Water Supply System Assessment in Urban Areas Using Geospatial Techniques: A Case Study of Baghdad City

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Abstract. This study shows, how to linked GPS, RS, LiDAR and GIS mapping facilities of urban distribute network, positioning of the water projects and the storage water reservoirs for the water supply systems, with consideration of the earth's surface properties, land-use change and ownership. Moreover, the use of the Global Positioning System (GPS) with Remote Sensing imagery in surveying, modernizing and developing Baghdad city complex water supply network is discussed. The data of land-use and current water supply system was generated using the Quick Bird Satellite Image (0.6m resolution data, 2015) with a map of the city of Baghdad at scale 1:25000 and field update survey. The necessary water supply system maps and data were collected from the Mayoralty of Baghdad (MoB). The Digital Elevation Model (DEM) and the contour map were generated from the LiDAR point cloud. All these techniques and geospatial data were mapped and analyzed in ArcGIS 10.2.2 software. The outputs of the study were the water distribution network with the position of projects, reservoirs, pipelines, etc. The interpretation of the geospatial database with analytical tools allowed the water distribution network to be planned more economically and effectively.

1. Introduction

Water is one of the most important natural resources, is vital for man’s survival and without it; there would be no life on earth as well as civilization cannot develop. The water is required for various uses of humankind such as drinking, domestic, sanitation, agriculture, industrial, power generation, etc. [1]. To provide for these various uses, the supply of water must meet the demand of the users, be satisfactory in quality and adequate in quantity, be readily available to users, and be relatively inexpensive. The total water requirement is on the increasing demand and the per capita water consumption is also on the increase due to population growth, civilization develops, and climate change. So there is a huge gap between supply and demand of water. Therefore, many people have faced massive challenges to meet the increasing demand of water [2].
During the past decade, the advancement of data acquisition technologies has led to a massive increase in the amount of digital geospatial data available. Geospatial techniques have been used wildly in infrastructure services, especially those facilities that integrate several spatial features. A well surveyed and planned water distribution network plays an immense role in the provision of water supply. A sufficient water distribution system is fundamental to environmentally sustainable development in any city. The design of water supply systems is one of these issues that can be mapping and analyses using GPS, RS, LiDAR and GIS techniques.

Water Supply System (WSS) is a complex system that integrates several spatial features and is part of the master planning of communities, counties, and municipalities. There are many factors such as location, land use, water distribution network (WDN), future growth, leakage, pressure, etc. are believed to be responsible for the frequent shortage of water supplies to the city [3]. Therefore, it should be well surveyed, modernized, developed, distributed and managed. Conference Geospatial in 2005 UK, while examining “buried services, more details about the problems of location, identification and geospatial positioning of a wide range of buried services such as water, sewers, gas, electricity, etc.

Geospatial technologies are the range of modern tools to geographic mapping and analysis of the earth and human societies through satellite imagery allowed image capturing, airborne LiDAR (point cloud) sensing technology and collect ground control points (GCPs) [4], in additionally, it is needed to use multi-support programs for geospatial technique of the data digital set. The fact that the location and geospatial positioning of engineering infrastructure, which include water infrastructure of major problems. Geospatial technological advancement has led to tremendous growth in the water supply system. It has not been translated into the improved water supply. This paper discusses some aspects of working on a geospatial technological-based WSS in urban areas.

2. Research Objective

The basic aim of the study is to illustrate the use of resolution satellite data along with GPS, LiDAR and GIS surveys for the water supply system in the Baghdad city. The objectives of the study are as follows.

- To determine the geospatial data required for the surveying, planning, modernizing or design of a comprehensive Baghdad city water distribution network and to produce the vector models of the water infrastructure.
- To examine the location and survey of water projects, reservoirs and distribution pipeline routes from source to the consumer level.

