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Graduation Project Report

Hydraulic Modeling of the Water Supply Network in Yasid Village

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Abstract

Yasid suffers from many problems in the water network that feeds it. In addition to its inability to supply some users with water due to urban expansion and geographical problems. In addition to the high rate of Non-Revenue water and thus cause environmental and economic problems.

The project estimates the number and density of the population in the village of Yasid until the planning horizon of 2053, and evaluates water consumption. Defines the area to be served and divides it into major watersheds according to the current situation using the topographic map and site visits. The methodology covered:

- Information and data collection: this includes the nature of the project area, its climate, water resources, water consumption, statistical information, contour mapping, etc.

- Preparing, applying and analyzing the questionnaire. It covers water practices among households in Yasid.

- Evaluate the current water situation and design a water network identifying design standards and requirements. The analysis and design is to use the computer programs: GIS, WaterCAD, Geomolg.

- The project includes a description of the current water situation in the village of Yasid. A water network will be designed to cover all areas of Yasid.

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1. Introduction

The State of Palestine (SoP) suffer from water shortages in general due to the limited water resources and Israeli occupation control over these resources. This leads to depriving the Palestinians of their share of water. Water resources in Palestine come from surface and groundwater sources. There are eight groundwater basins in the Historic Palestine; four of them are located within the 1948 occupied Palestine (Tiberias, Western Galilee, Carmel, and the Negev basins), while the other four are located in the West Bank (the northern-eastern, the Eastern and the Western aquifer basins) and in Gaza (the coastal aquifer basin). *(Bader, 2001).*

Palestine depends mainly on water extracted from groundwater sources, which amounts to about 80% of the total available water. For the Palestinian the amount of water pumped from groundwater wells (the eastern basin, the western basin, and the northeastern basin) in the West Bank for the year 2019 amounted to about 101 million cubic meters (MCM). (*(PCBS), 2019).*

This project has been prepared to update the existing water network supply system in Yasid. The plan prioritizes and the actions required to allow the Yasid village Water Supply System (YVWSS) to deliver water efficiently to its customers up to the year 2053 after considering all restrictions. Yasid village suffers from an acute shortage of water as a result of its reliance on wells to collect rainwater. Recently, a water network was established in the village and was provided with water, this helped secure water for Yasid village and solve the water problems, especially in the summer.

Yasid is a Palestinian village located about 15 km north of Nablus. It is built on a mountain, 690 meters above sea level. The present service area of YVWSS extends over 9.5 km^2, which has a population of 2483 according to the PCBS *(2017).*

The main objective of the project is to analyze the water network of Yasid village and check its design as it to meet the requirements for the next 30 years (2023-2053). This will be done through collecting data on the population census, population growth rate, water consumption, and urban sprawl areas.

2. Methodology

The proposed methodology for the development of the master plan, which addresses the currently serviced areas, includes the following steps:

- Review the previous Yasid master plan and determine acceptable proposals that can be considered.
- Collect information and reliable data.
- Assessing the future demand for water, as the increase in the population will increase the demand, and studying the water gap that the Yasid Council will suffer from.
- Based on available supply, the project will estimate future water gap for the different planning years, 2028, 2033 and 2053.
- Develop a plan for the next 30 years with a description of the different proposed interventions. In addition, the project will prioritize the different interventions and develop a cost estimate for the different plan components.
- Utilizing the data, including the GIS map, to develop a WATERCAD hydraulic model for the existing water distribution system.
- Determining the limits of the council's current water sources and identifying potential new water sources that the council may use to meet the needs of its customers in the future.

The expected outcome from this project can be summarized in the following:

- A hydraulic model of a water distribution system. Hydrological modeling helps inunderstanding, forecasting and managing water resources.
- An updated and improved GIS database and a GIS map for the sections of the water network system.
- Maps including the locations of each well, the locations of the conveying lines and the locations of the reservoirs.
- Verifying input parameters for water Balance calculations.

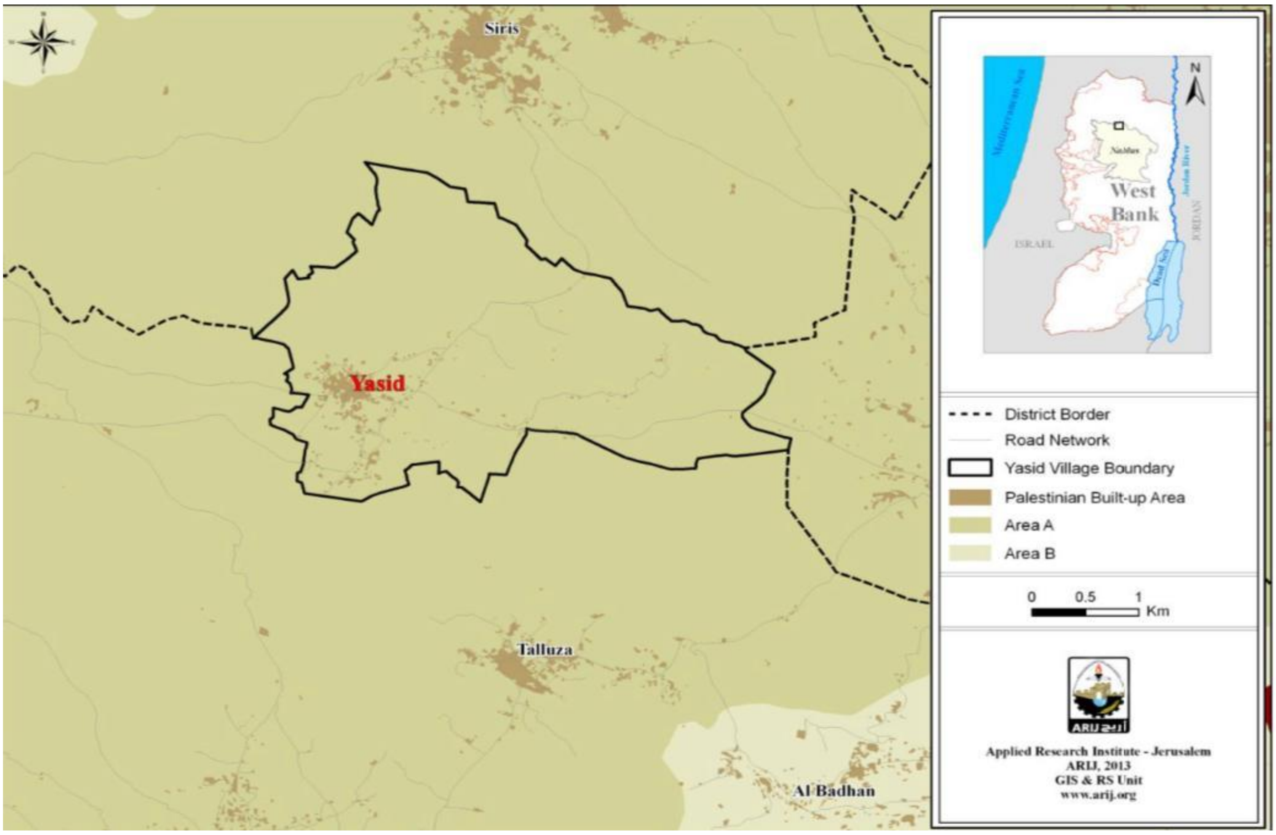


Figure 1 Yasid location and boundaries

3. Study Area

This project will take in consideration the area of Yasid village in general. Yasid located north of Nablus, about 15 km away in northern West Bank. Yasid is bordered by Wadi al Far'a to the east, the village of Siris to the north, Beit Imrin and Jaba' to the west, and Talluza and 'Asira ash Shamaliya villages to the south (ARIJ-GIS, 2014).

The total area of Yasid village is about 9.5 km^2. According to Palestinian Central Bureau of Statistics, Yasid Villgae has an estimated population 2732 of in 2022 year. Table 1 lists the population of Ysid during the years 2017-2026.

Table 1 Yasid Population for the years 2017-2026

Name	Code	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Yasid	150695	2483	2531	2580	2630	2681	2732	2784	2836	2888	2940

3.1Topography

The village of Yasid is a mountainous area located on a mountain, 690 meters above sea level

(Figure 2 explains the counter's and elevation difference in Yasid).

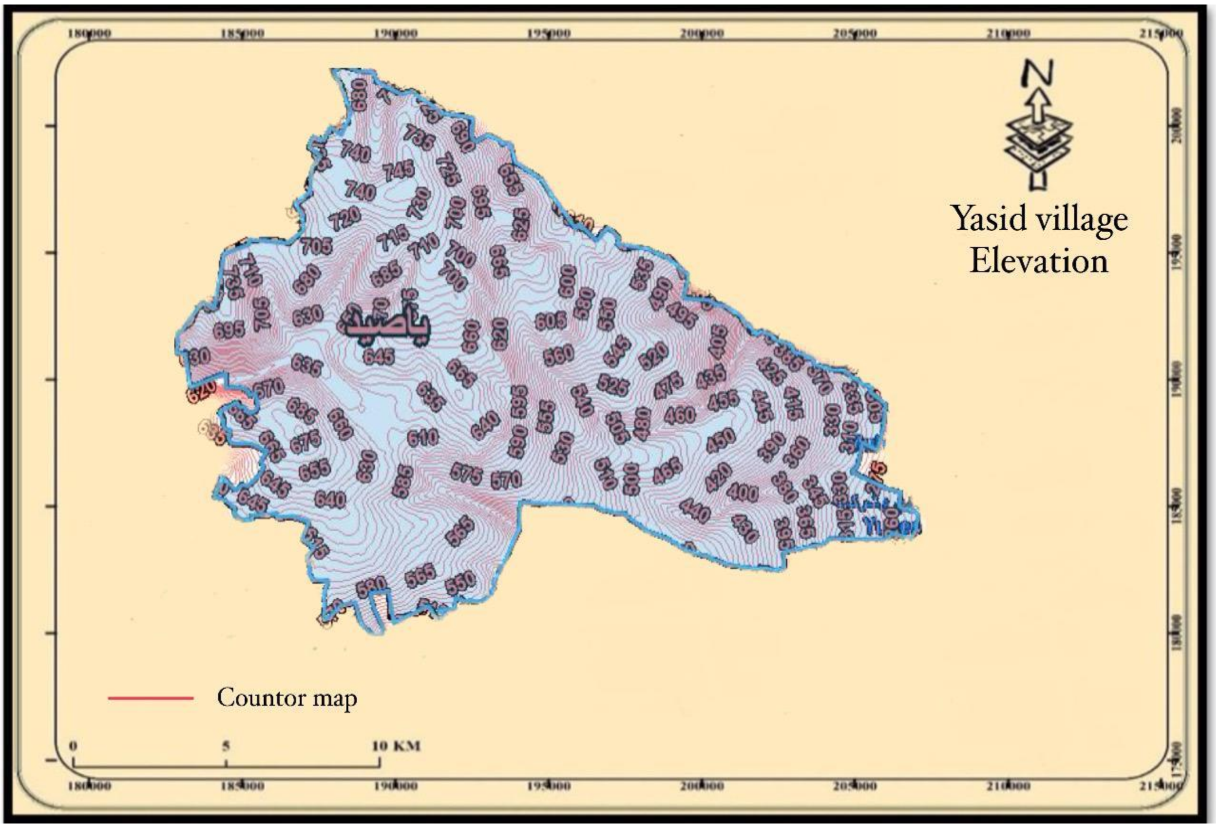


Figure 2 Yasid topograpgic map

3.2 Demography

According to the Palestinian Central Bureau of Statistics (PCBS), the total population of Yasid in 2017 was 2483. There were 394 households registered as living in 475 housing units.

Age Groups and Gender The General Census of Population and Housing carried out by PCBS in 2017 showed the distribution of age groups in Yasid as follows: 39.6% were less than 15 years of age, 56.4% were between 15 and 64 years of age, and 4% were 65 years of age or older. Data also showed that the sex ratio of males to females in the village was 100:103.8, meaning that males and females constituted 50.9% and 49.1% of the population, respectively.

3.3 Climate

Palestine is characterized by a mild climate, hot dry summer and cold rainy winter, the average annual rainfall in Yasid is 520 mm, the average annual temperature in Yasid is 16 °C, and the average annual humidity is 60% (ARIJ-GIS, 2014). Figure 3 shows the average temperature in Palestine governorates.

