,500 meters) west of Piers E4 and E5, which included the two foraging coves. A lower density estimate was calculated from the areas east of Piers E4 and E5, and beyond 4,921 feet (1,500 meters) north and south of the bridge. Calculated California sea lion density was a per day estimate of sea lions in a 1 square kilometer area during the fall/winter or spring/summer seasons (Table 5).

6.1.3. Northern Elephant Seal Density Estimates

Northern elephant seal density in the project area was calculated from the stranding records of the MMC, from 2004 to 2014. These data included both injured or sick seals and healthy seals. Approximately 100 elephant seals were reported in the Bay during this time; most of these hauled out and likely were sick or starving. The actual number of individuals in the Bay may have been higher because not all individuals would necessarily have hauled out. Some individuals may have simply left the Bay soon after entering. Data from the MMC show several elephant seals stranding on Treasure Island,

and one healthy elephant seal was observed resting on the beach in Clipper Cove in 2012. Elephant seal pups or juveniles also may have stranded after weaning in the spring and when they returned to California in the fall (September through November).

6.1.4. Harbor Porpoise Density Estimates

Harbor porpoise density was calculated from all observations during SFOBB Project monitoring, from 2000 to 2014. These observations included data from baseline, pre, during and post-pile driving, and onshore implosion activities. Over this period, the number of harbor porpoises that were observed entering and using the Bay increased. During the 15 years of monitoring in the SFOBB Project area, only nine harbor porpoises were observed, and all occurred between 2006 and 2015 (including two in 2014 and five in 2015). All harbor porpoise observations within a 1-square kilometer area were used in the estimate. Distances were recorded using a laser range finder (Bushnell Yardage Pro Elite 1500; ± 1.0 yard accuracy).

6.1.5. Gray Whale Density Estimate

Gray whale density was estimated for the entire Bay as no observations have occurred of gray whales in the SFOBB Project area. Each year, two to six gray whales enter the Bay, presumably to feed, in the late winter through spring (February through April), per the MMC. Gray whales rarely occur in the Bay from October through December. Therefore, a density of 0.00004 gray whales per 1 square kilometer was used for the calculations, based on one sighting in early winter (Thorson, pers. comm., 2014).

6.2. Pile Driving and Pile Removal Activities

6.2.1. Distances to Marine Mammal Criteria for Pile Driving and Pile Removal Activities

As discussed in Section 5, NMFS has established interim sound threshold criteria for behavioral disturbance (Level B harassment) and PTS (Level A harassment) to marine mammals from pile driving and other similar activities (Table 3). The current IHA, issued to the Department on July 17, 2015, authorizes the take, by Level B harassment, of a small number of marine mammals incidental to pile installation and removal activities. The distance to the marine mammal threshold criteria for vibratory and impact driving of sheet piles, H-piles, and pipe piles equal to or less than 36 inches (0.91 meter) in diameter, authorized under the current IHA, were based on hydroacoustic measurements collected in 2008 and 2009, during the vibratory and impact driving of 42-inch-diameter (1.07 meters) pipe piles of the Self-Anchored Suspension Span Temporary Towers. The distances to the marine mammal threshold criteria for these pile driving and pile removal activities are shown in Table 6. These distances are conservative for the proposed driving

of smaller piles. The use of these conservative distances were agreed on previously by the Department and NMFS, under both the 2013 and July 2015 IHAs for the SFOBB Project.

Table 6. Distances to Levels A and B Harassment Threshold Criteria for Impact and Vibratory Pile Driving and Pile Removal

Pile Installation/ Removal Method	Pile Type/Size	Level B Harassment Behavioral Disturbance		Level A Harassment Slight Injury (PTS)	
		Distance to 120 dB re 1 µPa RMS	Distance to 160 dB re 1 µPa RMS	Distance to 180 dB re 1 µPa RMS	Distance to 190 dB re 1 µPa RMS
Vibratory Driving and Removal	Pipe Pile ≤ 36 inch (0.91 meter)	6,562 feet (2,000 meters)	NA	NA	NA
	Sheet Pile	6,562 feet (2,000 meters)	NA	NA	NA
Attenuated Impact Driving	Pipe Pile ≤ 36 inch (0.91 meter)	NA	3,281 feet (1,000 meters)	771 feet (235 meters)	312 feet (95 meters)
Unattenuated Proofing	Pipe Pile ≤ 36 inch (0.91 meter)	NA	3,281 feet (1,000 meters)	771 feet (235 meters)	312 feet (95 meters)
Unattenuated Impact Driving	H-Piles	NA	3,281 feet (1,000 meters)	771 feet (235 meters)	312 feet (95 meters)
Source: NMFS 2015					

6.2.2. Number of Marine Mammals, by Species, that May be Taken by Pile Driving and Pile Removal Activities

The numbers of marine mammals by species that may be taken by pile driving were calculated based on distance to the marine mammal threshold criteria, duration of the activity, and the estimated density of each species in the ZOI. The density of each species was calculated over the entire area of each threshold criteria zone and for each of the two seasons. For example, the harbor seal behavioral zone extends out to 6,562 feet (2,000 meters), which is an area of 4.85 square miles (12.57 square kilometers). For the higher density western half of the area extending towards YBI, the estimated number of harbor seals exposed to pile driving sounds that would cause a behavioral reaction during the fall/winter season is 688 harbor seals (0.83 x 6.285 square kilometers x 132 days of pile driving). The lower density eastern area is 174 harbor seals (0.21 x 6.285 square kilometers x 132 days of pile driving). The total for the entire area would be 862 harbor seals exposed within the behavioral response threshold zone. If pile driving days also occur in the fall and summer, then the harbor seal density would be lower and the number of animals potentially exposed would be less.

The Department anticipates that a maximum of 996 animals may be taken by Level B harassment during pile driving activities (Table 7). These animals would be temporarily

exposed to continuous (vibratory pile driving and removal) sounds greater than 120 dB RMS and impulse (impact driving) sounds greater than 160 dB RMS. The majority of the animals take by Level B harassment would be harbor seals (Table 7), the most numerous marine mammal in the SFOBB Project area. The Department does not anticipate any individuals will be taken by Level A harassment. With proposed monitoring and the establishment of marine mammal exclusion zones (MMEZ), discussed further in Section 11, Level A harassment of marine mammals will be avoided. If a cetacean is observed in the 180 dB RMS MMEZ or a pinniped in the 190 dB RMS MMEZ, pile driving will be delayed until the animal has moved out of the area or has not been observed for 20 minutes for sea lions, harbor seals and porpoises, and 30 minutes for elephant seals and gray whales. With implementation of the avoidance measures, exposure of marine mammals to sound levels that could result in PTS, Level A harassment will be avoided.

Table 7. Estimated Take of Marine Mammals from Pile Driving and Pile Removal Activities

Species	Level B Harassment Behavioral Harassment	Level A Harassment Slight Injury
	Behavioral Response and Temporary Threshold Shift 120 or 160 dB re 1 µPa RMS	Permanent Threshold Shift 180 or 190 dB re 1 µPa RMS[1]
Pacific Harbor Seal	862	0
California Sea Lion	108	0
Northern Elephant Seal	13	0
Harbor Porpoise	13	0
Gray Whale	0.016	0
Total	996	0

Note:
1. Impact pile driving would not begin if a marine mammal is within the 180 to 190 dB re 1 µPa RMS threshold zone of 771 feet (235 meters) for cetaceans and 312 feet (95 meters) for pinnipeds.

6.2.3. Species Impacts from Pile Driving Activates

Pacific Harbor Seal: Harbor seals are the most numerous marine mammal species in the SFOBB east span area. Based on estimated species density and distances compared to the Level B behavioral harassment threshold criteria, the Department anticipates a maximum of 862 harbor seals may be exposed to continuous sounds greater than 120 dB RMS and impulse sounds greater than 160 dB RMS during pile driving. With the proposed monitoring and the establishment of the MMEZ, discussed in Section 11, slight injury, PTS Level A harassment will be avoided.

Many of the harbor seals observed during prior monitoring appeared to be transiting the area, but some remained in the area to forage (15 minutes to 2 hours). Seals observed

foraging in the Level B harassment monitoring zone did not appear affected by activities. Although harbor seals may be present in the Level B harassment monitoring zone during pile driving, their exposure to sound generally would be for a short duration, and those seals that may remain to forage are expected to be unaffected.

Both juvenile and adult harbor seals were observed during prior monitoring. Establishing the gender of harbor seals in the water is difficult, unless the animal rolls over. However, it is assumed that both male and female harbor seals have the potential to be present. Although YBI is an important haul-out site in the Central Bay, it is not a pupping site. Pups are unlikely to be exposed to noise from pile driving.

Based on the known behavioral patterns, results of past monitoring, reduced sound levels, and implementation of avoidance and minimization measures (discussed further in Section 11), the Department has determined that the pile driving activities would not result in Level A harassment or mortality to any harbor seals. Pile driving activities may result in Level B behavioral harassment of a small number of both juvenile and adult harbor seals transiting or foraging in the SFOBB Project area.

California Sea Lion: Although less numerous than harbor seals, sea lions have been observed in the SFOBB east span area during previous monitoring. Based on estimated species density and distances compared to the Level B behavioral harassment threshold criteria, the Department anticipates a maximum of 108 sea lions may be exposed to continuous sounds greater than 120 dB RMS and impulse sounds greater than 160 dB RMS during pile driving. With the proposed monitoring and the establishment of the MMEZ, discussed in Section 11, slight injury, PTS Level A harassment will be avoided.

Generally, during previous SFOBB Project pile driving activities, sea lions were transiting only through the area and generally did not stop to forage, with a few exceptions. Although sea lions may enter the Level B behavioral harassment monitoring zone during pile driving activities, the exposure to sound would be a short duration. Exposure to the pile driving sounds may cause a short-term behavior response, such as altering their travel path through the area, but is unlikely to affect their reproductive, foraging or hearing abilities.

Sub-adult and adult male sea lions can be distinguished from females by the sagittal crest on the head, but in the water, the gender of juveniles up to 3 years old is indistinguishable. During previous monitoring, sub-adult males, adult males and juveniles (gender undistinguished) were observed. This is expected because female sea lions are less common in the San Francisco Bay than males. Adult females remain near the

rookeries in southern California throughout the year, continuing to alternate between foraging and nursing their pups on shore until close to the next pupping/breeding season. After the breeding season, adult and sub-adult males migrate northward along the coast to northern California. Because of the gender and reproductive phase-specific distribution of animals, fewer females than males and no pups presumably would be affected by pile driving activities.

Based on the known behavioral pattern of California sea lions, results of past monitoring, anticipated sound levels and implementation of avoidance and minimization measures (discussed further in Section 11), the Department has determined that pile driving would not result in Level A harassment or mortality of California sea lions. Pile driving activities may result in Level B harassment of a small number of adult male, sub-adult male, and juvenile sea lions that are transiting or foraging in the SFOBB Project area.

Northern Elephant Seal: Based on estimated species density and distances compared to the Level B behavioral harassment threshold criteria, the Department anticipates a maximum of 13 elephant seals may be exposed to continuous sounds greater than 120 dB RMS and impulse sounds greater than 160 dB RMS during pile driving. With the proposed monitoring and the establishment of the MMEZ, discussed further in Section 11, slight injury, PTS Level A harassment will be avoided.

Most of the elephant seals that have been observed around YBI or Treasure Island were stranded, sick, or injured animals, picked up by the MMC. No elephant seals have been observed within the immediate vicinity of the SFOBB. Although elephant seals may be present in the Level B harassment monitoring zone during pile driving, their exposure to sound generally would be for a short duration.

Based on the known behavioral patterns, results of past monitoring, reduced sound levels, and the implementation of avoidance and minimization measures (discussed further in Section 11), the Department has determined that the pile driving activities would not result in Level A harassment or mortality to any elephant seals. Pile driving activities may result in Level B behavioral harassment of a small number of juvenile elephant seals transiting near the SFOBB Project area.

Harbor Porpoise: Based on estimated species density and distances compared to the Level B behavioral harassment threshold criteria, the Department anticipates a maximum of 13 harbor porpoises may be exposed to continuous sounds greater than 120 dB RMS and impulse sounds greater than 160 dB RMS during pile driving. With the proposed

monitoring and the establishment of the MMEZ, discussed further in Section 11, slight injury, PTS Level A harassment will be avoided.

All the harbor porpoises observed during previous monitoring appeared to be transiting the area. Although harbor porpoises may be present in the Level B harassment monitoring zone during pile driving, the exposure to sound generally would be for a short duration, and thus they are expected to be unaffected.

Both juvenile and adult harbor porpoises were observed during previous monitoring. Establishing the gender of harbor porpoises in the water is difficult. However, it is assumed that both male and female harbor porpoises have the potential to be present.

Based on the known behavioral patterns, results of past monitoring, reduced sound levels, and implementation of avoidance and minimization measures (discussed further in Section 11), the Department has determined that the pile driving activities would not result in Level A harassment or mortality to any harbor porpoises. Pile driving activities may result in Level B behavioral harassment of a small number of both juvenile and adult harbor seals transiting or foraging in the SFOBB Project area.

Gray Whale: Based on estimated species density and distances compared to the Level B behavioral harassment threshold criteria, the Department anticipates that no gray whales will be exposed to continuous sounds greater than 120 dB RMS and impulse sounds greater than 160 dB RMS during pile driving. With the proposed monitoring and the establishment of the MMEZ, discussed further in Section 11, slight injury, PTS Level A harassment will be avoided.

No gray whales have been observed within 6,562 feet (2,000 meters) of the SFOBB Project area, but they have been observed just north of Treasure Island and southwest of Oakland Harbor. Although gray whales may be present in the Level B harassment monitoring zone during pile driving, their exposure to sound generally would be for a short duration, and those whales are expected to be unaffected.

Based on the known behavioral patterns, results of past monitoring, reduced sound levels, and implementation of avoidance and minimization measures (discussed further in Section 11, the Department has determined that the pile driving activities would not result in Level A harassment or mortality to any gray whales. Furthermore, pile driving activities are not anticipated to result in Level B behavioral harassment of gray whales. However, in the unlikely event that a gray whale or calf cow pair transit or forage in the

SFOBB Project area during pile driving activities, the Department is requesting authorization for the take of up to two individuals.

6.3. Implosion of Piers E4 and E5

6.3.1. Distances to Marine Mammal Criteria for Underwater Blasting

As discussed in Section 5, NMFS has established interim sound pressure threshold criteria for take of marine mammals from underwater blasting (Table 4). Before the controlled implosion of Pier E3 in 2015, the Department performed hydroacoustic modeling to estimate the distance to marine mammal threshold criteria for underwater blasting and to verify distances to sound pressure threshold criteria. A detailed description of the hydroacoustic modeling performed for the Pier E3 implosion demonstration project is provided in Appendix C.

The peak pressure levels measured during implosion of Pier E3 were consistent with predicted modeled levels. The measured peak pressure level fall-off curve had approximately the same fall-off rate as the predicted modeled curve, with a +2 dB offset. The measured cumulative SEL levels were lower than predicted modeled levels. This difference in measured versus modeled levels was most pronounced with distance from the implosion. The measured cumulative SEL curve had a faster fall-off rate than the predicted curve, with levels 5 dB lower than predicted modeled levels at a distance of 500 to 4,000 feet (152 to 1,219 meters) from the implosion. Hydroacoustic monitoring results, including a comparison of measured versus modeled sound pressure levels, are provided in Appendix D.

The Department has decided to use measured distances to marine mammal threshold criteria from the implosion of Pier E3 as predicted distances to these thresholds for the implosions of Piers E4 and E5 (Table 8) (Department 2015a). The use of measured peak pressure, cumulative SEL, and impulse levels from the Pier E3 implosion provide a conservative estimate for the proposed implosions of Piers E4 and E5. The Piers E4 and E5 caisson structures are smaller than the Pier E3 caisson structure and will require fewer explosive charges to implode. The maximum charge weight for the implosions of Piers E4 and E5 is 35 pounds/delay, the same as used for the implosion of Pier E3. However, the total explosive weight, number of individual detonations, and total time of implosion event will be less for these smaller piers.

The criteria for lung injury and mortality to marine mammals are dependent on the mass of the animal and the depth of the animal in the water column; animals smaller in mass are more susceptible to injury from impulse pressures. The criterion is an impulse metric,

Table 8. Measured Distances to Underwater Blasting Threshold Criteria for Levels A and B Harassment and Mortality from the Pier E3 Implosion

Species	Level B Criteria		Level A Criteria			Mortality
	Behavioral Response	TTS Dual Criteria*	PTS Dual Criteria*	Gastro-intestinal Track	Lung Injury	
Pacific Harbor Seal	2,460 feet (750 meters)	**1,658 feet (505 meters)** 104 feet (32 meters)	**507feet (155 meters)** 65 feet (20 meters)	<100 feet (30 meters)	<100 feet (30 meters)	<100 feet (30 meters)
California Sea Lion	387 feet (118 meters)	**261 feet (80 meters)** 104 feet (32 meters)	**80 feet (24 meters)** 65 feet (20 meters)	<100 feet (30 meters)	<100 feet (30 meters)	<100 feet (30 meters)
Northern Elephant Seal	2,460 feet (750 meters)	**1,658 feet (505 meters)** 104 feet (32 meters)	**507 feet (155 meters)** 65 feet (20 meters)	<100 feet (30 meters)	<100 feet (30 meters)	<100 feet (30 meters)
Harbor Porpoise	8,171 feet (2,491 meters)	**5,580 feet (1,701 meters)** 400 feet (122 meters)	**1,777 feet (542 meters)** 249 feet (76 meters)	<100 feet (30 meters)	<100 feet (30 meters)	<100 feet (30 meters)

Note:
* For the TTS and PTS criteria thresholds with dual criteria, the largest criteria distances (i.e., more conservative) are shown in bold.
Source: Department 2015a

expressed in pascal-second or psi-msec (Table 4). The estimated mass of the juveniles (6 to 16 months old) of each species was used in the lung injury and mortality calculations, because these would be the smallest animals potentially exposed to the Piers E4 and E5 implosions (44 to 155 pounds [20 to 75 kilograms]) in October, November and December (Table 9). The depth at which the animal is exposed also affects the criteria threshold calculation. The area around Piers E4 and E5 is relatively shallow at 40 to 50 feet (12 to 15 meters), and marine mammals traveling through the area surface frequently. Therefore, an average depth of 20 feet (6 meters) was used in the threshold calculations.

6.3.2. Number of Marine Mammals, by Species, that May be Taken by Implosion of Piers E4 and E5

The number of marine mammals by species that may be taken by implosion of Piers E4 and E5 were calculated based on distances to the marine mammal threshold criteria, duration of the activity, and the estimated density of each species in the ZOI.

Table 9. Mass and Depth Ranges Used in the Calculation of Lung Injury and Mortality Criteria Thresholds

Species	Age	Mass	Depth
Harbor Seal	5–7 months	66 pounds (30 kilograms)	20 feet (6 meters)
California Sea Lion	17–18 months	66 pounds (30 kilograms)	20 feet (6 meters)
Northern Elephant Seal	9–10 months	155 pounds (75 kilograms)	20 feet (6 meters)
Harbor Porpoise	5–7 months	44 pounds (20 kilograms)	20 feet (6 meters)
Source: Add Conservation of Migratory Species of Wild Animals 2015			

The density of each species was calculated over the entire area of each Level A, Level B, and mortality threshold criteria zone for implosion. For example, the harbor seal behavioral zone extends out to 2,460 feet (750 meters), which has an area of 0.68 square miles (1.77 square kilometers). For the higher density western half of the area extending towards YBI, the estimated number of harbor seals exposed to sounds or pressures that would cause a behavioral reaction during the fall/winter season is 0.735 harbor seals (0.83 x 0.885 square kilometers) plus the lower density eastern area is 0.186 harbor seals (0.21 x 0.885 square kilometers), for a total of 0.920 harbor seals for one pier implosion.

Based on the distances to the marine mammal threshold criteria and estimated species density, approximately three harbor seals and one harbor porpoise may be taken by Level B harassment during the implosions of Piers E4 and E5 (Table 10); no take of any other species is anticipated, and no take of any marine mammal by Level A harassment is anticipated.

6.3.3. Species Impacts from the Implosion of Piers E4 and E5

Pacific Harbor Seal: The harbor seal will be the most vulnerable species to sounds or pressures originating from the Piers E4 and E5 implosions. They are the most numerous marine mammal in the Bay and most likely to be in the Piers E4 and E5 area. However, most of the observations made during monitoring for the SFOBB have been of seals transiting through the Piers E4 and E5 area rather than remaining there to forage. The exception is the new foraging area for young seals at Pier E2 of the new Bay Bridge, but that site is used only occasionally.

If a harbor seal remained undetected and entered the established MMEZ during the implosion, it may be subject to effects ranging from slight lung, GI track, and inner ear injury (PTS), to mortality. However, active monitoring will be implemented so that harbor seals at the surface are likely to be detected by observers. The long dive durations

Table 10. Combined Estimated Exposures of Marine Mammals to the Pier E4 and E5 Implosions for Levels A and B, and Mortality Threshold Criteria

Species	Level B Exposures[1]		Level A Exposures[2]			Mortality[2]
	Behavioral Response	Temporary Threshold Shift	Permanent Threshold Shift	Gastro-Intestinal Track Injury	Slight Lung Injury	
Pacific Harbor Seal	2 (1.841)	1 (0.832)	0 (0.078)	0 (0.006)	0 (0.006)	0 (0.006)
California Sea Lion	0 (0.008)	0 (0.00)	0 (0.0003)	0 (0.0005)	0 (0.0005)	0 (0.0005)
Northern Elephant Seal	0 (0.053)	0 (0.024)	0 (0.002)	0 (0.0002)	0 (0.0002)	0 (0.0002)
Harbor Porpoise	1 (0.819)	0 (0.382)	0 (0.039)	0 (0.0001)	0 (0.0001)	0 (0.0001)
Total	3	1	0	0	0	0

Notes:
1. Exposures are presented as whole number of animals exposed with the actual calculated value presented.
2. No implosion would occur if any marine mammal is within the Level A or mortality threshold criteria zones.

of harbor seals (generally up to 10 minutes, with a maximum of 30 minutes) suggest that an individual could swim through the established MMEZ without surfacing. To reduce this possibility, the implosion will be delayed if a harbor seal is observed within the MMEZ. The implosion will not proceed until the individual leaves the MMEZ or at least 20 minutes have passed since the last observation.

Behavioral responses by harbor seals in response to the implosion may involve rapid movement away from and short-term abandonment of the Piers E4 and E5 area. Alternatively, seals foraging in Coast Guard and Clipper coves may continue foraging as they do during pile driving, mechanical demolition, and test blast activities. Long-term abandonment of the Piers E4 and E5 area is not expected because SFOBB construction has been ongoing since 2003, including the Pier E3 implosion in 2015, with continued use of the area by harbor seals.

Based on the calculated density estimates and the distances to the marine mammal threshold criteria, the Department estimates that three harbor seals may be exposed to sound thresholds within the larger Level B harassment monitoring zone. Two of those exposures will be within the Level B behavioral response criteria threshold and one will be within the TTS threshold criteria. Because of the measures to be implemented before the controlled implosion of Piers E4 and E5, such as the acoustic deterrent devices (discussed further in Section 13), and the monitoring in place to detect harbor seals at the surface, no harbor seals are expected to be exposed to sound thresholds that will result in Level A PTS, lung or GI tract injury, or mortality exposure.

California Sea Lion: The California sea lion will be the second most vulnerable species to controlled implosion because it is the most numerous marine mammal species in the Bay, after the harbor seal. California sea lions may occur in the Piers E4 and E5 area during the implosions, but similar to the discussion for harbor seals, California sea lions at the surface are likely to be detected by the observers during monitoring. Unlike harbor seals, sea lions are not long-duration divers, and it is unlikely that a sea lion will swim through the MMEZ without surfacing and being detected. In addition, sea lions tend to spend more time at the surface while swimming than do harbor seals.

If a sea lion remained undetected and entered the established exclusion zone during the implosion, it may be subject to lung injury, GI tract injury, inner ear injury (PTS), or mortality. Behavioral responses of sea lions to the controlled implosion are likely to include rapid movement away from and short-term abandonment of the Piers E4 and E5 area. As with harbor seals, long-term abandonment of the Piers E4 and E5 area by sea lions is not expected because SFOBB construction has been ongoing since 2003, including the Pier E3 implosion in 2015, with continued use of the area.

Based on the calculated density estimates and the distances to the marine mammal threshold criteria, the Department estimates that no sea lions will be exposed to the sound thresholds within the larger Level B harassment monitoring zone. Because of the avoidance and minimization measures to be implemented before the controlled implosion of Piers E4 and E5, such as the acoustic deterrent devices (discussed further in Section 13) and the monitoring in place to detect sea lions at the surface, no sea lions are anticipated to be exposed to sound thresholds that will result in Level A PTS, lung or GI tract injury, or mortality exposure.

Northern Elephant Seal: Northern elephant seals are infrequently found near Treasure Island and are unlikely to be in the Piers E4 and E5area. Elephant seals at the surface are likely to be detected by the observers during monitoring before the controlled implosions. However, elephant seals are very long-duration divers, which suggests that an individual could swim through the MMEZ without surfacing, although many of the elephant seals that enter the SFOBB area may be ill or starving, and therefore their diving ability will be greatly reduced. The implosion will be delayed if an elephant seal is observed within the MMEZ. The implosion will not proceed until the individual leaves the MMEZ or at least 30 minutes have passed since the last observation.

If an elephant seal remains undetected and enters the established exclusion zone during the implosion, it may be subject to lung injury, inner ear injury, or mortality. Behavioral

responses of elephant seals to the controlled implosion likely will include rapid movement away from and short-term abandonment of the Piers E4 and E5 area. Long-term abandonment of the Piers E4 and E5 area by elephant seals is not expected because SFOBB construction has been ongoing since 2003, with limited, continued use of the area for transit or resting.

Based on the calculated density estimates and the distances to the marine mammal threshold criteria, the Department estimates that no elephant seals will be exposed to sound thresholds that fall within the larger Level B harassment monitoring zone. Because of the avoidance and minimization measures that will be implemented before the controlled implosions, such as the use of acoustic deterrent devices (discussed further in Section 13) and monitoring in place to detect elephant seals at the surface, no elephant seals are predicted to be exposed to sound thresholds that will result in Level A PTS, lung or GI tract injury, or mortality exposure.

Harbor Porpoises: Impacts on harbor porpoises are unlikely. This species rarely occurs in the Piers E4 and E5 area. Their common behavior of traveling in pods of two or more animals along with frequent surfacing events make it very likely that observers will detect any harbor porpoises in the MMEZ. In addition, real-time acoustic monitoring also will be used to detect harbor porpoises.

If a harbor porpoise remains undetected and enters the established exclusion zone during the implosions, it may be subject to lung injury, inner ear injury, or mortality. Behavioral responses of harbor porpoises from the controlled implosions are likely to be rapid movement away from and short-term abandonment of the SFOBB area. Long-term abandonment is not expected because SFOBB construction has been ongoing since 2003, with limited, continued use of the area for transit or foraging.

Based on the calculated density estimates and the distances to the marine mammal threshold criteria, the Department estimates that one porpoise may be exposed to the sound thresholds that fall within the larger Level B harassment monitoring zone. Because of the avoidance and minimization measures that will be implemented before the controlled implosion, such as the acoustic deterrent devices and real-time acoustic monitoring (discussed further in Section 13), and the monitoring in-place to detect harbor porpoises at the surface, no individuals are anticipated to be exposed to sound thresholds that will result in Level A PTS, lung or GI tract injury, or mortality exposure.

6.4. Amount of Take Requested for the Implosion of Piers E4 and E5

The estimated number of marine mammals exposed to implosion SPLs for each threshold criteria (Table 10) are based on current density estimates of marine mammals in the SFOBB east span area (Table 5). However, the number of marine mammals in the area at any given time is highly variable. Animal movement depends on time of day, tide levels, weather, and availability and distribution of prey species. Therefore, the Department requests the following number of allowable harassment takes for each Level B harassment criteria threshold (Table 11).

Table 11. Level B Harassment Take of Marine Mammals Authorized for the Pier E4 and E5 Implosions

Species	Level B Harassment Take[1]	
	Behavioral Response	Temporary Threshold Shift
Pacific Harbor Seal	12	6
California Sea Lion	3	1
Northern Elephant Seal	2	1
Harbor Porpoise	6	3
Total	23	11

Note:
1. Test blasts or pier implosions would be delayed if any marine mammals are detected within any of the Level A or mortality threshold criteria exclusion zones.

6.5. Test Blasts

In addition to the implosions of Piers E4 and E5, one to two test blasts will be conducted per pier. Test blasts are small charges that are used to test the BAS and acoustic monitoring equipment before the controlled implosion. The BAS will be in operation during all tests. Tests will use a charge weight of approximately 18 grain (0.0025 pound).

A pinniped exclusion zone of 45 feet (14 meters) will be monitored, which likely will be within the BAS; therefore, it is unlikely that any pinniped will approach this closely. A harbor porpoise exclusion zone of 270 feet (82 meters) will be used. Previous observations of harbor porpoises were 2,625 to 4,921 feet (800 to 1,500 meters) west of Piers E4 and E5. Because of the very small exclusion zones, it is unlikely that pinnipeds or harbor porpoises will enter the exclusion zones. Therefore, no harassment takes are allotted for these activities, but standard monitoring will be implemented (discussed further in Sections 11 and 13).

Chapter 7. The Anticipated Impact of the Activity

The numbers shown in Tables 7 and 10 represent estimated exposures to each harassment threshold criteria zone under the MMPA. These calculated values are conservative (i.e., over predictive) estimates of harassment. The estimates for pile driving assume 132 days of pile driving activity, but it is likely that the work will be accomplished in fewer days. Therefore, not as many marine mammals will be exposed to pile driving or removal sound. The threshold zones for the implosion of Piers E4 and E5 are based on measurements collected during the Pier E3 implosion. Pier E3 was larger than either Pier E4 or Pier E5; therefore, Pier E3 required more explosives and resulting in greater SEL and impulse levels than will occur for smaller piers. Because of this analysis and through implementation of avoidance and minimization measures, the Department has determined that the controlled implosions of Piers E4 and E5 and pile driving activities will result only in Level B harassment. Based on the best available science, exposures to marine mammal species and stocks from controlled implosions or pile driving activities is anticipated to result in only short-term effects on individuals exposed, will likely not affect annual rates of recruitment or survival, and employed mitigation measures will prevent any Level A exposures or mortality.

Based on 15 years of previous SFOBB construction and demolition activities associated with the SFOBB east span and the protective measures described herein, no permanent injury or mortality will occur to animals, and no impacts (short or long term) will occur on the populations or stocks of marine mammals that regularly inhabit or occasionally enter the Bay.

Chapter 8. The Anticipated Impacts on Subsistence Uses

Non-applicable; none of the species or stocks of marine mammals regularly found in the San Francisco Bay are used for subsistence uses.

Chapter 9. The Anticipated Impacts on Habitat

No designated critical habitats exist for marine mammals in the Bay. The primary source of effects on marine mammal habitat will be temporary noise and pressure exposures from controlled blasting and pile driving activities, and isolated changes in water quality. The SFOBB Project is not expected to have any substantial effects on marine mammal habitat. Short-term impacts on water clarity may result from minimal disturbance of sediment during pile driving, pier implosions, and clean-up of debris from the pier implosions.

The removal of the SFOBB east span is not likely to negatively affect the habitat of marine mammal populations because no permanent loss of habitat will occur, and only a minor, temporary modification of habitat will occur. The original SFOBB area is not used as a haul-out site by pinnipeds or as a major foraging area. Therefore, demolition of the concrete marine foundations and pile installation and removal activities are unlikely to permanently decrease fish populations in the area and are unlikely to affect marine mammal populations.

Project activities will not affect any pinniped haul-out sites or pupping sites. The YBI harbor seal haul-out site is on the opposite site of the island from the SFOBB Project area. Because of the distance and the island blocking the sound, underwater noise and pressure levels from the SFOBB Project will not reach the haul-out. During previous monitoring efforts, the airborne pile driving noise could be faintly heard, on occasion, by the monitors at the YBI haul-out site or when the sound reflected off passing cargo ships. In addition, harbor seals on YBI commonly are subjected to high levels of disturbance, primarily from watercraft, ship wakes, and traffic noise. This is particularly true during the summer, when the numbers of small recreational watercraft in the Bay increase (San Francisco State University 1999b). Other haul-out sites for sea lions and harbor seals are at a sufficient distance from the SFOBB Project area that they will not be affected. The closest recognized harbor seal pupping site is at Castro Rocks, approximately 8.7 miles (14 kilometers) from the SFOBB Project area. No sea lion rookeries are found in the Bay.

The addition of underwater sound from SFOBB Project activities to background noise levels can constitute a potential cumulative impact on marine mammals. However, these potential cumulative noise impacts will be short in duration, and presumably they will be negligible because of the high background noise in the Bay from other anthropogenic sources. During breaks in previous pile driving, the Department’s hydroacoustic monitors took background noise measurements of the Bay near the SFOBB Project area. The

measurements indicated that background levels range from about 110 to 140 dB RMS, but more typically range from 110 to 120 dB RMS (Department 2005). Boat traffic, including cargo ships, powerboats, and tugboats, use the shipping channel south of the SFOBB Project area and contribute to background noise levels.

SPLs from impact pile driving and pier implosion have the potential to injure or kill fish in the immediate area. During previous pier implosion and pile driving activities, the Department has reported mortality to marine mammals' prey species, including northern anchovies and Pacific herring. These few isolated fish mortality events are not anticipated to have a substantial effect on prey species population or their availability as a food resource for marine mammals.

Based on the discussion in this section, no effects on marine mammals will occur from loss or modification of marine mammal habitat, including changes to food resources or haul-out habitat.

Chapter 10. Anticipated Effects of Habitat Impacts on Marine Mammals

The removal of Piers E4 and E5 through controlled implosions and pile installation and removal is not likely to negatively affect the habitat of marine mammal populations because no loss of habitat will occur, and only a minor, temporary modification of habitat will occur from the hydroacoustic impacts of the controlled implosions and pile driving activities. The SFOBB area is not used as a haul-out site by pinnipeds, and demolition of the concrete marine foundations is unlikely to permanently decrease fish populations. The physical effects from pressure waves generated by underwater impulse sounds (e.g., underwater implosions or impact pile driving) may result in minor injury and mortality to fish but will not affect fish populations within proximity of SFOBB Project activities. The abundance and distribution of fish near Piers E4 and E5 may be altered for a few hours after the implosion or during pile driving. These fish populations will be replenished as SFOBB Project activities cease and the local population mixes again. Vibratory pile driving and removal is unlikely to affect fish populations.

Based the discussions above and in Section 9, no impacts will occur on marine mammals resulting from loss or modification of marine mammal habitat. No designated critical habitat occurs in the Bay. The SFOBB Project is not expected to result in substantial loss of marine mammal habitat (i.e., no destruction of haul-out sites or destruction of important reef areas will occur). Therefore, no impacts will occur.

Chapter 11. Mitigation Measures

11.1. Minimization of Impacts from Pile Driving

To minimize potential impacts on marine mammals, the Department will limit both the size of piles and duration of impact pile driving, to the extent feasible. Larger piles are expected to generate higher SPLs than smaller piles. Limiting the size of piles to 36 inches (0.91 meter) in diameter or smaller will minimize potential noise impacts.

All pipe piles initially will be installed with a vibratory hammer. The vibratory hammer will be used to drive the majority of the total pile lengths. In the event that a pipe pile is entirely installed with a vibratory hammer, it still will be subject to final "proofing" with an impact hammer. A maximum of 10 percent of the piles installed completely with a vibratory hammer may be proofed with an impact hammer, without the use of a marine pile driving energy attenuator. Proofing of piles will be limited to a maximum of two piles per day, for less than 1 minute per pile, administering a maximum of 20 blows per pile. Although both vibratory and impact pile driving have the potential to affect marine mammals, impact driving is expected to generate higher SPLs. Requiring the use of the vibratory hammer will reduce the duration of impact driving and potential exposure to higher SPLs.

Use of a marine pile driving energy attenuator (i.e., air bubble curtain system), or other equally effective sound attenuation method (e.g., dewatered cofferdam), will be required during impact driving of all pipe piles, with the exception of pile proofing. Requiring the use of sound attenuation will reduce SPLs to below levels that can result in Level A harassment and will minimize the ZOI for Level B harassment.

11.2. Monitoring Plan and Establishment of Marine Mammal Exclusion Zones

A project-specific marine mammal monitoring plan for pile driving activities (discussed further in Section 13) will be employed to avoid the potential for individual exposure to Level A harassment and to document the number and species potentially exposed to Level B harassment. The plan will be similar to the previously NMFS-approved, 2013 Revised Marine Mammal Monitoring Plan (Department 2013d) for SFOBB Project pile driving activities. Before the start of impact pile driving activities (with the exception of pile proof testing), the MMEZs will be established. The MMEZs are intended to include all areas where the underwater SPLs are anticipated to equal or exceed thresholds for slight injury—PTS Level A harassment thresholds of 180 dB RMS for cetaceans and 190

dB RMS for pinnipeds. NMFS-approved observers will survey the MMEZs so that no marine mammals are seen within the MMEZ before pile driving activities start. If marine mammals are found within the MMEZ, pile driving will be delayed until the animal has moved out of the exclusion zone, either verified through sighting by an observer or by waiting until enough time has elapsed without a sighting (20 minutes for harbor seal, sea lion, and harbor porpoise, and 30 minutes for elephant seal and gray whale), to be able to assume the animal has moved beyond the MMEZ. The elapsed time without a sighting is based on examination of the diving behavior of these species, discussed in Section 4. With implementation of this avoidance and minimization measure, exposure of marine mammals to SPLs that can result in PTS Level A harassment will be avoided.

