Mapping Submerged Features at Ada Estuary Using Side Scan Sonar: A Multi-Instrumental Approach to Riverbed Characterization

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1. SUMMARY

Side scan sonar (SSS) technology provides critical capabilities for detecting and mapping submerged features in shallow-water environments, supporting both navigation safety and environmental monitoring objectives. This study employed an integrated survey approach combining side scan sonar, echo sounder, and Global Positioning System (GPS) technology to investigate the riverbed morphology and identify submerged objects at Ada Estuary, Ghana. The research methodology incorporated systematic transect lines spaced at 20-meter intervals to ensure comprehensive coverage of the survey area. Data processing was conducted using specialized hydrographic software including HYPACK, Quizzy, and Surfer for visualization and analysis. Results revealed a relatively flat riverbed topography with minimal submerged contacts, primarily consisting of tree stumps, pipes, and scattered debris. The findings demonstrate the effectiveness of recreational-grade side scan sonar systems for small-scale hydrographic surveys, with applications extending to navigation safety, environmental assessment, and coastal zone management.

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2. INTRODUCTION

Hydrographic surveying represents a critical discipline for understanding underwater topography and detecting submerged hazards that may impact navigation safety and marine operations [12]. Side scan sonar technology has emerged as a fundamental tool for creating detailed images of seafloor and riverbed environments, enabling the identification of both natural features and anthropogenic objects. The technology operates by transmitting fan-shaped acoustic beams perpendicular to the vessel's track, with returned signals processed to generate high-resolution imagery of the substrate [2-5].

The importance of submerged feature detection extends beyond navigation safety to encompass environmental monitoring, archaeological investigations, and infrastructure management. In estuarine environments such as Ada Estuary, where tidal dynamics and sediment transport create complex morphological conditions, comprehensive mapping becomes essential for understanding ecosystem health and supporting sustainable development practices [3, 7, 9, 11].

Recent technological advances have made side scan sonar systems more accessible and cost-effective, with recreational-grade equipment demonstrating capabilities comparable to professional survey instruments for many applications. Studies by Hamill et al. (2018) demonstrated that recreational-grade side scan sonar could achieve substrate classification accuracies of 80% for sand, 49% for gravel, and 61% for boulders when combined with automated texture analysis techniques [4].

Side scan sonar systems utilize acoustic backscattering principles to generate detailed imagery of submerged surfaces, with applications spanning marine archaeology, environmental monitoring, and navigation safety. The technology has proven particularly valuable for detecting small-scale features and objects that may be missed by conventional bathymetric survey methods [6, 8, 11].

Automated processing techniques for side scan sonar data have advanced significantly, with machine learning approaches enabling real-time object detection and classification. Recent developments in neural architecture search (NAS) combined with detection transformer (DETR) architectures have achieved state-of-the-art performance in underwater object detection applications [8, 16, 18].

Contemporary hydrographic survey practices emphasize integrated multi-sensor approaches that combine positioning systems, depth measurement technologies, and imaging capabilities. The International Hydrographic Organization (IHO) standards specify requirements for survey accuracy, data quality control, and positioning precision that must be maintained throughout the data acquisition process [12]. Quality control procedures represent critical components of hydrographic surveying, with continuous monitoring of positioning accuracy, depth measurement precision, and feature detection reliability required throughout the survey process. Best practices include systematic line planning, equipment calibration protocols, and crossline verification procedures to ensure data integrity.

Estuarine environments present unique challenges for hydrographic surveying due to tidal variations, sediment transport, and variable water clarity. Studies in similar environments have demonstrated the effectiveness of side scan sonar for detecting both natural features such as sediment deposits and anthropogenic objects including infrastructure and debris [10, 14].

