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# ANALYSIS OF WATER TABLE MOVEMENT FOR FLOOD MITIGATION IN CALABAR MUNICIPALITY, CROSS RIVER STATE

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## Abstract

*A study was carried out to analyze water table movement for flood mitigation in Calabar Municipality of Cross River State with a view to controlling the water table at high level due to fluctuation within the area. Six different existing boreholes were used for this study. Using fiber tape attached to a weight, static water levels were obtained during the morning hours before pumping began. The use of questionnaire to assess research question was employed. Four hypotheses where formulated, one null hypothesis was accepted while other three where rejected. The hydrograph shows regions of rising, peak and failing limbs with the month of July having highest rainfall value of 828.2m$^{-}$. The results indicate highest static water level on locations closer to the Calabar River compared to other far-away locations. Heavy rainfall among other factors is identified as the major cause of flooding within the study areas. Flooding at Ikot Uduak followed by Essien Town was observed to be more severe to other locations. This calls for proper design and construction of channels to convey water from flood affected lands. Lowering the water table level improved field trafficability and timeliness of crop management operations. Pumping system and water control structures are recommended as these can be managed to create either a constant water table depth or a fluctuating water table level.*

**Keywords:** Water table, Flood mitigation, Surface water, Static water level, Hydrograph.

## Introduction:

Water table is often misused as a synonyms for ground water, however, the water table is actually the boundary between the unsaturated and saturated zones. It represents the upper surface of the groundwater; it is the level at which the hydraulic pressure is equal to atmospheric pressure. The water level found in unused wells is often the same level as the water table (Vietira et al, 1994). Based on petrographic analysis, (Onyeagocha, 1980) concluded that rocks are made up of about 95 – 99% quartz grains, $Na^{+}K$ Mica, 1-2.5% feldspar 0.5-1% and dark coloured minerals 2.3%. This composition allows easy permeability of water to water table or an aquifer.

A confining bed is a geologic unit which is relatively impermeable and does not yield useable quantities of water. It is also referred as aquitards, it restricts the movement of ground water into or out of the adjacent aquifer. Flood are essentially large volumes of water, which arrive at and occupy stream or river channels and their plains in a time too short to prevent damages to economic activities including homes. In essence, flood is an abnormal overland flow arising from inability of streams, flood plains and channels to cope with the discharge, it is one of the most common natural or manmade disaster.

Calabar like many major towns in Nigeria is faced with urban flooding. Flood occurs throughout Nigeria in three main forms coastal flooding, river flooding and urban flooding (Gobo 1988). Urban flooding are common on a yearly basis and this is caused largely by;

i) High intensity of rains of long duration (average annual rainfall (2405.2mm).
ii) Inadequate drainage of low-lying areas.
iii) Silted channels
iv) Unethical use of drains as water receptacles.
v) Defective storm water drainage design and construction.
vi) Urbanization and abuse of town planning building guideline.
vii) Inaccurate characterization of the numerous catchments areas supposed to contribute to the storm drainage systems (Abam, et al 1991).

One of the most important attributes of ground water is its protection against the vagaries of climatic regimes in its area of occurrence. Though ground water level fluctuates in response to seasonal and diurnal climatic variations, obvious overall abnormal depletion or replenishment is hardly observed as a result. However persistent long-term departures from observed prevalent climatic situations can induce positive or negative responses in the system (Offodile, 1979).

Rainfall which is the major contributing factor to flooding has a direct impact on water table, water on the surface is in excess as a result of inability of saturated soil to absorbed more water and lack of drainage facilities to allow water flow inform of runoff, water with time percolate to the ground thereby increasing water table (Christiansen, 1980)

Flood water reaches the ground water through percolation by a wide range of variables, recharge to ground water can be estimated by a number of different methods including hydrological and tracer methods. If the water table level is extremely high and reaches the root zone, it provides water for evapo-transpiration even in dry soil condition, in such situation recharge from flood is estimated as the difference between mean rainfall and mean potential evapo-transpiration (Bidroell, 1991).

For economic reasons, the best defence against floods is an understanding of the way people treat their environment and ginger awareness on the challenges of environmentally responsible growth. Every member of the society ought to know his or her role in making where he or she lives better. Every one bears a huge responsibility for the environment. The divorce between urbanization with its attendant economic prosperity and environmental management must therefore be addressed for sustainability (Carlos, 2005).

Calabar like many town, in Nigeria requires urgent attention on flood mitigation as most crops, constructed structures, lives are highly affected. It is therefore the objective of this study to analyze the water table movement of Calabar Municipality with the aim to providing mitigation measures and where considered inadequate, make recommendations for improvement.

