Palestine Polytechnic University

College of Engineering and Technology
Civil & Architecture Engineering Department

Project Title

Design Of Storm water Drainage system

For Beit JalaCity

Project Team

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Hebron – Palestine

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Design Of Storm water Drainage system

For Beit Jala City

BY

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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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The Senior Project Entitled:

Design Of Storm water Drainage system
For Beit Jala City

Prepared By:

Khaled Sadoq　　　　Wesam Abuhameda

In accordance with the recommendations of the project supervisor, and the acceptance of all examining committee members, this project has been submitted to the Department of Civil and Architectural Engineering in the College of Engineering and Technology in partial fulfillment of the requirements of the department for the degree of Bachelor of Science in Engineering.

Project Supervisor　　　　**Department Chairman**

2015 , Jan

إهـــداء

بدأنا بأكثر من يد وقاسينا أكثر من هم وعانينا الكثير من الصعوبات وها نحن اليوم والحمد لله نطوي سهر الليالي وتعب الأيام وخلاصة مشوارنا بين دفتي هذا العمل المتواضع.

إلى منارة العلم والامام المصطفى إلى الأمي الذي علم العالمين إلى سيد الخلق إلى رسولنا الكريم سيدنا محمد صلى الله عليه وسلم.

إلى الينبوع الذي لا يمل العطاء الي من حاكت سعادتي بخيوط منسوجة من قلبها إلى والدتي العزيزة.

إلى من سعى وشقى لأنعم بالراحة والهناء الذي لم يبخل بشيء من أجل دفعي في طريق النجاح إلى الذي علمني أن ارتقي سلم الحياة بحكمة وصبر إلى والدي العزيز.

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ABSTRACT

Design of Storm water Drainage system for Beit Jala City

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The disposal of storm water in streets and roads creates major traffic and environmental problems .

Sewage facilities in many Palestinian cities do not exist , The storm water has been seeping into the streets and roads through the overflows causing serious problems .

Beit Jala is such as Bethlehem district cities , do not contains storm water drainage system . The accelerated development and grow of Beit Jala city has led to change in the hydrological and geomorphological features . all of the areas of Beit Jala city do have not a natural drainage outlet . Heavy rainfall causes storm water to collect in low areas and flood streets and walk way . Rapid growth has decreased the open area available for percolation and rain water has greatly increased the runoff to low laying areas .

In view of this prevailing condition , Drainage system in Beit Jala city would have a new characteristic and development of storm water drainage system is very necessary to drain excess water from streets .

In this project a trial was made to design a storm water drainage system for Beit Jala city, and we find that the drainage system must contain four main and six submain lines as main trunks that make drainage for water in the rain fall events . These main trunks cover a large percentage area of Beit Jala . And they ara efficient in minimizing traffic problems .

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CHAPTER ONE

"INTRODUCTION"

1.1 General

Storm water is water that originates during precipitation rains, or it may also water resulting from the melting of snow, Storm water is of concern for two main issues one related to the volume and timing of runoff water (flooding), the other related to potential contaminants that the water is carrying.

At the present time, Storm water is a resource and ever growing in importance as the world's human population demand exceeds the availability of readily available water, Techniques of storm water harvesting with point source water management and purification can potentially make urban environments self-sustaining in terms of water.

like other countries , Palestine needs a storm water drainage networks , Beit Jala , one of cities in Palestine have no a storm water drainage networks , there for , and because what has been mentioned , design of storm water drainage system study for Beit Jala city have been conducted .،

Data must be developed on topography, geology, hydrology climate, ecological elements and social and economic conditions. Topographic maps with existing and proposed streets provide the most important information for preliminary flow routing.

1.2 Problem Definition.

Water drainage is very important due to water accumulation on the streets as a result of heavy precipitation, population growth, and the development and extension of West Bank cities.

Beit Jala city is located in a semi arid region with rainfall generally limited to autumn and winter months. In the past, the open area of the city easily observed most of this rainfall and provided the primary source for recharging the ground water aquifer. All of the areas of Beit Jala city do not have a natural drainage outlet, heavy rainfall causes storm water to collect in low areas and flood streets and walk ways.

Rapid growth has decreased the open areas available for percolation of rain water and has greatly increased the runoff to flow laying areas.

In view of this condition, design of storm water drainage system in Beit Jala city becomes very essential.

1.3 Objectives of the Project

This Project "Design a storm water drainage network for Beit Jala city", which include the following:-

1- Determine the sub catchments and catchments of the study area with the help of aerial photogrammetric map and Geographical information system (GIS).

2- Design of storm water drainage system of the city.

3- Prepare all of the tables and drawing needs to implement the drainage system.

4- Prepare A Bill of Quantitys.

1.4 Methodology

1- Many site visits to Beit Jala city and cooperation with Beit Jala Municipality to make sufficient system

2- All needed maps and the previous studies that contain different information about Beit Jala City were obtained.

3- The amount of rain fall in the last years, the rainfall rate, and the maximum quantities were obtained.

4- The different layouts of the purposed storm water collection system were completed.

5- The necessary calculations for the quantity of storm water.

6- The necessary calculations for design of the storm water drainage system were completed.

7- Tables, Maps, Drawings and bill of quantities were completed.

8- Writing the report.

1.5 Phase of the Project.

The Project will consist of the four phases as shown in Table (1.1):-

Title	Duration								
	14/2	14/3	14/4	14/5	14/6	14/9	14/10	14/11	14/12
Data collection and survey									
Preparing layout for storm water collection system and calculate the amount of storm water									
Design of storm water collection system									
Writing the report and preparing maps									

Table (1.1): Phases of the Project with Their Expected Duration

1.5.1 First Phase: - Data collection and Survey

In this phase, available data and information were collected from different sources.

Moreover, many site visits to both city and municipality were done. This phase includes the following tasks:-

1- Collecting of aerial and topographical maps for all areas.

2- Collecting of metrological data (temperature, rainfall … etc) from different sources.

1.5.2 Second Phase:-Preparing Layout for Storm Water Collection System and calculate The Amount of Storm Water.

In this phase layout was prepared and put in its final shape and then quantities of storm water will determine.

This phase includes the following tasks:

1- Draw the layout of storm water collection system and check it more than one time to make sure that is correctly , later compare layout with the real situation in Beit Jala city then make adjustment and draw the final layout , this step is the most important one .

2- Evaluation of the contour maps and matching it with actual ground levels in the city.

3- Determination of the storm water quantities.

1.5.3 Third Phase: - Design of Storm water collection system

In this phase the necessary calculations needed for the design of main trunks was completed, this phase includes the following tasks:

1- Establish a system layout, which includes the areas that are going to be served, existing streets, roads, topography … etc

2- Establish the catchments and sub-catchments areas and routes of the sewers.

3- Establish the design criteria and conducting the needed sewer diameter calculations.

4- Preparing needed different drawings for the designed sewers.

1.5.4 Fourth Phase: - Writing the report and preparing

After finishing the design calculations of the main trunks the project team was prepared the specification drawing, bill of quantities preliminary maps. Final report prepared and submitted to the Department of Civil and Architectural Engineering at Palestine Polytechnic University.

1.6 Organization of the Project

The study report has been prepared in accordance with the objectives and of work.

The report consists of six chapters.

The first chapter entitled "Introduction" outlines the problem, project objectives, and phases of the project.

Chapter two entitled "Project Area" which deals with the metrological data, geographic data, rainfall, temperature, water supply.

Chapter three entitled "Design Criteria" which deals with the storm water runoff, hydraulic consideration, design of storm water sewers.

Chapter four entitled "Analysis and Design" which deals with the layout, design computations, storm water drainage system and profiles of drainage channels.

Chapter five entitled "Bill of quantities" which deals with the quantities needed to complete the design system.

Chapter six entitled "Conclusions" which deals with the conclusions of the study.

CHAPTER TWO

"PROJECT AREA"

2.1 GENERAL

In this chapter, the basic data of Beit Jala will be briefly discussed. The location,topography, and climate will be described. The water supply and rainfall quantity will be briefly presented.

2.2 Project Area

Beit Jala City is located 10 km south of Jerusalem, on the western side of the Hebron road, opposite Bethlehem , Beit Jala is bordered by Bethlehem city to the east, Jerusalem city and Gilo settlement to the north, Al Walaja and Battir villages to the west, and Ad Doha city and Al Khader town to the south , as shown on the project location maps as shown in Figures (2.1) , and (2.2) the average elevation of the City is 779 m above sea level ,The economy in Beit Jala is dependent on several economic sectors, mainly: services sector, which absorbs 30% of the city workforce , The other sector is agricultural , Beit Jala lies on a total area of about 9,749 Acres of which 7,305 Acres are considered arable land, and 913Acresare residential land , The total population of Beit Jalain 2007 was 13,845; of whom 6,859 are males and 6,986 are females .

Maps must use to analysis and discuss this data so triangulated irregular Network map (TIN) map is prepared for the Beit Jala city as Shown in fig (2.3) , then Digital Elevation Model is prepared for the area and this is shown in fig (2.4) , then Flow Direction map which shown in fig (2.5) , then Flow Accumulation Map is prepared for the city and is shown in the fig (2.6) ,then Stream Network map also is constructed as shown in fig(2.7), This maps show the highest point in the city which is in the west of the city and the lowest point which in the north .

Flow direction is running by gravity to enter the lowest point which located in the south.

Not that the accumulated form the east to reach the south formed stream network that end the south.

2.3 Meteorological Data

The hydrology of region depends primarily on its climate, and secondarily on its topography. Climate is largely depends on geographical position of the earth surface, humidity, temperature, and wind. These factors are affecting evaporation and transpiration. So this study will include needed data about these factors, since they play big role in the determination of rainfall.

Each year, Beit Jala receives just less than 563 mm of rain, almost all coming during a short winter, from late November to early March. During these months temperatures can become fairly chilly and rainy, with rare flurries of snow and freezing temperature ,The summer, in contrast, is long, hot, and dry, receiving virtually no rain, with temperatures as high as 39 degrees Celsius during midday Average temperatures range from 9-18° C in winter to 26- 30° C in summer .

2.3.1 Rainfall

The average annual rainfall in Beit Jala city is 563 mm. Rainfall occurs between September and May, while it stop raining in the summer season from June to August. The monthly rainfall of Beit Jala city 2013 is shown in the table (2.1). [8]

2.3.2 Temperature

The temperature is characterized by considerable variation between summer and winter times. The average annual temperature is 17˚ C, The mean temperature values at Beit Jala city are given in Table (2.1). [7]

The following minimum and maximum values were shown:

- The mean maximum temperature: 18° C

-The mean minimum temperature: 9° C

2.3.3 Relative Humidity

The average annual humidity is 60.5 %. The relative humidity of Beit Jala City is shown in Table (2.1). [3]

Month	Rainfall (mm)	Maximum Temperature (C°)	Minimum Temperature (C°)	Relative Humidity (%)
Jan	255.0	24	-4	73
Feb	69.1	26	-7	70
Mar	5.6	30	-1	66
Apr	20.2	35	-1	53
May	2.7	39	5	49
Jun	0.0	40	8	52
Jul	0.0	39	11	54
Aug	0.0	42	13	60
Sep	2.4	37	9	61
Oct	0.0	37	7	59
Nov	0.0	33	0	62
Dec	191.9	29	-1	70
Total	544.5			

Table (2.1): Meteorological Conditions at Beit Jala City Weather Station for (2013)

CHAPTER THREE

"DESIGN CRITERIA"

3.1 General

Rapid effective removal of storm runoff was a luxury not found in many cities in the early nineteenth century. Today, the modern city dweller has come to think of this as an essential service. Urban drainage facilities have progressed from crude ditches and stepping stones to the present intricate coordinates systems of curbs, gutters, inlets, and under ground conveyance.

The design must consider meteorological factors, geomorphological factors, and the economic value of the land, as well as human value considerations such as aesthetic and public safety aspects of the design. The design of storm water detention basins should also consider the possible effects of inadequate maintenance of the facility.

3.2 Storm Water Runoff

Storm water runoff is that portion of precipitation which flows over the ground surface during and a short time after a storm. The dependence parameters that controlled the quantity of the storm water which carried by a storm or combined sewer are the surface of the drainage area (ha), the intensity of the rainfall (l/s.ha), and runoff coefficient C dimensionless (the condition of the surface). There are many methods and formulas to determine the storm flow.

3.2.1 Rational Method

The rational method has probably been the most popular method for designing storm systems. It has been applied all over the world and runoff is related to rainfall intensity by the formula,

$$Q = C.i.A \tag{3.1}$$

Where Q = peak runoff rate (l/sec).

C = runoff coefficient, which is actually the ratio of the peak runoff rate to the average rainfall for a period known as the time of concentration.

i = average rainfall intensity, mm/min, for period equal to the time of concentration.

A= drainage area (ha).

For small catchments areas, it continues to be a reasonable method, provided that it is used properly and that results and design concepts are assessed for reasonableness. This procedure is suitable for small systems where the establishment of a computer model is not warranted.

The steps in the rational method calculation procedure are summarised below:

1- The drainage area is first subdivided into sub-areas with homogeneous land use according to the existing or planned development.

2- For each sub-area, estimate the runoff coefficient *C* and the corresponding area *A*.

3- The layout of the drainage system is then drawn according to the topography, the existing or planned streets and roads and local design practices.

4- Inlet points are then defined according to the detail of design considerations. For main drains, for example, the outlets of the earlier mentioned homogeneous sub-areas should serve as the inlet nodes. On the other hand in very detailed calculations, all the inlet points should be defined according to local design practices.

5- After the inlet points have been chosen, the designer must specify the drainage sub-area for each inlet point A and the corresponding mean runoff coefficient *C*. If the sub-area for a given inlet has non-homogeneous land use, a weighted coefficient may be estimated.

6- The runoff calculations are then done by means of the general rational method equations for each inlet point, proceeding from the upper parts of the watershed to the final outlet. The peak runoff, which is calculated at each point, is then used to determine the size of the downstream trunk drain using a hydraulic formula for pipes flowing full.

7- After the preliminary minor system is designed and checked for its interaction with the major system, reviews are made of alternatives, hydrological assumptions are verified, new computations are made, and final data obtained on street grades and elevations. The engineer then should proceed with final hydraulic design of the system.

3.2.2 Runoff Coefficient, C

Runoff coefficient is a function of infiltration capacity, interception by vegetation, depression storage, and evapotranspiration. It is requires greatest exercise of judgment by engineer and assumed constant, actually variable with time. It is desirable to develop composite runoff coefficient (weighted average) for each drainage area as:

$$C = \frac{\sum Ci.Ai}{\sum Ai} \qquad (3.2)$$

Where Ai = i^{th} area.

Ci = i^{th} runoff coefficient.

The range of coefficients with respect to general character of the area is given in the following tables (Table 3.1 and Table 3.2).

Description of Area	Runoff Coefficients
Business	
Down town Neighborhood	0.70 to 0.95 0.50 to 0.70
Residential	
Single-Family Multi-unit, detached Multi-unit, attached	0.30 to 0.50 0.40 to 0.60 0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Industrial	
Light Heavy	0.50 to 0.80 0.60 to 0.90
Parks, Cemeteries	0.10 to 0.25
Playground	0.20 to 0.35
Railroad yard	0.20 to 0.35
Unimproved	0.10 to 0.30

Table (3.1): The Range of Coefficient with Respect to General Character of the Area (Sarikaya, 1984)

Character of Surface	Runoff Coefficients
Pavement	
Asphalt and concrete	0.70 to 0.95
Brick	0.70 to 0.85
Lawns, Sandy soil	
Flat, 2 percent	0.05 to 0.10
Average,2to7percent	0.10 to 0.15
Steep, 7 percent	0.15 to 0.20
Roofs	0.75 to 0.95
Lawns, Heavy soil	
Flat, 2 percent	0.13 to 0.17
Average,2 to 7percent	0.18 to 0.22
Steep, 7 percent	0.25 to 0.35

Table (3.2): The Range of Coefficient With Respect to Surface Type of the Area (Sarikaya, 1984)

3.2.3 Rainfall Intensity, i

In determining rainfall intensity for use in rational formula it must be recognized that the shorter the duration, the greater the expected average intensity will be. The critical duration of rainfall will be that which produces maximum runoff and this will be that which is sufficient to produce flow from the entire drainage area. Shorter periods will provide lower flows since the total area is not involved and longer periods will produce lower average intensities. The storm sewer designer thus requires some relationship between duration and expected intensity. Intensities vary from place to another and curves or equations are specified for the areas for which they were developed.

The rainfall intensity depends on many factors through which we can do our calculations; we can list these factors as follow:

1- Average frequency of occurrence of storm (n) or (f).

Average frequency of occurrence is the frequency with which a given event is equaled or exceeded on the average, once in a period of years. Probability of occurrence, which is the reciprocal of frequency, (n) is preferred by sum engineers. Thus, if the frequency of a rain once a 5-year (f=5), then probability of occurrence n=0.20. Selection of storm design rain frequency based on cost-benefit analysis or experience. There is range of frequency of often used:

a. Residential area: f = 2 to 10 years (5 year most common).
b. Commercial and high value districts: f = 10 to 50 (15 year common).
c. Flood protection: f = 50 year.

2- Intensity, duration and frequency characteristics of rainfall.

Basic data derived from gage measurement of rainfall (Point rainfall) over along period can be used to obtain a rainfall height diagram that show the relation between the height of rain (mm) and time (min). The slope of the curve or rain height per unit time is defined as rain intensity:

i= (Δ height of rain / Δ time) $\left[\frac{mm}{\min}\right]$

The rain intensity in litter per second. Hectare is equal:

$$i(\frac{l}{s.ha}) = 166.7i\left[\frac{mm}{\min}\right]$$

In order to drive intensity-duration-frequency curves long-term observation of rainfall is needed. Analysis of such observation is given in any text in sanitary engineering.

3- Time of Concentration

The time of concentration is the time required for the runoff to become established and flow from the most remote part (in time) of the drainage area to the point under design.

$$t_c = t_i + t_f \qquad (3.3)$$

Where t_c: time of concentration.
t_i: inlet time.
t_f: flow time.

Time of flow in storm, $t_f = \dfrac{\text{Length of pipe line (L)}}{\text{Velocity of flow (v)}}$ (3.4)

Inlet time (t_i): is the time required for water to flow over ground surface and along gutters to drainage inlet. Inlet time is function of rainfall intensity, surface slope, surface roughness, flow distance, and infiltration capacity and depression storage.

3.2.4 Catchments Area, A

Most of the catchments are partly developed with residential facilities. The catchments are moderately flat with rural, residential and commercial land uses. The rural areas are located at the downstream end of the catchments.

3.3 Hydraulic Consideration

3.3.1 Introduction

Wastewater systems and (storm water) are usually designed as close channels except where lift stations are required to overcome topographic barriers. The hydraulic problems associated with these flows are complicated in some cases by the quality of the fluid, the highly variable nature of the flows, and the fact that an unconfined or free surface exists. The driving force for open-channel flow and sewer flow is gravity. For the hydraulic calculations of sewers, it is usually assumed uniform flow in which the velocity of flow is constant, and steady flow condition in which the rate discharge at any point of a sewer remains constant (Metcalf,1982).

3.3.2 Hydraulic Design Equations

In principle all closed channel flow formulas can be used in hydraulic design of sewer pipes. The following are the most important formulas:

1. Chezy's formula:

$$V = C\sqrt{RS} \tag{3.5}$$

Where V: the velocity of flow (m/s).

C: the Chezy coefficient; $C = \dfrac{100\sqrt{R}}{m+\sqrt{R}}$, where m = 0.35 for concrete pipe

or 0.25 for vitrified clay pipe

R: the hydraulic radius (m)

S: the slope of the sewer pipe (m/m).

2. Darcy-Weisbach formula: It is not widely used in wastewater collection design and evaluation because a trial and error solution is required to determine pipe size for a given flow and head loss, since the friction factor is based on the relative roughness which involves the pipe diameter, making it complicated. Darcy-Weisbach formula states that

$$H = \lambda \frac{L \times V^2}{D \times 2g} \quad (3.6)$$

Where H: the pressure head loss

L: the length of pipe (m).

D: the diameter of pipe (m)

λ : the dimensionless friction factor generally varying between 0.02 to 0.075.

3. The Manning formula: Manning's formula, though generally used for gravity conduits like closed channel, it is also applicable to turbulent flow in pressure conduits and yields good results, provided the roughness coefficient n is accurately estimated. Velocity, according to Manning's equation is given by:

$$V = \frac{1}{n} R^{2/3} S^{1/2} \quad (3.7)$$

Where n: the Manning's roughness coefficient [1/n (k_{str}) = 75 $m/s^{1/3}$].

R: the hydraulic radius = area /wetted perimeter (R= A/P).

- For circular pipe flowing full, R=D/4.
- For open channel flowing full, R=A/P.

The Manning's roughness coefficient depends on the material and age of the conduit. Commonly used values of n for different materials are given in Table (3.3).

Material	Commonly Used Values of n
Concrete	0.013 and 0.015
Vitrified clay	0.013 and 0.015
Cast iron	0.013 and 0.015
Brick	0.015 and 0.017
Corrugated metal pipe	0.022 and 0.025
Asbestos cement	0.013 and 0.015
Earthen channels	0.025 and 0.003

Table (3.3): Common Values of Roughness Coefficient Used In the Manning Equation (Sarikaya, 1984)

3.3.3 Hydraulics of Partially Filled Section

The filling rate of a sewer is an important consideration, as sewers are seldom running full, so storm water sewers designed for 40% or 50% running full, that is means only 40 % to 50 % of the pipe capacity should be utilized to carry the peak flow.

Partially filled sewers are calculated by using partial flow diagram and tables indicating the relation between water depth, velocity of flow and rate flow .The hydraulic characteristics are similar as for closed channels, but the velocity of flow is reduced by increased air friction in the pipe with increasing water level, particularly near the top of the pipe. The velocity of flow and the flow rate are reduced at filling rates between 60% and 100%; the water level in the pipe is unstable at filling rates above 90% or 95%.

3.4 Storm Water Sewers Design

Designing a community storm system is not a simple task. It requires considerable experience and a great deal of information to make proper decisions concerning the layout, sizing, and construction of a storm network that is efficient and cost-effective. The design engineer needs to generally undertake the following tasks (Qasim, 1985, Peavy, 1985):

1. Define the service area.
3. Conduct preliminary investigations.
4. Develop preliminary layout plan and profile.
5. Selection of design parameters.
6. Review construction considerations.
7. Conduct field investigation and complete design and final profiles.
8. Prepare contract drawing and specifications.

3.4.1 Service area

Service area is defined as the total area that will eventually be served by the drainage system... It is important that the design engineers and project team become familiar with the surface area of the proposed project.

3.4.2 Preliminary Investigation

The design engineer must conduct the preliminary investigations to develop a layout plan of the drainage system. Site visits and contacts with the city and local planning agencies and state officials should be made to determine the land use plans, zoning regulations, and probable future changes that may affect both the developed and undeveloped land. Data must be developed on topography, geology, hydrology, climate, ecological elements, and social and economic conditions. Topographic maps with existing and proposed streets and other utility lines provide the most important information for preliminary flow routing (Qasim, 1985).

If reliable topographic maps are not available, field investigations must be conducted to prepare the contours, place bench marks, locate building, utility lines, drainage ditches, low and high areas, stream, and the like. All these factors influence the sewer layout.

3.4.3 Layout Plan

Proper storm sewer layout plan and profiles must be completed before design flows can be established. The following is a list of basic rules that must be followed in developing a sewer plan and profile (Qasim, 1985).

