# Water Supply Situation in the Crystalline Hydrogeological Province of Northern Nigeria: A Case Study of Nasarawa Town and Environs, Northcentral Nigeria

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## Abstract

*This study focuses on the piped water supply to Nasarawa town of about 100,000 residents in north central Nigeria. Hydrogeological mapping of the area entailed location of rock outcrops and measurements of ground water table in hand dug wells. The area is underlain by the Precambrian Basement Complex Crystalline rocks such as schist, gneiss, migmatiteandgranite. These rocks are dominantly fractured in NNE-SSW and N-Sdirections. These structures have effect on the drainage pattern and influence both the groundwater and surface water flow directions in the area. Static water resources of the Nasarawa dam drainage basin upstream from the embankment are1, 814x 106 m3. Total dynamic water resources are 90,547,182 m3/a out of which 45,273,591 m3/a, are utilizable dynamic water resources while the remaining 45,273,591 m3/a, are non-utilizable dynamic water resources. Current water demand in Nasarawa town and environs is 4.0 x 106 m3/a while the ultimate water demand was estimated at22.5 x 106 m3/a. Groundwater in the study area is enough to supplement surface water to meet the current as well as the future water demand of people in the area.*

**Keywords:** Water supply, Nasarawa, Static water, Dynamic water, Water demand

## *1. Introduction*

Nasarawa town is located within the crystalline hydrogeological province of the North Central Nigeria bounded bylatitudes 8$^{o}$ 30’ N to 8$^{o}$40’ N and longitudes 7$^{o}$34’ E to 7$^{o}$ 45’ E, and the total area coverage is 370.7 km$^2$ (Figure 1). The area falls within Topographical Map of Nigeria (Nigeria Survey Agency, 2008), 1:50,000sheet 208Keffi SW. The study area lies within the Guinea Savannah and has tropical climate with mean annual depth of rainfall of about 1,357 mm/a (Nigerian Meteorological Agency, Lafia 2012). The rainfall starts in March and lasts till October while dry season starts from November and lasts till February.The rainy season on average lasts for 215 days while the dry season lasts for 150 days. The mean annual temperature

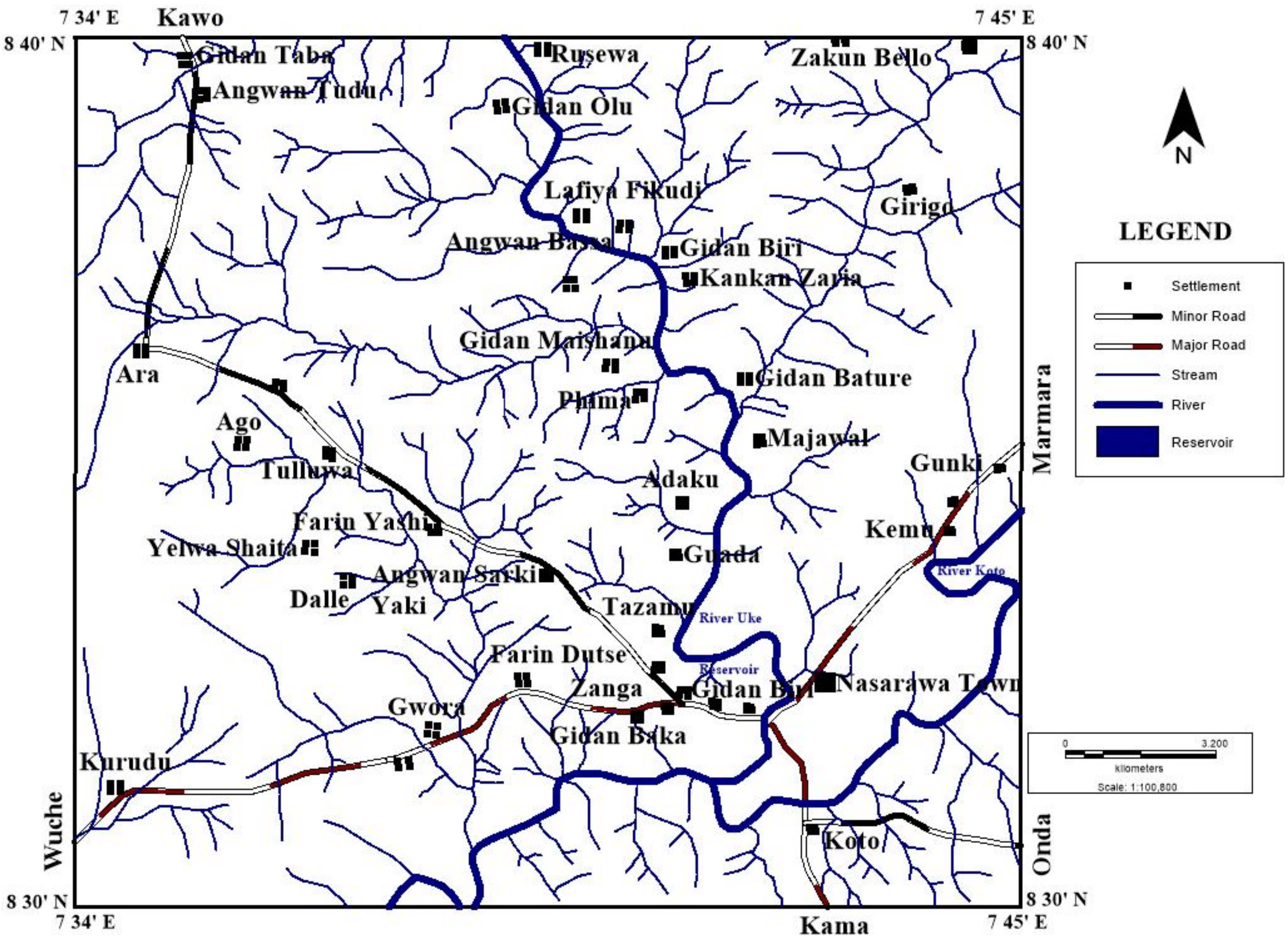



**Figure 1: Location map of Nasarawa town and environs (Extracted and Modified from topographical map sheet 208 Keffi SW produced by Federal Survey Agency, 2008)**

