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MSIMBAZI WETLAND PARK

RESTORATION OF AN URBAN FLOOD PLAIN IN DAR ES SALAAM, TANZANIA

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Master thesis, 30 HEC
Landscape Architect Programme
Uppsala 2016

Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Urban and Rural Development, Division of Landscape Architecture
Master thesis for the Landscape Architect programme
EX0504 Degree Project in Landscape Architecture, 30 HEC
Level: Advanced A2E

Title in English: Msimbazi Wetland Park - Restoration of an urban flood plain in Dar es Salaam, Tanzania
Title in Swedish: Msimbazi Vattenpark - Restaurering av ett urbant flodområde i Dar es Salaam, Tanzania
Related appendix (A1 sheets): Appendix to Msimbazi Wetland Park - Restoration of an urban flood plain
Supervisor: Ylva Dahlman, Department of Urban and Rural Development
Examiner: Gunilla Lindholm, Department of Urban and Rural Development
Assistant examiner: Rolf Johansson, Department of Urban and Rural Development
Cover image: Illustration, Elin Lindström
Other photos and illustrations: all photographs are taken by the authors in 2015 unless othervise stated. All featured, texts and illustrations are property of the authors unless otherwise stated. Other materials are used with permission from copyright owner.
Original format: A4
Keywords: Floods, Flood water management, Pollution reduction, Urban river restoration, Urban wetland
Online publication of this work: http://epsilon.slu.se

ACKNOWLEDGEMENTS

Without the help from all fantastic people we have come across during this study, the project never would have become what it is and would lack substance and meaningfulness.

A special thanks to; **Daniel**, who welcomed us to Ardhi University and helped us with the project and all the paperwork needed. **Jaffar**, who offered a lot of his time to help us to understand the complexity of the Msimbazi River. **Emmanuel**, our lifesaver in Dar who introduced us to our neighbourhood and became a good friend. **Gloria** and **Mwanaisha**, who accompanied us during the site visits and helped us to see places we never would have been able to go by ourselves. **Habiba**, who showed us Suna and gave us her view of the life along Msimbazi River. **Ylva**, for invaluable support and advice. **Rolf**, for introducing us to the subject and helping us apply for the MFS scholarship in time.

Last but not least, all other people that we have come across during our time in Tanzania and Dar es Salaam. Asante!*

/Elin & Karin
Uppsala, january 2016

**Asante = Thank you, in Swahili*

ABSTRACT

Degradation of urban river systems is a global problem that poses a challenge in Tanzania and other low-income countries, as well as in the rest of the world. In general, rivers in urban areas tend to be severely degraded in terms of ecology and morphology. To a large extent this is a result of fast urbanization and pollution that changes and deteriorate natural riverine systems and their ecosystems. Another increasing problem in urban river systems is floods, mainly as a result of fast urbanization and especially in countries with a tropic climate affected by seasonal rains. Floods severely damages the urban river ecosystems as well as built structures, causing huge amounts of sediments, sewage water and waste to mix with the river. The people who are most vulnerable to these threats are usually those who live in informal settlements, which tend to be located in high-risk flood areas.

Over the past ten years a rapid urbanization and population growth has occurred in Tanzania, particularly in Dar es Salaam. This has increased the demand of basic urban services and infrastructure such as housing, sanitation, water and roads and also resulted in fast expanding informal settlement. In the meantime, the city planning in Dar es Salaam has lacked to follow set plans, regulations and to organize urban services and update the plans. As a result of this, the city is now struggling with spatial disorder, poor infrastructure and inadequate city planning.

One site struggling with all these problems, and also the study site for this project, is the Msimbazi river flood plain. It is situated in central Dar es Salaam and has become seriously affected by urbanization at the same time as the river and flood plain environment is severely ecologically degraded and pollution levels in the water and soil have reached very high percentages. Heavy seasonal rains, lack of infrastructure and clogging of drainage channels also causes large problems with floods in the area. Due to the recent urbanization and lack of planning, the flood plain can no longer maintain and control the flood water in a sustainable way. Large parts of the flood plain have also been built upon and now mainly houses informal settlement which are flooded every year.

The thesis therefore focuses on managing flood water, decreasing pollution levels in the water and soil, and restoring the riverine ecosystem. Four main research themes; *restoration of urban river systems*, *flood water management*, *pollution reduction in urban watercourses* and *turning flood plains into multiple-use spaces*, leads to specific design strategies that are presented to be applied on this specific site in Dar es Salaam and also on similar sites around the world.

The project combines theoretical and practical knowledge in order to obtain a design proposal which considers strengths and weaknesses on site, restore the urban wetland and is also realistic to implement. The developed design proposal for the Msimbazi river and flood plain, Msimbazi Wetland Park, creates a multi-use green space which combines all of these strategies as well as important social and recreational functions. With this transformation and restoration, Msimbazi flood plain can restore its function as a retention area for floods as well as become a sustainable public green space for the citizens of Dar es Salaam. The design proposal is presented in a large, strategic scale accompanied by selected design interventions in detail where ecological, multifunctional and social principles are more explained.

Photo. *Part of Msimbazi flood plain seen from on top of a building in the higher elevated area of Upanga, west of the flood plain.*

SAMMANFATTNING

I denna del presenteras en sammanfattning av examensarbetet. Syftet med varje del förklaras tillsammans med en kort beskrivning av avsnittet.

INLEDNING

Detta arbete är ett examensarbete i landskapsarkitektur som presenterar designstrategier och ett gestaltningsförslag för ett översvämningsområde utmed en urban flod i Dar es Salaam, Tanzania. Arbetet är ett resultat av en dryga två månader lång fältstudie på plats i Tanzania under hösten 2015, en fältstudie som möjliggjordes tack vare ett MFS-stipendium från Sida. Examensarbetet består av två delar, denna rapport och ett tillhörande gestaltningsförslag. Rapporten fördjupar sig i den specifika platsen, dess förutsättningar och problem, samt en teoretisk studie som leder till designstrategier. Gestaltningsförslaget visar på hur designstrategierna anpassas till en specifik plats för att lösa den komplexitet av styrkor och svagheter som identifierats på platsen.

SYFTE

Syftet med detta examensarbete är att presentera designstrategier och att göra ett gestaltningsförslag för en specifik del av översvämningsområdet kring Msimbazi River i Dar es Salaam. Uppsatsen fokuserar på hantering av översvämningsvatten, minskning av föroreningar i vatten och jord och restaurering av flodens ekosystem. Syftet för gestaltningsförslaget är att skapa ett multifunktionellt område som kombinerar dessa aspekter med viktiga sociala och rekreativa funktioner.

Examensarbetet är ämnat att fungera som ett strategiskt förslag som i framtiden kan implementeras och replikeras på platser med liknande förutsättningar och utmaningar. I arbetet används en kombination av teoretisk och praktisk kunskap för att uppnå en hållbar design.

Frågeställning:

Hur kan ett urbant flodområde, såsom Msimbazi, förvandlas till ett blå-grönt område som kan hantera översvämningar samt förbättra ekologiska och sociala funktioner?

För att lättare kunna svara på frågeställningen används två delfrågor:

- *Hur kan ett område kring en urban flod gestaltas för att minimera påverkan av översvämningar?*
- *Hur kan mängden föroreningar i vatten och jord reduceras med biologiska metoder?*

METOD

Uppsatsen är uppbygd i fem delar; Introduktion, Msimbazi, Konceptuellt ramverk, Design och Autro, samt ett gestaltningsförslag som presenteras separat.

I arbetet har en kombination av flera olika metoder använts:

- litteraturstudier
- semi-strukturerade intervjuer
- platsbesök
- kartläggning och analys
- designprocess

Litteraturstudier användes till två ändamål; först för att samla information och få en förståelse för Tanzania, Dar es Salaam och kontexten kring Msimbazi River Valley, därefter till en teoretisk studie kring fyra teman formulerade efter analys av platsen. Dessa teman är: *Restaurering av urbana flodområden*, *Hantering av översvämningsvatten*, *Minskning av föroreningar i urbana vattendrag* samt *Omvandling av översvämningsområden till multi-funktionella områden.*

Semi-strukturerade intervjuer användes som en första introduktion till platsen och dess förutsättningar. För att förstå den specifika platsen som är i fokus i arbetet, gjordes nogranna **platsbesök** med fotografering, dialoger med boende i området, skisser och anteckningar. För att sammanställa platsbesöken **kartlades** platsen i olika kategorier och **analyserades** sedan genom en SWOT-analys. I SWOT-analysen identifierades styrkor, svagheter, möjligheter och hot på platsen. Några svagheter och styrkor valdes ut och formade fyra teman som låg till grund för det konceptuella ramverk som resulterade i designstrategier att applicera i gestaltningsförslaget.

Gestaltningsprocessen pågick genom skisser och utveckling av ideer under stora delar av arbetet med projektet för att ta fram ett gestaltningsförslag för platsen.

