
DEVELOPMENT OF A HYDRAULIC MODEL FOR STORMWATER DRAINAGE NETWORK USING SEWERGEMS SOFTWARE: A CASE STUDY OF KAMARHATI MUNICIPALITY

*A thesis submitted towards the partial fulfilment of the requirements for the
degree of Master of Engineering in Water Resources and Hydraulic Engineering*

Submitted by

ARITRA SATPATI

Class Roll No: 002130302023
Examination Roll No.: M6WRP24020

Under the guidance of

(Prof.) DR. ASIS MAZUMDAR

Professor & Director
School of Water Resources Engineering
Jadavpur University
&

DR. GOURAB BANERJEE

Assistant Professor
School of Water Resources Engineering
Jadavpur University

School of Water Resources Engineering

*M.E. (Water Resources & Hydraulic Engineering) course affiliated to
Faculty Council of Engineering & Technology*

*Jadavpur University
Kolkata 700032, India*

2024

Development of a Hydraulic Model for Stormwater Drainage Network using SewerGEMS Software: A Case Study of Kamarhati Municipality

*A thesis submitted toward partial fulfilment of the requirements
for the degree of*

MASTER OF ENGINEERING

in

Water Resources and Hydraulic Engineering

**Course affiliated to Faculty Council of Engineering & Technology
Jadavpur University**

submitted by

ARITRA SATPATI

Class Roll No: 002130302023

Registration No. 160508 of 2021-2022

Examination Roll No.: M6WRP24020

Under the guidance of

(Prof.) DR. ASIS MAZUMDAR

Professor & Director

School of Water Resources Engineering Jadavpur University

&

DR. GOURAB BANERJEE

Assistant Professor

School of Water Resources Engineering

Jadavpur University

School of Water Resources Engineering

*M.E. (Water Resources & Hydraulic Engineering) course affiliated to
Faculty Council of Engineering & Technology*

Jadavpur University

Kolkata 700032, India

2024

Dedicated to

Frontline Workers against COVID-19 Pandemic

Declaration of Originality and Compliance of Academic Ethics

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of my Master of Engineering in Water Resources & Hydraulic Engineering in the Faculty Council of Interdisciplinary Studies, Law & Management, Jadavpur University during academic session 2023-2024.

All information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name : Aritra Satpati
Exam Roll Number : **M6WRP24020**
Registration No. : **160508 of 2021-2022**
Thesis Title : Development of a Hydraulic Model for Stormwater Drainage Network using SewerGEMS Software: A Case Study of Kamarhati Municipality

Signature with Date:

29 May 2024

ARITRA SATPATI

Page i

CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"Development of a Hydraulic Model for Stormwater drainage Network using SewerGEMS Software: A Case Study of Kamarhati Municipality."**

is a Bonafede work carried out by Mr. Aritra Satpati under my supervision and guidance for partial fulfillment of the requirement for the Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academicsession 2023-2024.

THESIS ADVISOR

**Prof. Dr. Asis Mazumdar
Professor & Director**

School of Water Resources Engineering
Jadavpur University, Kolkata - 700 032

THESIS ADVISOR

**Dr. Gourab Banerjee
Assistant Professor**

School of Water Resources Engineering
Jadavpur University, Kolkata-700 032

**Prof. Dr. Asis Mazumdar
DIRECTOR**

School of Water Resources Engineering
Jadavpur University, Kolkata - 700 032

DEAN

Faculty Council of Interdisciplinary Studies, Law & Management
Jadavpur University

Certificate of Approval **

This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed, or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

Committee of Final Examination
for the evaluation of the thesis.

** Only in case the thesis is approved.

Acknowledgement

I express my sincere gratitude to my supervisor Prof. Dr. Asis Mazumdar, Emeritus Professor and Dr. Gourab Banerjee, Assistant Professor of School of Water Resources Engineering, Jadavpur University under whose supervision and guidance this work has been carried out. It would have been impossible to carry out this thesis work with confidence without his wholehearted involvement, advice, support, and constant encouragement throughout. He has not only helped me in my thesis work but also has given valuable advice to proceed further in my life.

I also express my sincere gratitude to Prof. (Dr). Asis Majumder Director & Professor, Director of School of Water Resources, Prof. (Dr.) Pankaj Kumar Roy, Faculty of Interdisciplinary Studies, Law and Management, School of Water Resources Engineering, Jadavpur University Dr. Subhasis Das, Associate Professor, School of Water Resources Engineering, Jadavpur University, Dr. Rajib Das, Assistant Professor, School of Water Resources Engineering, Jadavpur University for their valuable suggestions.

I sincerely thank all the staffs and my batchmates of School of Water Resources Engineering of Jadavpur University for their help and support.

Date: 29-05-2024

Place: Jadavpur University

ARITRA SATPATI

(Exam Roll No: **M6WRP24020**)

Abstract

Rapid urbanization has led to significant challenges in managing storm water runoff from developed areas. If left unaddressed, this can result in urban flooding and degradation of water quality in rivers and receiving waters. Effective urban drainage systems are crucial to mitigate these impacts and ensure sustainable urban development.

This study assesses the storm water drainage system in Kamarhati (Ward numbers 10-15), Kolkata, using statistical analysis, GIS, Google Earth Software, and SewerGEMS software. The research identifies construction, management, and design problems as the main challenges facing the existing drainage system. SewerGEMS software is used to analyze the system, and mitigation measures are proposed to address these problems. The study recommends periodic cleaning and modification of slope to avoid construction alignment problems.

"SewerGEMS" software, developed by Bentley Systems, USA, was extensively used in this study to analyze and propose mitigation measures for the drainage system in Kamarhati region. The software's dynamic, multi-platform capabilities enabled efficient and cost-effective project completion. Input data was entered into the software, and results were interpreted to identify drainage system shortcomings. Probable solutions were proposed to address these issues, including periodic cleaning and modification of slope to avoid construction alignment problems. The study demonstrates the effectiveness of "SewerGEMS" in developing sustainable drainage systems, highlighting its potential for future applications.

Keywords: Storm water drainage, Urban flooding, Sustainable urban development, SewerGEMS, Google Earth Software, Drainage system design

Table of Contents

Declaration of Originality and Compliance of Academic Ethics.....	i
CERTIFICATE OF RECOMMENDATION.....	ii
Certificate of Approval **.....	iii
Acknowledgement	iv
Abstract.....	v
Table of Contents	6
1 INTRODUCTION	10
1.1 <i>General Background.....</i>	<i>10</i>
1.2 <i>Description of Study Area.....</i>	<i>14</i>
1.3 <i>Research Gap.....</i>	<i>15</i>
1.4 <i>Objective of the Study</i>	<i>16</i>
1.5 <i>Brief Methodology of the Study.....</i>	<i>16</i>
1.6 <i>Possible Outcome of the Study</i>	<i>16</i>
1.7 <i>Outline of the Thesis.....</i>	<i>17</i>
1.8 <i>Brief Description of the project.....</i>	<i>17</i>
2 LITERATURE REVIEW	20
3 DESCRIPTION OF THE STUDY AREA.....	32
3.1 <i>Location.....</i>	<i>32</i>
3.2 <i>Silent Features of Kamarhati Municipality.....</i>	<i>32</i>
4 METHODOLOGY	34
4.1 <i>Data Collection</i>	<i>37</i>
4.2 <i>Topographical Survey.....</i>	<i>37</i>
4.3 <i>Consumer Survey.....</i>	<i>38</i>
4.4 <i>Field Investigation</i>	<i>38</i>
4.5 <i>Hydraulic simulation and optimization.....</i>	<i>38</i>
4.6 <i>Sewer GEMS model creation</i>	<i>39</i>
5 DESIGN & ANALYSIS OF DISTRIBUTION NETWORK	43
5.1 <i>Evaluation of Drainage Network Analysis</i>	<i>43</i>
5.2 <i>Design Philosophy</i>	<i>47</i>
5.3 <i>Applications in Software (SEWERGEMS, QGIS, AUTOCAD)</i>	<i>66</i>
6 RESULT AND DISCUSSIONS.....	73
7 CONCLUSION & RECOMMENDATION	84
8 REFERENCES	87
9 APPENDIX.....	91
9.1 <i>Hydraulic analysis of Stormwater Drainage Network Design</i>	<i>91</i>
9.2 <i>Manhole Table.....</i>	<i>114</i>

Tables

Table 1:-Flood affected area (1998-2022) Statistics at State level.	12
Table 2:-Statistical information	18
Table 3:- Salient Features	32
Table 4:- Ward wise Population	32
Table 5:-Recommended design return period for various types of urban catchments	45
Table 6:-Selected extreme rainfall events between 01st January 1989 to 31st December 2019	49
Table 7:-Maximum monthly rainfall value between year 1989 to 2019.	51
Table 8:-Time intensity values of storms	55
Table 9:-Coefficient of roughness for channel flow for use in manning's	56
Table 10:-CENCUS POPULATION OF DISTRICTS OF NORTH 24 PARGANAS OF 1971,1981,1991,2001,2011	58
Table 11:-population and pollution load calculation	58
Table 12:-Census_2011 & Survey Data	58
Table 13:- Summary of Stormwater Calculations	60
Table 14:- Runoff coefficient as per CPHEEO	63
Table 15:-Hydrological and Hydraulic Analysis Results	82
Table 16:-Calculation	82
Table 17:-Details the hydraulic analysis of the proposed drainage network	83

Table of Figures

Figure 1:- Flood Affected areas in India.	11
Figure 2:-Blue area depicts the flood prone districts of West Bengal	13
Figure 3:- Kamarhati ward Map (Study Area)	15
Figure 4:- Study Area	18
Figure 5:-Study Area	33
Figure 6:-Showing input and output of SewerGems	35
Figure 7:- Methodological Design of the Study	36
Figure 8:- Bentley Sewer GEMS V8i environment look	40
Figure 9:- FlexTable	41
Figure 10:-Calculation Executive Summary Dialogue Box	41
Figure 11:- Precipitation - Catchment and Watershed	46
Figure 12:- Rainfall analysis considering IMD gridded data (daily rainfall along with yearly rainfall)	48
Figure 13:-Rainfall analysis considering IMD gridded data (maximum (monthly sum) and average (monthly sum) rainfall for each year)	49
Figure 14:-Rainfall extreme events (10th July 2015 and 21st October 2017)	50
Figure 15:-Rainfall extreme events (24th September 1999 and 08th October 2003)	50
Figure 16:- Month wise Rainfall Variation	51
Figure 17:-Maximum daily rainfall month wise between year 1989 to 2019	52
Figure 18:-IDF curve using hourly IMD data (2-year, 5-year and 100-year return period)	54
Figure 19:- Duration vs Intensity of Storms	55
Figure 20:-Mannings Roughness Coefficients	57
Figure 21:-Different Routes of Runoff	64
Figure 22:- Hydrologic Cycle	65
Figure 23:- CAD File of study area.	67
Figure 24:-Calculation Dialogue Box	68
Figure 25:- Locating Study area in Google Earth	68
Figure 26:- Kamarhati existing drain from survey exported in QGIS	69
Figure 27:-Model	73
Figure 28:-Bar Chart Graphical Representation	74
Figure 29:- Bar Chart	75
Figure 30:-Profile	76

Figure 31:-Profile.....	77
Figure 32:- Base Map of Kamarhati in CAD.....	78
Figure 33:- Drainage Network.....	79
Figure 34:- Graph Bar Chart.....	80
Figure 35:- Contour Map of Study Area.....	81

1 INTRODUCTION

1.1 General Background

The condition of storm water drainage infrastructure in most of the Indian cities is in a dilapidated state on various accounts. There is a need to investigate this aspect to avoid undue misery to the masses and the associated losses in the city. Some examples of past urban flooding in India that led to huge monetary and human loss is Hyderabad (2016), Chennai (2015 and 2021), Srinagar (2014), Mumbai and Kolkata (2013). Therefore, making cities adaptable to such climate-change and anthropogenic related disaster is the need of hour. One of the few mitigations to minimize the causes and effects from the same is by re-designing of the existing drainage network in the city through modelling of extreme flood events. Urban flooding is a pressing issue affecting cities worldwide, causing damage to infrastructure, properties, and posing a threat to human life. Stormwater urban flooding occurs when the urban drainage system is overwhelmed by heavy rainfall, resulting in water accumulation on streets, buildings, and other urban areas.

As per UN Habitat 80% of the world's population lives in urban areas, making them vulnerable to urban flooding. As per World Bank 30% of urban areas are at risk of flooding due to inadequate drainage infrastructure. As per Lloyd's City Risk Index \$120 billion: average annual cost of urban flooding globally. As per IPCC 15-20%: increase in flood risk due to climate change. As per FEMA 2-3 times: increase in flood damage costs due to urbanization.

Stormwater drainage is a critical aspect of urban planning and management, as it directly impacts the environment, public health, and safety. Rapid urbanization and climate change have exacerbated the challenges associated with stormwater drainage, making it a pressing global issue.

Urbanization has led to an increase in impervious surfaces, such as roads, buildings, and parking lots, which reduce the natural ability of soil to absorb rainwater. This results in increased runoff, causing flooding, erosion, and water pollution. Climate change has also led to more frequent and intense rainfall events, further straining stormwater drainage systems.

Urban flooding is a growing concern worldwide, affecting millions of people and causing significant economic and social impacts. It occurs when urban areas experience heavy rainfall, storm surges, or snowmelt, overwhelming drainage systems and causing water to accumulate on streets, buildings, and other urban infrastructure.

The frequency of urban flooding has increased significantly in recent years, posing severe socio-environmental hazards that lead to traffic congestion and disruption of urban life. Devastating floods in cities like Hyderabad (2001 and 2012), Delhi (2002, 2003, 2009, 2010 and 2011), Chennai (2004 and 2015), Mumbai (2005, 2008 and 2009), Kolkata (1978 and 2007), Surat (2006), Jamshedpur (2008), Guwahati (2010), Jaipur (2012), Jammu & Kashmir (2014) and Kerala (2018) have resulted in substantial economic losses and losses of lives. To mitigate urban flooding, stormwater drainage systems must be planned and implemented in a structured manner, considering design,

operation, maintenance, and economic aspects. The formulation of a national manual is crucial to address the need for effective urban stormwater drainage systems, including planning, rainfall analysis, design, detailed engineering, construction, operation, maintenance, rehabilitation, and refurbishing of existing underperforming drainage systems. Urban stormwater drainage systems have become a priority in India, after drinking water supply and sewerage projects, due to rapid urbanization and migration from rural areas.

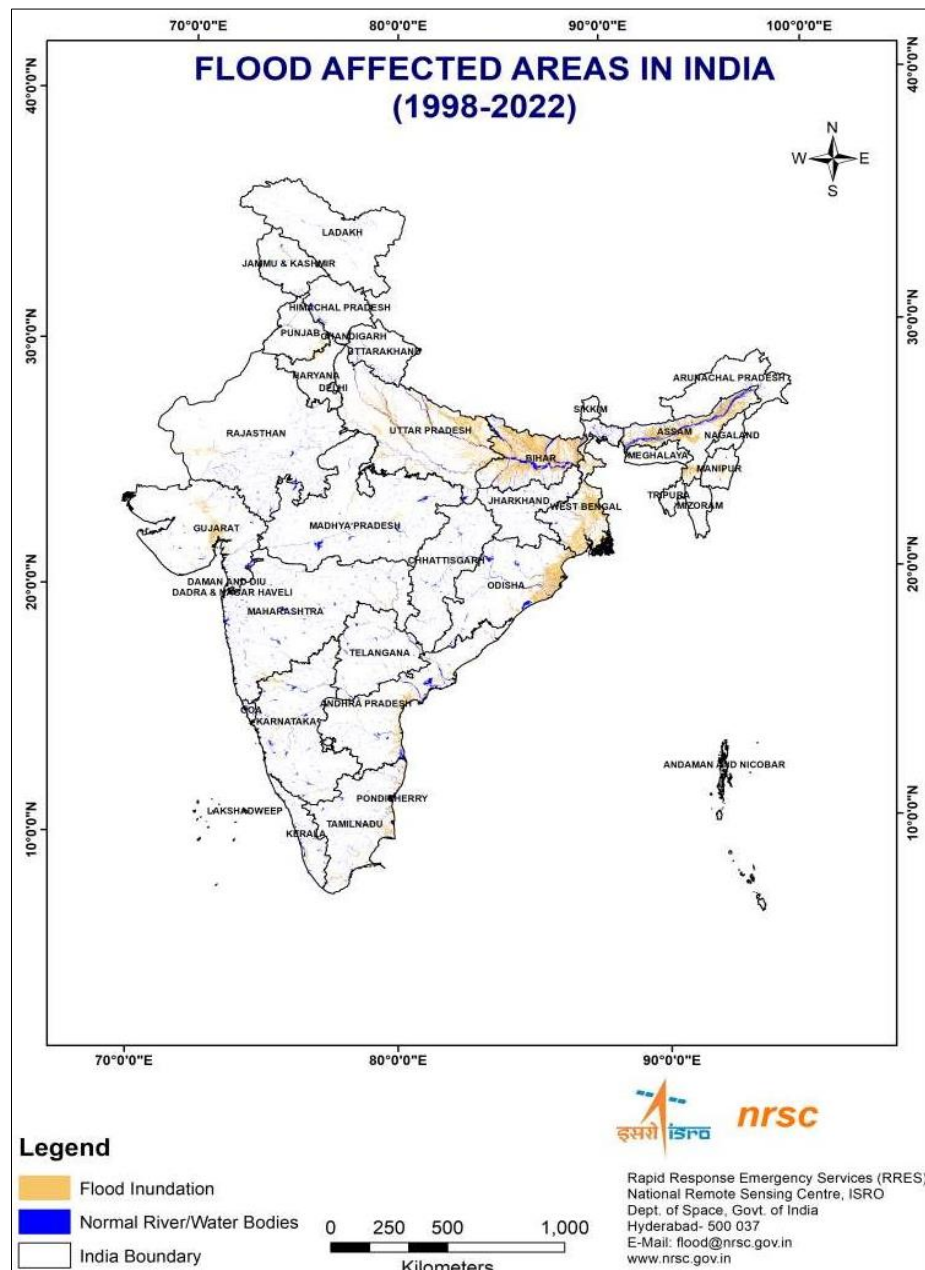


Figure 1:- Flood Affected areas in India.

(Source: - National Remote Sensing Centre (NRSC) Indian Space Research Organization (ISRO))

There are several causative factors for flooding in the country. Inadequate capacity of the rivers to contain the high flows brought down from the upper catchment (outside of India) due to heavy rainfall, leads to flooding. Area having poor drainage characteristic

gets flooded by accumulation of water due to high intensity of rainfall. Excess irrigation water applied to command area and increase in ground water level due to seepage from canals and irrigated field accentuate the problem of water logging, subsequently it will have impact on floods. Flooding is accentuated by erosion and silting of the riverbeds resulting in reduction of carrying capacity of river channel, leading to changes in river courses & obstructions to flow due to landslides, synchronization of floods in the tributary rivers and retardation due to tidal effects. With the increase in population and developmental activity, there has been tendency to occupy the flood plains, which has resulted in more serious nature of damage over the years. Because of the varying rainfall distribution, many a times, areas which are not traditionally prone to floods also experience severe inundation. Thus, flood is the single most frequent disaster faced by the country. Floods have different dimensions, inundation due to spills over the banks, drainage congestion due to poor drainage characteristics, erosion due to change in river course are the main causes for flooding.

Table 1:-Flood affected area (1998-2022)
Statistics at State level.

(Source: - National Remote Sensing Centre (NRSC) Indian Space Research Organization (ISRO))

Sl Nos.	State	No. of Districts Affected	Flood Affected Area (Ha)
1	Andhra Pradesh	24	738200
2	Arunachal Pradesh	5	3373
3	Assam	35	2464958
4	Bihar	38	3976861
5	Chhattisgarh	12	12029
6	Delhi	7	5848
7	Gujarat	16	517770
8	Haryana	9	67852
9	Jammu & Kashmir	10	43022
10	Jharkhand	2	2966
11	Karnataka	26	280156
12	Kerala	10	79377
13	Madhya Pradesh	30	210809
14	Maharashtra	20	233590
15	Manipur	9	88352
16	Meghalaya	2	8787
17	Odisha	23	1424313
18	Punjab	15	142692
19	Rajasthan	10	155144
20	Tamil Nadu	24	552010
21	Telangana	14	102318
22	Uttar Pradesh	72	2662942
23	Uttarakhand	2	7604
24	West Bengal	20	1969750
Total		435	15750723

West Bengal falls mainly in the Ganga Region as the southern and central parts of the State are covered by the river Ganga and its tributaries. Some of the northern parts are covered under the Brahmaputra Region through its tributaries like Teesta, Raidak, Torsa etc. The State has three distinct drainage basins namely Brahmaputra, Ganga, and

Subarnarekha. West Bengal is one of the prime flood prone States in the country with 42 per cent (37660 sq. km.) of its total geographical area (88752 sq. km.) being susceptible to floods. West Bengal, being located at the tail-end of the Ganga Basin, is a hydrologically subsidized State, which receives huge volume of transboundary water. However, the supply of this water is so skewed that West Bengal bears the brunt of flood during monsoon and faces shortage of water during the lean months. The floods of West Bengal have special characteristics. Heavy rainfall at origin or catchment areas of main flooding rivers of this State cause flood, but these catchment areas are mainly lying outside the State. West Bengal is flooded by water from adjoining states or countries. Along with flooding, various allied problems like bank erosion, drainage congestion and cyclonic disaster exacerbate the flood situation. Major contributing factors to floods in North Bengal region are heavy local rainfall, discharge from upper basin areas and also outfall condition in the neighboring countries. In South Bengal, floods become voluminous because of the shape of the catchment area, its steep slope starting from a high plateau area and sloping sharply down to a flood terrain near the outfall of limited capacity. Flood in deltaic region is a disaster, which can destroy the total environmental set up of the area. It causes riverbank erosion, depression of land, shifting of river course, river channel widening etc., due to its high discharge, elevation, volume, and duration. When flood water recedes, affected areas are often blanketed in silt and mud. The water and landscape can be contaminated with hazardous materials, such as sharp debris, pesticides, fuel, and untreated sewage. Residents of flooded areas can be left without power and clean drinking water, leading to outbreaks of deadly waterborne diseases like typhoid, hepatitis A and cholera.

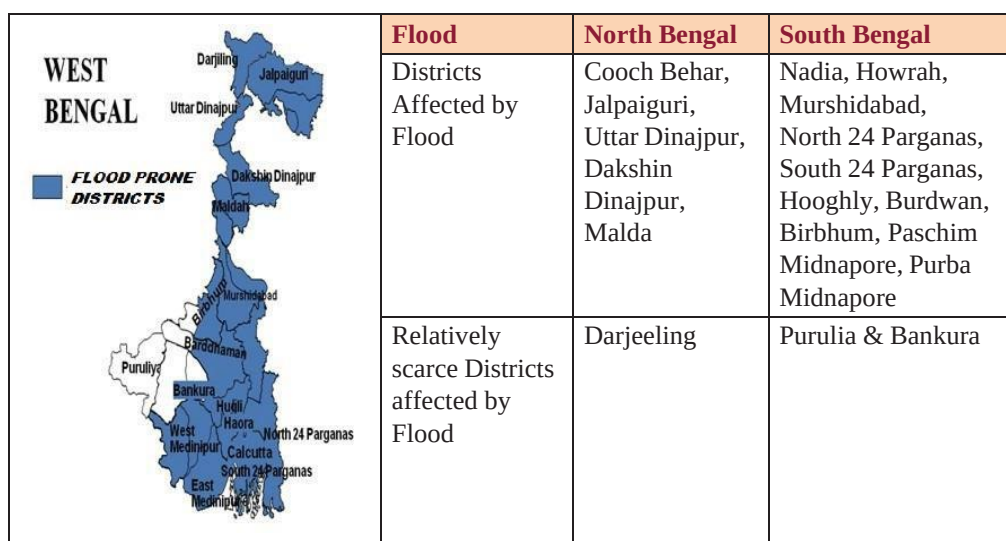


Figure 2:-Blue area depicts the flood prone districts of West Bengal

(Source: - CAG.gov.in <https://cag.gov.in>)

West Bengal being the lowermost riparian state of Ganga Basin and situated at the foothills of several Himalayan rivers of Brahmaputra Basin, the problem of flood management and drainage is quite acute here. Most of the rivers in the State originate from outside the State boundary and thus they are either of inter State or International category. The State has often witnessed destructive flood, even without any substantial rainfall within the geographical limits of its own. Along-with flood and water logging,

various allied problems like bank erosion, embankment breach, drainage congestion and cyclonic storm has often accentuated the flood disaster. The coastal areas along the Sundarban delta, which happens to be the largest delta of the world, often experience

high tidal surges resulting in severe erosion and inundation to the country sides. In a nutshell, West Bengal has about 42.5% of its geographical area as flood prone, happens to be one of the prime floods affected States in the country. The flood and water related disasters and associated problems in West Bengal has become almost an annual feature. Many parts of the State get onslaught of flood water almost every year resulting in severe loss to standing crops, cattle, and properties. Statistically, this flood fury has increased during the last two decades. To protect the countryside from flood ingress during peak monsoon and high tide, flood embankments are constructed along the vulnerable riverbanks. Those embankments constructed in various districts of the State in general and in the deltaic Sundarbans in particular, are used as prime communication links, particularly during the period of natural calamity for safe passage of people and relief materials. It virtually serves as vital lifeline to the affected areas during adverse situation. Disruption of such communication links by way of subsidence and sudden breach during flood creates disaster. Daily life in the affected areas get jeopardized as the areas become devoid of basic amenities of life. Factors such as intensity and duration of rainfall, sedimentation of riverbed, imprudent reservoir control, tidal lockage, obstruction, and encroachment in natural waterways play vital role in the occurrence of flood. Basin-wise study of flood factors and evaluation of flood hazards are indispensable for chalking out future effective plans for flood control and management measures. Accordingly, Irrigation & Waterways Directorate at the end of every flood season ritually brings out an Annual Flood Report incorporating the history of rainfall patterns of the monsoon season, district rainfall records, and major river gauge levels across the State, reservoir inflow-outflow and major flood events of the year. Throughout the year, overall average rainfall of the State is 15.1% below normal. The rainfall in the north is 6.2% less than normal while in the south, it is 23% below normal i.e., deficient. Significant incessant rainfall in frequent spells observed in the month of June for North Bengal while in August for South Bengal made few rivers to flow in high stages and as a consequence some damages had occurred. Few damages had also occurred at vulnerable spots of the coastal earthen embankments due to effect of Bhora Kotal synchronized with rain and easterly wind. However, the restoration works were well undertaken by the Department during the year 2022.

This study will investigate the hydraulic design of Storm Water Drainage system in Kamarhati area in terms of flow and design parameters from the Manhole to the outfall points using SEWERGEMS software.

1.2 Description of Study Area

Area (**Kamarhati municipality**) considered under this study falls under North 24 Parganas district which is in the southern part of West Bengal, of eastern India. North 24 Parganas extends in the tropical zone from latitude $22^{\circ} 11' 6''$ North to $23^{\circ} 15' 2''$ North and from longitude $88^{\circ} 20'$ East to $89^{\circ} 5'$ East. Barasat is the district headquarters of North 24 Parganas.

Kamarhati, situated at 22.67°N 88.37°E, is a municipality that encompasses several neighborhoods, including Belgharia, Ariadaha, and Dakshineswar. The Kamarhati Municipality is headquartered at Rathtala on B.T. Road. Geographically, Kamarhati is bounded by Khardaha and Panihati to the north, North Dum Dum to the east, Baranagar to the south, and the Hooghly River to the west. This strategic location makes Kamarhati an important urban centre in the region.



Figure 3:- Kamarhati ward Map (Study Area)

1.3 Research Gap

The design of hydraulic storm water drainage networks faces numerous challenges, including optimizing pipe sizing and material selection for efficiency and sustainability. Accurate and efficient hydraulic modeling techniques are needed for complex urban drainage systems. Climate change impacts must be considered in network design and performance. Green infrastructure, such as green roofs and permeable pavements, can reduce storm water runoff and improve water quality. Integrated storm water management systems combining grey and green infrastructure are crucial. Artificial intelligence and machine learning can optimize network design and operation. Efficient maintenance and rehabilitation strategies are essential for aging infrastructure. Land use changes, such as urbanization and development, affect network performance and design requirements. Advanced technologies like sensors and IoT can enhance monitoring and control. Finally, comprehensive, and integrated approaches considering multiple objectives (flood control, water quality, environmental sustainability) are vital for effective storm water drainage network design. Addressing these challenges can lead to more resilient, sustainable, and efficient urban drainage systems.

1.4 Objective of the Study

The objective of this research work is to create a holistic flood resilience solution for Wards in Kamarhati Municipality. The proposed interventions, as outlined in this report, encompass hydraulic network improvements, and the. These measures collectively seek to alleviate waterlogging issues, providing a sustainable and effective solution for the well-being of the community in the specified wards. The report is now presented for departmental review, seeking valuable feedback and guidance to refine and advance the proposed flood mitigation strategies. Based on the information presented, techno economic appraisal concludes that this is necessary for the benefit of people and economy of the area. Thus, the socio-economic benefits of this studies are large. Hence, this is feasible technically, socially, and economically. The recommended measures for short-term, mid-term and long-term are covered. In this analysis vulnerable flood zone have been identified considering 1 in 2-year and 1 in 5-year return period. Vulnerable drain length in different wards is also identified considering 1 in 2 year and 1 in 5-year return period rainfall event.

1.5 Brief Methodology of the Study

The layout map for the whole drainage System in relation to Kamarhati Municipality in the North 24 Parganas District of the State of West Bengal has been studied for this study. The required data for the design have been taken from the available topo-survey drawing of the study area.

The model has been prepared by assigning the proper input parameters to the different element such as the pipes are given the Input values length, trial diameter (based on experience and engineering judgement) and Roughness co- efficient, import topographic data and create a digital elevation model (DEM). Use the "Runoff" tool to calculate stormwater runoff from each sub catchment. Run the "Hydraulic" tool to simulate stormwater flow through the network The model is simulated and checked against the relevant CPHEEO clauses and modified if found any error/warning.

The whole network is then sub-divided into Catchments based on some criteria and have been re-modified and re-simulated to get the final design.

1.6 Possible Outcome of the Study

The following are the research outputs,

- To integrate and develop an optimized Drainage network in the study area.
- To design a drainage network hydraulic model.
- Analyzing the existing storm water drainage system, water bodies / water ways in the study area using standard computer modelling software and after consultations with various stakeholders providing realistic technical solutions that are technically, economically, socially, environmentally, and institutionally acceptable to the community.
- To maintain optimum/stipulated flow parameters in the entire system.

1.7 Outline of the Thesis

The thesis consists of six chapters.

Chapter 1 describes the overview of the research study; Chapter 2 contains literature review. Chapter 3 illustrates the study area and the research methodology. Chapter 4 reveals the governing equations and the relevance of numerical model Sewer GEMS for the design and Analysis of the Drainage Network. Chapter 5 presents data analysis and result. Finally, the summery of the research study describes in conclusions and recommendations with the future scope of the study which are provided in chapter 6. References are given at end of the dissertation.

1.8 Brief Description of the project

Bay of Bengal is often subjected to natural calamities like cyclone, heavy rainfall, storms etc. The Subdivision is thickly populated and there has been unplanned development in the past. Drainage problems are a day-to-day affair during rainy season in the area. Many parts of the area get submerged during rainy season and it takes hours and even days together for passage of the accumulated flood water from the locality. Recent years have seen an increased frequency of localized flooding. To avoid this situation Govt. of West Bengal has decided to prepare drainage master plan.

The main objectives of the present work are: To prepare a GIS based comprehensive Drainage Plan and Detailed Project Report for implementation of comprehensive storm water drainage system within Barrackpore Subdivision consisting of the Kamarhati Municipal areas.

The overall purpose of the Project is to prepare a comprehensive Drainage Plan and Detailed Project Report for implementation of comprehensive storm water drainage system within Kamarhati Municipality areas.

To solve water logging problem as well as pollution abatement of major canals/khals. The entire study will have an integrated approach to Urban Watershed Management.

The specific objectives of the study are determined as:

Investigation about the primary causes of waterlogging along with their individual and cumulative impacts. Analysis of the present condition of drainage system of Kamarhati and identification of the spatial-temporal patterns of waterlogging. Assessment of the impacts of waterlogging on the socio-economic environment of the areas. Formulation of a sustainable management strategy to tackle the problem of waterlogging. Redesign the existing drainage system. Design the new drains considering integrated approach to Urban Watershed Management.

Area considered under this project falls under North 24 Parganas district which is in the southern part of West Bengal, of eastern India. North 24 Parganas extends in the tropical zone from latitude $22^{\circ} 11' 6''$ North to $23^{\circ} 15' 2''$ North and from longitude $88^{\circ} 20'$ East to $89^{\circ} 5'$ East. Barasat is the district headquarters of North 24 Parganas. North 24 Parganas is West Bengal's most populous district and the second most populated district in the

whole of India. The river Ganga flows along the western border of the district.

Kamarhati is a city and a municipality of North 24 Parganas district in the Indian state of West Bengal. It is a part of the area covered by Kolkata Metropolitan Development Authority (KMDA).

As per gazette notification of 1st. August 1899 Administrative boundaries was in west Hooghly River, in north- Border of Panihati Municipality, in east- border of North Dum Dum Municipality and in south- border of Baranagar Municipality. Boundary Kamarhati municipality in east - North Dum Dum Municipality, in west - Ganges River, in North - Panihati Municipality, in south - Baranagar Municipality. Kamarhati municipality is one of the municipalities falling under our study area under Barrackpore subdivision. The municipality comprises of 35 nos. of wards. Kamarhati municipality divided into two parts – 7 wards lying on the eastern side of the railway tract and the remaining 28 nos.in the western side. The municipality is bounded by Baranagar municipality in the south, Panihati Municipality in the North, North Dum Dum Municipality in the east and river Hooghly in the west. The main canal passing through the municipality is a part of the Bagjola canal. Another canal runs along the boundary of Kamarhati Municipality and Baranagar municipality is the Udaipur Canal. Besides these canals, a no. of nayanjalis is present in the municipality where untreated or partially treated sewage mixed with storm water is disposed.

Table 2:-Statistical information

1	Area (in sq. K.M.)	10.96 sq. k.m.
2	Population (Census 2011)	331163
2.a	Density of Population	30215.602/Sq,Km
2.b	Male	53.59 %
2.c	Female	46.41 %
3	Percentage (%) of Literacy	75.68 %
3.a	Male	42.65 %
3.b	Female	33.03 %
4	No. of House Holds	39122 Nos.
5	Population under BPL	11.72%
6	GPS COORDINATES	DD COORDINATES: - 22.67111 88.37472
		DMS COORDINATES: - 22°40'16.00" N 88°22'28.99" E

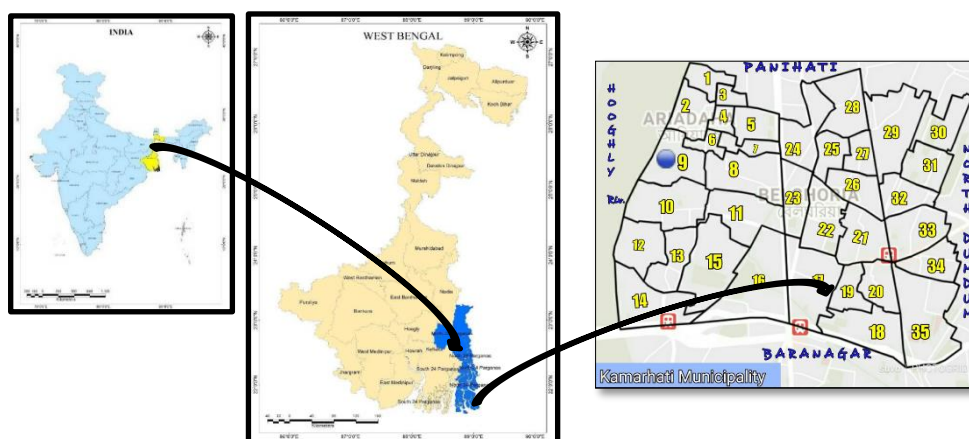


Figure 4:- Study Area

This study will investigate the hydraulic design of Storm water drainage Network system in Kamarhati area in terms of design parameters as per the CPHEEO Manual on Storm Water Drainage Systems using Sewer GEMS Software

2 LITERATURE REVIEW

A literature review is a comprehensive and critical analysis of existing research on a specific topic or issue, providing a thorough overview of the current state of knowledge in the field. It synthesizes and summarizes the findings of previous studies, identifying patterns, themes, and debates, while also evaluating the methodological quality and limitations of previous research. By demonstrating a deep understanding of the theoretical and conceptual frameworks that underpin the research, the literature review sets the stage for the research question, hypothesis, or objectives, and provides a rationale for the current study and its significance. Ultimately, a well-crafted literature review serves as a solid foundation for the research, showcasing the researcher's expertise and preparing the groundwork for the investigation to come.

Lee, E.H., et al. (2019), discussed about a new reliability index for urban drainage systems that incorporates three crucial factors: flood volume, nodes, and damage. The index aims to prioritize both structural and nonstructural measures for improving urban drainage systems in the face of extreme rainfall events. Synthetic rainfall data are generated for simulations, and a Distance Measure Method is employed to calculate a dimensionless reliability index. The study applies this index to the city of Jeongup, Korea, revealing reliability values for flood volume, nodes, and damage. The proposed index provides a comprehensive evaluation of urban drainage systems, considering the impact of failure, particularly in terms of flood damage. The study underscores the importance of such a multidimensional reliability assessment and suggests potential applications in urban planning, design, and management. Additionally, the research highlights the need for future studies to establish appropriate weightings for the index components.

Haque, M. M., et al. (2012), discussed about the crucial need for an integrated drainage system design in municipalities of Bangladesh, with a focus on the Akhaura municipality as a case study. The country's susceptibility to natural calamities and its rapid economic growth underscores the importance of effective stormwater management. The paper advocates for the adoption of advanced GIS tools to design sustainable drainage systems scientifically, accurately, and rationally. The study reveals existing challenges in Akhaura, including drainage congestion and waterlogging, emphasizing the lack of a planned and adequate drainage network. The project conducted under the Department of Public Health Engineering aimed to design an integrated water supply, drainage, sanitation, and solid waste management system for municipalities. The conclusion emphasizes the importance of preserving natural drainage systems, highlights the creation of a drainage model for Akhaura, and advocates for the continued use of modern tools like GIS for planning and designing drainage systems to benefit society in the face of urban development challenges.

SENTHAMIZHSELVAN T (2020), discussed in technical terms, the project focused on designing an efficient sewerage network and stormwater drainage system for Karaikal town. The assessment of the current sewerage and drainage system involved utilizing water supply and population data, rainfall data, and a coefficient of runoff to estimate the quantity of wastewater and stormwater. The rational method was applied to design the storm drain. AutoCAD was used to create maps of the sewerage network and stormwater drainage. The technical conclusions indicate challenges in Karaikal's sewage distribution and stormwater drainage, including a high percentage of open

drainage networks and water stagnation due to improper maintenance. Calculations yielded a total sewer line length of 8731 m with a diameter of 700 mm and a calculated discharge quantity of 0.576 m³/s. The distribution factor exceeded 500, leading to the direct discharge of wastewater into the Arasalar river. The technical aspects also include the drawn maps of the sewerage and stormwater drainage network system and a preliminary cost estimate.

Mishra, S., et al (2020), discussed in technical terms, the presented project focuses on the design of a stormwater drainage system for a city, aiming to address flood-prone areas and mitigate the impact of waterlogging on stakeholders. The storm drain system is crucial for draining excess runoff and groundwater from various surfaces such as streets, parking lots, and roofs. The paper emphasizes the need for a sustainable and economic stormwater drainage system in India, considering the increasing incidents of flooding, especially during monsoons. The technical conclusion underscores the importance of innovative practices to reduce runoff at the source for a sustainable drainage system. Climate change impacts, including trends of prolonged periods without rain followed by sudden excessive rainfall, necessitate resilient and adaptive stormwater management strategies. Additionally, the conclusion emphasizes the significance of regular operation and maintenance for ensuring the functionality of the drainage system, contributing to the prevention of loss of lives and property during extreme weather events.

Ress, L. D., et al (2020), this study examines the impact of urbanization on hydrologic response in small watersheds, considering factors beyond impervious surfaces. The research focuses on the Rocky Branch Watershed, analyzing rainfall and stormflow data from two subcatchments with varying impervious areas and drainage densities. The results show that Impervious areas increase runoff volumes, but storm sewer densities accelerate hydrologic responses, reducing lag times. Drainage densities based on open channels underestimate conveyance in urbanized watersheds. Road networks and storm sewer systems significantly impact stormwater arrival times and flood risk. Including storm sewer and urban drainage system densities in analyses improves understanding of urbanization's hydrologic impacts and flood risk mitigation. The study highlights the importance of considering multiple factors in urban hydrology and suggests that reframing the focus from solely impervious surfaces to a more comprehensive approach can lead to more effective flood risk management and mitigation strategies.

Santhanam, N., et al. (2013), Discussed The study conducted in the Palayam area of Calicut City in Kerala, India, emphasizes the critical need for efficient stormwater management in urban environments, particularly in developing countries like India. The existing stormwater drainage infrastructure is often inadequate, leading to environmental threats and potential damage during heavy storms. The study employs the Rational Method for stormwater drain design, which considers various factors such as catchment basin characteristics, land use patterns, soil cover, and infiltration details. The Rational Method has proven effective in determining the runoff coefficient ('C'), a crucial parameter in stormwater design. The runoff coefficient calculation involves careful consideration of catchment basin conditions, and in this study, meticulous efforts were made to accurately estimate these parameters. The findings indicate that

existing drainage sections in the study area are insufficient in numerous locations to handle the runoff effectively, leading to inundation issues. One key observation is that the inundation problems are often caused by blockages in the drains at various points. The study underscores the importance of regular maintenance of existing drains to prevent blockages and ensure their proper functioning. Additionally, in areas where space constraints pose challenges, the study suggests considering the replacement of trapezoidal sections with existing rectangular sections to optimize the drainage system's efficiency. The technical conclusion emphasizes the significance of adopting a rational approach to stormwater management, incorporating accurate data collection and analysis for designing effective drainage systems. The study not only identifies shortcomings in the existing infrastructure but also provides practical recommendations for improvements, highlighting the need for ongoing maintenance and potential modifications in specific drainage sections to enhance overall system performance.

