Ajayi Crowther Journal of Pure and Applied Sciences
https://acjpas.acu.edu.ng

Ajayi Crowther J. Pure Appl. Sci. 2023, 2(2), pp. 12-25
https://doi.org/10.56534/acjpas.2023.02.02.12

Article

Sedimentological Investigation of the Seafloor in Bope Field Offshore Niger Delta Using Acoustic Remote Sensing

***Hope Chibuzor Chuku, Ekaete Enamekere Umoh, Peace Oluwaseyi Agbaje**

Department of Earth Sciences, Faculty of Natural Sciences, Ajayi Crowther University, Oyo, Oyo State, Nigeria.
hc.chuku@acu.edu.ng (H.C.C); ee.umoh@acu.edu.ng (E.E.U); po.fasina@acu.edu.ng (P.O.A.)

* Correspondence: (H.C.C.) hc.chuku@acu.edu.ng

Article history: *received, Aug. 15, 2022; revised, Sept. 10, 2022; accepted, Sept. 15, 2022; published: May 30, 2023.*

Abstract

Acoustic remote sensing is used for mapping sediments and seafloor structures. Recent technological advances have brought the objective of complete area mapping into the mind of marine geoscientists. The survey includes several profiles, run on parallel and cross tracks with a certain amount of overlap at survey speed of 3-3.5knots. Continuous-coverage of side scan imageries, bathymetric, and subbottom surveys of 1km block; 500m x 500 area around Bope was conducted to assess the variability of the seafloor and to improve our understanding of the processes that control the complex distribution of bottom sediments. The seafloor topography around Bope field is extremely variable over short distances and controlled by a combination of the subsurface stratigraphy and the modern hydraulic regime. Areas of high backscatter on the side scan image reflect boulder sediments. Sand waves occur in patches both north and south of the area, but they never exceeded 0.5 m in height or 20 m in wave length and seafloor gradient < 0.370. Water depth of survey Corridor ranges between 28.9m to 31.89 m reduced to LAT Calabar River Approach.

Keywords: Seafloor, Signal Processing, Sediments, Sand Waves, Backscatter.

1. Introduction

The transport and fate of sediments is a critical factor affecting, coastal embayments, riverine, lacustrine, and continental shelf environments [1]. A geophysical and sedimentological study of the. Bope field as a part of pre or post lay project was conducted to determine: 1) the primary drivers of sediment erodibility within a depositional system, 2) if these drivers can be accurately measured through sedimentological and acoustic information, and 3) the spatial and seasonal variability of erosion within the field. Previous studies indicate that increased erodibility within the field is mainly due to recent sediments deposition, whereas lower erodibility is associated with eroded or reworked conditions. By studying key sedimentological and acoustic parameter, we can more generally apply knowledge gained on relationships among sediment facies, seabed erodibility, and the recent history of deposition, erosion, consolidation, and reworking[2].Estuaries, coastal embayments, riverine shelves, and continental slope regions are often covered with muddy fine-grained sediment. Previous studies have shown that fine-grained sediment can have a detrimental impact on water quality, especially in estuarine systems. Previous studies have shown that the erodibility of sediment beds is a complex function of grain size, water content, mineralogical composition, deposition and erosion history. Over the past few decades, hundreds of studies have utilized geologic acoustic mapping in order to analyze the seabed.

1.1 Related Research

1.1.2 Sediment Properties-Flocculation and Deposition

Depending on the degree of convergent sediment transport and the strength of waves and currents, fine-grained sediment particles can exist in four various states: mobile-suspended sediment (including various degrees of particle aggregation), high near bed sediment concentrations (fluid mud), unconsolidated sediment deposits, or consolidated sediment bed. When comparing flocculated/aggregated grains to individual primary particles, the settling velocity can range several orders of magnitude greater [7] and [12].

1.1.2 Sediment Properties-Erosion

As stated previously, not all sediment is deposited and consolidated on the seabed. When the bottom shear stress, caused by the friction of water flowing over the bed surface, exceeds the seabed's resistance to erosion, sediment is resuspended [13]. The greater the shear stress of water acting on the sediment surface, the higher the erosion potential.

1.1.2 Turbidity Maxima

Fine sediment resuspension is commonly noted within estuarine turbidity maxima (ETMs) [9] and [7]. Residual water circulation and salinity fronts are thought to be the primary mechanisms for forming ETMs in partially-mixed estuaries, while tidal asymmetry is thought to be increasingly important as tidal energy increases [8] and [9].

1.1.2 Acoustic Mapping

Over the past two centuries, hydrographic surveys have been conducted to map bathymetry of the world's oceans, coasts, and navigable waterways [1] and [11]. Early mapping techniques utilized lead lines or sounding poles with triangular positioning in order to capture sounding depths [6] and [1]. With the advent of acoustic technology, new mapping tools became available to increase the accuracy of bathymetric maps using echo-sounders [14]. Early mapping techniques utilized lead lines or sounding poles with triangular positioning in order to capture sounding depths [6] and [10]. With the advent of acoustic technology, new mapping tools became available to increase the accuracy of bathymetric maps using echo-sounders [14]. Further advances in technology led to a shift to digital from paper data and allowed for a greater resolution via the development of swath bathymetry, airborne laser, sidescan sonar, etc.

1.2 Study Area and Location

Over the years, many research projects have been conducted within the Niger Delta (Figure 1) making it an increasingly well-documented study locale. Though the studies have ranged from sedimentology and stratigraphy, many have looked at the physical and geologic properties of the Basin.

1.3 Aim

The aim of the seabed survey is to determine the present seabed condition within the Bopearea to allow Rig navigation/move.

2. Methods

On the 25th-26th of February, 2019 team of geologists on board the survey vessel - MV Serah proceeded to BOPE Location for seabed survey work. At BOPE, the crew began rigging up of geophysical equipment on board MV Serah to commence the planned survey work at the location (figure 1). The following sections below provide details of the infield test and checks on equipment done online with the survey procedure approved for the research.

