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Aquifer Delineation inOmuma Local Government Area of Rivers State, Nigeria Using Vertical Electrical Sounding Techniques

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***Abstract*:** *Nine Vertical Electrical Resistivity Soundings Were Conducted In OmumaLocal Government Area Of Rivers State, Nigeria Using Schlumberger Configurationto Delineate Groundwater Potential Aquifer Zones.TheData Acquired Were Analyzed And Interpreted With A RESISTSoftware, While The Subsurface Maps Were Generated Using SURFER8software. The Resistivity Range Of The Area Lies Between 25Ωm And 7356.5Ωm And A Maximum Depth Of 70m Was Penetrated. The Quantitative And Qualitative Analysis Delineates 4-5 Distinct Subsurface Geo-Electric Layers And Total Of Six Different Geo-Electric Curves Types Were Obtained;AKQ,KQQ,AK,HQ,KHK, And HK. Theaquifer Thickness And Iso-Resistivitymaps Delineated The Area Of Study Into Grade1,Grade11 And Grade111 Groundwater Potential Zones Base On The Aquifer Thickness And Resistivity Values Derived From The Survey. The Entire Southern Region and Few Parts Of The West Shows Good Prospect Of Underground Water With Aquifer Thickness Of 56m And Above. More So, The Study Shows That The Area Is Favored With Huge Amount Of Underground Water And The Result Can Be Used To Address Challenges Experienced Within The Area Such As The Drying Up Of Wells Especially During Dry Seasons.*

Keywords: *Vertical Electrical Sounding, Groundwater, Aquifer, Resistivity, Hydro-Geological*

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I. Introduction

Groundwater Is The Water Found Within The Saturation Region In The Subsurface And It Is Currently The Preferred Source Of Portable Water Which Has Been Selected Out Of The Other Sources To Be Reliable And Less Polluted. It Is From Where Runoffs, Wells Are Recharged From; They Are Retained By Formations In The Subsurface.Many Researchers Has Used Electrical Resistivity Surveys For A Wide And Diverse Application Apart From Its Unique Applications In Geological, Mining And Geotechnical Investigations And Today It Plays Majority Roles In Environmental Studies [1].A Work On The Geo-Electric Characterization Of A New Development Area Focusing On Greater Port Harcout, Phase1 Was Done In Rivers State, Nigeria[2]. In Umuahia And Environs, Geoelectric Data Was Used To Study The Hydro-Geophysical Characteristics Of Imo River Basin [3]. Groundwater Resource Development In The Niger Delta, Its Problems And Prospects Was Also Examined In Details[4].The Study Area Is Filled With Completed, Failed And Abandoned Dug Wells Which Were Awarded To The "So Called Contractors" By Either Government, Non-Governmental Organizations Or Individuals, And Most Of These Contractors Are Unprofessional That Assumes Thatsince The Niger Delta Is Favored With Enormous Groundwater, That Pre-Drilling Investigation Is Not A Pre-Requisite For Groundwater Exploitation. This Assumption Is One Of The Reasons Why The Study Area Is Covered With Numerous Abandoned Water Projects. There Are Numerous Reasons Why We Have Failed Boreholes Which Includes Inadequate Or No Hydro-Geologic Information Before Drilling, Poor Knowledge Of Personnel During Drilling And In Most Cases, Wells Dug Are Not Developed Properly [5]. The Minimum Amount Of Borehole In Each Of The Villages Is Three And Despite The Numerous Amounts Of Wells Availabe, The Populace Still Relies On Surface Water As Their Source Of Portable Water With A Reason That The Water From Most Wells Either Has Dissatisfying Taste, Drying Up Or Dropping To Minimum Yield During The Dry Seasons Which Can Be Attributed To Lack Of Hydro- Geological Information [6]. Hence, This Research Is Necessary Because A Logical And Technical Method Is Required If These Challenges Within The Area Is To Be Prevail Over [5].

