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Engineering Pelagic Conditionality Advantage of Ibaka/Effiat Mbo Littoral Zone for Deep Seaport

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ABSTRACT : *Identifying a suitable location for a deep seaport requires a comprehensive study of the surrounding pelagic conditions to ensure its sustainability and economic viability. The Ibaka/Effiat Mbo Littoral Zone in Nigeria has been identified as a potential site for a deep seaport, but a thorough investigation of the pelagic conditionality advantage of this location is required to determine its feasibility. This study aims to explore the engineering pelagic conditionality advantage of the Ibaka/Effiat Mbo bay Littoral Zone. The research will focus on analyzing its navigation channel, including water depth and tidal variations for deep seaport citing considering the flows at full tide and ebb tidal waves fluctuations, of which occurrences usually take place diurnal (daily cycles). Field studies were conducted using sonars and other equipment to measure water depths at regular intervals - 5m chainage and also important noticeable watermarks. For full tide, the initial chainage point (first point) which is the upstream, the values from the first to third chainages were zeros and then each subsequent point has its values (water depth) with respect to that location, exception of the last chainage point (Downstream) which at the first and third chainages have values of zeros while the second chainage has a depth of 3.97m. Similarly, for low tide, the initial chainage (Upstream) has zeros values from the first to third chainages with each subsequent chainage also with values of zeros exception of the last chainage point (Downstream) which at second chainage has a depth of 0.15m. The aspect ratio of the channel is about 5.83 and a bifurcation factor of about 0.13 enabling it to have excellent maneuverability which gives it assurance of openness with no difficulty to access berthing quay for large vessels. The zero reading up to five (5) chainages shows the essential nature of dry or gently moist shore towards the sea without water and suddenly a little further distance enters into deep water. Results validate the accessible of the beach area and its penetrability from the coast. Indeed, Ibaka/Effiat Mbo bay is a natural habour.*
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KEYWORDS: *Seaport, Water Depth, Habour, Berthing, Gulf of Guinea*

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I. INTRODUCTION

Nigeria is one of the largest economies in Africa, with a population of over 200 million people. However, the country's maritime sector is yet to achieve its full potential due to a lack of commitment in deep seaport development and decentralization. Deep seaports are essential for the efficient movement of large ships that transport goods and raw materials transnationally, thereby boosting economic growth and prosperity. Today, over 80% of all trade is seaborne (Stopford, 2009; UNCTAD, 2015). World merchandise trade volumes have grown at a modest rate of 2.3% in 2014 following the global gross domestic product (GDP) growth rate of 2.5%, indicating a strong correlation between trade and GDP (UNCTAD, 2015). The history of urban development also reveals that economic advancement is especially apparent in cities with seaports (Shan et al.,2014). Statistics show that over 60 percent of all imports to West Africa are Nigeria-bound which is an indicator of a remarkable market opportunity for businesses in marine operation (Paul, E.U. 2014).

The Ibaka/Effiat Mbo Littoral Zone located in the Gulf of Guinea has an average area of 50 km^2 and centers on Latitude 4.65^o N and Longitude 8.34^o E has been identified for citing a deep seaport. The harbor has an average non- dredged draft of 13.5 meters and is part of Cross River Estuary that empties into the northern Gulf of Guinea, which is a part of the Atlantic Ocean. Preliminary investigations showed that the proposed deep seaport has several competitive and comparable advantages over existing seaports in the country. This deep harbor has been locally observed and monitored for over six decades and the sediment deposits seemed to have reached equilibrium state in the Bay (AKSG Official Site 2014). However, the engineering pelagic conditionality advantage of this area has not been adequately studied. The concept of pelagic conditionality advantage refers to the properties of the water bodies and their propensity to support the development of marine infrastructure and systems that can operate effectively in a range of conditions, from calm seas to stormy weather and rough seas. This requires a deep understanding of the physical and metocean properties of the bay.

The retinue of phenomenal features such as deep water access (18m in the channel), 5,129 radars for port development, proximity to major shipping routes, short distance to destination markets, a large gateway market size to attract direct vessel service and sizeable trans-shipment cargo for feeder shipping network connection as well as a combined deep seaport and free trade zone development in Akwa Ibom State make the Ibom/Effiat Mbo Deep Sea Port (IEDSP) unique and strategic to the maritime economy and international trade portfolio of the country and serve as the Eastern Gateway of Nigeria and will provide vital port capacity for the country, (Li et al, 2000).

Several studies have been conducted on the engineering pelagic conditionality advantage of different areas for the construction of marine infrastructure. For instance, a studies conducted by, Luo et al. (2021), Li et al. (2020), Cui et al. (2020), Wang et al. (2019) all attest to fact that study of this nature is imperative and results showed that the pelagic conditionality of the water column was a key factor in determining the suitability of a location and construction of any marine infrastructure and requires consideration of various factors, including the physical environment, such as ocean currents, waves, and water depth.

