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REVIEW ARTICLE - ENGINEERING

A Review of Hydraulic Pressure for Water Supply Unites Considering Iraqi Geodetic Reference

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Abstract

The hydraulic pressure head of the flowing water (between the entrance and exit pipes) in water distribution networks depends on the length and the slope of these pipes, which can represent the head losses for each meter length, where the slope and length of the water supply network pipes are dependent on specified datum ground elevations. This ground elevation may result in a reduction in head losses with hydraulic grade pressure. As a result, the precision of the measured data used to observe ground elevations is critical to decrease the error of these losses and apply an accurate local reference. It's critical to comprehend the implications of using Geographic Information System (GIS) application technology for water distribution network models to evaluate the hydraulic grade head with Iraqi Geodetic Reference. These GIS input data are based on an analysis of the relationship between selected spatial data resolution and the precision of the expected hydraulic head for selected stations with a distribution network. This research aims to review the literature and try to track the conversion of geodetic references and datums to accurately identify the hydraulic pressure for the selected locations of the water supply network. It was found that recent researches tend to use GIS application to create novel methods to reduce head losses and error.

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Keywords: Hydraulic Pressure; Previous Studies; Hydraulic Grade Head; GIS; Datum; Geodetic Reference.

1. Introduction

Water is distributed to users through a service connection in a water network. Such a distribution network may have varied configurations depending on how the ground is laid out using geodetic datum. Estimates of water conception serve as the basis for calculating service demand for water supply units and distribution network systems since water demand fluctuates as demographic, environmental, and agricultural populations change [1]. Large water distribution networks with looped and branched configurations of pipelines and a layout plan of the city highways and streets are pumped to sustain water pressure in flat terrain. Water treatment projects that are commonly known based on a specific ground elevation reference, distribution system of storage and pumping supply point locations, and hydraulic network analysis consider the impact of the elevation datum on the water supply network when analyzing hydraulic head losses. The elevation head with the specified datum has a direct effect on the hydraulic grade pressure of this network [2]. Satellite stations located within WGS84 for known local geodetic datum coordinates are the main components for converting between any local geodetic datum and the WGS84 datum. Because of the variety of datums in use, the same location can be referenced by different coordinates depending on the datum. The Geographic information system (GIS) and national Geodetic Reference of this hydraulic network are used as powerful tools to analyze the hydraulic pressure and national Geodetic Reference [3]. It is important to understand the implications of using GIS applications for water distribution network models to predict and evaluate the hydraulic grade head. This research can be combined with remote sensing and GIS to automate the extraction of monitoring hydraulic heads with water supply unit regions, at a low cost, and with standard accuracy assessment, and will describe the water supply network with the hydraulic pressure and the geodetic references. Several researches have been carried out on tracking the geodetic references and datums conversion to pinpoint the hydraulic pressure for the selected locations of the region with the water supply network; this overview explores the available studies with the changes in hydraulic pressure, as shown in Table 1.

2. Water Distribution Network

A water supply distribution system is a hydraulic infrastructure that transports water from its source to consumers; it consists of water intake works, treatment and storage facilities, transmission mains, and a distribution network. Surface water sources such as rivers, lakes, and man-made reservoirs are common sources of raw water. To extract water from these sources, intake structures, and pumping stations are built [20].

Nomenclature & Symbols			
GIS	Geographic Information System	ITRF	International Terrestrial Reference Frame
GPS	Global Positioning System	NEMPC	Non-linear Economic Model Predictive Control
GCS	General Commission of Surveying	CORS	Continuously Operating Reference System
WDN	Water Distribution Network	PM	Pressure Management
GNSS	Global Navigation Satellite System	WGS84	World Geodetic System 1984
IGRS	Iraqi Geospatial Reference System	NAD 83	North American Datum of 1983
PDMs	Pressure-Dependent Models		

The ability of a system to provide an adequate level of hydraulic pressure to consumers under both normal and abnormal conditions is defined as system reliability. For this reliability, many optimization programs are run. The ground slope and length between the water network nodes can be calculated using the (GIS) of a study area to locate the frictional loss during the hydraulic grade pressure between the two sequential nodes of the network will be considered to predict the hydraulic pressure.

