CityAdapt

RECONNECTING CITIES WITH NATURE

LATINAMERICA AND THE CARIBBEAN

Nature-based Solutions

Sustainable Urban Drainage Design Guidelines

UN environment programme

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JAMAICA

Stability Wise
High Quality Solutions

SUSTAINABLE URBAN DRAINAGE DESIGN GUIDELINE

ABSTRACT

As urbanization continues to reshape our cities, sustainable urban drainage design has emerged as a critical component of resilient, eco-conscious urban planning. This progress report provides an overview of ongoing efforts to develop guidelines for the planning, implementation and monitoring of sustainable urban drainage and filtration systems in urban environments.

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Acronyms

DVRP: Disaster Vulnerability Reduction Project

EIA: Environmental Impact Assessment

GIS: Geographic Information Systems

HVAC: Heating, Ventilation, and Air Conditioning

JSIF: Jamaica Social Investment Fund

LHA: Local Highway Authority

LID: Low Impact Development

NbS: Nature-based Solutions

NWA: National Works Agency

ODPEM: Office of Disaster Preparedness and Emergency Management

RHS: Rainwater Harvesting Systems

SuDS: Sustainable Urban Drainage Systems

WMU: Watershed Management Unit

WRA: Water Resource Authority

1 Introduction

1.1 Background

The CityAdapt initiative, spearheaded by the United Nations Environment Programme (UNEP), focuses on climate change adaptation for cities in Latin America and the Caribbean (LAC). The challenges of ecosystem degradation and climate change in the LAC region pose a direct threat to urban communities, making them more vulnerable to natural disasters. This specific activity under the CityAdapt initiative aims to establish comprehensive guidelines for promoting sustainable development in urban areas within Jamaica. The project supported local governments and residents navigate the effects of climate change by incorporating Ecosystem-based Adaptation (EbA) into medium- to long-term urban planning initiatives. This comprehensive approach aimed to strengthen cities' resilience in the face of climate impacts such as rising sea levels, heatwaves, and extreme weather events caused by climate change. By disseminating knowledge and guiding professionals such as urban planners, architects, and engineers, the initiative aimed to foster innovative solutions to complex drainage challenges, optimize flood mitigation, improve water quality, and strengthen overall climate resilience in urban environments.

1.2 Overview

In an era where the effects of climate change and urbanization are reshaping our landscapes, the need for innovative and environmentally conscious solutions to manage water resources has never been more pressing. Historically, urban designers valued permeability, which allowed water to flow freely through the landscape and infiltrate the ground. However, the use of paved surfaces such as asphalt and concrete became increasingly popular in construction, and these impermeable surfaces have led to increased surface runoff during heavy or prolonged rainfall events, contributing to urban flooding.

Figure 1.1: Flooded section of Marcus Garvey Drive following heavy rainfall event on Thursday, June 8, 2023. (Our Today, 2024)

With the increase in extreme weather occurrences due to climate change, urban areas now must quickly adjust to the new reality of urban floods. Rising sea levels, variable rainfall, and unexpected storms are no longer distant concerns, but rather urgent challenges requiring innovative solutions. These changes put a huge strain on existing urban infrastructure, endangering not just the stability of urban areas but also the safety and well-being of residents. It is critical to evaluate and redesign our urban environments to increase resilience to the effects of climate change, with a particular emphasis on limiting the dangers associated with urban flooding.

Figure 1.2: Rate of infiltration on a greenfield site compared to urbanized site.

2 Gaps and Shortcomings in Jamaica's Urban Drainage System

Jamaica's diverse topography includes mountains, hills, valleys, and coastal areas. This varied terrain affects drainage patterns, with certain regions vulnerable to flash floods and landslides, while others are more likely to experience coastal erosion. A major concern is coastal erosion, especially in low-lying areas such as Kingston. Erosion can result in land loss, infrastructural damage, and changes in coastal habitats. Runoff from the ground can generate sedimentation, which can deteriorate water quality and make drainage even more difficult.

Jamaica's approach to drainage systems in urban areas has primarily emphasized rapid runoff and the efficient removal of stormwater. This 'fast and efficient' approach has typically involved the use of conventional, concrete-lined drains and underground pipe networks (*See Figure 2.1 Existing stormwater management drainage infrastructure*).

The drainage system throughout the Kingston and St. Andrew (KSA) area is illustrated in Figure 2.3, derived from Mona GIS. This figure highlights the various gullies within the KSA region and indicates where the drainage outflow points are located. The map provides a comprehensive overview of the drainage infrastructure, allowing for a better understanding of how water flows across the area. Understanding this network is crucial for identifying areas prone to flooding and for planning improvements to mitigate such risks. Additionally, it helps stakeholders and planners determine where SuDS components could be most effectively implemented to enhance stormwater management and reduce flood risks.

Figure 2.1: Existing stormwater management drainage infrastructure – section of Sandy Gully (left) and a concrete-lined drain (right) within the Kingston Metropolitan area, specifically in Barbican St. Andrew.

However, not much emphasis is placed on sustainable urban drainage practices that can contribute to improved resilience and environmental sustainability when faced with the challenges from urbanization coupled with climate change. One noteworthy aspect is the limited integration of Nature-based Solutions (NbS) or green infrastructure elements, such as vegetated swales and permeable surfaces in development plans. A NbS is described as an action that uses natural features and processes to protect, conserve, restore, use sustainably, and manage natural or modified ecosystems to address socio-environmental challenges while providing measurable co-benefits to both people and nature *(U.S. Department of the Interior, 2024).* These NbS can significantly enhance drainage systems by reducing surface runoff, improving water quality, and providing habitats for local wildlife.

While the historical approach successfully mitigated immediate flood risks, it often overlooked the long-term environmental and ecological consequences. The focus is on water removal, with less attention given to water quality, groundwater recharge, and the preservation of natural ecosystems. In the face of climate change, urbanization, and the growing recognition of the importance of sustainability, there is a growing imperative to transition toward a more balanced and ecologically aware approach to urban drainage. Integrating green infrastructure practices into drainage planning is seen as a means of achieving both flood resilience and environmental sustainability.

The incorporation of SuDS practices, including green infrastructure components, has become a central tenet in modern drainage system design and urban planning. These practices aim to strike a balance between efficient stormwater management and ecological sensitivity. As Jamaica's urban areas continue to develop, there is a growing need to transition from historical drainage practices toward more sustainable and ecologically responsible approaches to ensure the resilience of urban areas in the face of climate-related challenges.

To address these challenges, it is essential to assess the current state of the drainage infrastructure, consider the impacts of climate change, and implement sustainable urban drainage solutions that can improve resilience, reduce the risk of flooding, and enhance environmental sustainability. This involves both upgrading existing infrastructure and incorporating NbS into existing as well as future urban development planning.

Jamaica’s urban drainage system faces several gaps and shortcomings that need to be addressed to achieve alignment with international best practices and SuDS standards. Improved infrastructure, real-time monitoring, SuDS integration, policy coordination, water quality management, and public awareness are areas where Jamaica can make significant progress. Enhancing the resilience of urban areas and promoting sustainable water management are essential for addressing the challenges posed by urbanization and climate change. Regular assessments and investments are crucial to bridge the gaps and enhance the country’s urban drainage system.

Some of the prominent issues include:

1. **Climate change** is increasing the frequency and intensity of extreme weather events in Jamaica, exacerbating drainage challenges. Jamaica’s urban areas often lack adequate drainage infrastructure to handle heavy and prolonged rainfall events *(Smith, 2022)*. Many older urban centers were not originally designed to handle the demands of modern urbanization in addition to the effects of climate change. Many critical infrastructure components, such as roads

and other utilities are vulnerable to flooding and erosion. *(See figure 2.2 for further details concerning areas at risk).*

2. Drainage channels and water bodies are **susceptible to sedimentation and pollution** from urban runoff, which can harm aquatic ecosystems and affect water quality. In the absence of regular maintenance, the buildup can also obstruct the free flow of water, increasing the risk of localized flooding during heavy rain events *(PeopleFirst, 2022).*

3. While there has been a growing emphasis on SuDS principles, the **full integration of SuDS practices in urban development remains inconsistent**. This gap results in missed opportunities to manage stormwater in a sustainable and effective manner, mitigating the impact of urbanization and climate change. *(Jacobs, 2023)*

4. A lack of **public awareness and engagement** regarding urban drainage and SuDS hinders the broader adoption of these practices. Greater public education is required to encourage community involvement and support for sustainable drainage initiatives. *(Energy, 2023)*

Comparison with International Best Practices and SuDS Standards

1. International best practices emphasize the importance of comprehensive urban drainage planning that **considers the entire urban water cycle**. This includes collecting, conveying, treating, and reusing stormwater to achieve holistic water management. *(CIRIA, 2023)*

2. Jamaica should align its approach with this principle.

3. The establishment of **real-time monitoring networks for rainfall and river flow is critical**. These networks provide timely data to assess the state of drainage systems and take proactive measures during weather events. (*Energy, 2023*)

4. The promotion of the full integration of SuDS in urban development is an international best practice which stress the importance of **green infrastructure, permeable surfaces, and decentralized drainage solutions** to manage stormwater effectively and enhance urban resilience. *(Energy, 2023)*

5. There needs to be effective coordination among government agencies to ensure that **policies and regulations align** with international best practices and SuDS standards *(Fioretti et al., 2020)*. This is because a harmonized policy framework can support sustainable drainage design.

Environmental Impacts of the Current Drainage System

The current drainage system in Jamaica has significant environmental impacts, including flooding, erosion, pollution, and habitat degradation as mentioned above. However, there are ample opportunities for enhancing environmental sustainability through the integration of SuDS, green infrastructure, floodplain management, water quality improvement, community education, and policy alignment.

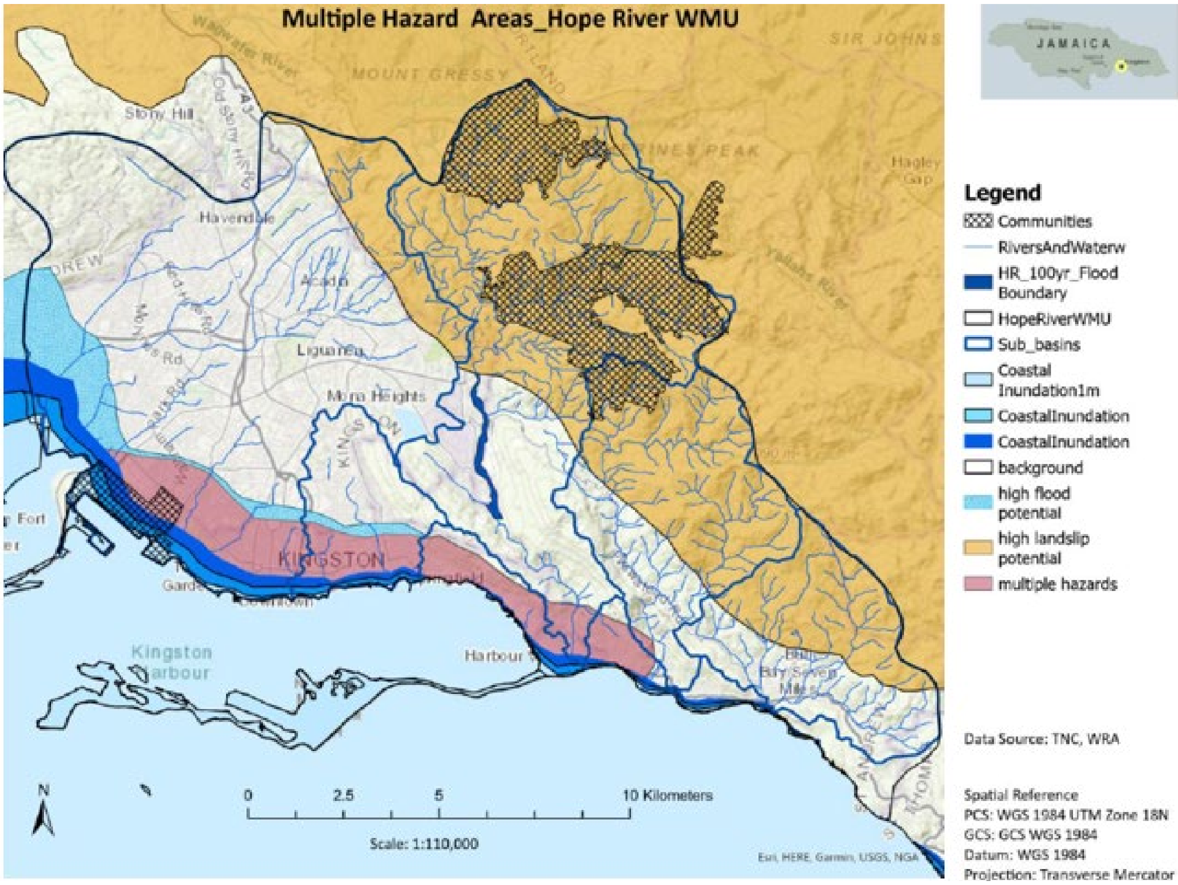


Figure 2.2: Multiple hazard risk areas in the Hope River Watershed Management Unit (CityAdapt, 2023)

Figure 2.3: from Mona GIS showing the different gullies within the KSA area and the drainage outflow points (Mona GeoInformatics Institute, 2023).