This work aimed at investigating the engineering pelagic conditionality advantage of the Ibaka/Effiat Mbo bay littoral zone and the viability of deepening the approach channel to the bay as part of a larger study on stability of morphodynamics in Ibaka/Effiat bay. Field studies were conducted, by establishing eleven (11) points within the estuary, to collect current and wave data as well as information on the dominant sediment characteristics in the bay. Sampled data were analyzed and used to calibrate and verify a coupled wave, circulation, and sediment numerical model which will be a boost to existing literature.

II. MATERIALS AND METHODS

A. SITE TOPOGRAPHY

Ibaka/Effiat Mbo bay located at the Gulf of Guinea as shown in Plate 1.0, has the northern Gulf of Guinea seafloor drops off rapidly, reaching a natural depth of more than 15 meters in less than 2 km from the mouth of the Bay.

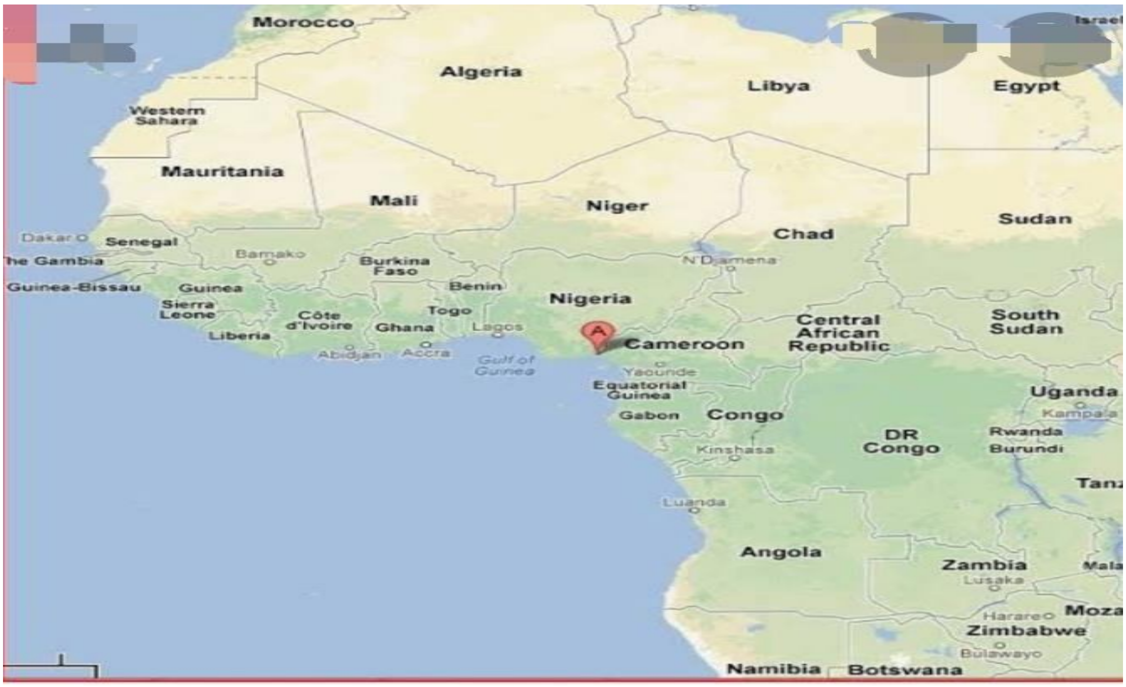


Plate. 1.0. A section of a physical map of Africa showing Ibaka bay

Large vessels, such as C9 containership, can navigate freely in open waters until they are within 2 km to the harbor. Using an average vessel speed of 2.5 m/s, piloting and other major navigation guides will be required in the dredged channel for about 15 minute travel time into and out of the harbor. Other major ports in Nigeria can only be accessed through travelling in dredged navigation channels for some hours. Ibaka/Effiat Mbo community hosts one of the Nigerian Naval bases (Forward Operation Base, Ibaka). The Navy helps to secure Ibaka and its coastal waters against external invasion and sea pirates. It also collaborates with civilian researchers to conduct some Oceanographic and environmental engineering research in the Bay and surrounding waters in Cross River Estuary. (Paul, 2014). The project site also has an adjacent beach, The Ibaka/Effiat Beach as shown in Plate 2.0. The sediment on the beach is mostly coarse ($d50 \approx 0.32$ mm) sand. This shiny coarse sand gives the beach an aesthetic look. The beach is not yet developed for tourism and other recreational activities (AKSG Official Site, 2014).

Plate. 2.0. A Section of Mbo Map Showing Ibaka/Effiat Bay

B. MATERIALS

a. Sonar (Sound Navigation and Ranging)

Sonar is a technique that uses sound propagation (usually underwater) to navigate and measure distances (ranging) and for collecting oceanographic data. It works by emitting sound waves from a transducer, which travels through the water and bounces off objects in its path, such as the seafloor or fish. The reflected sound waves are then detected by the transducer and converted into an electrical signal, which can be analyzed to create an image or map of the ocean environment. In this context the Side scan sonar that emits a narrow beam of sound waves that sweeps back and forth across the seafloor was employ in depth data collection. The reflected sound waves create a two-dimensional image of the seafloor, with darker areas indicating harder, more reflective surfaces. After the sonar data were collected, it was processed to create usable images or maps. This involves cleaning the data to remove any noise or interference, and correcting for factors such as water depth and sound velocity. The processed data is then analyzed.