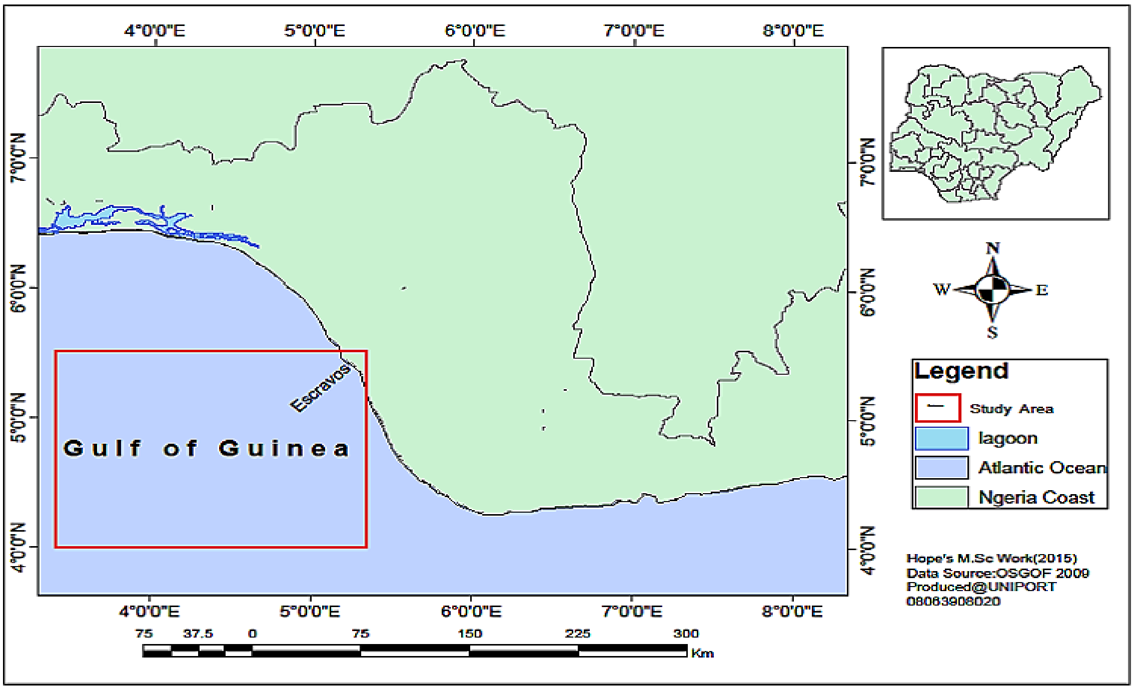


Figure 1: Map of the Study Location and coordinates, 25.82km offshore Western Niger Delta Nigeria (Modified after [4] and [5]).

2.1 *Geoacoustic Equipment Calibrations*

2.1.1 Single Beam Echosounder

The ODOM Hydrotrac Echo sounder was function tested at the dock prior to survey. The tests indicated that the transducer was functional. Offshore, the echo sounder was calibrated for bar check and index error (see appendix). Velocity of sound in water was read and the value obtained was inputed into the echo sounder unit. Further calibration was done by bar check [13]. The index error was found to be less than 0.1m. To clear the error, the draft setting on the echo sounder was adjusted to bring the reading at par with that measured in the bar check. The echo sounder was also checked to have unhindered communication with the navigation system [2].

2.1.2 C-NAV DGPS Receiver (DGPS)

The C-Nav. 2050 DGPS Receiver was used to carry out the survey. A GPS verification was done at the jetty in the absence of known survey controls to determine the accuracy of the Receiver. The GPS verification determined the difference between calculated and measured difference between two GPS antennas. The two C-Nav GPS antenna positions were logged simultaneously and the difference was computed in an excel sheet and compared with the measured difference. The difference between the computed and measured distance was 0.3m [3].

2.1.3 Side Scan Sonar (SSS)

The Side Scan Sonar equipment was calibrated for rub test and range test in water only. Subbottom Profiler. The sub-bottom profiler was tested for pinging on the ground and wet test in water.

2.1.4 S G Brown Gyro Compass

An integrity and function test of the gyro- compass was carried out at the dock prior to mobilization. The gyro- compass was aligned in the direction of the bow of the vessel in the survey room. The captain was directed to turn the vessel in the opposite direction to achieve 1800 turn. The gyro-compass readings were within tolerance limits and compared favourably with the vessel's gyro – compass (see appendix).

2.1.5 MutibeamEchosounder (MBES)

The Edge Tech 4600 Swath Multibeam system was used to carry out the survey. The equipment was calibrated for patch test. Roll, Heave, Pitch, Yaw and GPS Latency. The multibeam was side mounted and the transducer was defined as the vessel datum in the navigation software. Data acquisition was carried out simultaneously with the analogue survey.

2.1.6 Motion Reference Unit (MRU)

The heave compensator sensor unit placed on the wooden box on deck was shaken. The perturbation produced output was displayed on the navigation system. These values were applied to the echo sounder readings to adjust for vessel heave, pitch and roll during the survey. Positioning was by C –NavDGPS. The relative offsets from the GPS antenna to the various survey sensor deployment points were determined using tape measurements. These measurements were independently checked by a different crew member and compared with scale drawings of the vessel (see appendix).

2.1.7 Vertical Datum

All offsets between the datum point and the antenna / sensors on the survey vessel were taken. The positioning system performed as designed. There was no failure from the C- NAV or crashes from the navigation software. All bathymetric data were reduced to metres and decimeters and referenced to the Lowest Astronomical Tide (LAT) using predicted tides Opobo River Approach.

2.2 Data Acquisition

Data capture commenced on the 25th-26th February, 2019 from survey container sea fastened on board MV Serah, a 38m-length survey vessel customized for bathymetric and geophysical surveying work. The vessel was equipped with a Differential Global Positioning System (DGPS) allowing for precise navigation along pre-planned survey lines (figure 3).The survey lines were designed based on the observations made on sonar records during data acquisition