1. Select the site for disposal of the storm water at the end of the network, generally the lowest elevation of the entire drainage area.
2. The preliminary layout of storm sewers is made from the topographic maps. In general, sewers are located on streets, or on available right-of-way; and sloped in the same direction as the slope of the natural ground surface.
3. The trunk storm sewers are commonly located in valleys. Each line is started from the intercepting sewer and extended uphill until the edge of the drainage area is reached, and further extension is not possible without working downhill.
4. Main storm sewers are started from the trunk line and extended uphill intercepting the laterals.
5. Preliminary layout and routing of storm sewage flow is done by considering several feasible alternatives. In each alternative, factors such as total length of storm sewers, and cost of construction of laying deeper lines versus cost of construction, operation, and maintenance of lift station, should be evaluated to arrive at a cost- effective drainage system.
6. After the preliminary storm sewer layout plan is prepared, the street profiles are drawn. These profiles should show the street elevations, existing storm sewer lines, and manholes and inlets. These profiles are used to design the proposed lines.

Finally, these layout plans and profiles are revised after the field investigations and storm sewer designs are complete (Viessman, 1985).

3.4.4 Selection of Design Parameters

Many design factors must be investigated before storm sewer design can be completed. Factors such as design period; peak, average, and minimum flow; storm sewer slopes and minimum velocities; design equations …etc. are all important in developing storm sewer design. Many of the factors are briefly discussed below.

1. **Design Flow Rate:** Storm water sewers should be designed to carry the largest storm that occurred in the period of design; commonly it is 25 years because of consideration of the cost and the frequently factors.

2. **Minimum Size:** As mentioned earlier, the minimum storm sewer size recommended is 250 to 300 mm for closed system, and for open channel depend on the type of profile that selected.

3. **Minimum and Maximum Velocities:** In storm water sewers, solids tend to settle under low-velocity conditions. Self-cleaning velocities must be developed regularly to flush out the solids. Most countries specify minimum velocity in the sewers under low flow conditions. The minimum allowable velocity is 0.75 m/s, and 0.9 m/s is desirable. This way the lines will be flushed out at least once or twice a day. The maximum velocities for storm water system are between 4 to 5 m/s. The maximum velocity is limited to prevent the erosion of sewer inverts.

4. **Slope:** For closed system minimum slopes determined from minimum velocities, for minimum velocity 0.9 m/s, the slopes are shown in Table 2.4.

Pipe Diameter (D)		Slope (min)	Slope (max) =1/D
mm	**inch**	**mm**	**cm**
250	10	0.00735	0.04
300	12	0.00576	0.033
450	18	0.00336	0.0222
600	24	0.00229	0.0167

Table (3.4): Minimum Recommended Slopes of Storm Sewer (n = 0.015) (Sarikaya, 1984)

Note: for a velocity of 0.75m/s the slopes shown above should be multiplied by1.56.

Maximum slopes determined from maximum velocities, 0.9/D (cm) can be used as a guide.

5. Depth: The depth of storm sewers when using closed system is generally just enough to receive flow but not less than 1 m below the ground surface. Depth depends on the water table, lowest point to be served, topography, and the freeze depth. But for the open channel it is at the ground surface.

6. Appurtenances: Storm Sewer appurtenances include manholes, inlets, outlets and outfall, and others. Appropriate storm sewer appurtenances must be selected in design of storm water sewers.

7. Design Equations and Procedures: Storm water sewers are mostly designed to flow partially full. Once the peak, average, and minimum flow estimates and made general layout and topographic features for each line are established, the design engineer begins to size the sewers. Design equations proposed by Manning, Chezy, Gangullet, Kutter, and Scobey have been used for designing sewers and drains. The Manning equation, however, has received most widespread application. This equation is expressed below:

$$V=\frac{1}{n}R^{2/3}S^{1/2} \qquad (3.7)$$

And as mentioned earlier, the runoff flow is calculated using the following formula:

$$Q = C.i.A \qquad (3.1)$$

Various types of monographs have been developed for solution of problems involving sewers flowing full. Monographs based on Manning's equation for circular pipe flowing full and variable n values are provided in Figure 2.1. Hydraulic elements of circular pipes under partially-full flow conditions are provided in Figure 2.2. It may be noted that the value of n decreases with the depth of flows Figure 2.1. However, in most designs n is assumed constant for all flow depths. Also, it is a common practice to use d, v, and q notations for depth of flow, velocity, and discharge under partial flow condition while D, V, Q notations for diameter, velocity, and discharge for sewer flowing full. Use of equations 2.1 and 2.7 and Figures 2.1 and 2.2, one can design the drainage system.

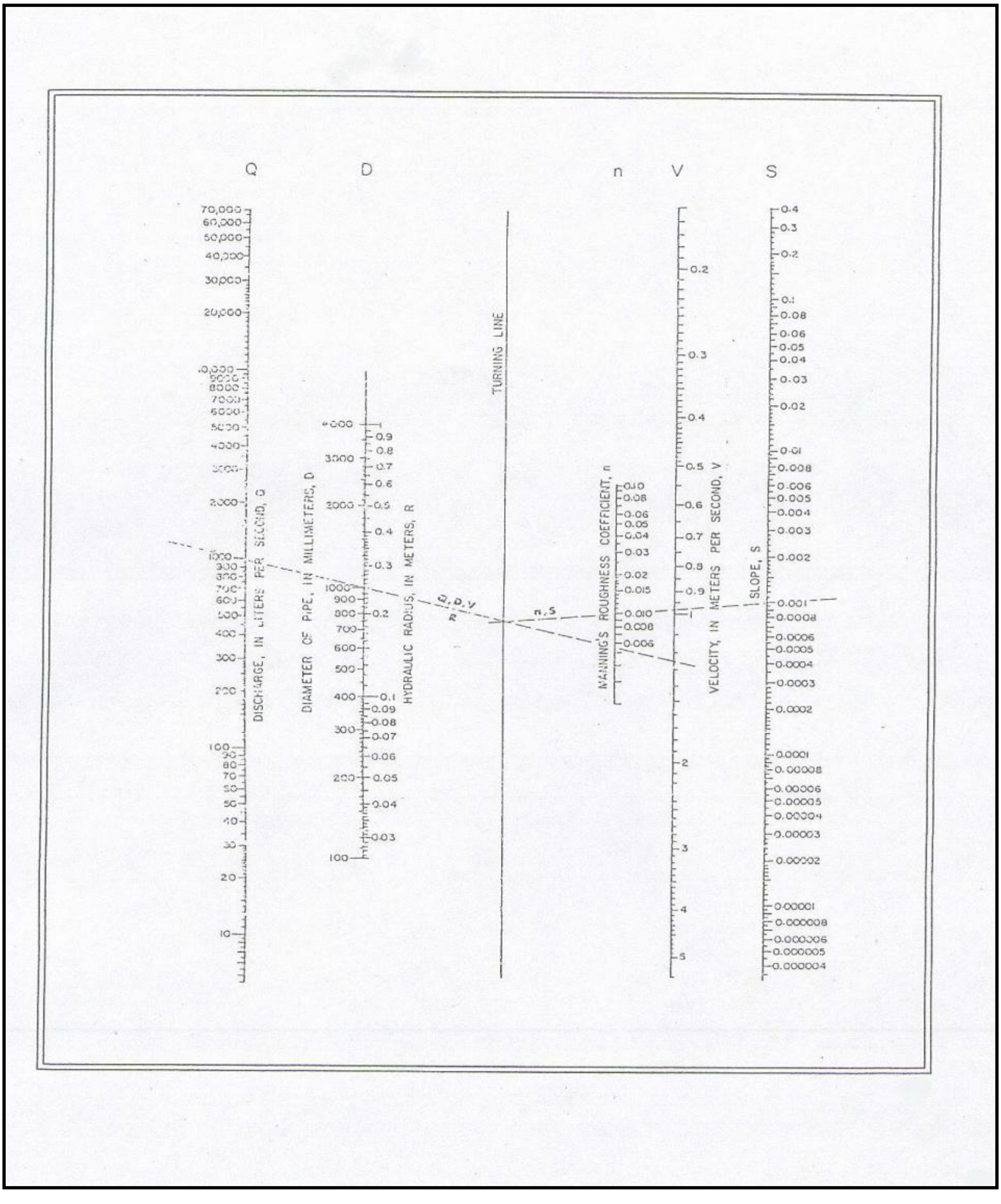
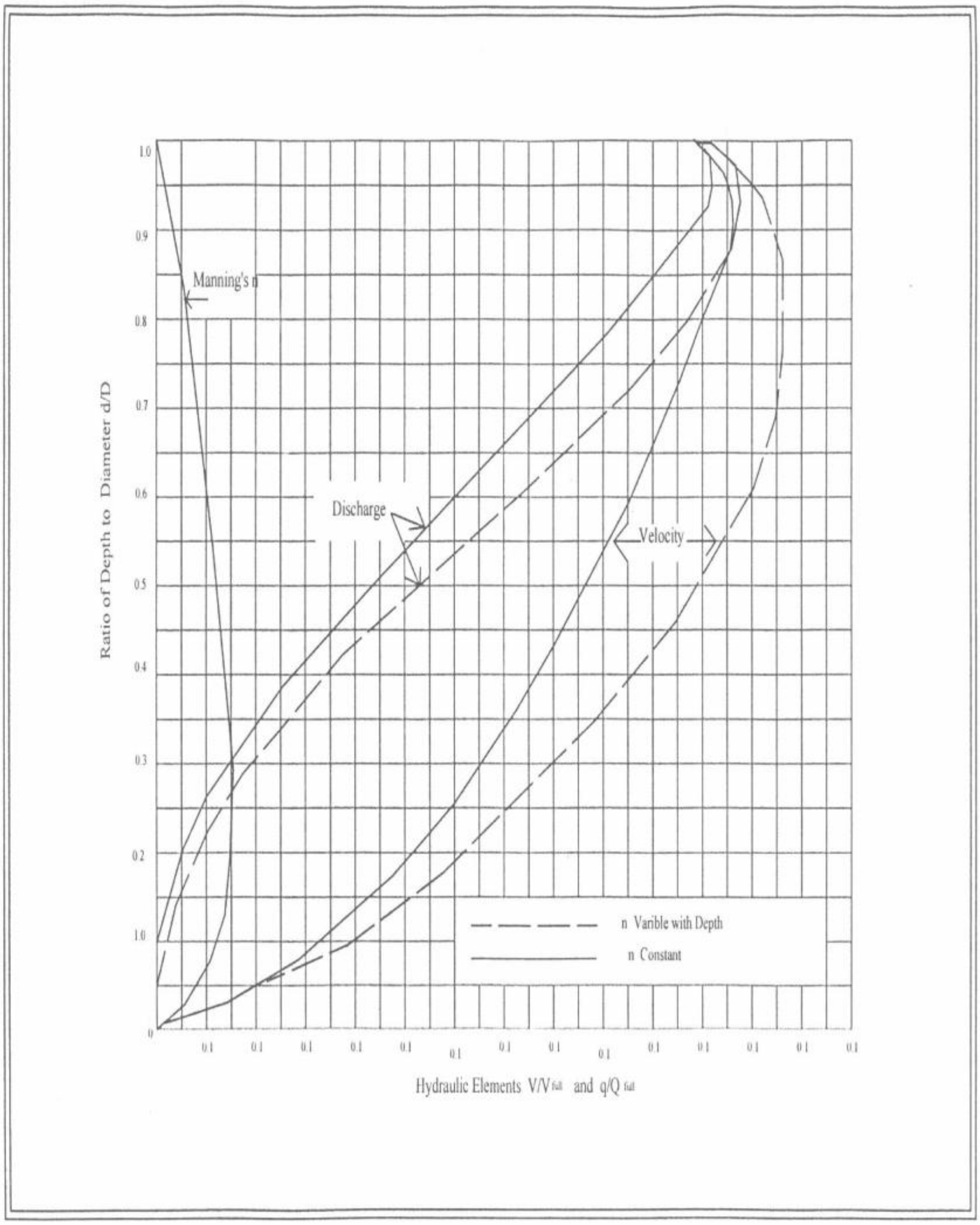


Figure 3.1: Diagram for Solution of the Manning Formula



Fig, 3.2: Hydraulic Properties of Circular Sewer

3.4.5 Design Computations

After the preliminary sewer layout plan is prepared, the design computations are accomplished. Design computations for sewers are repetitious and therefore, are best performed in a tabular format. Table 2.5 is typical of the way in which data can be organized to facilitate computations for closed system.

3.4.6 Preparation of maps and profile

It is important that the detailed drawings be prepared and specifications completed before the bid can be requested. The contract drawings should show (1) surface features, (2) depth and character of material to be excavated, (3) the existing structures that are likely to be encountered, and (4) the details of sewer and appurtenances to be constructed.

The specifications should be prepared by writing clearly and completely all work requirements and conditions affecting the contracts. As an example, technical specifications should cover items such as site preparation, excavation and backfill, concrete work, sewer materials and pipe lying, and acceptance tests (Qasim, 1985).

3.5 Summary

In this chapter, municipal storm water drainage systems in general have been described. The method of calculating the storm water runoff has been presented. The flow equations of sewer pipes and channels have been brought out. Finally the design and construction of community storm water drainage system has been briefly discussed.

Table (3.5) Typical Computation Sheet for Storm Water Design of Closed System

NUMBER	LOCATION			LENGTH	LENGTH COMULATIVE	AREA of Street	C FACTOR Street	AREA of Land	C Factor of land	SUM(AC) COMULATIVE	Tc	(i)	Q	Qi
	LINE NAME	UPPER MH. NO.	LOWER MH. NO.	(m)	(m)	(ha)				(ha)	(min)	(l/s.ha)	(l/s)	(l/s)
1	A	1	2											
2	A	2	3											
3	A	3	4											
4	A	4	5											
5	A	5	6											
6	A	6	7											
7	A	7	8											
8	A	8	9											
9	A	9	10											
10	A	10	11											
11	A	11	12											
12	A	12	13											
13	A	13	14											
14	A	14	15											
15	A	15	16											
16	A	16	17											
17	A	17	18											
18	A	18	19											
19	A	19	20											
20	A	20	21											

CHAPTER FOUR

"ANALYSIS AND DESIGN"

4. 1 General

In this project, design of storm water drainage system for the Beit Jala, in order to solve the problem causes by the cumulative flooded storm water in the streets will be prepared.

In this chapter, the layout of the system established will be presented followed by discussion of detailed design computations and the final design and profile of the suggested storm water drainage system.

4.2 Layout of the System

The first step in designing a storm water drainage system is to establish an overall system layout that includes a plan of the area, showing roads, streets, buildings, other utilities, topography.

In suggesting the layout of storm water drainage system for the Beit Jala, the following basic steps were followed:

1. Obtain a topographic map of the area to be served.
2. Visit the location.
3. Locate the catchment of the site and determine the area of this catchment.
4. Sketch in preliminary closed pipe system to serve the area.
5. Sewer layout is followed natural drainage ways so as to minimize
6. Excavation and pumping requirements (if it needed).
7. Establish preliminary pipe diameter that can drain the required water runoff.
8. Revise the layout so as to optimize flow-carrying capacity at minimum cost.

   Note that: To determine the catchment area and sub-catchment area and to determine the flow direction we must use maps prepared in Ch2, these maps are TIN, DEM, Flow Direction, and flow accumulative, Net Work Stream.

The final layout of storm water drainage system for Beit Jala City is illustrated in the
(Fig 4.1) and (Fig 4.2) and drawing (D1), (D2) in Appendix

4.3 Quantity of Storm Water

After preparing the layout of storm water drainage system the quality of storm water that the system must carry it will be calculated using the data collected about the area.

Example:

Design a gravity flow storm water drainage pipe for the area of Beit Jala city use line sub-main b1 as an example this is line shown in (Fig 4.4). Assume that the following design criteria have been developed and adopted based on an analysis of local conditions and codes.

1. For weighted Runoff coefficient (C) uses 0.65
2. For Inlet time (t_i) use 10 minutes
3. For Concentration time (t_c) use equations:

$$t_c = t_i + t_f \quad (3.3)$$

4. For Runoff rate depending on the formula:

$$Q = C.i.A \quad (3.1)$$

5. For Rainfall intensity use (Fig 4.3).

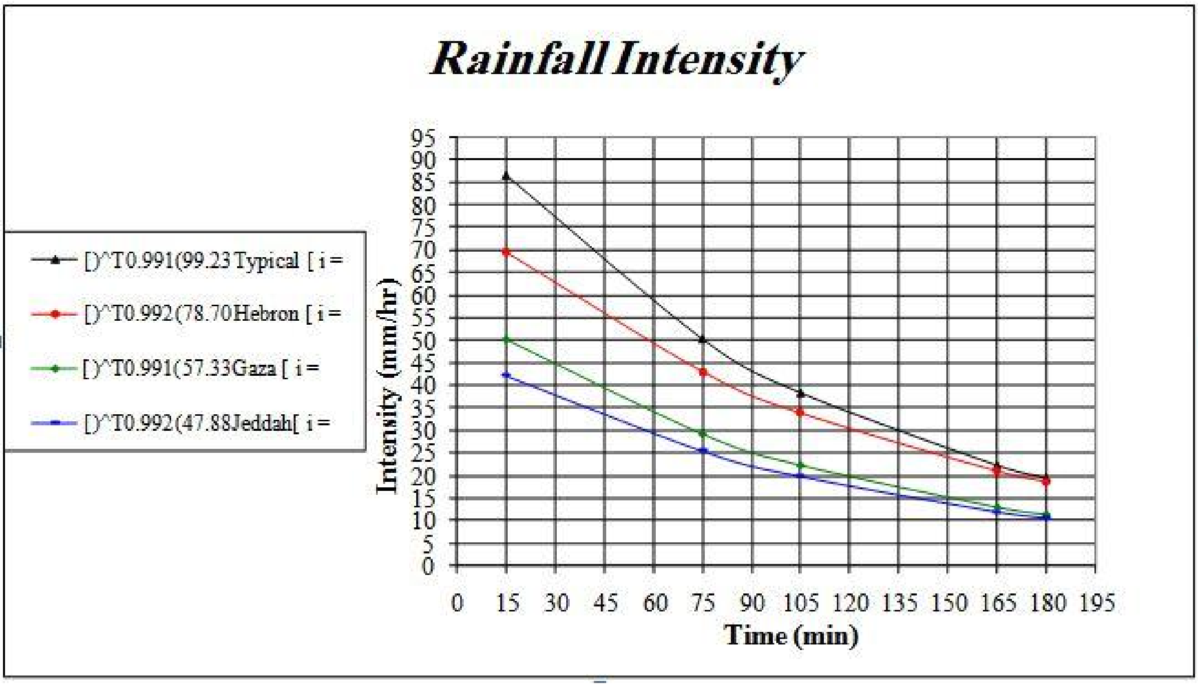


Fig 4.3 The Rainfall Intensity-Duration Curve For Several Areas

Soluion

a. Layout the storm water sewer. Draw a line to represent the proposed sewer.
b. Locate and number the upper and lower points of the line (sub-main b1).
c. The necessary computations for the storm water sewer shown in Fig(4.4) presented in the Table 4.1. The data in the table are calculated as follow:

   1. The entries in columns 1 through 6 are used to identify the point locations, their numbers and the length between them.

   2. The entries in columns 7 used to identify the sewer area; column 7 shows the partial sewered area in hectare.

   3. The entries in columns 8 through 14 are used to calculate the design flow. Runoff coefficient (C) is entered in column 8. The partial sewered area in hectare is multiplied by runoff coefficient (C) and the result is given in column 9. The cumulative multiplication of the sewered area in hectare is multiplied by runoff coefficient (C) are given in column 10. The concentration time is shown in column 11 and rainfall intensity (L/s.ha) is shown in column 12. Column 14 shows the quantity of storm water separately between two inlets.

Four main and six sub-main trunks is proposed and located on the layout of the area and the quantity of storm water for each is illustrated in table in Appendix A

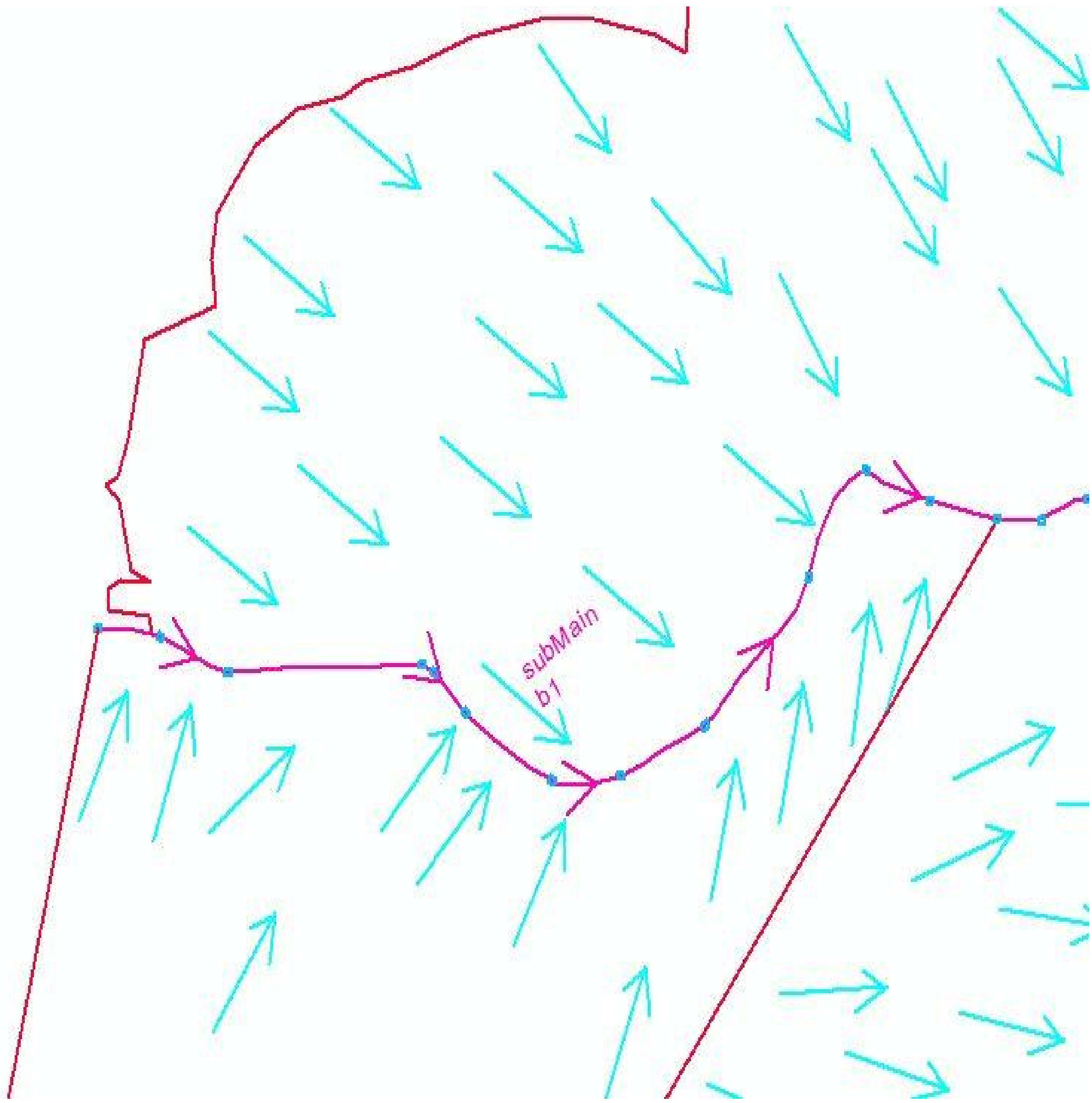


Fig (4.4)

StormWater Design Computations

Line submain b1

NUMBER	LOCATION: LINE NAME	LOCATION: UPPER MH. NO.	LOCATION: LOWER MH. NO.	LENGTH (m)	LENGTH COMULATIVE (m)	AREA of Street and industry (ha)	C FACTOR Street and industry	C.A STREET (ha)	SUM(AC) COMULATIVE (ha)	Tc (min)	(i) (l/s.ha)	Q (l/s)	Qi (l/s)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	submain b1	1	2	46.84	46.84	1.78	0.650	1.16	1.16	10.78	12031.06	13943.09	13943.09
2	submain b1	2	3	56.52	103.36	1.28	0.650	0.83	1.99	11.72	11940.37	23807.12	9864.03
3	submain b1	3	4	147.62	250.98	4.51	0.650	2.93	4.93	14.18	11706.72	57673.35	47809.32
4	submain b1	4	5	9.61	260.59	0.34	0.650	0.22	5.15	14.34	11691.67	60180.55	12371.23
5	submain b1	5	6	33.51	294.10	1.10	0.650	0.72	5.86	14.90	11639.34	68233.80	55862.56
6	submain b1	6	7	75.60	369.70	1.99	0.650	1.29	7.15	16.16	11522.14	82428.46	26565.89
7	submain b1	7	8	54.26	423.96	0.79	0.650	0.52	7.67	17.07	11438.75	87727.39	61161.50
8	submain b1	8	9	68.75	492.71	1.15	0.650	0.75	8.42	18.21	11333.96	95390.89	34229.39
9	submain b1	9	10	117.24	609.95	10.49	0.650	6.82	15.23	20.17	11157.46	169982.74	135753.35
10	submain b1	10	11	77.85	687.80	4.32	0.650	2.81	18.04	21.46	11041.78	199209.56	63456.21
11	submain b1	11	12	52.43	740.23	4.66	0.650	3.03	21.07	22.34	10964.55	231045.41	167589.20
12	submain b1	12	13	53.31	793.54	1.52	0.650	0.99	22.06	23.23	10886.58	240163.81	72574.62
13	submain b1	13	14	31.74	825.28	1.51	0.650	0.98	23.04	23.75	10840.42	249778.28	177203.66
14	submain b1	14	15	38.62	863.90	1.63	0.650	1.06	24.10	24.40	10784.52	259932.32	82728.66
15	submain b1	15	16	82.33	946.23	2.74	0.650	1.78	25.88	25.77	10666.31	276085.77	193357.11
16	submain b1	16	17	39.33	985.56	2.30	0.650	1.50	27.38	26.43	10610.30	290512.23	97155.12

Table 4.1

4.4 Sewer CAD Program Works:

a. Open Sewer CAD, select file → import → DXF Background to import the DXF file, Fig (4.5) below shows this step.

