Study of a proposal for the development of a water supply network for Irbid City, Jordan.

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Abstract
A water distribution network is the means of getting water from the source to the consumer. It serves to convey the water from the water source and treatment works where necessary to the point where it is delivered to the consumer. The distribution system of a water works consists of the pipes, valves, hydrants and appurtenances used for distributing the water, the elevated tank and reservoir used for fire protection and for equalizing pressures and pump discharges and meters. Water distribution networks is an important component of any water supply system accounting for up to 80% of the total cost of the system and as a result operation and maintenance cost may soar higher if they are poorly designed, hence the need to have a well-planned, designed and constructed water distribution network cannot be over emphasized especially because of its importance to industrial growth and water's crucial role in society for health, firefighting and quality of life.

Keywords: Water distribution network, water supply network, Irbid City, Water management, Water network

Acknowledgement:

Water is a basic necessity for every human being and is used for various purposes like drinking, cleaning, sanitation, etc. This shows the fact that how important it is to make water available for residential locales, industries and other such commercial establishments. Designing is an important part in the construction of any major infrastructure. Supplying and availability of water is an integral part of construction now-a-days. With the advent of technology, the authors have now designed, analyses, studied and modified various types of pipes and pipe networks for complex and sophisticated conditions.

1. INTRODUCTION:

Jordan faces a complex set of development challenges stemmed from the chronic water scarcity. The situation is aggravated by climatic conditions, geography and, region's geopolitical environment. Water scarcity poses a serious challenge that affects the well King Abdul being, security and economic future of all Jordanians. Water management in Jordan has focused on supplying water for human consumption. However, increasing demands on the country to be more resilient and better prepared for future pressures on its water supply, as well as the urgent need to

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enhance sanitation coverage, trigger the need to review Jordan's development plans and strategic options. Water needs to be considered in the context of other crucial resources, i.e., the production of food and generation of energy, hence the need for a better understanding of the water-food-energy.

2. BACKGROUND:

Water-CAD is a specialized and specialized water network design program because the program is run using -1 Windows. It is able to shorten the time in the network component audit and design test. It also gives us important reports about the elements of the network and the design modification process. Which is easy to deal with by this program that we can modify an element and see its impact on the rest of the elements in a simple and fast.

3. THE PROGRAM IS CHARACTERIZED BY:

- Possibility of drawing and design.
- The possibility of dealing with other computer programs and the exchange of graphics and data and results, such as programs (AutoCAD-GIS).
- Ease of dealing with specialized data entry programs such as Excel – Access.
- Flexibility and high-end capabilities as well as ease of data entry and review and evaluation of results.
- Easy to make adjustments to the input and re-analysis of hydraulic in a simple and fast.
- Shorten a lot of time in checking network elements and design testing.
- High possibility of reviewing results and reporting to all network elements.
- Ability to test design for different design situations and see effects on network elements such as changes in speeds and pressures.[9]

4. SURFACE WATER:

Surface water in Jordan contributes about 28% of the total water supply in the country. The country's three main rivers, the Jordan, Yarmouk and Zarqa, are a major part of the country's surface water system. However, the available water supply from each has become highly unreliable. Upstream diversion and over-pumping in Syria (Yarmouk River and its tributaries) and Palestine (Jordan River) directly affects water availability in Jordan. In the past, one of the main water resources in Jordan was the Jordan River, with a flow of 1.3 billion m3 per year (BCM/yr). A 2010 study found that the Lower Jordan River has been reduced to 2% of its historic flow.
Water quality has also deteriorated sharply, with high levels of salinity and pollution from agricultural fertilizer and untreated wastewater upstream in Israel and the West

4-1 Objectives:

To Designing a water network for Huwara in Irbid for 20 years , is to determine the flow of water and velocity in all the pipes in the network and the pressure at all junctions of the pipe system.

4-2 Study area:

On which the network is designed. our studied area located about 4 miles east of the center of Irbid governorate at Petra street and covers an area of 2.1345 m2, the highest elevation is 577 m above sea level and the lowest elevation is 553 m above sea level.[10]

There are different buildings in the area where each building has a certain population, so we have to count the population on the organization's map to find out the water they need.

