An-Najah National University
Faculty of Graduate Studies

HYDRAULIC PERFORMANCE OF PALESTINIAN WATER DISTRIBUTION SYSTEMS

(*JENIN WATER SUPPLY NETWORK AS A CASE STUDY*)

Prepared by

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Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Water and Environmental Engineering, Faculty of Graduate Studies, at An-Najah National University, Nablus, Palestine.

2003

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ACKNOWLEDGEMENTS

I wish to express my gratitude to my supervisor, Dr. Hafez Shaheen, for his efforts, useful suggestions, and encouragements, which provided valuable guidance.

Also I would like to acknowledge the advice and assistance of Dr. Anan Jayyousi of An-Najah National University, and a specific gratitude is given to Dr. Isam AL-Khatib of Birzeit University.

Specific gratitude is given to Eng. Abdel Fatah Rasem, at the Municipality of Jenin, for his valuable assistance; also specific recognition is given to Eng. Maher Abu Madi, Eng. Steffen Macke, Eng. Gada Al-Asmar for their valuable help.

A special word of thanks is extended to my family, father; mother; brothers and sisters.

Finally, I wish to thank all those who have helped me by one way or another during this research.

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LIST OF ABBREVIATIONS

DN	Nominal diameter.
l/c/d	Liter capita per a day.
m.a.s.l	Meter above sea level.
MCM	Million cubic meters.
MOPIC	Ministry of planning and international cooperation.
PCBS	Palestinian central bureau of statistics.
PDO	Pressure dependent outflow.
PECDAR	Palestinian economic council for development and reconstruction.
P.F	Peak factor.
PWA	Palestinian water authority.
S.I	International system.
UFW	Unaccounted for water.
U.S	United states.
WSCs	Water supplies companies.

Abstract

The design of municipal water distribution systems in Palestine is implemented by using universal design factors without taking into consideration the effects of local conditions such as intermittent pumping, which is a way of operating the water distribution systems in most cities of developing world. By this way the water systems are divided into several pressure zones through which water is pumped alternatively and provided a large number of homes with a high quantity of water in a shorter period. This way makes the using of the roof storage tanks is very efficient during the non – pumping intervals, so that the hydraulic performance of the water networks expected to be affected by affecting the pressure and velocities values.

To investigate the behavior of the water systems under the action of intermittent pumping, the Jenin water distribution network has been taken as a case study and a procedure of modeling the system as in reality depending on operational factors, ways of operating and managing the system, representing each cluster of houses by one consumption node, making control by check valves, modeling the system by using (WaterCad Program). The outputs show that the network is exposed to relatively high values of pressure and velocity, which have negative effects on the performance of the network. The comparison of pressure results and field measurements at specific locations shows a reasonable and small difference.

The modeling of the system as continuous supply system depending on assumptions considering with future water consumption, availability of water, overcoming the problems of high pressures by using pressure reducing valves at specific locations, and assuming steady state analysis, shows the ability of the existing system to serve the Jenin area and to cope the future extension. The output values of velocities are parallel reasonably to the assumed limits of velocities (0.1 m/s – 0.3 m/s) to avoid stagnation and quality water problems, also the pressure values are within the limits of the design pressures in the residential areas.

Further evaluation has been carried out to investigate the daily water consumption, daily peak factors and to study the variations of water levels in roof tanks under the conditions of continuous supply by implementing an experiment of monitoring daily water consumption for different consumers at different locations for a period of 15 days. The average daily peak factor was calculated to be 2.0, and a value of 75 l/c/d was recorded as average daily water consumption.

Studying the reaction of domestic water meter on air in the intermittent water supply networks over a two supply periods in two locations in the system by applying an arrangement consists of a regular and additional water meter, check valves and air release valve shows that the readings of the regular water meter are larger than the measurements of the additional water meter with a range of 5% - 8%. This difference depends on factors of location; consumer’s behavior and pressure drop in the system.

The evaluation study of the water hammer in the Jenin distribution system, which has been implemented to investigate the effects of this phenomena shows that the water hammer values increase by increasing the velocity of water in pipes, and the values of shock pressures were within the limits of the shock pressures in water pipes systems.

Chapter One

Introduction

1.1 General Background

The continuous and repeated deficiency in the performance of the Palestinian water supply networks became one of the most critical issues in the water supply sector that requires immediate action.

As the demand on water increases due to the population growth rate, and the increase in per capita consumption, the defect in the performance of the water network led to the negative influence in most of the socioeconomic sectors. This occurs because of the aged pipe system (especially in the old parts of the Palestinian cities)

Water distribution systems are designed to adequately satisfy the water requirements for a combination of domestic, commercial, industrial, and fire fighting purposes. The system should be capable of meeting the demands placed on it at all times and at satisfactory hydraulic performance [1]. It should enable reliable operation during irregular situations and perform adequately under varying demand loads [2].

In our region the design of water distribution systems is implemented by using universal design factors without taking into account the effects of local conditions, so that the design parameters should be modified to achieve water requirements.

Many sectors of water distribution systems in most cities of Palestine suffer from the deficiency of water supply quantities and sharp deficiency in the pressure, so that to achieve the consumer demand at satisfactory levels, it must improve and increase the efficiencies of the water distribution operating and management systems.

The availability of water makes it possible for pumping water to the consumers at 24 hours with a constant flow rate, if water is not available in sufficient quantities then it should be pumped for shorter time periods at higher flow rate to meet the demand of the consumers, and a storage tank in this case for the entire city is usually provided in order to provide storage where the pumping rate is higher than the demand at night times, and this storage can be used in the case that the pumping rate is below the needed demand , and to equalize the pressure in the network in the cases of pressure increasing.

The scarce source of water is a common problem of the Middle – East region, forcing people to collect water individually, by means of ground or /and roof tanks. These roof tanks satisfy the water demand during its high periods by providing storage space. By tapping water from their own tanks, the consumers there do not rely on the pressure in the distribution system, as long it is sufficient to provide refilling of the tank at certain period of the day. Unlike in continuous supply, this creates smaller range of hourly peak factors allowing fairly stable supply through the distribution pipes. Balancing of the actual demand is therefore done individually for each household, whereby replenishing of the volume will happen somewhere later for the consumers located faraway from the supplying points. Despite the risks of water contamination this way of water supply is still seen as the only possibility for even share of limited resources [3].

The water shortage and the conditions of topographic in most of Palestinian cities forces to divide the water distribution networks in the serving area into several pressure zones through which water is pumped alternatively. This procedure of operating was not considered in the design assumptions, and means that every zone, and so that the network will be under the action of intermittent pumping. This way makes the using of the roof storage tanks that are available at the roof of the houses is very efficient for storage water during the non-pumping intervals.

The above-mentioned way of operating the municipal water supply networks will affect the expected performance of the network by affecting the pressure values and the velocities. It also increases pipes breakage rates. The breakage in mains results from oscillating pressures due to providing a large number of homes with a high quantity of water in a short period [4].

This research is part of studies in which researchers study the performance of water distribution systems. This study is to investigate the state of the existing water distribution systems (Jenin water distribution system as a case study) and to evaluate the hydraulic performance of the supply network under varying conditions of supply.

1.2 Problem Statement and Hypothesis

The hypothesis of this research is that the performance of any water distribution system is strongly related to appropriate design assumptions and exercised management model.

This study intends to determine the extent to which the hydraulic performance of the Palestinian water networks (Jenin water distribution network as a case study) is affected by the intermittent supply, operational ways and management system.

The understanding of the performance of water supply networks and their behavior in our region taking into account the effects of local conditions, such as (intermittent pumping) in which the network is divided into several pressure zones and this way of pumping was not considered in the design process, will lead to appropriate design assumptions, and cost effective design for water supply networks.

To lead appropriate design, we must study the hydraulic parameters, the variations, and the relations between them and other factors, which control the performance of the water supply networks; also it must investigate the effects of local conditions and improve them for increasing the efficiencies of the water distribution systems.

In Palestine there is a need to evaluate the performance of the water distribution systems and to define the appropriate design requirements.

1.3 Objectives of the study

The main goal of this study is to evaluate the hydraulic performance of the water supply networks (Jenin water supply network as a case study) taking into account the effects of local operating conditions.

The detailed objectives of the study are the following:

1- Investigate the efficiencies of the existing water supply networks and identify the existing water supply problems.
2- Investigate the effects of local operating conditions (pumping, pressure zoning, management) on the hydraulic performance of the water supply networks.
3- Study the hydraulic parameters in the water distribution system (pressure, velocity), the relations between them and other factors such as the time.
4- Model the existing water supply system as an intermittent supply system, and as a continuous system in order to study the effects of the two models on the performance of the system.
5- Develop appropriate design parameters for water supply network, which lead to a better network operation under the action of intermittent pumping.

6- Study the variations of the water level in roof tanks and measured the water consumption each day for a certain period to derive the daily peak factors for different consumers.

1.4 Main components of the methodology of the study

1- The Jenin water distribution system and representative sectors in the network have been investigated as a case study.

2- Detailed information and maps of the Jenin water distribution system that are necessary to carry out the study have been provided by the municipality of Jenin, and a letter has been sent to the municipality of Jenin to explain the goals and the objectives of the study in order to contribute in the work and to have an approval.

3- Field measurements for the variations of the water levels in number of roof tanks for different consumers have been measured by periodic readings and these readings have been analyzed to study the change in the water level of the storage tanks and the water consumption in order to develop the daily peak factors for different consumers and calculate the average peak factor.

4- Field measurements, which have been done in previous studies in a pilot zone have been studied and investigated to get a better idea about the distribution system of Jenin city. The results of measurements carried out in the pilot zone used to determine the unaccounted for water (UFW) for the whole network and the consumption figures.

5- The existing water supply network has been modeled using a computer program (WaterCad) as in reality (intermittent water system) depending on the existing situation of operating the different parts of the network.

6- The water supply system of Jenin city has been redesigned as a continuous supply depending on fixed pattern, assuming the availability of water sources, and the using of pressure-reducing valves to reduce the high pressures in the system.

1.5 Literature Review

Several researches have been made to study the behavior of water distribution systems, and to reach an optimal solutions and assumptions in order to improve the hydraulic performance, cost effective, and to increase the efficiencies of the water supply networks.

Jarrar H (1998) studied the hydraulic performance of water distribution systems under the action of cyclic pumping; the results show that the network under consideration is exposed to relatively high-pressure values throughout. The velocity of the water through the network attained also high values. These high values of pressure and velocity have negative effects on the performance of the network [4].

Masri M (1997) studied the optimum design of water distribution networks. A computerized technique was developed for the analysis and optimal design of water distribution networks. The results show that the selection of the hydraulic restrictions should be reasonable and reflects the real capacity of the water distribution system [5].

Naeeni S (1996) developed a computer program, which enables to obtain the optimum design of various kinds of water distribution networks so that all constraints such as pipe diameters, flow, velocities, and nodal pressures are satisfied [6].

AL-Abbase R (2000) showed that the optimum design of water distribution systems is a theoretical purpose, and cannot be achieved completely. His study dealt with evaluation the performance of five big sectors in Mosul city. A computerized technique was developed to obtain the optimum design, which achieves the demands of the consumers at lowest cost using the commercial pipes [7].

James, Liggest and Chen (1994) made a study about distribution systems. Data about pressure and flow rate were obtained by continuous monitoring of their system. Transient analysis, time lagged calculations and inverse calculations were applied as a tool for calibration and leak detection [8].

James E.Funk (1994) studied the behavior of water distribution systems during transient operations. He concluded that during transient operations, pressure much higher than steady state values could develop. The causes of transient operation can be a result of pumps stopping or starting, valves opening or closing, and system startup or shut down [2].

Genedese,Gallerano and Misiti (1987) were involved in the optimal design of closed hydraulic networks with pumping stations and different flow rate conditions. Their study had two aims in the design of water distribution systems. The first is minimum values of peizometric heads at the nodes. The second is maximum values of velocities in the branches [9].

Perez,Martinez and Vela(1993) suggested a method for optimal design by considering factors other than pipe size. Pressure reducing valves were suggested to reduce the pressure in the down stream pipes [10].

Vairavamoorthy, Akinpelu,Lin and Ali (2000) suggested a new method of design sustainable water distribution systems in developing countries. They developed a modified mathematical modeling tool specifically developed for intermittent water distribution systems. This modified tool combined with optimal design algorithms with the objective of providing an equitable distribution of water at the least cost forms the basis of this new approach. They also develop guidelines for the effective monitoring and management of water quality in intermittent water distribution systems. A modified network analysis program has been developed that incorporates pressure dependent outflow functions to model the demand [11].

Battermann A and Macke S (2001) developed a strategy to reduce technical water losses for intermittent water supply systems in AlKoura District-Jordan. This work describes the development of a practical simulation model for the intermittent supply of water. Standard software is used to implement the model: Arc View GIS and the free hydraulics software EPANET. The model has been applied to the water supply network of the village Judayta (AlKoura District) and successfully calibrated with a loggin campaign [12].

Vairavamoorthy and Lumbrs (1998) studied the leakage reduction in water distribution systems depending on optimal valve control. The inclusion of pressure- dependent leakage terms in network analysis allows the application of formal optimization techniques to identify the most effective means of reducing water losses in distribution systems. They describe the development of an optimization method to minimize leakage in water distribution systems through the most effective settings of flow reduction valves [13].

M.Y.Abdel-Latif (2001) assess the hydraulic behavior and evaluate the global performance of Bani Suhila City water distribution network by developing a computer model for a distribution network under actual existing and alternative conditions, especially involving intermittent supply. The performance of the network was evaluated from a hydraulic point view using a systematic, engineering approach, and the results indicated that the performance was adequate and the system provided an acceptable level of service based on pressure considerations [14].

Yan J (2001) modeling contaminant intrusion into water distribution systems. He develops measures to minimize the risk of contamination, and improve the management of water quality in drinking water distribution systems. As a result of his research, a contaminant ingress model will be developed, consisting of three main components: 1. A pipe condition assessment to evaluate the condition of the pipe. 2. A contaminant seepage component that simulate contaminant flow. 3. A contaminant ingress component to predict the pollution prone areas where contaminants may enter into the pipes of water distribution systems [15].

Saleh A (1999) made a study, considering with the internal evaluation of Palestinian water industry. His study analyses the performance of Palestinian water supply companies (WSCs). The study shows that large-scale Palestinian water supply companies perform much better than small-scale companies. Moreover, the delegated public water supply companies perform better than the municipal water departments [16].

1.6 Study Structure

This research consists of seven chapters including the introduction.

In chapter two, description of Palestinian water resources and the state of the existing water distribution systems, also the challenges to be faced the water sector in the Palestinian territories.

Chapter three, details on the water distribution systems, types of the supply systems, methods of distribution, components and principles of pipe network hydraulics in addition to the main hydraulic design parameters were investigated and studied.

Chapter four contains details on the concept of intermittent water supply systems, the problems of the intermittent systems, comparison between the continuous supply and the intermittent systems, and the proposed methods of modeling the intermittent water supply systems.

Chapter five describes the state of the jenin water distribution network, theoretical background, existing situation, storage facilities, pipes and materials, valves and regulating devices, tertiary network and ways of delivery to customers.

Chapter six, modeling the jenin water distribution network as an intermittent supply system and continuous supply system, studying a pilot zone in the network to develop the water consumption and unaccounted for water (UFW), studying the variations in levels of roof tanks to derive the peak factors, and analyze the outputs of these works, study the effects of air release valves at customer meters, and evaluation the effects of water hammer phenomena in the system.

In chapter seven, results, and logical conclusions of modeling the network as intermittent and continuous supply system that will lead to a better network performance are stated.

Chapter Two

Palestinian Water Resources

2.1 Introduction

Present water supplies in the palestinian regions are neither adequate to provide acceptable standards of living for the palestinian people, nor sufficient to facilitate economic development as a result of the limitation on supply and restrictions on developing new water resources and supply infrastructure.

Current average daily consumption rate in the West Bank for the 86% population that is served from the piped system is only about 50 liters/person, while in Gaza Strip, despite the fact that 98% of the population have access to a piped water supply with an average per capita consumption of 80 l/c/d, considering the quality of water is only 14% of the recommended world health organization (WHO) minimum.

The limited water resources in the Palestinian governorates face the challenge not only to supply the various water sectors with their water demand, but also has to secure water to meet the increasing needs for people in the future.

The present situation in the water sector on Palestine and the challenges to be faced are summarized below:

- Water resources in the region are extremely scarce and disputable.

- Water demand is continuously growing.
- Water supply and sanitation services are inefficiently delivered and inadequate.
- Tariffs are generally inadequate.
- Consumption and water losses are excessive.
- Insufficient water harvest activities.
- Wastewater is unavailable, inadequate or not well functioning.

The Israeli occupation of Palestinian land had adverse impacts in many respects. In the water sector, these have included the illegal control, by Israeli military order, of all water resources in Palestine, including the licensing, operation, and administration of wells, prohibition of new well drilling without authorization, over extraction from and degradation of aquifers, inequitable allocation of water between Israeli settlements and Palestinian municipalities [18].

The one fact that is indisputable, however, is that the Palestinians have no decision making power in their own water future [19].

2.2 Main Water Resources in Palestine

The water resources of Palestine include:

1.Ground water: is the main source of water in Palestine.

- West Bank Mountain Aquifer: is the main source of water. It is mainly composed of Karstic Limestone and Dolomite formations of the Cenomanian and Turonian ages and is mostly recharged from rainfall on the west bank mountains of heights greater than 500 meters above mean sea level. The annual renewable freshwater of this aquifer ranges from 600 MCM to 650 MCM [18].

The west bank aquifer system has three major drainage basins:

1- The western basin, supplied and recharged from the West Bank mountains, located within the boundaries of the West Bank and 1948 occupied territories [20].
2- The northeastern basin, which is located inside the West Bank near Nablus and Jenin and drains into the Eocene and Cenomanian–Turonian aquifer under the north of the west bank [20].
3- The eastern basin, which is located within the West Bank and the springs from which represent %90 of spring discharge in this area [20].

West Bank Palestinians exploit currently a mere 115 MCM – 123 MCM, The other amount is exploited by the Israelis [20]. The existing situation and the present water crisis is not chiefly one of insufficient supply, but of unquotable and uneven distribution.

- Gaza Coastal Aquifer: it is part of the coastal aquifer, has been continuously over-pumped for quite some time in large part to serve the high population. Its annual safe yield is 60 MCM - 65 MCM [21].

The water table has been pumped to far below the recharge rate, and there is evidence of deteriorated water quality of the aquifer [20].

The main Gaza Aquifer is a continuation of the shallow sandy/sandstone coastal aquifer, which is of the pliocene-pleistocene geological age. About

2200 wells tap this aquifer with depths mostly ranging between 25 and 30 meters [21].

Table (2.1)

*Ground water resources in Palestine (in MCM /year)

Basin	Israeli consumption	Palestinian consumption from wells	Palestinian consumption from springs	Quantities available for development	Total estimated yields of aquifers
Western	340	20	2		362
Northeastern	103	25	17		145
Eastern	40	24	30	78	172
Gaza aquifer					55
Total	483	69	49	78	734

***Data taken from Article 40 of Oslo B Agreement [24] .**

2.Jordan River

It is the only river, which the west bank has access to. The west bank uses nothing of its water. The average annual flow of this river is about 1200 MCM [22]. The riparian of the Jordan River are Lebanon, Syria, Palestine and Jordan. Only three percent of the Jordan River's basin falls within the land pre 1967 boundaries.

3.Springs

There are 297 springs in the West Bank, 114 out of which are considered to be the main ones with substantial yield quantities. Usually there are fluctuations in the yield of some of these springs in the different years, depending on the rainfall quantities, and thus the recharge to ground water. However, their average annual yield is estimated to be around 60.8 MCM /year [23].

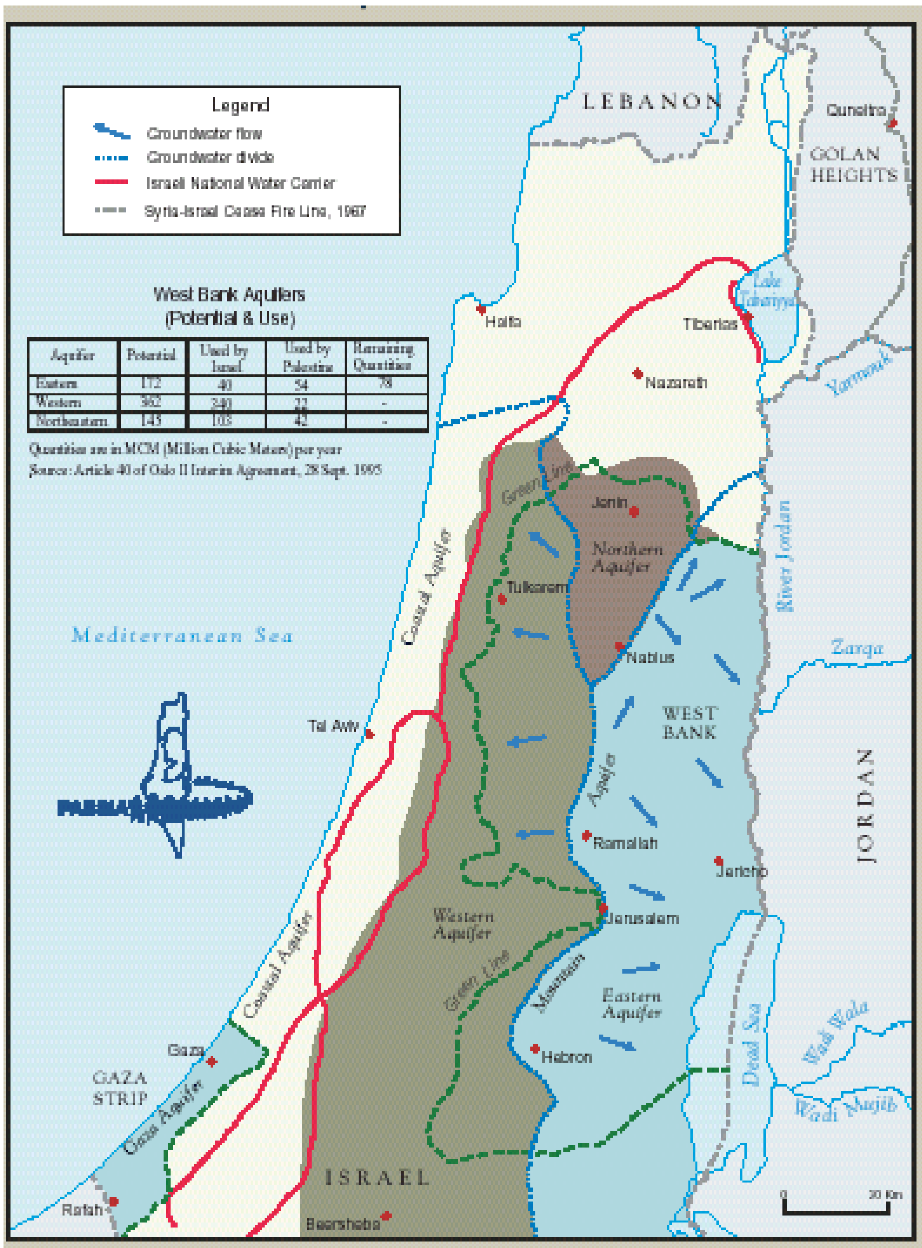
4.Non-conventional water resources-Cisterns

Cisterns are of major importance in the west bank governorates. The water quantities in the cisterns are used mainly for domestic purposes. The typical form of these cisterns is to collect water from the roofs of the buildings in the winter season and store it in an underground hole in most of the cases [20].

Cisterns act as a major source of domestic water supply in the localities that do not have water supply networks. It is estimated that 6.6 MCM is utilized from the cisterns. In localities where water networks exist, cisterns still act as another “good” source of domestic water supply [25].

Map (2.1)

Water resources in Palestine



Aquifer	Potential	Used by Israel	Used by Palestine	Remaining Quantities
Eastern	172	40	54	78
Western	362	340	22	-
Northeastern	145	103	42	-

Adapted from: 'Water and War in the Middle East' Info Paper No.5 , July 1996,
Center for Policy Analysis on Palestine/ The Jerusalem Fund, Washington D.C.
The Aquifers' boundaries are approximate, Adapted from Gvirtzman, 1994

2.3 Water supply

Around 88% residing in 345 localities in the West Bank have piped water supply systems, while 12% of inhabitants residing in 282 localities do not have the service. In terms of localities (i.e., towns and villages), 55% of the localities in the west bank have piped water supply systems and 45% are without this service [20].

2.4 Water Demand

The indicator for measuring the level of water consumption is the amount of water consumed per capita per day (l/c/d). Water consumption is a function of availability, religion, climate conditions, and affordability. Another indicator used in measuring the level of water consumption is the quality of delivered water. In general, water utilities have to follow WHO standards for domestic water [16].

The total water use by municipal and industrial sectors in Palestine during the year 1999 was estimated to be 101 MCM. An amount of 52 MCM was used in the West Bank , whereas a total of approximately 49 MCM was used in the Gaza Strip . The water consumed by the agricultural sector is estimated to be 172 MCM [26].

2.5 Future potential water demand

A demand of 432 MCM is projected for the year 2020. This estimation is based on WHO minimum and average domestic water consumption standards of 100 l/c/d and 150 l/c/d [20]. The estimated agriculture water demand by the year 2020 is about 353 MCM [26].

If the projections of Palestinian demand are based on equal municipal and industrial Israeli per capita water consumption, then the total municipal and industrial Palestinian water demand will be 852 MCM for the year 2020 [27].

The Palestinian water sector should achieve an amount of around 785 MCM/year by the year 2020. This amount is about three times the available supply at present, but at the same time not higher than the Palestinian water rights from the renewable water resources [20].

