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Reviving traditional practices, integrating modern knowledge

using rivers and streams as SuDS for urban flooding risk management in Uyo

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Landscape Architecture for Global Sustainability

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Reviving traditional practices, integrating modern knowledge -using rivers and streams as SuDS for urban flooding risk managment in Uyo

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Preface

This master's thesis marks the end of our two years in Landscape Architecture for Global Sustainability at the Norwegian University of Life Sciences (NMBU). During our masters, some of the world's most urgent issues got addressed, from climate change, environmental deterioration, natural hazards, regional conflicts, poverty, and migration.

The studio courses during the masters were mainly focused on water-related issues such as sea level rise, flooding, and stormwater management. Working with these projects made us want to look further into the issues of urban flooding and how rivers as a mitigation strategy to gain knowledge and the possibility to come up with recommendations for this urgent issue.

We want to give special thanks to our supervisor Lei Gao who has guided us with her professional input in this master's thesis. We also want to thank her for challenging us to take on this issue in a global context and broaden our knowledge, and insight on how landscape architecture can attempt to find solutions that can go beyond geography, culture, and climatic differences.

We want to also thank the voluntary organization Oslo Elveforum, Alnaelvas Venner, and the civil engineer from Uyo for their knowledge and their input to our thesis. We want to thank them for making time to have interviews/conversations with us, and for handing over resources that were useful to us in the master thesis.

To our fellow classmates and master students, congratulations we made thank you, guys, for making this period memorable. A special thanks to the master room with Ahmed, Ane, Emilie, Kristine, and Inga, who always filled the room with good vibes we shared good memories in a short time.

Special big thanks to our parents for giving us unconditional love and support during our two-year journey. Also, to my aunt, Aunty Etokebe thank you for always supporting me and checking up on me no matter the time. To my close friends, I have no words all I can say is I cherish you all.

Finally, to the authors of this thesis, you crossed the finish line. Congratulations.

Abstract

It is expected that climate change will cause more frequent and more intense precipitation events, which again will increase flood events. With more than half of the population in the world living in cities, the problem of more frequent rain is a global problem that will require a common and immediate effort to solve issues of stormwater and urban flooding.

Regarding managing stormwater, conventional pipe-based systems have been a crucial component of city infrastructure to transport stormwater and wastewater out of densely populated areas. The increased rain causes the overload of capacity on the conventional pipe-based drainage systems. The expansion of these structures is not sustainable as the system is not flexible during unexpected events of precipitation. Arguably based on case studies an alternative solution that is more adaptable to the change of climate is necessary. The concept of Sustainable Drainage systems (SuDS) offers a more holistic and adaptable approach to urban flooding and stormwater management. SuDS Solutions vary from permeable surfaces, vegetation, green roofs, and rivers, and in this master, we focused on rivers as a SuDS strategy to mitigate against stormwater.

This master thesis deals with the complex issue of urban flooding in the city of Uyo in southern coastal Nigeria. The area is experiencing several flooding events and their approach to managing the extensive water is to expand and reconstruct the piped drainage system. We wish to explore the possibility of rivers as SuDS in Uyo and to manage to do that we are Investigating how Oslo; Norway had a paradigm shift from a conventional pipe-based system to integrate rivers as a strategy to manage urban flooding. To give Uyo a more sustainable solution we came up with this problem statement:

How can rivers/streams be used as Sustainable Drainage Systems (SuDS) to solve urban flooding in Uyo, Akwa Ibom, with lessons learned from the rivers in Oslo as a case study?

This thesis aims to find solutions for flood risk management in the city of Uyo, with a focus on the use of rivers as Sustainable Drainage Systems. Further, the research explores the importance of local participation and traditional knowledge in river management, as there is much to understand from these approaches to climate change adaptation.

The goal of the master thesis is to propose recommendations for sustainable river management that contribute to flood risk mitigation in Uyo, which can be used for other cities.
We outlined steps to make this shift possible. The steps are mapping historical rivers, SuDS in urban planning, open stormwater projects, and involving the people, and the steps are outlined so it can be used in other places.

Abstrakt

Det er forventet at klimaendringer vil føre til hyppigere og mer intense nedbørshendelser, som igjen vil øke flomhendelsene. Med mer enn halvparten av befolkningen i verden som bor i byer, er problemet med hyppigere regn et globalt problem som vil kreve en felles og umiddelbar innsats for å løse problemer med overvann og byflom.

Når det gjelder håndtering av overvann, har konvensjonelle rørbaserte systemer vært en avgjørende komponent i byens infrastruktur for å transportere overvann og avløpsvann ut av tettbefolkede områder. Det økte regnet forårsaker overbelastning av kapasiteten på de konvensjonelle rørbaserte avløpssystemene. Utvidelsen av disse strukturene er ikke bærekraftig da systemet ikke er fleksibelt under uventede nedbørshendelser. Basert på casestudier er det nødvendig med en alternativ løsning som er mer tilpasningsdyktig til klimaendringene. Konseptet Sustainable Drainage Systems (SuDS) tilbyr en mer helhetlig og tilpasningsdyktig tilnærming til byflom og overvannshåndtering . SuDS- løsninger varierer fra permeable overflater, vegetasjon, grønne tak og elver, og i denne masteren fokuserte vi på elver som en SuDS- strategi for å avbøte mot overvann.

Denne masteroppgaven tar for seg det komplekse problemet med byflom i byen Uyo i sørlige kystnigeria . Området opplever flere flomhendelser, og deres tilnærming til å håndtere det omfattende vannet er å utvide og rekonstruere det rørlagte dreneringssystemet. Vi ønsker å utforske muligheten for elver som SuDS i Uyo og for å klare å gjøre det undersøker vi hvordan Oslo; Norge hadde et paradigmeskifte fra et konvensjonelt rørbasert system til å integrere elver som en strategi for å håndtere byflom. For å gi Uyo en mer bærekraftig løsning kom vi med denne problemformuleringen:

Hvordan kan elver/bekker brukes som Sustainable Drainage Systems (SuDS) for å løse urban flom i Uyo , Akwa Ibom, med erfaringer fra elvene i Oslo som casestudie?

Denne oppgaven har som mål å finne løsninger for håndtering av flomrisiko i byen Uyo, med fokus på bruk av elver som bærekraftige dreneringssystemer. Videre utforsker forskningen viktigheten av lokal deltakelse og tradisjonell kunnskap i elveforvaltningen, ettersom det er mye å forstå fra disse tilnærmingene til klimatilpasning.

Målet med masteroppgaven er å foreslå anbefalinger for bærekraftig elveforvaltning som bidrar til å redusere flomrisiko i Uyo, som kan brukes for andre byer.Vi skisserte skritt for å gjøre dette skiftet mulig. Trinnene er kartlegging av historiske elver , SuDS i byplanlegging , åpne overvannsprosjekter og involvering av folk, og trinnene er skissert slik at de kan brukes andre steder.

It is expected that climate change will cause more frequent and more intense precipitation events, which again will increase flood events. With more than half of the population in the world living in cities, the problem of more frequent rain is a global problem that will require a common and immediate effort to solve issues of stormwater and urban flooding.

Regarding managing stormwater, conventional pipe-based systems have been a crucial component of city infrastructure to transport stormwater and wastewater out of densely populated areas. The increased rain causes the overload of capacity on the conventional pipe-based drainage systems. The expansion of these structures is not sustainable as the system is not flexible during unexpected events of precipitation. Arguably based on case studies an alternative solution that is more adaptable to the change of climate is necessary. The concept of Sustainable Drainage systems (SuDS) offers a more holistic and adaptable approach to urban flooding and stormwater management. SuDS Solutions vary from permeable surfaces, vegetation, green roofs, and rivers, and in this master, we focused on rivers as a SuDS strategy to mitigate against stormwater.

This master thesis deals with the complex issue of urban flooding in the city of Uyo in southern coastal Nigeria. The area is experiencing several flooding events and their approach to managing the extensive water is to expand and reconstruct the piped drainage system. We wish to explore the possibility of rivers as SuDS in Uyo and to manage to do that we are Investigating how Oslo; Norway had a paradigm shift from a conventional pipe-based system to integrate rivers as a strategy to manage urban flooding. To give Uyo a more sustainable solution we came up with this problem statement:

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Chapter 1. Introduction

Background: Increasing flood risks in Nigerian cities under urbanization

Researchers across the globe agree that the more frequent occurrence of severe weather can be attributed to global warming and climate change. Statistics show that there is an increasing trend of urban floods worldwide. Among numerous examples of extreme events in recent years are: Pakistan (2022), Nigeria (2012, 2015, 2022), the US (2015, 2019), India (2013), China (2020), and so on. However, climate change is not the sole cause of the surge in urban floods, nor should it serve as a justification for neglecting mitigative and adaptive efforts. The most significant causes of the rising frequency of urban flood events, in addition to extreme weather events, are growing urbanization and improperly constructed or inadequate drainage infrastructure (Nie et al., 2009; Torgersen & Navrud, 2018).

Due to swift urbanization, a larger population desires to live in urban cities, necessitating the conversion of more natural land to accommodate this increase. There are both environmental and socio-economic reasons for utilizing existing space and infrastructure to settle more people. According to Torgersen and Navrud (2018), the term "urban densification" is frequently construed positively by politicians and urban planners. However, this strategy often results in the construction of more hard and other impervious surfaces, which reduces the capacity to collect and absorb water. He further asserts that the concept of urban densification should be linked with an increased risk of flooding (Torgersen & Navrud, 2018).

With more than half of the world's population living in urban areas, (United Nations, 2018 p.1), the projected levels of flood impacts give urgency to make flood risk management in urban areas a high priority on the political and policy agenda (Jha et al., 2012, p.20; United Nations, 2018, p.1). Understanding the causes and effects of flood impacts, investing, designing, and implementing measures that minimize the disastrous impacts of floods has become part of the development thinking and is embedded into the wider development goals (Jha et al., 2012, p.20).

In this regard, urban drainage systems have become a crucial component of city infrastructure that collects and transports stormwater and wastewater out of densely populated areas (Chocat et al., 2007; Larsen & Gujer, 1997; Zhou, 2014).

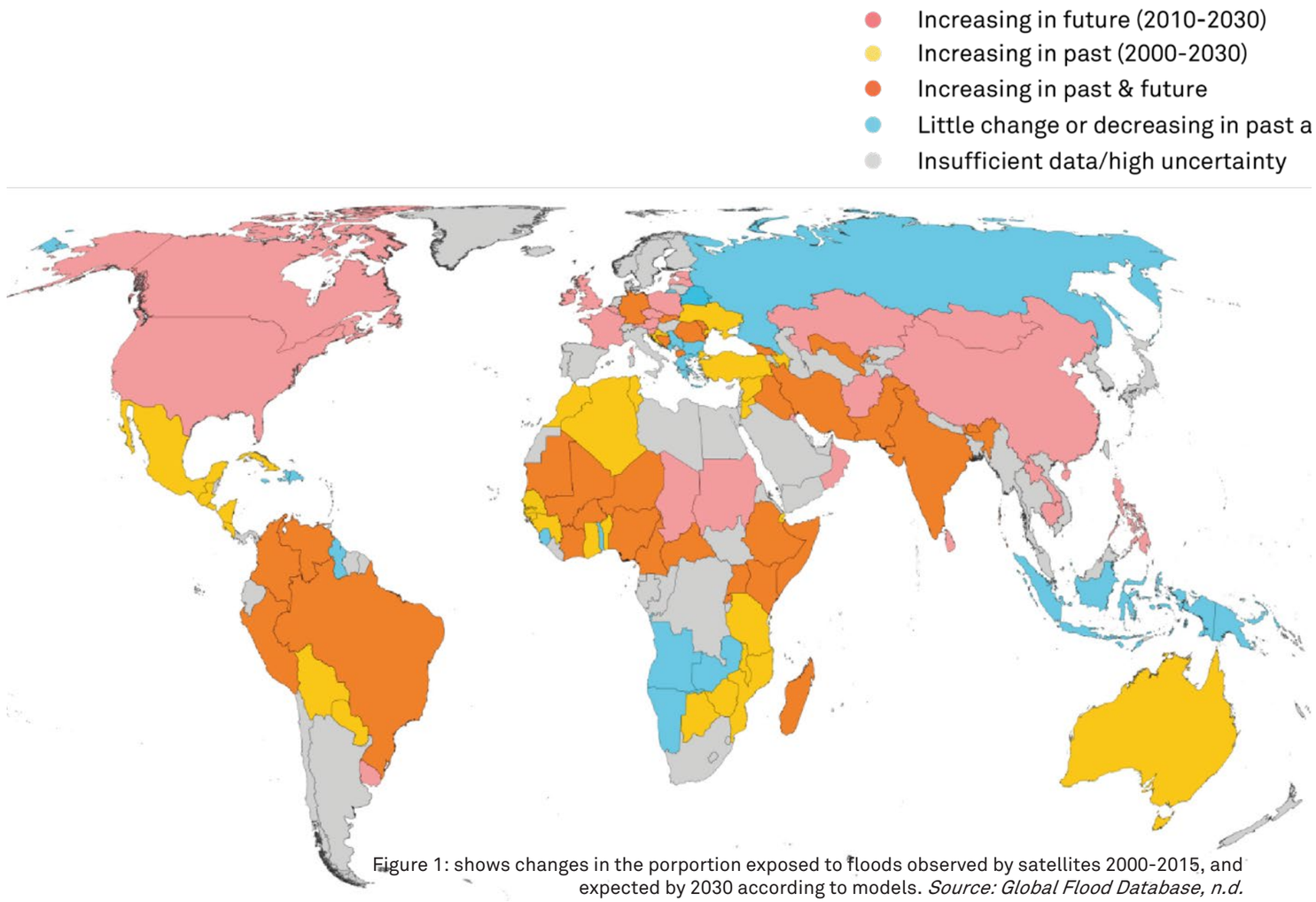


Figure 1: shows changes in the porportion exposed to floods observed by satellites 2000-2015, and expected by 2030 according to models. *Source: Global Flood Database, n.d.*

In this regard, urban drainage systems have become a crucial component of city infrastructure that collects and transports stormwater and wastewater out of densely populated areas (Chocat et al., 2007; Larsen & Gujer, 1997; Zhou, 2014). Despite development over the years, it remains a significant challenge to design an effective and efficient drainage system. Massive volumes of water washed off paved surfaces and roads during such heavy rainstorms, overwhelm drains and culverts resulting in flash floods. These flash floods occur quickly with little advance notice, posing a serious threat to life, and causing significant property and infrastructure damage. As a result, the conventional drainage system of pipe-based drainage frequently needs to be expanded gradually and is therefore not flexible enough to respond to urgent and random situations (Krebs & Larsen, 1997; Zhou, 2014). Additionally, expanding the typical conventional underground pipe-based system in response to climate change and urbanization may not adhere to the general sustainable standards acknowledged today (Chocat et al., 2007; Hellström et al., 2000; Zhou, 2014).

Nigeria's vulnerability to climate change impacts can be linked to its geography, climate, vegetation, economic structure, population, and so on (Olorunfemi, 2011). Most of Nigeria's states especially the southern coastal region experience annual flooding more frequently during the rainy seasons due increased precipitation linked to climate change (Aja & Olaore, 2014; Echendu, 2020).

At present there is no clear legislative framework or flood control strategy to deal with this issue (Adekola & Lamond, 2018; Akinloye, 2018; Echendu, 2020).

Historically, the southern coastal Nigerian floods occurred in cycles of 25 to 39 years, but since the late decades when large climatic disturbances began in sub-Saharan Africa, floods have grown erratic and have no evident pattern (Ekpoh, 2015). According to Robert and Raimi (2019), recurrent flooding is a major issue in southern Nigeria's coastal cities, including Lagos, Port Harcourt, Calabar, Uyo, Warri, Yenagoa, and Asaba (Robert & Raimi, 2019). It is commonly acknowledged that the entire coastal region of Nigeria is prone to flooding, and urgent action is needed to develop resilience, take ownership, and mitigate the impact of this inevitable calamity (Robert & Raimi, 2019).

The topography of the southern region of Nigeria, which is mostly flat and low-lying, poses a significant challenge to surface runoff evacuation through surface drains. This, in addition to climate change and urbanization, contributes to the recurring flooding issue in the region.

Though government hands have intervened to provide relief materials and possible technical solutions to the flooding in these areas, the problem persists. In Uyo the capital of Akwa Ibom state, after the 2012 flood there were headlines pushing to establish the pipe-jacking system to ravage the flood menace in the city. More rainfall fell in 2015 causing intense floods bypassing all the drainage works implemented (Ekpoh, 2015).

As seen above, the flooding problems in southern coastal areas of Nigeria may be brought on by topographic features, extensive urbanization, an inadequate drainage system, and of course climate change.

The city of Uyo in Akwa Ibom is our selected study because of our personal relationship with Uyo and we have a better understanding of the city making it convenient for us to collect data for this research. We see this as an opportunity to provide suggestions for mitigating the flood problem in Uyo and lessons from this project can be applied in other coastal southern states of Nigeria.

With these factors contributing to the flooding issue, the government adopts a control and command approach focusing on the engineering physical infrastructure (conventional pipe-based drainage system) and excludes other perspectives. This is why in our thesis we highlight the values and importance of introducing natural perspectives.

Research Questions

This project explores the following question and seeks to answer the possibility of rivers as a mitigation and adaptation strategy for urban flooding in Uyo.

How can rivers/streams be used as Sustainable Drainage Systems (SuDS) to solve urban flooding in Uyo, Akwa Ibom, with lessons learned from the Alna River in Oslo as a case study?

This thesis aims to find solutions for flood risk management in the city of Uyo, with a focus on the use of Sustainable Drainage Systems (SuDS). There are several SuDS strategies and the SUDS strategy we will explore in this thesis is the use of rivers. The history of most urban cities in the US and Europe have had a tendency of canalizing and misusing rivers, and instead implement infrastructure to cope with stormwater specifically the underground piped drainage systems (Tarr, 2010, p.72). The rivers that were once a mode of transportation and beneficial to communities were now seen as an issue due to wastewater contamination and air pollution. Hence the full or partial closing of these rivers and full implementation of the conventional drainage system to handle stormwater and flooding. With heavier precipitation and more cases of floods, more developed countries in the past few decades have had a paradigm shift to re-opening rivers to daylight and using rivers as a multi-functional asset in stormwater management strategies, recreational areas, and are seen as part of the urban cities. Nigeria is a country endowed with large water resources, we use this to suggest the use of rivers as a stormwater management strategy in Uyo, Nigeria.

Figure 2: shows a scence of flopding in Uyo urban areas. *Source: Anthony 2021*

DET KONGELIGE
MILJØVERNDEPARTEMENT

Meld. St. 33

(2012–2013)

Melding til Stortinget

Klimatilpasning i Norge

Figure 3: white paper on climate change in norway *Source: St.meld. nr. 33 (2012-2013)*

This thesis attempts to highlight the issues that arise when the response to flood disasters are only conventional drainage systems and investigate the possibility to use the river patterns in Uyo as a mitigation and adaptation strategy for flood control. This project attempts to answer three sub-questions in exploring this possibility:

- **How have rivers and streams been used as drainage systems in urban areas?**
- **How can SUDS be implemented in Uyo?**
- **What recommendation can be given to improve the current understanding of SuDS?**

Research Methods

As the main question of this research project seeks to answer how rivers/streams can be used as a Sustainable Drainage System (SuDS) strategy, the role of rivers/streams in a SuDS strategy needs to be examined. Also, this project seeks to promote traditional/cultural knowledge in river management strategies, hence traditional knowledge in the theory and in the selected study location needs to be explored before suggesting how an implementation can take place.

Our research design is a mixed methods approach, this includes secondary data analysis of documents and field studies which included field observations and interviews.

Document research

A literature study aims to provide a summary and evaluation of the existing knowledge on a particular topic or research question and as such there are different types of materials used for different purposes. The literature studies used for this thesis were published sources (articles and books) and for us to understand the studied case material such as maps, archives, and publications were used.

The project relies on existing knowledge to create a design by examining published material on these key topics: Sustainable Drainage Systems (SuDS), Traditional knowledge methods, Urban flooding, Urban Stormwater Management, and River Values. To acknowledge the possibilities and benefits of using the rivers in an urban context as a natural mitigation/adaptation strategy, we are studying the management of rivers in Oslo to understand the shift from a conventional piped drainage system to a more holistic sustainable strategy of re-opening and utilizing rivers as a flood control strategy. The documents studied include:

- Meld. St. 33 (2012–2013) Parliamentary announcement, Climate adaptation in Norway (*Melding til Stortinget, Klimatilpasning i Norge*)
- “Our city, our future” Municipal plan for Oslo 2018, Social element with urban development (*“Vår by, vår framtid” Kommuneplan for Oslo 2018, Samfunnsdel med byutvilingstrategi*)
- Urban Ecology Program 2011-2026 (*Byøkologisk Program 2011-2026*)
- Strategy for stormwater management 2013-2030 (*Strategi for overvannshåndtering I Oslo 2013-2030*)
- Climate Strategy for Oslo towards 2030 (*Klimastrategi for Oslo mot 2030*)

Field studies

It was not enough to study and evaluate existing knowledge, some fieldwork was essential as gave us first-hand data to support our discussion/analysis at the end of this project. We did this by conducting field observations in Oslo and Uyo and carrying out unstructured informal interviews.

Field observations

The field observation in Oslo was conducted to see ways rivers have been integrated into the dense city areas. We went through some parts of the Alnaelva, Hovinbekken and Akerselva stretches to see how they established the relationship between the environment and the people around it.

The fieldwork in Uyo included site observations along some of the drainage lines, parts of the city, and some rural areas to get information on traditional or cultural (historical) management practices as well as information on the history of the people. This exercise was crucial as it was very challenging, if not impossible, to find some information about the people and their ways in the media and papers.

We spent most of our time in the city trying to understand the overall drainage system. The terrain, drainage networks in the city, and the rivers running through rural areas were documented using notes, photos, and videos. The days were spent attempting to gain an understanding of Uyo's urban growth. It was crucial to record the city's urban design, landscape, and building structure because this project revolves around establishing Sustainable Drainage System (SuDS) in the urban context.

