

Mapping and Identification of Water Pipeline Leakages in Bauchi Metropolis, Bauchi State

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Abstract

This research aimed at identifying pipeline leakage points on the water distribution network in Bauchi metropolis. This was achieved by first updating the base map and identifying the leakages on the laid-down pipes. The method adopted in this study was a field survey in which positions of leakages distributed within sampled settlements of the eleven wards (11) of the study area were captured. The results for the field observations were analyzed in ArcGIS 10.3, in which the highest percentage of leaks was observed in Majidadi "B" and Tirwun wards with about 17%, while the lowest of 0% was observed in Makama "A." Reservoirs with a capacity of 11000 m³ each and 2,575,870 gallons of water, making a total of 18,031,090 gallons of water, were obtained as the result for the maximum amount of water needed in the entire study area. The leak's buffer points resulted in the production of a map of settlements affected by the leakages. It was concluded that the leak percentage is proportional to its rate of occurrence in a settlement. Further research in this area is recommended to use real-time modern water leak sensors detectors for precise monitoring, identifying and locating any macro or micro loss of water on the system.

Keywords: Bauchi, Water, Pipeline, Mapping, Leakage.

Introduction

Mapping is the graphic depiction on a flat surface of the physical features of the whole or part of the earth or other body, using shapes to represent objects and symbols and labels to represent the feature properties or descriptions. Maps generally use a specified projection and indicate the direction of orientation. Map elements include the title, north arrow, scale bar, descriptive text, symbol, legend and map frame which provides the principal display of geographic information (Rauph, 2015). Humans have long recognized the importance and value of mapping utilities. Indeed, the history of mapping can be traced to more than 5,000 years ago. Maps are essentially tools which for the map maker, record the location of places of interest for others, are a source of learning about the geography of the mapped area. National Research Council (2006) stated that Facility Mapping has the capabilities of mapping and storing information about utilities in different layers thereby providing multiple ways of generating focused maps from a single and consistent database. For servicing, detailed maps showing the accurate location of facilities in need of repair are

essential. For planning, coarse scale maps may be sufficient as only overall distribution of the facilities infrastructure may be of interest. The facilities infrastructures are linked to a database that holds detailed attribute information about each facility. By querying the map, information about each facility and its relationship to other facilities can be obtained for operational planning and management purposes.

Water Facility Mapping is the process of digitally identifying and mapping facilities infrastructure with the explicit goal to improve operational management and planning tasks such as dispatching, inventorying and maintenance National Research Council (2006). One of the objectives of Water Facility Mapping is to display Water Distribution Facilities within a particular geographic area. Water Distribution Facilities carry drinking water from a centralized treatment plant or well and supplies to consumers' taps. These systems consist of pipes, pumps, valves, storage tanks, reservoirs, meters, fittings and other hydraulic appurtenances (Walski et al., 2003).

Generally, in Africa, the provision of water facilities is mostly supplied in an urban area. An urban settlement is a concentrated city that constitutes high density of human created structures together with socio - economic activities and other natural built-up settings. In an attempt to arrest the migration of people to urban areas, governments of African countries have promoted schemes to bring urban infrastructure such as functional water distribution facilities to villages as well as urban centres (John, 2010). But the provision of the water to urban areas requires major capital investment in storage, treatment and supply networks. Furthermore, the per capita consumption of water has generally increased rather than decrease, although this can be expected to be a function of life style and population density (Jansen, 2002). Water Distribution System account for 40% - 70% of the total cost of Water Supply Scheme (Sarbu & Borza, 1997), hence its Proper planning, design, operation and layout is of great importance.

In Nigeria, water availability controls population distribution. Settlements that are provided with modern water supply networks are usually those situated along the major trade and transportation networks and all improved water supply in the country is from public water supplies, the pattern of water supply varies from one settlement to another, generally as the population of a settlement increases, the service efficiency to the expanding population decreases, this usually creates a great disparity in supply to different zones of the settlement (Oyebande, 2005).

Statement of the Problem

In the year 2000, the Global Water Supply and Sanitation Assessment report revealed that the Global percentage of people served with some form of improved water rose from 79% in 1990 to 82% in 2000. Same period, one sixth of the world's population was without access to improved water supply. The majority of these people live in Asia and Africa where two out of five Africans lack improved water supply coverage. According to Millennium Development Goal, the African largest cities have only 43% house connection to water

supply services. Nigeria as an African country has an approximate population of 140 million people with about 55 million people representing thirty-nine percent (39%) of the estimated population but lacked access to drinking water in many of its cities despite the progress made by MDG projects (UNICEF, 2014).

National Commission Population (2006) census shows that Bauchi state is one of the Nigerian cities with an approximate population of about 4.6 million people of which 30% lived in urban areas. With this population figure, only 36% have access to piped due to waste of water through leakages. The determination of pipe water discharges was a great challenge in the urban water sector's institutional frame work and serious management problem within the Bauchi State Water Board (B.S.W.B), the main service provider for Bauchi town water supply and distribution. Findings by the Water Sanitation and Hygiene [WASH] (2015) shows that seventy-three per cent (73%) of the waterborne disease outbreaks such as diarrhoea and enteric in the state were all associated with poor water distribution facilities.

Objectives of the Study

The objective of this study is to:

1. Update the existing water facility map of the study area
2. Identify pipelines with problem of leaks within the study area.
3. Produce the map covering the settlements affected by the leakages.

Literature Review

In Nigeria, economic and social development, good quality of life and good health heavily depends on physical infrastructure for delivering essential services to communities. Good infrastructure leads to good quality of life (Hudson et al., 1997). Infrastructure, a Latin word meaning "the structure underneath," encompasses all the systems that provide a society with diverse and valuable services for example, sewers, pipes, pumps and manholes are elements of the water infrastructure and decisions related to these components require important economic resources. This means that all decisions influencing infrastructure development and use-asset management without an appropriate and technical evaluation method inevitably misuse economic, environmental, social and cultural funds (Lemer, 1998).

