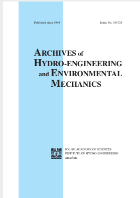
Archives of Hydro-Engineering and Environmental Mechanics 70 (2023), pp. 101–113, doi: 10.2478/heem-2023-0007

sciendo

ARCHIVES OF HYDRO-ENGINEERING AND ENVIRONMENTAL MECHANICS

Published since 1954 ISSN 1231–3726



Addressing Water Scarcity in Samdrupjongkhar Thromde, Bhutan: Feasibility Study and Design of a Sustainable Gravity Water Supply System

Vasker Sharma*, **Phurba Tamang, Rigden Yoezer Tenzin, Dawa Tshering**

Department of Civil Engineering and Surveying, Jigme Namgyel Engineering College, Royal University of Bhutan;

*Corresponding author: e-mail: vaskersharma.jnec@rub.edu.bt

(Received 18 August 2023; revised 05 October 2023)

Abstract. The provision of a reliable water-supply system is essential for the development and well-being of urban communities. Samdrupjongkhar Thromde, located in Bhutan, has been facing water supply challenges despite the presence of a water treatment plant. The non-perennial nature of the current water source coupled with malfunctions in water pumps has led to acute water shortages in the municipality. To address this issue, this study carried out a feasibility investigation and designed a gravity water supply system by conducting an EPANET (Environment Protection Agency Network Evaluation Tool) analysis. The study involved field visits to identify potential water sources, and a topographic survey using RTK (Real Time Kinematics) technology to determine the optimal pipeline route. The EPANET analysis was then conducted to evaluate the hydraulic performance of the initial route. Based on these findings, a final water pipeline route was selected considering factors such as terrain characteristics, construction feasibility, avoidance of negative water pressure, and minimum encroachment of private land. The results showed that the maximum pressure head within the pipeline system reached 296 m with a maximum water flow velocity of 5 m/s. However, at the outlet, the pressure head decreased to 70 m and the velocity decreased to 2 m/s. Two Break Pressure Tanks (BPT) were strategically placed to achieve this pressure reduction. The chosen pipe materials and their placement ensure the long-term reliability and functionality of the water supply system, while considering maintenance convenience and terrain characteristics.

Key words: water supply, gravity water flow, EPANET analysis, water pipe system design

List of Acronyms

BPT:	Break Pressure Tank
DDA:	Demand Driven Analysis
DEM:	Digital Elevation Model
DI:	Ductile Iron

EPANET: Environment Protection Agency Network Evaluation Tool
HDPE: High Density Polyethylene
LPS: Liters per second
MLD: Million Liters per day
PDA: Pressure Demand Analysis
QGIS: Quantum Geographic Information System
RTK: Real Time Kinematics
Sq. km: Square kilometers
SRTM: Shuttle Radar Topography Mission
WTP: Water Treatment Plant

1. Introduction

Access to clean, safe, and reliable drinking water is not only a basic human right, but also a crucial element for urban development, contributing to the overall well-being and livelihood of a community. Despite having abundant water resources, Bhutan faces challenges in providing accessible water owing to the complex topography of the region (Kuensel 2018). Although a significant volume of water flows through rivers, it is not readily available for drinking. Extracting water from rivers requires substantial resources and energy, which many people cannot afford owing to financial limitations. In Bhutan, communities typically rely on spring water and small streams for water supply. However, these sources have become increasingly unreliable in recent years, likely because of anthropogenic activities leading to land and forest degradation. Although several water projects are being geared up to provide clean and safe drinking water in Bhutan (De-suung 2023), the sustainability of such projects remains dubious owing to the lack of detailed feasibility studies.

Samdrupjongkhar Thromde (town) (*hereafter Samdrupjongkhar is referred to as Thromde only*), a municipality located in the southeastern part of Bhutan with a population of 10,545 residing in an area of 4.47 sq. km, is currently confronted with significant challenges concerning water availability and distribution (Wangchuk 2021a, World News Platform 2022). The acute drinking water shortage in the region stems from the absence of a perennial water source in the immediate vicinity of the municipality. This limitation poses a critical obstacle in ensuring a consistent and adequate supply of potable water to meet the needs of the growing population.

