An-Najah National University

Faculty of Engineering and Information Technology

جامعة النجاح الوطنية

كلية الهندسة و تكنولوجيا المعلومات

Graduation Project Report 2

Design of a water distribution network for an unserved area in Jenin City

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DEDICATION

نهدي هذا النجاح إلى من أشعل أول شمعة في قنديل نجاحنا ، إلى ملجأنا و ملاذنا بعد الله ، إلى من تحمل كل لحظة ألم في حياتنا ، و حولها إلى لحظات فرح ، إلى من ساندنا يوم ضعفنا ، و سهر الليل من أجلنا ، و دعا لنا وقت حاجتنا و غير حاجتنا ، إلى من نسي نفسه و تذكرنا ، إلى من ذرف الدموع من أجلنا ، إلى من سقانا الحب في صغرنا حتى ارتوت منه عروق جسدنا ، إلى من ارتحلت لهم روحنا تعانق روحهم الطاهرة العذبة النقية.

إلى آبائنا و أمهاتنا الغاليين ، الذين سهروا الليالي حتى نصل إلى هذا اليوم وهم فخورين بنا. كتبنا و نكتب و سنكتب لكم ونحن نعلم أن كتاباتنا إختراقٌ غير مأمون المشاعر لتفاصيلكم الرائعة ، و لذاتكم الملائكية ، و لروحكم النقية ، و لعمركم النازف بكل حب و عطاء. أدام الله عليكم الصحة والعافية.

كما نشكر نجوم سمائنا المتلألئة ، و سندنا في حياتنا – إلى إخوتنا و أخواتنا يعجز اللسان عن وصف شخصكم الرائع و روحكم الزكية ، دمتم لنا سنداً و نجوماً في حياتنا.

كما و نشكر أصدقائنا الذين كانوا سنداً في حلو و مر الأيام. نقف اليوم و نفتخر أنكم جزء من أيامنا ، شكراً لكم إخوتنا و أصدقائنا.

كما و نشكر كل شخص كان له دور في نجاحنا ، و كل شخص دعا لنا في ظهر الغيب ، دامت المحبة بيننا ، و حفظكم الله من كل سوء.

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{ قُلْ هَلْ يَسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لَا يَعْلَمُونَ}

الحمد لله رب العالمين حمدًا لشُكرهِ أداءً ولحقهِ قضاءً، ولِحُبهِ رجاءً ولفضلهِ نماءً ولثوابهِ عطاءً.

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إلى جميع زملائنا و عائلتنا الكبيرة في قسم الهندسة المدنية لكم منا كل الشكر على مشاركة سنوات الدراسة المرهقة و الممتعة كذلك. شكراً إلى الأخ قسم الهندسة في بلدية جنين على تقديم الدعم المعنوي و كامل المعلومات اللازمة لاستمرار المشروع دون تقصير. إلى الدكتور محمد نهاد المصري لك منا كل الشكر على التعاون في توفير كافة المعلومات في أسرع وقت و أفضل جودة.

إلى من مر بحياتنا و لم يكن مجرد عابر , كل الشكر من القلب على كل شيء كل الشكر على الوقوف بجانبنا في الظروف الصعبة شكراً على توجيهاتكم. على أمل تحقيق المشروع على أرض الواقع بإذن الله.

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WDN: water distribution network.

GIS: geographic information system

Eps: Extended Period Simulation

Abstract:

Water is important for life. without water we cannot perform the main vital functions. and in order to perform the main vital functions, water must be consumed. and in order for us to consume water, it must arrive from its source to us. there must be a properly designed and implemented water distribution network.

In this project, the water distribution network of Al-Kahlishah will be design. Al-Kahlishah area is located 5 Km from the center of Jenin. the total surface area is about 780 Dunum It rises around 250 m above mean sea level.

Because of the lack of a water distribution network, the residents of the area resorted to other sources to obtain drinking water, which increases the cost of water for the people of the area. in addition to the lack of other sources permanently.

Based on the above, we designed a water distribution network for the Al-Kahlishah area by pumping water from a well belonging to the Municipality of Jenin, sufficient to meet the needs of the residents of the area.

We visited the Al-Kahlisha area, collected information, and conducted interviews with the residents of the area to find out the water needs of individuals and to see the nature and topography of the area.

After that, we inserted the area maps and contour lines into the (GIS) program to obtain the shape of the existing and proposed streets in order to know the initial shape of the network.

We entered this information into the (WaterCAD) program to calculate the appropriate diameters and pumps to design the network work at the best efficiency.

Chapter one
Introduction

1.1. Background:

Water is a needed for all living things, from the most basic to the most sophisticated, like humans. Our everyday lives depend on water. Living on earth is impossible without water.

قال تعالى: ((وَجَعلَنَا مِنَ الْمَاء كُلَّ شَيْءٍ حَيٍ أفلا يؤمنون)) سورة الأنبياء آية 30

Hence, everyone has the right to have enough, and good quality water to meet their own need to have a normal basic life

The water distribution network in cities generally consists of three types of pipes according to their function: transmission lines that transport water from the main collection tanks (or purification plant) to the distribution system, and distribution mains that transport water through transmission pipes and distribute it in throughout the city, and service pipes branching from the distribution pipes and transporting water from them to consumption sites such as buildings, industrial facilities, and others.

Residents who live in areas deprived of a water distribution network suffer from difficulty in obtaining water. They use secondary sources in order to obtain water, such as distribution tanks on homes or rainwater collection wells, which increases the cost of obtaining water, which is one of the highest human rights

In this project, we designed a water distribution network for the Al-Kahlisha area, which has an area of about 780 dunums, where the residents of that area suffer from the lack of a water distribution network and resort to other ways in order to obtain water, which constitutes an additional burden on the residents of the area and additional costs to obtain water, which is the basis of life.

1.2. Objectives:

The objectives of this graduation project are:

1. To determine the water demand for Al-Kahlisha area.
2. Design of a water distribution network for the Al-Kalisha area.

1.3. Methodology:

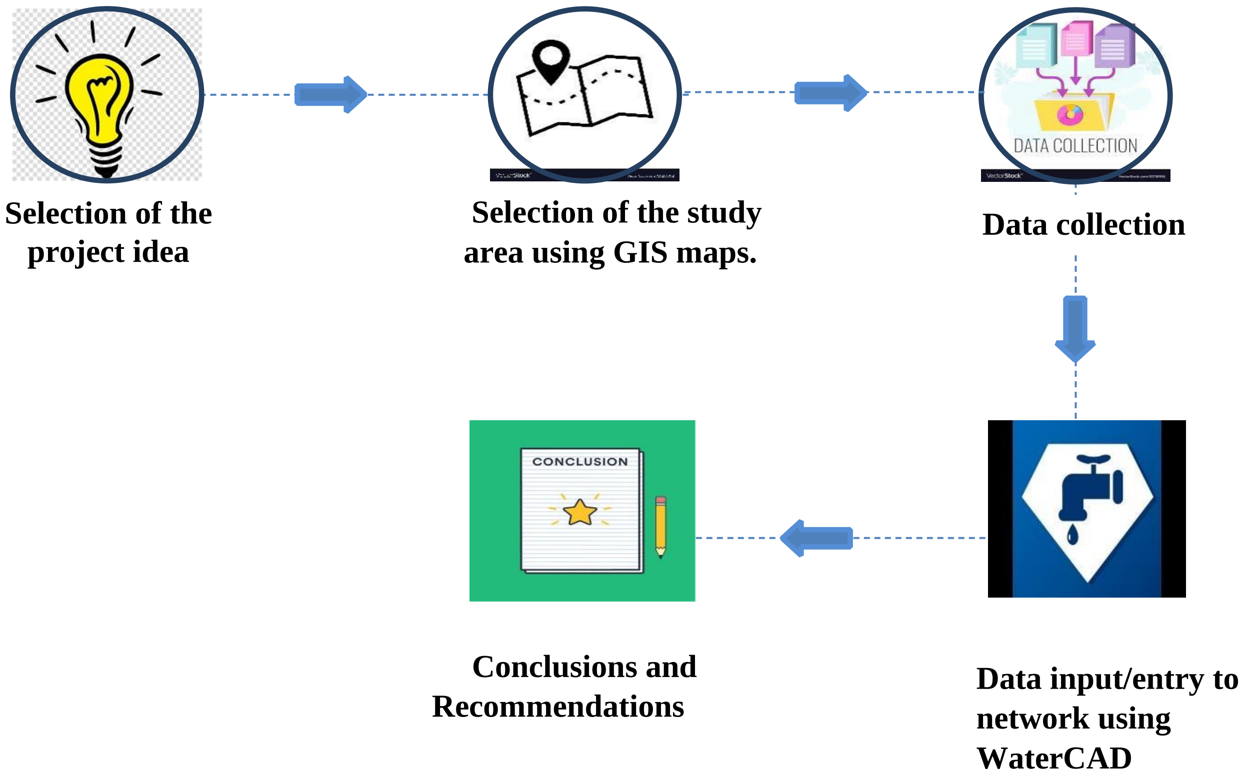

Figure 1.1: Representation of Methodology .

1.3.1 Selection of the project idea:

The idea of this project is based on providing a service that is not currently available to resident. by providing all information, designs and drawings for a new network for distributing potable water and providing everything necessary for the implementation party, which is mostly the Municipality of Jenin.

1.3.2 Selection of the study area:

Al-Kahlisha area is not have WDN and the people living in this area used another way to get water because it is a new residential area, residents have recently come to it and use primitive water WDN. This increases the cost to get the water and not be avalible at any time. Therefore, it was selected to analyze and design the water distribution network.

1.3.3 Data collection:

The data in this project was collected with the help of :

- Engineers and crews of the water department in Jenin Municipality
- Ministry of Local Government
- A field visits to the project site
- Geomolg online website

We collected information about the water sources in Jenin as well as the water consumption rate from Jenin municipality. We obtained from the Palestinian Central Census the population in the studied area as well as the rate of personnel in the Palestinian family. We extracted from the Geomolg the shapefiles of the area. We identified the coordinates of the reservoir in the space and information about the wells and water consumption in the area through field visits and asking questions to the residents of the area.

