Mapping the Spatial Distribution of Water Borehole Facilities in Part of Rivers State using Geographical Information System (GIS) Techniques

Okwere ANWURI O, HartLAWRENCE; Jackson KUROTAMUNO PEACE, Nigeria

Keywords: Borehole; Geographical Information System; Buffering Analysis; ArcGIS

ABSTRACT

The challenge of urbanization heightens the issue of water supply in relation to available water quantity and quality. Consequently, there is an alarming gap between consumption and potentially available safe water resources. This has led to the multiplicity of water borehole facilities location in the urban area of Rivers State of Nigeria without recourse to the environmental impact, land use, urban population growth, and land readjustment. This study is aimed at mapping the spatial distribution of water borehole facilities in Bori and part of Port Harcourt in Rivers using Geographical Information Systems (GIS) technologies. The spatial information of the water borehole facilities were determined using hand-held GPS equipment in addition to their attribute data. The data generated was analyzed using Geographic Information System Application ArcGIS 10.1 software. A total of 197 borehole facilities were identified within an area of 8,033 square kilometers. The buffering analysis in the Bori area indicated that 71 boreholes are located within 500 square meters radius. Similarly, the total area of Woji was 30,195 square kilometers with 1756 borehole facilities. The analysis further revealed that a maximum of 1,284.51 metric tonnes and minimum of 98.48 metric tonnes of sand and clay was removed within the study area. This research brings to bare that with the multiplicity of these private water boreholes the risk of possible land subsidence is very high. Hence, the absence of thematic map for borehole facilities has hampered the effective monitoring and planning of citing these facilities in Rivers State. We therefore recommended that a geospatial information system be developed with the view of minimizing land encumbrances by these facilities and its related environmental and social impacts.

Mapping the Spatial Distribution of Water Borehole Facilities in Part of Rivers State using Geographical Information System (GIS) Techniques

Okwere ANWURI O, HartLAWRENCE; Jackson KUROTAMUNO PEACE, Nigeria

1.0 INTRODUCTION

Several successive governments in Nigeria at the Federal, state and local levels have made frantic efforts to provide portable and adequate water supply to its citizen. These strides of water supply services, where they exist are unreliable, and not sustainable because of obvious difficulties in management. In the light of this, the World Bank (2002) stated that one of the key issues emerging in our time is access to clean water. It is estimated that just 12% of the global population consumes 86% of the available water while 1.1 billion people (one sixth of the world's population) has no access to adequate water supplies. As global demand for clean water is increasing, changes in climate and pollution are reducing potable raw water. This leads to an emerging interest in improving safe water access through small-scale water projects at the household, (provision of personal water boreholes) to arrest the problems posed by water crisis.

Following the adoption of the National Water Supply and Sanitation policy in January2000, the Nigerian Government considered the provision of water supply services to be the domain of the Federal, State and Local governments. However, the public sector has not been successful in meeting more than a small portion of the demand for water by residential and commercial users. Services are in critically short supply. For example, out of the 85 million people living in urban and semi-urban areas, more than half have no reasonable access to reliable water supply (FMWR, 2000).

1.1 Research Problem

The increasing rate of population growth, rising demands for food and cash crops, increasing urbanization and rising standards of living represent major factors for shortage in water supply. Following the inability of government at various levels to provide portable and accessible quality water, citizens have resorted to providing private borehole water for both domestic and agricultural usage within the urban cities. The indiscriminate location of these water boreholes without recourse to future development and other environmental considerations poses a big danger to the study area. The multiplicity of borehole water facilities by private individual and corporate bodies also undermines the stability of the earth crust thereby exposing the citizens to potential crustal changes and phenomena that has great damaging effect.

1.1.1 Research Objective

The objective hereto, is the identification of spatial location of water borehole facilities within the study area (Woji and Bori) Rivers State using hand-held Garmin GPSMAP 76c receiver. Also, to produce the map of the spatial distribution of these water boreholes, to highlight and bring to fore the number of boreholes in addition to carryout neighbourhood analysis of these facilities within the study area. The corresponding analysis will provide the necessary information and underscore the potential threat of the continual citing of these facilities to our environment.

