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ASSESSMENT OF TIDAL AND CURRENT EFFECTS ON BATHYMETRIC DATA ACCURACY IN SOKU CREEK, NIGERIA

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Abstract

Bathymetric data collection is essential for understanding underwater topography, navigation safety, and coastal resource management. However, the accuracy of bathymetric surveys is significantly impacted by tidal and current dynamics, particularly in estuarine environments such as the Soku Creek. This study evaluates the extent to which tides and currents influence bathymetric data accuracy in Soku Creek, a critical coastal system. By integrating field measurements, tidal predictions, and current velocity analyses, the study identifies variations in depth readings caused by tidal fluctuations and flow dynamics.

The research reveals that tidal range variability introduces systematic depth deviations, leading to inconsistencies during surveys conducted at different tidal stages. Initial depth measurements, referenced to uncorrected GNSS heights, exhibited vertical deviations up to ±0.45 m, with a mean absolute error of 0.38 m, primarily attributed to unmodeled tidal height variations and lateral current shear. Post-processing included the application of harmonic tidal constituents and velocity corrections derived from in-situ ADCP (Acoustic Doppler Current Profiler) measurements. These corrections reduced depth deviations to within ±0.12 m and lowered the mean absolute error to 0.09 m, representing a 76.3% improvement in vertical accuracy. Crossline comparisons revealed a reduction in mean depth offset from 0.41 m to 0.08 m, while spatial consistency across survey lines improved by 35.7%. The findings underscore the necessity for integrating tidal corrections and current modeling during bathymetric surveys to minimize errors. This research contributes to enhancing the reliability of bathymetric data in dynamic coastal regions and provides practical recommendations for survey planning and coastal resource management. Future studies should focus on incorporating real-time tidal monitoring systems and hydrodynamic models to further improve survey accuracy in tidal-influenced areas.

Keywords: Bathymetry, Coast, Depth, current, Tide

1.0 INTRODUCTION

The dynamic nature of coastal environments, influenced by the interaction of tides and currents, presents significant challenges and opportunities in the collection of bathymetric data. Bathymetry, the study of underwater topography, is fundamental for understanding coastal processes, managing marine resources, and supporting activities such as navigation, coastal construction, and environmental conservation. However, the precision and accuracy of bathymetric data are profoundly impacted by tidal fluctuations and hydrodynamic forces, necessitating meticulous evaluation and adaptation during data acquisition and analysis.

Tides, driven primarily by gravitational interactions between the Earth, Moon, and Sun, cause periodic fluctuations in sea level. These fluctuations influence the depth measurements critical to bathymetric mapping. Similarly, currents, caused by wind, density differences, and tidal forces, generate horizontal water movements that can alter instrument positioning and compromise data accuracy. Both factors are particularly pronounced in coastal zones, where their effects are amplified by the complex interplay of shallow waters, topographic variations, and anthropogenic influences.

Accurate bathymetric data collection is vital for understanding sediment transport dynamics, predicting coastal erosion, and assessing the impacts of climate change, such as sea-level rise. For instance, sediment transport processes, which are highly influenced by tidal currents, dictate the evolution of coastal morphology over time [10]. Moreover, bathymetric data is integral to the development of hydrodynamic models that simulate coastal behavior, supporting sustainable coastal management and the design of resilient infrastructure [10, 13].

The integration of real-time tidal corrections and hydrodynamic modeling into bathymetric surveys is critical to addressing these challenges. Techniques such as multi-beam echo-sounders, GNSS tidal measurements, and current profilers enable the collection of high-resolution data that accounts for tidal variations and current-induced distortions [13]. However, gaps in spatial and temporal data coverage, particularly in remote or dynamic coastal zones, highlight the need for innovative methodologies and enhanced data processing techniques.

Accurate and reliable bathymetric data, which provides insights into the underwater topography of coastal areas, is of paramount importance for a wide range of applications, including coastal management, navigation, infrastructure development, and environmental conservation. Bathymetric data is instrumental in monitoring the ever-changing conditions of coastal regions, such as erosion, sediment transport, and sea level rise. To ensure the precision and utility of this data, it is essential to consider the profound influence of tides and currents in these environments [9].

In situ and real-time monitoring is driven by the necessity to provide rapid and tangible responses to urgent problems that the community must face, such as accidental outflow and spreading of pollutants, so that data is acquired for time periods of few days during when the survey is carried out along specific routes in confined sea areas. The main consequence of this policy of intervention is a large and growing amount of assessed hydrodynamic data, gathered in coastal data sets, [12]. The diversity and density of data from marine sensors and measuring instruments is an established fact, regardless of user demands. Therefore, the key point is the necessity to convert with specific tools these data into information. In this regards, users may learn from data, which is not intended as a simple repository. For example, a time series of current velocities recorded along the water column at an investigated site might appear to be just a simple sequence of data, [8]. If an accurate analysis is executed on its peak values, within specific time intervals, some information can be derived on flood or ebb tidal dominance at that site, as this is induced by the velocity peaks, and consequently on the direction and magnitude of net landward or seaward water movement

However, the delicate equilibrium of coastal environments is under constant pressure due to the effects of climate change, sea level rise, and anthropogenic factors. Understanding the intricacies of these environments is essential for their sustainable management [5]

Tides, governed by gravitational interactions between the Earth, moon, and sun, manifest as periodic fluctuations in sea levels along coastlines [13] The amplitude and frequency of tidal variations are influenced by geographical features, lunar phases, and oceanographic conditions. Tidal dynamics exert a profound influence on bathymetric data collection, introducing vertical variations in water depth that affect depth measurements obtained by acoustic survey techniques. The magnitude of tidal range variation and its spatial distribution are critical factors influencing the accuracy and resolution of bathymetric surveys, particularly in shallow coastal areas.

Empirical studies have investigated the relationship between tidal dynamics and bathymetric data quality. For instance, research by [5, 6] conducted bathymetric surveys in a tidal flat environment to assess the impact of tidal range variation on depth measurements. The study revealed significant variations in depth readings across different tidal phases, highlighting the importance of accounting for tidal effects in data processing and analysis. Similarly, a study [6] utilized numerical modeling techniques to simulate the influence of tidal dynamics on sediment transport patterns in a coastal estuary, emphasizing the need for integrating tidal data into bathymetric surveys for accurate sediment budgeting and erosion prediction.

Several studies have examined the influence of tidal currents on bathymetric surveys. For example, research by [13] conducted field measurements to assess the impact of tidal currents on the spatial distribution of suspended sediment concentrations in a coastal inlet. The study revealed distinct patterns of sediment dispersion and transport associated with tidal current dynamics, underscoring the importance of considering current effects in bathymetric data interpretation. Furthermore, a study by [1] deployed autonomous underwater vehicles (AUVs) equipped with acoustic sensors to investigate the three-dimensional structure of tidal currents and their implications for bathymetric data collection. The findings elucidated the complex interactions between tidal currents and bathymetric features, highlighting the need for advanced instrumentation and modeling techniques to capture current-induced variations in data quality.

To address the challenges posed by tides and currents in bathymetric data collection, researchers have proposed various mitigation strategies and technological advancements. One common approach is the integration of real-time kinematic (RTK) positioning systems with bathymetric surveys to compensate for tidal variations and improve data accuracy [14]. Moreover, advancements in remote sensing technologies such as satellite-derived bathymetry (SDB) offer alternative methods for collecting bathymetric data in areas with challenging tidal and current conditions [13].

