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Geocoding and Implementation of a Web-Based Water Distribution Geospatial Information System for Ilorin Metropolitan City, Kwara State, Nigeria

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Abstract

Water is essential for human life and activities, but its supply depends on the proximity and interconnection network with the populations or cities that need it. Moreso, the proper functioning of water supply systems (WSS) relies on the expertise and experience of field workers who rely on information from maps or field surveys, whose processes and mapping methods are labour-intensive, time-consuming, and are done relatively infrequently. The study aims to utilised a spatial-based online Map plugin in the Quantum Geographic information system (QGIS) environment to host a web-based GIS platform to view the transmission, and delivery of Drinking Water Distribution (DWD) network in the Ilorin township, from source to household users. It explores modern spatial information and Web-GIS capabilities in managing water infrastructure for an expanding metropolitan city. The resultant comparison results range from 60% to 75% in meeting users' needs for pipe network, road connection, DWD layout, catchment boundary, slope, and sub-catchment geometric properties demonstrate GIS technological web-based tools as a data management, scenario analysis, and decision support tool in managing water infrastructure for an expanding metropolitan city. Our configured web-based system offers real-time accessibility and user-friendly interaction that significantly support the decision-making process.

Keywords: Geocoding, QGIS, water distribution network, water supply systems, web-based

1 Introduction

Sustainable access to drinking water is one of the problems of Third World cities [1]. Demographic growth and the extension of cities make it more and more difficult to supply drinking water to the populace. The topographical contrasts and the anarchy in land use reinforce the difficulties of water distribution. As a result, the distribution companies of the drinking water supply (DWS) network face technical, logistical, and intricate service provider problems mostly from lack and sometimes inadequate modern spatial databases for meaningful progress to be made to water supply schemes (WSS). The study focused on the transmission and delivery of drinking water from the source to household users according to the capacities planned for the DWD system. It responds to research questions on the users' requirement and purpose of the web-based QGIS; which web development framework will be used and examines the extent to which present existing water infrastructure assets could be digitized for future expansion support. The implementation could aid in geocoding a web-based platform in viewing the transmission, and delivery of the DWD network by WSS for meaningful technical progress in managing water infrastructure assets for an expanding metropolitan city like Ilorin, Kwara State.

Ilorin city is immense in increasing water demands to meet the needs of its rapidly growing and urbanizing population, changing lifestyles, and economic growth [2]. The city is challenged with a water crisis caused by inadequate water asset documentation, insufficient infrastructure maintenance, digitalization and investment in water network distribution, inequities in water access, and a lack of skilled water practitioners who rely on outdated maps in this era of a rapidly changing environment. In many instances of these problems, the proper functioning of water supply systems (WSS) relies on the expertise and experience of field workers, a good organization structure with an adequate digital database containing all the key hydraulic infrastructure, to support its management and operational guidelines, to be able to perform optimally. However, most of this essential information is either inadequate or quite staggering for successful implementation of the WSS. At most, much of the existing information is in old maps or antiquated sketches which are too difficult to update and to keep up with modern times. This development calls for a decision-support tool for sustainable water transmission schemes (WTS), and water distribution networks (WDN) to enhance the efficient management of these infrastructures.

Geographical Information System (GIS) allows the creation and management of spatially referenced data to be useful in many fields or situations [3,4]. The significant expansion of the internet and growing public interest in accessing online geospatial information bore the fore need to investigate water distribution networks(WDN), and water transmission schemes (WTS) to enhance the efficient management of these infrastructures and ensure functional water supply monitoring. GIS has proven to be an effective and powerful tool in the water distribution industry [5]. It could aid the preservation and delivery of water infrastructure from the source to the end users. Thanks to their various spatial representation in the cloud. The use of modern spatial remote-sensing data and integration into GIS web-based has progressed over the past years for water supply, water allocation, water management, and flood estimation [6-14]. Thus, the application of spatial remote sensing data and visualization of WTS is essential in an expanding, dense population and increasing demand for accessible portable water supply for the teaming populace.

GIS-remote sensing has provided numerous solutions and convenience to characterizing biophysical and geophysical land surface processes and properties, many of which are well related to hydrologic and hydraulic science systems [15-17]. Satellite data have emerged as a viable alternative or supplement to in-situ observations due to their easier accessibility and applicability over vast areas in a catchment [18]. Spatial representation of WDN can provide surface data relevant to specific WTS to help alleviate some of the prolonged bottlenecks in resolving the water supply problems. Amongst these are: to enhance the efficient management of these infrastructures; highlight the need for alternative water supply routes; quantify surface water transmission links; evaluate water conservation measures and fair water allocation policies and provide guidelines for future non-traditional water supply projects. Maintaining data integrity has led to the development of web mapping applications like QGIS Cloud, geo-server, and map-server for the betterment of society.

Today, many models are used in different climatic zones to aid and enhance decision support systems (DSS) for water transmission. These range from the customization and integration of an open-source WebGIS system, and PostgreSQL/PostGIS as the relational database for dissemination, extraction, and analysis of water utility information online [19-23]. The extension works by [24] explored the combined application of GIS as a framework for data management and optimization of hydraulic parameters alongside three other hydraulic plugins: Ghydraulics, OpenLayer, and Qgis2threejs through hydraulic simulation in EPANET for the possible route, terrain navigation, least pipe network and spatial topographic profile representation is of immense benefit while literature work by [25] on the integration of free-of-charge open-source software, e.g. QGIS and EPANET, and engineering practices applicable to water distribution network design have expanded the space for more innovation and expansion of knowledge.

