Research article

WATER RESOURCES OF KUBANNI DAM AND OTHER DRAINAGE BASINS AROUND AHMADU BELLO UNIVERSITY, ZARIA, KADUNA STATE, NIGERIA

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Abstract

This work provide basis of understanding groundwater potential and solving the water scarcity of the study area. Water demand of the study area was determined. Water demand of the Teaching and Administrative area is 2,847 m^3/d, for area "A" is 212 m^3/d, for area "C" is 130 m^3/d, for area "BZ" is 278 m^3/d, for area "F" is 187 m^3/d, for area "G" is 88 m^3/d, for area "E" is 82 m^3/d, for Catering Flats near Staff Club is 16 m^3/d, for Quarters III is 90 m^3/d, for Waterworks Junior Staff Quarter is 10 m^3/d, for Silver Jubilee is 200 m^3/d, for Aviation Site II is 60 m^3/d, medical students is 93.6 m^3, Shika Hospital is 154 m^3/d/ respectively giving the total water demand of the study area 4,354 m^3 . The water demand /requirement for the hospital is 77,000 lpcd (77 m^3/d). Boreholes and hand dug wells in the study area were located on the map. Geological map of the study area was upgraded. Map of configuration of groundwater table and its flow direction was plotted. Water budget map of the study area was produced. Volume of base flow and surface runoff in the Campus were calculated. Surface runoff and grey water disposal were proposed. Surface and Groundwater Resources of the Campus were calculated to determine its reserves. Hydrogeological map of the study area was produced.

Keywords: Surface and groundwater resources, water budget, water demand, water scarcity, reserves and hydrogeology

INTRODUCTION

There are two aquifers in the Kubanni Dam Drainage Basin: the Regolith Aquifer and the Fractured Crystalline Aquifer. The weathering of the crystalline Basement rocks under tropical condition is well known to produce a sequence of unconsolidated materials whose thickness and lateral extent vary extensively Dearmaun, et al (1978). Groundwater localization within the Basement Complex occurs either in the weathered mantle or in the fracturing, fissuring, and jointing systems of the bedrock Olayinka and Olurunfemi (1992)

These unconsolidated materials are known to reflect some dominant hydrologic properties, and the highest groundwater yield in Basement Complex area are found in areas of thick overburden overlying fractured zones and are characterised by relatively low resistivity Olurunfemi and Fasuyi (1993).

As common in Crystalline Basement area, the Regolith Aquifer is developed as a result of intense and prolonged *in situ* chemical weathering (saprolite). The extent chemical weathering and hence thickness of the regolith depends on the basement rock: On metamorphic rocks the thickness is up to 30 metres, with depth to water table at the end of dry season about 6 metres, making thickness of the water saturated interval up to 24 metres, while on the granitic rocks regolith, even if present, has thickness greatly varying but not more than 10 metres, making water saturated zone, if any, not more than 4 metres. It means, that on metamorphic rocks water is easily accessible for well sinkers, with no risk of sinking an abortive hand dug well, and if a well is technically properly constructed it yields water perennially in quantities sufficient for rural water supply. On granitic rocks however, there is high failure ratio in sinking hand dug wells and even if water is found, often the well dries up towards the end of dry season. Water table typically throughout year occurs at shallow levels of less than 10 m to 15 m with the wells being mostly seasonal. This aquifer is shallow, it also serves as a conduit that transport leachates and highly polluted groundwater from the densely populated Samaru Town and the surrounding villages into the Kubanni drainage system. The most common abstraction method from the aquifer is by hand dug wells mostly unlined which are found in almost each of the compounds in the area both in Samaru Town and the surrounding villages.

METHODOLOGY

The study area (Figs. 2 and 3) form the base location and geological map which were used for calculation of area and determination of the type of formation. For calculation of the static groundwater resources in the Soft overburden aquifer, it was assumed that the average thickness of the soft overburden on granite is 0–10m, on metamorphic rocks is 20–30m, and on meta-sediments is 0–5 m, while average depth to the groundwater table of granite is 5–10 mbgl, on metamorphic is 3–7 mbgl, and on meta-sediments is 5–10 mbgl; Average effective voidity of the soft overburden aquifer was assumed as 0.028 Schoeneich at al (1991), Krzysztof et al (1994), and Schoeneich verbal information (2011). For calculation of static groundwater resources in the fractured crystalline aquifer, it was assumed, that the thickness of the fractured zone below soft overburden is on average 15 meters, irrespectively of petrological composition, while the average effective voidity is 0.00145, also irrespective of the petrology of the matrix rocks.

