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GROUNDWATER POTENTIALS IN THE OFFSHORE NIGER DELTA ENVIRONMENT, NIGERIA

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Oil and allied companies whose activities are predominantly located offshore of the Niger Delta are known to encounter the ever recurring problem of potable water supply to meet offshore operational requirements. A technical study was commissioned to look at the possibility of drilling a potable water borehole at the offshore location of one of the oil companies in the Niger Delta. The Niger Delta water resources are drawn mainly from the Eastern littoral hydrological and the Niger South hydrological zones. Infiltration and percolation processes from these broad recharge networks flow southwards into the underlying aquifers of Benin Formation beneath the Continental Shelf. The results of this study show that a depth range of 1,000-1,250 ft is a suitable zone for screening the borehole to obtain potable water for offshore operations.

INTRODUCTION

Experience shows that oil companies whose activities are predominantly located offshore of the Niger Delta Area (Figure 1) are known to encounter the ever recurring problem of potable water supply to meet offshore operational requirements. In 2006 a near water crisis situation at the offshore locations led an oil company to carry out an in-house study to find an enduring and cost effective solution to the problem and the following options were proposed:

1. Use of water processing plant to process sea water to potable water.
2. Use of service boat to supply potable water from shore to offshore locations.
3. Drilling of potable water borehole close to the location.

For a rational decision to be taken, the various options for the offshore supply of potable water were tested using a set of objective criteria for selecting the most preferred (or viable) choice. To make the analysis easy, a set of four objective criteria were assumed:

· Reliability of Supply Source: The reliability of supply source was measured by the frequency of possible breakdown or disruption of the supply source.

· Convenience of Supply Source: This was determined by how readily potable water can be consistently obtained without undue difficulty.

· Quality of Source: The quality of source was determined by how safe the source of potable water is for human consumption.

· Financial Outlay: The financial outlay was determined by the ability to accommodate the source of potable water within company budget.

