# DIGITAL MAPPING AND ADEQUACY ASSESSMENT OF HYDROLOGICAL FACILITIES (BOREHOLES) IN MAIDUGURI METROPOLIS

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*Abstract*

In spite of numerous scholarly and professional recognition of the importance of water, it is acute in short supply to significant number of people in Nigeria. Inadequate provision of hydrologic facilities (boreholes) which is the major source of water poses a great negative impact on both social and economic activities in Maiduguri metropolis. The current water supply through hydrologic supply in the area was assessed using GIS techniques. Attempt was made to take the inventory of the hydrologic facilities and also map out the spatial distribution as well as creating a comprehensive database for these facilities within the study area. Hand held GPS was used to take coordinate of the facilities. The coordinate were transformed in to the regional standard map projection and datum i.e. UTM zone 33, Clark 1880 Minna datum using ilwis GIS software. Five different software packages were used in data manipulation. These include Corel draw 11, Microsoft word 2003, Arc view 3.2a, Ilwis 3.1 and ArcGIS 9.2. Eight of the fifty three boreholes mapped in the study area were not functioning. About ninety five boreholes have been proposed making the total sum of 148 boreholes for adequate supply of water in the study area. Results from the analysis in this study indicate that the hydrologic facilities in the area are far behind being adequate. This inadequacy poses a great negative impact on both social and economic activities in the area thus requiring fast and effective planning and decision making.

## *Introduction*

Water is a vital natural resource that is needed for the existence and survival of plants and animals on earth. It occupies a high percentage of both the earth surface and underground in dynamic and static forms.

Areola *et al* (1978) stated that, about 67% of the earth surface is covered by water. However, the distribution of water across the globe is uneven in terms of quality and quantity, while it is found in abundance in some places; it is scarce in others.

Water serves as a basic requirement for life, e.g. agricultural production and industrial development. It is the most important natural resource in many communities. It is freely available in the streams, rivers, oceans and lakes. It is only in water deficient environment such as desert or semi-arid area that water is given proper accord and due recognition as a valuable resource.

Shortage of drinking water for both human and animal consumption is the main limiting factor on economic and social development in the developing countries. Evaluation and assessment of the impact of water supply programme in the developing countries is necessary to forecasts its effects on social and economic development.

Water supply is one of the most basic human needs that must be in adequate quality and quantity to sustain life with minimum health hazards. It is needed not only for drinking, nutrition and personal purpose but also for environmental sanitation such as disposal of waste.

According to a report on National Urban Policy (1986), the situation in the country is far from being satisfactory. Observations show that only limited number of towns are fully supplied with pipe borne water, the report went further to explain that in many places, water supply becomes a problem, people then resort to buying water from water vendors regardless of the source. These are among other factors that are responsible for the prevalence of water borne diseases in most of the towns of the developing countries.

It is in this regard that foreign organizations such as World Health Organizations (WHO) and United Nations International Children Emergency Fund (UNICEF) have cooperated with the government in the developing countries to meet up the demand for water, among others. Consequently, project embarked upon include the construction of wells, boreholes and pipe borne water in many areas.

Despite the efforts made by the government and other related parastatals to overcome the problem of distribution of water to all consumers through boreholes and pipe borne water, portable water supply in Maiduguri metropolis is still far from been satisfactory. The main sources of water supply in Maiduguri Metropolis are the hydrologic facilities and pipe borne water.

Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advance water supply management.

In this study, attempt is made to take inventory of the hydrologic facilities in Maiduguri metropolis, the spatial distribution of these facilities and adequacy assessment of the facilities as well as creating a comprehensive database for these facilities within the study region.

*Focus of the study*

This study aimed at taking inventory, creating database and also carrying out adequacy analysis of the hydrologic facilities in the study area with the specific objectives of:

- producing digital map of the hydrologic facilities in Maiduguri Metropolis.
- creating a comprehensive database of the hydrologic facilities and
- demonstrating the application and the potential of GIS techniques for inventory of hydrologic facilities in the study region based on conventional data.

*The study area*

Maiduguri is located at the northeastern part of Nigeria which lies between latitudes $11^{0}$48’N and $11^{0}$52’N and longitudes $13^{0}$06’E and $13^{0}$14’E. It covers a total area of 543sq.km. This makes it the largest city in the northeastern region of Nigeria. Maiduguri has four districts with several villages and ward units. Maiduguri Metropolitan council has now been divided into two local government areas: Maiduguri and Jere local government areas. For the purpose of this study, Maiduguri metropolis was selected as it is the capital city of Borno State. There are15 wards within Maiduguri Metropolis, these include Shehuri North, Shehuri South, Bulabulin, Lamisula, Gwange I, Gwange II, Gwange III, Fezzan, Gamboru, Bolori I, Bolori II, Limanti, Hausari, Maisandari and Mafoni.

