

Urban Hydrology and Storm-water Management for Smart Cities

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Abstract— This study explores the complex interplay among urban growth and the field of hydrology with a special emphasis on storm-water control techniques. The hydrodynamic patterns in our cities have been drastically altered by urbanization, creating enormous barriers to the management of water resources sustainably. In this paper we examine the effects of urbanization on hydrological processes in urban settings using a thorough examination of the literature, observations in the field, and hydrodynamic modelling. We investigate several storm-water management methods, including conventional infrastructure and cutting-edge green alternatives, and evaluate how well they reduce the discharge from cities and improve water quality.

Keywords— runoff; infiltration; permeable pavements

I. INTRODUCTION

A. Background

Urban hydrology and storm water management are critical aspects of urban planning and environmental sustainability.[1] This field mainly focuses on the management of water in urban areas. People in urban areas are facing problems during monsoon season due to continuous heavy rainfalls the storm-water starts draining from the roads because there is no other option to stop this water from draining from roads because there is no open land in which the stormwater can seep into the ground [2]. Approximately more than 95% of lands are covered by buildings and roads in urban areas so the storm-water starts draining and also causes floods and few disasters and this may also affect the transportation facility as we can see in few news channels stating that roads are blocked due to heavy rainfalls in which this results in forming cracks on roads due to high pressure of storm-flow [3].

Natural hydrological systems have been disturbed by urbanization, which is characterized by an increase in permeable surfaces as well as altered runoff patterns, causing flash floods, a decline in water quality, and ecological devastation[4].

B. Related Work

Over the last few decades, our government is taking few steps to resolve these issues in urban areas and to prevent this major cause by establishing some new projects like

1. National Urban Sanitation Policy (NUSP)

2. Atal Mission for Rejuvenation and Urban Transformation (AMRUT):

The main of this project is to ensure a proper supply of water and a sewage connection in every household. To develop green and well-maintained open spaces and parks to increase the pleasantness value of the cities.

3. Jal Shakti Abhiyan:

This project focuses on water conservation and rainwater harvesting. By digging pits so that infiltration process takes place. Renovation of traditional and other water tanks

4. National River Conservation Plan (NRCP):

The main objective of this project is to improve the quality of water of rivers which are the major source of fresh water in country, though, the implementation of diminishing works such as setting up sewage treatment plants.

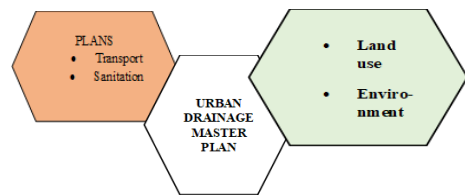


Fig. 1. Urban master plan in smart cities

We discover best practices and lessons gained regarding environmentally friendly urban water management by looking at real-life examples of effective storm-water management issues is further highlighted by this research, which emphasizes the value of cross-disciplinary cooperation amongst urban designers, technologists, scientists studying the environment, and policymakers, Fig. 1. Understanding and minimizing the effects of urbanization on hydrology and developing resilient storm-water management systems are essential for the welfare of urban residents as well as the environment as urban populations continue to rise.

C. Contributions

One significant contribution in storm-water management and urban hydrology is the adoption of Sustainable Urban Drainage Systems (SUDS). SUDS are creative, environmentally friendly methods for controlling storm-water in cities. Rather than quickly diverting rainfall away through traditional drainage systems, they capture, process, and integrate it into the ground in an effort to replicate natural water processes.

D. Structure

The paper is organized as follows. Section II describes the overall structure of our proposed Urban Hydrology, tools and factors affecting urban runoff. Section III explains Urbanisation and its impact on hydrology. Section IV describes the feature-extraction algorithm. Section V describes the importance of storm-water techniques in urban areas, in Section VI. A case study is discussed and Conclusions are drawn in Section VII.

II. URBAN HYDROLOGY

The field "urban hydrology" is dedicated to the study of water in urban settings. Analysis of the motion, distribution, quality, and management of water within urban environments is part of this field. [5] [12]

A. Models and tools used for hydrological analysis and simulation, Fig. 2.

1. Hydrologic Modelling System - Hydrologic Engineering Unit (HEC-HMS):

It is capable of simulating streamflow, runoff, infiltration, and precipitation.

2. SWAT (Soil and Water Assessment Tool):

This model simulates how climate change, land use, and management techniques affect the quality of water in a watershed.

3. HYDRUS:

This specialized model is used to simulate the movement of solutes, heat, and water in the zone of vadose (unsaturated soil). Incorporate models involving root water uptake that stimulate the relationship between vegetation and watershed.

4. FLO-2D:

This flood modelling programme simulates the processes of rainfall and runoff, such as channel and in-depth simulations that are required to develop efficient flood mitigation and handling plans, FLO-2D is a successful instrument for flood forecasting and risk evaluation.

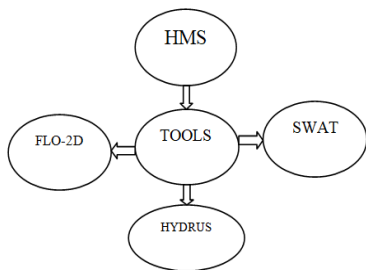


Fig. 2. Tools used to check Urban Hydrology

B. factors affecting urban runoff, Fig. 3.

It has a substantial impact on urban hydrology. How urban runoff affects urban hydrology is shown here.