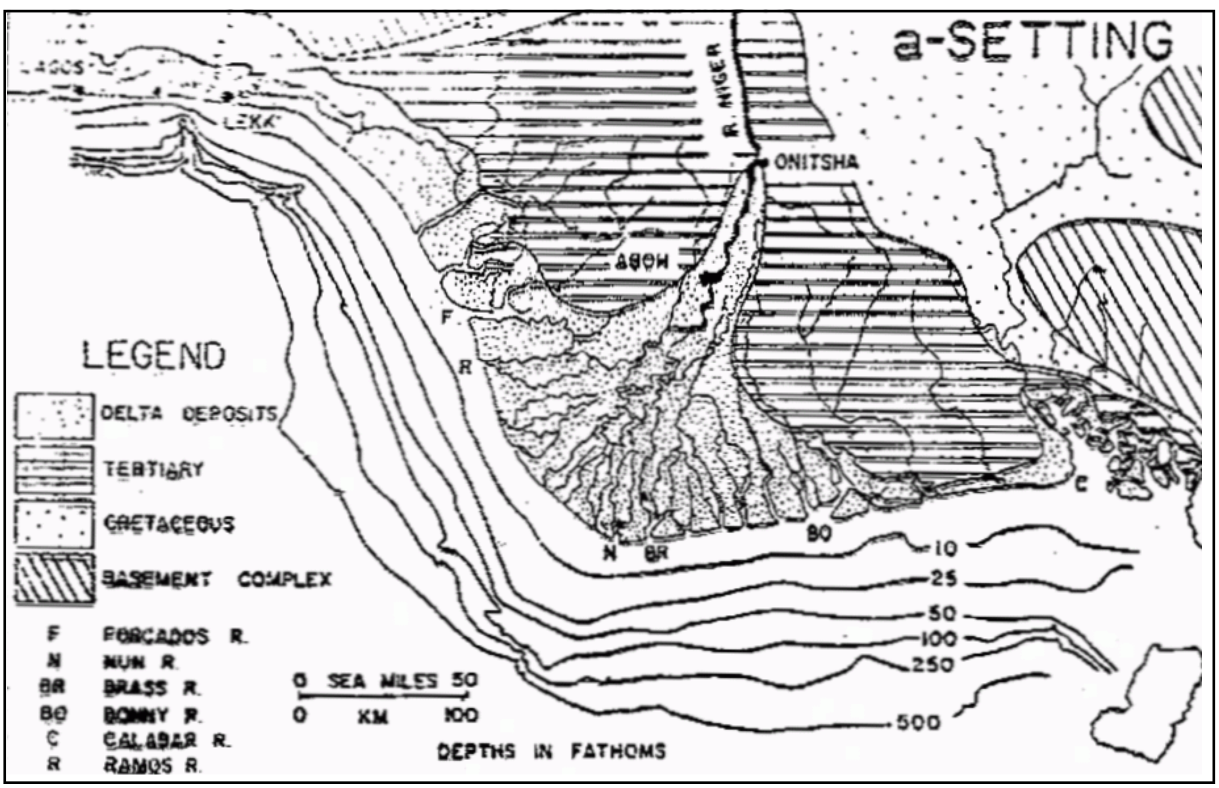

Figure 1. Map of Niger Delta showing offshore environment.

These objective criteria were integrated with the three major sources of potable water supply mentioned above to build a decision model used for evaluating the relative preference for any choice. The decision model shows that drilling potable water borehole offshore is an attractive option when viewed on all the four characteristics.

Based on the above recommendations, a technical study was commissioned to look at the possibility of drilling a potable water borehole at the offshore location for the company.

One of the major problems faced by this study was the issue of depth of screening of such a well to avoid the problem of salt water intrusion. In tackling the depth question, inferences were drawn from the theoretical foundation provided by notable authorities on groundwater resources. The results of the empirical studies are presented.

THEORETICAL FRAMEWORK

The Niger Delta Water resources are drawn mainly from the Eastern littoral hydrological and the Niger South hydrological zones. Infiltration and percolation processes from these broad recharge networks flow southwards into the underlying aquifers of the Benin Formation beneath the Continental Shelf (submerged part of the continent, Figure 2).

Both the structural and stratigraphic setting of the Niger Delta favors hydraulic gradient flow towards the coast, and hence into the Continental Shelf. This forms the basis of most fresh water aquifers located within this Continental Shelf (Figure 3). Studies by Clifton et al. (1971), Hoyt and Weimer (1963), and many others confirm a characteristic seaward dipping of geosynclinal basins like the Niger Delta.

The issue of the shape of the fresh-salt water interface in the coastal aquifers is discussed by many, and notable among them is the Ghyben–Hertzberg relation. However, recognizing the approximations inherent in this relation, more exact solutions for the shape of the interface have been developed from potential flow theory (Charmonsman, 1965; Cooper et al., 1964). The result has this form:

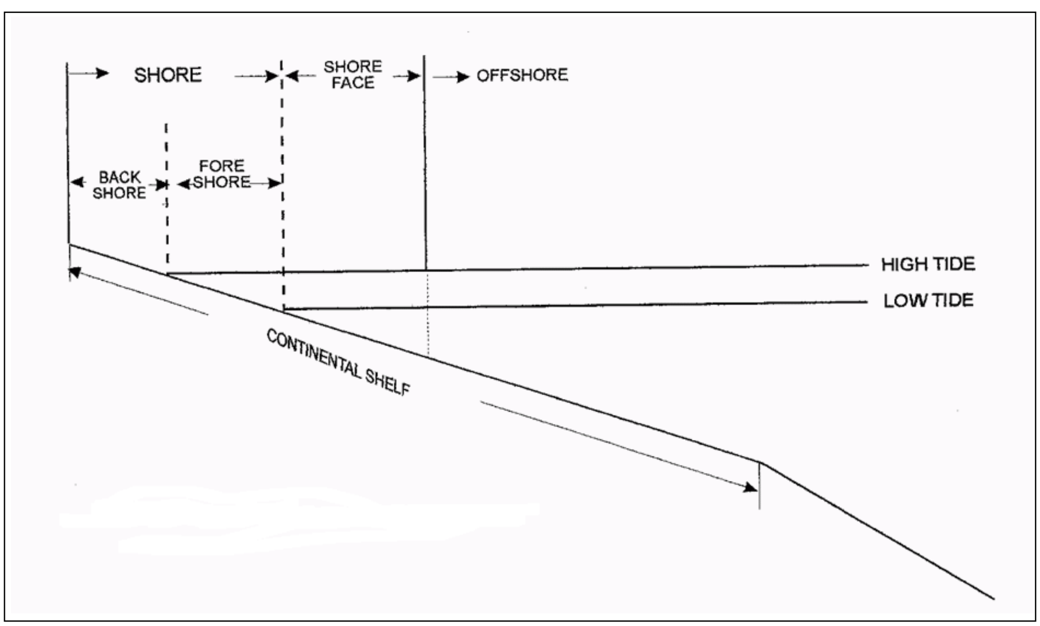

Figure 2. Sketch showing offshore zones.