Additionally, it was crucial to visit locations close to rivers and record these informal management techniques to comprehend the traditional/cultural management techniques employed in rural areas. Understanding the people's relationship with water and how this influences their way of managing water was gained by speaking with locals and reading archival sources on their history and the people's way of life in this part of the world.

The information acquired during our visit identified several problems, both significant and minor, that if not addressed, may worsen both in urban and rural areas. For instance, when contaminated, these rivers also spread disease, which is more damaging in rural regions due to the lack of sufficient medical care.

it was an active political time, so it wasn't advised to be out after certain times. In the urban areas, some of the drainage locations were bounded by fences, and not just anyone could enter the sites mainly for safety reasons.

We requested official documents on existing and future drainage planning and management of these rivers from the Ministry of Environment & Solid Minerals in Uyo because they were not made available to the public. Unfortunately, we did not receive a response in time before submitting this thesis, t herefore we ended up having to move forward without these formal documents.

Interviews

We were able to get in contact with a civil engineer who has worked on some of these government-funded drainage projects and was able to get an overview of the drainage systems, although not in detail. He was quite helpful in taking us to various locations and describing the systems to us. No private or personal information was recorded because the talk was informal. Documenting recent developments and people's daily lives will help us to understand the problems that they encounter.

An interview with the Oslo Elveforum helped us in understanding how the voluntary group works, getting information that confirms what documents say, and get an overview of how they work with the local people and the government.

Thesis Structure

This chapter provides background of this study, the problem statement, research questions and methods.

1. Introduction

what is this thesis about?

This chapter gives more insight into the flood problem in Uyo and its causes, as well as highlighting the traditional human-river relationship in Uyo.

3. Uyo

Unfolding the problem

Current drainage systems.

Traditional river management in rural Uyo.

2. Literature study

Theorietical base

This chapter gives a theoritical base into Sustainable Drainage Systems (SuDS), River managment and Values of rivers, as well as benefits of Traditional/ Indigenous Knowledge.

4. Oslo

Experiences

This chapter is a case study of river management in Oslo: how the perceptions and treatments of the rivers have changed and why.

5. Analysis

Solution for the problem

This chapter provides a synthesis of the previous chapters to give a possible answer to the research sub questions.

- SuDS (scientific/technical perspectives)
- River management
- Values of rivers

Nigeria: Traditional human-river relationships (cultural/spiritual perspectives)

Oslo: Changing perceptions and treatments of rivers, and the significance of voluntary groups (social and political perspectives)

Chapter 2

The Role of Rivers in SuDS – a Literature Study

To provide a theoretical basis for our exploration of using rivers in managing urban floods in a sustainable manner, this chapter looks at five themes: urban stormwater management; diverse values of rivers; the role of rivers in SuDS; river management; and traditional river management and sustainability. Relevant concepts and terms will be discussed, and knowledge and experiences from existing research will be extracted and synthesized.

On urban stormwater management

TSince the inception of urbanization, Urban drainage systems have been an essential element of city infrastructure, collecting and conveying stormwater and wastewater out of densely populated areas (Chocat et al., 2007; Larsen & Gujer, 1997; Zhou, 2014). The primary goal of urban stormwater drainage is to prevent flooding by managing stormwater (Chocat et al., 2007) and this was done mainly through underground pipelines (Charlesworth et al., 2003 p.99; Mguni et al., 2016).

Urban drainage is a significant part of urbanization as it helps in navigating water flow and rainfall from its natural system of drainage (Read, 2014).

Prior to the 1960s, sewer systems were constructed in most cities, and the primary technical approach was to collect and convey both stormwater and wastewater from residences in a single pipeline known as a combined system. Following the late 1960s, the conventional approach has been to utilize a two-pipe system (separate system), with one pipeline for sewage and the other for stormwater (Torgersen & Navrud, 2018).

However, due to climate change, the duration of heavy rain causing floods has changed from minutes to hours and sometimes several days. And due to an increase in impervious surfaces, almost immediately this rain can cause flooding in urban areas.

Urban flooding can be categorized into various types depending on the source. These sources could be overflowing rivers, tidal waters, groundwater, snowmelt, or heavy rainfall that surpass the drainage and sewer system capacity (Jha et al., 2012; Torgersen & Navrud, 2018). However, studies that have contributed to this comprehension of the flooding concept have been centred on the most common form of urban flooding, which is caused by heavy rainfall. These are referred to as pluvial floods.

Figure 4: grorudparken with peopel interacting with the river instructure. *Source: Byantikvaren i oslo, 2009*

According to Chocat et al. (2007), conventional drainage systems are constructed to rapidly collect and transfer rainwater and runoff from urban zones through sewer systems and water treatment plants to the nearest receiving water bodies (Chocat et al., 2007). Numerous scholars have expressed their worries about the durability of conventional drainage approaches by studying their harmful effects on the urban environment (Hellström et al., 2000; Roy et al., 2008; Stewart & Hytiris, 2008; Wong & Eadie, 2000; Zevenbergen et al., 2008; Zhou, 2014).

Conventional drainage systems have limited capacity and cannot retain the collected surface water for long periods. Additionally, climate change will add to the existing loads and put more pressure on surface water drainage, increasing the risk of damage to buildings and infrastructure (Burkhard et al., 2000; Forening & Association, 2010; St.meld. nr. 33 (2012-2013), 2013; Thodesen et al., 2022).

The global trend is towards environmentally friendly strategies for dealing with stormwater runoff. Municipalities are adopting measures to lessen the amount of stormwater runoff starting from its source and of these emerging approaches is Sustainable Drainage Systems (SuDS) (Rathnayke & Srishantha, 2017; Sieker, 1998; van der Sterren et al., 2009)

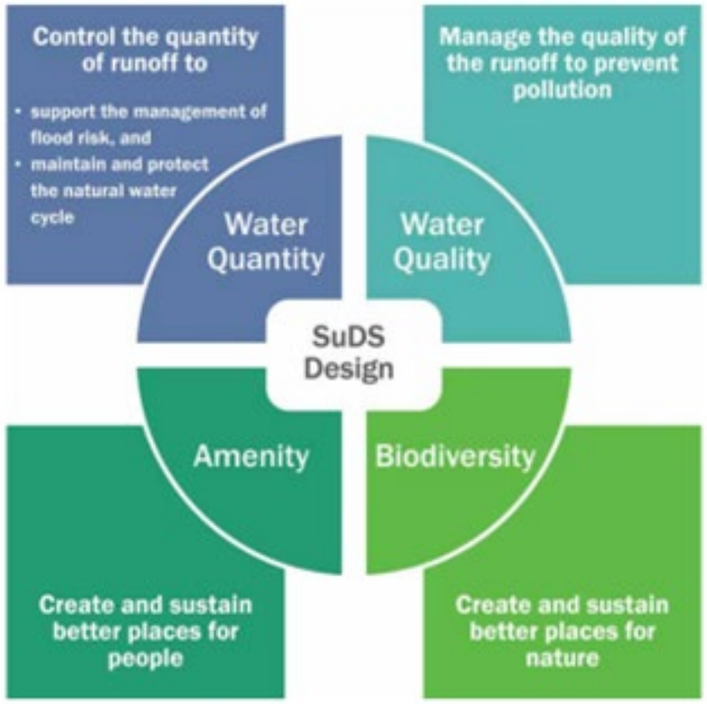


Figure 5: this shows the design objectives in SUDS design. *Source: SUDS manual, 2015, p.6*

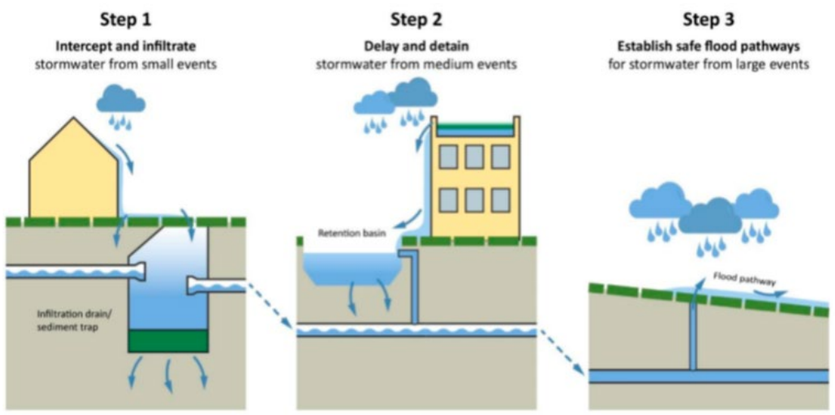


Figure 6: shows an example of the management train for stormwater management used in most European cities *Source: Thodesen et al., 2022.*

Sustainable Drainage Systems (SuDS)

"*Surface water drainage systems developed in line with the ideals of sustainable development are collectively referred to as SuDS*" (Woods-Ballard et al., 2007 p.39).

The term "Sustainable Drainage Systems" or SuDS, was first coined in October 1997 by Jim Conlin of Scottish Water (Fletcher et al., 2015). While D'Arcy (1998) introduced the idea of the "sustainable drainage triangle" which encompasses three aspects: quantity, quality, and habitat/amenity (Fletcher et al., 2015).

There are systems that drain stormwater in a way more sustainable than the conventional pipe-based drainage system. The systems in place at a specific location are designed to address both the management of environmental risks arising from urban runoff and, where feasible, contribute to environmental improvements (Woods-Ballard et al., 2007, p.39).

The design objectives in SuDS design are 1. Improving stormwater quality (pollution) by providing passive treatment of collected surface water before discharge onto land or a watercourse; 2. Reducing runoff quantity (flooding) through source control and delaying runoff velocity; 3. Improving amenities; and 4. Sustaining biodiversity (fauna and flora) (Ashley et al., 2015; Charlesworth et al., 2003; Mguni et al., 2016; Woods-Ballard et al., 2007).

The sustainable drainage system's guiding principle is to maximize the advantages and reduce the drawbacks of surface water runoff from dense areas. The most widely used SuDS techniques today are filter and infiltration trenches, permeable surfaces, water storage, swales, water harvesting, detention basins, wetlands, and ponds (Elliott & Trowsdale, 2007; Zhou, 2014).

SuDS (Sustainable Drainage Systems) are based on the concept of a SuDS management train, which involves a series of components working together to manage various aspects of runoff (Thodesen et al., 2022). This includes controlling the frequency of runoff, regulating flow rates and volumes of runoff, and reducing the concentration of contaminants to acceptable levels. Essentially, the SuDS management train provides a comprehensive set of processes to effectively manage surface water and promote sustainable urban drainage. This includes four key aspects source control, pre-treatment, retention, and infiltration (Thodesen et al., 2022).

How rivers/streams relate to SuDS

The purpose of SuDS is to mimic natural drainage systems and promote sustainable water management in urban areas. Hence, rivers are important aspects to consider when implementing SuDS. Rivers are natural watercourses that form part of the wider water cycle, and they are directly impacted by land use changes and the way we manage surface water runoff.

One of the primary goals of SuDS is to manage surface water runoff in a way that reduces the negative impacts of urbanization on watercourses. Because rivers are an important natural component of the water cycle, they play a critical role in SuDS and as such should be a key consideration in sustainable stormwater management.

The Bishan-Ang Mo Kio Park in Singapore provides an example of how rivers can be used as a SuDS approach. The project involved the restoration of a storm drain that was previously canalized and transformed into a 3-kilometer naturalized meandering river with a vegetated bank and flowers. This initiative has a range of benefits, including the prevention of flooding and erosion due to the natural vegetation, as well as reducing the impacts of droughts (Opperman et al., 2018).

Rivers are important for biodiversity, they help in the migration of species between different habitats, in other words, they function as ecological corridors. In a naturalized stream, you see a whole range of biodiversity that you cannot see in the utilitarian drain. Rivers also help to reduce urban heat island effects; they can function as flood prevention, and they are great for well-being and recreation.

SuDS vs Conventional drainage systems

Sustainable drainage systems can significantly reduce the negative effects of non-point source pollution in urban water bodies, in contrast to conventional drainage which concentrates on the “end-of-pipe” or “at the point of the problem” remedies (D’Arcy & Frost, 2001; Echols, 2007; Faram et al., 2010; Haitjema & Mitchell-Bruker, 2005; Zhou, 2014).

SuDS handles stormwater close to where it falls and frequently mirrors the natural drainage process (Dung, 2020). Many conventional drainage systems have key characteristics that raise the risk of flooding relative to natural drainage systems, including faster flow accumulation and greater flood peaks (Dung, 2020).

More significantly, the conventional system consists of numerous structural components, including concrete pipes. The drainage network installation and restoration are already extremely expensive and time-consuming (Wilderer, 2004; Zhou, 2014). So, in cases of unexpectedly high amounts of precipitation, the next step would be expansion. Most times expanding the conventional drainage underground pipe system may not meet the general criteria of sustainability (Chocat et al., 2007; Hellström et al., 2000; Zhou, 2014), and if the conventional drainage system frequently needs to be expanded incrementally, it thus lacks the flexibility to adapt to pressing and unexpected circumstances (Krebs & Larsen, 1997; Sieker et al., 2008; Zhou, 2014).

The primary objective of conventional drainage systems is to manage stormwater flows, preventing or lessening urban flooding. Due to the current climatic fluctuations, these pipe systems are unable to handle the unexpectedly increasing amount of water because they are intended for a specified maximum flow rate (Sharma, 2008).

Whereas the SuDS is designed aiming for long-term sustainability with flexibility and reversibility (Larsen & Gujer, 1997; Sands, 1992; Stahre, 2006; Zhou, 2014).

With a focus on water quantity regulation, the conventional drainage system is primarily a single-objective-focused design. The necessity to intentionally incorporate other critical factors of urban water management, such as runoff quality, visual amenity, recreational value, ecological protection, and various water uses, in today’s drainage systems is one of the strong points of Sustainable Drainage System (Chocat et al., 2007; Echols, 2007; Ferguson, 1991; France, 2002; Stahre, 2006; Zhou, 2014).

Applying SuDS

It is essential to employ knowledge that has been updated for relevant future situations when implementing flood prevention measures, considering factors such as rainfall volume, frequency, population growth, etc. More significantly, the conventional system consists of numerous structural components, including concrete pipes, which could necessitate more investments for expansion if the construction is too small. On the other hand, by constructing too large, one runs the risk of drawing criticism for overspending and wasting money that could have been put to better use (Torgersen & Navrud, 2018).

Figure 7: shows an example of a piped drainage overflowing *Source: watercolor managment, n.d.*

Fundamentally, evaluation entails a challenge against natural factors. The future dimensions of rainfall amounts are unknown for certainty. The amount of pressure that the systems will have to endure is very unpredictable. The fact that the situation is uncertain should not be a reason for delaying inquiries or altering policies.

Figure 8: a guy spiritually engaging with water. *Source: AiR Atman in Ravi, 2022*

Willems (2012) suggests it is not necessary to make extensive investments in upgrading all infrastructure immediately because climate change happens gradually (Torgersen & Navrud, 2018). Rather, we should consider uncertainties by utilizing flexible and sustainable approaches (Refsgaard et al., 2013; Torgersen & Navrud, 2018). It is possible to implement an adaptive strategy that involves both adaptability and the ability to reverse changes. This differs from the conventional engineering method, which is viewed as more fixed and frequently relies on design regulations determined by engineers (Arnbjerg-Nielsen et al., 2013; Torgersen & Navrud, 2018).

As per the socio-economic theory, the utilization of flexible measures is expected to have greater social and economic benefits than the utilization of rigid measures. The shift towards incorporating more Sustainable Drainage Systems (SuDS) could be regarded as an environmentally conscious adjustment for future circumstances where predictions are presently uncertain.

Values of rivers

Traditionally, rivers have been managed to set values including hydropower, industry, agriculture, and water supply for cities, which support a significant share of the global economy (Opperman et al., 2018, p.20). However, rivers provide values that exceed the value of the water they carry. Faced with climate change, rapid development, and a world of increasing water risk, understanding these diverse values from rivers, and then devising policies and practices to safeguard them is a formidable challenge (Opperman et al., 2018, p.8).

During early modern times rivers were considered dangerous, this would not be the case if the role of water in everyday life was taken into consideration (Oestigaard & Syse, 2010, p.36). To carry out their daily activities people needed to be in direct contact with rivers, streams, and other open sources of fresh water. The risk of drowning was high, and children were warned to stay away from rivers and their unsafe currents, making riverbanks dangerous places (Oestigaard & Syse, 2010, p.36).

From a societal perspective, rivers have a strong value in the perceptions of worldviews, spiritualism, and religion (Oestigaard & Syse, 2010, p.10; Wantzen et al., 2016, p.8). In some cultures, the personalization of water as the source of life or flood as an intimidating, destructive force may be the reason why so many rivers have been and still are considered divinities in many countries (Wantzen et al., 2016, p.8). The Ganges River and The Jordan River are examples that are considered sacred to various religions, and rivers are central to the cultural and spiritual identity of many indigenous groups (Opperman et al., 2018, p.33; Wantzen et al., 2016, p.8). It is important to recognize and respect the diverse needs and beliefs of the people when managing rivers, and specific spiritual values can be protected or restored during planning for river management (Opperman et al., 2018, p.33).

The recreational value of rivers is growing in importance. In addition to the recreational value of freshwater fisheries, rivers also provide value in the form of other recreational activities, such as swimming, kayaking, and rafting (Opperman et al., 2018, p.33). In urban spaces and cities, hiking areas and parks could be integrated into riverside hiking areas and parks which will add value to the recreational aspect for humans and the ecosystem.

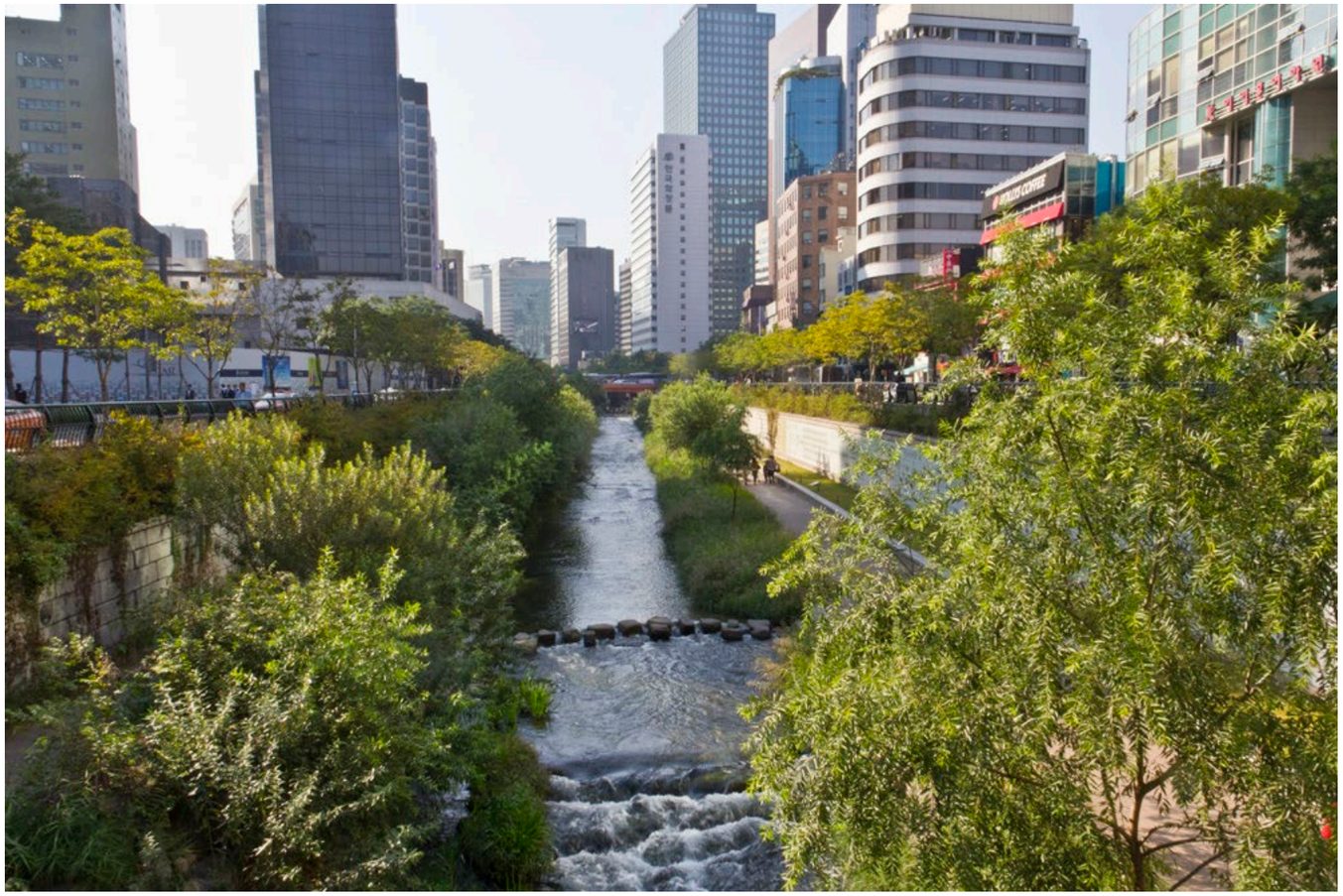


Figure 9: Cheonggyecheon stream in Seoul, South Korea, daylighted from sewers in 2003
Source : Kaizer Rangwala, 2003

Freshwater biodiversity is constantly shrinking due to intensive river engineering and increasing demand for water as a resource (Wantzen et al., 2016, p.9). The ecological status of rivers worldwide is decreasing at a much faster pace than most planetary ecosystems. Most riverine landscapes are now modified or highly modified by human activities and there is a huge distinction between the needs of humans and the needs of the ecosystem (Wantzen et al., 2016, p.9).

Because of human needs, river ecosystems, and resources experience dramatic declines in much of the industrialized world (Opperman et al., 2018, p.14). Rivers are now used as waste disposal systems, resulting in widespread and often severe water pollution. Also, the creation of water-management infrastructure, such as levees and dams has resulted in the widespread fragmentation of rivers, disconnecting them from their productive floodplains and hindering the routes used by migratory fish and other species (Opperman et al., 2018, p.14).

