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Subsurface Models for Spill Delineation in Niger Delta Basin

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Abstract:

Petroleum spills occur frequently due to heavy transportation activities involvedand the potential operational accidents that may occur. Spills when they occur need to be delineated in its totality to decipher its percolation depthwise and spread across the impacted area. The Isosurface (subsurface) modeling approach is being suggested as best practice method for spill delineation with the ultimate objective for remediation of the impacted site. In this study, the I–data was used, the modeling was performed with RockWares' Rockwork software version 2017. The subsurface (isosurface) models indicated that the spilled oil (petroleum) is predominant in the North and East direction of the impacted site and the depth of maximal present of the spilled oil was between the surface and 2ft deep. The 3D solid models and the vertical profile map showed areas of interest and the profile index map showed the distribution of the sample point across the impacted site of study.

Keywords: Petroleum Spill, Solid Model, Profile Map, Remediation, Rockworks.

1.0.Introduction.

Petroleum is a necessity in our industrial society, over years it has become a major component of our lifestyle, most of the world's activities has rested on the pillar of petroleum, petroleum in the form of energy is needed to move from one place to another, is also needed to drive industrial heavy and light machines and for most domestic activities.Development in the social, economic and political sector of most nations depends on petroleum especially for oil producing countries.

The day-to-day activities involves the transport of petroleum (crude oils),different transport modes are involved including pipelines, railtrucks and tank trucks, there is good possibility that accidents can happen during any of the transportation process or storage times. Accidents also occur during drilling and production which majorly results in oilspillage(Allison & Mandler, 2018).

Crude Oil spillage has been a perennial occurrence in the Niger Delta Basin, its has been attributed to either vandalization by the locales or due to mechanical failure which include incidental spill due to damages such as dents, and scrapes on pipeline which deteriorates overtime or operational failure which includes accidental spill by equipment operators(Stout & Wang, 2016). These can impact on the soil, making it unfit for farming and habitat of flora and fauna.

Onshore spillages can be delineated with respect to their percolation and surface flow, percolation describes the downward migration of the spill through various layers of the soil. There has been reports on spill that have percolated to about 12 feet below the surface(W A N G , et al., 1998). The distribution of the spilled oil in the subsurface has been a concern, where properly delineated, it will serve to safe manhours and provide job specificity in approach regarding areas in the surfaces containing the spills and in view to remediation.

The best practice approach to the issue is being postulated by this research to be subsurface (Isosurface) 3D solid models(Wainwright & Mulligan, 2004), these models are based on I–data, which is also known as interval data, this type of data is obtained based on interval samples that are obtainedapplying regular grid multiple sampling system(Scheer, Class, & Flemisch, 2021). Whereby samples are obtained at regular interval down depth at a particular point.The solid model file is a three-dimensional array of numbers that represent interpolated values for each block or voxel within the model. The model represents the downhole interval sampled databased on anisotropic modeling which uses inverse-distance weighting limited to the closest eight control points to interpolate values for each voxel(RockWorks & Wares, 2020).

1.1Geologyof the Niger Delta.

The Niger Delta basin is divided into three sedimentary environments, these are

The continental environment which comprises the alluvial environment including the braided stream and meander systems. The sediment deposited in this environment are predominantly sand with feldspar grains which are fairly common. The next environment is the transitional environment which comprises brackish water lower delta plain (mangrove swamps, flood plains) and coastal areas with beaches, barrier bars and lagoons.

The third environment is the marine environment, and it includes a submarine which is the delta fringe with fine sand, silt and clay, and it grades into the holomarine environment. However, stratigraphically, the Niger Delta basin is subdivided into three stratigraphic units these are;

The Benin Formation which is the most shallow and predominantly sandy with few shale intercalations, the intercalations become more frequent towards the base of the Formation.

The Agbada formation is next after the Benin Formation, it is characterized by the alternation of sandstone and sand bodies with shale layers. The upper unit is mainly made up of thin sandstone –shale intercalations, while the lower unit consist mainly shale units. The Akata Formation is the last and is characterized by a uniform shale development.