The availability of a perennial water source is fundamental to sustaining a reliable water supply. Currently, Thromde relies on the "Rickhey chhu" as its primary water source, located in Pinchina, approximately 4 km away from the municipal area. To ensure the delivery of potable water, a 2.5 MLD (million liters per day) water treatment plant (WTP) was established. However, despite these efforts, the region has faced persistent water shortages, particularly during the winter months, when the water source dries up because of its non-perennial nature (Wangchuk 2021b). The inadequacy of the existing water supply system further exacerbates the issue, especially in cases of malfunctioning water pumps, resulting in a severe water crisis within the locality.

The reliance on the "Rickhey chhu" as the current water source, although temporarily addressing the water scarcity issue, is a short-term measure that is unsustainable in the long run. The non-perennial nature of the source presents logistical and operational difficulties for maintaining a consistent water supply throughout the year. During the winter months, when the water source dries up, the situation worsens, intensifying the water crisis and adversely affecting the daily lives of residents. Moreover, the reliability of the existing water supply system is further compromised by the occurrence of malfunctions in the water pumps. These malfunctions lead to disruptions in the distribution of water, exacerbating the scarcity issue, and increasing the vulnerability of the community to prolonged periods without access to safe drinking water. These recurring challenges necessitate immediate attention and innovative solutions to ensure the provision of a sustainable and reliable water-supply system for Thromde.

One of the ways to design a water supply distribution is to use the EPANET tool. EPANET is a widely used computer program developed by the United States Environmental Protection Agency (USEPA) and is instrumental in the simulation and design of pressurized water distribution networks. Additionally, it can simulate water quality. EPANET networks consist of pipes, junctions, pumps, valves, and tank/reservoirs (Rossman et al 2000). These network features can be utilized, depending on the nature of the problem being resolved.

Numerous studies (Abdu et al 2022, Mohseni et al 2022, Fallah Morsali et al 2022, Knight et al 2023) have explored its application in evaluating the hydraulic performance of water-supply systems, including the assessment of pressure profiles, water velocity, and network optimization. Studies conducted in the field of water supply engineering highlight the effectiveness of EPANET in simulating and analyzing gravity water supply systems. The capabilities of the software, such as hydraulic modeling and network analysis, enable engineers and researchers to evaluate various parameters and scenarios to optimize the performance of water supply systems. EPANET has proven valuable in assessing the feasibility and effectiveness of gravity water-supply systems by simulating different scenarios and evaluating the performance of alternative water-supply routes. These studies (Aathira and Elangovan 2022, Safitri et al 2023) provided valuable insights into the application of EPANET in the design and optimization of water distribution networks. Studies have also been carried out using EPANET coupled with some other tools like Adaptive Neuro Fuzzy Inference System (ANFIS), and R (Hassanvand et al 2021, Mohseni et al 2022, Marques et al 2022) to understand the different hydraulic parameters and simulate different water supply scenarios.

In light of the pressing water issues faced by Thromde, this work attempts to conduct a feasibility study by identifying a potential viable water source for the water supply and designing an appropriate gravity water supply system using EPANET.

This study analyzed the distribution of water from the source to the existing WTP located in the Thromde. A water supply system has been proposed and recommended for the thrombus considering the sustainability and ease of maintenance, eliminating the use of pumps in the system. Based on the recommendations of the Thromde and stakeholders, the water supply has been planned such that Ductile Iron (DI) will be laid along the road point, while High-Density Polyethylene (HDPE) will be laid along the forest and complex terrain, while also minimizing the encroachment of private land for pipeline distribution. This approach was envisaged to minimize the costs incurred for routine maintenance and water disputes in the community.

2. Study Area

Samdrupjongkhar Thromde is located in southeastern Bhutan, with a population of 10,545, as shown in Figure 1. It is bordered by the Indian states of Assam to the south and Arunachal Pradesh to the east. The Thromde includes the towns of Samdrupjongkhar and Dewathang. The Dzongkhag (district) consists of 11 gewogs (sub-districts).