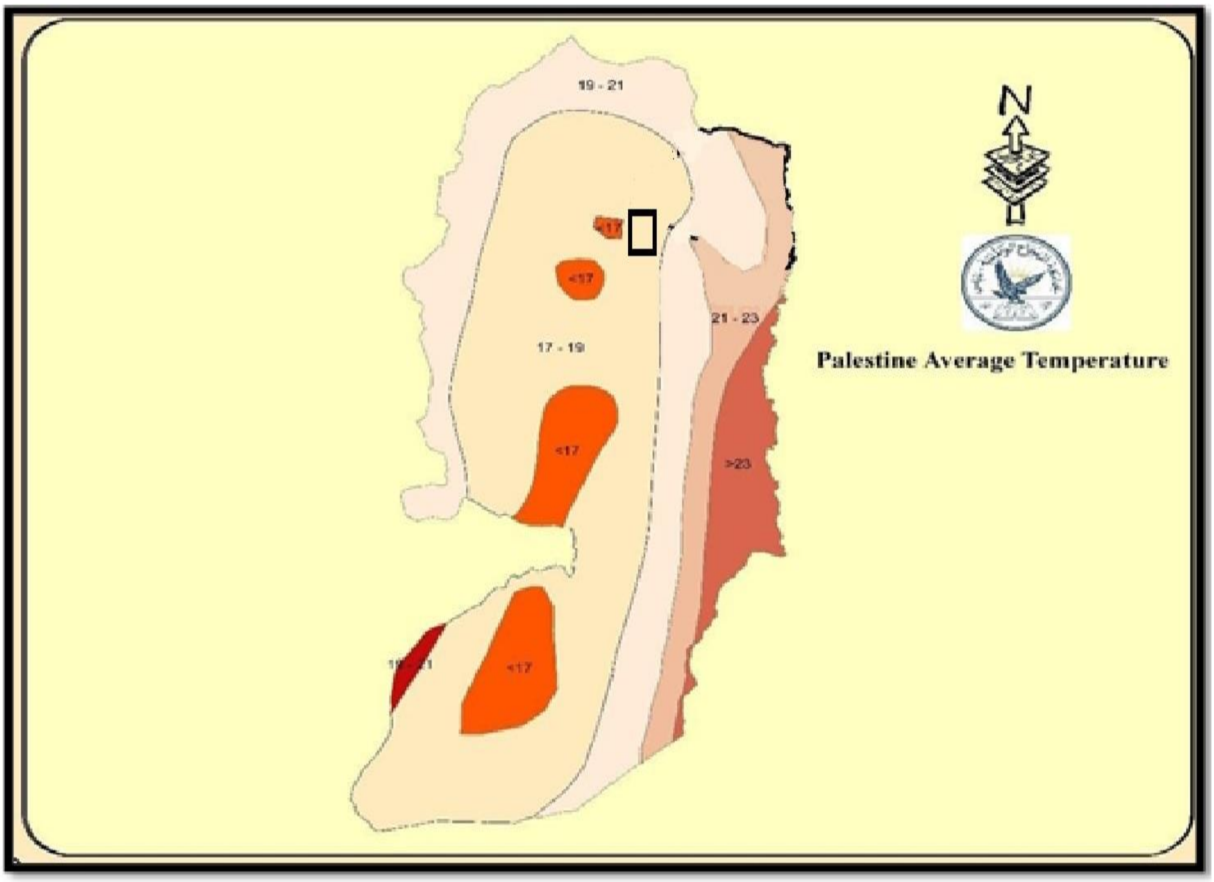


Figure 3 Average Temperature in Palestine Governorates

3.4 Socio-economy

The economy in Yasid has many sectors. The primary sector is the Government or other public employees sector, which absorbs 41% of the village's workforce. (See Figure 4).

The results of a field survey conducted by the ARIJ team in 2017 looking at the distribution of labor according to economic activity in Yasid are as follows:

- Government or other public employees sector (41%)
- Agricultural sector (40%)
- Israeli labor market (8%)
- Industry (5%)
- Trade sector (3%)
- Services sector (3%)

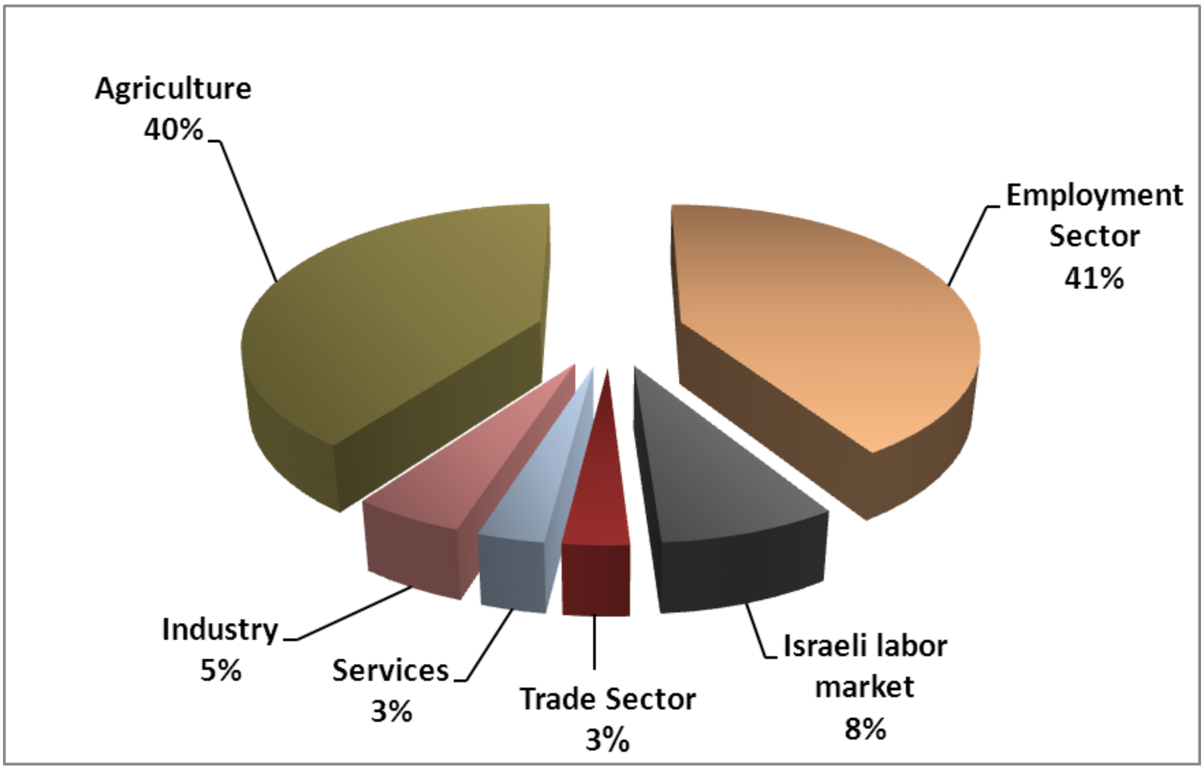


Figure 4 the distribution of labor force among main economic activities Yasid

In 2022, the unemployment rate in Yasid reached 25% and the groups most affected economically by the Israeli restrictions were: workers in the agricultural sector, specifically the workers in olive oil production. *(Yasid Village Council, 2022).*

3.5 Yasid Village Council

Yasid village council serves these village, in general Yasid Village Council (YVC) is concerned with everything related to serving citizens in terms of supervising the providing of water and its distribution in a way that every capita takes his share of water according to certain specifications, either if it's for human use or other purposes.

Since this study will be concentrated on this village, related data is shown in Table 2 concerning, population and elevation.

Table 2 Related Data About region served by YVC

Yasid Information	
Area (km^2)	**9.5**
Population	**2732**
Elevation (m)	**690**

3.6 Existing Infrastructure

3.6.1 Transportation Services

There are many means of transportation available in the Yasid village. There are transportations to Nablus. The village still lacks many infrastructure services.

Table 3 Roads in Yasid Village (Source: Yasid Village Council, 2022)

Status of Internal Roads	Road Length (km)	
	Main	Secondary
1. Paved & in good condition	8	0
2. Paved & in poor condition	0	5
3. Unpaved	7	8

3.6.2 Electricity and Telecommunication Services

Yasid has been connected to a public electricity network since 1985. It is served by the North Electricity Company, which is the main source of electricity in the village, and approximately 90% of the housing units in the village are connected to the network. The village residents face a number of problems concerning electricity, primarily the sudden disconnection of power supply in some cases *(Yasid Village Council, 2022).*

3.6.3 Water

Water network of yasid was designed knowing that the water network does not provide adequate service and does not meet the needs of citizens in providing an adequate amount of water. So people in Yasid buy water at high prices. We will redesign the water network to provide the required efficiency. *(Yasid village council, 2022).*

3.7 Geopolitical Status in Yasid village

According to the Oslo II Interim Agreement signed between the Palestinian Liberation Organization (PLO) and Israel on 28th September 1995, all the village lands of Yasid are classified as area "A" consisting of 9.5 Km^2, where the Palestinian National Authority (PNA) has complete control over the civil and administrative issues.

4. Description of the Existing Water Supply System

4.1 Water Resources

The village served by Yasid Village Water Supply System (YVWSS) is fed with water from two water production wells and from the rainfall collected in cisterns tanks, and water is not supplied from external water supply companies (Israel Water Supply Companies). Figure 5 shows the geographical location of the production wells supplying the areas served by YVWSS.

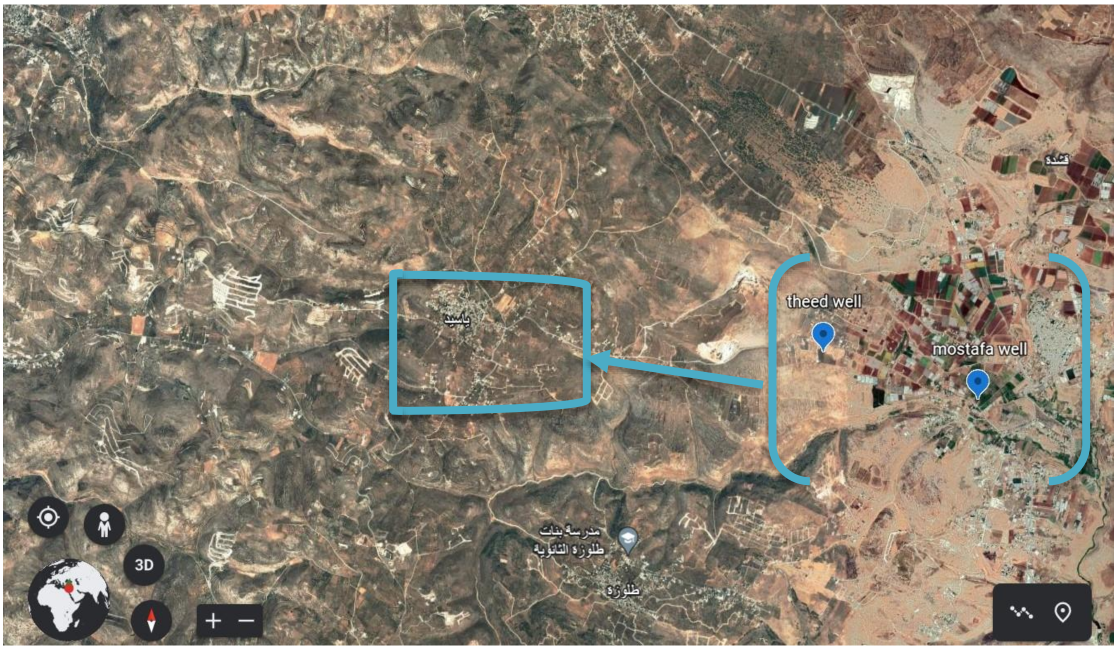


Figure 5 Production Wells Geographic location

4.2 Water Production Wells

At the present time, there are two productive wells that supply the village with water, the first is primary through which water is pumped with a capacity of 70 cubic meter per hour, and the other well is a reserve well that is used in emergency cases with a capacity 28 m^3/h the (table 4 show the production wells characteristics).

Table 4 Production Wells Characteristics

Well Location	Well Name	Year of Construction	Elevation (m)	Depth (m)	Pump Setting (m)	Water Level (m)	Well productivity (m^3/h)	Diameter (in)
Al-Far'a	**Theeb Mashaqi Well**	**2010**	**290**	**420**	390	**220**	**70**	**18**
Al-far'a	**Mostafa Mashaqi Well**	**2009**	**195**	**320**	**---**	**130**	**28**	**18**

4.2.1 Theeb Mashaqi Well

The Yasid well (Theeb Mashaqi) was drilled in 2009 and its use was authorized by the authorities in 2010 at a depth of 420 meters below ground level. It is located at the last point of the village of Yasid towards Al Fara'a. Its elevation is (290 meters) above sea level with a productivity of 70 m^3 / hour 45 m^3/h for Yasid and 25 m^3/h for other uses.

One pump with a capacity of (70 m^3/h) are installed. The diameter of the well is 18 inches, and the water level in this well can reach 220 m. This may vary due to the season of the year because it affects the demand quantity. The well is operated 10 hours/day. Figure 6 shows a picture of the Theeb well.

Figure 6 Theen Mashaqi well

Theeb Well supplies the village of Yasid with water, taking into account that the village of Yasid is one area according to the elevated tank.

4.2.2 Mostafa Mashaqi Well

The well was drilled in 2009 to a depth of 320 m below ground level with a diameter of 18 inches, and has an elevation 195 m above sea level, the well located in Al- Far'a village, and has a productivity of 28 m^3/h, and the water level in this well can reach 130 m. This well is not operating at the present time and is designated for emergency cases.

Figure 7 Mostafa Mashaqi Well

4.3 Conveyance Lines in YVWSS Service Zone

4.3.1 Conveyance lines in the YVWSS Zone.

In the YVWSS Zone There are one Conveyance line divided into three sections as described below and summarized in Table 5:

Table 5 Characteristics of conveyance lines in The YVWSS Zone

No.	From	to	Diameter (in)	Material (m)	Length (m)	Date of Construction
L1	**Theeb Mashqi well**	**Storage Tank I**	**4**	**HDPE**	**70**	**2020**
L2	**Storage Tank I**	**Storage Tank II**	**4**	**ductile**	**3500**	**2008**
L3	**Storage Tank II**	**Elevated tank**	**4**	**ductile**	**1500**	**2013**

1. From Theeb Mashaqi well to storage tank I: This line was constructed in 2020, its length is about 70 m and made of steel as a main material, it has a diameter of 4 inches, its main function is to supply water from the Theeb Mashaqi well to the collection tank.

2. From storage tank I to the storage tank II: This line was constructed in 2008, its length is about 3500 m and made of ductile as a main material, moreover its diameter is 4 inches, Its main function is to transfer water from the collection tank to the purification tank.

3. From the storage tank II to elevated tank : This line was constructed in 2013, its length is about 1500 m and made of ductile as a main material, and its diameter is 4 inches, Its main function is to transfer water from the storage tank II to the elevated .

The construction of conveyance lines and the types of materials used are shown on Figure 8.