II. Location And Geology Of The Study Area

The Study Area Is Omuma Local Government Area (Figure 1) Bounded With A Geographical Coordinates That Lies Between Latitude $05^{0}09^{I}27.3^{ii}$north And Longitude $007^{0}13^{I}08.21^{II}$ East. It Is Situated On The Coastal Plain Of South Eastern Nigeria, Underlain By The Benin Formation [7]. ItIs In South Eastern Niger Delta Basin Surrounded At The North By Imo State, East By AbiaState, And South By EtcheLocal Government Area. ItForms Part Of Niger Delta Complex With The Usual Benin Formation And Low Land Zones Of

South- Eastern Nigeria. The Niger Delta Covers Most Areas Of Rivers StateIncluding Omuma Local Government. It Is Made Up Of Extensive Riverrine Area All The Way Through Which The River Niger Links The Atlantic, Divided Into Several Distribution Which Empty In The Sea.The Deltaic Plains Consists Of Sands That Are Not Consolidated, And The Sizes Of Grains Ranges From Coarse To Medium Forming Lenticular Layers With Intercalation Of Peaty Matter Andlenses Of Soft, Silt Clay And Shales. Gravelly Layers That Make Up To About 10m In Thickness Have Been Recorded . The Uppermost Sediments Are Aerated, Made Up Sandstones That Are Not Consolidated And Have A Extremely Unpredictable Thickness All Over The Zone. Benin Formation That Is Sandy And Are Well Connected To Allow Easily Passage Of Water, The Lying On Top Of The Laterite Earth And Unconsolidated Top Of The Formation Coupled With The Shale Beneath That Makes Up The Bende – Ameki And Ogwashi – Asaba Series Provide The Conditions Hydrologically That Favours The Formation Of Acquifer In The Locality [7].

