Storm Water Management through Water Sensitive Urban Design and Planning: Case of a University Campus in India

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Abstract: The outline of almost all urban contours are characterized by accelerated urbanization, depleted assets, population growth, ageing infrastructure, and degraded environments, which are made worse by rising climate uncertainty. The projections show that by 2040, approximately half of the world population will reside in areas with significant water stress. The immense pressure on land due to expansion of urbanized area has led to a significant increase in impervious/paved surfaces, reducing the rate of infiltration. In urban areas, however, this cycle is discontinuous in context to impermeable pavements, surface water do not get time to percolate instead they drain off to sewer. This misleading of storm water leads to flooding, and other water issues. The goal is to find techniques that can feasibly integrate the hydrological cycle with impactful water-sensitive spatial design considerations. This paper presents a detailed analysis of Women's Polytechnic and Sarojini Naidu Hall at Aligarh Muslim University (AMU), Aligarh, India based on storm water management and water sensitive parameters that can be implemented in the whole campus by using both qualitative as well as quantitative research methods in relation with the Sustainable Development Goals 2030.
***Keywords*:** hydrological cycle, infiltration rate, storm water, urbanisation, water sensitive urban design, Aligarh, India

1. Introduction

Water Sensitive Urban Design and Planning (WSUDP) is an analytical vision of urban planning and design aimed at minimizing the hydrological impact of urban development on the surrounding environment (Lloyd et al., 2002). When it comes to urban environmental planning and design, WSUD represents a new paradigm in addressing concerns about water sustainability and environmental protection (Garg et al., 2023). The term "water sensitivity" refers to a new concept of "Integrated Urban Water Management" (IUWM) through efficient urban solutions, WSUD ensures that water plays a key role in the urban design process (Brown & Clarke, 2007). According to data, Mouritz is known to have first mentioned the term Water Sensitive Urban Design (WSUD) in 1992. In India, the enormous urbanization has resulted in the generation of massive amounts of storm water that are unused and the existing urban water infrastructure has no treatment plans for them. (Gogate et al., 2017) Despite being addressed in the development plan, storm water drainage doesn't get enough attention because storm water isn't a major issue until a major failure has occurred in India's seasonal monsoon. The United Nations also recognized the urgency of comprehensive and sustainable development and proposed a special agenda on water and development, the so-called SDG-6, Sustainable Development Goal 6 – Clean Water and Sanitation(Mishra & Padhi, 2021).

2. Research Methodology

This study is conducted to explore the storm water practices in university campuses with the possibilities of integrating the existing urban area with water cycle loop through water-sensitive design. The research initiates with questions like; what is the concept of Water Sensitive Urban Design (WSUD)? What are the techniques of WSUD? How to integrate urban cycle and water cycle? To address these questions, the mixed-methodological framework is adopted. This study involves the four main steps; first, the study benefits from the existing literature, mapping the secondary data to assess the need of storm water as a resource and understand the concepts regarding water sensitive urban design and planning in campuses. In the second step, appropriate case studies related to the research problem were studied through online sources, research paper, articles and journals in order to understand the different aspects of possibilities and outcomes on the related subject and practical situations. Then the primary data collection through site visits and the documentation of present scenario of storm water surfaces on the selected site and identification of issues on site by preparing a base plan. Finally, analysis and propose the design solution on the selected site prototypical model with water sensitive urban design techniques to evolve the Aligarh Muslim University (A.M.U.) campus as water sensitive campus in upcoming years.

3. Literature Review

3.1 Water in Cities

There are three forms of appearance of water in cities: potable water, storm water, and grey water that is regulated by the local government. To prevent flooding, keep roads and buildings dry, and maintain safety, storm water must seep into the ground or drain on hard surfaces as roofs, streets, etc. (Hoyer et al., 2011). Studies show that nearly four billion people, two-thirds of the world's population, face severe water scarcity at some point in the year (United Nations, 2021). Existing water management practices have not helped cities to become more aware of their water resources (Kamal, 2016). Water naturally behaves in loop of hydrological cycle of runoff, seepage, precipitation and evaporation (Fig. 1.a). In cities, however, this cycle is interrupted and no longer maintained (Fig. 1.b). City water is contaminated and cannot seep into the ground due to the tough paved surface, resulting in rapid flow and draining into public sewers without any time to evaporate. Therefore, it has negative effects on city climate, water supply, water quality as well as quantity, and groundwater recharge (Hoyer et al., 2011). Each of these problems outwardly demonstrates the fact that enhanced urban water management solutions are required (Fig 1.c).

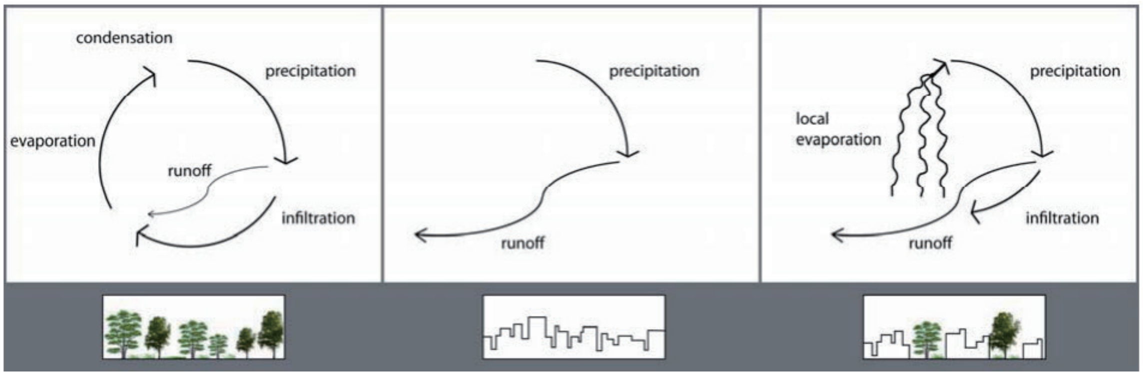

Figure 1: Water cycle in different phases a) in natural system (left); b) in urban area without sustainable storm water management (middle); c) in an urban area with sustainable storm water management (right)

3.2 The Conventional Approach

Practices for managing storm water are always changing. Since the 1970s, urban storm water management in Ontario has been done to prevent flooding. Storm water management was acknowledged as a crucial tool for raising water quality and lowering lake and river pollution in the 1990s. Since then, centralized storm water storage has been the main focus of this practice. This is also referred to as "storm water treatment at the pipe end. (Goulden et al., 2018). There are two types of sewerage systems:

(1) Combined sewerage systems: These systems collect both storm water and wastewater in a single network of pipes. This water mixture is transported to a treatment facility where it is cleaned up before being released into the river.