Is 28$^{o}$C and evapotranspiration in the area varies based on the season. The vegetation type is an open forest. It is affected in most places by human activities. Human activities have intensely reduced the vegetation to tree savannah (mostly economic trees) where clusters of trees stand amongst grass and shrubs. Economic trees, mostly cashew, mango, bananas, oranges, guava, oil palm trees and so on, have replaced most of the natural tree vegetation in the area. The relief of the study area is relatively undulating highlands to average height of about 450 m above sea level. River Uke and River Kotto constitute the main drainage system with other seasonal streams as their tributaries giving a dendritic pattern of drainage. All rivers flow through the study area from the north to the south, to empty their water into River Benue.

Nasarawa town has a piped water supply, but does not meet water demand and is supplemented by boreholes and hand-dug wells, especially during dry season when the yields of open wells and boreholes fall and surface water from rivers, streams and impounding reservoirs is becoming scarce. This area that used to have excess water supply throughout the year in the late 80s and early 90s, when people from neighboring towns used to come to this area to get water for their domestic use, but for some years from late 90s till now, the story is not the same. Little or nothing has been done to investigate the inadequacy of the piped water supply. Reasons of the failure of some boreholes drilled and the fall in yield of many open wells in the area are yet to be investigated. Waterworks was constructed with an installed capacity of 570 $m^3$/din early 80s to supply piped water to the inhabitants of the area. The waterworks since the time of its establishment, supply water to the old part of Nasarawa town, but for some years now it only serves few streets around the water works. The area has expanded with new settlement since the creation of Nasarawa State in 1996. However, the aims of continues water supply to the residents has not been met even within the old part of the Nasarawa town.

The Directorates of Rural Development in conjunction with the State Ministry of Water Resources and also with help from UNICEF are responsible for providing non-piped water to residents of are as in which the piped water cannot cover, as well as newly developed areas within the study area. Some boreholes drilled by these agencies are no longer functioning and those that are still active cannot serve the growing population of the inhabitants of the area. Effort was made by the last administration, with the help from UNICEF, to sink more boreholes across the state. The project was started but later abandoned, perhaps because of change in the administration in the State, or perhaps due to inefficient use of funds.

Greater demand on the supply of safe drinking water will be needed because of increase in population and economic development. Decree 101 of 1993 of Nigeria's water resources law is the major tool available to all tiers of government for the planning and management of water resources. Residential water supply in the study area is inadequate, taps are dry, failure of some boreholes and fall in yield of hand dug wells have not been correctly identified and addressed. The aim of this paper is to examine and identify the reasons for the inadequate water supply in Nasarawa town and environs.

## 2. Methodology

Depth to water level in hand dug wells at the peak of dry season, were measured using water level indicator and located on the topographical maps and the co-ordinates of each sampled locations were taken using satellite navigator. This instrument beeps a sound when the tip of the lowered probe touches water in the well. It consists of a calibrated tape in meters and in feet. The water level values were subtracted from the values of the elevation of wells and plotted on the topographical map. All data plotted on the topographical map were used for the preparation of water table configuration maps for the peak of dry season.

The groundwater configuration maps were produced using conventional method as well as using GIS (MapInfo Professional 11.0) method of maps production. The contour maps plotted were for the aquifer tapped by the hand dug wells in the study area.

Data from various agencies like the Nigerian Metrological Agency, Nasarawa State Ministry of Water Resources, Nasarawa State National Population Commission, and National Bureau of Statistics were used to achieve desire objectives. Data from the Nigerian Metrological Agency were used to calculate the mean annual rainfall in the study area for a period of eleven years. The result (mean annual rainfall) was used to calculate the amount of surface water and groundwater in the study area. Geophysical data obtained from Nasarawa State Ministry of Water Resources were used to study/ interpret the different layers of the subsurface to know the thickness of these layers. Data for the population of people in the study area and the population growth in Nasarawa State were obtained from Nasarawa State National Population Commission and National Bureau of Statistics. Current population of people in the study area and the population growth were used to calculate the projected population of people in the study area in 44 years from 2006 population census. These data were used to calculate the current water demand as well as the future water demand of people within the study area.