1.3.4 Data input/entry to network using WaterCAD :

We designed a water distribution network that will serve the area for the largest expected number of residents in the future by pumping water from an underground well that meets the needs of the residents of that area. Design will be in accordance with the required standards and constraints in terms of pressure, velocity and use of suitable diameter for pipes.

Chapter two

Description of the study area

2.1 Location and Topography:

Al-Kahlisha is a Palestinian small area located in the West Bank, It is located 5 Km south of Jenin City. The total area of Al-Kahlisha is about 0.781 Km^2. It is bounded by Qabatia from east. The area lies between 200m to 300 m above mean sea level.

Figure 2.1: Location of Al-Kahlisha with refernces to neighboring villages

2.2 Climate:

Climate of Al-Kahlisha area is similar to surrounding towns, and this is due to the great similarity in the environmental and natural terrain between them. Moderate climate, rainy in winter, while hot and dry in summer.

The annual average temperature in summer is 32 C° and 3 C° in winter. The mean rainfall in the town is around 370 mm.

2.3 Land use:

The patterns of land use in the area of Kahlisha are classified into different categories, Palestinian urban areas, forest sites and agricultural areas, where these lands are planted with olive trees.

2.4 Population:

According to Palestinian central bureau of statistics , and according to the data of Jenin Municipality the total population in Al-Kahlisha was 450 capita in 2023. Most of the Resident are employed in several fields, while others work in trade and self-employment.

We calculated the expected future population for this region. Where we calculated the surveyed area to be built on, which is equal to about 51,600 square meters, and we assumed that the area of each residential unit is equal to 1000 square meters, and each residential unit consists of two apartments, and we assumed that the number of floors allowed to be built is four floors (according to the classifications of the municipality), and we assumed that the number of people The family is five members (according to the Palestinian census data).

We calculated the number of residents as the largest possible number that could live in this area in order to obtain the largest diameter of pipes in a way that would serve the area if the population number reached this number. and as a result:

Total residential area(m2)= 516000

Assume every residential units = 1000(m2)

Then: total number of residential units = 516000/1000 = 516 units

↓

total number of floors = 516* 4 =2064 floors

↓

total number of apartment = 2064* 2 = 4128 apartments (families)

↓

total number of persons = 4128 * 5 = 20640 persons

Chapter three Design of The Water Distribution Network

3.1 Water Resources:

Water in Al-Kahlisha area supplied to people is from private (Alawneh well) underground water well. And the other source is collection house wells.

3.2 Water Tank:

The area contains one main tank made of steel structure in addition to three tanks supplying the main tank, with a total capacity of 150 m^3. It is the main water resource in the area, where water is pumped from a groundwater well to reservoirs for subsequent distribution to the water network. Located on a mountain with an altitude of 260 meters above sea level.

3.3 Water demand:

Water demand can be defined as the amount of water needed by the people serving this network. To estimate the expected number to the maximum capacity population of the area which equals 20640 capita.

To estimate the per capita consumption rate, we visited the Municipality of Jenin to find out the statistics of water consumption of the residents of that area, and we adopted the consumption rate of 100 liters per capita per day.

3.4 Design of the Network using WaterCAD:

The world is now going through a technological revolution in both everyday life and engineering. Programs relating to water work have made significant progress. WaterCAD is an engineering program that streamlines the analysis and design of a water network so that everyone in the field of water engineering uses it or a program very much like it. The engineer can create a network model and place it in the proper location using the network's coordinates. He can then input data into the program, run the model, and watch as issues, descriptions, and results of the network materialize.

3.4.1 Capabilities of WaterCAD:

1) WaterCAD can import files from other programs such as GIS and AutoCAD.
2) Draw grid quickly and easily to save time.
3) Make an exchange such as deleting or adding to the network.
4) WaterCAD can show errors in the model then it can be edited.

3.4.2 Equations Used in WaterCAD:

1) Darcy-Weisbach equation:

Darcy-Weisbach equation concern with head loss, which is results from friction along the length of the pipe and its relation with velocity and diameter.

$$hf = f\ \frac{LV^2}{D\ 2g}$$

Where:

h_f: Head loss (m)
F: coefficient of friction.

L: tube length (m).

D: The diameter of the tube (m).

V: velocity (m / s).

g: gravitational acceleration = 9.81 m/s^2

2) Hazen - William Equation:

It is an empirical formula, which relates the flow of water in a pipe with the physical properties of the pipe and the pressure drop caused by friction.

$$hf = K\frac{Q^{1.852}}{(Chw^{1.852})*(D^{4.87})}\ L$$

h_f: Head loss (m).
L: pipe length (m).
D: pipe diameter (m).
C_{hw}: Hazen - william coefficient.
Q: the flow rate (m^3 /s).
K: 10.685 for SI units and 1.21 * 10^{10} for Q in L / s & D in mm.

3) Energy equation:

The main principle that the whole work build in.

$$\left(\frac{P1}{\gamma}\right)+\left(\frac{V1^2}{2g}\right)+Z1+hp=\left(\frac{P2}{\gamma}\right)+\left(\frac{V2^2}{2g}\right)+Z2+h_L$$

There is conservation energy between any two points in the system where:

P: Water pressure (KPa).

γ: Specific weight of water 9810 (N / m).

V: Velocity of water (m/s).

g: Acceleration due to gravity 9.81 (m/s^2).

Z: Elevation (m) hp: Head of pump (m).

h1: Head loss due to friction and local losses (m).

4) Continuity equation:

The algebraic sum of flow rates in the pipes that meet at a node together with any external flows is zero

Q1 + Q2 = Q3 + demand.

Where:

Q is the flow in the tubes (m^3/s).

Figure 3.1 illustrates the concept of the continuity equation.

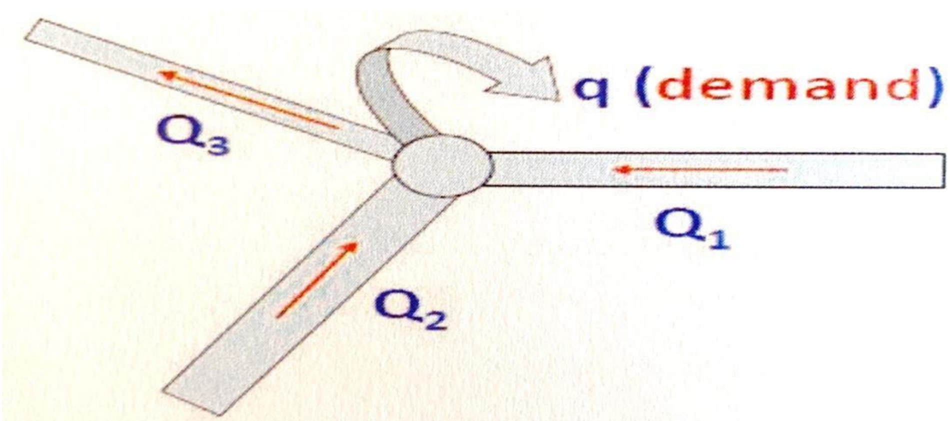

Figure3.1 : Continuity at node

5) Energy conservation:

For all paths around closed loops the accumulated energy loss including minor losses minus any energy gain or heads generated by pumps must be zero. Figure 3.2 shows the concept of the head loss in a loop.

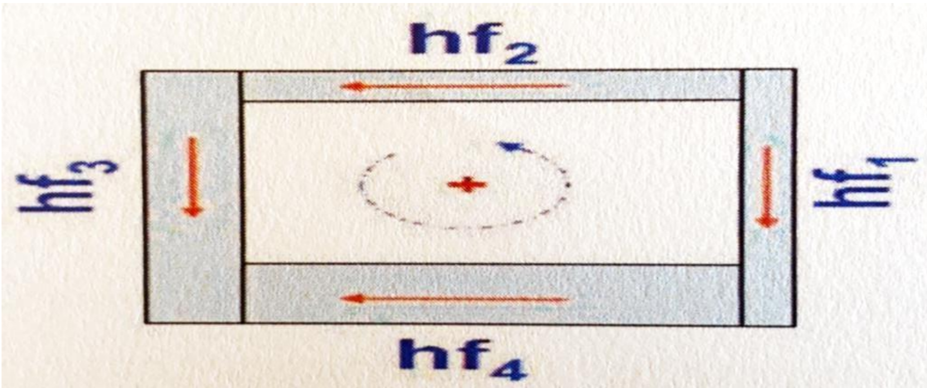

Figure3.2 : head loss in a loop

So, if we apply energy conservation principle we will obtain this: - hf1 - hf4 + hf3 + hf2 = 0

3.4.3 The Area in WaterCAD

The shapefile is listed for the road network and then draws the network of pipes on it.