For the calculation of the dynamic water resources and surface runoff, the mean annual rainfall of the area adopted was 1054 mm/a, while base flow and surface runoff coefficient corresponding to the depth of rainfall are 0.10 and 0.18 respectively giving total runoff of 0.28 (Fig. 1). The study generally involved the static groundwater, the surface and groundwater resources were deduced for the Teaching and Administrative Area, Residential Area A. BZ, C. Aviation site II residential estate, ABU Teaching Hospital, ABU farm, underdeveloped part of the existing campus, surface and Silver Jubilee area of ABU (Ahmadu Bello University Zaria) constituting the study area.

RESULT AND DISCUSSION

Static Groundwater Resources of the study area.

The static water resources of the study area were deduced for the teaching and administrative area, underdeveloped part of the existing campus, university farm, ABU Teaching Hospital, Aviation site II , residential estate, residential areas C, BZ and A. The details of the first two are discussed below, while the results of the whole study areas are summarized on Table 2. The Teaching and Administrative Area is located on the granite and on the metamorphic rocks (Fig.2). Part located on the metamorphic rocks measures 536,340 m^2 while that of the Older Granites was 5,899,743 m^2, making the total 6,436,083 m^2. Total static groundwater resources in the soft overburden aquifer in the part of the teaching and administrative area located on the granites were calculated using the effective voidity of the soft overburden on the Precambrian crystalline rocks to be 0.028 according to Schoeneich et al (1991). Thickness of the soft overburden, in boreholes drilled in the student hostels according to Baba (2007) is on average 20 metres while average depth to the water table at the peak of dry season is 5m.

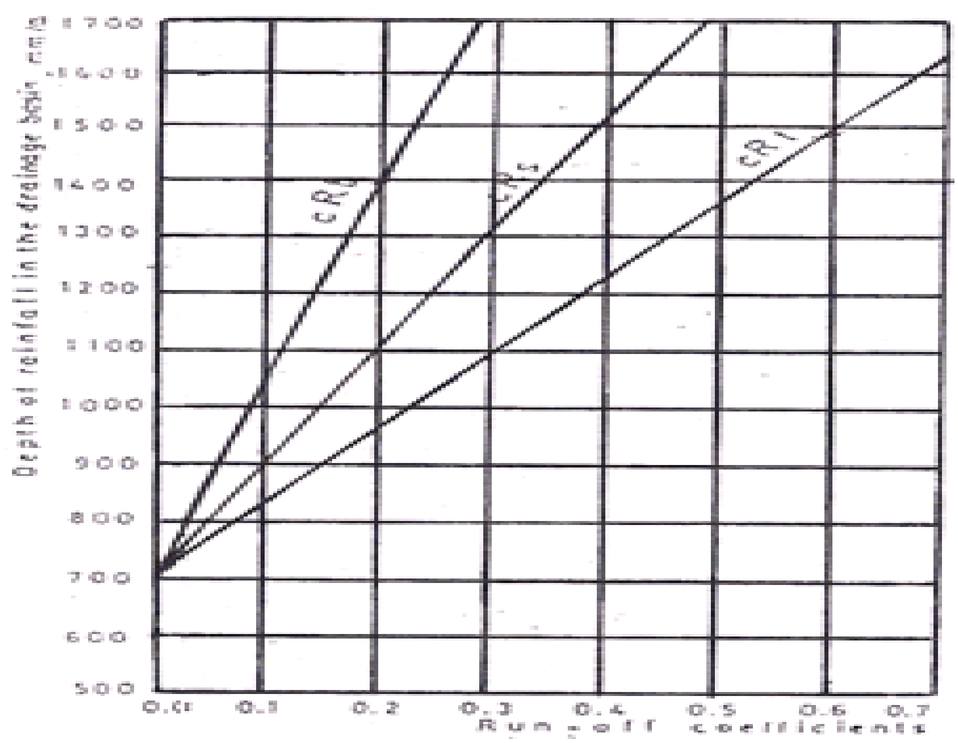

FIGURE 1: CORRELATION BETWEEN RUNOFF COEFFICIENTS AND DEPTHS OF RAINFALL IN THE DRAINAGE BASINS.

Legends: cRt = Total Coefficient; cRs = Surface runoff Coefficient; crb = Base flow Coefficient, which is almost the same as infiltration. Note that rainfall 700 mm/a and less does not produce runoff Schoeneich, (1998).

This implies that the teaching and administrative area located on the Older Granites gives the total static groundwater resources (sGWRt) in the soft overburden aquifer at the peak of dry season as follows:
sGWRt = (20 m – 5 m) $\cdot$ 0.028 $\cdot$ 5,899,743 m^2 = 2,477,892 m^3.
The total static groundwater resources in the soft overburden aquifer in the part of the teaching and administrative area located on the metamorphic rocks were calculated using the effective voidity of the soft overburden the same as above 0.028, while from Table 1 the average thickness of the soft overburden on metamorphic rocks has been estimated as 25m and depth to the water table at peak of dry season 5 m bgl. Thus, the total static water resources in the soft overburden aquifer at the peak of dry season are:
sGWRt = (25m –5 m) $\cdot$ 0. 028 $\cdot$ 536,340 m^2 = 300,350 m^3
The total static groundwater resources in the soft overburden aquifer, of the teaching and administrative area (both on granite and on metamorphic rocks) are sGWRt = 2,477,892 m^3 + 300,350 m^3 = 2,778,242 m,^{3} however below soft overburden aquifer, there is fractured crystalline aquifer. Thickness of the fractured crystalline aquifer, irrespective of the petrology of underlying rocks, for the purpose of this calculation has been assumed as 15 metres while its effective voidity as 0.00145 Schoeneich (1991).

