ARDHI UNIVERSITY

SCHOOL OF EARTH SCIENCES, REAL ESTATES, BUSINESS AND INFORMATICS

DEPARTMENT OF GEOSPATIAL SCIENCE AND TECHNOLOGY

PROGRAM: BSc GEOGRAPHICAL INFORMATION SYSTEMS AND REMOTE SENSING

DEVELOPING A WEBGIS FOR ENHANCED MANAGEMENT AND CONSERVATION OF SURFACE WATER SOURCES

CASE STUDY: PANGANI RIVER BASIN

BY

GODWONDER VIAN BWEMERO

25853/T.2020

DEVELOPING A WEBGIS FOR ENHANCED MANAGEMENT AND CONSERVATION OF SURFACE WATER SOURCES

By

GODWONDER VIAN BWEMERO

A dissertation submitted in the department of Geospatial Science and Technology in partial fulfillment of the requirements for the award of Bachelor Geographical Information Systems and Remote Sensing at Ardhi University

CERTIFICATION

The undersigned hereby declare that, he has supervised and proof read the dissertation and recommend for acceptance by The Ardhi University a dissertation document entitled "Developing a Webgis For Enhanced Management and Conservation of Surface Water Sources, case study of Pangani river basin." In fulfilment of the requirements for the Bachelor of Science degree in Geographical Information Systems and Remote Sensing at Ardhi University

…… ……

Dr Dorothea Deus

Supervisor

Date …….

Dr Zakaria Ngereja

Supervisor

Date…….

DECLARATION AND COPYRIGHT

I, **Godwonder Vian Bwemero,** declare that the contents of this dissertation are the results of my own findings, obtained through studies and investigations. To the best of my knowledge, it has not been presented to any other university as a thesis for an award of Diploma, Degree or similar professional award.

…….

GODWONDER VIAN BWEMERO

Date……...

ACKNOWLEDGMENTS

I would like to express my deepest gratitude and appreciation to the Almighty God, who has continued to amaze me throughout this dissertation, by His endless support and wonderful love, Holy God you are wonderful

I would like to thank deeply and sincerely my supervisors, Dr Dorothea Deus and Dr Zakaria Ngereja that have tirelessly supervised and guided me throughout this entire study, not only that but also supporting me in carrying out this study. I would like to give my thanks to the staffs of the Department of geospatial science and technology for their moral and academic support

I won't be of good character, if I would not appreciate the support of my friends and colleagues from Geographic information system and remote sensing and Ardhi at large, thank you lot for your support. My deepest regards also goes to all other friends and colleagues that are not part of Ardhi University but in one way or another have contributed a lot in accomplishing this study, I cannot mention you all but may God bless for your support.

I would like also to express my thanks to my family for the continuous support, prayers and continuous motivation

.

DEDICATION

I would like to dedicate this dissertation to my parents my late father Vian Bwemero , my mother Beatrice Moses and my siblings Gabriel, Garvirilla and Gracious, for your superb and wonderful devotion on our each other dreams.

.

ABSTRACT

Unlike ground water source, surface water sources are the one that are largely affected by the anthropogenic activities as well natural forces and changes in a way that there is a need to monitor their dynamic changes for proper management of these vital resources. There is no specific geospatial platform/tool which has been designed to make sure that the status of water sources is known on both spatial and temporal coverage. This study aims at developing a webGIS for enhanced management and conservation of surface water sources which has been named websur, and Pangani River Basin being a case study.

The study was conducted using Rapid Application Development methodology, firstly as for any system development identification of functional and user requirements was done this was followed by conceptual designing, that led to setting up the environment for the websur development. Data collection and preparation was also done so as to have data to visualize, this was followed by developing the front end and the back end of the webgis, and at the end the websur was tested against the user and functional requirements.

The key findings in this particular study are the web map depicting the surface water sources and the webgis namely websur that has both front end and back-end components. Through websur when its completely deployed, as now it is hosted in local machine, surface water resources information can be easily accessible as the distributive GIS technology is at work, optimizing the dissemination of surface water resources information.

In a nutshell the webgis has been developed and it can visualize the surface water sources such as rivers and lakes as well as dams, not only that but various basemaps have been added to optimize the visualization process. The study also offered some recommendations such as there should be a dataset of surface water sources that provides names for these features, websur can be enhanced by Pangani Basin Water Board as per other requirements and be utilized so as to aid in water resource management, and the study can be expanded further by conducting it nationwide as well as including groundwater water sources.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CSS	Cascading Style Sheet
EPSG	European Petroleum Survey Group
GIS	Geographic Information System
HTML	Hyper Text Markup Language
PHP	Hypertext Preprocessor
QGIS	Quantum GIS
WEBGIS	Web based Geographic Information System
WEBSUR	WebGIS for surface water resources

CHAPTER ONE
INTRODUCTION

1.1 Background

Water as other kind of resources is scarce, and this is very relevant to human activities that may require this resource for their operation or survivability. There are various sources of water but depending on which position they are found either on the surface of the earth or below the surface of the earth they can generally be categorized into surface water and ground water source respectively (Sensorex, 2022). On the part of surface sources, this includes rivers, lakes, man-made reservoirs, wetlands and inundated areas, dams and so on, while for the ground sources this constitutes aquifers, wells and springs, (Wang, et al., 2020) define surface water sources as rivers, lakes, ponds, reservoirs, swamps, glaciers, and other water bodies that exist on Earth's surface.

Most of the earth's surface is covered by water, oceans being the one that constitutes much of this percent and whose water cannot be utilized in several anthropogenic activities, this has also been highlighted by (Prigent & Lettenmaier, 2016) "About 97 % of the total amount of water on Earth is found in the oceans and 2 % is stored in the Greenland and Antarctic ice sheets. It is only the remaining 1 % that is the amount of water available for the biospheric processes and for all human needs".

The one percent mentioned above includes both surface and subsurface or ground water sources, and as accessibility is regarded in terms of acquiring water in an easier way, much of the surface water coming from dams and rivers are the one that are utilized a lot when compared to ground sources that need mechanism such as drilling to access its water.

With such painful reality, demand of water inflicted by human and their activities has been increasing rapidly to the extent water availability is declining as time goes, (Tottrup & Druce, 2022) As the global population grows, there is an increasing need to balance the competing demands for water resources and have more efficient ways to manage water supply.

Unlike ground resources that are not affected largely by anthropogenic activities and atmospheric changes, surface water resources are in much contact with these scenarios in a way that experience much effects mostly adverse ones from these elements, in a way that the increasing

effects on surface water resources threatens the availability as well as management of water resource.

Surface water resources still faces interferences from climate change, population growth in a way that there is a need to monitor their dynamic changes.

With the recognition of a need to put close ties with surface water resource, different methods have been applied including remote sensing that has proven to be useful. (International Space Science Institute., 2016) observed that for the past 10-15 years, remote sensing has demonstrated their excellent capability to monitor several components of water balance of large rivers, lakes and reservoirs on time scale ranging from months to decades.

Remote sensing provide vast amount of data that are needed in monitoring of water resources ranging from optical to microwave remote sensing that are different in terms wavelength they are utilizing, but are still applicable in observing surface water dynamics as time goes by, this have elaborated further by (Wang, et al., 2020) Remote sensing image data have the characteristics of comprehensive coverage, high revisit frequency, rich information and low cost, which supplies the possibility for quantitative estimation of longtime series of reservoir water body areas .

In situ gauging networks have been used for several decades from now, for monitoring of water resources such as river discharge and water levels in dams and lakes based on gauging stations. (Johnson, 2009) However gauging networks are not densely distributed, in a way that that the information obtained from these stations to be inadequate as not all surface water resources are captured especially at points where there are no gauges, making monitoring of these resources harder, but through remote sensing and web-based GIS a lot of information can be captured concerning surface water resources. The objective of this study is to develop a webgis that will enhance the conservation and management of surface water sources.

1.2 Statement of the research problem

Water is one of the basic and necessary resource for sustainability of human life as well as their activities ranging from agriculture to industrial conducts, according to (Li & Su, 2017) Water is vital natural resource for human livelihood and is also an important basic resource for sustainable development of economy and society globally and regionally. Due to the influence of human activities and natural phenomena like Climate change and variability understanding the status of water sources is key to support decision making and sustainable conservation. There is no specific geospatial platform/tool which has been designed to make sure that the status of water

sources is known on both spatial and temporal coverage. Based on that there is a need to develop a webgis which could be used for visualization and monitoring of water sources.

1.3 Objectives of the study

1.3.1 Main objective

To develop a webGIS for visualization of surface water sources for enhancement and management of surface water sources in Pangani Basin

1.3.2 Specific objectives

The following are the objectives of this study

- To identify the user and WebGIS system function requirements
- To map the surface water sources
- To design and develop the webGIS
- To test the developed system

1.4 Research questions

The following are the research questions of this study

- What could be key user and system functional requirements?
- How are the surface water sources distributed spatially?
- How the water sources monitoring system will be design and developed?
- How will the developed webGIS be tested?

1.5 Significances of the study

The significances of the study are as follow

- Assessment of the status and visualization of the water sources will be enhanced
- The management and conservation of water sources will be also improved as the status of these surface water sources will be known

1.6 Study area

Pangani Basin is a trans-boundary basin shared by Tanzania and Kenya; which covers 54,600 Km^2 ; where 5 % of this area lies in Kenya. In the Tanzanian part, there are 20 Districts falling within the administrative Regions of Manyara, Arusha, Kilimanjaro and Tanga (Table 1.1). It

includes two cities and one municipality of Arusha, Tanga and Moshi respectively. The Basin has an estimated population of 3.7 million people, 80% of whom rely, either directly or indirectly, on agriculture for their livelihoods (IUCN 2003). The Basin is comprised of nine catchments: Kikuletwa, Ruvu, Pangani Mainstem, Mkomazi, Luengera, Msangazi, Zigi, Mkulumuzi and Umba which all independent drain to the Indian Ocean. The Pangani River has two main tributaries, Kikuletwa and Ruvu Rivers, which join at Nyumba ya Mungu, a large manmade water body with a surface area of 140 km^2.The highest mountain in Africa is Mt. Kilimanjaro (5,985 masl) which together with Mt. Meru (4,566 m.a.s.l) provide the source of Kikuletwa river flow, while the Ruvu, Mkomazi and Luengera Rivers drain part of Kilimanjaro, Pare and Usambara mountains and the springs emerged in Kenyan side. There are two unique lakes in the Basin namely Jipe and Chala which are Trans-boundary water bodies. The Basin is also endowed with high potentials for groundwater. Only 5% of all the water used in the Basin is derived from groundwater sources. Boreholes yielding > $100m^3/h$ have been drilled at TPC in Moshi, Majimoto area in Hai District, Valeska-Mbuguni in Arumeru District and Seed Farm in Arusha District Council in Kikuletwa catchment. Below is Table 1.1 that gives a summary of area of the basin in given regions in kilometers, and Figure 1.1 that describe the area of study.

