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Design and Optimization of Water Distribution Network Using Watergems Software: A Case Study of Adhewada, Bhavnagar

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Abstract: This research focuses on the analysis and optimization of the water distribution network in Zone 5 of the Adhewada area, Bhavnagar, where water is supplied through a zone-wise and time-based system. The increasing population, rising water demand, and the need for structured infrastructure development have made it necessary to redesign the existing system. Current sources are inadequate to meet the minimum requirement of 140 liters per capita per day (lpcd), highlighting the need for a reliable and sustainable water supply solution. Real-time data was collected from the Bhavnagar Municipal Corporation (BMC) and used to simulate the network using WaterGEMS software. The study aims to assess the current distribution pattern, identify pressure-related issues, and propose improvements to enhance efficiency and equity in supply. By integrating actual field data with hydraulic modeling, the research provides practical recommendations for strengthening the reliability and performance of the water distribution system in the selected zone.
Keywords: Heads, Hydraulic Parameters, Junction, Node, Pressure, WaterGEMS, Elevation, velocity.

I. INTRODUCTION

The provision of a reliable and equitable water supply is a fundamental component of sustainable urban infrastructure. With rapid urbanization and population growth, many cities face increasing challenges in meeting the rising demand for potable water. Bhavnagar city, located in Gujarat, is no exception.

The Adhewada area in particular is witnessing significant development and population expansion, leading to elevated water demand. In this context, designing an efficient and optimized water distribution network is crucial to ensure consistent water availability while minimizing losses and improving pressure management.

Currently, water distribution in Bhavnagar is managed through a zone-wise, time-based supply system, where different zones receive water at different times of the day. Zone-based distribution can often result in pressure fluctuations, uneven supply, and potential losses due to outdated infrastructure or lack of hydraulic analysis. Zone 5 of Adhewada was selected as the focus area for this study due to its growing population and frequent complaints of low pressure and irregular supply.

This research aims to analyze and optimize the water distribution network in Zone 5 of Adhewada using WaterGEMS, a widely adopted hydraulic modeling software. The study incorporates real-time data collected from the Bhavnagar Municipal Corporation (BMC), including population statistics, pipe network layout, water demand, and supply schedule. Based on this data, a detailed hydraulic model was created to simulate the existing water distribution system.

The primary objectives of the research include evaluating the performance of the current distribution network, identifying areas with inadequate pressure or flow, and proposing design improvements for better efficiency and reliability. Furthermore, the study emphasizes the need for sustainable design strategies that can meet the minimum per capita water requirement of 140 liters per day. Given that existing sources are insufficient to meet future demands, the research also advocates for the inclusion of additional sustainable water sources and infrastructure upgrades.

By integrating real-world data with advanced hydraulic modeling tools, this research contributes practical solutions for urban water management in medium-sized cities like Bhavnagar. The outcomes of this study can be used as a reference by municipal authorities and planners to improve water service delivery, ensure equitable distribution, and support future infrastructure planning.

II. OBJECTIVES

1) To analyze the existing water distribution system in the Adhewada area and identify inefficiencies related to pressure, flow, and supply duration.
2) To collect pipe reports and junction reports of existing networks .
3) To analyze the data by using WaterGEMS Software.
4) To contribute practical recommendations for future urban water supply planning and infrastructure development based on the outcomes of the simulation and analysis.
5) To identify critical issues such as low pressure zones, uneven distribution, and pipe losses that affect the overall service quality.

III. LITERATURE REVIEW

The design and planning of an effective water distribution network (WDN) is a core component of any urban infrastructure system. With the rising demand for uninterrupted water supply in growing cities, the focus has steadily shifted from traditional manual planning methods to advanced hydraulic modeling and simulation tools. One such tool, WaterGEMS, has become a widely used software in both academic research and real-world applications due to its powerful simulation, optimization, and analysis features.