[25,26] use a QGIS 3.14 version alongside the Environmental Protection Agency Network (EPANET 2.2) to analyze the design of a water distribution network for the Agiliti community in the Kosofe Local Government Area of Lagos State, Nigeria. [28] dwell on new expansion using the plugin GHydraulics of QGIS and the MapBasic language of MapInfo. Despite the significant challenge of ensuring optimal water delivery to multiple locations with appropriately sized infrastructure compatible with existing systems, antiquated and manual drawings are still employed in this modern era. As useful as most of these invented tools and models have proved to be, the use of an intuitive web-based approach linking urbanization with human analysis in assessing water distribution networks(WDN), and water transmission schemes (WTS) is limited to few studies or has not received much attention in this clime. Hence, this study combined the use of in-situ measurements and remotely sensed data in digitizing physiographic information for Ilorin water supply, distribution network assessment, and water transmission schemes to the different end users in a fast, safe and convenient mode in resolving many bottlenecks associated with technical WSS challenges in real-time.

The study acknowledges and benefits from the works of literature while further on the intuitive usage of spatial data in meeting both the supply and demand side in solving water distribution and network problems in third-world countries. Therefore, this study sought to establish the applicability of a web-based in-situ PostgreSQL database to host spatial data and visualize the city water distribution networks in real-time. The study presents a digitalized and secure database for Ilorin's water infrastructure, ranging from its storage reservoirs to the end-user distribution network in digital format. Other necessary information entails water infrastructure and utilities such as pipes, fire hydrants, washouts, water meters, pumps could be easily displayed without printing as a softcopy map. The study would assist decision-makers in upgrading the existing water distribution system with spatial data and ensure future expansion with updated information for effective redesigning, planning, and management for near-future increasing users. The study would also be useful for people who know nothing about GIS due to its simplicity, and ease of supporting multi-user interface requirements.

1.1 Study Area Description

The study area (Ilorin) has 3 Local Government Areas (LGAs) namely the Ilorin West, Asa, and Moro LGA. As one of the most densely populated areas, Ilorin City occupies most state assets [29]. Ilorin is situated in Kwara state North Central region of Nigeria. It is located between latitudes 8°30'N and 4°33'E (Figure 1). The study area occupies a land area of 765km² and an estimated population of 732,199 [30]. It harbours the State Ministry of Water Resources and Sanitation which is responsible for developing policies, strategies, and plans for water resources management and executing water supply projects within the state's boundaries while the Kwara State Water Corporation (KWWC) manages, controls, and operates water supply

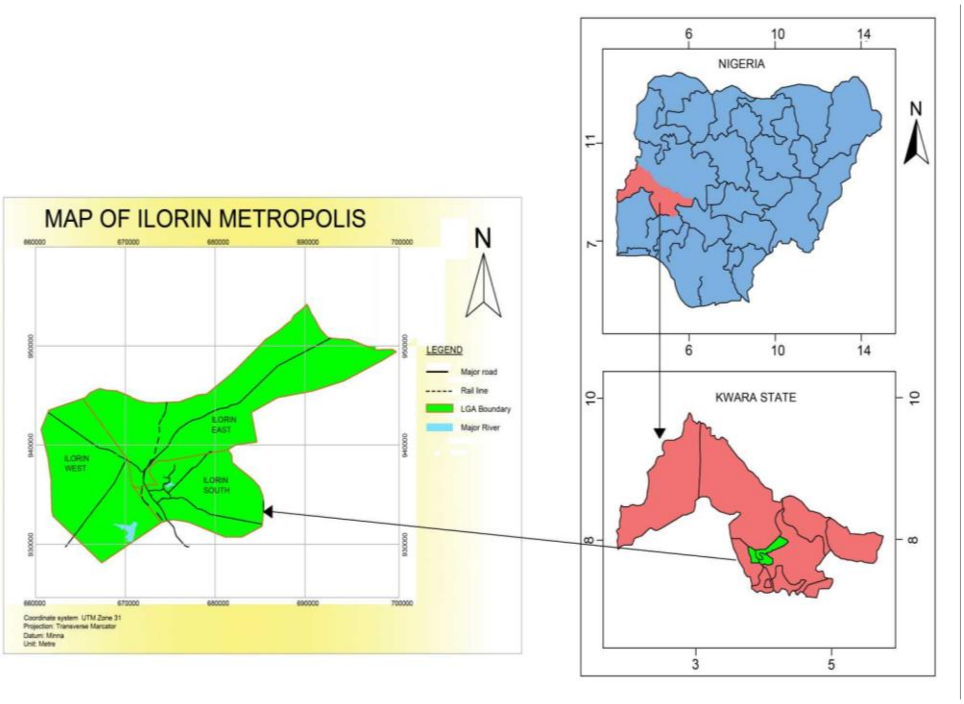

Figure 1. Map of Ilorin showing its three local government areas in relation to Nigeria

infrastructure within urban areas and suburb towns in the state. Fig. 1 depicts the Map of the study area in relation to Nigeria.

The study area WDS consists of the sources, dams, water treatment plants, transmission and distribution networks, and reservoirs(tanks). The Ilorin water scheme consists of 3 Nos of dams namely Asa Dam, Agba Dam, and Sobi Dam, 5 Nos of water treatment plants (WTPs), 13 Nos of elevated reservoirs, 5 Nos of ground reservoirs, 2 weirs, and 1 underground reservoir, all located in the city of Ilorin metropolis, the state capital.

2 Materials and Methods

To address the objective, the aggregated views of stakeholders within the Water management sector were solicited through questionnaires which gives the expertise side to the expected web-based development for verification. The content of the questionnaire instrument was structured in the modified Likert fashion 1 being the lowest and 5-point being the largest. Participants were then instructed to respond to their degree of agreement with the statements contained in the instrument. These questions were sufficient in answering users' requirement features for a web-based water distribution system users wanted to be held on the internet. At various spatial and temporal scales, the relevant datasets framework needed to create and compile the old and new database for the study area description (Ilorin water supply scheme) evolved, and a centralized spatial database for all the water infrastructures was identified, digitized updated new data-based inventory was set up for the study area. Thereafter, analyses and querying of the developed database management system were embarked on before evaluating the performance of the developed web-based monitoring system for the area water supply and distribution networks which enriched the data visualization techniques used in the web mapping interface. Details of the applied procedural step are hereby presented.