3. Study Area

Baghdad, the capital of Iraq, lies in the middle of Iraq. The geographical coordinate system extent of the study area is approximated 33°25'28" to 33°27'34" N latitude and 44°13'39" to 44°33'14" E longitude and Zone (38N). It covers an approximate total area 204.2 square kilometers according to the Mayorality of Baghdad (MoB). Baghdad relies on surface water specifically on the Tigris River, where the river runs from north to south to divide the city into two parts. The general geographical information of the city is a terrain of Baghdad has characterized nearly flat topography. The elevation varies from 33 to 37 m above mean sea level (AMSL) with an average elevation of 34 m AMSL. The area slopes down to the south with an inclination of less than 0.1%. Baghdad is the most populous city in Iraq and has a population of 7180889 inhabitants in 2018 according to the Central Committee of Statistics. The climate of the city is hot and dry with a limited winter precipitation pattern. Winter temperatures range between a maximum average of 18°C and a minimum average of 5°C, while summer temperatures range between a maximum average of 46°C and a minimum average of 25°C. Almost 90 percent of the annual rainfall happens between November and April, most of it in the winter months from December meantime March. The remaining 6 months, specially the hottest ones of June, July, and August, are dry. Rainfall measures only 42 mm/ year in the studied area, where it reaches an average of 185 mm/year. The study area is shown in Figure 1,
which represents Baghdad city utilizing satellite Quick Bird resolution 0.6 m (dated 2015). The water supply requirement of Baghdad was managed by a water Baghdad department.

![Figure 1. Location map of the study area.](image)

### 3.1 Geospatial Data

Many of these problems in urban areas can only be resolved with high quality field survey and analysis performed using Geospatial techniques. Geospatial data can be referred to data that identifies the geographic location of features and boundaries on the surface of the earth, such as natural or constructed features, and more. It is usually stored as coordinates and topology, and is data that can be mapped. The types of data to be collected depend upon user requirement and availability. Geometric data are usually collected in digital form from a variety source. Groot et al. 2000, linked geospatial data to geospatial data infrastructure, to encompass the networked geospatial databases and data handling facilities, institutional, organization, technological, sharing, access to and responsible use off geospatial data at affordable costs for a specific application domain or enterprise.

### 3.2 Geospatial data in water distribution network

Water distribution networks play an important role in modern societies being its proper operation directly related to the population’s well-being. Although the size and complexity of WDS may vary dramatically, they all have the same basic purpose, to deliver supply water from its source to the point of usage (consumer). The source of water usually determines the nature of collection, purification, transmission and distribution works. Common sources are rainwater, surface water and ground water. The distribution components form a large proportion of total costs in any water supply system [6]. Water distribution network contains all the various components of a water supply system. These components include water reservoir, water pipelines, water pumps, storage tanks, junctions, valves, and other appurtenances are required to convey water from the source to the users. Researches have shown that more than 80% of all information can be geographically referenced [7]. Geospatial data are the basic ingredient for the physical
planning, design and development of infrastructure [8]. Geo-spatial information, which exists in real world in terms of space (with location) and time, can be represented in the form of maps, databases and statistical representation [3]. Coordinates are geospatial data used to represent the location of natural or man-made features on the earth’s surface. They are set of values that define a position within a spatial reference [9]. Geospatial data plays a significant role in the surveying, planning, design, modernizing, location and maintenance management of water distribution infrastructure (WDI). Furthermore, most components of water infrastructure are referenced to the surface of the earth [10].

4. Methodology

The methodology is not a formula but a set of practices. The data type to be collected depends upon user requirements and availability. The data types collected were primary and secondary data. Primary data was collected by using remote sensing, a high resolution satellite image QuickBird 0.60m resolution (2015) data covering the study area. QuickBird Satellite an image is very useful to the water supply network and land use into consideration. Also, QuickBird image and digital elevation model (DEM) are used for train visualization. Field survey capturing of data were based on surveying principles and techniques. A DGPS was also used in collecting data on the geographic position (Lat/Long) of ground control points (GCPs). Then using this GCPs geo-referencing of satellite image and digital map is done. As well as, the geospatial data of all the components of the water distribution network such as including reservoirs, pumping stations and the water distribution pipelines were acquired using the established GPS controls and Geomatics techniques on the field. DEM was generated from LiDAR point cloud data and analysis DEM database with ArcGIS software can used to determine where pressures are low and head losses high and grow elevation. Secondary data is referred to easily available data such as population estimate in 2018 according to (Central Committee of Statistics), digital maps of the study area from (the Design Department of the Capital Municipality) to the scales (1:25000) and (1:30000), obtained details and maps of the water distribution network from (the Baghdad Water Department) to the scale (1:30000). Summary of the dataset and their attributes used in the course of the research in Table 1. This paper addresses the WSS in Baghdad city as case study. These Spatial, aspatial and non-spatial dataset were combined for the analysis and results.

