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RESEARCH ARTICLE

INTEGRATION BETWEEN GIS MODEL AND WATER DETECTORS FOR MONITORING AND MANAGING OF WATER NETWORK IN KHARTOUM CENTER AREA

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ABSTRACT

The core of this paper is to integrate between a Geo-database model and detector instrument (version-XTpc pipe and cable locator, and HWg-WLD detector) for monitoring the network operation; breakdowns, leakages, flow and pressure variations can be adopted and linked directly from cable telephone line(or wireless internet service) to a control room. HWg-WLD detects water leaks or water floods along the entire length of the sensing cable. The sensing cable detects even the smallest volume of water; HWg-WLD features a built-in web server. In case of an alarm, the device sends an e-mail to the manager of the control room. The computerized model of the Khartoum Center Water network is established have a lot of benefits of an automated system, i.e. high capacity storage; easy retrieval, easy plotting the breakdowns and leakage location for quick maintenance. This model also has a benefit of updating are gained. This Geo-database model of the study area consists of different diameter sizes of pipes, valves, detectors, and flow control valves. Finally, this paper highlights the importance of GIS techniques for water utility monitoring and management. Besides the open source tools of GIS (ArcGIS10.1) can be effectively utilized for the creation of an online water information system which can provide necessary input at all levels for effective decision making.

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INTRODUCTION

Drinking water entailed huge challenges for the Khartoum governmental water supply system, which this section outlines in more detail. Two main sources of drinking water exist in Greater Khartoum, which has an arid desert climate, groundwater and river water from the Nile. Groundwater is recharged by rainwater to a small extent, and by the Nile to a greater extent [Njiru, 2004]. Accordingly, drinking water in Greater Khartoum is produced by groundwater wells of varying depth and productivity, and by water treatment plants, which extract river water from the Nile.

Leak detection and GIS program can lead other important water system activities, such as:

- Inspecting hydrants and valves in a distribution system in the study area;
- Updating distribution system maps;
- Using detectors for ongoing monitoring and analysis of source, transmission, and distribution facilities. Remote sensors and monitoring software can alert operators to leaks, fluctuations in pressure, problems with equipment integrity, and other concerns; and
- Inspecting pipes, lining, and other maintenance efforts to improve the distribution system and prevent leaks and ruptures from occurring [Georgia Environmental Protection Division, 2007].

Statement of Khartoum Water Supply System problems: The study is focused on the Khartoum center area, because this area represents the most importance area in the grater Khartoum state. The major problems of the Khartoum Water Supply System, which are caused by many factors such as:

- A lot of Maps and records of the transition and distribution system are incomplete and inaccurate, hampering the ability of Khartoum State Water Corporation (KSWC) personnel to efficiently operate and maintain the system and respond to the emergency.

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- Absence of leak detection methods: some water losses occur due to lack of efficient methods to detect the location of the leakage quickly.
- The difficulty of identifying the exact location of the faults, and the control valves due to heaps of dirt accumulated goes on as time.
- Most of the network pipes are of small diameters; this should be replaced by suitable diameter size, taking into consideration the high-rise buildings.

Objectives of Paper

This paper is included of many objectives

- To Establish a computerize data archiving system and thus all the benefits of an automated system, i.e. high capacity storage, easy retrieval and updating are gained.
- To monitor water pipe lines by water pipeline network leak detectors(version-XTpc pipe and cable locator, and HWg-WLD detector)
- To minimize leakage in Khartoum center water network and Improved operational efficiency.
- To establish accurate and comprehensive model of network information for monitoring, reporting, decision making and data interchanging.

