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OIL SPILL ANALYSIS USING ELECTRICAL RESISTIVITY METHOD AND GIS: A CASE STUDY IN OSHIE COMMUNITY, IN AHOADA-WEST LOCAL GOVERNMENT AREA OF RIVERS STATE NIGERIA.

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ABSTRACT

The investigation of oil spill analysis was made to determine the level of pollution in an oil spill site in Oshie community, in Rivers State Nigeria. A two-dimensional resistivity survey of seven profiles and one VES was acquired using ABEM Terrameter, SAS 1000 with Res2Divn, IPI2win, and Surfer 16 software for processing, in which five profiles are polluted and two are control profiles. The Wenner configuration was used to achieve vertical and lateral resistance distribution for the location under investigation. The results indicate that Contaminated zones were detected in layer 1, 2, and 3, with topsoil, consist of brownish-black, poorly sorted clayey sands with depths ranging from 2 to 3 m, and contaminated zones correspond to high resistivity near the surface, with true resistivity ranging from 40 to 109 Ωm. The oil spill migrates through the dry sandstone and coarse formation of the first layer into the second layer. The second layer, which contains a thickness ranging from 2.2 to 5.38 m, displays resistivity ranging from 20 to 250 Ωm. It is a permeable layer and it does not prevent the vertical infiltration of crude oil. The third layer with a depth ranging from 5 to 8.6 m is partially contaminated while Layer 4 shows no contamination plumes. The path of migration of the crude oil on the surface reveals that the oil spillage is moving toward the Orashi river which has a lower altitude. The 3D modeling indicates that communities along the Orashi River is affected by oil spill.

Keyword: Wenner configuration, VES, GIS, Oil spill, 3D modeling, pollution

INTRODUCTION

Oil spillage has been a great threat to human life in Niger Delta as means of lively-hood are destroyed by contamination. Oil spills due to Hydrocarbon exploration and exploitation, crude oil theft and sabotage of facilities as well as illegal refining has been a major problem in Niger delta (Nwankwo, et al., 2015). These oil spillages have destroyed lands being used for agricultural purpose, polluted rivers being used for harvesting fish and as well as a major water source for normal domestic usage and destroyed sand which is supposed to be used for construction purpose in Bayelsa state, Rivers State and Delta State (Ojimba, & Iyagba., 2012). More than 30 oil-producing communities in the Niger-Delta region have suffered large oil spills with negative environmental impacts such as fire, death of aquatic lives, water pollution, soil pollution, and ecosystem degradation. From the report by the Directorate of Petroleum Resources, over 6000 spills activities had been documented for 40 years now of oil exploitation in Nigeria with lost to the ecosystem (Odu, et al., 1985). Other pollution activities caused by humans are indiscriminate disposal of chemicals into the river (Christensen, et al., 2004).

Drilling and chemical analysis of core samples for an oil-polluted area is rather expensive (Scott, & Zhendi., 2016). In the last decade, according to Albaigés, et al., (2015a), many geophysical methods, especially electric and electromagnetic methods, have been used to characterize oil pollution in the geological environment.

Geophysical methods that are sensitive to lateral changes to the resistivity of the earth are useful in the discovery of contaminated zones (Ogbeibu., 2011). The resistance contrast between areas contaminated with oil and surrounding rocks depends on the age of spill occurrence (Ojimba, & Iyagba., 2012). The low resistivity anomaly in polluted areas appears six to eight months after the spill ("mature spill"), but in the case of a fresh spill, the presence of a high resistive anomaly is expected (Dahlmann., 2003). Therefore, the age of spill influences the selection and optimization of the applied technology. Research from Albaigés, et al., (2015b) has shown that oil contamination in sandy clay is easier to detect than in pure sand. Oil pollution increases the population of oil-changing bacteria, surfactants in water and salinity of groundwater up to 5 times and reduces groundwater resistance ((Dahlmann., 2003). In the first stage of pollution, mineral oil products and infiltrates concentrate in the sand layer but are eventually absorbed by clay (Christensen, et al., 2004).

In this work, the vertical electrical resistivity method was used to determine the horizontal and vertical extent of the spilled hydrocarbon contamination zones or plume and map the crude oil migration route on the surface and beneath the subsurface.

THE STUDY AREA.

The study area is the Oshie community of Egeni clan, in Ahoada-West local government Area of Rivers State. It is located between $5^{o}60"0'N - 6^{o}50"0N$ and $6°28"0'E - 6^{o}30"0'E$ (Figure. 1). Oshie community is among the communities of the Rivers South Senatorial District and it lies within the Niger Delta sedimentary Basin. The community is an oil and gas producing community with pipelines and flow lines seen above the ground. The study area has a natural freshwater pond with fish, freshwater snails, and edible worms (grub). The occupations of the people in the community are farming (cassava, plantain, and banana) and fishing. The river in the study area is the Orashi River.

The study area is located in the southern lowlands in humid tropical zones and experiences a well-distributed annual rainfall. Temperature is generally high, with an average monthly maximum of 27oC – 34oC and minimum temperatures varying 20oC - 24oC.

The geology is of the Niger Delta sedimentary Basin has been described fully in details by Allen (1965), Reyment (1965), Short and Stauble (1967), Etu-Efeotor and Akpokodje (1990) and many others where the basin consists of Akata, Agbada and Benin Formations (Short and Stauble, 1967). The geologic units of the Niger Delta are summarized in Table 1.