Figure 8 conveyance Pipelines Construction

4.4 Storage Facilities in the YVWSS

Table 6 Characteristics of Reservoirs and Tanks YVWSS Zone

No.	Name	Location	Elevation* (m)	Height (m)	Capacity (m^3)	Operation Mode	Date of Construction
T1	Storage Tank I	*Al-Far'a village*	290	3	400	storage	2010
T2	Storage Tank II	*Yasid village*	600	4	150	Service	2010
T3	Elevated tank	*Yasid village*	710	4.10	350	Distribution	2013

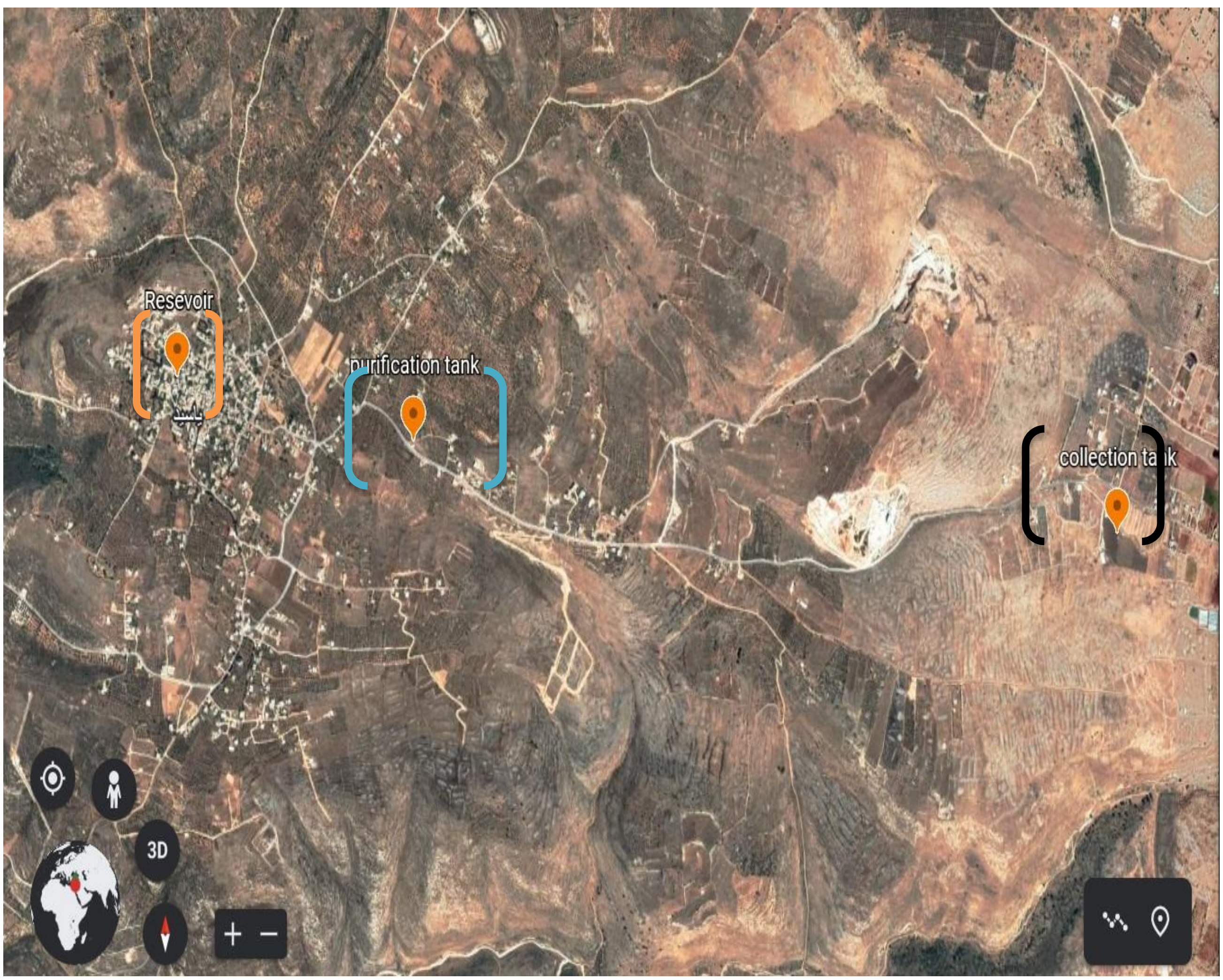


Figure 9 Storage facility in YVWSS locations

4.4.1 Storage Facilities in Yasid Village

In the Yasid village there are three reservoirs as described below and summarized in Table 6.

1) **Storage tank I**: This tank was constructed in 2010, it is located in Al-Far'a at an elevation of 290m and has a height of 3 m, its capacity is 400 m^3, it receives water from Theeb well, and then the water is pumped to the storage tank II.

Figure 10 Storage tank I

2) **Storage tank II**: This tank was constructed in 2010, it is located in Yasid with an elevation of 600 m and has a height of 4 m, its capacity is 150 m^3, it receives water from collection tank, and then Water is delivered to elevated tank, which is at the high point of Yasid.

Figure 11 Storage tank II

3) **Elevated tank**: means the tank constructed for holding water as storage and hydraulic control. This tank was constructed in 2013, it is located in Yasid village with a height of 710 m for bottom point of tank and has a height of 16 m, and dimensions of tank is (4.10 m depth, 9.2 m length) its capacity is 350 m^3.

Figure 12 Yasid elevated tank

4.5 Main Pumping and Booster Stations

4.5.1 Main pump station.

The main job of this station is to lift up water from the groundwater well to the storage tank II, the station is located in between Yasid and Al-Far'a , with a useful flow of up to 45 m^3/h, the station is at an elevation of 300 meters above mean sea level, The head of this pumps is 400 meters, and has a centrifugal impeller.

Figure 13 the main pump in Yasid

4.5.2 Yasid Booster Pump Station

Table 7 Yasid Booster Pumps

Pump NO.	Location	Status	Impeller type	Placement configuration	Flow m^3/h	Elevation	Head (m)
B1	Yasid Booster Station	Working Alternate	Centrifugal	Horizontal	20	600	132.5
B2	Yasid Booster Station	Working Alternate	Centrifugal	Horizontal	20	600	132.5

Yasid booster pumping station consists of two boosters operating alternately with a useful flow of up to 20 m^3 /h from its outlet, However, when there is a need, the two boosters can be switched on at the same time, both of which are 600 meters above mean sea level, Moreover, the head of these pumps is 132.5 meters, and each has a centrifugal impeller. Figure 14 shows a picture of the Yasid booster station.

Water is pumped from the storage **II** tank to the elevated tank and to be delivered to consumers by networks and distribution system.

Figure 14 Yasid booster station

4.5.3 Controlling and Monitoring

Controlling and monitoring is a vital process to adjust quality of service in a proper way to serve citizens and detecting any defects or problems that the supply system can suffer from, Figure 14 shows a controlling device for Theeb well pump and boosters.

Figure 15 Controlling device for Yasid Pump and booster's station

4.6 Water Networks

4.6.1 Yasid water network

This Yasid water network distributes water to the citizen's houses in Yasid village, several diameter sizes are used for pipes and it varies according to the amount of flow running inside the pipe, Moreover, ductile iron is used in main pipes and high-density polyethylene (HDPE) for minor pipes, the network length totals 14 Km.

Pipes are divided into two main groups according to its function and destination: house connection and main connection.

1) House connections

Table 8 House connection pipes.

house connection	
Diameter	Length (m)
0.5 inch	4000
1 inch	2000
Total	6000

2) Main distribution lines

Table 9 main connection pipes.

Main connection	
Diameter	Length(m)
2 inches	3000
3 inches	5000
Total	8000

Problems experienced by the Yasid water network include:

1) After the establishment of the network, the residential area of Yasid expanded to include areas at high elevation that are more than the height of the elevated water tank distributed and feeding the network, which led to the difficulty of delivering water to these areas and the need for adding pumps.

2) A noticeable increase in the water loss, which amounts to 30%, due to leaks and malfunctions in the network, or due to illegal theft of water.

3) Excessive use of mechanical meters, which leads to the accumulation of debts and non-payment of bills on time.

4) The large number of local losses due to the structure of the network in which there are many elbows of water, this leads to a great burden on the pumps and the need for higher electrical energy to operate them.

4.7 Water meters

Water meters are the last point within the water networks it is the responsibility of the Council, as it works to count the quantities (volume) of water consumed by the customers, After these meters, it is the responsibility of the customers to maintain any internal extensions to deliver water to roof tanks or directly to points of use.

4.7.1 Mechanical water meter system

Mechanical meters are used to calculate the volume of water per m3, It is widely used in Palestine and in YVWSS have been used mechanical mater since the beginning of the establishment of water the network in Yasid. A monthly bill is issued based on the meter reading.

Figure 16 Mechanical water meter

4.7.2 Prepaid water meter (PPWM) system overview

The PPWM system consists of metering, dispensing (vending), and credit-loading components. The customer purchases a specific amount of water at the vending station by charging their PPWM cards. The purchased (credited) water is registered into media (token), The payment for credited water will be automatically transmitted to the customer database in the center of billing system. Vending stations (sale points) are established at the most accessible points with flexible hours for customer to conveniently charge their cards:

1. The prepayment environment will be made up of the following equipment and components: The metering device, includes the user interface for the loading of credit and other data. The metering device must be securely mounted to prevent tamper.
2. The credit and data transfer device: Token.
3. The vending station, specifically the hardware, software and interface to the token.
4. Flexible and user defined reports from the software to allow reporting on all aspects of the system and the consumer consumption and spend. Trend analysis must form part of the reporting options.

Figure 17 inter a card (token)

Figure 18 PPWM

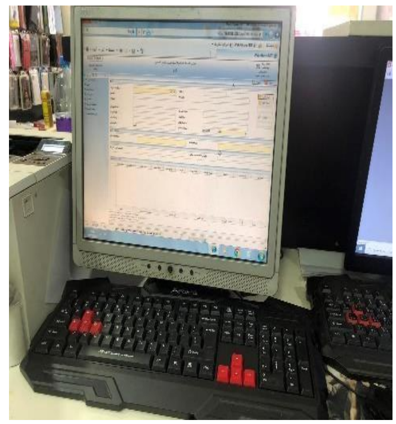


Figure 19 Database computer

Vending stations shall be established at accessible points for customer's convenience for extended hours. A vending station per 1,000 customers is suggested by the supplier the equipment necessary for vending station will be PC system including software, the device for charging credit, etc., and one staff shall be deployed at each station. Vending station can be outsourced to supermarkets or to companies which offer credit charging services like Pal pay Company in Palestine. Convenient and hassle -free payment methods; properly located charging centers (vending stations) with extended service hours and friendly/knowledgeable staff are established. The software are used on a standard computer with an attached card read.

4.7.3 Advantage and disadvantage of PPWM

Advantage and disadvantage of PPWM for YVWSS and the customers are summarized below. The PPWM system has many advantages for YVWSS but less disadvantage including initial cost of PPWM. For customer, water supply condition may improve and water charge are reduced.

Advantage to YVWSS:

- Almost 100% collection ratio and increase in water revenue and collection of part of the previous debt.
- No need for regular meter reading/bill collection.
- No reading error and input error.
- Higher accuracy of data on water consumption and customer information.
- Easier control and decrease in illegal connections and leakage.
- Reduce in work load.
- Save the salaries of readers andcollectors
- Easier customer management system with PPWMs.
- Higher customer satisfaction and change in public attitudes toward payment of water.
- Decrease in water consumption, increase in water availability over time, and supply to more customers.
- Reduction of consumption and deferral of the investment of water supply facilities.
- Long-term rationalization of consumption.

Disadvantage to YVWSS:

- Initial cost for PPWM.
- Use of new software and itstraining.

Advantage to customers:

- The customer is more conscious about water consumption, resulting in reduction
- Of water consumption and water charge.
- Payment of water charge by correct meter consumption

- Decrease in water consumption, increase in water availability over time, and supply to more customers.
- The capital cost required for upgrade the facilities would be decreased or upgrading can be deferred. Deferral of the investment of facilities eases water tariff increase.
- In many cases, water meters are installed by water works for free.

Disadvantage to customers:

- They have to pay water cost in advance.
- They have to go and buy charge at the vending machine.
- Customers of unwilling to pay bill have to pay.

4.7.4 Existing water meter

The water meter on YVWSS is mainly a mechanical meter. Prepaid water meter, a few of which have been installed.

It is assumed when converting mechanical meters into prepaid meters you should use the strategy:

1. Any new connection must be with PPWM.
2. Free replacement of existing meters. Increase customer awareness of PPWM water supply service.
3. Facilitate an easy mechanism for collecting all debts with PPWM.

Table 10 YVWSS Water meter

	Mechanical M	PPWM
Yasid	386	26

*Mechanical Meter =Traditional water meter

*PPWM =Pre paid water meter

4.7.5 PPWM in Yasid Village

A social survey was conducted on citizen's' opinion of PPWM in the village. The results of the social survey on opinion of PPWM are summarized as follows.

- 85 % prefer PPWM and 15% don't.

The reasons for accepting and not accepting PPWM are listed below:

Table 11 Specifications of PPWM

Reasons for accepting PPWM	Reasons for not accepting PPWM
1. Customer pays regularly 2. Makes customer periodic 3. To get water every day without cutting 4. This system is better 5. Easier for customers and municipality 6. More accurate and depends on how muchpeople consume 7. No need to pay attention for bills everymonth 8. Water will be available always 9. Better control of consumption	1. Not enough money to charge regularly 2. It costs more money 3. Don't trust council 4. We already pay my water bill in cash, so I don't need this system. 5. This water meter reads more than actual consumption 6. Not suitable for poor people 7. More difficult system 8. Paying every month is better, and thefinancial status is bad

The results of the following questions regarding to Questionnaire answered by citizens fromYasid Village are shown in Figure 20, the main Satisfactions is:

1. Distance to the vending station.
2. Frequency of credit charging.
3. Satisfaction with payment.
4. Difficulty in using PPWM system.
5. Maintenance of PPWM.
6. Would you recommend PPWM?