Nazif, S., et al. (2013), this study addresses the critical issue of the impact of climate change on urban drainage systems, particularly in the northeastern part of Tehran, Iran. Using a comprehensive system approach to urban watershed analysis, the research employs a multicriteria optimization model to select the best management practices (BMPs) for flood management in the face of changing climate conditions. The optimization model considers three key objective functions: maximizing the reliability of the drainage system, minimizing flood damages, and minimizing BMP costs. A novel reliability index is introduced to evaluate system performance, taking into account both flooding volume and duration. The study utilizes the nondominated sorting genetic algorithm II (NSGA II) and data envelopment analysis (DEA) in a two-stage multicriteria decision-making process to select the most efficient alternatives. The case study involves simulation of the urban watershed using the stormwater management model (SWMM) and considers future climate scenarios based on the Hadley Center Coupled Model, version 3 General Circulation Model (HadCM3 GCM). The results indicate an increasing risk of flooding due to the projected increase in extreme rainfalls, emphasizing the need for optimal BMPs to enhance system performance. The study highlights the sensitivity of system reliability and flood damage costs to changes in BMP development costs and application schemes. The selected alternative, emphasizing the implementation of BMPs, particularly detention ponds, demonstrates significant improvements in drainage system performance. However, the study acknowledges the uncertainties in climate change predictions, including different global climate models (GCMs) and their limitations. This emphasizes the importance of a probabilistic approach in implementing watershed infrastructure improvements, considering the uncertainties in climate change predictions. The study underscores the need for risk-based flood management strategies, including ensemble modelling, to account for different climate change patterns and realizations. The consideration of 3 (Three) sources of uncertainty—input data, model structures, and parameter estimation—is highlighted as a crucial aspect in climate change studies, similar to flood risk assessment. Overall, the research provides valuable insights into the complexity of

climate change impacts on urban drainage systems and the necessity for adaptive, probabilistic approaches in planning and management.

Abd-Elhamid et al. (2020), demonstrates the significant impact of urban growth on storm water drainage systems, emphasizing the crucial role of runoff coefficients in system design. The assessment conducted using Hyfran, StormCAD, and GIS models in three zones in Dammam, Kingdom of Saudi Arabia, reveals that changing runoff coefficients due to urbanization affects various design parameters such as outfall discharge, velocity, lag time, and construction costs. The developed empirical equation successfully predicts maximum discharge for different catchments, validated through a case study in South Korea. The findings underscore the hydrologic implications of urban growth, particularly the increase in impermeability leading to higher flood risks. The StormCAD software proved effective in assessing the impact of varying runoff coefficients on discharge, velocity, lag time, and cost. Additionally, the study highlights a two to threefold cost increase in storm water drainage systems with rising urbanization, necessitating a careful consideration of the relationship between cost and runoff coefficient for decision-makers and designers. By integrating land use change models with hydrological models, this research proposes a valuable tool for evaluating the impact of urban growth, essential for watershed management, water resource planning, and flood management in the context of sustainable development. The study recommends the incorporation of low-impact development systems, such as swales, bioretention, and constructed wetlands, to mitigate the adverse effects of urban growth on storm water drainage systems. Overall, the technical conclusions stress the importance of proactive measures and informed decision-making in managing the hydrological impact of urbanization on storm water drainage networks.

Zinabie, A., et al. (2020), this study reveals significant deficiencies in the existing storm water drainage system of the studied area, exacerbated by urbanization-related challenges such as increased impervious surfaces, altered drainage patterns, and blockages caused by silt and garbage. The evaluation of hydraulic performance using spatial analyses with Arc GIS, Bentley FlowMaster, Google Earth Pro, and AutoCAD highlights a critical need for immediate rehabilitation or reconstruction of the drainage system. The measured depths and widths of drainage channels in sub-catchments 6, 7, and 8 indicate substantial increases, signifying a compromised drainage capacity. The design discharge calculations, based on a 25-year return period, further emphasize the inadequacy of the existing drainage system to handle current runoff. The disparities between existing and design discharges underscore the urgent need for improvements in the integration of road and drainage structures. Recommendations include the integration of solid waste management systems to prevent blockages and overflow, proper maintenance of drainage structures, and suitable measures to ensure the sustainable functioning of both roads and storm water drainage systems. The study concludes that the current drainage system suffers from extensive defects, necessitating immediate attention and comprehensive rehabilitation. Additionally, there is a recognition of inadequate coverage, poor physical condition, and ineffectiveness in the

development of the drainage system. Within the town. The findings emphasize the importance of considering design capacities that align with the increasing urbanization and runoff challenges for sustainable storm water management.

Kummamuru et al. (2015), focuses on urban stormwater management in a specific region of Vellore town, considering the challenges posed by increased imperviousness due to urbanization. Three storm drainage system alternatives were proposed: construction of a new underground circular sewer system (Alternative 1), repair and expansion of existing surface sewer system (Alternative 2), and construction of swales (Alternative 3). The evaluation concluded that, while Alternative 2 was found to be economical, Alternatives 1 and 3 were considered more efficient and aesthetically preferable. Urbanization leads to changes in flow patterns, increased runoff volumes, and higher peak flood discharges, necessitating effective stormwater drainage systems. The inadequacies of existing systems under higher levels of urbanization highlight the importance of proper urban water management. The study identifies two major types of elements in a typical urban drainage system: location elements (water storage, treatment, use, and wastewater treatment) and transfer elements (channels, pipelines, storm sewers, sanitary sewers, and streets). The storm sewer system alternatives presented in the project involve repair and expansion of existing surface storm sewers, construction of an underground circular storm sewer, and construction of swales. The choice among these alternatives depends on factors such as stormwater volume, available layout area, economic considerations, and aesthetic preferences. Notably, vegetated swales are recognized for their potential in reducing peak flows and pollutant removal from storm runoff. In conclusion, the technical findings stress the importance of selecting a stormwater drainage system that balances efficiency, aesthetics, and economic considerations. The study provides valuable insights into the challenges of urban water management and offers alternative solutions to address the specific needs of the studied urban region in Vellore town.

Satyaji Rao et al. (2015), focuses on Storm Water Management Model (SWMM) was employed to simulate stormwater floods in the existing drainage networks of Patna and Chennai urban areas. Input data for the model were extracted from various sources and GIS maps, with catchments delineated using Digital Elevation Model (DEM) and flow direction within the drainage network. Despite considering the original designed dimensions of the drainage networks without any blockages, the simulations revealed inadequacies in handling runoff, particularly for a two-year return period rainfall in both urban areas. The micro-level drainage systems in Patna and Chennai were found to be deficient, with limited connectivity to the macro-level drainage system. The maintenance of the conveyance system was reported as poor, exacerbated by the disposal of garbage, polythene bags, and waste from markets directly into the drains. The study emphasizes the urgent need for awakening public awareness and addressing the poor condition of the drainage systems through renovation and proper maintenance. Furthermore, the existing design of the drainage network proved insufficient to handle rainfall events with a two-year return period. The drainage simulations provided valuable information for preparing surface inundation maps, aiding in the identification of flood-prone areas. This information is crucial for implementing Best Management Practices (BMP), including the design of sumps or ponds, and determining pump capacities. In conclusion, the technical findings underscore the importance of addressing the deficiencies in urban drainage systems, emphasizing the need for comprehensive renovation, improved maintenance practices, and community involvement to mitigate stormwater flood risks.

Bastia et al. (2021), emphasizes the critical importance of strategic stormwater management in rapidly urbanizing areas, focusing on the metropolitan city of Lucknow, India. The absence of a robust stormwater management policy at the state level has led to vulnerabilities in urban water systems, manifesting in low infiltration rates, increased peak river discharge, and recurrent floods. In contrast to conventional centralized approaches, the study investigates the efficacy of onsite and decentralized stormwater infiltration facilities, drawing inspiration from successful implementations in higher income countries. Through Gridded ModClark rainfall-runoff modeling in the Kukrail river basin, a significant drainage basin in Lucknow, the study evaluates the physical viability of infiltration facilities. The HEC-HMS model, integrated into the Watershed Modeling System (WMS), simulates stormwater runoff under various scenarios of land use and rainfall intensities. The introduction of onsite infiltration facilities as part of land use measures demonstrates a substantial reduction (48% to 59%) in peak discharge. Correlation analysis and multiple regression contribute to understanding the intricate relationship between rainfall and runoff. Furthermore, the study underscores the significant reduction in stormwater runoff achieved through decentralized infiltration systems. The conclusion advocates for the adoption of such non-conventional, decentralized stormwater management practices in rapidly urbanizing cities of developing nations, where conventional systems prove inadequate. The need for mainstreaming these practices into vulnerable communities is emphasized, particularly in the context of complex stormwater challenges in developing cities. The study contends that replenishing surface and groundwater through natural processes is essential for maintaining the geo-hydrological balance, emphasizing the threats posed by urbanization and climate change. Conventional flood management systems are deemed insufficient, prompting a call for learning from decentralized systems adopted in developed countries. However, the study acknowledges the necessity of tailoring these practices to local conditions, incorporating advanced scientific knowledge, and encouraging further research to address challenges in conventional stormwater management systems. In conclusion, the technical findings advocate for the implementation of decentralized stormwater management strategies as a crucial element in mitigating the adverse impacts of urbanization and climate change on waterbodies in developing urban areas like Lucknow.

Vishwakarma, R. K., et al. (2023), carried out a meticulous evaluation of urban stormwater management sustainability in six Indian cities, categorized as Tiers I and II. Utilizing key indices proposed by the Government of India, the study spans a decade from 2010 to 2020, assessing individual indices and an overall sustainability index. Among Tier I cities (Delhi, Mumbai, Chennai), significant challenges in natural drainage, permeability, water logging, flood moderation, and rainfall intensity are observed, with poor compliance. Tier II cities (Varanasi, Chandigarh, Roorkee) show marginally better results, with Chandigarh standing out as the most sustainable. The study underscores the critical need for stormwater treatment and pollution control measures. Chandigarh emerges as the most accomplished city, highlighting the dynamic nature of urban development and the necessity for adaptive solutions. The research serves as a valuable resource for policy refinement, climate-adaptive strategies, and fostering resilient and environmentally responsible urban environments. The findings emphasize the imperative requirement for sustainable stormwater management in rapidly urbanizing regions.

Xu et al. (2014), focuses on quantifying non-stormwater entries into storm drains in a Shanghai downtown area using a water flow balance approach. Analyzing data from 2008

to 2011, it reveals severe sewage connections and misconnections between surfaces water and storm drains, leading to frequent non-stormwater pumping discharges. The methodology estimates inappropriate sewage flow, groundwater infiltration, and river water backflow. Findings indicate that approximately 51% of total sewage flow results from inappropriate discharge, and effective pollution control measures involve end-of-storm pipe interceptor sewers. Misconnections, identified through continued pumping events, suggest the need to repair surface water backflow. The developed water flow balance approach provides a valuable tool for estimating non-stormwater flow entries, guiding pollution control activities, and enhancing the efficiency of storm drains in managing floods during storm events.

Tomar et al. (2021), presents an integrated approach using remote sensing, GIS, and field surveys to identify and predict urban flood-prone areas, with a focus on Delhi's Yamuna River National Capital Territory (NCT). The methodology considers the inefficiencies in the urban drainage system as a cause of flooding, supplementing existing forecasting models. The approach proves effective for disaster risk mapping and management, offering a valuable tool for early warning, risk assessment, and relief planning. By establishing a baseline framework and utilizing a linear regression model for precipitation and gauge level records, the study provides essential data for flood risk reduction and decision support in urban planning. The findings emphasize the need for improved construction practices, site suitability analysis, and budgeting for flood-affected areas.

Ramachandran et al. (2019), focuses on the critical issue of managing stormwater in the face of climate uncertainty, particularly in Chennai, a major coastal city in India prone to frequent flooding. The research evaluates the current state of stormwater drains in the flood-prone Velachery zone and proposes mitigation measures to enhance resilience. Using IPCC CMIP5 models and Representative Concentration Pathways, the study develops future climate change scenarios for the city. By analyzing daily rainfall data from 1975 to 2015, the study generates Intensity-Duration Frequency (IDF) curves for various return periods under current and future climate scenarios. The storm drainage network is delineated using DGPS survey, and integrated hydraulic and hydrological modeling is conducted to assess the flood carrying capacity. Vulnerable hotspots are identified, and mitigation measures are recommended. The observed IDF curves indicate a significant increase in rainfall intensity, with a 162% rise from a 2-year to a 100-year return period. Comparisons between observed and projected IDF curves under changing climate scenarios reveal a 12% increase for a 2-year return period and an 87% increase for a 100-year return period. The study identifies critical flood-prone areas, particularly near Velachery Lake and Pallikarani marshland, highlighting nine hotspots out of 234 nodes. These hotspots experience inundation for nearly 24 hours during storm events. The study recommends routine maintenance, obstruction-free road construction, and redesigning storm drains. Increasing the width of Okkiam Maduvu weir and channel improvements are suggested to enhance flood management. The holistic approach integrates climate knowledge with urban storm drainage network analysis to address pluvial flooding. The study successfully combines scientifically reliable climate information with hydrologic and hydraulic models, supported by field data and actual flow measurements. While the study uses high-resolution DEM, it suggests the desirability of even finer resolution for better results. Additionally, the incorporation of real-time flood forecasting and Low Impact Development practices in future studies is recommended for a more accurate and effective flood management system.

Ferguson, C., et al. (2020) explores the potential of catchment-scale Natural Flood Management (NFM) interventions, such as in-channel woody debris and catchment afforestation, in managing water levels in downstream urban watercourses. Using a coupled modeling approach, the research evaluates the impact of NFM on drainage outfalls during different storm scenarios. Results suggest that NFM interventions, particularly during frequent storm events, can significantly reduce the time of outfall inundation, offering benefits to downstream drainage performance. The study emphasizes the importance of considering the rural-urban interface and complex interdependencies in achieving effective water-level management strategies, especially in the context of climate change, urban development, and aging drainage infrastructure. The case study underscores the significance of considering the "rural-urban" interface for understanding urban drainage response. Elevated river levels negatively impact drainage performance in a housing estate, emphasizing the importance of managing the interplay between outfalls, storm severity, and upstream interventions. The study reveals that Natural Flood Management (NFM) interventions can facilitate free discharge at outfalls, but their effectiveness is influenced by complex factors. While mitigating downstream water levels is crucial, the key finding is that desynchronizing rural and urban responses leads to substantial reductions in surface flood volumes. Delays in rural response, even slight ones, show consistent benefits, particularly during severe storms. However, this should be weighed against increased fluvial flood risk. The drainage benefits are modest, suggesting limited alleviation of significant surface flood risk, but potential mitigation of nuisance flooding. The study acknowledges that realizing benefits requires substantial changes in catchment land management practices. Further research could enhance feasibility by incorporating sophisticated opportunity mapping and engaging landowners. A catchment-wide implementation strategy might extend to other interventions but cost and practicality must be evaluated against potential benefits. While reducing downstream nuisance flooding alone may not justify large-scale interventions, the study suggests that NFM could bring broader benefits, including ecosystem, biodiversity, and water quality improvements, in addition to enhancing surface drainage outfalls' effectiveness.

Katti et al. (2015), introduces Bentley SewerGEMS V8i as an advanced modeling and design software application for sewage networks, emphasizing its efficiency in accomplishing projects with speed and cost-effectiveness. This multi-platform solution, integrating GIS, CAD, and Stand-Alone capabilities, offers a fully dynamic approach for sanitary and combined sewer modeling. The software provides comprehensive hydraulic design features, including transit and total flow computations, pipe diameter/slope modeling, and advanced graphic representation based on AutoCAD technology. The efficiency of SewerGEMS V8i is highlighted by its time-saving tools for labeling, automatic data updates, and pipe diameter calculations, making it particularly suitable for designing large sanitary sewer networks. The output includes detailed maps and drawings in a widely accepted ".dwg" file format. Overall, SewerGEMS V8i stands out as a valuable tool for sewage system design, ensuring accuracy, speed, and versatility in the modeling process.

Joshi, D., et al. (2022), focuses on addressing challenges and opportunities for improved stormwater management practices in urban and developing areas in India, considering the adverse effects of urbanization and climate change on natural hydrological regimes. Emphasizing the need for effective drainage systems, the study presents various stormwater management technologies, with a particular focus on green roofs. The green roof technique proves to be sustainable, mitigating the impacts of rapid urbanization and

climate change by retaining stormwater, reducing air pollution, providing habitats, increasing roof lifespan, and offering energy savings. Other techniques discussed include permeable pavements, bioswales, bioretention basins, and constructed wetlands. In the case of Shahapur, a developing area, implementing these techniques is recommended to maintain the natural hydrological cycle and address water scarcity issues, showcasing the potential for environmentally friendly stormwater management approaches.

Shah, J., et al. (2019), the implementation of the Smart City mission in India, focusing on optimizing city functions through smart technologies, emphasizes the importance of integrating such technologies into stormwater drainage infrastructure. This paper explores studies conducted in Gujarat, showcasing the significance of efficient stormwater management for preventing economic losses, environmental impacts, and potential loss of life. With rapid urbanization leading to increased surface runoff, the use of smart technologies, including software like StormCAD and GeoSWMM, plays a crucial role in analyzing and designing effective stormwater drainage networks. Additionally, the integration of geographical information systems (GIS) further enhances drainage

network management. The findings highlight the need for proper stormwater management to support green infrastructure, emphasizing sustainability and the utilization of advanced techniques for urban development. Integrating drainage networks with natural features like lakes proves effective in reducing waterlogging issues. Overall, the study underscores the importance of smart technologies in addressing the complex challenges associated with stormwater drainage in the context of urban development and sustainability.

Khan, A. A., et al. (2014), deals with the case study on Raipur city in India highlights the pressing issues of unorganized drainage patterns and poor sewage systems, leading to flooding and degradation of natural water bodies. The municipality's efforts to retrofit existing infrastructure by interlinking stormwater drains with lakes show a promising approach. The integration of drains with lakes not only prevents flooding but also enhances water quantity, provides recreational opportunities, and restores ecosystems. Challenges include limited data, uncontrolled urban expansion, and legal issues. Despite obstacles, the city's focus on sustainable stormwater management demonstrates the need for comprehensive urban drainage and sanitation plans in parallel with infrastructure development, especially in areas with natural water bodies.

Raval, S. K. (2018)., discussed about the rapid urbanization and growth of cities necessitate effective stormwater disposal systems. This note focuses on the assessment and augmentation of the stormwater drainage network in Ahmedabad, particularly in the urban town of Bopal. The design considers rainfall data from the past 20 years, applying the Rational Method and accounting for 60% of the impervious area. The outfalls are directed to Sarkhej Lake, eventually meeting the Sabarmati River. The importance of preventing rainwater escape to the ocean is highlighted, emphasizing the need for sustainable stormwater management. The note underscores the role of urban hydrology in addressing water-related challenges, especially in the context of urbanization's impact on local environments. It emphasizes the significance of effective planning, flow path management, and the use of performance indicators for urban storm drainage to mitigate issues like flooding and enhance water quality. The design considerations emphasize proper sizing of pipes and slopes for optimal stormwater management.

Rentachintala, L. R. N. P., et al. (2022), discussed about urban stormwater management

faces significant challenges due to rapid urbanization, climate change, and alterations in land use and drainage infrastructure. Various approaches such as Sustainable Urban Drainage Systems (SUDS), Low Impact Development (LID), Best Management Practices (BMP), Water Sensitive Urban Design (WSUD), and Sponge City Programmes (SCP) are being adopted globally. The review emphasizes the need for detailed studies on urban hydrology, evaluation of precipitation trends, establishment of region-specific rainfall-runoff relationships, and consideration of key drivers impacting urban stormwater management. Barriers to understanding peak flows and uncertainties in integrated urban hydrologic models need attention. The review also highlights the emerging area of stormwater reuse and stresses the urgency of assessing the impact of climate change on precipitation in urban environments. The development of realistic regional climate models, real-time monitoring, periodic supervision of standards, and the application of IoT, AI, and ML for resilient stormwater management are identified as crucial aspects for future research and implementation. Overall, the integration of sustainable and resilient measures, along with real-time governance, is essential for successful urban stormwater management.

Mugume et al. (2015)., emphasizes the importance of building resilience in urban drainage systems to address a wide range of threats contributing to urban flooding, including structural failures like equipment malfunction, pipe collapse, and blockages. The study introduces a Global Resilience Analysis (GRA) approach to evaluate system performance under various failure scenarios. Resilience is defined as minimizing the magnitude and duration of service failure under exceptional conditions. The research suggests that current hydraulic reliability-based approaches may be insufficient, and the GRA methodology offers a promising tool to assess system resilience comprehensively. The study concludes that building resilience in urban drainage systems requires explicit consideration of different failure modes and calls for investments in both inherent system properties and asset management strategies.

Harsha, V. (2022)., emphasizes the urgent need for Indian cities, particularly in the face of rapid urbanization and increasing climate change-induced flooding, to adopt efficient climate change adaptation (CCA) strategies. Despite India's vulnerability to climate hazards, the focus has primarily been on mitigation, and urban flooding remains a critical issue. The paper provides a macro-level framework for developing robust CCA strategies, highlighting flood impacts, vulnerable districts, and crucial indicators. While the Indian government has initiated adaptation efforts, major challenges include a lack of robust policy frameworks, insufficient climate-resilient infrastructure, and funding gaps. The study advocates for an interdisciplinary approach, breaking traditional boundaries, and mainstreaming adaptation strategies into sustainable planning processes to effectively address the impacts of climate change, especially in the context of urban flooding.

Kamuni et al. (2023)., explores sustainable and cost-effective drainage design solutions for an urban road scenario, evaluating alternatives based on the Modified Rational Method. The study emphasizes the importance of optimizing drainage assets to reduce

Carbon footprint, construction costs, and achieve long-term savings while meeting regulatory requirements. Hydraulic software applications, specifically MicroDrainage, are highlighted as effective tools for designing and analyzing drainage systems. The paper presents three drainage design alternatives, comparing them against various parameters to arrive at an optimized and cost-effective solution. The overall cost comparison indicates that Option 3 (Combination of Existing drainage and Proposed CKDs with pipe system), incorporating existing and proposed assets, proves to be the most economical

over the system's full design life, considering installation, capital, and maintenance costs. The study underscores the significance of regular maintenance for the proper functioning of the drainage system and emphasizes the role it plays in the overall cost over the system's lifespan.

Kalwani, M. P., et al. (2021)., discuss the rapid expansion of concrete infrastructure on land surfaces, combined with intense short-duration rainfall, has led to increased runoff and reduced infiltration, resulting in flash flooding. Traditional methods have proven inadequate in identifying the root causes of failures in stormwater drainage systems. Therefore, this study employs the Storm Water Management Model (SWMM) to conduct a comprehensive hydrological and hydraulic analysis of urban stormwater catchments, building on previous research. The Modified Green-Ampt infiltration model and Dynamic wave flow routing model are applied, utilizing peak annual rainfall data to assess the real-time performance of the existing drainage network in the Aundh area of Pune city, India. The urban runoff modeling reveals flooding conditions in the drainage pipe networks, manholes, and sub-catchments through detailed hydraulic profiles and time series plots. The findings indicate that the stormwater drainage system has failed to handle flash flood loads, supported by scientific data. To enhance the functionality of the present stormwater drainage system, this study recommends both technical and behavioral corrective measures.

Agonafir, C., et al. (2023). Deals with Urban flooding is a growing concern due to climate change and urbanization, leading to increased frequency and severity of extreme storms. The consequences of urban flooding are dire, including loss of human life, property damage, and economic impacts. To combat this, agencies and organizations are implementing novel modeling methods, including hydraulic-hydrologic models and artificial intelligence/machine learning techniques. This review provides a comprehensive overview of urban flooding, including its causes, impacts, and modeling endeavors. It synthesizes urban flood studies, primarily with a United States focus, and discusses contemporary approaches, including data-driven methods and AI/ML algorithms. The review highlights the importance of understanding urban flooding and its drivers, including urbanization, climate change, and inadequate stormwater infrastructure. It also emphasizes the need for improved modeling and prediction methods to mitigate the effects of urban flooding.

Kumar et al. (2015) conducted a study in Vijayawada on storm water drainage design. Rational method was successfully used for Vijayawada city with a good determination coefficient of 0.871 to estimate storm wise discharge. In order to reach the value of the runoff coefficient, diligent efforts are needed to estimate these parameters. Care was taken in that study to determine the runoff coefficient value, C. Periodic maintenance of existing drains in Vijaywada was therefore essential.

3 DESCRIPTION OF THE STUDY AREA

3.1 Location

Kamarhati, situated at 22.67°N 88.37°E, is a municipality that encompasses several neighborhoods, including Belgharia, Ariadaha, and Dakshineswar. The Kamarhati Municipality is headquartered at Rathtala on B.T. Road. Notably, the revered Dakshineswar Kali Temple is located within the municipal boundaries.

Geographically, Kamarhati is bounded by:

Khardaha and Panihati to the north, North Dumdum to the east

Baranagar to the south, the Hooghly River to the west

3.2 Silent Features of Kamarhati Municipality

Table 3:- Salient Features

Source: <https://weatherandclimate.com/india/west-bengal/kamarhati>

Items	Statistics
Area	10.96 sq. k.m. Sq. Km.
Major Rivers	Hooghly River, South & West - Dantia / Bagzola, South & East - Udaypur
Soil Type	Alluvial to Clay Loam
Population (Census 2011)	3,30,211
Population Density (Census 2011)	10,967 per sq.km
Rainfall Average annual precipitation	150.36mm (5.92in)
Temperature	9 °C to 40 °C
Annual Humidity	60.54 %

Table 4:- Ward wise Population

Ward	Population	Area(Sq Km)	Ward	Population	Area(Sq Km)	Ward	Population	Area(Sq Km)
1	11659	0.138232	13	8456	0.286231	25	5452	0.177541
2	18942	0.255919	14	6180	0.462801	26	7506	0.247102
3	16067	0.089481	15	7234	0.576583	27	4764	0.154942
4	18321	0.078848	16	7783	0.723698	28	6727	0.335205
5	12296	0.177393	17	9392	0.525171	29	9524	0.552165
6	12488	0.074023	18	10211	0.436213	30	7788	0.33018
7	10495	0.153343	19	4919	0.195012	31	6849	0.252126
8	15162	0.48255	20	5899	0.220991	32	4493	0.251483
9	9737	0.340169	21	9652	0.353929	33	10192	0.337453
10	10736	0.485908	22	10414	0.356121	34	6707	0.208055
11	13095	0.386507	23	8529	0.254552	35	9234	0.691175
12	7719	0.32675	24	5589	0.369571			

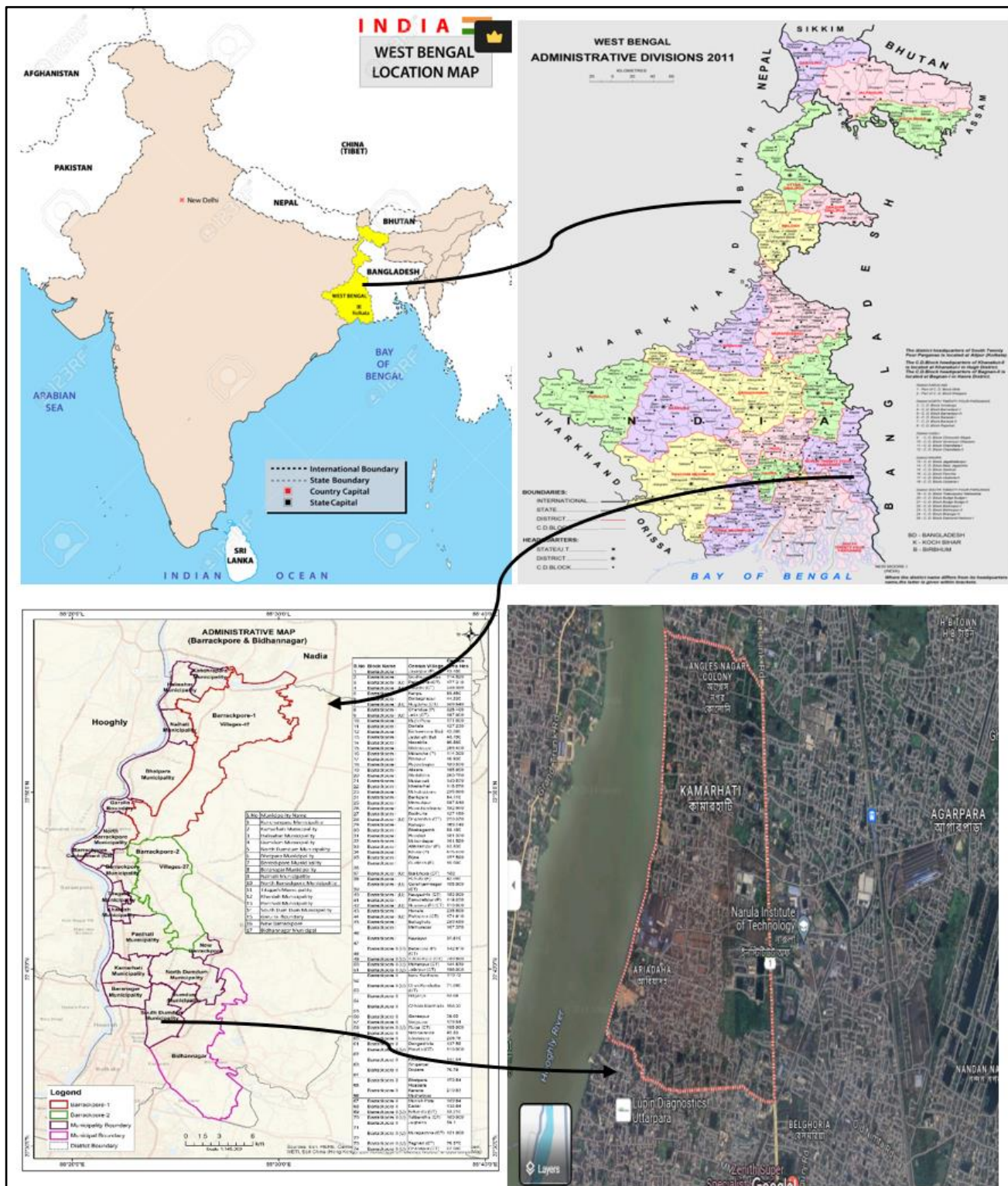
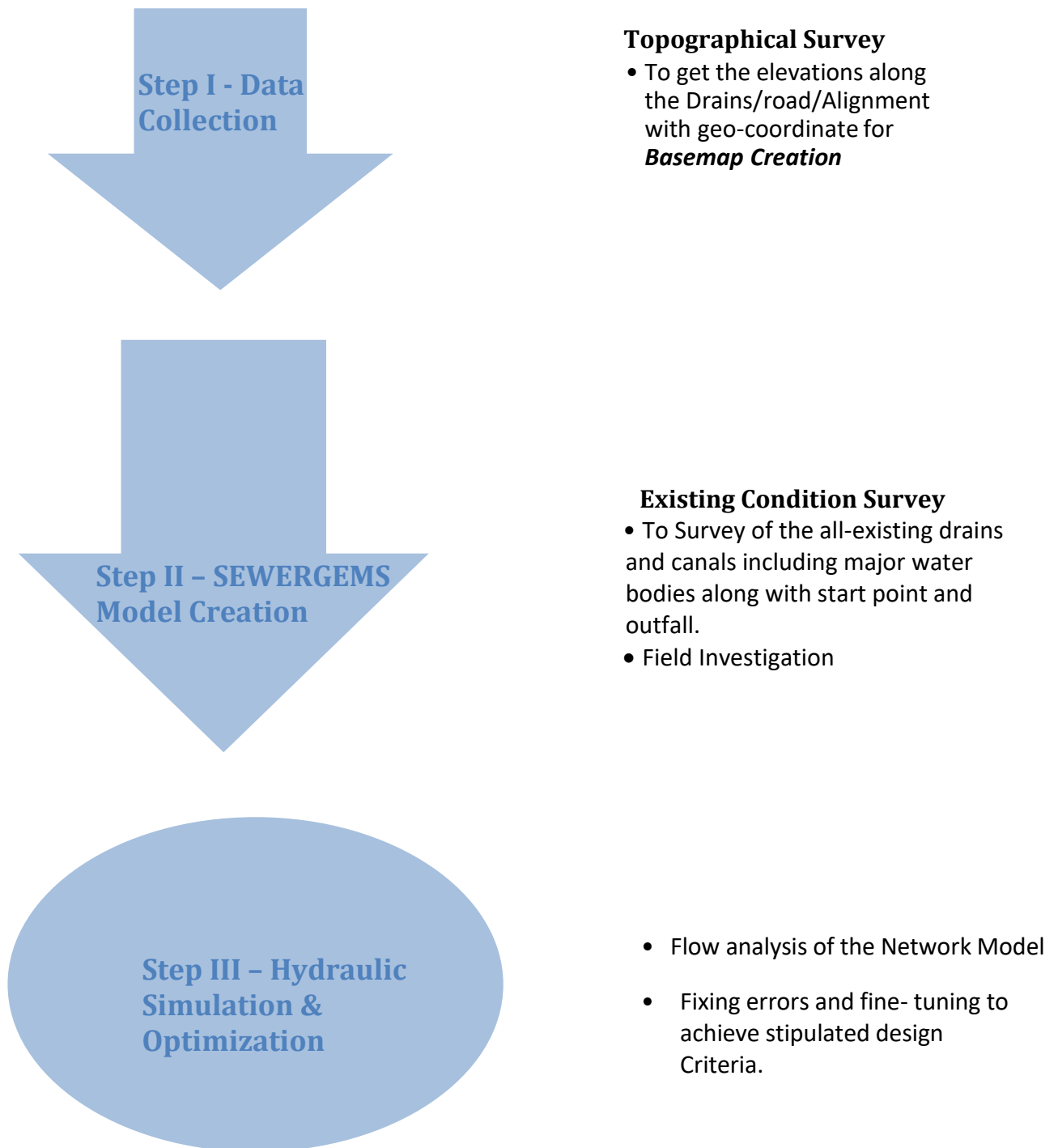


Figure 5:-Study Area

The study area for this paper is the Kamarhati Municipality, which is an urban local body in the North 24 Parganas district of West Bengal, India. Specifically, the study focuses on the stormwater drainage network within the municipality.

4 METHODOLOGY

In this chapter, methodologies to achieve various activities of the study objectives are discussed. The various activities carried out in the study is shown through the flow chart. The detailed description of methodology is as below:



Layout: - Methodology of Study

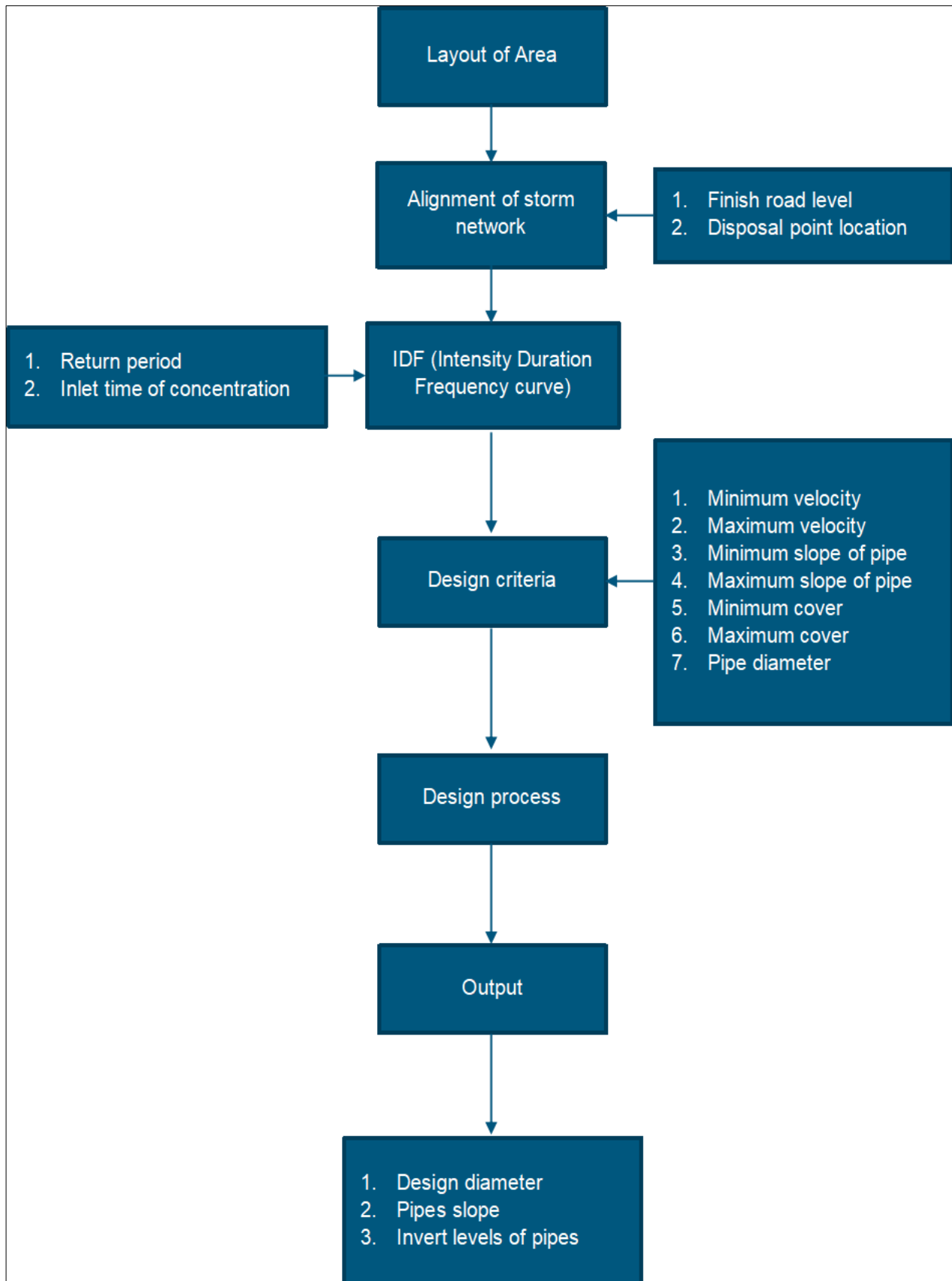


Figure 6:-Showing input and output of SewerGems.

Methodological design of the study

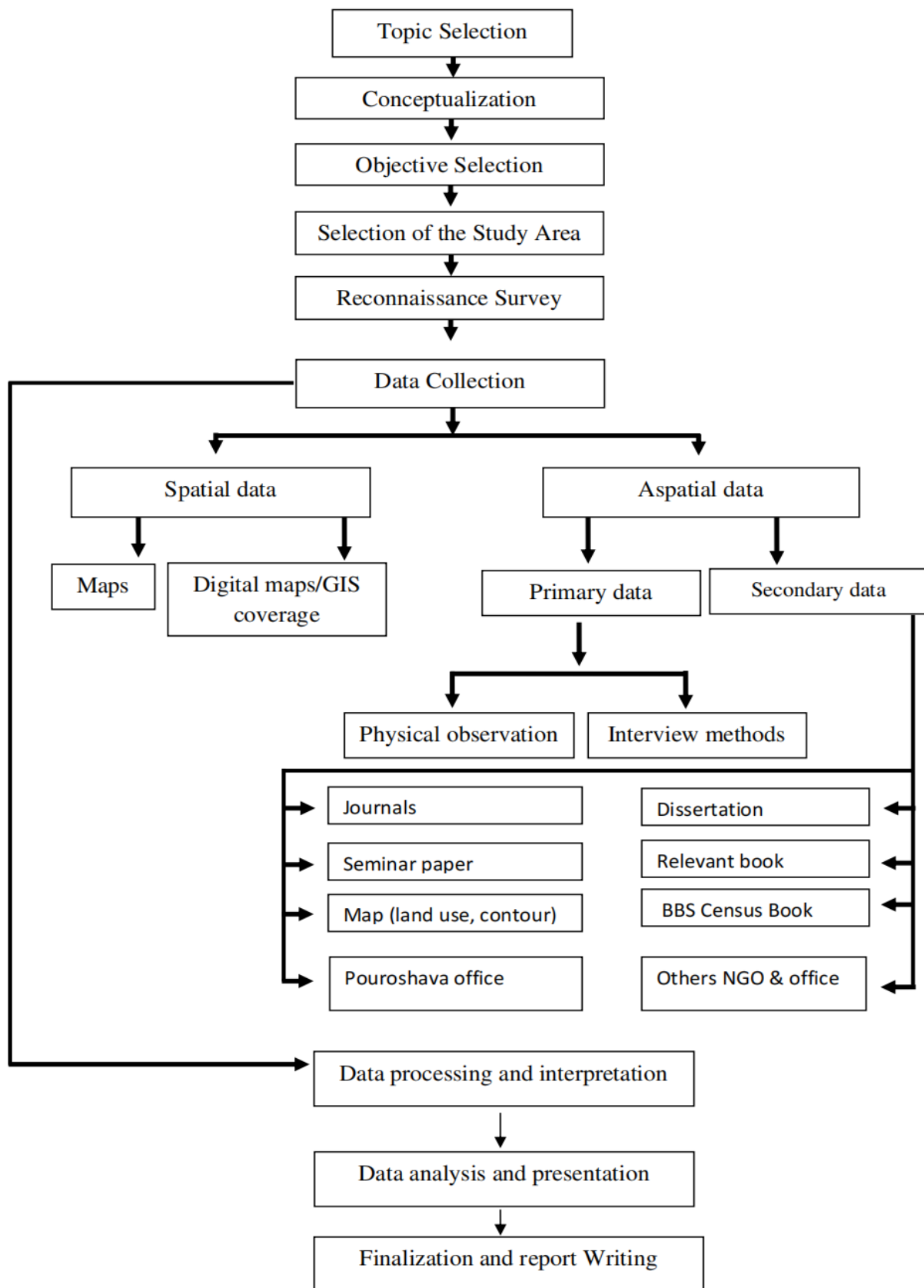


Figure 7:- Methodological Design of the Study

4.1 Data Collection

The necessary investigation required for design of storm water drain network shall relate to design, operate, and maintain these networks effectively, accurate and reliable data is essential. This guide outlines the necessary data collection requirements for stormwater drainage networks.

Network Geometry: Drain/Pipe lengths, diameters, and invert elevations. Manhole and catch basin locations, depths, and diameters. Pipe material, roughness, and condition.

