# PROJECT REPORT
# ON

# DESIGN OF WATER SUPPLY SYSTEM
# FOR GREEN CITY (BATHINDA)

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# CERTIFICATE

This is to certify that project report entitled "**THE DESIGN OF WATER SUPPLY SYSTEM FOR GREEN CITY, BATHINDA"**, submitted by **ASHUTOSH and ABHINAV SINGLA** in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

**Date:** **Supervisor's Name**

**Designation**

# ACKNOWLEDGEMENTS

We would like to thank our Project Guide, Dr. VEERESH GALI, for his continuous support and encouragement. It was he who provided an aim and direction to this project and constantly pushed us to work harder on it. We would also thank the officials of Punjab Water Supply and Sewerage Board (PWSSB) Bathinda for their help and cooperation.

**ABSTRACT**

In water supply system the function of carrying water is done through well planned distribution system choosing suitable diameter of pipes as it comprises the major investment in the system. Analysis and design of a pipe network system is a complex and time taking work. Now a day's lot of pipe software is available which can be used suitably for layout and analysis of pipe network system. Working with professional software requires both money and training. Sometimes it is required to design a simple pipe network system for which an easy method will be suitable. In this present project work, a simple method is discussed which can be used suitable for optimal design of pipe networks for the water distribution system. The problem in this report has thus been solved with a view to reduce the total cost of pipe network satisfying the required amount discharge in the outlet. Hardy Cross method has been used for estimating the required discharge in each outlet of the pipe network, and optimization of the system has been done to reduce the cost with the help of Microsoft-excel.

We also come across useful software EPANET 2.0 which is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps.

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# CHAPTER 1 INTRODUCTION

## 1.1 INTRODUCTION TO WATER SUPPLY SCHEME

Water is present in abundant quantities on and under the Earth's surface, but less than 1 percent of it is liquid fresh water. Most of Earth's estimated 1.4 billion cubic km (326 million cubic miles) of water is in the oceans or frozen in polar ice caps and glaciers. Ocean water contains about 35 grams per litre (4.5 ounces per gallon) of dissolved minerals or salts, making it unfit for drinking and for most industrial or agricultural uses. There is ample fresh water—water containing less than 3 grams of salts per litre, or less than one-eighth ounce of salts per gallon—to satisfy all human needs. It is not always available, though, at the times and places it is needed, and it is not uniformly distributed over the Earth. In many locations the availability of good-quality water is further reduced because of urban development, industrial growth, and environmental pollution.

But with the advancement of civilization the utility of water enormously increased and now such a stage has come that without well organized public water supply scheme, it is impossible to run the present civic life and the develop the towns. The importance of water from only a quantity viewpoint was recognized from the earliest days and the importance of quality come to be recognized gradually in the later days.

The objectives of the community water supply system are:

1. to provide whole some water to the consumers for drinking purpose.
2. to supply adequate quantity to meet at least the minimum needs of the individuals
3. to make adequate provisions for emergencies like fire fighting, festivals, meeting etc
4. to make provision for future demands due to increase in population, increase in standard of living, storage and conveyance
5. to prevent pollution of water at source, storage and conveyance
6. to maintain the treatment units and distribution system in good condition with adequate staff and materials
7. to design and maintain the system that is economical and reliable.

After treatment, water is to be stored temporarily and supplied to the consumers through the network of pipelines called distribution system. The distribution system also includes pumps, reservoirs, pipe fittings, instruments for measurement of pressures, flow leak detectors etc. The cost of distribution is about 40 to 70% of the total cost of the entire scheme. The efficiency of the system depends upon proper planning, execution and maintenance. Ultimate air is to supply potable water to all the consumers whenever required in sufficient quantity with required pressure with least lost and without any leakage.

## 1.2 OBJECTIVES

The objective here is to:

1. Determine the headloss in each pipe in the given section considering a particular diameter of pipes and calculating the water required by using population forecasting method.
2. Determine the headloss in each pipe using EPANET2.0 and comparing its values with manual reading and hence determine the most suitable and economical material that can be used for the pipes.

## 1.3 SCOPE OF STUDY

In a water distribution system, water is supplied to consumers, through a series of system. Raw water collected from a reservoir is treated in a water treatment plant and make it suitable for drinking purpose which is then stored in an elevated water tank. From the tank, water is supplied in a controlled way to the consumer through a complex network system. This system for distributing water contains pipes, reservoirs, pumps, valves of different types, which are connected to each other to provide water to consumers. It is a vital component of the urban infrastructure and requires significant investment. The process of distributing water generally consists of different phases like proper layout for distributing system, designing of pipe network and process of operation, water treatment in the plant. The problem of optimal design of water distribution networks has various aspects to be considered such as hydraulics, reliability, material availability, water quality, and infrastructure and demand.

The problem of optimizing network requires the determination of pipe sizes from a set of commercially available diameters ensuring a feasible least cost solution. The cost of realizing the network is a function of the diameters. The smaller the diameter, the lower is the price. However the energy head at the consumers also decrease, therefore the problem is to minimize the cost under the constraint that the energy heads at the interior nodes are above some given lower limits.

The algebraic sum of the pressure drops around a closed loop must be zero. This secures the overall mass balance in the network.

The desired discharge value for the predetermined loop of the network system is optimized, considering the diameters of the pipes in the network as decision variables, the problems can be considered as a parameter optimization problem with dimension equal to the number of pipes in the network. Market constraints, however, dictate the use of commercially available pipe diameters. With this constraint the problem can be formulated in Microsoft Excel.

Running under Windows, EPANET provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots.

EPANET's Windows user interface provides a visual network editor that simplifies the process of building piping network models and editing their properties and data. EPANET provides an integrated computer environment for editing input data. Various data reporting and visualization tools are used to assist in interpreting the results of a network analysis. These include:-

- Color-coded network maps,
- Data tables,
- Energy usage,
- Reaction,
- Calibration
- Time series graphs,
- Profile plots
- Contour plots.

# CHAPTER 2 LITERATURE REVIEW

## 2.1 IMPORTANCE AND NECESSITY FOR PLANNED WATER SUPPLIES

Water is a precious resource and vital for life. Without it we would die within days. Access to a safe and affordable supply of drinking water is universally recognized as a basic human need for the present generation and a pre-condition for the development and care of the next. Water is also a fundamental economic resource on which people's livelihoods depend. In addition to domestic water use, households use water for productive activities such as farming and livestock rearing in rural areas, or horticulture and home-based microenterprises in urban settlements. Water shortage, poor quality water, or unreliable supply have profound effects on people's well-being. Providing safe water alone is not enough.

Public water supply in Bathinda started around 1955, when a number of tube wells were dug in the inner part of city area and the water supplied through reservoirs located at the Fort and Subhash Park. Later the raw water was taken from the Bathinda branch of Sirhind canal.

Talking about water portability in BATHINDA, drinking water supply in Talwandi Sabo and Sangat blocks of the district is not upto the desired level. Since ground water is highly contaminated due to heavy use of pesticides, residents of some of the villages in these blocks are suffering from innumerable diseases e.g., skeletal diseases, flurosis, cancer, etc. Some of studies carried out by NGOs and PGI, Chandigarh have confirmed this. The menace can be suitably addressed through RIDF/Swajaldhara Project for "Safe Drinking Water" in the affected villages.

## 2.2 NEED FOR PROTECTED WATER SUPPLY

The working group appointed by the planning commission while suggesting strategies for achieving the above goal emphasized that potable water from protected water supply should be made available to the entire population. Pure and whole some water is to be supplied to the community alone can bring down the morbidity rates. The objectives of the community water supply system are:-

1. To provide whole some water to the consumers for drinking purpose.
2. To supply adequate quantity to meet at least the minimum needs of an Individual.
3. To make adequate provisions for emergencies like fire fighting, festivals, meeting etc.

4. To make provision for future demands due to increase in population, increase in standard of living, storage and conveyance.

5. To prevent pollution of water at source, storage and conveyance.

6. To maintain the treatment units and distribution system in good condition with adequate staff and materials.

7. To design and maintain the system that is economical and reliable.

The complete outline of the water supply scheme is as follows:-

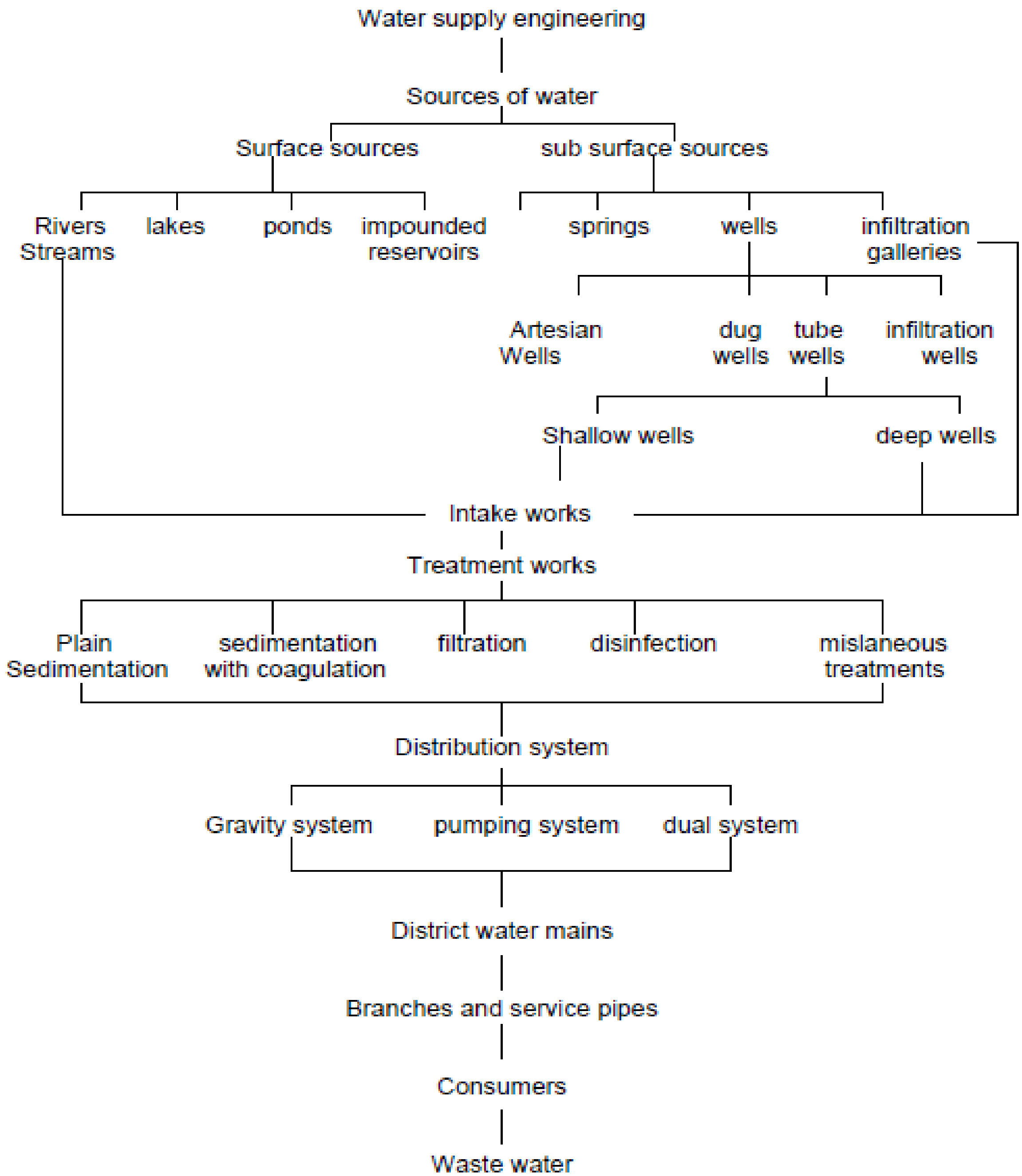


**Fig.2.2:** Flowchart for Water Supply Scheme

## 2.3 VARIOUS TYPES OF WATER DEMANDS

Following are the various types of water demands of a city or town:

i. Domestic water demand

ii. Industrial demand

iii. Institution and commercial demand

iv. Demand for public use

v. Five demand

vi. Loses and wastes

i. **DOMESTIC WATER DEMAND-** The quantity of water required in the houses for drinking, bathing, cooking, washing etc is called domestic water demand.

ii. **INDUSTRIAL DEMAND-** The water required in the industries mainly depends on the type of industries, which are existing in the city. The water required by factories, paper mills, Cloth mills, Cotton mills, Breweries, Sugar refineries etc. comes under industrial use.

iii. **FIRE DEMAND-** The quantity of water required for fire fighting is generally calculated by using different empirical formulae. For Indian conditions kuchings formula gives satisfactory results.

$$Q=3182\sqrt{p}$$

Where 'Q' is quantity of water required in litres/min.

'P' is population of town or city in thousands.

iv. **LOSSES AND WASTES-** All the water, which goes in the distribution, pipes does not reach the consumers. The following are the reasons.

a) Losses due to defective pipe joints, cracked and broken pipes, faulty valves and fittings.

b) Losses due to, consumers keep open their taps of public taps even when they are not using the water and allow the continuous wastage of water.

c) Losses due to unauthorized and illegal connections.

## 2.4 POPULATION FORECASTING METHODS

When the design period is fixed the next step is to determine the population of a town or city population of a town depends upon the factors like births, deaths, migration and annexation.

