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A Review of Runoff Strategies in Developed and Developing Countries: Using Polymer Materials for Stormwater Management

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Abstract

Urban hydrology is essential to the system used to manage urban runoff. Stormwater drainage in metropolitan areas has become a problem as a result of rapid urbanization, the depletion of vegetation, deteriorating drainage infrastructure, and climate change. The natural hydrological cycle is impacted by urbanization by raising peak flows and reducing lag times. Urban areas experience more floods as a result, while the environment suffers as a result of accelerated erosion and increased pollutants. To regulate surface runoff is to manage stormwater. It can be used in rural regions (for example, to collect rainwater), but it is crucial in cities where runoff cannot permeate due to impermeable surfaces. The major goal of conventional stormwater management is to drain away high peak flows. This paper is intended to give an overview of the studies and initiatives about environmentally friendly stormwater management strategies that have been carried out in both developed and developing countries for managing runoff in urban areas. This paper examines the utilization of polymer materials in developed and developing countries to solve runoff difficulties. It provides a comprehensive overview of the advantages, applications, and influence of these composites on sustainable water management methods. This study highlighted the various methods for managing urban stormwater in some regions as LID, BMP, SUDS, and WSUD. Furthermore, it examines the areas in South Delhi, India that are prone to waterlogging, emphasizing the need for sustainable stormwater management practices in this specific location.

Keywords: Urban water, polymer materials, urban drainage, runoff strategies, sustainable urban drainage system (SUDS)

INTRODUCTION

The global and national water crises have made government agencies everywhere realize that they are going to face major water crises shortly. Water has an impact on many dimensions of society’s growth and development which is connected to clean water and sanitation, and life on land sustainable development goals. (Source: sdgs.un.org) Population growth and economies depend on groundwater, which represents 97% of the world's freshwater resources, yet its degradation is more extensive and hazardous than thought previously, it promotes economic expansion and protects health.

Due to their durability, adaptability, and efficacy, polymer composites are important in modern runoff management. This section describes how polymer composites are used in developed and developing countries to handle runoff issues, including their benefits, applications, and effects on sustainable water management ecosystems, and is vital to life

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itself [1-3]. The World Bank estimates that 2.2 billion people lack access to managed drinking water services, 4.2 billion individuals do not have access to properly managed sanitation facilities, while 3 billion do not access basic hand washing services. According to IPCC climate variability and projected changes in the environment would cause more periodic hydrology extremes, deglaciation, and rise in sea level. Now it's become more important globally how they can overcome this water crisis by using different practices for sustainable stormwater management. The objective of this study is to investigate sustainable techniques that are used for the control of excessive runoff in both developed and developing nations. Rain gardens are one way to reduce the amount of microplastics in the environment.

These landscapes, which are also called bioretention cells, are constructed in a depression using native plants, engineered soil, organic materials, and mulch, among other things.

Climate change and urbanization are causing increased stress on nature, particularly urban stormwater runoff, prompting numerous countries to propose effective urban stormwater management strategies [4-6]. In urban and suburban regions, pavement and buildings cover a large portion of the land's surface, preventing rain and snowmelt from penetrating the soil [7]. Instead, the majority of built-up regions depend on storm drains to transport a lot of rainwater from roofs and paved surfaces to neighboring waterways [8]. Urban water system sustainability has received more attention in recent years, not only from an environmental perspective as well as in terms of its broad societal and economic implications. Managing stormwater was the primary focus in developed nations, stormwater control needs to be part of planning for water in cities [9-11].

Various soil types interact with water and other substances determined by their chemical properties; this interaction influences the quality and quantity of discharge. Runoff and soil chemistry interact in the following ways: Soil chemistry impacts the accessibility of essential nutrients, including potassium, phosphorus, and nitrogen. High nutrient content in soils, especially from fertilizers, can contribute to water quality problems such as eutrophication in bodies of water through nutrient-rich discharge. Due to poor nutrient retention, nutrient leaching into discharge may occur in soil types with low cation exchange capacity (CEC), such as sandy soils. Runoff from soils rich in trace elements or heavy metals can impair aquatic life and water quality. Due to increased organic matter or clay content, buffering soils can resist pH or nutrient fluctuations. This moderates runoff chemistry and reduces its effects.

