Design a Water Distribution Network for a Small Tourist Resort

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Abstract: A well-planned water distribution network is an essential infrastructure component to ensure a reliable supply of clean water for guests and staff in a tourist resort, as well as to support recreational facilities like pools, spas, and gardens. A comprehensive water distribution network is created using EPANET software to ensure efficient water flow and adequate pressure throughout the resort. The network is designed to cater to peak and off-peak water demands, with special attention paid to maintaining pressures within safe limits. Firstly, the water consumption model is used to calculate water consumption for the resort. Secondly, the water distribution network is designed based on water consumption. A water distribution network using EPANET is developed to simulate and manage the water consumption of the resort. Thirdly, the main components that mainly affect the performance of water distribution systems include pumps, junctions, reservoirs, pipes, valves, and tanks, so the length of pipes, roughness of pipes, number of junctions, the height of houses reservoirs, tanks and wells are vital to the distribution of water. Finally, the water distribution network and its parameters (such as the length of pipes, and roughness of pipes) are designed and analyzed. Taking all the above factors into account comprehensively, a reliable and efficient system can be designed that ensures a consistent and safe water supply for all guests and resort facilities.

1 INTRODUCTION

Water to human life, agriculture, industry, and maintaining ecosystems grows more important, as decreasing world's water resources, growing populations and environmental changes. As tourism resorts develop, well-designed water distribution systems are essential to ensure guests have access to reliable and clean water, and therefore impact the overall visitor experience. The need for conservation of water resources and sustainable management is vital to support the world and address future challenges.

The EPANET software in water distribution network (WDN) analysis has been widely explored in various case studies, demonstrating its value in optimizing and ensuring the reliability of water supply systems. Adeniran and Oyelowo (2013) employed EPANET to analyze the water distribution network at the University of Lagos, Nigeria, including data collection, nodal demand estimation, network construction, network parameters design and result analysis. The study revealed deficiencies in the existing system, suggesting that improvements in pipes and the biggest tank. Similarly, Gupta et al. (2013) developed WDNs using EPANET and concluded that the results simulation of EPANET were close to the actual network. Bartkowska (2014) investigated the dynamics of water consumption in a tourist resort, emphasizing the importance of understanding consumption patterns and monitoring water consumption in designing WDN. Studies by Kakadiya et al. (2016) in Surat City further confirmed EPANET's role in simulating existing networks, showing how it helps validate the system's response to various conditions, such as the pressure at all junction and the flows even peak demand and operational stress. Venkata Ramana and Chekka (2018) extended these analyses by validating continuous water supply systems using EPANET. Their work demonstrated how simulations help maintain constant flow and pressure by setting appropriate values for parameters, which is critical for reliable water service. In the Thakur et al. (2020) study, water networks for NIT Srinagar were designed, reinforcing the value of EPANET in

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assessing different pipeline configurations for optimal performance. Košarac et al. (2019) and Mazouz (2021) explored optimization techniques using EPANET for efficient WDN design and management, underscoring their application in both new and existing systems. Lastly, Veer et al. (2022) discussed the role of EPANET in designing WDNs, affirming its importance for planning and addressing future demand challenges.

This article mainly studies the water distribution network of resorts, focusing on the theory, tools of water distribution systems, WDN design and analysis of a resort. How to use tools to simulate and manage the water demand of resorts is vital to the sustainable development of resorts.

2 WATER DISTRIBUTION NETWORK

2.1 Water Distribution Network

A water distribution network (WDN) refers to the interconnected network of pipes, pumps, valves, and storage facilities that transport water from sources to end users, such as homes, and entertainment facilities (Adeniran and Oyelowo 2013, Kakadiya et al. 2016, Thakur et al. 2020).

It is a crucial part of the water supply infrastructure, ensuring that clean and sufficient water is delivered efficiently to guests in the resort. Pipelines, junctions, pipes, pumping stations, reservoirs and storage tanks, valves and pressure-regulating devices are key components of a water distribution network. The design and operation of a water distribution network are essential for ensuring reliability, safety, and the long-term sustainability of water supply systems.