BAKGRUND

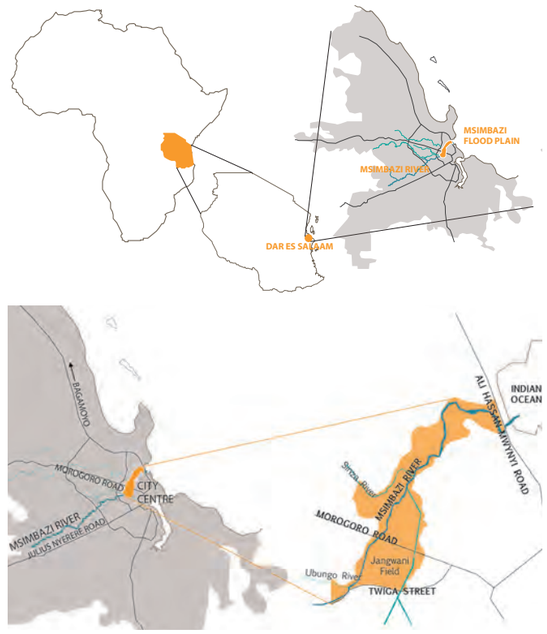
Degradering av urbana flodsystem är ett globalt problem som skapar utmaningar både i Tanzania och främst andra låginkomstländer i resten av världen. Generellt sett tenderar floder i urbana miljöer att vara allvarligt degraderade vad det gäller ekologi, jämfört med rurala motsvarigheter (Gurnell et al. 2007, s.1119). Till stor del beror detta på urbanisering och föroreningar som försämrar miljön i och omkring floderna och skadar deras ekosystem, vilket också har en negativ påverkan de ekosystemtjänster flodområdena annars kan erbjuda (Liu et al. 2011, s.1). Ett annat ökande problem är översvämningar, främst till följd av snabb urbanisering i länder med tropiskt klimat som har intensiva regnperioder. Översvämningar ger ofta stora skador på såväl byggnader och infrastruktur som ekosystem, samt orsakar att stora mängder sediment, avloppsvatten och avfall blandas i floden. De människor som främst drabbas av dessa problem är vanligtvis de som lever i informella bosättningar, vilka tenderar till att ligga i områden med hög risk för översvämningar (Global Climate Partnership 2011, s.24).

De senaste årtiondena har Tanzania genomgått en snabb urbanisering och befolkningstillväxt, framförallt i Dar es Salaam, vilket ökat efterfrågan på grundläggande samhällsservice som infrastruktur, bostäder, rent vatten, avlopp, och sophantering. Samtidigt har stadsplaneringen i Dar es Salaam varit eftersatt och misslyckats med att följa planer och regler, vilket lett till att staden nu brottas med dålig infrastruktur, snabb expansion av informella bostäder och en otillräcklig stadsplanering (UN-Habitat 2010, s.17).

Msimbazi River är en av de urbana floder i Dar es Salaam som för närvarande är hårt drabbad av urbaniseringen. Översvämningsområdet kring floden och floden i sig är väldigt degraderad och föroreningsnivåerna är så höga att floden inte längre kan erbjuda grundläggande funktioner. Intensiva säsongsregn, dålig infrastruktur, igenproppade kanaler och dräneringskanaler skapar stora problem med översvämningar i området. Förr var området kring floden beväxt och obebyggt varpå det klarade av att bli översvämmat, men till följd av urbanisering och otillräcklig planering har området fyllts upp med jordmassor och kantzonerna bebyggts med informella bostäder som översvämmas varje år.

Översvämning av gata och busshållplats i Dar es Salaam. Foto: Jaffar Jongo, 2011.

Samtidigt gör det centrala läget att området är viktigt för bostäder och som mötesplats för stadens invånare, och skulle kunna berika staden med välbehövlig grönyta. Med en restaurering av floden och området omkring, lösningar för hantering av översvämnngar



Kartor som visar Msimbazi översvämningsområde i centrala Dar es Salaam, Tanzana.

samt minimering av föroreningar i vatten och jord, skulle Msimbazi översvämningsområde kunna bli ett hållbart rekreationsområde som även klarar översvämningar.

MSIMBAZI

Msimbazi River Valley är beläget i centrala Dar es Salaam. Floden Msimbazi har ett stort upptagningsområde och rinner från områdena väster om staden, genom stadens centrala delar och sedan ut i Indiska Oceanen. Floddeltat är ett naturligt översvämningsområde som fylls med vatten årligen under säsongsregnen, däremellan råder en torrperiod under vilken vattennivåerna istället är väldigt låga. Utsläpp av dagvatten samt igentäppta kanaler och tunnlar förvärrar översvämningarna. I den existerande stadsplanen för Dar es Salaam, som sträckte sig till 1999 men ännu inte har uppdaterats, är området utmed floden benämt som 'hazard land' vilket inte får inte bebyggas. Ändå har den snabba urbaniseringen lett till en etablering av informella bosättningar i kantzonerna, och en höjning av marknivån för nya byggnader på flera platser, något som orsakar ännu högre översvämningsnivåer.

Floden Msimbazi och området omkring är väldigt förorenat, främst orsakat av avfall som historiskt dumpats på soptippar längre uppströms utmed floden, illegal dumpning av avfall i floden, ofiltrerat avfallsvatten från fabriker samt flera avlopps- och dagvattenkanaler som rinner direkt ut i floden ofiltrerade. Detta har lett till höga halter av föroreningar i både vatten och mark.

Informell bebyggelse i bostadsområdet Suna, Dar es Salaam.

Kvinnor och barn i området Magomeni Bondeni, Dar es Salaam.

Den snabba urbaniseringen i Dar es Salaam har samtidigt resulterat i en etablering av många informella bosättningar i översvämningsområdets kantzon. Här bor många människor trots de allvarliga miljöproblemen och att deras hem översvämmas årligen. Detta beror troligtvis mestadels på att de inte har några bättre alternativ, men också för att de har bott i sina områden under en lång tid och känner sig hemma där.

INVENTERING OCH ANALYS

Området som är i fokus för gestaltningsförslaget utmed Msimbazi River har flera olika karaktärer. En stor yta används till fotbollsplaner och stora event, medan våtmarker, odling och ett mangroveträsk hör till de främsta övriga karaktärerna.

Platsbesök och analys visar på att situationen på platsen är komplex, det finns både många problem att lösa och positiva aspekter att ta till vara. Det är ett centralt beläget naturområde, dock otroligt förorenat. Det är också en stor barriär som är svår att korsa och besöka, och det finns inga egentliga gångvägar. Samtidigt har området flera kvaliteter; det är fortfarande delvis ett naturligt floddelta som lämnar mycket utrymme för floden att utvecklas fritt och det erbjuder även stora naturliga grönytor och våtmarker.

TEORI

Från inventering och analys av området formulerades fyra teman att undersöka för att hitta designstrategier för gestaltningen. Dessa fyra teman är:

- Restaurering av urbana flodsystem
- Strategier för hantering av översvämningsvatten
- Minskning av föroreningar i urbana vattendrag
- Omvandling av översvämningsområden till multi-funktionella områden

Restaurering av urbana flodsystem

Anpassning av gestaltning till den naturliga floddynamiken är att föredra när det kommer till biodiversitet och ekologi. Detta tillåter floden att utvecklas naturligt genom att identifiera dess 'self dynamic river limit'(gräns inom vilken det lämnas plats för naturlig utveckling och förändring av floden) samt att utveckla växtbeklädda bufferområden utmed flodens kantzoner som minskar erosion och stabiliserar flodkanten.

Strategier för hantering av översvämningsvatten

Fördröjning och uppsamling av vatten, permeabla ytor för infiltration av regnvatten och stabilisering av jord för att förhindra erosion och sedimentering, är några av de viktigaste strategierna för hantering av översvämningsvatten. Ytor, funktioner och utrustning inom översvämningsområdet måste också anpassas till att tåla höga vattennivåer. Genom att identifiera flodens 'flood limit', kan vattennivåerna vid olika väderförhållanden (t.ex. säsongsskiftningar) bli tydlig och ligga till grund för en hållbar planering av översvämningsområdet, i synnerhet bostadssituationen. De värst drabbade husen kan behöva omlokaliseras till säkra platser medan andra istället kan anpassas att klara övervämningar på olika sätt, t.ex. genom att byggas på pålar, hus som kan flyta, eller med en översvämningstålig bottenvåning.

Minskning av föroreningar i urbana vattendrag

Genom den biologiska metoden fytoremidering kan växter hjälpa till att rena vatten och jord. Detta sker genom att växterna tar upp och på olika sätt hanterar förorenande ämnen. Till exempel kan akvatiska växter användas för vattenrening och inom jordbruket kan markrenande arter användas växelvis med de vanliga grödorna och sedan avlägsnas från platsen vid skörd.

Biofördröjning och så kallade "flytande öar" är andra metoder. I dem omvandlar mikrober föroreningar i vatten till ofarliga ämnen. Utöver detta finns flertalet ytterligare metoder som kan bidra till att minska föroreningar i vattendrag och jord, bland annat akvatiska djur och biofiltrering.

Omvandling av översvämningsområden till multifunktionella områden

Med en multifunktionell design av ett översvämningsområde kan ytan erbjuda många olika aktiviteter och klara av att översvämmas periodvis utan allt för stora skador som följd. Genom att säkerställa en infrastruktur med upphöjda gångvägar där det går att röra sig till viss del även under översvämningar och platser i olika nivåer, kan viktiga funktioner säkerställas trots stora vattenmängder.

Odling, sportfält och liknande, med permeabla ytor i olika nivåer, som kan ta hand om vatten och är utformade med vattentålig utrustning, är exempel på multifunktionella strategier för design.

GESTALTNING

Designstrategierna som presenteras i det konceptuella ramverket leder vidare till utveckling av ett koncept för gestaltningen: **Restore, Manage, Reduce** & **Use** (restaurera, hantera, reducera & använda). Konceptet är ämnat att fungera som fyra lager som anpassas till varandra och där designstrategierna används för att lösa de styrkor och svagheter som identifierats på platsen.

Gestaltningsförslag

Gestaltningsförslaget är ämnat att fungera som en strategisk idé för hur översvämningsområdet kring Msimbazi River kan designas för att kunna hantera översvämningar och förbättra ekologiska och sociala funktioner. Gestaltningsförslaget innebär att området översvämmas kontrollerat i olika steg där de viktigaste ytorna sparas till sist så att effekterna av översvämningarna minskar. Samtidigt kopplas området samman med intilligande bostadsområden och görs tillgängligt som rekreationsområde med stora ytor för vattenfördröjning, rening av vatten och jord samt jordbruk. En översvämnngsgräns samt bostadsstrategi för översvämningssäkra bostäder är identifierad och beväxta bufferområden skapas kring floden. Anlagda gångvägar gör det möjligt för besökare att komma nära de olika naturtyperna och på nära håll få en förståelse för de positiva effekter en våtmark tillför, samt hur fördröjning och biologisk rening av vatten går till.