## 3. Geology and Structural Features of the Study Area

Nasarawa town falls within the North central Nigerian Basement Complex. The area is underplayed by four litho logical units of schists, gneisses, migmatites, and granites, with pegmatite's and quartz veins as minor intrusions (Figure 2).The first litho logical unit, the schist, mostly mica schist covers about 5 % and occurs to the east of the study area. The second lithological unit, the gneisses, mostly coarse and porphyroblastic gneisses and little fine - grained gneiss cover about 60 % of the area. The third litho logical unit, the migmatite, covers nearly 25 % of the study area. The last units, the granite, which covers about 10 % of the area, are mostly exposed on the northwestern and southwestern parts of the study area. They mostly form batholiths, which are extensive in size. They are mostly coarse-grained granite and porphyritic granite. Apart from these four major rock types, there are other rocks types inform of minor intrusions such as pegmatite's and quartz veins. They are closely associated with the granitic rocks and the gneisses. These cut across one another and are generally characterized coarse textures. They occur as dykes, sill lenses and phenocrysts. They contain quartz, feldspars, and some minerals of precious quality such as tourmaline, emerald, aquamarine, epidotite (Wright *et al*., 1985).

The basement is generally fractured with North-South and Northeast-Southwest direction. Kehinde*et al.*, (2013) observed NW-SE, N-S, and ENE-WSW lineaments in schist and gneisses; N-S, NE-SW and NW-SE in porphyritic granite of the basement complex of Nigeria.

Fractures are linear or curvilinear features on rocks outcrops, which depict the weaker zone of bed rocks and are considered as secondary aquifer in hard rock regions and could be the target area for groundwater exploration. These lineaments can be mapped with the help of satellite data and can be correlated with faults, fractures, joints, bedding planes and litho logical contacts. Structural lineaments were extracted from Landsat EMT+ multispectral datasets. Using statistical analyses, lineament lengths, density and intersection were determined (Figure 3). The fractures were plotted on GIS software to generate rose diagram. The rose diagram of the fractures delineated on the imagery show the dominant trends to be NNE-SSW direction (Figure 4).

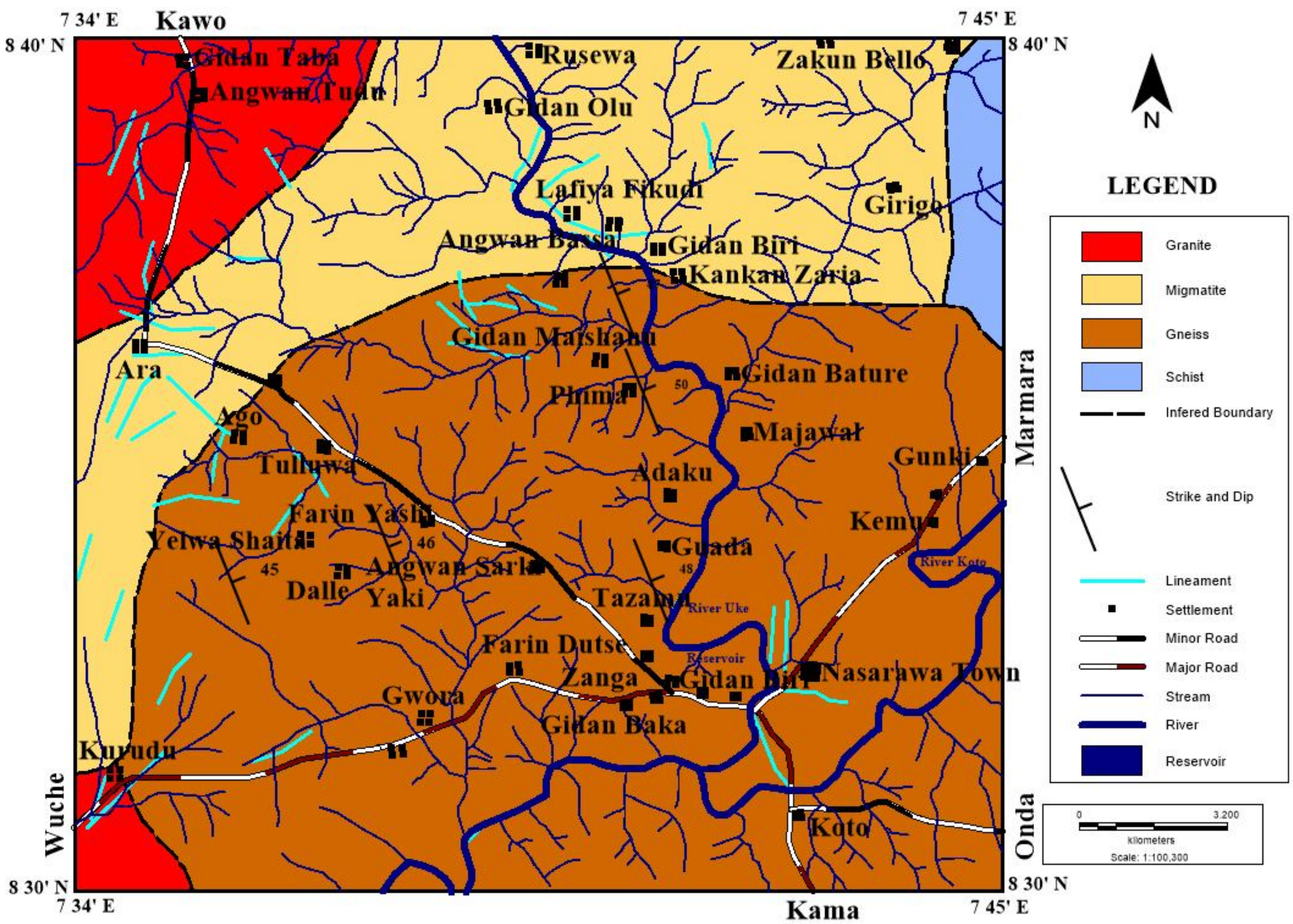
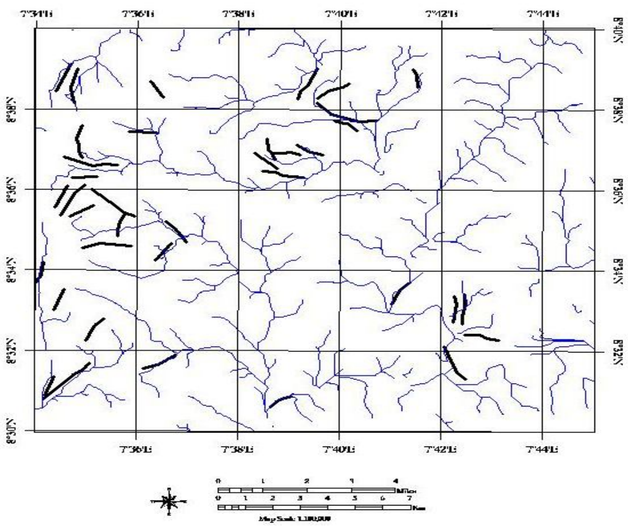