1.2 Concept of Water Borehole (Water well)

A water well is a hole, shaft or excavation used for the purpose of extracting ground water from the subsurface. Water may flow to the surface naturally after excavation of the hole or shaft. Most wells are vertical shafts, but they may also be horizontal or at an inclined angle. Some wells are used for purposes other than obtaining ground water, investigation of subsurface conditions, shallow drainage, artificial recharge and waste disposal. The location of any borehole (well) is mainly based on the underlying purpose which is an important consideration. The hydrogeological assessment should be done by qualified professional drillers. The determination of the suitability, availability of sufficient ground water and appropriate quality, are dependent on several factors. These factors include the knowledge of the system of the ground water, experience in similar areas and diverse array of information such as land surface topography, local vegetation, rock fracturing (location dependent), geophysical measurements among other factors.

Generally, the main thrust of the design and construction of water borehole is to create a structurally stable, long-lasting, efficient well that has enough space to have pumps or other extraction devices. It will ensure that ground water move effortlessly and sediment-free from the aquifer into the well at the desired volume and quality, and prevents bacterial growth and material decay in the well http//waterquality.ucanr.org and http//groundwater.ucdavis.edu. Figure 1.0 shows the typical private water borehole drilling process through the aquifer layer.

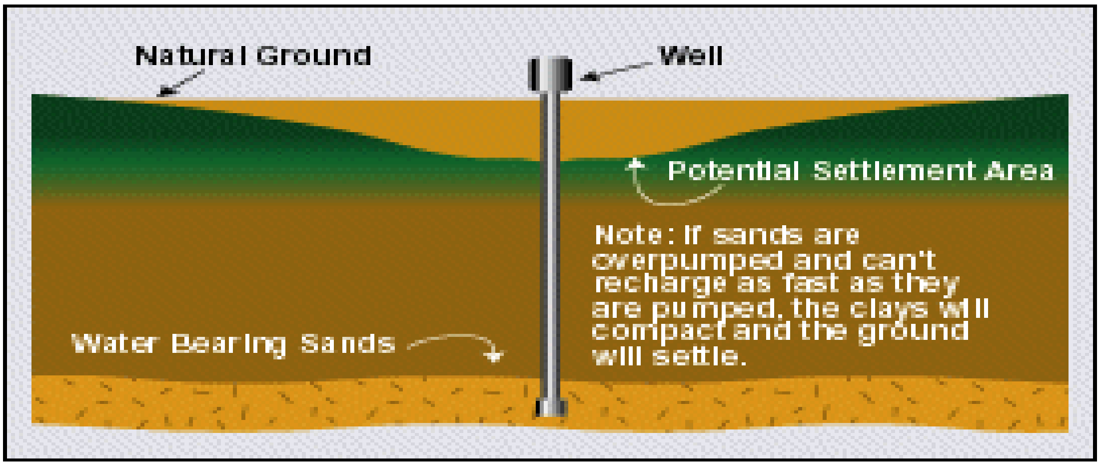

Fig. 1.0: A Specimen of Underground Water Borehole and Aquifer Layer (Adapted from San Jacinto River Authority)

1.2.1 Water Borehole Facilities and Environmental Effect

Water from rainfalls, are majorly absorbed into the ground and also as plant nutrients. The remaining that is not used by plants moves downward through pores and spaces in the rock until it reaches a dense layer of rock. The water trapped below the ground in the pores and spaces above the dense rock barrier is called ground water or aquifer, and this is the water we get when we drill wells. The removal of water in its natural state through geo-drilling activities creates a disequilibrium of the earth crust which in turn can lead to land subsidence. This is one of the major environmental effects that is associated with multiplicity of borehole facilities. Over time, as more water is removed from the area, the ground drops and creates a cone. Land subsidence can lead to many problems, including changes in elevation, damage to structures such as storm drains, sanitary sewers, roads, railroads, canals, levees and bridges; structural damage to public and private building, and damages to wells. Most commonly, though, subsidence is known for causing an increase in the potential for flooding. Figure 1.1 shows the typical private water borehole location in a residential apartment with its corresponding concrete surface water tank for storage and distribution.

