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Design And Simulation of a Sustainable Water Distribution Network in Iseyin, Southwestern Nigeria, Using EPANET 2.0 Hydraulic Software

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ABSTRACT

Efficient water distribution systems ensure water quality and a reliable supply. In Iseyin, the existing water distribution networks are non-functional, despite recent population growth. This research thus designs and simulates a sustainable water distribution network for Iseyin town Southwestern Nigeria using the Environmental Protection Agency Network (EPANET) 2.0 software to enhance water resources management. Climatic data such as temperature, precipitation, humidity, rainfall days, sunlight, and evaporation rate values were obtained from the Nigerian Meteorological Agency between 2014 - 2024. Population data were sourced from the National Population Commission and projected for 50 years using the geometric mean approach. Water samples from Atoori and Ajumoda reservoirs were analyzed for physico-chemical and bacteriological parameters. Water demand and Water Quality Index (WQI) were estimated. The water distribution network was simulated using EPANET software to compute demand, pressure, velocity, and headloss at 1:00, 12:00, and 24:00 hours. Annual climatic conditions revealed that temperature ranged from 23.90°C to 28.40°C, precipitation from 7.00 mm to 188.00 mm, humidity from 47% to 85%, rainfall days from 1 to 19, sunlight hours from 3.30 to 8.90, and evaporation from 9.21 mm to 17.19 mm. The projected population of 1,491,036 by 2052 yields a total water demand of 213,005,142.86 Lpd. WQI indicates that Ajumoda was moderately polluted in the rainy season but excessively polluted in the dry season with WQI of 73.03 and 303.89 respectively. In contrast, Atoori was excessively polluted in both rainy and dry seasons with WQI of 261.74 and 498.29 respectively. The simulated network at different times indicates that Atoori has greater fluctuations in demand, headloss, and pressure. This study emphasizes optimizing reservoirs, pressure regulation, and responsive network design to address variations.

INTRODUCTION

The quality and availability of water resources globally are increasingly under pressure due to population growth, urbanization, industrialization, and climate change (Mishra, 2023). Furthermore, water distribution involves an intricate network of infrastructure designed to deliver potable water from its source to consumers, encompassing pipelines, pumps, reservoirs, and treatment facilities (Mala-Jetmarova *et al.*, 2017). Simulation of water distribution using various hydraulic systems is pivotal in modern water engineering for optimizing network performance and ensuring reliable water supply. These simulations utilize advanced software tools to model complex networks, including pipes, pumps, valves, and storage facilities, under diverse operational scenarios (Balekelayi and Tesfamariam, 2017). EPANET assists in assessing alternative management strategies for improving water quality throughout a system. It has been used to design a water distribution system for Kathgarh (Arjun *et al*., 2015) and found that at a maximum supply of 8 hours per day, different nodes show different variations of pressure and demand. Reddy *et al.,* (2021) use EPANET to design for Village Balapanur and submits that to fulfill the water demand of the continuously growing population, it is essential to provide a sufficient and uniform quantity of water through the designed network of pipes. Teja *et al.,* (2024) use EPANET to design for the Dargamitta area in Nellore District, Andhra Pradesh, and report that the designed systems must be capable of distributing water efficiently, reliable, robust, and durable for which engineering teams must carefully plan the design, operation, maintenance and ensure that the water distributed through these designed network delivers the water at a known pressure in the designed time intervals. The current water distribution system in Iseyin town, particularly in the areas served by Ajumoda and Atoori reservoirs, faces significant challenges that hinder efficient water delivery. Existing infrastructure struggles with inconsistent water pressure, frequent supply interruptions, and inefficiencies that fail to meet the growing demand of the local population. This inadequacy in the distribution network affects residential, agricultural, and industrial activities, leading to water scarcity and adversely impacting the quality of life and economic development in Iseyin town. Moreover, the lack of a modern, well-designed distribution network makes it difficult to adapt to fluctuating demand patterns and environmental changes, exacerbating the problem. To address these critical issues, this study designs and simulates an optimized water distribution network using EPANET 2.0 hydraulic software specifically utilizing Ajumoda and Atoori reservoir as sources for water distribution.

