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Rethinking SuDS, A Way Forward for Sustainable Urbanization

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Title

Rethinking SuDS, A Way Forward for Sustainable Urbanization

Degree: Master in Urban Climate & Sustainability

Abstract:

The aim of this research is to critically reassess the potentiality of Sustainable Urban Drainage Systems (SuDS)and propose them as the reliable way forward for sustainable urbanization in a present context when urban areas everywhere are facing extreme climate events and surging flood risks due to disrupted natural hydrological cycles. The issues are likely to get worse in the coming years.
Considering UNSDG goals as the universally accepted benchmark of a sustainable world, the "more than meets the eye", suds' benefits are philosophically tallied against them while also zooming at some best practices. Advancing the research, it is identified that very limited awareness about SuDS prevails, and some effective strategies for unsealing are provided in a real-world scenario yielding general recommendations for SuDS implementation in the end.
The dissertation reveals that SuDS align well with the UN SDGs demonstrating their potential to resolve modern urban challenges while catering to the sustainable way ahead.
This study underscores the necessity of re-embracing SuDS as a means to balance urbanization and environmental integrity and, this time as the centerpiece, for more-than just water managing solutions. It also urges that the very first thing to do is fill up the suds literacy gap. The research can be important for professionals working with SuDS and UNSDG goals as it makes us rethink that SuDS have the capacity to rephrase the narratives of not only urban water management systems but whole urban systems in a broader framework.

Keywords: SuDS, Sustainable Urbanization, 'UN SDG' Goals

Originality statement. I hereby declare that this master's dissertation is my own original work, does not contain other people's work without this being stated, cited and referenced, has not been submitted elsewhere in fulfilment of the requirements of this or any other award.	**Signature**

Dedication

“This work is dedicated to my parents, who blindly believed in me and thought I would do okay somehow. Hopefully someday I will manage something better to dedicate to them again.

This thesis is also partly dedicated to ‘Pragya’ sitting in the chair in the living room of Oberauer Strasse, and to her ‘Satya’ staring at the moon in another part of the world.”

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Chapter 1

1. INTRODUCTION

1.1 Rationale

It is estimated that by 2050, close to 72 percent of the global population will live in urban locales (Zhang, 2016). This will increase the urban regions by six times compared to the present situation. This means that urban areas will continue to come under pressure, and existing multiple challenges will escalate. There is a crucial need to urgently find a way for sustainable urbanization and its effective management.

Among several issues cities are facing worldwide, stormwater management tops the list. The replacement of natural lands with pavements and buildings disrupts the natural hydrological cycle in urban areas. As a result, rainwater (storm water) accumulates on surfaces instead of being absorbed by the land, straining conventional drainage systems, and polluting nearby water bodies. Uncontrolled water accumulation on land leads to flooding.

Due to climate change, extreme weather events, including intense and extended rainfall and drought periods, are projected (Bąk and Barjenbruch, 2022), i.e., the precipitation events will increase (Golden and Hoghooghi, 2018) in the coming days, and so will the runoff acceleration. Consequently, pluvial flooding risk have become a crucial concern in the realm of management of urban water resources (Rosenzweig et al., 2018). Along with potential human life risks if nothing is done by 2050, damages caused by floods in European cities are projected to be five times greater in Europe alone (Pearce, n.d.). The issue is similarly significant, if not severe in some cases, in other parts of the world like the USA, China, the UK, India, etc. They consistently face these issues. For example, recently in July 2023, the southeast cities of China received torrential rainfalls (Reuters ,2023), which caused both the urban floods and their horrendous effect. Thus, urban floods disrupt and endanger daily life.

In this vicious scenario, Sustainable Urban Drainage Systems (SuDS) have emerged as the beacon of hope in so many cities. Also known as the sponge city concept, water sensitive urban design (WSUD) or 'green infrastructure integration', in these systems, more natural elements such as plants, soil, water, etc. are used (US EPA, 2015). The core idea of this micro level design approach is to re-connect urban areas with the underlying soil, making infiltration and storage of storm water possible (Irvine et al., 2021).

There have been several successful projects around the world time and again, proving that SuDS are an effective sustainable approach for stormwater management in urban areas and for flooding. But they are taking too long to be fully integrated into mainstream urban planning and development practices. In western Europe, the adoption of green infrastructure processes has encountered reservations and caution (Cettner et al., 2013).

SuDS encompass a wide array of technologies and strategies (Fletcher et al., 2015), and since they are based on nature, their benefits in cities are of a wide range too if properly implemented. They protect water bodies, provide aid to biodiversity, and improve liveability in cities (Cotterill and Bracken ,2020), and the list is long.

Hence, in this light, where it's imperative that cities today find solutions for solving a wide range of issues brought by unmanaged urbanization, this research intends to investigate and re-assess if SuDS properly implemented, can contribute to promoting overall sustainability in urban neighbourhoods.

The city of Dresden, Germany, is planning for "The Federal Garden show" in 2033 (BUGA 2033), which is a unique and significant occasion (Dresden, 2023). For this, the city of Dresden wants to develop two green/blue belts in Dresden. One is 'Blaues Band Geberbach' (Dresden, 2023) which means "Blue Ribbon Geberbach" and it holds multifarious ambitions of social wellbeing and interactions all along the Geberbach river. For this reason, Geberbach needs to be flowing throughout the year while not being a flood risk for the city & people. Last year, in 2022, it dried up in summer questioning the essence of the whole project and piling up dreams. This research is also about finding the basic concept to keep Geberbach alive even during the summer through the integration of sponge city ideas along the neighbourhood.

As one of the pioneering nations to engage in in-depth investigations on sustainable stormwater management, Germany was also the first to implement on-site stormwater management practices, notably focusing on infiltration (Zhengyue, 2005). And despite that, the project area where the research will focus and try to come up with some solutions for flooding through this thesis project is in Germany. Thus, the research will also try to explore why SuDS are taking so long to become mainstream, as discussed before.

1.2 Aims and objectives.

The main aim of this research project is to critically rethink and review Sustainable Urban Drainage Systems (SuDS) as the living system that could be the basis of sustainable urbanization.

The basis of this critical rethink is exploring the co-relation of SuDS and its benefits with 'UN SDG' goals, the universally accepted benchmark and shared dream of an ideal sustainable world. It also examines the effectiveness and advantages of integrating green infrastructure into flood management in a real-life problem scenario in Prohlis, Dresden, while making recommendations for a small neighbourhood context. The project aims to provide ideas for unsealing and the basic concept of rainwater storage to the city of Dresden.

The objectives are to:

a. Analyse the linkage between SuDS and UN SDG goals.
b. Evaluate the awareness of SuDS among the public.

c. Suggest different strategies for sustainable urban drainage systems, the concept of rainwater storage, and ideas for unsealing for effectiveness for the chosen case study of Prohlis.
d. Provide site-specific design recommendations for implementing suds.
e. Provide general recommendations for the universal implementation of SuDS.

1.3 Research question

This study intends to find the answers to the following research questions, with a focus on the literature review and the neighbourhood context of Prohlis, Dresden.

Question 1: How are SuDS and UN SDG goals aligned with each other? Can they come together to create sustainable neighbourhoods?

Question 2: What is the state of SuDS literacy among people? Why is SuDS taking so long to become mainstream practice?

Question 3: How can we unseal the neighbourhood of Prohlis while managing water for the creek Geberbach for its driest days?

1.4 Dissertation Structure

This thesis is divided into five parts, as follows:

Chapter 1 is **Introduction** to the research topic, aims, and objectives, followed by the research questions and dissertation structure.

Chapter 2 is **Literature review** that discusses sustainable drainage systems (SuDS) and links them to UN SDG goals, followed by the identified research gap.

Chapter 3 is **Case study** that offers an introduction to the case study area, followed by a brief site analysis and climate analysis.

Chapter 4 is **Methodology,** which outlines the research methods adopted for the study.

Chapter 5 is **Results,** where the SuDS benefits, and best practices examples are analyzed with UNSDG goals. Also, learnings from the literature review and existing best practices are implemented into the real-life case study scenario as discussed in Chapter 3 while deriving the recommendations too.

Chapter 6 is **Analysis** that analyses the co-relationship between “SuDS” and “UN SDG” goals.

Chapter 7 is **Conclusion** provides the conclusion of this research.

Chapter 2

2. LITERATURE REVIEW

2.1 Sustainable Drainage (SuDs)

Sustainable drainage systems are drainage systems that mimic the natural drainage principle and follow patterns of the same (CIRIA, 2015). As water risks are projected to increase day by day, SuDS fit as solutions as they are based on the ideology of increasing the benefits and reducing the harms of surface water, especially runoff. Sustainable drainage systems offer various ways to manage water effectively while also making places more liveable and valuable. These systems help create better spaces while ensuring proper water control (A guide for master planning sustainable drainage into developments Prepared by the Lead Local Flood Authorities of the South East of England, n.d.).

SuDs reduce flood risk at the local level, reboot local climates, and help enhance biodiversity. Since SuDS primarily involves managing surface water runoff within the soil, it plays a dual role by facilitating groundwater recharge and contributing to the preservation of the essential baseflow levels in water bodies such as rivers. This function becomes very important during dry periods like droughts.

Most importantly, they are also economical compared to conventional drainage systems when they are considered in the early stages of urban planning and design.

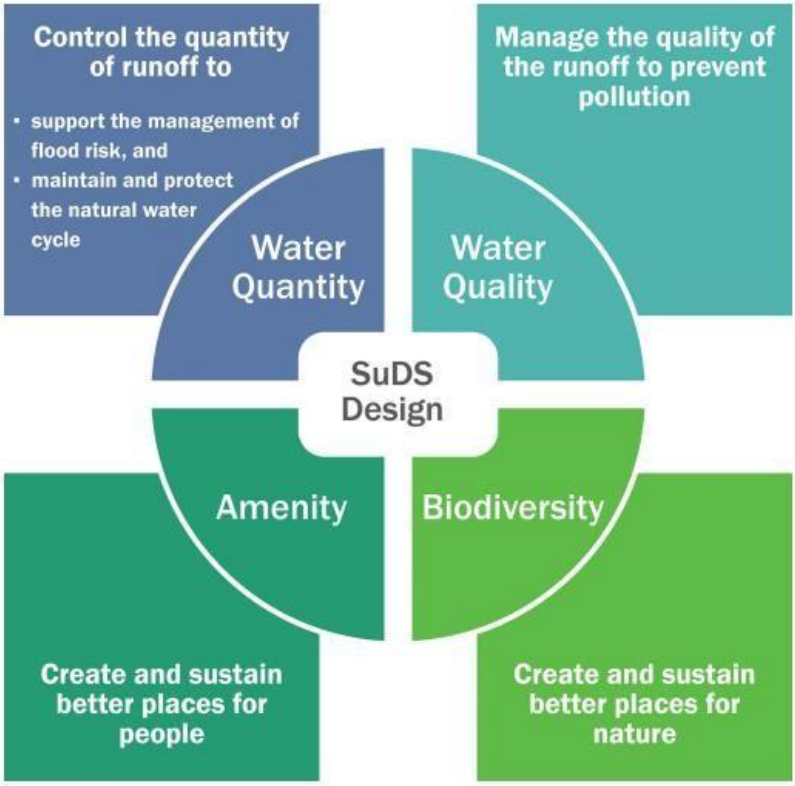


Figure 1. Four pillars of SuDS (Source: CIRIA Manuel)

The multifarious advantages of SuDS are largely categorized under four broad categories: water quality, water quantity, amenity, and biodiversity (CIRIA, 2015). They are also known as the four pillars of SuDS, with each pillar having a specific design objective as shown in Fig.1. Similarly, some of the different benefits of suds are listed in Table (1).

SuDS benefit category	SuDS Benefits
Water quantity	Help reduce flood risk by decreasing and slowing down the runoff
	Support groundwater recharging and assist in preventing low flow of rivers in summer
	Reduction in both pollution and erosion
	Collect Rainwater for domestic use
	Reduce pressure on sewer system leading to the less needs for their upgrades
Water quality	Decrease pollution in river by reducing the quantity of pollutants
	Decrease the quantity of sewage in urban area
	Decrease erosion and reduce the quantity of suspended materials in water bodies
	Decrease the frequency of improper connections to sewage systems
	Lessen the use of chemicals for maintaining paved surfaces
	Minimize sewage overflow pollution
Natural environment	Help in keeping urban trees healthy
	Aid in preserving and promoting biodiversity
	Aid in valuable species and recreational amenities
	Aid in protecting river ecology
	Aid in maintenance of natural morphology of rivers
	Aid in protecting natural resources
Built environment	Elevate the visual and recreational appeal of a developed area.
Cost reductions	Minimize the funds needed for drainage construction
	Assist in long-term cost savings.
	Aid in cost savings through the use of simpler construction methods
Sustainability	Superior in Effectiveness compared to conventional sewage system
	Aid in decreasing the environmental impact of a development.

Table 1: Lists of SuDS benefits adapted from (Charlesworth and Booth, 2016), originally derived from (CIRIA, 2001)

However, the positive implications of proper implementation of SuDS are even greater, as shown in Fig. 2 below, as proposed by Charlesworth. It implies SuDs ultimately help mitigate climate change as they co-benefit by reducing urban heat stress, reducing energy usage, and contributing to carbon storage. It also contributes to positive human health.

