

Seabed Mapping and Characterization for Feature Detection in Niger Delta

Morrison, T. Tamunotonye, N. Okpobiri, O. E.

Department of Geology, Rivers State University Port Harcourt

DOI: <https://doi.org/10.51244/IJRSI.2026.1308000133>

Received: 19 August 2026; Accepted: 24 August 2026; Published: 08 September 2026

ABSTRACT

Seabed mapping and characterization of part of offshore Niger Delta was carried out using advanced subsea surveying techniques. The objectives were to generate precise seabed imagery, determine depth ranges, detect and locate underwater metallic anomalies like pipelines, and to correlate the various data for proper seabed assessment and management. The study used technologies such as Multibeam Echo Sounder (MBES), Side-Scan Sonar (SSS), Sub-bottom Profilers (SBP), and Geographic Information System (GIS) to create high resolution model of the seabed within a 500m x 500m area around an Exxon Mobil Single Point Mooring (SPM) facility. The methodology involved thorough data acquisition, calibration and processing of sonar, magnetometer and bathymetric data. The analyses revealed essential seabed features, including a depth range of 25.6 to 27.3m, dominant silty clayey sand sediments, high-reflective patches around anchor chains. It also revealed significant magnetic anomalies indicative of exposed pipeline and anchor chains. Sub-bottom profiling data also indicated sediments layers with recently deposited sands overlying lithified sand layers. The study demonstrates the value of integrating different survey methods to address the unique challenges posed by the dynamic and sediment laden offshore environment of the Niger Delta. The findings support improved infrastructure safety, sustainable resource management and environmental conservation, offering a reliable basis for future decision-making in offshore exploration and exploitation of the vase resources in this economically critical region.

Keywords: Seabed mapping, features detection, Multibeam Echo-Sounder, Side-Scan Sonar, Subbottom Profiler.

INTRODUCTION

The Niger Delta, apart from been one of the world's most bio diverse and ecologically sensitive region, is rich in terms of natural resources. It is the centre of the petroleum business of the West Coast of Africa with numerous on-shore and off-shore petroleum exploration and exploitation activities. There is an observed continuous expansion of offshore activities, especially in the oil and gas sectors. This has necessitated the need to understanding the seabed's topography and composition, not only for resource management and environmental protection, but also for ensuring navigation and other operational efficiencies (Nwito et al., 2010).

The Niger Delta, as one of the most significant location of the off shore oil and gas operations in the world, accurate seabed mapping and feature detection are critical for the exploration and exploitation of oil and gas resources, as well as for environmental monitoring, hazard free navigation and coastal infrastructural development (NOAA, 2023) .The seabed, its structure and composition is complex. Its complexity, including underwater channel, slope and geological structures pose significant challenges to off-shore activities. Also, abundant wreckages, damaged off-shore pipelines are potential hazards that need to be identified and avoided.

Accurate mapping of the seabed to detect underwater features become crucial in other to avoid potential hazards like underwater obstructions (abandoned wreckages, broken off-shore pipelines), seabed instability and areas of sediment buildup and erosion (Smith et al., 2015).

Traditional surveying technique may lack the provision needed for mapping the complex and dynamic underwater topography of the Niger Delta as even small but significant seabed features that could course potential hazard in operations need to be detected. There is therefore need to integrate advanced technologies like Multibeam Echo Sounder (MBES), Side Scan Sonar (SSS), and Geographic Information System (GIS) in processing survey data to fully optimize the seabed mapping of the Niger Delta.

This study involved using advanced hydrographic surveying techniques to generate high resolution map of the seabed of the project area in the Niger Delta. It aims to provide valuable insights into the regions underwater landscape, and guided decision making in off-shore activities in the Niger Delta.

Its primary objectives are to generate high resolution imagery of the survey area, determine the depth range of the location, also to detect and locate the positions of pipelines and other metallic anomalies, and to correlate the various acquired data into a regional form.

Project Location

The study is located off-shore, about on the coast of Nigerian Niger Delta. The study was done around a Single Point Mooring (SPM) facility off-shore. The survey parameters are represented by a 500m by 500m square with SPM at the centre. The geographical location of the SPM is given by the coordinates 004°13'05.42"N and 008°02'44.95"E. A Google Earth image of the location is presented in Figure 1.

