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WEB-BASED WATER RESOURCES INFORMATION MANAGEMENT SYTEM

A Case study of Water Resources Management Authority

Moffat G. Magondu, Moses M. Ngigi, Charles M. Ndegwa, Eunice W. Nduati, George W. Chege and Eric O. Opiyo

***Abstract*—** Reliable information is of utmost importance for planning and decision making. Various challenges face the water resources management sector in regard to water resources information management. The main challenges include lack of well defined processes of information flow between various organizations and different storage formats hindering proper information sharing resulting to duplication of information. At present Water Resources Management Authority (WRMA) uses emails, cds and dvds to send the data once it is collected. It is then added into existing databases at the regional or headquarters offices. The study sort to address this problem by developing a web-based water resources information management system with an aim of providing a proper water information collection, storage and dissemination platform. The proposed system is composed of three subcomponents: a single database, web-based mapping component and a website. The database provided is centralized, mapping component provides tools for data updating and visualization while the website hosts the mapping component and also provides additional information related to water resources use. To develop the system stable GIS softwares and other Open Source softwares were used. The system contained surface water, ground water and watershed protection information. Adoption of the system will aid WRMA in fulfilling its mandate of regulating water use nationally and regionally by effectively managing the valuable water resource information.

***Keywords*—** Open Source, GIS, Water resources Information, WRMA

I. INTRODUCTION

The need for water is universal. Water is present everywhere, and without water, life, as we know it, will simply cease to exist [1]. The high rates of urbanization and increasing demand for drinking water is putting stress on existing water sources. The mounting challenges posed by the changing demand for and supply of the resource highlights the importance of water in any development and growth agenda. The ability of developing countries to make more water available for domestic, agricultural, industrial and environmental uses will depend on better management of water [2].

Water resources management aims at optimizing the available natural water flows, including surface water and groundwater, to satisfy human needs. Climate change will increase the complexity of managing water resources, in some parts of the world, there will be more available water but in other parts, including the developing world, there will be less [2].

All water resources in Kenya remain vested in the state. The Ministry of Water and Irrigation is tasked with the responsibility of creating institutions to manage water resources and provide water services. In 2002, the water sector reforms in Kenya culminated in the passing of the Water Act, gazetted in October 2002 [3]. The Water Act introduced new water management institutions to govern water and sanitation. The water reforms saw the introduction of the commercialization of water resources as part of the decentralization process and the participation of stakeholders in the management of national water resources. Policy and regulation responsibilities were separated. The devolution of responsibilities for water resources management and water services provision to local level functions has been the principal mechanism for improving accountability and transparency in the water and sanitation sector [4].

The Water Act provides a legal framework for the creation of water institutions and limits the Ministry's role to policy formulation; overseeing the implementation of the policies; and resource mobilization. The Ministry is also responsible for irrigation, drainage, and land reclamation. As a result of the provisions in the Water Act of 2002, the Water Resources Management Authority (WRMA) was created. Its mission is to manage, regulate and conserve all water resources in an effective and efficient manner by involving the stakeholders, guaranteeing sustained access to water and equitable allocation of water while ensuring environmental sustainability [3]. Other duties of the WRMA include: To ensure Rational and equitable allocation of water resources, water quality monitoring, testing and surveillance to ensure compliance with drinking water standards and other standards for various water uses and effluent discharges into public sewers and the environment and mapping and publishing of key water catchment areas, groundwater resources and flood prone areas [4].

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Water resource monitoring is one of the key factors of water resources management. The ultimate goal of monitoring is to provide the information needed for planning, decision making and operational water management at the local and national levels. Currently WRMA is involved in monitoring the surface water, ground water, rainfall and water quality. Among the major challenges and key issues on water resource monitoring are water resources data and information generation, storage and sharing between the involved organization and the rest of the public who may want to use the data.

These challenges can be addressed by applying information technology to provide potential solutions to the problems of data accessibility. Current advances in computational speed, storage, World Wide Web and software provide great opportunities to develop decision and management support systems with the advantage of information dissemination for decision-makers.