A study by Patel and Mehta (2022) focused on designing a continuous water supply system for Surat city using WaterGEMS. Their work demonstrated how hydraulic modeling can help in understanding flow behavior and pressure distribution across large networks. Similarly, Mehta et al. (2022) analyzed and redesigned an existing 24/7 water supply system using WaterGEMS. Their study identified network inefficiencies and proposed solutions to improve the overall water delivery mechanism.

Another significant contribution was made by Dhumal et al. (2018), who emphasized the importance of switching from intermittent to continuous water supply systems. They used WaterGEMS to simulate improved system performance and reduce water losses. In a related approach, Netaji and Thorvelt (2020) compared existing intermittent supply systems with proposed continuous models, highlighting better service coverage and pressure management in the latter. Switnicka et al. (2017) explored optimization techniques within WaterGEMS to enhance network efficiency. They applied penalty-based optimization methods to balance cost and performance in network design. Gebremedhin and Tesseme (2020) conducted a case study in Wukro Town, Ethiopia, where they used WaterGEMS to redesign the town’s network, focusing on capacity improvement and future scalability.

Several researchers have taken a broader perspective. Rai and Dohare (2019) reviewed how WaterGEMS can support hydraulic planning for large-scale events, like Simhastha Mela in Ujjain, where demand surges in short periods. In their critical review, Navin and Dohare (2022) compared WaterGEMS and EPANET, discussing their respective advantages in modeling complex systems. More recently, Trinh and Loan (2024) examined the potential of WaterGEMS in addressing water scarcity by enabling sustainable water distribution planning. Yennawar (2024) also supported this viewpoint, focusing on its role in designing smarter, more adaptable urban water networks.

Across all these studies, one common theme emerges: WaterGEMS enhances the ability to simulate real-world conditions, analyze pressure zones, optimize pipe sizing, and visualize system behavior. However, there are still areas for improvement. Most existing models rely on static data, lacking real-time demand patterns. There's also limited integration of smart technologies like IoT sensors or predictive analytics, which could further enhance the responsiveness and sustainability of such systems.

Recognizing these gaps, the present study focuses on designing a practical water distribution network for the Adhewada area in Bhavnagar, using real field data provided by the Bhavnagar Municipal Corporation. By using WaterGEMS, this research aims to address current limitations in zone-wise planning, pressure optimization, and equitable service delivery, while contributing practical insights for sustainable urban water management.

IV. STUDY AREA

Bhavnagar is a coastal city on the eastern coast of Saurashtra, also known as Kathiawar, located at 21.77°N 72.15°E.It has an average elevation of 24 metres (78 ft.). The total area of the town is 10,034 sq. Kms. Bhavnagar city is considered the economic, industrial and educational hub of the region. Adhewada village is located in Bhavnagar Tehsil of Bhavnagar district in Gujarat, India. It is situated 2km away from Bhavnagar, which is both district & sub-district headquarter of Adhewada village. As per the census record 2001 total area of Adhewada village is 994.49 HA. Bhavnagar is a coastal city on the eastern coast of Saurashtra, also known as Kathiawar, located at 21.77°N 72.15°E. It has an average elevation of 24 metres (78 ft.). It occupies an area of 53.3 km2 (20.6 sq. mi). The general slope dips towards the northeast at the apex of Gulf of Khambhat. A small non-perennial river named Kansara Nala passes through the outer area of the city. The adhewada area distribution system distributed in zone wise. Whole adhewada distributed in 5 zone like ; zone 1, zone 2,…zone 5.In this study the analysis of Zone-5 is performed using hydraulic simulation software waterGEMS.