Calibration and correction techniques are fundamental strategies employed to compensate for the influence of tides and currents on depth measurements obtained during bathymetric surveys. These methods typically involve applying empirical or model-based corrections to raw survey data, accounting for variations in tidal elevations and current velocities. By calibrating survey

instruments and applying appropriate corrections, researchers can minimize errors attributable to tidal and current effects, thus improving the overall accuracy of bathymetric data, [7].
Real-time data integration represents an innovative approach to mitigating tidal and current effects on bathymetric surveys. By incorporating live data from tide gauges, current meters, and GPS receivers, surveyors can dynamically adjust survey parameters and instrument settings to optimize data acquisition under varying environmental conditions. This adaptive approach ensures that survey operations are conducted with precision, even in the presence of fluctuating tidal and current dynamics, ultimately enhancing data quality and reliability, [2].

Statement of Problem

Accurate bathymetric data is critical for maritime navigation, resource management, and coastal engineering. However, the dynamic interplay of tides and currents poses significant challenges to achieving reliable measurements, particularly in complex and dynamic environments like the coasts of Soku Creek. This region is characterized by intricate tidal patterns, variable current velocities, and fluctuating water levels, all of which introduce uncertainties in depth readings and positional accuracy during bathymetric surveys. The study is aim to evaluate the impact of tides and current on bathymetric data collection in the coast of Soku creek, Rivers State.

2.0 MATERIALS AND METHODS

Study Area

Soku is a community located in the Akuku-Toru Local Government Area of Rivers State, Nigeria. Situated in the southern region of the country which lies between latitude 6°40'12.936"N, 6°47'11.148"N and longitude 4°40'56.136"E, 4°45'53.100"E Soku is known for its rich cultural heritage and strategic location along the Niger Delta region, characterized by a network of tidal rivers, estuaries, and creeks. The study area exhibits a semi-diurnal tidal pattern with significant current activity influenced by tidal flows and freshwater discharge. The community is predominantly inhabited by the Ijaw ethnic group, with a vibrant mix of traditional customs and modern influences shaping its identity.
Economically, Soku plays a significant role in the region, primarily due to its proximity to oil and gas resources. The community is situated within the Niger Delta, a major oil-producing region in Nigeria, and is home to various oil and gas installations and facilities operated by multinational corporations. As such, Soku contributes to Nigeria's oil industry, which is a vital component of the country's economy.
In addition to its economic importance, Soku boasts natural beauty and biodiversity, with lush mangrove forests, rivers, and creeks dotting its landscape. The area is known for its diverse wildlife, including various bird species and aquatic life, making it of interest to ecotourism enthusiasts and environmental researchers.
However, like many communities in the Niger Delta, Soku faces challenges such as environmental degradation, pollution, and socio-economic disparities. Efforts to address these issues are ongoing, with initiatives focused on sustainable development, environmental conservation, and community empowerment. Figures 1 and 2 show information about the study area.

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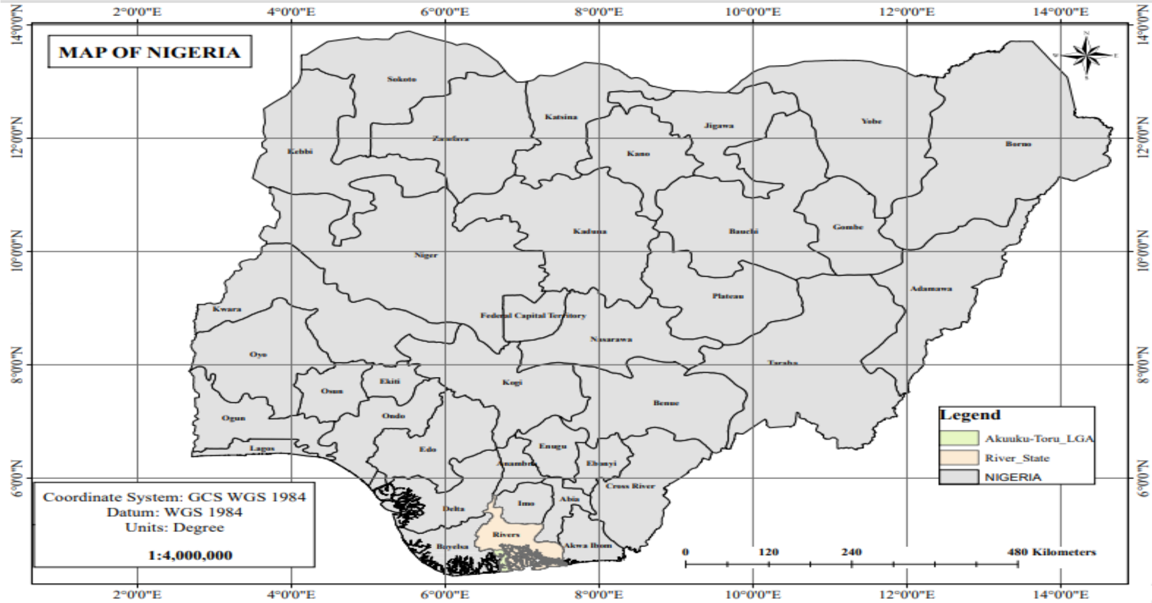

Figure 1: Map of Nigeria showing River State.

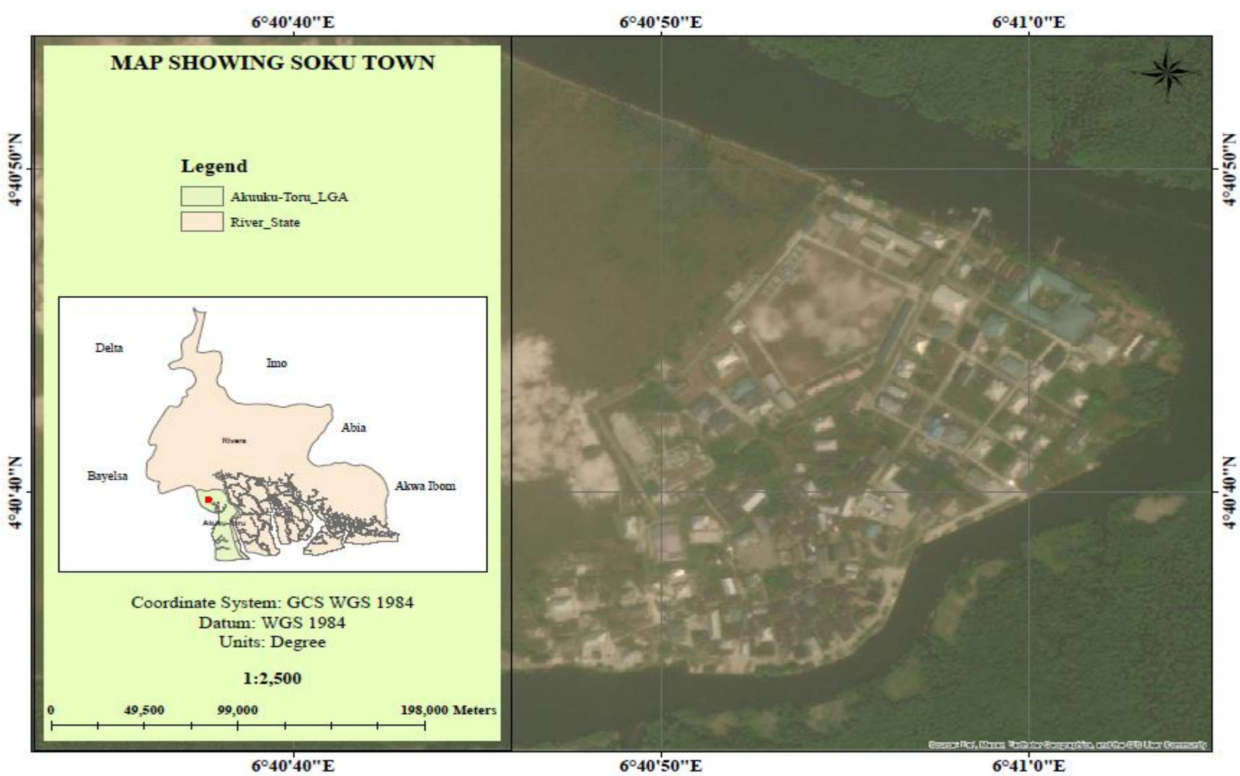

Figure 2: Map of Akuku-Toru (LGA) Showing Satellite imagery of Soku Community in River State.

