Acoustic Corer with synthetic aperture sonar for subsurface imaging of buried obstructions in the Hudson River

Introduction

Kraken Robotics was contracted by Weeks Marine, Inc., on behalf of The Gateway Development Commission (GDC) to carry out an Acoustic Corer (AC) survey within the Hudson River, New York, USA. The AC survey was part of the Hudson River Ground Stabilization (HRGS) project, with the aim of installing a new subway tunnel underneath the Hudson River. The AC data was used to identify buried objects that may cause an obstruction to the HRGS project.

The AC, equipped with synthetic aperture sonar (SAS) processing protocols, is an advanced geophysical imaging tool designed to map subsurface anomalies with unparalleled precision, supporting complex infrastructure projects (Kilic and Laidley, 2024). The survey was conducted in a dynamic, shallow-water environment where standard geophysical tools often struggle to resolve near-surface features with adequate fidelity.

The HRGS project targeted a 366-meters section of the Hudson River's Manhattan shoreline, where soft silt (Ott, 2023) required stabilisation to support tunnel boring (Figure 1). The AC's capability to resolve small-scale anomalies—such as construction debris, moorings, or pier remnants—at depths up to 20 m below the riverbed was critical. This paper presents the implementation of the AC across 102 locations, outlines deployment strategy, data processing techniques, and demonstrates the accuracy of AC imaging through a real-world example where an anomaly was confirmed by client excavation.