Figure 3.3: The current road network from the municipality

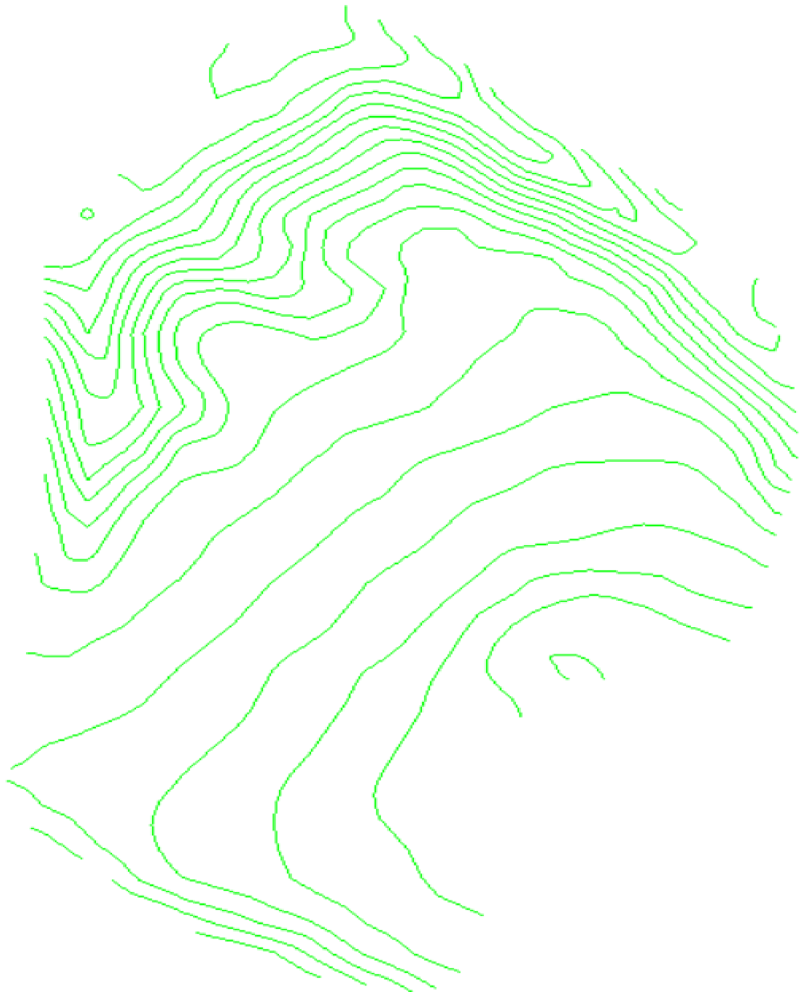

Figure3.4: Contour map of Al-Kahlisha area

The elevation of the nodes and the reservoir should be entered into WaterCAD using contour shape file and the TRex tool, the junctions and the reservoir elevation was computed as shown in the following figures

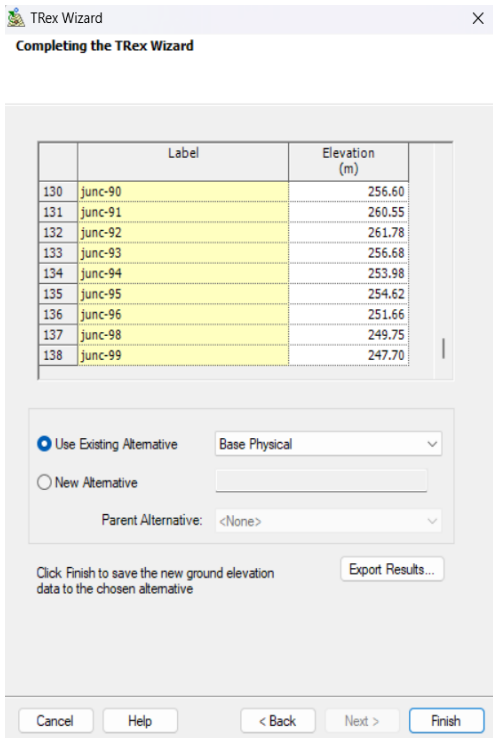

Figure3.5: Elevation of nodes definition

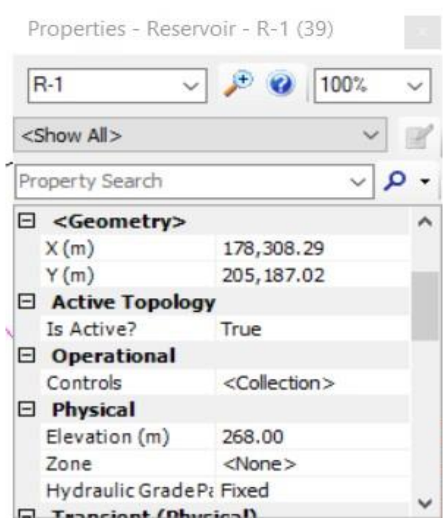

Figure3.6: Elevation of reservoir definition

3.4.4 Create demand area using GIS program:

WDN exported from WaterCAD to GIS software for drawing service areas (demand area).

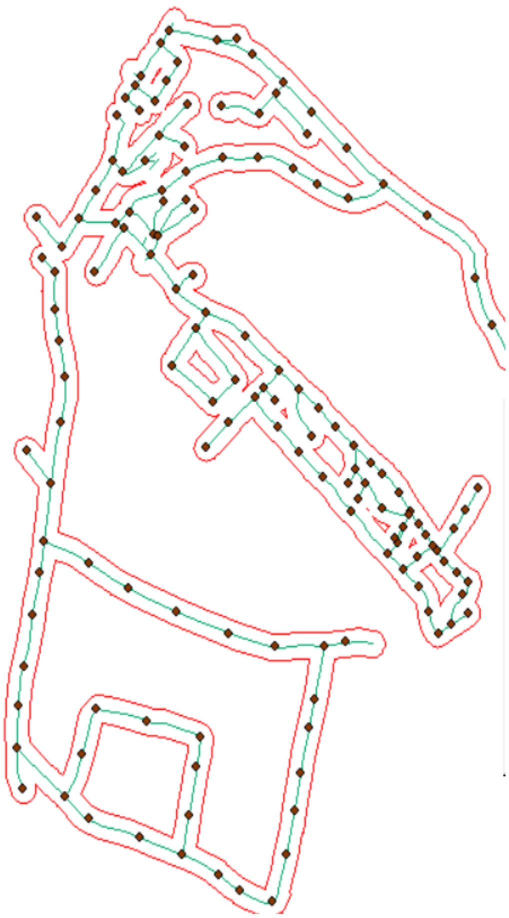

Figure3.7: Demand area for Al--Kahlisha area

3.4.5 Thiessen polygon:

The THIESSEN POLYGON METHOD has been used to determine the amount of demand for each node, which is made by dividing the demand area into spaces so that each node takes a certain area from the demand area.

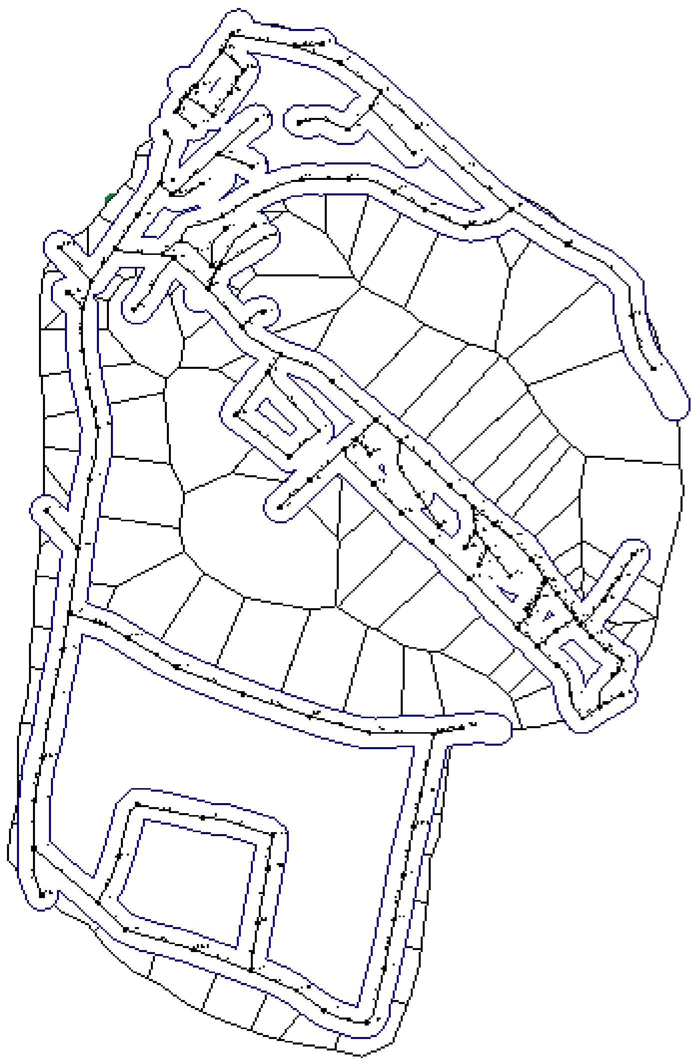

Figure3.8: Demand area distribution for each node

To have waterCAD calculate each junction demand the load builder is used, the used optionis the area load data, proportional distribution by area where each node have a Thiessen polygon calculated previously.