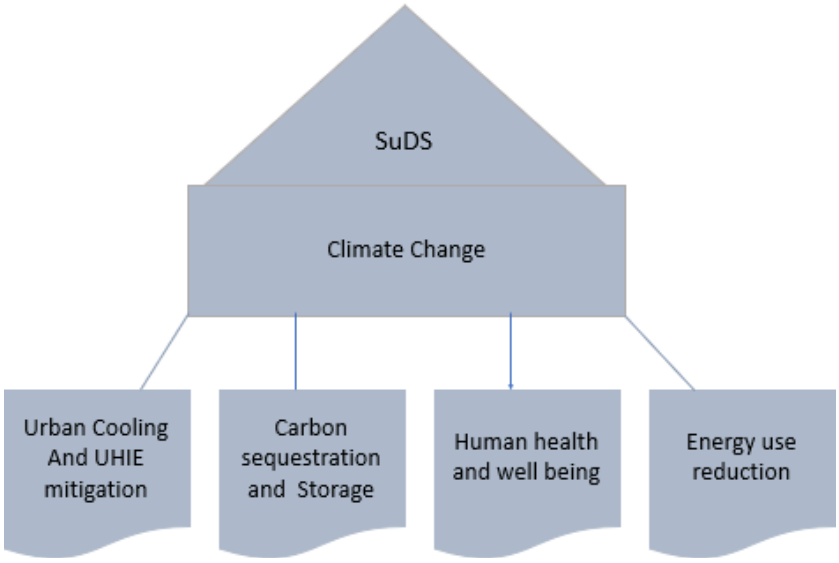


Figure 2 SuDS Rocket re-illustrated by author (Source: Charlesworth,2010)

2.1.1 SuDS Principles

According to (susdrain,2019), SuDS are based on the following principles:

a. Capturing the runoff and slowly releasing it, known as attenuation.
b. Utilizing the rain close to where it falls.
c. Letting water percolate into the ground and be absorbed, known as infiltration.
d. conveying water slowly over the surface.
e. Removal of pollutants by filtration.
f. Regulating water flow to enable the settling of sediments.

2.1.2 SuDS Management Train

The fundamental concept behind sustainable drainage 'SuDS' is that before allowing runoff to enter nearby water bodies, it should be infiltrated, absorbed, or treated through source control, site control, and regional control techniques. While a single measure can be sufficient in some cases, it's common to strategically combine multiple strategies for maximum benefits. This is termed SuDS management or treatment train. In fact, the optimal solution frequently involves the effective combination of multiple methods (Woods-Ballard, 2007, 5.1).

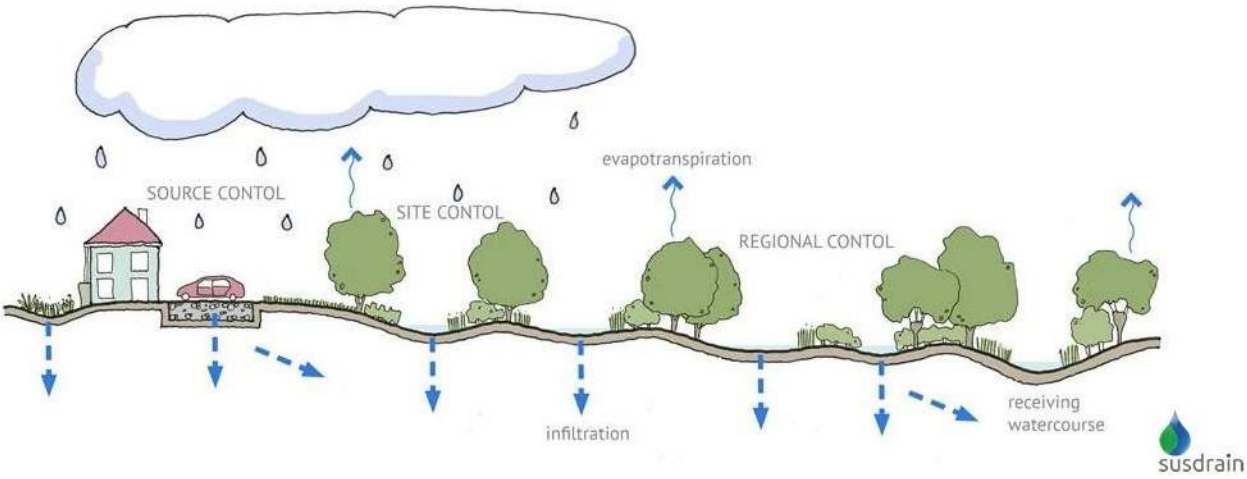


Figure 3. SuDS Management Train (Source: SuSDrain.org)

2.1.3 Different strategies at a glance

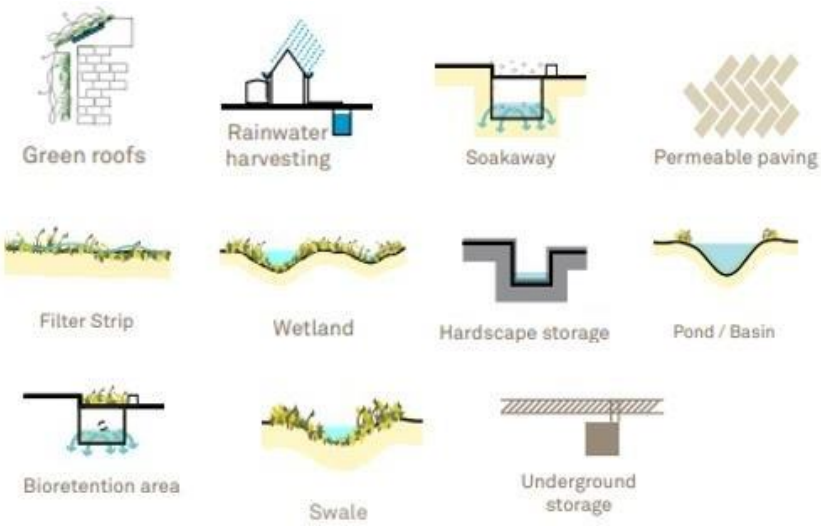


Figure 4. Different strategies of SuDs (Source. Water, people, places)

Strategy	Definition
Green roofs	Green roofs are roofs on buildings where vegetation is intentionally planted.
Rainwater harvesting	It is the process of collecting, storing, and reusing rainwater, usually from roof tops or other paved surface areas.
Soak-away	Soak-away are constructed to let water quickly infiltrate underground, passing through gravel or rubble.
Filter strips	Vegetated bands usually dense grass placed in the streets perpendicular to the incoming runoff.
Permeable Pavement	Permeable pavements are interconnected concrete blocks with centrally located empty spaces in them which can be filled with soil, sand, or gravel. These infilled materials allow the infiltration of rainwater into the ground.
Swales	Swales are broad vegetated channels or drains used to transport runoff slowly.

Wetlands	Wetlands are shallow water bodies with lots of vegetation in them.
Detention Basins	Detention basins are dry ponds where huge volumes of water are stored for a period of time.
Ponds/Basins	Ponds are water bodies designed to collect and store water.
Underground storage	Underground storage are tanks for storing water, are made from concrete or plastic.
Bio retention areas	Bioretention are depressed areas in land that resemble ponds in structure. These areas incorporate other different elements such as plants, layers of soil and overflow structures, and might also contain an optional drainage system underneath.

Table 2. Different strategies of SuDS

2.1.4 Factors affecting SuDS implementation.

The choice of SuDS for any site depends on its typology and on several site characters and factors. Some of the main factors affecting the implementation of SuDS in any place are as follows:

a. **Natural Drainage Pattern**
As the core idea is to manage the drainage naturally, the suds design follows the natural drainage pattern. Hence, an analysis of the natural flow route of the site and the changes brought in by the development should be undertaken.

b. **Groundwater level for infiltration**
As with SuDS strategies, we are mainly looking to filtrate the water as much as possible into the ground, one should be careful not to alter the groundwater with pollutants from runoff. Hence, before adopting infiltration techniques, it should be made sure that the groundwater level is below one meter (CIRIA, 2015).

c. **Existing Sewage Infrastructure**
The benefits of SuDS can be achieved more economically if the strategies are combined with the existing sewage infrastructure. As new urban lands are less compared to already built urban spaces, this makes much more sense.

d. **Existing vegetation, especially Trees**
Healthy green trees are always assets because of their huge ecosystem services, and they take several years to grow fully. So, it is important that we pay attention to existing trees while implementing SuDS. According to Michigan State University, it is popularly believed that the root system underneath the ground for a tree is usually a mirror image of its canopy's outer edge line known as the 'Dripline' (Protect tree roots from soil compaction, 2016). But the roots of trees can expand even beyond in proper soil and other favorable conditions. Thus, while implementing SuDs, it is recommended to refrain at least one meter outside of the existing Tree Dripline.

2.1.5 Maintenance of SuDs

SuDs are networks of different strategies, and the core benefit is possible to achieve remarkably and maximally if only adopted over a large area or neighbourhood. Thus, the maintenance of each suds comes down to each person's behaviour in the community. Also, the maintenance needs might vary according to the type of suds. It must also be monitored regularly in any case. A table below, adapted originally from SuDS Manuel (CIRIA, 2007), briefly discusses how to take care of some SuDS techniques.

Strategy	Annual or sub annual maintenance	Intermittent and/or remediation
Green roofs	Remove waste and debris every 6 months. Remove weeds every 6 months.	------
Simple rainwater harvesting	Clean inlets and outlets, gutters, & tanks every year.	-----
Advanced rainwater harvesting	Self-cleaning and coarse filter checks every 3-6 months. and clean every 6-12 months. Check/clean roof & gutters 6-12 months. UV unit operation check every year. Pump operation check every year	-----
Soak away	Remove debris. Clean gutters/ filters	------
Filter strip	Remove litter & debris every month. Cut the grass every month. Manage vegetation every year.	Make sure silt is not piled up. Remove debris and oils.
Permeable pavement	Brush and vacuum every 6 months.	Regularly mow and stabilize linked surfaces. Remove weeds. Instantly repair any broken areas. Rehabilitate surfaces with major clogging issues.
Swales	Remove litter and debris every Month, Cut grasses every year. Manage weed every year. Remove bad vegetation/reseed every year.	Repair erosion. Maintain the level of surfaces regularly. Remove debris and oils.
Wetlands	Remove debris and trash. Cut the grass in landscaped areas 2-3 times per year. Cut meadow grasses every year. Remove weeds and unnecessary vegetation.	Remove debris from silt traps. Repair erosions Repair/replace inlets, outlets, and overflows.
Detention basin	Remove trash and debris every month. Cut grass of landscaped areas 2-3 times per year. Cut meadow grasses every year. Remove weeds and unnecessary vegetation.	Remove debris from silt traps. Repair erosions Repair/replace inlets, outlets, and overflows.

Table 3. Maintenance of Different Suds, adapted from (Environment agency,2015), originally from (CIRIA,2007)

2.1.6 Considerations to be taken while implementing SuDs

When incorporating certain SuDS, it's important to consider the impact on the building foundation, especially harmed by lots of infiltration. Therefore, it is advisable to avoid the implementation of the infiltration-based SuDS techniques within a 5-meter range from the buildings (Using SuDS close to buildings, n. d.). The same rule applies to situations involving roads or sites with unstable conditions.

2.2 UN SDG goals

This part attempts to explain why UNSDG goals are important and why they are regarded as the benchmarks of a sustainable world globally.

2.2.1 UNSDG – A vision for a sustainable world.

The United Nations General Assembly introduced the UN SDG goals in 2015. Representatives from 193 United Nations member countries came to a consensus on the 'Sustainable Development Goals', known as SDGs in short, which are a set of 17 goals with 169 specific targets (United Nations, 2015).

The United Nations considers the UN SDG goals as the roadmap to a sustainable future that benefits everyone (United Nations, 2015). By addressing a range of worldwide challenges in a sustainable manner (Jan et al., 2021), these 17 interconnected global goals serve as a framework or as the standards for an ideal sustainable society. At the same time, they can be used as practical benchmarks for assessing sustainability, development along and quality of life. The purpose behind formulating the UNSDG goals was to encourage organizations from all over the world to embrace sustainability, meet the demands of current and future stakeholders, and ultimately advance societal sustainable development (Fonseca and Carvalho, 2019).

According to Antonio Guterres, the ninth and current secretary of the United Nations as of 2023, "The sustainable goals are more important than ever as now is the time to secure the wellbeing of people, economies, societies, and our planet." (SDG indicators, n. d.)

The 17 goals are as follows:

Goal 1: No Poverty
Goal 2: Zero hunger
Goal 3: Good health and wellbeing.
Goal 4: Quality Education
Goal 5: Gender equality and women's empowerment
Goal 6: Clean Water and Sanitation
Goal 7: Affordable and clean energy
Goal 8: Decent works and Economic growth
Goal 9: Industry, Innovation, and Infrastructure
Goal 10: Reduced Inequalities
Goal 11: Responsible consumption and production
Goal 13: Climate Action
Goal 14: Life below water
Goal 15: Life on Land
Goal 16; Peace, justice, and strong institutions
Goal 17: Partnerships for the Goals

2.2.2 Knowledge gap

Though both the aims and objectives of UNSDG goals and SuDS is to create a sustainable world, ultimately, UNSDG goals have a wider focus to encompass social, economic, and environmental aspects of sustainability. Sustainable Urban Drainage Systems (SuDS) are considered micromanaging tools for urban runoff primarily to control urban floods and reduce water pollution. But the advantages of SuDS are even greater than that. The studies to analyse and critically review the linkage between UN SDG goals and Suds' philosophy and relationship to foster the common goals have been very limited or null. This research work attempts to address this gap.