Table 1. 1:Summary of study area in square km

S/No	Region	Region Area (Km2)	% of Basin Area
1	Kilimanjaro	11,071.00	20.35
2	Manyara	16,664.86	30.63
3	Arusha	2,431.99	4.47
4	Tanga	22,295.98	40.98
5	United Republic of Kenya	1,936.89	3.56
	Total	**54,400.72**	**100**

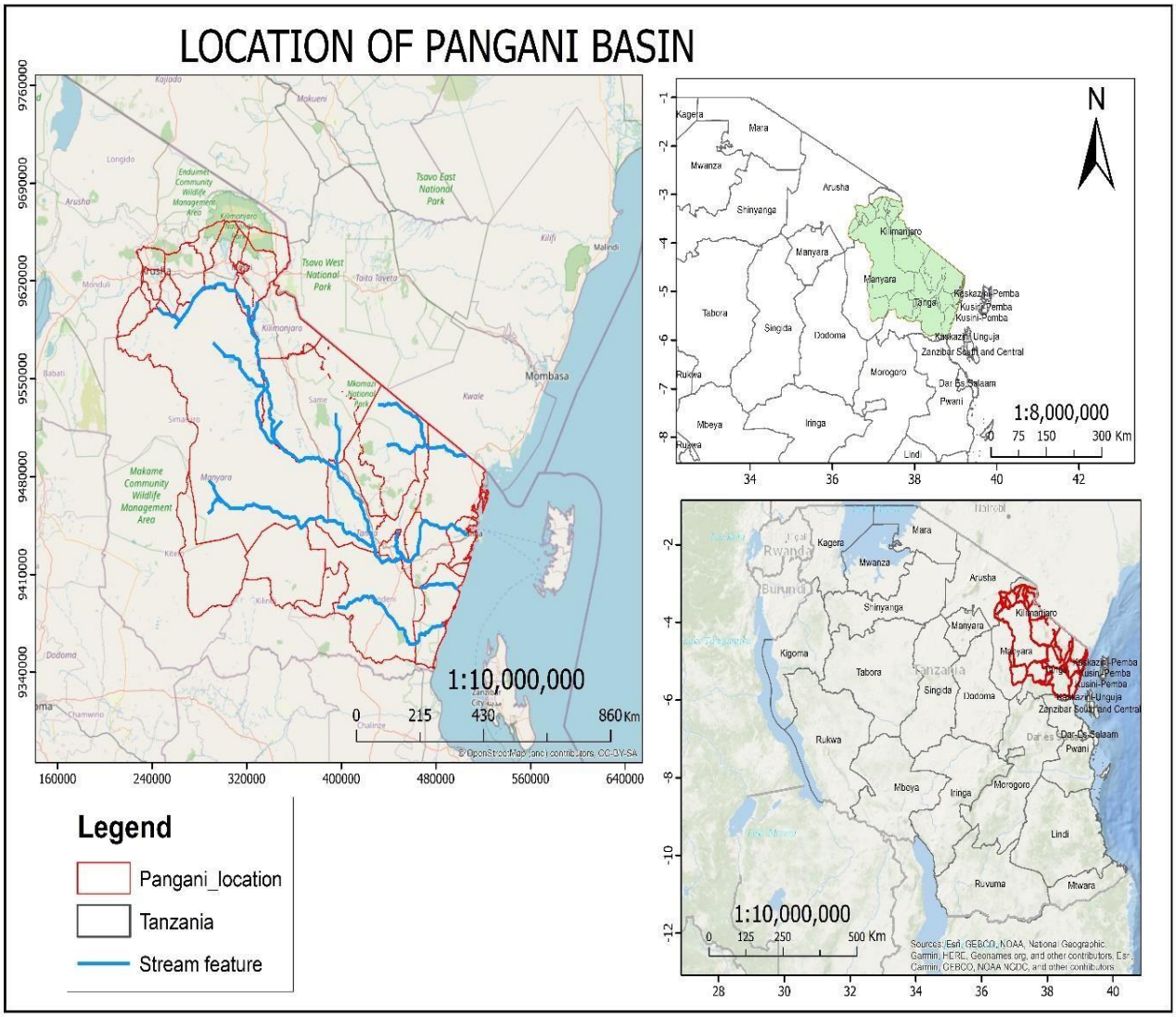

Figure 1. 1: Study area

1.6 Organizational structure of the report

Chapter one is introduction, consisting of background of the study, statement of the research problem, as well objectives, research questions, significance of the study as well study area. Chapter two entails literature review of different related works.

Chapter three encompasses methodology that has been used in developing the webgis, starting from identification of the user and functional requirements and ending at testing and debugging of the webgis. Chapter four is all about the results obtained through out the undertaking of the study.

Chapter five discusses the key findings with other related literatures. Chapter six entails conclusion and recommendation of the study

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

This chapter entails different concepts as well as literary works that are associated with the research at hand.

2.2 Surface water sources

Surface water sources refer to the sources of the water that are on the surface of the earth, (Huang & Chen, 2018) surface water refers to the water on the surface of the earth, such as river, lake, wetland and the ocean, this has also been portrayed by (Wang, et al., 2020) on which surface water is defined as rivers, lakes, ponds ,reservoirs, swamps, glaciers and other water bodies that exist on the surface of the earth, this has also been portrayed by (Nery, 2020) defining surface water body a as discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water.

Oceans are usually excluded from surface water category due to their vast large sizes though the smaller saline water bodies are included, (Huang & Chen, 2018) Usually, the ocean is excluded in the definition because it is so large and because it is salty, though smaller saline water bodies are usually included.

2.3 Geographic information system

Geographic information system is the computerized system that can capture, store, manipulate analyze, display and present geo referenced or geospatial data, according to (Jolaiya, 2020) geographical information system is the computer based system used for collecting, storing, manipulating and analyzing spatial data which is the data that can be referenced to a particular location on the earth, that is to say that the system is a data driven one. In general perspective GIS can be viewed to geospatial data management that has the ability to store the georelated data and facilitate the processing on it such as manipulation and analysis as well as its visualization, this has been portrayed by (Johnson, 2009) who entailed that in its totality, a GIS can be viewed as a data-management system that permits access to and manipulation of spatial data and visual portrayal of data and analysis results.

Geographic information system is usually associated with five components which are hardware, software, data, procedure and people, this has so been entailed by (Dangermond, 1988) GIS consists of five basic elements: “data, hardware, software, procedure and people”. Hardware including different physical electronic components such as computer in which software that are computer programs designed to undertakes particular tasks are embedded and run upon them. Data entails different spatial and non-spatial data that is to be stored and processed in GIS environment in a given sequence or series of activities which adds up the procedure component, as well as experts of GIS discipline which encompasses the people element of GIS. GIS is also useful when it comes on handling and utilization of big data such as satellite images form the visualization to the examination of these data, providing a platform for monitoring changes caused by anthropogenic activities, (Moreno-Salamanca, 2021) GIS enables us to visualize and analyze massive collections of satellite monitoring data. Establishing a base for determining cause and effect, GIS tracks ecological change and provides chains of evidence of human impact

GIS has various applications in different vast and minor disciplines from mining, environment, as well as water resource management and in this latter application GIS is very useful as various components of water resource management is location based, this has been described by (Johnson, 2009) who stated that information about water resources and the environment is inherently geographic.

2.4 WebGIS

WebGIS can be defined as extension of the geographic information system in the web technology or in the World Wide Web, enhancing its interactivity and dissemination capabilities of geospatial data, (Jolaiya, 2020) defined webGIS as an advanced geographical information system available n web platform. It has been noted that frequently the terms web mapping and webgis have been used interchangeably but the latter is a wider one and introduces various aspects of geoprocessing functions according to (Li, Dragićević, & Veenendaal, 2011) Web GIS, often used as an interchangeable term for web mapping, brings in additional functionality for spatial analysis and exploration supported by geoprocessing functions.

Web GIS is a modern approach to providing Geographic Information System (GIS) functionality through web-based maps. This technology enables people from all over the world to easily

access and utilize geographical data and information. By leveraging the power of the internet, Web GIS makes it possible to access and interact with maps, geospatial data, and other location-based information from any device with an internet connection. This provides a convenient and efficient way for individuals, businesses, and organizations to work with geographic data and make informed decisions based on location-based insights. Overall, Web GIS has revolutionized the way we interact with geographic information, making it more accessible and easier to use than ever before (Esri, 2018) Web GIS is a new pattern for delivering GIS capabilities through maps on the

web, allowing people everywhere to access and use geographic information.

With the webGIS data dissemination becomes more efficient and a wider concept, not only that but also the retrieval of data s more enhanced than in traditional GIS, (Liu & Mason, 2016) Web enabled GIS brings interactive query capabilities and data sharing to a much wider audience.

2.4.1 WebGIS in water resource monitoring

Webgis has proven to be useful in different cases concerning water resource monitoring, for instance in Hungary due to the emergency of the COVID-19, webgis was used to publish and share water quality data, in a way that there were no physical meetups, limiting the possibility of infections but still being able to acquire the required data and be able to use in different aspects, this is according to (Balla & Zichar, 2022) In the epidemiological emergency of the COVID-19 pandemic, the provision of webGIS-based data services on water quality has become a priority for both the state and public administration sectors. Currently, geographical, monitoring and decision support systems, typically based on web-based geoinformatics technology, greatly help to share and analyze spatial and temporal data of environmental databases in real time.

Webgis has gathered much attention with regard to geospatial and ICT tools advancements, that has led to emergence of trending technologies such as distributive GIS, and with water being at stake due to different aspects such as pollution and other anthropogenic activities, these emerging technologies such as webgis have been applied to enhance management of water resources. India being of one country with large population, water scarcity have been experienced much, and by knowing this, the state along with other stakeholders initiated a project of developing a web enabled geospatial information system for water resource monitoring, so as the community and different stakeholders can access, visualize and analyze the

related data and see themselves the status of the water resources, according to (Esri, 2020) the project aimed at generation of database and implementation of web enabled water resources information system of India' short named as India-WRIS WebGIS. Single Window solution of all water resources & related data and information in a standardized GIS format to all concerned departments, organizations and stakeholders. The thin client scalable web enabled information system provides comprehensive, authoritative and consistent data of India's water resources along with allied natural resources data & information, web enabled tools to search, access, visualize, understand, look into context and study the spatial pattern.

As water monitoring is not only easy to conduct while the citizens are left behind, webgis gas also provided a way to connect different stakeholders and the community, in a way that the quality of water can be known by the community too, this has been accomplished through the a collaborative platform known as SIMILE ("Integrated monitoring system for knowledge, protection and valorization of the subalpine lakes and their ecosystems"), that enable producers of water quality parameters map being on one of the platform, to reach the society through the other end of it, on which a user can access and visualize the published water quality maps, this is elaborated by (Toro Herrera, Carrion, & Brovelli, 2021) In this work, we present the design and implementation of a collaborative web platform for sharing remote sensing-based maps (i.e., water quality parameters maps) that have been produced for SIMILE project. This work focuses on the development of the IT infrastructure to support the management of water resources. Its main goal is to enhance the decision-making process and access to data through a strategic tool for water quality monitoring in the Insubric Area. In here it can also be seen that webgis is also used in decision making associated with water monitoring.

Due to the presence open data ad tools, webgis make it a lot easier when it comes to the dissemination and analysis of geospatial tools, enhancing more the process of decision making on water resource management and monitoring, this also supported by (Mishra, et al., 2020) have developed a prototype of a spatial decision support system based on Web-based GIS for watershed management. It provides watershed delineation, map interfaces and data preparation, a hydrologic model for hydrologic/water quality impact analysis and web interface programs for operation through the Internet. Therefore, one of the greatest benefits of using WebGIS technology in decision making is to utilize its potential to overcome limitations in terms of cost, distance and geospatial data transfer.

2.5 Remote sensing

Remote sensing is the science of acquiring and collecting information of a given object or phenomenon without actual physical contact with the object, according to (Konecny, 2014) Remote sensing is a method of obtaining information from distant objects without direct contact, this has also been described by (Nelson & Khorram, 2019) where it is stated that Remote sensing can be characterized as being the science of acquiring any information about an object or a phenomenon on the surface of the Earth without coming into physical contact with it. Remote sensing has various applications for instance hydrology and assessment of flooded areas , by the presence of various of active and passive sensors these have been possible, (Ogilvie, et al., 2018) Images from a variety of active and passive sensors have been used successfully in hydrology to inventory, to assess flooded areas, river stage levels and widths, as well as to investigate hydrological processes and water balance issues.

2.5.1 Remote sensing in water resource monitoring

Remote sensing also has a wider range of applications ranging from agriculture, mining, environment monitoring, as well as management of natural resources. Water as one among of the resources, remote sensing has and is playing a vital role in monitoring of these scarce phenomenon, (Johnson, 2009) Remote-sensing technologies play a primary role in water resources monitoring. With the use of satellites remote changes in surface water sources can be recognized and assessed over a given period, hence aiding monitoring of surface water sources, (Moreno-Salamanca, 2021) Satellites are particularly advantageous in the monitoring and identification of changes in water surfaces, as researchers can track a particular lake in great detail over time.

Remote sensing also a bigger role in measuring the surface water quality and unlike laboratory techniques used for acquiring surface water quality, remote sensing is incur less cost and provide more coverage in terms of spatial and temporal aspects (Din, 2018) Surface water quality assessment is widely performed using laboratory analysis, which is costly, labor intensive, and time consuming, In contrast, remote sensing has the potential to assess surface water quality because of its spatial and temporal consistency.