Public and private organizations in the Nigeria have recognized that the nation's water and wastewater infrastructure face important challenges over the coming decades in maintaining, operating and renewing infrastructure assets like pipes, treatment plants and other related components. Some Organizations like Water Aid (2006) have reported that the management of water facilities is ineffective in Nigeria because there is inadequate and inequitable distribution of adequate surface and groundwater supplies: hence there is a significant zonal and state variation in the proportion of people using improved water sources.

Based on the NBS (2006) survey report, of the six geopolitical zones in Nigeria, improved water coverage ranged from 30.7% to 73.5% with the South West Zone has the lowest coverage of (30.7%). This indicates that Water Systems will require capital improvements of over \$20 million a year to comply with and meet the needs of new developments and to replace or renew aging and obsolete infrastructure. Some estimates that for years 2000 – 2019, annual costs for investment will average between \$13 million and \$20.9 million for Water Systems (Budget Office, 2007). Therefore, changes in management practices and the adoption of new technologies can increase efficiency and reduce costs. Those funds could pay for training in and the purchase of new technological improvements in water companies. The bottom line is that the adoption of effective management technologies is a cost-effective solution in this critical phase of our national infrastructure status.

Many organizations have started to use Geographic Information System (GIS) in the management process of infrastructure. There is wide room to develop more advanced tools and methodologies to increase efficiency in the diverse phases of infrastructure management (Ramiro, 2009). Various research and relevant literatures have been consulted, among which are: (Zaharaddeen, 2018) who carried out a research on the Geospatial mapping of water distribution system in Bauchi metropolis with a view of identifying areas without such facilities. He updated the existing domestic water distribution map of the study area, developed a functional geo-database that facilitates water distribution and analyzed the spatial accessibility to the existing water facilities thereby identifying places that require the extension of water facilities. However, the research did not provide any point location and attributes of pipes associated with problem of leakages. Pindiga et al., (2015) mapped the water distribution network in Bauchi using Geospatial technique. They Scanned; Geo-referenced and Digitized the old water distribution base map using GPS and ArcGIS software.

Their study did not provide any information on pipelines which is the major facility in water distribution network, the main distribution pipelines that convey water from Gubi dam was not incorporated in the distribution network; they mapped the pipelines and made queries to identify the location of nodes, hydrants and buster stations on the map only. Also, their map did not have a designed database for the different buried pipelines. Audu & Ehiorobo (2015) applied geospatial technology for water distribution modeling in Warri Port Complex; they used Google Earth Imagery in their study. Marry (2008) also used the Google Earth Imagery to study the GIS representation and assessment of water distribution system in Thailand. The present research filled the missing gap by developing a revised water facility Map showing water facility and the leakages on the pipelines. The average water required for the different sampled settlements of the study area was computed to determine the amount been lost to leakages. The research applied Pleiades Satellite Imagery to ensure effective and accurate representation of features on the map against Google map.

Materials and Methods

The Study Area

Bauchi metropolis is a city in Northeast Nigeria, the capital of Bauchi State of the Bauchi Local Government Area within that state and of the traditional Bauchi Emirate. The city was founded by Yaqub ibn Dadi, the only Non-Fulani flag-bearer of the Sokoto Empire. The name was derived from a hunter called Baushe, who advised Yaqub to build his city west of the Warinje Mountain in return Yaqub promised to name his city after the hunter. Bauchi metropolis located at latitude $10^{\circ}17'00''$ N and longitude $09^{\circ}49'00''$ E on the Northern edge of the Jos-Plateau at an elevation of 616m (Abubakar, 2006). The local government area covers an area of 3,687 km² and lies on the Port Harcourt - Maiduguri railway line.

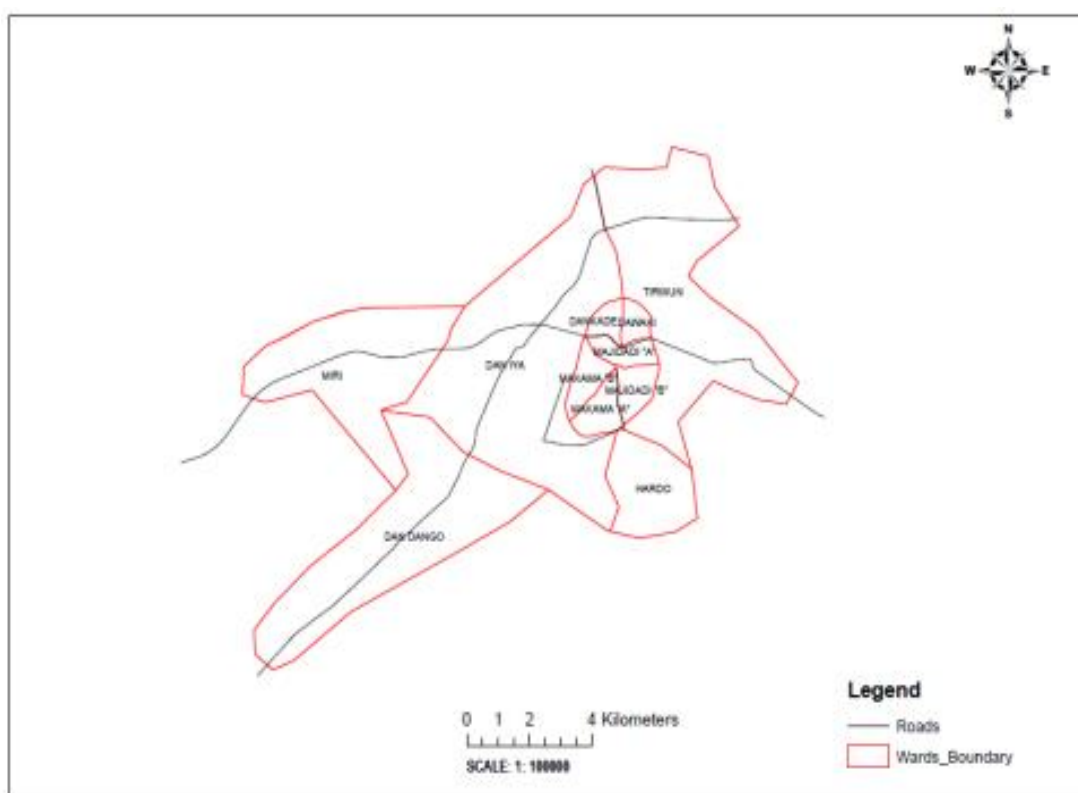


Figure 1: Map of the study area

Source: Author's Analysis, 2021

Methodology

The methodology flow chart in Figure 2 is a diagram showing a clear representation of sources of data collection, method of data processing and analysis which finally leads to production map of the settlements affected by leaks.