Geographic Information Systems (GIS) have had a profound effect on water resource management. Various GIS tools are now commonly used for data preparation and developing water resource management systems. There have been various systems developed in different parts of the world using geospatial technologies. They vary in terms of the approaches adopted and also on the capabilities of the resulting systems. Integrated GIS-based water resources information and assessment system was build for the state of Georgia in the USA to be used as a guide in managing water resources in a sustainable manner to support the state's economy, to protect public health and natural systems, and to enhance the quality of life for all citizens [5].Web-based GIS and spatial decision support system for watershed management and a GIS-based water resources information system provided a web-based SDSS (Spatial Decision Support System) framework in terms of system components and data flow. The SDSS uses web-GIS for watershed delineation, map interfaces and data preparation routines, a hydrologic model for hydrologic/water quality impact analysis and web communication programs for Internet-based system operation [6].

This project explored how GIS technologies can be applied in managing water resources in various water catchment regions in the country. The project describes a conceptual web-based framework in terms of system components for the development of a web based water management system using web-GIS for water resources data collection, storage, mapping, visualization, analysis and map outputs.

II. PROBLEM STATEMENT

Kenya is classified as a water scarce country with only 647 cubic meters of renewable freshwater per capita. The same is characterized by high spatial and temporal variability and extremes of drought and floods [7]. This stresses the need for proper water resources management.

The Water Resources Management Authority (WRMA) was operationalzed in 2005 as a lead agency in management of water resources in the country [3]. Water monitoring responsibilities were then transferred from MWI to WRMA. There are several key challenges and issues facing WRMA as a water resources management organization.

One of the main challenge is having different systems in various local and regional offices that are used to store the water information, such as Access database and Excel spreadsheet which hampers the sharing of this information between these offices. There is also often conflicting information about the same water resources due to scattered database among different regional offices and organizations hence making it difficult to check for consistency of the information stored in the databases as shown in Fig. 1. The lack of proper tools to collect and store water related information is also another main problem which has lead to some of relevant information not to be formally recorded [3].

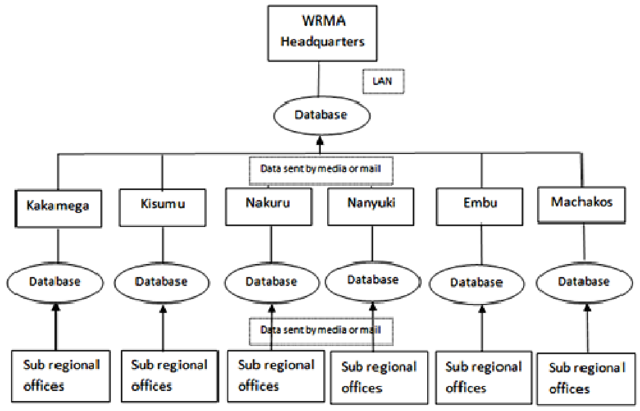

Fig. 1 Diagram showing the database duplication in both regional and headquarters offices

There has also been inefficient use of Geographical Information Systems (GIS) in WRMA. This is due to the lack of trained personnel as well as the challenge in use of the available database. Complicated interface of the existing server system is also an issue, as it is difficult for most of the staff that are not specialized in IT to adequately use it.

Another issue facing WRMA is shortage of manpower. It has only one ICT officer and one database administrator who currently have the responsibility of managing the entire water related database at the national scale. The data includes river monitoring, ground water, surface water, water quality and some meteorological data [3]. The database administrator is tasked to administer the database and also perform monitoring, supervision and checking the quality of data received from the six regional offices. He should also supply the needed information either internally or for a specific project being undertaken that require water related data. In addition to that he should provide the necessary maps in GIS format.

III. OBJECTIVES OF THE STUDY

The broad objective of the research project was to develop a web-based system for water resources information management. The system would be used to address the problem of information management being experienced by Water Resources Management Authority (WRMA). This will provide proper water information collection, storage, dissemination, improved access and decision making for sustainable management of water resources.