2.1. GPS

Differential (GPS) measurement precision is typically within a centimeter. For structural identification applications, this level of precision is insufficient. (GPS) technology can be used for continuous all-weather monitoring and automated monitoring, recording, and calculating [21]. The Global Positioning System (GPS) is composed of 24 satellites that orbit the Earth every 12 hours to provide global location, time, and velocity data. GPS calculates the distance between satellites to determine an exact location on the planet [22].

2.2. GIS

Since geographic information is so important, methods known as GIS have been developed to gather and use spatial data in conjunction with geographic information. Geographic Information Systems (GIS) are computer-aided systems that collect, hold, analyze, and disseminate geographical data. Geographic information systems (GIS) are computer systems that are well-organized in terms of hardware, software, geographic data, and personnel. Spatial analysis and GIS are involved with feature locations as well as their characteristics and properties [23].

Table 1. Summary of the previous studies

Authors	location	Research objectives	Results
Elizabeth Ramsey,2020 [2]	northwest U.S.A	Through an agent-based modelling approach, the goal of this study was to investigate and test the hydraulic feasibility of a micro-trading system.	This study created a novel water management system to advance the use of decentralized infrastructure and smart city technologies for improving the built environment's sustainability.
Attilio Fiorini Morosini, 2020 [4]	Southern Italy	Evaluated Praia a Mare's water distribution network in Italy.	The created binary classification model had the higher precision for categorizing and evaluating the included urban water network's water distribution system, and thus it can be used as a powerful tool to identify the water network's performance. Based on the importance of the current issue, other artificial intelligence approaches could be used in future research.
Tamer Nabil,2020 [5]	Ismailia, Eygpt	Proposed a novel method for investigating the effects of water leaks on water distribution network performance	Matlab-Simulink was used to simulate the operation of the actual solenoid valve. The simulation's findings indicate that the valve's response to the step-down pressure regulator signal was over-dulled high oscillatory, with a minimal error at a steady state of 2% and a settlement time of 0.6 seconds.
Urszula Kepa,2020 [6]	Poland	The operation of the water delivery system was investigated.	According to the investigation, the network is currently unstable. When demand was normal, water was delivered to all customers; however, there are areas of the network with high pressure. However, during peak water demand, there are water shortages that cannot be compensated for by the functioning pumping system due to limited water supply to the water reservoir, which supplies the majority of the network.
Olivier Piller,2020 [7]	France	This study described a new method of solving the steady state of pressure-dependent models (PDMs) with flow control valves.	Water flow rate and node heads were calculated for pipes and valves by reducing deviations from objectives at the check valve and resolving a restricted least-squares problem to satisfy the state equations (energy and mass saving).
Adnan M. Abu-Mahfouz, 2019 [8]	Gauteng, South Africa	Created a real-time dynamic hydraulic model framework for reducing potable water loss.	This model includes background leak detection, pressure management, and water demand forecasting. A background leakage detection technique was proposed, which enabled the identification of potentially important network nodes or pipes with increased leakage flow, as well as pressure control.