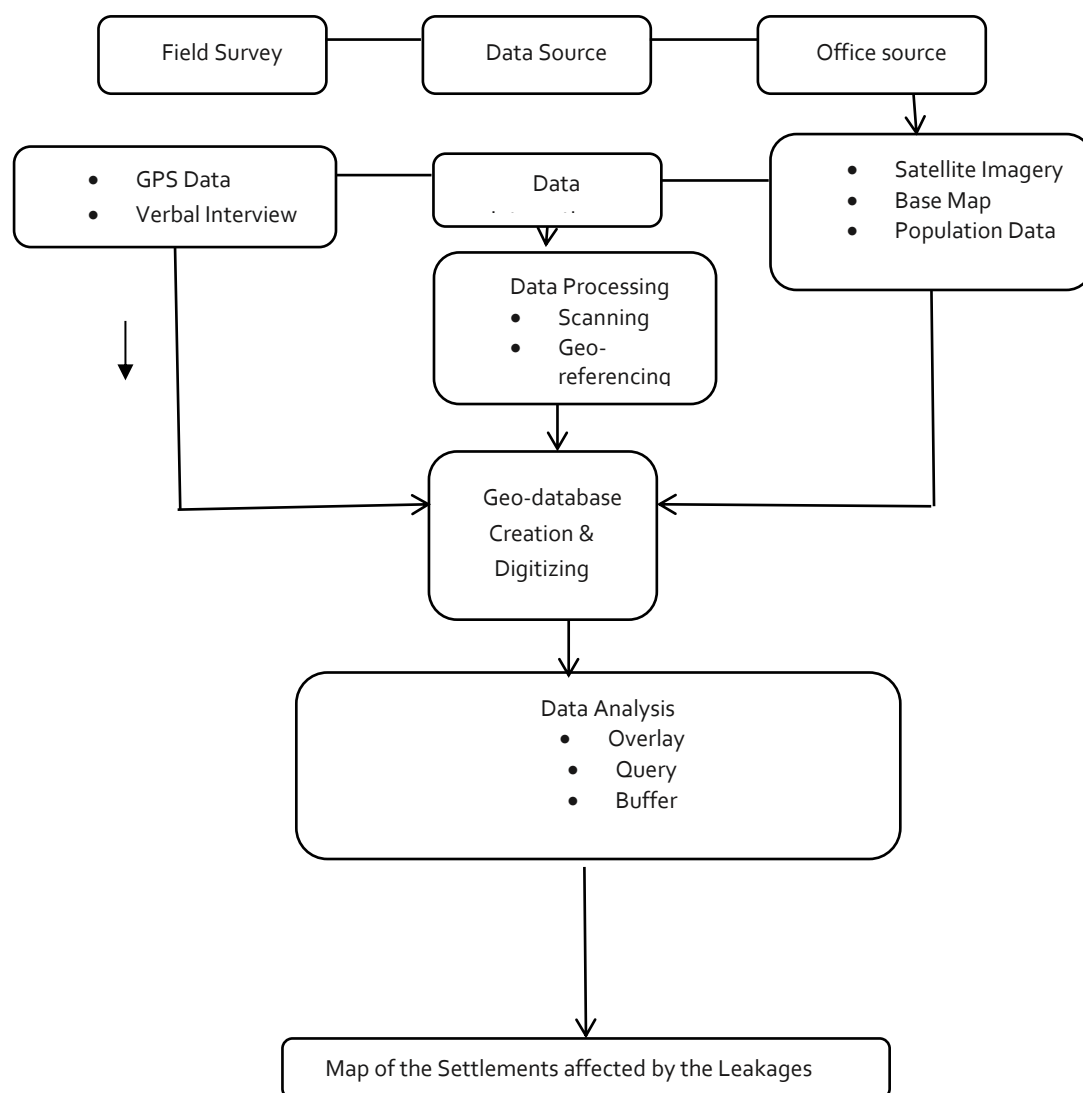
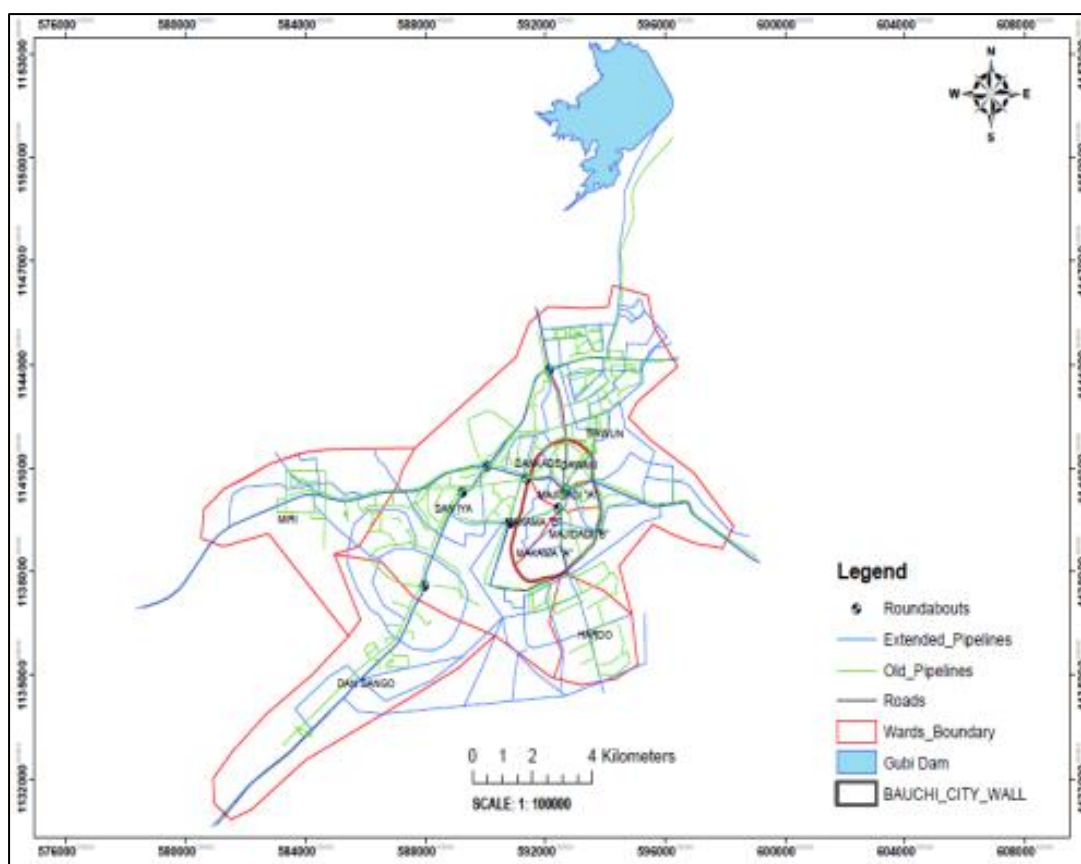