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Table 1: Projection parameter

Geodetic Datum	'Minna' Parameters
Satellite Ellipsoidal Datum	WGS 84
Name of spheroid	WSG 84
Semi Major Axis (a)	6378137.00
Semi minor Axis (b)	635752.314
First Eccentricity Squared (eˆ2)	0.008694379
Inverse Flattening (1/f)	298.2572236

Table 2: Projection parameter

Local Ellipsoidal Datum	Minna
Name of Spheriod	Clarke 1880 (Modified)
Semi Major Axis (a)	6378249.145
Semi Minor Axis (b)	6356514.870
First Eccentricity Squared (eˆ2)	0.006803511283
Inverse Flattening (1/f)	293.468

Table 3: Projection parameter

Projection	Mid Belt
Name	Minna Mid Belt
Type	Traverse Mercator
Central Meridian	80 30' 00"E
Latitude at Origin	40 00' 00" N
False Easting	670553.98Em
False Northing	0.00Nm
Scale factor at CM	0.99975Metre

Datum Shift Transformation Parameters

The datum shift, rotation and scale parameters to be used for the conversion of the WGS 84 coordinates are as follows:

$\delta x = +111.916$ $\delta y = +87.852$ $\delta z = 114.499$

$\Omega x = -1.87527$ sec $\Omega y = -0.20214$ sec $\Omega z = -0.21935$ sec

Scale factor = -0.03245ppm.

Data Collection

Bathymetric survey data was collected using multi-beam echo sounder mounted on a hydrographic standard vessel measuring 7 m in length and 3 m in width and powered by 75 HP Yamaha engines. The transducer was mounted on the port side of the vessel, and the RTK-GNSS antenna was mounted in synergy vertically above it, resulting in zero offsets.

The navigation and positioning on the survey boat, fitted with the depth sounding equipment was with Hemisphere LUKA VS250 dual frequency DGPS system. These were setup on the survey vessel with offset measurements between the GPS antenna and transducer positions, made and registered in the survey navigation software HYPACK. This enabled position co-ordinate determination of the Echo sounder transducer position for every sounding point. The survey computer runs the HYPACK navigation software, which was configured to received and log raw data in real-time from the interfaced DGPS, gyro compass and Echo Sounder systems. The software also transformed the logged raw GPS co-ordinate from WGS-84 format to local grid reference to Nigeria Mid Belt co-ordinate system using a set of 7 datum shift parameters. The computer received GPS derived coordinates in WGS84 from the GPS system to output the final grid coordinates in Universal Transverse Mercator system. Before the commencement of the sounding work a bar check was carried out on the multi-beam Echo sounder to ensure the echo sounder is working properly and to ensure its configuration is still perfectly in order. This is done by using a calibrated bar plate placed directly under the transducer. Depth 1m, 2m and 3m was checked respectively and found to be working perfectly. This was also carried out at the end of the sounding activity.

Bar Check Calibration

The effect of a varying velocity of sound propagation is measured by performing bar check calibration which is the most common depth calibration technique used for depths about 20- 30 meters [4].

Procedure: As shown in Figure 3, The suspended bar as a bar check apparatus is constructed of flat stainless steel or aluminum plate suspended by two precisely marked lines to a known depth of 1m, 2m, 3m etc below the water surface and under the transducer. When applying the bar check, method, a reflective bar or plate, is lowered beneath the transducer on marked lines at various depths. A series of depth intervals are observed during a bar check, down to the project depth. The observed depths are compared with the known depths on the lowering bar or plate. Schematic Depiction of Bar Check Calibration, Bar check not only measure the sound velocity errors due to temperature, salinity, or other suspended or dissolved sediment variations, but also static draft fluctuations resulting from varying vessel displacement and instrumental errors-index, mechanical, and electrical [11]. The necessary corrections for velocity of sound propagation can be computed by comparing the observed depths.

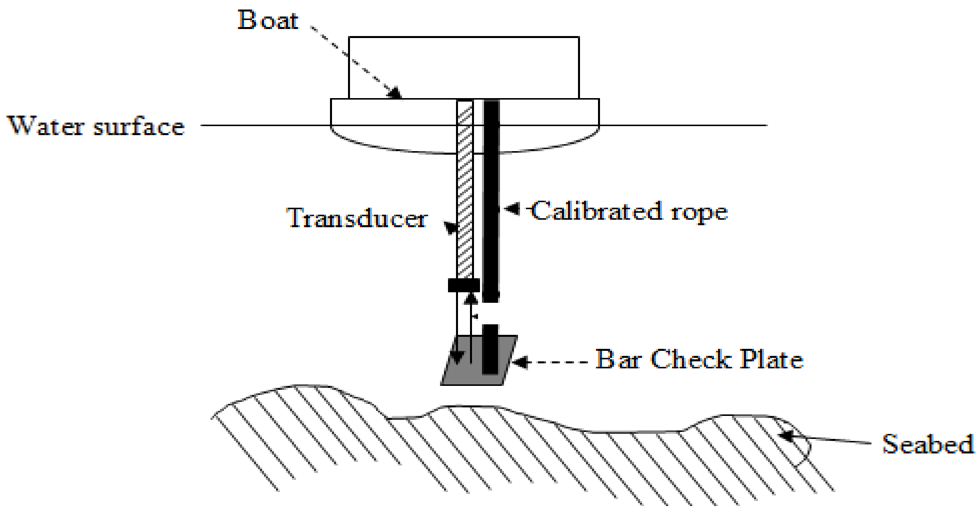

Figure 3: Bar Check Calibration, Source: [11]

The predefined transect lines spaced at 50 m intervals already loaded into the Hypack software were traversed using the onscreen user guide provided by the software vendor.

Tidal Data Collection

Tidal data were recorded using **tide gauges** strategically deployed at key locations along the creek. These instruments measure water level fluctuations caused by tidal forces. The data provide insights into tidal cycles, amplitude, and phase differences, essential for understanding temporal variations in water depth. Locations were chosen based on the need to capture a comprehensive representation of tidal behavior across the survey area. This includes areas near inlets, constrictions, or regions of significant hydrodynamic activity. The tidal data were later used for depth corrections in bathymetric surveys, ensuring that depth measurements accurately reflect seabed elevations relative to a consistent vertical datum. Plate 1 shows the position of tide gauge.

Plate 1: Tide gauge for water level reading

Current Velocity Measurement

Current velocities were measured using Acoustic Doppler Current Profilers (ADCPs), which use the Doppler effect to calculate water movement in the vertical and horizontal dimensions. Measurements were taken during different tidal phases (e.g., flood, ebb, slack) to capture the complete range of hydrodynamic conditions. The velocity profiles helped in understanding the dynamics of sediment transport and their potential impact on seabed morphology. Additionally, these measurements provide critical data for hydrodynamic modeling and simulations.

Survey Timing and Strategy: Surveys were conducted during different tidal stages (low, mid, and high tide) to assess how water depth variability influences bathymetric readings. This approach ensures that any tidal corrections applied during data processing are robust and that depth measurements accurately reflect seabed elevations under varying conditions. The variability assessments provide insights into tidal-driven morphodynamics and highlight potential areas prone to erosion or sediment deposition.