2.1 Research Objectives

This investigation aimed to characterize the riverbed morphology and identify submerged features at Ada Estuary using an integrated approach combining side scan sonar, echo sounding, and GPS positioning. Specific objectives included:

1. Detection and classification of submerged features within the survey area.
2. Analysis of feature characteristics including size, shape, and distribution patterns.
3. Development of comprehensive bathymetric and feature maps for the study region.
4. Assessment of survey methodology effectiveness using recreational-grade equipment

3. METHODOLOGY

3.1 Site Location – Ada Estuary

The research was conducted in Ada, a community located in the Greater Accra region of the Ada East District of Ghana. The Ada Estuary in Ghana is a vital and ecologically significant region where the Volta River converges with the Atlantic Ocean, sustaining the ecological integrity of its aquatic ecosystems and serving as a local hub for tourism and economic activities. The Ada East District is one of 29 districts in Ghana's Greater Accra Region, and it is located between latitude 5° 45' and 6° 00' (North) and longitude 0° 20' to 0° 35' (East) covering a section of the Volta River estuary system. The district is bordered on the north and east by the Volta Region's North Tongu district, and to the west by the Ada West district. The district covers a total size of 3,245 square kilometers. This location was selected due to its navigational importance and the presence of various submerged features requiring characterization.

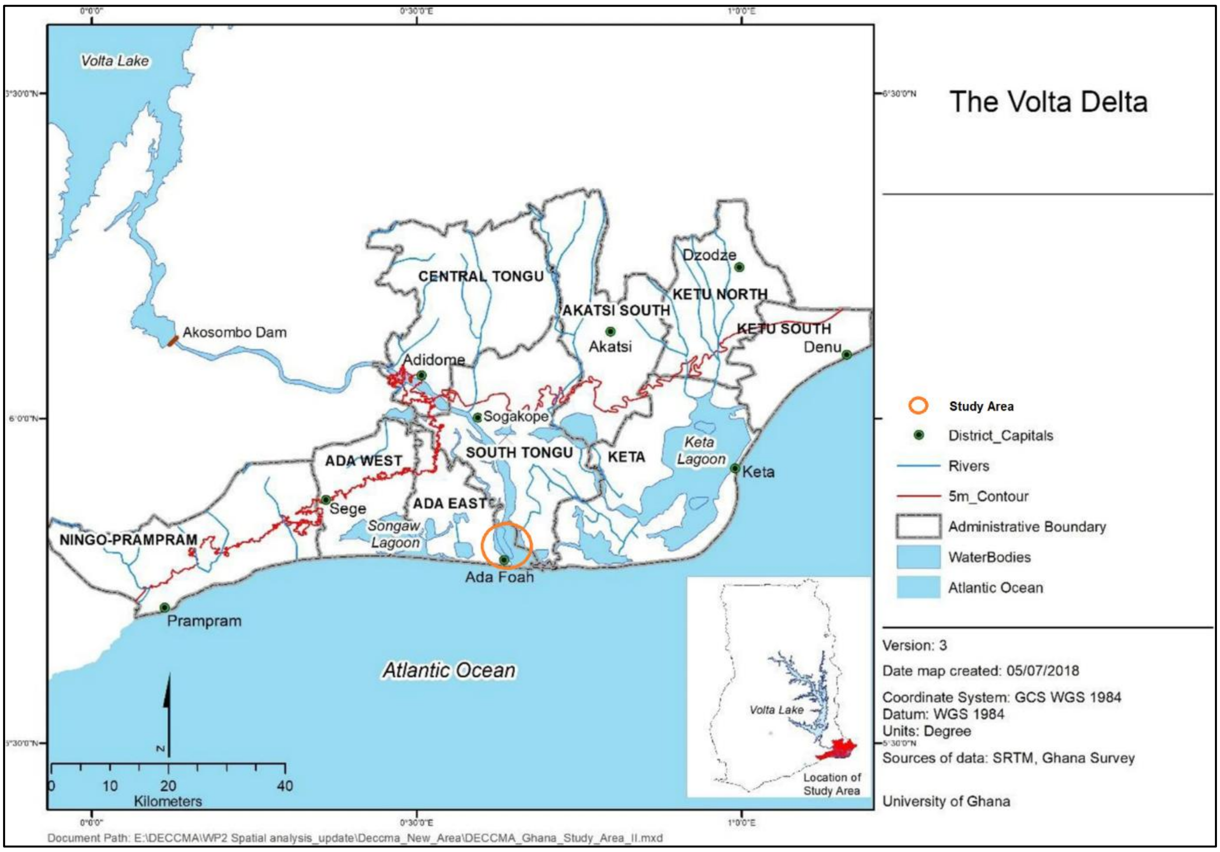

Figure 1: Volta delta showing the Ada Estuary and the adjoining administrative districts (Source: Appeaning Addo et al. 2018)

3.2 Survey Equipment and Configuration

The survey employed a multi-sensor approach utilizing the following equipment configuration:

Side Scan Sonar System: A StarFish side scan sonar unit was deployed for underwater feature detection and imaging. The system operated through direct cable connection to the survey computer, enabling real-time data visualization and recording.