MATERIALS AND METHODS

The Study Area and Infrastructure Data

Iseyin town is located on Latitude: 7° 57' 59.99" N Longitude: 3° 35' 59.99" E. The study involved collecting climatic data such as rainfall, temperature, and evaporation rates, from 2014 - 2024. This data was sourced from the Nigerian Meteorological Agency in Iseyin, providing valuable insights into the local climate. The data collected were then analyzed to identify trends and patterns over the period. Additionally, infrastructure data, such as the state of roads, water supply systems, and public facilities, contributed to understanding the region's development and environmental challenges, such as soil degradation and water scarcity.

Geographic and Demographic Data

Geographic data for the study area were obtained using ArcGIS 10.8 software. This GIS tool enabled detailed spatial analysis by integrating various data sets, offering a comprehensive understanding of the region. Topographic map data were used to generate accurate regional mappings that illustrated the area’s geographic characteristics. Population and land use characteristics data were essential for optimizing water distribution planning (Reddy *et al.,* 2021). Demographic and Population data were collected from the National Population Commission (NPC) Iseyin and the official website of the Nigeria Population Commission (www.citypopulation.de). The data was analyzed using the geometric mean method to project population distribution, density, and composition from 1932 to 2052. Land use characteristics were examined using ArcGIS 10.8, mapping agricultural, residential, commercial, and industrial areas. This analysis informed the design and simulation of the water distribution system in the study area.

Sampling and Laboratory Analysis of Water Quality

Samples were collected in clean, sterilized 2 L containers to prevent contamination and maintain sample integrity. Samples were taken from Ajumoda and Atoori reservoirs. Both reservoirs derive their water from nearby springs regarded as Ajumoda and Atoori springs respectively. From each location, three samples were collected at separate points for both the rainy and dry seasons, resulting in a total of six samples and twelve in the study areas. This complies with the standards enabling the identification of patterns, variations, and potential sources of contamination likely to be missed by examining only one point (QH 2024). Each sample was labeled with the date, time, and exact location of collection, ensuring precise documentation for subsequent analysis. The length, breadth, and depth of the various reservoirs were taken using a laser distance meter. Laboratory physicochemical and biological parameters of the water samples were analyzed for key indicators such as pH, turbidity, microbial content, and contaminant levels, adhering to standards. The pH level of the water was measured following the standard method specified by the American Public Health Association (APHA 2017). Turbidity was evaluated using nephelometric methods as outlined by the United States Environmental Protection Agency (EPA 2009). Furthermore, microbial analysis was conducted to identify the presence of pathogens such as bacteria, viruses, and protozoa, using membrane filtration as recommended by the (APHA 2017; EPA 2009; WHO 2017; WHO 2024) set standards for total coliform bacteria at zero per 100 ml of water, ensuring the biological quality of the water met health safety standards. Contaminant levels, including heavy metals, pesticides, and industrial pollutants were measured using methods such as atomic absorption spectroscopy and gas chromatography, following standards set by the (EPA 2009; WHO 2017). The water quality index (WQI) was determined from the obtained water quality parameters using the Weighted Arithmetic Index Method using equation (1) as outlined by Chidiac *et al.,* (2023).

$$\text{WQI} = (\sum(Q_n * W_n)) / (\sum W_n) \quad (1)$$

Where: Q_n is the quality rating for each parameter given as;

$$Q_n = (100*(V_n - V_O)) / (S_n - V_O)$$

V_n is the observed value of the nth parameter

V_O is the ideal value of the nth parameter in pure water

S_n is the standard permissible value of the nth parameter

W_n is the unit weight for each parameter given as;

$$W_n = K / S_n$$

K is a constant of proportionality

Design and simulation of water distribution network

The estimation of water demand was done by the analysis of population data obtained from NPC, Iseyin to project current and future water needs in the study area using Equation 2 below:

$$r = \sqrt[NG_i]{GI_1 + GI_2 + \ldots GI_n} \quad (2)$$

Where: *r* is the Geometric mean.

NG_i is the Number of geometric increments.

Gin is Geometric increment.

The estimation of water demand involves various factors, including domestic use, institutional demand, fire demand, and unaccounted-for (losses or unmeasured consumption) water with water consumption measured in liters per capita per day (Lpcd). The unaccounted-for water is estimated at 15% of the combined total of domestic, institutional demand, and fire demand. All these were used for determining water requirements in the area with projected population using geometric increase method equation 2, (APSEd, 2022).

$P_n = P_0 * [1 + (r/100)]^n$

(3)

Where:

P_n is the projected population after n number of decades in years.