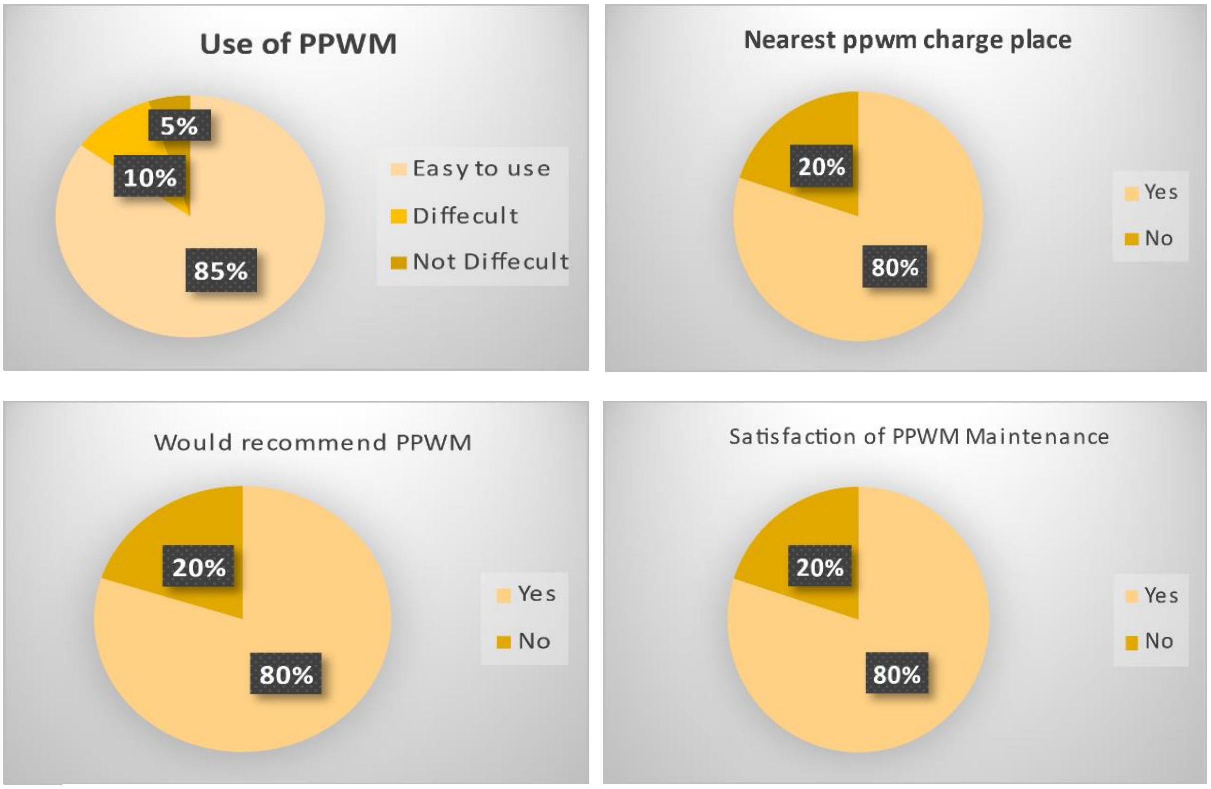


Figure 19 PPWM card charge

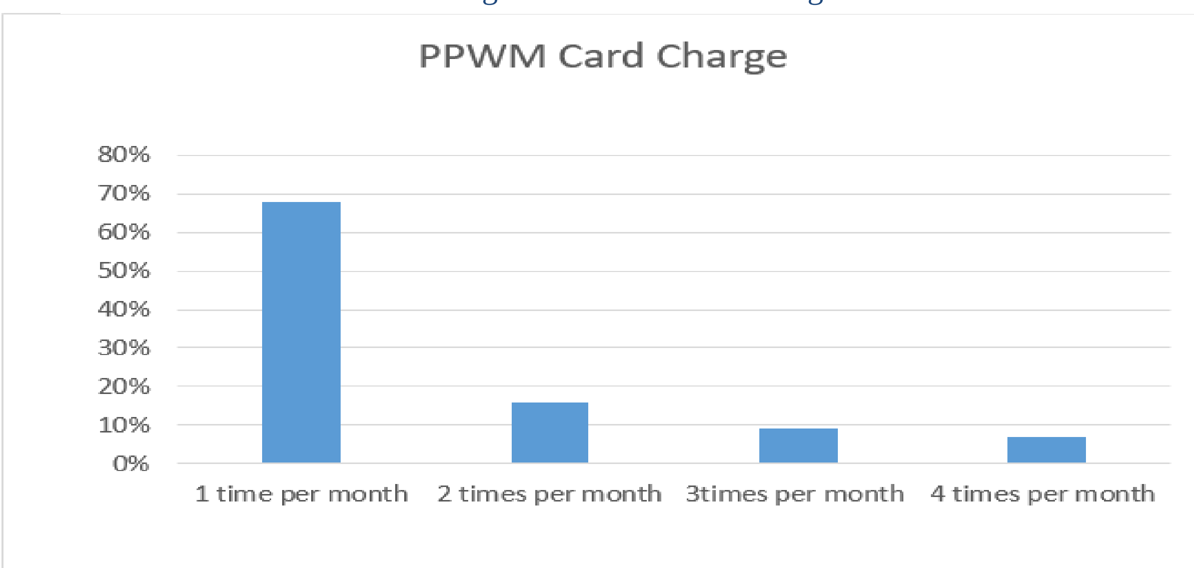


Figure 20 PPWM card charge

In general, as seen in the figure above, the users are highly satisfied with the PPWM andrecommend to others. The reasons for their satisfaction are as follows.

1. The charge center for PPWM card is close and within 0.1-1km for most of them. Distance to them charge center has a high impact of the satisfaction.
2. Most of the user's charge once a month and it is more convenient to them.

4.8 NON-REVENUE WATER

4.8.1 Water balance

Understanding water balance is the first crucial step in NRW Management. In simple terms, water balance show much water was produced, how much was supplied, how much reached the customers, and where the rest went. This also indicates where the major problems lie.

4.8.1.1 International Water Balance and its Components

The IWA Standard Water Balance (Table 12) shows the international best practice of water balance. It lists and defines various components of water balance including non-revenue water (NRW). *(International Water Association, 2016)*

Table 12 IWA standard water

(1) System Input Volume (SIV) **حجم المياه الداخله للشبكة**	(2) Authorized Consumption الاستهلاك القانوني	(2-1) Billed Authorized Consumption الاستهلاك القانوني المُفوتر	(2-1-1) Billed Metered Consumption الاستهلاك المفوتر المُقاس	Revenue Water ايراد المياه
			(2-1-2) Billed Unmetered Consumption الاستهلاك المُفوتر غير المُقاس	
		(2-2) Unbilled Authorized Consumption الاستهلاك القانوني وغير المُفوتر	(2-2-1) Unbilled Metered Consumption الاستهلاك غير المفوتر المُقاس	**Non-Revenue Water (NRW)** الفاقد من المياه
			(2-2-2) Unbilled Unmetered Consumption الاستهلاك غيرالمُفوتر وغير المُقاس	
	(3) Water Losses فاقد المياه	(3-1) Apparent (Commercial) Losses **الفواقد التجاريه**	(3-1-1) Unauthorized Consumption الاستهلاك غير القانوني	
			(3-1-2) Customer Metering Inaccuracies عدم دقة عداد المشترك	
		(3-2) Real (Physical) Losses الفاقد الحقيقي	(3-2-1) Leakage on Transmission and/or Distribution Mains التسرب في خطوط النقل والتوزيع الرئيسية	
			(3-2-2) Leakage and Overflows at Utility's Storage Tanks تسرب وفيضان خزانات مرافق المياه	
			(3-2-3) Leakage on Service Connections up to point of Customer Metering التسرب في الوصلات المنزلية الممتدة الى عداد المشترك	

4.8.1.2 Definition of Terms Related to Standard IWA Water Balance

1. System Input Volume:

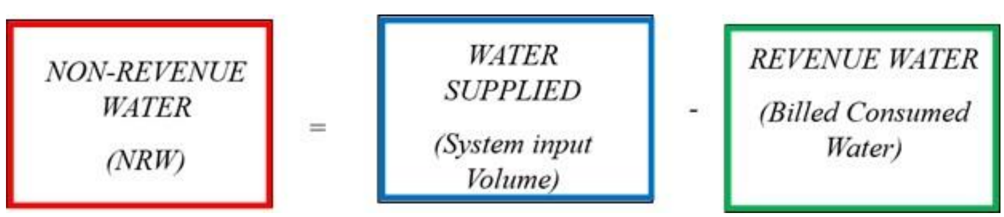
   The system input volume is the total volume of treated water, from all sources of water includingPalestinian Water Authority (PWA) wells, private agriculture wells contracted by the council, and imported from outside the council.

2. Authorized Consumption:

   The volume of metered and/or unmetered water taken by registered customers or organizations authorized to use water. Authorized consumption may include items such as water taken for firefighting, fire training exercises, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, amongst others. These may be billed or unbilled, metered orunmetered.

4.8.2 Definition of NRW

NRW is defined as the difference between system input volume and billed authorized consumption. In other words, NRW is the difference between volume of water supplied and volume of water billed.



NRW includes any water which is authorized to use (such as firefighting) but not billed. This component is known as ‘Unbilled Authorized Consumption’ in Standard IWA Water Balance.

4.8.3 Examples of IWA Standard Water Balance components from YVWSS

The following is an example of water balance components in IWA water balance format. In this table all components of water balance have been identified individually.

Table 13 Examples of IWA Standard Water Balance components from YVWSS

<table>
<tr>
<td rowspan="8">System Input Volume (SIV)
كمية المياه المدخلة للنظام المائي
=
164,250 m^3
100%</td>
<td rowspan="4">Authorized Consumption (AC)
الاستهلاك المصرح به
=
115,632 m^3
70.40%</td>
<td rowspan="2">Billed Author. Cons. (BAC)
الاستهلاك المصرح به المفوتر
115632 m^3
70.40%</td>
<td>Billed metered (BMC)
115632 m^3 70.4%</td>
<td rowspan="2">Revenue Water (RW)
المياه المحاسب عليها
115632 m^3
70.40%</td>
</tr>
<tr>
<td>Billed Unmetered (BUC)
0 m^3 0.00%</td>
</tr>
<tr>
<td rowspan="2">Unbilled Author. Cons. (UAC)
الاستهلاك المصرح به غير المفوتر
0 m^3
0.00%</td>
<td>Unbilled metered (UMC)
0 m^3 0.00%</td>
<td rowspan="6">Non-Revenue Water (NRW)
المياه غير المحاسب عليها
48618 m^3
29.60%</td>
</tr>
<tr>
<td>Unbilled Unmetered (UUC)
0 m^3 0.00%</td>
</tr>
<tr>
<td rowspan="4">Total Losses (WL)
الفاقد الكلي
=
48618 m^3
29.60%</td>
<td rowspan="2">Apparent Losses (AL)
الفاقد التجاري (الظاهري)
2975 m^3
6.12%</td>
<td>Unauthorized Consumption (UC)
40.75 m^3 1.37%</td>
</tr>
<tr>
<td>Metering Inaccuracies (MI)
2934 m^3 4.75%</td>
</tr>
<tr>
<td rowspan="2">Real Losses (RL)
الفاقد الحقيقي (تسرب)
45643 m^3
23.48%</td>
<td>Leakage and Overflows at Utility's Storage
0 m^3 0.00%</td>
</tr>
<tr>
<td>Leakage on Transmission Mains/Distribution Pipes and Service Connections up to point of Customer metering
45643 m^3 23.48%</td>
</tr>
</table>

4.8.4 Importance and Benefits of Reducing NRW.

The following figure shows how much water was supplied and how much of that was lost as NRW in YVWSS

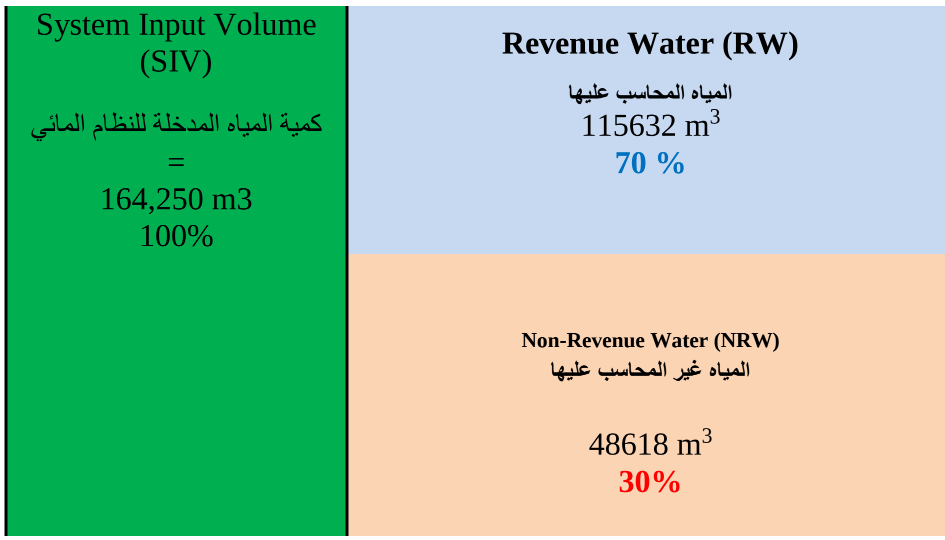


Figure 21 System input and NRW volumes of YVWSS in 2020

Non-Revenue Water is enough to supply to 1110 people @ 120 L/c/day
Where is this water going?

If the NRW is converted to monitory term, say at the average selling price of water in Yasid (about 7 NIS/m^3), it is equivalent to 340,000 NIS.

That means YVWSS loss about 340,000 NIS in potential revenue of water in year 2022

The benefits of reducing Real Loss are many:

1. Water will be saved from wastage.

2. Operational costs will be reduced. There will be less need of leak repair materials, tools, less travels to the field to repair leaks / bursts.

3. Water availability will be improved. More water will be available for consumption and therefore revenue will increase. Increased revenue could be utilized to further improve water system.

4. Reliability of water supply will improve as water supply interruption due to repairs will be minimized.

5. The water quality will be preserved as chances of dirty water getting into pipe during leak repair or from leaking holes during non-supply period will be minimized.