Figure 2: StarFish Side Scan Sonar Unit

Echo Sounder: Depth measurements were obtained using a calibrated echo sounder system for bathymetric data collection. The instrument transmitted acoustic pulses to the riverbed with depth calculations based on two-way travel time measurements.

Figure 3: The Kongsberg EA440SP Dual Frequency (38/200 KHz) Single Beam Echo Sounder

Positioning System: Topcon GR3 Dual-frequency GPS receivers operating in differential mode provided positioning accuracy for feature geolocation. Primary GPS antennas were co-located with echo sounder transducers, while secondary antennas were positioned adjacent to side scan sonar towfish.

3.3 Survey Design and Data Acquisition

The survey employed systematic transect lines spaced at 20-meter intervals to ensure complete coverage of the study area. This line spacing was selected to provide overlapping side scan sonar coverage while maintaining survey efficiency. Crosslines were incorporated at the completion of primary surveys to provide data quality verification.

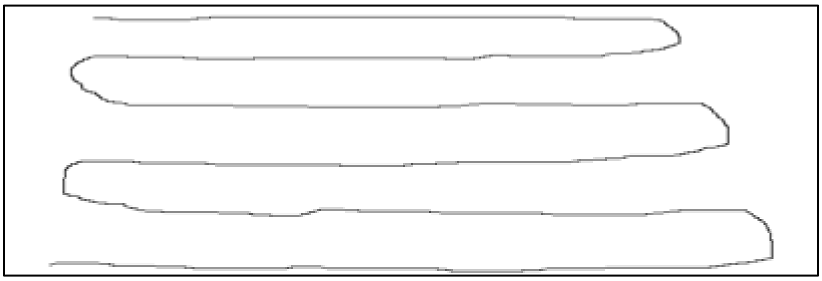

Figure 4: Transect lines spaced at 20-meter intervals

Data acquisition procedures followed established hydrographic survey protocols with continuous monitoring of positioning accuracy, depth measurement quality, and side scan sonar image clarity. Survey operations were conducted from a dedicated survey vessel equipped with appropriate mounting systems for all sensors.

3.4 Data Processing and Analysis

Post-processing of survey data was conducted using specialized hydrographic software packages including HYPACK for data integration, Sonarwiz for side scan sonar image processing, and Surfer for contour generation and visualization. Quality control procedures included verification of positioning accuracy, depth measurement consistency, and feature detection reliability. Side scan sonar images underwent systematic analysis to identify and classify submerged features based on acoustic signature characteristics, shadow patterns, and geometric properties. Features were categorized according to size, shape, and probable composition using established interpretation techniques.

4. RESULTS AND DISCUSSION

Bathymetric Characteristics

The survey revealed relatively uniform bathymetry across the study area, with water depths ranging from 2 to 8 meters. The riverbed exhibited generally flat topography with minimal relief variations, consistent with typical estuarine sedimentation patterns. Three-dimensional visualization of the bathymetric data confirmed the absence of significant topographic features or depth anomalies.