The fractured crystalline groundwater resources of teaching and administrative area on granite is = area (536,340.3 m^2) x average effective porosity (0.00145) x average saturated thickness (15 m) = 11,666 m^3. The fractured crystalline aquifer groundwater resources of teaching and administrative area on metamorphic is = area (5,899,743 m^2) x average effective porosity (0.00145) x average saturated thickness (15 m) = 128,319 m^3. After adding, the, total static water resources in the fractured crystalline aquifer under the teaching and administrative area are: sGWRt = 15 m · 0.00145 · 6,436,083 m^2 = 139,985 $m.^3$

Total static groundwater resources in the both aquifers - soft overburden aquifer and fractured crystalline aquifer under the teaching and administrative area are sGWRt = 2,778,242 m^3 + 139,985 m^3 = 2,918,227 m^3

Static Groundwater Resources in the University Farm

The University Farm, with its total area measured in Location Map in Figure 3 as 11,931,875 m^2, is located both on the metasediments and on the metamorphic rocks as the geological map in Figure 2 shows. The part located on metasediments was measured as 1,704,554 m^2 while part located on metamorphic 10,227,321 m^2.

The Soft Overburden Aquifer Groundwater Resources of University Farm on metasediments is = area (1,704,554 m^2) x average effective porosity (0.028) x average water saturated thickness (-3 m) = zero cubic metres.

sGWRt = 1,704,554 m^2 · 0.028 · 0 m = 0 m^3

Negative value (-3) means the Soft Overburden does not contain water and the water in the Fractured Crystalline Aquifer is 3 below top of this aquifer. Thus, on the metasediments the very thin soft overburden is completely dry, while average thickness of the water saturated part of the Fractured Crystalline Aquifer, 15 meters – 3 meters = 12 metres, is reduced to 12 metres only.

The static groundwater resources in the part of Soft Overburden Aquifer located on metamorphic is: area (10,227,321 m^2) x average effective porosity (0.028) x average saturated thickness (20 m) = 5,727,300 m^3.

sGWRt = 10,227,321 m^2 · 0.028 · 20 m = 5,727,300 m^3

Thus, static groundwater resources in the Soft Overburden Aquifer of the University Farm are sGWRt = 0 m^3 + 5,727,300 m^3 = 5,727,300 m^3

The Fractured Crystalline Groundwater Resources of University Farm, part located in the metasediments is: area (1,704,554 m^2) x average effective porosity (0.00145) x average saturated thickness (12 m) = 29,659 m^3.

sGWRt = 1,704,554 m^2 · 0.00145 · 12 m = 29,659 m^3

The Fractured Crystalline Groundwater Resources of University Farm on metamorphic is = area (10,227,321 m^2) x average effective porosity (0.00145) x average saturated thickness (15 m) = 222,444 m^3. sWRt = 10,227,321 m^2 · 0.00145 · 15 m = 222,444 m^3

Groundwater resources of the study area

The Static Groundwater Resources of the Study area as at August 2008 is shown in Table 8. The total dynamic groundwater resource is defined by (area x infiltration coefficient x rainfall depth). The utilizable dynamic Groundwater Resources is defined by multiplying the total dynamic groundwater resource of the area by a factor that is (area x infiltration coefficient x depth of rainfall x abstraction) or (Total Dynamic Groundwater Resources x Abstractions in percentage) and the value may be less because most of the lands are built up, the buildings are close together producing high run-off with little infiltration which shows approximation of the impermeability of various surfaces, estimated flow velocities of various hydrologic processes (Newson,1997) and correlation between runoff. It was observed that before the boreholes were sunk every household had a well to supplement the water supply from Zaria Water Board but at present the wells dry immediately the rain stops. Dried or collapsed wells, when abandoned are turned into repositories for household wastes and could result to polluting the groundwater. These types of water holes are not well secured, since most of them are not properly maintained, with most lacking cover, and in most places the villagers carry out their laundry very close to the wells. Considering the flow path of groundwater in the area, this poses a great danger since groundwater adds to stream flow both during peak and low flow, hence indirectly contributing pollutants to the dam. In the fractured crystalline aquifer water is found both in the variably weathered/transition zone and in the fractures, joints and cracks of the crystalline basement. This aquifer cannot be tapped by local well sinkers but is usually exploited by boreholes. The fractured crystalline aquifer unlike the regolith aquifer is highly permeable, with the water being contained within the fractured zones.

