# A Comprehensive Review of Stormwater Drainage Systems: Challenges, Innovations and Methods

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***Abstract:*** **Stormwater drainage systems are essential for managing runoff and preventing flooding in urban areas. This review focuses on challenges like Urbanization, maintenance requirements etc and explores innovative solutions for upgrading drainage networks. It highlights methods used for designing stormwater drainage systems.**

***Keywords*****: Rainfall-Runoff, SewerGEMS, Earth Pro, Maintenace of a drainage system.**

## I. INTRODUCTION

Urbanisation is taking place at a brisk pace in India. In the first decade of the 21st century, the number of towns increased from 5161(2001) to 7935(2011)[1]Similarly, most urban areas, be they large metropolises or small municipal towns, severely lack effective stormwater drainage facilities. In recent years, the frequency of urban flooding has increased and the issue is getting more pronounced day by day due to its enormous socio-environmental hazards.
Some notable cases of flooding that caused devastating impacts on economic loss, as well as the loss of lives, are urban flooding in Hyderabad (2001 and 2002), Delhi (2002,2003,2009, 2010 and 2011), Chennai(2004 and 2015), Mumbai (2005,2008, and 2009)[1]. The natural drainage systems in most of the cities are in jeopardy and the problem of flooding is worsening with time due to the non-availability of properly engineered stormwater drainage infrastructure.

Given the existing status of drainage systems in urban areas, that causes frequent flooding leading to loss of property and life. Therefore a good stormwater drainage should be designed as it controls stormwater runoff generated within the catchment area. The magnitude of peak flow that has to be accommodated will depend on reducing surface water saturating during rainfall that can damage structural foundations.

In cities, surfaces like roads, sidewalks, and rooftops block rainwater from soaking into the ground as it naturally would. Instead, this stormwater flows quickly into storm drains, gully networks, and drainage ditches, which can lead to problems like urban flooding. Stormwater management and green infrastructure focus on capturing and reusing stormwater to help restore or maintain natural water processes.

One way this is done is by using permeable surfaces, which allow rainwater to soak into the ground. Stormwater management also includes traditional "grey" infrastructure like culverts, storm sewers, and pipe networks. These systems are designed to mimic the natural water cycle, but when land is developed, that cycle gets disrupted. More paved or impervious surfaces mean more rainwater turns into runoff, which can carry pollutants like dust and debris. In areas with heavy development, up to 55% of rainfall can become runoff.

This review aims to provide a comprehensive overview of stormwater drainage systems,highlights there strengths, weaknesses and emerging trends.

## 2. LITERATURE SURVEY

Sundara Kumar Pitta and Tannru Venkata Praveen P. Manoj Srivatsav1, S V Sreekanth Reddy, M Anjaneya Prasad and T V Praveen [2] state that rainfall intensity and catchment area characteristics are the major factors in designing urban stormwater drainage facilities. The model utilises rainfall in developing a stormwater drainage system, which has about 20 years of data for the study. The methods used were runoff estimation, population forecasting, Incremental increase and Geometric increase and the velocity and area of the storm drain were determined using computed discharge. It also states that the drainage system is not completely underground sewerage leading to issues such as entry of matter into open drains, stagnation of sewage and deterioration of river water quality. Technologies for stormwater infiltration basins, trenches, soak-away pits, bioretention systems and porous pavement to improve stormwater quality and manage runoff.

Pooja N. Patel, Mr. Utkarsh Nigam, and Mr. N. N. Borad [3] explain that the design of urban stormwater drainage systems depends heavily on rainfall intensity and the characteristics of the catchment area. One of the main issues leading to severe flooding is the poor drainage system in place. In some areas, the lack of a proper drainage network leads to the uncontrolled release of wastewater into water bodies. The study used 34 years of rainfall data and applied the rational method, a commonly used technique for estimating stormwater runoff. The primary reason for flooding in the study area was the blockage of drains, making regular maintenance critical. In the Navrangpura area, the rational method was effectively used to estimate storm discharge and tools like remote sensing and GIS were also suggested for planning stormwater management.