Fig.1: Map of Study Area

Table 1: Geological units of the Niger Delta (after Short and Stauble, 1967).

Age	Geological Unit	Lithology
Quaternary	- Alluvium (general) fresh water back swamp meander belt. - Mangrove and salt water. - Back Swamps - Active/Abandoned Beach ridges - Sombreiro Warri Delataic plain.	- Gravel, sand, clay, silt, sand, clay, some silt, gravel. - Medium-fine sands, - Clay and some silt.
Miocene	Benin Formation (coastal plain sand)	Coarse to medium grain sand with subordinate silt and clay lenses; Fluviatile marine
Eocene	Agbada Formation	Mixture of sand, clay and silt, fluviatile marine.

METHODOLOGY

Oil Spills Data Collection

The oil spill date was gotten from NOSDRAS website along OSHIE 15s flow line Oshie, Rivers State with unknown amount of unspecified contaminants spilled due to sabotage/theft. Spills ID 1902352.2019/LAR/109/184, incident date: 10/4/2019 and spill location; latitude: $5^0$6’14.50” and longitude: $6^0$28’59.60”. Five (5) profiles of 2Dimensional Resistivity survey using Wenner configuration was carried out in the study area close to the spillage source. The location of the profiles was planned to cut across the expected flow direction of the crude oil spill in the study area. Measurements were taken by an ABEM Terrameter model SAS 1000 in this survey. Five (5) meters electrode spacing was being used. All the profiles run along the strike direction of the outcrops, i.e. SW - SE. A shallow borehole was dug up to 14m. Alongside, additional 2 profile of 2Dimensional Resistivity survey using Wenner configuration was done on an unpolluted area in the study area as well as a 1Dimensional Resistivity survey was also acquired using Schlumberger configuration in the unpolluted zone to enable us have an accurate litho-stratigraphic log of the e study area. Results from the field was filtered and analyzed using Res2DInv, ZondIP, Res3DInv and ArcGIS.

RESULTS AND DISCUSSION

A borehole log, a 1D and a 2D resistivity information was collected and interpreted. The 2D data collected was further collated together to make a 3D and subsequently interpreted. GIS and Remote sensing was futher used to model the result in other to get accurate flow direction of the spillage.

Results from the 1D and borehole log show that the litho-stratigraphic information of the study area are as follows: between the surface and 1.7 m depth, the soil is made up of brownish black, poorly sorted clayey sands with resistance value of 109 Ωm. This lithology turns brownish from 1.7 m to a depth of about 2.2m where it is also poorly sorted and medium to coarse in texture and have a resistance value of 383 Ωm. From 2.2m to 7.1m the clayey sands become gravelly, mottled and remain poorly sorted with its resistance value of 461ohm.m. From this depth to the drilled depth of about 14m, we have gravelly, whitish, poorly sorted sand which is the aquiferous layer in the study area and its resistance value is 186 Ωm. (Fig: 2). Table 2 shows the

Geoelectrical modeled parameters (Apparent Resistivity, Depth and Thickness) obtained from the interpretation of the 1D Geoelectrical Soundings.

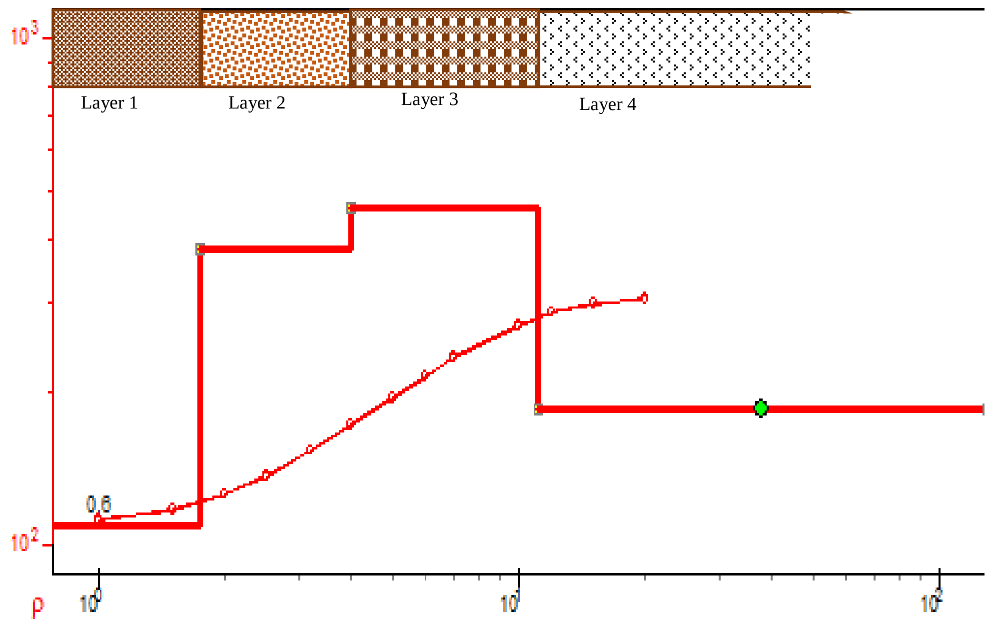

Fig: 2. 1D inversion result with borehole log data

Table: 2. Geoelectrical modeled parameters obtained from the interpretation of the 1D Geoelectrical Soundings.