As mentioned by Wantzen et al. (2016), ecological services provided by river systems such as fish are not available anymore, or because people have lost the notion of a healthy river due to pollution. Traditional-cultural use of river-borne resources and management are not considered to be economically feasible and there is a preference to have the river canalized and covered by concrete.

However, important financial elements are overlooked as the economics behind the views mentioned are incomplete (Wantzen et al., 2016, p.9). For example, channelize a river upstream to control the river could potentially create bigger flood events for the residents' downstream areas of the river.

The natural features of rivers and their basins are critical to maintaining the flows of clean water that billions depend on (Opperman et al., 2018, p.24). For example, forested watersheds with deep soils promote infiltration and decrease the amount of nutrients and sediment that enter water supplies by reducing excess surface erosion.

"*Healthy floodplains can promote groundwater recharge and have the potential to be managed in combination with water-management reservoirs*" (Opperman et al., 2018, p.24).

"*Along with the alarming loss of biodiversity, we register a loss of cultural diversity linked with rivers and floodplain wetlands*" (Wantzen et al., 2016, p.9).

The positive effects of dynamic rivers on humans are multiple, including stress reduction, positive effects on the microclimate, livelihood benefits for a fisherman, and reduction of respiratory diseases (Tickner et al., 2017; Wantzen et al., 2016, p.11). While rivers in a bad ecological state provoke negative effects due to bad smell, and visible waste, rivers in a good ecological state increase the attractiveness of the entire region (Wantzen et al., 2016, p.11). Diverse river flows have a great aesthetical value and restoration of river ecological status and services may lead to an increase in the value of a river.

It is not surprising that many cities such as Frankfurt at the Main River or Oslo at the Alna River have re-established their rivers in their areas and developed impressive waterfront architecture only after overcoming post-war water pollution. Recognizing these positive values of healthy rivers for human well-being and economic development is an important element to address when we are discussing the possibility and the need to reopen rivers (Wantzen et al., 2016, p.11).

Figure 10: The Lower Granite Dam on the lower Snake River in southeastern Washington
Source : Greg Vaughin,2003

Our argument based on our literature study is finding back the ‘‘rhythm” or the historical patterns of the waters appear to be one of the major problems in modern river management, such as in dense areas and urban spaces (Wantzen et al., 2016, p.12). The problems can be broken down into two questions: “How to find space for rivers in diked and colonized floodplains, and how to re-establish appropriate environmental flows to maintain historic patterns of river flooding?” (Wantzen et al., 2016, p.12). Solutions often come at a cost to the users of the floodplains who are reluctant to lose irrigation water or electricity in the interests of their activities. The values for decision-making need to be reconsidered. There could be several solutions such as recalculating economic budgets including costs for environmental restoration and public healthcare resulting from short-term use of riverine resources may be one way out of the dilemma. Another solution could be techniques such as a flood-mitigating architecture, and adequate use of riverine e cosystem services may be another (Wantzen et al., 2016, p.12).

A shifting paradigm of River Management

“*The number of free-flowing rivers has dropped dramatically over time*”, a trend Nilsson noticed 15 years ago (Nardini & Conte, 2021, p.1). In the study of Nardini and Conte, they are referring to Belletti who estimated the presence of more than one million barriers in EU rivers. The anthropogenic intervention of river configuration of the morphology and the set of mechanisms to control the river is to some extent unavoidable and will increase in the future (Nardini & Conte, 2021, p.1).

The history of the exploitation and degradation of river systems is not a new concept. The Yellow River in China has been regulated for at least 4000 years, and in Europe drainage schemes and large flood embankments were in place prior to the 11th century (Smith et al., 2014, p.249). Moving forward, in the eastern United States dam construction had created a fragmented and regulated river system by the 1840s (Smith et al., 2014, p.249).

From approximately the 1950s to the 1970s and 1980s, the exploitation and interventions of rivers accelerated. The view of rivers was channeled to convey water as quickly as possible to the sea, or a resource to be exploited (Smith et al., 2014, p.249). The rivers were straightened, diverted, dredged, and culverted, for flood protection, and navigation requirements, and dammed for storage (Smith et al., 2014, p.249; Wantzen et al., 2016).

The environmental movement that emerged during the 1960s and 1970s raised awareness of the environmental degradation that was caused by traditional engineering approaches to the environment (Smith et al., 2014, p.250). Awareness of the negative effects of river regulation emerged from this movement in broader societal values. The shift challenged the relationship between society and nature and influenced the science and practice of river management (Smith et al., 2014, p.250).

Realization of economic costs and the limitations of traditional engineering schemes, and their tendency to displace problems elsewhere in the river system created the force to explore more natural ways to work with rivers (Smith et al., 2014, p.250). Engineered infrastructure generally strives to alter natural processes and the lacking acceptance of the dynamic nature of rivers. As a result, structures such as dams and levees are among the leading causes of the loss of floodplain productivity and habitats, fish, and wildlife (Opperman et al., 2018, p.31; Wantzen et al., 2016, p.11).

The major problem identified with river management is the attempt to ‘‘correct the river course’’, ‘‘taming the floods’’ and other metaphors showing that river management is still considered rather a war against nature than a harmonious coexistence, using the natural power for human benefit (Wantzen et al., 2016, p.10-11). Many hard engineering schemes were undermined and required frequent maintenance, while at the same time, it was shown that many flood defence schemes did little to protect against flooding (Smith et al., 2014, p.250).

Approaches to river management based exclusively on physical science and engineering analyses have proven to be unsustainable (Johnson et al., 2020, p.3). The problems that these approaches were intended to solve, such as flood damage and water scarcity, have not been solved.

Figure 11: Sanya Mangrove Park
Source : Turenscape,2021

On the contrary, annual expected damages associated with river-related problems are accelerating, and "*long-term deterioration in river environments and ecosystems has materially reduced the capacity of the world's rivers to continue meeting the needs of society*" (Johnson et al., 2020, p.3).

Towards the end of the 20th century, beginning in the United States and then spreading quickly to other countries, rivers began to be seen as important environmental assets rather than systems to be exploited or hazards to be managed (Johnson et al., 2020, p.3; Nardini & Conte, 2021, p.1; Smith et al., 2014, p.250).

Growing recognition of the limitations of conventional approaches led river scientists to argue for a shift in river management, and historical trends of degradation and deterioration, and so emerged the practice of river restoration (Johnson et al., 2020, p.3). By the 1980s restoration projects were being carried out across several European countries, and successful legal challenges to proposed channelization and drainage schemes supported this process (Smith et al., 2014, p.250).

Increased environmental awareness throughout the 1970s and 1980s provided the introduction of a range of legislation that provided the enabling conditions for river restoration to grow (Smith et al., 2014, p.253). In different countries, important changes in legislation and the creation of various institutions tasked with implementing this legislation have changed the focus of river restoration (Smith et al., 2014, p.253).

In Europe, national and environmental legislation is transposed into national laws by directives at the European level (Smith et al., 2014, p.253). The EU Water Framework Directive in 2001 has become the primary legislation controlling fluvial ecosystems in Europe. The EU Floods Directive of 2007 emphasizes natural approaches to flood risk management that are more consistent with conservation and restoration activities (Smith et al., 2014, p.253).

In South Africa, the National Water Act of 1998 emphasizes environmental protection and the right of the environment to water alongside human needs and access (Smith et al., 2014, p.253). This is an explicit recognition within the legislation of the need to set environmental flows to sustainably manage river systems and has strongly influenced approaches to restoration (Smith et al., 2014, p.253).

"*River management has experienced a paradigm shift from a long-established debate about flood defense to a more open-ended debate on river restoration*" (Chou, 2016, p.2).

River degradation has motivated the investigation of more adaptive and sustainable management practices, among which are river restoration efforts (Fox et al., 2017). Even though this debate is current among river specialists, in practice it seems to indicate that river restoration means different to different people (Chou, 2016, p.2). In terms of scope and scale, it can be a complete structural and functional return to the pre-disturbance state, a recovery of the part conditions of rivers, a recovery of the natural state of a river ecosystem without really aiming at the pristine, pre-disturbance state, or an improvement of the present state of rivers and their surrounding areas with the intention of enhancing their ecological, economic, social, or aesthetic features.

While it is unrealistic to expect any restoration approach will achieve a pristine state for a river, the possibilities of restoration should be determined to indicate attainable targets. For example, improved water quality, riparian management, in-stream habitats, fish passage, bank stabilization, aesthetics, recreation, education, and stormwater management are frequently stated as goals for river restoration in the USA (Chou, 2016, p.2). As the decision of whether to restore a river, and how to restore it, is fundamentally linked to prevailing societal values, perceptions of nature, and priorities (Smith et al., 2014, p.252). the reasons for restoration can be expected to change according to the way in which these values change (Smith et al., 2014, p.252).

River restoration has been closely associated with flood prevention. While river restoration is framed as a measure to lessen flood risk, the challenge is that risk perception and water safety are important aspects of public attitudes towards changes to rivers (Chou, 2016, p.2-3). Restoring rivers usually raises local concerns about the impact on flood prevention and community safety, due to the dynamic river features, such as the speed, height, and volume of flow, that intensify the uncertainty in water management and generate potential fears about the dangers of flooding. Public participation and local support are fundamental to river restoration projects. The local public frames the success or expectations of river restoration in their own terms. The urban setting may be mainly based on the reduction of flood risk and the improvement of recreational and aesthetic values. This obviously involves multi-functional amenity outcomes for urban waters and riparian areas (Chou, 2016, p.3).

In common with trends in the broader scientific community, A central part of restoration projects is the importance of community participation. The overall picture is one of the increasing importance of community and civil society groups in the process, and blended models of engagement between scientists and non-scientists (Smith et al., 2014, p.253).

The degree of participation in river restoration varies from country to country. In Australia, because of limited government resources put into the restoration, they have emphasized community and volunteer approaches and participatory frameworks for river management, such as the Rivercare program (Smith et al., 2014, p.253). In New Zealand River management is highly decentralized and there is a long history of community involvement in environmental management. The study of Smith et al. 2014, it is highlighted that Gregory et al. (2011) note that in a comparison of participation in New Zealand and in Europe there is a requirement for public participation under the Water Frame Directive, and local stakeholders have little space to influence the decision-making process as the overall goals of the legislation are already decided (Smith et al., 2014, p.253).

Despite a large body of literature on integrated river basin management, which are combining different use forms, flood protection, and conservation, the riverine reality is still far from experiencing holistic approaches, especially in the Global South (Wantzen et al., 2016, p.9).

Errors in environmental management such as excessive damming, closing, and canalization of rivers have been performed in Europe and the United States for decades, and now are being repeated in developing countries, although measures are taken to correct these errors in their countries of origin. There has been a recent resurgence of dam building, closing, and canalizing rivers that threaten the remaining pristine environments of rivers, the current need for management is to mitigate these pressing issues rather than use and conserve river ecosystems to solve the issues (Wantzen et al., 2016, p.9).

Economic and institutional development often focuses on fulfilling the needs of the human population at the expense of the river environment (Wantzen et al., 2016, p.10). Many if not most politicians are willing to sacrifice the integrity of rivers and such services as fisheries in favour of a nationwide supply of commodities such as electricity or irrigation water, ignoring the long-term effects that put entire societies at stake by destroying life support systems and by risking wars against essential resources such as water (Wantzen et al., 2016, p.10).

Countries that have not yet invested heavily in flood management systems or blue-green infrastructure can fully consider the benefits of incorporating these types of solutions when they do begin to invest (Opperman et al., 2018, p.32). There are examples such as the lower Mississippi, and the Netherlands, where engineers originally tried to fully control rivers within levees and dikes. In the face of repeated floods, there has been a realization that the river would need some room to spread during the largest floods. So, in the cases that have been mentioned, they have now reconnected rivers to their floodplains in key areas. Later developing countries can avoid this by learning from these mistakes and "getting it right" the first time by taking maximum advantage of the multiple benefits of existing floodplains (Opperman et al., 2018, p.32).

It is important to highlight that healthy floodplains are not the only answer to reducing current and future risks of floods or heavy precipitation (Opperman et al., 2018, p.32). Floodplains rather offer some advantages within a diversified portfolio approach to flood management and should be part of the solution (Opperman et al., 2018, p.32).

The rivers carry a broader set of services that deliver immense benefits to economics, nature, and people, which far too often is not a priority for river management until the problems appear from their neglect (Opperman et al., 2018, p.5).

River management and river restorations are not new concepts to handle flooding and stormwater management. An example of this is the Emerald Necklace in Boston, USA. Frederick Law Olmsted created the Emerald Necklace from 1878-1896 with places for both active and passive recreation, open green spaces that offer relief and refreshment from the tension and pressures of everyday life (Emerald Necklace Coservancy, 2022). "*In hydrologic terms, the Emerald Necklace is situated in parts of two small urban watersheds, known as the Muddy River and Stony Brook, which affect its "blue" processes and performance*" (Marks et al., 2015, p.12). The Muddy River and Stony Brook are part of small urban waterways that are streamed to the larger Charles River which drains 35 communities before discharging into the Boston Harbor (Marks et al., 2015, p.13). The Boston Water and sewer commission manages the rivers primarily for functional purposes such as stormwater catchment, stormwater transportation to the Charles River, and flood mitigation (Marks et al., 2015, p.12).

Another example of strategies to mitigate against flood is the concept of "Sponge City". The concept was officially revealed by the Chinese president at a conference in 2013 (Hamidi et al., 2021, p.2). The reason for the concept is linked to the frequency of urban pluvial flooding in Chinese cities and in 2015 and 2016 30 cities in China were selected as pilot projects (Hamidi et al., 2021, p.2).

"*With this has come a more nuanced assessment of the appropriate paradigms for river management and the relative position and importance of different stakeholders and different types of knowledge in the process*" (Smith et al., 2014, p.253).

The concept can be described as a city that can absorb, infiltrate, retain, and purify water when there is heavy precipitation and release water when the outside is dry (Guan et al., 2021, p.2). The construction of urban environments has resulted in the removal of natural rainwater-retaining infrastructure. The Sponge City concept is composed of wetlands, forests, natural rivers, lakes, green roofs, and so on (Guan et al., 2021, p.2; Nguyen et al., 2019, p.2). The concept embodied foreign experience and the wisdom of ancient Chinese philosophy (Yin et al., 2022). The sponge city concept is a good example of combining the traditional knowledge of coping with climate change and flooding with modern solutions (Yin et al., 2022).

Traditional knowledge & Sustainability

Adapting and mitigating climate change is not a new concept, humans have survived multiple ice ages and planetary transformations before, largely as a function of traditional knowledge and Indigenous wisdom (Ogar et al., 2020, p.162). Traditional knowledge is embodied and embedded in cultures and communities around the world, and wisdom has informed human societies for hundreds of thousands of years. The knowledge forms sustainable living in each place and manifests as oral histories, songs, art, and material and spiritual. This rich world of traditional knowledge and Indigenous wisdom represents an often-forgotten world that still exists and provides for the livelihoods and well-being of millions of people in communities deeply anchored by their cultures and languages (Ogar et al., 2020, p.162).

Tran et al. (2009) in their paper "Indigenous Knowledge in river basin management" defined indigenous knowledge as *"institutionalized local knowledge that has been built upon and passed on from one generation to the other by word of mouth"* (Tran et al., 2009, p.4).

The term Indigenous knowledge appears under several terms such as traditional knowledge, local ecological knowledge, and local knowledge, and these definitions often overlap, and in the thesis, we will not distinguish between these definitions. This knowledge is the origin of local-level decision-making in many rural communities (Tran et al., 2009, p.4).

Indigenous knowledge has also value for scientists and planners striving to improve conditions in rural localities and not only for the culture in which it evolves. The knowledge base is shaped by the previous generations' experiments and observations and provides an inherent connection to the surroundings and environment. Indigenous knowledge is argued to not be only transferable but also provides relationships that connect people directly to their environments and the changes that occur within them, including climate change (Tran et al., 2009, p.4).

Academics have demonstrated that there is much to understand from indigenous and community-based approaches to climate change adaptation, resilience, and disaster preparedness (Makondo & Thomas, 2018, p.84). Folke et al. (2002) and Davidson-Hunt & Berkes (2003) demonstrate that different types of knowledge can enhance resilience. Overlooking traditional knowledge can lead to increased vulnerability of life and property (Tran et al., 2009, p.4). Communities have through their knowledge been able to maintain and develop local or regional coping strategies, "Their knowledge and practices can provide an important basis for today's efforts in dealing with even greater challenges of climate change" (Makondo & Thomas, 2018, p.84).

Nyong et al. (2008) looked at the value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel (Nyong et al., 2007). The study investigated developmental projects that have been created, funded, and managed by outside resources and introduced into rural communities. The projects did not consider the culture of the people and the communities and resulting in low success rates and participation. As a result of these failures, there was a growing interest in the incorporation of local knowledge and traditions to increase project participation rate and provide environmentally sound approaches to development (Nyong et al., 2007, p.794).

Further, the study of Nyong et al (2007) shows how Indigenous knowledge adds value to climate change studies (Nyong et al., 2007). This study analysed five points, but we will look at three as these are relevant to our thesis. The first is Indigenous knowledge is increasingly demonstrating a resemblance with modern scientific methods as many methods and ideas in traditional knowledge that were once regarded as misguided, and primitive are now seen as sophisticated and appropriate (Nyong et al., 2007, p.794).

Secondly, Indigenous knowledge systems provide mechanisms for participatory approaches. Local populations must be seen as partners in projects with joint ownerships, for the sustainability of any projects in local communities. This is best achieved when the communities participate effectively in the implementation and design of such projects. Lastly, Traditional knowledge systems *"can facilitate understanding and effective communication and increase the rate of dissemination and utilization of climate change mitigation and adaptation options"* (Nyong et al., 2007, p.794).

"*Indigenous knowledge is also very much about the present, rooted in the wisdom of the past*" (Ogar et al., 2020, p.162).

As mentioned by Chou (2016), river restoration is closely associated with flood prevention (Chou, 2016). The possibility of using knowledge of local communities in river restoration has started to be appreciated, mainly in the aspect of indigenous people. The study of Szałkiewicz et al. (2020) looked at the incorporation of local ecological knowledge in river restoration and management plans (Szałkiewicz et al., 2020). Reports about local ecological knowledge applications are still rare, and in practice, traditional management is mainly used to keep or restore valuable ecosystems in the floodplains, but local knowledge about the river is not usually described or considered. In the study, they explored the case of the Janupe River in Latvia. The Latvian River restoration initiative “Place a Stone in a Stream” presents an important case where scientists closely cooperated with all possible stakeholders, such as authorities, landowners, non-governmental organizations, and local communities, and actively engaged them in actions of river ecosystem improvement. These actions were also sourced and inspired by former traditional methods and local ecological knowledge of river purifications. Their approach in the case of the Janupe River has so far led to successful ecological state results and understanding the sites of the people staying close to the rivers has increased their lasting in the future (Szałkiewicz et al., 2020).

Even though nature is overall better conserved in areas controlled by Indigenous peoples, Western science seems too often to overlook such successes. Ogar et al. (2020) underline that there is a need to embrace Indigenous knowledge, be intimately led and guided by the people who hold the knowledge, and where appropriate, consider it alongside the best scientific understanding of priorities needed to prevent ecosystem collapse (Ogar et al., 2020, p.162). Respecting and embracing Indigenous rights and knowledge will help us to survive the present century and plan for a brighter future (Ogar et al., 2020, p.162).

Two major problems that can be identified as obstacles to integrating indigenous knowledge into formal climate change mitigation and adaptation strategies are: recognizing the need to, and how to integrate indigenous knowledge into formal Western science (Nyong et al., 2007, p.794). It is important to emphasize that not all indigenous knowledge can provide the right solution for a given problem. Before adopting indigenous knowledge, and integrating it into development programs, their practices need to be studied for their suitability just as any other technology. In addition to local evidence, scientific proof, and the sociocultural background in which the traditional practices are embedded, there is also a need to consider the process of validation and evaluation of Indigenous knowledge (Nyong et al., 2007).

Whereas the SuDS is designed aiming for long-term sustainability with flexibility and reversibility (Larsen & Gujer, 1997; Sands, 1992; Stahre, 2006; Zhou, 2014).

With a focus on water quantity regulation, the conventional drainage system is primarily a single-objective-focused design. The necessity to intentionally incorporate other critical factors of urban water management, such as runoff quality, visual amenity, recreational value, ecological protection, and various water uses, in today’s drainage systems is one of the strong points of Sustainable Drainage System (Chocat et al., 2007; Echols, 2007; Ferguson, 1991; France, 2002; Stahre, 2006; Zhou, 2014).

Summary

In urban areas, there is an anticipation of more frequent and intense precipitation events, necessitating the implementation of actions, measures, and designs that can withstand the effects of climate change and ensure sustainable stormwater management. Such efforts must be undertaken with a view to preventing regrettable outcomes in the future.

If a river is channelled upstream in urban areas to control it, it could potentially lead to more significant flooding downstream for residents who live near the river. The primary issue with river management is that it is often seen as a struggle against nature, rather than a collaborative coexistence that harnesses natural power for human benefit. This is reflected in attempts to alter the course of the river. Considering the limitations of conventional approaches, experts have increasingly shifted towards a new approach to river management and restoration, inspired by the historical trends of degradation and deterioration. Restoring the ecological status and services of a river can also lead to an increase in its aesthetic value, as diverse river flows are now highly valued.