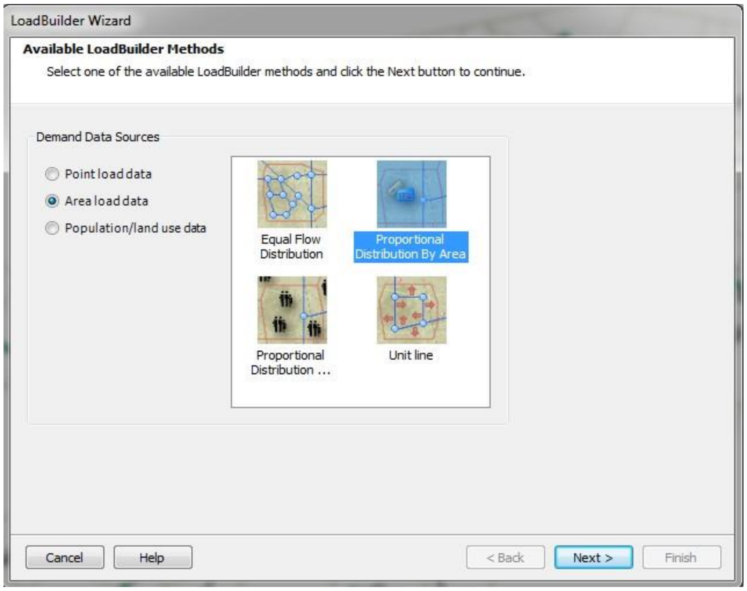

Figure3.9: proportional distribution by area

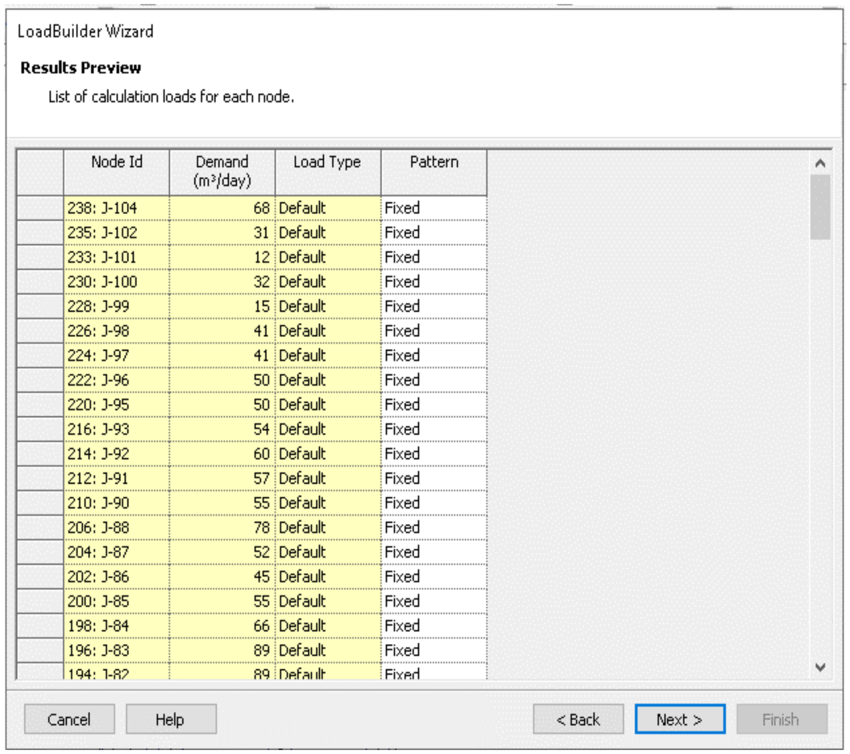

Figure3.10: Demand for each node

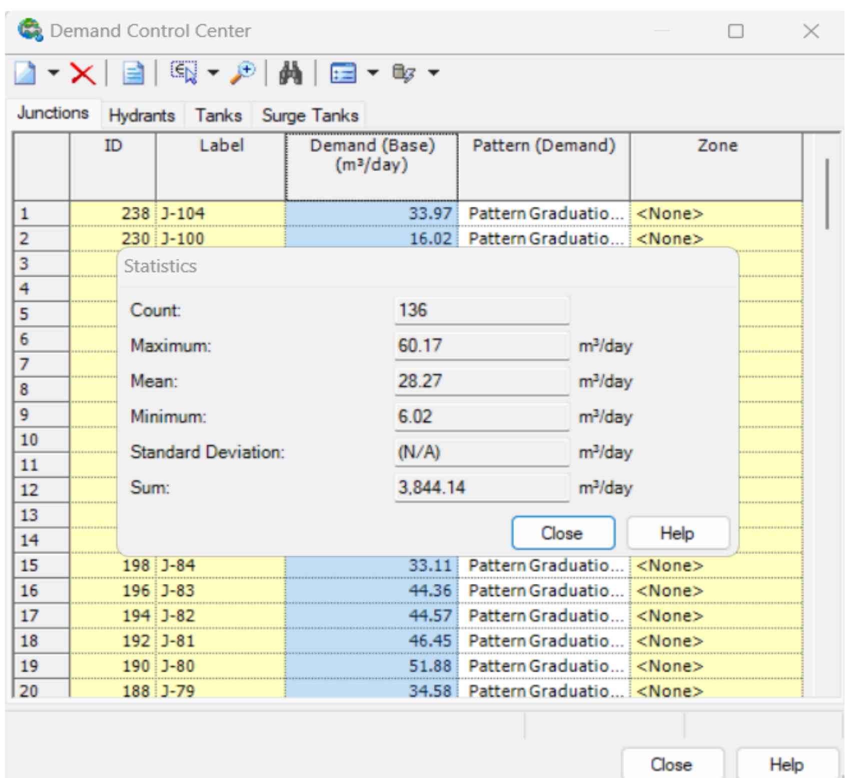

Figure3.11: Statistics for all nods

3.5.1 Define Pipe material and Hazen-William:

FlexTable: Pipe Table (Current Time: 0.000 hours) (water cad 22-12.wtg)

	ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (in)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss Coefficient (Local)	Flow (m³/day)	Velocity (m/s)
239: P-106	239	P-106	61	J-69	J-104	4.0	Ductile Iron	130.0		0.000	1,743	2.49
348: P-160	348	P-160	13	R-1	PMP-1	6.0	Ductile Iron	130.0		0.000	3,844	2.44
352: P-163	352	P-163	30	PMP-1	PRV-1	6.0	Ductile Iron	130.0		0.000	3,844	2.44
353: P-164	353	P-164	6	PRV-1	J-1	6.0	Ductile Iron	130.0		0.000	3,844	2.44
43: P-6	43	P-6	78	J-1	J-8	6.0	Ductile Iron	130.0		0.000	3,821	2.42
257: P-115	257	P-115	51	J-104	J-113	4.0	Ductile Iron	130.0		0.000	1,517	2.17
262: P-117	262	P-117	37	J-113	J-116	4.0	Ductile Iron	130.0		0.000	1,491	2.13
266: P-119	266	P-119	56	J-116	J-118	4.0	Ductile Iron	130.0		0.000	1,450	2.07
268: P-120	268	P-120	49	J-118	J-119	4.0	Ductile Iron	130.0		0.000	1,421	2.03
199: P-86	199	P-86	82	J-80	J-84	2.0	Ductile Iron	130.0		0.000	351	2.00
270: P-121	270	P-121	53	J-119	J-120	4.0	Ductile Iron	130.0		0.000	1,393	1.99
272: P-122	272	P-122	70	J-120	J-121	4.0	Ductile Iron	130.0		0.000	1,359	1.94
357: P-166	357	P-166	8	PRV-3	J-9	6.0	Ductile Iron	130.0		0.000	3,031	1.92
356: P-165	356	P-165	33	J-8	PRV-3	6.0	Ductile Iron	130.0		0.000	3,031	1.92
47: P-8	47	P-8	76	J-9	J-10	6.0	Ductile Iron	130.0		0.000	3,018	1.92
337: P-155	337	P-155	72	J-152	J-153	2.0	Ductile Iron	130.0		0.000	333	1.90
49: P-9	49	P-9	74	J-10	J-11	6.0	Ductile Iron	130.0		0.000	2,974	1.89
274: P-123	274	P-123	91	J-121	J-122	4.0	Ductile Iron	130.0		0.000	1,317	1.88
201: P-87	201	P-87	78	J-84	J-85	2.0	Ductile Iron	130.0		0.000	318	1.81
365: P-171	365	P-171	75	J-122	PMP-2	4.0	Ductile Iron	130.0		0.000	1,242	1.77
366: P-172	366	P-172	11	PMP-2	J-124	4.0	Ductile Iron	130.0		0.000	1,242	1.77
359: P-167	359	P-167	54	J-11	PRV-4	6.0	Ductile Iron	130.0		0.000	2,778	1.76
360: P-168	360	P-168	8	PRV-4	J-60	6.0	Ductile Iron	130.0		0.000	2,778	1.76
155: P-64	155	P-64	67	J-60	J-62	6.0	Ductile Iron	130.0		0.000	2,725	1.73
296: P-134	296	P-134	51	J-132	J-133	2.0	Ductile Iron	130.0		0.000	297	1.69
363: P-170	363	P-170	8	PRV-5	J-67	6.0	Ductile Iron	130.0		0.000	2,634	1.67