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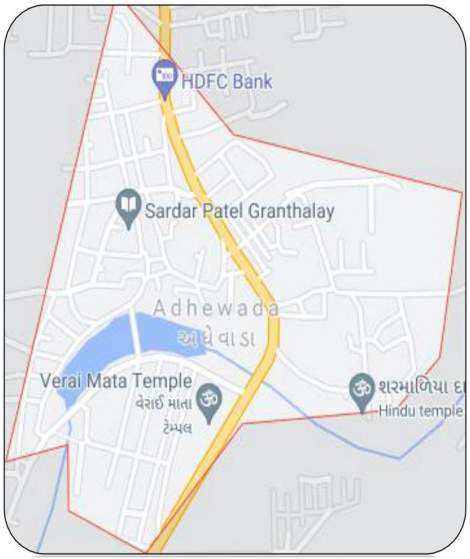
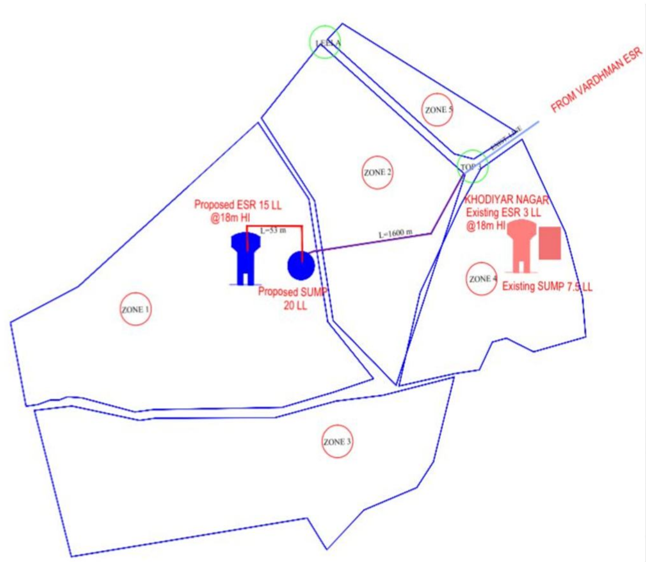


LOCATION MAP



AREA MAP (ZONE WISE)

V. DATA COLLECTION

The map and detailed information of the existing Water Distribution System for the Adhewada area were collected from the Hydraulic Department of the Bhavnagar Municipal Corporation (BMC). For hydraulic modeling and simulation in WaterGEMS software, several key input parameters were required. These included the length and diameter of pipes, the elevation of each junction, water demand at individual nodes and junctions, pump specifications, and the location and capacity of reservoirs. All the necessary data was gathered from BMC's engineering division to ensure accurate modeling of the existing network conditions. This comprehensive dataset formed the foundation for evaluating the performance of the current system and designing an optimized water distribution network for the selected zone.

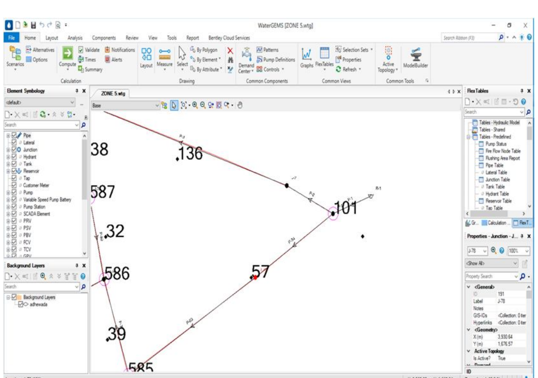
VI. METHODOLOGY

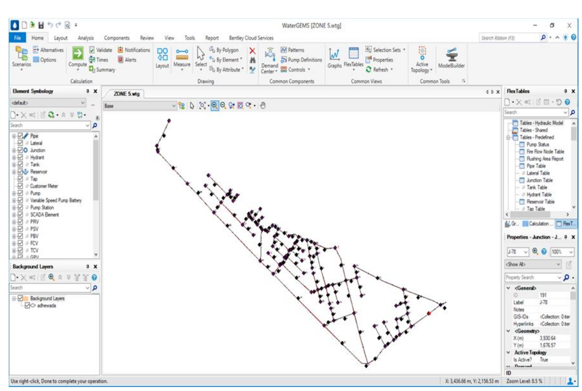
As mentioned earlier, the required data for simulation in WaterGEMS software was collected from the Hydraulic Department of the Bhavnagar Municipal Corporation (BMC) and field surveys. WaterGEMS serves as a powerful and user-friendly decision support tool for modeling, analyzing, and optimizing water distribution systems. It allows engineers to visualize, simulate, and evaluate the hydraulic behavior of water supply networks under varying demand and pressure conditions.