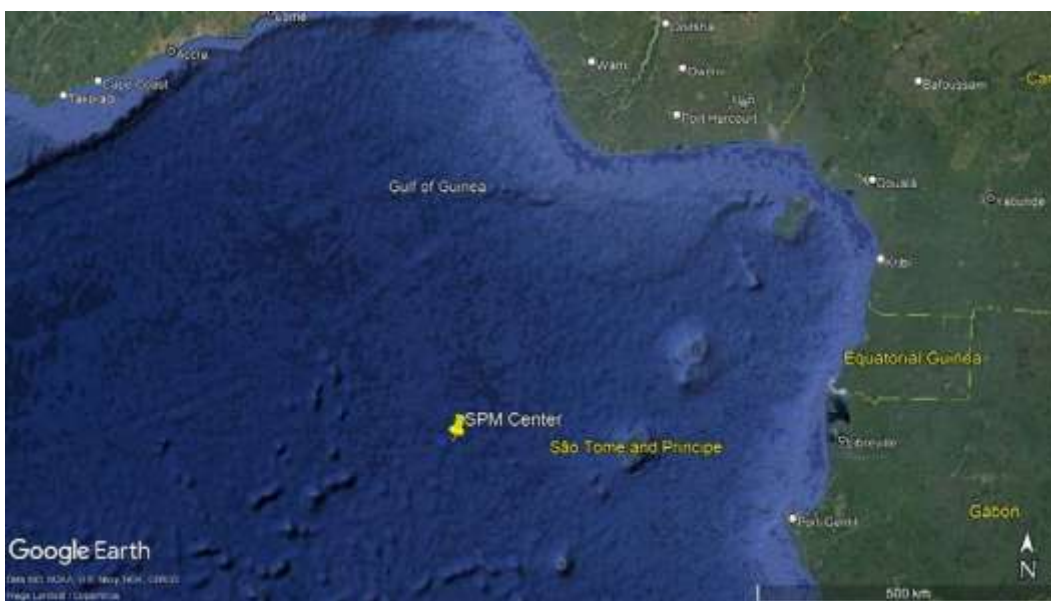


Fig. 1: Study Location Map

Source: Google Earth

Geology of the Area

The Niger Delta's offshore environment presents unique challenges for seabed mapping and surveys. The regions complex topography, influenced by both riverine sediments input and oceanic processes make accurate mapping difficult. The Niger Delta is also prone to sedimentary processes such as deposition, erosion and mass wasting events (Smith, et al. 2015). These processes affect the stability of the seabed increasing the risk associated with offshore installations such as oil platforms and pipelines.

Meteorological Conditions of the Area

The major meteorological parameters considered are: Mean Annual Temperature, Mean Annual Precipitation and Mean Annual Humidity.

The Mean Annual Temperature range from 29°C during the brief cold Hamattan period of December through February and over 34°C during the hot dry period of March to October each year. For the Mean Annual Precipitation, rainfall occurs almost throughout the year though the maximum precipitation occurs within the months of May to October while the minimum rainfall occurs between the months of December to March each year. The humidity is directly related to the rainfall patterns in the area. The most humid months being May to October each year, while the least humid months occur between the months of November through February.

MATERIALS AND METHODS

The under listed equipments were used to carry out the seabed survey.

Table 1: List of survey equipment

Equipment	Qty
G882 magnetometer	1
Side-scan sonar	1
Multibeam echo-sounder	1
Sub-bottom profiler	1
Gyro compass-SG Brown	1

Survey line plan

The SPM1 Survey area was designed into a 500m by 500m block, with the SPM1 facility as the center coordinate. See Figure 2 below.

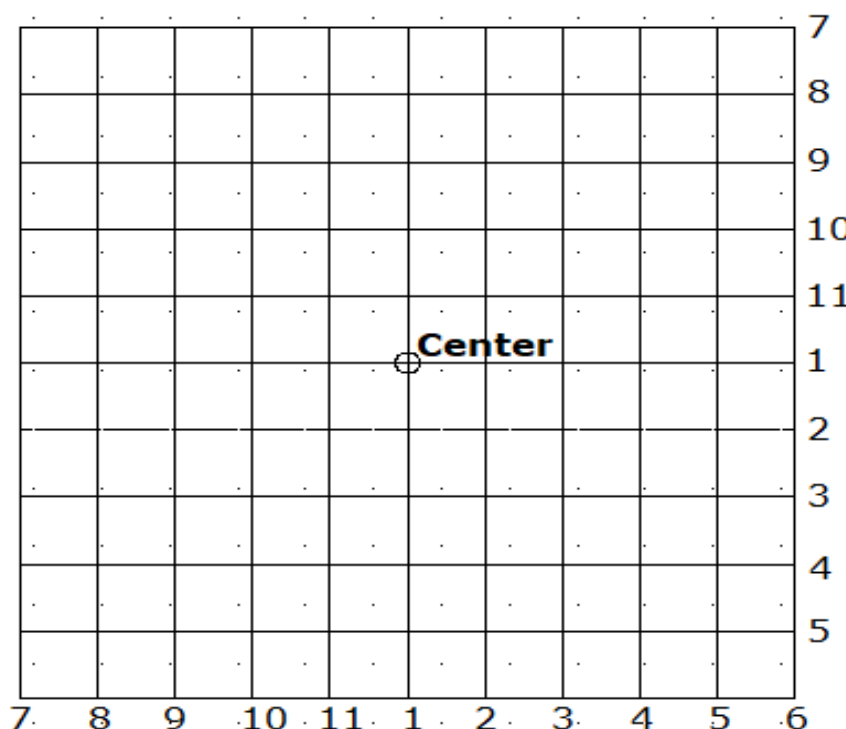


Figure 2: Survey Runline plan

Geodetic Parameters

All survey and positioning shall be referenced to the WGS 84 datum and ellipsoid.

Datum	World Geodetic System 1984 (WGS 84)
Spheroid	WGS 84
Semi-Major Axis a =	6 378 137.000 metres
356 752.314 metres	Semi-Minor Axis b =
Eccentricity e2 =	0.006 694 379 99013
Inverse Flattening =	298.257 223 563

Survey Datum

Datum	Minna
Spheroid	Clarke 1880
Semi-Major Axis a =	6 378 249.14500 meters
Semi-Minor Axis b =	6 356 514.86955 meters
Eccentricity e2 =	0.006 803 511 283
Inverse Flattening =	6293.465

Projection Parameters

Projection type	Transverse Mercator
Zone	Nigerian mid Belt
Central meridian (C.M.)	008° 30' E
Origin Latitude	004° 00' N
False Easting	670553.984m
False Northing	0 000 000m
Scale Factor at C.M	0.99975
Unit of Measure	International Meter

Data Acquisition

A survey vessel with installed compass was acquired. The Common Reference Point (CRP) on board the survey vessel was defined as the echo-sounder position. All the X, Y, Z offset of the survey sensor, including the positioning sensors were measured with reference to the CPR. The measurements were cross checked and then entered within the relevant acquisition systems.