6. Public image of the council will be improved as people think the water department is doing a good job.

7. Need for investment in new sources will be postponed.

The benefits of reducing Apparent Loss are:

1. The main benefit of reducing Apparent Loss is increase in revenue. This increased revenue can be used to further improve the water supply system.
2. People who use water illegally do not mind wasting water as it is free for them. Reducing Apparent Losses by reducing illegal users will reduce this waste.
3. Eliminating the illegal connections will reflect the Council fairness towards treating the customers and this will increase the trust from the social point of view.

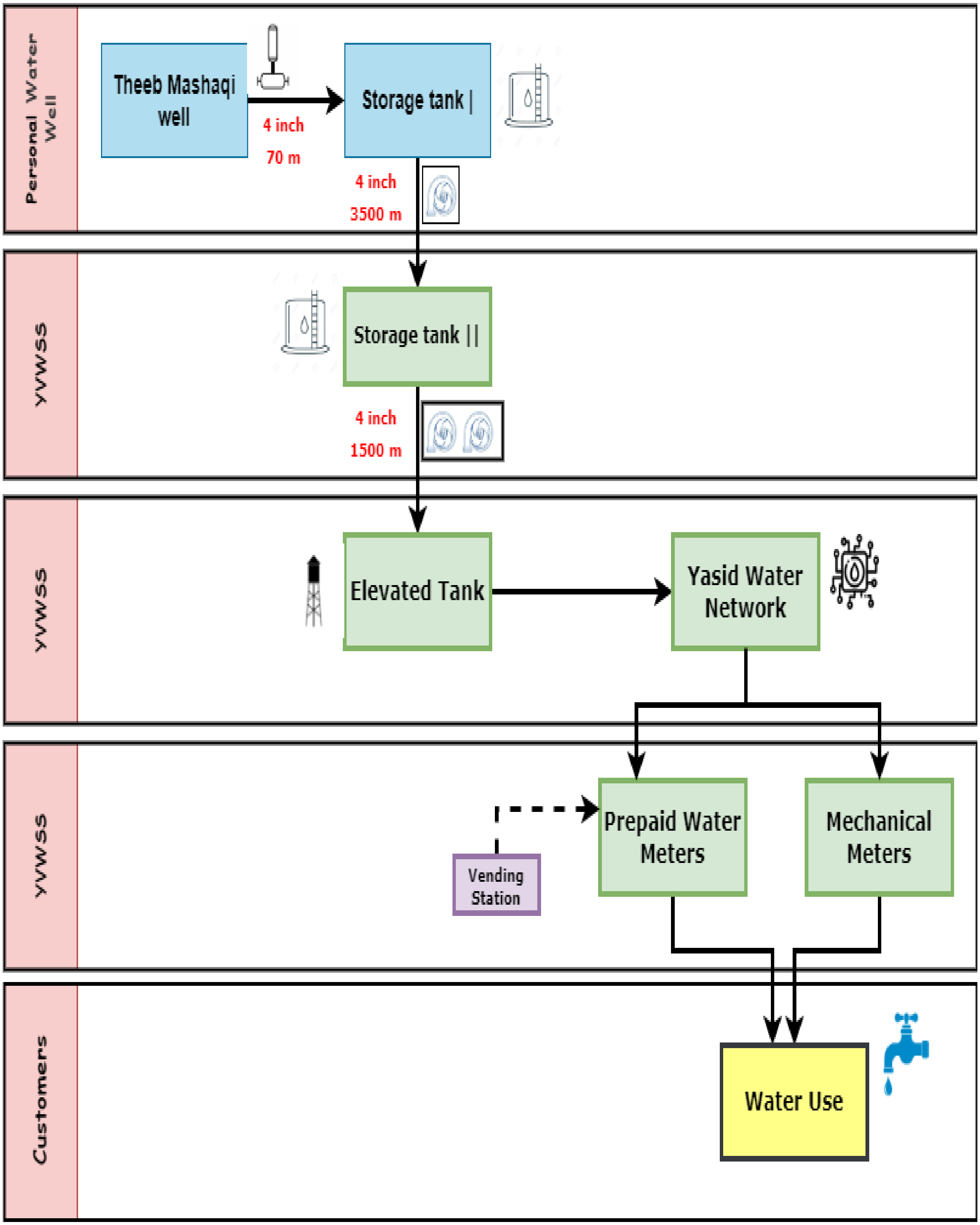
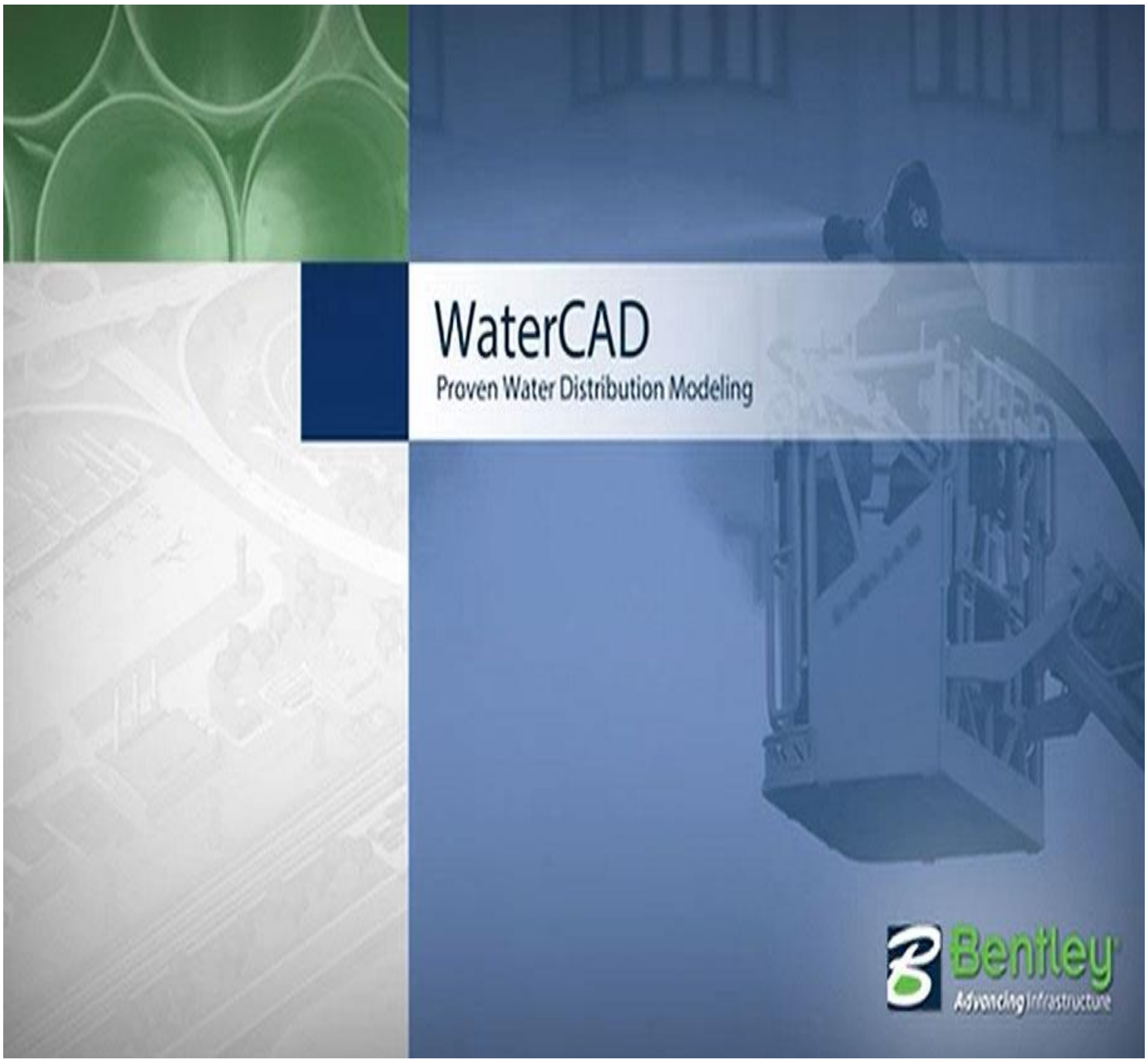


Figure 22 Systematic water supply in Yasid village.

5. Water CAD Program

5.1 Background

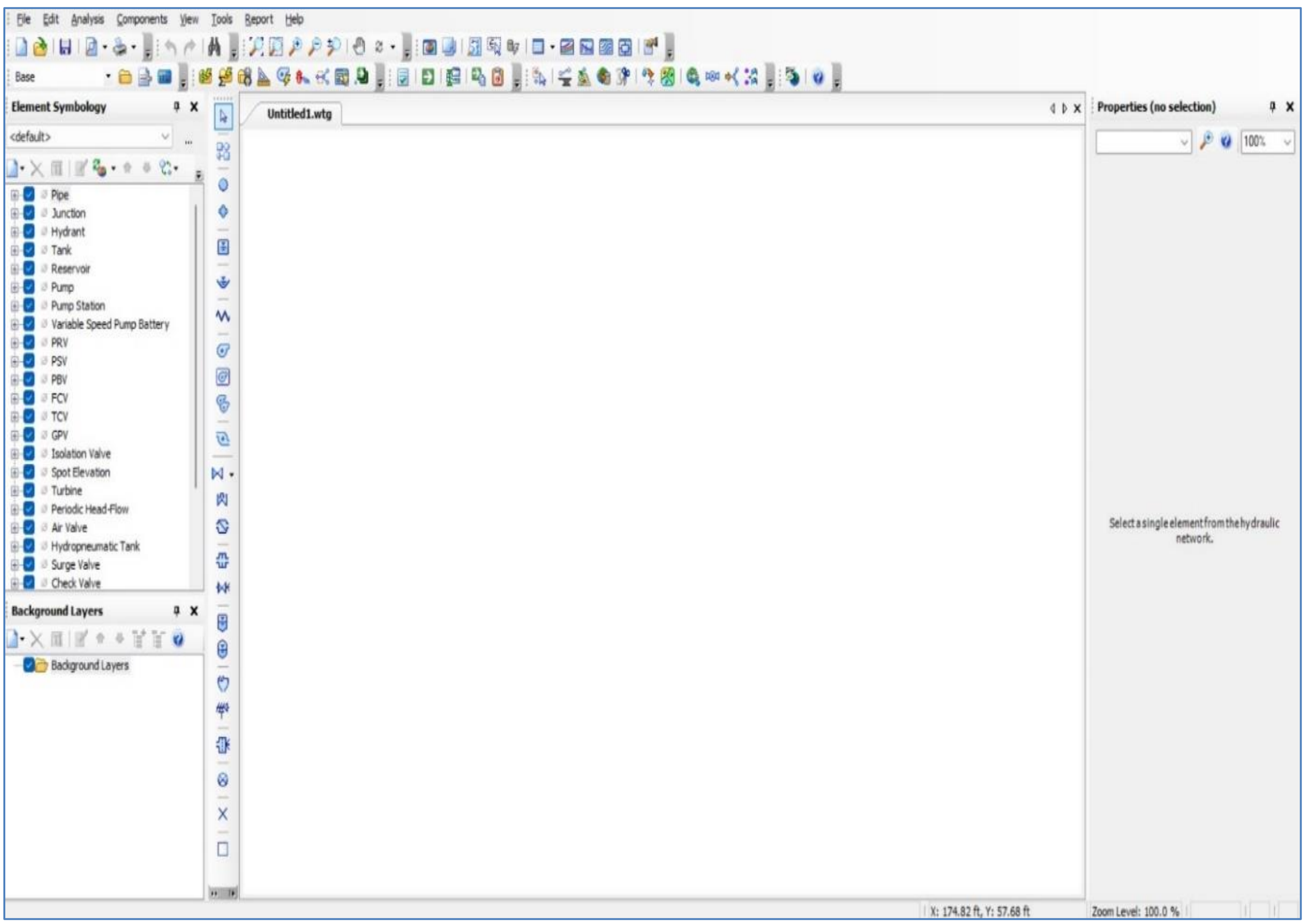
Bentley WaterCAD is one of the software package design. It's used to design a water network system but this program is characterized by easy in use and accuracy of the results. In addition to, this program allows the designer to use detailed properties of the network making it easier to understand the network structure.



5.2 Capabilities

WaterCAD program is an idea created in order to help all the designers to design and analysis water networks through the inclusion of properties and facilities operations in the input and output data and show these characteristics and capabilities in this program through the following.

1. WaterCAD can be used to select more than one benefit, for example, operational studies, pipe sizing, tank and pump sizing....etc.
2. Compute friction head loss using the Hazen-Williams, the Darcy Weisbach.
3. Perform extended period simulation to analyses the piping systems response to varying supply and demand schedules.
4. Model various types of valves.



5.3 Equation used in WaterCAD

5.3.1 Hazen-Williams Equation

Empirical equation developed in special circumstances have been created by Hazen -Williams and the advantage of being frequently used in the design and analysis of water networks that because it is more accurate in getting the results compared to other.