Literature review

Background and previous studies about the water network in Khartoum center: The water distribution system of Khartoum center is considered as loop network, because it is designed to provide a continuous flow of pressurized water throughout the network, even when some sections of the network are temporary insolated for repair and replacement activities. Operating a water system valves can isolate areas of the water network. The looping of the water mains requires fittings such as Ts and crosses to connect multiple pipes at a junction. Other fittings, such as couplers, bends, and reducers, permit the connection of separate physical pipe segments. In Khartoum center there are 14 streets running East / West and 25 streets running North / south. Town pipe of 21" diameter (cast iron) coming from the Mogran Water Treatment plant (WTP) Feeds the western part of Khartoum. The 18" main pipeline in El Sayyed Abdurrahman street (throttled to 16" diameter),feeds the inside distribution network of small diameters(8",6",4") inside the center. From Burri WTP four transmission main lines (two 16" diameters and two 14” diameters), feeds the eastern part of the center through Osman Dignah Street (10"diameter main). From Mogran WTP two transmission main lines 21" diameter, constructed in 1964, feeds the southern part of Khartoum (outside the study area). A new fiberglass network funded by an Italian grant was constructed to cover the city center with 24" maximum diameter and 10" minimum diameter. Only two lines of this new network (one with 10" diameter along Algamaa' a street and the other of 14" diameter along Salih Basha street) were operated, due to insufficient water supply [Elmasri and Navathe, 1994]. The water sources in Khartoum State consist of two main types: surface (Rivers) and sub-service (boreholes). At present, in Khartoum center sub-surface water is used no more. Sub-service water sources are scattered in some local residential areas around the center, with a total supply of 125000 m3/day production. Table (1) shows the supply of the five treatment plants, which indicates that the total supply of Greater Khartoum is 541000 m3 /day. A proposed Water Treatment Plant (WTP) at Suba (south of Khartoum) is used to feed the network by 300000 m3 /day. When this is finalized the total supply will satisfy 80% of the real need. According to the feasibility study named as" Khartoum Area Water Project" conducted by Gannet Fleming Corddy and Carpenter Inc. Under financial Corporation of the World Bank released in 1978-1979 (simply called "the 1979 study report") the water demand was estimated as 165900m3/day in 1988. The population at that time was 995000 [Gannet Fleming Corddy and Carpenter Inc feasibility study, 1988]. At the present, the population is estimated at 6.2 million. The study report covered the analysis of existing facilities and forecasting the future water demand, establishment of project design criteria, preliminary design, cost estimate and financial planning with a minimum cost water supply target in the year 1993. After the 1979 study report several studies were conducted for rehabilitation and / or expansion. Table (1) is shown the estimation of water Demand in the years 2000-2025 for Khartoum center.

Basic Components of Khartoum Centre Water Network: In general, the distribution system comprises a network of pipes of different sizes and types, valves, ground tanks, elevated tanks, booster pumps… etc. The system delivers water for domestic, commercial, industrial and fighting fire purposes. Elevated storage tanks or underground reservoirs with booster pumps used to reserve water for peak periods of consumption and fire fighting. Safety valves are located at strategic points throughout the piping system to provide control of any section or service outlet, including fire hydrant. These valves are used to isolate units requiring maintenance and to ensure that main breaks affect only a small section of the network. A service connection to a residence includes a corporation stop tapped into the main, a service line controlled by a shut off valve and a water meter to register water consumption. In this paper the Khartoum center water network was consisted of different components [Abd Elgadir Ahmed Awadalla, 2003]:

The main sizes of existing water pipelines of Khartoum center consist of different sizes of pipes such as Town pipe of 21" diameter (cast iron) coming from Mogran WTP Feeds the western part of Khartoum. The 18" diameter, 16" diameter, 10"diameter, the inside distribution network of small diameters (8", 6", 4") is established inside Khartoum center area. There are wide varieties of pipes materials and pipe coupling used for water systems. The study area is presented by ArcGIS10.1) the most common types and their relative coupling, which are used in Khartoum city center, are:

- Cast iron and Ductile iron couplings**;**
- Asbestos Cement (AC) Pipes couplings;
- Steel pipe couplings;
- Polyvinyl chloride (PVC) Pipes couplings;
- Polyester (plastic) and
- The Valves (Flow control valves, Check valves, Pump Control valves and Plug Valves) [Abd Elgadir Ahmed Awadalla, 2003].