The four methods used were complementary, each focused to achieve specific objective as:

- The magnetometer survey was to detect metallic signature
- Side-scan sonar (SSS) was to detect and image objects and seabed features
- Multibeam echosounder (MBES) was to give accurate bathymetric, seabed morphology and object orientations
- Sub-bottom profiler (SBP) detects buried objects and shallow subsurface sediments.

A detailed methodology of each of survey methods which involved data acquisition, calibration, processing and data quality control is presented below:

Magnetometer Survey

Magnetometer Data Acquisition

The magnetometer survey was carried out using a G882 magnetometer. Details of the acquisition process are presented below:

Survey speed	4 knots nominal
Sampling	10Hz
Tow distance	60m behind vessel
Tow altitude	4m above seabed
Main line spacing	10m
Infill spacing	4m
Tie lines	100m spacing
Time synchronization	GPS
Turns	Outside survey block

Calibration

This was done to ensure that the magnetic configuration (sensor type), Tow fish configuration (tow height, tow speed), sampling rate are maintained and appropriate.

Magnetic Survey Quality Control

To ensure the quality of data generated by the magnetometer, the following quality control measures were put in place. Before operation, there was a check on the magnetometer for sensor operation, cable connection, sensitivity, instrument calibration and time synchronization.

Also, the magnetic profile was monitored in real time to avoid sudden spikes, step changes, data gaps and excessive noise, periodic oscillations, and vessel interference. Speed variation, Tow attitude, missing magnetic data, excessive spikes were all put in check.

Side-Scan Sonar (SSS)

An Edge Tech 4600 dual side scan Sonar system was used for the survey. The system is a side viewing sonar that transmits and receives acoustic signals from transducer, mounted on an underwater towfish, towed by the vessel.

Frequency used	100kHz
Range	50M/side = 100 swath
Speed	3.5 knots
Towfish position	7m above seabed

Calibration

Calibration checks were made before deployment of the Side-scan sonar. These included towfish heading, cable connections, transducer operations, pulse length, range, gain/TVG settings and time synchronization. These ensured adequate bottom coverage, and no excessive striping and noise. Cable out noted at the start of each line and whenever there were alterations.

Quality Control

The QC was to ensure that there are no gaps and excessive overlap during operation. Also, the gain/TVG settings were reviewed to ensure steady recording.

Multibeam Echosounder (MBES)

The MBES emits multiple beams at different angles to gather information about the seabed, which it uses to create a detailed bathymetric map of the seafloor and other seafloor features. An Edge Tech 4600 Swath Multibeam System was used to carry out the survey. The data acquisition was carried out using the following parameter values below:

Frequency	400kHz
Speed	4 knots
Swath	100°
Ping rate	High as water depth

The Multibeam was side mounted and the transducer was defined as the vessel datum in the navigation software.

Calibration

First, a proper patch test was done which was to determine errors related to latency, pitch and sensors offsets. This ensures steady sound-velocity profile during the test. A sound velocity casts were conducted at the start of the survey and periodically as the survey progresses.

Quality Control

The quality control measures carried out included checking the position jumps and DGPS outages during navigation. Also, anomalous profiles, incorrect time and cast locations were checked. Striping, outer-beam distortions, line-to-line offsets were screened in the bathymetry results. At the end of the day, quality checks were made of the patch-test corrections, current SVP, data gaps.

Sub-bottom Profiler (SBP)

The Edge Tech SB 216-S Sub-bottom profiler was used during the survey. This is a high-resolution subsurface profiler that uses wide band Frequency Modulation (FM) acoustic pulses to investigate seabed and the depth to reflecting discontinuities in the shallow subsurface. The SBP system consists of two transceivers in a towed vessel which allows the deployment of acoustic transducers about 4 meters below the water line. The sub-bottom profiler sends acoustic energy into the seabed and records reflections from subsurface interfaces. The data acquisition parameters are as follows

Frequency	5 kHz
Vessel speed	4 knots
Ping interval	
Record length	100-200 ms
Navigation	RTK-DGPS
Line spacing	20m

Calibration

The Sub-bottom profiler was tested for pinging on the ground and wet test in water. Checks carried out included transducer and receiver operations, GPS, time synchronization, frequency, noise level and pulse length. A test line was run to establish seabed reflection penetration, vertical resolution and acoustic noise.

Quality Control

To maintain quality, the seabed reflector was clearly identified and monitored. Also, sufficient penetration was ensured while noise and multiple reflections were monitored to adjust vessel speed, transducer position and operating frequency. Other quality measures included monitoring time offsets and gaps during operation.

Data Processing

The data processing method was automated using various software. The list of softwares used are:

- **CodaOctopus GeoSurvey:** This provides a total solution for recording, viewing, interpreting and reporting Side-scan Sonar and Sub-bottom profiler data.
- **MagPick v 3.23:** Magnetic data processing and interpretation.
- **Microsoft Excel:** Handling large data automation and processing.
- **Google Earth:** For high resolution map imagery

Data Cleaning

The data cleaning process focused on removing unwanted noise and correcting errors that can arise from a variety of sources. Filtering was done to receive noise, which helps eliminate random errors that can distort the seafloor representation (Lurton & Augustine, 2010). Filtering help smooth the data by reducing the impact of isolated noise points.