Remote sensing has proved a cost-effective method when compared to other conventional methods (Sharma & Singh, 1989)Satellite remote sensing has been proved to be a cheap and

useful tool for mapping and monitoring water resources of large areas in comparison with conventional hydrological methods.

CHAPTER THREE

METHODOLOGY

3.1 Overview

This chapter entails the methodology used in this particular study of developing a webgis for visualization of surface water sources, section 3.2 entailing the identification of functional and user requirements, section 3.3 entailing conceptual designing of the webgis architecture, section 3.4 is about configuring and setting up the environment for the webgis development, section 3.5 encompasses data collection and preparation, section 3.6 and 3.7 entailing developing the front end and the back end of the webgis respectively, section 3.8 describe the integration of the web application and the database and lastly but not least section 3.9 discuss the testing and debugging of the webgis. All of key steps involved have been depicted in the flowchart as shown in the Figure 3.1. Generally, the overall method used in developing the webgis is Rapid Application Development (RAD) which is a software development approach that prioritizes speed and flexibility in the application development process. It emphasizes iterative development and prototyping to quickly create functional software systems. In other words, in this methodology rather than dealing with one component till the end, the entities can be built in parallel manner.

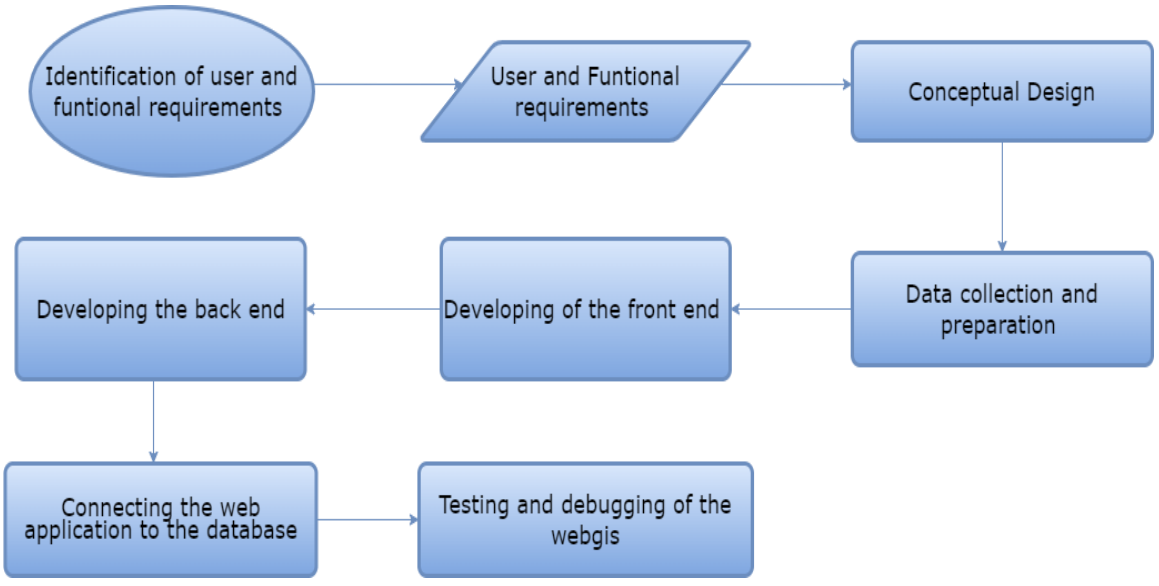

Figure 3. 1: flowchart

3.2 Identification of user and functional requirements

This part involved identifying different requirements that the webgis to be developed should have and this was done mostly by review existing related literature as well as looking on trends of various related webgis and the following requirements were determined

3.2.1User Requirements:

The following are the user requirements obtained;

- The WebGIS should be user-friendly and easy to navigate.
- The WebGIS should be able to display a comprehensive map of surface water sources in Pangani River Basin.
- The WebGIS should be able to provide detailed information on each surface water source, such as location and type
- The WebGIS should be able to provide tools for users to measure and analyze the surface water sources data.
- The WebGIS should be able to provide users with the ability to search for specific surface water sources by name and location.

3.2.2 Functional Requirements:

The following are the functional requirements obtained;

- The WebGIS should be able to display a base map of Pangani River Basin with clearly demarcated surface water sources.
- The WebGIS should be able to provide users with the ability to customize the display of surface water sources data.
- The WebGIS should be able to allow the user to zoom in and out the map layers
- The WebGIS should allow be able to geo locate the user position
- The WebGIS should be able to provide the users with search tool that will enable the user search for various locations

The above user and functional requirements are the one that have been identified as the ones that are relevant to this particular study

3.3 Conceptual designing of the webgis architecture

In this part, as webgis is as any software, it should have a system architecture, and the webgis concerned architecture's is common, which is the server client architecture, in a way that the system would have client side on which the visualization would take place and the server side on which data would be stored and also retrieved from. The conceptual design of the webgis has four components and they are as follow

- Front-end: The front-end of the WebGIS is the user interface that users will interact with. This typically includes the web pages, maps, and other visual elements that make up the user interface.
- Back-end: The back-end of the WebGIS is responsible for processing user requests and serving up data to the front-end. This typically includes a web server, application server, and database. The database component of the WebGIS is where all the spatial and non-spatial data will be stored.
- GIS libraries: This GIS component of the WebGIS is responsible for processing spatial data and performing geospatial analysis, in this study leaflet was used as geospatial JavaScript library.

3.4 Configuring and setting up of the environment

Due to the above conceptual design for the webgis development, there was a need for installing different software and packages, so as to create an inducive environment for developing the system. This involved the following mechanisms

3.4.1 Installation and configuring of Xampp

XAMPP is a free and open-source software package that provides a complete web development environment for Windows, macOS, and Linux. The name XAMPP stands for cross-platform, Apache, MySQL, PHP, and Perl.

XAMPP includes several components that are necessary for web development, including:

1. Apache HTTP Server: A web server that can be used to serve web pages and applications. This include apache and apache tomcat

2. MySQL: A relational database management system that can be used to store and manage data for web applications.

3. PHP: A programming language that is commonly used for server-side web development.

4. Perl: A scripting language that is commonly used for server-side web development.

The installation process proceeded as follows;

- Downloading the XAMPP installer through the XAMPP website (https://www.apachefriends.org/index.html). The appropriate installer has to be downloaded with regard to the operating system and bit system, that is used, for this study xampp v3.330 was downloaded. Form here normal installation proceeds.
- Starting the XAMPP control panel: Once the installation was completed, the XAMPP control panel was started so as to see if it's working. It's on this control panel, that the platforms within the xampp can be turned on and off, for this study the apache was the one needed hence its one that usually was runt, but for it to run java development kit had to be downloaded and installed too. The Xampp control panel has been depicted on figure 3.2

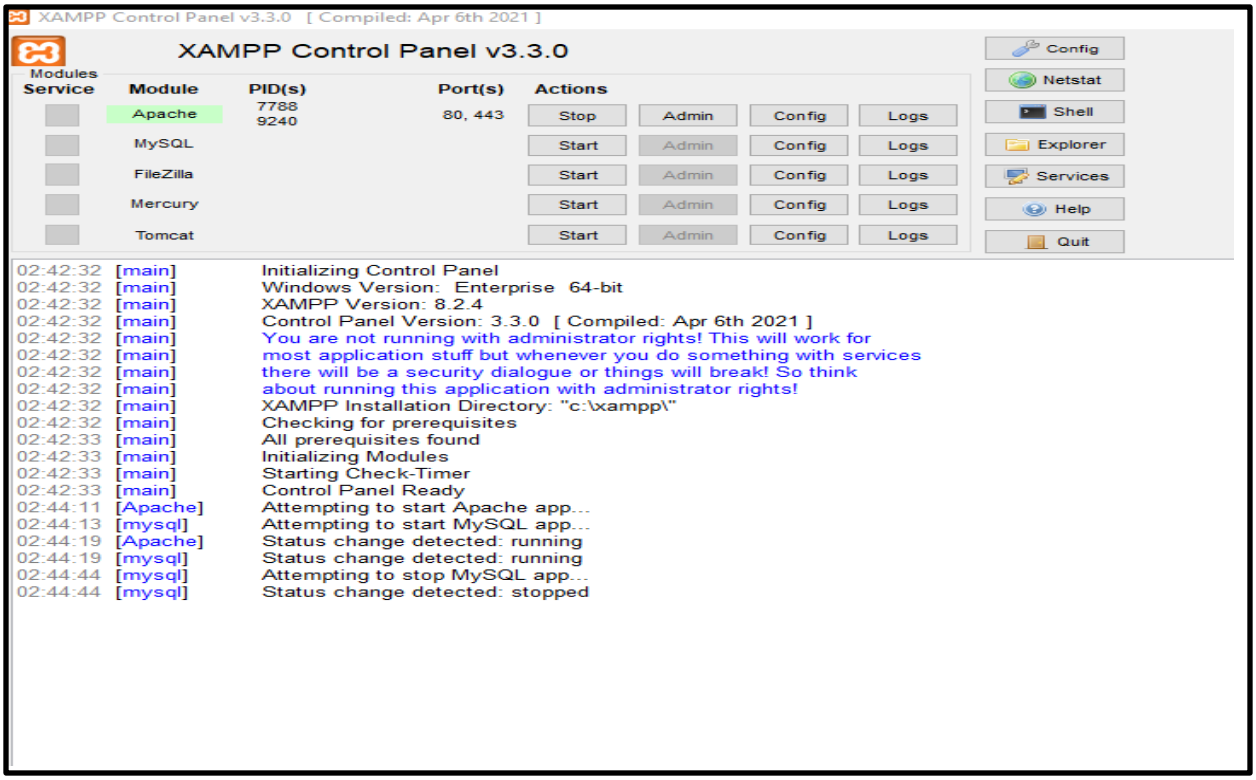

Figure 3. 2: xampp control panel

3.4.2 Installation and Configuring of the PostgreSQL

This process encompasses the below steps in installing and setting up the database

- Downloading and installing PostgreSQL: PostgreSQL installer was downloaded from the official website at https://www.postgresql.org/download/, whereby one has to choose appropriate version for his or machine operating system and then the installation wizard was followed.
- Setting up the PostgreSQL environment: After installation, there was a need to set up the PostgreSQL environment variables, that is to say setting the PATH variable to include the PostgreSQL bin directory.
- Start the PostgreSQL server: On Windows, you can start the PostgreSQL server by running the "pg_ctl" program from the command prompt with the "start" option, alternatively PostgreSQL can also be started through pg admin, and form it different servers can be accessed as well as databases

3.4.3 Installation and configuring of the Quantum GIS

This procedure entailed the following steps;

- Downloading and installing QGIS; QGIS installer was downloaded from, the official website of the Quantum GIS ,which is https://www.qgis.org/en/site/forusers/download.html, here also appropriate package has to be chosen depending on the operating system, incase of this study window was the operating and then installation wizard was followed install QGIS on the computer.
- Setting up the QGIS; this involved addition of qgis2web plugin, that s essential for the web map making as well adding of web mapping services such as global surface water. Additionally, a project workspace was initiated as well as setting coordinate system, which was EPSG 4326 for WGS84

3.5 Data collection and preparation

This entailed acquiring the datasets that are related to the surface water sources located in the Pangani river basin, and this included the water bodies shapefile as well as river streams of Tanzania.

After these data were gathered preparation followed, which involved making the datasets collected ready to use in the visualization of the surface water source, and this entailed first of all reprojecting the datasets to WGS 84 coordinate system, and this was done so as to make the data compatible to various web mapping services that they would be used as basemaps or as additional or aiding information, clipping of the two datasets followed so as to have the surface water source that are found in the Pangani river basin and this was done in open GIS software known as Quantum GIS.

3.6 Developing the front end of the webgis

Developing a front-end for a webGIS for visualizing surface water sources for the Pangani River Basin involved creating a user interface that will allow users to interact with and explore the data in an intuitive and meaningful way. This involved developing the following components;

3.6.1 Developing the welcome page

In creating the welcome page for the web GIS involved several matters were considered, First, the front-end was designed that the resulting user interface would be both visually appealing and user-friendly.

The programming languages that were used to create the welcome page using HTML, CSS, and JavaScript. The HTML was used to create the basic structure of the page, including headings, paragraphs, and other content. CSS was used to style the page, including setting the colours, fonts, and layout of the elements on the page. JavaScript was used to add interactivity to the page, such as drop-down menus and tooltips.