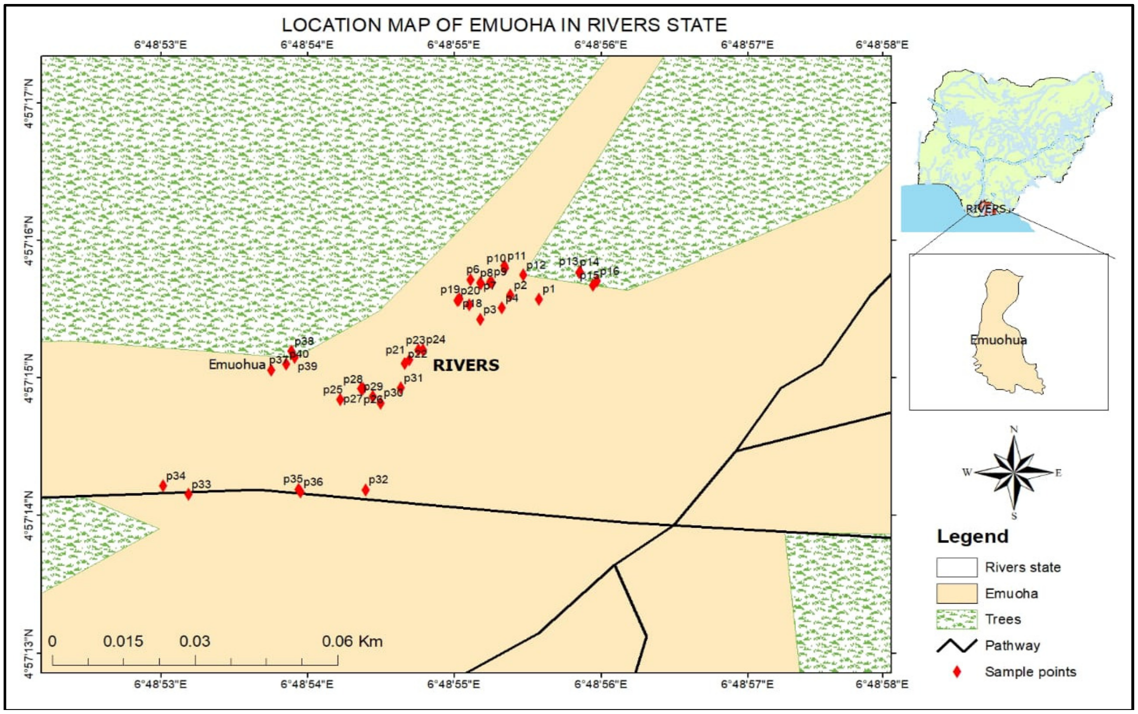

Figure1. The location of oil impacted area showing the sample points. (Ibba in Emohua)

2.0. Method and Materials

Samples are oil contaminated soils, sampling was performed by applying regular grid multiple sampling system, that provides for obtaining samples at regular interval down depth at a particular point.Interval samples are used for generating interval data (I–data). The data of interest is the TPH (Total Petroleum hydrocarbon)(Kuppusamy, Maddela, Megharaj, & Venkateswarlu, 2020)

The oil contaminated soil samples were obtained from spill impacted area at regular interval of 1ft for two samples step–down after the surface sample, they were stored in properly labelled sample bags and kept a chest of ice to preserve sample compositional integrity. Sample chain of custody was not broken till analysis. GPS coordinates were obtained for each sample spot.

The samples were treated by dilution using n–hexaneto achieve 1ug/uL for a GC–FID analysis for TPH (total petroleum hydrocarbon) analysis.The GC–FID analysis of the extracted oil was performed using a Hewlett Packard 5890 series II Plus chromatograph equipped with a 50 m x 0.2 mm x 0.5µm film thickness (DB-1) column with a flame ionization detector (FID). Hydrogen (H2) was the carrier gas and was allowed to flow at a flow rate of 300 ml/sec and the oven was programmed from 30ºC to 305ºC at 5ºC/min.

2.1 Modeling

The isosurface (subsurface) modeling was performed with Rockwork version 2017. The GPS coordinates which were obtained in sexagesimal format was converted to the UTM (Universal Transverse Mercator) format before modeling. The model was viewed by slices showing distribution of specific concentration of oil in the subsurface. The I–data profile across impacted area is generated(Turner, Kessler, & Van der Meulen, 2021).

3.0 Results and Discussion

Table 1. GPS coordinates of sample points and TPH of samples PA (0ft), PB (1ft, PC(2ft) TPH.