Also, a compensation for vessel motion, which is a major component of error correction was done. Heane, pitch, roll and yaw corrections were applied to act for the movement of the survey vessel which can alter the geometry of the sounding. Additionally, tide correction was applied to adjust for changes in water depth caused by tidal fluctuations using the tide gauge. These corrections are vital for producing accurate depth measurements that reflect the true seafloor positions (Combelle et al. 2014).

Bathymetric Data processing

Bathymetric Data Processing involved several stages including data gridding, Interpolation, and Digital Terrain Model (DTM) generation. Bathymetric data is a collection of discrete depth sounding, but are processed into a continuous surface using guiding techniques (Ware et al., 2017). The aim is to produce a DTM that represents the seafloor in a visually accurate and meaningful way. After gridding, other data enhancing process involved slope analyzing, cantoning, and shading. These stimulate how light interact with the seafloor providing a more initiative representation of underwater features.

Magnetometer Data Processing

This involved time synchronization, magnetic spike editing, removal of vessel/equipment interference, diurnal and IGRF corrections. Other processes carried out included microlevelling, determination of magnetic anomalies, gridding and generation of magnetic contours. Details are presented in the results table.

Side-scan Sonar (SSS) Data Processing

The focus of SSS data processing is on imaging of the sea floor rather than measuring depth. Side Scan Sonar emits sound waves to the seafloor and measures the strength of the reflections, creating an acoustic

image of the seabed. The following actions were carried out during the SSS data processing; slant-range correction, geo-referencing, and mosaick preterm correction, noise reduction, bottom tracking and target detection. Slant-range corrections account for the varying distance between the sonar transducers and the seafloor by ensuring that the final sonar image features are bright (Pavloponlos et al., 2017). After correction, the sonar data was geo-referenced to integrate it with other spatial data sets.

Multibeam Echo-sounder (MBES) Data Processing

This involved time synchronization, navigation processing. Also, various corrections were done such as patch-test, tide/water level. It involved determination of beam depths, generation of point cloud and bathymetric surface. The processing was automated, using the softwares which at the end generated the bathymetric surface and the final DEM.

Sub-bottom Profiling Data Processing

Sub-bottom Profilers (SBPs) provide critical information about geological structures beneath the seafloor. Its data processing is focused on enhancing acoustic reflections to reveal subsurface layers and features such as sediment deposits, fault and buried objects. It is done by sending low frequency sound pulses into the seabed and recording the reflected signals from different sediment layers (Bang et al., 2011). The processing involved band pass filtering and gain adjustments to improve signal clarity. This removes noise from outside the frequency range of interest and also enhances weaker reflections from deeper subsurface layers. Also carried out were majorly time synchronization, seafloor tracking, time-to-depth conversion, interpretation and identification of reflectors.

Data Integration and Visualization

One of the most significant challenges in this study was the integration of various data sets from multiple sources during data processing. However, the Geographic Information Systems (GIS) became an essential tool in integrating the various data. GIS was used to integrate bathymetric, side scan sonar, and sub-bottom profiler data. GIS provided platform for advanced spatial analysis and seafloor visualization which gives a clear view of the features.

Correlation of Processed Data

The results of the processed data were correlated in AUTOCAD 2018. This was to ensure that magnetic anomalies, such as the pipeline, correspond to the positions of the corresponding sonar features (Irisarri et al., 2020). The result of the correlation is presented in Figure 3 & 4 showing correlation between the two oppositions.



Fig. 3: SSS extract showing section of seabed

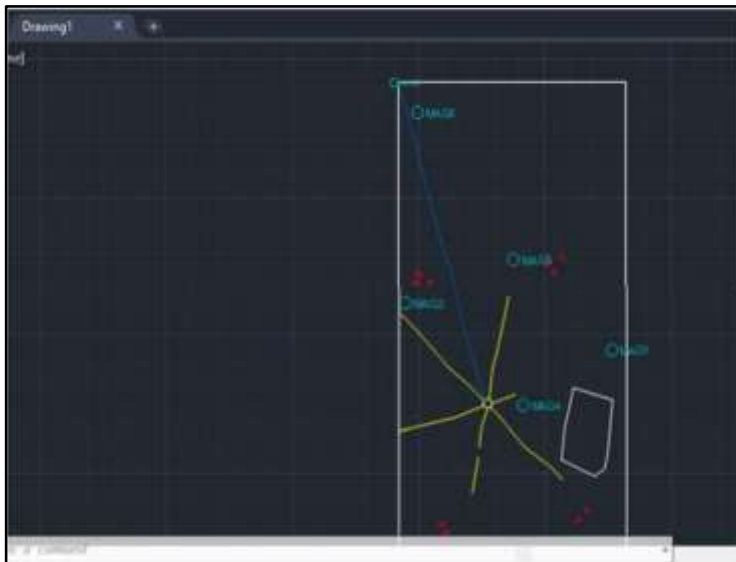


Fig. 4: AutoCAD extract showing sonar image correlated with magnetic anomalies

RESULTS

Magnetic Data and Processing

This section shows the raw data before and during processing in various software environments. Presented in Table 2 is the raw magnetic data presented in Excel environment. Magnetic anomalies observed on the seabed were due to existing pipeline, anchor chains and structures. Details of some of the detected features are presented graphically in Figures 6 to 9 and in Tables 3 and 4. While Figure 6 and 7 are row magnetic data in Magpick environment, Figure 8 and 9 are processed data indicating negative magnetic and dipole magnetic anomalies respectively.