b. Acoustic Doppler and Current Meter: Acoustic Doppler flow monitoring equipment is one of the equipment deployed to measure the velocity of the water. It provided a better understanding of the dynamics of water flow in this research. It works by emitting high-frequency sound waves into the water, which is reflected off particles in the water. The equipment then measures the frequency shift of the reflected sound waves, which is directly proportional to the velocity of the water. Acoustic Doppler flow monitoring equipment help provide real-time data on the water velocity and direction, as well as information on the depth, turbulence and geomorphology of the water which help in validating data gathered from other equipment used. A current meter is an instrument used in monitoring the tidal currents in the bays and the velocity of water currents in bay. It basically consists of a propeller or impeller that is rotated by the water flow and connected to a device that records the rotation rate. The rotation rate is then used to calculate the velocity of the water.

c. Measuring Rope

Measuring rope makes an ideal drag chain that can be used for making rough surveying measurements. Measuring tape and rope are commonly used materials for data collection in various fields of research. For this research, measuring tape and rope were used for several purposes, including measuring water depth, determining the location of underwater structures, and mapping the seafloor topography. To measure water depth, a measuring tape or a rope marked at regular intervals can be lowered into the water until it reaches the seafloor. The length of the tape or rope that reaches the seafloor can be recorded and used to calculate the water depth at that location. This method is known as a sounding and can be used to create a bathymetric map of the seafloor. The seafloor topography was measured using the rope by towing a weight along the seafloor while measuring the length of the rope. This method is known as a transect (Karim et al., 2019) and can be used to create a detailed map of the seafloor topography, including the depth and shape of underwater canyons and ridges.

C. METHODS

Fig. 1.0 shows an illustrative diagram of the application of sonar in depth measurement as used in this work. Eleven points at various location within the estuary were investigated to determine an optimumnavigation channel for the port and berthing infrastructure. These points were established laterally in three rows after one point being established at both ends of the upstream and downstream. One standalone point at the upstream (U/S), Three points across laterally taken in turn to the extreme location (east - west) ends with one midpoint between the two, midpoint has three subsequent point located similar to the upstream and finally three points located downstream (D/S). The orientation of these locations are similar to the previous, while the last stand alone point was also established. This navigation channel was adjudged the optimum channel in terms of cost effectiveness, operational efficiency, and legal consideration (Okon and Ndekhedehe, 2019).

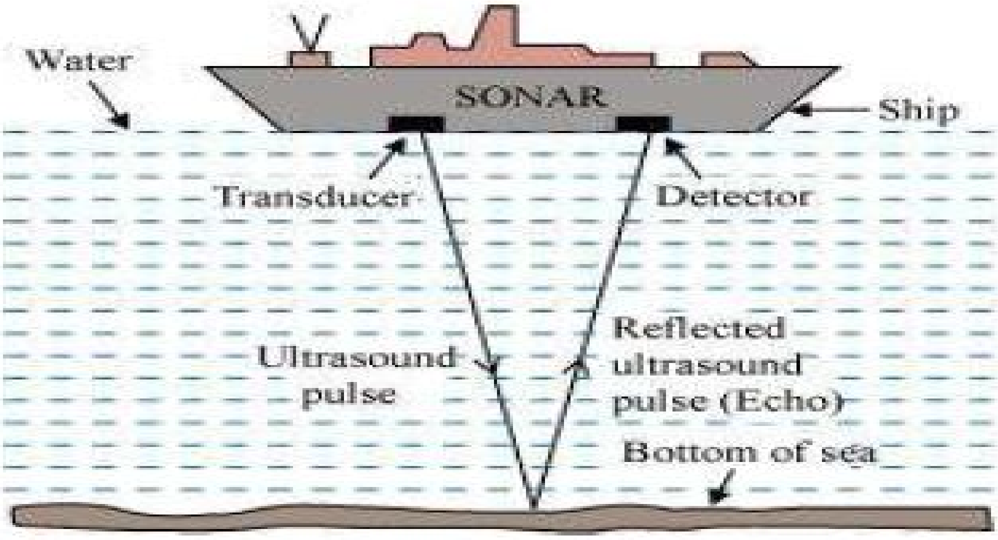


Fig.1.0: Data Collection Process Using Sonar

D. CONTOUR MAP

A contour line joins points of equal elevation (height) above a given level, such as Mean Sea Level (MSL). A contour map is a map illustrated with contour lines, for example a topographic map, which shows valleys and hills and the steepness or gentleness of slopes. A contour interval of a contour map is the difference in elevation between successive contour lines, and the gradient of the function is always perpendicular to the contour lines. This lines when they are close together the magnitude of the gradient is large; the variation is steep. A level set a generalization of a contour line for functions of any number of variables (Hughes- Hallet. et al. 2013). Fig. 2.0 is a contour map that shows the terrain of the environment.