Hydrological Data: Rainfall intensity and duration data. Watershed boundaries and characteristics. Runoff coefficients and curve numbers.

Hydraulic Data: Flow rates and water levels at key locations. Drain/Pipe flow velocities and pressures. Inlet and outlet capacities of stormwater management facilities.

Asset Condition and Performance Data: Drain/Pipe condition (e.g., cracks, corrosion, blockages). Structural integrity of manholes and catch basins. Performance metrics (e.g., flow capacity, overflow frequency).

Climate and Weather Data: Historical rainfall and weather patterns. Climate change projections and scenarios. Other Relevant Data: Existing Pumping Station and outfalls & Nearby water bodies and receiving waters.

4.2 Topographical Survey

Storm water drainage is mainly designed by gravity system and therefore accurate topographic survey of the project area based on street levels is of prime importance to the design of the system and its subsequent efficient performance.

Preparation of contour maps showing the major drains and their catchment areas, major outfalls, flow patterns and preparation of preliminary longitudinal sections and cross sections of drain reaches.

The available Topographic survey data for the Base map preparation (in AutoCAD format), showing the attributes and alignment of the drains , roads have been used for the study.

The survey data however is updated and validated with the concerned authority to provide for pipeline networks in all roads / pathways to provide accessibility to all the properties and provide for service connections.

Topographical survey has been carried along existing road network / pathways as maybe required for detail design. The survey shall update all objects/ roads / steps / drains/ gully pits/ culverts etc., on both sides of the road (black bituminous top or concrete or brick) edges including road portion. Type and width of road and offset distance of important structures within or adjacent to road, from a fixed point shall be shown in the map.

The entire topographic survey has been carried out by DGPS and/or Total Station having facility of transferring data to computer. All traverse stations shall be recorded with X, Y and Z coordinates and shall be checked to eliminate any error. The BMs have been

connected for X and Y coordinates by Total Stations with closing at intervals.

Indicating the existing inundation areas clearly showing the probable depth of water accumulation in case of heavy rainfall intensities. Assessing the reasons for such inundation based on the information collected.

Reconnaissance survey was carried out to identify the Lake boundaries and Major drain alignments. All the nodal points on boundary shown were captured using GPS instrument and transferred on to Google Earth / Survey of India topo sheets to plan the survey works. General Topography of the project area along with constraints if any was assessed during the reconnaissance survey.

Detailed inventory and Field Investigations are carried out to collect the information regarding the existing storm water drainage network, alignment of drains, catchment characteristic details, Land use pattern, geometry of the drains, details of cross drainage structures like culverts, bridges, encroachment details, tank details etc.

4.3 Consumer Survey

The finalized consumer data have been considered for the study. The survey has been done to arrive at the present population to calculate and population forecast it for Year (2050). The consumer survey taken note of the following parameters: -

Details with regards to property number, name, address, village and habitation, contact numbers, Number of resident members (male, female, children), Categories of properties (domestic, institutional, commercial, slums, residential, mixed usage etc.).

4.4 Field Investigation

The field investigations have been carried out to report the actual site conditions and to assess the following features.

Geometry of the drains (includes shape, size, material, disposals etc.) Identification of natural drains and constructed drains. Flow conditions in the drains Catchment area characteristics (counter checking with land use plan) Verification of land use pattern Updating the catchment plans as required from site conditions if any Information related to cross drainage structure.

4.5 Hydraulic simulation and optimization

SewerGEMS is a software tool used for hydraulic simulation and optimization of stormwater drainage systems.

SewerGEMS uses mathematical models to simulate the flow of stormwater through drainage systems, taking into account factors like pipe sizes, slopes, and roughness. It can simulate various stormwater scenarios, including rainfall events and flooding. Based on the simulation results, SewerGEMS can optimize the drainage system's performance by identifying the most effective pipe sizes, layouts, and control strategies.

It can also optimize the system's operation, such as pump schedules and valve control, to minimize flooding and reduce costs.

4.6 Sewer GEMS model creation

Overview and modelling capabilities of Sewer GEMS software:

SewerGEMS is a sewer network modeling and analysis software developed by Bentley Systems. It is used to design, optimize, and manage sanitary and combined sewer systems, including pipes, pumps, and treatment plants. Here is an overview of SewerGEMS' modeling capabilities:

Hydraulic Modeling: Simulates sewer flow, depth, and velocity. Accounts for friction losses, pipe roughness, and minor losses. Supports steady-state and transient analysis.

Network Modeling: Builds and edits network topology. Supports multiple pipe materials and sizes. Includes node and link elements (e.g., manholes, junctions, pumps).

Sanitary and Combined Sewer Modeling: Simulates separate and combined sewer systems. Accounts for infiltration, inflow, and runoff.

Pump and Valve Modeling: Simulates pump performance curves and efficiency. Models valve operation, including control and pressure management.

Treatment Plant Modeling: Simulates wastewater treatment processes. Accounts for plant capacity, efficiency, and effluent quality.

Water Quality Modeling: Simulates pollutant transport and fate. Accounts for sediment, nutrients, and other water quality parameters.

Rainfall and Runoff Modeling: Simulates rainfall and runoff events. Accounts for watershed characteristics, land use, and hydrology.

Network Optimization: Optimizes pipe sizing, material, and layout. Identifies energy-efficient pump operations. Suggests valve and control strategies.

Scenario Management: Creates and manages multiple scenarios (e.g., "what-if" analyses). Compares results and evaluates trade-offs.

Integration and Interoperability: Supports data import/export with other software (e.g., GIS, CAD). Integrates with other Bentley Systems products (e.g., WaterGEMS, StormCAD).

SewerGEMS is the industry's hydraulic modelling solution according to a recent industryStudy for:

Urban Sewer Planning: SewerGEMS enables you to produce optimal urban sewer planning and overflow remediation analysis designs in an easy-to-use environment.

Overflow Remediation Analysis: SewerGEMS allows users to design and operate sanitary or combined conveyance sewer systems by using built-in hydraulic and hydrology capabilities with a variety of dry- and wet-weather calculation methods.

1D/2D Hydraulic Analysis: SewerGEMS has user-friendly tools that connect 1D network elements with 2D surface flows. It helps you to better understand surface flooding depth and velocity, flood hazard, and inundation times, and communicate this information to stakeholders with versatile mapping and reporting tools.

SewerGEMS is a highly efficient tool for designing storm or sanitary sewer networks, making it easy to create a schematic or scaled model. The software automatically handles link-node connectivity, pipe labeling, and node labeling, streamlining the process. When importing a scanned schematic drawing, pipe lengths can be manually entered or automatically calculated from the drawing's scaled position. For this research, the network was created in AutoCAD (.dxf file format) and imported into SewerGEMS using the Model Builder feature, leveraging the software's capabilities for efficient network design and analysis."

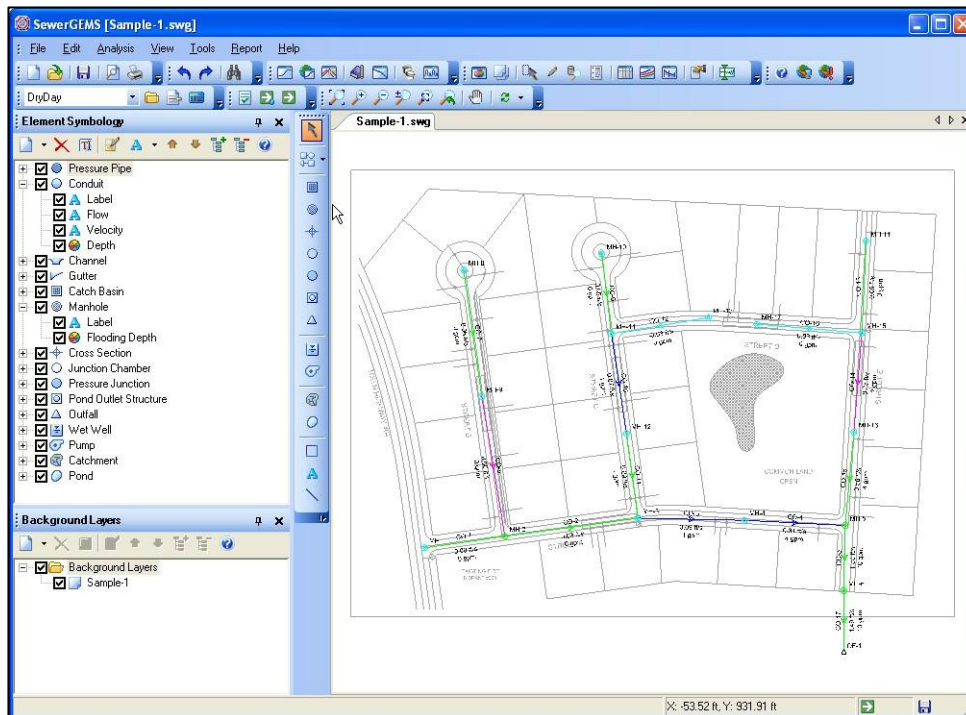


Figure 8:- Bentley Sewer GEMS V8i environment look.

SewerGEMS users enjoy the power and versatility of working across CAD, GIS, and stand-alone platforms while accessing a single, shared, source of project data. With SewerGEMS, utilities and consultants have built-in support for four interoperable platforms, all packaged in one product: stand-alone Windows for ease of use, accessibility and performance, ArcGIS for GIS integration, thematic mapping and publishing, Micro Station for bridging geospatial planning and design environments, and AutoCAD for integrated compatibility. Utilities and consultants can use different interfaces to share a single dataset, and modeling teams can leverage engineering skills from various departments. Engineers can flatten learning curves by selecting the environment they already know and delivering results that can be viewed on multiple platforms.

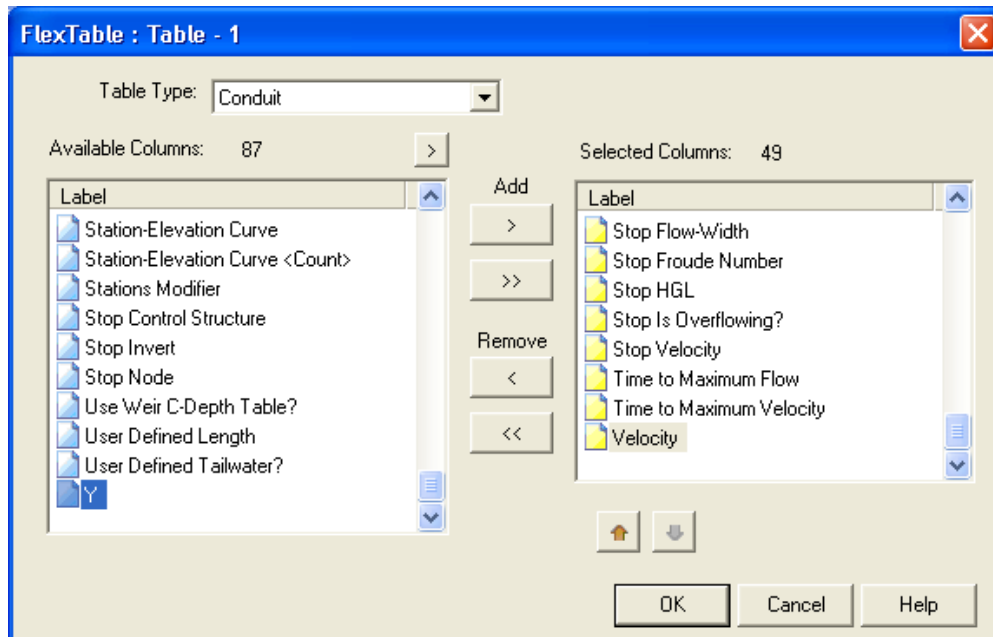


Figure 9:- FlexTable

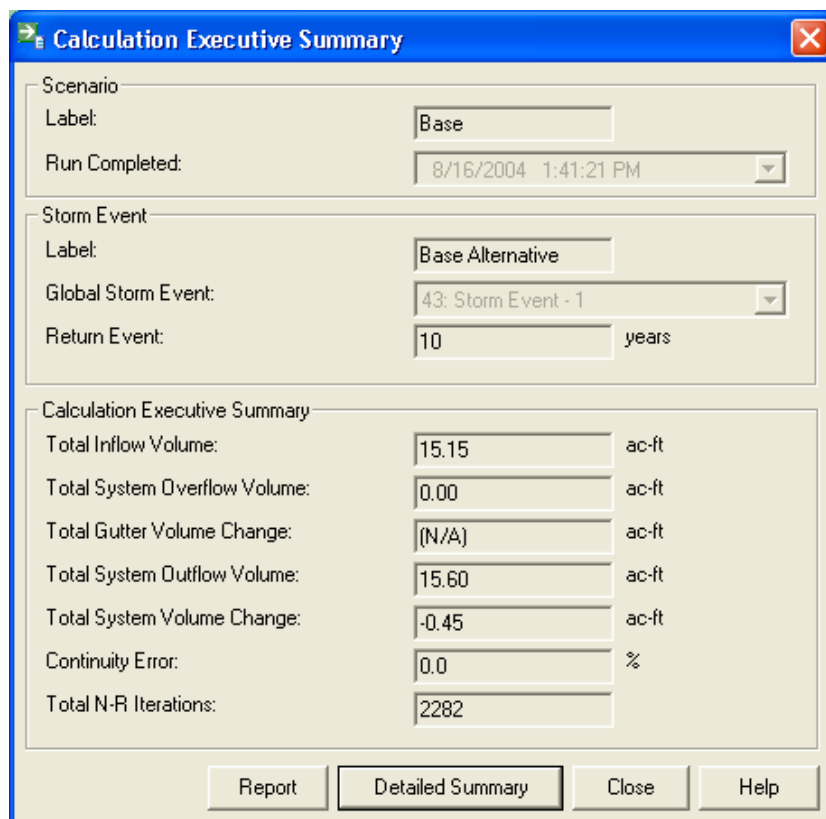


Figure 10:-Calculation Executive Summary Dialogue Box

Data Management: Store and organize data on network components, such as pipes, channels, and manholes. Data Analysis: Perform calculations, filtering, and sorting to gain insights into network performance. Network Design: Use Flex Tables to design and optimize stormwater drainage networks. Scenario Management: Create and manage different scenarios to evaluate various design options. Reporting: Generate reports and export data for further analysis or sharing with stakeholders.

By utilizing Flex Tables in SewerGEMS, you can streamline your stormwater drainage

network design process, making it more efficient and effective.

Storm Water Drainage Network Analysis is a comprehensive evaluation of a storm water drainage system, involving the following detailed steps:

Data Collection: Rainfall data (intensity, duration, frequency). Topography (elevation, slope, aspect). Land use (urban, rural, industrial, residential). Soil type and infiltration rates. Existing drainage infrastructure (pipes, channels, ponds). Water quality data (pollutant loads, concentrations).
Hydrologic Analysis: Estimating runoff rates and volumes using methods like:

Rational Method, NRCS Curve Number Method, SWMM (Storm Water Management Model), Calculating peak flows, time of concentration, and runoff coefficients

Hydraulic Analysis: Modeling pipe flow, pressure, and velocity using:

Manning's Equation, Darcy-Weisbach Equation, Hazen-Williams Equation, calculating pipe sizes, flow rates, and pressure drops.

Network Modeling: Creating a digital representation of the drainage network using software like: SWMM, HEC-RAS (Hydrologic Engineering Center's River Analysis System), Storm CAD, Defining nodes (junctions, manholes), links (pipes, channels), and boundaries. **Simulation and Scenario Analysis:** Running simulations to test the network's performance under various storm events (e.g., 10-year, 50-year, 100-year storms) Evaluating scenarios like: Existing conditions, Future development, Infrastructure upgrades, Climate change. **Optimization and Design:** Identifying bottlenecks and areas for improvement Sizing pipes and designing new infrastructure (e.g., detention ponds, green infrastructure). Optimizing system performance using techniques like: Linear programming, Dynamic programming, Genetic algorithms **Water Quality Analysis:** Evaluating pollutant loads and concentrations Assessing water quality impacts on receiving waters Designing strategies to minimize environmental impacts (e.g., sedimentation, filtration). **Sensitivity Analysis:** Assessing how changes in inputs or parameters affect the network's performance Identifying critical variables and uncertainties.

5 DESIGN & ANALYSIS OF DISTRIBUTION NETWORK

5.1 Evaluation of Drainage Network Analysis

Stormwater drainage design is an essential component of both site specific and complete stormwater management strategy. Good drainage design must strive to maintain compatibility and minimize interference with present drainage patterns; control flooding of property, structures, and roadways for design flood events; and minimize potential environmental impacts on stormwater runoff. Stormwater collection systems must be designed to provide adequate surface drainage while meeting other stormwater management objective such as water quality, bank protection, habitat protection and groundwater recharge. The history of Urban Drainage from medieval period to modern time has been concisely documented by Burian, S. J., & Edwards, F. G. (2015). In the article they chronicled despite the significant technological advancements in modern engineering, ancient civilizations achieved impressive engineering feats, including building sophisticated infrastructure systems for urban drainage. Urban drainage encompasses two types of fluids: wastewater and stormwater, which have been managed through combined or separate sewer systems throughout history. This paper explores the historical perspectives on urban drainage, revealing that it has been viewed as a vital resource, a cleansing mechanism, a waste transport medium, a flooding concern, a nuisance, and a transmitter of disease. These perspectives have shaped the planning, design, and urban drainage systems over time.

Ancient civilizations, including the Indus, Minoan, Persian, Mesopotamian, and Etruscan, constructed sophisticated urban drainage systems despite limited planning and design capabilities. These systems aimed to collect rainwater, prevent nuisance flooding, and convey wastes, with some civilizations viewing urban runoff as a vital natural resource, a nuisance, and a waste conveyor.

The Indus civilization built technologically advanced systems with features like sumps and cunnettes, while the Persians considered urban runoff sacred and collected it for potable uses. The Mesopotamians and Minoans constructed elaborate systems with separate conduits for sewage and rainwater, viewing urban runoff as a flooding concern, waste conveyor, and vital resource. The Etruscans designed skillful drainage systems using natural slopes and paved streets.

Despite the lack of optimization and the use of trial-and-error construction methods, numerous ancient urban drainage systems can be rated very successful. Lewis Mumford summarized the state of ancient urban infrastructure as an "uneconomic combination of refined technical devices and primitive social planning."

These ancient civilizations demonstrated a remarkable understanding of urban drainage, and their perspectives on urban runoff continue to influence modern approaches to water management. They viewed urban drainage as a vital natural

resource, a nuisance flooding concern, and a waste conveyance mechanism, and their systems were designed to address these concerns. The rise of environmental consciousness in the 1960s coincided with the dawn of computer technology. In October 1969, the first proposal for Earth Day was presented in San Francisco, while California universities began networking computers, laying the groundwork for the Internet. This convergence of technology and awareness empowered a group of water modelers to revolutionize urban water management.

SWMM's original developers were driven by their dedication, enthusiasm, and desire to help others, as noted by Mitch Heineman, who has contributed to SWMM's advancement since the 1990s. Over the past five decades, their work has significantly improved cities' ability to address stormwater flows, leading to a transformative impact on urban water quality. Perhaps the oldest combined sewerage system in India is in the city of Kolkata (Calcutta), which was the capital of the British Empire in India till 1911. The first brick sewer in Kolkata was commissioned in 1876, and it was designed to cope with 6.35 mm/h of rainfall with 100 per cent of runoff. Attempts were made in the 1970s to increase the capacity to cater for 12.7 mm/hr rainfall. However, Kolkata received 54 mm in one hour in the year 2003, which caused severe flooding. Ad hoc measures, such as installing additional pumps to pump out water from the low-lying areas, are quite expensive in the short term and often ineffective, since the power supply is not dependable, particularly during heavy rainfall when power lines are sometimes dislodged. Sustainable infrastructure development is a more promising solution and efforts are now being made in this direction. For example, various pilot projects are now being carried out for using constructed wetlands for treating domestic wastewater in small urban settlements.

"The history of man is reflected in the history of sewers..." By Victor Hugo, *Les Misérables*

"The sewer is the conscience of the city." By -Victor Hugo, *Les Misérables*

"The sophistication of a civilization can often be judged by its attention to the issue of drainage infrastructure," -Wright and Valencia Zegarra (2000)

The change in rainfall runoff event and the performance of drainage system is affected because of the amount of impervious area due to increasing population and new urban development's (Semadeni-Davies et al., 2008).

Safe and efficient drainage of stormwater is important to maintain public health and safety, avoiding the potential impact of flooding on life and property and to protect the environment and to reduce cost of the drainage network pipes. Therefore, to achieve this, it is necessary to assess the performance of the existing stormwater drainage system within the area, to upgrade the system and to design new systems when necessary to allow accommodation for future development.

Researchers have utilized various software, including GIS, CAD, SewerGEMS, and AutoCAD, to design and analyze piped networks for efficient and economical sewer systems. These studies demonstrate the benefits of using hydraulic modeling software, including reduced design time, user-friendly interfaces, and improved decision-making

capabilities. The literature highlights the potential of GIS-based modeling to enhance the design process, reduce costs, and promote sustainable drainage network development.

Design frequency / return period

The design storm frequency also known as return period is an average period after which it reoccurs, for a given rainfall magnitude or more corresponding to a particular duration of time. This is integral part of IDF curve based on analysis of past rainfall data, used for designing of storm water drainage systems. Depending on importance of the drainage area, socio-economic conditions of the city and other constraints such as funding for infrastructure and availability of space for construction of drains, the design return period of storm should be judiciously adopted in estimation of storm runoff. The recommended design return period of storms frequency, for various types of catchments based on catchment characteristics is given in the table below:

Table 5:-Recommended design return period for various types of urban catchments

(Source: Manual on Storm Water Drainage Systems, CPHEEO.)

Sr. No.	Urban catchment	Return period	
		Class I cities**	Other cities*^*
1.	Central business and commercial	Once in 5 Years	Once in 2 years
2.	Industrial	Once in 5 Years	Once in 2 years
3.	Urban residential	Once in 5 Years	Once in 2 years
4.	Airports and other critical infrastructure*	Once in 100 years	Once in 50 years

Note: -

*Critical infrastructure includes railway stations, power stations, etc.

** Class I cities are cities having population 1 lakh and above

*** Other cities are cities having population less than 1 lakh

Note: 1. It may not be always feasible to design / retrofit the storm water drains for the recommended return period in all the cities. In cases where redesigning / retrofitting is not feasible as per recommended return period due to city profile / site constraints, efforts are made to adopt recommended return period by adopting 'Best Management Practices, (BMP) like in-situ rainwater harvesting methods within premises / plots, along the storm water channels / conduits and storm retention/ detention structures to accommodate the excess runoff.

If drainage system outfall is close to river, CWC guidelines will also be considered for design purpose. IS Code 8835:1978 stipulates that drains may be designed for 3-day rainfall of 5-year return period. However, in specific cases requiring higher degree of protection, return period of 10 or 15 year may also be adopted. Adoption of higher return period rainfall should be justified in term of economics. Cross drainage works should be designed for 3-day rainfall of 50-year return period.

Theory of Storm Water Drainage Network Analysis:

The theory of storm water drainage network analysis involves the application of hydraulic and hydrological principles to design, analyze, and optimize storm water drainage systems. The goal is to ensure efficient and safe removal of storm water runoff,

preventing flooding, erosion, and water pollution. Key concepts include.

- Hydrologic Cycle: Understanding precipitation, runoff, infiltration, and evaporation processes.
- Watershed Analysis: Identifying drainage areas, water flow paths, and runoff characteristics.
- Network Analysis: Modeling the entire drainage network, including pipes, nodes, and junctions.
- Storm Water Management: Designing systems to manage runoff, reduce flooding, and improve water quality.
- Hydraulic Gradient: Understanding the relationship between water depth, velocity, and pressure in pipes.
- Manning's Equation: Calculating pipe flow velocity and depth using roughness coefficients and hydraulic radius.
- Rational Method: Estimating peak runoff rates and designing drainage infrastructure.
- SWMM (Storm Water Management Model): A widely used software for simulating and analyzing storm water drainage networks.



Figure 11:- Precipitation - Catchment and Watershed

5.2 Design Philosophy

Design Procedure for IDF curve generation

The rainfall intensity-duration-frequency (IDF) relationship is one of the most used tools in water resources engineering, either for planning, designing or operating of water resource projects, against floods and urban drainage design. The combined effect of rainfall intensity and duration on maximum discharges of runoff from urban watersheds was first demonstrated by Kuichling (1889). Current infrastructure design concepts to deal with flooding and precipitation are based on local rainfall Intensity-Duration-Frequency (IDF) curves. Given the observed increase in heavy precipitation events, it is needed that the IDF curves should be updated to account for a changing climate, especially for urban infrastructure design.

Generally historical rainfall data ranging from 25 -30 years, is considered. In unavoidable circumstances, when data is available for less than 30 years, the same may also be considered. However, frequency analysis should not be adopted if the rainfall data is available for less than 10 years. The most frequently used tool for the design and planning of drainage systems is the intensity-duration-frequency (IDF) relationship of maximum rainfall amounts. Rainfall intensity and duration are inversely correlated. As the duration increases, the intensity decreases. This approves the common-sense observation that heavy rainfall events only last a short time, but drizzle can go on for long time periods. Also, frequency and intensity are related, as rarer events (greater return periods events) tend to have higher intensities (for a given time).

Hyetograph is a plot of rainfall depth against the time duration. It is usually represented as a bar chart. The Hyetograph translated from IDF curve can be used in the rainfall runoff model for calculating runoff from the catchment for which IDF curve is constructed. Corresponding Hyetograph for once in 2-year and once in 5-year return period will be use for the drainage system design. Based on the methods mentioned in the CPHEEO Manual on Storm Water Drainage Systems Vol.1 Part A: Engineering Design, the hourly rainfall data received from the IMD for past 32 years (January 1989 to August 2021) for the area (at located stations) will be analyzed and IDF curves and rainfall hyetographs will be estimated. The climate change factors will apply on the current scenario rainfall to arrive at the future scenario rainfall hyetographs.

Design Criteria for minimum and maximum velocity

Robert manning suggested in 1890 and in USA as most of the developing countries.

$$v = 1 / n * R^{2/3} * S^{1/2} \quad (\text{SI unit}) \quad (4.1)$$

v = velocity of flow in drain (m/sec)

S = hydraulic gradient or slope of the conduit (m/m)

R = hydraulic mean radius $R = A/P$ (m)

The flow rate in circular pipe running full.

$$R = A/P = D/4 \quad (4.2)$$

$$Q = 0.463/n * D^{8/3} * S^{1/2} \quad (4.3)$$

Q = discharge (m³ /sec), n = Manning's coefficient varies with pipe types

In storm water from urban catchments, generally comprising of sand particles of 0.09 mm with a specific gravity of 2.65 a minimum velocity of 0.6 m/s act as a self-cleaning velocity and a maximum velocity of 3.0 m/s is to be adopted to ensure structural protection of drainage channel (Source: WPCF, ASCE, 1982).

Minimum & maximum longitudinal gradient: -Minimum and maximum longitudinal gradient are to be judiciously selected in order to achieve the self-cleansing and non-scouring velocity. However, where the gradient becomes very much steep intermediate drops are provided between the stretches in order to restrict the velocity within the permissible limits i.e., between 0.6 m/s and a maximum velocity of 3.0 m/s.

Inlet spacing: -Minimum spacing should not be less than 10 m and the maximum should not be greater than 30 m. This will be decided for each section based on detailed design.

Freeboard: -The freeboard is the vertical distance from the water surface of designed flow condition to the top of the channel. The importance of this factor depends on the consequence of overflow of the channel bank. Freeboard should be sufficient to prevent waves, super elevation changes, or fluctuations in water surface from overflowing the sides.

Rainfall analysis: -For rainfall analysis the cumulative average of IMD gridded rainfall data of six points are considered. shows daily rainfall along with yearly rainfall. Figure 2-2 shows maximum (monthly sum) and average (monthly sum) rainfall for each year.

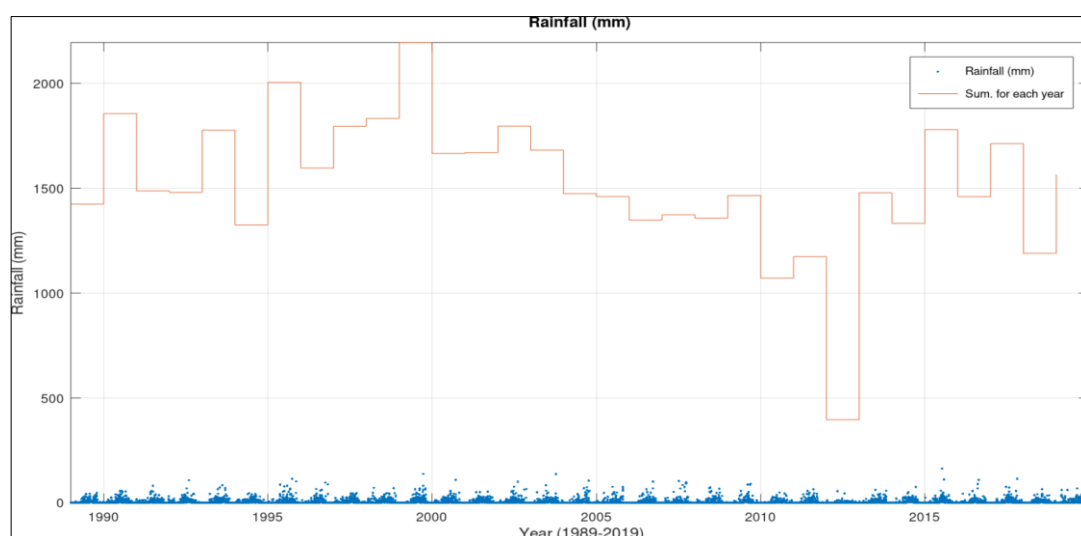


Figure 12:- Rainfall analysis considering IMD gridded data (daily rainfall along with yearly rainfall)

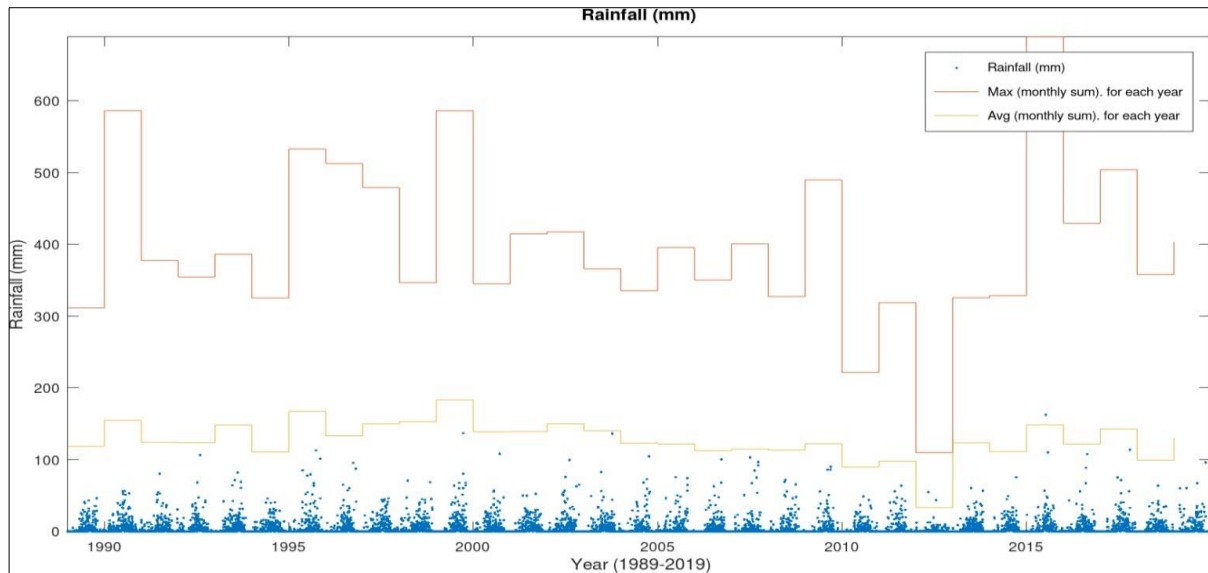


Figure 13:-Rainfall analysis considering IMD gridded data (maximum (monthly sum) and average (monthly sum) rainfall for each year)

An erratic nature but a high-intensity rainfall pattern has a significant impact on urban flood. Rainfall criterion raster map of the study area was prepared using the most preferable method, interpolation technique, in spatial analysis tool of ArcGIS 10.8 environment using IMD precipitation data as an input. Firstly, average of all these six grid points were taken. For the current study, four extreme rainfall events between 1st January 1989 to 31st December 2019 (i.e., 31 years period) have been considered as shown in the table.

Table 6:-Selected extreme rainfall events between 01st January 1989 to 31st December 2019

Date	Average Rainfall (6IMD Grid Point)	Latitude and Longitude (IMD Gridded Points)					
		22.50° N and 88.25° E	22.50° N and 88.50° E	22.75° N and 88.25° E	22.75° N and 88.50° E	23.00° N and 88.25° E	23.00° N and 88.50° E
7/10/2015	162.50	79.00	147.00	205.00	161.00	143.00	240.00
9/24/1999	149.83	231.00	150.00	145.00	142.00	109.00	122.00
10/8/2003	174.50	390.00	194.00	143.00	152.00	92.00	76.00
10/21/2017	178.50	568.00	128.00	94.00	124.00	45.00	112.00

These four events have been interpolated and the respective rainfall contours are shown in Figure 2-3 and Figure 2-4. It can be seen that the rainfall variations during these four extreme events range between 100 mm per day to 220 mm per day in the study area.

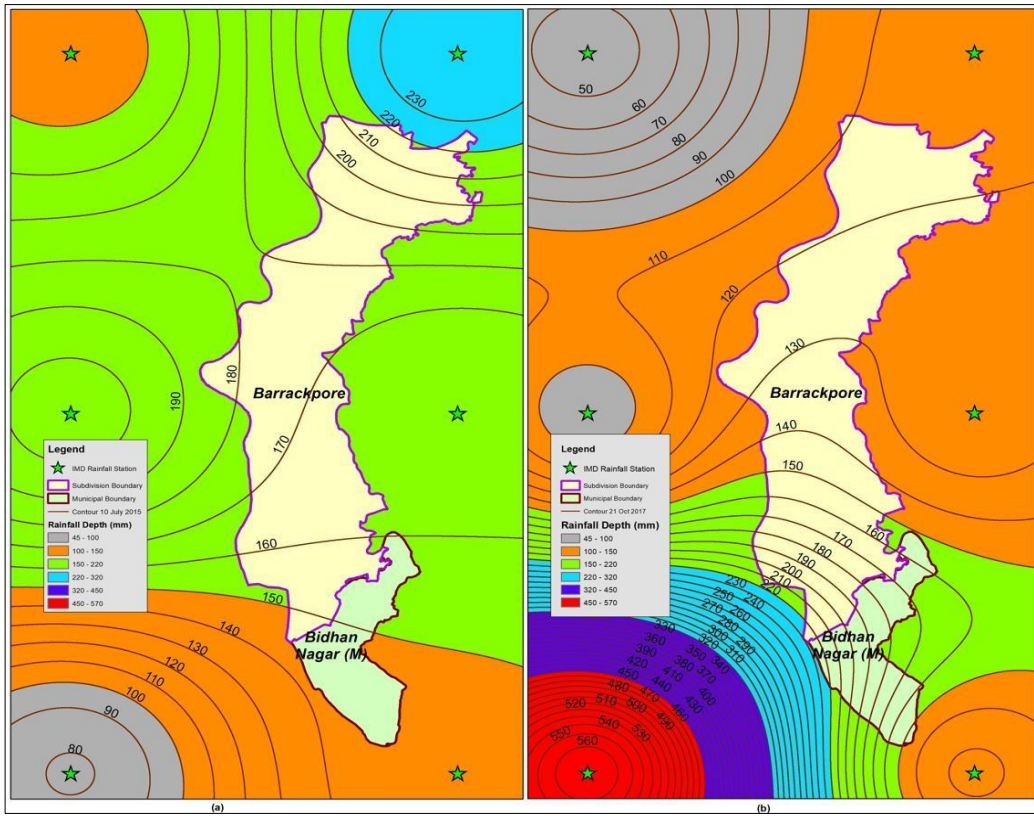


Figure 14:-Rainfall extreme events (10th July 2015 and 21st October 2017)

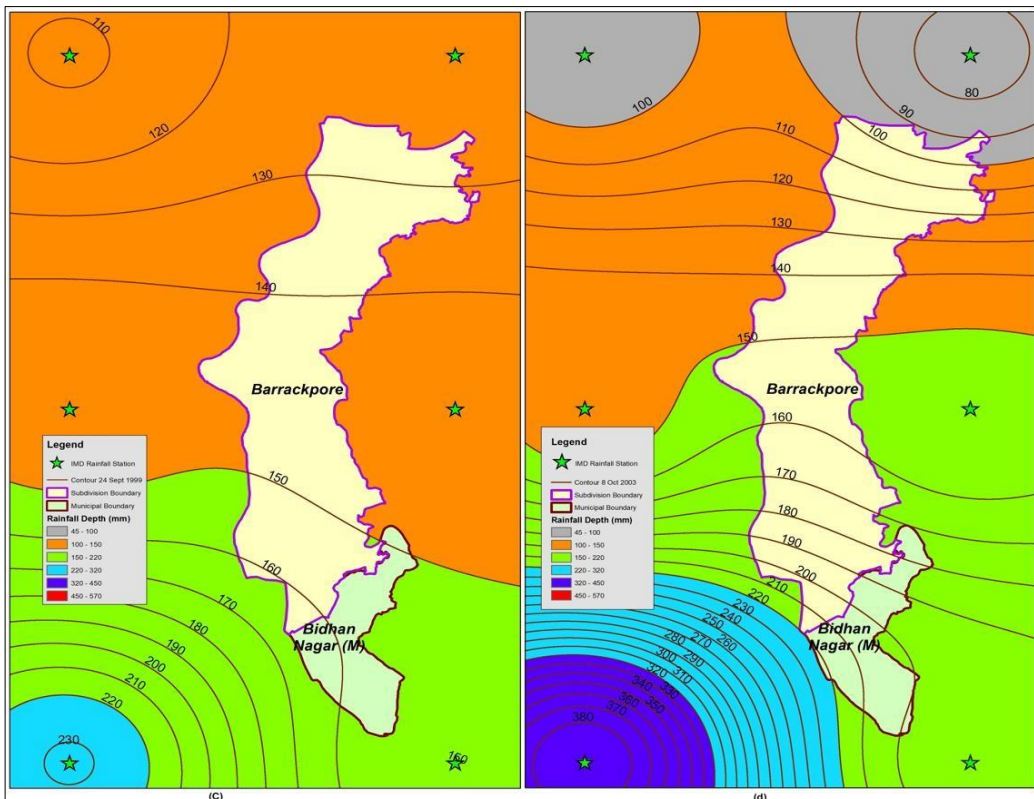


Figure 15:-Rainfall extreme events (24th September 1999 and 08th October 2003)

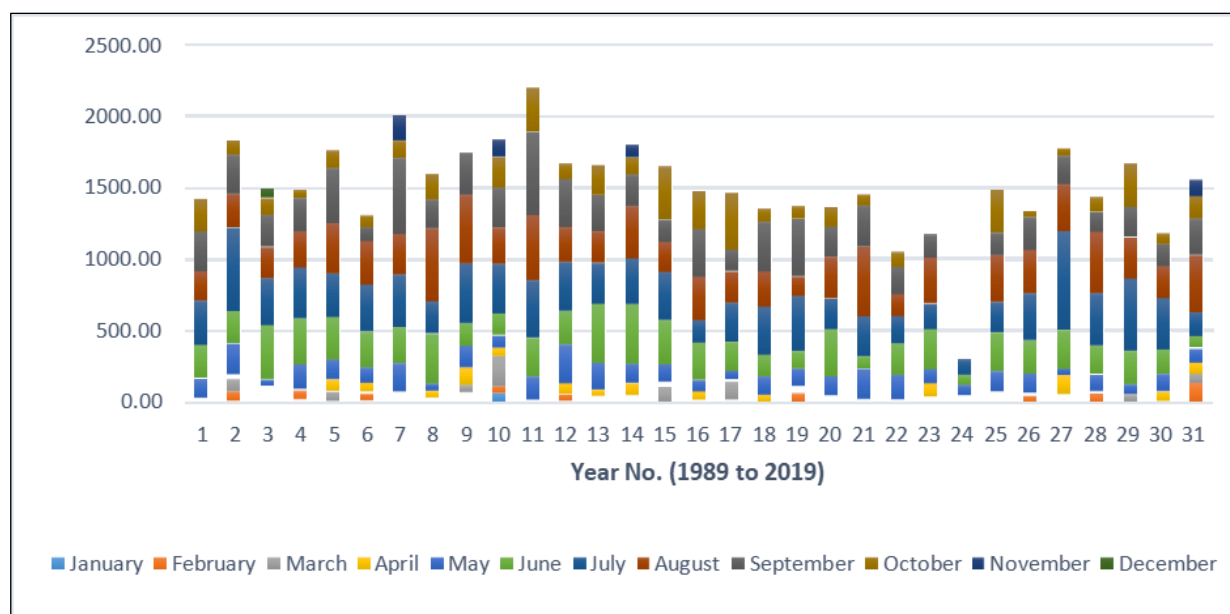


Figure 16:- Month wise Rainfall Variation

The histogram plot (Figure 2-5) shows month wise rainfall variations between 01st January 1989 to 31st December 2019. Table 2-2 shows the maximum daily rainfall month wise between year 1989 to 2019.

Table 7:-Maximum monthly rainfall value between year 1989 to 2019.