N	ρ	h	z
1	109.02	1.74	0/0
2	382.80	2.2	1.74
3	461.08	7.08	3.97
4	185.52		11.06

Five (5) 2D profiles were acquired to cover our area of insterest. Profile 1 was acquired very close to the spill source at about 10m away (Figure 3).

The first layer is a layer of moderate resistivity ranging from 120 to 450 Ωm which represents the brownish black, poorly sorted clayey sands Formation as interpreted for the borehole log and

1D with a thickness ranging from 1.25m to 5m. Several anomalies of high resistivity indicating plumes was detected within this zone. This anomalous high resistivity represents the locations of freshly spilled oil contamination. The contamination have invaded to a maximum depth of about 10meters.

The second layer, which has a thickness ranging from 6 to 13 m, shows a range of resistivity from 90 to 250 Ωm. This range of resistivity refers to the poorly sorted and medium to coarse sand formation. It is seen that contamination have moved from the topsoil through this medium into the aquifer because contaminated locations were detected in this layer, perhaps due to the contamination being recent as well as to the high permeability of the formation, the ground water resistivity value is now relatively low.

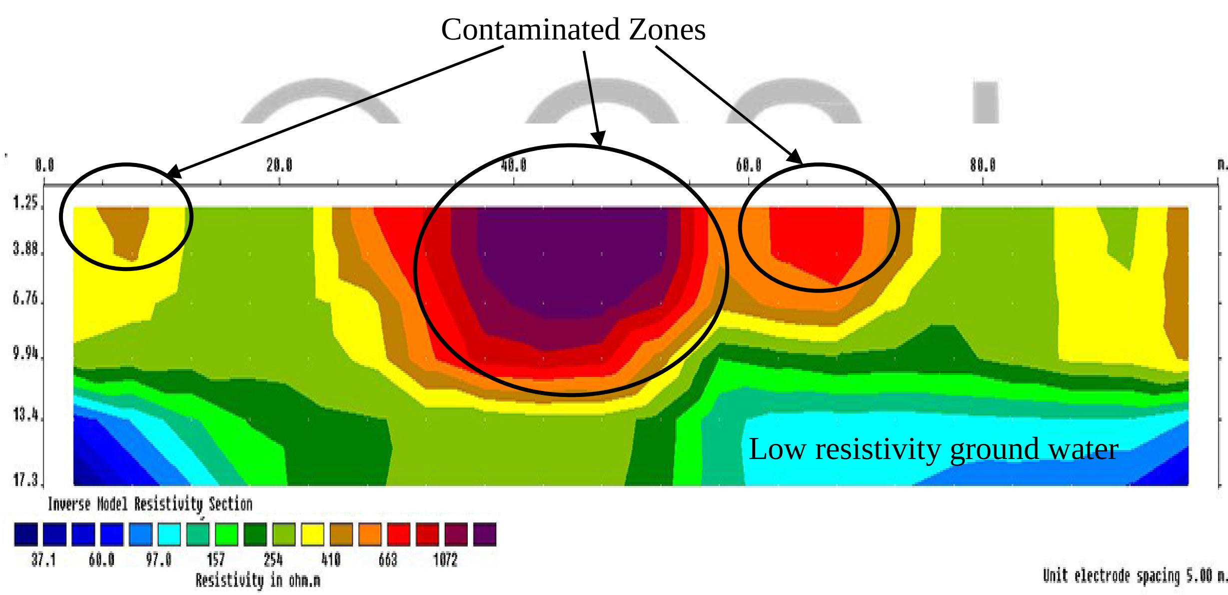

Fig: 3 Inversion result of profile 1.

The second profile was acquired at about 30m from the spill source. The result from profile 2 sounding is shown in Figure 4. The first layer is a layer of high resistivity ranging from 110 to 420 Ωm which represents the brownish black, poorly sorted clayey sands Formation as interpreted for the borehole log and 1D and it have a thickness ranging from 1.25m to 4m. Several anomalies of extremely high resistivity were detected within this zone; they represent the locations of oil contamination. The contamination have invaded to a maximum depth of about 7 meters.

The second layer, which has a thickness ranging from 3 to 8 m, with resistivity ranging from 97 to 254 Ωm have also be affected by the spill. It is seen that contamination have moved from the top soil through this medium into the aquifer. The groundwater in the aquifer is characterized by low resistivity values because of this contamination.