P_0 last known population

r is the growth rate and

n is the number of decade years between P_0 and P_n

The EPANET 2.0 hydraulic software was employed to design and simulate a water distribution network centered on Ajumoda and Atoori reservoirs as the primary water sources in Iseyin town. The design phase involved mapping out the layout of pipes, valves, and storage tanks to ensure efficient water distribution and meet projected demand under different conditions, including peak demand periods, to optimize network performance. Demand, head, and pressure variations were analyzed at 1:00, 12:00, and 24:00 hours. The simulations revealed dynamic fluctuations in flow, velocity, and head loss, demonstrating the network's responsiveness to changes in demand throughout the day.

RESULTS AND DISCUSSION

Climatic and Environmental Data

The average temperature in Iseyin town ranges from 23.90°C in August to 28.40°C in March, reflecting a moderately warm climate with no extreme fluctuations. This climatic data highlights the monthly variations in key weather parameters, offering valuable insights into the environmental conditions relevant for designing and simulating a water distribution network using EPANET 2.0. This temperature pattern is consistent with findings by Ayejoto, (2023), who observed similar seasonal temperature variations in the southwestern region of Nigeria. The temperature fluctuations in the study area, with a minimum of 21.50°C and a maximum of 35.30°C, highlight the diurnal variations. This emphasizes the need to consider temperature-related factors in water distribution system simulations, as temperature can impact both the hydraulic properties of water and the durability of pipe materials. Precipitation in Iseyin is characterized by significant variation throughout the year, with the wet season from April to September receiving markedly higher rainfall compared to the dry months as depicted in Table 1.

The highest precipitation occurs in July with 188 mm, and the lowest in January with only 9 mm. This pattern correlates with typical tropical climatic zones, where rain is most frequent during the middle of the year. Ndehedehe (2019) made a similar observation, noting the distinct wet and dry seasons in other parts of West Africa, highlighting the significance of this information for the effective design of water distribution networks.

Furthermore, the relative humidity in Iseyin consistently remains high, particularly from May to October, exceeding 80% from June to October. This suggests a humid tropical environment, which could impact the evaporation rates and subsequently influence the water demand. High humidity levels are known to reduce water evaporation, leading to potentially higher water consumption during the wet months. This is consistent with the findings of Yang *et al*., (2023), who emphasized the impact of high humidity on local water demand, especially in urban areas. Additionally, the data shows a gradual increase in the number of rainy days from April to June, reaching a peak of 19 days in July. The information on the frequency of rainfall events supports the understanding of seasonal variability in water availability, a factor that is essential when simulating pipe network operations under variable conditions. Additionally, the average sun hours also show a gradual decrease from January to June, with a sharp dip during the rainy season, from 8.90 hours in January to just 4.00 hours in July.

Table 1: Mean Monthly Climatic Data of the Study Area.

Parameters	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temp (°C)	27.20	28.30	28.40	27.50	26.50	25.00	24.10	23.90	24.40	25.30	26.70	26.90
Min. Temp (°C)	21.70	23.10	24.10	24.10	23.60	22.60	21.80	21.50	21.90	22.40	23.10	21.60
Max. Temp (°C)	34.30	35.30	35.10	33.50	31.60	29.50	28.40	27.90	29.00	30.30	32.50	33.80
Precipitation (mm)	9.00	19.00	50.00	89.00	132.0	165.0	182.00	188.00	176.00	111.0	21.00	7.00
Humidity (%)	47.00	53.00	64.00	73.00	79.00	84.00	84.00	84.00	85.00	82.00	71.00	53.00
Rainy Days	1.00	3.00	7.00	11.00	15.00	17.00	19.00	18.00	18.00	14.00	3.00	1.00
Avg. Sun Hours	8.90	8.50	7.80	6.50	5.20	4.20	4.00	3.30	3.80	4.60	6.70	8.60
Evaporation Rate (mm)	14.70	16.97	17.19	15.30	13.38	10.84	9.49	9.21	9.92	11.31	13.75	14.12

Data: *1991 - 2023: Min. Temperature (°C), Max. Temperature (°C), Precipitation / Rainfall (mm), Humidity (%), Rainy days (d), and Sun hours (hours).*
Source: *The Nigerian Meteorological Agency Iseyin.*

This trend is indicative of the cloud cover associated with the wet season and can influence water temperature, evaporation rates, and ultimately the energy needs for water treatment. Similar trends were observed by Cascone (2019), who emphasized the role of solar radiation in the evapotranspiration process, which directly impacts the design parameters of water systems, particularly in terms of energy consumption. Finally, the evaporation rates, ranging from a high value of 17.19 mm in March to a low of 9.21 mm in August, suggest that the area experiences moderate evaporation, with a clear seasonal decrease during the rainy months. Previous studies, such as the one by (Wanniarachchi and Sarukkalige, 2022), highlighted the importance of incorporating evaporation data in water system designs to improve accuracy in predicting water loss and ensuring efficient water supply management.