Month	Maximum daily rainfall month wise (mm)
January	23.00
February	60.00
March	70.67
April	40.00
May	85.00
June	82.67
July	162.50
August	110.00
September	136.67
October	136.00
November	101.33
December	30.33

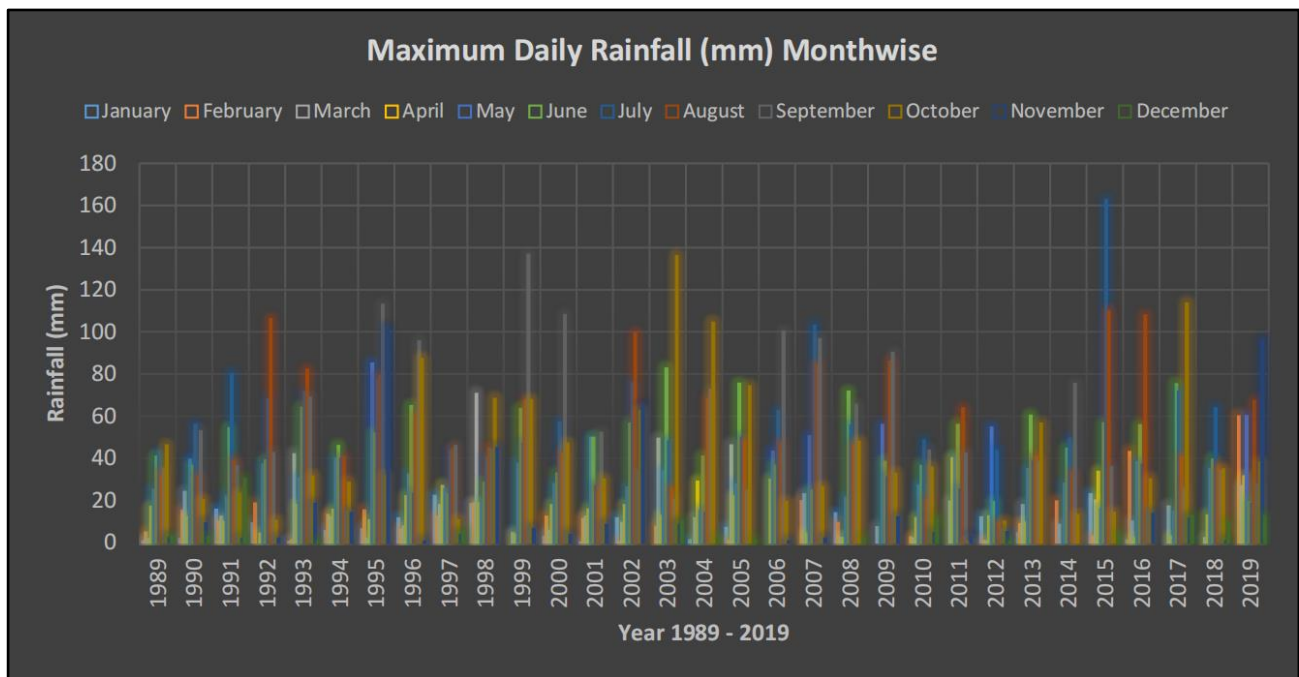


Figure 17:-Maximum daily rainfall month wise between year 1989 to 2019

IDF Curve

The most frequently used tool for the design and planning of drainage systems is the intensity-duration- frequency (IDF) relationship of maximum rainfall amounts. Rainfall intensity and duration are inversely correlated. As the duration increases, the intensity decreases. This approves the common-sense observation that heavy rainfall events only last a short time, but drizzle can go on for long time periods. Also, frequency and intensity are also related, as rarer events (greater return periods events) tend to have higher intensities (for a given time). The rainfall intensity-duration-frequency (IDF) relationship is one of the most commonly used tools in water resources engineering, either for planning, designing or operating of water resource projects, against floods i.e., Urban drainage design projects. Current infrastructure design concepts to deal with flooding and precipitation are based on local rainfall IDF curve on the other hand observed increase in heavy precipitation events, it is needed that the IDF curves should be updated to account for a changing climate, especially for urban infrastructure design. The Gumbel method of frequency analysis is based on extreme-value probability distribution for analysing the magnitude frequency relation of annual peak.

Rainfall does not occur uniformly; variations in its intensity occur not only from the centre to the peripheries of the storm rainfall but also temporally at a given point. In many design problems related to urban watershed management i.e., urban drainage design, it is necessary to know the rainfall intensities of different durations and return periods. One of the first steps in many hydrologic design projects is the determination of the rainfall event or event to be used for design purposes. Rainfall IDF curves are derived from the statistical analysis of single storm rainfall records over a period, and they are used to capture important characteristics of point rainfall for any desired shorter durations. In other word, it is defined as the calculation of average design rainfall

probability over a range of duration.

The typical technique for establishment of the IDF curves can be achieved after the execution of the following steps.

- a. Processing and selection of reliable of maximum annual single storm rainfall.
- b. Finding the best fit as the reliable PDF to each group of the data values for a set of specific durations.
- c. From the fitted relationships the rainfall intensity for any duration and return period can be derived.
- d. Finally, the IDF curves can be obtained in two different ways, either by plotting the intensity versus duration for different return periods or the rainfall intensity is related in functional relationship to the rainfall duration and the return period using regression analysis.

Based on the methods mentioned in the CPHEEO Manual on Storm Water Drainage Systems Vol.1 Part A: Engineering Design, hourly rainfall data received from the IMD (January 1989 to June 2018), Dum Dum airport station (Station Index: 42809) were analysed and IDF curves and rainfall hyetographs were estimated. The estimated rainfall has been used to study the urban flooding over the project area.

Also, the IDF curve for the different return period were prepared using the hourly rainfall data received from the IMD (January 1989 to August 2021), Dum Dum airport station (Station Index: 42809) were analysed and IDF curves and rainfall hyetographs were estimated. The following section presents the results from the IDF analysis.

Gumbel Extreme Value Distribution

This is one of the most widely used method for calculating extreme values in hydrological and meteorological studies for the prediction of extreme meteorological events such as flood peaks and maximum rainfalls. The Gumbel distribution can be applied to model maximum or minimum values (extreme values) of a random variable. The extreme value distribution introduced by Gumbel is commonly known as Gumbel distribution. It is widely used probability distribution function for extreme values in hydrologic and meteorological studies for prediction of flood peak and maximum rainfall etc. Gumbel distribution is widely used in Indian sub-continent.

The Gumbel distribution can be used to calculate the maximum value of expected rainfall (X_T) corresponding to any return period (T) using the below equation:

$$X_t = u + \alpha y_t \quad (4.4)$$

Where u and α are the mode of distribution and sample moments respectively which is given by the following equation.

$$u = \bar{X} - .5772 \alpha \quad (4.5)$$

$$\alpha = (\sqrt{6} / \pi) \sigma \quad (4.6)$$

$$y_t = -\ln \left| \ln \left(\frac{T}{T-1} \right) \right| \quad (4.7)$$

Where,

X_t = T year return period value

$\bar{X}$ = Mean of N observations

σ = standard deviation of N observations = $\sqrt{\frac{\sum (X - \bar{X})^2}{(N-1)}}$

T = Storm return period

N = Sample size

An analysis of the dataset for the past 32-year period (1989 to 2021) has been conducted utilizing existing hourly IMD rainfall data and statistical tools to derive the intensity duration frequency (IDF) relationships. Estimation of rainfall intensities over various timescales and recurrence intervals (2 Year Return Period – T2, 5 Year Return Period – T5, and 100 Year Return Period -T100) have been used to construct the IDF relationships (Figure 2-7, Figure 2-8). The relationship between rainfall intensity, storm duration, and return periods from rainfall data for the study area was developed using the Gumbel Extreme Value Distribution method explained in the CPHEEO storm water drainage manual. Study area IDF plot for once in 2-year, once in 5-year, and once in 100-year return period are shown below:

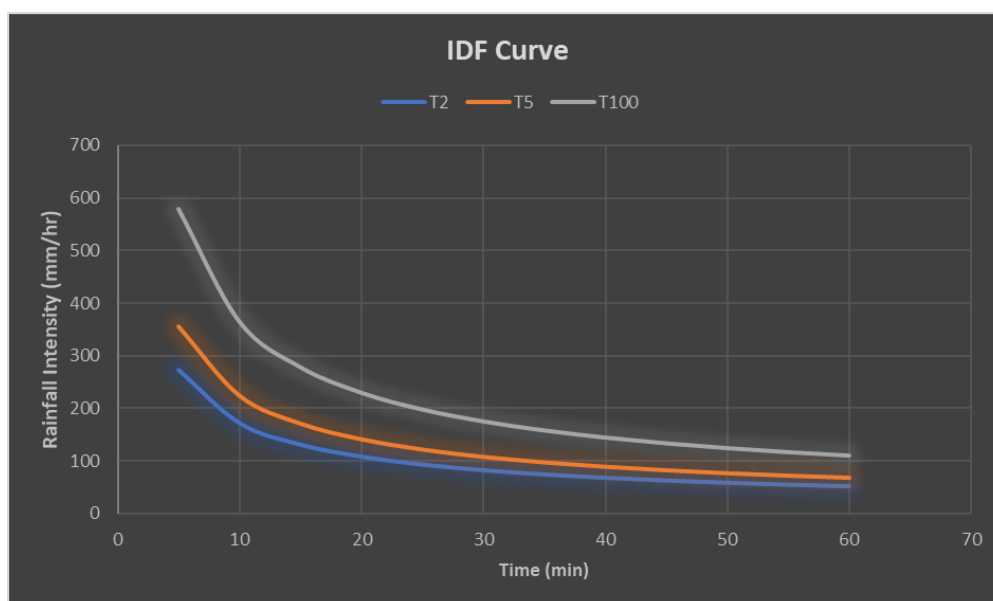


Figure 18:-IDF curve using hourly IMD data (2-year, 5-year and 100-year return period)

Intensity of Precipitation

The intensity of rainfall decreases with duration. Analysis of the observed data on intensity and duration of rainfall of past records over a period of years in the area is necessary to arrive at a fair estimate of intensity-duration for given frequencies. The longer the record available, the more dependable is the forecast. In Indian conditions, intensity of rainfall adopted in design is usually in the range of 12 mm/hr to 20 mm/hr or based on the actual record. Figure 21 gives the analysis of the frequency of storms of

stated intensities and durations during 26 years for which rainfall data were available for a given town.

The stepped line indicates the location of the storm occurring once in 2 years, i.e., 13 times in 26 years. The time-intensity values for this frequency are obtained by interpolation from Table below.

Duration in Minutes	Intensity mm/hr	30	35	40	45	50	60	75	100	125
		No. of storms of stated intensity or more for a period of 26 years								
5						100	40	18	10	2
10				90	72	41	25	10	5	1
15			82	75	45	20	12	5	1	
20		83	62	51	31	10	9	4	2	
30		73	40	22	10	8	4	2		
40		34	16	8	4	2	1			
50		14	8	4	3	1				
60		8	4	2	1					
90		4	2							

Figure 19:- Duration vs Intensity of Storms

Table 8:-Time intensity values of storms

(Source: CPHEEO)

i (mm/hr)	t (min)	i (mm/hr)	t (min)
30	51.67	50	18.50
35	43.75	60	14.62
40	36.48	75	8.12
45	28.57		

The relationship may be expressed by a suitable mathematical formula, several forms of which are available. The following two equations are commonly used:

$$i = \frac{a}{t^n} \quad (4.8)$$

$$i = \frac{a}{t+b} \quad (4.9)$$

where, i : Intensity of rainfall (mm/hr)

t : Duration of storm (minutes)

a, b and n : Constants

The available data on *i* and *t* are plotted, and the values of the intensity (*i*) can then be determined for any given time of concentration, (*t_c*).

Manning's Formula

A mathematical formula for calculating wastewater flows in sewers.

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \quad (4.10)$$

- **Q** means flow in cubic feet per second (CFS) (cubic meters per second (m³/s)).
- **n** means the Manning pipe or channel roughness factor.
- **A** means the cross-sectional area of the flow in square feet (sq ft) (square meters (m²)).
- **R** means the hydraulic radius in feet (meters) where R equals A/P. P is the wetted perimeter of the channel or pipe in feet (meters).
- **S** means the slope of the channel or energy grade line in feet per foot (ft/ft) (meters per meter (m/m)).

Table 9:-Coefficient of roughness for channel flow for use in manning's

(Source: Manual on Sewerage and Sewage Treatment Systems, by CPHEEO, 2013)

Type of Material	Condition	Manning's n
Salt-glazed stoneware pipe	(a) Good	0.012
	(b) Fair	0.015
Cement concrete pipes (With collar joints)	(a) Good	0.013
	(b) Fair	0.015
*Spun concrete pipes (RCC & PSC) with S / S Joints (Design value)		0.011
Masonry	Neat Cement Plaster	0.018
	Sand and Cement Plaster	0.015
	Concrete, steel troweled	0.014
	Concrete, wood troweled	0.015
	Brick in good condition	0.015
	Brick in rough condition	0.017
	Masonry in bad condition	0.020
Stonework	Smooth, dressed ashlar	0.015
	Rubble set in cement	0.017
	Fine, well-packed gravel	0.020
Earth	Regular surface in good condition	0.020
	In ordinary condition	0.025
	With stones and weeds	0.030
	In poor condition	0.035
	Partially obstructed with debris or weeds	0.050
Steel	Welded	0.013
	Riveted	0.017
	Slightly tuberculated	0.020
Cast Iron / Ductile iron	With spun cement mortar lining	0.011
	Unlined	0.013
	With spun cement mortar lining	0.011
Asbestos Cement		0.011
Plastic (Smooth)		0.011
FRP		0.01
HDPE / UPVC		0.01

The proposed project should be able to benefit the entire population of the project area for the horizon year 2050.

Type	Characteristics	Range of Manning's n		
		Minimum	Normal	Maximum
Cement	Neat surface	0.010	0.011	0.013
	Mortar	0.011	0.013	0.015
Concrete	Trowel finish	0.011	0.013	0.015
	Float finish	0.013	0.015	0.016
	Finished, with gravel on bottom	0.015	0.017	0.020
	Unfinished	0.014	0.017	0.020
	Guniting, good section	0.016	0.019	0.023
	Guniting, wavy section	0.018	0.022	0.025
	On good excavated rock	0.017	0.020	—
	On irregular excavated rock	0.022	0.027	—
Concrete bottom float finished with sides of	Dressed stone in mortar	0.015	0.017	0.020
	Random stone in mortar	0.017	0.020	0.024
	Cement rubble masonry, plastered	0.016	0.020	0.024
	Cement rubble masonry	0.020	0.025	0.030
	Dry rubble or riprap	0.020	0.030	0.035
Grouted riprap	—	0.028	0.030	0.040
Stone masonry	—	0.030	0.032	0.042
Soil cement	—	0.020	0.022	0.025
Asphalt	—	0.016	0.016	0.018
	Smooth	0.013	0.013	—
Brick	Glazed	0.011	0.013	0.015
	In cement mortar	0.012	0.015	0.018
Masonry	Cemented rubble	0.017	0.025	0.030
	Dry rubble	0.023	0.032	0.035
Dressed ashlar	—	0.013	0.015	0.017

Figure 20:-Mannings Roughness Coefficients

Source: -USFHWA (2005); Chow (1959)

Table 10:-CENCUS POPULATION OF DISTRICTS OF NORTH 24 PARGANAS OF 1971,1981,1991,2001,2011

Name of Municipalty	AREA	POP_1971	POP_1981	POP_1991	POP_2001	POP_2011
Barrackpore Subdivision						
KAMARHATI MUNICIPALITY	10.96	169,404	234,951	266,889	314,507	330,211

Table 11:-population and pollution load calculation

Municipality	POP_2050						Estimated Pollution load		
	AIM	GIM	IIM	Exponential Graphical	Linear Graphical	Adopted Population	LPCD	80% sewage generated	MLD (Pop x LPCD x 80% sewage generated))/10^6
KAMARHATI	486,998	490,162	328,248	650,100	223,985	486,998	165	80%	64.28

Table 12:-Census_2011 & Survey Data

Ward	Population	Area	Ward	Population	Area
1	11659	0.138232	19	4919	0.195012
2	18942	0.255919	20	5899	0.220991
3	16067	0.089481	21	9652	0.353929
4	18321	0.078848	22	10414	0.356121
5	12296	0.177393	23	8529	0.254552
6	12488	0.074023	24	5589	0.369571
7	10495	0.153343	25	5452	0.177541
8	15162	0.48255	26	7506	0.247102
9	9737	0.340169	27	4764	0.154942
10	10736	0.485908	28	6727	0.335205
11	13095	0.386507	29	9524	0.552165
12	7719	0.32675	30	7788	0.33018
13	8456	0.286231	31	6849	0.252126
14	6180	0.462801	32	4493	0.251483
15	7234	0.576583	33	10192	0.337453
16	7783	0.723698	34	6707	0.208055
17	9392	0.525171	35	9234	0.691175
18	10211	0.436213			
Kamarhati Total Population: - 330211					

Flood Estimation of proposed Storm Water Drain

The Rational Method, a widely accepted approach for predicting potential flooding, was employed for estimating the design discharge in the catchment area of Kamarhati Municipality (Wards 10-15). This method focuses on determining the peak flow, representing the flow rate when the entire catchment contributes to its outlet. The peak flow is calculated using the formula:

$$Q_p = 10 C I A \quad (4.11)$$

where, Q_p = Peak flow at the point of design, m^3/s ,

C = Runoff Coefficient, Dimensionless

I = Rainfall intensity (2-year return period), mm/hr ,

A = Catchment Area in ha (Hectares)

The Runoff Coefficient (C) is determined based on land use, falling in the range of 0.3 to 0.4. Rainfall Intensity (I) for a 2-year return period, estimated at 52 mm/hr , is derived from IMD gridded rainfall data as per CPHEEO. Kamarhati Municipality ward 10-15 stormwater survey data is shown in Below figure.

While considering the flow in sewers, the hydraulic analysis is made simple by assuming steady flow condition. But in the case of large storm water channels or in pumping mains, where surge or water hammer is predominant, the flow is unsteady. In most of the cases sewers have turbulent flows with streamline along the boundaries. An appropriate sewer will carry the peak flow for which it is designed and at the same time transport the suspended solid in such a way that deposit in the sewer is kept to the minimum.

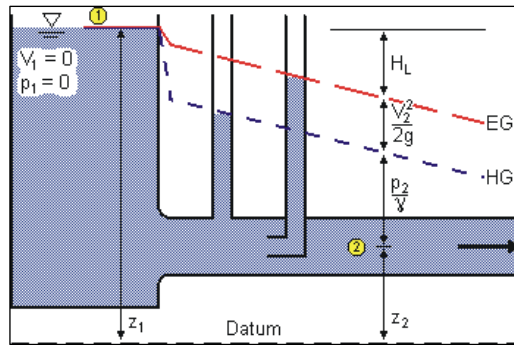
The Rational Method has probably been the most popular method for designing storm systems. It has been applied all over the world and many refinements of the method have been produced.

For small catchment areas, it continues to be a reasonable method, provided that it is used properly and that results, and design concepts are assessed for reasonableness.

The design process involves a combination of hydrology, hydraulics and water quality. Hydrologic considerations determine the flows at each point in the drainage system. Runoff flows will collect pollutant loads. The resulting hydrographs and pollutographs are then routed downstream according to hydraulic principles. Water quality can be improved by treatment devices, which in turn affect the runoff and hydraulics (by, for example, introducing additional head losses). Because of the interaction between hydrology, hydraulics, and water quality all aspects need to be considered together.

Assume that the flow direction in the pipe is from junction (1) to (2) and its value is the pressure and elevation head and the mean velocity at (1) are P_1 , Z_1 and V_1 respectively, the total pressure, elevation head and mean velocity at (2) are P_2 , Z_2 and V_2 respectively, the total friction and fitting head losses from (1) to (2) are h_L , the pump's head is h_p , all heads are in m . for this system:

$$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} + h_p = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g} + h_L \quad (4.12)$$



The objective of BMPs is to minimize the adverse effects of development by mimicking, as closely as possible, the runoff characteristics of the site in its undeveloped state. These characteristics include:

- Moderation of runoff peak flows and volumes to minimize downstream erosion and damage to in-stream aquatic habitat.
- Removal of pollutants such as sediment, nutrients, pathological bacteria, and heavy metals.
- Infiltration of rainfall to replenish the water table and provide stable base flow to streams.

The preferred stormwater management approach is to preserve the natural storage, infiltration, and pollutant-treatment functions of each drainage area where practical, and where not practical to construct BMPs that mimic those natural functions as closely

as possible. Stormwater calculations are required to analyze a proposed new development for its impacts on peak flows and volumes. Stormwater programs in North Carolina typically include provisions to control and treat a certain volume of stormwater runoff and/or provisions to control the peak stormwater discharge rate. Additional calculations are required to design BMPs with appropriate treatment capacity and correctly sized outlet structures. Table 3-1 summarizes the stormwater calculations and allowable methods that will be presented in this chapter.

Table 13:- Summary of Stormwater Calculations

Calculation of:	Allowable Methods
Peak Flow	Rational Method
Runoff Volume	Simple Method Discrete SCS Curve Number Method
Storage Volume	Stage-Storage Table
Hydraulic Performance of the Outlet Device	Weir Equations Orifice Equation
Stage-Storage-Discharge	Chainsaw Routing Others: HEC-HMS, WinTR-55, SWIMM
Channel Geometry	Manning Equation
Nutrient Loading	DWQ Neuse TN Export Worksheet DWQ Tar-Pamlico Nutrient Export Worksheet
Pollutant Removal of BMPs	Stand-alone BMPs Multiple Drainage Areas BMPs in Parallel BMPs in Series

The design procedures presented here assume that the flow is consistent and uniform within each storm drain segment. This means that each segment's discharge and flow depth is assumed to be constant in time and distance. Also, since storm inlet conduits are typically prismatic, the average systems are variable and the flow conditions at each inlet are not really steady or even. Since the usual hydrological methods used in the design of storm drains are:

Rational Method- only for drainage areas less than 50 hectares (0.5 km²).

SCS and other Unit Hydrograph Methods- for drainage areas greater than 50 hectares (0.5 km²).

Watershed Regression Equations- for all routine designs at sites where applicable.

Log Pearson III Analyses- preferable for all routine designs provided there is at least 10 years of continuous or synthesized record for 10-years discharge estimates and 25 years for 100-year discharge estimates, and

Suitable Computer Programs- such as HYDRAIN's HYDRO, HEC 1 and TR-20 will be used to facilitate hydrologic calculations.

The Rational Method (or Rational Formula) is:

$$Q = C_f C_i A \quad (4.13)$$

Where: Q = Peak flow in cubic feet per second (cfs)

C_f = Runoff coefficient adjustment factor to account for reduction of infiltration and other losses during high intensity storms

C = Runoff coefficient to reflect the ratio of rainfall to surface runoff

i = Rainfall intensity in inches per hour (in/hr)

A = Drainage area in acres (ac)

Limitations and assumptions in the Rational Method are as follows:

- The drainage area should not be larger than 200 acres.
- The peak flow is assumed to occur when the entire watershed is contributing runoff.
- The rainfall intensity is assumed to be uniform over a time duration equal to or greater than the time of concentration, T_c.
- The peak flow recurrence interval is assumed to be equal to the rainfall intensity recurrence interval. In other words, the 10-year rainfall intensity is assumed to produce the 10-year flood.

Log Pearson III Analyses

Log Pearson type III distribution is widely used for frequency analysis for stream flows and can also be used for rainfall. The values obtained by Log Pearson type III distribution is more satisfactory as it has 3 parameter distribution that considers mean, standard deviation and skewness of data series. Process of computations described as follows:

- The variate (data series) is transformed into logarithmic form either on base (10

or

e) and the transformed data is then analyzed.

- If X is the variate of random hydrologic series, then the series of z variates where $z = \log X$

I-D-F Data

Intensity-duration-frequency (I-D-F) data includes:

- I-D-F Curves
- I-D-F Tables
- I-D-F e, b, d Equation

I-D-F Curves

I-D-F (Intensity-Duration-Frequency) curves provide the engineer with a means of determining the rainfall intensity for the frequency and duration of a given storm.

Reading an I-D-F Curve the resulting average intensity is 5 inches (12.7 cm) an hour for 12 minutes, for example, a 5-year frequency. In other words, if for a period of 12 minutes an average intensity of 5 cm / hour falls, it would be considered a 5-year event.

I-D-F Tables

Bentley SewerGEMS allows you to enter I-D-F data into a table and save data so that other models can use it again. Entering the design intensities is a very simple process of searching and entering data from a graph into the I-D-F table.

I-D-F e, b, d Equation

I-D-F curves can be fit to equations. The most common form of these equations is:

$$i = b/(T+d)^e \quad (4.14)$$

where,

i = rainfall intensity (cm/hr.)

T = rainfall duration (min.)

e,b,d = rainfall equation coefficients

This equation represents the mathematical relationship between the intensity of the rainfall and the duration of the rainfall for a storm at a given frequency and location. The coefficients of the rainfall equation vary with the frequency of storm data and the location of storm data.

Using rainfall equations properly requires that they yield results consistent with the design locale's historical rainfall data. If this consistency is not provided by the preceding equation, it is not appropriate for your design.

The Coefficient of Runoff (C) is a dimensionless parameter that represents the ratio of runoff to precipitation received. It is influenced by various factors, including the shape of the sub-catchment, percentage of imperviousness, time of concentration, evaporation, interception, infiltration, depression storage, soil moisture, and antecedent precipitation. Initially, the Coefficient of Runoff increases gradually as pervious surfaces take time to saturate, but once saturated, it remains fairly constant for a given area. The Coefficient of Runoff can be expressed as the product of several factors, which take into account the complex interactions between these influencing

factors.

- Coefficient of imperviousness.
- Coefficient of distribution of rainfall.
- Coefficient of retention.
- Coefficient of retardation.

The runoff co-efficient varies from 0 to 1. When watershed consists of many lands uses and soil types, weighted runoff coefficient has to be calculated. The runoff coefficients are reported in table.

Table 14:- Runoff coefficient as per CPHEEO

(Source: Manual on Sewerage & Sewage Treatment Plants, CPHEEO, 2013)

Duration, t, minutes	10	20	30	45	60	75	90	100	120	135	150	180
Weighted Average Coefficient												
1. Sector concentrating in stated time												
a. Impervious	0.525	0.588	0.642	0.70	0.740	0.771	0.795	0.813	0.828	0.840	0.850	0.865
b. 60% Impervious	0.365	0.427	0.477	0.531	0.569	0.598	0.622	0.641	0.656	0.670	0.682	0.701
c. 40% Impervious	0.285	0.346	0.395	0.446	0.482	0.512	0.535	0.554	0.571	0.585	0.597	0.618
d. Pervious	0.125	0.185	0.230	0.277	0.312	0.330	0.362	0.382	0.399	0.414	0.429	0.454
2. Rectangle (length = 4 × width) concentrating in stated time												
a. Impervious	0.550	0.648	0.711	0.768	0.808	0.837	0.856	0.869	0.879	0.887	0.892	0.903
b. 50% Impervious	0.350	0.442	0.499	0.551	0.590	0.618	0.639	0.657	0.671	0.683	0.694	0.713
c. 30% Impervious	0.269	0.360	0.414	0.464	0.502	0.530	0.552	0.572	0.588	0.601	0.614	0.636
d. Pervious	0.149	0.236	0.287	0.334	0.371	0.398	0.422	0.445	0.463	0.479	0.495	0.522

Runoff from a catchment is the portion of precipitation that produces surface flow, serving as the catchment's output in response to precipitation over a given time period. However, before runoff can begin, initial losses must be accounted for, including interception, evapo-transpiration, infiltration, and detention storage requirements. Once these losses are satisfied, the excess rainfall flows over the surface as storm runoff, marking the commencement of runoff. This process highlights the complex interactions between precipitation, catchment characteristics, and runoff generation.

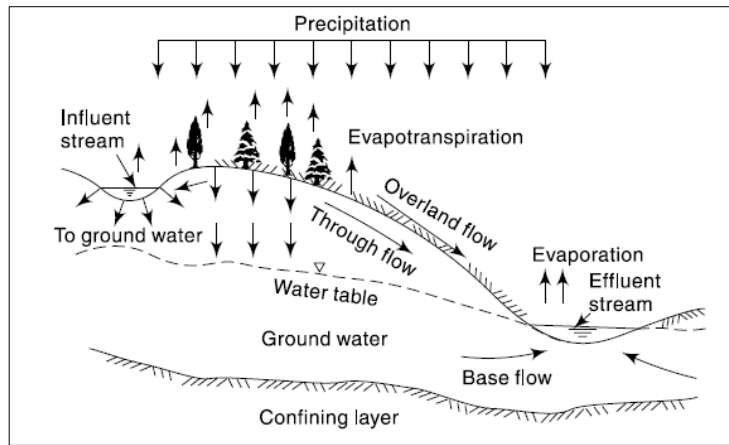


Figure 21:-Different Routes of Runoff

(Source: Manual on Storm Water Drainage Systems, CPHEEO)

Storm water drains are designed with the peak flow in mind, which is the maximum flow rate that occurs when the entire catchment contributes to the outlet simultaneously. This peak flow is reached when a given intensity of rainfall starts suddenly and continues until the time of concentration, which is the time it takes for the entire catchment to respond to the rainfall and contribute to the outlet.

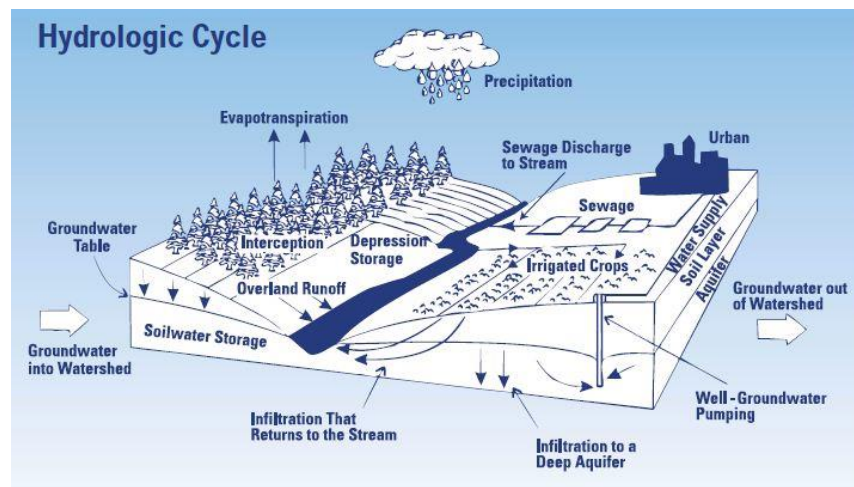


Figure 22:- Hydrologic Cycle

5.3 Applications in Software (SEWERGEMS, QGIS, AUTOCAD)

SewerGEMS users enjoy the power and versatility of working across CAD, GIS, and stand-alone platforms while accessing a single, shared, source of project data.

Modelling capabilities

Modeling: SewerGEMS allows users to create 3D models of sewer and stormwater systems, including pipes, manholes, and other components. The software can model complex systems with multiple sub-systems and hydraulic elements. **Analysis:** SewerGEMS can perform a wide range of analyses, including steady-state and dynamic hydraulic analysis, water quality analysis, and sediment transport analysis. The software can also perform pump sizing and energy cost analysis. **Simulation:** SewerGEMS can simulate the flow of wastewater and stormwater through sewer systems, including the impact of rainfall and other external factors. The software can help engineers and planners predict the performance of sewer systems under various conditions. **Optimization:** SewerGEMS can help users optimize sewer system design and performance by identifying problem areas, suggesting improvements, and testing different scenarios. **Integration:** SewerGEMS can integrate with other software tools, such as geographic information systems (GIS) and computer-aided design (CAD) programs. This makes it easier for users to import and export data and create detailed models of sewer systems.

Data input in Sewer GEMS software

SewerGEMS is a software tool for designing, analyzing, and optimizing sanitary and combined sewer systems. It allows users to create and edit sewer network models, including pipes, nodes, pumps, and valves. The software performs hydraulic and water quality analysis and offers scenario management and optimization tools. SewerGEMS integrates with AutoCAD and GIS software and offers reporting and visualization tools. It helps users design efficient and sustainable sewer systems and ensures compliance with regulations and standards. The input parameters of some elements are shown below.

With Bentley SewerGEMS, the following can be done.

Assess the impact of inflow and infiltration.

Optimize lift station and system storage capacities.

Determine developer connection fees.

Implement real-time control strategies.

Model relief sewers, overflow diversions, and inverted siphons

Accurately simulate operations with variable-speed pumping and logical controls.

Simulate out-of-service or proposed sewers within the same model.

Tabular reporting (FlexTables) - Customize tabular views of all or portions of the network; view all elements in a model, all elements of a specific type, or any subset of elements. FlexTables can be filtered, sorted, and globally edited.

Model-Level Options - Modify global options including unit settings, drawing layout and

display settings, and element labeling.

The term Nodes refers to any of the available point element types:

Catch basins, Manholes, Cross Section Nodes, Junction Chamber, Pressure Junction, Outlet Structures, Outfalls, Wet Wells, Pumps.

The term links refers to any of the available line elements: Pressure Pipe and Conduits Channels and Gutters.

Bentley (2011) By constructing a Stormwater network model in Dronagiri with the use of Civil Storm and the Dutch technique, researchers were able to better understand the issue of flooding during the heavy rain season and ensure appropriate drainage of the Dronagiri area (Navi Mumbai). (Bentley, 2011: Analysing complex StormWater systems with holding ponds below high tide levels in a Navi Mumbai archipelago.

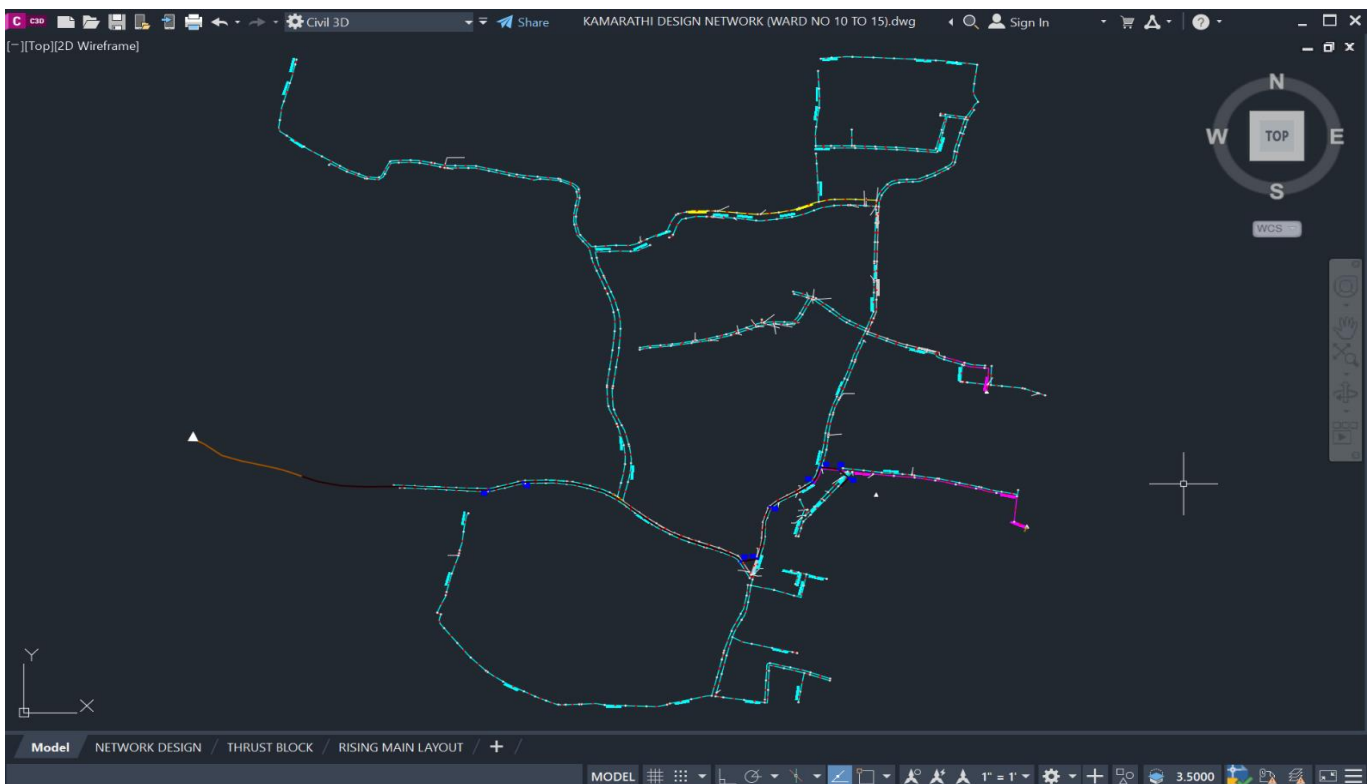


Figure 23:- CAD File of study area.

Steps to extract a DXF file from AutoCAD for use in SewerGEMS software:

1. Open your drawing in AutoCAD.
2. Go to the "File" menu and select "Save As".
3. In the "Save As" dialog box, select "DXF" as the file type.
4. Choose the desired version of DXF (e.g., R2010, R2013, etc.).
5. Select the desired layers or objects to export.
6. Click "Save" to export the DXF file.
7. Open SewerGEMS software and import the DXF file.

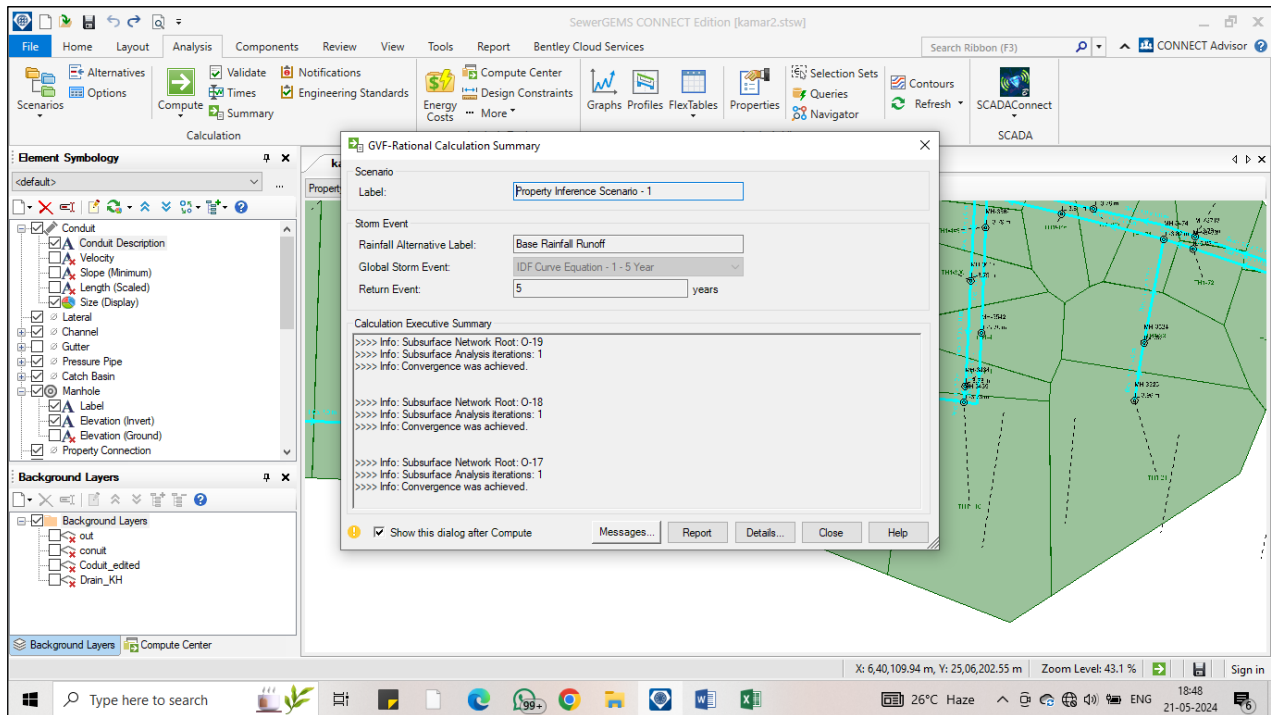


Figure 24:- Calculation Dialogue Box

Creating and model the network directly within our primary drafting environment. This gives us access to all drafting and presentation tools, while still enabling you to perform Bentley SewerGEMS modelling tasks like editing, solving, and data management. This facility provides the most flexibility and the highest degree of compatibility with other CAD-based applications and drawing data maintained.