**Materials and Methods:**

Calabar is the capital of Cross River State in South South of Nigeria. It is the city that houses the famous Tinapa project. It lies on latitude $4^{0}30^{1}$ and $5^{0}00$N, and longitude $5^{0}15^{1}$ and $8^{0}45^{1}$E of the equator. Calabar is bounded to the south by the Atlantic Ocean, to the East by Republic of Cameroun, to the North by Ebonyi and Benue States and to the West by Akwa Ibom and Abia State respectively. Calabar is located within the tropical climatic region and enjoys all the climate condition attributed to this region. It has a uniform temperature throughout the year about $28^{0}$C, cloudiness and heavy precipitation helps to moderate the daily temperature, regular land and sea breezed, relative humidity is constantly vary between 70% - 90% (Akak, 1982).

A set of questionnaires was designed for the purpose of information collection, information sought included relationship of the surface and the sub-surface and the sub-surface water sources of the flooded areas, nature of the hydrograph system, predominant environmental factors that contributes to flooding within the area and if any management practices carried out in the area as regards flood control.

The questionnaires were administered during field visits by giving them to the respondent to fill and retrieved while additional items of information were gathered through direct measurement of static water level (SWL) for six (6) designated boreholes within the study areas. A fiber tape attached to a weight was dropped into each borehole until the weight touches the water surface at which points the fiber tape becomes lighter to the hand. The point of contact of the weight with water was noted and recorded. This measurement was done during the dry and rainy seasons in the early hours of the day before pumping took place. The measurement was carried out on weekly bases and an average for each month was recorded. The static water level was recorded from the surface of the earth to the level of the unused water in the borehole, while depth of each borehole was recorded from the drillers record.

The Pearson Product Moment Correlation formula by Karl Pearson was used to correlate the rainfall and static water levels of the study areas. The correlation coefficient, $r^2$ is given by:

$$r^2 = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

The responses obtained through the questionnaire were analysis to answer the postulated research questions. T-test means and standard deviation was applied in testing the hypothesis at 5% levels of significant and with 3 degree of freedom. A change in water table involves a change in the volume of groundwater stores in the soil. If the effective porosity of a zone in which the water table change occur is known the change in groundwater storage over a given period can be calculated by the expression.

$$S = U\,h$$

Where:

S = Change in storage of ground water
Per unit of horizontal surface area (m)
Over a given period

U = Effect porosity of the soil (Dimensionless)

h = Change in water table elevation (m) over the given period (m)s.

**Results and Discussion:**

The results are discussed under the following titles:

i) Surface water sources in Calabar Municipality
ii) Annual rainfall distribution for Calabar Municipality represented in table
iii) Environmental factors affecting flood pattern within the study area and,
iv) The hydrograph system of Calabar Municipality

**a) Surface water sources in Calabar Municipality.**

The utilizable amount of ground water depends not only on the quantity of water available in that area but also its quality, apart from exploitation of fossil water, the upper limit for exploiting ground water would be its annual recharge. Table 1 shows main sources of surface water that were identified as partly contributing to the flooding of the study area. It is however observed that though some streams like Idim Effanga and Obot Idim do not overflow it banks, and hence contributes to the flooding of the area, and also serve as reservoirs that are used on demand. These storage reservoirs regulate the stream so that the natural flow is adjusted to meet as nearly, as possible, the rate of demand. Other sources of water that is becoming increasingly important in the area is industrial and agricultural waste water (especially from Cross River Basin Development Authority and Calabar Free Trade Zone) on daily basis which may affects flooding of the area. Water resources are insufficient to meet the long term requirements of agriculture, industry and other users unless their judicious and economic uses are ensured.

**b) Annual Rainfall Distribution for Calabar Municipality.**

Table 2 shows the relationship between rainfall and static water level within the Calabar Municipality. It indicates the highest and lowest static water level for the different study locations within the area. It may be observed that, static water levels are higher during the rainy season compare to the dry season which may be due to high recharge of water table by rainfall. The table also reveals that static water level increases as the location approaches the Calabar River (for instance Essien Town and NTA region of Calabar). The water level rises due to lateral seepage from the Calabar River and falls as the distance increases away from Calabar River. Figure 1 shows that Basin Town is the farthest from the Calabar River (i.e. about 10km) and has the lowest static level of an average value 20.4m during the rainy season and 24.0m during the dry season.