Chapter 3

Unfolding Flood Problems in Uyo, Nigeria

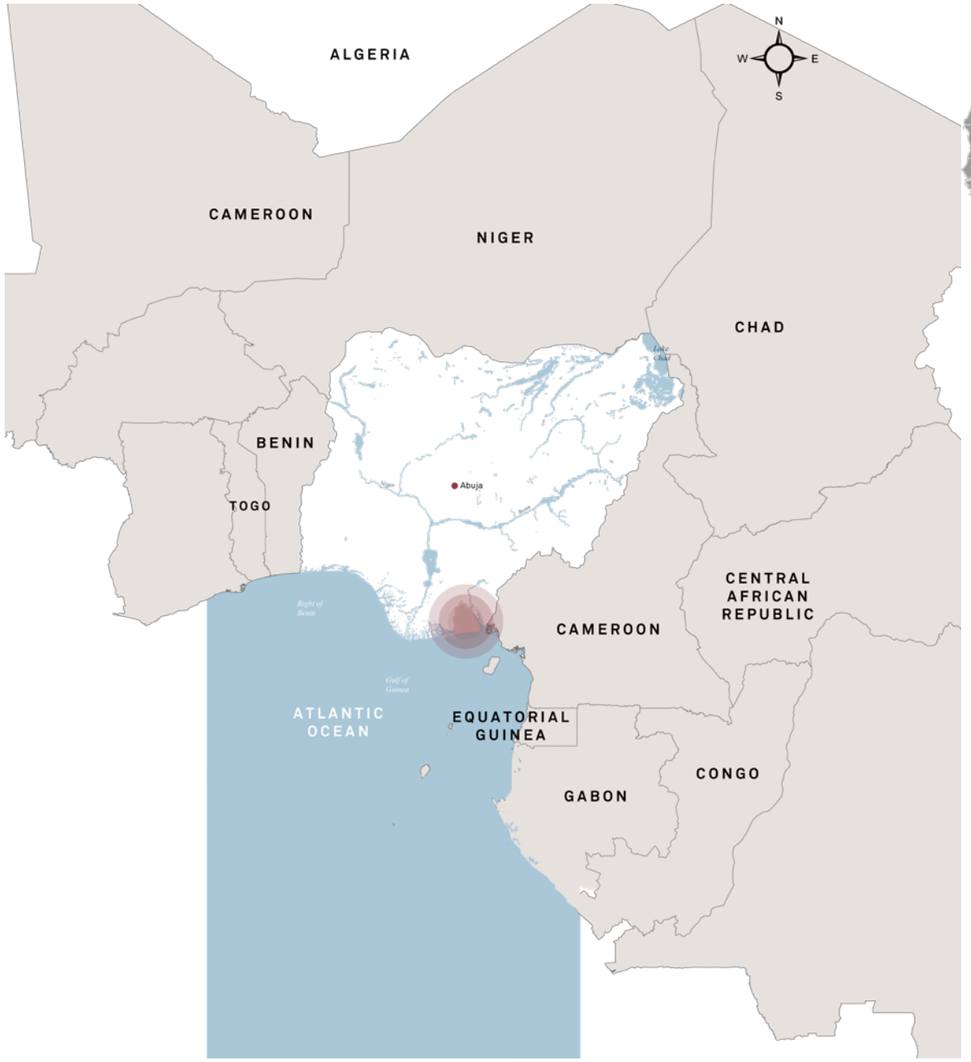
Nigeria: A Developing Nation

The Federal Republic of Nigeria is regarded as one of the most well-known emerging/developing nations and the country with the largest population in Africa, with a population of over 200 million people and a growth rate of 2.406% annually (The World Counts, 2023). It has an area of 923,768 square kilometers of land and water (inland) combined, having 98.6% and 1.4% respectively (Falola, 2001). Abuja, a city in the heart of the nation, serves as its capital. The former capital of Nigeria, Lagos, which is situated on the coast in southwest, continues to hold prestigious status as a prominent port and hub for business and finance (Falola, 2001).

Nigeria borders the Gulf of Guinea to the south; to the north is the Niger Republic, to the east are Chad and Cameroon, and Benin to the west (Figure 12) (Falola, 2001). The geography of the nation is varied, with plateaus and hills in the center region, lowlands in the south, and plains in the north, while the climate is tropical varying from arid to equatorial and alternating dry and wet seasons. The far north has a dry climate; the west and north have a wet and dry savanna climate, the southeast has a wet climate, with heavy rainfall (Falola, 2001).

Nigeria has abundant mineral and agricultural resources. Nigeria's petroleum industry is considered the backbone of the Nigerian economy. Nigeria is the top oil producer in Africa and the world's No. 11 crude oil producer (Awosika & Folorunsho, n.d.). The industry accounts for a massive portion of both the GDP and total exports. Urbanization has facilitated the concentration of manufacturing in a few cities. Most of the other groups, mainly in rural areas, have turned to agriculture, while those that live near significant rivers and along the coast have established fishing industries (Falola, 2001)

Nigeria is a multi-ethnic country with over 250 ethnic groups, each of which has its own distinct language and set of cultural traits (Falola, 2001). People that belong to the same ethnic group (for example, the Ibibio in the south) speak their native language or one of their dialects, belonging to the same group also means have a shared history and believe to have a common ancestor. Nigeria's official language is English. however, there are over 200 native languages and most people in rural areas still speak their native languages. The most common native languages are Yoruba, Igbo, Hausa, and Fulani (Falola, 2001).



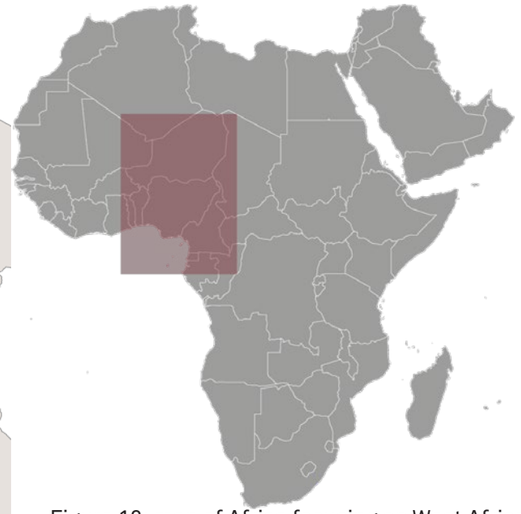


Figure 12: map of Africa focusing on West Africa

Figure 13: shows Nigeria with its neighboring countries and higlights Akwa ibom in the south

The drainage system of Nigeria can be described as a connected network of streams and rivers that originate from the Precambrian Basement Complex and flow over sediment in their lower sections (Ibrahim et al., 2022). Although there are many rivers and streams that provide nationwide basins in the country, there are three main basins that act as drainage areas: Lake Chad, the Niger-Benue, and the coastal basins see Table (1) (Ibrahim et al., 2022).

The quantity of runoff from drainage basins is highly variable and influenced by a range of factors, including the amount and intensity of precipitation, climate, vegetation, and geological, geographical, and topographical characteristics of the region (Ibrahim et al., 2022).

Uyo - Akwa Ibom state

Akwa Ibom state located in the coastal southeastern part of Nigeria, is one of the 36 states in the Federal Republic of Nigeria (see Figure xx). By Military Decree No. 24, Akwa Ibom State was established as a distinct state on September 23, 1987, from the former Cross Rivers State (Government of Akwa Ibom State, n.d.). The state has 31 local government areas, including Uyo, the capital. It is bordered by Cross River to the east, Abia to the north, Rivers, and Abia to the west, and the Atlantic Ocean to the south see Figure (xx)

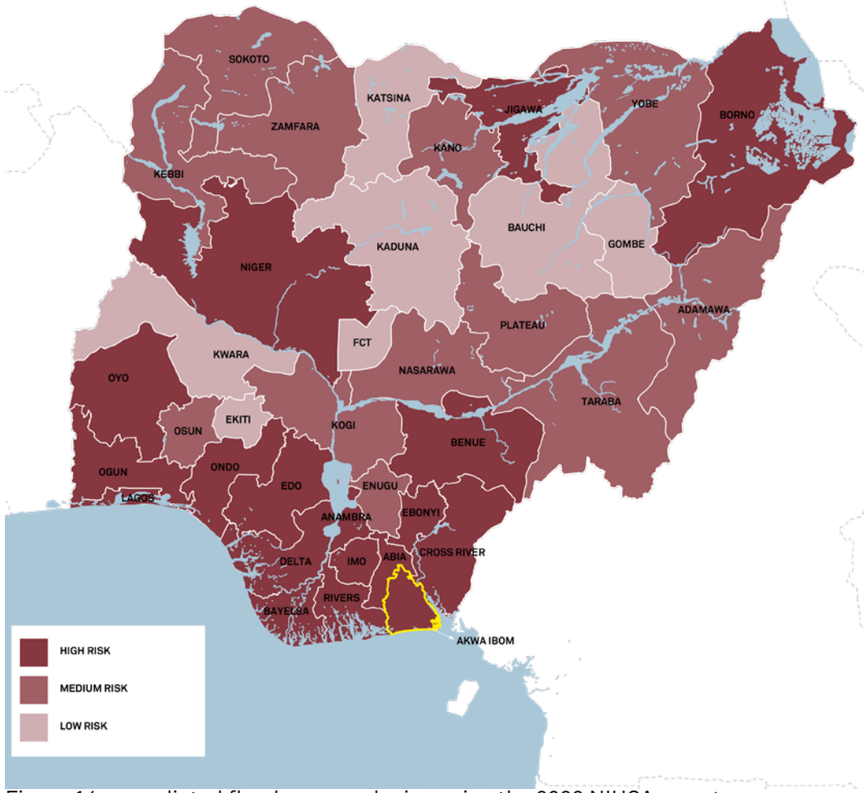


Figure 14: a predicted flood map producing using the 2023 NIHSA report.

Figure 15: map of Akwa ibom with its major waterways and highlighting the captial Uyo.

The mean annual temperature of 32.3°C / 90.14°F which is -0.99% lower than Nigeria's averages, and annual relative humidity of between 79.5%, coupled with the mean annual rainfall of 3033 millimeters favors quick plant growth (Weather and Climate, n.d.). Akwa Ibom typically receives about 342.56 millimeters (13.49 inches) of precipitation. The climate is often humid and tropical with 294.37 rainy days (80.65% of the time) annually (Weather and Climate, n.d.).

Three significant rivers – Imo River, Kwa Iboe River, and Cross River – drain the state, which is in Nigeria's sedimentary region (Ekpoh, 2015). Around 75% of the state is made up of coastal terrain and the remaining 25% is made up of Ameke formation sandstone and the Imo Shale underneath it (Ekpoh, 2015).

The capital city of Akwa Ibom state, Uyo is situated in the state's central region with over 1 million inhabitants (World population review, 2023). It is a fast-growing urban center with all the accouterments of concrete buildings, asphalt streets, corrugated iron, and aluminum roofing. The population growth in 2022 was 64,648, representing a 5.11% annual change. Due to Uyo's age, efforts to modernize and revitalize the city have not been without challenges, particularly when it comes to drainage rehabilitation (The World Counts, 2023).

Flooding in Nigeria

Nigeria's population is on the increase. More than 60% of the nation's population will reside in cities by 2030, as the population of the country increases, the environmental situation in various geographic areas of the country worsens (Durodola, 2022).

In the North, deforestation, drought, overgrazing, and desertification have all been exacerbated by wind erosion that has swept away homes and farmland (Durodola, 2022). In the middle-belt region, gully erosion and flooding are displacing residents, who must now live in camps for internally displaced people spread out over the area. While in the southern coastal portions of the nation, numerous waves, seasonal and flash flooding, and sea level rises brought on by climate change have caused millions of people to count their loss (Durodola, 2022).

Flooding is not unusual in Nigeria's population-dense urban cities and rural areas. Nigeria's water resources and hydrological systems are already experiencing the effects of climate change, which are projected to be severe. As a result, the associated environmental and socioeconomic challenges are now considered among the most significant issues facing Nigeria (Nouban et al., 2020), and with every year the floods keep getting worse. An example will be the 2022 flood which has been reported to be the country's worst in at least a decade with an estimate of 3.0 million people affected (IFRC, n.d.). et al., 2016; Olajuyigbe et al., 2012; Onwuemele, 2018; Sule et al., 2016).

Available studies have shown that there is a frequent occurrence of flooding in Nigeria (Bamidele & Badiora, 2019; Ejenma et al., 2014; Ishaya et al., 2009; Kolawole et al., 2011; Komolafe et al., 2015; Mfon et al., 2022; Nkwunonwo et al., 2016; Olajuyigbe et al., 2012; Onwuemele, 2018; Sule et al., 2016) As the most severe and frequent natural calamity, flooding poses a threat to infrastructure, communities, and means of subsistence. Cities in southern and coastal regions are particularly in danger of flooding due to sea level rise, which is a result of climate change leading to increased rainfall/ precipitation, and inadequate land use planning. Lower basin states throughout southern Nigeria have experienced a 20 percent increase in recorded volumes of torrential rains in the past 40 years (USAID, 2021). This has accelerated gully erosion in the southeastern where many riverbanks have collapsed (Lohdip & Gongden, 2013; USAID, 2021).

Akwa Ibom state: Insufficient attention to flooding

The Nigeria Hydrological Services Agency (NIHSA) released the General Highlights of the 2023 Annual Flood Outlook (AFO) in February (NIHSA, 2023). This report forecasts that many states are at high risk of flooding Figure (14), especially riverine communities. This report also shows predictions of coastal flooding that would occur in several states including Akwa Ibom (NIHSA, 2023).

Figure 5: shows an example of the management train for stormwater management used in most European cities *Source: Thodesen et al., 2022.*

In preceding years, headlines such as “120 houses submerge as flood sacks Uyo communities” (Bassey, 2021) “Residents vs floods! Who stands to win?” (Akwa Ibom Online, 2014), “Uyo residents cry out as flood submerges houses” (Anthony, 2021), “Uyo residents battle persistent flooding” (admin, 2021), dating back to 2014 all have one thing in common. Even with the residents expressing their discomfort and calls for help there is little to no attention paid to these issues.

There are some studies about flooding in Akwa Ibom and to understand the problem from the roots we carried out fieldwork in the city of Uyo.

Flooding generally happens in various locations across the city during storms and periods of heavy rain. Amid this flooding, “Aims to End Flooding in Uyo” (Davies, 2013), the government has adopted this control and command approach when it comes to stormwater management. It focuses on the engineering physical infrastructure (conventional drainage system) and excludes other perspectives (Davies, 2013).

Flooding continues in the city despite all efforts to install drains and limit erosion. Then the question stems from “*What causes flooding in this urban city*?”

We were able to get in contact with a civil engineer who has worked with the government in these urban drainage projects. He was of outstanding help, breaking down the drainage system and showing us some locations of urban rivers and drainage construction points. This helped us in understanding the urban drainage flow in the city.

In Uyo, the drainage system designed is the combined system. A system where both storm and wastewater flow through one pipe channel but instead of a treatment plant as previously explained it flows to a running/flowing river. This is deemed good and preferable because a flowing river will run the waste down its length and empties into a bigger watercourse, river, or lake then into the ocean.

Most of the drainage systems were built decades ago, however, they were too insufficient, and underdeveloped to stop the flood threat. There was an urban plan designed decades ago that did not handle urban flooding cities (Abraham et al., 2022). It wasn’t until 2010 that attempts were made to repair both outdated drainage systems and then the implementation of the underground pipe jacking system. Despite this, many of the outdated drains that need to be removed and replaced have been neglected, which has contributed to the regular flooding in the impacted areas (Abraham et al., 2022).

To get a general and more informed knowledge of the drainage systems in the city, we asked the Ministry of Environment & Solid Minerals for official drainage masterplan documents and documents showing all the urban rivers in the state past and present as these were not opened to the public. Unfortunately, we didn’t get a response, so we progressed without these official documents. We were however able to use GIS to obtain the data on the waterways see Figure (21).

Some of the drainage sites we could not access without a licensed government official which we had the civil engineer take us through. We got to see some drainage points see Figure (16-17), a few of them have been abandoned but the materials are still there. Also, we got to inspect the outfall discharge point – this is the part where all the pipes terminate and run through to a river or stream nearby. We learned that over time the government does regular maintenance at this point but when we visited the maintenance had not been carried out (see Figure (16). We were told of one combined stormwater – open and underground – a project that is not public access guarded by a fence mainly for safety reasons.

Our thesis is on using rivers/streams as a sustainable drainage system, so it made perfect sense to go through the river paths in the city and see how the government and people have used the rivers in the past and present. We believe lessons can be learned by looking into the traditional methods and to do that we had to read up on the history of the people.

Getting an overview of the history of the people was done mostly through interacting with the natives. Even as an indigene of the state I still wasn’t familiar with the history of my people. Learning the history of the people and knowing how they moved into the current Akwa Ibom was an interesting part of this research. Most books and articles start the history of the people of Akwa Ibom with the formation of the state in 1987 after leaving Cross River State, not many papers go into the history of the people.

Figure 16: shows the state of the outfall the drainage discharge point. *Source: Fieldwork, 2023*

Figure 17: shows one of the major drainagepaths in Uyo city. *Source: Fieldwork, 2023*

Tradition and Heritage

Information about the origins of the people of Akwa Ibom is highly speculative and varied. Johnson (2013) in his paper is of the opinion that a homogenous population in Akwa Ibom state is thought to have descended from a single ancestral stock (Ituen & Johnson, 2014). Other traditional sources say many diverse groups of people migrated to the current Akwa Ibom.

The Ibibio people are the largest subdivision of people living in the southeastern Akwa Ibom state and are ranked the fourth largest ethnic group in Nigeria (Northrup, 1981). Ibibio also refers to their language which is generally accepted and used for both cases. The name was given due to Ibibio's brief way of doing things. Prior to the existence of Nigeria as a Nation, the Ibibio people were self-governed. The name "*Agbisherea*" was first used by European explorers in the nineteenth century to describe Ibibio inhabitants, but apparently died out soon after. The major Ibibio sub-groups include the Oron, Eket, Ibuno, and Annang and there are also some Ibibio communities in most of the fishing settlements along the estuary of the Cross River (Northrup, 1981).

Available traditional sources suggest that the earliest stock of the Ibibio included the Afaha clan whose ancestral home is believed to be Usak Edet (Isangele) in South-western Cameroon (Northrup, 1981). The Ibibio people became a part of the Eastern Nigeria of Nigeria under British colonial rule (Northrup, 1981).

The Ibibio largely engage in farming, fishing, and trading. While farming is the principal occupation of the Ibibio uplands, the river-side Ibibio traditionally works as fishermen at fishing ports and use the river as their main means of transportation (Northrup, 1981). Trading is done by middlemen who act as brokers between the producers of goods and the consumers (Northrup, 1981).

Water is precious

In the state, there are two sources of water supply: modern supply sources and natural sources. About 80% to 90% of the state's population, which is largely rural, is served by natural sources these are mainly streams, ponds, rivers, etc (Akpabio, 2008). The natural supply of water is typically community-based and community-driven. While the British Empire brought in the modern era of water supply (Akpabio, 2008).

In Akwa Ibom state, there is a clear distinction between how water is managed in urban and rural areas. Whilst the formal rights system which includes rules established by an institution according to certain processes to water (human, property, and contractual rights) are applicable and enforceable in urban areas, rural communities, on the other hand, view water as a common property administered within the framework of the commons.

This practice is reinforced by the traditional recognition of water bodies as God-given (*Mmoog edi eke Abasi*). There is a distinct line between land and water, which suggests that while one can have exclusive land rights, no one person has exclusive rights over water bodies. This distinction serves as the framework and rationale for the communities' cooperative management and control of the available water resources.

The way people perceive water shapes their attitudes to management. Traditionally the management of water is governed by a mix of beliefs, customs, value systems, and local consensus arrangements. As previously stated, water is traditionally recognized as a God-given gift or nature-given (*mmoog edi eke Abasi* in Ibibio) hence it is also the prevailing belief among the locals that water bodies are the dwelling place for the spirits (animistic tendencies). These values and beliefs combine to determine many forms of management decisions and practices.

Depending on the individual or collective background, different communities have different meanings, images, and understandings of water. They did, however, have shared meanings and commonalities among the many ethnic groups. There were two main interpretations that were frequently used: "free gift from nature" and "embodiment of spirits" hence the strictness and control in the management practices.

The belief in water spirits was mentioned among the household respondents, but more emphasized among traditional rulers.

Sacred groves and streams in secret society territories are of such high spiritual and religious importance that restricted access is openly enforced by some ancient access restrictions to keep them sane. Such water sources draw different kinds of submissions and offerings. The name was given due to Ibibio's brief way of doing things. Prior to the existence of Nigeria as a Nation, the Ibibio people were self-governed. To the point that on some days women are not allowed to enter these water bodies.

In these rural areas, there are three main agents or actors in water management; (a) domestic users, the daily practical users of water, primarily women and children; (b) farmers-seasonal water users; (c) village council members or traditional rulers, who make up daily water governance groups and engage in a range of spiritual and practical measures to protect and manage available water sources (Akpabio, 2011).

The role of the traditional rulers in water management revolves around the regular performance of spiritual, regulation, and enforcement duties with respect to the use and protection of available water sources. They uphold the cultural values and norms attached to water sources through regular traditional sacrifices to the gods and spiritual beings, and strict regulations governing daily interactions and relationships with the resource are enforced without compromise. Regular maintenance of water sources includes path improvements, restricting farming around riparian areas, regulations against waste dumps, and enforcement of good practices of cooperative water use and management.

One such method of management we noticed was the placing of large woven baskets at the edges of river paths to catch solid waste, an informal implementation of infiltration. Also, the planting of mangrove trees at the edge of rivers helps in the filtering process and helps reduce the river currents see Figure (i). Another is there are certain parts of the rivers used for specific functions, like fishing, swimming, bathing, drinking, and washing. This is so one function does not contaminate the other.

Figure 18: shows a running river where the pipe terminates in a rural area. *Source: Fieldwork, 2023*

Figure 19: running river with woven basket and the banks to filter the water. *Source: Fieldwork, 2023*

Figure 20: state of a current discharge point
Source: Fieldwork, 2023

IIn their daily interactions with water, the communities are often concerned when available sources are not flowing well or when there is too much pressure on a particular source. These concerns inform several related practices and regulations to protect such water sources and enhance their flows (Akpabio, 2011). For example, forbidding entry into certain streams and rivers on some days was understood to protect the water bodies against overfishing, as well as give such a water body a necessary chance for recuperation (Akpabio, 2011).

As another management measure, it is traditionally forbidden to farmlands surrounding water sources, and no property right is assigned to any individual to surroundings declared protected by the community (Akpabio, 2011). If farming is done around a riparian area, it is a commonly held belief that spirits will be destabilized and angry, which consequently will result in the siltation of its nearby stream source (Akpabio, 2011).

Now with the current urban drainage systems, these rivers' sources are facing major contamination. The discharge points of these drainage systems are running rivers that run through other communities see Figure (xx). But the thing with individuals in rural areas facing this issue is they still make use of these natural sources.