Figure 1.1: A sample of Private Water Borehole Facility within the Study Area (Source: Hart, L & Jackson K.P, 2014

1.2.2 Geospatial Data

Geospatial data can be referred to data that identifies the geographic location of features and boundaries on earth, such as natural or constructed features, oceans, and more. It is usually stored as coordinates and topology, and is data that can be mapped. Geospatial data is often accessed, manipulated or analyzed through Geographic Information Systems. Groot et al., 2000, linked geospatial data to geospatial data infrastructure, to encompass the networked geospatial databases and data handling facilities, institutional, organizational, technological, human and economic resources that interact with one another and underpins the design, implementation and maintenance mechanisms that facilitate the standardization, sharing, access to and responsible use off geospatial data at affordable costs for a specific application domain or enterprise.

2.0 RESEARCH SCOPE

The scope of this research involved data acquisition and data processing. The Geographical Information System (GIS) techniques and processes were deployed in the accomplishment of this scope. Since, geospatial maps are produced by the combined efforts of many professions using a variety of technologies (Lo and Yeung, 2002). Therefore, the input and output specifics used in the work are as explained below.

2.1 Data Acquisition

Data Acquisition is a primary operation in digital mapping or GIS operation. The type of data to be collected depends upon user requirement and availability. Geometric data are usually collected in digital form from a variety sources (Ndukwe, 2001). In this research the following data were collected and used in the analysis**.** A High-resolution satellite image 2015 data covering the study area(s) was extracted from Google earth web site. Field (site) capturing of data were based on basic survey principles and techniques. Field visitation was equally conducted with handheld Garmin GPSMAP 76c receiver to pick the coordinate of the existing borehole within the study area. Also, A420 Cannon power shot Digital Camera was used to picture the area, so as to aid better visual appreciation and spatial analysis of the area.

2.2 Data processing

2.2.1 Georeferencing

The processing of the spatial data includes georeferencing, on screen digitization, map visualization. The download Google image was imported into GIS environment were the reference system was defined, in this study the projected reference system , WGS 84 ,UTM zone 32N was defined. The next operation was georeferencing which involve the aligning of geographic data to a known coordinate system so it can be viewed, queried, and analyzed with other geographic data. Georeferencing may involve shifting, rotating, scaling, skewing, and in some cases warping, rubber sheeting, or ortho-rectifying the data. The four corners of the imagery of which their coordinate were captured from Google earth and were used as input in georeferencing process. The georeference tool in ArcGIS 10.1 was turn on. The four (4) edges (corners) coordinates of the map were selected as the control for the georeferencing. The georeferencing tool in ArcGIS 10.1 was deployed to carry out the georeferencing operation. The add control tool was used to register the coordinates.

2.2.2 Digitization

The digitizing process starts by creating layer in arc Catalogue. The features on the image were geometrically represented as polyline, polygon and point. The layer created with the same reference system was added to arc Map environment where the sketch tool was used as a pencil to trace the spatial feature. The road network was then carefully extracted using polyline. The important buildings were also extracted using polygon.

2.2.3 Visualizations of GPS Point

The spatial distribution of the existing boreholes were displayed in GIS environment. The handheld GPS field record which were downloaded into the computer system using GARMIN Map Source 4.09 software as interface provided the ease of analysis. The downloaded GPS points were later converted to text file and were added to excel. In arc catalogue the create feature from x, y was used to display the GPS point into Arc GIS environment.

2.2.4 Proximity analysis (Buffer)

The buffer of 500m and 250m was defined along the major location such as Woji Town hall, Sofene Model School in Woji Study Area and Prince Igbara in Bori to evaluate the number of boreholes points within the specified radius. In this process, the analysis tool in arc toolbox in an ArcGIS 10.1 was used. The major road (Woji Town hall, Sofene Model School and Prince Igbara) was put as input feature the distance (500m and 250m) was defined and the output feature was save as buffer shapefile.

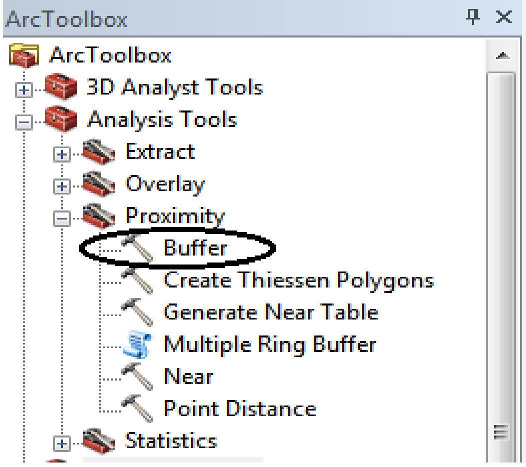

Figure 1.2: Showing buffer toolset in Arc toolbox

3.0 DATA PRESENTATION AND DISCUSSION OF RESULTS

There are about One Thousand, Seven hundred and fifty-nine (1759) and One hundred and ninety-seven (197) boreholes distribution within Woji and Bori respectively. The large disparity is a result of the fact that the former is entirely an urban settlement whereas the latter is a semi-urban settlement.