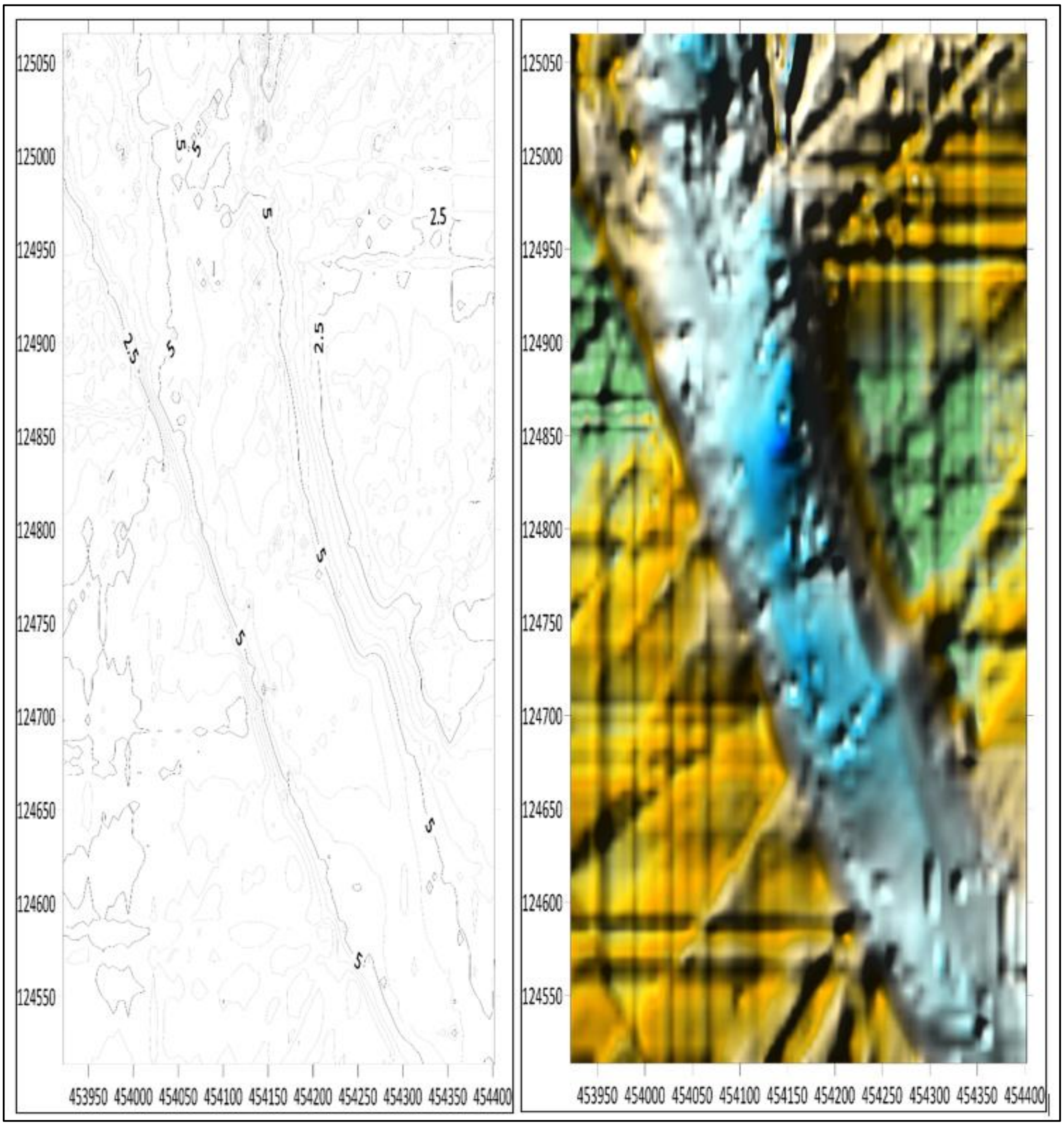

Figure 5: bathymetric map and image showing the topography of the riverbed

Submerged Feature Detection
Side scan sonar imagery identified several categories of submerged features within the survey area:
Natural Features: Tree stumps and root systems were detected along the riverbed, representing remnants of terrestrial vegetation from historical land surfaces. These features exhibited characteristic acoustic signatures with distinct shadow patterns enabling reliable identification.

Anthropogenic Objects: Pipe sections and structural debris were located at various positions within the survey area. These objects demonstrated higher acoustic reflectivity compared to natural sediments, facilitating detection and classification.

Scattered Debris: Various small objects of indeterminate origin were distributed throughout the survey area, potentially including both natural and anthropogenic materials.