**Figure 2: Geological Map of Nasarawa Town and Environs (Extracted and Modified from Nigerian Geological Survey Agency, 2006a)**



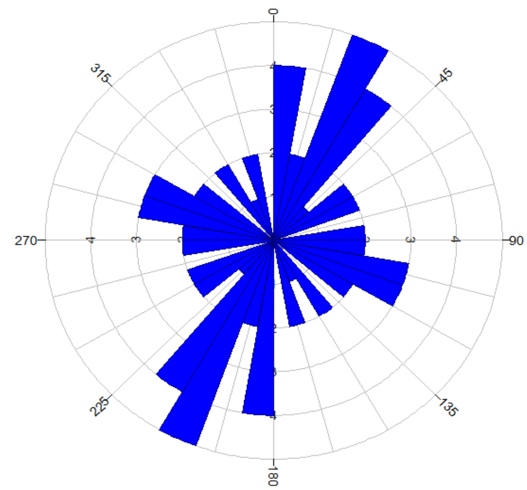



**Figure 3: Map of Lineaments Superimposed Figure 4: Rose Diagram of Lineament on the Drainage of the Study Area in the Study Area**

## *4. Results and Discussions*

### 4.1 Water Table Configuration and Directions of Groundwater Flow

Measurement of water table in the study area was done at the peak of dry season (Table 1). Most of the hand dug wells measured are shallow, the deepest being 13.3 m at Gunki. The average depth to water table at the peak of the dry season was 7.53 m. Data of depth to water table measured in the field were used for the construction of water table map. Water table configuration was depicted by thick contours of water table elevation above mean sea level in cyancolour. The groundwater that results from recharge flows towards streams and river channels; this is indicated by arrows drawn perpendicular to equipotential lines and tends to diverge from the recharge areas (watershed) and converge towards the drainage channels (Figure 5).

Movement of water is strongly influenced by topography; recharge is mainly by percolating rainwater and in some places by seepages from adjacent surface water. Recharge areas consists of decomposed and fractured rocks in which pressure heads quickly spread through local water-bearing fissures and interconnected voids, thereby leading to abrupt rise in discharges in response to precipitation (Idowu*et al*., 1999). Groundwater flow directions are dictated by surface topography. This may be a reflection of varying degrees of weathering at different groundwater fronts and the occurrence of the fresh basement at different depths at different locations. The water table map enables identification of major areas of recharge and these are Ara, Ago, and YelwanShaita in the west and Zakun Bello, Rusewa and GidanOluin the north. Groundwater flows on the opposite sides of the water divide towards Uke River and Koto River in the study area.

**Table 1: Results of Groundwater Table at the Peak of Dry Season in Nasarawa Town and Environs**

| S/N | Location | Coordinates | Depth to Water Table (masl) | Well Elevation (masl) | Water Table Elevation (masl) |
|---|---|---|---|---|---|
| 1 | AngwanBiri | 8° 32' 13.3" N<br>7° 41' 08.4" E | 5.8 | 200 | 194.2 |
| 2 | FarinDutse | 8° 32' 31.3" N<br>7° 39' 05.4" E | 10.0 | 220 | 210.0 |
| 3 | Gwora | 8° 31' 27.0" N<br>7° 38' 13.4" E | 13.0 | 193 | 180.0 |
| 4 | Dalle | 8° 33' 46.4" N<br>7° 37' 07.0" E | 12.0 | 270 | 258.0 |
| 5 | Ara (Ugi) | 8° 36' 21.5" N<br>7° 35' 11.9" E | 5.5 | 280 | 274.5 |
| 6 | Ara | 8° 36' 38.3" N<br>7° 34' 46.9" E | 4.4 | 285 | 280.6 |
| 7 | KauyanSarkinYaki | 8° 33' 39.9" N<br>7° 39' 35.8" E | 8.3 | 280 | 271.7 |
| 8 | Lower Oversea | 8° 32' 46.8" N<br>7° 42' 25.3" E | 5.3 | 190 | 184.7 |
| 9 | Upper Oversea | 8° 33' 28.4" N<br>7° 42' 21.8" E | 5.9 | 205 | 199.1 |
| 10 | Kankan Zariya | 8° 37' 19.9" N<br>7° 41' 06.9" E | 5.2 | 214 | 208.8 |
| 11 | AngwanBassa | 8° 37' 55.2" N<br>7° 40' 38.5" E | 7.8 | 215 | 207.2 |
| 12 | Passali | 8° 35' 19.8" N<br>7° 39' 32.9" E | 6.8 | 228 | 221.2 |
| 13 | Gunki | 8° 35' 00.6" N<br>7° 44' 40.1" E | 13.3 | 220 | 206.7 |
| 14 | Kemu | 8° 34' 24.2" N<br>7° 44' 19.5" E | 6.3 | 206 | 199.7 |
| 15 | Tammah | 8° 33' 43.0" N<br>7° 43' 23.2" E | 7.3 | 212 | 204.7 |
| 16 | Low-cost | 8° 33' 00.4" N<br>7° 43' 03.1" E | 3.2 | 210 | 206.8 |
| 17 | AngwanBaidu | 8° 32' 13.8" N<br>7° 42' 46.6" E | 4.5 | 196 | 191.5 |
| 18 | MangoroGoma | 8° 31' 28.1" N<br>7° 42' 30.7" E | 5.0 | 193 | 188.0 |
| 19 | Kotto | 8° 30' 43.1" N<br>7° 42' 42.5" E | 11.3 | 200 | 188.7 |
| 20 | Angwan Rake | 8° 31' 54.3" N<br>7° 42' 22.2" E | 9.7 | 198 | 188.3 |