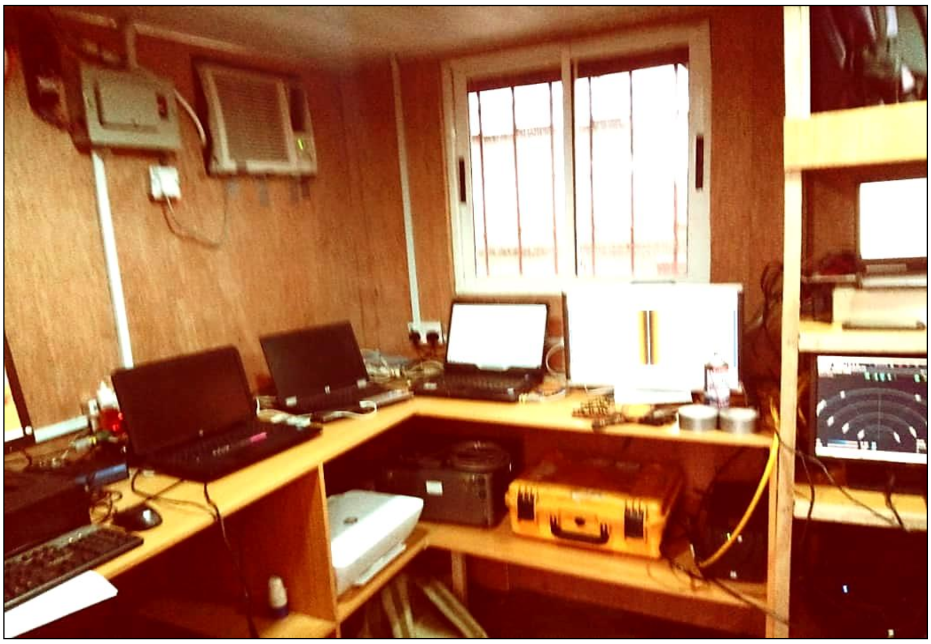


Figure 2: Survey Equipment setup onboard MV Serah

All the data pertaining to different survey sensors was logged simultaneously over the relevant systems / software to have a digital data set. Thermal paper prints were interfaced with the systems to have a real time output of the data on a paper record. Backup of the survey data into an external hard drive was be performed once in a day without impeding the survey operations. The research specific acoustic equipment such as Side Scan Sonar, Sub-bottom Profiler, Magnetometer and Echo Sounder were deployed during survey to achieve the survey objective. All the data pertaining to different survey sensors was logged simultaneously over the relevant systems / software to have a digital data set. Thermal paper prints were interfaced with the systems to have a real time output of the data on a paper record. Backup of the survey data into an external hard drive was be performed once in a day without impeding the survey operations.

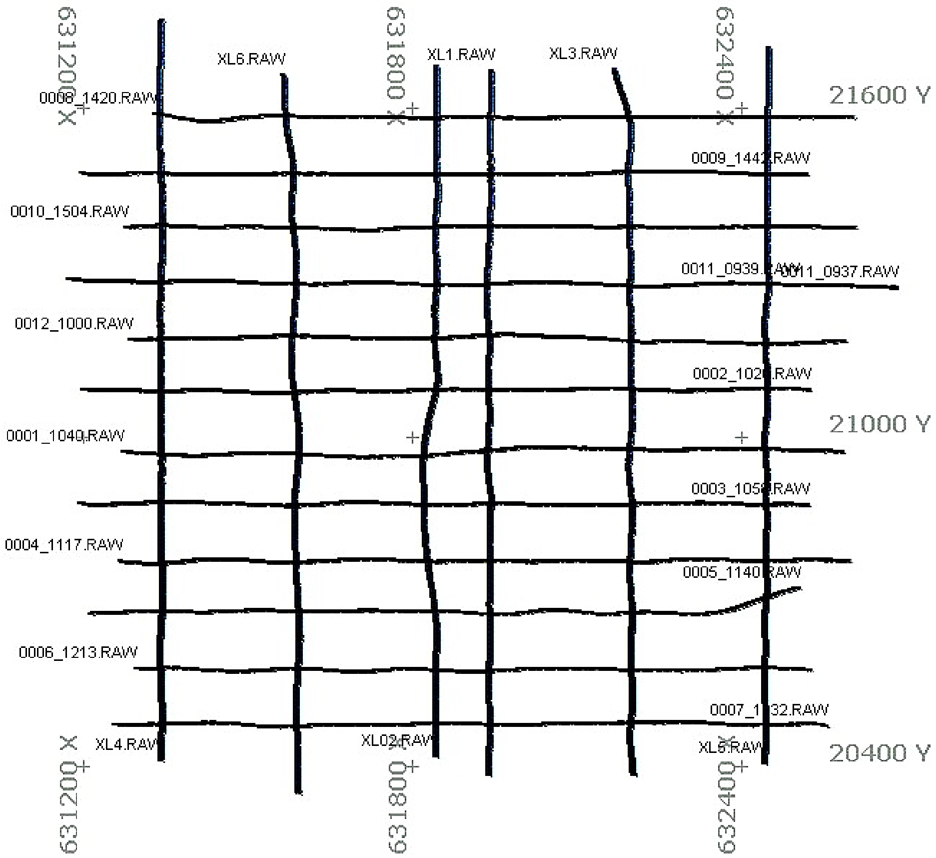


Figure 3: Navigation Gride/Trackplot of Bope Field

3. Results and Discussion

The survey results consist of bathymetric and geophysical survey data and are presented in the following sections below.

3.1 Water depth ranges between 28.9m to 31.89m within the Bope surveyed corridor.

The sonar records of the Bope infer the dominant presence of Low and High Reflective Sediments, interpreted to be composed of Silty Sand and Clay in the southern portion of the Bope surveyed corridor (Figures 4, 5 and 6). However, High reflective sediments, interpreted to be composed of pebbly Sand were observed also accumulating around the Bope Jacket area and pipelines, associated with fluctuating wave regimes and these are in the northern portion of the surveyed area (Figures 8 and 9).

Gradually fading off two sets of spud cans (Figure 7) were also captured about 340m North East and 220m North West of Bope respectively (Table 1). Debris measuring 6m by 3m was also seen about 340m south South East of Bope. There is also a 7m shift along Bope corridor 2.75′′ pipeline.

Table 1: Bope SSS Processed Data

Bope SSS Processed Data						
Feature	**code**	**Easting**	**Northing**	**Length (m)**	**Width (m)**	**Orientation (°)**
Jacket	Bope jacket	631898.07	21031.66			
SuspectedAnchor Debris	deb	631925.21	20694.17			
Pipeline Crossing		631931.39	20895.14			
Spud Can	Spud can 1	631935.15	21006.73			
	Spud can 2	631935.65	21046.55			
	Spud can 3	631970.98	21023.65			
	Faded Spud can 4	631806.32	21222.67			
	Faded Spud can 5	631787.81	21262.57			
	Faded Spud can 6	631829.77	21251.46			
	Faded Spud can 7	632246.13	21201.96			
	Faded Spud can 8	632238.59	21168.06			
	Faded Spud can 9	632210.37	21189.81			
	Faded Spud can 10	632169.9	21034.8			
	Faded Spud can 11	632185.6	21006.8			
	Faded Spud can 12	632144.4	21001.1			
Spud drag	Sdrag 1	632026	21020.02			
	Sdrag 2	632050.73	21024.96			
	Sdrag 3	632073.9	21033			
	Sdrag 4	632092.75	21044.43			
	Sdrag 5	632105.73	21055.56			
	Sdrag 6	632119.95	21066.99			
	Sdrag 7	632133.72	21076.88			
	Sdrag 8	632148.79	21091.95			
	Sdrag 9	632164.63	21109.32			
	Sdrag 10	632177.51	21123.8			
	Sdrag 11	632194.84	21142.84			
	Sdrag 12	632212.81	21160.58			
	Sdrag 13	632230.93	21177.47			
	Sdrag 14	632238.74	21189.93			
scar 1	sc 1	631609.79	21171.35			
	sc 2	631598.05	21136.62			