| S/N | Data Name           | Data type | Year | Source                       | Format | Resolution |
|-----|---------------------|-----------|------|------------------------------|--------|------------|
| 1.  | QuickBird image of  | Primary   | 2015 | Private Company              | Digital| 0.60 m     |
|     | Baghdad            |           |      |                              |        |            |
| 2.  | Relative positional | Primary   | 2018 | Private Company GPS GR3      | Digital| N/A        |
|     | x,y,z coordinaded of facility |           |      |                              |        |            |
| 3.  | LiDAR point cloud   | Primary   | 2018 | Private Company              | Digital| 0.10 m     |
|     |                     |           |      |                              |        |            |
| 4.  | Map of Baghdad city | Secondary | 2018 | Baghdad Water Department     | Printed paper | N/A        |
| 5.  | WDN map of Baghdad  | Secondary | 2018 | Baghdad Water Department     | Printed paper | N/A        |

Table 1. A breakdown of datasets specifications.
4.1 Base Map Creation
Satellite image QuickBird of 2015 (0.6 resolution), map at 1:25000 and layout of the water distribution network of Baghdad at 1:30000 were used for base map preparation. As WSS uses spatial data, the whole water supply network data has collected by DGPS surveyed and DGPS is used for taking ground control points (GCPs). All GCPs data was converted to a text file and were added to excel. In Arc catalogue a create a feature from x, y was used to display the GCPs into Arc GIS 10.2.2 software as a format shape-file. The city is divided into 24 zones for supply water. These zones were made with the help of the base map as shown in Figure 2. There are some projects and reservoirs outside the study area, which are accessed for security reasons and did not appear on the satellite image for security reasons.

5. Land use/ Land cover
The planning and management task is hampered due to insufficient information on rates of land use/land cover (LULC) change. The LULC changes occur naturally in a progressive and gradual way. However, sometimes it may be rapid and abrupt due to anthropogenic activities. Most converting definition has land cover relating to the type of feature on the surface of the earth such as built-up land, water body, road, etc. Land use associates the cover with a socioeconomic activity such as water network, school, space, and park. For the calculation of water demand at present and future from land use information, it was necessary to track patterns of land use. For the identification and interpretation of land use pattern of the image interpretation through remote sensing data (Quick bird 0.6m resolution) were adopted Figure 3.

![Figure 2. The projects, reservoirs and zones map of the Study Area.](image-url)
Figure 3. a. Quickbird image of Baghdad City        b. Land use map of major LULC categories for Baghdad City in 2018.

6. Creating Digital Elevation Model (DEM)
In recent years, LiDAR has become the main data source for producing a high-resolution digital elevation model (DEM) or digital terrain model (DTM) and digital surface model (DSM). The nature of LiDAR data offers the potential for extracting surface information fit for many applications. The extraction of discrete features such as buildings for land-use change, surface topographic and mapping purposes presents many research challenges. For many applications, however, relatively simple filtering procedures can provide information fit for their purpose. The DSM of the study area is shown in Figure 4 and Figure 5.