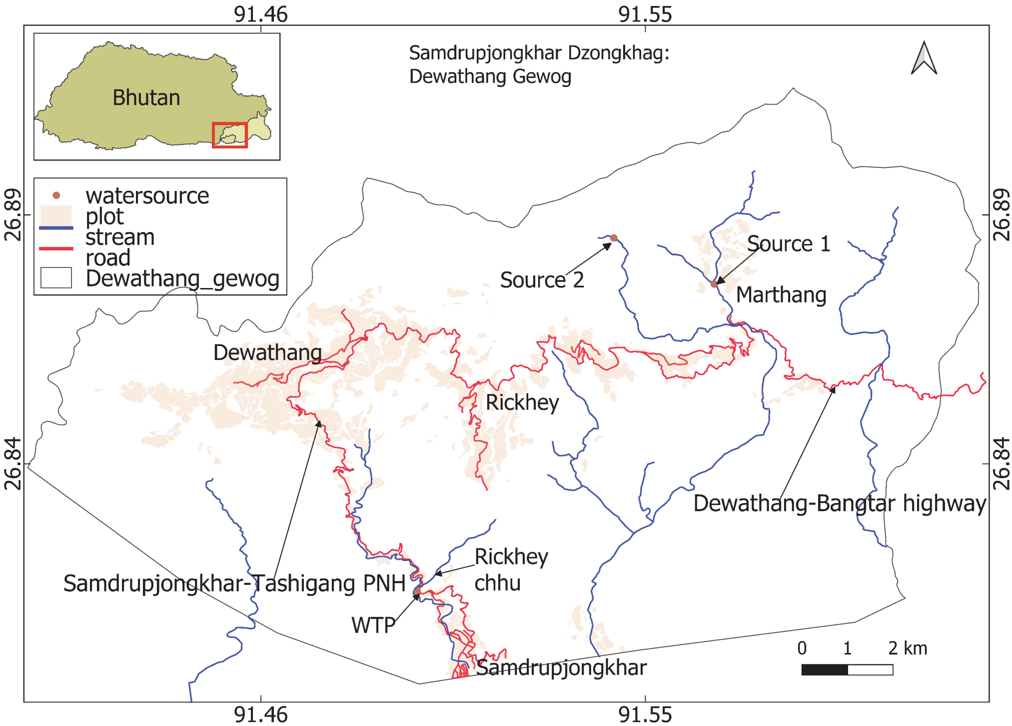


Fig. 1. Study area

The Thromde has established a 2.5 MLD WTP at *Pinchina*, 4 km away from the municipality. Currently, water is tapped from non-perennial “Rickhey Chhu” and is being delivered to the WTP. However, Thromde is exploring additional perennial water sources along a stream located in the vicinity. Samdrupjongkhar is located 18 km from the town of Dewathang. The WTP is located 211 m above the mean sea level.

3. Data and Methods

3.1. Field Visit to Confirm the Water Source

The initial phase of the study involved conducting extensive field visits and a reconnaissance survey. The study team, in collaboration with relevant stakeholders and officials from the Thromde, identified two distinct water sources. Source 1 was situated approximately 3 km away from the nearest road point, located at an elevation of 800 m. On the other hand, Source 2 was approximately 5 km away from the nearest road point, positioned at an elevation of 1150 m.

Both sources exhibited sufficient water flow; however, due to challenging terrain and turbulent stream water conditions, it was not possible to accurately measure the discharge and velocity of the stream. Nonetheless, local residents from the area reported that the flow remained consistent during both the summer and winter months.

Based on these observations gathered during the field visits, the study naturally progressed to exploring the potential utilization of these two water sources for the distribution of water supply.

3.2. Topographic Survey Using RTK along the Intended Water Pipeline Route

To determine the optimal route for the water pipeline, a topographic survey was conducted along the proposed alignment. Real-Time Kinematic (RTK) technology was employed to obtain precise elevation data and other topographic features along the route. The survey aimed to capture detailed information about the terrain, including slopes, obstacles, and any potential challenges that may affect the pipeline's alignment and construction.

The acquired RTK points from the topographic survey were integrated with the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) in Quantum GIS (QGIS). This integration allowed for comprehensive visualization and analysis of the topography, enabling the identification of suitable locations for the water pipeline route. By overlaying the RTK points on the DEM, the team gained valuable insights into the terrain characteristics and potential elevation changes along the intended route.

