The management of water distribution network using GIS application case study: AL-Karada area

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Abstract. Clean water supply is one of the major factors contributing significantly to society's socio-economic transformation by improving living standards, health, and increasing productivity. It is imperative to plan and construct appropriate water supply systems in modern society, which supply various segments of society with safe drinking water according to their requirements to ensure adequate and quality water supply. In the current study, here was an attempt to develop a model for geographic information systems to manage the assets of the water distribution networks in the Karrada region and to evaluate the network geometrically, and from the results of the engineering analysis of the network it was found that the network does not contain engineering errors and depends on scientific and engineering foundations, and many tools have been used and a number of orders to manage the water distribution networks, inquire about their assets in full, and explain the importance of using these tools in order to inquire about the possibility of malfunctions in the network and help maintenance professionals in this and take immediate action to identify problems (for example, in the case of broken pipes, service areas ) In the system followed by rapid solutions to optimize network maintenance work, providing a framework for continuous improvement. Finally, the study recommended the authorities to establish a comprehensive central database for water networks with continuous updating of it, and to take advantage of new updates of water distribution networks management programs to help maintenance professionals to monitor faults in the network.

Key Word: Water supply, GIS Application, Management, Analysis

1. Introduction

Water is one of the essential elements of life, from early day’s men soon realized that rivers and streams in their natural states seldom provide, adequate water to satisfy their needs. Water is vital for human existence, without Water there is no life on earth [1]. In the last century, rapid technological and economic developments have led to the emergence and spread of many human settlements worldwide. However, It should provide basic amenities needed for the people who live in there. A system for distributing water can be described as a complex and centralized collection of components. as a basic and yet most complex infrastructure in all cities. [2, 3].
There is an increased need for advanced water networks due to modern technological requirements and environmental concerns. The other issue involves water provision and waste systems management. One common problem that produces one major interruption is the water pollution brought about by a leak. The maintenance staff should be ready to come to the scene as soon as the outage occurs in order to minimize the citizens who are temporarily impacted. Because speed is crucial, then maintaining the most efficient and effective method of solving the problem is essential. The application of Geospatial Information System (GIS) in the area of water management could possibly make all the difference for residents who have issues concerning their water services. [4, 5]. GIS is a way to store, retrieve, manipulate, analyse, and display all kinds of data, whether it is over the internet or on paper. There are various fields and institutions which have contributed in non-linear terms to the GIS area over the past 40 years, which today makes very strong and widely used GIS [6].

Changes in the utility world and explosion of data require more sophisticated ways to manage, examine and communicate useful information. ArcGIS for Utilities is a powerful toolkit that combines the power of data management with analytic programming tools to create interactive maps and apps. [7]. In keeping with the spatial nature of water resources, GIS is advantageous for enhancing water models. Another good part of GIS is that it can accurately figure out the water networks from existing databases and produce reports and graphical information based on it. [8]. With the rapid growth of the Internet and online devices, many successful efforts have been made to solve operational problems in various areas. [9, 10].

A web-based online system offers all-round access without the need of a particular application to software data and utilities, and can run the operations requested simultaneously by a large number of users. [11]. The majority of water distribution network software applications currently depend on the desktop and on their data version [12]. One of the most frequently used GIS solutions for water utilities is the Water Utility Network Application. First, the most expensive, and longest step in GIS implementation. Water Utility Network Reporting tools provide network tracking, profiling and export besides increasing the speed and quality of data edition. The editing and reporting tools enhance the core functionality of ArcGIS [13].

In this study, a geographic information system will be developed to manage water supply networks in Al-Karrada region, with the R9 network taken as a case study for this research. The aim of proposing water supply systems is to facilitate the management of water works by helping to save the recorded numbers of the quantities of water leaked from the network and provide information about All parts of the water network, such as pipes, valves, etc., and assisting the concerned authorities in making the correct and orderly decisions regarding the development and operation of water networks

2. Material and Methods

2.1. Case Study Description

Al-Karada water supply is located near the zone of Al-Rasafa section on the eastern bank of the Tigris and has an area of 11.96 km² and the population of 92400 capita, as shown in Figures 1 and 2. Water supply network R9 is supplied from Sharik Dijla treatment plant by the main transmission pipeline and from Al-Jadria & Abu-Nuass Compact Unit as show in Figure 3. R9 network supplied potable water to the districts (901,903,905,907,909,911, 913,915, 919,921, 923,925,929) in Al-Karada sector, [14].
Figure 1. Sector from Baghdad city represent Al-Karada water supply (R9 ZONE). [15].