The GNSS RTK antenna height is measured from the antenna reference point to the water level to provide continuous readings of the water level, while the echo-sounder measures the top of water level to the seabed using acoustic signal. With this, it also allows for the direct measurement of seabed elevation relative to the datum. The echo sounder provided the depth, while RTKGNSS provided the corresponding horizontal coordinates.

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To understand how an echo sounder uses acoustic pulse energy to determine depth, equation 1 below [3] is typically applied. Plate 2 is a diagram that demonstrates this principle,

Plate 2: Bathymetric equipment inside survey boat and the crew members

the basic principle involves sending an acoustic pulse from the transducer, which travels through the water and reflects off the seafloor. The echo sounder measures the time it takes for the pulse to return, and from this, it calculates the depth.

Equation for Depth Determination

The key equation is derived from the relationship between the speed of sound in water, the time taken for the acoustic pulse to travel to the seafloor, and the depth. The formula for depth D is:

$$D = \frac{c-t}{2} \quad (1)$$

Where:
D is the depth (in meters)
c is the speed of sound in water (in meters per second, m/s)
The speed of sound c varies with factors like water temperature, salinity, and pressure. Typically, it's around 1500 m/s in seawater at 25°C, but it can range between 1400 m/s to 1600 m/s.
t is the time taken for the acoustic pulse to travel to the seafloor and back (in seconds)

Since the pulse travels to the seafloor and back, the distance the sound travels is twice the depth, hence the division by 2 in the formula.

RTK-GNSS for Horizontal Coordinates

RTK-GNSS (Real-Time Kinematic Global Navigation Satellite System) provides precise horizontal positioning, which can be used in combination with the depth to determine the exact location of the measurement.
If you have both depth and horizontal coordinates, the full position of a point on the seafloor can be represented as:

$$Position = (X, Y) \quad (2)$$

Where,
(X, Y) are the horizontal coordinates obtained from RTK-GNSS?
D is the depth calculated from the echo sounder.
This gives the 3D location of the measurement point on the seafloor.

Plate 3: GNSS RTK base station on a control point

Data Processing

Tide models are used to correct depth measurements for tidal variations and establish a consistent vertical reference frame. Data filtering algorithms identify and remove outliers or spurious measurements caused by turbulent water or sensor noise, ensuring data integrity and consistency.

Data Analysis Techniques

Data analysis is the process of examining, cleaning, transforming, and interpreting data to discover meaningful insights, inform decision-making, and derive actionable conclusions. It serves as a fundamental step in research, business intelligence, and scientific inquiry, enabling individuals and organizations to extract valuable knowledge from vast amounts of information.
The data collected was converted to comma-separated values (CSV) format right there on the field after the sounding was completed with the aid of south28D Software as follows; double click on the folder were the job was save. Then open the file name click on replay. It will replay the whole job done click on end. To end the replay process, click on file then export to CSV file. You can now view the job in excels format then copy to your laptop. Table 4 shows the tide data.

Table 4: Shows Tide measurement collected for day 1 and day 2

TIME	TIDE
11.45	0.729
12.00	0.713
12.15	0.661
12.30	0.614
12.45	0.585
13.00	0.59
13.15	0.63
13.30	0.692
13.45	0.762
14.00	0.84
14.15	0.902
14.30	0.96
14.45	1.008
15.0	1.044
15.15	1.079
15.30	1.111
15.45	1.143
16.00	1.16
16.15	1.205
16.30	1.222

TIME	TIDE
11.15	1.131
11.30	1.09
11.45	1.048
12.00	1.002
12.15	0.95
12.30	0.9
12.45	0.854
13.00	0.801
13.15	0.764
13.30	0.742
13.45	0.75
14.00	0.78
14.15	0.827
14.30	0.87
14.45	0.912
15.00	0.959
15.15	1.00
15.30	1.042
15.45	1.075
16.00	1.102

Table 5: Shows sounding data collected within the study area.

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RAW BATHY DATA_WELL 18			
TIME	EASTING	NORTHING	DEPTH
2:04:14 PM	462501.89	71324.21	1.49
2:04:17 PM	462500.27	71326.3	1.4
2:04:20 PM	462498.45	71327.56	1.02
2:04:23 PM	462496.25	71327.71	0.76
2:04:26 PM	462493.69	71326.22	0.65
2:04:28 PM	462491.71	71324.74	1.56
2:04:30 PM	462489.3	71323.18	1.48
2:04:32 PM	462486.47	71322.16	1.17
2:04:34 PM	462483.57	71321.57	1.32
2:04:36 PM	462480.86	71321.11	0.99
2:04:38 PM	462478.27	71320.94	0.89
2:04:40 PM	462475.87	71320.95	0.86
2:04:42 PM	462473.63	71320.89	0.83
2:04:44 PM	462471.47	71320.7	0.81
2:04:46 PM	462469.39	71320.56	1.3
2:04:48 PM	462467.38	71320.47	0.99
2:04:50 PM	462465.29	71320.21	1.05
2:04:52 PM	462463.2	71319.86	1.52
2:04:54 PM	462461.06	71319.49	0.94
2:04:56 PM	462458.87	71319.2	1.04
2:04:58 PM	462456.61	71318.93	1.14
2:05:00 PM	462454.36	71318.76	1.19
2:05:02 PM	462452.17	71318.82	1.26
2:05:04 PM	462450.08	71319.08	1.28
2:05:06 PM	462448	71319.38	1.32
2:05:08 PM	462445.84	71319.62	1.39
2:05:10 PM	462443.66	71319.83	1.39
2:05:12 PM	462441.47	71320	1.38
2:05:14 PM	462439.3	71320.17	1.41
2:05:16 PM	462437.08	71320.33	1.45
2:05:18 PM	462434.87	71320.44	1.45
2:05:20 PM	462432.64	71320.51	1.46
2:05:22 PM	462430.41	71320.54	1.49
2:05:24 PM	462428.18	71320.56	1.49
2:05:26 PM	462425.93	71320.52	1.49

RAW BATHY DATA_WELL 18			
2:05:28 PM	462423.71	71320.44	1.48
2:05:30 PM	462421.55	71320.34	1.49
2:05:32 PM	462419.45	71320.23	1.45
2:05:34 PM	462417.39	71320.1	1.41
2:05:36 PM	462415.39	71319.92	1.41
2:05:39 PM	462412.54	71319.55	1.4
2:05:42 PM	462409.81	71318.94	1.42
2:05:45 PM	462407.43	71317.97	1.38
2:05:48 PM	462405.47	71316.59	1.37
2:05:52 PM	462403.63	71314.41	1.38
2:05:56 PM	462402.59	71312.27	1.35
2:05:59 PM	462402.31	71309.77	1.36
2:06:02 PM	462403.28	71307.05	1.41
2:06:04 PM	462404.6	71305.55	1.43
2:06:06 PM	462406.32	71304.51	1.59
2:06:08 PM	462408.29	71304.08	1.46

Bathymetric data, which represents the depth of the seafloor, is collected using techniques like multibeam echo sounders (MBES), single beam echo sounders (SBES), and LiDAR bathymetry. Given the complexities involved in marine environments and instrumentation, errors in bathymetric data are inevitable.

ERROR CALCULATION (QUANTIFICATION)

Uncertainty Modeling

Bathymetric processing systems (e.g., CARIS HIPS and SIPS,) often use Total Propagated Uncertainty (TPU) models.
TPU combines:
Horizontal and vertical positioning uncertainty from GNSS/INS.
Heave, pitch, roll, yaw errors.
Sound speed profile uncertainty.
Tidal model uncertainty.
The total uncertainty for each sounding is calculated as:

TPU vertical = $\sqrt{(Depth\ Error)^2 + (Heave\ Error)^2} + (Sound\ Speed\ Error)^2 + Tideh\ Error)^2$

TPU horizontal =$\sqrt{(CNSS\ Error)^2 + (Altitude\ Error)^2}$

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Statistical Filtering
Outliers can be detected using statistical methods like standard deviation thresholds, median filters, or more complex methods like CUBE (Combined Uncertainty and Bathymetric Estimator).
CUBE incorporates both the measured depth and the uncertainty to estimate the "true" depth via a maximum likelihood approach.