Urbanization and Its Impact on Sustainable Stormwater Management

Reduced penetration capacity of watershed surfaces as a result of increasing impermeable surfaces and soil compaction, which diminishes the soil's ability to absorb water. Decreased surface storage space as a result of urban surfaces becoming "smoother" than natural ones. Lower evapotranspiration due to soil loss, reduced vegetation wetness, and plant interception. Lower impermeable portions and larger depression storage imply runoff volumes and peak discharges are not necessarily as high as expected in catchments with similar population concentrations in developed countries(Figure.1) [12].

LITERATURE REVIEW

This review Table 1 identifies different types of stormwater management strategies that are used in both developed and developing countries for managing excess amounts of rainwater in urban areas through infiltration and groundwater recharge techniques.

Stormwater Management in Developing Countries

Due to rapid urbanization rainwater infiltration and groundwater recharge have reduced. Recharging groundwater and rainwater harvesting are emphasized in different countries. Urban groundwater recharge differs from rural recharge. In addition to natural recharge from precipitation, urban groundwater recharge requires consideration of new components [13-14]. This study examines the obstacles to SUSM, (Sustainable Urban Stormwater Management) adaptation in Brazil, a developing nation with harsh urban stormwater management issues [15].

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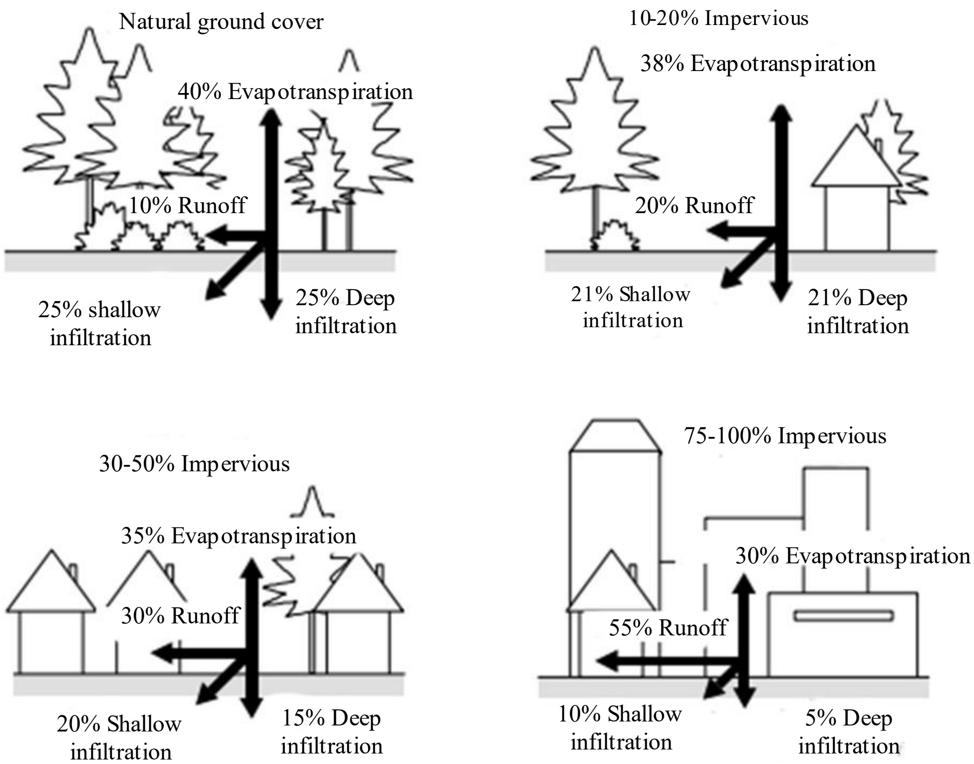

Figure 1. Shows the different percentages of impervious material in urban and suburban areas.
(Source: Adapted from Amold and Gibbons,1996, Lensa Jotte Et Al. 2017.[12]

Ireland

Ireland's typical SUDS include filter drains, infiltration trenches, and permeable pavement(Figure.2) Infiltration basins, wetlands, retention ponds, and swale treatment systems use site control [16-17].