Figure 3.12: Define Pipe material and Hazen-William

3.5.2 Add Valves and pumps

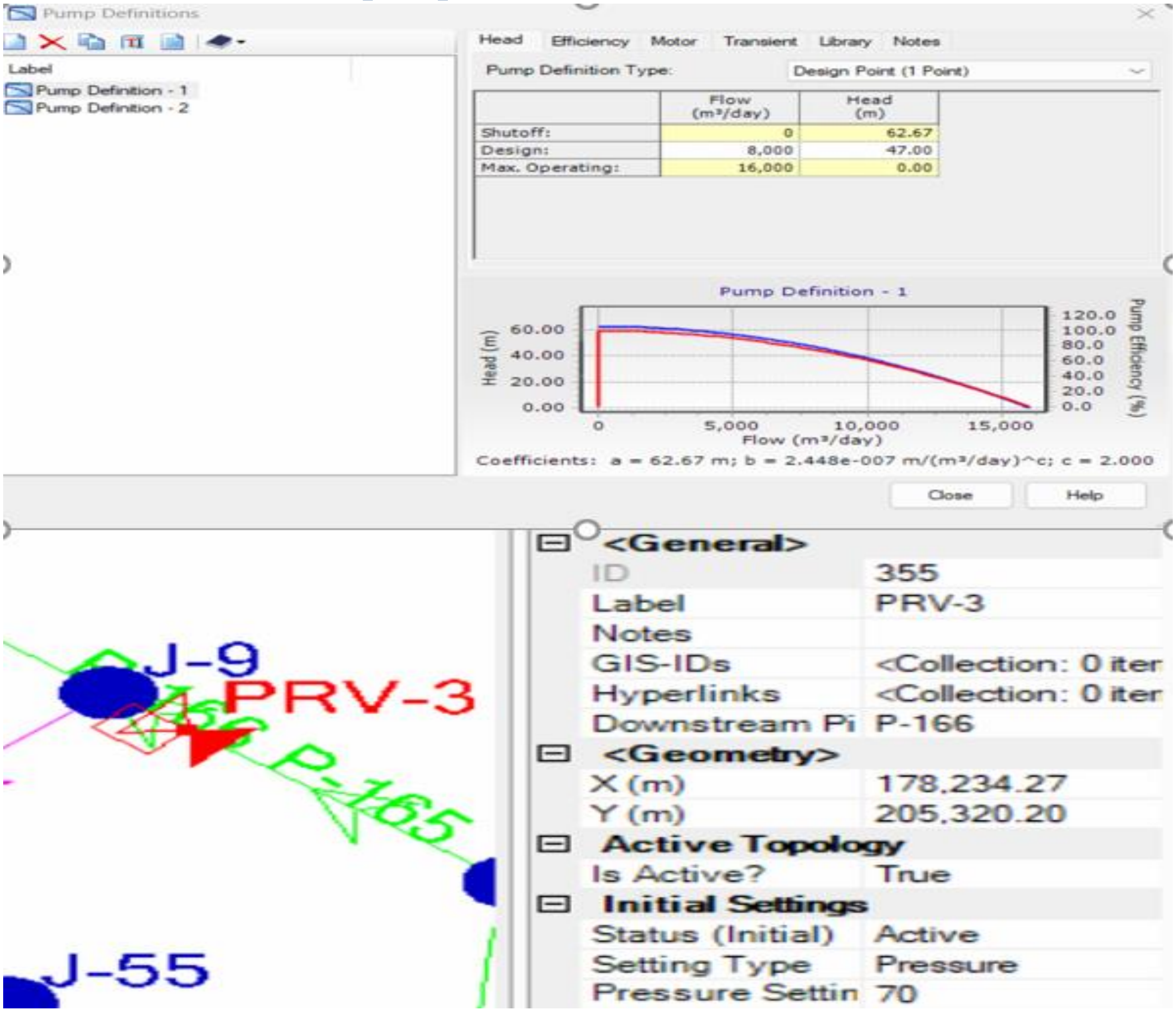

Figure 3.13:Add valves and pumps

3.5.3 Check problems

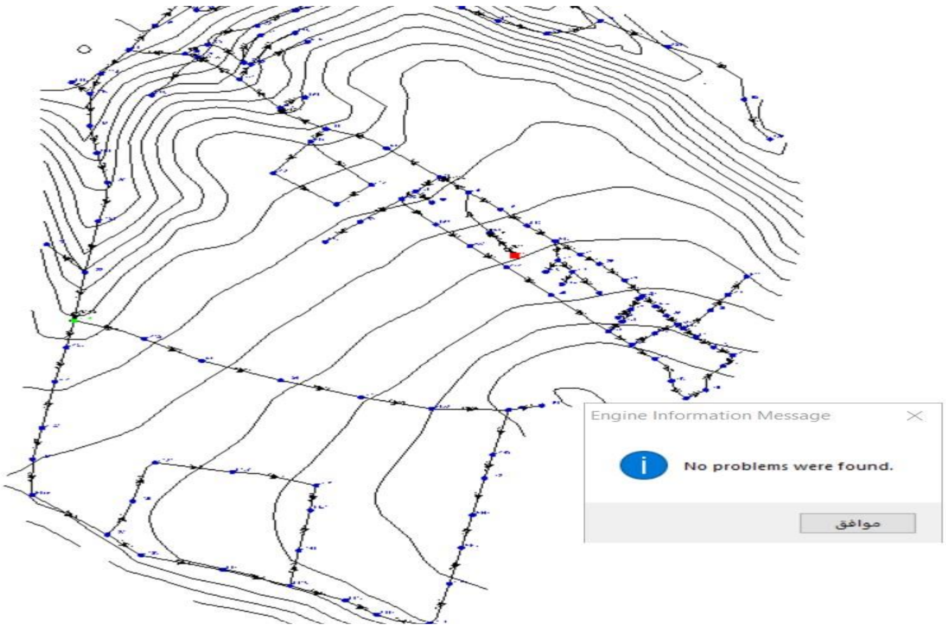

Figure 3.14:Vaildate Check

3.5.4 Run the Models

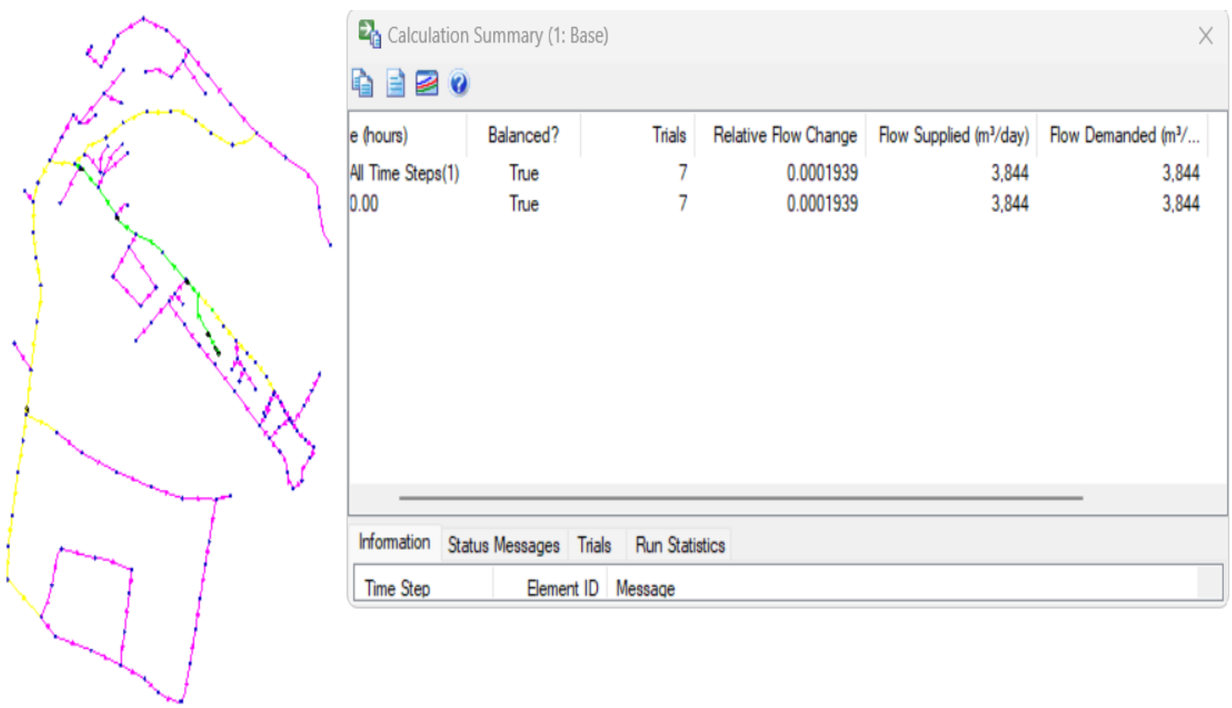

Figure 3.15: Run Model

Chapter four

Design result

After completing the design for the water distribution network, an analysis was made on the results and the existing problems in velocity and pressure were solved, then we calculated the sum of the lengths for each diameter separately. The table below (see Table 4.1) shows the sum of total length of each pipe diameter .

Table 4.1: length of each diameter

Diameter (inch)	Total length (m)
2	5,286
4	1,810
6	520
Total	7,616

We have adopted velocity and pressure constraint in the design process, each of which is as follows:

Table 4.2: constraint velocity and pressure

	Max	Min
Velocity (m/s)	3	.03
Pressure (m H20)	80	20

The figure above shows the distribution of pipes in the grid by different diameters, where we observe the use of 6 inches diameter at the beginning of the grid in the middle of the tank due to the high speed and then the speed began to decrease in the limbs and smaller diameters were used in proportion to the speed not exceeding 3m/s

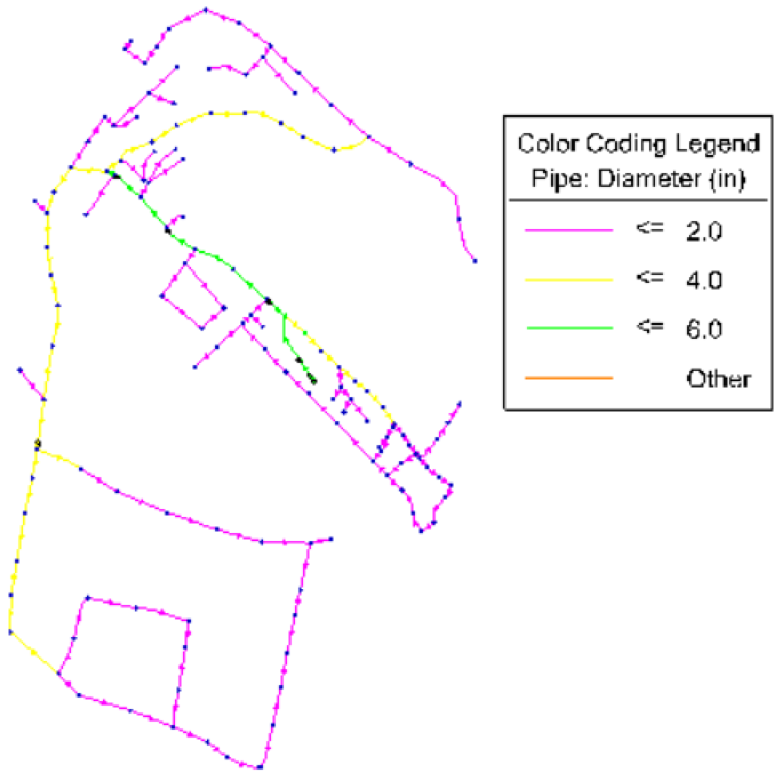

Figure 4.1 : Network Layout

4.1 Steady results

The two graphs below show the distribution of points for the chart between (pressure/node) and (velocity/node), where we observe the maximum and minimum value of each of them which was according to the required criteria, where pressure increases the lower junction fall from the tank level, and speed increases the lower the pipe diameter.