The following are the standard methods by which the forecasting population are performed:

i. Arithmetical increase method

ii. Geometrical increase method

iii. Incremental increase method

iv. Simple graph method

In this report we will be using Arithmetic increase method for the reasons that will be discussed later in the report.

2.5 LAYOUTS OF DISTRIBUTION SYSTEM

Generally in practice there are four different systems of distribution which are used. They are:

1. Dead End or Tree system
2. Grid Iron system
3. Circular or Ring system
4. Radial system

In this report we will be using **Grid Iron system** which is as follows:-

From the mains water enters the branches at all Junctions in either directions into
sub mains of equal diameters. At any point in the line the pressure is balanced from two directions because of interconnected network of pipes.

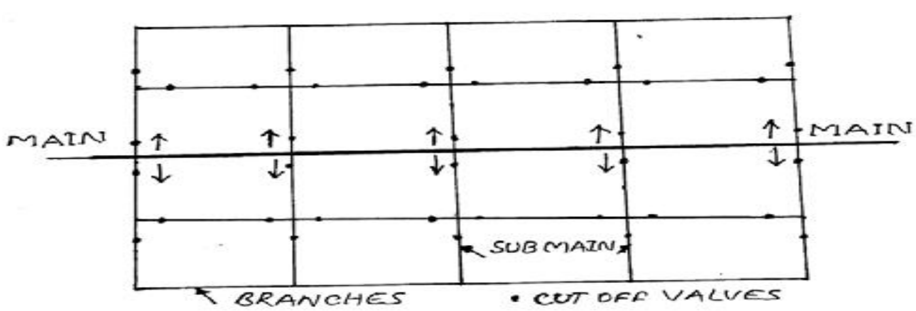


**Fig.2.5:** Water Distribution In Grid Iron System

ADVANTAGES

1. In the case of repairs a very small portion of distribution are a will be affected
2. Every point receives supply from two directions and with higher pressure

3. Additional water from the other branches are available for fire fighting

4. There is free circulation of water and hence it is not liable for pollution due to stagnation.

DISADVANTAGES

1. More length of pipes and number of valves are needed and hence there is increased cost of construction.

2. Calculation of sizes of pipes and working out pressures at various points in the distribution system is laborious, complicated and difficult.

## 2.6 PIPES AND REQUIREMENTS

Pipes convey raw water from the source to the treatment plants in the distribution system. Water is under pressure always and hence the pipe material and the fixture should withstand stresses due to the internal pressure, vaccum pressure, when the pipes are empty, water hammer when the values are closed and temperature stresses.

REQUIREMENTS OF PIPE MATERIAL

1. It should be capable of withstanding internal and external pressures
2. It should have facility of easy joints
3. It should be available in all sizes, transport and errection should be easy.
4. It should be durable.
5. It should not react with water to alter its quality.
6. Cost of pipes should be less.
7. Frictional head loss should be minimum.
8. The damaged units should be replaced easily.

TYPES OF PIPES ARE:-

1. Cast Iron
2. Steel
3. Prestressed concrete
4. R.C.C
5. D.I. Pipes

6. Galvanized Iron (G.I)
7. P.V.C and plastic pipes

## 2.7 OVERHEAD STORAGE TANKS(OHSR)

When water is to be distributed at very high pressure elevated tanks may be constructed with steel or R.C.C. R.C.C elevated tanks are very popular because of,

1. Long life
2. Little maintenance
3. Decent appearance

Service reservoirs perform several functions including ensuring sufficient head of water in the water distribution system and providing hydraulic capacitance in the system to even out peak demand from consumers enabling the treatment plant to run at optimum efficiency. Large service reservoirs can also be managed so that energy costs in pumping are reduced by concentrating refilling activity at times of day when power costs are low.

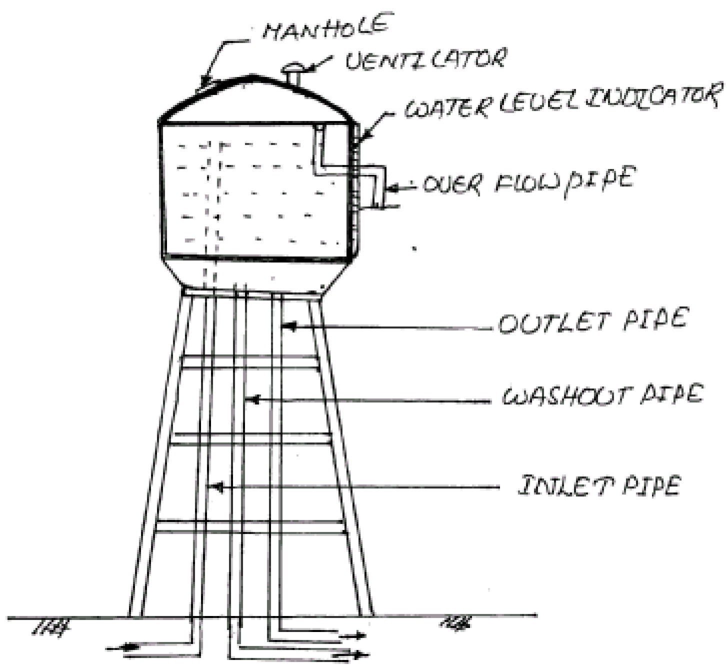


**Fig. 2.7:** Overhead Storage Tank

## 2.8 HARDY CROSS METHOD

This method consists of assuming a distribution of flow in the network in such a way that the principle of continuity is satisfied at each junction. A correction to these assumed flows is then computed successively for each pipe loop in the network, until the correction is reduced to an acceptable magnitude.

Now, expressing the head loss ($H_L$) as

The formula used in this method is, $\Delta = \underline{-\Sigma H_L}$

$= n.\Sigma (H_L/Q_a)$

Where, $\Delta$ = correction = $Q-Q_a$

$H_L = K.Q^n$ , where n= 2 for Darcy-Weisbatch and 1.85 for Hazen- Williams

$Q_a$ = assumed flow

Q = actual flow = $Q_a + \Delta$ .

## 2.9 EPANET 2.0

EPANET provides a fully equipped, extended-period hydraulic analysis package that can:

- Simulate systems of any size.
- Compute friction head loss using the Hazen-Williams, the Darcy Weisbach, or the Chezy-Manning formula.
- Include minor head losses for bends, fittings, etc.
- Model constant or variable speed pumps.
- Compute pumping energy and cost.
- Model various types of valves, including shutoff, check, pressure regulating, and flow control.
- Account for any shape storage tanks (i.e., surface area can vary with height).
- Consider multiple demand categories at nodes, each with its own pattern of time variation.
- Model pressure-dependent flow issuing from sprinkler heads.
- Base system operation on simple tank level, timer controls or complex rule-based controls.

EPANET helps water utilities maintain and improve the quality of water delivered to consumers. It can be used to

- design sampling programs,
- study disinfectant loss and by-product formation,

- conduct consumer exposure assessments,
- evaluate alternative strategies for improving water quality, such as altering source use within multi-source systems,
- modify pumping and tank filling/emptying schedules to reduce water age,
- use booster disinfection stations at key locations to maintain target residuals, and
- plan cost-effective programs of targeted pipe cleaning and replacement.

## 2.10 OTHER APPURTENANCES USED

Fittings are used to join two or more pipes, a pipe to a device or a pipe to a cap or a plug.


**Fig.2.10.1:** Fittings Used for Connections

Types of fittings are shown above and are explained below:

1 Offset- Fitting joining two pipes so that the pipe can bypass an obstacle.
2 U-Bend- Fitting joining two pipes in order to change their direction by 180°.
3 Trap- U-shaped pipe beneath a fixture containing a quantity of water to prevent sewage gases from escaping.
4 Y-Branch- Fitting joining three pipes, one of which is oblique to the other two.
5 Tee- Fitting joining three pipes, one of which is perpendicular to the other two.
6 90° Elbow- Fitting for joining two pipes in order to change their direction.

7 45° Elbow- Fitting for joining two pipes in order to change their direction by 45°.

# CHAPTER 3 THE DATA ACQUISITION

## 3.1 POPULATION GROWTH RATE BATHINDA CITY: 1901-2011

The share of population of Bathinda to the total urban population of the state was 2.63 in the year 2001. The growth rate of Bathinda was 95.12% during 1971-81 mainly because of the expansion of limits of Municipal Committee as to include the two major industries i.e. Thermal Power Plant and National Fertilizer Limited which were established during that decade. During the decade of 1971-1981 the population grew from 0.65 lacs to 1.27 lacs, which was highest in the state. The details of population growth of Bathinda city from 1901 to 2001 is given in table below:

| **Years** | **Population** | **Decadal Growth Rate (%)** |
|---|---|---|
| 1901 | 13185 | -- |
| 1911 | 15035 | 14.05 |
| 1921 | 20154 | 34.03 |
| 1931 | 22771 | 12.99 |
| 1941 | 24833 | 9.06 |
| 1951 | 36991 | 40.91 |
| 1961 | 52253 | 49.33 |
| 1971 | 65318 | 25.00 |
| 1981 | 127363 | 95.12 |
| 1991 | 159042 | 24.79 |
| 2001 | 217256 | 36.60 |

**Table 3.1:** Population Data as Per PWSSB

## 3.2 POPULATION FORECAST

We can calculate the population of the year 2045 by various methods like Incremental increase method, arithmetical increase method and Geometric increase method. The formulae for the above methods are as follows:-

a. Arithmetic or Zero Order

$$\frac{dP}{dt} = K_a$$

$$P = P_1 + K_a (t - t_1)$$

$$K_a = \frac{P_2 - P_1}{t_2 - t_1}$$ Where,

$P$ = population

$t$ = time

$K_a$ = arithmetic growth constant

b. Geometric or First Order

$$\frac{dP}{dt} = K_g P$$

$$\ln P = \ln P_1 + K_g (t - t_1)$$

$$K_g = \frac{\ln P_2 - \ln P_1}{t_2 - t_1} = \frac{\ln(P_2/P_1)}{t_2 - t_1}$$

Where,

$P$ = population

$t$ = time

$K_g$ = geometric growth constant

Note: $\lim (1+K)^{1/K} = e = 2.718\ldots$ base of the natural logarithms

c. Incremental increase method

$Pn = P + n.X + \{n (n+1)/2\}.Y$

Where, $Pn$ = Population after nth decade

$X$ = Average increase

$Y$ = Incremental increase

Consulting the above formulas the population forecast was as follows:

| Sno. | YEAR | GEOMETRIC INCREASE | ARITHEMATIC INCREASE | INCREMENTAL INCREASE |
|---|---|---|---|---|
| 1 | 2011 | 285813 | 285813 | 285813 |
| 2 | 2013 | 305145 | 294174 | 300313 |
| 3 | 2015 | 325784 | 302535 | 305400 |
| 4 | 2030 | 532243 | 365241 | 393430 |
| 5 | 2045 | 869541 | 427947 | 504485 |

**Table 3.2:** Population Calculated Using Different Formulas

## 3.3 AREA AND CALCULATED POPULATION:-

The total area of Bathinda city according according to Surveyor General of India, the district covers an area of 336725 Hectares and is sixth in terms of area in the State .The area figures of the tehsils are as under:-

| **Name of Tehsil** | **Area (in Hectares.)** |
|---|---|
| Bathinda | 151845 |
| Rampuraphul | 87516 |
| Talwandisabo | 97364 |
| Total | 336725 |

**Table 3.3:** Total Area under Consideration

The area for the designing of 615 hectares with the population density of 5 people per plot has been considered. According to population density survey 1 square kilometers holds 414 persons. As we have designed for 615 hectares, our population density is complying with the given density.

Now, coming on to the population in the area to be calculated we will choose incremental increase method as the graph of population vs year will be as follows:

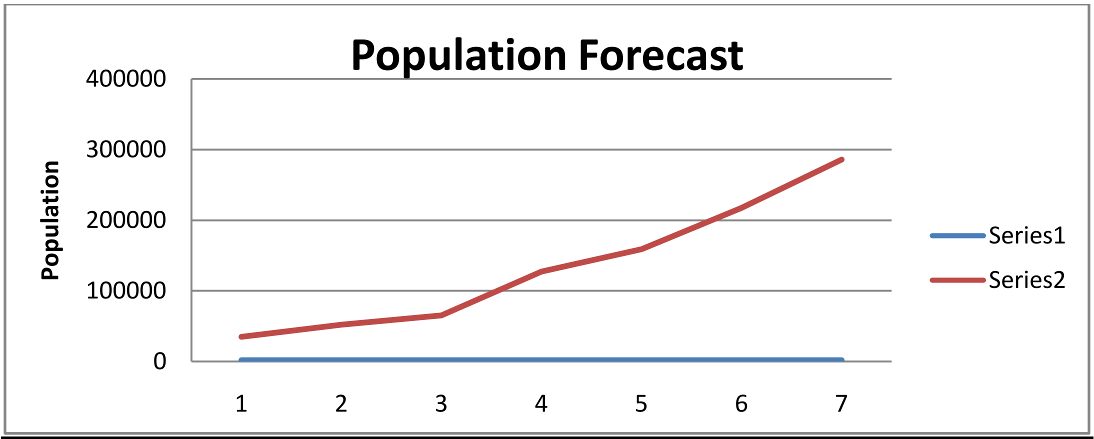


**Fig. 3.4:** Population Forecast for Design Period

SERIES 1- Decades (along X-axis)

SERIES 2- Population Increment

As we can see that the graph is linearly increasing for the last 5 decades we can say that we can use Incremental increase method.