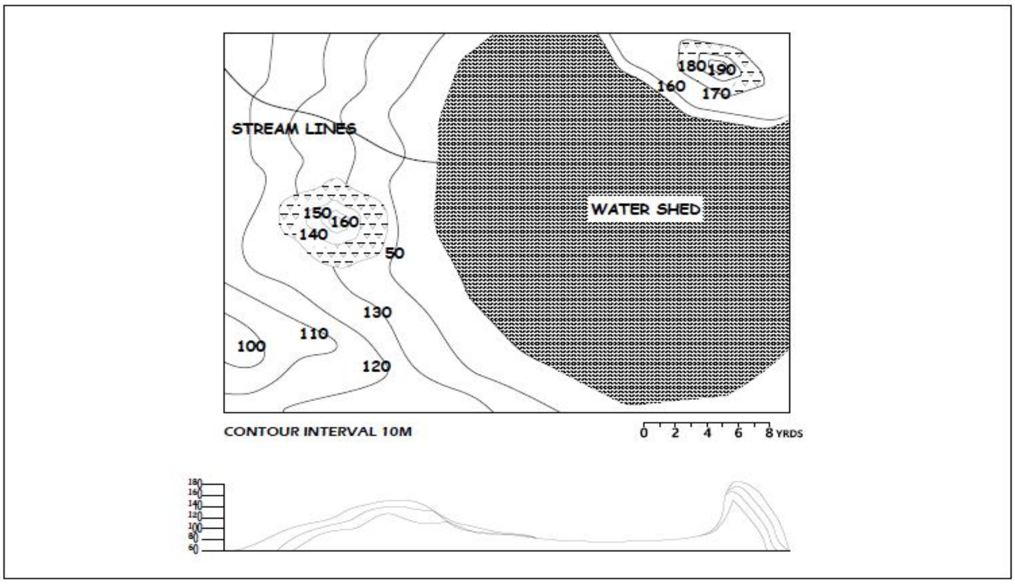


Fig. 2.0: Contour Map Showing the Terrain of the Area

D. CALCULATION OF WATERSHED

Contour interval = 10m

a. Area in Square Meters

Grid lines are drawn in watershed area, each $10.0m^2$

Full squares from half of watershed area = $1000.0m^2\ half$

Half squares of half watershed area, $\frac{205}{2} = 102.50m^2$

Total = 1102.5m^{2}.

Full area of watershed $1102.50 \times 2 = 2205m^2$

Total area of watershed $2205.0m^2$

b. Slope of the Elevation

X is the difference between two points picked in X-axis;

$X = 0, 10$

Y is the difference between two points picked in Y-axis;

$Y = 0, 20$

$\frac{y_2 - y_1}{X_1 - X_2} = \frac{20}{10} = 2$

c. The Length of the Stream Line

Offsetting 10.0m on the stream line, we found that the distance:
L = 51m

III. RESULTS AND DISCUSSION

This study revealed that seasonal changes and estuary's tidal prism played a significant role in sediment transport in the Bay. Only rainy season meteorological forces exceed the threshold bottom shear stresses based on the dominant sediment characteristics inthe Bay to initiate sediment transport in the Bay. A good knowledge on sediment geotechnical properties is important as they define the hydrodynamic velocity for which sedimentation occurs, whether it is cohesive sediments (mud) and of non-cohesive sediments (sand).

The available tidal prism isso dependent on the geometry of the basin in terms of surface area and mean water depth and also the tidal range, the frictional forces and, to a lesser extent, freshwater inflow. Therefore, the largerthe tidal prism related to the river flow, the more determinant for the sedimentation and erosion processes, in the estuary, is the tide and tide flow. Nevertheless, it therefore makes engineering sense to assume (based on historical site conditions) that the rate and distribution of sediment deposition during dry season will be minimal and will increase in rainy season which affect the water depth of the bay.

A. DATA COLLECTION/ANALYSIS

Different locations within the estuary about eleven (11) points were established and investigated to determine an optimum navigation channel for the port. Such investigations have been demonstrated to save cost and enhance safety in Barbers Point Harbor, Oahu, Hawaii (Briggs et al, 2003). The tables below show's a typical data sample (water-depth) with respect to points and location of data collection from the harbor.

Table 1.0 shows analyses of data (water depths) for High ebb tide from the starting point which is the upstream, intermediate point, midpoint, intermediate point and then downstream with respect to distance (at 5m interval) for the high ebb tide. This result show's an increase in the water depth relating to distance at subsequent points and also the variation in depth, ("Water depth, Table 1.0, Tangential depth" Table 2.0) depending on first, second or third points base on location of data collection (Table 3.0).