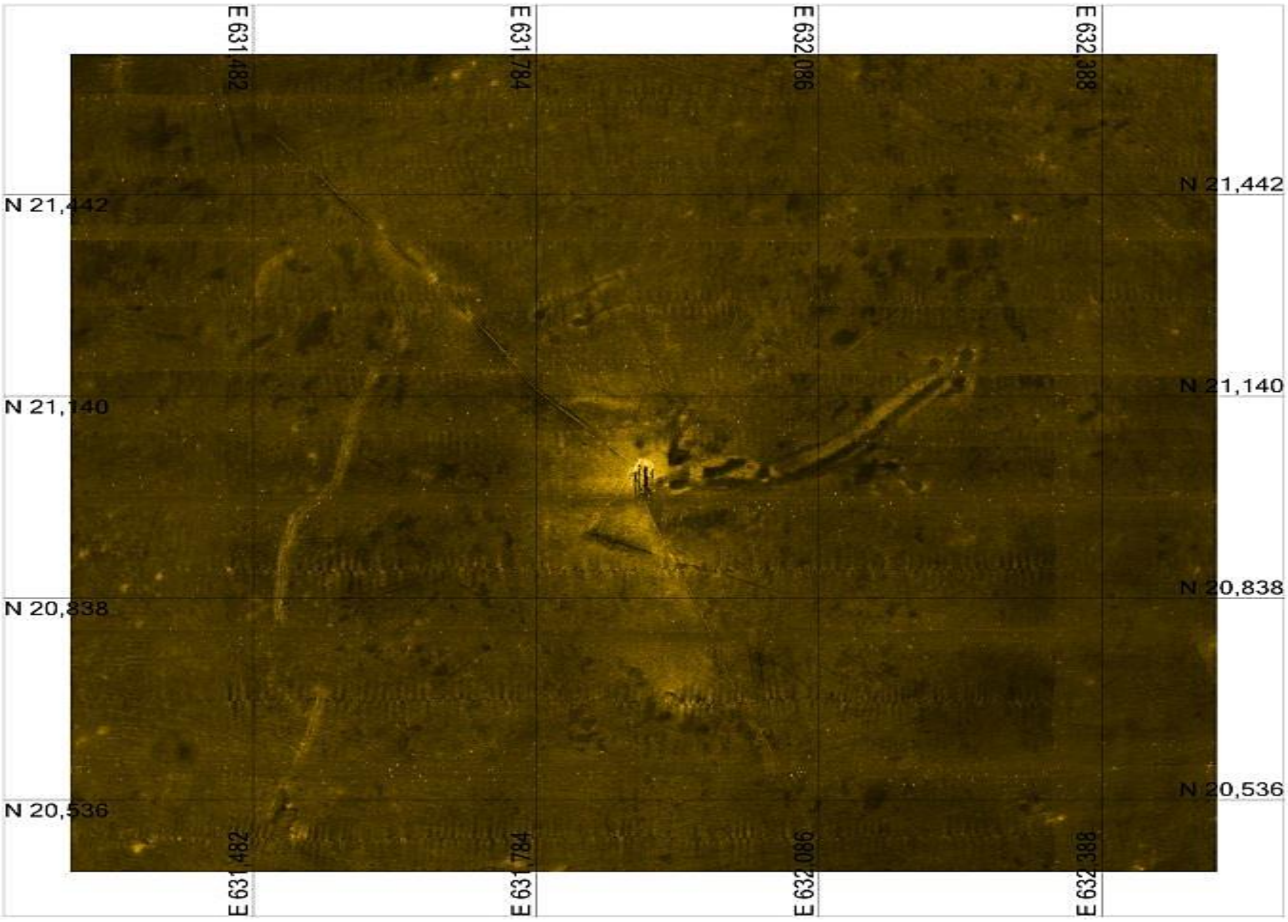


Figure 4: Bope 500m Radius Mossaic

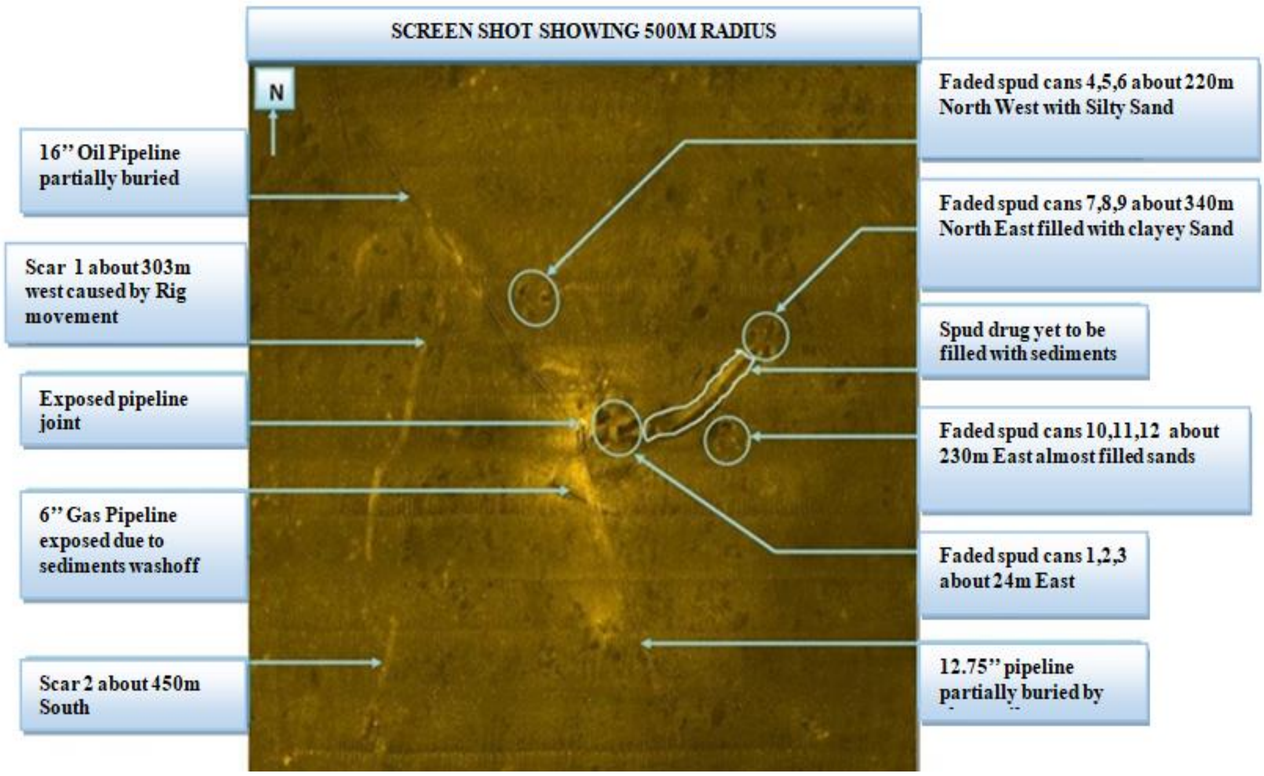


Figure 5: Screen Shot Showing 500m RADIUS of Bope Jacket

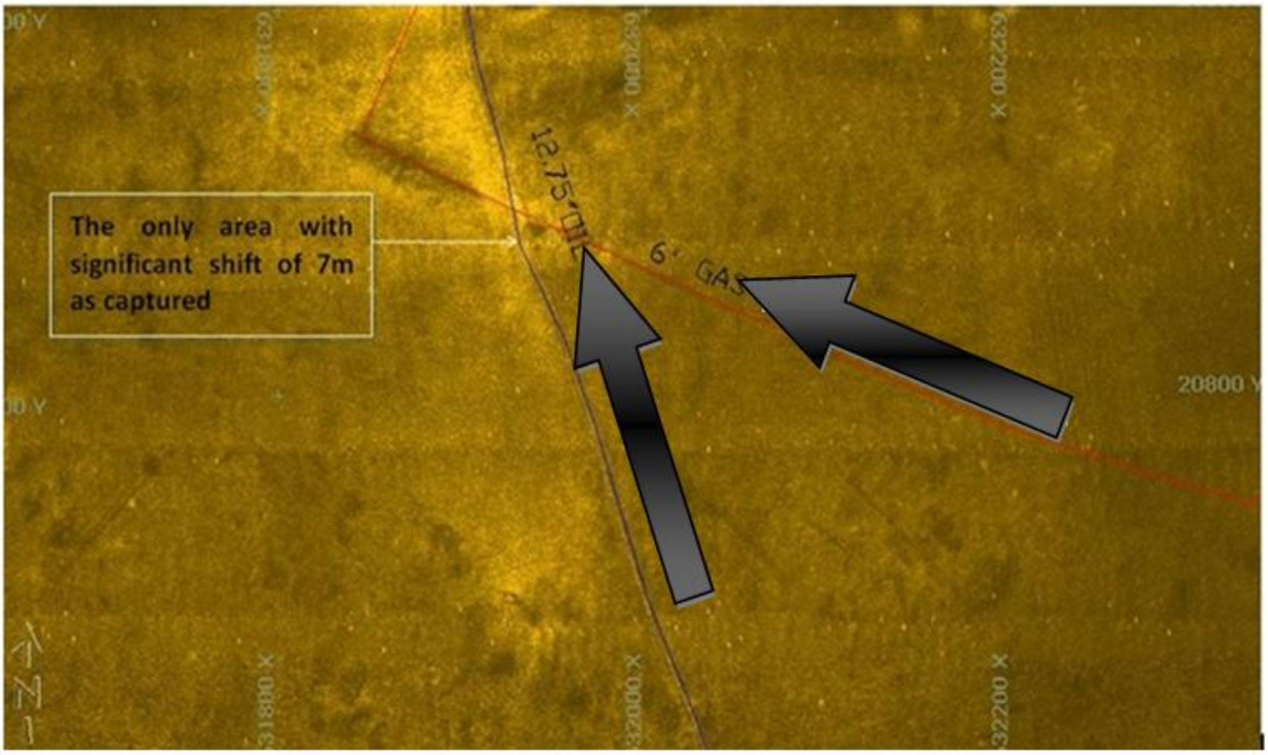


Figure 6: Screen shot showing area with 7m shift on 12.75″ Bope Oil Pipeline