Aviation site II depends on water tankers from ABU Waterworks to supply water as the Zaria Water Board do not serve them efficiently.

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TABLE 1: HYDROGEOLOGICAL EXPLANATION TO GEOLOGICAL MAP SHOWN IN FIGURE 2.EXPECTED GROUNDWATER CONDITIONS IN THE GEOLOGICAL FORMATIONS OF THE STUDY AREA.

Key	Rock	Minimum to maximum thickness of soft overburden (m)	Depth to groundwater table peak of dry season mbgl	Recommended water intake	Expected water intake yield (m^3/h)	Expected aquifer yield (m^3/day per hectare)	Remarks
	Recent alluvium, clayey sand	1 – 5	< 2 (average 1)	Water hole, hand dug well, tube well, gallery	<10	< 10	Thickness more on crystalline metamorphic, negligible on granite and quartzite
	Granites	0 – 10 (average 5)	5 – 10 (average 5)	Blasted hand dug well with hand pumps only	< 3	< 5	Avoid boreholes with submersible pumps
	Psammitic metasediments mostly quartzite, subordinate schist	0 – 5 (average 2)	5 – 10 (average 5)	Blasted hand dug well with hand pumps only	< 5	< 5	Avoid boreholes with submersible pumps
	Gneisses and crystalline schists	20 – 30 (average 25)	3 – 7 (average 5)	Borehole with hand pumps or low yield submersible pumps	< 5	< 5	Install low yield submersible pump or hand pump, depending on water demand

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TABLE 2: LOCATION, AREA, PETROLOGY AND GROUNDWATER RESOURCES UNITS WITHIN ABU SAMARU CAMPUS. Area of occurrences of granite, .metasediments, and metamorphic rocks were measured on geological map in Fig.2, static groundwater resources were calculated using data from Table 1. Dynamic groundwater resources were calculated using infiltration coefficient read from Fig. 1.

WATER POLICY UNITS			Area (m^2)				Static groundwater resources, m^3				Ground water Dynamic (m^3/a)
			Granite	Metamorphic	Meta sediment	Total	Granite	Metamorphic	Meta sediment	Total	
Developed part of the campus	Teaching and Administrative area		5,899,742	536,340	0	6,436,083	2,489,558	428,669	0	2,929,938	678,363
	Residential	Area “A”	8 59,200	0	0	859,200	18,688	0	0	18,688	90,559
		Area “BZ”	672,000	0	0	672,000	14,616	0	0	14,616	70,828
		Area “C”	0	1,145,000	0	1,145,000	0	666,104	0	666,104	120,683
		Area “E”	0	246,400	0	246,400	0	134,343	0	143,343	25,970
		Area “F”	0	556,800	0	556,800	0	323,918	0	323,918	58,688
		Area “G”	0	291,200	0	291,200	0	619,405	0	619,405	30,692
		Catering Flats	15,000	0	0	15,000	326,000	0	0	326,000	1,581
		Quarter III	108,800	0	0	108,800	2,366	0	0	2,366	11,468
		Waterworks Quarters	4,800	0	0	4,800	104	0	0	104	506
		Silver Jubilee	47,025	0	0	47,025	1,025	0	0	1,025	4,956
		Aviation Site II	495,000	0	0	495,000	10,7660	0	0	10,766	52,173
	Shika Hospital		0	4,674,442	803,153	5,477,595	0	2,753,240	13,980	2,727,220	577,338
	University Farm		0	10,227,321	1,704,554	11,931,875	0	5,949,744	29,659	5,979,403	1,903,420
Undeveloped land			7,216,920	7,389,006	0	14,605,297	0	4,298,555	156,968	4,455,523	1,539,398
Total						36,455,992				18,218,374	

TABLE 3: SUMMARY OF GROUND AND SURFACE WATER RESOURCES WATER DEMAND, RUNOFF AND GREY WATER.