Table 2: Raw magnetic data in excel environment: First 21 of 92830 total entries

	A	B	C	D	E
1	MAG (nT)	Date	Time	Easting	Northing
2	22188.341	15/04/2019	9:57:03:03	620670.899	24830.602
3	19129.144	15/04/2019	9:57:03:03	620670.822	24830.492
4	14841.981	15/04/2019	9:57:04:04	620670.722	24830.37
5	27503.038	15/04/2019	9:57:04:04	620670.644	24830.271
6	17746.695	15/04/2019	9:57:04:04	620670.544	24830.138
7	28318.47	15/04/2019	9:57:04:04	620670.455	24830.028
8	17039.365	15/04/2019	9:57:04:04	620670.366	24829.906
9	28838.91	15/04/2019	9:57:04:04	620670.277	24829.796
10	16472.968	15/04/2019	9:57:04:04	620670.188	24829.674
11	29419.797	15/04/2019	9:57:04:04	620670.111	24829.575
12	15933.991	15/04/2019	9:57:04:04	620670.033	24829.464
13	13473.293	15/04/2019	9:57:04:04	620669.977	24829.354
14	14351.253	15/04/2019	9:57:05:05	620669.922	24829.243
15	14119.754	15/04/2019	9:57:05:05	620669.866	24829.133
16	30419.823	15/04/2019	9:57:05:05	620669.811	24829.022
17	16612.263	15/04/2019	9:57:05:05	620669.766	24828.911
18	17312.993	15/04/2019	9:57:05:05	620669.7	24828.79
19	20527.217	15/04/2019	9:57:05:05	620669.644	24828.679
20	25106.112	15/04/2019	9:57:05:05	620669.6	24828.569
21	27541.073	15/04/2019	9:57:05:05	620669.544	24828.458
22	30079.387	15/04/2019	9:57:05:05	620669.488	24828.337

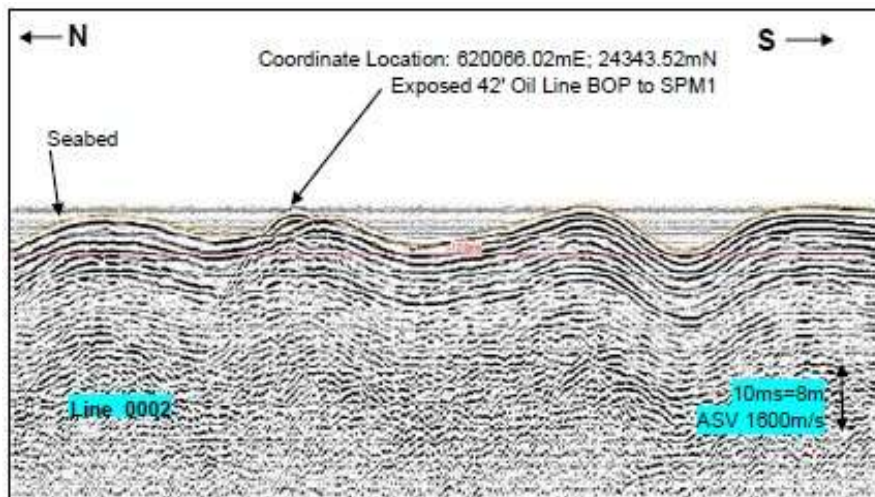


Figure 5: SSS data extract at 500m of approach showing seabed conditions

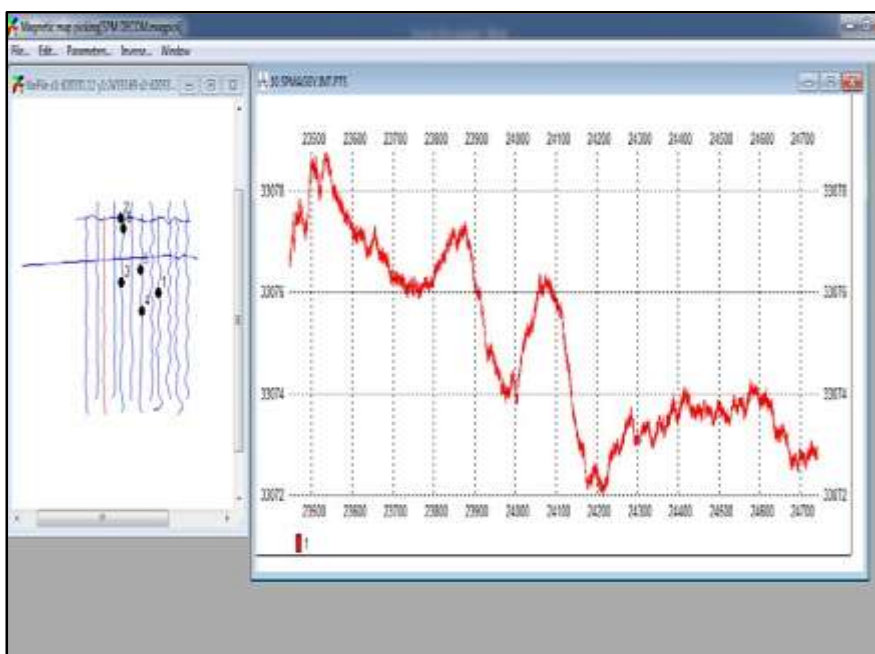


Fig. 6: Raw magnetic data in MagPick environment: first window shows trackplot of sensor and second window shows the magnetic profile of current line.