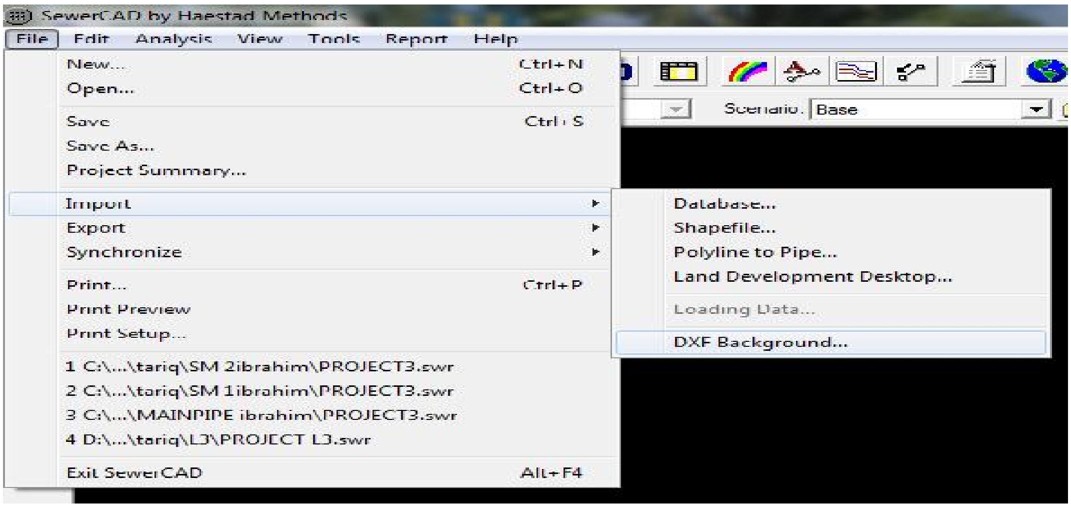


Fig (4.5)

b. Specify file location is then press open, Fig (4.6) below shows this step. And Fig (4.7) shows line (Sub main a3).

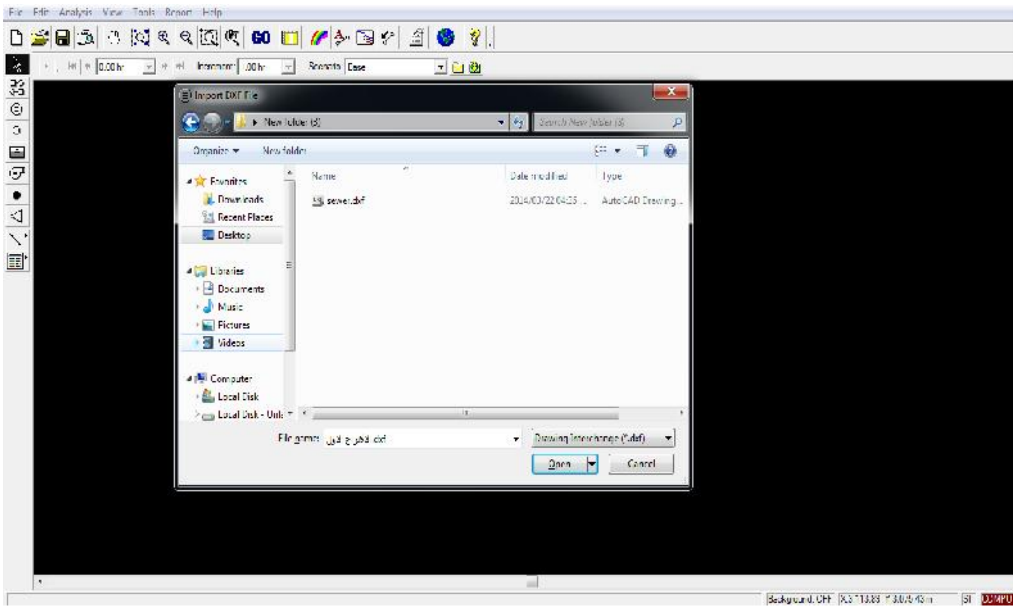


Fig (4.6)

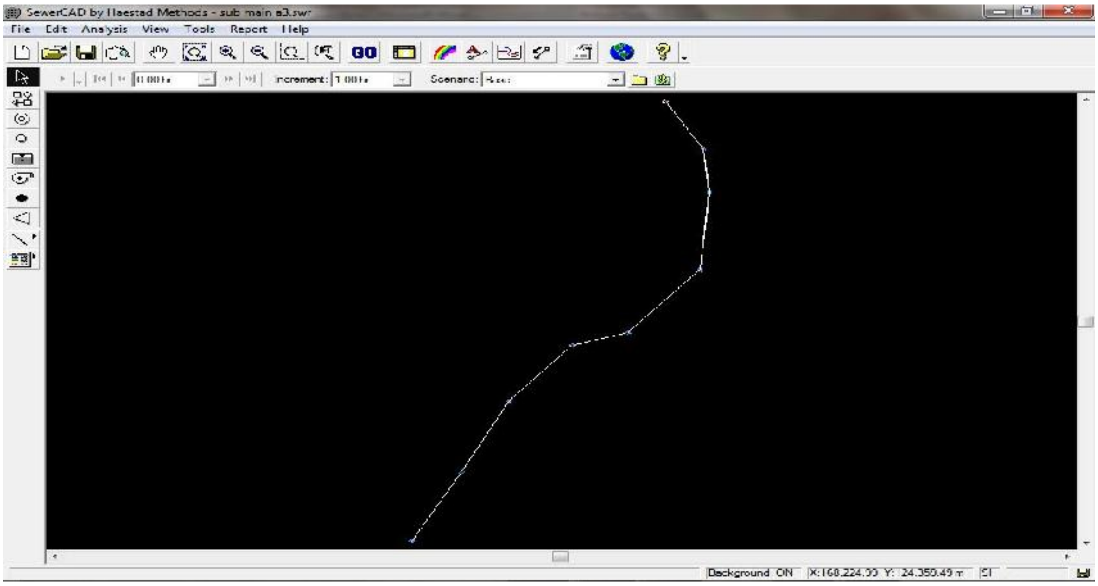


Fig (4.7)

c. Press pipe icon, a massage will appear tell you to create a project see Fig (4.8).

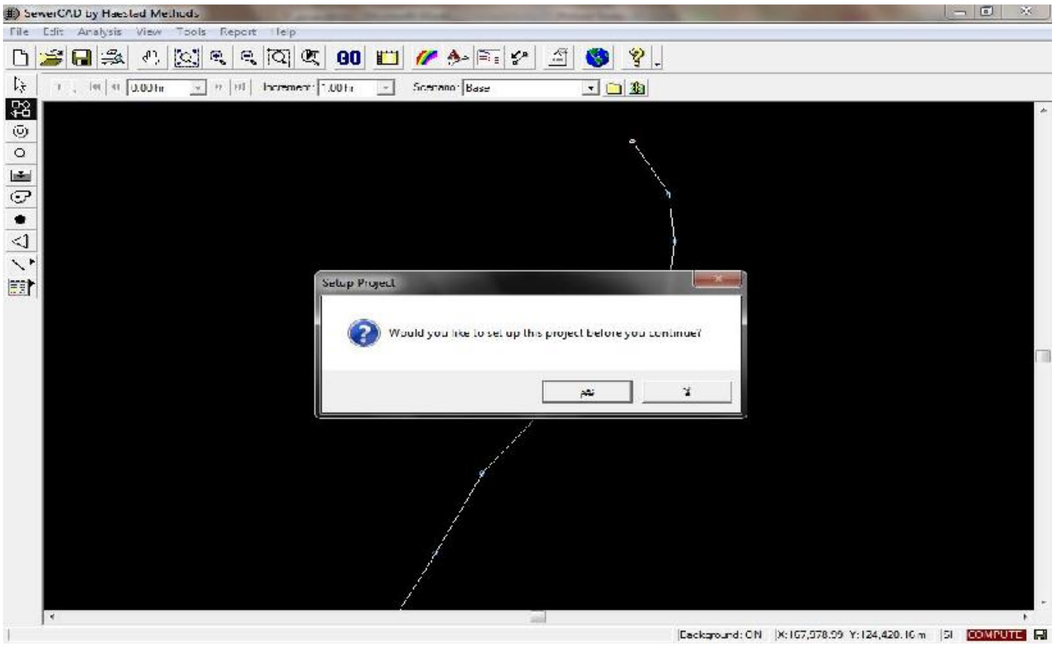


Fig (4.8)

d. Press yes and define the project then press next twice, then select finish, the Fig (4.9) below show this step.

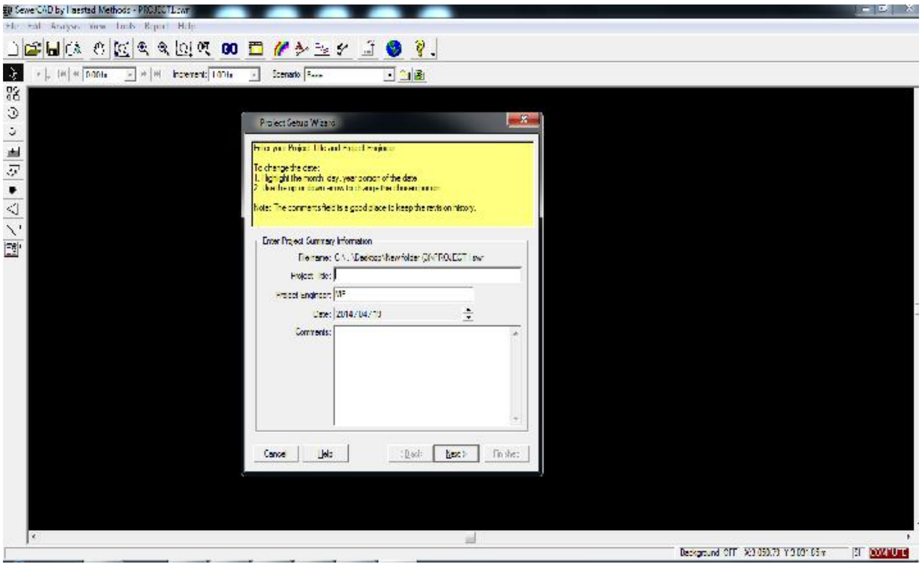


Fig (4.9)

e. Press pipe icon and connect between inlets, Fig (4.10) below shows the step.

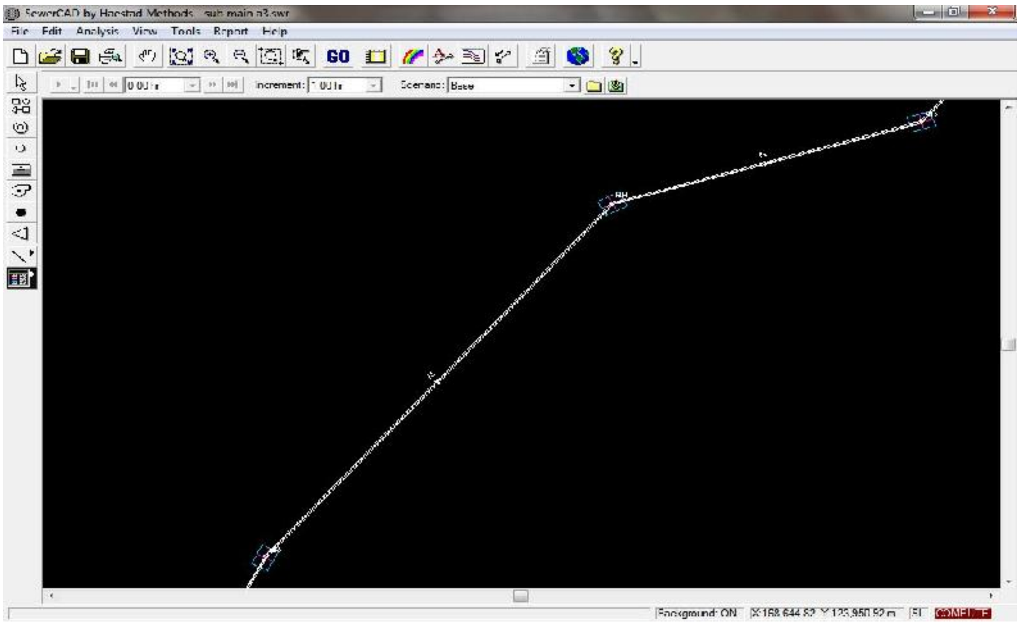


Fig (4.10)

f. After you connect between all inlets, press on the out let icon and click on the last inlet, then press yes to replace the inlet with outlet, the Fig (4.11) below shows the step.

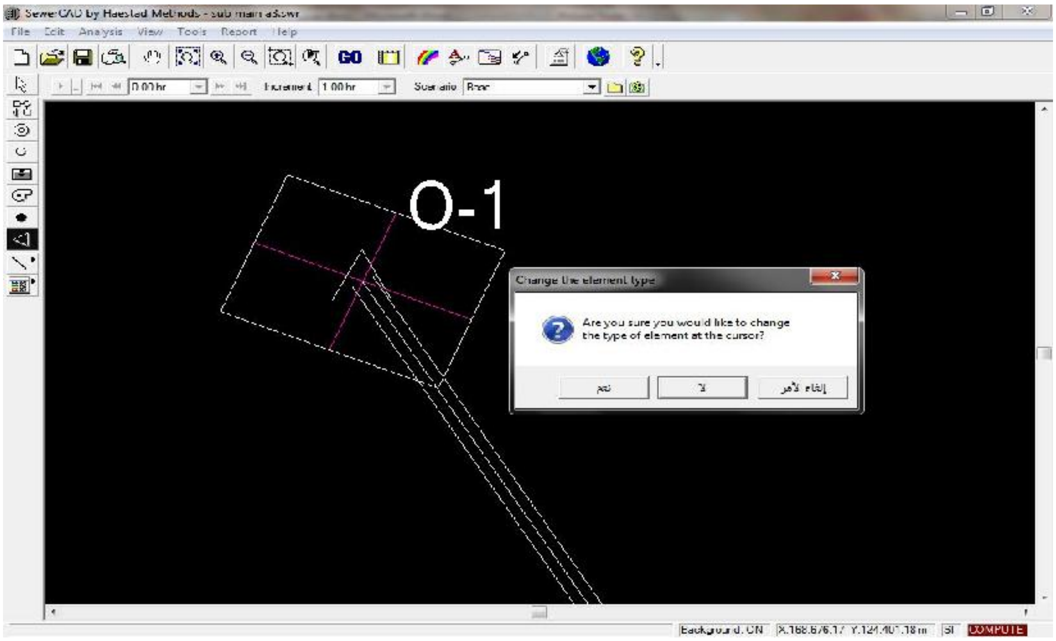


Fig (4.11)

g. Save your project, then select analysis → alternatives → physical properties → edit, then start editing gravity pipe, see Fig (4.12).

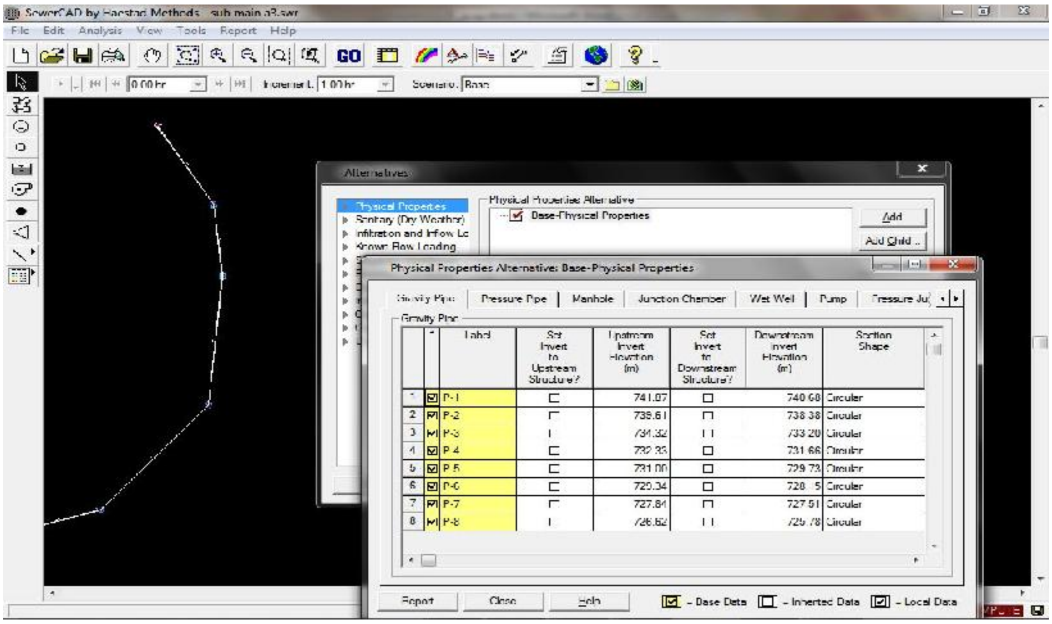


Fig (4.12)

h. Select inlet to enter the ground elevations of inlets, then select out let to enter its elevation. Then press close. Fig (4.13) below shows the step.

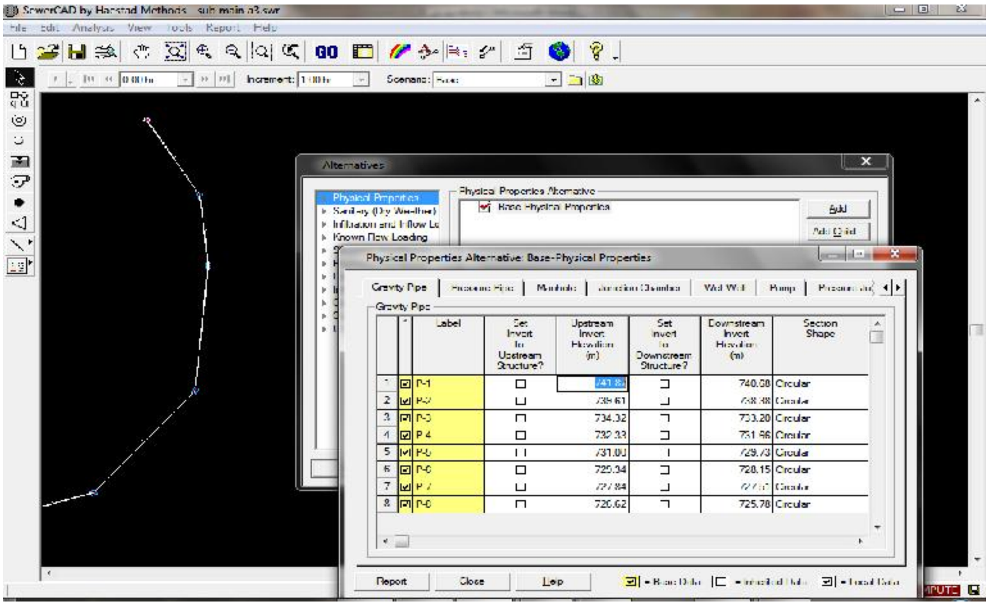


Fig (4.13)

i. Select sanitary (dry weather) → edit → manhole to select the type of load and to enter the load for each inlet, Fig (4.14) below shows the step.

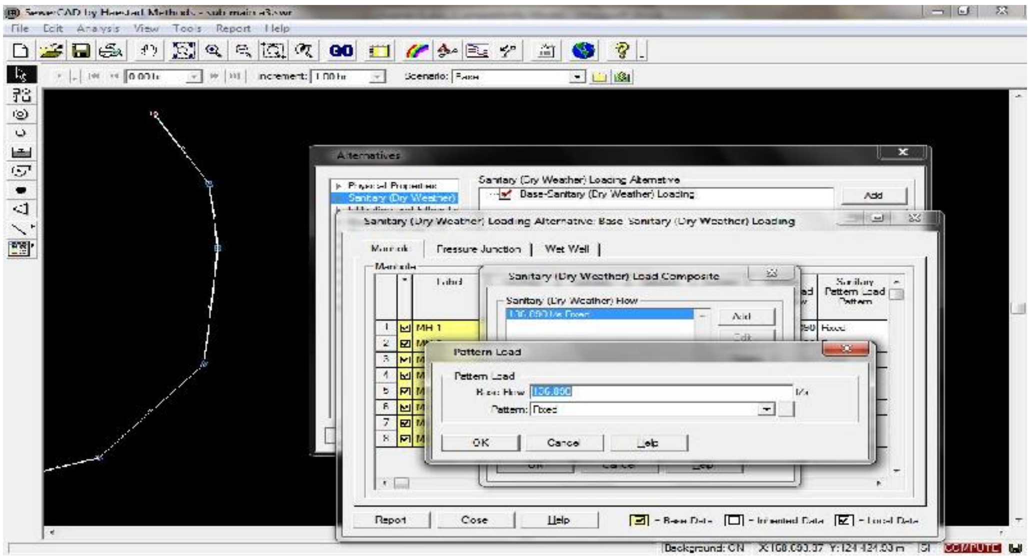


Fig (4.14)

j. After doing this for each inlet press close, then select design constrains → edit to enter the design specifications, Fig(4.15) below shows the step.

