# Appendix A: Description of Equipment

**Introduction**

In the Sand Survey Activities Environmental Assessment (EA), Table 2-1 summarizes survey equipment and methods. Previous documents (BOEM 2017, Crocker and Fratantonio 2016, BOEM 2014a, BOEM 2014b) provide a more detailed characterization of these proposed sources and their sound propagation characteristics, particularly as they relate to activities similar to those proposed here. Source level, frequency, and operational restrictions are outlined in the proposed action, with mitigations discussed in Appendix B. No airguns or sparkers are proposed for use.

Frequency (i.e., number of cycles per second, with hertz [Hz] as the unit of measurement) and amplitude (i.e., loudness, measured in decibels, or dB) are typically used to describe sound. The frequency is often proportional to the resolution of acquired data. The source level is the equivalent of the sound power and is measured as an acoustic pressure at a reference distance of 1 meter (m) (3 feet [ft]) from the source. Sound source levels are typically based on manufacturer's specifications or, where available, field measurements. Use of manufacturer's specifications often represents a conservative estimation, as equipment power settings and sound output is often adjusted given data needs and/or site-specific conditions.

The level of sound in water can be expressed in several different ways, but always in terms of dB relative to 1 microPascal (1 µPa) at 1 meter (m). Each 10 dB increase represents a 10-fold increase in sound pressure. Peak pressure level is the maximum Sound Pressure Level (SPL; highest level of sound) in a signal measured in dB re 1 µPa. The root-mean-square (rms) SPL can be thought of as a measure of the average pressure for at least 1 second, or as the "effective" pressure over the duration of an acoustic event. "Source level" refers to the rms SPL when measured at 1 m from the source. Each 10 dB increase in acoustic intensity corresponds to a ten-fold increase in sound pressure.

When sounds travel from the source to the receiver (i.e., an animal in the water), the sound waves experience transmission loss due to geometric spreading, absorption, and repeated reflections off the ocean surface and ocean bottom (i.e., the multiple "paths" the signal takes). Because these multiple paths travel different lengths (depending on the angle of reflection and thus the number of bottom-surface bounces), by the time the sound reaches the receiver, the time window of the signal has spread out. Because, from the perspective of an animal, the duration of a signal is an important element to consider, the Sound Exposure Level (SEL) is a metric that is used to quantify the total acoustic energy that is received. SEL is the integration over time of the square of the acoustic pressure in the signal and is thus an indication of the total acoustic energy received. SEL can be used to characterize the source level or the received level. Cumulative SEL represents the total SEL that may be received over the duration of an acoustic event that includes several signals and is stated in dB re 1 $\mu Pa^2 \cdot s$.

**Geophysical Equipment and Techniques**

Geophysical surveys would be undertaken to identify OCS sand resources. Geophysical surveys use a high-resolution, low-energy electromechanical sound source and receiver system towed behind a vessel. Electromechanical sound sources, like the ones used in the proposed action, create an oscillatory overpressure through vibration of a surface, using either electromagnets or the piezoelectric effect of transducer materials. Transducers produce an acoustic wave of a specific peak frequency, often in a highly directive beam. Sub-bottom profiling would use a chirp and/or boomer system. Chirps are much more commonly used compared to boomer systems. The primary goal of sub-bottom profiler data collection is to provide an accurate depiction of the geologic framework and near-surface sand thickness (isopach) that can be further evaluated for possible recovery and placement as beach restoration material. The chirp system is generally towed at depth off the seafloor, whereas the boomer is towed at or near the surface. Based on data needs, BOEM does not anticipate that neither the chirp nor boomer would operate above 205 dB re 1 µPa rms SPL.