To be able to achieve the overall main objective, the study in particular set out to establish a centralized spatial enabled database for use by all WRMA offices. The study also set out to avail a web-based mapping interface. The interface would enable the users to update the data, visualize the data and utilize other capabilities in the system including outputting maps. Also to achieve its main goal a general website was created to host the mapping interface and also be used to relay additional water resources information.

IV. SCOPE OF THE STUDY

The study focused on management of the water resources information in Kenya. First was to investigate and analyze how water resources are managed in the country. This involved identifying the various stake holders and their responsibilities in the process. One of the major players in the water resources management was found to be the Water Resources Management Authority (WRMA) whose primary role is monitoring and assessment of water resources.

The organization was found to be facing major challenges in managing water resources information. The research then focused on addressing these problems by developing a web based water resources management information system. The system was developed using various open source technologies and by use of geospatial softwares.

The geographical scope of the study was limited to cover Athi River catchment which is one of the six main catchments in Kenya. The catchment lies in one of the five main drainage basins in Kenya which is the Athi river basin. The catchment covers Kiambu, Nairobi, Kajiado, Machakos, Kitui, Makueni, Kilifi, Taita Taveta, Tana River, Kwale, and Mombasa counties Fig.2.

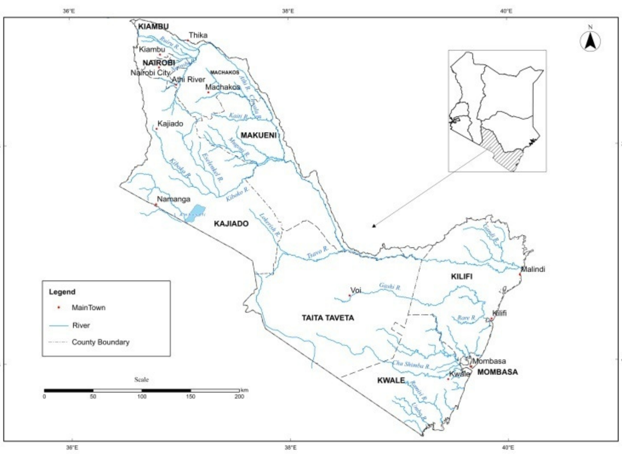

Fig. 2 Location of Athi River Catchment Area showing counties administrative boundaries, major rivers and the major urban centers.

V. METHODOLOGY

The approach taken to achieve the set objectives involved carrying several steps: user need evaluation and data collection, data processing, system development and system implementation Fig. 3.

The first phase involved the collection of relevant data as per system user need evaluation. The data was obtained from various organizations dealing with management of water resources.

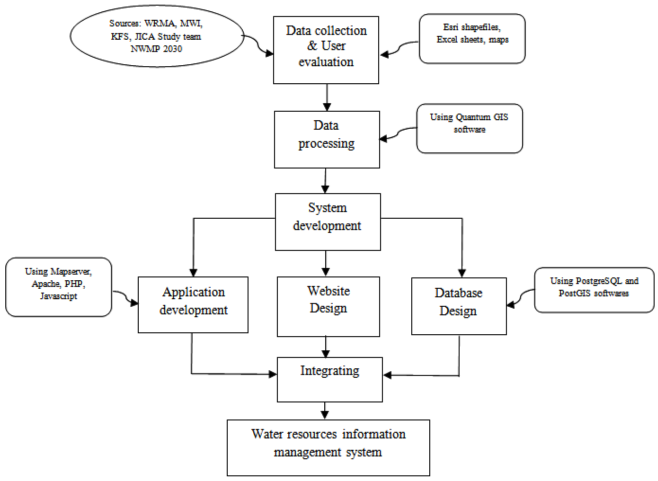

Fig. 3 workflow diagram

The data was in different formats depending on the type of data and the source or organization from which the data was obtained as shown in Table I.