Table 1.0: Water Depth For High Water Ebb Tide

High Water Ebb Tide						
Point		**Upstream**	**Intermediate Point**	**Midpont**	**Intermediate Point**	**Downstream**
		(U/S)	**(I.P)**	**(M/P)**	**(I.P)**	**(D/S)**
Chainage (M)		0+00	0+05	0+10	0+15	0+20
		Depth (M)	**Depth (M)**	**Depth (M)**	**Depth (M)**	**Depth (M)**
No Of Points	**First**	0+00	0.42	1.55	2.81	
	SECOND		0.88	1.67	2.94	3.97
	THIRD		0.83	1.61	2.92	

Table 2.0: Tangential Length At Each Locations And Points For High Water Ebb Tide

High Water Ebb Tide [AT EACH 5m INTERVAL] First Point					
Points (M)	0.00	5	10	15	20
Tanngential Depth (M)	0.00	5.02	5.23	5.74	0.00

Second Point					
Chainage (M)	0.00	5	10	15	20
Tanngential Depth (M)	0.00	5.08	5.27	5.80	6.38
Third Point					
Distance (M)	0.00	5	10	15	20
Tanngential Depth (M)	0.00	5.07	5.25	5.79	0.00

Table 3.0: Water Depth For Low Water Ebb Tide

Low Water Ebb Tide						
Location		**Upstream**	**Intermediate Point**	**Midpont**	**Intermediate Point**	**Downstream**
		(U/S)	**(I.P)**	**(M.P)**	**(I.P)**	**(D/S)**
Distance (M)		0	5	10	15	20
		Depth (M)	**Depth (M)**	**Depth (M)**	**Depth (M)**	**Depth (M)**
No Of Points	**First**	0.00	0.00	0.00	0.00	
	Second		0.00	0.00	0.00	0.15
	Third		0.00	0.00	0.00	

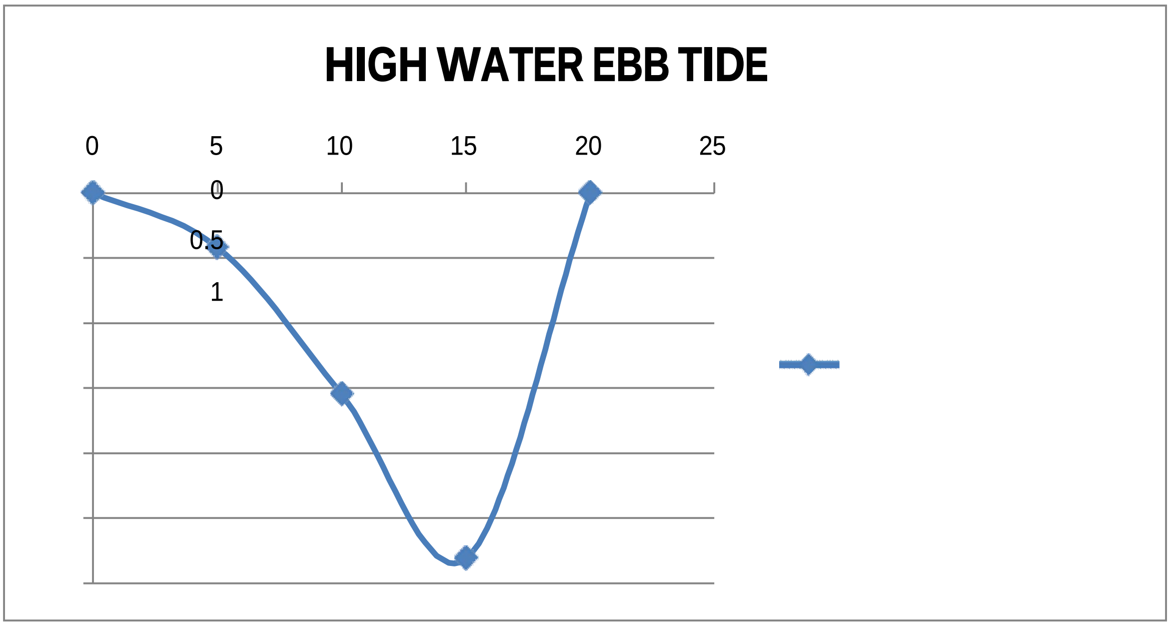
For low ebb tide, it was observed that from the upstream, intermediate point, midpoint and the next intermediate point, water depth was 0.00m and natural river bed from this points were sandy associated with little silt, while the last point (downstream) has a depth of 0.15m. The graphs presented below show's a relationship between water-depth and the Mean Sea Level (MSL) of the harbor considering it locations and points for both High water ebb tide (HWET) and Low water ebb tide (LWET).

Table 4.0: Increase in Water Depth with Respect to Locations and Points for High Water Ebb Tide

High Water Ebb Tide						
Point		**Upstream**	**Intermediate Point**	**Midpont**	**Intermediate Point**	**Downstream**
		(U/S)	**(I.P)**	**(M/P)**	**(I.P)**	**(D/S)**
Point (M)		0	5	10	15	20
		Depth (M)	**Depth (M)**	**Depth (M)**	**Depth (M)**	**Depth (M)**
No Of Points	**First**	0.00	0.42	1.55	2.81	0.00
	Second	0.00	0.88	1.67	2.94	3.97
	Third	0.00	0.83	1.61	2.92	0.00