3 Overview of Sustainable Urban Drainage Systems (SuDS)

3.1 What are SuDS?

Sustainable Urban Drainage Systems (SuDS), often referred to as Low Impact Development (LID) in some regions, represents a holistic and nature-based approach to urban drainage. They are designed to manage surface water runoff in a manner that mimics natural processes, ensuring the sustainable and controlled flow of stormwater.

Traditional stormwater management systems use concrete infrastructure, such as drains and pipes. This can result in increased runoff, water pollution, and urban flooding.

In contrast, NbS offers a more environmentally friendly and resilient approach to stormwater runoff control. The incorporation of green infrastructure in urban areas is a key aspect of NbS in stormwater management. Some examples of NbS that aids with the absorption and the reduction of the volume of runoff entering drainage systems are **green roofs, permeable pavements, and urban green spaces**. The use of vegetation plays an important role in preventing water runoff from overwhelming the drainage systems. Wetlands, bioswales, and retention basins are also designed to control stormwater by capturing, absorbing, and filtering water runoff. They also aid with the removal of pollutants, and allow water to slowly percolate into the ground, mimicking the natural hydrological processes.

The integration of green infrastructure and natural elements into urban planning allows communities to enhance their ability to adapt to climate change and reduce the risk flooding. NbS does not only contribute to effective water management but also to the overall resilience of urban areas. They provide benefits such as increased biodiversity, improved air quality, and enhanced recreational spaces, creating more liveable and sustainable urban environments.

The SuDS approach involves slowing down and reducing the quantity of surface water runoff from a developed region to manage downstream flood risk and reduce the danger of pollution caused by that runoff. This is accomplished by:

- harvesting,
- infiltrating,
- slowing,
- storing, conveying,
- and treating runoff on site.

Where possible, on the surface rather than underground. SuDS are not only environmentally friendly, but they also fulfil multiple functions facilitated by their various components.

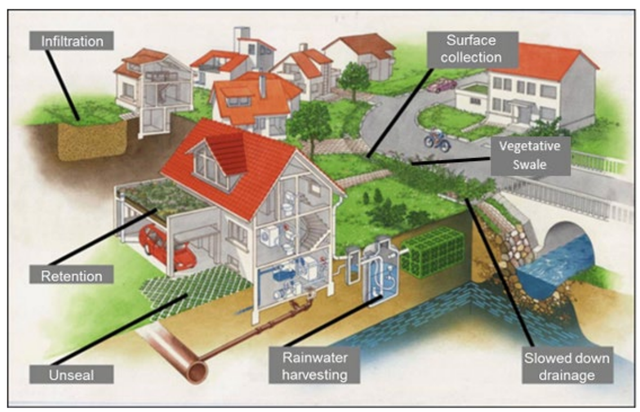


Figure 3.1: SuDS approach in managing stormwater runoff. (Sieker,2024)

3.2 SuDS Concepts

There are several concepts used to manage stormwater runoff which includes:

1. **Mimicking of natural drainage:** the collection of rainfall in features at or near the surface which slows and filters water as in nature.
2. **Management train:** refers to a sequence of SuDS techniques that collaboratively work to control the volume and flow of storm water runoff.
3. **Source control:** managing rainfall as close as possible from the initial area of the rainfall event.
4. **Sub-catchments:** smaller drainage areas within larger catchment areas that handles runoff locally.

3.3 Functions of SuDS

Rainwater Harvesting Systems (RHS)

The system seamlessly integrates multiple components to effectively capture and store rainwater, enabling its optimal utilisation within the surrounding environment.

Permeable Surfacing System

These surfaces possess the ability to facilitate the passage of water, thereby mitigating the adverse effects of runoff and the potential for flooding.

Infiltration System

This element of the system plays a vital role in facilitating the efficient movement of water into the ground. Additionally, it can also serve as a temporary storage solution, allowing for a gradual and controlled release of water into the soil.

Conveyance System

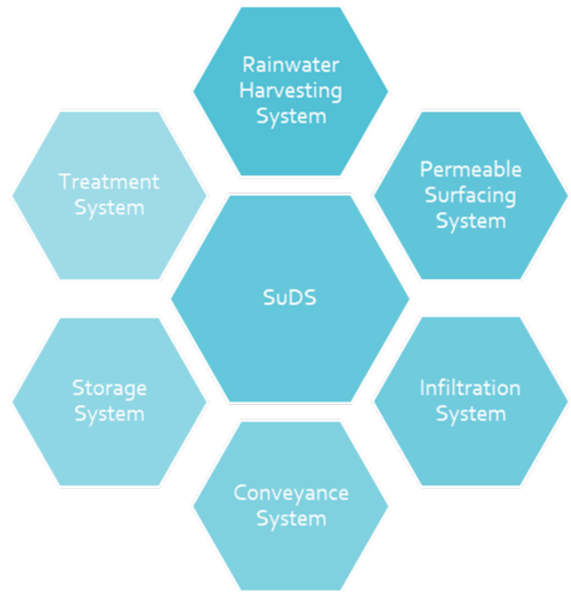
This particular component facilitates the management of water flow in downstream storage systems, enabling precise control over both flow rates and volume.

Storage System

Storage systems, also known as runoff control components, play a crucial role in managing the flow and volume of rainwater. These systems effectively collect and store rainwater, allowing for its controlled release over time.

Treatment System

The treatment components play a crucial role in facilitating the removal or degradation of contaminants present in rainwater runoff.



3.4 SuDS Components or Structures

SuDS functions are often performed by a variety of components or structures. These components may be used separately or in various combinations to perform various functions. Among the components are:

Permeable Surfaces

Utilising innovative materials such as permeable pavements or porous asphalt can effectively facilitate the infiltration of rainwater into the ground, thereby mitigating surface runoff and augmenting the replenishment of groundwater resources. These surfaces are highly conducive to construction and development, facilitating the creation of roads, pedestrian-friendly areas, and parking lots, all the while enabling efficient water infiltration into the soil or underground storage systems.

Wetlands and Ponds

Incorporating the implementation of constructed wetlands and retention ponds can greatly enhance the overall ecological infrastructure of the area. These innovative systems serve as natural filtration mechanisms, effectively capturing and containing pollutants. Additionally, they foster a thriving biodiversity, contributing to the preservation and promotion of various species. Furthermore, these strategically placed wetlands and ponds play a crucial role in flood control, mitigating the adverse impacts of excessive water accumulation.

Infiltration Trenches

Incorporating underground trenches filled with stone or aggregate as a means of effectively managing stormwater is a strategic approach that facilitates gradual infiltration into the ground. This method serves to bolster the replenishment of groundwater resources.

Green Roofs

Installing vegetation on rooftops to reduce stormwater runoff and offer insulation benefits, contributing to reduced energy consumption. Green roofs reduce runoff by absorbing and holding rainwater, enhance water quality by filtering contaminants, and help to regulate peak flows during heavy rainfall. They also encourage biodiversity, improve environmental quality, and offer an environmentally ecofriendly alternative to urban stormwater management. Green roofs contribute to energy efficiency by acting as natural insulation, reducing heat transfer through the roof, and providing a cooling effect through evapotranspiration. This lowers the demand placed on Heating, Ventilation, and Air Conditioning (HVAC) systems in buildings and ultimately saves energy.

Bioretention systems

Bioretention systems, also known as environmentally friendly stormwater management practises, have been strategically developed to capture, treat, and manage rainwater runoff. These systems are designed to allow the rainwater to temporarily pond, providing an opportunity for it to undergo filtration through the vegetation and soil. These innovative stormwater management features are commonly referred to as rain gardens, bioretention basins, or biofiltration systems.

Detention Basins

Landscaped depressions, also known as rainwater collection basins, are strategically designed to efficiently gather drained rainwater. These basins are specifically engineered to regulate the flow of water, enabling them to gradually fill up and effectively provide attenuation. The basins in question typically experience arid conditions, except during periods of immediate precipitation.

Vegetated or Bio Swales

Constructing landscaped channels with native vegetation to slow, filter, and absorb stormwater runoff, improving water quality and providing habitat for wildlife.

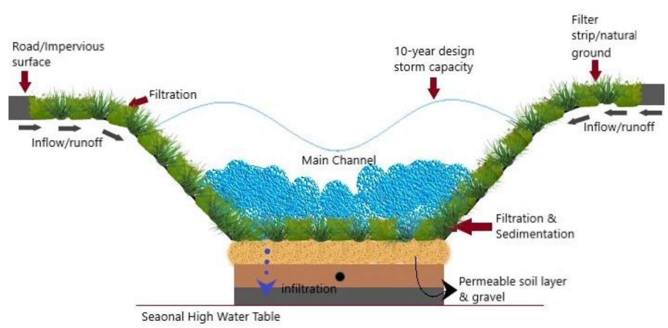


Figure 3.2: Reproduction of a Vegetative Swale. (Ekka et al, 2020)

3.5 Key Characteristics of Sustainable Drainage Systems

SuDS are systems that are designed to manage surface water runoff in a more environmentally friendly and sustainable manner. The key characteristics are:

❶

SuDS mimic or replicate natural drainage processes by **using natural processes like infiltration, evaporation, and storage**. The reliance on this natural process is however reduced through the alteration of the natural landscape by way of land development and urbanization.

❷

SuDS **manages water as close to its source as possible.** Land use priorities or preferences may affect the source control measures implemented.

❸

SuDS promotes the **infiltration of water into the ground.** Infiltration is limited in areas with poor soil conditions or contamination which contributes to the overall effectiveness of SuDS.

❹

SuDS **incorporates vegetation and green spaces**. The maintenance of these green infrastructures will require adequate management to prevent decline.

❺

SuDS includes features to **treat and filter surface water**. The capacity of SuDS exceeds during extreme weather events which may pose a challenge to ensuring consistent water quality.

❻

SuDS are designed to be **resilient to climate change**. To adequately adapt to evolving climate conditions will require continuous monitoring and modifications, which may require substantial resources.

❼

SuDS serve multiple purposes beyond drainage, such as enhancing biodiversity, providing amenity space, and improving water quality. The integration of multiple functions of SuDS may lead to complex designs and increased maintenance requirements.

3.6 Specificities to urban spaces

It is critical to seamlessly integrate SuDS features with urban design and optimize land use by creating multi-functional spaces. It is also important to engage communities through education and outreach to build awareness and foster community involvement. Consideration should also be given to the adaptation to existing infrastructure challenges and addressing urban heat island effect. Offering incentives to private property owners or developers is a strategic approach in the implementation of SuDS in urban spaces to promote widespread adoption.

The employment of efficient stormwater management solutions in high-density areas critical and should be designed with flexibility for dynamic environments in urban spaces.

3.7 SuDS Initiatives in Jamaica

The Government of Jamaica has completed a comprehensive national drainage plan aimed at improving the country's drainage system (*Office of the Prime Minister, 2019).* The initiative is being carried out to mitigate flooding issues in flood-prone areas, including the Corporate Area and towns such as May Pen, Santa Cruz, and Port Maria. The primary beneficiaries of the new drainage plan include the Tinson Pen, Maxfield Avenue Areas, St. Andrew West Central and St. Andrew East Central constituencies. These locations are often prone to heavy flooding during rainfall events and need significant improvements, to ensure increased resilience against adverse weather conditions.

Whereas there are no direct SuDS initiatives in Jamaica, we see where there is an increase with the number of Developers incorporating various components of SuDS in their designs such as permeable pavements and green spaces to not only aid with reducing flood risk but also contribute positively to the well-being of communities and the preservation of Jamaica's natural ecosystems.

