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Analysis of Current and Future Water Demand Situation in Gondar City Administration, Northwest Ethiopia

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Abstract: Water scarcity will affect the majority of the world's countries by 2025. The majority of developing countries in Africa and Asia are severely impacted by issues related to access to clean and safe potable drinking water. Water production and demand are unbalanced, and as a result of the continuous interruption of the water supply system, residents are experiencing water-related problems. Clean water resources are becoming scarce as a result of climate change and population growth. The main objective of the study is to analyze the current and future water demand situation in the Gondar city administration. In this study, the researcher used a cross-sectional research design based on the ground that helps advantageous to collect details of data from organizational reports of Gondar city water and sanitation office and Gondar city municipal in a short period of time. All data used in this study were secondary obtained from Gondar city water supply and sanitation offices daily, monthly and annual reports and from Gondar city municipal. Secondary research or desk research data analysis methods were used to achieve the study's general and specific objectives. The data obtained from secondary sources has been combined and presented in the form tables, charts, and figures combined with empirical evidence. A quantitative study was carried out in this research. The secondary sources include the National Water and Sanitation authority of Ethiopia, Gondar city Gondar city water supply and sanitation offices, and Gondar city municipality, Total population covered by the public water supply system, Per capita water demand per day, Design capacity and actual water production of Gondar public water supply system, and daily operational hours of public water supply system. Analysis of the current conditions was completed by evaluating the performance of the current water supply. The result was showing all water source were produced under their capacity because of detail study problem, management problem, energy inconsistency, seasonality of precipitation, electromechanically inefficiency, high migration to the city and high urbanization rate. The future water demand for casting were did from 2021-2034 the results again show that their water demand and supply imbalance will continue until 2029. Because of high population growth rate and urbanization expansion. Based on the present water design of the city the water balance between demand and supply will fully recovery after 2029. In generally to fill the gap between demand and water supply the city water supply and sanitation office should give attention to solve water scarcity of the Gondar city in the coming 12 years.

Keywords: Current and Future, Water Demand, Situation

1. Introduction

1.1. Background of the Study

Water scarcity will affect the majority of the world's countries by 2025. Fresh water reservoirs and glaciers around the world are drying up or melting, causing a water shortage in the agricultural and domestic sectors. This is a major global issue because it affects both water resources and the availability of safe drinking water for the population. The growing population and economic growth place significant strain on the hydrologic cycle and water resources. Water consumption, urbanization, and rising living standards all have a strong correlation, putting additional strain on available water resources. These pressures reduce the per capita availability of water in cities [2].

The majority of developing countries in Africa and Asia are severely impacted by issues related to access to clean and safe potable drinking water. Similarly, most developing countries, including Ethiopia, are still unable to obtain adequate potable water and have low potable drinking water supply coverage, causing citizens to face a water shortage [14].

Most urban planning and sustainable development decisions are heavily reliant on the availability of water resources and forecasting future water demand. Forecasting water demand is possible by developing a suitable mathematical water demand model based on the various factors (variables) that affect water consumption. It is also necessary for assessing the efficacy of management measures and developing guidelines and strategies such as water tariff setting. In general, water demand forecasts are very important in modern societies in order to ensure water availability and meet the need for water design for a sustainable economic water supply scheme [14].

Water demand forecasting would use historical data of urban water consumption as well as some correlation factor historical data to extrapolate future demand. Water demand forecasting can be accomplished by developing appropriate mathematical models based on the predictor variables that influence water demand [10].

Water production and demand are unbalanced, and as a result of the continuous interruption of the water supply system, residents are experiencing water-related problems. Furthermore, 20.38 percent and 24 percent of the water produced is lost in the distribution system before reaching the end-users, respectively [14].

Emphasis was put on examining the nature of the problems of water supply and challenges the service providers and households faced. The study has confirmed that the town water supply service could not cover the demand of it with present existing capacity and based on the research outcome only 43.3% of the respondents get water through their own private taps. All areas of the town could not get equal and proportional service and the tariff set is neither fair among the poor and rich households nor generates sufficient revenue to cover investment costs. The root causes of the challenging problems are institutional, financial, human and material resource constraints. That is, the water supplying service in the town is unsustainable; it is socially inequitable, economically inefficient and environmentally unsound [1].

In both urban and rural Ethiopia, access to the water supply is among the lowest in Sub-Saharan African countries, with existing service levels falling short of the required levels [19].

The situation in the study area, Gondar town, is not different to such realities. Therefore, the study was intended to Analysis of current and future water demand situation in the Gondar city administration.

1.2. Statement of the Problem

Water demand includes water delivered to the system to meet consumer needs, water supply for firefighting and system flushing, and water needed to operate the treatment facilities properly [13].

The volume of water requested by users to meet their needs is referred to as water demand. In a simplified sense, it is often considered synonymous with water consumption, despite the fact that the two terms do not have the same conceptual meaning [12].

Clean water resources are becoming scarce as a result of climate change and population growth. Water scarcity affects approximately 1.6 billion people (one-quarter of the world's population). Clean water resources are required by humans for industrial, agricultural, and residential purposes. Over the last century, water consumption has increased at twice the rate of population growth. Water scarcity has two primary causes: physical scarcity and economic scarcity. Water's physical availability is determined by natural water sources as well as technological advances such as desalination and rainwater harvesting techniques. Water use is increasing at twice the rate of population growth, implying that there is another source of scarcity. Surface water, underground water, and other sources provide the water that people require. Meanwhile, water demand is increasing [11].

Human demand for water is growing in tandem with economic development and population growth. Water is a valuable resource that cannot be replaced. Many countries and regions are currently experiencing varying degrees of water scarcity. According to the United Nations, one-quarter of the world's population is water-stressed. Over the last century, water consumption has increased at twice the rate of population growth. Water scarcity has two primary causes: physical scarcity and economic scarcity. Physical scarcity occurs when a region's water supply is insufficient to meet demand. Where water exists, but poor management and a lack of infrastructure limit the availability of clean water, there is economic scarcity. Many scientists believe that climate change and population growth will exacerbate the problem of water scarcity. Other reasons for water scarcity could include: Personal consumption increasing, as industrial consumption, and pollution is increasing, and depletion of the supply of fresh water [7] water supply cannot fulfil consumer demand for water because of Obsolete supply systems, electric power supply problems, lack of institutional capacity and budget shortage are the basic factors for this imbalance., the average per capita consumption was found to be less than the recommended standard, which is approximately at least 20 L of water per person per day. In line with this, the most frequent complaints by water customers were regular interruption of water supply and unfair water distribution Consequently, in order to narrow the supply and demand gap, expansion of water supply services that match with the town development must be carried out, the town water supply service enterprise should devise a mechanism so as to assure the equitable distribution of water among the residents and the concerned stakeholders should discharge their respective responsibilities properly [5].

Water resources are the source of contention between the economic and social systems and the ecological and environmental systems, as well as the link and bridge that connects the two systems. However, water resource allocation and security are vulnerable to risks arising from uncertainties in natural phenomena, social phenomena, and human activities, such as changes in precipitation runoff, population changes and economic development, policy changes, wars, and human understanding of the objective world. To maximize the economic benefits of regional water, use under the uncertainty of water supply and demand, we should rationally plan the water use of each sector, make scientific predictions, and allocate water resources in the region [21].