Figure 7: Screen Shot Showing 150m Radius of Bope Jacket

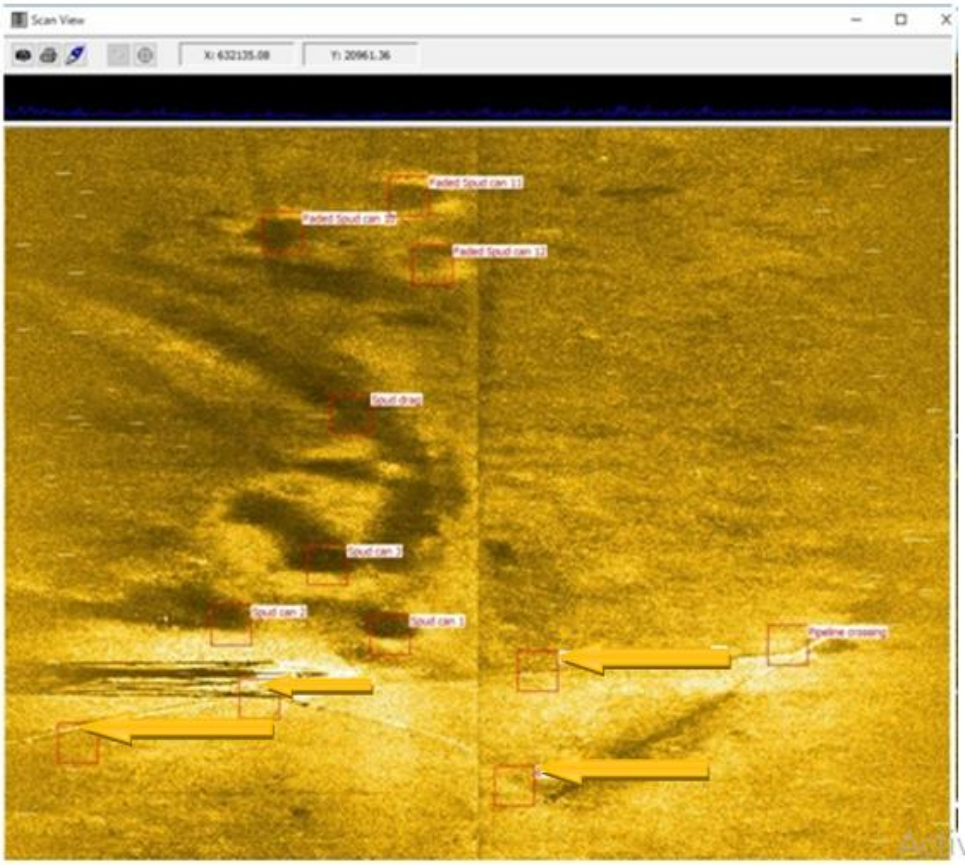


Figure 8: Screen Shot showing 16'' Oil Bope N to S PP, 12.75 Oil Bope E to W, 6’’ Gas GR2 (GV) to Bope S pipelines, Spud cans 1, 2, 3, Spud drag, pipeline crossing and faded Spud cans 10, 11, 12