BOREHOLE	LATITUDE	LONGTITUDE	ELEVATION	PA (ppm)	PB (ppm)	PC (ppm)
P1	4□57'15 572"N	6□48'55 573"E	17.3	40870	2204	1598
P2	4□57'15 601"N	6□48'55 380"E	17	10892	366.02	1270
P3	4□57'15 423"N	6□48'55 173"E	17.65	2977	4361	1574
P4	4□57'15 508"N	6□48'55 322"E	17.32	12247	4857	2492
P5	4□57'15 693"N	6□48'55 257"E	17.57	8570	1978	397.59
P6	4□57'15 714"N	6□48'55 108"E	17.42	10939	2583	1003
P7	4□57'15 692"N	6□48'55 173"E	17.9	47183	1988	1995
P8	4□57'15 688"N	6□48'55 180"E	17.22	5084	372.39	452.5
P9	4□57'15 697"N	6□48'55 241"E	17.65	9900	1877	3943
P10	4□57'15 797"N	6□48'55 344"E	17.58	4507	1113	2840
P11	4□57'15 814"N	6□48'55 340"E	17.88	5403	454.83	5323
P12	4□57'15 747"N	6□48'55 468"E	17.12	392.15	46.23	3049
P13	4□57'15 772"N	6□48'55 852"E	17.01	9273	3869	2837
P14	4□57'15 768"N	6□48'55 849"E	17.77	6601	3946	1100
P15	4□57'15 673"N	6□48'55 942"E	17.67	3655	797.57	1408
P16	4□57'15 704"N	6□48'55 968"E	17.23	54236	4712	4983
P17	4□57'15 530"N	6□48'55 099"E	17.71	5138	3957	3907
P18	4□57'15 575"N	6□48'55 032"E	17.82	35358	2928	1996
P19	4□57'15 569"N	6□48'55 028"E	17.19	39654	5768	1408
P20	4□57'15 561"N	6□48'54 019"E	17.96	1031	624.4	748.95
P21	4□57'15 128"N	6□48'54 690"E	17.75	590.06	6978	308.57
P22	4□57'15 099"N	6□48'54 662"E	15.97	28776	2164	861.45
P23	4□57'15 203"N	6□48'54 754"E	17.26	24749	2639	3252
P24	4□57'15	6□48'54 785"E	17.4	54172	3064	2379

	204"N					
P25	4□57"14 839"N	6□48'54 219"E	17.5	1239	1239	1341
P26	4□57"14 917"N	6□48'54 378"E	17.31	591.71	1421	471.6
P27	4□57"14 921"N	6□48'54 361"E	17.86	3294	6175	2557
P28	4□57"14 914"N	6□48'54 366"E	17.25	18178	791.26	325.33
P29	4□57"14 861"N	6□48'54 443"E	17.47	827.3	8330	231.23
P30	4□57"14 814"N	6□48'54 496"E	17.22	8024	771.05	870.29