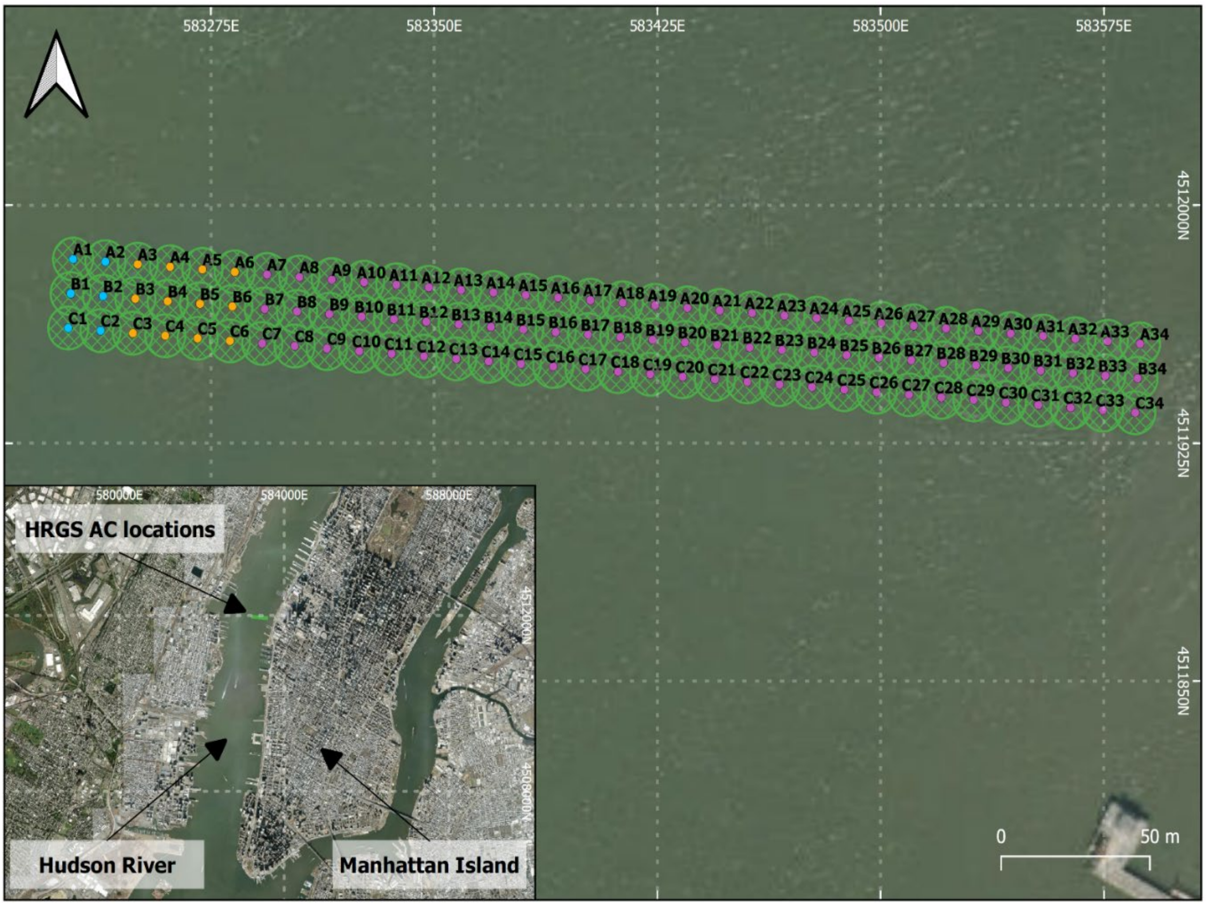

Figure 1 *Proposed AC locations within the HRGS project survey area.*

Acoustic Core Technology

The "Acoustic Corer (AC)" (Guigné et al., 2012) is, a stationary seabed/surface deployed unit, a volumetric acoustic imaging system capable of acquiring high-resolution Synthetic Aperture Sonar (SAS) data by integrating High Frequency (HF) chirp, Low Frequency (LF) chirp and Innomar/Parametric Synthetic Aperture Sonar (SAS) data. The AC conducts acoustic data acquisition in the 1.5 kHz to 15 kHz frequency, producing high-resolution, three-dimensional volumetric image—referred to as "acoustic core"—with a diameter of approximately 14 m and a penetration depth of up to 60 m below the seabed or riverbed, depending on soil conditions. The AC excels in detecting discrete and clustered non-specular returns such as buried debris, timber piles, and metallic infrastructure, offering critical insights in urban riverbeds and seabeds with anthropogenic layers.

Data Acquisition

Two types of data were acquired during the survey: Synthetic Aperture Sonar (SAS) data and JYG-Cross multi-fold data. The SAS data were used for subsurface interpretation, while the JYG-Cross data is used the construction of a velocity model for Kirchhoff time migration applied to the SAS data. Given the soft silt riverbed and strong current conditions, conventional geophysical equipment faced limitations. Weeks Marine designed a deployment method using a pile with an attached strut (arm), on which the AC sits without the use of tripod legs, to secure the AC during scanning (Figure 1). This rigid setup ensured consistent placement across all sites and offered a geometric reference, which was later used during data processing for positioning corrections. Since each AC scan revolved around this pile and imaged the attached strut, the strut response appeared consistently in all datasets, forming a reliable basis for geometric corrections. During data acquisition, the offshore team performed continuous Quality Assurance and Quality Control (QA/QC) procedures, which were implemented throughout data acquisition to ensure that the highest data quality was being acquired. After each scan, corresponding QA/QC reports were generated, which included positional charts and data coverage plots to confirm all positions and desired landed locations had been achieved. Additional data plots such as echograms, spectrograms and noise analysis were also provided to the client.

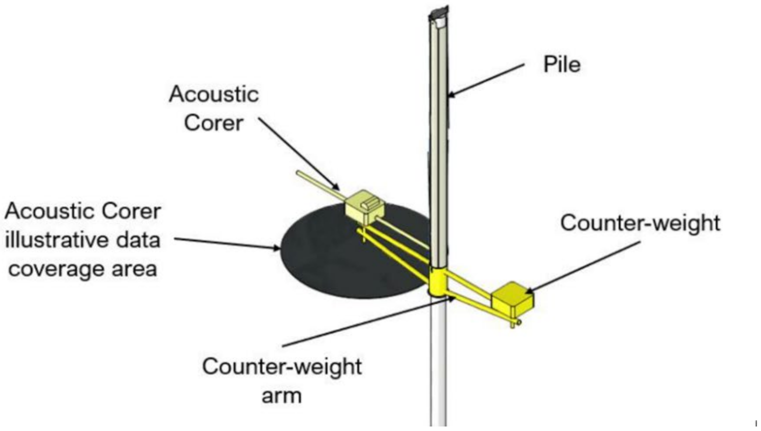

Figure 1 *The Acoustic Corer (without tripod legs) mounted on the counter-weight arm, which is attached to the pile. The counter-weight arm can be lifted off and positioned in four different directions, 90° to each other.*