For instance, there is a local proverb that says *mmoog-mmoog eyet idir, knkpr, idir knkpr iyette mmoog* (it is only water that can wash away dirt, dirt cannot clean or purify water). The inherent belief is that anything associated with and given by God is presumed perfect. This notion tends to encourage the usage of any water regardless of quality or the source. There are other beliefs that if any complaint is made to the gods of the stream regarding its physical state it would result in natural punishment.

Some rivers I could not access because of the processions needed to go to that area. In these areas, one must get permission from the local authorities to speak with the water spirit before entering the river, as stories were told of people who went there without following rituals and faced the consequences.

All in all, it was an educative experience, enlightening us about the traditional and spiritual beliefs of these people, and seeing how much they value water to the way they are willing to protect and not alter its course is something we believe contemporary water management strategies can learn from. Through infiltration, less work around the river (restricted work), regular maintenance, and engaging the people promoting local ownership.

Summary

While climate change has led to more rain than in the past which has increased the incidence of flooding, what we can deduce from this study is that Uyo's urban flooding issue is also human induced. Through:

- *Unregulated urbanization*: Both developing and developed cities experience a correlation between flooding and urbanization. Nigeria is experiencing a rapid pace of urbanization, and cities like Uyo are expanding without having adequate urban infrastructure and facilities. To meet housing demands, agricultural lands are being converted to residential areas more frequently. Development is carried out without the necessary infrastructure or regulations in place, which makes flooding a bigger problem (Dan-Jumbo et al., 2018; Echendu, 2020).

- Poor or non-existent drainage systems: A significant human-caused escalation of the flooding Uyo is currently experiencing is poor drainage systems. It is typical for buildings and other infrastructure to be built in a way that obstructs these drainage channels, resulting in flooding during the rainy season. Most residential areas in Uyo lack a stable drainage system and occasionally rely on natural drainage channels. As Uyo becomes more urbanized, a greater percentage of the ground surface has been concreted, preventing water from percolating, and preventing surface runoff from being adequately drained.

- Poor waste management system: Another main element causing and exacerbating the city's flooding issue is poor management of waste. Numerous research has highlighted and explored how poorly individuals see waste disposal (Echendu, 2020; Eneji et al., 2017; Ojo & Adejugbagbe, 2017; Olukanni et al., 2014; Sridhar & Ojediran, 1983). In Nigeria's densely populated urban centers, drainage obstructions associated with inadequate sanitation practices are a typical occurrence. Uyo is one of the urban locations where this issue is present. During the rainy season, there is a lot of roadside dumping, canal dumping, and dumping in the rain, which results in blockages and flooding.

Additionally, belief systems, perceptions, realities, and attitudes that have positive effects on the management of rivers in rural areas have generally been ignored in the search for efficient and sustainable water management techniques in urban areas. However, each of these factors is important for sustainable stormwater management, particularly in developing countries. How, for instance, can tradition and religion impact how people view water? We think that utilizing these natural water resources in a comprehensive way would be a big help in developing flood mitigation techniques for Uyo.

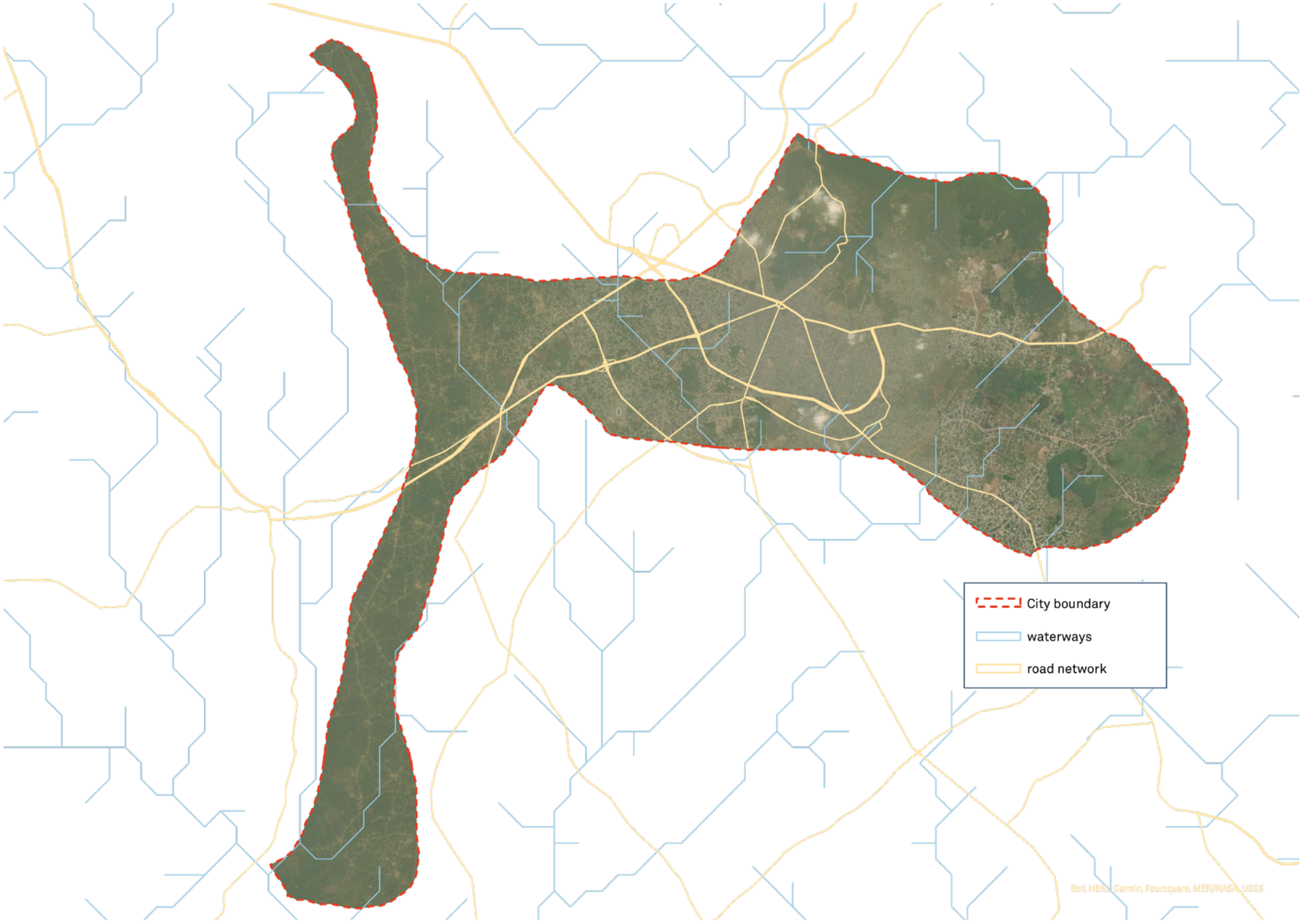


Figure 21: Map showing waterways in Uyo. *Source: GIS, 2023*

Chapter 4

Rivers in Oslo: From closed to open drainage systems

This chapter examines river management in Oslo as a case study to provide practical experiences of the role of rivers as a SuDS strategy. We will first give an overview of the flood risks and stormwater management in Norway then in Oslo. To understand why the city went from managing stormwater through drainage pipes to more sustainable stormwater management, using rivers as a SuDS measure, we explored the history of Oslo rivers to learn what were the drivers for the shift. Further, for a better understanding of the process. we analyzed some important plans, reports, and documents for Oslo municipality regarding stormwater and river management.

Flood Risks in Norway

Norway is exposed to a long coastline and vast mountainous areas that stretch into the Arctic. Weather and climate affect almost all parts of society and are an important part of everyday life for most people (St.meld. nr. 33 (2012-2013), p.5). Over the last century, it has become warmer and the amount of precipitation in Norway has increased by around 20%, and it is predicted to increase in the future (St.meld. nr. 33 (2012-2013), p.5).

In the 2013 parliamentary announcement for climate adaptation in Norway, the calculations indicate that rainfall may increase by between 5 and 30 percent. These projections also reveal that there will be more intense rainfall, which in turn may increase the risk of floods and landslides (St.meld. nr. 33 (2012-2013), p.6).

In a changed climate, more intense precipitation is expected, which will lead to increased volumes of stormwater in urban areas.

An increasing proportion of the Norwegian population lives in urban areas, and It Is expected that the cities will continue to grow (St. meld. nr. 33 (2012-2013), p.8). The cities have a lot of infrastructure, and these infrastructures increase the probability of floods and are vulnerable to more rainfall damage. Since the largest cities in Norway are located on the coast or next to waterways, the change in climate will leave great demands on stormwater management in cities (St.meld. nr. 33 (2012-2013), p.8). To meet this challenge, the government has taken several different measures to handle the increased amount of stormwater in a changing climate (St.meld. nr. 33 (2012-2013), p. 6,52).

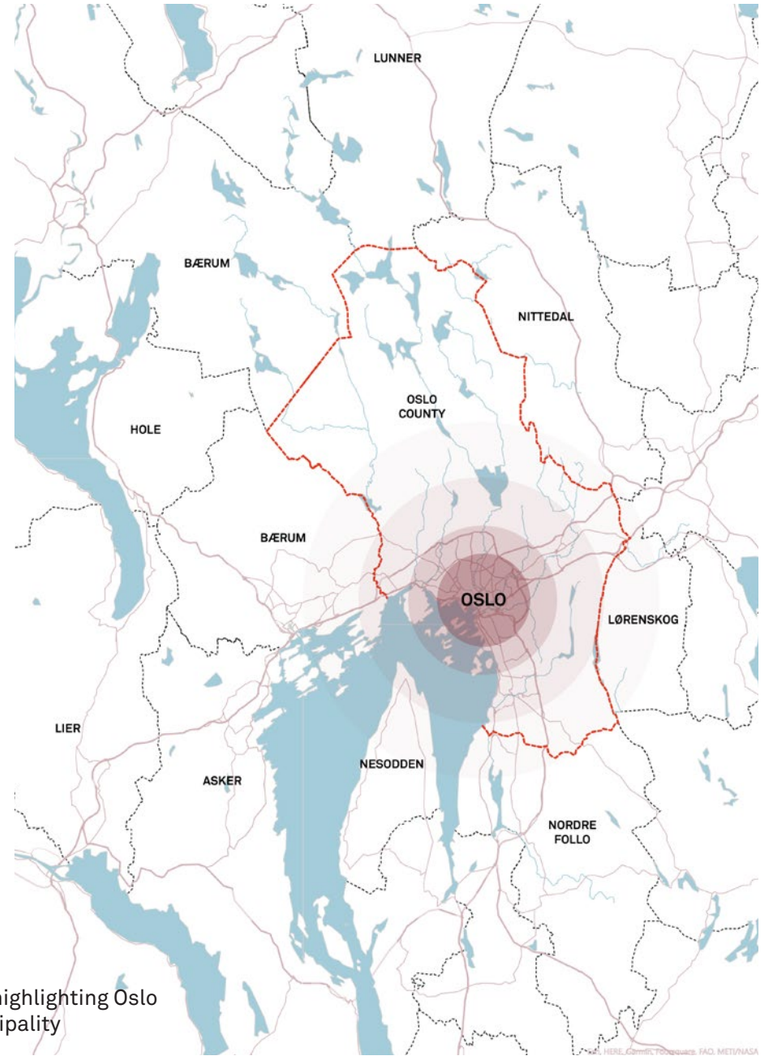


Figure 23: map highlighting Oslo County and Mucipality

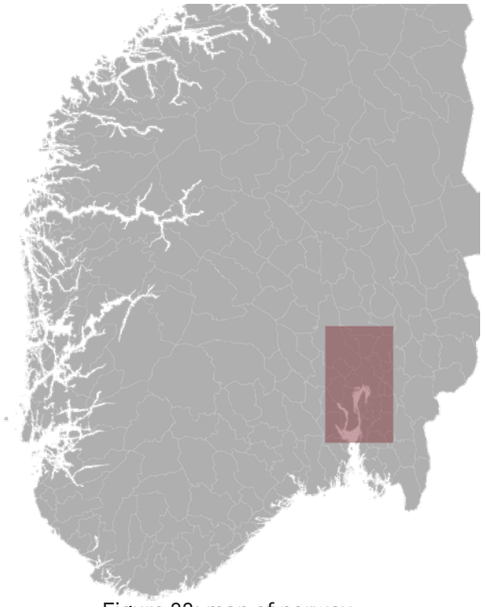


Figure 22: map of norway

"*The insurance companies' damage figures show that water that cannot be properly drained in conventional drainage systems causes great and increasing damage, especially in cities where people live close together*" (St.meld. nr. 33 (2012-2013), p.6).

Flood Risks and Stormwater Management in Oslo

Climate change projections in Oslo is as the same as the changes that will occur in the rest of the country (Oslo kommune, 2018a, p.4; Oslo kommune, 2019, p.4). The climate has become warmer and wetter, and the changes present the city with new challenges. (St.meld. nr. 33 (2012-2013), p.5).

According to the climate profile for Oslo, the average temperature has increased by 1.7 degrees since the beginning of the 20th century, and rainfall has increased by 15% in the same period. The increase in precipitation is primarily due to an increase in extreme rainfall, and not in the number of rainy days. With this as the bases, it has become important to deal with uncertainty related to climate change and be prepared to make changes along the way for the benefit of Oslo citizens (Fagernæs, 2015, p.1; Oslo kommune, 2018a, p.4).

Oslo for many years has grown strongly and become one of the fastest-growing capitals in Europe. At the start of 2018, Oslo had approximately 673,000 inhabitants, the latest population projection indicates that Oslo will have 100,000 more inhabitants by 2030, and in 2040 the proximity is around 850,000 inhabitants (Oslo kommune, 2018b, p.4). Population growth led to Oslo densifying and developing new urban areas to meet the needs for housing and other infrastructure and services (Oslo kommune, 2018b, p.5).

Figure 24: The flooding in Kværnebyen 2015 *Source: OSLO BRANN OG REDNINGSETAT*

Figure 25: The flooding in Kværnebyen 2015 *Source: Vidar Ruud, 2015*

Stormwater and urban flooding are complex problems linked to how cities are built. Oslo is a densely built-up city with many hard impervious surfaces (Oslo kommune, 2014, p.2; Oslo kommune, 2019, p.9). Stormwater runoff on these hard surfaces, where there is an increase in hard surfaces, the possibility of uncontrolled runoff or accumulation of large quantities of contaminated water is presented which then leads to urban flooding and increased pollution (Oslo kommune, 2014, p.6; Oslo kommune, 2019, p.2). Additionally, Oslo has a pot-shaped topography, with many steep hills close to the fjord, which means in cases of increased rainfall water would be carried through the city's streets at great intensifying urban flooding (Oslo kommune, 2019, p.6).

Seeing this as a problem, Oslo municipality handled stormwater management and urban flooding by closing streams and rivers (Oslo kommune, 2022, p.8). Enclosing rivers and streams within pipes, culverts, or tunnels facilitated the transport of pollution away from urban areas. This allowed for the development of housing, schools, businesses, railways, and roads, as space was freed up (Oslo kommune, 2022, p.8).

Drainage pipes were built with the capacity to handle stormwater, now with the unexpected climate change the pipes are not able to cope. With these errors and lack of maintenance, the results are sewage mixed with rain, snowmelt, and the likes discharged, polluting the rivers, streams, and fjords when the pipes are full (Oslo kommune, 2014, p.2). There have been several costly river flooding incidents in Oslo because of heavy precipitation. An example is the flooded underground drainage system of a stretch in the Alnaelva in 2015, which resulted in the flooding of the newly built Kværnerbyen (Oslo kommune, 2019, p.7-9). The flooding caused damage to infrastructure and urban life such as power outages, flooded basements, and evacuations of kindergartens. Such conditions can be experienced if there is no plan or strategy to direct the stormwater away in a controlled manner (Nesheim et al., 2020, p.24; Oslo kommune, 2019, p.8; Wold, 2020, p.35).

Wetter weather and increased densification raise the challenges of dealing with stormwater, and the municipality of Oslo after the 1990s began to seek strategies to solve the challenges in the best way possible (Oslo kommune, 2014, p.2). The importance of water flowing and diverting naturally without causing problems was prioritized. Prompting Oslo municipality to for a more sustainable approach of reopening old rivers canalized or covered with vegetation (Oslo kommune, 2018b).

Figure 26: shows how the river is integrated in cities

"*With this has come a more nuanced assessment of the appropriate paradigms for river management and the relative position and importance of different stakeholders and different types of knowledge in the process*" (Smith et al., 2014, p.253).

Some necessary and concrete measures were taken, both in the short and long term, to avoid the negative consequences of inefficient stormwater management (Oslo kommune, 2014, p.2). In addition, the municipality utilized the green areas the city already. has Allowing water to flow naturally within the urban environment and utilizing available opportunities to minimize the adverse effects of inefficient stormwater management (Oslo kommune, 2014, p.2).

Asides from opening streams and securing critical infrastructure the municipality also prioritized m apping out flood zones (Oslo kommune, 2018b, p.48). It was important to have an overview of flood zones around these rivers and built areas for adequate urban planning. Oslo has since been working to reopen closed waterways to control water volumes and create good blue-green strategies (Oslo kommune, 2019) (Oslo kommune, 2019, p.9).

By taking care of stormwater above ground with open and flexible solutions flood risk and damage can be reduced. Asides from flood risk reduction, opening rivers, and streams can establish new accessible green areas, parks, squares, and walking paths (Oslo kommune, 2014, p.2,47). Urban development presents a distinct opportunity to rebuild areas and accommodate more people, and Oslo is striving to capitalize on those opportunities. Meanwhile, the Oslo municipality is addressing the challenges posed by stormwater overflow for those already residing in the city (Oslo kommune, 2014, p.2).

The growth and densification of urban areas can put pressure on a city's green spaces, rivers, streams, biodiversity, and climate adaptation (Oslo kommune, 2014). However, it also presents a unique opportunity to plan the city in a way that takes care of stormwater sustainably (Oslo kommune, 2014, p.5). Key measures that have been used to address stormwater in Oslo include creating space for open streams and rivers, mapping flood zones, securing critical infrastructure, and preserving valuable vegetation (Oslo kommune, 2018b, p.76).

Why use Oslo as a case study

The concerns of climate change and urban flooding is not only a problem for Uyo and Oslo, but a global issue that must be addressed. With the global context of managing stormwater, there could be an argument on why we did not choose another Sub-Saharan city to compare with Uyo, or another city from Scandinavia or Europe to compare with Oslo. The claim would make sense based on the geographical, cultural, and climatic aspects. One of the purposes and goals of reviewing the cases of Uyo and Oslo is our interest to attempt to detect lessons and solutions that go beyond geographical placement and cultural and climatic differences.

Another factor is that our experience of living and studying in Norway has given us insight into how the Norwegian government approaches flooding issues. The government has developed extensive documents and regulations outlining strategies for flood management in Oslo municipality, such as the "Reopening of rivers and streams in Oslo" management document (Oslo kommune, 2022). This document can be used by private developers, consultants, and employees of Oslo municipality involved in spatial planning and implementation of stream opening projects (Oslo kommune, 2022, p.7). By analyzing these documents, we have gained a comprehensive understanding of how the government works towards integrating and reopening rivers in Oslo municipality.

The paradigm shift from a closed drainage system to more sustainable stormwater management makes Oslo a good case study. To understand how and why the change from a conventional piped drainage system to a more sustainable stormwater management strategy happened, it is important to understand the history and the driving forces for those changes. Further in the thesis, we will give a short introduction of the rivers in Oslo, its development, related policies, and management structure to be able to extract knowledge and experience that can be beneficial in the case of Uyo.

The rivers in Oslo

In Oslo, there are ten main waterways: Akerselva, Alneelva, Ellingsrudelva, Frognerelva, Gjersjøelva Hovinbekken, Hoffselva, Lysakerelva, Ljanselva, and Mærradalsbekken. Two of the rivers are not urban streams, Gjersøelva and Ellingsrudelva, and eight of them are urban waterways that flow through densely built-up areas (Oslo kommune, 2022, p.12). In this thesis we will not analyse each and one of the rivers, however, we will mention them in the context of when we e m p h a s i z e examples and points to make.

The size of the catchments and the length of the rivers in Oslo vary. Alnaelva is the longest, with 15 km, while Akerselva has the largest catchment area (Oslo kommune, 2022, p.12).

Countries that have not yet invested heavily in flood management systems or blue-green infrastructure can fully consider the benefits of incorporating these types of solutions when they do begin to invest (Opperman et al., 2018, p.32). There are examples such as the lower Mississippi, and the Netherlands, where engineers originally tried to fully control rivers within levees and dikes. In the face of repeated floods, there has been a realization that the river would need some room to spread during the largest floods. So, in the cases that have been mentioned, they have now reconnected rivers to their floodplains in key areas. Later developing countries can avoid this by learning from these mistakes and "getting it right" the first time by taking maximum advantage of the multiple benefits of existing f l o o d p l a i n s (Opperman et al., 2018, p.32).

It is important to highlight that healthy floodplains are not the only answer to reducing current and future risks of floods or heavy precipitation (Opperman et al., 2018, p.32). Floodplains rather offer some advantages within a diversified portfolio approach to flood management and should be part of the solution (Opperman et al., 2018, p.32).

The rivers carry a broader set of services that deliver immense benefits to economics, nature, and people, which far too often is not a priority for river management until the problems appear from their neglect (Opperman et al., 2018, p.5).

River management and river restorations are not new concepts to handle flooding and stormwater management. An example of this is the Emerald Necklace in Boston, USA. Frederick Law Olmsted created the Emerald Necklace from 1878-1896 with places for both active and passive recreation, open green spaces that offer relief and refreshment from the tension and pressures of everyday life (Emerald Necklace Coservancy, 2022). "*In hydrologic terms, the Emerald Necklace is situated in parts of two small urban watersheds, known as the Muddy River and Stony Brook, which affect its "blue" processes and performance*" (Marks et al., 2015, p.12). The Muddy River and Stony Brook are part of small urban waterways that are streamed to the larger Charles River which drains 35 communities before discharging into the Boston Harbor (Marks et al., 2015, p.13). The Boston Water and sewer c o m m i s s i o n manages the rivers primarily for functional purposes such as stormwater catchment, stormwater transportation to the Charles River, and flood mitigation (Marks et al., 2015, p.12).