2.2 Bernoulli Equation with Local and Friction Losses

Bernoulli equation with local and friction losses is equation (1) for per unit volume flow for real fluid (Subramanian, 2024)

$$\frac{v_1^2}{2g} + h_1 + \frac{p_1}{pg} = \frac{2}{2g} + h_2 + \frac{p_2}{pg} + \Delta E \quad (1)$$

$$\Delta E = \Delta E_{local} + \Delta E_{friction} \quad (2)$$

$$\Delta E_{loc} = \zeta \frac{v2}{2g} \quad (3)$$

$$\Delta E_{friction} = f \frac{L}{d} \frac{v2}{2g} \quad (4)$$

Where, $\Delta E_{friction}$: head loss.

f: the friction factor from the Moody chart.

L: length of the pipe.

d: diameter of the pipe.

v: velocity of the fluid at a point.

g: acceleration due to gravity.

h: the elevation of the point above a reference plane.

P: the pressure at the chosen point.

ζ:loss coefficient of P.

In fluid dynamics, $\Delta E_{friction}$ equation is the Darcy–Weisbach equation, which is an empirical equation that relates the head loss, or pressure loss, due to friction along a given length of pipe to the average velocity of the fluid flow for an incompressible fluid. Pipe flow and velocity are calculated using the equation (1).

2.3 EPANET

EPANET is a widely used software developed by the United States Environmental Protection Agency (EPA) for modelling water distribution systems. It allows engineers and planners to simulate the flow of water, pressure in pipes, and the quality of water within a network of pipes over time.

EPANET can be used for hydraulic analysis, water quality simulation, system design and operations. The downloading link of the software EPANET is https://www.epa.gov/water-research/epanet.

3 THE PROCESS OF EPANET SIMULATION

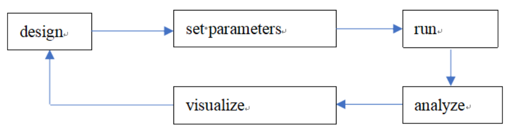

Figure 1: The process of EPANET simulation (Photo/Picture credit : Original)

Figure 1 shows the process of EPANET simulation as the following:

(1) Design a water distribution network and determine the number of pipelines, junctions, pipes, pumping stations, reservoirs and storage tanks, valves and so on.

(2) Set some parameters of equation (1).

(3) Run the water distribution network.
(4) Analyze the results of the water distribution network
(5) Visualize outputs of the water distribution network
(6) Reset the parameters of the water distribution network and refine the water distribution network until Reasonable results are obtained.

Through EPANET simulation, it is possible to determine whether it is consistent with the calculations using equations (1), (2), (3), and (4), as well as whether it meets various water requirements in actual situations.

4 THE DESIGN OF THE WATER DISTRIBUTION NETWORK IN A SMALL TOURIST RESORT

4.1 A Small Tourist Resort

A water distribution system for a small tourist resort which sits on a foothill was designed. The resort comprises 20 houses, each with 4 apartments and 5 guests in each of them. The resort also includes a restaurant with a social club and a swimming pool, along with a dedicated water supply for firefighting purposes.

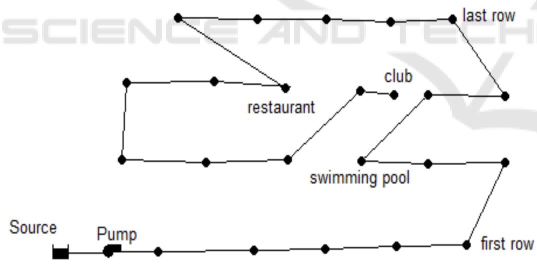

Figure 2: The network of a small tourist resort (Photo/Picture credit : Original).

The houses are arranged in 4 rows, with an elevation difference of 20 meters between the first and last rows. The resort is located 200 meters from an underground aquifer, with a constant water level 16 meters lower than the lowest row of houses. The network of a small tourist resort is designed using EPANET, which is shown in Figure 2. The little dots of Figure 2 represent facilities such as houses, swimming pools, clubs and restaurants. Section 4.2 is the designing detail.