Data Processing

Data processing was performed using Kraken Robotics' proprietary signal processing software, ZoomSpace™, based on the standard seismic processing steps. The raw data were pre-processed using frequency-specific filters: matched filter pulse compression—applied only to HF SAS data—to optimise the signal-to-noise ratio (SNR) of the received signal, and a band-pass filter to remove frequency components outside the AC's bandwidth. This was followed by Pre-stack Kirchhoff time migration to produce high-resolution 3D volumes. To prepare the data for interpretation, a series of post-processing steps were applied, including time-to-depth conversion and amplitude scaling for visualisation and analysis. The same steps were applied to the 102 AC cores. Due to site-specific elevation changes across the 102 AC locations, static corrections were applied to unify the AC cores to a common datum. This ensured a precise interpretation of the full volume.

The alignment of the Fibre Optic Gyro (TOGS), which provides the heading of the acquired data, on the AC resulted in an angular offset in each data core, which required correction. As shown in the left image of Figure 3, without a TOGS correction, the acoustic response of the strut (shown as the rectangular yellow feature in Figure 3) did not align with the landed and pile positions of the site. To determine the necessary rotation for each site location, a preliminary time migration was carried out on each Parametric data set and, using a third-party software, the strut position identified in the data set was obtained. The angular difference between the "as picked" strut position and the pile location provided by the client was then calculated and used as the angle of rotation during pre-processing.

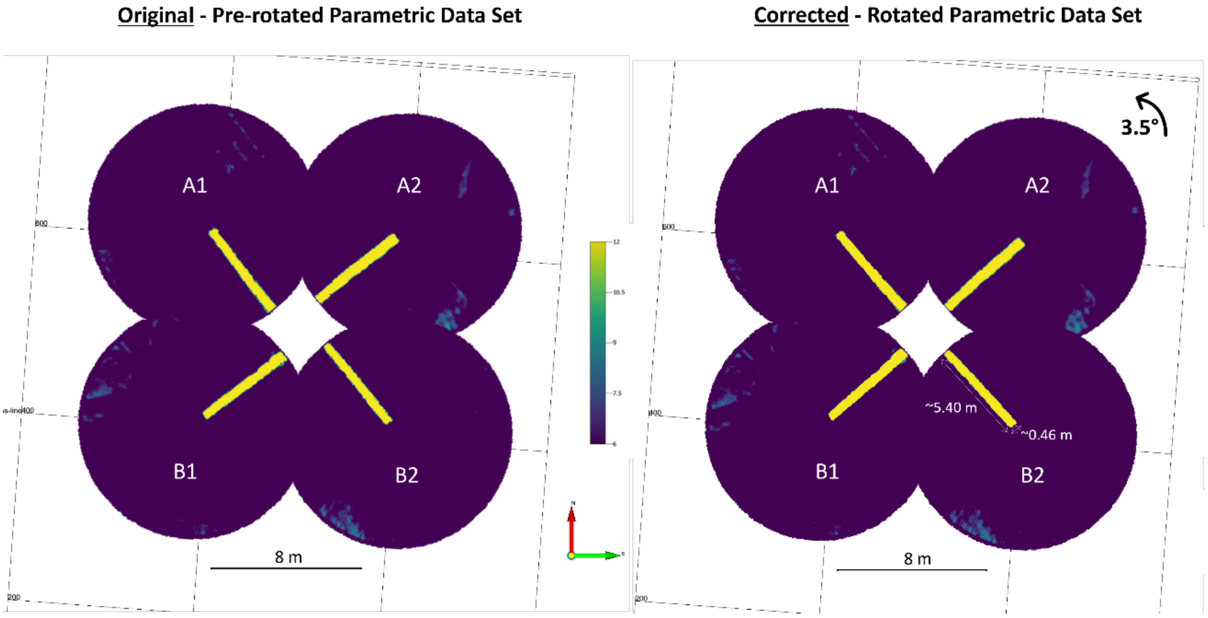

__Figure 3__ Before (left) and after (right) the rotational correction.

Results

Across the 102 AC scan locations covering the HRGS survey area, 520 acoustic anomalies are interpreted. Of these anomalies, 306 are present in the uppermost 1.0 m of the overburden, 175 are interpreted between 1.0 m and 2.0 m below riverbed and 39 between 2.0 m and 3.5 m. Correlation between HF and parametric datasets increased confidence in anomaly identification.