(2) Separate sewerage systems: In this arrangement, two separate sewerage systems each collect storm water and wastewater. While the wastewater is transported to the treatment facility, the rainwater either discharges directly into the receiving source (contaminant-free) or is treated separately before being discharged into the river (Hoyer et al., 2011).

3.3 Water Sensitive Urban Design

Water Sensitive Urban Design (WSUD) is an ecological viewpoint to urban planning and design that seeks to reduce the hydrological effects of urban development on the environment (Lloyd et al., 2002).This term used to describe urban planning and design that is ‘sensitive' to issues of environmental protection and water sustainability (Brown & Clarke, 2007). WSUD approach essentially centres the storm water quantity and quality. By reducing the amount of impervious surfaces, minimizing the changes to the natural water balance, and enhancing storm water quality, the WSUD approach provides a substitute to the conventional approach to storm water management. For water sensitive urban design to work, storm water management must be integrated. This comprehensive strategy takes into account all aspects of storm water runoff within a development area, including environmental, social, and cultural concerns, and views storm water as a resource rather than a threat (Victorian, 1999).

3.4 Water Sensitive Design Principles

The water sensitive design principles are summarized as below:

Preserve nearby water sources (lakes, ponds, and wetlands) to access more water supplies.

Using landscape elements (such as vegetated ditches and buffer zones, biological note system) to manage rainwater in public areas, including open spaces in cities

Natural wastewater recycling and reuse (cheap/low energy).

Improve water conservation strategies at various scales (building/campus) by implementing water-saving techniques, landscaping (e.g., planting native species), and using water-saving irrigation techniques, thereby reducing the strain on the city and groundwater supply systems. Reduced water scarcity can also be achieved through in-situ water conservation and rainwater harvesting (CSE, 2017).

3.5 Water Sensitive Design Strategies

3.5.1 Grassed Swales

A swale is a shallow, wide, gently sloping, open field channel with grass that filters and slows down rainwater that runs off of roofs, driveways, and lawns (Fig. 2). In some buildings, swales are used in place of gutters and curbs. Swales transport runoff from one place to another, making them connectors as well as management techniques (Fox, 2018). Design Considerations: Swales should generally be placed at least 10 feet away from building foundations, 50 feet away from septic system fields, and 100 feet away from wells. It shouldn't be used in areas with steep slopes (more than 4%), as this causes erosion due to the water's rapid flow. Refrain from constructing swales in areas where the soil is compacted or contains a lot of clay. Water will not enter quickly and may result in mosquito problems if it is left standing for longer than seven days.

Figure 2: The grass swales

3.5.2 Rain Garden

A rain garden is a small depression where ornamental grasses and perennial flowers can grow. The plants should be native to the area and able to survive in moist soil after heavy rains (Fig 3). However, these are not gardens with ponds of still water (Shah et al., 2019). Rain gardens collect and slowdown runoff to improve soil infiltration. These stunning gardens help buildings and complexes to reduce storm water runoff and keep pollutants from running off roofs and hard surfaces into streams and lakes. Design Consideration: The most crucial factors to take into account when planning rain gardens are the location, size, and depth. It is recommended to keep a rain garden at least 10 feet away from a house. If standing water is not desired and desired, the depth of the rain garden should be 2 to 6 inches and about 18 inches, respectively. The rain garden should be roughly 70 square feet in size. The landscape's drainage system should be reflected in the shape or design. To prevent digging around or over utilities while building a rain garden, water mains, electrical lines, and all other utilities should be clearly marked (Stiffler, 2013)

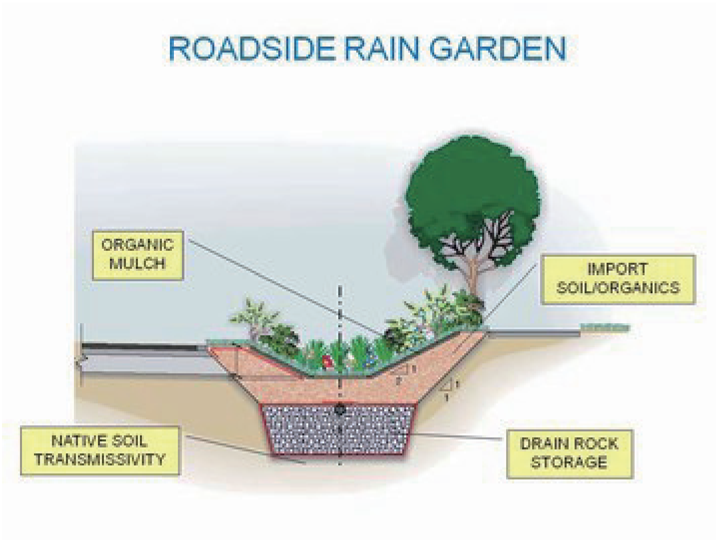

Figure 3: The details of the rain garden

3.5.3 Infiltration Trench

An infiltration trench is a shallow ditch filled with gravel or rubble that is used to filter rainwater into a groundwater aquifer by permeating permeable soil (Fig. 4). It is frequently used to transport sewage from impermeable surfaces like sidewalks and parking lots in areas with poor rainwater drainage. Seepage ditches are used to create underground reservoirs for runoff that seep into the surrounding soil over the design period. These are relatively narrow construction pits filled with gravel or other highly porous material. Infiltration trenches are thought to have the ability to dampen the flow and are a low impact development (Pusalkar et al., 2020). Design considerations: The ditch geometry should allow the drain pipe to drain in 96 hours. The surface gravel layer should be at least 0.5 feet thick. Observation wells of at least 4 inches in diameter are required. Use weatherproof caps. Seepage: Do not dig trenches within 100 feet of private wells, septic tanks, or sewers due to potential groundwater contamination (Stauffer, 2018).

