

Assessing the Effect of Existing Water Distribution Networks on Water Availability in Abuja Municipal Area Council, Abuja, Nigeria

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ABSTRACT

Water is a vital resource available to support human life. Developing countries face challenges in meeting water demand for residential and commercial users. This study assessed the effect of existing water distribution networks on water availability in Abuja Municipal Area Council, Abuja. The study analysed the existing water distribution network, its effects on spatial distribution networks, and factors influencing water demand and distribution. Baseline data on the existing water distribution network was utilized to map the distribution network in the districts of Maitama, Wuse, Garki, Central Business District, and Asokoro. Three hundred twenty-five (325) questionnaires were purposefully administered to elicit responses from the population on factors influencing water demand and supply. The results indicate dense and substantial spatial water distribution networks in AMAC. The increasing failure of public water distribution (supply versus demand) necessitate a greater percentage of the population to count more on alternative sources such as water borehole and water tanker vendors. The findings suggest that planners and decision-makers in the water sector should take cognisance of future development patterns and make provisions for expansion.

Keywords: Water, Pipeline, Distribution, Demand, Infrastructure

1. INTRODUCTION

Water supply largely depends on consumer demand (Bandyopadhyay, 2016). Thus, population projections are essential in determining how much water needs to be abstracted, treated, and distributed for different purposes in a given location (Berardi, Laucelli, Ugarelli, & Giustolisi, 2015). However, the greatest paradox of all time is establishing an efficient water supply system that can meet the needs of the ever-growing population. A previous study argued that an increase in population and industrialisation is directly proportional to the rise in potable water demand (Ahmadi et al., 2020). For decision-makers, it is essential to plan for effective and adequate delivery of potable water to cities. Network operators are critical in managing and

maintaining an efficient distribution system that optimally supplies water to populations with zero losses and malfunctions (van den Berg, 2015).

They are pushing the system to unimaginable limits to satisfy fresh demand due to population growth resulting in water supply failure. Therefore, (Huang and Lee, 2019) believe that population projections are necessary to design the best water supply system to accommodate population growth over 50 years. As such, water policymakers rely on population projections to assess future demands for this much-needed commodity (Sanchez et al., 2020). The population change necessitates these projections with time as a result of births and the arrival of migrants, which add individuals to a population, whereas deaths and

the departure of migrants subtract individuals from a population (Grouillet *et al.*, 2015). In short, A water supply system has two primary requirements. Firstly, it must deliver adequate water to meet consumption and free flow requirements. Secondly, the water system needs to be reliable; the required amount of water needs to be available 24 hours a day.

Water demand can be expressed in various terminologies with special importance directed

2. THE STUDY AREA

The Abuja Municipal Area Council is the local government responsible for the administration of the city. The city planners divided it into 'Phases.' The critical development takes a concentric form with Phase 1, which consists of the city's inner districts-Central Area, Maitama, Asokoro, Wuse, Wuse II, Garki, Garki II, and Guzape II - as its core spreads out from the foot of Aso Rock hill (see Figure 1).

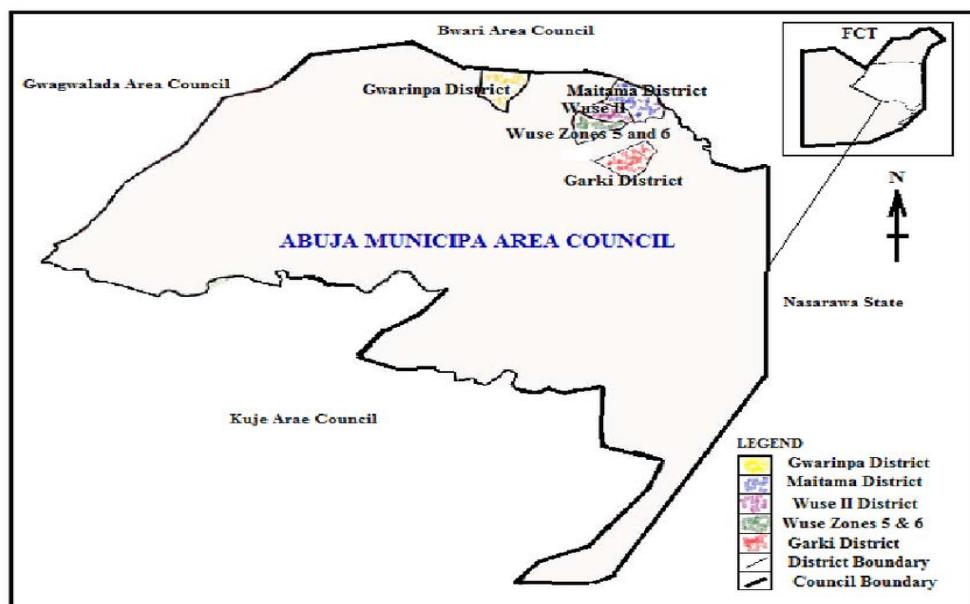


Figure 1: The Study Area - The Abuja Municipal Area Council (AMAC), Abuja, Nigeria