XTpc Pipe and Cable Locator: This detector is used for precise underground locating of utilities including cable TV lines, fiber optic lines, gas lines, irrigation lines, tracer wire, power lines, streetlight wiring, water lines and sewer lines. Cable and pipe detectors have both a transmitter and a receiver. The transmitter induces an electric current that circulates through an object creating a magnetic field, which is then detected by the receiver (See Figure 1). The XTPC is made in two frequencies. In general, 82 kHz is useful in tracing gas and water lines while 33 kHz is a better choice for tracing electrical lines. You select a single frequency before purchase [www.schonstedt.com/wp-content/uploads/2014/ 04/ XTPC-BROCHURE1.pdf.].

HWg-WLD water leak detector: Figure 2 shows the usage of HWg-WLD detects water leaks or water floods along the entire length of the sensing cable. The sensing cable detects even the smallest volume of water, ethylene glycol, or other conductive liquid. HWg-WLD can be ordered in two versions depending on the supply of power (power adapter or PoE IEEE 802.3af).The sensing cable detects as little as a few drops of the liquid, and can be used to detect condensation. After flooding, the cable can be dried and reused. HWg-WLD features a built-in web server and SNMP support. In case of an alarm, the device sends an e-mail or SNMP trap. Alarms can be also signaled by switching a remote relay over the Ethernet. When a leak is detected, HWg-WLD activates a relay of a remote Poseidon [www.hw-group.com/products/HWg-WLD/ WLD_water_leak_detection_en.html.].

The switch can be turned on remote alarm signal if water detected over the network Details on the last page of a starting guide section. The steps of connecting the cables include:

- Connect the unit to the Ethernet (patch cable to a switch, or a crossover cable to a PC).
- Plug the power adapter into a power outlet and connect it to the HWg-WLD power connector.
- Greener Power & Mode LED in the RJ45 connector lights up.
- If the Ethernet connection works properly, the LINK(yellow) LED lights up after a short while, and then flashes whenever data transfer takes place (activity indication).
- After power up, the LINK LED flashes rapidly to indicate the IP address negotiation over DH.

Marko and Ivan Zvonimir in 2005 are reviewed the technique of leak detection in underground water pipeline only without GIS in Croatia country [Marko, 2005]. Osama Hunaidi in 2000 has used the technique for leak detection in underground water pipeline in Canada [Osama Hunaidi, 2000].

MATERIALS AND METHODS

Study area: The urban study area which is selected as a case study is a central of Khartoum among of Al Nile road from the north direction , Alimam alhadi road from south direction, Armed forces bridge from the east direction and white Nile bridge from the west direction. The urban study area equals (5.940) km^2. Reference spheroid for the coordinates of the study area is Clarke 1880, Universal Transverse Mercator (UTM) Projection. Grid zone is 36, and Adindan Datum. The water network data were established in the base map by ArcGIS10.1 according to the actual coordinates (See Figure 5).

Methodology steps: The base map of the study area and all services together with collected data have been stored in an ESRI geodatabase structure made up of classes and subclasses. This document is not intended to describe how geodatabases work or how they are designed. However, it is important to have a general understanding of how a geodatabase is organized. The following major terms are important for understanding how the geodatabases are designed and organized. Figure (3) shows a flow- chart diagram of the methodology of the research comprising data collection, database building, scanning, vectorization, editing, constructing topology, adding attribute data, constructing of geodatabases and data entities of the study area model, analyzing data, laying out, and plotting. In this paper, all these steps of Khartoum water pipeline network model were performed using ArcGIS10.1 software. Major terms which are important for understanding how the getodatabases of a water pipeline network model of this paper were designed and organized (was illustrated in Figure (4)).