Figure 2. Ireland's SUDS. Photo: Transport Infrastructure Ireland
(Source: Lensa Jotte et al. 2017) [16]

Norway

Runoff is treated in sedimentation ponds in Norway. Pre-sedimentation and permanent water main ponds are sedimentation ponds (Figure.3) The Norwegian Road Administration is studying ditch filter materials for pretreatment or full treatment. Wetlands, infiltrating ponds, and ditches are utilized [16].

Several municipalities have adopted sustainable stormwater management strategies, which are supported by different state and federal agencies. An author review of the integrated urban stormwater management (USWM). Several factors influencing integrated USWM are discussed, including climate change, water quality, reuse, and treatment of USW [18].

Figure 3. A norwegian sedimentation pond with a forebay and a main Pond.(Photo: Sondre Meland, *Source:Lensa Jotte Et Al. 2017) [16]*

Table 1. A Literature Review Concerning Integrated Stormwater Management Strategies.

References	Year	Main Aspect	Other Aspect	Application	Finding
Ganbaatar Khurelbaatar et al.	2021	LID	The urban stormwater management	MUST-B Method used	Effectively handle and control the volume and flow of stormwater within an urban environment.
Swatantra Kumar Dubey et al.	2020	Hydrology	Climate change	SWAT	Strategies for integrating stormwater concerns into planning.
Ireneusz Nowogoński	2020	Low Impact Development		SWMM	LID techniques used for imperviousness
Wenbin Zang et al.	2020	LID	Empirical study for urban planning to minimize flood effect.	SWMM or SWAT	Evaluation of Stormwater Management for Runoff Volume Control
Desmond O. Anim	2019	SCM application	Intensive implementation of SCMs	2D Hydraulic Model	The benefit of stormwater control measures
Wenbin Zang	2019	Hydrology	Landuse	SWAT	The study examines the daily flood peak and annual runoff patterns.
Melika Mani et al.	2019	Stream Hydraulic	Flood Mitigation	SWMM, MOALOA	LID Stormwater control measures
Jason Motsinger	2016	Best management practice	Water Quality	SWAT MODEL	Impact of Various BMP Implementation
Chew-Hung Chang	2014	LID	Rainfall Extreme		Flood and Drought
Allison H. Roy	2008	LID, WSUD	Watershed-ScaleUrban Stormwater Management	SWMM	Impediments and Solutions to Sustainable Stormwater Management
Rebekah R. Brown	2007	BMP		SUWM	Sustainable Urban Water Futures

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STORMWATER MANAGEMENT IN DEVELOPED COUNTRIES

The majority of recent stormwater management practices in the United States and Australia rely on traditional storm sewers that offer limited detention or retention basin treatment [19-20]. SUDS control runoff techniques were reviewed by the author in North Carolina such as green roofs, swale, Soak away, Filter/buffer strips, infiltration basins, Retention (wet) ponds [21] (Figure4-5).

Figure 4. Two bioretention cells in North Carolina: an ultra-urban applicable cell in Charlotte, NC [21]

Figure 5. A grassed cell on the campus of North Carolina State University in Raleigh, NC [21].

This research reviews sustainable stormwater management in different European countries. Therefore, sustainable (urban) drainage systems (SUDS), low-impact development (LID), water-sensitive urban design (WSUD), and best management practices (BMPs) have been created to manage excess runoff in urban areas [22].

This study aims to look into the idea of bioswales and suggest possible places in a residential area of the City of Niš where they could be used. This research aims to promote bioswales in urban planning theory and practice. The author discussed the concept, design, and importance of bioswale with examples in Canada and the USA [23]. Multiple factors have slowed the adoption of WSUD in the US and Australia. This study compares Australia and the US, two developed nations with conventional stormwater infrastructure and degrading stream ecosystems [24] to identify governance factors of sustainable stormwater management and provide examples of successful regional implementation in China and Sweden [25].