Water does not continuously flow in each individual's house at any time, in the required amount, and is not accessible everywhere in Gondar city administration. Regarding water-borne diseases, the study shows that, while water quality has improved in recent years, quantity supply still needs progress due to the low amount of water received per day [22].

The water supplying service in Gondar town in general is unsustainable; it is socially inequitable, economically inefficient and environmentally unsound improving the existing water supply service in the town in terms of quantity, reliability and sustainability means upgrading the socioeconomic welfare of the people in the town hence the authority should focus on it [1].

So, this study is intended to analyze the current and future water demand situation in Gondar city administration.

1.3. Objectives of the Study

1.3.1. General Objective

The main objective of the study is to analyze the current and future water demand situation in the Gondar city administration.

1.3.2. The Specific Objectives of the Research Were as Follows

1) To evaluate and represented the source, type, status and coverage of water supply in the area
2) To assess the functionality and service level of the existing water supply system in the city
3) To evaluate the water production, consumption and loss in the water supply system of the town
4) To forecast future water demand situation in the area

1.3.3. Research Questions

1. what are the represented source, type, status and coverage of water supply in the study area?
2. what are the functionality and service levels of the existing water supply system in the city?
3. How water is produced and consumed in the water supply system of the city?
4. what is the future water demand appearance of the city?

1.4. Significance of the Study

The significance of this study is to indicate the current and future water demand situation in supplying clean drinking water as well as viewing the way of the current and the future for policymakers and policy implementers.

2. Literature Review

2.1. Water Demand Definition

Water demand is the amount of water that the treatment plant must produce in order to meet all of the community's water needs. Water demand includes water delivered to the system to meet consumer needs, water supply for firefighting and system flushing, and water needed to operate the treatment facilities properly. Furthermore, virtually all systems have some amount of leakage that cannot be economically removed, so total demand usually includes some leakage. Unaccounted water is the difference between the amount of water sold and the amount delivered to the system. Unaccounted water can be caused by system flushing, leakage, fire suppression, meter inaccuracies, and another non-metered usage. Water demand varies seasonally, with winter usage being the lowest and summer usage being the highest. Demand varies according to the time of day as well. Diurnal peaks typically occur in the morning and early evening, with the lowest usage occurring during the day [13].

The current focus is to provide clean water for all of us. The supply of water must take into account the physical availability of water. Of course, social factors influence the availability and distribution of clean water. For example, a lack of adequate sanitation can cause a decrease in water quality. When analyzing issues of water scarcity, the following types of questions must be considered. (1) What are the geological, topographical, and ecological reasons for water scarcity; (2) The water scarcity problem is how to aggravate; (3) What is the potential for new or alternate sources of water (4) What are the demographic and health-related problems tied to water scarcity? So, it has great significance to study the problem of water scarcity [7].

When economic activities do not harness water's productive potential and do not protect against water's destructive impacts, water can challenge growth and act as a drag on the economy. In Ethiopia, REACH has identified specific water-related risks to growth and the potential for economic drag such as the fragmented decision-making for groundwater management to sustain the industry and human development. This fragmentation has been identified as an emerging threat to human development as it potentially reduces water quantity and quality [18].

According to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), climate change Population growth, economic activities, and the impacts of climate change give rise to the scarcity of water, a condition in which the water demand grows beyond the available water supply because of its physical unavailability and an insufficient water management structure. When the demand surpasses the available supply, then water allocation fails to meet the required demand which causes a decrease in the per capita water availability. This situation intensified further by increasing demands in the case of rapid urbanization and the improvement of living standards along with the impact of severe climate conditions [2].

2.1.1. Factors Affecting Water Demand

One of the most important significant activities in the effort of demand management of residential water demand is trying to understand the factors that affect residential water demand. Understanding of the factors that affect HHs' water source choice decisions and the respective quantity demanded is of a good interest for institutions and individuals charged with residential water supply. Based on the findings of this study and a review of relevant literature it is concluded that: Demographic and socio-economic factors were found to be a significant determining factor in both residential water demand and HHs water source choice [8].

If water supply utilities are planning to implement proper demand management strategies, they have to give due emphasis for the changes in the demographic and socio-economic factors that affect demand or should explore and identify those factors that are called shift variables in the demand curve. An increase in income (with expenditure as a proxy) has lead HHs to have more water demand related with change in the lifestyles of better off HHs is a signal for water supply office in that increase in come leads to more water demand. Future studies need to properly assess the impact of HH income generating activities on the quantity of water demanded. A very significant share (81%) of respondents who do not have private connections responded that their primary reason not to have private pipes was their inability to afford the connection payment, clearly indicating that Policies like subsidizing connection costs and supplying credit facilities for connection payment could enable HHs to get piped connection, although the capacity of the piped water system would need to be adequate so that this would not increase the number of days in which HHs experience a service scramble. Because a significant number of HHs in the town are obtaining water from public stand pipes, mechanisms such as cross-subsidization of prices by better off HHs who obtain water from private pipes to the worse off HHs who obtain water from public stand pipes of the municipality would enable the poor HHs to obtain cheaper services [8].

The problem of water service delivery would be very easy if the root causes of poor service delivery were easily recognizable and understood in water supply i e., production and distribution of water. As a result, the respondents were asked to identify the main challenges that contribute for inadequate, inaccessible and unaffordable water service delivery in the town. Among them limited capacity of Nation, regional and zone (technological and institutional incapability; inadequate finance, a decline of water sources, shortage of water and destruction of water boreholes, rapid urbanization and shortage of pumping machines are very common in Gondar city water supply. In line with this, the interview conducted with some of the employees of the water supply and sanitation sector revealed the constraints that hinder the sector in the delivery of water services. These include: - The continuous growth of population in the town due to the natural increase & migration coupled with the expansion of the town imposed a higher burden on the utility of organization of the town and it becomes difficult to accommodate the ever-growing population. In general, the problem is exacerbated by the failure to design optimum use of water for the town due to underestimation of population growth based on the national population growth while the growth rate for Gondar two is high (i e., 2.5%) [19].

2.1.2. Categories of Household Water Demand

The primary categories of water needed by residential households are water for drinking, cooking, washing, bathing, laundry, toilet flushing, home cleaning, home maintenance, and sports and recreation (the water demand categories might not be applicable to every household). The characteristics of the different water demand categories are mainly independent, where each water category exists on a parallel basis and generally does not overlap with other categories. Water for drinking refers to water directly consumed by residents on a daily basis, including directly consumed municipal tap water, bottled water, and boiled water. This category does not include other products primarily made up of water, such as bottled water and drinks. Water for cooking refers to water used during cooking processes, such as washing vegetables, cooking, frying dishes, cooking soup, and washing pots and plates. Water for washing refers to water used for daily activities such as washing hands, washing faces, brushing teeth, washing feet, washing fruits, washing milk bottles and toys, and so on. Water for toilet flushing refers to water used for toilet flushing, while water for bathing refers to water used for bathing (showering, bathing, etc.) Water for home cleaning refers to water used for mopping, wiping, cleaning cooker hoods, and washing cars, while water for home maintenance refers to water used for humidification, watering plants, and rearing fish. Water for sports and entertainment refers to water-based toys and indoor swimming pools, while water demand refers to water used for purposes other than those covered in the categories stated above [17].