Sanjana Londhe, Shilpa S. Kasulla, and Dr. Seema Jagtap [4] discuss urban floods, which happen in cities when heavy rainfall exceeds the capacity of drainage systems. Urban flooding can cause serious problems, including loss of life and property, disruption of transportation and power supplies, the spread of diseases during monsoon seasons, and significant economic and infrastructure damage. The study highlights poor planning and the neglect of environmental and geographical factors as major causes of flooding in the Vasai-Virar area, where rapid urbanization has made the issue worse. One of the key challenges is that the existing drainage system functions as a combined sewer and stormwater system, which makes things difficult for municipal engineers. Drainage channels that carry water from higher elevations to the sea often get blocked by construction, and since these channels are not marked on development plans, managing stormwater becomes even more complicated. The paper emphasizes the importance of properly designing drainage systems to address these issues.

Shuchi Mishra and Gaurav Tanwer [5] present a new design for an urban stormwater drainage system in their paper. They created a detailed project report to provide a practical plan for implementing the drainage scheme. The current drainage system is in poor condition, with many parts in need of repair and others encroached upon, so a major overhaul is necessary. The plan involves upgrading all existing kuccha (temporary) open drains into both permanent open and closed drains. To estimate stormwater runoff, they applied the rational method, analyzing rainfall intensity data over 47 years. They also developed intensity-duration-frequency (IDF) curves for rainfall events occurring once and twice a year. For a more sustainable approach, they suggest adopting innovative methods to reduce runoff at the source, such as green roofs, wetlands, detention ponds, and soakaways. The paper emphasizes that, along with a strong drainage system, regular maintenance is essential for keeping it functional.

Subrata Bhattacharjee [6] The paper speaks about a city experiencing rapid urbanisation led to inadequate stormwater drainage systems and flooding issues, particularly high intensive rainfall. The existing stormwater and sewerage systems are not segregated hence causing complications. Low land levels in certain areas such as Saat Rasta, Lower Parel, and Grant Road face flooding during high tide and heavy rainfall. The innovative measures mentioned were developing holding spaces and modifying design criteria for the stormwater network to accommodate rainfall intensity higher than 50 mm per hour. Increasing the capacity of drains by deepening, widening and replacing them with larger pipes and conduits. To do a comprehensive study of BRIMSTOWARD to address larger issues of climate change and urban development and consider heavy rainfall events. The adequate spread of hydro-meteorological observation stations to improve monitoring and planning.

P. Raji, E. Uma and J. Shyla[7] speak about the conservation of natural water resources as necessary to eliminate problems like droughts or water scarcity and rainwater harvesting can meet such demands. An area where runoff occurred during the rainy season was selected and a study was done to analyze rainfall-runoff characteristics. It was measured using a rectangular notch and the relation between the discharge head was calculated. It has been observed that the water table level has been increased by constructing rainwater recharge structures using rainfall-runoff analysis in the particular area where this study was conducted. Based on the maximum intensity-duration relationship and representative unit hydrograph, any water harvesting structure can be designed in that area and also reduction in soil erosion can be seen respectively.

T. Siva Subramanian, Tharini Cheyapalan, T. Selvaraj and Dr V. E. Nehaji Mariappan[8] focused on a study that has been done in Chennai which encompasses a

metropolitan area. The service life of urban infrastructure is influenced by the urban stormwater and in order to design new urban stormwater drainage facilities, the rainfall intensity and catchment area characteristics play an important role in it. The innovative measures that were taken were the use of a topographic map, satellite imagery and GPS data to integrate the roads and urban stormwater drainage infrastructure also by using an intensive GPS, altitudes of all the drains and information of geographic coordinates have been obtained.