DATA COLLECTION AND INTERPRETATION

This research examines the utilization of stormwater best management strategies that employ natural processes to enhance water quality and augment the volume of infiltration [26-27]. Fig 6 shows the various types of practices or strategies that are used in different countries or cities to manage the excess runoff such as:

- LID (Low Impact Development)
- BMP (Best management practice)
- SUDS (Sustainable Urban Drainage System)
- WSUD (Water Sensitive Urban Design)
- SCP (Sponge City Program)

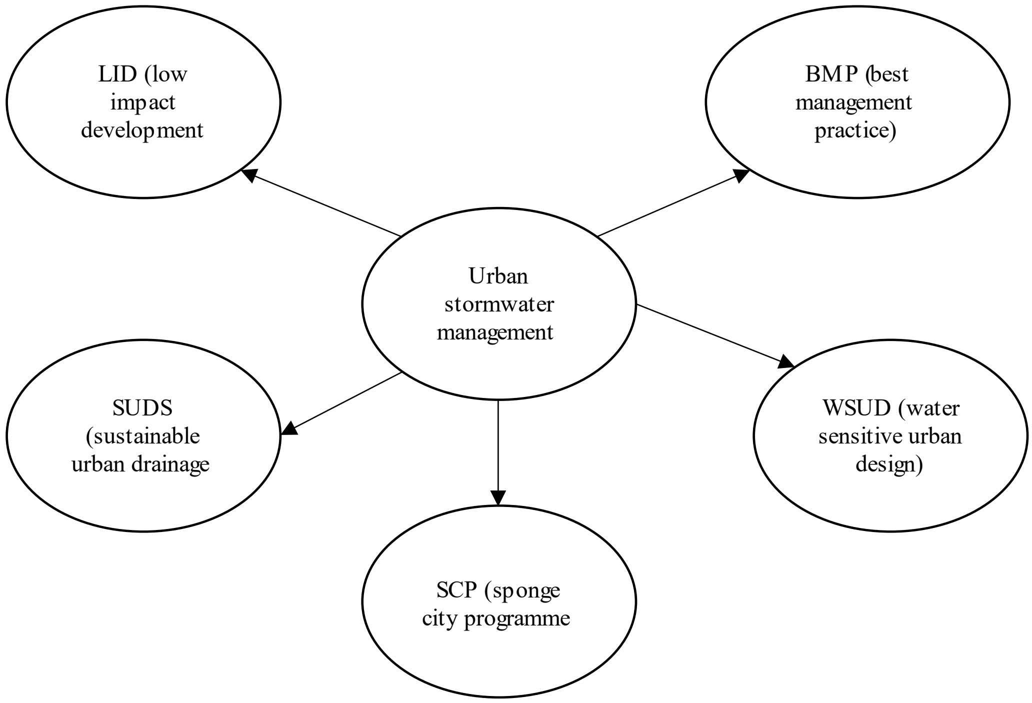

Figure 6. Graphical abstract of urban stormwater management.
(*Source: Lakshmi Raghu Nagendra Prasad Rentachintala et al. 2022)*

Stormwater management systems can be used in addition to removing unwanted water from cities; they can also be an important part of the beautification of structures and roadways [28]. SUDS, WSUD, and LID have similar objectives, such as sustainable management of municipal water, preservation of natural-like flow conditions, maintenance of water quality and receiving waters, and overall conservation of water resources [29-30]. Many studies discuss that Best Management Practices (BMPs) are commonly used to manage flood runoff, Low Impact Development (LID) offers a decentralized approach to mimic natural flow by controlling stormwater runoff at the source, rather than centralized locations in the watershed [31-37].