Another example of strategies to mitigate against flood is the concept of "Sponge City". The concept was officially revealed by the Chinese president at a conference in 2013 (Hamidi et al., 2021, p.2). The reason for the concept is linked to the frequency of urban pluvial flooding in Chinese cities and in 2015 and 2016 30 cities in China were selected as pilot projects (Hamidi et al., 2021, p.2).

Oslo is an area with deposits of marine clay from the last Ice Age, which means that several of the rivers are clay waterways, and the water can often appear cloudy (Oslo kommune, 2022, p.12). The water quality in the city is otherwise affected by many sources of pollution and is poor or very poor in many locations. Sources of pollution are runoff from waste landfills, industrial activity, leaks from wastewater networks, runoff from roads, and more. Despite all the pollution on the water quality, there are sign og trout in most of the rivers, and salmon in the Lysakerelva, Akerselva, and Gjersjøelva (Oslo kommune, 2022, p.12,13).

As mentioned in previous sections, the rivers and streams were closed and laid in pipes, but now, the daylighting of rivers is a priority for Oslo municipality, and there are currently several re-opening projects ongoing in Oslo (Oslo kommune, 2022, p.8). The restoration of rivers and streams was one of the reasons why Oslo won the European Green Capital of Europe in 2019. The jury's explanation on re-opening the river was: "The city's waterways have been subjected to a new revolutionary strategy which has completely reversed the previous approach of enclosing rivers and streams to make space for a growing city. 3,000m of biodiversity-rich streams and rivers have already been re-opened to make them accessible to the public, facilitating the development and restoration of habitats and helping to efficiently manage stormwater" (Directorate-General for Evvironment, 2019). This was not always the case, as in the explanation from the jury as the previous approach of closing rivers and using the pipe to manage stormwater (Directorate-General for Evvironment, 2019; Oslo kommune, 2022, p.8).

River management and drainage systems in Oslo 1600-2020s

To understand the paradigm shift from conventional piped drainage systems to use rivers as a stormwater mitigation strategy we must highlight the history of Oslo's drainage systems. Since the establishment of Christiania (the former name of Oslo) in 1624 the city has been growing rapidly for over many years (Hartwig et al., 2010; Oslo Byleksikon, n.d., p.27). 2022, p.12).

Already around the 1600s, the rivers were used as sewage discharge points and landfills, and regulation was made to prohibit these types of activities. Then around the 1830s population increased expanding quickly resulting in more sewage and wastewater leaving houses and water posts (Hartwig et al., 2010, p.27; Oslo Byleksikon, n.d.).

Right up until around 1840, the streets in the city center had both open and closed gutters that carried surplus water from the water posts straight into the nearby rivers (Hartwig et al., 2010, p.27). Additionally, private drainage pipes were connected to these gutters, so the stormwater and wastewater went the same way. Eventually, the rivers and the streams became the City's sewage system, and as resulting in polluted rivers/ waterways (Hartwig et al., 2010, p.27).

Industrialization and the ripple effect it created gave Oslo greater growth in the mid-19th century (Hartwig et al., 2010; Oslo Byleksikon, n.d., p.27). Large factories were built along these rivers increasing the pollution and health hazards and worsening the situation dramatically. As a result, the response was to close most of the streams in Oslo city (Hartwig et al., 2010, p.27). From 1900 and onwards a separate sewage system was in place, which relieved the waterways, but the closing process continued for a long time (Hartwig et al., 2010, p.27).

The closing of rivers and streams in the suburbs was not carried out until the 1920s-1930s, the late arrival was seen as a negative factor by some locals (Hartwig et al., 2010, p.27). An article from the Østre Aker newspaper in 1929 highlights that the resident associations from Bryn and the surrounding area had concerns that flooding could happen at the stream, and the resident association had made recommendations to close the stream to the municipality, the municipality delayed, and a flood occurred in Østensjøbekken. The association used the media to make a case that if the municipality had taken action to close the river, the flood could have been prevented. Eventually, by the start of the 1930s, Østensjøbekken was also closed, as many other rivers and streams in Oslo during this time (Hartwig et al., 2010, p.27).

Looking into the Alnaelva as an example, the most extensive change occurred in 1922, leading to the river's mouth and lower course disappearing from the map. The river was laid in a new tunnel through Ekebergåsen with an outlet at Kongshavn, approximately 800 meters south of the original mouth. Another major closing of the river occurred in 1985 at Alnabru. Here, approximately one kilometer of the river was laid in pipes to make room for a new track change for the railway (Nistad, 2013, p.26). Apart from previously mentioned reasons such as pollution, bad smells, and so on another reason for closing the streams was because the residents close to the rivers were afraid that the children could drown (Oslo Elveforum & Alnaelvas venner, 2023).

The same was not the case for Akerselva. Over several years, the Akerselva had been prioritized differently from the other waterways (Tvedalen, 2022, p.40). Since 1915 the municipality had worked on a plan to establish a continuous park belt along the riverbanks and around 1960, the river got a short-lived association of friends who exerted pressure on the municipality to address challenges with pollution and littering of the river (Tvedalen, 2022, p.40).

Katrine Tvedalens's study on "Conservation of Streams and Rivers in Oslo" discussed the paradigm shift in the 1960s that happened due to the nature conservation breakthrough at the national level in the 1960s and 1970s which has a positive impact on the municipalities' work with environmental and pollution problems (Tvedalen, 2022, p.40). There was also an increase in competence in the field of water and sewage, and the preservation of nature was a theme in the Nature Conservation Act from 1970, making the preservation of nature and watercourses a familiar concept at the time (Tvedalen, 2022, p.40).

The fight against stream closures was pursued tenaciously by a small minority in the Oslo City Council throughout the 1960s and 1970s (Hartwig et al., 2010, p.31). In 1970, the new Water Pollution Act and nature conservation act marked a breakthrough in environmental protection in Oslo (Tvedalen, 2022, p.40). Oslo municipality had to map pollution discharges to water and waterways in connection with an application for a discharge permit and create a plan for how they were to handle the wastewater. This uncovered a ground-breaking survey uncovering many new emissions and water pollution far more serious than what was known previously (Tvedalen, 2022, p.40).

Figure 28: Working on closing the Alna River by the hospital.


28.

Figure 29: The closing of Hovinbekken in 1959 (Oslo bilder, 1959)


29.

An environmental protection council was formulated around the 1980s on the bases of this survey, an interdepartmental water protection group (Hartwig et al., 2010, p.32). The years 1982 and 1985 stand out as historical marking years for rivers and streams, the old practice of laying rivers and streams in pipes was coming to an end. In 1982 the environmental protection council established a principal program to protect rivers, streams, and waterways, which later in 1985 was adopted by The City Council of Oslo. The City Council decided that: "*The closing of rivers and streams is not permitted. This also applies to the refilling of ponds, lakes, other waterbodies, or the seabed. The construction or placement of buildings or other constructions and facilities closer to open streams, ponds, rivers, and other waterbodies than 20 meters is not permitted. The same applies to digging, blasting, and filling work*" (Hartwig et al., 2010, p.32).

Oslo municipalities were attempting to spare the waterways from harmful pollution. New visions and a new assessment of nature became a demand, not just a ban on stream closures. It was also stated in the program that "all waterways should be in ecological equilibrium with natural species richness" (Hartwig et al., 2010, p.32).

Figure 30: Picture of Akerselva between 1930-1940 (Oslo bilder n.d)

Oslo's river policy was later strengthened through new resolutions which include: the City Council Declaration of 2000 and the Urban Ecology Program for 2002-2014, which states that "Oslo's rivers are to be cleaned and piped drainage sections are to be reopened where possible" (Hartwig et al., 2010, p.33). During these times, in 2001, Oslo Elveforum was formed, a working community for 11 active river groups working to rehabilitate and strengthen rivers in Oslo (Hartwig et al., 2010, p.40). This would be explained in detail further in later sections.

Moving forward, it became a political objective to reopen as many of Oslo's closed stream and river stretches as possible.

The importance of open rivers as a stormwater management approach and an adaptation and mitigation strategy became more obvious (Fagernæs, 2015 , p.1,3). Politicians' emphasis and commitment to the "blue" became visible in more plans, most recently in Oslo's Municipal Plan 2018: "Our city, our feature" reopening of river and stream were mentioned in association with recreation, strengthening the blue-green city, climate adaption (Oslo kommune, 2018b, p.47-48) and storm-water management (Oslo kommune, 2018b, p.81).

Oslo municipality's goal for the restoration of waterways is to be given a natural design, with an exchange of water between the surrounding groundwater and the stream/river (Fagernæs, 2015, p.10). If possible, the stream/river must be reopened in an approximately historical manner and be accessible to public traffic and accommodation (Fagernæs, 2015, p.10).

Laws, plans, and strategies

The history of rivers and conventional drainage systems clarifies that new knowledge, with the environmental movement, and painful lessons changed the perception of how Oslo authorities viewed rivers. All this accumulated to the change of policies, laws, and regulations in Norway and Oslo in favor of river restoration. To understand how the authorities in Oslo operate on the reopening of streams and maintenance, we will present what some of the plan's state about stormwater management and urban flooding.

Several laws, plans, and strategies have been developed and adopted to govern the management of Norwegian waterways. Norway has committed itself to adhere to international conventions, targets, and regulations, including the United Nations' sustainability goals, which are being pursued through Norway's 2030 action plan to achieve these goals (Nesheim et al., 2020, p.25). Additionally, the European Union's Water Framework Directive has been incorporated into Norwegian legislation through the Water Regulations, which are reinforced by various other plans (Nesheim et al., 2020, p.25; Oslo kommune, 2022, p.21).

There are several laws and regulations that one must comply with when reopening streams and rivers, such as the Planning and Building Act, the Water Resources Act, and the Salmon and Inland Fisheries Act to name a few (Oslo kommune, 2022, p.21).

Norway also has several parliament reports that provide guidelines for the management of waterways, such as the Norwegian action plan for natural diversity (St.Meld. 14, 2015-2016), Climate change adaptation in Norway (St.Meld. 33, 2012-2013) and NOU Flood water in cities and towns (2016) to mention few (Nesheim et al., 2020, p.25).

For Oslo municipality, the most important governance mechanisms are the municipal plan and sub-plans, as well as the municipal budget and letters of allocation from higher levels to subordinate agencies (Nesheim et al., 2020, p.30). The work to reopen closed streams and rivers in Oslo municipality is also anchored in the Urban Ecology Program from 2011, Strategy for stormwater management 2013, Climate Strategy for Oslo towards 2030, and Municipal Plan for Oslo from 2018, as well as above mentioned national and international guidelines such as the Water Regulations, Climate change adaptation in Norway (St.Meld. 33, 2012-2013), the EU directives and the UN's sustainability goals (Oslo kommune, 2022, p.21).

In this master thesis, most of the information regarding river management in Oslo is collected from these documents. We will further highlight the content of some of the important documents to showcase what the documents state about stormwater and river management, and important strategies to cope with these issues. Additionally, some information overlaps between documents, so information from each plan are specific to each document.

Figure 31: shows the goals norway integrate into their policies and laws. Source: The UN, n.d.

Plans and reports:

Meld. St. 33 (2012–2013) Parliamentary announcement, Climate adaptation in Norway / Meld. St. 33 (2012–2013) Melding til Stortinget, Klimatilpasning i Norge

The most common approach to transporting water was down in drains and away in pipes. For many years, stormwater has exclusively been seen as a problem (St.meld. nr. 33 (2012-2013), p.52). This document underlines that water should rather be perceived as a resource for recreation and as a positive element in the local environment. At the same time, conventional drainage systems have sometimes been proven to be expensive or efficient enough. There has also been a significant increase in insurance companies' payouts for flood damage to buildings and infrastructure. In the parliamentary announcement it is also highlighted that "The urban waterways and stormwater should be planned and treated as a whole" (St.meld. nr. 33 (2012-2013), p.52). This way of handling stormwater requires a strong link between stormwater management and spatial and landscape planning (St. meld. nr. 33 (2012-2013), p.52). contamination issues, as they only transfer pollution from one location to another.

"Our city, our future" Municipal plan for Oslo 2018, Social element with urban development / "Vår by, vår framtid" Kommuneplan for Oslo 2018, Samfunnsdel med byutvilingstrategi:

The municipal plan is the overall management document for Oslo municipality and concerns everyone who works in and lives in Oslo. It points out the long-term development and shows the direction for the city, without going into detail in all areas (Oslo kommune, 2018b, p.3).

The plan underlines that creating places where the water can flow and be diverted naturally and not in a conventional piped drainage system, such as when the ground is covered with vegetation or when you reopen old streams that have been laid in pipes (Oslo kommune, 2018b, p.81).

Stormwater management is a prioritized climate adaptation and mitigation measure. Opening streams and rivers, mapping flood zones, working with green roofs, securing critical infrastructure, and preserving valuable vegetation are important measures (Oslo kommune, 2018 p. 48). For the follow-up of the land-use element of the municipal plan, it is underlined that there should be ensured good capacity in the city's waterways and to have a long-term perspective in stormwater management (Oslo kommune, 2018b, p.76).

Urban Ecology Program for Oslo 2011-2026 / Byøkologisk program for Oslo 2011-2026:

The Urban Ecology program is considered one of the most important documents for stormwater management and river management. The document emphasizes that Oslo has to adapt to climate change by, among other things, developing a strategy for handling stormwater, including the restoration of waterways, and mapping areas at risk of flooding (Oslo kommune, 2011, p.4). The city should work systematically to re-open river and stream stretches that have been laid in pipes and develop hiking trails along Oslo's rivers where this is possible and appropriate (Oslo kommune, 2011, p.15).

The document highlights that reopened stretches of the rivers should follow the historical course of the waterway (Oslo kommune, 2011, p.15). When old river and stream closures are brought to the daylight it is important to improve the watercourses' self-cleansing ability and he ability to prevent pollution damage. In the document, there is a measuring indicator for the success of the re-opening project, and the municipal determines the success by measuring the number of meters of the stream- and river stretches that have been opened (Oslo kommune, 2011).

Strategy for stormwater management 2013-2030 / Strategi for overvannshåndtering I Oslo 2013-2030:

In the document for strategy for stormwater management 2013-2030 there is a emphasis on the importance of that all the stakeholders in Oslo have a common stormwater management goal to work towards (Oslo kommune, 2014, p.5). For this comprehensive overarching goal to be possible to work towards, the stormwater management goals have been made a little more concrete in the document (Oslo kommune, 2014, p.5).

Population growth means that the municipality of Oslo must densify and develop new urban spaces. The growth gives the city a unique opportunity to take care of stormwater management in a sustainable way, and as highlighted in the document, "It is an opportunity we cannot pass up" (Oslo kommune, 2014, p.5).

Further, the municipality must ensure that they learn from all the solutions they have established, both those that are being established, and those that are to be implemented (Oslo kommune, 2014, p.7). Evaluating both the implementation and how they work in practice and implementing improvements will ensure even better solutions in the future. "To dear and testing new solutions, and learning lessons is important for the future of stormwater" (Oslo kommune, 2014, p.7).

Climate Strategy for Oslo towards 2030 / Klimastrategi for Oslo mot 2030 (2020):

Over the years, Oslo has opened and restored many of the city's rivers and streams, it has also become an important measure to reduce stormwater in the event of heavy rainfall (Oslo kommune, 2020, p.20).

In this document, the municipality uses the so-called "three-step strategy" as the basis for the city's work in managing stormwater: "Step 1 is about ensuring infiltration of water to the ground, step 2 is to delay and slow down the water in the event of heavy rainfall, and the last step is to direct the water to safe floodways" (Oslo kommune, 2020, p.20). The municipal is also using a "Norm for blue-green factor" which is a tool in planning and construction to ensure a minimum of open and local stormwater solutions to cope with stormwater and urban flooding in housing projects. "The work on better management of stormwater, to reduce the risk of urban flooding, continues and is strengthened" (Oslo kommune, 2020, p.20).

Figure 32: The Grorud park is an excellent example of combining stormwater management strategy combined as a park for the residents. *Source: LMR Arkitecktur, 2003*

Stakeholders:

Central organizations

When reopening a river/stream, several municipal and private actors have been involved in this process (Fagernæs, 2015, p.1). The democratic power distribution system in Norway means that the state has primary responsibility for policy and legislation in all areas but has delegated authority in some areas to regional and local governing bodies (Colbjørnsen, 2019, p.10).

The ministries formulate policy, including by providing professional input to policy documents and exercise formal sector governance via regulations, corporate governance, agency governance and financial instruments, and informal governance through dialogue, meetings, advice, information, and guidance (Colbjørnsen, 2019, p.10). Long-term plans are occasionally developed for overarching goals for the next ten years, and specific focus areas for the coming four-year period (Colbjørnsen, 2019, p.9). The following ministries and government agencies on a national level are particularly relevant for a comprehensive restoration of Oslos Rivers: the Ministry of Climate and the Environment, The Ministry of Transport, The Norwegian Directorate of Water Resources and Energy (Nesheim et al., 2020, p.23).

Ministry of Climate and the Environment / Klima- og miljødepartementet (KLD):

In regards to stormwater management and river management, the Ministry of Climate and the Environment develops and implements its own measures to be a driving force for the various sectorauthorities(Regjeringen,2014). They have also the responsibility for coordinating the government's environmental and climate policy goals and ensuring that the policies regarding climate and the environment are followed up (Regjeringen, 2014). International climate and environmental cooperation are a prerequisite for being able to meet the regional and global environmental challenges, and the ministry has also the responsibility for the implementation of the EU's water directive and national restoration strategy which affects stormwater management and re-openingprojectsofrivers(Nesheim et al., 2020, p.23; Regjeringen, 2014).

The Ministry of Transport / samferdselsdepartementet (SD):

If we evaluate the aim to reopen the Alnaelva as an example, the ministry has an important role in relation to the implementation of measures regarding the reduction of polluted runoff from national roads and railways (Nesheim et al., 2020, p.24). The ministry also has a central responsibility for helping to find good solutions for reopening Alnaelva where this comes into conflict with roads and railways.

The Norwegian Directorate of Water Resources and Energy / Norges vassdrags og energidirektorat (NVE):

Norway's Directorate of Water Resources and Energy, which is under the Ministry of Oil and Energy is responsible for management under the Water Resources Act and the Water Resources Regulation Act, which means that they have central responsibility for the regulation and management of hydropower plants, other water outlet and physical interventions in waterways. They also have overall responsibility for preventing floods anderosion(Nesheimetal.,2020,p.24).

Oslo municipality:

The municipality is responsible for sewage, drinking water, agriculture, land use, living conditions, follow-up of strategic goals, and implementation of the water regulations for the Oslo waterways(Nesheimetal.,2020,p.27).

A simplified figure showcasing how the municipality is structured highlighting the most important department and agencies. Further, we will explain the roles of some of the important agencies in Oslo municipality.

Agency for Planning and Building Services:

The Agency for Planning and Building Services takes care of Oslo municipality's landowner responsibilities, which include the acquisition, development, and sale of municipal property. The agency negotiates development agreements with property developers deal with the financing of blue-green infrastructure in transformation areas (Fagernæs, 2015, p.5; Nesheim et al., 2020, p.27; Oslo kommune, 2022, p.16). The agency has also the responsibility for the regulation of areas for green areas and stream opening projects (Oslo kommune, 2022, p.16).

Agency for Real Estate and Urban Renewal:

The Agency for Real Estate and Urban Renewal is the municipality's planning and building authority, a driving force for good development in Oslo, the executive body for the development of a municipal plan and ensures re-opening projects through municipal area plans and processing of private planning proposals (Oslo kommune, 2022, p.16). The agency contributes to the implementation of feasibility studies for the restoration of closed stretches of rivers and streams and has the responsibility for coordinating the municipality's efforts with stormwater management (Oslo kommune, 2022, p.16).

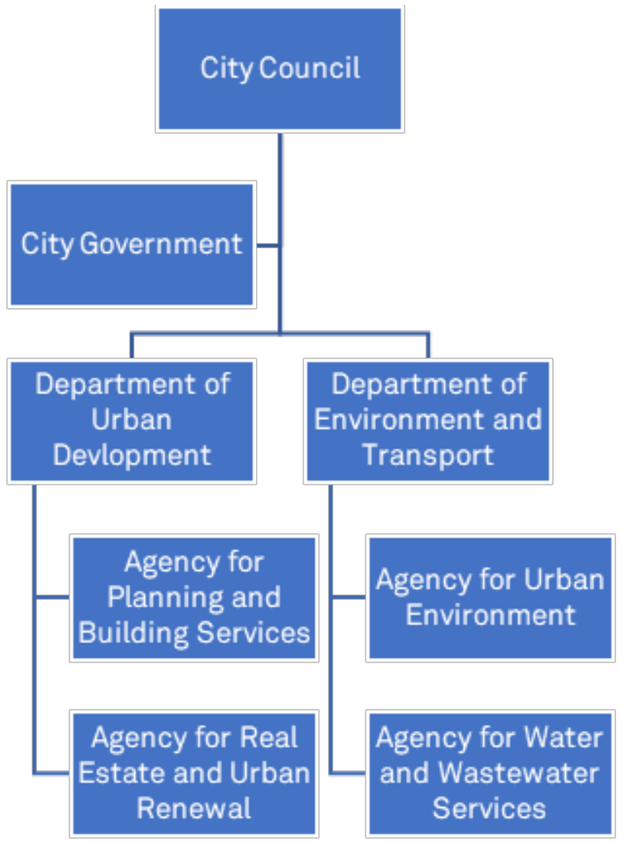


Figure 33: Simplied organisational structure of Oslo Municipality

Agency for Urban Environment:

The agency holds the municipality's main expertise in biological diversity and ecology related to waterways (Fagernæs, 2015, p.5; Oslo kommune, 2022, p.16). The agency has the responsibility to plan, construct, operate, and maintain the areas around a river or stream. In many of the reopening projects, the agency will be given the operational responsibility for the "living part" of reopened stream stretch. This means that they will have management/operational responsibility for vegetation in and along the water, as well as other life in and along the water, such as fish and benthic animals, birdlife, etc. (Fagernæs, 2015, p.5; Oslo kommune, 2022, p.16).