to average demand, specific demand or consumption, and unaccounted-for water (UFW). Average demand is the mean value of water demand derived from annual records. At the same time, specific water consumption is defined as the average demand divided by the number of consumers (unit consumption per capita). The precise and accurate forecasting of water demand is crucial when analysing the hydraulic performance of a water distribution system (Sanchez *et al.*, 2020; Trifunovic, 2006). The population demand is key to ensuring an optimal supply of water in urban areas (Zhao, Jin, Zhou, Wang, and Pu, 2018). Water managers consider many factors when designing water distribution systems, often accompanied by an unavoidable component of water demand: water supplied free of charge (Liu *et al.*, 2018; Xiao *et al.*, 2014). In developing countries, this is the most significant consumer of water, accounting for over 50% of the total water delivery. This results from physical leakages in the system (Zaman, Tiwari, Gupta, & Sen, 2020).

3. MATERIALS AND METHODS

Baseline data on the existing water distribution network was utilized to map the distribution network in the districts of Maitama, Wuse, Garki, Central Business District, and Asokoro. The water utility base maps of the study area were scanned and imported into the ArcGIS environment for further processes. ArcGIS 10.3 software was used to convert the scanned Water Utility Map (WUM) into vector entities by first geo-referencing the map with coordinates of points taken from the field with the GPS. The image was registered to Universal Traverse Mercator (UTM). ArcGIS software provides an image processing extension, a module used in viewing and processing images stored in (tiff) format.

All the water distribution features on the map, such as pipelines, valves, and reservoirs, were digitized on screen. A geo-database file was created in ArcCatalog, and the feature class (containing the features) was created. The pipes were represented as lines, the reservoirs as polygons, while other features, such as sluice

valves, washouts, water points, air valves, and reducers, were as points.

A structured questionnaire, interview schedules, and documentary records were designed and used to collect information and data for this study. The questionnaires were purposeful administered to collect data from different households in the study area especially concerning water distribution and demand. The questionnaires are designed to have closed, and open-ended questions covering areas like the availability of water points and whether water demand is always met. Interview was schedules using the same questions on the questionnaire for the illiterate population, and their responses filled in the questionnaires. Generally, a total of 325 questionnaires were administered across the study areas (Table 1). the table shows Maitama has the highest percentage of response rate, 84%, while Garki, CBD, Asokoro, and Wuse recorded 83%, 80%, 81%, and 78% responses, respectively.

Table 1: Field survey Responses on the factors influencing water demand and distribution

Study locations	Number of questionnaires returned	Response rate (%)
Garki	67	83
CBD	60	80
Asokoro	65	81
Wuse	70	78
Maitama	63	84
Total	325	81

Source: Field survey, 2021

Similarly, the administrative data (national housing and population census reports, water bill statements, and meter readings from the FCT Water Board) was acquired to complement the field survey data. The census report is important in approximating the population of the area. The population serves as a pointer to the number of water demands and projects the future water demands. The field survey data were subjected to descriptive analysis using frequency tables and percentages to identify respondents' water demand, availability, and accessibility.

4. RESULTS AND DISCUSSION

4.1 Water Network

Figure 2 is a digitised map that shows the broad water distribution in the districts of AMAC, namely Garki, Asokoro, Wuse, Maitama, and Central Business District. The water distribution system is a hydraulic infrastructure consisting of pipes, tanks, reservoirs, pumps, and valves (Venkata et al., 2015). This set the

