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Design of pipe distribution network for Wagholi village using Bentleys' WaterGEMS

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***Abstract*— India is well-known as a developing country, as well as a country with a significant rural population. In a developing nation like India, it is crucial to provide basic facilities to the people, including healthcare, transportation infrastructure, education, and access to clean water in every household. Designing a rural water supply scheme is particularly important in such a context. The Maharashtra government's department, Maharashtra Jeevan Pradhikaran, has developed a water supply scheme to fulfill the water demands of the rural population in the state. The scheme ensures a water supply of 55 liters per capita per day (LPCD) in rural areas. This study focuses on the design of the pipe distribution network for Wagholi village, located in the Osmanabad district of Maharashtra. To design the pipe network for Wagholi village, Bentley's WaterGEMS software is utilized, with AutoCAD DXF file of same village as a background reference, obtained from MJP Osmanabad. The pipe distribution network for Wagholi village is divided into two zones, with separate tanks providing water to each zone. According to the regulations of Maharashtra Jeevan Pradhikaran, the network should maintain a pressure between 7 m-H_2O and 22 m-H_2O at each junction, with a velocity in each pipe of up to 1.2 m/s and a head loss gradient of up to 10 m/km. TCVs (Throttle Control Valves) are employed in specific areas to regulate the flow under certain conditions, such as during construction or drainage system maintenance in the village.**

Index Terms- Rural Pipe Distribution Network, Bentleys' WaterGEMS, CPHEEO Manual,

I. INTRODUCTION

India, renowned for its diverse rural landscape and population, faces significant challenges in providing access to clean and safe water in rural areas. The establishment of an efficient water distribution network across rural India holds paramount importance in ensuring that communities have reliable water sources to meet their daily needs. Overcoming obstacles related to infrastructure, financing, water source availability, technical expertise, operations, and cultural factors is crucial for successfully implementing and maintaining the network. By prioritizing investments in rural water distribution infrastructure and implementing comprehensive solutions, India can make substantial progress in addressing water access disparities and improving the quality of life for its rural population. Wagholi, a sizable village in Osmanabad district, boasts a well-connected road network with neighboring villages. The village has been developing as a livable place, thanks to the presence of good educational facilities and a market that provides essential commodities. Formerly, residents lived in old mud houses; however, many have now migrated to nearby villages or Malran to fulfill their household needs, resulting in the establishment of a new settlement. Unfortunately, the existing water supply system is inadequate to cater to the new settlement or the increased population. Hence, the implementation of a new water supply system is imperative.

Map of Wagholi

II. LITERARURE

The existing water network can be more accurately represented in digital form with the assistance of WaterGEMS. The literature shows that the software gives the user the ability to model various network components such as pipes, pumps, valves, tanks, and more. WaterGEMS is becoming increasingly popular as a result of its capacity to simulate a wide variety of scenarios, including the operation of the system in response to varying demand patterns, the investigation of fire flow, and the administration of pressure zones. The data from GIS, Google Earth, and AutoCAD can be imported into the WaterGEMS software, making it extremely user-friendly. When designing a continuous water system, employing software like WaterGEMS makes the process much simpler because it cuts down on the amount of time needed to do so and produces correct results in a shorter amount of time. In addition to this, it improves the efficiency of the distribution network in terms of both cost and performance. Additionally, WaterGEMS assists in analyzing the dependability of the future network. Engineers and water utility experts who are working on the study and design of water distribution systems often choose this software because of its powerful simulation engine, its capacity to be scaled, and its broad analysis capabilities.

III. Approach Methodology

Designing a pipe distribution network using Bentley's WaterGEMS involves several steps.

