International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

Design and analysis of water supply system: A case study

Shweta Patil *, Niteen M. Survase, Siddhesh Gosavi, Harita Gollapelli, Ajay Ghavhane, Sailee Sali and Samruddhi Dhane

Department of Civil Engineering, HOD Mr. Pravin M. Wale, Sinhagad Institute of Technology and Science, India.

International Journal of Science and Research Archive, 2025, 15(03), 679-687

Publication history: Received on 26 April 2025; revised on 07 June 2025; accepted on 09 June 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.15.3.1762

Abstract

"Design and Analysis of Water Distribution System" focuses on developing an efficient water supply system for rural areas, particularly in regions with limited access to clean and safe water. The project aims to optimize water distribution, maintain water quality, and address issues like water loss and inadequate pressure within the network. Using advanced software such as WaterCAD, the project analyzes the water demands of selected villages in Malshiras Taluka, Maharashtra, India, and designs a system to meet these needs. Key design elements include population forecasting, water demand estimation, hydraulic modeling, pipe sizing, pump selection, the construction of elevated service reservoirs, water distribution network. The towns' water supply network is analysed and developed using Bentley's WATERCAD programme. Water distribution network systems are designed to distribute water from a source to all or any single user in a sufficient amount, quality, and pressure. The project employs both conventional and advanced methodologies for water treatment, distribution, and optimization to ensure a reliable and sustainable water supply for the region through 2054.

Keywords: Water Supply System; Water Distribution Network; WATERCAD; Rural Area; Population Forecast; Water Demand.

1. Introduction

1.1. General

Water is an essential component of life and plays a critical role in sustaining public health, economic productivity, and environmental quality. In developing countries like India, the disparity between urban and rural water infrastructure is a persistent challenge. Despite various national schemes and five-year plans targeting rural development, a significant portion of the rural population still lacks access to safe, reliable, and sufficient drinking water. Malshiras Taluka in Maharashtra exemplifies this rural infrastructure gap, where many villages face recurring issues such as inadequate pressure, intermittent supply, and poor water quality. Contaminated water is a leading cause of waterborne diseases including cholera, typhoid, and diarrhea, which adversely affect health and livelihoods in these communities. In response to these issues, there is an urgent need for a technically sound, economically viable, and environmentally sustainable water supply solution. This research addresses the design and hydraulic analysis of a rural water supply system tailored for six villages in Malshiras Taluka—Jambud, Neware, Vitthalwadi, Malkhambi, Khalawe, and Dasur. The study adopts a comprehensive approach that includes population forecasting, water demand assessment, intake and treatment plant design, zoning, and the development of a robust distribution network. The design horizon extends to the year 2054, incorporating long-term sustainability and scalability. Modern tools like WaterCAD are utilized to model the hydraulic behavior of the network under varying conditions, ensuring that critical parameters such as pressure, velocity, and head loss remain within permissible limits. The integration of forecasting methods with hydraulic simulations bridges the gap between theoretical planning and practical implementation, ultimately aiming to

* Corresponding author: Shweta Patil

deliver safe drinking water efficiently to every household in the region. This paper thus contributes to the broader discourse on rural infrastructure development by providing a case-specific, data-driven, and software-aided solution for water distribution system planning and analysis.

1.2. Problem Statement

Rural regions in India often suffer from inadequate access to clean and reliable drinking water due to outdated infrastructure, lack of planning, and poor maintenance of existing systems. In Malshiras Taluka of Maharashtra, six villages—Jambud, Neware, Vitthalwadi, Malkhambi, Khalawe, and Dasur—face water scarcity, intermittent supply, and inconsistent pressure in their existing distribution systems. Rapid population growth, climate variability, and inefficient use of available water sources further strain the already limited infrastructure. Moreover, the absence of a hydraulic performance-based design often leads to uneven distribution and energy inefficiencies.