Figure 2a. Pictures of Sample Location

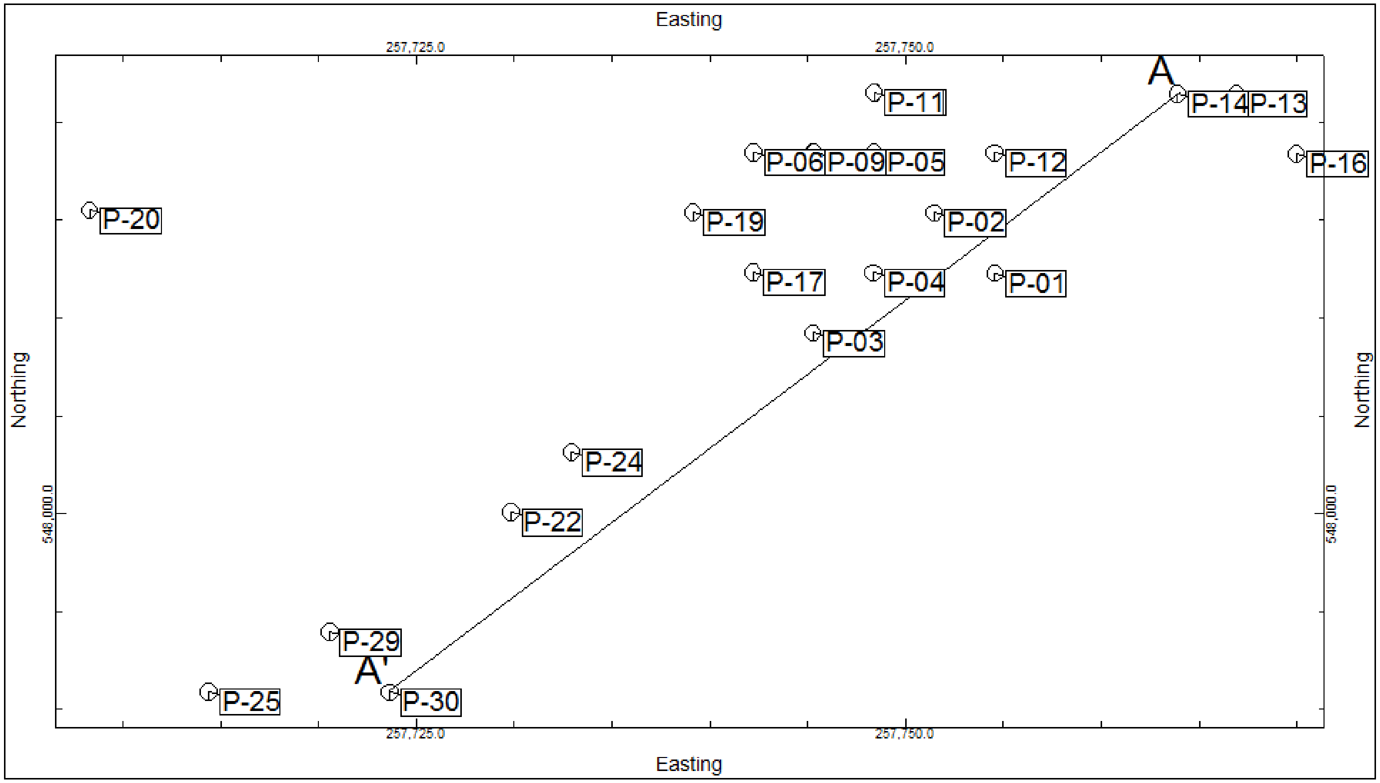

Figure 2b. The I–data profile index Map (based on Eastings and Northings)