4.2 Water Distribution Network

A comprehensive water distribution network will be created using EPANET modelling software to ensure efficient water flow and adequate pressure throughout the resort.

The network will be designed to cater to peak and off-peak water demands, with special attention paid to maintaining pressures within safe limits (2.0 to 6.0 bars).

(1) Water Consumption Patterns

There are twenty houses and eighty apartments in the resort. At most, there can be 400 guests here. The water consumption needs of different types of residents may be different in order to better plan the water distribution network. The water demands must be met during the peak period. Generally, people use different amounts of water at different times of the day, and there is a peak in water usage before and after meals. The largest peak is before dinner or after dinner. Water usage typically peaks just before dinner, with the highest demand occurring before dinner as guests use water for showering and other daily routines.

Based on the average monthly water consumption per person (3 cubic meters), the daily water usage per person is 100 litres (3000/30=100 litres). Considering peak demand periods, the maximum flow rate could reach 0.1 liters per second(LPS). Table 1 is the water consumption demand for the resort.

Table 1 The water consumption demand.

house	Swimming pool	club
0.1LPS	0.17LPS	0.1LPS
restaurant	hydrant	
0.1LPS	5LPS	

For the swimming pool, if 60 people swim every day and each person swims for 10 hours per day, the water consumption of swimming per second would be 0.33 liters per second.

$$100\times60 \div(10\times3600)\approx0.17 \text{ LPS} \quad (5)$$

The hydrant is used for firefighting, and a flow rate of 5 liters per second provides a substantial amount of water that is sufficient for smaller fire emergencies. In general, the hydrant is put the place which is closer to the water well or the entrance of the resort.

(2) Water Consumption Model

A diagram of water consumption patterns will be created using 24-hour patterns with hour coefficients. This will help identify peak and off-peak consumption periods, which will inform the design of the water distribution system. A model is created with a diagram of water consumption for groups. One house is in a node. One junction for the restaurant, one junction for the club and one junction for the pool are needed.

Parameters of network simulation experiments are determined. The network's performance is observed by adjusting parameters such as time step size and network complexity. The model is then refined based on experimental results. A model diagram of water consumption is created, and the water consumption of each room is calculated. Adjustments should be made according to real-world conditions to achieve more accurate conclusions in network simulation experiments.

(3) Pump Selection

Assume that water is obtained from an underground aquifer with a constant water level 16m lower than the lowest row of houses, located 200m from the resort. So pump is the main water supply of this resort. A pump will be selected based on the need to provide sufficient pressure to the highest elevation house during maximum consumption periods, while also ensuring that pressures do not exceed 6 bars and are not lower than 2 bars anywhere in the network during minimum consumption. The pump will be sized to draw water from the underground aquifer and deliver it to a central water storage tank or directly into the distribution network.

When water consumption is low, the reservoir stores the excess water, and during peak periods, it helps distribute water to consumers.

When water consumption is high, the reservoir is needed to distribute to the consumers. It's up to the reservoir to calculate and have enough storage of that reservoir for the consumers. The goal is to observe how the pump operates during low and high consumption, so the pattern is selected over a twenty-four-hour period.

A pump curve, pressure control and frequency regulation are combined to monitor the system's dynamic needs.

A pump curve shows how a pump’s flow rate and pressure are related, which helps to determine how the pump will perform under different conditions and is essential in selecting the right pump for specific applications.

Pressure control is necessary to maintain consistent water pressure throughout the system in a water distribution system. If pressure is too high, it can strain the system. If it is too low, water may not reach all users effectively.

Frequency regulation aims to vary the speed of the pump, and therefore the system can control both the flow rate and the pressure.

In a resort's water supply network, during low-demand hours, the pump speed can be reduced using frequency regulation, keeping the system running at a lower pressure and saving energy. During peak hours, the pump speed is increased to maintain the necessary water pressure and flow, ensuring guests have adequate water for showering and other activities. The pump curve helps to predict how the system will behave under these varying conditions.