Figure 2: Methodology Flow Chart

Source: Author's Analysis, 2021

Result and Discussion

The results obtained from the described methods and processes were presented as figures and tables with their interpretations and discussions based on the research objectives. The results are for the updated map for water facilities, assessment of settlement's water requirements based on identified leakages, geo-database creation for the water facilities and the spatial coverage of the affected areas by leakages.



Source: Author's Analysis, 2021

Figure 3 produced an updated water facility map of the study area after the digitized old pipelines on the base map were overlaid on the newly extended pipelines. The map was updated with map features and elements such as grids, layout, scale, legend and coordinate system etc. the interval values positioned at the edge of the layout signifies UTM grid coordinates while the cardinal points (N, E, S, & W) indicate True North Direction placed at top-right corner. The roundabouts and major roads appeared on the map were to provide a reference guide for locating some water facilities while the labeled wards and their shapes is to aid in both spatial & attribute queries.

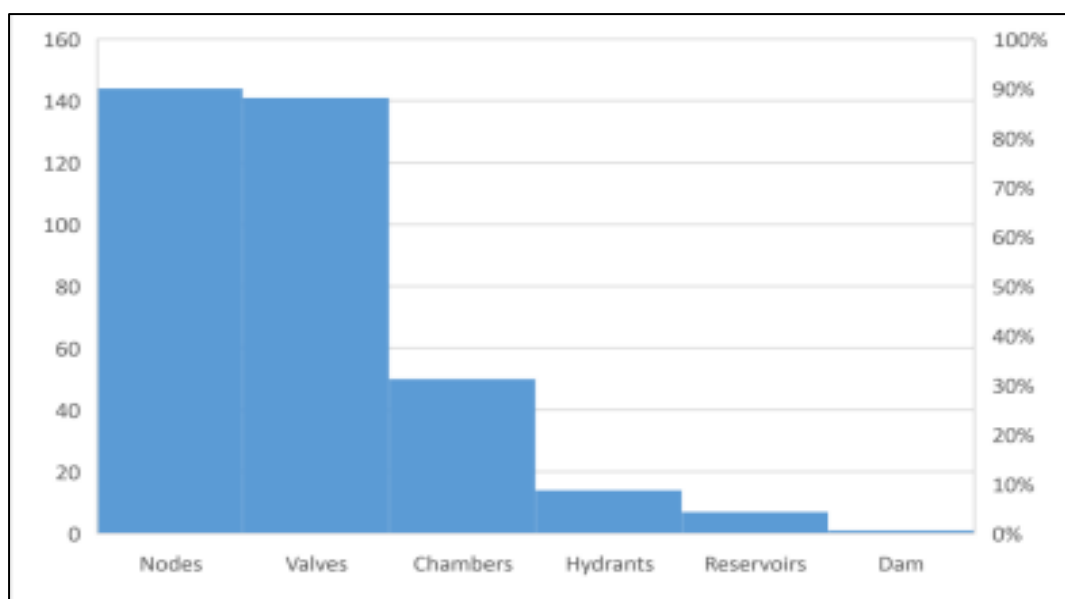


Figure 4: Distribution of water facilities within the network

Source: Author's Analysis, 2021

Figure 4 shows a total number of 357 water facilities within the distribution network. The distribution of the facilities was simplified to represent one-forty-four (144) nodes, 141 water valves, fifty (50) water chambers, fourteen (14) hydrants and seven (7) reservoirs with 2 located at Dutsen Warinje, Dutsen Tanshi and Tudun G.R.A respectively while one (1) is at Dutsen Kobi. Only one (1) dam is serving the whole wards. This dam is known as Gubi dam and it is the major source of water supply from the treatment plant through the connection of 1000mm pipeline to the reservoirs at Warinje hill to the town through the network of different diameter pipelines as shown.

Identified Leaks on the Pipelines

Leaks are major factor for unaccounted water losses in almost every water distribution network. Pipeline leaks may result, for example, from bad workmanship or any destructive cause, due to sudden changes of pressure, corrosion, cracks, defects in pipes or lack of maintenance (Dimitris, 2010). Therefore, the positions of the leaks were presented in Table 1.