4-3 Methodology:

Before starting the hydraulic analysis process on WaterCAD program, we have to collect the information which was needed for analysis such as: study area and population regulation, flow calculation and street map.

4-4 Population:

Before starting the hydraulic analysis process, we must collect the information we need for analysis, the most important of which is the flow calculation.

This network is supposed to serve the region for 20 years and therefore it is important to calculate the population increase, so we should know the rate of population increase in Jordan.

The rate of population increase varies each year according to the circumstances surrounding the region.

Therefore, we calculated the average of increase rate for 5 years ago and obtained an increase rate of **2.5%**.[6]

Now that we know the rate of population increase, we must calculate the current and expected population through the map of the organization, which shows the type of buildings .[11]In general we relied on the estimate of the population in each building through a] **German study** on Jordan, this study shows the type of each building and the average population They live in every building.[12]

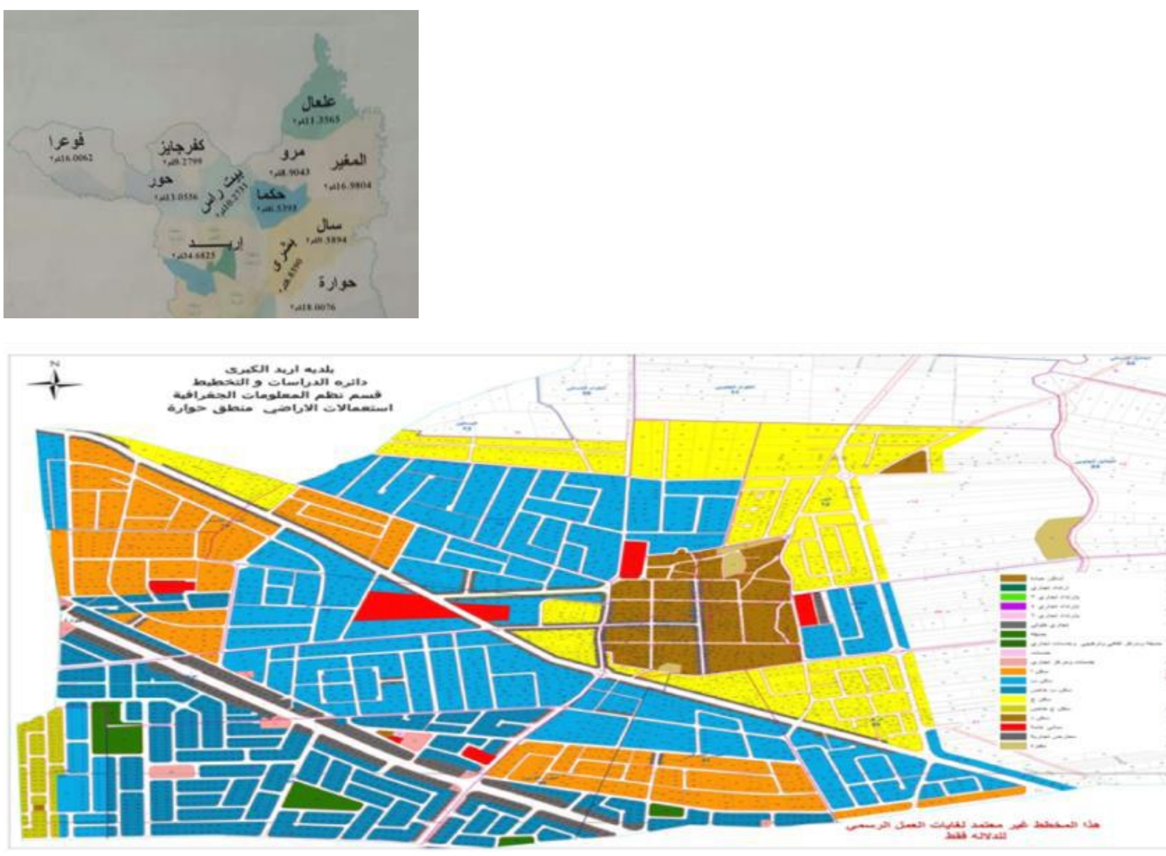

Figure (1): Huwara location.