The climate of the study area is semiarid with two seasons: a long dry season from October to April when a dry dusty wind blows off the Sahara desert with daytime temperatures of 32-42°C (90-107 °F) and nighttime temperatures of 28-34°C (82-93°F), and a short wet season, from about May to September with daily maximum temperature of 40°C (104°F) and a mean annual value of about 35°C (95°F). Relative humidity is about 40-70 %.Rainfall is generally low with a mean annual value of about 625 mm, while the mean annual evaporation rate is about 1600 mm. vegetation in the study area can be described as Savannah woodland i.e Sahel savannah The types of Trees include Acacia nilotica, Acacia Senegal, and Acacia Seyal, the last two are major source of Arabic gum. The vegetation also includes the non leguminous Ziziphus and Balanites aegyptiaca, though between 1975 and 1995, the acacia suffered mild depletion.

Maiduguri was estimated to have a population of 1,197,497 by 2009 as of 2007. Its residents are mostly Muslim and consist of Kanuri, (Shuwa) Arab, Bura, Fulfulde and other smaller ethnic groups. There is also a considerable Christian population, Maiduguri is home to two markets, a museum and is served by the Maiduguri International Airport. It is the principal trading hub for northeastern Nigeria. Its economy is largely based on services and trade with a small share of manufacturing. The city lies at the end of a railway line connecting Port Harcourt, Enugu, Kafanchan, Kuru,Bauchi, and finally Maiduguri.

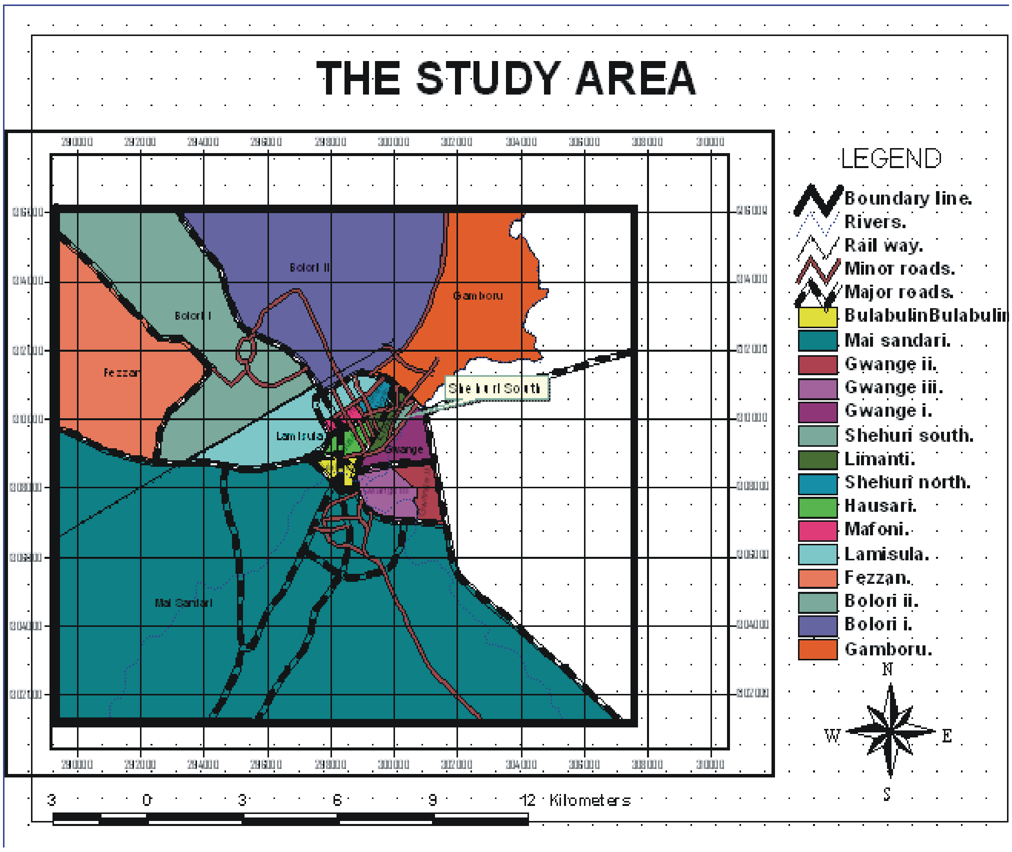



Fig 1.1 Showing the Study Area Fig 1.1 Showing the Study Area

*Materials and methods*

Here, a general description of the research methodology is offered. The notable stages include: data collection, data input, data manipulation, data analysis, production of GIS models and data output. The result of each of the stages is presented as follows.