Sound characteristics for equipment used in sand survey activities in Table A-1 were tested by Crocker and Fratantonio (2016) (also presented in Crocker et al. 2018). SEL and SPL source levels used in this analysis were derived from the maximum measured source level (as reported in Crocker and Fratantonio 2016) for the most frequently used equipment. Cumulative SEL was estimated based on an assumption that an animal may directly experience a sound source for 10 transmissions, which is conservative given that either one or both of the survey vessel and animal will be in motion. Source characteristics were used to calculate distances to thresholds for Level A (using SEL cumulative) or Level B (using rms SPL) Harassment of marine mammal hearing groups based on how sound propagates through the somewhat shallow shelf depths of the Study Area (Table A-2). The distances to Levels A and B Harassment were calculated using a transmission loss formula of 20 Log R up to a 50-m (164-ft) radius (matching a 50-m maximum survey depth), then transitioning to a 15 Log R formula. This calculation also accounted for the beam pattern restricting the zone of ensonification by about 30 percent. The threshold for Level A Harassment varies from 173 to 219 dB cumulative SEL, varying for each of the marine mammal hearing groups (NOAA 2016 and Table 3-1 of the EA), while the Level B Harassment threshold is consistent across groups at 160 dB rms SPL for geophysical sources and 120 dB rms SPL for vibracoring. Since only the chirp and boomer primary frequencies are within the hearing ranges of marine animals, distances to harassment levels are only reported for these sources in Table A-2. In Tables A-1 and A-2, all source levels are in dB re 1 µPa @ 1 m, while SEL values are in dB re 1 $\mu Pa^2 \cdot s$.

### *Geophysical sources likely to be detected by marine species*

Chirp Sub-bottom: Chirp sonar uses a transducer to emit a frequency-modulated sound pulse towards the seafloor and to receive the return of the pulse once it is reflected from the seafloor or from the contacts between sedimentary layers near the seafloor (with different acoustic impedance). For optimal data quality, the chirp system is typically towed at water depths where the towfish remains within approximately 10 feet (3 m) above the seafloor (Figure A-1). Chirp systems are generally single channel systems that operate around a central frequency that is swept electronically across a range of frequencies to provide improved resolution. The most probable system consists of towfish with an internal transducer that imparts an acoustic signal with frequencies potentially ranging from 500 Hz up to 24 kilohertz (kHz) approximately every 0.5 to 1 seconds. Chirp signals are generally very short and therefore sound something like a bird chirp, hence their name. Although the sounds of a chirp sub-bottom profiler are less than one second, they are considered to be non-impulsive sound sources because the sound waves of the different frequency components are not adding coherently as a single rise in pressure, nor is there a sharp negative pressure component to the pulse they sweep.

Boomer: A boomer is a low-energy towed device typically consisting of a multi-channel acoustic source that uses a magneto-restrictive plate diaphragm to impart an acoustic pressure signal into the water column. The signal output is generally set to less than 100-350 joules and frequency ranges between 300 and 10,000 Hz. Boomers are fixed-frequency sources, but they do operate across a range of frequencies with a broadband signal. The boomer imparts an acoustic signal approximately every 0.5 to 1 second and is also considered to be a non-impulsive source for the same reasons described above for chirps. A secondary cable of passive hydrophones is used as a signal receiver. Typical tow length for the boomer is approximately 75-100 ft (23-30 m) behind or alongside the vessel, and the hydrophones are towed at about 100-125 ft (30-38 m) from the vessel. Both are towed at the water's surface; the boomer plate is installed on a small catamaran or sled structure (Figure A-1).