Population Data

The population data presented in Fig. 1. highlights the significant growth trajectory of Iseyin town, projected from 1932 to 2052. This analysis is instrumental for designing and simulating a water distribution network, as population growth directly affects water demand and infrastructure requirements. The data demonstrates a geometric progression in population figures, which provides a basis for planning and sustainable development. The population increases from 10,654 individuals indicating an exponential rise, with population figures expected to cross 1 million by 2042 at around 1,491,036 by 2052 derived from equation 2 using 2022 projected population of 365,300 obtained from (www.citypopulation.de). This anticipated growth, driven by an annual population change rate of approximately 4.38% derived from equation 1, underscores the urgency for robust water distribution infrastructure. There are similar population growth trends in places near the study area, Odeyale (2023).

Land Use Characteristics Data

Tables 2 and 3 depict the analysis, conducted using Google Earth and ArcGIS 10.8, revealing the distinct distribution of land use categories across these areas, reflecting the unique socio-economic and infrastructural dynamics. In the Ajumoda area, which covers 115,635.45 m², residential land dominates with 64.27%, followed by agricultural use at 19.41%. The prominence of residential areas indicates a densely inhabited region with a high likelihood of concentrated water demand, especially in households. Table 2 shows that commercial spaces account for 3.52%, while mixed-use areas comprise 7.16%, suggesting moderate economic activity and multi-purpose land use in Ajumoda. Table 3 shows 4.15% and 3.09% respectively for Atoori.

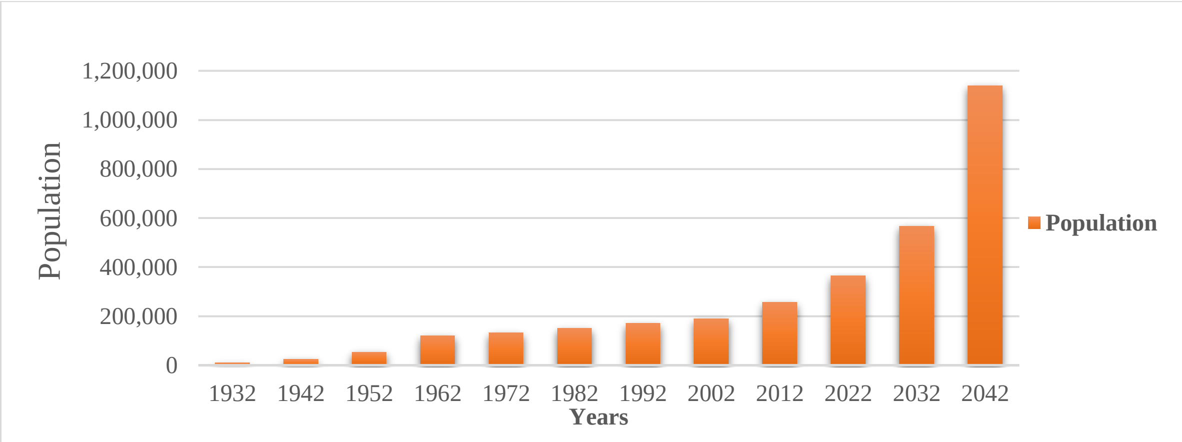

Fig. 1: Projected Population Growth (1932–2052) of the study area.

Source: Authors' Projections from Population Data Derived from https://www.citypopulation.de/en/nigeria/admin/oyo/NGA031016iseyin/

Table 2: Land Use Distribution and Area Coverage in the Ajumoda area.

Land use characteristics	Area covered (m^2)	Percentage (%)
Residential	74318.13	64.27
Commercial	4065.90	3.52
Mixed-Use	8280.80	7.16
Agricultural	22447.12	19.41
Transportation/Infrastructure	6523.50	5.64

Table 3: Land Use Distribution and Area Coverage in the Atoori area.