ERROR CORRECTION TECHNIQUES

Sound Speed Corrections

Using CTD (Conductivity, Temperature, Depth) casts to measure sound speed profile.
Real-time SVP (sound velocity profiler) data is integrated into the system or corrected during post-processing.

Tidal Corrections

Apply tidal models or real-time tide gauge data.
Vertical datums are used (e.g., MLLW, LAT) and referenced through models like VDatum (NOAA).

Positioning and Attitude Corrections

GNSS post-processing using differential or real-time kinematic (RTK) methods.
Inertial Navigation Systems (INS) for improved motion compensation.
Heave filtering (e.g., delayed heave models to correct phase lag).

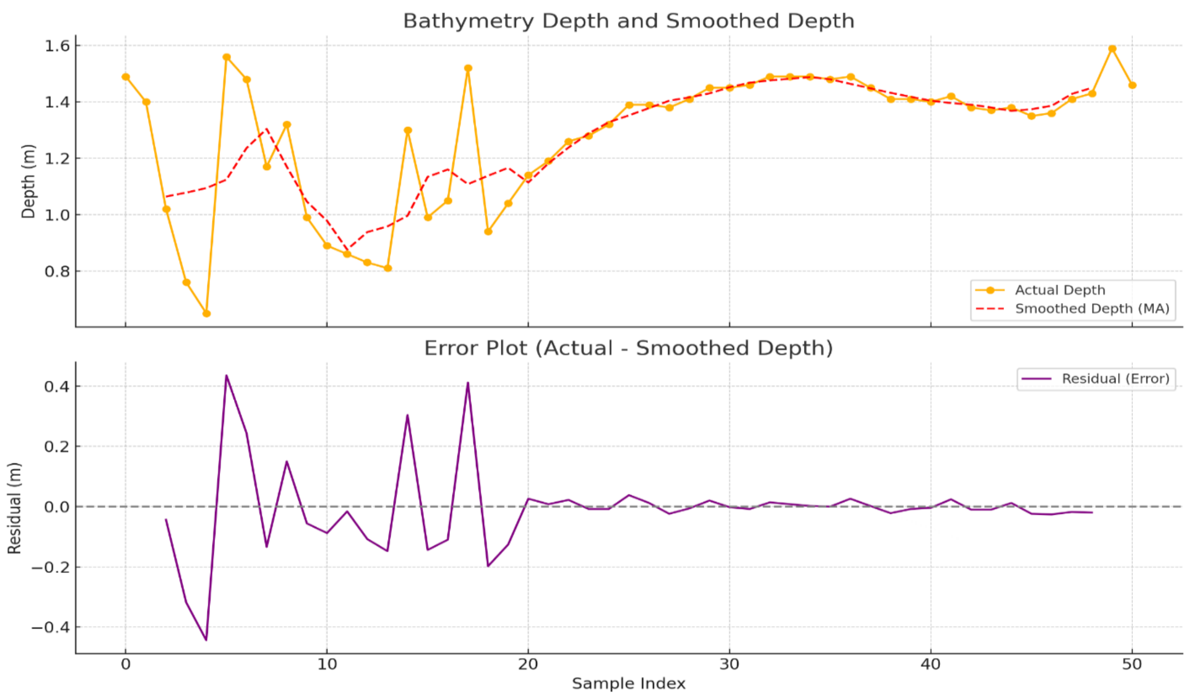

Figure 4: The error plot of the depth

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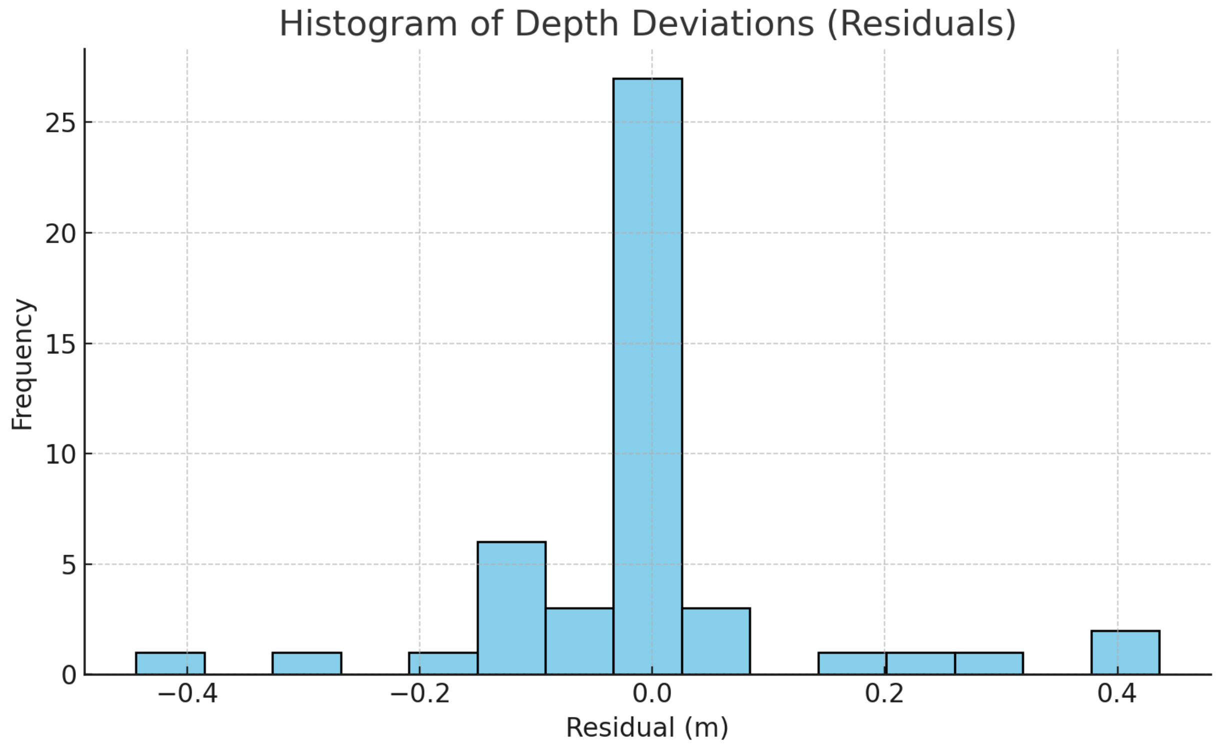

Figure5 : Histogram depth deviation

3.0 RESULTS AND DISCUSSIONS

The data collected was processed using Microsoft Excel software for the analysis.

Tidal Chart Analysis

Tidal values were collected for two days using Tide gauge. Figure 4 shows the tidal chart collected on the first day of the data collection from 11:45 am. to 4:30 pm. with an interval of 15minutes. In which tide ranges from 0.585m as at 12:45 pm (Lowest tide) to 1.222m as at 4:30 pm (highest tide) for day one.