The following steps were carried out using WaterGEMS software:

A. Drawing The Layout

The first step is to create a new hydraulic model. As per the existing network drawing first, draw the drawing in waterGEMS software.





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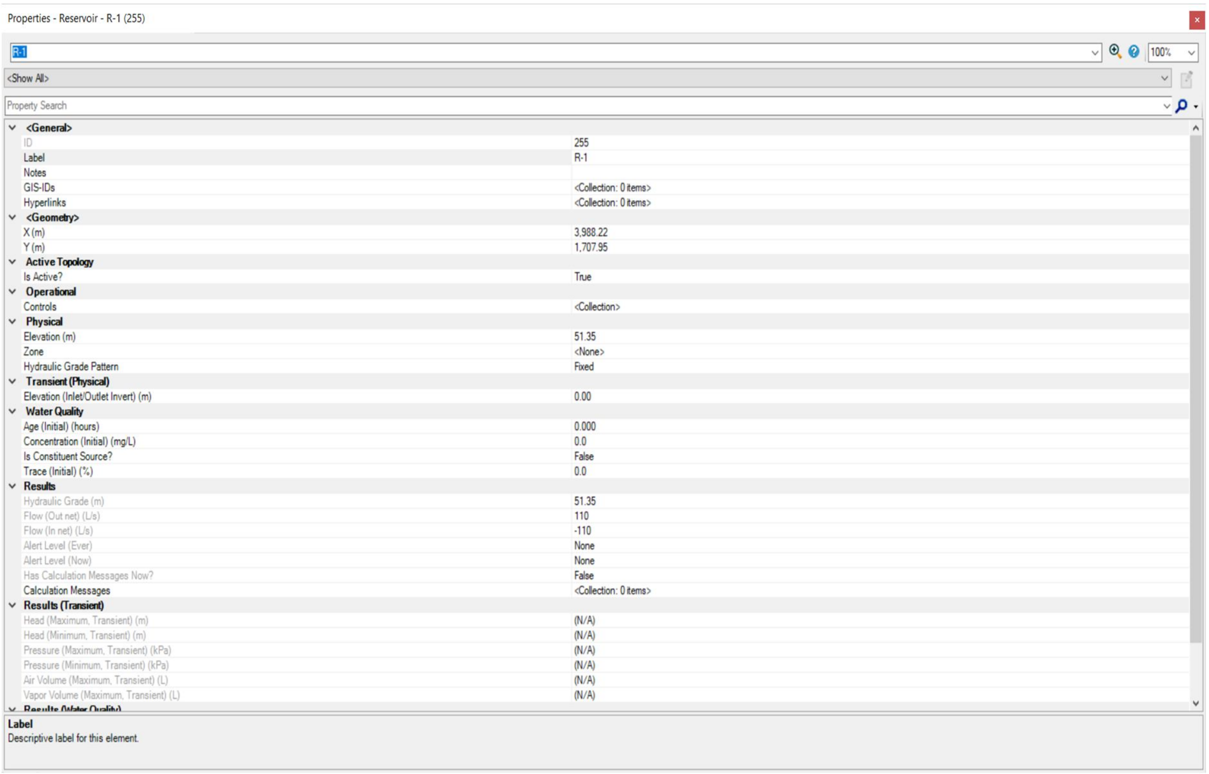
VII. DATA ENTRY

With the help of collected data, the following data were entered into the software; Length of pipes, Diameter, Demand, Elevation , Material, etc. From property editor imports data for Reservoir, Junction, Pipes.