*Data collection*

Eliable and comprehensive data were generated from different sources. The township map of the study area was obtained from the State Ministry of Land and Survey. The ward boundaries were sourced from the Department of Information and Communication Maiduguri Metropolis. Data on the population of the study area was obtained from the public data clearing house on the internet. Hand held Global Positioning System (GPS) equipment Germin 72 was used to record the coordinates and the elevation points of all the hydrologic facilities within the study area. Gen-X digital camera was used to take the photographs and video-cover the activities within the vicinity of the hydrologic facilities. Descriptive attributes of the facilities such as depth, Yield, year drilled, aquifer position, etc were obtained from the Ministry Of Urban and Rural Water Supply Borno State.

*Data Input*

Hp Office-jet scanner 5600 series and Hp Laptop were used for the data input. The map of the study area was scanned into the computer. Details of the hydrologic facilities were inputted using the keyboard into the computer. The video-coverage and the photographs of the activities within the vicinity of the boreholes were saved on SD Memory Card and were transferred into the computer using a Card Reader.

*Data Manipulation*

Five different software were used in the data manipulation. These include Corel Draw 11, Microsoft Word 2003, Arc view 3.2a, Ilwis 3.1 and ArcGIS 9.2. The UTM coordinates of the hydrologic facilities were collected; these coordinates were used to develop the database for the research.

The township map was scanned using Corel Draw11 and was exported into Ilwis where it was georeferenced. The coordinate values of the four corners of the map were used for the georeferencing; four points were selected as tie-points. The map was resample to the georeferenced corner object, this georef tie points ensures the features have the correct ground coordinates.

Prominent features on the map and the fifteen wards of the study area were digitized as themes using on-screen digitizing capability of the Arc view software.

The attributes of all the hydrologic facilities and the population of each of the fifteen wards were to create the database. These are linked to the main view for further analysis.

*Data Analysis*

Arc view 3.2a was used to analyze the data generated. From the database, the "find" icon of the software was used to find the location of any of the hydrologic facilities which are immediately highlighted in yellow. This can also be generated by the use of the query menu. The "query" and the "identifier" menus are very important menus for data analysis. When the identifier menu is used, all the information based on the fields in the database such as ward, elevation, depth, yield, status and year drilled of any desired borehole appear at once on the screen.

On the other hand, the whole table can be displayed and each of the boreholes can be selected at the same way as in the map. The selected records can be sorted or rearranged either in ascending or descending orders. Selected records can be collected together at the uppermost part of the table through the use of the "promote" menu. So many analyses can be performed using the "query" or the "identifier" in GIS.

*Results and Discussion*

Analysis and results were generated during field survey of the study area. The analyses were carried out using Arc View 3.2a and ArcGIS 9.2 software.

*Mapping of the study region*

Fig. 1.2 below shows the digitized map of the study area containing all the fifteen (15) wards in the area. The map compilation is considered to be a key issue and absolute pre-requisite to high quality theme map creation. The fifteen (15) wards are differentiated from each other by the use of different colours. The names of each of the wards with their corresponding colours are displayed as legend at the right side of the map. Fifty three (53) hydrologic facilities found in the study area are represented as point features on the map. The point features all fall at their respective positions which indicate that the pixel resolution of the base map commensurate with the accuracy of the GPS.