Pressure control and frequency regulation are achieved by adjusting the pump's operating frequency to prevent the system from overloading under high-pressure conditions, ensuring a stable water supply.

Performance of the pump may be affected under low consumption and high-pressure conditions, so it is necessary to find the best solution. Adding pressure control and frequency control during the simulation process to address this issue.

(4) Pipe Sizing and Water Flow Analysis

Pipe dimensions must be determined through detailed flow analysis, considering the varying water demands and elevations of the houses. The goal is to minimize pressure fluctuations and ensure a smooth, uninterrupted water supply to all parts of the resort.

How to determine the appropriate pipeline size based on pressure and pipeline diameter when simulating water flow. It is necessary to consider the method of obtaining water. The water source provided by the resort is groundwater, then select the appropriate pipeline based on the pressure and water level of the groundwater. During the simulation process, it is possible to observe whether the minimum pressure requirement is met by adjusting the diameter and height of the pipeline. In addition, water flow can be better understood by viewing maps and link values. Finally, it is necessary to check the pipeline loss to ensure that it is within a certain range (Gössling, 2017).

The selection of pipe diameter should be based on an analysis of pressure loss, including both maximum and minimum pressure. Through simulation calculations, the optimal pipe diameter can be determined.

Firstly, it is necessary to understand the pressure loss of the pipeline, including the maximum and minimum pressures. Then, through simulation calculations, find the optimal pipe diameter. In the resort project, it is possible to avoid relying too much on the manufacturer's recommendations when selecting pumps, and instead choose based on the actual situation. Finally, the optimal pipeline diameter found will be applied to practical engineering design to achieve the best results.

In pipeline design, pressure-regulating valves can be used to adjust the pressure of the pipeline system. Firstly, connect an old pipeline to the port of a new pipeline, and then set a pressure reduction setting. Next, by changing the valve settings, the output pressure of the pipeline system is reduced. During this process, it can be observed that both upstream and downstream pressures are changing.Finally, by adjusting the pressure regulating valve, the pressure of the pipeline system can reach ten meters.

Diagrams of pressure heads during the day will be presented for two selected nodes: the lowest and highest houses. They will illustrate how pressure varies throughout the day, based on changing water demands and pump operation.

(5) Simulation of Water Distribution Net

The parameter values of the junctions,pipes, the pump and the aquifer of figure 2 are set up according to the above design of water distribution net, the project is run and the figure 3 and figure 4 are derived.

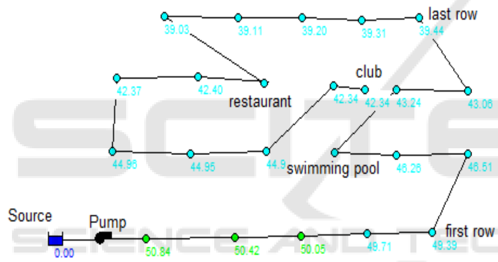

Figure 3: A small tourist resort with pressure (Photo/Picture credit : Original).

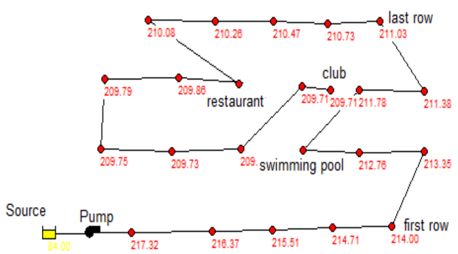

Figure 4: A small tourist resort with head (Photo/Picture credit : Original).

5 CONCLUSION

The study designed and simulated a water distribution system for a small tourist resort located on a foothill using a comprehensive approach. By carefully considering the site layout, water demands, pressure requirements, pump selection, pipe sizing and water flow analysis, a reliable and efficient system can be developed that ensures a consistent and safe water supply for all guests and resort facilities. When designing a water pump system, how to use these components (such as pipelines) needs to be closely integrated with actual needs, and each component plays an important role in the system.

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