Figure 2. R9 Zone and location. (Researcher’s work by GIS).
2.2. Data collection

2.2.1 Data for water supply network management

The data and plans used in this research were obtained from the Baghdad Water Department or its affiliated sites from other departments not linked to the Municipality of Baghdad such as the Ministry of Planning and the Ministry of Trade to obtain data on population densities as well as historical data about the net water network and the companies that installed these networks.

2.2.2 GIS network element data

- There are three kinds of network elements:
- The Edges are elements that connect to other elements (junctions) and are the links over which resources flow.
- The Junctions connect edges and facilitate navigation from one edge to another.
- Turn elements record information about movement between two or more edges.

Edges and junctions form the basis of any multilayer network. Connectivity in a network addresses edges and interconnections. Turns are optional elements to store information on a particular rotational movement, for example, a turn from one specific edge to another is limited [16].

The information about network elements includes, Pipes (length, roughness, diameter, and material) Pumps (number of pumps in the pumping station and pump curve or pumps characteristics),

Figure 3. The project and compact units feeding R9 water network, (Researcher’s work).
Valves (minor losses coefficient, material type of valve, type operation, diameter), Reservoir (number of compartments, volume and connections, shape, elevation), [17, 18].

2.3. Geographic information systems for Water Utilities

It is a collection of Esri products specifically designed for a water utility and organized through workflows that integrate the five GIS patterns to meet business needs. These types of workflows in focus maps and applications (apps) help utilities improve operations and enhance customer service through the use of geographic information, [19]. ArcGIS for Water Utilities includes a few ArcGIS for Desktop solutions for editing water networks and ensuring the quality of the data:

1) Water Utility Network Editing: Tools for comprehensive distribution of water, wastewater and storm water can be used by the mapping technicians. The toolbar contains a range of tools that make data editing much faster when working with infrastructure data, as shown in Figure 4.

2) Data Reviewer for Water Utilities: is a preconfigured set of data checks for performing quality control.

2.4. Geographic information systems and exist water network

There is a significant increase in the use of geographic information systems software in analysing water distribution networks. This part of the project explains how to deal with water distribution systems using geographic information systems, taking the water distribution network for the Karrada region as a case study, [20]. To clarify the existing water distribution system in karada, the interview is made with the head, manager, and water networks operators to clarify WDS and de- scribe O&M system which the municipality depends on for management water networks, [21]. Arc GIS 10.4 was used in the process of water network analysis and generation of the engineering network required to develop the geodatabase and utility network analysis and water utility network editing and as following:

1) The triangle of irregular networks (TIN) for the al-Karrada region was found as shown in the following Figure 5.
2) The main water pipeline network has been established and Water sources and reservoirs for the R9 network are located as shown in Figure 6.

![Figure 5. TIN For Al-Karada region (Researcher’s work by GIS).](image1)

![Figure 6. Al-Karada Distribution Network (Researcher’s work by GIS).](image2)

3. Result and Discussions

3.1. Analysis of the pipe lines of the Al-Karrada distribution network

The equation (Hazen-Williams) and roughness factor used in the analysis of flow velocities inside the distribution network depend on the line diameter and the type of line material. For this purpose, the pipe lines of the AL-Karrada water network were analysed, [22, 23]. The results as show in Table 1.
Table 1. The result of pipe line analysis (Researcher’s work).

| objected | Diameter (mm) | material    | c  | Sum. Length (m) |
|----------|---------------|-------------|----|-----------------|
| 1        | 1200          | Ductile Iron| 120| 5315.98         |
| 2        | 900           | Ductile Iron| 120| 1701.20         |
| 3        | 800           | Ductile Iron| 120| 849.52          |
| 4        | 700           | Ductile Iron| 120| 2010.19         |
| 5        | 600           | Ductile Iron| 120| 3309.41         |
| 6        | 500           | Ductile Iron| 120| 683.95          |
| 7        | 450           | Ductile Iron| 120| 2794.39         |
| 8        | 400           | Ductile Iron| 120| 4395.32         |
| 9        | 300           | Ductile Iron| 120| 3167.93         |
| 10       | 250           | Ductile Iron| 120| 2276.5          |
| 11       | 200           | Ductile Iron| 120| 387.33          |

3.2 Geometric Network Editing

Geometric Network Editing in ArcMap helps to analyze network architecture, connectivity, and fix errors. [26], Figure 7 shows the engineering analysis of the study area as it turns out that it is free from engineering errors.