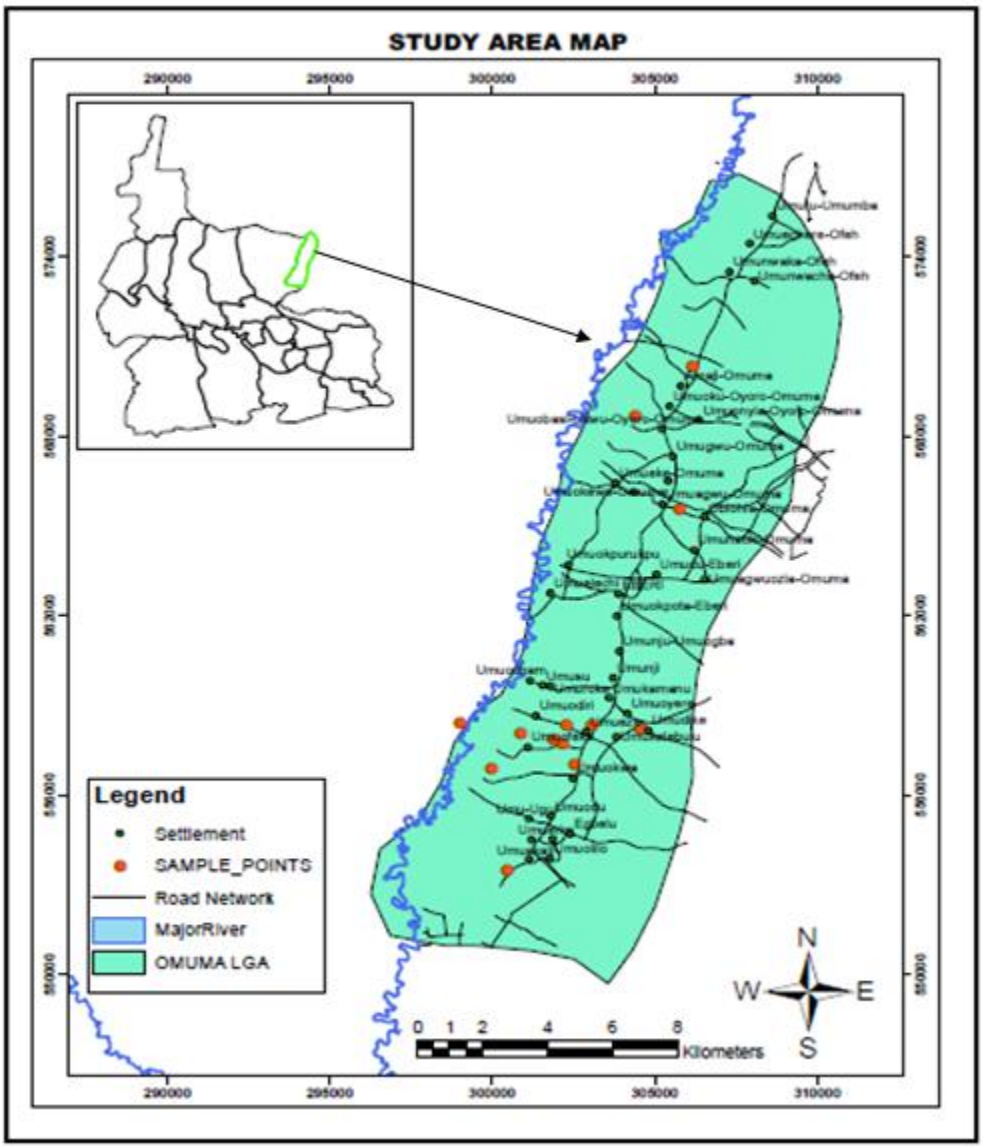

Figure 1: Map of the study area

III. Materials And Methods

Variation Of Electrical Resistivity Was Investigated In The Work With The Help OfVertical Electrical Soundings (VES) Technique Withschlumberger Configuration. BothWere Instrumental During The Stage Of Acquisition Of Data At Each Station In The Areas Of Interest. The Trend In Which Resistivity Varies Within Penetrated Formations Will Be Crucial In Describing Dissimilar Layers Of Formation With The Aid Of ABEM SAS 300 Terrameter. The Study Areais A Very Small Area, Therefore The Selection Of VES Station Was Not At Random, But To Ensure That Parts In The Three (3) Clans That Make Up The Local Government Is Sampled During The Survey. Nine (9) VES Points Were Selected And With 300 – 400m As The Maximum Range For

The Electrode Spread.During Field Measurement, The Resistance (R) Of The Penetrated Formations That Falls Within The Electricalspace Of The Electrode Configuration Was Recorded By The Terrameter, Compared And Converted To Apparent Resistivity Values By Multiplying It With The Geometric Factor (K) For Schlumberger Such That:

$$\rho_a = \text{KR} \quad (1)$$

Where,

$$\text{K} = \pi\left(\frac{a2}{b} - \frac{b}{4}\right) \quad (2)$$

Hence

$$\rho_a = \pi\left(\frac{a2}{b} - \frac{b}{4}\right)\text{R} \quad (3)$$

The Set Of Apparent Resistivity Values Versus Half Current Electrodes Were Plotted With Half Current Electrodes Spacing To Generate Geo-Electric Curves Through Computer Iteration (Resist) Interpretation Software To Obtain The Geo-Electrical Parameters. The Electrodes Array Was Laid Along Each Transect And Readings Were Taken At Three To Four Hundred Meters. Since We Have Different Electrode Spacing, Different Readings Were Also Taken.During The Survey, Potentialelectrodes Were Generally Kept Small And Fixed While Only The Current Electrode Spacing Is Expanded Outward After Every Reading. However, When A Large Output Is Obtained Relative To The Ratio Of The Distance Between AB, That The Potential Difference Becomes Difficult To Measure, The Potential Electrode Is Changed. The Ratio Of Spacing Within AB And MN May Be Taken As 5:1 [8][9]. Hence, Since The Local Surface Resistivity Variations At The Potential Electrode Can Cause Irregularities In The Apparent Curve, It Is Claimed That The Schlumberger Configuration Produces Smooth Data [5] And It Has Practical, Operational And Interpretational Advantages Over Other Methods [8], While The Subsurface Maps (Aquifer Thickness And Iso-Resistivity Map) Were Generated Using The Result Obtained From Survey Together With The Coordinates Of The Area With The Aid Of A SURFER8 Package.