FIRST LOCATION

Depth

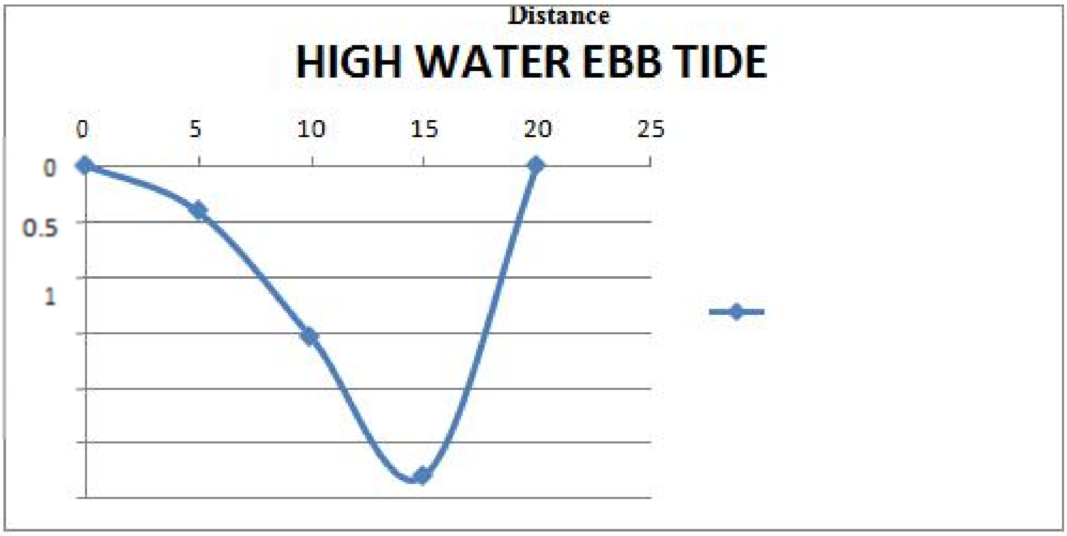


Distance

Fig. 3.0: Depth Variation at the First Location.

Second Location

Depth

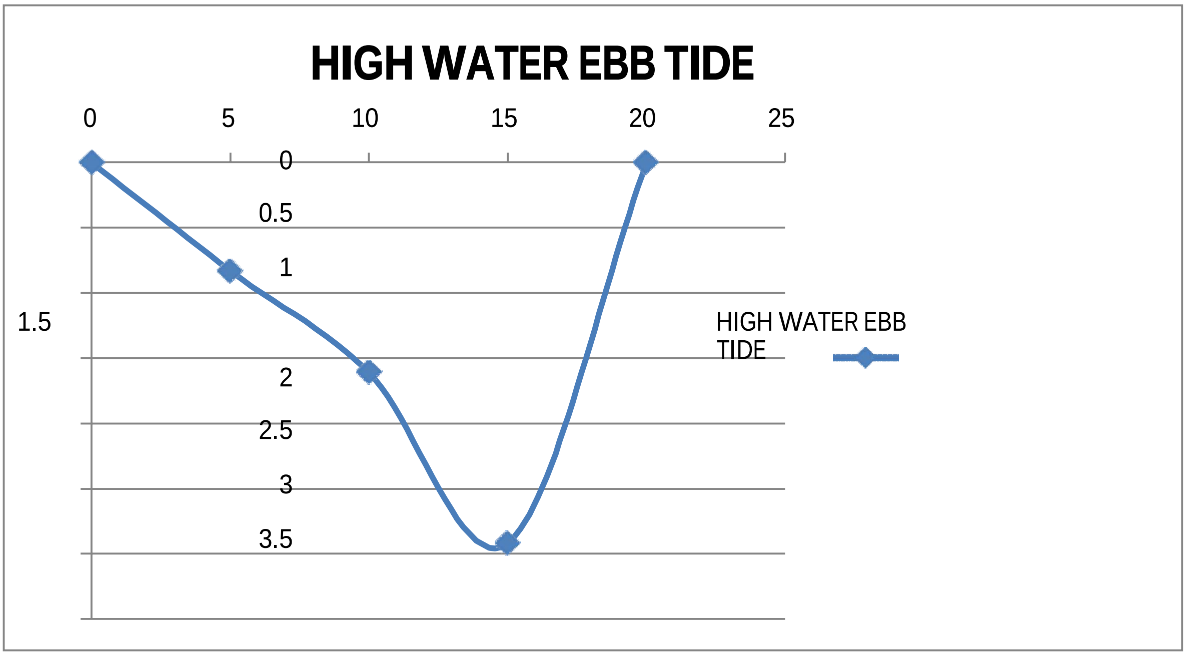


Distance

Fig. 4.0: Depth Variation at the Second Location.