Table 1: The list of leaks on the pipelines

S/No	Settlements	Wards	Easting	Northing	No of Leaks
1	Dutsen Tanshi	Makama "A"	591511	1138025	0
2	Wayan Makafi	Makama "A"	592533	1138219	0
3	Sabuwar Kasuwa	Makama "A"	592139	1138891	0
4	Kofar Idi	Majidadi "B"	593634	1139501	1
5	Kofar Dumi	Majidadi "B"	593103	1139196	4
6	Kofar Wase	Majidadi "B"	592841	1138629	1

7	Bakaro	Majidadi "A"	593443	1140143	1
8	Wunti Market	Majidadi "A"	591932	1140421	1
9	Bayi	Majidadi "A"	592880	1139958	1
10	Kofar Wambai	Dawaki	593446	1140854	2
11	Makwalla	Dawaki	592796	1141168	1
12	Bayan Ibb Square	Dawaki	593129	1141538	2
13	Baba Sidi / Mal. Goje	Dan Kade	592452	1141015	1
14	Igbo Quarters	Dan Kade	591650	1140764	2
15	Rariya	Dan Kade	592229	1141506	1
16	Jahun	Makama B	591402	1138761	0
17	Unguwar Galadima	Makama B	591834	1139382	1
18	Gwallaga	Makama B	591462	1140253	0
19	Tambari	Miri	585553	1139534	1
20	Wuntin Dada	Miri	584616	1140893	2
21	Miri Shafa	Miri	581003	1139619	0
22	Gudun Hausawa	Hardo	593215	1134976	1
23	Gudun Sayawa	Hardo	594606	1136145	1
24	Bayan Railway	Hardo	592625	1137421	0
25	Gwallameji	Dan Dango	585296	1133515	1
26	Sabon Kaura	Dan Dango	585627	1138110	0
27	Yelwa Atbu	Dan Dango	587858	1135840	2
28	Ibrahim Bako Quarters	Tirwun	597182	1140170	1
29	Tirwun	Tirwun	594372	1139220	3
30	Unguwar Sarakuna	Tirwun	593800	1144490	2
31	Games Village	Dan Iya	590810	1137617	1
32	GRA	Dan Iya	589330	1140117	0
33	Specialist Hospital	Dan Iya	592027	1142712	0
Total number of leaks					34

Table 1 shows a total number of thirty-four (34) Physical leaks identified on the facilities and their relative positions acquired with GPS receivers during field operations. These leaks were distributed across the thirty-three (33) sampled settlements within the study area and have their corresponding coordinates for easy identification in case of repair or replacement of the facility. As shown in Table 1, the highest number of leaks is four (4) affecting Kofar Dumi settlement within Majidadi "B" ward. Tirwun has three (3) leaks situated at Tirwun settlement while lowest number of one (1) was observed in some of the wards. A number zero (0) signifies non-presence of any leak in the sampled settlements.

Analysis of the Leak Percentage for Wards

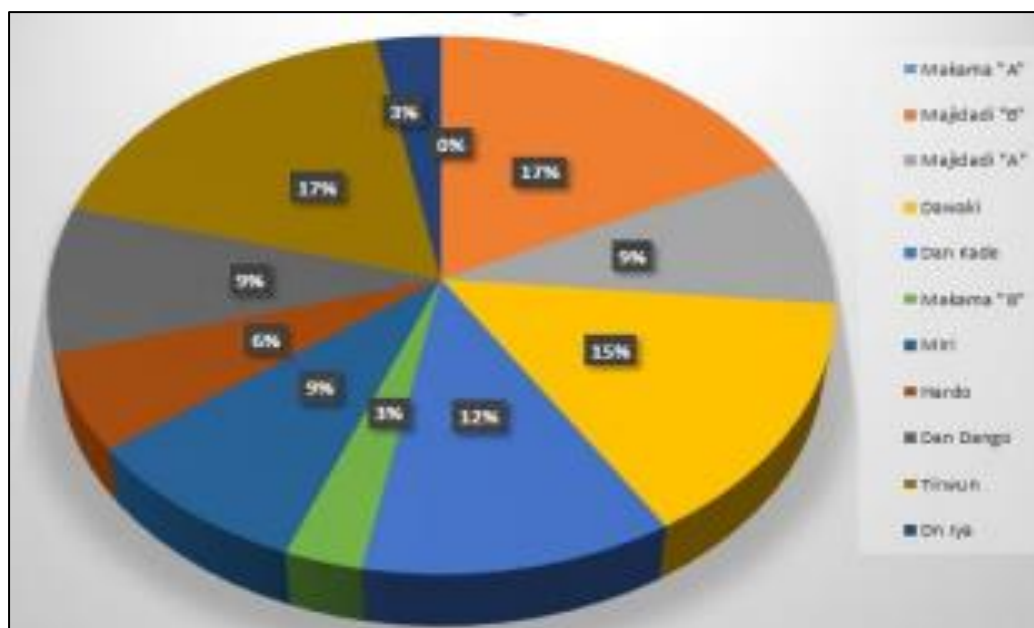


Figure 5: Percentage distribution of leaks within the wards

Source: Author's Analysis, 2021

As presented on figure 5, leak percentage of 17% was recorded highest in both Majidadi "B" & Tirwun wards. Dawaki and Dan Kade wards have 15% & 12% respectively while Dan Dango, Miri & Majidadi "A" recorded 9% each. The lowest percentage was observed in Makama "A" with about 0% leak.