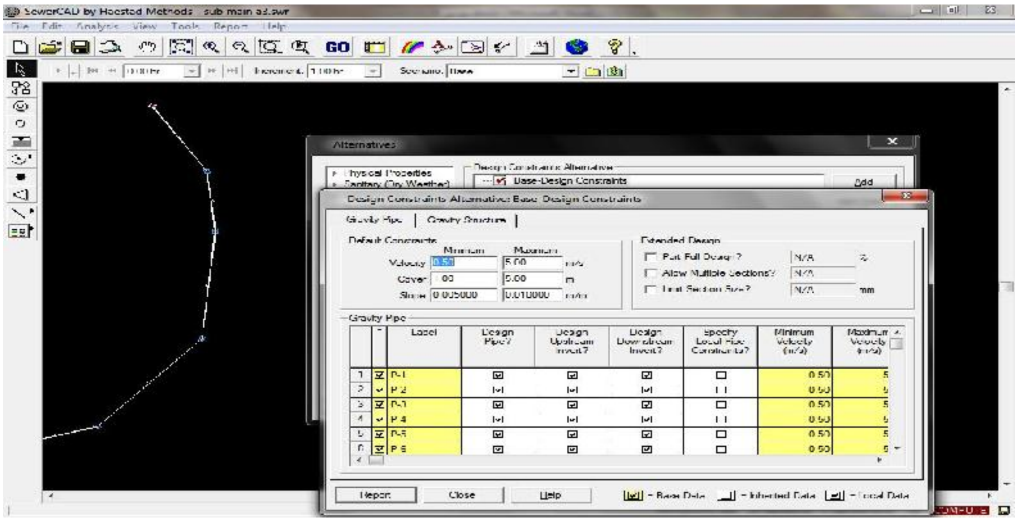


Fig (4.15)

k. Last step press save, press GO button to start design then press on GO, Fig (4.16) below shows the step.

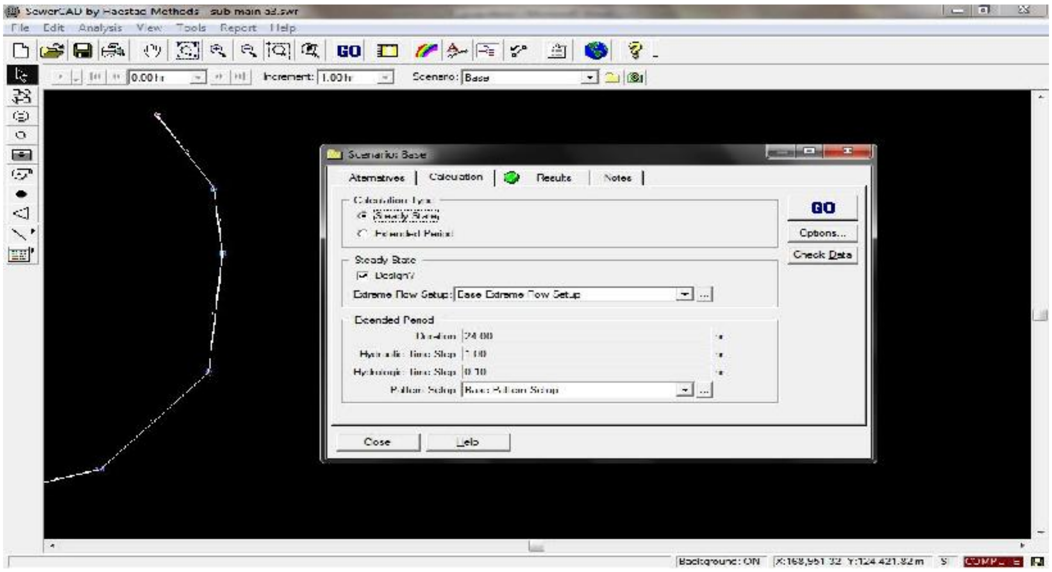


Fig (4.16)

NOTE: If you have green light that mean there is no problems in the design work, but if you have yellow or red light that's mean there is problem, read the massages and fix these problems.

m. After finishing design work we need to show the pipe line profile and the profile, gravity pipe report and manhole report. Press profile button to make the profile see Fig (4.17), here we should put the scale of the profile. The profiles for this project are attached in appendix C.We can get the required tables by pressing tabular report button see Fig (4.18), and then choose gravity pipe report and manhole report. The required reports for this project are attached in appendix B.

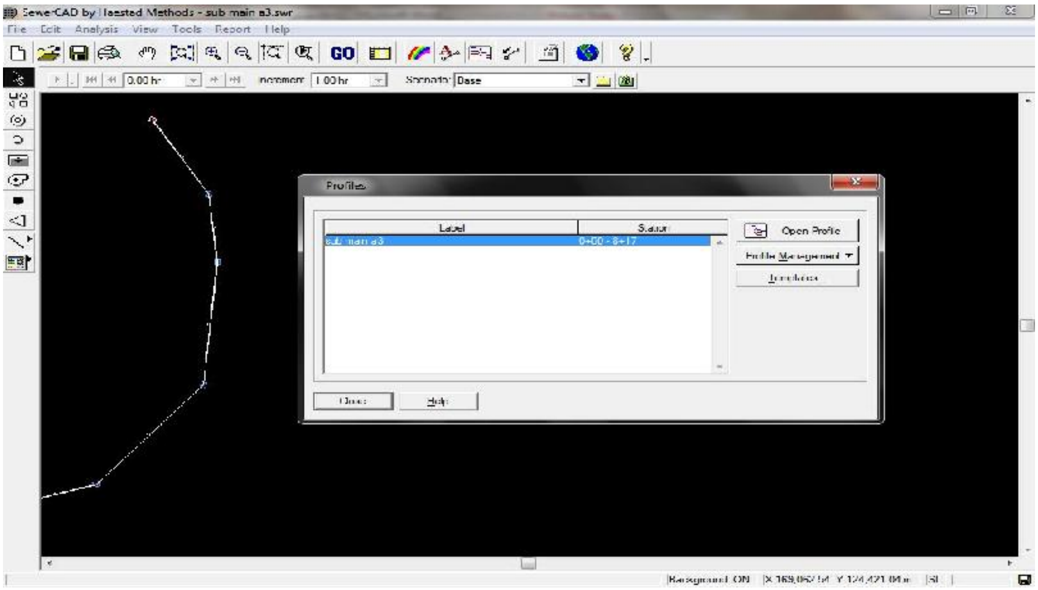


Fig (4.17)

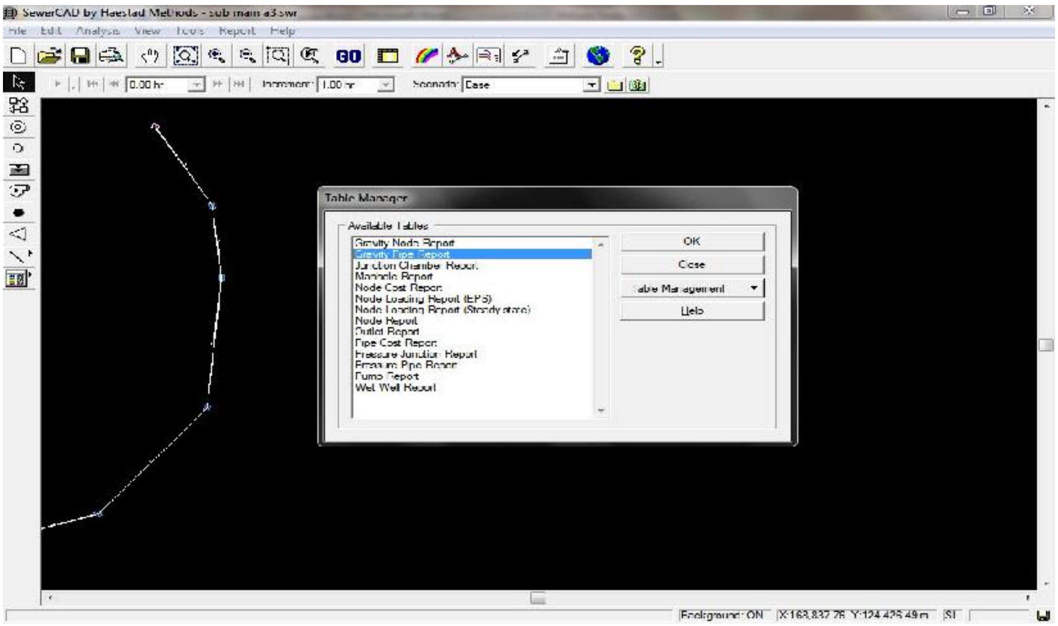
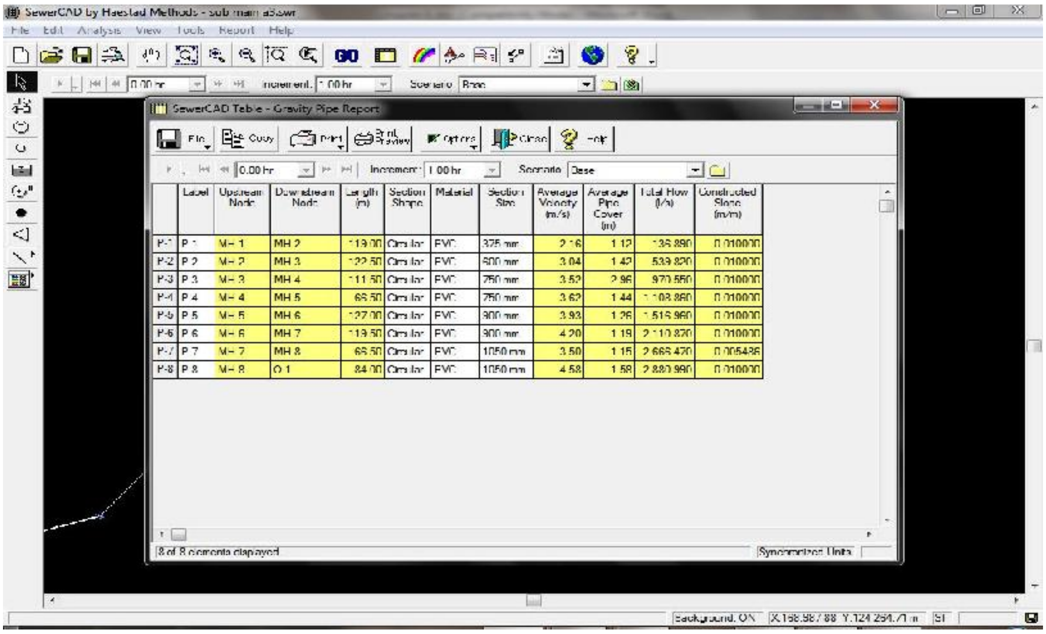


Fig (4.18)



	Label	Upstream Node	Downstream Node	Length (m)	Section Shape	Material	Section Size	Average Velocity (m/s)	Average Pipe Cover (m)	Total Flow (l/s)	Constructed Slope (m/m)
P-1	P 1	M-1	MH 2	119.00	Circular	PVC	375 mm	2.16	1.12	135.890	0.010000
P-2	P 2	M-2	MH 3	122.50	Circular	PVC	600 mm	3.04	1.42	539.820	0.010000
P-3	P 3	M-3	MH 4	111.50	Circular	PVC	750 mm	3.52	2.96	970.550	0.010000
P-4	P 4	M-4	MH 5	65.50	Circular	PVC	750 mm	3.62	1.44	1,103.860	0.010000
P-5	P 5	M-5	MH 6	127.00	Circular	PVC	900 mm	3.93	1.26	1,515.960	0.010000
P-6	P 6	M-6	MH 7	119.50	Circular	PVC	900 mm	4.20	1.19	2,110.870	0.010000
P-7	P 7	M-7	MH 8	65.50	Circular	PVC	1050 mm	3.50	1.15	2,665.470	0.005436
P-8	P 8	M-8	O 1	84.00	Circular	PVC	1050 mm	4.58	1.58	2,880.990	0.010000

Fig (4.19) Example of Storm Water Table

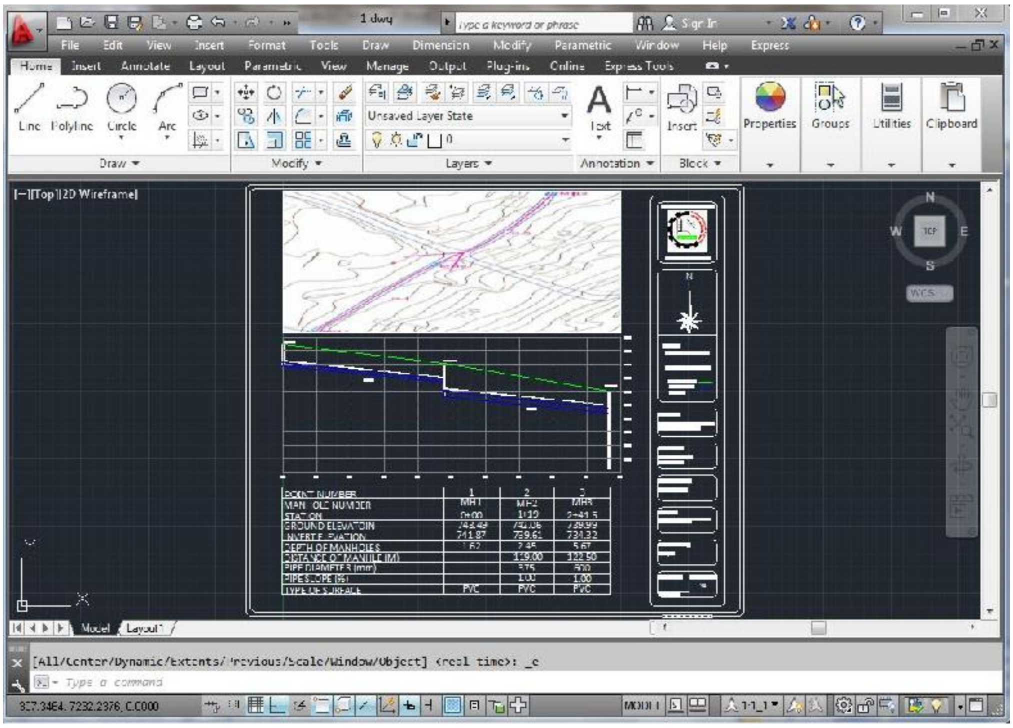


Fig (4.20) Example of storm water profile

Figure (4.21) showing an example on profile line (sub main a3). And Table (4.2) showing an example on storm water design report.

Table(4.2) Storm Water Design Report For (Sub main a3)

Manhole Report						Pipe Report										
Label	Ground Elevation (m)	Rim Elevation (m)	Sump Elevation (m)	Manhole Diameter (m)	Manhole Depth(m)	Label	Upstream Manhole	Down Stream Manhloe	Length (m)	Total Flow(l/s)	Section Shape	Section Size(mm)	Average Velocity (m/s)	Constracted slope (mm)	Average Pipe Cover(m)	Material
MH-1	743.49	743.49	741.87	1.2	1.62	P-1	MH-1	MH-2	119	136.89	Circular	375 mm	2.16	0.0069	0.01	PVC
MH-2	742.06	742.06	739.61	1.2	2.45	P-2	MH-2	MH-3	122.5	539.82	Circular	600 mm	3.04	0.04	0.01	PVC
MH-3	739.99	739.99	734.32	1.2	5.67	P-3	MH-3	MH-4	111.5	970.55	Circular	750 mm	3.52	0.0069	0.01	PVC
MH-4	734.97	734.97	732.33	1.2	2.64	P-4	MH-4	MH-5	66.5	1,108.86	Circular	750 mm	3.62	0.0069	0.01	PVC
MH-5	733.42	733.42	731	1.2	2.42	P-5	MH-5	MH-6	127	1,516.96	Circular	900 mm	3.93	0.0069	0.01	PVC
MH-6	731.64	731.64	729.34	1.2	2.3	P-6	MH-6	MH-7	119.5	2,110.87	Circular	900 mm	4.2	0.0069	0.01	PVC
MH-7	730.06	730.06	727.99	1.2	2.07	P-7	MH-7	MH-8	66.5	2,666.47	Circular	1050 mm	3.5	0.0069	0.005486	PVC
MH-8	730	730	726.77	1.2	3.23	P-8	MH-8	O-1	84	2,880.99	Circular	1050 mm	4.58	0.005	0.01	PVC

Label	X coordinate (m)	Y coordinate (m)
MH-1	168,386.91	123,726.97
MH-2	168,443.43	123,831.89
MH-3	168,497.92	123,941.80
MH-4	168,569.41	124,027.09
MH-5	168,632.96	124,046.73
MH-6	168,715.25	124,143.54
MH-7	168,725.74	124,262.59
MH-8	168,719.08	124,328.75

The profiles for Storm Water network are attached in appendix C, and the gravity pipe reports and manhole reports are attached in appendix B.

CHAPTER FIVE

"BILL OF QUANTITYS"

5.1 BILL OF QUANTITY FOR THE PROPOSED STORM WATER DRAINAGE SYSTEM

No.	EXCAVATION	UNIT	QTY	UNIT PRICE		TOTAL PRICE	
				$	C	$	C
A1	Excavation of pipes trench in all kind of soil for one pipe diameter 250 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	454.5				
A2	Excavation of pipes trench in all kind of soil for one pipe diameter 300 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	540.5				
A3	Excavation of pipes trench in all kind of soil for one pipe diameter 375 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	628				
A4	Excavation of pipes trench in all kind of soil for one pipe diameter 450 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	694.5				

A5	Excavation of pipes trench in all kind of soil for one pipe diameter 600 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	1274				
A6	Excavation of pipes trench in all kind of soil for one pipe diameter 750 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	1018				
A7	Excavation of pipes trench in all kind of soil for one pipe diameter 900 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	889.5				
A8	Excavation of pipes trench in all kind of soil for one pipe diameter 1050 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	751				
A9	Excavation of pipes trench in all kind of soil for one pipe diameter 1200 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	524.5				

A10	Excavation of pipes trench in all kind of soil for one pipe diameter 1350 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	528.5				
A11	Excavation of pipes trench in all kind of soil for one pipe diameter 1500 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	411				
A12	Excavation of pipes trench in all kind of soil for one pipe diameter 1650 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	914				
A13	Excavation of pipes trench in all kind of soil for one pipe diameter 1800 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	115				
A14	Excavation of pipes trench in all kind of soil for one pipe diameter 1950 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	117.5				

A15	Excavation of pipes trench in all kind of soil for one pipe diameter 2100 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	490.5				
A16	Excavation of pipes trench in all kind of soil for one pipe diameter 2700 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	318.5				
A17	Excavation of pipes trench in all kind of soil for one pipe diameter 3600 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	795				
Sub-Total							
B	**PIPE WORK**						
B1	Supplying, storing and installing of PVC	LM	**10464.5**				
	Sub-Total						
C	**PIPE BEDDING AND BACKFILLING** **Dimension and material**						

C1	Supplying and embedment of sand for one pipe diameter 250 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	454.5				
C2	Supplying and embedment of sand for one pipe diameter 300 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	540.5				
C3	Supplying and embedment of sand for one pipe diameter 375 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	628				
C4	Supplying and embedment of sand for one pipe diameter 450 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	694.5				

C5	Supplying and embedment of sand for one pipe diameter 600 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	1274				
C6	Supplying and embedment of sand for one pipe diameter 750 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	1018				
C7	Supplying and embedment of sand for one pipe diameter 900 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	889.5				
C8	Supplying and embedment of sand for one pipe diameter 1050 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	751				

C9	Supplying and embedment of sand for one pipe diameter 1200 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	524.5				
C10	Supplying and embedment of sand for one pipe diameter 1350 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	528.5				
C11	Supplying and embedment of sand for one pipe diameter 1500 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	411				
C12	Supplying and embedment of sand for one pipe diameter 1650 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	914				

C13	Supplying and embedment of sand for one pipe diameter 1800 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	115				
C14	Supplying and embedment of sand for one pipe diameter 1950 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	117.5				
C15	Supplying and embedment of sand for one pipe diameter 2100 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	490.5				
C16	Supplying and embedment of sand for one pipe diameter 2700 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	318.5				

C17	Supplying and embedment of sand for one pipe diameter 3600 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	795				
Sub-Total							
D	**INLETS, Details according to the drawing**						
D1	Supplying and installing of precasted inlet including excavation pipe connection, epoxytar coating, 25-ton cast iron cover and backfill, size 1200mm, depth up to 1.00m.	NR	156				
Sub-Total							
E	**Concrete Surround**						
E1	Suppying and installing of reinforced concrete (B 200) protection concrete encasement for sewer pipe.	LM	**10464.5**				
Sub-Total							
F	**Air And Water Leakage Test**						
F1	Air leakage test for sewer pipe lines for all diameters from 250 mm to 3600 mm according to specifications, including for all temporary works.	LM	**10464.5**				

F2	Water leakage tests for inlet, depth up to 1.00 meter according to specifications.	NR	156				
Sub-Total							
G	**Survey work**						
G1	Topographical survey required for shop drawings and as built DWGS using absoluet Elev. And coordinate system	LM	**10464.5**				

CHAPTER SIX

"CONCLUSION"

Conclusion

1- A storm water drainage system for Beit Jala city is obtained and it will cover all of the area.

2- The drainage system is consisting of four main lines and six sub-main lines.

3- All lines in the drainage system are running by gravity.

4- The range of sewer diameters is lying from 250mm-3600mm.

5- The max velocity in the pipe does not exceed 5m/s in the pipes.

6- The max cover in all sewers was 7m where the min was 1m.

7- This design is based on the rational method which is the most popular in calculating the quantity of storm water and it also based on manning equation in the design calculation.

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APPENDIX-A

CALCULATIONS TABLES FOR

STORM DRAINAGE

APPENDIX-B

GRAVITY PIPE REPORTS AND MANHOLE REPORTS

FOR STORM DRAINAGE

Palestine Polytechnic University

College of Engineering and Technology
Civil & Architecture Engineering Department

Project Title

Design Of Storm water Drainage system

For Beit JalaCity

Project Team

WESAM ABUHMEDA KHALED SADOQ

Project Supervisor

Eng. Samah Al-Jabari

Hebron – Palestine

Jan,2015

Design Of Storm water Drainage system

For Beit Jala City

BY

Khaled Sadoq Wesam Abuhameda

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF ENGINEERING

IN

CIVIL & ARCHITECTURAL ENGINEERING DEPARTMENT

Project Supervisor

Eng. Samah Al-Jabari

CIVIL &ARCHITECTURAL ENGINEERING DEPARTMENT

COLLEGE OF ENGINEERING AND TECHNOLOGY

PALESTINE POLYTECHNIC UNIVERSITY

HEBRON- WEST BANK

PALESTINE

Jan, 2015

CERTIFICATION

Palestine Polytechnic University

(PPU)

Hebron- Palestine

The Senior Project Entitled:

Design Of Storm water Drainage system
For Beit Jala City

Prepared By:

Khaled Sadoq Wesam Abuhameda

In accordance with the recommendations of the project supervisor, and the acceptance of all examining committee members, this project has been submitted to the Department of Civil and Architectural Engineering in the College of Engineering and Technology in partial fulfillment of the requirements of the department for the degree of Bachelor of Science in Engineering.

Project Supervisor **Department Chairman**

2015 , Jan

إهــداء

بدأنا بأكثر من يد وقاسينا أكثر من هم وعانينا الكثير من الصعوبات وها نحن اليوم والحمد لله نطوي سهر الليالي وتعب الأيام وخلاصة مشوارنا بين دفتي هذا العمل المتواضع.