Land use characteristics	Area covered (m^2)	Percentage (%)
Residential	272898.05	51.87
Commercial	21848.14	4.15
Mixed-Use	16246.10	3.09

Agricultural	176155.15	33.48
Open Space/Recreational	19944.94	3.79
Transportation/Infrastructure	19029.96	3.62

The comparative analysis of water quality parameters for the Ajumoda and Atoori sites demonstrates significant variations influenced by seasonal changes and site-specific. These differences are crucial in understanding the dynamics of water quality and ensuring an effective design of the water distribution network using EPANET 2.0. at Atoori and Ajumoda,\ as shown in Table 4. pH levels at both sites generally remain within the standard range of 6.5 to 8.5 as observed by (Park et al., 2011). pH varies by season as observed by Wang et al., (2021) -pH levels in water sources tend to vary during dry seasons due to higher concentrations of dissolved contaminants. Temperatures ranged from 29.6 to 30.0 °C, while Atoori recorded higher values between 33.1 and 34.0 °C, particularly during the dry season. Both sites remained within the (Park et al., 2011) temperature limit of 35 °C. The elevated temperatures at Atoori, particularly those approaching 34.0 °C, could promote microbial activity, aligning with findings by Atangana and Oberholster, (2021) which link temperatures above 30 °C to increased Biochemical Oxygen Demand.

Table 4: Comparative analysis of water quality parameters across the study area.

PARAMETER	AJUMODA (Rain)	AJUMODA (Dry)	ATORI (Rain)	ATORI (Dry)	WHO 2019 (standard)
PH	7.29	6.85	8.60	5.40	6.5 - 8.5
Temperature (°C)	29.60	30.00	33.10	34.00	35
Dissolved Oxygen (DO) (mg/L)	7.20	4.20	6.60	4.20	5
Total Dissolved Solids (TDS) (mg/L)	0.03	0.05	0.42	3.48	1000
Biochemical Oxygen Demand (BOD) (mg/L)	3.34	7.20	1.10	3.00	3
Electrical Conductivity (EC) (µS/cm)	623.12	1150.50	8430.00	8756.70	1400
Turbidity (mg/L)	3.20	6.10	126.80	130.30	5
Nitrate (NO^{3-}) (mg/L)	10.60	14.20	14.30	17.80	50
Phosphate (PO_4^{3-}) (mg/L)	0.34	2.37	0.42	2.58	0.1
Chloride (Cl^-) (mg/L)	0.23	0.67	0.22	0.51	250
Sulphate (SO_4^{2-}) (mg/L)	0.01	0.25	1.12	1.80	250
Calcium (Ca^{2+}) (mg/L)	37.90	42.00	88.20	98.32	75
Magnesium (Mg^{2+}) (mg/L)	50.75	54.10	100.34	117.80	50

Water Quality Index (WQI) ratings for Ajumoda and Atoori highlight significant seasonal variations, providing critical insights for water resource management. Calculated using the Weighted Arithmetic Index Method, these ratings reveal the pollution levels affecting water quality in these locations as presented in Tables 5 and 6. There was observed lesser pollution due to diluted runoff during rainfall (Atangana and Oberholster, 2021) and excessive pollution due to accumulation in stagnant water during dry periods (Aladejana *et al.,* 2020).

Design and Simulation of Water Distribution Network

Estimation of the Water Demand

The total water demand for domestic use was calculated by adding up the sub-total, which amounts to 50 Lpcd (Abu-Bakar *et al.*, 2021). With a population of 1,491,036, the total water demand for domestic purposes is estimated to be 74,551,800 Litre per day. This calculation aligns with the findings of Abu-Bakar *et al.*, (2021) who also estimated domestic water demand in urban areas based on similar per capita usage values for different activities. Domestic water consumption is estimated at around 35% of the total water requirement for a place (WQE 2024). Also, institutional water demand was considered. Various types of facilities such as health centers, hotels, restaurants, offices, and markets contribute to the overall water demand. Each facility type is assigned a specific water consumption rate altogether regarded as industrial and commercial water demand which sums up to 30% of the total water requirement for a place (WQE 2024) amounting to 63,901,542.86Lpd. The fire demand is calculated to be 21,300,514.29 Lpd at 10% of the total amount of water (WQE 2024), reflecting the considerable volume of water required during emergencies, (Mortula *et al.,* 2020). The estimation of unaccounted water, which includes water losses due to leakage, theft, or inaccuracies in metering calculated as 15% of the total demand (Ali 2024) but at 25% of the total demand by (WQE 2024) amounting to 53,251,285.71 Litres. The gross/ overall water demand adds up all the water demands to 213,005,142.86 Lpd.