Table 4.3 designed result (Steady)

Constraint	Min value	Max value
Pressure (m H_2O)	20	82
Velocity (m/s)	0.05	2.49

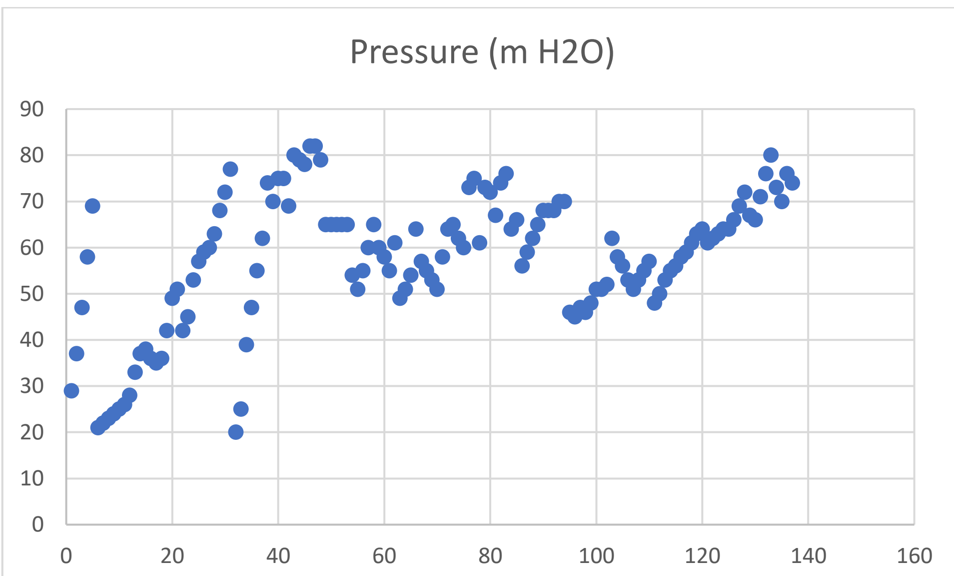

Figure 4.2: pressure (steady state)

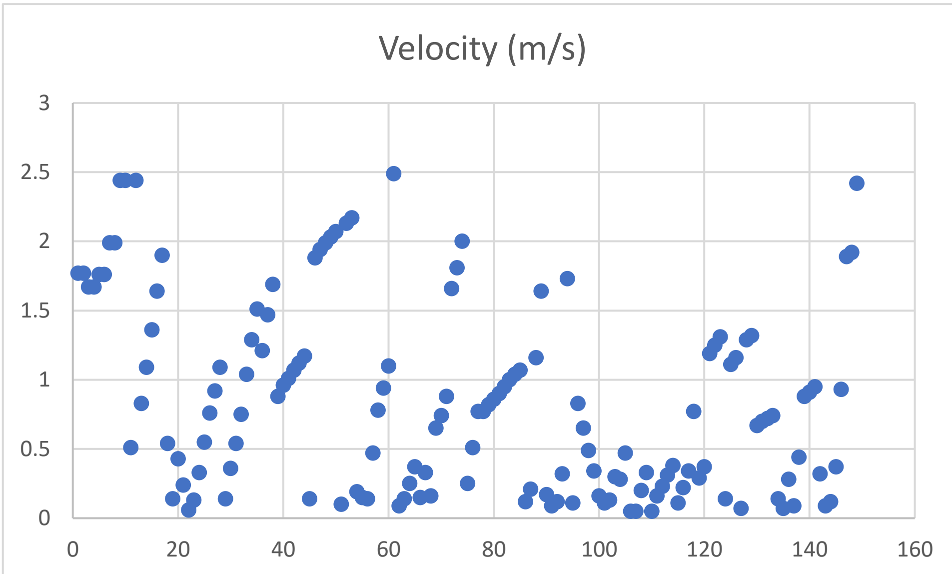

Figure4.3:Velocity (steady state)

4.2 Eps case:

Extended Period Simulation (EPS) type analysis is used when you want to understand the hydraulics of a system over a specified period of time. EPS is basically a series of Steady State runs performed for multiple time steps. When you analyze a model for steady state analysis the hydraulic results obtained are for that particular instance. EPS does this analysis over a period of time.

The two graphs below show the distribution of points for the chart between (pressure/node) and (velocity/node), where we observe the maximum and minimum value of each of them which was according to the required criteria, where pressure increases the lower junction fall from the tank level, and speed increases the lower the pipe diameter.

Table 4.4 factor Eps

Hour	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
Factor	0.45	0.27	0.45	1.80	1.35	0.99	0.90	0.99	1.08	1.80	1.17	0.72

Table 4.5 designed result (Eps 6:00 pm)

Constraint	Min value	Max value
Pressure (m H_2O)	27	83
Velocity (m/s)	0.02	2.98

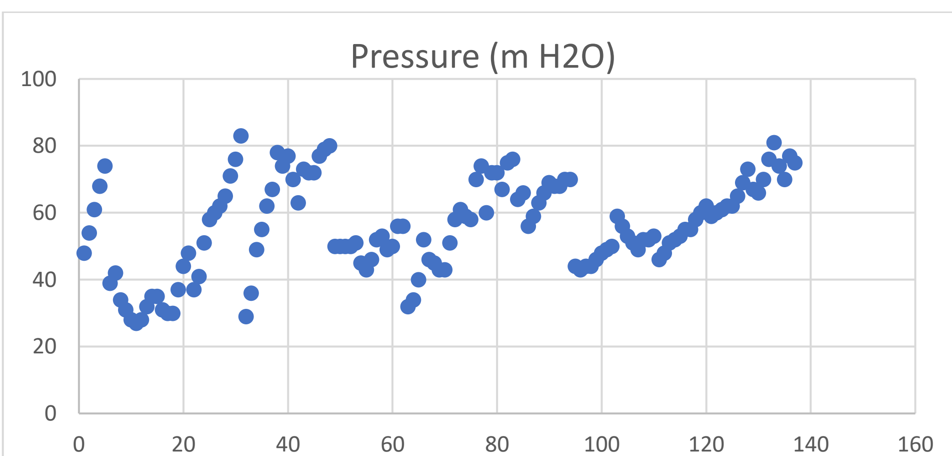

Figure 4.4: pressure (Eps 6:00 pm)

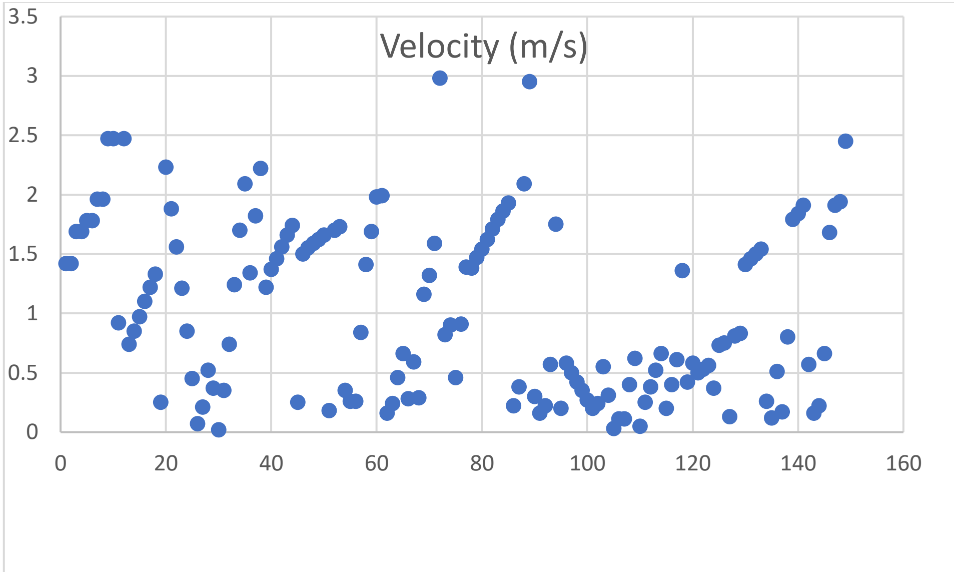

Figure4.5:Velocity (Eps 6:00 pm)

4.3 Discussion:

In this project, a water distribution network is designed to serve and meet the needs of the largest number of people in the future in this unserved area. During the design there were some problems with pressure and velocity, as the pipe diameters were changed to meet the required velocity standards to not exceed (3m/s)(Because at high velocity, the pipes wear out, and at low velocity, deposition occurs in them) but there were also few velocity (below 0.3m/s) that were dealt with by reducing the pipe diameter to 2 inches but some velocity remained low as well , because is not possible to use a diameter less than 2 inches. On the other hand, there was considerable pressure in some areas and little in others, so two pumps were placed next to the tank and some of the reducing valves were placed to regulate the pressure in the grid to no more than (80mH2O) and no less than (20mH2O) .

Chapter five
Conclusion and Recommendation

5.1 Conclusion:

The water distribution system is designed to serve the largest expected population by the recommended and appropriate standards, thus solving the problem of the lack of a water distribution system that regulates and meets the population's water needs and preserves water sources in the area. Total population requirement was total demand (3844m3/d) and velocity values ranged from ((0.05 – 2.49)m/s) to pressure ((20 – 82)m H2O), and diameter values were for pipes(2,4,6 and 8 inches).

5.2 Recommendation:

We recommend that this project be implemented because of the need of the area under consideration for a water system that will facilitate the current and future consumption of water and preserve the region's water sources.

We also recommend the design and establishment of a sanitation network serving the population and the region.

We note that many water sources in the region need to be collected and preserved

Chapter six
References and Appendices

6.1 References :

1) **Palestinian Central Bureau of Statistics.https://www.pcbs.gov.ps/.**
2) **Jenin Municipality.**
3) **Ministry of Local Government (GeoMolg).**
4) **Dr. Muhammad Nassar Al-Masry's website.**

6.2 Appendices

Appendix 1:

Table 2: **summarized the length, start and end nodes, Diameter, Material, Hazen-Willian coefficient, Flow, Velocity and head loss for each pipe.**