إلى منارة العلم والامام المصطفى إلى الأمي الذي علم العالمين إلى سيد الخلق إلى رسولنا الكريم سيدنا محمد صلى الله عليه وسلم.

إلى الينبوع الذي لا يمل العطاء الي من حاكت سعادتي بخيوط منسوجة من قلبها إلى والدتي العزيزة.

إلى من سعى وشقى لأنعم بالراحة والهناء الذي لم يبخل بشيء من أجل دفعي في طريق النجاح إلى الذي علمني أن ارتقي سلم الحياة بحكمة وصبر إلى والدي العزيز.

إلى من حبهم يجري في عروقي ويلهج بذكراهم فؤادي إلى أخواتي وأخواني إلى من سرنا سوياً ونحن نشق الطريق معاً نحو النجاح والأبداع إلى من تكاتفنا يداً بيد ونحن نقطف زهرة العلم إلى اصدقائي وزملائي.

إلى من علمونا حروفاً من ذهب وكلمات من درر وعبارت من أسمى وأجلى عبارات في العلم إلى من صاغو لنا علمهم حروفاً ومن فكرهم منارة تنير لنا سيرة العلم والنجاح إلى أساتذتنا الكرام .

فريق العمل

خالد صدوق

وسام أبوحميدة

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We would like to express our thanks and gratitude to Allah, the Most Beneficent, the most Merciful who granted us the ability and willing to start and complete this project. We pray to his greatness to inspire us the right path to his content and to enable us to continue the work started in this project to the benefits of our country.

We wish to express our deep and sincere thanks and gratitude to Palestine Polytechnic University, the Department of Civil & Architectural Engineering, College of Engineering & Technology. We wish to express our thanks to Eng.Samah Al-Jabari, for a valuable help, encouragement, supervision and guidance in solving the problems that we faced from time to time during this project.

We can find no words to express our sincere, appreciation and gratitude to our parents, sisters and brothers, for their endless support and encouragement, we are deeply indebted to you and we hope that we may someday reciprocate it in someway.

Work Team

Khaled Muneer Sadoq

Wesam Abuhameda

ABSTRACT

Design of Storm water Drainage system for Beit Jala City

Prepared By:

KHALED SADOQ WESAM ABUHAMEDA

Supervised By:

Eng. Samah Al-Jabari

The disposal of storm water in streets and roads creates major traffic and environmental problems .

Sewage facilities in many Palestinian cities do not exist , The storm water has been seeping into the streets and roads through the overflows causing serious problems .

Beit Jala is such as Bethlehem district cities , do not contains storm water drainage system . The accelerated development and grow of Beit Jala city has led to change in the hydrological and geomorphological features . all of the areas of Beit Jala city do have not a natural drainage outlet . Heavy rainfall causes storm water to collect in low areas and flood streets and walk way . Rapid growth has decreased the open area available for percolation and rain water has greatly increased the runoff to low laying areas .

In view of this prevailing condition , Drainage system in Beit Jala city would have a new characteristic and development of storm water drainage system is very necessary to drain excess water from streets .

In this project a trial was made to design a storm water drainage system for Beit Jala city, and we find that the drainage system must contain four main and six submain lines as main trunks that make drainage for water in the rain fall events . These main trunks cover a large percentage area of Beit Jala . And they ara efficient in minimizing traffic problems .

TAPLE OF CONTENTS

CHAPTER FOUR : ANALYSIS AND DESIGN

CHAPTER FIVE: BILL OF QUANTITYS

CHAPTER SIX: CONCLUSION

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CHAPTER ONE

"INTRODUCTION"

1.1 General

Storm water is water that originates during precipitation rains, or it may also water resulting from the melting of snow, Storm water is of concern for two main issues one related to the volume and timing of runoff water (flooding), the other related to potential contaminants that the water is carrying.

At the present time, Storm water is a resource and ever growing in importance as the world's human population demand exceeds the availability of readily available water, Techniques of storm water harvesting with point source water management and purification can potentially make urban environments self-sustaining in terms of water.

like other countries , Palestine needs a storm water drainage networks , Beit Jala , one of cities in Palestine have no a storm water drainage networks , there for , and because what has been mentioned , design of storm water drainage system study for Beit Jala city have been conducted .،

Data must be developed on topography, geology, hydrology climate, ecological elements and social and economic conditions. Topographic maps with existing and proposed streets provide the most important information for preliminary flow routing.

1.2 Problem Definition.

Water drainage is very important due to water accumulation on the streets as a result of heavy precipitation, population growth, and the development and extension of West Bank cities.

Beit Jala city is located in a semi arid region with rainfall generally limited to autumn and winter months. In the past, the open area of the city easily observed most of this rainfall and provided the primary source for recharging the ground water aquifer. All of the areas of Beit Jala city do not have a natural drainage outlet, heavy rainfall causes storm water to collect in low areas and flood streets and walk ways.

Rapid growth has decreased the open areas available for percolation of rain water and has greatly increased the runoff to flow laying areas.

In view of this condition, design of storm water drainage system in Beit Jala city becomes very essential.

1.3 Objectives of the Project

This Project "Design a storm water drainage network for Beit Jala city", which include the following:-

1- Determine the sub catchments and catchments of the study area with the help of aerial photogrammetric map and Geographical information system (GIS).

2- Design of storm water drainage system of the city.

3- Prepare all of the tables and drawing needs to implement the drainage system.

4- Prepare A Bill of Quantitys.

1.4 Methodology

1- Many site visits to Beit Jala city and cooperation with Beit Jala Municipality to make sufficient system

2- All needed maps and the previous studies that contain different information about Beit Jala City were obtained.

3- The amount of rain fall in the last years, the rainfall rate, and the maximum quantities were obtained.

4- The different layouts of the purposed storm water collection system were completed.

5- The necessary calculations for the quantity of storm water.

6- The necessary calculations for design of the storm water drainage system were completed.

7- Tables, Maps, Drawings and bill of quantities were completed.

8- Writing the report.

1.5 Phase of the Project.

The Project will consist of the four phases as shown in Table (1.1):-

Title	Duration								
	14/2	14/3	14/4	14/5	14/6	14/9	14/10	14/11	14/12
Data collection and survey	■	■							
Preparing layout for storm water collection system and calculate the amount of storm water		■	■	■					
Design of storm water collection system					■	■	■	■	■
Writing the report and preparing maps		■	■	■	■	■	■	■	■

Table (1.1): Phases of the Project with Their Expected Duration

1.5.1 First Phase: - Data collection and Survey

In this phase, available data and information were collected from different sources.

Moreover, many site visits to both city and municipality were done. This phase includes the following tasks:-

1- Collecting of aerial and topographical maps for all areas.

2- Collecting of metrological data (temperature, rainfall … etc) from different sources.

1.5.2 Second Phase:-Preparing Layout for Storm Water Collection System and calculate The Amount of Storm Water.

In this phase layout was prepared and put in its final shape and then quantities of storm water will determine.

This phase includes the following tasks:

1- Draw the layout of storm water collection system and check it more than one time to make sure that is correctly , later compare layout with the real situation in Beit Jala city then make adjustment and draw the final layout , this step is the most important one .

2- Evaluation of the contour maps and matching it with actual ground levels in the city.

3- Determination of the storm water quantities.

1.5.3 Third Phase: - Design of Storm water collection system

In this phase the necessary calculations needed for the design of main trunks was completed, this phase includes the following tasks:

1- Establish a system layout, which includes the areas that are going to be served, existing streets, roads, topography … etc

2- Establish the catchments and sub-catchments areas and routes of the sewers.

3- Establish the design criteria and conducting the needed sewer diameter calculations.

4- Preparing needed different drawings for the designed sewers.

1.5.4 Fourth Phase: - Writing the report and preparing

After finishing the design calculations of the main trunks the project team was prepared the specification drawing, bill of quantities preliminary maps. Final report prepared and submitted to the Department of Civil and Architectural Engineering at Palestine Polytechnic University.

1.6 Organization of the Project

The study report has been prepared in accordance with the objectives and of work.

The report consists of six chapters.

The first chapter entitled "Introduction" outlines the problem, project objectives, and phases of the project.

Chapter two entitled "Project Area" which deals with the metrological data, geographic data, rainfall, temperature, water supply.

Chapter three entitled "Design Criteria" which deals with the storm water runoff, hydraulic consideration, design of storm water sewers.

Chapter four entitled "Analysis and Design" which deals with the layout, design computations, storm water drainage system and profiles of drainage channels.

Chapter five entitled "Bill of quantities" which deals with the quantities needed to complete the design system.

Chapter six entitled "Conclusions" which deals with the conclusions of the study.

CHAPTER TWO

"PROJECT AREA"

2.1 GENERAL

In this chapter, the basic data of Beit Jala will be briefly discussed. The location,topography, and climate will be described. The water supply and rainfall quantity will be briefly presented.

2.2 Project Area

Beit Jala City is located 10 km south of Jerusalem, on the western side of the Hebron road, opposite Bethlehem , Beit Jala is bordered by Bethlehem city to the east, Jerusalem city and Gilo settlement to the north, Al Walaja and Battir villages to the west, and Ad Doha city and Al Khader town to the south , as shown on the project location maps as shown in Figures (2.1) , and (2.2) the average elevation of the City is 779 m above sea level ,The economy in Beit Jala is dependent on several economic sectors, mainly: services sector, which absorbs 30% of the city workforce , The other sector is agricultural , Beit Jala lies on a total area of about 9,749 Acres of which 7,305 Acres are considered arable land, and 913Acresare residential land , The total population of Beit Jalain 2007 was 13,845; of whom 6,859 are males and 6,986 are females .

Maps must use to analysis and discuss this data so triangulated irregular Network map (TIN) map is prepared for the Beit Jala city as Shown in fig (2.3) , then Digital Elevation Model is prepared for the area and this is shown in fig (2.4) , then Flow Direction map which shown in fig (2.5) , then Flow Accumulation Map is prepared for the city and is shown in the fig (2.6) ,then Stream Network map also is constructed as shown in fig(2.7), This maps show the highest point in the city which is in the west of the city and the lowest point which in the north .

Flow direction is running by gravity to enter the lowest point which located in the south.

Not that the accumulated form the east to reach the south formed stream network that end the south.

2.3 Meteorological Data

The hydrology of region depends primarily on its climate, and secondarily on its topography. Climate is largely depends on geographical position of the earth surface, humidity, temperature, and wind. These factors are affecting evaporation and transpiration. So this study will include needed data about these factors, since they play big role in the determination of rainfall.

Each year, Beit Jala receives just less than 563 mm of rain, almost all coming during a short winter, from late November to early March. During these months temperatures can become fairly chilly and rainy, with rare flurries of snow and freezing temperature ,The summer, in contrast, is long, hot, and dry, receiving virtually no rain, with temperatures as high as 39 degrees Celsius during midday Average temperatures range from 9-18° C in winter to 26- 30° C in summer .

2.3.1 Rainfall

The average annual rainfall in Beit Jala city is 563 mm. Rainfall occurs between September and May, while it stop raining in the summer season from June to August. The monthly rainfall of Beit Jala city 2013 is shown in the table (2.1). [8]

2.3.2 Temperature

The temperature is characterized by considerable variation between summer and winter times. The average annual temperature is 17˚ C, The mean temperature values at Beit Jala city are given in Table (2.1). [7]

The following minimum and maximum values were shown:

- The mean maximum temperature: 18° C

-The mean minimum temperature: 9° C

2.3.3 Relative Humidity

The average annual humidity is 60.5 %. The relative humidity of Beit Jala City is shown in Table (2.1). [3]

Month	Rainfall (mm)	Maximum Temperature (C°)	Minimum Temperature (C°)	Relative Humidity (%)
Jan	255.0	24	-4	73
Feb	69.1	26	-7	70
Mar	5.6	30	-1	66
Apr	20.2	35	-1	53
May	2.7	39	5	49
Jun	0.0	40	8	52
Jul	0.0	39	11	54
Aug	0.0	42	13	60
Sep	2.4	37	9	61
Oct	0.0	37	7	59
Nov	0.0	33	0	62
Dec	191.9	29	-1	70
Total	544.5			

Table (2.1): Meteorological Conditions at Beit Jala City Weather Station for (2013)

CHAPTER THREE

"DESIGN CRITERIA"

3.1 General

Rapid effective removal of storm runoff was a luxury not found in many cities in the early nineteenth century. Today, the modern city dweller has come to think of this as an essential service. Urban drainage facilities have progressed from crude ditches and stepping stones to the present intricate coordinates systems of curbs, gutters, inlets, and under ground conveyance.

The design must consider meteorological factors, geomorphological factors, and the economic value of the land, as well as human value considerations such as aesthetic and public safety aspects of the design. The design of storm water detention basins should also consider the possible effects of inadequate maintenance of the facility.

3.2 Storm Water Runoff

Storm water runoff is that portion of precipitation which flows over the ground surface during and a short time after a storm. The dependence parameters that controlled the quantity of the storm water which carried by a storm or combined sewer are the surface of the drainage area (ha), the intensity of the rainfall (l/s.ha), and runoff coefficient C dimensionless (the condition of the surface). There are many methods and formulas to determine the storm flow.

3.2.1 Rational Method

The rational method has probably been the most popular method for designing storm systems. It has been applied all over the world and runoff is related to rainfall intensity by the formula,

$$Q = C.i.A \tag{3.1}$$

Where Q = peak runoff rate (l/sec).

C = runoff coefficient, which is actually the ratio of the peak runoff rate to the average rainfall for a period known as the time of concentration.

i = average rainfall intensity, mm/min, for period equal to the time of concentration.

A= drainage area (ha).

For small catchments areas, it continues to be a reasonable method, provided that it is used properly and that results and design concepts are assessed for reasonableness. This procedure is suitable for small systems where the establishment of a computer model is not warranted.

The steps in the rational method calculation procedure are summarised below:

1- The drainage area is first subdivided into sub-areas with homogeneous land use according to the existing or planned development.

2- For each sub-area, estimate the runoff coefficient *C* and the corresponding area *A*.

3- The layout of the drainage system is then drawn according to the topography, the existing or planned streets and roads and local design practices.

4- Inlet points are then defined according to the detail of design considerations. For main drains, for example, the outlets of the earlier mentioned homogeneous sub-areas should serve as the inlet nodes. On the other hand in very detailed calculations, all the inlet points should be defined according to local design practices.

5- After the inlet points have been chosen, the designer must specify the drainage sub-area for each inlet point A and the corresponding mean runoff coefficient *C*. If the sub-area for a given inlet has non-homogeneous land use, a weighted coefficient may be estimated.

6- The runoff calculations are then done by means of the general rational method equations for each inlet point, proceeding from the upper parts of the watershed to the final outlet. The peak runoff, which is calculated at each point, is then used to determine the size of the downstream trunk drain using a hydraulic formula for pipes flowing full.

7- After the preliminary minor system is designed and checked for its interaction with the major system, reviews are made of alternatives, hydrological assumptions are verified, new computations are made, and final data obtained on street grades and elevations. The engineer then should proceed with final hydraulic design of the system.

3.2.2 Runoff Coefficient, C

Runoff coefficient is a function of infiltration capacity, interception by vegetation, depression storage, and evapotranspiration. It is requires greatest exercise of judgment by engineer and assumed constant, actually variable with time. It is desirable to develop composite runoff coefficient (weighted average) for each drainage area as:

$$C = \frac{\sum Ci.Ai}{\sum Ai} \tag{3.2}$$

Where Ai = i^{th} area.

Ci = i^{th} runoff coefficient.

The range of coefficients with respect to general character of the area is given in the following tables (Table 3.1 and Table 3.2).

Description of Area	Runoff Coefficients
Business	
Down town	0.70 to 0.95
Neighborhood	0.50 to 0.70
Residential	
Single-Family	0.30 to 0.50
Multi-unit, detached	0.40 to 0.60
Multi-unit, attached	0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Industrial	
Light	0.50 to 0.80
Heavy	0.60 to 0.90
Parks, Cemeteries	0.10 to 0.25
Playground	0.20 to 0.35
Railroad yard	0.20 to 0.35
Unimproved	0.10 to 0.30

Table (3.1): The Range of Coefficient with Respect to General Character of the Area (Sarikaya, 1984)

Character of Surface	Runoff Coefficients
Pavement	
Asphalt and concrete	0.70 to 0.95
Brick	0.70 to 0.85
Lawns, Sandy soil	
Flat, 2 percent	0.05 to 0.10
Average,2to7percent	0.10 to 0.15
Steep, 7 percent	0.15 to 0.20
Roofs	0.75 to 0.95
Lawns, Heavy soil	
Flat, 2 percent	0.13 to 0.17
Average,2 to 7percent	0.18 to 0.22
Steep, 7 percent	0.25 to 0.35

Table (3.2): The Range of Coefficient With Respect to Surface Type of the Area (Sarikaya, 1984)

3.2.3 Rainfall Intensity, i

In determining rainfall intensity for use in rational formula it must be recognized that the shorter the duration, the greater the expected average intensity will be. The critical duration of rainfall will be that which produces maximum runoff and this will be that which is sufficient to produce flow from the entire drainage area. Shorter periods will provide lower flows since the total area is not involved and longer periods will produce lower average intensities. The storm sewer designer thus requires some relationship between duration and expected intensity. Intensities vary from place to another and curves or equations are specified for the areas for which they were developed.

The rainfall intensity depends on many factors through which we can do our calculations; we can list these factors as follow:

1- Average frequency of occurrence of storm (n) or (f).

   Average frequency of occurrence is the frequency with which a given event is equaled or exceeded on the average, once in a period of years. Probability of occurrence, which is the reciprocal of frequency, (n) is preferred by sum engineers. Thus, if the frequency of a rain once a 5-year (f=5), then probability of occurrence n=0.20. Selection of storm design rain frequency based on cost-benefit analysis or experience. There is range of frequency of often used:

a. Residential area: f = 2 to 10 years (5 year most common).
b. Commercial and high value districts: f = 10 to 50 (15 year common).
c. Flood protection: f = 50 year.

2- Intensity, duration and frequency characteristics of rainfall.

Basic data derived from gage measurement of rainfall (Point rainfall) over along period can be used to obtain a rainfall height diagram that show the relation between the height of rain (mm) and time (min). The slope of the curve or rain height per unit time is defined as rain intensity:

i= (Δ height of rain / Δ time) $\left[\dfrac{mm}{\min}\right]$

The rain intensity in litter per second. Hectare is equal:

$$i(\frac{l}{s.ha}) = 166.7i\left[\frac{mm}{\min}\right]$$

In order to drive intensity-duration-frequency curves long-term observation of rainfall is needed. Analysis of such observation is given in any text in sanitary engineering.

3- Time of Concentration

The time of concentration is the time required for the runoff to become established and flow from the most remote part (in time) of the drainage area to the point under design.

$$t_c = t_i + t_f \qquad (3.3)$$

Where t_c: time of concentration.
t_i: inlet time.
t_f: flow time.

Time of flow in storm, $t_f = \dfrac{\text{Length of pipe line (L)}}{\text{Velocity of flow (v)}}$ (3.4)

Inlet time (t_i): is the time required for water to flow over ground surface and along gutters to drainage inlet. Inlet time is function of rainfall intensity, surface slope, surface roughness, flow distance, and infiltration capacity and depression storage.

3.2.4 Catchments Area, A

Most of the catchments are partly developed with residential facilities. The catchments are moderately flat with rural, residential and commercial land uses. The rural areas are located at the downstream end of the catchments.

3.3 Hydraulic Consideration

3.3.1 Introduction

Wastewater systems and (storm water) are usually designed as close channels except where lift stations are required to overcome topographic barriers. The hydraulic problems associated with these flows are complicated in some cases by the quality of the fluid, the highly variable nature of the flows, and the fact that an unconfined or free surface exists. The driving force for open-channel flow and sewer flow is gravity. For the hydraulic calculations of sewers, it is usually assumed uniform flow in which the velocity of flow is constant, and steady flow condition in which the rate discharge at any point of a sewer remains constant (Metcalf,1982).

3.3.2 Hydraulic Design Equations

In principle all closed channel flow formulas can be used in hydraulic design of sewer pipes. The following are the most important formulas:

1. Chezy's formula:

$$V = C\sqrt{RS} \tag{3.5}$$

Where V: the velocity of flow (m/s).

C: the Chezy coefficient; $C = \frac{100\sqrt{R}}{m+\sqrt{R}}$, where m = 0.35 for concrete pipe or 0.25 for vitrified clay pipe

R: the hydraulic radius (m)

S: the slope of the sewer pipe (m/m).

2. Darcy-Weisbach formula: It is not widely used in wastewater collection design and evaluation because a trial and error solution is required to determine pipe size for a given flow and head loss, since the friction factor is based on the relative roughness which involves the pipe diameter, making it complicated. Darcy-Weisbach formula states that

$$H = \lambda \frac{L \times V^2}{D \times 2g} \tag{3.6}$$

Where H: the pressure head loss

L: the length of pipe (m).

D: the diameter of pipe (m)

λ : the dimensionless friction factor generally varying between 0.02 to 0.075.

3. The Manning formula: Manning’s formula, though generally used for gravity conduits like closed channel, it is also applicable to turbulent flow in pressure conduits and yields good results, provided the roughness coefficient n is accurately estimated. Velocity, according to Manning’s equation is given by:

$$V = \frac{1}{n} R^{2/3} S^{1/2} \tag{3.7}$$

Where n: the Manning's roughness coefficient [1/n (k_{str}) = 75 $m/s^{1/3}$].

R: the hydraulic radius = area /wetted perimeter (R= A/P).

- For circular pipe flowing full, R=D/4.
- For open channel flowing full, R=A/P.

The Manning's roughness coefficient depends on the material and age of the conduit. Commonly used values of n for different materials are given in Table (3.3).

Material	Commonly Used Values of n
Concrete	0.013 and 0.015
Vitrified clay	0.013 and 0.015
Cast iron	0.013 and 0.015
Brick	0.015 and 0.017
Corrugated metal pipe	0.022 and 0.025
Asbestos cement	0.013 and 0.015
Earthen channels	0.025 and 0.003

Table (3.3): Common Values of Roughness Coefficient Used In the Manning Equation (Sarikaya, 1984)

3.3.3 Hydraulics of Partially Filled Section

The filling rate of a sewer is an important consideration, as sewers are seldom running full, so storm water sewers designed for 40% or 50% running full, that is means only 40 % to 50 % of the pipe capacity should be utilized to carry the peak flow.

Partially filled sewers are calculated by using partial flow diagram and tables indicating the relation between water depth, velocity of flow and rate flow .The hydraulic characteristics are similar as for closed channels, but the velocity of flow is reduced by increased air friction in the pipe with increasing water level, particularly near the top of the pipe. The velocity of flow and the flow rate are reduced at filling rates between 60% and 100%; the water level in the pipe is unstable at filling rates above 90% or 95%.

3.4 Storm Water Sewers Design

Designing a community storm system is not a simple task. It requires considerable experience and a great deal of information to make proper decisions concerning the layout, sizing, and construction of a storm network that is efficient and cost-effective. The design engineer needs to generally undertake the following tasks (Qasim, 1985, Peavy, 1985):

1. Define the service area.
3. Conduct preliminary investigations.
4. Develop preliminary layout plan and profile.
5. Selection of design parameters.
6. Review construction considerations.
7. Conduct field investigation and complete design and final profiles.
8. Prepare contract drawing and specifications.

3.4.1 Service area

Service area is defined as the total area that will eventually be served by the drainage system... It is important that the design engineers and project team become familiar with the surface area of the proposed project.