11.3. Minimization of Impacts from Implosion of Piers E4 and E5

The methods proposed to demolish Piers E4 and E5 will provide the least impact on marine mammal stocks and their habitat. A BAS will be used for all activities that produce impulse sounds, including controlled implosions. The use of controlled charges for demolition will decrease the cumulative amount of marine habitat affected and the effects on individual marine mammals within this habitat that are exposed to potentially harmful sound thresholds.

An analysis of the potential effects on marine mammals from the alternative use of mechanical methods to remove Pier E3 was completed (see Appendix E). In summary, the analysis concluded that the cumulative area subject to Level B behavioral harassment will be much greater for mechanical removal because of the increased time required for the impact driving of the large number of piles needed to construct a dewatered cofferdam around the pier, capable of holding back Bay waters. The mechanical methods for removal of Piers E4 and E5 are the same as those analyzed for Pier E3, and will result in a similar impact on marine mammals. The actual risk of Level A harassment exposure to individual marine mammals from either demolition method is unlikely, because of implementation of exclusion zones and monitoring. Exposure to Level B (TTS) harassment of three harbor seals may occur from the controlled implosion. In contrast, the increased time (months to years) required to install the cofferdam, along with historical monitoring data, suggest a potential exists for greater TTS exposure under this method.

11.4. Blast Attenuation System

As described previously in this application, a BAS will be used around Piers E4 and E5 during implosions. Based on the results of acoustic monitoring for the Pier E3 implosion,

BAS performance is anticipated to provide approximately 80 percent attenuation of implosion-related pressure waves.

11.5. Monitoring Plan and Establishment of Marine Mammal Exclusion Zones

During the Piers E4 and E5 implosions, a project-specific monitoring plan (discussed further in Section 13) will be used to avoid the potential for individual exposure to Level A harassment and to document the number and species potentially exposed to Level B harassment. This plan will be similar to the previously NMFS-approved Pier E3 Demonstration Project Biological Monitoring Programs. In particular, monitors will observe the MMEZ and will delay the implosions if any individuals are within this zone. A similar plan was successfully implemented for the Pier E3 implosion, and no marine mammals were exposed to SPLs with the Level A or mortality threshold criteria. This project-specific monitoring plan will be transmitted to NMFS ahead of the implosion for review and concurrence.

11.6. Acoustic Deterrent Devices

Acoustic Deterrent Devices (ADDs) commonly are used in commercial fishing and at fish farms to scare marine mammals away from nets or structures, and for the first time were used around the pinniped exclusion zone during the Pier E3 implosion. Determining the success of the ADDs is difficult because the three marine mammals observed near the Pier E3 area remained just outside the exclusion zone (Department 2015b). Marine mammals, particularly harbor seals that are resident to the Bay, are unlikely to have encountered ADDs. Therefore, ADDs should be an effective deterrent for the short time they will be used before detonation (1 to 2 days for several hours).

11.7. Minimization of Impacts from Test Blasts

A pinniped exclusion zone of 45 feet (14 meters) will be monitored, which likely will be within the BAS. Therefore, it is unlikely that any pinniped will approach this closely. A harbor porpoise exclusion zone of 270 feet (82 meters) will be used. Previous observations of harbor porpoises were 2,625 to 4,921 feet (800 to 1,500 meters) west of Piers E4 and E5. Because of the very small exclusion zones, pinnipeds or harbor porpoises are unlikely to enter the exclusion zones. Therefore, no harassment takes are allotted for these activities, but standard monitoring (with three marine mammal observers) will be implemented.

Chapter 12. Arctic Plan of Cooperation

Not applicable; no activities will occur within Arctic subsistence hunting areas.

Chapter 13. Monitoring and Reporting

Specific marine mammal monitoring plans for pile driving activities and implosion of Piers E4 and E5 will be developed and employed to avoid the potential Level A harassment of marine mammals and to document the number individuals by species taken by Level B harassment.

13.1. Monitoring Plan for Pile Driving

The marine mammal monitoring plan for pile driving activities will be similar to the NMFS-approved 2013 Revised Marine Mammal Monitoring Plan for the SFOBB Project (Department 2013d). The monitoring plan will include exclusion and behavioral harassment monitoring zones extending out to pre-determined distances from the pile driving activity, based on conservatively estimated distances to acoustic threshold criteria.

The following are the general elements of the plan; a detailed monitoring plan will be developed (in cooperation with NMFS) that includes all monitoring requirements and final conditions of the IHA.

Level A Harassment PTS Exclusion Zone: The MMEZs will include all areas where the underwater SPLs are anticipated to equal or exceed thresholds for Level A harassment PTS: 180 dB RMS for cetaceans and 190 dB RMS for pinnipeds. The measured distances to these thresholds from previous pile driving activities are discussed in Section 6 and area shown in Table 6; and will be used to establish initial MMEZs for pile driving activities. Vibratory pile driving and vibratory pile removal do not produce SPLs that equal or exceed 180 dB or 190 dB RMS thresholds. Therefore, MMEZs will not be implemented during vibratory pile driving or removal. Before impact pile driving (with the exception of pile proof testing), initial MMEZs will be established at a radial distance of 771 feet (235 meters) for cetaceans and 312 feet (95 meters) for pinnipeds (Table 12). After impact pile driving begins, hydroacoustic measurements will be collected for the specific activity (location and size/type of pile). These hydroacoustic monitoring results will be provided to NMFS, and the radius of the exclusion zone will be adjusted (reduced), based on measured SPLs. The MMEZs will be monitored by marine mammal observers (MMOs), and if any marine mammals are observed inside the MMEZs, impact pile driving will be delayed until the animal leaves the area or at least 20 minutes have passed since the last observation of a harbor porpoise, harbor seal, or sea

lion, and at least 30 minutes have passed since the last observation of a gray whale or elephant seal.

Table 12. Marine Mammal Level A Exclusion Zones and Level B Monitoring Zones for Pile Driving Activities

Group	Level B Harassment and TTS Monitoring Zones		Level A PTS Exclusion Zones
	Vibratory Pile Driving and Removal	Impact Pile Driving	Impact Pile Driving
Pinnipeds	6,562 feet (2,000 meters)	3,281 feet (1,000 meters)	312 feet (95 meters)
Cetaceans	6,562 feet (2,000 meters)	3,281 feet (1,000 meters)	771 feet (235 meters)
Source: NMFS 2015			

Level B Behavioral Harassment Monitoring Zones: Behavioral harassment monitoring zones will include areas where the underwater SPLs are anticipated to equal or exceed thresholds for Level B behavioral response and TTS: 160 dB RMS for impulse sounds (impact pile driving), and 120 dB RMS for continuous sounds (vibratory pile driving and removal), for both cetaceans and pinnipeds. The measured distances to these thresholds from previous pile driving activities are discussed in Section 6 and are shown in Table 6, and will be used to establish initial behavioral harassment monitoring zones for pile driving activities. The initial behavioral harassment monitoring zone for impact pile driving will be established at a radial distance of 3,281 feet (1,000 meters) from the activity (Table 12). The initial behavioral harassment monitoring zone for vibratory pile driving and pile removal will be established at a radial distance of 6,562 feet (2,000 meters) from the activity (Table 12). After the pile driving activity begins, hydroacoustic measurements will be collected for the specific activity (location and size/type of pile). These hydroacoustic monitoring results will be provided to NMFS, and the radius of the behavioral harassment monitoring zone will be adjusted (reduced), based on measured SPLs.

Marine Mammal Monitoring during Pile Driving: The MMEZs will be monitored during all impact pile driving (attenuated or unattenuated), except pile proof testing. The Level B harassment zone will be monitored during all unattenuated impact pile driving, except pile proof testing. To estimate the approximate number of animals exposed to impulse sounds greater that 160 dB RMS and continuous sounds greater than 120 dB RMS, the Level B harassment zones will be monitored during 20 percent of the attenuated impact pile driving and 20 percent of vibratory pile driving and pile removal. The Department will not perform marine mammal monitoring during the unattenuated

pile proof testing, because the proofing of a pipe pile will require less than 1 minute of impact driving per pile, with a maximum of 2 piles per day. The logistics of scheduling and mobilizing a monitoring team for activities that will last less than 2 minutes per day is not practical. Monitoring effort and frequency is summarized in Table 13.

Table 13. Pile Driving Monitoring Frequency

Pile Installation/ Removal Method	Level B Harassment Zone Monitoring Frequency		Level A PTS Exclusion Zone Monitoring Frequency	
	120 dB RMS 6,652 feet (2,000 meters)	**160 dB RMS 3,281 feet (1,000 meters)**	**180 dB RMS 771 feet (235 meters)**	**190 dB RMS 312 feet (95 meters)**
Vibratory Driving and Removal	20 percent	NA	NA	NA
Attenuated Impact Driving	NA	20 percent	100 percent	100 percent
Unattenuated Proof Testing	NA	Not Monitored (activity lasts less than 2 minutes/day)		
Unattenuated Impact Driving	NA	100 percent	100 percent	100 percent
Source: NMFS 2015				

Monitoring of the MMEZs and Level B harassment zones will be conducted by a minimum of three NMFS-approved MMOs. The MMOs will begin monitoring at least 30 minutes before the start of the pile driving/removal activities. The MMOs likely will conduct the monitoring from small boats, bridge piers, YBI and/or Treasure Island, the new SFOBB bike path, or construction barges. The number and distribution of observers will be dependent on the construction site (taking into account barges, bridge piers or other visual obstructions in the area) and the size of the MMEZs or Level B harassment zones.

If any marine mammals are observed inside the MMEZs before the start of impact pile driving, that activity will be delayed until the animal leaves the area or at least 20 minutes have passed since the last observation for harbor porpoises, harbor seals, and sea lions, or 30 minutes for gray whales and elephant seals. After driving of a pile starts, the operation will continue uninterrupted until the pile has reached its predetermined depth, unless pile driving is stopped for 30 minutes or more, then resuming pile driving will go through the same protocol for startup as described above. Monitoring will continue throughout the pile driving activity and will end approximately 30 minutes after the activity has been completed.

Observations will be made using binoculars during daylight hours. Each member of the monitoring team will have a mobile phone (and small VHF radios for backup) for contact with the Lead MMO and other MMOs. The Lead MMO will be positioned on the pile

driving barge to warn the construction crew if any marine mammals are sighted in the MMEZ.

Data on all observations will be recorded in waterproof notebooks and will include items such as species, numbers, sex and age class (when possible), behavior, time of observation, location, direction of travel, time that the pile driving or mechanical dismantling begins and ends, and other acoustic or visual disturbances.

13.2. Monitoring Plan for Implosion of Piers E4 and E5

The marine mammal monitoring plan for implosion of Piers E4 and E5 will be similar to the NMFS-approved marine mammal monitoring plan that was implemented for the implosion of Pier E3. The monitoring plan will include Level A injury exclusion and Level B TTS and behavioral harassment monitoring zones extending out to a pre-determined distance from Piers E4 and E5, based on conservatively estimated distances to acoustic threshold criteria.

The following are the general elements of the plan; a detailed monitoring plan will be developed (in cooperation with NMFS) that includes all monitoring requirements and final conditions of the IHA.

Level A Harassment Injury and Mortality Exclusion Zones: The MMEZs will include the area for both the mortality and Level A harassment thresholds (i.e., PTS, GI track injury, and slight lung injury), using the criteria threshold that extends out the furthest. The measured distances to these thresholds from the implosion of Pier E3 are discussed in Section 6 and are shown in Table 8, and will be used to establish the MMEZs for the implosions of Piers E4 and E5. The isopleth for PTS extends out to a radius of 507 feet (155 meters) for harbor seals and elephant seals, and covers the entire area for both Level A harassment and mortality for all pinnipeds, including sea lions that have a smaller zone for behavioral response. Therefore, the pinniped exclusion zone will be established at a radial distance of 507 feet (155 meters) from Piers E4 and E5 (Table 14, Figure 9). For harbor porpoise, the isopleth for PTS extends out to a radius of 1,777 feet (542 meters) and covers the entire area for both Level A harassment and mortality to harbor porpoise. Therefore, the harbor seal exclusion zone will be established at a radial distance of 1,777 feet (542 meters) from Piers E4 and E5 (Table 14, Figure 10). The MMEZs will be monitored by MMOs, and if any marine mammals are observed inside the MMEZs, the implosion will be delayed until the animal leaves the area or at least 20 minutes have passed since the last observation of a harbor porpoise, harbor seal, or sea lion, and at least 30 minutes since the last observation of an elephant seal.

Table 14. Marine Mammal Level A Exclusion Zones and Level B Monitoring Zones for Pier E4 and E5 Implosions

Species/Group	Level B Harassment and TTS Monitoring Zones	Level A Injury and Mortality Exclusion Zones
Pinnipeds (harbor seal, sea lion and elephant seal)	2,460 feet (750 meters)	507 feet (155 meters)
Harbor Porpoise	8,171 feet (2,491 meters)	1,777 feet (542 meters)
Note: Exclusion and monitoring zones are based on measured distances to threshold criteria from the implosion of Pier E3 (Department 2015a).		

Level B Harassment and TTS Monitoring Zones: The Level B harassment monitoring zones will cover the area through both the Level B harassment zones for behavioral response and TTS, using the criteria threshold that extends out the furthest. The measured distances to these zones from the implosion of Pier E3 are discussed in Section 6 and are shown in Table 8; and will be used to establish the Level B harassment monitoring zones for the implosions of Piers E4 and E5. For harbor seals and elephant seals, the isopleth for behavioral response extends out to a radius of 2,460 feet (750 meters) and covers the entire area for both behavioral response and TTS for all pinnipeds, including sea lions that have a smaller zone for behavioral response. Therefore, the pinniped Level B harassment monitoring zone will be established at a radial distance of 2,460 feet (750 meters) from Piers E4 and E5 (Table 14, Figure 9). For harbor porpoise, the isopleth for behavioral response extends out to a radius of 8,171 feet (2,491 meters) and covers the entire area for both behavioral response and TTS for harbor porpoise. Therefore, the harbor porpoise Level B harassment monitoring zone will be established at a radial distance of 8,171 feet (2,491 meters) from Piers E4 and E5 (Table 14, Figure 10).

Marine Mammal Observers: A minimum of eight MMOs will be required during the Piers E4 and E5 implosions so that the MMEZs and Level B harassment zones can be monitored. One MMO will be designated as the Lead MMO and will receive updates from other MMOs on the presence or absence of marine mammals within the MMEZ. This Lead MMO will notify the Environmental Compliance Manager of a cleared MMEZ before the start of the implosion.

Monitoring Protocol: Implosions of Piers E4 and E5 will be conducted only during daylight hours and with enough time for pre and post-implosion monitoring, and with good weather (i.e., clear skies and no high winds). This work will be completed so that MMOs will be able to detect marine mammals within the MMEZs and beyond. The Lead MMO will be in contact with other MMOs. If any marine mammals enter an MMEZ within 30 minutes of blasting, the Lead MMO will notify the Environmental Compliance

Source: ESRI 2015 (imagery); compiled by AECOM in 2016

Figure 9. Pinniped Level A Injury Exclusion Zone and Level B Harassment Monitoring Zone

Source: ESRI 2015 (imagery); compiled by AECOM in 2016

Figure 10. Harbor Porpoise Level A Injury Exclusion Zone and Level B Harassment Monitoring Zone

Manager that the implosion may need to be delayed. The Lead MMO will keep the Environmental Compliance Manager informed about the disposition of the animal. If the animal remains in the MMEZ, blasting will be delayed until it has left the MMEZ. If the animal dives and is not seen again, blasting will be delayed at least 20 minutes for a harbor porpoise, harbor seal, or sea lion, and 30 minutes for an elephant seal. After the implosion has occurred, the MMOs will continue to monitor the area for at least 60 minutes.

Although any injury or mortality from the implosions of Piers E4 and E5 is very unlikely, boat or shore surveys will be conducted for 3 days following the event, to determine whether any injured or stranded marine mammals are in the area. If an injured or dead animal is discovered during these surveys or by other means, the NMFS-designated stranding team will be contacted to pick up the animal. Veterinarians will treat the animal or will conduct a necropsy to attempt to determine whether it stranded because of the Piers E4 and E5 implosions.

Data Collection: Each MMO will record the observation position, start and end times of observations, and weather conditions (i.e., sunny/cloudy, wind speed, fog, visibility). For each marine mammal sighting, the following will be recorded, if possible:

1. Species
2. Number of animals (with or without pup/calf)
3. Age class (pup/calf, juvenile, adult)
4. Identifying marks or color (e.g., scars, red pelage, damaged dorsal fin)
5. Position relative to Piers E4 or E5 (distance and direction)
6. Movement (direction and relative speed)
7. Behavior (e.g., logging [resting at the surface], swimming, spy-hopping [raising above the water surface to view the area], foraging)
8. Duration of sighting or times of multiple sightings of the same individual

Communication: All MMOs will be equipped with a radio and mobile phone as a backup. One channel will be dedicated to the MMOs. One person will be designated as the Lead MMO and will be in constant contact with the Environmental Compliance Manager. The Lead MMO will coordinate marine mammal sightings with the other

MMOs. The Lead MMO will contact other MMOs when a sighting is made within the MMEZ or near the MMEZ, so that the MMOs within overlapping areas of responsibility can continue to track the animal and the Lead MMO is aware of the animal. If it is within 30 minutes of blasting and an animal has entered the MMEZ or is near it, the Lead MMO will notify the Environmental Compliance Manager and will keep him/her informed of the disposition of the animal.

13.3. Test Blast

A pinniped exclusion zone of 45 feet (14 meters) will be monitored, which likely will be within the BAS. Therefore, no pinniped is likely to approach that closely. A harbor porpoise exclusion zone of 270 feet (82 meters) will be used, and previous observations of harbor porpoises were 2,625 to 4,921 feet (800 to 1,500 meters) west of Piers E4 and E5. Because of the very small exclusion zones, pinnipeds or harbor porpoises are unlikely to enter the exclusion zones. Therefore, no harassment takes are allotted for these activities, but standard monitoring (using three MMOs) will be implemented as described for pile driving.

Acoustic Deterrent Devices: ADDs commonly are used in commercial fishing and at fish farms to scare marine mammals away from nets or structures (Gordon et al. 2007; Brandt et al. 2013; Gotz and Janik 2013; Schakner and Blumstein 2013) and were used for the first time during the Pier E3 implosion to deter marine mammals from entering the exclusion zones.

The pulse of ADDs used during the Pier E3 implosion had a frequency of 10 kHz, a source sound level of 132 dB re 1 μPa, with regular or random interpulse intervals of 4 seconds (Airmar Porpoise ADD, Milford, NH). Insufficient data exists to determine the effectiveness of the ADDs during the Pier E3 implosion, although three pinnipeds swam past the ring of ADDs around the exclusion zone after the implosion but remained outside the ADDs. Those ADDs will be used again for the implosions of Piers E4 and E5.

Marine mammals may habituate to ADDs over time because nets or fish farms are a regular source of food. Marine mammals, particularly harbor seals that are resident to the Bay, are unlikely to have encountered ADDs. Therefore, ADDs should be an effective deterrent for the short time they will be used before detonation (i.e., 1 to 2 days for several hours). Up to 20 ADDs will be attached to the buoys delineating the pinniped exclusion zone, and to monitoring boats or other Bridge piers near Piers E4 or E5 to deter marine mammals from entering the monitoring area.

Stranding Plan: A stranding plan for the Pier E3 implosion was prepared in cooperation with the local NMFS-designated marine mammal stranding, rescue, and rehabilitation center. An updated version of this plan will be implemented during implosions of Piers E4 and E5. Although avoidance and minimization measures likely will prevent any injuries, preparations will be made in the unlikely event that marine mammals are injured. Elements of that plan will include the following:

1. The stranding crew will prepare treatment areas at an NMFS-designated facility for cetaceans or pinnipeds that may be injured from the implosions. Preparation will include equipment to treat lung injuries, auditory testing equipment, dry and wet caged areas to hold animals, and operating rooms if surgical procedures are necessary.

2. A stranding crew and a veterinarian will be on call near the Piers E4 and E5 area at the time of the implosions, to quickly recover any injured marine mammals, provide emergency veterinary care, stabilize the animal's condition, and transport individuals to an NMFS-designated facility. If an injured or dead animal is found, NMFS (both the regional office and headquarters) will be notified immediately, even if the animal appears to be sick or injured from causes other than the implosions.

3. Post-implosion surveys will be conducted immediately after the event and over the following 3 days to determine whether any injured or dead marine mammals are in the area.

4. Any veterinarian procedures, euthanasia, rehabilitation decisions, and time of release or disposition of the animal will be at the discretion of the NMFS-designated facility staff and the veterinarians treating the animals. Any necropsies to determine whether the injuries or death of an animal was the result of an implosion or other anthropogenic or natural causes will be conducted at an NMFS-designated facility by the stranding crew and veterinarians. The results will be communicated to both the Department and to NMFS as soon as possible, followed by a written report within a month.

Real Time Acoustic Monitoring: Although harbor porpoises were not expected to be in the Demonstration Project area in November 2015, real-time acoustic monitoring to confirm species absence was used as an additional avoidance measure monitoring tool, to supplement active monitoring by trained observers during the Pier E3 implosion. Harbor porpoises vocalize frequently with other animals within their group and use echolocation

to navigate and locate prey. Unfortunately, because of the high ambient noise in the Bay (up to 133 dB) and the high frequency sounds produced by harbor porpoises (i.e., high frequency sound attenuates much faster underwater than low frequency sound), the real-time acoustic monitoring was effective only over a range of 656 feet (200 meters). It is reasonable to assume that, if present, the animals would have been detected visually before detection with acoustic monitoring equipment. This acoustic monitoring provided no additional benefit in detecting harbor porpoises. Therefore, this system will not be used for future pier implosions.

Chapter 14. Suggested Means of Coordination

A marine mammal monitoring plan for pile driving and mechanical demolition was developed by the Department and was submitted to NMFS in 2004, and a revised plan was submitted to NMFS in 2013 (Department 2004 and Department 2013d). This revised plan provides information on the required monitoring methods as well as reporting requirements. An IHA application for the removal of a bridge pier using implosion was submitted to NMFS in March 2015 (Department 2015c). The application provided detailed information on the use of implosion to remove a pier, estimated distances to the NMFS impulse sound criteria thresholds, and included an expanded monitoring plan to further mitigate potential impacts on marine mammals. A draft report of the marine mammal monitoring of the Pier E3 implosion has been submitted to NMFS and shows that the monitoring plan and protective measures that were implemented prevented any Level A harassment takes or mortality of any marine mammals (Department 2015b). A draft report of the acoustic monitoring has been submitted to NMFS and provides the basis of new and reduced harassment threshold criteria zones for the implosion of the smaller Piers E4 and E5 (Department 2015a).

Chapter 15. List of Preparers

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Appendix A. Pier E3 Blast Attenuation System Details

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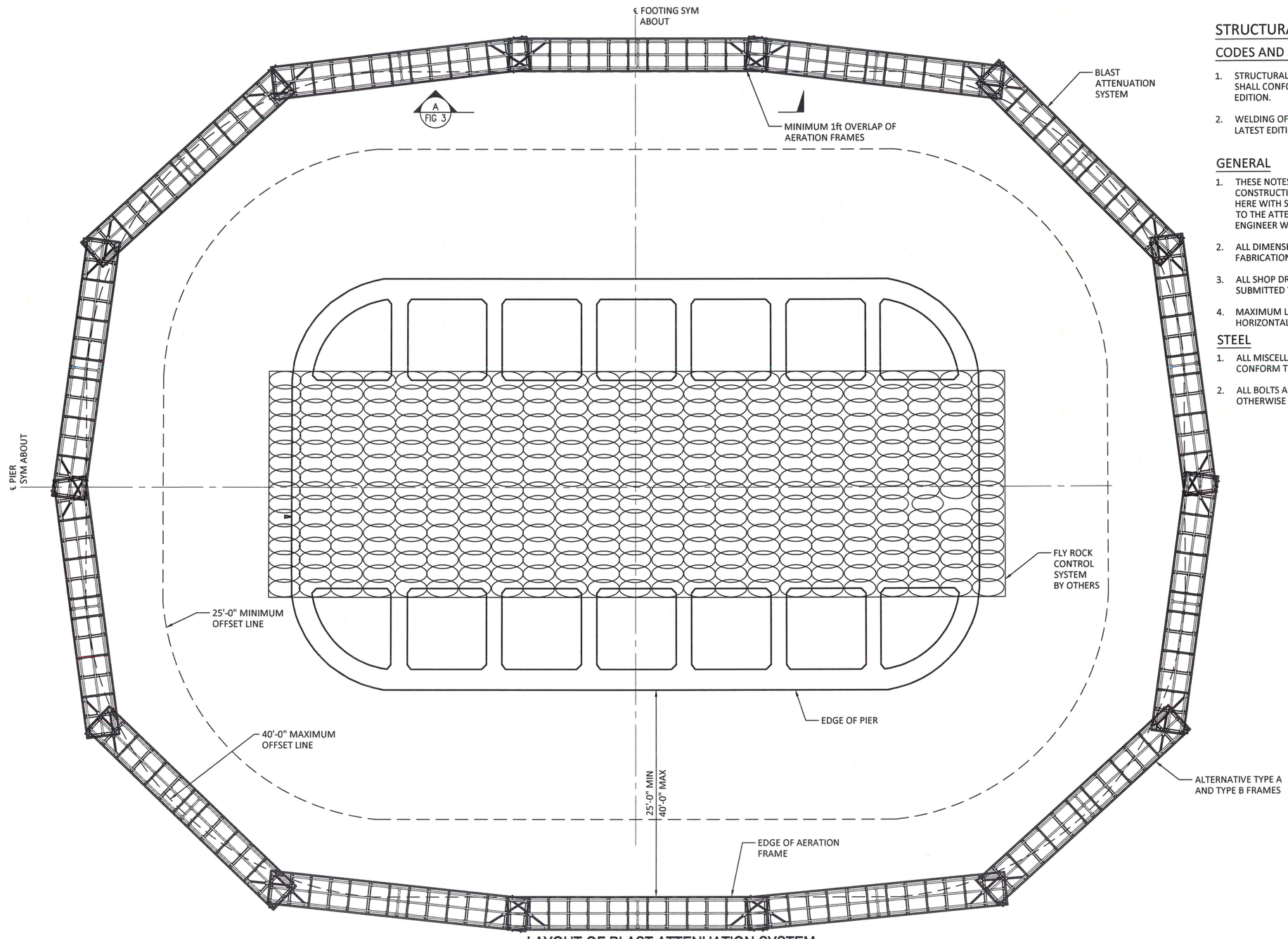

LAYOUT OF BLAST ATTENUATION SYSTEM

SCALE: 1"=10'-0"(34x22) 1"=20'-0"(11x17)

1" = 10' 10 0 10 20 scale feet

STRUCTURAL NOTES

CODES AND STANDARDS

1. STRUCTURAL AND MISCELLANEOUS STEEL FABRICATION AND ERECTION THEREOF SHALL CONFORM TO THE "AISC MANUAL OF STEEL CONSTRUCTION," FOURTEENTH EDITION.
2. WELDING OF STRUCTURAL AND MISCELLANEOUS STEEL SHALL CONFORM TO THE LATEST EDITION OF "STRUCTURAL WELDING CODE - STEEL" (AWS D1.1).

GENERAL

1. THESE NOTES CONTAIN GENERAL INFORMATION AND ARE NOT COMPLETE FOR CONSTRUCTION PURPOSES. CONTRACTOR SHALL VERIFY INFORMATION GIVEN HERE WITH SPECIFICATIONS AND OTHER DOCUMENTS AND BRING ANY CONFLICTS TO THE ATTENTION OF THE ENGINEER BEFORE BEGINNING AFFECTED WORK. THE ENGINEER WILL RESOLVE ANY SUCH CONFLICT.
2. ALL DIMENSIONS AND DETAILS SHALL BE VERIFIED BY THE CONTRACTOR PRIOR TO FABRICATION AND CONSTRUCTION.
3. ALL SHOP DRAWINGS AND MATERIAL CERTIFICATIONS FOR STEEL, SHALL BE SUBMITTED TO AND REVIEWED BY THE ENGINEER PRIOR TO FABRICATION.
4. MAXIMUM LOAD AT EACH PICK POINT = 20,000 LBS VERTICAL AND 9000 LBS HORIZONTAL.

STEEL

1. ALL MISCELLANEOUS STEEL SHAPES AND PLATES, EXCEPT AS NOTED BELOW, SHALL CONFORM TO ASTM A 36, FY = 36 KSI
2. ALL BOLTS AND NUTS SHALL CONFORM TO ASTM A 307, UNLESS SPECIFICALLY NOTED OTHERWISE ON THE DRAWINGS.

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DESIGN BY MGW
CHECK BY EWO
PROJ MGR MGW

KIEWIT/MANSON
SFOBB EAST SPAN DISMANTLING PROJECT
BUBBLE CURTAIN DESIGN

LAYOUT OF BUBBLE CURTAIN FRAME SIGMENTS

DRAWING NO. FIG-1
PROJECT NO. A15.0136.00
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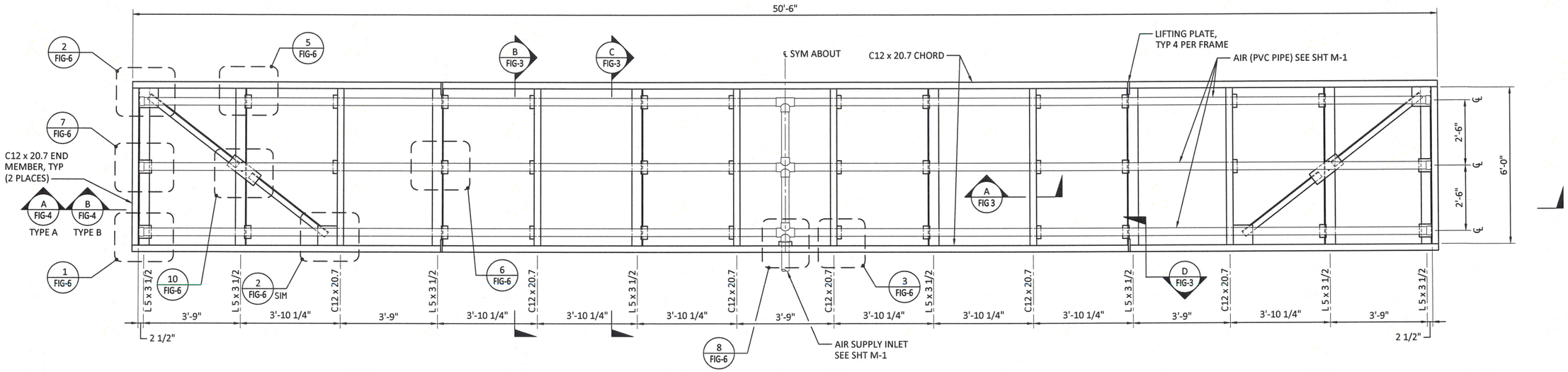

PLAN - AERATION FRAME TYPE A (TYPE B SIMILAR)

SCALE: 1/2"=1'-0"

1/2" = 1'-0" 2 0 2 4 scale feet

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SFOBB EAST SPAN DISMANTLING PROJECT
BUBBLE CURTAIN DESIGN

FRAME DETAILS

DRAWING NO. FIG-2
PROJECT NO. A15.0136.00
DATE: 2/9/15
SHEET NO. 2 OF 7

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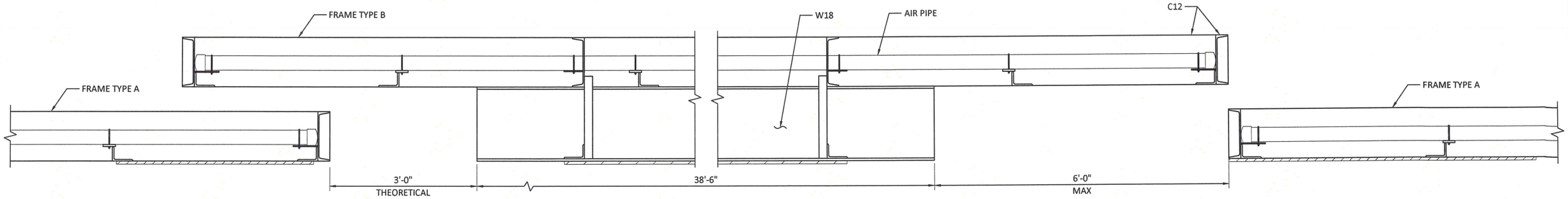
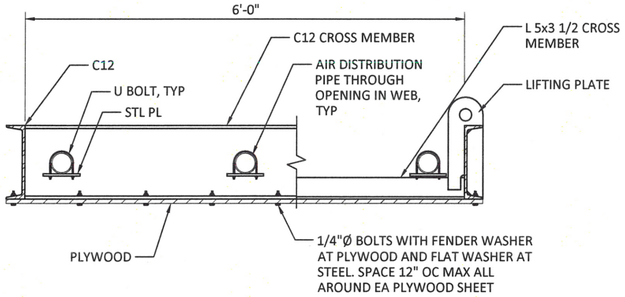
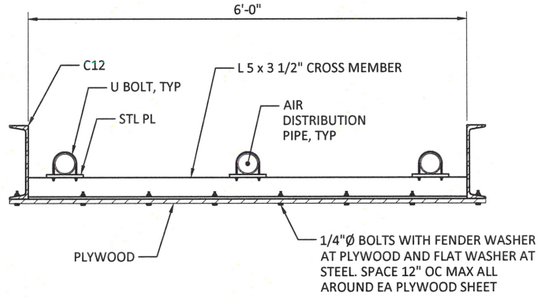


A FIG-1 **ELEVATION**
SCALE: 1"=1'-0"

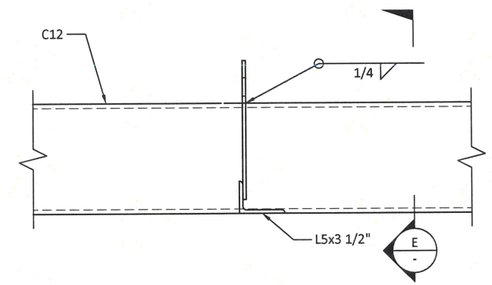


NOTE:
FOR FRAME TYPE B, SEE D -

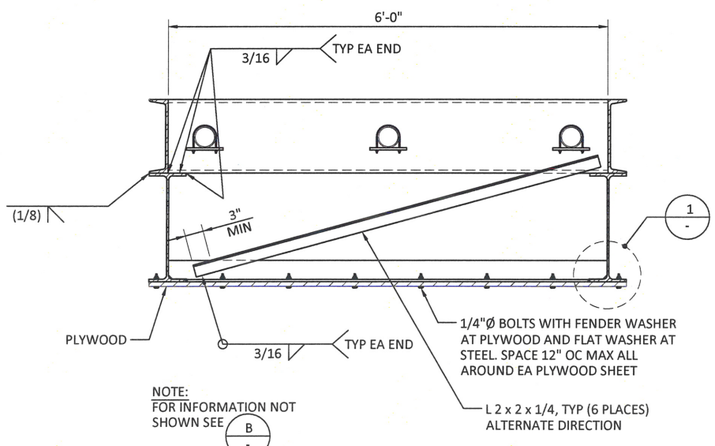
B FIG-2 **SECTION - FRAME TYPE A**
SCALE: 1"=1'-0"



C FIG-2 **SECTION - FRAME TYPE A**
SCALE: 1"=1'-0"

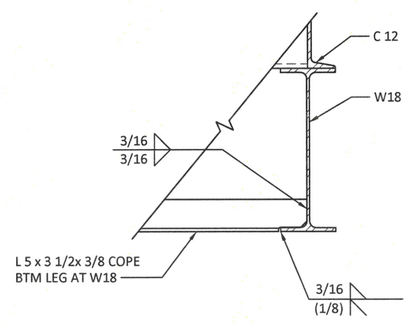


D FIG-2 **SECTION - LIFTING PLATE**
SCALE: 1 1/2"=1'-0"

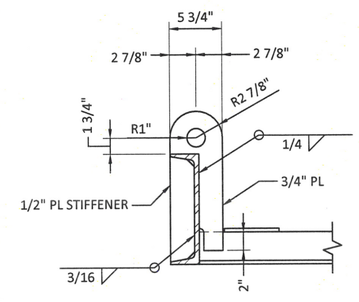


NOTE:
FOR INFORMATION NOT SHOWN SEE B -

D - **SECTION - FRAME TYPE B**
SCALE: 1"=1'-0"



1 - **DETAIL**
SCALE: 1 1/2"=1'-0"



E - **SECTION**
SCALE: 1 1/2"=1'-0"

1" = 1'-0" scale 1 0 1 2 feet

1-1/2" = 1'-0" scale 8 0 8 16 inches

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BUBBLE CURTAIN DESIGN

FRAME DETAILS

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PROJECT NO. A15.0136.00
DATE: 2/9/15
SHEET NO. 3 OF 7