![Geometric network analysis result for Al-Karada network (Researcher’s work by GIS).](image)

3.3 Water Network Management

Utility Network Analyst and water Utility Network editing can be used Distributing the water signed to the geographic information systems program to perform a number of tasks that can be done, through which the existing water network is analysed and managed and inquire about assets completely [24]. And, these systems can provide answers to specific questions related to network elements such as pipes, valves, pumps, etc. They can also perform a number of tasks through which the existing
drinking water networks can be analysed and managed through several analytical commands available in the system, [25], as follows:

3.3.1 Flow Direction Tasks Analysis.

Knowledge of the water flow direction along the lines or borders is essential for water network applications. The flow direction in the network determining the flow direction in each line in the network determines the direction in which the flow direction is determined, in addition to the determination of possible and not possible characteristics, by connecting network lines and determining the locations of the sources and drains of the network. The direction of flow in the R9 network water lines has been determined as shown in Figure 8.

![Flow Direction Analysis](image.png)

**Figure 8.** Flow direction analysis result for Al-Karada network (Researcher’s work by GIS).

3.3.2 Connected or disconnected network elements analysis.

To find which part of the water network is disconnected and use that information to find how to reconnect it. Figure 9. shows the result of the connected analysis, Where the red line indicates that the network is connected.
3.3.3 Path Upstream Analysis

This analysis determines the path of the water transported from the source point to the specified point (point of failure, for example) in order to identify defective pipelines. Figure 10. shows the result of the analysis of the path task for Al Karada network, as it shows the path of water from a source in the event that there is a specific fault point in the network.
3.3.4 **Looped or circuited network elements analysis**

This analysis is used to determine the pipelines connected with each other in the form of Loops (closed circles), where the presence of water pipes in an annular form leads to the problem of low water pressure in the pipelines due to the conflict of directions of water inside the device, Figure 11 show the result of analysis for loop task analysis for Al-Karada network Where the red line indicates loops in a network.

![Figure 11. Looped Network Analysis Result For Al-karada network (Researcher’s work by GIS)](image)

4. **Conclusions**

In this study, there was an attempt to develop a model for geographic information systems to manage the assets of the water distribution networks in the Karrada region and to evaluate the network geometrically, and from the results of the engineering analysis of the network it was found that the network does not contain engineering errors and depends on scientific and engineering foundations, and many tools have been used and a number of Among the recent orders to manage the water distribution networks, inquire about their assets in full, and explain the importance of using these tools in order to inquire about the possibility of malfunctions in the network and help maintenance professionals in this and take immediate action to identify problems (for example, in the case of broken pipes, service areas ) In the system followed by rapid solutions to optimize network maintenance work, providing a framework for continuous improvement. As for the most important conclusions and recommendations that we reached, they were as follows:

1) The applications of geographic information systems technology for the design and effective management of networks Water distribution is nowadays used in many areas, which is a very important issue. the authorities to establish a comprehensive central database for water networks with continuous updating of it, and to take advantage of new updates of water distribution networks management programs to help maintenance professionals to monitor faults in the network

2) The rate of significant increase in population in developing countries compared to the severe shortage of Quantities of water forced engineers to rethink more effective ways to manage
Water network assets, the use of GIS applications has been from Successful keys that helped in an integrated way to solve this problem.

3) The proposed project will assist municipalities and stakeholders in managing and operating water networks efficiently, and in developing a long-term plan for financial projections to develop and maintain network assets as part of the process of adopting continuous improvements to water network assets management.

4) As this system provides coverage for the entire life of water networks, starting from planning to switching, and is useful at the same time in forecasting and future projections for networks, so the analysis process can be performed to manage assets up to 10 to 40 years, and it also gives the manager and engineers the opportunity to make adjustments and the necessary expansions in a way that ensures high efficiency in the management process of water networks.

5) The use of geographic information systems in managing the assets of the water distribution networks gives more accurate results if linked to other programs related to hydraulic analysis the design and management of water distribution systems like (water cad, epanet software’s)

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