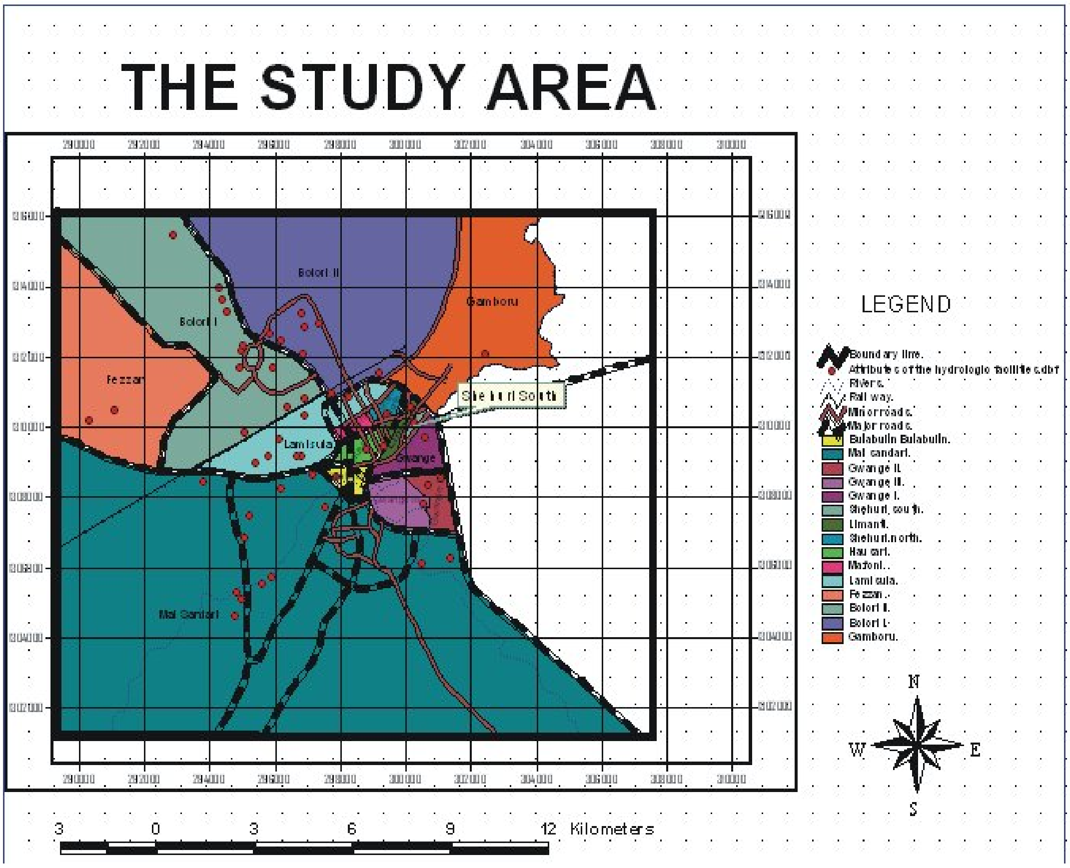
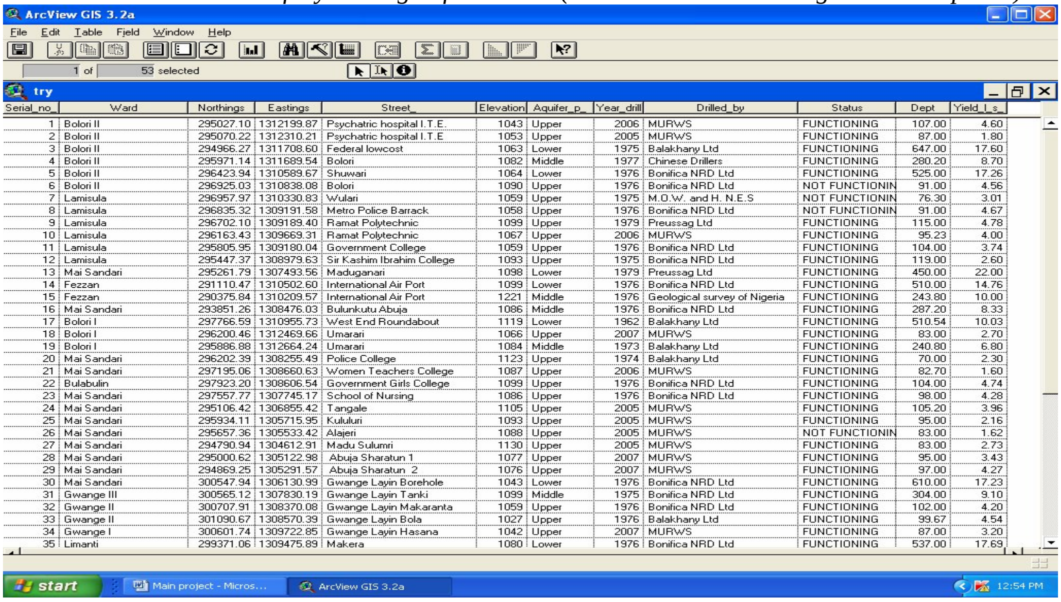



*Figure 1.2 The spatial distribution of the Hydrologic Facilities(boreholes).*

Detail information of the existing hydrologic facilities inventory is displayed in the table below. The development of this table is based on the data collected from the Ministry of Urban and Rural Water Supply Borno State.

*Table 1.1 databases of hydrologic facilities (boreholes in maiduguri metropolis)*