Some additional information was noted down on the field itself such as length breath and width and then cross-checked with the data obtained in CoC. The challenge this study encloses is the mismatch of road length with drain length which could possibly result in the dampening of water in the rainy season it also suggests that the stormwater drain gaps should be filled before the next rainy season.

Supiah Shamsudin, M.Sc.,Normala Hashim,M.sc.,[9] The study focuses on estimating rainfall runoff using the MIKE 11 NAM model. The model was calibrated for achieving peak flow and efficiency index and root mean square error. It emphasizes the importance of accurate rainfall runoff estimating for water resources planning, flood forecasting, and pollution control. The calibration faced challenges such as data acquisition issues, uneven rainfall distribution, and unexpected floods, which resulted in missing data. This model effectively simulated peak flow discharges and highlighted the need for more automatic rainfall stations in the Layang watershed to enhance runoff estimations.

The methods mentioned are
1. MIKE 11 NAM model which was used for estimating rainfall runoff discharge.
2. The Efficiency Index was used to assess the model's reliability indicating perfect performance.
3. Root mean square Error (RMSE) was applied to evaluate the reliability of the MIKE11 model measuring error between computed and observed flows.
4. Double mass curve method employed to test the reliability of rainfall data.
5. Adjustments Procedures included interpolation and method of proportion in rainfall-runoff relationship.

Ismail Fathy, Gamal M. Abdel-Aal, Maha Rashad Fahmy, Amira Fathy, and Martina Zelenakova [10] highlight that stormwater drainage systems help remove excess water from roads caused by heavy rainfall, preventing disruptions to daily activities in urban areas. However, one of the main challenges is ensuring timely maintenance, as blockages in the pipes can significantly reduce the network's efficiency. Their experimental study focused on a stormwater network system and how well it handled discharge. They found that as blockages in the grates increased, the efficiency of the system decreased. They also developed an equation to estimate the system's efficiency under varying conditions.

Yogesh Chintanwar, Pranay Burde, Pranakshu Lanjewar, Suarabh Sukhadeve, Sarvesh Akanpalliwar, Shubham Gadap, and Anurag Parkhi [11] focus on addressing the waterlogging problem at the Mominpura underpass in Nagpur, which causes traffic disruptions and promotes the spread of diseases. Their proposed solutions include enhancing the drainage system, incorporating cleaning mechanisms, installing an underground storage tank, and using an efficient pumping system. The design process was guided by soil testing to ensure appropriate measures were taken. They also utilized tools like Google Earth and AutoCAD for topographical analysis and design, along with studying rainfall patterns. The paper concludes that implementing these measures could reduce waterlogging by 70% to 80%, and it stresses the importance of regular maintenance of storm drains to maintain effectiveness.

Anushree A. Chandragade and Rajesh Gupta's [12] study introduces a new approach for estimating peak flows in sewer networks, particularly focusing on Gadchiroli City, India. The study considers the Central Public Health and Environmental Engineering Organization's (CPHEEO) peak factor recommendations and applies them node-wise, depending on the population contributing to each node. This method improves the continuity of flow throughout the sewer network. They address flow imbalances caused by the current peak factor (PF) guidelines, which often lead to sudden reductions in PF. To overcome this, multiple design iterations may be necessary to resolve constraints and find feasible solutions. Key innovations include applying peak factors on a node-wise basis and using higher PFs for smaller populations to prevent steep sewer gradients. Their methodology uses design criteria that span 30 years for sewer networks and 15 years for pumping machinery. They calculate sewage flow as 80% of the water supply, with an additional 10% accounting for groundwater infiltration. The study also employs

Manning's formula for velocity and recommends a minimum sewer diameter of 150 mm for RCC sewers. They divide the sewer system into two zones, each served by its own treatment plant, with further subdivisions for design purposes.