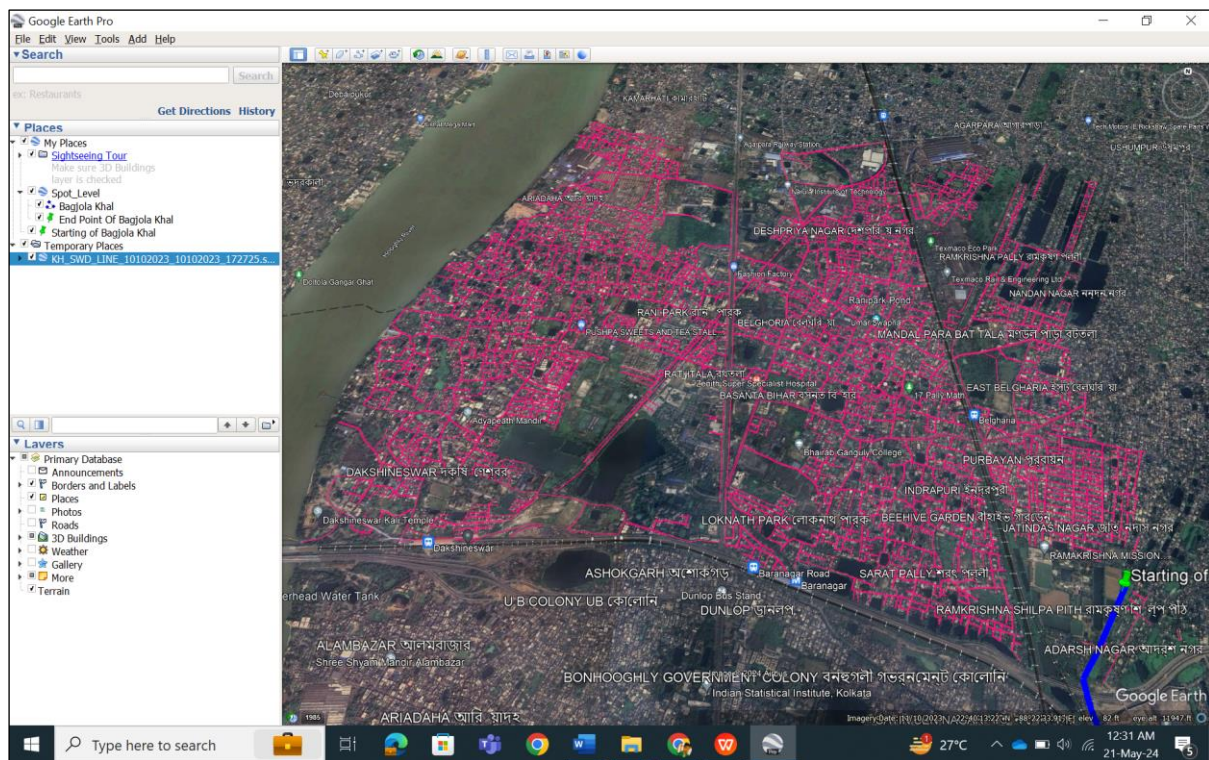


Figure 25:- Locating Study area in Google Earth

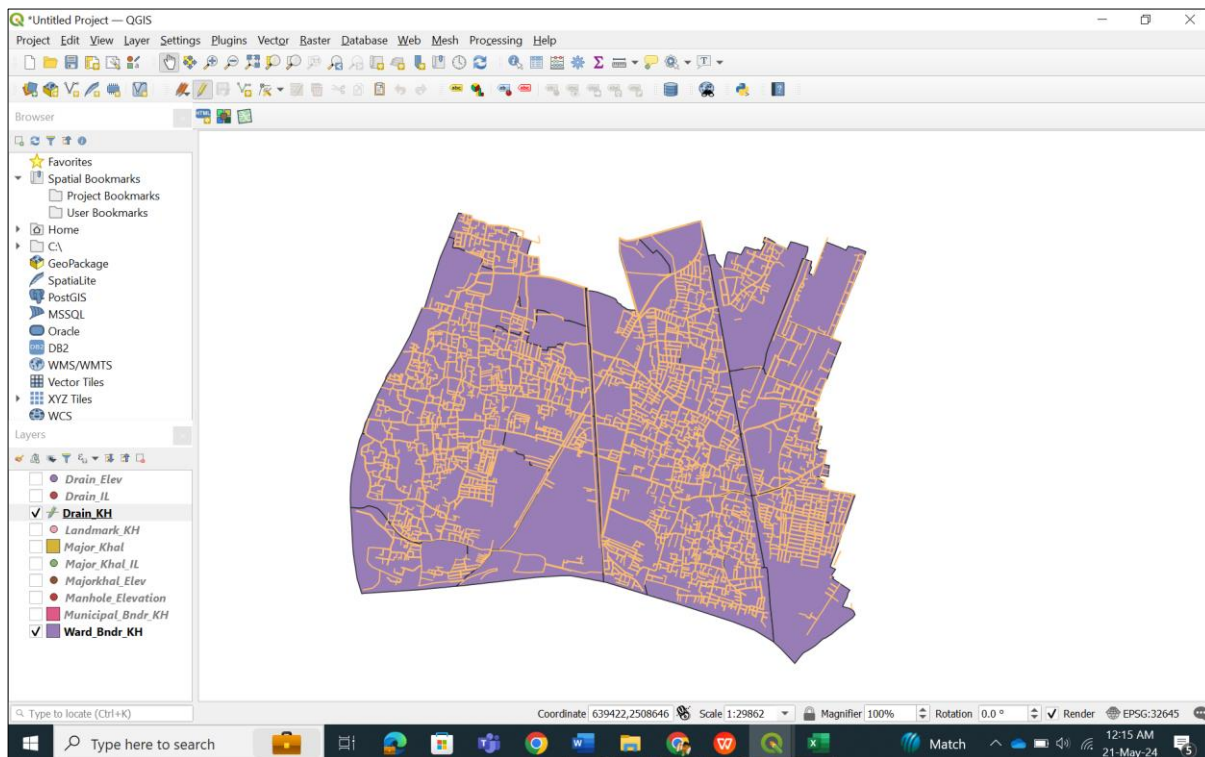


Figure 26:- Kamarhati existing drain from survey exported in QGIS

QGIS can be used to model and design a stormwater drainage network for SewerGEMS by following these steps:

1. Import the project area's shapefiles or CAD files into QGIS.
2. Create a new vector layer for the stormwater drainage network.
3. Digitize the drainage network features (e.g., pipes, channels, manholes) using QGIS editing tools.
4. Attribute the features with relevant information (e.g., pipe sizes, materials, slopes).
5. Export the drainage network layer as a Shapefile or CSV file.
6. Import the exported file into SewerGEMS for further modeling and analysis.
7. Use SewerGEMS to simulate and optimize the stormwater drainage network.

Under Atal Mission for Rejuvenation and Urban Transformation (AMRUT), storm water drainage is an admissible component which involves construction and improvement of drains / storm water drains in order to reduce and eliminate flooding. So far, 799 projects worth ₹2,973 crore in the storm water drainage sector have been grounded across 19 States / Union Territories (UTs). Of these, 655 projects worth ₹1,284 crore have been completed and 144 projects worth ₹1,688 crore are under implementation. Through these completed projects, 2,381 water logging points have been eliminated by laying / construction of 896 km of storm water drainage network.

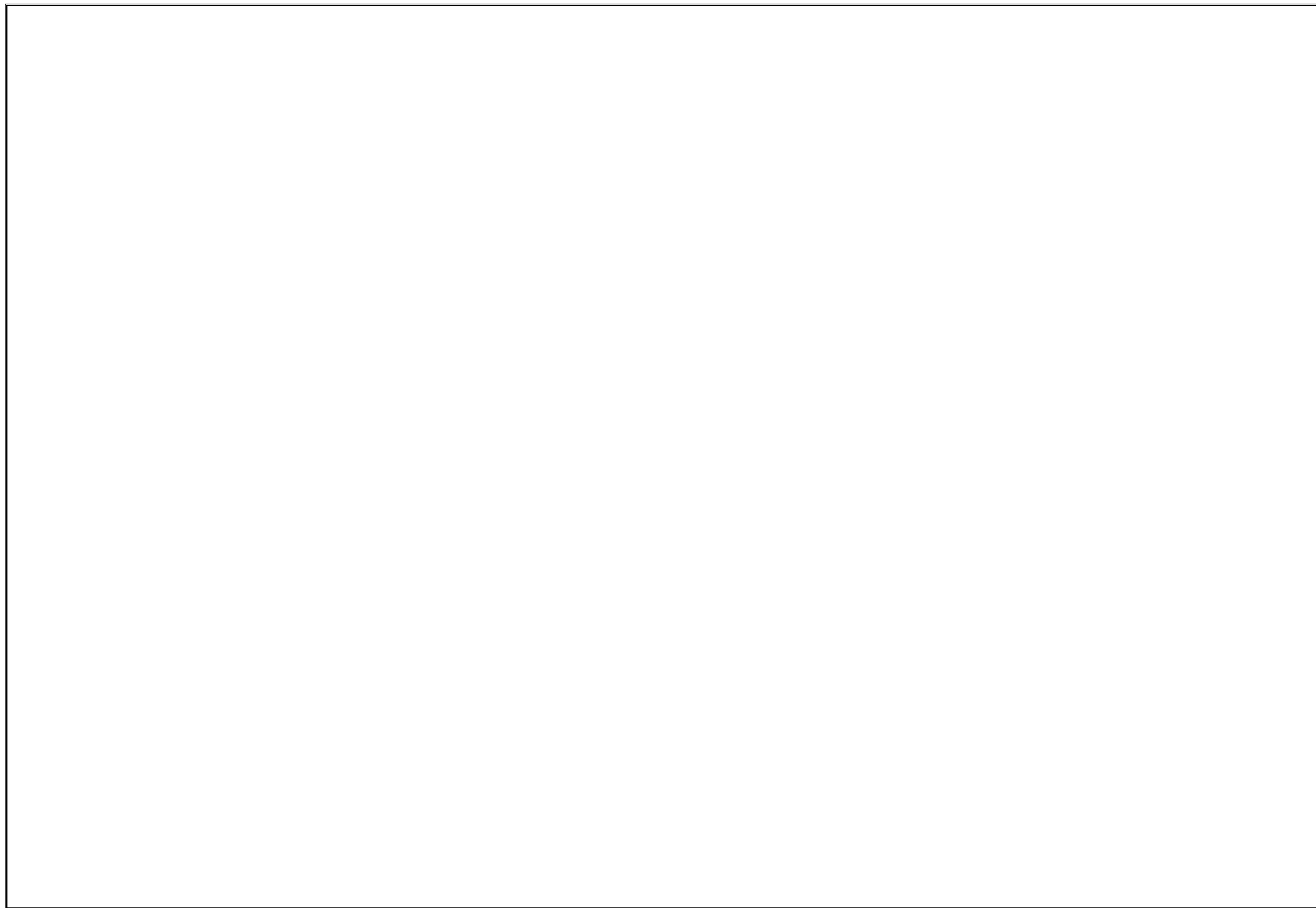
The Ministry of Housing and Urban Affairs (MoHUA) has also brought out Standard Operating Procedure on Urban Flooding, 2017 which focuses on specific actions required to be undertaken by various departments and agencies of the city / town and also organizations under the district administration as well as State Government for responding to urban flooding of any magnitude. The Standard Operating Procedure has been circulated to all the States and UTs for their guidance.

MoHUA had also published manual on Storm Water Drainage Systems, 2019. This manual assists the States / UTs and Urban Local Bodies (ULBs) and other stakeholders on the planning, design, operation and maintenance of Storm water drainage systems. The manual also works as guidance documents in recommending effective measures in flood prevention.

The list of 66 cities where 2,381 water logging points have been eliminated through the projects completed under AMRUT are at Annexure.

Under AMRUT, projects have been selected, appraised, approved and implemented by the concerned States / UTs / ULBs as per their local conditions / constraints and the requirement, which may result in reduction of flooding in their area. States / UTs have mainly taken projects for new drainage network, rehabilitation & cleaning of existing drainage networks, covering of drains to protect from dumping of garbage, installation of pumps etc. to mitigate urban flooding.

AMRUT Mission encourages sharing of good practices being carried out in any AMRUT city with all other Mission cities. Further, States / UTs / ULBs are free to adopt any suitable technique / method based on their local conditions.



6 RESULT AND DISCUSSIONS

The chapter below report and discuss the results obtained from the study. After collecting and computing data of the drainage network of the study area, the parameters like pressure, flow, slope, and velocity have been computed using SEWERGEMS.

This paper concerns for the design of Storm water drainage systems in Kamarhati area consisting of 10.686 Kms of Drainage and serving to a design population within the Kamarhati ward no's 10 to 15 in the North 24 Parganas district. The model consists of Conduit Description, Invert, Length, Velocity and Slope.

In this study, the furthest points in ward are taken care off and described below.

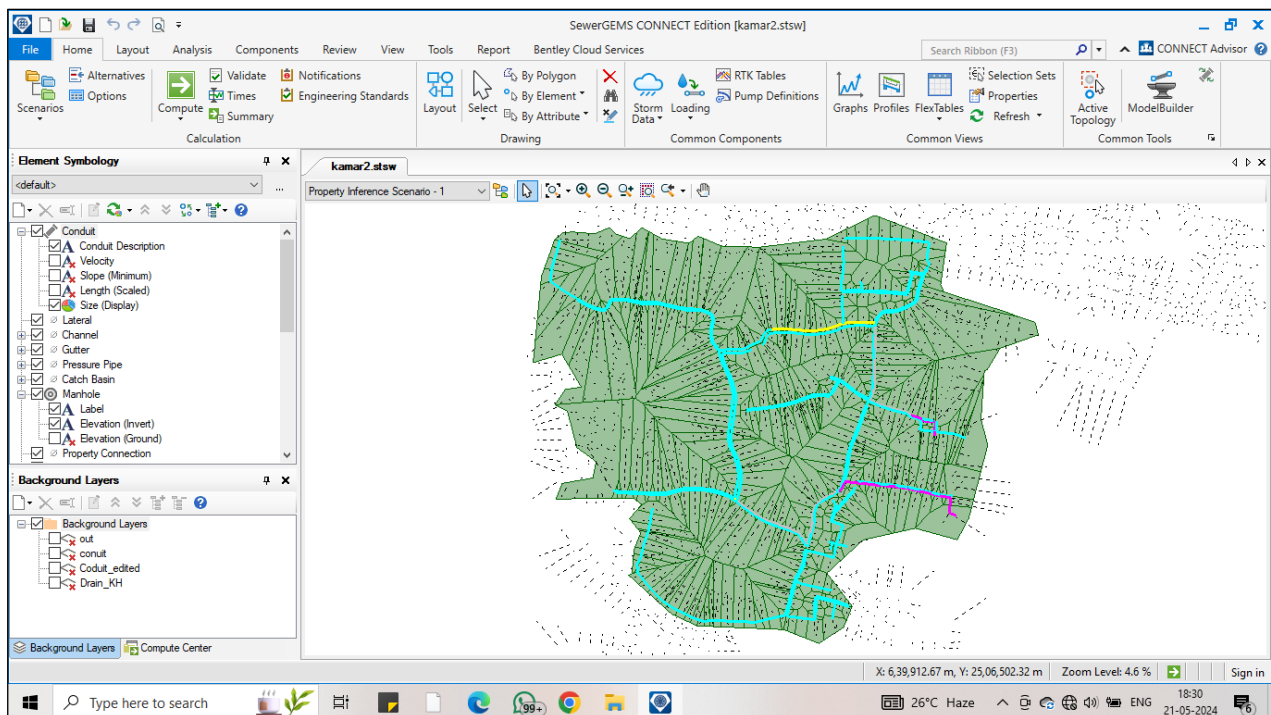


Figure 27:-Model

The figure 29 shows the entire study area drainage network in Software interface of SEWERGEMS.

The entire drainage network with manhole are plotted in this.

When using ModelBuilder to integrate GIS data into Bentley SewerGEMS, it's crucial to have a unique identifier (Key/Label field) for each element in your model. Ensure your data source tables have clear column labels, as ModelBuilder will default to using the first row as column headers if not specified. Utilize powerful GIS and database tools to perform joins (Database, Spatial, and Update) to format your data appropriately, making it suitable for use in ModelBuilder. This will enable a seamless integration of your GIS data into your model.

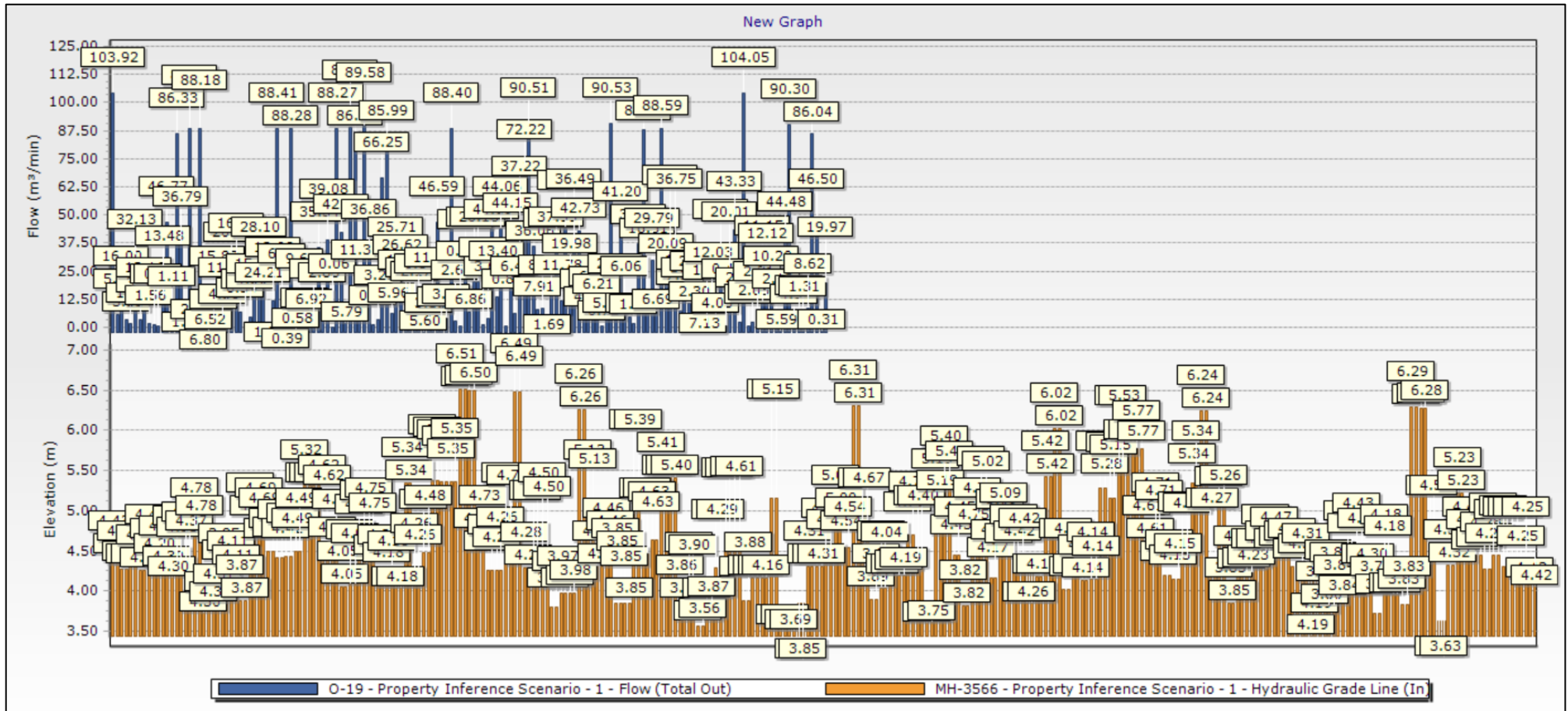


Figure 28:-Bar Chart Graphical Representation

Ground Elevations and Invert Elevations- The start node of invert elevation of the outfall was taken as 0 by default and the stop node of invert elevation was taken as 6.31 meters. All other values of the elevations were entered for all the manholes as per the hydraulic sheet.

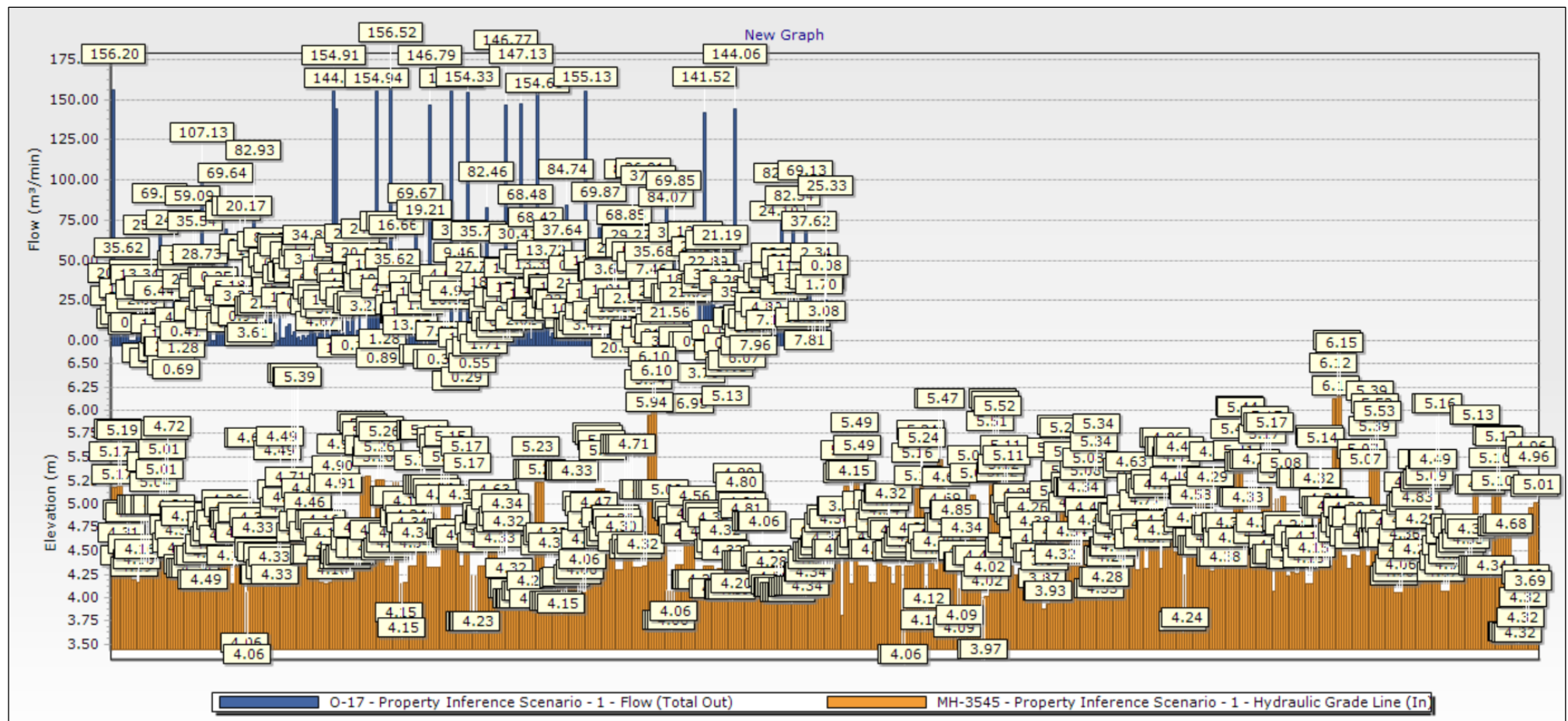


Figure 29:- Bar Chart

Pipe Length- Pipe length here refers to the distance between two consecutive manholes. The maximum distance between two manholes is usually 15 meters. However, in case of extra loading in certain location, manholes might be placed more closely.

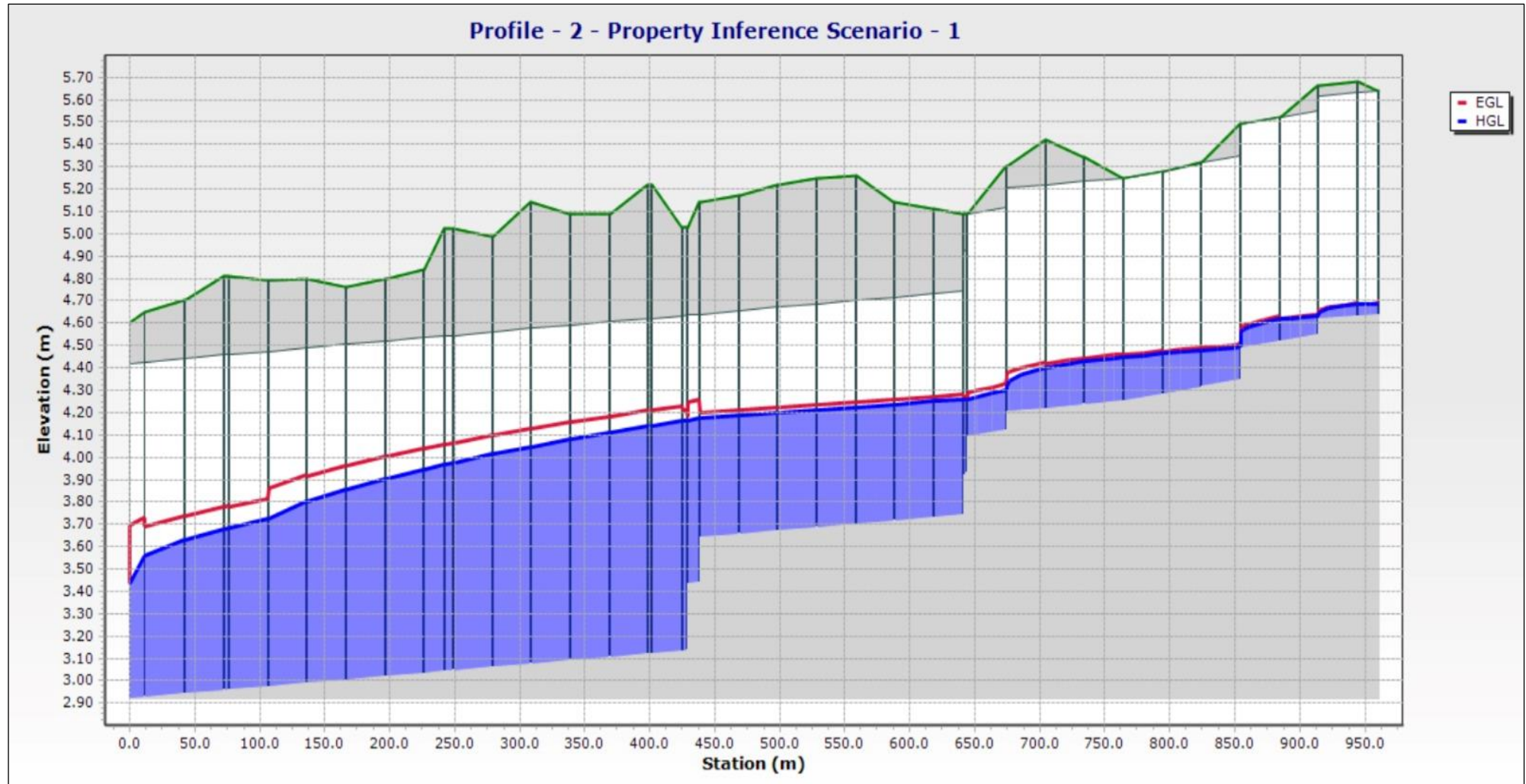


Figure 30:-Profile

The Profile view dialog box opens, displaying the selected three nodes and two links. The graphical representation shows a blue line indicating the calculated Hydraulic Grade Line (HGL), a green line representing the ground elevation, and parallel vertical lines symbolizing the node elements. Notably, red marks are superimposed over the node elements, signifying the maximum HGL calculated for each node. This visual display provides a clear and comprehensive overview of the hydraulic profile, enabling easy analysis and understanding of the system's behavior.

Profile - 1 - Property Inference Scenario - 1

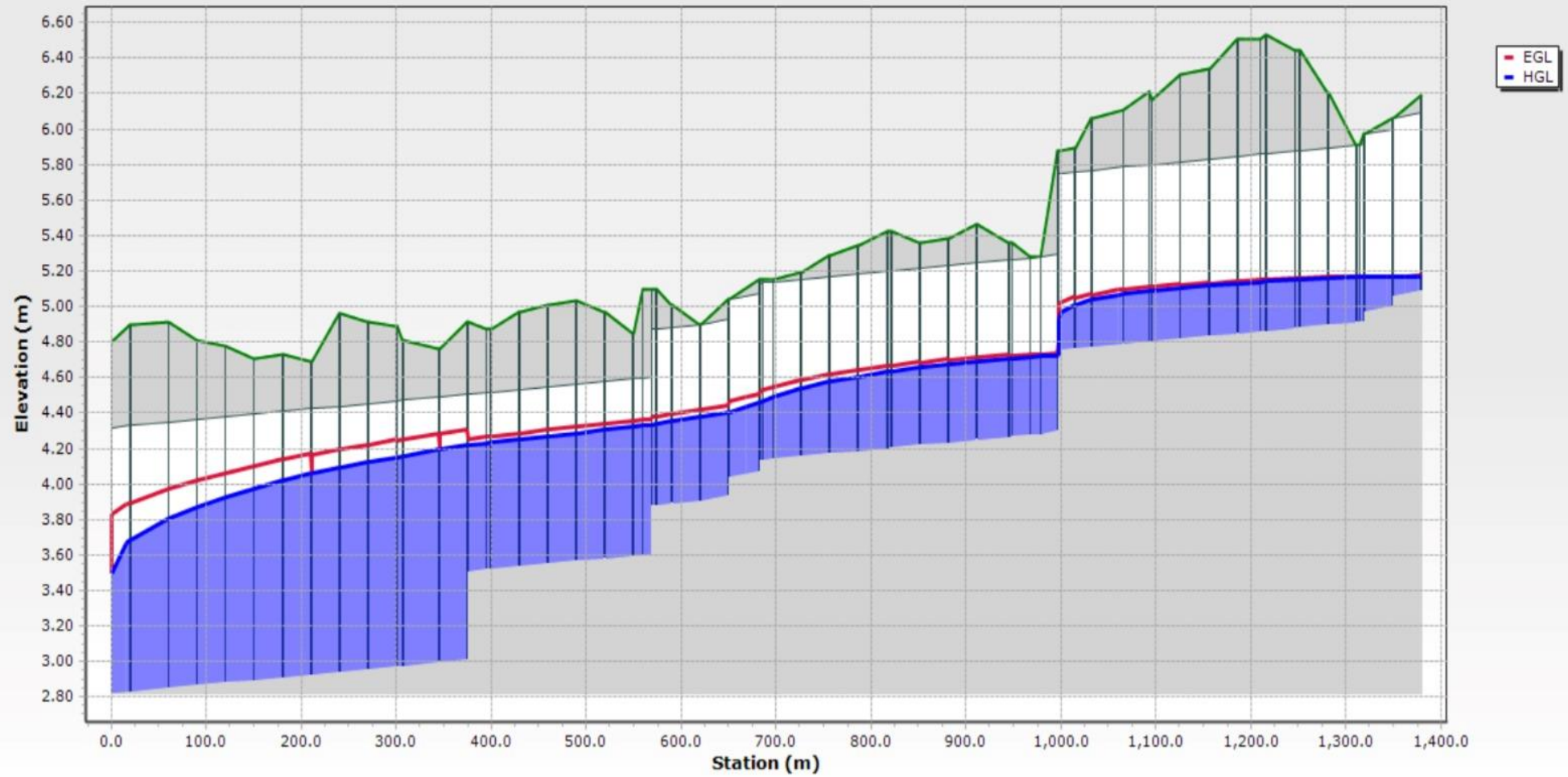


Figure 31:-Profile

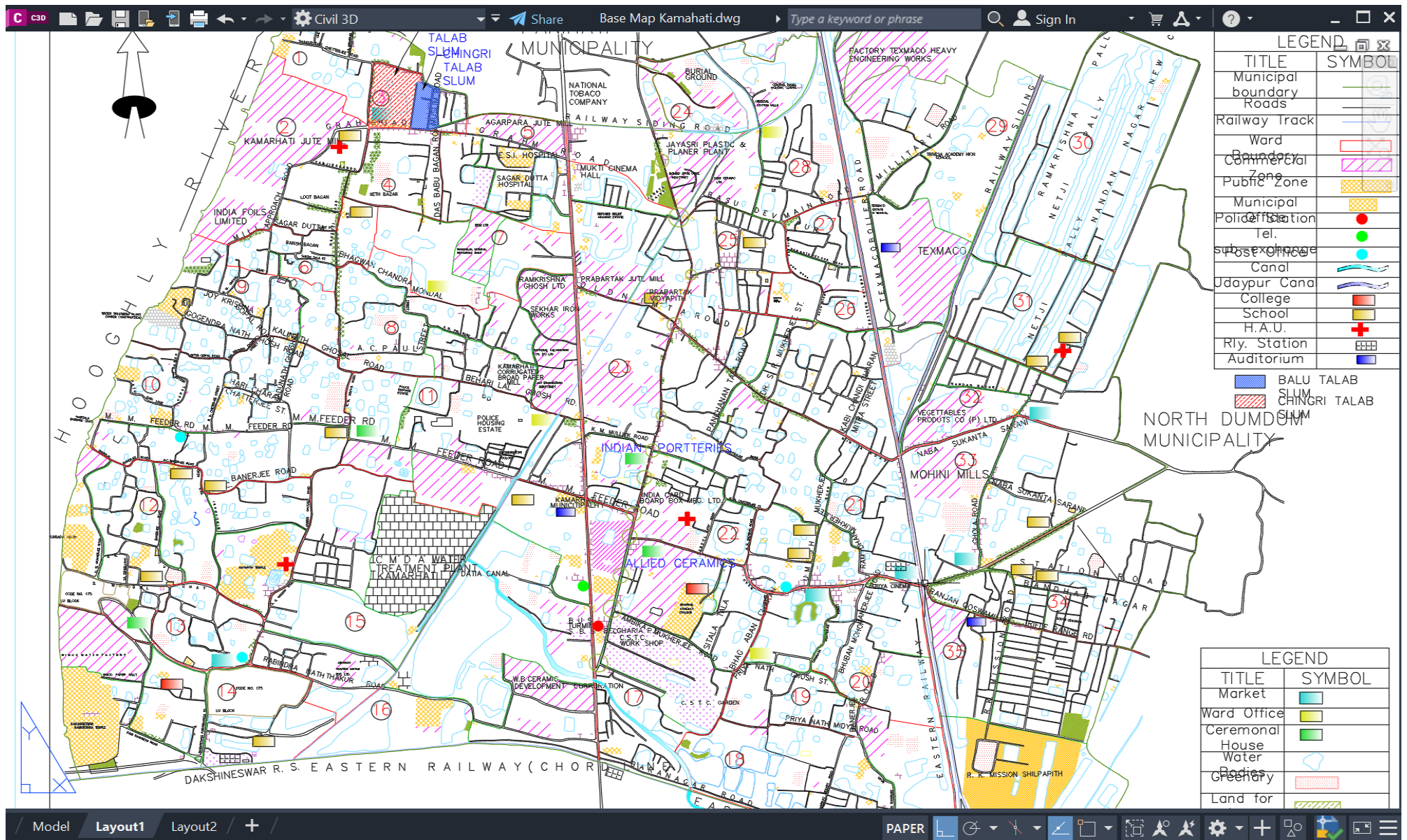


Figure 32:- Base Map of Kamarhati in CAD

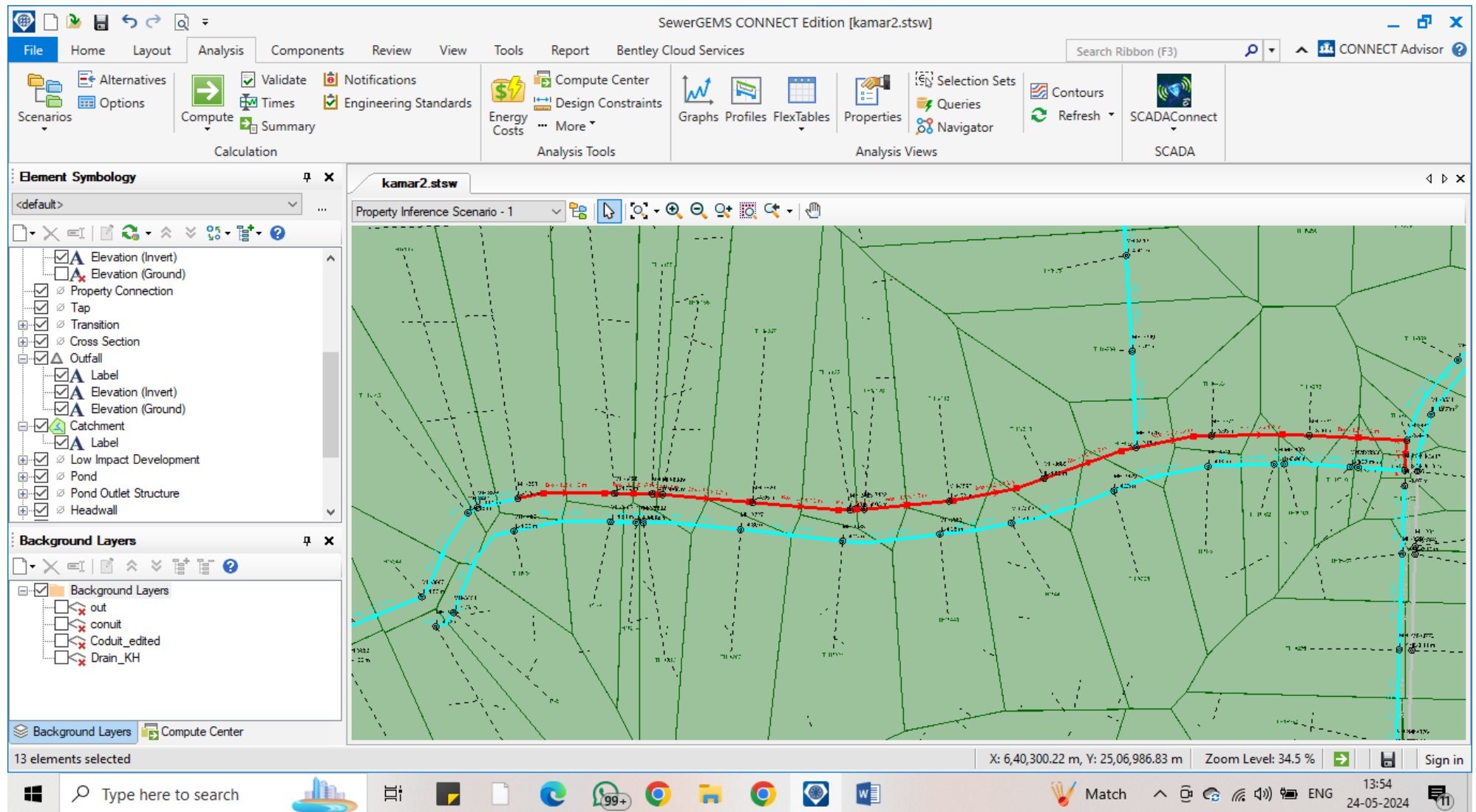


Figure 33:- Drainage Network

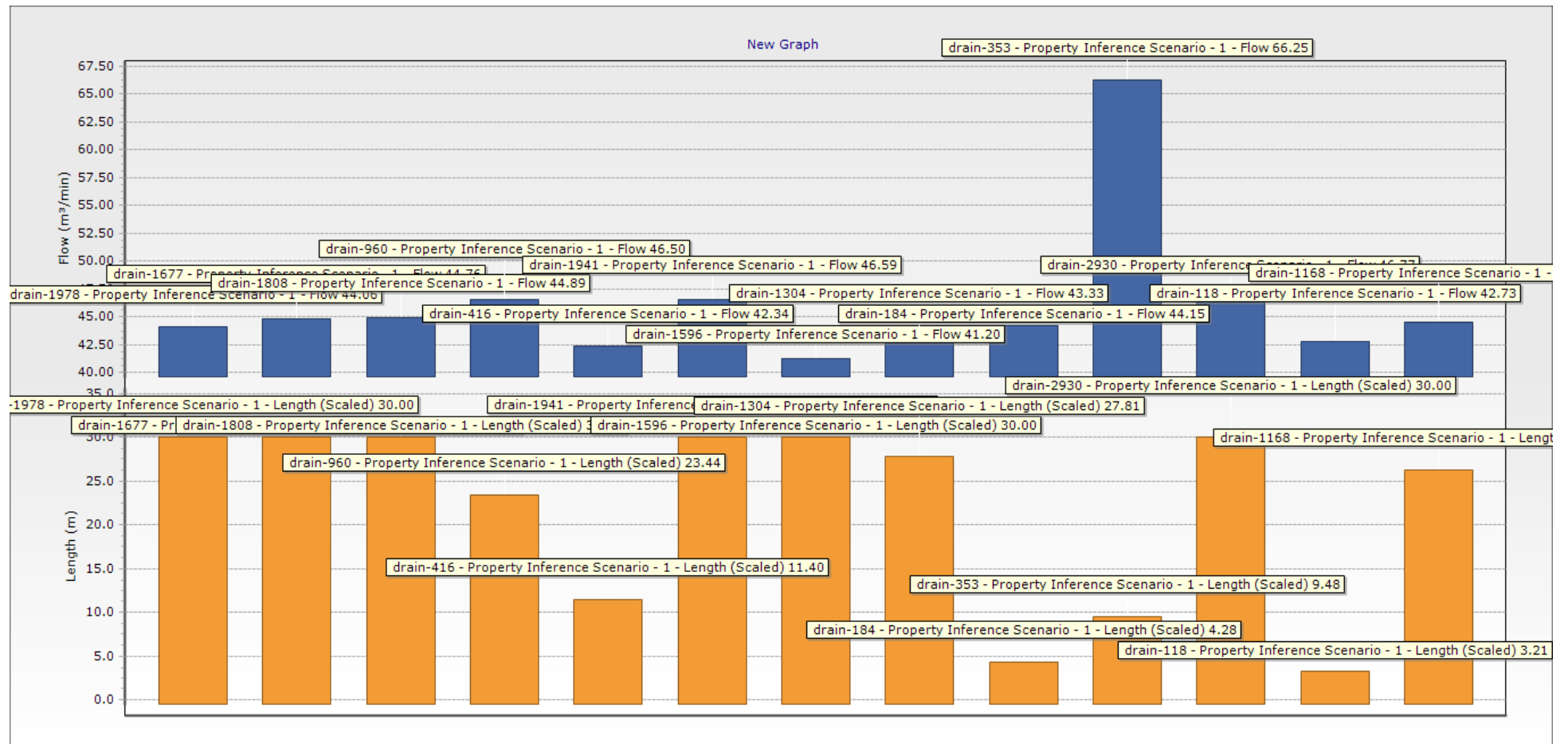


Figure 34:- Graph Bar Chart

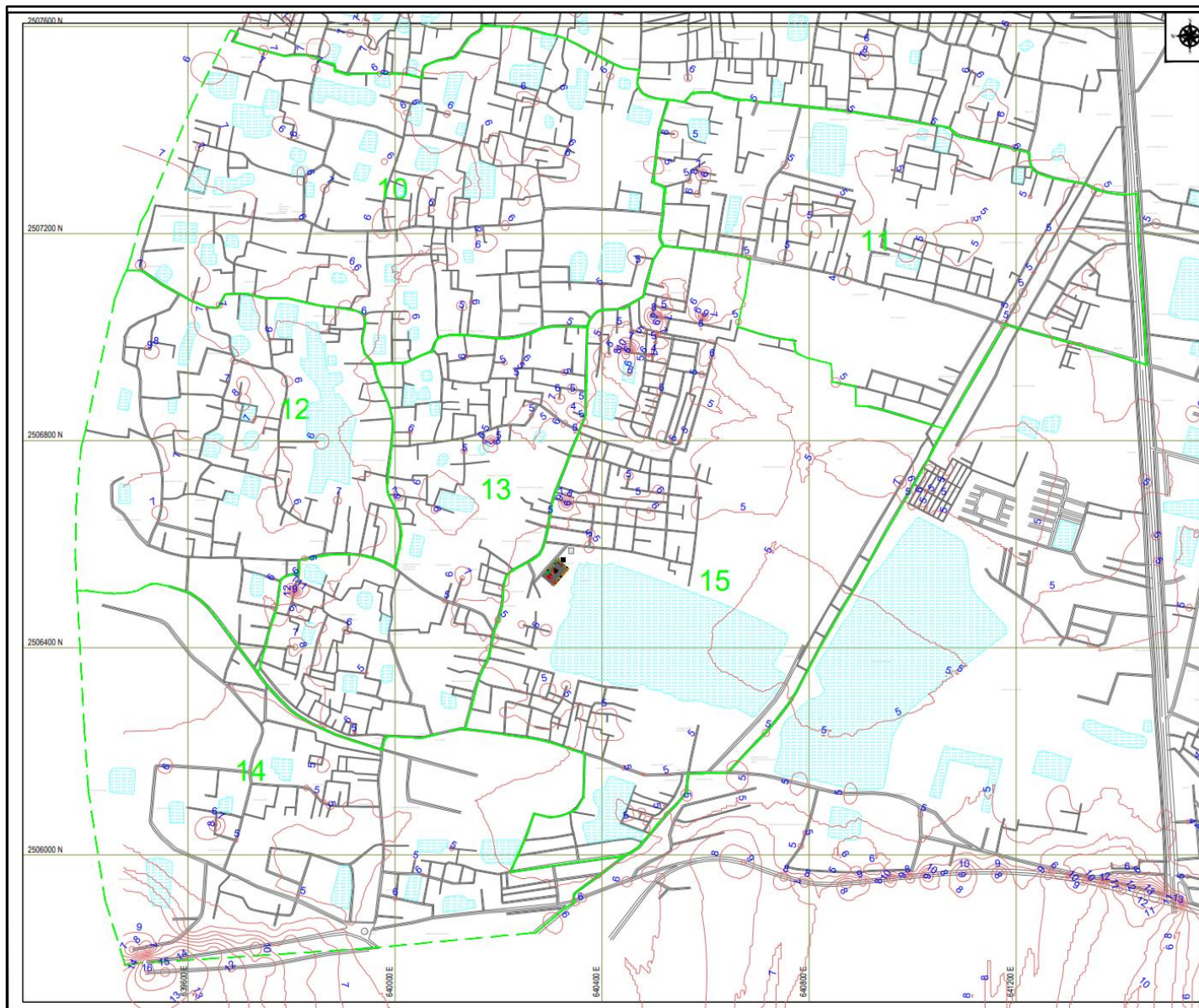


Figure 35:- Contour Map of Study Area

Table 15:-Hydrological and Hydraulic Analysis Results

Catchment Area (A)	69 ha
Runoff co-efficient (C)	0.3
Rainfall Intensity 1 in 2 years return period (I)	52 mm/hr
Catchment Runoff (Q=CIA)	177.91 m ³ /min
	2.97 m ³ /sec
Discharge at the drain outfall (Outfall ID: O17) into the pond after the analysis	156.2 m ³ /min
	2.60 m ³ /sec

Catchment Runoff Calculation:

Utilizing the rational method, the catchment runoff is calculated as 177.91 m³/min or 2.97 m³/sec. This provides an initial estimate of the potential runoff that needs to be effectively managed within the drainage network.