One of the more recent projects being carried out by the Jamaica Social Investment Fund (JSIF) under the Disaster Vulnerability Reduction Project (DVRP) valued over 245 million dollars is the Myton Gully drainage improvement project. The project is aimed at mitigating flooding in the St Catherine community and surrounding areas for over 37,000 residents. (*Linton, 2023*)

3.8 Policy and Legislative Framework

The drainage guidelines for proposed developments were formulated by the National Works Agency (NWA), Water Resource Authority (WRA) and Office of Disaster Preparedness and Emergency Management (ODPEM) under their respective ministries as stakeholders in the national housing development process. The guidelines set out the minimum information to be included in the preparation of hydrologic and hydraulic design reports on drainage systems for proposed sub-divisions *(The Ministry of Transport, Works and Housing et al., 2015).*

The guidelines do not explicitly outline a framework for SuDS; however, the design requirements emphasize the incorporation of water detention or retention features to reduce the increase of run-off from the development. Furthermore, the guideline outlines measures to be utilized for sediment control during construction through the use of sediment control fences such as berms, silt fences, sumps, swales, sediment/siltation control basins etc. These methods are used to prevent sediments from infiltrating or clogging sinkholes and depression areas. Waterways with high flow discharge rates are directed to use check dams, erosion control aprons, and similar structures in areas vulnerable to construction-related disruption. These interventions are intended to reduce high flows while also successfully trapping and retaining sediments.

Specific development orders are issued for regions or areas in Jamaica. The development orders also do not outline a framework for SuDS. It does however outline the requirements for land use and development, including drainage and water management standards. They include provisions for green spaces due to their environmental, recreational, and aesthetic benefits.

Furthermore, green spaces are seen as a sustainable design practice that play a crucial role in managing stormwater runoff through absorption and infiltration.

3.9 Design Objectives

SuDS have the potential to offer and expand green space within developments, as well as connect to larger green networks. It is essential for surface water management to be considered from the beginning of the development planning process and throughout as this will impact not just the site layout and design, but also the use and features of urban spaces. An interdisciplinary team working together from the beginning of a development project ensures that all aspects of the project are considered cohesively. This not only results in more thorough and sustainable designs, but it also speeds the planning and implementation processes.

SuDS provide a diverse toolkit for effective surface water management by way of offering cost-effective solutions. The successful integration of SuDS relies on selecting and implementing components that aligns with the unique characteristics of the site, the proposed development, and the surrounding context. When utilizing SuDS, careful consideration should be given to the site's topography, soil composition, and existing drainage patterns.

The benefits associated with SuDS fall into four main categories: water quantity, water quality, amenity, and biodiversity, collectively referred to as the four key aspects of user design. *(Woods-Ballard et al., 2015*)

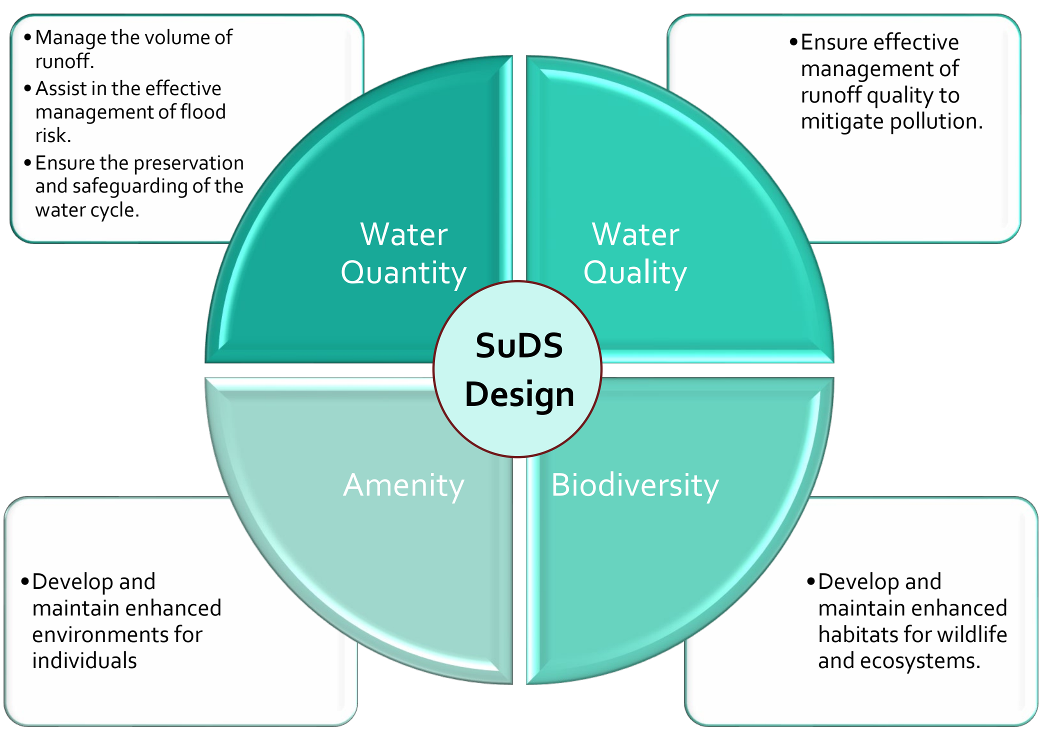


Figure 3.3: SuDS Design Objectives (Woods-Ballard et al., 2015).

3.9.1 Water Quantity Design Objective

The primary aim of this design objective is to regulate the volume of water runoff, thereby facilitating the efficient handling of flood events and preserving the integrity of the natural water cycle. It will take into consideration the rate of runoff, that is how fast runoff is discharged from the site and how much runoff is discharged. Flooding is reduced with SuDS that are meant to moderate the rate and quantity of water discharge. The natural water cycle is not only conserved in this manner, but the risk associated with the erosion of banks and riverbeds, which increases sediment loads and degrades the ecological health of the watercourse, is also reduced. An effective water quantity design strategy must also account for potential downstream impacts to prevent exacerbating flood risks in other parts of the catchment area.

It is essential to control the peak rates of surface water discharge because it can lead to the likelihood of flooding and erosion. In developed areas, less water can penetrate the ground due to the impermeable surfaces as mentioned previously. This causes the water to drain off the surface at a much faster rate than a greenfield site. To limit the rate of this rapid runoff, the incorporation of SuDS that slows and stores the runoff onsite and then discharges it is essential. It is advantageous to design drainage systems that capture and use surface water because this helps to reduce runoff volumes from the site and allows the water to be put to good use.

Figure 3.4: Predevelopment discharge rate compared to the post development discharge rate (Simplified Civil, 2022).

Efficiently designed drainage systems are critical in reducing runoff volumes on a given site, hence contributing to sustainable water management techniques. These systems capture and harness surface water, which not only helps to minimize erosion and flooding, but also provides an opportunity to recycle the water for productive applications. This integrated approach to drainage, whether for irrigation, landscaping, or other purposes, not only improves environmental sustainability but also maximizes the use of our natural water resources.

Furthermore, an efficient drainage system reduces stress on public infrastructure, lowers maintenance costs, and minimizes disruptions caused by flooding or water damage. By effectively managing stormwater, these systems help prevent costly repairs and extend the lifespan of roads, buildings, and other critical infrastructure. Additionally, reducing the risk of flood-related damage contributes to greater safety for the community and supports uninterrupted business operations, leading to a more robust local economy.

Key principles

- protection of people and property on the site from flooding
- Protection of areas up and downstream in the catchment from the impact of a development on flood risk.

Water quantity design considerations:

❶

Using surface water runoff as resource, harvesting, storing, and reusing surface water runoff.

❷

Preservation, protection, and enhancement of natural water systems on sites. Incorporating natural drainage into the design and development of sites.

❸

Designing systems to manage flood risk onsite. Stormwater/rainwater should be managed at it point of contact and system implemented along the course to manage runoff downstream during frequent rainfall event and during extreme rainfall events such as a storm or hurricane.

❹

Designing of systems for adaptability to environmental changes.

Design criteria for managing water quantity

Peak Flow Reduction & Runoff Volume Control

- Design measures to **reduce peak flow rates** during rainfall events that aim to mimic natural hydrological conditions. Incorporate detention basins, retention ponds, and other storage systems that attenuate and control the release of stormwater.
- Integrate green infrastructure that aids in controlling and managing the volume of stormwater runoff.
- Minimize the number of impervious surfaces in development projects to reduce surface runoff and encourage the use of permeable materials and open space in urban planning.

Climate Resilience

- Consider climate change projections and variability in designing stormwater management systems. Plan for increased intensity and frequency, allowing for adaptability and resilience.

Regulatory Compliance

- Adhere to local, regional, and national regulations and guidelines related to stormwater management.

3.9.2 Water Quality Design Objective

The water quality design criteria take into consideration the integration of SuDS that are capable of effectively treating and purifying runoff. To ensure the protection of both surface waters and groundwaters, the potential risks associated with the site should be evaluated to ensure the implementation of appropriate measures. Risks can be effectively mitigated to acceptable levels, thereby safeguarding the receiving environment. This not only helps to minimise flood risk and maintain the integrity of water resources but also contributes to the overall ecosystem within a development.

Interception, as a method of pollution control, plays a crucial role in retaining pollutants within surface vegetation, soil, or other material layers, allowing for natural degradation. By employing pervious surfaces and vegetated collection systems, this approach effectively hinders runoff and mitigates the associated pollution load. The utilization of interception techniques contributes to a reduction in the overall pollution discharged to surface waters over time, promoting environmentally sustainable practices in managing water quality. SuDS components such as vegetated swales, bioretention basins, and constructed wetlands can aid with effectively reducing the levels of contaminants in water runoff by way of natural filtration, sedimentation, and biological processes.

Water quality design considerations:

❶ Implementing measures that control and reduce the volume and speed of stormwater runoff to reduce the risk of soil erosion and pollution transportation.

❷ Designing of systems for adaptability to environmental changes.

❸ Include measures that promote infiltration, allowing the stormwater to percolate through the soil which helps with filtering contaminants.

❹ Incorporating vegetated buffer zones along water bodies to capture and filter pollutants.

❺ Utilizing constructed wetlands or biofiltration methods to encourage microbial activities that breaks down pollutants.

❻ Implementing monitoring programs and planned maintenance to ensure the optimum functioning of SuDS components.

Design criteria for managing water quality

Runoff Volume Reduction

- Aim to reduce the volume of stormwater runoff by incorporating permeable surfaces, green roofs, and infiltration practices.

Green Infrastructure Sizing

- Size components based on the anticipated rainfall volume and intensity to handle stormwater effectively.
- Plan for overflow to prevent system failure during extreme rainfall events and design components with consideration for easy access and maintenance.

Vegetation Selection

- Choose vegetation in bio-retention areas and swales that is effective in capturing pollutants and promoting biological treatment.
- Ensure a sufficient hydraulic residence time in treatment features to allow for effective pollutant removal.

First Flush Management & Infiltration Rate

- Design systems to capture and treat the initial runoff (first flush) to address higher concentrations of pollutants in the early stage of rainfall.
- Determine appropriate infiltration rates for permeable surfaces and infiltration systems.
- Specify the expected efficiency of filtration systems.

3.9.3 Amenity Design Objective

The proposed design criteria aim to seamlessly integrate water elements into the fabric of the urban landscape. Utilising surface water management systems in urban design can greatly enhance the aesthetic appeal and recreational potential of the landscape, while simultaneously fostering a healthier and more sustainable environment.

Adequate surface water management strategies can also yield multiple advantages, including temperature reduction, habitat creation, environmental education opportunities, and fostering a strong sense of community and prosperity. SuDS present unique prospects for enhancing the visibility and audibility of water as it gracefully traverses the landscape

.

Amenity design considerations:

1. Maximising functionality of the system.

2. Designing of systems for adaptability to environmental changes.

Design criteria for managing water quality

Multifunctional Spaces

- Design features that serve multiple purposes.
- Design features that support biodiversity and harmonizes with the natural and built environment.

Visual Integration

- Use design elements that complement the existing aesthetics of the area.
- Select low-maintenance plantings and materials that require minimal upkeep.

Green Infrastructure

- Integrate more green spaces.
- Use vegetation that supports both functionality and aesthetics.

3.9.4 Biodiversity/Amenity Design Objective

The pursuit of this design objective is commonly coupled with the amenity design objective. The integration of various components within SuDS greatly contributes to the overall enhancement of urban living, creating a vibrant and sustainable environment that promotes health and well-being. The primary focus of these design objectives is to ensure that the systems are aesthetically pleasing, functional, and harmonious with the surrounding environment, thereby enriching the local communities. Incorporating well-designed systems into the urban landscape is crucial for a comprehensive and visionary approach.