Table 5: Water Quality Index (WQI) Classification.

WQI Rating	**Classification**
25-50	Slightly Polluted
50-75	Moderately Polluted
75-100	Polluted (Very Poor)
>100	Excessively Polluted

Table 6: WQI Ratings and Pollution Levels.

S/N	**Sampling Points**	**WQI Rating**	**Classification**
1	AJUMODA (Rain)	73.03	Moderately Polluted
2	AJUMODA (Dry)	303.89	Excessively Polluted
3	ATORI (Rain)	261.74	Excessively Polluted
4	ATORI (Dry)	498.29	Excessively Polluted

Simulation of Water Distribution Network

The node results for Atoori and Ajumoda provide an in-depth analysis of the water distribution network, focusing on demand, head, and pressure variations at 1:00, 12:00, and 24:00 hours Fig.2 The findings highlight dynamic fluctuations in flow, velocity, and Headloss, emphasizing the network's response to demand changes throughout the day. These values reflect the variations in hydraulic conditions within the system, providing a detailed look at how different links behave over time under simulated conditions using EPANET 2.0. At 1:00 hours, most nodes in the Atoori area exhibit a demand of 0.4 LPS, with corresponding high values for head and pressure. For instance, Node J01 registers a head of 429.51 meters and a pressure of 131.61 N/m^2. This is indicative of strong water flow and pressure at the onset of the day, which is typical when consumption patterns are high, and water systems are under severe strain. However, by 12:00 hours, there is a noticeable reduction in demand, with most nodes showing a decreased demand of 0.2 LPS. This reduction is accompanied by a decline in both head and pressure, as exemplified by Node J01, where the head drops to 425.38 meters and pressure to 127.48 N/m^2. This trend continues into the 24:00-hour period, with demand at most nodes stabilizing at around 0.25 LPS, and pressure reaching its lowest points, such as at Node J01, where the pressure drops to 77.28 N/m^2. This progression suggests that the system is experiencing lower demand during late hours, which corresponds to a reduced need for water flow and pressure. In contrast, the results from the Ajumoda area demonstrate more stable readings, particularly at nodes with very low demand, such as J21 and J25, which show a consistent head and pressure at all-time intervals. Notably, these nodes exhibit minimal fluctuation in demand, with values consistently hovering around 0.07 LPS during the 1:00-hour and 12:00-hour periods, and maintaining a similar low level of pressure. This stability may reflect the characteristics of areas where water consumption is less variable or located near reservoirs with higher operational stability. This finding is consistent with research by (Kafle *et al*., 2022), who found that in areas with lower water demand and proximity to reservoirs, pressure fluctuations tend to be more controlled and consistent over time. The decline in demand and subsequent reduction in pressure observed at nodes such as J01 in Atoori and J22 in Ajumoda reflects broader trends seen in urban water distribution systems as presented in Figure 2. As demand drops during off-peak hours, the pressure and head naturally decrease, which has been noted in various studies examining the effects of time-of-day usage on water systems (Tian *et al*., 2023). These studies show that such fluctuations are crucial considerations when designing water distribution networks, as they directly influence system performance and the need for adequate storage and pressure management. However, the simulation also reveals areas where the network's performance might be less efficient, particularly at nodes far from the reservoirs. For example, the pressure at Node J03 in Atoori drops from 40.89 N/m^2 at 1:00 hours to 29.59 N/m^2 at 24:00 hours. This drop is particularly pronounced for nodes located further from the reservoir, suggesting that pressure losses due to pipe resistance and distance are significant, a phenomenon well-documented in hydraulic studies (Zhang 2020), this indicates that the design of the network must consider the impact of distance from the reservoirs and the potential for pressure loss in the transmission lines.