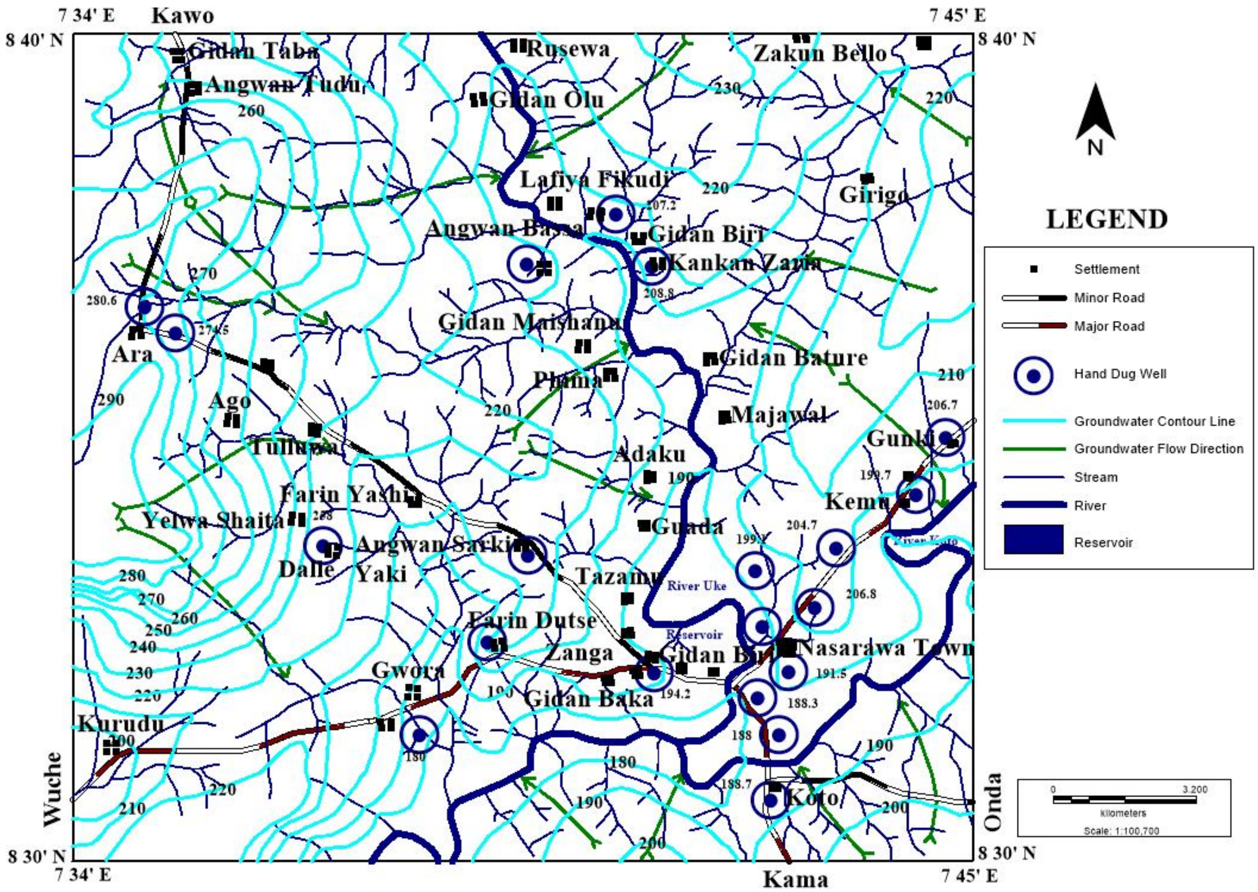



**Figure 5: Map of Configuration of Groundwater Table at the Peak of Dry Season in Nasarawatown and Environs**

### 4.2 Surface Water

There are two large semi perennial rivers within the study area called Uke and Kotto Rivers. The drainage systems comprise many smaller rivers and streams and the Uke and Kotto Rivers into which all the smaller rivers and streams discharge. Both rivers meet within the study area and drain into River Benue. Within the study area there is only one artificial dam called Nasarawa dam. It was constructed with a storage capacity of 0.6 x $10^6$ $m^3$, crests length of 60 m, the dam catchment area/drainage basin is 170 $km^2$ (Nigeria Register of Dams, 1995- Table 2); and 10,000 $m^2$ as area of open water table (Compendium of Dams in Nigeria, 2007).