CONTENTS

1 INTRODUCTION

In this part, the subject of the thesis is presented, along with a short background, an explanation of the objectives of study and methods used to achieve them.

PART 1 CONTENTS

Photo. *Street in the higher parts of residential area Suna. The vegetated Msimbazi flood plain and buildings in the district of Upanga can be spotted in the far back.*

BACKGROUND

INTRODUCTION TO THE PROJECT

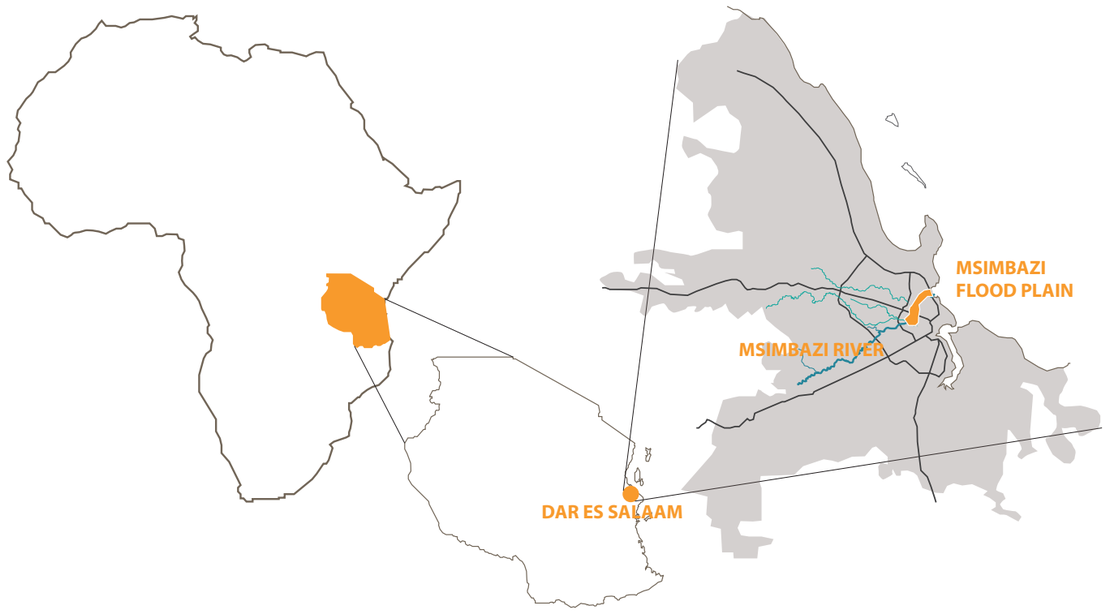
This Master Thesis in Landscape Architecture presents a design intervention for the Msimbazi flood plain in central Dar es Salaam, Tanzania. The thesis is a result of a Minor Field Study (MFS) scholarship from Sida, which enabled us to travel to Tanzania in September 2015 to collect information for the thesis through a field study. We applied with the objective to study an urban river and blue-green infrastructure in Dar es Salaam and the specific site choice later fell on Msimbazi river due to its complex situation and central location in the city.

The project is divided into two parts, this report and the final design proposal, which is presented separately.

TANZANIA FACTS

Official name: United Republic of Tanzania
Regime: Republic. *President John Magufuli (2015-)*
Inhabitants: 50,8 million, 2014
Population growth rate: 3 % (2014)
Capital: Dodoma (411 000 inhabitants, 2012)
Largest city: Dar es Salaam (officially 4,4 million inhabitants, 2012)
Population living in urban areas: 30.9 %
Annual BNP/capita: 998 USD

(Landguiden, 2015)



Map showing location of Msimbazi flood plain in central Dar es Salaam, Tanzania.

DEGRADATION OF URBAN RIVER SYSTEMS – A GLOBAL CHALLENGE

Degradation of urban river systems is a global problem that poses a challenge in Tanzania and other low-income countries as well as in the rest of the world. In general, rivers in urban areas tend to be severely degraded in terms of ecology and morphology compared to their rural counterparts (Gurnell, Lee & Souch 2007, pp.1119, 1124). Liu, Lu & Wang (2011, p.1) points out that the rapid urbanization has made the pollution situation of urban rivers increasingly critical, which damages the many ecological services that these river systems can offer. The urban development has resulted in an increase of impervious surfaces and stormwater drainage as well as constraining the space and environment in which the rivers can develop. This has brought extensive changes to the functions and characteristics of river systems, transforming the natural river flows and sediment movements, as well as cutting off the connection between river and flood plain (Gurnell et al. 2007, p.1119).

The water quality in urban rivers is also gravely affected by pollution (Gurnell et al. 2007, p.1119). A large amount of pollution originates from outlets of waste- and stormwater (U.S. EPA 2010, p.2), a problem which is increasing as urban areas of the world are expanding, covering larger and larger areas of the ground with impervious surfaces and decreasing the amount of natural infiltration areas. According to the United States Environmental Protection Agency, U.S. EPA (2010, p.2), there is a strong connection between increase of impervious covered areas and a degradation of water quality. The impervious cover causes increased stormwater runoff, which transports pollutants directly to nearby water bodies or infiltrates to the ground water (U.S. EPA 2010, p.2).

The impact on the ecosystems in the contaminated sites are largely damaging, most of all in industrialized areas with dense population. Saier Jr. and Trevors (2008) says: "It is precisely these areas that pose the greatest threat to human and ecosystem health". Dar es Salaam is one of many such areas.

Another increasing problem in urban river systems is floods. Of all natural disasters worldwide, floods are the ones which affects the largest number of people and makes the greatest structural damage (UN n.d., p.26). This is a particular problem in countries with seasonal rain periods, but also a threat in other parts of the world due to climate change aspects such as raised sea levels and more extreme weather with heavier rains. Floods severely damages the urban river ecosystems as well as built structures located in flood prone areas. The excess water causes erosion along the riverbanks as well as destroying buildings and causing huge amounts of sediments, sewage water and waste to mix with the river, which makes the water turbid and settles in houses, drainage channels and sewage systems.

According to Olorunfemi (2010, p.1) there is also, in many African countries, a socio-economic aspect to this as the increasing frequency of natural disasters such as floods, not only poses threats from direct exposure to the disaster, but also stops people from escaping poverty. This due to the social and economic systems not being sufficient enough to handle the aftermath of destruction. The most vulnerable people are usually those who live in informal settlements, which tend to be located in high-risk flood areas (Global Climate Adaptation Partnership 2011, p.24). It is in these areas that flood adaptive and resilient measures are most needed and should be prioritized (Olorunfemi 2010, p.1).

RAPID URBANIZATION AND INFORMAL SETTLEMENTS IN DAR ES SALAAM

A rapid development and massive population growth has occurred over the past ten years in the urban centres of Tanzania. Today, one third of the total urban population in Tanzania lives in Dar es Salaam and the population grows with a rate of almost 5 per cent per year (UN-Habitat 2010, p.21).

The rapid growth has increased the demand of basic urban services and infrastructure such as housing, sanitation, water and roads. The increasing population pressure also results in urban sprawl and fast expanding informal settlements (Pan-African START Secretariat et al. 2011, p.12). These informal settlements are a huge part of the "poverty urbanization" taking place

in most low income countries today, a rapid process in which global poverty moves into and spreads across urban areas around the world (UN-habitat 2003, p.5). World Bank (2002, p.7) defines the situation with informal settlements in Tanzania as follows:

> "These [informal settlement] areas are characterized by a lack of basic infrastructure and the ever-increasing poverty of their residents means that many do not have the ability to pay for services. Many urban residents cannot afford housing, and authorities themselves have few resources with which to improve or maintain infrastructure and services. Consequently the housing, health and environmental conditions in the growing informal settlements of Tanzania's cities are extremely poor"
>
> (World Bank 2002, p.7).

According to UN-Habitat (2010, p.7) the public authorities in Dar es Salaam cannot cope with the large demand for housing, and today, as much as 80 per cent of the city's population live in unplanned areas. These unplanned settlements continues to grow, since planned land does not meet the demand in terms of quantity, price and location.

The planning in Dar es Salaam has been mainly centralised and lacking to follow set plans and regulations and to organize the needs of informal settlement dwellers as well as the management of the environment. As a result of this, and the rapid population growth, the city is now struggling with spatial disorder, poor infrastructure and inadequate city planning (UN-Habitat 2010, p.17).

RECONSTRUCTION OF MSIMBAZI FLOOD PLAIN

One of the urban rivers in Dar es Salaam that is currently facing severe problems due to the rapid urban development, pollution and flooding, is the Msimbazi River. It flows across Dar es Salaam city, north of the Central Business District and discharges into the Indian Ocean. The flood plain environment is severely degraded and pollution levels in the river have reached such high percentages they can no longer provide basic functions needed by the population (GIZ water programme, 2014).

The seasonal rains, in combination with a lack of infrastructure and clogging of drainage channels and streams, also causes large problems with floods in the area (WGA, 2015). The natural flood plain surrounding the Msimbazi river has historically been vegetated and thus managed to handle the large amounts of excess water that enters the areas during rain seasons. However, due to the recent urbanization and lack of planning, large parts of the flood plain have been built upon. These dwellings are mainly informal settlements which get flooded every year, forcing the inhabitants to evacuate.

Despite these problems, the central location of the Msimbazi flood plain makes it an important area for housing and social gatherings while at the same time providing the city with much needed vegetated space. Due to its location and the fact that the river still has not been channelized or restrained by walls, it provides valuable opportunities for improving both environmental, social and recreational factors. A reconstruction of Msimbazi flood plain could also restore its function as a retention area for floods, enhance the ecological functions and make it a better environment both for wildlife, vegetation and humans, as well as become a sustainable public green space for the citizens of Dar es Salaam.