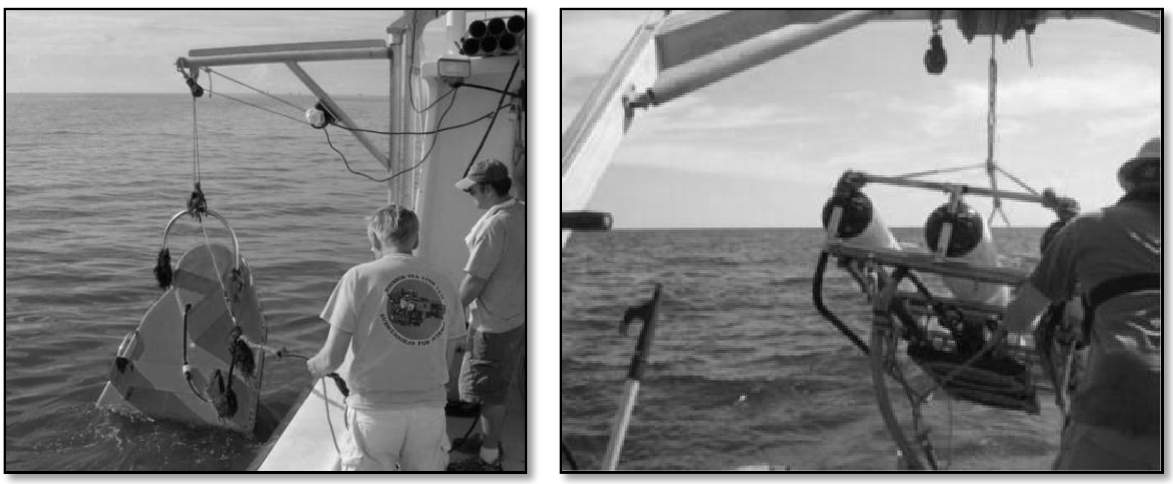

**Figure A-1. Chirp Towfish Deployment from Port (left); Boomer Sled Deployment from Stern (right)**

*Geophysical sources less likely to be detected by marine species*

Other geophysical data could be collected using a combination of equipment and techniques, but the primary frequency range at which these sources would operate is above the known hearing range of marine species. Multibeam or interferometric swath bathymetry is used to gather information about water depths/seafloor topography/seafloor condition. Not only do such systems provide information on the seabed, but the reflected acoustical signal (backscatter) can also be used to characterize the seabed with regard to archaeological resources, benthic habitat, and sediment composition (Dartnell and Gardner, 2004). Due to the relatively high frequency nature of their signal, they do not penetrate very far into the bottom.

Multibeam Bathymetry: Multibeam bathymetry systems transmit and receive relatively high frequency acoustic pulses through the water which reflects off the seafloor and returns to the receiver. The time elapsed between the pulse being emitted and received is converted to a distance by multiplying this number by the speed of sound in water. The source level (rms SPL) for multibeam bathymetry ranges from about 210 to 230 dB re 1 µPa @1 m. The peak and primary frequency range would typically be limited to above 180 kHz to avoid/reduce noise impacts on marine mammals. The system records with a sweep appropriate to the range of water depths in the survey area. A bathymetry system is useful in areas characterized by complex topography or fragile habitats.

In addition to identifying sediment features, acoustic backscatter data can be collected using multibeam bathymetry and analyzed to provide valuable information on archaeological resources and sediments. Surface shape and roughness influence backscatter strength from coarser sediments and from other hard surfaces like reefs and shipwrecks (Gustav 2008). When this type of technique is validated by geologic samples or underwater photography, accuracy is approximately 70-80 percent (Gustav 2008). No additional equipment would be needed to implement this approach; however, different software/analytical techniques would be employed.

Interferometric Swath Bathymetry: In contrast with multibeam bathymetry, interferometric swath bathymetry uses two outward-facing transducers, as opposed to an array, to transmit and receive acoustic pulses. The elevation angle of a target on the seafloor is measured from the phase difference between the signals received on the two separate receivers. Peak and primary frequency range would be limited to above 180 kHz to avoid/reduce noise impacts on marine mammals. Source level (rms SPL) ranges from approximately 200 to 220 dB re 1 μPa. Acoustic backscatter can be used as a substitute for side-scan sonar data, provided that data quality standards are met. Depending on water depth, fewer track lines could be surveyed using an interferometric swath system, in comparison to multibeam, to achieve the same coverage.

Side-Scan Sonar: Side-scan sonar generates an image of seabed morphology, submerged objects, and other features by emitting a high-frequency acoustic pulse, which typically has frequency ranges from 100 to 900 kHz, which attenuates rapidly in the water column. However, to limit sound exposure, any use of side-scan sonar would be limited to operating at frequencies greater than 180 kHz. Source level ranges from approximately 200 to 240 dB re 1 μPa (rms SPL).