ID	Label	Length (Sc	Start Nod	Stop Node	Diameter (in)	Material	Hazen-Williams	Flow (m^3/day)	Velocity (m/s)	Headloss Gradient (m/m	Length (m)
43	P-6	78	J-1	J-8	8	Ductile Iron	130	6876	2.45	0.028	78
47	P-8	76	J-9	J-10	8	Ductile Iron	130	5433	1.94	0.018	76
49	P-9	74	J-10	J-11	8	Ductile Iron	130	5353	1.91	0.018	74
51	P-10	28	J-11	J-12	2	Ductile Iron	130	294	1.68	0.07	28
53	P-11	69	J-12	J-13	2	Ductile Iron	130	115	0.66	0.012	69
55	P-12	87	J-13	J-14	2	Ductile Iron	130	39	0.22	0.002	87
57	P-13	51	J-15	J-14	2	Ductile Iron	130	28	0.16	0.001	51
58	P-14	100	J-12	J-15	2	Ductile Iron	130	100	0.57	0.009	100
60	P-15	45	J-8	J-16	4	Ductile Iron	130	1339	1.91	0.04	45
62	P-16	40	J-16	J-17	4	Ductile Iron	130	1292	1.84	0.037	40
64	P-17	41	J-17	J-18	4	Ductile Iron	130	1253	1.79	0.035	41
66	P-18	34	J-18	J-19	2	Ductile Iron	130	139	0.8	0.018	34
68	P-19	24	J-19	J-20	2	Ductile Iron	130	30	0.17	0.001	24
70	P-20	25	J-19	J-21	2	Ductile Iron	130	89	0.51	0.008	25
72	P-21	25	J-21	J-22	2	Ductile Iron	130	22	0.12	0.001	25
74	P-22	47	J-21	J-23	2	Ductile Iron	130	46	0.26	0.002	47
76	P-23	35	J-18	J-24	4	Ductile Iron	130	1077	1.54	0.027	35
78	P-24	26	J-24	J-25	4	Ductile Iron	130	1053	1.5	0.025	26
80	P-25	40	J-25	J-26	4	Ductile Iron	130	1021	1.46	0.024	40
82	P-26	33	J-26	J-27	4	Ductile Iron	130	987	1.41	0.023	33
84	P-27	5	J-27	J-28	4	Ductile Iron	130	580	0.83	0.008	5
86	P-28	21	J-28	J-29	4	Ductile Iron	130	569	0.81	0.008	21
88	P-29	20	J-29	J-30	2	Ductile Iron	130	22	0.13	0.001	20
90	P-30	25	J-29	J-31	4	Ductile Iron	130	528	0.75	0.007	25
92	P-31	22	J-31	J-32	4	Ductile Iron	130	513	0.73	0.007	22
94	P-32	35	J-32	J-33	2	Ductile Iron	130	66	0.37	0.004	35
96	P-33	23	J-27	J-34	4	Ductile Iron	130	391	0.56	0.004	23
98	P-34	20	J-34	J-35	4	Ductile Iron	130	373	0.53	0.004	20
100	P-35	19	J-35	J-36	4	Ductile Iron	130	353	0.5	0.003	19
102	P-36	29	J-37	J-36	2	Ductile Iron	130	-102	0.58	0.01	29
103	P-37	31	J-33	J-37	2	Ductile Iron	130	-74	0.42	0.005	31
105	P-38	10	J-36	J-38	2	Ductile Iron	130	238	1.36	0.047	10
107	P-39	44	J-38	J-39	2	Ductile Iron	130	107	0.61	0.011	44
109	P-40	33	J-39	J-40	2	Ductile Iron	130	70	0.4	0.005	33
111	P-41	38	J-40	J-41	2	Ductile Iron	130	34	0.2	0.001	38
113	P-42	20	J-38	J-42	2	Ductile Iron	130	116	0.66	0.013	20
115	P-43	26	J-42	J-43	2	Ductile Iron	130	92	0.52	0.008	26

117	P-44	25	J-43	J-44	2	Ductile Iron	130	67	0.38	0.005	25
119	P-45	23	J-44	J-45	2	Ductile Iron	130	44	0.25	0.002	23
121	P-46	49	J-46	J-45	2	Ductile Iron	130	-9	0.05	0	49
125	P-48	35	J-33	J-48	2	Ductile Iron	130	109	0.62	0.011	35
127	P-49	44	J-48	J-49	2	Ductile Iron	130	69	0.4	0.005	44
129	P-50	35	J-49	J-50	2	Ductile Iron	130	20	0.11	0	35
130	P-51	26	J-50	J-46	2	Ductile Iron	130	20	0.11	0	26
132	P-52	36	J-9	J-51	2	Ductile Iron	130	5	0.03	0	36
134	P-53	20	J-51	J-52	2	Ductile Iron	130	-55	0.31	0.003	20
136	P-54	59	J-52	J-53	2	Ductile Iron	130	95	0.55	0.009	59
138	P-55	52	J-53	J-54	2	Ductile Iron	130	41	0.24	0.002	52
140	P-56	26	J-51	J-55	2	Ductile Iron	130	36	0.2	0.001	26
142	P-57	59	J-52	J-56	4	Ductile Iron	130	-192	0.27	0.001	59
144	P-58	53	J-56	J-57	4	Ductile Iron	130	-249	0.35	0.002	53
146	P-59	54	J-57	J-58	4	Ductile Iron	130	-297	0.42	0.002	54
148	P-60	69	J-59	J-58	4	Ductile Iron	130	349	0.5	0.003	69
149	P-61	88	J-59	J-32	4	Ductile Iron	130	-404	0.58	0.004	88
153	P-63	34	J-60	J-61	2	Ductile Iron	130	36	0.2	0.001	34
155	P-64	67	J-60	J-62	8	Ductile Iron	130	4905	1.75	0.015	67
157	P-65	29	J-62	J-63	2	Ductile Iron	130	100	0.57	0.009	29
159	P-66	72	J-63	J-64	2	Ductile Iron	130	38	0.22	0.002	72
161	P-67	74	J-63	J-65	2	Ductile Iron	130	28	0.16	0.001	74
167	P-70	84	J-67	J-68	2	Ductile Iron	130	53	0.3	0.003	84
169	P-71	15	J-67	J-69	6	Ductile Iron	130	4650	2.95	0.055	15
171	P-72	29	J-69	J-70	4	Ductile Iron	130	1465	2.09	0.047	29
173	P-73	52	J-70	J-71	2	Ductile Iron	130	67	0.38	0.005	52
175	P-74	55	J-71	J-72	2	Ductile Iron	130	38	0.22	0.002	55
177	P-75	67	J-70	J-73	4	Ductile Iron	130	1349	1.93	0.04	67
179	P-76	49	J-73	J-74	4	Ductile Iron	130	1306	1.86	0.038	49
181	P-77	63	J-74	J-75	4	Ductile Iron	130	1256	1.79	0.035	63
183	P-78	59	J-75	J-76	4	Ductile Iron	130	1196	1.71	0.032	59
185	P-79	63	J-76	J-77	4	Ductile Iron	130	1135	1.62	0.029	63
187	P-80	45	J-77	J-78	4	Ductile Iron	130	1082	1.54	0.027	45
189	P-81	56	J-78	J-79	4	Ductile Iron	130	1031	1.47	0.024	56
191	P-82	64	J-79	J-80	4	Ductile Iron	130	969	1.38	0.022	64
193	P-83	85	J-80	J-81	2	Ductile Iron	130	244	1.39	0.05	85
195	P-84	134	J-81	J-82	2	Ductile Iron	130	160	0.91	0.023	134

195	P-84	134	J-81	J-82	2	Ductile Iron	130	160	0.91	0.023	134
197	P-85	76	J-82	J-83	2	Ductile Iron	130	80	0.46	0.006	76
199	P-86	82	J-80	J-84	4	Ductile Iron	130	632	0.9	0.01	82
201	P-87	78	J-84	J-85	4	Ductile Iron	130	572	0.82	0.008	78
203	P-88	65	J-85	J-86	2	Ductile Iron	130	523	2.98	0.203	65
205	P-89	65	J-86	J-87	2	Ductile Iron	130	278	1.59	0.063	65
207	P-90	61	J-87	J-88	2	Ductile Iron	130	232	1.32	0.045	61
211	P-92	23	J-86	J-90	2	Ductile Iron	130	203	1.16	0.035	23
213	P-93	81	J-90	J-91	2	Ductile Iron	130	51	0.29	0.003	81
215	P-94	41	J-90	J-92	2	Ductile Iron	130	103	0.59	0.01	41
217	P-95	66	J-92	J-93	2	Ductile Iron	130	48	0.28	0.002	66
225	P-99	35	J-96	J-97	2	Ductile Iron	130	116	0.66	0.013	35
227	P-100	35	J-97	J-98	2	Ductile Iron	130	80	0.46	0.006	35
229	P-101	42	J-98	J-99	2	Ductile Iron	130	43	0.24	0.002	42
231	P-102	18	J-99	J-100	2	Ductile Iron	130	29	0.16	0.001	18
239	P-106	61	J-69	J-104	6	Ductile Iron	130	3138	1.99	0.027	61
241	P-107	52	J-104	J-105	2	Ductile Iron	130	347	1.98	0.095	52
243	P-108	51	J-105	J-106	2	Ductile Iron	130	296	1.69	0.071	51
247	P-110	21	J-106	J-108	2	Ductile Iron	130	246	1.41	0.05	21
249	P-111	80	J-108	J-109	2	Ductile Iron	130	147	0.84	0.019	80
251	P-112	66	J-109	J-110	2	Ductile Iron	130	45	0.26	0.002	66
253	P-113	46	J-109	J-111	2	Ductile Iron	130	46	0.26	0.002	46
255	P-114	44	J-108	J-112	2	Ductile Iron	130	61	0.35	0.004	44
257	P-115	51	J-104	J-113	6	Ductile Iron	130	2730	1.73	0.021	51
262	P-117	37	J-113	J-116	6	Ductile Iron	130	2684	1.7	0.02	37
264	P-118	28	J-116	J-117	2	Ductile Iron	130	32	0.18	0.001	28
266	P-119	56	J-116	J-118	6	Ductile Iron	130	2611	1.66	0.019	56
268	P-120	49	J-118	J-119	6	Ductile Iron	130	2558	1.62	0.018	49
270	P-121	53	J-119	J-120	6	Ductile Iron	130	2507	1.59	0.018	53
272	P-122	70	J-120	J-121	6	Ductile Iron	130	2446	1.55	0.017	70
274	P-123	91	J-121	J-122	6	Ductile Iron	130	2370	1.5	0.016	91
276	P-124	64	J-122	J-123	2	Ductile Iron	130	44	0.25	0.002	64
280	P-126	48	J-124	J-125	4	Ductile Iron	130	1218	1.74	0.033	48
282	P-127	62	J-125	J-126	4	Ductile Iron	130	1162	1.66	0.031	62
284	P-128	83	J-126	J-127	4	Ductile Iron	130	1090	1.56	0.027	83
286	P-129	56	J-127	J-128	4	Ductile Iron	130	1021	1.46	0.024	56
288	P-130	63	J-128	J-129	4	Ductile Iron	130	961	1.37	0.021	63