2.1 Sample design, and rationale

Due to the nature of this research, which requires the insights of experts, and scientists who are well-grounded in GIS, geocoding, and water management. The non-probability, snowball sampling method was adopted in selecting the participants. In non-probability sampling, elements do not have an equal chance of being selected [31] while in snowballing, a researcher collects data from a few people (participants) whom he or she can find, then asks the same people (participants) to recommend where potential participants may be found or people whom such participants relate with. Hence, the researcher continuously solicits referrals for other potential participants till all the contacts have been exhausted [32,33].

29 employees at the State Ministry of Water and Environmental Sanitation (MWES), Ilorin, and an expert consultant (CIWAT) were consulted. Amongst these 29 employees, the researcher retrieved 25 completed questionnaires. The remaining questionnaires were either not filled out or filled out incompletely (which makes them void). The questionnaire design was done in such a simple way that elucidates worthwhile information from respondents. Table 1 presents the respondents' demographic data responses.

Table 1 shows a fair proportion of the respondents' responses were from informed sources who understand the research subject. The respondents were knowledgeable enough to state their desired function requirement for web hosting of water distribution network systems. Also, the stakeholder input through questionnaires shows the respondents' experience ranged from 2 to 20 years, which the researcher considered fit for the study. Most of the respondents had more than six years of work experience. This is significant, as their insightful comment guide in pipe layout and geometry consideration in data gathering to ensure that collected data is reliable. Also, their input serves as the reference point in validating the web design criteria consideration Hence, the research design and adopted method are well-suited and robust for the data collection.

2.2 Data Collection and Datasets

Historical data and Information were sourced from the Kwara State Water Cooperation and CIWAT consultants on the expansion project [34]. The data source includes sketches of the very old network layout for installing AC pipes in late 1976. For ease of delineating places where future expansion for supply will be needed,

Table 1. Respondents' years of experience and experts' field

Year of experience/Expert field	1-5yrs	6-10yrs	11-15yrs	16-20yrs	Over 20yrs	Total	Mean
Soil expert	0	0	1	2	2	5	1.0
GIS-coding	2	0	3	5	1	11	2.1
Water supply	0	2	1	1	1	5	1.0
Irrigation	**0**	**1**	**2**	**1**	0	**4**	**0.8**
Total	**2**	**3**	**7**	**9**	**4**	**25**	

and due to the constant surge in household population, the three local governments (Asa, Moro, and Ilorin West) boundaries are included as one unit as Ilorin township cities. Also, since most sketches and existing drawings were done with old software, their accuracy and positioning were slightly doubtful. Hence, we embarked on a Field survey with Garmin GPS 78sc to pick different points for the existing water infrastructure including pipes, Fire hydrants, washouts, valves, etc. Google Earth aided in the realignment of the expanded distribution network for Ilorin township. The realigning of the following pipe sizes (100mm,150mm,200mm, and 250mm Upvc) from new waypoints is necessary. This was due to some newly made shift road construction to avoid rock blasting and keep the project within budget, without jeopardizing its geometry slope grade that allows for gravity flow. Although, major rehabilitation and expansion works have been done in Ilorin West.

The site reconnaissance survey was done with the assistance of senior Kwara State Water Corporation staff, it was confirmed that sketches made with hard copy coordinates documentation are mostly accurate using Garmin GPS. The major updated works included in this study are the expansion of rising mains of 800mm/600mm/400mm diameter pipes and ductile Iron pipes of about 38km. Older pipe networks constructed in the 70s are now mostly located in the middle of roads due to dualization works, especially in Ilorin West. Even though some of these pipes are in use, they should all be replaced at most in the next 20 years. All pipes laid were asbestos cement pipes ranging from 80mm to 350mm, and they all have a lifespan of just over 50 years. Furthermore, the distribution pipe network included 500mm, 450mm, 400mm 350mm, 300mm, 250mm, 200mm, and 100mm ductile iron/Upvc pipes totaling over 100km were equally and adequately digitized and geoprocessing. Thereafter, the new coordinates for all the pipe layouts were noted and are well reprocessed in the new web-based in-situ PostgreSQL database to host the spatial data and visualize the city water distribution networks in real-time. The new spatial data are met to enhance the easy accessibility of information and future expansion scheme studies for researchers.

The GPS was also used in picking the storage tanks around the Ilorin metropolis some are not presently in use, but these are well documented in the GIS software with their attribute. However, it must be noted that there exist some potential drawbacks in GPS measurement, accuracy, and difficulties experienced during data gathering and how we overcome these challenges. Since GPS signals are at terrestrial receivers which tend to be relatively weak, acquiring and tracking the satellite signals may be difficult or impossible. The field data gathering was done under open-clear sky conditions which enhanced calibration precision and helped to navigate obstacles and fitness tracking.

Furthermore, both random and systematic errors were mitigated by taking several measurements of the object in question. Random error mainly affects precision, which is how reproducible the same measurement is under equivalent circumstances. In contrast, to systematic error. Even though GPS satellites broadcast their signals in space with a certain accuracy, the receiver design features/quality may inhibit its accuracy especially when these devices must travel through remote areas. Thus, to mitigate this, the GPS was constantly checked so as not to lose its signal and recalibrated repeatedly to ensure correct measurement was picked or when picking the auxiliary water infrastructure features. However, most of these challenges could be minimal through repeatability, and constant calibration and revalidation of the instrument when not in use. Table 2 lists the various tools used in the system development while Table 3 states the applied attributes in the database creation.

Table 2. presents applied software and its function.

No.	Tools	Function
1.	Quantum GIS 3.26	Spatial data creation
2.	PostgreSQL 13.5.2	Spatial database creation
3.	Post GIS	Data Conversion/Visualization
4.	CAD2 Shape Version 8	Conversion of AutoCAD file to Shapefile
5.	Global Mapper 22	Georeferencing

6.	GIS Cloud	An online platform for hosting, publishing, editing, and sharing maps, data, and services on the internet.

2.3 Spatial Data Creation and Analysis

The installed Quantum GIS 3.26 software was used for spatial data processing. This interfaced with Google Earth, Global Mapper, and CAD to create and import vector layers in digitizing the pipe network. GPS was used to map accurate coordinates for the distribution network while realigning to digitized area maps on Google Earth. All created shapefiles were imported on QGIS for further conversion into their corresponding relational tables for processing in the PostgreSQL database. PGadmin 4 v 7 and PostGIS 3.4 in the PostgreSQL database were used in creating the new Ilorin water Supply Scheme database. This process was repeated for each vector layer created for the entire study area. Table 3 presents the summary of all available field data collected.