Third Location

Depth



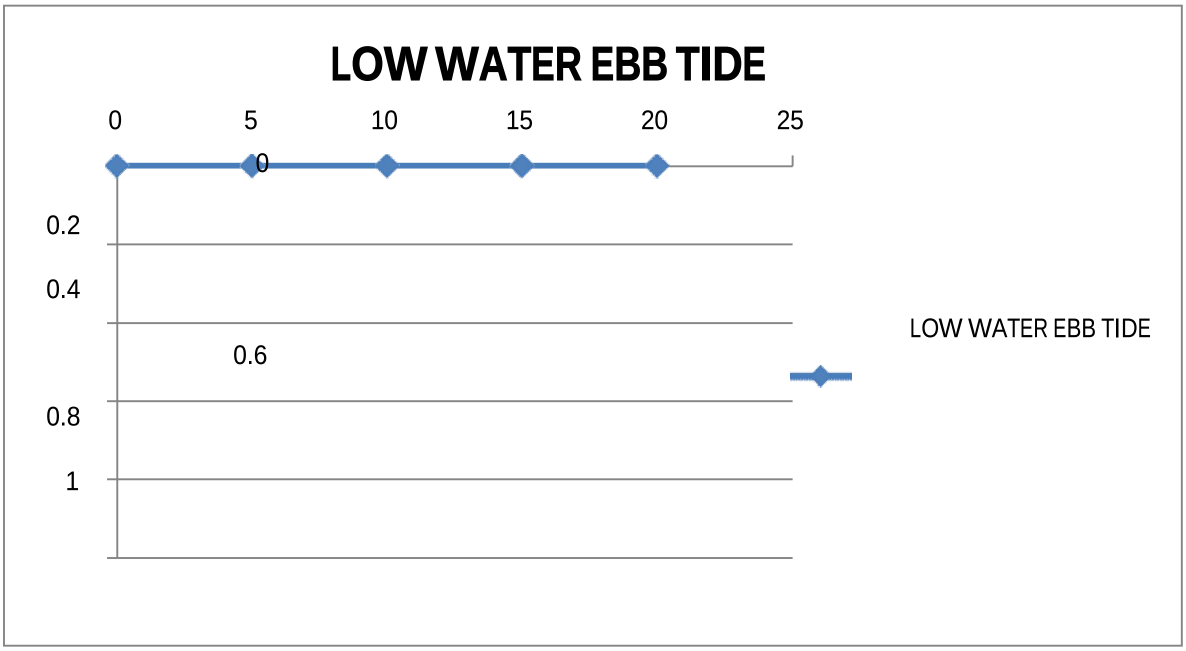
Distance

Fig. 5.0: Depth Variation at the Third Location

Table 5.0: Increase in Water Depth with Respect to Locations and Points for Low Water Ebb Tide.

Low Water Ebb Tide						
Point		**Upstream**	**Intermediate Point**	**Midpont**	**Intermediate Point**	**Downstream**
		(U/S)	**(I.P)**	**(M.P)**	**(I.P)**	**(D/S)**
Chainage (M)		0	5	10	15	20
		Depth (M)	**Depth (M)**	**Depth (M)**	**Depth (M)**	**Depth (M)**
No Of Points	**First**	0.00	0.00	0.00	0.00	0.00
	Second	0.00	0.00	0.00	0.00	0.15
	Third	0.00	0.00	0.00	0.00	0.00

First Location

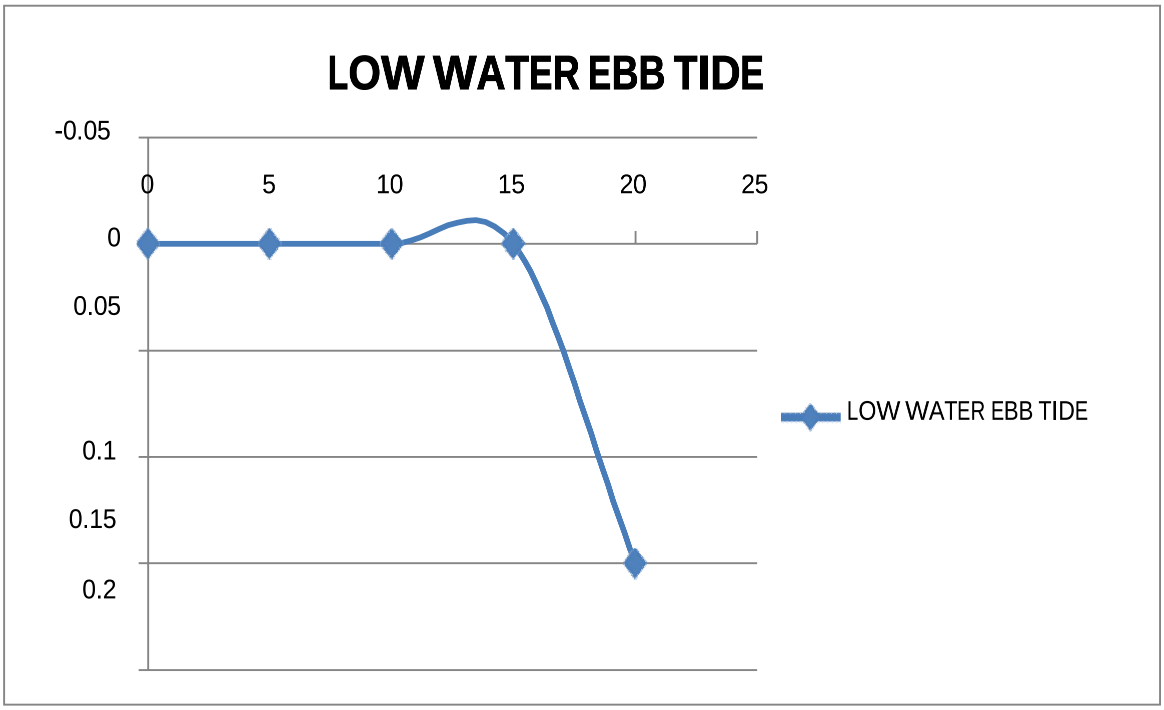


Depth

Distance

Fig. 6.0: Depth Variation at the First Location.