Chapter 3

3. CASE STUDY

3.1 Project Area -Prohlis Development Area

Prohlis district lies to the southeast of Dresden, the German city of the arts and culture of the state of Saxony. It is approximately 7.4 km from Dresden's city centre. The other surrounding other districts of Dresden are Blasewitz, Leuben, and Altstadt in the east and Plauen in the north. It is the new development area, mostly popular for prefabricated high-rise buildings of the 70s and 80s constructed as a solution to the housing scarcity of East German times (Dresden history, studies of the exceptional & moved story, n. d.). The district is often regarded as the one necessitating focused developmental support (Diverse Neighbourhoods in Prohlis, 2022).

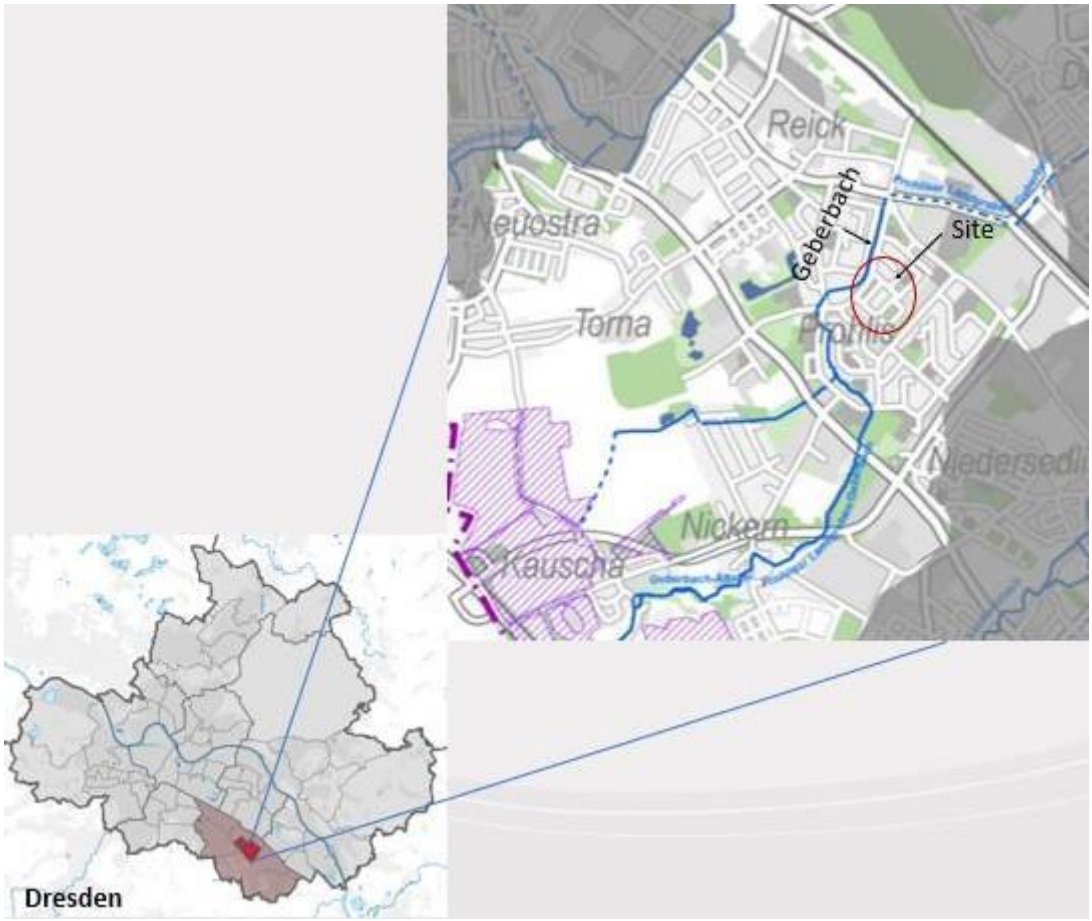


Figure 5. Prohlis Development Area in Map of Dresden showing the site and Geberbach creek (Source. Dresden.de & Gewaessersteckbrief-Prohliser Landgraben/Geberbach)

Masterplan Prohlis 2030

To improve the current social image of Prohlis while also managing the flood risk of Geber bach river, the Project Masterplan-Prohlis 2030 has been proposed by the city of Dresden. The project builds upon the ambitious green belt project called 'Blaus Band Geberbach' which means "Blue Ribbon Geberbach".

3.1.1 The Geber Bach

The Creek Geber Bach meaning 'Giver stream 'in German, is 10.5 km long. It originates from the Rippein community of Possendorf and enters Dresden at Kauscha Dam, where it is controlled and regulated to a flow of 2 cubic metre/second as one of the flood risk reduction strategies for Dresden. Flowing through the Nickern area, the stream enters the Prohlis development area and runs through the Georg-Palitsche Strasse and the Spreewalder strasse neighborhoods. It is also called Prohliser Landgraben after it enters this built-up area. The stream is piped from Muglener Strasse up to another 1.4 km, opened at Pirnaer Strasse and then released to Niedersedlitz ditch (Gewaessersteckbrief-Prohliser Landgraben/Geberbach, 2011).

One of the objectives of 'Blue Ribbon Geber Bach' project mentioned above is to free the piped section of Geberbach and connect it with the Elbe River to manage the flood (Dresden, 2023). Other than big flood events engulfing the whole city of Dresden like in 2002 and 2013, Geberbach exhibits the flood risks in the area of its proximity during heavy rainfall. This is because lots of surface runoff from the built environment enters to the Geberbach through the sewage systems of the municipality which are mainly different discharge points (Gewaessersteckbrief-Prohliser Landgraben/Geberbach, 2011).

Figure 6. Geberbach at different points nearby site

According to LFULG (Saxon state office for environment, agriculture and geology), status 1, the chemical state of Geberbach is found polluted along the stretches of Prohliser Landgraben with the presence of mercury and mercury compounds as well as Polycyclic aromatic hydrocarbons (PAH) which is also called fluoranthene (Gewaessersteckbrief-Prohliser Landgraben/Geberbach,2011).

3.1.2 The site

The neighborhood opposite the Gamigstrasse-14 of Prohlis Nord at 51°00'28.9" N Longitude and 13°47'46.3" E Latitude has been taken as the site of this research. It is chosen because it is significant as the most immediate neighborhood, situated right next to the parking area across the street, which many experts consider suitable for long term rainwater storage for Geberbach from the Prohlis Neighborhood. The site area is approximately 7.4 ha. The ratio of green surfaces to impervious surfaces is 1.7, as per

AutoCAD and manual calculations. Over the past 20 years, as seen in the Google images down below in Fig. 6, not many changes have occurred in the neighborhood. The ratio of impervious areas to pervious area has been the same. One very positive thing is that trees have grown and become more intense over the years, adding a lot of green to the site. There are 18 high rises attached to each other in an L-shape in the outer line, with another 18 small apartments attached and placed in such a way that two courtyards are formed in between them, as shown in the site image below. The buildings are mostly residential in use, but some social organizations and some businesses also exist in them.

Figure 7. Site at Prohlis over the years (Source. Google earth)

According to the site's character and usage, it can be divided into the following catchments, as shown in the fig. for our reference.
Catchment A – 'Area aimed for rainwater storage.'
Catchment B – Street aligned parking (B1 and B2)
Catchment C – Neighbourhoods with Courtyards C1 and C2.
Catchment D – Site part behind the buildings. (Refer fig.8)

Figure 8. Approx. catchment division of Site (Source. Google earth)

Figure 9. Inside and around the site (Source. Author)

3.2 Site Analysis for Sustainable drainage systems (SuDS)

The site's character was assessed based on following criteria as identified from literature (CIRIA,2015).

1. **Site topography** – Slight slope with varying contours. Rain water storage 'A' is at the lowest point of the catchment.

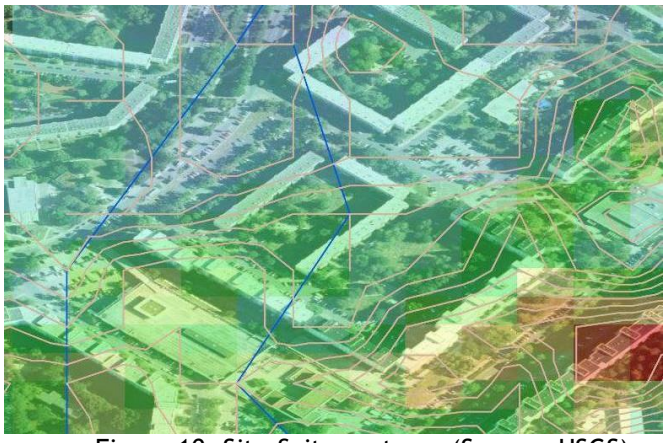


Figure 10. Site & its contours (Source. USGS)

Figure 11. Site & its topography (Source. Author)

2. Existing flow routes/ discharge points

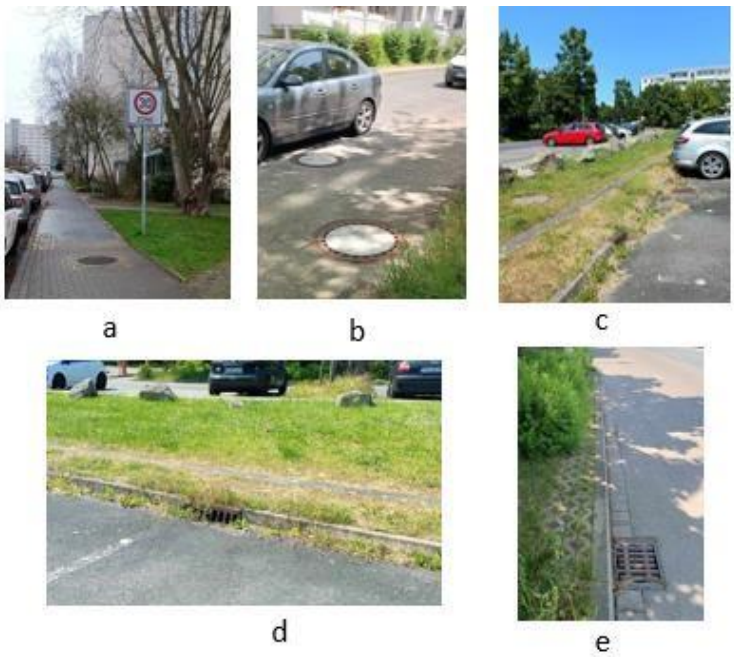


Figure 12. Different discharge points around site (Source. Author) Figure 13.Discharge at Geberbach

Throughout the site, different inlets and culverts are distributed. As seen in Figure 13, these sewage points eventually transfer the surface runoff to Creek Geberbach.

3. Existing site land use

As discussed before, the site is mostly residential, with some nonprofits and businesses present in the apartments.

4. Potentials for infiltration

As per the website 'Themenstadtplan' of the City of Dresden, the current groundwater measure of the nearest station (Doboritz 5022) is 6.15 m below ground level, which implies the site has no issues for infiltration strategies.

5. Site flood risks

As mentioned before in 3.1.1, the surrounding area around the creek is prone to flood risks due to the surface runoff discharged at the creek during heavy rainfall events.

3.3 Climate Analysis

Because Prohlis lies in Dresden, it is important to understand the climate of Dresden. The capital city of Eastern Germany, Dresden, lies in the state of Saxony. According to climatestotravel.com, the climate is moderately continental, with warm summers and cold winters. With the nearby river Elbe influencing the climate sometimes, the precipitation is 635 mm, i.e., 25 inches on average every year, though the pattern differs every year. The rainfall is fairly distributed throughout the year, with July and August being the wettest times of the year (Dresden climate: weather by month, temperature, precipitation, when to go, n. d.).

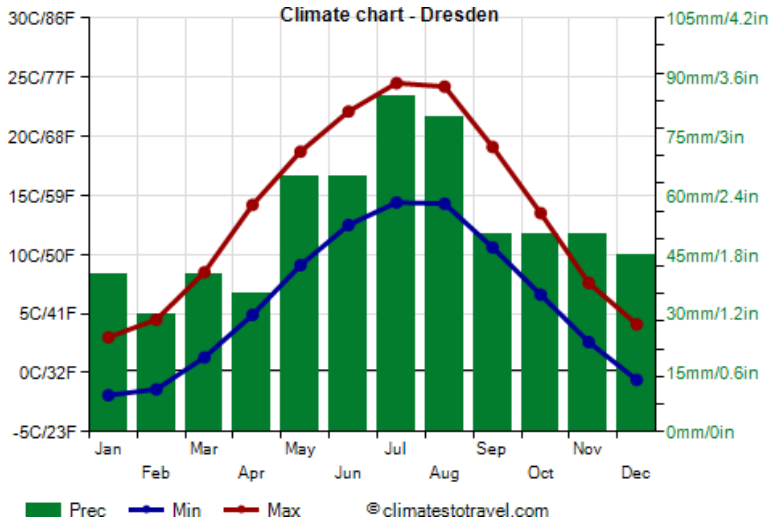


Figure 14. Temperature and rainfall chart for Dresden (Source. Climatestotravel.com)

On examining the broader climate context from 1962 to 2022 as seen in Figure.15, the rainfall pattern of Dresden has shown some notable fluctuations. This period witnessed years marked by high precipitation levels, intervals of drier-than-average conditions, and years where precipitation adhered to normal ranges. Thus, it can be said that there has been no clear and consistent trend in Dresden's precipitation pattern over the past six decades. However, it is worth noting that there has been a decline of approximately -0.34 mm/year in precipitation, which has been contributing to lower groundwater levels and reduced soil moisture (Körner, 2023).