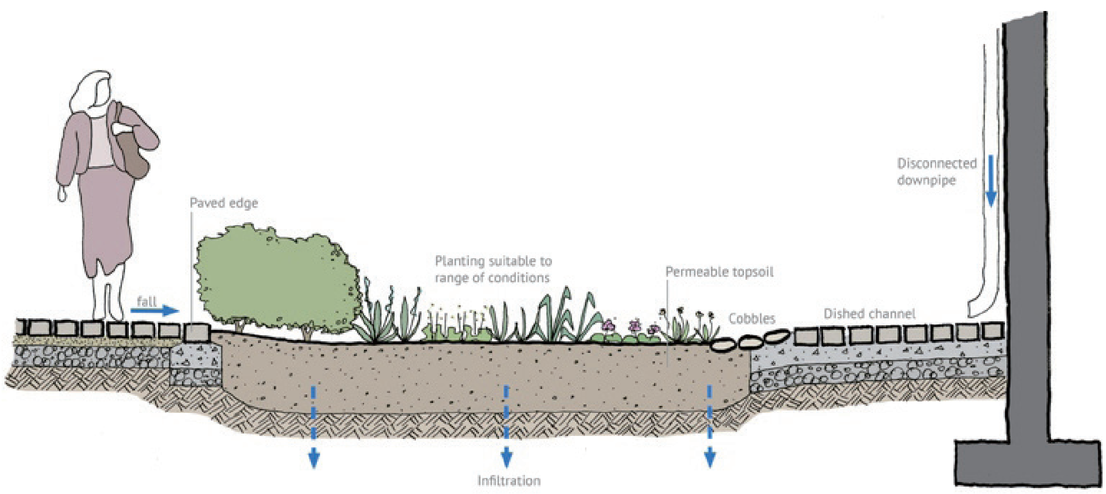

Figure 4: The details of infiltration trench

3.5.4 Vegetated filter strips

Vegetated filter strips (also known as grassed filter strips, filter strips, and grassed filters) is a tropic surface used to handle sheet flow from s.0urrounding surfaces (Fig. 5) Filter strips work by slowing runoff, filtering silt and other contaminants, and allowing them to penetrate into the underlying soil. Tamper strips were originally used for agricultural treatment, which later developed into urban use. Filter strips can remove relatively high levels of contaminants if properly designed and maintained. Design considerations::To significantly improve water quality, the channel length on the green filter strip should be at least 5 meters. Filter strips are most effective at dealing with near-surface impermeable runoff that causes stratified flow. The gradient of the filter strip should be between 1% and 5%. Trap strips should only be used when season.

Figure 5: Filter Strips

4. Comparative Analysis of Case Studies

The comparative analysis of different case studies have summarized in Table 1.

Table 1: Comparative Analysis of Case Studies

Parameter	Case 1: IIM Kozhikode, India	Case 2: Portland, Oregon, USA	Case 3: Penn state university, Pennsylvania	Recommendations
Ground	Rainwater harvesting: Natural contours reduce the surface drain time of storm water & allow the water to infiltrate and enter a catchment area below, a rainwater collection pond.	Wet Weather program: Aims to manage storm water as close to its source as possible and used landscaping/vegetation to slow the surface runoff and filter storm water to ground.	Vegetated infiltration bed : A vegetated subsurface Infiltration Bed is located immediately adjacent to an existing, uncontrolled parking lot allows surface water to infiltrate to ground.	Infiltration Bed as well as natural contours to reduce the surface drain time of storm water allows the storm water to infiltrate into the ground.
Streets		Green street program Green Street is a sustainable storm water strategy that uses turf pavers to surface more porous, which allows the storm water to infilterate.	Infiltration trench Shallow digging ditch designed to filter rainwater through permeable soil into an aquifer of groundwater. Porous concrete sidewalks Porous asphalt parking lot, The runoff from the portion of the building is conveyed to the parking lot adjacent to the road.	Turf pavers can be used which to make surface porous allows the storm water to infilterate.
Terraces	Rainwater harvesting: Rainwater collection is implemented at IIMK using storm water runoff from the roofs of campus buildings using downpipes and gutters leading to rainwater ditch.	Eco roof Innovative: The eco-roof consists of a layer of vegetation on a growing medium over a waterproof synthetic membrane. Green roof reduces storm water runoff, saves energy, reduces pollution and erosion.		A green roof can be provided which significantly reduces storm water runoff, saves energy, and reduces pollution and erosion.

5. The Site Selection

5.1 About the city

In western Uttar Pradesh, there is a district called Aligarh with highly fertile soil. It is located between latitudes 27034'26" and 28010'46"N and longitudes 77029'17" and 78029'02"E, and it contains a small section of the Ganga-Yamuna (Ayub, 2011). The climate in the Aligarh district is sub-humid, with the summer season being hot and humid and the winter

season being cold and dry with average highest temperature of 33.65 degrees and with lowest temperature of 10.9 degrees. The average rainfall is 646 mm annually (Asif, 2014)in the fringe areas of Aligarh city located in the plains of North India. In reality, it is a consequential phenomenon of urbanization characterized with predominance of non-agricultural pursuits, high density of population, fast pace of life, availability of improved civic amenities, and affluences. Urban growth and encroachment of agricultural lands in urban fringe of Aligarh city are the main components of the research paper. An enumeration of process and parameters has been attempted and examined on the basis of eight parameters that have led encroachment of agricultural lands for urban uses. The research work involved an extensive gamut of data and information which has been used to analyze and assess the phenomena. In the end, the paper arrived to conclude that, as a result of physical and socio-cultural advancement, the city of Aligarh spares out continuously over large areas, and the process of encroachment of rural lands continues far and in wide areas for the use of urban activities.","author":[{"dropping-particle":"","family":"Asif","given":"Kamal","non-dropping-particle":"","parse-names":false,"suffix":""}],"container-title":"Asian Geographer","id":"ITEM-1","issue":"2","issued":{"date-parts":[["2014"]]},"page":"129-148","title":"Encroachment of agricultural land in urban fringe areas of Aligarh city, India – process and parameters","type":"article-journal","volume":"31"},"uris":["http://www.mendeley.com/documents/?uuid=22ad89c3-c9f2-4c96-8b58-75406927674b"]}],"mendeley":{"formattedCitation":"(Asif, 2014.