- Define the Project Requirements: Start by clearly defining the project requirements, including the service area, population, water demand, and any regulatory constraints. Consider factors such as peak hour demand, fire flow requirements, and future growth projections.
- Gather Data: Gather relevant data such as topographic maps, land use information, existing infrastructure data, water sources, and hydraulic boundary conditions .Obtain information on pipe network components, including pipe materials, diameters, lengths, elevations, and available pumps and tanks.
- Create or Import the Model: Create a new hydraulic model in Bentley WaterGEMS or import an existing model from other software (e.g., AutoCAD, GIS) using the appropriate import options. Set the model's coordinate system and map georeferencing if applicable.
- Define Demand Patterns: Define demand patterns for different customer types and time periods. Specify variations in demand throughout theday and different days of the week. Assign demand patterns to nodes or zones within the network.
- Set Boundary Conditions: Define the hydraulic boundary conditions, such as fixed or variable pressures at system inlets and reservoir/tank levels. Assign appropriate demands, sources, and controls at boundary nodes.
- Perform Hydraulic Analysis: Run a hydraulic analysis in WaterGEMS to evaluate the current system performance. Verify that the model accurately represents the existing system by comparing simulated results to measured data, if available. Identify areas of concern such as inadequate pressure, excessive velocities, or undersized pipes.
- Design Improvements: Identify areas for improvement based on the hydraulic analysis results and project requirements. Determine the required pipe sizes, pump capacities, and tank volumes to meet the design criteria. Consider optimizing the network layout by adding, removing, or reconfiguring pipes, pumps, and tanks.
- Run Design Scenarios: Create and analyze different design scenarios to compare alternatives and select the most suitable design. Evaluate the performance of each scenario in terms of pressure, velocity, water age, and other relevant parameters. Adjust pipe sizes, pump capacities, and tank locations as necessary.
- Optimize the System: Use WaterGEMS' optimization tools to automatically optimize pipe sizes, pump schedules, or tank locations. Define optimization goals, such as minimizing energy consumption, minimizing capital cost, or maximizing system reliability. Run the optimization analysis and review the recommended design changes.
- Finalize Design: Incorporate the recommended design changes into the model based on the selected scenario and optimization results. Validate the final design through additional hydraulic simulations to ensure the system meets the desired performance criteria.

- Documentation and Reporting: Document the methodology, assumptions, and results of the design process. Prepare reports, drawings, and documentation to communicate the design to stakeholders or clients. Include specifications and construction drawings for the recommended pipe network design.

1. Total Demand of Wagholi

The following table 1 shows the diameter, flow, and velocity in the pipe.

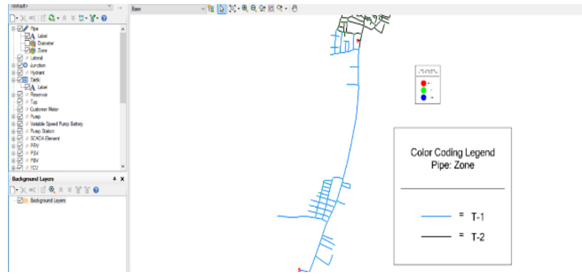
YEAR	2023	2038	2053
Population	5702	5702	5702
Floating Population	570.2	570.2	570.2
Domestic Water Demand (55 lpcd)	313610	313610	313610
Floating Water Demand (45 lpcd)	25659	28872	32085
Institutional Demand	2315	2658	3220
Total Demand	341584	383310	427455
15⁄ Loss	51237	57496	64118
Total Demand (lpcd)	392821	440806	491573
Peak Factor	1178463	1322418	1474719

Table 1

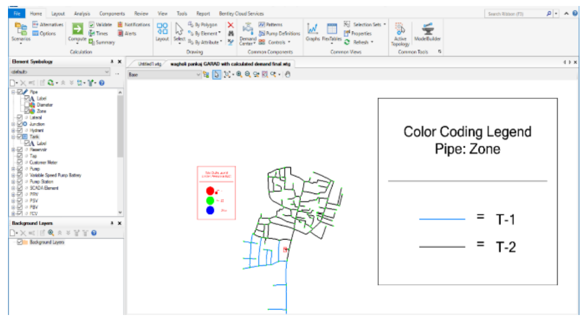
2.DESIGN VOLUME OF ESRs

Both elevated service reservoirs (ESRs) are to be designed to meet the water demand of the village throughout the day. This can be achieved by adjusting the frequency of water filling in the ESRs, such as filling them three times or two times a day. By designing the ESRs with a capacity of half or one third of the total demand, the required volume and cost of the ESRs can be reduced. For Wagholi village, considering a future total demand of 1,474,719 liters per day, both ESRs should be designed with a capacity equal to half of the demand. Therefore, each ESR should have a volume of 370,000 liters.