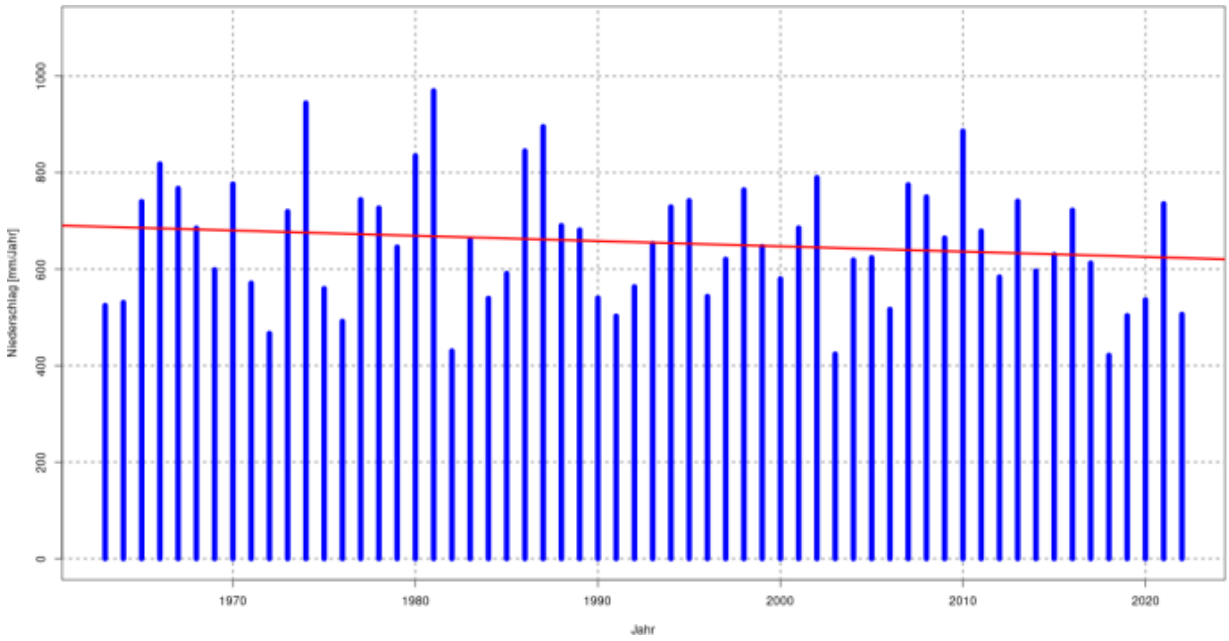


Figure 15. Precipitation of Dresden (1962-2022) (source. Dr. Philipp Korner, Sponge city conference 2023)

According to Ideenskizze, a conceptual sketch for BUGA 2033, some of the note-worthy climatic events in Dresden include:

1. severe flooding in 2002 and 2013, coupled with an increasing occurrence of intense rainfall events.

2. Drought periods between 2018-2020 led to significant damage to approximately fifty percent of the urban trees.
3. The year 2020 witnessed a remarkable surge in the count of hot days, surpassing double the number recorded during the standard climate period of 1961-1990. (Dresden,2023)

Chapter -4

4. Methodology

This chapter explores and introduces the methodologies and philosophical approaches employed to address the knowledge gap and accomplish the stated objectives of this research. A combination of various methods was utilized to attain the various objectives.

Approach & Research Methods

This is an explanatory literature review based on qualitative research. A simple overview of the research method looks like figure 16 below, and each step is further elaborated in detail.

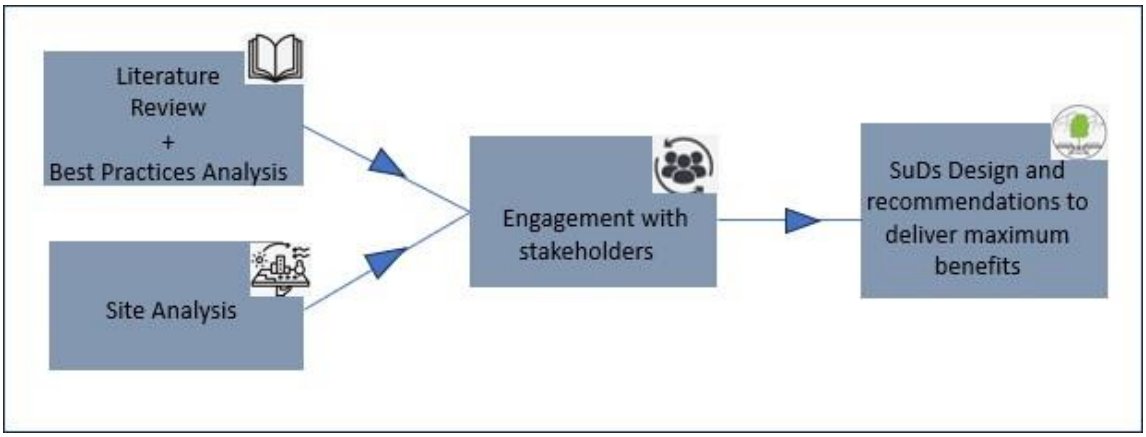


Figure 16.Simple methodological diagram for research

4.1 Literature review

The literature review was done majorly online based on extensive reading of nearly 100 plus papers, including grey literature, to understand sustainable drainage systems (SuDS) and the various theories, principles, strategies, and applications of SuDs. Important attention was given to the wide ranges of SuDS benefits. This guided the development of research questions, methodologies, and analytical approaches. "Ciria SuDs Manual" (Ballard et al,2015) was widely used as the basis of this research.
A thorough study of the United Nations Sustainable Development Goals (UN SDGs) was also conducted to understand philosophically each goal and target. This was important to achieve the first objective mentioned in Chapter 1.
This research closely examines three case studies of SuDS application as closely as possible, mostly analysing them from the point of view of successful implementation and creative use of different SuDS to address the flood issues over there. The analysis for all of them ended with a wider analysis or sustainability analysis based on 'UNSDG' goals to see what else impact SuDS created there. All of the case studies are almost equally well known to Blue-green infrastructure enthusiasts. The reason behind choosing them is that, in some way they are relatable to the site. The first case study 'Cloudburst Management' plan is a river and neighbourhood scenario, which can be linked with the creek and neighbourhood context. The Rotterdam case study presents ideas for integrating blue spaces, in public spaces which can be inspiration for the site. The third case study of Hamburg is selected because it is in Germany and hence more relatable to the site than the first two case studies in terms of social context.

The literature also followed the holistic understanding of site area, Prohlis history and development and upcoming plans of city of Dresden regarding it.

4.2 Site Analysis

The researcher has visited the site multiple times and done site analysis through personal observation. Google Earth, ArcGIS, and USGS were also used as per the need. A few official and other websites related to Dresden were also researched for some of the information.

4.3 Engagement with the stakeholder

In an attempt to transfer knowledge on SuDs to local people and to also benefit for research questions as well, the researcher participated in the two-day 'NBS participatory workshop' with posters about a basic introduction to SuDs and some best examples. The workshop was organized near the site, which added precious value in understanding the grassroot state of suds literacy. Only questions regarding floods in urban areas were asked in the workshop. This hinted at some gaps in 'suds literacy' which inspired further intensive surveys. Posters made for workshops and sample questionnaires for surveys are both included in the annex of this research paper.

Engagement with the stakeholders was also done through semi structured survey questions and direct interactions with the residents of the neighbourhood. The researchers tried their best to gather different genders and different age groups as much as possible to achieve multiple perspectives.

A total of 8 survey questions were asked to find out the awareness, benefits, engagement, and knowledge of SuDS among the participants. Some of the sample questions are as follows:

a. How aware are people of the real cause of floods in urban areas?
b. How would people in the neighbourhood benefit if SuDs were implemented?
c. How do ideas of SuDs excite people without them knowing they are SuDS? (Should we refrain from technical words?)
d. How many people know about the different strategies of SuDs?

4.4 SuDs designs and recommendations to deliver maximum benefits.

The literature review and site analysis eventually helped to yield qualitative suggestions for unsealing the site and integrating blue elements while also coming up with a basic concept for long term the rainwater storage, which is the third objective of this research. The SuDS strategy suggestions are then again analysed from the perspective of UNSDG goals as in what other co-benefits can be garnered along with rainwater management ideas.
Besides design suggestions, several site visits and site observations were optimized for making site specific recommendations for not only SuDS implementation but also the overall upliftment of sense of a placemaking for the neighbourhood. This and the case study analysis finally helped in formulating the general recommendations for implementing SuDS anywhere as the basis for the way forward for sustainable urbanization.

Finally, to summarize the linkage between SuDS and UNSDG goals, the SuDS rocket found in the literature was repurposed as the final and most important outcome of the whole research. Figure 17 below illustrates each step of the methodology in detail.

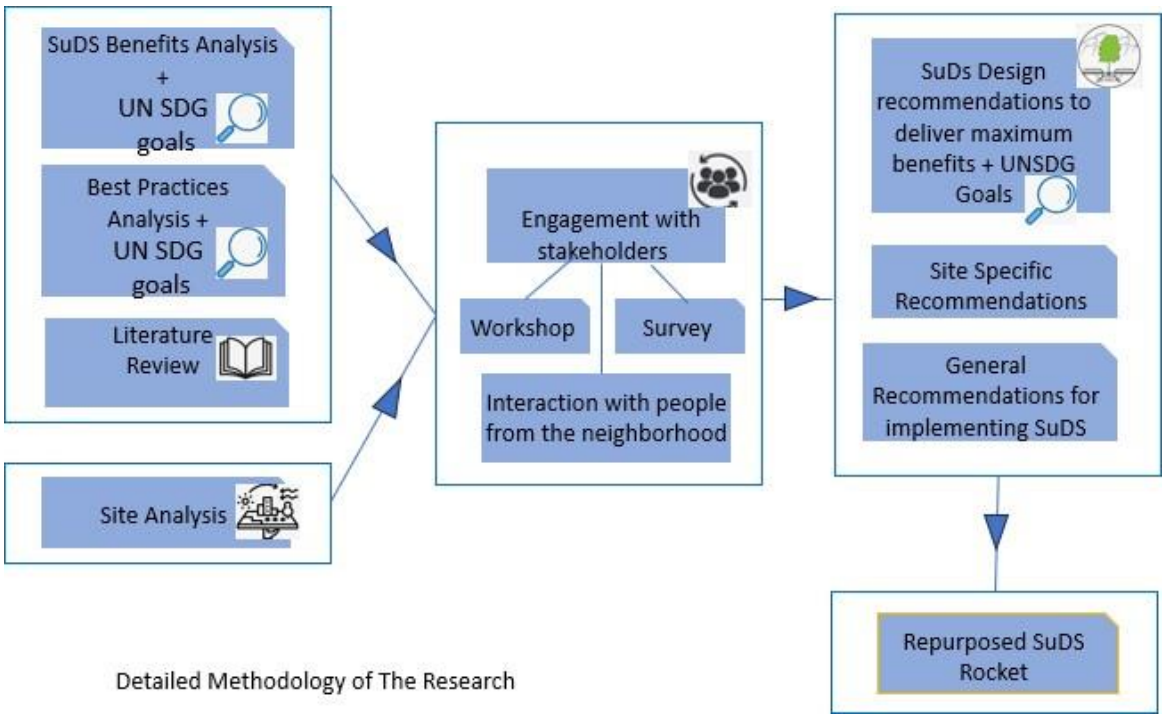


Figure 17. Detailed methodology

Chapter 5

5. Results

This chapter presents the outcomes of qualitative studies organized into five distinct sections. These sections encompass the analysis of SuDS benefits with UNSDG goals, analysis of three best practices of SuDS, findings from survey and workshops, design suggestions tailored for Prohlis site and finally the general recommendations for the implementation of SuDS.

5.1 SuDS benefits analysis with 'UN SDG' goals

Within this specific section, the various advantages associated with SuDS as previously discussed in section 2.1 and listed in Table 1, are philosophically aligned with the 17 UNSDG goals outlined in section 2.2.1. In the following Table 4, the foremost and bold goal demonstrates the highest degree of alignment.