S/No	Location	Population	Area (m^2)	Total Static Groundwater Resources (m^3)	Total Dynamic Groundwater Resources,m^3/a	Water demand (m^3/d)	Surface runoff (m^3/a)	Surface Water Resources 2008(m^3/a)	Grey water (m^3)
1	Teaching area	35,426	6,436,083	2,918,227	678,363	2,847**	1,221,053		
2	Area "A"	2,120	859,200	18,688	90,559	212	163,007		
3	Area "C"	1,300	1,145,000	666,104	120,683	130	217,229		
4	Area "BZ"	2,780	672,000	14,616	70,828	278	127,491		
5	Area "F"	1,870	556,800	323,918	58,687	187	105,636		
6	Area "G"	880	291,200	619,405	30,692	88	55,246		
7	Area "E"	820	246,400	143,343	25,970	82	46,747		
8	Catering Flats	160	15.000	326,000	1,581	16	2,845		
9	Quarters III	900	108,800	2,366	11,468	90	20,641		
10	Waterworks Quarters	102	4,800	104	506	10	910		1,901
11	Silver Jubilee	2,000	47,025	1,025	4,956	200	8,921	None	80
12	Aviation Site II	600	495,000	10,766	52,173	60	93,911	None	24
13	Shika Hospital	1,540	5,477,595	2,727,2200	577,338	154***	1,039,209		
14	University Farm	-	11,931.875	5,979,403	1,903,420	-	2,263,715	349,911	
15	Undeveloped area	-	14,605,927	4,455,523	1,539,398	-	2,771,036	1,568,725*	
	Total	51,434	42,892,705	18,206,708	5,166,623	4,354			

* ABU, 2008 **Baba, 2007 ***Baba, 2009

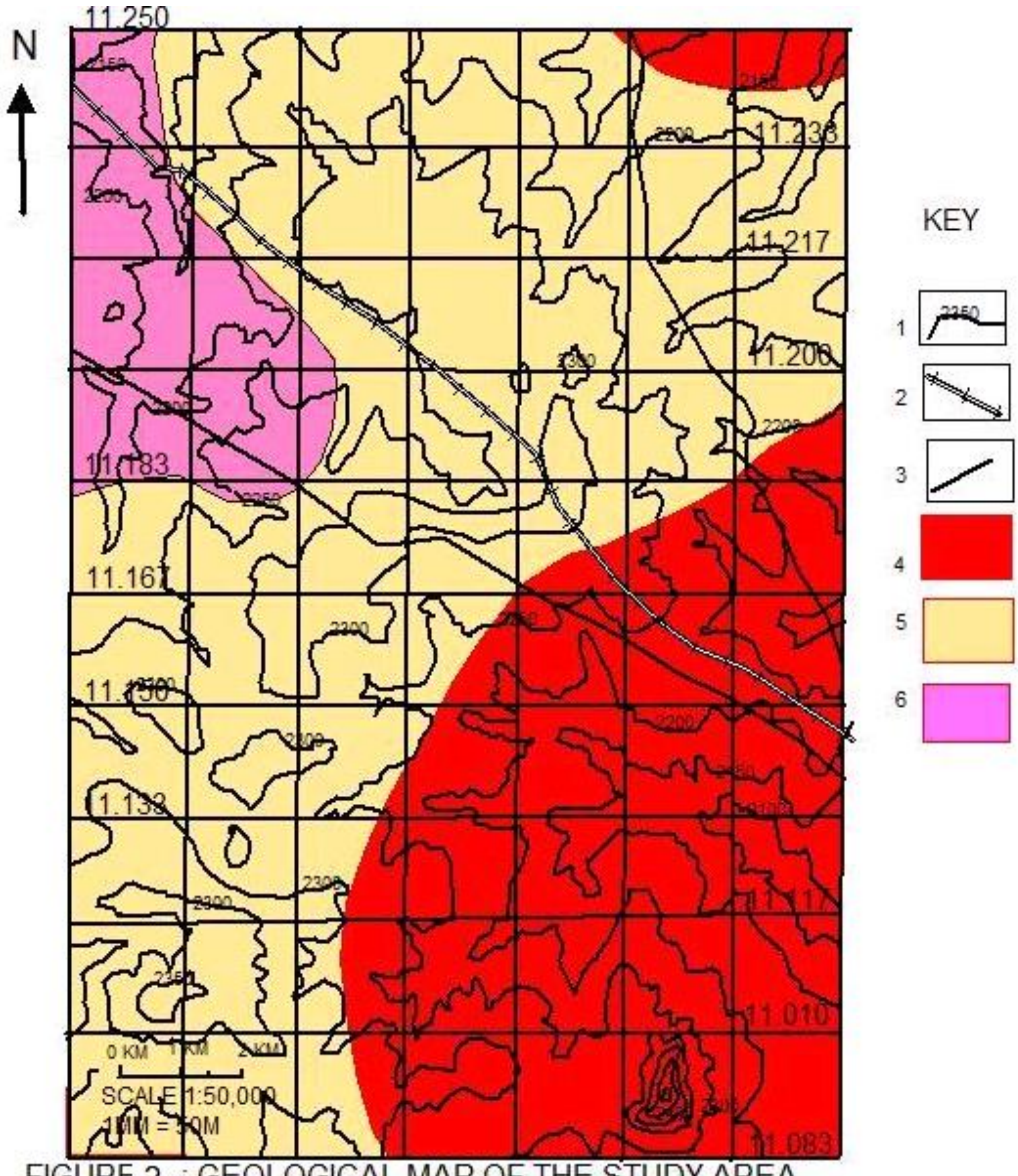

FIGURE 2 : GEOLOGICAL MAP OF THE STUDY AREA

MODIFIED AFTER GARBA 2009. EXPLANATIONS: 1 - GROUND SURFACE CONTOUR, 2 - RAIL, 3 - ROAD, 4 - GRANITE, 5 - GNEISS, METASEDIMENT.