These systems serve not only aesthetic purposes but also provide valuable opportunities for recreational activities. The implementation of these systems can yield numerous advantages for the community. These include enhancing the health and overall well-being of residents, ensuring a secure and reliable water supply, promoting biodiversity and ecological balance, contributing to the improvement of air quality, and assisting in the regulation of temperature and reduction of carbon emissions. To maximise the delivery of biodiversity value, it is crucial to consider the implementation of various strategies. These strategies can range from small, isolated schemes to larger schemes that are seamlessly integrated within the broader environment. By adopting a comprehensive approach, we can effectively enhance biodiversity and promote its value in a sustainable manner.

Biodiversity design consideration:

1

Maximising multi-functionality of the system.

2

Systems that support and protect natural habitats, while enhancing visual character.

3

Systems that contribute to maintaining the ecosystems within communities.

4

Designing self-sustainable resilient systems for adaptability to environmental changes.

5

Designing self-sustainable resilient systems for adaptability to environmental changes.

4 SuDS Design Measures

Constructability

- Can be easily and safely constructed.

Maintainability

- Can be easily and safely maintained.

Cost-effectiveness

- The site meets service standards while maximising benefits at an affordable cost for both the developer and long-term maintenance.

Health & Safety

- The system is safe for residents, visitors, and those involved in its operation and maintenance.

4.1 Selection of SuDS component

The selection of the SuDS component will be contingent upon the desired design criteria, along with the level of integration between the surface water management system and the development and surrounding landscape *(The SUDS Manual, 2016*). Components can be designed in a myriad of ways, whether from a technical or visual perspective based on the strategic end goal of the system being implemented. Components can also serve dual purposes, typically dependent upon the magnitude of runoff event *(see table 4.1 below for a comprehensive overview of the design criteria that can be achieved by various components).*

The type of SuDS component plays a crucial role in the collection and management of water in urban areas. Water collection can occur over the ground surface, involving lateral collection, or be directed to specific points. Importantly, a single system component can serve one or more design criteria, depending on the strategic objectives set for the water management system. This adaptability underscores the versatility of SuDS in meeting diverse criteria and strategic goals within urban water management, emphasizing their effectiveness in addressing a range of environmental considerations.

Component Type	Collection mechanism	Design criteria					
		Water Quantity			*Water Quality*	*Amenity*	*Biodiversity*
		Peak Runoff rate	Runoff volume				
			Small events	Large events			
Rainwater harvesting system	Point		✓	✓		✓	
Green roof	Surface	x	✓		✓	✓	✓
Swale	Lateral		✓	✓	✓	✓	✓
Bioretention system	Point		✓	✓	✓	✓	✓
Trees	Point		✓		✓	✓	✓
Pervious Pavements	Surface	✓	✓	✓	✓	x	x
Attenuation storage tanks	Point	✓					
Detention Basin	Point	✓	✓		✓	✓	✓
Ponds/wetlands	Point	✓			✓	✓	✓

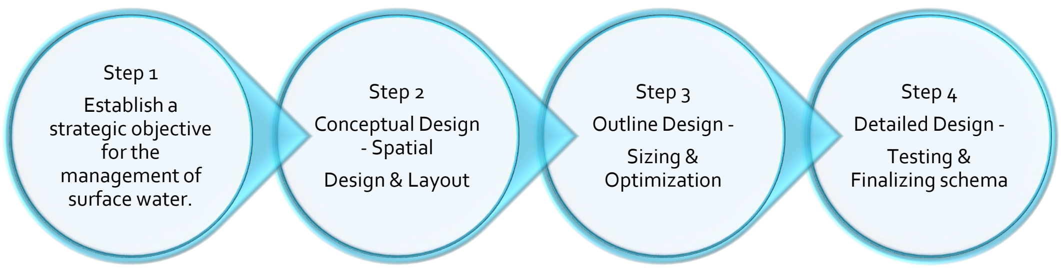
Table 4.1: SuDS component type, collection mechanism and associated design criteria. (Derived from Woods-Ballard et al., 2015).

✓ - Likely valuable contribution to delivery of design criterion
x - some potential contribution to delivery of design criterion

5 SuDS Design Process

When contemplating designs for sustainable drainage systems, this should begin as early as possible, from the feasibility stage in a project. When incorporated into the early development vision, water features can offer a spectrum of creative possibilities ranging from character to layout of the space. By utilizing water to mold and enrich the development space, these features can optimize functionality, enhance value, and increase the overall appeal of the development. It is important to acknowledge that the SuDS design process is an integral component of the broader development and land use process. Consequently, it may occasionally necessitate revisions or iterations in order to achieve a satisfactory outcome.

Ideally, the SuDS design process should go as follows in the chart below:



5.1 Step 1: Establish a strategic objective

To define a specific or targeted goal related to the management of surface water runoff, how the water will be controlled throughout the space. In step 1 there should be discussions with the relevant stakeholders such as community members, local planning authorities, and other regulatory agencies. It is very important to engage the community effectively, facilitating participatory approaches and consultations. The integration of diverse perspectives highlights the importance of a gender-inclusive framework. Collaboration with local planning authorities and regulatory agencies is crucial to align SuDS initiatives with overarching urban development goals and regulatory frameworks.

Designers and Developers should use the local planning guidelines and policies to guide the objectives. Step 1 will also see the undertaking of relevant environmental impact assessment (EIA) and flood assessment as needed. This process allows for early identification of potential environmental risks, enabling a proactive approach to mitigation. As a result, the steps outlined contribute to a more sustainable and resilient urban environment, offering benefits for both people and the natural ecosystem.

Objectives should include but not limited to:

- Flood risk management
- Water quality management
- Community, social and amenity planning. This should take into accountwell lit and secured areas that allows for adequate mobility.
- Climate resilience requirements
- Habitat and biodiversity strategy
- SuDS long-term maintenance plan
- Regulatory compliance

Surface water management should be considered early in the design process so that designers can employ SuDS that respond to the local context and character, enriching both the natural and built environments. Surface water management systems can be utilized to boost development viability by achieving the defined design criteria by completely integrating surface water management with the larger development objectives and recognizing all space as potentially multi-functional.

5.2 Step 2: Conceptual design

In the realm of spatial design and layout, the conceptual design stage encompasses the crucial phase of the design process wherein fundamental ideas, themes, and overarching concepts are developed prior to delving into the intricacies of planning and execution. The initial phase holds the utmost significance in laying the groundwork for a project, be it in the realm of architectural design, urban planning, or sustainable urban drainage.

Prior to commencing the design process, it is necessary to identify and assess the site for the SuDS scheme. This entails identifying and comprehending the relevant features of the site and the surrounding area factors that may influence design possibilities. Following that, determine the key elements of the proposed development that may influence the design criteria and design possibilities for the implementation of potential system components to manage urban drainage.

Areas of assessment for site characterisation

1. **Site topography**

This aids with identifying the appropriate natural routes for surface runoff to efficiently drain the site.

2. **Existing land use and site infrastructure**

The type and intensity of land use have a significant impact on the generation of surface water runoff. On a brownfield site, it is important to document and map existing infrastructure to determine what infrastructure could or should be reused in the SuDS scheme.

3. **Existing flow routes and discharge points**

The extent to which the existing flow routes and discharge points will be affected by development is important to determine the best way to integrate the SuDS components.

4. **Flood risk**

The identification of pre-development flood risks is crucial to determine how it will be affected or be influenced by any surface water management. Incorporate climate change scenarios, particularly those predicting increased rainfall and altered weather patterns, into the design process to address and mitigate the flood risk associated with changing climate conditions.

5. **Potential for infiltration**

Characterization of the site region is critical, especially in determining its potential for infiltration. This entails assessing regions based on their suitability for infiltration, classifying them as having good, poor, or no infiltration potential. This analysis tries to identify zones where infiltration could efficiently manage surface water runoff, places suitable for deploying interception systems with limited infiltration capacities, and zones where infiltration is either not practicable or should be avoided for a variety of reasons.

Areas of assessment for development characterisation

1. **Proposed topography and land use**

Topographic changes for development, such as raising land for flood risk management or contaminant remediation, must be carefully examined. The scale of the development, building density, projected land uses, and landscape strategy will all have an impact on the overall design approach.

2. **Proposed site infrastructure**

Planned infrastructure should be mapped and evaluated for its impact on the SuDS design. Early consideration of SuDS may allow for the flexibility to route planned services around SuDS locations.

3. **Proposed flood risk management strategy**

An assessment should be completed to determine how surface water management for the site can be affected by or affect the flood risk management strategy.

4. **Proposed maintenance plan**

The future maintenance of the SuDS should be considered as well as the likely level of maintenance (See Section 6: Monitoring and Evaluation Framework).

5.2.1 Establish SuDS design criteria

Create a comprehensive set of SuDS design criteria for the system, with the goal of meeting each criterion (water quantity, water quality, amenity, biodiversity) to the highest practicable extent possible for the site. Consider the strategic surface water management objectives and include site and development characterization findings.

5.2.2 Identify possible points of discharge

Prioritize the destination of surface water runoff and examine the environmental restrictions. Consultations should be made on the existing sewage capacity for any potential constraints or opportunities for connection.

5.2.3 Define surface water sub-catchments and flow routes

The definition of sub-catchments and flow routes is a linked process. Each sub-catchment is expected to provide interception for impermeable areas. Where practical, the runoff should be treated, and flow and volume control should be incorporated with infiltration employed where practical.

5.2.4 Select SuDS components

The selection of SuDS components is determined by design criteria and the integration of the surface water management system with the development and its surrounding landscape. (See table 4.1: SuDS component type, collection mechanism and associated design criteria.).

Following the design of the preliminary scheme for the site, the complete plan should be thoroughly reviewed against the defined design criteria, maybe using indicators if available (See Section 6: Monitoring and Evaluation Framework). SuDS components should be re-examined if the design falls short of achieving the criteria or fails to optimize benefits. This comprises looking into better alternatives or changing the design of components to increase their worth to the development.

5.3 Step 3: Outline design

The initial phase of the design process where key parameters, dimensions, and overall proportions of a system or structure are determined. During this stage, designers create a broad framework or outline that establishes the basic characteristics and scale of the design. The emphasis is on defining the structure's size and conducting preliminary optimization to meet specified criteria.

The outline design should be developed alongside the agreed layout and design of the development, and landscape and building characteristics. The outline design will confirm how the SuDS will function, the scale, depth, relative levels, appearance and character of the SuDS. The key steps in the outline design are:

5.3.1 Size SuDS components

Determine the appropriate dimensions, capacities, and specifications for SuDS elements within the associated development or construction site.