- **To solve for velocity:**

$V = 0.85C\ R_h^{0.63}\ S^{0.54}$ unit …………… (S.I)

- **To solve for head loss :**

$h_f = (10.67 * L * Q1.85) / (C1.85 * D\ 4.87)$ unit …………… (S.I)

Where: - h_f = *head loss (m)*

Q: flow rate

V = Velocity of the fluid (m/s)

L= Length (m)

C = Hazen-Williams Roughness Coefficient CHW

D = Diameter of pipe (m)

R = Hydraulic Radius = [Cross - sectional flow area / wetted perimeter] (m)

S= Slope of the hydraulic gradient (m/m)

Material	Hazen-Williams Coefficient - *c* -
ABS - Acrylonite Butadiene Styrene	130
Aluminum	130 - 150
Asbestos Cement	140
Asphalt Lining	130 - 140
Brass	130 - 140
Brick sewer	90 - 100
Cast-Iron - new unlined (CIP)	130
Cast-Iron 10 years old	107 - 113
Cast-Iron 20 years old	89 - 100
Cast-Iron 30 years old	75 - 90
Cast-Iron 40 years old	64-83
Cast-Iron, asphalt coated	100
Cast-Iron, cement lined	140
Cast-Iron, bituminous lined	140
Cast-Iron, sea-coated	120
Cast-Iron, wrought plain	100
Cement lining	130 - 140
Concrete	100 - 140
Concrete lined, steel forms	140
Concrete lined, wooden forms	120
Concrete, old	100 - 110
Copper	130 - 140
Corrugated Metal	60
Ductile Iron Pipe (DIP)	140
Ductile Iron, cement lined	120
Fiber	140
Fiber Glass Pipe - FRP	150
Galvanized iron	120
Glass	130
Lead	130 - 140
Metal Pipes - Very to extremely smooth	130 - 140
Plastic	130 - 150
Polyethylene, PE, PEH	140
Polyvinyl chloride, PVC, CPVC	150
Smooth Pipes	140
Steel new unlined	140 - 150
Steel, corrugated	60
Steel, welded and seamless	100
Steel, interior riveted, no projecting rivets	110

Figure 23 Hazen-Williams Constant

5.3.2 Darcy-Weisbach Equation

The Darcy-Weisbach equation is a phenomenological equation, which relates the head loss or pressure loss due to friction along a given length of pipe to the average velocity of the fluid flow. The equation is named after Henry Darcy and Julius Weisbach. The Darcy-Weisbach equation contains a dimensionless friction factor, known as the Darcy friction factor. This is also called the Darcy-Weisbach friction factor or Moody friction factor. The equation is a theoretically based equation for use in the analysis of pressure pipe systems. It is a general equation that applies equally well to any flow rate and any incompressible fluid.

- Darcy-Weisbach equation

$$h_f = f\frac{L}{D}\frac{V^2}{2g}$$

Where: - *hf = the head loss (m)*

f= Darcy-Weisbach friction factor

L= Length (m)

v = Velocity of fluid (m/s)

D= Diameter of pipe (m)

g = Gravitational acceleration (m/s2)

5.3.3 Manning's Equation

Manning's Equation is an empirical formula that most commonly used equations governing for open channel flow, but can be applied to water flow in closed conduits as well. The resistance component of this equation includes a factor (n), which is generally a function of pipe material and condition.

- Manning's Equation :

$V = \frac{1}{n} R^{2/3}{}_{h} \sqrt{S_f}$ Unit …………… (S.I)

$h_f = (n * V / 1.00 * R_h^{2/3})^2 * L$ Unit …………… (S.I)

Where: -- *hf = head loss (m)*

V = Velocity of the fluid (m/s)

L = Length (m)

n = Manning's friction coefficient

R = Hydraulic Radius = [Cross - sectional flow area / wetted perimeter] (m)

Material	Manning's
Metals	
Brass	0.011
Cast Iron	0.013
Smooth Steel	0.012
Corrugated Metal	0.022
Non-Metals	
Glass	0.010
Clay Tile	0.014
Brickwork	0.015
Asphalt	0.016
Masonry	0.025
Finished Concrete	0.012
Unfinished Concrete	0.014
Gravel	0.029
Earth	0.025
Planed Wood	0.012
Unplaned Wood	0.013
Corrugated Polyethylene (PE) with smooth inner walls	0.009-0.015
Corrugated Polyethylene (PE) with corrugated inner walls	0.018-0.025
Polyvinyl Chloride (PVC) with smooth inner walls	0.009-0.011
Excavated Earth Channels	
Clean	0.022
Gravelly	0.025
Weedy	0.030
Stony, Cobbles	0.035
Natural Streams	
Clean and Straight	0.030
Major Rivers	0.035
Sluggish with Deep Pools	0.040
Floodplains	
Pasture, Farmland	0.035
Light Brush	0.050
Heavy Brush	0.075
Trees	0.15

Figure 24 Manning's roughness coefficient values for some common materials

6. Preparing Design

6.1 Water Distribution Network

6.1.1 Introduction

Effective water supply system is of great importance in designing new water network system or expanding the existing one, tis can be through, the water distribution system are designed to adequately satisfy the water requirements for a combination of domestic, commercial and industrial purposes. The system should be capable of meeting the demands placed on it all times and satisfactory pressure. The water distribution network is comprised of a number of links connected together. The water distribution network in general contains the main elements that will be mentioned in the next section.

6.1.2 Elements of water distribution system

❖ Pipe material

The selection of pipe material, consideration should be given to factors such as loading from the surrounding soil and traffic, chemical attack from the soil and groundwater and the water in the pipe. Consideration must also be given to properties such as lifetime, and to the cost of purchase, operation and maintenance of the network.

❖ Pressure and Velocity

According to the Palestinian Water Authority, the highest pressure in the public water supply network should not exceed 10 bar (100-meter pressure head) at the point of connection in order to prevent damages and leakages in sanitary installations. The lowest pressure in a public water supply network should not be less than 2 bar (20-meter pressure head).

- The rate of velocities in the pipeline According to the Palestinian Water Authority should not exceed (0.3 to 3.0) m/s to control corrosion of the pipes and other reason.

6.1.3 Water Distribution Methods

When designing the water system, it is distributing water to consumers in different ways, the difference results from several factors, these factors to local conditions and other considerations that may assume the designer. The methods used in the process of water distribution to consumers are:

❖ **Gravity System**

This system is appropriate when the supply of water such as reservoirs is located at some elevation above the served community. This is to make sure that sufficient pressure head is available to distribute water in the existing water network by gravity. This system is appropriate when the supply of water such as reservoirs is located at some elevation above the served community. This is to make sure that sufficient pressure head is available to distribute water in the existing water network by gravity. This method is commonly practiced in some areas where topography is suitable to construct an elevated reservoir that served the entire area mostly by gravity. This system allows some of the positive characteristics that are represented in the absence of the cost of operation and a waste of energy. In addition, to the low maintenance costs and not to change the sudden pressure compared to the system pumping, which will show in the next section, but this system is bounded by some of the problems and disadvantages that it is less flexible for the extension and future needs larger diameters due to the small slope available.

❖ **Pumping system**

This system used when the source of water is lower than the served area when we need to distribute water to consumers. The source cannot maintain minimum pressure required. This system is complicated in terms of operation and maintenance and dependent on reliable power supply.

➢ **Note**:

In some cases, it is used in the combined system of the distribution process and this works with reservoirs and pumping stations have a considerable volume provided for balancing of daily variation in consumption. With more or less storage, in this method the excess water pumped during periods of low consumption is stored in elevated tanks or reservoirs.

6.1.4 Type of system of the network

❖ **Branching system**

This system is designed to be feeding at each point in the pipe network from one direction, this is the most common since it is founding in the villages and developing communities. When development takes place, new branches flow that development Branching system, in which a branch reaches to dead end.

❖ **Circulation system**

This system is designed so that feed on each point in the network of two or more pipes that mean for a circulation system that covers the whole area under service. In this system there are no dead ends, this allowing maintenance without interrupting or shut of the system.

❖ **Radial system**

This system divided the served are into subareas, in the center of each subarea a water storage tank is placed.

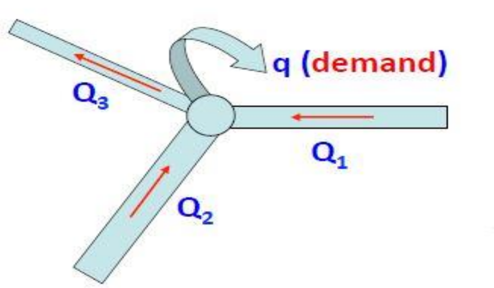
6.1.5 Analysis of Water Distribution Pipe Network

Pipe network problems are usually solved by numerical methods using a computer since any analytical solution requires the use of many simultaneous equations.

Flow in a water pipe network, satisfies two basic principles, conservation of mass at nodes and conservation of energy around the hydraulic loops.

➢ **Flow Continuity Equation**

Consider the junction J shown in figure where three pipes are interconnected and there is an outflow demand. The directions of flows Q_1, Q_2 are entering the junction **J,** while the directions of flows Q_3 are leaving the junction **J**. The mass balance equation for each node can be represented as:

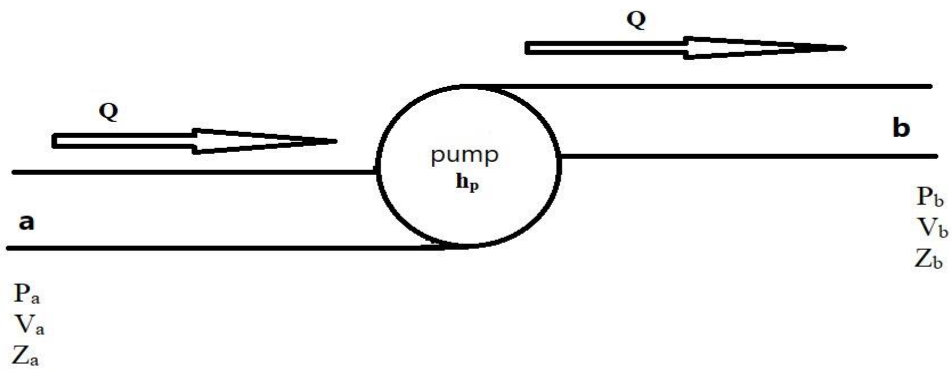


This means that at any junction or node "The sum of the inflows entering the junction equals to the sum of the outflows leaving the junction" and this is the Flow Continuity Equation:

$$\Sigma \text{ Inflow} = \Sigma \text{ outflow}$$

- **Energy Equation**

The second governing equation is a form of conservation of energy that describes the relationship between the energy loss and pipe flow.



Assume that the flow direction in the pipe is from junction (a) to (b) and its value is Q, the pressure and elevation head and the mean velocity at (a) are (**P_a, Z_a, V_a**) respectively, the pressure and elevation head and the mean velocity at (b) are (**P_b, Z_b, V_b**) respectively, the total friction and fitting head losses from (a) to (b) are **h_L**, the pump's head is **h_p**, all heads in are in meter. For this system:

$$P_a + Z_a + \frac{{V_a}^2}{2g} + h_p = P_b + Z_b + \frac{{V_b}^2}{2g} + h_L$$

Since the flow and pipe diameter are the same at junctions (a) and (b) thus the kinetic head at (a) equals the kinetic head at (b), the energy equation is reduced to:

$$[P_a + Z_a] – [P_b + Z_b] = h_L - h_p$$

- ✓ In other words, "the difference in hydraulic head between any two junctions within any pipe system equals to the net head losses between the junctions”.

6.2 Preparing Design "Design criteria"

6.2.1 General procedures of the network analysis

The distributing network is either designed new or recommends an improvement or rehabilitation to the existing network system. The general procedures of analyzing any pipe networks are:

1. The layout of the pipe network should be determined.
2. The characteristics of all the network components should be determined from the source to the area to be protected.
3. The two basic hydraulic equations are applied:-

    A) Flow Continuity Equation

    B) Energy Equation

6.2.2 Design criteria

In this project design criteria will be identified and the design criteria that have been identified by the visit of the site and the information that was taken from the Yasid municipality through the establishment of an effective network of water for the village and it will be to clarify the criteria as follows:

1. Gravity feed (reservoir high in the source) and determines the elevation of reservoir (total head).
2. Each node represents a group of houses to be served by the network and you are given the population size at the design period.
3. All nodes are given elevation according to topographic contours.
4. Minimum pressure head as we have mentioned previously according to the Palestinian Water Authority, the permitted range (20-100) meters and the Minimum and maximum velocity are (0.3 - 3) m/s.
5. Daily consumption per capita is equal (120 Liter).
6. Average number of person in each house is equal (7).
7. The number of population in year 2017 is (2482).
8. The design period is 30 years.
9. In this project will be used the type of material in pipeline is Ductile iron for main pipe.
10. The coefficient of Hazen Williams for type ductile iron is equal 140.

7. Design the Water Network

7.1 Introdution

Any water distribution system must be designed to adequately satisfy the water requirements. Since a future distribution, system is expected to provide effective services for many years and the future requirements such as future population, future per capita water demand rates.

7.2 Population prediction

P_{2017} =2483

P_{2022}=2732

P_n=P $(1+i)^n$

2732=2483 $(1+i)^5$

Growth rate (I) = 0.0193

P_{2023}=2784

P_{2053}=P_{2023} $(1+i)^n$

P_{2053}=2784 $(1+0.0193)^{30}$ = 4848 Person

Figure 25 Distribution of houses in Yasid village

7.3 Demand consumption

Demand consumption:

Table 14 Per capita consumption every 10 years

Year	Consumption L/C/D
2023	90
2033	100
2043	110
2053	120

Max. Demand per Capita in L/Day = 120

Total demand = 120 * 4848 =**581760 L/Day**

Min. Demand per Capita in L/Day = 35

Avg. Demand per Capita in L/Day = 77.5

Avg. demand = 77.5 * 4848 =**375720 L/Day**

Peak hourly factor = 1.5 (Max. daily demand / Avg. daily demand) [11]

Peak hourly factor = 1.5 (581760 / 375720) = **2.3**

Peak daily factor = 1

Peak demand = 2.3*1*581760 =**1338048 L/Day**

7.4 Location of the Reservoir

Reservoirs typically need to be situated at a sufficient height to maintain enough pressure in the downstream pipe network to enable the water to be raised up to the top of buildings. A service reservoir stores the water and supplies it at the required pressure to the farthest point in the area. The pressure in the water supply system depends upon the water level in the service reservoir. A water supply system needs to guarantee a minimum pressure even at the most remote point in the area. Therefore, it is essential that the hydraulic gradient line always be above the required pressure.