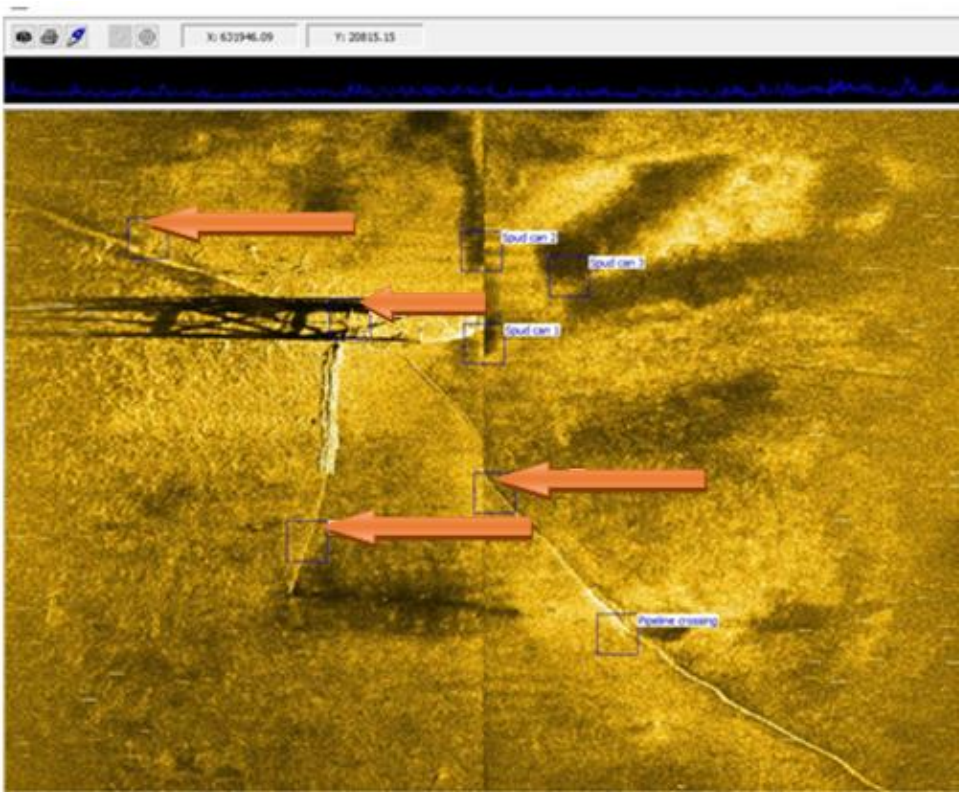


Figure 9: Screen Shot showing 16'' Oil Bope A to Bope PP, 12.75 Oil Bope B to Bope A, 6’’ Gas to Bope SA pipelines, Spud cans 1, 2, 3, pipeline crossing

3.2 Bope Subsea Facility and Existing Installations

The detected pipelines within the survey corridor of Bope were entirely exposed. The existing installations detected include three (3) pipelines. The verified pipeline positions by survey are consistent with Chart provided for the survey. MagLog provide the details of the magnetic anomalies observed within the surveyed area, which are associated with the Bopejacket.

Table 2: Magnetic anomalies observed within the surveyed area

MAGNETIC CONTACT ID	FEATURES	COODINATES		LINENO	TIME (Hrs)
		Easting	Northing		
Mg 1	16" OIL Bope I- Bope I PP	631645.28		8	142345
Mg 2 33068nT	16" OIL Bope I- Bope I PP	631588.728	21397.801	9	145234
Mg 3 33066nT	16" OIL Bope A-Bope PP	631721.821	21313.863	10	150855
Mg 4 33095nT	16" OIL Bope A- Bope PP	631930.542	21114.34	12	100647
Mg 5 33976nT	Bope A JACKET AND 12.75" OIL Bope B-Bope A	631941.603	21002.509	2	102635
Mg 6 33032nT	6" GAS TO Bope SA	631901.587	20899.257	1	104006
Mg 7 33053nT	6" GAS GR2(GV) TO Bope SA	632027.001	20792.251	3	110358
Mg 8 33047nT	12.75" OIL Bope B-Bope A	631988.472	20789.571	3	110418
Mg 9 33072nT	12.75" OIL Bope B-Bope A	632040.37	20701.701	4	112430
Mg 10 34096nT	6" GAS TO Bope SA	632529.13	20624.175	5	114125