| Serial_no_ | Ward | Northings | Eastings | Street_ | Elevation | Aquifer_p_ | Year_drill | Drilled_by | Status | Dept | Yield_l_s_ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bolori II | 295027.10 | 1312199.87 | Psychatric hospital I.T.E. | 1043 | Upper | 2006 | MURWS | FUNCTIONING | 107.00 | 4.60 |
| 2 | Bolori II | 295070.22 | 1312310.21 | Psychatric hospital I.T.E | 1053 | Upper | 2005 | MURWS | FUNCTIONING | 87.00 | 1.80 |
| 3 | Bolori II | 294966.27 | 1311708.60 | Federal lowcost | 1063 | Lower | 1975 | Balakhany Ltd | FUNCTIONING | 647.00 | 17.60 |
| 4 | Bolori II | 295971.14 | 1311689.54 | Bolori | 1082 | Middle | 1977 | Chinese Drillers | FUNCTIONING | 280.20 | 8.70 |
| 5 | Bolori II | 296423.94 | 1310589.67 | Shuwari | 1064 | Lower | 1976 | Bonifica NRD Ltd | FUNCTIONING | 525.00 | 17.26 |
| 6 | Bolori II | 296925.03 | 1310838.08 | Bolori | 1090 | Upper | 1976 | Bonifica NRD Ltd | NOT FUNCTIONIN | 91.00 | 4.56 |
| 7 | Lamisula | 296957.97 | 1310330.83 | Wulari | 1059 | Upper | 1975 | M.O.W. and H. N.E.S | NOT FUNCTIONIN | 76.30 | 3.01 |
| 8 | Lamisula | 296835.32 | 1309191.58 | Metro Police Barrack | 1058 | Upper | 1976 | Bonifica NRD Ltd | NOT FUNCTIONIN | 91.00 | 4.67 |
| 9 | Lamisula | 296702.10 | 1309189.40 | Ramat Polytechnic | 1099 | Upper | 1979 | Preussag Ltd | FUNCTIONING | 115.00 | 4.78 |
| 10 | Lamisula | 296163.43 | 1309669.31 | Ramat Polytechnic | 1067 | Upper | 2006 | MURWS | FUNCTIONING | 95.23 | 4.00 |
| 11 | Lamisula | 295805.95 | 1309180.04 | Government College | 1059 | Upper | 1976 | Bonifica NRD Ltd | FUNCTIONING | 104.00 | 3.74 |
| 12 | Lamisula | 295447.37 | 1308979.63 | Sir Kashim Ibrahim College | 1093 | Upper | 1975 | Bonifica NRD Ltd | FUNCTIONING | 119.00 | 2.60 |
| 13 | Mai Sandari | 295261.79 | 1307493.56 | Maduganari | 1098 | Lower | 1979 | Preussag Ltd | FUNCTIONING | 450.00 | 22.00 |
| 14 | Fezzan | 291110.47 | 1310502.60 | International Air Port | 1099 | Lower | 1976 | Bonifica NRD Ltd | FUNCTIONING | 510.00 | 14.76 |
| 15 | Fezzan | 290375.84 | 1310209.57 | International Air Port | 1221 | Middle | 1976 | Geological survey of Nigeria | FUNCTIONING | 243.80 | 10.00 |
| 16 | Mai Sandari | 293851.26 | 1308476.03 | Bulunkutu Abuja | 1086 | Middle | 1976 | Bonifica NRD Ltd | FUNCTIONING | 287.20 | 8.33 |
| 17 | Bolori I | 297766.59 | 1310955.73 | West End Roundabout | 1119 | Lower | 1962 | Balakhany Ltd | FUNCTIONING | 510.54 | 10.03 |
| 18 | Bolori I | 296200.46 | 1312469.66 | Umarari | 1066 | Upper | 2007 | MURWS | FUNCTIONING | 83.00 | 2.70 |
| 19 | Bolori I | 295886.88 | 1312664.24 | Umarari | 1084 | Middle | 1973 | Balakhany Ltd | FUNCTIONING | 240.80 | 6.80 |
| 20 | Mai Sandari | 296202.39 | 1308255.49 | Police College | 1123 | Upper | 1974 | Balakhany Ltd | FUNCTIONING | 70.00 | 2.30 |
| 21 | Mai Sandari | 297195.06 | 1308660.63 | Women Teachers College | 1087 | Upper | 2006 | MURWS | FUNCTIONING | 82.70 | 1.60 |
| 22 | Bulabulin | 297923.20 | 1308606.54 | Government Girls College | 1099 | Upper | 1976 | Bonifica NRD Ltd | FUNCTIONING | 104.00 | 4.74 |
| 23 | Mai Sandari | 297557.77 | 1307745.17 | School of Nursing | 1086 | Upper | 1976 | Bonifica NRD Ltd | FUNCTIONING | 98.00 | 4.28 |
| 24 | Mai Sandari | 295106.42 | 1306855.42 | Tangale | 1105 | Upper | 2005 | MURWS | FUNCTIONING | 105.20 | 3.96 |
| 25 | Mai Sandari | 295934.11 | 1305715.95 | Kululuri | 1093 | Upper | 2005 | MURWS | FUNCTIONING | 95.00 | 2.16 |
| 26 | Mai Sandari | 295657.36 | 1305533.42 | Alajeri | 1088 | Upper | 2005 | MURWS | NOT FUNCTIONIN | 83.00 | 1.62 |
| 27 | Mai Sandari | 294790.94 | 1304612.91 | Madu Sulumri | 1130 | Upper | 2005 | MURWS | FUNCTIONING | 83.00 | 2.73 |
| 28 | Mai Sandari | 295000.62 | 1305122.98 | Abuja Sharatun 1 | 1077 | Upper | 2007 | MURWS | FUNCTIONING | 95.00 | 3.43 |
| 29 | Mai Sandari | 294869.25 | 1305291.57 | Abuja Sharatun 2 | 1076 | Upper | 2007 | MURWS | FUNCTIONING | 97.00 | 4.27 |
| 30 | Mai Sandari | 300547.94 | 1306130.99 | Gwange Layin Borehole | 1043 | Lower | 1976 | Bonifica NRD Ltd | FUNCTIONING | 610.00 | 17.23 |
| 31 | Gwange III | 300565.12 | 1307830.19 | Gwange Layin Tanki | 1099 | Middle | 1975 | Bonifica NRD Ltd | FUNCTIONING | 304.00 | 9.10 |
| 32 | Gwange II | 300707.91 | 1308370.08 | Gwange Layin Makaranta | 1059 | Upper | 1976 | Bonifica NRD Ltd | FUNCTIONING | 102.00 | 4.20 |
| 33 | Gwange II | 301090.67 | 1308570.39 | Gwange Layin Bola | 1027 | Upper | 1976 | Balakhany Ltd | FUNCTIONING | 99.67 | 4.54 |
| 34 | Gwange I | 300601.74 | 1309722.85 | Gwange Layin Hasana | 1042 | Upper | 2007 | MURWS | FUNCTIONING | 87.00 | 3.20 |
| 35 | Limanti | 299371.06 | 1309475.89 | Makera | 1080 | Lower | 1976 | Bonifica NRD Ltd | FUNCTIONING | 537.00 | 17.69 |