Salman N. Dawood, 2019 [9]	Baghdad, Iraq	By reducing the difference between the geoid and ellipsoid WGS84, a new geodetic reference was created.	The discrepancy between geoid and ellipsoid (WGS84) was reduced by proposing a new coordinate system to achieve high precision in coordinates. The average difference with a vertical elevation between the (WGS84 / ITRF08) for the identified points of Baghdad city was about (-1.349) UTM, and the average difference with horizontal distances of the same study was about (East = 0.3384m) UTM and (North =0.3674m) UTM.
J.C. Agonwamba ,2018 [10]	Nigeria	Water CAD and Epanet were used to assess hydraulic performance.	Poor pressure management system performance was discovered to be caused by incorrect valve placement in the system, resulting in the valves having little or no influence on the system. Several pipes in the system were insufficient, resulting in extremely high velocities at specific sites with high nodal demands. This is to blame for the massive pipe leaks and bursts that plague the distribution system, causing system performance to suffer. Furthermore, low reservoir height results in negative pressures in the distribution system.
A.N. M. AL-Hameedawi, 2018 [11]	Sulaimaniya /Arbat city-Iraq	The effect of different map projections and datums on precision was investigated using the 7 parameters method and root mean square errors (RMSE) A major public engineering problem's positional inaccuracy and the source of errors that led to inaccurate measurement	We performed datum transformations between the global datum (WGS1984-UTM-Zone-38N) and the local datum (Karbala1979-UTM-Zone-38N), as well as the production of new maps for comparison. The UTM projection and local datum (Karbala1979-UTM-Zone-38N) provided the best study area, according to the RMSE test.
Ye Wang, 2017 [12]	Spain	The water network distribution control model was investigated using nonlinear differential-algebraic equations for hydraulic pressure and flow variables.	The two-layer Non-linear Economic Model Predictive Control (NEMPC) method was deemed an acceptable control technique for the operational management of the 515 WDN. The bottom layer's challenge was to achieve the best pump flow inside a specific range. However, it was necessary to broaden the pump's service life by decreasing the number of switches, which will be considered in the pumping scheduling technique as part of a future study.
Dilbarkhon Fazilova, 2017 [13]	Uzbekistan	The goal of this study was to evaluate the accuracy of the currently used transformation parameters from various sources in the region and to make preliminary recommendations for using these sets.	As a result of the research, standard parameter sets (GOST P 51794-2001) are recommended for use on Uzbekistan's territory. In the future, new transformation parameters will be projected for zones of the Republic based on the designed network.
D. J. Vicente; 2016 [14]	Madrid	Having been researched for water distribution systems, pressure management (PM) is a common practice (WDSs).	A qualitative analysis of the results addressed four issues: (1) the objectives of PM; (2) the types of regulation, such as enhanced control systems through electronic controllers; (3) novel district-planning techniques; and (4) the creation of PM-related optimization models. It was investigated and discussed how the four aforementioned aspects evolved. Regarding how each component is doing right now,
Alaa A. Hussein1, 2016 [15]	Baghdad University compass	Determining geoid undulation using 2D polynomial models,	Increased the accuracy of the polynomial by using a variety of techniques, which include equitable adjustments from the reference points to the interpolated points and the squares collocation strategy.
Dr. Oday Y. M. Zeki Alhamadani, 2016 [16]	Baghdad, Basra, Erbil, Najaf, Tikrit, Kut	Using a variety of Global Navigation Satellite System (GNSS) methodologies, assess the accuracy of local geodetic networks.	GNSS experiments were conducted to highlight the characteristics of each GNSS observation technique. In addition, the precision of each positioning approach is thoroughly evaluated to determine the proportion of acceptable deviation and appropriateness for various geodetic purposes.
Dr.Abbas Zedan 2015 [17]	ThiQar City/ Iraq	By creating new Matlab software that performed the conversion in a low-cost, precise, and quick manner, it was possible to note a mathematical model for the old (Karbala79) and new (WGS84) datums.	Whenever the datum was transformed using the technique for the precision of (0.03) meters in the east and (0.02) meters in the north, the result was extremely precise.

P. Sivakumar, 2014 [18]	India	When nodal requirements outweigh the peak flow, such as in the event of a fire, pump failure, pipe breaks, valve failure, and so on, a pressure-deficient situation develops in the water distribution network (WDN). It generated no-flow or partial flow based on the available pressure head at the nodes.	The M-PDNA operating principle was used to propose a head-discharge connection. Some toolkits are also easily accessible for modifying the demand-driven solver in EPANET 2 to fit pressure-driven analysis and then using it to analyze pressure-deficient networks. This paper also included a variation on the M-PDNA technique that did not require the use of the EPANET toolbox, which had previously been shown to be capable of modelling both pressure-sufficient and pressure-deficient conditions in a single hydraulic simulation.
Abdelrahim Elgizouli ,2013 [19]	Sudan	Observed and calculated using traditional triangulation techniques based on the local datum (Adindan) and lowered by the Clarke 1880 ellipsoid parameters at Sudan's national geodetic network stations.	This finding implied that ITRF observations were superior to absolute GPS measurements for establishing national networks. Finally, the scale parameter of the WGS84 and Clark 1880 ellipsoid transformation parameters could be ignored (on Adindan Sudan datum).