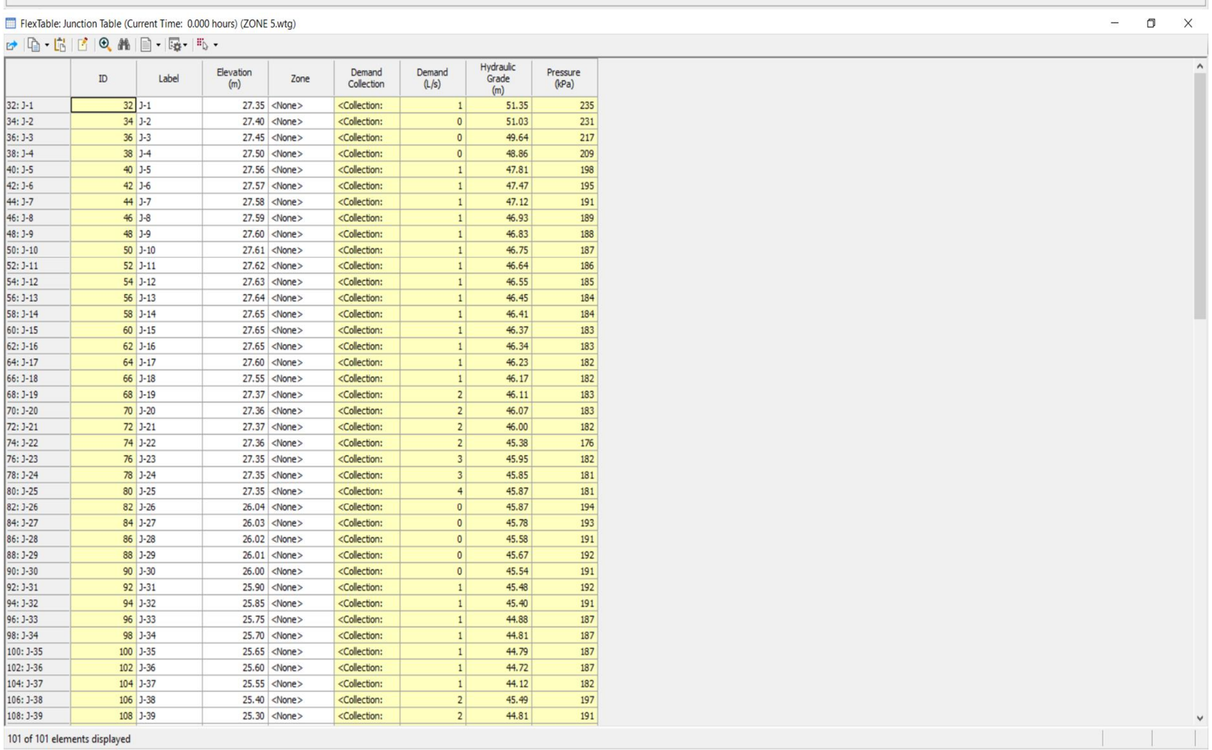


Properties - Reservoir - R-1 (255)

R-1 | 100%
<Show All>
Property Search

<General>	
ID	255
Label	R-1
Notes	
GIS-IDs	<Collection: 0 items>
Hyperlinks	<Collection: 0 items>
<Geometry>	
X (m)	3,988.22
Y (m)	1,707.95
Active Topology	
Is Active?	True
Operational	
Controls	<Collection>
Physical	
Elevation (m)	51.35
Zone	<None>
Hydraulic Grade Pattern	Fixed
Transient (Physical)	
Elevation (Inlet/Outlet Invert) (m)	0.00
Water Quality	
Age (Initial) (hours)	0.000
Concentration (Initial) (mg/L)	0.0
Is Constituent Source?	False
Trace (Initial) (%)	0.0
Results	
Hydraulic Grade (m)	51.35
Flow (Out net) (L/s)	110
Flow (In net) (L/s)	-110
Alert Level (Ever)	None
Alert Level (Now)	None
Has Calculation Messages Now?	False
Calculation Messages	<Collection: 0 items>
Results (Transient)	
Head (Maximum, Transient) (m)	(N/A)
Head (Minimum, Transient) (m)	(N/A)
Pressure (Maximum, Transient) (kPa)	(N/A)
Pressure (Minimum, Transient) (kPa)	(N/A)
Air Volume (Maximum, Transient) (L)	(N/A)
Vapor Volume (Maximum, Transient) (L)	(N/A)
Results (Water Quality)	

Label
Descriptive label for this element.