Thus, we know that the area is almost 7-8% of the total area, therefore the total population for which we should be designing the supply scheme is 3200 people.

### 3.4 BASIC DETAILS FOR DESIGNING

The basic details we will be using are like per capita use of water per day, percentage of the wastage etc as given in the table:-

**Table 3.4:** Basic Details for Design Of Water Supply Scheme

| | |
|---|---|
| Water demand per capita | 135lpcd |
| Water demanding including wastage (HIH)(15%) | 200lpcd |
| Design population for the year 2045 | 4100persons |
| Daily demand for the year 2045 | 0.636Ml |

## 3.5 DESIGNING OF VARIOUS ELEMENTS

### I. Design of water treatment plant:-

| 1. WATER TREATMENT PLANT | PARAMETERS |
|---|---|
| Daily water demand for 2045 | 0.636Ml |
| Add 5% losses and wastage | 0.032Ml |
| Total WTP capacity required | 0.668Ml |

**Table 3.5.1:** Parameters for Water Treatment Plant

### II. Design of storage and sedimentation tank:-

| 2. STORAGE AND SEDIMENTATION TANK | PARAMETERS |
|---|---|
| Daily water demand for 2045 | 0.636Ml |
| Canal closure period | 15 days |
| S&S capacity required | 9.543Ml |
| Total capacity(include 15% losses) | 10.974 Ml (10974cum) |
| Working depth of S&S tank | 4.00m |
| Area required | 2743sqm |
| Area required to build S&S tank | 0.573Acres |

**Table 3.5.2:** Parameters for Design of Storage and Sedimentation Tank

III. Clear water tank:-

| 3. CLEAR WATER TANK | PARAMETERS |
|---|---|
| Daily water demand for 2045 | 0.636Ml |
| CWT capacity required=25% of demand | 0.159Ml |

**Table 3.5.3:** Parameters for Design of Clear Water Tank

## 3.6 MODEL FORMULATION

The model which has been formulated to accomplish the required task is done by formulating a hydraulic module which deals with the hydraulic aspects and the optimization module which deals with the optimization aspect and then compiling both the processes using a solver application in Microsoft excel spreadsheet which will be shown later in result.

Hydraulic Module:

The hydraulic module consists of hydraulics part where pipe flow analysis is done using Hardy-cross method.

Analysis of Pipe Network:

For the analysis of pipe network, the following two necessary conditions must be satisfied.

1. The algebraic sum of the pressure drops around a closed loop must be zero, i.e. there can be no discontinuity in pressure.
2. The flow entering a junction must be equal to the flow leaving the same junction; i.e. the law of continuity must be satisfied.

Based upon these two basic principles, the pipe networks are solved by the method of successive approximation because any direct analytical solution is not possible. The analysis of a pipe network requires many equations, most of which being nonlinear, to be solved simultaneously.

3.7 HARDY CROSS METHOD

The procedure suggested by Hardy and Cross requires that the flow in each pipe be assumed by the designer (in magnitude as well as direction) in such a way that the principle of continuity is satisfied at each junction ( i.e. the inflow at any junction becomes equal to the outflow at that junction). Correction to these assumed flows is then computed successively for each pipe loop in the network, until the correction is reduced to an acceptable magnitude.

Now, expressing the head loss ($H_L$) as

The formula used in this method is, $\Delta = \underline{-\Sigma\, H_L}$

$= n.\Sigma\,(H_L/Q_a)$

Where, $\Delta$ = correction = $Q-Q_a$

$H_L = K.Q^n$ , where n= 2 for Darcy-Weisbatch and 1.85 for Hazen- Williams

$Q_a$ = assumed flow

Q = actual flow = $Q_a + \Delta$ .

3.8 DIVISION OF SECTIONS AND LENGTH FOR HEAD LOSS CALCULATION

We have divided our given area into four sections and drawn each of these sections by scale from the map provided by PWD and Water supply department of Bathinda. Sections and their respective number of plots are given below. These plots include and both residential and commercial plots along with the parks.

| SECTION | PLOTS |
|---|---|
| SECTION1 | 112 |
| SECTION2 | 138 |
| SECTION3 | 123 |
| SECTION4 | 215 |

Thus, the total number of plots are 588.Now the drawing of all sections are given below along with their calculations of Discharge(Q) and head loss (H).For the calculation of head loss we have used the Hardy Cross Method discussed before in the report.