2.1.3. Some Empirical Studies on Water Demand Analysis

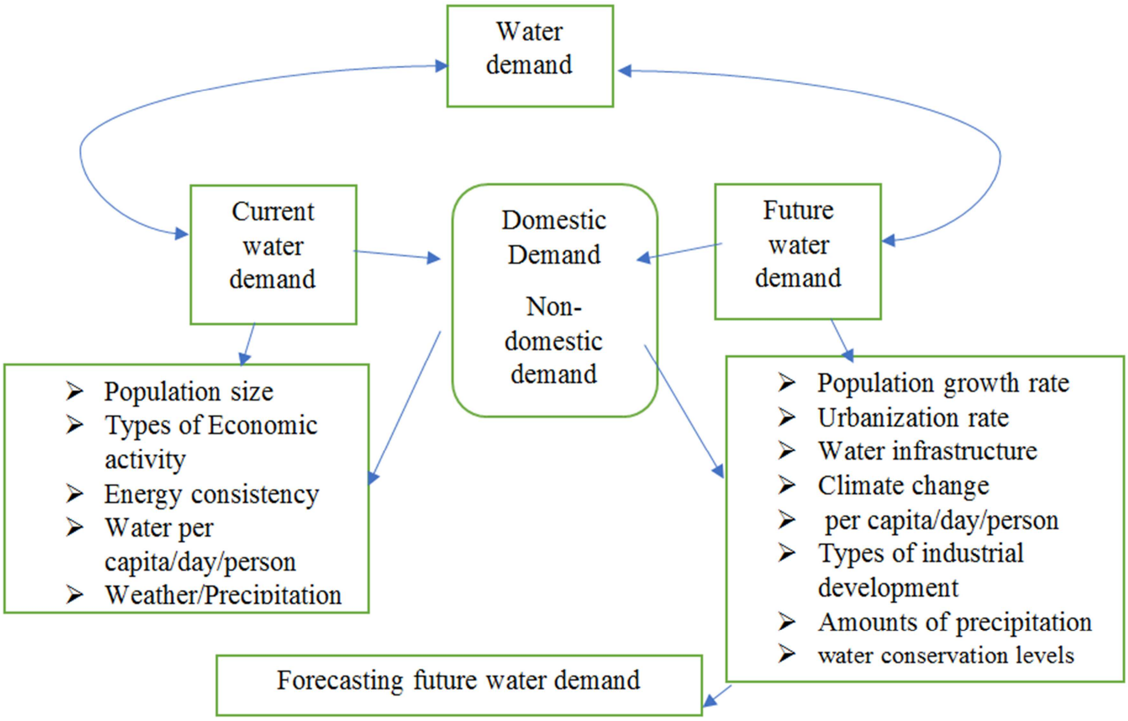
At the national level Studies in Dilla Town [5] indicate that the town's water supply cannot fulfil consumer demand for water. Obsolete supply system, electric power supply problems, lack of institutional capacity and budget shortage are the basic factors for this imbalance. According to the survey results, the average per capita consumption was found to be less than the recommended standard, which is approximately at least 20 L of water per person per day. In line with this, the most frequent complaints by water customers were regular interruption of water supply and unfair water distribution. The collected data also showed that there is prolonged water shortage in the town.

Additional work [15] in Yejube Town, Ethiopia the municipal average daily water consumption per capita was 14.3l/c/day and 16l/c/day respectively in 2017 and 2018. The water supply coverage of the town is low when we compare the regional and international standards. Water production and demand are unbalanced, due to continuous interruption of the water supply system inhabitants are facing water-related problems. And also, 20.38% and 24% of the water production lost in the distribution system before reaching to the end customers. The population of the town in 2040 is expected to reach 24807 with an average daily per capita water consumption of 36.7l/day.

At a Gondar city level [1] Studies show us, that the town water supply service could cover its demand of it with its present existing capacity and based on the research outcome only 43.3% of the respondents get water through their own private taps. All areas of the town could not get equal and proportional service and the tariff set is neither fair among the poor and rich households nor generates sufficient revenue to cover investment costs. The root causes of the challenging problems are institutional, financial, human and material resource constraints. That is, the water supplying service in the town is unsustainable; it is socially inequitable, economically inefficient and environmentally unsound.

2.2. Water Demand Conceptual Framework

Water demand can be defined as a society's willingness and capacity to consume water goods or water services at any given stage of development, subject to environmental and geographical constraints such as natural endowment, water availability, and environmental capacity. The water demand framework is based on indicators of economic development and their impact on water development. Water development provides resources, material assistance, and services to support economic development. Economic development, in turn, can promote water development.



Source: Source: own survey result (June, 2022)

Figure 1. *Conceptual frame work.*

3. Research Methods

3.1. Description of the Study Area

The city of Gondar is situated in the North-western part of Ethiopia, Amhara Regional State. It is at12°3’N latitude and 37°28’E. Gondar has located 727 km from Addis Ababa, the capital city of the federal government of Ethiopia, and 120 km from Bahir Dar, the capital city of Amhara National Regional State. Gondar has a total area of 192.3 km^2 with undulating mountainous topography [4].

3.1.1. Map of the Study Area

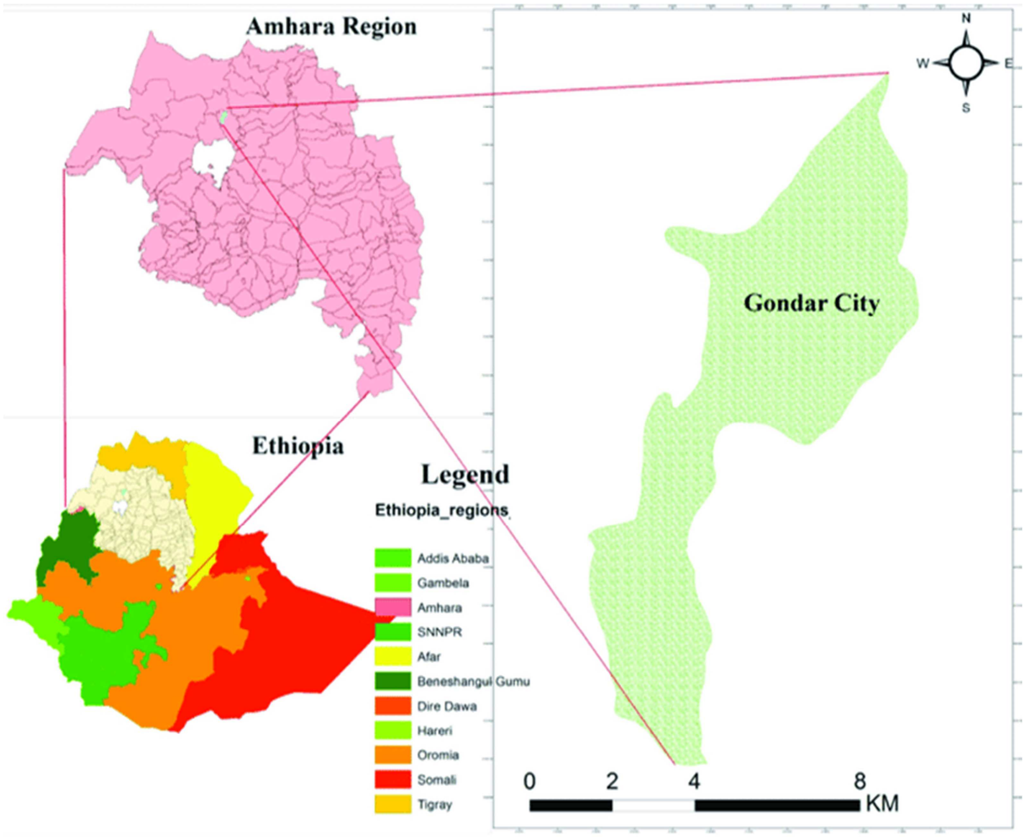


Figure 2. *The map of Gondar city Administration.*

3.1.2. Climate

The warm season lasts for 3.8 months, from January 29 to May 23, with an average daily high temperature above 80°F. The hottest month of the year in Gondar is April, with an average high of 83°F and a low of 60°F. The rainfall of Gondar city is erratic and characterized by fluctuations. Under normal conditions, it deviates from the mean value. The mean annual rainfall in Gondar city has been 1025mm in the past 26 years [16].