7.5 Quantities and Costs estimate

Total length of pipelines **= 13551 m**

Prices of pipelines are according to the diameter of pipelines

Prices of pipelines are per 1m

Excavation dimensions shown in (figure F-27)

Filling materials and their depths are shown in (figure F-27)

All costs in dollar$

All costs calculated from costs of present and past projects

Table 15 Resources used in the water network

Resources	Units	Price $	quantity / 1m	Total quantities
Excavation	m^3	7	0.42 m^3	5691.42 m^3
sand	m^3	27	0.18 m^3	2439.18 m^3
Agg.	m^3	18	0.24 m^3	3252.24 m^3
concrete	m^3	175	0.03 m^3	406.53 m^3
labor	$/m	27	1 m	365877 $
pipe	m	32	1 m	13551 m

Total direct cost for 1m = 76.43 $

Job overhead cost = 0.1 * 76.43 = 7.643 $

Operating overhead cost = 0.03 * (76.43 + 7.643) = 2.523 $

Total cost = 76.43 +7.643 + 2.523 = 86.595 $

Profit = 0.15 * 86.595 = 12.989 $

Total price of the 1m = 86.595 + 12.989 = 100 $ / m

Total price of the network = **1355100 $.**

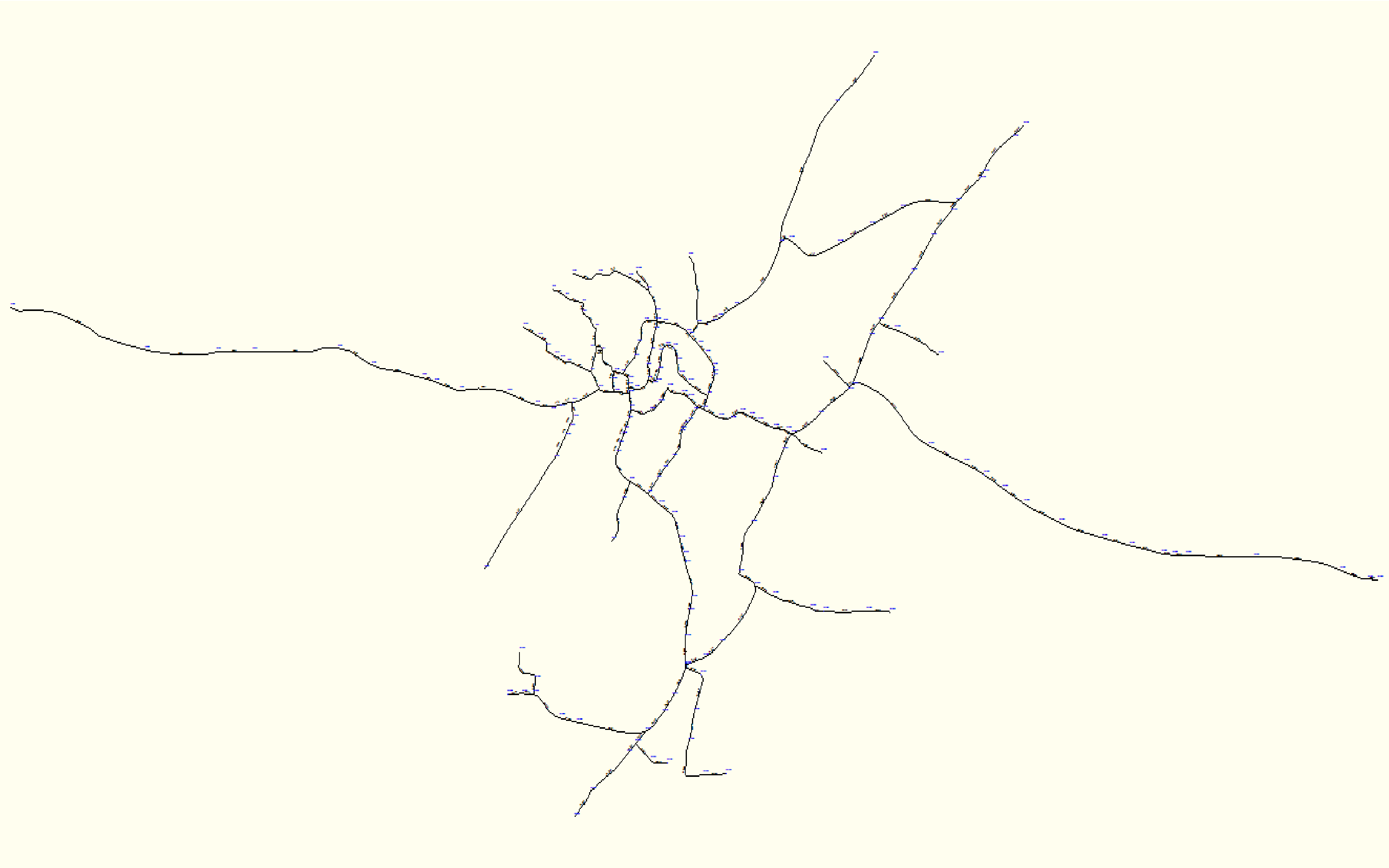


Figure 26 Water network in Yasid

In cross section Fig-27 we put a layer of sand to distribute loads on the pipeline

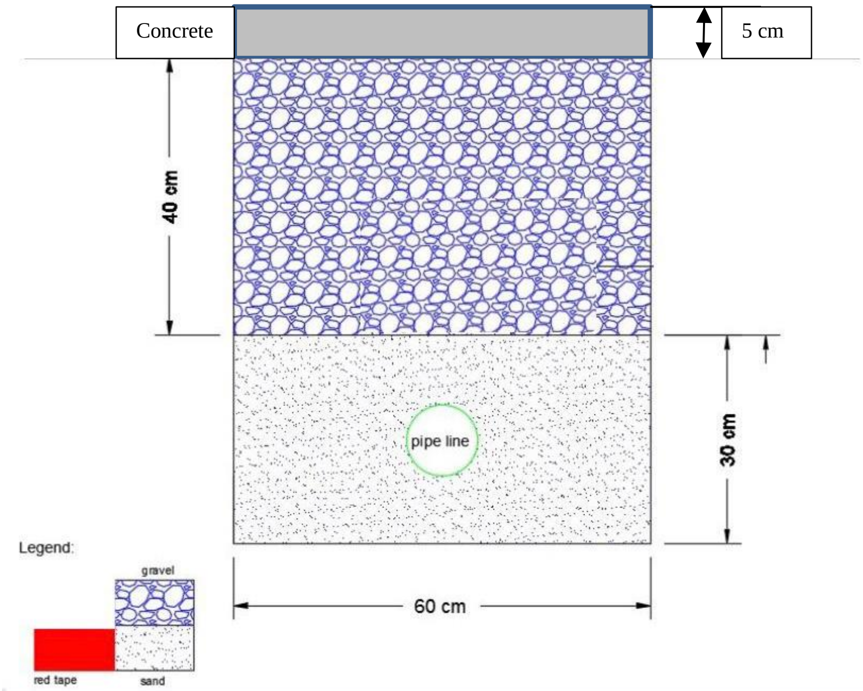


Figure 27 cross section of the tunnel

8. Conclusions and Recommendations

8.1 Conclusions

After completing the design of the water network in the village of Yasid, we can draw the following several conclusions.

The diameters of the pipes that were used in constructing the network may be affected by excessive pressure, so the best diameters that make the water distribution network work at the best rate were chosen.

The use of equal diameter (2", 3") which seems to lead to a suitable piping capacity for the water demand. It will be ideal if the future design of the water network meets the acceptable range of pressure and speed for each node, so that the network operates in it with maximum efficiency and serviceability as it is planned. The pressure head values at each node must be above 20 m, and the pipe velocities must also be within the limits (0.3 -3) m/s.

In this project, work was done on redesigning the network using WaterCAD to solve a number of problems that the network contained:

1. The network path was changed with a design that had many elbows, to reduce the loser values that were a big burden on the pump.
2. Prepaid meters were installed to solve the problem of Non-Revenue water, in addition to adding manholes on each main branch to read the amount of water entering and assist in maintenance work.

8.2 Recommendations

This village contains topographic differences, so we use pressure reducing valves in this village, in addition to taking urban expansion in areas higher than the level of the reservoir. It is recommended to use a pump to supply water to these areas or replace the current reservoir with a reservoir of a higher level.

Noticed that a few number of junction has a small velocity that lower than lower limit (0.3 m/s) that might because low demand in the junction that are joined with these pipes, although it still acceptable, but in future if the velocity become as obstacle this problem could be solved by using booster pumps to increase the velocity, but it’s very expensive solution compare with its benefits.

9. References

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10) https://www.scribd.com/document/420107807/Hazen-Williams-Pipe-Coefficient-Value

11) https://byjus.com/question-answer/the-ratio-between-peak-hourly-water-demand-and-maximum-daily-demand-per-hour-of-course/

Appendix

Label	Length (Scaled) (m)	Material	Diameter (in)	Hazen-Williams C	Flow (m³/day)	Velocity (m/s)
P-1	26	Ductile Iron	3	140	303.739	0.77
P-2	45	Ductile Iron	2	140	15.079	0.09
P-4	51	Ductile Iron	2	140	14.316	0.08
P-5	24	Ductile Iron	2	140	13.819	0.08
P-6	53	Ductile Iron	2	140	13.38	0.08
P-7	43	Ductile Iron	2	140	12.873	0.07
P-8	62	Ductile Iron	3	140	288.317	0.73
P-9	71	Ductile Iron	2	140	9.331	0.05
P-10	22	Ductile Iron	2	140	8.803	0.05
P-11	18	Ductile Iron	2	140	8.523	0.05
P-12	36	Ductile Iron	2	140	8.122	0.05
P-13	38	Ductile Iron	2	140	7.538	0.04
P-14	48	Ductile Iron	2	140	6.913	0.04
P-15	46	Ductile Iron	3	140	278.531	0.71
P-16	83	Ductile Iron	3	140	179.28	0.46
P-17	35	Ductile Iron	3	140	150.735	0.38
P-18	19	Ductile Iron	3	140	150.476	0.38
P-19	55	Ductile Iron	3	140	150.04	0.38
P-20	86	Ductile Iron	3	140	148.653	0.38
P-21	141	Ductile Iron	3	140	145.532	0.37
P-22	76	Ductile Iron	3	140	140.422	0.36
P-23	37	Ductile Iron	3	140	137.21	0.35
P-24	151	Ductile Iron	3	140	130.093	0.33
P-25	108	Ductile Iron	3	140	117.173	0.3
P-26	249	Ductile Iron	3	140	85.585	0.22
P-27	106	Ductile Iron	3	140	64.979	0.16
P-28	208	Ductile Iron	3	140	48.1	0.12
P-29	409	Ductile Iron	2	140	22.236	0.13
P-30	40	Ductile Iron	3	140	28.1	0.07
P-31	25	Ductile Iron	3	140	27.612	0.07
P-32	22	Ductile Iron	3	140	27.308	0.07
P-33	61	Ductile Iron	3	140	26.619	0.15
P-34	69	Ductile Iron	3	140	405.843	1.03
P-35	25	Ductile Iron	3	140	280.801	0.71
P-36	52	Ductile Iron	3	140	127.783	0.32
P-37	34	Ductile Iron	3	140	127.494	0.32
P-38	60	Ductile Iron	3	140	127.037	0.32
P-39	35	Ductile Iron	3	140	126.47	0.32
P-40	21	Ductile Iron	3	140	26.041	0.15
P-41	59	Ductile Iron	3	140	25.615	0.15
P-43	62	Ductile Iron	2	140	19.579	0.11

P-45	96	Ductile Iron	2	140	18.816	0.11
P-46	83	Ductile Iron	2	140	14.339	0.08
P-47	20	Ductile Iron	3	140	155.045	0.39
P-48	77	Ductile Iron	3	140	154.644	0.39
P-49	5	Ductile Iron	3	140	154.399	0.39
P-50	35	Ductile Iron	3	140	154.018	0.39
P-51	165	Ductile Iron	2	140	11.352	0.06
P-52	47	Ductile Iron	3	140	142.017	0.36
P-53	18	Ductile Iron	3	140	141.572	0.36
P-54	55	Ductile Iron	3	140	140.896	0.36
P-55	203	Ductile Iron	3	140	137.341	0.35
P-56	373	Ductile Iron	2	140	24.852	0.14
P-57	159	Ductile Iron	2	140	13.156	0.08
P-62	11	Ductile Iron	2	140	1.465-	0.01
P-63	45	Ductile Iron	2	140	1.838	0.01
P-64	35	Ductile Iron	3	140	92.655	0.24
P-65	18	Ductile Iron	3	140	81.697	0.21
P-66	44	Ductile Iron	3	140	23.459	0.06
P-67	16	Ductile Iron	3	140	23.127	0.06
P-68	12	Ductile Iron	3	140	22.978	0.06
P-69	9	Ductile Iron	3	140	22.852	0.06
P-70	64	Ductile Iron	3	140	22.25	0.06
P-71	38	Ductile Iron	3	140	20.95	0.12
P-72	31	Ductile Iron	3	140	20.362	0.12
P-73	44	Ductile Iron	2	140	19.963	0.11
P-74	61	Ductile Iron	3	140	104.885	0.27
P-75	51	Ductile Iron	2	140	8.731	0.05
P-76	105	Ductile Iron	2	140	7.243	0.04
P-77	84	Ductile Iron	3	140	114.248	0.29
P-78	21	Ductile Iron	3	140	115.294	0.29
P-79	25	Ductile Iron	3	140	115.679	0.29
P-80	14	Ductile Iron	3	140	116.024	0.29
P-81	27	Ductile Iron	3	140	116.358-	0.3
P-82	26	Ductile Iron	3	140	116.644	0.3
P-83	38	Ductile Iron	3	140	223.700	0.57
P-84	42	Ductile Iron	3	140	223.048	0.57
P-85	48	Ductile Iron	3	140	98.720-	0.25
P-86	19	Ductile Iron	3	140	124.82	0.32
P-87	32	Ductile Iron	3	140	124.674	0.32
P-88	331	Ductile Iron	2	140	21.487	0.12
P-89	22	Ductile Iron	3	140	152.875	0.39
P-90	19	Ductile Iron	3	140	152.749	0.39
P-91	12	Ductile Iron	2	140	0.757	0