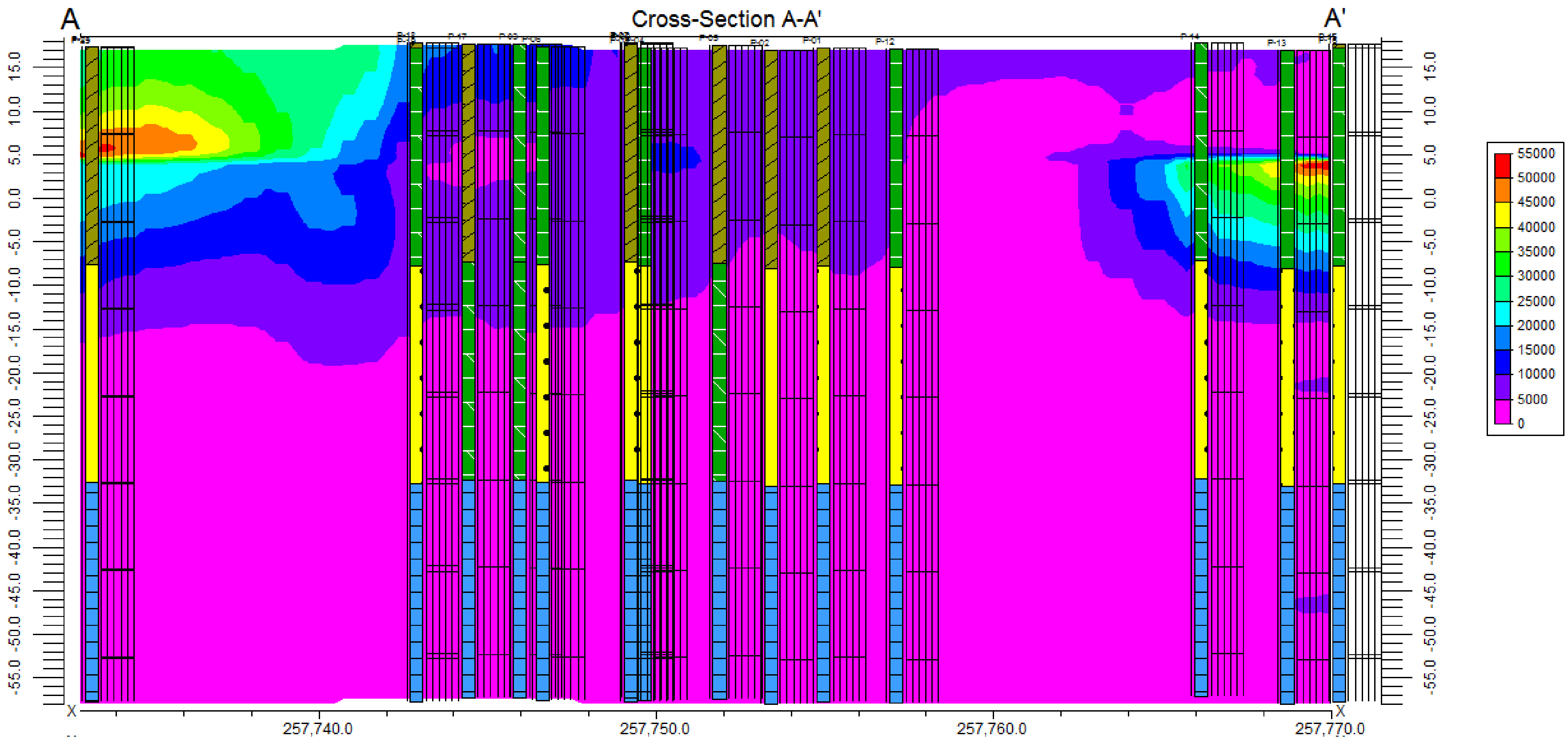

Figure 3. The I–data profile showing a subsurface vertical slice representing the transverse in figure 2b