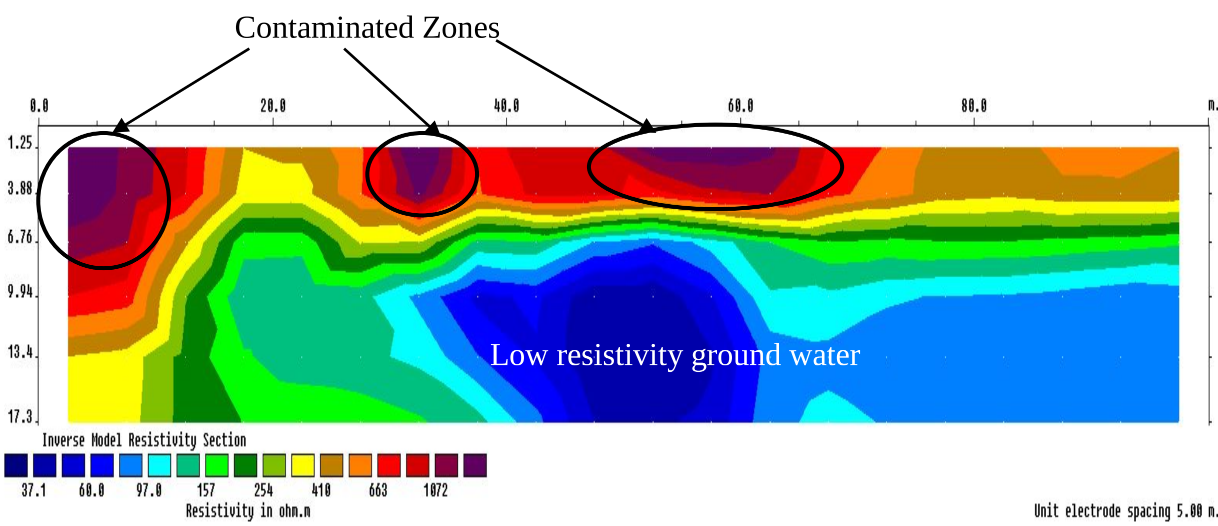

Fig. 4: Inversion result of profile 2.

The third profile was acquired at about 50m away from the spill source. The inverse section of profile 3 sounding shows the appearance of three sorts of layers (Figure 4). The first is a layer of high resistivity ranging from 33 to 150 Ωm which represents a clayey sand Formation and have a thickness ranging from 1.25m to 4.2m. Plumes was detected within this zone; they represent the locations of oil contamination. The contaminated locations were detected in the brownish black, poorly sorted clayey sands Formation. The contamination have invaded to a maximum depth of about 7 meters.

The second layer, which has a thickness ranging from 5 to 9 m, shows a range of resistivity from 11 to 127 Ωm. This range of resistivity refers to the poorly sorted and medium to coarse sand formation. It is seen that contamination have moved from the topsoil through this medium into the aquifer because contaminated locations were detected in this layer, perhaps due to the contamination being recent as well as to the high permeability of the formation, the ground water resistivity value is now relatively low.

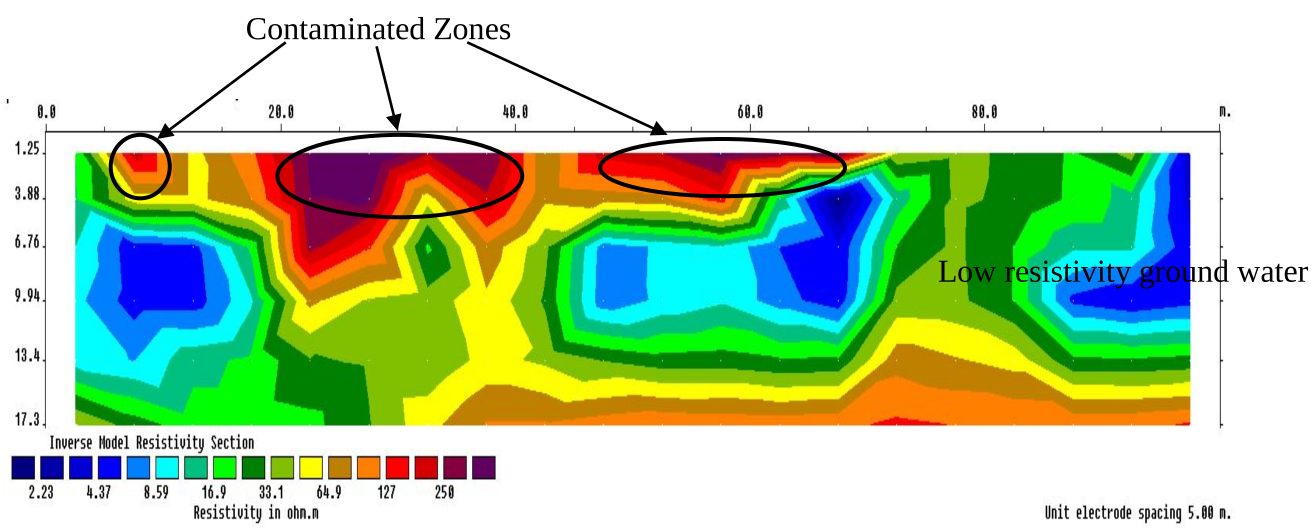

Fig. 5: Inversion result of profile 3.

The fourth profile was acquired at about 100m from the spill source. The inverse section of profile4 sounding shows the appearance of three sorts of layers (Figure 5).The first is a layer of high resistivity ranging from 40 to 100 Ωm which represents a sand Formation and have a thickness ranging from 1.25 m to 3.5 m. Plumes was detected within this zone; they represent the locations of oil contamination. The contaminated locations were detected in the brownish black, poorly sorted clayey sands Formation. The contamination have invaded to a maximum depth of about 4 meters.

The second layer, which have a thickness ranging from 6 to 15 m, shows apparent resistivity values ranging from 20 to 133 Ωm. This range of resistivity refers to the poorly sorted and medium to coarse sand formation (layer 2). The second layer shows no sign of contamination because of the distance from the spill source.