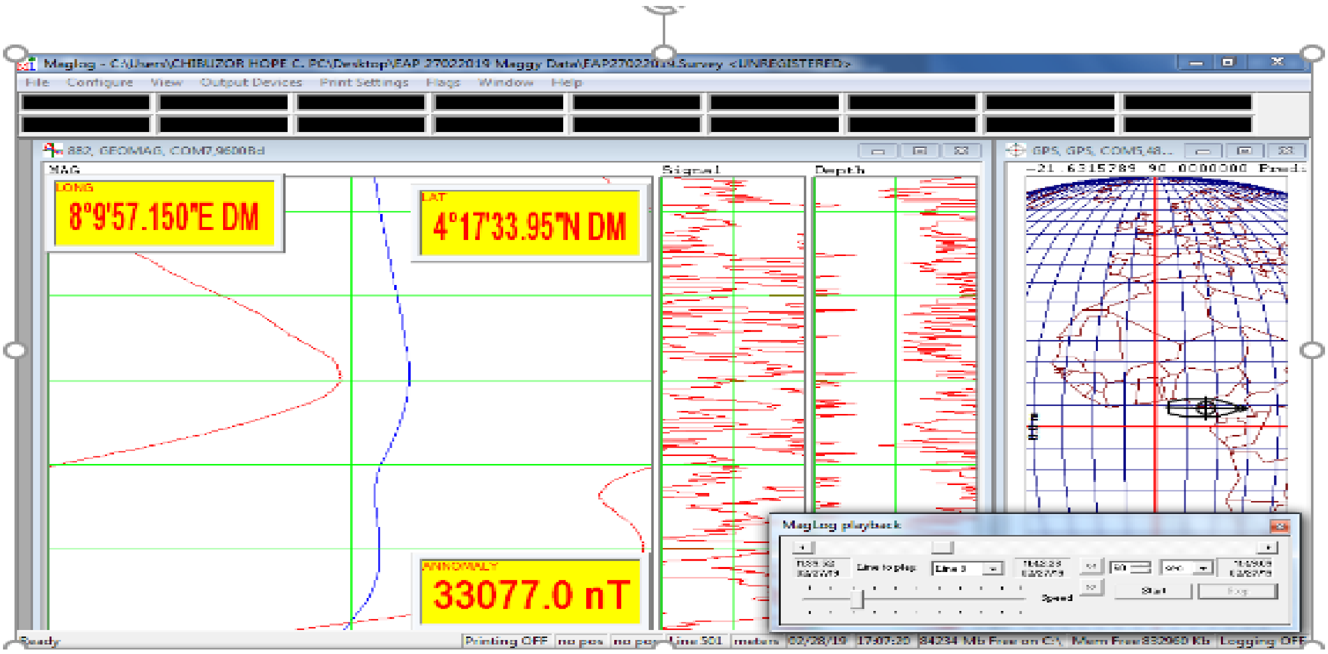


Figure 10: MagLog Extract showing magnetic anomaly corresponding to 16'' Oil pipeline in Bope field.

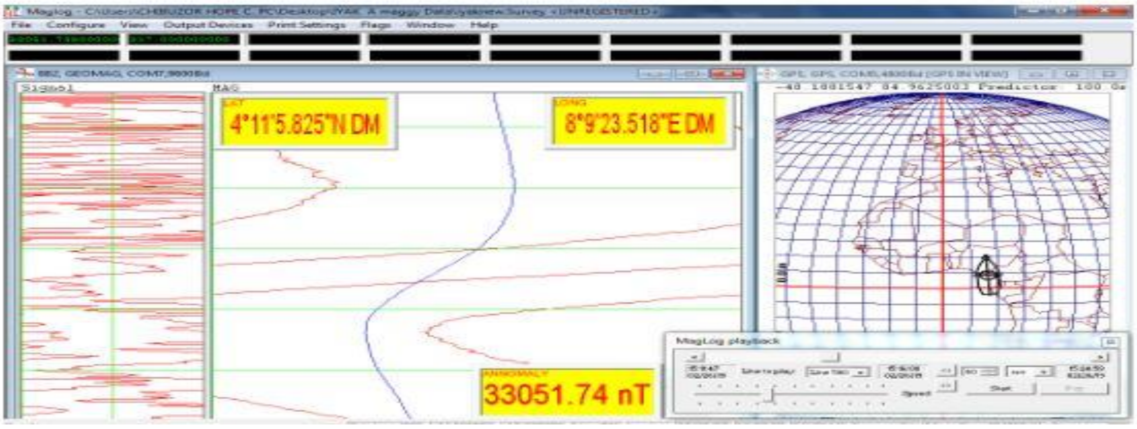


Figure 11: MagLog Extract showing magnetic anomaly corresponding to 6'' Oil pipeline in Bope field.

The subbottom profiler data is uniform across the survey area showing one reflector that varies between 2.88m and 3.65m below seabed (figures 12 & 13). No other significant structure can be seen within the data set underlying the reflector apart from the tails of diffractions from various pipelines within the survey corridor of Bope field.

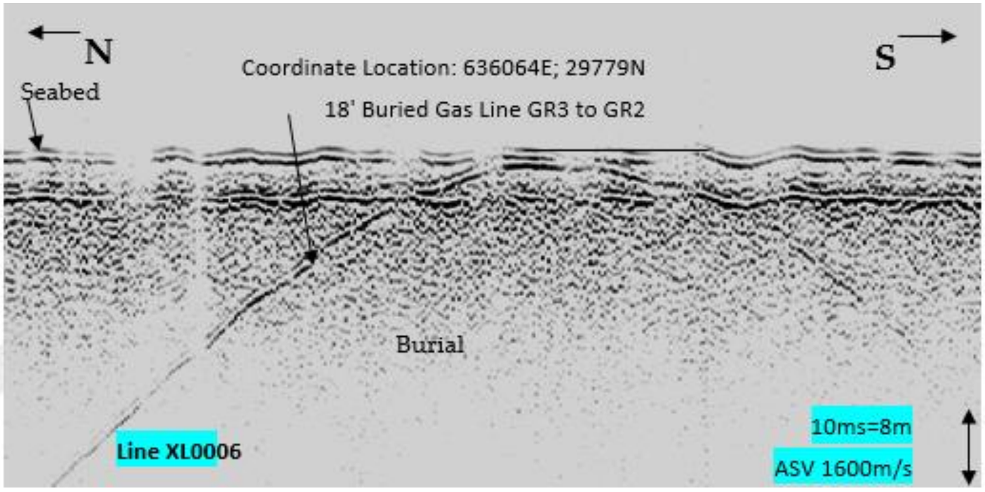


Figure 12: SBP Data Extract of Survey Cross Line showing Buried Pipeline South West of Bope field

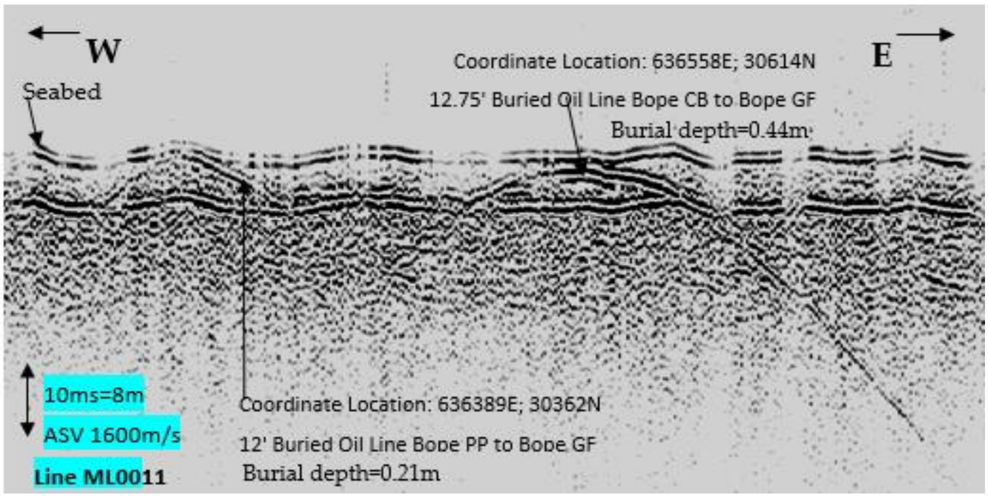


Figure 13: SBP Data extract of survey Cross line showing two adjacent Buried Pipeline Northward of Bope field