Drainage Network Analysis:

Following a detailed analysis of the drainage network, accounting for all losses and factors, the estimated discharge at the drain outfall is determined to be 156.2 m³/min or 2.60 m³/sec. This refined figure considers the intricacies of the network, providing a more accurate representation of the actual discharge.

Table 16:-Calculation

Calculation for wet well for full capacity (Circular)			
Flow in minutes (Q _{min})	=	80.00	m ³ /min
Retention Time (provided)	=	10.00	min
Volume (Q _{min} * Retention Time)	=	800.00	m ³
Diameter of wet well (D) (provided by Client)	=	12.00	m
Height of wet well (Volume/(3.14*(D/2) ²))	=	7.00	m
Flow in seconds (Q _{sec}) (80/60)	=	1.33	m ³ /sec
Velocity (Assumed)	=	2.10	m/sec
Area (Q _{sec} * Velocity)	=	0.64	m ²
Radius of RM (r = (Area/3.14) ^(1/2))	=	0.45	m
Diameter of RM (r * 2 *1000)	=	900.00	mm
Section Size at Inlet	=	1.35 X 1.5	m

Details the hydraulic analysis of the proposed drainage network.

Table 17:-Details the hydraulic analysis of the proposed drainage network.

Sl No	Drain Size (m)	Drain Length (m)
1	1 x 1	9182.30
2	1.2 x 1.2	295.70
3	1.2 x 1.5	717.90
4	1.5 x 1.5	490.20
Total Length (m)		10686.10

The Ministry of Housing and Urban Affairs (MoHUA) has also brought out Standard Operating Procedure on Urban Flooding, 2017 which focuses on specific actions required to be undertaken by various departments and agencies of the city / town and also organizations under the district administration as well as State Government for responding to urban flooding of any magnitude. The Standard Operating Procedure has been circulated to all the States and UTs for their guidance.

MoHUA had also published manual on Storm Water Drainage Systems, 2019. This manual assists the States / UTs and Urban Local Bodies (ULBs) and other stakeholders on the planning, design, operation and maintenance of Storm water drainage systems. The manual also works as guidance documents in recommending effective measures in flood prevention.

The list of 66 cities where 2,381 water logging points have been eliminated through the projects completed under AMRUT are at Annexure.

Under AMRUT, projects have been selected, appraised, approved and implemented by the concerned States / UTs / ULBs as per their local conditions / constraints and the requirement, which may result in reduction of flooding in their area. States / UTs have mainly taken projects for new drainage network, rehabilitation & cleaning of existing drainage networks, covering of drains to protect from dumping of garbage, installation of pumps etc. to mitigate urban flooding.

AMRUT Mission encourages sharing of good practices being carried out in any AMRUT city with all other Mission cities. Further, States / UTs / ULBs are free to adopt any suitable technique / method based on their local conditions.

7 CONCLUSION & RECOMMENDATION

In this study, the empirical analysis of the Storm water Drainage network in the Kamarhati area of the North 24 Parganas has been carried out using SewerGEMS, a computer-based simulation software. Prelude to the analysis, a review of literature was carried out. The current conditions of Drainage system in the study has been studied to explore the real need to have Proper Storm water Drainage Network within the study area. Relevant data required for the analysis were collected. The results of all the analysis were supported by charts, screenshots & pictures in adherence to the CPHEEO manual.

With the use of this software one can indeed analyze the network at the desk and can foresee the error, if any, in the design and consequently the changes required to be done in such designs for its successful execution at site. The result reveal that the software used for the design has the capability to handle various drainage network problems without changing in model of or mathematical formulation.

From all the studies discussed in the section is included in this chapter, it is evident that climate change is an established fact now and it has several significant impacts on stormwater drainage systems in urban areas like New Delhi, which are already grappling with complex water management challenges. Some of the specific impacts are described below:

Increased Flooding: Rising temperatures can lead to more intense rainfall events, which can overwhelm drainage systems in urban areas. This increased rainfall intensity can result in more frequent and severe flooding, especially in low-lying or poorly drained areas of the city.

Reduced Infiltration: Urbanization and the expansion of impermeable surfaces like roads and buildings reduce the natural infiltration of rainwater into the ground. This leads to increased runoff that strains drainage systems.

Increased Evaporation: Climate change can significantly affect evaporation losses from water retention lakes or reservoirs. Changes in temperature, humidity, wind patterns, and the duration of warm seasons primarily drive the impact of climate change on evaporation losses.

Waterlogging: The combination of heavy rainfall and inadequate drainage systems can lead to waterlogging, causing traffic disruptions, property damage, and health hazards.

Sewage Overflow: If stormwater and sewage systems are interconnected, even illegally, heavy rainfall can overwhelm these systems, leading to sewage overflowing into streets and water bodies.

Erosion and Sedimentation: Intense rainfall can cause erosion in urban areas, washing away soil and increasing sedimentation in drainage systems. This sediment can clog pipes and reduce drainage capacity.

Infrastructure Damage: Frequent flooding and waterlogging can damage drainage infrastructure, including stormwater drains, culverts, and pumping stations, requiring costly repairs and maintenance.

Increased Maintenance Costs: Climate change-induced impacts, such as flooding and

sedimentation, increase drainage systems' maintenance and operational costs in urban areas.

Water Quality Issues: Stormwater runoff can carry pollutants from streets and other surfaces into drainage systems, degrading water quality in urban water bodies and posing environmental and health risks. Flooding could also directly impact Water Treatment Plants.

Social and Economic Disruption: Frequent flooding and waterlogging can disrupt daily life in urban areas, affecting transportation, businesses, and residents' quality of life, including productive working days.

Based on the information presented, techno economic appraisal concludes that this is necessary for the benefit of people and economy of the area. Thus, the socio-economic benefits of this studies are large. Hence, this is feasible technically, socially, and economically. The recommended measures for short-term, mid-term and long-term are covered.

In this analysis vulnerable flood zone have been identified considering 1 in 2-year and 1 in 5-year return period. Vulnerable drain length in different municipalities is also identified considering 1 in 2 year and 1 in 5-year return period rainfall event. The conclusions shall be correlated for subsequent milestones –

Condition assessment of existing stormwater drainage infrastructure

Primary Survey findings with GIS integration

Issues in drainage System and recommendation to address issues.

This study aims to create a holistic flood resilience solution for Wards in Kamarhati Municipality. The proposed interventions, as outlined in this report, encompass hydraulic network improvements. These measures collectively seek to alleviate waterlogging issues, providing a sustainable and effective solution for the well-being of the community in the specified wards. The report is now presented for departmental review, seeking valuable feedback and guidance to refine and advance the proposed flood mitigation strategies.

Recommendations: - It is recommended to provide storm water retention/detention by integrating the existing water bodies in study areas with the proposed storm water drainage infrastructure considering the ground water quality, soil characteristics, the dependence of rural population on these water bodies/ponds for non-potable uses and social acceptability.

Short-term measures

Recommended short term measures to reduce the storm water problem are mentioned below. Desilting & cleaning of drains. Repairs and up gradation of the storm water drains in the flood prone areas. Initiation of the procurement of the maintenance equipment and devices. Initiation of the rehabilitation works of existing outfall drains (Laterals, Mains, Submains, Trunk drains leading to canals).

Mid-term measures

Initiate the source control strategies of excess Storm water. Initialization of construction/rehabilitation works of the new drains/existing drains based on the

conditional assessment. Finalization of planning of RWH structures / ground water recharge initiatives. Finalization of Construction Works, Source Control Installations, New Drains, Outfall structures based on the outcome of studies/Designs carried out during immediate measures. Finalization procurement of the maintenance equipment. Augmentation of the Storm water Drainage Management system to meet the demands of developing city. Generation of public awareness with respect to stop dumping and chocking of open drains by Solid Wastes. Replacements of components as per outcome of their condition.

Long-term measures

Effective stormwater management requires a comprehensive approach to design and construction. To achieve this, the top of the drain should be designed above road level, with catch pits provided to prevent solid waste dumping. Additional measures include installing cover slabs and fencing at vulnerable locations, ensuring sufficient operation and maintenance personnel are available, and designing drains with proper slope to facilitate efficient water flow. Rain harvesting structures should be integrated into the design, along with features like catch pits and gratings. Culverts should be rehabilitated and redesigned to match the size of the drains, with proper slope ensured throughout. A single agency should complete the construction of a stretch up to the outfall, ensuring a seamless and comprehensive system without discontinuity, and providing logical disposal points. By taking a holistic approach, effective stormwater management can be achieved.

Future Scope of Study

It is extremely difficult to develop a theoretical model that accurately simulates every physical phenomenon that can occur in a hydraulic system. Therefore, every hydraulic model involves some approximations and simplifications of the real problem. The field data can be calibrated for the accuracy assessment of the model.

The differences between computer model results and actual system measurements are caused by several factors which requires detailed emphasis and rigorous study. The case study presented in this report may be magnified for the research and further works.

8 REFERENCES

1. Santhanam, S., Needhidasan, S., & Nallanathel, M. (2013). Design of storm water drains by rational method – an approach to storm water management for environmental protection. *International Journal of Engineering and Technology*, 5(4), 3203-3214.
2. Karamouz, M., & Nazif, S. (2013). Reliability-based flood management in urban watersheds considering climate change impacts. *Journal of Water Resources Planning and Management*, 139(5), 520-533.
3. Manual on Storm Water Drainage Systems. (2019). Published by Ministry of Housing and affairs Government of India.
4. Abd-Elhamid, H., Zelenakova, M., Vranayova, Z., & Fathy, I. (2020). Evaluating the impact of urban growth on the design of storm water drainage systems. *Water*, 12(6), 1572.
5. Rahman, M. M. (2013). Designing an effective drainage system for Magura Pourashava: A GIS-based approach (master's thesis). Urban and Rural Planning Discipline, Khulna University, Khulna 9208, Bangladesh.
6. Zinabie, A., & Kebede, B. (2020). Hydraulic Analysis of Storm Water Drainage System in Alamata Town, South Tigray, Ethiopia. *Iranian Journal of Energy and Environment*.
7. Kummamuru, P., Barik, D., & Manideep, C. (2015). A comparative study of storm water drainage methods for urban storm water management. *Indian Journal of Science and Technology*, 8(33), 1-9. DOI: 10.17485/ijst/2015/v8i33/78310
8. Rao, Y. R. S., & Ramana, R. V. (2015). Title of the publication. Deltaic Regional Centre, National Institute of Hydrology, Kakinada, Andhra Pradesh.
9. Bastia, J., Mishra, B. K., & Kumar, P. (2021). Integrative assessment of stormwater infiltration practices in rapidly urbanizing cities: A case of Lucknow City, India. *Hydrology*, 8(2), 93.
10. Vishwakarma, R. K., Joshi, H., & Goonetilleke, A. (2023). Sustainability evaluation of the stormwater drainage system in six Indian cities. *Sustainability*, 15(20), 14906. DOI: 10.3390/su152014906
11. Xu, Z., Yin, H., & Li, H. (2014). Quantification of non-stormwater flow entries into storm drains using a water balance approach. *The Science of the Total Environment*, 487C, 381-388. DOI: 10.1016/j.scitotenv.2014.04.035
12. Tomar, P., Singh, S. K., Kanga, S., Meraj, G., Kranjčić, N., Đurin, B., & Pattanaik, A. (2021). GIS-based urban flood risk assessment and management—A case study of Delhi National Capital Territory (NCT), India. *Sustainability*, 13(22), 12850. DOI: 10.3390/su132212850
13. Ramachandran, A., Palanivelu, K., Mudgal, B. V., Jeganathan, A., Balu, A., & Sankar, G. (2019). Performance of urban storm drainage network under changing climate

- scenarios: Flood mitigation in Indian coastal city. Scientific Reports, 9, 1-12. DOI: 10.1038/s41598-019-43859-3
14. SewerGEMS V8i User's Guide Manual, Bentley, January 2016.
 15. Subramanya, K. (2013). Engineering Hydrology. Fourth Edition McGraw-Hill Education (India) Private Limited, New Delhi.
 16. Ferguson, C. R., & Fenner, R. A. (2020). The potential for natural flood management to maintain free discharge at urban drainage outfalls. Journal of Flood Risk Management, 13(3), e12617. DOI: 10.1111/jfr3.12617
 17. Katti, M., Krishna, B. M., & Manoj Kumar, B. (Year of publication). Title of the publication. (Unpublished thesis). Department of Environmental Engineering, Sri Jayachamrajendra College of Engineering, Mysore-570006.
 18. Borse, S., Kedar, H., Sawale, R., Tare, D., & Joshi, D. (2022). Storm water management by new techniques. DOI: 10.55041/IJSREM12642.
 19. JOURNALS, G. R. D., & Noel, P. (2019). Critical Review on Smart Systems adopted in Stormwater Drainage Design. GRD Journals.
 20. Khan, A. A., & Ahmad, M. (2014). Integration of stormwater drains with lakes: Expectations and reality - A case of Raipur, India. Journal of Environmental Science and Technology, 6(2), 1-8. DOI: 10.4172/2157-7587.1000166
 21. Raval, S. K. (2018). Storm water drainage solutions for urban areas. International Journal of Innovative Research in Science, Engineering and Technology, 7(4), 1-8. DOI: 10.15680/IJIRSET.2018.0704074
 22. Satyaji Rao, Y. R., & Venkata Ramana, R. (2015). Storm water flood modeling in urban areas.
 23. Prasad, R. L. R., Gangireddy, M., & Mohapatra, P. (2022). Urban stormwater management for sustainable and resilient measures and practices: A review. Water Science and Technology, 85(1), 1-12. DOI: 10.2166/wst.2022.017
 24. Mugume, S., Gomez, D., Fu, G., Farmani, R., & Butler, D. (2015). A global analysis approach for investigating structural resilience in urban drainage systems. Water Research, 82, 347-357. DOI: 10.1016/j.watres.2015.05.030
 25. Senthamizhselvan, T. (2020). Design of sewer and storm water drainage network for Karaikal. Bharathiyar College of Engineering and Technology, Karaikal.
 26. Harsha, V. (2022). Climate change adaptation in India in the context of urban flooding. International Centre for Environment Audit and Sustainable Development, Occasional Research Paper Series, 6.
 27. Vidya, K. N. (2021). Runoff assessment by Storm water management model (SWMM)- A new approach. Journal of Applied and Natural Science, 13 (SI), 142 - 148. <https://doi.org/10.31018/jans.v13iSI.2813>
 28. Garg, S.K., 2012, —Sewage disposal and air pollution engineering||, Khanna publishers, New Delhi.
 29. Census of India 2011. WEST BENGAL. SERIES-20. PART XII-A. DISTRICT CENSUS HANDBOOK. NORTH TWENTY-FOUR PARGANAS. VILLAGE AND TOWN DIRECTORY. DIRECTORATE.

30. Ress, L. D., Hung, C.-L. J., & James, L. A. (2020). Impacts of urban drainage systems on stormwater hydrology: Rocky Branch Watershed, Columbia, South Carolina. *Journal of Flood Risk Management*, 13(3), e12643. DOI: 10.1111/jfr3.12643.
31. American Society of Civil Engineers. (1852). <https://ascelibrary.org/journals>
32. Abd-Elhamid, H. F., Zelenáková, M., Vranayová, Z., & Fathy, I. (2020). Evaluating the impact of urban growth on the design of storm water drainage systems. *Water*, 12(6), 1572. DOI: 10.3390/w12061572

9 APPENDIX

9.1 Hydraulic analysis of Stormwater Drainage Network Design

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning's n	Slope (Calculated) (m/m (H: V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
1	CO-31	Box - 1.5 x 1.5 m	MH-3412	2.96	MH-3413	2.96	3.80	0.013	2,000	0.98	48.30	1.50	1.50
2	drain-3001	Box - 1.5 x 1.5 m	MH-3475	3.05	MH-3476	3.04	9.30	0.013	2,000	1.02	78.50	1.50	1.50
3	drain-1079	Box - 1.5 x 1.5 m	MH-3591	2.94	MH-3433	2.93	31.20	0.013	2,000	0.98	44.00	1.50	1.50
4	drain-1443	Box - 1.5 x 1.5 m	MH-3425	2.99	MH-3476	3.01	30.00	0.013	-2,000	1.05	80.50	1.50	1.50
5	drain-1612	Box - 1.5 x 1.5 m	MH-3413	2.96	MH-3591	2.94	30.00	0.013	2,000	0.98	46.90	1.50	1.50
6	drain-1802	Box - 1.5 x 1.5 m	MH-3713	2.88	MH-3714	2.86	30.00	0.013	2,000	1.15	68.60	1.50	1.50
7	drain-1993	Box - 1.5 x 1.5 m	MH-3740	2.91	MH-3741	2.89	30.00	0.013	2,000	1.15	73.00	1.50	1.50
8	CO-33	Box - 1.5 x 1.5 m	MH-3750	2.94	MH-3402	2.92	30.00	0.013	2,000	1.09	76.20	1.50	1.50
9	drain-2101	Box - 1.5 x 1.5 m	MH-3611	2.97	MH-3412	2.96	30.00	0.013	2,000	0.98	49.30	1.50	1.50
10	drain-2146	Box - 1.5 x 1.5 m	MH-3759	2.95	MH-3750	2.94	30.00	0.013	2,000	1.09	77.40	1.50	1.50
11	drain-2351	Box - 1.5 x 1.5 m	MH-3402	2.92	MH-3740	2.91	30.00	0.013	2,000	1.14	74.80	1.50	1.50
12	drain-2436	Box - 1.5 x 1.5 m	MH-3741	2.89	MH-3713	2.88	30.00	0.013	2,000	1.15	71.00	1.50	1.50
13	drain-2651	Box - 1.5 x 1.5 m	MH-3456	2.97	MH-3759	2.95	30.00	0.013	2,000	1.09	78.40	1.50	1.50
14	drain-2951	Box - 1.5 x 1.5 m	MH-3714	2.86	MH-3786	2.85	30.00	0.013	2,000	1.15	65.60	1.50	1.50
15	drain-2792	Box - 1.5 x 1.5 m	MH-3425	2.99	MH-3455	2.97	37.90	0.013	2,000	1.07	79.70	1.50	1.50
16	CO-23	Box - 1.5 x 1.5 m	MH-3786	2.85	MH-3548	2.83	40.10	0.013	2,000	1.15	60.60	1.50	1.50
17	CO-21	Box - 1.5 x 1.5 m	MH-3433	2.93	O-19	2.92	11.40	0.013	2,000	1.01	38.30	1.50	1.50
18	CO-22	Box - 1.5 x 1.5 m	MH-3548	2.83	O-17	2.82	19.80	0.013	2,000	1.16	51.10	1.50	1.50
19	CO-21(2)	Box - 1.5 x 1.5 m	MH-3455	2.97	MH-3456	2.97	6.70	0.013	2,000	1.07	79.00	1.50	1.50

SnNo.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H: V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
20	drain-45	Box - 1.2 x 1.5 m	MH-3341	3.12	MH-3342	3.12	2.50	0.013	2,000	0.94	67.80	1.20	1.50
21	CO-28	Box - 1.2 x 1.5 m	MH-3416	3.14	MH-3417	3.13	4.00	0.013	2,000	0.91	68.50	1.20	1.50
22	drain-178	Box - 1.2 x 1.5 m	MH-3420	3.08	MH-3421	3.08	4.20	0.013	2,000	0.94	78.80	1.20	1.50
23	drain-234	Box - 1.2 x 1.5 m	MH-3446	3.14	MH-3447	3.13	5.20	0.013	2,000	0.91	79.10	1.20	1.50
24	drain-270	Box - 1.2 x 1.5 m	MH-3453	3.05	MH-3454	3.04	6.50	0.013	2,000	0.95	61.90	1.20	1.50
25	drain-569	Box - 1.2 x 1.5 m	MH-3518	3.40	MH-3519	3.39	15.80	0.013	2,000	0.91	64.50	1.20	1.50
26	drain-572	Box - 1.2 x 1.5 m	MH-3454	3.04	MH-3520	3.03	16.00	0.013	2,000	0.95	61.30	1.20	1.50
27	drain-852	Box - 1.2 x 1.5 m	MH-3565	3.41	MH-3518	3.40	22.20	0.013	2,000	0.91	64.60	1.20	1.50
28	drain-967	Box - 1.2 x 1.5 m	MH-3417	3.13	MH-3341	3.12	23.40	0.013	2,000	0.94	68.20	1.20	1.50
29	drain-971	Box - 1.2 x 1.5 m	MH-3576	3.09	MH-3420	3.08	23.50	0.013	2,000	0.94	78.80	1.20	1.50
30	drain-1042	Box - 1.2 x 1.5 m	MH-3583	3.10	MH-3576	3.09	24.60	0.013	2,000	0.94	78.90	1.20	1.50
31	drain-1260	Box - 1.2 x 1.5 m	MH-3610	2.99	MH-3611	2.97	30.00	0.013	2,000	0.95	52.10	1.20	1.50
32	drain-1495	Box - 1.2 x 1.5 m	MH-3651	3.06	MH-3453	3.05	30.00	0.013	2,000	0.95	62.80	1.20	1.50
33	drain-1586	Box - 1.2 x 1.5 m	MH-3669	3.15	MH-3446	3.14	30.00	0.013	2,000	0.91	78.90	1.20	1.50
34	drain-1620	Box - 1.2 x 1.5 m	MH-3421	3.08	MH-3675	3.06	30.00	0.013	2,000	0.94	78.70	1.20	1.50
35	drain-1702	Box - 1.2 x 1.5 m	MH-3694	3.12	MH-3583	3.10	30.00	0.013	2,000	0.94	79.00	1.20	1.50
36	drain-1735	Box - 1.2 x 1.5 m	MH-3697	3.43	MH-3565	3.41	30.00	0.013	2,000	0.91	64.90	1.20	1.50
37	drain-1773	Box - 1.2 x 1.5 m	MH-3708	3.18	MH-3669	3.15	30.00	0.013	1,000	1.20	78.20	1.20	1.50
38	drain-1822	Box - 1.2 x 1.5 m	MH-3719	3.02	MH-3720	3.00	30.00	0.013	2,000	0.95	57.90	1.20	1.50
39	drain-1851	Box - 1.2 x 1.5 m	MH-3675	3.06	MH-3475	3.05	30.00	0.013	2,000	0.94	78.60	1.20	1.50

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
40	drain-1999	Box - 1.2 x 1.5 m	MH-3487	3.46	MH-3742	3.44	30.00	0.013	2,000	0.91	65.30	1.20	1.50
41	drain-2050	Box - 1.2 x 1.5 m	MH-3742	3.44	MH-3697	3.43	30.00	0.013	2,000	0.91	65.10	1.20	1.50
42	drain-2188	Box - 1.2 x 1.5 m	MH-3520	3.03	MH-3719	3.02	30.00	0.013	2,000	0.95	59.90	1.20	1.50
43	drain-2219	Box - 1.2 x 1.5 m	MH-3764	3.09	MH-3765	3.08	30.00	0.013	2,000	0.95	65.40	1.20	1.50
44	drain-2264	Box - 1.2 x 1.5 m	MH-3447	3.13	MH-3694	3.12	30.00	0.013	2,000	0.94	79.10	1.20	1.50
45	drain-2321	Box - 1.2 x 1.5 m	MH-3765	3.08	MH-3651	3.06	30.00	0.013	2,000	0.95	64.20	1.20	1.50
46	drain-2354	Box - 1.2 x 1.5 m	MH-3773	3.11	MH-3764	3.09	30.00	0.013	2,000	0.95	66.40	1.20	1.50
47	drain-2726	Box - 1.2 x 1.5 m	MH-3519	3.30	MH-3708	3.27	30.00	0.013	1,000	1.20	71.00	1.20	1.50
48	drain-2824	Box - 1.2 x 1.5 m	MH-3720	3.00	MH-3610	2.99	30.00	0.013	2,000	0.95	55.40	1.20	1.50
49	drain-2886	Box - 1.2 x 1.5 m	MH-3342	3.12	MH-3773	3.11	30.00	0.013	2,000	0.95	67.40	1.20	1.50
50	drain-118	Box - 1.2 x 1.2 m	MH-3389	4.32	MH-3390	4.32	3.20	0.013	-2,000	0.82	30.60	1.20	1.20
51	drain-184	Box - 1.2 x 1.2 m	MH-3422	4.03	MH-3423	4.03	4.30	0.013	-2,000	0.82	48.20	1.20	1.20
52	drain-353	Box - 1.2 x 1.2 m	MH-3416	3.44	MH-3481	3.44	9.50	0.013	-2,000	0.90	61.00	1.20	1.20
53	drain-367	Box - 1.2 x 1.2 m	MH-3486	3.89	MH-3487	3.89	9.90	0.013	2,000	0.88	46.70	1.20	1.20
54	drain-416	Box - 1.2 x 1.2 m	MH-3390	4.32	MH-3498	4.32	11.40	0.013	-2,000	0.82	33.80	1.20	1.20
55	drain-960	Box - 1.2 x 1.2 m	MH-3574	3.93	MH-3575	3.95	23.40	0.013	-1,000	1.09	43.70	1.20	1.20
56	drain-1168	Box - 1.2 x 1.2 m	MH-3592	4.02	MH-3422	4.03	26.20	0.013	-2,000	0.83	47.30	1.20	1.20
57	drain-1304	Box - 1.2 x 1.2 m	MH-3620	4.05	MH-3389	4.08	27.80	0.013	-1,000	1.07	49.40	1.20	1.20
58	drain-1596	Box - 1.2 x 1.2 m	MH-3498	4.32	MH-3501	4.34	30.00	0.013	-2,000	0.81	38.00	1.20	1.20
59	drain-1677	Box - 1.2 x 1.2 m	MH-3689	4.00	MH-3592	4.02	30.00	0.013	-2,000	0.83	45.50	1.20	1.20