Table (1) : Current population (Po) for each type of building

Land type	A	*B*	*Private B*	*C*	
Avg. # people residents of the building (Po)	*4*	*4*	*4*	*5*	
# buildings in study area	*302*	*1250*5*	*127*	*66*	
Sum of people (Po)	**1208**	**25000**	**508**	**330**	**27046**

The population is calculated in 50 years according to the following equation:

Pn = Po (1 + Ka (T))

Where :

Pn : Population after T years .

Po : Current population .

Ka : The rate of population increase which equal to 2.5% .

T : # of years.[6]

From the above equation, we will calculate the population after 20 years for each building, because the per capita share varies according to the type of building.

Table (2): Population after 20 years for each type of building

Land type	A	*B*	*Private B*	*C*	
Avg. # people residents of the building (Po)	*6*	*6*	*6*	*8*	
# buildings in study area	*302*	*1250*5*	*127*	*66*	
Sum of people (Po)	**1812**	**37500**	**762**	**528**	**40602**

We know that when hydraulics analysis is done, several data are needed. The most important of these is the amount of water demand by the area served by the network to be designed.

5- CONSUMPTION OF WATER:

To calculate the amount of flow, we must know the per capita daily consumption in addition to the number and type of buildings as calculated in advance as the amount of water consumed varies according to the type of building.

As we know that the per capita daily consumption is different from world, where in Jordan the average consumption per capita (70-90) liters per person per day, a small amount compared to the countries rich in water.

We relied on a German study on buildings in Jordan to determine the amount of water needed in a building.

Once we know the per capita share and the population, we can't calculate the amount of flow because in the design process we can't take average consumption but we must take the peak value per capita consumption.

Table (3) : Quantity of daily consumption per capita by types of land .

Land type	**Number of people or visitors (Pn)**	**Number building in study area**	**Peak per capita consumption(m3)**	**Daily consumption rate (m3)**
A	*6*	*302*	*0.145*	*263*
B	*6*	*1250*5*	*0.126*	*4725*
Private B	*6*	*127*	*0.126*	*97*
C	*8*	*66*	*0.126*	*67*
Garden	*100*	*1*	*0.05*	*5*
Services	*100*	*13*	*0.04*	*52*
Trade shows	*100*	*215*	*0.02*	*430*
Public	*200*	*4*	*0.05*	*40*
Sum				**5679**

It is known that Jordan is a poor country with water, so the water deliveries to citizens are not continuous, but the process of flow once a week for only one day, so we must calculate the quantities of water per week. Then the amount of water within a week is **39753** m3.

5-1 Modelling structure:

Through which the map of the area is introduced and the location of the streets where the pipes will be drawn and then exported to the WaterCAD program.

Figure (3): map of area.

The following data is essential for building up a decent hydraulic model of the Water Distribution Network, to analyse the network of the pipe line, the following input data is mandatory.

5-2 Reservoirs

The nodes where the volume of stored water that vary with time during a simulation is reservoir data, the primary input property for reservoir is **elevation, where** the water comes to network from two main reservoirs, Houfa and Zubda, which will be placed on both ends of the network, Assuming that the water in both tanks is 15 meters high, the water surface in both tanks is 585 and 590 m respectively.[10]

5-3 Pipes

Pipes are the links that allows the water to flow from one point to other in the allowed network, The hydraulic input variable for pipes include material, length, fraction factor coefficient and diameter .

5-4 Pipe material

From about material we will use **Ductile iron** because it has Long life, ability to withstand internal pressure and external loads, available in Jordan at a reasonable price and toughness and imperviousness.

5-5 Pipe length

The length of the pipe is not computed arithmetically, but when drawing the network for the street plan, the length of the pipe is ready in the program and represents the length of the real street through which the pipe passes.

6- Fraction Factor Coefficient:

The **Hazen–Williams** equation is an empirical relationship which relates the flow of water in a pipe with the physical properties of the pipe and the pressure drop caused by friction. It is used in the design of water pipe systems. such as fire sprinkler systems, water supply networks, and irrigation systems.

The **Hazen–Williams** fraction factor coefficient of Ductile Iron **C = 130** .[8]

6-1 Pipe diameter

All water pipes and water mains must be sized to meet the flow demands and pressure requirements But the information was not enough to use the equation of diameter but Estimate the pipe sizes on the basis of water demand, and local code requirements, we use 4 in diameter for all pipes.