2.6 Palestinian water supply industry indicators

Eight performance indicators were distinguished as water severs indicators, for the Palestinian water supply industry. There are [16]:

1. Low service timing: 3 – 7 days per week
2. Very low water consumption: 35 – 120 l/c/d
3. High level of UFW: 22.3% - 50.4%
4. Wide range of the level of productivity: 6.5 – 12.9 staff/1000 connection
5. Very wide range of an average tariff: 0.19 – 1.69 $/ m^3$
6. Very wide range of price of new connections: 86 – 627 $/connection
7. Low figures of cost recovery: 62% - 188%
8. Reasonable bill collection efficiency: 80% - 175%

The strategies proposed to overcome the problem of water crisis can be summarized as following:

- The Palestinian water rights should be secured.
- To make the water institutions are able to govern and manage water effectively it should be strengthen.
- Implement a combination of water supply and demand measures.
- Agriculture sector should be reform and modernize.
- Protect water quality and enhance the sanitation sector.
- Generate knowledge and help in the uptake of existing knowledge in relation to water use efficiency and water quality [20].

Chapter Three

Water Supply Systems

3.1 Introduction

The objective of water distribution systems is to deliver water of suitable quality to individual users in an adequate amount and at a satisfactory pressure. It should be capable of delivering the maximum instantaneous design flow at a satisfactory pressure.

The water distribution networks should meet demands for potable water. If designed correctly, the network of interconnected pipes, storage tanks, pumps, and regulating valves provides adequate pressures, adequate supply, and good water quality throughout the system. If incorrectly designed, some areas may have low pressures, poor fire protection, and even health risks [32].

The water distribution networks, which is typically the most expensive component of a water supply system, is continuously subject to environmental and operational stresses which lead to its deterioration. Increased operation and maintenance costs, water losses, reduction in the quality of service and reduction in the quality of water are typical outcomes of this deterioration [33].

3.2 Types of Water Distribution Systems

3.2.1 Branching Systems

This type of distribution networks is the most economical system, and common in the developing countries due to its low cost. In this system, when there is need for developing the network, new branches follow that development and new dead ends will be constructed.

The branching systems have some disadvantages such as the following:

- The dead ends cause accumulation of sediments, which result in increasing contamination and health risks.
- The maintenance operation upstream of the network will prevent water to reach the down stream due to the interruption of the whole area of maintenance.
- The fluctuating demand causes high-pressure oscillations.

3.2.2 Grid Systems

There are no dead ends in this type of distribution networks. The maintenance operation did not effect the interruption on the whole area as in the branching system, this type of layout is highly desirable because, for any given area on the grid, water can be supplied from more than one direction. This results in substantially lower head losses than would otherwise occur and, with valves located properly, allows for minimum inconvenience when repairs or maintenance activities are required. The whole area is covered with mains that form the grid system.

3.2.3 Ring Systems

The mains form a ring around the area under service, secondary pipes connecting the mains and delivering the water to the consumers.

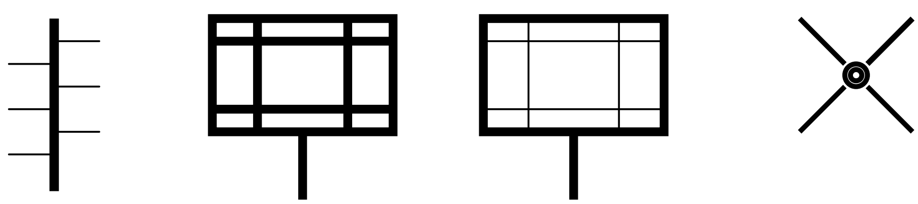
3.2.4 Radial Systems

The area under service in the radial system is divided into subareas , and a storage tank is placed in the center of each subarea to supply water to the consumer.

The following figure shows the types of the water distribution systems

Figure (3.1)

Types of the water distribution systems



Branch System **Grid System** **Circular System** **Radial System**

3.3 Methods of Water Distribution

3.3.1 Gravity Distribution

This is possible , when the source of supply water is at some elevation above the city , so that sufficient pressure can be maintained in the mains for domestic and fire services . The advantage of this method of distribution is saving power that needed for pumping.

3.3.2 Distribution by Pumping Without Storage

In this method of distribution, water is pumped directly into the mains with no other outlet than the water actually consumed.

The pumping rate should be sufficient to satisfy the demand. This method is the least desirable way of distribution; the power failure leads to complete interruption in water supply.

An advantage of direct pumping is that a large fire service pump may be used which can run up the pressure to any desired amount permitted by the construction of mains [28].

3.3.3 Distribution by means of pumps with storage

In this method an elevated tanks or reservoirs are used to maintain the excess water pumped during periods of low consumption, and these stored quantities of water may be used during the periods of high consumption.

This method allows fairly uniform rates of pumping and hence is economical [28].

3.4 Principles of Pipe Network Hydraulics

Flow in a pipe network satisfies two basic principles, conservation of mass, and conservation of energy.

3.4.1 Conservation of Mass- Flows Demands

Conservation of mass states that, for a steady state system, the flow into and out of the system must be the same [29]. This principle is a simple one, at any node in the system under incompressible flow conditions; the total volumetric or mass flow in must equal the mass flow out (less the change in storage).

This relationship holds for the entire network and for individual nodes.

One mass balance equation is written for each node in the network as:

$$\sum Q_{in} - \sum Q_{out} = Q_{demand} \qquad (3.1)$$

Where: $\sum Q_{in}$: flows in pipes entering the node.

$\sum Q_{out}$: flows in pipes exiting the node.

Q_{demand} : the user demand at that location.

Separating the total volumetric flow into flows from connecting pipes, demands, and storage, we obtain the following equation [32]:

$$\sum \boldsymbol{Q}_{\textbf{in}}\ \Delta \mathbf{t} = \sum \boldsymbol{Q}_{\textbf{out}}\ \Delta \mathbf{t} + \Delta \cancel{\mathbf{V}}_{\mathbf{S}} \tag{3.2}$$

Where : $\sum Q_{\text{in}}$: the total flow into the node.

$\sum Q_{\text{out}}$: the total demand at the node.

$\Delta \cancel{V}_S$: is the change in the storage.

Δt : is the change in time.

The continuity equation at node *j* can be expressed as following :

$$\sum_{i=1}^{i=NP_{(j)}} Q_{ij} - C_j = 0 \tag{3.3}$$

Where: $\sum Q_{ij}$: is the algebraic sum of the flow rates in the pipes meeting at the node j .

C_j : is the external flow rate at node j.

$NP_{(j)}$: is the number of pipes meeting at junction j.

3.4.2 Conservation of Energy

It is the second governing equation that describes the relationship between the energy loss and pipe flow. The head losses through the system must balance at each point. For pressure networks, this means that the total head loss between any two nodes in the system must be the same regardless of what path is taken between two points.

The head loss must be sign consistent with the assumed flow direction (gain head when proceeding opposite the direction of flow, and lose head when proceeding with the flow) [32].

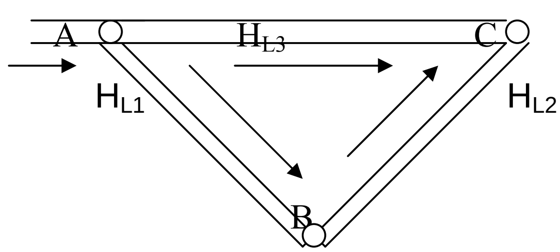
As shown in the figure (3.2) below, the combined head loss around a loop must equal zero in order to achieve the same hydraulic grade that was started with.

Loop from A to A:

$$0 = H_{L1} + H_{L2} - H_{L3} \qquad (3.4)$$

Figure (3.2)

Conservation of Energy



3.5 The Energy Equation

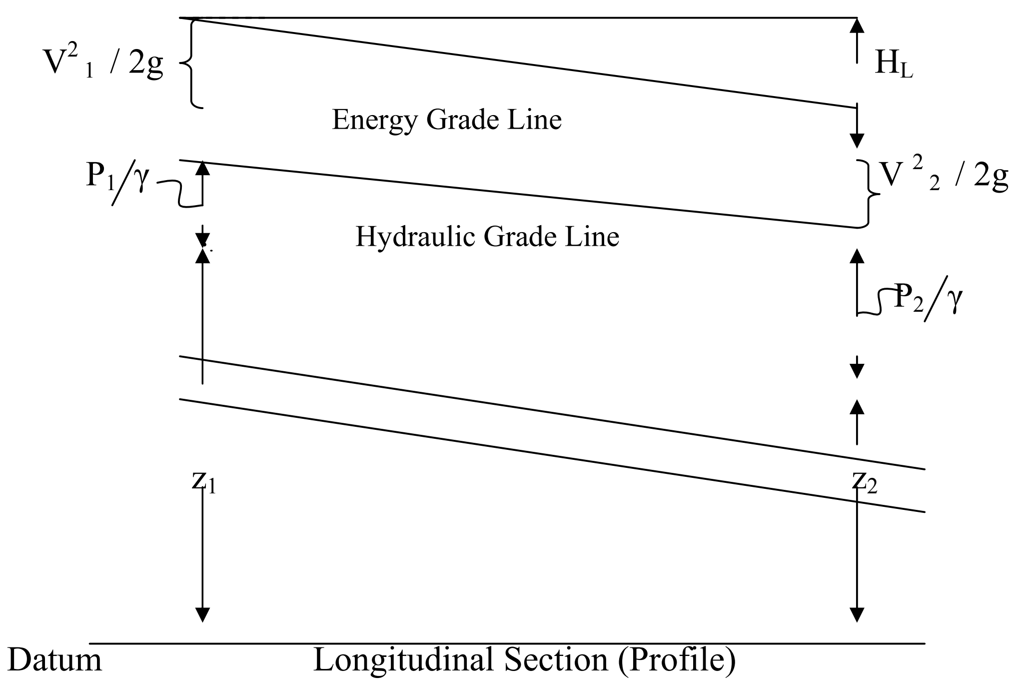
The Energy equation is known as Bernoulli's equation [30]. It consists the pressure head, elevation head, and velocity head. There may be also energy added to the system (such as by a pump), and energy removed from the system (due to friction). The changes in energy are referred to as head gains and head losses.

In the hydraulic applications, energy values are often converted into units of energy per unit weight resulting in units of length.

Balancing the energy across any two points in the system. The energy equation will be as follow:

Figure (3.3)

The Energy Principle



$$P_1 / \gamma + z_1 + V^2_1 / 2g + H_G = P_2 / \gamma + z_2 + V^2_2 / 2g + H_L \qquad (3.5)$$

Where : P : is the pressure (Ib/ft^2 or N/m^2)

γ : is the specific weight of the fluid (Ib/ft^3 or N/m^3)

z : is the elevation at the centroid (ft or m)

V : is the fluid velocity (ft/s or m/ s)

g : is gravitational acceleration (ft/s^2 or m/ s^2)

H_G : is the head gain, such as from a pump (ft or m)

H_L : is the combined head loss (ft or m)

3.6 Energy Losses

There is a combination of several factors that cause the energy losses. The main reason of the energy loss is due to internal friction between fluid particles traveling at different velocities. The movement of any fluid through a conduit results in a resistance to flow and this resistance or energy loss is referred to as friction .

The other reason causes energy loss is due to localized areas of increased turbulence and disruption of the stream lines such as disruptions from valves and other fittings in a pressure pipe [32].

The rate of losing energy a long a given length is called friction slope .It is usually presented as a unit less value, or in units of length per length (ft/ft , m/m , etc.)

3.6.1 Friction Losses

Hazen-Williams equation and the Darcy-Weisbach equation are the most commonly methods used for determining head losses in pressure piping systems.

The assumptions for a pressure pipe system can be described as the following:

- Pressure piping is almost always circular, so the area of flow, wetted perimeter, and the hydraulic radius can all be directly related to diameter.

- Through a given length of a pipe in a pressure piping system, flow is full, so the friction slope is constant for a certain flowrate. This means that the energy grade and hydraulic grade drop linearly in the direction of flow.

- The velocity must be constant, since the flowrate and cross-area are constant. This means that the hydraulic grade line (the sum of the pressure head (P/γ), and the elevation head (z)), and the energy grade line (the sum of the hydraulic grade line and the velocity head ($v^2 / 2g$)).

Equations that represent the friction losses associated with the flow of a liquid through a given section can all be described by the following general equation:

$$V = KCR^X S^Y \tag{3.6}$$

Where: V: mean velocity.

C : flow resistance factor

R : hydraulic radius (A/P_w)

$R_{Circular}$: $\dfrac{\pi.D^2 / 4}{\pi .D} = \dfrac{D}{4}$

P_w : wetted perimeter (ft or m)

A: cross sectional area (ft^2 or m^2)

D : pipe diameter (ft or m)

S : friction slope

x , y : exponents

k : factor to account for empirical constant , unit conversion, etc.

3.6.1.1 Hazen – Williams equation

The most frequently equation used in the design and analysis of water distribution networks, it was developed by the experiment and used only for water within temperatures normally experienced in potable water systems.

$$V = KCR^{0.63}S^{0.54} \qquad (3.7)$$

Where : V : mean velocity (ft/s or m/s)

K : 1.32 for U.S. standard units , or 0.85 for S.I. units

C : Hazen –Williams roughness coefficient.

R : Hydraulic radius of the pipe in meters

S : the dimensionless slope of the energy grade line

3.6.1.2 Darcy – Weisbach (Colebrook-White) Equation

This equation is a theoretically based equation , and its common use in the analysis of pressure pipe systems. For any flowrate and any incompressible fluid . It can be applied to open channel flow (free-surface flow)

$$V = \sqrt{\frac{8g\ RS}{f}} \qquad (3.8)$$

Where : V : flow velocity (ft/s or m/s)

g : gravitational acceleration (ft/s^2 or m/ s^2)

R : hydraulic radius (ft or m)

f : Darcy-Weisbach friction factor

S : Friction slope

The Darcy – Weisbach friction factor, *f,* can be found using the Colebrook equation as follows:

$$\frac{1}{\sqrt{f}} = -2 \log \left[\frac{K}{14.8\,R} + \frac{2.51}{R_e \sqrt{f}} \right] \qquad (3.9)$$

Where : K : roughness height (ft or m)

R_e : Reynolds number

3.6.1.3 Reynolds Number

It is an index used to classify flow as either laminar flow (it is a flow characterized by smooth flow lines) or turbulent flow (it is a flow characterized by the formation of eddies within the flow)

$$R_e = \frac{4\,V\,R}{\nu} \qquad (3.10)$$

Where: R_e : Reynolds number.

V : Mean velocity (ft/s or m/s)

R : Hydraulic radius (ft or m)

ν : Kinematics viscosity (ft^2 / s or m^2 /s)

If the number below 2000, flow is laminar. The number is above 4000 the flow is turbulent. Between 2000 and 4000, may be either turbulent or laminar flow.

3.6.2 Minor Losses

Minor losses are a result of localized areas of increased turbulence and are frictional head losses, which cause energy losses within a pipe. A drop in the energy and hydraulic grades caused by valves, meters, and fittings, the value of these minor losses is often negligible relative to friction and for long pipes, and they are often ignored during analysis.

Minor head losses (also referred to as local losses) can be associated with the added turbulence that occurs at bends, junctions, meters, and valves. The importance of such losses will depend on the layout of the pipe network and the degree of accuracy required.

The resulting head loss is computed from the following equation:

$$H_m = \frac{K\,V^2}{2g} \qquad (3.11)$$

Where : H_m : minor loss (ft or m)

K : minor loss coefficient for the specific fitting .

V : velocity (ft/s or m/s)

g : is gravitational acceleration (ft/s^2 or m/s^2)

3.6.3 Water Hammer

When the velocity of flow in a pipe changes suddenly , surge pressures are generated as some , or all , of the kinetic energy of the fluid is converted to potential energy and stored temporarily via elastic deformation of the system. As the system rebounds and the fluid returns to its original pressure, the stored potential energy is converted to kinetic energy and a surge pressure wave moves through the system. Ultimately , the exess energy associated with the wave is dissipated through frictional losses . This phenomenon , generally known as “water hammer” , occurs most commonly when valves are opened or closed suddenly , or when pumps are started or stopped . The excess pressures associated with water hammer can be significant under some circumstances.

The maximum pressure surge caused by abruptly stopping the flow in a single pipe is given by :

$$a = \frac{4660}{[\,1 + Kd/Et\,]^{0.5}} \qquad (3.12)$$

Where: *k* : bulk modulus of the fluid, pounds per square inch

d : internal diameter of the pipe , inches

E : modulus of elasticity of the pipe materials, pounds per square inch.

t : thickness of the pipe wall, inches

The magnitude of the maximum potential water hammer pressure surge as illustrated by the above equation is a function of fluid velocity, and the pipe material . In water distribution systems , water hammer is usually not a problem because flow velocities are typically low , when higher than normal flow velocities are expected , consideration should be given to the use of slow-operating control valves, safety valves , surge tanks, air chambers, and special pump control systems.

3.7 Hydraulic Design Parameters

The main hydraulic parameters in water distribution networks are the pressure and the flowrate , other relevant design factors are the pipe diameters , velocities , and the hydraulic gradients [5].

3.7.1 Pressure

The pressure at nodes depends on the adopted minimum and maximum pressures within the network, topographic circumstances , and the size of the network [5].

The minimum pressure should be maintained to avoid water column separation and to ensure that consumers demands are provided at all times. The maximum pressure constraints results from service performance requirements such fire needs or the pressure –bearing capacity of the pipes , also limit the leakage in the distribution system , especially that there is a direct relationship between the high pressure and the increasing of leakage value in the system.

3.7.2 Flowrate

It is the quantity of water passes within a certain time through a certain section.

Velocity is directly proportional to the flowrate . for a known pipe diameter and a known velocity , the flowrate through a section can be estimated.

Low velocities affect the proper supply and will be undesirable for hygienic reasons (sediment formation may cause due to the long time of retention).

The effect of the velocity on the diameters of pipe system can be observed from the following equation :

$$V = \frac{4Q}{\pi . D^2} \qquad (3.13)$$

$$D = \sqrt{\frac{4Q}{\pi . V}} \qquad (3.14)$$

Where : D : diameter of the pipe (m)

Q : discharge (m^3 /sec)

V : velocity (m/sec)

From the above equation it is clear that the velocity increasing should decrease the diameter value.

Chapter Four

Intermittent water supply systems

4.1 Introduction

The available water sources through the world are becoming depleted and this has brought into focus the urgent need for planned action to manage water resources effectively for sustainable development.

The problem of water scarcity in urban areas of developing countries is of particular concern and as the water quantity available for supply generally is not sufficient to meet the demands of the population, water conservation measures are employed [11].

Providing a water supply for a community involves tapping the most suitable source of water, ensuring that it is safe for domestic consumption and then supplying it in adequate quantities.

The world health organization defines [36]. :

Safe water as; water that does not contain harmful chemical substances or micro-organisms in concentrations that cause illness in any form, and adequate water supply as; one that provides safe water in quantities sufficient for drinking, and for culinary, domestic and other household purposes so as to make possible the personal hygiene of members of the household. A sufficient quantity should be available on a reliable, year-round basis near to, or within the household where the water is to be used.

One of the most common methods of controlling water demand is the use of intermittent water supplies, usually by necessity rather than design. It has been widely reported in the literature that the majority of water supply systems in developing countries are intermittent.

It is of interest to note that 91% of systems in South East Asia are intermittent as reported by WHO survey [31]. Practically all-Indian cities are reported to operate intermittent systems [34].

The design of water distribution systems in general has been based on the assumption of continuous supply. In most developing countries water supply is not continuous but intermittent, and this could have been foreseen at the design stage. This has resulted in severe supply, pressure problems in the network and great inequities in the distribution of water.

Most design engineers in the developing world are aware that their approach to design is incorrect, but argue there is no alternative since there are no proper design tools developed specifically for intermittent systems [11].

It is evident from literature surveyed that the design of distribution networks operating intermittent supplies has in general been based on the assumption of continuous supply, the concepts and methods used are identical with those used in the developed countries [35].

4.2 Intermittent supply

An important component of a water supply system is the distribution network, which conveys water to the consumer from the sources. These systems constitute a substantial proportion of the cost of a water supply system, in some cases as much as half the overall cost of the system [35].

The design of supply systems in most of the developing regions based on the assumption of direct supply, although most of these systems are intermittent systems, which result in severe supply, pressure losses and great inequities in the distribution of water.

The problems of the intermittent supply systems:

- Overall shortage of water.
- Insufficient pressure in the distribution system (several areas in the network had zero pressure)
- Inequitable distribution of the available water.
- Very short duration of supply.

A serious problem arising from intermittent supplies, which is generally ignored, is the associated high levels of contamination. This occurs in networks where there are prolonged periods of interruption of supply due to negligible or zero pressures in the system. The factor that is most related to contamination is duration of supply [35].

Both continuous and intermittent water distribution systems might suffer from the contaminant intrusion problem, and the intermittent systems were found more vulnerable of contaminant intrusion [15].

As reported by several studies, the disadvantages of the intermittent supply systems can be summarized as follows:

- Systems do not operate as designed.
- Reservoir capacities are underutilized.
- There is frequent wear and tear on valves.
- More manpower is needed.
- Contaminated water requires consumer treatment.
- High doses of chlorine are needed.
- Over sizing the network is needed to supply the necessary quantities in a shorter time.
- Consumers have to pay for storage and pumping.
- Water meters malfunction, which can lead to a loss of revenue and customer disputes.
- In case of fire, immediate supply is unavailable.

4.3 Modeling of direct (continuous) supply systems and intermittent supply systems

4.3.1 Modeling of Direct (continuous) supply systems

In the continuous supply systems, water is conveyed through the distribution network continuously without interruptions. The consumers use water at any time without any need for individual roof and or ground storage tanks [3].

The main factors required to achieve direct water supply are summarized as follows:

- Enough water at source: to meet consumer's requirements for water (the demand increases due to availability of water)
- A good and reliable distribution network: to guarantee enough water with acceptable pressure to all consumers.
- Effective system parameters: capable pump stations, and suitable pie diameters.
- Successful monitoring policy: to discover any interruptions, and to detect damaged pipes early as possible, to reduce leakage.

Operating of system components, pumps and reservoirs, in the continuous supply systems is a result of consumers needs: with reduced demand in the night periods, pumps may operate at lower level and balancing reservoirs may be refilled, whereas during the maximum demand periods, the pumps will operate at their maximum capacity and the reservoirs will supply parts of the distribution network.

The water distribution network in the continuous supply systems should be designed to wish stand the range of pressures corresponding to the minimum and maximum supply conditions.

In the continuous supply systems, the hydraulic relation between the demand and supply water is clear. The demand in the nodes or nodal water demand is the water consumption multiplied by the number of residents living around. The average demand will be subjected to hourly variations, which mean the demand pattern based on the differences in living standards, industrial water use, etc.

4.3.2 Modeling of Intermittent supply systems

The regime of intermittent water supply, is applied as mentioned in the developing areas, due to the scarcity of drinking water, and deteriorated distribution networks.

In the intermittent supply systems, the consumers depend on the individual roof and /or ground storage tanks to provide their daily needs of water for domestic, industrial, and other uses. This means that in the periods of use, the consumption of water is not necessarily provided from the network directly, but may be from the roof tanks and /or ground storage tanks in which water was stored when the pressure head in the system was higher than the reservoir. In this case the consumers of water are not restricted only by the pressure that is available in the distribution network, but also they are restricted by the capacity of the roof tanks and ground storage tanks.

From the hydraulic point view, when the consumers are using the water from their roof tanks, they are disconnected from the distribution system, and two independent patterns can be distinguished in this case: the first pattern at the consumer's tap which is actually a consumption pattern and may be equal for all domestic consumers, and the second pattern is at the tank which is actually a filling pattern, and it is a consequence of the hydraulic operation of the network, representing a pressure related discharge , and its different for each node in the network.

The consumers faraway from the source of water supply in the intermittent systems will need to be more patient, especially that the refilling of their roof tanks will start later and go slower than for those consumers closer to the water source.

Intermittent supply yields afundamentaly different demand pattern than continuous supply, in fact there is no demand pattern: the storage tanks of the customers will fill up whenever the systems provides water, until they are full and the float valve closes [12].

4.4 Proposed methods for modeling inermittent water supply systems

The overall shortage in water availability in the most developing countries necessitates intermittent supply at a low per capita supply rate. These conditions force consumers to collect water in storage tanks.

Storage is an important feature of such systems since it is the storage facilities that provide water during non-supply hours. Because of the low supply rate of water and the intermittent nature of supply, the demand for water at the nodes in the network are not based on notions of diurnal variations of demand related to the consumers behavior (as with networks in developed countries), but on the maximum quantity of water that can be collected during supply hours [35].

4.4.1 Modified analysis tools

A modified network analysis program has been developed by the water development research unit at south bank university (London) that incorporates pressure dependent outflow functions (PDO) to model the demand. This model consists of four main components. This approach is far more sophisticated and may provide superior results, and it requires more specialized software:

1. Demand model

This model forecasts the end-users demand profile (intensity and distribution of usage over a given period of supply). Data needed for this model includes: type of connection, time of supply, duration of supply, and pressure regime [35].

2.Secondary network model

In this model, the primary node assumed to be a constant head, and this node providing water to the secondary network. Such methods have been developed and take into account the hydraulic behavior of the secondary network [37].

3.Network charging model

This model predicts the time at which different users receive water and simulates the charging up of the network after supply resumes [35].

4.Modified network analysis method (pressurized flow)

This model has been developed to model the demand or outflow. The network governing equations are solved using the gradient algorithm of Todini and Pilati (1987) [38].