Establishing a computerized model of Khartoum center water using ArcGIS10.1: Database design is defined as an information system planning activity where the contents of the intended database are identified and described.

Database design is the information system planning activity where the contents of the intended database are identified and described. Database design is usually divided into three major activities [Lobban, 2007].

- Conceptual data modeling: to identify data content and describe data at an abstract, or conceptual, level.
- Logical database design: translation of the conceptual database design into the data model of a specific software system; and don't think so logical model is to put user requirement in a table field and records basically.
- Physical design: representation of the data model in the schema of the software in the hardware.

Ten Steps to Designing Geodatabases:

- Identify information products to be produced with your GIS;
- Identify key thematic layers based on information requirements;
- Specify scale ranges and spatial representations for each thematic layer;
- Group representations into data sets;
- Define tabular database structure and behavior for descriptive attributes;
- Define the spatial properties of your datasets;
- Propose a geodatabase design;
- Implement, prototype, review, and refine your design;
- Design workflows for building and maintaining each layer; and
- Document your design using appropriate methods [Tomlinson, 1994].

The Action Plan for Water Pipeline Monitoring System Implementation

GIS and Monitoring system: According to the geodatabase of the study area, Khartoum State Water Corporation (KSWC) must now devise a GIS Management Program for monitoring water pipeline by HWg-WLD Detector or an action plan for achieving them.

Table 1. An Estimation of water Demand in the years 2000-2025 for Khartoum center

Year	Population the center greater Khartoum area	Total State Demand m3/day	Khartoum Centre Demand m3/day	Khartoum Centre Demand %age
2000	797250	1,060,000	167472	15.8%
2005	847476	1,500,000	182207	12.1%
2010	900866	2,200,000	207199	9.4%
2015	957622	3,200,000	239406	7.5%
2020	1,017,952	4,750,000	279937	5.9%
2025	1,082,083	7,000,000	324625	4.6%