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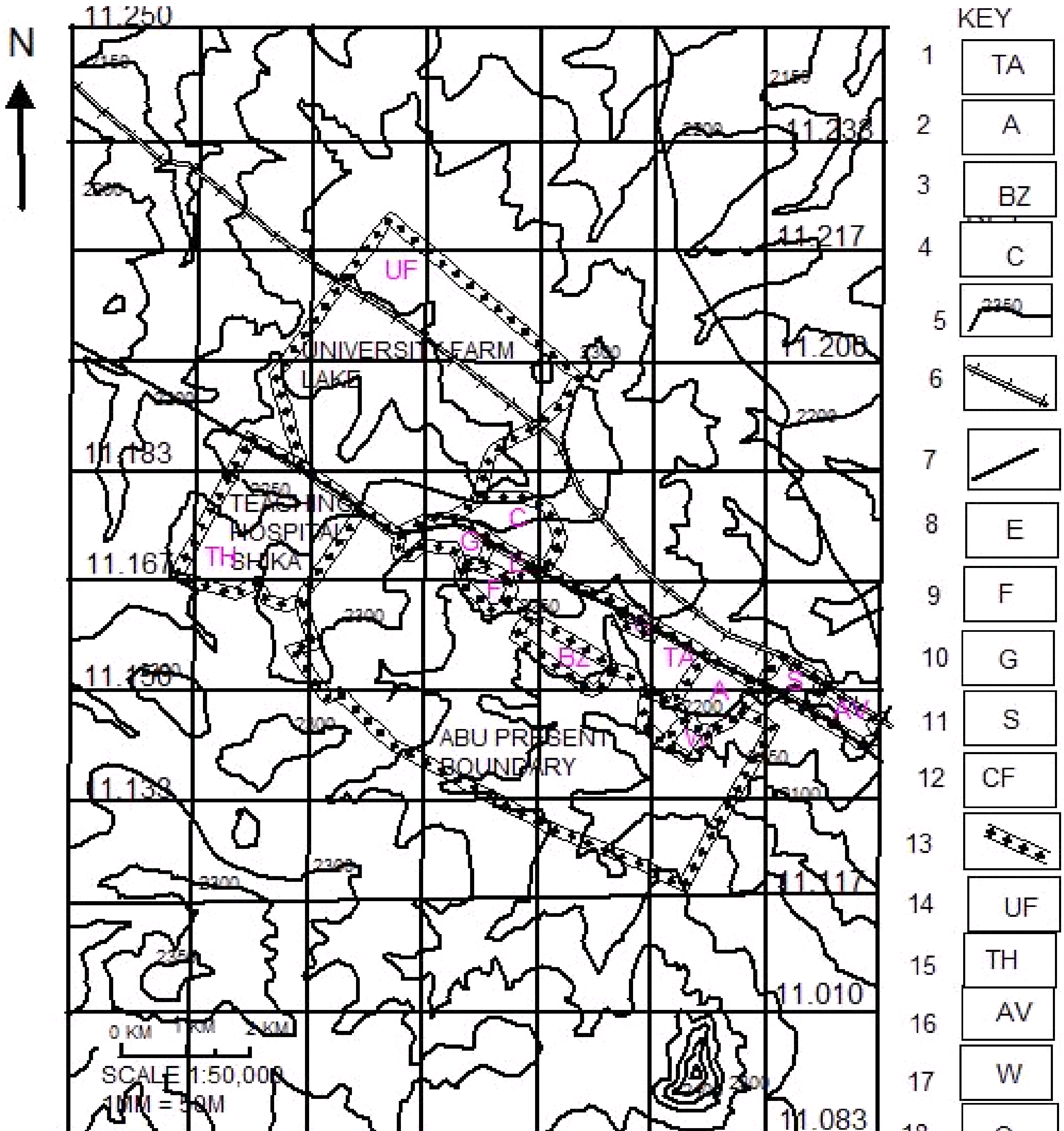

FIGURE 3 : LOCATION MAP OF THE STUDY AREA

EXPLANATIONS: 1 - TEACHING AND ADMINISTRATIVE AREA, 2 - AREA "A", 3 - AREA "BZ", 4 - AREA "C", 5 - CONTOUR, 6 - RAIL, 7 - ROAD, 8 - AREA "E", 9 - AREA "F", 10 - AREA "G", 11 - SILVER JUBILEE, 12 - CATERING FLATS, 13 - STUDY LOCATION, 14 - UNIVERSITY FARM, 15 - TEACHING HOSPITAL, 16 - AVIATION, 17 - WATERWORKS QUARTERS, 18 - QUARTERS III.