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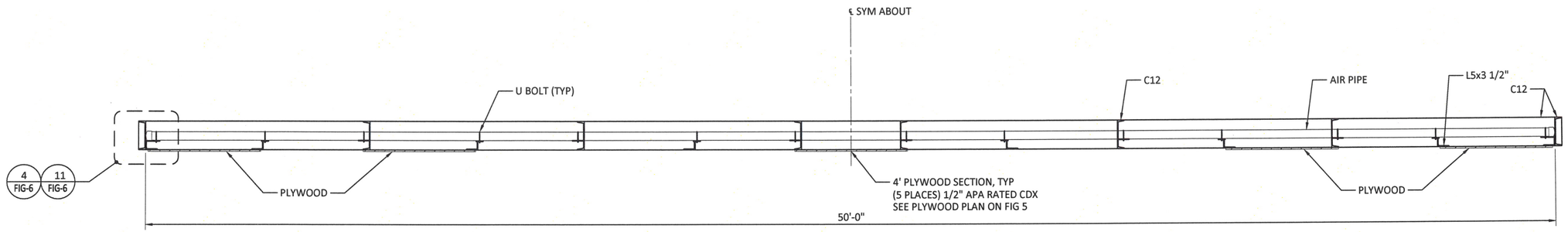
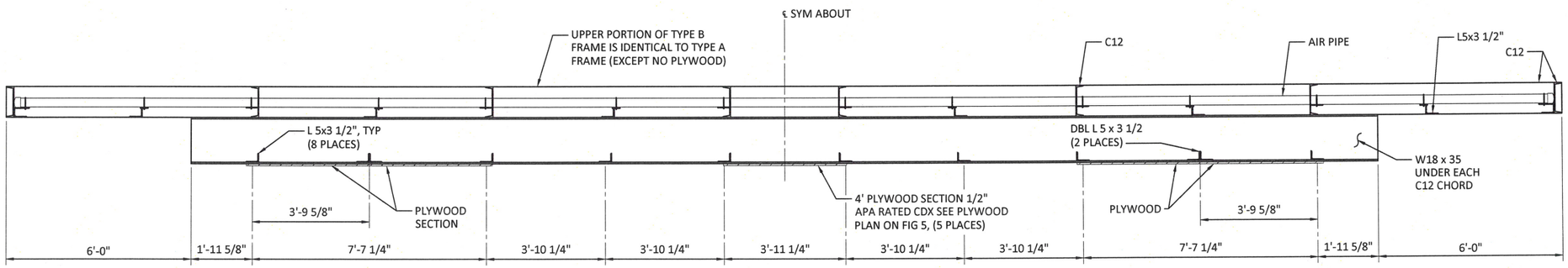


A FIG-2 **SECTION - TYPE A**
SCALE: 1/2"=1'-0"



B FIG-2 **SECTION - TYPE B**
SCALE: 1/2"=1'-0"

1/2" = 1'-0" 2 0 2 4 scale feet

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BUBBLE CURTAIN DESIGN

FRAME DETAILS

DRAWING NO. **FIG-4**
PROJECT NO. A15.0136.00
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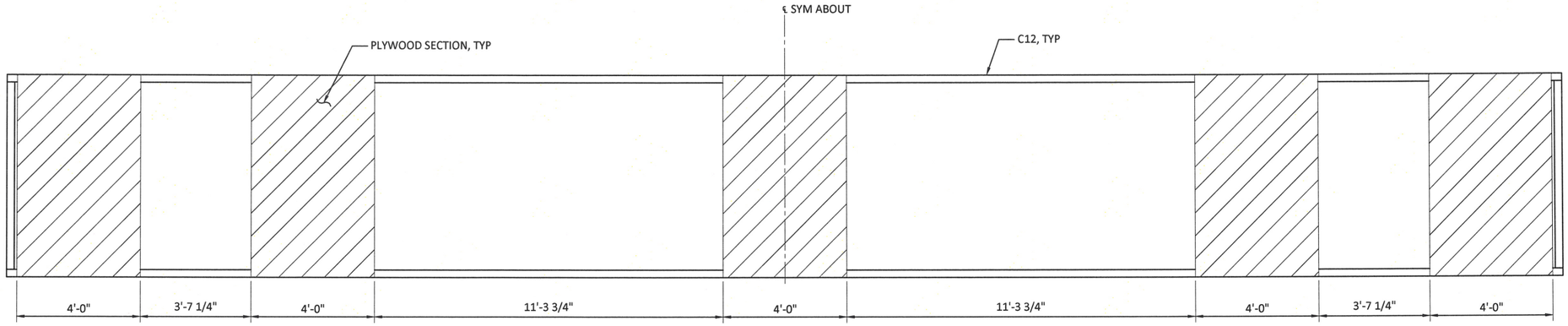
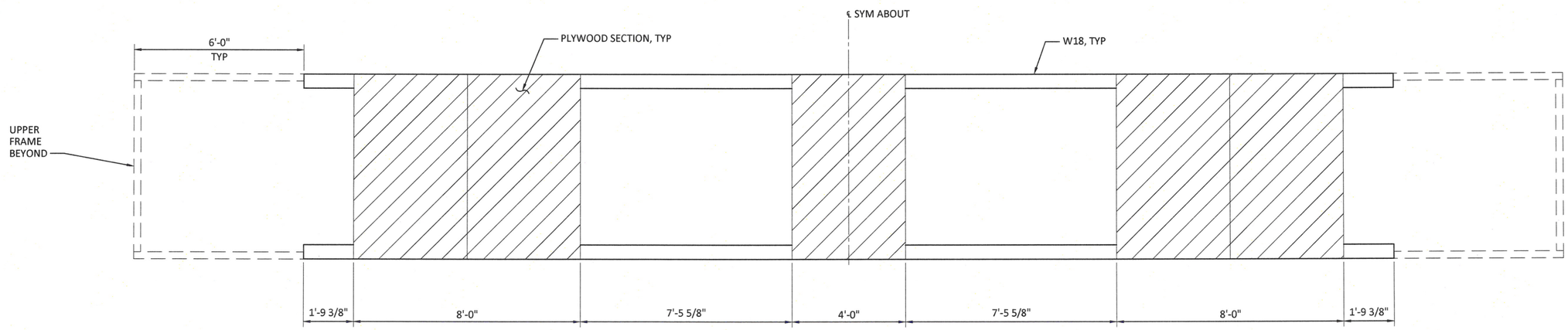


PLYWOOD PLAN - FRAME TYPE A (NO STAND OFF)

SCALE: 1/2"=1'-0"

NOTE:
AERATION FRAME MEMBER
NOT SHOWN FOR CLARITY



NOTE:
INTERNAL AERATION FRAME
MEMBERS NOT SHOWN FOR
CLARITY

PLYWOOD PLAN - FRAME TYPE B (W/W18 STAND OFFS)

SCALE: 1/2"=1'-0"

1/2" = 1'-0" 2 0 2 4 scale feet

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BUBBLE CURTAIN DESIGN

FRAME DETAILS

DRAWING NO. FIG-5
PROJECT NO. A15.0136.00
DATE: 2/9/15
SHEET NO. 5 OF 7

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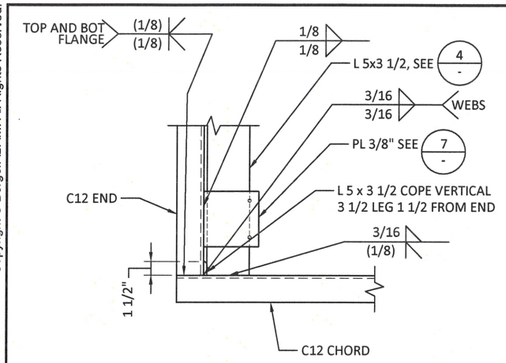
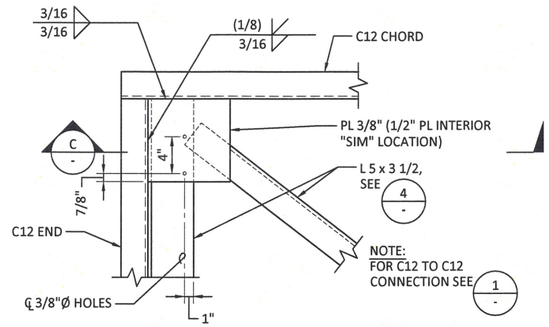
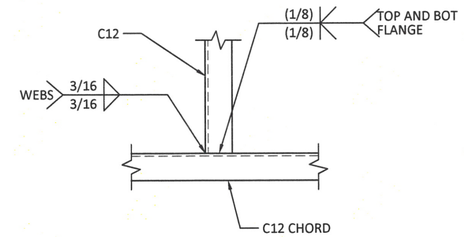


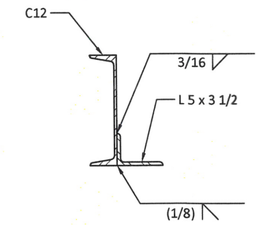
1 FIG-2 DETAIL- CORNER C12 TO C12
SCALE: 1 1/2"=1'-0"



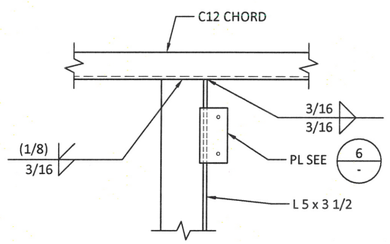
2 FIG-2 DETAIL - CORNER L 5 x 3 1/2 TO C12
SCALE: 1 1/2"=1'-0"



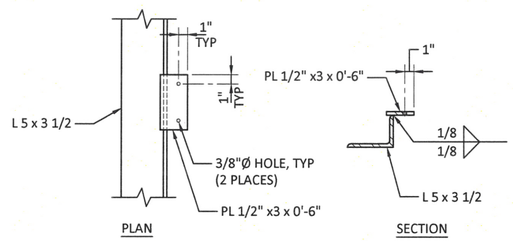
3 FIG-2 DETAIL - MID SPAN C12 TO C12
SCALE: 1 1/2"=1'-0"



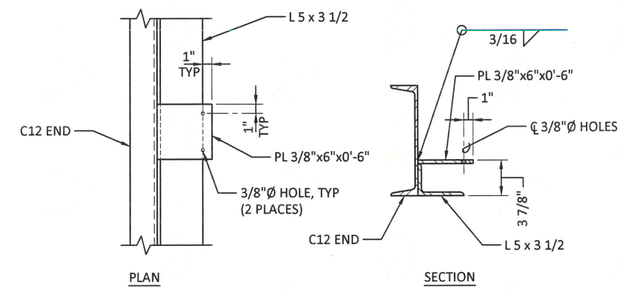
4 - DETAIL - END L 5 x 3 1/2 TO C12
SCALE: 1 1/2"=1'-0"



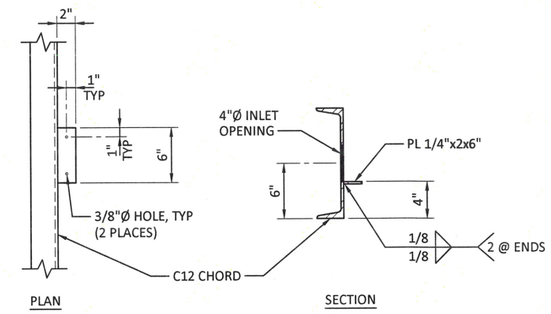
5 FIG-2 DETAIL- MID L 5 x 3 1/2 TO C12
SCALE: 1 1/2"=1'-0"



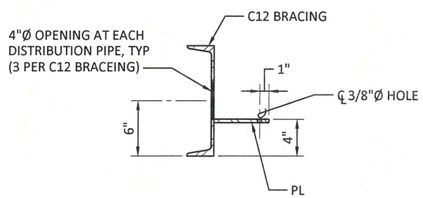
6 FIG-2 DETAIL- C4 BRACING @ C4
SCALE: 1 1/2"=1'-0"



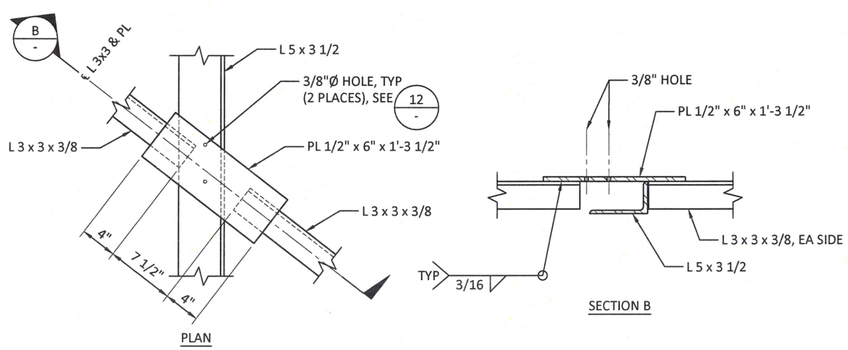
7 FIG-2 DETAIL - PLATE TO END C12
SCALE: 1 1/2"=1'-0"



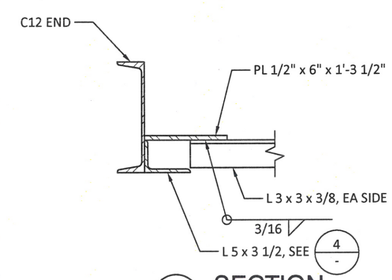
8 FIG-2 DETAIL - PLATE TO C12
SCALE: 1 1/2"=1'-0"



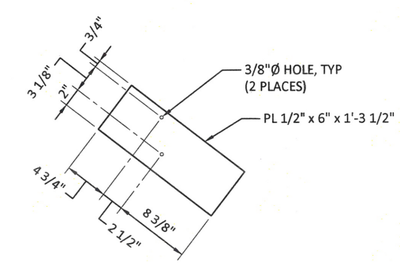
A FIG-2 SECTION - C12
SCALE: 1 1/2"=1'-0"



10 FIG-2 DETAIL - DIAGONAL MID SPAN CONNECTION
SCALE: 1 1/2"=1'-0"



C - SECTION
SCALE: 1 1/2"=1'-0"



12 - DETAIL - DIAGONAL PLATE
SCALE: 1 1/2"=1'-0"

1-1/2" = 1'-0" 8 0 8 16 scale inches

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FRAME DETAILS

DRAWING NO. FIG-6
PROJECT NO. A15.0136.00
DATE: 2/9/15
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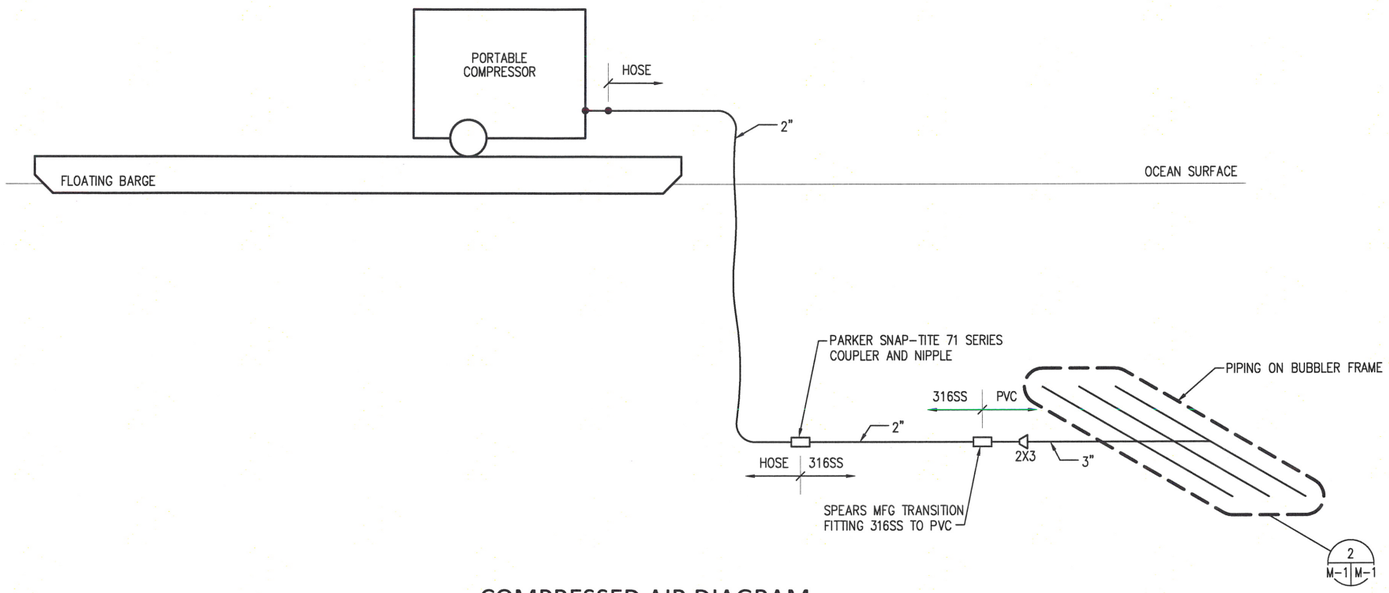
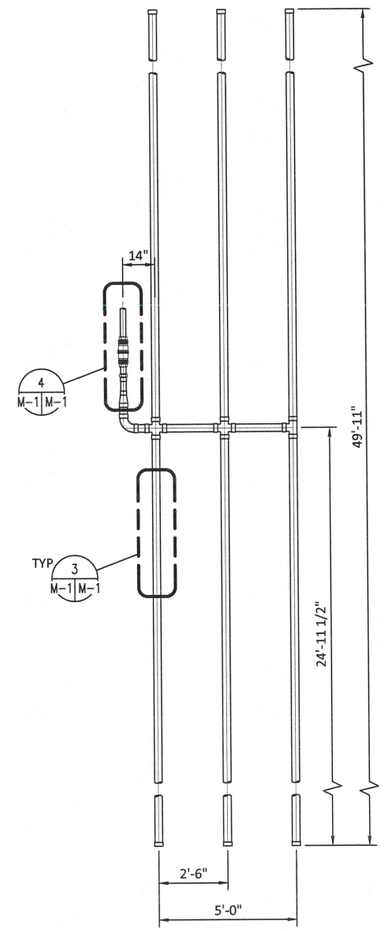
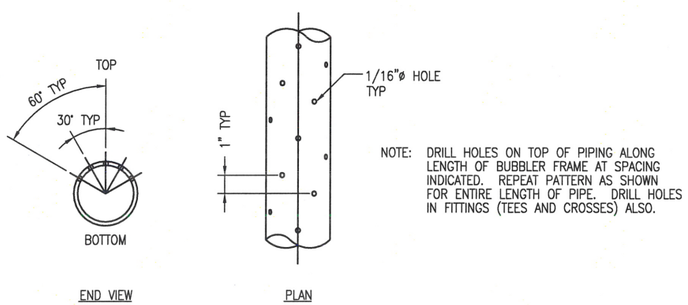


COMPRESSED AIR DIAGRAM

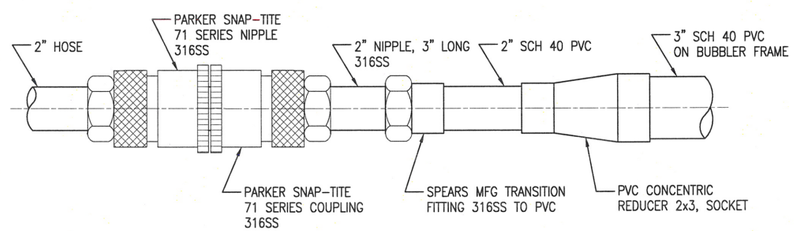


AIR BUBBLER PIPING ENLARGED PLAN 2 M-1 M-1



NOTE: DRILL HOLES ON TOP OF PIPING ALONG LENGTH OF BUBBLER FRAME AT SPACING INDICATED. REPEAT PATTERN AS SHOWN FOR ENTIRE LENGTH OF PIPE. DRILL HOLES IN FITTINGS (TEES AND CROSSES) ALSO.

BUBBLER HOLE LOCATION DETAIL 3 M-1 M-1



AIR BUBBLER PIPING CONNECTION DETAIL 4 M-1 M-1

MARK	REVISION DESCRIPTION	BY	APP.	DATE

BergerABAM
33301 9th Avenue South, Suite 300
Federal Way, Washington 98003-2600
(206) 431-2300 Fax: (206) 431-2250

KIEWIT/MANSON, AJV

REGISTERED PROFESSIONAL ENGINEER CARL ERIK LARSON REG. NO. 31268 MECHANICAL STATE OF CALIFORNIA 2/9/15

DRAWN BY TJB
DESIGN BY TJB
CHECK BY CEL
PROJ MGR CEL

KIEWIT/MANSON
SFOBB EAST SPAN DISMANTLING PROJECT
BUBBLE CURTAIN DESIGN

AIR BUBBLER PIPING DIAGRAM AND DETAILS

DRAWING NO. M-1
PROJECT NO. A15.0136.00
DATE: 2/9/2015
SHEET NO. 7 OF 7

Last Saved by: Cpeck on: Feb 9, 2015 3:50 PM File: G:\2014\1407310\DWG\MM-1.dwg

Appendix B. Test Blast Hydroacoustic Monitoring Results

ILLINGWORTH & RODKIN, INC.
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Preliminary Summary of Test Blast Results

Test blasts were conducted during a low slack tide on November 5, 2015 alongside Pier E3 in order to assess the measurement techniques to be used for hydroacoustic monitoring of the Pier E3 Demolition Implosion scheduled for November 14, 2015. The source was an 18 grain blasting cap positioned approximately 20 feet from Pier E3 at a depth of 20 feet below the surface. Illingworth & Rodkin, Inc. (I&R) monitoring locations were 20 feet and 75 feet away from the Pier and the blast, as illustrated in the sketch shown in Figure 1. The depths of both sensors were 20 feet below the water surface. The data acquisition systems were placed on the Pier and on the barge supporting the compressors used for the eastern half of the blast attenuation system (BAS). A third location was also monitored from the barge at the southwest corner, at a distance slightly more than 100 feet from the blast, at a depth of 20 feet. Two blasts were produced and monitored; one while the BAS was supplied with air at 30 psi and one approximately 20 minutes later while the BAS was supplied with air at 100 psi.

The peak sound pressure levels measured for the first blast are shown in Figure 2 superimposed on a photograph of the measurement set up as viewed from the barge. The results for both blasts are shown in Table 1. The modeled results for peak pressure and cumulative SEL are shown in Table 2. The reported values include the peak pressure level, the SEL, and the RMS level, as monitored at both the 20-foot and 75-foot distances. The levels at Location 3 (100 feet) were too low to be measured relative to the background noise due to the ambient and instrumentation noise. Ambient levels were measured to be approximately 140 dB at 20 feet, 119 dB at 75 feet, and 139 dB at 100 feet.

The levels at Location 1 (20 feet) were lower than expected; however, it appears that these measurements were actually made within the BAS bubble stream. The signals at this location were only slightly higher than the background ambient noise, and reported levels may be actually inflated by this background noise. The pressure signals at Location 2 (75 feet from Location 1) propagated more fully through the BAS and are significantly lower in level. The difference between Blast 1 and Blast 2 was different at Locations 1 and 2. Close to the blast at Location 1, the higher air pressure supplied during Blast 2 resulted in lower levels for all three metrics, as compared to Blast 1. At Location 2, the different metrics for Blast 2 ranged from slightly lower to slightly higher than Blast 1. The actual pressure versus time histories for Locations 1 and 2 were quite different on account of the differences in the metrics. Given that there are only two measurement locations, one being within the BAS and the other outside the BAS, a fall-off rate for these cannot be determined. When compared to the noise criteria established by the National Marine Fisheries Service, however, the levels at 75 feet are below the 206 dB peak pressure criteria for injury to all fish, below the 187 and 183 dB SEL criteria for injury to fish greater than and less than 2 grams, respectively, and below the 150 dB RMS criteria for behavioral response to fish.

Table 1: Test Blast Noise Levels

Pier E3 Data (20ft from Blast)			
Metric	Blast 1	Blast 2	Reference
Peak	207.1	201.9	dB re 1µPa
SEL	180.9	178.2	dB re 1µPa2-sec
RMS	192.6	189.2	dB re 1µPa

Barge Data (75ft from Blast)			
Metric	Blast 1	Blast 2	Reference
Peak	153.9	157.1	dB re 1µPa
SEL	136.4	135.9	dB re 1µPa2-sec
RMS	142.7	149.1	dB re 1µPa

Table 2: Predicted Peak Pressures by Distance

Criteria	
Distance	**PEAK Level**
20 feet from blast	235 dB
88 feet from blast	206 dB
100 feet from blast	205 dB

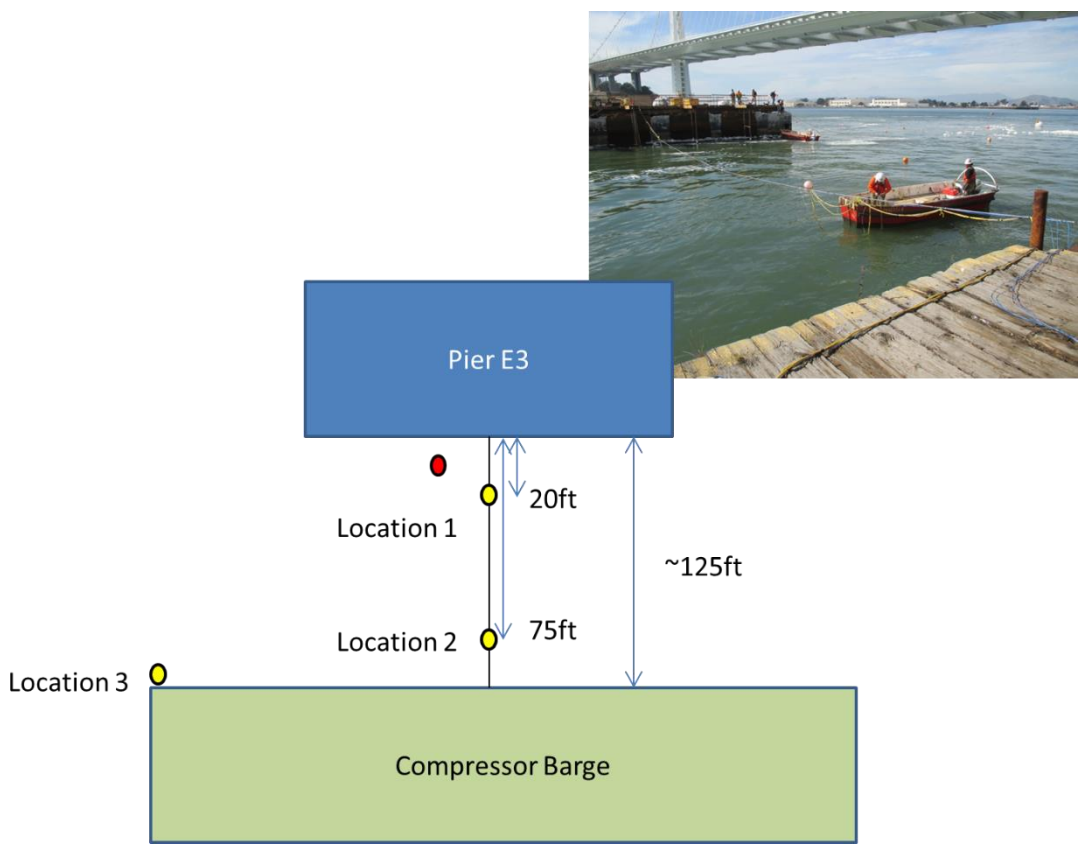


Figure 1: Test blast measurement geometry sketch

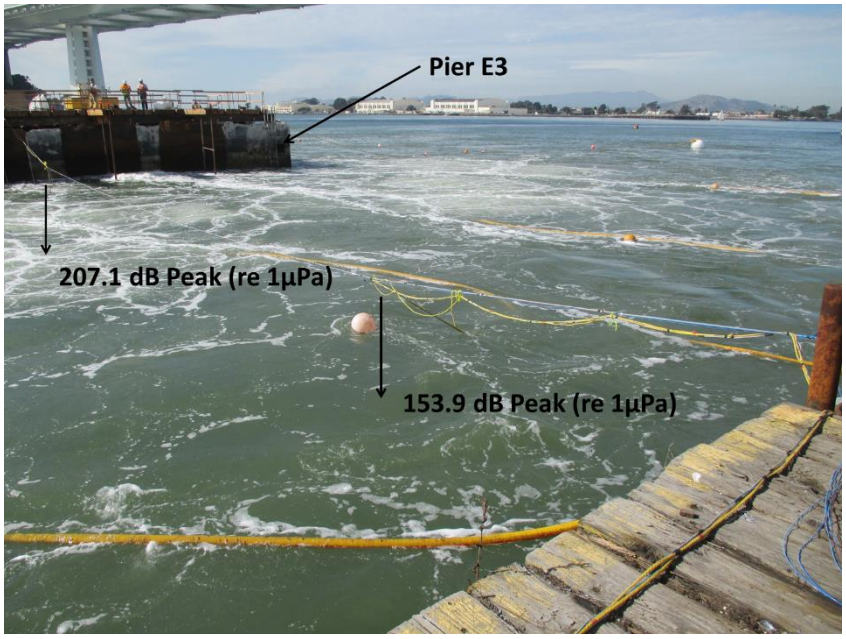


Figure 2: Photograph test blast measurement set up with peak pressure levels

Appendix C. Hydroacoustic Modeling for the Pier E3 Demonstration Project Alternatives Analysis

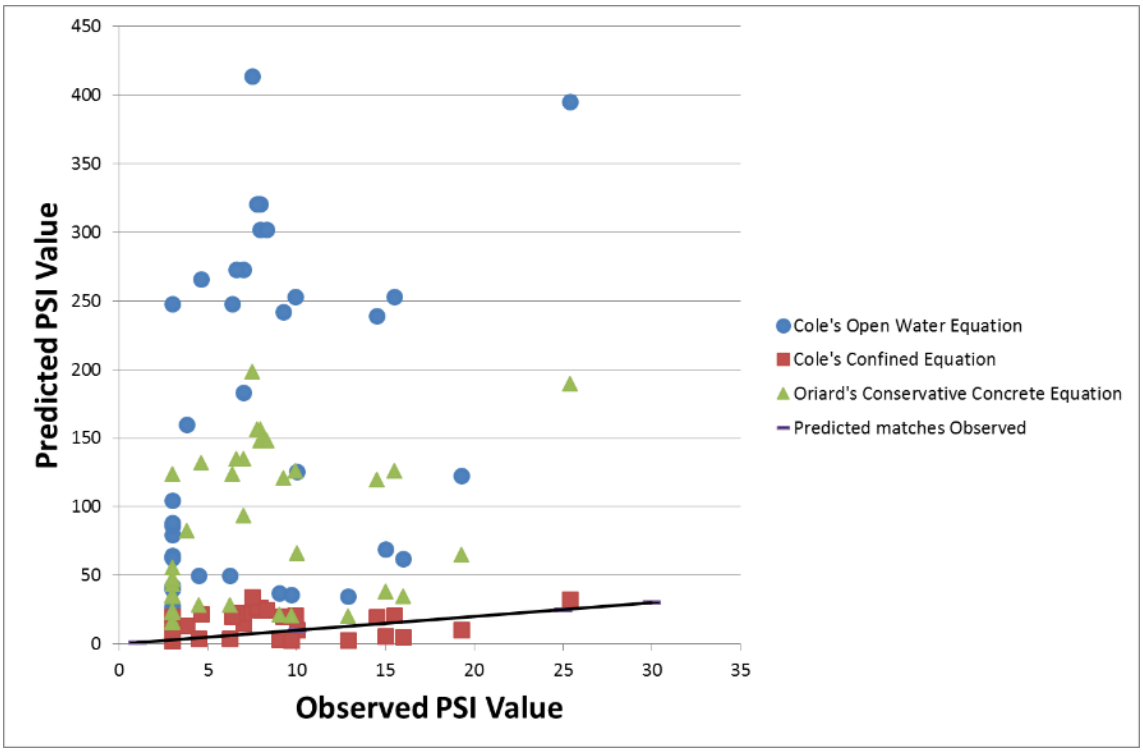
HYDROACOUSTIC MODELING THE FOR THE SFOBB PIER E3 DEMONSTRATION PROJECT

BLAST CONFINEMENT

A degree of confinement was incorporated into the blast model for the Pier E3 implosion, rather than modeling it as an open-water blast. Confinement is a concept in blasting that predicts the amount of blast energy expected to be absorbed by the surrounding structural material, resulting in the fracturing necessary for demolition. The energy beyond that absorbed by the material is the energy which produces the pressure wave propagating away from the source. Modeling with confinement was determined to be appropriate for the Pier E3 blast by evaluating blast results from case study data for other similar underwater implosions. In addition, case study results were compared to published blast models that incorporated a degree of confinement.

Data from 39 underwater concrete blasts (Figure 1) were used to evaluate potential equations for modeling blast-induced peak pressures and subsequent effects on marine mammals (Kiewit-Mason, pers. comm., 2015). All 39 blasts occurred in approximately 55 feet (16.8 meters) of water, similar to the maximum water depth around Pier E3. In addition, all blasts had burdens (i.e., distance from the charge to the outside side of the material being fractured) of approximately 1.5 to 2 feet (0.5 to 0.6 meter). Burdens for Pier E3 also are estimated to be in this range. Data considered included the charge weight, observed peak pressure, distance of peak pressure observation, and the modeled peak pressure using Cole's confined equation, Cole's unconfined equation, and Oriard's conservative concrete equation (Cole 1948; Oriard 2002).

Using these data from real events, an appropriate equation for modeling the associated hydroacoustic impacts from the Pier E3 Demonstration Project implosion was selected. Cole's unconfined equation greatly overestimated peak pressures for all blasts, while Cole's confined equation appeared to most accurately predict observed peak pressures. Oriard's conservative concrete equation overestimated peak pressures, but not as dramatically as under Cole's unconfined equation. As a demonstration study and because of some uncertainty in predicting the hydroacoustic effects, Oriard's equation was used when modeling potential hydroacoustic impacts on marine mammals. The Department opted to use more conservative methods, to provide an additional level of safety when predicting the monitoring zone and potential impact areas on marine mammals from the Pier E3 Demonstration Project.



Note: Based on data from three implosion projects.
Source: Kiewit-Mason, pers. comm., 2015

Figure 1. Observed and Predicted Peak Pressure Values for 39 Underwater Concrete Blasts under Different Equations for Estimating Peak Pressure

PIER E3 HYDROACOUSTIC MODELING

This discussion presents the methods used to estimate underwater noise metrics as a function of distance for the implosion of Pier E3 of the SFOBB original east span. The applicable metrics discussed are the peak pressure (P_{pk}) expressed in decibels (dB), the accumulated Sound Exposure Levels (SEL) also expressed in dB, and the positive acoustic impulse (I) in Pa-sec. The criteria for marine mammals are grouped by behavioral response, slight injury, mortality, and the specific acoustic thresholds depend on group and species. These are summarized in Table 1. The metrics for these are criteria defined as:

<u>Peak Pressure Level</u>

$$L_{pk} = 20\ Log_{10}\left(P_{pk}/P_{ref}\right) \qquad (1)$$

where L_{pk} is the peak level in dB and p_{ref} is the reference pressure of 1μPa;

<u>Sound Exposure Level</u>

$$SEL = 10\ Log_{10}\left(\int_0^T \frac{P^2(t)\,dt}{P_{ref}^2 \cdot T_{ref}}\right) \qquad (2)$$

where T is the duration of the event, $P^2(t)$ is the instantaneous pressure squared and, T_{ref} is the reference time of 1 second;

Impulse:

$$I = \int_0^T \left(P(t)dt \Big/ P_{ref} \right) \qquad (3)$$

where T is the duration of the initial positive portion of p(t). To calculate these quantities, p(t) for the blast event is needed as a function of distance from the blast, or alternatively, empirical relationship can be used for L_{pk} and I. As shown in Table 1, for SEL criteria, different designations exist for SEL for each group/species. These refer to group/species-specific filter shapes that are to be applied to the pressure signal. For L_{pk} and I, no filters are specified.

GENERAL ASSUMPTIONS

The blast event for Pier E3 consisted of 588 individual delays of varying charge weight, the largest being 35 pounds/delay and the smallest being 21 pounds/delay. The blasting sequence was rather complex. On the full height walls, 30-pound weights were used for the portion below the mudline, 35-pound weights were used in the lower structure immediately above the mudline, 29.6-pound weights were used in the mid-structure, and 21-pound weights were used in the upper structure. Blasts started in several interior webs of the southern portion of the structure, followed by the outer walls on the south side. The blasts in the inner walls occurred just before the adjacent outer walls. The interior first, exterior second blast sequence continued across the structure, moving from south to north. The time for the 588 detonations was 5.3 seconds, with a minimum delay time of 9 milliseconds (msec) between detonations. As the blasting progressed, locations east, north, and west of the pier were shielded from the blasting on the interior of the structure from the still-standing exterior walls of the pier. However, towards the conclusion of the blast, each direction experienced blasts from the outer walls that were not shielded.

To estimate P_{pk} and $P^2(t)$, several assumptions were made. For simplification, only one blast distance was assumed, and it was anticipated to be at the closest point on the pier from the receiver point. In actuality for almost all explosions, distances from the blast would be greater because the pier was approximately 135 feet (41 meters) across and 80 feet (24 meters) wide. Based on these dimensions, the actual blast point would have been up to 135 feet (41 meters) further from the receptor point that was used for the calculation. Therefore, the calculated peak level was the maximum expected for one 35-pound blast, although the other levels would be lower, depending on the distance from the actual blast location to the calculation point and weight of the charge. In other words, the pressure received at the calculation point would not be 588 signals of the same amplitude, but would be from one at the estimated level for a 35-pound charge and 587 of varying lower amplitudes. Similarly, in the vertical direction, the location varied over a height of about 50 feet (15 meters), and those blasts that were not at the same depth as the receiver also would be lower. This effect of variation in assumed blast to receiver distance were most pronounced closer to the pier, although at distances of about 1,000 feet (305 meters) or greater, the effect would be less than 1 dB.