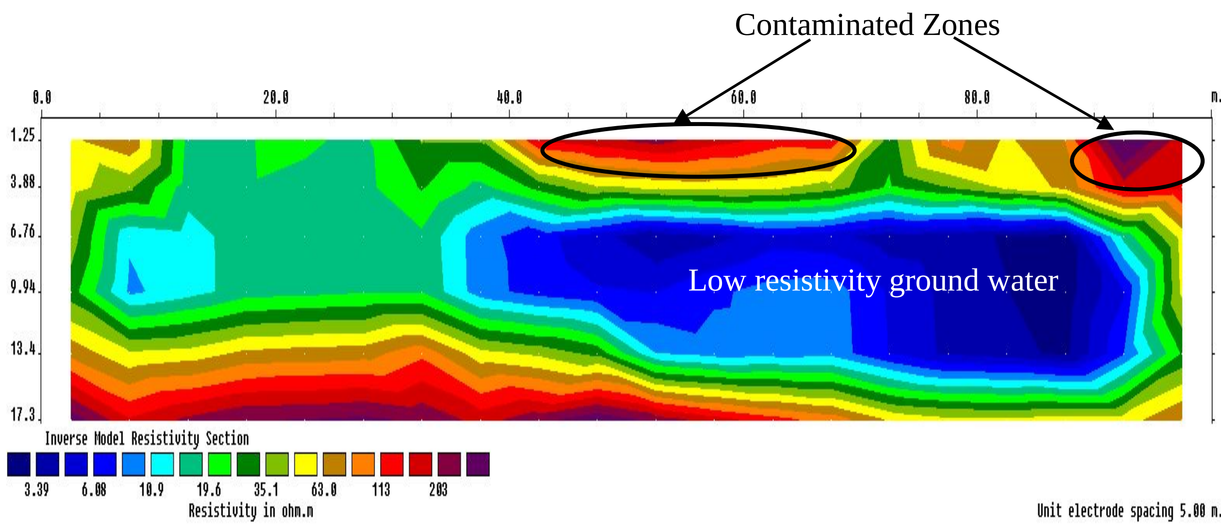

Fig. 6: Inversion result of profile 4.

The fifth profile was acquired at about 150m from the spill source. The inverse section of profile 5 sounding shows the appearance of three sorts of layers (Figure 7). The first is a layer of high resistivity ranging from 28 to 100 Ωm which represents a clayey sand formation and have a thickness ranging from 1.25m to 3.8m. Contamination is barely seen in this profile probably because of the distance from the spill source.

The second layer, which has a thickness ranging from 7 to 10 m, shows a range of resistivity from 24 to 98 Ωm. Due to the contamination being recent as well as to the high permeability of the formation, the ground water resistivity value is now relatively low.

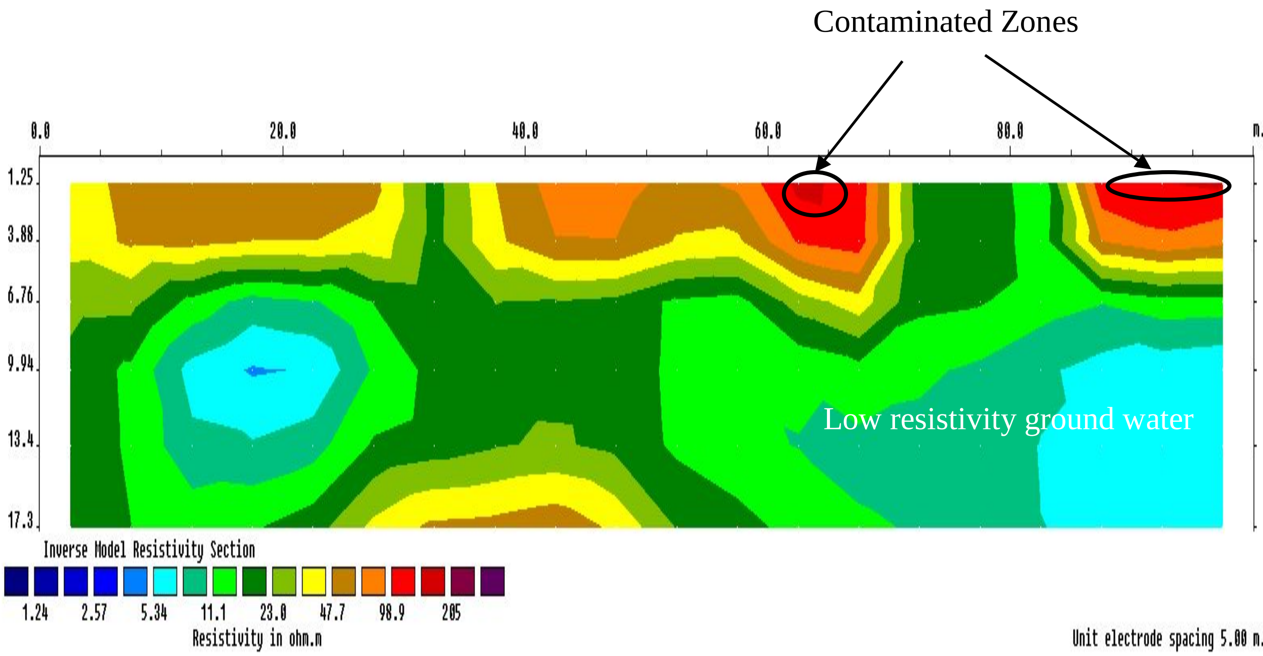

Fig. 7: Inversion result of profile 5.