1. SECTION-1

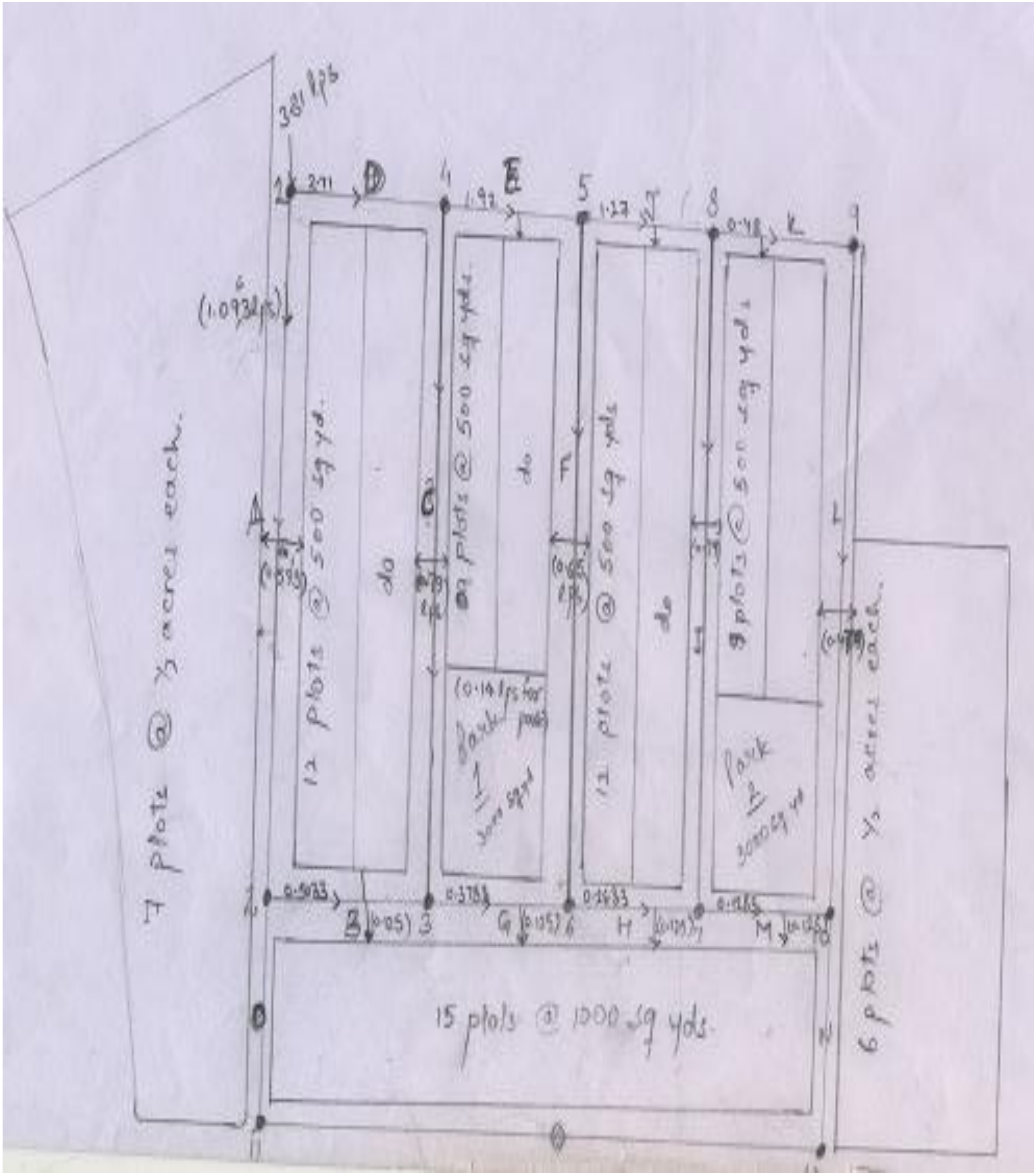


**Fig. 3.8.1:** Section-1 Layout

2. SECTION-2

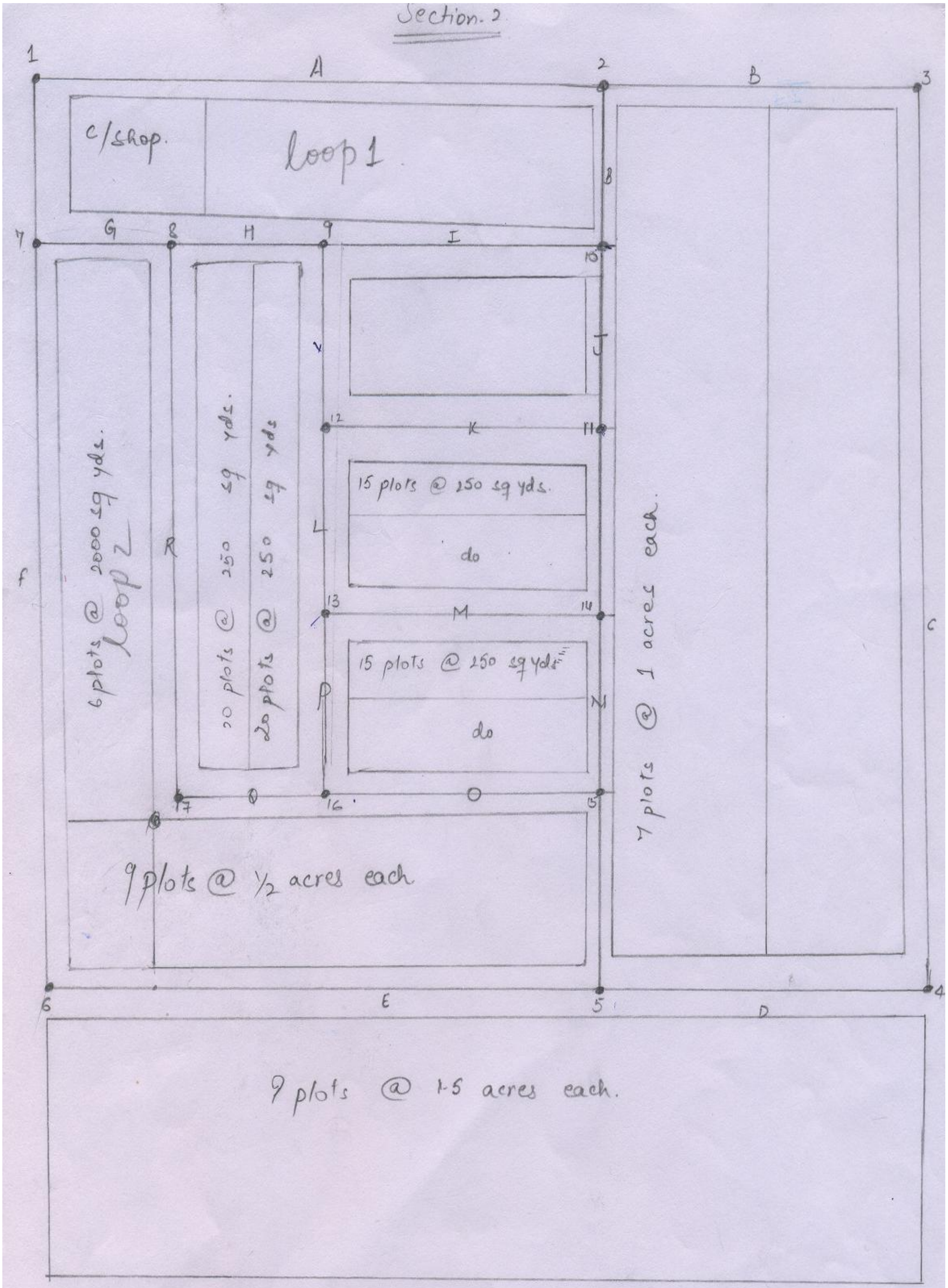


**Fig. 3.8.2:** Section-2 Layout

3. SECTION-3

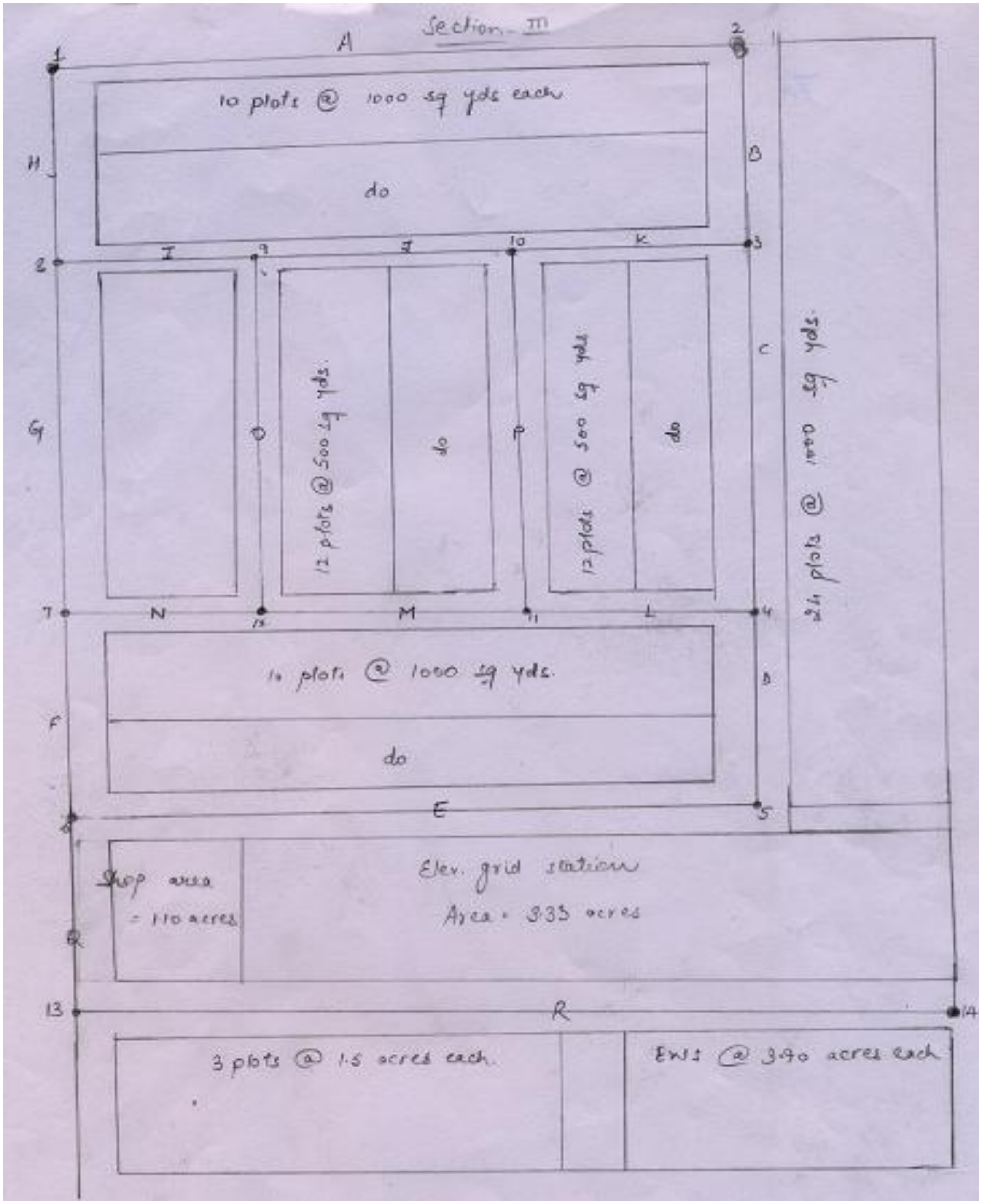


**Fig. 3.8.3:** Section-3 Layout

4. SECTION-4

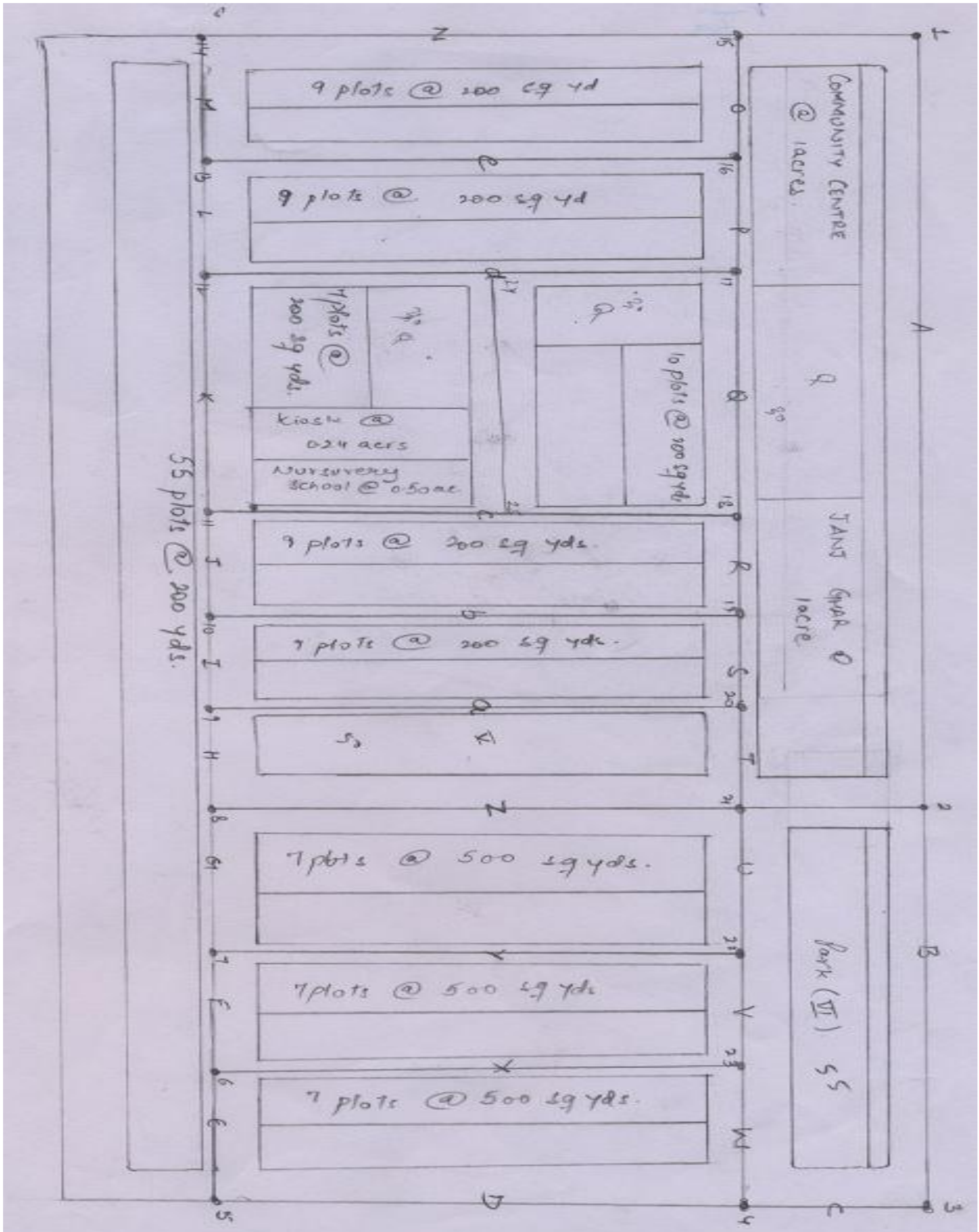


**Fig. 3.8.4:** Section-4 Layout

3.9 USE OF EPANET2.0

Taking the section-1 for evaluation we will be comparing the values obtained by Hardy Cross method and also observe the headloss values using Chezy mannings formula and Darcy weisbach formula.

Project Default ID Labels

The ID Labels page of the Defaults dialog form is shown in Figure 5.1 below. It is used to determine how EPANET will assign default ID labels to network components when they are first created. For each type of object one can enter a label prefix or leave the field blank if the default ID will simply be a number. Then one supplies an increment to be used when adding a numerical suffix to the default label. As an example, if J were used as a prefix for Junctions along with an increment of 5, then as junctions are created they receive default labels of J5, J10, J15 and so on. After an object has been created, the Property Editor can be used to modify its ID label if need be.

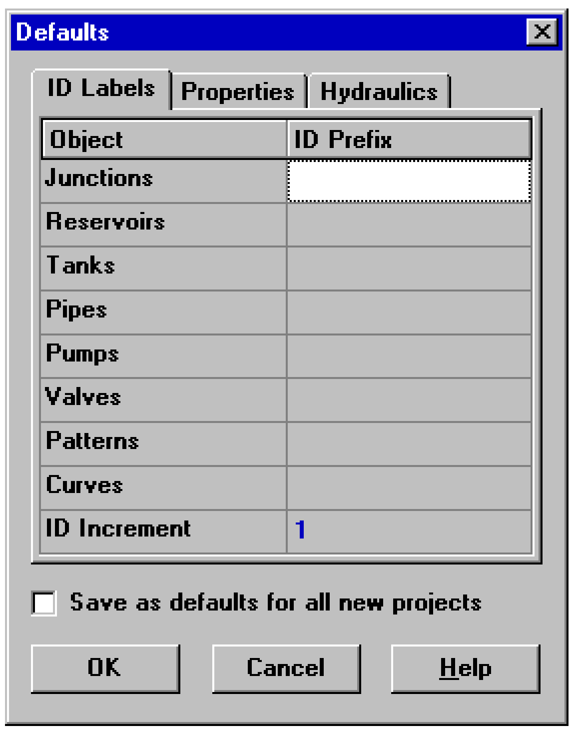


**Fig. 3.9.1: "**DEFAULTS" Dialogue Box

The Properties page of the Defaults dialog form is shown in Figure 5.2. It sets default property values for newly created nodes and links. These properties include:

- Elevation for nodes
- Diameter for tanks

- Maximum water level for tanks
- Length for pipes
- Auto-Length (automatic calculation of length) for pipes
- Diameter for pipes
- Roughness for pipes

When the Auto-Length property is turned on, pipe lengths will automatically be computed as pipes are added or repositioned on the network map. A node or line created with these default properties can always be modified later on using the Property Editor.

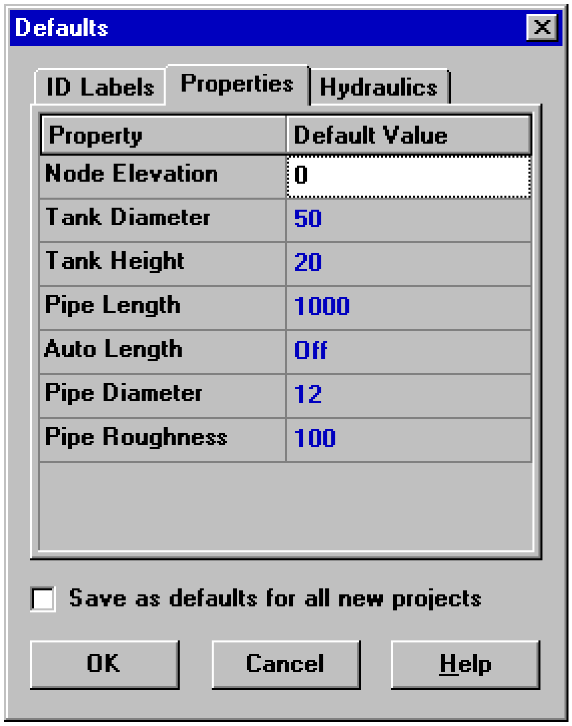


**Fig. 3.9.2:** Properties Page of the Project Defaults Dialog

3.10Major Components Of EPANET2.0

i.)Junction

Junctions are points in the network where links join together and where water enters or leaves the network. The basic input data required for junctions are:

- elevation above some reference (usually mean sea level)
- water demand (rate of withdrawal from the network)

- initial water quality.

The output results computed for junctions at all time periods of a simulation are

- hydraulic head (internal energy per unit weight of fluid)
- pressure
- water quality.

Junctions can also:

- have their demand vary with time
- have multiple categories of demands assigned to them
- have negative demands indicating that water is entering the network
- be water quality sources where constituents enter the network
- contain emitters (or sprinklers) which make the outflow rate depend on the pressure.

The dialogue box for designing of the junction and laying is as shown on the next page:-

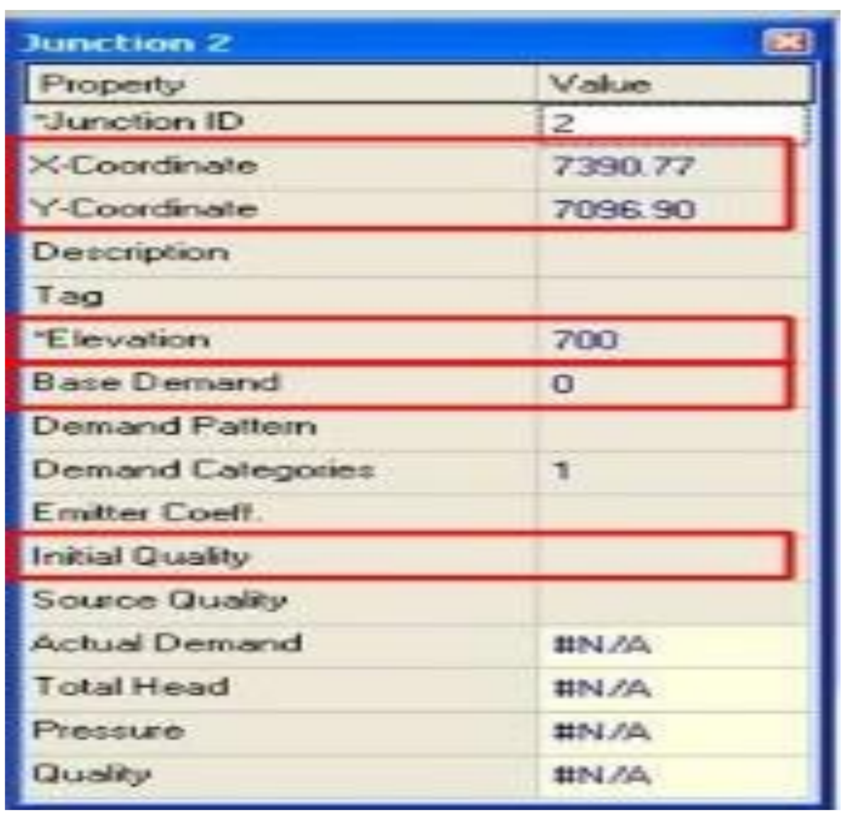


**Fig. 3.10.1:** Junction Dialogue Box

ii.) Reservoirs:-

Reservoirs are nodes that represent an infinite external source or sink of water to the network. They are used to model such things as lakes, rivers, groundwater aquifers, and tie-ins to other systems. Reservoirs can also serve as water quality source points.