3.1 Buffering and Neighourhood Analyses

In order to assess the impact of the water bore-hole facility within the study area in relation to the human population and the type of human settlement, a buffer was created employing the geospatial tool and the results is as shown on the table 1.0 below:

Table 1.0: A Table Depicting the Results of the Buffered Analysis

S/No	Buffered Location	Buffered Radius (m)	Number of Borehole Points
1.	Woji Town Hall, Woji	500	294
2.	Sofene Model School, Woji	500	300
3.	Prince Igbara, Bori	500	71
4.	Prince Igbara, Bori	250	23

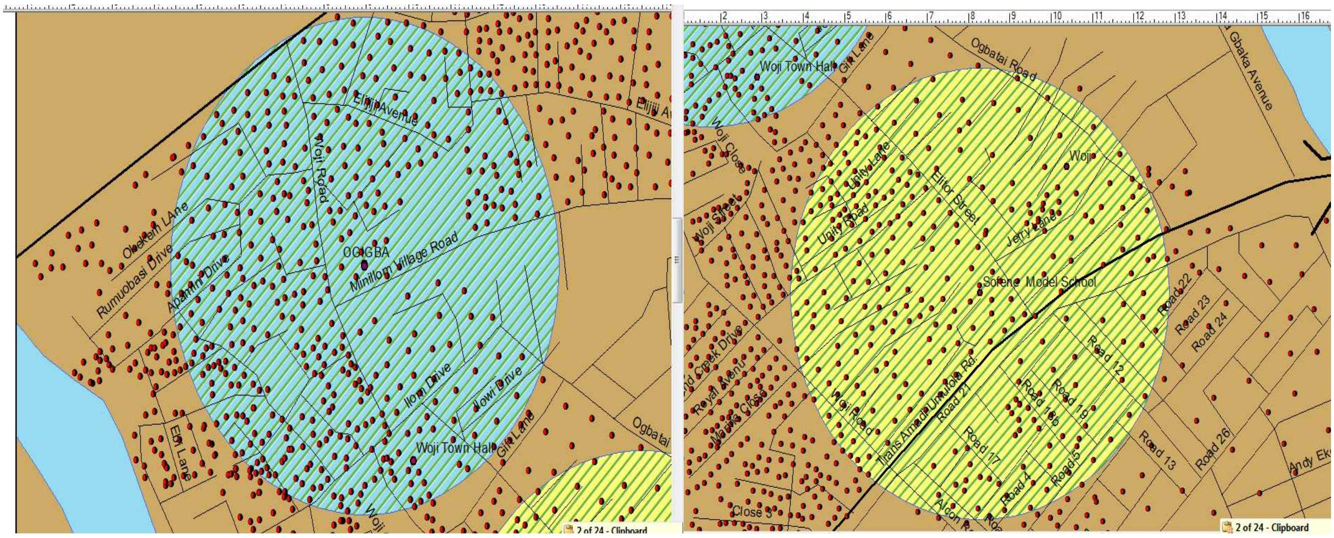

Figure 1.3: A Figure Depicting a Buffer (500m) at Woji and Sofene Model School

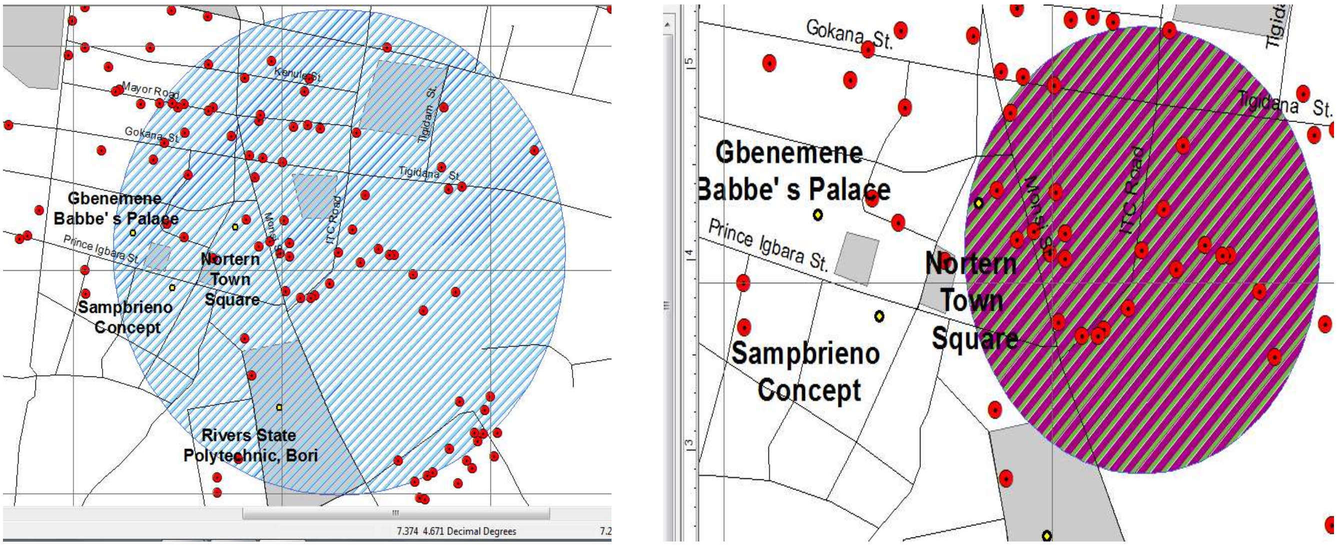

Figure 1.4: A Figure Depicting a Buffer (500m and 250m at Prince Igbara Street, Bori

Table 2.0: A Table Depicting the Results of the Buffered Analysis and Volume of Earth-Work Extracted

S/No	Buffered Location	Buffered Radius (m)	Area of Buffered (Hectares)	Number of Borehole Points	Volume of Earth-Work (Metric Tonnes)
1.	Woji Town Hall, Woji	500	78.54	294	1,258.82
2.	Sofene Model School, Woji	500	78.54	300	1,284.51
3.	Prince Igbara, Bori	500	78.54	71	304.00
4.	Prince Igbara, Bori	250	19.63	23	98.48

Figure 2.0, highlights the quantity of earthworks that are removed for the number of boreholes within a buffered radius of 500meters. The analysis revealed that a maximum of 1,284.51 metric tonnes and minimum of 98.48 metric tonnes of sand and clay was removed within the study area. Figures 1.5 and 1.6 shows the spatial distribution of private water boreholes facilities in the study area. The density of these facilities within the study area reinforces the view that if there are no control measure, the consequence on urban area will be grave. The spatial analysis further revealed that the minimum distance between two (2) nearest neighbourhood boreholes was 7 meters and it can be smaller in certain areas of the city.