The designed network is as shown below.



ZONE 1 -TANL 1



ZONE 2 -TANL 2

IV. RESULTS

The following table 2 shows the diameter, flow, and velocity in the pipe.

Label	Diameter (mm)	Flow (L/s)	Velocity (m/s)
P1	132.3	8.87	0.64526
P2	132.3	8.157	0.59333
P3	132.3	7.878	0.57306
P4	132.3	7.645	0.55613
P5	132.3	7.449	0.54185
P6	132.3	7.375	0.53644
P7	132.3	5.435	0.39537
P8	132.3	4.475	0.32552
P9	132.3	4.038	0.29375
P10	132.3	3.799	0.27633
P205	84.8	2.34	0.41425

P206	84.8	2.234	0.39546
P207	70.4	0.037	0.00955
P208	84.8	0.227	0.04011
P209	70.4	0.016	0.00406
P210	84.8	0.141	0.0249
P211	70.4	0.014	0.00365
P212	84.8	0.049	0.00876
P213	132.3	8.19	0.59578
P214	132.3	8.034	0.58439
P215	70.4	0.043	0.01102

The following table 3 shows the demand and pressure in the junction.

Label	Elevation (m)	Demand (L/s)	Pressure (m H2O)
J1	666.75	0.555	9
J2	647.99	0.089	10
J3	647.83	0.032	10
J4	647.52	0.054	10
J5	646.98	0.029	11
J6	646.84	0.077	11
J7	646.63	0.024	11
J8	646.6	0.038	11
J9	646.57	0.092	11
J10	647.12	0.043	11
J188	647.43	0.092	19
J189	647.4	0.083	20
J190	647.34	0.015	20
J191	647.24	0.148	20
J192	647.09	0.117	20
J193	647	0.028	20
J194	646.81	0.112	20
J195	646.49	0.025	20
J196	646.23	0.155	21
J197	646	0.035	21
J198	645.6	0.031	21

Table 3

(Due to the length of the paper, only a few pipes and junctions are provided)

The following table 4 shows TCV result in network.

Label	Elevation (m)	Diameter (Valve) (mm)	Flow (L/s)
TCV1	645.74	70.4	2.308
TCV2	646.21	70.4	0.728
TCV3	645.91	70.4	1.395
TCV4	645.72	70.4	0.583
TCV5	645.52	70.4	0.062
TCV6	644.55	70.4	1.394
TCV7	644.94	70.4	0.412
TCV8	647.3	70.4	1.516
TCV9	656.33	70.4	3.184
TCV10	655.93	70.4	3.184

Table 4

V. CONCLUSION

The primary focus of this study is to design a pipe distribution network for Wagholi village. The objective has been successfully achieved as the designed network not only complies with all safety criteria but also proves to be cost-effective for actual implementation. In the proposed design of the pipe distribution network in the study area, each junction ensures sufficient pressure distribution, and all pipes maintain an adequate flow velocity. Consequently, the designed system will supply water to every household, maintaining a design pressure ranging from 7 m H_2O to 22 m H_2O, in accordance with the CPHEEO manual rules for water distribution. By incorporating TCVs (Throttle Control Valves) in the network, water flow can be halted in any situation, such as pipe bursts due to pressure or pipe network damage caused by excavation work in specific areas of Wagholi village. The designed pipe network is designed to fulfill the water supply requirements of Wagholi village for the next 30 years, until 2053.

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