The primary input properties for a reservoir are its hydraulic head (equal to the water surface elevation if the reservoir is not under pressure) and its initial quality for water quality analysis.

Because a reservoir is a boundary point to a network, its head and water quality cannot be affected by what happens within the network. Therefore it has no computed output properties. However its head can be made to vary with time by assigning a time pattern to it.

iii.) Tanks:-

Tanks are nodes with storage capacity, where the volume of stored water can vary with time during a simulation. The primary input properties for tanks are:

- Bottom elevation (where water level is zero)
- diameter (or shape if non-cylindrical )
- initial, minimum and maximum water levels
- initial water quality.

The principal outputs computed over time are:

- hydraulic head (water surface elevation)
- water quality.

Tanks are required to operate within their minimum and maximum levels. EPANET stops outflow if a tank is at its minimum level and stops inflow if it is at its maximum level. Tanks can also serve as water quality source points.


**Fig. 3.10.2:** Tank Dialogue Box

iv.) PIPES

Pipes are links that convey water from one point in the network to another. EPANET assumes that all pipes are full at all times. Flow direction is from the end at higher hydraulic head (internal energy per weight of water) to that at lower head. The principal hydraulic input parameters for pipes are:

- Start and end nodes
- Diameter
- Length
- Roughness coefficient (for determining headloss)
- Status (open, closed, or contains a check valve).

The status parameter allows pipes to implicitly contain shutoff (gate) valves and check (non-return) valves (which allow flow in only one direction).
The water quality inputs for pipes consist of:

- Bulk reaction coefficient
- Wall reaction coefficient.

Computed outputs for pipes include:

- flow rate
- velocity
- headloss
- Darcy-Weisbach friction factor
- average reaction rate (over the pipe length)
- average water quality (over the pipe length).

The hydraulic head lost by water flowing in a pipe due to friction with the pipe walls can be computed using one of three different formulas:

- Hazen-Williams formula
- Darcy-Weisbach formula
- Chezy-Manning formula

The Hazen-Williams formula is the most commonly used headloss formula in the US. It cannot be used for liquids other than water and was originally developed for turbulent flow only. The Darcy-Weisbach formula is the most theoretically correct. It applies over all flow regimes and to all liquids.

The dialogue box for pipe designing and laying is as shown below:-

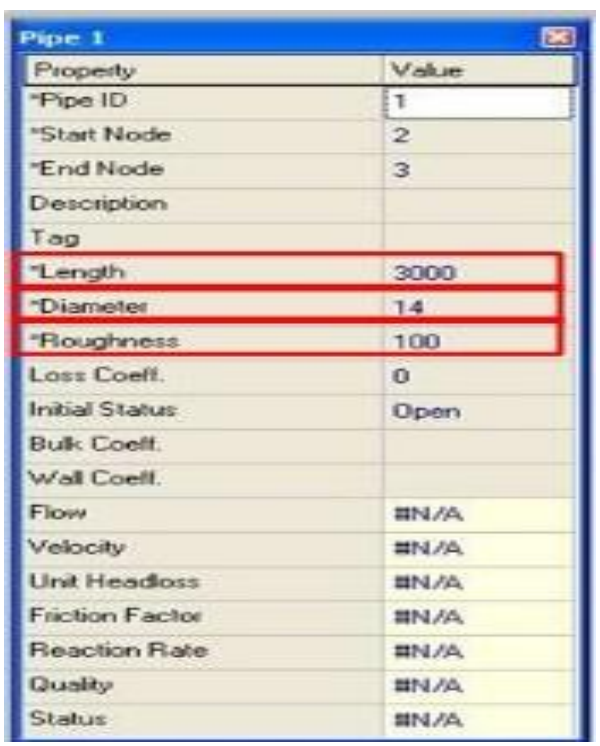


**Fig.3.10.3:** Pipe Dialogue Box

3.11FORMULAE USED IN EPANET 2.0

With the Darcy-Weisbach formula EPANET uses different methods to compute the friction factor f depending on the flow regime:

- The Hagen–Poiseuille formula is used for laminar flow (Re < 2,000).
- The Swamee and Jain approximation to the Colebrook-White equation is used for fully turbulent flow
  (Re >4,000).
- A cubic interpolation from the Moody Diagram is used for transitional flow (2,000 < Re < 4,000).

| *Formula* | *Resistance Coefficient* | *Flow Exponent* |
|---|---|---|
| Hazen-Williams | $4.727\ C^{(-1.852)}\ d^{(-4.871)}\ L$ | 1.852 |
| Darcy-Weisbach | $0.0252\ f(e,d,q)d^{(-5)}L$ | 2 |
| Chezy-Manning | $4.66\ n^{(2)}\ d^{(-5.33)}\ L$ | 2 |

**Table 3.11.1:** Formulae used in EPANET 2.0

Notes:

C = Hazen-Williams roughness coefficient

e = Darcy-Weisbach roughness coefficient (ft)

f = friction factor (dependent on e, d, and q)

n = Manning roughness coefficient

d = pipe diameter (ft)

L = pipe length (ft)

q = flow rate (cfs)

Roughness Coefficients for New Pipe

| *Material* | *Hazen-Williams C (unitless)* | *Darcy-Weisbach e (feet x 10-3)* | *Manning's n (unitless)* |
|---|---|---|---|
| Cast iron | 100 | 0.12 | 0.011-0.013 |
| Ductile iron | 130 | 0.26 | 0.011-0.015 |
| Poly vinyl chloride | 150 | 0.0015 | 0.009-0.011 |

**Table 3.11.2:** Roughness Coefficients for Different Pipe Materials

These values will be used to determine the most suitable material that can be used for the pipes that is the strongest and most economical for the contractor.

**CHAPTER 4** ANALYSIS OF WATER SUPPLY SYSTEM

## 4.1 HARDY CROSS METHOD

With respect to pipe network analysis, the traditional approach is known as the Hardy Cross method. This method is applicable if the entire pipe sizes (lengths and diameters) are fixed, and either the head losses between the inlets and outlets are known but the flows are not, or the flows at each inflow and outflow point are known, but the head losses are not.

The procedure involves making a guess as to the flow rate in each pipe, taking care to make guesses in such a way that the total flow into any junction equals the total flow out of that junction. Then the headloss around each loop is calculated, based on the assumed flows and the selected flow vs. headloss relationship. Next, the system is checked to see if the headloss around each loop is zero. The detailed procedure is as follows.

1. Define a set of independent pipe loops in such a way that every pipe in the network is part of at least one loop, and no loop can be represented as a sum or difference of other loops. The easiest way to do this is to choose all of the smallest possible loops in the network.
2. Arbitrarily choose values of $Q$ in each pipe, such that continuity is satisfied at each pipe junction (sometimes called nodes). Choose a sign convention for each loop; one easy option choice is to consistently define $Q$ to be positive if the (assumed) direction of flow is clockwise with respect to loop under consideration. This convention means that the same flow in a given pipe might be considered positive when analyzing one loop, and negative when analyzing another.
3. Compute the headloss in each pipe, using the same sign convention for headloss as for flow, so that $h_f$ in each pipe has the same sign as $Q$, when analyzing any given loop.
4. Compute the headloss around each loop. If the headloss around every loop is zero, then all the pipe flow equations are satisfied, and the problem is solved. Presumably, this will not be the case when the initial, arbitrary guesses of $Q$ are used.
5. Change the flow in each pipe in a given loop by $\Delta Q$. By changing the flow rates in all the pipes in a loop by the same amount, we assure that the increase or decrease in the flow into a junction is balanced by the exact same increase or decrease in the flow out, so that we guarantee that the continuity equation is still satisfied. The trick is to make a good guess for what $\Delta Q$ should be, so that the headloss around the loop approaches zero.

Hardy Cross method has been used for estimating the required discharge in each outlet of the pipe network, and optimization of the system has been done to reduce the cost with the help of Microsoft-excel. The proposed optimization setup has been very close to the original value, thereby validating its use for optimization. We can observe the following figure and get an idea about how to use Hardy cross method in the excel and make our calculations much easier. We will see the results of headloss in the next chapter.

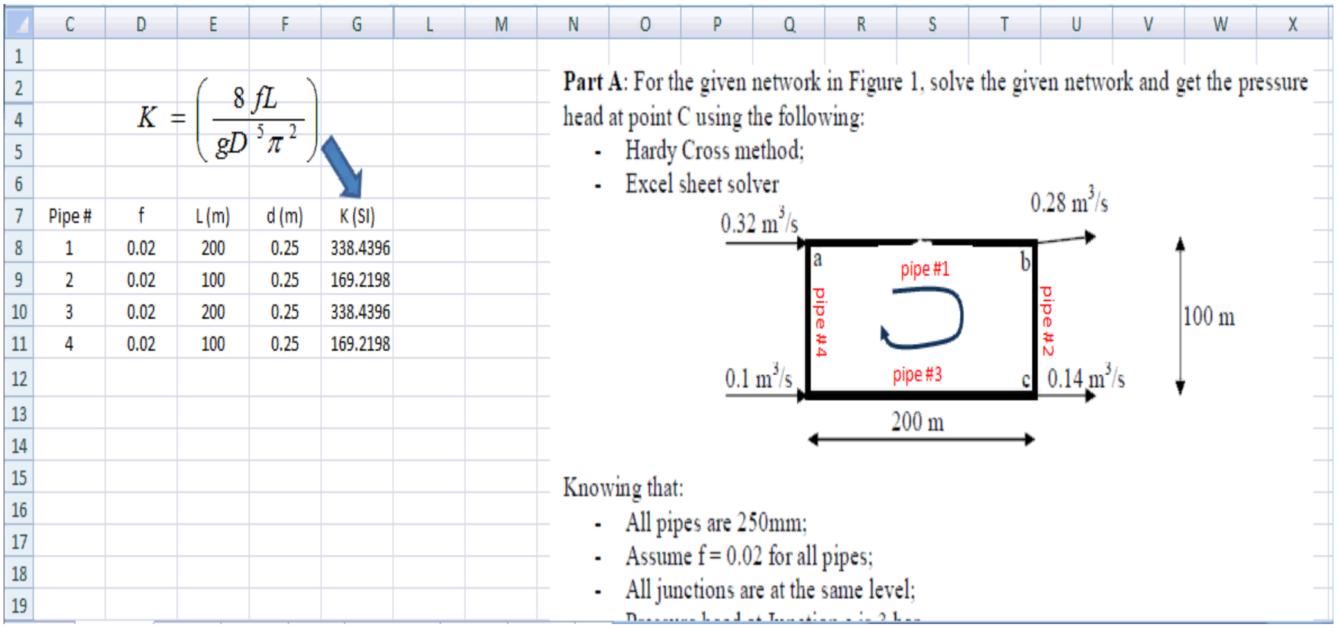


**Fig. 4.1.1:** Excel Snapshot for Solving Numerical using Hardy Cross Method

## 4.2 USE OF EPANET 2.0

### i.) ADDING A NODE

To add a Node using the Map Toolbar:

1. Click the button for the type of node (junction , reservoir , or tank ) to add from the Map Toolbar if it is not already depressed.

2. Move the mouse to the desired location on the map and click.

To add a Node using the Browser:-

1. Select the type of node (junction, reservoir, or tank) from the Object list of the Data Browser.
2. Click the Add button.
3. Enter map coordinates with the Property Editor (optional).

ii.) ADDING A LINK

To add a straight or curved-line Link using the Map Toolbar:

1**.** Click the button for the type of link to add (pipe , pump , or valve ) from the Map Toolbar if it is not already depressed.

2**.** On the map, click the mouse over the link's start node.

3**.** Move the mouse in the direction of the link’s end node, clicking it at those intermediate points where it is necessary to change the link’s direction.

4**.** Click the mouse a final time over the link's end node. Pressing the right mouse button or the Escape key while drawing a link will cancel the operation.

To add a straight line Link using the Browser:

1**.** Select the type of link to add (pipe, pump, or valve) from the Object list of the Data Browser.

2**.** Click the Add button.

3**.** Enter the From and To nodes of the link in the Property Editor.

After setting up the pipes and nodes we get a following diagram drawn on the backdrop of the original sectional map of section-1.

iii.) USING A BACKDROP MAP

The Network Map provides a planar schematic diagram of the objects comprising a water distribution network. The location of objects and the distances between them do not necessarily have to conform to their actual physical scale. Selected properties of these objects, such as water quality at nodes or flow velocity in links, can be displayed by using different colors. The color-coding is described in a Legend, which can be edited. New objects can be directly added to the map and existing objects can be clicked on for editing, deleting, and repositioning. A backdrop drawing (such as a street or topographic map) can be placed behind the network map for reference. The map can be zoomed to any scale and panned from one position to another. Nodes and links can be drawn at different sizes, flow direction arrows added, and object symbols, ID labels and numerical property values displayed. The map can be printed, copied onto the Windows clipboard, or exported as a DXF file or Windows metafile. Using a backdrop map and insertion of nodes and pipes will give us a following figure.