3.1.3. Population

Gondar has one of the largest urban populations in Ethiopia. According to the Gondar city mayor office report the population of Gondar was estimated to be 750,000 in 2021 E. C. [16]

3.1.4. Economic Activity

Gondar is a major tourist and business hub in North-West Ethiopia. Among many tourist attraction sites of Gondar, Fasiledes Castles within the city and the Semen National Park, located 120 Km to the northwest of Gondar can be found. The city earns a significant amount of money from hotels and tourism. Trade is also a key economic activity in Gondar. The city's success in trade is attributable to the surrounding areas, for instance, Metema, and Humera produce cotton and sesame [16].

3.2. Research Design

In this study, the researcher used a cross-sectional research design based on the ground that helps advantageous to collect details of data from organizational reports of Gondar city water and sanitation office in a short period time.

3.3. Data Source and Type

All data used in this study were secondary obtained from Gondar city water supply and sanitation offices daily, monthly and annual reports, from Gondar city mayor office and city municipal.

3.4. Methods of Data Analysis and Presentation

Secondary research or desk research data analysis methods were used to achieve the study's general and specific objectives.

The data obtained from secondary sources has been combined and presented in the form tables, charts, and figures combined with empirical evidence.

3.5. Research Approach

A quantitative study was carried out in this research. The secondary sources include the National Water and Sanitation authority of Ethiopia, Gondar city water supply office, and Gondar city municipality, Total population covered by the public water supply system, Per capita water demand per day, Design capacity and actual water production of Gondar public water supply system, and daily operational hours of public water supply system.

4. Analysis and Discussion

The analysis and discussion of the water supply in the Gondar city is focused on the current conditions, identifying the shortages of water, and determining the future needs based on a growing population.

4.1. Current Conditions

Analysis of the current conditions was completed by evaluating the performance of the current water supply system, which included the WTPs, wells and headwater. Performance evaluation for the WTPs, wells and headwater were done by analyzing the actual water production data in the year 2021/2022.

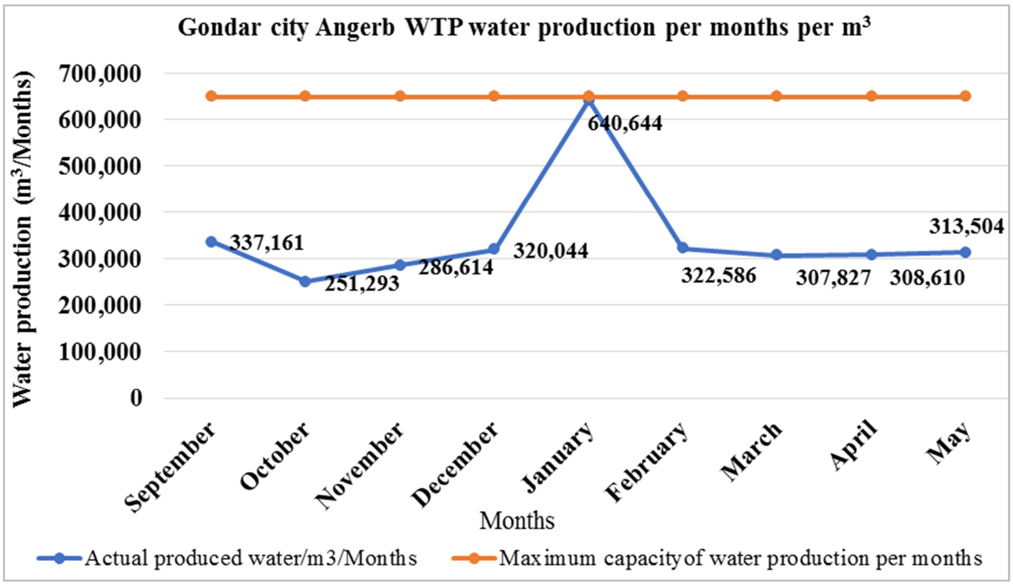
4.1.1. Angerb Water Treatment Plants

Water sources for urban areas of Gondar city include both surface water and groundwater. The type of surface water used is river Angerb water. The raw water from the river is pumped to WTPs for treatment before being distributed. The monthly water production of Angerb water treatment plant in 2021/22 in Gondar city has been analyzed as follows. The maximum capacity of Angerb WTP is 324,000m3/month.

Table 1. *Angerb water treatment plant performance of 2021/22.*

Months	Actual Water production (m3/month)
July	204,817
August	239,667
September	322,609
October	241,122
November	252,869
December	274,098
January	278,308
February	278,214
March	251,267
April	260,109
May	266,436
June	159,317
Total	3,028,833.20

Source: Gondar city water supply office (2022)



Source: own survey result (June, 2022)

Figure 3. *Gondar city Angerb water treatment plant water production/months/m³.*

As we can understand from the figure the minimum average water production was on June that was 159,317. Water productivity was low in June because there was no rain; however, after the June water production increased and reached a peak in September with 322,609 m3.

The amount of water produced in December January and February was nearly identical. Because the Angerb river is a seasonal river, the main cause of Angerb water production fluctuation is seasonality. During times of precipitation, there is low water production because of high turbidity and high flocculation and also low during the dry season because of water quantity decrease. In general, we can conclude that the Angerb water treatment plant's monthly production is less than its capacity, except in September, due to a variety of factors including river seasonal fluctuations, high turbidity and high flocculation, electric power, due to electromechanical problem and sometimes water treatment chemical supply lag.