Photo. *Solid waste dumped in and around the Msimbazi River.*

OBJECTIVE OF STUDY

The objective of this study is to present strategies for design and to make a design proposal for a specific part of the the flood plain surrounding the Msimbazi River in Dar es Salaam. The thesis will focus on managing flood water, decreasing pollution levels in the water and soil, and restoring the riverine ecosystem. The aim for the design proposal is to create a multi-use green space which combines all of these aspects as well as important social and recreational functions.

The project is meant to work as a strategic intervention to a part of the river, that in the future might be implemented and replicated at sites with similar conditions and challenges.

Within this thesis, a combination of theoretical and practical knowledge is used in order to achieve a sustainable design. To help answer the main research question, two complementary questions are used.

RESEARCH QUESTION:

How can an urban watercourse, such as a part of the Msimbazi flood plain, be transformed into a blue-green space that prevents damages of floods and enhances ecological and social functions?

- *How can an area surrounding an urban river be designed to minimize the effects of floods?*
- *How can damage from pollution in water and soil be reduced?*

LIMITATIONS

The main aspects of this thesis are flood water management, restoration of urban rivers, reduction of pollution in urban rivers and multi-use spaces, which have steered the content of the thesis. The extent of problems in the Msimbazi River Valley area has enforced a selection regarding which ones to be in focus. Problems on a governmental scale, such as regulations of pollution discharge and land use or solid waste management, will therefore not be considered in this thesis.

The thesis focuses on the last part of the Msimbazi flood plain in Dar es Salaam, and is not aimed to present a solution to the whole river system, thus limiting the ecological improvement to those addressable on the chosen site. These methods could then be replicated to other sites in the future to sustain a large beneficial impact on the overall river water quality. The specific site along Msimbazi River was selected from site visits and according to criterias decided in the beginning with the work with the thesis. The criterias were; a site affected by seasonal floods and urbanization, central position in the city and informal use of it as public space. The site is limited to the flood plain and by infrastructural barriers such as roads.

Regarding the design proposal, illustrative plans, sections and visualizations are made to describe and explain the design. Focus is on showing functions, design strategies and examples, rather than detailed solutions.

TARGET GROUP

The aim of this thesis is to provide examples, knowledge and inspiration for landscape architects, landscape architecture students, municipalities and other stakeholders connected to restoration of urban rivers and flood management design. In order to reach an international audience and make it understandable for people in the country of the chosen site, Tanzania, the thesis is written in English.

EXPLANATIONS

BRT - Bus Rapid Transit. The new rapid bus system currently under construction in Dar es Salaam.

Flood plain - "An area of low-lying ground adjacent to a river, formed mainly of river sediments and subject to flooding" (Oxford Dictionaries, 2015).

MFS - Minor Field Study. A scholarship program for field studies in developing countries sponsored by Sida. The MFS scholarship is intended for students at Swedish universities to collect information to their bachelor or master thesis for a period of 8-10 weeks. The purpose is to provide the students with knowledge of developing countries and their issues (Sida, 2014-06-30).

Msimbazi flood plain - In this thesis used as a definition for the area around the Msimbazi River which is prone to flooding - it is also the area in focus for this thesis.

Msimbazi River - In this thesis used specific as a definition when talking specifically about the river.

Msimbazi River Valley -In this thesis used as a definition for the area that includes the whole stretch of Msimbazi River, the floodplain and also parts around the river which do not flood but still can be seen as a part of the area belonging to the river.

Phytoremediation - Biological cleaning of polluted water or soil by the use of plants.

Sida - Swedish International Development Cooperation Agency. "Sida is a government agency working on behalf of the Swedish parliament and government, with the mission to reduce poverty in the world" (Sida, 2014-06-27).

Stormwater - "Surface water in abnormal quantity resulting from heavy falls of rain or snow" (Oxford Dictionaries, 2015).

UN-habitat - United Nations Human Settlement Programme. A United Nation programme with the mission to promote development of human settlements that are socially and environmentally sustainable (UN-habitat, 2015-11-14).

Waste water - "Water that has been used in the home, in a business, or as part of an industrial process" (Oxford Dictionaries, 2015).

METHODS

As it is hard to find a singular method suitable for a project like this, a mixture of several methods have been used in this thesis. The multiple methods have enabled several combinations of theory and practice that could be used in different parts of the project. The thesis consists of five parts; 'Introduction', 'Msimbazi', 'Conceptual framework', 'Design' and 'Autro', together with the full 'Design proposal' which is presented separately.

WORK PROCESS

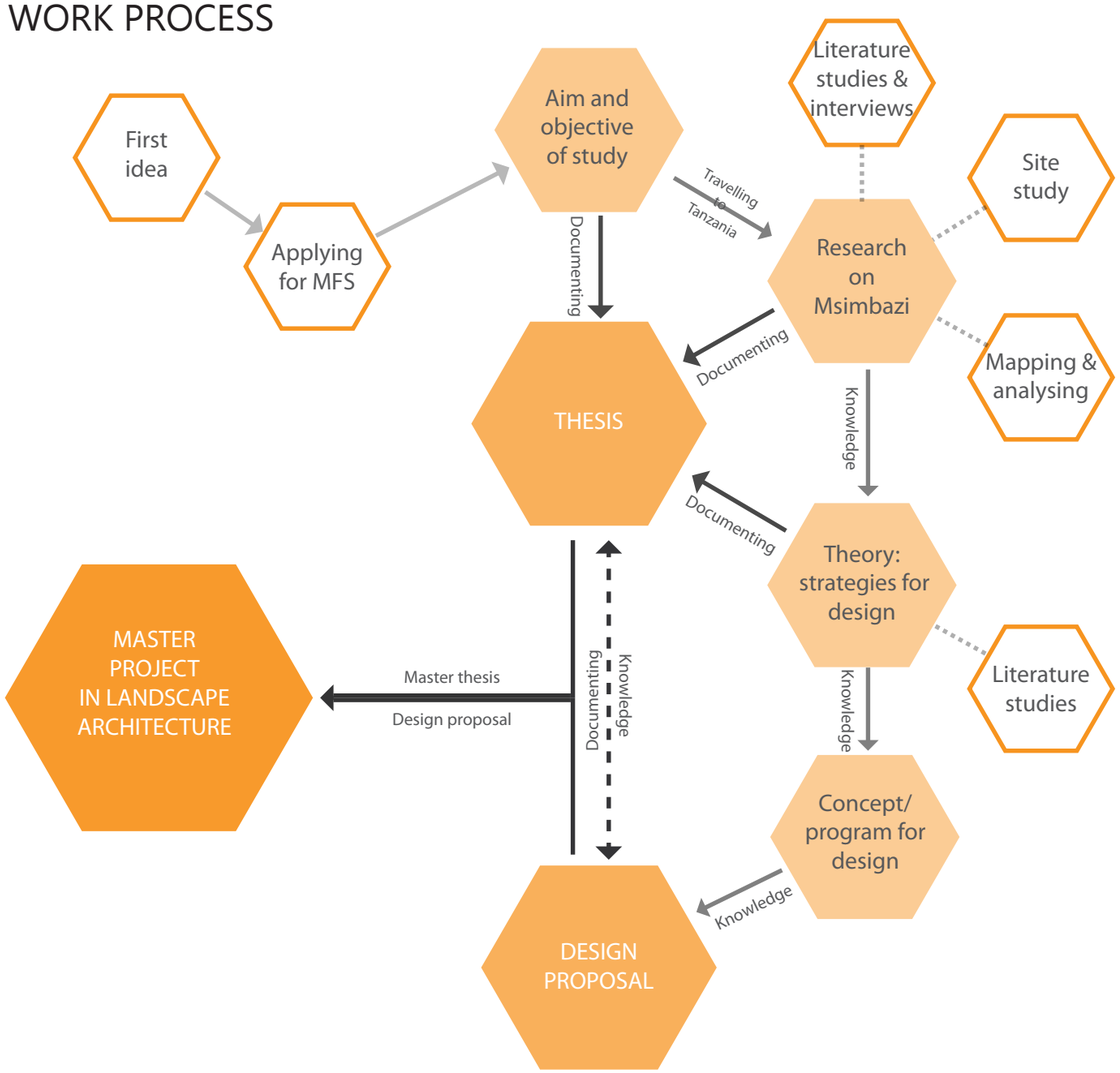


Figure explaining the work process of the project.

LITERATURE STUDIES

There were two main purposes of the literature studies; firstly to collect information and develop an understanding about Tanzania, Dar es Salaam and the context of Msimbazi River Valley with its previous and current situation. Secondly, to find strategies on how to solve the weaknesses and enhance the strengths identified in the SWOT analysis. In the second study, four research themes were used; *Restoration of urban river systems*, *Flood water management*, *Pollution reduction in urban watercourses* and *Turning floodplains into multiple-use spaces.*

The collected literature comes from articles, reports, theses and books, mainly in electronic form. The literature studies started off with searches on the sites Libris, Epsilon, Primo, Google scholar and Google for sources relevant to the topic. The search was useful in order to find recently published sources and the found references in the literature were checked, leading to other sources on the subject. The following search words and combinations were used; floodings +"urban rivers", 'Msimbazi river' (+'Dar es Salaam'), 'Msimbazi river' (+ pollution), phytoremidation, pollution in urban rivers, 'urban rivers', watershed+'Msimbazi river'.

As a complement, the contact persons at Ardhi University, Dr Daniel Mbisso and Phd Student Jaffar Jongo were consulted and provided some relevant literature, articles, photographs and maps.

SEMI-STRUCTURED INTERVIEWS

As there is very little information written and published about Msimbazi River and the river valley, complementary information was gained through semi-structured interviews with Phd Student Jaffar Jongo at Ardhi University. As Jaffar is focusing on the watershed of Msimbazi River in his PhD thesis, which has not been published yet, he is well experienced in the subject and the Msimbazi River Valley. Through these interviews, a starting ground for a deeper understanding of Msimbazi, its complexity, surroundings and problems, was conducted.