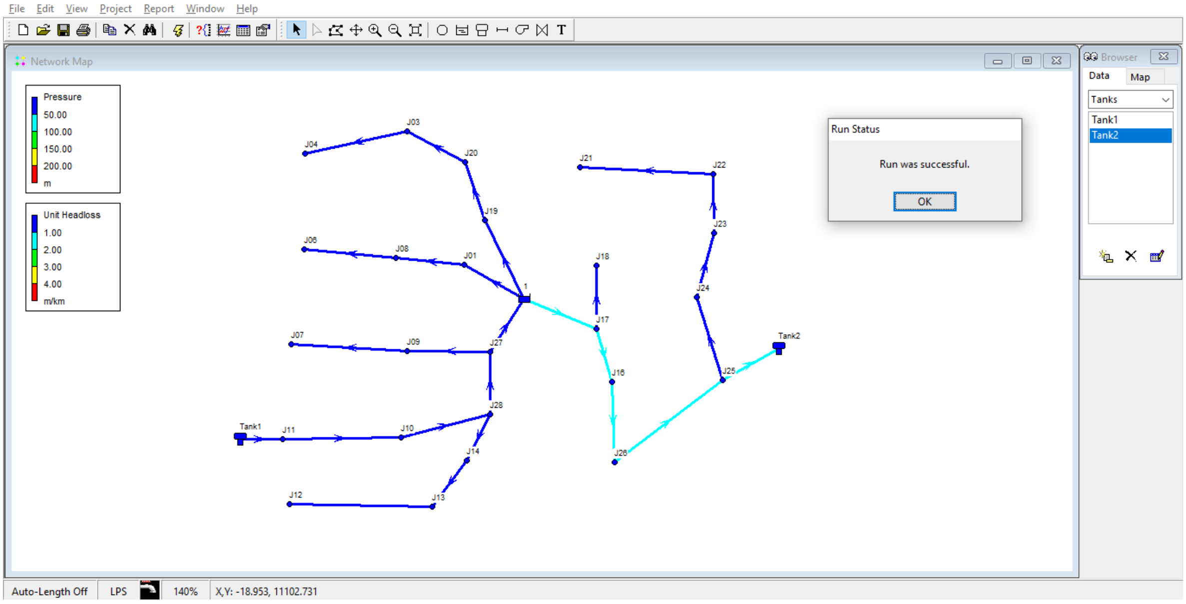

Fig.2: Design and Simulation of the Ajumoda Water Distribution Network.

Moreover, discrepancies between demand and pressure at certain nodes point to potential operational inefficiencies or issues with the network's configuration. For instance, Tank 2 in Ajumoda shows considerable fluctuations in demand and pressure, with demand of 50.87 LPS at 1:00 hours to 44.15 LPS at 24:00 hours, while pressure also fluctuates, reaching a low of 12.07 N/m^2 at 24:00 hours. This behavior suggests that the tank may be experiencing pressure regulation issues or inefficiencies in water distribution during peak times. Similar operational challenges have been noted in urban water distribution networks where poorly regulated tanks can exacerbate pressure fluctuations (Joseph *et al.*,2022). In Atoori, for example, several links show negative flow values, such as Link IDs 1, 2, 3, and 4, with the flow ranging from -139.29 LPS at 1:00 hrs to -136.89 LPS at 12:00 hrs and decreasing further to -97.43 LPS by 24:00 hrs. These negative values indicate reverse flow, which could be attributed to a variety of factors such as pressure fluctuations, demand variations, or incorrect system configurations. The velocities for these links are relatively high, ranging from 1.94 m/s to 2.0 m/s, reflecting the significant flow in the system, despite the negative flow values. Additionally, the headloss values for these links show a consistent decline, dropping from 10.35 m/km at 1:00 hrs to 5.34 m/km at 24:00 hrs. This reduction in headloss could indicate a more stable system or less resistance in the pipes over time. Moreover, Link ID 10, however, displays a distinct pattern with positive flow values of 21.28 LPS at 1:00 hrs, increasing to 30.06 LPS at 12:00 hrs and reaching a peak of 110.03 LPS at 24:00 hrs. This flow behavior is associated with increasing demand or system operation at higher flow rates, which might be linked to specific peak demand periods during the day. The velocities here also increase accordingly, from 0.3 m/s at 1:00 hrs to 1.56 m/s at 24:00 hrs, and headloss increases from 0.32 m/km at 1:00 hrs to 6.69 m/km at 24:00 hrs, indicating more energy loss due to friction as flow increases. In contrast, in Ajumoda, the results for Link IDs 33, 34, and 35 suggest minimal flow at all-time intervals. Link 33, for example, shows flows of 0.21 LPS at 1:00 hrs, 1.25 LPS at 12:00 hrs, and 0.77 LPS at 24:00 hrs, with velocities ranging from 0.02 m/s to 0.01 m/s and minimal headloss stable around 0.07m. These results likely reflect a less active or lower-demand section of the network. Similarly, Link ID 36 shows a sudden positive flow of 8.25 LPS at 1:00 hrs but quickly drops to 7 LPS and 6.49 LPS at the later time intervals, with consistent low velocities and minor headloss. These characteristics suggest that Ajumoda's water distribution network might experience less variation in flow compared to Atoori, possibly due to lower overall demand or less complex network dynamics as illustrated in Figure 3.