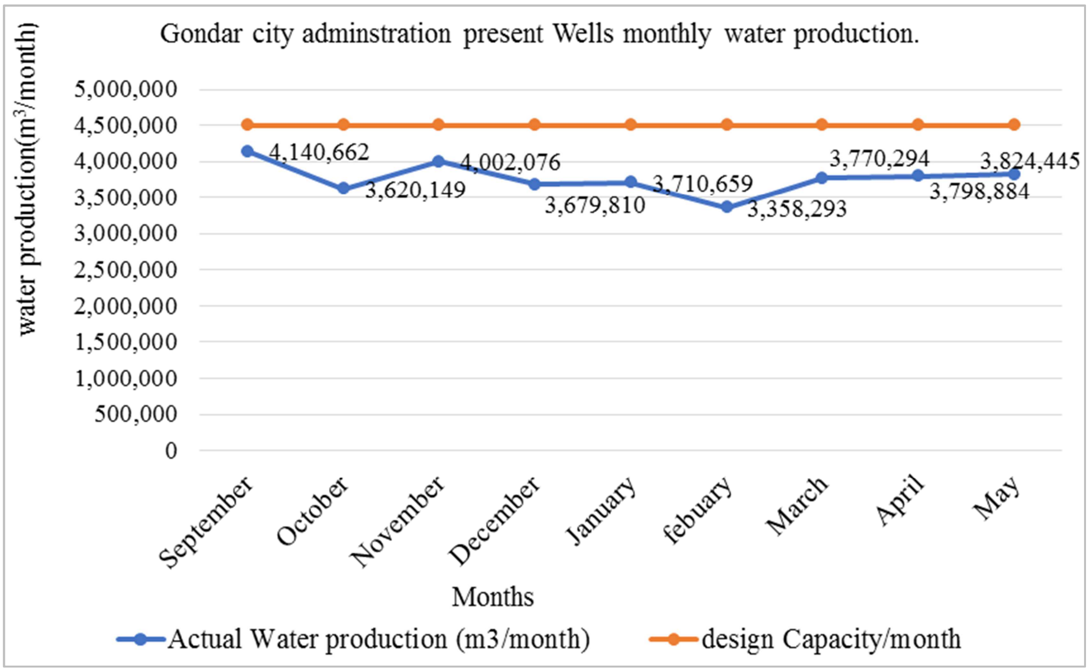
4.1.2. Groundwater Wells

The total number of wells public water supply in Gondar city areas is 17 Groundwater Wells Maximum production design Capacity/month of wells water is 525,000 M^3.

Table 2. *Monthly actual water production and its design capacity of the groundwater wells.*

Months	Actual Water production (m3/month)
July	72,634
August	86,463
September	120,953
October	89,083
November	110,642
December	111,224
January	69,384
February	94,360
March	118,340
April	112,854
May	101,085
June	98,848
Total	1,185,870

Source: Gondar city water supply office (2022)



Source: own survey result (June,2022)

Figure 4. *Data is from the report of, Water Supply of Gondar city (2022).*

As shown in Figure 2, the monthly water production from wells in Gondar city administration in 2021/22. To understand the above table out of 17 wells only 9 are functional the other 8 are not functional due to electromechanical problem, discharge drawdown, interference case, so The actual water production of nine months performance is shown in the graph as the well is less than its design capacity throughout the entire 9 past months with up and down water supply fluctuation. Even worse, in January. Wells monthly production was significantly lower than design capacity. This could have occurred as a result of a combination of a lack of consistent power supply and low production, interference problem, discharge drawdown, and integrated water resource management problem.

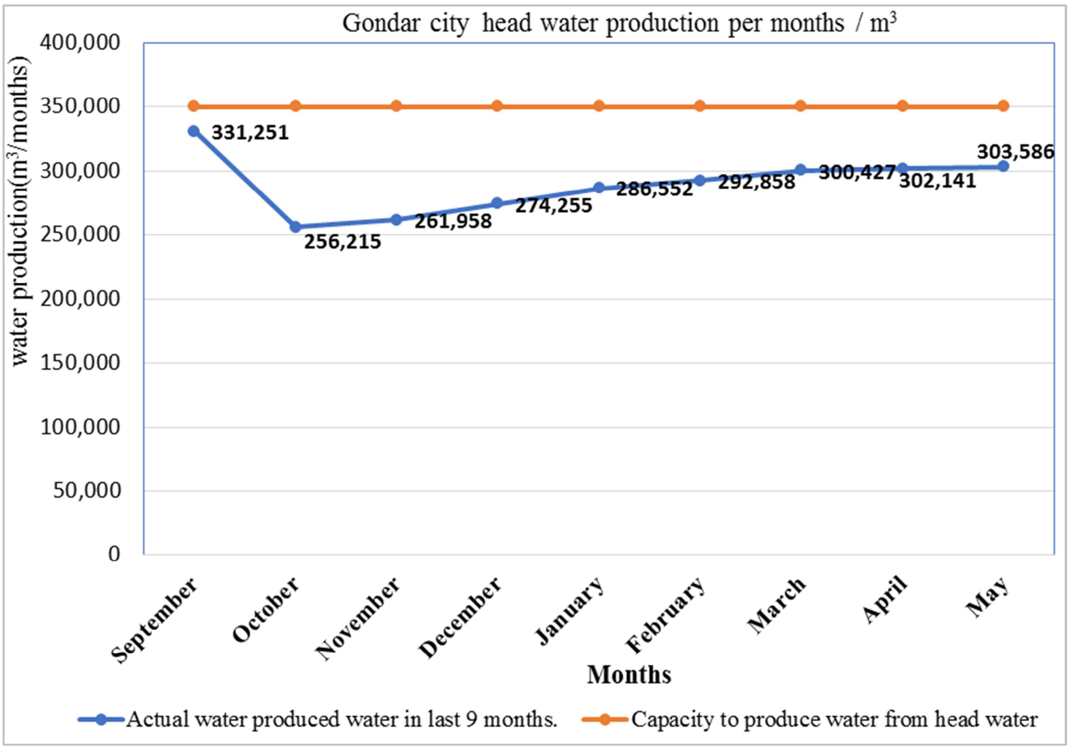
4.1.3. Head Water

Head waters 2021/2022 According to Gondar city water supply office the Maximum production Capacity/month of head water is 35,520 M^3.

Table 3. *Head water production performance in Gondar city per/m^3/months.*

Months	Actual Water production (m^3/month)
July	13,199
August	16,584
September	12,620
October	51,283
November	27,900
December	33,589
January	29,063
February	19,809
March	18,480
April	11,049
May	10,158
June	9,104
TOTAL	252,838.00

Source: Gondar city water supply office (2022)



Source: own survey result (June, 2022)

Figure 5. *Gondar city Head water production per month/m^3.*

The graphs show that the monthly head water production of Gondar city administration in the last 12 months has been less than the production capacity. Even the worst month, June, produced only 9,104 m3/month. The availability of rainfall distribution and integrated wells management was the primary cause of low head water production. It is possible that it will be produced above capacity at times of high rainfall durability. It may be lower during the dry season than the current data allocation. In general, the headwater production show under capacity production the maximum headwater production was in December which was 33,589 m3/ Month the reason was that there was abundant water and wet season.

4.1.4. Water Distribution System

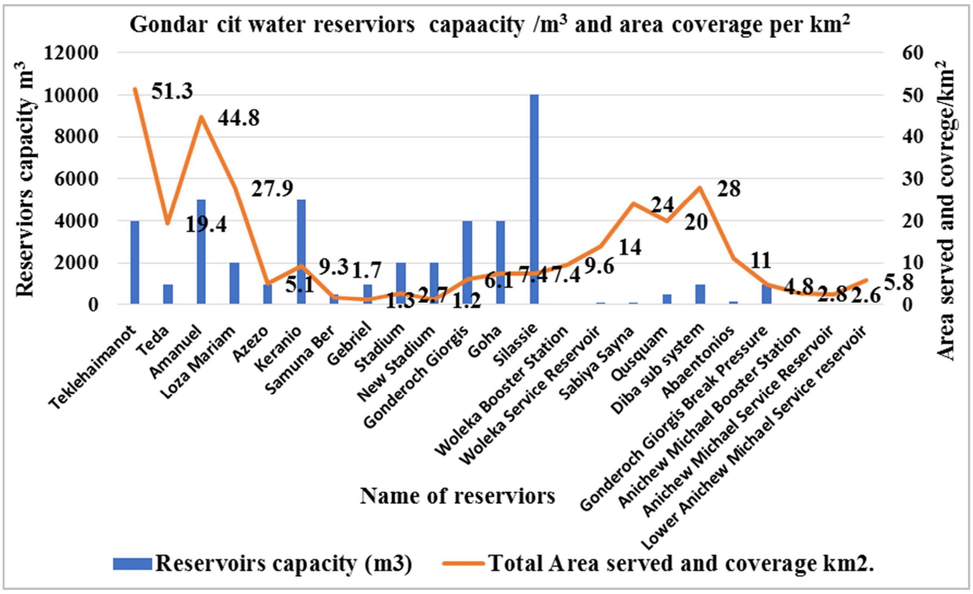
The distribution system is comprised of 14 distribution reservoirs and 3 are transmitters.