SuDS benefit category	**SuDS Benefits**	**'UN SDG Goals'**	**'UN Goal Target'**
Water quantity	Help reduce flood risk by decreasing and slowing down the runoff	**'Goal 6: Clean Water and Sanitation'**	Target 6.6
	Support groundwater recharging and assist in preventing low flow of rivers in summer	**'Goal 6: Clean Water and Sanitation'**	Target 6.4
	Reduction in both pollution and erosion	**'Goal 14: Life Below water '**	Target 14.1
	Collect Rainwater for domestic use	**'Goal 6: Clean Water and Sanitation'**	Target 6.3
	Reduce pressure on sewer system leading to the less needs for their upgrades	**'Goal 6: Clean Water and Sanitation'**	Target 6.3
Water quality	Decrease pollution in river by reducing the quantity of pollutants	**'Goal 6: Clean Water and Sanitation'**	Target 6.3
	Decrease the quantity of sewage in urban area	**'Goal 6: Clean Water and Sanitation'** 'Goal 11: Sustainable cities and communities'	Target 6.3
	Decrease erosion and reduce the quantity of suspended materials in water bodies	**'Goal 6: Clean Water and Sanitation'** 'Goal 14: Life below water'	Target 6.3

	Decrease the frequency of improper connections to sewage systems	**'Goal 6: Clean Water and Sanitation'** 'Goal 11: Sustainable cities and communities'	Target 6.3
	Lessen the use of chemicals for maintaining paved surfaces	**'Goal 11: Sustainable cities and communities'** 'Goal 12: Responsible consumption and production' 'Goal 3: Good health and well-being'	Target 11.6
	Minimize sewage overflow pollution	**'Goal 6: Clean Water and Sanitation'** 'Goal 11: Sustainable cities and communities'	Target 6.3
Natural environment	Help in keeping urban trees healthy	**'Goal 15: Life on Land'** 'Goal 11: Sustainable cities and communities' 'Goal 13: Climate Action'	Target 15.3
	Aid in preserving and promoting biodiversity	**'Goal 15: Life on Land'** 'Goal 13: Climate Action'	Target 15.5
	Aid in valuable species and recreational amenities	**'Goal 15: Life on land'** 'Goal 11: Sustainable cities and communities' 'Goal 3: Good health and well-being'	Target 15.9
	Aid in protecting river ecology	**'Goal 14: Life below water'** 'Goal 15: Life on land' 'Goal 6: Clean Water and Sanitation' 'Goal 11: Sustainable cities and communities'	Target 14.1 Target 15.1

	Aid in maintenance of natural morphology of rivers	**'Goal 6: Clean Water and Sanitation'**	Target 6.6
	Aid in protecting natural resources	**'Goal 15: Life on land'** 'Goal 6: Clean Water and Sanitation' 'Goal 13: Climate Action' 'Goal 14: Life below water' 'Goal 12: Responsible consumption and production'	Target 15.3
Built environment	Elevate the visual and recreational appeal of a developed area	**'Goal 11: Sustainable cities and communities'** 'Goal 3: Good health and well-being' 'Goal 5: Gender equality'	Target 11.7
Cost reductions	Minimize the funds needed for drainage construction	**'Goal 9: Industry, Innovation, and Infrastructure'** 'Goal 6: Clean Water and Sanitation' 'Goal 11: Sustainable cities and communities'	Target 9.1
	Assist in long term cost savings	**'Goal 12: Responsible consumption and production'** 'Goal 11: Sustainable cities and communities'	Target 12.8
	Aid in cost savings through the use of simpler construction methods.	**'Goal 9: Industry, Innovation, and Infrastructure'** 'Goal 11: Sustainable cities and communities'	Target 9.1

		'Goal 12: Responsible consumption and production'	
Sustainability	Superior in effectiveness compared to conventional sewage system	**'Goal 6: Clean Water and Sanitation'** 'Goal 11: Sustainable cities and communities' 'Goal 3: Good health and well-being'	Target 6.3
	Aid in decreasing the environmental impact of a development.	**'Goal 13: Climate Action'** 'Goal 11: Sustainable cities and communities'	Target 13.2 Target 11.6

Table 4. Lists of SuDS benefits philosophically aligned with UNSDG goals, benefits originally adapted from (CIRIA, 2001)

As it is seen in the above Table (4), different SuDS benefits exhibit alignment with many SDGs and hence can be concluded that when implemented properly, SuDS can really act as the accelerator or catalyst of many UNSDG goals mainly Goal 6 (Clean water & Sanitation), Goal 11 (Sustainable Cities and Communities and Goal 13 (Climate Action). Also, since they are interlinked goals, they create ripple effect and bring along many other SDG benefits that address multiple contemporary urban issues. This collective impact paves the way for a firm path towards a sustainable urbanization catering a balance between environment, people, and economy. Thus, effective incorporation of SuDS can play a vital role, actively contributing to the achievement of the United Nations Sustainable Development Goals (UNSDGs).

5.2 Best Practices Analysis with UN SDG goals

5.2.1 Cloudburst Management Plan (Copenhagen)

The heavy & unprecedented cloudbursts of July 2011 hitting Copenhagen led the city to formulate Cloudburst Management Plan 2012. For a city depending on combined sewer system of mid-19th century (City of Copenhagen,2011), 50 mm of rainfall in half an hour (Ziersen, Clauson-Kaas and Rasmussen, 2017) resulted in an overall claim of more than 800 million euros (Lerer et al, 2017) in Insurance claims as the aftermath of the flood.
The Cloudburst Management plan 2012, with a budget of 1.3 billion euros, outlined 350 diverse interventions such as green roads and cloudburst tunnels. They also included retention spaces and boulevards (Ziersen, Clauson-Kaas and Rasmussen, 2017) based on the hydraulic modelling conducted for seven different catchment areas within the city. As per C40 Cities in 2016, the city successfully collaborated with the water utility to comprehensively restructure its drainage structure. This involved separating rainwater from wastewater and redesigning the streetscape where it could use roads as rivers

during periods of heavy rainfall. The roads are reprofiled to V shape (Liu, Fryd and Zhang,2019) and they slowly transport the runoff towards lakes and harbours. Along these routes, dry detention basins are planned in the form of plazas and parks which can store huge volumes of water. All of these reprofiled roads and dry basins are constructed such that they enhance social values (Liu, Fryd and Zhang, 2019). Biodiversity has also been prioritized by planting native and drought resistant plants (Sørup *et al.,* 2019). These all were complemented by other SUDS such as construction of green rooftops, gardens, bioswales etc. to slow down rainwater. Thus, in this project multiple strategies of landscapes are properly integrated to achieve the goals of stormwater management as well as various other urban benefits (Liu, Fryd and Zhang, 2019).

Taking into account of UN SDG goals, it can be inferred that "Goal 6" of "clean water & Sanitation", "Goal 11" of "Sustainable cities and communities" and "goal 15" of "life on land" are directly realized.

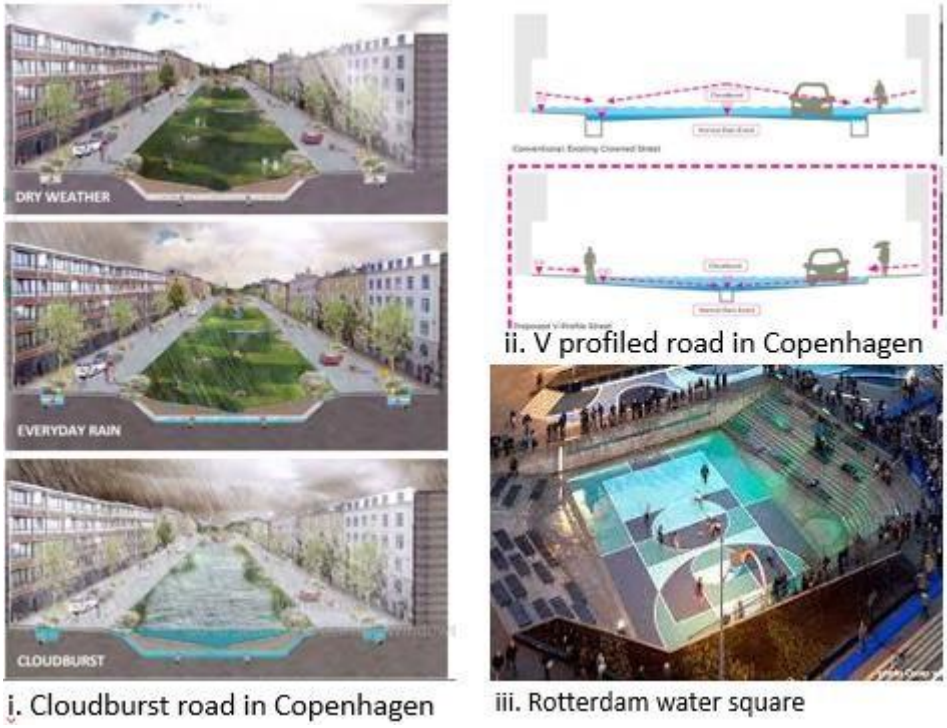


Figure 18. Stormwater management in Copenhagen & Netherlands (Source: i. & ii. Rambol studio Dreiseitl, iii. Inhabitat.com)

5.2.2 Rotterdam Water Square (Netherlands)

A public area 'Water Square', as seen in Fig.18 (iii) was created in Rotterdam as a GI measure for controlling stormwater runoff. This popular one Benthemplein Water Square was completed in 2013. It is based on the concept that it can be used as a square and basketball court, skating area etc. all for public during dry days but can store rainwater when it rains (Ilgen, Sengers and Wardekker, 2019). The water square is depressed and has three basins. The outer two basins are shallow, and they collect the rainwater or runoff from nearby connected spaces. The central main basin is filled up only during very heavy rainfall. The square can store water of a capacity of up to 1.7

million gallons and reduces the instant pressure on the sewage system. The water stored during wet days is stored till dry periods and can be reused for the plants too. Other suds like rain gardens and permeable pavement are also present. Thus, the project was successful in lowering the neighbourhood's risk of flooding while also adding a new public amenity.
Considering UN SDG goals, goal 6 "Clean water and sanitation" is directly addressed as the aim of treating wastewater is met while facilitating reuse and promoting water efficiency. Similarly, the effective strides in making cities and human settlements safe and resilient with inclusive public spaces caters goal 11 of "sustainable cities and communities." Equally significant is Goal 13 of "climate action" which encompasses climate adaptation strategies to mitigate the impacts of climate change.

5.2.3. Bluegreenstreet , Hamburg (Germany)

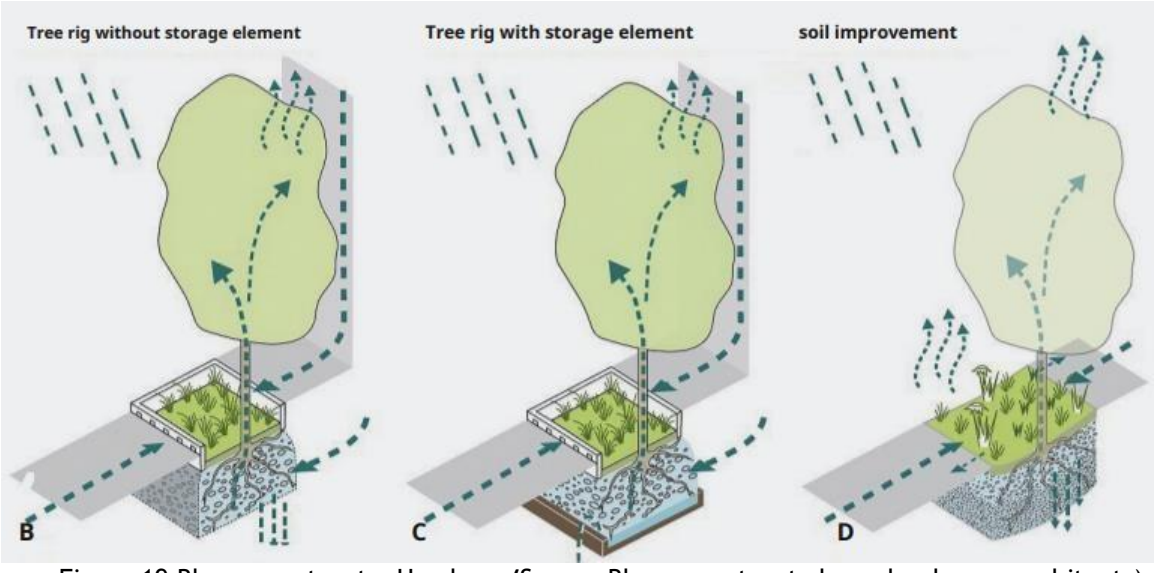


Figure 19 Bluegreenstreets, Hamburg (Source Bluegreenstreets,bgmr landscape architects)

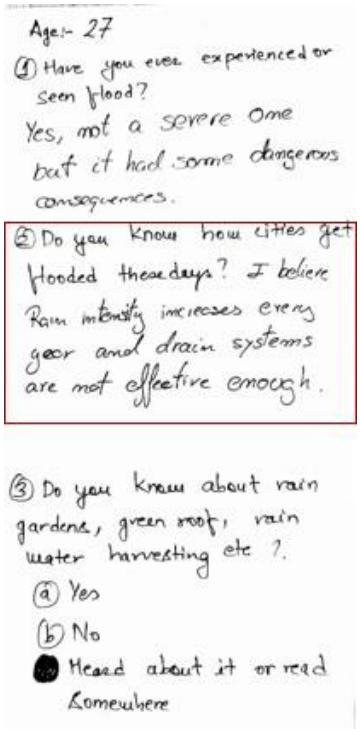
This famous project of Hamburg is a part of 'Resource-efficient city quarters' and is more about streetscapes (BlueGreenStreets – Resource-efficient urban districts, n.d).
It aims to add and maintain green on the streets while managing stormwater (Blue) through tree trench systems and hence the project is named Bluegreenstreets. As drought issues are also increasing in the cities as the effect of climate change, this project showcases how stormwater can be dealt with the help of street trees to slow them down while the trees store more water and grow healthier plus green. In this recent project of 2020, lots of tree trenches were constructed in Hamburg using the bentonite mat seals to control the seepage of extra water (KG,2021).
Along with Goal 6, this project works in alignment to the UN SDG goals 11 and 13 as it is targeted for making cities sustainable while trying to cope with effects of climate change.

5.3 Survey + Workshop Findings

Like the answer written by one of the participants of the workshop, it seems that people have noticed the changed patterns in Climate, and they know that there is some relationship between increasing rain intensity and drains systems, but they do not seem

to be clearly aware about the role paved surfaces play in creating flood by disturbing the natural water balance. Only one response directly tapping on the keyword 'Too much sealed ground' was achieved by the researcher. A serious knowledge gap about hydrological cycle and paved surfaces among people has been identified and concluded by both interview and workshop.

The finding was also like of (Everett et al., 2016) that people do not know about the solutions and functions presented by Sustainable Drainage systems (SuDs). Mixed response was achieved over the question if they know how the rainwater on their rooftop is managed. Participants have noticed drainpipes at the least and they know water is collected or directed by it. All of them think children would enjoy playing safe water related games and they think they will let their kids play safe water games. However, one participant with toddler expressed the concern of pollution and safety which is valid.