This study addresses the critical need for a well-structured, scientifically designed water supply system using advanced planning techniques and simulation tools. By integrating historical data, demand forecasting, and hydraulic modeling, this project aims to establish a framework for delivering clean water efficiently and equitably to all six villages up to the year 2054.

Objectives

- To determine water demand.
- To design water supply system.
- To design water distribution network.
- To design and analyse water distribution system using Water Cad

2. Literature Review

Le Huynh Tuyet Trinh, et al. (2024) highlight the use of WaterGEMS software in simulating complex water distribution networks and identifying inefficiencies such as low pressure, water loss, and high energy consumption. Its advanced features, including pressure management, leak detection, and demand forecasting, aid in effective decision-making. The Darwin Designer tool optimizes pipe sizing and enhances system performance. In water-scarce regions, WaterGEMS supports the development of sustainable strategies by modeling various supply-demand scenarios. This enables municipalities and utilities to plan efficiently, reduce water losses, and allocate resources effectively, promoting resilient and adaptive water distribution systems globally.

Rushikesh Ramesh Rao Yennawar et al. (2024) emphasize the improvement in designing Water Distribution Networks (WDNs) using tools like WaterGEMS and Google Earth. These technologies enable accurate mapping of pipes, junctions, and tanks, offering better insight into system behavior. Studies show that initial simulations often reveal issues like negative pressure or insufficient flow at junctions. In the Taroda WDN case, Darwin Designer was used to optimize pipe sizes and layouts, reducing non-compliant junctions from 177 to 7. Such software-driven adjustments enhance pressure management, ensuring reliable water delivery and strengthening the overall efficiency and resilience of the distribution network.

Amitsingh Chavan, et al. (2024) highlight that efficient water supply management is crucial for urban areas facing rapid population growth and rising demand. Modern distribution systems are designed to ensure reliable, convenient access to water at the consumer level, thereby improving service quality. A key component of this efficiency is effective pressure management, which reduces water loss and leakage. Controlling pressure within the network enhances overall system performance, decreases operational costs, and conserves valuable water resources. These improvements collectively contribute to building resilient, sustainable urban water supply systems that can meet current and future needs effectively.

Indu Bala, et al. (2024) discuss the evolution of optimization algorithms from manual methods to advanced computational techniques. Before the 1960s, optimization relied heavily on time-consuming manual calculations. The emergence of computer technology transformed this process, enabling efficient analysis of complex problems. A notable advancement is the Comprehensive Learning Gravitational Search Algorithm (CLGSA), which simulates gravitational interactions among agents in the solution space. CLGSA enhances traditional models by incorporating a learning strategy, improving exploration and solution accuracy. This hybrid approach, combining physical laws with computational intelligence, exemplifies the shift toward intelligent, nature-inspired optimization techniques in engineering applications.

Rohitashw Kumar, et al. (2023) emphasize that water distribution is vital for the efficient use of water resources. A major challenge lies in the wide variety of available pipe sizes, which complicates network optimization. There is no universally accepted method for optimizing water distribution systems, as key parameters like pipe dimensions, water demand, and layout differ significantly across regions. This variability hinders the development of a one-size-fits-all solution. Therefore, effective optimization must consider all influencing factors to balance cost-efficiency with reliable network performance, ensuring sustainable and adaptable water distribution systems across diverse environments.

Sandesh Shitole, et al. (2023) outline a structured methodology for addressing aging water distribution networks. The process begins with a detailed survey using tools like Google Earth to map the geographical layout and assess existing infrastructure. An evaluation of the current system's performance is then conducted to identify deficiencies. A new network is designed using software such as WaterGEMS, incorporating projected population growth and future water demand. The proposed design is validated against key hydraulic parameters including flow, pressure, and pipe capacity. This comprehensive approach ensures the development of a reliable, efficient, and future-ready water distribution system.