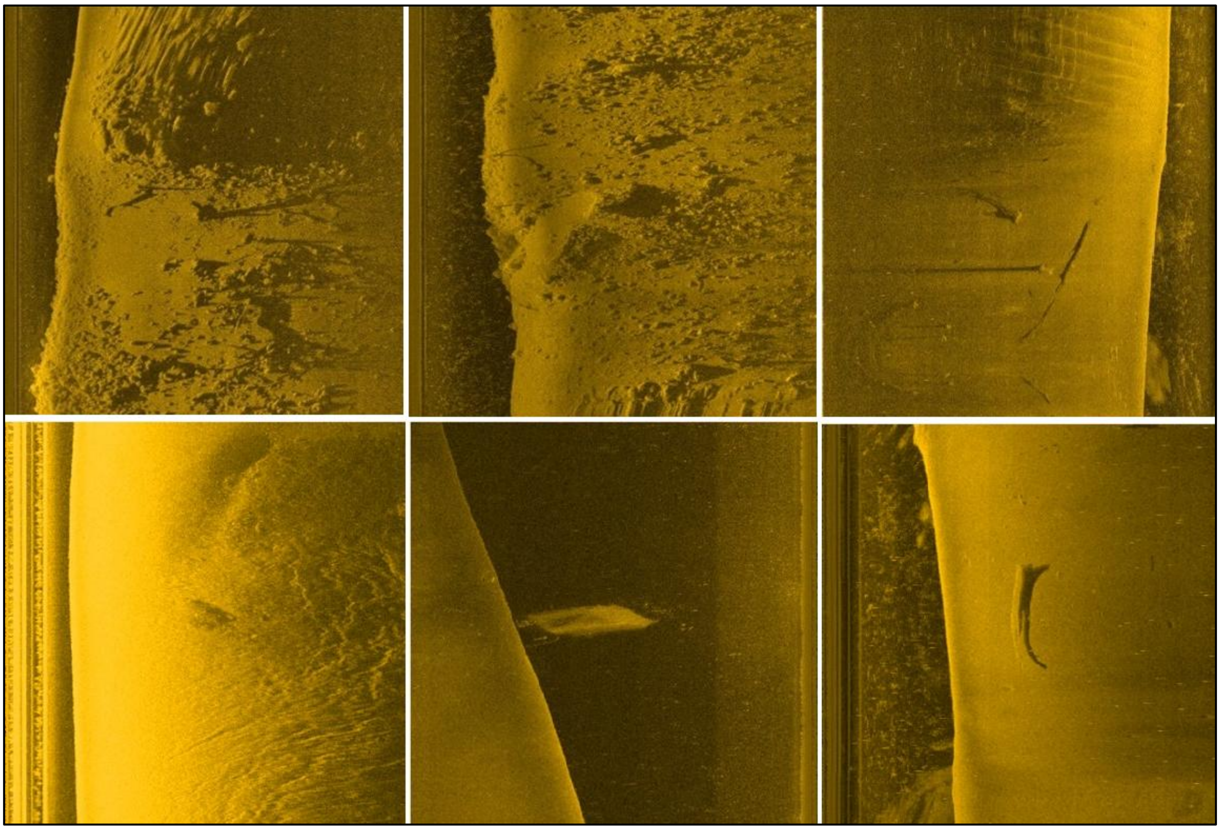

Figure 6: Side Scan Sonar imagery showing categories of submerged features within the survey area

Feature Classification and Distribution
Analysis of detected features revealed predominantly linear and point-source geometries. Linear features were primarily associated with pipe sections and elongated debris, while point

sources corresponded to tree stumps and isolated objects. The spatial distribution of features appeared random with no apparent clustering or alignment patterns.

Shadow analysis techniques proved effective for feature characterization, with object height and orientation estimates derived from shadow length and direction measurements. This approach is consistent with established side scan sonar interpretation methodologies documented in recent literature [4, 5, 8, 10].

Methodological Assessment
The integrated survey approach demonstrated effectiveness for comprehensive riverbed characterization using recreational-grade equipment. Data quality metrics indicated acceptable positioning accuracy and depth measurement precision for the survey objectives. The 20-meter transect line spacing provided adequate side scan sonar coverage while maintaining survey efficiency.

Crossline verification confirmed the reliability of feature detection and positioning, with consistent results obtained during repeat survey passes. This validation approach aligns with established hydrographic survey best practices recommended by international standards [12].

Applications and Implications

Navigation Safety: The identification and mapping of submerged features provides essential information for navigation safety in Ada Estuary. Pipe sections and debris represent potential hazards for vessel operations, particularly for shallow-draft vessels operating in the area. The comprehensive feature database enables informed navigation planning and risk assessment.