Analysis for the Amount of Water Required in the Sampled Settlements

Table 2: Water requirement for the sampled settlements

S/N o	Sampled Settlements	Popula- tion	Minreq (litres)	Averreq (litres)	Maxreq (litres)
1	Dutsen Tanshi	9,321	372,840	559,260	745,680
2	Wayan Makafi	12,427	497,080	745,620	994,160
3	Sabuwar Kasuwa	13,031	521,240	781,860	1,042,480
4	Kofar Idi	7,123	284,920	427,380	569,840
5	Kofar Dumi	17,467	698,680	1,048,020	1,397,360
6	Kofar Wase	6,890	275,600	413,400	551,200
7	Bakaro	19,112	764,480	1,146,720	1,528,960
8	Wunti Market	21,134	845,360	1,268,040	1,690,720
9	Bayi	13,156	526,240	789,360	1,052,480
10	Kofar Wambai	23,178	927,120	1,390,680	1,854,240

11	Makwalla	16,192	647,680	971,520	1,295,360
12	Bayan Ibb Square	11,212	448,480	672,720	896,960
13	Baba Sidi /Mal. Goje	18,234	729,360	1,094,040	1,458,720
14	Igbo Quarters	8,256	330,240	495,360	660,480
15	Rariya	11,678	467,120	700,680	934,240
16	Jahun	15,301	612,040	1,224,080	918,060
17	Unguwar Galadima	25,233	1,009,320	1,513,980	2,018,640
18	Gwallaga	7,345	293,800	440,700	587,600
19	Tambari	3,021	120,840	181,260	241,680
20	Wuntin Dada	14,451	578,040	867,060	1,156,080
21	Miri Shafa	8,501	340,040	510,060	680,080
22	Gudun Hausawa	2,123	84,920	127,380	169,840
23	Gudun Sayawa	3,210	128,400	192,600	256,800
24	Bayan Railway	2,001	80,040	120,060	160,080
25	Gwallameji	9,112	364,480	546,720	728,960
26	Sabon Kaura	3,134	125,360	188,040	250,720
27	Yelwa Atbu	6,256	250,240	375,360	500,480
28	Ibrahim Bako Qtrs	10,001	400,040	600,060	800,080
29	Tirwun	18,842	753,680	1,130,520	1,507,360
30	Unguwar Sarakuna	9,876	395,040	592,560	790,080
31	Games Village	5,431	217,240	325,860	434,480
32	GRA	7,654	306,160	459,240	612,320
33	Specialist Hospital	12,112	484,480	968,960	726,720
Tot.		372,015	14,880,600	22,869,160	29,212,940

Source: Author's Analysis, 2021

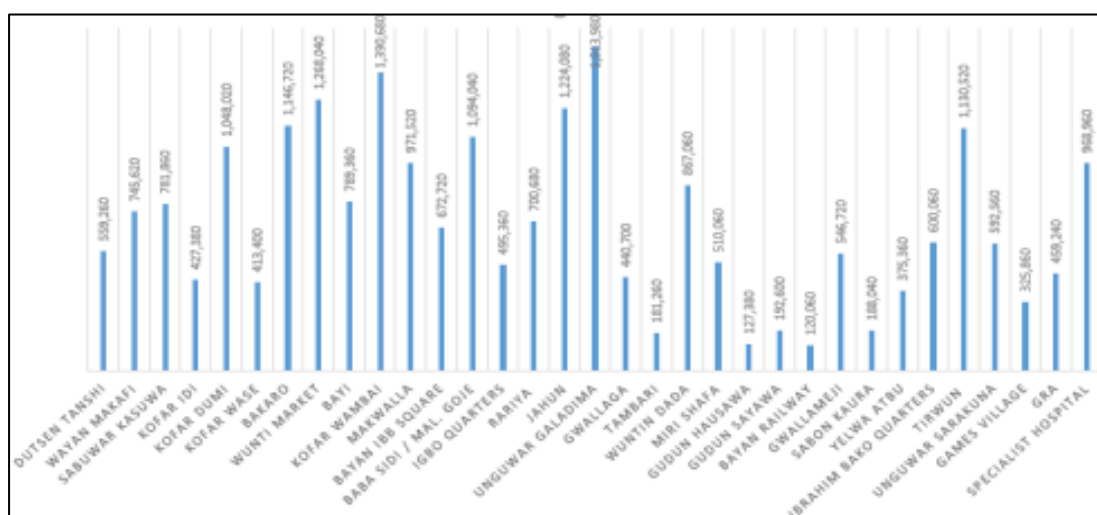


Figure 6: Minimum water requirements for the settlements

Source: Author's Analysis, 2021

The result of the water requirements clearly defined the amount of litres of water needed in every settlement based on their respective populations.

Figure 6 shows the highest record of Minimum Water required per day in Unguwar Galadima with about 1 million litres of water. Kofar Wambai, Wunti Market and Bakaro recorded about 927,000, 845,000 and 764,000 litres of water respectively. The lowest record of Minimum Water Requirement was observed in Bayan Railway with about 80,000 litres

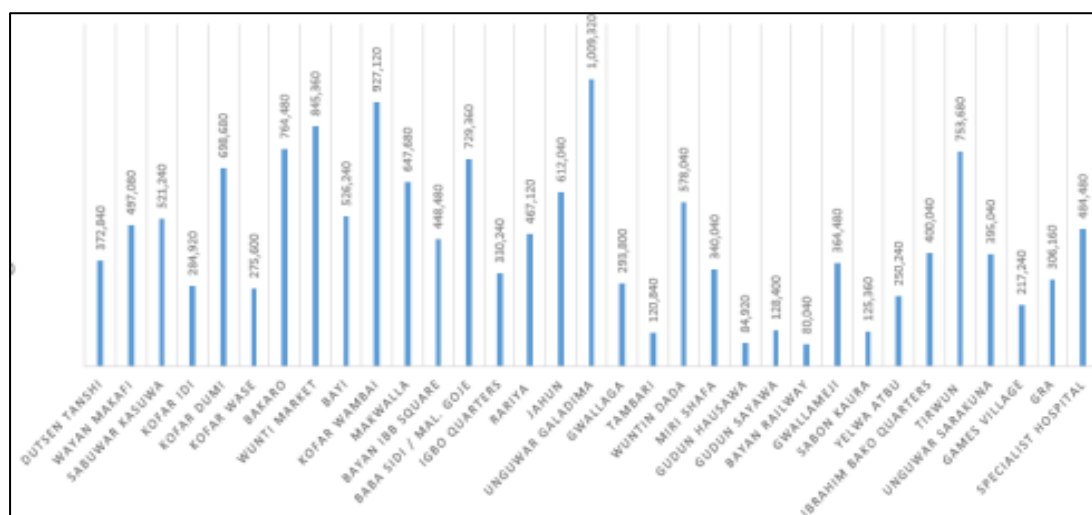


Figure 7: Average water requirements for the settlements

Source: Author's Analysis, 2021

Figure 7 shows the highest record of Average Water required per day in Unguwar Galadima with about 1.5 million litres of water. Kofar Wambai, Wunti Market and Bakaro recorded about 1.3 million, 1.2 million and 1.1 million litres of water respectively. The lowest record of Minimum Water Requirement was observed in Bayan Railway with about 120,000 litres.

