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Assessment of Flow Velocity and Its Effects on and Network Efficiency by WaterGEMS and GIS Case Study of Ramadi City

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ABSTRACT

The flow rate of water in a pipeline system significantly affects hydraulic efficiency, water quality, and infrastructure durability. This study examines flow velocity distribution in the water distribution network of Ramadi City, Iraq, using advanced modeling techniques with WaterGEMS and GIS. The field data was analyzed to identify areas with low flow velocities, which can cause sediment buildup and bacterial growth. Our findings show that about 28.57% of the network has velocities below 0.5 m/s, indicating limited connections and higher pressure in these pipelines. Meanwhile, 48.98% of the network operates within the optimal range of 0.5 to 2.0 m/s, while 22.45% exceeds 2.0 m/s, which can lead to pressure loss and pipe deterioration. Low average daily demand results in moderate flow speeds in some pipelines, increasing the risk of stagnation and negatively impacting water quality. Maintaining adequate flow rates is crucial for protecting water quality and ensuring efficient operations. This study highlights how integrating GIS with WaterGEMS can improve the assessment of water distribution infrastructure issues.

1. Introduction

Flow velocity is one of the fundamental parameters in the design and operation of water distribution systems. It directly affects the efficiency of water deliver [1] . Models of water supply systems serve as effective decision support tools for formulating diverse management scenarios aimed to enhance the efficiency and reliability of current networks and establishing new ones. The hydraulic relative equations are employed in the water distribution network (WDN) to calculate hydraulic parameters, including flow rate, velocity, and water pressure [2].

The slow speed leads to water pollution in the pipes, which has a health impact on the quality of water in the network, as the water remaining for a long period inside the pipes allows bacteria to grow and multiply [3]. The flow velocity is not excessive in some pipes due to the low average daily demand. This indicates that the volume of water required by

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consumers within certain periods is relatively minimal [4]. According to [5] Research indicated that over 12% of the velocities surpassed the established threshold, resulting in leaks and pipe fractures at multiple locations throughout the system. A hydraulic model developed using GIS and EPANET to replicate the municipality of Chatoyance in Algeria; GIS supplies network data, including length and topographic information, derived from analytical results. The study revealed that, among the 306 pipes analyzed, 200 exhibited a velocity of less than 0.5 m/s, potentially resulting in deposit accumulation due to sedimentation. Conversely, 64 pipes recorded velocities ranging from 0.5 to 1.5 m/s, which fall within acceptable parameters, while the remaining pipes surpassed a velocity of 1.5 m/s. [6] examined the functionality of the water distribution network at the Federal University of Agriculture in Makurdi, utilizing WaterCAD and WaterGEMS software to ascertain velocity and flow rate values. The results showed that 15% of the network pipes went faster than the design speed. Both software programs can be used together because no statistical differences are found[7]. The simulation results indicated that the speed in the main pipes always stays within the allowed range. However, the speed in the lateral pipes goes over the allowed range during times of low demand and then drops below the allowed range at dead flow junctions. The velocity distribution in the lateral pipes was observed in the distributary pipes for analogous reasons [8]. The previous study revealed that the calibrated the WaterGEMS hydraulic model using measured data from nine randomly selected nodes. The model results indicate that a significant portion of the velocity and pressure inside the water distribution system fell below the minimum suggested thresholds. The specified minimum pressures and velocity levels demonstrate insufficient water pressure in the distribution network to adequately serve all areas of Ejere Town. Ultimately, they determined that the community's availability of potable water was inadequate [9]. The analysis revealed that during peak hours, 78.15% of the velocity in the water distribution network was within the acceptable range, but 21.85% of the velocity during peak hours fell below 0.6 m/s, and no velocity was beyond 2 m/s [10]. The research revealed that the network pipes in the PSA region are comparatively antiquated. The velocity in the PSA region is comparatively low, which promotes particle settling and results in a progressive reduction of the active diameter [11]. The modeling results showed that the Janmeda, Teferi Makonnen, Belay Zeleke, Entoto, and Ras Kassa supply systems show how well Addis Ababa's water distribution system works when things go wrong. The examined subsystems are failing to uphold the specified minimum and maximum velocity thresholds [12]. Many researchers showed that the integration of GIS with different models may enhance the performance of its operational efficiency [1,2,3,4]. This study aims to evaluate flow velocity as one of the key hydraulic performance indicators of the water distribution network, utilizing Geographic Information Systems (GIS) and the WaterGEMS software, in order to enhance the understanding of network performance and improve its operational efficiency.