3.4.2 Preliminary Investigation

The design engineer must conduct the preliminary investigations to develop a layout plan of the drainage system. Site visits and contacts with the city and local planning agencies and state officials should be made to determine the land use plans, zoning regulations, and probable future changes that may affect both the developed and undeveloped land. Data must be developed on topography, geology, hydrology, climate, ecological elements, and social and economic conditions. Topographic maps with existing and proposed streets and other utility lines provide the most important information for preliminary flow routing (Qasim, 1985).

If reliable topographic maps are not available, field investigations must be conducted to prepare the contours, place bench marks, locate building, utility lines, drainage ditches, low and high areas, stream, and the like. All these factors influence the sewer layout.

3.4.3 Layout Plan

Proper storm sewer layout plan and profiles must be completed before design flows can be established. The following is a list of basic rules that must be followed in developing a sewer plan and profile (Qasim, 1985).

1. Select the site for disposal of the storm water at the end of the network, generally the lowest elevation of the entire drainage area.
2. The preliminary layout of storm sewers is made from the topographic maps. In general, sewers are located on streets, or on available right-of-way; and sloped in the same direction as the slope of the natural ground surface.
3. The trunk storm sewers are commonly located in valleys. Each line is started from the intercepting sewer and extended uphill until the edge of the drainage area is reached, and further extension is not possible without working downhill.
4. Main storm sewers are started from the trunk line and extended uphill intercepting the laterals.
5. Preliminary layout and routing of storm sewage flow is done by considering several feasible alternatives. In each alternative, factors such as total length of storm sewers, and cost of construction of laying deeper lines versus cost of construction, operation, and maintenance of lift station, should be evaluated to arrive at a cost- effective drainage system.
6. After the preliminary storm sewer layout plan is prepared, the street profiles are drawn. These profiles should show the street elevations, existing storm sewer lines, and manholes and inlets. These profiles are used to design the proposed lines.

Finally, these layout plans and profiles are revised after the field investigations and storm sewer designs are complete (Viessman, 1985).

3.4.4 Selection of Design Parameters

Many design factors must be investigated before storm sewer design can be completed. Factors such as design period; peak, average, and minimum flow; storm sewer slopes and minimum velocities; design equations …etc. are all important in developing storm sewer design. Many of the factors are briefly discussed below.

1. **Design Flow Rate:** Storm water sewers should be designed to carry the largest storm that occurred in the period of design; commonly it is 25 years because of consideration of the cost and the frequently factors.

2. **Minimum Size:** As mentioned earlier, the minimum storm sewer size recommended is 250 to 300 mm for closed system, and for open channel depend on the type of profile that selected.

3. **Minimum and Maximum Velocities:** In storm water sewers, solids tend to settle under low-velocity conditions. Self-cleaning velocities must be developed regularly to flush out the solids. Most countries specify minimum velocity in the sewers under low flow conditions. The minimum allowable velocity is 0.75 m/s, and 0.9 m/s is desirable. This way the lines will be flushed out at least once or twice a day. The maximum velocities for storm water system are between 4 to 5 m/s. The maximum velocity is limited to prevent the erosion of sewer inverts.

4. **Slope:** For closed system minimum slopes determined from minimum velocities, for minimum velocity 0.9 m/s, the slopes are shown in Table 2.4.

Pipe Diameter (D)		Slope (min)	Slope (max) =1/D
mm	**inch**	**mm**	**cm**
250	10	0.00735	0.04
300	12	0.00576	0.033
450	18	0.00336	0.0222
600	24	0.00229	0.0167

Table (3.4): Minimum Recommended Slopes of Storm Sewer (n = 0.015) (Sarikaya, 1984)

Note: for a velocity of 0.75m/s the slopes shown above should be multiplied by1.56.

Maximum slopes determined from maximum velocities, 0.9/D (cm) can be used as a guide.

5. Depth: The depth of storm sewers when using closed system is generally just enough to receive flow but not less than 1 m below the ground surface. Depth depends on the water table, lowest point to be served, topography, and the freeze depth. But for the open channel it is at the ground surface.

6. Appurtenances: Storm Sewer appurtenances include manholes, inlets, outlets and outfall, and others. Appropriate storm sewer appurtenances must be selected in design of storm water sewers.

7. Design Equations and Procedures: Storm water sewers are mostly designed to flow partially full. Once the peak, average, and minimum flow estimates and made general layout and topographic features for each line are established, the design engineer begins to size the sewers. Design equations proposed by Manning, Chezy, Gangullet, Kutter, and Scobey have been used for designing sewers and drains. The Manning equation, however, has received most widespread application. This equation is expressed below:

$$V=\frac{1}{n}R^{2/3}S^{1/2} \qquad (3.7)$$

And as mentioned earlier, the runoff flow is calculated using the following formula:

$$Q = C.i.A \qquad (3.1)$$

Various types of monographs have been developed for solution of problems involving sewers flowing full. Monographs based on Manning's equation for circular pipe flowing full and variable n values are provided in Figure 2.1. Hydraulic elements of circular pipes under partially-full flow conditions are provided in Figure 2.2. It may be noted that the value of n decreases with the depth of flows Figure 2.1. However, in most designs n is assumed constant for all flow depths. Also, it is a common practice to use d, v, and q notations for depth of flow, velocity, and discharge under partial flow condition while D, V, Q notations for diameter, velocity, and discharge for sewer flowing full. Use of equations 2.1 and 2.7 and Figures 2.1 and 2.2, one can design the drainage system.

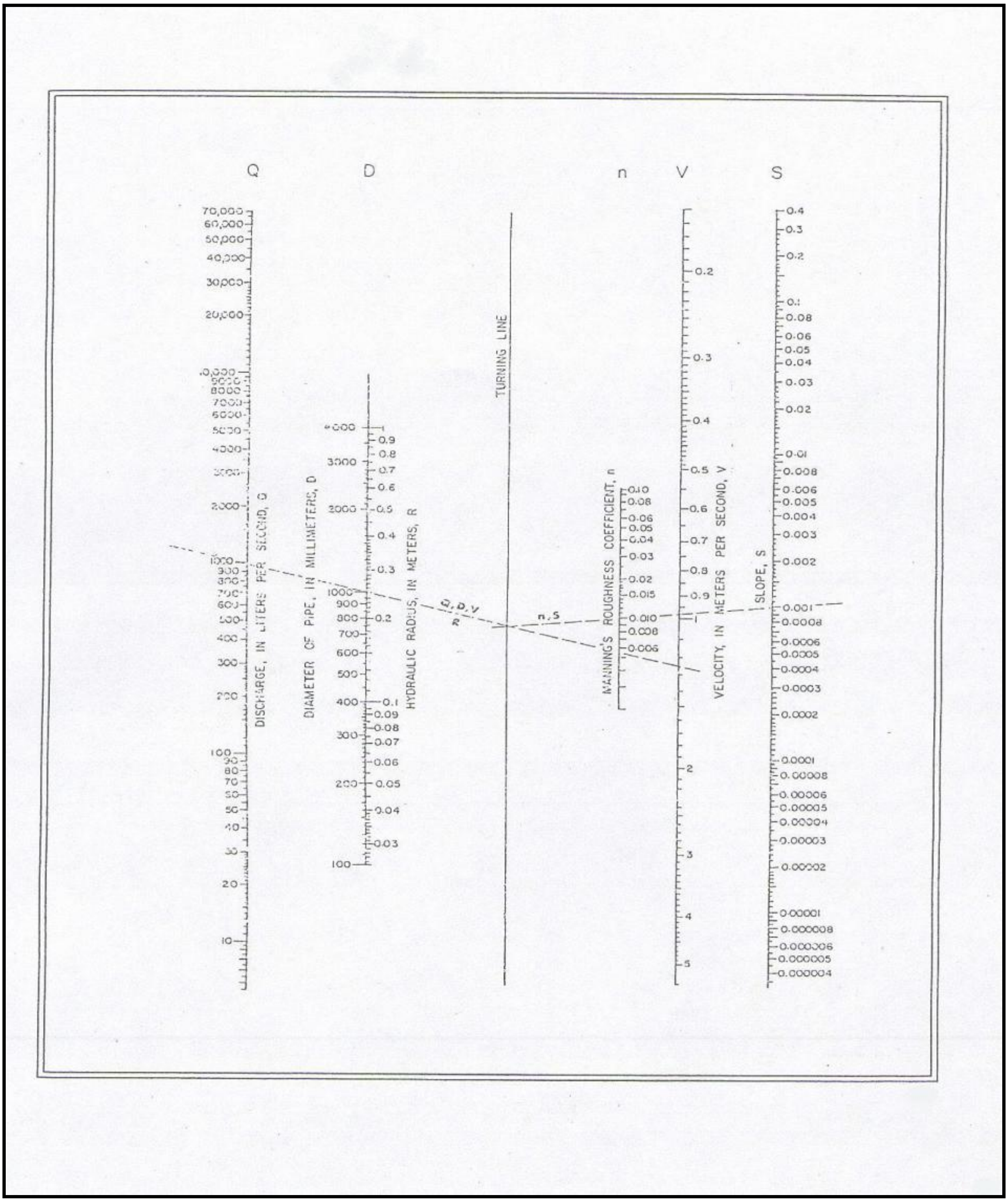
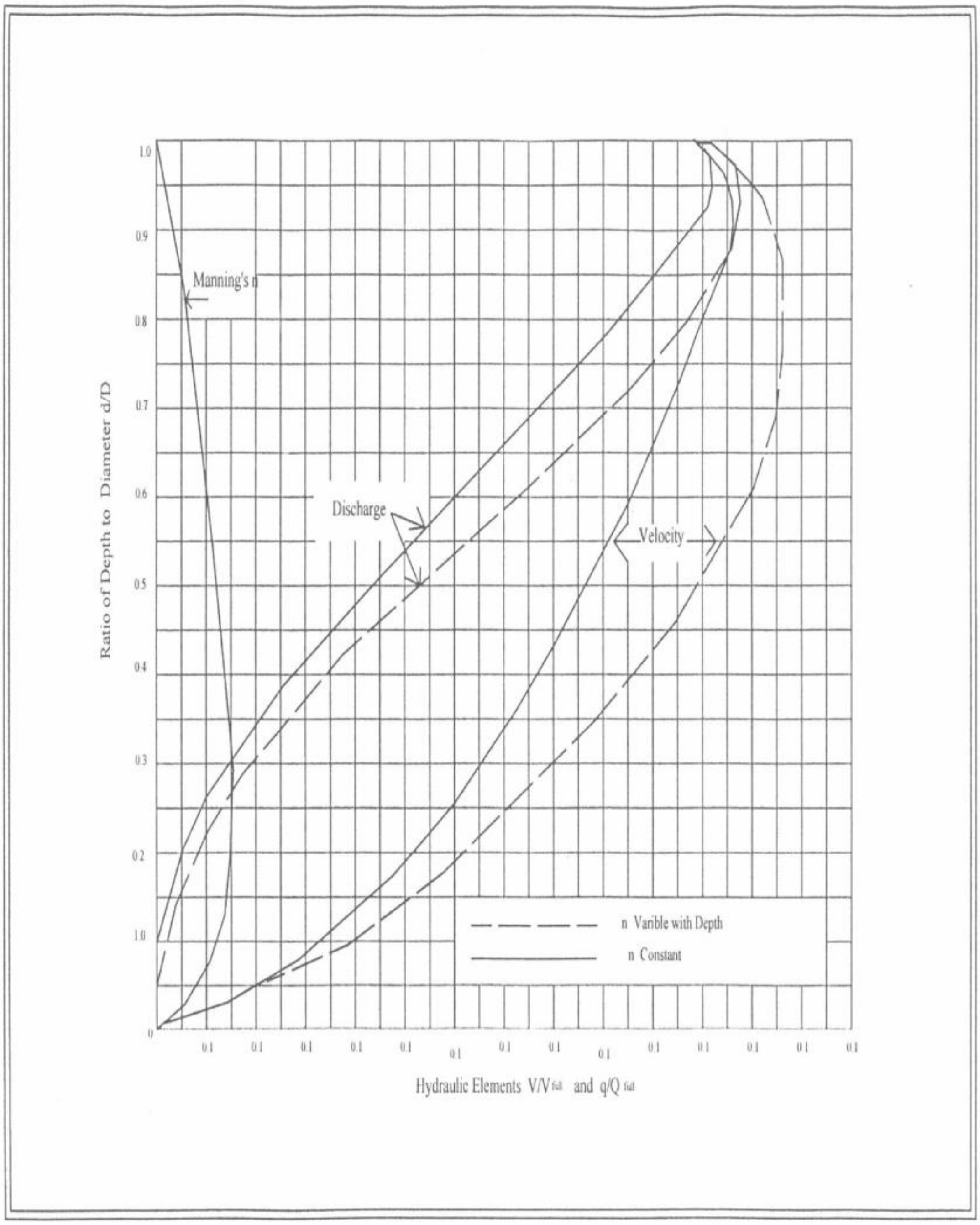


Figure 3.1: Diagram for Solution of the Manning Formula



Fig, 3.2: Hydraulic Properties of Circular Sewer

3.4.5 Design Computations

After the preliminary sewer layout plan is prepared, the design computations are accomplished. Design computations for sewers are repetitious and therefore, are best performed in a tabular format. Table 2.5 is typical of the way in which data can be organized to facilitate computations for closed system.

3.4.6 Preparation of maps and profile

It is important that the detailed drawings be prepared and specifications completed before the bid can be requested. The contract drawings should show (1) surface features, (2) depth and character of material to be excavated, (3) the existing structures that are likely to be encountered, and (4) the details of sewer and appurtenances to be constructed.

The specifications should be prepared by writing clearly and completely all work requirements and conditions affecting the contracts. As an example, technical specifications should cover items such as site preparation, excavation and backfill, concrete work, sewer materials and pipe lying, and acceptance tests (Qasim, 1985).

3.5 Summary

In this chapter, municipal storm water drainage systems in general have been described. The method of calculating the storm water runoff has been presented. The flow equations of sewer pipes and channels have been brought out. Finally the design and construction of community storm water drainage system has been briefly discussed.

Table (3.5) Typical Computation Sheet for Storm Water Design of Closed System

NUMBER	LOCATION			LENGTH	LENGTH COMULATIVE	AREA of Street	C FACTOR Street	AREA of Land	C Factor of land	SUM(AC) COMULATIVE	Tc	(i)	Q	Qi
	LINE NAME	UPPER MH. NO.	LOWER MH. NO.	(m)	(m)	(ha)				(ha)	(min)	(l/s.ha)	(l/s)	(l/s)
1	A	1	2											
2	A	2	3											
3	A	3	4											
4	A	4	5											
5	A	5	6											
6	A	6	7											
7	A	7	8											
8	A	8	9											
9	A	9	10											
10	A	10	11											
11	A	11	12											
12	A	12	13											
13	A	13	14											
14	A	14	15											
15	A	15	16											
16	A	16	17											
17	A	17	18											
18	A	18	19											
19	A	19	20											
20	A	20	21											

CHAPTER FOUR

"ANALYSIS AND DESIGN"

4. 1 General

In this project, design of storm water drainage system for the Beit Jala, in order to solve the problem causes by the cumulative flooded storm water in the streets will be prepared.

In this chapter, the layout of the system established will be presented followed by discussion of detailed design computations and the final design and profile of the suggested storm water drainage system.

4.2 Layout of the System

The first step in designing a storm water drainage system is to establish an overall system layout that includes a plan of the area, showing roads, streets, buildings, other utilities, topography.

In suggesting the layout of storm water drainage system for the Beit Jala, the following basic steps were followed:

1. Obtain a topographic map of the area to be served.
2. Visit the location.
3. Locate the catchment of the site and determine the area of this catchment.
4. Sketch in preliminary closed pipe system to serve the area.
5. Sewer layout is followed natural drainage ways so as to minimize
6. Excavation and pumping requirements (if it needed).
7. Establish preliminary pipe diameter that can drain the required water runoff.
8. Revise the layout so as to optimize flow-carrying capacity at minimum cost.

   Note that: To determine the catchment area and sub-catchment area and to determine the flow direction we must use maps prepared in Ch2, these maps are TIN, DEM, Flow Direction, and flow accumulative, Net Work Stream.

The final layout of storm water drainage system for Beit Jala City is illustrated in the
(Fig 4.1) and (Fig 4.2) and drawing (D1), (D2) in Appendix

4.3 Quantity of Storm Water

After preparing the layout of storm water drainage system the quality of storm water that the system must carry it will be calculated using the data collected about the area.

Example:

Design a gravity flow storm water drainage pipe for the area of Beit Jala city use line sub-main b1 as an example this is line shown in (Fig 4.4). Assume that the following design criteria have been developed and adopted based on an analysis of local conditions and codes.

1. For weighted Runoff coefficient (C) uses 0.65
2. For Inlet time (t_i) use 10 minutes
3. For Concentration time (t_c) use equations:

$$t_c = t_i + t_f \tag{3.3}$$

4. For Runoff rate depending on the formula:

$$Q = C.i.A \tag{3.1}$$

5. For Rainfall intensity use (Fig 4.3).

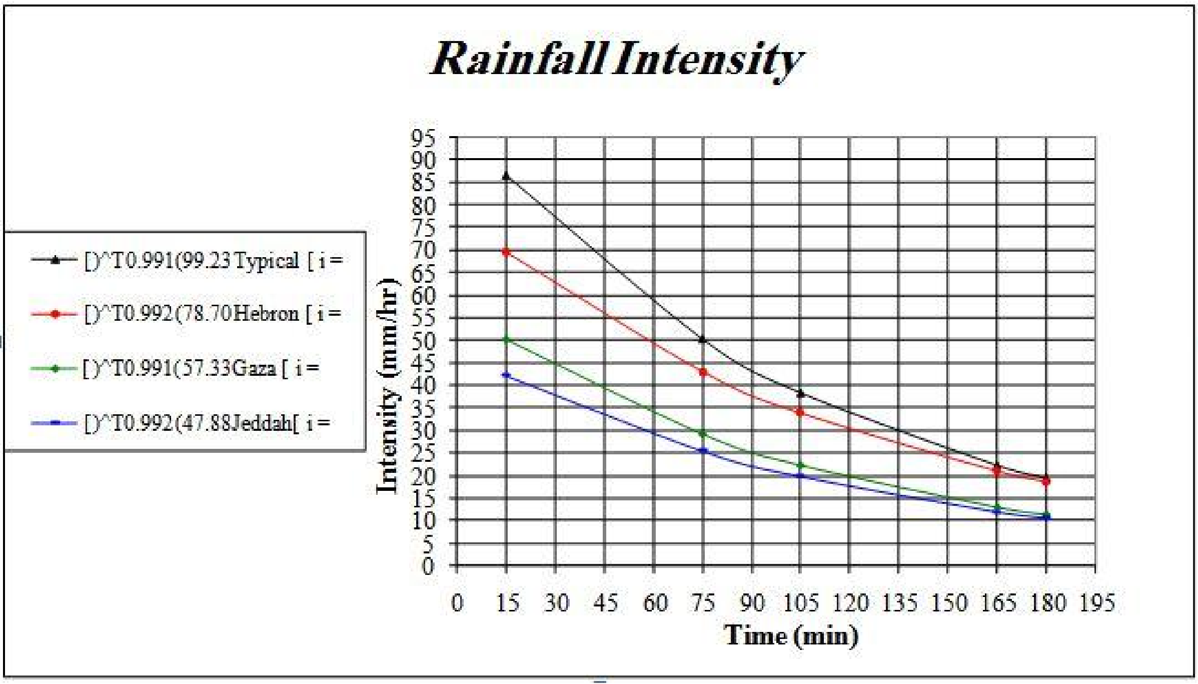


Fig 4.3 The Rainfall Intensity-Duration Curve For Several Areas

Soluion

a. Layout the storm water sewer. Draw a line to represent the proposed sewer.

b. Locate and number the upper and lower points of the line (sub-main b1).

c. The necessary computations for the storm water sewer shown in Fig(4.4) presented in the Table 4.1. The data in the table are calculated as follow:

   1. The entries in columns 1 through 6 are used to identify the point locations, their numbers and the length between them.

   2. The entries in columns 7 used to identify the sewer area; column 7 shows the partial sewered area in hectare.

   3. The entries in columns 8 through 14 are used to calculate the design flow. Runoff coefficient (C) is entered in column 8. The partial sewered area in hectare is multiplied by runoff coefficient (C) and the result is given in column 9. The cumulative multiplication of the sewered area in hectare is multiplied by runoff coefficient (C) are given in column 10. The concentration time is shown in column 11 and rainfall intensity (L/s.ha) is shown in column 12. Column 14 shows the quantity of storm water separately between two inlets.