Prof. Dr. M. N. Shelar, et al. (2022) conducted a study using WaterGEMS to design and analyze the water distribution system for Kharwal Village. The system configuration included pipes, junctions, and reservoirs, based on projected population growth and per capita water usage. Hydraulic analysis identified pressure and flow inefficiencies, which were addressed using the Darwin Designer tool to optimize pipe sizing and layout. Low-pressure zones were resolved through design refinements. The project emphasized minimizing water loss and leakage, resulting in a reliable, sustainable, and scalable distribution system that ensures efficient water delivery.

Usman Mohseni, et al. (2022) conducted a study using EPANET software to analyze the water distribution network of Saveetha University. The system includes 14 pipelines and 14 nodes, all connected to a central overhead tank. The network uses a uniform pipe diameter of 250 mm. The objective was to evaluate the hydraulic performance of the system, focusing on flow and pressure compliance to ensure reliable water supply. EPANET was employed to simulate the network's behavior under various conditions, helping identify inefficiencies, pressure drops, or capacity issues, and guiding necessary improvements for optimized and consistent water distribution.

Qamar Sultana et al. (2021) describe the design of a water distribution system as involving several key steps. The process begins with surveying maps to gather geographical and topographical data, which serve as the foundation for planning. A tentative layout is then drafted, considering pipe routes, infrastructure placements, terrain, and population distribution. Pipe diameters are calculated based on water demand, pressure, and flow rates, often using hydraulic equations like Hazen-ssWilliams. EPANET software is employed to simulate and optimize the system's performance, analyzing pipes, pumps, and tanks under various conditions. Essential data such as maps, elevation, and water demand are crucial for accurate, sustainable design.

Survase N.M., et al. (2021) presented the design and analysis of a rural water supply system for villages in Jharkhand's Bhageya region. Due to inadequate sources like wells and hand pumps, the study proposed a community-based system using Damodar River surface water. Population forecasts guided demand estimation at 55 LPCD per CPHEEO norms. A 3.5 MLD treatment plant was designed with standard processes, and the distribution network, divided into three zones, was analyzed using Bentley WaterCAD. The system ensures sustainable and equitable supply and demonstrates the utility of software tools for efficient water infrastructure planning.

Rushikesh Jagtap, et al. (2021) analyze the existing water supply network of the ADYPU campus in Lohegaon, Pune. The study involves collecting pipe and junction reports to assess the current infrastructure. The primary goal is to evaluate the discharge and pressure head within the system to ensure efficient operation. EPANET software is utilized to simulate and analyze hydraulic parameters, helping identify areas that require improvement or redesign. This approach aims to optimize the campus's water distribution system, ensuring it meets the demand while maintaining efficient performance and sustainability.

3. Methodology

3.1. Data Collection and Preliminary Survey

A detailed survey was conducted to gather essential baseline data, which included:

- Historical population data (1991–2011) from census records.
- Existing water infrastructure details.
- Topographic features including elevation profiles of the villages
- Accessibility and proximity to water sources (primarily the Bhima River)

3.2. Population Forecasting

Accurate estimation of future population is critical for infrastructure planning. Forecasts were generated up to the year 2054, using the following standard methods:

- Arithmetic Increase Method: Assumes a constant population increase per decade.
- Geometric Increase Method: Applies a fixed percentage growth rate based on historical trends.
- Incremental Increase Method: Enhances the arithmetic method by factoring in the trend of increase in growth rate.
- State Average Method: Uses the average state growth rate as a benchmark.

3.3. Water Demand Estimation: Water demand was calculated based on CPHEEO norms:

- Domestic Demand: 55 liters per capita per day (lpcd) at consumer end.
- System Losses: 15% added to account for leakages and wastage.
- Gross Demand: 65 lpcd, inclusive of losses.