Shushma R, Rajeshwari K, and Lakshmi C [13] explore the design of a stormwater drainage network for the ITPL road in Mahadevapura, Bangalore, using SewerGEMS V8i software. The study aims to tackle urban flooding, especially during the monsoon season, by designing an efficient stormwater system. Key challenges identified include the increased use of impervious surfaces, which reduces the soil's natural ability to absorb water, and poor drainage design, which results in 85% of runoff water being wasted. This poor management of stormwater not only damages roads and infrastructure but also creates public health risks, such as waterlogging and hazards like hydroplaning. The study's innovative measures include using SewerGEMS V8i for design and incorporating an integrated road drainage system. They used Civil 3D software for topographical analysis to identify areas where water runoff is collected. The design factors include rainfall intensity, pipe slopes, and pipe sizing, all geared to prevent issues like water hammering while ensuring efficient self-cleaning. The system was tested for different return periods to ensure it could manage expected stormwater loads without flooding.

Kashev Basnet and Manoj Neupane [14] observed that in urban areas like Lamachaur, Pokhara, and Nepal, roads frequently turn into streams during the rainy season due to inadequate stormwater drainage. Urbanization and migration have increased runoff, adding pressure to roadside drains. These catchments respond quickly to rainfall, leading to overflows that can damage property and even threaten lives. To address these issues, their study conducted a hydrological analysis to improve stormwater management, focusing on the Lamachaur area. Using rainfall data from the past 15 years, they found that the daily data was insufficient for accurate drainage design, so they constructed a rain gauge to collect real-time precipitation data. By comparing the rainfall from their gauge with data from a meteorological station, they ensured accuracy. Using the rational method and Manning's equation, they calculated surface discharge and determined the required size of roadside drains. A comparison with the existing drainage system revealed inadequacies, highlighting the need for an upgrade to solve overflow problems in the area.

## 3. CHALLENGES IN DESIGNING STORMWATER DRAINAGE SYSTEMS.

One of the biggest challenges is urbanization as increased impervious surface in urban areas reduces the land's ability to absorb rainwater. Climate change also affects stormwater drainage networks changing rainfall patterns significantly. Many stormwater drainage systems are ageing and in need of repair or replacement, leading to reduced capacity and increased risk of failure. Improper stormwater drainage systems can lead to flooding, property damage and risk to public health and safety. Stormwater runoff can carry pollutants in water to harm aquatic ecosystems.

## 4. INNOVATION IN DESIGNING STORMWATER DRAINAGE SYSTEMS.

Google Earth Pro to measure the area, elevation, and slope of the study area which is used to approach data collection. Many models are used to measure rainfall runoff like MIKE11 NAM. The use of topography maps, satellite and GIS data to integrate roads and stormwater drainage. The sewerGEMS software is used for the optimization of a stormwater drainage system which can help to reduce construction costs and meet hydraulic design requirements and Civil 3D is used to find high and low points where water runoff is collected. Advanced technologies like sensors, data analytics and real-time monitoring to optimize stormwater drainage system performance.

## 5. METHODS IN DESIGNING STORMWATER DRAINAGE SYSTEMS

Designing a stormwater drainage system involves key methods to manage urban flooding. The rainfall intensity and catchment area are analyzed to estimate runoff with the rational method and Manning's equation helps to determine velocity and drain size. It also highlights the importance of using GIS and satellite imagery to map drainage networks and hydrological analysis for accurate design in rapid response catchment. Drainage like infiltration basins, soak-away pits and porous pavement to reduce runoff and also regular maintenance, cleaning and upgrading of the drainage system are important to prevent blockages and inefficiencies.

## 6. CONCLUSION

Designing an effective stormwater drainage system

requires careful considerations like rainfall patterns, catchment characteristics and runoff estimation, by using Mannig's equation for velocity and pipe sizing. Ensuring efficient water through the system and using GIS and topography data helps with precise design. Regular maintenance and timely upgrades are crucial to avoid blockages and ensure long-term system reliability in urban areas.

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