When possible, backscatter data for multibeam and/or interferometric swath surveys would be used as a substitute to side-scan sonar, provided along-track resolution is less than 1 m at 100-m (3 ft at 328-ft) slant range. Side-scan sonar and/or swath bathymetry backscatter data would be used to construct a mosaic image to provide a true plan view with 100 percent coverage of the area of interest. The resulting image would be automatically corrected for slant range, lay-back, and vessel speed. As an added data feature, the rate of signal attenuation backscatter can indicate surficial sediment type or seafloor habitat information.

Magnetometer: The marine magnetometer is a passive remote-sensing device (i.e., no energy is transmitted) that identifies materials with ferrous or ferric components or other objects having a distinct magnetic signature. For surveys such as these, variations would be caused by local deposits of ferromagnetic material that could be attributable to unexploded ordnances, objects of archaeological significance, or seafloor hazards such as buried cables. The magnetometer sensor should be towed as closely as possible to the seafloor not to exceed an altitude of greater than 20 ft (6 m) above the seafloor, and using line spacing not to exceed 98 ft (30 m). The sensor should be towed in a manner that minimizes interference from the vessel hull and other survey instruments.

**Acoustic Characteristics of Geophysical Sources**

There are numerous and complex factors to consider when describing the propagation of sound emitted from a geophysical source in the marine environment. The perception of sound is equally complex and depends on several factors, such as the hearing range of the animal, the intensity of the sound, etc. As sound propagates away from a source, its amplitude, or loudness, decreases exponentially and is influenced by environmental factors including source characteristics, directionality, beamwidth, the sound speed profile, and the signal's interaction with ocean boundaries (e.g., the sea surface and the seafloor). These factors ultimately determine the distance and characteristics of the transmitted signal and how it will compare to the local ambient noise.

**Table A-1. Characteristics of Electromechanical Sources Proposed for Geophysical Surveys***

| Source | Operational Frequency Range | Peak Source Level | Representative Beam Pattern (Horizontal and Vertical) | Frequency for Testing[1] | Representative Pulse Length (ms) | RMS SPL (dB) | SEL (dB) | Cumulative SEL (dB), 10 seconds |
|---|---|---|---|---|---|---|---|---|
| **Boomer (surface tow)** | 300 Hz - < 10 kHz | < 220 dB | Horizontal: omnidirectional Vertical: downward focused | 6.2 kHz | 0.6 | 205 | 172 | 182 |
| **Chirp sub-bottom profiler (tow above seafloor)** | 500 Hz -24 kHz | < 220 dB | Horizontal: omnidirectional Vertical: downward focused | 4-20 kHz (wideband) | 4.6 | 180 | 156 | 166 |
| **Side-scan sonar (near-surface tow)** | > 180- 900 kHz | < 240 dB | Along-track: very narrow Across-track: wide | 445 kHz | 0.1 | 223 | 182 | 192 |
| **Multibeam (hull or davit mounted)** | > 180-500 kHz | < 230 dB | Determined by number of beams, beam spacing, frequency, etc. Along-track: very narrow Across-track:wide | 300 kHz | 0.3 | 221 | 185 | 195 |
| **Interferometric Swath (davit mounted)** | > 180-600 kHz | < 220 dB | Depends on frequency Along-track: very narrow Across-track: wide | 234 kHz | 0.2 | 218 | 180 | 190 |
| **Single Beam (hull mounted)** | > 180-540 kHz | < 230 dB | Horizontal: omnidirectional Vertical: Downward | 200 kHz | 0.7 | 194 | 163 | 173 |

*Shading indicates the operational frequency is beyond hearing range of cetaceans, manatees, seals, sea turtles, and most fish. [1]Testing by Crocker and Fratantonio 2016; see report for details. All source levels are in dB re 1 µPa @ 1 m, while SEL values are in dB re 1 µPa$^2$ · s.