Table I Data type, format and source

Data	Type	Format	Source
Rainfall, surface and ground water monitoring stations	primary	Microsoft Excel sheet	WRMA and MWI
Rivers	primary	Esri Shapefile, Maps	WRMA and JICA study team
Dams	primary	Microsoft Excel sheet	WRMA and MWI
Forest	primary	Esri Shapefile	KFS
Wetlands	primary	Esri Shapefile	MWI
Floodplains	primary	Esri Shapefile	MWI
Major pipeline	primary	Esri Shapefile	WRMA and JICA study team
County, district and division water resources information	secondary	Microsoft Excel sheet, Microsoft Word	WRMA, MWI and JICA study team
Catchment water resources information	secondary	Microsoft Excel sheet, Microsoft Word	WRMA, MWI and JICA study team

The data collected was then converted to the desired formats. The spatial data was linked to respective non spatial data. To process the data, Quantum GIS software was used. The processed data was then imported into PostgreSQL database. The data stored in the database was then used in system development. System development involved designing the database, building the web-based mapping application using Mapserver, designing a website using Joomla and integrating all this to makeup the system. The last step of the methodology was testing the system on a local area network. This was done to evaluate the various features of the prototype against the user needs evaluation and the various refinement needed on the prototype were done.
Several OpenSource tools and technologies were used to develop the system. Mapserver for windows (ms4w) was used as the server on the localhost. Apache Web Server was primarily used to serve both static content and dynamic Web pages on the localhost. PHP script and Java scripts used to create web pages, application dynamic content, tools and functionalities. To create the database PostgreSQL and PostGIS were used. Quantum GIS was used to process the data and create the digital map.

VI. RESULTS AND DISCUSSION

Fig 4 shows the concept of the resulting water resources information management system. The system is centralized and hence accessible to all WRMA offices and other stakeholders.

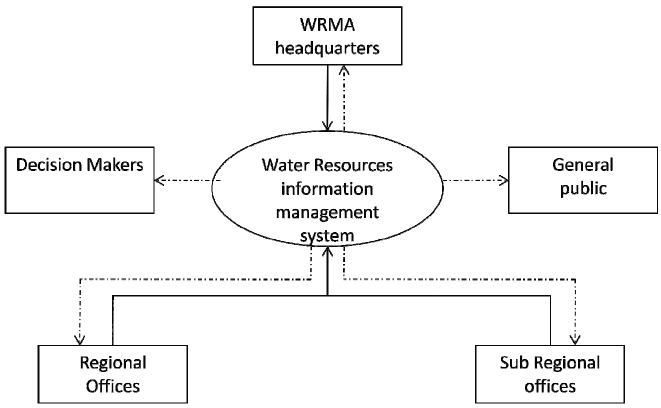

Fig. 4 Prototype system model

The resulting System had three main components. First component was the spatial enabled database which was single and centralized for use by all the WRMA offices. Several tables where created in the database and grouped into surface water, ground water, water shed conservation and administrative groups. The surface water group contained rivers, dams, surface stations, rain stations, major pipes and water transfer scheme tables. The ground water group contained boreholes and monitoring boreholes tables. The water shed conservation group had forests, wetlands, flood plains and deforested areas tables. The administrative group contained WRMA main catchments, sub regional management regions, counties, roads and major towns tables.
The other component was the main website. It hosted the mapping user application which was embeded on it. It also contained other information related to water resources management such us detailing the various functions of WRMA, describing other services provided by WRMA and also providing the instruction to various users on how to use the system. The other major importance feature on this component was the login section. By entering the various details required the user can access the mapping interface as illustrated by Fig 5.