3.3. EPANET Analysis on the Initial Route

To evaluate the hydraulic performance and feasibility of the initial water pipeline route, an EPANET analysis was conducted. EPANET, a widely used software tool for water distribution system analysis, was utilized to simulate and analyze the flow of water through the pipeline network (Rossman et al 2000). The analysis considered factors such as elevation profiles, pressure head profiles, water velocity, and potential issues related to negative water pressure or inadequate flow rates. The EPANET analysis provided crucial information for assessing the effectiveness and viability of the initial route.

In this study, pumps and valves have not been integrated into the network because the water supply network has been designed based on gravity water flow. The water supply distribution has been designed by utilizing the general topography of the region and minimizing the use of additional energy for pumping. This approach has been used to minimize and ease the maintenance work for the Thromde. Although the EPANET has an option for choosing the Demand Driven Analysis (DDA) and Pressure Demand Analysis (PDA), this study utilizes the DDA for the analysis of the water supply system. In DDA, the demand at the nodes is kept constant while changing the pressure head at each junction. This sometimes led to a negative pressure head at the junction along the pipelines. Nevertheless, by re-aligning the pipeline along the topography the negative pressure head was avoided. The water distribution system has been designed with a demand of 20 liters/second (LPS) (~ 1.73 MLD) at the WTP, which can be effectively treated at the existing 2.5 MLD WTP. Further, to avoid excessive pressure heads along the pipeline, a break pressure tank (BPT) was introduced in the EPANET analysis.

EPANET offers different friction head loss formulas as shown in Table 1, that can be used in the simulation. However, in this study, Hazen-Williams (H-W) formula has been adopted as it is the most commonly used head loss formula and it can only be used for water flow in turbulent conditions. The Darcy-Weisbach (D-W) formula is the most theoretically correct and it applies to all flow regimes and all liquids. The Chezy-Manning (C-M) formula is more commonly used for open channel flow (Rossman et al 2000).

In Table 1, the following coefficients are used:
C = Hazen-William roughness coefficient,
ϵ = Darcy-Weisbach roughness coefficient (ft),
f = friction factor (dependent on ϵ, d, q),
n = Mannings roughness coefficient,
d = pipe diameter (ft),
L = length of pipe (ft),
q = flow rate (cfs).

The head loss due to friction between two nodes is calculated from the equation

$$h_f = Aq^B, \tag{1}$$

where:

h_f – head loss due to friction (length),
q – flow rate (volume/time),

A – resistance coefficient,
B – flow exponent.

The relationships for the resistance coefficient A and the values of the flow exponent for each formula are listed in Table 1.

Table 1. Coefficients for different formulae

Formula	Resistance coefficient (A)	Flow exponent (B)
H-W	$4.727C^{(-1.852)}d^{(-4.871)}L$ (eq. 2)	1.852
D-W	$0.0252f(\epsilon, d, q)d^{(-5)}L$ (eq. 3)	2
C-M	$4.66n^2d^{(-5.33)}L$ (eq. 4)	2

Table 2 below lists the general ranges of roughness coefficients for different types of new pipe materials. It is to be noted that a pipe's roughness coefficient can change considerably with the age of pipe.

Table 2. Roughness coefficients for new pipes

Material	Hazen-Williams C, (unitless)
Cast Iron	130–140
Concrete or Concrete Lined	120–140
Galvanized Iron	120
Plastic	140–150
Steel	140–150
Vitrified clay	110

Since the route for the pipelines involves the installation of numerous bends and fittings, minor head loss due to bends and fittings has been calculated. Minor head losses are the losses that occur due to turbulence at the bends and pipe fittings. It is given by equation (5):

$$h_L = k\frac{V^2}{2g}, \tag{5}$$

where k = minor loss coefficient for bends and pipe fittings.

In this study the coefficients listed in Table 3 have been used.