One of the most compelling results was an anomaly, which exhibited a linear shape and high reflectivity in both HF and parametric data. The object, interpreted as part of a cable or piping, measured approximately 34.2 m in length (across three AC volumes) and was located a depth at from 1.2 m below riverbed down to 2.2 m (Figure 4). Variations in depth values arise due to the undulating nature of the anomaly along the riverbed. Weeks Marine divers later excavated this anomaly and confirmed it used to be a part of a 3-4 cm diameter mooring line that had decayed, solidified and is covered by shells, validating the AC system's positioning accuracy and interpretive reliability. This field confirmation underscores the value of AC technology in pre-construction site investigations.

Conclusions

The AC system, integrated with synthetic aperture sonar, proved highly effective for sub-riverbed imaging of buried obstructions in the shallow, dynamic Hudson River environment. Despite environmental challenges like high currents in the Hudson River, the AC provided interpretable volumetric datasets that enabled reliable identification of shallow hazards. Client-verified anomaly confirmation further supports the system's value for urban subsurface risk mitigation.

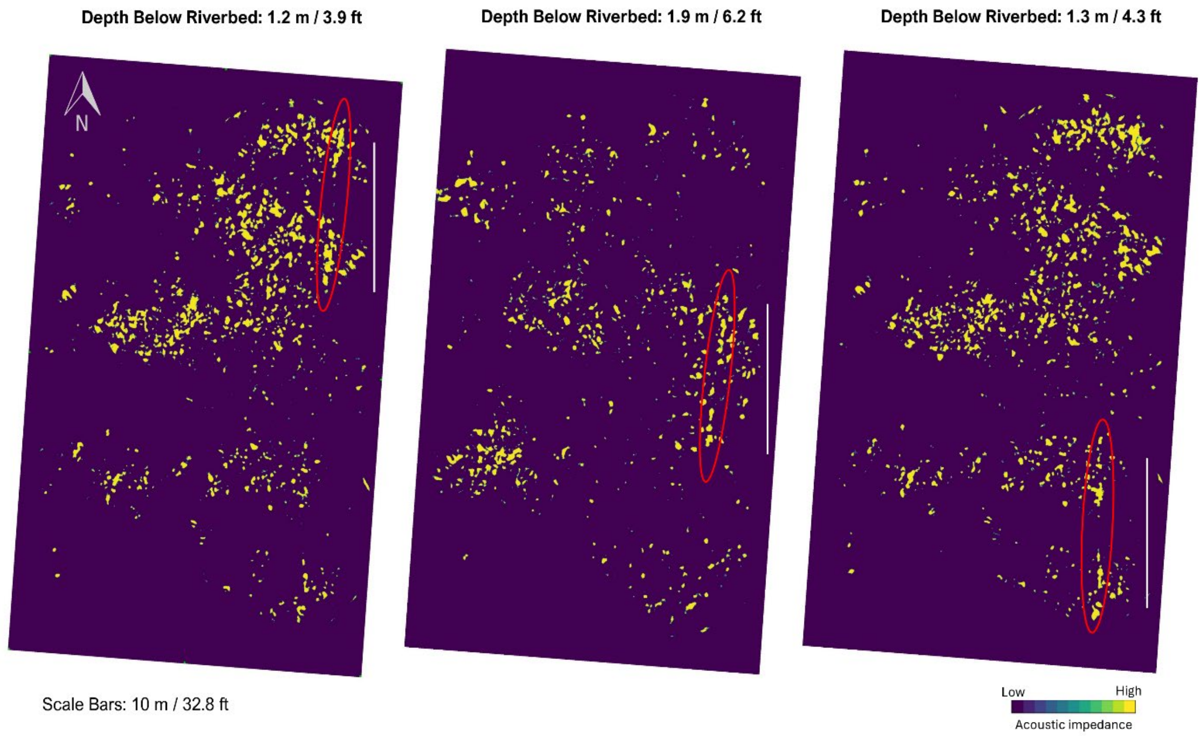

Figure 4 *A linear anomaly that span the entirety of the survey coverage approximately north to south, suggestive of a cable or piping.*

Acknowledgements

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