6-2 Junction

These are the points in the network, where the links join together and at which, the water enters and leaves the network. The input data required for the junctions are:

6-3 Elevation

Google earth Is a mapping and geographic information program. The program raws a map of the earth by installing images obtained from satellite imagery, aerial photography and 3D geospatial information systems. The main purpose of using Google Earth is to know the heights that we need in the process of input the data for each junction, reservoir and others.

6-4 Water demand

To calculate the amount of water required, we perform a rough calculation for each node according to the surrounding buildings, the calculation method is as follows:

WD =Σ(# of visitors by type of building * share per person * 7days a week) *(Building number of the same type)

Table (4): Elevation and demand of some of junction.

Demand (m^3/week)	Elevation (M)	Label		Demand (m^3/week)	Elevation (M)	Label
250	563	J-57		120	570	J-24
250	566	J-43		98	570	J-284
344	562	J-60		148	569	J-25
265	555	J-173		678	569	J-240
104	562	J-32		124	569	J-293
254	566	J-40		200	566	J-26
475	559	J-304		100	566	J-29
159	555	J-101		244	566	J-28
872	561	J-232		118	568	J-299
122	570	J-194		366	566	J-54
927	558	J-61		170	567	J-30
146	568	J-195		120	561	J-300

7- Calibration:

After the data is entered as in the previous chapter, we must start the hydraulic analysis process through the WaterCAD program.
After the results are shown we perform the calibration process to reach the ideal values.

7-1 Standard value for Pressure and Velocity:

Velocities **above 3 ft/sec** help keep any solids from depositing in the pipeline.
Velocities **over 10 ft/sec** may erode the pipe lining and damage valves.
Typical Pressure in a distribution system is (**450-520**) **KPa** .
Maximum allowable pressure is **1030 KPa** .[7]

8- Preliminary Analysis Results:

We will initially set values for the results of the initial analysis. Values are the highest value and lowest value for both pressure and velocity.

Table (5): Max. & Min. Value for Pressure and Velocity after preliminary analysis.

	Pressure in Junction (KPa)	Velocity in Pipe (ft/s)
Maximum Value	**- 4,178**	**97.15**
Minimum Value	**- 7,362**	**0.00**

We also note that the results of the analysis showed irrational values and cannot be applied to reality, and this is due to several problems, the most important of which is the existence of negative pressure and the use of one diameter for all the tubes. The following is a solution to these problems.

8-1 Negative Pressure:

Negative pressures are generated in the hydraulic simulation any time that the hydraulic grade dips below the nodal elevation.

1) Too high elevations at negative pressures could be the result of a number of different things such as certain nodes.
2) Too high a head loss in the system (caused by high pipe velocities or high pipe roughness).
3) Too high a demand in the system.
4) System disconnections.
Knowing the causes of negative pressure helps us solve this problem, so we will start to solve these reasons gradually and will start by adding pumps to the network.[8]

9- Pumping:

9-1 Introduction:
Pump, a device that expends energy in order to raise, transport, or compress fluids.
Pumps that increase the pressure within the distribution system or raise water into an elevated storage tank are called booster pumps. most water distribution pumps are of the centrifugal type, in which a rapidly rotating impeller adds energy to the water and raises the pressure inside the pump casing.[8]
9-2 Definition Pump in WaterCAD:
To solve the negative pressure problem we will start with the easiest solution is adding pumps to the network, to define the pump on the WaterCAD program must be two important elements are the amount of flow on the system in addition to the head provided by the pump to the system.
In Jordan, pumps can be used up to 100 m. As for the flow, we have already learned that the total flow is about 40,000 m3 during the day of pumping.
This amount will be divided equally between the two reservoirs, meaning that in each tank will be put a number of pumps carrying 20,000 m3 and raise the head hundred meters.
We will put two pumps on series in each reservoir, the system will consist of 4 pumps, and the following table and figure shows the pump information:

Table (6) : Pump information , Flow & Head .