P-92	17	Ductile Iron	3	140	151.932	0.39
P-93	49	Ductile Iron	3	140	151.762	0.39
P-94	36	Ductile Iron	3	140	55.226	0.14
P-95	38	Ductile Iron	3	140	55.057	0.14
P-96	50	Ductile Iron	3	140	54.866	0.14
P-97	24	Ductile Iron	3	140	54.688	0.14
P-98	15	Ductile Iron	3	140	96.386	0.24
P-99	8	Ductile Iron	3	140	96.308	0.24
P-100	25	Ductile Iron	3	140	96.218	0.24
P-101	53	Ductile Iron	3	140	96.018	0.24
P-102	20	Ductile Iron	3	140	95.862	0.24
P-103	17	Ductile Iron	3	140	95.731	0.24
P-104	32	Ductile Iron	3	140	95.564	0.24
P-105	35	Ductile Iron	3	140	95.301	0.24
P-106	33	Ductile Iron	3	140	95.091	0.24
P-107	63	Ductile Iron	3	140	94.81	0.24
P-108	61	Ductile Iron	3	140	106.819	0.27
P-109	33	Ductile Iron	3	140	106.248	0.27
P-110	47	Ductile Iron	3	140	105.896	0.27
P-111	48	Ductile Iron	3	140	105.672	0.27
P-112	22	Ductile Iron	3	140	105.454	0.27
P-113	32	Ductile Iron	3	140	105.287	0.27
P-114	40	Ductile Iron	3	140	124.432	0.32
P-115	45	Ductile Iron	3	140	123.766	0.31
P-116	62	Ductile Iron	3	140	122.408	0.31
P-117	40	Ductile Iron	3	140	121.132	0.31
P-118	20	Ductile Iron	3	140	120.365	0.31
P-119	87	Ductile Iron	3	140	119.052	0.3
P-120	30	Ductile Iron	3	140	117.934	0.3
P-121	62	Ductile Iron	3	140	116.617	0.3
P-122	63	Ductile Iron	3	140	114.45	0.29
P-123	6	Ductile Iron	3	140	69.071	0.18
P-124	79	Ductile Iron	3	140	45.828	0.12
P-125	47	Ductile Iron	3	140	44.405	0.11
P-126	66	Ductile Iron	3	140	43.235	0.11
P-127	42	Ductile Iron	2	140	16.22	0.09
P-128	34	Ductile Iron	2	140	12.417	0.07
P-129	138	Ductile Iron	2	140	11.001	0.06
P-130	77	Ductile Iron	2	140	8.033	0.05
P-131	202	Ductile Iron	3	140	25.783	0.15
P-132	52	Ductile Iron	2	140	22.195	0.13
P-133	95	Ductile Iron	2	140	19.735	0.11
P-134	34	Ductile Iron	2	140	11.976	0.07

P-135	42	Ductile Iron	2	140	11.288	0.06
P-136	35	Ductile Iron	2	140	7.113	0.04
P-137	102	Ductile Iron	2	140	4.92	0.03
P-138	60	Ductile Iron	2	140	3.193	0.02
P-139	48	Ductile Iron	2	140	1.66	0.01
P-140	48	Ductile Iron	2	140	22.872	0.13
P-141	95	Ductile Iron	2	140	21.618	0.12
P-142	71	Ductile Iron	2	140	20.063	0.11
P-143	134	Ductile Iron	2	140	19.1	0.11
P-144	67	Ductile Iron	2	140	16.018	0.09
P-145	60	Ductile Iron	2	140	5.215	0.03
P-146	55	Ductile Iron	3	140	44.816	0.11
P-147	59	Ductile Iron	3	140	44.378	0.11
P-148	173	Ductile Iron	3	140	40.933	0.1
P-149	58	Ductile Iron	3	140	29.669	0.08
P-150	113	Ductile Iron	3	140	27.053	0.15
P-151	39	Ductile Iron	2	140	23.33	0.13
P-152	125	Ductile Iron	2	140	18.1	0.1
P-153	68	Ductile Iron	2	140	11.627	0.07
P-154	58	Ductile Iron	2	140	10.092	0.06
P-155	126	Ductile Iron	2	140	8.413	0.05
P-156	120	Ductile Iron	2	140	4.945	0.03
P-157	75	Ductile Iron	2	140	2.075	0.01
P-158	48	Ductile Iron	2	140	1.318	0.01
P-159	98	Ductile Iron	2	140	5.233	0.03
P-160	49	Ductile Iron	3	140	174.137	0.44
P-161	37	Ductile Iron	3	140	173.123	0.44
P-162	28	Ductile Iron	3	140	172.396	0.44
P-163	30	Ductile Iron	3	140	171.706	0.44
P-164	27	Ductile Iron	3	140	170.905	0.43
P-165	48	Ductile Iron	3	140	169.964	0.43
P-166	37	Ductile Iron	3	140	169.254	0.43
P-167	18	Ductile Iron	3	140	168.752	0.43
P-168	91	Ductile Iron	3	140	164.379	0.42
P-169	111	Ductile Iron	3	140	162.861	0.41
P-170	99	Ductile Iron	2	140	4.07	0.02
P-171	11	Ductile Iron	3	140	157.447	0.4
P-172	121	Ductile Iron	2	140	15.258	0.09
P-173	45	Ductile Iron	2	140	16.934	0.1
P-174	52	Ductile Iron	2	140	13.952	0.08
P-175	141	Ductile Iron	2	140	12.127	0.07
P-176	152	Ductile Iron	3	140	32.387	0.08
P-177	99	Ductile Iron	3	140	35.215	0.09

P-178	87	Ductile Iron	3	140	37.795-	0.1
P-179	25	Ductile Iron	3	140	40.476	0.1
P-180	90	Ductile Iron	3	140	49.669	0.13
P-181	13	Ductile Iron	3	140	43.446	0.11
P-182	121	Ductile Iron	3	140	39.624	0.1
P-183	45	Ductile Iron	3	140	33.923	0.09
P-184	163	Ductile Iron	3	140	92.367	0.23
P-185	99	Ductile Iron	3	140	96.363	0.24
P-186	103	Ductile Iron	3	140	99.309	0.25
P-187	158	Ductile Iron	3	140	103.099	0.26
P-188	33	Ductile Iron	3	140	106.904	0.27
P-189	275	Ductile Iron	3	140	170.858	0.43
P-190	112	Ductile Iron	3	140	164.302	0.42
P-191	63	Ductile Iron	3	140	160.46	0.41
P-192	63	Ductile Iron	3	140	156.74	0.4
P-193	72	Ductile Iron	3	140	151.822	0.39
P-194	112	Ductile Iron	3	140	144.945	0.37
P-195	130	Ductile Iron	3	140	135.779	0.34
P-196	81	Ductile Iron	3	140	126.755	0.32
P-197	95	Ductile Iron	3	140	118.53	0.3
P-198	32	Ductile Iron	3	140	114.078	0.29

Label	Demand (m^3/day)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	0.419	703.74	14.6
J-2	0.344	703.51	15.7
J-3	0.763	703.5	15.2
J-4	0.497	703.5	16.7
J-5	0.439	703.5	18.5
J-6	0.507	703.5	18.5
J-7	12.873	703.5	21.7
J-8	0.455	703	17.3
J-9	0.528	703	21
J-10	0.28	703	21.7
J-11	0.401	703	22.1
J-12	0.584	703	22.7
J-13	0.625	703	21.1
J-14	6.913	703	18
J-15	0.531	702.64	19.5
J-16	0.446	702.36	23.9
J-17	0.259	702.28	27.6
J-18	0.436	702.23	29.5
J-19	1.387	702.09	35
J-20	3.121	701.89	42
J-21	5.11	701.56	49.5
J-22	3.212	701.4	50.9
J-23	7.118	701.32	52.9
J-24	12.92	701.04	65.7
J-25	31.588	700.88	73.1
J-26	20.606	700.66	82.6
J-27	16.879	700.61	86.8
J-28	25.863	700.55	96.3
J-29	22.236	700.52	117.9
J-30	0.488	702.36	25.5
J-31	0.304	702.35	27.7
J-32	0.689	702.35	29.9
J-33	5.132	702.35	35.5
J-34	0.222	702.68	13.1
J-35	0.142	702.48	13.2
J-36	0.289	702.39	15
J-37	0.457	702.32	17
J-38	0.567	702.22	24
J-39	0.071	702.15	28.6
J-40	0.426	702.15	30.6
J-41	0.821	702.15	32
J-42	0.763	702.14	30.2

J-44	4.477	702.14	27
J-45	14.339	702.13	22.4
J-46	0.401	702.1	32.3
J-47	0.245	701.9	42.5
J-48	0.123	701.89	42.7
J-49	0.65	701.8	50.9
J-50	11.352	701.79	71.4
J-51	0.445	701.69	61
J-52	0.676	701.65	64.1
J-53	3.555	701.53	73.5
J-54	5.585	701.11	70.5
J-55	11.697	701.08	30.9
J-56	13.156	701.07	14.9
J-57	0.282	701.89	45.6
J-58	0.386	701.89	46.5
J-59	0.725	701.89	46
J-60	0.331	701.89	44.8
J-61	0.373	701.89	43.3
J-62	0.316	701.89	38
J-63	0.216	701.85	35.7
J-64	0.131	701.86	34
J-65	0.332	701.86	31.1
J-66	0.149	701.86	29.9
J-67	0.125	701.86	29.6
J-68	0.603	701.86	29.8
J-69	1.299	701.85	33.4
J-70	0.588	701.84	35.3
J-71	0.4	701.84	36.1
J-72	0.416	701.84	38.8
J-73	0.632	701.91	35.6
J-74	1.489	701.91	40.6
J-75	7.243	701.91	52.7
J-76	1.046	702.03	29.8
J-77	0.385	702.05	27.7
J-78	0.345	702.09	25.7
J-79	0.334	702.11	24.7
J-80	0.286	702.15	22.6
J-81	0.237	702.19	20.5
J-82	0.105	702.38	17.2
J-83	0.346	702.59	17
J-84	0.146	702.64	14.9
J-85	21.487	702.32	57.2
J-86	0.126	702.43	14.6

J-87	0.06	702.38	16.2
J-88	0.171	702.33	16.8
J-89	0.15	702.21	18.6
J-90	0.169	702.2	18
J-91	0.191	702.18	20.6
J-92	0.178	702.16	25.9
J-93	0.078	702.19	19.8
J-94	0.09	702.18	20.4
J-95	0.2	702.16	21.4
J-96	0.157	702.1	26.8
J-97	0.131	702.08	31.1
J-98	0.166	702.06	32.5
J-99	0.263	702.03	30.9
J-100	0.211	701.99	29.6
J-101	0.281	701.95	32.3
J-102	0.572	702.1	21.3
J-103	0.352	702.06	21.5
J-104	0.224	702	23
J-105	0.218	701.94	27.8
J-106	0.167	701.91	30.4
J-107	0.665	701.77	41.9
J-108	1.358	701.69	44.7
J-109	1.276	701.58	49.7
J-110	0.767	701.51	53.2
J-111	1.313	701.48	54.9
J-112	1.118	701.34	62
J-113	1.317	701.29	64.4
J-114	2.168	701.19	69.6
J-115	0.562	701.09	73.9
J-116	0.371	701.09	74.3
J-117	1.424	701.07	80.7
J-118	1.169	701.06	83.4
J-119	1.232	701.04	87.7
J-120	0.61	701.04	89.1
J-121	1.415	701.04	90.6
J-122	2.968	701.04	95.5
J-123	8.033	701.03	99.5
J-124	3.588	701.02	101.9
J-125	2.459	701	104.9
J-126	0.647	700.96	107.4
J-127	0.688	700.8	110.2
J-128	11.288	700.61	111.4
J-129	2.193	700.89	101.9

J-130	4.92	700.8	88
J-131	1.534	701.04	89.1
J-132	1.66	701.04	89.3
J-133	1.253	701.09	74.1
J-134	1.555	701.08	81.8
J-135	0.964	701.08	86.6
J-136	3.082	701.07	94
J-137	16.018	701.07	94.2
J-138	5.215	702.15	34.6
J-139	0.438	701.08	70.6
J-140	3.445	701.06	67.5
J-141	1.172	701.02	65.1
J-142	2.615	701.01	70.6
J-143	3.723	701	79.4
J-144	5.23	701	82.6
J-145	6.473	700.99	93.6
J-146	11.627	700.99	96.4
J-147	1.679	701.02	62.3
J-148	3.468	701.02	61.5
J-149	2.87	701.02	57.6
J-150	0.758	701.02	59.7
J-151	0.458	701.02	62.7
J-152	5.233	701.02	69.7
J-153	1.013	701.7	39.7
J-154	0.727	701.58	43.4
J-155	0.69	701.49	47.4
J-156	0.801	701.4	51.3
J-157	0.941	701.32	54.3
J-158	0.71	701.18	58.9
J-159	0.502	701.07	61.5
J-160	1.518	700.76	70.2
J-161	1.344	700.44	79.5
J-162	4.07	700.44	74.9
J-163	1.847	700.41	79.4
J-164	1.676	700.42	72.2
J-165	1.502	700.42	68.7
J-166	1.825	700.41	72.3
J-167	12.127	700.39	71.6
J-168	2.827	700.44	58.2
J-169	2.58	700.46	49.1
J-170	2.682	700.48	41.5
J-171	2.221	700.48	39.2
J-172	6.223	700.45	35.7

J-173	3.822	700.45	35.9
J-174	5.702	700.43	33.4
J-175	33.923	700.42	33.1
J-176	3.997	700.65	58.5
J-177	2.946	700.75	63.5
J-178	3.789	700.87	68.4
J-179	3.805	701.07	68.9
J-180	6.555	699.56	104.4
J-181	3.843	699.24	111
J-182	3.72	699.06	112.1
J-183	4.918	698.9	115.6
J-184	6.878	698.71	119.7
J-185	9.166	578.4	6.9
J-186	9.024	578.14	13.5
J-187	8.225	577.99	17.8
J-188	4.452	577.84	22.9
J-189	2.188	577.8	24.2
J-190	12.559	577.74	26.5
J-191	30.479	577.52	46.2
J-192	21.644	577.37	74.8
J-193	4.255	577.35	85.1
J-194	42.952	577.3	89