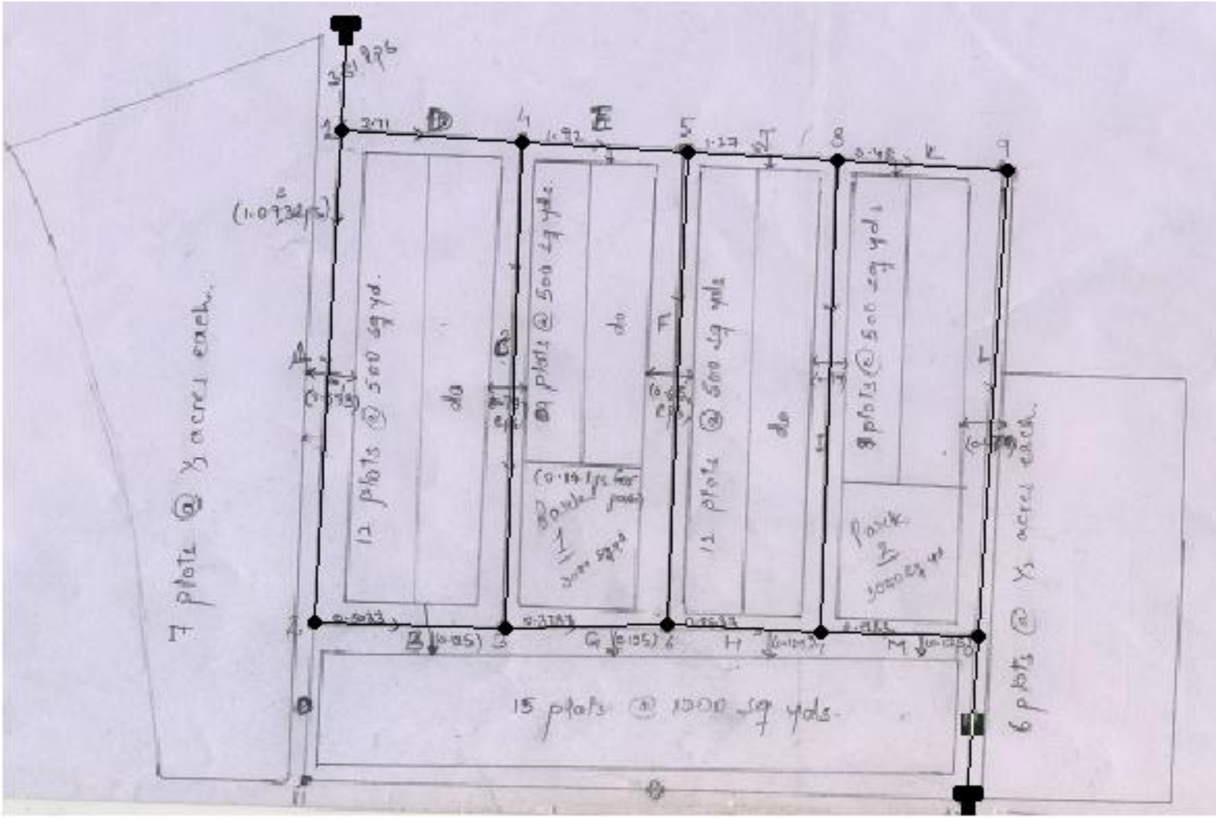

**Fig.4.1.2:** SECTION-1 With Nodes and Pipes

iv.) ANALYSING THE FORMED NETWORK

There are five categories of options that control how EPANET analyzes a network: hydraulics, Quality, Reactions, Times, and Energy. To set any of these options:

**1.** Select the Options category from the Data Browser or select **Project** >> **Analysis Options** from the menu bar.

**2.** Select Hydraulics, Quality, Reactions, Times, or Energy from the Browser.

**3.** If the Property Editor is not already visible, click the Browser's Edit button (or hit the **Enter** key).

**4.** Edit your option choices in the Property Editor.

Running an Analysis

To run a hydraulic/water quality analysis:

**1.** Select **Project** >> **Run Analysis** or click on the Standard Toolbar.

**2.** The progress of the analysis will be displayed in a Run Status window.

**3.** Click **OK** when the analysis ends.

If the analysis runs successfully the icon will appear in the Run Status section of the Status Bar at the bottom of the EPANET workspace. Any error or warning messages will appear in a Status Report window. If you edit the properties of the network after a successful run has been made, the faucet icon changes to a broken faucet indicating that the current computed results no longer apply to the modified network.

v.) Troubleshooting Results

EPANET will issue specific Error and Warning messages when problems are encountered in running a hydraulic/water quality analysis. The most common problems are discussed below:

3 Pumps Cannot Deliver Flow or Head

EPANET will issue a warning message when a pump is asked to operate outside the range of its pump curve. If the pump is required to deliver more head than its shutoff head, EPANET will close the pump down. This might lead to portions of the network becoming disconnected from any source of water.

4 Network is Disconnected

EPANET classifies a network as being disconnected if there is no way to provide water to all nodes that have demands. This can occur if there is no path of open links between a junction with demand and either a reservoir, a tank, or a junction with negative demand. If the problem is caused by a closed link EPANET will still compute a hydraulic solution (probably with extremely large negative pressures) and attempt to identify the problem link in its Status Report.

- Negative Pressures Exist

  EPANET will issue a warning message when it encounters negative pressures at junctions that have positive demands. This usually indicates that there is some problem with the way the network has been designed or operated. Negative pressures can occur when portions of the network can only receive water through links that have been closed off.

- System Unbalanced

  A System Unbalanced condition can occur when EPANET cannot converge to a hydraulic solution in some time period within its allowed maximum number of trials. This situation can occur when valves, pumps, or pipelines keep switching their status from one trial to the next as the search for a hydraulic solution proceeds. For example, the pressure limits that control the status of a pump may be set too close together. Or a pump's head curve might be too flat causing it to keep shutting on and off.

To eliminate the unbalanced condition one can try to increase the allowed maximum number of trials or loosen the convergence accuracy requirement. Both of these parameters are set with the project's Hydraulic Options. If the unbalanced condition persists, then another hydraulic option, labeled "If Unbalanced", offers two ways to handle it. One is to terminate the entire analysis once the condition is encountered. The other is to continue seeking a hydraulic solution for another 10 trials with the status of all links frozen to their current values.

- Hydraulic Equations Unsolvable

  Error 110 is issued if at some point in an analysis the set of equations that model flow and energy balance in the network cannot be solved. This can occur when some portion of a system demands water but has no links physically connecting it to any source of water. In such a case EPANET will also issue warning messages about nodes being disconnected. The equations might also be unsolvable if unrealistic numbers were used for certain network properties.

Viewing Results with a Table

EPANET allows you to view selected project data and analysis results in a tabular format:

- A Network Table lists properties and results for all nodes or links at a specific period of time.
- A Time Series Table lists properties and results for a specific node or link in all time periods.

Tables can be printed, copied to the Windows clipboard, or saved to file. An example table is shown in Figure shown below.

To create a table:-

**1.** Select **View >> Table** or click on the Standard Toolbar.

**2.** Use the Table Options dialog box that appears to select:

- the type of table
- the quantities to display in each column
- any filters to apply to the data.

| Node ID | Demand GPM | Head ft | Pressure psi | Chlorine mg/L |
|---|---|---|---|---|
| Junc 10 | 0.00 | 1010.67 | 130.28 | 1.00 |
| Junc 11 | 210.00 | 992.42 | 122.37 | 0.85 |
| Junc 12 | 210.00 | 980.17 | 121.40 | 0.78 |
| Junc 13 | 140.00 | 977.08 | 122.23 | 0.30 |
| Junc 21 | 210.00 | 977.24 | 120.13 | 0.74 |
| Junc 22 | 280.00 | 976.29 | 121.88 | 0.49 |
| Junc 23 | 210.00 | 975.76 | 123.82 | 0.30 |
| Junc 31 | 140.00 | 970.32 | 117.13 | 0.53 |

Network Table - Nodes at 4:00 Hrs

**Fig.4.2.1:** Example Network Nodes Table

The Table Options dialog form has three tabbed pages as shown in Figure shown below. All three pages are available when a table is first created. After the table is created, only the Columns and Filters tabs will appear.

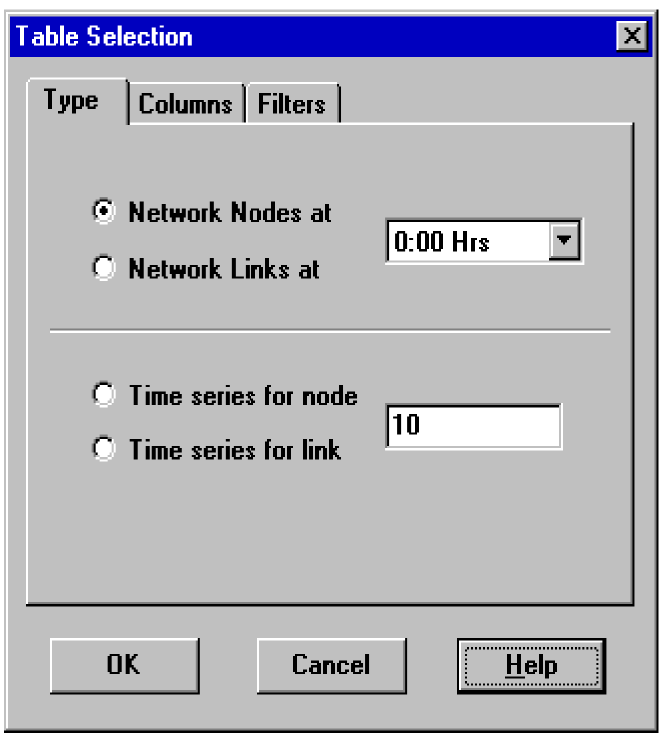


**Fig.4.2.2:** Table selection dialogue

**CHAPTER 5** RESULTS AND DISCUSSIONS

5.1 POPULATION FORECAST-

Attaining the details of the previous year population from PUNJAB WATER SUPPLY AND SEWAGE BOARD (PWSSB) we calculated the total population of our area of 615 hectares to be 3200 people in the year 2045.

5.2 DESIGN OF WATER SUPPLY COMPONENTS

i. The storage and sedimentation tank capacity was calculated as 10.974Ml and the area required for its construction is 0.57 acres.

ii. The water treatment plant capacity was calculated as 0.668Ml.

iii. The clear water tank should have a capacity of 0.159Ml.

Using the Hardy Cross Method we have shown the results of the head loss due to the calculated discharge and assumed diameter of 200mm.

5.3 PRICE CALCULATION

The price for laying the pipes in all the four sections has been shown in the table below with the market price of DI pipe of 200mm as Rs1300/m.

| SECTION | PIPE LENGTH(m) | COST (Rs per m) | TOTAL PRICE (Rs) |
|---|---|---|---|
| 1 | 5016 | 1300 | 6520800 |
| 2 | 3048 | 1300 | 3962400 |
| 3 | 2635.73 | 1300 | 3426449 |
| 4 | 2993.52 | 1300 | 3891576 |

**Table 5.3.1:** Calculation of Total Cost for Pipe Layout

The total price for all the four sections for the pipe material is Rs17801225.

## 5.4 CALCULATION OF HEADLOSS USING EXCEL

In the present work the spreadsheet *Microsoft Excel* has been used in the definition, analysis and optimization of systems and processes whose performance can be described by means of a mathematical model expressed as a system of non-linear algebraic equations.

The following excel sheets provide us with the headloss and discharge in each pipe along with the the total cost for laying each pipe. The values are later compared to the values obtained from EPANET2.0 software to double check the headloss in these pipes.