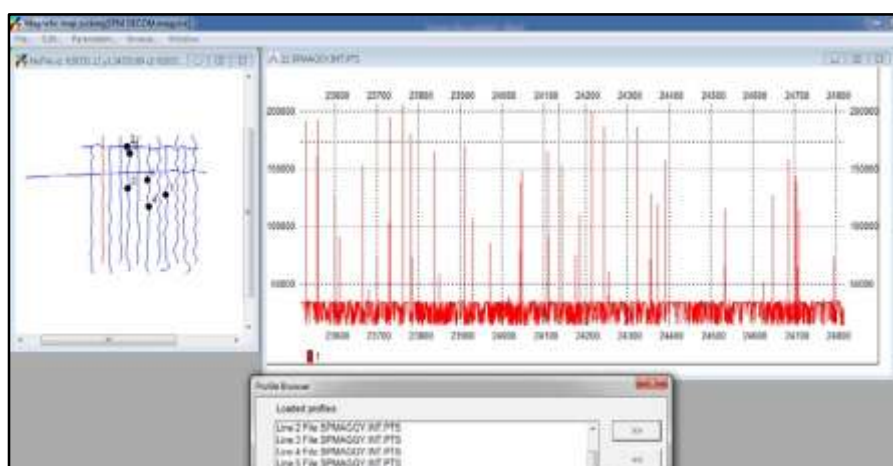


Fig. 7: Raw magnetic data in MagPick environment: first window shows trackplot of sensor and second window shows noise caused by anchor chains on seabed.

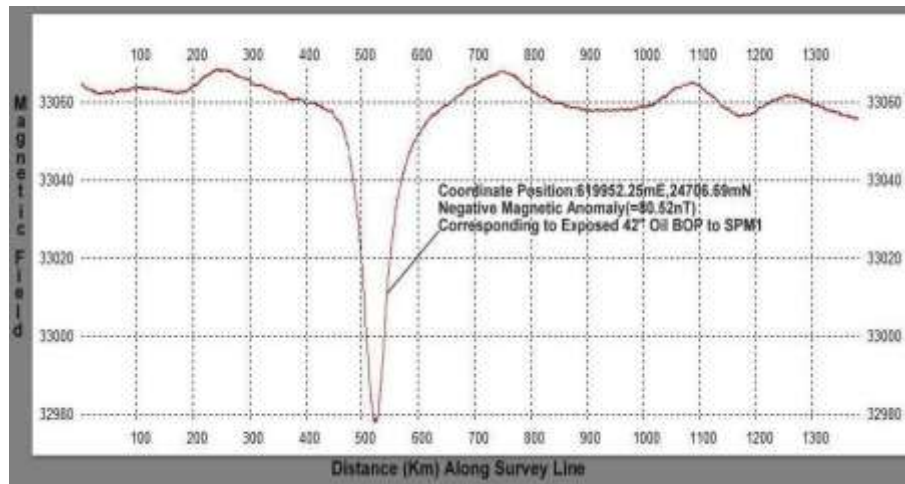


Fig. 8: Processed magnetic data in MagPick environment: Negative magnetic anomaly.

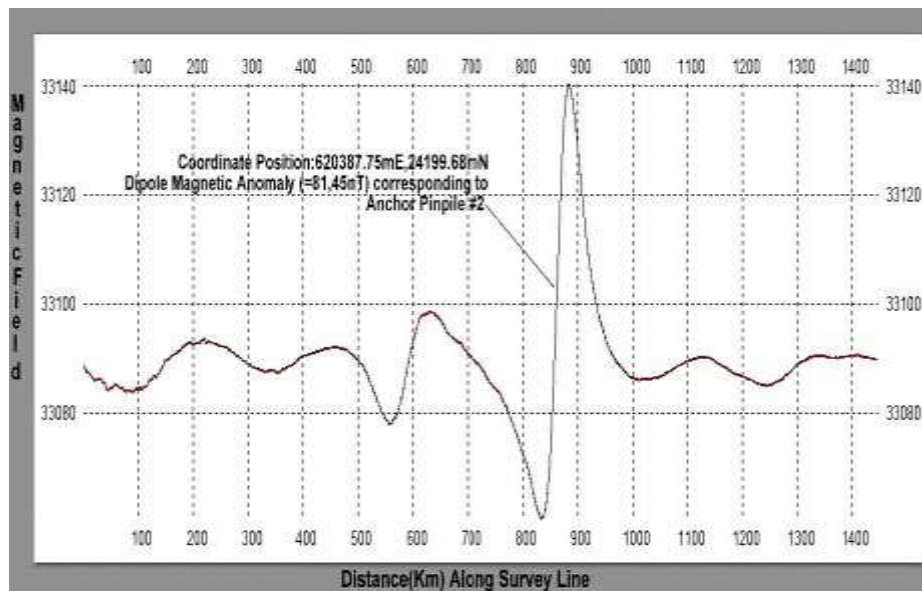


Fig. 9: Processed magnetic data in MagPick environment: Dipole magnetic anomaly.

Table 3: List of Magnetic anomalies

MAG ID	Easting (m)	Northing (m)	Type	AMPLITUDE (nT)
1	620382.25	24221.96	Positive	71.96
2	619952.25	24706.69	Negative	75.79
3	619962.13	24294.00	Dipole	77.15
4	620195.00	24109.10	Dipole	83.13
5	620177.63	24373.80	Dipole	87.39
6	619987.44	24639.34	Dipole	218.82

Side-Scan Sonar (SSS) Data

The SPM facility along with six mooring chains and a 42" oil pipeline running North West of the SPM facility were entirely exposed on the seabed. Spud can depressions were observed around the six anchor pile positions of the SPM bouy. Presented in Figure 5 above is SSS data extract showing seabed conditions.

Numerous spud can depressions of varied diameters were observed around the anchor piles of the SPM facility. Details of these depressions are provided in Figure 10 and Table 2.

