IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 6, Issue 6 Ver. I (Nov. – Dec. 2018), PP 48-55
www.iosrjournals.org

Over-Water Geotechnical Sand Investigation along Kalaibiama Creek in the Niger Delta for Shoreline Reclamation

Ngerebara, Owajiokiche Dago[1*], Teme, Songo Clifford[1]
1 *Department of Geology, Rivers State University, Port Harcourt, Nigeria*
Corresponding Author: Ngerebara, Owajiokiche Dago

Abstract: *The search for solution to the menace of coastline erosion and submergence resulting from wave action and relative sea-level rise is seriously paving way for increasing sand search within the intertidal flats and offshore environments for beach nourishment. A very important aspect of this beach nourishment projects inevitably involves identification of potential offshore sand sources, the grain size pattern, its estimated volume and the mode of delivery of the sediment and its placement on the envisaged area to be reclaimed. To achieve this, an over water geotechnical sand search method was adopted, making use of a locally fabricated floating platform on which was mounted a Shell and-Auger Percussion Rig to survey the channel in and around the supposed dredging sites as to locate, map-out, and evaluate areas of near-shore sand deposit within the inter-tidal flat of Kalaibiama (near Opobo Town), that might be suitable as fill material for the foreshore reclamation. At the end of the investigation, two potential sand borrow pits were identified and available quantity of sand in them were estimated at 879,934.19 tons which guarantees the possibility of replenishment of this shoreline.*

Key Words: *Geotechnical, Sand Search, Beach Nourishment, Shell and-Auger Percussion Rig, Borrow Pit, Erosion*

Date of Submission: 26-11-2018 Date of acceptance: 10-12-2018

I. Introduction

Studies have shown that about 75% of the world's coastlines are presently eroding (USACE, 2000), thus making beach erosion a major problem along most of the world's sandy shores. However, this public perception of beach erosion problem is largely oriented to developed shores where the public resides or recreates. It appears not much has been noted about coastal land loss along many muddy coasts where mangroves and salt marshes are drowned by relative sea-level rise and slumping due to mining of the underlying sand. Erosion, submergence, shoreline retreat (resulting from lack of sedimentary input) and wave action have resulted in extensive areal land loss of many muddy coasts (Penland *et al.*, 1990, 2005; Stone *et al.*, 2003) .

Beach nourishment has to be employed if the beaches and muddy coastlines must be preserved. In doing this offshore sand resources are explored, using strategies that divulge contemporary marine sedimentary environments and the paleo-depositional settings on drowned coastal and deltaic plains (Finkl et al, 2003, 2005; Kulp *et al*., 2005). The search for offshore sand deposits along muddy shores employs similar procedures but there are complicating factors related to thickness of mud overburden and removal-storage of muddy cover sediments to access sandy layers at certain depth (Finkl and Khalil, 2005). Muddy littorals along deltas often require specialized geophysical and geotechnical search patterns due to the complexity of deltaic sedimentary environments that are impacted by variable sediment loadings in channels, avulsion, localized and regional subsidence, presence of ravine surfaces and positional instability of shorelines.

The artificial placement (nourishment or replenishment) of sand on any shore is one of several shore-protection techniques available to reduce erosion effects. Beach nourishment has global appeal as a common and effective measure to safeguard coastlines and hinterlands. According to National Research Council (1995), beach nourishment creates a "soft" (i.e., nonpermanent) structure by adding sand from an outside source to make a large sand reservoir, which pushes the shoreline seaward. For this reason, large volumes of sand fill may be required for projects that call for shore restoration and periodic re-nourishment. Thus, the availability of large volumes of sand from a nearby source area and the performance of the fill material on the nourished beach are key elements for a successful beach fill design (Meisburger, 1990). A crucial part of beach nourishment projects inevitably involves identification of potential offshore sand sources, the grain size pattern, its estimated volume and the mode of delivery of the sediment and its placement on the envisaged area to be reclaimed (Rowland, 1993). Hence, geological investigation of the substrata and bathymetric survey of the channel in and around the dredging sites is a very important first step procedure required for the success of any sand dredging project. Therefore, the purpose of this investigation was to locate, map-out, and evaluate areas of near-shore sand deposit within the inter-tidal flat of Kalaibiama, near Opobo Town, that might be suitable as fill material for the Kalaibiama foreshore reclamation (Figure 1).