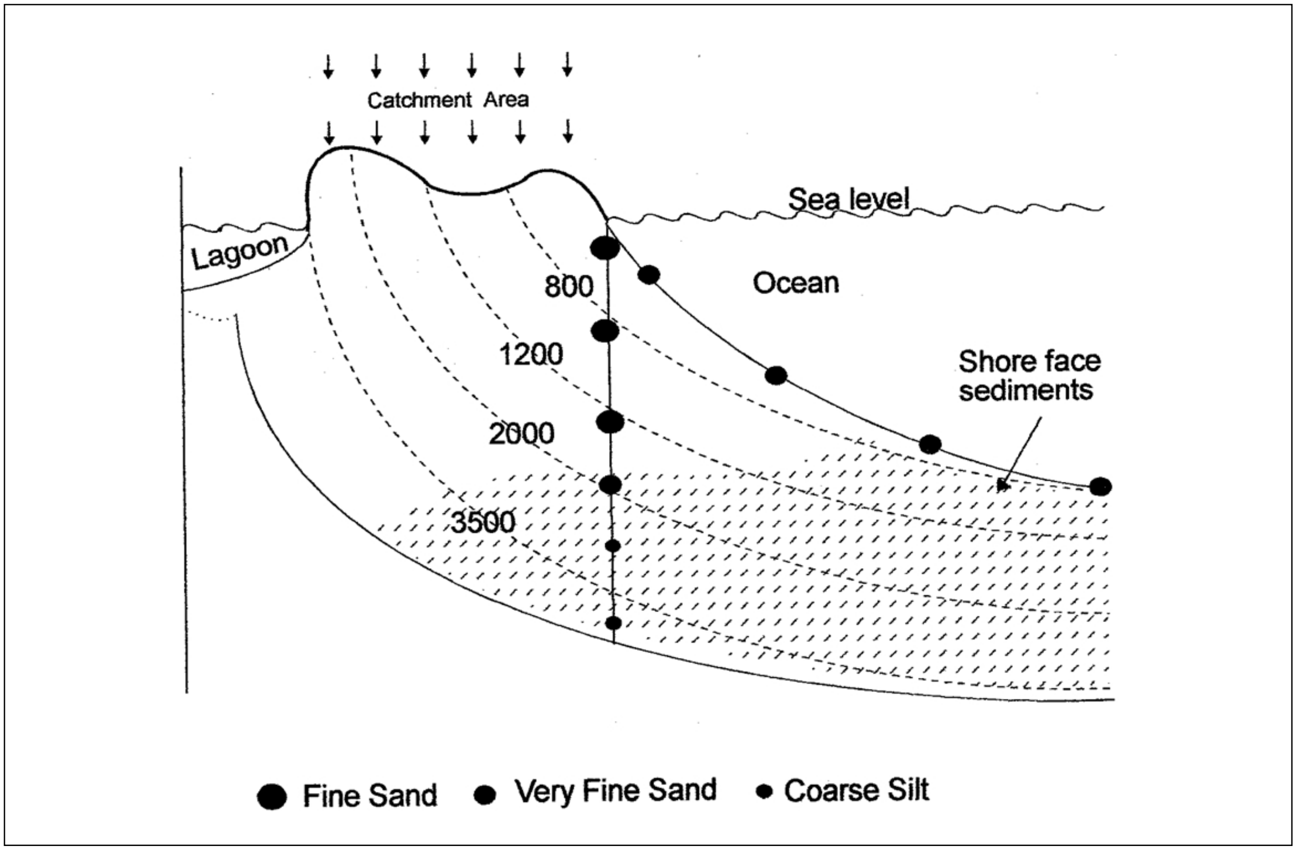

Figure 3. A prograding barrier island showing catchment area relation with continental shelf aquifer.

$$Z^2 = \frac{2eq^x}{\Delta ek} - \left(\frac{eq}{\Delta ek}\right)^2 \tag{1}$$

where Z and X are as shown in fig. 4

$\Delta e = e_s - e_f$

e_s = density of saline water, e_f = density of fresh water

k = hydraulic conductivity of the aquifer

q = fresh water flow per unit length of shoreline.

The corresponding shape for the water table is then given by

$$hf = \left[\frac{2\Delta eq^x}{(e+\Delta e)k}\right]^{1/2} \tag{2}$$

The width X_0 of the submarine zone through which fresh water discharges into the sea can be obtained for

Z = 0, yielding

$$X_0 = \frac{eq}{2\Delta ek} \tag{3}$$

The depth of the interface beneath the shoreline Z_0 occurs where $X = 0$ so that

$$Z_0 = \frac{eq}{\Delta ek} \tag{4}$$

In the field this interface is not as sharp as shown in Figure 4; rather there exists a brackish transition zone of finite thickness separating the two fluids. In the case of a confined aquifer, there exists a zero interface with sea water. In general, the near absence of boreholes at the coastal environments and the corresponding little impact on flow means there is little or no impact on the transition zone.

EMPIRICAL SURVEY

Given the strong theoretical support for the existence of fresh water aquifers offshore, a thorough analysis of the resistivity of groundwater from offshore and backshore wells for depths between 100 – 3,500 ft along the Niger Delta Continental Shelf was made based on their total dissolved solids and resistivity, Tables 1a and 1b.

The resistivity concentration curves for these wells were plotted as shown in Figure 5. In relatively porous formations, the resistivity is controlled more by water content and quality within the formation than by the rock resistivity. For aquifers composed of unconsolidated materials, the

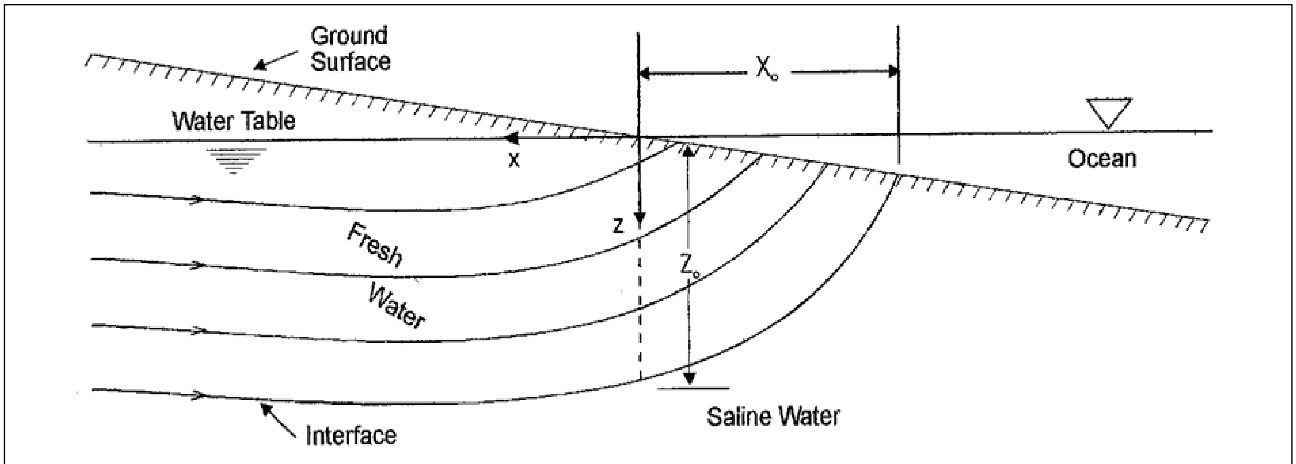

Figure 4. Flow pattern of fresh water in an unconfined coastal aquifer.