In this research paper water logging areas study is performed in India’s capital Delhi and the data collected from Delhi traffic police department. On August 30, 2016, the capital city saw a significant rainfall event, getting a total of 63 mm of precipitation over three hours. August 2019 rains in Delhi caused commuters to struggle through knee-deep water and flooded automobiles and buses, worsening traffic in the 20-million-person city. And this year 08-09 July 2023, Delhi received 126.1 mm of rainfall since 2003. This intense rainfall resulted in an emergence of severe flooding on the city's roadways. Source: Delhi traffic police, 8 July 2023.

In July 2023, waterlogging was seen including Max Hospital Press Enclave Road. Sun Dial Park Ring Road, Under AIIMS Flyover, Sangam Vihar, Qutub Minar Anuvrat Marg, Okhla Underpass and Sarita Vihar Chowk. According to Delhi Traffic Police data, the water-logging locations are mentioned in Table 2, which creates urban flooding in South Delhi.

In this paper GIS, and field survey techniques used to identify and forecast urban areas that are flood prone. GIS is a cost-effective tool for comprehending the movement and management of groundwater. This GIS Map Figure.7 is showing the water logging points in South Delhi.

MATERIAL AND METHOD

This review paper uses a keyword-based search through Google Scholar, Science Direct, MDPI, and Research Gate database approach to explore stormwater management, rainwater harvesting, rainfall

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frequency, Climate changes, and urban flooding in developed and developing countries using various databases. The 36 papers that met these screening requirements were chosen for study. This study aims to find out the peak runoff at the selected site Max Hospital, Press Enclave Road, South Delhi. For example, the maximum rainfall is 124 mm/hr on 24 July. (Source: NASA). Figure. 8 shows the rainfall pattern of year 2023 at Max Hospital, Press Enclave Road, South Delhi.

Table 2. Different places of water logging area of South Delhi

S. no	Location	Circle
1.	Max Hospital	Press Enclave Road- Saket
2.	Sun Dial Park, Ring Road	Lajpat Nagar
3.	Under AIIMS flyover, Aurobindo Marg Defence Colony	Saket
4.	Qutub Minar, Anuvrat Marg	Mehrauli
5.	Okhla Underpass	Sarita Vihar
6.	Sarita Vihar Chowk	Sarita Vihar
7.	Pul Prahladpur	Badarpur
8.	Aurobindo Marg Near IIT Flyover	Hauz Khas
9.	MB Road Sangam Vihar	Sangam Vihar
10.	Ambedkar Nagar Depot	Sangam Vihar

(Source: Delhi traffic police,8 July 2023)