Table 3. Coefficients used in the study

Coefficient	DI	HDPE
Roughness coefficient (C)	130	140
Minor loss coefficient (k)	0.4	0.4

3.4. Finalization of Water Pipeline Route

Based on the findings from the EPANET analysis and considering factors such as hydraulic performance, terrain characteristics, and construction feasibility, the water pipeline route was finalized. The selection of the final route took into account the avoidance of negative water pressure, adherence to topographic suitability, and minimum encroachment of private land to avoid disputes. To avoid the encroachment of private land, land plot details were acquired from the Thromde and overlapped in QGIS to determine the optimal route. The chosen route aimed to ensure a reliable and efficient gravity water supply system for the Thromde, addressing the existing water scarcity issues.

4. Results and Discussions

4.1. EPANET Analysis

Based on the findings of the EPANET analysis, it was determined that attempting to deliver water from Source-1 would result in a negative pressure head along the intended route. Consequently, Source-1 was rejected, leading to the selection of Source-2 for the water supply. From Source-2, two different routes were considered for delivering water to the WTP in Thromde as shown in Figure 2.

The first route involved supplying water through the *Source2-Rickhey-Dewathang--WTP* route, spanning a total distance of 32 km. On the other hand, the second route entailed supplying water via the *Source 2–Rickhey–WTP* route, which covered a distance of 16.2 km. However, upon analysis, it was determined that delivering water through the option 1 route would result in a negative pressure head. As a result, the option 2 route was ultimately chosen as the preferred option for supplying water. To avoid an excessive pressure head along the second route, two break pressure tanks (BPT) were introduced in the EPANET analysis, which would eliminate the pipe bursting condition in the field. BPT1 and BPT2 were located 8 km and 12 km from the source, respectively.

Additionally, increasing the water demand at the WTP in Thromde beyond 20 LPS resulted in negative water pressure along the route. Consequently, the water demand was restricted to 20 LPS to ensure optimal water supply conditions. The elevation, velocity, pressure head, and unit head loss along the second route are shown in Figure 3.

Based on Figure 3, it can be observed that the maximum pressure head generated within the pipe system reached 296 m, accompanied by a maximum water flow velocity of 5 m/s. However, both the pressure head and the velocity decreased at the outlet of the system. The pressure head drops to 70 m, while the water velocity reduces to 2 m/s. This reduction in pressure head is primarily achieved by incorporating two BPTs into the system. The strategic placement of these BPTs enables the desired reduction in pressure along the pipeline.