	Flow (m3/day)	**Head (m)**
Shutoff	0	133.33
Design	20,000	100.00
Max. Operating	40,000	0.00

After adding pumps to the network and with several attempts to change the head of pumps and increasing the number of pumps results were unsatisfactory, where it remained negative pressure problem, the following table shows the results after the addition of pumps.

Table (7) : Max. & Min. Value for Pressure and Velocity after adding pump .

	Pressure in Junction (KPa)	Velocity in Pipe (ft/s)
Maximum Value	**- 2,278**	**96.73**
Minimum Value	**- 5,432**	**0.05**

So we will solve the second problem to get rid of the negative pressure is the presence of pipes with high speeds.

9-3 Pressure and Velocities Calibration

We also know that the pipes near the reservoir have high speeds and vice versa, to reduce this speed through the **Hazen- Williams equation** with the same height stability is increasing the diameter of the tube.

At the same time and with the results of the preliminary analysis there are speeds of not more than **3 ft/sec** second so we reduce the diameter of the tube to increase speed in this solution we can solve the problems of speed and negative pressure.

V = 0.849 CHW Rh

CHW : Hazen- Williams Coefficient .

Rh : hydraulic radius (Rh = A/P = D/4).

S : slope of EGL or head loss per unit length (S = hf / L) .

) , m=1.85 .[8] 1.5

CHW = (KQm) ,(K= 4.73L/D4.87 Hf

The Hazen- Williams equation shows that the velocities depend on several factors the Hazen-Williams Coefficient, which is directly proportional to the velocity, in addition to the diameter of the tube.

After several attempts to modify the velocities by changing the pipe diameters based on the amount of flow and the location of the pipes. The increase of pipe diameters is in the vicinity of the reservoir and the reduction of the diameters is in the centre of the network and the areas with low speeds.

Table (8) : pipe diameter and place of them.

Diameter of pipes	**Place of pipes**	**Number of pipes**
12	**Pipes out of tanks**	14
8	**High speed pipes**	10
6	**Normal speed pipes**	19
4		89
2	**Low speed pipes**	120

Changing the type of material made from the pipes such as the PVC, which has Hazen- Williams Coefficient =150 .[8]

The following table shows the change in velocities after changing the type of material from ductile iron to PVC in pipes with a speed of less than 3 ft/s .

Table (9) : Pipe speeds after use PVC

Pipes	**Pipe using ductile iron (ft/s)**	**Pipe after using PVC (ft/s)**
P-82	1.89	2.18
P-105	1.09	1.26
P-388	1.76	2.03
P-504	1.91	2.20
P-566	1.00	1.15

10- The Final Results:

To obtain optimal values for pressure in the pipes and at the junction with a maximum value equal to (931 KPa) , and a small value equal to (521 KPa), these values are within the permissible values (450-1030) KPa.

Table (10) : final pressure of some of junction.

Pressure (kPa)	Hydraulic Grade (m)	Demand (m^3/day)	Elevation (m)	Label
931	653.08	369	558	J-292
914	651.36	80	558	J-287
914	653.35	129	560	J-298
908	652.73	173	560	J-289
906	658.55	200	566	J-26
805	653.47	120	561	J-300
895	651.5	185	560	J-290
889	651.8	173	561	J-288
885	656.44	366	566	J-54
882	649.16	475	559	J-304
882	656.14	100	566	J-29
880	652.94	420	563	J-49
879	658.86	148	569	J-25
878	649.75	230	560	J-35
878	655.68	244	566	J-28
877	659.65	120	570	J-24