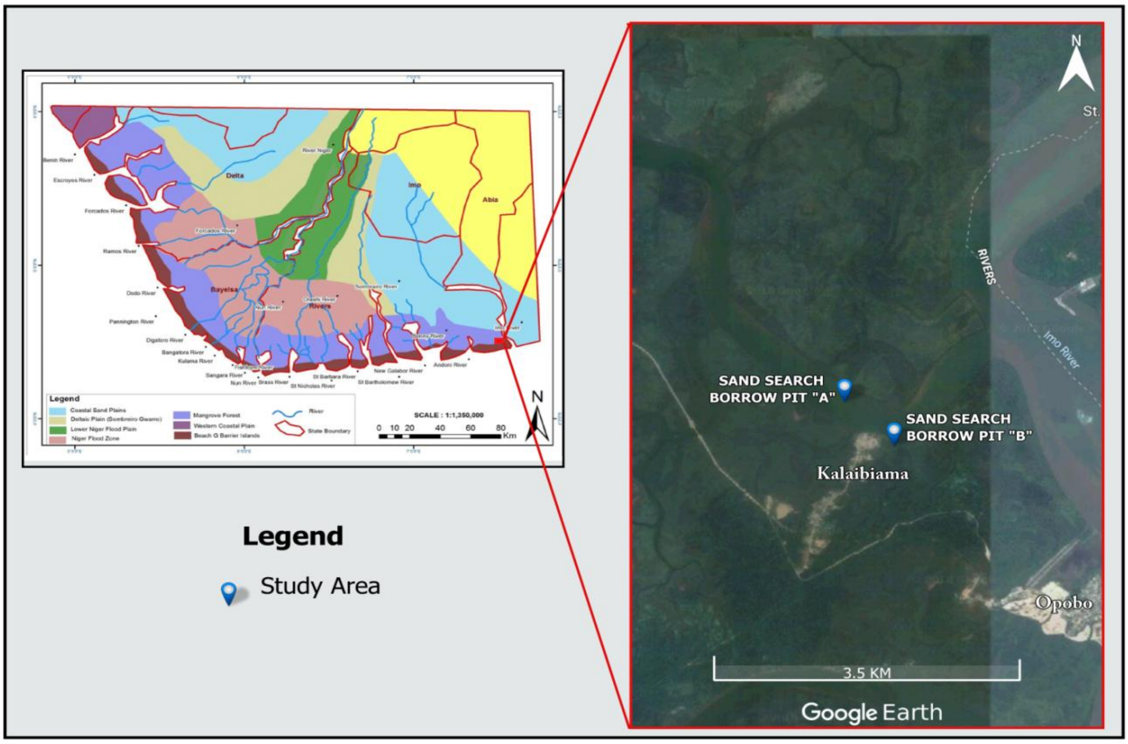


Figure 1: Niger Delta Showing the Study Area at Kalaibiama

Site Description and Regional Geology

The study area, Kalaibiama creek, near Opobo Town in Rivers State is located close to Imo River estuary within the Niger Delta region. The development of the delta has relied mainly on the balance between the rate of sedimentation and the rate of subsidence thus, giving rise to a succession of transgressions and regressions of the sea. This in-turn has resulted to the three main subsurface lithostratigraphic units found in the region. According to Short and Stauble (1967), the first depositional cycle of the three which took place in the Niger Delta began with a marine transgression in the mid-Cretaceous and ended by a minor folding phase shortly after it resulted in the Akata shale Formation. The depositional environment was mainly a deep sea and low energy environment giving rise to fine-grained sediments with thickness up to 1,000m. The group is made up of marine clay, shale and limestone. The second episode occurred when the sea transgressed and marine shales were deposited, whereas coarse heterogeneous sediments were formed in the coastal and deltaic environments during the period of sea regression. These events produced the intervening units of alternating sandstone and shale of the Agbada with thickness as much as 1,700m. This cycle of deposition covered the period from late cretaceous to early Tertiary (Paleocene).

The third cycle from Eocene to recent marked the continuous growth of the main Niger Delta. The Benin Formation was deposited during this third phase after the final advance of the Tertiary delta. Its sandy sediments mark the high energy environmental deposits of river and tidal channel activities. The occasional clay intercalations were deposited in the low energy environment on the flood plain between the rivers and the tidal channels. This Formation has a total thickness estimated to be more than 2,000m.

Quarternary deposits of about 100m in thickness comprising recent deltaic sediments made up of sand, silt and clay beds overlies the Benin Formation in the swampy delta areas.

Hence, the Niger delta is a region of redistribution of water and sediments of the Rivers Niger and Benue into the Gulf of Guinea. The rivers, creeks and canals are inter-connected, forming a network of fluvial system for this conveyance. Abam (2001) noted that before the Kainji hydro-dam came into operation, the average yearly discharge at the confluence of the Benue and Niger rivers at Lokoja was 21 x 10^9 m^3, giving a daily average of 7000 m^3 s^{-1} which started decreasing due to impoundment in the several dam reservoirs that were introduced later. A corroboration to this fact was noted by Ekpete (2012) who recorded the average flow velocity in Bonny-New Calabar river system as 0.3m/s.

II. Methodology

Sand search within the study area was carried out over water by means of a locally fabricated floating platform on which was mounted a Shell and-Auger Percussion Rig (Figure 2). A total number of fifteen (15) borings each to twenty (20) meters depth and geo-referenced were drilled and soil samples retrieved at every 1.50 meters depth interval below sea bed down to the final depth for purposes of visual examinations, laboratory analyses and classifications.

Figure 2: Over water Geotechnical Investigation for Sand at Kalaibiama Creek

III. Results And Discussion

Strata logs of soil profiles from the boreholes and water depth at each boring point and the depth to sand are shown in figures 3a and 3b and in table 1. Results of the fifteen boreholes were grouped into three categories based on the cumulative depth of water and depth to sand bodies with respect to dredger boom. Hence we have "Acceptable" for Borrow Pit A (comprising BH10, BH11, BH12, BH13 and BH14), "Fairly Acceptable" for Borrow Pit B (comprising BH2, BH3, BH4, BH5 and BH6) and "Not Acceptable" (comprising BH1, BH7, BH8, BH9 and BH15) as shown in table 1 and figure 3.