Agency for Water and Wastewater Services

The department is responsible for the pipe network for stormwater, water, and sewage, including the operation and maintenance of technical inlet and outlet structures when streams and rivers are re-opened (Fagernæs, 2015, p.5; Nesheim et al., 2020, p.27; Oslo kommune, 2022, p.16). The agency also provides technical and water-related input and professional assistance within the areas of responsibility for re-opening projects of streams carried out by other stakeholders such as private sector, municipal and state developers (Fagernæs, 2015, p.5; Nesheim et al., 2020, p.27; Oslo kommune, 2022, p.16).

Oslo Elveforum as a voluntary actor

In Norway, there is a culture for doing voluntary work, "*dugnadsånd*", which is roughly translated to voluntary spirit. Several voluntary actors at the national and regional or watercourse level work to promote the natural environment, protection, and restoration of rivers and streams in Oslo (Nesheim et al., 2020, p.32). Such voluntary actors play an important role in gaining attention from the population and politicians. These actors also represent the potential for contribution to restoration work through increased involvement and collaboration. One of the voluntary actors that have played a significant role in river management and river restoration projects in Oslo is Oslo Elveforum (Nesheim et al., 2020, p.32).

Oslo Elveforum (*Oslo Rivers Groups*) is a working community formed by eleven active, voluntary river groups and non-profit associations. It works to rehabilitate and strengthen Oslo's blue-green infrastructure (Hartwig et al., 2010, p.39; Oslo Elveforum, n.d.). Oslo Elveforum represents "the civil society" and without such a functioning community of volunteers, the organization does not believe that many societal tasks would not be solved or would only be solved at a significantly slower pace (Hartwig et al., 2010, p.39). Regardless of organizational form, each of the eleven river groups carries out their work in contact with welfare associations, history groups, resident associations, nature, and environmental associations, and the local environment (Hartwig et al., 2010, p.39; Oslo Elveforum, n.d.).

Oslo Elveforum sees its main task as to support the effort of Oslo municipality, neighboring municipalities, and other public and private institutions to recreate the city's blue-green waterways from the marka (the hilly and forested area surrounding Oslo) to the Oslo fjord (Hartwig et al., 2010, p.9; Oslo Elveforum, 2016, p.4). The organization aims to be a driving force in an environmental network that works towards clean and purified rivers and streams, with optimal water flow, richer life for animals and plants, and green riverbanks open to the public (Hartwig et al., 2010, p.9; Oslo Elveforum, 2016, p.4).

The organization does not only collaborate with the municipality of Oslo, but they also participate in consultation statements to the authorities and to that planning development along a watercourse or body of water (Hartwig et al., 2010, p.43). Oslo Elveforum attempts to contact the people responsible for consultation statements, and the local knowledge of the organization's representative is often positively valued and taken into consideration (Hartwig et al., 2010, p.43).

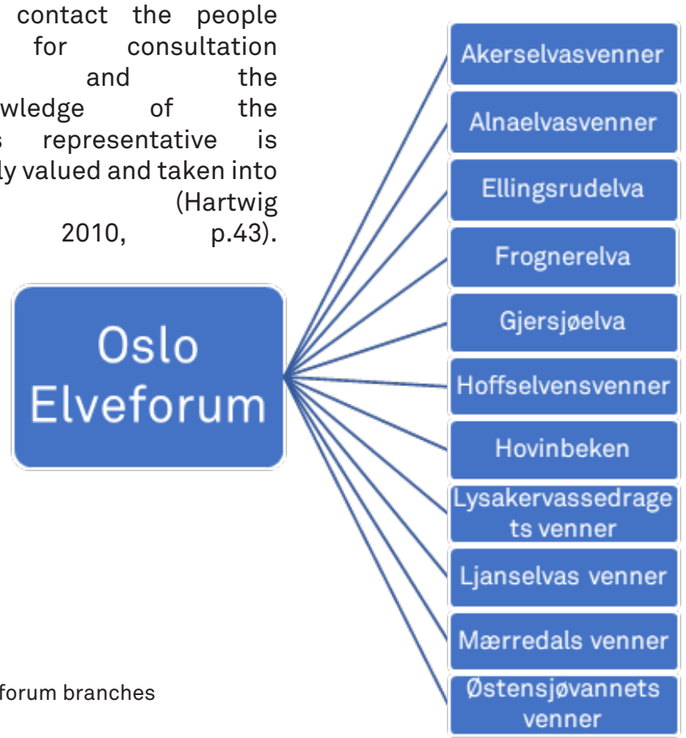


Figure 34: Oslo Elveforum branches

An example of the benefit of the collaboration is when they made a "Historic blue list" with the Water and Sewage agency (Hartwig et al., 2010, p.40). This is a digital and map-based document that shows the connection between open and closed watercourses, and which has proven to be a good aid in the work of reopening rivers and streams (Hartwig et al., 2010, p.40).

The second main task of Oslo Elveforum is to involve local people, particularly children and young people, this was done through the Blue Green Capital Action project (Hartwig et al., 2010, p.9; Oslo Elveforum, 2016, p.4).

Oslo Elveforum works to inform the importance of Oslo's blue-green structure as an element for enjoyment and well-being in the local environment. The organizations' goal is to ensure that as many people as possible are inspired and engaged in having a feeling of local ownership for the rivers. The organization works through an arrangement with river adoption for schools, housing associations, companies, institutional companies, and other interested public parties (Hartwig et al., 2010, p.9; Oslo Elveforum, 2016, p.4).

Projects that show the organization doing this is in 2001, the Oslo Elveforum started a group to create an information booklet that could stimulate the use and conservation of, and enjoyment of the waterways, and in 2006 the project for schools to adopt a river started (Hartwig et al., 2010, p.49). This is done in close collaboration with the local river groups. The schools received adoption letters, signed by Oslo's mayor, the school's principal, and a representative from Oslo Elveforum, to which they committed (Hartwig et al., 2010, p.49):

- Experience and get to know natural and cultural values.
- Pay attention to plants, animals, and cultures.
- Report illegal pollution and keep water and shorelines free of waste.

Their aim in developing this form of local ownership is that people will take greater responsibility for maintenance (Hartwig et al., 2010, p.15). The project on river adoption and local ownership will, according to Oslo Elveforum, "undoubtedly play an important role in the people's attitude and commitment towards the blue-green structure in the future" (Hartwig et al., 2010, p.9).

Reopening rivers in Oslo / Alna River: lessons learned from the interview with Oslo Elveforum and Alnaelvas Venner

Alnaelvas venner is the voluntary association for the care and development of Alna River and its surrounding areas as a public outdoor recreation area (Alnaelvas venner, 2023). Alnaelvas Venner collaborates with Oslo Elveforum, the municipality's agencies and districts, schools, associations, and private individuals to promote Alnaelva's interests (Nesheim et al., 2020, p.32-33).

The interview section looked at opening rivers and streams, with a focus on Alnaelva, but we did not talk in-depth about what it means to stormwater management. This section presents the main findings from the interview. We grouped their experiences into three parts: influencing politicians, changing local people's perceptions, and eliminating pollution regarding river management.

Influencing politicians:

The Oslo Elveforum was created after the political regulations in 2000 about 2 years after it was politically decided to reopen streams where possible (Oslo Elveforum & Alnaelvas venner, 2023). Oslo Elveforum, Alnaelvas venner and the other river groups were formed to collaborate with Oslo municipality, work on behalf for rivers/streams and to put pressure on politicians when river restoration projects are on the agenda (Oslo Elveforum & Alnaelvas venner, 2023).

The growing concerns about climate change, mental health, and recreational areas have generated a widespread interest in opening rivers and streams. Several organizations have taken an interest in Alnaelva and the surrounding areas, and some have proposed building housing, infrastructure, and other developments near the rivers or over the closed parts of the waterways. The responsibility of groups like Alnaelvas venner is to ensure that the river is not overlooked or negatively impacted by such projects (Oslo Elveforum & Alnaelvas venner, 2023).

The last decades the politicians have started to understand the importance and value of river restoration projects, slowly but surely. The municipality and the politicians are showing an eagerness to re-open rivers, but the river organizations have encountered difficulties (Oslo Elveforum & Alnaelvas venner, 2023).

Changing local people's perceptions:

Changing people's perceptions can happen with floods and catastrophes, but the organization's role is to make people realize that a flowing stream is good to be around and is a great mitigation strategy for stormwater management (Oslo Elveforum & Alnaelvas venner, 2023).

Local public actions can be powerful and not always in a positive manner, sometimes the organization meets resistance from the local population who live there and may be against stream opening. They have experienced during the early phase of reopening projects the residents in the areas were afraid that the children could drown, and the Oslo municipality wanted to stay away from the projects due to the pressure from the local population. The example gives an indication of how important people's perception of rivers can play in river openings. In the interview, they also specify when people who move to the streams, the waterways are seen as having nice and beautiful recreational value. When people live in areas where there are projects to open rivers and streams, the local habitats tend to complain because they are afraid. The river groups view the changing of people's perspectives and values on rivers as one of their main tasks (Oslo Elveforum & Alnaelvas venner, 2023).

The representatives pointed out that "how you look at rivers and streams depend on which glasses you wear: park glasses, biodiversity glasses, forest glasses, etc." (Oslo Elveforum & Alnaelvas venner, 2023) For the regular person, a park where the grass is cut in millimeter precision and a stream that goes in a straight line could be seen as beautiful, but for a person who thinks about animal life and stormwater management the same park can be seen as a "biodiversity desert" and not effective in mitigate against heavy precipitation (Interview, 2023).

The organizations have made different kinds of information campaigns for people to understand the positive effects of streams and rivers, both aesthetical and in stormwater management, in the city to attempt to change people's perspective on rivers and streams (Oslo Elveforum & Alnaelvas venner, 2023).

Eliminating pollution

Even though the politicians understand the importance of blue-green infrastructure as a mitigation strategy, the politicians are still not willing to spend money on cleaning the river from pollution and garbage disposal (Oslo Elveforum & Alnaelvas venner, 2023). There are 15 garbage dumps along the Alnaelva and "they are almost impossible to get rid of" (Oslo Elveforum & Alnaelvas venner, 2023). No one will take the cost and there is no requirement to take the garbage dump at lower parts of e.g., Kalbakkvei (part of Alnaelva), which pollutes the fjord and the river.

Another issue pertains to the aftermath of closing and burying the streams and dumping trash over them from the early 1900s until the 1960s, which still has an impact on the river today. As per the interview, there is no knowledge of the type of waste that was disposed of underground (Interview, 2023). Additionally, the interviewee cited a case where a chlorine leakage occurred in Akerselva in 2011, resulting in the near extinction of all life in the river due to the catastrophic event (Oslo Elveforum & Alnaelvas venner, 2023).

In the conversation Oslo Elveforum and Alnaelvas Venner underline that "nature repairs itself, we just need to remove the poison" (Interview, 2023). Several long stretches in the Alna River which have been "forgotten" and are left alone to clean naturally. They highlight that we must facilitate for the nature to succeed by e.g., sunlight, air, and vegetation that cleans the river. An example that was brought up was the Hovinbekken by Hasle, where the water is already quite clean by the time the water reaches the river/pond because of the function of the vegetation (Oslo Elveforum & Alnaelvas venner, 2023).

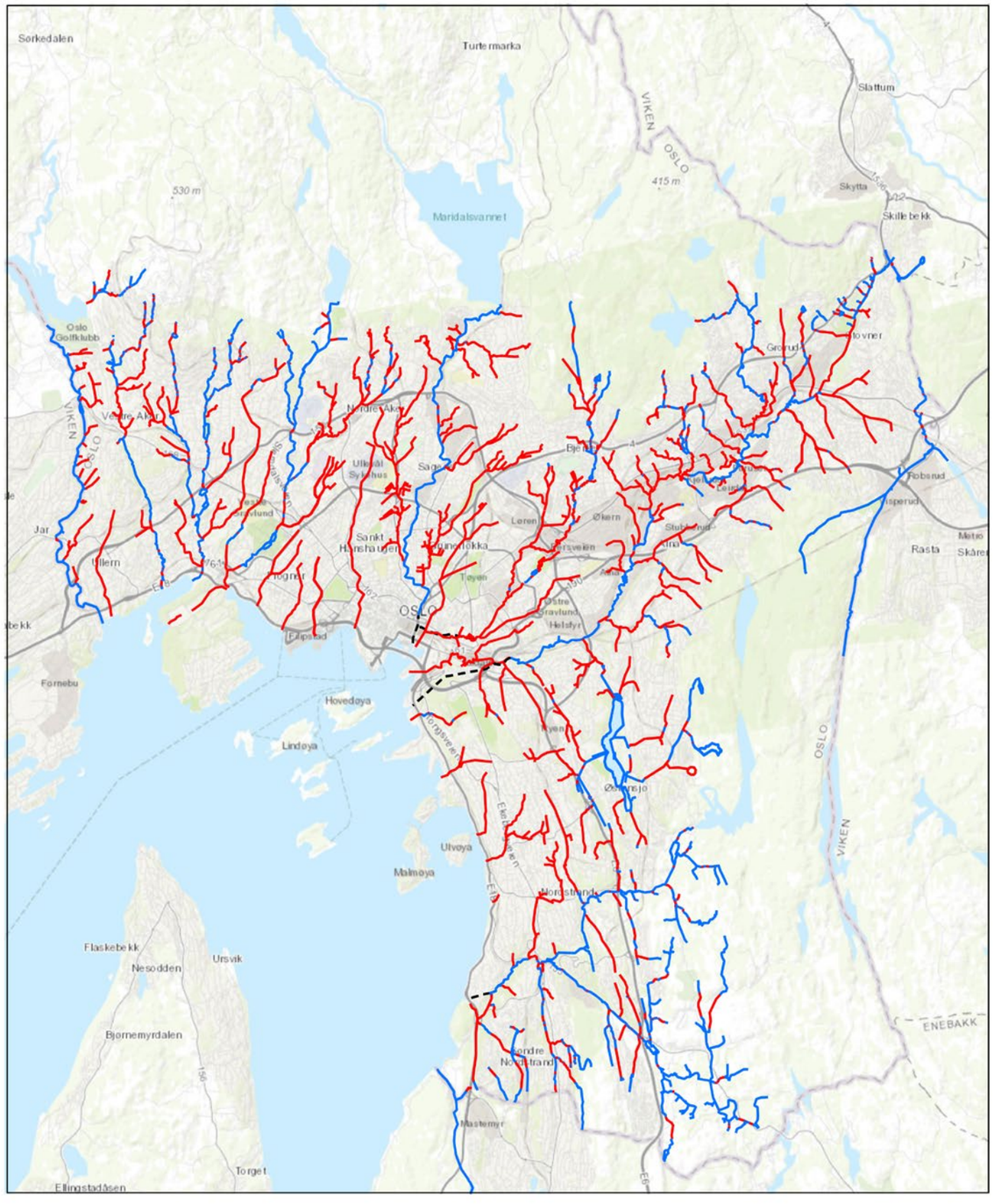
Summary

The case of Oslo showcase that there has been a paradigm shift from piped drainage system to a sustainable and holistic approach to stormwater management. Rivers and streams are an important part of the solutions to mitigate floods and stormwater. The political regulations and laws, both international, national and at municipal level, and plans made an impact on the views and values on rivers and streams.

The interview and documents display that there is a collaboration between the Oslo municipality and the river groups with Oslo Elveforum at the lead, which represents the "civil society", in re-opening projects and the maintenance of rivers and streams. There is a positive progression in the sense of re-opening rivers and streams, but the river groups are experiencing issues related to spending money on cleaning the river from pollution and garbage dumps.

All the measurements and issues that has been mentioned in the conversations will be important for Uyo. It is important to emphasize that these organizations are voluntary work, there is active members and board members. Volunteering takes a lot of energy for example when they have lightwalkingevents.Althoughthereisa willingness and dedication among the population, the organizations experienced it got a bit easier to influence the politicians because of the political regulations and frameworks, and this will be important to Uyo and Nigeria.

Historic Stream and River course



Legend

- Closed
- Open
- Tunnel

Scale 1: 144 448

0 0.75 1.5 3 mi
0 1.25 2.5 5 km

ArcGIS Web AppBuilder
Esri, HERE, Garmin, USGS, NGA

Chapter 5

Analysis: Using rivers and streams as SuDS system for stormwater management in Uyo

The purpose of this research is to understand how rivers and streams are used as urban drainage systems in different countries and based on this, to find solutions for stormwater management in Uyo, Nigeria. By reviewing the literature in this field and delving into the case studies of Uyo and Oslo, Norway, we see patterns, correlations, and differences across time and space.

This chapter discusses the findings of the previous chapters and proposes recommendations for sustainable river management that contribute to flood risk mitigation in Uyo. Both "hard" engineering/technical solutions and "soft" solutions were reviewed in our analysis. On the technical dimension, with our profession as landscape architects, we want to evaluate the possibilities of the use of rivers and streams as a Sustainable Drainage System (SuDS) and highlight what the drivers are in giving rivers a greater function. We also analyzed the topic from social-cultural dimensions as a river "has been and still is an integral part of social interactions and perceptions of worldviews and religions" (Lykke Syse & Oestigaard, 2010. p.10) We have realized from this research that the technical and social-cultural dimensions are interconnected and influence each other.

This chapter gives an extended analysis of both our fieldwork and literature review to answer our three research sub-questions.

How have rivers and streams been used as drainage systems in urban areas

The role of rivers has changed over time. From "controlling" the river path and flow by channelize and laying rivers in pipes, to where the dynamics of the rivers became a key consideration as a mitigation/adapting to climate and ecological role in as a SuDS solution. as they are now recognized as an important natural component of the water cycle and a key consideration in sustainable stormwater management (WWF, 2018 p.32; Wantzen et al., 2016 p.10-11).

Many hard engineering schemes undermined and required frequent maintenance, while at the same time, it was revealed that many flood defense schemes did little to protect against flooding. Both in Uyo and Oslo there is a correlation in that both cases have been using conventional drainage methods to handle stormwater management and urban flooding.

Figure 35: how vegetation plays a role in river management.

By the standards of the time, the pipes were built with the capacity to manage stormwater out of densely populated areas. In both cases, with climate change and more precipitation, the conventional pipe-based drainage systems became inadequate or could not withstand the unexpected change in the climate. The pipes are no longer larmeasureo cope with the volumes of the stormwater, and the measurement to deal with these issues is either to expand the capacity of the pipes or to decide for a different approach.

The analysis displays that there was an attitude in Oslo to channel and put rivers in pipes. While Oslo has changed its strategies to cope with stormwater to a more sustainable approach, in Uyo the case is the expansion of pipes to handle more volumes of stormwater, and this has been the pattern for many years. Restoration and installation of these systems are extremely expensive and time-consuming. The main aim of expanding the capacity of the systems is to hopefully handle the increased volume of water, but the climate change projections indicate that with the years the intensity and frequency will rise, and the upgrade of these systems will go on an ongoing loop.

The shift from a pipe-based drainage system to a sustainable stormwater management solution in Oslo can be explained by the environmental movement that emerged during the 1960s and 1970s in the USA and Europe. The history of Oslo follows the same pattern as the rest of Europe. By the 1980s and 1990s river restoration projects were being carried out in Oslo and plans to reopen channelized/closed rivers in Oslo are still ongoing and are important strategies to manage stormwater.

The environmental legislation and directives at the European level that are implemented into national laws have been an important driver for the changes in Oslo. Many of the municipal documents and plans mention that Directives from the EU, goals from the UN, and laws and regulations are essential in river restoration projects. The authorities in Oslo have a sense of responsibility to solve the issues climate change causes, by managing the problem in a sustainable manner. Making river restoration a political objective has made it easier to have re-opening projects, but it is not always easy to re-open rivers in an urban site.

One of the main goals in the management of stormwater in Oslo is the attempt to re-open the rivers and streams as much as possible back to their pristine state. The questions asked by Wantzen et al. (2016) "How to find space for rivers in diked and colonized floodplains, and how to re-establish appropriate environmental flows to maintain historic patterns of river flooding?" are questions that are appropriate to consider in an urban context (Wantzen et al., 2016 p.12). In urban environments where other infrastructures such as roads, buildings, and so on take up space, there is in some cases no room to re-open rivers back to their natural state. The possibility of restoration of rivers and streams should be determined to reasonable targets, such as improved water quality, riparian management, fish passage, recreation, etc.

In the context of Uyo, the main approach to managing urban flooding is the conventional pipe-based drainage system. In the urban areas the rivers are using the rivers as dumping ground and as discharge points for the conventional drainage systems. Rural communities hold significant regard for rivers, considering them of utmost importance. In their approach to preserving the river's natural state and regulating its flow, they rely on informal techniques.

The water from the city drains to the rivers in the rural areas. This situation got us to investigate how the management of the rivers is taken care of in these areas.

The traditional knowledge of the rural part of Uyo indicates that there is knowledge of the management of rivers. In these rural areas, there are three main actors in water management: the domestic users, seasonal farmers and traditional rulers, and village council members. The management practices are ruled by the spiritual values in these areas to make practical measures to protect and manage available water sources. The management of the waterways includes path improvements, restricting farming around riparian areas, regulations against waste dumps, and enforcement of good practices of cooperative water use and management.

The management practices of the rivers in the rural part of Uyo point towards the fact that the local community is being included in the management of the rivers. The traditional practices of managing rivers and the perception of the rivers seem to be a little like the strategy of Oslo Elveforum. While the values of rivers may be different, the rural people of Uyo have a more spiritual value, and Oslo and Oslo Elveforum have a more environmental value, the inclusion of local populations is an important factor for the successful management of the rivers.

How can SUDS be implemented in Uyo?

Recognition of SuDS

Our research case study on Uyo revealed a pattern of recurring flooding events (see p.10-12 in Chapter 4). Our findings indicate that the current drainage systems are insufficient to handle the increasing precipitation due to climate change and other external factors. Although conventional drainage systems are designed to manage the stormwater flow and prevent flooding, they are limited by their fixed-pipe structure.