**Table A-2. Distance to Level A and Level B Harassment of Marine Mammal Hearing Groups***

| Source | Range to Level B (m) | Range to Level A (m) | | | | |
|---|---|---|---|---|---|---|
| | All Marine Mammals (160 dB) | Low-frequency Cetaceans (199 dB) | Mid-frequency Cetaceans (198 dB) | High-frequency Cetaceans (173 dB) | Phocid Pinnipeds (201 dB) | Otariid Pinnipeds (219 dB) |
| **Boomer (surface tow)** | 192 @ 205 dB<br>89 @ 200 dB | < 1 | < 1 | <3 | < 1 | < 1 |
| **Chirp sub-bottom profiler (tow above seafloor)** | 7 @ 180 dB | < 1 | < 1 | < 1 | < 1 | < 1 |

*Only sources with operational frequencies (peak and primary) within hearing range of cetaceans, manatees, seals, sea turtles, and most fish reported.

**Geological Equipment and Techniques**

Information from geological surveys (i.e., sediment sampling) would be used in tandem with geophysical data to ground-truth geophysical data and to determine the geometry, volume, and quality of offshore sand resources/deposits. Sediment sampling would occur at selected locations where existing geophysical data indicate promising targets for quality sand. Some samples would be taken at sites on the flanks of the geomorphic features or sand resource areas to determine the footprint and other geologic characteristics, and other samples would be taken in the center of the resource areas to verify data regarding the thickness and textural properties of the sand resource. Sediment sampling could be completed using a vibracore or a grab sampler. In general, grab sampling is conducted when surficial sediment composition needs to be studied as opposed to sediment thickness and stratigraphy. The two techniques of sediment sampling are discussed below.

Vibracoring: A 3- or 4-inch (7.6- or 10.1-centimeter [cm]) diameter aluminum core barrel mounted on a platform or support assembly would be used to penetrate sediments in the upper 20 feet (6 m) of the seafloor. A sediment sample of 5-20 feet (1.5 to 6 m) would be acquired to determine sediment characteristics and sand resource thickness. To penetrate seafloor sediments, the core barrel is vibrated by a pneumatic or electric vibrahead, which results in local liquefaction of sediment along the core barrel surface, facilitating penetration into the sediment (Fugro 2003, ISSMGE 2005). Penetration typically occurs within 5-10 minutes. Some operations use a single, non-reusable aluminum core barrel to collect and preserve the core sample, whereas others have a reusable core barrel that is lined with a plastic or Kevlar sleeve that collects and preserves the sample. A typical vibracore survey would obtain 15 cores approximately 20 feet (6 m) into the seafloor in an area measuring 1 square mile (640 acres or 259 hectare) per day. The vibratory mechanism on the vibracorer would introduce sound into the substrate and some sound would be radiated into the water column as well. The vibratory mechanism produces a relatively short, broadband noise with peak frequency less than 1 kHz. Source levels are generally expected to be less than 180-190 dB re 1 μPa @ 1 m depending on the intensity of the vibrations, barrel material, and nature of sediment penetration (Reiser et al., 2011). Vessels may be dynamically positioned, live boated, or anchored, under permissible circumstances, during vibracoring (Figure A-2), which may also contribute to the radiated noise during the operation.

**Figure A-2. Deployment of a 20-foot Vibracore from Stern A-frame**

Grab Samplers: Grab samplers are one of the most common methods of retrieving sediment samples or biological samples from the seabed. A grab sampler is a device that collects a sample from the surface of the seabed by bringing two steel clamshells together. The grab is lowered to the seabed and activated either automatically or by remote control. The shells swivel together in a cutting action and by so doing remove a section of seabed. The sample is recovered to the ship for examination. One grab sample takes approximately 5-15 minutes to obtain. Grab sampling penetrates from a few inches to a few feet below the seafloor. The greatest noise associated with grab sampling is expected to be vessel noise, which would also be 150-170 dB re 1 μPa @ 1 m (CEDA 2011).