Result from the 3D section (Figure 8) shows that contamination from the oil spill penetrated to a maximum depth of 8.63m cutting across 3 layers. Layer 1 with a total depth of 2.5 m is highly contaminated by the oil spill as pollution have taken over 2/3 of the surveyed area. Layer 2 with a total depth of 5.38 m is contaminated by the oil spill as well, pollution have taken over 1/3 of this layer in the surveyed area. Layer 3 with total depth of 8.68 m is partially contaminated by the oil spill as pollution is seen in spots. Layer 4 with total depth of 16.9 m shows no contamination plumes.

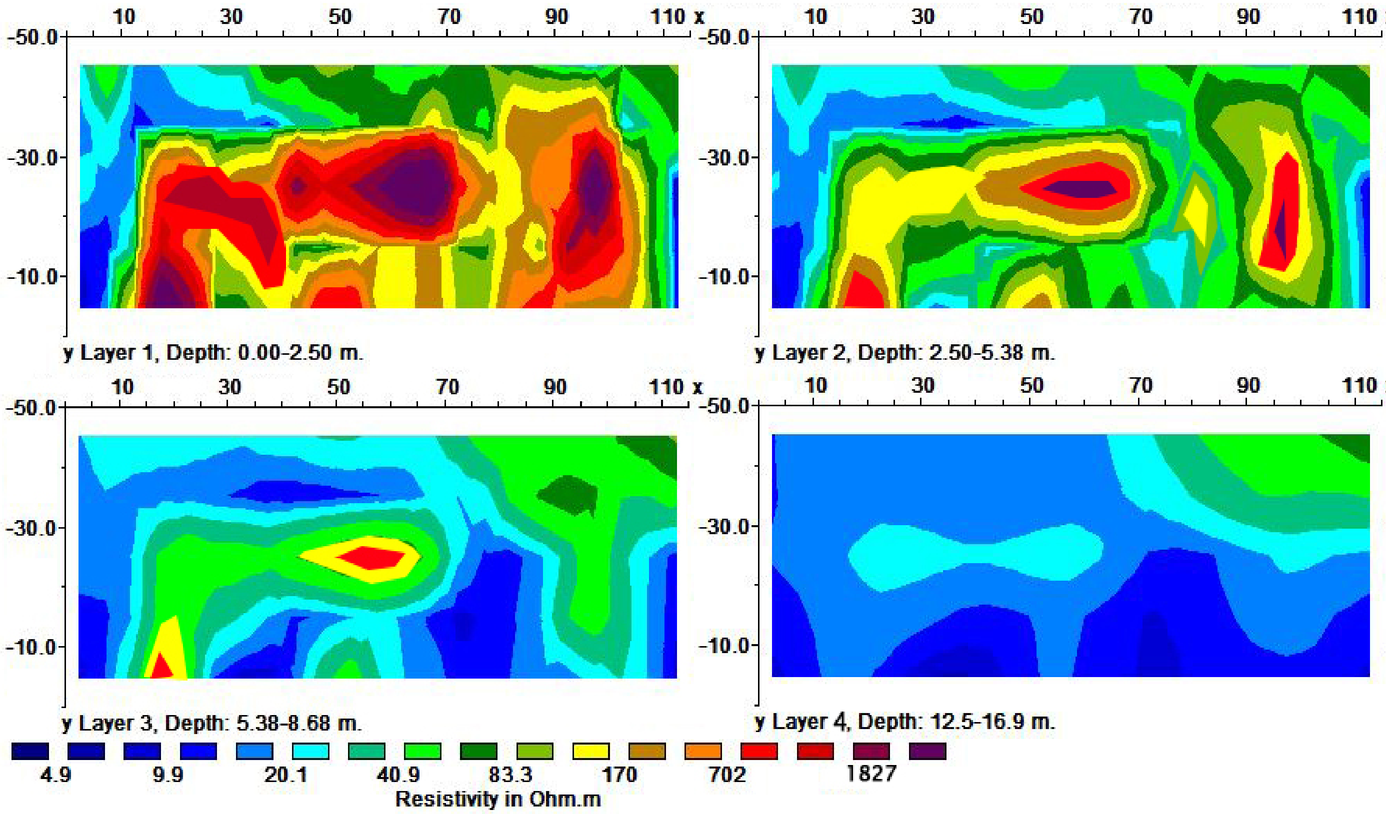

Figure 9 and 10 display results from the control unit taken 2.17kilometers away from the oil spill source. The result shows no contamination.