Table 3. Summary of the attribute field data details on QGIS

	Pipe	Valve	Hydrants	Air Valve	Washout	Endcaps	Tanks
Installation date	A	A	A	A	A	A	A
Length	A	N/A	N/A	N/A	N/A	N/A	N/A
Route Name	A	A	N/A	N/A	N/A	N/A	A
Manufacturer	A	A	A	A	A	A	A
Material	A	A	A	A	A	A	A
Maintenance	A	A	A	A	A	A	A
Diameter	A	A	N/A	N/A	N/A	N/A	A

Volume/Capacity	N/A	N/A	N/A	N/A	N/A	N/A	A

*Where A = APPLICABLE N/A =NOT APPLICABLE

Moreso, the thought processes that go into selecting/arriving at a technique employed go beyond the periphery parameter measurement. Existing field data for area, perimeter, or length for a GIS data file need to be recalculated to verify the unprojected data set for a new geometry feature. It is also important to note that before any water asset calculations are made, the data must be projected, and units must be set, and when performing field calculations, the edition of the data must be done within an editing session, by so doing, the coordinate system of the data source or the data frame is on and helps in better precision measurement. Field mapping information on pipe network, road connection, drinking water distribution layout, catchment boundary, and sub-catchment geometric properties consideration was well documented and geo-reference in QGIS. Table 4 depicts the attributes' detailed representation in the QGIS environment.

Table 4. Data set used for the study of their attributes

No.	Data Type	Data Subtype	Geometry Type
1.	Boundary	i) Local government boundary ii) Roads	Polygon Polyline Polyline
2.	Topographical Features	i) River ii) Buildings iii) Railway line	Google satellite Google Satellite Polyline
3.	Water Network	i) Air Valve ii) End Cap iii) Fire hydrants iv) Meter v) Reducer	Point Polyline Point Point Point

	vi)	Sluice/Gate Valves	Point
	vii)	Washout	Point
	viii)	Water Tanks	Polygon

Table 4 depicts the dataset attributes used to create the QGIS database for the Ilorin township water supply scheme. The created table contains all the shape files including the original coordinates and geometry feature that define each. This process identified all previous pipe network layouts in the city (Ilorin) created and digitized new features to update the water supply network schemes. The subsequent sessions highlighted how the developed database management system was used to create a centralized spatial database for all water infrastructures which were later hosted in the developed web-based platform in updating the spatial information system, before analyses and querying their performance.

3 Results and Discussions

3.1 Web-Based Development and Data Upload

To have a QGIS database web page for the Ilorin township water supply scheme, the spatial data was made available online using QGIS Cloud, a powerful Web-GIS platform built for sharing maps, data, and services online. It supports all QGIS functionalities, enabling users to create and edit maps directly within the platform. QGIS Cloud acts as a spatial data infrastructure on the Internet, which could enable the publication of QGIS projects, maps, and vector data to be hosted on the Internet[35]. One of its key features is the ability to share spatial data with others. QGIS Cloud was selected for this project due to its user-friendly interface, freely accessible by anyone, and the fact that its online output closely mirrors the experience of working on the desktop version. It does not require a local server where the uploader must always be online, another advantage over other types of platforms is that it does not require technical knowledge to understand its basic infrastructure. Once conversant with QGIS Desktop, transitioning to using QGIS Cloud is straightforward. Fig. 2

presents the QGIS assets database which includes information on pipe layout network, road connection, catchment boundary, slope, and sub-catchment geometric attribute properties, which can easily be retrieved, stored, and reclassified. Fig. 2 shows the attribute table of a typical pipe size which is the 300mm DI pipe, this attribute was also done for all pipe sizes to geocode all Ilorin water assets while Figure 3 depicts the QGIS Attribute table showing all the created fields table. The spatial datasets and their attributes created in Fig. 3 are useful for smart asset management and retrieval of spatial data layers as shown in Fig. 4 with their entire network connection.