Geological sampling disturbs the seafloor; however, due to the small size of the vibracores and associated platforms, the area of seabed to be disturbed during individual sampling events is estimated to range from 1 to 9 square feet (0.3 to 2.7 square meters). The total area of seafloor disturbed by bottom sampling and shallow coring activities would be a very small portion of the total Study Area.

**Survey Vessels, Timing, and Design**

Surveys can occur either through one mobilization for simultaneous collection of data, or through separate mobilizations (one to collect geophysical data and one to collect geological information) from regional ports and shorebases. Either mobilization could potentially use more than one vessel. Depending on the nature of operations, surveys would be conducted by vessels that could potentially remain offshore for 1-30 days of their survey duration, but could travel periodically to an onshore support base for fuel, supplies, equipment repairs, and crew changes. Before any geological sampling occurs, the area would be investigated by appropriate means to ensure impacts to sensitive resources are avoided; this could entail advance or real-time interpretation of geophysical data by qualified personnel or by divers assisting with vibracoring.  Data collection would be continuous during the survey but could stop while the vessel repositions or temporarily cease due to environmental considerations.  Survey plans that include details of mobilization and data collection expectations would be developed and approved prior to a specific project.

The survey time of year is largely constrained by seasonal sea-state conditions, with a desired conditions consisting of wave heights of less than 3 ft (1 m) for geophysical surveys and less than 5 ft (1.5 m) for geological sampling.  Surveys in the North and Mid-Atlantic are typically more efficient after the spring winds of May have subsided until mid-September/October, when the probability for nor'easters and other strong storms increases.  For the South Atlantic and Gulf of Mexico, opportune times for surveying are the same as the North and Mid-Atlantic; however, peak hurricane season from summer to fall could affect the ability to conduct surveys.  Geophysical activities usually occur during daylight hours, unless nighttime surveying occurs with consideration of a passive acoustic monitoring system (Appendix B). Sand survey activities would take into consideration areas designated as North Atlantic right whale critical habitat or dynamic/seasonal management areas (DMAs/SMAs) in the Atlantic (Appendix B).

Depending on the type of equipment being deployed, a vessel with an A-frame, boom, or davit could be required to assist with instrument deployment and retrieval.  Typically, survey equipment would be deployed from a single vessel ranging from approximately 28 to 120 ft (9 to 37 m) in length, depending on the survey activity to be conducted/equipment needs, and would survey at speeds between 3 and 5 kn (5.6 and 9.3 kilometers per hour [km/hr]), but may travel 10-12 kn (19-22 km/hr) while in transit. Vessels would be equipped with and transmit Automatic Identification System (AIS) (or equivalent) data to the extent practicable.  Vessels would be equipped with an integrated navigational system with layback ranging instrumentation to track the position and depth of towed survey equipment.  Bathymetric data would be tidally corrected using satellite altimetry, or in limited cases, coastal or temporarily-installed water level gauges.  Vessels with a vibracoring rig could be larger to support the rig and associated equipment.  In addition to a boat captain, a vibracoring operation team requires about 3-6 crew members, including a geotechnical engineer, 1-3 researchers, and protected species observers (PSOs) (refer to Appendix B for a discussion of observer requirements), depending on length of survey day.  Liftboats, or other spudded boats, would not be used as a vibracoring platform.

Depending on the size of the vessel and length of the geophysical survey, operations would generally be managed by a boat captain, crew (optional), 1-3 researchers, and PSOs.  Vessels would be generating continuous noise levels from bow-wave slap, wake bubble collapse, propeller cavitation, and engine noise; these sounds typically fall between 10 Hz and 100 kHz.  The slower a boat travels, the lower the noise levels that are radiated into the water column (Martin et al., 2012a; Zykov and Carr 2012).  Vessels would use dynamic positioning or live-boat during coring; anchoring would be avoided to the maximum extent possible.

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