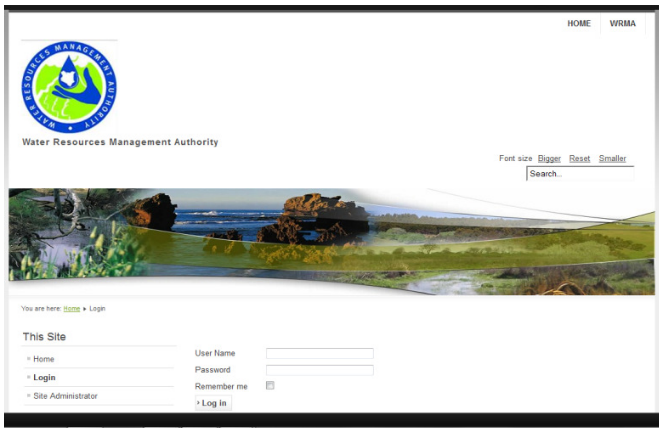

Fig. 5 Website welcome page showing the login section

The mapping component had various mapping features to aid the user in map viewing and navigation that included: Zoom to full extent ; this tool was used to view the whole map at the default minimum scale, Back and forward ; these tools allowed one to move back or forward to previous zoom level and hence help to locate point of interest on the map, Zoom in and out ; these are tools to allow one to increase or reduce the scale of the map so as to ease in locating features of interest, Pan ; this tool aid in navigating on the map and Clear selection ; tool used to make the map fresh again by removing selection made earlier. Fig. 6 shows the main interface of the mapping component.

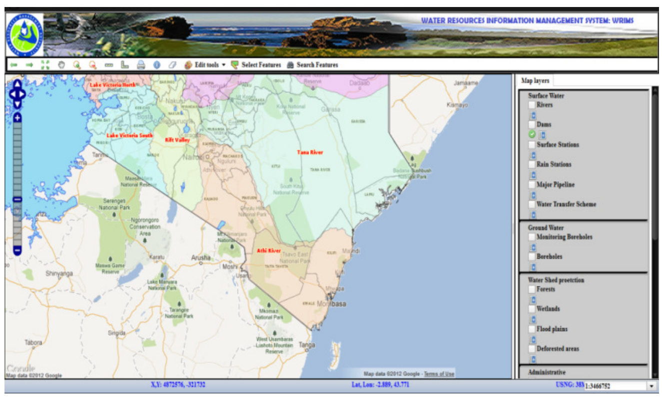

Fig. 6 Mapping interface showing map viewer section, various tools and map layers

On the mapping component also we had various capabilities that were added according to evaluation of user needs.
Data retrieval capability enables the user to obtain the information associated to various water resources and other features on the map. User is able to use the identify tool or the

select tool to extract specific data related to a given feature. The identify tool is used on a single feature while select tool is used when one wants to retrieve information of several features at same time Fig. 7 and 8.