5.2 The Justification of the Site

The selected site is Women's Polytechnic Department & Sarojini Naidu Hall, a girl's hostel, located in Aligarh Muslim University Campus, Aligarh, Uttar Pradesh. The site is composed of number of institutional and residential buildings with nearby Landmarks as Athletic Ground, Bibi Fatima Hall and Department of Physical Education, A.M.U. The particular site was chosen for the prototypical model because it includes two types of buildings: institutional and residential, the Women's Polytechnic Department (College building) G+2 Floor and S.N. Hall (Hostel building) G+2 Floor. To make the entire A.M.U. campus water sensitive, different building typologies must be studied, as water consumption patterns vary accordingly.

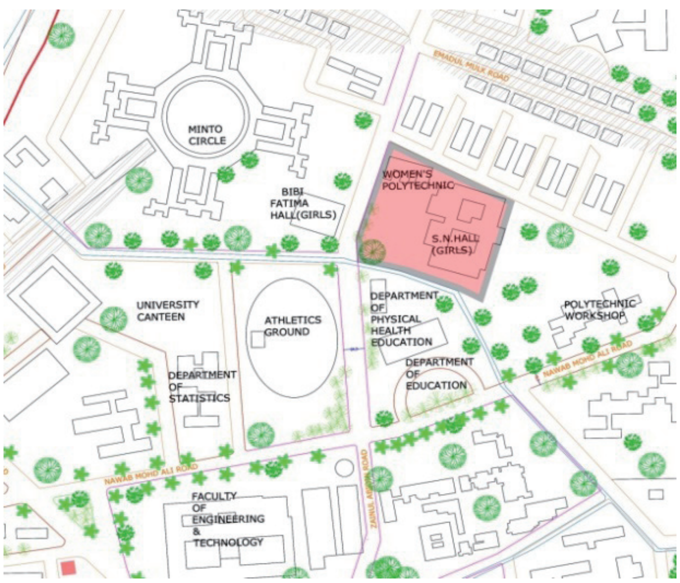

Figure 6: Location plan of the selected site in the University campus

5.3 The Selected Site

The primary research was used to create the selected site's base plan. The legend depicts various types of catchment surfaces such as ground, green, terraces, and pavements. The site context deals with the natural topography. Although the aim is to study the existing storm water management and propose the sustainable design solutions, making the whole campus as water sensitive campus.

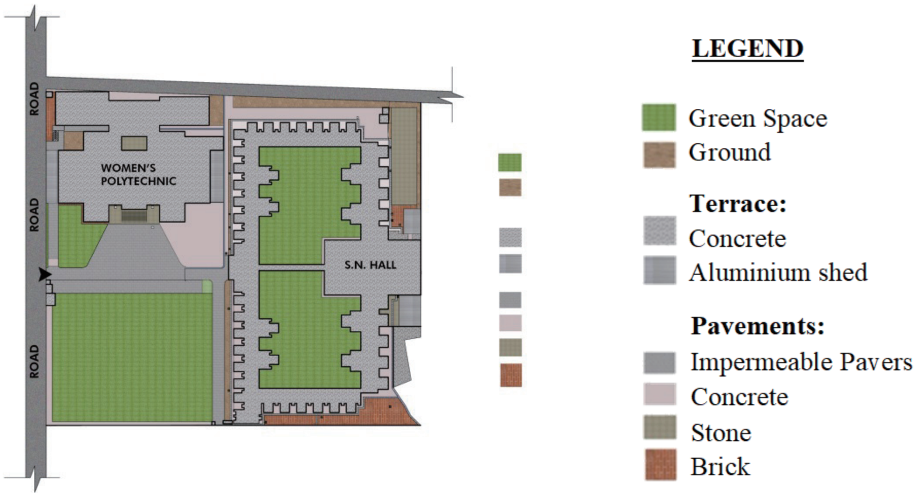

Figure 7: The Base Plan of the selected site

5.4 Area Calculation of Different Catchments

The Table 2 shows the area of different catchments

Table 2: Area Calculation of Different Catchments

Site Area	10945.42 sqm (2.7 acre)
Permeable Surfaces	
Green space	3817.14 sqm
Ground	347.52sqm
Total	4164.66sqm (38%)
Terrace	
Women's Polytechnic Area	1436.27sqm
S.N Hall	2131.48 sqm
Aluminium Shed	219.5sqm
Other Buildings	142.37 sqm
Total	3929.62 sqm (35%)
Pavements	
Concrete	1130.46 sqm
Impermeable pavers	1118.74sqm
Stone	358.58 sqm
Brick	270.85 sqm
Total	2878.63 sqm (26.2%)

This demonstrates that the site has the highest percentage of impermeable surfaces. As a result, the site has the potential to convert underutilized catchments into effective design solutions, transforming the campus into a water-sensitive campus.