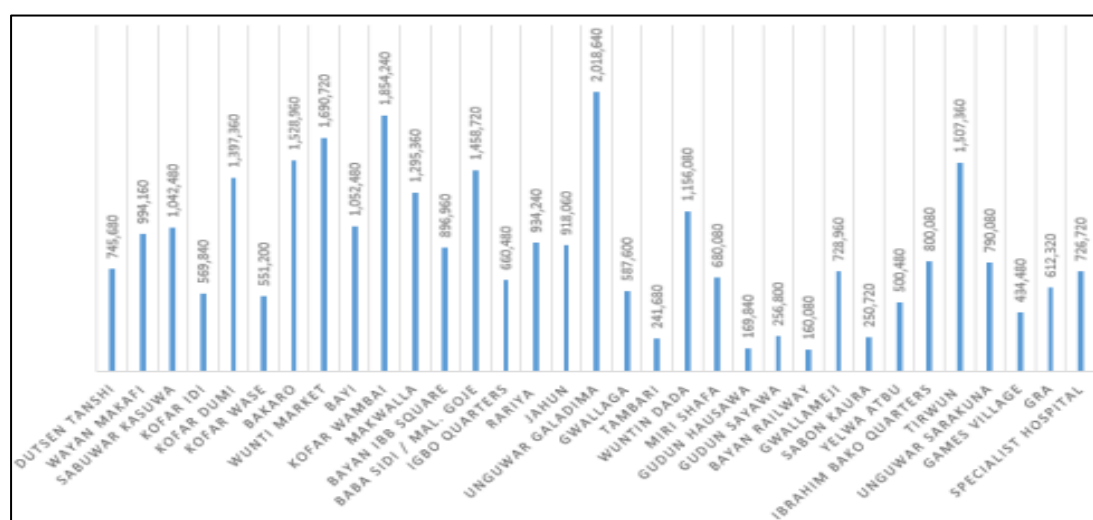


Figure 8: Maximum water requirements for the settlements

Source: Author's Analysis, 2021

Figure 8 shows the highest record of Maximum Water required per day in Unguwar Galadima with about 2 million litres of water. Kofar Wambai, Wunti Market and Bakaro recorded about 1.8 million, 1.6 million and 1.5 million litres of water respectively. The lowest record of Maximum Water Requirement was observed in Bayan Railway with about 160,000 litres.

Table 3: Water requirement for the wards

S/No	Wards	Population	Minreq (litres)	Averreq (litres)	Maxreq (litres)
1	Majidadi "A"	63,917	2,556,680	3,835,020	5,113,360
2	Majidadi "B"	58,862	2,354,480	3,531,720	4,708,960
3	Makama "A"	62,141	2,485,640	3,728,460	4,971,280
4	Makama "B"	52,140	2,085,600	3,128,400	4,171,200
5	Hardo	8,004	320,160	480,240	640,320
6	Dan Kade	41,485	1,659,400	2,489,100	3,318,800
7	Dan Iya	53,494	2,139,760	3,209,640	4,279,520
8	Dawaki	51,889	2,075,560	3,113,340	4,151,120
9	Dan Dango	20,103	804,120	1,206,180	1,608,240
10	Miri	32,453	1,298,120	1,947,180	2,596,240
11	Tirwun	49,322	1,972,880	2,959,320	3,945,760
Total		493,810	19,752,400	29,628,600	39,504,800

Source: Author's Analysis, 2021

Geo-Database for the Laid Down Pipelines

The geo-database provides versatile means of application in case of incident in the system, these include but not limited to use of corresponding pipe coordinates in locating the pipes, identification of pipe material at various degree of obsolescence in case of rusting, determine the distance at which the various pipes can be re-structured or constructed etc.

Table 4: Extended pipeline geo-database

OBJECTID	SHAPE	PIPE TYPE	PIPE POSITION	PIPE LOCATION	PIPE DIMENSION	PIPE LENGTH	EAST (m)	NORTH (m)	PIPE MATERIAL	STATUS
1	Polyline	DISTRIBUTION MAI	ALONG GDA DUBU ROAD	TIRWUN	100mm	7.17 Km	584,523.647	1,147,881.943	ASBESTOS	NON LEAK
2	Polyline	SERVICE LINE	ALONG MADIDURI ROAD	YOLI	200mm	2.36 Km	585,238.747	1,144,125.567	GALVANIZED STEEL	NON LEAK
3	Polyline	SERVICE LINE	ALONG SARKI ROAD	UNGUWAR SARKINA	200mm	3.82 Km	582,167.205	1,143,870.159	GALVANIZED STEEL	NON LEAK
4	Polyline	DISTRIBUTION MAI	ALONG ASHINDI ROAD	DAN KADE	100mm	3.59 Km	582,617.968	1,142,188.057	ASBESTOS	NON LEAK
5	Polyline	DISTRIBUTION MAI	ALONG JOS - MADIDURI	MIRI - DAN IYA	100mm	16.02 Km	585,536.445	1,148,978.644	ASBESTOS	NON LEAK
6	Polyline	DISTRIBUTION MAI	ALONG T/BALEWA ROAD	DAN DANGO - DAN IYA	100mm	17.31 Km	587,367.921	1,136,336.333	ASBESTOS	NON LEAK
7	Polyline	DISTRIBUTION MAI	ALONG RAILWAY ROAD	MAJIDADI A - HARDO	100mm	8.30 Km	582,961.268	1,137,468.559	ASBESTOS	NON LEAK
8	Polyline	DISTRIBUTION MAI	ALONG GOMBE ROAD	MAJIDADI B - TIRWUN	100mm	7.31 Km	586,128.408	1,138,925.683	ASBESTOS	NON LEAK
9	Polyline	LATERAL PIPELINE	ALONG THE FOOTPATH	WITHIN ATBU KARIESTATE	500mm	2.44 Km	583,525.977	1,144,582.751	ASBESTOS	NON LEAK
10	Polyline	SERVICE LINE	ALONG THE ROAD	WITHIN FADAMBA MAJA	200mm	3.25 Km	583,395.158	1,143,825.551	GALVANIZED STEEL	NON LEAK
11	Polyline	LATERAL PIPELINE	ALONG THE ROAD	WITHIN TUDUN SALMANU	500mm	3.62 Km	584,322.852	1,142,784.636	ASBESTOS	NON LEAK