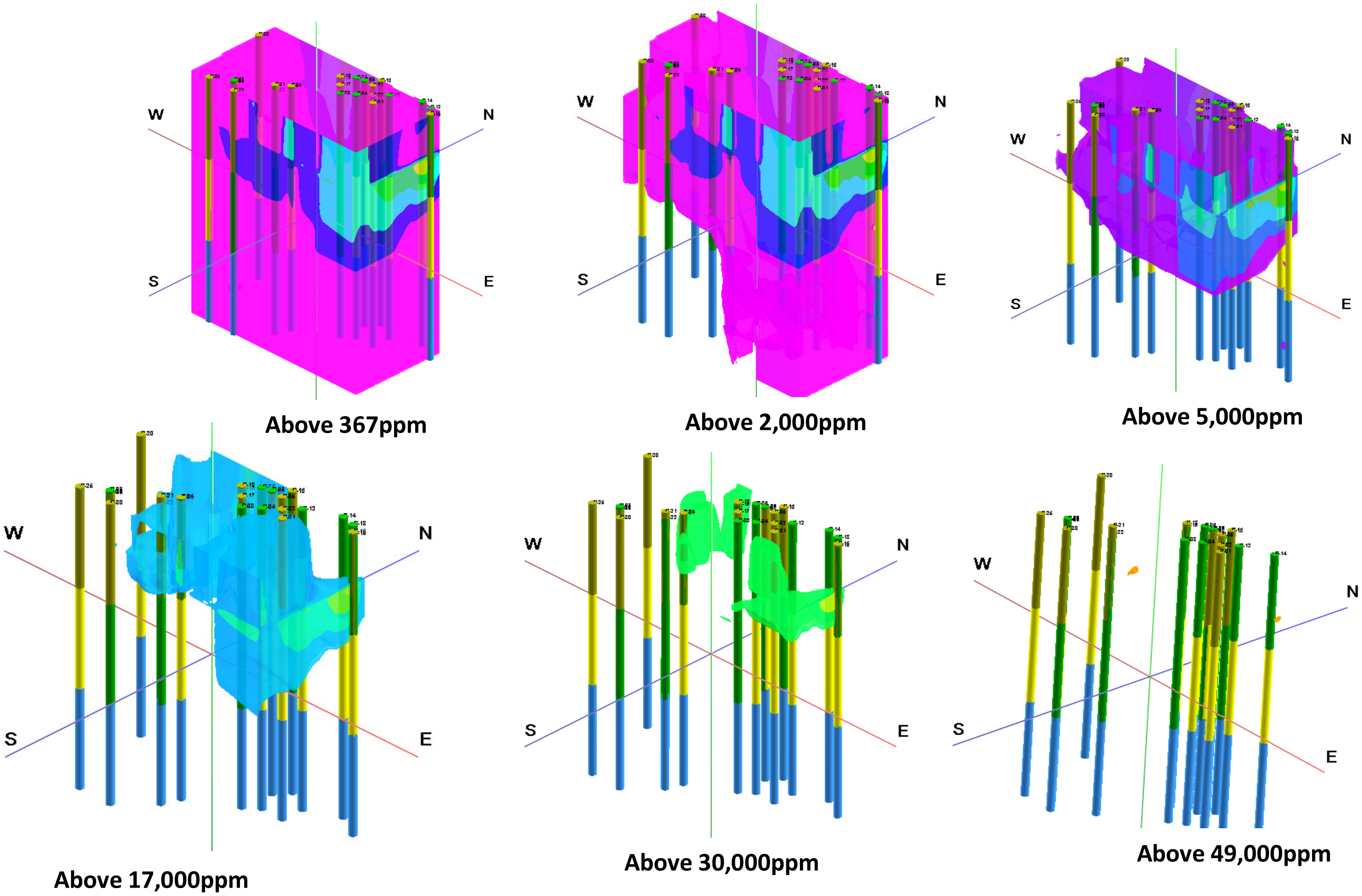

Figure 4. Various voulme above different threshold of the conentration oil in the marix of the spill impacted area, the voume of the matrix reduces at higher concentration, showing the oil bearing area in the subsurface.

3.1 Subsurface Distribution

The subsurface distribution of hydrocarbons can be virtualized in detail due to the complex modeling dynamics adopted. The modeling concept is such that uses I–data (interval data) and basically portraysthe impacted area in the subsurface(RockWorks & Wares, 2020).

The solid models are expressed as 3D diagrams. The model isa 3D array of numbers that represent interpolated values for each block or voxel within the model, the algorithm which expresses the modeling method is the inverse distance weighing anisotropic method, this method uses inverse distance weight limited to the closest eight control points to interpolate values for each voxel, whereby the model is built based on voxels or building blocks. The data used is the TPH data obtained at equal distance interval, this data is interpolated based on the IDW algorithm from the closest eight points(RockWorks & Wares, 2020).

Based on this principle a proper representative model is generated to depict the hydrocarbon distribution in the subsurface, also the areas of emphasis are noted, where potentially the spilled and percolated hydrocarbon/oil could exceed the intervention value. This information will help in deciphering the type of remediation and how it will be carried out.

3.2 Model Volumes

The model can be represented as volumes, this implies that the volume of the entire matrix that bears the spill oil above a certain threshold of concentration can be represent, this is another advantage of subsurface modeling for oil spill delineation relative to other methods such as VES (Vertical Electrical Sounding). This is portrayed in figure 4, the volume of the spill impacted matrix in the subsurface that bears spilled petroleum/oil above certain threshold can be visualized. With this information proper steps can be adopted towards remediating the spill impacted area. In this study, it is observed that the spill impacted area in the subsurface is more to the North and the East relative to the West and the South. The depth can also be noted, it can be observed that spill impacted matrix is mostly within one and two feet deep (represented as 25m to 50m in the model). Thus, the model is able to show areas that are lightly impacted and areas that are heavily impacted.

3.3 I-Data Profiles.

The I–data profile is derived from the I–data index profile map represented in figure 3. The map represents the possibility of viewing a vertical subsurface slice/dissect of the spill impacted subsurface matrix in different orientation of choice to validate the depth of impact and the subsurface spread of impact. Different orientation will provide information on areas of extensive percolation and if present, temporary accumulation of the oil. The shallow subsurface in the Niger Delta basin environment is frequently characterized by the present of sand and clay in alternating manner with extensively varied ratio of sand and clay and slit. This is a major driver to the complex manner the spill petroleum might impact the subsurface. The I–data vertical subsurface profiles are very valuable information for spill remediation. In this study the I–data profile in figure 3 can be observed to show that the spilled impacted depth is mostly within the first one ft. ranging from 1000ppm to 55,000ppm as can be observed from the borehole logs and legend. The cross-section represents the transverse of A to A' as represented in the I–data index profile map in figure 2b.

Several transverse of different orientations can be observed for a clearer understanding of the spread depthwise and cross-section wise, this approach is being suggested to be adopted as best practice approach for delineating oil (petroleum) spill impacted area with respect to the depth of percolation and extend of spread across width of the spill impacted area. These are vital information that are required before embarking on remediation of oil spill impacted area.

4.0Conclusion.

The isosurface or subsurface model approach provides for georeferencing of the sample location to google map.

The approach also provides an I–data index map that shows the sample locations and provides the flexibility of viewing various orientations of the I–data profile.

The approach also providessolid models that enable viewing matrix volume having excess of threshold of choice, thus providing for possibility of knowledge of volume of matrix impacted by specific concentrations.

In this study, the spill impacted depth is between the surface and one ft, across the impacted area of study. Various models representing the distribution of various concentration range is shown for remediation purposes.

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