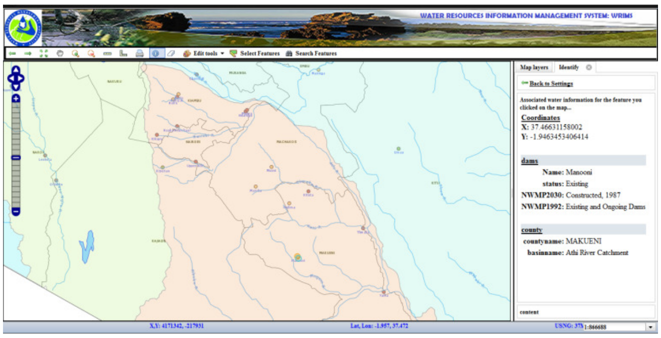

Fig. 7 Using ‘identify tool’ on a dam to get the associated information

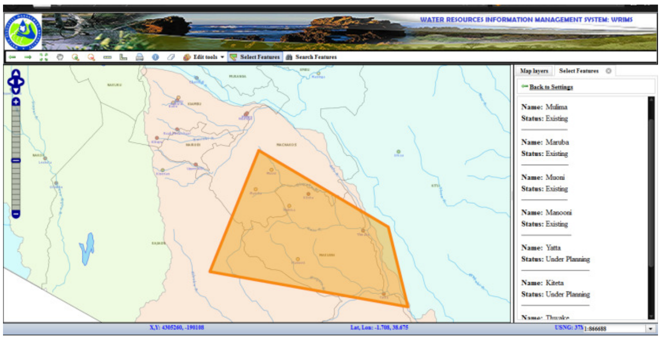

Fig. 8 Using ‘select feature tool’ on dams to get the associated information

Data visualization capability is also enabled on the system. The user is able to visualize the data againist a Google maps (street, physical and satellite) background as shown in Fig 9. This capability allows the users to better identify the location of various water resources features without the need of going physically on the ground to locate the features. Using this capability the users can also be able to detetmine if the various features for example the monitoring stations are located at the most optimal location or may require relocation. Also the users can be able to tell the condition of various water resources features without the need to carry out a field assessment by viewing them againist the google satellite images background.

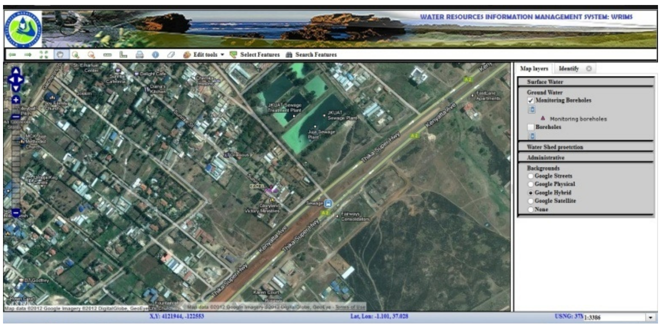

Fig. 9 Visualizing the location of a monitoring borehole

To use the printing map and downloading map capability, the user zooms into his area of interest the map at the required scale. Then using the print tool on the tool bar he can be able to print or download the map. The user is given an option to view the map in either image or HTML format Fig. 10.

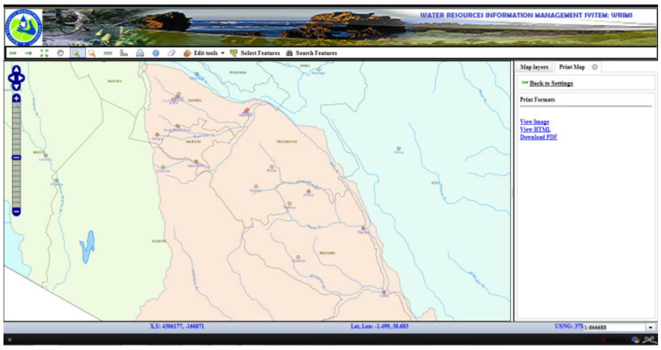

Fig. 10 Printing and downloading map options

Data export capability is only available to system administrators and other high level users. To export the data one has to login into the database web interface, select the table and then choose download option and export into Microsoft Office Excel format Fig. 11.

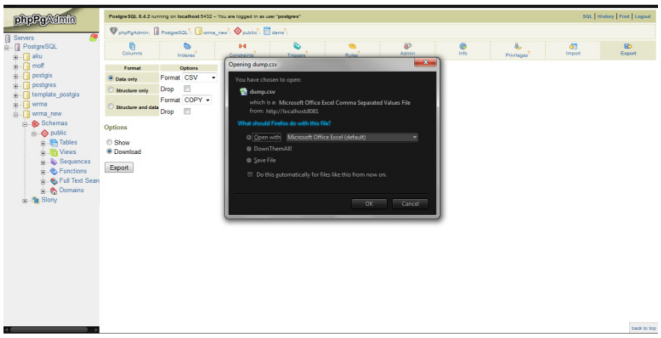

Fig. 11 Exporting data into Microsoft Office Excel format

Search feature tool provides the find specific feature capability. Using this tool the user can search for specific feature information from the database. The user can either use input that ‘belong to’, ‘begins with’ or ‘exactly matches’ the label of the feature Fig. 12.