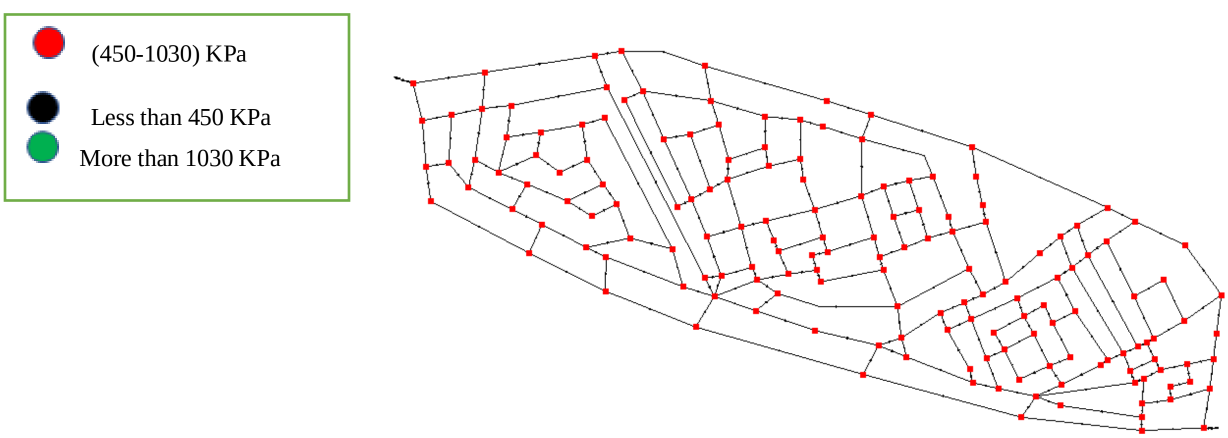

Figure (4): pressure of junction

In addition to the use of two pumps in each reservoir, each pump with a flow of 20,000 cubic meters and a 35 meter head.

Table (10) : Final Pump information , Flow & Head .

	Flow (m3/day)	**Head (m)**
Shutoff	**0**	**46.67**
Design	**20,000**	**35.00**
Max. Operating	**40,000**	**0.00**

The velocities have obtained good values in most of the network, but in some pipes the speeds of ideal values have not reached due to several factors, including the large number of pipes and the different heights within the network.
The velocities calibration process may affect compression values if ideal values are to be obtained across the entire network.

Table (11) : final flow and velocity of some of pipes

Velocity (ft/s)	**Flow (m^3/day)**	**Diameter (in)**	**Length (m)**	**Label**
10.39	19958	12	3	P-562
9.78	2088	4	27	P-421
9.74	-2079	4	8	P-501
9.72	4668	6	113	P-558
9.67	-8260	8	32	P-381
9.44	-8064	8	10	P-524
9.35	-499	2	41	P-321
9.07	4359	6	28	P-132
8.96	7652	8	29	P-331
8.79	-4222	6	35	P-372
8.73	-466	2	31	P-114
8.61	-460	2	28	P-396
8.55	-1826	4	17	P-229
8.3	-3985	6	13	P-506
8.27	-442	2	64	P-553
8.13	3907	6	101	P-514
8.12	3902	6	39	P-420
8.11	-1731	4	56	P-559
7.92	423	2	14	P-183
7.87	-3781	6	40	P-512
7.72	3711	6	19	P-505
7.65	3674	6	43	P-42
7.64	19994	12	6	P-551