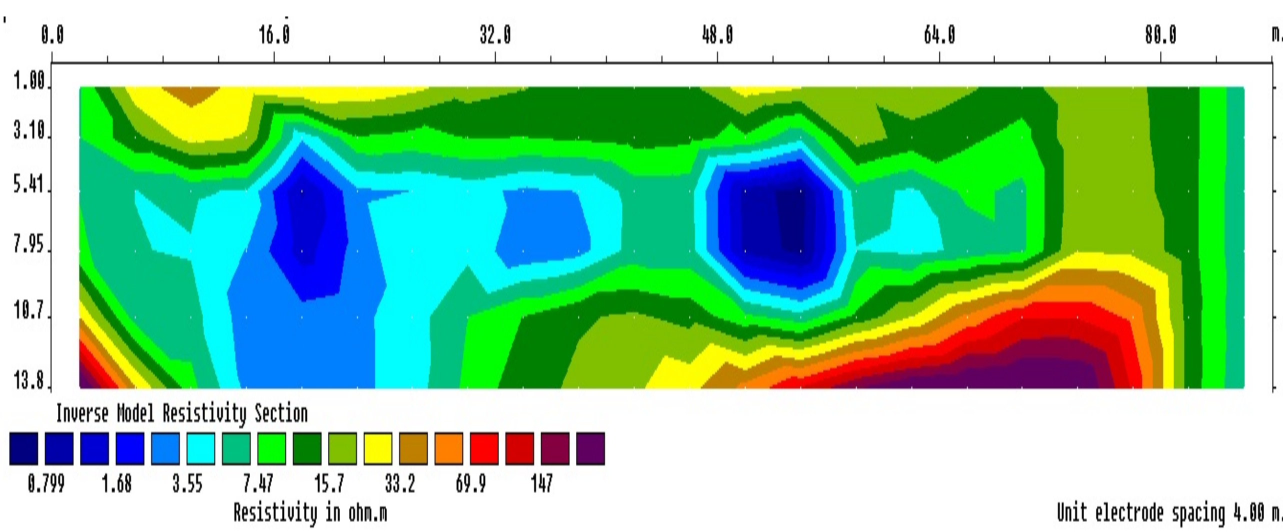

Fig. 9: Inversion result of profile 6.

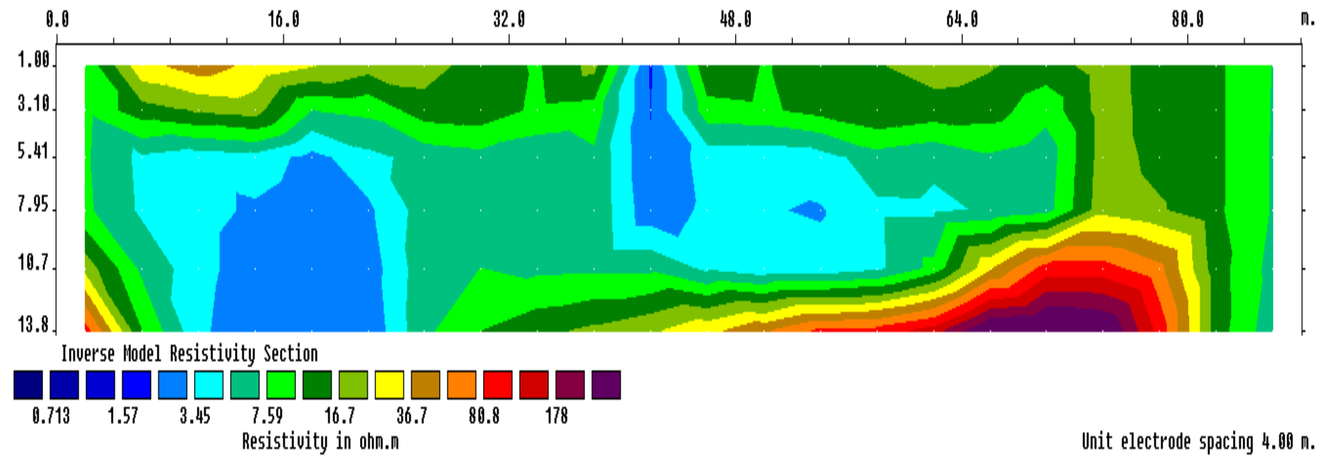

Fig. 9: Inversion result of profile 7.

Spatial Analysis using Geographical Information Systems

The spatial distribution maps for assessment of contamination in Orashi River using Arc GIS software in Arc tool box to generate surface map in spatial analysis tool using the inverse distance Weighted method IDW to assess the likely communities that will be affect due to the river flow from North to South and also using Arc Scene to produce 3D Modeling showing

pollution contamination route Thus, GIS enables us to look into the cause and effect relationship with visual presentation. From this study, depending on the results obtained from interpretation from the field data, a map was prepared showing the path and subsurface migration of the spilled crude oil, as shown in Figure 10. The migration of the spillage is in the dip direction. SW. flowing toward the blue colour which represent low attitude 7m to 11m.