Table 1a. Total dissolved solids (T.D.S.) concentration with depth.

Depth (ft)	T.D.S. mg/l	Depth (ft)	T.D.S. mg/l	Depth (ft)	T.D.S. mg/l
100	360	1300	497	2500	2,560
200	395	1400	580	2600	3,740
300	525	1500	650	2700	3,850
400	535	1600	874	2800	3,890
500	560	1700	920	2900	4,080
600	562	1800	960	3000	4,540
700	540	1900	1,200	3100	4,650
800	548	2000	1,350	3200	4,750
900	538	2100	1,540	3300	4,882
1000	397	2200	1,790	3400	4,890
1100	479	2300	2,320	3500	4,950
1200	492	2400	2,440	3600	-

Table 1b. Resistivity with depth.

Depth (ft)	Resistivity Ohm-m	Depth (ft)	Resistivity Ohm-m	Depth (ft)	Resistivity Ohm-m
100	56.73	1300	50.23	2500	13.65
200	49.50	1400	28.95	2600	13.45
300	16.56	1500	25.56	2700	12.92
400	16.85	1600	22.25	2800	12.85
500	17.95	1700	20.45	2900	12.35
600	19.86	1800	16.94	3000	11.68
700	23.55	1900	16.56	3100	11.45
800	28.25	2000	15.65	3200	11.45
900	47.34	2100	15.32	3300	11.02
1000	124.00	2200	14.82	3400	10.89
1100	120.56	2300	14.28	3500	10.47
1200	115.45	2400	13.92	3600	-

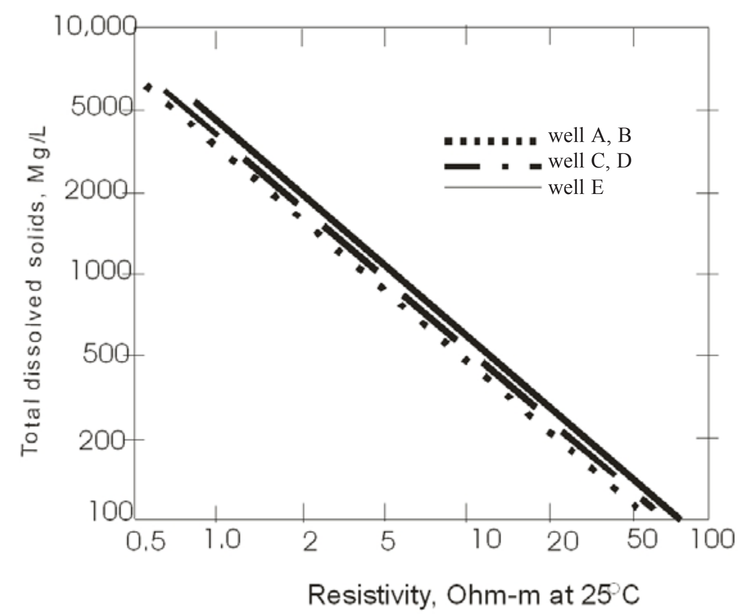

Figure 5. Resistivity concentration curves from a few of the analyzed borehole waters.

resistivity decreases with the degree of saturation and the salinity of the groundwater.

Again, looking at the specific conductance of these resistivity logs, total dissolved solids for the aquifers were also estimated and plotted as percentage of relative salinity, (SR) Figure 6.

The result here shows a similar linear trend with a 50% value of relative salinity (SR) representing the midline. The highest salinity value at depth 3,500 ft was approximately 4,950 mg/l. However, a small window exists at depths from 1,000 to 1,200 ft where the salinity drops before another rise from depth 900 to 100 ft.