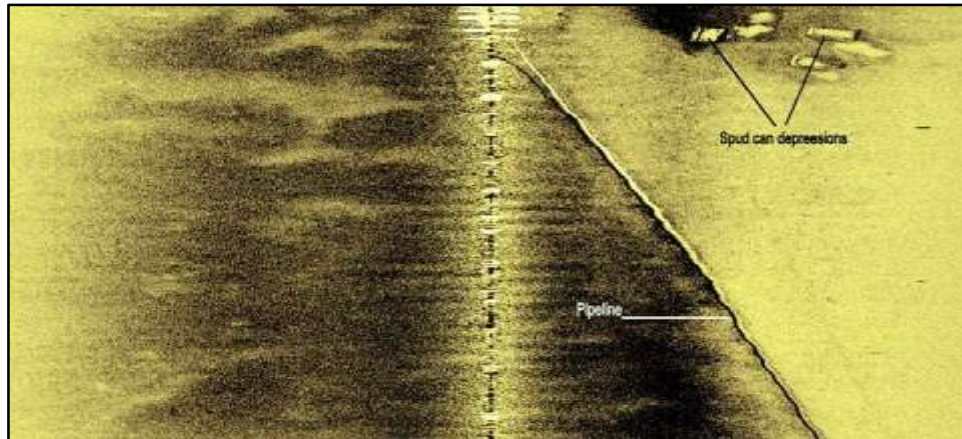


Fig. 10: SSS data in CodaOctopus software showing Spud Can depression

Table 4: Details of Spud can depressions

Detailed of the Spudcan Depression			
Easting(m)	Nothing (m)	Diameter (m)	Remarks
620283.7600	24389.8800	5.16	Spudcan depression Eastward of SPM1 Anchor Pile #1
620271.4200	24364.0800	3.49	Spudcan depression Eastward of SPM1 Anchor Pile #1
620258.3300	24375.6700	3.01	Spudcan depression Eastward of SPM1 Anchor Pile #1
620432.8700	24170.1500	3.00	Spudcan depression Southward of SPM1 Anchor Pile #2
620414.8500	24148.0600	3.00	Spudcan depression Southward of SPM1 Anchor Pile #2
620403.9700	24166.0700	2.27	Spudcan depression Southward of SPM1 Anchor Pile #2
620331.9100	23936.7700	3.54	Spudcan depression Southward of SPM1 Anchor Pile #3
620315.4636	23913.8475	4.77	Spudcan depression Southward of SPM1 Anchor Pile #3
620302.4100	23931.1500	2.76	Spudcan depression Southward of SPM1 Anchor Pile #3
620070.7600	23911.3700	6.64	Spudcan depression Northward of SPM1 Anchor Pile #4
6200519100	23889.7400	5.15	Spudcan depression Northward of SPM1 Anchor Pile #4
620042.2875	23904.8800	4.66	Spudcan depression Northward of SPM1 Anchor Pile #4

619910.3900	24118.5300	6.61	Spudcan depression Northward of SPM1 Anchor Pile #5
619882.1300	24098.0200	6.19	Spudcan depression Northward of SPM1 Anchor Pile #5
619882.1803	24144.0640	6.05	Spudcan depression Northward of SPM1 Anchor Pile #5
620021.8300	24338.1800	3.95	Spudcan depression Northward of SPM1 Anchor Pile #6
620010.0800	24325.9200	3.80	Spudcan depression Northward of SPM1 Anchor Pile #6
619993.9900	24333.8300	3.79	Spudcan depression Northward of SPM1 Anchor Pile #6
619987.9662	24342.9188	4.71	Spudcan depression Northward of SPM1 Anchor Pile #6

Possible Spudding Pit

A pit was detected between anchor pit #2 & PIT #3. The pit occupies an area of approximate 12596.17sqm in a water depth of about 26.5m.

Figure 7.4 and 7.5 shows the seabed conditions at 500m and 350m radius of approach to the SPM 1 facility.

Pin/Anchor Piles

Six (6) anchor piles were used to anchor the SPM 1 facility. However, only anchor pile #1 was detected to be exposed in the seabed at coordinates 620191.48mE, 24401.95mN. The remaining 5 anchor piles were completely buried under seabed sediments.

Seabed Sediments

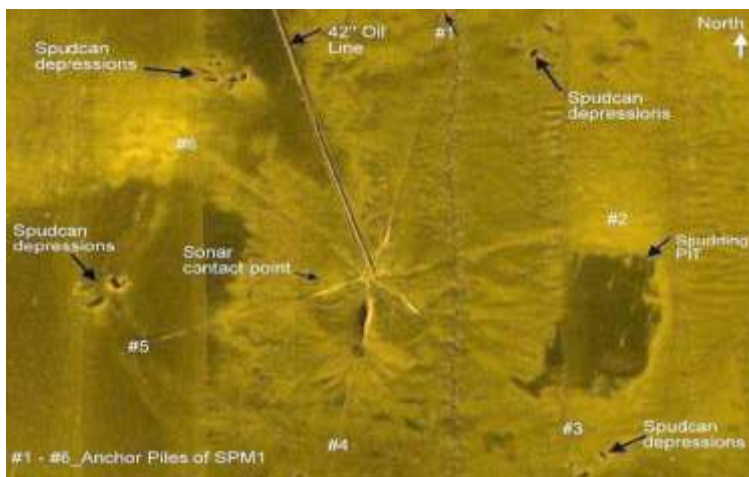


Fig. 11: SSS data extract at 500m of approach showing seabed conditions

The sonar records of the seabed infer the dominant presence of low reflective sediments all over the area covered by this study. This is interpreted to be composed of silty clayey sand (Mostier et al., 2007) However, high reflective sediments, interpreted to be clayey, silty sand was observed as patches around pipelines and the SPM platform area. This is indicated in Figure 11.