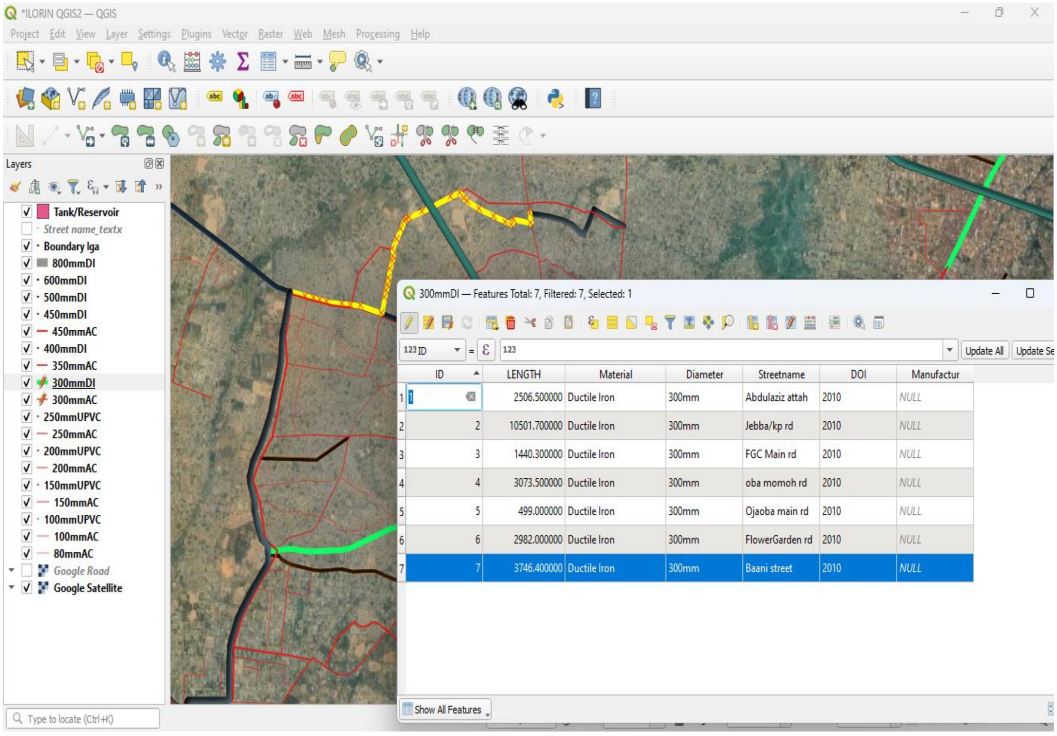

Figure 2. QGIS Attribute table showing details of 300mm DI

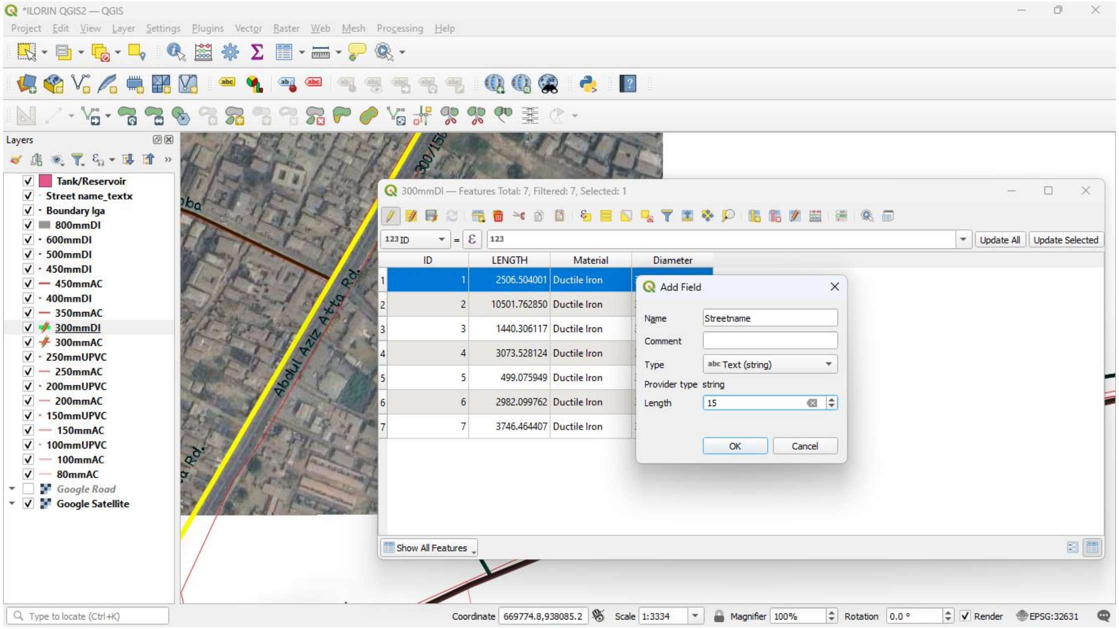

Figure 3. QGIS Attribute table showing the creation of field table

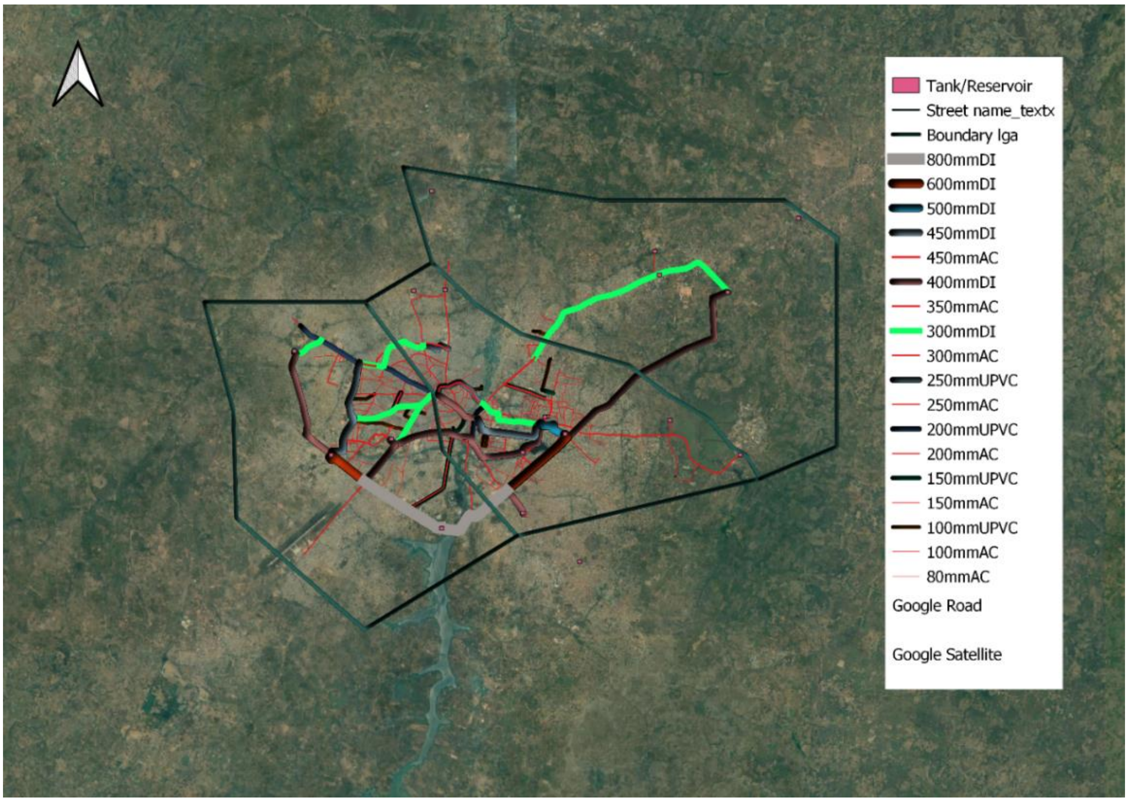

Figure 4. Spatial Pipeline network connection and distribution in Ilorin

Fig. 4 depicts the developed integrated water information system (IWIS) useful for detailing analysis and risk mitigation projection from the proposed water supply network that can match population growth based on various map queries and interactions exported and imported from another platform compatible with the query search engine. The figure shows the different pipeline network connections and distribution layouts in Ilorin. These pipes range from 800mm to 80 mm AC/UPVC, etc.