Table 1. Marine Mammal Impact Criteria and Thresholds for Underwater Blasting

Group	Species	Behavior		Slight Injury			Mortality
		Behavioral (for ≥2 pulses/24 hours)	TTS	PTS	Gastro-Intestinal Tract	Lung	
Low-frequency Cetaceans	Mysticetes	167 dB SEL (LFII)	172 dB SEL (LFII) or 224 dB peak SPL	187 dB SEL (LFII) or 230 dB peak SPL	237 dB SPL or 104 psi	39.1 M1/3 (1+[DRm/10.081])1/2 Pa-sec Where: M = mass of the animals in kg DRm= depth of the receiver (animal) in meters	91.4 M1/3 (1+[DRm/10.081])1/2 Pa-sec Where: M = mass of the animals in kg DRm= depth of the receiver (animal) in meters
Mid-frequency Cetaceans	Most delphinids, medium and large toothed whales	167 dB SEL (LFII)	172 dB SEL (LFII) or 224 dB peak SPL	187 dB SEL (LFII) or 230 dB peak SPL			
High-frequency Cetaceans	Porpoises and Kogia spp.	141 dB SEL (HFII)	146 dB SEL (HFII) or 195 dB peak SPL	161 dB SEL (HFII) or 201 dB peak SPL			
Phocidae	Hawaiian monk, elephant, and harbor seal	172 dB SEL (PWI)	177 dB SEL (PWI) or 212 dB peak SPL	192 dB SEL (PWI) or 218 dB peak SPL			
Otariidae	Sea lions and fur seals	195 dB SEL (OWI)	200 dB SEL (OWI) or 212 dB peak SPL	215 dB SEL (OWI) or 218 dB peak SPL			

Source: Finneran and Jenkins 2012 and NMFS 2013

In the calculations, it also was assumed that no self-shielding of the pier as the explosions progressed. Based on calculations measured from the blast sequence, some shielding of the blasts along the interior of the pier did occur. However, the blasts that occurred in the outer wall (towards the end of the implosion) would not have shielded for all the explosions. A blast in the outer wall that had a direct line of sight to the receptor calculation point would not be shielded and would generate the highest peak pressure relative to the L_{pk} criterion. However, the cumulative SEL and the root-mean-square (RMS) levels would be reduced to some degree by the outer walls until they were demolished, because these metrics were defined by the pressure received throughout the entire 5.3-second event. However, because of the complexity of the blast sequence, this shielding effect was not considered in the calculated SEL and RMS levels.

The delays were placed in 2-3/4 to 3-inch-diameter (7 to 7.6 centimeters) holes, drilled into the concrete pier structure. The outer walls of the pier are nominally 3 feet-11-1/2 inches (1.5 meters) thick, and the inner walls are nominally 3 feet (0.9 meter) thick. Individual blasts would not be exposed to open water and some confinement of the blasts would be expected. For confined blasts, the predicted pressures can be reduced by 65 to 95 percent (Nedwell & Thandavamoorthy 1992; Rickman 2000; Oriard 2002; Rivey 2011), corresponding to multiplication factors from 0.35 to 0.05, respectively. Based on a review of the available literature and recent data from similar explosive projects, a conservative confinement factor of K=7500 (equating to a 65 percent reduction in pressure and by a multiplication factor of 0.3472) were used.

Another assumption was to consider only the direct wave from an individual blast. In shallow water, the signal at the receiver point could consist of the direct wave, surface-relief wave generated by the water/air interface, a reflected wave from the bottom, and a wave transmitted through the bottom material (USACE 1991). For estimating P_{pk}, only the direct wave was considered as it would have the highest magnitude and would arrive at the receiver location before any other wave component. However, P(t) after the arrival of the direct wave peak pressure would be affected. The surface-relief wave would be negative so that when it arrived at the receiver location, it would reduce the positive pressure of the direct wave and could make the total pressure negative at times after the arrival of the initial positive peak pressure. Because SEL is a pressure squared quantity, any negative pressure also can contribute to SEL. However, the amplitude and arrival time of the surface-relief wave depended on the geometry of the propagation case, that is, depth of water, depth of blast, and distance and depth of the receiver point. The effect of this assumption is discussed further in the section on SEL.

ESTIMATION OF PEAK PRESSURE

Peak pressures were estimated by following the modified version of the Cole Equation for prediction of blasts in open, deep water (Cole 1948). The peak pressure is determined by:

$$P_{pk} = K(\lambda)^{-1.13} \qquad (4)$$

where P_{pk} is peak pressure in pounds per square inch (psi), and λ is the scaled range given by $R/W^{1/3}$ in which R is the distance in feet and W is the weight of the explosive charge in pounds. A modified version

of the Cole Equation has been documented in United States Army Corps of Engineers (USACE) Technical Letter No. 1110-8-11(FR) and is applicable to shallow water cases such as that of the Pier E3 demolition (USACE 1991). The constant *K* factor multiplier in the USACE calculation is 21,600 for an open-water blast instead of the 22,550 from the original Cole Expression. This factor is slightly less (approximately 4 percent) than the original Cole Equation. The decay factor (-1.13) used in the USACE-modified equation remains the same as the original Cole Equation. To account for the confining effect of the concrete pier structure, a conservative *K* factor of 7,500 was used corresponding to multiplying USACE P_{pk} by a factor of 0.3472. With a minimum delay between each individual blast of 9 msec, the individual delays would be spaced sufficiently far in time to avoid addition of the peak pressures. In this case, the peak pressure is defined by that calculated for the largest charge weight of 35 pounds/delay. A Blast Attenuation System (BAS) was specified in the Blast Plan. Based on the literature and recent results from similar projects, reductions in the pressure peak of 85 to 90 percent or more were expected. For determining P_{pk} in this analysis, a conservative reduction of 80 percent has been used. Based on values of confinement, BAS performance, and the General Assumptions above, the calculated peak pressures were expected to be conservative.

ESTIMATION OF SEL VALUES

Estimating the weighted SEL values for the different groups/species is a multiple-step process. The first step is to estimate SEL values as a function of distance from the blast pressure versus time histories for each of the six charge weights as a function of distance. The open water equation used for this calculation was that modified by USACE (1991) based on methods pioneered by Cole (1948). Pressure as a function of time is given by:

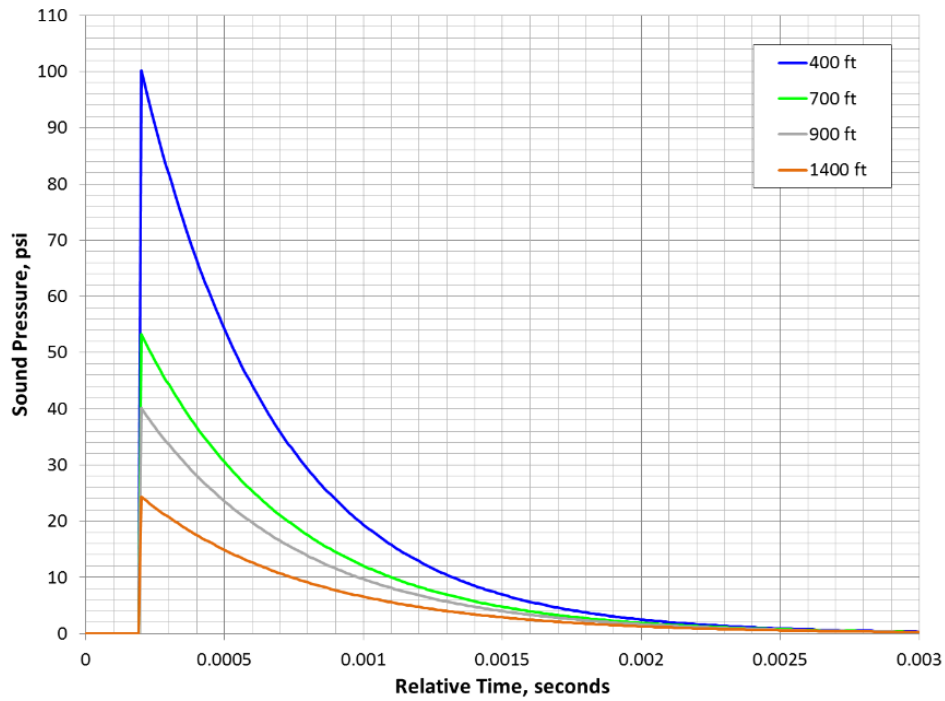
$$p(t) = P_{pk} e^{-\left(\frac{t-t_a}{\theta}\right)} \qquad (5)$$

where t_a is given as R/5000 and θ is:

$$\theta = 6.0x10^{-5} W^{1/3} (\lambda)^{0.18} \qquad (6)$$

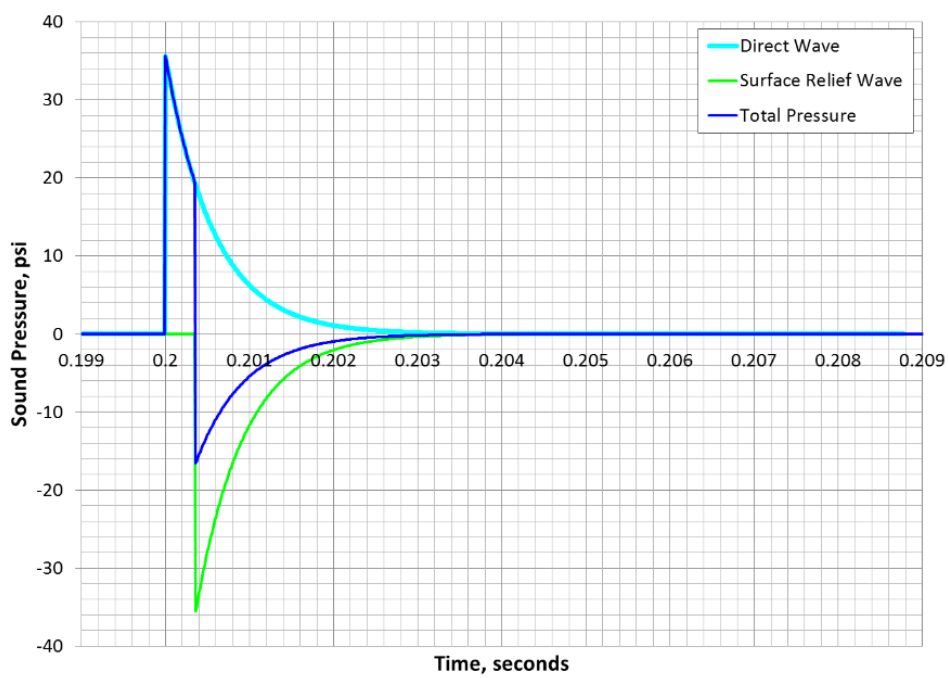
Some of the time histories produced by these equations are shown in Figure 2 for varying distances from the blast. These calculations then were extended to distances out to 160,000 feet (48.8 kilometers).

As discussed previously, other wave components exist that could be considered in SEL estimation, including the surface relief wave, reflection from the bottom, and transmission through and re-radiation from the bottom. Little or no contribution was expected from the bottom, based on its sedimentary nature and previous experiences from measuring noise from underwater pile driving in the area around Pier E3. The negative surface relief wave could be a factor in SEL estimation. This wave could either increase or decrease SEL, depending on its arrival time relative to the direct wave. For small differences in arrival time, the surface relief would decrease the total SEL because a portion of the positive direct wave would be negated by the addition of the negative surface relief wave. This is shown in Figure 3 for a blast and receptor depth of 30 feet (9 meters) and a range of 1,000 feet (305 meters). In this case, the surface relief wave essentially balances the direct wave so that the total SEL is within a few tenths of a decibel of the



Source: Prepared by Illingworth and Rodkin for this analysis

Figure 2. Blast Wave Forms versus Time Relative the Same Arrival Time Calculated for Different Blast Distances



Source: Prepared by Illingworth and Rodkin for this analysis

Figure 3. Total Pressure Versus Time History for Combined Direct and Surface Relief Wave 1,000 feet from the Blast (with Source and Receptor 30 feet deep)

direct wave only. For closer distances and when the receptor and blast locations are near the bottom, the total SEL would become greater than the direct wave SEL, but only by less than 3 dB. However, whenever the source or receiver is near the surface, the direct wave SEL would be greater than the total SEL and would approach being 10 dB greater for distances beyond 1,000 feet (305 meters). Therefore, the surface relief wave was ignored in this analysis, knowing that the surface relief wave would tend to produce only lower SEL values than the direct wave.

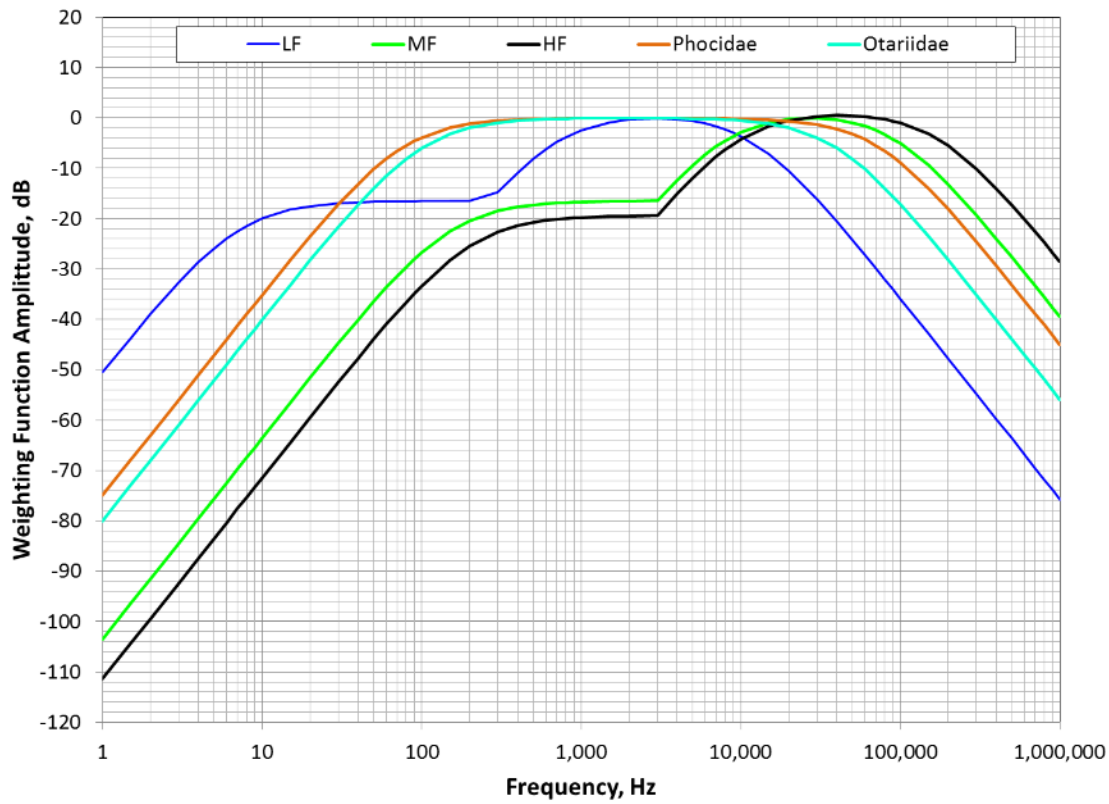
Considering only the direct wave, the time histories such as those in Figure 3 were squared and summed in a numerical version of Equation 2 to calculate single blast SEL for the each blast weight. These calculations then were extended to distances out to 160,000 feet (48.8 kilometers). To determine the cumulative SEL for all 588 blasts, the single blast SEL values as a function of distance were calculated for the other charge weights of 35, 32.5, 30, 29.6, 26, 24, 22.5, and 21 pounds. For each weight, the cumulative SEL was determined by adding 10Log (N), where N is the number of the blasts for each weight. For example, 21.3 dB was added to the 35-pound single-blast SEL to account for 135 blasts of this charge weight. The values for all of the charge weights are shown in Table 2. These cumulative SEL values for each charge weight then were summed (on an energy basis) to get the total accumulative SEL for the unconfined blast sequence. To account for the confinement factor of 0.3472 (*K*=7500), 20Log(0.3472) or -9.2 dB was added to the unconfined values.

Table 2. Charge Weights per Delay, Number of Delays, and Added Level to Accumulate Number of Blasts

Pounds/Delay	Total Number of Delays, N	10Log(N), dB
35	135	21.3
32.5	24	13.8
30	135	21.3
29.6	111	20.5
26	24	13.8
24	12	10.8
22.5	12	10.8
21	135	21.3
Total	**588**	

Source: Department 2015

For each of the marine mammal groupings included in Table 2, specific filter shapes apply to each group. The filters corresponding to Low-Frequency Cetaceans (LF_{II}), Mid-Frequency Cetaceans (MF_{II}), High-Frequency Cetaceans (HF_{II}), Phocidaes (P_{WI}), and Otariidaes (O_{WI}) are shown in Figure 4. To apply this weighting, the Fast Fourier Transform (FFT) was calculated for the time histories at each analysis distance. Each FFT then was filtered using the frequency weight specified for each group/species from Figure 4. Filter factors then were determined for each distance by subtracting the filtered result from the unfiltered FFT data and determining the overall noise reduction in decibels. These filter factors were applied to the accumulated SEL, determined for the entire blast event for each distance from the pier.

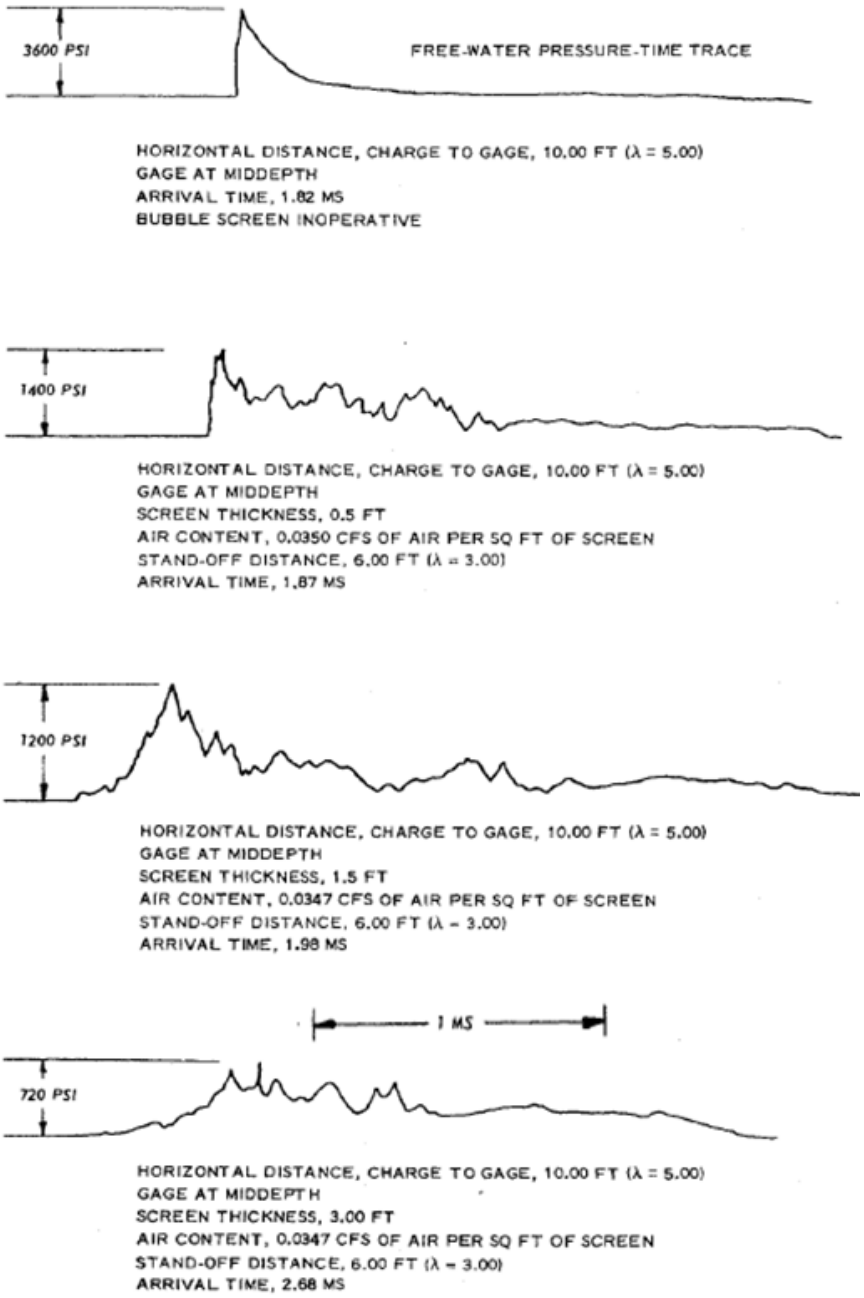


Note:
low-frequency = LFII; mid-frequency = MFII; high-frequency = HFII; Phocidae = PWI; Otariidaes = OWI
Source: Prepared by Illingworth and Rodkin for this analysis

Figure 4. Filters for Marine Mammal

BAS EFFECTIVENESS

The BAS would have an effect on the wave after a blast wave passed through it. In a research report published by USACE, the performance of a BAS was examined in detail (USACE 1964). USACE reported that the BAS reduced the peak pressure and elongated the pressure time history, as shown in Figure 5. It also has been found that for an energy metric such as SEL, the reduction produced by the BAS is equal to or greater than the reduction of the peak pressure (USACE 1991; Rude 2002; Rude and Lee 2007; Rivey 2011). To estimate the reduction for SEL values because of the BAS, SEL was reduced by 80 percent. Effectively, this was done by reducing SEL by 20 Log (0.20), or 14 dB. Delays below the mudline, which were located below the BAS, also were reduced by 80 percent, based on an assumption that the outside pier walls (not being removed) and Bay mud sediments would provide a similar level of attenuation. These SEL values and those without the BAS then were compared to the appropriate criteria for each marine mammal group. Because the calculation of SEL is based on the peak pressure, these estimates for the direct wave component were expected to be conservative for the same reasons as described for the peak pressures.



Source: Cole 1948

Figure 5. The Effect of Bubble Screens of Different Parameters on Underwater Unconfined Blast

ESTIMATION OF POSITIVE IMPULSE

To estimate positive impulse values, the expression originally developed by Cole for open water was used (Cole 1948). This expression includes only contributions from the direct wave, neglecting any contribution from the surface relief, bottom reflected, and bottom transmitted, consistent with the assumptions used to estimate SEL. In this case, impulse is given by:

$$I = 2.18 \times W^{1/3} \times \left(\frac{W^{1/3}}{R}\right)^{1.05} \qquad (7)$$

with the variables defined in Equation 4. The impulse also can be calculated equivalently from wave forms. Equation 5 produces impulse values in psi-msec, which were converted to Pa-sec by multiplying by 6.9 for comparison to the marine mammal criteria.

Unlike P_{pk} and SEL, no reduction by the BAS was assumed for the impulse calculation. The area under the p(t) curve undergoes little change after passing the BAS. The peak pressure was reduced, as noted previously; however, because the p(t) expands in duration, the area change is minimal. This behavior is well documented in the literature (Cole 1948; USACE 1964; USACE 1991; Rickman 2000). As discussed above, this is not the case for SEL, which is determined by the area under the $p^2(t)$ curve.

SUMMARY

The estimated distances (Table 3) to the marine mammal criteria for peak pressure, SEL, and impulse were based on established relationships between charge weight and distance from the literature. The estimated distances were determined assuming unconfined open water blasts from the original Cole equations or the Cole equations modified by USACE. The assumption of open water neglects several effects that could produce lower levels than estimated. These include no shielding by the pier structure before a specific blast, confining of the individual delays in the holes drilled into the pier structure, and longer distances to individual blasts than assumed by closest distance between the pier and the receptor point. For SEL, the assumption of open water blasts neglects the surface relief wave that, at longer distances from the pier, would tend to reduce SEL because of interference with the direct wave. Although the estimated levels and distances were conservative, sufficient uncertainty existed in the blast event and its propagation so that further, less conservative adjustments were not appropriate.

Table 3. Estimated Distances to NMFS Marine Mammal Impulse Criteria for Level B Harassment, Level A Harassment, and Mortality from the Pier E3 Implosion

Species	Level B Criteria		Level A Criteria			Mortality
	Behavioral Response	TTS Dual Criteria	PTS Dual Criteria	Gastro-Intestinal Track Injury	Lung Injury	
Pacific Harbor Seal	9,700 feet (2,957 meters)	5,700 feet (1,737 meters)	1,160 feet (354 meters)	35 feet (11 meters)	450 feet (137 meters)	205 feet (63 meters)
California Sea Lion	800 feet (244 meters)	470 feet (143 meters)	97 feet (30 meters)	35 feet (11 meters)	450 feet (137 meters)	205 feet (63 meters)
Northern Elephant Seal	9,700 feet (2,975 meters)	5,700 feet (1,737 meters)	1,160 feet (354 meters)	35 feet (11 meters)	450 feet (137 meters)	205 feet (63 meters)
Harbor Porpoise	44,500 feet (13,564 meters)	26,500 feet (8,077 meters)	5,800 feet (1,768 meters)	35 feet (11 meters)	450 feet (137 meters)	205 feet (63 meters)

Notes:
ft = feet; m = meters; GI = gastrointestinal; PTS = Permanent Threshold Shift; TTS = Temporary Threshold Shift
A BAS with 80 percent efficiency in acoustic attenuation was assumed for the implosion. The largest criteria distance (i.e., more conservative) is presented.
Source: Prepared by Illingworth and Rodkin for this analysis

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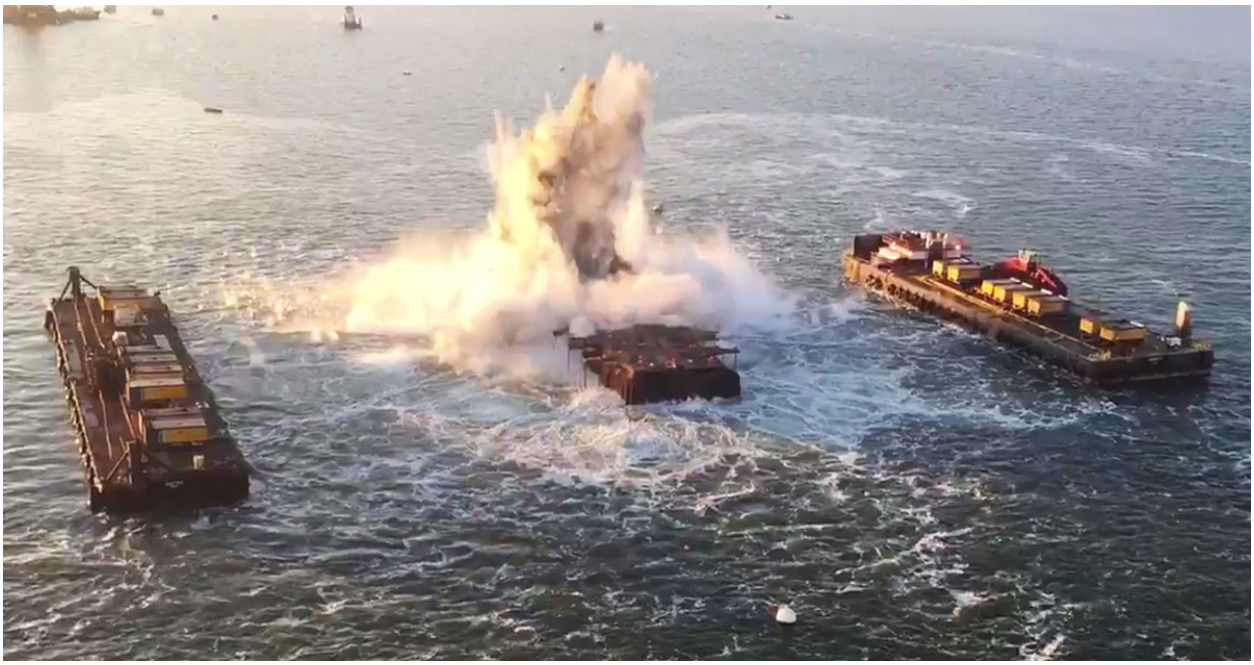
Appendix D. Draft Hydroacoustic Monitoring Results for the Pier 3 Demonstration Project

San Francisco – Oakland Bay Bridge
East Span Seismic Safety Project

PIER E3 DEMONSTRATION PROJECT

HYDROACOUSTIC MONITORING RESULTS

Final Draft



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EXECUTIVE SUMMARY

The California Department of Transportation (Department), as part of the San Francisco–Oakland Bay Bridge (SFOBB) East Span Seismic Safety Project (SFOBB Project), is in the process of dismantling the original east span of the SFOBB. As part of the dismantling phase of the SFOBB Project, the Department completed a demonstration project to remove Pier E3 via highly controlled charges (Demonstration Project). To minimize impacts on biological resources and determine the level of hydroacoustic noise from the Demonstration Project, the Department implemented several monitoring efforts.

Pier E3 was located on the original east span, west of the Oakland Touchdown (OTD) area, approximately 1,535 feet (468 meters) east of YBI near the coordinates 37048'56.75"N 122021'14.75"W, and within San Francisco County. Pier E3 rested in a depth of water approximately 50 feet (15 meters). Top dimensions of the pier cap were 80 feet (24 meters) by 134.5 feet (41 meters), not including the fender apron. Exterior walls along the perimeter of the caisson were 4 feet (1.2 meters) wide, while the interior walls of the rectangular chambers were 3.3 feet (1 meter) in width. The mudline (i.e., the bottom of the Bay floor) at Pier E3 ranged in elevation from -43 to -51 feet (National Geodetic Vertical Datum of 1929 [NGVD29]).

To complete the implosion, charges were loaded into the drilled boreholes, defined in a Blast Plan for the Demonstration Project (Department 2015b). The controlled implosion was accomplished using hundreds of small charges with delays between individual charges, the entire detonation sequence lasted 5.3 seconds. To minimize impacts on marine biological resources in the Bay, a Blast Attenuation System (BAS) was installed around the base of the pier to minimize noise and pressure impacts generated by the controlled implosion.

The Demonstration Project implosion took place on November 14, 2015 consisting of 588 individual blasts that detonated 9 milliseconds apart. The underwater sound pressure monitoring occurred at numerous strategic positions around Pier E3 ranging in distance, including, at two locations within the BAS at approximately 23.5 and 24.5 feet, at four near field locations outside the BAS at distances ranging from 74.5 to 153 feet, and at seven far field locations ranging from 500 to 4,000 feet. Near field monitoring was conducted with PCB pressure transducers capable of measuring up to 1,000,000 hertz (Hz). Further away from Pier E3 at 500 feet, PCB pressure transducers and hydrophones capable of 170,000 Hz were placed for underwater monitoring. Only the hydrophones were used for monitoring at the remaining far field locations.

Results

Monitoring of the implosion was specific to two regions around Pier E3 with unique methods, approaches, and plans for each of these regions. These regions included the "near field" and the "far field." For Pier E3, the near field comprised of measurements taken within 200 feet of the pier, while the far field comprised of measurements taken at 500 to 4,000 feet. Due to the peak pressures that were expected within 500 feet, pressure transducers were required for data acquisition instead of the conventional hydrophones. In the near field, the dimensions of the pier were relatively large compared to the measurement distance. As a result,

the relationship between sound pressure and distance from the Pier E3 was complex, as the pressure from any one blast would depend not only on distance from the pier but also on the position of the blast along the face of the pier. Beyond 500 feet, sound levels were expected to display a more consistent logarithmic fall off with distance.

Figure 1 below presents the results including the highest peak pressure level (L_{pk}) and cumulative sound exposure level (SEL_{cum}) measured at each location in the near field and far field. The calculated fall-off curves and the established fish criteria for underwater noise are indicated by the representative colored lines. As shown in the figure, the decrease in level with distance is indicated by a fall-off rate for the measured L_{pk} was approximately 23.9 times the logarithm of distance while the SEL_{cum} fall-off rate was approximately 28.4. The measured L_{pk} fall-off curve had about the same fall-off rate as the calculated curve with a +2 decibel (dB) offset. The measured SEL_{cum} curve had a faster fall-off rate than the calculated and was over 5 dB below the calculated curve from within 500 feet to 4,000 feet.

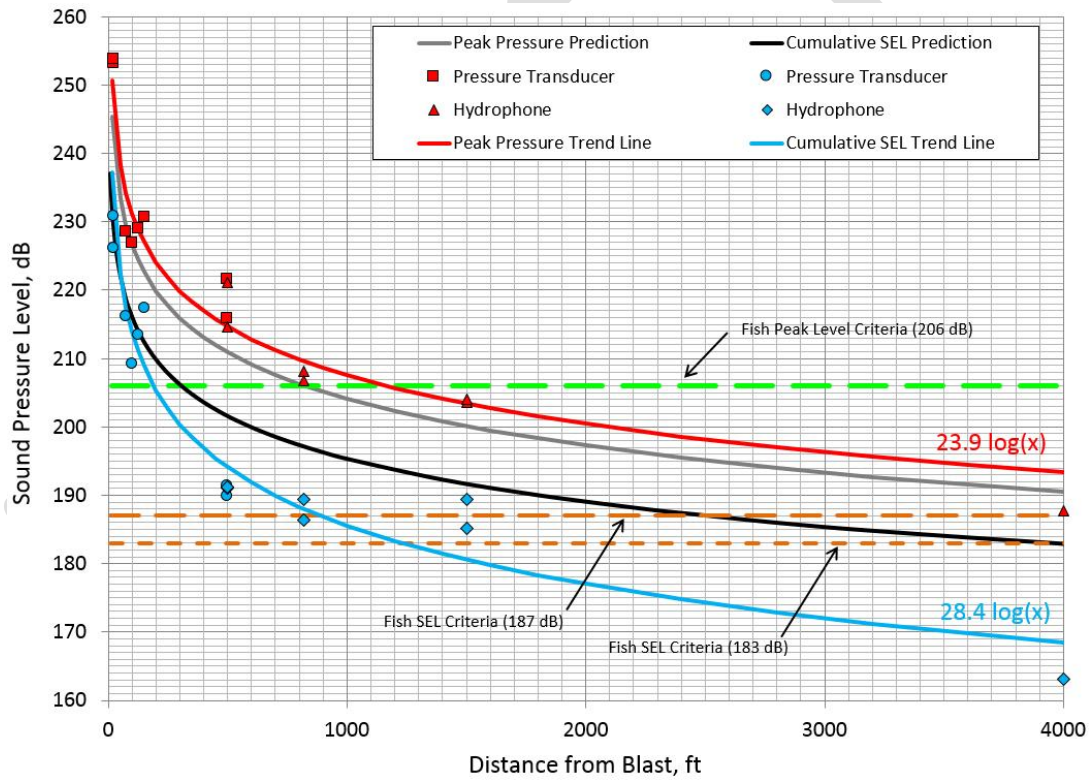

Figure 1: Summary of peak pressure level and cumulative sound exposure level results

Using the peak pressure level and cumulative sound exposure results presented in Figure 1, the distances to the fish and marine mammal criteria were determined based on the logarithmic trend lines through the data points. A comparison of calculated distances and those determined from the monitoring measurements are presented in Figure 2 for the fish criteria and marine mammal temporary threshold shift (TTS) and permanent threshold shift (PTS) criteria. The results of Figure 2 indicate that the distances determined for the measured SEL_{cum} metrics were

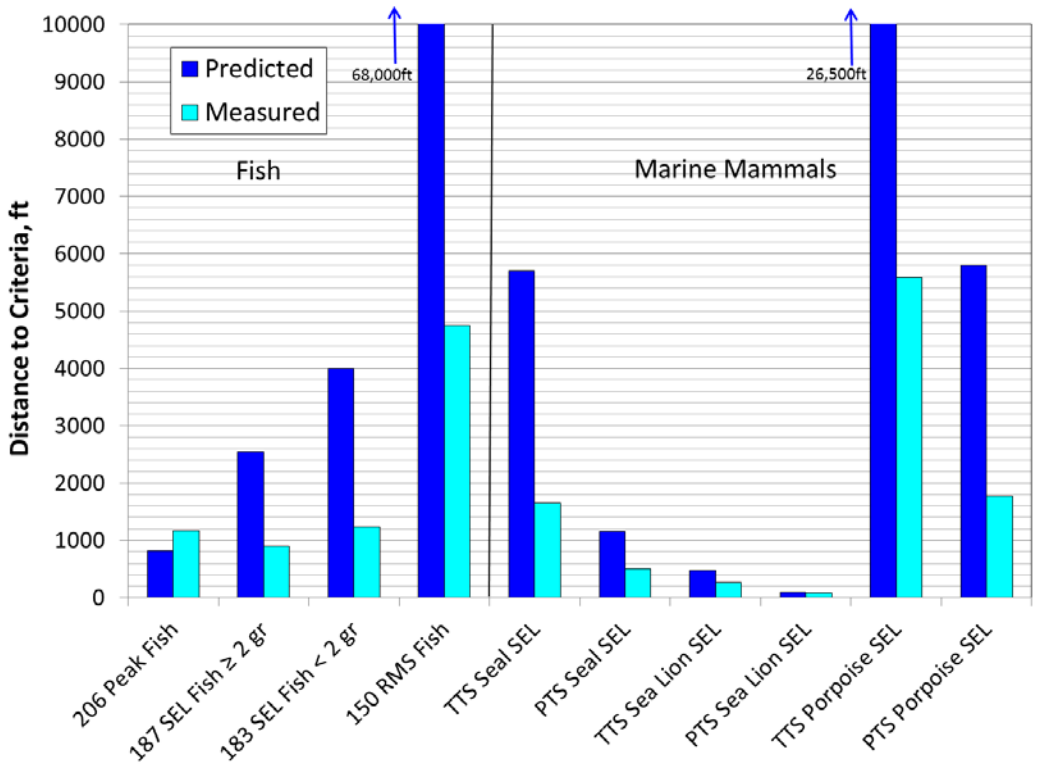

Figure 2: Summary of the calculated distances to criteria and those indicated by measurements

consistently below of those estimated from the calculations. For peak pressure, the distance determined from the measurements is slightly greater than that estimated from the calculations.