Four main and six sub-main trunks is proposed and located on the layout of the area and the quantity of storm water for each is illustrated in table in Appendix A

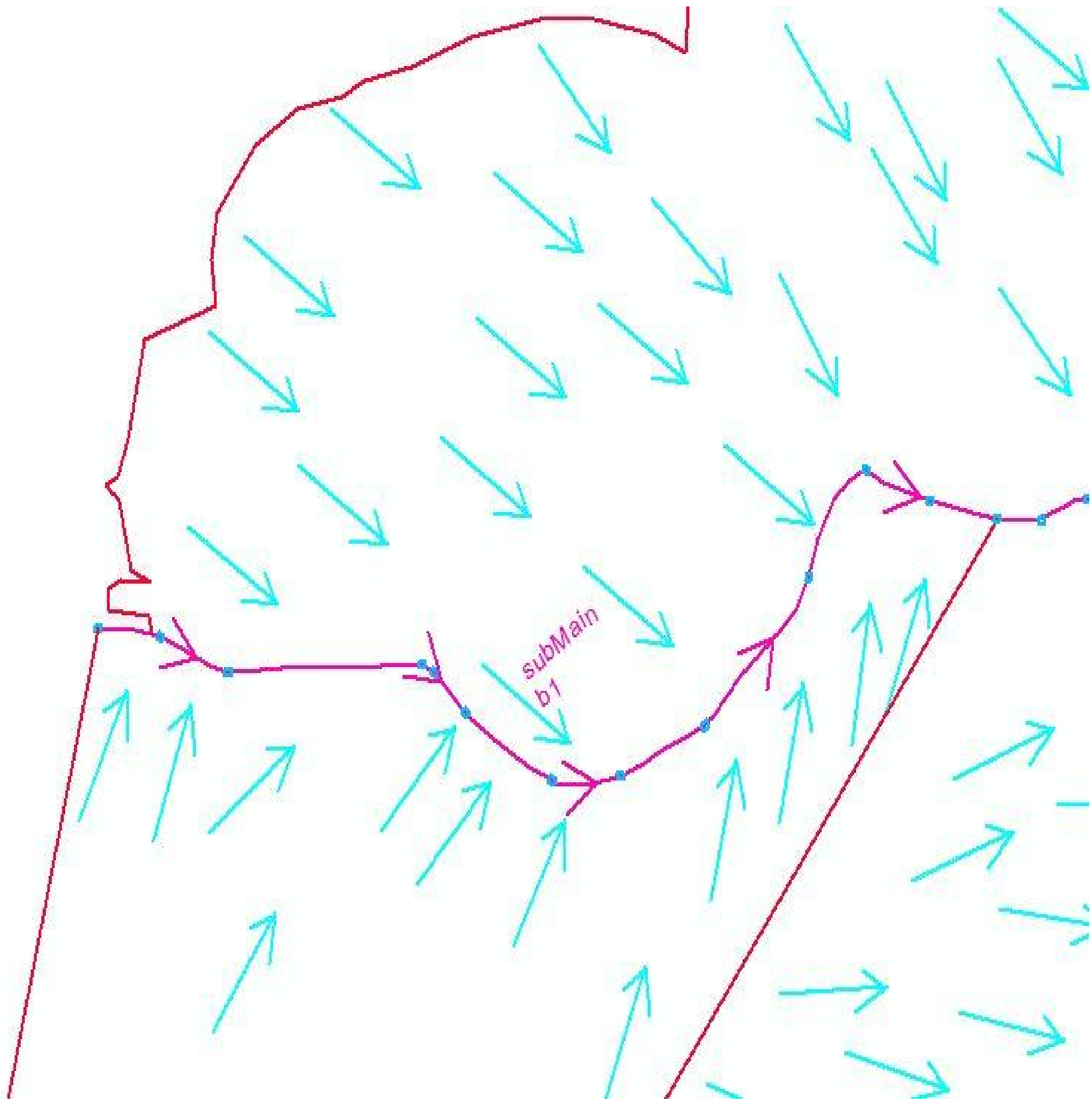


Fig (4.4)

StormWater Design Computations

Line submain b1

NUMBER	LOCATION: LINE NAME	UPPER MH. NO.	LOWER MH. NO.	LENGTH (m)	LENGTH COMULATIVE (m)	AREA of Street and industry (ha)	C FACTOR Street and industry	C.A STREET (ha)	SUM(AC) COMULATIVE (ha)	Tc (min)	(i) (l/s.ha)	Q (l/s)	Qi (l/s)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	submain b1	1	2	46.84	46.84	1.78	0.650	1.16	1.16	10.78	12031.06	13943.09	13943.09
2	submain b1	2	3	56.52	103.36	1.28	0.650	0.83	1.99	11.72	11940.37	23807.12	9864.03
3	submain b1	3	4	147.62	250.98	4.51	0.650	2.93	4.93	14.18	11706.72	57673.35	47809.32
4	submain b1	4	5	9.61	260.59	0.34	0.650	0.22	5.15	14.34	11691.67	60180.55	12371.23
5	submain b1	5	6	33.51	294.10	1.10	0.650	0.72	5.86	14.90	11639.34	68233.80	55862.56
6	submain b1	6	7	75.60	369.70	1.99	0.650	1.29	7.15	16.16	11522.14	82428.46	26565.89
7	submain b1	7	8	54.26	423.96	0.79	0.650	0.52	7.67	17.07	11438.75	87727.39	61161.50
8	submain b1	8	9	68.75	492.71	1.15	0.650	0.75	8.42	18.21	11333.96	95390.89	34229.39
9	submain b1	9	10	117.24	609.95	10.49	0.650	6.82	15.23	20.17	11157.46	169982.74	135753.35
10	submain b1	10	11	77.85	687.80	4.32	0.650	2.81	18.04	21.46	11041.78	199209.56	63456.21
11	submain b1	11	12	52.43	740.23	4.66	0.650	3.03	21.07	22.34	10964.55	231045.41	167589.20
12	submain b1	12	13	53.31	793.54	1.52	0.650	0.99	22.06	23.23	10886.58	240163.81	72574.62
13	submain b1	13	14	31.74	825.28	1.51	0.650	0.98	23.04	23.75	10840.42	249778.28	177203.66
14	submain b1	14	15	38.62	863.90	1.63	0.650	1.06	24.10	24.40	10784.52	259932.32	82728.66
15	submain b1	15	16	82.33	946.23	2.74	0.650	1.78	25.88	25.77	10666.31	276085.77	193357.11
16	submain b1	16	17	39.33	985.56	2.30	0.650	1.50	27.38	26.43	10610.30	290512.23	97155.12

Table 4.1

4.4 Sewer CAD Program Works:

a. Open Sewer CAD, select file → import →DXF Background to import the DXF file, Fig (4.5) below shows this step.

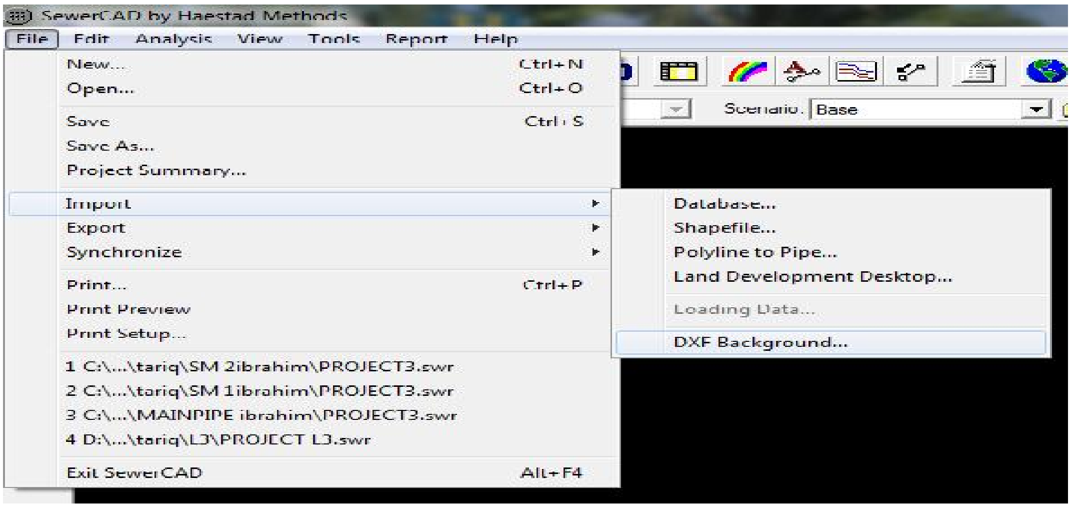


Fig (4.5)

b. Specify file location is then press open, Fig (4.6) below shows this step. And Fig (4.7) shows line (Sub main a3).

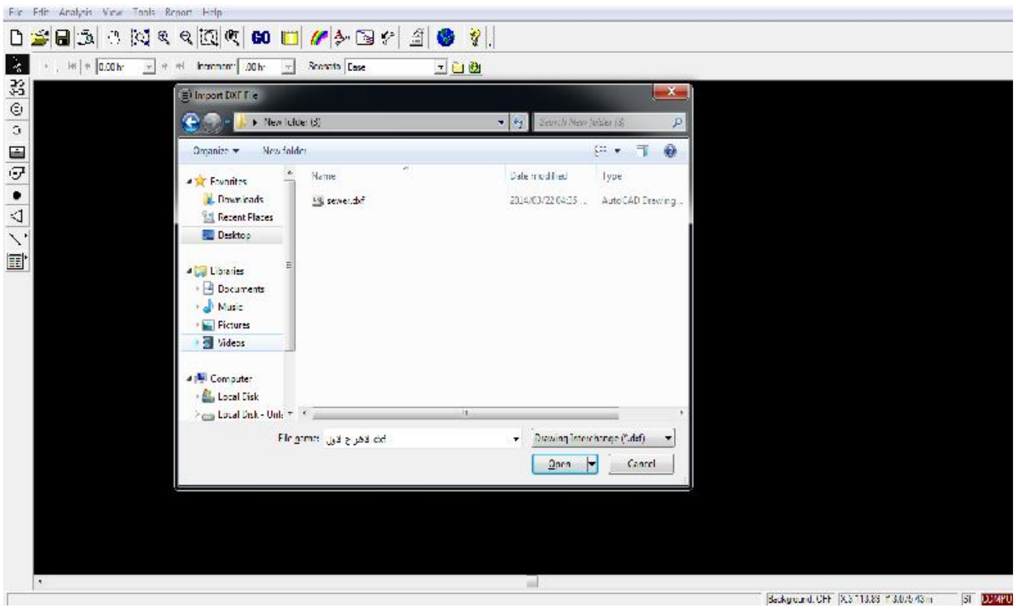


Fig (4.6)

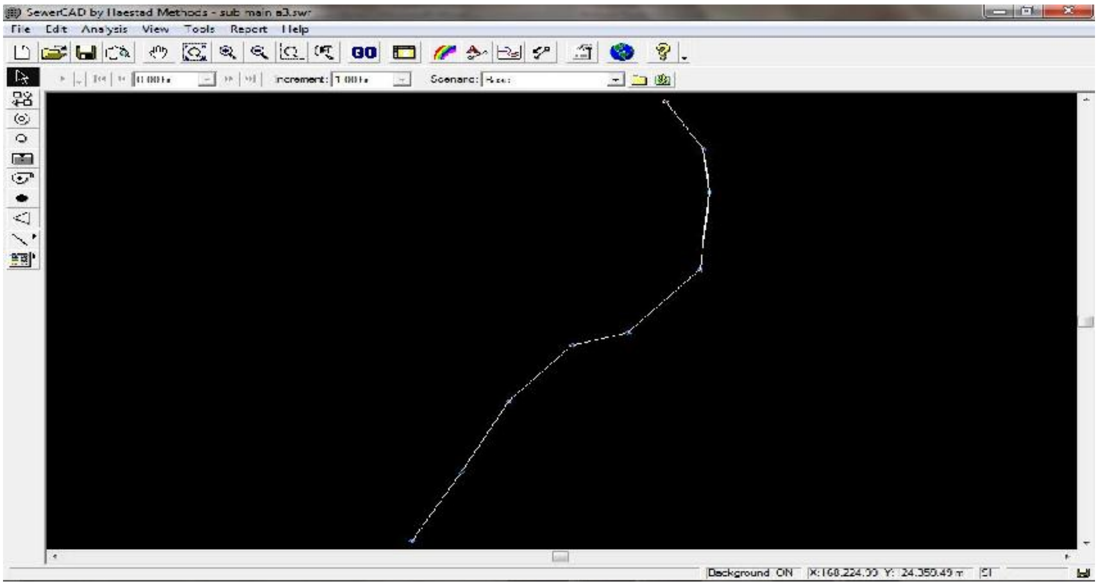


Fig (4.7)

c. Press pipe icon, a massage will appear tell you to create a project see Fig (4.8).

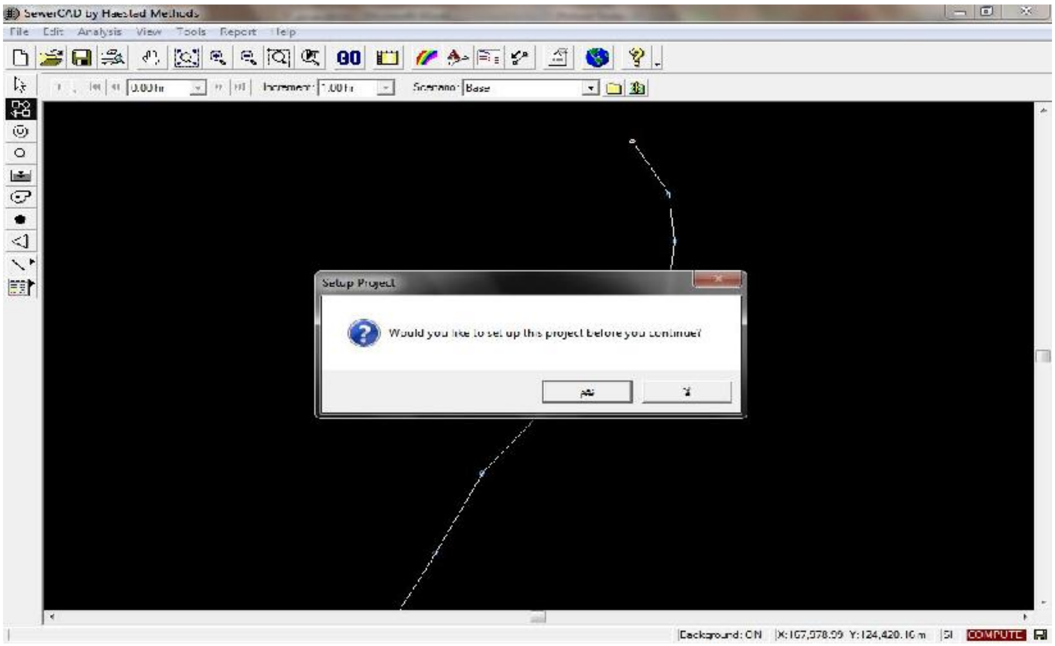


Fig (4.8)

d. Press yes and define the project then press next twice, then select finish, the Fig (4.9) below show this step.

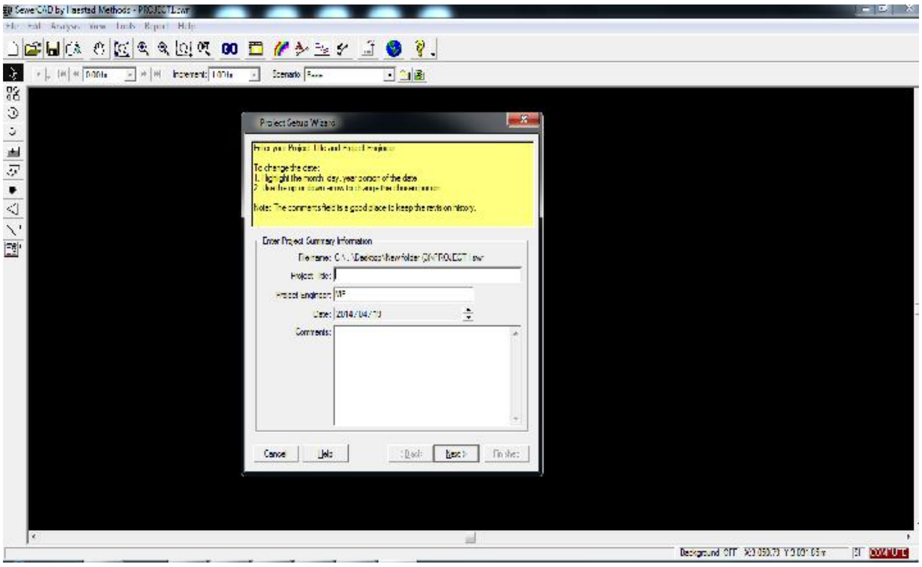


Fig (4.9)

e. Press pipe icon and connect between inlets, Fig (4.10) below shows the step.

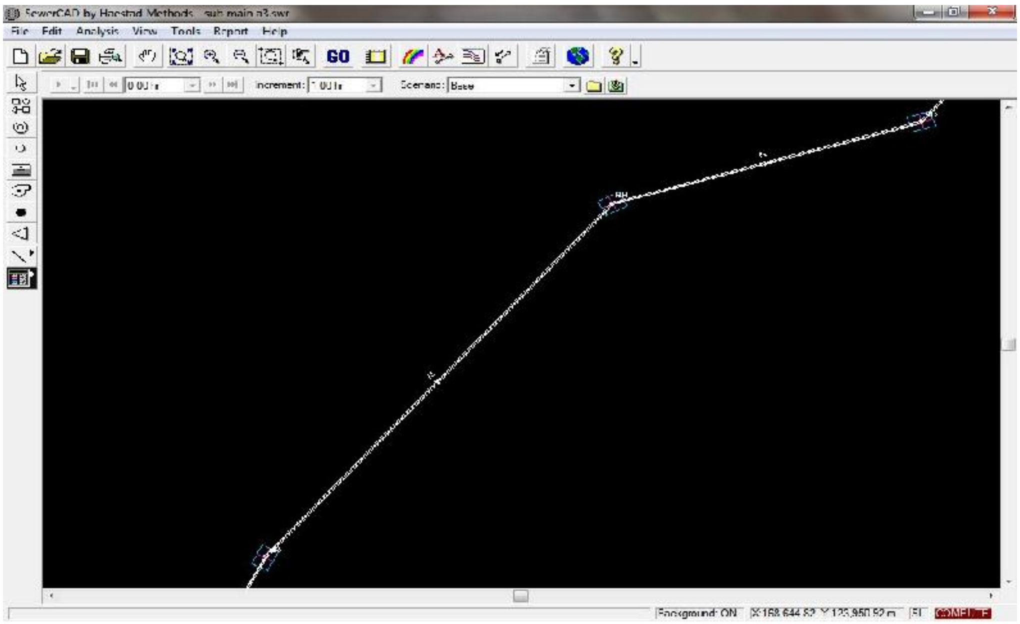


Fig (4.10)

f. After you connect between all inlets, press on the out let icon and click on the last inlet, then press yes to replace the inlet with outlet, the Fig (4.11) below shows the step.

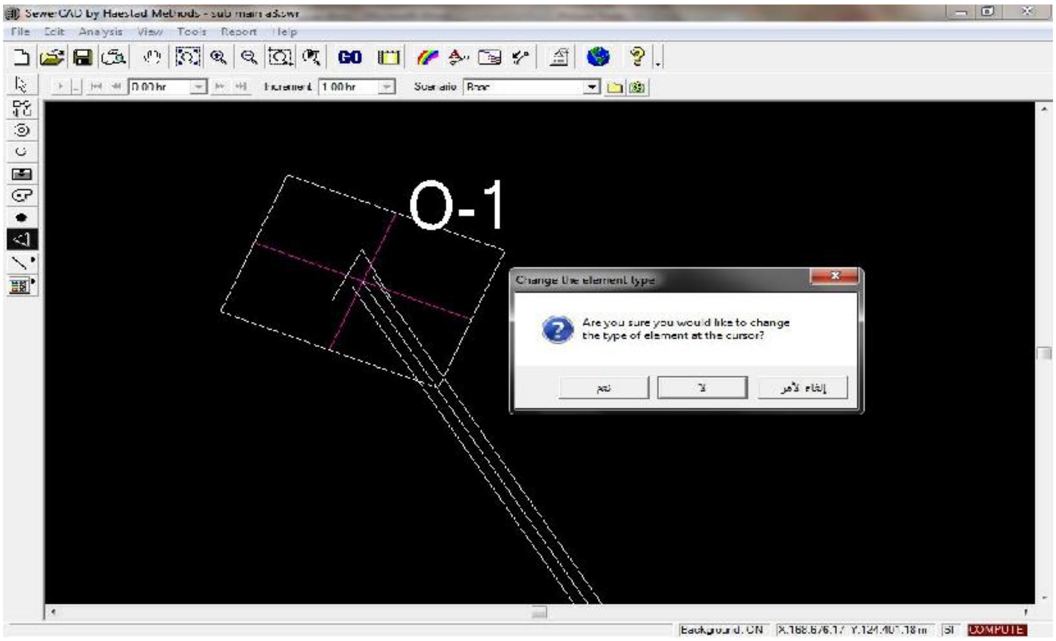


Fig (4.11)

g. Save your project, then select analysis → alternatives → physical properties → edit, then start editing gravity pipe, see Fig (4.12).

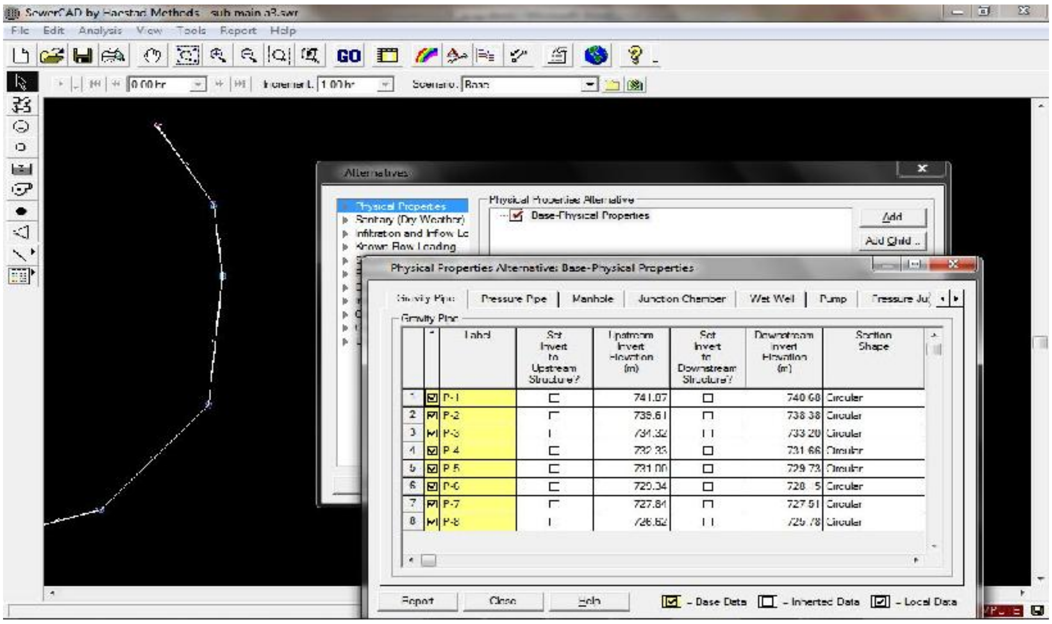


Fig (4.12)

h. Select inlet to enter the ground elevations of inlets, then select out let to enter its elevation. Then press close. Fig (4.13) below shows the step.

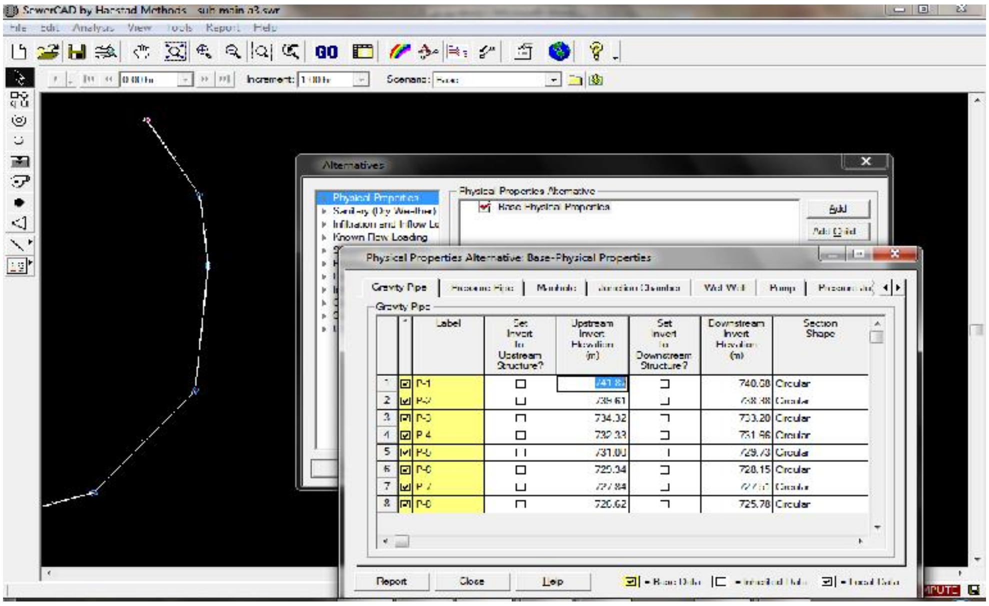


Fig (4.13)

i. Select sanitary (dry weather) → edit → manhole to select the type of load and to enter the load for each inlet, Fig (4.14) below shows the step.

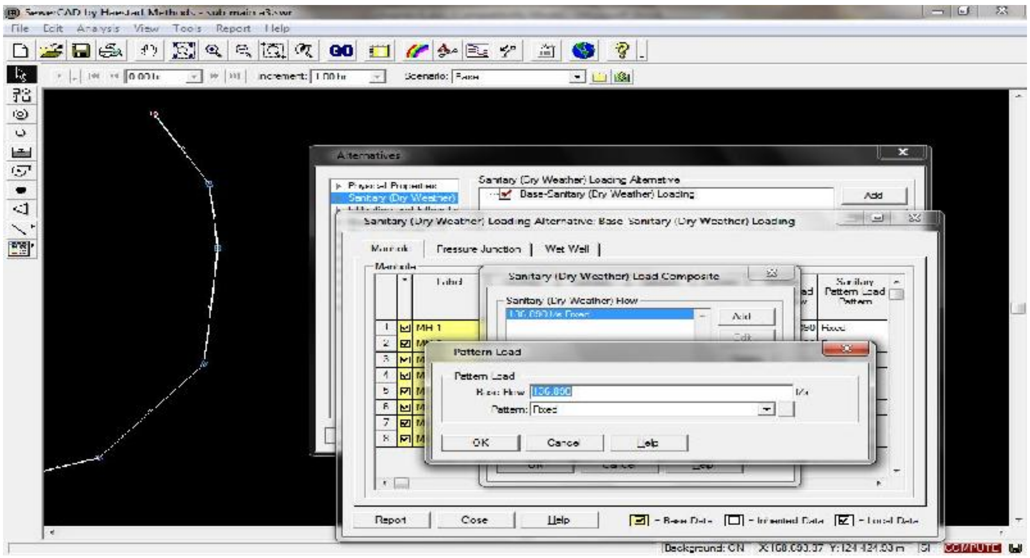


Fig (4.14)

j. After doing this for each inlet press close, then select design constrains → edit to enter the design specifications, Fig(4.15) below shows the step.