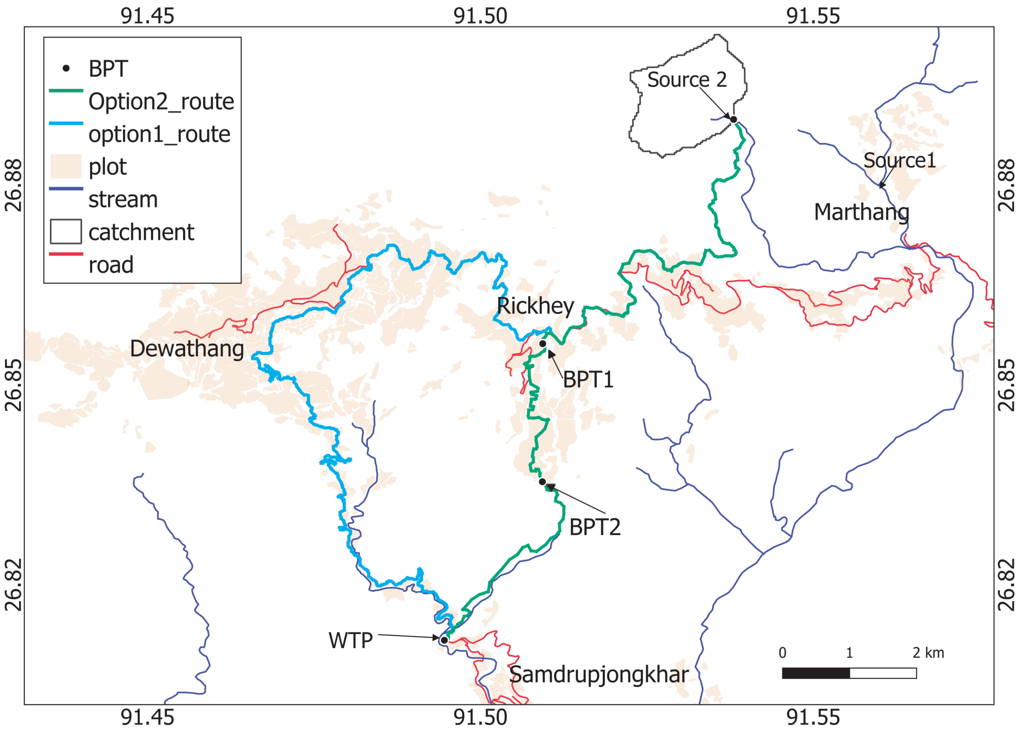


Fig. 2. Pipeline route options

To ensure the convenience of routine maintenance and align with the recommendations of the Thromde, specific considerations were made regarding the types of pipes used. In the analysis, DI pipes were predominantly chosen to be installed along road points, prioritizing ease of access for maintenance activities. On the other hand, HDPE pipes were selected for areas characterized by forests and complex terrain. This choice was made to accommodate the specific requirements and challenges posed by such environments, enhancing the efficiency and effectiveness of the water supply system.

By adopting this approach, the project aims to strike a balance between the practicality of maintenance operations and the suitability of the pipe materials for different terrains. This decision ensures the long-term reliability and functionality of the water supply system in Thromde while considering the unique characteristics of the surrounding landscape.

4.2. Selection of Pipes and Pressure Rating

The study involved the selection of Ductile Iron k-9 and HDPE PN12.5 pressure class pipes. The choice of these pipes was based on the pressure head calculated in the EPANET analysis. The DI pipe experienced a maximum pressure head of 296 m,

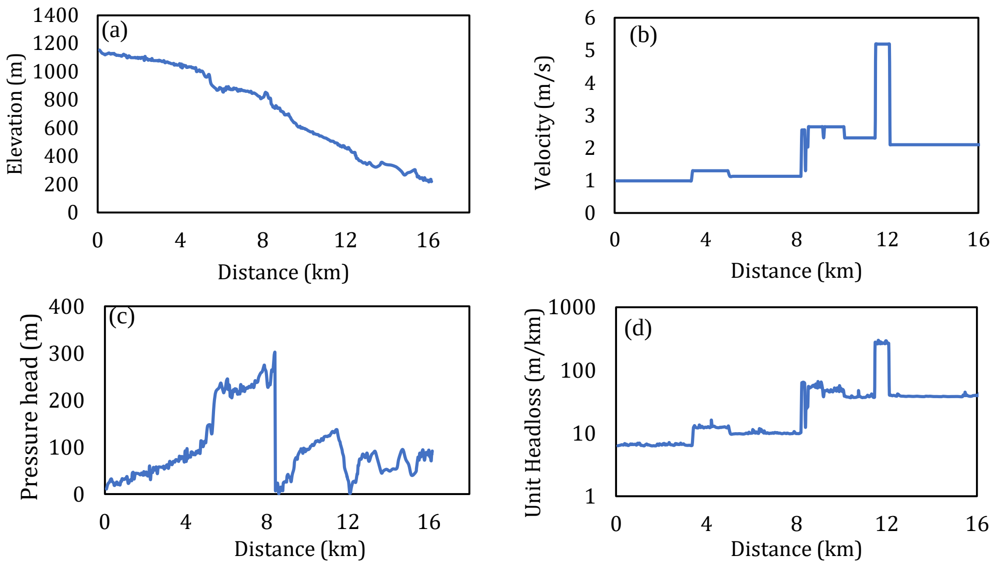


Fig. 3. Variations of calculated quantities along route 2: (a) elevation profile, (b) velocity profile, (c) pressure head profile, (d) unit head loss profile

while the HDPE pipe reached 113.20 m. According to the Bureau of Indian Standards (2005), based on IS 8329:2000, the Maximum Operating Pressure (MOP), including surge pressure, for both 100 mm and 150 mm diameter ductile iron k-9 pipes, is 7.7 MPa, which is equivalent to 785.20 m of water head. Similarly, as per the Bureau of Indian Standards (2002) based on IS 4984:1995, the maximum permissible working pressure for PN12.5 HDPE pipe is 1.25 MPa, equivalent to 127.5 m of water head. Therefore, the selected pipes are expected to withstand the pressure conditions in the field.