3. Methodology

3.1. study Area

The study was carried out in the Al-Mu'allimin district of Ramadi, situated in Anbar Governorate, western Iraq Figure 1 [13] The Greater Ramadi Water Project serves the region, utilizing a 450 mm transmission pipe for water conveyance and a looping PVC pipe network for distribution, with diameters varying from 110 mm to 160 mm. The research area encompasses roughly 10.311 kilometers of water pipelines. This research methodology examines the flow velocity distribution in the water distribution network of Ramadi City. The methodology integrated field data gathering, hydraulic modeling with WaterGEMS, and spatial analysis through GIS software.

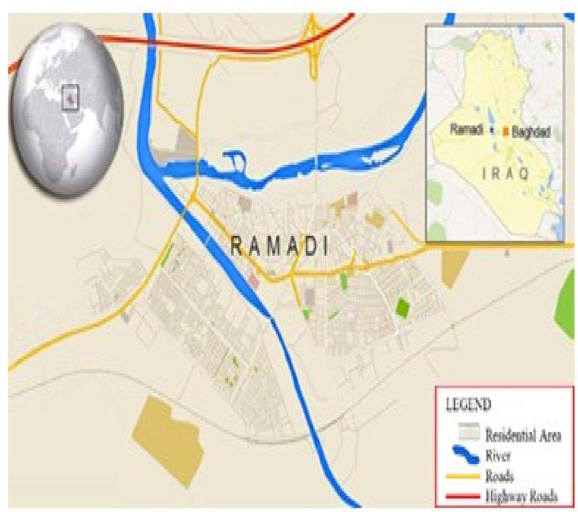

Figure 1. Geographical location of Ramadi city [13].

3.2. Data Collection

Primary data from 23 sample locations are collected by using GPS and pressure gauges during peak consumption periods in the summer. Flow velocities are determined via using pipe diameter and discharge information. Secondary data are acquired from AL-Ramadi Water Supply Administration and technical reports detailing pipeline specifications and installation dates.

3.3. Method of Data Analysis

The research employed many materials and instruments to examine the gathered data. Microsoft Excel was utilized to categorize, arrange, and analyze the data. AutoCAD. was employed to identify and delineate the water distribution system. ArcGIS and the Water Geospatial Engineering Modeling System [14] (WaterGEMS) were utilized to evaluate the hydraulic efficiency of the distribution system. The analysis evaluated parameters such as pressure and velocity [5,6,7].

3.4. Hydraulic Simulation Utilizing WaterGEMS

The Water GEMS program was utilized to model the hydraulic dynamics of the water distribution system. Included data comprises [15]. Lengths, diameters, and materials of pipes Elevations and node requirements Figure 2 • Hazen-Williams roughness coefficient (C = 150 for PVC) Steady-state simulation for evaluating pressure and velocity distribution [16].

NO.	Pipe diameter	Pipe Length	Material
1	225 mm	2065 m	PVC
2	160 mm	3523 m	PVC
3	110 mm	4723 m	PVC