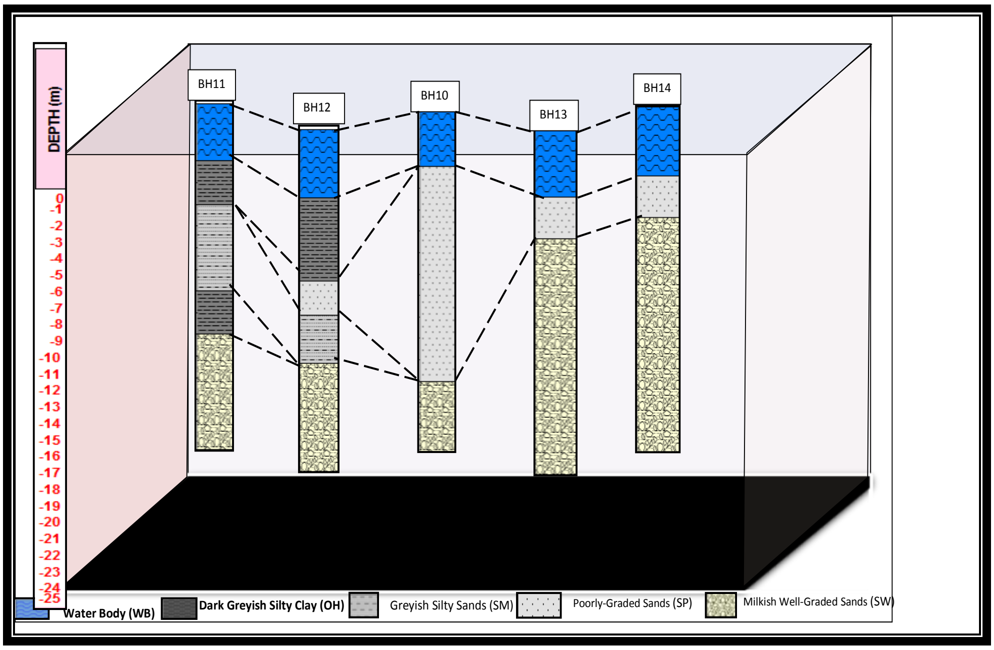


Figure 3a: Fence Diagram of Strata Logs of Borrow-Pit A

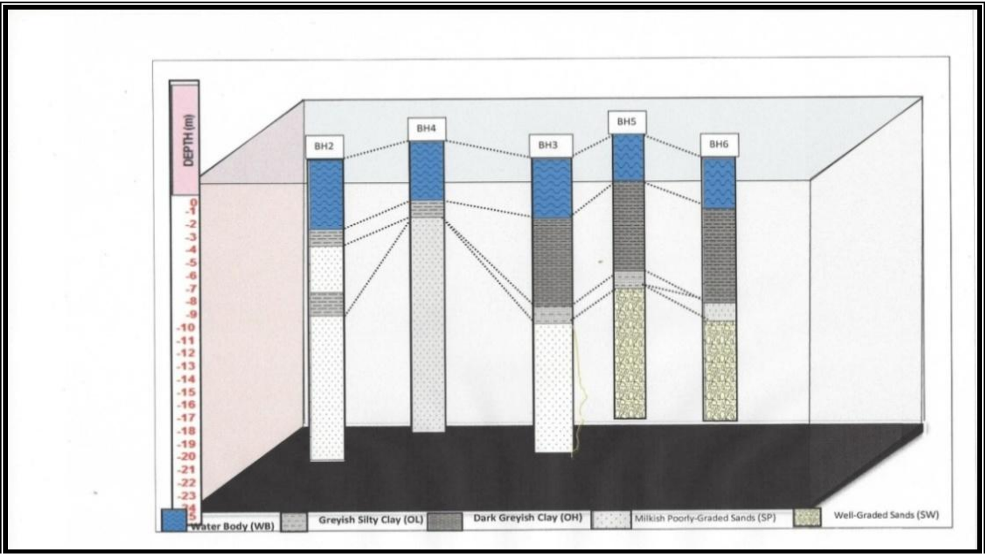


Figure 3b: Fence Diagram of Strata Logs at Borrow-Pit B

Table 1: Water Depth and Depths to Sand Bodies at Each Boring Location.