Figure 4. DSM of Baghdad city from Lidar point cloud data.
7. Results and Discussion
The pattern of urban expansion and land use modification is identified by field survey and satellite image. The digital satellite imagery Figure 2, acquired during this study, has provided reliable, update data of the study area. The existing water projects, water distribution network and transmission network supply system. All water projects and water network from source to distribution network digitize by ArcGIS software. Data was collected by the DGPS survey for water projects and the estimated capacity are presented in Table 3. The Universal Traverse Mercator (UTM) projection system coordinates of the established GCPs at zone 38 N with WGS 84 as a datum has been used. The GCPs (coordinates) played significant roles in the location and geospatially positioning of the entire water distribution network of the study area. Besides, the various components of mayoralty of Baghdad water distribution system can be planned, designed, constructed and maintained on the basis of the computerized. According to [11], [12] and [13], most of the engineering infrastructure located on, beneath or above the Earth's surface is spatial objects information, which include coordinates as well as other information concerning topography, geology, and population, among others. The digital surface model and contour maps of the study area are shown in Figure 4 and Figure 5. Terrain elevations play major roles in the distribution and flow of water in the natural landscape of the study area. Moreover, they contribute extremely in the determination of the actual location of the ground level storage reservoir. The ground elevations are very useful when evaluating the hydraulic grades and operating elevations within the pressure systems. The maps are over layed with land use and land cover map. The present population and expected rate of growth are critical factors in design of water distribution network in Baghdad city. In Baghdad city there are 14 projects operating for the Baghdad water department for drinking water supply with a production capacity of 4.205 million liters in Table 2. The city has 11 reservoirs with a storage capacity of 909000 liters according to (Baghdad Water Department, 2018) in Table 3. The city is divided into 24 zones for supply water and water distribution pipelines as shown in Figure 6. A review of the existing condition indicates that mayoralty of Baghdad may not have been involved in the design, according to the growth rate by means of urbanization and population. It has been shown that the water distribution network in the Baghdad city
combines two systems: circle system and grid system, and more project sites feed the areas directly and this is affected by the nature of weather conditions and power outages, most pipelines carry water for long distances, affecting internal pressure and thus water flow. All these reasons lead to a gap between the status supply and demand for water.

**Table 2. Projects and production sources specifications of the Baghdad water supply (2018).**

| No  | Name project  | Location of project | Coordinates (M) | Elevation (M) | Total production per day (m³/hour) |
|-----|---------------|---------------------|-----------------|--------------|-----------------------------------|
| 1   | Karkh T.P     | Tarmiyah            | 438693.320      | 37.402       | 1150000                          |
| 2   | Rasafa T.P    | Bob Al- Sham        | 442529.013      | 36.711       | 910000                           |
| 3   | Shark Dijla T.P | Saba Abkar        | 439428.613      | 35.806       | 850000                           |
| 4   | Karama T.P    | Otaifiya            | 440391.416      | 36.165       | 155000                           |
| 5   | Qadessia T.P  | Qadessia            | 440950.432      | 37.017       | 110000                           |
| 6   | Doura T.P     | Athorians           | 441851.004      | 34.499       | 100000                           |
| 7   | Wathba T.P    | Al-Ayawadiya        | 441906.352      | 35.932       | 90000                            |
| 8   | Wahda T.P     | Karada              | 448632.516      | 36.031       | 65000                            |
| 9   | Rasheed T.P   | Rasheed             | 449107.047      | 36.486       | 60000                            |
| 10  | Sadr W.T.P    | Kasrah and Atash    | 447660.153      | 35.004       | 90000                            |
| 11  | Jaderiya T.P  | Jaderiya            | 443011.336      | 36.510       | 58000                            |
| No. | Name reservoirs | Location of reservoirs | Coordinates (M) | Storage capacity (m³) |
|-----|----------------|------------------------|-----------------|----------------------|
|     |                |                        | Easting | Northing | Elevation |
| 1   | Northern       | Shola                  | 433768.875 | 3691137.540 | 34.109    | 254000    |
| 2   | Southern       | Saidiya                | 437492.205 | 3680231.627 | 34.709    | 180000    |
| 3   | Amin           | Amin                   | 455803.482 | 3686104.703 | 35.035    | 5000      |
| 4   | Kamaliya       | Kamaliya               | 455718.470 | 3689857.004 | 35.372    | 5000      |
| 5   | Obaidi         | Obaidi                 | 455581.356 | 3692421.537 | 35.272    | 5000      |
| 6   | Rostmia        | Rostmia                | 456057.285 | 3683258.903 | 34.736    | 5000      |
| 7   | R3             | Sadr                   | 448168.710 | 3690187.628 | 36.210    | 120000    |
| 8   | R5             | Nahda                  | 445828.447 | 3690187.572 | 35.430    | 75000     |
| 9   | R7             | Mashtal                | 453216.264 | 3688372.129 | 35.370    | 120000    |
| 10  | R9             | Karada                 | 442972.034 | 3681371.326 | 36.402    | 30000     |
| 11  | R14            | Sadr                   | 450399.552 | 3690477.429 | 35.083    | 110000    |

**Source:** Baghdad Water Department, Mayoralty of Baghdad, 2018.

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