A reservoir is used for the storage of water from the WTPs, wells and headwater. In this case, water is first pumped from the WTPs and/or wells to the reservoir at the higher elevation, and then distributed to the distribution zones.

Table 4. *Water capacity of existing reservoirs and their capacity with total area coverage.*

S. No	Name of Reservoirs	Reservoir Capacity (m3)	Total area coverage
1	Teklehaimanot	500	5.3km^2
2	Teda	200	14.4km^2
3	Amanuel	1,000	34.8km^2
4	Loza Mariam	2,000	10.9km^2
5	Azezo mechayel	500	5.1km^2
6	Keranio	4,000	19.3km^2
7	Samuna Ber	500	1.7km^2.
8	Gebriel	1,000	1.3km^2
9	Stadium	1,000	2.7km^2
10	Goha 1	300	1.7km^2
11	Goha 2	500	7.4km^2
12	Silassie	2,000	7.4km^2
13	Woleka	20	9.6km^2
14	Qoladba	1000	-
15	Dersgie marayam	1000	-
16	Angereb treatment plant	1000	-
17	Esatadga	300	2.8km^2

Source: Gondar city water supply office (2022)



Source: own survey result (June, 2022)

Figure 6. *Water capacity of existing reservoirs and their capacity with total area coverage.*

As we can see from the image, there are currently 17 water reservoirs in Gondar city. As a result, the Keranio water reservoir has the highest capacity of 4,000m^3, it covers 19.3 km^2, implying that water reservoir design needs to be based on the average place to ensure fair water distribution for all because comparatively, it covers large area with the highest Capacity of the city reservoirs. In contrast, the wolqa water reservoir has the lowest capacity of 20 m^2 covers 9.6 km^2, indicating that water distribution may not be evenly distributed in the city in terms of distance from reservoirs and wells as well as the amount of water distribution. As a result, water reservoir construction in the city requires consideration for the future. Of course, population density per km^2 is one factor in reservoir site selection. In general, as shown by the graph, there is no equitable distribution of reservoirs per km^2, necessitating attention in the coming year to ensure equitable water distribution in society. However, further research in the area of high demand/day low demand/day in the city is required to stabilize the fair water supply among sub-city administration.

4.1.5. Identification of Shortages

A definition of shortages is required in order to identify shortages. In this study, word shortages are classified into two types: system shortages and operation shortages. Daily water production is hampered by operational constraints. A system shortage occurs when the system's capacity does not meet demand. To identify system shortages, the system capacity is assessed using Equation 1 below based on per capita water provided.

Per capita water provided per/day= Total domestic water/Total population cover

The total domestic water in 2021/2022 accounts for 43.6% of the total water production, while the other 56.4% accounts for the water used for non-domestic, as well as water losses during the distribution due to leakage, water meter inefficiency. The calculation of per capita water provided was based on the 2021/2022 total water production of the WTPs, headwater and groundwater wells. The 2021/2022 total water production was 13,500 m3/day. The total population covered was 750,000 Therefore, the average per capita water provided per day in 2021/2022 was 0.018 m3 or equal to 18 litres [9].

4.2. Future Needs

4.2.1. Population And Water Demand Projection

The population and water demand have been worked out in detail on the existing situation assessment report. Here, the summary of water demand has been presented.

4.2.2. Population

A water supply scheme includes huge and expensive structures, which cannot be replaced or increased in their capacities effortlessly and conveniently. Hence all scenarios affecting the water supply system should have to be thoroughly accessed before the system is designed. One of the scenarios that have a great impact on estimating the water demand of a particular project is the projection of the population sizes. Hence, the planning of any water supply system has to be based on the forecast of population size, population growth rate and distribution.

4.2.3. Design Period

The design period (planning horizon) is the length of time for which the system is expected to provide a community with good quality and sufficient quantity of water supply service. As per the design criteria, the design period of 20 years of service after implementation from 2025 to 2044 is selected.

4.2.4. Base Population

The city currently has six sub-cities including Fasil, Jantekel, Arada, Zobel, Maraki, and Azezo Teda Sub Cities.

According to the figure obtained from the city administration office of Gondar Town, the population of the Town and rural areas for the year 2021 sums 750,000 Among the sub-cities, Jantekel, and Arada have fully urban kebeles and the other sub-cities including Fasil, Zobil, Maraki, and Azezo-Teda have both urban and rural kebeles.

4.2.5. Growth Rate

The population growth rates are taken from the "Central Statistical Agency, Population Projections for Ethiopia-2007-2037, Addis Ababa". The projection is given for the periods beginning from 2008 -2037. However, our project is designed for a 20 years period from 2025 up to 2044. The trend line method is used to estimate the corresponding growth rates for the remaining years beyond the year 2037.

Table 5. *Growth rates of Gondar city.*

Year	2021	2025	2029	2034
Population Growth Rates Gondar city	5.7%	5.1%	4.6%	3.9%

Source: CSA Projection (2022)

Table 6. *Projected Population.*

Year	Population projection of Gondar city
2021	750,000
2025	886,807
2029	1,039,882
2034	1,252,379

Source: CSA projection (2022)

4.3. Water Demand

In the design of any water supply project, it is essential to estimate the amount of water that is required to be supplied. The water demand is dependent on many factors including the overall economic activities of the beneficiary area, the living standard of the society, the temperature, the water tariff, the availability of adequate and good quality water and other social factors. The estimation of the future water demand involves the determination of the number of people to be served, model mode of service, the per capita water consumption and analysis of the factor that may operate to affect consumption.

4.3.1. Mode of Service

The household connection (HC) is a Connection directly linked to a house or apartment, equipped with sanitary facilities: flush toilets, shower, bathroom, kitchen, and occupied by a family.

The Yard Connection Owned (YCO) is a Connection linked to a compound with a low standard house, not equipped with sanitary facilities, and occupied by a family.

The Yard Connection Shared (YCS) is a Connection linked to several compounds with a low standard house, not equipped with sanitary facilities, and occupied by several families. Each family is going to the tab to draw the water, sometimes there is an "informal" distribution network.

The Public Tap (PT), managed by a tab keeper, and paid by the water company, is open a few hours per day. The consumer draws the water from the tab and pays immediately in cash. The tariff is official. The table below depicts the mode of service per percentage for each Kebele as per the socio-economy survey undertaken.

4.3.2. Per-Capita Demand

As the living standards of the dweller's increases due to economic improvement and other reasons, their water consumption increases depending on their mode of service. To estimate the projected per capita water demand, it requires reviewing previous studies of similar nature together with the socioeconomic field survey. Hence, for this project, the following per capita demand figures are adopted for this study to determine the water demand as per the mode of service.