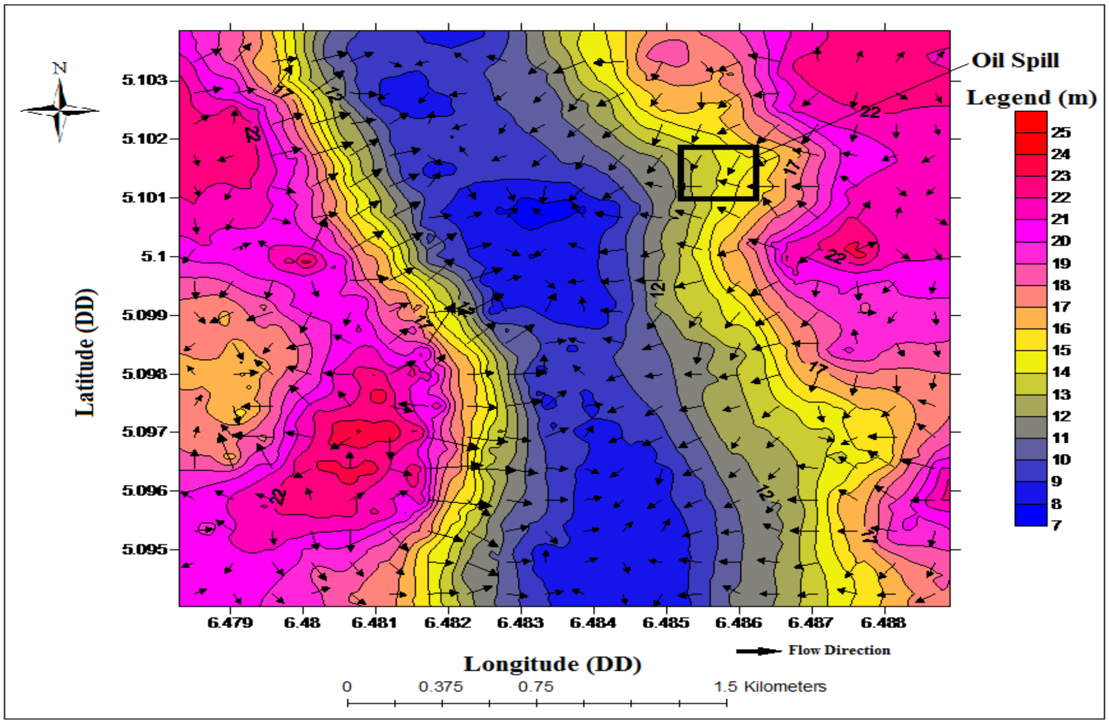

Fig. 10: 2D Map showing pollution contamination route.

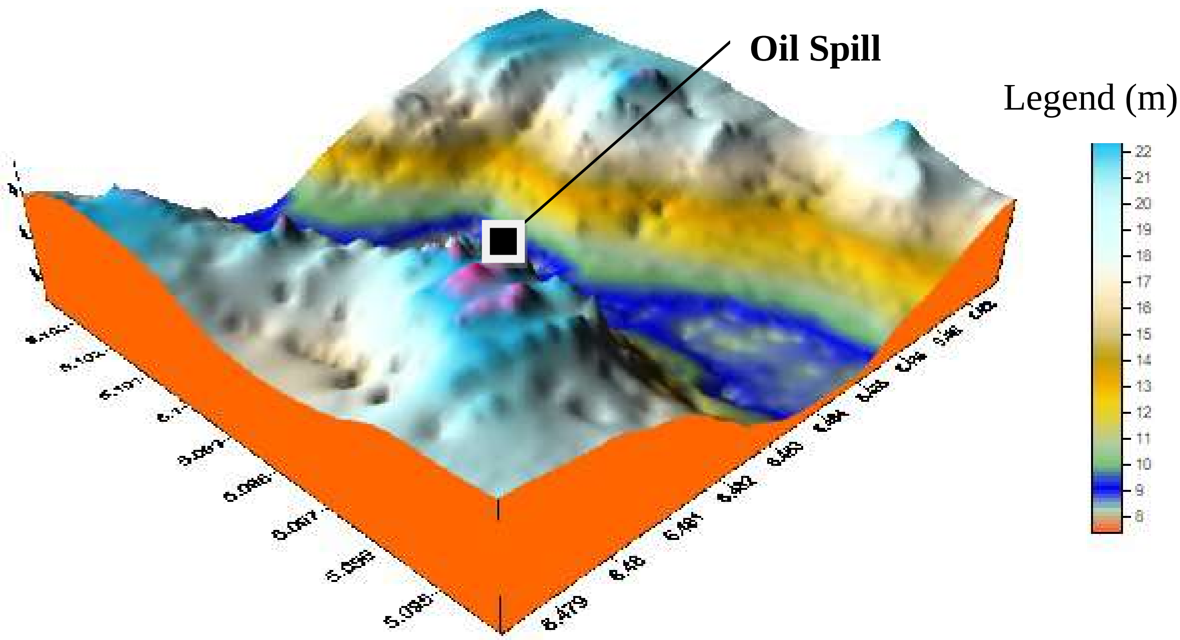

Fig. 11: 3D Modeling showing pollution contamination route

From Figure 11 Shows better image of how the terrain is generally in the area and direction of flow. The 3D Modeling indicate that the oil spill is flowing toward the Orashi River which have altitude 8 m to 13 m. This implies that the Orashi River is likely Polluted with Hydrocarbon and the Orashi river serves as a major source of drinking water, cooking and fish farming for not only to the people of Oshie community but to other neighboring communities sharing this river also. The communities likely to suffer for this contamination like Oshie, are Akinima, Mbiama, Akigbologbo ,Okarki etc.

CONCLUSIONS

2D resistivity imaging proved to be very effective for detecting the exact location of crude oil plumes of around 3 months duration. Subsurface images of good resolution were obtained using 5-metre electrode spacing. Contaminated zones were detected in layer 1, 2 and 3. The topsoil (Layer 1) consist of brownish black, poorly sorted clayey sands with depths ranging from 2 to 3 m. The results show that the contaminated zones correspond to high resistivity near the surface, with true resistivity ranging from 40 to 109 Ωm. Migration of the oil spill was detected moving through the dry sandstone and coarse formation of the first layer into the second layer.

The second layer, which has a thickness ranging from 2.2 to 5.38 m, displays resistivity ranging from 20 to 250 Ωm. It is a permeable layer and it does not prevent the vertical infiltration of crude oil. The Third layer with depth ranging from 5 m – 8.6 m is partially contaminated. Layer 4 shows no contamination plumes.

The crude oil migration is along the dip of the outcrops moving from the SW of the area and from the 3D modeling, it shows that the oil spill affect both River and shoreline communities sharing the Orashi River. so the government should try and stop oil sabotage in the area and endure there is provision for portable water and alternate source of income for people living along the Orashi River and proper oil spill clearing need to done in the area.

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