This involved adding information about the webgis which is known as websur, as well as navigation bar such as home, login and sign up. These navigation bars are linked up to home page, sign up and login form

3.6.2 Creating a Sign-up form or page

This involved making a registration form on which a user can register so as to be able to login to the webgis. This was developed in a sense of that the users would be workers of Pangani River Basin Board, hence the form was created with four details to be filled which are the full name as well as the email and the phone number of the worker, with the password through which the user would be able to access his or her account that was to be created when he is she is registered.

3.6.3 Creating a login form

This entailed constructing a form through which through which a registered user can be able to login into the webgis and be able to visualize the surface water sources of Pangani river basin.

3.6.4 Creating and customizing the map page

This started with making of a web map of the Pangani river basin's surface water sources which consisted of Pangani polygon like waterbodies such as lakes and linear features, that is to say river streams. For visualization purposes, various web map services were added to the datasets as basemaps, and this included the open street map layer as well as the terrain layer provided by google so as to aid the exploration and visualization of the surface water sources.

Creation of the web map was conducted on the Quantum GIS, and this required a plugin known as qgis2web, that make it possible to create web maps. With qgis2web installed the web map was made by using the leaflet mapping library. This has been illustrated in figure 3.3

A preview was done so as to see how would the web map would look like and after few adjustments, such as which tools to be visible, the web map was exported. Figure 3.4 depicts the web map preview done on Quantum GIS

The map page was made to visualize the surface water sources, after the user has successfully registered and login into the websur. Map page was made by customizing the web map that was made using Quantum GIS. The customization involved the creation of a map page html and putting a web map link so as when a map page is opened, the web map is displayed, furthermore the web map size was adjusted so as to fit well the screen while being able to visualize well too.

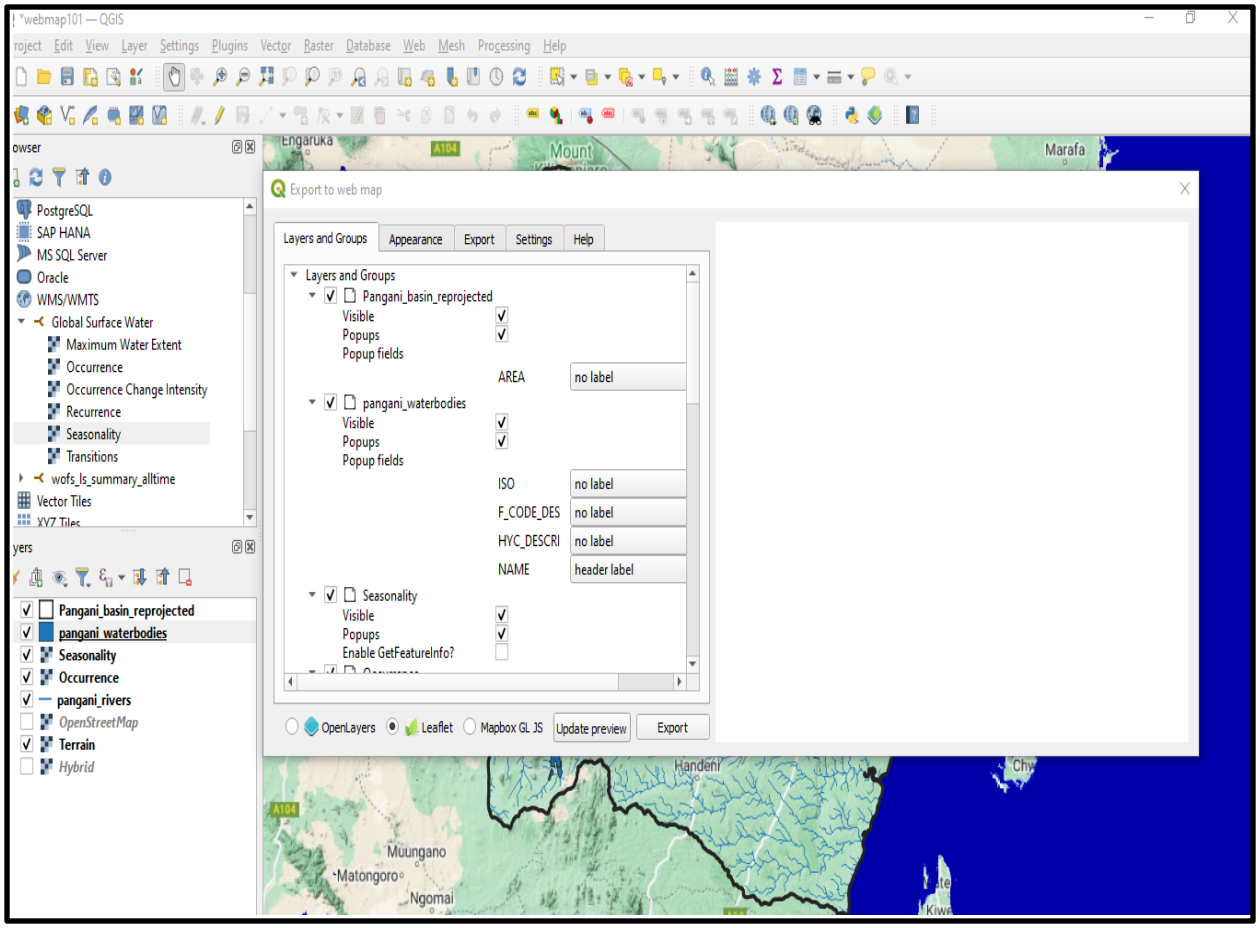

Figure 3. 3: Creation of a web map

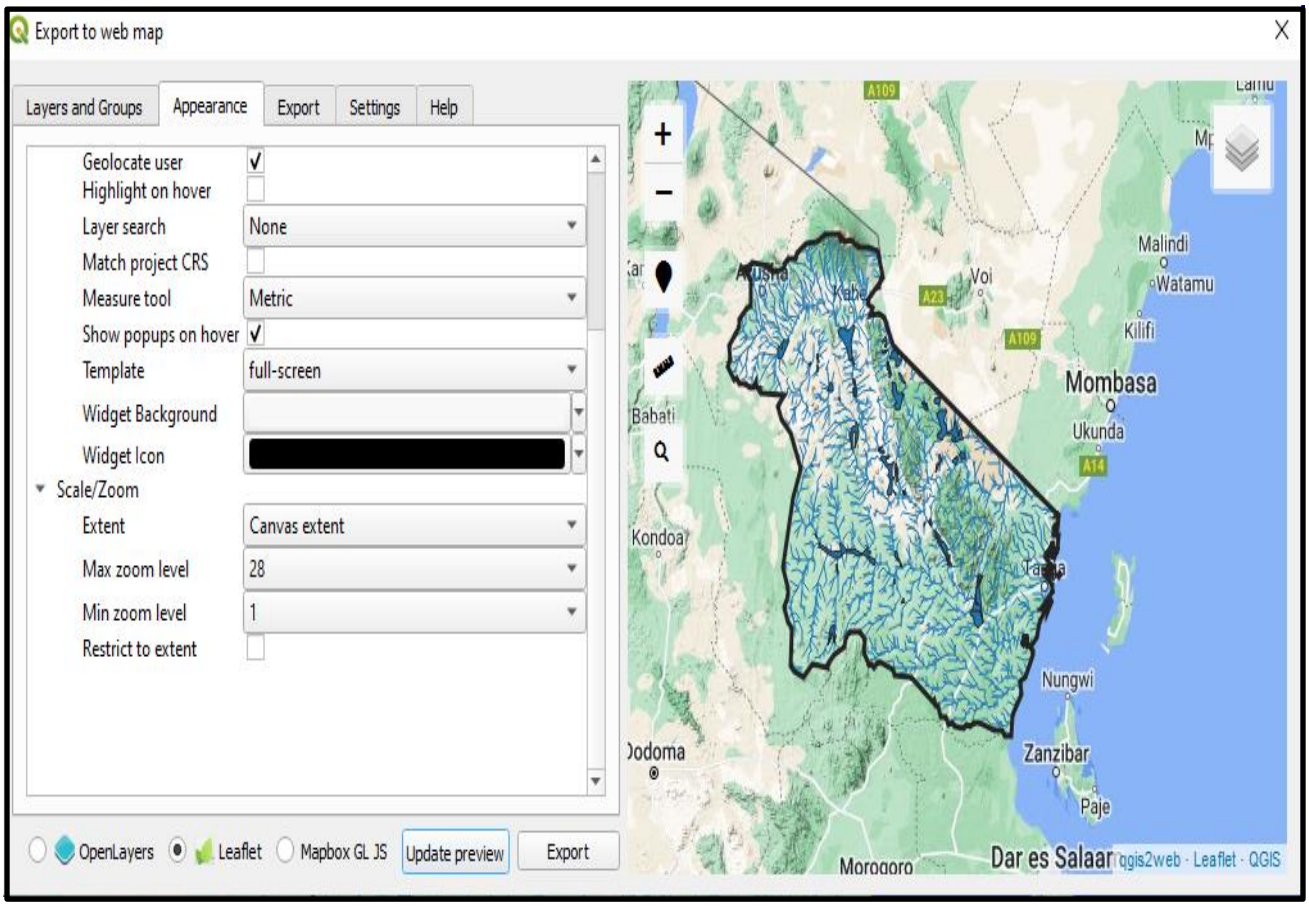

Figure 3. 4: Preview of the webmap

3.7 Developing a back end of the webgis

Developing the back-end of a web GIS was done using, xampp, PostgreSQL, php, this involved the following procedures

- Webserver establishment; the webserver used was xampp, to establish it as a webserver of the webgis, the websur codes had to be keep in one folder, and this folder had to be inserted into the xampp htdocs folder.

- Plan the database structure: The first step in developing the back-end of the web GIS is to plan the database structure. This involves identifying the tables and fields needed to store the data required by the web GIS. For this study if the web GIS is visualizing surface water sources for the Pangani River Basin, the database might include tables for river basins water sources.

- Creation of the database; in this step a database was created in a PostgreSQL, under the default server, so as to be able store different relevant data relevant to this study. This is illustrated in the figure 3.5

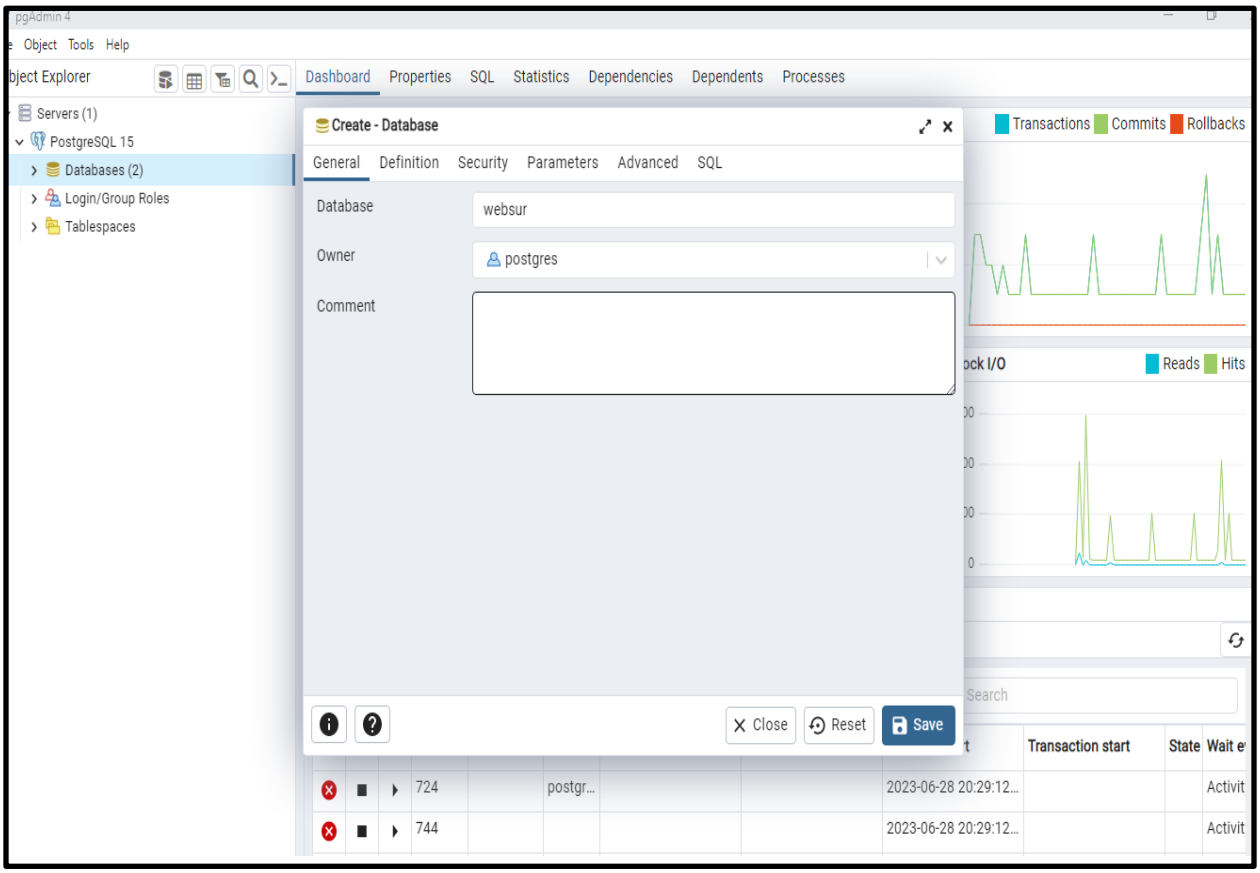

Figure 3. 5: Creation of a database

- Creation of tables; As registration involves collecting of user information so as to make the user able to login in the webgis, this information of the users had to be stored, and that is essence of creating a table in a database, that will be keeping user's name, phone number, email and password, figure 3.6 shows the creation of user table in a websur database.