4.3. Pipeline Layout

To facilitate comprehension and practical application, a summarized pipe layout has been created in Table 4, outlining the pipeline lengths and specifying the pipe materials required at various junctions. Additionally, Table 5 provides a comprehensive overview of the types, sizes and lengths of pipes employed in the analysis. This information serves as a valuable resource for estimating the quantity of pipes needed for the water supply system.

Table 4. Details of designed pipeline

Junction		Distance from Source	Distance between nodes (km)	Diameter (mm)	Pipe Type	Remarks
From	To					
		12 m	0.012	150	DI	Intake weir to headwater tank
1	83	0–3.37 km	3.37	160	HDPE	Source (node 1) Elevation: 1153 m X: 354797.754 Y: 2975079.790
83	122	3.37–4.98 km	1.61	140	HDPE	
122	184	4.98–8.197 km	3.217	150	DI	
184	188	8.197–8.362 km	0.165	100	DI	
188	189	8.362–8.397 km	0.035	100	DI	BPT1 (node 189) Elevation: 766.48 m X: 351905.319 Y: 2971381.290
189	193	8.397–8.502 km	0.105	160	HDPE	
193	217	8.502–9.149 km	0.647	140	HDPE	
217	218	9.149–9.195 km	0.046	150	DI	
218	244	9.195–10.087 km	0.892	140	HDPE	
244	273	10.087–11.461 km	1.374	150	DI	
273	288	11.461–12.089 km	0.628	100	DI	BPT2 (node 288) Elevation: 460.594 m X: 351873.111 Y: 2969084.133
288	343	12.089–16.167 km	4.078	110	HDPE	WTP (node 343) Elevation: 211.87 m X: 350378.610 Y: 2966463.590
		Total Length (km)	16.179			

Table 5. Pipe types and lengths required

Pipe Type	Length (km)
150 mm DI	4.649
100 mm DI	0.828
160 mm HDPE	3.475
140 mm HDPE	3.149
110 mm HDPE	4.078
Total length	16.179

5. Conclusions

The provision of a reliable water supply system is crucial for the development and well-being of the Thromde in Bhutan. The existing water scarcity issues in the region, stemming from the reliance on a non-perennial water source located several kilometers away, have led to persistent challenges in meeting the growing population's water needs. The collaboration between the local premier engineering college and the Thromde to conduct a feasibility study using EPANET has aimed to address these pressing issues.

Through field visits and a reconnaissance survey, two potential water sources were identified, and their suitability for the distribution of water supply was explored. A topographic survey using the RTK technology allowed for the precise mapping of the proposed pipeline route, taking into account the terrain characteristics and potential obstacles. The integration of the RTK points with the SRTM DEM in QGIS facilitated a comprehensive analysis of the topography, aiding in the identification and realigning of an optimal route. An EPANET analysis was conducted to assess the hydraulic performance and feasibility of the initial pipeline route. The software simulated the flow of water through the network, considering factors such as pressure head, water velocity, and potential issues related to negative pressure. Based on the analysis, the initial route was refined, and the final water pipeline route was selected, ensuring reliability, efficiency, and minimal encroachment on private land.

The study also involved the selection of appropriate pipe materials, with DI pipes chosen for road points and HDPE pipes selected for forested and complex terrains. This strategic decision aimed to facilitate routine maintenance and optimize the functionality of the water supply system.

The results of the EPANET analysis indicated a maximum pressure head of 296 m and a maximum water flow velocity of 5 m/s within the pipe system. The introduction of BPTs along the pipeline route allowed for a reduction in pressure head to 70 m and a velocity decrease to 2 m/s, ensuring optimal conditions for the water supply.

The proposed gravity water supply system, based on the findings and analysis conducted in this study, offers a sustainable solution to address the water scarcity challenges in the Thromde. By leveraging the capabilities of EPANET and considering the specific characteristics of the region, the project aims to ensure a reliable and efficient water supply system that can cater to the needs of the growing population while allowing for routine maintenance.

References

Aathira M., Elangovan K. (2022) *Design and Analysis of Water Distribution Network Using EPANET and GIS for Pattanam Rural Area of Coimbatore District*, https://doi.org/10.4108/eai.7-12-2021.2315102.