3. Datum – Map Reference System

A geodetic datum is a tool for defining the shape and size of the Earth, as well as a reference point for the numerous coordinate systems used for mapping the Earth. Hundreds of different datums have been used throughout history, every one modifying with the earth views of the time [24]. As a result of the assessment of datums presently used with today's advanced technology to acquire global positioning coordinates and elevations with sub-centimeter precision, adequate datum selection and coordinates transformation between dissimilar datums has become critical [25]. Before the advent of satellite geodesy, all national datums had to be defined independently of one another [26]. There are over 120 map reference systems worldwide, including NAD83 for North America, CH - 1903 for Switzerland, as well as WGS84 for a world standard [27]. The Karbala 79 from Clack 1880 map reference system datum is appropriate for Iraq [17]. While the heights (i.e., vertical coordinate) ellipsoidal is not frequently used as a level surface of the gravity field that most closely approximates mean sea level, the ellipsoid is frequently used as a reference surface for horizontal coordinates in geodetic networks. [28].

4. Iraqi Geospatial Reference System

The Iraqi Geospatial Reference System (IGRS) aims to establish six reference CORS stations and 64 ground stations in four cities to adjust the 3D first class [29]. The Iraqi General Commission of Surveying (GCS) aimed in 2007 the followings:

- To base the new coordinate system on the Worldwide Terrestrial Reference Frame (ITRF)system.
- To use an ellipsoid from the World Geodetic System 1984 (WGS84) as a reference system.
- To establish a newly developed network with seven CORS reference stations that are connected to the internet.
- To increase the number of ground control stations in specific cities.

5. Local Geodetic Reference System of Baghdad City with Aided International Terrestrial Reference Frame (ITRF)

The coordinate systems (WGS84) and (ITRF) are consistent, and several countries have recently converted their datum to WGS84 (ITRF). As a result, (ITRF) is regarded as a high-accuracy coordinate system that is updated every two years [30]. To establish local 3D geodetic datums, global (large scale) and regional (small scale) networks (GPS) and the Continuously Operating Reference System (CORS) are used.

6. Results Analyses and Discussions

Many studies have been conducted on monitoring the Geodetic References and datums transformation to identify the hydraulic pressure for selected stations in the water supply network area. Copernicus (GLO-30) satellite DEM and GIS techniques were used to monitor the spatial distribution of the selected water supply network in Baghdad for the years 2021-2022. It was found that recent researches tend to use GIS application to create novel methods to reduce head losses and error.

A study identified the grade hydraulic pressure for a specified station of the chosen supply water network by using a local national reference that is unified with a geodetic reference (Ellipsoid WGS84 ITRF08). To determine the grade hydraulic pressure for each station, the satellite DEM with the specified area of the water supply network is delineated.

7. Conclusions

The ability of a system to provide an adequate level of hydraulic pressure to consumers under both normal and abnormal conditions is defined as system reliability. For this reliability, many optimization programs are run. Much literature related to reference conversion and hydraulic pressure assessment in global regions was reviewed in this paper and a set of conclusions were reached.

- Hydraulic grade analysis with ground elevation reference for distribution system in water treatment projects are known based on a given ground datums which used to determine flow and pressure demand at any point of the system

- Water supply represents the basic variables that have a direct impact on the quality-of-life standards for residents, and therefore it is important to society, politicians, and general managers
- Countries with limited water resources and high populations need more investments in managing water resources.
- Most of the studies used modern survey methods such as geographic information systems (GIS) and remote sensing strategies to assess the hydraulic pressure with the spatial delineation of the water pipes network.

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