FlexTable: Junction Table (Current Time: 0.000 hours) (ZONE 5.wtg)

	ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Hydraulic Grade (m)	Pressure (kPa)
32: J-1	32	J-1	27.35	<None>	<Collection:	1	51.35	235
34: J-2	34	J-2	27.40	<None>	<Collection:	0	51.03	231
36: J-3	36	J-3	27.45	<None>	<Collection:	0	49.64	217
38: J-4	38	J-4	27.50	<None>	<Collection:	0	48.86	209
40: J-5	40	J-5	27.56	<None>	<Collection:	1	47.81	198
42: J-6	42	J-6	27.57	<None>	<Collection:	1	47.47	195
44: J-7	44	J-7	27.58	<None>	<Collection:	1	47.12	191
46: J-8	46	J-8	27.59	<None>	<Collection:	1	46.93	189
48: J-9	48	J-9	27.60	<None>	<Collection:	1	46.83	188
50: J-10	50	J-10	27.61	<None>	<Collection:	1	46.75	187
52: J-11	52	J-11	27.62	<None>	<Collection:	1	46.64	186
54: J-12	54	J-12	27.63	<None>	<Collection:	1	46.55	185
56: J-13	56	J-13	27.64	<None>	<Collection:	1	46.45	184
58: J-14	58	J-14	27.65	<None>	<Collection:	1	46.41	184
60: J-15	60	J-15	27.65	<None>	<Collection:	1	46.37	183
62: J-16	62	J-16	27.65	<None>	<Collection:	1	46.34	183
64: J-17	64	J-17	27.60	<None>	<Collection:	1	46.23	182
66: J-18	66	J-18	27.55	<None>	<Collection:	1	46.17	182
68: J-19	68	J-19	27.37	<None>	<Collection:	2	46.11	183
70: J-20	70	J-20	27.36	<None>	<Collection:	2	46.07	183
72: J-21	72	J-21	27.37	<None>	<Collection:	2	46.00	182
74: J-22	74	J-22	27.36	<None>	<Collection:	2	45.38	176
76: J-23	76	J-23	27.35	<None>	<Collection:	3	45.95	182
78: J-24	78	J-24	27.35	<None>	<Collection:	3	45.85	181
80: J-25	80	J-25	27.35	<None>	<Collection:	4	45.87	181
82: J-26	82	J-26	26.04	<None>	<Collection:	0	45.87	194
84: J-27	84	J-27	26.03	<None>	<Collection:	0	45.78	193
86: J-28	86	J-28	26.02	<None>	<Collection:	0	45.58	191
88: J-29	88	J-29	26.01	<None>	<Collection:	0	45.67	192
90: J-30	90	J-30	26.00	<None>	<Collection:	0	45.54	191
92: J-31	92	J-31	25.90	<None>	<Collection:	1	45.48	192
94: J-32	94	J-32	25.85	<None>	<Collection:	1	45.40	191
96: J-33	96	J-33	25.75	<None>	<Collection:	1	44.88	187
98: J-34	98	J-34	25.70	<None>	<Collection:	1	44.81	187
100: J-35	100	J-35	25.65	<None>	<Collection:	1	44.79	187
102: J-36	102	J-36	25.60	<None>	<Collection:	1	44.72	187
104: J-37	104	J-37	25.55	<None>	<Collection:	1	44.12	182
106: J-38	106	J-38	25.40	<None>	<Collection:	2	45.49	197
108: J-39	108	J-39	25.30	<None>	<Collection:	2	44.81	191