Lowered Groundwater Recharge: In cities, impermeable surfaces limit the quantity of water that can seep in and replenish groundwater reserves [13]. This may result in dropping groundwater levels, which could have long-term effects on ecosystem health and the availability of water.

1. Impervious surfaces

Water cannot seep into the earth through impermeable surfaces like parking lots, sidewalks, rooftops, and highways. Rather, precipitation flows down these surfaces and enters storm-water drainage networks.

2. Land use

Urban hydrology can be improved by land use that includes parks, gardens, green spaces, and vegetated areas. Because

of the increased rainwater infiltration made possible by these green areas, runoff reduces and the urban heat island effect is lessened.

3. Precipitation patterns

The patterns of precipitation are essential in determining the urban hydrology. The distribution, timing, and intensity of precipitation events have a significant impact on water supplies, urban infrastructure, and the flow of water through metropolitan areas. [3]

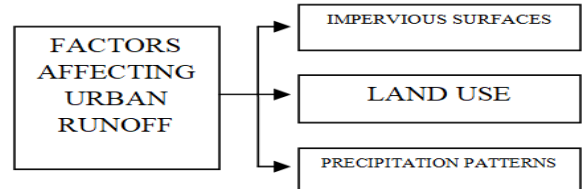


Fig. 3. Factors affecting urban runoff

TABLE I. BENEFITS AND LIMITATIONS OF STORMWATER TECHNIQUES

STORM-WATER TECHNIQUES	BENEFITS	LIMITATIONS
DETENTION BASIN	1. Inexpensive 2. Take up less space 3. Often completely dry between storms	-
PERMEABLE PAVEMENT	1. Permeable pavement doesn't produce a 'heat island' (Hopton, M. E. 2017) 2. It can be made using recycled materials 3. there won't be any iceformation on it	1. It is more expensive to install as compared to traditional pavements. 2. The maintenance requirements of permeable pavement are quite different.
GREEN INFRASTRUCTURE	1. It is more expensive to install as compared to traditional pavements. 2. The maintenance requirements of permeable pavement are quite different.	1. Only manage small amounts of rainfall (D. F. 1982)

C. quantitative analysis of hydrological parameters and characteristics

The following important hydrological parameters and traits are frequently examined quantitatively:

- Precipitation
- Evapo-transpiration

III. URBANISATION AND ITS IMPACT ON HYDROLOGY

Urbanization significantly alters the transport of pollutants and consequently has a degrading impact on urban stream biota. [14]

A. IMPACTS

In urban areas, water cycle problems include:

Pollution

Waterway flushing Flooding

Decreased soil moisture

IV. STORM-WATER TECHNIQUES IMPORTANCE IN URBAN AREAS

Storm-water management means to manage surface runoff, Fig. 4, Table 1.

1. DETENTION BASIN

A detention basin, also known as a detention pond, holds excess water generated by storms to prevent flooding. The detention basin gradually dries out following the storm.

2. PERMEABLE PAVEMENT

Permeable pavement is a pavement type with a porous surface that is composed of concrete permeable pavement types include:

- a. Traditional Concrete/Asphalt:
- b. Plastic Pavers
- c. Concrete Pavers

3. GREEN INFRASTRUCTURE

"Green Infrastructure" refers to storm-water management techniques that modify the characteristics of the flow into separate or combined sanitary or storm sewers, or that lower the volume and flow of wet weather/storm-water. [9] [10]

Green Infrastructure includes:

- Simple disconnection
- Pervious pavements
- Bio-retention systems/rain gardens
- Downspout planter boxes
- Rainwater harvesting systems
- Bioswales

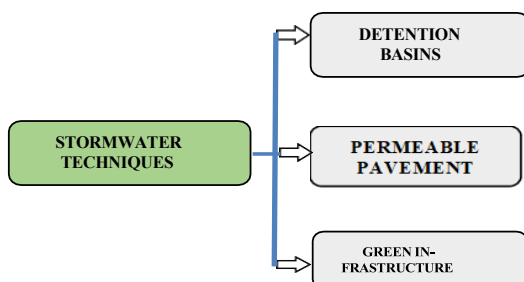


Fig. 4. Storm-water techniques

V. CASE STUDY

Tamil Nadu: Chennai Floods (2015) and Subsequent Planning for Urban Hydrology and Storm-water Management. Background:

The floods were caused by an unusually heavy and prolonged monsoon season, and they revealed significant deficiencies in Chennai's storm-water drainage and flood management systems. [15]

Challenges:

The Chennai floods of 2015 exposed several critical challenges related to urban hydrology and storm-water management:

1. Outdated Infrastructure:
2. Urban Expansion:
3. Poor Maintenance:

Response and Actions:

1. Restoration of Water Bodies
2. Flood Warning System
3. Construction of Retention Ponds

Outcomes:

The post-2015 flood initiatives had several positive outcomes:

1. Reduced Flooding
2. Enhanced Resilience
3. Improved Water Quality
4. Sustainable Urban Planning

While challenges remain, the proactive measures taken in response to the disaster have made Chennai more prepared for extreme weather events and have improved the overall quality of life for its residents.

VI. CONCLUSION

To sum up, storm-water and urban hydrology are essential components of sustainable urban development in the twenty-first century. Effective storm-water management is essential as the globe grows more urbanized and faces problems from climate change, fast urbanization, and environmental degradation. Furthermore, by recycling and reusing storm-water, this field encourages the prudent use of water resources, which not only eases the burden on portable water supplies but also advances long-term water to overcome these issues, it will be crucial to have strong legislative frameworks, creative technologies.

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