SECTION-1

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | PIPE NO. | NODE FROM | NODE TO | LENGTH(m) | DIAMETER | POPULATION | DISCHARGE(lpm) | DISC.(cumec/sec) | HEAD LOSS(m/km) | DISC^1.85 | H/Q | PRICE PER PIPE |
| 2 | A | 1 | 2 | 616 | 50 | 95 | -151.75 | 0.002534225 | 6.79 | 1.57439E-05 | 2679.320108 | 800800 |
| 3 | B | 2 | 3 | 242 | 50 | 20 | -116.25 | 0.001941375 | 13.2 | 9.61618E-06 | 6799.304617 | 314600 |
| 4 | C | 3 | 4 | 616 | 50 | 105+PARK | -40 | 0.000668 | 1.56 | 1.33609E-06 | 2335.329341 | 800800 |
| 5 | D | 1 | 4 | 242 | 50 | 0 | 76.25 | 0.001273375 | 0.28 | 4.40727E-06 | 219.8880927 | 314600 |
| 6 | E | 4 | 5 | 242 | 50 | 0 | 92.5 | 0.00154475 | 0.05 | 6.30068E-06 | 32.36769704 | 314600 |
| 7 | F | 5 | 6 | 616 | 50 | 105 | 50 | 0.000835 | 2.41 | 2.01892E-06 | 2886.227545 | 800800 |
| 8 | G | 3 | 6 | 242 | 50 | 20 | -45 | 0.0007515 | 0.29 | 1.66138E-06 | 385.8948769 | 314600 |
| 9 | H | 6 | 7 | 242 | 50 | 20 | -68.5 | 0.00114395 | 0.1 | 3.61454E-06 | 87.41640806 | 314600 |
| 10 | I | 7 | 8 | 616 | 50 | 105+PARK | -17.5 | 0.00029225 | 0.71 | 2.89498E-07 | 2429.426861 | 800800 |
| 11 | J | 5 | 8 | 242 | 50 | 0 | 22.5 | 0.00037575 | 0.01 | 4.60854E-07 | 26.61343979 | 314600 |
| 12 | K | 8 | 9 | 242 | 50 | 0 | 20 | 0.000334 | 0.58 | 3.70622E-07 | 1736.526946 | 314600 |
| 13 | L | 9 | 10 | 616 | 50 | 75 | 5 | 0.0000835 | 2.06 | 2.85181E-08 | 24670.65868 | 800800 |
| 14 | M | 7 | 10 | 242 | 50 | 20 | -16 | 0.0002672 | 6.2 | 2.45272E-07 | 23203.59281 | 314600 |
| 15 | | | | | | | | | | | | Total-6520800 |
| 16 | | | | | | | Assumed price for DI pipe= Rs 1300/meter | | | | | |
| 17 | | | | | | | TOTAL PRICE OF PIPES TO BE LAID IN SEC-1 = Rs 6520800 | | | | | |

**Table 5.4.1:** Headloss calculation in Excel using Hardy-Cross Method for SECTION-1

SECTION-2

| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | PIPE NO. | NODE FROM | NODE TO | DIAMETER(mm) | LENGTH(m) | POPULATION | OUTFLOW(l/m) | DISCHARGE(L/M | DISC.(cumec/sec) | Q^1.85 | HEAD LOSS(m) | H/Q | PRICE PER PIPES |
| 4 | A | 1 | 2 | 50 | 262 | NA | 0 | 50 | 0.000835 | 2.01892E-06 | 0.03 | 35.92814371 | 340600 |
| 5 | B | 2 | 3 | 50 | 168 | NA | 0 | 30 | 0.000501 | 7.84693E-07 | 0.04 | 79.84031936 | 218400 |
| 6 | C | 3 | 4 | 50 | 329 | 35 | 7.5 | 22.5 | 0.00037575 | 4.60854E-07 | 0.08 | 212.9075183 | 427700 |
| 7 | D | 4 | 5 | 50 | 168 | 25 | 5.625 | 16.875 | 0.000281813 | 2.70661E-07 | 0.12 | 425.8150366 | 218400 |
| 8 | E | 5 | 6 | 50 | 262 | 90 | 9.375 | -20 | 0.000334 | 3.70622E-07 | 0.15 | 449.1017964 | 340600 |
| 9 | F | 6 | 7 | 50 | 282 | 45 | 7.5 | -27.5 | 0.00045925 | 6.68022E-07 | 0.09 | 195.971693 | 366600 |
| 10 | G | 7 | 8 | 50 | 74 | NA | 0 | 200 | 0.00334 | 2.6238E-05 | 0.02 | 5.988023952 | 96200 |
| 11 | H | 8 | 9 | 50 | 40 | NA | 24.375 | 150 | 0.002505 | 1.54097E-05 | 0.89 | 355.2894212 | 52000 |
| 12 | I | 9 | 10 | 50 | 161 | PARK(390P EOPL | 11 | 49 | 0.0008183 | 1.94486E-06 | 0.29 | 354.3932543 | 209300 |
| 13 | J | 10 | 11 | 50 | 74 | NA | 3.75 | 65.25 | 0.001089675 | 3.30369E-06 | 0.05 | 45.88524101 | 96200 |
| 14 | K | 11 | 12 | 50 | 161 | 150 | 31.875 | -20 | 0.000334 | 3.70622E-07 | 0.17 | 508.9820359 | 209300 |
| 15 | L | 12 | 13 | 50 | 67 | PARK(300 PEOPL | 8.5 | -61.5 | 0.00102705 | 2.96104E-06 | 0.15 | 146.0493647 | 87100 |
| 16 | M | 13 | 14 | 50 | 161 | 150 | 2.5 | -4 | 0.0000668 | 1.88728E-08 | 0.14 | 2095.808383 | 209300 |
| 17 | N | 14 | 15 | 50 | 47 | NA | 45 | 12.75 | 0.00021292 5 | 1.61146E-07 | 0.13 | 610.5436186 | 61100 |
| 18 | O | 15 | 16 | 50 | 161 | 75 | 30 | -10.25 | 0.000171175 | 1.07613E-07 | 0.04 | 233.6789835 | 209300 |
| 19 | P | 13 | 16 | 50 | 74 | 30 | 0 | -5 | 0.0000835 | 2.85181E-08 | 0.34 | 4071.856287 | 96200 |
| 20 | Q | 16 | 17 | 50 | 40 | NA | 16.5 | -1.25 | 0.000020875 | 2.19437E-09 | 0.35 | 16766.46707 | 52000 |
| 21 | R | 11 | 14 | 50 | 67 | NA | 0 | 53.75 | 0.000897625 | 2.30795E-06 | 0.03 | 33.42152903 | 87100 |
| 22 | S | 17 | 8 | 50 | 188 | 100 | 24.375 | -25.625 | 0.000427938 | 5.86211E-07 | 0.47 | 1098.291222 | 244400 |
| 23 | T | 1 | 7 | 50 | 47 | NA | 0 | -287.5 | 0.00480125 | 5.13459E-05 | 0.09 | 18.74511846 | 61100 |
| 24 | U | 2 | 10 | 50 | 47 | NA | 0 | 20 | 0.000334 | 3.70622E-07 | 0.03 | 89.82035928 | 61100 |
| 25 | V | 9 | 12 | 50 | 74 | 35 | 0 | -90 | 0.001503 | 5.98927E-06 | 1.7 | 1131.071191 | 96200 |
| 26 | W | 5 | 15 | 50 | 94 | | 0 | -27.5 | 0.00045925 | 6.68022E-07 | 0.59 | 1284.703321 | 122200 |
| 27 | | | | | | | | | | | | | Total-3962400 |

**Table 5.5.2:** Headloss calculation in Excel using Hardy-Cross Method for SECTION-2

SECTION-3

| PIPE NO. | NODE FROM | NODE TO | DIAMETER(mm) | LENGTH(m) | DISCHARGE(lpm) | DISC.(cumec/sec) | Q^1.85 | HEAD LOSS | H/Q | PRICE PER PIPE |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | 2 | 200 | 223.6 | 200 | 0.00334 | 2.6238E-05 | 0.031563492 | 9.450147164 | 290680 |
| B | 2 | 3 | 200 | 102.59 | 170 | 0.002839 | 1.94248E-05 | 0.010721197 | 3.776399132 | 133367 |
| C | 3 | 4 | 200 | 224 | 180 | 0.003006 | 2.15913E-05 | 0.026020156 | 8.656073268 | 291200 |
| D | 4 | 5 | 200 | 110.64 | 177.5 | 0.00296425 | 2.10398E-05 | 0.012523822 | 4.224954605 | 143832 |
| E | 6 | 5 | 200 | 223.6 | -10 | 0.000167 | 1.02808E-07 | 0.000123674 | 0.740564817 | 290680 |
| F | 7 | 6 | 200 | 110.64 | -43.8 | 0.00073146 | 1.58035E-06 | 0.000940691 | 1.286045805 | 143832 |
| G | 8 | 7 | 200 | 224 | -110 | 0.001837 | 8.68164E-06 | 0.010462422 | 5.695384866 | 291200 |
| H | 1 | 8 | 200 | 102.6 | -217.5 | 0.00363225 | 3.06426E-05 | 0.016914328 | 4.65670803 | 133380 |
| I | 8 | 9 | 200 | 73.76 | 100 | 0.00167 | 7.27822E-06 | 0.002888209 | 1.72946662 | 95888 |
| J | 9 | 10 | 200 | 73.76 | 43.125 | 0.000720188 | 1.53559E-06 | 0.000609365 | 0.846119932 | 95888 |
| K | 10 | 3 | 200 | 73.76 | 32.5 | 0.00054275 | 9.09934E-07 | 0.000361088 | 0.665293133 | 95888 |
| L | 11 | 4 | 200 | 73.76 | -20 | 0.000334 | 3.70622E-07 | 0.000147073 | 0.440339536 | 95888 |
| M | 12 | 11 | 200 | 73.76 | -69.375 | 0.001158563 | 3.70042E-06 | 0.001468433 | 1.267461368 | 95888 |
| N | 7 | 12 | 200 | 73.76 | -50 | 0.000835 | 2.01892E-06 | 0.000801167 | 0.959481682 | 95888 |
| O | 9 | 12 | 200 | 223.6 | 40 | 0.000668 | 1.33609E-06 | 0.001607276 | 2.406102188 | 290680 |
| P | 11 | 10 | 200 | 223.6 | -17.5 | 0.00029225 | 2.89498E-07 | 0.000348257 | 1.191640944 | 290680 |
| Q | 6 | 13 | 200 | 80.4 | 5.85 | 0.000097695 | 3.81297E-08 | 1.64931E-05 | 0.168822299 | 104520 |
| R | 13 | 14 | 200 | 263.5 | -0.225 | 3.7575E-06 | 9.19524E-11 | 1.30354E-07 | 0.034691816 | 342550 |
| S | 5 | 14 | 200 | 80.4 | 165.5 | 0.00276385 | 1.84842E-05 | 0.007995398 | 2.892848056 | 104520 |
| | | | | | | | | | | Total-3426449 |

**Table 5.5.3:** Headloss calculation in Excel using Hardy-Cross Method for SECTION-3

SECTION-4

| PIPE NO. | NODE FROM | NODE TO | DIAMETER(mm) | LENGTH(m) | DISCHARGE(lpm | DISCH.(cumec/se | Q^1.85 | HEAD LOSS(m) | H/Q | PRICE PER PIPE |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | 2 | 200 | 353.76 | 78.5 | 0.00131095 | 4.65087E-06 | 0.008851673 | 6.752105348 | 459888 |
| B | 2 | 3 | 200 | 221.76 | 18 | 0.0003006 | 3.04986E-07 | 0.000363869 | 1.21047582 | 288288 |
| C | 3 | 4 | 200 | 36.96 | 18 | 0.0003006 | 3.04986E-07 | 6.06448E-05 | 0.20174597 | 48048 |
| D | 4 | 5 | 200 | 108.24 | 15.2 | 0.00025384 | 2.23067E-07 | 0.000129899 | 0.511736164 | 140712 |
| E | 5 | 6 | 200 | 73.92 | -0.5 | 0.00000835 | 4.02828E-10 | 1.60201E-07 | 0.019185704 | 96096 |
| F | 6 | 7 | 200 | 73.92 | 4 | 0.0000668 | 1.88728E-08 | 7.50552E-06 | 0.112358059 | 96096 |
| G | 7 | 8 | 200 | 73.92 | -23.85 | 0.000398295 | 5.13309E-07 | 0.000204138 | 0.512528901 | 96096 |
| H | 8 | 9 | 200 | 29.04 | -20 | 0.000334 | 3.70622E-07 | 5.79042E-05 | 0.173365783 | 37752 |
|  | 9 | 10 | 200 | 42.24 | -45.6 | 0.00076152 | 1.70259E-06 | 0.000386916 | 0.508083746 | 54912 |
| J | 10 | 11 | 200 | 47.52 | -52.5 | 0.00087675 | 2.20963E-06 | 0.00056491 | 0.644322231 | 61776 |
| K | 11 | 12 | 200 | 150.48 | -58.6 | 0.00097862 | 2.70792E-06 | 0.002192286 | 2.240180602 | 195624 |
| L | 12 | 13 | 200 | 42.24 | -111.85 | 0.001867895 | 8.95369E-06 | 0.002034737 | 1.089320749 | 54912 |
| M | 13 | 14 | 200 | 42.24 | -75.25 | 0.001256675 | 4.30093E-06 | 0.000977392 | 0.777760198 | 54912 |
| N | 15 | 14 | 200 | 108.24 | -92.75 | 0.001548925 | 6.33222E-06 | 0.003687451 | 2.380651861 | 140712 |
| O | 15 | 16 | 200 | 42.24 | 150 | 0.002505 | 1.54097E-05 | 0.003501874 | 1.397953597 | 54912 |
| P | 16 | 17 | 200 | 42.24 | 80 | 0.001336 | 4.81662E-06 | 0.001094582 | 0.819297585 | 54912 |
| Q | 17 | 18 | 200 | 150.48 | 68.5 | 0.00114395 | 3.61454E-06 | 0.002926268 | 2.558038311 | 195624 |
| R | 18 | 19 | 200 | 47.52 | 56.5 | 0.00094355 | 2.53113E-06 | 0.000647104 | 0.685818015 | 61776 |
| S | 19 | 20 | 200 | 42.24 | 20 | 0.000334 | 3.70622E-07 | 8.42242E-05 | 0.252168411 | 54912 |
| T | 20 | 21 | 200 | 29.04 | 24.5 | 0.00040915 | 5.39489E-07 | 8.42872E-05 | 0.206005616 | 37752 |
| U | 21 | 22 | 200 | 73.92 | 50 | 0.000835 | 2.01892E-06 | 0.000802905 | 0.961562987 | 96096 |
| V | 22 | 23 | 200 | 73.92 | 35.3 | 0.00058951 | 1.06025E-06 | 0.000421651 | 0.715256369 | 96096 |
| W | 23 | 4 | 200 | 73.92 | 4.3 | 0.00007181 | 2.15746E-08 | 8.57998E-06 | 0.119481708 | 96096 |
| X | 23 | 6 | 200 | 108.24 | 15 | 0.0002505 | 2.17668E-07 | 0.000126755 | 0.506007122 | 140712 |
| Y | 7 | 22 | 200 | 108.24 | -1.35 | 0.000022545 | 2.53013E-09 | 1.47337E-06 | 0.065352584 | 140712 |
| Z | 21 | 8 | 200 | 108.24 | 17.75 | 0.000296425 | 2.97196E-07 | 0.000173066 | 0.583845132 | 140712 |
| a | 9 | 20 | 200 | 108.24 | -11.75 | 0.000196225 | 1.38546E-07 | 8.06799E-05 | 0.411160368 | 140712 |
| b | 19 | 10 | 200 | 108.24 | 12 | 0.0002004 | 1.44049E-07 | 8.38843E-05 | 0.418584477 | 140712 |
| c | 18 | 11 | 200 | 108.24 | 7 | 0.0001169 | 5.31443E-08 | 3.09476E-05 | 0.264735629 | 140712 |
| d | 12 | 17 | 200 | 108.24 | -30 | 0.000501 | 7.84693E-07 | 0.000456951 | 0.912078306 | 140712 |
| e | 16 | 13 | 200 | 108.24 | 55.5 | 0.00092685 | 2.44888E-06 | 0.001426059 | 1.538608387 | 140712 |
| f | 24 | 25 | 200 | 147.6 | 21.5 | 0.00035905 | 4.23679E-07 | 0.000336438 | 0.937023158 | 191880 |
|  |  |  |  |  |  |  |  |  |  | Total-3891576 |