Demand was further categorized into:

- Domestic use
- Institutional and public use
- Fire demand
- Industrial and commercial use (minimal for rural setting)

3.4. Zoning for Efficient Supply

The six villages were grouped into three zones, each containing two villages. Zoning was based on geographic proximity and elevation similarity to:

- Minimize pipeline lengths and pumping head.
- Simplify network layout.
- Enable phased implementation and maintenance

3.5. Hydraulic Design of Components

- Intake Well: Designed to extract sufficient raw water from the Bhima River.
- Rising Main: Pipeline from intake to Water Treatment Plant (WTP), designed for minimal friction losses.
- WTP: Designed as a conventional plant with a 2.60 MLD capacity using aeration, flocculation, filtration, and chlorination units.
- ESRs: Elevated Service Reservoirs designed to hold ~40% of daily demand for each village.
- Distribution Network: Pipe diameters selected using Hazen-Williams formula to ensure sufficient pressure and velocity.

3.6. Pump Selection and Pipeline Design: Pumps were selected based on

- Required discharge rates and total dynamic head.
- Availability of power supply and daily pumping duration (16 hours).

PVC Class 10 pipes were used across the network, with diameters ranging from 90 mm to 160 mm depending on flow requirements. Water hammer calculations were performed to ensure structural integrity under transient flow conditions.

3.7. Hydraulic Simulation Using WaterCAD: The entire network was simulated using Bentley's WaterCAD software.

- Step 1: Create a network representation of the distribution system or import a text file with a basic description of the network.
- Step 2: Modify the attributes of the system's components. It entails changing the attributes of numerous objects such as reservoirs, pipes, nodes, and junctions, as well as entering the necessary data.
- Step 3: Explain how the system functions.
- Step 4: Choose from a number of different analysis options.
- Step 5: Conduct a hydraulic/water quality investigation.
- Step 6: Examine the analysis' findings, which may be seen in a variety of ways, including tables and graphs.
- Step 7: Repeat the procedure for all other distribution networks.