The impounding reservoir which is the source of surface piped water supply in the study area is a concrete dam constructed on river Ukefor waterworks with an installed capacity of 570 m3/d. In 1995, Nigeria Register of Dams reports that the construction work started around 1980;impoundment was done around 1982; and the completion date of the dam was in 1984; the purpose of the construction was to supply water to the inhabitants of Nasarawa town and environs; the dam was engineered and constructed by GLEESON (Table 2).

### 4.3 Groundwater in the Study Area

The lithosphere consists of water in soil and rocks under the soil. On a large scale, it is the largest reservoir of fresh water available for human consumption, although exact measurements of its volume are elusive. The estimates of groundwater volume (water in the saturated zone) range from 8 million $km^3$ to 10 million $km^3$ (Shiklomanov, 1993). The parameters that described any given well include location, total depth, diameter and static water level. Static water level in Nasarawa town ranges from 3.2m at Lowcost and 13.3 m at Gunki with an average of 7.53 m.

**Table 2: Published Parameters of the Nasarawa Impounding Reservoir (Nigeria Register of Dams, 1995)**

| | |
|---|---|
| Name of Dam | Nasarawa Dam |
| Owner | NSWB |
| Longitude | $7^{o}$ 45' E |
| Latitude | $8^{o}$ 30' N |
| River | Uke |
| Nearest Town | Nasarawa |
| State | Nasarawa |
| Type of Dam | Concrete |
| Purpose | Water Supply |
| Engineered by | GLEESON |
| Constructed by | GLEESON |
| Year of Completion | 1984 |
| Crest Length | 60 m |
| Maximum Height | 3 m |
| Catchment Area | 170 $km^2$ |
| Reservoir Storage Capacity | 0.6 mcm |
| Active Storage Capacity | 0.4 mcm |
| Dead Storage Capacity | 0.2 mcm |
| Spillway Type | BROAD CRESTED WEIR |
| Spillway Design Flood | 150 $m^3/s$ |

Groundwater in the study area occurs in the soft overburden aquifer and fractured bedrock aquifer. Hand dug wells within the study area are shallow therefore they tap water only from soft overburden aquifer. It is only some boreholes that tap water from fractured bedrock aquifer because they are drilled with mechanized equipment. The thickness of soft overburden aquifer in the study area is between 10 m and 30 m (Nasarawa State Ministry of Water Resources, Lafia 2006).

Wells tapping the crystalline basement complex have always been a traditional source of water supply in both urban and rural areas, where surface water network are sparse and seasonal. By virtue of their formation, soft overburden aquifers are generally shallow in depth and their yielding capacity is subject to seasonal fluctuation. However, with optimal water resources planning, this means of water supply can be harnessed and exploited for domestic uses, since water supply from waterworks is epileptic.

### 4.4 Static Water Resources of the Study Area

Static water resources depend on the hydrogeology of any given area. Hydrogeology determines static groundwater resources which constitute most of the total static water resources and to a lesser extent static surface water resources. According to the Nigeria Register of Dam (1995), total area covered by the Nasarawa dam drainage basin is 170 $km^2$= 170 x $10^6$ $m^2$. Total drainage area as calculated from Geological Map of Nigeria on scale 1: 2,000,000 (Geological Survey of Nigeria, 1974) are 3,240 $km^2$ = 3,240 x $10^6$ $m^2$. Depth of rainfall in the study area is 1,357 mm/a = 1.357 m/a. Therefore volume of rainfall is 3,240 x $10^6$ $m^2$ x 1.357 m = 4,397 x $10^6$ $m^3$/a. According to the Nigeria Geological and Mineral Resources Map of North Central Zone on scale 1: 1,000,000 (Nigeria Geological Survey Agency, 2006b) drainage basin of Uke River, upstream of the Nasarawa impounding reservoir is underlain mostly by metamorphic rocks. As such the average thickness of the soft overburden developed on these rocks is 30 m (Nasarawa State Ministry of Water Resources, Lafia 2006) with an average depth to water table in the study area is 7.53 m (Table 1). The probable thickness of the water saturated zone in the soft overburden aquifer at the peak of dry season is 20 m (Nasarawa State Ministry of Water Resources, Lafia 2006). The average effective porosity of the soft overburden aquifer in Nigeria estimated as 0.028 (Schoeneich and Garba, 2010). The static water resources in the drainage basin of Uke River upstream of the dam are: 3,240 x $10^6$ $m^2$ x 20 m x 0.028 = 1,814 x $10^6$ $m^3$ as static groundwater resources in the soft overburden aquifer of the Uke River upstream from Nasarawa dam drainage basin.

### 4.5Dynamic Water Resources of the Study Area

Dynamic water resources are related to the climatic condition of an area. The study area lies within the Guinea Savannah region of the country and has tropical climate with moderate rainfall. Any area that lies within savannah region has less dynamic water resources as compared to every other area in the rain forest region of the country.