S/No	Boreholes Drilled (BH)	Water Depth at High Tide (m)	Depth to Sand Deposit beneath River bed (m)	Approximate length of Dredger boom to Sand body [from vertical] (m)	Remarks	BORROW PIT
1.	**BH 1.**	***8.0m***	**7.50**	**15.50**	**Not Acceptable**	**Not Acceptable**
2.	**BH 2.**	***8.5m***	**1.50**	**10.00**	**Fairly Acceptable**	
3.	**BH 3.**	***5.5m***	**7.50**	**13.00**	**Fairly Acceptable**	
4.	**BH 4.**	***9.2m***	**1.50**	**10.70**	**Fairly Acceptable**	
5.	**BH 5.**	***4.0m***	**7.50**	**11.50**	**Fairly Acceptable**	**BORROW PIT “B”**
6.	**BH 6.**	***4.0m***	**7.50**	**11.50**	**Fairly Acceptable**	
7.	**BH 7.**	***4.5m***	**15.0**	**19.50**	**Not Acceptable**	
8.	**BH 8.**	***10.0m***	**10.00**	**20.00**	**Not Acceptable**	
9.	**BH 9.**	***5.5m***	**9.00**	**14.50**	**Not Acceptable**	**Not Acceptable**
10.	**BH 10.**	***6.5m***	**0.00**	**6.50**	**Acceptable**	
11.	**BH 11.**	***5.0m***	**3.00**	**8.00**	**Acceptable**	
12.	**BH 12.**	***0.9m***	**12.0**	**12.90**	**Acceptable**	**BORROW PIT “A”**
13	**BH 13.**	***5.0m***	**0.00**	**5.00**	**Acceptable**	
14	**BH 14.**	***6.2m***	**0.00**	**6.20**	**Acceptable**	
15	**BH 15.**	***5.0m***	**12.0**	**17.00**	**Not Acceptable**	**Not Acceptable**

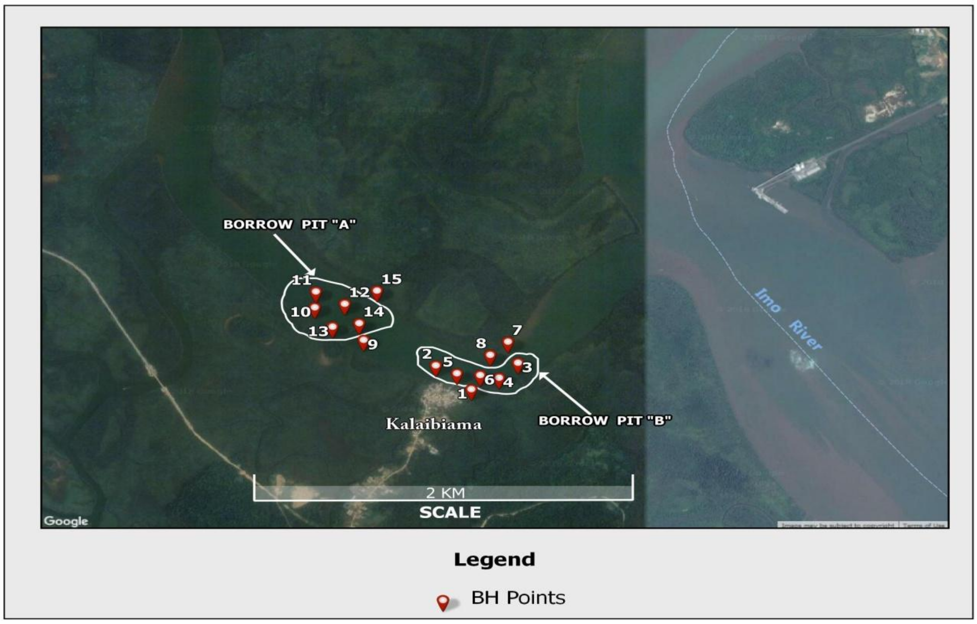


Figure 4: Satellite Imagery showing Location of all Boring Points

Analyses of the soil profiles below sea bed in the various boreholes show relative depth differences to sand body which can impact on its mining cost. The deeper the location of sand and the depth of water, the more its extraction cost which involves the removal of the non-required clay and silty clayey materials overlying the sand and the use of longer dredger boom for maximum extraction.

Using two parameters of depth to sand and depth of water, which cumulatively determines the dredger boom length, the fifteen (15) number boreholes were classified as “Acceptable”, “Fairly Acceptable” and “Not Acceptable”. Based on this, two Borrow Pits A and B were delineated as shown in figure 4 and table 1.

Borrow Pit A comprising BH10, BH11, BH12, BH13 and BH14 appears more promising because, Poorly sorted or Well graded sand (PS & WS) were encountered from the sea bed (0.0m) in BH10 with water depth of 6.5m, in BH13 with water depth of 5.0m, in BH14 with water depth of 6.2m, and from 3.0m depth below sea bed in BH11 with water depth of 5.0m and from 12.0m depth below sea bed in BH12 with water depth of 0.9m (Table 1).

Based on the thickness of sand strata, distance between boreholes (cell) and approximate width of the river, estimates of quantities of sand in Borrow Pits A and B were calculated as shown in appendices A, B, C and D. The distances between boring points are taken as cells and measured for the purpose of calculating volume of sand reserve in each of the borrow pits**.**

IV. Conclusion

The overall cumulative water depth range to sand bodies in Borrow Pit A varies from 5 to 12 meters, having a total sand tonnage of 405, 384.35 tons; that of Borrow Pit B varies from 10 to 13 meters, with a total sand tonnage of 474,529.84 tons. Cumulative water depth of those classified as “not acceptable” varies from 14 to 20 meters. This hopefully, will make it easier for any dredgers with average Boom length to work effectively even at high tide in Borrow Pits A and B because the Dredger Boom Length determines the maximum depth of sand that can be mined especially during high tide.