3.2 Findings Discussion

The employed geocoding skills and innovative geospatial integration of water supply assets and digitalization of water distribution infrastructure play a critical role in developing and implementing geospatial hydrology and remote sensing methodologies that enhance water management and productivity. To address the water asset documentation issues, the user must be smart with all this available information. Table 5 depicts the averaged response summary on how the developed web-based features meet users' requirements.

Table 5. Significant features that users wanted the web system to be capable of.

No.	Desired Function	Average
1	General view and layout region	3
2	Interaction with maps	4
3	Accessibility to Internet	3
4	Adding new pipes	4
5	Adding new bulk meters & appurtenances	3
6	Location of new network	3
7	Pipe attributes illustration	4

8	Indicate property boundaries	3
9	Print/export maps	5
10	Perform searches(query)	4

From Table 5, the designed web system effectively met these needs. From the analysis, system users expected the web hostage to be able to support querying/viewing and updating spatial data(4/5). Users also wanted the web hosting to be able to add new bulk meters and their appurtenances(4/5), be flexible in locating new water networks(3/5), enrich map creation with detail attributes(4/5), perform and analyze water supply flow rate distribution(3/5). Hence, an overall performance of 75% in meeting users' needs is a good rating between the user expectations and the Web-GIS capabilities testing.

No doubt, the stakeholder and expert inputs help shape the overall configuration and preference testing of the performance of the QGIS Cloud server in generating and hosting the maps on the internet. Fig. 5 depicts the results of the various attributes for the sub-catchment surface layer feature. Fig. 5 depicts a search query on each local layer database showing the attribute layer features while the results obtained through interacting with the developed web-based are diagrammatically illustrated in Fig. 6.