Environmental Monitoring: The survey results contribute to understanding of estuarine ecosystem dynamics and human impacts on riverbed environments. The presence of both natural features (tree stumps) and anthropogenic objects (pipes, debris) reflects the complex interaction between natural processes and human activities in estuarine systems.

Survey Technology Assessment
The successful application of recreational-grade side scan sonar equipment demonstrates the potential for cost-effective hydrographic surveys in shallow-water environments. This finding supports recent research indicating comparable performance between recreational and survey-grade systems for specific applications [7, 10].

Limitations and Challenges

Equipment and Operational Constraints
Several challenges were encountered during survey operations, including equipment rental costs, vessel maneuverability restrictions due to submerged obstacles, and water surface disturbances from other vessel traffic. The side scan sonar system's optimal performance in shallow water (up to 30 meters depth) proved appropriate for the estuarine environment.

Data Quality Considerations
False depth readings (spikes) were observed in echo sounder data, requiring post-processing correction to obtain accurate bathymetric measurements. This issue is common in shallow-water surveys and emphasizes the importance of comprehensive quality control procedures [12].

Recommendations for Future Research

Survey Enhancement
Future investigations should consider multi-beam sonar systems for improved bathymetric accuracy and feature detection capabilities. Integration of sub-bottom profiling technology would provide insights into sediment stratigraphy and buried feature detection [12].

Automated Processing
Implementation of automated feature detection algorithms, such as those demonstrated in recent machine learning applications, could enhance survey efficiency and reduce interpretation subjectivity. Development of standardized classification schemes for estuarine features would improve consistency across survey projects [5, 8, 10].

Long-term Monitoring
Establishment of regular survey programs would enable monitoring of temporal changes in riverbed morphology and feature distribution. Such monitoring would support understanding of sediment transport processes and human impact assessment.

Extended Coverage
Expansion of survey operations to encompass the entire Ada Estuary system would provide comprehensive characterization for navigation planning and environmental management. Integration with regional hydrographic databases would enhance the utility of survey results.

5. CONCLUSION

This study successfully demonstrated the application of integrated side scan sonar, echo sounder, and GPS technology for comprehensive riverbed characterization at Ada Estuary. The survey identified various submerged features including natural elements (tree stumps) and anthropogenic objects (pipes, debris) distributed across a relatively flat riverbed topography. The methodology proved effective for shallow-water hydrographic surveys using cost-effective recreational-grade equipment.

The research contributes to understanding of estuarine environment dynamics and provides essential information for navigation safety and environmental management. The successful application of accessible survey technology demonstrates potential for expanded hydrographic mapping in resource-constrained settings. Future investigations should focus on automated processing techniques, expanded spatial coverage, and long-term monitoring programs to enhance the scientific and practical value of such surveys.

The integration of multiple sensor systems proved essential for comprehensive feature characterization, with each technology contributing unique capabilities to the overall survey objectives. This multi-instrumental approach represents best practice for contemporary hydrographic surveying and should be adopted for similar investigations in comparable environments [12].

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BIOGRAPHICAL NOTES

Sebastian Senyo Botsyo is a geomatics and hydrographic survey specialist with robust, cross-disciplinary expertise in Geographic Information Systems (GIS), hydrographic and bathymetric data acquisition, and advanced geospatial analysis. With over 15 years of experience in both public and academic sectors, Sebastian has held key roles including Officer in Charge of Hydrography at the Ghana Lands Commission, where he was instrumental in establishing hydrographic surveying unit and developing critical oceanographic databases.

Sebastian's track record includes organizing technical workshops, leading survey teams, and conducting GIS analysis. He is recognized for his analytical rigor, quality assurance, and collaborative approach across multi-disciplinary teams, and has contributed to professional education as a student representative, lecturer and webinar speaker.

Sebastian holds a MSc in Hydrography from the University of Plymouth (UK), an MPhil in Geographic Information Systems and BSc Geomatic Engineering from Kwame Nkrumah University of Science and Technology (Ghana), and an Advanced Diploma in Geoinformatics from the University of Twente (Netherlands). He is an active member of several professional bodies, including the Hydrographic Society UK, Ghana Institution of Surveyors, RICS, and the International Federation of Surveyors' Young Surveyors Network.

He is committed to advancing innovation and professional standards in hydrographic and land surveying, with a deep interest in leveraging GIS for practical, data-driven solutions to modern surveying challenges.

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