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INTRODUCTION

On November 14, 2015 at about 7:17 a.m., Pier E3 of the original east span of the San Francisco-Oakland Bay Bridge was demolished by means of a controlled implosion, occurring largely underwater. This means of demolition was proposed as an alternate method to mechanical methods for dismantling Pier E3. Mechanical methods were expected to result in more in-water work days, have a greater impact on aquatic resources, and require a longer time frame for completion. The implosion was proposed to demonstrate the effective use of controlled charges so that this method could be considered for dismantling subsequent, remaining piers of the original SFOBB East Span. As part of this demonstration, hydroacoustic monitoring was performed during the implosion at strategic locations around the Pier E3. The purpose of hydroacoustic monitoring during the controlled implosion of Pier E3 was twofold: 1) to evaluate distances to specific fish and marine mammal impact noise criteria; and 2) to improve the calculation of underwater noise impacts that controlled implosion removal of remaining in-water piers may have.

The criteria used for potential impacts to fish are those currently established by the National Marine Fisheries Service (NMFS) for underwater impact pile driving along the U.S. west coast. These criteria, for the onset of injury, include a cumulative sound exposure level (SEL_{cum}) of 187 dB re 1 μPa^2-s for fishes more than 2 grams and 183 dB re 1 μPa^2-s for fishes less than 2 grams, and a single-strike peak level (L_{pk}) of 206 dB re 1 μPa for all sizes of fishes.[1] Noise criteria for marine mammals used for the implosion of Pier E3 follow the interim underwater explosive criteria established by the National Oceanic and Atmospheric Administration (NOAA) and consist of SEL, L_{pk}, and acoustic impulse. The SEL criteria are complex as the levels vary by species and have individual frequency weightings also varying by species. A full list of these criteria is included in the final Pier E3 Demonstration Project Biological Monitoring Programs document of October 2015.[2]

The Pier 3 implosion consisted of 588 individual blasts of 8 different charge weights, ranging from 21 to 35 lb/delay. The duration of the event was approximately 5.3 seconds from the first detonation to the last with individual charges separated by 9 milliseconds. Close to the pier, the individual blasts are distinguishable from each other. For any one measurement location, the highest peak pressure could occur at any time during the implosion event. The structure was about 135 feet long in the north/south direction and 80 feet wide in the east/west direction at its largest cross section. During the demolition event, the pier was encircled with a Blast Attenuation System (BAS), which produced a stream of air bubbles surrounding the structure, as shown schematically in Figure 3 and in a photograph of the water surface around Pier E3 in Figure 4. Blast mats were positioned on the top and sides of the structure to control fly rock.

As part of the process for permitting the demonstration implosion, underwater sound levels were calculated based on accepted theory for open water blasts. These equations were modified to account for confinement of the individual charges imbedded in the concrete structure and an assumed efficiency of the BAS to reduce the underwater blast pressures. A critical component of the analysis of the hydroacoustic results is the comparison of these estimated and actual measured levels. This report includes a description of the methods used to calculate the estimated hydroacoustic levels, a description of the monitoring measurements, a summary of the results,

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and a discussion on the implications for future calculated and monitoring based on the Pier E3 implosion experience.

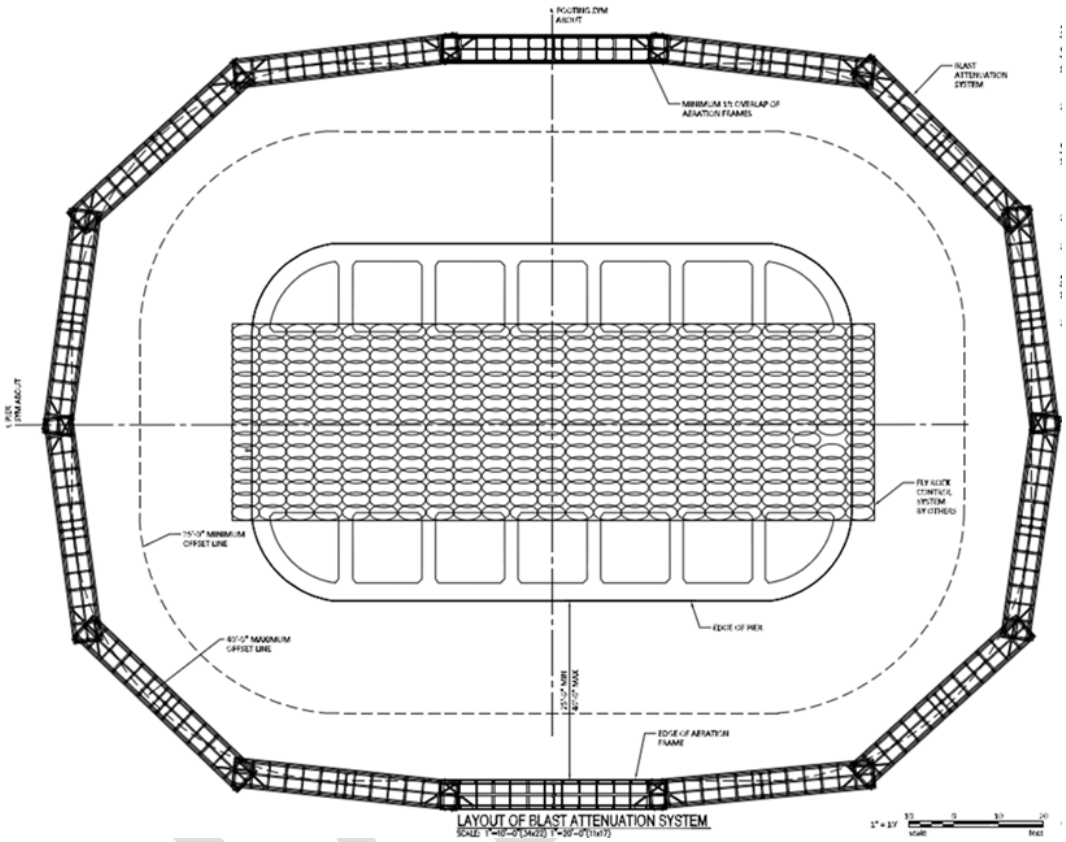

Figure 3: Blast attenuation system schematic

Figure 4: Aerial photograph with the BAS in operation prior to the implosion

ESTIMATED LEVELS

Metrics

To compare with appropriate marine mammal and fish sound criteria, the implosion's pressure signals were reduced and analyzed to obtain maximum peak pressure level, impulse, cumulative SEL, and root mean square (RMS) levels. The pressure versus time signals from the near and far field monitoring locations were processed using the same algorithm to calculate the required metrics. Peak pressure level is defined as:

$$L_{pk} = 20\ Log_{10}\left(P_{pk}/P_{ref}\right) \quad (1)$$

where L_{pk} is the peak level in dB, and P_{ref} is the reference pressure of 1 μPa. The acoustic impulse which is the time integral of the energy under the greatest positive peak pressure is given as:

$$Im = \int_{t_1}^{t_2} P(t)\ dt \quad (2)$$

where $P(t)$ is the instantaneous positive pressure, t_1 is the start of the positive pressure corresponding to highest positive peak in the blasting event, and t_2 is end of the positive pressure. To calculate the impulse numerically, a discrete summation was used for the implosion of the form:

$$Im = \sum_{i=0}^{N} P_n t_n \quad (3)$$

where t_n is the time resolution of the pressure versus time signal (e.g., 0.005 milliseconds for the 2,000,000 Hz signals), P_n is the pressure in a specific increment of time, and N is sufficiently that $N \times t_n$ covers the duration of the positive pressure pulse. Cumulative SEL is given by:

$$SEL_{cum} = 10\ Log_{10}\left(\int_0^T \frac{P^2(t)\ dt}{P_{ref}^2}\right) \quad (4)$$

where T is the duration of entire implosion, $P^2(t)$ is the instantaneous pressure squared, and P_{ref} is the reference pressure of 1 μPa. The numerical calculation used for the analysis of the near and far field locations is determined similarly to the impulse, except that integration is applied to the pressure squared and the integration time includes the entire blasting event, not just a single positive pressure pulse. Cumulative SEL is calculated as a summation by:

$$SEL_{cum} = 10Log_{10}\left(\sum_{i=0}^{t} \frac{p_i^2}{p_{ref}^2} \Delta t_i\right) \quad (5)$$

where Δt_i is the time resolution of the pressure versus time signal, p_i^2 is the pressure squared in a specific increment of time, and t is the total duration of the blasting event. For the SEL in general, the limits or duration of the summation are harder to determine than impulse values, as the waveform can contain both positive and negative pressures. The RMS level is given by:

$$p_{RMS} = \sqrt{\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} p^2\ (t)dt} \quad (6)$$

$$L_{RMS} = 20\ Log_{10}\left({p_{rms}}/{p_{ref}}\right) \quad (7)$$

where T_1 is the time at the beginning of the blasting event, and T_2 is the time at the end. Numerically, the RMS calculation is given by:

$$L_{RMS} = 20\,Log_{10}\left\{\sqrt{\frac{1}{T_2-T_1}\sum_{T_1}^{T_2} p_i^2\,\Delta t_i}\Big/ p_{ref}\right\} \tag{8}$$

Metric Calculations

General Assumptions

The blast event consisted of a total of 588 individual explosions of varying charge weight; the largest was 35 lb/delay, and the smallest was 21 lb/delay. The blasting sequence was rather complex and is shown schematically in Figure 5. Blasts would start in several interior walls of

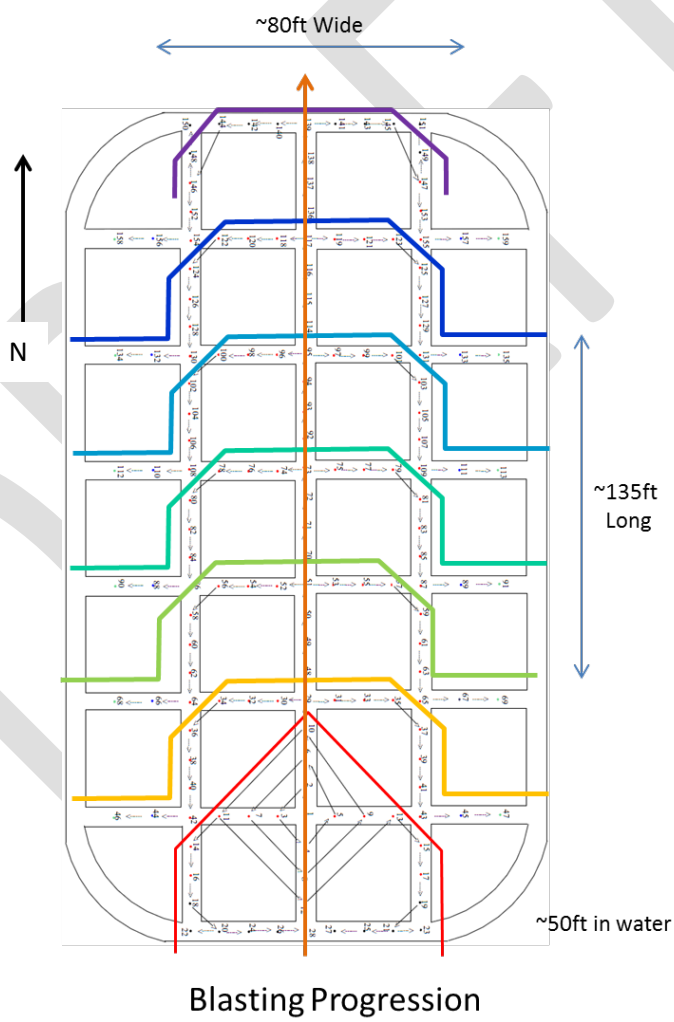

Figure 5: Sequence of the firing of individual charges

the southern portion of the structure followed by the outer walls of the south side. The blasts in the inner walls were planned to occur just prior to the adjacent outer walls. The interior first, exterior second blast sequence continued across the structure, moving from south to north. The time for the 588 detonations was 5.3 seconds, with an average delay time of 9 milliseconds (ms) between individual detonations. As the blasting progressed, locations to the east, north, and west of the pier were shielded from the blasting on the interior of the structure from the still standing exterior walls of the Pier. However, towards the conclusion of the blast, each direction experienced blasts from the outer walls that were not shielded.

To calculate P_{pk} and $P(t)$, several assumptions were made. For simplification, it was assumed that there was only one blast distance, and it would occur at the closest point on the Pier from the receiver point. In actuality for almost all explosions, distances from the blast were greater, as the Pier is approximately 135 feet across and 80 feet wide. Based on these dimensions, the actual blast point can be up to the diagonal distance of 157 feet further from the receptor point used for the calculation. As a result, the calculated peak level is the maximum expected for one 35-lb blast, while the other levels should be lower, depending on the distance from the actual blast location to the calculation point and weight of the charge. In other words, the pressure received at the calculation point would not be 588 signals of the same amplitude but would be from one at the calculated level for a 35-lb charge and 587 of varying lower amplitudes. Similarly, in the vertical direction, the location varies over a height of about 50 feet, and those blasts that were not at the same depth as the receiver would also be lower. This effect of variation in assumed blast-to-receiver distance would be most pronounced close to the Pier, while at distances of about 1,000 feet or greater, the effect would be less than 1 dB.

In the calculations, it was also assumed that there would be no self-shielding of the Pier as the explosions progressed. From the above discussion of the blast sequence, some shielding of the blasts along the interior of the Pier is expected. However, the blasts that occurred in outer wall (towards the end of the detonation) would not be shielded for all blasts. A blast in the outer wall that has a direct line-of-sight to the receiver calculation point would not be shielded and would generate the highest peak pressure relative to the L_{pk} criterion. The cumulative SEL and the RMS levels however, would be reduced to some degree by the outer walls until they are demolished, as these metrics are defined by the pressure received throughout the entire 5.3 second event. Due to the complexity of the blast sequence, this shielding effect was not considered in the calculated SEL and RMS levels.

The explosives were placed in 2¾- to 3-inch diameter holes drilled into the concrete pier structure. The outer walls of the Pier are nominally 3 feet and 11½ inches thick and inner walls are nominally 3 feet thick. Individual blasts should not be exposed to open water and some confinement of the blasts was expected. For confined blasts, the calculated pressures can be reduced by 65% to 95%,[3,4,5,6] corresponding to multiplication factors from 0.35 to 0.05, respectively. Based on a review of the available literature and recent data from similar explosive projects, a conservative confinement factor of K=7500 was assumed. This equated to a reduction in pressure by a multiplication factor of 0.3472.

Another assumption was to consider only the direct wave from an individual blast. In shallow water, the signal at the receiver point could consist of the direct wave, surface-relief wave

generated at the water/air interface, a reflected wave from the bottom, and a wave transmitted through the bottom material, as illustrated in Figure 6[7]. For estimating P_{pk} , only the direct wave was considered as it was expected to have the highest magnitude and will arrive at the receiver location before

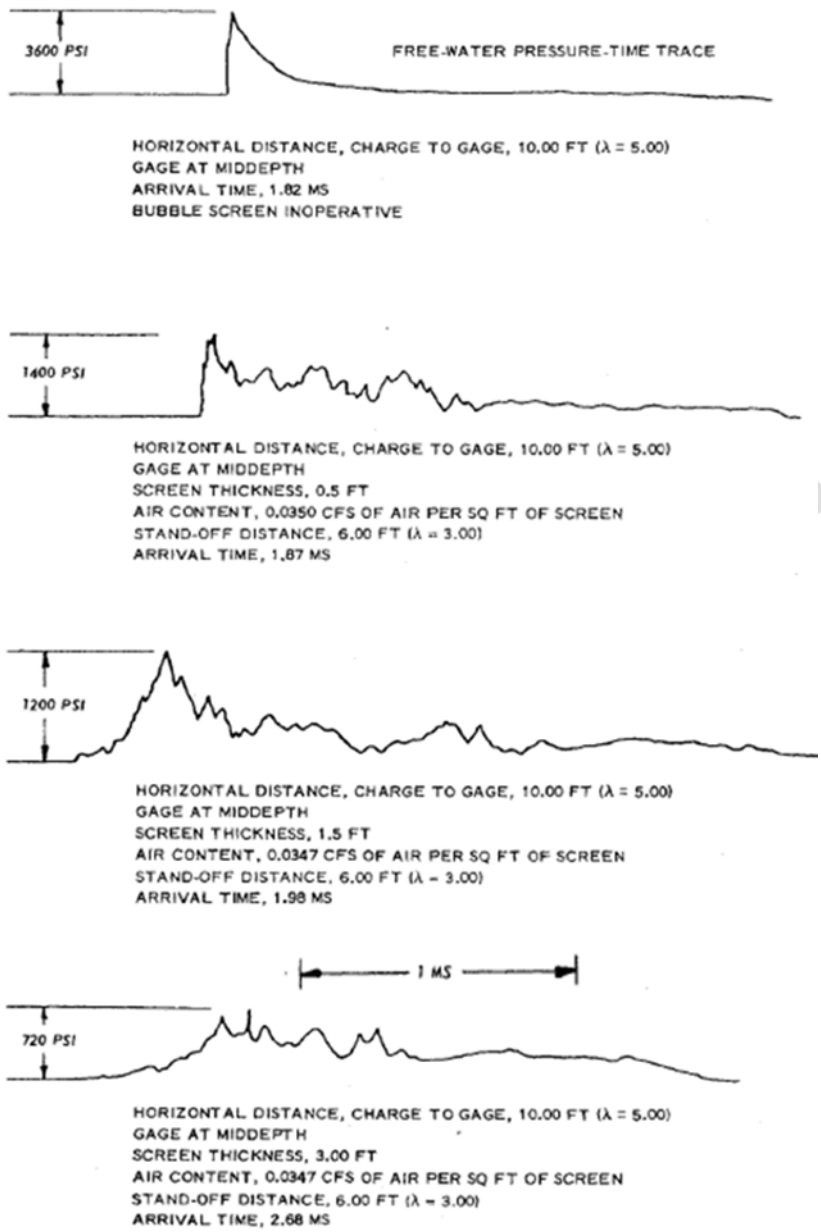

Figure 6: The effect of bubble screens of different parameters on underwater unconfined blast[7]

any other wave component. However, *P(t)* after the arrival of the direct wave peak pressure will be effected. The surface-relief wave is negative so that when it arrives at the receiver location, it will reduce the positive pressure of the direct wave and can make the total pressure negative at times after the arrival of the initial positive peak pressure. Since the SEL is a pressure squared quantity, any negative pressure can also contribute to the SEL. However, the amplitude and

arrival time of the surface-relief wave depends on the geometry of the propagation case, that is, depth of water, depth of blast, and distance and depth of the receiver point. The effect of this assumption is discussed further in the section on SEL.

Calculation of Peak Pressure

Peak pressures were calculated by following the modified version of the Cole Equation for calculation of blasts in open, deep water[8]. The peak pressure is determined by:

$$P_{pk} = K(\lambda)^{-1.13} \quad (9)$$

where P_{pk} is peak pressure in psi, and λ is the scaled range given by $R/W^{1/3}$, in which R is the distance in feet and W is the weight of the explosive charge in pounds. A modified version of the Cole Equation has been documented in U.S. Army Corps of Engineers (USACE) Technical Letter No. 1110-8-11(FR) and is applicable to shallow water cases, such as that of the Pier E3 demolition[9]. The constant K factor multiplier in the USACE calculation is 21,600 for an open-water blast instead of the 22,550 from the original Cole Expression. This factor is slightly less (~4%) than the original Cole. The decay factor (-1.13) used in the USACE modified equation remains the same as the original Cole Equation. To account for the confining effect of the concrete pier structure, a conservative K factor of 7,500 was used, corresponding to multiplying USACE P_{pk} by a factor of 0.3472. With a minimum delay between blasts of 9 ms, the individual explosions were planned sufficiently apart in time to avoid individual blasts combining into a higher peak pressure. As a result, the peak pressure was taken as that calculated for the largest charge weight of 35 lb/delay. A blast attenuation system (BAS) was specified in the blast plan. Based on the literature and recent results from similar projects, reductions in the pressure peak of 85% to 90% or more were expected. For determining P_{pk} in this analysis, a conservative reduction of 80% was used. Based on values of confinement, anticipated BAS performance, and the general assumptions above, the calculated peak pressures were expected to be conservative.

Calculation of SEL Values

To calculate SEL values as a function of distance from the blast, pressure versus time histories for all of the 8 charge weights were calculated for varying distances. The open-water equation used for these calculations was that modified by the USACE[9], and based on methods pioneered by Cole[8]. Pressure as a function of time is given by:

$$p(t) = P_{pk} e^{-\left(\frac{t-t_a}{\theta}\right)} \quad (10)$$

where t_a is given as $R/5000$ and θ is:

$$\theta = 6.0x10^{-5} W^{1/3} (\lambda)^{0.18} \quad (11)$$

Some of the time histories produced by these equations are shown in Figure 7 for varying distances from the blast.

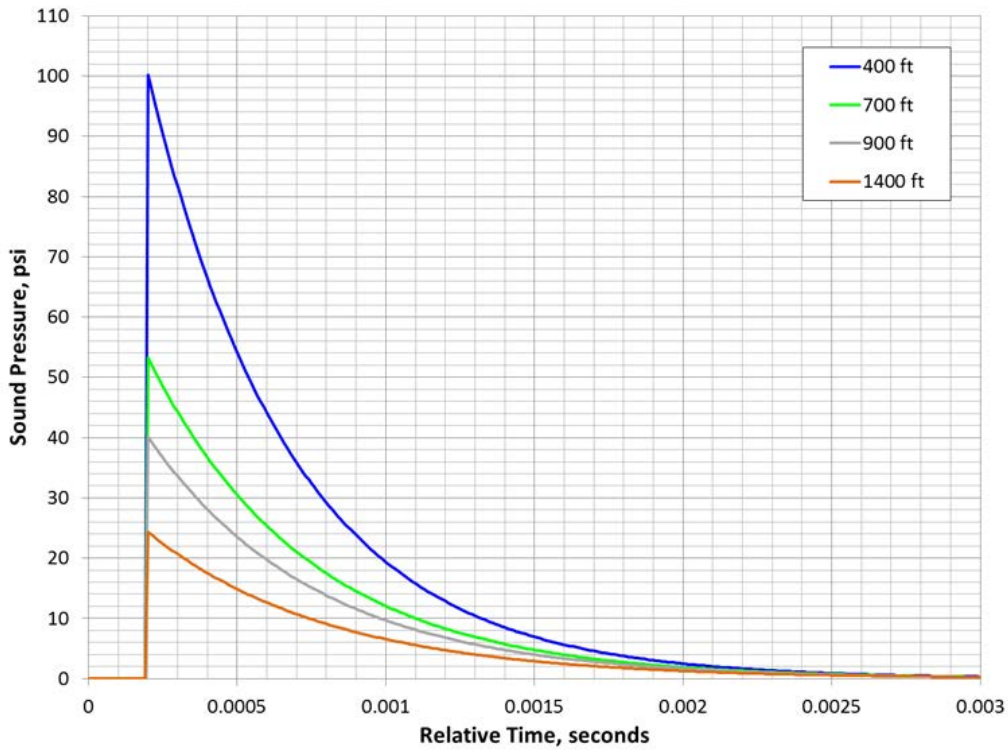

Figure 7: Blast wave time histories for different blast distances

As discussed previously, there are other wave components that could have been considered in the SEL calculation, including the surface relief wave, reflection from the bottom, and transmission through and re-radiation from the bottom. Little or no contribution was expected from the bottom, based on its sedimentary nature and previous experiences measuring noise during underwater pile driving in the area of the San Francisco Bay around Pier E3. The negative surface relief wave could be a factor in the SEL calculation. This wave could either increase or decrease the SEL, depending on its arrival time relative to the direct wave. For small differences in arrival time, the surface relief wave would decrease the total SEL as a portion of the positive direct wave is negated by the addition of the negative surface relief wave. This is illustrated in Figure 8 for a blast and receiver depth of 30 feet and at a range of 1,000 feet. In this case, the surface relief wave essentially balances the direct wave so that the total SEL is within a few tenths of a decibel of the direct wave only. For closer distances and when the receiver and blast locations are near the bottom, the total SEL can become greater than the direct wave SEL, but only by less than 3 dB. However, whenever the source or receiver is near the surface, the direct wave SEL would be greater than the total SEL and could approach being 10 dB greater at distances beyond 1,000 feet. Since the accumulated SEL values only approach the criteria at distances greater than about 2,300 feet, the surface relief wave is ignored in this analysis, knowing that the surface relief wave would only tend to produce lower SEL values than the direct wave.

Considering only the direct wave, the time histories such as those in Figure 7 were squared and summed in a numerical version of Equation 2 to calculate single blast SEL for each blast weight.

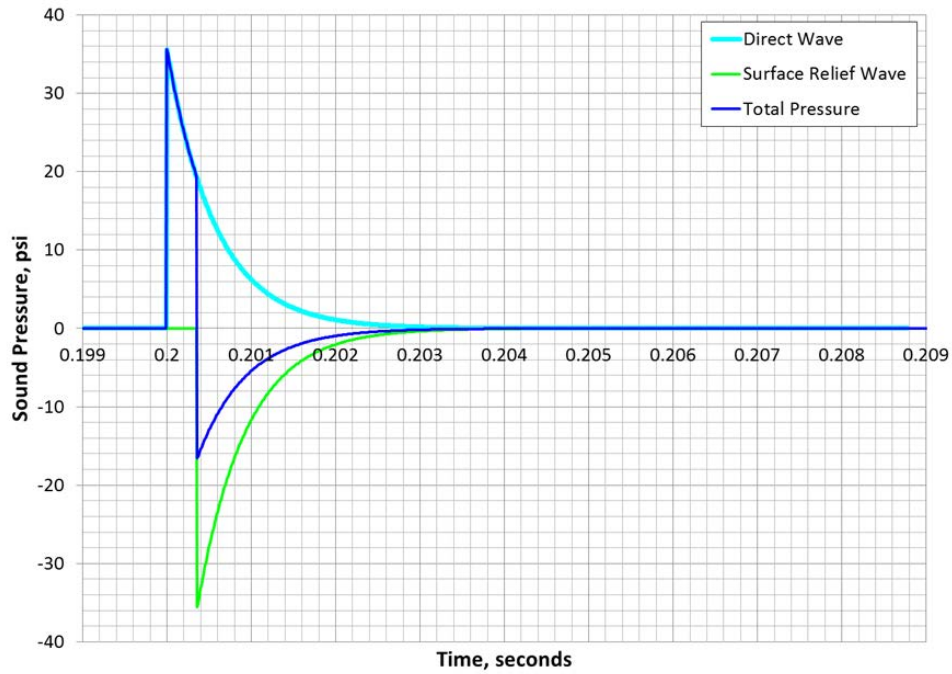

Figure 8: Calculated total pressure versus time history for combined direct and surface relief wave 1,000 feet from the blast with source and receptor 30 feet deep

These calculations were then extended to distances out to 160,000 feet. To determine the cumulative SEL for all 588 blasts, the single blast SEL values, as a function of distance, were calculated for the other charge weights of 35, 32.5, 30, 29.6, 26, 24, 22.5, and 21 lbs. For each weight, the cumulative SEL was determined by adding 10Log(N), where N is the number of the blasts for each weight. For example, 21.3 dB was added to the 35-lb single blast SEL to account for 135 blasts of this charge weight. The values for all the charge weights are summarized in Table 1. These accumulative SEL values for each charge weight were then summed (on an energy basis) to get the total accumulative SEL for the unconfined blast sequence. To account for the confinement factor of 0.3472 (K=7500), 20Log(0.3472) or -9.2 dB was added to the unconfined values.

Table 1: Charge weights per delay, number of delays, and added level to accumulate number of blasts

lbs/Delay	Total Number of Delays, N	10Log(N), dB
35	135	21.3
32.5	24	13.8
30	135	21.3
29.6	111	20.5
26	24	13.8
24	12	10.8
22.5	12	10.8
21	135	21.3
Total	588	

The BAS would have an effect on the wave once a blast passes through it. In a research report by USACE in 1961, the performance of BAS was examined in detail. It was reported that a BAS reduces the peak pressure and elongates the pressure time history. It has also been found for an energy metric, such as SEL, that the reduction produced by the BAS was equal to or greater than the reduction of the peak pressure[2,7,8]. To estimate the reduction for SEL values due to the BAS proposed blast design, SEL was reduced by 80%. Effectively, this was done by reducing the SEL by 20Log(0.20), or 14 dB. These SEL values and those without the BAS were then compared to the fish criteria of 183 dB and 187 dB. Because the calculation of SEL is based on the peak pressure, these calculated values for the direct wave component were expected to be conservative for the same reasons as described for the peak pressures.

Calculation of RMS Levels

The RMS levels were derived from the cumulative SEL values. Comparing Equations 2 and 3, the difference between SEL and RMS is that RMS is divided by the interval from the start of the blast to the end of the blast (ΔT). The "end" of the blast is somewhat ill-defined, however. The SEL is concluded when the received energy stops increasing with time. The time over which this occurs is not a factor. For RMS, time is a factor, and the RMS value is inversely related to ΔT. If ΔT is too short such that it does not include all of the energy from the blast, the RMS value may be overestimated. For calculations of RMS level for the Pier E3 blast event, the blast time of 5.3 seconds was used. The time over which energy is received, however, was probably slightly longer than this due to the elongating effect of the BAS and outward propagation of the wave. Given the 9-ms delay between detonations, the error should be quite small, and values calculated would be conservative. To calculate the RMS levels, 10Log($^{1}/_{5.3}$), or -7.2 was added to the SEL values.

Calculation of Impulse Values

To calculate positive impulse values, the expression originally developed by Cole for open water was used[8]. This expression includes only contributions from the direct wave neglecting any contribution from the surface relief, bottom reflected, and bottom transmitted, consistent with the assumptions used to calculate SEL. In this case, impulse is given by:

$$I = 2.18 \times W^{1/3} \times \left(\frac{W^{1/3}}{R}\right)^{1.05} \qquad (12)$$

with the variables described previously. The impulse can also equivalently be calculated from wave forms as shown in Figure 7. Equation 10 produces impulse values in psi-msec, which were converted to Pa-sec by multiplying by 6.9 for comparison to the marine mammal criteria.

Unlike P_{pk} and SEL, no reduction by the BAS was assumed for the impulse calculation. As illustrated in Figure 6, the area under the $p(t)$ curve under goes little change after passing through the BAS. The peak pressure is reduced, as noted previously; however, since the $p(t)$ expands in duration, the area change is minimal. This behavior is well-documented in the literature[4,5,6,7]. As discussed above, this is not the case for SEL, which is determined by the area under the $p^2(t)$ curve.

Marine Mammal Weighting

For marine mammals, five groupings are considered in the criteria. These include Low-Frequency Cetaceans (LFII), Mid-Frequency Cetaceans (MFII), High-Frequency Cetaceans (HFII), Phocidaes (PWI), and Otariidaes (OWI). In the San Francisco Bay around Pier E3, the mammals of concern were identified to be Pacific Harbor and Northern Elephant Seals (Phocidae), Sea Lion (Otariidae), and Harbor Porpoise (High Frequency Cetaceans). The filters corresponding to these three groupings are shown in Figure 9. To apply these weightings, the Fast Fourier Transform (FFT) was calculated for the pressure time histories at each analysis distance (see Figure 7). Each FFT was then filtered using the frequency weighting specified for each group/species from Figure 9. Filter factors were then determined for each distance by subtracting the filtered result from the unfiltered FFT data and determining the overall noise reduction in decibels due to the filters. These filter factors were then applied to the cumulated SEL determined for the entire blast event for each distance from the Pier.

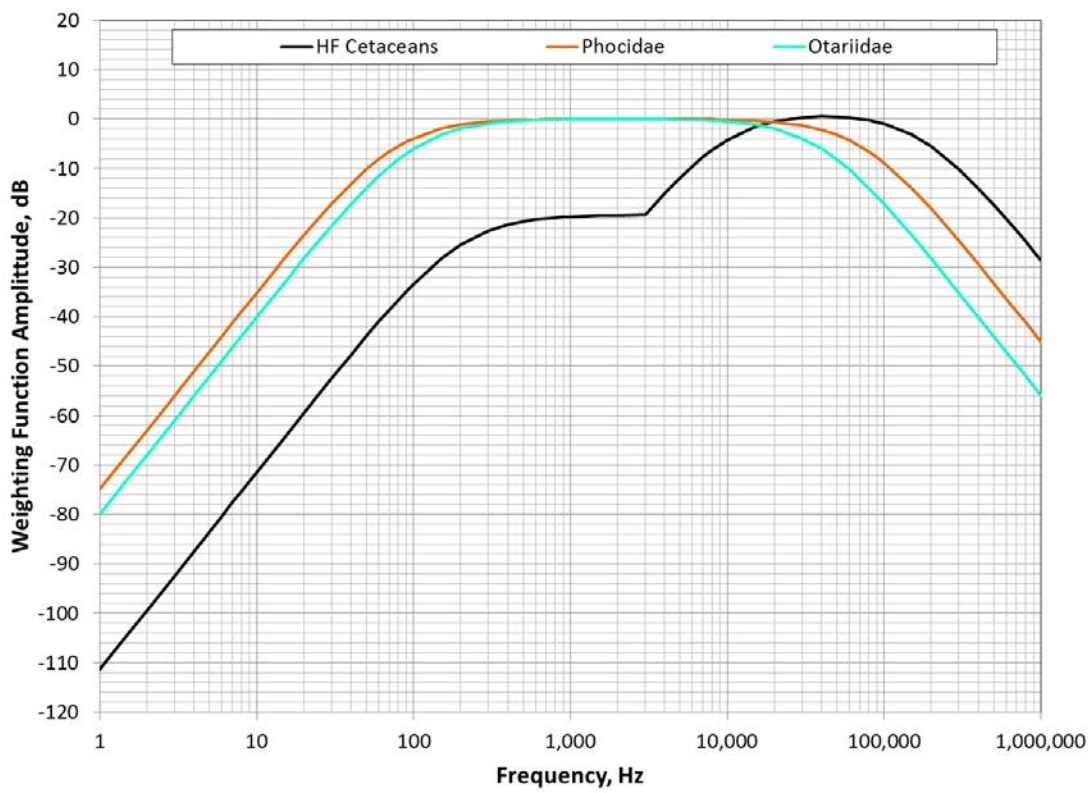

Figure 9: Weighting functions for marine mammal species of concern for the Pier E3 implosion

Results of Calculations

As discussed above, the peak pressure and SEL values were calculated for each of the eight charge weights. An example of this is provided in Table 2 for a distance of 1,000 feet. Corresponding values were calculated for distances from 10 to 160,000 feet.

Table 2: Calculated peak pressure and single and cumulative SEL values for each charge weight at 1,000 feet

lbs/Delay	Peak Pressure, dB	Single Blast SEL, dB	Total Number of Delays, N	10Log(N), dB	Cumulative SEL for Each Weight
35	204.1	168.6	135	21.3	189.9
32.5	203.9	168.3	24	13.8	182.1
30	203.6	167.9	135	21.3	189.2
29.6	203.6	167.8	111	20.5	188.3
26	203.1	167.3	24	13.8	181.1
24	202.9	166.9	12	10.8	177.7
22.5	202.7	166.6	12	10.8	177.4
21	202.4	166.3	135	21.3	187.6
Total			588		195.4

Fish Criteria

Plots of the calculated peak pressure level, cumulative SEL, and RMS pressure level are shown in Figures 10 and 11, along with the respective criteria levels for fish. The intersection of the criteria lines and the calculated lines are also indicated, giving the calculated distance to criteria threshold values given in Table 1.