Figure 1. XTpc Pipe and Cable Locator

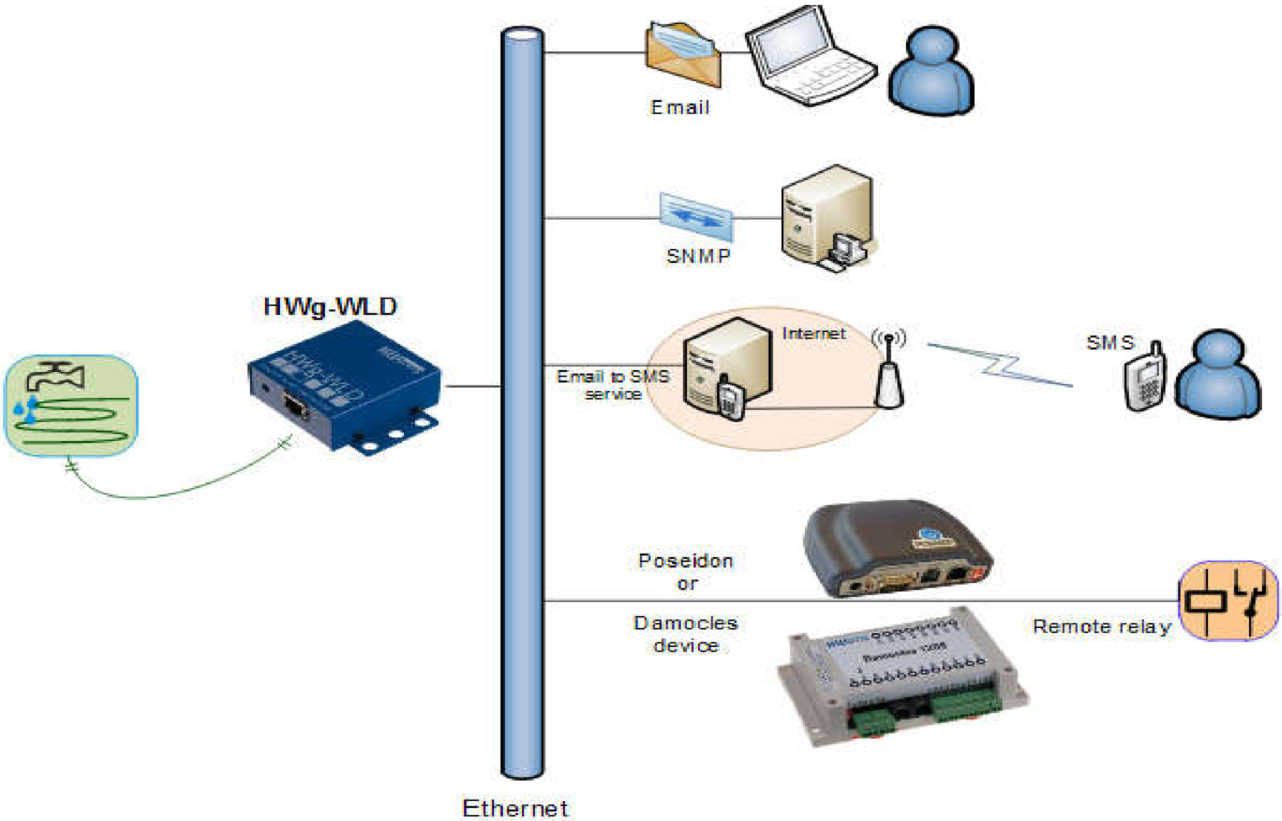

Figure 2. HWg-WLD Detector usage [7]