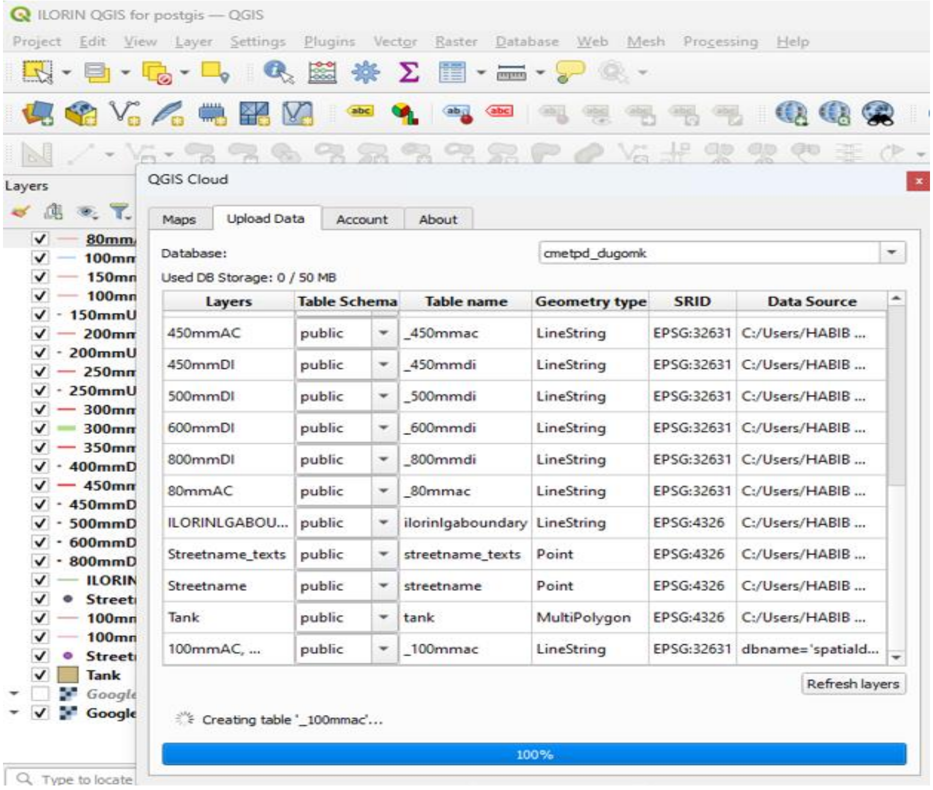

Figure 5. Local layers databased being uploaded

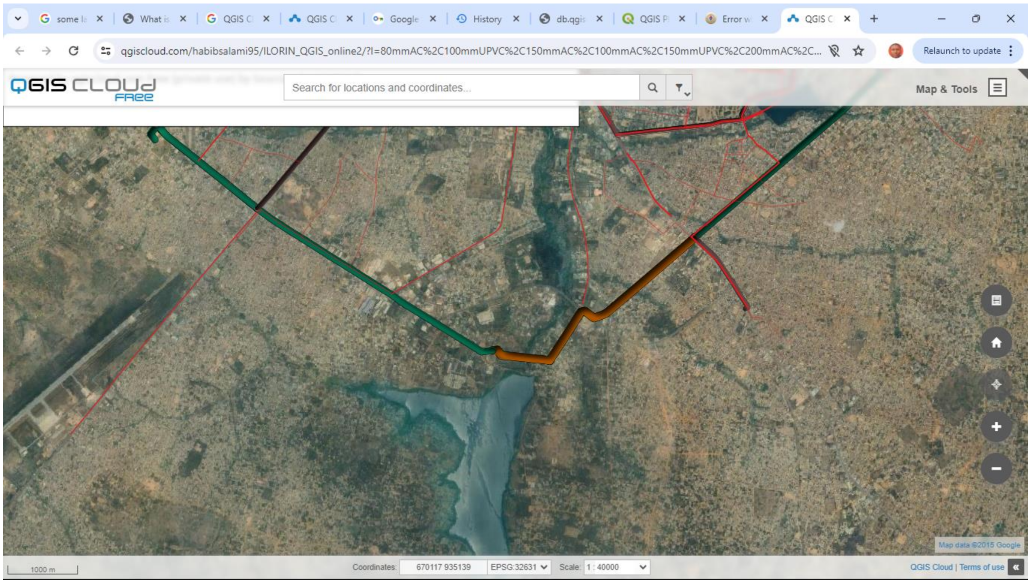

Figure 6. Uploaded file now on the internet

Fig. 6 shows the local layers being uploaded to the database in the QGIS Cloud database. These layers include all the different pipe sizes, tanks, reservoir modules; weirs and pumps; pressurised pipes; street names; pumps and storage. These data are now imported from the local shapefiles into the QGIS Cloud PostgreSQL database. Figure 6 shows evidence and potential change in the city network with a view of slow pace to rapid-onset long-term change in extreme events. The design and host web-based QGIS Cloud PostgreSQL database retrieval query and other high-performance computing simulation systems depict what the future landscape holds for the city expansion in real-time, on-site maintenance, and innovative criticism to achieve a sustainable urban water distribution network. It was important to know that these data sources in the project could be exchanged while the original shape files would no longer be visible, but instead, the data from the QGIS database would be displayed. Hence, the water supply distribution layout, network design, and operation module are embedded in the QGIS Cloud services which are interfaced with complex WDNs in geographic map layers. Thus, providing easy access to visualize and retrieve its spatial database over the internet within limited nano-speed time intervals. The link for the cloud data now is https://qgiscloud.com/habibsalami95/ILORIN_QGIS_online2/. After it was uploaded the link was revisited as shown in Fig. 7.

3.3 Web-System connection to the QGIS cloud

Figure 7 illustrates the created Postgresql database using the spatial extension in pgadmin by importing all vector layers from QGIS to connect to the database, all components of the system in the post-GIS and Postgresql assist the QGIS Cloud server in generating the maps on the internet. The WSS problems generally require intensive evaluation of spatial information and analysis to hold the dataset, thus we use the database “cmetpd_dugomk,” as shown in Fig. 7 to randomly generate and display the map on the internet.

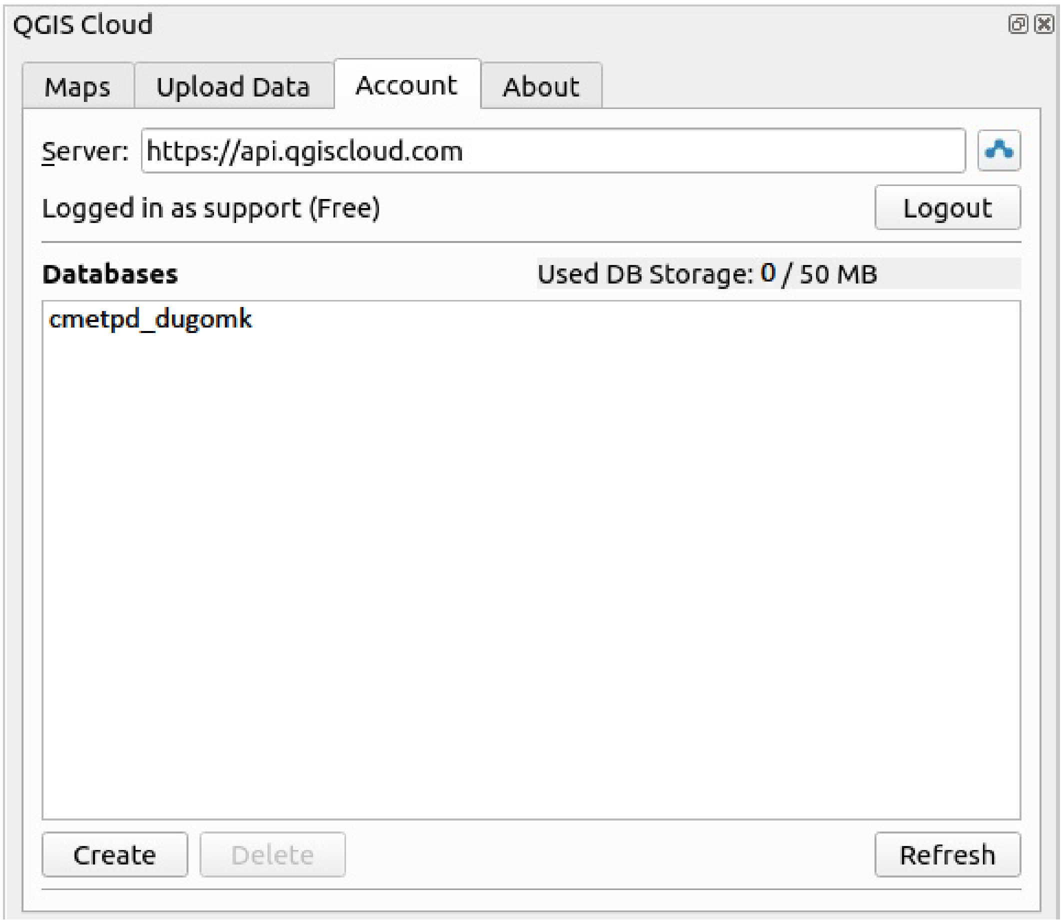

Figure 7. The created Database cmetpd_dugomk files

By default, the data is loaded into the database schema public. In the default list, the local layers are listed. However different schemas can be selected for different databases. Since only one database was used and only one schema was employed. Only one database was used for the entire distribution network. Among the many different available server services providers like Map Server or Geoserver. The QGIS Cloud server was chosen because it offers a more friendly environment as against the alternative drawback of hosting and publishing maps with more complex map definitions. The QGIS Server understands the projects created in the QGIS PC environment, so there's no need for additional map definitions. The map will appear exactly as it does on the desktop. In case where a raster file was used, it is important to create another database.