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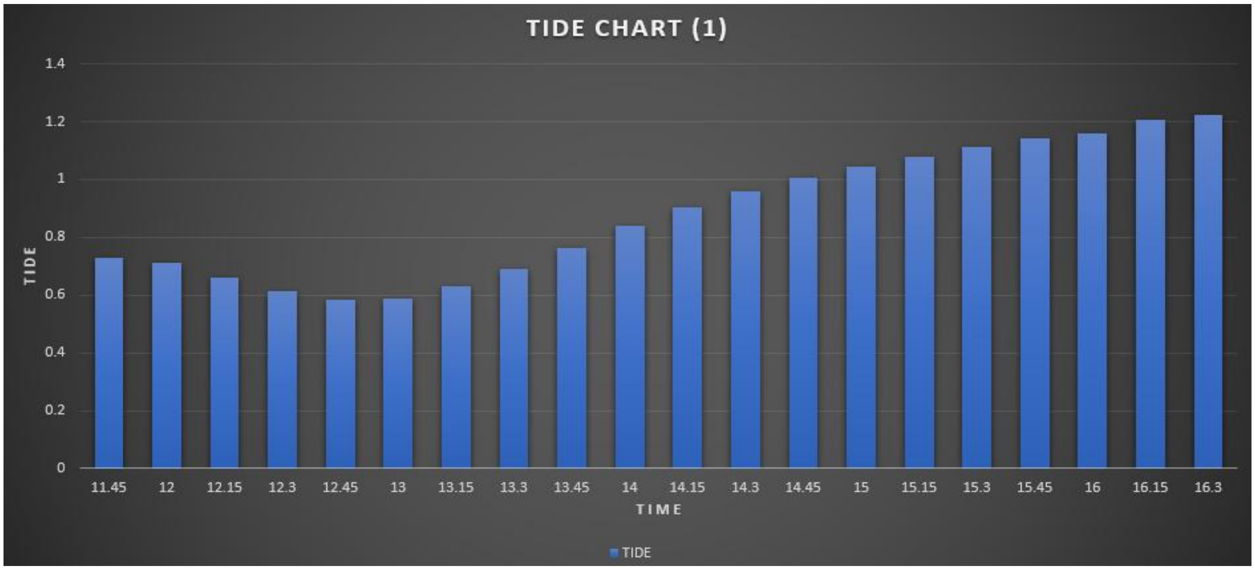

Figure 6: Tidal Chart of Soku well, Day 1.

Figure 7 shows the tidal chart collected on the second day of the analysis from 11:15 am to 4:00 pm with an interval of 15minutes. In which tide ranges from 0.742m as at 01:30 pm (Lowest tide) to 1.131m as at 11:15 pm (highest tide) for day two

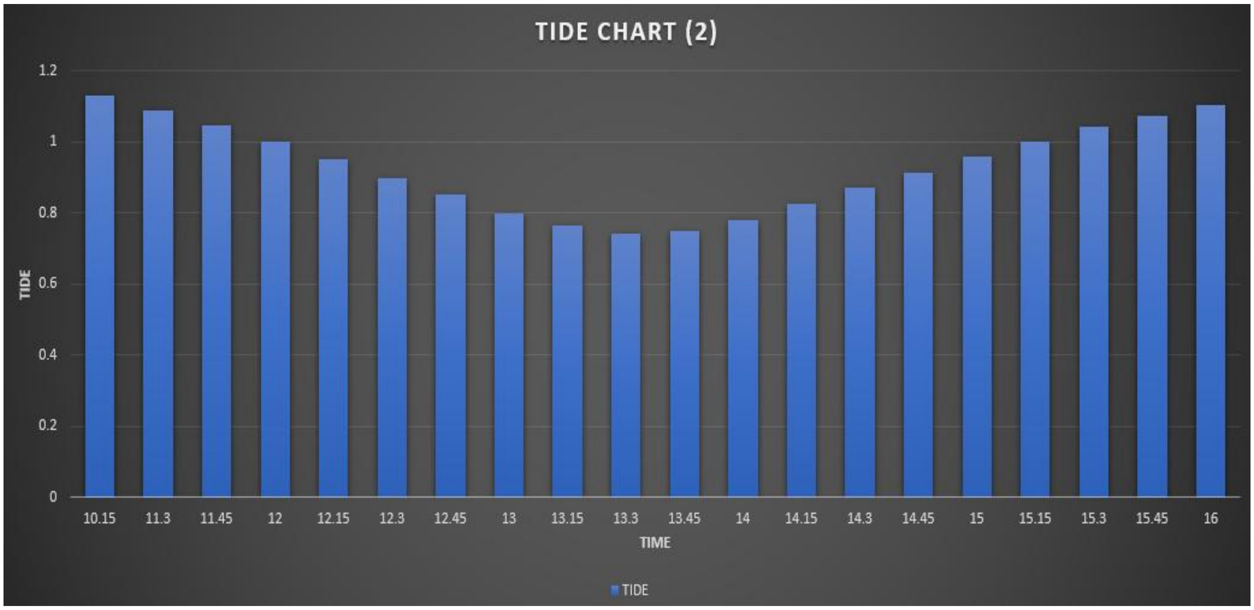

Figure 7: Tidal Chart of Soku well Day 2.

"Implement effective data collection methodologies and correction techniques to account for tidal and current variations, ensuring the quality of bathymetric information"

Implementing effective data collection methodologies and correction techniques to account for tidal and current variations is essential for ensuring the quality and accuracy of bathymetric

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information, especially in marine and coastal environments where tides and currents play significant roles.

Bathymetric Analysis

Extraction of Sea depth using Google Earth Pro. The google Earth Pro application was launched, and the study area was located, "add path" option was selected and points were picked along the extent of the study area and then exported as kmz.
Then searched gps visualizer online to convert the kmz file from google earth into elevation data and be exported as text file.
The text file was now launched into the Arc GIS Software, exported as X, Y, Z data and saved as a shapefile.
Arctool box was used to carry out the TIN (Triangulation Irregular Network) analysis and the result were displayed