Abdu M., Asrasal A., Sayfullah, M. (2022) Analysis of The Puncak Tumada Drinking Water Network System Using Epanet Software, *SCEJ (Shell Civil Engineering Journal)*, **7** (1), 41–51, https://doi.org/10.35326/scej.v7i1.2577.

Bureau of Indian Standards (2002) *High Density Polyethylene Pipes for Potable Water Supplies - specification (fourth revision): IS 4984: 1995 (reaffirmed 2002)*, Bureau of Indian Standards.

Bureau of Indian Standards (2005) *Centrifugally cast (Spun) Ductile Iron Pressure Pipes for Water, Gas and Sewage-Specification (third revision): IS 8329 : 2000 (Reaffirmed 2005)*, Bureau of Indian Standards.

De-suung (2023) *Water Project*, De-Suung. https://desuung.org.bt/category/water/.

Fallah Morsali M., Ramezani Etedali H., Bijankhan M., Mahdavi Mazdeh A. (2022) Evaluation of the application of automatic flow control valves to increase the water uniformity distribution in the drip irrigation system in sloping lands and modeling by EPANET software (Case study: Barajin park, Qazvin), *Irrigation Sciences and Engineering*, https://doi.org/10.22055/jise.2022.38621.1991.

Hassanvand M. R., Salimi A. H., Kisi O., Omidvar Mohammadi H., Abouzari N. (2021) Investigating Application of Adaptive Neuro Fuzzy Inference Systems Method and Epanet Software for Modeling Green Space Water Distribution Network, *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, **45** (4), 2765–2777, https://doi.org/10.1007/s40996-021-00625-8.

Knight J., Pradeep C., Lendzemo E. (2023) Modeling International Rural Low-Cost Water Supply Projects with EPANET: Application and Best Practices? A Case Study, [In:] *World Environmental and Water Resources Congress 2023*, 422–434, https://doi.org/doi:10.1061/9780784484852.041.

Kuensel (2018, June 18) Water shortage in water abundant Bhutan? *Kuensel*, https://kuenselonline.com/water-shortage-in-water-abundant-bhutan/#:~:text=The problem of water shortage, are running short of water.

Marques S. M., Silva F., Das Silva A. T., Barbedo M. D., Marcondes M. C., Alves S., Reis J. A. (2022) Evaluation of hydraulic behavior of water distribution network varying reservoirs levels, roughness, and diameters with the use of R and EPANET, *Ambiente & Agua-An Interdisciplinary Journal of Applied Science*, https://doi.org/https://doi.org/10.4136/ambi-agua.2893.

Mohseni U., Pathan A. I., Agnihotri P. G., Patidar N., Zareer S. A., Kalyan D., Saran V., Patel D., Prieto C. (2022) Design and Analysis of Water Distribution Network Using Epanet 2.0 and Loop 4.0 – A Case Study of Narangi Village BT, [In:] *Intelligent Computing & Optimization* (eds. P. Vasant, I. Zelinka, G.-W. Weber); 671–684, Springer International Publishing.

Rossman L. A., Woo H., Tryby M., Shang F., Janke R., Haxton T. (2000) *EPANET 2 . User Manual*, United States Environmental Protection Agency.

Safitri A., Wahyudi S. I., Soedarsono (2023) Simulation of Pipe Networks Using EPANET to Optimize Water Supply: A Case Study for Arjawinangun Area, Indonesia, *Archives of Hydro-Engineering and Environmental Mechanics*, **70** (1), 17–28, https://doi.org/10.2478/heem-2023-0002.

Wangchuk K. (2021a) *Water scarcity continues in Samdrup Jongkhar Thromde*, Bhutan Broadcasting Service, http://www.bbs.bt/news/?p=147209.

Wangchuk K. (2021b, July 2) De-Suung water project eases water scarcity, *Kuenselonline*, https://kuenselonline.com/de-suung-water-project-eases-water-scarcity/.

World News Platform (2022) New water distribution channel to solve Samdrup Jongkhar Thromde's water woes, *The World News*, https://theworldnews.net/bt-news/new-water-distribution-channel--to-solve-samdrup-jongkhar-Thromde-s-water-woes.