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
60	drain-1808	Box - 1.2 x 1.2 m	MH-3575	3.99	MH-3689	4.00	30.00	0.013	-2,000	0.83	42.80	1.20	1.20
61	drain-1941	Box - 1.2 x 1.2 m	MH-3734	3.90	MH-3574	3.93	30.00	0.013	-1,000	1.09	42.20	1.20	1.20
62	drain-1978	Box - 1.2 x 1.2 m	MH-3423	4.03	MH-3620	4.05	30.00	0.013	-2,000	0.82	49.00	1.20	1.20
63	drain-2930	Box - 1.2 x 1.2 m	MH-3481	3.88	MH-3734	3.90	30.00	0.013	-2,000	0.84	35.20	1.20	1.20
64	drain-14	Box - 1.0 x 1.0 m	MH-3327	4.08	MH-3328	4.07	2.00	0.013	2,000	0.40	8.50	1.00	1.00
65	drain-3033	Box - 1.0 x 1.0 m	MH-3329	3.86	MH-3330	3.87	2.00	0.013	-2,000	0.61	47.10	1.00	1.00
66	drain-25	Box - 1.0 x 1.0 m	MH-3331	4.64	MH-3332	4.64	2.20	0.013	2,000	0.35	6.10	1.00	1.00
67	drain-35	Box - 1.0 x 1.0 m	MH-3333	4.11	MH-3334	4.11	2.30	0.013	2,000	0.40	24.80	1.00	1.00
68	drain-37	Box - 1.0 x 1.0 m	MH-3335	3.97	MH-3336	3.97	2.40	0.013	2,000	0.50	20.70	1.00	1.00
69	drain-39	Box - 1.0 x 1.0 m	MH-3337	3.92	MH-3338	3.92	2.40	0.013	1,000	0.63	42.30	1.00	1.00
70	drain-44	Box - 1.0 x 1.0 m	MH-3339	4.58	MH-3340	4.58	2.40	0.013	-2,000	0.78	56.70	1.00	1.00
71	drain-57	Box - 1.0 x 1.0 m	MH-3343	4.00	MH-3344	3.99	2.60	0.013	2,000	0.31	34.80	1.00	1.00
72	drain-59	Box - 1.0 x 1.0 m	MH-3345	4.02	MH-3346	4.02	2.60	0.013	2,000	0.49	32.80	1.00	1.00
73	drain-61	Box - 1.0 x 1.0 m	MH-3347	3.94	MH-3348	3.94	2.60	0.013	2,000	0.44	39.60	1.00	1.00
74	drain-58	Box - 1.0 x 1.0 m	MH-3349	4.68	MH-3350	4.69	2.70	0.013	-2,000	0.75	65.60	1.00	1.00
75	drain-67	Box - 1.0 x 1.0 m	MH-3351	4.19	MH-3352	4.19	2.70	0.013	2,000	0.33	9.30	1.00	1.00
76	drain-72	Box - 1.0 x 1.0 m	MH-3353	3.69	MH-3354	3.70	2.70	0.013	-2,000	0.45	36.60	1.00	1.00
77	drain-70	Box - 1.0 x 1.0 m	MH-3355	4.00	MH-3356	4.00	2.70	0.013	-2,000	0.50	44.60	1.00	1.00
78	drain-71	Box - 1.0 x 1.0 m	MH-3357	4.18	MH-3358	4.18	2.70	0.013	2,000	0.77	62.30	1.00	1.00
79	drain-73	Box - 1.0 x 1.0 m	MH-3359	4.08	MH-3360	4.07	2.80	0.013	2,000	0.39	12.80	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
80	drain-74	Box - 1.0 x 1.0 m	MH-3361	4.01	MH-3362	4.01	2.80	0.013	-2,000	0.32	30.70	1.00	1.00
81	drain-76	Box - 1.0 x 1.0 m	MH-3360	4.07	MH-3363	4.07	2.80	0.013	2,000	0.39	12.70	1.00	1.00
82	drain-83	Box - 1.0 x 1.0 m	MH-3364	3.70	MH-3365	3.70	2.90	0.013	-2,000	0.41	11.50	1.00	1.00
83	drain-3032	Box - 1.0 x 1.0 m	MH-3366	3.88	MH-3367	3.88	3.30	0.013	-2,000	0.17	45.80	1.00	1.00
84	drain-87	Box - 1.0 x 1.0 m	MH-3368	4.09	MH-3369	4.09	3.00	0.013	1,000	0.45	12.70	1.00	1.00
85	drain-89	Box - 1.0 x 1.0 m	MH-3370	4.58	MH-3371	4.59	3.00	0.013	-2,000	0.32	5.50	1.00	1.00
86	drain-93	Box - 1.0 x 1.0 m	MH-3372	4.09	MH-3373	4.08	3.00	0.013	2,000	0.47	26.60	1.00	1.00
87	drain-94	Box - 1.0 x 1.0 m	MH-3374	3.75	MH-3375	3.75	3.00	0.013	-2,000	0.39	31.40	1.00	1.00
88	drain-101	Box - 1.0 x 1.0 m	MH-3376	4.80	MH-3377	4.80	3.10	0.013	-2,000	0.57	29.10	1.00	1.00
89	drain-105	Box - 1.0 x 1.0 m	MH-3378	5.94	MH-3379	5.94	3.10	0.013	2,000	0.53	14.10	1.00	1.00
90	drain-106	Box - 1.0 x 1.0 m	MH-3380	4.00	MH-3343	4.00	3.10	0.013	2,000	0.31	34.70	1.00	1.00
91	drain-110	Box - 1.0 x 1.0 m	MH-3381	4.02	MH-3382	4.03	3.10	0.013	-2,000	0.28	29.20	1.00	1.00
92	drain-112	Box - 1.0 x 1.0 m	MH-3383	3.98	MH-3384	3.98	3.10	0.013	2,000	0.50	21.10	1.00	1.00
93	drain-113	Box - 1.0 x 1.0 m	MH-3385	4.26	MH-3386	4.26	3.20	0.013	-2,000	0.63	44.30	1.00	1.00
94	drain-115	Box - 1.0 x 1.0 m	MH-3387	3.92	MH-3388	3.92	3.20	0.013	1,000	0.58	10.40	1.00	1.00
95	drain-126	Box - 1.0 x 1.0 m	MH-3391	4.22	MH-3392	4.22	3.30	0.013	2,000	0.17	7.70	1.00	1.00
96	drain-121	Box - 1.0 x 1.0 m	MH-3393	4.24	MH-3394	4.24	3.40	0.013	-2,000	0.43	22.20	1.00	1.00
97	drain-132	Box - 1.0 x 1.0 m	MH-3395	4.91	MH-3396	4.91	3.40	0.013	2,000	0.40	25.60	1.00	1.00
98	drain-137	Box - 1.0 x 1.0 m	MH-3397	4.13	MH-3398	4.13	3.40	0.013	2,000	0.70	32.90	1.00	1.00
99	drain-138	Box - 1.0 x 1.0 m	MH-3399	4.55	MH-3400	4.55	3.40	0.013	-2,000	0.79	46.30	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start)(m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
100	drain-3029	Box - 1.0 x 1.0 m	MH-3401	3.67	MH-3402	3.67	3.60	0.013	2,000	0.53	39.10	1.00	1.00
101	drain-149	Box - 1.0 x 1.0 m	MH-3403	3.92	MH-3404	3.93	3.60	0.013	-2,000	0.54	33.60	1.00	1.00
102	drain-152	Box - 1.0 x 1.0 m	MH-3405	3.90	MH-3406	3.90	3.60	0.013	2,000	0.33	40.80	1.00	1.00
103	drain-153	Box - 1.0 x 1.0 m	MH-3407	3.75	MH-3408	3.75	3.60	0.013	-1,000	0.76	57.70	1.00	1.00
104	drain-157	Box - 1.0 x 1.0 m	MH-3409	3.67	MH-3401	3.67	3.60	0.013	2,000	0.37	38.90	1.00	1.00
105	CO-16	Box - 1.0 x 1.0 m	MH-3410	3.74	MH-3411	3.73	3.70	0.013	2,000	0.21	41.90	1.00	1.00
106	drain-167	Box - 1.0 x 1.0 m	MH-3414	3.76	MH-3415	3.77	3.90	0.013	-2,000	0.46	55.10	1.00	1.00
107	drain-174	Box - 1.0 x 1.0 m	MH-3418	4.76	MH-3419	4.76	4.00	0.013	1,000	0.81	46.50	1.00	1.00
108	drain-187	Box - 1.0 x 1.0 m	MH-3424	3.76	MH-3425	3.76	4.30	0.013	2,000	0.41	43.50	1.00	1.00
109	drain-195	Box - 1.0 x 1.0 m	MH-3426	3.81	MH-3427	3.81	4.50	0.013	1,000	0.42	50.50	1.00	1.00
110	CO-32	Box - 1.0 x 1.0 m	MH-3428	3.88	MH-3429	3.87	4.50	0.013	2,000	0.72	46.00	1.00	1.00
111	drain-207	Box - 1.0 x 1.0 m	MH-3430	4.20	MH-3431	4.20	4.50	0.013	-2,000	0.68	43.40	1.00	1.00
112	drain-203	Box - 1.0 x 1.0 m	MH-3432	3.65	MH-3433	3.65	4.60	0.013	2,000	0.61	19.40	1.00	1.00
113	drain-208	Box - 1.0 x 1.0 m	MH-3434	3.73	MH-3435	3.73	4.60	0.013	2,000	0.25	60.70	1.00	1.00
114	drain-211	Box - 1.0 x 1.0 m	MH-3436	3.52	MH-3437	3.52	4.70	0.013	-2,000	0.78	71.60	1.00	1.00
115	drain-213	Box - 1.0 x 1.0 m	MH-3438	4.91	MH-3395	4.91	4.70	0.013	1,000	0.49	25.30	1.00	1.00
116	drain-217	Box - 1.0 x 1.0 m	MH-3439	4.13	MH-3347	4.13	4.80	0.013	2,000	0.26	21.20	1.00	1.00
117	drain-221	Box - 1.0 x 1.0 m	MH-3440	4.86	MH-3441	4.86	4.80	0.013	-2,000	0.68	54.70	1.00	1.00
118	drain-225	Box - 1.0 x 1.0 m	MH-3442	4.15	MH-3443	4.15	5.00	0.013	2,000	0.78	58.90	1.00	1.00
119	drain-228	Box - 1.0 x 1.0 m	MH-3444	4.88	MH-3445	4.88	5.00	0.013	2,000	0.50	27.50	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
120	drain-3035	Box - 1.0 x 1.0 m	MH-3366	3.88	MH-3330	3.88	5.10	0.013	2,000	0.46	46.00	1.00	1.00
121	drain-249	Box - 1.0 x 1.0 m	MH-3448	3.71	MH-3447	3.71	5.60	0.013	2,000	0.60	61.20	1.00	1.00
122	drain-257	Box - 1.0 x 1.0 m	MH-3449	4.86	MH-3450	4.86	6.50	0.013	2,000	0.51	28.10	1.00	1.00
123	drain-261	Box - 1.0 x 1.0 m	MH-3451	3.69	MH-3452	3.69	6.00	0.013	-2,000	0.45	64.40	1.00	1.00
124	drain-281	Box - 1.0 x 1.0 m	MH-3457	3.70	MH-3364	3.70	6.80	0.013	-2,000	0.41	11.00	1.00	1.00
125	drain-282	Box - 1.0 x 1.0 m	MH-3458	4.79	MH-3418	4.79	6.80	0.013	2,000	0.62	44.00	1.00	1.00
126	drain-291	Box - 1.0 x 1.0 m	MH-3459	4.00	MH-3460	4.01	7.00	0.013	-1,000	0.19	33.20	1.00	1.00
127	drain-292	Box - 1.0 x 1.0 m	MH-3461	5.24	MH-3462	5.24	7.00	0.013	-2,000	0.11	2.20	1.00	1.00
128	drain-295	Box - 1.0 x 1.0 m	MH-3463	4.73	MH-3464	4.73	7.30	0.013	2,000	0.25	4.80	1.00	1.00
129	drain-296	Box - 1.0 x 1.0 m	MH-3465	3.94	MH-3466	3.95	7.00	0.013	-1,000	0.30	31.70	1.00	1.00
130	drain-317	Box - 1.0 x 1.0 m	MH-3467	4.64	MH-3331	4.64	7.90	0.013	2,000	0.34	7.50	1.00	1.00
131	drain-319	Box - 1.0 x 1.0 m	MH-3468	6.39	MH-3469	6.39	8.00	0.013	-2,000	0.34	11.60	1.00	1.00
132	drain-330	Box - 1.0 x 1.0 m	MH-3470	4.09	MH-3372	4.09	8.40	0.013	2,000	0.46	26.50	1.00	1.00
133	drain-336	Box - 1.0 x 1.0 m	MH-3471	4.92	MH-3472	4.92	8.60	0.013	2,000	0.71	37.40	1.00	1.00
134	drain-341	Box - 1.0 x 1.0 m	MH-3473	3.83	MH-3474	3.82	8.80	0.013	2,000	0.17	51.50	1.00	1.00
135	drain-351	Box - 1.0 x 1.0 m	MH-3477	4.47	MH-3478	4.46	9.40	0.013	1,000	0.96	43.80	1.00	1.00
136	drain-363	Box - 1.0 x 1.0 m	MH-3482	4.08	MH-3327	4.08	9.70	0.013	2,000	0.39	9.80	1.00	1.00
137	CO-15(1)	Box - 1.0 x 1.0 m	MH-3483	3.71	MH-3479	3.70	9.80	0.013	1,416	0.10	45.20	1.00	1.00
138	drain-365	Box - 1.0 x 1.0 m	MH-3484	3.59	MH-3485	3.60	9.80	0.013	-2,000	0.77	73.00	1.00	1.00
139	drain-370	Box - 1.0 x 1.0 m	MH-3488	4.58	MH-3339	4.58	10.00	0.013	-2,000	0.78	56.10	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
140	drain-383	Box - 1.0 x 1.0 m	MH-3489	4.98	MH-3490	4.97	10.50	0.013	2,000	0.69	40.60	1.00	1.00
141	drain-385	Box - 1.0 x 1.0 m	MH-3491	4.27	MH-3492	4.28	10.60	0.013	-2,000	0.62	43.90	1.00	1.00
142	drain-396	Box - 1.0 x 1.0 m	MH-3493	4.14	MH-3397	4.13	10.80	0.013	2,000	0.70	34.30	1.00	1.00
143	drain-398	Box - 1.0 x 1.0 m	MH-3494	3.84	MH-3495	3.83	10.90	0.013	1,000	0.23	49.90	1.00	1.00
144	CO-15(2)(2)	Box - 1.0 x 1.0 m	MH-3480	3.72	MH-3496	3.73	11.20	0.013	-2,000	0.28	43.00	1.00	1.00
145	drain-412	Box - 1.0 x 1.0 m	MH-3497	3.70	MH-3452	3.69	11.30	0.013	2,000	0.44	64.00	1.00	1.00
146	drain-425	Box - 1.0 x 1.0 m	MH-3495	3.80	MH-3500	3.79	11.80	0.013	2,000	0.22	53.70	1.00	1.00
147	drain-448	Box - 1.0 x 1.0 m	MH-3501	4.54	MH-3399	4.55	12.60	0.013	-2,000	0.79	40.50	1.00	1.00
148	drain-469	Box - 1.0 x 1.0 m	MH-3502	4.34	MH-3486	4.33	13.20	0.013	1,000	0.92	29.40	1.00	1.00
149	drain-476	Box - 1.0 x 1.0 m	MH-3496	3.73	MH-3411	3.73	13.40	0.013	-2,000	0.26	42.30	1.00	1.00
150	drain-478	Box - 1.0 x 1.0 m	MH-3503	3.68	MH-3409	3.67	13.40	0.013	1,000	0.43	38.20	1.00	1.00
151	drain-479	Box - 1.0 x 1.0 m	MH-3504	4.66	MH-3505	4.67	13.40	0.013	-2,000	0.77	65.00	1.00	1.00
152	drain-484	Box - 1.0 x 1.0 m	MH-3506	3.98	MH-3507	3.97	13.60	0.013	2,000	0.37	36.70	1.00	1.00
153	drain-513	Box - 1.0 x 1.0 m	MH-3336	3.97	MH-3416	3.96	14.30	0.013	2,000	0.50	20.50	1.00	1.00
154	drain-518	Box - 1.0 x 1.0 m	MH-3508	4.08	MH-3509	4.07	15.00	0.013	2,000	0.58	34.30	1.00	1.00
155	CO-18	Box - 1.0 x 1.0 m	MH-3510	3.71	MH-3480	3.72	14.50	0.013	-1,333	0.32	43.80	1.00	1.00
156	drain-545	Box - 1.0 x 1.0 m	MH-3511	4.22	MH-3512	4.20	15.30	0.013	1,000	0.22	15.40	1.00	1.00
157	drain-560	Box - 1.0 x 1.0 m	MH-3513	4.41	MH-3514	4.42	15.70	0.013	-1,569	0.23	8.00	1.00	1.00
158	drain-563	Box - 1.0 x 1.0 m	MH-3515	4.63	MH-3516	4.64	16.10	0.013	-2,000	0.18	5.00	1.00	1.00
159	drain-565	Box - 1.0 x 1.0 m	MH-3517	3.67	MH-3432	3.65	15.80	0.013	1,000	0.63	21.20	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
160	drain-582	Box - 1.0 x 1.0 m	MH-3521	4.32	MH-3522	4.33	16.20	0.013	-2,000	0.49	14.90	1.00	1.00
161	drain-587	Box - 1.0 x 1.0 m	MH-3523	4.00	MH-3361	4.01	16.50	0.013	-2,000	0.32	31.10	1.00	1.00
162	drain-592	Box - 1.0 x 1.0 m	MH-3524	3.94	MH-3525	3.96	16.60	0.013	-1,000	0.31	38.90	1.00	1.00
163	drain-596	Box - 1.0 x 1.0 m	MH-3526	3.89	MH-3428	3.88	16.70	0.013	2,000	0.72	46.60	1.00	1.00
164	drain-597	Box - 1.0 x 1.0 m	MH-3527	3.91	MH-3338	3.92	16.70	0.013	-1,667	0.54	42.80	1.00	1.00
165	drain-603	Box - 1.0 x 1.0 m	MH-3528	4.02	MH-3529	4.01	16.90	0.013	2,000	0.22	32.70	1.00	1.00
166	drain-610	Box - 1.0 x 1.0 m	MH-3530	4.75	MH-3531	4.76	17.10	0.013	-2,000	0.62	21.40	1.00	1.00
167	drain-635	Box - 1.0 x 1.0 m	MH-3532	3.78	MH-3500	3.79	17.90	0.013	-1,223	0.44	54.70	1.00	1.00
168	drain-554	Box - 1.0 x 1.0 m	MH-3531	4.76	MH-3533	4.77	18.00	0.013	-2,000	0.61	26.20	1.00	1.00
169	drain-648	Box - 1.0 x 1.0 m	MH-3534	4.02	MH-3417	4.01	18.40	0.013	2,000	0.64	23.60	1.00	1.00
170	drain-660	Box - 1.0 x 1.0 m	MH-3492	4.28	MH-3530	4.30	18.70	0.013	-1,000	0.80	43.20	1.00	1.00
171	drain-665	Box - 1.0 x 1.0 m	MH-3367	3.88	MH-3535	3.90	18.80	0.013	-1,000	0.18	44.80	1.00	1.00
172	drain-670	Box - 1.0 x 1.0 m	MH-3536	3.81	MH-3495	3.80	18.90	0.013	2,000	0.12	52.90	1.00	1.00
173	CO-17	Box - 1.0 x 1.0 m	MH-3537	3.69	MH-3479	3.70	19.10	0.013	-2,000	0.11	46.00	1.00	1.00
174	drain-684	Box - 1.0 x 1.0 m	MH-3386	4.26	MH-3491	4.27	19.40	0.013	-2,000	0.63	44.10	1.00	1.00
175	drain-686	Box - 1.0 x 1.0 m	MH-3328	4.03	MH-3387	4.01	19.50	0.013	1,000	0.55	10.40	1.00	1.00
176	drain-690	Box - 1.0 x 1.0 m	MH-3538	4.05	MH-3539	4.04	19.60	0.013	2,000	0.64	32.10	1.00	1.00
177	drain-709	Box - 1.0 x 1.0 m	MH-3363	4.04	MH-3540	4.02	20.10	0.013	1,000	0.49	16.70	1.00	1.00
178	drain-711	Box - 1.0 x 1.0 m	MH-3476	3.51	MH-3436	3.52	20.20	0.013	-2,000	0.78	71.40	1.00	1.00
179	drain-716	Box - 1.0 x 1.0 m	MH-3541	4.00	MH-3383	3.98	20.30	0.013	1,000	0.62	20.60	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
180	drain-720	Box - 1.0 x 1.0 m	MH-3384	3.98	MH-3335	3.97	20.30	0.013	2,000	0.50	20.90	1.00	1.00
181	drain-719	Box - 1.0 x 1.0 m	MH-3542	3.78	MH-3435	3.76	23.90	0.013	2,000	0.34	56.80	1.00	1.00
182	drain-738	Box - 1.0 x 1.0 m	MH-3543	3.75	MH-3414	3.76	20.70	0.013	-2,000	0.67	55.40	1.00	1.00
183	drain-745	Box - 1.0 x 1.0 m	MH-3544	4.72	MH-3545	4.70	20.80	0.013	2,000	0.68	47.10	1.00	1.00
184	drain-746	Box - 1.0 x 1.0 m	MH-3546	4.61	MH-3547	4.60	20.90	0.013	2,000	0.72	38.40	1.00	1.00
185	drain-1151(1)	Box - 1.0 x 1.0 m	MH-3550	4.06	MH-3551	4.07	21.10	0.013	-1,529	0.10	25.50	1.00	1.00
186	drain-769	Box - 1.0 x 1.0 m	MH-3509	4.07	MH-3552	4.06	21.20	0.013	2,000	0.61	34.20	1.00	1.00
187	drain-768	Box - 1.0 x 1.0 m	MH-3553	3.75	MH-3532	3.78	30.00	0.013	-1,000	0.48	56.90	1.00	1.00
188	drain-772	Box - 1.0 x 1.0 m	MH-3554	4.60	MH-3555	4.62	30.00	0.013	-2,000	0.31	8.50	1.00	1.00
189	drain-779	Box - 1.0 x 1.0 m	MH-3556	3.75	MH-3403	3.74	21.40	0.013	2,000	0.59	51.40	1.00	1.00
190	drain-784	Box - 1.0 x 1.0 m	MH-3557	4.66	MH-3558	4.65	21.80	0.013	2,000	0.69	45.40	1.00	1.00
191	drain-813	Box - 1.0 x 1.0 m	MH-3352	4.19	MH-3368	4.18	21.90	0.013	2,000	0.35	7.30	1.00	1.00
192	drain-817	Box - 1.0 x 1.0 m	MH-3559	3.88	MH-3560	3.87	21.80	0.013	2,000	0.39	42.90	1.00	1.00
193	drain-825	Box - 1.0 x 1.0 m	MH-3561	3.81	MH-3562	3.79	30.00	0.013	2,000	0.32	53.90	1.00	1.00
194	drain-853	Box - 1.0 x 1.0 m	MH-3563	4.10	MH-3486	4.09	22.20	0.013	2,000	0.78	42.40	1.00	1.00
195	drain-854	Box - 1.0 x 1.0 m	MH-3564	4.85	MH-3450	4.86	24.20	0.013	-2,000	0.52	28.40	1.00	1.00
196	drain-859	Box - 1.0 x 1.0 m	MH-3566	4.25	MH-3567	4.24	22.30	0.013	2,000	0.45	17.90	1.00	1.00
197	drain-868	Box - 1.0 x 1.0 m	MH-3568	3.73	MH-3403	3.74	22.40	0.013	-2,000	0.68	51.90	1.00	1.00
198	drain-743	Box - 1.0 x 1.0 m	MH-3569	3.74	MH-3407	3.75	22.40	0.013	-2,000	0.60	58.30	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
199	drain-884	Box - 1.0 x 1.0 m	MH-3570	3.99	MH-3571	3.97	30.00	0.013	2,000	0.16	32.60	1.00	1.00
200	drain-931	Box - 1.0 x 1.0 m	MH-3346	4.02	MH-3337	4.01	23.10	0.013	2,000	0.49	33.30	1.00	1.00
201	drain-949	Box - 1.0 x 1.0 m	MH-3572	3.96	MH-3347	3.94	23.30	0.013	2,000	0.41	39.00	1.00	1.00
202	drain-953	Box - 1.0 x 1.0 m	MH-3408	3.85	MH-3573	3.87	23.30	0.013	-1,000	0.75	47.00	1.00	1.00
203	drain-983	Box - 1.0 x 1.0 m	MH-3577	3.81	MH-3578	3.84	30.00	0.013	-1,000	0.44	24.00	1.00	1.00
204	drain-1016	Box - 1.0 x 1.0 m	MH-3545	4.70	MH-3579	4.69	24.70	0.013	2,000	0.68	46.90	1.00	1.00
205	drain-1026	Box - 1.0 x 1.0 m	MH-3580	4.46	MH-3370	4.48	24.30	0.013	-1,000	0.42	6.40	1.00	1.00
206	drain-1040	Box - 1.0 x 1.0 m	MH-3581	4.98	MH-3582	4.99	24.60	0.013	-2,000	0.27	10.30	1.00	1.00
207	drain-1104	Box - 1.0 x 1.0 m	MH-3406	4.23	MH-3584	4.24	25.40	0.013	-2,000	0.28	8.00	1.00	1.00
208	drain-1121	Box - 1.0 x 1.0 m	MH-3585	4.19	MH-3357	4.18	25.60	0.013	2,000	0.77	62.70	1.00	1.00
209	drain-1125	Box - 1.0 x 1.0 m	MH-3472	4.92	MH-3586	4.90	25.70	0.013	2,000	0.71	31.10	1.00	1.00
210	drain-1143	Box - 1.0 x 1.0 m	MH-3587	4.14	MH-3333	4.11	25.90	0.013	1,000	0.47	23.50	1.00	1.00
211	drain-1160	Box - 1.0 x 1.0 m	MH-3588	3.75	MH-3589	3.74	26.10	0.013	2,000	0.24	31.50	1.00	1.00
212	drain-1157	Box - 1.0 x 1.0 m	MH-3590	3.62	MH-3429	3.60	26.20	0.013	2,000	0.51	72.40	1.00	1.00
213	drain-1177	Box - 1.0 x 1.0 m	MH-3540	3.79	MH-3424	3.76	26.40	0.013	1,000	0.50	42.10	1.00	1.00
214	drain-1180	Box - 1.0 x 1.0 m	MH-3593	6.05	MH-3594	6.08	30.00	0.013	-1,000	0.59	21.90	1.00	1.00
215	drain-1185	Box - 1.0 x 1.0 m	MH-3595	3.92	MH-3596	3.91	30.00	0.013	2,000	0.45	42.60	1.00	1.00
216	drain-1198	Box - 1.0 x 1.0 m	MH-3365	3.70	MH-3597	3.72	26.60	0.013	-2,000	0.34	11.50	1.00	1.00
217	drain-1200	Box - 1.0 x 1.0 m	MH-3598	5.29	MH-3599	5.26	30.00	0.013	1,000	0.77	20.30	1.00	1.00
218	drain-1206	Box - 1.0 x 1.0 m	MH-3362	4.01	MH-3381	4.02	26.70	0.013	-2,000	0.30	30.00	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
219	drain-3031	Box - 1.0 x 1.0 m	MH-3596	3.91	MH-3366	3.88	26.70	0.013	1,004	0.56	44.60	1.00	1.00
220	drain-1207	Box - 1.0 x 1.0 m	MH-3379	5.71	MH-3598	5.68	30.00	0.013	1,000	0.76	19.70	1.00	1.00
221	drain-1210	Box - 1.0 x 1.0 m	MH-3600	3.88	MH-3527	3.91	30.00	0.013	-1,000	0.66	44.60	1.00	1.00
222	drain-1219	Box - 1.0 x 1.0 m	MH-3601	3.77	MH-3556	3.75	30.00	0.013	2,000	0.59	50.60	1.00	1.00
223	drain-1218	Box - 1.0 x 1.0 m	MH-3602	4.79	MH-3376	4.80	26.90	0.013	-2,000	0.58	28.90	1.00	1.00
224	drain-1221	Box - 1.0 x 1.0 m	MH-3603	4.21	MH-3604	4.22	27.00	0.013	-2,000	0.45	23.60	1.00	1.00
225	drain-1222	Box - 1.0 x 1.0 m	MH-3605	3.78	MH-3415	3.77	26.90	0.013	2,000	0.39	54.40	1.00	1.00
226	drain-1224	Box - 1.0 x 1.0 m	MH-3560	3.87	MH-3606	3.86	30.00	0.013	2,000	0.58	43.90	1.00	1.00
227	drain-1239	Box - 1.0 x 1.0 m	MH-3607	3.99	MH-3355	4.00	27.20	0.013	-2,000	0.52	45.20	1.00	1.00
228	drain-1242	Box - 1.0 x 1.0 m	MH-3608	4.10	MH-3508	4.08	27.20	0.013	2,000	0.35	33.50	1.00	1.00
229	drain-1246	Box - 1.0 x 1.0 m	MH-3373	4.05	MH-3345	4.02	27.30	0.013	1,000	0.61	31.60	1.00	1.00
230	drain-1254	Box - 1.0 x 1.0 m	MH-3609	3.73	MH-3597	3.72	27.30	0.013	2,000	0.33	11.10	1.00	1.00
231	drain-1269	Box - 1.0 x 1.0 m	MH-3612	3.96	MH-3613	3.94	30.00	0.013	2,000	0.22	35.50	1.00	1.00
232	drain-1282	Box - 1.0 x 1.0 m	MH-3614	6.03	MH-3615	6.00	30.00	0.013	1,000	0.51	12.00	1.00	1.00
233	drain-1288	Box - 1.0 x 1.0 m	MH-3616	3.76	MH-3617	3.75	30.00	0.013	2,000	0.21	58.30	1.00	1.00
234	drain-1301	Box - 1.0 x 1.0 m	MH-3618	4.34	MH-3619	4.37	27.80	0.013	-1,000	0.44	11.70	1.00	1.00
235	drain-1305	Box - 1.0 x 1.0 m	MH-3615	5.97	MH-3378	5.94	27.80	0.013	1,000	0.57	15.40	1.00	1.00
236	drain-3034	Box - 1.0 x 1.0 m	MH-3330	3.87	MH-3600	3.88	28.00	0.013	-2,000	0.53	46.50	1.00	1.00
237	drain-1334	Box - 1.0 x 1.0 m	MH-3621	3.70	MH-3622	3.72	30.00	0.013	-2,000	0.68	52.30	1.00	1.00
238	drain-1337	Box - 1.0 x 1.0 m	MH-3623	4.68	MH-3557	4.66	30.00	0.013	2,000	0.69	45.90	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
239	drain-1341	Box - 1.0 x 1.0 m	MH-3624	3.75	MH-3609	3.73	30.00	0.013	2,000	0.31	10.70	1.00	1.00
240	drain-1342	Box - 1.0 x 1.0 m	MH-3625	4.62	MH-3626	4.63	30.00	0.013	-2,000	0.78	61.70	1.00	1.00
241	drain-1349	Box - 1.0 x 1.0 m	MH-3415	3.84	MH-3627	3.86	28.30	0.013	-1,415	0.39	46.70	1.00	1.00
242	drain-1355	Box - 1.0 x 1.0 m	MH-3628	3.80	MH-3629	3.78	30.00	0.013	2,000	0.59	48.60	1.00	1.00
243	drain-1357	Box - 1.0 x 1.0 m	MH-3630	3.75	MH-3631	3.78	30.00	0.013	-1,000	0.15	38.80	1.00	1.00
244	drain-1390	Box - 1.0 x 1.0 m	MH-3632	4.15	MH-3493	4.14	28.70	0.013	2,000	0.69	36.90	1.00	1.00
245	drain-1401	Box - 1.0 x 1.0 m	MH-3633	3.53	MH-3634	3.55	30.00	0.013	-2,000	0.78	72.00	1.00	1.00
246	drain-1412	Box - 1.0 x 1.0 m	MH-3475	3.63	MH-3635	3.65	30.00	0.013	-2,000	0.71	58.80	1.00	1.00
247	drain-1417	Box - 1.0 x 1.0 m	MH-3636	4.21	MH-3637	4.22	30.00	0.013	-2,000	0.51	14.80	1.00	1.00
248	drain-1428	Box - 1.0 x 1.0 m	MH-3638	3.66	MH-3639	3.67	30.00	0.013	-2,000	0.68	53.20	1.00	1.00
249	drain-1439	Box - 1.0 x 1.0 m	MH-3640	4.64	MH-3641	4.62	30.00	0.013	2,000	0.70	43.60	1.00	1.00
250	drain-1446	Box - 1.0 x 1.0 m	MH-3642	3.71	MH-3374	3.74	29.20	0.013	-1,000	0.52	33.80	1.00	1.00
251	drain-1453	Box - 1.0 x 1.0 m	MH-3641	4.62	MH-3546	4.61	30.00	0.013	2,000	0.71	41.50	1.00	1.00
252	drain-1459	Box - 1.0 x 1.0 m	MH-3643	5.60	MH-3644	5.63	30.00	0.013	-1,000	0.72	19.30	1.00	1.00
253	drain-1467	Box - 1.0 x 1.0 m	MH-3645	5.48	MH-3643	5.51	30.00	0.013	-1,000	0.80	22.20	1.00	1.00
254	drain-1473	Box - 1.0 x 1.0 m	MH-3404	4.09	MH-3636	4.12	30.00	0.013	-1,000	0.65	17.70	1.00	1.00
255	drain-1480	Box - 1.0 x 1.0 m	MH-3646	5.09	MH-3647	5.06	30.00	0.013	1,000	0.30	9.50	1.00	1.00
256	drain-1483	Box - 1.0 x 1.0 m	MH-3626	4.63	MH-3648	4.65	30.00	0.013	-2,000	0.78	63.10	1.00	1.00
257	drain-1486	Box - 1.0 x 1.0 m	MH-3481	3.64	MH-3638	3.66	30.00	0.013	-2,000	0.68	53.50	1.00	1.00
258	drain-1477	Box - 1.0 x 1.0 m	MH-3649	3.72	MH-3569	3.74	30.00	0.013	-2,000	0.60	59.30	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
259	drain-1490	Box - 1.0 x 1.0 m	MH-3639	3.67	MH-3650	3.69	30.00	0.013	-2,000	0.68	52.90	1.00	1.00
260	drain-1505	Box - 1.0 x 1.0 m	MH-3652	4.63	MH-3653	4.66	30.00	0.013	-1,000	0.31	7.50	1.00	1.00
261	drain-1519	Box - 1.0 x 1.0 m	MH-3654	3.63	MH-3590	3.62	30.00	0.013	2,000	0.50	71.10	1.00	1.00
262	drain-1523	Box - 1.0 x 1.0 m	MH-3655	5.22	MH-3645	5.25	30.00	0.013	-1,000	0.83	24.00	1.00	1.00
263	drain-1524	Box - 1.0 x 1.0 m	MH-3558	4.65	MH-3640	4.64	30.00	0.013	2,000	0.69	44.70	1.00	1.00
264	drain-1536	Box - 1.0 x 1.0 m	MH-3656	5.05	MH-3657	5.02	30.00	0.013	1,000	0.86	38.90	1.00	1.00
265	drain-1541	Box - 1.0 x 1.0 m	MH-3658	3.96	MH-3659	3.97	30.00	0.013	-2,000	0.30	37.30	1.00	1.00
266	drain-1544	Box - 1.0 x 1.0 m	MH-3660	4.14	MH-3661	4.11	30.00	0.013	1,000	0.23	29.90	1.00	1.00
267	drain-1551	Box - 1.0 x 1.0 m	MH-3662	3.90	MH-3526	3.89	30.00	0.013	2,000	0.72	47.60	1.00	1.00
268	drain-1557	Box - 1.0 x 1.0 m	MH-3400	4.55	MH-3663	4.56	30.00	0.013	-2,000	0.78	49.50	1.00	1.00
269	drain-1558	Box - 1.0 x 1.0 m	MH-3431	4.20	MH-3664	4.22	30.00	0.013	-2,000	0.68	43.70	1.00	1.00
270	drain-1561	Box - 1.0 x 1.0 m	MH-3634	3.55	MH-3665	3.56	30.00	0.013	-2,000	0.78	72.30	1.00	1.00
271	drain-1563	Box - 1.0 x 1.0 m	MH-3666	4.66	MH-3467	4.64	30.00	0.013	2,000	0.32	8.50	1.00	1.00
272	drain-1570	Box - 1.0 x 1.0 m	MH-3433	3.65	MH-3457	3.68	30.00	0.013	-1,000	0.54	10.20	1.00	1.00
273	drain-1576	Box - 1.0 x 1.0 m	MH-3667	4.24	MH-3668	4.25	30.00	0.013	-2,000	0.48	19.60	1.00	1.00
274	drain-1591	Box - 1.0 x 1.0 m	MH-3670	4.75	MH-3671	4.73	30.00	0.013	2,000	0.66	47.00	1.00	1.00
275	drain-1606	Box - 1.0 x 1.0 m	MH-3672	4.76	MH-3440	4.79	30.00	0.013	-1,000	0.88	62.60	1.00	1.00
276	drain-1618	Box - 1.0 x 1.0 m	MH-3673	4.17	MH-3674	4.18	30.00	0.013	-2,000	0.69	41.40	1.00	1.00
277	drain-1622	Box - 1.0 x 1.0 m	MH-3412	3.68	MH-3676	3.70	30.00	0.013	-2,000	0.23	3.70	1.00	1.00
278	drain-1629	Box - 1.0 x 1.0 m	MH-3677	4.29	MH-3678	4.31	30.00	0.013	-1,500	0.43	18.20	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
279	drain-1632	Box - 1.0 x 1.0 m	MH-3579	4.69	MH-3623	4.68	30.00	0.013	2,000	0.69	46.50	1.00	1.00
280	drain-1636	Box - 1.0 x 1.0 m	MH-3371	4.59	MH-3554	4.60	30.00	0.013	-2,000	0.32	7.30	1.00	1.00
281	drain-1640	Box - 1.0 x 1.0 m	MH-3679	4.23	MH-3541	4.21	30.00	0.013	2,000	0.48	13.60	1.00	1.00
282	drain-1641	Box - 1.0 x 1.0 m	MH-3680	4.24	MH-3681	4.22	30.00	0.013	2,000	0.75	63.90	1.00	1.00
283	drain-1659	Box - 1.0 x 1.0 m	MH-3647	5.00	MH-3438	4.97	30.00	0.013	1,000	0.43	18.20	1.00	1.00
284	drain-1660	Box - 1.0 x 1.0 m	MH-3665	3.56	MH-3682	3.58	30.00	0.013	-2,000	0.78	72.60	1.00	1.00
285	drain-1663	Box - 1.0 x 1.0 m	MH-3445	4.88	MH-3449	4.86	30.00	0.013	2,000	0.51	27.80	1.00	1.00
286	drain-1664	Box - 1.0 x 1.0 m	MH-3683	4.27	MH-3566	4.25	30.00	0.013	2,000	0.43	17.80	1.00	1.00
287	drain-1666	Box - 1.0 x 1.0 m	MH-3684	4.13	MH-3685	4.12	30.00	0.013	2,000	0.78	54.50	1.00	1.00
288	drain-1669	Box - 1.0 x 1.0 m	MH-3594	6.13	MH-3686	6.16	30.00	0.013	-1,000	0.57	15.60	1.00	1.00
289	drain-1671	Box - 1.0 x 1.0 m	MH-3687	3.79	MH-3605	3.78	30.00	0.013	2,000	0.38	53.00	1.00	1.00
290	drain-2024	Box - 1.0 x 1.0 m	MH-3688	4.60	MH-3625	4.62	29.90	0.013	-2,000	0.78	60.10	1.00	1.00
291	drain-1679	Box - 1.0 x 1.0 m	MH-3690	4.17	MH-3442	4.15	30.00	0.013	2,000	0.78	60.00	1.00	1.00
292	drain-1686	Box - 1.0 x 1.0 m	MH-3348	3.94	MH-3595	3.92	30.00	0.013	1,272	0.52	40.80	1.00	1.00
293	drain-1689	Box - 1.0 x 1.0 m	MH-3691	3.74	MH-3543	3.75	30.00	0.013	-2,000	0.67	55.90	1.00	1.00
294	drain-1695	Box - 1.0 x 1.0 m	MH-3692	4.46	MH-3693	4.49	30.00	0.013	-1,000	0.57	11.30	1.00	1.00
295	drain-1696	Box - 1.0 x 1.0 m	MH-3441	4.86	MH-3655	4.89	30.00	0.013	-1,000	0.86	53.60	1.00	1.00
296	drain-1698	Box - 1.0 x 1.0 m	MH-3358	4.18	MH-3690	4.17	30.00	0.013	2,000	0.78	61.60	1.00	1.00
297	drain-1711	Box - 1.0 x 1.0 m	MH-3478	4.27	MH-3680	4.24	30.00	0.013	1,000	0.97	63.30	1.00	1.00
298	drain-1715	Box - 1.0 x 1.0 m	MH-3560	4.23	MH-3695	4.25	30.00	0.013	-2,000	0.52	15.70	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
299	drain-1729	Box - 1.0 x 1.0 m	MH-3648	4.65	MH-3504	4.66	30.00	0.013	-2,000	0.78	64.20	1.00	1.00
300	drain-1730	Box - 1.0 x 1.0 m	MH-3644	5.78	MH-3696	5.81	30.00	0.013	-1,000	0.72	17.70	1.00	1.00
301	drain-1731	Box - 1.0 x 1.0 m	MH-3678	4.31	MH-3580	4.34	30.00	0.013	-1,000	0.45	16.20	1.00	1.00
302	drain-1738	Box - 1.0 x 1.0 m	MH-3698	3.97	MH-3607	3.99	30.00	0.013	-2,000	0.54	46.40	1.00	1.00
303	drain-1742	Box - 1.0 x 1.0 m	MH-3699	3.69	MH-3700	3.71	30.00	0.013	-2,000	0.68	57.50	1.00	1.00
304	drain-1744	Box - 1.0 x 1.0 m	MH-3701	3.85	MH-3329	3.86	30.00	0.013	-2,000	0.61	47.60	1.00	1.00
305	drain-1745	Box - 1.0 x 1.0 m	MH-3702	4.95	MH-3471	4.92	30.00	0.013	1,000	0.91	38.60	1.00	1.00
306	drain-1749	Box - 1.0 x 1.0 m	MH-3586	4.49	MH-3502	4.46	30.00	0.013	1,000	0.92	30.80	1.00	1.00
307	drain-1751	Box - 1.0 x 1.0 m	MH-3658	3.65	MH-3654	3.63	30.00	0.013	2,000	0.50	69.70	1.00	1.00
308	drain-1903	Box - 1.0 x 1.0 m	MH-3703	4.27	MH-3677	4.29	30.00	0.013	-1,498	0.45	19.60	1.00	1.00
309	drain-1757	Box - 1.0 x 1.0 m	MH-3704	4.96	MH-3581	4.98	30.00	0.013	-2,000	0.32	11.00	1.00	1.00
310	drain-1765	Box - 1.0 x 1.0 m	MH-3432	3.65	MH-3705	3.68	30.00	0.013	-1,000	0.62	20.80	1.00	1.00
311	drain-1767	Box - 1.0 x 1.0 m	MH-3706	4.05	MH-3528	4.02	30.00	0.013	1,000	0.17	30.80	1.00	1.00
312	drain-1769	Box - 1.0 x 1.0 m	MH-3707	3.78	MH-3616	3.76	30.00	0.013	2,000	0.18	56.80	1.00	1.00
313	drain-1777	Box - 1.0 x 1.0 m	MH-3693	4.86	MH-3709	4.89	30.00	0.013	-1,000	0.54	10.10	1.00	1.00
314	drain-1778	Box - 1.0 x 1.0 m	MH-3599	5.15	MH-3710	5.12	30.00	0.013	1,000	0.77	20.50	1.00	1.00
315	drain-1788	Box - 1.0 x 1.0 m	MH-3711	3.83	MH-3701	3.85	30.00	0.013	-2,000	0.61	48.40	1.00	1.00
316	drain-1795	Box - 1.0 x 1.0 m	MH-3627	3.86	MH-3523	3.89	30.00	0.013	-1,000	0.43	44.20	1.00	1.00
317	drain-1798	Box - 1.0 x 1.0 m	MH-3709	4.92	MH-3712	4.95	30.00	0.013	-1,083	0.49	10.20	1.00	1.00
318	drain-1804	Box - 1.0 x 1.0 m	MH-3715	4.12	MH-3716	4.15	30.00	0.013	-1,000	0.70	23.00	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
319	drain-1813	Box - 1.0 x 1.0 m	MH-3375	3.75	MH-3577	3.78	30.00	0.013	-1,000	0.47	29.90	1.00	1.00
320	drain-1815	Box - 1.0 x 1.0 m	MH-3369	4.09	MH-3359	4.08	30.00	0.013	2,000	0.38	12.80	1.00	1.00
321	drain-1818	Box - 1.0 x 1.0 m	MH-3717	3.68	MH-3699	3.69	30.00	0.013	-2,000	0.69	57.90	1.00	1.00
322	drain-1819	Box - 1.0 x 1.0 m	MH-3718	3.79	MH-3707	3.78	30.00	0.013	2,000	0.15	55.30	1.00	1.00
323	drain-1829	Box - 1.0 x 1.0 m	MH-3650	3.69	MH-3621	3.70	30.00	0.013	-2,000	0.68	52.60	1.00	1.00
324	drain-1833	Box - 1.0 x 1.0 m	MH-3573	4.04	MH-3715	4.07	30.00	0.013	-1,000	0.73	28.70	1.00	1.00
325	drain-1834	Box - 1.0 x 1.0 m	MH-3721	4.62	MH-3515	4.63	30.00	0.013	-2,000	0.24	4.00	1.00	1.00
326	drain-1839	Box - 1.0 x 1.0 m	MH-3622	3.72	MH-3568	3.73	30.00	0.013	-2,000	0.68	52.10	1.00	1.00
327	drain-1841	Box - 1.0 x 1.0 m	MH-3722	3.91	MH-3426	3.88	30.00	0.013	1,000	0.39	42.20	1.00	1.00
328	drain-1855	Box - 1.0 x 1.0 m	MH-3723	4.75	MH-3672	4.76	30.00	0.013	-2,000	0.69	64.10	1.00	1.00
329	drain-1865	Box - 1.0 x 1.0 m	MH-3635	3.65	MH-3724	3.66	30.00	0.013	-2,000	0.70	58.60	1.00	1.00
330	drain-1871	Box - 1.0 x 1.0 m	MH-3725	3.79	MH-3726	3.76	30.00	0.013	1,000	0.22	7.90	1.00	1.00
331	drain-1873	Box - 1.0 x 1.0 m	MH-3332	4.52	MH-3727	4.49	30.00	0.013	1,000	0.46	7.60	1.00	1.00
332	drain-1878	Box - 1.0 x 1.0 m	MH-3685	4.12	MH-3563	4.10	30.00	0.013	2,000	0.78	50.20	1.00	1.00
333	drain-1889	Box - 1.0 x 1.0 m	MH-3728	6.02	MH-3729	6.04	30.00	0.013	-2,000	0.54	22.40	1.00	1.00
334	drain-1891	Box - 1.0 x 1.0 m	MH-3427	3.81	MH-3687	3.79	30.00	0.013	2,000	0.36	51.50	1.00	1.00
335	drain-1893	Box - 1.0 x 1.0 m	MH-3555	4.62	MH-3652	4.63	30.00	0.013	-2,000	0.30	8.60	1.00	1.00
336	drain-1899	Box - 1.0 x 1.0 m	MH-3500	3.83	MH-3730	3.86	30.00	0.013	-1,000	0.41	48.90	1.00	1.00
337	drain-1917	Box - 1.0 x 1.0 m	MH-3334	4.11	MH-3470	4.09	30.00	0.013	1,590	0.47	25.60	1.00	1.00
338	drain-1919	Box - 1.0 x 1.0 m	MH-3344	3.99	MH-3506	3.98	30.00	0.013	2,000	0.34	35.60	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
339	drain-1920	Box - 1.0 x 1.0 m	MH-3731	4.82	MH-3732	4.83	30.00	0.013	-2,000	0.55	29.10	1.00	1.00
340	drain-1922	Box - 1.0 x 1.0 m	MH-3733	4.26	MH-3618	4.29	30.00	0.013	-1,000	0.55	18.60	1.00	1.00
341	drain-1945	Box - 1.0 x 1.0 m	MH-3735	3.81	MH-3628	3.80	30.00	0.013	2,000	0.59	47.60	1.00	1.00
342	drain-1959	Box - 1.0 x 1.0 m	MH-3736	6.35	MH-3468	6.38	30.00	0.013	-1,000	0.48	13.00	1.00	1.00
343	drain-1965	Box - 1.0 x 1.0 m	MH-3668	4.25	MH-3737	4.28	30.00	0.013	-1,000	0.59	19.00	1.00	1.00
344	drain-1974	Box - 1.0 x 1.0 m	MH-3414	3.82	MH-3711	3.83	30.00	0.013	-2,000	0.61	49.20	1.00	1.00
345	drain-1980	Box - 1.0 x 1.0 m	MH-3738	5.21	MH-3739	5.18	30.00	0.013	1,000	0.73	31.90	1.00	1.00
346	drain-1990	Box - 1.0 x 1.0 m	MH-3724	3.66	MH-3717	3.68	30.00	0.013	-2,000	0.70	58.30	1.00	1.00
347	drain-2003	Box - 1.0 x 1.0 m	MH-3663	4.56	MH-3488	4.58	30.00	0.013	-2,000	0.78	54.00	1.00	1.00
348	drain-2009	Box - 1.0 x 1.0 m	MH-3743	4.70	MH-3744	4.72	30.00	0.013	-2,000	0.73	65.30	1.00	1.00
349	drain-2019	Box - 1.0 x 1.0 m	MH-3744	4.72	MH-3745	4.73	30.00	0.013	-2,000	0.72	65.00	1.00	1.00
350	drain-2026	Box - 1.0 x 1.0 m	MH-3388	3.71	MH-3517	3.68	30.00	0.013	1,000	0.60	18.80	1.00	1.00
351	drain-2034	Box - 1.0 x 1.0 m	MH-3710	4.82	MH-3458	4.79	30.00	0.013	1,000	0.78	42.80	1.00	1.00
352	drain-2035	Box - 1.0 x 1.0 m	MH-3582	4.99	MH-3746	5.02	30.00	0.013	-1,000	0.30	8.60	1.00	1.00
353	drain-2040	Box - 1.0 x 1.0 m	MH-3747	3.72	MH-3691	3.74	30.00	0.013	-2,000	0.67	56.40	1.00	1.00
354	drain-2060	Box - 1.0 x 1.0 m	MH-3658	3.65	MH-3748	3.66	30.00	0.013	-2,000	0.46	68.20	1.00	1.00
355	drain-2062	Box - 1.0 x 1.0 m	MH-3749	3.83	MH-3735	3.81	30.00	0.013	2,000	0.59	46.70	1.00	1.00
356	drain-2791	Box - 1.0 x 1.0 m	MH-3562	3.79	MH-3542	3.78	30.00	0.013	2,000	0.33	55.40	1.00	1.00
357	drain-2084	Box - 1.0 x 1.0 m	MH-3681	4.22	MH-3751	4.21	30.00	0.013	2,000	0.75	63.70	1.00	1.00
358	drain-2086	Box - 1.0 x 1.0 m	MH-3752	4.23	MH-3753	4.25	30.00	0.013	-2,000	0.66	44.50	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
359	drain-2092	Box - 1.0 x 1.0 m	MH-3613	3.94	MH-3754	3.93	30.00	0.013	2,000	0.25	37.00	1.00	1.00
360	drain-2102	Box - 1.0 x 1.0 m	MH-3755	5.10	MH-3656	5.08	30.00	0.013	2,000	0.66	35.90	1.00	1.00
361	drain-2126	Box - 1.0 x 1.0 m	MH-3392	4.22	MH-3756	4.21	30.00	0.013	2,000	0.22	8.40	1.00	1.00
362	drain-2142	Box - 1.0 x 1.0 m	MH-3606	3.86	MH-3757	3.84	30.00	0.013	2,000	0.58	44.80	1.00	1.00
363	drain-2144	Box - 1.0 x 1.0 m	MH-3758	4.18	MH-3587	4.17	30.00	0.013	2,000	0.32	18.30	1.00	1.00
364	drain-2158	Box - 1.0 x 1.0 m	MH-3760	5.21	MH-3461	5.24	30.00	0.013	-1,131	0.18	2.70	1.00	1.00
365	drain-2166	Box - 1.0 x 1.0 m	MH-3512	4.20	MH-3758	4.18	30.00	0.013	2,000	0.24	16.90	1.00	1.00
366	drain-2174	Box - 1.0 x 1.0 m	MH-3695	4.25	MH-3733	4.26	30.00	0.013	-2,000	0.47	19.50	1.00	1.00
367	drain-2175	Box - 1.0 x 1.0 m	MH-3761	4.89	MH-3444	4.88	30.00	0.013	2,000	0.49	27.10	1.00	1.00
368	drain-2177	Box - 1.0 x 1.0 m	MH-3617	3.75	MH-3434	3.73	30.00	0.013	2,000	0.24	59.80	1.00	1.00
369	drain-2182	Box - 1.0 x 1.0 m	MH-3762	3.73	MH-3553	3.75	30.00	0.013	-2,000	0.41	59.10	1.00	1.00
370	drain-2209	Box - 1.0 x 1.0 m	MH-3763	3.83	MH-3725	3.80	30.00	0.013	1,000	0.11	3.90	1.00	1.00
371	drain-2220	Box - 1.0 x 1.0 m	MH-3766	4.49	MH-3767	4.52	30.00	0.013	-1,000	0.47	8.00	1.00	1.00
372	drain-2221	Box - 1.0 x 1.0 m	MH-3768	4.32	MH-3766	4.35	30.00	0.013	-1,000	0.53	15.10	1.00	1.00
373	drain-2229	Box - 1.0 x 1.0 m	MH-3732	4.83	MH-3564	4.85	30.00	0.013	-2,000	0.53	28.80	1.00	1.00
374	drain-2236	Box - 1.0 x 1.0 m	MH-3769	4.38	MH-3513	4.41	30.00	0.013	-1,000	0.36	9.60	1.00	1.00
375	drain-2249	Box - 1.0 x 1.0 m	MH-3671	4.73	MH-3544	4.72	30.00	0.013	2,000	0.67	47.20	1.00	1.00
376	drain-2281	Box - 1.0 x 1.0 m	MH-3406	3.90	MH-3559	3.88	30.00	0.013	2,000	0.39	41.70	1.00	1.00
377	drain-2284	Box - 1.0 x 1.0 m	MH-3737	4.28	MH-3768	4.31	30.00	0.013	-1,000	0.57	17.60	1.00	1.00
378	drain-2290	Box - 1.0 x 1.0 m	MH-3474	3.82	MH-3561	3.81	30.00	0.013	2,000	0.31	52.50	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
379	drain-2291	Box - 1.0 x 1.0 m	MH-3696	6.01	MH-3728	6.02	30.00	0.013	-2,000	0.56	17.80	1.00	1.00
380	drain-2297	Box - 1.0 x 1.0 m	MH-3748	3.66	MH-3770	3.68	30.00	0.013	-2,000	0.46	66.70	1.00	1.00
381	drain-2298	Box - 1.0 x 1.0 m	MH-3437	3.52	MH-3633	3.53	30.00	0.013	-2,000	0.78	71.70	1.00	1.00
382	drain-2306	Box - 1.0 x 1.0 m	MH-3771	3.78	MH-3588	3.75	30.00	0.013	1,000	0.20	29.40	1.00	1.00
383	drain-2308	Box - 1.0 x 1.0 m	MH-3547	4.54	MH-3477	4.51	30.00	0.013	1,000	0.96	41.20	1.00	1.00
384	drain-2333	Box - 1.0 x 1.0 m	MH-3772	3.99	MH-3459	4.00	30.00	0.013	-2,000	0.21	34.30	1.00	1.00
385	drain-2342	Box - 1.0 x 1.0 m	MH-3529	4.01	MH-3380	4.00	30.00	0.013	2,000	0.28	33.90	1.00	1.00
386	drain-2363	Box - 1.0 x 1.0 m	MH-3410	3.74	MH-3630	3.75	30.00	0.013	-2,000	0.16	41.10	1.00	1.00
387	drain-2364	Box - 1.0 x 1.0 m	MH-3774	3.70	MH-3510	3.71	30.00	0.013	-2,000	0.32	45.10	1.00	1.00
388	drain-2370	Box - 1.0 x 1.0 m	MH-3443	4.15	MH-3684	4.13	30.00	0.013	2,000	0.78	57.40	1.00	1.00
389	drain-2373	Box - 1.0 x 1.0 m	MH-3487	3.96	MH-3698	3.97	30.00	0.013	-2,000	0.55	47.60	1.00	1.00
390	drain-2388	Box - 1.0 x 1.0 m	MH-3629	3.78	MH-3601	3.77	30.00	0.013	2,000	0.59	49.60	1.00	1.00
391	drain-2400	Box - 1.0 x 1.0 m	MH-3775	4.04	MH-3550	4.06	30.00	0.013	-2,000	0.17	26.90	1.00	1.00
392	drain-2404	Box - 1.0 x 1.0 m	MH-3396	4.91	MH-3761	4.89	30.00	0.013	2,000	0.45	26.20	1.00	1.00
393	drain-2430	Box - 1.0 x 1.0 m	MH-3776	3.91	MH-3405	3.90	30.00	0.013	2,000	0.32	40.00	1.00	1.00
394	drain-2453	Box - 1.0 x 1.0 m	MH-3745	4.73	MH-3723	4.75	30.00	0.013	-2,000	0.71	64.60	1.00	1.00
395	drain-2476	Box - 1.0 x 1.0 m	MH-3350	4.69	MH-3743	4.70	30.00	0.013	-2,000	0.74	65.50	1.00	1.00
396	drain-2486	Box - 1.0 x 1.0 m	MH-3377	4.80	MH-3731	4.82	30.00	0.013	-2,000	0.56	29.20	1.00	1.00
397	drain-2531	Box - 1.0 x 1.0 m	MH-3777	3.71	MH-3497	3.70	30.00	0.013	2,000	0.43	63.00	1.00	1.00
398	drain-2542	Box - 1.0 x 1.0 m	MH-3686	6.33	MH-3736	6.35	30.00	0.013	-2,000	0.43	10.90	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
399	drain-2546	Box - 1.0 x 1.0 m	MH-3394	4.24	MH-3778	4.25	30.00	0.013	-2,000	0.42	21.70	1.00	1.00
400	drain-2604	Box - 1.0 x 1.0 m	MH-3661	4.11	MH-3608	4.10	30.00	0.013	2,000	0.25	32.10	1.00	1.00
401	drain-2607	Box - 1.0 x 1.0 m	MH-3779	3.68	MH-3780	3.66	30.00	0.013	2,000	0.18	48.80	1.00	1.00
402	drain-2608	Box - 1.0 x 1.0 m	MH-3716	4.25	MH-3521	4.28	30.00	0.013	-1,000	0.66	15.30	1.00	1.00
403	drain-2619	Box - 1.0 x 1.0 m	MH-3637	4.22	MH-3667	4.24	30.00	0.013	-2,000	0.49	18.80	1.00	1.00
404	drain-2620	Box - 1.0 x 1.0 m	MH-3729	6.04	MH-3593	6.05	30.00	0.013	-2,000	0.50	22.90	1.00	1.00
405	drain-2636	Box - 1.0 x 1.0 m	MH-3781	3.81	MH-3718	3.79	30.00	0.013	1,662	0.10	53.60	1.00	1.00
406	drain-2641	Box - 1.0 x 1.0 m	MH-3659	3.97	MH-3772	3.99	30.00	0.013	-2,000	0.27	35.80	1.00	1.00
407	drain-2647	Box - 1.0 x 1.0 m	MH-3712	4.95	MH-3704	4.96	30.00	0.013	-2,000	0.35	11.20	1.00	1.00
408	drain-2661	Box - 1.0 x 1.0 m	MH-3537	3.69	MH-3779	3.68	30.00	0.013	2,000	0.15	47.30	1.00	1.00
409	drain-2674	Box - 1.0 x 1.0 m	MH-3757	3.84	MH-3749	3.83	30.00	0.013	2,000	0.59	45.70	1.00	1.00
410	drain-2692	Box - 1.0 x 1.0 m	MH-3664	4.22	MH-3752	4.23	30.00	0.013	-2,000	0.67	44.30	1.00	1.00
411	drain-2698	Box - 1.0 x 1.0 m	MH-3782	3.84	MH-3473	3.83	30.00	0.013	2,000	0.14	50.50	1.00	1.00
412	drain-2706	Box - 1.0 x 1.0 m	MH-3589	3.74	MH-3503	3.72	30.00	0.013	2,000	0.30	32.90	1.00	1.00
413	drain-2716	Box - 1.0 x 1.0 m	MH-3783	5.13	MH-3755	5.10	30.00	0.013	1,000	0.82	36.20	1.00	1.00
414	drain-2747	Box - 1.0 x 1.0 m	MH-3784	3.68	MH-3774	3.70	30.00	0.013	-2,000	0.36	46.50	1.00	1.00
415	drain-2752	Box - 1.0 x 1.0 m	MH-3739	5.18	MH-3783	5.16	30.00	0.013	2,000	0.61	32.50	1.00	1.00
416	drain-2775	Box - 1.0 x 1.0 m	MH-3448	3.71	MH-3649	3.72	30.00	0.013	-2,000	0.61	60.50	1.00	1.00
417	drain-2777	Box - 1.0 x 1.0 m	MH-3746	5.12	MH-3785	5.15	30.00	0.013	-1,000	0.27	3.20	1.00	1.00
418	drain-2778	Box - 1.0 x 1.0 m	MH-3785	5.18	MH-3760	5.21	30.00	0.013	-1,000	0.23	2.40	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
419	drain-2797	Box - 1.0 x 1.0 m	MH-3354	3.70	MH-3642	3.71	30.00	0.013	-2,000	0.44	35.90	1.00	1.00
420	drain-2801	Box - 1.0 x 1.0 m	MH-3435	3.73	MH-3777	3.71	30.00	0.013	2,000	0.41	61.50	1.00	1.00
421	drain-2809	Box - 1.0 x 1.0 m	MH-3419	4.76	MH-3670	4.75	30.00	0.013	2,000	0.65	46.80	1.00	1.00
422	drain-2815	Box - 1.0 x 1.0 m	MH-3575	4.29	MH-3769	4.32	30.00	0.013	-1,000	0.41	18.10	1.00	1.00
423	drain-2833	Box - 1.0 x 1.0 m	MH-3767	4.52	MH-3721	4.55	30.00	0.013	-1,000	0.39	9.00	1.00	1.00
424	drain-2871	Box - 1.0 x 1.0 m	MH-3673	4.17	MH-3632	4.15	30.00	0.013	2,000	0.69	39.60	1.00	1.00
425	drain-2874	Box - 1.0 x 1.0 m	MH-3682	3.58	MH-3484	3.59	30.00	0.013	-2,000	0.78	72.80	1.00	1.00
426	drain-2902	Box - 1.0 x 1.0 m	MH-3490	4.97	MH-3702	4.95	30.00	0.013	1,213	0.84	39.80	1.00	1.00
427	drain-2912	Box - 1.0 x 1.0 m	MH-3770	3.68	MH-3451	3.69	30.00	0.013	-2,000	0.45	65.30	1.00	1.00
428	drain-2926	Box - 1.0 x 1.0 m	MH-3726	3.76	MH-3624	3.75	30.00	0.013	2,000	0.27	9.80	1.00	1.00
429	drain-2929	Box - 1.0 x 1.0 m	MH-3474	3.84	MH-3524	3.87	30.00	0.013	-1,000	0.35	48.30	1.00	1.00
430	drain-2934	Box - 1.0 x 1.0 m	MH-3382	4.03	MH-3775	4.04	30.00	0.013	-2,000	0.24	28.40	1.00	1.00
431	drain-2936	Box - 1.0 x 1.0 m	MH-3657	5.01	MH-3489	4.98	30.00	0.013	1,000	0.87	40.50	1.00	1.00
432	drain-2940	Box - 1.0 x 1.0 m	MH-3571	3.97	MH-3612	3.96	30.00	0.013	2,000	0.20	34.10	1.00	1.00
433	drain-2941	Box - 1.0 x 1.0 m	MH-3404	3.93	MH-3465	3.94	30.00	0.013	-2,000	0.26	32.80	1.00	1.00
434	drain-2961	Box - 1.0 x 1.0 m	MH-3754	3.93	MH-3776	3.91	30.00	0.013	2,000	0.30	38.50	1.00	1.00
435	drain-2966	Box - 1.0 x 1.0 m	MH-3700	3.71	MH-3747	3.72	30.00	0.013	-2,000	0.68	57.00	1.00	1.00
436	drain-2974	Box - 1.0 x 1.0 m	MH-3751	4.21	MH-3585	4.19	30.00	0.013	2,000	0.76	63.30	1.00	1.00
437	drain-1657	Box - 1.0 x 1.0 m	MH-3787	3.93	MH-3662	3.90	30.10	0.013	1,000	0.92	47.90	1.00	1.00
438	drain-1247	Box - 1.0 x 1.0 m	MH-3778	4.25	MH-3703	4.27	30.70	0.013	-2,000	0.41	20.80	1.00	1.00