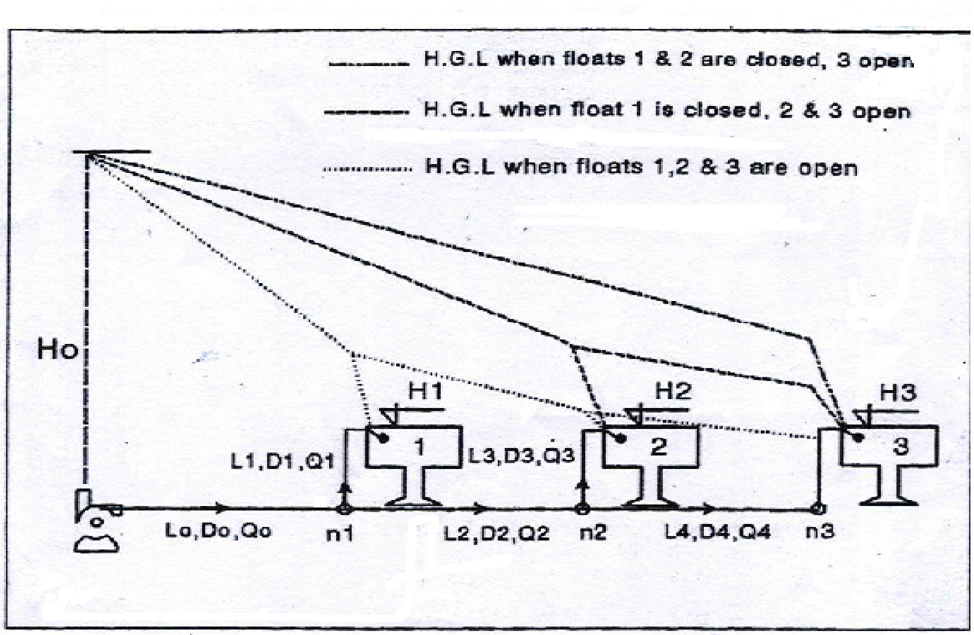
4.4.2 Modeling of nodal demand as pressure related demand

The relation between pressure and demand can be illustrated obviously by the relation between leakage losses in the water distribution networks and the pressure. At low peaks through night hours the pressure in the system will be high and the leakage losses are expected to increase. At high peaks, the pressure will be small and the leakage losses are expected to decrease.

When the pressure in the system is higher than the elevation of the tank, the filling will start. It is clear that, the higher the pressure is, more water will enter into the tank, following the Bernoulli equation.

Figure (4.1)

Illustration of Reservoir Operation



The filling of the roof tanks is output of pressure related demand, so it could be justified to model them as pressure related demand, but the results will not take into account the level variation in the tank, this lead to the conclusion that the tank not necessarily be empty, when the pressure in the nodes is not sufficient.

4.4.3 Modeling as equivalent reservoir

The principle of this approach is representing each cluster of roof tanks in the distribution system by one large but shallow reservoir. The assumed reservoir should have a large surface area with volume equal to the total volume of roof tanks and a depth of 1 m (as in reality), and this reservoir should be given an elevation equals to the house height [3].

This way of modeling represents the water level variations in the roof tanks in the case of using special software which taking into account the demand in the tanks. It can be also used in the process of modeling nodal demand as pressure related demand.

In this model, the demand in the actual nodes modeled as zero, and the water consumption is specified at the reservoirs. The water utilization is based on the availability of water in the individual storage tanks or proposed reservoirs.

Chapter Five

State of the Jenin Water Distribution Network

5.1 Theoretical Background

5.1.1 Geographical, Topographical and Geological Situation

The Jenin city is located in the northern part of Palestine, it is bounded by the Nablus and Tulkarm districts from the south and southwest, and by the 1948 cease- fire line from the other directions, lying in the southern corner of the Marj – Ibn – Amer plain. It is consider one of the best agricultural areas in Palestine [39].

Topographically, the Jenin district is located between 90 and 750 m above sea level [39]. The altitude levels of Jenin city range from 100 to 280 meter above sea level, the legal boundaries of the city have been extended, to now cover 18.2 km^2 [40].

The soil conditions in Jenin are dominated by sand and clay for the lower areas, mainly along Wadi Jenin (Nablus road) up to the Sabah al Khair region in the north; the slopes of the two hills Al Gaberiat and Al Marah are dominated by rock [40].

Map (5.1)

Map of Palestine showing the location of Jenin City

5.1.2 Hydro-geological, climate, Temperature, and Rainwater patterns

Ground water resources in the Jenin area are derived from the northeastern and western aquifer system. There are two aquifer systems utilized in the Jenin district, the two exposed aquifer systems are, Upper cenomanian – turonian aquifer system, which is composed of carbonate rocks "dolomite and limestone" with thickness ranging from 185 m to 475 m, and the Eocene aquifer system, this aquifer system overlies the upper cenomanian – turonian aquifer system, with a transition zone of chalk of variable thickness ranging from 0 to 480 m is in between, in this system, lime stone rocks form an aquifer while chalk rock form an aquiclude [41].

The static water level in the Jenin district shows that they directly recharge from rainfall, and yields from Eocene wells are highly dependent on seasonal rainfall, ranging from zero to 100 m^3/h. The water levels in the Jenin area can be found at 50 m below ground level, unless they appear on the surface in the form of springs, either at the interface of chalks, or as a result of faults [40].

The climate of the Jenin area is governed by its position on the eastern Mediterranean; the summer season in the Jenin area is dry and hot, while the winter is moderate and rainy. The average maximum temperature from June to August is 33.6 c, and the average minimum is 19.3 c [39].

The mean annual rainfall in the Jenin area is 528 mm; the rainy season in the Jenin district starts in the middle of October and continues to the end of April. Approximately 3.2% of the annual rainfalls in October, while almost

80% falls during November through February. In March, precipitation usually decreases to 12% of the rainfall [39].

Snowfall is rare in the Jenin district. From 1983 to 1996, snowfall was recorded only in January and February 1992, which as considered an exceptionally cold and wet year [40].

5.1.3 Industrial and economic development

The dominant economic activity in the Jenin district is agriculture, particularly in the historically fertile Marj-Ibn-Amer and the plains around Jenin city where irrigated agriculture predominates.

Recently, industry has started to play an important role as a source of income in this district, plastic, fodder, food and beverages, paper and cartons in addition to concrete block and stone-cutting factories and workshops, have been established.

Jenin town presently has no major industry, besides small scale enterprises and the busy market, the future development will be directly connected to the political situation, currently there are preparations to set up a huge industrial zone in the north of Jenin town close to the borders, this project will certainly have a major influence on the development of the town, but its influence cannot be estimated at the moment.

5.1.4 Population Projection

The figures regarding the population of Jenin vary from source to source, these differences not only for the present population, according to sources of Jenin municipality, PCBS, PECDAR, PWA, MOPIC, but also the growth factors for the years to come.

The figure for the present population of Jenin was set as being 41300,this estimating is an interpolation between the present population according to PCBS statistics (38400) [42], and the figures derived from the number of house connections multiplied with the average house hold size (44200) [40].

The average population growth considered being (4.08% for 1999 and changing to 2.31% up to the year of 2024, according to PCBS figures [42].

5.1.5 The Structure of The Town

Jenin city is one of the main urban centers in the north of the West Bank, maintenance and expansion of infrastructure was almost not existent during the years of occupation. The existing infrastructure lacks integrated planning, in poor conditions, short of capacity and generally cannot meet present standards of basic infrastructure requirements [40]. The existing division of the Jenin town consists of 31 wards.

5.1.6 OSLO – II- Convention limitations

With the Madrid conference in October 1991, the Oslo II interim agreement was signed in 1995 between the Palestinian authorities and the occupations authorities, according to this convention, the utilization of water resources in the West Bank is regulated. This convention is an interim agreement only and might be subject to changes in the future.

In article 40 of the interim agreement (1995), it was agreed that the Palestinian would be allowed to use 196 MCM/year as shown in the following table:

Table (5.1)

* Israeli and Palestinian share of the West Bank ground water:

Aquifer	Palestinian share (MCM/year)	Israeli share (MCM/year)	Total (MCM/year)
Eastern Aquifer	132	40	172
North- Eastern Aquifer	42	103	145
Western Aquifer	22	340	362
Total	196	483	679

* Source: (Jenin water supply project) [40].

The allocation of the water resources is not definite at this agreement. Israel is committed to supplying the Palestinians in Jenin with 1.4 MCM/year for domestic purposes [39]. The Jenin district derives its ground water from the North- Eastern Aquifer and Western Aquifer.

5.2 Existing Situation of the Jenin water distribution system

5.2.1 The Primary Network: Existing sources, and Storage Facilities

5.2.1.1 The City Well (Jenin no.1)

The location of the city well in the south of the city, beside Nablus Street, nears the municipality building. The pump house was constructed some 40 or 50 years ago and at that time it might have been located at a suitable spot, whereas now its location in the center of the town is far from being perfect [43].

The safe yield of the well ranges normally from 45 m^3 /hr in the summer up to 90 m^3 /hr in winter, the drought seasons resulting in a yield of 22 m^3 / hr [43].

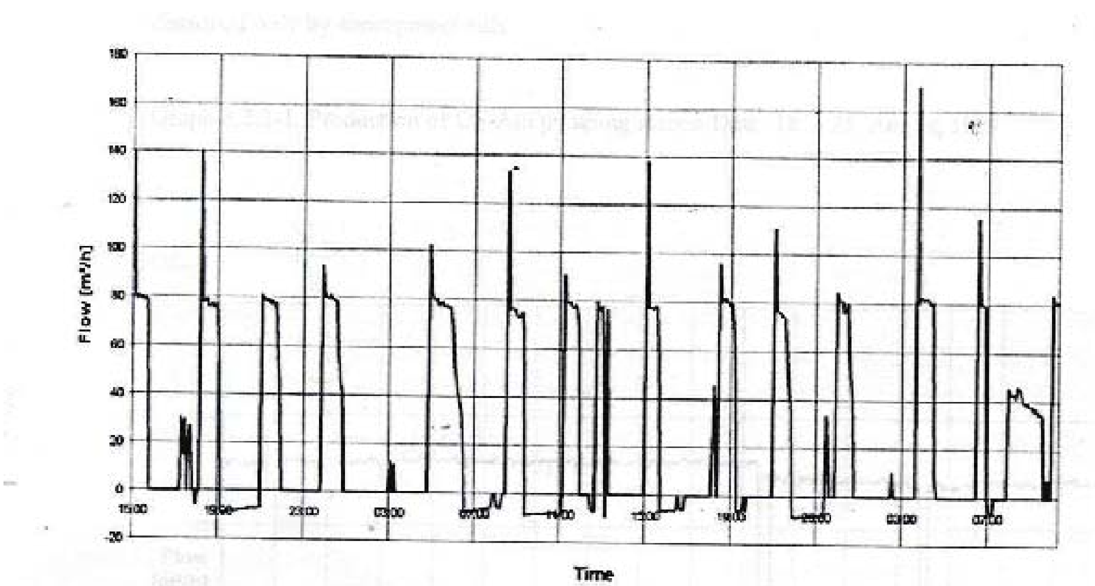
The well is not a well in its classical sense but rather a collection basin which is fed by a channel which conducts the water to the basin from the actual ground water aquifer which is located 10 m from the well, and the well has a depth of 18 m only .The well provide the water to AL-Marah reservoir through a rising main has a diameter of (8”). The quality of the water is still within the allowable ranges according to WHO standards [40].

Ultra sonic flow measurements executed between the 23 and 25 of August 1999 along the rising main to AL-Marah reservoir showed a discharge of the well of 530.04 m^3 /day, the water meter reading established a figure of 581.7 m^3 /day. According to the water meter readings of the municipality, the discharge might reach up to 2000 to 3000 m^3 / day as a maximum during the rainy season [40].

The production of the city well, and the frequency at which the pumps are working, shown at the following graph. The maximum quantity of water transported to AL-Marah reservoir was 169.76 m^3 /h, and the maximum back flow to the well was 9.05 m^3 /h.

Figure (5.1):

* Production of The City Well (jenin no.1)



*Source: (jenin water supply project) [40].

The pumps in the pumping station of the Jenin well no.1 are three shaft driven vertical pumps. The chlorine is added directly into the well, because there is no feeding pump. This procedure of adding chlorine has caused deterioration of the pumps.

There are no air release valves on the rising main from the jenin well no.1 to the reservoir, which is received its water from this well by a cast iron rising main has a diameter of 8”.

5.2.1.2 New Well – Jenin No. 2

The project of drilling Jenin no. 2 well, was a part of a water supply project financed by the USAID, to provide 11 villages in the northwest of Jenin city in addition to the town of Jenin, and the project was finished in 1999. This well represent the most important source of water for Jenin city as it supplies 53% of the total water production.

The safe yield of the Jenin well no.2 is said to be approximately 200m^3/hr. flow measurements and meter readings done by consultant indicated 197.8m^3/hr. and according to water meter readings taken along the rising main to the Jenin city, the amount of water pumped to Jenin can reach a value of 195m3/hour to 208m^3/hour.

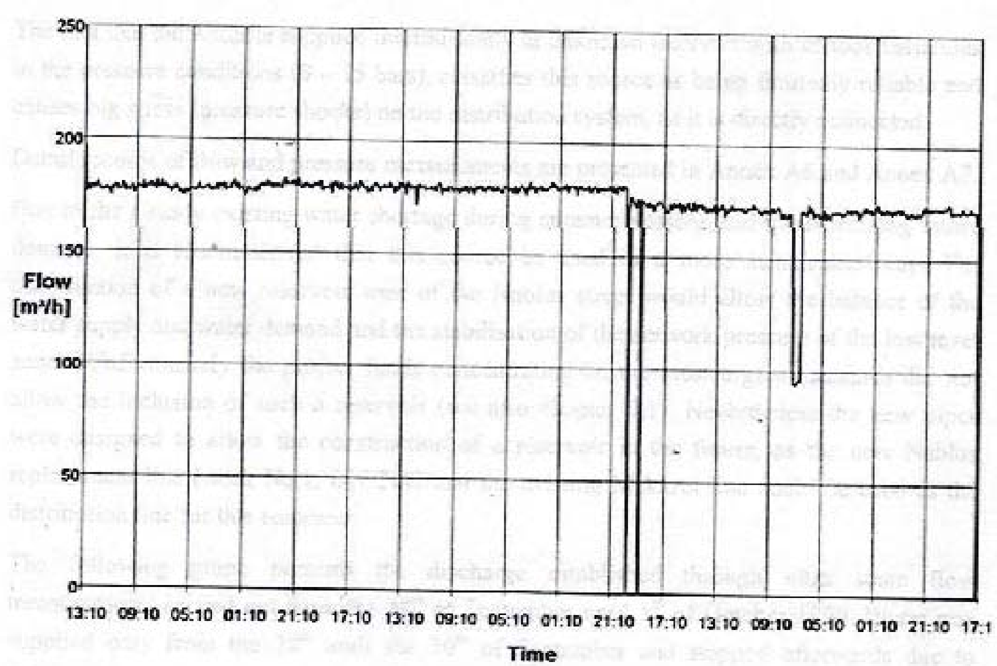
The pumping station of the Jenin well no.2 contains two sets (3 pumps each set) of multistage pumps. The theoretical capacity of the first set is 184 m^3/hour (varying head) used to pump water to 11 villages in the north west of Jenin city, and the other is 108 m^3/hr (175 m head) extract water out of two balancing tanks with a capacity of 50 m^3 for each, or a reservoir beside the well and has a capacity of 1600 m^3 [40].

The water from the deep well is discharged from a deep aquifer (895 m depth) to the reservoir and the two balancing tanks beside the well through an old shaft driven vertical turbine pump

The production of water from the Jenin well no.2 is shown in the following graph.

Figure (5.2):

* Production of Jenin Well No.2:



*Source: (Jenin water supply project) [40].

The Jenin well no.2 tapping the upper cenomanian turonian aquifer system, which is represented by Jerusalem and Bethlehem formations, the total depth of the well is 933 m and the artesian water level upraised to a depth of 150 m to 200 m below the ground surface [39].

5.2.1.3 Supply through Mekorot

Mekorot is a bulk supply Israeli Water Company, whose network covers the whole Israeli territory, as well as part of the West Bank. Mekorot is a bulk supplier for the Palestinian communities: 80 communities buy their water and these communities represent 10.4% of the population of the West Bank (164,000 inhabitants) [16].

Jenin city received water from Mekorot through a pipeline has a diameter of 200mm/150 mm, which was constructed in 1970; the inflow point from Mekorot to Jenin city lies in the Nablus street. And the water supply by Mekorot is conveyed to Jenin city from the Araabeh /Sanur well to the south of Jenin district.

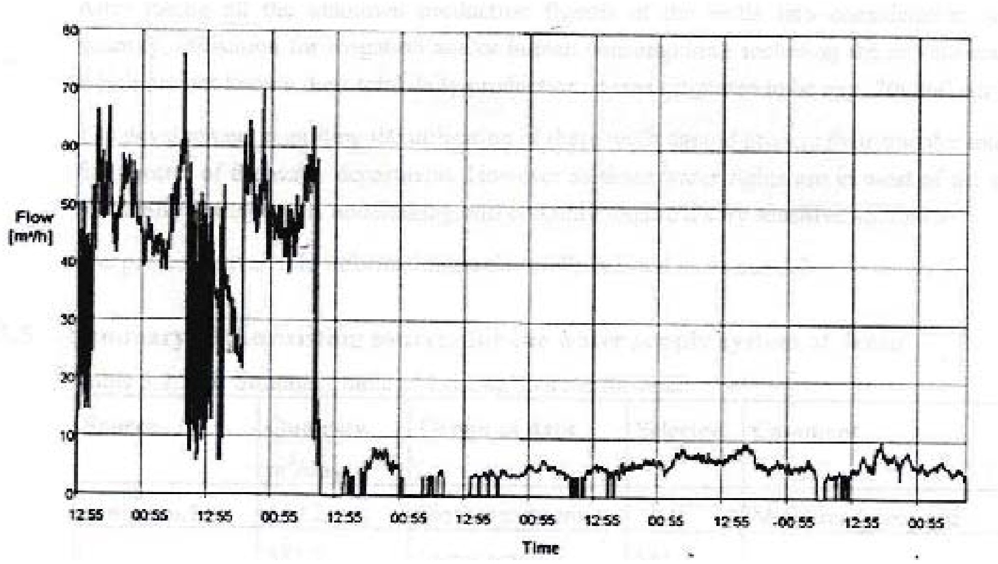
The average monthly supply through Mekorot pipeline according to records taken by the water department in the Jenin municipality varies between 750m^3/day to 3600 m^3/day. The flow measurements and meter readings carried out in the project of developing Jenin water system in 1999 by Schneider and Partner [40], shows a figure of 680.7 m^3/day and 1000.7 m^3/day.

The water supply through Mekorot line is intermittent supply at unknown intervals with large variations in pressure measurements (0-15 bars), which cause pressure shocks and big stress on the network. The excessive pressure frequently blows up water meters of house connections.

The amounts of water conveyed to Jenin city by Mekorot is a quantity not used by the military and Israeli settlements, and at any time may be zero water supply. This source is limited to the minimum amount possible due to the high cost (2.38 shekel /m^3) [43].

Figure (5.3):

* Flow measurement Mekorot



* Source: (jenin water supply project) [40].

5.2.1.4 The Irrigation wells

The irrigation wells are shallow wells extracting water from the upper cenomanian aquifer, the same aquifer from which Jenin well no.1 is extracting its water [40]. These wells reduce the water that is available for the municipality on the one hand. On the other hand they provide a part of water for people in the city, taking into account that about 26% of the existing water or available water for Jenin city is extracted from these irrigation wells.

The irrigation wells within the Jenin town were originally drilled to serve for irrigation purposes and are shallow wells [39].

Part of the irrigation wells is legal, and the other is illegal. The legal wells have the licenses for the exploitation from the Palestinian water authority, and these wells are out of the control of the Jenin municipality.

Table (5.2)

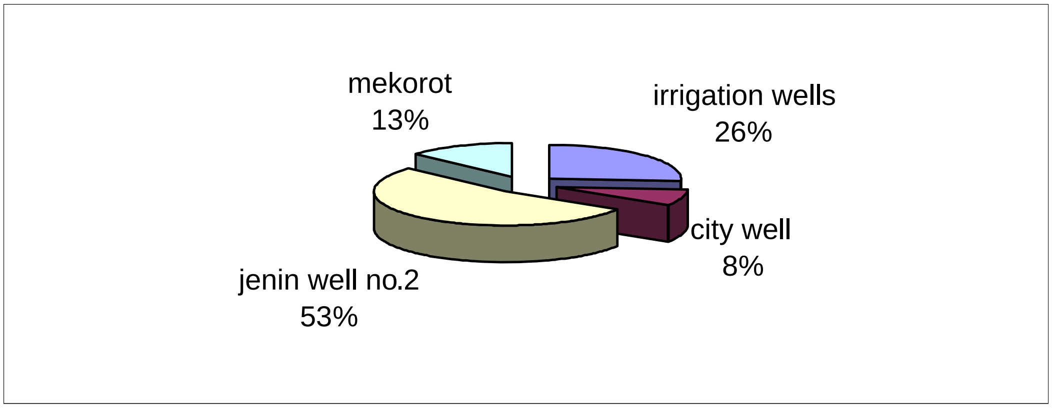
* Summary Table of The Existing Water Sources for Jenin City

Source	Quantity m^3/day	Origin of data	Selected	Comment
Jenin no.1	530.2	Flow measurement		
	581.7	Meter reading	581.7	Meter readings used
Jenin no.2	4190	Flow measurement		
	3400	Jenin municipality		This is a figure agreed in an interim meeting between 11 villages and Jenin
	4166.7	Meter reading	4166.7	
Mekorot	680.7	Flow measurement		Inflow varies considerably
	750 to 3600	Data 1996,1997,1998		Over the year. Consultant
	1007.9	Meter reading	1007.9	Used worst case scenario
Available			5756.3	
Irrigation wells	830			Recorded information
	2000	Information from water department	2000	PWA including local knowledge of water department
Existing			7756.3	

* Source: (Jenin water supply project) [40].

Figure (5.4):

* Water production of Jenin and percentage distribution



* Source: (Jenin water supply project) [40].

5.2.2 Storage Facilities

5.2.2.1 Al Marah Reservoir

Two reservoirs represent Al Marah Reservoir: the larger has a capacity of 2000 m^3, and round shape from concrete. It was constructed in 1993, the smaller is old, and has a capacity of 450 m^3, round shape, from concrete, it was constructed in 1950.

This storage facility is situated at al Marah hill, and has the level of 242 m.a.s.l from its bottom [40].

5.2.2.2 Al Gaberiat Reservoir

This storage facility is situated at al Gaberiat hill; the bottom of the reservoir is set at 272 m.a.s.l., adjacent refugee camp.

It was constructed in 1997, has a capacity of 2000 m^3, round shape, from concrete. The purpose of construction this storage facility is improving the supply conditions and increasing the pressure in the distribution network. Al Gaberiat reservoir is in good condition, and is very well done.

5.2.3 The Secondary Network of Jenin Water Supply System

5.2.3.1 Introduction

The existing secondary network of Jenin city is no longer capable of providing the necessary needs and quantities of water due to the increasing of water demand as a result of increasing the density of inhabitants.

Most of the lines in the distribution network which installed in the past have a DN of 2” and smaller. The network did not developed in a structured way due to the financial constraints, shortage of water, which is necessary for the needs of people, and the topographic situation of the area.

A basic feature of the network is the difficulty to distinguish functionally between distribution mains, service lines and house connections. In principle the diameter of a pipe does not indicate the function of the pipe [40].

5.2.3.2 Pipes Net and Materials

The length of the entire distribution system including service lines is approximately 85 km and comprises all pipe diameters from DN (1/2”) up to DN (10”) [40].

A length of 55 km can be considered as mains in the distribution network (DN (2”) and above). The table below shows the networks diameters.

Table (5.3)

* Existing diameters in the Jenin network:

Diameter (inch)	**1/2**	**3/4**	**1**	**2**	**3**	**4**	**5**	**6**	**8**	**10**	**14**
Length (m)	**7417**	**5168**	**12162**	**37474**	**1808**	**8613**	**51**	**5450**	**586**	**5922**	**500**
Total Length (m)	**85151**										

* Source: (Jenin water supply project) [40].

5.2.3.3 Valves and Regulating Devices

According to water department information, there are approximately 500 valves installed, the diameters are between DN 50 mm up to DN 250 mm. important valves are normally installed in chambers. About 90% of the valves were never operated because their locations were not recorded or construction work executed later buried them completely, most of the valves with DN over 100 mm are located in chambers.

Approximately 50% of all accessible valves were installed before 1960. Many of them are out of operation or difficult to operate and needed to be replaced. The average depth of valves in underground chambers is 0.8 to 1.0 meters. There are no pressure regulating devices in the distribution system, although the variation of altitude is large (between 270 m.a.s.l and 110 m.a.s.l)

5.2.4 Tertiary Network – Delivery to the customer

5.2.4.1 General

The work for the tertiary network is not performed according to standards, the consumers are connected to pipes, which satisfy the most reliable water supply, and not connected through the shortest route. This process results in service lines more than 100-meter length and above. The houses along the service lines will connect their service lines directly to the service line and not to the distribution main, which adding the complex to the system.

5.2.4.2 Connection to the supply network

The average house connection in Jenin city is 30 meters long, which is approximately 3 times the standard length of service lines compare to similar towns [40]. At present 80% of the house connection lines are welded directly, either vertically or horizontally, to the main or secondary pipes, and for the diameters of the secondary pipes less than DN 50 mm, the connection is performed by installing a threaded tee – piece, after the connection, a stop cock is usually installed for safety reasons.