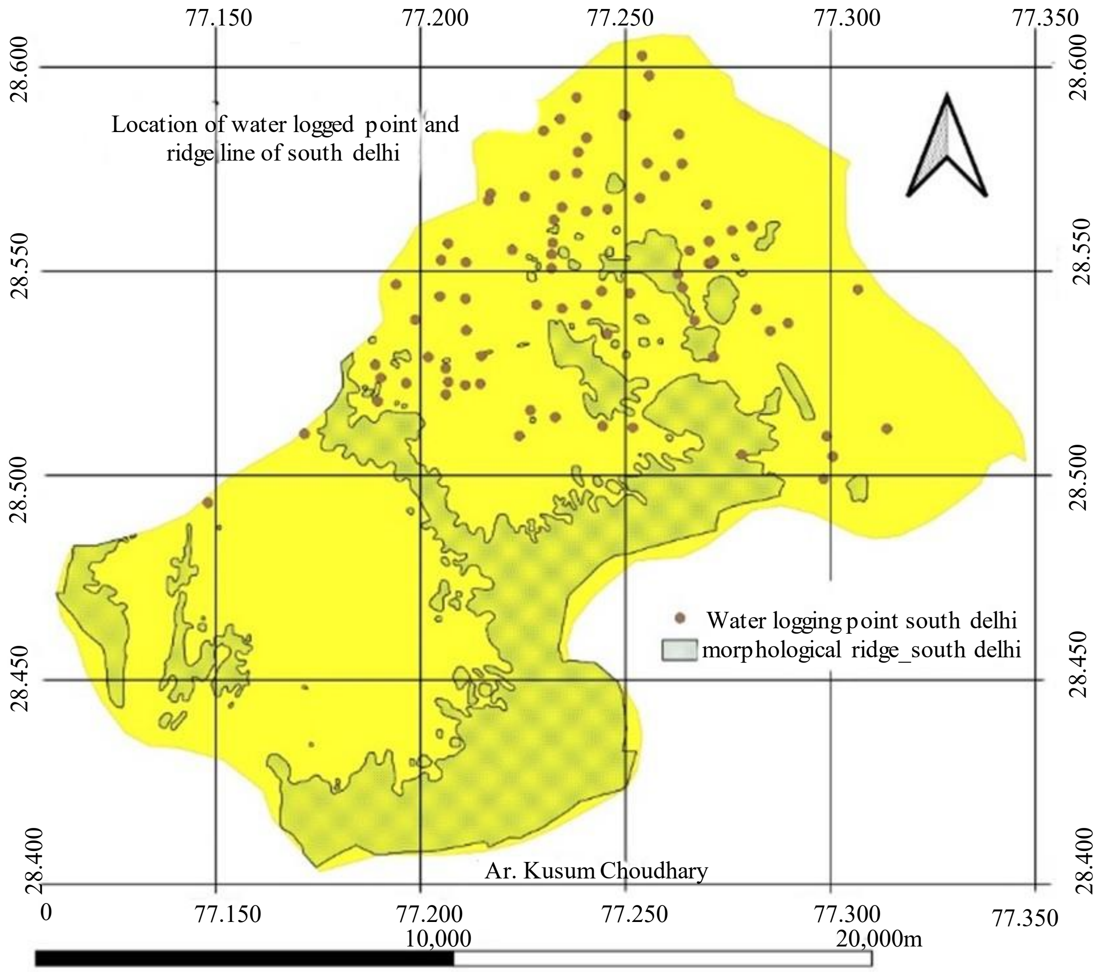

Figure 7. GIS map study of waterlogging point of South Delhi, 2023.

Modified Rational Method

An empirical formula that is commonly used in urban areas for computing peak runoff rates to design drainage structures is established by the rational method (Source: Amer Public Works Assn, 1974). The Modified Rational Method (MRM) is an expanded version of the rational method that generates uncomplicated runoff hydrographs. The MRM is commonly referred to as the rational hydrograph method. The application of the Modified Rational Method (MRM) results in the generation of a hydrograph of runoff and the calculation of the total volume of runoff. In contrast, the application of the rational method only calculates the peak design discharge (Q).

Figure 9. Shows the geographical sample study area as below:

- Location- Press Enclave Road, Max Hospital, Delhi. Coordinates- Latitude 28°31'40.02" N Logitude77°12'45.12" E.
- Total Area of green space (Eid Gah Hauz Rani Park) 84000 sq mt.
- Rainfall 124 mm/hr on 11 July 2023.
- Catchment area 12 m width road X 1000 m length = 2.7acer.

The runoff was calculated by using the modified rational method.

$$Q = CIA \tag{1}$$

Here, Q= Peak Flow; C= Runoff Coefficient = 0.70; I = Rainfall Intensity = 4.8 in/hr & A = Area in Acer = 2.7 acer. The Calculated Peak flow is 9.072 cubic feet /sec