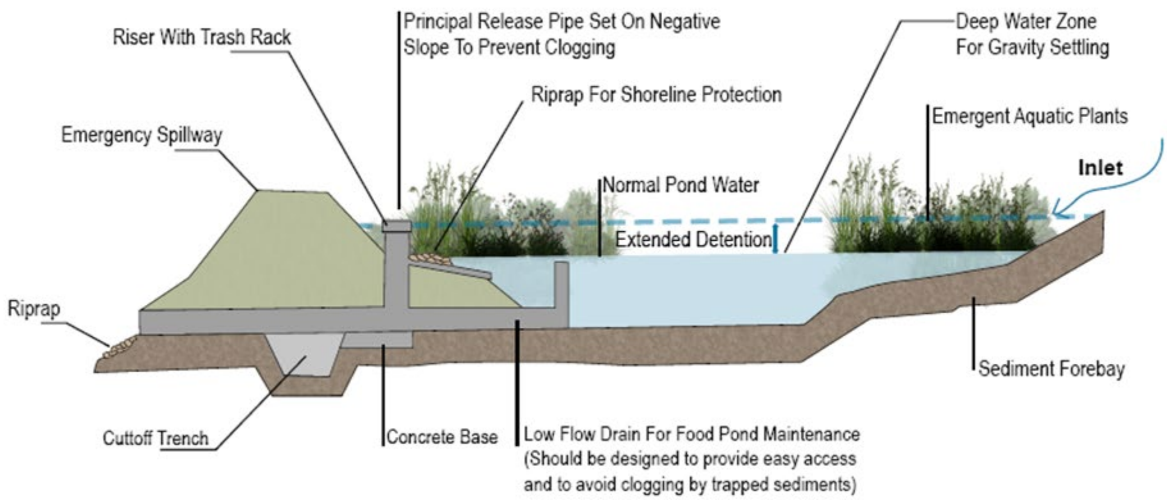


Figure 5.1: Section through a retention pond
Source: Donia Gohary, Urban Designer/Landscape Architect

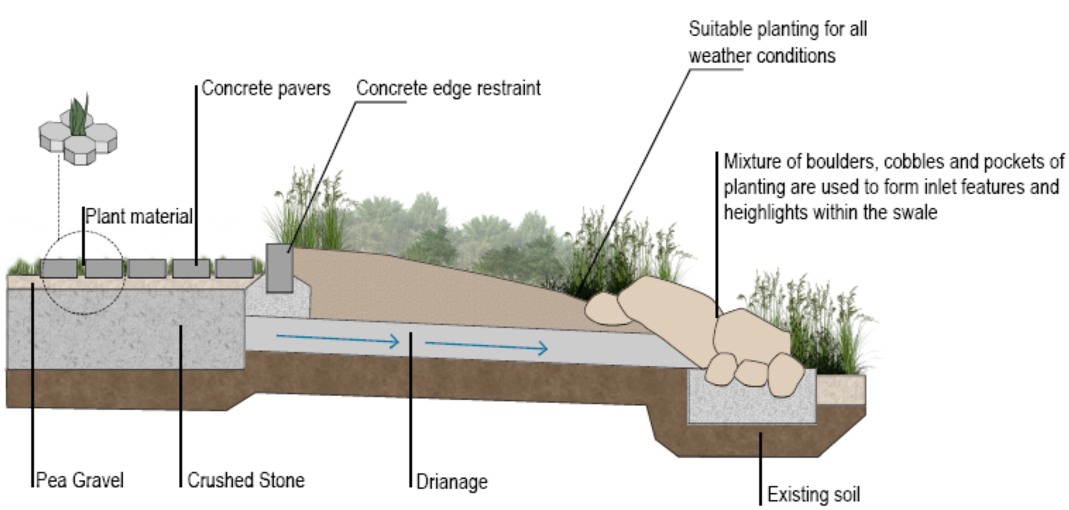


Figure 5.2: Section through permeable pavement
Source: Donia Gohary, Urban Designer/Landscape Architect

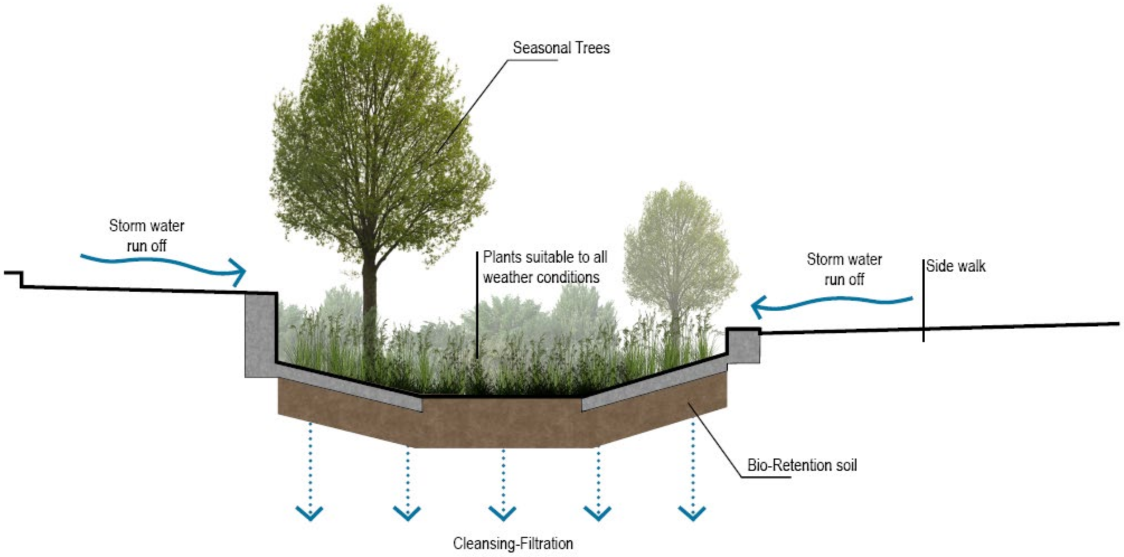


Figure 5.3: Section through a bioswale
Source: Donia Gohary, Urban Designer/Landscape Architect

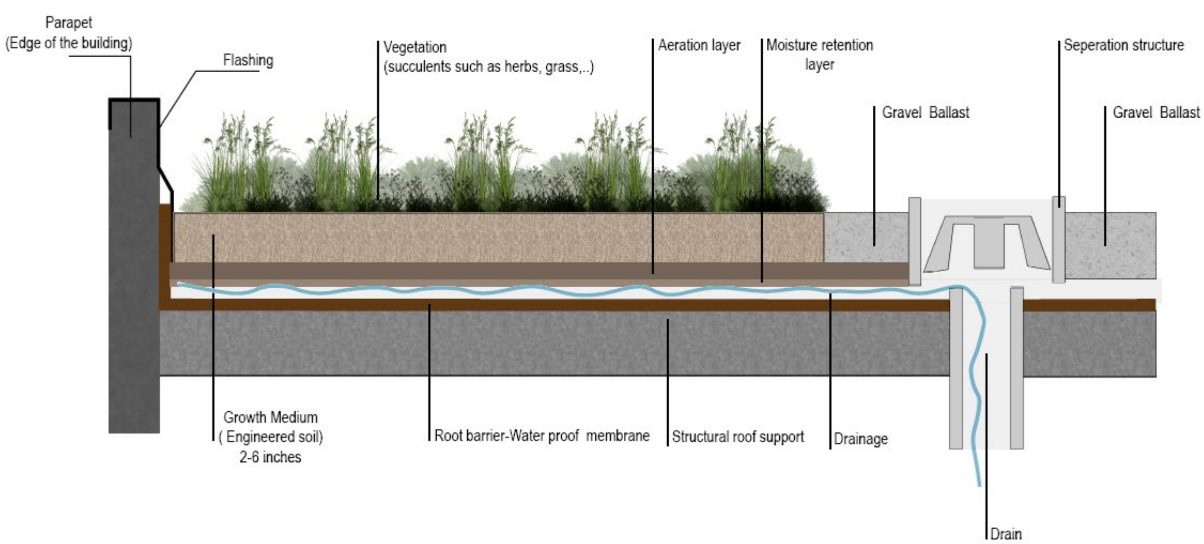


Figure 5.4: Section through a green roof
Source: Donia Gohary, Urban Designer/Landscape Architect

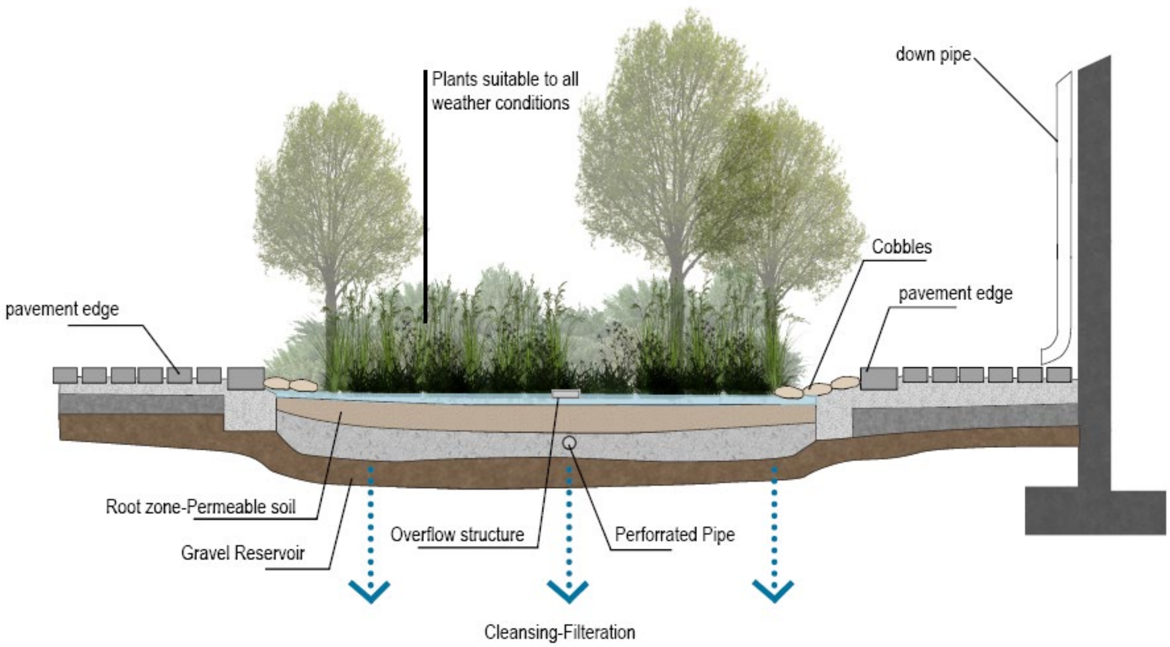


Figure 5.5: Section through a rain garden
Source: Donia Gohary, Urban Designer/Landscape Architect

5.3.2 Develop design at sub-catchment scale

Plan and specify the components of the stormwater management system for a specific subset or subdivision of a larger drainage or catchment area.

The individual SuDS components should be sized, and their designs refined. Any assumptions made at conceptual design stage, such as infiltration capacities, groundwater levels and existing sewerage infrastructure and capacities, should be confirmed, using robust evaluation methods. This stage involves detailed modeling and analysis to ensure the sub-catchment design can handle the expected volumes of stormwater without causing overflow or localized flooding. Additionally, the designs must account for both current conditions and potential future changes, ensuring flexibility and adaptability in the SuDS system. It's essential to ensure proper coordination with relevant stakeholders, including local authorities and environmental agencies, to address any regulatory requirements and community concerns.

5.3.3 Check design feasibility

It is important to thoroughly assess the feasibility and ease of maintenance of the proposed SuDS scheme.The SUDS design must clearly show how runoff is collected and cleaned before it enters the hierarchy of storage for the development and then how it flows to the outfall for the site.

5.4 Step 4: Detail Design

The detailed design stage is an essential phase in the project development process, which comes after the initial concept and outline design phases. During this phase, the comprehensive design is further developed, and precise designs are generated to provide guidance for the actual construction or implementation of the project.

The detail design proposals should include the following:

- Final layout drawing with levels.
- Detail drawing of all SUDS elements for the scheme.
- Appropriate calculations to show how storage volumes have been determined with location and volume of storage. This should also factor in climate change scenarios.
- Location and details of inlets, outlets and control structures.
- Details of low flow pathways, overflow arrangements and exceedance routes.
- Copies of all relevant permissions or agreements.
- A Management Plan.

5.4.1 Testing the hydraulic

Testing the hydraulic performance of the system to identify the worst case hydraulic condition for each component for all design return periods and make adjustments where necessary.

5.4.2 Design requirement verification

Verify that the final plan satisfies all of the site-specific design requirements.

5.4.3 Refine to agreed standards

Refine the size and flow controls of SuDS components where standards are not met.

5.4.4 Finalise design

Finalize detail design and specification for the SuDS scheme. The cost should be taken into consideration along with any health and safety risk, constructability and maintenance factors.

5.4.5 Designing for very flat sites

There are several challenges when designing a surface water management system for a very flat site which includes:

- Attaining adequate gradients for runoff drainage
- Meeting the desired outlet levels for existing watercourses
- The effects of downstream water levels on the performance of the drainage system

To address these challenges, engineers and designers need to take into account various factors such as groundwater levels, soil infiltration rates, and existing infrastructure when designing surface water management systems on flat sites. Utilizing shallow SuDS components, such as swales or permeable pavements, offers distinct advantages, particularly when constructing piped drainage systems with adequate slopes becomes problematic on very flat sites. These shallow systems can be designed to promote surface water infiltration and gradual runoff without requiring significant changes in elevation. In cases where traditional drainage systems would require excessive depth, or if the endpoint of the drainage system falls below the minimum allowable outfall level, a pumping station may be needed to maintain effective drainage.

5.4.6 Designing for urban environments

The efficient integration of SuDS into urban design involves the early incorporation of surface water management in an integrated design process. This entails encouraging collaboration across several disciplines, such as developers, engineers, planners, landscape architects, and architects as well as engaging with the local population.

A collaborative, interdisciplinary design team guarantees that SuDS implementation is holistic and multifaceted, contributing to the overall success of urban development initiatives.