IV. Results And Discussion

Nine Vertical Electrical Soundings Were Conducted In The Study Area To Ascertain The Groundwater Potential Of The Area. The Data Acquired Was Analyzed And Interpreted Using Curve Matching Techniques With A WIN-RESIST Software And The Results Obtained Were Summarized And Presented In Table 1.The Study Area Showed Six Geo-Electric Curve Types (Figure 2) With AKQ Prevalent: AKQ(3),AK(2), HQ, HK, KQQ And KHH (Table1**).** The Topmost Layer Consists Mainly Of Humid And Dry Clay Sand With Resistivity Ranges Of 25.6 – 1242.6ΩmAnd A Thickness Of 0.5 – 2.8m. The Second Layer Is Predominately Coarse SandsAnd Has Resistivity Range Of 158.7- 7356.5ΩmAnd A Variable Thickness Range Of 4.2 – 18.6m. Third Layer Has A Drop In The Resistivity Value From The Previous Layer To A Range Of 228.7 – 3785.5ΩmAnd A Good Thickness Range Of 8.5 – 49.8m Which Is Mainly A Sandy Formation.The Fourth Layer Consist Of Clayey Sand And Fine Grain Sand With A Little Trace Of Coarse Sand (VES 5) And Resistivity Ranges From 100.9 To 3655.1Ωm And A Thickness Of 11.2m To 56.0m. The Fifth Layer Which Is The Last Layer Of The Investigation Consist Of Medium To Coarse Grain Sand With Resistivity Value Between 111.4Ωm To 5158.4Ωm And An Undefined Thickness. This Is Estimated To Be The Prolific Aquifer In The Study Area As It Contains Good Quality Groundwater.