Nasarawa drainage basin area is 3,240 km$^2$= 3,240 x 10$^6$ m$^2$. Depth of rainfall in Nasarawa Dam drainage basin is 1,357 mm/a = 1.357 m/a. Therefore volume of rainfall is 3,240 x 10$^6$ m$^2$ x 1.357 m/a = 4,397x 10$^6$ m$^3$/a. Total runoff coefficient (dynamic water resources) corresponds to depth of rainfall 1,357 mm/a, is 0.5 (Schoeneich and Garba, 2010 – Figure 6). Therefore,

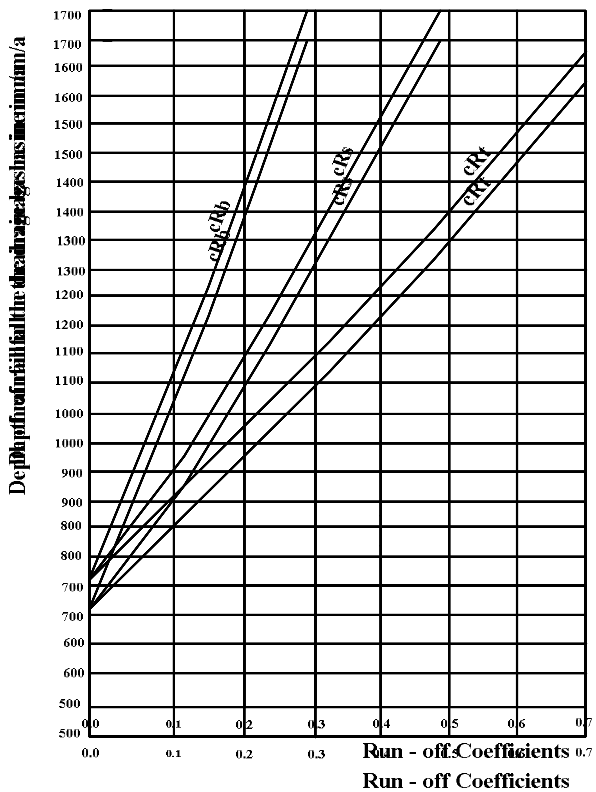



**Figure 6: Correlation between Depth of Rainfall and Runoff Coefficient in Drainage Basins (Schoeneich and Garba, 2010). Legend: Crt = Total Runoff Coefficient; Crs = Surface Runoff Coefficient; Crb = Base Flow Coefficient**

4,397x 10$^6$ m$^3$ x 0.5 = 2,199 x 10$^6$ m$^3$/a, of water is flowing through the spillway. Since annual evaporation in the study area is 4.615 m$^3$/a; 2,199 x 10$^6$ m$^3$/a – 4.615 m$^3$/a = 2,194 x 10$^6$ m$^3$/a as amount of water flowing through the spillway.

Dynamic Groundwater Resources of the study area is calculated as follows: area covered by Nasarawa town and environs is 370.7 km$^2$ or 370,700,000 m$^2$. Depth of rainfall in the study area is 1,357 mm/a = 1.357 m/a. Base flow coefficient corresponds to depth of rainfall 1,357 mm/a, is 0.18 (Schoeneich and Garba, 2010). Volume of rainfall over the study area is 370,700,000 m$^2$ x 1.357 m/a = 503,039,900 m$^3$/a. Therefore, volume of base flow is 503,039,900 m$^3$/a x 0.18 = 90,547,182 m$^3$/a as dynamic water resources of the study area.

Utilizable Dynamic Water Resources of the study area can be found based on the following assumptions: out of the total dynamic water resources of the study area, 10 % is set aside for blue belt protection, 20 % is set aside for losses during dry season, and 20 % is set aside for unaccountable water loss due to wastages and environmental degradation. Therefore Utilizable Dynamic Water Resources will be 50 % of the Total Dynamic Water Resources of Nasarawadam drainage basin: 2,199 x 10$^6$ m$^3$/a x 50 % = 1,097 x 10$^6$ m$^3$/a. And Utilizable Dynamic Water Resources of Nasarawa and environs will also be 50 % of the Total Dynamic Water Resources of the study area, 90,547,182 m$^3$/a x 50% = 45,273,591 m$^3$/a.

### 4.6 Population of Water Consumers

According to 2006 National Population Census, Nasarawa Local Government Area has a population of 189,835 people (Table 3). However, the population of Nasarawa town and environs is about 100,000. The National Bureau of Statistics put the growth rate of Nasarawa State based on the 2006 census at 3 % = 0.03. This figure will be used to calculate the population projection of the study area from 2006 to 2050 (that is 44 years from 2006). This is because the population of Nigeria is expected to stabilize by the year 2050 and for a viable water resources management plan of an area, the planning horizon should be at least for 30 years. Therefore the population of Nasarawa town and environs is projected for the next 44 years using the formula: P $e^{rn}$ (Kpedekpo, 1982); Where P is the present population, *e* is exponential, r is the population growth rate, and n is the projected year. Therefore, population of the study area in 44 years from 2006 census is: 100,000 $\boldsymbol{e}^{0.03 \times 44}$= 100,000 $\boldsymbol{e}^{1.32}$ = 374,342 people.