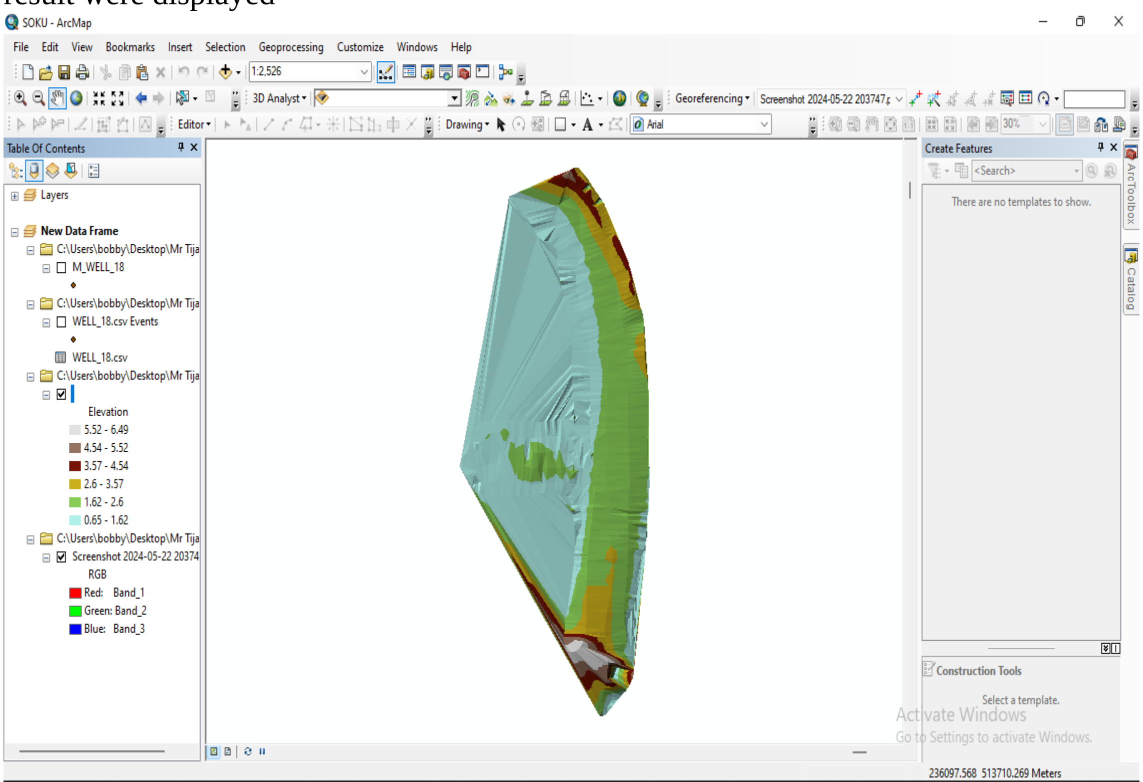

Figure 8: Shows ArcMap user interface of the TIN

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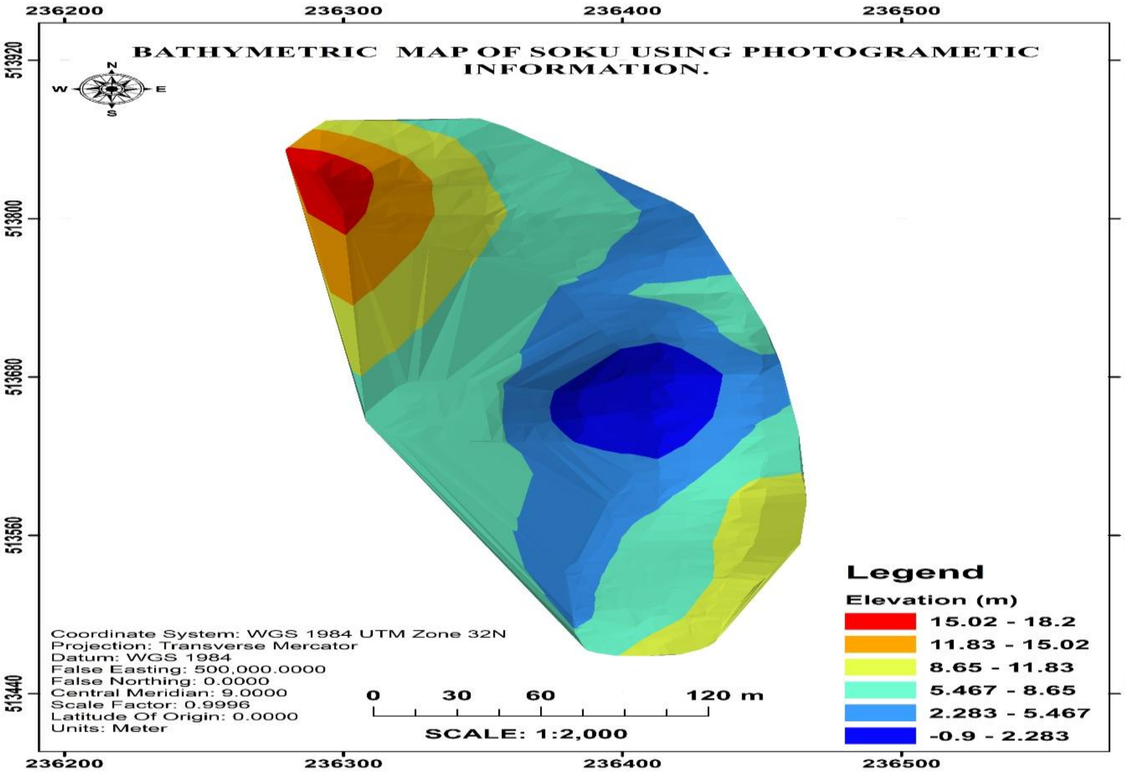

Figure 9a: Bathymetric Map of Soku using Photogrammetric Information

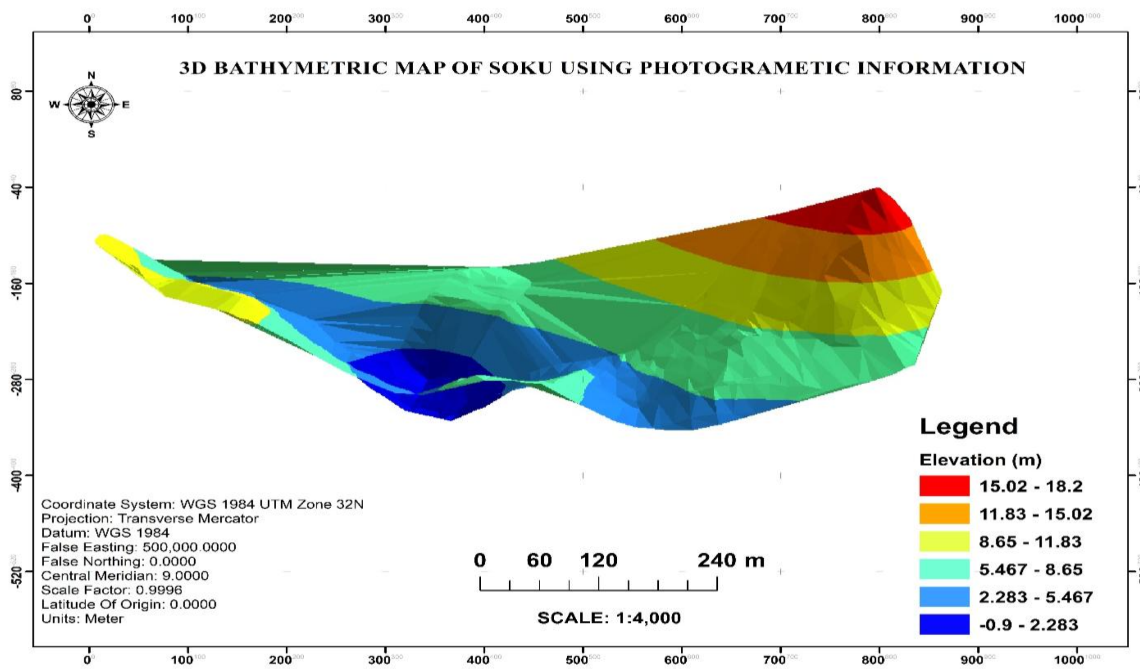

Figure 9b: 3D Bathymetric Map of Soku using Photogrammetric Information.

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Plate 7a and 7b show the Map of study area (soku, well 18) using Multibeam Echo sounder to determine the depth of the study area. In which the depth varies from 0.65m (lowest) to 5.52m (highest). This was analyzed and displayed both in Aerial View and in 3D view.