294	P-133	106	J-129	J-132	4	Ductile Iron	130	852	1.22	0.017	106
296	P-134	51	J-132	J-133	2	Ductile Iron	130	389	2.22	0.118	51
298	P-135	91	J-133	J-134	2	Ductile Iron	130	319	1.82	0.081	91
300	P-136	76	J-134	J-135	2	Ductile Iron	130	235	1.34	0.046	76
302	P-137	65	J-132	J-136	2	Ductile Iron	130	367	2.09	0.105	65
304	P-138	74	J-136	J-137	2	Ductile Iron	130	298	1.7	0.072	74
306	P-139	84	J-137	J-138	2	Ductile Iron	130	218	1.24	0.04	84
308	P-140	92	J-138	J-139	2	Ductile Iron	130	129	0.74	0.015	92
310	P-141	44	J-139	J-140	2	Ductile Iron	130	62	0.35	0.004	44
312	P-142	73	J-140	J-141	2	Ductile Iron	130	4	0.02	0	73
313	P-143	62	J-135	J-141	2	Ductile Iron	130	64	0.37	0.004	62
315	P-144	65	J-135	J-142	2	Ductile Iron	130	91	0.52	0.008	65
317	P-145	42	J-142	J-143	2	Ductile Iron	130	38	0.21	0.002	42
319	P-146	58	J-144	J-143	2	Ductile Iron	130	13	0.07	0	58
321	P-147	76	J-145	J-144	2	Ductile Iron	130	79	0.45	0.006	76
323	P-148	65	J-146	J-145	2	Ductile Iron	130	150	0.85	0.02	65
325	P-149	58	J-147	J-146	2	Ductile Iron	130	211	1.21	0.038	58
327	P-150	66	J-148	J-147	2	Ductile Iron	130	274	1.56	0.061	66
329	P-151	42	J-149	J-148	2	Ductile Iron	130	328	1.88	0.086	42
331	P-152	81	J-150	J-149	2	Ductile Iron	130	390	2.23	0.118	81
333	P-153	36	J-150	J-151	2	Ductile Iron	130	44	0.25	0.002	36
335	P-154	82	J-124	J-152	4	Ductile Iron	130	930	1.33	0.02	82
337	P-155	72	J-152	J-153	4	Ductile Iron	130	853	1.22	0.017	72
339	P-156	91	J-153	J-154	4	Ductile Iron	130	771	1.1	0.014	91
341	P-157	90	J-154	J-155	4	Ductile Iron	130	681	0.97	0.011	90
343	P-158	78	J-155	J-156	4	Ductile Iron	130	597	0.85	0.009	78
344	P-159	82	J-156	J-150	4	Ductile Iron	130	516	0.74	0.007	82
348	P-160	13	R-1	PMP-1	8	Ductile Iron	130	6917	2.47	0.028	13
350	P-162	71	J-88	J-96	2	Ductile Iron	113.5	161	0.92	0.03	71
352	P-163	30	PMP-1	PRV-1	8	Ductile Iron	130	6917	2.47	0.028	30
353	P-164	6	PRV-1	J-1	8	Ductile Iron	130	6917	2.47	0.028	6
356	P-165	33	J-8	PRV-3	8	Ductile Iron	130	5490	1.96	0.019	33
357	P-166	8	PRV-3	J-9	8	Ductile Iron	130	5493	1.96	0.019	8
359	P-167	54	J-11	PRV-4	8	Ductile Iron	130	5000	1.78	0.016	54
360	P-168	8	PRV-4	J-60	8	Ductile Iron	130	5000	1.78	0.016	8
362	P-169	51	J-62	PRV-5	8	Ductile Iron	130	4741	1.69	0.014	51
363	P-170	8	PRV-5	J-67	8	Ductile Iron	130	4741	1.69	0.014	8
365	P-171	75	J-122	PMP-2	6	Ductile Iron	130	2235	1.42	0.014	75
366	P-172	11	PMP-2	J-124	6	Ductile Iron	130	2235	1.42	0.014	11

Table 2: summarized the values of Elevation, Demand and Pressure for each node.

ID	Label	Elevation (m)	Demand (m^3/day)	Hydraulic Grade (m)	Pressure (m H2O)
40	J-1	251.21	41	326.25	75
42	J-8	246.48	47	324.05	77
44	J-9	244.03	54	314.53	70
46	J-10	239.07	80	313.16	74
48	J-11	231	59	311.85	81
50	J-12	233.89	79	309.89	76
52	J-13	238.58	76	309.04	70
54	J-14	243.2	67	308.9	66
56	J-15	242.25	72	308.95	67
59	J-16	249.12	46	322.25	73
61	J-17	251.76	39	320.78	69
63	J-18	254.61	37	319.33	65
65	J-19	256.33	21	318.74	62
67	J-20	256.83	30	318.72	62
69	J-21	257.55	22	318.55	61
71	J-22	258.3	22	318.54	60
73	J-23	259.74	46	318.44	59
75	J-24	256.21	24	318.4	62
77	J-25	257.27	32	317.73	60
79	J-26	258.97	34	316.77	58
81	J-27	260.95	16	316.02	55
83	J-28	261.2	11	315.98	55
85	J-29	262.6	19	315.81	53
87	J-30	263.96	22	315.8	52
89	J-31	264.56	16	315.64	51
91	J-32	266.94	43	315.48	48
93	J-33	269.5	31	315.33	46
95	J-34	262.34	18	315.93	53
97	J-35	263.39	20	315.86	52
99	J-36	264.14	13	315.79	52
101	J-37	266.38	28	315.5	49
104	J-38	264.36	15	315.33	51
106	J-39	261.36	37	314.86	53
108	J-40	258.83	35	314.7	56
110	J-41	255.3	34	314.65	59
112	J-42	264.84	24	315.08	50
114	J-43	265.6	25	314.87	49
116	J-44	266.3	23	314.76	48
118	J-45	268.51	35	314.71	46
120	J-46	270.55	29	314.7	44
124	J-48	270.46	39	314.94	44
126	J-49	271.64	49	314.73	43
128	J-50	270.97	0	314.71	44
131	J-51	244.02	25	314.53	70
133	J-52	244.37	41	314.59	70
135	J-53	245.81	54	314.08	68
137	J-54	245.76	41	313.98	68
139	J-55	245.68	36	314.49	69
141	J-56	248.6	57	314.66	66

143	J-57	252.06	48	314.75	63
145	J-58	255.48	52	314.88	59
147	J-59	259.2	56	315.11	56
150	J-60	223.36	59	289.4	66
152	J-61	225.5	36	289.35	64
154	J-62	212.25	64	288.4	76
156	J-63	213.43	33	288.13	75
158	J-64	221.18	38	288.01	67
160	J-65	215.42	28	288.06	72
164	J-67	199.57	39	271.34	72
166	J-68	211.15	53	271.09	60
168	J-69	196.78	47	270.52	74
170	J-70	198.8	48	269.16	70
172	J-71	211.01	29	268.92	58
174	J-72	209.64	38	268.83	59
176	J-73	205.65	44	266.44	61
178	J-74	205.97	50	264.57	58
180	J-75	211.24	60	262.36	51
182	J-76	217.86	61	260.48	43
184	J-77	215.15	54	258.63	43
186	J-78	212.34	51	257.43	45
188	J-79	209.71	62	256.05	46
190	J-80	202.29	93	254.66	52
192	J-81	210.75	84	250.45	40
194	J-82	213.57	80	247.4	34
196	J-83	215	80	246.92	32
198	J-84	197.73	60	253.85	56
200	J-85	197.08	49	253.21	56
202	J-86	189.72	41	239.94	50
204	J-87	186.28	47	235.8	49
206	J-88	180	71	233.06	53
210	J-90	187.42	49	239.12	52
212	J-91	192.88	51	238.89	46
214	J-92	196.04	54	238.71	43
216	J-93	192.99	48	238.55	45
222	J-96	180	45	230.96	51
224	J-97	180	37	230.51	50
226	J-98	180	37	230.3	50
228	J-99	180	14	230.21	50
230	J-100	180	29	230.2	50
238	J-104	188.78	61	268.9	80
240	J-105	184.75	50	263.99	79
242	J-106	183.27	50	260.39	77
246	J-108	186.99	39	259.31	72
248	J-109	185.21	56	257.77	72
250	J-110	184.4	45	257.63	73
252	J-111	194.84	46	257.67	63
254	J-112	189.19	61	259.15	70
256	J-113	190.83	46	267.84	77

256	J-113	190.83	46	267.84	77
261	J-116	193.38	41	267.1	74
263	J-117	189.17	32	267.06	78
265	J-118	198.8	53	266.03	67
267	J-119	203.43	51	265.13	62
269	J-120	209.27	61	264.21	55
271	J-121	214.39	76	263.04	49
273	J-122	225.67	91	261.59	36
275	J-123	232.09	44	261.46	29
277	J-124	236.03	87	319.2	83
279	J-125	241.13	56	317.59	76
281	J-126	244.24	72	315.7	71
283	J-127	247.83	70	313.46	65
285	J-128	249.75	60	312.12	62
287	J-129	250.16	108	310.76	60
293	J-132	250.88	97	308.93	58
295	J-133	251.36	70	302.93	51
297	J-134	254.6	84	295.56	41
299	J-135	255.33	80	292.03	37
301	J-136	253.96	69	302.04	48
303	J-137	252.94	80	296.73	44
305	J-138	256.69	88	293.35	37
307	J-139	261.53	67	291.94	30
309	J-140	261.78	58	291.77	30
311	J-141	260.57	68	291.77	31
314	J-142	256.68	53	291.51	35
316	J-143	256.62	50	291.44	35
318	J-144	259.44	67	291.46	32
320	J-145	264.31	70	291.93	28
322	J-146	266	62	293.23	27
324	J-147	267.06	63	295.46	28
326	J-148	268.14	54	299.54	31
328	J-149	268.87	62	303.18	34
330	J-150	270.76	82	312.74	42
332	J-151	273.37	44	312.66	39
334	J-152	243.87	77	317.55	74
336	J-153	248.39	82	316.3	68
338	J-154	253.82	90	315.01	61
340	J-155	259.41	84	313.99	54
342	J-156	264.89	81	313.29	48