4. Results and discussion

4.1. Study Area, Population Forecasting and water demand

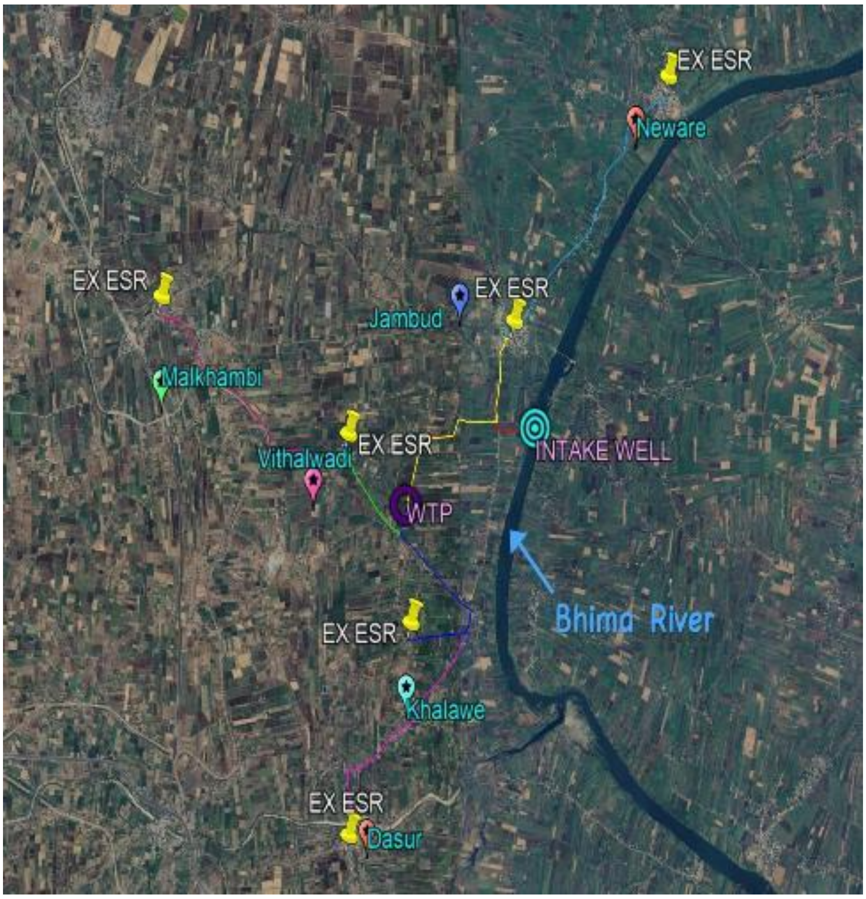

Figure 1 Study Area

Table 1 Population Forecast and Demand

Sr. No.	Village Name	Population				Demand(MLD)		
		2011	**2024**	**2039**	**2054**	**2024**	**2039**	**2054**
1	Jambud	4854	5496	6485	7255	0.3572	0.4215	0.4716
2	Neware	2978	4640	5475	6125	0.3016	0.3559	0.3981
3	Vitthalwadi	859	1411	1665	1863	0.0917	0.1082	0.1211
4	Malkhambi	2780	3704	4371	4889	0.2408	0.2841	0.3178
5	Khalawe	2121	4370	5157	5768	0.2841	0.3352	0.3749
6	Dasur	1979	3005	3546	3967	0.1953	0.2305	0.2579
TOTAL		15571	22626	26699	29867	1.4707	1.7354	1.9414

4.2. Design of intake well

- Intake well to WTP.
- Length : 2466 m.
- Pipe material: PVC of class 10kg, Pipe Diameter: 160 mm.
- Pump Capacity: 5HP.
- Overall demand : 2.603 MLD.
- Total pumps provided: 2 Working and 1 Stand by.

4.3. Capacity Calculations of WTP

Table 2 Capacity Calculations of WTP

Sr.No.	Description	Details	Unit
A	CAPACITY OF WATER TREATMENT PLANT		
1	Population (Year 2036)	26699	Souls
2	Gross Demand	1.735	MLD
3	Hours of pumping	16	Hours
4	Capacity of WTP	2.60	MLD
	Say	2.60	MLD

4.4. Summary of Design of ESR

Table 3 Summary of Design of ESR.

Sr. No.	ESR	Capacity (Lit)	Staging Height (m)	Levels	
				LSL (m)	FSL (m)
1	Jambud	86000	497	480	497
2	Neware	81000	502	480	502
3	Vithalwadi	23000	512	495	512
4	Malkhambi	62000	515	495	515
5	Khalawe	47000	525	482	525
6	Dasur	46000	517	482	

4.5. Pure Water Rising Main

- From Node -1 to ESR at Jambud (Zone-1) : - Diameter proposed is 140 mm PVC class 10Kg having 71 m length.
- From Node -1 to ESR at Neware (Zone-1) : - Diameter proposed is 110 mm PVC class 10Kg having 3680 m length
- From Node 2 to ESR at Vithalwadi (Zone-2) :- Diameter proposed is 90 mm PVC class 10Kg having 103 m length.
- From Node 2 to ESR at Malkhambi (Zone-2) : - Diameter proposed is 110 mm PVC class 10Kg having 3190 m length.
- From Node 3 to ESR at Khalawe (Zone-3) : - Diameter proposed is 110 mm PVC class 10Kg having 821 m length.
- From Node 3 to ESR at Dasur (Zone-3) : - Diameter proposed is 110 mm PVC class 10Kg having 3200 m length.