The 10% value of 495 mg/l corresponds to this window at a depth of 1,250 ft. Therefore, the range of 1,000 – 1,250ft was chosen as a suitable zone for tapping good groundwater.

CONCLUSIONS

Geoelectric investigation of the groundwater potentials of the offshore environment has yielded data interpretable in terms of total dissolved solids (TDS) and percentage relative salinity.

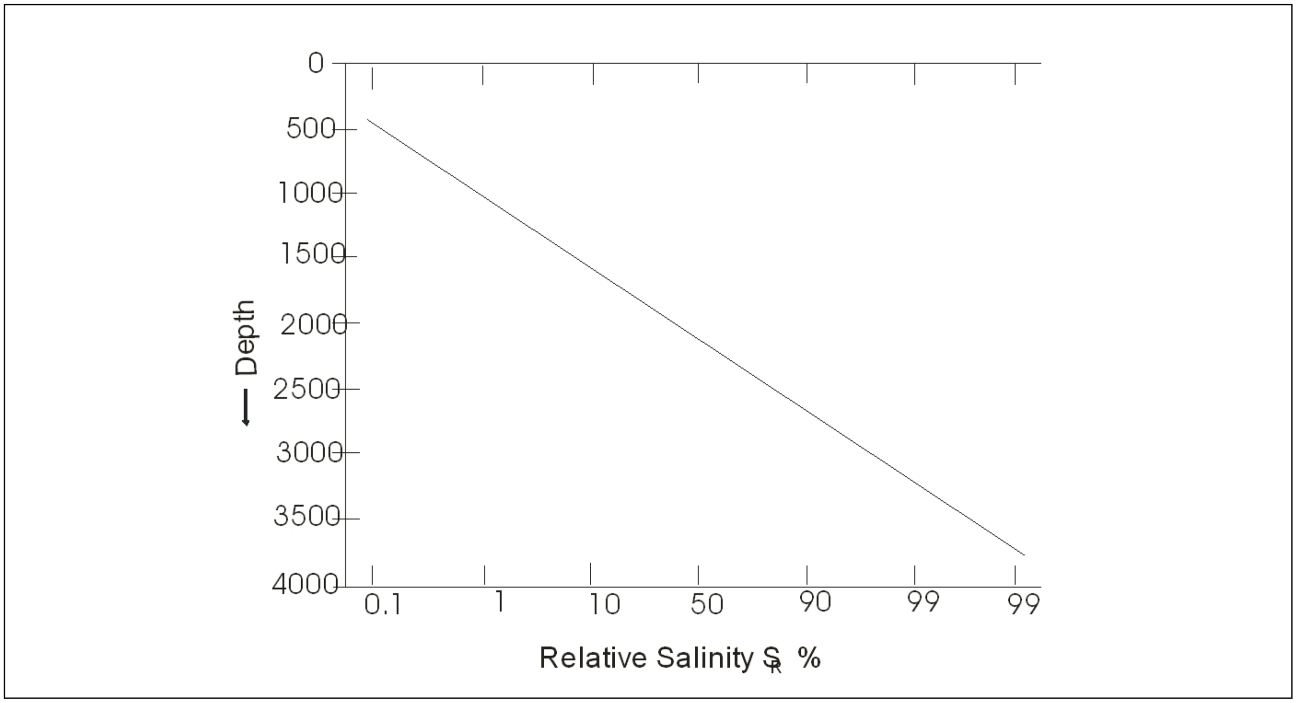

Figure 6. Increase in salinity with depth through the transition zone.

It is pertinent to note however, that this study forms a partial picture of the hydrological parameters of the area. One salient feature of the results is the near uniformity and consistency of aquifer characteristics of the area.

It is concluded that, given the strong theoretical support for the existence of fresh water aquifers offshore, a thorough analysis of the resistivity of groundwater from offshore and backshore wells for depths between 100 – 1,250 ft along the Niger Delta Continental Shelf should be based on total dissolved solids, ionic concentration and relative salinity.

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