4. Conclusions

The following survey information concludes the seabed survey of Bope field carried out on the 25th-26th of February, 2019. The water depth ranges between ranges between 28.9m to 31.89m within the Bopesurveyed corridor.The sonar records of the Bope infer the dominant presence of Low and High Reflective Sediments, interpreted to be composed of Silty Sand and Clay in the southern portion of the Bope surveyed corridor. However, High reflective sediments, interpreted to be composed of pebbly Sand were observed also accumulating around the Bope Jacket area and piplines, associated with fluctuating wave regimes and these are in the northern portion of the surveyed area.The seismic profile of the Bope field suggests the variation in sediment thickness between 2.88m and 3.65m, this layer or reflector is uniform across the entire area within the survey corridor.No other significant structure can be seen within the data set underlying the reflector underneath the seabed apart from the tails of diffractions from various pipelines within the survey corridor of Bope. The existing installations detected includes; three (3) existing pipelines, exposed. The verified pipeline positions by survey were based on reconstructions of Sub-Bottom Profiler and Magnetometer data and findings were consistent with the field Chart for the survey. The detected pipelines and associated subsea structures within the Bope Survey Corridor were found to be buried. The measured burial depth of detected pipelines is between 0.11m and 0.44m. The major seabed feature of the Bope survey corridor is sand waves indicative of strong underwater current shaping the seafloor of the survey corridor resulting in the accumulation of High Reflective Sediments observed around the detected pipelines and platform Areas .A total of seven (7) sonar contacts were detected within the surveyed corridor ofBope.Magnetic anomalies observed within the Bope surveyed corridor were due to existing pipelines and platform structures.Spudcan depression indicative of previous rig approach and work over location were observed within the Bope survey corridor.

5. Recommendations

Acoustic remote sensing should be used for quick wide area coverage of the seabed and development.The study area is free of impediments to seagoing vessels, drilling rig and emplacement of subsea facilities. From the sonar record of the Bope survey corridor, there is no observed seabed features or obstructions that may pose constraints or hazards to the planned Rig move

Funding: Not applicable.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: Not applicable

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Andersen, T.J. (2001). Seasonal Variation in Erodibility of Two Temperate, Microtidal Mudflats. *Estuarine Coastal and Shelf Science* 53: 1-12.
2. Betteridge, K.F.E., Williams, J.J., Thorne, P.D. and Bell, P.S. (2003). Acoustic instrumentation for measuring near-bed sediment processes and hydrodynamics. *Journal of Experimental Marine Biology and Ecology* 285-286: 105-118.
3. Caiti, A. (2006). Acoustic Sensing Techniques for the Shallow Water Environment. Springer, New York.
4. Chuku, H. C. and Ibe, A.C. (2015). Topography and Lithofacies of the seafloor in Meren field, offshore Western Niger Delta. *IJSIT* 4(6): 524-551.
5. Chuku,C.H., Odigi,M.I., Ibe,C.A. and Ideozu, R.U. (2018). Geophysical and geotechnical investigations of the seafloor sediments for offshore subsea facility installation in “Emobs” oil fields, Western Niger Delta Nigeria. *AJARR* 1(1):1-16.
6. Cohen, P.M. (1970). Bathymetric Navigation and Charting. United States Naval Institute, Annapolis.
7. Dyer, K.R. (1995). Sediment Transport Processes in Estuaries, in: Perillo, G.M.E. (Ed.), Geomorphology and Sedimentology of Estuaries. Elsevier Science, Amsterdam, pp. 423-446
8. Dyer, K.R. (1986). Coastal and Estuarine Sediment Dynamics. Wiley, Chichester; New York.
9. Geyer, W. (1993). The importance of suppression of turbulence by stratification on the estuarine turbidity maximum. *Estuaries and Coasts* 16: 113-125.
10. Gustavson, T.C., (1975). Bathymetry and sediment distribution in proglacialMalaspina Lake, Alaska. *Journal of Sedimentary Research* 45: 451-461.

11. Hill, P. S. and McCave. I. N. (2001). Suspended particle transport in benthic boundary layers. *In*, Boudreau B. P. and Jorgensen B. B. (eds.), The Benthic Boundary Layer: Transport Processes and Biogeochemistry. Oxford University Press, pp. 78-103.
12. Mikkelsen, O. A., Hill, P. S. and Milligan, T. G. (2007). Seasonal and spatial variation of floc size, settling.
13. Whitehouse, R. (2000). Dynamics of Estuarine Muds: A Manual for Practical Applications. T. Telford, London.
14. Wright, D.J. and Bartlett, D.J. (2000). Marine and Coastal Geographical Information Systems. Taylor and Francis, London; Philadelphia.

Cite article as:

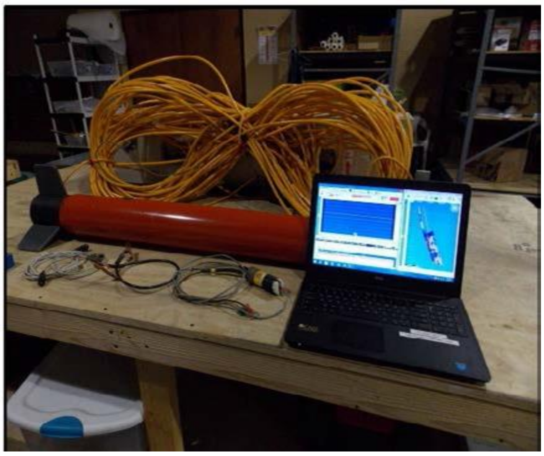
Chuku, H. C., Umoh, E.E., Agbaje, P.O. Sedimentological Investigation of the Seafloor in Bope Field Offshore Niger Delta Using Acoustic Remote Sensing. *Ajayi Crowther J. Pure Appl. Sci.* **2023**, 2(2): 12-25. https://doi.org/10.56534/acjpas.2023.02.02.12.

APPENDIX

Side Scan Sonar (SSS) System Setup

Sub Bottom Profiler (SBP) System

Multibeam EchoSounder (MBES) Setup System



Seaspy Magnetometer (Maggy) System

SG Brown Gyro Meridian Compas

Geosurvey Mobile Vessel