Sub-bottom Profiler (SBP) Shallow Geology

The Sub-bottom Profiler (SBP) data showed the seabed between 30 to 32ms (24m to 25.6m) and the data is limited to only about 12ms (9.6m ASV 1600m/s) of interpretable data due to limited penetration and random burst of noise within the data after more regular noise has been filtered with a frequency filter.

The Sub-bottom Profiler (SBP) data is uniform across the survey area showing one reflector which is interpreted to be recently deposited sand from the seabed at a distance between 2.24m and 2.55m below seabed and lithified sand from that point. A parabolic structure was detected and interpreted to a pipeline.

DISCUSSION

The study focused on mapping and analyzing seabed features within the offshore region of the Niger Delta, an area vital for oil and gas exploration. Due to the regions complex geological structures and sedimentary dynamics, traditional seabed mapping techniques were found insufficient for precise feature detection. The use of advanced hydrographic technologies such as Multibeam Echo-Sounders (MBEs), Side Scan Sonar (SSS) and Sub-bottom Profiler (SBP), integrated with Geographic Information Systems (GIS) was to create detailed imagery of the survey area to determine depth ranges, locating metallic anomalies (Constantinoiu et al., 2024).

Data processing utilized Coda Octopus Geo-survey and encompassed several stages: error correction gridding, and interpolation for bathymetric data; magnetic data interpretation for anomaly detection, and sonar mosaicking for high resolution seabed imagery. The analyses revealed the following:

- **Depth of Water:** The depth of water was revealed to be in the range between 25.6m and 27.3m.
- **Composition of Seabed Sediments:** The dominant sediment type was interpreted to be silty clayey sand (low reflection on the sounder), although accumulation of high-reflective sediments (larger grain sizes) were observed near the SPM anchor chains.
- **Metallic Anomalies:** Magnetic data revealed the presence of pipelines and anchor chains exposed on the seabed, likely due to sediment displacement. Anomalies in magnetic reading were associated with metallic objects, validating pipeline positions and assisting in hazard assessment.
- **Geological Information:** The analyses of the sub-bottom profiling data revealed the geological features of the seabed. It indicated recently deposited sand above more lithified sand layers, with depths ranging from 2.24 to 2.55m below the seabed.

CONCLUSION

The study demonstrated the effectiveness of modern hydrographic survey techniques in capturing high-resolution seabed data essential for offshore exploration and environmental management in the Niger Delta. The results indicate that high resolution bathymetric mapping, combined with targeted geophysical survey (such as magnetic and sub-bottom profiling) can significantly improve the accuracy and reliability of seabed data in regions with complex marine environments. They study revealed high-resolution data of detailed bathymetric model identifying depth variations, underwater structures and areas of potential hazards. Also, sediment types and seabed conditions were demarcated. These are crucial for safe navigation offshore maintenance, assessment of potential hazard and planning and management of offshore marine operations.

The study therefore provides vital data for sustainable resources extraction in offshore oil and gas activities in the Niger Delta.

REFERENCES

1. Bang, E.S., Woo, K.S. & Lee, H.W. (2011). Sub-bottom profiling data interpretation using advanced acoustic signal processing techniques. *Marine Geophysical Research*, 32(1), 145-158.
2. Compbell, B.A., Rogers, D.P. & Williams, S.D. (2014). The role of sub-bottom profiling in oil and gas exploration. *Journal of Geophysical Research Oceans*, 119(8), 5989-6006.
3. Constantinoiu, I., Marmescu, G. & Grigore, A. (2024). The role of hydrographic survey in environmental and marine spatial planning. *Journal of Marine Engineering and Technology*, 29(2), 124-133.
4. Hughes, C.J. (2018). *Multibeam echosounders: Technology and applications in hydrographic surveys*. International.

5. Irisarri, J., Rouault, M. & Bezuidenhout, D. (2020). Applications of machine learning in hydrographic data processing. *Journal of Coastal Research*, 36(5), 1034-1047
6. Leick, A. Rapoport, L. & Van Sickle, J. (2015). *GPS satellite surveying* (4th ed.) Wiley.
7. Lurthon, X., Augustin, J.M. (2010). A review of underwater acoustic methods for the characterization of seafloor habitats. *Marine Geophysical Research*, 31(4), 259-272.
8. Mayer, L.A., Calder, B.R. & Cartwright, D. (2002). Shallow water multibeam echo-sounding and its impact on coastal mapping. *Hydrographic Journal*, 104:3-10.
9. Mosher, D.C. Cambell, B.A. & Williamson, S.D. (2007). The role of sub-bottom profiling in marine geology. *Journal of Marine Geology*, 240(1), 89-100.
10. National Oceanic and Atmospheric Administration (NOAA). (2023). *Introduction to Hydrographic Surveying and Coastal Mapping*. NOAA office of Coastal Survey.
11. Nwilo, P.C., Orji, M.O & Peters, M.O (2010). Coastal erosion in Nigeria: Case study of the Niger Delta. *International Journal of Environmental Studies*, 67(6), 867-878.
12. Pavlopoulos, K. Dimas, X., & Dellapasqua, F. (2017). Advances in sonar mosaicking for seabed mapping. *Journal of Marine Science and Technology*, 25(4), 623-631.
13. Smith, S.T. Robinson, S.P. & Kastrisiers, D. (2015). Seabed characterization for subsea pipelines in the Niger Delta. *Offshore technology conference*, Houston Texas.