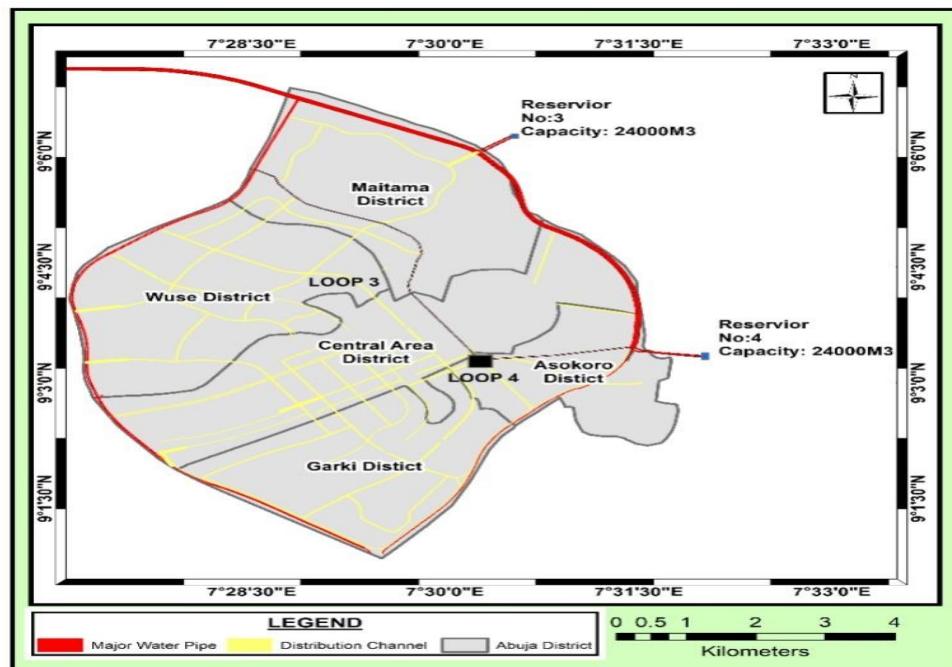


Figure 2: The Broad Water Distribution Network in the Districts of AMAC.

stage upon which the districts' water distribution analyses were based.

Figure 3 shows the combined water distribution network across the study area. It illustrates a reservoir in Asokoro and by the side of Maitama District, which are the main source of water supply to the districts. There is also a loop at Wuse and Asokoro, respectively, while several boosters, pump stations, and junctions exist in all the districts. The general pattern indicates that the eastern flank of the study has a high density of water distribution network compared to the western flank. (Nyende-Byakika et al., (2012) averred that greater emphasis should be put on the distribution system for water to be efficiently supplied.

Table 2 shows water sources for the Federal Capital City to Areas by Existing Piped Water Supply System. Table 2 indicates that the water

supply to the study areas is from two major sources (Lower Usman Dam and Gurara Inter Water Basin). Generally, water supply to areas is by a pipe system. The water is supplied on Phase by Phase basis in the Federal Capital City. Treated bulk water is usually supplied from Lower Usman Dam treatment plants through four transmission mains to major tanks covering water supply areas (approx. 44 km). Four bulk meters enabling FCTWB to measure inflow volume to the whole piped water supply system are also installed along these transmission mains at the outlet from the dam. There were 16 major concrete tanks in the existing piped water supply system, to which water is supplied by gravity and partially pumped up. Table 3 depicts that a total of 325 questionnaires accounting for 81%, were returned.