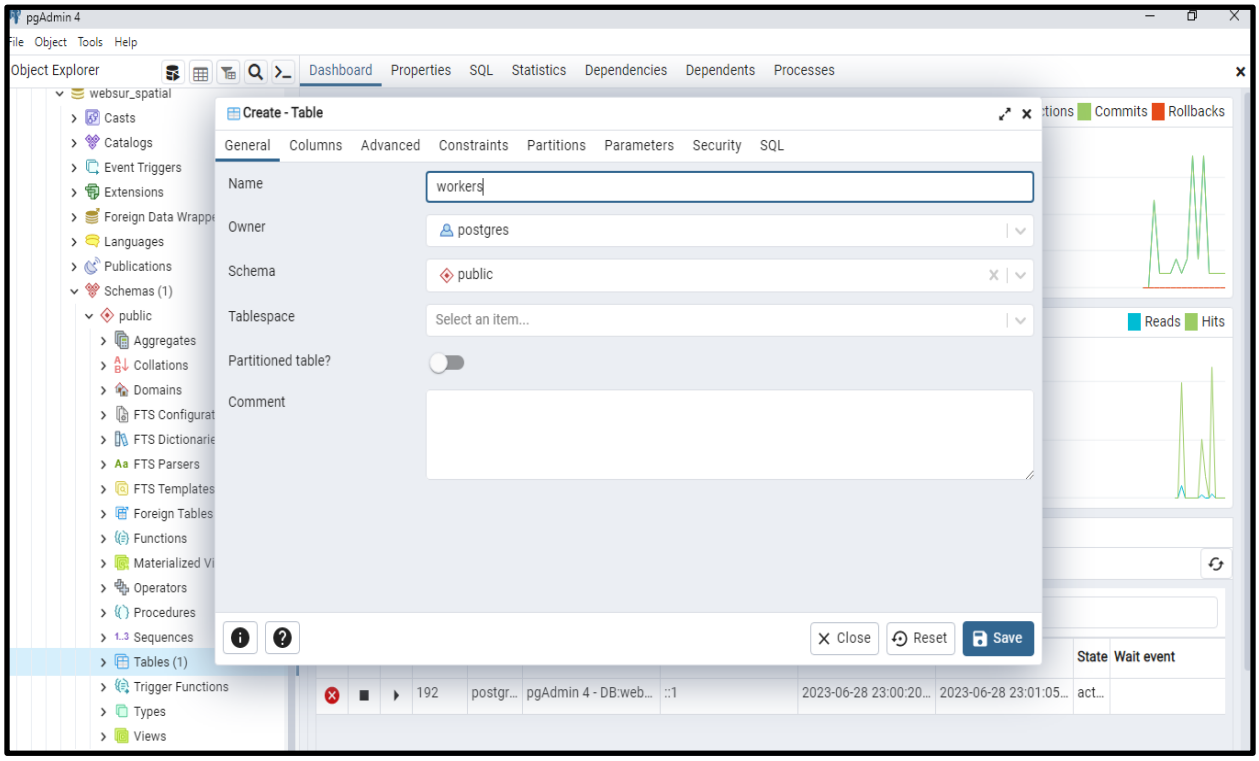

Figure 3. 6: Creation of the table

- Creating a postgis extension; as the database wont, be holding just non-spatial data such as names and emails, but it will also be storing spatial data such linear features such as rivers and polygon features such as lakes, a postgis extension was added to the database of websur, so as to enable the dataserver to be able to handle spatial data as PostgreSQL is not by itself a spatial database. Figure 3.7 depicts the postgis extension creation to the database.

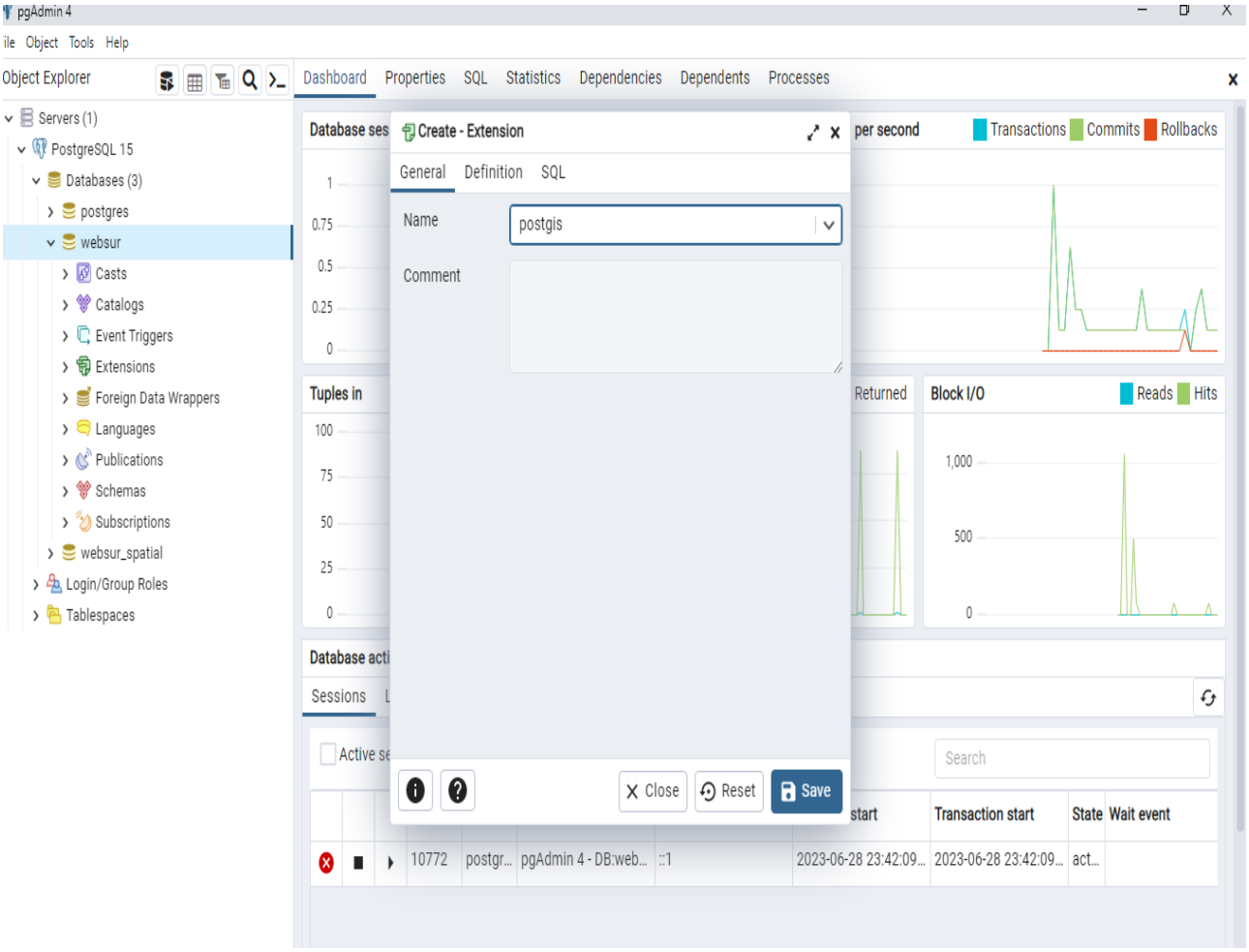

Figure 3. 7: Creation of postgis extension for the database

- Viewing connection details; in this step the connection between the postgis bundle sand the database was established so as to be able to import data to the database. This is shown in the Figure 3.8.

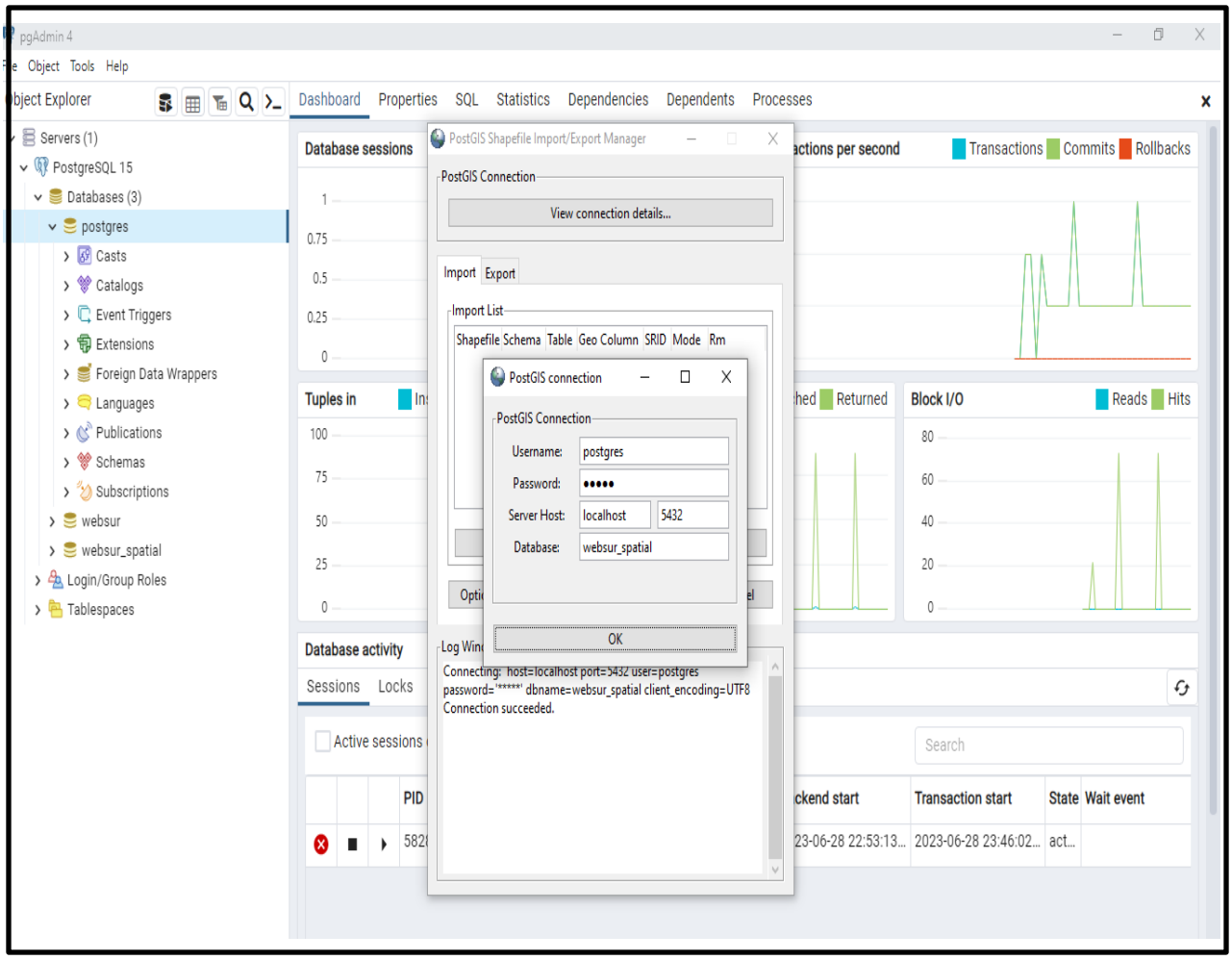

Figure 3. 8: Viewing connection details

- Importing Shapefiles to the database; after the connection went successful between the postgis bundle and the database, data was imported to the database, this is illustrated in the Figure 3.9