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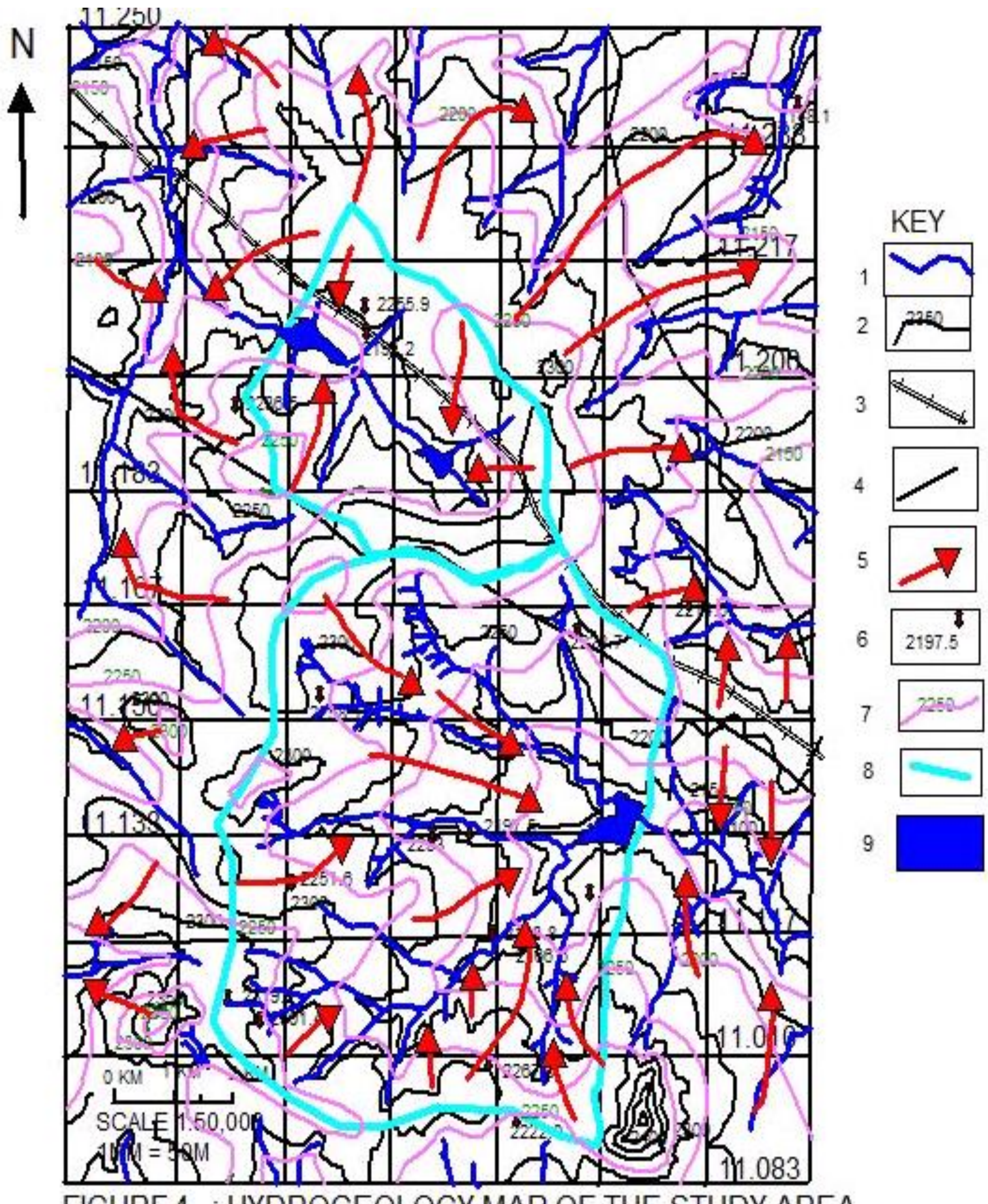

FIGURE 4 : HYDROGEOLOGY MAP OF THE STUDY AREA
EXPLANATIONS: 1 - RIVER, 2 - GROUND SURFACE CONTOUR, 3 - RAIL, 4 - ROAD, 5 - GROUNDWATER FLOW DIRECTION, 6 - WELL POINT, 7 - GROUNDWATER CONTOUR, 8 - DRAINAGE BASIN, 9 - DAM.