Acknowledgements

The authors sincerely acknowledge Teks Geotechnical Consultancy (Nigeria) Limited for all the assistance during the field investigation at the project site, Laboratories and their permission to produce a manuscript of the report for publication.

References

[1]. Abam, T. K. S. (2001). Regional hydrological research perspectives in the Niger Delta. Hydrological Science Journal. **46 (1), 13-25**

[2]. Ekpete B (2012). "The flow pattern of the Bonny and New Calabar river systems of Niger Delta region, Nigeria,"

[3]. Finkl, C.W.; Andrews, J., and Benedet, L., (2003). Shelf sand searches for beach re-nourishment along Florida Gulf and Atlantic coasts based on geological, geomorphological, and geotechnical principles and practices. Proceedings of Coastal Sediments ’03 (March 2003, Clearwater, Florida). Reston, Virginia: American Society of Civil Engineers, CD-ROM.

[4]. Finkl, C.W.; Benedet, L., and Andrews, J.L., (2005). Interpretation of seabed geomorphology based on spatial analysis of high-density airborne laser bathymetry (ALB). Journal of Coastal Research, **21(3), 501-514.**

[5]. Finkl, C.W. and Khalil, S.M., (2005). Offshore exploration for sand sources: General guidelines and procedural strategies along deltaic coasts. Journal of Coastal Research, Special Issue **44: 198-228.**

[6]. Kulp, M.; Penland, S.; Williams, S.J.; Jenkins, C.; Flock, J., and Kindinger, J., (2005). Geological framework, evolution, and sediment resources for restoration of the Louisiana coastal zone. In: Finkl, C.W. and Khalil, M., (eds.), 2005. Saving America’s Wetland: Strategies for Restoration of Louisiana’s Coastal Wetlands and Barrier Islands. West Palm Beach and Baton Rouge: The Coastal Education & Research Foundation and the Louisiana Department of Natural Resources

[7]. Meisburger, D., (1990). Exploration and Sampling Techniques for Borrow Areas. Vicksburg, Mississippi: U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Technical Report CERC-90-18.

[8]. National Research Council (NRC) (1995). Beach nourishment and protection. Marine Board, Commission on Engineering and Technical Systents. Washington, DC: National Academy Press. I

[9]. Penland, S; Roberts, H.H.; Williams, S.J.; Sallenger, A.H.; Cahoon, D.R.; Davis, D.W., and Groat, C.G., (1990). Coastal land loss in Louisiana. Transactions of the Gulf Coast Association of Geological Sciences, **90: 685-699**.

[10]. Penland, S.; Connor, P.E.; Beall, A.; Fearnley, S., and Williams, S.J., (2005). Changes in Louisiana’s shoreline: 1855-200. In: Finkl, C.W. and Khalil, M., (eds.), 2005. Saving America’s Wetland: Strategies for Restoration of Louisiana’s Coastal Wetlands and Barrier Islands. West Palm Beach and Baton Rouge: The Coastal Education & Research Foundation and the Louisiana Department of Natural Resources.

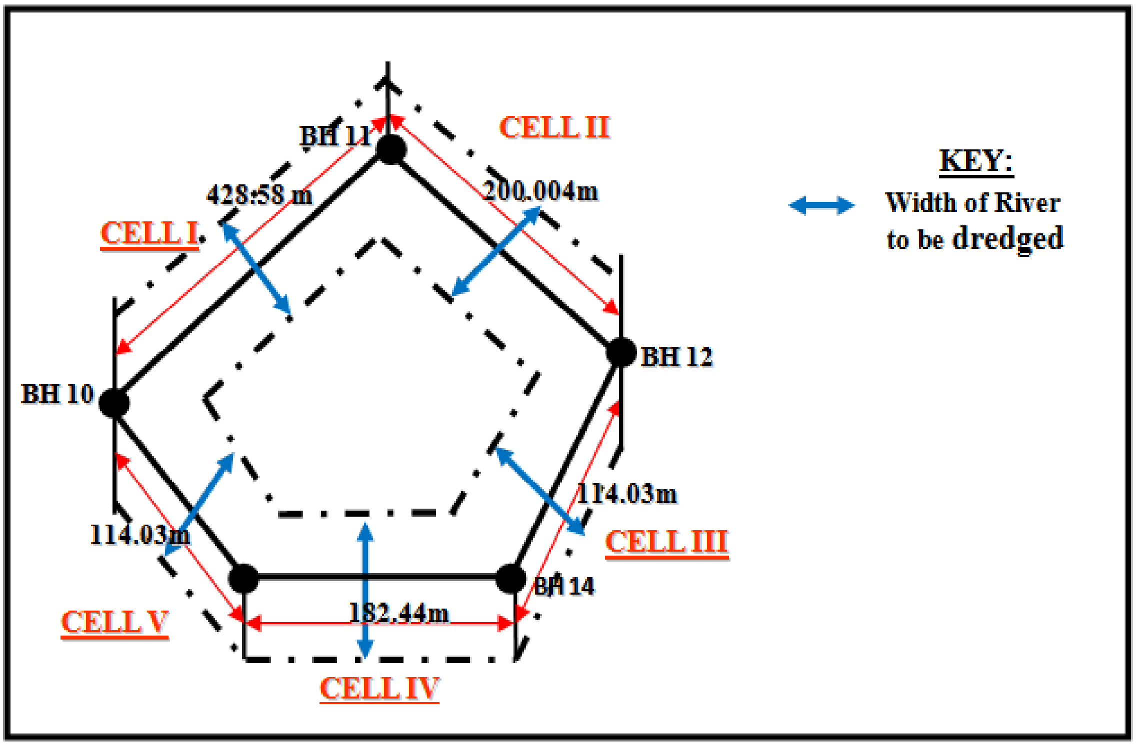
[11]. Rowland, T. J.(1993). Assessment of offshore sand bodies for coastal projects. Proc. 6th Natl. Conf. on Beach Preservation Technology, pp. 519-526f Tallahassee: Florida Shore & Beach Preservation Association.