**c) Environmental Factors Affecting Flood Pattern**

Water is the most common compound on the surface of the earth, with a current total volume of 1.36billion km$^3$. This quantity has remained relatively constant, even though water is continuously lost from the system, escaping to space or breaking down and forming new compounds with other elements. Rainfall has been identified as the most predominant environmental factor that may cause flooding among other factors. The situation becomes worsened because of unplanned urbanization pattern leading to blockage of existing drainages, rapid population explosion (from 143,089 in 1991 to 332,178 in 1995 as projected by National Population Census) and poor sanitary habits of the dwellers as a result of dumping volumes of refuse in gutters, drainage outlets, poor drainage characteristics of the superficial top soils. This situation is corroborated by other researchers (Gobo, 1990; Person, 1966 and Peace, 1979).

According to Gobo, (1990), the factors that may cause flooding includes, heavy rainfall, snow melt and dam failure. Insufficient drainages and heavy rainfall could be responsible for flooding the study area. Calabar is an area with relatively minor changes in water table which is usually regarded as discharge area. It is generally represented by low-lying lands and topographical depression which receive continuous inflow of groundwater from adjacent higher ground. It was observed that, flooding within the study area is made possible if the static water level during the rainy season is less than 11m, where the soil pores spaces becomes saturated and can’t accept more water through infiltration, and static water level above 30m, the study area becomes save from flooding.

d) The Hydrograph System of Calabar Municipality

Fig. 8 shows the hydrograph of Calabar Municipality indicating a rising limb. (Jan. – June), Peak Discharge (July) and falling limb (Aug. – Dec.) The shape of the hydrograph may be influence by vegetation or precipitation among other factors.

A further confirmation of this factors was listed by (Brown 1996), to include soil permeability and thickness, drainage density, duration of rainfall and precipitation intensity and type, land use (e.g. Agriculture, Urban Development, Forestry Operation), Topography and Geology, Evapotranspiration Rates etc.

Calabar has dense vegetation and canopies which intercept rainfall; in particular the significant volume of water held in the weather evaporates before reaching ground. Plant root system facilitates infiltration of the precipitation rather than generating more surface runoff.

The hypothesis on whether there is significant difference between surface and sub-surface water sources for study area we rejected and alternative hypothesis accepted, since the value of t-calculated 5.16 was greater than t-critical 3.18 at 3 degree of freedom at 5% level of significance.

**Table 1: Surface Water Sources within Calabar Municipality**

| Sources of surface water | Generic name |
|---|---|
| Lakes | i) Esuk Utan<br>ii) Ebat Idim<br>iii) Water Intake |
| Streams | i) Idim Effanga<br>ii) Obot idim<br>iii) Idim Technical<br>iv) Barrack Stream<br>v) Idim Esuk<br>vi) Assembly Stream |
| Rivers | Calabar River<br>Adiabo Rive |

**Table 2: Relationship Between Rainfall and Static Water Level for Calabar Municipality.**

| | | STATIC WATER LEVELS (M) | | | | | |
|---|---|---|---|---|---|---|---|
| **MONTH** | **RAINFALL(MM)** | **BASIN TOWN** | **ESSIEN TOWN** | **IKOT UDUAK** | **STATE HOUSING** | **IBOM LAYOUT** | **NTA** |
| January | 33.8 | 23.4 | 14.2 | 21.8 | 22.0 | 21.8 | 13.0 |
| February | 35.3 | 23.2 | 14.0 | 20.6 | 21.8 | 21.6 | 12.6 |
| March | 295.7 | 23.0 | 13.6 | 19.8 | 20.6 | 21.2 | 12.4 |
| April | 299.9 | 22.0 | 13.0 | 19.6 | 20.2 | 20.4 | 12.2 |
| May | 263.9 | 21.2 | 12.8 | 19.4 | 20.0 | 20.0 | 12.0 |
| June | 615.6 | 20.4 | 12.0 | 19.2 | 19.2 | 19.4 | 11.2 |
| July | 828.2 | 20.6 | 12.2 | 19.2 | 19.4 | 19.2 | 11.0 |
| August | 634.4 | 20.8 | 12.6 | 19.6 | 19.6 | 19.2 | 11.0 |
| September | 230.4 | 21.4 | 12.8 | 19.9 | 19.8 | 19.4 | 11.4 |
| October | 279.8 | 21.8 | 13.4 | 20.4 | 20.2 | 19.6 | 12.0 |
| November | 182.3 | 22.2 | 13.8 | 20.6 | 20.4 | 19.8 | 12.4 |
| December | 71.5 | 24.0 | 14.0 | 21.0 | 21.0 | 20.2 | 12.8 |