Age:- 27

① Have you ever experienced or seen flood?

Yes, not a severe one but it had some dangerous consequences.

② Do you know how cities get flooded these days? I believe Rain intensity increases every year and drain systems are not effective enough.

③ Do you know about rain gardens, green roof, rain water harvesting etc ?

ⓐ Yes

ⓑ No

● Heard about it or read somewhere

Figure 20. A response from workshop depicting knowledge gap.

None of them have seen rainwater being collected and converted into water features like ponds, fountains etc. and some believe it would be useful to do so. One participant responded it might become a place of social exchange if people have access to one common water source rather than their private ones and this could strengthen relationships within the neighbourhood. Thus, there is attraction, hope, and a positive attitude towards managing water due to its multiple benefits around biodiversity, recreation, and social bonding (Everett et al., 2016). Participants think an underground cistern is a better idea than a pond for long term storage of rainwater as they think pond will dry out soon.

A few other insights were collected from the workshop. For example. One woman from workshop shared that last year she demanded green roofs in all houses of the neighbourhood with city council. Much hype and expectations around the techniques like green roof have been generated which is good but it would be better if people would also know that even though green roofs are effective way of adding green in urban built environment as they might have their own implications on water of nearby water bodies.

A little gap in the co-ordination among the stakeholders was also hinted at by the workshop talks.
Another woman from the neighbourhood while looking at the posters of 'Sustainable Rainwater Management' shared that last night due to rain, she and her family were scared thinking of rising water levels of creek Geberbach. Some intelligent participants believed the stream 'Geberbach' was small and a little unnoticeable for the probable users. They suggested it would be great if the stream would be accessible for kids while maintaining safety procedures. The researcher noticed that most of the participants from the neighbourhood were old, aged people. Also, it was interesting to see how some old people showed up on both days of the workshop very excitedly. This also implied they are lonely and are in desperate need of socially engaging spaces where they would feel valued.

5.3.1 Summary of 'Survey and workshop' findings at a glance

Climate changes & drainage systems	-Participants have noticed changed climatic patterns. - They seem to be aware of relationship between rain intensity and drainage.
Paved Surfaces & floods	-They lack knowledge about the role of paved surfaces in creating urban floods. - They lack knowledge about hydrological cycle, paved surfaces and SuDS.
Rainwater management on rooftops	-They have some knowledge like drainpipes are coming down from terraces for collecting rainwater
Rainwater collection and water features	-Participants have not seen rainwater collected and converted to ponds/fountains. -Positive attitude towards managing rainwater. -Some participants think such created water features would be wonderful for social exchange though.
Long term rainwater storage	-They prefer underground cisterns over ponds.
Understanding of Green roofs	-Some participants demanded green roofs in the neighborhood. - They don't seem aware of the probable implications of use of green roof over the nearby creek. -Some co-ordination gap between stakeholders for sustainable rainwater management.
Water related games for children	-Participants believe children would enjoy themselves there. - There were some concerns about pollutions & safety.
Accessible stream 'Geberbach'	-Suggestions to make it safe and accessible for kids. -It also has the potential to be socially engaging spaces for elderly.

Table 5. Summary of survey & workshop findings

5.4 Design recommendations for Prohlis site

5.4.1 Design Principal Guide – Sense of Placemaking

The lifespan of Buildings is usually long, over the years and years unless some catastrophe happens. The occupants, humans are mortal, and they usually move to different spaces to meet their different living needs. This fact has a robust consequence especially in the case of housing and shared apartments where many families live and

continuously move in and move out. As the former UK prime minister Winston Churchill said once how we construct our buildings later influences us. When it comes to the neighbourhoods and surroundings too, they have similar if not higher impact on the user's growth and experience, especially on growing children and teenagers. This is where the concept of 'Sense of place' intrudes.
According to Norberg-Schultz, the main purpose of place-making is achieved in a place when it can impart security, safety, ownership and sense of pride (Norberg-Schultz, 1980) Thus, the essence of place-making is beyond physical infrastructures that score functional utility only. The idea is that it should be people centred, full of spaces and elements that provoke social interaction and exchanges among the occupants of all age groups. It could be full of playful activities and fun so that it becomes a lively experience and vivid joyful memory to look back throughout life for its continuously changing users.

Water For Creating Memories
Water has always fascinated humans because of its diverse and inseparable relationship with them. The untamed or flexible nature of water as well as its cooling effect has the power to relax any mind of any age at least for some time. As we all know, creative use of water magnifies the value of space promptly. Thus, with some use of imagination and creativity, water can be used to create everlasting memories or short time relaxation as per the user's need.

Figure 21. Children trying to play with water-guns in Prohlis site (Source: Author)
Figure 22. Children enjoying water in shallow detentions (Source: Author)

In fact, according to BBC, after ten years of research, it has been confirmed that blue spaces are very beneficial for human health even more than green spaces (Latham, F.A. and K., n.d.). Likewise, it also confirms that the specialists from Glasgow Caledonian University have currently revealed that blue space has a potential benefit on tackling various mental health issues such as depression and anxiety and those resulted by no physical activity such as obesity. Thus, integration of blue elements is also advantageous for the dwellers from the perspective of both mental and physical health.
Thus, while looking into managing surface water or to use water as a resource, it's a wise idea to design the neighbourhoods integrating water or using water considering its presence, flow and interaction with other elements to score holistic urban design and self-sustaining ecosystems.

5.4.2 SUDs Design to deliver maximum benefits.

A. Rainwater storage for site at Catchment A

Figure 23. Overall basic concept of rainwater storage for site (Source. Google earth)

The basic concept for long term rainwater storage for Geberbach while doing surface water management for the selected neighbourhood can be illustrated in the given fig. The rainwater on the roof from the buildings of neighbourhood and from the paved surfaces of the catchment can be collected and diverted like shown in fig. Since the purpose is to collect rainwater for the creek, as green roofs on the buildings of neighbourhood are likely to absorb nearly 60 percent of total rainwater (Zheng *et al.*, 2021), it is suggested to either not use green roof or use partial green roofs in the neighbourhood. Similarly, hydrated channels can be used to convey the water with bioswales combined at some points to treat the collected water. Since the directed water will need to cross the main street to reach the proposed storage area, it will be polluted during the conveyance as discussed before in chapter 3.1(Geber bach). Hence, it should be treated at this point before the collected water is stored to recharge the groundwater.

i) Size of the rainwater storage

The creek Geberbach went dry for few weeks in 2022. To store rainwater for long term for the driest days of Geberbach, it's important to check the climate history and make a proper analysis of projected number of dry days in coming years. Then minimum flow requirement at that point of the creek intended for rainwater storage to feed the water should be determined.
According to WEAP service website, minimum flow requirement is the minimum amount of water flow required by the river per month to fulfil the basic and urgent requirements such as for plants, aquatic animals like fishes, recreational activities etc.
Here, for Geberbach, we are considering the minimum water required by the vegetations along the bank of the creek and the water required by fish. The identified minimum flow of the creek at this point is 0.05 cubic meters per second (Kurzdokumentation Maßnahme ,n.d.).
Thus, for the size of rainwater storage, the following formula can be used if we are looking to feed the creek entire time:

Size of the Rainwater storage = minimum flow of the creek per minute × total minutes in dry season.

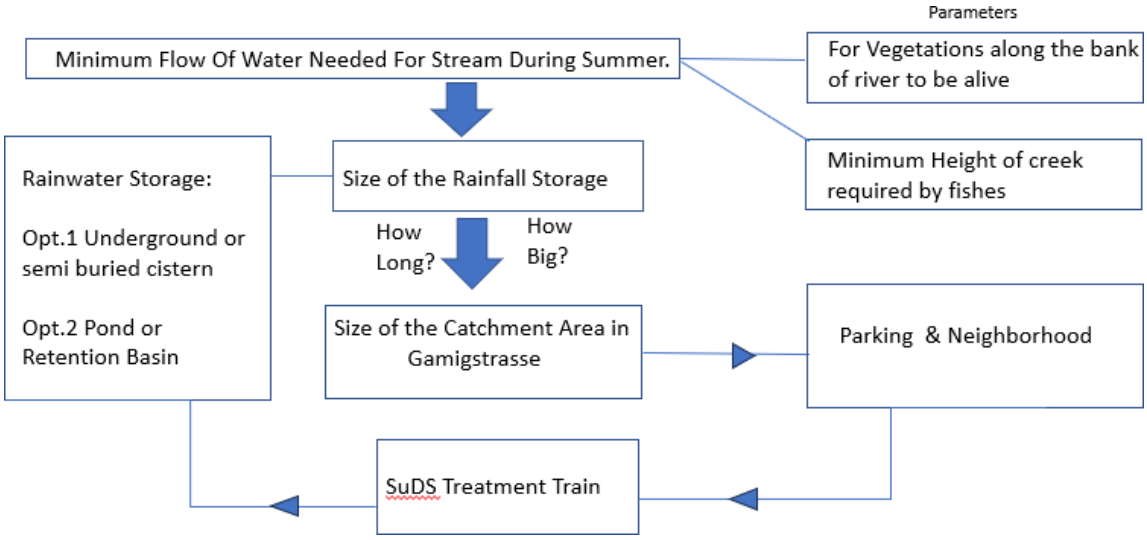


Figure 24. Author's understanding for Rainwater storage

Both the role of evapotranspiration in microclimate and climate change allowances should also be considered.
This idea of rainwater collection and storage can be repeated over different points along the stretch of Geberbach and the proposed green belt can be kept alive even during its driest days. An outline of the overall basic concept for rainwater storage is given in above figure 23.

ii) Strategies for Rainwater Storage

For long term storage of rainwater, the selection of the storage mechanism can be influenced by the several factors including topography, geology, soil profile, construction expenses etc. Furthermore, the selection can depend on the diverse set of anticipated community objectives.
Some of the strategies that can be adopted are as follows:

a. Ponds/Retention ponds

Ponds are one of the most common mechanisms of storing water for a long period. It has been in practice for ages around the world, mainly for agriculture and domestic use. This kind of surface storage can bring a huge aesthetic and ecological value to the locality. However, it needs to be properly sized and well connected with SuDS treatment train to avoid the drying out of pond in long dry periods. It becomes difficult to maximize the ecological benefits with small ponds (Individual NWRM Retention ponds, n. d.). The loss of retained water through seepage and evapotranspiration can also be a problem. In Kathmandu valley of Nepal, the ponds are integral part of traditional surface water management system (Molden, 2019). Some of the traditional ponds there are lined with special formula of black cotton soil mix to ensure self-recharge of water as well as reduce its seepage(OnlineKhabar English News,2020).
Considerations of different design and safety precautions should be taken while using ponds for long term storage of rainwater. This will help to seize maximum benefits with lower risk.

b. Underground tank or cistern

According to Ciria Manual 2015, cisterns or tanks are voids underground for storing water. People have been using underground cisterns or tanks for water storage for ages (Mays, Antoniou and Angelakis ,2013) They can be constructed from concrete, geocells, plastic etc. One advantage of cisterns over ponds is there is less reduction of stored water due to evapotranspiration. Special considerations should be taken while designing underground tanks especially about its storage volume, influence of tank in the surrounding area such as infiltration etc.

Before the intended water enters any kind of rainwater storage, it should be made pass through some treatment systems to treat. One method could be bioretention systems described below.

Bioretention systems

Bioretention are depressed areas in land that look like ponds in structure and along with other different surfaces such as plants, layers of soil, overflow structures and might also contain an optional drainage system underneath (Liu et al, 2014). They are designed or constructed to effectively filter the runoff to eliminate or remove pollutants before the runoff enters the main water body. They treat stormwater being based on ecological functions of soil, plants, and microbes (Nazarpour, Gnecco, and Palla, 2023). Bioretention systems can be designed for treating the types of contaminants present in the stormwater and it usually depends on the type of plant species that is selected (Cosgrove and Bergstrom, 2003). These systems are very adaptive and can be designed anywhere like along parking lots to roadsides to various open fields (Davis, 2007).

B. Different solutions / strategies for rest catchments

i) Catchment B1

Catchment B1 is a parking lot along the streets and the site is rich in trees. Hence, a combination of semi permeable pavement and tree trench system is recommended as shown in fig. 25.