Table 7. *Per capita demand (l/c/d).*

Mode of services	2021	2025	2029	2034
PT	25	25	25	30
YCS	30	30	30	40
YCO	25	25	25	35
HC	80	80	100	100

Source: Ethiopian constriction design and supervision works corporation, 2022

4.3.3. Domestic Demand

The domestic demand of Gondar city was projected based on the per capita and the number of populations of each urban and rural Kebeles.

4.3.4. Adjustment to the Socio-Economic Condition

The water demand projection should also consider the socioeconomic conditions of the towns. In those with higher economic activities and developments, the standard of living will be high requiring more water for domestic as well as non-domestic consumption. Thus, the average domestic water demand has been adjusted taking into account the situation of the project area's socio-economic activities.

Considering the socio-economic situation of Gondar, the city can be considered under category B, a town has a very high potential for development, but lower living standards at present. Thus, a socio-economic factor of 1.05 has been used [9].

4.3.5. Public and Institutional Demand

The water requirement of all schools, hospitals, public facilities, hotels and industries, governmental offices etc. are included in this demanding category. Studies made in Ethiopia on towns with metered water supply facilities indicate that the public water demand ranges between 10 to 30% of domestic water consumption depending on the size of the town, type and extent of commercial, economic and industrial activities. On the other hand, the non-domestic water consumption was determined from the collected data. The result indicates that the non-domestic consumption is between 11% for Abiye Egzi kebele up to 72% for Keha Eyesus kebele. For this study, the actual percentage of domestic demand is considered for each kebele. However, for rural kebeles 10% of domestic demand is considered as non-domestic demand.

4.3.6. Unaccounted for Water

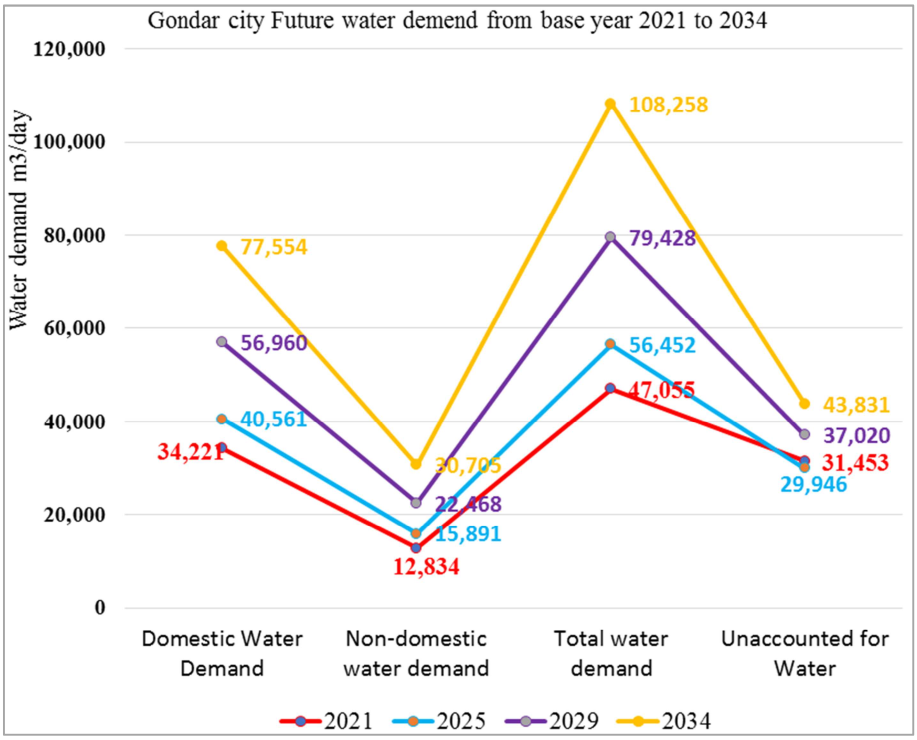
All the water that goes in the distribution pipe does not reach the consumer. Some portion of this is wasted in the pipelines through defective joints in between pipes, cracks on surface of pipes, and faulty valves and fitting. Some consumer keeps their taps open or public taps open even when they are not using the water and allow continuous wastage of water. The unaccounted water also includes illegal connection, unmetered usages such as: flushing, overflows from the components of the water supply system etc.

In estimating the future water loss in the distribution pipe network, it is recommended to do a non-Revenue assessment in order to obtain the actual water loss within the system. However, rough estimation of the water loss of the current condition of the project is estimated by considering the actual production and consumption of the project.

Table 8. *Future Total demand water Demand for Gondar city calculated based on W. CP+S+U for each year.*

Year	Domestic Water Demand m^3/day	Non-domestic demand m^3/day	Total (Domestic + non-domestic) m^3/day	UFW m^3/day
2021	34,221	12,834	47,055	31,453
2025	40,561	15,891	56,452	29,946
2029	56,960	22,468	79,428	37,020
2034	77,554	30,705	108,259	43,831

Data from Ethiopian constriction design and supervision works corporation (2022)



Source: own survey result (June 2022)

Figure 7. *Future water demand and unaccounted for water from 2021-2034.*

As we can see in Figure 7 above, this will increase over time. As a result, the Gondar City Water Supply Office must design a new water supply to meet domestic water demand over the next 12 years. The same work will be expected of the institution in terms of non-domestic water demand. Domestic and non-domestic water demand is expected to rise in general. The water supply office must design new water treatment plants and build water reservoirs throughout the city over the next 12 years. Water shortages must be addressed in the future because, unaccounted are expected to rise, except in 2025, when they will be less than in 2021 a good expectation. The total demand for water is increase in the coming years serially.

4.4. Future Need Calculation

Water is indispensable; therefore, as the population grows and the Gondar city develops, more water will be needed. The Gondar city water and sanitation Office has established a Strategic Development plan for 2021-2044, which aims to provide continuous water supply in urban and rural areas by the year 2044. In order to ensure this target can be achieved, water demand estimation of the future population has been determined to assess whether the current design capacity of the public water supply system will still be adequate to fulfil future water demand.

The forecasting method used to calculate the total future water demand is based on the population growth, total daily water demand, total sectorial daily water demand, per capita water demand and Unaccounted for water [20] According to Idowu et al 2012 cited in the article [6] The future total water demand is determined by using the following Equation.

$$W = CP + S + U$$

W: total daily water demand

C: per capita water demand per day = Total domestic water/Total population cover

P: Total population of the area of interest

S: Total sectorial daily water demand

U: unaccounted for water

Accordingly, we can calculate the total daily water demand of the population of Gondar based on our data from 2021/2020 to 2034 total population projection, total daily water demand, per capita water per day, total sectorial daily water demand and unaccounted for the water of the city.