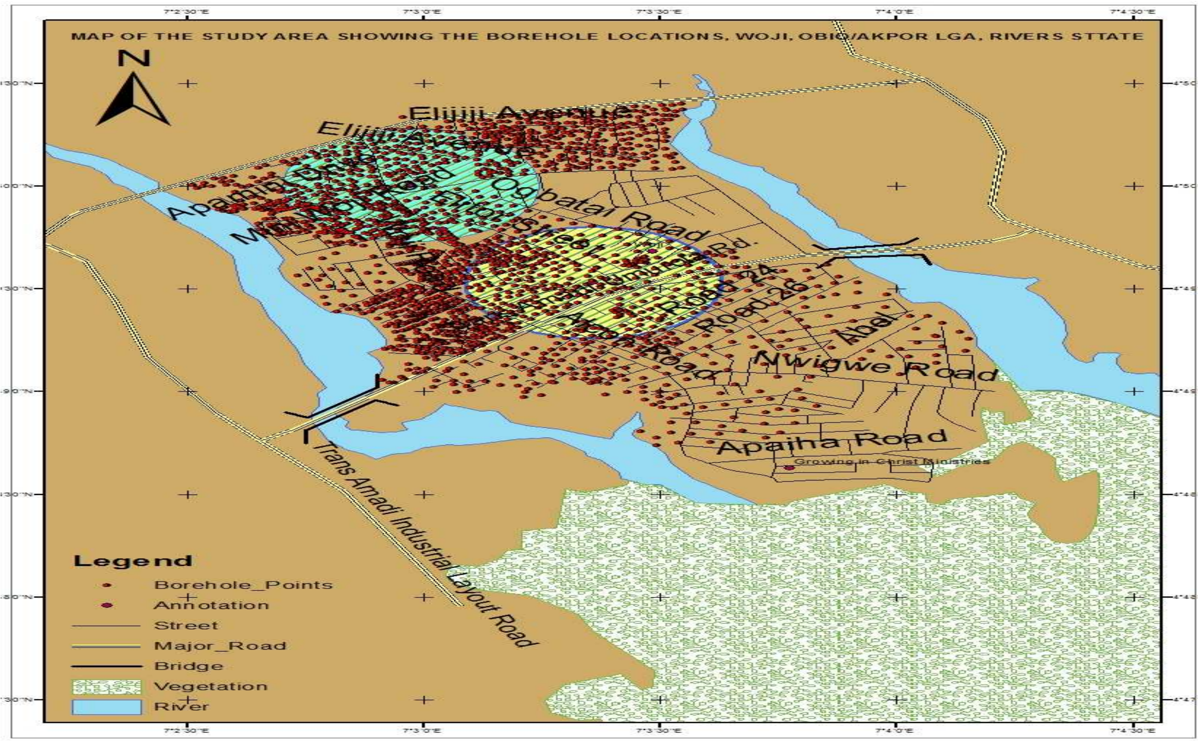

Figure 1.5: A Figure Depicting Spatial Location of Boreholes within the Woji of Port Harcourt, Rivers State