About 30% - 40% of the tertiary network system is laid above ground. In some cases, the rocky subsoil conditions made lying in trenches impossible [40].

The water department performs all works of connection. The trenching is organized and performed by the customer, including materials needed for the house connection.

5.2.4.3 House connection and water meter

The water department is responsible for the connection of the service lines with the distribution main and installation the water meter. Private properties are allowed to be connected only with DN 250mm (1”) and smaller.

According to water department information, the number of the installed water meters is about 6800 meter, and the principle of their work depend on the velocity of the water.

Each customer has to buy his own water meter, register at the water department, and apply for installation by the water work staff. According to the information from the water department, each month about 50 to 100 water meter become defective, the main reason is the solid particles, which stop the turbine of the flow meter. The main supplier of water meters is the Israeli company ARAD, almost 100%.

The water meters are installed either inside the houses or at outside walls of the houses in bathrooms or even toilets.

5.2.4.4 Ground tanks, roof tanks, and underground reservoirs

All people at Jenin town have installed water tanks on the roofs of their houses, due to the shortage of water supply, the capacity of these roof tanks between 500 liter to 10000 liter, most houses in areas of low pressure have ground tanks.

About 20% of the houses, especially the new buildings, constructed over the last years, have enormous underground reservoirs with capacities of 50 m^3 and more.

The reservoirs are used as rain water harvesters during the winter season, to store water for the dry times, and either is supplied by the public network or by water tankers.

The advantage of the ground and roof tanks is avoiding the daily peak demand for the undersized water distribution network, on the other hand the disadvantage of these tanks that they represent a large number of possible draw off which endangers the full pressurizing of the system.

Chapter Six

Modeling of Jenin Water Distribution Network

6.1 Modeling of Jenin Distribution Network as Intermittent Water Supply

6.1.1 Introduction

Intermittent water supply may be defined as a piped water supply service that delivers water to users for less than 24 hours in 1 day. It is a type of service that although little found in developed countries is very common in developing countries.

The primary cause of intermittent water supply is extending distribution systems beyond their hydraulic capacities to provide 24 – hour service, and the unavailability of sufficient quantities of potable water to serve all consumers at the same time.

6.1.2 Procedure of modeling the system as intermittent system

In the case of Jenin water distribution system, the option of modeling the system as an intermittent supply system was followed to describe the existing system as in reality.

6.1.2.1 Data Collection

The following data have been needed for implementation the modeling of the system:

- Maps with layout of the existing distribution system.
- Contour maps to determine the elevations of the consumption nodes.
- Capacity and elevation of the central storage reservoirs.
- Modes of operation the system (zoning).
- Sources of water and available quantities of potable water.
- Demand patterns for domestic consumption.
- Commercial, industrial, public consumption.
- The values of the unaccounted for water (UFW).
- Population figures to estimate the consumption at the nodes.
- Field measurements of pressure, flow, roof tanks levels variation.

All above data have been taken from the water department at Jenin municipality, or have been carried out by the researcher to make the modeling of the system, as intermittent supply system is able.

6.1.2.2 Assumptions of the study

In modeling this pipe water supply system as intermittent supply system, the following assumptions have been taken into consideration:

- The demand for each node of consumption was calculated as follows:

Demand = number of residence * water consumption per capita per day.

The demand of water for domestic uses was assumed to be (80 l/c/d) as a large result of measurements by study the variations of water levels in roof tanks and the field campaigns carried out in project of developing Jenin water distribution system, which has been implemented in 1999 by Schneider and Partner [40].

- The industrial, commercial and institutional consumption of water are included in the domestic consumption as its common in Palestinian's territories, therefore the domestic consumption enlarge to be (110 l/c/d). The values of the industrial, commercial and institutional consumption depend on records of the water department at Jenin municipality.

- For unaccounted for water (UFW) calculations, and according to reports of the water department at Jenin municipality, their data shows a maximum value of 60% as unaccounted for water. The data collection campaigns carried out by Schneider and Partner in 1999 [40], in which the (UFW) figures for the whole system, established through meter readings and population projections, shows a range of values for (UFW) between 42.5% to 49.7% as (UFW) for domestic consumption and for the whole uses of water. A value of 45% as unaccounted for water has been adopted in the modeling of the system, and a value of 31% of the total consumption has been adopted to model the technical losses of water in the system, which is a result of records of the water department at Jenin municipality and field measurements carried out by Schneider and Partner in 1999 [40].

- The total consumption, which is used in modeling the demand for each node assumed to be 160 (l/c/d), as shown in the table (6.1).

Table (6.1):

Assumed water demand for the analysis of the network as intermittent system

Type	Consumption (l/c/d)
Domestic	80
Add industrial, commercial and institutional	110
Technical losses (31%)	50 (31% * 160)
Total	160(l/c/d)

- In this model, the pipes of diameters 2” and above were considered to limit the length of the network, and due to the difficulty for distinguishing small pipes and their demands as shown in table (6.3)

- Taking into account that, this amount of water is to be pumped in different periods of time for different zones. A study the way of operation, zoning, and changing valves setting in the distribution system is necessary, in order to calculate the peak factors, especially that the needed demand for consumption nodes will be pumped at high flow rates at shorter times to satisfy the demands of the nodes. This assumption represents the key of difference between the continuous supply systems and the intermittent water supply systems, so there is a need to enlarge the consumption of the nodes where there is not continuous supply to provide their needs of water in short periods of times as it is explained by the following example.

e.g., : A zone in the Jenin water distribution system receives its needs of water for 24 hour each 72 hour , and has a population of 1300 person , then:

Demand = number of residence * water consumption per capita per day

= 1300 person * 160 (l/c/d)

= 208000 l/d

= 208 m^3 /d

Which gives an hourly average of: 8.7 m^3 /hr.

Taking into account that, this amount of water is to be pumped in 24 hours each 72 hours. The peak factor is:

72 hr / 24 hr = 3

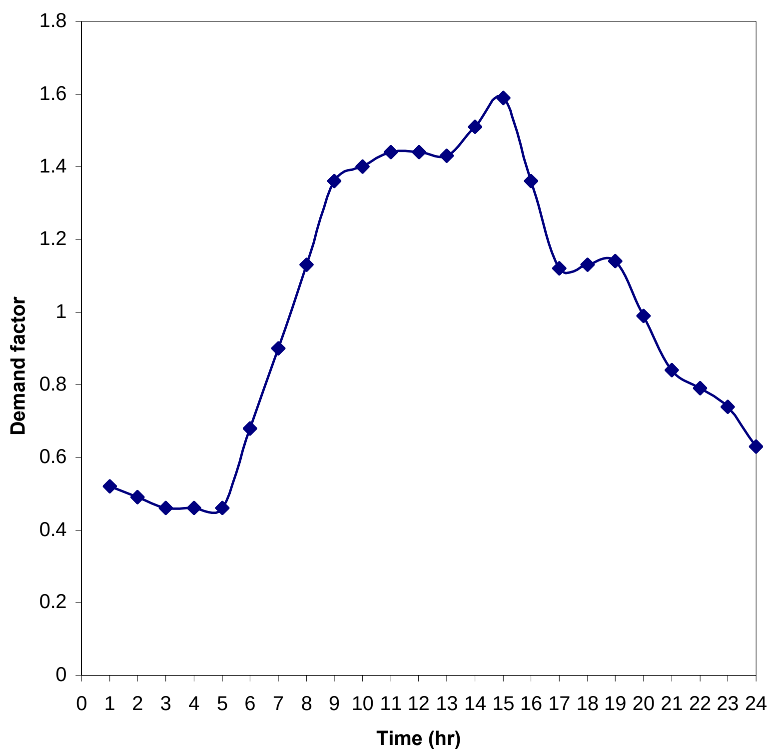
Which resulted a design flow rate of: 3 * 8.7 m^3 /hr = 26.1 m^3 /hr. This is 7.25 l/s.

By this procedure, the demand for each node was calculated and analyzed depending on the number of inhabitants for each consumption node, and the period of supplying water to calculate the peak factor of demand for each node as shown in table (6.2).

- The demand pattern which has been adopted at the nodes of the distribution system is a roof tank demand pattern (not fixed demand as in the continuous supply systems) to simulate the variations of demands in nodes in the intermittent systems, and the values of this pattern has been taken from previous studies in which the daily variations of water demand was recorded as shown in figure (6.1).

Figure (6.1):

Demand Pattern Curve for Daily Water Consumption (Roof tank Pattern):



- The analysis of the water system under these conditions is performed using a (WaterCAD) software, which has been developed by the Haestad Methods, and represents a powerful; easy to use that helps in design and analyzes water distribution systems. This package of software enables the designer to model complex hydraulic situations. The input data needed to perform the analysis by the WaterCad Technique comprise the demand in the nodes, their elevations, pipes lengths, diameters, materials, reservoirs and their elevations, demand patterns, valves with different types and their control, also if there are pumps in the system, they can be modeled depending on their operating curves.

- The population figures, which have been adopted in this model, depend on the statistics of the figures derived from the number of house connections multiplied with the average household size and estimated by 44200 as shown in table (6.2)

- Each cluster of houses has been modeled in this model as one consumption node, and its consumption was calculated depending on the number of inhabitants in each of them as shown in figure (6.2)

Figure (6.2)

Layout of the Existing water system of Jenin city

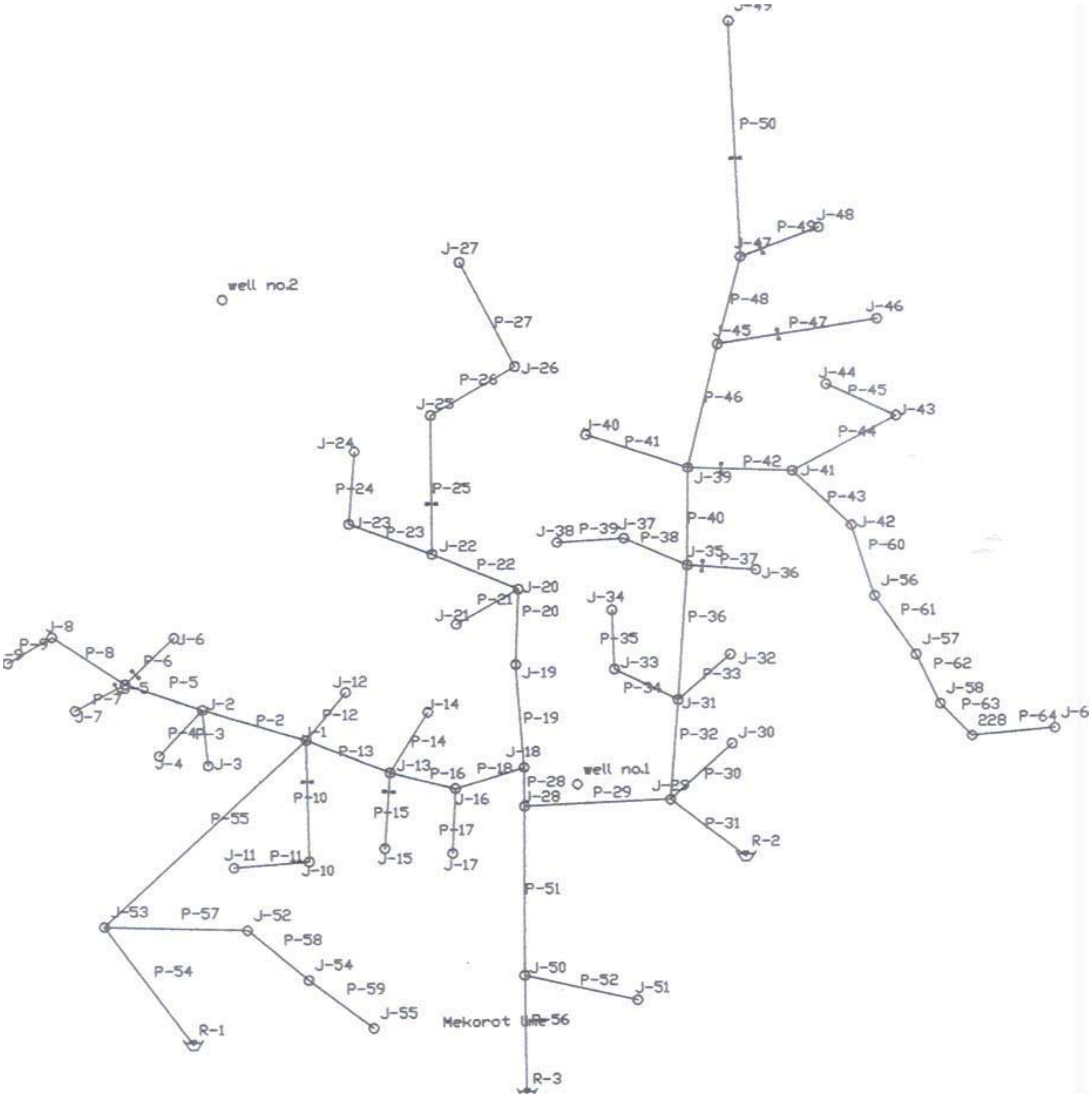


Table (6.2)

Current consumption, and Nodes of the Jenin Water System

No	Node No.	Elevation (asl)	Population (number)	Consumption per capita	Consumption /node (l/s)	Period of service	Operation factor
*****	**R1**	**275**	**AL-Gabriat Reservoir**				
1	**J-1**	**140**	**790**	**160**	**1.5**	**24/24**	**1**
2	**J-2**	**145**	**640**	**160**	**1.12**	**24/24**	**1**
3	**J-3**	**155**	**1240**	**160**	**2.3**	**24/24**	**1**
4	**J-4**	**165**	**540**	**160**	**1**	**24/24**	**1**
5	**J-5**	**150**	**540**	**160**	**1**	**24/24**	**1**
6	**J-6**	**140**	**640**	**160**	**2.4**	**12/24**	**2**
7	**J-7**	**160**	**940**	**160**	**3.5**	**12/24**	**2**
8	**J-8**	**150**	**540**	**160**	**1**	**24/24**	**1**
9	**J-9**	**170**	**240**	**160**	**0.45**	**24/24**	**1**
10	**J-10**	**170**	**1240**	**160**	**6.9**	**24/72**	**3**
11	**J-11**	**175**	**290**	**160**	**1.62**	**24/72**	**3**
12	**J-12**	**160**	**1490**	**160**	**2.76**	**24/24**	**1**
13	**J-13**	**140**	**640**	**160**	**1.2**	**24/24**	**1**
14	**J-14**	**145**	**240**	**160**	**0.45**	**24/24**	**1**
15	**J-15**	**130**	**1040**	**160**	**5.8**	**24/72**	**3**
16	**J-16**	**180**	**2040**	**160**	**3.8**	**24/24**	**1**
17	**J-17**	**180**	**490**	**160**	**0.91**	**24/24**	**1**
18	**J-18**	**131**	**390**	**160**	**0.73**	**24/24**	**1**
19	**J-19**	**124**	**1040**	**160**	**1.93**	**24/24**	**1**
20	**J-20**	**118**	**390**	**160**	**0.723**	**24/24**	**1**
21	**J-21**	**160**	**310**	**160**	**0.574**	**24/24**	**1**
22	**J-22**	**190**	**440**	**160**	**0.815**	**24/24**	**1**
23	**J-23**	**190**	**240**	**160**	**0.45**	**24/24**	**1**
24	**J-24**	**140**	**190**	**160**	**0.352**	**24/24**	**1**
25	**J-25**	**145**	**390**	**160**	**3.3**	**16/72**	**4.5**
26	**J-26**	**115**	**690**	**160**	**5.8**	**16/72**	**4.5**
27	**J-27**	**90**	**1290**	**160**	**10.8**	**16/72**	**4.5**
28	**J-28**	**137**	**1240**	**160**	**2.3**	**24/24**	**1**
*****	**R2**	**245**	**AL-Marah Reservoir**				
29	**J-29**	**135**	**290**	**160**	**0.54**	**24/24**	**1**
30	**J-30**	**180**	**360**	**160**	**0.67**	**24/24**	**1**
31	**J-31**	**145**	**840**	**160**	**1.6**	**24/24**	**1**
32	**J-32**	**145**	**440**	**160**	**0.815**	**24/24**	**1**
33	**J-33**	**138**	**390**	**160**	**0.74**	**24/24**	**1**
34	**J-34**	**150**	**1840**	**160**	**3.41**	**24/24**	**1**
35	**J-35**	**164**	**1790**	**160**	**3.315**	**24/24**	**1**
36	**J-36**	**150**	**640**	**160**	**2.37**	**12/24**	**2**
37	**J-37**	**140**	**390**	**160**	**0.73**	**24/24**	**1**
38	**J-38**	**125**	**390**	**160**	**0.73**	**24/24**	**1**
39	**J-39**	**115**	**540**	**160**	**1**	**24/24**	**1**
40	**J-40**	**108**	**540**	**160**	**1**	**24/24**	**1**
41	**J-41**	**132**	**740**	**160**	**2.74**	**12/24**	**2**
42	**J-42**	**130**	**340**	**160**	**1.26**	**12/24**	**2**
43	**J-43**	**132**	**640**	**160**	**2.4**	**12/24**	**2**
44	**J-44**	**110**	**320**	**160**	**1.2**	**12/24**	**2**
45	**J-45**	**138**	**1240**	**160**	**2.3**	**24/24**	**1**

Table (6.2) (continue)

No	Node No.	Elevation (asl)	Population (number)	Consumption per capita	Consumption /node (l/s)	Period of service	Operation factor
46	**J-46**	**132**	**390**	**160**	**3.25**	**16/72**	**4.5**
47	**J-47**	**130**	**1340**	**160**	**2.5**	**24/24**	**1**
48	**J-48**	**134**	**1540**	**160**	**12.9**	**16/72**	**4.5**
49	**J-49**	**132**	**1290**	**160**	**3.6**	**48/72**	**1.5**
*****	**R3**	**250**	**Reservoir instead of pressurized Mekorot line**				
50	**J-50**	**165**	**1870**	**160**	**3.5**	**24/24**	**1**
51	**J-51**	**210**	**1240**	**160**	**2.3**	**24/24**	**1**
52	**J-52**	**237**	**810**	**160**	**1.5**	**24/24**	**1**
53	**J-53**	**240**	**250**	**160**	**0.5**	**24/24**	**1**
54	**J-54**	**238**	**810**	**160**	**1.5**	**24/24**	**1**
55	**J-55**	**232**	**810**	**160**	**1.5**	**24/24**	**1**
56	**J-56**	**235**	**189**	**160**	**0.7**	**12/24**	**2**
57	**J-57**	**260**	**189**	**160**	**0.7**	**12/24**	**2**
58	**J-58**	**250**	**189**	**160**	**0.7**	**12/24**	**2**
59	**J-228**	**215**	**189**	**160**	**0.7**	**12/24**	**2**
60	**J-60**	**226**	**181**	**160**	**0.67**	**12/24**	**2**

Table (6.3)

Links in the Jenin Water Distribution System:

No.	Link Label	Length (m)	Diameter (inch)	Initial Node	Final Node
1	P-54	168	10	R1	J-53
2	P-2	230	6	J-1	J-2
3	P-10	150	4	J-1	J-10
4	P-12	200	2	J-1	J-12
5	P-13	270	6	J-1	J-13
6	P-3	150	4	J-2	J-3
7	P-4	150	2	J-2	J-4
8	P-5	300	6	J-2	J-5
9	P-6	200	2	J-5	J-6
10	P-7	200	2	J-5	J-7
11	P-8	200	6	J-5	J-8
12	P-9	250	2	J-8	J-9
13	P-11	120	2	J-10	J-11
14	P-14	150	2	J-13	J-14
15	P-15	120	4	J-13	J-15
16	P-16	320	6	J-13	J-16
17	P-17	180	2	J-16	J-17
18	P-18	290	6	J-16	J-18
19	P-19	200	6	J-18	J-19
20	P-28	150	6	J-18	J-28
21	P-20	170	6	J-19	J-20
22	P-21	150	2	J-20	J-21
23	P-22	200	6	J-20	J-22
24	P-23	180	4	J-22	J-23
25	P-25	270	4	J-22	J-25
26	P-24	270	2	J-23	J-24
27	P-26	180	2	J-25	J-26
28	P-27	250	2	J-26	J-27
29	P-51	250	8	J-28	J-50
30	P-29	200	6	J-28	J-29
31	P-30	150	2	J-29	J-30
32	P-32	200	6	J-29	J-31
33	P-31	250	6	R2	J-29
34	P-33	250	2	J-31	J-32
35	P-34	180	4	J-31	J-33
36	P-36	250	6	J-31	J-35
37	P-35	250	4	J-33	J-34
38	P-37	180	2	J-35	J-36
39	P-38	250	4	J-35	J-37
40	P-40	230	6	J-35	J-39
41	P-39	220	2	J-37	J-38
42	P-41	500	2	J-39	J-40
43	P-42	190	4	J-39	J-41
44	P-46	350	6	J-39	J-45

Table (6.3) (continue)

No.	Link Label	Length (m)	Diameter (inch)	Initial Node	Final Node
45	P-43	700	2	J-41	J-42
46	P-44	600	4	J-41	J-43
47	P-60	62	6	J-42	J-56
48	P-45	250	2	J-43	J-44
49	P-47	350	2	J-45	J-46
50	P-48	220	4	J-45	J-47
51	P-49	200	4	J-47	J-48
52	P-50	950	4	J-47	J-49
53	P-52	400	4	J-50	J-51
54	P-55	913	10	J-53	J-1
55	P-57	488	10	J-53	J-52
56	P-56	174	8	R3	J-50
57	P-58	435	6	J-52	J-54
58	P-59	500	6	J-54	J-55
59	P-61	121	4	J-56	J-57
60	P-62	268	4	J-57	J-58
61	P-63	41	4	J-58	J-228
62	P-64	42	4	J-228	J-60

6.2 Modeling of Jenin Water Distribution Network as Continuous Water Supply System

6.2.1 Introduction

The redesign and analysis of Jenin water distribution system as a continuous supply system to verify the ability of the existing system to serve the jenin area in the future has been discussed depending on number of assumptions and facts considering with the future water consumption, availability of water, and other factors.

The design and analysis of the water distribution system is till the end of the year 2020. According to figures of population increase taken out of summary statistics, the population of the city is expected to be 84,327 inhabitants with a rate of growth about 2.57.

6.2.2 Assumptions of the study

In modeling Jenin water distribution system, the following assumptions have been taken into consideration.

- The water distribution system is designed to cope mainly with the domestic demand. As it is common in Palestine, the consumption for industrial, commercial, and institutional demands are included in the domestic consumption figure to form a total water demand per person and day. According to studies carried out by the Jenin municipality and Schneider and Partner (1999) [40], in which the predicted future water consumption till the year 2024 was estimated depending on the future domestic consumption, decreasing the (UFW) and technical losses, development the economy and industry. The theoretical water demand will be as mentioned in table (6.4):

Table (6.4):

Assumed demand for design and analysis of the network as continuous system:

Type	Consumption (l/c/d)
Domestic	120
Add industrial, commercial and institutional	140
Technical losses (18%)	30(18% * 170)
Total	170(l/c/d)

Source: (Jenin water supply project) [40]:

As mentioned in the above table, the total consumption per capita per a day will be assumed to be 170 l/c/d by the year 2019 – 2020.

- The average rate of population growth considered being 2.57%, and according to statistics of (PCBS), the population of Jenin city will be 84,327 by the year 2019 – 2020 as shown in table (6.5).

- The new housing areas such as Co-operation housing committees, Al-Sweitat area, which have high density of population, have been taken in consideration a shown in figure (6.3) and table (6.6).

- The water should be pumped to the Jenin city from the following sources:

1- From Jenin well no.1, with a fluctuating flow ranging from 45 m^3 /hr to 90 m^3 /hr. the water is pumped from the well to AL- Marah reservoir, and according to information from the municipality the discharge might reach up 2000 to 3000 m^3/ day as a maximum during the rainy season.

2- Jenin well no.2. The discharge of this well is about 200 m^3 /hr and pumped to Al-Gabriat reservoir.

3- Mekorot pipe, which satisfy a discharge of 100 m^3 /hr, and assumed to pump its water to a new reservoir at the end of Mekorot pipe, and also this reservoir will recharge from additional source of water.

The availability water for Jenin city is very limited, and there is a need to a new reliable source with a discharge range of at least 200 m^3 /hr. According to information from Jenin municipality, an existing well in the south of Jenin could be utilized as an additional source of water. In this study it is assumed that this additional source and the Mekorot pipe will pump its water to a new reservoir at the end of Mekorot pipe, and has an elevation of 300 m (asl).

- The demands of the consumption nodes have been approximated depending on the number of inhabitants for each node as shown in table (6.5) The demand pattern, which has been adopted, is a fixed demand pattern assuming that, there will be availability of water, and enhancement of operation and management of the water supply system.

- Pressure reducing valves assumed to be installed at specific location to minimize the pressure to needed pressures. Also a two booster stations (pumps) were installed to provide the necessary quantities of water to the hills and new areas located in high elevations.