Table 9. *Calculation of per capita water per day in Gondar city.*

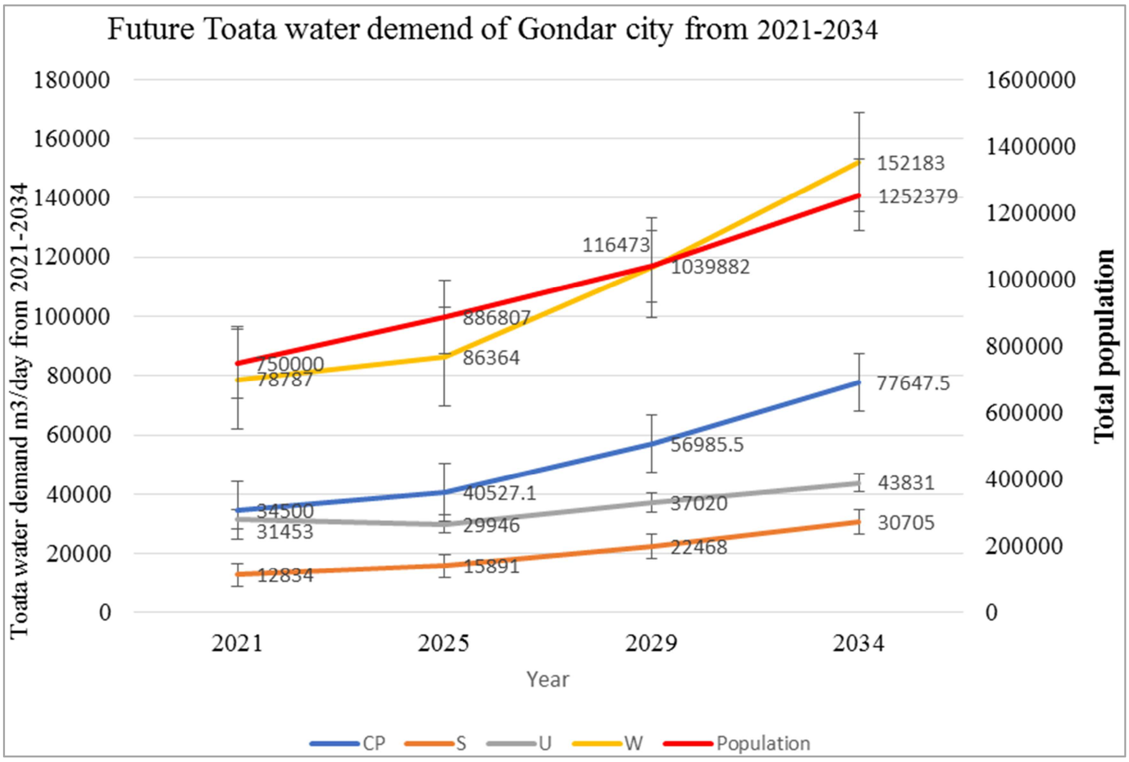
Year	Total population	Population growth rate	per capita water demand per day
2021	750,000	5.7%	46 litters/day
2025	886,807	5.1%	45.7 litres/day
2029	1,039,882	4.6%	54.8 litres/day
2034	1,252,379	3.9%	62 litres/day

Source: Ethiopian constriction design and supervision works corporation, 2022

Table 10. *Future total daily water demand in Gondar city from 2021-2034.*

Year	C	P	CP	S	U	W
2021	0.046M^3	750,000	34,500 m^3	12,834m^3	31,453m^3	78,787m^3
2025	0.0457 m^3	886,807	40,527.1 m^3	15,891m^3	29,946m^3	86,364.1m^3
2029	0.0548m^3	1,039,882	56,985.5 m^3	22,468m^3	37,020m^3	116,473.5m^3
2034	0.062m^3	1,252,379	77,647.5 m^3	30,705m^3	43,831m^3	152,183.5m^3

Source: own survey result (June 2022)



Source: own survey result (June 2022)

Figure 8. *Future water Total demand and total population comparison for water from 2021-2034.*

As we can understand from above Figure 8 there is a huge gap between total population and total water demand until 2029. If all things are constant After 2029 there will be excess water for, may it will go above 50 litres per day per person. The population will be a huge factor for both domestic and non-domestic water demand in the next coming 12 years.

Interims of Unaccounted for water it will be increase as it shows as on the graph that may will change from 31453-43831 needs attention to minimizing water loss. In the coming 12 years per capita /day/person water demand will be expected increasing from time to time since there will expect continuous population growth. Again, the graph shows us based on the population growth rate and urbanization it will be expected water scarcity until 2029. Water demand in the future may be influenced by weather factors (temperature, precipitation, etc.), economic development standards (income, water consumption devices, etc.), household size and composition, water conservation awareness levels, etc.

5. Conclusion and Recommendations

5.1. Conclusion

This study presents water demand scenario analysis in the 2021/2022 experiences as well as future 12 years based on data from Gondar city water and sanitation office records reports, plans.

The main objective of this paper to analysis the current existing water supply system and future water demand forecast. This study identifies the gap between supply and demand in the city in the past 12 months of water production in 2021/2022 experience was show below the capacity of the source that it could be produce per day.

The analysis was focused on the evaluation of existing water supply coverage in the city based on the city daily, monthly and annual reports of water consumption and population of the city, forecasting of water demand for the next 12 years from base year of 2021-2034. Water demand forecasting is a vital element in urban planning and sustainable development of a city. The present water demand and water production capacity show that it does not meet for the reason, of electricity inconsistency, capacity of water production per person/day, integrated water resource management problem, city high population growth, economic activity and low wells water production/day 'maintenance cost and high amounts of unaccounted for water was the main problem faced in water demand balance of the city. In addition, the water production in 2021/2022 was all water from WTP, Wells and head water show below capacity production /months this indicates that the average per capita water coverage of the city is less than 80 L/day. So, the aggregated average water consumption level was below the minimum requirement when compared with the national and worldwide standard levels that have to be needed in each household for different purposes. There is a huge gap between supply and demand with regard to the per capita consumption of the dwellers. To illuminate the gap between and supply in the future proper estimation of water demand in the town plays a vital role. The future water demand of the town can be forecasted based on population growth rate and urbanization rate and per capita per day/person. Besides domestic demand, non-domestic demand will be considered such as industrial, commercial, firefighting and other accounted factors with appropriate adjustment factors due to socio-economic and climate factors. The forecasted average water demand of the city in 2025 is 0.0457 m3/day and at 2034 water demand per Person /day will increases to 0.062m3/day. Up to 2029 the existing source cannot fulfil the water production based on the present projection. until 2029 the town needs an additional source to balance supply and demand in the town do to increase in population. Generally, most decision-making in urban planning and sustainable development programs is highly dependent on water resource accessibility and future water demand forecasts.

5.2. Recommendations

To improve the performance and operation of the current water supply system is needs essential attention should give to following:

1. Secure water resources this is needed for the WTPs because it depends on the quantity of the raw water intake from the rivers.
2. Power supply is another major issue affecting the consistent flow in the current water supply system. This can be addressed by providing a backup generator for each WTP and well, therefore when there are electricity outages, the WTPs and wells can continue to operate.
3. Capacity building for the staff is critical because right now the staff are the people who are directly responsible for operating the water supply system. Capacity-building should not only be limited to the operations of WTPs and wells, but also extended to other aspects including performance of regular maintenance, conducting asset management, and providing solutions to suddenly occurring issues. Periodic training is also needed, especially for the technical staff.
4. Increase the total design capacity of the current water supply system. The current capacity of the public water supply system will not be adequate in meeting future demands of all of Gondar population. One of solution is to build new WTPs and/or wells, and also reservoirs for seasonal storage. In order to build new WTPs and/or wells, further research needs be conducted on water resources carrying capacity.
5. Additional water source must be injected to the existing system.
6. Detail study and source identification must properly applied.

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