4.6. Pipe distribution network from WATERCAD of Dasur.

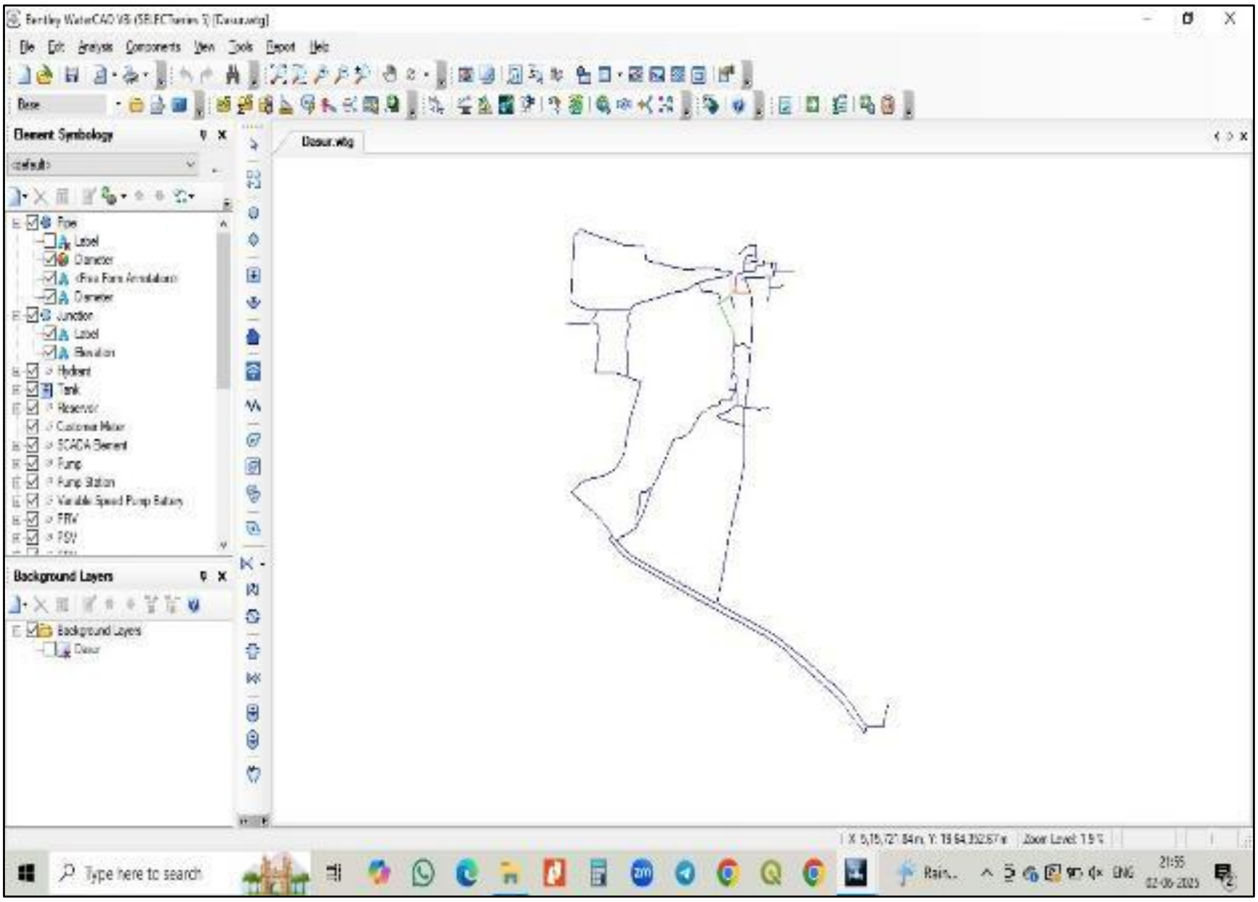

Figure 2 Pipe distribution network from WATERCAD of Dasur.

5. Conclusion

This project focused on designing a practical and reliable water supply system for six villages in Malshiras Taluka. The design was done step-by-step, starting from forecasting the future population and water needs, to creating a proper layout of pipelines, tanks, pumps, and treatment units. We divided the villages into three zones based on their location and height to make the system more efficient and reduce extra work and cost. We used WaterCAD software to test how the system would perform in real conditions. This helped us check if there would be enough water pressure, if the pipe sizes were suitable, and if any improvements were needed. The water treatment plant was designed using standard methods, and all major components like intake wells, rising mains, and elevated tanks were planned with accurate calculations. In terms of actual on-site work, we tried to keep the system simple and easy to maintain, especially keeping in mind the rural conditions. Materials like PVC pipes and pumps were chosen based on availability and ease of use. Backup pumps were also planned to make the system more reliable. Overall, the project connects technical planning with real-world execution. It is not just a theoretical design but a complete plan that can be implemented on the ground to provide safe drinking water to these villages for years ahead.