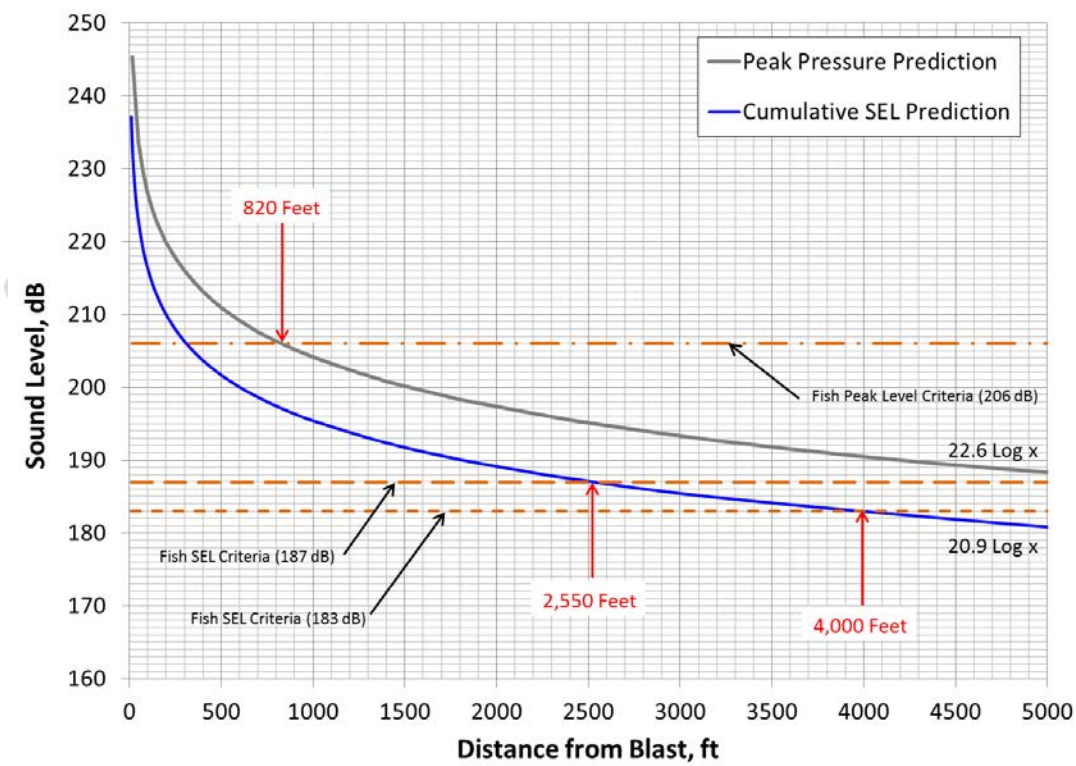

Figure 10: Calculated peak pressure level and cumulative SEL values with fish criteria and distances to threshold levels

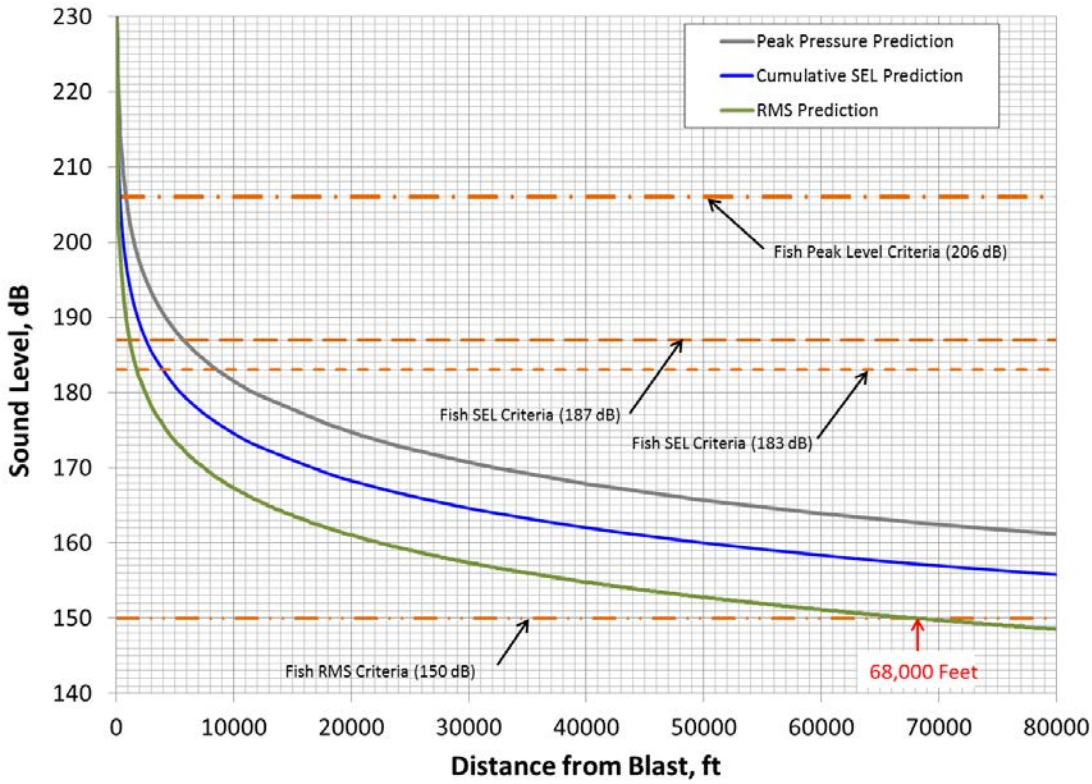

Figure 11: Calculated RMS levels with criteria and distance to threshold level along with peak pressure level & cumulative SEL values

Marine Mammal Criteria

For marine mammals, three SEL threshold values are prescribed corresponding to behavioral, temporary hearing threshold shift (TTS), and permanent hearing threshold shift (PTS). The values of the thresholds are also specific to each species grouping. The calculated SEL values and specific thresholds are shown in Figures 12 through 14 for seals, sea lions, and porpoises, respectively. The distances to the each of the thresholds for each of species are also shown in these figures. There are also criteria for gastro-intestinal (GI) tract injury, lung injury, and mortality. The GI threshold is quantified in peak pressure and the lung and mortality are in impulse, based on mammal weight and depth. The GI threshold for all categories of species is a peak pressure of 237 dB. The calculated peak pressures, criterion level, and distance to threshold are shown in Figure 15. For lung damage, the threshold is expressed as an impulse value of 13.7 psi-ms and applies to all categories. For mortality, the threshold is 32.02 psi-ms, and it also applies to all categories of marine mammals. The calculated impulse values, lung and mortality criterion level, and distance to these thresholds are shown in Figure 16.

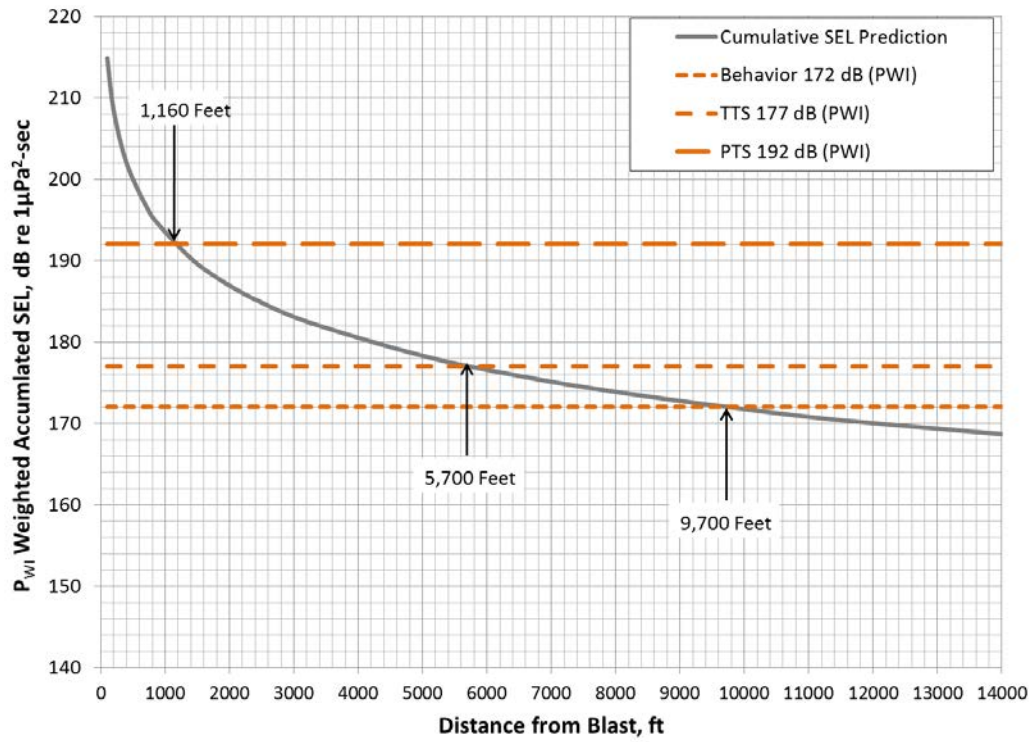

Figure 12: Calculated cumulative P_{WI} weighted SEL for seals with criteria and distance to thresholds indicated

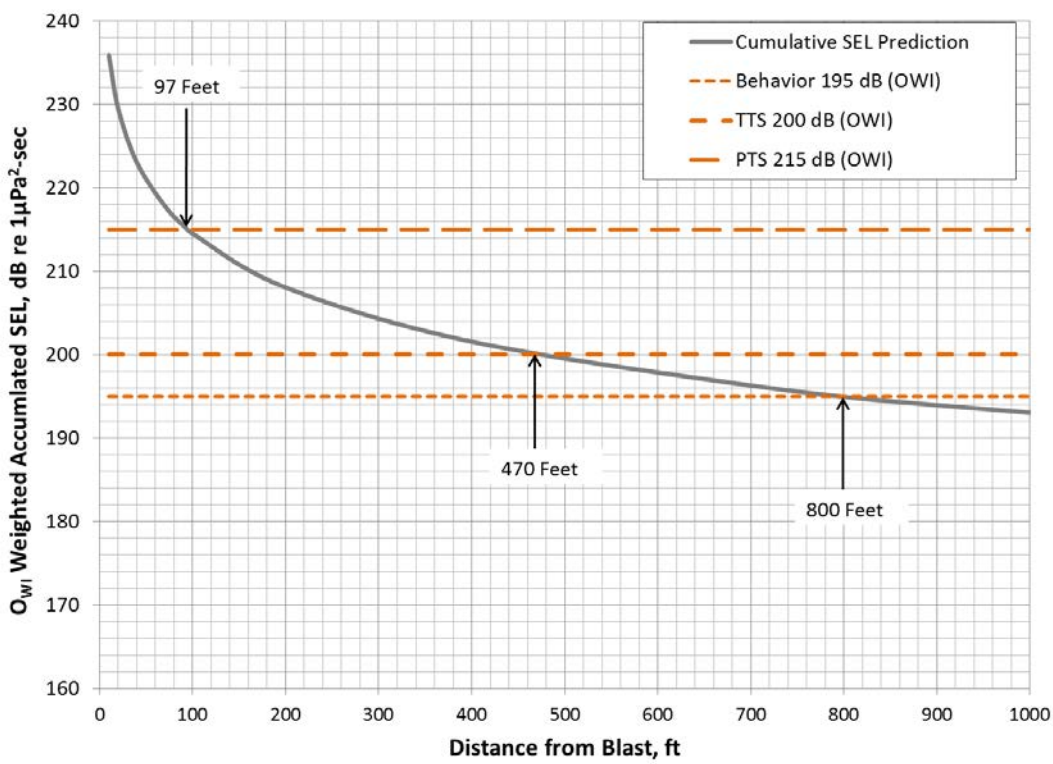

Figure 13: Calculated cumulative O_{WI} weighted SEL for sea lions with criteria and distance to thresholds indicated

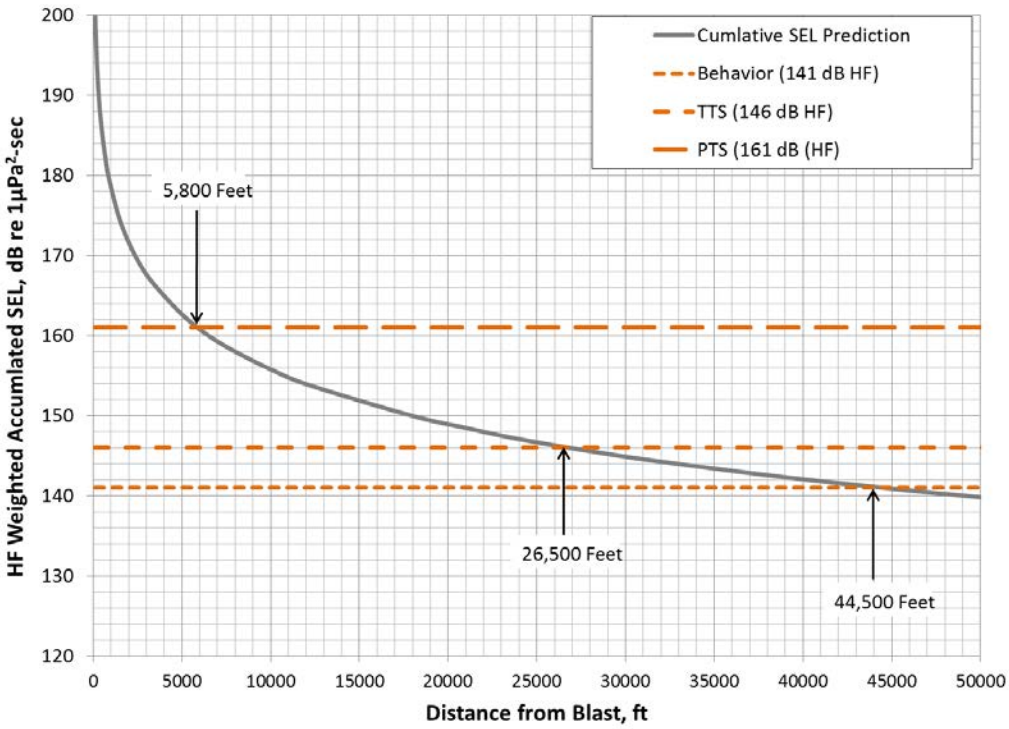

Figure 14: Calculated cumulative HF_{II} weighted SEL for porpoises with criteria and distance to thresholds indicated

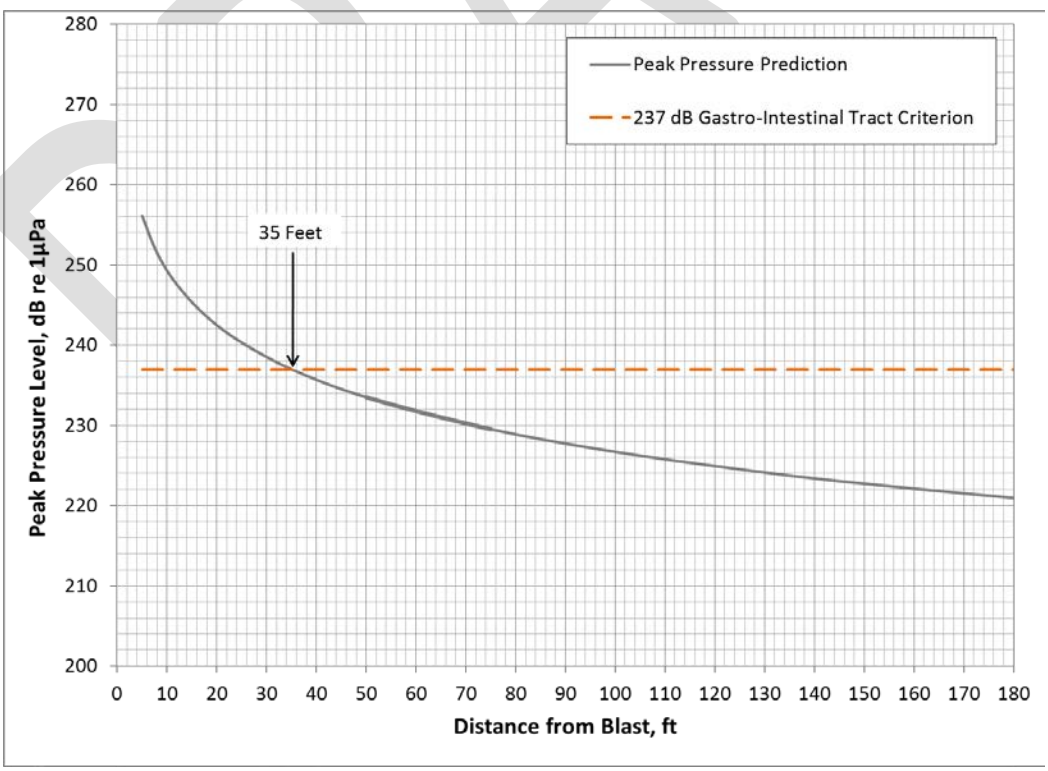

Figure 15: Calculated peak pressure level with GI criteria and distance to thresholds indicated

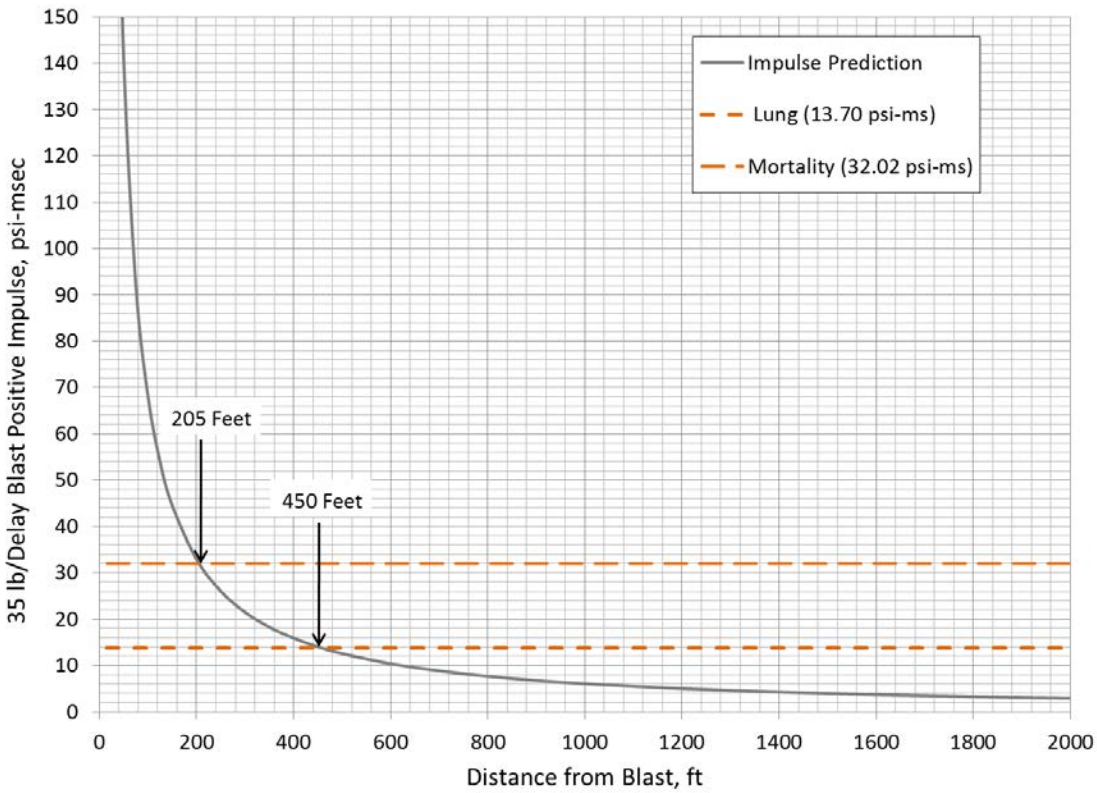

Figure 16: Calculated impulse calculation with lung & mortality criteria and distance to thresholds indicated

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DESCRIPTION OF HYDROACOUSTIC MONITORING PLAN

Monitoring of the implosion was specific to two regions around Pier E3 with unique methods, approaches, and plans for each of these regions. These regions included the "near field" and the "far field." For Pier E3, the near field comprised of measurements taken within 200 feet of the pier, while the far field comprised of measurements taken at 500 to 4,000 feet. Due to the peak pressures that were expected within 500 feet, pressure transducers were required for data acquisition instead of the conventional hydrophones. In the near field, the dimensions of the pier were relatively large compared to the measurement distance. As a result, the relationship between sound pressure and distance from the Pier E3 was complex, as the pressure from any one blast would depend not only on distance from the pier but also on the position of the blast along the face of the pier. Beyond 500 feet, sound levels were expected to display a more consistent logarithmic fall off with distance. The blasting contractor limited the personnel and materials within 1,500 feet of the implosion.

Measurement Locations

Near Field Locations

The near field monitoring plan consisted of 13 total monitoring locations in the north, south, and east directions from Pier E3 with the measurements taken at depths of 20 feet below the water surface. At three distances in the south line, measurements were also planned at depths 2 feet above the mudline resulting in a total of 16 pressure sensor locations as shown in Figure 17. The south line was selected to be along the line of the caged fish study out to a distance of 350 feet and to align with the far field monitoring line. Recordings of the pressure signals were to be performed with high speed devices on the east side barge. However, during preparation for the blast, it was determined that measurements at further out distances of 250 and 350 feet were not feasible due to recommendations by the sensor supplier on acceptable cable lengths to minimize electronic background noise.

For the implosion event, data was successfully acquired at five locations along the north line and at one location in the east line. The south line lost power prior to the implosion event, and no data could be collected. Along the north line, one monitoring location was positioned within the BAS at approximately 24.5 feet from Pier E3. The other locations along the north line were positioned at 74.5, 101, 126.5, and 153 feet from Pier E3 and outside the BAS. The successful measurement along the east line was located within the BAS, approximately 23.5 feet from the pier. The two planned locations outside the BAS along the east line were affected by flying debris and resulted in contaminated data, which could not be used for analysis.

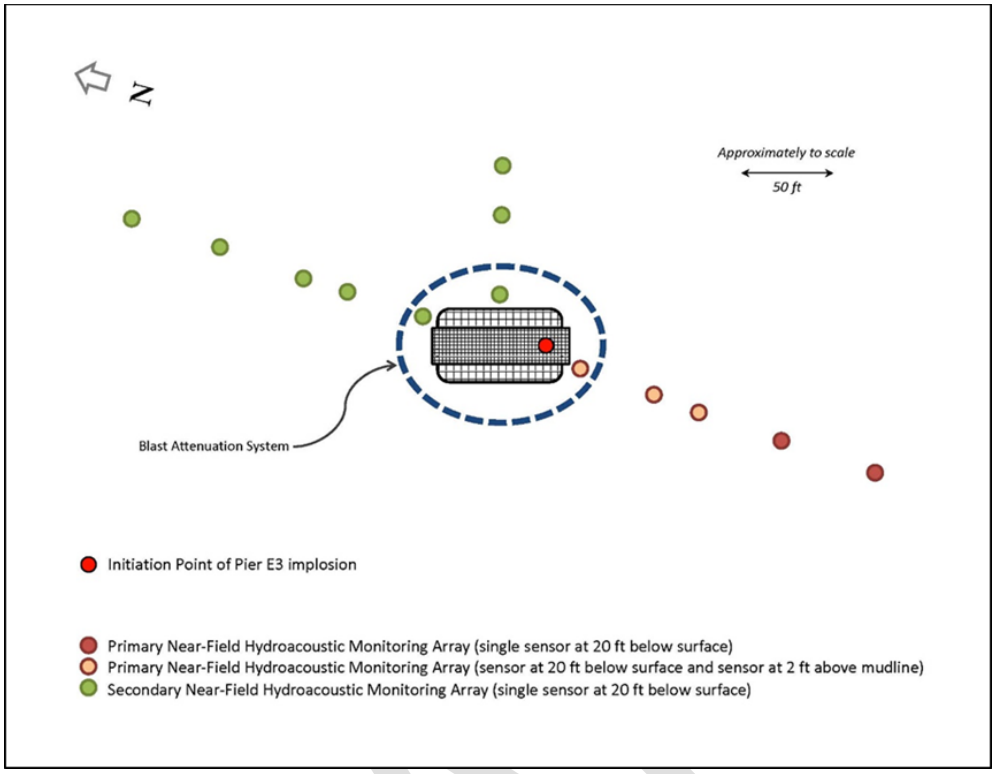

Figure 17: Location of all near field monitoring locations

Far Field Locations

Far field monitoring was planned at 10 locations in the east, south, and southwest directions, with the south and east lines measured at a logarithmic progression of 500, 1,000, 2,000, and 4,000 feet. The south line was selected to be a continuation of the south near field line and to be in deeper water. The east line was selected to provide comparable data to the south line, but in shallower water. It was of interest to examine the sound propagation differences between the shallower and deeper water to determine if significant differences occur as the remaining piers to the east are in shallower water. Two locations in the southwest direction were planned at distances of 500 and 1,000 feet that would complement the data at the same distances to the south and east. At the 500 feet locations, it was planned that the data would be taken from boats with the instrumentation operated by hydroacoustic monitoring personnel. This plan was later modified due to a requirement that a buffer zone of 1,500 feet surrounding Pier E3 be maintained in which only personnel directly involved with the blasting were allowed. It was also important to obtain data toward the end of the caged fish line, located at approximately 820 feet from Pier E3. The 11 resultant planned monitoring locations are shown in Figure 18. Due to 1,500 feet buffer limitation, it was determined that measurements at the closer distances would need to be unattended due to safety reasons.

For the implosion event, data was successfully captured at a total of seven locations in the south and east directions. Along the east line, data was measured at 500, 820, and 1,500 feet. Along the south line, data was measured at 500, 820, 1,500, and 4,000 feet. For these locations, all of the

monitoring was conducted at depths of 20 feet from the water surface or at mid-depth for shallower locations. Data for three locations (southwest 820 feet, east 2,500 feet, and east 4,000 feet) are not available due to loss of power. At 2,500 feet in the south direction, the buoy supporting the measurement recorder could not be found and was presumed to be struck by a water craft operating in the area.

Figure 18: Location of all far field monitoring locations

Instrumentation

Near Field Monitoring

Within the BAS where pressures from the implosion were highest, the rise time of the pressure signals were very short and required high speed acquisition of data. To meet this requirement, PCB 138A05 high pressure transducers capable of measuring up to 5,000 psi were used. Outside the BAS at each near field location, PCB 138A01 pressure transducers capable of measuring up to 1,000 psi were used in order to improve the measurement resolution. These transducers were capable of capturing signals of frequencies greater than 1,000,000 Hz. Due to the design of the pressure transducers, there is no method for field calibration of either of these pressure transducers. For these pressure transducers, the manufacturer supplied calibration obtained within six months of the demolition. The voltage signals proportional to pressure were recorded by an eight channel MREL DataTrap II high speed recorder sampling at 1,000,000 Hz (one record per 0.001 milliseconds) per the Near Field Hydroacoustic Monitoring Plan. With the expected rapid rise time of pressure from individual blasts in the implosion event, the sampling rate of 1,000,000 Hz was determined to be the appropriate for capturing the true peak pressures.

Far Field Monitoring

500 Feet Locations. At both of the 500-foot monitoring locations, high speed Dash 8HF recorders were used to capture the voltage signals proportional to pressure. These units provided a sampling rate of 2,000,000 Hz. The input signals were generated using two methods. The first consisted of a PCB 138A01 pressure transducer (as used in the near field monitoring outside the BAS), which was powered by a PCB 482A22 signal conditioner with a frequency range greater than 1,000,000Hz. The second signal was produced by a Reson TC4013 hydrophone with an upper frequency range of 170,000 Hz. In order to avoid extraneous noise, the output of the hydrophone was passed through a PCB 422E04 in-line charge converter limited to an upper frequency range of 100,000 Hz. This signal was then conditioned with a second channel of the PCB 482A22. The output of each system was split and fed into two channels of the recorder set to two different voltage ranges in order to capture an optimize signal. As the more distant monitoring locations used hydrophones only, the 500-foot systems were used as a comparison point between the high speed/high frequency pressure transducer system and the more moderate speed hydrophone-based systems. The hydrophone systems are more sensitive, provide less electronic floor issues, and are more suitable for the lower levels estimated for the distant locations.

Due to the large number of samples generated at 2,000,000 samples per second, the Dash recorder could not be left continuously collecting data without quickly filling its memory. As a result, the Dash recorder was triggered by the incoming signal of blast sequence. This trigger was armed when the unit was deployed about two hours prior to the implosion. The Dash recorder did not have internal electrical power and had to be powered with heavy-duty batteries supplying 12-volt DC power to an inverter, which in turn provided 110-volt AC power to the recorder. The signal conditioner was also powered by external batteries. As a backup to the high speed recorder, a solid state Roland R-05 audio recorder captured the hydrophone signal as well. The sampling rate for this recorder was 96,000 samples per second. The input to this recorder was split at the output of the signal condition with one signal going to the Dash recorder and one to the Roland.

The complete recording systems with batteries were housed in 48-gallon, weather-resistant plastic storage containers. For the two 500-foot positions, the recording systems were placed in skiffs anchored at each location where previously deployed buoys marked the position. Once transferred to the skiff, the separate pressure transducer and hydrophone lines were lowered into the water with a weighted line to a depth of 20 feet and attached to the skiff. This deployment method reduced any possibility of flow induced vibration of the lines producing extraneous strumming sounds in the recordings. Since the measurements occurred during slack tide, no additional measures were necessary to reduce strumming effects. Then the high speed Dash recorder trigger was armed, and the Roland solid state recorder was turned on to begin continuously recording signals through the time of the blast.

820 Feet Locations. At the 820-foot locations to the south and east, unmanned rafts were deployed and secured to an anchor line attached to a buoy about two hours prior to the implosion. For the south position, a system identical to those at the 500-foot locations was placed into the raft. Prior to the placing the raft into the water, the Dash recorder was installed, powered,

and armed. The raft was then placed into the water over the side of the boat with some difficulty, and in the process, power to the recorder was lost. It was not possible to confirm the status of the instrumentation once the raft was in the water. However, the backup Roland recorder was not affected and produced usable data. For the east location, the acquisition system consisted of only a Roland recorder with a Reson TC4033 hydrophone, a PCB 422E13 charge converter, and a PCB 482A22 signal conditioner. Compared to the TC4013, the TC4033 had more sensitivity but is limited to a maximum frequency response of 140,000 Hz. Similar to the 500 feet positons, the hydrophone lines were loosely attached to the raft and suspended down a separate weighted line to a depth of 20 feet.

1,500 Feet Locations. At 1,500 feet, attended monitoring systems in the south and east direction were deployed from boats alongside buoys that were set out and positioned the afternoon before the implosion. Two engineers with multiple years of experience in hydroacoustic monitoring were on each boat. The data acquisition systems used were similar to those at the east 820 feet location except that TC4013 hydrophones were used at these locations. The voltage signals were also captured with Roland R-05 solid state recorders.

4,000 Feet Location. At 4,000 feet in south direction, an autonomous unit was deployed about one hour prior to the implosion. This unit consisted of a TC4013 hydrophone, a PCB 422E13 charge converter, and a PCB 480E09 signal conditioner all housed in a water-tight cylindrical case about five inches in diameter and 12 inches long. The unit was guided down the anchor and buoy using a separate, weighted line that was secured to the buoy. The autonomous unit was positioned at a depth of 20 feet.

Data Processing

Calibration

The various pieces of equipment used for measuring the implosion required different calibration methods, For the PCB 138A05 and 138A01 pressure transducers, the sensitivities supplied by the manufacturer were used to convert the measured voltages into pressure versus time. The accuracy of the MREL DataTrap II and Dash 8HF recorders was supplied by the sources of the recorders. For the TC4013 and TC4033 hydrophones, direct calibration was possible using a traceable pistonphone (calibrator). For these hydrophones, a G.R.A.S. 42AC Pistonphone, high pressure, Class 1 was used. This pistonphone was calibrated to produce a 165.3 dB sound pressure level at 250 Hz when used with a G.R.A.S. RA0078 Calibration Coupler for the TC4013. When used with G.R.A.S. RA0043 coupler, the pistonphone produces a level of 156.5 dB for the TC4033. For systems using the Roland R-05 solid state recorder, the calibration tone was directly recorded and used to determine hydrophone sensitivities for the complete instrument chain. The resultant sensitivities are shown in Table 3.

Table 3: Summary of resultant sensitivities for each far field sensor

Direction	Distance	Measurement Transducer	Sampling Rate	Sensitivity
East	500 feet	PCB	2,000,000 Hz	5.208 mV/psi
		Hydrophone	2,000,000 Hz	1.0436×10^8 μPa/mV
		Hydrophone	96,000 Hz	2.1656×10^8 μPa/mV
	820 feet	Hydrophone	96,000 Hz	4.4046×10^7 μPa/mV
	1,500 feet	Hydrophone	96,000 Hz	2.6334×10^7 μPa/mV
South	500 feet	PCB	2,000,000 Hz	5.005 mV/psi
		Hydrophone	2,000,000 Hz	1.0436×10^8 μPa/mV
		Hydrophone	96,000 Hz	3.7187×10^8 μPa/mV
	820 feet	Hydrophone	96,000 Hz	2.8989×10^7 μPa/mV
	1,500 feet	Hydrophone	96,000 Hz	3.1199×10^7 μPa/mV
	4,000 feet	Hydrophone	96,000 Hz	2.8319×10^7 μPa/mV

Data Capture

For far field measurements at 500 feet, data were recorded directly into high speed recorders sampling at 2,000,000 samples/second. Also at 500 feet, signals were captured by a Roland solid state audio recorder sampling at 96,000 samples/second. At the other distances, the signals were captured by the Roland solid state recorders. The analog signals from these recordings were played back into the high speed recorder and sampled at 200,000 samples/second. Since the playback signals were analog, not digital, they were sampled at a rate twice the playback rate to be certain that the fluctuations were captured properly.

Dash 8HF-HS High Speed Recorder. At 500 feet in the east and south directions, a Reson TC4013 hydrophone and a PCB 138 transducer measured underwater data that was recorded in a Dash 8HF-HS high speed recorder at a rate of 2,000,000 Hz. Data from both transducers were recorded in voltage units, and two voltage ranges were used for both transducer types. For the hydrophone, input ranges on the Dash recorder were set to 1 and 10 V, while the input ranges for the PCB transducer were set to 0.1 and 1 V. This was done to ensure that the peak pressures were captured with both transducer types. The Dash recorder was programmed to trigger automatically when the hydrophone signal measured 0.05 V. Data was collected for eight seconds, with 800 ms being pre-trigger data so the entire blasting event was recorded.

Roland R-05 Solid State Recorder. Each far field measurement location included a medium speed Roland R-05 solid state recorder with a maximum sampling rate of 96,000 Hz. At each location, either a Reson TC4013 or a Reson TC4033 hydrophone measured underwater data that was recorded with a Roland solid state recorder. At the unattended locations (i.e., 500, 820, and 4,000 feet), the Roland devices started recording at the time the hydrophone was deployed and continued for up to 14 hours until the equipment was collected following the blasting event. At the attended locations at 1,500 feet, the recorders were manually started prior to the blast and stopped following the blast. During post-processing, the audio recordings from the solid state devices were played into the Dash 8HF-HS high speed recorder so analysis of the voltage outputs could be consistent for all far field measurement locations. The Dash high speed recorder was programmed to record voltage at a sampling rate of 200,000 Hz; however, the hydrophone

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audio recordings would remain limited to the maximum sampling rate of the Roland solid state recorder (96,000 Hz).

Data Analysis

To compare with appropriate marine mammal and fish sound criteria, the implosion's pressure signals were reduced and analyzed to obtain peak pressure level, impulse, cumulative SEL, and RMS levels. The PCB transducers used at each near field location and at the 500-foot far field locations were designed to capture the true peaks in signals with rapid rise times, and as such, have excessive instrumentation noise. To eliminate this noise, each PCB signal was filtered using a low pass filter to reduce the high frequency content not due to the blasting event. Based on the signal, cutoff frequencies used for the near field analysis ranged from 8,000 to 50,000 Hz. The 500-foot signals were filtered with a cutoff frequency of 50,000 Hz. The hydrophone signals did not contain the high frequency noise found with the PCB transducers and did not require filtering.

Spreadsheet Calculations. The high speed recordings (1,000,000 to 2,000,000 Hz) from the near field and 500-foot far field locations were programmed to record up to eight seconds of data during the implosion event. The near field time signatures were provided in pressure units of pounds per square inch (psi) in text format. The sampling rate of 1,000,000 Hz translated to approximately 8 million lines of data at each location. The high speed far field time signatures were exported in voltage units from the Dash 8HF-HS device in text format, as well, with 16 million total number of lines for both 500-foot locations. Once the medium speed recordings (96,000 Hz) at the far field locations were scanned to isolate the implosion and captured in the Dash device, the time signatures were also exported in voltage units to text format. With the Dash device programmed to record at 200 ,000 Hz, the data set for each far field location totaled 1.6 million lines. All text files were imported into Microsoft Excel and converted into micro-Pascals (μPa) using either 6.89×10^9 μPa/psi for near field measurements or the corresponding sensitivities shown in Table 3 for each far field location.

The pressure versus time signals from the near field and far field monitoring locations were processed using the same algorithm to calculate the required metrics. The peak pressure levels were determined by identifying the maximum pressure in each signal and calculating the level as defined in Equation 1. For the PCB transducers, the other quantities, as defined in Equations 2 through 8, were calculated using the numerical equivalent of these equations.

Real-Time Analyzer Calculations. For signals captured with at 96,000 samples/second, a Larson-Davis 3000 real-time analyzer (RTA) was used for some of the data processing. This instrument can be directly calibrated from the calibration signals recorded using the Roland solid state recorders and offers an improved dynamic range as the signals can be amplified on playback. However, the sampling rate of the RTA is limited as it is designed for the frequency range of human audibility. The RTA can directly capture and report the SEL value or alternatively, it can report the average of the sound pressure level over a time interval of 2.5 ms. These average levels can also be summed using Equation 5 to calculate. Both methods give identical results. As a result, the RTA can be effectively used for determining SEL values. This was verified by comparison to SEL values determined for the 500 feet hydrophone data recorded

with both the high speed and the Roland recorders. For the high speed recorder, the SEL values were calculated with the spreadsheet method described above and then compared to those from the RTA. These compared to each other within 0.1 and 0.2 dB. As a result, the reported SEL values were determined using the RTA. This method also provides the opportunity to examine the frequency content in the frequency range from 25 to 20,000 Hz.