Figure (6.3)

Layout of the proposed water system of Jenin city

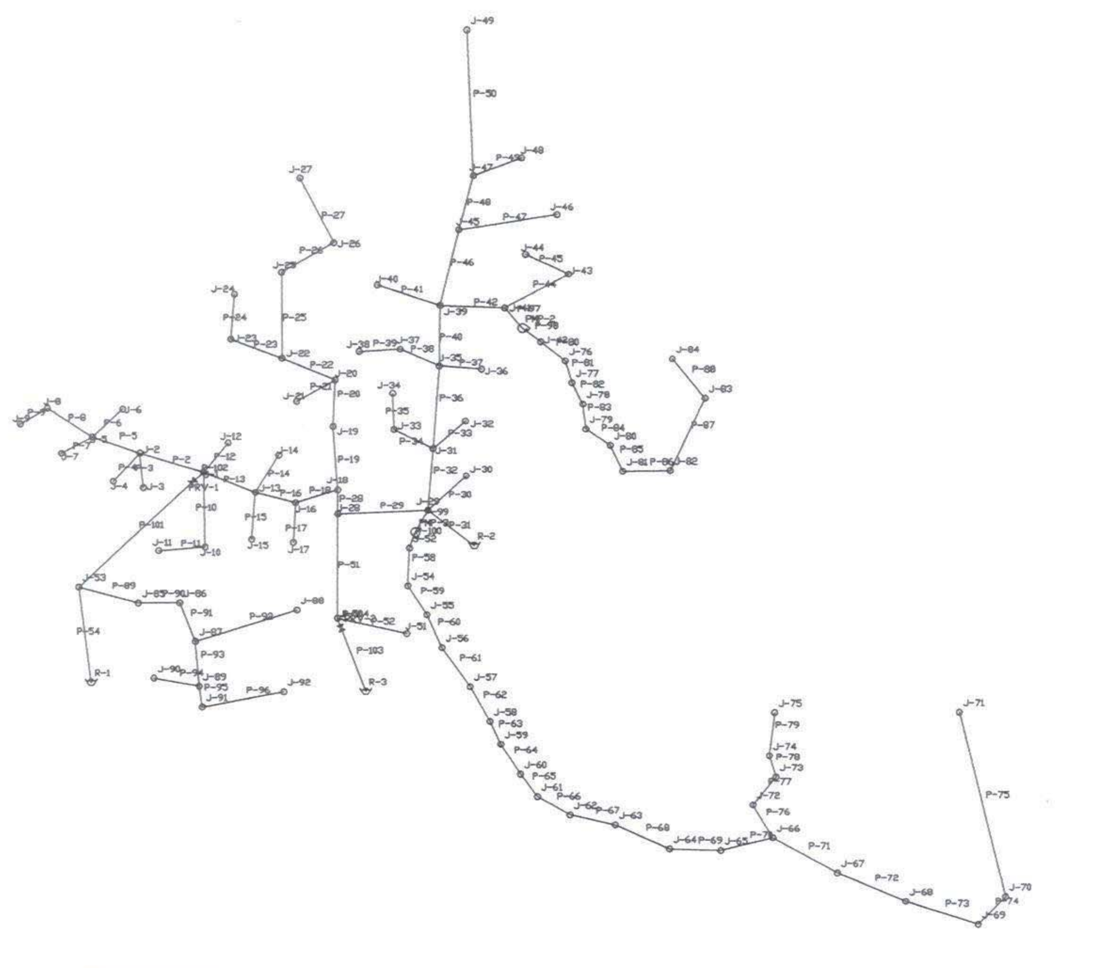


Table (6.5)

Theoretical Population's consumption, and Nodes in the Proposed Jenin Water Supply System:

No.	Node No.	Elevation (asl)	Population (number)	Consumption per capita	Consumption /node (l/s)
*	R1	275	AL-GABRIAT Reservoir		
1	J-1	140	1438	170	2.83
2	J-2	145	1287	170	2.5323
3	J-3	155	1887	170	3.713
4	J-4	165	1187	170	2.3355
5	J-5	150	1187	170	2.3355
	J-6	140	1287	170	2.5323
7	J-7	160	1587	170	3.1226
8	J-8	150	1187	170	2.3355
9	J-9	170	887	170	1.745
10	J-10	170	1887	170	3.713
11	J-11	175	937	170	1.844
12	J-12	160	2137	170	4.205
13	J-13	140	1287	170	2.533
14	J-14	145	887	170	1.7453
15	J-15	130	1687	170	3.32
16	J-16	180	2689	170	5.29
17	J-17	180	1138	170	2.24
18	J-18	131	1037	170	2.04
19	J-19	124	1687	170	3.32
20	J-20	118	1037	170	2.04
21	J-21	160	957	170	1.883
22	J-22	190	1088	170	2.14
23	J-23	190	889	170	1.75
24	J-24	140	839	170	1.65
25	J-25	145	1037	170	2.04
26	J-26	115	1337	170	2.63
27	J-27	90	1936	170	3.81
28	J-28	137	1888	170	3.7148
*	R2	245	AL-MARAH Reservoir		
29	J-29	135	937	170	1.8436
30	J-30	180	1007	170	1.9814
31	J-31	145	1487	170	2.92581
32	J-32	145	1087	170	2.1388
33	J-33	138	1037	170	2.04
34	J-34	150	2487	170	4.8934
35	J-35	164	2437	170	4.795
36	J-36	150	1287	170	2.5323
37	J-37	140	1037	170	2.0404
38	J-38	125	1037	170	2.0404
39	J-39	115	1187	170	2.3355

Table (6.5) (continue)

No.	Node No.	Elevation (asl)	Population (number)	Consumption per capita	Consumption /node (l/s)
40	J-39	115	1187	170	2.3355
41	J-40	108	1387	170	2.73
42	J-41	132	178	170	0.35
43	J-42	130	966	170	1.9
44	J-43	132	1887	170	3.713
45	J-45	138	1887	170	3.713
46	J-46	132	1037	170	2.04
47	J-47	130	1987	170	3.91
48	J-48	134	2185	170	4.3
49	J-49	132	1937	170	3.812
*	R3	300	New Reservoir		
50	J-50	165	2517	170	4.952
51	J-51	210	1888	170	3.7148
52	J-53	240	296	170	0.5824
53	J-52	237	108	170	0.212
54	J-54	238	108	170	0.212
55	J-55	232	108	170	0.212
56	J-56	235	108	170	0.212
57	J-57	260	137	170	0.27
58	J-58	250	137	170	0.27
59	J-59	253	137	170	0.27
60	J-60	256	137	170	0.27
61	J-61	266	136	170	0.2683
62	J-62	266	136	170	0.2683
63	J-63	268	136	170	0.2683
64	J-64	270	136	170	0.2683
65	J-65	265	136	170	0.2683
66	J-66	265	136	170	0.2683
67	J-67	270	0	170	0
68	J-68	266	136	170	0.2683
69	J-69	271	136	170	0.2683
70	J-70	272	136	170	0.2683
71	J-71	250	136	170	0.2683
72	J-72	255	136	170	0.2683
73	J-73	257	136	170	0.2683
74	J-74	257	136	170	0.2683
75	J-75	260	136	170	0.2683
76	J-76	172	456	170	0.8968
77	J-77	177	456	170	0.8968
78	J-78	185	456	170	0.8968
79	J-79	200	456	170	0.8968
80	J-80	202	457	170	0.9
81	J-81	202	457	170	0.9
82	J-82	190	203	170	0.4
83	J-83	192	183	170	0.36
84	J-84	177	183	170	0.36

Table (6.5)(continue)

No.	Node No.	Elevation (asl)	Population (number)	Consumption per capita	Consumption /node (l/s)
85	J-85	217	559	170	1.1
86	J-86	211	1266	170	2.49
87	J-87	193	1067	170	2.1
88	J-88	206	1016	170	2
89	J-89	246	152	170	0.3
90	J-90	259	1067	170	2.1
91	J-91	246	305	170	0.6
92	J-92	200	1067	170	2.1

Table (6.6):

Links in the Proposed Design of Jenin Water Distribution System:

No.	Link Label	Length (m)	Diameter (inch)	Initial Node	Final Node
1	P-54	168	10	R1	J-53
2	P-2	230	6	J-1	J-2
3	P-10	150	4	J-1	J-10
4	P-12	200	2	J-1	J-12
5	P-13	270	6	J-1	J-13
6	P-3	150	4	J-2	J-3
7	P-4	150	2	J-2	J-4
8	P-5	300	6	J-2	J-5
9	P-6	200	2	J-5	J-6
10	P-7	200	2	J-5	J-7
11	P-8	200	6	J-5	J-8
12	P-9	250	2	J-8	J-9
13	P-11	120	2	J-10	J-11
14	P-14	150	2	J-13	J-14
15	P-15	120	4	J-13	J-15
16	P-16	320	6	J-13	J-16
17	P-17	180	2	J-16	J-17
18	P-18	290	6	J-16	J-18
19	P-19	200	6	J-18	J-19
20	P-28	150	6	J-18	J-28
21	P-20	170	6	J-19	J-20
22	P-21	150	2	J-20	J-21
23	P-22	200	6	J-20	J-22
24	P-23	180	4	J-22	J-23
25	P-25	270	4	J-22	J-25
26	P-24	270	2	J-23	J-24
27	P-26	180	2	J-25	J-26
28	P-27	250	2	J-26	J-27
29	P-51	200	8	J-28	J-50
30	P-29	200	6	J-28	J-29
31	P-30	150	2	J-29	J-30
32	P-32	200	6	J-29	J-31
33	P-99	87.5	6	J-29	PUMP-3
34	P-31	250	6	R2	J-29
35	P-33	250	2	J-31	J-32
36	P-34	180	4	J-31	J-33
37	P-36	250	6	J-31	J-35

Table (6.6)(continue)

No.	Link Label	Length (m)	Diameter (inch)	Initial Node	Final Node
38	P-35	250	4	J-33	J-34
39	P-37	180	2	J-35	J-36
40	P-38	250	4	J-35	J-37
41	P-40	230	6	J-35	J-39
42	P-39	220	2	J-37	J-38
43	P-41	500	2	J-39	J-40
44	P-42	190	4	J-39	J-41
45	P-46	350	6	J-39	J-45
46	P-44	600	4	J-41	J-43
47	P-97	125	6	J-41	PUMP-2
48	P-80	62	6	J-42	J-76
49	P-45	250	2	J-43	J-44
50	P-47	350	2	J-45	J-46
51	P-48	220	4	J-45	J-47
52	P-49	200	4	J-47	J-48
53	P-50	950	4	J-47	J-49
54	P-52	400	4	J-50	J-51
55	P-89	488	10	J-53	J-85
56	P-101	836	10	J-53	PRV-1
57	P-103	173.5	8	R-3	PRV-2
58	P-58	82	6	J-52	J-54
59	P-59	222	6	J-54	J-55
60	P-60	192	6	J-55	J-56
61	P-61	181	6	J-56	J-57
62	P-62	44	6	J-57	J-58
63	P-63	40	6	J-58	J-59
64	P-64	127	6	J-59	J-60
65	P-65	167	6	J-60	J-61
66	P-66	47	6	J-61	J-62
67	P-67	44	6	J-62	J-63
68	P-68	98	6	J-63	J-64
69	P-69	67	6	J-64	J-65
70	P-70	40	6	J-65	J-66
71	P-71	31	6	J-66	J-67
72	P-76	33	6	J-66	J-72
73	P-72	60	6	J-67	J-68
74	P-73	120	6	J-68	J-69
75	P-74	22	6	J-69	J-70
76	P-75	184	6	J-70	J-71
77	P-77	34	6	J-72	J-73
78	P-78	30	6	J-73	J-74
79	P-79	35	6	J-74	J-75
80	P-81	121	4	J-76	J-77
81	P-82	268	4	J-77	J-78
82	P-83	41	4	J-78	J-79

Table (6.6) (continue)

No.	Link Label	Length (m)	Diameter (inch)	Initial Node	Final Node
83	P-84	42	4	J-79	J-80
84	P-85	239	4	J-80	J-81
85	P-86	123	2	J-81	J-82
86	P-87	100	2	J-82	J-83
87	P-88	200	2	J-83	J-84
88	P-90	300	10	J-85	J-86
89	P-91	322	10	J-86	J-87
90	P-92	411	8	J-87	J-88
91	P-93	435	6	J-87	J-89
92	P-94	700	6	J-89	J-90
93	P-95	151	6	J-89	J-91
94	P-96	601	6	J-91	J-92
95	P-98	125	6	PUMP-2	J-42
96	P-100	20	6	PUMP-3	J-52
97	P-102	10	10	PRV-1	J-1
98	P-104	2	8	PRV-2	J-50

6.3 Variations of Water Levels in Roof Tanks

A study of variations of the water level in three roof tanks for three different consumers in different areas in Jenin city has been registered during the month October 2003 for a period of fifteen days.

The records give the change in the water level of the storage tanks and thus the water consumption measured each day.

The analysis of these data gives an idea about the peak factors and enables for deriving the daily water consumption in order to compare these results with a study has been carried by Schnider and Partner (1999) [40], and finally calculate the actual water consumption.

The study has been implemented by installing three water meters at the outlets of three roof tanks in different areas in Jenin city, and a daily monitoring and recording the readings of the water meters for each of them have been taken.

The daily water consumption for each consumer was calculated by subtracting the readings of the water meter for the next day from the previous day reading as shown in table (6.7).

The installed arrangement consists of a roof tank, water meter, check valve as shown in the following figure (6.4) and photo (6.1):

Figure (6.4):

Arrangement of water level variations experiment:

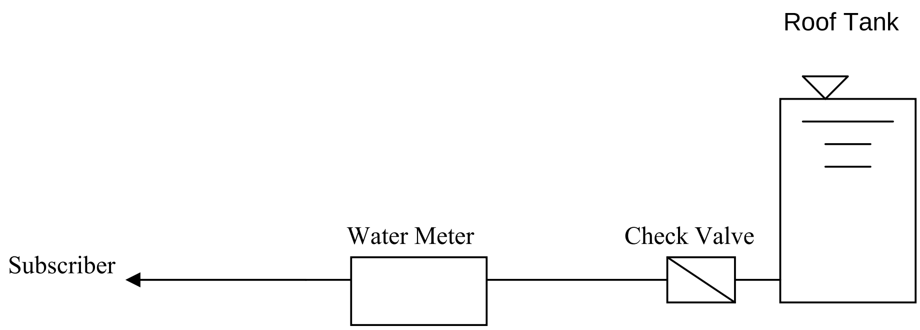


Photo (6.1):
Arrangement of water level variations experiment

Table (6.7)
Daily measurements of water level variations in roof tanks:

Day	Daily Consumption (m^3) Home No.1	Daily Consumption (m^3) Home No.2	Daily Consumption (m^3) Home No.3
1-(4/10/2003)	0.31	0.231	0.421
2	0.33	0.36	0.251
3	0.151	0.511	0.32
4	0.36	0.525	0.212
5	0.22	0.49	0.29
6	0.41	0.412	0.231
7	0.812	1.02	0.601
8	0.651	0.69	0.45
9	0.31	0.395	0.225
10	0.22	0.35	0.39
11	0.163	0.43	0.316
12	0.31	0.485	0.25
13	0.212	0.58	0.239
14	0.512	0.991	0.41
15	0.322	0.42	0.21
Total	5.293 m^3	7.89 m^3	4.816 m^3
No. of inhabitants/Home	5	7	4
Average consumption/day	0.35287	0.526	0.32106
Peak factor (P.F) = Max./Av.	2.301	1.939	1.8719
Av. P.F = Sum of peaks/no.		2.037	

As shown above and by dividing the peak daily water consumption by the average, the daily peak factors for the three different consumers are 2.301,1.939,1.8719 respectively. The average peak factor for these values is 2.037.

The daily water consumption versus time is plotted in figures (6.5), (6.6), (6.7)

Figure (6.5)
Daily water consumption of consumer no.1

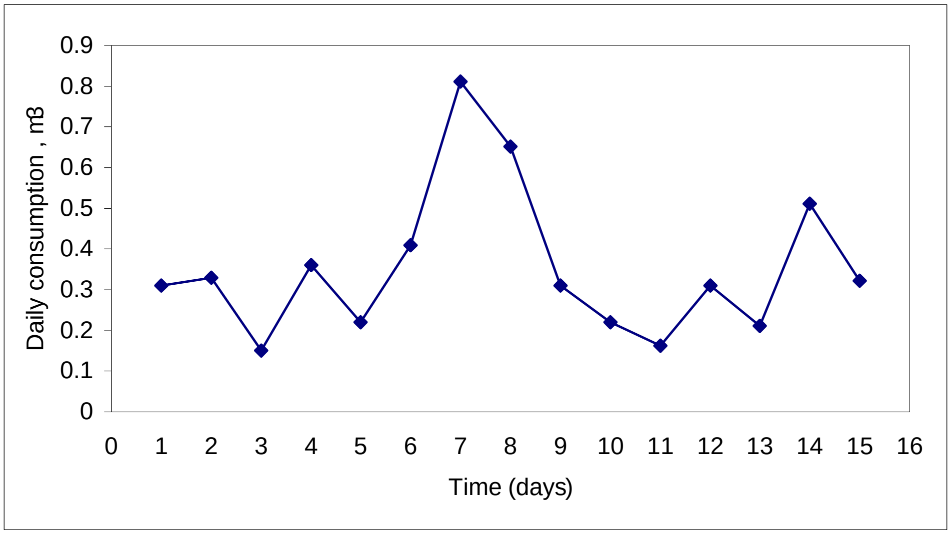


Figure (6.6)
Daily water consumption of consumer no.2

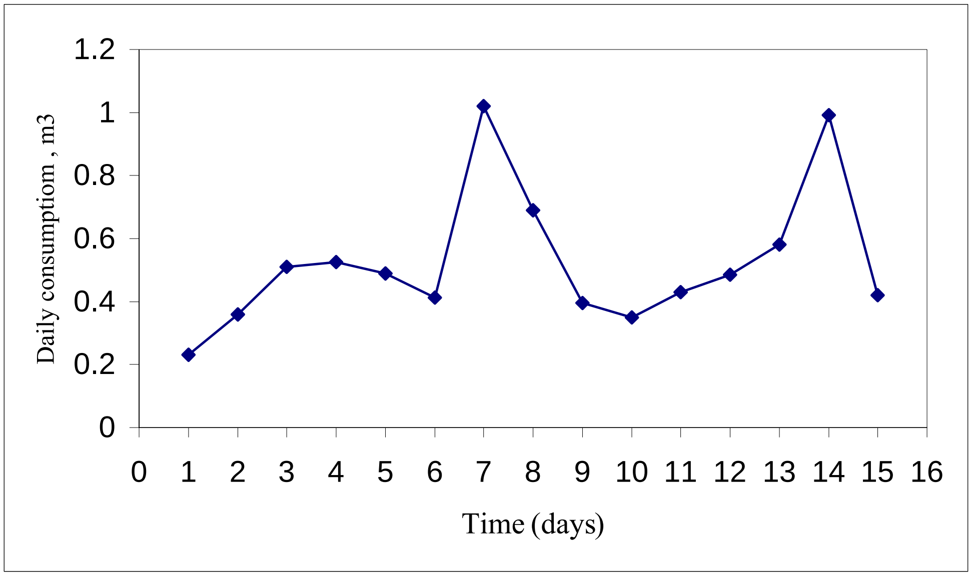
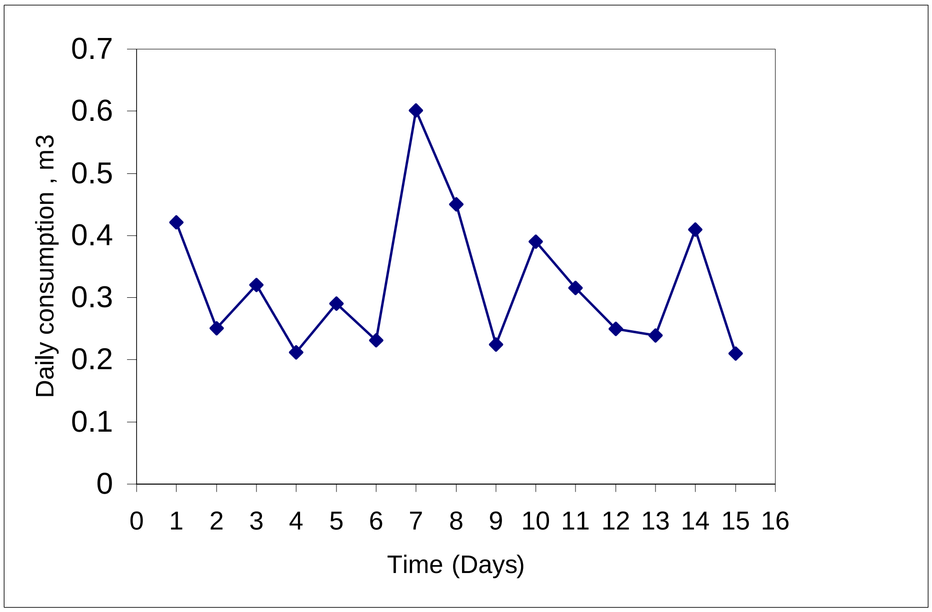


Figure (6.7)
Daily water consumption of consumer no.3



The present consumption in terms of per capita and day (L/c/d) for the three different consumers depending on the number of inhabitants and the total consumption in the period of measurements are summarized in the following table:

Table (6.8):

Average daily water consumption from measurements of water variations in roof tanks

No. of Home	No. of Inhabitants	Average Consumption (m^3/day)	Consumption
Home no.1	5	0.352867	70.5
Home no.2	7	0.526	75
Home no.3	4	0.321067	80
Average:		75 (L/c/d)	

In comparison with measurements have been implemented in project of developing Jenin water distribution system by Schneider and Partner (1999) [40], in different sectors of Jenin city, in which five sectors in the distribution system were chosen. The sectors located in different areas of the town, with different consumption habits and population figures.

Table (6.9) shows the results achieved for each sector, and the average consumption, which is representative for all Jenins's distribution system.

Table (6.9):

Water meter readings in five zones – Jenin distribution network

Sector	No. of Person	No. of water meter	Average network pressure(bar)	Supply time (h/d)	Consumption (L/c/d)
Al-Almania	68	11	1.0	12	67
Abu-Dheir	150	15	0.9	21	70
Al-Sebat	47	11	4.0	24	70
Refugee camp	130	12	1.0	12	79
Al-Hadaf	183	13	1.0	16	56
Total	578	62	-----	-----	68

Source: (Jenin Water Supply Project) [40] .

The water meter readings in a pilot zone, which have been implemented also by Schneider and Partner (1999) [40], October 1999, showed a daily consumption varied between 71 and 79 liters per person and day.

The results of the study of water level variations for different consumers, water meter reading campaigns in different districts, and the pilot zone measurements, showed a little difference in the daily water consumption. These differences are a result of different consumption habits, population figures, and standard of living, also the difference of water supply times, and the network pressure will affect the values of the daily water consumption.

6.4 Unaccounted for water (UFW) for Jenin city

The unaccounted for water is divided into physical, and non-physical water losses. Physical water loss are defined as " that amount of water which is lost without being used due to failures and deficiencies in the distribution facilities.". Non-physical water loss is defined as " the amount of water which is not registered, due to incorrect reading of the measuring instruments installed (measurement errors) and/or absent or inaccurate estimates in the absence of measuring instruments (estimation errors) [17].

The establishment of the (UFW) for Jenin city based on some assumptions and measurements carried out by the water department at Jenin municipality and Schneider and Partner (1999) [40], taking into consideration the number of consumers connected to the water distribution system, recorded data by the metering section, flow measurements and meter readings for sources of water, and for different districts.

The calculation of the (UFW) has been implemented by two procedures. The first procedure depend on the total quantity of water which is produced by the sources of water versus the amount of water sold in two months and their value taken from the billing section of the water department at Jenin municipality, as shown in the table (6.10)

Table (6.10)

UFW figure no.1 for Jenin city

Item	Calculation	Unit	Result	Percentage %
Total production (Jenin No.1 + No.2+Mekorot) from flow measurements.	**(581.7 + 4166.7 + 1007.9)**	**m^3/d**	**5756.3**	**100.0**
Domestic consumption from metering section.	**89274 for Aug. 89289 for Sep.**	**m^3/d**	**2880**	**49.7**
Industrial, public and commercial consumption from metering section.	**13897 for Aug. 12786 for Sep.**	**m^3/d**	**430**	**7.4**
Unaccounted For Water (UFW)	**5756.3 – (2880+430)**	**m^3/d**	**2446.3**	**42.5**

Source :(Jenin Water Supply Project) [40].

The second procedure depend on the total quantity of water which is produced by the sources versus the present water consumption (the number of population multiplied by the present consumption per capita per a day) as shown in table (6.11) in addition to industry and commercial consumption's measurements.

Table (6.11)

UFW figure no.2 for Jenin city

Item	Calculation	Unit	Result	Percentage %
Total production (Jenin No.1 + No.2+Mekorot) from flow measurements.	**(581.7 + 4166.7 + 1007.9)**	**m^3/d**	**5756.3**	**100.0**
Domestic consumption depending on the daily water consumption and the number of connected population with the network.	**$\frac{70 * 36380}{1000}$**	**m^3/d**	**2546**	**43.8**
Industrial, public and commercial consumption from water meter readings .	**740**	**m^3/d**	**740**	**12.8**
Unaccounted For Water (UFW)	**5756.3 – (2546+740)**	**m^3/d**	**2470.3**	**42.9**

Source: (Jenin Water Supply Project) [40].

6.5 The Effects of Air Release Valves at Customer Meters in the Intermittent Systems

In the intermittent water supply systems, the air is sucked and pushed depending on the status of supply because of empty running pipes.

The water filling the pipes at the beginning of the supply period causes the air to be pressed upward, and the air should be sucked in the end of the supply period as a result of empty running pipes and could turn back the domestic water meters and cause an enhancement of unaccounted for water.

Two sites have an elevation of approximately 200 m above sea level were chosen for examining the reaction of domestic water on air in the distribution network and have been tested over a two supply periods.