[12]. Stone, G.W.; Sheremet, A.; Zhang, X.; HE, Q.; Liu, B., and Strong, B., (2003). Landfall of two tropical systems seven days apart along south-central Louisiana, U.S.A. Proceedings of the Coastal Sediments'03 (Clearwater Florida), CD-ROM, 14p

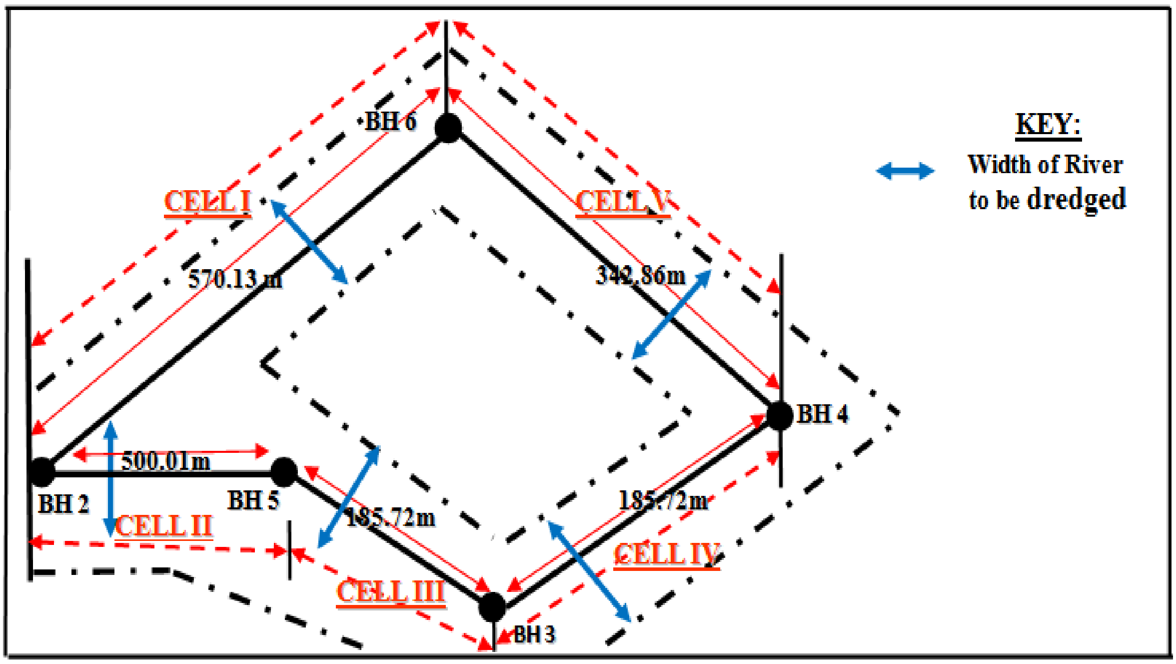
[13]. Short, K.C and Stauble, A.J (1967). Outline of the geology of the Niger Delta. AAP Bull. **51:761-769.**

[14]. USACE, 2000. FINAL feasibility report and environmental impact statement on Hurricane protection and beach erosion control, dare county beaches (Bodie Island Portion), Dare County, North Carolina.

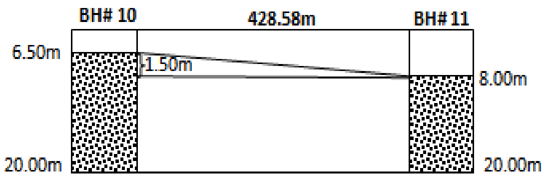
APPENDIX A 1: Schematic Cross-Section of Boring Locations, Distances In-Between and Approximate Width of Creek at Borrow Pit A



APPENDIX A 2: Schematic Cross-Section of the Project Site Showing Boring Locations, Actual Distances and Approximate Width of Creeks at Borrow Pit ''B"



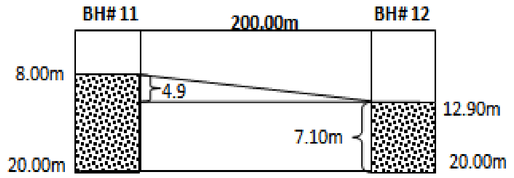
BORROW PIT "A" **CELL I (*BH10 & BH11*)**



Assuming Width of river in *Cell I* ≈150m
Distance between *BH10 & BH11 = 428.58m*