Sn No.	Label	Conduit Description	Start Node	Invert (Start) (m)	Stop Node	Invert (Stop) (m)	Length (m)	Manning' sn	Slope (Calculated) (m/m (H:V))	Velocity (m/s)	Depth/Rise (%)	Width (m)	Depth (m)
439	drain-1902	Box - 1.0 x 1.0 m	MH-3507	3.97	MH-3572	3.96	30.70	0.013	2,000	0.39	37.80	1.00	1.00
440	drain-1396	Box - 1.0 x 1.0 m	MH-3505	4.67	MH-3349	4.68	32.30	0.013	-2,000	0.76	65.30	1.00	1.00
441	drain-2210	Box - 1.0 x 1.0 m	MH-3756	4.21	MH-3351	4.19	31.10	0.013	2,000	0.30	9.10	1.00	1.00
442	drain-2659	Box - 1.0 x 1.0 m	MH-3674	4.18	MH-3430	4.20	31.30	0.013	-2,000	0.69	42.80	1.00	1.00
443	drain-1609	Box - 1.0 x 1.0 m	MH-3356	4.00	MH-3603	4.03	31.60	0.013	-1,000	0.60	43.10	1.00	1.00
444	drain-1310	Box - 1.0 x 1.0 m	MH-3464	4.69	MH-3666	4.66	33.60	0.013	1,000	0.39	8.40	1.00	1.00
445	drain-2218	Box - 1.0 x 1.0 m	MH-3727	4.30	MH-3683	4.27	31.50	0.013	1,000	0.50	16.60	1.00	1.00
446	drain-1415	Box - 1.0 x 1.0 m	MH-3539	4.04	MH-3534	4.02	33.50	0.013	2,000	0.64	29.60	1.00	1.00
447	drain-497	Box - 1.0 x 1.0 m	MH-3789	4.24	MH-3391	4.22	32.40	0.013	2,000	0.12	6.80	1.00	1.00
448	drain-2071	Box - 1.0 x 1.0 m	MH-3398	4.07	MH-3787	4.04	32.60	0.013	1,000	0.91	37.50	1.00	1.00
449	drain-1720	Box - 1.0 x 1.0 m	MH-3567	4.24	MH-3679	4.23	33.10	0.013	2,000	0.47	17.30	1.00	1.00
450	drain-2968	Box - 1.0 x 1.0 m	MH-3401	3.67	MH-3353	3.69	33.20	0.013	-1,305	0.54	37.80	1.00	1.00
451	drain-1487	Box - 1.0 x 1.0 m	MH-3340	4.58	MH-3688	4.60	33.80	0.013	-2,000	0.78	58.00	1.00	1.00
452	drain-1507	Box - 1.0 x 1.0 m	MH-3552	4.06	MH-3538	4.05	33.90	0.013	2,000	0.63	33.40	1.00	1.00
453	drain-1975	Box - 1.0 x 1.0 m	MH-3533	4.77	MH-3602	4.79	33.50	0.013	-2,000	0.59	27.90	1.00	1.00
454	drain-1580	Box - 1.0 x 1.0 m	MH-3753	4.25	MH-3385	4.26	33.70	0.013	-2,000	0.65	44.40	1.00	1.00
455	drain-1658	Box - 1.0 x 1.0 m	MH-3604	4.22	MH-3393	4.24	33.70	0.013	-2,000	0.44	22.80	1.00	1.00
456	drain-2743	Box - 1.0 x 1.0 m	MH-3429	3.72	MH-3762	3.73	33.90	0.013	-2,000	0.42	60.70	1.00	1.00
457	drain-1770	Box - 1.0 x 1.0 m	MH-3522	4.33	MH-3692	4.36	34.00	0.013	-1,000	0.59	16.10	1.00	1.00
458	CO-25	Box - 1.0 x 1.0 m	MH-3429	3.60	MH-3485	3.60	9.40	0.013	2,000	0.77	73.00	1.00	1.00
459	CO-26	Box - 1.0 x 1.0 m	MH-3780	3.66	MH-3455	3.66	12.80	0.013	2,000	0.20	49.80	1.00	1.00
460	CO-28	Box - 1.0 x 1.0 m	MH-3784	3.68	MH-3456	3.67	30.00	0.013	2,000	0.39	48.00	1.00	1.00

9.2 Manhole Table

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3341	5.22	3.12	86.33	85.99	4.14
MH-3342	5.22	3.12	86.47	86.33	4.14
MH-3765	5.14	3.08	88.91	88.28	4.05
MH-3548	4.90	2.86	122.54	121.21	3.60
MH-3786	4.91	2.88	120.07	119.50	3.70
MH-3764	5.09	3.09	88.42	87.73	4.08
MH-3750	4.96	2.97	111.85	111.18	3.95
MH-3454	5.02	3.04	88.51	88.41	3.97
MH-3773	5.09	3.11	87.54	86.92	4.11
MH-3453	5.02	3.05	88.79	88.40	3.98
MH-3742	5.41	3.44	68.88	68.48	4.33
MH-3420	5.01	3.08	83.43	82.93	4.12
MH-3421	5.01	3.08	84.45	84.07	4.12
MH-3583	5.03	3.10	82.54	82.14	4.16
MH-3651	4.99	3.06	89.14	88.59	4.01
MH-3576	5.01	3.09	82.75	82.34	4.14
MH-3759	4.91	2.99	111.27	110.72	3.98
MH-3714	4.81	2.90	119.98	119.46	3.76
MH-3417	5.03	3.13	88.58	86.04	4.16
MH-3416	5.03	3.14	73.19	72.22	4.16
MH-3456	4.89	3.00	110.77	110.64	4.00
MH-3476	4.91	3.04	108.52	108.22	4.06
MH-3487	5.33	3.46	68.69	68.42	4.36
MH-3713	4.78	2.91	120.18	119.58	3.81
MH-3475	4.91	3.05	108.56	107.13	4.07
MH-3697	5.29	3.43	69.31	68.85	4.31
MH-3412	4.81	2.96	91.27	90.51	3.69
MH-3413	4.81	2.96	90.59	90.53	3.68
MH-3694	4.97	3.12	82.62	82.24	4.18
MH-3611	4.79	2.97	90.17	89.58	3.73
MH-3675	4.88	3.06	85.36	84.74	4.10
MH-3520	4.84	3.03	88.46	88.27	3.95
MH-3610	4.80	2.99	89.90	89.17	3.80

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3455	4.81	3.01	111.12	110.59	4.01
MH-3740	4.73	2.94	119.67	118.98	3.89
MH-3719	4.80	3.02	88.60	88.18	3.90
MH-3741	4.71	2.93	120.12	119.42	3.85
MH-3591	4.70	2.94	90.65	90.30	3.63
MH-3720	4.76	3.00	88.81	88.31	3.86
MH-3565	5.15	3.41	69.58	69.13	4.29
MH-3402	4.69	2.96	120.77	118.55	3.92
MH-3425	4.76	3.03	111.92	111.08	4.04
MH-3519	5.03	3.30	69.95	69.67	4.25
MH-3433	4.65	2.93	108.49	104.05	3.56
MH-3447	4.85	3.13	82.62	82.46	4.20
MH-3446	4.85	3.14	69.96	69.64	4.21
MH-3481	5.14	3.44	67.24	66.25	4.18
MH-3434	5.41	3.73	0.98	0.94	4.19
MH-3435	5.41	3.73	4.06	3.80	4.19
MH-3449	6.53	4.86	7.61	7.53	5.14
MH-3564	6.51	4.85	8.29	8.19	5.13
MH-3450	6.51	4.86	7.85	7.81	5.14
MH-3518	5.04	3.40	69.70	69.36	4.27
MH-3777	5.33	3.71	4.57	4.41	4.19
MH-3708	4.77	3.18	70.20	69.87	4.23
MH-3497	5.28	3.70	4.83	4.72	4.18
MH-3530	5.88	4.30	14.51	14.38	4.72
MH-3452	5.26	3.69	4.86	4.82	4.18
MH-3444	6.44	4.88	7.05	6.94	5.15
MH-3445	6.44	4.88	7.50	7.46	5.15
MH-3621	5.26	3.70	20.12	19.98	4.23
MH-3650	5.25	3.69	20.27	20.09	4.21
MH-3451	5.24	3.69	4.92	4.90	4.18
MH-3639	5.22	3.67	20.29	20.13	4.20
MH-3700	5.26	3.71	20.79	20.51	4.19
MH-3747	5.25	3.72	20.10	19.86	4.20
MH-3629	5.29	3.78	12.20	12.08	4.27
MH-3638	5.17	3.66	20.58	20.37	4.19
MH-3691	5.25	3.74	19.59	19.38	4.22

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3732	6.34	4.83	9.23	9.07	5.12
MH-3770	5.19	3.68	5.23	5.12	4.18
MH-3429	5.10	3.60	32.53	32.07	4.18
MH-3560	5.37	3.87	12.20	11.15	4.31
MH-3669	4.65	3.15	70.13	69.85	4.22
MH-3748	5.16	3.66	5.36	5.27	4.18
MH-3699	5.18	3.69	21.90	21.53	4.17
MH-3731	6.31	4.82	10.21	10.02	5.11
MH-3542	5.26	3.78	2.27	2.22	4.19
MH-3640	6.12	4.64	23.23	22.89	5.08
MH-3389	5.54	4.08	43.49	43.33	4.67
MH-3586	5.95	4.49	24.54	24.36	4.85
MH-3606	5.32	3.86	11.44	11.31	4.30
MH-3757	5.30	3.84	11.72	11.57	4.29
MH-3558	6.10	4.65	21.53	21.39	5.10
MH-3648	6.10	4.65	36.51	36.24	5.28
MH-3486	5.33	3.89	62.08	59.09	4.41
MH-3559	5.32	3.88	3.39	3.33	4.31
MH-3641	6.06	4.62	24.90	24.53	5.05
MH-3626	6.06	4.63	36.76	36.47	5.26
MH-3357	5.60	4.18	35.31	34.89	4.81
MH-3358	5.60	4.18	35.95	35.77	4.80
MH-3622	5.14	3.72	20.16	20.01	4.24
MH-3717	5.10	3.68	23.00	22.61	4.15
MH-3376	6.21	4.80	11.00	10.95	5.09
MH-3592	5.43	4.02	45.06	44.76	4.58
MH-3601	5.18	3.77	12.23	12.12	4.27
MH-3393	5.64	4.24	4.69	4.66	4.41
MH-3616	5.16	3.76	0.62	0.59	4.19
MH-3628	5.20	3.80	12.16	12.03	4.28
MH-3405	5.29	3.90	1.98	1.94	4.31
MH-3406	5.29	3.90	3.38	3.20	4.31
MH-3504	6.05	4.66	36.26	36.06	5.31
MH-3598	6.68	5.29	12.82	12.72	5.53
MH-3658	5.04	3.65	7.03	6.73	4.18
MH-3568	5.11	3.73	20.13	20.01	4.25

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3659	5.35	3.97	1.61	1.56	4.18
MH-3698	5.35	3.97	9.63	9.46	4.36
MH-3373	5.42	4.05	6.12	6.07	4.30
MH-3390	5.69	4.32	42.92	42.73	4.70
MH-3498	5.69	4.32	42.86	42.34	4.75
MH-3543	5.12	3.75	19.16	19.03	4.23
MH-3585	5.56	4.19	34.11	33.60	4.83
MH-3693	5.86	4.49	5.23	5.05	4.63
MH-3349	6.04	4.68	32.52	32.13	5.34
MH-3377	6.16	4.80	10.73	10.57	5.09
MH-3394	5.60	4.24	4.53	4.43	4.41
MH-3557	6.02	4.66	21.31	21.15	5.12
MH-3623	6.04	4.68	21.36	21.19	5.14
MH-3762	4.95	3.59	32.61	32.31	4.15
MH-3350	6.04	4.69	30.25	29.79	5.34
MH-3403	5.09	3.74	20.77	19.97	4.26
MH-3505	6.02	4.67	36.33	35.54	5.32
MH-3575	5.29	3.95	47.12	46.50	4.48
MH-3372	5.42	4.09	5.59	5.55	4.30
MH-3589	5.07	3.74	1.66	1.61	3.93
MH-3607	5.32	3.99	9.31	9.00	4.37
MH-3655	6.22	4.89	19.14	18.79	5.42
MH-3689	5.33	4.00	45.20	44.89	4.54
MH-3590	4.94	3.62	7.29	7.16	4.18
MH-3602	6.11	4.79	12.27	12.05	5.07
MH-3612	5.28	3.96	0.69	0.67	4.31
MH-3654	4.95	3.63	7.07	6.95	4.18
MH-3686	7.48	6.16	5.17	5.09	6.31
MH-3579	6.00	4.69	21.27	21.10	5.16
MH-3728	7.33	6.02	9.84	9.68	6.24
MH-3761	6.20	4.89	6.40	6.27	5.16
MH-3710	6.12	4.82	13.46	13.35	5.24
MH-3749	5.13	3.83	11.92	11.78	4.29
MH-3533	6.06	4.77	13.62	13.34	5.04
MH-3563	5.39	4.10	37.86	37.62	4.58
MH-3603	5.32	4.03	6.15	5.95	4.38

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3614	7.32	6.03	3.61	3.61	6.15
MH-3670	6.04	4.75	17.76	17.56	5.21
MH-3706	5.34	4.05	0.21	0.21	4.28
MH-3723	6.04	4.75	24.67	24.21	5.39
MH-3743	5.99	4.70	28.51	28.10	5.35
MH-3500	4.83	3.55	35.61	34.87	4.05
MH-3541	5.27	4.00	6.62	6.52	4.20
MH-3501	5.59	4.34	41.77	41.20	4.82
MH-3532	4.81	3.56	32.88	32.66	4.08
MH-3613	5.19	3.94	1.02	0.97	4.31
MH-3617	5.00	3.75	0.89	0.84	4.19
MH-3685	5.37	4.12	37.91	37.64	4.65
MH-3332	5.76	4.52	2.69	2.67	4.61
MH-3485	5.10	3.86	0.07	0.07	4.06
MH-3525	5.20	3.96	0.92	0.92	4.19
MH-3690	5.41	4.17	37.36	36.91	4.77
MH-3343	5.23	4.00	1.64	1.63	4.28
MH-3379	6.94	5.71	12.19	12.10	5.94
MH-3380	5.23	4.00	1.66	1.62	4.28
MH-3411	4.91	3.68	3.78	3.70	3.81
MH-3422	5.26	4.03	44.60	44.48	4.61
MH-3423	5.26	4.03	44.44	44.15	4.61
MH-3540	5.02	3.79	3.57	3.52	4.04
MH-3645	6.48	5.25	16.79	16.51	5.53
MH-3400	5.77	4.55	38.39	37.99	5.02
MH-3428	5.10	3.88	25.40	25.27	4.20
MH-3430	5.42	4.20	21.13	20.96	4.63
MH-3431	5.42	4.20	20.35	20.17	4.63
MH-3529	5.23	4.01	1.31	1.27	4.28
MH-3724	4.88	3.66	23.54	23.24	4.13
MH-3735	5.03	3.81	12.06	11.92	4.28
MH-3776	5.13	3.91	1.97	1.90	4.31
MH-3388	4.92	3.71	5.97	5.96	3.89
MH-3399	5.76	4.55	39.34	39.08	5.00
MH-3561	5.02	3.81	1.90	1.86	4.19
MH-3634	5.01	3.80	0.96	0.92	4.06

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3665	5.03	3.82	0.78	0.75	4.06
MH-3729	7.25	6.04	8.80	8.62	6.26
MH-3753	5.46	4.25	18.29	17.91	4.69
MH-3506	5.18	3.98	2.80	2.72	4.28
MH-3566	5.45	4.25	5.04	4.94	4.43
MH-3574	5.13	3.93	46.78	46.59	4.45
MH-3620	5.25	4.05	44.42	44.06	4.65
MH-3637	5.42	4.22	7.27	7.13	4.40
MH-3684	5.33	4.13	37.80	37.52	4.69
MH-3696	7.01	5.81	10.33	10.20	6.02
MH-3734	5.10	3.90	47.03	46.77	4.39
MH-3347	5.13	3.94	4.80	4.67	4.28
MH-3348	5.13	3.94	4.71	4.70	4.28
MH-3478	5.46	4.27	29.34	29.22	4.89
MH-3509	5.26	4.07	13.69	13.48	4.42
MH-3539	5.23	4.04	16.10	16.00	4.35
MH-3552	5.25	4.06	15.39	15.19	4.40
MH-3556	4.94	3.75	12.27	12.16	4.26
MH-3604	5.41	4.22	5.15	5.03	4.39
MH-3663	5.75	4.56	37.51	37.26	5.09
MH-3727	5.49	4.30	3.61	3.53	4.46
MH-3344	5.17	3.99	2.20	2.16	4.28
MH-3553	4.75	3.57	32.92	32.63	4.11
MH-3633	4.97	3.79	1.17	1.13	4.06
MH-3635	4.83	3.65	23.65	23.43	4.10
MH-3636	5.30	4.12	7.71	7.58	4.30
MH-3410	4.91	3.74	0.62	0.58	3.81
MH-3442	5.32	4.15	37.33	37.06	4.74
MH-3443	5.32	4.15	37.42	37.33	4.73
MH-3535	5.07	3.90	0.21	0.21	4.27
MH-3538	5.22	4.05	16.01	15.82	4.37
MH-3573	5.04	3.87	12.18	11.89	4.23
MH-3404	5.09	3.93	8.73	8.54	4.26
MH-3523	5.05	3.89	2.24	2.19	4.24
MH-3550	5.22	4.06	0.34	0.33	4.24
MH-3567	5.40	4.24	5.70	5.60	4.42

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3674	5.34	4.18	21.84	21.56	4.60
MH-3722	5.07	3.91	1.73	1.73	4.24
MH-3328	5.18	4.03	4.57	4.56	4.15
MH-3488	5.73	4.58	37.38	37.22	5.13
MH-3597	4.87	3.72	2.16	2.12	3.83
MH-3644	6.78	5.63	10.54	10.45	5.84
MH-3752	5.38	4.23	19.57	19.21	4.67
MH-3763	4.98	3.83	0.06	0.06	3.85
MH-3448	4.85	3.71	13.07	12.97	4.20
MH-3546	5.75	4.61	25.62	25.33	5.01
MH-3625	5.76	4.62	36.73	36.49	5.23
MH-3664	5.36	4.22	20.32	20.03	4.65
MH-3682	4.97	3.83	0.55	0.52	4.06
MH-3738	6.35	5.21	10.72	10.72	5.52
MH-3766	5.49	4.35	4.14	4.03	4.49
MH-3370	5.61	4.48	2.08	2.06	4.56
MH-3531	5.89	4.76	14.05	13.91	5.01
MH-3656	6.18	5.05	18.97	18.79	5.44
MH-3660	5.27	4.14	0.42	0.42	4.42
MH-3707	4.91	3.78	0.41	0.39	4.19
MH-3718	4.92	3.79	0.27	0.26	4.19
MH-3772	5.12	3.99	1.14	1.11	4.18
MH-3331	5.76	4.64	2.32	2.30	4.71
MH-3467	5.76	4.64	2.21	2.17	4.73
MH-3502	5.46	4.34	24.48	24.34	4.67
MH-3503	4.80	3.68	2.33	2.26	3.92
MH-3507	5.09	3.97	3.29	3.23	4.28
MH-3511	5.34	4.22	0.36	0.36	4.32
MH-3521	5.40	4.28	8.00	7.72	4.46
MH-3526	5.01	3.89	25.35	25.13	4.26
MH-3580	5.46	4.34	2.58	2.52	4.47
MH-3673	5.29	4.17	21.81	21.64	4.57
MH-3337	5.03	3.92	6.83	6.76	4.28
MH-3554	5.71	4.60	1.80	1.77	4.68
MH-3599	6.26	5.15	12.99	12.90	5.39
MH-3721	5.66	4.55	1.77	1.72	4.63

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3787	5.04	3.93	24.85	24.48	4.35
MH-3327	5.18	4.08	3.60	3.58	4.17
MH-3385	5.36	4.26	16.64	16.46	4.70
MH-3386	5.36	4.26	15.52	15.36	4.71
MH-3408	4.85	3.75	12.39	12.25	4.22
MH-3436	4.87	3.77	1.24	1.23	4.06
MH-3437	4.87	3.77	1.19	1.16	4.06
MH-3494	4.94	3.84	0.41	0.41	4.05
MH-3572	5.06	3.96	3.88	3.78	4.28
MH-3619	5.47	4.37	2.33	2.33	4.48
MH-3646	6.19	5.09	0.86	0.86	5.17
MH-3667	5.34	4.24	6.66	6.54	4.43
MH-3679	5.33	4.23	6.35	6.21	4.40
MH-3692	5.46	4.36	5.83	5.67	4.52
MH-3716	5.25	4.15	9.80	9.40	4.35
MH-3746	6.12	5.02	0.89	0.86	5.09
MH-3754	5.03	3.93	1.64	1.56	4.31
MH-3368	5.18	4.09	2.64	2.59	4.20
MH-3381	5.11	4.02	1.58	1.55	4.24
MH-3387	5.01	3.92	5.34	5.30	4.04
MH-3473	4.92	3.83	0.35	0.33	4.19
MH-3496	4.78	3.69	2.76	2.73	3.82
MH-3569	4.83	3.74	13.00	12.85	4.22
MH-3571	5.06	3.97	0.54	0.52	4.31
MH-3587	5.23	4.14	2.98	2.89	4.31
MH-3596	5.00	3.91	4.96	4.89	4.28
MH-3643	6.60	5.51	15.10	14.64	5.77
MH-3688	5.69	4.60	37.08	36.79	5.19
MH-3783	6.22	5.13	15.89	15.73	5.49
MH-3335	5.05	3.97	6.92	6.86	4.18
MH-3336	5.05	3.97	6.93	6.92	4.17
MH-3361	5.09	4.01	1.93	1.91	4.24
MH-3362	5.09	4.01	1.82	1.77	4.24
MH-3364	4.78	3.70	3.76	3.74	3.82
MH-3365	4.78	3.70	3.91	3.66	3.82
MH-3382	5.11	4.03	1.29	1.24	4.24

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3398	5.15	4.07	23.66	23.43	4.43
MH-3414	4.84	3.76	19.11	18.88	4.24
MH-3457	4.76	3.68	4.38	4.29	3.80
MH-3687	4.87	3.79	3.02	2.97	4.24
MH-3695	5.33	4.25	8.05	7.91	4.44
MH-3702	6.03	4.95	23.50	23.31	5.34
MH-3712	6.03	4.95	3.59	3.41	5.06
MH-3351	5.26	4.19	2.16	2.08	4.28
MH-3352	5.26	4.19	2.37	2.34	4.28
MH-3415	4.84	3.77	5.65	5.34	4.24
MH-3426	4.88	3.81	2.18	2.15	4.24
MH-3440	5.86	4.79	20.77	20.69	5.40
MH-3524	4.94	3.87	1.29	1.28	4.19
MH-3534	5.09	4.02	16.26	16.10	4.30
MH-3544	5.79	4.72	20.30	20.05	5.19
MH-3547	5.61	4.54	28.22	27.76	4.96
MH-3555	5.69	4.62	1.73	1.70	4.70
MH-3578	4.91	3.84	2.46	2.46	3.96
MH-3605	4.85	3.78	3.21	3.16	4.24
MH-3649	4.79	3.72	13.15	13.01	4.21
MH-3744	5.79	4.72	26.93	26.62	5.37
MH-3760	6.28	5.21	0.43	0.42	5.24
MH-3363	5.10	4.04	3.37	3.34	4.14
MH-3438	5.97	4.91	3.26	3.20	5.17
MH-3466	5.01	3.95	0.84	0.84	4.26
MH-3508	5.14	4.08	11.57	11.01	4.42
MH-3513	5.47	4.41	1.36	1.34	4.49
MH-3609	4.79	3.73	2.11	2.05	3.84
MH-3647	6.06	5.00	2.30	2.26	5.17
MH-3769	5.38	4.32	2.05	2.01	4.49
MH-3779	4.80	3.74	0.32	0.30	3.82
MH-3480	4.75	3.70	2.61	2.48	3.82
MH-3515	5.68	4.63	0.83	0.82	4.69
MH-3545	5.75	4.70	20.89	20.73	5.17
MH-3594	7.13	6.08	5.65	5.59	6.29
MH-3618	5.34	4.29	4.50	4.45	4.47

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3653	5.71	4.66	0.93	0.93	4.72
MH-3715	5.12	4.07	11.31	10.92	4.29
MH-3758	5.23	4.18	1.84	1.79	4.32
MH-3774	4.79	3.74	1.59	1.55	3.83
MH-3775	5.09	4.04	0.93	0.89	4.24
MH-3339	5.62	4.58	36.91	36.86	5.15
MH-3340	5.62	4.58	37.02	36.75	5.15
MH-3464	5.73	4.69	1.71	1.70	4.77
MH-3477	5.51	4.47	29.02	28.73	4.91
MH-3632	5.19	4.15	22.14	21.92	4.53
MH-3354	4.73	3.70	5.18	5.10	3.93
MH-3360	5.10	4.07	3.13	3.13	4.16
MH-3418	5.79	4.76	14.99	14.90	5.23
MH-3479	4.73	3.70	0.53	0.52	3.82
MH-3495	4.83	3.80	0.71	0.69	4.05
MH-3562	4.82	3.79	2.06	2.02	4.19
MH-3577	4.81	3.78	2.87	2.83	3.95
MH-3615	7.00	5.97	5.19	5.13	6.12
MH-3671	5.76	4.73	19.04	18.81	5.20
MH-3681	5.25	4.22	30.72	30.41	4.86
MH-3709	5.92	4.89	4.39	4.22	5.01
MH-3730	4.89	3.86	1.93	1.93	4.05
MH-3745	5.76	4.73	26.08	25.71	5.38
MH-3756	5.24	4.21	1.61	1.53	4.30
MH-3771	4.81	3.78	0.30	0.30	3.93
MH-3778	5.28	4.25	4.18	4.09	4.43
MH-3785	6.18	5.15	0.70	0.67	5.19
MH-3329	4.88	3.86	13.27	13.26	4.27
MH-3359	5.10	4.08	3.18	3.12	4.17
MH-3366	4.90	3.88	5.25	5.18	4.27
MH-3371	5.61	4.59	1.91	1.87	4.65
MH-3391	5.24	4.22	0.36	0.35	4.30
MH-3397	5.15	4.13	22.55	22.46	4.45
MH-3401	4.69	3.67	8.63	8.48	3.92
MH-3474	4.84	3.82	1.76	1.71	4.19
MH-3527	4.93	3.91	8.10	7.96	4.28

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3624	4.77	3.75	1.76	1.69	3.85
MH-3701	4.87	3.85	13.59	13.44	4.26
MH-3704	5.98	4.96	2.55	2.45	5.08
MH-3705	4.70	3.68	6.47	6.47	3.88
MH-3711	4.85	3.83	13.87	13.72	4.25
MH-3330	4.88	3.87	13.48	13.21	4.27
MH-3353	4.70	3.69	5.52	5.49	3.93
MH-3374	4.75	3.74	3.78	3.76	3.94
MH-3392	5.23	4.22	0.72	0.70	4.30
MH-3468	7.39	6.38	3.13	3.11	6.50
MH-3490	5.98	4.97	22.46	22.35	5.38
MH-3491	5.28	4.27	14.91	14.82	4.71
MH-3493	5.15	4.14	22.55	22.31	4.48
MH-3517	4.68	3.67	6.81	6.73	3.87
MH-3581	5.99	4.98	2.02	1.91	5.09
MH-3608	5.11	4.10	2.39	2.31	4.42
MH-3631	4.79	3.78	0.14	0.14	3.81
MH-3657	6.02	5.01	19.73	19.58	5.41
MH-3725	4.80	3.79	0.41	0.39	3.85
MH-3768	5.32	4.31	5.03	4.92	4.48
MH-3333	5.11	4.11	3.44	3.38	4.31
MH-3334	5.11	4.11	4.60	4.53	4.31
MH-3338	4.92	3.92	7.02	6.99	4.28
MH-3345	5.02	4.02	6.49	6.41	4.29
MH-3346	5.02	4.02	6.64	6.62	4.29
MH-3355	5.00	4.00	7.89	7.71	4.37
MH-3356	5.00	4.00	6.90	6.71	4.37
MH-3367	4.88	3.88	0.34	0.33	4.27
MH-3369	5.09	4.09	2.91	2.88	4.20
MH-3375	4.75	3.75	3.35	3.30	3.94
MH-3378	6.94	5.94	8.46	8.35	6.10
MH-3383	4.98	3.98	6.73	6.68	4.19
MH-3384	4.98	3.98	6.82	6.80	4.19
MH-3395	5.91	4.91	3.50	3.49	5.17
MH-3396	5.91	4.91	5.01	4.96	5.16
MH-3407	4.75	3.75	12.61	12.53	4.22

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3409	4.67	3.67	2.72	2.68	3.92
MH-3419	5.76	4.76	16.77	16.66	5.23
MH-3424	4.76	3.76	3.66	3.61	4.04
MH-3427	4.81	3.81	2.61	2.60	4.24
MH-3432	4.65	3.65	13.60	13.40	3.87
MH-3439	5.13	4.13	1.01	1.01	4.28
MH-3441	5.86	4.86	20.45	20.18	5.41
MH-3458	5.79	4.79	13.95	13.84	5.23
MH-3459	5.00	4.00	0.56	0.55	4.18
MH-3460	5.01	4.01	0.25	0.25	4.18
MH-3461	6.24	5.24	0.25	0.24	5.26
MH-3462	6.24	5.24	0.10	0.10	5.26
MH-3463	5.73	4.73	0.94	0.94	4.78
MH-3465	4.94	3.94	1.03	1.02	4.26
MH-3469	7.39	6.39	2.18	2.18	6.51
MH-3470	5.09	4.09	5.43	5.32	4.30
MH-3471	5.92	4.92	23.86	23.70	5.30
MH-3472	5.92	4.92	24.18	24.10	5.28
MH-3482	5.08	4.08	3.27	3.27	4.18
MH-3483	4.71	3.71	0.07	0.07	3.82
MH-3484	4.85	3.85	0.24	0.24	4.06
MH-3489	5.98	4.98	21.33	21.14	5.39
MH-3492	5.28	4.28	14.59	14.51	4.72
MH-3510	4.71	3.71	2.05	2.01	3.82
MH-3512	5.20	4.20	0.89	0.88	4.32
MH-3514	5.42	4.42	0.58	0.58	4.50
MH-3516	5.64	4.64	0.39	0.39	4.69
MH-3522	5.33	4.33	6.64	6.44	4.49
MH-3528	5.02	4.02	0.71	0.68	4.28
MH-3536	4.81	3.81	0.14	0.14	4.05
MH-3537	4.71	3.71	0.45	0.43	3.82
MH-3551	5.07	4.07	0.08	0.08	4.24
MH-3570	4.99	3.99	0.31	0.31	4.31
MH-3582	5.99	4.99	1.24	1.19	5.09
MH-3584	5.24	4.24	1.31	1.31	4.32
MH-3588	4.75	3.75	0.89	0.87	3.93

Label	Elevation (Ground) (m)	Elevation (Invert) (m)	Flow (Total In) (m ³ /min)	Flow (Total Out) (m ³ /min)	Hydraulic Grade Line (Out) (m)
MH-3593	7.05	6.05	6.79	6.69	6.28
MH-3595	4.92	3.92	4.86	4.80	4.28
MH-3600	4.88	3.88	8.38	8.28	4.28
MH-3627	4.86	3.86	2.48	2.43	4.24
MH-3630	4.75	3.75	0.30	0.29	3.81
MH-3642	4.71	3.71	4.61	4.55	3.94
MH-3652	5.63	4.63	1.54	1.51	4.72
MH-3661	5.11	4.11	0.91	0.89	4.42
MH-3662	4.90	3.90	25.17	24.93	4.31
MH-3666	5.66	4.66	1.94	1.91	4.75
MH-3668	5.25	4.25	6.16	6.06	4.45
MH-3672	5.76	4.76	22.12	21.86	5.40
MH-3676	4.70	3.70	0.72	0.72	3.75
MH-3677	5.29	4.29	3.71	3.63	4.45
MH-3678	5.31	4.31	3.42	3.31	4.46
MH-3680	5.24	4.24	29.92	29.69	4.88
MH-3683	5.27	4.27	4.50	4.40	4.45
MH-3703	5.27	4.27	3.84	3.78	4.44
MH-3726	4.76	3.76	1.18	1.11	3.85
MH-3733	5.26	4.26	5.87	5.79	4.46
MH-3736	7.35	6.35	4.41	4.36	6.49
MH-3737	5.28	4.28	5.71	5.60	4.46
MH-3739	6.18	5.18	13.33	13.23	5.51
MH-3751	5.21	4.21	32.34	31.89	4.85
MH-3755	6.10	5.10	17.88	17.73	5.47
MH-3767	5.52	4.52	2.97	2.88	4.62
MH-3780	4.81	3.81	0.14	0.14	3.83
MH-3781	4.81	3.81	0.08	0.08	4.19
MH-3782	4.84	3.84	0.22	0.22	4.19
MH-3784	4.81	3.81	0.64	0.64	3.85
MH-3789	5.24	4.24	0.15	0.15	4.30