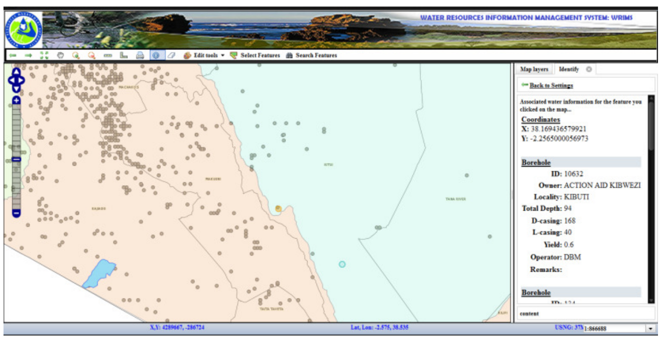

Fig. 12 Search results for a borehole

The users can also be able to edit the data in system directly on the mapping interface. By using the edit tool the user can add point, line or polygon. He can also be able to edit the attributes of a given feature Fig 13.

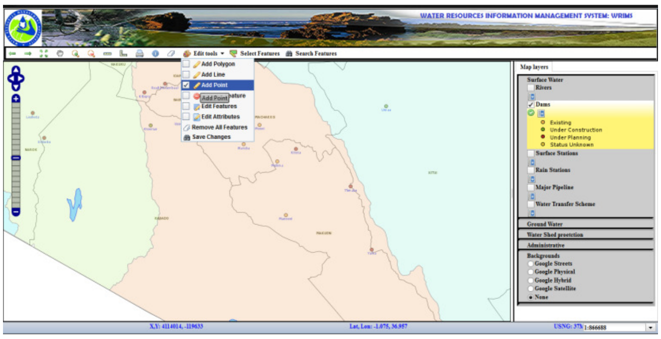

Fig. 13 Using the feature edit tool to add a point

The users can also be able to carry out length and area measurement on the map using the length and area measurement tools respectively. The length can be measured in various units that include; feet, yard, inches, meters and kilometers. The area can also be measured in square feet, square yards, square meters, square kilometers and square miles Fig. 14.

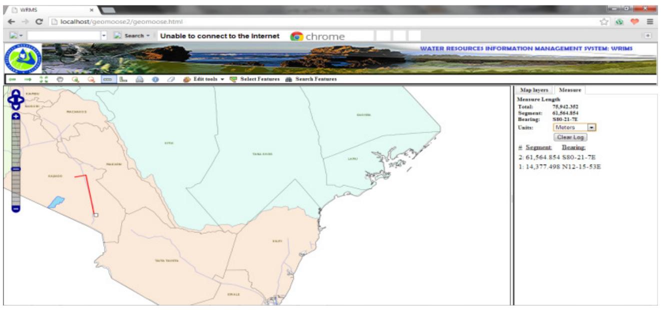

Fig. 14 Measuring the length of a pipeline

VII. CONCLUSION

The study lead to the development of a Web-based water resources information management system (WRIMS). The system offered a solution to management of water resources information, by providing one shared database hence reducing duplication and lowering maintenance cost. It also offered a mapping interface that ensures WRMA leverages advancement in GIS technology in its service delivery. The system also offers a streamlined flow of information by having one system accessible to all WRMA offices hence ensuring there is well structured process of collecting, storing and disseminating information.

From the study one can draw conclusions that Web-based GIS is a prospective application in GIS and represents an important advancement over the traditional desktop GIS. Its application eliminates duplication and inconsistency and makes location information conveniently and intuitively accessible across organizations, at a lower cost per user. Internet provides a medium for processing geo-related information and spatial information to users at an amount larger than traditional GIS.

The study lays the foundation of proper management of the water resources. It aids in realization of the social strategy under The Kenya Vision 2030 in developing water and sanitation sector which is one of the key social sector. This project can be extended to create a nationwide WRIMS that can provide services for a wide range of users, starting with government institutions and ending with private individuals.

Further improvements of the system could be made to include more water resources information and also capabilities improved to carry out analysis using the available data. Also the systems functionality can be improved such that it supports all of the procedures that are involved in the water resources management like allocation of water use licences.

ACKNOWLEDGEMENT

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