**Table 3: Environmental Factors that causes flooding in various locations of the world by some authors**

| S/No. | Factor | Location | Reference |
|---|---|---|---|
| 1 | Insufficient drainage and rainfall | London | Pearson (1966) |
| 2 | Rainfall | Makurdi | Oguntoyinbo (1977) |
| 3 | Snow melt and heavy rainfall | United States | Pearle (1979) |
| 4 | Rainfall | Niger Delta | Gobo (1990) |
| 5 | Absence of Drainage/Rainfall | Port Harcourt | Abam/Gobo (1991) |
| 6 | Heavy Rainfall | England | Turkey (2007) |
| 7 | Heavy Rainfall | Calabar | Obio (2008) |

## Conclusion

The flooding of Calabar Municipality among other factors is caused by heavy rainfall and the poor drainage characteristics of the superficial top soils. Calabar suffers from Urban flooding as a result of insufficient drainage capacity and uncoordinated with poorly maintained drainages. The situation is worsened because of unplanned urbanization patterns leading to blockage of existing drainages, rapid population explosion and poor sanitary habits as a result of dumping volumes of refuse in gutters, drainages outlets and adjoining creek. The pumping system and water control structures can be managed to create a constant water table depth or a fluctuating water table. Lowering the water table improves field traffic ability and timeliness of crop management operations such as field preparation, planting and harvesting which can extend the growing season by allowing earlier access to the field.

## Recommendations

Based on the results obtained from the research, the water table level increases as the study point get closer to the Calabar River. In the light of these findings, the following recommendation are made, that measurement of static water level could be automatic by using a water level sensor installed midpoint between sub-surface drain laterals, where the sensor can switch the pump on or off. That it is better to monitor the water table fluctuation by establishing monitoring wells in the field.

Furthermore, that subsurface drainage should be improved since it encourages traffic ability, hence field conditions for more timely planting and harvesting operations and helps decrease crop damage that may result from saturated soil and standing water.

That frequent cleaning of the existing drainages should be encouraged to avoid blockage by refuse.

That water-logged area be reclaim to meet agricultural development and improve living conditions for the people.

That sub-irrigation practice be encouraged as loss of water through deep seepage is negligible, and runoff of irrigation water rarely occurs. For a long-term solutions, a regional approached based on a master-plan for flood and erosion control in the entire area is advocated. This will involve reclamation of sites, construction of dykes, polders and canalization.

## References


Abam, T. K. S. (2004). Geohydrology: with application to Environmental Management pp. 101-113.

Akak, E. O. (1982). Culture and Superstition: Efiks of Old Calabar Vol. 3 Paico Press Ltd, Calabar. Pp. 14-17.

Bidwell, V. J. Callender, P. F. Moor E. R. (1991). An Application time series Analysis to groundwater investigation and management in central Canterbury New Zealand.

Brown, L. C. (1996). Understanding Agricultural Drainage. Ohio State University Extension. P. 4-9.

Christiansen, J. E. (1980). Groundwater studies in relation to Drainage, Agric. Eng. Vol. 24 pp.339 – 342.

Distance, N. G. (1978). Effective Rainfall in irrigated Agriculture. FAO Irrigated Agriculture. FAO Irrigation and Drainage Paper 25.pp.5-15.

Evans, R. O. (1988). Economic of controlled drainage and sun-irrigation system. North Carolina State University Extension Service, pp. 18-21.

Gobo, A. E. (1988). Relationship between Rainfall trends and flooding in the Niger Benue Rivers Basins. The Journal Amaterology. Vol. 13, No. 132. Pp. 318 – 324.

Gobo, A. E. (1990).Rainfall Data Analysis as an Aid for Designs for Maximum Drainage and flood control works in Port Harcourt. Vol. 2 No.4

Gobo, A. E. and Abam, T.K.S. (1991). The 1988 floods in the Niger Delta. The case of Ndoni, the Journal of meteorology. Vol. 16, No. 163. Pp. 293-299.

Michael A. M. (1978). Irrigation: Theory and practice Vikas Publishing House PvT Ltd, New Delhi, India.

Nwa, E. U. (2003). History of Irrigation, Drainage and Flood Control in Nigeria from Pre-colonial to 1999.

Offodile, M. E. (1979). Groundwater Study and Development in Nigeria.

Richardson, E. V. (1990). Evaluating Scour at Bridges Hydraulic Engineering Circular No. 18 U.S. Dept. of Transportation, Federal Highway Administration.

Santosh, K. G. (2007). Irrigation Engineering and Hydraulic Structures. Khana Publishers, Delhi.

Schwab, G. O. and R. K. Frevert (1993). Soil and Water Conservation engineering pp. 507-518

Sharma, M. L. (2000). Measurement and prediction of Natural Groundwater recharge. An overview, New Zealand, Journal of Hydrology, Vol. 2 (1) pp. 49-54.