The arrangement of the experiment consists of a regular domestic water meter, additional water meter, air release valve, and check valve. The air release valve is fitted behind the regular domestic water meter, and the additional water meter is fitted behind the air release valve with check valve. The check valve is installed on a bypass parallel to the existing pipe as shown in the figure (6.8), and photo (6.2).

The water is flowing over the domestic water meter during the filling period, and the water meter will record the billed quantities of water. During this filling period the bypass, which is parallel to the existing pipe will be close due to the check valve. This causes that the air will escape through the air release valve, and the additional water meter will record the actual quantity of water flowing to the consumer.

Figure (6.8)

Arrangement and Flow during the supply period

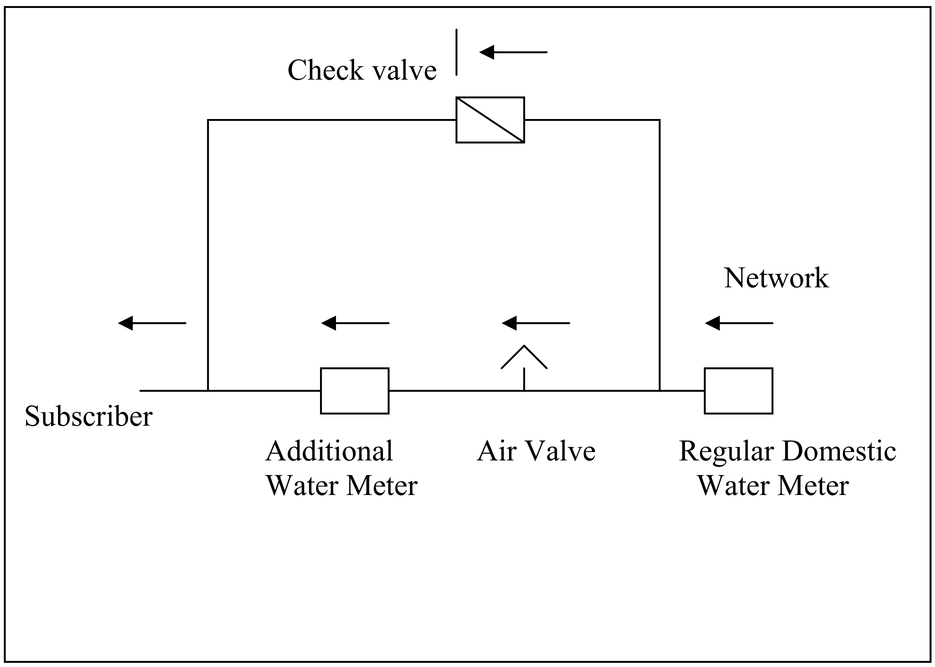


Photo (6.2)

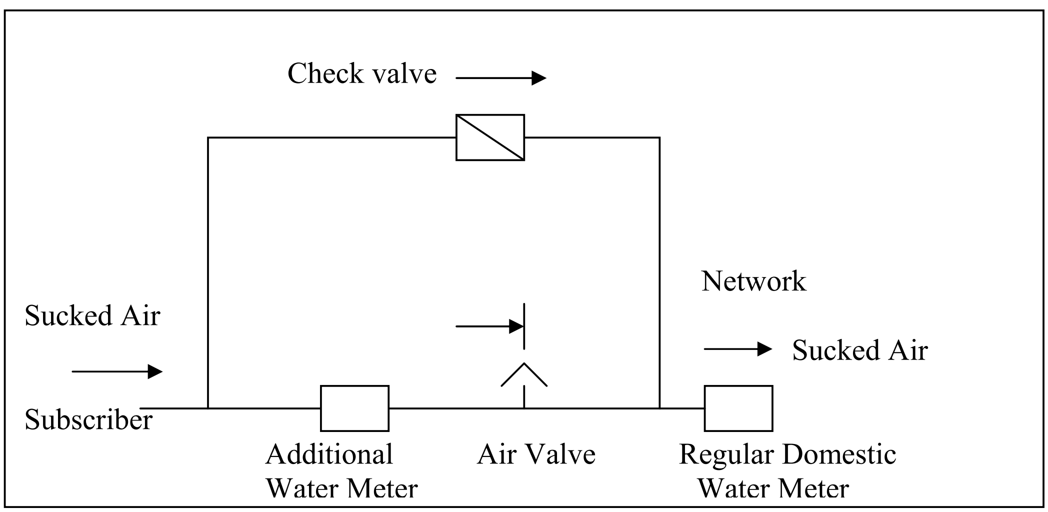
Photo showing the arrangement of the air release valves at customer meters

When the supply period is finish, and the feeding pipe is closed in order to supply another zone, the pipe will empty into the lower tanks of the supply zone as shown in figure (6.9).

The measurement of the additional water meter will not change because the air is sucked by the bypass or air valve, and the backflow may be recorded by the regular domestic water meter.

Figure (6.9)

Arrangement and Flow after supply period



The results of the study as shown in table (6.12) showed a variation of measurements between the additional water meter and the regular domestic water meter for the two supply periods. The readings of the regular water meter are larger than the measurements of the additional water meter with a range of 5% - 8%. The table below shows the results of the measurements.

Table (6.12)

Results of Measurements of Regular and Additional Water Meters

Supply Period	Location	Regular Water Meter (m^3)	Additional Water Meter (m^3)	Difference	%Percent
1^{st} period	1 (10/10/03)	2.3	2.116	0.184	8%
2^{nd} period	1 (17/10/03)	3.1	2.945	0.155	5%
1^{st} period	2 (10/10/03)	4.2	3.969	0.231	5.5%
2^{nd} period	2 (17/10/03)	4.5	4.23	0.27	6%

The difference between the actual and billed consumption might depend on some factors, such as the location, the consumer's behavior and the pressure drops.

In this study the back flow and the sucked air did not enhance the reading of the regular domestic water meter in order to decrease the big difference between the additional and regular water meter.

If the consumers open their tanks before the starting of the supply period, the air pushed on a high elevation will be low and the mistake by pushed air will decrease, because the air escapes at the customers below.

For a better measurement of domestic consumption, installations of air release valves are opportunity, but in the same time the air release valves are costly, and require additional supervision and maintenance, also there will be a need to increase the price of the water to cover the enhancement of water metering.

6.6 Evaluation of The Water Hammer in The Jenin Water System

Water hammer is a series of pulsations of varying magnitude within a pumped liquid. The amplitude and period depend on the velocity of the fluid, as well as on the material, size and strength of the pipe. Shock results from these pulsations when the liquid is suddenly stopped, such as by closing of a valve.

This force is a destructive force that can damage residential or commercial plumbing systems and cause leaking at joints.

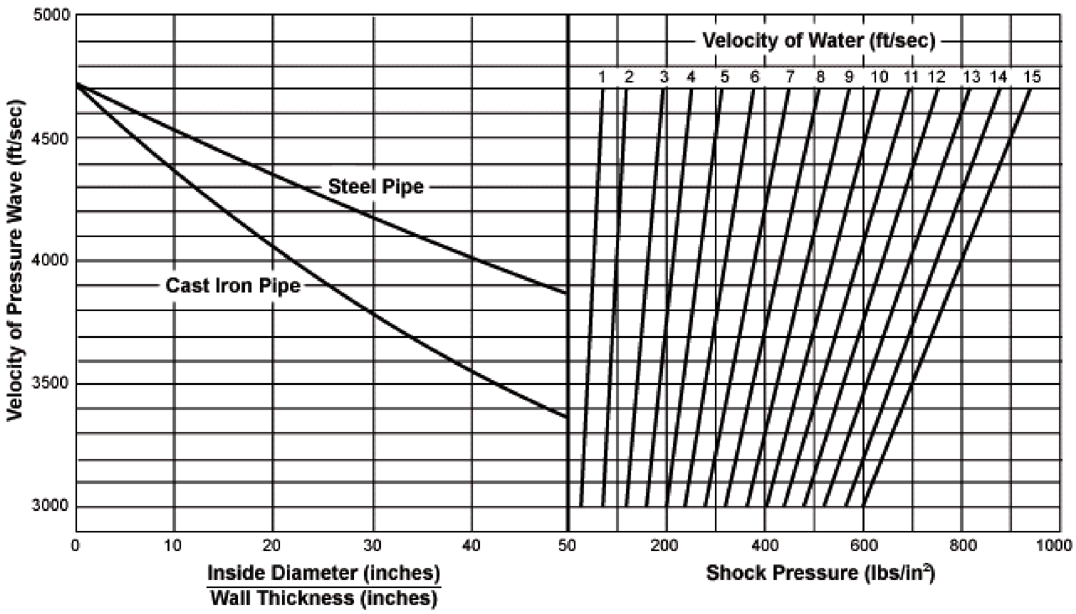
An evaluation of the water hammer in the Jenin distribution system has been implemented to investigate the effects of this force on the system, depending on simple calculation to estimate the maximum shock pressure by using figure (6.10) [44].

The factors affecting the water hammer presence in the water systems include [45]:

- Improperly sized supply lines for given peak water flow velocity.
- Excessive system water pressure and lack of pressure – reducing apparatus.
- Excessively long straight runs with no bends.
- Lack of expansion tank or other dampening system, such as water hammer arresters.

Figure (6.10)

Maximum shock pressure caused by water hammer



To use the above figure, first it should divide the inside diameter of the pipe by the wall thickness, and enter the figure at this value, then project upward until making an intersection with the curve for either cast iron or steel pipe. This gives the velocity of the pressure wave to the left of the figure. Project this value horizontally to the right to intersect with the water speed line, then project down to get the value for the shock pressure.

As shown in table (6.13), different pipes in the system having different diameters, and velocities were chosen to calculate the shock pressure in the system.

Table (6.13)

Maximum shock pressure caused by the water hammer

Pipe no.	Material	Diameter (inch)	Actual Inside Diameter (inch)	Wall Thickness (inch)	Velocity of Wave (ft/sec)	Velocity of Water (ft/sec)	Shock Pressure (Ibs/in^2)
P-26	Steel	2	2.067	0.154	4475	17	900
P-27	Steel	2	2.067	0.154	4475	11.5	690
P-25	Steel	4	4.026	0.237	4400	5.0	300
P-6	Steel	2	2.067	0.154	4475	5.0	300
P-7	Steel	2	2.067	0.154	4475	10	600
P-9	Steel	2	2.067	0.154	4475	8	490
P-49	Steel	4	4.026	0.237	4400	3.3	200
P-43	Steel	2	2.067	0.154	4475	5	300

As shown in table (6.13), it is obvious that the values of the maximum shock pressure caused by the water hammer is related strongly to the values of water velocity in the system, this mean that the value of the shock pressure and their effect will increase by increasing the water velocity.

Also a considerable note can be observed by making a comparison between the values of the shock pressure for different pipes diameters. It’s observed that the value of the shock pressure is equal for different pipes when their velocities are equal.

In typical water pipes, shock waves travel at up to 4500 ft/sec, and can exert tremendous instantaneous pressures, sometimes reaching 150 to over 1,000 PSI [45], and as its shown from the table (6.13) , the values of the shock pressures lies within the limits that are common in the water pipes systems.

Chapter Seven

Results and Discussion

7.1 Results and discussion of the intermittent model

The discussion of results which are produced by the modeling of Jenin water distribution system as an intermittent supply systems depends on some facts about the behavior of the Jenin water supply system under these conditions of providing water for consumers, taking into consideration some theoretical assumptions about the intermittent water systems.

- The modeling of the system as an intermittent system shows a high service values of pressure up to 13 bar, which is a characteristic of the intermittent water systems .The highest value of pressure was recorded at the node (J-1) with a value of 12.85 bar as shown in figure (7.1). This point of demand located below the reservoir no.1 (AL-Gabriat Reservoir), with a high difference of level up to (130 meter). Such high values of pressures are registered at nodes (J-8, J-20, J-40), and presented in figures (7.2), (7.3), (7.4). These nodes of demand located at different locations in the distribution system.

- When an evaluation between the pressure values at the nodes illustrated in figures (7.1), (7.2), (7.3), (7.4) has been done, it is noticeable that the decreasing of pressure at the nodes faraway from the source of supplying water is more obvious than for those nodes nearest to the sources, also the range of difference between the maximum and minimum values of pressures at the nodes faraway from the sources is large and reaches a value of zero pressure as shown in figure (7.4).

- The range of difference between the maximum and minimum values of pressure at nodes nearest to the sources is small in comparison to the difference for the farthest nodes, as shown in figures (7.1), (7.2), (7.3).

- Figures (7.5), (7.6) illustrate the variation of pressures at nodes (J-45), (47), which are located faraway from the sources, and have 24 water supply. There is a wide range of difference between pressure values and these values decrease to the levels less than zero.

- Large set of demand points in the distribution system shows a high values of pressures as it is observed from table (7.1), table (7.2), which contain the results of consumptions, and pressures at nodes at different times and supply periods.

- One of the main causes of high values of pressure in the system is the wide range of levels between the sources of water (reservoirs) and the consumption nodes, also the absence of pressure reducing valves to counteract the high pressure from the reservoirs contributes in increasing this problem of high pressures in the system.

- It is obvious from the tables (7.1), (7.2) that the high values of pressure appear at the nodes nearest to the sources of water, and/or have a clearly difference of levels. Also they have a 24 water supply services.

- The values of pressure at the consumption nodes are not fixed, and varying with time, because the demand pattern, which has been adopted in modeling the intermittent supply system, is not fixed, and represents the demand at the roof tank. The losses and demands at the system are varying with time due to the demand pattern also.

- The change setting valves in the distribution system to provide the needed amounts of water to the consumers affects the values of pressure in the system, and the closing valves cause increasing the pressure in the system by decreasing the losses in the system.

- These high values of pressure may affect adversely the hydraulic performance of the water distribution network. Also they produce high velocities, which accelerate the deterioration and corrosion of the pipes in the distribution system.

- For the parts of the system that are located faraway from the sources, or have high elevation, it is clearly obvious that they are suffering from low-pressure values or even zero values of pressure. This emphasizes the hypothesis, which state that there is a wide range of variations in pressure values in the intermittent systems.

- The normal pressure values in residential areas ranges between 3.0-4.0 bars. This means that the 12.85 bars recorded at Junction (J-1) at time 3 hr. after the beginning of the supply period is about 3.67 times the normal pressure value in a distribution system. Thus the network will be under excessive pressure during the period of supply and will release to zero pressure during non-supply periods, and this type of loading will affect the life of pipes and increase the leakage and breakage rates.

- When a comparison between the demand figures and the pressure progress has been done, it is concluded that when the demand values increase, there will be a decrease in pressure values as shown in figures (7.7), (7.8), which illustrate the demand and pressure at the nodes (J-29). This is because, the increasing of losses and demand in the distribution system will decrease the values of pressure.

- The local service pressures have a certain influence on demands and losses in the network. Higher pressures lead to increase consumption and losses, and vice versa. Also it is reasonable to conclude that the consumer faraway from the supply points will need to be more patient because the refilling of their roof tanks will start later and go slower than for those nearest to the sources points.

- The negative or zero values of pressures at the consumption nodes as shown in table (7.1), (7.2), is an indication of presence control for the pipes supplying these nodes at this moment, e.g., the consumption nodes (J-6), and (J-7) are closed at time 12 hr and will be open at time 24 hr, that cause zero value of pressures at this time.

- The zero values of discharges in the pipes as shown in tables (7.3), (7.4), which illustrate the discharges and velocities in the pipes at different times of supplying water, are also indicate to the presence of control for the pipes at this moment. It is obvious at the pipes (P-6), (P-7) at time 12 hr., which providing the water for junctions (J-6) and (J-7) respectively.

- The negative sign of discharges as shown in tables (7.3) and (7.4) is an indication to the wrong in assuming direction of flow through pipes in the distribution system.

- When a comparison has been done between the outputs of the intermittent model and the available field measurements which have been done by a consultant, some of similarity can be observed as its shown in figures (7.9), (7.10), which illustrate the pressure versus time at Junction (J-49) (This consumption node represents Sabah AL-Khair district).

- Generally the outputs of the intermittent model match to some level of accurate with the field measurements which have been done by a consultant from the point view, that the system showing high pressures, and the farthest regions suffering from low pressures, but the complexity of understanding the procedure of managing and operating the Jenin water distribution system, repeated shortcuts of supplying water to the consumers, and the continuous modification and changing of the supplying intervals will appear differences between the field measurements and the theoretical results of modeling the system as intermittent system.

- The intermittent model shows high values of velocities, and this result is a suspected outcome of the intermittent systems due to the high pressures in the system. The largest registered velocity is 12.18 m/s at Junction (J-26), and this value is larger than the design values of velocities (1.2 m/s –2.0 m/s), which are used to determine the most economic diameters by (10.15-6.09) times, and at the same time it's larger than the absolute minimum velocities (0.1 m/s – 0.3 m/s), that have to be avoided in order to avoid stagnation and water quality problems in the water systems by (121.8 – 40.6) times. These high velocities will affect adversely causing pipes deterioration.

Table (7.1)

Results of Consumptions and Pressures at Nodes, Time : 12 hr, Intermittent Model

Node Label	Elevation (m)	Demand (l/s)	Calculated Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	140	1.5	2.16	259.2	118.903
J-2	145	1.12	1.613	256.35	111.073
J-3	155	2.3	3.312	255.79	100.538
J-4	165	1	1.44	252.84	87.614
J-5	150	1	1.44	254.66	104.396
J-6	140	2.4	3.456	0.00	0.00
J-7	160	3.5	5.04	0.00	0.00
J-8	150	1	1.44	254.62	104.352
J-9	170	0.45	0.648	253.28	83.067
J-10	170	6.9	9.936	252.87	82.662
J-11	175	1.62	2.333	246	70.821
J-12	160	2.76	3.974	228.52	68.345
J-13	140	1.2	1.728	245.64	105.372
J-14	145	0.45	0.648	244.84	99.584
J-15	130	5.8	8.352	243.15	112.866
J-16	180	3.8	5.472	236.74	56.598
J-17	180	0.91	1.31	233.2	53.061
J-18	131	0.73	1.051	231.87	100.614
J-19	124	1.93	2.779	223.44	99.192
J-20	118	0.723	1.041	217.28	99.03
J-21	160	0.574	0.827	216.02	55.879
J-22	190	0.815	1.174	210.77	20.722
J-23	190	0.45	0.648	210.68	20.626
J-24	140	0.352	0.507	209.76	69.585
J-25	145	3.3	4.752	156.02	10.988
J-26	115	5.8	8.352	0	0
J-27	90	10.8	15.552	0.00	0.00
J-28	137	2.3	3.312	233.14	95.901
J-29	135	0.54	0.778	227.48	92.248
J-30	180	0.67	0.965	225.8	45.688
J-31	145	1.6	2.304	194.98	49.857
J-32	145	0.815	1.174	190.97	45.851
J-33	138	0.74	1.066	192.97	54.835
J-34	150	3.41	4.91	191.03	40.931
J-35	164	3.315	4.774	163.45	-0.553
J-36	150	2.37	3.413	0.00	0.00
J-37	140	0.73	1.051	163.04	22.983

Table (7.1)(continue)

Node Label	Elevation (m)	Demand (l/s)	Calculated Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-38	125	0.73	1.051	160.16	35.07
J-39	115	1	1.44	142.41	27.343
J-40	108	1	1.44	130.69	22.628
J-41	132	2.74	3.946	0.00	0.00
J-42	130	1.26	1.814	0.00	0.00
J-43	132	2.4	3.456	0.00	0.00
J-44	110	1.2	1.728	0.00	0.00
J-45	138	2.3	3.312	127.88	-10.093
J-46	132	3.25	4.68	55.22	-76.582
J-47	130	2.5	3.6	86.92	-42.967
J-48	134	12.9	18.576	68.73	-65.101
J-49	132	3.6	5.184	78.78	20.207
J-50	165	3.5	5.04	237.48	72.302
J-51	210	2.3	3.312	235.99	25.921
J-53	240	0.5	0.72	272.18	32.096
J-52	237	1.5	2.16	272.13	35.044
J-54	238	1.5	2.16	271.91	33.819
J-55	232	1.5	2.16	271.83	39.732
J-56	235	0.7	1.008	0.00	0.00
J-57	260	0.7	1.008	0.00	0.00
J-58	250	0.7	1.008	0.00	0.00
228	215	0.7	1.008	0.00	0.00
J-60	226	0.67	0.965	0.00	0.00

Table (7.2)
Results of Consumptions and Pressures at Nodes, Time :24 hour, Intermittent Model

Node Label	Elevation (m)	Demand (l/s)	Calculated Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	140	1.5	0.945	267.72	127.396
J-2	145	1.12	0.706	267.1	121.793
J-3	155	2.3	1.449	266.98	111.696
J-4	165	1	0.63	266.34	101.083
J-5	150	1	0.63	266.73	116.439
J-6	140	2.4	1.512	261.6	121.293
J-7	160	3.5	2.205	256.42	96.172
J-8	150	1	0.63	266.72	116.429
J-9	170	0.45	0.283	266.43	96.191
J-10	170	6.9	4.347	0.00	0.00
J-11	175	1.62	1.021	0.00	0.00
J-12	160	2.76	1.739	261.07	100.814
J-13	140	1.2	0.756	257.2	116.902
J-14	145	0.45	0.283	257.02	111.741
J-15	130	5.8	3.654	0.00	0.00
J-16	180	3.8	2.394	247.71	67.541
J-17	180	0.91	0.573	246.94	66.775
J-18	131	0.73	0.46	240.65	109.372
J-19	124	1.93	1.216	238.82	114.533
J-20	118	0.723	0.455	237.49	119.186
J-21	160	0.574	0.362	237.21	77.02
J-22	190	0.815	0.513	236.08	45.962
J-23	190	0.45	0.283	236.06	45.941
J-24	140	0.352	0.222	235.86	95.616
J-25	145	3.3	2.079	224.21	79.013
J-26	115	5.8	3.654	58.82	-56.035
J-27	90	10.8	6.804	-44.88	-134.544
J-28	137	2.3	1.449	240	102.735
J-29	135	0.54	0.34	239.47	104.207
J-30	180	0.67	0.422	239.11	58.958
J-31	145	1.6	1.008	232.43	87.208
J-32	145	0.815	0.513	231.56	86.34
J-33	138	0.74	0.466	231.99	93.756
J-34	150	3.41	2.148	231.57	81.367
J-35	164	3.315	2.088	225.6	61.44
J-36	150	2.37	1.493	221.08	70.902
J-37	140	0.73	0.46	225.51	85.292
J-38	125	0.73	0.46	224.88	99.631
J-39	115	1	0.63	221.04	105.771
J-40	108	1	0.63	218.5	110.218

Table (7.2) (continue)

Node Label	Elevation (m)	Demand (l/s)	Calculated Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-41	132	2.74	1.726	218.22	85.999
J-42	130	1.26	0.794	155.18	25.112
J-43	132	2.4	1.512	217.1	84.887
J-44	110	1.2	0.756	215.32	105.056
J-45	138	2.3	1.449	217.89	79.688
J-46	132	3.25	2.047	202.15	69.969
J-47	130	2.5	1.575	209.01	78.816
J-48	134	12.9	8.127	205.07	70.894
J-49	132	3.6	2.268	207.25	0
J-50	165	3.5	2.205	239.99	74.802
J-51	210	2.3	1.449	239.67	29.592
J-53	240	0.5	0.315	273.76	33.671
J-52	237	1.5	0.945	273.75	36.654
J-54	238	1.5	0.945	273.7	35.608
J-55	232	1.5	0.945	273.68	41.577
J-56	235	0.7	0.441	155.17	-79.633
J-57	260	0.7	0.441	155.08	-104.655
J-58	250	0.7	0.441	154.97	-94.79
228	215	0.7	0.441	154.96	-59.886
J-60	226	0.67	0.422	154.96	-70.86

Table (7.3)
Pipes, Lengths, Discharges, and Velocities, Time :12 hr, Intermittent Model

Link Label	Length (m)	Diameter (in)	Material	Initial Status	Current Status	Discharge (l/s)	Headloss (m)	Velocity (m/s)
P-54	168	10	Steel	Open	Open	83.183	2.82	1.70
P-2	230	6	Steel	Open	Open	18.389	2.85	1.04
P-10	150	4	Steel	Open	Open	12.269	6.33	1.56
P-12	200	2	Steel	Open	Open	3.974	30.69	2.02
P-13	270	6	Steel	Open	Open	39.191	13.57	2.22
P-3	150	4	Steel	Open	Open	3.312	0.56	0.42
P-4	150	2	Steel	Open	Open	1.44	3.52	0.73
P-5	300	6	Steel	Open	Open	12.024	1.69	0.68
P-6	200	2	Steel	Open	Closed	0	0	0.00
P-7	200	2	Steel	Open	Closed	0	0	0.00
P-8	200	6	Steel	Open	Open	2.088	0.04	0.12
P-9	250	2	Steel	Open	Open	0.648	1.34	0.33
P-11	120	2	Steel	Open	Open	2.333	6.87	1.19
P-14	150	2	Steel	Open	Open	0.648	0.8	0.33
P-15	120	4	Steel	Open	Open	8.352	2.49	1.06
P-16	320	6	Steel	Open	Open	28.463	8.9	1.61
P-17	180	2	Steel	Open	Open	1.31	3.55	0.67
P-18	290	6	Steel	Open	Open	21.68	4.87	1.23
P-19	200	6	Steel	Open	Open	35.631	8.43	2.02
P-28	150	6	Steel	Open	Open	-15.002	1.28	-0.85
P-20	170	6	Steel	Open	Open	32.852	6.16	1.86
P-21	150	2	Steel	Open	Open	0.827	1.26	0.42
P-22	200	6	Steel	Open	Open	30.984	6.51	1.75
P-23	180	4	Steel	Open	Open	1.155	0.1	0.15
P-25	270	4	Steel	Open	Open	28.656	54.76	3.65
P-24	270	2	Steel	Open	Open	0.507	0.92	0.26
P-26	180	2	Steel	Open	Open	23.904	763.31	12.18
P-27	250	2	Steel	Open	Open	15.552	478.63	7.92
P-51	250	8	Steel	Open	Open	-47.059	4.34	-1.50
P-29	200	6	Steel	Open	Open	28.745	5.66	1.63
P-30	150	2	Steel	Open	Open	0.965	1.68	0.49
P-32	200	6	Steel	Open	Open	73.915	32.5	4.18
P-31	250	6	Steel	Open	Open	46.913	17.52	2.66
P-33	250	2	Steel	Open	Open	1.174	4.02	0.60
P-34	180	4	Steel	Open	Open	5.976	2.01	0.76
P-36	250	6	Steel	Open	Open	64.462	31.54	3.65
P-35	250	4	Steel	Open	Open	4.91	1.94	0.63
P-37	180	2	Steel	Open	Closed	0	0	0.00
P-38	250	4	Steel	Open	Open	2.102	0.4	0.27
P-40	230	6	Steel	Open	Open	54.173	21.03	3.07