### *Adequacy assessment analysis*

As seen on the map, the hydrologic facilities are unequally distributed in the fifteen wards within the study area. Each of the hydrologic facilities has its yield in litres per second depending on the dept and the aquifer potential. The yield per day and the number of jerry cans per day were also calculated as would be explained in details later . The table below shows the fifteen wards and the number of boreholes in each of the wards found in the study area.

*Table 1.2 adequacy analysis of boreholes in maiduguri metropolis*

| S/NO | WARD | No of b/holes | J/DAY | POP | J/HEAD | ADEQUACY |
|---|---|---|---|---|---|---|
| 1 | Bolori I | 6 | 311817.6 | 119506 | 2.61 | Adequate |
| 2 | Bolori II | 11 | 306028.8 | 107774 | 2.84 | Adequate |
| 3 | Gwange I | 1 | 13824 | 95799 | 0.14 | Inadequate |
| 4 | Gwange II | 2 | 37756.8 | 59874 | 0.63 | Inadequate |
| 5 | Gwange III | 1 | 39312 | 71849 | 0.55 | Inadequate |
| 6 | Shehuri N | 1 | 17712 | 48010 | 0.37 | Inadequate |
| 7 | Shehuri S | 1 | 18792 | 47850 | 0.39 | Inadequate |
| 8 | Limanti | 2 | 95817.6 | 35824 | 2.68 | Adequate |
| 9 | Gamboru | 1 | 97977.6 | 83824 | 1.17 | Inadequate |
| 10 | Lamisula | 7 | 77198.4 | 107876 | 0.72 | Inadequate |
| 11 | Fezzan | 2 | 106963.2 | 59812 | 1.79 | Inadequate |
| 12 | Hausari | 1 | 73180.8 | 95697 | 0.76 | Inadequate |
| 13 | Maisandari | 14 | 333892.8 | 131867 | 2.53 | Adequate |
| 14 | Bulabulin | 1 | 20476.8 | 48011 | 0.43 | Inadequate |
| 15 | Mafoni | 0 | 0 | 83824 | 0 | Inadequate |

From table 1.2 above, the yield in litters per second of all the boreholes in a particular ward were summed up together. The value obtained gives the total yield for the boreholes within the ward in litters per second. This is then multiplied by 3600 to obtain the total yield per hour. The 3600 was obtained from the fact that there are 60 seconds in a minute and 60 minutes in an hour, multiplying 60 by 60 gives the 3600 seconds in an hour. The value was further multiplied by 24 (since there are 24 hours in a day) to obtain the total yield per day in a particular ward.

The adequacy assessment was carried out considering the report by the World Bank that about 45 litres (2.25 Jerry Can) will be sufficient for a person in a day.

The total population of the study area was obtained from the public data clearing house on the internet as shown in the table above

If each person in the fifteen (15) wards within the study area is to use 45 litres which is equivalent to 2.25 jerry cans of water in a day, then the number of jerry cans that could be used per head is obtained from the analysis by dividing the total number of population in a ward with the total yield of a borehole per day.

The number of jerry cans per day was obtain by dividing the yield in litres per day by twenty (20) (since each jerry can = 20litres). The total yield in jerry cans per day for each of the wards is further divided by the population of the corresponding ward. This will give the number of jerry cans that could be used per head in each of the wards.

*Hot-linking Photographs*

Another way to provide additional information on a view is to set up hot links between the features in a theme and external files. Photographs and videos of the activities taking place around the boreholes were taken. These were stored in an external file and were hot linked to the point features representing the boreholes on the map.