5.1. Future Scope of Study

- While the present study provides a solid foundation for a functional and sustainable rural water distribution system, several avenues remain open for future exploration. One direction is the integration of smart monitoring systems that go beyond traditional metering using real-time data to dynamically adjust flow, detect leaks, and minimize losses with greater precision.
- Additionally, the dependence on conventional energy for pumping can be reconsidered; introducing decentralized solar-powered units may not only reduce operational costs but also offer greater reliability in areas with unstable electricity supply.
- Another critical area involves understanding how shifting climate patterns could affect long-term water availability in the Bhima River and surrounding sources. Incorporating climate-resilient infrastructure planning could make the system more robust in the face of variability.

Compliance with ethical standards

Acknowledgments

The successful completion of this case study would not have been possible without the valuable support and cooperation of several individuals and institutions. We extend our thank to our guides for providing essential data and logistical support throughout the work. Our appreciation goes to our Head of Department and guide for their continuous encouragement, critical feedback, and guidance during every phase of this study.

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this case study. This research was conducted independently, and no financial or personal relationships influenced the findings, interpretations, or conclusions presented in this report.

References

[1] Amitsingh Chavan, G. K. Patil, (2024). Design And Analysis of Pipe Distribution SystemUsing Watergems For Asoada Town In Jalgoan District, Maharashtra State.

[2] Indu Bala, Anupam Yadav, Joong Hoon kim,et al (2024). Optimization for cost-effective design of water distribution networks: a comprehensive learning approach.

[3] Le Huynh Tuyet Trinh , Dinh Thi Hong Loan,(2024). Overview of WaterGEMS Software:Applications in Optimizing Water Distribution Systems and Addressing Water Scarcity.

[4] Prof. Dr. M. N. Shelar, Pratik Deepak Bhadane, Harshal Jaywant Patil, Om Sunil Tajane, Nakul Anil Wagh, (2022). Design of Water Distribution System In WATERGEMS For KharwalVillage.

[5] Qamar Sultana, Asma Sultana,(2021). Design of Water Supply Distribution System: A Case Study.

[6] Rohitashw Kumar, Junaid Khan, Dineshkumar Vishwakarma,(2023). Optimization ofWater Distribution Systems Using Genetic Algorithms: A Review

[7] Rushikesh jagtap, Rakesh Gawali, Vinayak Kanade, Sanket Thite, Prof PR Gayake,(2021).A review paper on design and analysis of water distribution system of ADYPU Campus.

[8] Rushikesh Ramesh Rao Yennawar,(2024). Design and analysis of Water Distribution Networks.

[9] Sandesh Shitole, Shambhuraj Chavan, (2023). Analysis & Design of Water distribution network of urban area by Watergems Software.

[10] Usman Mohseni, Azazkhan, (2022). Development of optimal water distribution system design and operation approach considering hydraulic and water quality criteria in manyobjective optimization framework.

[11] Survase Niteen Madhukar, Dr. M.L.Waikar (2021). Design of multi-village rural water system.

[12] https://jalshakti-ddws.gov.in/en/cpheeo-manual-water-supply-and-treatment

[13] https://theconstructor.org/structures/intake-structures-types-of-intakes/11233/

[14] https://iwaponline.com/aqua/article/70/7/1002/83539/Defining-domestic-water- consumption-based-on

[15] Manual for preparation of Detailed Project Report for Rural Piped Water Supply Schemes issued by Govt. of India Ministry of Drinking Water & Sanitation issued date 20th February2013.

[16] Water supply engineering: A Book by Dr. B.C. Punmia

[17] Water Supply System For Pune City Detailed Project Report February, 2014 Studio GalliIngegneria, life first.