**Table 3: Details of the Breakdown of Nasarawa State Provisional 2006 Census Results by Local Governments (Source: Nasarwa State National Population Commission, Lafia, 2006)**

| LGA | Population | Males | Females |
|---|---|---|---|
| Karu | 205477 | 107308 | 98169 |
| Keffi | 92664 | 47801 | 44863 |
| Kokona | 109749 | 54941 | 54808 |
| Akwanga | 113430 | 57023 | 56407 |
| Wamba | 72894 | 36542 | 36352 |
| NasarawaEggon | 149129 | 77888 | 71241 |
| Lafia | 330712 | 169398 | 161314 |
| Awe | 112574 | 56205 | 56369 |
| Obi | 148874 | 74412 | 74462 |
| Keana | 79253 | 39233 | 40020 |
| Doma | 139607 | 70545 | 69062 |
| Nasarawa | 189835 | 95168 | 94667 |
| Toto | 119077 | 59092 | 59985 |
| **State Total** | **1863275** | **945556** | **917719** |

### 4.5 Water Demand in the Study Area

Current water demand is above the current water supply in the country (Schoeneich, 2007). Water consumption within the study area is mainly for domestic use (urban residential water consumption). In Nigeria, the average daily domestic water demand is estimated to range from about 70 lits/ person/ day in the rural areas to 150 lits/ person / day in the urban areas and semi urban towns (Offodile, 2002). In 2007, Baba found unit water demand as 107 lpcd in her study on the water availability in ABU, Zaria Main Campus. In 2005, Ojonugwa in Baba (2007) measured his own unit water consumption of students leaving outside the campus of ABU, Zaria with sources of water away from his house, with no plumbing in the house as 50 lpcd. In 2007, Schoeneich in his work on water resources management in Nigeria gave 50 lpcd for urban dwellers and 15 lpcd for rural dwellers. In 2009, Ochenemi in his study on water supply situation in Lokoja town measured unit water demand in Lokoja and got 63 lpcd. For the purpose of this research 50 lpcd will be adopted as minimum value and 100 lpcd as maximum value. Therefore, for minimum value 50 lpcd or 0.05 $m^3$/d x 100,000 people = 5,000 $m^3$/d or 1,825,000 $m^3$/a, while for maximum value 100 lpcd or 0.1 $m^3$/d x 100,000 people = 10,000 $m^3$/d or 3,650,000 $m^3$/a, assuming there is a continuous piped water supply.

In 2007, Baba estimated 10 % of water demand in ABU, Zaria as amount of spillages and wastages plus amount of water for gardening and refill of swimming pool under continuous water supply. This value is adopted here by the author, because to measure the amount of wastages and spillages in study area is going to be difficult considering the size of the area. Therefore, 100,000 people x 0.1 $m^3$/d = 10,000 $m^3$/d as present (maximum) total water demand. So 10 % of 10,000 $m^3$/d is 1,000 $m^3$/d. Total water demand 10,000 $m^3$/d + 1,000 $m^3$/d = 11,000 $m^3$/d or 4,015,000 $m^3$/a. In 44 years from 2006, water demand of Nasarawa town and environs will be: 374,342people x 0.1$m^3$/d = 37,434 $m^3$/d. 10% spillages and wastages of 37,434 $m^3$/d is 3,743 $m^3$/d. Therefore, the estimated water demand in 44 years from 2006 is 37,434 $m^3$/d + 3,743 $m^3$/d = 41,177 $m^3$/d or 15,029,605 $m^3$/a.

It is expected that in 44 years from 2006, well advanced and mechanized agriculture will be established and this perhaps will take 50% of the future estimated water demand in the study area, which is 50% of 15,029,605 $m^3/a$ = 7,514,802.5 $m^3/a$. This gives a total of 15.029,605 $m^3/a$ + 7,514,802.5 $m^3/a$ = 22,544,407.5 $m^3/a$.

### 4.8 Water Budget for Nasarawa Town and Environs

Current water demand in the study area is 11,000 $m^3/d$ or 4,015,000 $m^3/a$, while the current water supply from Nasarawa water works is 570 $m^3/d$ or 208,050 $m^3/a$. The projected water demand at the planning horizon in 44 years from 2006 is41, 177 $m^3/d$ or 15,029,605 $m^3/a$. At that time (44 years from 2006), if well advanced and mechanized agricultural system is established in the study area to provide food security, 50 % of the future estimated water demand in the town will be allocated to this agricultural system, which is 50 % of 15,029,605$m^3/a$ = 7,514,802.5 $m^3/a$. This gives a total of 15,029,605 $m^3/a$ + 7,514,802.5 $m^3/a$ = 22,544,407.5 $m^3/a$. With ultimate water demand of 61,765.5 $m^3/d$ or 22,544,407.5 $m^3/a$ in the study area, 61,195.5 $m^3/d$ or 22,336,357.5 $m^3/a$ will need to be extracted from groundwater to meet the demand. If this is achieved, the utilizable dynamic groundwater resources of the area which is 45,273,591 $m^3/a$, can meet the ultimate water demand of the area and there is going to be excess deposit of 22,937,233.5 $m^3/a$.

## *5. Conclusion*

Water supply is grossly inadequate in the area covered by this study. Surface water supply from waterworks is supplemented by groundwater through boreholes and hand dug wells. This results in over-stretching of the existing boreholes and hand dug wells. Nasarawa town and environs has total dynamic groundwater resources of 90,547,182 $m^3/a$, which can supplement surface water to meet the present and future water demand of people in the area. 4,015,000 $m^3/a$, is the current maximum water demand for an estimated population of 100,000 people in the study area. With the projected population of 374,342 in the next 44 years at the growth rate of 3.0 %, the demand will be 15,029,605 $m^3/a$.During the ultimate planning horizon when the area is expected to have well advanced and mechanized agricultural system, the demand will be 22,544,407.5 $m^3/a$.

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