Table (7.3) (continue)

Link Label	Length (m)	Diameter (in)	Material	Initial Status	Current Status	Discharge (l/s)	Headloss (m)	Velocity (m/s)
P-39	220	2	Steel	Open	Open	1.051	2.88	0.54
P-41	500	2	Steel	Open	Open	1.44	11.73	0.73
P-42	190	4	Steel	Open	Closed	0	0	0.00
P-46	350	6	Steel	Open	Open	35.352	14.53	2.00
P-43	700	2	Steel	Open	Open	6.811	290.17	3.47
P-44	600	4	Steel	Open	Open	5.184	4.88	0.66
P-60	62	6	Ductile Iron	Open	Open	4.997	1.22	0.28
P-45	250	2	Steel	Open	Open	1.728	8.53	0.88
P-47	350	2	Steel	Open	Open	4.68	72.66	2.38
P-48	220	4	Steel	Open	Open	27.36	40.96	3.49
P-49	200	4	Steel	Open	Open	18.576	18.19	2.37
P-50	950	4	Steel	Open	Open	5.184	8.15	0.66
P-52	400	4	Steel	Open	Open	3.312	1.5	0.42
P-55	913	10	Steel	Open	Open	75.983	12.97	1.55
P-57	488	10	Ductile Iron	Open	Open	6.48	0.04	0.13
P-56	174	8	Ductile Iron	Open	Open	55.411	2.52	1.76
P-58	435	6	Ductile Iron	Open	Open	4.32	0.23	0.24
P-59	500	6	Ductile Iron	Open	Open	2.16	0.07	0.12
P-61	121	4	Ductile Iron	Open	Open	3.989	0	0.51
P-62	268	4	Ductile Iron	Open	Open	2.981	0	0.38
P-63	41	4	Ductile Iron	Open	Open	1.973	0	0.25
P-64	42	4	Ductile Iron	Open	Open	0.965	0	0.12

Table (7.4)

Pipes, Lengths, Discharges , and Velocities , Time :24 hour, Intermittent Model

Link Label	Length (m)	Diameter (in)	Material	Initial Status	Current Status	Discharge (l/s)	Headloss (m)	Velocity (m/s)
P-54	168	10	Steel	Open	Open	53.406	1.24	1.1
P-2	230	6	Steel	Open	Open	8.045	0.62	0.5
P-10	150	4	Steel	Open	Closed	0	0	0.0
P-12	200	2	Steel	Open	Open	1.739	6.65	0.9
P-13	270	6	Steel	Open	Open	34.159	10.52	1.9
P-3	150	4	Steel	Open	Open	1.449	0.12	0.2
P-4	150	2	Steel	Open	Open	0.63	0.76	0.3
P-5	300	6	Steel	Open	Open	5.26	0.37	0.3
P-6	200	2	Steel	Open	Open	2.91	5.13	1.5
P-7	200	2	Steel	Open	Open	5.90	10.32	3.0
P-8	200	6	Steel	Open	Open	0.913	0.01	0.1
P-9	250	2	Steel	Open	Open	5.0	0.29	2.5
P-11	120	2	Steel	Open	Open	1.021	1.22	0.5
P-14	150	2	Steel	Open	Open	0.283	0.17	0.1
P-15	120	4	Steel	Open	Closed	0	0	0.0
P-16	320	6	Steel	Open	Open	29.466	9.49	1.7
P-17	180	2	Steel	Open	Open	0.573	0.77	0.3
P-18	290	6	Steel	Open	Open	26.498	7.06	1.5
P-19	200	6	Steel	Open	Open	15.589	1.83	0.9
P-28	150	6	Steel	Open	Open	10.45	0.65	0.6
P-20	170	6	Steel	Open	Open	14.373	1.34	0.8
P-21	150	2	Steel	Open	Open	0.362	0.27	0.2
P-22	200	6	Steel	Open	Open	13.556	1.41	0.8
P-23	180	4	Steel	Open	Open	0.505	0.02	0.1
P-25	270	4	Steel	Open	Open	12.537	11.86	1.6
P-24	270	2	Steel	Open	Open	0.222	0.2	0.1
P-26	180	2	Steel	Open	Open	10.458	165.39	5.3
P-27	250	2	Steel	Open	Open	6.804	103.71	3.5
P-51	250	8	Steel	Open	Open	1.054	3.90E-03	0.0
P-29	200	6	Steel	Open	Open	7.947	0.52	0.4
P-30	150	2	Steel	Open	Open	0.422	0.36	0.2
P-32	200	6	Steel	Open	Open	32.338	7.04	1.8
P-31	250	6	Steel	Open	Open	25.153	5.53	1.4
P-33	250	2	Steel	Open	Open	0.513	0.87	0.3
P-34	180	4	Steel	Open	Open	2.615	0.44	0.3
P-36	250	6	Steel	Open	Open	28.202	6.83	1.6
P-35	250	4	Steel	Open	Open	2.148	0.42	0.3
P-37	180	2	Steel	Open	Open	1.493	4.51	0.8
P-38	250	4	Steel	Open	Open	0.92	0.09	0.1
P-40	230	6	Steel	Open	Open	23.701	4.56	1.3

Table (7.4) (continue)

Link Label	Length (m)	Diameter (in)	Material	Initial Status	Current Status	Discharge (l/s)	Headloss (m)	Velocity (m/s)
P-39	220	2	Steel	Open	Open	0.46	0.62	0.2
P-41	500	2	Steel	Open	Open	0.63	2.54	0.3
P-42	190	4	Steel	Open	Open	6.974	2.82	0.9
P-46	350	6	Steel	Open	Open	15.466	3.15	0.9
P-43	700	2	Steel	Open	Open	2.98	63.04	1.5
P-44	600	4	Steel	Open	Open	2.268	1.12	0.3
P-60	62	6	Ductile Iron	Open	Open	2.186	0.01	0.1
P-45	250	2	Steel	Open	Open	0.756	1.78	0.4
P-47	350	2	Steel	Open	Open	2.047	15.74	1.0
P-48	220	4	Steel	Open	Open	11.97	8.87	1.5
P-49	200	4	Steel	Open	Open	8.127	3.94	1.0
P-50	950	4	Steel	Open	Open	2.268	1.77	0.3
P-52	400	4	Steel	Open	Open	1.449	0.32	0.2
P-55	913	10	Steel	Open	Open	50.256	6.04	1.0
P-57	488	10	Ductile Iron	Open	Open	2.835	0.01	0.1
P-56	174	8	Ductile Iron	Open	Open	2.6	0.01	0.1
P-58	435	6	Ductile Iron	Open	Open	1.89	0.05	0.1
P-59	500	6	Ductile Iron	Open	Open	0.945	0.02	0.1
P-61	121	4	Ductile Iron	Open	Open	1.745	0.09	0.2
P-62	268	4	Ductile Iron	Open	Open	1.304	0.11	0.2
P-63	41	4	Ductile Iron	Open	Open	0.863	0.01	0.1
P-64	42	4	Ductile Iron	Open	Open	0.422	2.10E-03	0.1