**Table 5.4.4:** Headloss calculation in Excel using Hardy-Cross Method for SECTION-4

## 5.5 CALCULATION OF HEADLOSS USING EPANET 2.0

Using the EPANET2.0 we have attained the headloss values for different types of pipes i.e. PVC, Ductile Iron and Cast Iron in order to know the best and most economical material that can be used. We have used three different methods to calculate the headloss and determined the most suitable method. In India we generally use Chezy Manning's formula and avoid using Hardy Cross method the reason for which will be discussed later.

A snapshot for one of the SECTION-1 is giving us the values of discharge and flows through all pipes which is shown below.

Network Table - Links

| Link ID | Flow LPS | Velocity m/s | Unit Headloss m/km | Friction Factor | Reaction Rate mg/L/d | Quality | Status |
|---|---|---|---|---|---|---|---|
| Pipe 1 | 0.46 | 0.23 | 2.69 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 2 | 0.25 | 0.13 | 0.83 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 3 | 0.09 | 0.05 | 0.10 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 4 | 0.25 | 0.13 | 0.83 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 5 | 0.34 | 0.17 | 1.51 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 6 | 0.37 | 0.19 | 1.75 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 7 | 0.03 | 0.01 | 0.01 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 8 | 0.34 | 0.17 | 1.51 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 9 | 0.37 | 0.19 | 1.75 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 10 | 0.09 | 0.05 | 0.10 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 11 | 0.25 | 0.13 | 0.83 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 12 | 0.25 | 0.13 | 0.83 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 13 | 0.46 | 0.23 | 2.69 | 0.048 | 0.00 | 0.00 | Open |
| Pipe 14 | 0.71 | 0.36 | 6.50 | 0.048 | 0.00 | 0.00 | Open |

**Table.5.5.1:** EPANET 2.0 RESULT FOR SECTION-1

## 5.6 HEADLOSS IN SECTION-1 FOR DIFFERENT PIPE MATERIALS

Following are the results for headloss of different pipe materials taking into account all the three methods to determine the most suitable material for lying of the pipes.

a.) HEADLOSS FOR DUCTILE IRON PIPES

| METHOD USED | HW | DW | CM |
|---|---|---|---|
| Link ID | Unit Headloss m/km | Unit Headloss m/km | Unit Headloss m/km |
| Pipe 1 | 1.77 | 2.78 | 2.69 |
| Pipe 2 | 1.22 | 0.87 | 0.83 |
| Pipe 3 | 1.97 | 0.12 | 0.10 |
| Pipe 4 | 1.71 | 0.87 | 0.83 |
| Pipe 5 | 1.12 | 1.58 | 1.51 |
| Pipe 6 | 5.37 | 1.82 | 1.75 |
| Pipe 7 | 0.29 | 0.02 | 0.01 |
| Pipe 8 | 0.77 | 1.58 | 1.51 |
| Pipe 9 | 0.02 | 1.82 | 1.75 |
| Pipe 10 | 0.00 | 0.12 | 0.10 |
| Pipe 11 | 0.07 | 0.87 | 0.83 |
| Pipe 12 | 1.12 | 0.87 | 0.83 |
| Pipe 13 | 2.93 | 2.78 | 2.69 |
| Pipe 14 | 5.34 | 6.04 | 6.50 |
| Pipe 15 | 5.37 | 6.04 | 6.50 |

**Table 5.6.1:** Headloss for DI pipes

b.) HEADLOSS FOR CAST IRON PIPES

| METHOD USED | HW | DW | CM |
|---|---|---|---|
| Link ID | Unit Headloss m/km | Unit Headloss m/km | Unit Headloss m/km |
| Pipe 1 | 4.53 | 2.77 | 2.69 |
| Pipe 2 | 8.41 | 0.86 | 0.83 |
| Pipe 3 | 1.32 | 0.11 | 0.10 |
| Pipe 4 | 0.23 | 0.86 | 0.83 |
| Pipe 5 | 0.00 | 1.57 | 1.51 |
| Pipe 6 | 2.65 | 1.79 | 1.75 |
| Pipe 7 | 0.28 | 0.02 | 0.01 |
| Pipe 8 | 0.04 | 1.57 | 1.51 |
| Pipe 9 | 0.69 | 1.79 | 1.75 |
| Pipe 10 | 0.01 | 0.11 | 0.10 |
| Pipe 11 | 0.60 | 0.86 | 0.83 |
| Pipe 12 | 2.18 | 0.86 | 0.83 |
| Pipe 13 | 6.13 | 2.77 | 2.69 |
| Pipe 14 | 5.98 | 6.15 | 6.50 |
| Pipe 15 | 6.00 | 6.15 | 6.50 |

**Table 5.6.2:** Headloss for CI pipes

c.) HEADLOSS FOR POLY VINYL CHLORIDE PIPES

| METHOD USED | HW | DW | CM |
|---|---|---|---|
| Link ID | Unit Headloss m/km | Unit Headloss m/km | Unit Headloss m/km |
| Pipe 1 | 4.17 | 2.80 | 2.69 |
| Pipe 2 | 8.92 | 0.90 | 0.83 |
| Pipe 3 | 0.82 | 0.15 | 0.10 |
| Pipe 4 | 0.38 | 0.90 | 0.83 |
| Pipe 5 | 0.02 | 1.59 | 1.51 |
| Pipe 6 | 1.67 | 1.88 | 1.75 |
| Pipe 7 | 0.17 | 0.03 | 0.01 |
| Pipe 8 | 0.01 | 1.59 | 1.51 |
| Pipe 9 | 0.47 | 1.88 | 1.75 |
| Pipe 10 | 0.02 | 0.15 | 0.10 |
| Pipe 11 | 0.49 | 0.90 | 0.83 |
| Pipe 12 | 1.72 | 0.90 | 0.00 |
| Pipe 13 | 4.81 | 2.80 | 2.69 |
| Pipe 14 | 6.92 | 5.81 | 6.50 |
| Pipe 15 | 6.94 | 5.81 | 6.50 |

**Table 5.6.3:** Headloss for PVC pipes

## 5.7 COMPARISON OF VALUES

We will now compare the values attained from EPANET2.0 with the values of headloss calculated manually to double check the flow and headloss through the pipes:

SECTION-1

| PIPE NO. | HEADLOSS(MANUAL) | HEADLOSS(EPANET) |
|---|---|---|
| A | 6.79 | 4.53 |
| B | 13.2 | 8.41 |
| C | 1.56 | 1.32 |
| D | 0.28 | 0.23 |
| E | 0.05 | 0.00 |
| F | 2.41 | 2.65 |
| G | 0.29 | 0.28 |
| H | 0.1 | 0.04 |
| I | 0.71 | 0.69 |
| J | 0.01 | 0.01 |
| K | 0.58 | 0.60 |
| L | 2.06 | 2.18 |
| M | 6.20 | 6.13 |

**Table 5.7.1:** Comparison of Headloss Values for SECTION-1

SECTION-2

| PIPE NO. | HEADLOSS(MANUAL) | HEADLOSS(EPANET) |
|---|---|---|
| A | 0.03 | 0.03 |
| B | 0.05 | 0.03 |
| C | 0.08 | 0.07 |
| D | 0.12 | 0.10 |
| E | 0.15 | 0.12 |
| F | 0.09 | 0.07 |
| G | 0.02 | 0.02 |
| H | 0.89 | 0.89 |
| I | 0.29 | 0.28 |
| J | 0.05 | 0.04 |
| K | 0.17 | 0.14 |
| L | 0.15 | 0.11 |
| M | 0.14 | 0.13 |
| N | 0.13 | 0.13 |
| O | 0.04 | 0.04 |
| P | 0.34 | 0.34 |
| Q | 0.35 | 0.33 |
| R | 0.03 | 0.01 |
| S | 0.47 | 0.49 |
| T | 0.09 | 0.08 |
| U | 0.03 | 0.03 |
| V | 1.7 | 1.63 |
| W | 0.59 | 0.54 |

**Table 5.7.2:** Comparison of Headloss Values for SECTION-2

**CHAPTER6**

## 6.1 CONCLUSION

The three basic components which consist of water distribution system are pumps, storage tanks and pipe networks. Optimization helps in reducing the cost of pipe networks by selecting and recognizing to adopt the best possible diameter to guarantee the best flow rate. The design for optimal distribution of the network is a complex task, A number of search methods, complex programs and algorithms have been proposed and attempted for the main concern of designing the most least cost network simultaneously satisfying the required minimum pressure head and discharge at the demand nodes. However, Microsoft Excel was used here for optimization to achieve the minimum cost but at the same time it also holds some drawbacks as it does not involve complex mechanisms for optimization as in the case of many algorithms which employ complex mechanisms for search of global optimal solution.

As these methods involve complex algorithms, programs and function which require a lot of technical know-how's it becomes difficult to implement such mechanisms for optimization by everyone in many cases. So our approach was to provide with an easy method for optimization which doesn't involve such complexities.

Technically speaking, the cost of the project could have been much lower due to the following conditions:-

1. As we have used Darcy Weisbach's formula for determination of head loss and the value of n is assumed to be 2 for turbulent flows, whereas in many cases Hazen-William Equation has also been used and the value of n is taken near about 1.85, so this might be a cause for fluctuations in the total cost.
2. Other reason is we have assumed $\Delta q \rightarrow 0$ instead of $\Delta q=0$.

   For comparison and validation of the optimization method used in this paper, the application has been limited to two loop networks only. So there is a need to apply the same methodology for complex network also where more than two loops exist.

We also observe that the most suitable method that can be used to calculate discharge and headloss is Chezy Manning formula as the headloss is minimum using this formula and the pipe material used should be DI pipe.

Following points can be concluded from the above results:

5 We must avoid using Hazen William equation as it does not consider viscosity, but it also fails to differentiate between laminar and turbulent flow conditions.
6 Hazen William equation should only be used in the transition zone and slightly above, for large diameter pipelines with cool water.
7 Darcy-Weisbach formula EPANET uses different methods to compute the friction factor f depending on the flow regime.

Further on, after comparing the results we see a very minor and negligible difference between the values calculated manually and the values attained from the software.

## 6.2 REFRENCES


CENTRAL GROUND WATER BOARD Ministry of Water Resources Government of India North Western Region, CHANDIGARH.

Bhave, P.R. 1991. *Analysis of Flow in Water Distribution Networks*. Technomic Publishing.

Garg S.K. “Water Supply Engineering”, Environmental Engineering.
PUNJAB WATER SUPPLY AND SEWAGE BOARD (PWSSB).

Community water supply: Project Effectiveness and Sustainability by Christopher Dale Peltz.

Alperovits E., Shamir U. Design of optimal water distribution systems, Water Resources Research.

Design of potable water supply in rural areas by NATHAN W. Reents.

Technical manual, Headquaters- Department of the Army, October 1992

State Institute of Vocational Education Directorate of Intermediate Education, Govt. Of Andhra Pradesh 2005.
Use of Excel-Solver as an Optimization Tool in Design of Pipe Network by Ajeet Kumar and Briti sundar Sill- Under this paper we were able to learn about the use of EXCEL software for the calculation of the discharge through highly complex plans.

Globally Minimum Cost Water-Distribution Systems. Journal of Water Resources Planning and Management by G.V Greene- In this journal we were able to learn about the important methods of decreasing the effective cost of the pipe layout for a city.

Bhave, P.R. 1991. *Analysis of Flow in Water Distribution Networks*. Technomic Publishing. Lancaster, PA.

EPANET 2.0 manual by Lewis A. Rossman Water Supply and Water Resources Division National Risk Management Research Laboratory Cincinnati.