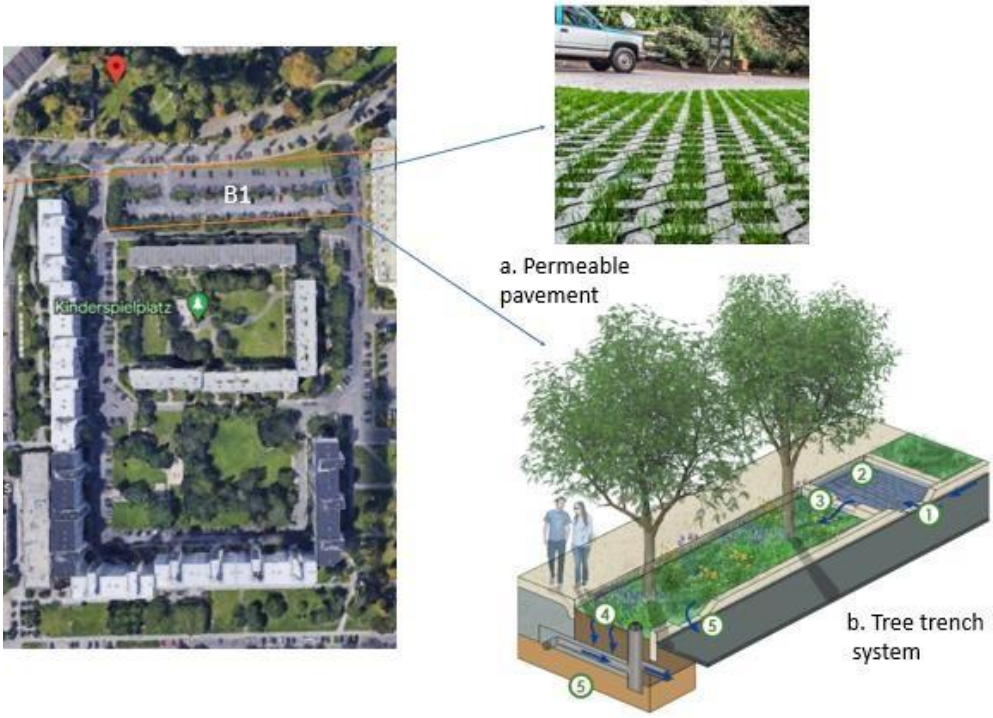


Figure 25. Strategies purposed along Catchment B1 (Source: a.mutualmaterials.com b.stormwaterinnovation.org)

a. Permeable pavement:

Permeable pavements consist of interconnected concrete blocks installed on the ground surface. These blocks contain central empty spaces in them that can be filled with soil, sand, or gravel (Brattebo and Booth, 2003). These infilled materials allow the infiltration of rainwater into the ground and hence permeable pavement are very common and important strategies of Sustainable urban drainage systems (SuDS). It is a better alternative for the reduction of concrete or asphalt in the urban areas as it enables more seepages of rainwater in urban catchments. They are comparatively easier to install than asphalt/concrete too and do not require complex drainage systems (*5 Ways Permeable Pavers Improve Parking Lot Design* ,2016) and eventually contribute to reducing urban heat island effects.

Using semi permeable pavements in parking lot at catchment B1 can help to source control the runoffs in the parking lot without compromising the specific functional requirements of existing parking zone. It is important to pay proper attention to maintenance for optimizing full benefits. A small explanation on how to monitor permeable pavement is mentioned previously in Table 3.

b. Tree Trenches

Tree trenches are pits with trees. These days streets are very busy and with lots of spatial and functional needs like traffic, pedestrians, greenery requirements etc. The concept of tree trenches fit well in the streets especially as they allow trees and the alternative stormwater management to come together while addressing these space requirements. (BlueGreenStreets – Resource-efficient urban districts, n. d). They are also called stormwater trees as they provide all benefits of infiltration strategies such as evapotranspiration, infiltration etc while retaining healthy tree canopies too. They help

to maintain greenery in urban areas while contributing to decrease air pollution and urban heat stress. For the application of tree trench systems, the underlying conditions of the soil and existing drainage system must be thoroughly studied.

As catchment B1 is rich in green trees, tree trenches are recommended along the existing streets and parking lots combining with semi permeable pavement. Referring to our climate analysis at chapter 3, regarding drought periods affecting trees in Dresden, this could be best solution.

ii) Catchment B2

One strategy to unseal the street along catchment B2 can be using filter strips.

Filter strips

They are one of the simplest yet economical stormwater measures best suited for streets. Also called Buffer strips, they are dense grass surfaces placed usually perpendicular against the flow of possible incoming runoffs (Deletic and Fletcher, 2006) They are bands of planted or native vegetations designed to remove pollutants from storm water through different processes like infiltration, absorption, decomposition (Muñoz-Carpena, Parsons and Gilliam, 1999) etc. Their performance depends upon the slope where they are placed and on the uniform flow distribution.

Using filter strips at some parts of the streets of catchment B2 can help to unseal the surfaces while also managing stormwater.

Iii) Catchment C1 and C2

Both the green courtyards C1 and C2 are centrally placed and well-fitted to facilitate the people living in the apartments around them. Though there are some play features already present in both courtyards, as previously discussed in 5.1 of this section, water integrated and more socially interactive designs are missing. As seen in Figure 20, the children were found trying to have fun with water guns by the author in Prohlis site which only indicates they crave water games and would definitely enjoy the idea of water integrated neighborhoods. Hence, a number of design ideas incorporating water are suggested with the pictures below.

Figure 26. Shallow detention basins of water as found in Cologne (Source: Author)

Figure 27. Stone and water as found in Pieschen, Dresden (Source: Author)

Figure 28. Nuremberg water wall (Hoyer,2011)

Figure 29. Rainwater Pavillion (Hoyer,2011)

Figure 30. Mound and mosaic tiles slide plus drain, Orange Park ,London(Ciria,2015)

Figure 31. Sidmouth amphitheatre, Birmingham (Source. CIWEM, Urban Drainage Group)

Use of the features like water wall fig. 28 and rainwater pavilion fig. 29 are already experimented creative ways of installing water in the courtyard which can be replicated in the site. As like of orange park fig. 30, with a little creativity, the slope of the site can increase in some specific spots and be used for play by kids and for social interactions by adults & old people.

Intended UN SDG Goals output for the case study:
Thus, by incorporating all above different strategies, "Goal 6: Clean water & Sanitation", "Goal 3: Health and wellbeing" and "Goal 11: Sustainable Cities and communities" can be achieved while also meeting "Goal 13 : Climate Action".

5.4.3 Other Site-specific recommendations

As based on the frequent site observations and site analysis, following are the recommendations for the overall betterment of the site:

a. The existing sewage infrastructure of the site should be well integrated while planning for sustainable drainage solutions of the neighbourhood.
b. The site is already green with lots of trees. They should be preserved.
c. Both the courtyards in the neighbourhood also possess plenty of trees. Especially courtyard C2 is already of required design standard for the surrounding neighbourhood and hence is marked blue. It should be preserved.
d. Some of the instant spaces next to the buildings are allocated for parking and used as trash space because of which a major potential space of green for social interaction and play remains unutilized. It is recommended to find a better alternative for both parking and trash bins.
e. The aesthetic value of the creek would be enhanced if its size could be increased. This would not only make the creek appealing but would also help to attract people's attention.
f. Creek should be made accessible to people of all age groups while strictly maintaining safety precautions especially for children.
g. Some of the design patches outside the compound (at catchment D) can be extended and connected with the streets leading the runoff in for infiltration as shown in image below.
h. The biodiversity of the site can also be enhanced by introducing rain gardens and lots of wildflowers instead of just grass.

Figure 32. Simple changes in catchment D can increase infiltration in site. (Source: Author)

5.5 General recommendations for implementing SuDS

Thus, after analysing the literature review, lessons from best practices and the site-specific recommendations, following recommendations can be derived for implementing SuDS as the basis for a sustainable neighbourhood anywhere:

1. **Inspire & Educate about SuDS**
   a. People should be educated on SuDS starting from the basic information to different types of SuDS and tell them it's possible to have a fun filled, water filled natural neighbourhood.
   b. Using augmented reality for recreating same neighbourhoods with different SuDS or videoes of successful best practices should be shown in small, small groups to each of them.

2. **Vision and Planning**
   a. Detailed action plans and long-term visions that integrate SuDS as the cornerstone of neighbourhood sustainability should be developed. Action plans to guide the implementation of sustainable drainage solutions aligning with neighbourhood's overall sustainability goals should be formulated.
   b. All the residents, stakeholders and experts should collectively take part in SuDS design to ensure it meets people's needs and aspirations.

3. **Multifunctionality**
   a. SuDS element should be designed keeping multifunctionality in core addressing not only stormwater management but also social, ecological and aesthetic aspects.
   b. Underutilized spaces in the neighbourhood should be reimagined into creative blue-green spaces that encourage social interaction, play and community engagement.

4. **Green spaces and biodiversity**
   a. Existing trees should be safeguarded and integrated.

b. Rain gardens, native plants and wildflowers should be introduced and reinforced in the neighbourhood.

5. **Resilience and adaptability**
    a. Suds should be designed to adapt to changing climatic patterns to provide effective stormwater management both in normal and extreme conditions.
    b. It should be ensured that SuDS elements are adaptable to future growth and urban development, maintaining functionality and sustainability over time.

6. **Retaining natural water bodies**
    a. In case any natural water bodies exist in the neighbourhood, they should be preserved and made them the focal points of the neighbourhood enhancing their visibility.
    b. Pathways, seating zones as well as play areas near and with water bodies should be designed making them accessible for all age groups while keeping safety in top notch priority.

7. **Monitoring and evaluation**
    a. Monitoring systems should be implemented for assessing the efficacy of SuDS Elements to manage stormwater, improve water quality and enhance the community wellbeing.

8. **Living system approach**
    a. It should be emphasized that SuDS are like living systems that need continuous care for their effectiveness and longevity.
    b. A culture of taking pride for maintaining SuDS in their neighbourhood should be developed.
    c. Recreational spaces, outdoor seating and sports facilities should be created out of SuDS elements so that it encourages physical activity while being an integral part of neighbourhood people.

6. Analysis

Referring to Table 4, where the multifaceted benefits of SuDS with UN SDG goals and their targets was aligned, it is seen that SuDS can actually and significantly contribute to several specific SDGs. Similarly, from the best practices analysis the same results were seen specially with goals 6, 11 and 13. Thus, the efficacy of SuDS on UNSDG goals on work nature and principles can be summarized in the table below:

Goal 6: Clean water and sanitation - Manage & treat stormwater runoff before it reaches natural water bodies. - Reduce pollution. - Improve water quality. - Reduce the burden on centralized sewer system. - Support groundwater recharge - Collect rainwater for domestic use. SuDS assist in better water management and hence increase the access to clean water.	**Goal 3: Good health & well-being** - Foster social interaction and bond among humans through green blue public spaces. - Bring green back in nature and can help to detoxicate being connected to it. - Promote mental well-being. - Reduce air pollution. - Reduce water pollution. SuDS help to create livable cities with quality of life
Goal 9: Industry, Innovation, and Infrastructure - Reduce the money required for drainage construction. - Help save money using less complex construction methods. - Requires innovative engineering skills & techniques to create green jobs. SuDS promotes economy and infrastructure in sustainable urban planning & water management.	**Goal 11: Sustainable Cities and Communities** - Unseal paved areas. - Integrate and reinstate green in urban landscapes. - Localize water management spaces in cities. Make Human settlement safe & resilient. SuDS help to create livable cities with quality of life.
Goal 12: Responsible consumption and production - Promote water efficient landscaping. - Reduce the need for resource intensive drainage systems.	**Goal 13: Climate Action** - Reduce flood, erosion. - Promote and reinstate greenery. - Help to mitigate Urban heat island effect. - Reduce air pollution. - Incorporate green infrastructure and water retention techniques.

SuDS promote sustainable land use practices.	SuDS help to mitigate the impacts of Climate change.
Goal 14: Life below water - Reduce the number of contaminants entering the water bodies. - Assist to preserve marine ecosystems. - Protect aquatic life from pollution. SuDS supports biodiversity on water.	**Goal 15: Life on Land** - Systems like swales, wetlands and planted areas can provide sustenance to many species ranging from microbes. - Promote different native as well as wild species in urban areas. SuDS supports biodiversity on land.

Table 6. Summarizing advantages of SuDS on UNSDGs

Besides these, implementing sustainable urban drainage systems (SuDS), requires collaboration between different stakeholders such as governments, engineers, urban planners, and local communities at the local, regional, and national levels, which helps to achieve **UNSDG Goal 17: Partnerships for the goal.**

Thus, just as how urban challenges in cities are interconnected (Hoang and Fenner, 2015), SuDS and UNSDGs are also directly linked due to their nature and objectives to work against these challenges. As summarized in the table above, it can be concluded that SuDS can be the accelerator of multifarious UN SDG goals that ultimately help to achieve what the United Nations (United Nations, 2015) aspires to seek through UNSDG goals:" protect the planet and improve the lives and prospects of everyone, everywhere" (Sustainable development goals, n.d.). It can be said that SuDS and UN SDG goals both align together in their nature and philosophy to build an ideal and sustainable world, which can be simply diagrammatically represented as below:

Figure 33. End goal of SuDS & UNSDGs

6.1 Rethinking SuDS: a sustainable way forward

Thus, it can be concluded that SuDS should not only be taken as the stormwater management system integrating blue and green, but that the impacts of SuDS on sustainability, and human life, and environment can be beyond what is possible if properly implemented. It helps to imagine a world where rainwater is not a problem but a solution that enhances our communities, environment, and wellbeing. It should be developed as a natural living system rather than anything alternative. Apart from the complex and technical SuDS, SuDS can be simplified and installed on urban fabrics and nodes to reboot neighbourhoods while inspiring all people, including children and youth. SuDS can be made fun, interesting, and creative to intrigue people.

When people talk about UN SDG goals, it sounds boring, distant, and detached from their lives like some dogmas or principles. SuDS can be crafted as something people can understand and relate to in their day-to-day lives. Hence, it's high time SuDS be kept in the spotlight, like a headline, not just as a footnote. All the United Nations and other organizations working with UN SDG goals should prioritize SuDS and make it the central piece of their agenda.