Integrating SuDS in urban environments is seen not only as important for effective flood mitigation but these sustainable practices also contribute to creating greener, more resilient urban spaces, providing both environmental and aesthetic benefits for the community.

The following steps can be taken to incorporate SuDS into existing infrastructure:

Green roofs and green walls
Commercial, residential, and public buildings can all benefit from green roofs and green walls. Green roofs can be installed on existing structures to absorb and reduce stormwater flow. Green walls, which are vertical gardens, can be added to building facades, can be utilized to reduce roof runoff inside their substrate. It offers both stormwater benefits as well as aesthetic appeal.

Pervious Pavements
Traditional pavements in parking areas, sidewalks or even roads can be replaced with pervious pavements which reduces runoff by allowing water to infiltrate through the surface, recharging groundwater and reducing the burden on conventional drainage systems.

Infiltration Basins and Swales
Infiltration basins or swales can be constructed in open spaces, car parks or within areas that are underutilized to aid with capturing and treating stormwater before it enters the drainage system. The swales can also be incorporated along roadsides or within landscaped areas to direct and filter runoff.

Bioretention Areas
Bioretention areas, which absorb, filter, and infiltrate runoff using vegetation and engineered soils, can be integrated into landscaped zones or medians. They can be incorporated into parking lot islands, street medians, curb extensions, and along roadways to capture runoff from impervious surfaces. Bioretention areas serve a dual purpose in providing improving stormwater management and providing green spaces.

Underground Storage Tanks
Underground storage tanks can be installed beneath parking lots or open spaces to temporarily store stormwater during peak events. The tanks will operate as a buffer during heavy rainfall events, reducing the risk of flooding by retaining stormwater and releasing it slowly into the drainage system or allowing it to infiltrate into the ground. They are particularly useful in densely populated urban areas where space is restricted.

Detention basins and flood channels
Shallow detention basins and flood channels can be incorporated into public spaces. These elements can be designed and implemented in a way to seamlessly blend into parks, and other recreational spaces, providing both practical drainage solutions and aesthetic enhancements.

Design Surface Water Objectives

Establish methods of runoff collection from sites

Several technologies can efficiently collect runoff from developed surfaces. Pervious surfaces and green roofs improve permeability. Strategically placing SuDS components parallel to impermeable surfaces allows direct discharge onto filter strips, swales, or other surface channels. Kerb apertures and slopes can direct runoff into conveyance or storage. These methods provide diversified and effective runoff management in growth zones.

Select interception components for hard surfaces

A site's stormwater management strategy should prioritise interception for each impermeable region. Interception is achieved when stormwater management components including permeable pavements, green roofs, and rainwater harvesting systems being seamlessly integrated into runoff surfaces or collecting methods. If runoff is properly treated before discharging to groundwater, soakaways for roof water and infiltration from swales, bioretention areas, dry basins, and permeable surfaces can manage a significant portion of surface water. When infiltration is impractical or undesirable, very low infiltration rates and/or soil storage depths can be used for interception and conveyance to downstream attenuation and treatment components.

Select storage components

Attenuation storage can be integrated into different areas of development, such as beneath permeable paving or recreational spaces, to minimise the requirement for a large downstream facility. If rainwater harvesting is not feasible, it is important to effectively manage excess runoff. It can be directed to a slow-draining long-term storage or added to the main attenuation storage, which would increase the volume requirements. Phased developments should prioritise storage on individual lots, necessitating early agreements on access, ownership, and maintenance for strategically designed storage.

Select conveyance components to link interception & storage components

Establishing links between Sustainable Drainage System (SuDS) components is crucial as water progresses downstream. This can be achieved through conveyance systems like swales, linear wetlands, channels, rills, and pipes. These systems offer valuable treatment, infiltration, and retention capabilities. Vegetated surface conveyance elements enhance water quality, amenity, and biodiversity. They also play a crucial role in connecting habitat through biodiverse pathways. Proper management of surface water flow is crucial on steep terrains to prevent erosion. Methods such as natural waterfalls, check dams, and baffles can be utilised to reduce gradients. Maintaining water on the surface reduces the need for cover, thus reducing the requirement for deep excavations in piped systems. Accurate design is crucial on level sites to avoid excessive downstream systems due to conveyance gradients.

Establish treatment delivery

Creating a SuDS strategy should address pollution treatment needs across land uses. Low-contamination locations are good for rainwater collection, while low-to-medium contamination areas are safe for infiltration. To ensure infiltration or harvesting, clean runoff must not combine with dirty runoff. When possible, cluster land uses with different pollution potentials to improve management train design. Lot owners/operators can easily identify pollution sources with SuDS, enabling for remediation and upkeep. Pollution prevention techniques, sometimes required as conditions of use, may affect land use hazard characteristics and should be considered during planning.

Identify exceedance routes

The development design should include secure routes and designated storage areas for excess runoff. Exceedance routes may include roads, while storage areas can consist of car parks, and public open areas. It is crucial to ensure that repurposing these spaces for exceeding purposes does not compromise their regular functionality to the point of endangering people or property. Long-term maintenance feasibility should be ensured.

Figure 5.6: Design Surface Water Objectives . (Derived from Woods-Ballard et al., 2015)

6 Monitoring and Evaluation Framework

Objectives

- Objective 1: Improve stormwater management by improving drainage capacity and reduce the risk of urban flooding.
- Objective 2: Conduct ecosystems-based studies to support improving water quality and environmental sustainability.
- Objective 3: Retrofit or construct storm drains within key project areas and promote community awareness and engagement.

Data Collection

Methods

- Monitor and record flood incidents, including the number of days with interrupted traffic due to flooding, and measure water flow rates in key drainage areas.
- Conduct applicable ecosystem-based assessments to understand and manage the impacts of stormwater on ecosystems and urban environments.
- Track the progress of storm drain construction or retrofitting, record community engagement activities, and collect feedback from public consultations or surveys.

Frequency

- Flow rates: Continuous or frequent during storm events.
- Seasonal data collection for water quality, with annual or bi-annual ecosystem-based assessments to track ecosystem changes over time.
- Monthly progress reports on construction/retrofitting, with community engagement data collected after each event, and quarterly surveys to gauge public awareness.

Performance Metrics

Stormwater Volume Reduction

- Compare pre- and post-intervention runoff volumes.
- Assess the effectiveness of permeable surfaces and infiltration components.

Water Quality Improvement

- Track changes in pollutant concentrations (e.g., suspended solids, nutrients).
- Evaluate the effectiveness of sedimentation basins and vegetated components.

Adaptive Management

- Establish protocols for adaptive management based on monitoring results.

- ☐ Include triggers for adjustments or improvements to SuDS components.
- ☐ Maintain flexibility in the design to accommodate changing conditions.

Community Engagement

- ☐ Track community participation in educational programs and events.
- ☐ Measure the number of residents adopting sustainable practices.
- ☐ Conduct periodic surveys to gauge community perceptions and satisfaction.

Maintenance and Inspections

- ☐ Monitor the frequency and effectiveness of maintenance activities.
- ☐ Inspect SuDS components regularly for signs of wear, damage, or clogging.
- ☐ Document any repairs or improvements made based on inspections.

Financial and Resource Tracking

- ☐ Track project expenditures against the budget.
- ☐ Assess the cost-effectiveness of different SuDS components.
- ☐ Evaluate resource allocation efficiency.

Reporting and Documentation

- ☐ Develop regular reports summarizing monitoring results.
- ☐ Maintain a comprehensive database of monitoring data.
- ☐ Document changes made to the system based on evaluation outcomes.

Stakeholder Feedback

- ☐ Solicit feedback from stakeholders, including government agencies, local authorities, and the public.
- ☐ Consider public hearings, focus group discussions, or surveys for stakeholder input.

Key Performance Indicators (KPIs)

- ☐ Days (per event) of interrupted traffic due to flooding in Project areas
- ☐ Ecosystems-based studies completed
- ☐ Storm drains retrofitted/constructed.

Long-Term Impact Assessment

- ☐ Assess the long-term impact of SuDS interventions on flood risk, water quality, and community resilience.
- ☐ Consider factors such as urban development trends and climate change projections.

7 Recommendations

The preparation of the guidelines was supported by a comprehensive needs assessment, aimed at facilitating the collection and analysis of data to identify specific needs, gaps, challenges, and opportunities within the realm of sustainable urban drainage and filtration design (See Appendix 2 and 3). This assessment entailed conducting extensive desktop research into the principles of sustainable urban drainage and filtration design, alongside a thorough review of existing guidelines in the field.

The insights gleaned from this process pinpointed the crucial needs and requirements necessary for the development of sustainable urban drainage guidelines that are both comprehensive and effective.

Improving Jamaica's urban drainage infrastructure is crucial to reducing flooding and enhancing urban water management. It is important to assess the site for any existing SuDS scheme before design begins. Where SuDS are to be retrofitted, this should include existing roof areas, hard surfaces, green spaces and land ownership boundaries, in order to make the best use of the space. The suggestions that follow can be used as a guide to improve Jamaica's urban drainage system. The resilience of Jamaican urban areas in the face of urbanization and climate change problems will be increased by implementing a holistic and sustainable approach to drainage management, which will also enhance the general quality of life for residents.

1. Implement SuDS that **incorporate permeable surfaces, green infrastructure, and source control to manage stormwater runoff effectively**.

   SuDS for a single site could potentially be demonstrated to have limited impact, but it is the cumulative impact of all development in the catchment (combined with the potential effects of climate change) that should be taken into consideration.

   Key locations where components could be incorporated:
   - Permeable surfaces as mentioned with the design section can be used in parking lots (public and private), sidewalks, residential streets and driveways.
   - Rain gardens can be used along sidewalks, in residential front yards, or within parking lot medians.
   - Vegetated swales can be used along roadsides, parking lots, or in residential areas.
   - Green can be used on commercial and residential buildings.

2. Establish a **regular maintenance schedule** for drainage systems. This is critical for preventing blockages, ensuring functionality, mitigating erosion, protecting water quality, addressing vegetation growth, responding to changing conditions, enabling early issue detection, and minimizing disruption.

Conduct regular inspections of existing drainage infrastructure to identify areas in need of repair or improvement. Prioritize maintenance based on the condition of the infrastructure.

Invest in monitoring systems and data collection to assess the performance of drainage infrastructure. Real-time data can help authorities respond to emergencies and plan for future improvements.

3. In flood-prone areas, consider implement **resilient urban design that can withstand extreme weather events**. In addition, be mindful of the impact of climate change when designing and upgrading drainage systems. Projections for increased rainfall and extreme weather events should be factored into infrastructure planning.

4. Update and strengthen drainage design standards to **ensure that new developments incorporate sustainable drainage practices and are resilient to heavy rainfall**. Review and update existing regulations to ensure they support sustainable drainage practices and the integration of SuDS into urban development.
    - Local criteria relevant to SuDS may be set via the local planning authority's adopted planning instruments (including flooding and planning documents) and via standards set by drainage approving and/or adoption bodies.

Foster collaboration between government agencies, local authorities, and the private sector to pool resources, expertise, and knowledge for better drainage management. Develop a long-term strategy for urban drainage that takes into account population growth, land use changes, and climate impacts.

Invest in research and innovation to find new and cost-effective drainage solutions. Explore sustainable technologies and materials for improved drainage.

5. Launch **educational programs** and awareness campaigns to inform the public about responsible waste disposal, the importance of not blocking drains, and the benefits of sustainable drainage practices.

6. **Gender perspectives** should be considered within the design consultation process. This is to establish a more inclusive, resilient, and socially equitable process. This method aims to highlight all community members' opinions and considerations through inclusive workshops, gender-disaggregated data collecting, capacity building, and public awareness campaigns, resulting in a more sustainable and gender-responsive framework.

7.1 Implementation Strategy

Step 1: Preliminary Assessment

Conduct preliminary assessment of potential pilot project sites based on criteria such as flood-prone areas, existing drainage issues, and areas with a high potential for improvement. Ensure to engage local communities, regulatory agencies, and private stakeholders. Existing data should be collected on climate, rainfall patterns, and historical flooding events to inform the design process.

This could be potentially in low lying areas that are usually affected by flooding such as:

- Waltham Park
- Maxfield Ave
- Marcus Garvey Drive
- Molynes Road
- Tinson Pen
- New Haven (Sections of Duhaney Park)
- Sections of Downtown Kingston
- Sections of Mountain View Avenue
- Sections of Spanish Town Road

Step 2: Site and Development Characterization

A detailed site characterization should be performed and undertaken while considering the following existing conditions:

1. Land use,
2. topography,
3. surface water flow,
4. infrastructure,
5. flood risk,
6. water infiltration,
7. discharge points,
8. soil conditions,
9. and local ecosystems.