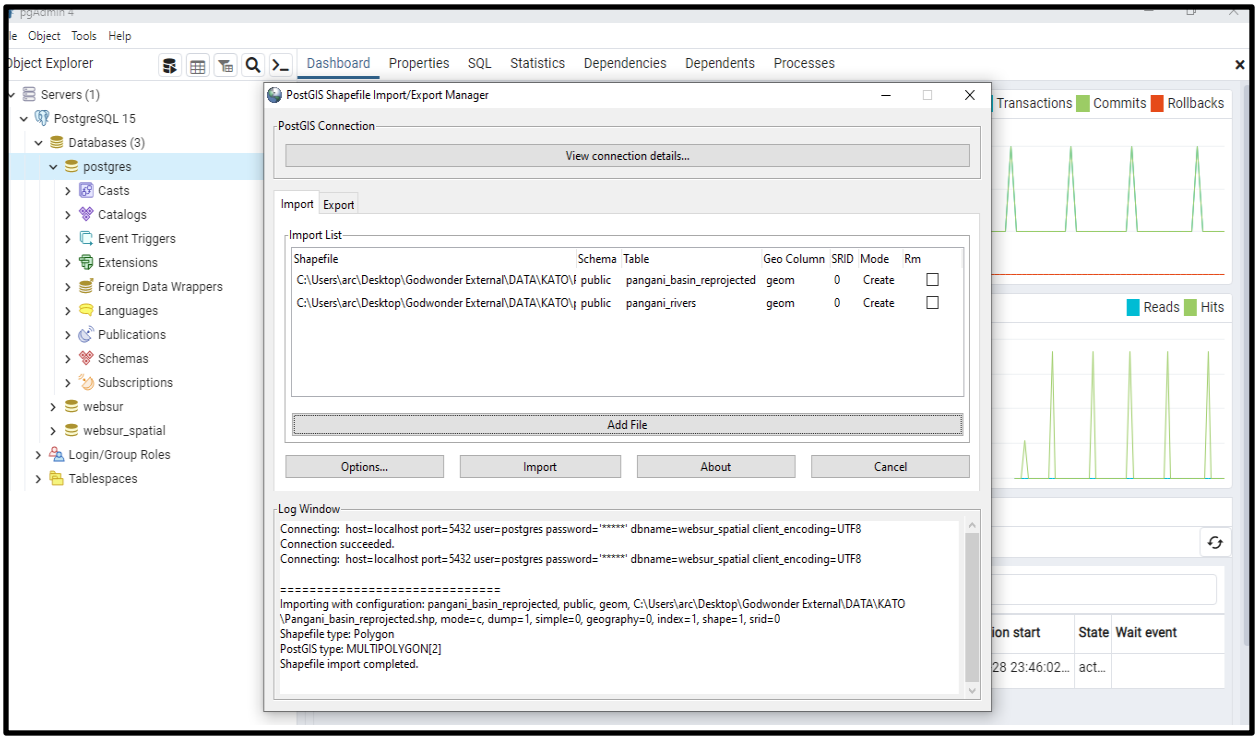

Figure 3. 9: importing shapefiles to the database

3.8 Connecting the database to the web application

So far, the front end and the back end of the webgis were connected or in other words, these two entities existed separately without any relation to it, and as webgis architecture demands the connection between these two components, for its functionality, front end and the back end of the webgis were connected using php language, that enable the connection between the webservers and dataserver.

With this connection established, registration as well the login is enabled as these two depends much on the connection

3.8 Testing and debugging webgis

As the webgis developed is generally a software, it need testing so as to make sure the functionality and performance of the system are as intended. Alpha testing was used to test the webgis workability.

During alpha testing, the webgis was tested for its functionality, performance, usability, The testing. With regard to the functional testing, this was done while comparing to the functional requirement of the webgis, in terms performance testing, the speed as well as stability was

looked upon, and coming to the usability testing, this was done with respect to the user requirements of the system. During this testing various errors aroused as well as malfunctions, and to counter this debugging was done, so as to be able to come up with efficient webgis.

CHAPTER FOUR

RESULTS

4.1 Overview

This chapter entails the results or outputs obtained in this study, section 4.2, section 4.3 entails the front end of the webgis, section 4.4 is about the back end of the webgis.

4.2 Conceptual design

This entail the conceptual design of the websur architecture, that is to say the webgis has two major components which are front end and back end as it is shown in Figure 4.1

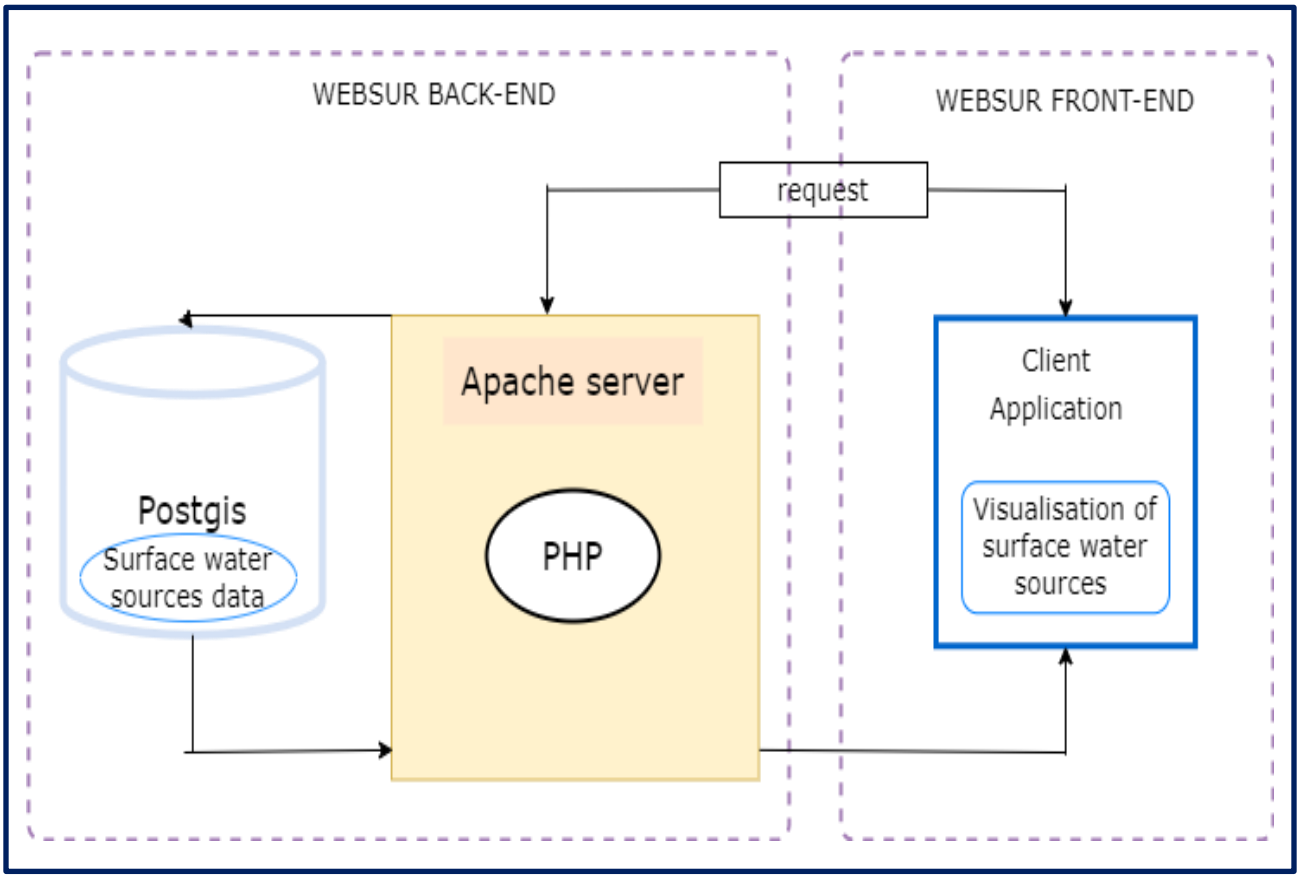

Figure 4. 1: Conceptual design of the websur

4.3 Front end of the webgis

This encompasses the user interface that enables users to interact with the system and access the GIS functionality of the websur. The front end of the webgis primarily has four webpages namely the homepage, the signup and login page as well as the map page.

4.3.1 Home page

A home page of the websur is the main page of a website that serves as the entry point for users, is also sort of a welcome page. It is typically the first page that users see when they navigate to a websur. The purpose of a home page is to provide an overview of the website's content, navigation options, and key features.

The content of a home page are as follows;

- Header: The header that typically includes the website name which is websur, navigation bars of sign up and login page.
- Hero Image; A hero image or video is a large visual element that is placed prominently on the home page, in case of the study, pangani river was placed right of the homepage content section.
- About Section: In this part of content section, the information about the websur was provided from what does it mean, as well its application.

Overall, a well-designed home page should provide a clear and compelling introduction to the website's content and encourage visitors to explore further. It should also be optimized for search engines and accessible to users on different devices and platforms. For this particular study the home page can be seen on Figure 4.2.

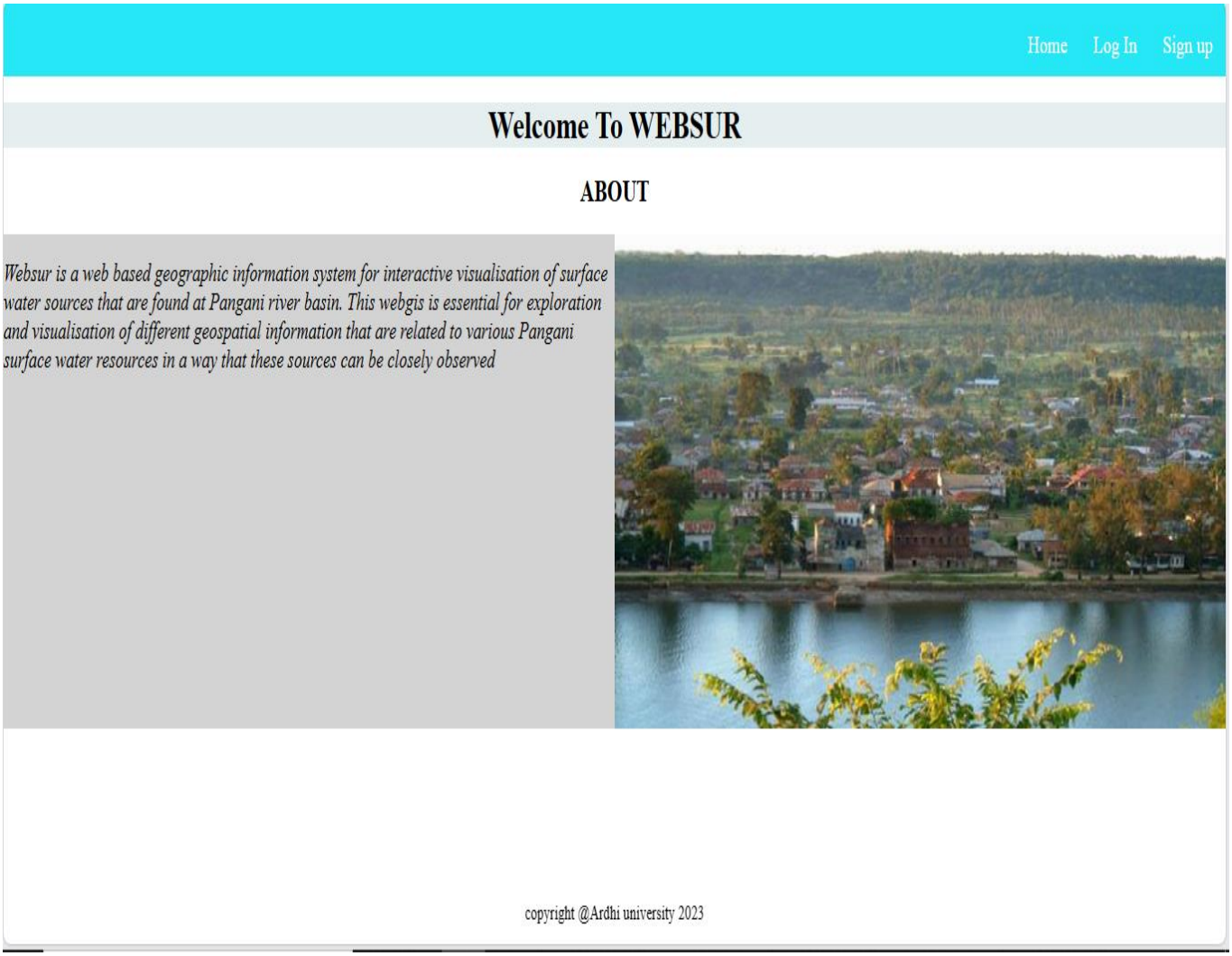

Figure 4. 2: homepage of websur

4.3.2 Sign up page

A sign-up page is a web page that allows users who in this case are workers to create an account on a websur. The purpose of a sign-up page is to collect user information and create a unique account that can be used to access the website's features and services. The sign-up page can be accessed through the home page navigation bar named sign up page.The content of a sign-up page of the websur has the following elements:

- Registration Form: The registration form is the main element of a sign-up page. It typically includes fields for users to enter their name, email address, password.
- Sign-Up Button: The sign-up button is prominently displayed and clearly labelled to encourage users to complete the registration process.

Overall, a well-designed sign-up page should be user-friendly, visually appealing, and provide clear instructions for users to follow, the sign-up page is as depicted in the figure 4.3

4.3.3 Login page

WebGIS login page typically requires users to enter their emails and password to access the websur application, that is to say one has to be registered to the system for him or she to be able to login. This page opens automatically when the user registration has gone successfully, or it can be accessed through the navigation bar on the home page named login, this is to be done to the users that have already been registered. Overall, a well-designed web GIS login page should provide a positive user experience, while also ensuring the security of user data, and the websur login page is as much as so, and it can be seen in the Figure 4.4

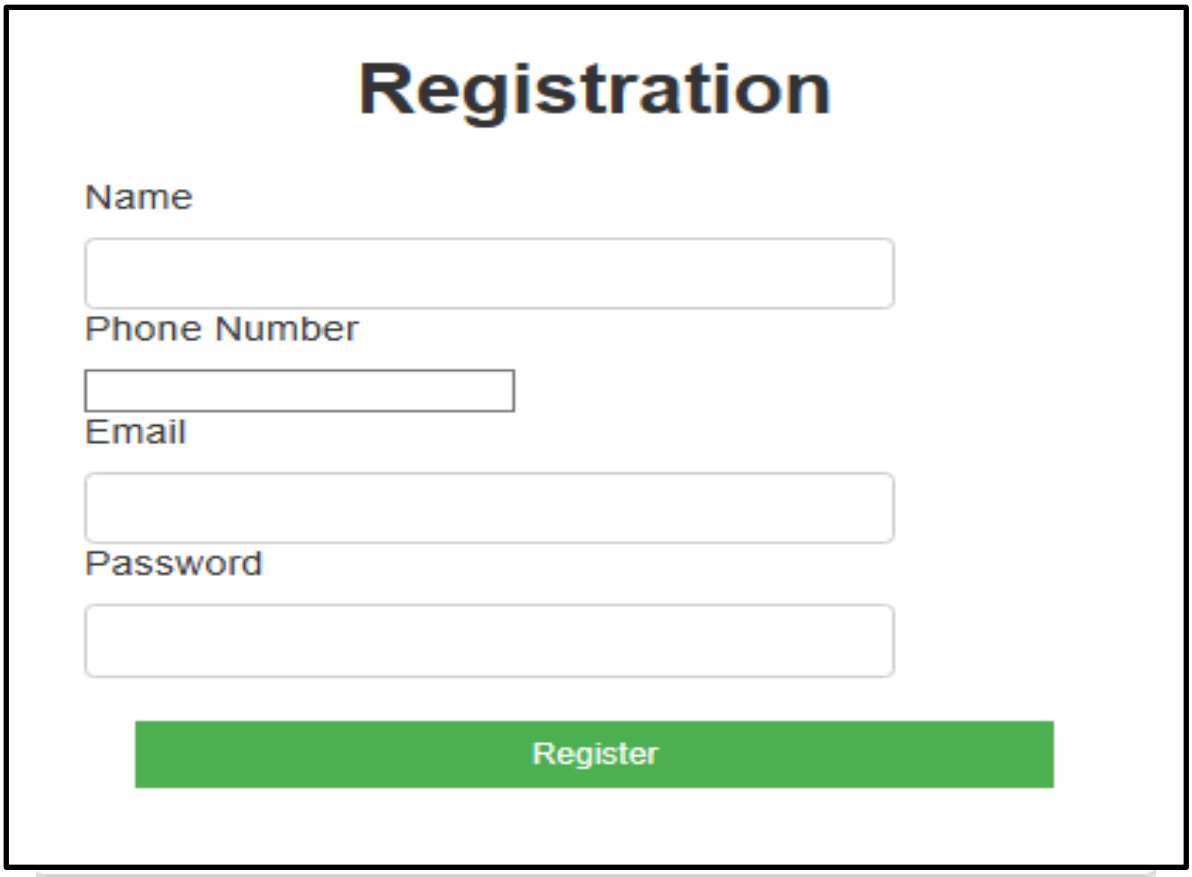

Figure4. 3: registration form

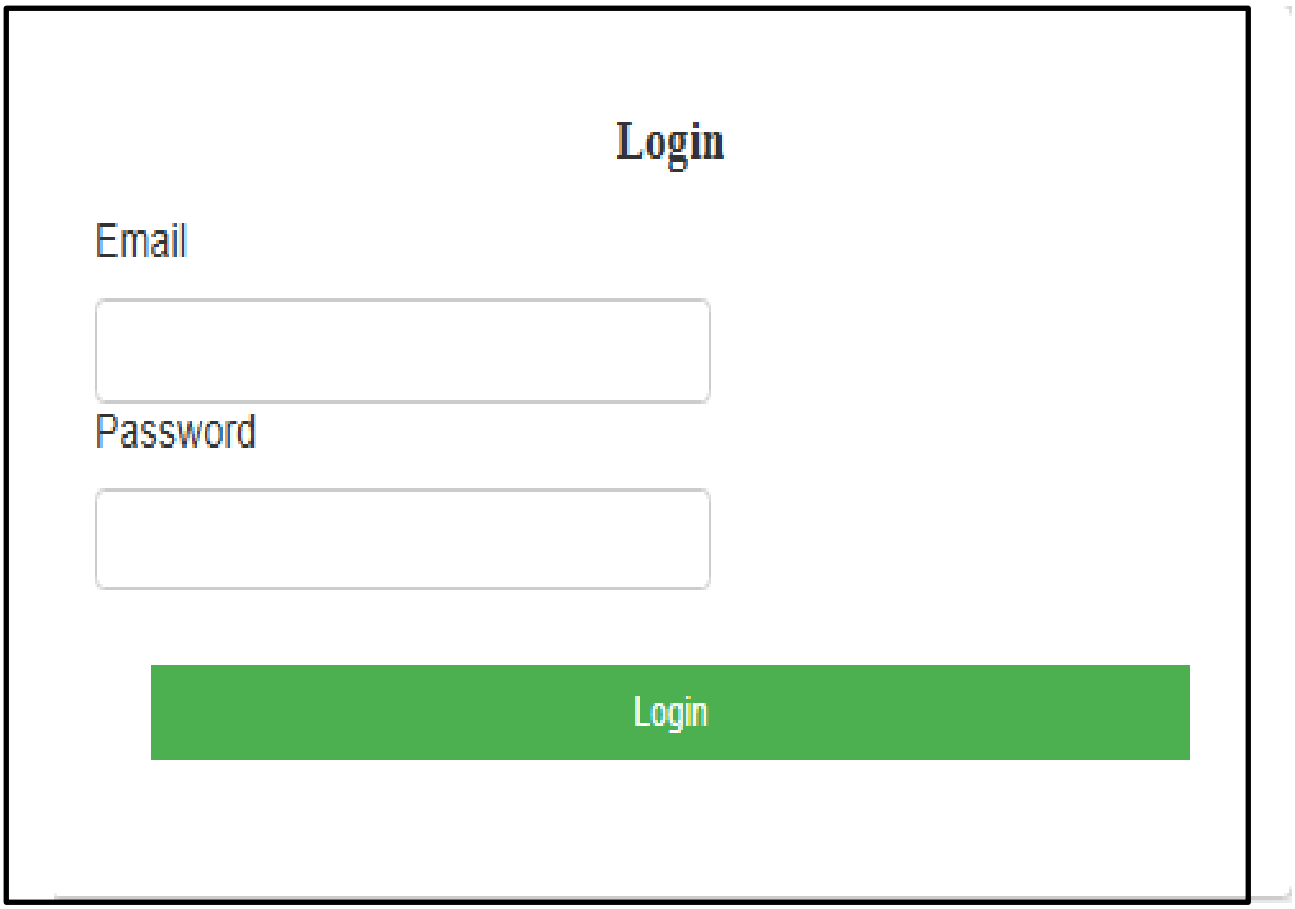

Figure4. 4: login page

Map page

This is generally the web page where the user is able to visualize the surface water sources that are located at Pangani, do common zoom in and out functions as well searching for a place without forgetting even geolocating his or her own position. This page is typically a web map that has been created using Quantum GIS, and it has different datasets, entailing pangani rivers, pangani waterbodies which encompasses polygon like surface water features found in pangani river basin such as lakes and dams.

Furthermore, user can also switch between the base map layers that are found on the top left corner of the page as collapsed and not expanded layers, in a way that visualization and exploration is enhanced in various perceptions. The custom map page is depicted in the Figure 4.5.