101 of 101 elements displayed

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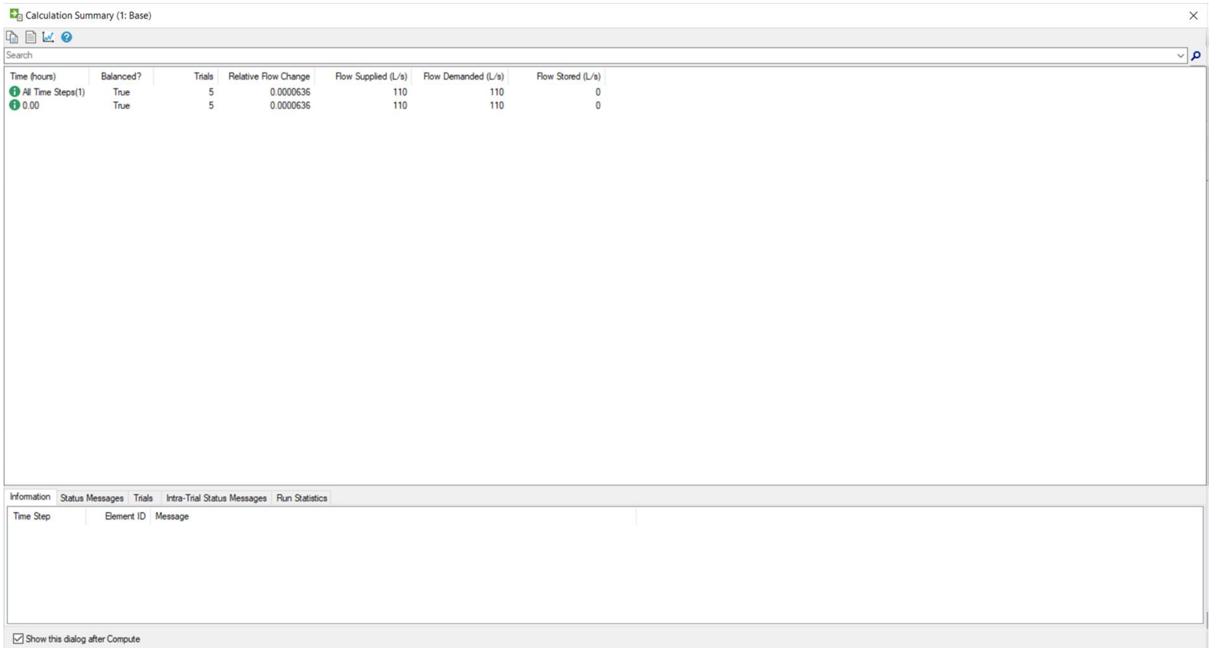
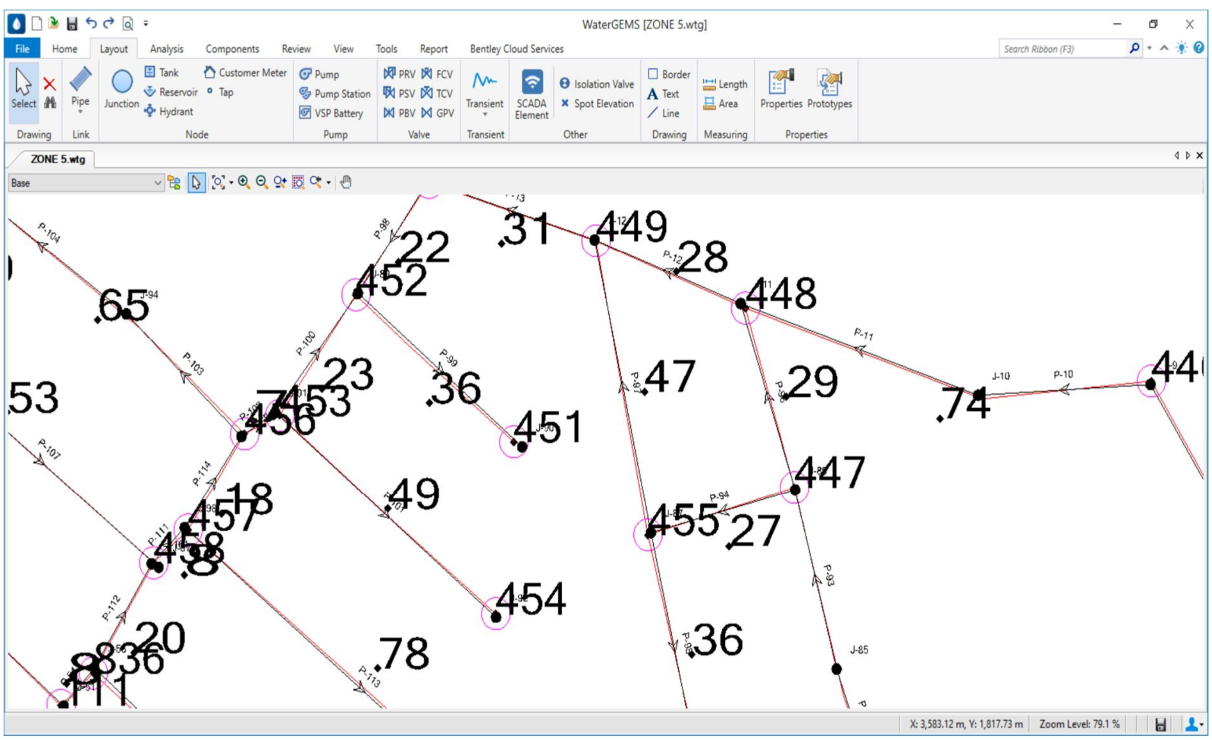
VIII. RUN THE MODEL