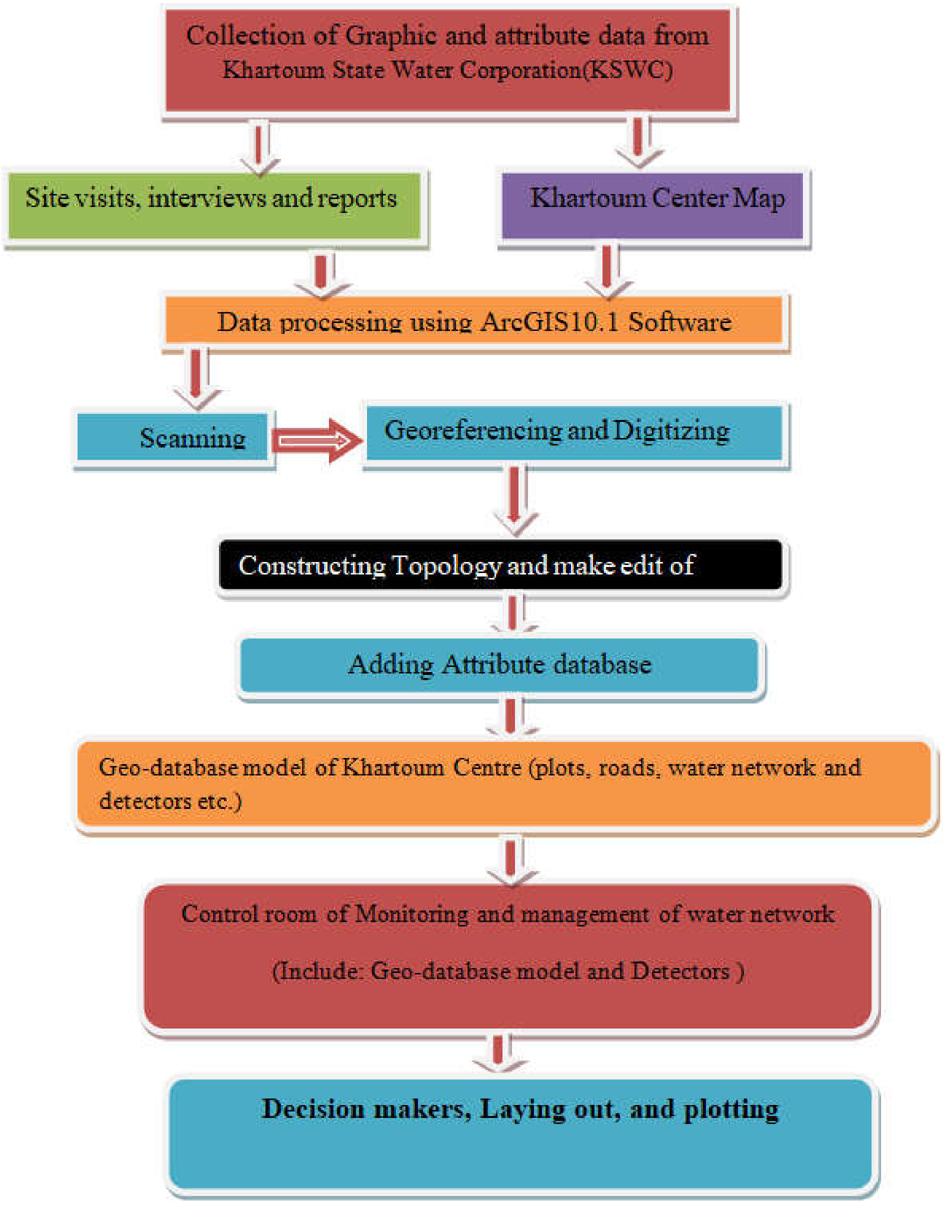

Figure 3. Chart diagram for methodology of the paper

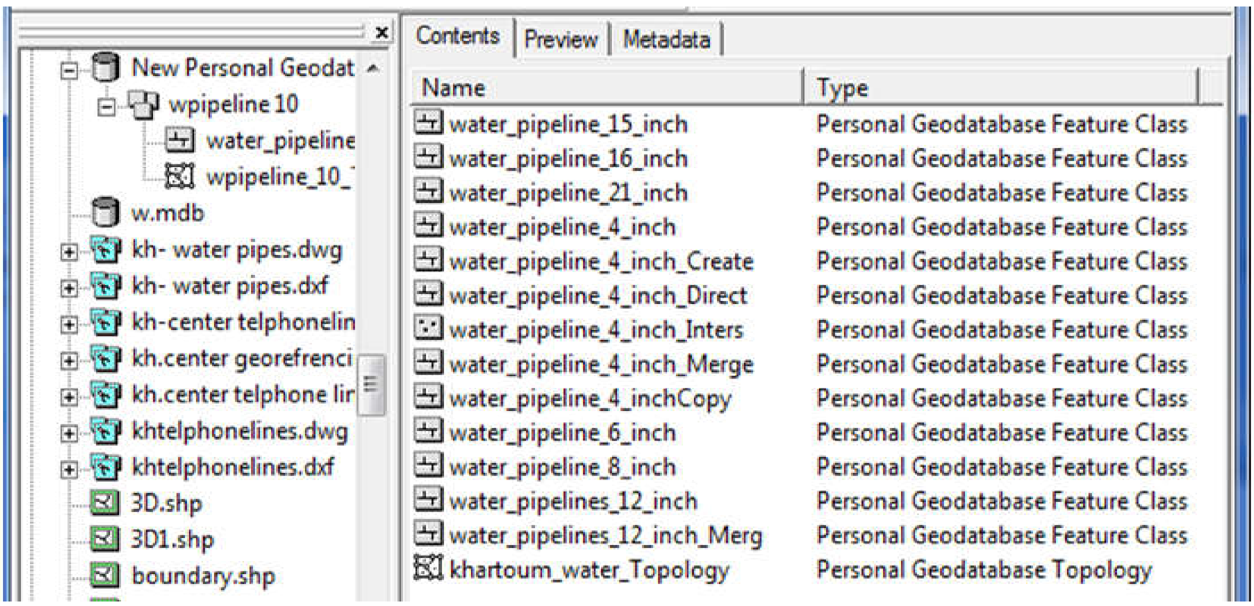

Figure 4. Khartoum Centre Water pipelines network Entities (ArcCatalog)