5.5 Existing Site Condition

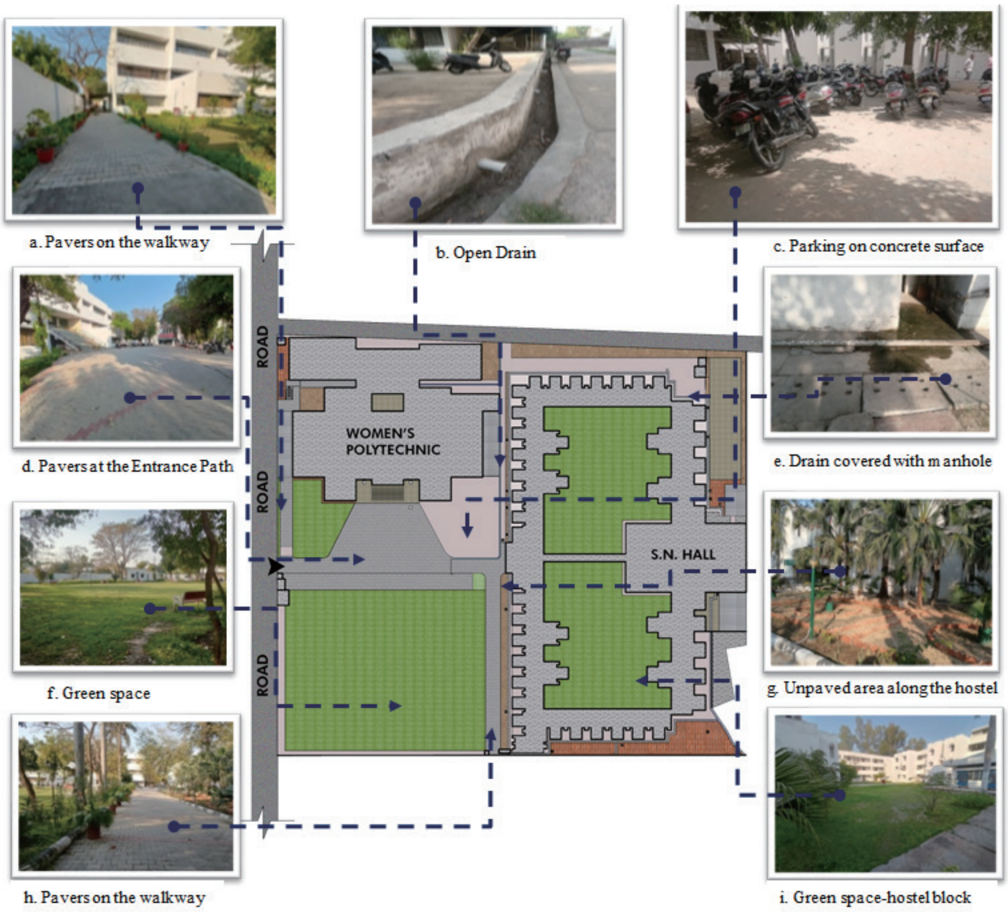

Figure 8: Visual analysis of the existing site condition

5.6 Existing Drain Layout

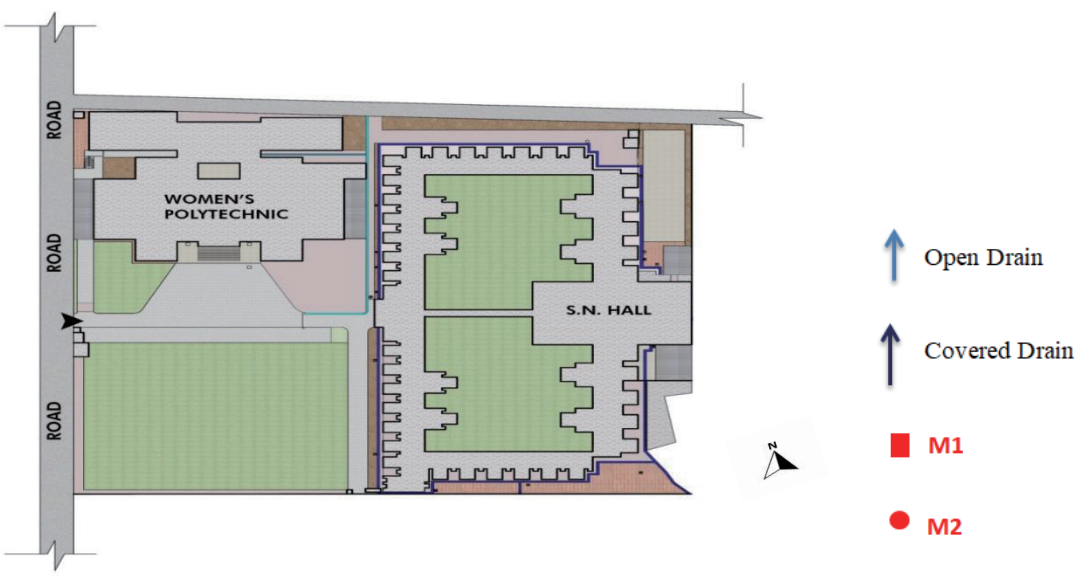

Figure 9: The drain layout of existing condition

5.7 Runoff coefficient of Different Catchments on Site

Table 3: On site runoff co-efficient of different catchments

Green Space	0.1- 0.25
Ground	0.0 – 0.3
Terrace	
Concrete	0.75 - 0.95
Aluminium shed	0.7- 0.9
Pavements	
Permeable Pavers	0.37- 0.45
Concrete	0.75 - 0.95
Stone	0.8- 0.95
Brick	0.7 - 0.85

5.8 Water Supply Demand

Aligarh's metro area currently has 12,79,000 residents, up 2.73% from 2021. It had a population of 12,45,000 in 2021, up 2.81% from 2020.As population grows gradually, so does the demand for water.

5.9 Rainwater Which Can Be Harvested through Rational Method Equation

A comprehensive way to calculate the maximum runoff from any given design storm. Because it assumes that the run-off is directly related to the contributing drainage area, the intensity of the rainfall, and the land cover, it is also a "common sense" type of approach. The peak runoff is predicted by the rational approach using the following formula:

$$Q = CiA$$

Rainfall Intensity x Runoff Volume = (C) Runoff Coefficient x (i) Sub-catchment region

Q is the maximum runoff rate in cubic feet per second.

where A is the sub-catchment area, i is the intensity of the rainfall, and C is a runoff coefficient (Burra Shyamsunder et al., 2021).