Subsequent to the assessments, analyse how the proposed changes will impact the SuDS design. This should include the proposed land use changes, topography, infrastructure plans, and stormwater management strategies.

Step 3: Design and Implementation of the SuDS

The design of the SuDS systems should be tailored to the specific needs of each site. The appropriate SuDS component should be incorporated considering the results of the environmental and infrastructure assessment. The design should integrate sustainable drainage practices that adequately address the environmental, social, and economic considerations (See figure 7.1 for sample design idea).

As a part of the implementation educational programs and awareness campaigns should be launched. This is to inform the public about their responsibility in supporting the initiative through proper waste disposal and maintaining the infrastructures. The importance of not blocking drains should be emphasized as well as the benefits of sustainable drainage practices and its implication

Figure 7.1: Greenwich Town sample design Idea for a SuDS plan
Source: Allison Griffiths, Landscape Architect/Designer

Step 4: Monitoring and Maintenance

A maintenance management plan is vital for sustainable urban drainage design because it guarantees the continuous operation, environmental sustainability, and economic viability of SuDS features. It benefits the community and the environment while advancing the long-term goals of managing stormwater in an environmentally conscious and sustainable manner.

Monitoring systems should be in place to help facilitate not just the performance of the drainage infrastructure but also the collection of data that will support future planning. A regular maintenance schedule for the implemented systems should be established and should include more frequent inspections. These inspections will also support the data collection and making the necessary prioritized maintenance. The data collected from monitoring and community feedback should be used to implement adaptive management strategies to continuously improve the drainage systems as needed. Metrics to track the progress and success of the implemented systems should also be developed. (See section 6: Monitoring and Evaluation Framework)

Step 5: Research and Innovation

Research and innovation play a major role by enabling tailored solutions to the evolving conditions and enhancing efficiency. Ongoing research and innovation should be a critical component explored to support new and cost-effective drainage solutions.

Step 6: Evaluation and Scaling

An in-depth evaluation of the pilot project's success should be conducted, taking into account stakeholder feedback and performance data. The lessons learned should be used to scale up the approach to other urban areas in Jamaica.A comprehensive long-term plan for SuDS should be initiated. It will require collaboration between local authorities, government agencies, and the private sector expertise, and knowledge for better drainage management.

7.2 Main Cost Categories

Cost Category	Item
Design and Planning	▪ Professional Services (Architects, Engineers, Urban Planners) ▪ Surveying and Site Analysis (Topographical Surveys, Data Collection) ▪ Permitting and Regulatory Compliance (Permit Fees, Compliance Assessment)
Construction and Implementation	▪ Materials cost ▪ Labor cost (Skilled and Unskilled Labor) ▪ Equipment and Machinery ▪ Site Preparation
Monitoring and Data Collection	▪ Sensor Systems ▪ Data Analysis (Tools, Software, Personnel) ▪ Maintenance of Monitoring Systems ▪ Long-Term Impact Assessment ▪ Monitoring and Evaluation Framework Implementation (M&E Personnel & Evaluation Tools)
Maintenance and Operations	▪ Routine Maintenance (Inspection, Upkeep or Repairs) ▪ Training and Capacity Building
Stakeholder Engagement and Education	▪ Educational Programs (Workshops, Seminars, Materials) ▪ Community Events ▪ Stakeholder Meetings ▪ Consultation ▪ Public Relations Services ▪ Marketing Materials
Research and Innovation	▪ Research & Pilot Projects ▪ Collaboration with Institutions ▪ Technology Adoption
Evaluation and Reporting	▪ External Evaluation ▪ Reporting and Documentation
Contingency Fund	▪ Scope changes ▪ Unplanned costs

Table 7.1: Main cost categories
Source: Derived from Woods-Ballard et al., 2015

7.3 Indicators

The CityAdapt initiative aims to tackle the effects of climate change in urban and peri-urban areas through ecosystem-based adaptation (EbA) strategies, with a particular emphasis on reducing the impact of urban flooding.To assess the impact of this initiative, a matrix of indicators has been created to track CityAdapt's progress and evaluate its effectiveness. This matrix allows for ongoing monitoring, offering insights into whether the program is achieving its intended outcomes. It also demonstrates how the implementation of the initiative affects the collected data.

The matrix includes several key output indicators to measure the effectiveness of CityAdapt in addressing climate change challenges. Among them are the number of days per event that traffic is interrupted due to flooding in project areas, the completion of ecosystems-based studies, and the number of storm drains that have been retrofitted or constructed. These output indicators help gauge the program's success in reducing flood-related disruptions and improving urban resilience.

By combining these quantitative measures with qualitative insights, CityAdapt provides a comprehensive framework for evaluating its impact and ensuring the continued effectiveness of its adaptation strategies.

Implementation	▪ Days (per event) of interrupted traffic due to flooding in Project areas[1] ▪ Ecosystems-based studies completed[2] ▪ Storm drains retrofitted/constructed[3]
Quantitative Impact	▪ Mean temperatures per annum (%) ▪ Estimated Affected Population Due to Heavy Rainfall and Flooding (urban/peri-urban areas)
Qualitative Impact	▪ Use of risk information for investment planning in the built and non-built environment

Source: CityAdapt Kingston: Product No.3 - Monitoring and Evaluation sections included in the 2 EbA guidelines developed by Jamaica 4-H Clubs.

See full matrix in Appendix 5 – Results Matrix for the Sustainable Urban Drainage Design Guideline

[1] World Bank. 2022. Jamaica Disaster Vulnerability Reduction Project (P146965) - Indicator provides a quantified measure for everted losses due to disaster risks.
[2] World Bank. 2022. Jamaica Disaster Vulnerability Reduction Project (P146965) - Indicator provides a measure for scientific studies provided as part of this Project for subsequent uses in planning and design.
[3] World Bank. 2022. Jamaica Disaster Vulnerability Reduction Project (P146965) - Indicator provides a measure of physical assets retrofitted/constructed which provides increased flood resilience and reduced risk of asset failure.

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9 Appendices

9.1 Appendix 1 – Glossary

B

Biodiversity: The variety of plant and animal life in a particular habitat, considered at both genetic and species levels.

Bioswales: Landscaped channels with native vegetation that slow, filter, and absorb stormwater runoff, improving water quality and providing habitat for wildlife.

Brownfield Site: A site that was previously used for industrial or commercial purposes and may be contaminated, requiring redevelopment.

C

Climate Resilience: The ability of a system or community to anticipate, prepare for, respond to, and recover from the adverse impacts of climate change.

Constructed Wetlands: Man-made wetlands designed to capture, filter, and manage stormwater runoff.

G

Green Infrastructure: The incorporation of natural elements and features into urban planning, providing environmental and social benefits.

Green Roofs: Roofs with vegetation that reduce stormwater runoff, offer insulation benefits, and contribute to reduced energy consumption.

I

Infiltration: The process of water slowly seeping into the ground, often facilitated by permeable surfaces, a key aspect of SuDS.

Infiltration Trenches: Underground trenches filled with stone or aggregate that manage stormwater by facilitating gradual infiltration into the ground.

N

Nature-based Solutions (NbS): Strategies that replicate and restore natural processes to manage water sustainably within urban, peri-urban, and rural settings.

P

Peak Runoff Rate: The maximum rate at which stormwater runoff is discharged from a site during intense precipitation.

Permeable Surfaces: Surfaces that allow water to pass through, reducing runoff and potential flooding, examples include permeable pavements.

R

Rain Garden: A designed area for the collection and absorption of rainwater, often featuring vegetation.

Retention Basins: Basins strategically designed to capture and contain stormwater, contributing to flood control and pollution reduction.

S

Sustainable Urban Drainage Systems (SuDS): Holistic and nature-based approaches to urban drainage that replicate natural hydrological processes, incorporating green infrastructure to manage water sustainably.

U

Urban Heat Island Effect: The phenomenon where urban areas experience higher temperatures than their rural surroundings, often mitigated by green infrastructure components of SuDS.

Urban Resilience: The capacity of urban areas to adapt and respond to various challenges and changes, including climate-related impacts.

V

Vegetated Swales: Linear, vegetated channels designed to slow, collect, and filter stormwater runoff.

9.2 Appendix 2 – Survey Instrument 1

Needs Assessment Survey For Experts In The Field: Sustainable Urban Drainage Systems

We extend our gratitude for your participation in this survey focused on the development of guidelines for Sustainable Urban Drainage Systems (SuDS). As a recognized expert in the field, your insights are crucial for advancing our understanding of SuDS planning and implementation.

The questionnaire focuses on key themes, including your professional background, experience with SuDS, knowledge of guidelines & collaboration, regulatory aspects, education & training, and future outlook.

Instructions

Kindly provide your responses based on your professional knowledge and experiences. Your time and expertise are valued greatly, and we appreciate your contributions to this important survey.

Professional Background

1. What is your gender?

2. What is your professional background and expertise in the field of sustainable urban drainage systems (SuDS)?
   - ☐ Landscape architect
   - ☐ Urban Planner
   - ☐ Engineer
   - ☐ Other (Specify)

   Click or tap here to enter text.

Experience with SuDS Implementation

3. How many years of experience do you have in planning, designing, or implementing SuDS projects?
   - ☐ 0-5 years
   - ☐ 6-10 years
   - ☐ 10+ years

4. Can you briefly describe some SuDS projects you have been involved in?
   Click or tap here to enter text.

Knowledge Of SuDS Guidelines And Integration In Urban Planning

5. Are you familiar with existing SuDS design guidelines and standards in your region?
   - ☐ Yes
   - ☐ No
   - ☐ Somewhat

6. To what extent do you believe SuDS is integrated into urban planning practices in your region?
   - ☐ Not at all
   - ☐ Somewhat
   - ☐ Very well

7. Can you share any challenges with the integration of SuDS into urban planning?
   Click or tap here to enter text.

8. What types of SuDS features do you find most effective in mitigating stormwater runoff and promoting sustainability?
   Click or tap here to enter text.

9. How important is the aesthetic integration of SuDS features in urban design?
   Click or tap here to enter text.

10. In your experience, how effectively do professionals from different disciplines collaborate on SuDS projects?
    - ☐ Not effectively
    - ☐ Moderately effective
    - ☐ Highly effective

11. What strategies have you found successful in fostering interdisciplinary collaboration?
    Click or tap here to enter text.

Regulatory Environment

12. Do you believe that the current regulatory environment supports or hinders the implementation of SuDS projects?
    - ☐ Supports
    - ☐ Neutral
    - ☐ Hinders

13. What regulatory changes, if any, would you recommend to facilitate the implementation of SuDS?
    Click or tap here to enter text.

Education and Training

14. How prepared do you think professionals in your field are regarding the design and implementation of SuDS?
    - ☐ Not well-prepared
    - ☐ Moderately prepared
    - ☐ Well prepared

15. What educational initiatives or training programs would you recommend to enhance the knowledge and skills pertaining to SuDS?
    Click or tap here to enter text.

Future Outlook

16. What emerging technologies do you see as promising in advancing SuDS?
    Click or tap here to enter text.

17. What trends or developments do you foresee in the future of SuDS and sustainable urban drainage?
    Click or tap here to enter text.

18. How can the industry further promote the adoption of SuDS principles and practices?

Click or tap here to enter text.

9.3 Appendix 3 – Survey Instrument 2

Needs Assessment Survey For Persons In Vulnerable Communities: Sustainable Urban Drainage Systems

This survey aimed to gather valuable insights into public perceptions and awareness regarding Sustainable Urban Drainage Systems (SuDS). SuDS are innovative, nature-based solutions designed to manage stormwater runoff in urban environments while promoting environmental sustainability and community well-being.

The questionnaire covers key themes, including flood awareness, personal experiences, knowledge of SuDS, community engagement, perceived benefits, preferences for SuDS features, concerns, community involvement, and education.

Instructions

All questions are to be answered based on your knowledge and experiences.

Awareness and Understanding

1. What is your gender?

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1. How familiar are you with flood risks in your community?
   ☐ Not familiar
   ☐ Somewhat familiar
   ☐ Very familiar

2. Have you experienced flooding in your area? If yes, how frequently and to what extent?
   ☐ Never
   ☐ Once per year
   ☐ Frequently (more than once a year)

3. On a scale of 1 to 10, how satisfied are you with the current drainage systems in your community?
   Click or tap here to enter text.