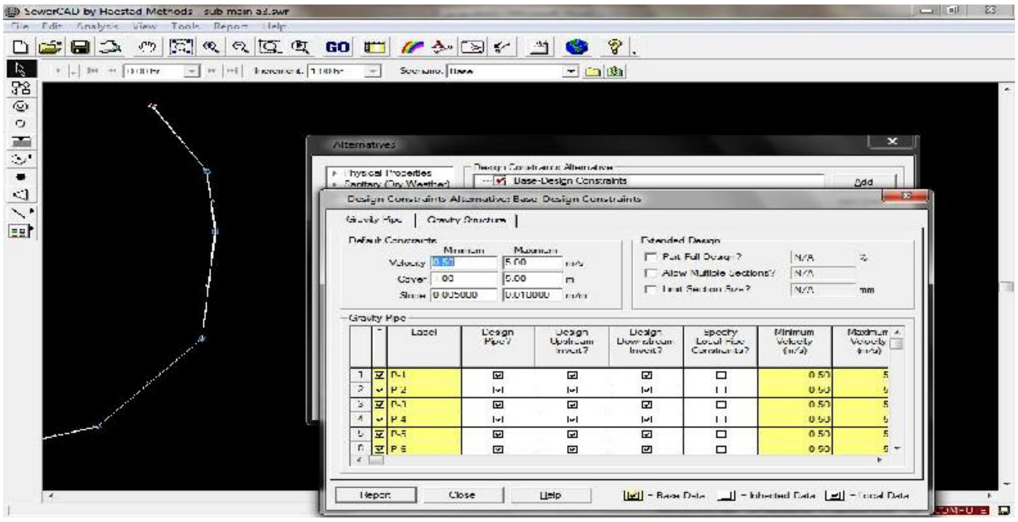


Fig (4.15)

k. Last step press save, press GO button to start design then press on GO, Fig (4.16) below shows the step.

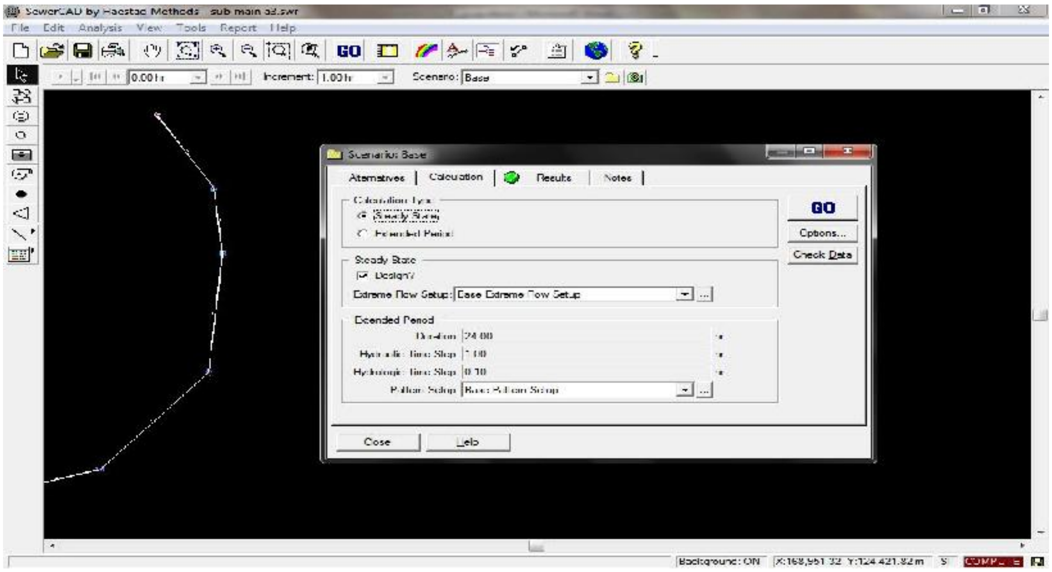


Fig (4.16)

NOTE: If you have green light that mean there is no problems in the design work, but if you have yellow or red light that’s mean there is problem, read the massages and fix these problems.

m. After finishing design work we need to show the pipe line profile and the profile, gravity pipe report and manhole report. Press profile button to make the profile see Fig (4.17), here we should put the scale of the profile. The profiles for this project are attached in appendix C.We can get the required tables by pressing tabular report button see Fig (4.18), and then choose gravity pipe report and manhole report. The required reports for this project are attached in appendix B.

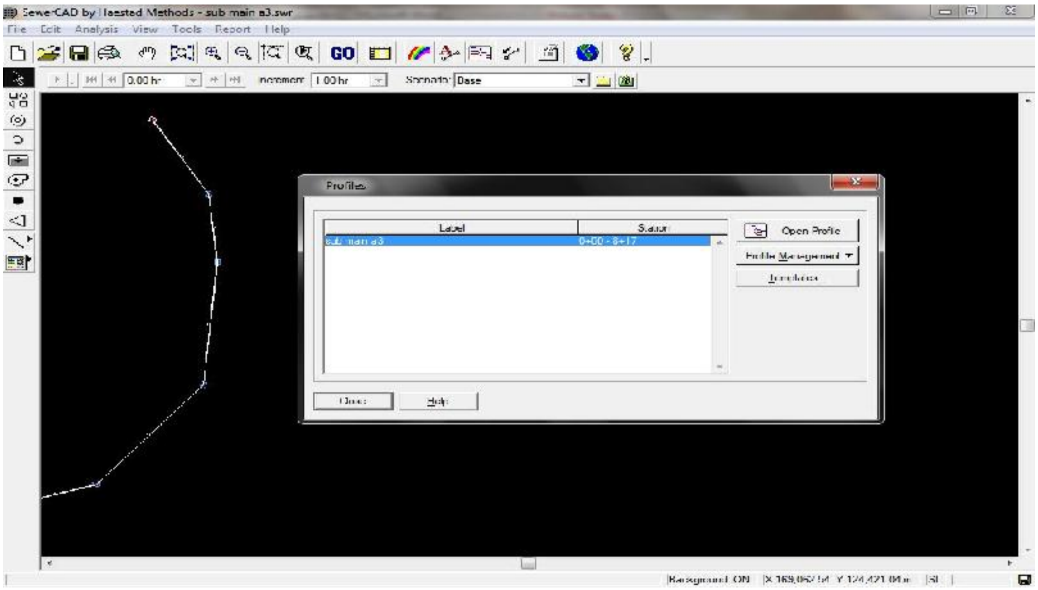


Fig (4.17)

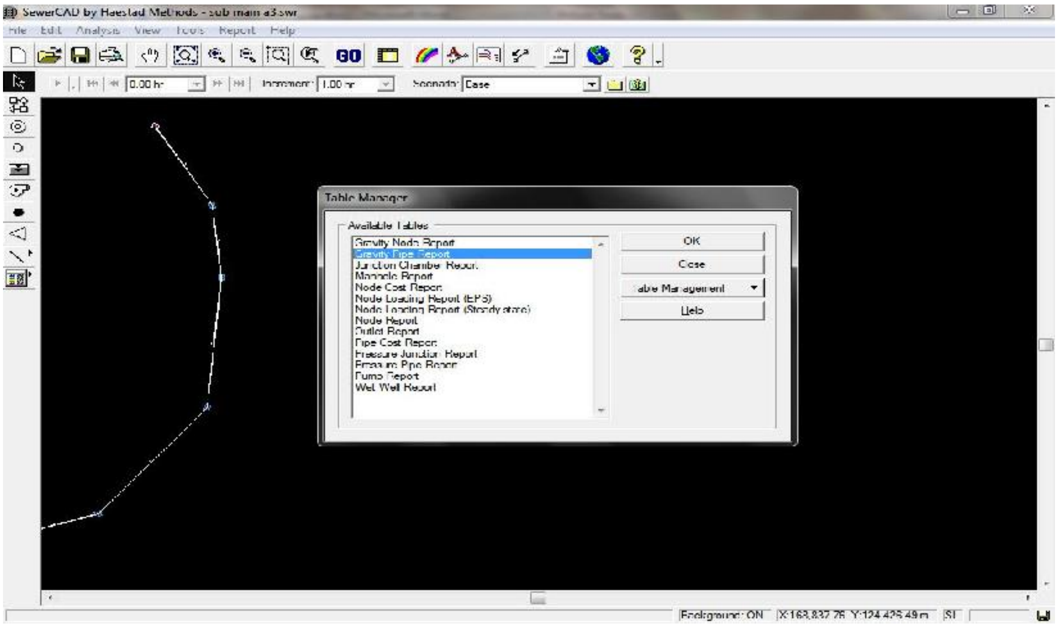


Fig (4.18)

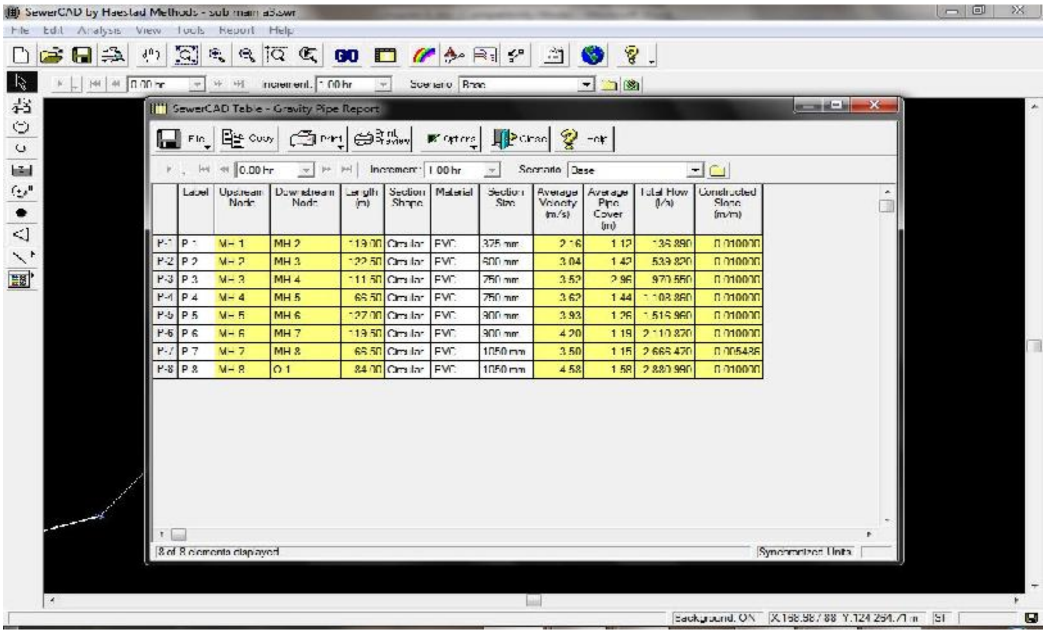


Fig (4.19) Example of Storm Water Table

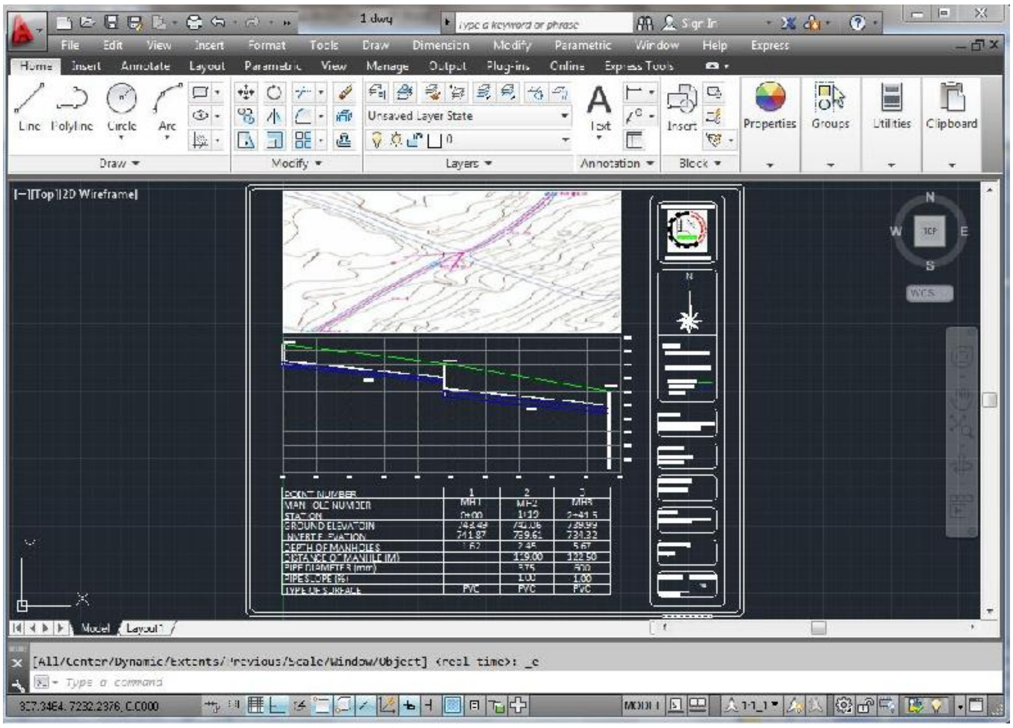


Fig (4.20) Example of storm water profile

Figure (4.21) showing an example on profile line (sub main a3). And Table (4.2) showing an example on storm water design report.

Table(4.2) Storm Water Design Report For (Sub main a3)

Manhole Report						Pipe Report										
Label	Ground Elevation (m)	Rim Elevation (m)	Sump Elevation (m)	Manhole Diameter (m)	Manhole Depth(m)	Label	Upstream Manhole	Down Stream Manhloe	Length (m)	Total Flow(l/s)	Section Shape	Section Size(mm)	Average Velocity (m/s)	Constracted slope (mm)	Average Pipe Cover(m)	Material
MH-1	743.49	743.49	741.87	1.2	1.62	P-1	MH-1	MH-2	119	136.89	Circular	375 mm	2.16	0.0069	0.01	PVC
MH-2	742.06	742.06	739.61	1.2	2.45	P-2	MH-2	MH-3	122.5	539.82	Circular	600 mm	3.04	0.04	0.01	PVC
MH-3	739.99	739.99	734.32	1.2	5.67	P-3	MH-3	MH-4	111.5	970.55	Circular	750 mm	3.52	0.0069	0.01	PVC
MH-4	734.97	734.97	732.33	1.2	2.64	P-4	MH-4	MH-5	66.5	1,108.86	Circular	750 mm	3.62	0.0069	0.01	PVC
MH-5	733.42	733.42	731	1.2	2.42	P-5	MH-5	MH-6	127	1,516.96	Circular	900 mm	3.93	0.0069	0.01	PVC
MH-6	731.64	731.64	729.34	1.2	2.3	P-6	MH-6	MH-7	119.5	2,110.87	Circular	900 mm	4.2	0.0069	0.01	PVC
MH-7	730.06	730.06	727.99	1.2	2.07	P-7	MH-7	MH-8	66.5	2,666.47	Circular	1050 mm	3.5	0.0069	0.005486	PVC
MH-8	730	730	726.77	1.2	3.23	P-8	MH-8	O-1	84	2,880.99	Circular	1050 mm	4.58	0.005	0.01	PVC

Label	X coordinate (m)	Y coordinate (m)
MH-1	168,386.91	123,726.97
MH-2	168,443.43	123,831.89
MH-3	168,497.92	123,941.80
MH-4	168,569.41	124,027.09
MH-5	168,632.96	124,046.73
MH-6	168,715.25	124,143.54
MH-7	168,725.74	124,262.59
MH-8	168,719.08	124,328.75

The profiles for Storm Water network are attached in appendix C, and the gravity pipe reports and manhole reports are attached in appendix B.

CHAPTER FIVE

"BILL OF QUANTITYS"

5.1 BILL OF QUANTITY FOR THE PROPOSED STORM WATER DRAINAGE SYSTEM

No.	EXCAVATION	UNIT	QTY	UNIT PRICE		TOTAL PRICE	
				$	C	$	C
A1	Excavation of pipes trench in all kind of soil for one pipe diameter 250 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	454.5				
A2	Excavation of pipes trench in all kind of soil for one pipe diameter 300 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	540.5				
A3	Excavation of pipes trench in all kind of soil for one pipe diameter 375 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	628				
A4	Excavation of pipes trench in all kind of soil for one pipe diameter 450 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	694.5				

A5	Excavation of pipes trench in all kind of soil for one pipe diameter 600 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	1274				
A6	Excavation of pipes trench in all kind of soil for one pipe diameter 750 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	1018				
A7	Excavation of pipes trench in all kind of soil for one pipe diameter 900 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	889.5				
A8	Excavation of pipes trench in all kind of soil for one pipe diameter 1050 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	751				
A9	Excavation of pipes trench in all kind of soil for one pipe diameter 1200 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	524.5				

A10	Excavation of pipes trench in all kind of soil for one pipe diameter 1350 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	528.5				
A11	Excavation of pipes trench in all kind of soil for one pipe diameter 1500 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	411				
A12	Excavation of pipes trench in all kind of soil for one pipe diameter 1650 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	914				
A13	Excavation of pipes trench in all kind of soil for one pipe diameter 1800 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	115				
A14	Excavation of pipes trench in all kind of soil for one pipe diameter 1950 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	117.5				

A15	Excavation of pipes trench in all kind of soil for one pipe diameter 2100 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	490.5				
A16	Excavation of pipes trench in all kind of soil for one pipe diameter 2700 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	318.5				
A17	Excavation of pipes trench in all kind of soil for one pipe diameter 3600 mm depth and disposing of the debris and the top soil unsuitable for backfill outside the site	LM	795				
Sub-Total							
B	**PIPE WORK**						
B1	Supplying, storing and installing of PVC	LM	**10464.5**				
	Sub-Total						
C	**PIPE BEDDING AND BACKFILLING** **Dimension and material**						

C1	Supplying and embedment of sand for one pipe diameter 250 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	454.5				
C2	Supplying and embedment of sand for one pipe diameter 300 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	540.5				
C3	Supplying and embedment of sand for one pipe diameter 375 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	628				
C4	Supplying and embedment of sand for one pipe diameter 450 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	694.5				

C5	Supplying and embedment of sand for one pipe diameter 600 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	1274				
C6	Supplying and embedment of sand for one pipe diameter 750 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	1018				
C7	Supplying and embedment of sand for one pipe diameter 900 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	889.5				
C8	Supplying and embedment of sand for one pipe diameter 1050 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	751				

C9	Supplying and embedment of sand for one pipe diameter 1200 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	524.5				
C10	Supplying and embedment of sand for one pipe diameter 1350 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	528.5				
C11	Supplying and embedment of sand for one pipe diameter 1500 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	411				
C12	Supplying and embedment of sand for one pipe diameter 1650 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	914				

C13	Supplying and embedment of sand for one pipe diameter 1800 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	115				
C14	Supplying and embedment of sand for one pipe diameter 1950 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	117.5				
C15	Supplying and embedment of sand for one pipe diameter 2100 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	490.5				
C16	Supplying and embedment of sand for one pipe diameter 2700 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	318.5				

C17	Supplying and embedment of sand for one pipe diameter 3600 mm, depth up to 1.00 meter and disposing of the debris and the top soil unsuitable for backfill outside the site.	LM	795				
Sub-Total							
D	**INLETS, Details according to the drawing**						
D1	Supplying and installing of precasted inlet including excavation pipe connection, epoxytar coating, 25-ton cast iron cover and backfill, size 1200mm, depth up to 1.00m.	NR	156				
Sub-Total							
E	**Concrete Surround**						
E1	Suppying and installing of reinforced concrete (B 200) protection concrete encasement for sewer pipe.	LM	**10464.5**				
Sub-Total							
F	**Air And Water Leakage Test**						
F1	Air leakage test for sewer pipe lines for all diameters from 250 mm to 3600 mm according to specifications, including for all temporary works.	LM	**10464.5**				

F2	Water leakage tests for inlet, depth up to 1.00 meter according to specifications.	NR	156				
Sub-Total							
G	**Survey work**						
G1	Topographical survey required for shop drawings and as built DWGS using absoluet Elev. And coordinate system	LM	**10464.5**				

CHAPTER SIX

"CONCLUSION"

Conclusion

1- A storm water drainage system for Beit Jala city is obtained and it will cover all of the area.

2- The drainage system is consisting of four main lines and six sub-main lines.

3- All lines in the drainage system are running by gravity.

4- The range of sewer diameters is lying from 250mm-3600mm.

5- The max velocity in the pipe does not exceed 5m/s in the pipes.

6- The max cover in all sewers was 7m where the min was 1m.

7- This design is based on the rational method which is the most popular in calculating the quantity of storm water and it also based on manning equation in the design calculation.

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REFERENCES

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APPENDIX-A

CALCULATIONS TABLES FOR

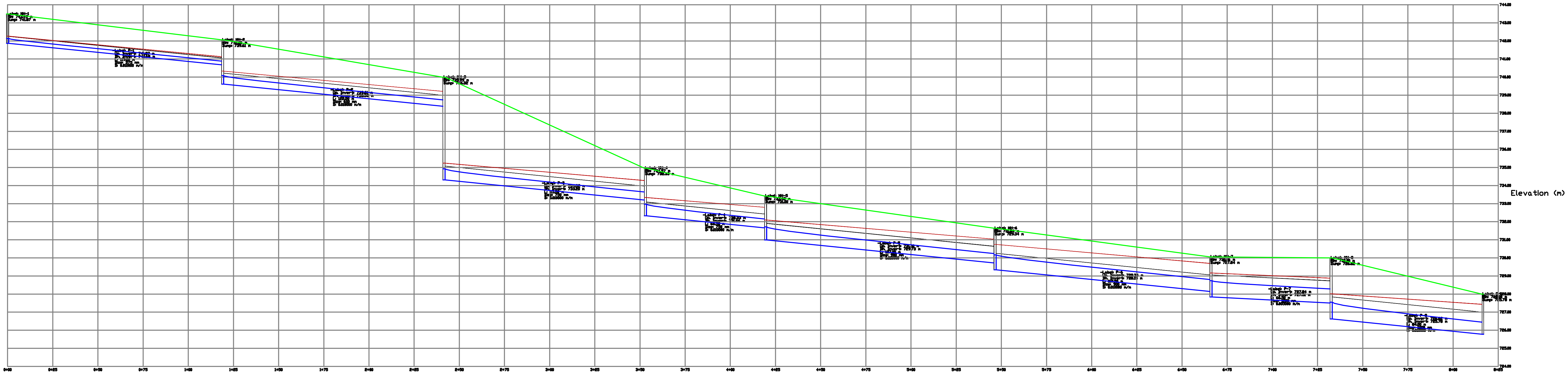
STORM DRAINAGE

APPENDIX-B

GRAVITY PIPE REPORTS AND MANHOLE REPORTS

FOR STORM DRAINAGE

Profile: sub main a3
Scenario: Base (0.00 hr)



Fig(4.21)