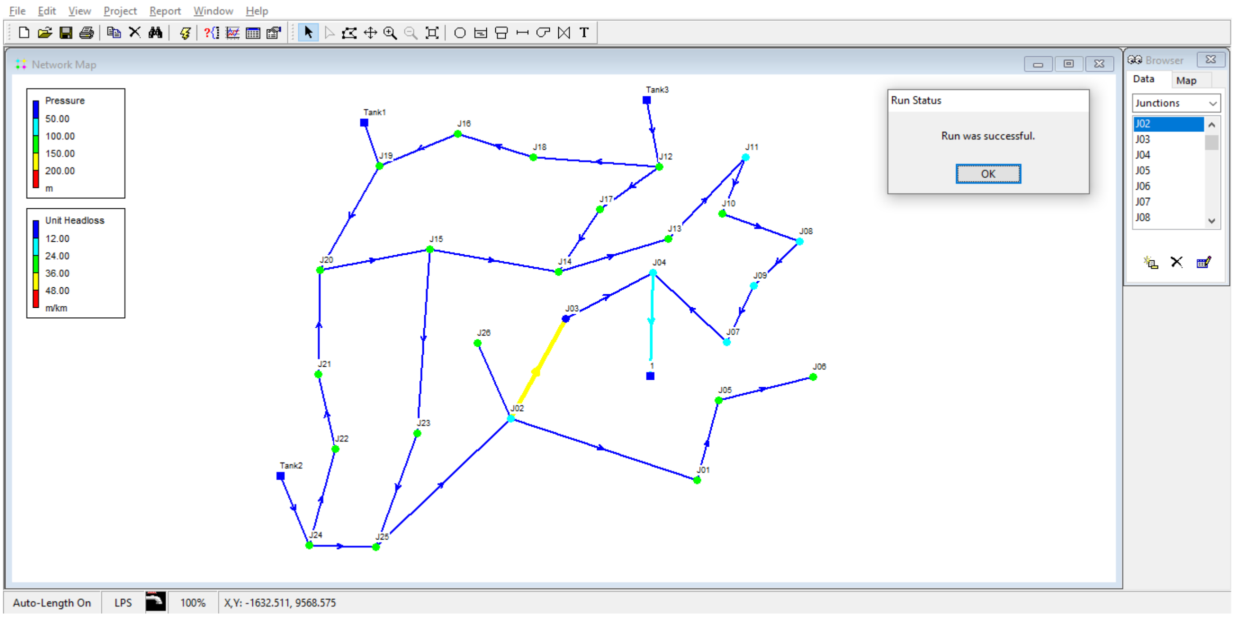

Fig. 3: Design and Simulation of the Atoori Water Distribution Network.

CONCLUSION

The research on Iseyin town highlights key factors essential for effective infrastructure planning. Seasonal climate variations influence water distribution design, while rapid urbanization and changing land use in Ajumoda and Atoori necessitate forward-thinking development strategies. Water quality analysis indicates seasonal and site-specific fluctuations in pH, turbidity, and conductivity, posing challenges for resource management. The estimated water demand of 213,005,142.86 Lpd highlights significant variations in demand, pressure, and headloss, particularly in Atoori, where fluctuations are most pronounced. The study revealed that there are varying demands in water, accompanied by head and pressure adjustments simultaneously due to variations in time and proximity of the nodes to reservoirs. Water pressures at Atoori ranged from 12.07 to 131.61N/m^2 depending on the time of the day and water demand Ajumoda area demonstrates more stable readings with consistent head and pressure at all times reaching 12.07N/m^2 at 24.00hours. There was reversed flow in some nodes at Atoori while positive demand flow ranged from 0.2 t0 110.03LPS while it ranged from 0.07 to 58.87LPS. There was a decline in headloss at Atoori from 10.35 to 5.34m/Km indicating a distinct pattern of positive flow but Ajumoda shows more stable readings with minimal headloss stabled around 0.07m. Velocity of flow ranged from 1.94 to 2.00m/s at Atoori and 0.01 to 0.02m/s at Ajumoda. These findings emphasize the need for optimized reservoirs, pressure regulation, and adaptive network designs to address these challenges effectively.

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