The interviews followed a semi-structured interview technique, which according to Bryman (2011, p.206) is a technique where predetermined themes and questions are brought up but also leaves room for attendant questions and the possibility for the respondents to freely formulate answers and bring up issues. By using a qualitative interview technique, focus is aligned to the respondent's point of view and hence is more flexible than a quantitative interview, which is reflecting the researcher view (Bryman 2011, p.413).

Before the interviews these following themes were predetermined:

- What is Msimbazi; past, present and future?
- Effects of seasonal floods; To what extent? When? Consequences? Affected areas?
- Main problems within Msimbazi flood plain?
- Planning documents, stakeholders
- Informal settlements – unplanned areas
- Pollution, pollution sources, solid waste dumping

SITE STUDY

The chosen site for this study was introduced by our contact persons at Ardhi University in Dar es Salaam, Dr Daniel Mbisso and PhD Student Jaffar Jongo. The site was selected due to its exposure to seasonal floods, urbanization, central position in the city and the informal use of it as public space.

Site visits

The purpose of the site visits was to get familiar with the chosen site. The main site visits were accomplished during a four-day period, where the floodplain and each of the residential districts surrounding the Msimbazi flood plain in the area of study - Magomeni bondeni, Suna, Hanna Nassif, Upanga and Jangwani - were visited. (For full Site visit schedule, see Appendix). During the site visits, following aspects were in focus; flood levels, vegetation, microclimate, topography, public and housing areas, the position of the river and surrounding wetlands, paths and use of the area. Focus was also on the effects of floods historically and at present, and how residents within the areas are affected by living with floods.

The field research was conducted together with a local guide; an architecture student from Ardhi University, Gloria Mtei. She was originally helping a Keny-

an student of architecture from the University of Nairobi, Mwanaisha Sakwa, who is doing a housing project in the same area of the Msimbazi flood plain. They both speak Swahili and were thus able to help with translation and interaction with the local residents.

Additionally, we were given the opportunity to join a local non-profit organisation, Center for Community Initiatives (CCI), in their work with taking coordinates of the river position during one whole day. This made it possible to walk along both sides of the river in the downstream flood plains between Morogoro Road and Ali Hassan Mwinyi Road, a large part of the site which would have been impossible to enter without their help.

Spontaneous dialogues

During the site visits, interaction with the users and residents of the Msimbazi flood plain enriched the research with invaluable stories about the area, opinions on the current situation and future, floods and the everyday life along the river. These spontaneous chats contributed to the overall understanding of the public life in Dar es Salaam and Msimbazi River Valley in particular. An understanding of how people get affected by the floods, what they think about their neighbourhood and what they wish it to look like in the future was also gained.

MAPPING AND ANALYSING

In order to better understand the site and its components, the site was mapped and analysed. The mapping and analysis was based on information gathered during the site visits and complemented by semi-structured interviews and literature.

The mapping enabled a better understanding of existing structures, patterns and land use, by focusing on specific aspects in order to address the most prominent issues of the site. Following aspects were mapped: t*opography*, *water levels during floods*, *land use*, *residential areas* and *pollution sources*.

To gain deeper knowledge about the site and to enable identification of problems and possibilities, the site was analysed based on the SWOT method.

SWOT analysis

The SWOT analysis is a model to identify and categorise characteristics and variables, in this case for a certain site. The characteristics and variables are categorised into *Strengths*, *Weaknesses*, *Opportunities* and *Threats*, where Strengths and Weaknesses are internal factors and Opportunities and Threats are external (Boverket 2006, p.44).

DESIGN PROCESS

After the SWOT analysis was conducted, some of the identified weaknesses and strengths were chosen to be in focus for the design proposal. Together with the analysis, mapping, literature studies and inspiration from overall impressions, feelings, traditional works and patterns of Dar es Salaam, a concept was developed. The concept then steered the direction of the design proposal together with the design theories that were conducted during the second part of the literature studies.

The design process is not a linear process, it has been an ongoing process since the start of the project through sketching and developing ideas, however, the main part of the design work was conducted when the site visits, mapping, analysing and mostly of the literature research was done.

Strolling through thick vegetation of different heights during the site study.

Pen, paper and camera at the ready.

Mapping and analysing at Ardhi University.

Afternoon traffic situation when riding the Dala dala (local bus).

Exploring a Mangrove Swamp.

2 MSIMBAZI

Part two presents the Msimbazi River and flood plain, its problems and possibilities, as well as the everyday life of the people living and using the area. It includes the result of both literature study, site study, mapping and analysis

PART 2 CONTENTS

Photo. *Informal settlements surround large parts of the Msimbazi River and flood plain.*

CURRENT SITUATION

This part aims to present the geographical situation, context and the complexity of the Msimbazi flood plain.

CONTEXT: DAR ES SALAAM

Dar es Salaam is the largest city in Tanzania located on the east coast of the country, bordering the Indian Ocean. The city stretches about 100 km from beyond the Mzinga River in the south to the Mpiji River in the north (Pan-African START Secretariat et al. 2011, p.18). Dar es Salaam was established in 1862 and is the national centre of industry, education and culture in Tanzania (UN-Habitat 2009, p.6).

Climate

The climate in Dar es Salaam is tropical wet and dry, with two distinct rain seasons: the long rains which fall from mid March to late May, and the short rains that fall from mid October to late December. Average annual rainfall is approximately 1100 mm. Dar es Salaam has a mean annual maximum temperature of 30,8 degrees and a mean annual minimum temperature of 21,3 degrees (Pan-African START Secretariat et al. 2011, p.19). As Dar es Salaam is located in a river delta, many areas of the city suffer from flooding and stagnant water during the rain seasons.

During dry season, there is often a shortage of water and drought is a common threat for agriculture even in the downstream flood plain area.

Blue-green infrastructure

Cluva (2013, p.36) uses Urban Morphology Types (UMT's) to describe the city structure and distribution of land uses within Dar es Salaam. Eleven different high level UMT's are used; Agriculture, Vegetation, Mineral workings and quarries, Recreation, Transport, Utilities & infrastructure, Residential, Community services and Retail, these are then subdivided into 43 more detailed UMT's.

According to this mapping, the Vegetation UMT includes different types of natural vegetation, such as forests and bushland, but also riverine vegetation and rivers. The Recreational UMT consist of a more diverse mixture of parks and sports areas as well as beaches and hotels. The recreational UMT stands for a total of 0,7% of the city structure. The amount of park area is about 6 % of the total recreational UMT, which means somewhere around 0,042 % of the total city structure (Cluva 2013, p.36).

The green infrastructure in Dar es Salaam is also used by local communities for a wide range of other purposes such as allotments, gardens and orchards. People in low-income areas often rely on these urban ecosystems to make a living, by provision of food and clean air and water. Therefore, degradation and loss of green spaces are strongly felt, particularly in these areas (Cluva 2013, p.44). According to Cluva (2013, p.39), riverine, bushland and rivers are the UMT's which provide the most ecosystem services in Dar es Salaam, but they cover only around 5 % of the city structure today. Since the need for these ecosystem services is higher than the current provision, the green and blue structures of Dar es Salaam needs to intensify existing services or increase the amount or size of areas where these services can be provided (Cluva 2013, p.38).

The quality of the green structure is also important as it provides temperature regulation services (2013, p.41). Dar es Salaam also have to consider surface urban heat island as the temperature increases with climate change. The greatest increase in temperature is generally experienced in the built UMT's, while the scattered settlements and apartment areas have the best regulated temperatures due to higher proportions of green structure (Cluva 2013, p.41). With an expanded green structure cover in the urban area, future local temperature increases can be minimized at the same time as other benefits such as shade can be provided. Sea breeze is another important resource to reduce temperatures in Dar es Salaam.

One of the main processes that decreases the green infrastructure is the increase of built structures and the densification and upgrading of existing scattered settlement areas. The largest losses of green infrastructures occurs in the outskirts of the city, as that is where there is unexploited land, but losses also occurs in more central locations. Cluva (2013, p.46) argues that attractive areas for urban development could be used more efficiently in the future by promoting high density settlements, which would lead to fewer losses of green areas. However, these densification strategies would have to be placed in areas which are not prone to flooding.

Plans for urban development

The existing Master Plan for Dar es Salaam was implemented in 1979 and was intended to run until 1999, but no new plan was developed to follow. Several years later, there were initiatives to form a new master plan that would run from 2012 until 2032. There is a draft of this plan but it is still not implemented, which means that today's planning in Dar es Salaam still rely on the master plan from 1979. There do exist Redeveloping plans for specific smaller areas which are implemented and guiding the urbanization in the absence of master plan[1].

In October 2007 the prime minister of Tanzania launched the Citywide Strategy for Upgrading Unplanned and Unserviced Settlements in Dar es Salaam. The goal with the plan is to upgrade 50 percent of all existing unplanned and unserviced areas by 2020 and also to prevent formation of new unplanned settlements in Dar es Salaam (UN-Habitat 2010, p.33). One part of this strategy is regularisation of unplanned areas.

MSIMBAZI FLOOD PLAIN TODAY

Msimbazi River is the longest river in Dar es Salaam, but in terms of catching area of water, it is the second after Kizinga River. It flows across Dar es Salaam city center from the higher areas of Kisarawe region west of the city and into the indian ocean. Several contributional rivers flows into the Msimbazi River, two of them are Ubungo River and Sinza River (locally known as Ng'ombe which means "cow dung" in Swahili), which are joining the main river from the north[1].

The flood plain of Msimbazi is a natural flood retention basin which has been an important resource for the citizens of Dar es Salaam for a long time[1].