Figure 5. Layout of Khartoum center water network map

The action plan is a continuous procedure of analyzing, improving and applying this management system in most important areas of grater Khartoum and different states of Sudan. An effective action plan of Water Pipelines Monitoring and Management System (WPMMS) for any water supply company such as KSWC needs to include the following:

- A schedule or time-frame in which the objectives of WPMMS are to be achieved.
- Identification of the employees responsible for achieving them.
- Measuring performance and efficiency, according to the comments of customers in Khartoum State Water Corporation.
- Monitoring of the anticipated benefits resulting from improvements, including the high pressure of water in pipes during the winter season and shortage of water during the summer season that be directly measured by this system.
- Formulation and quantification of investment costs and a budget for all the various phases of Water Pipelines Monitoring and Management System (WPMMS)implementation.
- Creation of dates for first and subsequent assessments, a regular review of progress to assist in identifying issues which may need to be addressed or to which special attention needs to be paid to ensure success.

Implementation of WPMMS: It is the most important for Khartoum State Water Corporation to provide all the necessary human, technology and financial resources for the action plan to be implemented. Having done so, the key factors affecting the general operation and ongoing success of the Emergency Management System(EMS) would be as follows:

- All personnel need to be aware of EMS benefits, objectives, procedures and targets, therefore staff training is very important, it is very significant and immediately improves staff competency and quality of service.
- Establishing a good communication system internally and externally and a receiving/responding system.
- Establishing a database to keep records of all relevant environmental materials, including review and revision or updates when necessary.
- Produce documented operating procedures for activities and processes to meet objectives and targets, as well as procedures relating to the significant goods, products and services used by KSWC.
- Preparing a budget for each project's development, costs will include staff and employee time, training, including any necessary consulting assistance, materials and equipment. A regular assessment and review of the EMS should take place through the Management Review process and any necessary improvements incorporated back into the EMS to improve its operation. A report based on the minutes of a review meeting can be used as documentary evidence that the review took place, and this can be used as evidence in any subsequent audit. The report should include a statement explaining why the review was conducted - whether it was a routine review or instigated by special circumstances. The investigation is carried out in this paper showed the most important of drinking water in Khartoum center. To avoid the potable water losses, in addition to the random repair of the pipeline crevices, sophisticated measuring equipment should be bought, operators educated and the distribution network systematically analyzed [Detector Company Archive, Vodovod, Slavonski Brod.].

Conclusion

In this paper the tests were carried out investigating the possibility of using GIS technology and two types of water pipeline detectors in the monitoring and management of Khartoum center water pipeline network. Beside GIS, the detectors were used (version-XTpc pipe and cable locator, and HWg-WLD detector).One of them to locate cable and water pipeline and another used to discover the leakage in water pipeline.

The study recommended using these detectors, because having many benefits for water customers (and their suppliers) such as increased knowledge about the distribution system of hidden water pipe lines. Also can be used to respond more quickly to emergencies and set priorities for replacement and Lowered water system operational cost, more accurate and the price of these detectors isn't more expensive it's about 2418.445 USD. Moreover the validity of these tests would be increased if integration between detectors and digital database were adopted. In this integrated system, it is possible to exchange data between the different bodies supporting the multi-purpose system. There is a possibility of creating a water pipeline network digital database and plotting maps to be used for different applications. Applications are varied such as site selection, monitoring and managing system, and presentation on specific location of graphs and histograms, plotting maps for the site location of maintenance of water pipeline. The massage of leak in water pipeline can be adopted and linked directly from cable telephone line (or wireless internet service) to a control room.

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