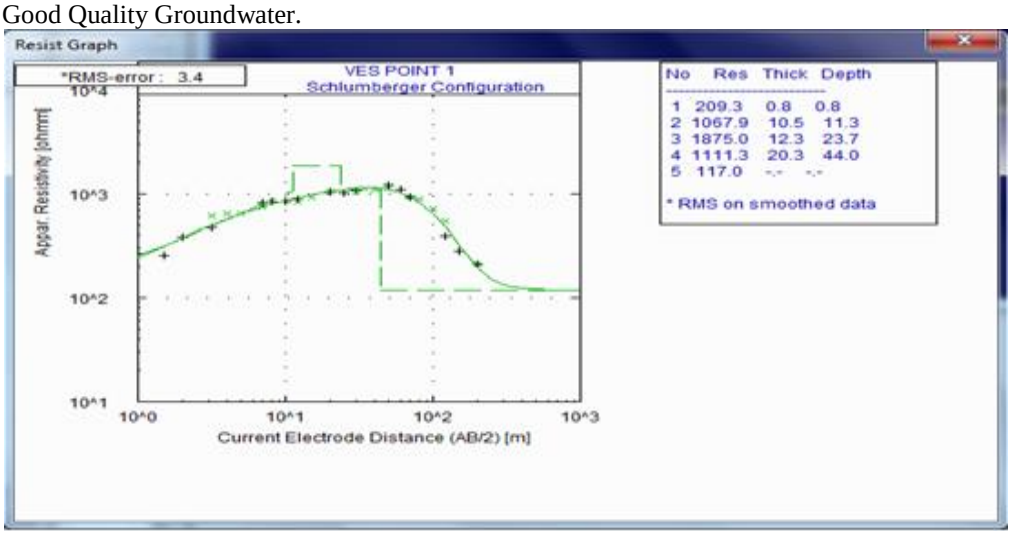

Figure 2: Typical modeled five layered vertical electrical sounding curves

Table 1.Summary of vertical electrical sounding results and curve types

VES	COORDINATE		RESISTIVITY (ohm-m)					THICKNESS(m)				DEPTH (m)				LAYER	CURVE TYPE
	NORTHINGS	EASTINGS															
1	559537.2	304540.8	209.3	1067.9	1875	1111.3	117	0.8	10.5	12.3	20.3	0.8	11.3	23.7	44.0	5	AKQ
2	560421.3	306865.5	423.1	7356.5	968.9	392.5	188.6	1.4	7.1	8.5	26.0	1.4	8.5	17	43	5	KQQ
3	564015.1	302544.5	83.2	1669.5	1639.2	736.9	-----	2.0	18.6	49.2	----	2.0	20.6	69.8	-----	4	KQ
4	560091.3	301752.4	777.5	5670.1	679	3655.1	831.5	1.6	5.2	14.3	42.2	1.6	6.8	21.1	63.3	5	KHK
5	564645.3	282482.7	578.4	777.8	2710.4	1012.6	----	2.8	11.8	44.5	----	2.8	14.6	59.1	----	4	AK
6	564379	304470.5	420.5	780.8	3147.4	529.2	168.8	0.5	11.5	19.9	19.3	0.5	12	31.9	51.2	5	AKQ
7	568564.8	305229	1242.6	666.6	3785.5	1198.2	----	1.3	4.2	18.3	----	1.3	5.5	23.8	----	4	HK
8	562642.4	302058.1	430.7	668	1848.6	545.5	111.4	0.7	4.9	18.9	39	0.7	5.6	24.5	63.5	5	AKQ
9	563267.2	305498.8	25.6	158.7	228.7	100.9	----	2.3	8.3	49.8	----	2.3	10.6	60.4	---	4	AK

4.1Aquifer Units Thickness Map

Aquifer Thickness And The Iso-Resistivity Maps Of The Study Area Were Generated Using Both SURFER8 Software And Values From Table 2. One Major Application Of Aquifer Thickness Map Is Where Ranking Of Geology Is Concerned, Because Good Volume Of Water From A Vertical Electrical StationIs Dependent On The Thickness Of The Aquifer[9].The Area Of Study Can Be Classified As Grade 1, 11 And 111 Groundwater Potential Zones Which Are Demarcated With Three Different Colors (Figure 3). The Areas That Falls Under Grade1 Groundwater Potential Zones Are Colored Green And They Are Areas That Corresponds To The Highest Aquifer Thickness With Values Of 56m Above And Majority Of The Study Area Is Observed To Fall Within This Zone Most Especially The Entire South And Few Areas In West.Grade11 Groundwater Potentialzones Are Demarcated With A Red Color And They Have A Range Of Values Of Aquifer Thickness Of 40m To 54m. Few Parts Of The North-East And North-West Fall Under This Zone And They Have Intermediate Aquifer Thickness Values.Grade111 Groundwater Potential Zones Falls Within Aquifer Thickness Range Of 40m And Below Which Implies That They Are Zones With The Lowest Aquifer Thickness, And Are Low Saturated Zones With Poor Water Potentials Demarcated With A Yellow Color. Parts OfNorth-East And North-West Fall With This Zone.

Table 2: Subsurface map parameters

VES Station	Northings	Eastings	Aquifer Depth (m)	AB/2 = 150m
1	559537.2	304540.8	44	280.4
2	560421.3	306865.5	43	250
3	564015.1	302544.5	69.8	1361.7
4	560091.3	301752.4	63.3	1793.1
5	564645.3	282482.7	59.1	1319.5
6	564379	304470.5	51.2	570.2
7	568564.8	305229	23.8	664.5
8	562642.4	302058.1	63.5	487.9
9	563267.2	305498.8	60.4	167.5