Urbanization of Msimbazi

Since the 1980-90's, Dar es Salaam has experienced a strong urbanization due to the establishment of the free market economy in 1985. The peak of the housing expansion occurred during a period of five years in the beginning of the 1990's, which put a lot of pressure on the areas surrounding the urban parts of Msimbazi River[1]. Before this period of time, these areas had formed an unexploited flood plain, working as a buffer zone for the excess water during the seasonal heavy rains. However, with the strong urbanization, the city became crowded and a lot of people that came searching for a home could not afford to buy plots in the planned areas of the city. Instead, they settled on the empty flood plain, built their houses and started small scale farms, growing seasonal crops[1].

In the Master Plan from 1979 the area around Msimbazi River is identified as 'Hazard Land', a category which includes areas that are subject to seasonal flooding, erosion and other physical limitations. In these areas, no structures of any kind are permitted and the areas are suggested for outdoor recreation, agriculture and salt operations (Monoghan 1987, p.103). In the, not implemented, *Dar es Salaam Master Plan 2012-2032*, the Msimbazi flood plain is identified as 'Contaminated hazard land' and as an area of environmental protection and is hence proposed to be used as playground or open space (Moss et al. n.d., pp. 46-47). The draft also classify the Mangrove forest as 'natural areas to protect' and the flood plain as 'wetland to protect' (Moss et al. n.d., p. 71).

Since the flood plain was written off as unuseful and hazardous, and simply claimed to be kept empty, there was no protection of the water and the land surrounding. More people came to the area and the farmers started to subdivide their lots and sell it to other people. Even though this was not permitted, there were soon large groups of people living in these flood prone areas and the authorities had not managed to control it[1].

The Msimbazi flood plain has continuously been reduced ever since the first settlers built their houses on it. This is due to land-based urbanization in combination with elevation of land through sedi-

[1] Jaffar Jongo, PhD fellow at AHO and lecturer at Ardhi University, Interview, 2015-09-25

mentation and solid waste dumping. On the east side of Morogoro Road, the flood plain has in recent years been violated by the construction of the new Bus Rapid Transit (BRT). A large portion of the land has been elevated by dumping of excess soil from the project, and another part was elevated to house a garage for the new buses, which was constructed in 2012[1].

Floods and Msimbazi

Dar es Salaam has several areas prone to urban and coastal flooding and the Msimbazi River Valley is one of these areas (Pan-African START Secretariat et al. 2011, p.75). Flooding data in Msimbazi River was started to be recorded in 1983 and according to Jongos'[1] predictions, this was when the first built structures within the flood plain appeared and there suddenly were people and houses affected by the floods.

As mentioned before, this natural flood plain has become widely reduced through the years. Hence, the area that can manage flood water has been largely decreased at the same time as sea level rise and increasing amounts of waste water from the city results in larger volumes of water for the flood plain to manage. Naturally, this pushes the water further out and causes overflows in adjacent places, mainly to larger parts of the informal settlements on the edges of the flood plain.

According to Pan-African START Secretariat et al. (2011, p. 25) it should be stressed that the flooding along Msimbazi River is not just an effect of extreme rainfall, it is actually largely a function of poor waste disposal and inadequate stormwater management. Even in dry periods, parts of the Msimbazi Valley tend to flood, due to clogged channels, pipes and bridge passages along the river (Pan-African START Secretariat et al. 2011, p.57).

Climate change poses another threat to the flood plain of Msimbazi and some of the flood plain have already been lost to sea level rise. The seawater colonization occurs at the river mouth, where seawater penetrates into the flood plain during high tide[1].This means there is even less space available for the rain water during the heavy rains. If the sea level continues to rise, the floods might increase even more in the future. Another consequence of the sea water colonization is high salt levels in the soil used for farming[1].
On the other hand, Dar es Salaam is also subjected to drought between the rain seasons as a result of increased temperatures. It is especially the agriculture and food production that is affected during the drought season as water resources are reduced (World Bank n.d., p.14).

Pollution of Msimbazi

The pollution of the Msimbazi River is a part of everyday life on all levels of society; regular people throw their garbage in the river, industries sends their discharge straight out into the water without filtering it and the authorities have put solid waste dumping sites beside the river for almost a century[1]. This has left the Msimbazi River among the most polluted water bodies in the city of Dar es Salaam.

According to analyses, it contains high levels of heavy metals, run-off from local industries, pollution from domestic households and pesticides (Blacksmith Institute, 2015). The polluted water is both an environmental and health hazard; it neither provides clean water for those living along the river, nor supplies a suitable environment for its own aquatic life.

According to Jongo[1], there are four main pollution sources in the Msimbazi River;

- solid waste deposition
- waste water from industries
- waste water from households
- stormwater from the city

There are also four large waste water stabilisation ponds in Dar es Salaam which receive waste water from industries and residential areas, two of which are situated in the valley of the Msimbazi River (Pan-African START Secretariat et al. 2011, p. 59). During rain season, these ponds also get flooded which means that the waste water is mixed with the rest of the water in the river before it has been cleaned.

Solid waste - Problems with solid waste in Dar es Salaam stretches far beyond the flood plain of Msimbazi. For one, there is no overall system for collection of solid waste in the city. The collection of waste is privatised and run by several different actors (World Care n.d., p.7). According to World Care (n.d., p.7) it operates inefficiently and does not cover all parts of the city. As a consequence of this, only 23% of the solid waste in Dar es Salaam is disposed at the main dumping site, the rest is burnt in piles on the streets or simply thrown away, ending up in drainage channels, streams and rivers (World Care n.d., p.7).

The main dumping site used at present is the crude dump in Pugu, it has been open since 2009. Previously the dump at Vingunguti was used, operating between 1965-1992, and situated next to the Msimbazi river. As a consequence of this, a lot of the waste end up in Msimbazi flood plain and follow it to the ocean and there is no separation of hazardous waste which leaves the ground water contaminated (Breeze 2012, p.18).

The Msimbazi flood plain itself is also being used as a gigantic, unofficial dumping site for solid waste from households in nearby areas. In the informal settlements, solid waste is also piled up along the river banks as an attempt to reduce the impact of floods (Pan-African START Secretariat et al. 2011, p.58). All of these factors contribute to the flood plain now housing contaminated water, polluted soil and large amount of waste spread out across the whole of the flood plain.

The City Council has, according to World Care (n.d., p.7), earmarked a few other places for disposal of solid waste, most of them also next to rivers or watersheds in Dar es Salaam.

Waste water from industries - Pollution of the urban rivers in Dar es Salaam is also caused by industries discharging untreated effluents directly to the nearest water courses, such as stormwater drains and streams, which eventually ends up in the ocean (World Care n.d., p.6).

When it comes to the Msimbazi River, the main pollutants are the industries along Nyerere Road industrial area (e.g. the slaughterhouse Vingunguti abattoir), Morogoro Road, Mandela Road, Tanzania Breweries Ltd and lechage from the above mentioned Vinguntinguti crude dump. In the Jangwani area, there is also a car washing facility right next to the river, which discharges dirty, oil-mixed water straight into the river (World Care n.d., p.6).

Tanzania Breweries, situated in Kariakoo south of Msimbazi flood plain, is letting out waste water into a channel flowing through the informal settlement of Jangwani before leading out to the river. The newly built Muhimbili Hospital also have drainage channels for waste water flowing out into the Msimbazi flood plain[1].

Waste water from households - The sewage system in Dar es Salaam was constructed in the 1950's, it is degenerated and only serves about 15 % of the city. This leaves about 80% of the households using on-site septic tanks or traditional pit-latrines (World care n.d., p.6). In the informal settlements on the Msimbazi flood plain, most households rely on pit-latrines and in other cases, the disposing of sewage is managed through open channels leading straight to the river unfiltered (Pan-African START Secretariat et al. 2011, p.58). During floods, the contents of the pit-latrines and open sewage systems are carried off and mixed with the rest of the water.

Stormwater - Disposal of sewage directly to Msimbazi River is common, and Msimbazi River has become a large outlet for storm water from different parts of the city. In Jangwani, the waste water channel from the brewery also carries stormwater from the area of Kariakoo.

The people of Msimbazi - Informal settlements

Most of the Msimbazi flood plain is regarded as non-residential land and the residential neighbourhoods at the edges of the flood plain mostly sustain of informal settlements. The residents of these areas are highly affected by the floods, the waste dumped at site and the polluted water.

Pan-African START Secretariat et al. writes, about the informal settlement of Jangwani area;

[1] Jaffar Jongo, PhD fellow at AHO and lecturer at Ardhi University, Interview, 2015-09-25

[1] Jaffar Jongo, PhD fellow at AHO and lecturer at Ardhi University, Interview, 2015-09-25

> "Due to its susceptibility to environmental threats, the area was declared "not residential" by the former Minister of Lands and Human Settlement Development. However, it is at pre sent highly inhabited, with a mixture of mud, wattle and modern housing constructed adjacent to the filthy sewage-based wetland area of Msimbazi River".
>
> (Pan-African START Secretariat et al. 2011, p. 58)

Every year during the seasonal rains, the residents of the informal settlements on the Msimbazi flood plain must be evacuated from their homes due to the excessive floods. The residents usually put all of their things on the roofs of their houses and evacuate to higher ground. Some stay with relatives and some are given shelter in nearby establishments such as schools. After the water washes away, they return to restore their house and start all over again. Since the flood water is very turbid, large amounts of sediment sets in the flooded areas every year, leaving the ground level more elevated after each flood. In some areas, houses have had to be abandoned simply because they have been filled to the ceiling with sediment.

The inadequate management of solid waste and sewage water in combination with the floods also contributes to the spreading of diseases in the informal settlements. Apart from the drinking water being contaminated, clogged drains also lead to a stagnation of the polluted water which offers an efficient breeding ground for mosquitos. This increases the spreading of malaria as well as water borne diseases such as dysenteriae and cholera (Pan-African START Secretariat et al. 2011, p.62). The informal settlement of Jangwani suffered from a large cholera outbreak as recently as in autumn 2015.