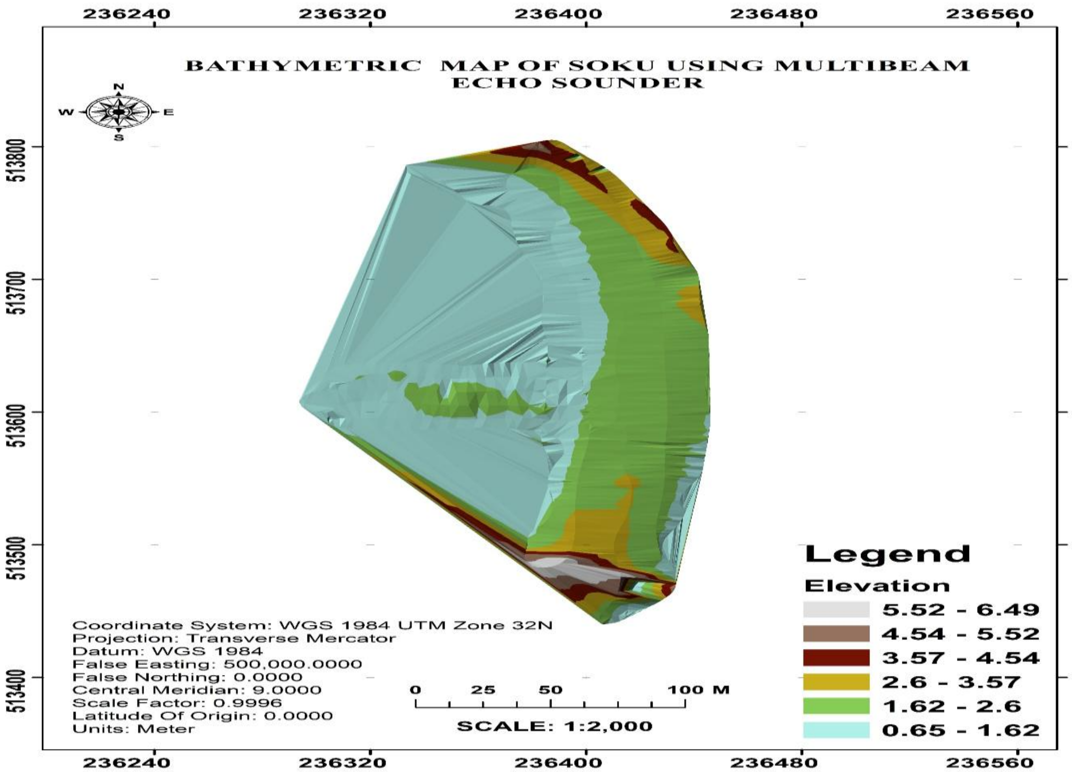

Figure 10a: Aerial view of Bathymetric Map of Soku using Multi-Beam Echo sounder

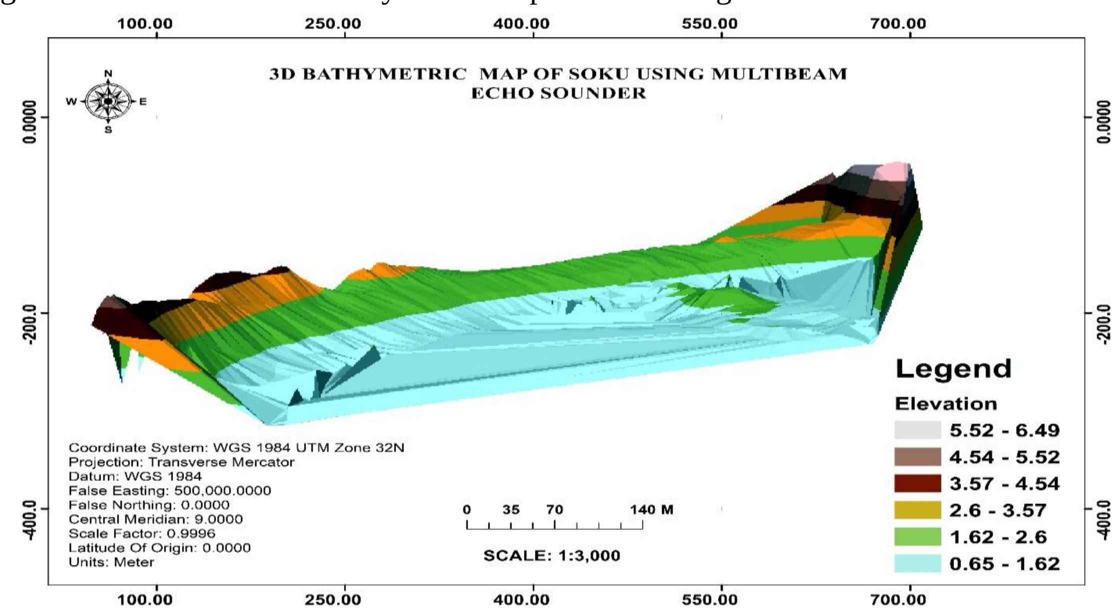

Figure 10b: 3D Figure 8Bathymetric Map of Soku using Multi-Beam Echo sounder

"To Investigate the implications of tides and currents on coastal morphodynamics, sediment transport, and environmental changes through the integration of bathymetric data"

Coastal Morpho dynamics

Tides and currents play a significant role in shaping coastal landforms and morphological features over time. By integrating bathymetric data, which provides information about underwater topography, researchers can analyze how tidal and current patterns contribute to erosion, deposition, shoreline evolution, and coastal geomorphology.

Investigating coastal morphodynamics helps identify vulnerable areas prone to erosion or accretion, assess coastal resilience to sea-level rise and storm events, and inform coastal management strategies aimed at mitigating erosion and protecting valuable coastal assets.

Sediment Transport

Tidal currents and wave action drive the movement of sediment along coastlines, influencing sediment transport pathways, sediment budgets, and sediment deposition patterns.

By integrating bathymetric data with information on tidal currents, researchers can quantify sediment fluxes, study sediment transport dynamics, and predict sedimentation patterns in coastal environments.

Bathymetric Data Integration

Combining bathymetric data with tidal and current measurements, it is possible to map the seafloor topography and track changes, model sediment transport and deposition patterns, simulate coastal morphodynamic responses to tidal and current forcing.

What Is Unique About Soku Creek?

Soku Creek has unique characteristics that influence bathymetric data: Soku Creek exhibits a distinctive hydrodynamic regime characterized by strong tidal asymmetry, pronounced ebb dominance, and significant current shear, especially during spring tide conditions. Unlike open coastal or uniformly tapering estuaries, Soku Creek features narrow, sinuous channels with complex meandering and variable channel widths, which enhance turbulence and cause localized velocity gradients. These morphological and hydrodynamic features amplify vertical and horizontal depth deviations, making standard tidal corrections insufficient unless augmented with real-time or model-derived current data. This makes Soku Creek a particularly valuable case study for testing integrated tide-current correction methods in bathymetric surveying.

The Deviations is Within Global Standards (IHO S-44)?

The International Hydrographic Organization (IHO) S-44 standards define maximum allowable Total Vertical Uncertainty (TVU) based on survey order. For **Order 1 surveys**, the allowable TVU is:

TVU = $\sqrt{a^2 + (b\,.\,d)^2}$

Where:

a=0.5 m

b=0.013

d=depth in meters

So at 5 m depth:

TVU= $\sqrt{(0.5)^2 + (0.013.5)^2}$ $= \sqrt{0.25 + 0.004225}$

$$\cong 0.50m$$

The corrected depth deviations observed in Soku Creek, with a standard deviation of 0.09 m and maximum residuals within ±0.12 m, fall well within the IHO S-44 Order 1 requirements across the surveyed depth range (2–7 m). The uncorrected dataset, however, frequently exceeded the allowable TVU, particularly during peak tidal flows, highlighting the necessity of dynamic corrections in such environments. The results confirm the efficacy of the applied method and establish the corrected dataset as compliant with international hydrographic standards.

Conclusion

The findings emphasize that the impacts of tides and currents on bathymetric surveys are multifaceted, requiring a combination of advanced technology, robust modeling, and localized calibration for effective mitigation. Addressing these challenges would significantly enhance the quality of bathymetric data, supporting more informed decision-making in navigation, coastal engineering, and ecosystem management within the dynamic environment of Soku Creek. It is recommended that: high-resolution tidal models and nearby tide gauges be applying subsequently for accurate tidal corrections to bathymetric data. This ensures that measurements are standardized to a common datum, reducing vertical errors.

Predictive tidal models that account for local tidal harmonics can be employ to provide real-time corrections during data collection.

Real-Time Kinematic (RTK) GPS and Inertial Navigation Systems (INS) can be integrated to correct for positional deviations caused by currents. These technologies provide high-precision positioning data and compensate for vessel movement.

Deployment of AUVs and ROVs equipped with bathymetric sensors can aid in maintaining stability and follow precise paths by reducing the impact of surface conditions on data quality.

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