5.10 Water Requirements for buildings

Table 4: Water requirement for hostel and institutional building

Type of Building	Total Consumption per Day (litres)
Hostels	135 per head
School/ College	45 per head

5.11 Storm water runoff Calculation

Using the rational method formula: Q = CiA ,

Runoff Volume (Q) = Runoff coefficient (C)x Rainfall intensity (i) x Sub-catchment area (A)

Table 5: Storm water runoff calculation

Surfaces	Type of surface	Runoff coefficient	Mean Runoff coefficient (C)	Avg. Annual Rainfall intensity (i)m	Sub-catchment area (A)sqm	Runoff Volume Q=CiA(cum)	Runoff Volume in cubic meters Annually	Runoff Volume in liters Annually	Total Storm Water runoff Annually	(%) Storm Water runoff Annually	Impervious/ Pervious Ratio
Permeable Surface									3756391.936		3.21
Green	Grass	0.10-0.25	0.175	0.64	3817.14	427.52	893.11	893114.2		23.78	
Ground	Soil	0.0-0.3	0.15	0.64	347.52	33.36					
Interlock Permeable pavers	Concrete Pavers	0.37-0.45	0.41	0.64	1118.74	293.56					
Brick	Brick Pavement	0.75-0.85	0.8	0.64	270.85	138.68					
Non-Permeable Surface											
Women's Polytechnic Area	Concrete	0.70-0.95	0.825	0.64	1436.27	758.35	2863.28	2863277.76		76.22	
S.N Hall	Concrete	0.70-0.95	0.825	0.64	2131.48	1125.42					
Aluminium Shed	Corrugated Metal sheet	0.70-0.90	0.8	0.64	219.5	112.38					
Other Buildings	Concrete	0.70-0.95	0.825	0.64	142.37	75.17					
Stone/Tiles	Kota Stone	0.8-0.9	0.85	0.64	358.58	195.07					
Concrete	Concrete	0.70-0.95	0.825	0.64	1130.46	596.88					

This shows: Impervious to Pervious ratio on site is 3.21 in an existing scenario.

5.12 Water Consumption Pattern

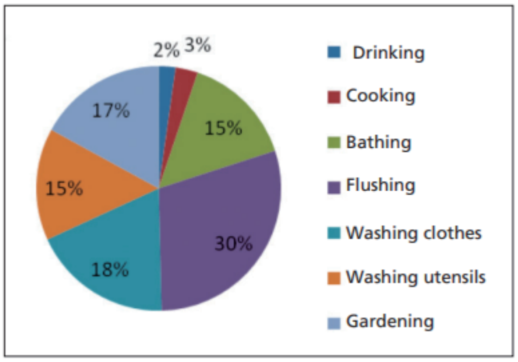

Figure 10: Water consumption break down per person

According to the analysis of water consumption patterns, approximately 70% to 80% of the water supplied is used for non-potable purposes. and approximately 60% of total water consumed comes out as grey water from a site with the potential to be recycled.

6. The Design Methodology

According to the report, Water Management to Water Sensitive Planning states that the impervious to pervious ratio is central to the idea of water sensitive urban design and planning. (Divya, 2020)In order to make any campus water sensitive, the impervious to pervious ratio has to be lowered. This implies that reducing the percentage of impervious surface will result in less runoff and a higher rate of infiltration. To achieve this concept, a design proposal is created to meet this requirement and create a prototypical model of the site as a water sensitive model and further can be implemented throughout the entire A.M.U. campus. The study is divided into two parts as summarized below.

Table 6: Pervious Sources / Impervious Control

Pervious Control	Impervious control
Green spaces, ground, Interlocking tiles	Storm Water from terraces
WSUD Strategies are used.	Rainwater collection tank has been provided.

6.1 The Design Approach

6.1.1 Pervious Control

Green spaces, soil, interlocking panels are permeable surfaces that allow rainwater to seep into the ground. To increase infiltration and maintain ground water levels, several water-sensitive design strategies can be implemented such as: Rain garden, Swales, Permeable grooves & Filter strips.