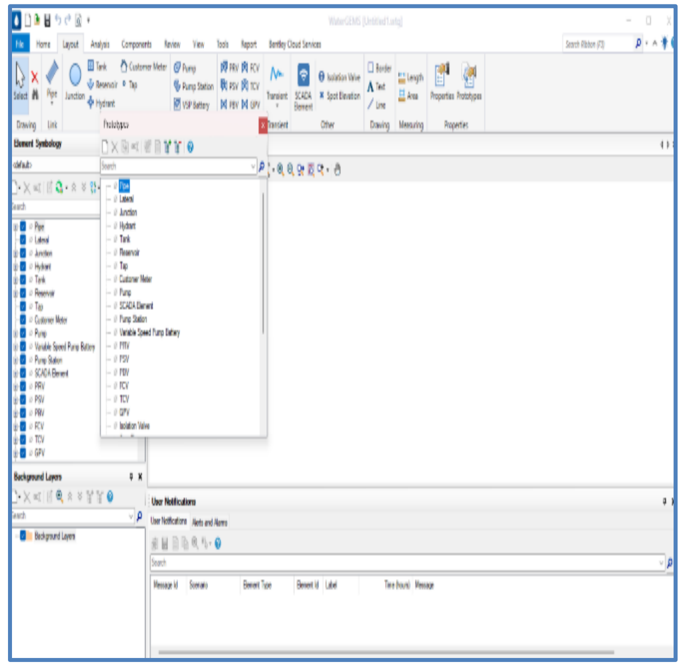

Figure 2. Interface WaterGEMS.

3.5. ArcGIS

ArcGIS is an extensive and multipurpose software used to manage water transmission and distribution systems within contemporary water supply frameworks. Nonetheless, it is the premier application for managing, manipulating, and maintaining geographic data, as well as for developing and sustaining asset management for contemporary water utilities globally [17] See figure 3.

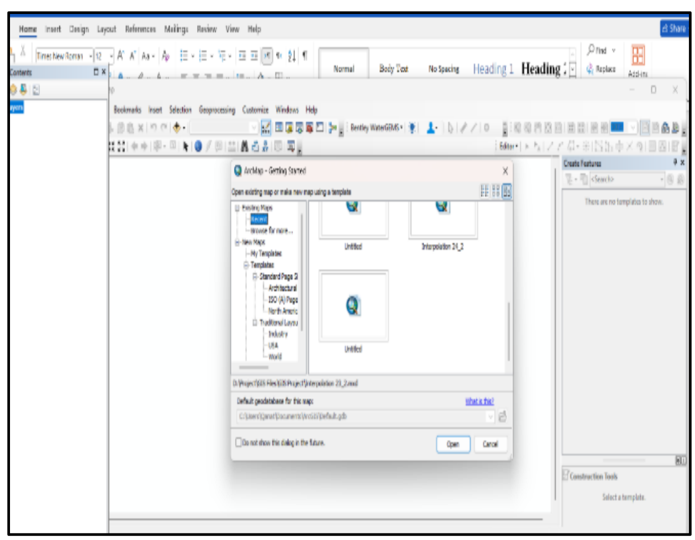

Figure 3. Interface *ArcGIS.*

3.6. Velocity Distribution During Peak Hour Utilization

During times of high demand, the way water speeds are distributed in water distribution networks is very important for the network to work well and keep service quality high. During times of high demand, when pipes are being used by both homes and businesses, water speeds often rise significantly, sometimes reaching or going beyond the limits that engineers recommend. This can have a negative impact on network performance, operational efficiency, and pipe integrity [18].

3.6. Spatial Analysis with GIS

Spatial analysis was performed utilizing ArcGIS Spatial Analyst Tools. The procedure involved categorizing the spatial data based on varying velocity levels[19] Furthermore, spatial statistical analysis tools are utilized to identify regions with significantly high or low water velocities. Thematic maps are created effectively to depict the spatial distribution of water resources [7,8,9,10]. The geographical distribution of water velocities over the network, enabling accuracy infrastructure development and administration.

4. Results and Disscssion

Hydraulic calculations conducted with WaterGEMS software revealed considerable discrepancies in flow velocities throughout the water distribution network in Ramadi. Velocities were categorized into three ranges, as illustrated in Figure 4. Less than 0.5 m/s (28.57%): Potential problems include stagnant water, sediment buildup, and bacterial growth. A velocity of between 0.5 and 2 m/s (48.98%) indicates an efficient flow rate [20]. This rate results in reduced pressure loss and fewer hydraulic problems. If the rate exceeds 2 m/s (22.45%), it can lead to excessive pressure loss and pipe corrosion over time.