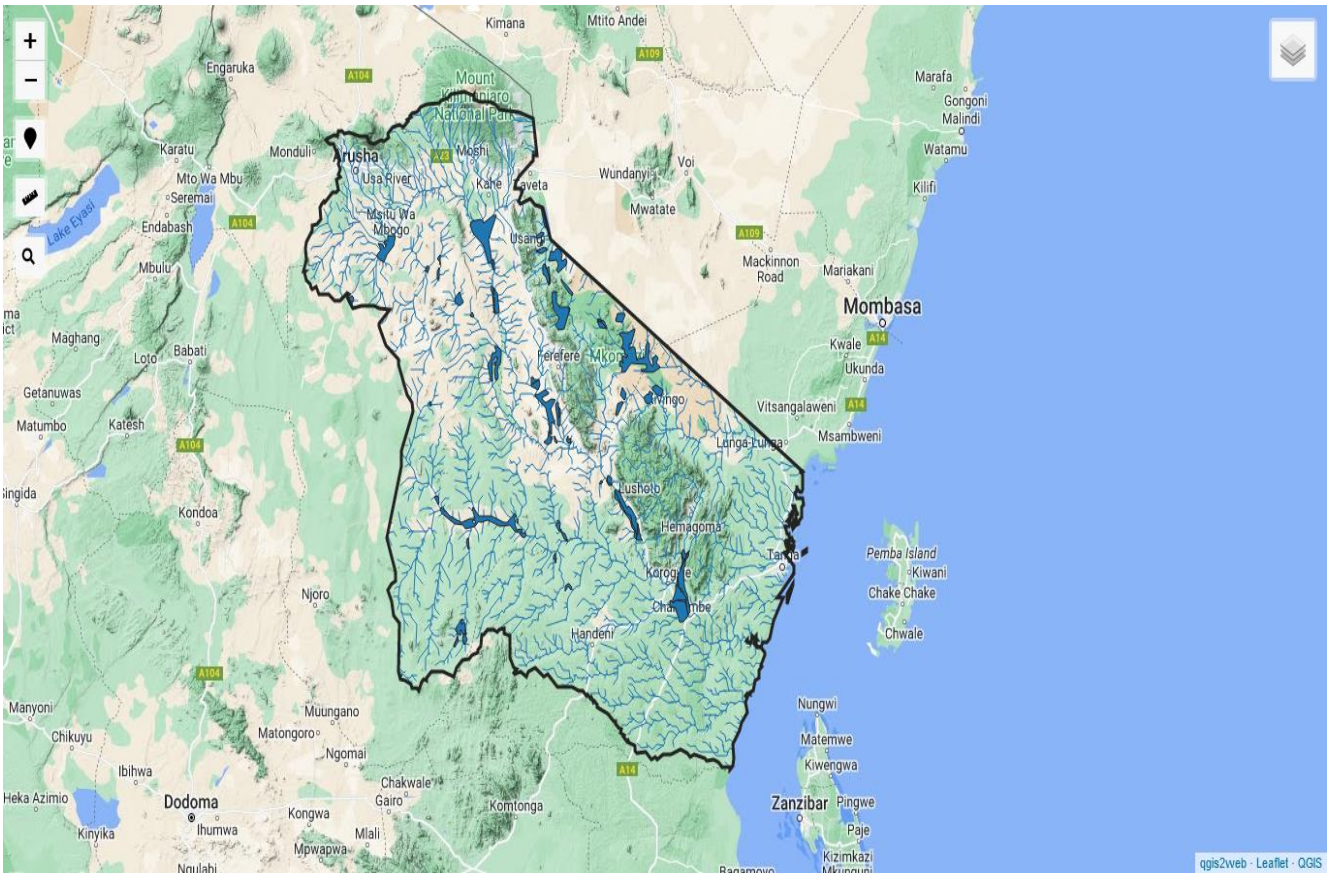

Figure 4. 5: custom map page

4.4 Backend of the webgis

In case of the backend of the websur web based geographic information system xampp, PostgreSQL with its extension Postgis was used in providing webservices and spatial data storage as well as retrieval of these datasets. A database was created and Postgis extension was added to it, so as enable it to have the capability to handle spatial data.

Apart from holding spatial data, the database has a table named worker was created so as to handle information of the users, that are to be gathered during the registration process of the users to the webgis.

CHAPTER FIVE
DISCUSSION

GIS software has made it easier to interpret spatial data, but not everyone has access to it or the time to use it effectively. Web GIS provides a cost-effective and accessible way to disseminate geospatial data and processing tools to a wider audience, including government organizations and households. With the widespread availability of internet technology, spatial data providers are exploring ways to use the internet to distribute geospatial information. However, successful implementation of web GIS requires a process-oriented approach that takes into account the available technology and application requirements. By doing so, organizations can distribute maps and processing tools without restrictions on time or location, making it easier for users to access and understand spatial information.

The main aim of conducting this study of developing this web-based GIS was to provide a geospatial platform, that will enable the Pangani Basin Water Board, to be able to visualize surface water sources, in a way that it will aid in various decision-making process as well management of these water sources as they are of great importance. This is not so far from why the study concerning developing Cooperative WebGIS interactive information systems for water resources data management was done, (Skoulikaris & Ganoulis, 2014) the principle aims of this geo-referenced information system developed for the transboundary aquifers in Africa was to provide appropriate tools under a web-based platform for water management institutions in the region.

Through websur when its completely deployed, as now it is hosted in local machine, surface water resources information can be easily accessible as the distributive GIS technology is at work, optimizing the dissemination of surface water resources information. This view has also been provided by Esri while introducing webgis for water utility, (Esri, 2018) Water utilities can greatly benefit by adopting the ArcGIS® platform and implementing Web GIS. This technology provides affordable and easy-to-use solutions that can be accessed across the organization anytime, from any device.

Websur has been designed to be user friendly so as to make the visualization be simpler as well optimized. This is because as webgis should have user friendly environment in a way that even a user with no or less information on usage of geospatial technologies can be to interact with it, this has been observed on the simile project, (Toro Herrera, Carrion, & Brovelli, 2021) The

WebGIS aims at being a user-friendly environment for the users to explore the water quality parameters products published on the GeoNode application, furthermore this has been considered in the development of the webgis to disseminate Iranian road information through the Internet, (Alesheikh, Helal, & Behroz, 2002)Ease of use, user-friendliness, and reducing the volume of data transfer were the critical issues considered in the development..

Websur is also a cross platform interms of web browsers as well as operating system, and this is very essential as different clients may be using different browsers to access the information in the webgis, being interoperable in various browsers ensure much greater function ability. This is well supported by, (Prasad, 2002) the majority of web GIS clients are web browsers: Internet Explorer, Mozilla Firefox, Apple Safari, Google Chrome, and so on. Because these web browsers largely comply with HTML and JavaScript standards, web GIS that relies on HTML clients will typically support different operating systems such as Microsoft Windows, Linux, and Apple MacOS.

Interactivity is very essential in developing the user interface as well as the map of the webgis and the websur has been designed that way so as to add more visualization parameters in it. This has been done by creating web map using QGIS that uses OGC standards on creating web map services, this has also been considered on simile study, (Toro Herrera, Carrion, & Brovelli, 2021) The interactive map uses OGCstandards, such as Web Mapping Services (WMS,http://www.ogc.org/standards/wms), to display maps published by the map providers.

CHAPTER SIX
CONCLUSION AND RECOMMENDATION

3.1 Overview
This chapter entails the conclusion as well as the recommendations associated with this study, section 3.2 encompasses the conclusion of the study, entailing generalization of the study findings and section 3.3 is about different recommendations that are targeted to various entities that are related or interested with the study.

3.2 Conclusion
The study was conducted with the aim of developing a webgis for visualization of surface water source, case study being Pangani river basin, and this was done while considering the specific objectives of the research. This has been done in a way that within the study there was identification of user and functional requirements for the system to be developed, a web map visualizing the surface water sources was created, and webgis named websur was developed and tested using alpha test to see its performance.

The webgis has been designed and developed with regard to the user and functional requirements that have been gathered through reviewing of other related studies, so as to ensure that the webgis developed is user friendly, ease to use as well provide basic functions of the webgis, and the requirements were also used in testing of the system. The webgis has been developed and it can visualize the surface water sources such as rivers and lakes as well as dams, not only that but various basemaps have been added to optimize the visualization process

3.3 Recommendations
Based on the developed system, the researcher recommends the following:

- The surface water data such as river stream data as well lakes and dams, has various attributes but names of this water features have not been covered greatly, hence there should be a dataset of surface water sources that provides names for these features
- As there is a need for webgis for visualization of surface water resources, the developed can be enhanced by Pangani Basin Water Board as per other requirements and be utilized so as to aid in water resource management. The system could also be optimized and connected to gauges so as to as to enhance monitoring of surface water sources

- Additionally, the other researchers may go further and develop webgis for ground water resources.
- Furthermore, the government can optimize the study and make it nationwide research as the country is blessed much with such resources and proper management of it is non-optional.

REFERENCES

Skoulikaris, C., & Ganoulis, J. (2014). Cooperative WebGIS interactive information systems for water resources data management. Hydrology in a Changing World, vol 2, 342-347.

Alesheikh, A., Helal, H., & Behroz, H. (2002). Web GIS: Technologies and Its Applications. Symposium on Geospatial Theory, Processing and Applications, vol 2, 1-30.

Ogilvie, A., Belaud, G., Massuel, S., Mulligan, M., Goulven, P. L., & Calvez, R. (2018). Surface water monitoring in small water bodies: potential and limits of multi-sensor Landsat time series. Open Access Hydrology and Earth Sciences,vol 2, 62-73.

Prasad, S. (2002). Concepts and Principles of Web GIS (3 ed.). Ranchi: Mukherjee University.

Toro Herrera, J. F., Carrion, D., & Brovelli, M. A. (2021). A Collaborative Platform For Water Quality Monitoring: Simile Webgis. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume 53-B4-2021 XXIV ISPRS Congress, 201-207.

Balla, D., & Zichar, M. (2022). Possibilities for Assessment and Geovisualization of Spatial and Temporal Water Quality Data Using a WebGIS Application. ISPRS, International Journal of Geo-information, vol 4, 55-100.

Dangermond, J. (1988). Introduction and overview of GIS. Paper presented at Geographic Information SystemsSeminar: Data sharing—Myth or reality (1st ed.). Ontario: Ministry of Natural Resources.

Din, E. H. (2018). Surface Water Quality Assessment Using A Remote Sensing, GIS, and Mathematical Modelling Framework (3 ed.). New Brunswick: University of New Brunswick.

Esri. (2018). How Web GIS Supports Water Utility(3 ed). New York: Esri.

Esri. (2020). India-WRIS WebGIS: Design and Development of Web Enabled Water Resources Information System of India. Arc India News, 5, 11-30.

Huang, C., & Chen, Y. (2018). Detecting, Extracting, and Monitoring Surface Water From Space Using Optical Sensors_ A Review of Geophysics. AGU Journals, vol 56 isue (2), 333-360.

International Space Science Institute. (2016). Remote Sensing and Water Resources. Space series of ISSI, vol 55, 40-75.

Johnson, L. E. (2009). Geographic Information Systems in Water Resource Engineering (2 ed.). Boca Raton: Taylor & Francis Group.

Jolaiya, E. (2020, December 7). WebGIS Section 1 – A Quick Introduction to GIS and WebGIS. Retrieved February 28, 2023, from GIS Lounge: www.gislounge.com

Konecny, G. (2014). Geoinformation; Remote Sensing, Photogrammetry and Geographic Information Systems, 2nd edition. Boca Raton: Taylor & Francis Group.

Li, J., & Su, B. (2017). Monitoring Water Resources and Water Use from Earth Observation in the Belt and Road Countries. Bulletin of Chinese Academy of Sciences.

Li, S., Dragićević, S., & Veenendaal, B. (2011). Advances in Web-based GIS,Mapping Services and Applications (2nd ed.). London: Taylor & Francis Group.

Liu, J. G., & Mason, P. J. (2016). Image Processing and GIS for Remote Sensing_ Techniques and Appications (Ist ed.). West Sussex: John Wiley & Sons, Ltd.

Mishra, S., Chander, S., Pradhan, R., Dubey, A. K., Oza , M. P., & Sharma, S. A. (2020). WebGIS for water level monitoring flood forecatsing using open source technology. Journal of Geomatics, 2, 49-54.

Moreno-Salamanca, E. A. (2021). Monitoring Surface Water Areas Using Satellite Remote Sensing and Cloud Computing: A Case Study of Lake Burdur, Turkey (1st ed.). Cambridge: Harvard.

Nelson, S. A., & Khorram, S. (2019). Image Processing and Data Analysis with ERDAS IMAGINE (1st ed.). Boca Raton: Taylor & Francis Group.

Nery, F. (2020). WISE GIS Guidance. Guidance on the reporting of spatial data to the Water Information System for Europe (WISE). Version 7.0.6. (2nd ed.). London: European Environment Agency.

Prigent, C., & Lettenmaier, D. P. (2016). Toward a High-Resolution Monitoring of Continental Surface Water Extent and Dynamics, at Global Scale:from GIEMS (Global Inundation Extent from Multi-Satellites) to SWOT (Surface Water Ocean Topography). Remote Sensing and Water Resources, 3, 148-165.

Sensorex. (2022, May 30). Groundwater vs. Surface Water – What's the Difference. Retrieved from Sensorex: https://sensorex.com/groundwater-vs-surface-water

Sharma, K. D., & Singh, ,. S. (1989). Role of satellite remote sensing for monitoring of surface water resources in an arid environment. Hydrological Sciences Journal, 4, 531-537.

Tottrup, C., & Druce, D. (2022). Surface water dynamics from space: A round robin intercomparison of using optical and SAR high-resolution satellite observations for regional surface water detection. Zurich Open Repository and Archive,, 3, 100-150.

Wang, R., Pan, L., Niu, W., Li, R., Zhao, X., Bian, X., . . . Chen, T. (2020). Monitoring the spatiotemporal dynamics of surface water body of the Xiaolangdi reservoir using Landsat-5/7/8 imagery and Gogle Earth Engine. Open Geosciences, 5, 50-62.