3.4 Performance Evaluation

To evaluate the success of this research work, user testing and performance were done. Users wanted the web hosting to be able to add new bulk meters and their appurtenances(4/5), be flexible in locating new water networks(3/5), enrich map creation with detail attributes(4/5), accessibility of the deploy web-GIS on the internet (3/5), perform and analyze water supply flow rate and distribution(3/5) among other. Hence, an overall performance of 75% in meeting users' needs is a good rating for the user expectations and the Web-GIS capabilities testing. Most QGIS Cloud server could empower a broad range of data users that permeate across disciplines to produce new and meaningful research and insights work across different field.

In the development stage, geocoding and utilization of PostgreSQL9.4, GeoQuery and webGIS may be challenging without sufficient training and experience. Also, the identification, and leveraging upon the right data usage for a particular task and bid can be difficult without expert input and insight. In all, continuous guardian from expert and literature works documentation [36,37] help overcome the technical challenge around a high-performance, computing environment and flexible data framework that could be interface with web-GIS. Also, the web- GeoQuery's codebase and post processing methodologies are open source, thereby reducing the barriers of finding and accessing geospatial data, thereby reducing processing time to a few or less minutes .

4 Conclusions

The utilization of various QGIS geocoding platforms for hosting a digitized web-based spatial information for water transmission and distribution layout in Ilorin township was carried out in this study. The study employed QGIS Cloud services interface with PGadmin 4 v 7 and PostGIS 3.4 in the PostgreSQL geocoding database in creating the new digitized Ilorin water supply scheme database. The implementation of a web-based QGIS hostage makes a valuable contribution to supporting future expansion programmes. provides a practical framework that can be adapted to any other context in decision-making. The application of various spatial physiographic information for the transmission, and delivery of drinking water from sources to household users has helped minimize resources spent on data collection, aided time spent in tracing faults and could helped make informed database design. The web-based GIS information hosted on the internet presents a centralized storage database that is useful for both present and near-future users. Thus, loss of data is not an excuse in today's cloud-range database storage. The study contributes to advancing the field of applied sciences and smart technologies in improving water distribution systems.

The cumulative result shows effectiveness in meeting users' requirement of a QGIS web-server capable of integrating many plugins in functionality that enrich the general web view, support created maps in different format, flexible in adding new pipes, bulk meters and appurtenances, capable of uploaded map creation with attributes that is internet friendly. The uploaded created map illustrates water geo-reference properties and geometry boundaries, which could enable data filtering and query, overlay data from external sources, and enrich attributes dataset tables in carrying out spatio - temporal analysis which could be deploy in determining the rate of infrastructure development. Most web GIS applications have built-in plugin support services necessary for large-scale project expansion and infrastructure development.

Despite the potential transmission lag-period shortcomings in viewing the hosted web-based imagery, the employed QGIS Cloud PostgreSQL database toolkits have been able to act as prototypes that will guide large-scale development of a web-based GIS application for Ilorin water assets information documentation which can aid future expansion. Also, the limited preferred spatial data format, was overcome through application of updated PostGIS databases which can do a lot of editing for ease of use by many stakeholders and decision-makers.

Georeferencing the dataset has help minimize GPS satellite broadcast signals in measurement thereby eliminate both random and relative errors in calculating and storing important attributes of Ilorin WDN and assets coordinate reference. This asset includes the length of pipes, Manufacturers, Date of installation, storage capacities of the tank, etc. Future water supply and distribution network modelling can be easily undertaken. The study effectively shows how QGIS's built toolkit aids in creating a spatial database for water network mapping and storage of many out-of-position features such as reservoirs, tanks, and pipe distribution networks.

The study provided a secure database for spatial documentation of Ilorin's water infrastructure. In addition to documenting and visualizing the water distribution network, the study offers a thorough and easily accessible platform that could enhance the sustainable development of the city's water infrastructure and water distribution network system. The employed QGIS web-based helps to visualize the spatial data attributes that is too numerous and critical for water distribution networks and application modification. Overall, the web system's effectiveness demonstrates spatial data storage and queries to help improve the presently existing system and provide real-time monitoring of services. The Web-QGIS interface can effectively present spatial information and analyze query map layers. It has provided a report module to illustrate data in many ways and facilitate decision analyses in coordinating geo-referenced database.

The open-source GIS toolkit provides a framework for the digitalization of all water supply infrastructures in Ilorin water distribution schemes. The centralized dataset performs well for different entities' users ranging from regional managers, engineers, distribution supervisors, meter testing supervisors, customer care supervisors, credit controller supervisors, and GIS officers, to provide real-time monitoring of services. We suggest the Kwara State Water Cooperation Board the statutory agency responsible for drinking water supply (DWS) services in the city would find the developed in-situ PostgreSQL application useful in resolving many of the existing bottlenecks related to the distribution and supply of drinking water. The board and any other relevant agencies would find it useful to adopt the built Web-based GIS interface as a data management, scenario analysis, and decision support tool in managing water infrastructure for an expanding metropolitan city like Ilorin, Kwara State.

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Author Contributions

Conceptualization, OG, H.A.;
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Ethical approval and consent to participate

Ethical clearance letters were collected from the University ethics committee for both the study participants and the researchers. During the survey, confidentiality was maintained by giving codes to each respondent rather than recording their name. The participants were informed to have full right to discontinue or refuse to participate in the study and all participants were fully informed of the objective of the study. They all gave their consent and participated freely in the research.

Declaration of interest

The authors declare that they have no competing interests in this manuscript.

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