Despite all the problems in the area, new residents continue to arrive. According to Pan-African START Secretariat et al. (2011, p.58), the Kinondoni part of Msimbazi River Valley even houses some of the fastest growing settlements in Dar es Salaam. They mention aspects such as closeness to the city centre, cheap house plots and inadequate enforcements of land-use regulations, as reasons for this development. Lack of reasonable alternatives seems to be one of the largest reasons for the people already living in the Msimbazi informal settlements to return every year. Most of these residents can barely afford food for the day, even less to buy a plot somewhere else. According to World Bank surveys in 2002, almost half of the residents in the informal settlements of Dar es Salaam considered themselves poor or very poor, and as much as 75 % were unemployed or under-employed (World bank 2002, p.8).

Photo. *People stranded in an informal settlement during a flood in the Msimbazi area. Photo: Jaffar Jongo, 2011.*

SITE SURVEY

The site survey includes information gathered during the site visits and the subsequent analysis of this information. The site is presented with pictures, maps and complementary text explaining the perceived current situation.

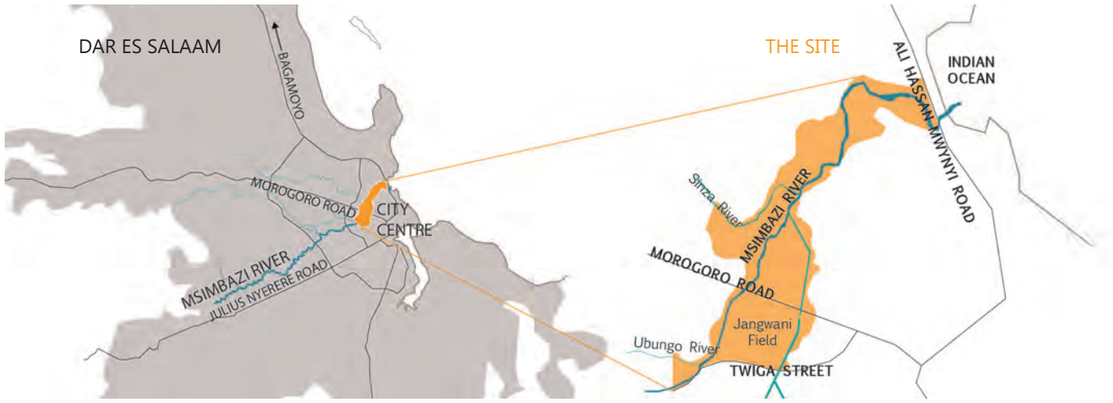
SITE LOCATION

The chosen site for the design proposal is the flood plain of the last part of Msimbazi River Valley, just before the river mouth escapes into the Indian Ocean. This site is situated very central in Dar es Salaam, between Twiga Street and Ali Hassan Mwinyi Road. Morogoro Road, which runs through the south part of the site, together with Ali Hassan Mwinyi Road, are two of the major road connections between the city centre and the rest of the city. The chosen site also includes the Jangwani field, mainly used for football but also as an important meeting point, widely used for demonstrations, ceremonials and similar events that gathers large amounts of people, as it is the largest informal public space in Dar es Salaam[1].

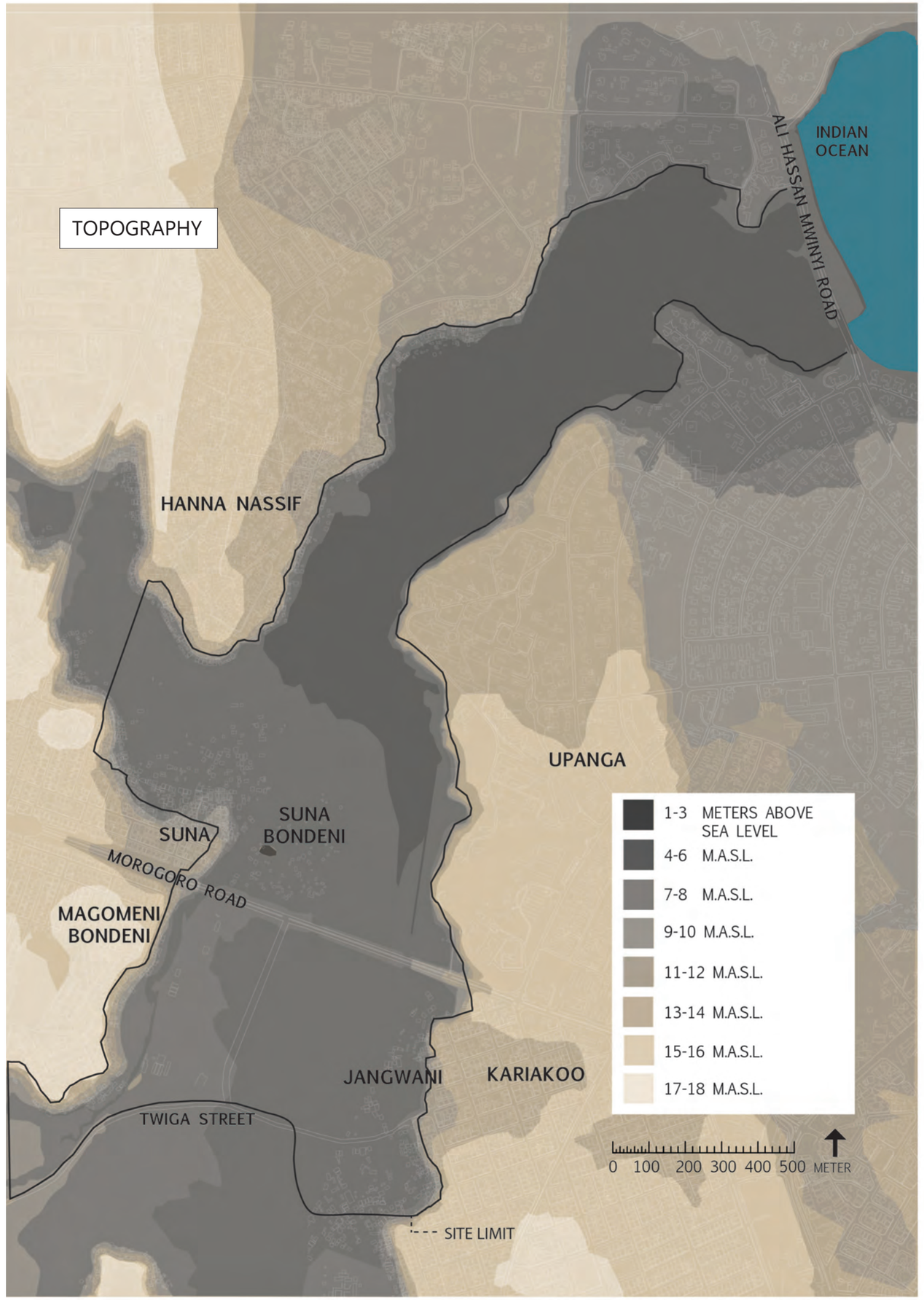
Due to its central location and the newly built Bus Rapid Transit system at Morogoro Road, the chosen site has potential to bring a lot of citizens to visit and use the site. Furthermore, it is an important blue-green link between the Indian Ocean and the rural landscape west of Dar es Salaam.

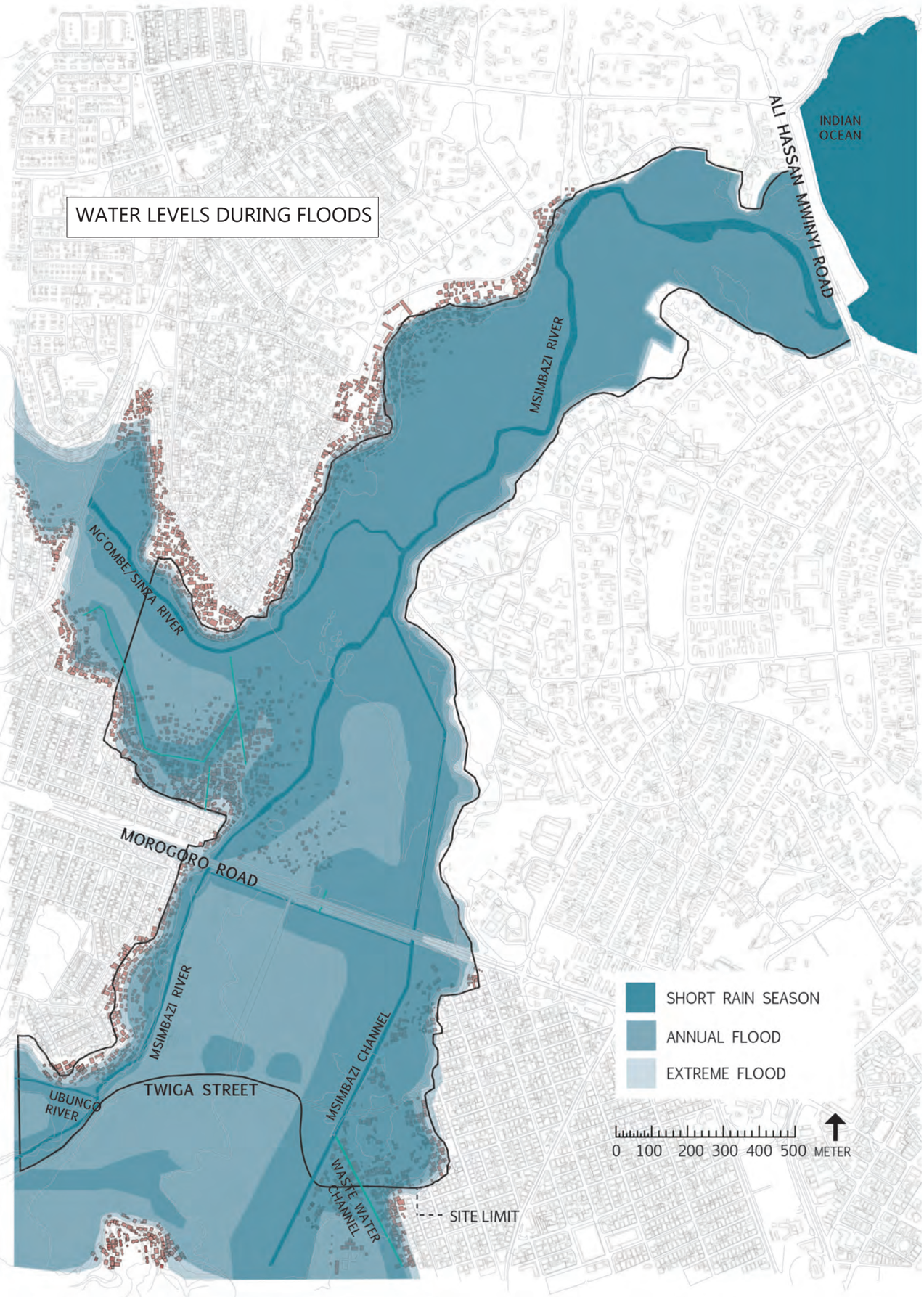
Engaging with local residents during site visits in Magomeni Bondeni.