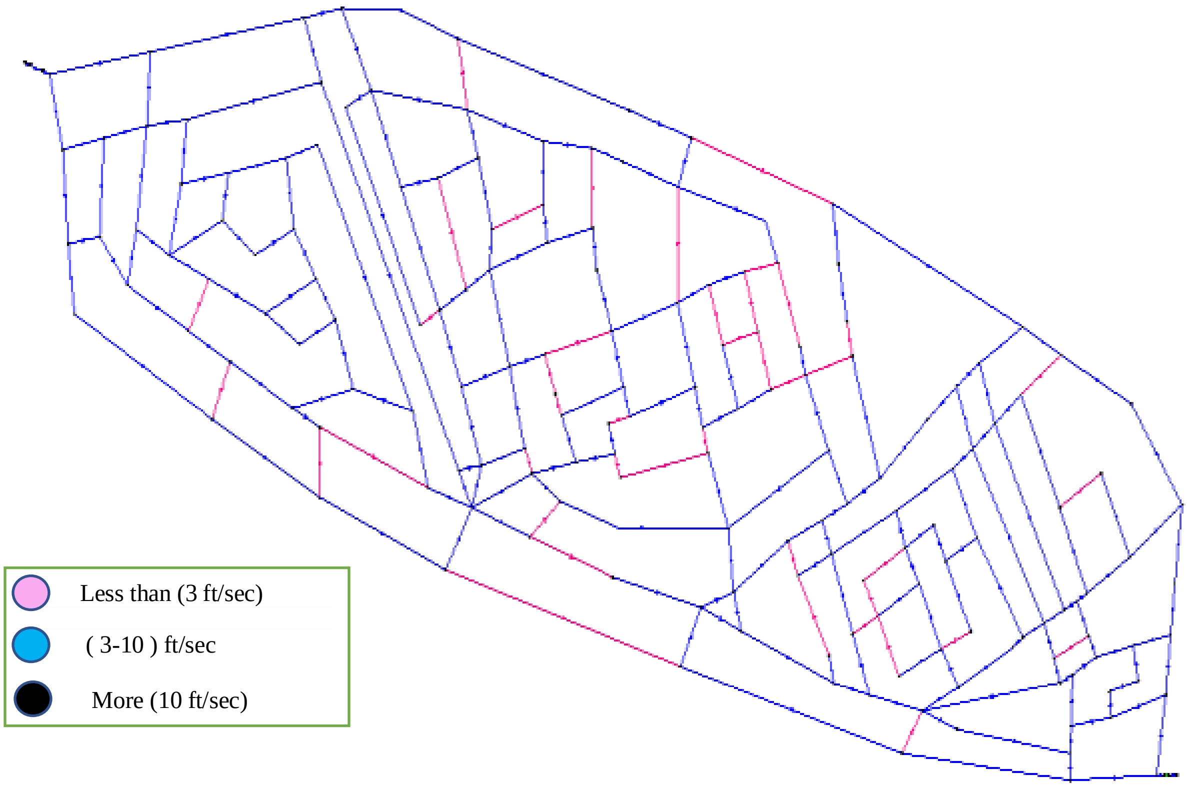

Figure (5): velocity of pipe

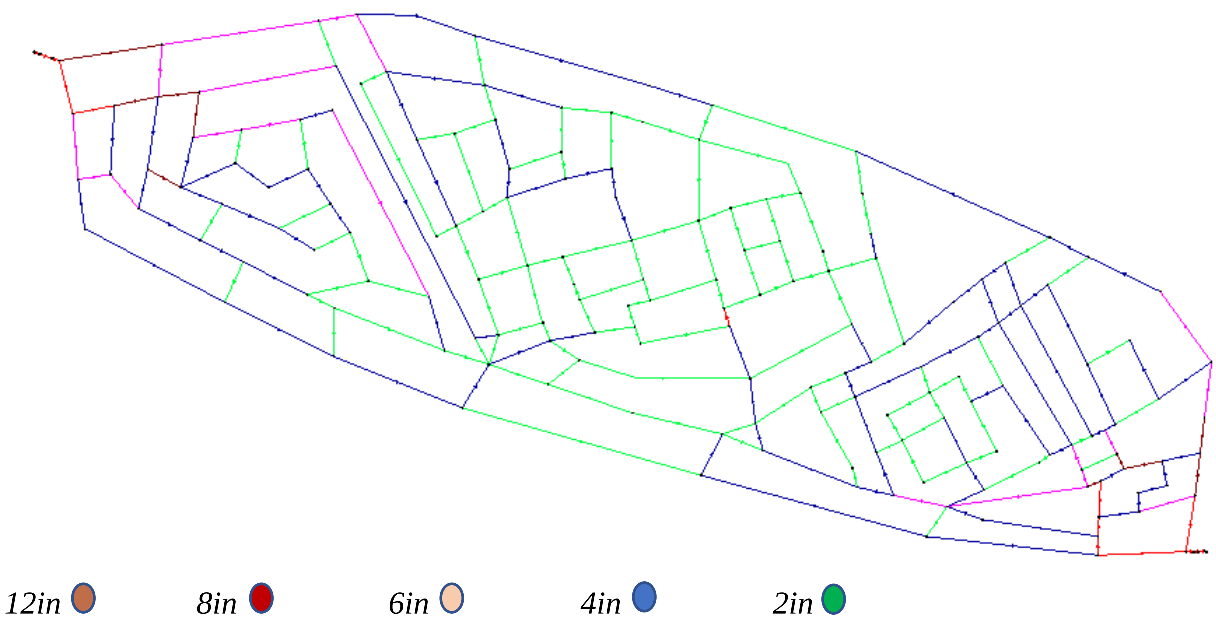

Figure (6): Diameter of pipes.

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