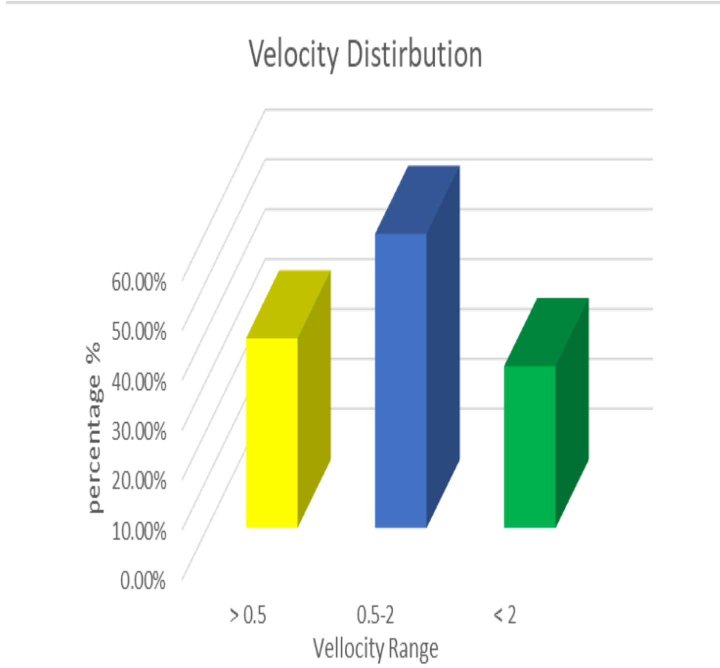

Figure 4. Velocity distribution in steady-state.

This signifies that although about fifty percent of the network functions under ideal hydraulic circumstances, over twenty-five percent experiences low-velocity flow, potentially resulting in various operational and water quality complications.

A color gradient was used to show the spatial velocity distribution. Warmer colors showed faster speeds and cooler colors showed slower speeds. Different-sized pipes are marked with different colors in the legend to make it easier to find areas that might have problems with velocity, as shown in Figure 5 below. For engineers and planners, this graphical analysis helps them figure out how efficient a network is and decide what improvements to make.

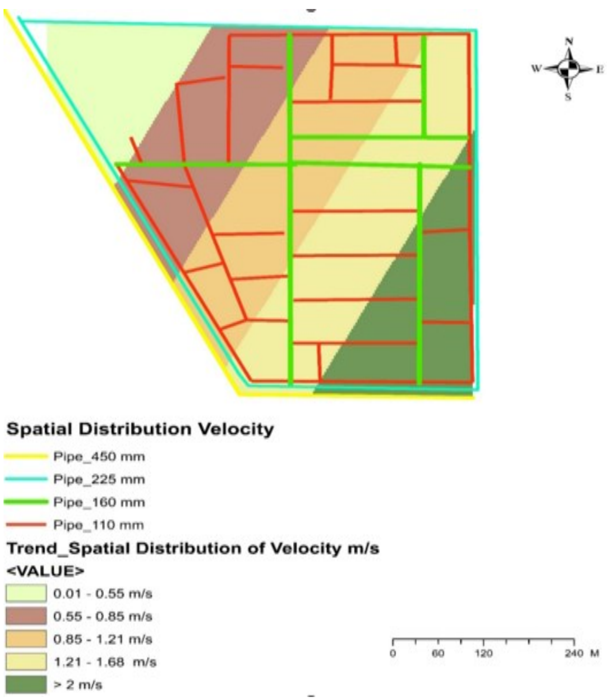

Figure 5. Spatial Distribution of Simulated and Pipeline Network Categorization.

5. Conclusion

Using advanced hydraulic modeling tools like WaterGEMS and GIS, this study looks at how the flow speeds are spread out across the water distribution network in Ramadi, Iraq. Geography Information Systems (GIS) were added to the WaterGEMS hydraulic model to help fix issues with the water distribution system. Furthermore, slow flow velocities in some pipelines resulted in low average daily demand. Based on this information, it looks like people don't need as much water at certain times, which means that it moves slowly through the distribution network. Velocities can lead to water stagnation, increasing the likelihood of siltation and microbiological growth, both of which are detrimental to water quality. Keeping the flow rate high enough is important to protect the water quality, make operations easier, and avoid problems with maintenance that come up when demand is low.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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