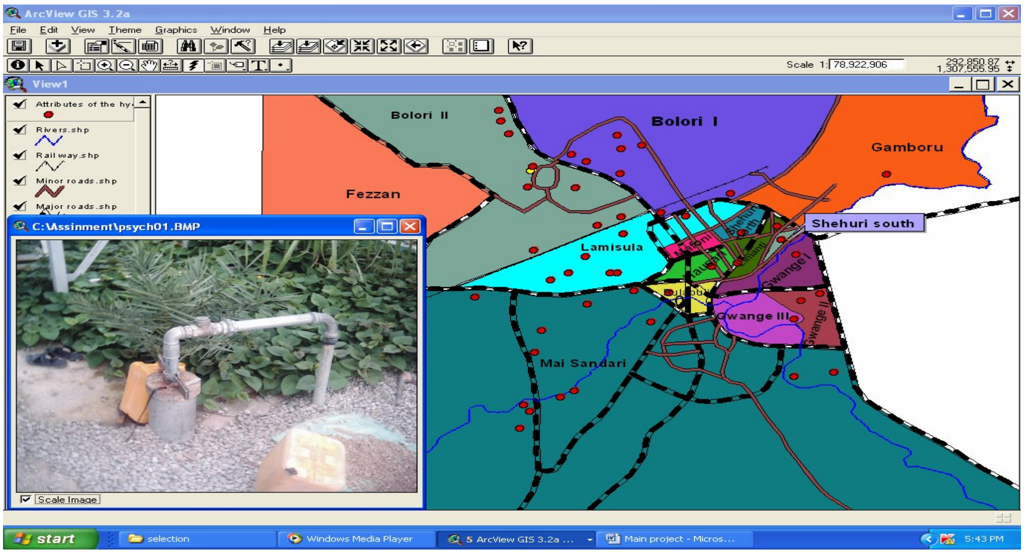



*Fig 1.3 showing the vicinity around a borehole obtained by hot linking.*

*Discussion of Results*

- As explained earlier, the boreholes are unequally distributed in the fifteen (15) wards within the study area. Maisandari ward which is the largest of all the wards it has the highest number of boreholes (14). Followed by Bolori II with 11, Limanti and Fezzan have two boreholes each. Gwange I and III, Shehuri North and South, Gamboru and Hauari all have one (1) borehole each and lastly Mafoni with no borehole at all.
- From the adequacy assessment carried out, the World Bank standard was considered, that 2.25 Jerry Cans of water could be sufficient per head in a day. The result of the analysis shows that only 4 out of the fifteen (15) wards meet up with this standard and are considered to have adequate supply of water. With the maximum of fourteen (14) boreholes in Maisandari ward though with the highest population (i.e. 131,867), it has about 2.53 Jerry cans per head. The ward with the maximum yield per day i.e. Bolori II with 2.84 Jerry can per head has about 0.31 jerry can above the World Bank standard. In fact up to 9 out of the fifteen wards have less than 50% of the standard. This indicates that water supply through hydrologic facilities is far behind being adequate in the study area.
- Despite the fact that surface water contributes about 45% of the water need in the study area. The supply is still not adequate. This is partly due to the seasonal nature of the rivers and partly due to environmental changes.
- Due to unevenly positioning of the boreholes, some people have to trek some distances in search for water. In Mafoni ward for example which has no borehole at all, people trek to the neighboring wards to fetch water or buy from water vendors.
- Eight (8) out of the fifty three (53) boreholes found in the study area were not functioning. This may be due to clogging of the borehole screen or improper borehole design.
- Even the fifty three (53) boreholes supplemented by the surface water produce by the water treatment plant popularly known as the mother cat. Did not meet to the water need of the study area.

*Recommendations and Proposal*

In view of the above discussion, the following recommendations and proposal are made based on the data collected and the analysis carried out using GIS technique as an effective tool for decision making.

- From the fact that the fifty three hydrologic facilities are not adequate to meet up to the water need of the study area, more boreholes are needed to be drilled in the affected wards.

To meet up to the World Bank standard, boreholes of at least 4 litres per second are to be drilled in the affected wards. The 4 litres per second yield was selected because the yield could be obtained from either the upper aquifer (which has a yield ranging from 2 to 5 litres per second), or the middle aquifer (with yield ranging from 5 to 10 litres per second). The middle aquifer is preferable since it is the most widespread and best exploited confined aquifer in the study area. The second reason is the cost implication of drilling, as the cost of drilling increases with dept. The table below shows the analysis of the proposal carried out to meet up to the water need of the study area.