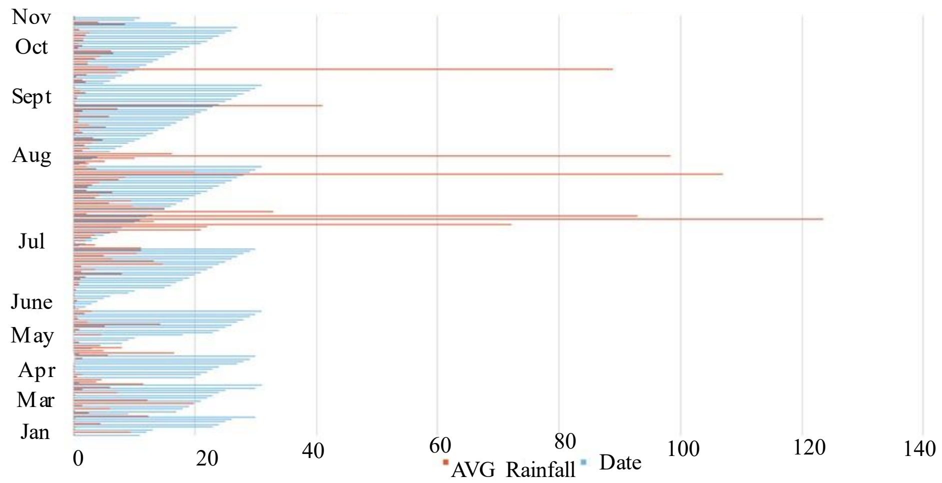

Figure 8. Rainfall data -Max Hospital, Press Enclave Road, Saket. Delhi,2023
(Source: Nasa).

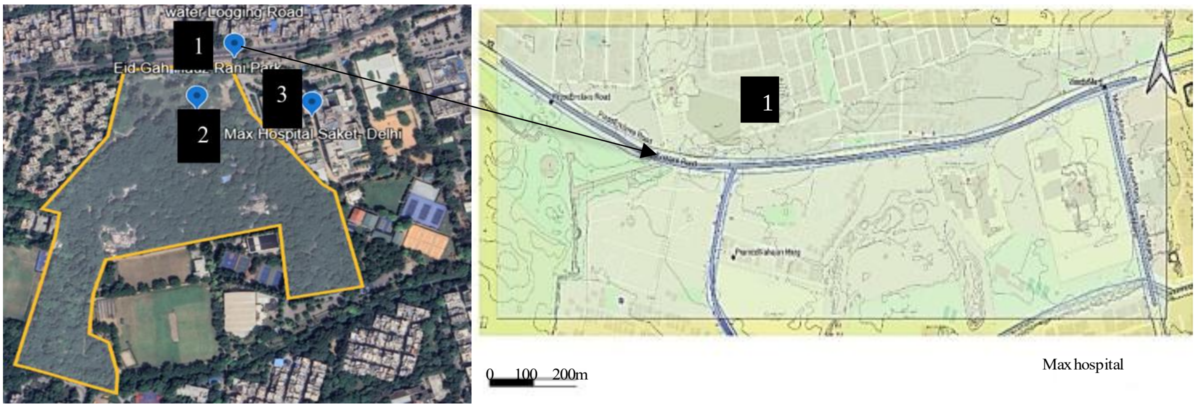

Figure 9. Sample study area max hospital, press enclave, road, Saket Delhi, 2023.
Waterlogging Area, 2. Eid Gah Hauz Rani Park, 3. Max Hospital) (Source: Google Earth.

CONCLUSION

The runoff was calculated by using the Modified Rational Method is 9.072 cubic feet /sec. which is quite high for a single day in average monsoon season in national capital Delhi. This runoff water can be utilized for groundwater recharge. The importance of efficient and enduring groundwater extraction and aquifer recharge has increased in water resource management due to the impact of climate change on hydro-meteorological parameters. This should include innovative technologies, an assessment of the impact of climate change, and an analysis of the uncertainty associated with prevalent aspects. Highway geometry can be designed to shorten the distance water must travel to leave the pavement, hence preventing flooding. Increasing the pavement surface texture depth by means such as grooving cement concrete. Drainage capacity at the tire-road contact can be improved by increasing pavement surface texture. The goal of urban drainage system planning is to direct rainwater back to the earth as close as possible to where it first hits the pavement or the right-of-way. If there isn't enough space, it should be piped along the right-of-way and dumped at the receiving body, in addition to being infiltrated into the ground at specific points. Understanding chemical interactions between soil, water, and other substances helps us manage runoff and safeguard water quality in developed and developing regions. There's been some research about updating and modernizing the drainage system.

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