Knowledge of Sustainable Urban Drainage Systems (SuDS)

4. How familiar are you with the concept of Sustainable Urban Drainage Systems (SuDS)?
   ☐ Not familiar
   ☐ Heard of it but do not know much

☐ Very familiar

5. Have you seen any SuDS features in your community? If yes, please describe.
   Click or tap here to enter text.

Community Engagement

6. Do you feel engaged or informed about flood mitigation and drainage planning in your community?
   ☐ Not engaged
   ☐ Somewhat engaged
   ☐ Very engaged

7. Would you be willing to participate in community workshops or initiatives related to sustainable drainage?
   ☐ Yes
   ☐ No
   ☐ Maybe

Perceived Benefits of SuDS

8. What benefits do you think SuDS could bring to your community in terms of flood mitigation and overall urban environment?
   Click or tap here to enter text.

9. How important do you think SuDS are in promoting a more sustainable and resilient community?
   ☐ Not important
   ☐ Somewhat important
   ☐ Very important

Preferences for SuDS Features

10. Are there specific types of SuDS features you would prefer to see in your community (e.g., permeable pavements, rain gardens, retention ponds)?
    ☐ Permeable pavements
    ☐ Retention ponds
    ☐ Vegetative swale
    ☐ Green roofs
    ☐ Rain gardens
    For additional information, please provide further details below:

Click or tap here to enter text.

Concerns and Challenges

11. What concerns do you have regarding the implementation of SuDS in your community?
    Click or tap here to enter text.

12. Are there potential challenges you foresee in the adoption or maintenance of SuDS features?
    ☐ Yes
    ☐ No
    ☐ Not sure

Community Involvement in Maintenance

13. Would you be willing to participate in the maintenance of SuDS features in your neighborhood? If yes, What types of community programs or incentives would encourage your involvement in SuDS maintenance?
    Click or tap here to enter text.

Education and Awareness

14. How would you prefer to receive information about flood risks and SuDS initiatives?
    ☐ Community meetings
    ☐ Online resources
    ☐ Social media
    ☐ Pamphlets
    ☐ Other (Specify)
    Click or tap here to enter text.

15. To what extent do you believe educational programs could improve awareness and understanding of SuDS in the community?
    ☐ Not at all
    ☐ Somewhat
    ☐ A substantial amount

SuDS Integration in Urban Planning

16. Do you think it is important for SuDS to be integrated into future urban development plans? If yes, do you believe that the local government should prioritize sustainable drainage in its planning and development policies?
    ☐ Yes
    ☐ No

☐ Not sure

9.4 Appendix 4 – SuDS Design Checklist

	The SUDS proposal must demonstrate
☐	The SUDS philosophy objectives have been met in the overall design: ▪ Control of flooding ▪ Prevention of pollution ▪ Benefits for the community ▪ Wildlife opportunities
☐	How the original drainage pattern for the site has been considered in the design.
☐	How existing flow patterns are modified to provide low flow routes, overflows, and exceedance pathways.
☐	The use of the management train concept in the drainage design.
☐	How source control measures have been used at the beginning of the SUDS.
☐	The division of the development into sub-catchments to manage runoff.
☐	How the storage hierarchy manages flows and volumes of runoff.
☐	The destination of runoff – to infiltration, watercourses, or the sewer as a last resort.
☐	The SUDS Design Process: ▪ SUDS infrastructure planning where possible ▪ Conceptual Drainage Design where appropriate ▪ Outline Drainage Proposals to allow full consultation ▪ Detail Design for final planning review
☐	Hydraulic criteria set out in the SUDS manual and agreed with the Environment Agency – generally, flow rates and storage volume.
☐	Sufficient treatment stages are provided for each sub catchment to manage pollution.
☐	First flush volumes are intercepted and treated at source.
☐	Appropriate SUDS components have been used to manage runoff.
☐	The Landscape proposals consider the requirements of SUDS.
☐	That the maintenance of the SUDS is simple and cost effective.

9.5 Appendix 5 – SuDS Components Checklist

	Green Roof
☐	Infiltration and Water Retention ▪ Determine the desired water retention capacity of the green roof. ▪ Design with appropriate slopes to encourage water flow and prevent ponding.
☐	Waterproofing Layer ▪ Appropriate high-quality, durable waterproofing membrane (e.g., PVC, EPDM, TPO). ▪ The thickness must be in accordance with local building codes and manufacturer recommendations. ▪ Implement the relevant root barrier to prevent plant roots from penetrating the waterproofing layer.
☐	Drainage Layer ▪ Implement an effective drainage system to prevent water buildup on the roof. ▪ Use appropriate lightweight, high-drainage materials (e.g., plastic or composite drainage boards). ▪ The thickness can be 1-2 inches.
☐	Growing Medium ▪ Suitable lightweight soil mix specifically designed for green roofs. ▪ General depth of 4-8 inches, depending on plant requirements. ▪ The composition can be a blend of organic and inorganic materials for optimal plant support and water retention.
☐	Vegetation Layer ▪ Locally adapted, drought-resistant plants with low maintenance requirements. ▪ Determine the appropriate spacing and coverage based on the desired aesthetics and environmental goals. ▪ Integrate features to enhance biodiversity, such as native plant species and habitats for beneficial insects
☐	Access and Maintenance ▪ Include walkways or pathways for maintenance access. ▪ Develop a maintenance plan.
☐	Sufficient treatment stages are provided for each sub catchment to manage pollution.

	Permeable Pavers
☐	Infiltration Rate ▪ Determine the desired infiltration rate based on local regulations and project goals. ▪ Conduct on-site infiltration tests to assess the permeability of the soil and guide the design.
☐	Stormwater Management ▪ Size the permeable pavement system to effectively manage the volume of stormwater based on local regulations and environmental considerations. ▪ Integrate storage and detention features to control stormwater flow and release it gradually. ▪ Design with appropriate slopes to encourage water flow and prevent ponding.

	▪ Include provisions for routine maintenance to ensure continued hydraulic performance.
☐	Drainage Area Planning ▪ Define the drainage area served by the permeable pavement and calculate the expected runoff. ▪ Consider the contribution from adjacent impervious surfaces and design for the combined runoff.
☐	Permeable Base Course ▪ Ensure the base course has sufficient porosity and permeability to facilitate water movement into the underlying soil. ▪ Specify the thickness and composition of the base course.
☐	Underdrain Systems ▪ Consider incorporating underdrain systems beneath the permeable pavement to manage excess water and prevent saturation. ▪ Size and design underdrains based on the anticipated flow rates.
☐	Access and Maintenance ▪ Include walkways or pathways for maintenance access. ▪ Develop a maintenance plan.
☐	Sufficient treatment stages are provided for each sub catchment to manage pollution.

	Swales
☐	Flow Rate ▪ Determine the expected flow rate of stormwater runoff that the swale needs to manage. ▪ Consider site conditions, and the drainage area contributing to the swale. ▪ Design the cross-sectional shape to accommodate the expected flow rates and minimize erosion.
☐	Slope and Gradient ▪ Establish the slope and gradient of the swale to facilitate water flow and prevent ponding. ▪ Align the slope with the natural topography of the site.
☐	Lining Material ▪ Specify erosion-resistant lining materials for the swale to prevent soil erosion and maintain stability. ▪ Options include erosion control blankets, geotextiles, or stabilized vegetation. ▪ Design the swale to promote subsurface infiltration to recharge groundwater.
☐	Vegetation Selection ▪ Select appropriate vegetation for the swale that can withstand periodic inundation and contribute to pollutant removal. ▪ Consider native, drought-resistant plants with deep root systems.
☐	Sizing and Dimensions ▪ Size based on the expected flow rates and volume. ▪ Use hydraulic design calculations to ensure the swale can handle peak flows. ▪ Design overflow features to handle extreme storm events and prevent flooding.
☐	Maintenance

	▪ Include provisions for routine maintenance.

	Bioretention System
☐	Flow Rate ▪ Determine the expected flow rate of stormwater runoff that the bioretention system needs to manage. ▪ Design underdrains based on the anticipated flow rates and ensure proper outlet control.
☐	Slope and Gradient ▪ Establish the slope and grading of the bioretention area to facilitate water flow and prevent ponding. ▪ Ensure that the grading directs water toward the center of the basin.
☐	Infiltration ▪ Design the bioretention area to promote subsurface infiltration to recharge groundwater. ▪ Incorporate permeable soils or aggregate layers beneath the bioretention basin.
☐	Vegetation Selection ▪ Select appropriate vegetation for the system that can withstand periodic inundation and contribute to pollutant removal. ▪ Consider native, drought-resistant plants with deep root systems. ▪ Design the soil mix based on soil percolation rates and pollutant removal goals.
☐	Sizing and Dimensions ▪ Size based on the expected flow rates and contributing drainage area. ▪ Determine the appropriate length, width, and depth of the bioretention area.
☐	Maintenance ▪ Include provisions for routine maintenance.

	Detention Basin
☐	Flow Rate ▪ Determine the design flow rate that the detention basin needs to manage. ▪ Consider local regulations, site conditions, and the drainage area contributing to the basin.
☐	Slope and Gradient ▪ Establish the slope and grading of the detention basin to facilitate water flow and maximize storage. ▪ Ensure that the basin is properly contoured to prevent sedimentation.
☐	Vegetation ▪ Consider incorporating vegetation in and around the detention basin for erosion control and aesthetic purposes. ▪ Select vegetation that can withstand periodic inundation.
☐	Sizing and Storage Capacity ▪ Size the detention basin to accommodate the anticipated volume of stormwater runoff.

	- Design the basin's storage capacity based on the required detention time and the expected peak flow rates. - Design an outlet structure to control the discharge rate from the detention basin.
☐	Maintenance - Include provisions for routine maintenance. - Include a sediment forebay or pretreatment area to capture sediments before they enter the main storage area which can be easily maintained.

9.6 Appendix 5 – Results Matrix for the Sustainable Urban Drainage Design Guideline

Results Level	Indicator	Target	Data Collection Method	Data Source	Frequency	Responsible MDA	Framework /Policy /Plan/Alignment for MEL System Sustainability
Impact	Mean temperatures per annum (%)	TBC	Document Review	*Meteorological Service of Jamaica website*	Annual	Met Service of Jamaica	Climate Change Policy Framework
	Estimated Affected Population Due to Heavy Rainfall and Flooding (urban/peri-urban areas)	TBC as per meteorological event	Document Review	*As reported to the ODPEM's Office of Disaster Preparedness and Emergency Management National Emergency Operations Centre (NEOC)*	Annual	Office of Disaster Preparedness and Emergency Management (ODPEM)	Economic and Social Survey Jamaica 2023
Outcome	Use of risk information for investment planning in the built and non-built environment[4]	1200	Document Review	Application Log	*Annual*	MEGJC /JSIF	Jamaica Social Investment Fund- Disaster Risk Vulnerability Project Indicator #1
	Population benefitting from improved critical facilities and infrastructure	247,271	Document Review	Annual Report	*Annual*	JSIF	Jamaica Social Investment Fund- Disaster Risk Vulnerability Project Indicator #2
Output	Days (per event) of interrupted traffic due to flooding in affected areas[5]	*TBC*	Document Review	Incident Reports	Annual	NWA/JSIF	Jamaica Social Investment Fund- Disaster Risk Vulnerability Project Indicator #10
	Ecosystems-based studies completed[6]	8	Document Review	Completion Report/Field Validation	Bi-annual	NEPA/JSIF	Jamaica Social Investment Fund- Disaster Risk Vulnerability Project Indicator #4
	Storm drains retrofitted/constructed[7]	8,350	Document Review	Completion Report and Site Inspection	Bi-annual	NWA/JSIF	Jamaica Social Investment Fund- Disaster Risk Vulnerability Project Indicator #11

[4] World Bank. 2022. Jamaica Disaster Vulnerability Reduction Project (P146965) - Indicator provides a measure for the use of risk information in investment planning to ensure that information generated in the Project is adopted and operationalized
[5] World Bank. 2022. Jamaica Disaster Vulnerability Reduction Project (P146965) - Indicator provides a quantified measure for everted losses due to disaster risks.
[6] World Bank. 2022. Jamaica Disaster Vulnerability Reduction Project (P146965) - Indicator provides a measure for scientific studies provided as part of this Project for subsequent uses in planning and design.
[7] World Bank. 2022. Jamaica Disaster Vulnerability Reduction Project (P146965) - Indicator provides a measure of physical assets retrofitted/constructed which provides increased flood resilience and reduced risk of asset failure.