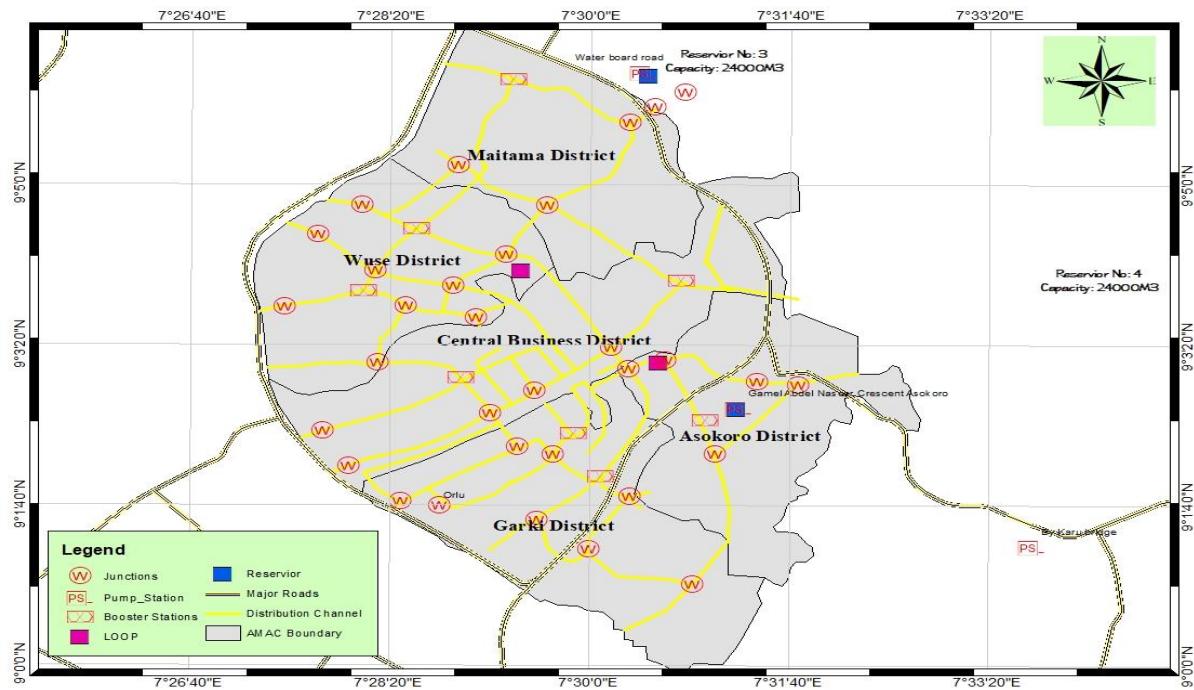


Figure 3: Existing Water distribution networks in AMAC.

Table 2: Water Sources for Federal Capital City

S/N	Water Source	Description
1	Lower Usman Dam (LUD)	Capacity: 100 million m ³
2	Gurara Inter Basin Water Transfer	Capacity: 880 million m ³ (Augmentation to LUD: 12m ³ /sec) Owned by: Federal Ministry of Water Resources

Source: Abuja Water Board

Table 3: Water Treatment plants in the existing piped water supply system

S/N	LUD	Water Treatment Plant	Description
1	WTP Phase – 1		Capacity:120,000m ³ /day, Year of Construction:1987
2	WTP Phase – 2		Capacity:120,000m ³ /day, Year of Construction:2000
3	WTP Phase – 3		Capacity:240,000m ³ /day, Year of Construction:2014
4	WTP Phase – 4		of Construction:2014

4.2 Households' Water Demand and Supply

Figure 4 shows the number of people living in a household, and it indicates that 4-6 persons accounting for 36.92%, live in a household, 7-9 persons representing 33.84%, 1 - 3 persons, which are about 18.76% while more than ten persons accounting for 10.46% live in a household respectively. The results indicate that the number of households influences the quantity of water demand in the study areas.