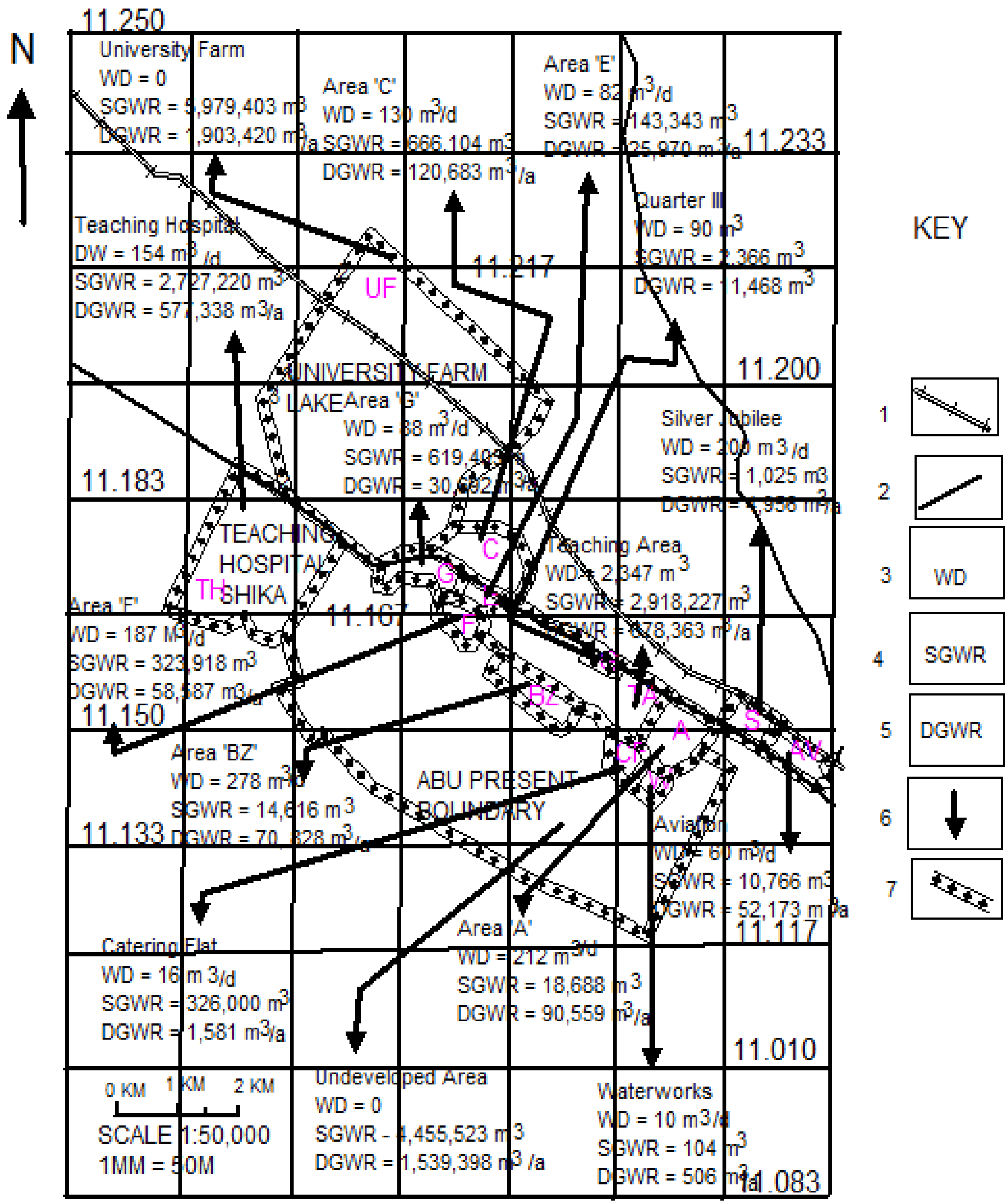

FIGURE 5 : WATER BUDGET MAP OF THE STUDY AREA

EXPLANATIONS: 1 - RAIL, 2 - ROAD, 3 - WATER DEMAND, 4 - STATIC GROUNDWATER RESOURCES, 5 - DYNAMIC GROUNDWATER RESOURCES, 6 - ARROW FROM THE STUDY PLACE, 7 - STUDY LOCATION.

CONCLUSION

The water resources of Kubanni Dam and other drainage Basins around Ahmadu Bello University, Zaria and Environs, Kaduna State, Nigeria was evaluated using data on aquifer level fluctuation and changes in water elevation with time. The general understanding of the groundwater potential and solving the water scarcity of the Ahmadu Bello University Zaraia Kaduna State, Nigeria was successful carried out. The various water demand/ requirement for various units, boreholes and handdug wells in the study area were located on the map. Geological map of the study area was upgraded. Map of configuration of groundwater table and its flow direction was plotted. Water budget map of the study area was produced. The volume of base flow and surface runoff in the campus were calculated surface runoff and grey water disposal were proposed. Surface and groundwater resources of the study area were calculated to determine its reserves and hydrogeological map was produced. These information is useful for water planners, managers and general administration of the Ahmadu Bello University, Zaria, Kaduna State, Nigeria to meet their water demand now and even the future.

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