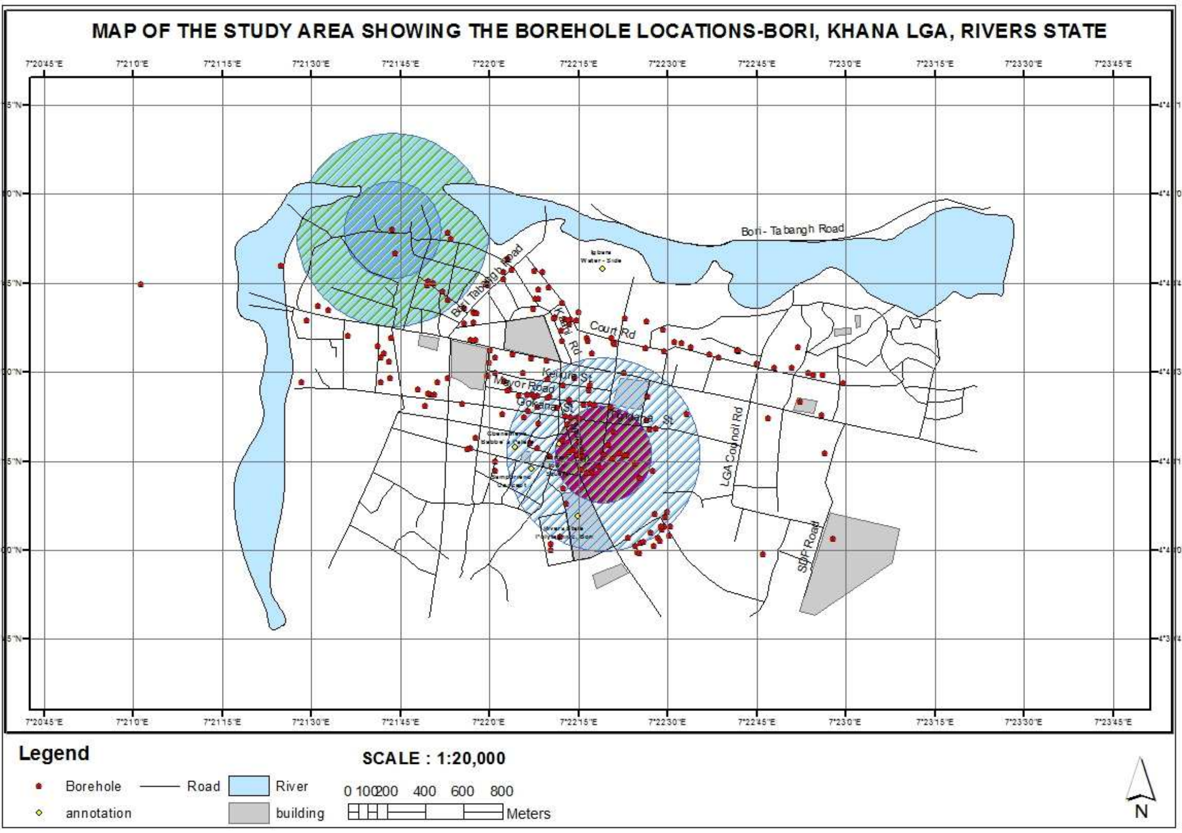

Figure 1.6: A Figure Depicting Spatial Location of Boreholes along the Prince Igbara Street, Bori

4.0 CONCLUSION AND RECOMMENDATION

The need to adhere to safety and development control procedure when planning and constructing water boreholes to avoid contamination and pollution for either the sources and/or groundwater becomes necessary in the light of issues of citing of water borehole facilities. The spatial location of these facilities mainly provided by private households and the neighbourhood analysis carried out in this research underlines the importance of reviewing the modalities of providing a safe and portable quality water supply to the citizens. This development can be compounded when a badly constructed facility (water borehole) can pose a danger not only to the owner but also to adjoining neighbours as most often there are no checks except things go wrong.

To this end, it becomes imperative to consider the following in the course of construction and citing of water borehole facilities in urban and semi urban area such as our study area:

- Prevailing Regulatory Controls and Procedure
- The issues of Health Safety and Environment
- The effect of leaking sewers, effuluent disposal from septic tanks
- Chemical storage, handling and accidental spillages of fuels and associated liquids

- The presence of underground facilities such as electric cables, telecommunication lines, oil and gas pipelines, etc.

We therefore recommended that a geospatial information system be developed with the view of minimizing land encumbrances by these facilities and its related environmental and social impacts.

REFERENCES

DeFries R.S., Field C.B., Fung I., Justice C.O., Los S., et al. (1995); “Mapping the land surface for global atmosphere-biosphere models: toward continuous distributions of vegetation’s functional properties.”*J. Geophys. Res. Atmos.* 100(D10):20867– 82.

Federal Ministry of Water Resources, National Water Supply and Sanitation policy (2000)

Fisher, P.F. and Lindenberg, R.E., (1989); “On Distinctions Among Cartography, Remote Sensing, and Geographic Information Systems.” In: Photogrammetric Engineering and Remote Sensing, Vol. 55, No. 10, pp. 1431 – 1434.

Groot, R. and McLaughlin, J (2000). Geospatial data infrastructure: concepts, cases and good practice. New York: Oxford University Press

Lo, C. P. & Yeung, A. K., 2002. *Concepts and Techniques of Geographic Information Systems.* 2nd ed. s.l.:Prentice Hall,Inc..

Ndukwe, N. K., 2001. *Digital Technology in Surveying and Mapping.* 2nd ed. Enugu, Nigeria: Rhyce Kerex.

Nkwunonwo U.C., Jackson K.P., Hart Lawrence, Adekunle I. (2013). Investigating changes in coastal environment using internet-based geospatial data. Ethiopian Journal of Environmental Studies and Management, Vol 6, No. 6, 2013.

William, B.M. and Turner, B.L. (1992). Human population growth and global land use land cover change. Annual Review of Ecological System, 23, 39-61.

World Bank Global Report on population and Access to Quality Water (2002).

CONTACTS

1. OKWERE, Anwuri O.
Department of Surveying and Geomatics
Rivers State University of Science and Technology
Port Harcourt, Rivers State, Nigeria
okwereo@yahoo.com
+2348037058974

2. HART, Lawrence
Department of Surveying and Geomatics
Rivers State University of Science and Technology
Port Harcourt, Rivers State, Nigeria
Lawrence.hart@ust.edu.ng; delawrencehart@yahoo.com
+2348037080317

3. JACKSON, Kurotamuno Peace
Department of Surveying and Geoinformatics
Rivers State Polytechnic, Bori, Rivers State, Nigeria
kurotamuno@gmail.com
+2348060337346