*Table 1.2 showing the proposed adequacy assessment analysis.*

| *S/No* | *Wards Affected* | *Present yield (J/day)* | *Proposed No. of Bore holes* | *Proposed yield (J/day)* | *Population* | *Expected yield in J/day* | *Expected yield J/Head* |
|---|---|---|---|---|---|---|---|
| *1.* | Lamisula | 77198.00 | 12 | 207360.00 | 107876 | 284558.00 | 2.64 |
| *2.* | Fezzan | 106963.20 | 4 | 69120.00 | 59812 | 176083.20 | 2.94 |
| *3.* | Gwange III | 39312.00 | 9 | 641520.00 | 71849 | 194832.00 | 2.71 |
| *4.* | Bulabulin | 20476.80 | 6 | 103680.00 | 48011 | 124156.80 | 2.59 |
| *5.* | Gwange II | 37756.80 | 7 | 120960.00 | 59874 | 158716.80 | 2.56 |
| *6.* | Gwange I | 13824.00 | 14 | 241920.00 | 95799 | 255744.00 | 2.67 |
| *7.* | Hausari | 73180.80 | 10 | 172800.00 | 95697 | 245980.80 | 2.57 |
| *8.* | Sehuri South | 18792.00 | 6 | 103680.00 | 48750 | 122472.00 | 2.51 |
| *9.* | Gamboru | 97977.00 | 7 | 120960.00 | 83824 | 218937.00 | 2.61 |
| *10.* | Shehuri North | 17712.00 | 7 | 120960.00 | 48010 | 138672.00 | 2.89 |
| *11.* | Mafoni | 0.00 | 13 | 224640.00 | 83824 | 224640.00 | 2.68 |

The yield of the proposed boreholes (in jerry can per day) was calculated, this was added to the present yield of boreholes in the affected wards and the result gives expected yield in jerry can per day. This was then divided by the population of the corresponding ward to get the yield in jerry can per head.

The map below shows the spatial distribution of the present boreholes as well the proposed boreholes expected to meet up to the water need of the study area.

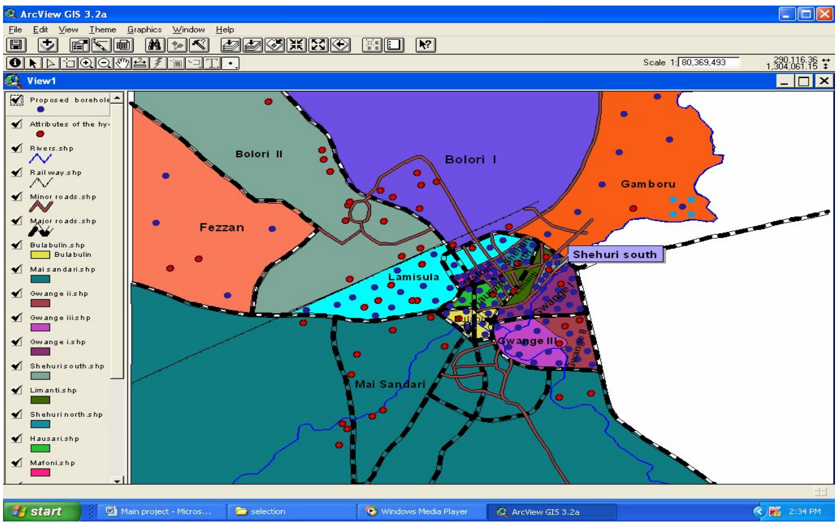



*Fig. 1.4 showing proposed and present boreholes in the study area.*

From the map above, the proposed boreholes are given blue colour. They are evenly distributed throughout the wards such that all the inhabitants could have access to these facilities.

- The eight boreholes that are not functioning are to be rehabilitated as this will aid in increasing the yield in the wards affected.
- The boreholes that are to be drilled should be evenly distributed through out the study area. This will make it easy for all the inhabitants of the Metropolis to have access to the water points.
- The Government and the staff of the Ministry of Rural and Urban Water supply of the state and the country at large should be sensitized on the importance of GIS technique as a tool that can be utilized for data creation, management, effective planning and decision making.
- From the data collected from the Ministry of Rural and Urban Water Supply, some of the boreholes are up to 40 years and above. This indicates that the yield of some of these boreholes might have been decreasing due to ageing. These boreholes need to be rehabilitated so as to increase the yields as they were when first drilled.
- From the adequacy assessment analysis carried out, ninety five (95) more boreholes have been proposed adding to the fifty three boreholes present in the study area to get a total of one hundred and forty eight (148) boreholes.

### *Conclusion*

Results from the analysis in this study indicate that the hydrologic facilities in the area are far from being adequate. This inadequacy poses a great negative impact on both social and economic activities in the area. Fast and effective planning and decision making need to be done.

A simple Geographic Information System (GIS) technique offers an effective tool which can be relied on. Use of this system enables global "at a glance" evaluation of groundwater resources through the available data, whilst in parallel reduces potential erroneous information introduced in the databases. As data handling potential of the system is practically limitless, it can accommodate diverse information on the studied aquifers. Easy handling of the tabulated information renders the system quite versatile as it can serve a wide variety of users.

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