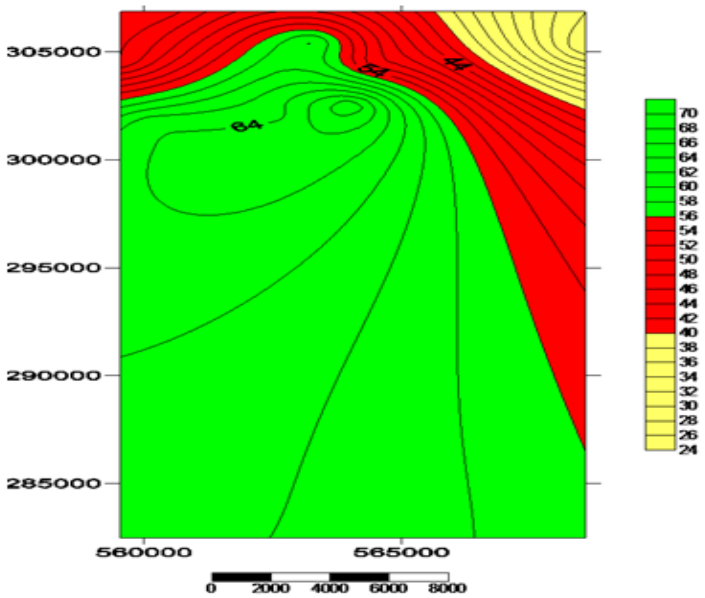

Figure 3: Aquifer thickness of the study area

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4.2Iso-Resistivity Map

Apparent Resistivity At 120m Spacing Ranges From 100 – 2700m And The Corresponding Map Is Presented In Figure4 With An Interval Of 100m. Almost Allareas In The Study Area Showed Very High Apparent Resistivity Values Except For Parts Of North–West And North-EastWhere Low And Intermediate Apparent Resistivity Values Were Observed. The Areas Color Coded Dark Green Represents The Highest Apparent Resistivity Observed Zones (1700 To 2700m) And They Are Areas That Have Very Good Groundwater Potentials And Which Coincide With The Grade1 Groundwater Potential Zone Which Entails That They Also Have Good Aquifer Thickness And The Possibility Of Finding Groundwater With The Areas Are Very High. The Areas Demarcated With Light Green Color Represents Zones With Intermediate Apparent Resistivity Values With Range Of 700 - 160m While The Remaining Areas Colored With Brown Indicates Areas That Has The Lowest Apparent Resistivity Values And They Are Very Low Groundwater Potential Areas. Both Zones Also Coincides With Grade 11 And 111 Of Groundwater Potential Zones Respectively.

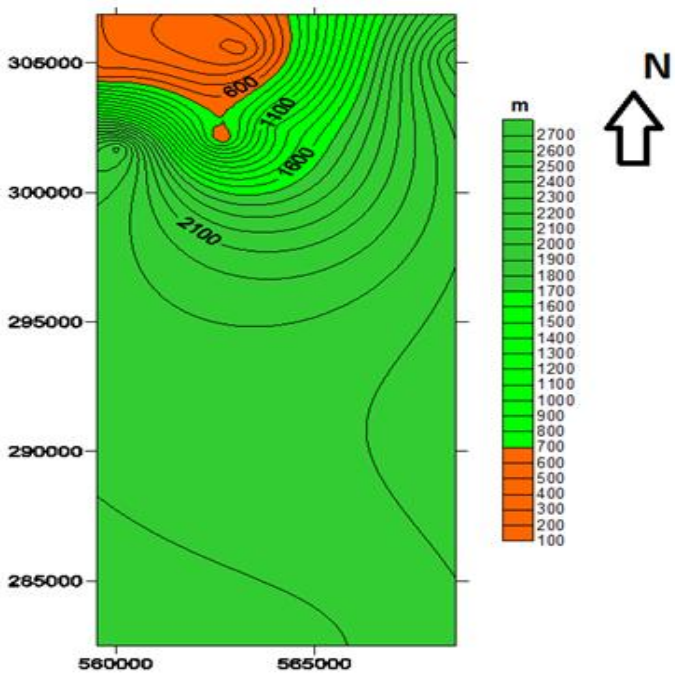

Figure 4: Iso-resistivity map at AB/2=120m

V. Conclusion

Electrical Resistivity Survey Hashelped To Delineate And The Study Area Into Three Potential Zones: Grade 1, 11 And 111groundwater Potential Aquifers Producing. Also The Subsurface Maps Indicate Good Prospects For Groundwater Development In The Study Area. The Productive Groundwater Potential Zones Are Identified At The Southern, EasternAnd WesternParts, While Few Areas In The Northern Part Indicated Low Apparent Resistivity And Aquifer Thickness Values. It Is Worthy To Note That Despite The Slight Differences Observed In The Low Potentials Zones, Groundwater Can Still Be Exploited Within The Zone, But The Difference Will Be The Thickness Of The Aquifers.

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