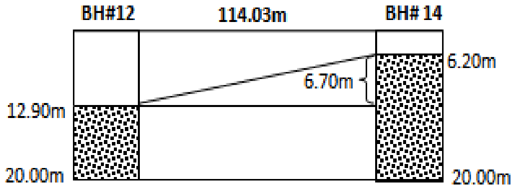
Volume of 'A' = [1/2×1.5×428.58×150] m^3 = **48,215.25 m^3**
Volume of 'B' = [12×428.58×150] m^3 = **771,444.00 m^3**
Total Volume of Cell I = 819,659.25 m^3
Density of Sands in Cell I ≈ 2.10kN/ m^3
Sand Tonnage for Cell I = 819,659.25 m^3× 2.10kN/m^3
= 1,721,284.43 kN × 0.1004 tons = 172,816.96 tons

CELL II (*BH11 & BH12*)



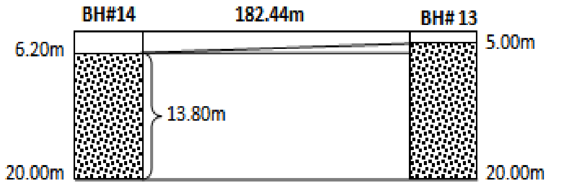
Assuming Width of river in ***Cell II* ≈150m**
Distance between ***BH11 & BH12 =200.00m***
Volume of 'A' = [1/2×4.90×200.00×150]m^3 = **73,500.00 m^3**
Volume of 'B' = [7.10×200.00×150] m^3 = **213,000.00 m^3**
Total Volume of Cell II = 286,500.00 m^3
Density of Sands in Cell II ≈ 2.10kN/ m^3
Sand Tonnage for Cell II = 286,500.00 m^3× 2.10kN/ m^3
= [601,650.00 kN× 0.1004tons] = 60,405.66 tons

CELL III (*BH12 & BH14*)



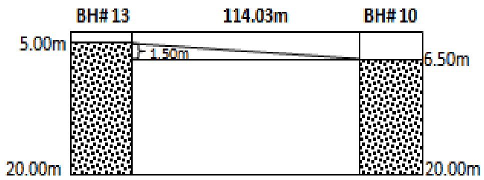
Assuming Width of river in ***Cell III* ≈150m**
Distance between ***BH12 & BH14 =114.03m***
Volume of 'A' = [1/2×6.7×114.03×150] m^3 = **57,300.08 m^3**
Volume of 'B' = [7.1×114.03×150] m^3 = **121,441.95 m^3**
Total Volume of Cell III = 178,742.03 m^3
Density of Sands in Cell III ≈ 2.10kN/ m^3
Sand Tonnage for Cell III = 178,742.03 m^3× 2.10kN/ m^3
= [375,358.26 kN× 0.1004 tons] =37,685.97 tons

CELL IV (*BH14 & BH13*)



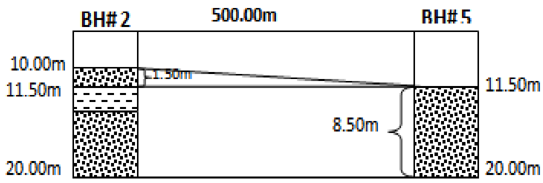
Assuming Width of river in ***Cell IV* ≈150m**
Distance between ***BH14 & BH13* = 114.03m**
Volume of 'A'= [1/2×1.2 × 182.44 ×150] m^3 = **16,419.60 m^3**
Volume of 'B'= [13.8 × 182.44 ×150] m^3 = **377,650.80 m^3**
Total Volume of Cell IV = 394,070.40 m^3
Density of Sands in Cell 6 ≈ 2.10kN/ m^3
Sand Tonnage for Cell IV = 394,070.40 m^3× 2.10kN/ m^3
= [827,547.84 kN× 0.1004tons] = 83,085.803 tons

CELL V (*BH13 & BH10*)



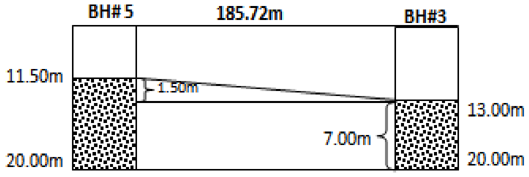
Assuming Width of river in ***Cell V* ≈150m**
Distance between ***BH13 & BH10 =182.44m***
Volume of 'A' = [1/2 × 1.5 × 114.03 ×150] m^3 = **12,828.38 m^3**
Volume of 'B' = [13.5 × 114.03 × 150] m^3 = **230,910.75 m^3**
Total Volume of Cell V = 243,739.13 m^3
Density of Sands in Cell V ≈ 2.10kN/ m^3
Sand Tonnage for Cell V = 243,739.13 m^3× 2.10kN/ m^3
= [511,852.173 kN× 0.1004tons] = 51,389.958 tons

BORROW PIT "B" CELL I (*BH 2 & BH 5*)