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DISCUSSION OF RESULTS

The implosion event consisted of 588 individual blasts of eight different charge weights lasting a duration of approximately 5.3 seconds from the first detonation to the last, with individual charges separated by 9 ms. Monitoring began prior to the first detonation and continued for approximately eight seconds. Near field monitoring was triggered electronically from the signal used to initiate the blast, and therefore, was time-synced with the detonation sequence. Due to the distances measured in the far field, monitoring operations could only be triggered by the received acoustic signal. As discussed above, the high speed recorders were programmed to trigger once a predetermined voltage threshold was exceeded. Using a pre-trigger recording feature, the recorders did capture the signal 0.8 seconds prior to the actual trigger point and continued to capture data for a total of eight seconds. At all other far field positions, hydroacoustic signals were recorded during the entire event, starting when the hydrophone was placed into position and ending when the hydrophone was collected after the event.

Sound Pressure Level and SEL versus Time

Sound Pressure Level vs. Time

Sound pressures were measured at six near field positions: one along the east line at 23.5 feet; and five along the north line at 24.5, 74.5, 101, 126.5, and 153 feet. Hydroacoustic data was taken at seven far field positions: three along the east line at 500, 820, and 1,500 feet; and four along the south line at 500, 820, 1,500, and 4,000 feet. All of the monitoring was done at a depth of 20 feet. Figures 19 and 20 show the time histories for the far field measurement locations along the east and south lines, respectively. Due to the number of data points captured with the 2,000,000 Hz and 200,000 Hz sampling rates, the results shown in Figures 19 and 20 were sampled at 100,000 Hz. Comparison of the peak sound pressure levels calculated with the 200,000 Hz and 100,000 Hz sampling rates resulted in negligible differences no greater than 0.3 dB. Therefore, the time histories shown in the figures for far field locations at 820 feet and beyond would be identical for the 200,000 Hz. At 500 feet, the peak sound pressure level is lower than it would be with the 2,000,000 Hz sampling. Note, the time for each figure is relative to the recordings and does not directly correlate to the timing of the blast event. Each recording was lined up starting at the time the first indication of the blast occurred.

In the east direction (Figure 19), the two highest peaks are located close together just prior to the one second mark occurring about 0.5 seconds after the initiation of the recording. These peak pressure levels were over 10 dB higher than any other peaks measured during the event. Aside from these two peaks, the other highest peaks in the first 4 seconds of the blast were typically between 190 and 199 dB. As noted in Table 2, the calculated peak sound pressure levels for the 588 individual charge weights cover a range of only about 2 dB relative to each other. The results of Figure 19 indicate that circumstances other than charge weight differences created the two high peak levels occurring around 0.5 seconds into the implosion event. Potential causes for these higher levels could be reduced confinement of these individual charges or inconsistency in the BAS along the path taken by these particular charges. This has some implication for future calculated peak levels for future similar implosion events. From Figure 19, the occurrence of the two higher peaks could be considered as random, higher level events relative to the more the

consistent peak levels that occur throughout the remainder of the event. From this viewpoint, the calculations correspond to the average of blasts about which higher and lower peaks may occur randomly. These two higher peaks also persist at the further distances from the Pier.

In the south direction (Figure 20), the highest peaks in the first two seconds are somewhat more consistent than in the east direction. From the highest peak occurring about 0.5 seconds into the event, the peaks tend to decrease in amplitude with time. For the blast plan as shown in Figure 5, this is expected as the blasting moves south to north, and the distance from the blasts to the monitoring locations increases. For the east direction (Figure 19), the blasts continue down the length of the Pier at a similar distance from the monitoring locations. For the south direction, it is particularly apparent that the "peaky-ness" of the sound pressure levels generally decreases with increased distance from the blasts. This can be seen by considering the peak that occurs at a time of approximately about 1,500 milliseconds shown in Figure 20. At the distances of 500 and 820 feet, the peak is much higher in level than the surrounding levels by about 20 dB. At 1,500 and 4,000 feet, this same peak is only about 10 dB greater than the surrounding levels. An interesting exception to this is the peak that occurs at the 1,000-ms grid line. In this case, the peak at 4,000 feet remains quite "sharp" and is about 20 dB higher than the surrounding data.

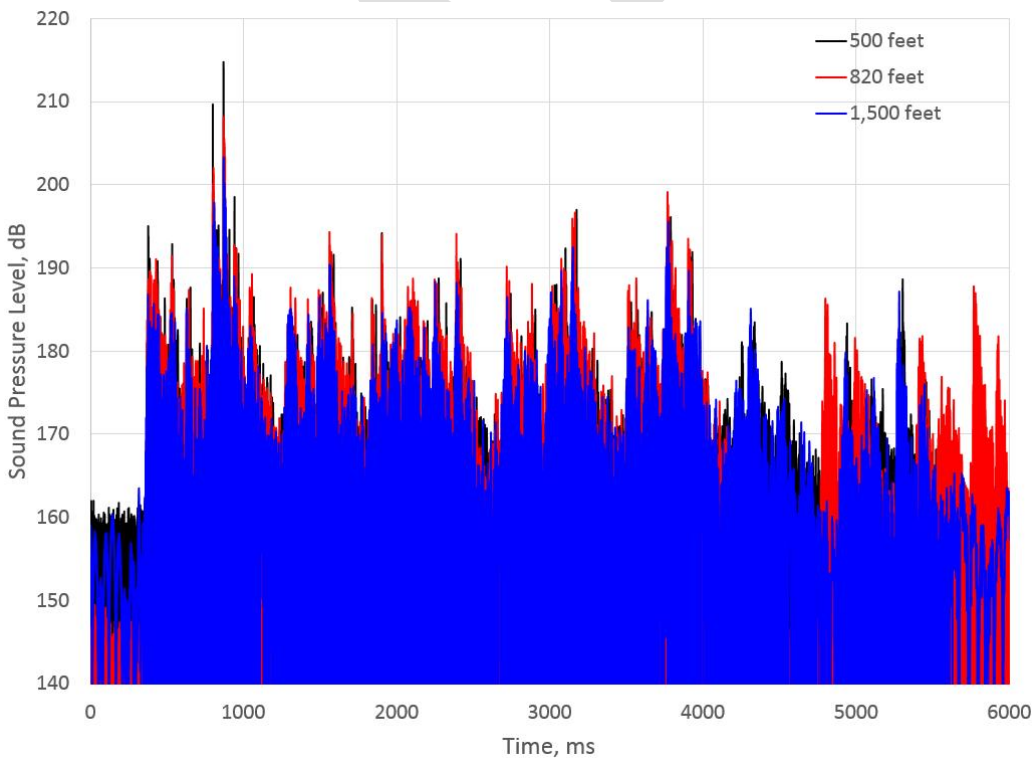

Figure 19: Far field time histories along the east line at 500, 820, and 1,500 feet, sampled at 100,000 Hz

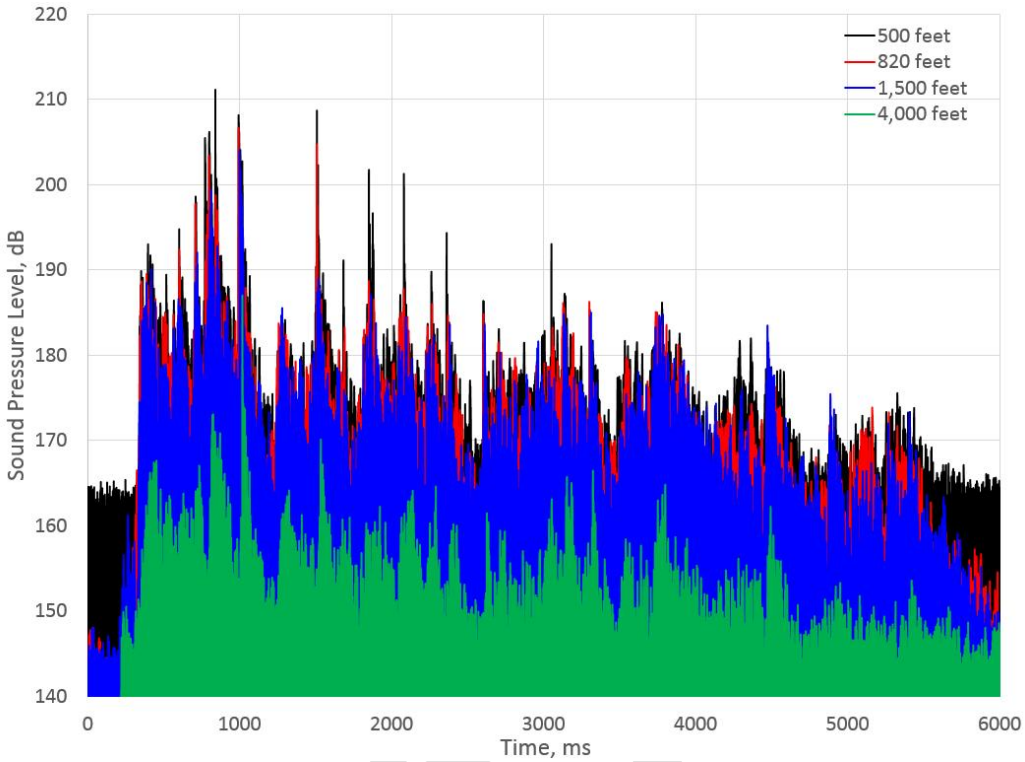

Figure 20: Far field time histories along the south line at 500, 820, 1,500, and 4,000 feet, sampled at 100,000 Hz

SEL vs. Time

The SEL_{cum} was calculated numerically for the 2,000,000 Hz PCB in the near field and at 500 feet. In the far field and 500 feet, SEL_{cum} was determined using the RTA for the hydrophone data sampled at the rate of 96,000 samples/second. At the overlapping positions at 500 feet, the SEL determined with the pressure transducers and the hydrophones were within 2 dB of each other. Since the SEL_{cum} calculated numerically for the PCB and with the RTA for the hydrophone differed only by these small amounts at the 500 feet locations, it was determined that the energy accumulated over the entire blasting event was captured adequately with the slower sampling rate. Unlike peak sound pressure level, the SEL values are not as sensitive to sampling rate at the closer monitoring locations.

Differences in the progression of the blasts noted for Figures 21 and 22 are also apparent in plots of the SEL versus time. For the accumulation of SEL in the east direction, as shown in Figure 21, the two large peaks noted in Figure 19 have a major effect in determining the ultimate SEL_{cum} value for the 500-foot monitoring distance. These peaks define a rise in SEL of about 12 dB in a short time, starting at about 1,600 milliseconds in Figure 21. After these two peaks, the SEL versus time curve flattens, increasing only about 1.5 dB in the remainder of the implosion event. For the further distances, the rise is not as pronounced, and the SEL continues to build over the duration of the event, increasing by about 3.5 dB and 4 dB for the 820 and 1,500 feet distances, respectively. For the 820 feet SEL, the final value actually exceeds the 500-foot result, as the more uniform peaks after about 2,300 milliseconds continue to increase the accumulated SEL. The effect of more uniform peaks is also seen at the 1,500-foot location, although the SEL

remains lower than the other two distances. The SEL_{cum} versus time in the south direction is shown in Figure 22. In this direction, the build-up of energy is slightly more gradual than in the east direction, as would be expected from Figures 19 and 20. Due to the general decrease in peak sound pressure level as the implosion progresses, there is little increase in SEL_{cum} after about the 2,000-ms mark. However, these data do indicate that the individual peak levels near the beginning of the event contribute to the SEL during the buildup of energy more in a step-wise fashion occurring before the 1,500-millisecond mark. Unlike the east direction, the SEL_{cum} in the south direction determioned at 500 feet was approximately 5 dB greater than the SEL_{cum} at 820 feet. The difference between the 820 and 1,500 feet SEL was about the same in the east and south direction.

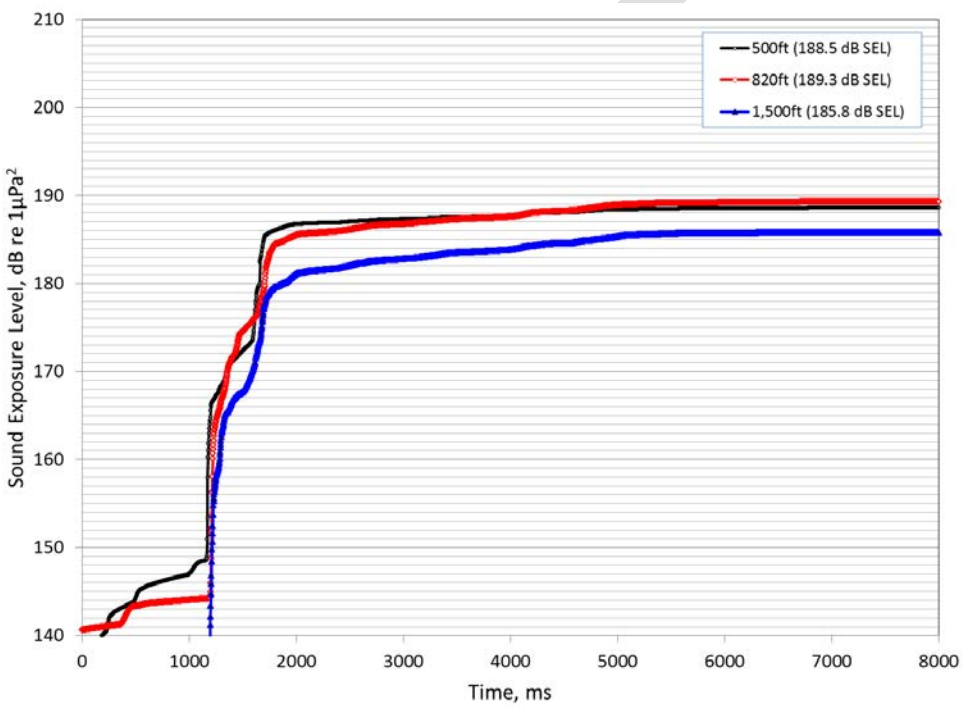

Figure 21: Far field SEL_{cum} along the east line at 500, 820, and 1,500 feet

Using the RTA, the frequency content of the SEL_{cum} can also be compared for the different distances and between the east and south directions. SEL_{cum} for the three distances in the east direction are compared in Figure 23 for one-third octave bands from 25 to 20,000 Hz. For these data, the spectra for all three distances are dominated by the energy below 1,000 to 2,500 Hz. The lower frequency content is noted to increase with distance, implying that the higher frequency energy attenuates more rapidly with distance. A similar plot for the south direction is presented in Figure 24. For the 500, 820, and 1,500 feet distances, the spectra are again dominated by lower frequencies, less than about 3,150 Hz. The spectrum for the 4,000-foot position is more complex. For both directions, there is a noticeable dip in the 1,500-foot spectrum beginning at 1,250 Hz and extending higher to about 4,000 Hz. At 4,000 feet in the south direction, a dip is seen at even lower frequencies, from about 125 to 800 Hz, and another dip is apparent between 1,250 and 6,300 Hz. These behaviors may be due to interference effects created by the surface release wave discussed in conjunction with Figure 8.

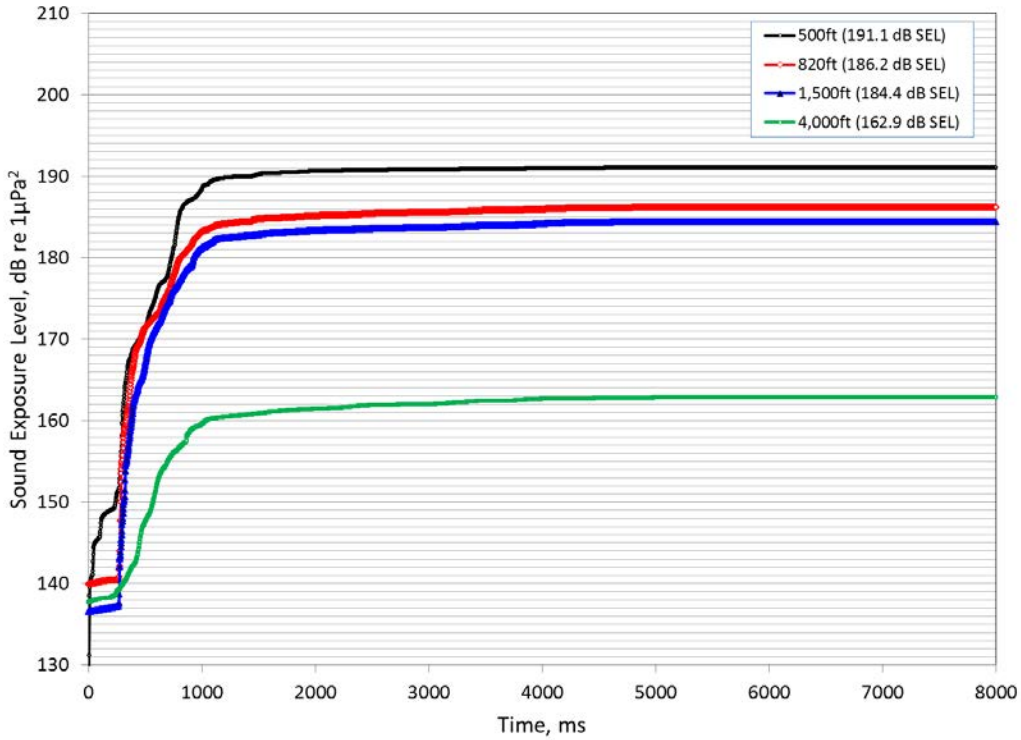

Figure 22: Far field SEL_{cum} along the south line at 500, 820, 1,500, and 4,000 feet

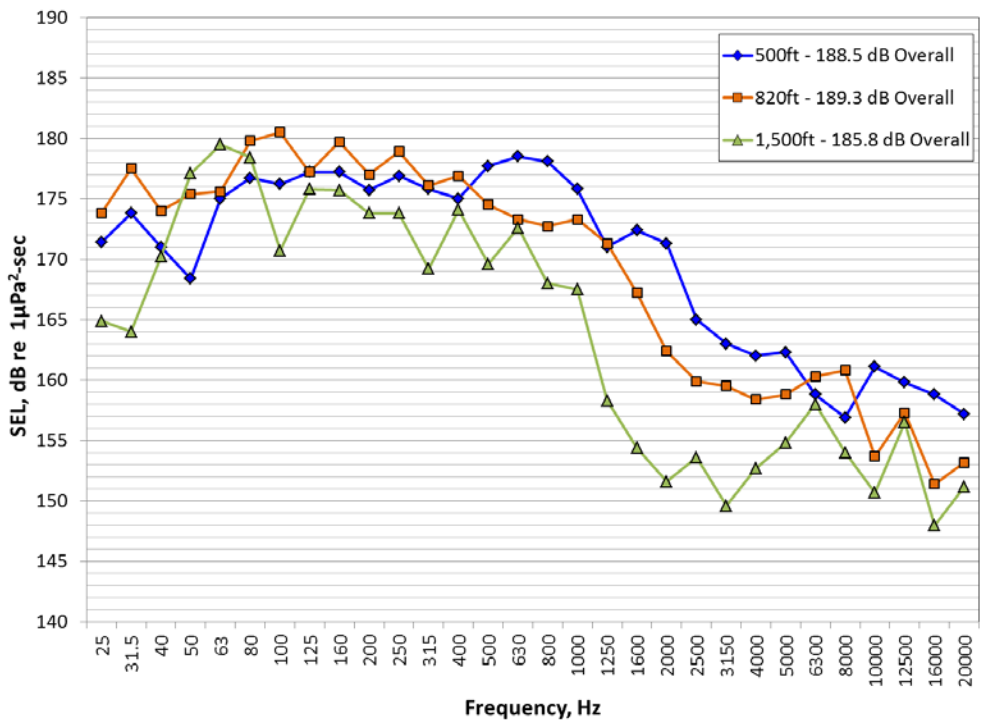

Figure 23: ⅓ Octave band levels for SEL_{cum} at the far field monitoring locations to the east

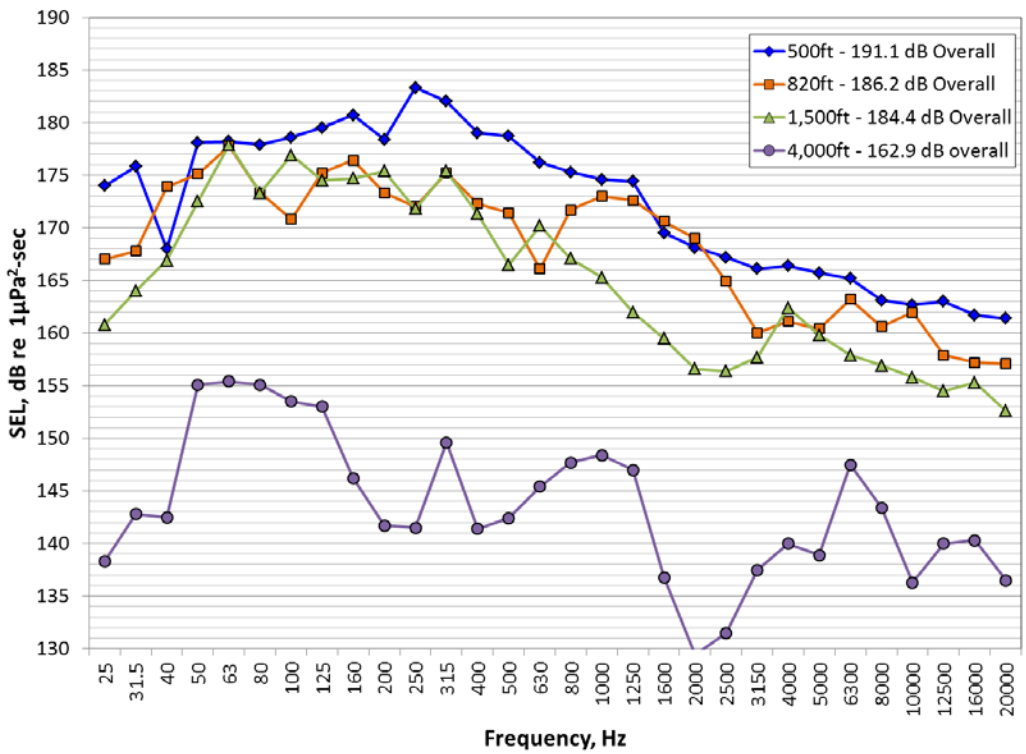

Figure 24: ⅓ Octave band levels for SEL_{cum} at the far field monitoring locations to the south

Results Related to Fish Criteria

The peak pressure levels and SEL values for all of the monitoring locations is presented in Figure 1 of the Executive Summary and compared to the corresponding fish criteria. The RMS sound pressure level results are presented in Figure 25 along with the calculated level, RMS criterion, and trend line of the measured data. Similar to the SEL results, the fall-off rate of the measured RMS levels is greater than the calculated rate, and the measured levels are below the calculated for 500 feet and beyond. The calculated and measured fall-off rate is the same as the corresponding rate of the SEL (see Figures 1 and 10). The calculated and measured distances to the peak, SEL_{cum}, and RMS levels are shown in the Table 4.

Table 4: Summary of the calculated distances to the fish criteria

Criteria	Threshold	Calculated Distance	Measured Distance
Peak Pressure	206 dB	820 feet	1,165 feet
Cumulative SEL, ≥ 2 grams	187 dB	2,550 feet	889 feet
Cumulative SEL, < 2 grams	183 dB	4,000 feet	1,230 feet
RMS Sound Pressure Level	150 dB	68,000 feet	4,752 feet

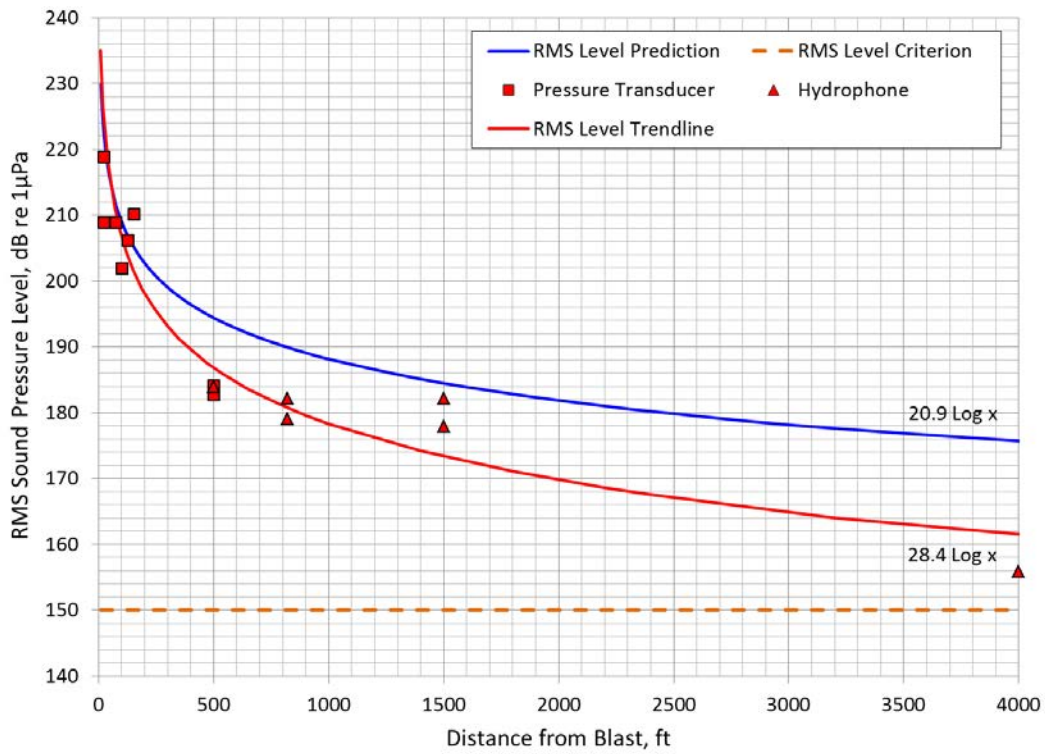

Figure 25: Comparison of measured RMS levels to calculated and data trend line

Results Related to Marine Mammals

In order to compare the measured SEL values to the marine mammal criteria for seals, sea lions, and porpoises, the weighting was first applied to the measured results. The same weighting factors used to produce the calculated levels shown in Figures 12 through 14 were subtracted from the measured SEL for each of the three species. These results are displayed in Figure 26 along with the calculated levels, which have fall-off rates ranging between 21.6 and 22.7 Log distance. Similar to the SEL results in Figure 1, the weighted values fall on or below the calculated levels, except at the 153-foot location north of Pier E3. The measurements were also used to establish logarithmic trend lines through the data points, as shown in Figure 27. As in the case of the unweighted SEL trend lines considered for fish, those for marine mammals display also fall-off rates higher than the calculated fall-off rates. With the added effect of the species weightings, the marine mammal fall-off rates are actually slightly greater than the unweighted SEL fall-off rates.

For all species of marine mammal, the same criterion level for GI tract damage applies. In Figure 28, the peak pressure levels measured during the implosion are compared to the GI criterion and the calculated levels. For all locations outside of the BAS, the measured peaks were below the criteria. The measured values display the same relation to the calculated values as discussed in regard to fish peak criteria (see Figure 1).

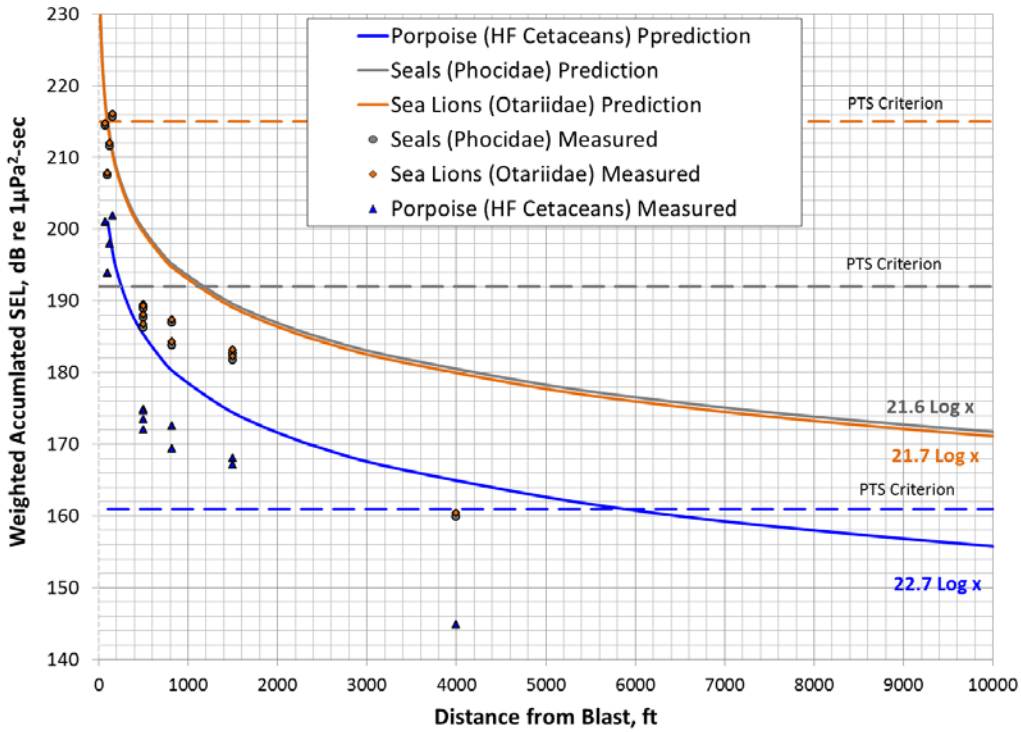

Figure 26: Marine mammal weighted measured levels compared to calculated values and criteria

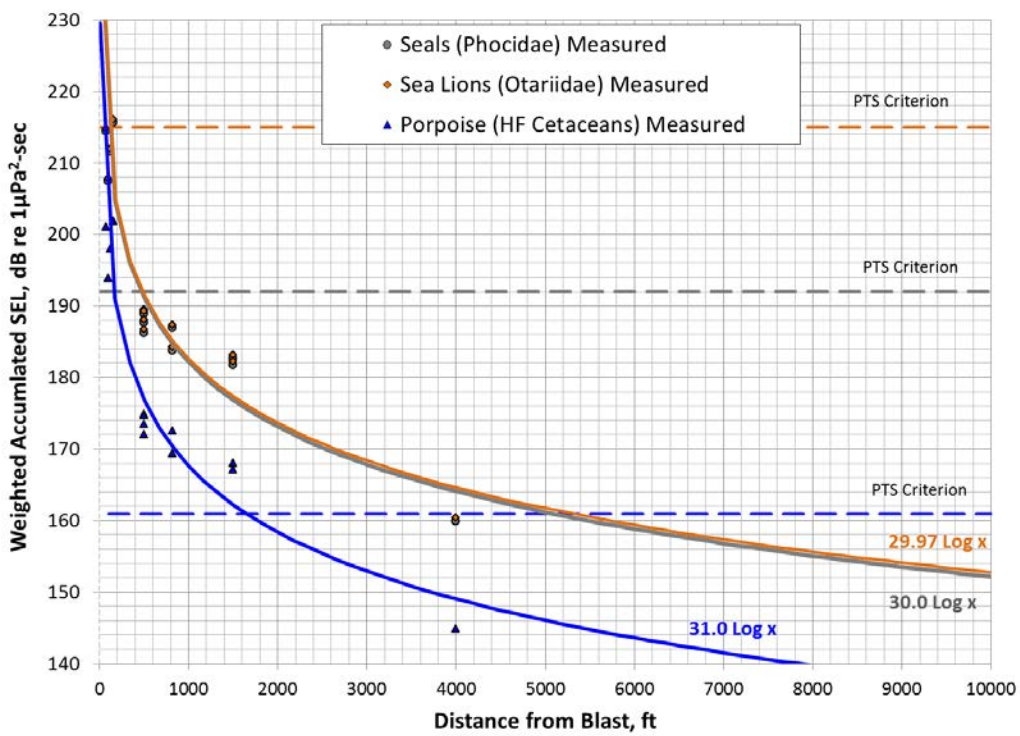

Figure 27: Marine mammal weighted measured levels and trend lines compared to criteria

Table 5 summarizes the distances to all marine mammal thresholds from Pier E3 based on the measurements for the implosion event. Since the distance to the SEL_{cum} threshold was always greater than to the L_{pk} threshold for behavior, TTS and PTS, all values shown in Table 5 are SEL_{cum} levels.

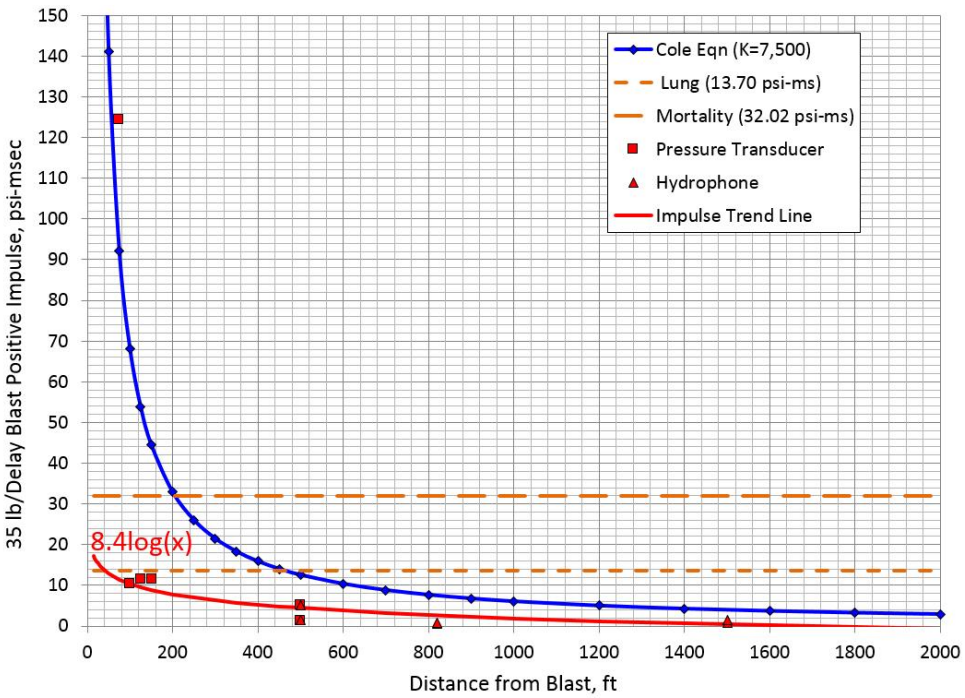

Figure 28: Summary of impulse results compared to the calculated and the marine mammal criteria

Table 5: Summary of the calculated distances to the marine mammal criteria

Criteria	Pacific Harbor & Northern Elephant Seal (Phocidae)			Sea Lions (Otariidae)			Porpoises (High Frequency Cetaceans)		
	Threshold	Calculated Distance	Measured Distance	Threshold	Calculated Distance	Measured Distance	Threshold	Calculated Distance	Measured Distance
Behavior	172 dB	9,700 feet	2,460 feet	195 dB	800 feet	387 feet	141 dB	44,500 feet	8,171 feet
TTS	177 dB	5,700 feet	1,658 feet	200 dB	470 feet	261 feet	146 dB	26,500 feet	5,580 feet
PTS	192 dB	1,160 feet	507 feet	215 dB	97 feet	80 feet	161 dB	5,800 feet	1,777 feet
GI Tract	237 dB	35 feet	14.5 feet	237 dB	35 feet	14.5 feet	237 dB	35 feet	14.5 feet
Lung Injury	13.7 psi-ms	450 feet	<100 feet	13.7 psi-ms	450 feet	<100 feet	13.7 psi-ms	450 feet	<100 feet
Mortality	32.02 psi-ms	205 feet	<100 feet	32.02 psi-ms	205 feet	<100 feet	32.02 psi-ms	205 feet	<100 feet

Tables of Measured Levels

All near and far field peak pressures are summarized in Table 6. These are the same values that were used to plot Figure 1. Within the BAS, the peak levels ranged from 253.1 to 253.8 dB. The peak pressure levels outside the BAS were 228.5 dB at 74.5 feet to 231.2 dB at 153 feet. While the peak levels increased slightly with distance between 74.5 and 153 feet, note the close proximity of each of these measurements. The PCB and hydrophone transducers at 500 feet were

within 0.5 to 1.2 dB of each other, with the measurements in the east direction being higher than the south by approximately 6 dB due to some directionality in the implosion. At 1,500 feet from Pier E3, the measurements in both directions were approximately 204 dB, which was below the 206 dB peak threshold. The SEL_{cum} levels for all of the measurement locations are shown in Table 7. These range from 230.8 dB inside the BAS to 162.9 dB 4,000 feet to the south of the former Pier E3.