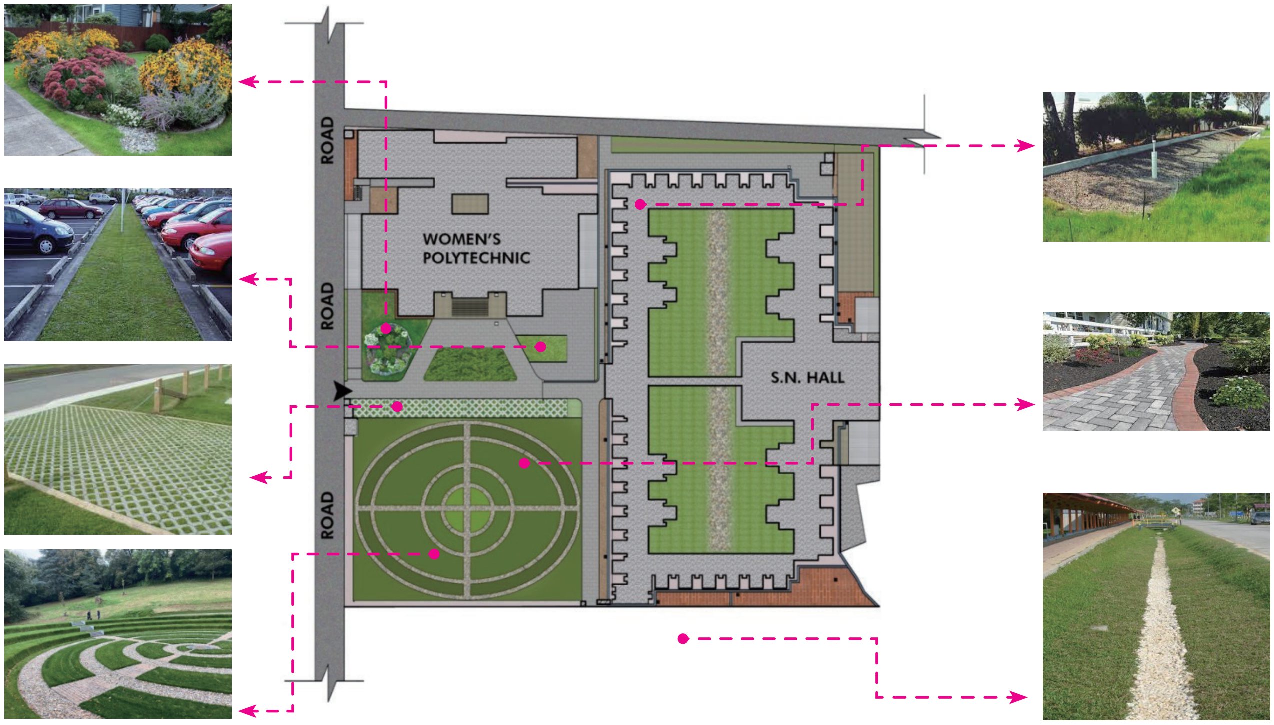

Figure 11: Design proposal on the existing site

6.1.1.1 Changes in Catchment Areas after WSUD Implementation

To improve percolation rates, impervious surfaces such as concrete roads and paved areas are converted into pervious catchments such as green patches, grounds, perforated tiles, and other water sensitive design measures.

Table 7: Changes in catchment areas after WSUD implementation

Surfaces	Type of surface	Existing Sub-catchment area (A)sqm	Sub-catchment area after WSUD (A)sqm	Change in area
Permeable Surface				
Green	Grass	3817.14	5919.14	2102
Ground	Soil	347.52	347.52	0
Interlock Permeable pavers	Concrete Pavers	1118.74	1633.26	514.52
Brick	Brick Pavement	270.85	270.85	0
Non-Permeable Surface				
Women's Polytechnic Area	Concrete	1436.27	1436.27	0
S.N Hall	Concrete	2131.48	2131.48	0
Aluminium Shed	Corrugated metal sheet	219.5	219.5	0
Other Buildings	Concrete	142.37	142.37	0
Stone/Tiles	Kota Stone	358.58	358.58	0
Concrete	Concrete	1130.46	582.54	-547.92

6.1.1.2 Storm water runoff Calculation after WSUD Strategies

After implementing WSUD measures, catchment areas get changed. This in turn alters the storm water runoff by lowering it, hence impervious to pervious ratio also changes.

Table 8: Calculation of storm water after WSUD strategies

Surfaces	Type of surface	Runoff coefficient	Mean Runoff coefficient (C)	Avg. Annual Rainfall intensity (i)m	Sub-catchment area after WSUD (A)sqm	Runoff Volume Q=CiA(cum)	Runoff Volume in cubic meters Annually	Runoff Volume in liters Annually	Total Storm Water runoff Annually	(%) Storm Water runoff Annually	Impervious/ Pervious Ratio
Permeable Surface									3837524.224		2.04
Green	Grass	0.10-0.25	0.175	0.64	5919.14	662.94	1263.55	1263548.2		32.93	
Ground	Soil	0.0-0.3	0.15	0.64	347.52	33.36					
Interlock Permeable pavers	Concrete Pavers	0.37-0.45	0.41	0.64	1633.26	428.57					
Brick	Brick Pavement	0.75-0.85	0.8	0.64	270.85	138.68					
Non-Permeable Surface											
Women's Polytechnic Area	Concrete	0.70-0.95	0.825	0.64	1436.27	758.35	2573.98	2573976.00		67.07	
S.N Hall	Concrete	0.70-0.95	0.825	0.64	2131.48	1125.42					
Aluminium Shed	Corrugated metal sheet	0.70-0.90	0.8	0.64	219.5	112.38					
Other Buildings	Concrete	0.70-0.95	0.825	0.64	142.37	75.17					
Stone/Tiles	Kota Stone	0.8-0.9	0.85	0.64	358.58	195.07					
Concrete	Concrete	0.70-0.95	0.825	0.64	582.54	307.58					

This demonstrates that the impervious to pervious ratio is reduced to 2.04 from 3.21 after implementing Water Sensitive Techniques, which increases infiltration.

The amount of impervious surface is reduced by (76.22- 67.07) %= 9.15%.

As a result, both the water table and the hydrological cycle will improve.

6.1.2 Impervious Control

Terraces have a high percentage of runoff that can be used by installing a rainwater collection tank. Storm water that has been collected in the tank can be filtered and used for non-potable tasks like cleaning and landscaping. We can provide a rainwater collection tank in accordance with the water demand determined on site and the various activities consumption patterns.

7. The Water Demand

a) **Women's Polytechnic**

No. of students in college - 300

Water requirement in college - 45x 300= 13500 litres per day

Campus maintenance and Landscaping- (1200-1500) litres per day

Total requirement of water in college - 13500+1500 = 15000 litres per day

b) **S.N Hall**

As per NBC, water demand for the Hostel building is 135 litres per head per day

No. of students in hostel = 300

Water requirement in hostel - 135x 300= 54000 litres per day

Campus maintenance and Landscaping - (1000-1200) litres per day

Total requirement of water in hostel building- 54000+1200 = 55200 litres per day

Net Total requirement of water in the campus - 55200+15000= 70200 litres per day

70200 × 365 = 25623000 litres annually

256 lakh litres annually

Rain-water collection tank

a) Women's Polytechnic

Surface Area of Roof Top (A) – 1436.27sqm

Average Annual Rainfall (R) – 0.64m (640 mm)

Runoff coefficient (C) - 0.82 (concrete)

Runoff volume = AxRxC = 753.75 cum = 753750 litres = 7.5 lakh litres annually (approx)

For the collection of roof top storm-water

80% of total runoff is considered- 0.8x 753750 = 603000 litres = 603cum= 6lakh annually (approx)

Determination of tank size by additional 20% as factor of safety= 1.2 x 603000 = 723600ltrres=7.2lakh ltr annually=723 cum

Hence, two collection tank of size 8mx8mx 5m can be provided.