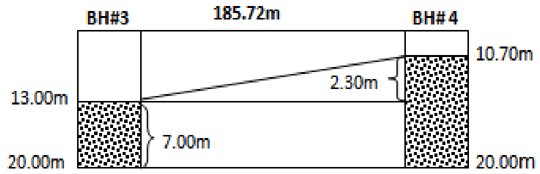
Assuming Width of river in ***Cell I* ≈ 150m**
Distance between ***BH2 & BH5 =500.00m***
Volume of 'A' = [1/2×1.5×500×150] m^3 = **56,250.00 m^3**
Volume of 'B' = [8.5×500.00×150] m^3 = **637,500.00 m^3**
Total Volume of Cell I = 693,750.00 m^3
Density of Sands in Cell I ≈ 2.10kN/ m^3
Sand Tonnage for Cell I = 693,750.00 m^3× 2.10kN/ m^3
= 1,456,875.00 kNx0.1004 tons = 146,270.25 tons

CELL II (*BH5 & BH3*)



Assuming Width of river in ***Cell II*** **≈150m**
Distance between ***BH5 & BH3 = 185.72m***
Volume of 'A' = [1/2×1.50×185.72×150]m^3= **20,893.50 m^3**
Volume of 'B' = [7.0×185.72×150] m^3 = **195,006.00 m^3**
Total Volume of Cell II = 215,899.5m^3
Density of Sands in Cell II ≈ 2.10kN/ m^3
Sand Tonnage for Cell II = 215,899.5 m^3× 2.10kN/ m^3
= **[453,388.95kN** × 0.1004tons] **= 45,520.25 tons**

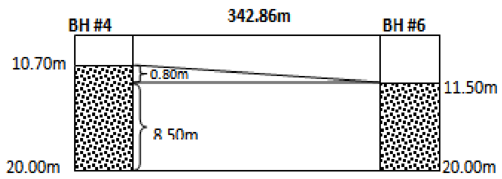
CELL III (*BH3 & BH4*)



Assuming Width of river in ***Cell III*** **≈150m**
Distance between ***BH3 & BH4 =185.72m***
Volume of 'A' = [1/2×2.30×185.72×150] m^3 = **32,036.70 m^3**
Volume of 'B' = [7.0×185.72×150] m^3 = **195,006.00 m^3**
Total Volume of Cell III = 227,042.70 m^3
Density of Sands in Cell III ≈ 2.10kN/ m^3
Sand Tonnage for Cell III = 227,042.70 m^3× 2.10kN/ m^3

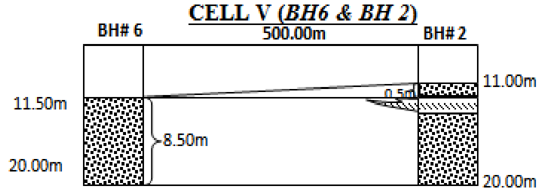
= [476,789.67 kN× 0.1004tons] = 47,869.68 tons

CELL IV (*BH4 & BH6*)



Assuming Width of river in ***Cell IV*** **≈150m**
Distance between ***BH4 & BH6 =342.86m***
Volume of 'A' = [1/2 x 0.8×342.86×150] m^3= **20,571.60 m^3**
Volume of 'B' = [8.50 ×342.86×150] m^3= **437,146.50 m^3**
Total Volume of Cell IV = 457,718.10 m^3
Density of Sands in Cell IV ≈ 2.10kN/ m^3
Sand Tonnage for Cell IV = 457,718.10 m^3 × 2.10kN/ m^3
[961,208.01kN× 0.1004tons] = 96,505.28 tons

CELL V (*BH6 & BH 2*)



Assuming Width of river in ***Cell V*** **≈ 150m**
Distance between ***BH6 & BH 2 =500.00m***
Volume of 'A' = [1/2 x 0.5 x 500.00×150] m^3= **18,750.00 m^3**
Volume of 'B' = [8.50×500.00×150] m^3 = **637,500.00 m^3**
Total Volume of Cell V = 656,253.00 m^3
Density of Sands in Cell V ≈ 2.10kN/ m^3
Sand Tonnage for Cell V = 656,253.00 m^3× 2.10kN/ m^3
[1,378,131.3 kN× 0.1004tons] =138,364.38 tons

TABLE 5.2a: SUMMARY OF ESTIMATED TONNAGE OF SAND TO BE DREDGED FROM BORROW PIT 'A'

CELLS	TONNAGE	REMARK
I	*172,816.96*	Borrow-Pit "A"
II	*60,405.66*	Borrow-Pit "A"
III	*37,685.97*	Borrow-Pit "A"
IV	*83,085.80*	Borrow-Pit "A"
V	*51,389.96*	Borrow-Pit "A"
TOTAL	405,384.35 Tons	Borrow-Pit "A"

TABLE 5.2b: SUMMARY OF ESTIMATED TONNAGE OF SAND TO BE DREDGED FROM BORROW PIT 'B'

CELLS	TONNAGE	REMARK
I	*146,270.25*	Borrw-Pit "B"
II	*45,520.25*	Borrw-Pit "B"
III	*47,869.68*	Borrw-Pit "B"
IV	*96,505.28*	Borrw-Pit "B"
V	*138,364.38*	Borrw-Pit "B"
TOTAL	474,529.84 Tons	Borrw-Pit "B"

Ngerebara, Owajiokiche Dago." Over-Water Geotechnical Sand Investigation along Kalaibiama Creek in the Niger Delta for Shoreline Reclamation ."IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) 6.6 (2018): 48-55.