Table 6: Summary of peak pressure levels measured at each near and far field location

Direction	Distance	Measurement Transducer	Peak Pressure, L_{pk}
North	24.5 feet	PCB	253.1 dB*
	74.5 feet	PCB	228.5 dB*
	101 feet	PCB	227.2 dB*
	126.5 feet	PCB	229.0 dB*
	153 feet	PCB	231.2 dB*
East	23.5 feet	PCB	253.8 dB*
	500 feet	PCB	221.6 dB*
		Hydrophone	221.1 dB
	820 feet	Hydrophone	208.2 dB
	1,500 feet	Hydrophone	203.6 dB
South	500 feet	PCB	215.9 dB*
		Hydrophone	214.7 dB
	820 feet	Hydrophone	206.7 dB
	1,500 feet	Hydrophone	204.1 dB
	4,000 feet	Hydrophone	187.7 dB

**The low pass filter used on the PCB data reduced peak pressures by 0.4 to 2.6 dB from the raw signals.*

Table 7: Summary of SEL_{cum} levels measured at each near and far field location

Direction	Distance	Measurement Transducer	Cumulative SEL, SEL_{cum}
North	24.5 feet	PCB	226.1 dB*
	74.5 feet	PCB	216.1 dB*
	101 feet	PCB	209.2 dB*
	126.5 feet	PCB	213.4 dB*
	153 feet	PCB	217.5 dB*
East	23.5 feet	PCB	230.8 dB*
	500 feet	PCB	189.9 dB*
		Hydrophone	188.5 dB
	820 feet	Hydrophone	189.3 dB
	1,500 feet	Hydrophone	185.3 dB
South	500 feet	PCB	191.3 dB*
		Hydrophone	191.1 dB
	820 feet	Hydrophone	186.2 dB
	1,500 feet	Hydrophone	184.4 dB
	4,000 feet	Hydrophone	162.9 dB

**Unfiltered signals contained too much high frequency noise to calculate SEL_{cum} so all calculations were conducted with filter signals.*

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The L_{RMS} was calculated by dividing the total duration of the blasting event, which was 5.283 seconds, by total energy accumulated during the event. The values for each near and far field location are summarized in Table 8. Similar to the peak and SEL_{cum} levels, the near field L_{RMS} get higher with distance. The RMS pressure levels were below the 150 dB L_{RMS} criteria for behavioral response to fish at 4,000 feet.

Table 8: Summary of L_{RMS} levels measured at each near and far field location

Direction	Distance	Measurement Transducer	RMS Level, L_{RMS}
North	24.5 feet	PCB	211.6 dB*
	74.5 feet	PCB	201.6 dB*
	101 feet	PCB	194.7 dB*
	126.5 feet	PCB	199.0 dB*
	153 feet	PCB	203.0 dB*
East	23.5 feet	PCB	216.4 dB*
	500 feet	PCB	175.4 dB*
		Hydrophone	174.0 dB
	820 feet	Hydrophone	174.8 dB
	1,500 feet	Hydrophone	171.3 dB
South	500 feet	PCB	176.3 dB*
		Hydrophone	176.1 dB
	820 feet	Hydrophone	171.2 dB
	1,500 feet	Hydrophone	169.4 dB
	4,000 feet	Hydrophone	147.9 dB

**Unfiltered signals contained too much high frequency noise to calculate L_{RMS} so all calculations were conducted with filter signals.*

The final metric calculated for the blasting event was impulse. Impulse is considered the summation of the positive energy in the greatest pressure pulse during a blast. However, since this project included 588 individual blasts, the greatest absolute peak pressure did not necessarily occur in the positive energy direction at the far field locations. Therefore, the energy summed for the impulse metric at each position may not have coincided with the L_{pk} discussed previously. At 500 feet in the south direction, for instance, the peak pressure level in Table 6 occurred in negative direction, and the highest positive pressure pulse used to determine the impulse value occurred at a slightly later time in the blasting event.

Table 9 summarizes the impulse pressures measured at each location in the near field and far field. At the two near field measurement locations inside the BAS, the impulse values ranged from 244.1 to 283.0 psi-ms, which reduced to 10.4 psi-ms at 101 feet. At 500 feet, direction of the measurement affected the impulse. In the east direction, the L_{pk} was in the positive direction and had a fast rise time, as discussed above, which translates to little energy in the impulse summation of that peak. In the south line, however, the L_{pk} was in the negative direction, which means the positive energy pulse used to calculate the impulse had a slower rise time and included more energy for the summation of the impulse metric. By 1,500 feet, the impulse measured at around 1 psi-ms and was less than 0.1 psi-ms at 4,000 feet. At all locations outside of the BAS, the measured impulse values were below the lung injury and mortality thresholds.

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Table 9: Summary of impulse values measured at each near and far field location

Direction	Distance	Measurement Transducer	Impulse Value
North	24.5 feet	PCB	283.0 psi-ms*
	74.5 feet	PCB	128.4 psi-ms*
	101 feet	PCB	10.4 psi-ms*
	126.5 feet	PCB	11.4 psi-ms*
	153 feet	PCB	11.5 psi-ms*
East	23.5 feet	PCB	244.1 psi-ms*
	500 feet	PCB	1.2 psi-ms*
		Hydrophone	1.5 psi-ms
	820 feet	Hydrophone	0.5 psi-ms
	1,500 feet	Hydrophone	0.7 psi-ms
South	500 feet	PCB	5.1 psi-ms*
		Hydrophone	5.0 psi-ms
	820 feet	Hydrophone	0.7 psi-ms
	1,500 feet	Hydrophone	1.4 psi-ms
	4,000 feet	Hydrophone	0.01 psi-ms

**Filtered signals were used to calculate the impulse metric.*

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APPLICATION TO FUTURE CALCULATION AND MONITORING

The implosive demolition of the Pier E3 was intended to be a demonstration of this technology for the possible demolition of the remaining piers of the original SFOBB east span. From a hydroacoustic viewpoint, there is considerable interest in assessing how the estimated levels compare to the actual measured levels. The Pier E3 implosion was a rather unique event due the nature and size of its structure and the expected confinement of the charges placed in holes drilled into the walls of the inner structure. Additionally, the actual performance of the BAS was hard to predict given the uniqueness of this underwater structure, the dynamic conditions of the San Francisco Bay, and the complexity of the implosion design. Beyond calculating and measuring hydroacoustic levels, there is interest in assessing the performance of the underwater noise monitoring and determining if changes may be needed for future demolitions.

Future Calculation

As evidenced by the results presented in Figure 1, given the assumptions that went into calculating noise levels, it appears that these estimations represented actual measured level well, in general. For peak pressure level, it was generally found that the measured levels were only slightly greater than the estimated (by about 2 to 3 dB). The decrease in measured peak pressure level with distance was remarkably similar to that estimated using conventional blast pressure calculation techniques, which are described in the Calculated Levels section of this report. As noted in regard to Figure 19 for the east monitoring line, the peak level was determined by just a few high level peaks out of the 588 individual blasts. To the east face of Pier E3, the distance to the blasts measured virtually the same as the implosion progressed from south to north. The expected pressures produced by individual charges were quite uniform even for the range of 21 to 35 lbs/delay (see Table 2), and the reason for elevated levels for two out of the 588 blasts is unclear. In future calculations, it may be appropriate to consider the estimated peak pressures statistically; that is, comprised of an expected average peak level based on calculations similar to those described and an additional factor or offset to account for the probability of a few peaks of greater than calculated amplitude. Based on the results presented in Figure 1, the calculated fall-off rate applies, regardless of the possible occurrence of random, higher level blasts.

For the SEL calculations, the trend through the measurements falls off at a more rapid rate than calculated. This higher fall-off may be expected from the discussion regarding the SEL calculation and influence of the surface relief wave at farther distances from the source. At the farther distances, the path length difference between the direct and reflected pulses becomes smaller and smaller, improving the chance for interference between the two waveforms. As noted, this will only tend to decrease the SEL from that expected for the direct waveform only. This effect would become even greater at larger distances from the pier. Given the rather extreme distances calculated for some of the criteria (e.g. the fish RMS criterion and porpoise SEL criteria), it may be appropriate to use the fall-off determined experimentally rather than the calculated rates. There is also some indication based on the 4,000 feet data that even the experimental fall-off rate would be conservative at the farther distances.

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Hydroacoustic Monitoring

Comparative data collection between pressure transducers and hydrophones at 500 and 820 feet were originally included in the far field hydroacoustic monitoring plan. Unfortunately, the pressure transducer acquisition at 820 feet failed, leaving only the 500 feet distance for comparison. However, results from three different acquisition system configurations were produced at both 500 feet distances. These included a pressure transducer with an upper frequency range of about 1,000,000 Hz, sampled at 2,000,000 samples/second (S/s), a hydrophone with an upper range of 170,000 Hz, sampled also at 2,000,000 S/s, and a hydrophone sampled at 96,000 S/s. The waveforms produced by the pressure transducer and the hydrophone are compared in Figure 29, as sampled at 2,000,000 S/s. Both devices track the peak pressure quite well and are virtually identical. For the pressure transducer, when the amplitude is less than about $5x10^{10}$ µPa, the signal contains electronic noise seen as the fluctuation around zero and mean level above zero. The hydrophone is inherently less noisy and has a higher sensitivity than the pressure transducer. As a result, the hydrophone is preferred over the pressure transducer for use as close as possible to the implosion location. However, its upper range is limited, compared to the pressure transducer, and it could overload if used too close to the blast detonations.

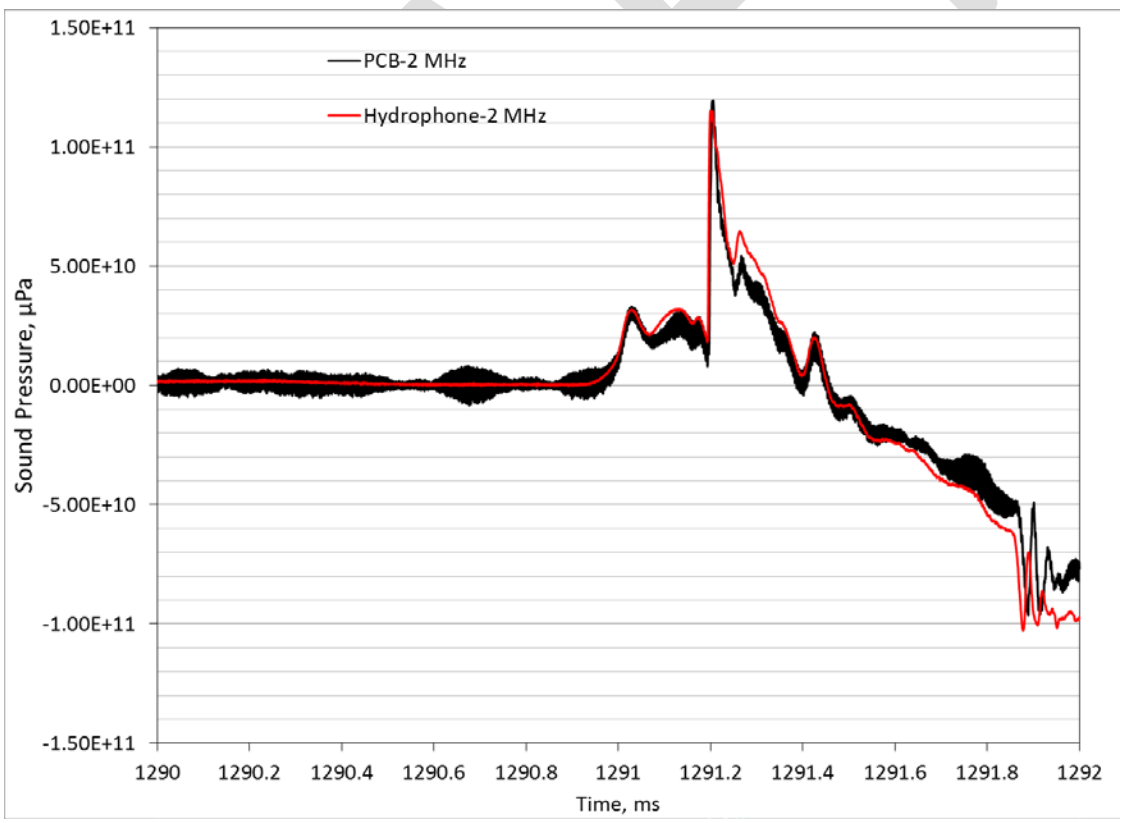

Figure 29: Pressure waveform at 500 feet in the east direction for a pressure transducer and hydrophone, both sampled at 2,000,000 samples/second

Figure 30 compares the same waveform, as measured by the hydrophone, but sampled at two different rates: 2,000,000 S/s and 96,000 S/s. The lower sampling rate does not capture the

waveform to the same fidelity as the higher rate and cannot respond to pressure fluctuations as quickly, resulting in a loss of some of the signal. In future monitoring, the hydrophone should be used as close to the pier being imploded as feasible without overloading the hydrophone but sampled at the higher rate. It is expected that at distances greater than 500 feet there will reach a distance where the high sample rate is not necessary in order to capture the signal accurately. This distance could not be determined at this time; although, it is suspected to occur around 1,000 feet, based on the results presented in Figure 1. This distance should be carefully considered and properly determined for future monitoring programs.

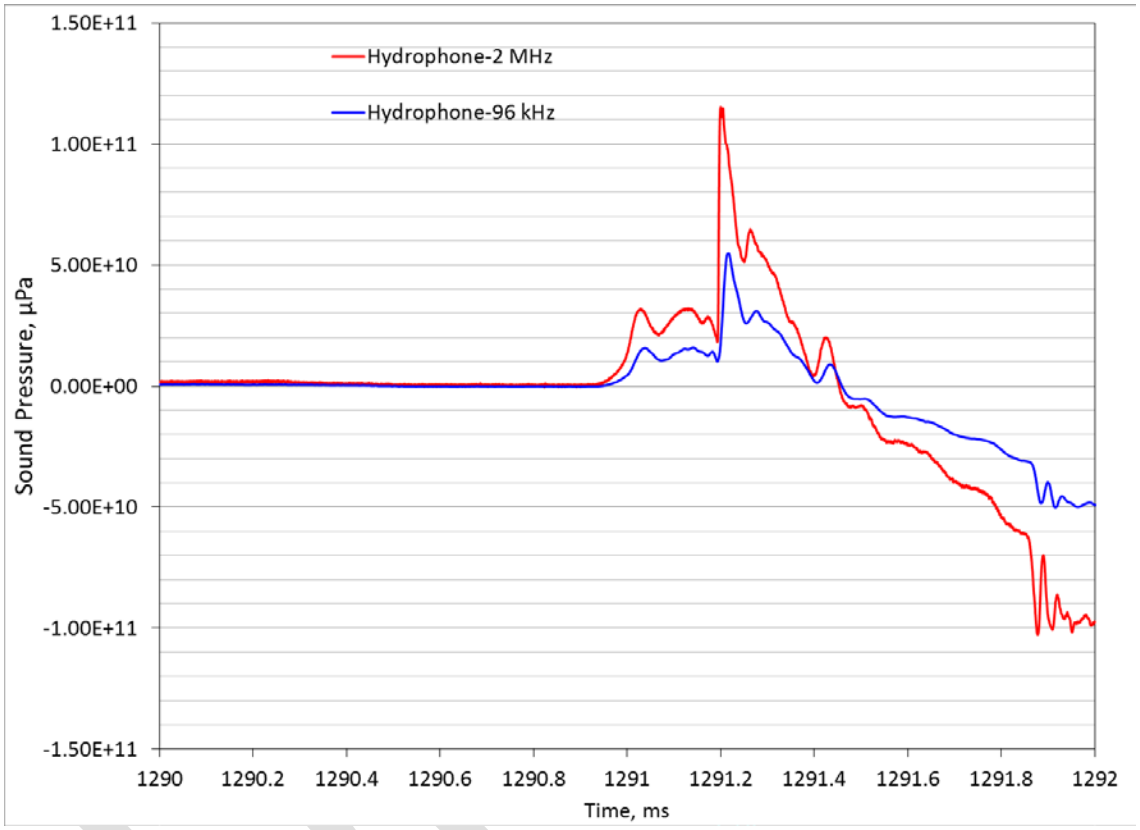

Figure 30: Pressure waveform at 500 feet in the east direction for a hydrophone sampled at both 2,000,000 and 96,000 samples/second

There has also been some concern expressed about the faster rise times and the use of a pressure transducer or a hydrophone relative to criteria. The fish peak pressure criterion used in the Pier E3 monitoring was developed for impact pile driving[1]. Impact pile driving is typically measured with hydrophones and not sampled at higher rates (typically less than 100,000 S/s). Shown in Figure 30, these lower rates may not capture the actual blast peak pressure, depending on distance. Conversely, the peaks measured with the pressure transducer could capture peaks with a much faster rise time than occur for impact pile driving and produce higher peak pressures accordingly. It is not the intent of this report to comment on the appropriateness of peak pressure criteria but rather to point out the differences that sampling rates could make in applying to the criteria. For fish criteria based on the SEL metric, the issue is not so ambiguous. The SEL criteria for fish were derived from blasting data sampled at a higher rate and with appropriate pressure transducers[10]. Further, as noted in the discussion of SEL vs. Time, the SEL produced with the

hydrophone sampled at 96,000 Hz was nearly identical to that sampled at 2,000,000 Hz with the pressure transducer. As a result, the choise of a pressure transducer or hydrophone for SEL is not critical.

The hydroacoustic monitoring of Pier E3 also produced some lessons learned for future monitoring. The modifications are suggested:

- Use TC4013 or TC4033 hydrophones at 500 feet and beyond, sampled at ~400,000 s/s;

- Deploy high speed recorders from skiffs or other vessels so the hydroacoustic monitor can verify (and adjust) the state of the measurement system as installed in the vessel during its final deployed state;

- Deploy the monitoring equipment as close as possible to the implosion time; do not rely on continued operation over a prolonged period of time (i.e., four or more hours);

- Plan for redundancy at each measurement location in case data is not captured by the primary system(s); given the one-time nature of an implosion event, capturing the signals in some fashion is better than capturing none; and

- Use attended measurements wherever and whenever possible; this allows the ability to modify and confirm the status of the instrumentation right up until the event.

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Appendix E. Alternatives Analysis

GANDA

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To: Mr. Stefan Galvez (SFOBB Environmental Compliance Manager)

From: Alex Pries

Date: January 30, 2015

RE: **SFOBB East Span Seismic Safety Project (SFOBB Project) Marine Mammal Impacts from Pier E3 Cofferdam Installation**

Removal of the marine foundations of the original east span of the San Francisco-Oakland Bay Bridge (SFOBB) is required as part of regulatory requirements for the SFOBB East Span Seismic Safety Project (SFOBB Project). Due to the schedule, cost, and environmental benefits when compared to mechanical demolition, the California Department of Transportation (Department) has proposed controlled implosion as the preferred alternative methodology of removal. Potential impacts to biological resources by the proposed demolition were previously presented in a biological evaluation. Up to a total of 22 marine foundations of the original east span may be removed to meet regulatory requirements. Three of these piers, E3 – E5, are deep-water caissons that require more complex methods for their removal.

The purpose of this memorandum is to present the evaluation of methodology and potential impacts to marine mammals from removal of Pier E3, the deepest marine foundation of the SFOBB, by means of installing a cofferdam around the structure prior to mechanical dismantling via ram hoe or saw cutting. This method is evaluated as an alternative to the preferred method of removing Pier E3 through controlled implosion.

Description of the Alternative to the Proposed Action:

For the purpose of analysis, the Department has prepared a conceptual plan for dismantling the concrete caisson supporting Pier E3, which is located approximately 1,535 feet (468 meters) east of Yerba Buena Island (YBI) in San Francisco Bay. Prior to demolition of this marine foundation, the Department would complete the removal of the above-water bridge superstructure, including the original cantilever span, truss, truss span, and supporting tower on Pier E3. Removal of the marine foundation via mechanical dismantling methods would require installation of a cofferdam, dewatering activities, and use of conventional equipment (i.e., ram

hoe or wire saw) to break the pier into smaller pieces for disposal.

Impacts to marine mammals from the proposed action would largely come from the marine propagation of impulse sound associated with the impact driving of piling to support and build the cofferdam. Exposure to impulse sound can result in short-term hearing loss (i.e., temporary threshold shift [TTS]), permanent hearing loss (i.e., permanent threshold shift [PTS]), and a variety of physical injuries up to mortality. Once installed, the area inside the cofferdam would be dewatered and the sound associated with mechanical dismantling is expected to be negligible in the marine environment. Thus, any impacts to marine mammals or their habitat from dismantling activities would be minimal. Impacts to marine mammals and their habitat from the sound associated with pile driving during cofferdam installation will be the key focus of this analysis. The use of vibratory methods to install piles is preferred and believed to have lesser impacts to marine mammals than impact pile driving methods. Vibratory installation of piles works well in soft sediments, but can be difficult if rocks, debris, or harder sediment layers impede installation of the pile. Additionally, for the Pier E3 cofferdam, obtaining a secure final elevation for the larger piles will be particularly critical to ensure the cofferdam's structural stability for holding back Bay waters and to create a safe working environment. As a result, Department engineers concluded for this analysis that the large diameter piles (e.g., 54" bulkhead pile and king pile) would require impact driving, and not vibratory methods, to obtain final, secure pile depth.

Installation of the Pier E3 cofferdam is anticipated to require the following pile array:

- Thirty six (36) 54" diameter 150 foot long bulkhead pipe piles [to prevent vessel impacts from breaching the cofferdam];
- One-hundred seventy (170) 145 foot long king or H-piles [HZM 1180M-D];
- Eighteen (18) 24" diameter 85 foot long support pipe piles;
- One-hundred seventy (170) 145 foot long sheet piles [AZ 26-700]

For the purpose of this analysis, installation of the above materials to a final elevation of approximately 57 feet below mudline (-114 feet 1929 NGVD) are as follows:

- All 36 bulkhead piles (54" diameter) would be impact driven with an attenuation system (i.e., bubble curtain) installed around the pile. An estimated 1,425 total strikes per pile would be required to reach final elevation. The anticipated impact hammer would be a Delmag D-100 with hammer energies between 214-360 kilojoules (kJ) per strike.
- All 170 king (H) piles would be impact driven with an attenuation system installed around the pile. An estimated 4,800 total strikes per pile would be required to reach final elevation. The anticipated hammer would be a Delmag D-100 with hammer energies between 214-360 kilojoules (kJ) per strike.
- All 18 support pipe piles (24" diameter) would be installed using a vibratory hammer, and then pile proofed to confirm elevation and stability. Pile proofing would involve a maximum of 20 strikes per pile using unattenuated impact driving. However, the use of an attenuation system is not practical given the amount of time required to set up

the system for a small number of strikes. The anticipated hammer for pile proofing of the support piles would be a Delmag 80 with hammer energies between 171-288 kJ per strike.

- All sheet piles (170 total) would be installed using a vibratory hammer, and one half (85 total) also would be proofed to confirm elevation and stability. As with the support piles, sheet pile proofing would involve a maximum of 20 strikes per sheet pile using unattenuated impact driving. The anticipated hammer for sheet pile proofing and unattenuated impact driving of sheet piles would be a Delmag D-46 with hammer energies between 71-166 kJ per strike.

Existing Guidance on SFOBB Pile-Driving Activities:

On December 18, 2013, the National Marine Fisheries Service (NMFS) issued an Incidental Harassment Authorization (IHA) to the Department for impacts to marine mammals from pile-driving activities associated with the SFOBB Project. The IHA distinguishes harassment into Levels A and B. Level A Harassment includes PTS, physical injury, or mortality. Level B Harassment is subdivided into Level B Behavioral Harassment, which may elicit a behavioral response from a marine mammal and Level B TTS Harassment. This document provided NMFS' guidance on the allowed amount of incidental exposure to Level B Behavioral Harassment for marine mammals from the SFOBB Project (Table 1). In addition, the IHA identifies temporary exclusion zones and Level B Behavioral harassment zones associated with Project pile-driving activities. Temporary exclusion zones are areas where individuals might be subject to Level B TTS Harassment and Level A Harassment during pile-driving activities. No pile driving is permitted to begin if a marine mammal is present in the temporary exclusion zone before activities begin. Pile-driving activities may occur when individual marine mammals are present in the Level B Behavioral Harassment zone. These zones are presented in Table 2, and include:

- Exclusion zones [Level B Harassment (TTS) or Level A Harassment (PTS or greater harm)] where sound pressure levels exceed 180 dB RMS (cetaceans) and 190 dB RMS (pinnipeds);
- A Level B Behavioral Harassment zone for impact pile driving noise level of equal to or greater than 160 dB RMS, and for vibratory pile driving noise level equal to or greater than 120 dB RMS.

Prior hydroacoustic monitoring of the area around the SFOBB has indicated that ambient noise levels often are greater than 120 dB, the level cited above for the onset of behavioral changes in marine mammals from vibratory pile driving. This portion of the Bay is a busy area with marine vessels transiting through the area on their way to the Port of Oakland. Because of this, it can be difficult to measure the distance to 120 dB RMS in the field. As a result, NMFS has established a distance of 2,000 meters from pile driving as the exposure area for Level B Behavioral Harassment from vibratory pile driving. This distance is assumed as the point where noise levels reach their baseline, or ambient, Bay conditions.

Table 1. Species and number of marine mammals allowed exposure (or 'take') to Level B Behavioral Harassment under the 2014 IHA for pile-driving activities.

Species	Take Allowed
Pacific harbor seal	50
California sea lion	10
Harbor porpoise	10
Gray whale	5

Table 2. Temporary Exclusion Zones [Level B (TTS) and Level A (PTS or greater harm) Harassment] and Level B Behavioral Harassment Zones for SFOBB pile-driving activities from 2014 IHA.

		Level B Behavioral Harassment Zone		Temporary Exclusion Zone [Level B (TTS) and Level A (PTS or greater harm) Harassment]	
Pile Driving Activity	**Pile Size**	**Distance to 120 dB RMS (m)[1]**	**Distance to 160 dB RMS (m)[2]**	**Distance to 180 dB RMS (m)[2] (cetaceans)**	**Distance to 190 dB RMS (m)[2] (pinnipeds)**
Vibratory Driving	24"	2,000	NA	NA	NA
	36"	2,000	NA	NA	NA
	Sheet pile	2,000	NA	NA	NA
Attenuated Impact Driving	24"	NA	1,000	235	95
	36"	NA	1,000	235	95
Unattenuated Pile Proofing	24"	NA	1,000	235	95
	36"	NA	1,000	235	95
Unattenuated Impact Driving	H-Pile	NA	1,000	235	95

[1] Threshold only applies to vibratory pile driving.
[2] Threshold only applies to impact pile driving.

Under the 2014 IHA, marine mammal observers are required to monitor areas around SFOBB prior to the initiation of pile driving activities. If individual marine mammals are within the identified temporary exclusion zones (180 dB or 190 dB RMS), pile driving activities will be delayed until the individual leaves the area. If an individual enters the 180 or 190 dB RMS exclusion zone after the commencement of pile driving, the Department is required to notify NMFS within 24 hours.

Hydroacoustic Analysis of Pier E3 Cofferdam (under current regulations)

A calculation of the distance to temporary exclusion (Level B [TTS] or Level A Harassment) zones and Level B Behavioral Harassment zones for installation of the Pier E3 cofferdam is presented below based on hydroacoustic analyses completed by Illingworth & Rodkin. Data

from the *Compendium of Pile Driving Sound Data* were used to establish the baseline source levels. The average RMS levels recorded for several projects were used to predict potential sound levels for the Pier E3 cofferdam installation. For installation of the 24" support pipe piles, data from the Amorco Wharf repair in San Francisco Bay, Tongue Point dock repair on the Columbia River in Oregon, Rodeo Dock repair in San Francisco Bay, Schuyler Heim Bridge replacement project in the Port of Long Beach, the Northern Rail project in Alaska, and the retrofit of the Richmond-San Rafael Bridge in San Francisco Bay were considered. For the 54" bulkhead pipe piles, data from the driving of 48" piles for the SFOBB Project were used exclusively. Distances were calculated for one impacted pile per day un-attenuated and attenuated with the assumption of 25 strikes per foot (1,425 total strikes per pile) for each pile type during impact driving. The maximum of 20 strikes per pile was assumed for unattenuated pile proofing of sheet piles and 24" support piles. Table 3 summarizes the distance to Temporary Exclusion and Level B Behavioral Harassment zones per pile activity for the Pier E3 cofferdam, under adherence to current SFOBB Project pile-driving regulations.

Table 3. Modeled Temporary Exclusion and Level B Behavioral Harassment Zones for the Pier E3 cofferdam.

		Level B Behavioral Harassment Zone		**Temporary Exclusion Zone (Level B [TTS] and Level A [PTS or greater harm] Harassment)**	
Pile Driving Activity	**Pile Size**	**Distance to 120 dB RMS (m)[1]**	**Distance to 160 dB RMS (m)[2]**	**Distance to 180 dB RMS (m)[2] (cetaceans)**	**Distance to 190 dB RMS (m)[2] (pinnipeds)**
Vibratory Driving	24"	2,000	--	--	--
	Sheet Pile	2,000	--	--	--
Attenuated Impact Driving	54"	--	338	23	6
	King Pile	--	225	15	4
Unattenuated Pile Proofing	24"	--	582	39	10
	Sheet Pile	--	508	34	9

[1] Threshold only applies to vibratory pile driving.
[2] Threshold only applies to impact pile driving.

SUMMARY

In summary, the total area subject to Level B Behavioral Harassment of marine mammals is much larger for the cofferdam installation scenario, largely due to the increased time required to install the piles than for the controlled implosion scenario. The cumulative area exposed to Level B (TTS) or Level A (PTS or greater harm) Harassment of marine mammals is higher for the one-day controlled implosion (109 acres) when compared at the 190 dB RMS threshold for pinnipeds (9.3 acres) during cofferdam installation. However, for cetaceans (the 180 dB RMS threshold), cumulative exposure during pile driving would be approximately one and a half times the area of the controlled implosion scenario (147 acres versus 109 acres). The actual risk of Level A Harassment exposure to individual marine mammals from either demolition method is unlikely

given the implementation of exclusion zones and monitoring. Exposure to Level B (TTS) Harassment of three harbor seals may occur from the controlled implosion. In contrast, the increased time (months to years) required to install the cofferdam, along with historical monitoring data, suggest there is a potential for equal, or greater, TTS exposure under this method. This could occur even with effective monitoring, because current regulations allow for continued pile driving if an individual enters the exclusion zone after work has commenced

The proposed installation of a Pier E3 cofferdam under adherence to current SFOBB Project IHA pile-driving regulations for marine mammals is achievable. The modeled distances for impact and vibratory driving of the piles required for the cofferdam are well within the accepted distances as defined in the Project's current IHA. However, the time and duration required to install all piles for the cofferdam also would increase the potential for individual exposure. With a total of 394 piles proposed for the Pier E3 cofferdam and more restrictive regulations on daily sound exposure from pile driving under the 2012 NMFS Biological Opinion (BO) for marine fish, pile driving for the cofferdam likely would occur for months to years. This increased duration for pile driving may increase the potential risk for individual exposure to harassment.

While marine mammal monitoring during pile driving for the E3 cofferdam may result in no exposures greater than behavioral harassment, the installation of piles for the cofferdam likely will result in a similar outcome as the controlled implosion (e.g., some TTS exposure). This is because the increased duration of pile driving actions (months/years) when compared to the controlled implosion (seconds) may increase the probability of exposing an individual to TTS. Since 2001, a total of 19 harbor seals and 3 California sea lions have been observed, during 210 days of monitoring for the SFOBB Project, entering the Level B (TTS) Harassment Zone after pile driving activities began. These numbers suggest there is about a 10% chance of encountering a harbor seal daily inside the Level B (TTS) Harassment Zone while pile driving. For California sea lions, this chance is about 1.5%. Using these values and an assumption of pile-driving for the cofferdam requiring 394 days (i.e, one pile per day), potential TTS exposure could occur to 39 harbor seals and six California sea lions.

In contrast, the current blast plan would remove Pier E3 down to mudline and the detonation sequence would last for approximately **5 to 6** seconds. On-site work in advance of the implosion would likely take months, but is anticipated to result in negligible disturbance to the marine environment when compared to the hydroacoustic impacts associated with pile driving. In late 2013, NMFS developed new regulatory thresholds for marine mammals subject to underwater blasting. The new thresholds use Sound Exposure Level (SEL) and peak pressure (in dB) thresholds to establish areas of potential behavioral harassment, Level A harassment, or Level B harassment for marine mammals. The new thresholds establish different threshold criteria for underwater explosions compared to pile driving. This makes comparisons to the same sound exposure threshold difficult. However, the difference in the area of exposure for a threshold at which an effect may occur remains a valid comparison. As a result, comparison of the total acres affected over time for the exclusion zone thresholds for cofferdam construction is compared to the total acres affected over time for exclusion zone thresholds for the controlled implosion.

Hydroacoustic analysis of the Pier E3 implosion using the revised (2013) thresholds indicates the largest distance to the Level B Behavioral Harassment zone would be 13,564 meters (44,500

feet) for harbor porpoise (the most acoustically sensitive species). The distance to Level B (TTS) Harassment Zone for harbor porpoise was modeled at 8,077 meters (26,500 feet). However, the likelihood of this species occurring within the Bay during the implosion is very low and the species has not been detected within the project area during 210 days of marine mammal monitoring to date. However, real-time acoustic monitoring for harbor porpoises will be proposed in advance and during the implosion to ensure this species is not in the immediate area. For the species expected to be present around Pier E3 (i.e., harbor seal, California sea lion, and Northern elephant sea), the modeled distance to the Level B Behavioral Harassment zone was 2,957 meters (9,700 feet). The distance to the Level B (TTS) Harassment zone was 1,737 meters (5,700 feet), which does include known foraging areas for harbor seals at YBI, Clipper Cove, and southeast of YBI. The distance to the Level A (PTS or greater harm) Harassment zone, which reflects the implosion's marine mammal exclusion zone, for these species is 354 meters (1,160 feet). This distance could be effectively monitored under the existing marine mammal monitoring plan for the SFOBB Project. Inclusion of the Level B Behavioral Harassment Zone into the implosion's exclusion zone is not feasible due to the high probability that harbor seals will occupy known foraging areas near YBI and Clipper Cove. Prevention of Level B (TTS) exposure to individual seals within these areas could delay the implosion during a small window of opportunity.

The Pier E3 blast was modeled to potentially result in Level B (TTS) Harassment exposure to three Pacific harbor seals. This assessment is based on historic marine mammal densities in the exposure area and the implosion's duration of 5 to 6 seconds. In addition, six harbor seals, one Northern elephant seal, and one harbor porpoise would potentially be within the implosion's behavioral response zone. Through the implementation of exclusion zones and monitoring, no individuals would be subject to Level A (PTS or greater harm) Harassment.

The duration of potential exposure to marine mammals affected from cofferdam installation can be expressed as the product of the daily amount of acres affected multiplied by the number of days of effect. This value also can be interpreted as the cumulative amount of acres exposed during installation of a Pier E3 cofferdam. Table 4 presents cumulative acre information for marine mammal exposure under the assumption of one pile driven per day plus an estimated exposure to marine mammals from the controlled implosion. In reality, the 2012 BO's more restrictive pile-driving regulations for marine fish would likely limit the amount of pile driving allowed on a daily basis. However, for the sake of this comparative analysis we have ignored this limitation.

Table 4. Comparison of Marine Mammal Hydroacoustic Impacts from Pier E3 Cofferdam Installation versus Controlled Implosion

				Level B Behavioral Harassment Zone				Temporary Exclusion Zone (Level B [TTS] and Level A [PTS or greater harm] Harassment)			
Construction Approach	**METHOD**	**Pile Type**	**Days Required[1]**	**Acres Affected to 120 dB RMS (Per Pile)**	**Acres Affected to 120 dB RMS (Total)**	**Acres Affected to 160 dB RMS (Per Pile)**	**Acres Affected to 160 dB RMS (Total)**	**Acres Affected to 180 dB RMS (Per Pile)**	**Acres Affected to 180 dB RMS (Total)**	**Acres Affected to 190 dB RMS (Per Pile)**	**Acres Affected to 190 dB RMS (Total)**
Cofferdam Installation	Vibratory[2] Driving	24”	18	3,113	56,034	N/A	N/A	N/A	N/A	N/A	N/A
		Sheet Pile	170	3,113	529,210	N/A	N/A	N/A	N/A	N/A	N/A
	Attenuated Impact Driving	Bulkhead 54”	36	N/A	N/A	88	3,168	0.4	14.4	0.03	1.1
		King Pile	170	N/A	N/A	39	6,630	0.2	34	0.01	1.7
	Unattenuated Pile Proofing	24”	18	N/A	N/A	262	4,716	1.2	22	0.08	1.4
		Sheet Pile	85	N/A	N/A	200	17,000	0.9	76.5	0.06	5.1
	Totals[3]	-	**497**	**6,226**	**585,244**	**589**	**31,514**	**2.7**	**147**	**0.18**	**9.3**
				Level B Behavioral Harassment Zone (Total Acres Affected)[4]		**Level B (TTS) Harassment Zone (Total Acres Affected)[5]**		**Temporary Exclusion Zone (Level A [PTS or greater harm] Harassment) (Total Acres Affected)[6]**			
Controlled Implosion	Attenuated Implosion	NONE	**1**	**4,401**		**1,854**		**109**			

[1] Assumption that one pile per day can be driven or vibrated.
[2] Vibratory drilling does not generate enough noise to reach Level B or Level A Harassment
[3] Totals tally Total Acres
[4] Area is calculated to 172 dB SEL Criteria
[5] Area is calculated to 177 dB SEL Criteria
[6] Area is to calculated to 192 dB SEL Criteria