Both Oslo and Uyo are urban cities vulnerable to urban flooding. However, they differ in their approach to managing this risk. While Uyo is primarily relying on conventional drainage systems, Oslo has shifted its focus towards Sustainable Drainage Systems (SuDS) and other nature-based solutions to adapt and mitigate the impact of flooding. The Oslo case study highlights the limitations of pipe-based drainage systems compared to Sustainable Drainage Systems (SuDS). Firstly, pipe systems are not designed to cope with unforeseen increasing extreme weather events, which are expected to occur more frequently in the future. Secondly, pipe systems cannot effectively address contamination issues, as they only transfer pollution from one location to another.

A positive aspect of Uyo is its recognition of urban flooding as an issue and its willingness to solve it. By recognizing the benefits of natural perspectives and not just focusing on technical engineering solutions, Uyo would be taking a step forward. The knowledge can later be implemented in other parts of the country where urban flooding is also an issue.

Recognizing added values of healthy rivers

Balancing economic considerations with environmental concerns can be difficult when the environment is undervalued. Rivers that are in a poor ecological state can have negative effects, such as bad smells and visible waste. On the other hand, rivers that are in a good ecological state can enhance the attractiveness of the entire region. Additionally, diverse river flows can have aesthetic value, and improving a river's ecological status and services can increase its overall value.

Rivers can add to the attractiveness of urban areas and bring them to life. Incorporating more blue-green infrastructure has numerous benefits for both people and the environment, including improved stormwater management, climate regulation, and habitat creation for a variety of species.

Recognizing these positive values of healthy rivers for human well-being and economic development is an important element to address when discussing the possibility and the need to open and utilize rivers and streams. Oslo recognized the value of healthy rivers which is why they invest heavily in re-opening rivers and river management, by re-establishing the rivers in their areas and developing impressive waterfront architecture only after overcoming post-war pollution and seeing the value of water. For Uyo to benefit from its rivers, it must recognize the value of working with them rather than against them or concealing them.

Considering SuDS in Urban Planning

Most urban cities follow a densification strategy due to the scarcity of land. The lack of space for floodplains and dynamic rivers has more negative effects than giving rivers space to flow. Hence the need for rivers and green spaces to be considered in urban planning stages.

From our literature study on Oslo, we noted that in 1982 the environmental protection council worked out a principal program to protect rivers, streams, and waterways:

¨*The closing of rivers and streams is not permitted. This also applies to the refilling of ponds, lakes, other waterbodies, or the seabed. The construction or placement of buildings or other constructions and facilities closer to open streams, ponds, rivers, and other waterbodies than 20 meters is not permitted. The same applies to digging, blasting, and filling work*" (Hartwig Et al. 2010 p.32)

In Oslo, blue-green infrastructure is considered during the planning stage, with a focus on long-term plans spanning a 10-year period. However, the city also takes four-year periods into account and does not force immediate upgrades to all infrastructure in response to gradual climate change. Instead, flexible, and sustainable approaches are used to accommodate uncertainties.

Urban growth and densification in Uyo place pressure on the city's green areas, biological diversity, and ability to adapt to climate change. However, this growth also presents an opportunity to plan the city in a way that manages stormwater sustainably. Measures such as preserving vegetation, mapping flood zones, securing critical infrastructure, and creating space for streams and rivers can be incorporated into a city master plan and implemented in phases for adaptability and reversibility.

To successfully integrate SuDS into urban planning, an interdisciplinary team within the government is needed. While urban planners have a broad knowledge base, expertise from different areas is required for successful implementation. For example, in Oslo, the Norwegian Directorate of Water Resources and Energy, the Ministry of Climate and the Environment, and the Ministry of Local Government and Districts work separately but with the same goal of ensuring regulated land use.

Mapping rivers and streams

For the government of Uyo to have an opportunity to open or redesign river paths, they must first map out their original locations to help prevent construction over these important historic patterns and ensure their preservation.

Restoring the natural flow and historical patterns of waterways is a significant challenge in modern river management, particularly in densely populated areas and urban environments. The case of Oslo, along the Alna River, has demonstrated the challenges of restoring rivers to their precise historical patterns. Where some of these historical patterns go through different infrastructures such as houses, business areas, and so on, which makes it difficult to make a case for opening rivers in their exact historical river course so those stretches remain closed.

While there may be a desire to design urban areas to resemble a natural state, practical considerations related to human infrastructure often come into play during the construction or design process. However, where possible there should be a desire to open rivers in their historical patterns.

One lesson learned from Oslo is that a 'historic blue list' was produced with collaboration between the government and an NGO (Oslo Elveforum). This blue list maps out opened, closed, historical, and tunneled river paths for all the rivers in Oslo, this has helped in preventing construction over these important patterns, ensuring their preservation, and aiding in planned reopening.

In addition to opening streams, protecting valuable vegetation, and securing critical infrastructure, it is essential to map out flood zones. This includes identifying flood zones surrounding existing rivers and streams, flood routes through built areas, locations of crucial culverts and bridges, and determining where the water flows when these structures are blocked.

Involving local people/communities

Promoting the natural environment, protecting, and restoring rivers and streams requires the involvement of voluntary actors at the national, regional, and local levels. Their participation is crucial in drawing attention from politicians and the public to these underlying issues. In addition, these actors have the potential to contribute significantly to restoration work through increased involvement and collaboration.

One of the voluntary actors that have played a significant role in river management and reopening projects in Oslo is Oslo Elveforum. The main task of Oslo Elveforum is to involve and engage local people, particularly children and young people in various river projects, this helps in building local ownership of rivers in the area. Another objective of Oslo Elveforum is to educate people about the significance of Oslo's blue-green structure as a fundamental component for enhancing the quality of life and promoting well-being in their local environment. This would be beneficial in Uyo urban areas, as the people don't feel much of a connection when it comes to government-funded projects.

The way people perceive water shapes their attitudes to management. In Uyo whilst the formal rights systems to water are applicable and enforced in urban areas, the rural communities on the other hand view water as a common property meaning they see water as a shared commodity, and everyone is responsible for the management of it.

There have been many indications of that public sector alone are not able to carry out high-quality maintenance on various infrastructures, they cannot be everywhere all the time, hence the need for society to have a sense of ownership to promote regular maintenance and use. So, involving the people in urban projects in the future would be a way of changing perceptions and promoting local ownership leading to a better attitude towards river management.

Based on the analysis we have made a diagram illustrating the steps of introducing SuDS in Uyo.

What recommendation can be given to improve the current understanding of SuDS?

Recommendations from this research project would be looking at the bigger context. This would mean the incorporation of ancient traditional knowledge, involving the community in sustainable solutions, and seeing how the solutions transcend from urban to rural areas.

To begin with, traditional knowledge and indigenous wisdom represent a frequently overlooked sector, but it remains present and supports the sustenance and livelihoods of millions of people in communities that have a strong connection to their cultures.

Our case study in Uyo showed how solutions implemented in urban areas affected rural areas. And in contrast, the case study demonstrated the value of traditional knowledge of river management in most rural areas. In addition to implementing SuDS, we aim to encourage the use of such knowledge to enhance resilience and foster local ownership.

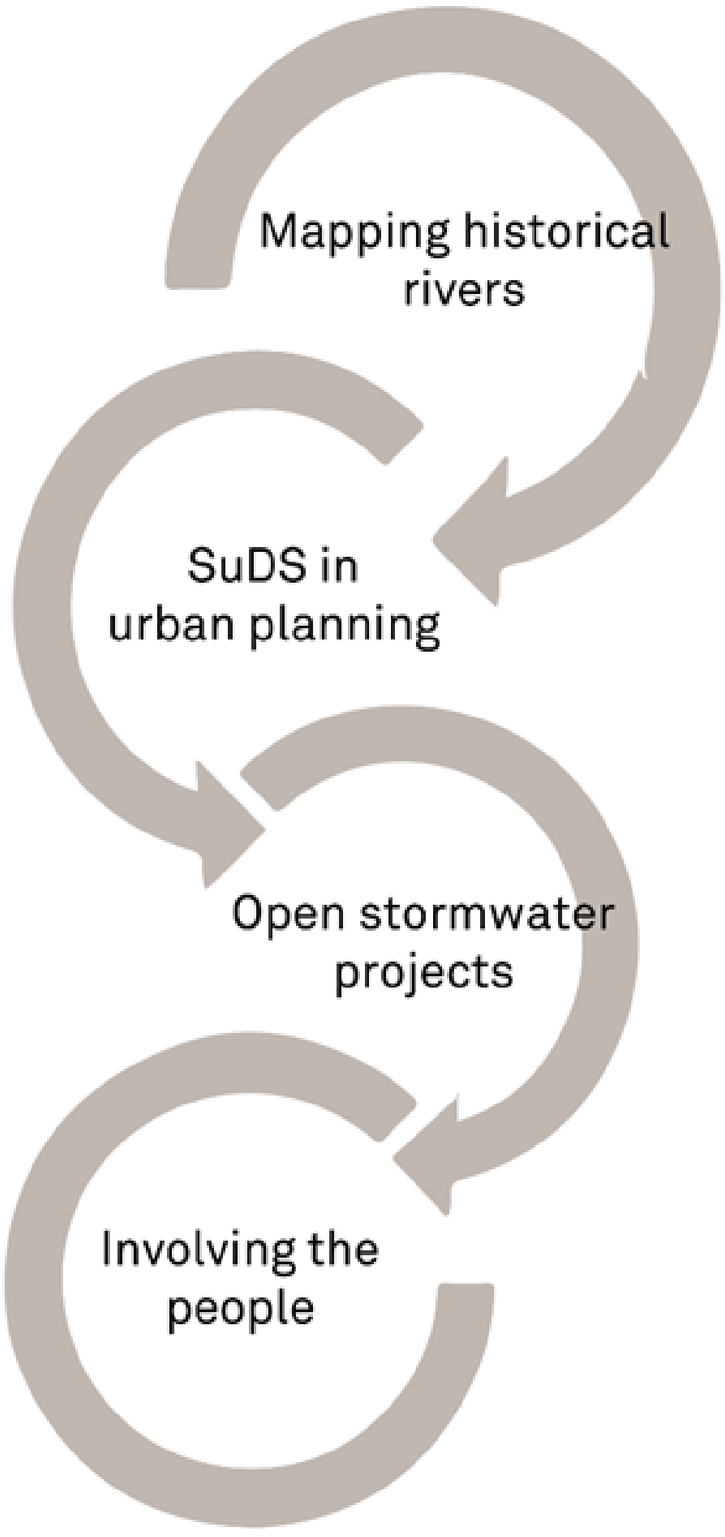


Figure 36*: Diagram illustrating the steps of introducing SuDS in Uyo.*

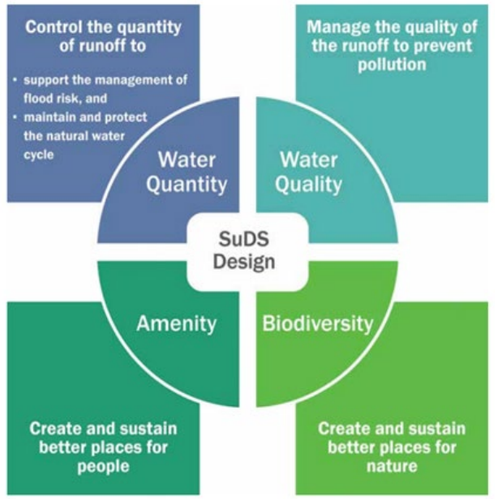


Figure 5: this shows the design objectives in SUDS design. *Source: SUDS manual, 2015, p.6*

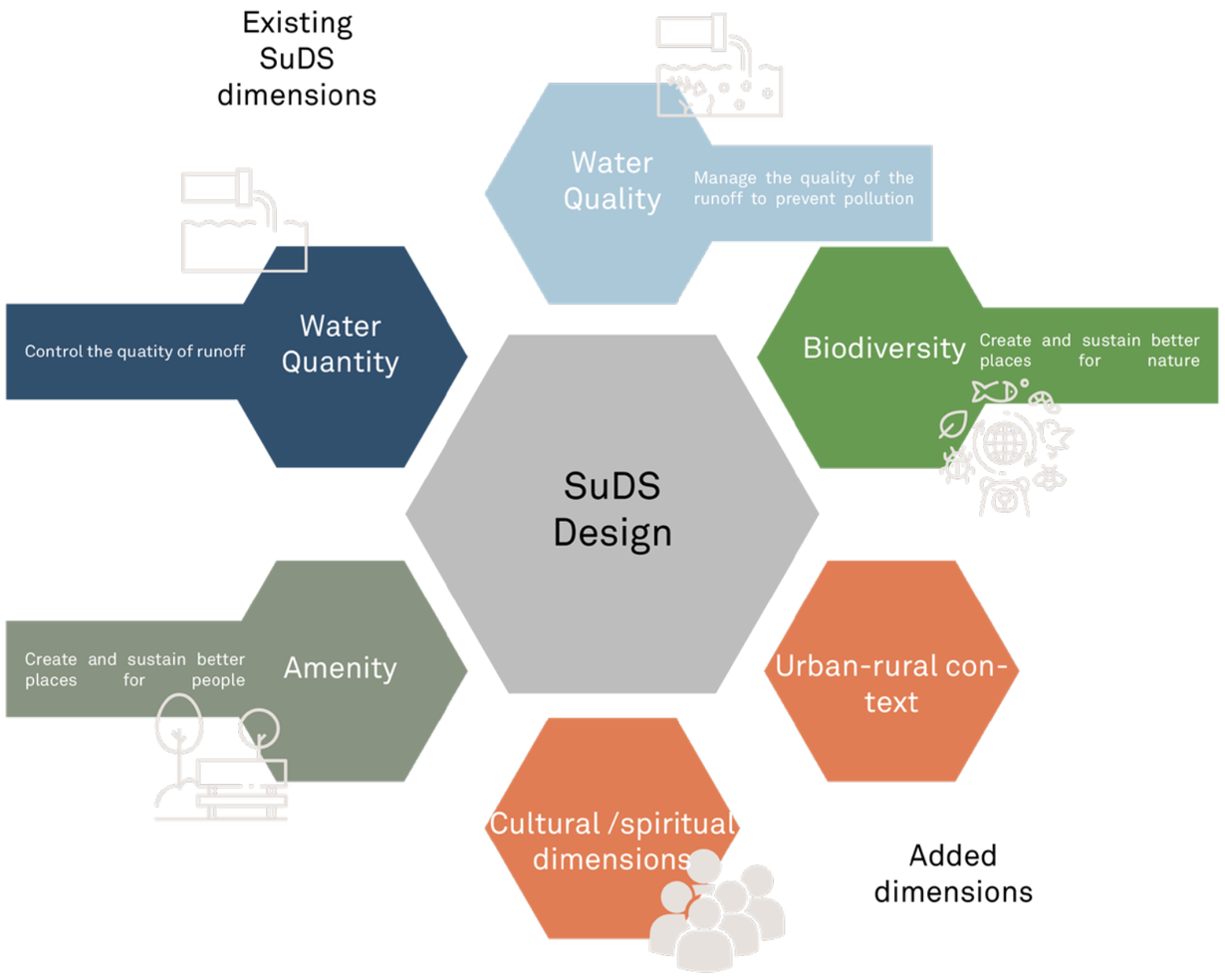


Figure 37: Shows the proposed design objectives for the SuDS strategy.

Our proposed approach for river management is to integrate the traditional knowledge of local communities with scientific measures in SuDS. Human studies suggest that people living in a particular place mostly depend on natural resources and develop local knowledge of the environment. This knowledge can be used to restore and maintain valuable natural resources in the rivers in Uyo. By appreciating and incorporating traditional knowledge, we aim to build greater resilience and promote local ownership in river management.

The integration of diverse knowledge systems can improve resilience. Failure to recognize and value informal/ancient knowledge can result in greater risks to human life and property (Davidson-Hunt & Berkes, 2003; Folke et al., 2002).

Another important point to consider is the increasing leadership roles that indigenous people have taken in river restoration and management over the years. Their relationships with water and the environment are crucial elements of river management. As seen in the Uyo case, water is not only viewed as natural resources that support livelihoods but also as shared commodities that require maintenance. We believe that this is an essential factor for effective river management.

Scholars have shown that indigenous and community-based approaches to climate change adaptation, resilience, and community inclusion offer valuable lessons (Thornton & Manasfi, 2010; Berkes, 2012). Borne out of their long-term experience and experimentation, indigenous people have often adapted to environmental change through techniques and methods using knowledge passed in practice from generation to generation promoting a sense of local ownership. Arguably their knowledge and practices can provide an important basis for today's efforts in dealing with even greater challenges of climate change.

Indigenous people have developed techniques and methods to adapt to environmental changes based on their long-term experience and experimentation. Their knowledge is passed down from generation to generation, already creating a sense of local ownership. This knowledge and practice can be a valuable basis for dealing with climate change challenges today.

Chapter 6
Conclusion

Conventional pipe-based drainage systems have been discovered to have negative impacts on the urban environment. These include reduced water quality of receiving water bodies due to increased sediment accumulation and decreasing hydrological features. It is further asserted that the pipe-based drainage method of managing stormwater is expensive in terms of its construction and maintenance, and its overall efficacy as a method of reducing flood risk.

The study confirmed that urban flood management in Uyo and the rest of Nigeria as well is still strongly associated with an engineering culture and shows that the improvement of drainage and sewer system has been a continuous process.

The goal of this study was to find a more sustainable approach that complements current engineering solutions for managing urban floods in the city of Uyo, with an emphasis on using rivers and streams. We first examined Sustainable Drainage Systems (SuDS) as a means of managing stormwater and mitigating urban floods. As an alternative to underground pipe-based drainage, SuDS offers favorable impacts on water quality and quantity in addition to providing increased recreational opportunities in the urban environment.

Furthermore, we studied Nigeria's own tradition of human-river relationships, and Oslo's experiences on river management, from which we learned that: urban river management needs to take a broader consideration by looking at how urban treatment will affect the rural areas, especially when rivers have a strong cultural/spiritual role to play; to reopen closed rivers and streams, it is vital to raise public awareness and encourage greater public engagement, and to influence politicians in order to get proposals implemented.

As conclusion, our first argument is opening rivers and streams as SuDS strategy. Rivers provide a wide range of services that yield significant advantages to both the environment and society, but unfortunately, the management of rivers often fails to prioritize these benefits until problems resulting from neglect arise. Acknowledging the beneficial impact of healthy rivers on human well-being, economic growth, as well as the climate, is a crucial aspect to consider when contemplating the feasibility and necessity of utilizing rivers.

Due to human demands, river ecosystems and resources have suffered significant degradation in many industrialized cities. Rivers have been repurposed as dumping grounds, leading to 'extensive and frequently severe water contamination, which in extreme cases would increase flood risk.

A key objective of SuDS is to manage surface water runoff by imitating natural drainage systems, with the aim of lessening the negative effects of urbanization on watercourses. Rivers are crucial in the realm of sustainable stormwater management, serving as a significant natural element in the water cycle. Offering various beneficial impacts on human life, such as decreasing stress levels, improving the microclimate, providing livelihood benefits to its environment, and reducing the frequency of respiratory ailments.

Our study uncovered some traditional methods that have been beneficial for river management strategies in some rural areas of Uyo. So, our second argument is that, in addition to scientific measures, there are benefits of instilling traditional/ancient knowledge in riv

The benefits of traditional knowledge extend beyond its originating culture. Experts and planners working towards improving conditions relating to climate change in both rural and urban areas can also benefit from this knowledge. This knowledge is usually built upon generations of experimentation and observation, providing an inherent understanding of the environment and its surroundings. Transferring traditional knowledge provides a connection between people and their environment, which we deduce is an important piece of the puzzle in sustainable development/solutions.

River management often involves attempts to control and command the river course to mitigate floods, which can lead to a conflict with nature. In some cases, the integrity of rivers has been sacrificed for limited economic gains, as exemplified by previous methods used in Oslo. Ignoring the long-term effects of such actions puts entire societies at risk. Instead of waging a war against nature, a harmonious coexistence, and the utilization of natural power for human benefit should be sought.

This research emphasizes the potential for rivers as a SuDS strategy to provide a practical solution for adaptation and stormwater management in Uyo and potentially be replicated in other urban cities in Nigeria.

Our primary concept for resolving river management and restoration problems involves valuing and incorporating local communities and their ecological expertise, in unification with scientific measures. It is widely recognized that people who reside in a particular area often depend on natural resources and with time develop unique ecological knowledge that is locally beneficial.

Studying the advantages of Rivers/Streams as a SuDS approach in Sub-Saharan nations such as Nigeria may offer valuable perspectives into the current investigations on SuDS as a potential no-regrets adaptation option for dealing with the impacts of climate change. Additionally, it might expand the appeal of SuDS beyond being a method for urban drainage and adaptation.

SuDS are relatively new fields, and there is scope for innovation in the design and implementation of SuDS. We as landscape architects can contribute to this by developing new and creative solutions to urban water management issues. We can also incorporate SuDS principles into the design of spaces and urban planning, this helps to create a multifunctional landscape that not only reduces flood risk but also enhances the aesthetic value of the built environment.

While this study provides valuable insights into the benefits of using rivers as a SuDS strategy in Uyo, there are several limitations to the research that should be considered. These include the difficulty of getting specific documents pertaining to the drainage system of Uyo, official documents showing the urban rivers and how rivers are managed in the city, and the short duration to go in-depth on the SuDS theory.

However, while the findings of this study are significant, they may not necessarily be applicable to other regions without further research. And although this study focuses on the use of SuDS for flood control, it is worth exploring its potential in mitigating droughts and other water-related issues.

Furthermore, a shifted approach from ‘defense’ to ‘living with rivers’ also makes room for a more qualitative approach. According to Jha et al. (2012), all these measures (structural and non-structural) are complementary and can be developed simultaneously. In this work, non-structural measures were regarded as a future-oriented way to meet the stormwater challenge. Characteristically, they are flexible and intend to optimize the drainage system in a sustainable way.

In addition, adopting a ‘living with rivers’ approach allows for a more qualitative perspective toward river management. As stated by Jha et al. (2012), both structural and non-structural measures can complement each other and be implemented simultaneously. Within this research, non-structural measures were deemed as a forward-thinking method of addressing stormwater management challenges and river management. These measures are characterized by their flexibility and aim to optimize the drainage system in a sustainable manner.

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