After all necessary data are imported , the model is Run. Then, Flow in the network will be shown in WaterGEMS , as shown in Fig





IX. CALCULATION SUMMARY

Once the model runs successfully, the next step is to review the results using the FlexTables. The Junction FlexTable displays details such as hydraulic grade line, pressure, and demand at each junction. The Pipe FlexTable includes parameters like flow, velocity, head loss, and pipe status. These reports help in assessing network performance and identifying elements that require design improvements.

X. RESULT AND DISCUSSION

The pipe report of the proposed network includes 115 pipes. The material used for all the pipes is ductile iron, with a Hazen-Williams roughness coefficient (C) value of 140. The observed velocity across the network ranges from 0.08 m/s to 1.45 m/s, which lies within acceptable hydraulic standards. The diameters of the pipes vary from 100 mm to 600 mm. The comparison between the existing network and the WaterGEMS simulation results shows a maximum error of 0.25 and a minimum error of -0.19.. Despite this, the network demonstrates adequate flow capacity to satisfy the projected water demand.

The junction report consists of 86 nodes analyzed using WaterGEMS software, with pressure head calculations based on the Hazen-Williams formula. As per the CPHEEO manual, a minimum pressure head of 7 meters is required to ensure reliable water supply across the network. The simulation revealed fluctuations in pressure head values at various junctions, with water demand ranging from 0.14 liters per second to 11.22 liters per second. These findings highlight critical areas in the system that may require hydraulic improvements to enhance distribution efficiency

XI. CONCLUSION

The present study successfully demonstrates the design and analysis of a water distribution network using WaterGEMS software for the Adhewada region of Bhavnagar. Through the integration of field data—such as pipe lengths, diameters, elevations, and nodal demands—the model provided a detailed understanding of the hydraulic behavior of the existing and proposed systems. The simulation results highlighted areas with insufficient pressure head and excessive head loss gradients, guiding necessary design adjustments to meet CPHEEO standards. The findings underscore the effectiveness of WaterGEMS as a decision-support tool in optimizing urban water infrastructure. This research contributes valuable insights for municipal planners and engineers aiming to improve water supply efficiency. Future research could incorporate real-time monitoring data, demand forecasting, and energy efficiency analysis to further enhance the reliability and sustainability of water distribution systems.

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