Table 4 described the designed geo-database for extended pipelines which comprises the Pipe Type, Position, Location, Dimension, Length, Coordinates (Easting & Northing), Material and its Status. The characteristics of laid down pipelines such as the pipe type, material type and pipes coordinates could help the water board to determine the different classification of their pipelines, know the pipes that are prone to leak and locate the exact position of the pipes for repair. The pipe lengths and their dimensions were designed to suggest the level of extension and provide a scale measure in either expanding or contracting the network coverage. Settlement I.D is a unique identity that differentiates one settlement to another while wards and pipeline's coordinates were to locate points.

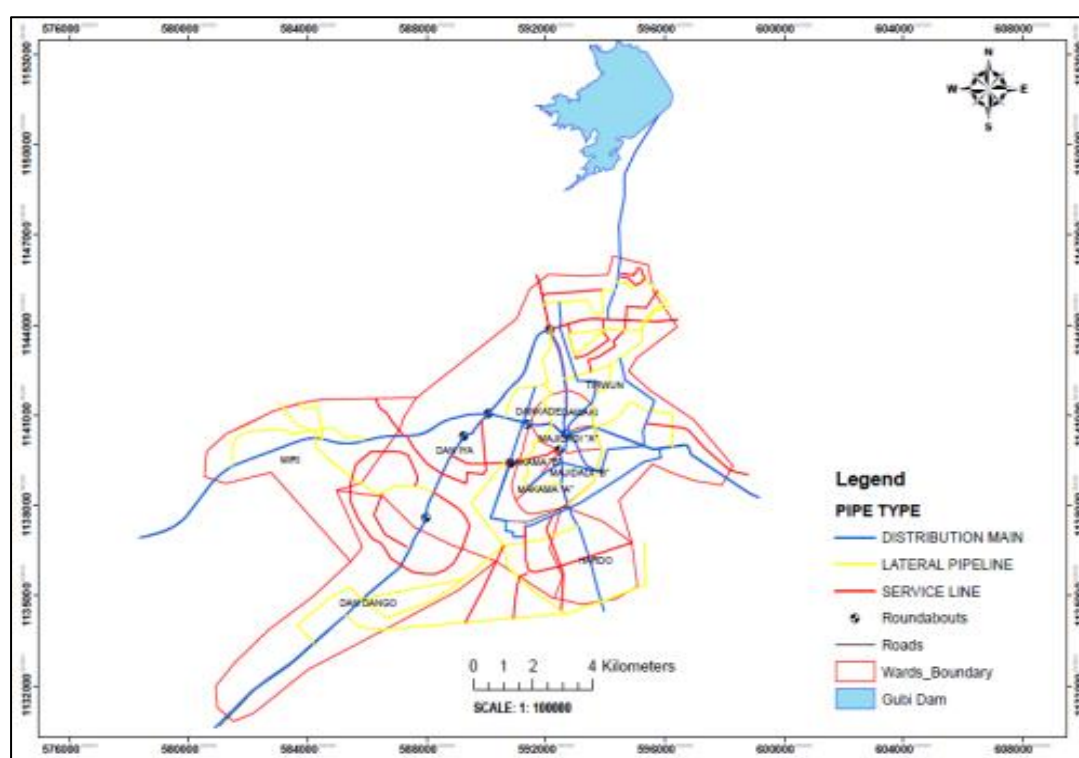


Figure 9: Map classifications of the extended pipelines

Source: Author's Analysis, 2021

Figure 9 described the buried water distribution pipelines categorized into two (2) namely Old Pipelines and Newly-extended pipelines. The newly-extended pipelines were further classified into three (3) different classes based on their diameter. Pipelines with 200mm diameter were described as Service Lines and coloured red, 500mm diameter pipelines were classified as Laterals and allocated a yellow cartographic colour while Distribution Mains were 1000mm diameter pipelines with blue colour. Distribution Main is the major pipe line that conveys water from the treatment plant through the major roads to the town as described above.

Conclusions and Recommendations

The aim of this project is mapping and identification of leaks on the water facilities of Bauchi metropolis. An updated map was produced showing the coverage of pipelines and their relative positions. Ground truthing on the updated base map was done with the obtained georeferenced Pleiades satellite imagery showing the comprehensive coverage of the study area in which the positions of features identified on both the imagery corresponded with reality on ground purposely to pre-test the reliability of the mapping entities. Observations on the different pipelines were recorded and various percentages were determined for leakages based on their spatial distributions in the study area to determine the minimum, average and maximum water requirement.

The leak's statistical data showed that leaks caused the shortage of water with respect to their percentage occurrences in a sampled data based on the computed result for the minimum, average and maximum water requirement. Also, the population figure of the sampled settlements is directly proportional to the amount of water required for the settlements. The final outcome of the various observations shows that Geographic Information System (GIS) produced map indicating specific locations where water leakages have occurred.

Recommendation

In the light of the problems associated with water pipeline leakages as revealed in this study; it therefore recommends that;

- Further research to be conducted in order to map and identify the existing watercourses such as rivers, streams, and ditches etc within the study area,
- Further research to be carried out by applying Water Leak Detectors such as HANVY Fiber Optics in locating any macro or micro loss of water on the system and also to obtain the measurements of the ground level so as to determine the height and depth areas for fixing up the alignment of the pipelines.

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