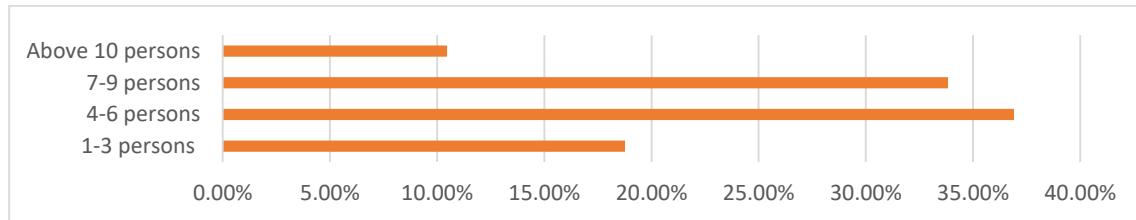


Figure 4: Number of persons in a household

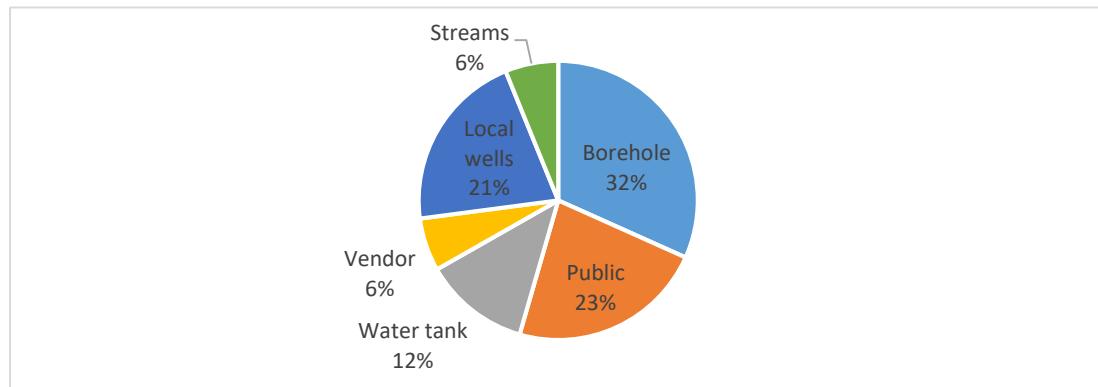


Figure 5: Sources of water Supply

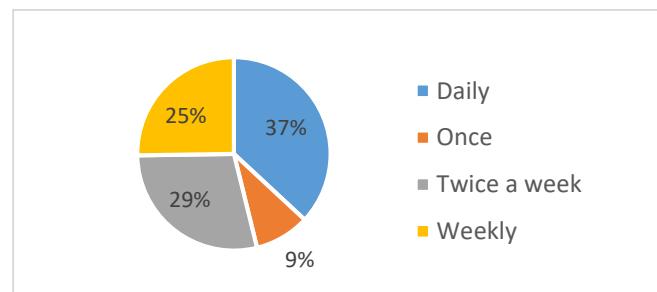


Figure 6: Frequency of water Supply

This finding agreed with (Chukwudi et al., 2017) that found strong relationship between population growth and water demand in Calabar. However, Liyanage & Yamada, (2017) shows that population growth has negative effect on water quality. Figure 5 illustrates sources of water supply to households. About 31.69% of the population identified boreholes as their dependable source of water supply as the FCT Water Board cannot be relied upon, while 20.92% and 22.76% do get their water from the public water supply source of the FCTWB and 12.30% said they do get their water from water tankers,

Figure 6 shows the frequency distribution of water supply in the study locations. Water supply daily in the study location accounts for 36.92%, and this can be attributed to the fact that AMAC is the First phase and most developed part of the FCT, while 28.61% get water supply twice a week, 25.23% and 9.23% gets water ones a week in the study location.

Water outages are primarily caused by faulty pumps, periodic engineering work at the city's water treatment plant, and pipe bursts during road construction in new districts, which signals a lack of coordination between the utility agency and the engineering secretariat responsible for road construction and maintenance.

The consequences of water scarcity are pervasive and costly, as many respondents complained of the loss of valuable time and money due to the need to purchase water from vendors or fetch water from other districts. Figure 7 shows the frequency distribution of water shortages. About 45.53% of the population attest to the fact that they usually experience a shortage of water once or twice a week, while 28% said it does occur on a weekly basis, and 26.46% experience water shortage daily. Based on the causes of water shortage, the result indicates that there have been water shortages in the study location. 43.07% of the

population blamed it on constant power outages, 20.30% on pipe breakage and leakage, 15.38% on irregular supply from FCTWB, 13.23% on system breakdown, while (8%) believed it the distance to the source of water.

Figure 8 identified the causes of water shortage in the study locations. The result shows that low water pressure is becoming an increasing problem in high-rise apartments, hilly areas of the Maitama and Asokoro districts, and high-density areas such as the Garki districts. Some of the respondents that reported this problem lamented that "the pressure will be so low to the extent that you cannot fill a bucket within 30 minutes" This problem buckles the sanitation system when water cannot be used for bathing or flushing toilets. Some other reasons are the shortage of chemicals and fuel required for water provision, caused by low budgetary allocations, and the failure of users to pay their bills, especially the political and economic elites. As a result, the utility agency introduced

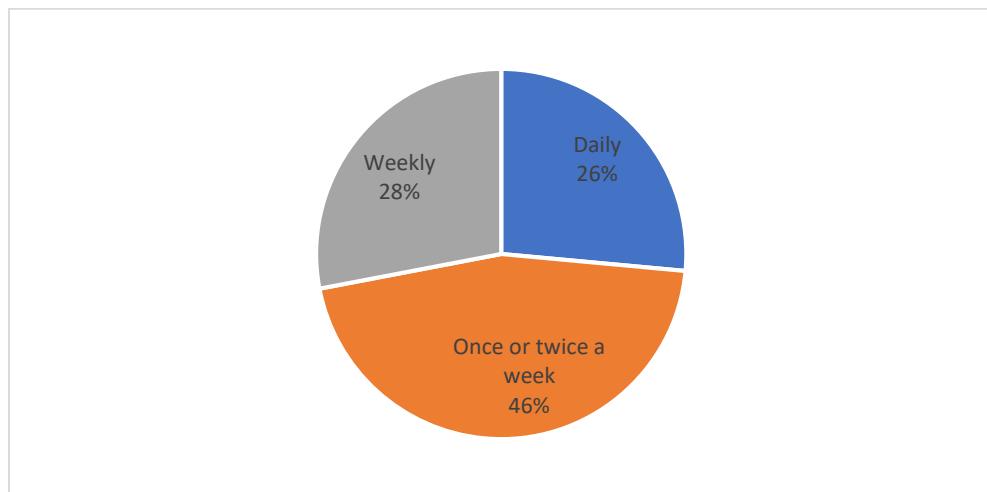


Figure 7: Frequency of water shortage.