Water requirement annually in landscaping = 1500 litres per day x365= 547500 litres =5.4 lakh annually (approx.)

As a result, whole landscaping water requirement will be met by rainwater storage tank.

b) The Sarojini Naidu Hall

Surface Area of Roof Top (A) – 2131.48sqm

Average Annual Rainfall (R) – 0.64m (640 mm)

Runoff coefficient (C) - 0.82 (concrete)

Runoff volume = AxRxC = 1118.60 cum = 1118600 litres= 11 lakh litres annually (approx)

For the collection of roof top storm water

80% of total runoff is considered- 0.8x 1118600 =894880ltr = 894cum= 8.9lakh annually (approx.)

Determination of tank size by additional 20% as factor of safety= 1.2 x 894880 litres =1073856 litres (10.7 lakh litres annually or 1073 cum)

Hence, two collection tank of size 12mx8mx6m can be provided.

Water requirement annually in landscaping = 1200ltr per day x365= 438000 ltr = 4.3 lakh annually (approx)

As a result, whole landscaping water requirement will be met by rainwater storage tank. Remaining 8.9-4.3= 4.6 lakh will be utilized in cleaning and other purpose on site.

8. Results and Discussions

The results of the analysis have been summarized in Table 8.

Table 9: Summary of the result of the study

Total demand on site (Women's Polytechnic and S.N. Hall)	256 lakh litres annually
Water required for landscaping on site	4.3+ 5.4 = 9.7 lakh litres annually
Storm water collected from women' Polytechnic Building terrace	6 lakh litres annually
Storm water collected from the S. N. Hall Building terrace	10.7 lakh litres Annually
Total	16.7 lakh litres storm water collected annually

As a result, according to the water consumption pattern, the storm water collected from the terraces of the Women's Polytechnic department and S.N. Hall will easily meet the site's landscaping needs. In which the rainwater collection tank meets 17% of the landscaping needs, and the remaining 2% to 3% can be used for cleaning or other non-potable purposes. This location lacks the potential of a treatment plant because it is a prototype model on a small scale. However, we can have a treatment plant to make the entire A.M.U. campus as water sensitive as possible. To allow this surface water to be used for potable activities as well as non-potable activities such as landscaping and cleaning.

9. Conclusions

A logical method of urban planning and design called "water sensitive design" seeks to reduce the disruption of the hydrological cycle brought on by urban development. The objective of the storm water management is to lower the runoff by treating surface water as close to its source as possible, ideally on-site. The term "treating" does not refer to the collection and disposal of storm water in the public sewer system, but rather to judicial treatment to lessen surface runoff and increase the rate of infiltration of storm water. Past events have demonstrated the misbehaviour of water, which contributes to the declination of current water table and climate crisis. This is due to the fact that the traditional approach to water management focuses mainly on quickly collecting storm water and draining it. In urban catchments, Water Sensitive Urban Design (WSUD) practices like rain gardens, swales, bio retention tanks, filtration trenches, and filter strips are frequently used. By making the best use of rainwater that falls on urban space, these measures can reduce runoff from various catchments and increase percolation. Rainfall-generated storm water enters catchments where it can recharge the groundwater, whereas impervious surfaces or hard surfaces with high runoff coefficient cause the storm water to drain away. This percolation rate is indicated by the sites impervious to pervious ratio. By following the application of water-sensitive techniques, the impervious to pervious ratio can be increased, leading to a high rate of storm water infiltration into the ground, balancing the hydrological cycle and groundwater table. This research focuses on water-sensitive urban design-level techniques that can be applied to make cities sustainable, achieving the objective of SDG's 2030 including clean water, sanitation and sustainable cities.

9.1 Recommendations

Storm water management includes management of terraces, soils, roads and footpaths that serve as collection points for surface water. For sustainable water-sensitive management, this surface water needs to be pumped towards permeable surfaces to increase infiltration rates. Apart from the design techniques described above, various design considerations can be incorporated at both the city and individual levels to make cities sustainable and increase percolation rates, such as:

As individuals, rainwater should be collected locally whenever possible to prevent runoff and pollution. When using individual plots as micro-catchments, care should be taken. To reduce runoff and increase replenishment at street level, different water-sensitive treatments, such as vegetative wetlands, infiltration devices, and porous paving materials, can be incorporated into the design depending on local conditions.

At the neighbourhood level, open areas like parks and playgrounds serve as urban catchments, enabling charging and percolation structures to reduce urban flooding.

The corresponding urban area should have an impervious to pervious ratio range of 2.3 to 3.5 and corresponding built up between 45% and 60% in order to maintain the balance level of urban development.(Divya, 2020)

Selecting low runoff coefficient materials reduces storm water surface drain time, allowing it to infiltrate into the ground and improving ground water table.

The paved area can work with the environment rather than against it by using turf pavers on the pathways and in the parking lots.

9.2 Research Limitations and Future Scope of Study

The objective of this research was to portray the Aligarh Muslim University campus as a water-sensitive campus by examining current storm water management procedures and suggesting design alternatives. Although it would be impractical to analyze the entire campus at once, a strategic area was chosen for in-depth analysis. In this study, a water-sensitive prototype is suggested that can be used throughout the entire campus. The results of using this prototype model can be taken into account in the future. Out of all the parameters, only storm water is included in this study due to the limited resources and feasibility. Due to these restrictions, research has advanced to the point where it now includes wastewater, potable water, and others, that can be used to create campuses more water sensitive. Other factors like urban drainage system and potential of urban storm water under sustainable city concept can also be further evaluated, posing the question of how effectively water management in a region could be used to partially meet local domestic water demands using the right technology and environmental safeguards. As a result, cities will develop the extent to remodel and manage aspect of life, resilience and long-term welfare.

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