Figure (7.1)
Pressure versus Time at Junction: J –1

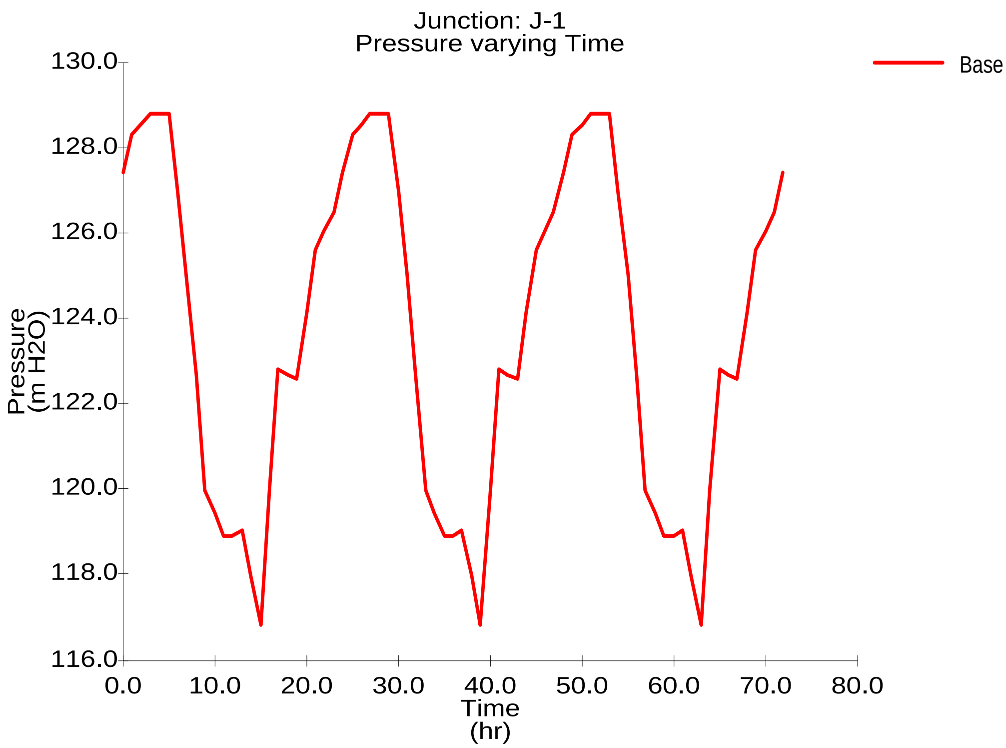


Figure (7.2)
Pressure versus Time at Junction: J-8

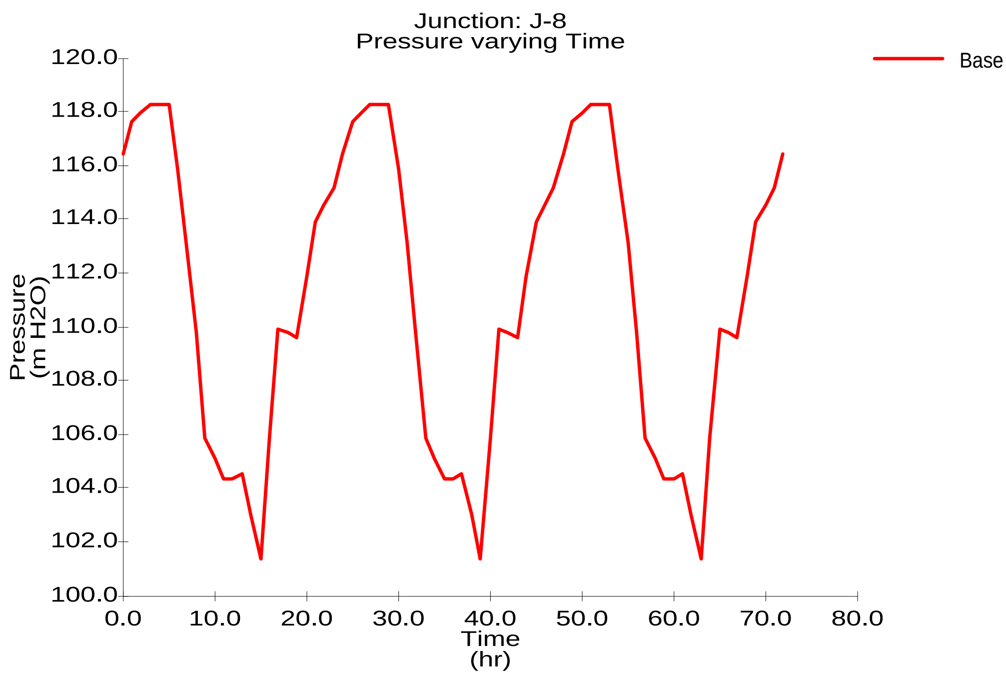


Figure (7.3)
Pressure versus Time at Junction: J-20

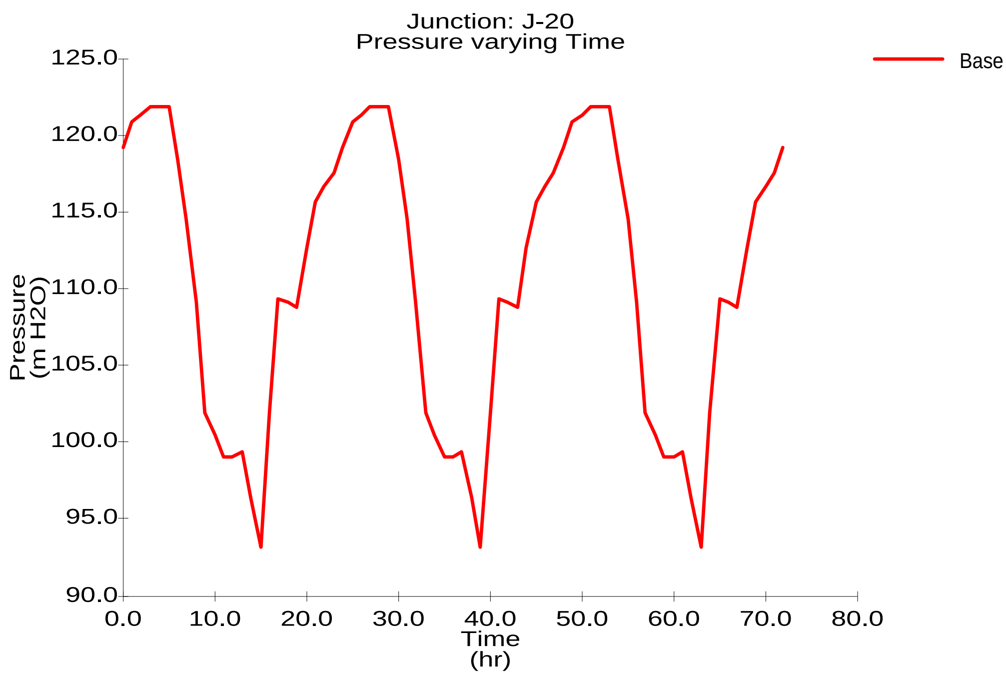


Figure (7.4)
Pressure versus Time at Junction: J-40

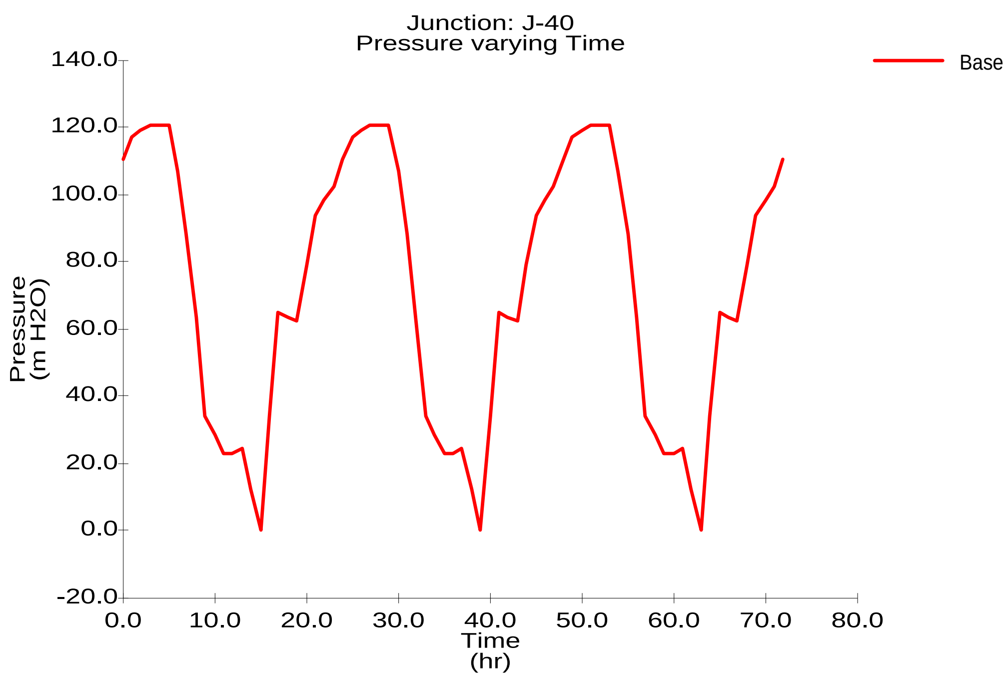


Figure (7.5)
Pressure versus Time at Junction: J-45

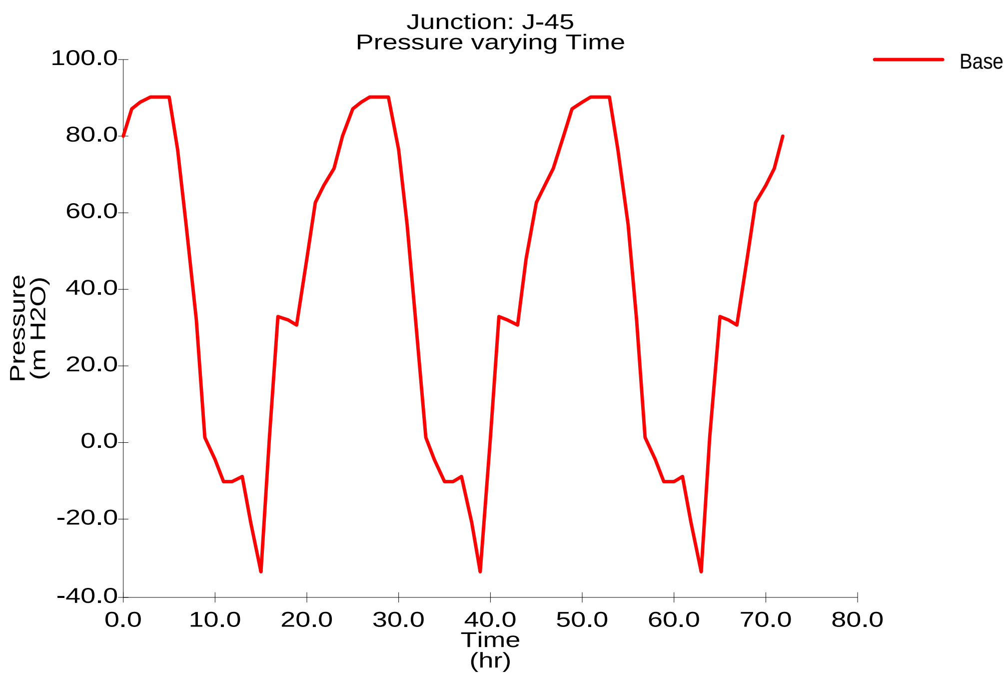


Figure (7.6)
Pressure versus Time at Junction: J-47

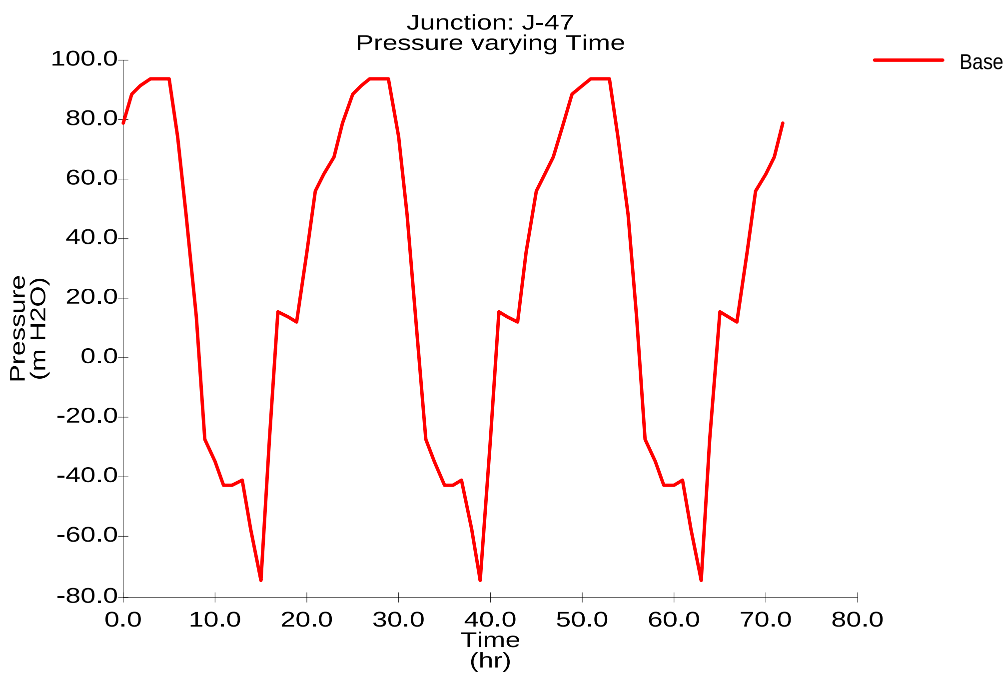


Figure (7.7)
Demand versus Time at Junction: J-29

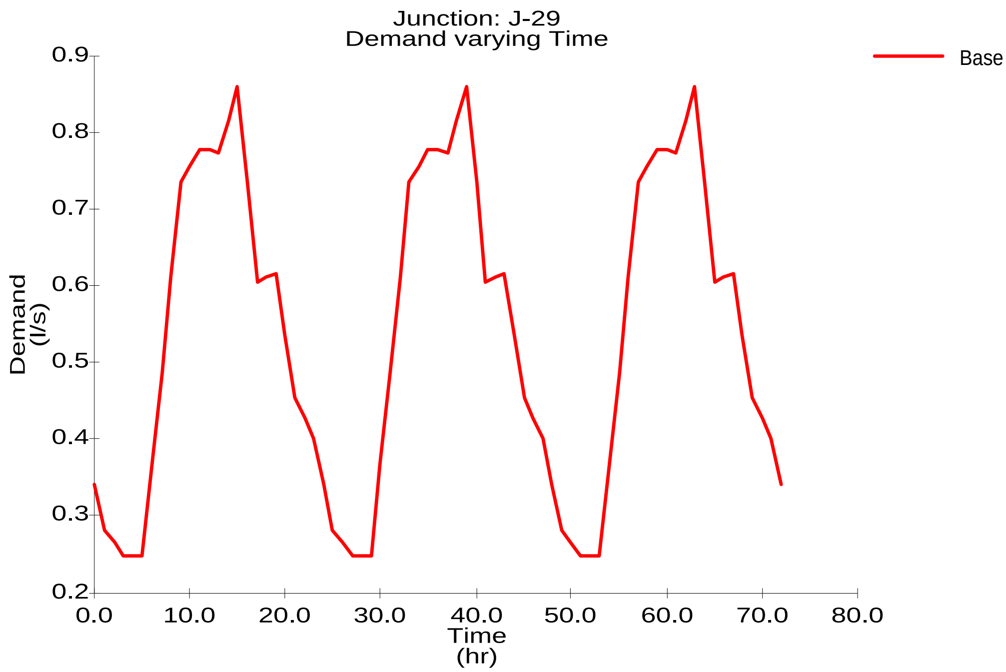


Figure (7.8)
Pressure versus Time at Junction: J-29

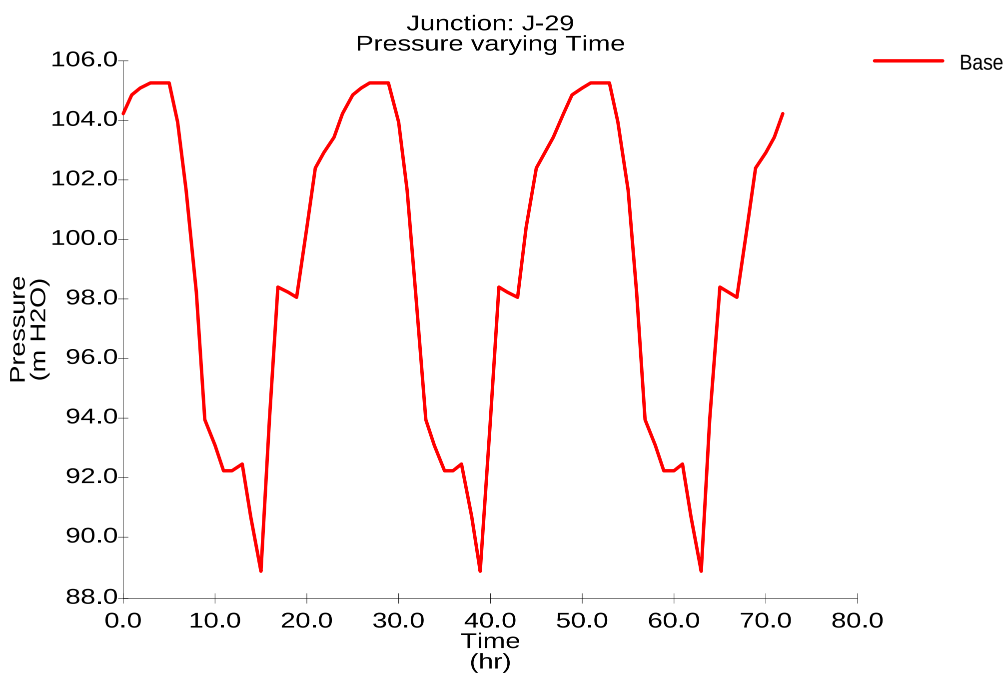


Figure (7.9)
Pressure versus Time at Junction: J-49

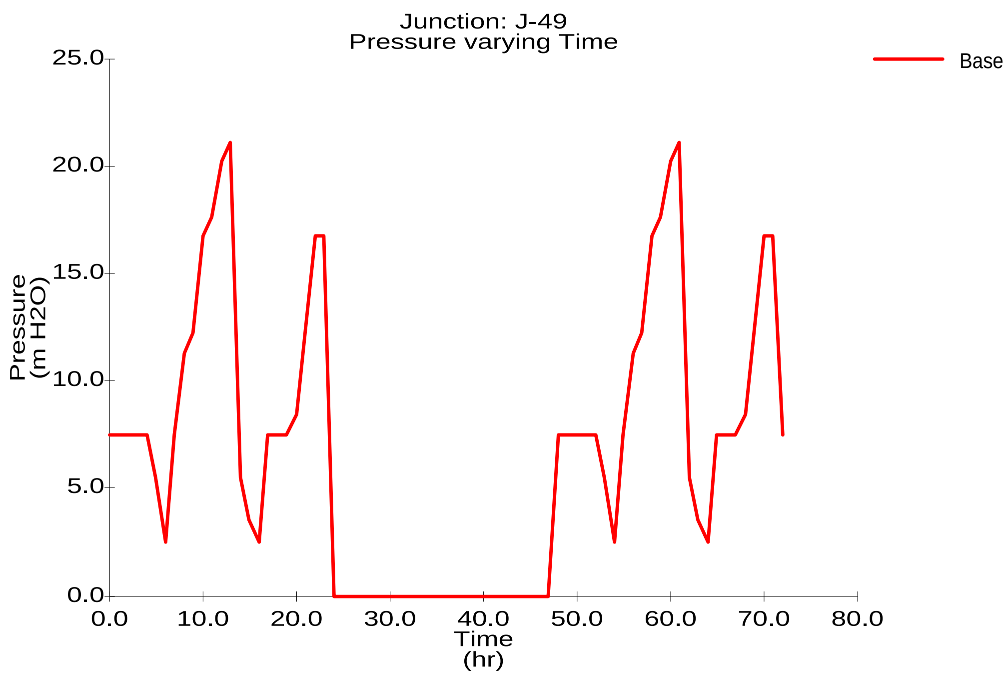
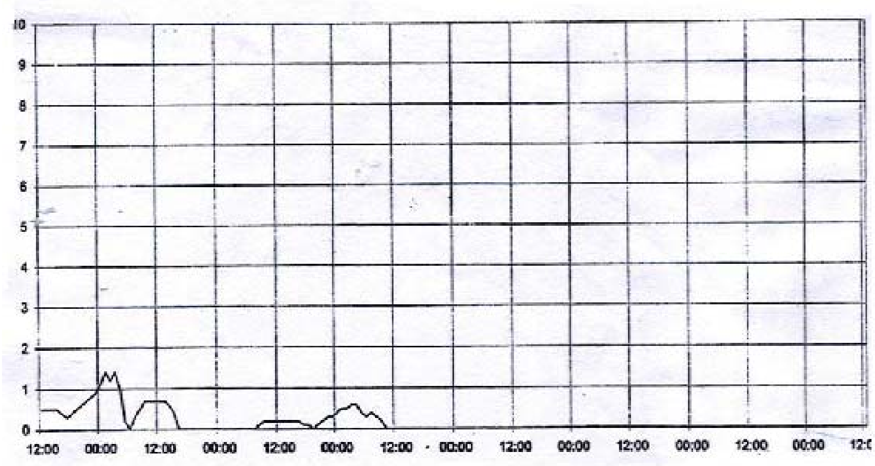


Figure (7.10)
Pressure measurement versus Time (Field measurement) at Junction: J-49



Pressure (bar)

Time

7.2 Results and discussion of the continuous model

The results of continuous model of Jenin water distribution network discuss the ability of the existing system with the assumed assumptions and development measures such as the availability of water, increasing of demand, reducing the losses and high pressures, to satisfy the requirements of demands, limits of velocities and pressures in order to provide the water by acceptable quantity and quality in the future.

The comparison of results of analysis the proposed model of continuous supply with the assumed limits of velocities which have been established to be 0.1-0.3 m/s. (minimum velocities), and represent the absolute minimum velocities that have to be avoided in order to avoid stagnation and water quality problems, the limits of maximum pressures were set at 6 bar and the minimum pressure for the main lines at 0.5 bar shows the following:

- It is obvious from the table (7.5), that the high values of pressure appear at the nodes nearest to the sources of water or booster stations as its shown in the intermittent systems which lead also to conclude that the consumer faraway from the supply points will need to be more patient, some high values of pressure are specified at the nodes (J-85: 5.6 bar, J-86: 6.2 bar, J-87: 8 bar, J-88: 6.7 bar, J-29: 8.3 bar, J-28: 8.2 bar, J-42: 8 bar).

- The demand nodes which are faraway from the sources or booster stations and have high levels suffer from low pressure values as its shown in table (7.5), and registered for example at the nodes (J-27 :

0.35 bar, J-49 : 1.6 bar, J-44 : 0.4 bar, J-46 : 1.4 bar, J-69 : 0.56 bar, J-70 : 0.46 bar).

- The results of the pressure values in the whole system as it is mentioned in the table (7.5), show the ability of the system to satisfy the needed pressures that are necessary with some extreme values neither smaller or larger than the specified values of pressure, and this conclusion lead to suggest the capability of the system to serve the people in the future in the case of adding some developing measures such as, providing the necessary quantities of water, using booster stations in the hill areas , and controlling the high pressures in the system.

- The results of the pressure values in the continuous system show the valuable of using pressure reducing valves to counteract the high pressure from the reservoirs and limit the pressures in the system to the specified or needed values. This way of manage the system will affect positively the hydraulic performance of the distribution network, especially that it will reduce the losses and velocities in the system and consequently reduce the adverse effects of the high velocities which cause deterioration of the pipes in the system, and save the water meter of the customers from blowing up due to the high pressures.

- The results of velocities in the continuous system as shown in table (7.6) appear a reasonable values of velocities, which are parallel to the assumed limits of velocities to avoid stagnation and quality water problems, also to save the pipes from deterioration due to the high velocities.

- The negative sign of the discharges in the pipes as shown in table (7.6) is an indication to the wrong in assuming direction only.

Table (7.5)

Results of Consumptions and Pressures at Nodes, Steady State Analysis, Continuous Model

Node Label	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	140	2.83	200.13	59.981
J-2	145	2.5323	196.6	51.47
J-3	155	3.713	195.91	40.803
J-4	165	2.3355	187.99	22.936
J-5	150	2.3355	194.89	44.781
J-6	140	2.5323	181.57	41.461
J-7	160	3.1226	175.25	15.216
J-8	150	2.3355	194.74	44.629
J-9	170	1.745	186.38	16.334
J-10	170	3.713	198.67	28.598
J-11	175	1.844	194.22	19.174
J-12	160	4.205	166.07	6.057
J-13	140	2.533	200.82	60.67
J-14	145	1.7453	195.8	50.674
J-15	130	3.32	200.37	70.195
J-16	180	5.29	203.69	23.632
J-17	180	2.24	194.13	14.096
J-18	131	2.04	209.11	77.916
J-19	124	3.32	205.87	81.665
J-20	118	2.04	203.86	85.642
J-21	160	1.883	198.08	37.984
J-22	190	2.14	202.36	12.327
J-23	190	1.75	201.65	11.621
J-24	140	1.65	193.5	53.369
J-25	145	2.04	196.6	51.472
J-26	115	2.63	129.15	14.119
J-27	90	3.81	93.68	3.671
J-28	137	3.7148	219.36	82.152
J-29	135	1.8436	218.3	83.086
J-30	180	1.9814	211.95	31.865
J-31	145	2.92581	195.48	50.352
J-32	145	2.1388	183.29	38.192
J-33	138	2.04	192.83	54.697
J-34	150	4.8934	190.91	40.804
J-35	164	4.795	176.45	12.421
J-36	150	2.5323	164.46	14.42
J-37	140	2.0404	175.07	34.986
J-38	125	2.0404	165.24	40.141
J-39	115	2.3355	165.72	50.597
J-40	108	2.3355	137.03	28.962
J-41	132	2.73	153.8	21.746
J-42	130	0.35	209.98	79.781
J-43	132	1.9	147.84	15.799
J-44	110	3.713	114.02	4.008
J-45	138	3.713	161.65	23.592
J-46	132	2.04	146.02	13.98

Table (7.5) (continue)

Node Label	Elevation (m)	Demand (l/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-45	138	3.713	161.65	23.592
J-46	132	2.04	146.02	13.98
J-47	130	3.91	152.71	22.649
J-48	134	4.3	151.49	17.448
J-49	132	3.812	148.09	16.051
J-50	165	4.952	225.08	59.927
J-51	210	3.7148	223.23	13.193
J-53	240	0.5824	273.31	33.228
J-52	237	0.212	277.26	40.155
J-54	238	0.212	277.21	39.106
J-55	232	0.212	277.08	44.963
J-56	235	0.212	276.97	41.868
J-57	260	0.27	276.88	16.842
J-58	250	0.27	276.87	26.797
J-59	253	0.27	276.85	23.789
J-60	256	0.27	276.8	20.752
J-61	266	0.2683	276.75	10.726
J-62	266	0.2683	276.74	10.713
J-63	268	0.2683	276.73	8.708
J-64	270	0.2683	276.71	6.693
J-65	265	0.2683	276.7	11.67
J-66	265	0.2683	276.69	11.664
J-67	270	0	276.69	6.676
J-68	266	0.2683	276.69	10.664
J-69	271	0.2683	276.69	5.674
J-70	272	0.2683	276.69	4.677
J-71	250	0.2683	276.69	26.621
J-72	255	0.2683	276.69	21.638
J-73	257	0.2683	276.69	19.642
J-74	257	0.2683	276.69	19.642
J-75	260	0.2683	276.69	16.65
J-76	172	0.8968	209.91	37.818
J-77	177	0.8968	209.17	32.093
J-78	185	0.8968	207.99	22.93
J-79	200	0.8968	207.86	7.845
J-80	202	0.9	207.79	5.774
J-81	202	0.9	207.57	5.553
J-82	190	0.4	205.76	15.716
J-83	192	0.36	205.1	13.072
J-84	177	0.36	204.74	27.674
J-85	217	1.1	273.15	56.013
J-86	211	2.49	273.07	61.915
J-87	193	2.1	273.02	79.814
J-88	206	2	272.99	66.826
J-89	246	0.3	272.51	26.446
J-90	259	2.1	272.36	13.322
J-91	246	0.6	272.46	26.392
J-92	200	2.1	272.32	72.142

Table (7.6)
Pipes,Lengths,Discharges,and Velocities, Steady State Analysis, Continuous Model

Link Label	Length (m)	Diameter (in)	Material	Initial Status	Discharge (l/s)	Headloss (m)	Velocity (m/s)
P-54	168	10	Steel	Open	38.77791	0.69	0.79
P-2	230	6	Steel	Open	20.6517	3.53	1.17
P-10	150	4	Steel	Open	5.557	1.46	0.71
P-12	200	2	Steel	Open	4.205	34.06	2.14
P-13	270	6	Steel	Open	-7.83819	0.69	0.44
P-3	150	4	Steel	Open	3.713	0.69	0.47
P-4	150	2	Steel	Open	2.3355	8.61	1.19
P-5	300	6	Steel	Open	12.0709	1.71	0.68
P-6	200	2	Steel	Open	2.5323	13.33	1.29
P-7	200	2	Steel	Open	3.1226	19.64	1.59
P-8	200	6	Steel	Open	4.0805	0.15	0.23
P-9	250	2	Steel	Open	1.745	8.37	0.89
P-11	120	2	Steel	Open	1.844	4.45	0.94
P-14	150	2	Steel	Open	1.7453	5.02	0.89
P-15	120	4	Steel	Open	3.32	0.45	0.42
P-16	320	6	Steel	Open	-15.43649	2.87	0.87
P-17	180	2	Steel	Open	2.24	9.56	1.14
P-18	290	6	Steel	Open	-22.96649	5.42	1.30
P-19	200	6	Steel	Open	21.263	3.24	1.20
P-28	150	6	Steel	Open	-46.26949	10.25	2.60
P-20	170	6	Steel	Open	17.943	2.01	1.02
P-21	150	2	Steel	Open	1.883	5.78	0.96
P-22	200	6	Steel	Open	14.02	1.5	0.79
P-23	180	4	Steel	Open	3.4	0.71	0.43
P-25	270	4	Steel	Open	8.48	5.76	1.08
P-24	270	2	Steel	Open	1.65	8.15	0.84
P-26	180	2	Steel	Open	6.44	67.45	3.28
P-27	250	2	Steel	Open	3.81	35.47	1.94
P-51	200	8	Steel	Open	-61.62719	5.72	1.96
P-29	200	6	Steel	Open	11.6429	1.06	0.66
P-30	150	2	Steel	Open	1.9814	6.35	1.01
P-32	200	6	Steel	Open	61.0523	22.82	3.46
P-99	87.5	6	PVC	Open	5.6842	0.06	0.32
P-31	250	6	Steel	Open	58.91861	26.7	3.34
P-33	250	2	Steel	Open	2.1388	12.19	1.09
P-34	180	4	Steel	Open	6.9334	2.64	0.88
P-36	250	6	Steel	Open	49.0543	19.03	2.78
P-35	250	4	Steel	Open	4.8934	1.93	0.62
P-37	180	2	Steel	Open	2.5323	12	1.29
P-38	250	4	Steel	Open	4.0808	1.38	0.52
P-40	230	6	Steel	Open	37.6462	10.73	2.13
P-39	220	2	Steel	Open	2.0404	9.83	1.04
P-41	500	2	Steel	Open	2.3355	28.69	1.19
P-42	190	4	Steel	Open	15.2002	11.92	1.94
P-46	350	6	Steel	Open	17.775	4.07	1.01

Table (7.6) (continue)

Link Label	Length (m)	Diameter (in)	Material	Initial Status	Discharge (l/s)	Headloss (m)	Velocity (m/s)
P-44	600	4	Steel	Open	5.613	5.96	0.72
P-97	125	6	Ductile Iron	Open	6.85	0.15	0.39
P-80	62	6	Ductile Iron	Open	6.50	0.07	0.37
P-45	250	2	Steel	Open	3.713	33.82	1.89
P-47	350	2	Steel	Open	2.04	15.64	1.04
P-48	220	4	Steel	Open	12.02	8.95	1.53
P-49	200	4	Steel	Open	4.3	1.21	0.55
P-50	950	4	Steel	Open	3.812	4.61	0.49
P-52	400	4	Steel	Open	3.71	1.85	0.47
P-89	488	10	Ductile Iron	Open	12.79	0.16	0.26
P-101	836	10	Steel	Open	25.4	1.57	0.52
P-103	173.5	8	Steel	Open	70.29	6.33	2.24
P-58	82	6	PVC	Open	5.47	0.05	0.31
P-59	222	6	PVC	Open	5.26	0.13	0.30
P-60	192	6	PVC	Open	5.04	0.1	0.29
P-61	181	6	PVC	Open	4.8362	0.09	0.27
P-62	44	6	PVC	Open	4.5662	0.02	0.26
P-63	40	6	PVC	Open	4.2962	0.02	0.24
P-64	127	6	PVC	Open	4.0262	0.04	0.23
P-65	167	6	PVC	Open	3.7562	0.05	0.21
P-66	47	6	PVC	Open	3.4879	0.01	0.20
P-67	44	6	PVC	Open	3.2196	0.01	0.18
P-68	98	6	PVC	Open	2.9513	0.02	0.17
P-69	67	6	PVC	Open	2.683	0.01	0.15
P-70	40	6	PVC	Open	2.4147	0.01	0.14
P-71	31	6	PVC	Open	1.0732	9.50E-04	0.06
P-76	33	6	PVC	Open	1.0732	1.00E-03	0.06
P-72	60	6	PVC	Open	1.0732	1.80E-03	0.06
P-73	120	6	PVC	Open	0.8049	2.10E-03	0.05
P-74	22	6	PVC	Open	0.5366	1.90E-04	0.03
P-75	184	6	PVC	Open	0.2683	4.50E-04	0.02
P-77	34	6	PVC	Open	0.8049	6.00E-04	0.05
P-78	30	6	PVC	Open	0.5366	2.60E-04	0.03
P-79	35	6	PVC	Open	0.2683	7.40E-05	0.02
P-81	121	4	Ductile Iron	Open	5.6104	0.74	0.71
P-82	268	4	Ductile Iron	Open	4.7136	1.19	0.60
P-83	41	4	Ductile Iron	Open	3.8168	0.12	0.49
P-84	42	4	Ductile Iron	Open	2.92	0.08	0.37
P-85	239	4	Ductile Iron	Open	2.02	0.22	0.26
P-86	123	2	Steel	Open	1.12	1.81	0.57
P-87	100	2	Steel	Open	0.72	0.65	0.37
P-88	200	2	Steel	Open	0.36	0.36	0.18
P-90	300	10	Ductile Iron	Open	11.69	0.08	0.24
P-91	322	10	Ductile Iron	Open	9.2	0.06	0.19
P-92	411	8	Steel	Open	2	0.02	0.06
P-93	435	6	Steel	Open	5.1	0.5	0.29
P-94	700	6	Ductile Iron	Open	2.1	0.16	0.12
P-95	151	6	Ductile Iron	Open	2.7	0.05	0.15

Table (7.6) (continue)

Link Label	Length (m)	Diameter (in)	Material	Initial Status	Discharge (l/s)	Headloss (m)	Velocity (m/s)
P-96	601	6	Ductile Iron	Open	2.1	0.13	0.12
P-98	125	6	Ductile Iron	Open	6.8572	0.15	0.39
P-100	20	6	PVC	Open	5.6842	0.01	0.32
P-102	10	10	Steel	Open	25.40551	0.02	0.52
P-104	2	8	Steel	Open	70.29399	0.07	2.24

Conclusions and Suggestions

Conclusions:

1. For the existing situation of the Jenin water distribution system, the following conclusions can be extracted:

- Insufficient availability of water combined with unreliability of sources.
- Unstructured network made of old pipes.
- Excessive service pressure.
- Intermittent supply, which is directly connected to the state of unavailability of water.
- Excessive rate of unaccounted for water.

2. The intermittent service is the procedure of providing water that is followed in operating most of the water distribution systems in Palestine.

3. The intermittent supply affects the hydraulic performance of the network and exposes it to high values of pressure and velocities.

4. The designers of the water supply networks as in the case of Jenin's water distribution system did not consider the effects of the intermittent supply on the value of the design factors.

5. There is adverse affect of the intermittent systems on the readings of the customer water meters due to the pushed and sucked air in the network.

6. The system shows the ability to cope the future extension in the case of providing the necessary requirements of developing and/or replacing the old pipes, providing the needed quantities of potable water and overcoming the problems of high pressures by using pressure reducing valves.

Suggestions and Recommendations

1. Specialized software should be developed to model the behavior of the intermittent systems in our region.

2. More local studies are recommended. This is to understand how the water systems in our region perform under the local conditions of operation and management.

3. The universal peak factors which are used in the design of water distribution systems should be modified and adjusted in the design of new water systems in Palestine according to the local conditions of operating and managing the distribution networks.

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الملخص

من الشائع في فلسطين تنفيذ تصميم شبكات المياه باستخدام معايير تصميم عالمية, دون الأخذ بعين الأعتبار تأثيرات الظروف المحلية التي تؤثر على أداء شبكات توزيع المياه, كنظام الضخ المتقطع, والذي يمثل أسلوب تشغيل شبكات التوزيع في معظم مدن الدول النامية, حيث يتم تقسيم شبكات المياه الى قطاعات متعددة, ويضخ الماء بصورة متناوبة, وضمن مدة محددة, ويؤدي هذا الأسلوب الى استخدام خزانات جمع المياه على الأسطح المنزلية بصورة فعالة خلال فترات انقطاع الضخ، وبذلك يتوقع أن يتأثر الأداء الهيدروليكي لشبكات توزيع المياه بتأثر قيم السرعة والضغط.

لتحري سلوك شبكات المياه تحت تأثير الضخ المتقطع, تم دراسة شبكة مياه مدينة جنين كنموذج يمثل أنظمة الضخ المتقطع, وتمثيلها بصورة مقاربة للواقع, وذلك بحساب معاملات التشغيل بتقسيم الزمن الحقيقي للضخ على الزمن المستهدف والذي يوفر كميات المياه المطلوبة في ظروف الضخ المستمر, ودراسة أسلوب تشغيل وادارة الشبكة, وتمثيل كل مجموعة من نقاط الاستهلاك المتجاورة والمتقاربة في المنسوب بنقطة استهلاك واحدة, مع تنفيذ تحكم بالضخ الى نقاط الاستهلاك المختلفة باستخدام محابس تحكم بالاعتماد على أسلوب تشغيل الشبكة الفعلي والمتبع من قبل الجهات المسئولة, ثم نمذجة ذلك باستخدام برنامج (WaterCad), حيث أشارت نتائج التحليل الى أن شبكة مياه جنين تتعرض الى قيم عالية من السرعة والضغط, والتي تؤثر سلبا على أداء الشبكة, كما ان مقارنة نتائج قيم الضغط مع قيم ضغط ناتجة من دراسات حقلية أظهرت بعض التقارب.

تم تحليل وتصميم شبكة مياه جنين بأعتبارها نظام تزويد مستمر, وبالأعتماد على فرضيات تتعلق بالأستهلاك المستقبلي للمياه, توفر كميات المياه اللازمة للأغراض المختلفة, والتغلب على مشاكل الضغط المرتفع في الشبكة باستخدام محابس تخفض الضغط في أماكن محددة في الشبكة.

أشارت نتائج التحليل الى قدرة الشبكة على خدمة المدينة, واستيعاب التوسع المستقبلي, وكانت نتائج قيم السرعة موازية الى حد مقبول للقيم التصميمية للسرعة في شبكات توزيع المياه (0.1 م/ث – 0.3 م/ث) المعتمدة لدى سلطة المياه الفلسطينية, والتي تستخدم لتجنب مشاكل ركود المياه, وتأثر النوعية سلبا في شبكات التوزيع. أما بالنسبة لقيم الضغط فقد كانت ضمن القيم التصميمية المستخدمة في المناطق السكنية.

تم انجاز تقييم اضافي, يتضمن دراسة الأستهلاك اليومي, معامل الذروة للأستهلاك اليومي, ودراسة التغيرات اليومية في استهلاك الماء من خزانات المياه في ظروف التزويد المستمر وذلك بتنفيذ مراقبة يومية للاستهلاك المائي لعدة مستهلكين في قطاعات مختلفة من الشبكة ولمدة 15 يوما, وكان معدل معامل الذروة للاستهلاك اليومي 2.0, ومعدل الأستهلاك اليومي 75 لتر/شخص/يوم, وبمقارنة هذه النتائج مع نتائج دراسات سابقة, كان هناك تقارب في القيم, ويمكن الأشارة هنا الى انه من العوامل التي تؤثر على الاستهلاك اليومي اضافة الى عادات الاستهلاك, أعداد السكان, مستوى المعيشة, أختلاف أوقات التزويد, وقيم الضغط في الشبكة.

تم دراسة تفاعل وتأثير الهواء المضغوط والممتص في أنظمة الضخ المتقطع على قراءات عدادات المياه, خلال فترتين من التزويد, وفي موقعين مختلفين بتطبيق تجربة تتكون من عداد مياه, عداد مياه أضافي، محبس تحكم، ومحبس لتفريغ الهواء . أظهرت النتائج أن قراءات عداد المياه الأصلي أكبر بنسبة(5% – 8%) من قراءات عداد المياه الأضافي والذي يقع بعد محبس تفريغ الهواء وذلك بفعل الهواء المضغوط, ولم تتحسن قراءة العداد الأصلي بفعل الهواء المسحوب عند اغلاق خط التزويد. ان نسبة الأختلاف في القيم تعتمد على عدة عوامل منها الموقع, سلوك المستهلك, وتغيرات الضغط في الشبكة.

أظهرت دراسة ظاهرة المطرقة المائية في شبكة مياه جنين بأن قيم الضغط الناتجة عن المطرقة المائية تزداد بزيادة سرعة الماء في الأنابيب, وتعتمد قيمتها على عدة عوامل مثل نوعية الأنابيب, القطر, وطول الأنابيب. حيث كانت نتائج الحسابات لقيم الضغط ضمن الحدود المقبولة لقيم الضط الناتجة عن المطرقة المائية في شبكات المياه.

جامعة النجاح الوطنية

كلية الدراسات العليا

الأداء الهيدروليكي لشبكات توزيع المياه في فلسطين

(شبكة مياه جنين كحالة دراسة)

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قدمت هذه الأطروحة استكمالا لمتطلبات درجة الماجستير في هندسة المياه و البيئة بكلية الدراسات العليا في جامة النجاح الوطنية في نابلس, فلسطين

2003