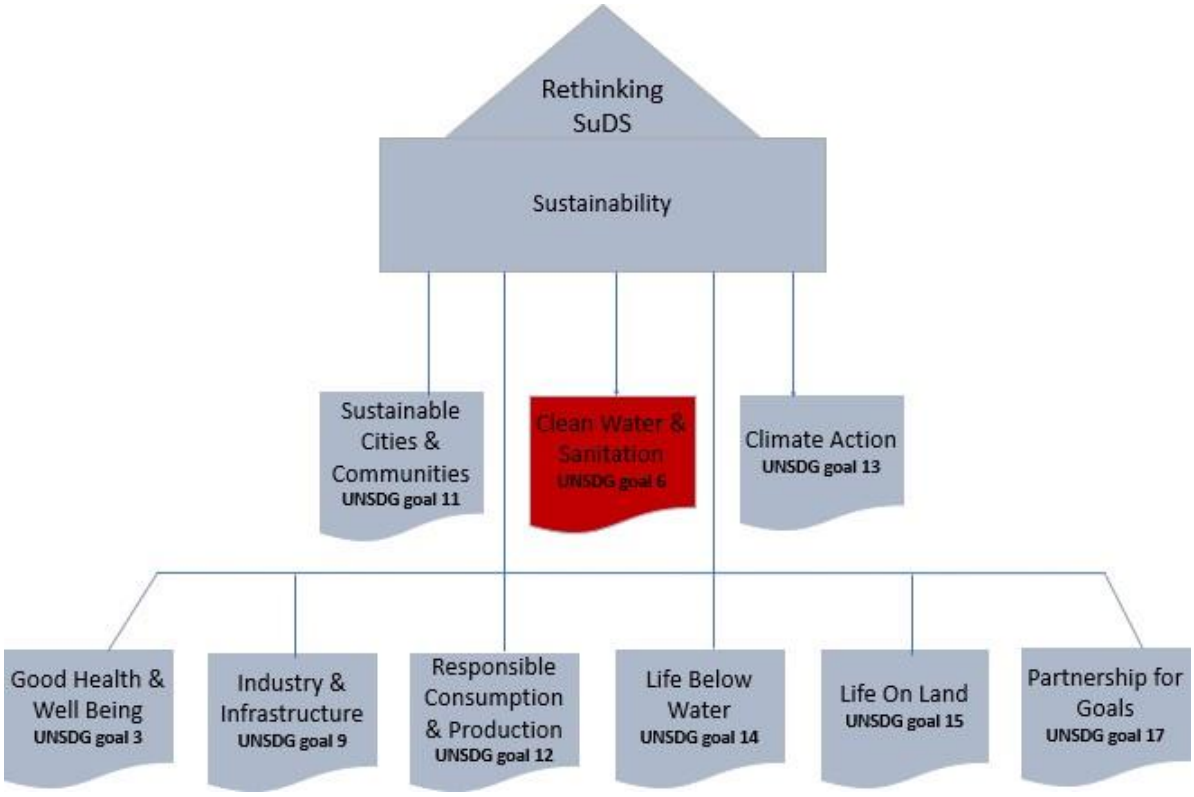


Figure 34. Repurposed SuDS Rocket, originally by (Charlesworth,2010)

The idea can be better understood with Figure 34. which is a newly proposed SuDS Rocket by Author. It says when SuDS is rethought and prioritized as beyond water managing solutions and adopted as way of living in society, it can accelerate so many other factors of sustainability which are also named by United Nations as UN SDG goals. The rocket has two tiers where the first tier has three clear benefits with 'Clean water & Sanitation' being the central benefits. The second tier has other added benefits that come eventually but surely in the long run.

Chapter 7

7. Conclusion

This chapter comprises two distinct sections. The initial section lists out the primary limitations of this research while trying to identify the potential avenues for further investigation. The final section is the conclusion of the research with final reflections from the author.

7.1 Limitations

1. The research is qualitative and hence simply makes suggestions of different strategies but does not talk about the implementation process and technical part of it.
2. Though an honest hint on the ground state of 'suds literacy' has been revealed through survey, the survey could not reach out to large number of people due to language barrier.
3. The survey does not include any expert's fresh opinion. All the participants were common people, at least not professionals related to urbanization or environmental engineering.
4. Being online based research, it was difficult to gather enough information and introspect the real impacts of SuDS in best practices.
5. An intensive site analysis would also have supported the research for more quantitative outcomes.
6. The basic concept of rainwater storage is researcher's own understanding studying various case studies unless mentioned and a strong literature is required for the detailed concept.
7. Using modelling software such as SWWM, STORM etc. for the site, quantitative outcomes can be generated as the extension of this research.
8. Literatures regarding co-relationship between UN SDG goals and SuDS were found very limited which leaves an ample space for further research.

7.2 Conclusion

As of 2023, every time it rains in Hyderabad, India these days, schools, colleges, and institutions are closed to escape from the probable dangers of flood (The Times of India, 2023). Till before 2020, Hyderabad never had this frequent flood in the city (The Times of India, 2023). These days, every time it rains, the mothers residing in the neighbourhood of Prohlis, Dresden are afraid and worried about the increasing levels of nearby creek Geberbach. These are just two examples from the two different parts of the world.

Throughout the world, in our cities, the impacts of disturbing natural hydrological cycle knowingly/unknowingly are surreal and are evident with the extreme climate changes. The destruction, effects, reasons, affected communities all could be of different range and level but everywhere the problem persists and will persist more & more unless we don't intervene with conscience & resilience.

Sustainable Drainage Systems (SuDS) are a set of best practices for managing stormwater runoff in a sustainable and environmentally friendly manner. Having their benefits wide and well aligned with UN SDG goals, SuDS provide us with the way forward to live in sustainable neighbourhoods having privileges of urbanization while naturally tackling the modern-day urban challenges. Thus, with suds, we can have the best of both worlds. With SuDS, we have the strong and undeniable chances to rewind our cities and develop them into green and sustainable. The fact that all SuDS benefits well align to UN SDG goals clearly says that SuDS are the fastest ways of achieving the ideal world that UN SDG has benchmarked.

But the interesting as well as complex aspect of stormwater management is that for the proper implementation, each individual house/building should install the stormwater attenuation system. Even with natural drainage, it's the same. We need all people committed to suds. This thesis research's finding proves that till date, only a handful of people, either professional or self-curious, know about SuDs. There has not been enough transfer of knowledge about SuDS worldwide. This makes seizing the benefits of SuDS in large scale impossible.

It's impressive that like in the city of Dresden, people in authorities are slowly understanding and they have included SuDS in their long-term vision but looks like they have left their main beneficiaries 'people', behind in the process. Without people involved in the process enthusiastically, it will take forever, and we might have to learn unnecessary hard lessons. SuDS should embody the soul of democracy, of the people, by the people, for the people. Thus, SuDS not only brings people close to nature but also brings people close to people.

It's important that we bridge this huge gap of suds literacy and for that, we need to treat SuDS education as basic education starting from schools/colleges. And it must start by creating awareness from basics of how paved surfaces interrupt in the water cycle and how this has serious implications like urban floods. Also, treating the commitment to SuDS' as moral or ethical behaviors could greatly contribute to this manifestation. In fact, SuDS clearly showcase a strong dedication for the preservation of the environment (Charlesworth and Booth, 2016). People really need to know there are more ways other than green roofs and green façade for creating a sustainable city. SuDS should be a lifestyle, way of living rather than any alternative because SuDS might not be the whole solution, but they are the only way to the solutions.

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ANNEX

Interview questions:

Hello. I am a master's student doing my final research project in this neighborhood on the topic 'Sustainable Drainage'. Your responses in the following questions will really help me in it. Please kindly spare some minutes and respond.

Hallo. Ich bin Masterstudent und schreibe in diesem Viertel mein Abschlussforschungsprojekt zum Thema „Nachhaltige Entwässerung". Ihre Antworten auf die folgenden Fragen werden mir wirklich helfen. Bitte nehmen Sie sich ein paar Minuten Zeit und antworten Sie.

Your Age/ Dein Alter :

1. Have you ever experienced or seen a flood anywhere? Haben Sie schon einmal irgendwo anders eine Überschwemmung erlebt oder gesehen?

   a. Yes.Ja b. No. Nein

2. Do you know how cities get flooded these days? Wissen Sie, wie Städte heutzutage überschwemmt werden?

4.How is the rainwater on your roofs being managed right now?

Wie wird derzeit mit dem Regenwasser auf den Dächern umgegangen?

☐ No idea what rainwater is. Keine Ahnung, was Regenwasser ist.

3. Do you think it is possible to collect rainwater from roof and paved surfaces to make a water feature like pond nearby? Denken Sie, dass es möglich ist, Regenwasser von Dächern und gepflasterten Flächen zu sammeln, um ein Wasserspiel wie einen Teich in der Nähe zu errichten?

a. Yes.Ja b. No. Nein

Have you seen anyone anywhere doing so? Please write a little about it. Haben Sie irgendwo jemanden gesehen, der das getan hat? Bitte schreiben Sie ein wenig darüber.

4. How do you think about having some water elements such as fountain, pond etc. might bring change in your existing neighborhood?

Wie denken Sie, dass einige Wasserelemente wie ein Brunnen, ein Teich usw. eine Veränderung in Ihrer bestehenden Nachbarschaft bewirken könnten?

5. Do you think kids would enjoy playing safe water related games?

Glauben Sie, dass Kinder Spaß daran haben würden, Spiele zum Thema sicheres Wasser zu spielen?

a. Yes. Ja
b. No. Nein

6. Would you let your children play safe water related games?

Würden Sie Ihre Kinder Spiele zum Thema sicheres Wasser spielen lassen?

c. Yes. Ja
d. No. Nein

7. Do you know about rain gardens, green roofs, rainwater harvesting etc? Kennen Sie sich mit Regengärten, Gründächern, Regenwassernutzung usw. aus?

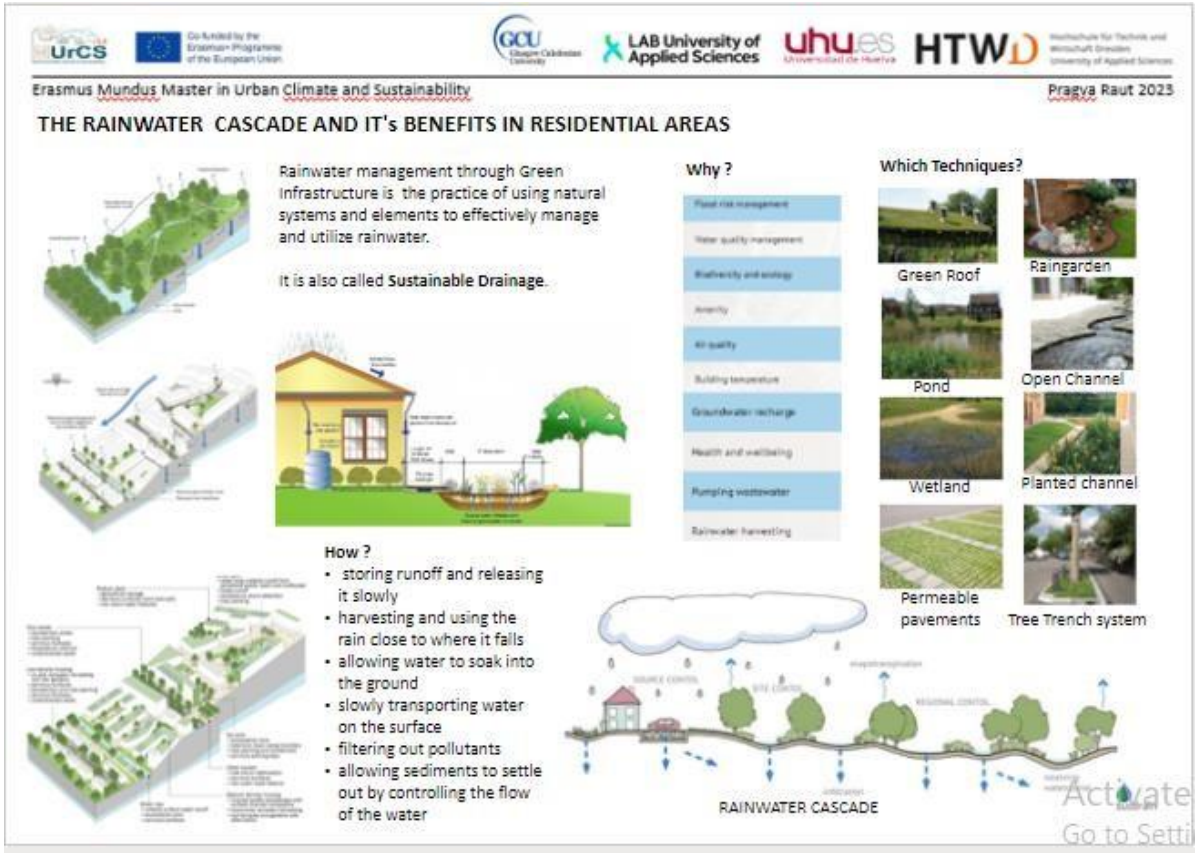
a. Yes. Ja b. No. Nein
b. Heard or read somewhere about them but don't know how they work. Ich habe irgendwo davon gehört oder gelesen, weiß aber nicht, wie sie funktionieren

8. What do you think might work effectively for storing rainwater from rainy season till dry seasons?

Was könnte Ihrer Meinung nach effektiv sein, um Regenwasser von der Regenzeit bis zur Trockenzeit zu speichern?

a. Pond. Teich b. Underground Tank. Unterirdischer Tank

Posters for NBS Participatory workshop



SOME PRACTICAL EXAMPLES

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BEST PRACTICE EXAMPLES

Water Square example -1

Rotterdam water square

Detention pond, Gelsenkirchen, Germany

Kunsthofpassage

Near Rhine River

The Circle, USA

Roads in Copenhagen

Activate
Go to Setti

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...AND IN YOUR NEIGHBORHOOD...

Have you ever experienced or seen flood?

Do you know how cities get flooded these days?

Do you think you would enjoy a neighborhood like this?

Activate
Go to Setti