Second Location

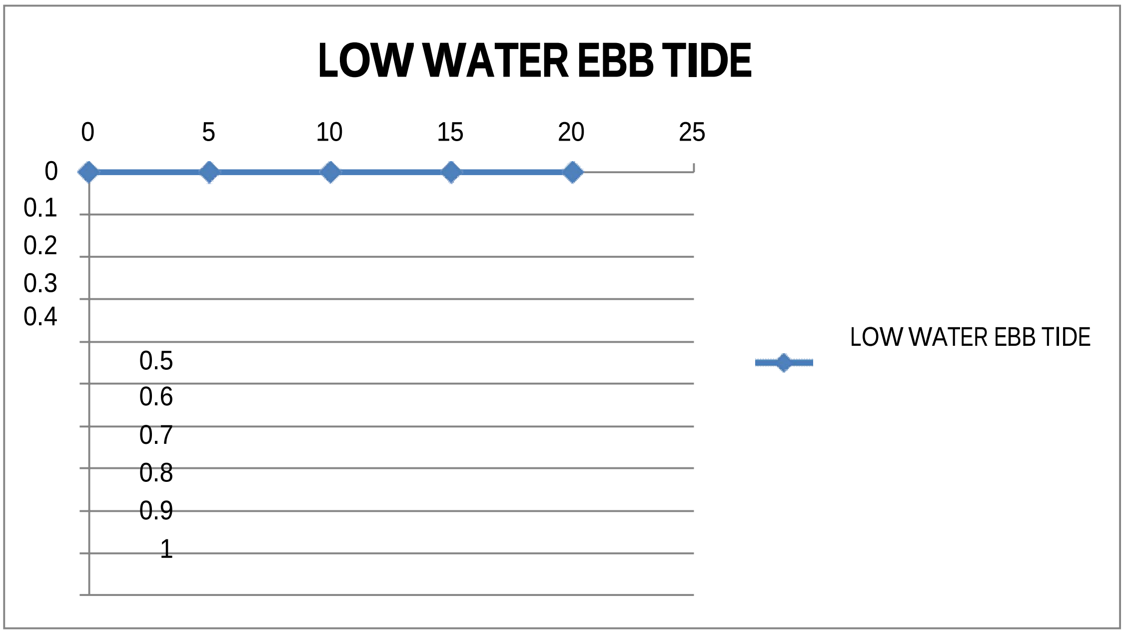


Depth

Distance

Fig. 7.0: Depth Variation at the Second Location.

Third Location



Depth

Distance

Fig. 8.0: Depth Variation at the Third Location.

B. DISCUSSION

The channel of activity for the proposed seaport pelagic conditionality has special features which from the result of geomorphological and hydrometric investigations conform. The aspect ratio of the channel is about 5.83 enabling it to have not only good but excellent maneuverability for vessels of large size and dimensions in terms of safety and insolvency in channel maintenance ability it has bifurcation factor of about 0.13 which makes it not too scary and gives assurance of openness with no difficulty to access the target point- berthing quay. Importantly, from the result of Acoustic Doppler flow monitoring and Current Meter assessment, the flow is most times at high tide, very calm and uniform with little ripples developing very manageable wave form that it does not pose danger even to smaller vessels and boats of laden therefore, it has good weather vining characteristics for vessel anchorage.

There are two significant critical tide conditions: the high tide and the low ebb tidal forms. The ebb tidal have very cautious moments exposing the sand dunes far into the seashore rendering very good picturesque and approachable smooth shoreline with no danger attached. The zero reading up to five (5) chainages shows the essential nature of dry or gently moist shore towards the sea without water and suddenly a little further distance enters into deep water. This makes the embarkation very easy and remarkable feature. Though flow in can be turbulent because of tidal forms building up the waves constructional infrastructure landing platforms can assuage the intensity of the raging waves. A deep study into the waveforms in the Gulf of Guinea is very essential.

IV. CONCLUSION

Ibaka/Effiat Bay is a natural harbor for a safe and reliable deep seaport. The site of this seaport has several advantages, such as direct access by nationals from neighboring six countries, blockage of offshore waves, favorable weather conditions, no breakwater and jetty requirements, few minutes of piloting services requirements to and from the harbor, presence of shiny coarsesand beach, and natural deep harbor depth. Seasonal influence on sediment processes in the Bay would facilitate efficient long-term simulations of morphological changes in the Bay. Detailed modeling of rainy season processes will yield reliable predictions of yearly seabed level changes in Ibaka/Effiat Bay. Navigation channel in the Bay will not amplify long wave energy reaching the shore. It will not alter the flushing characteristics and long-term sediment equilibrium of the Bay. The presence of the channel will not refocus incoming offshore waves to erode the adjacent beach; rather model results indicate that it will promote net sediment accretion in Ibaka/Effiat Beach.

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