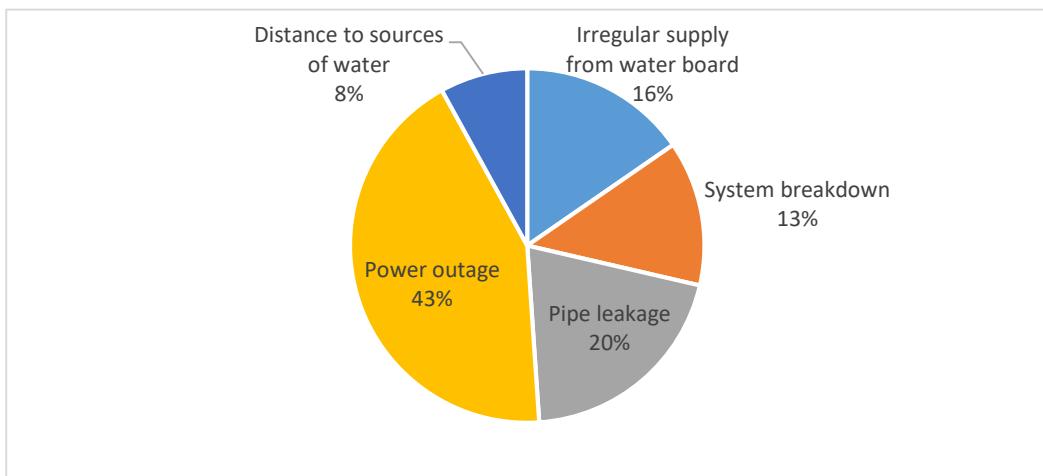


Figure 8: Causes of water shortage.

a rationing system, which is more stringent in the dry season. Aging water supply infrastructure is a growing concern to water utility managers worldwide. The water distribution network is the most expensive component of a water supply system, and its deterioration causes increased operation and maintenance costs, water losses, increased energy consumption, decreased level of service to the consumer, and decreased level of water quality. Consequently, the rehabilitation and upgrading of pipes is an important part of effectively managing a water distribution system.

Currently, the major effort that is applied toward the long-term planning of water distribution system rehabilitation seems to be very small relative to the size of problems on the ground. The long-term planning of the rehabilitation and upgrading of a water distribution system involves the selection of an appropriate rehabilitation measure for each pipe in the network (e.g., reline the pipe, or replace it with a larger diameter).

The complexity of the problem lies in the fact that due to deterioration, the system's hydraulic capacity diminishes over time, and maintenance and repair costs increase over time. Any change in the hydraulic capacity of any pipe causes a redistribution of flows throughout the network. Consequently, the operational mode of any pipe in the network depends on the characteristics of all other pipes. As a result, the rehabilitation of any pipe in the network will influence the choice of pipes to be rehabilitated and the timing and type of future rehabilitation alternatives.

5. CONCLUSION

The need for safe water is a rising trend in many parts of the world because it stabilizes the social system. The water distribution system of the case study was analysed to show and represent the network. The system consists of a reservoir, several boosters, a loop, pump stations, and junctions. Distribution mains are the pipelines from reservoirs (tanks) to water supply areas, sometimes as a part of the distribution network in FCTWB (approx. 296 km). There are 16 major concrete tanks in the existing piped water supply system, to which water is supplied by gravity and partially pumped up. The finding indicates dense and substantial spatial water distribution networks in AMAC. The finding was attributed to the planned nature of the study

area that takes cognizance of every needed resource and infrastructure. The findings suggest that planners and decision-makers in the water sector should take cognisance of future development patterns and make provisions for expansion. Also, the finding indicates there is a water supply shortage in the study area. Consequently, people are forced to source their water needs through various means, including water tanker vendors. This should facilitate regulating water vendors to make it a source of healthy and safe water for domestic, industrial, and municipal uses in other to have legal backing.

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