[1] Jaffar Jongo, PhD fellow at AHO and lecturer at Ardhi University, Interview, 2015-09-25.



Map showing the chosen part of the Msimbazi flood plain and its location within the city of Dar es Salaam.





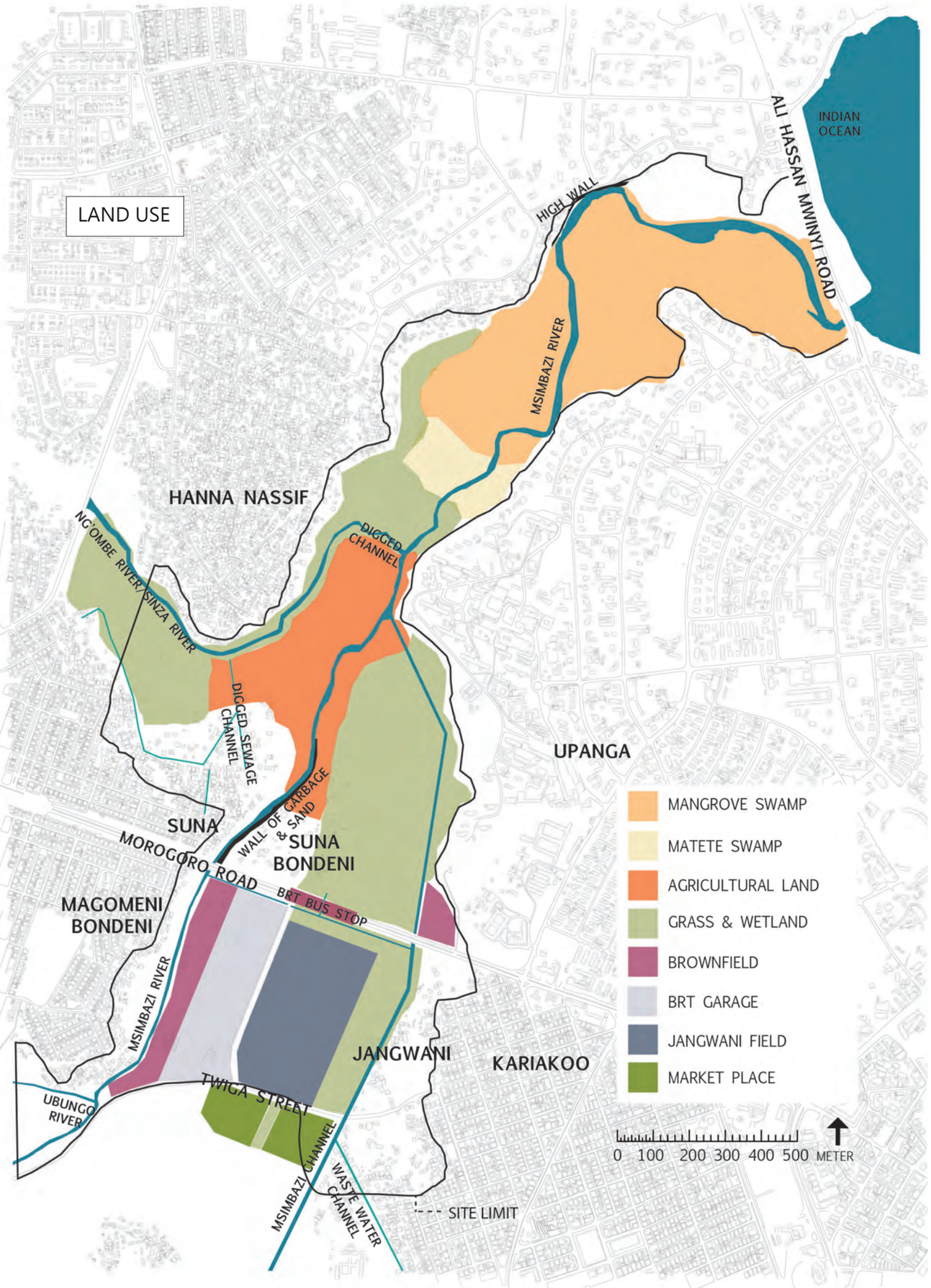
WATER LEVELS DURING FLOODS

The flood plain between Morogoro Road and Ali Hassan Mwinyi Road is the last outpost of the water before it discharges into the Indian ocean. This is also the first part of land to be flooded when the rains starts, and large parts of the plain is wet all year round. Due to its location by the sea, it will also be the first area to feel the impacts of sea level rise in the future.

Flooding along the Msimbazi River. Photo: Jaffar Jongo, 2011.

Extreme flood level in Jangwani area. Photo: Jaffar Jongo, 2011.

Flooding along the Msimbazi River. Photo: Jaffar Jongo, 2011.



LAND USE

Mangrove Swamp - the part closest to the sea. It is not accessible to the general public due to its ground cover of wet mud and large parts of it being under water for most of the year. The swamp houses mainly a dense vegetation of mangrove trees and is also home to a lot of crabs, mosquitos, spiders and various types of insects living in the mud. At the same time, it is a cemetery for a decade of garbage from the citizens of Dar es Salaam. As you move upstream along the river from the ocean, the levels of water in the mud decreases and the amount of garbage disposed increases. The part which houses most garbage is the part right before the Mangrove Swamp transcends into the Matete Swamp area.

Matete Swamp - a partly wet area with stagnant water throughout the year, mostly due to waste- and stormwater outlets being located nearby. It is mostly vegetated by the high Matete grass but includes a few wetland species, such as Water Lily, and a some smaller trees and shrubs. There are also a few dead mangrove trees and lots of garbage. The area is difficult to reach and not accessible to the public.

Grass and Wetland - several areas around the site next to the agricultural area is characterized by grasses of different heights, smaller trees and shrubs mixed with patches of agricultural land and escaped cultivated plants. Parts of the areas is wet with stagnant water, primarily next to watercourses.

Agricultural Land - large parts of the area are used by the local inhabitants for growing vegetables such as cucumber, corn, pumpkin, tomatoes and sugar cane. The soil in which the plants grow is highly polluted and the whole area houses large amounts of garbage sprinkled across the plain. In between the agricultural patches are grasses, trees and shrubs.

BRT garage - formerly a part of the Jangwani Field, the area now houses a garage and parking space for the future Bus Rapid Transit system. The actual building is located in the northern part, close to Morogoro Road, and the rest of the area is an asphalt covered parking lot. The whole area is closed off with a high wall, which is supposed to protect the garage from floods. However, even if the wall holds off the water, the surroundings will be flooded, leaving the garage an isolated island.

Brownfield Site - this abandoned stretch of land between the Msimbazi River and the BRT garage used to house industrial activities which were later relocated due to the problems with flooding. There are still remnants of an old wall that was constructed to protect the area from flood water. This worsened the flood problems on the oppositely situated Magomeni Bondeni area, until it eventually gave in to the water pressure and was destroyed.

Jangwani Field - its everyday function is as a football field, but it is also an important meeting place for large public gatherings such as demonstrations, political speeches and religious events. The ground cover consists of bare soil, sand and with some patches of low grass. Closest to Morogoro Road is remnants of an old channel which is filled with water all year around. Under Twiga Street are two tunnels with adjacent low lands which transports water between the areas during moderate floods

Market Place - on the opposite side of Twiga Street from the Jangwani Field is the Market Place. This area was also elevated during the construction of the BRT garage and is now housing a huge amount of wooden market stalls.

Msimbazi River in the Mangrove Swamp.

Matete Swamp.

Msimbazi River where it discharges into the Indian Ocean.

The Mangrove Swamp; home to crabs, mosquitos and huge anmounts of solid waste.

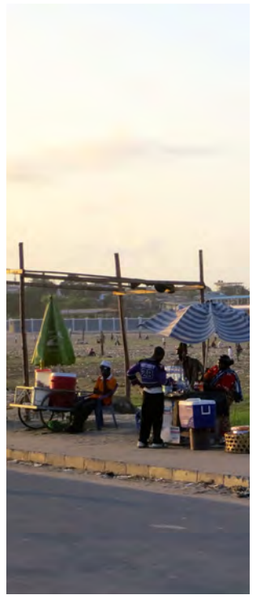
Grass area and housing in Hanna Nassif.

Farming in the lower parts of Magomeni bondeni.

Part of the agricultural land during dry season.

Tomato and pumpkin growing in the polluted flood plain soil.

The grass and wetlands area in Jangwani field houses waste water from Kariakoo and the brewery.



Local vendors on Twiga St.

Walkway across the playing field, on the left is the BRT garage.

People working with plastics at a part of the Brownfield site.

Football practice on Jangwani playing field at sunset.

Elevation of land in front of the BRT garage at Jangwani field.

The market place at sunset, seen from Jangwani field on the other side of Twiga Street.

THE RESIDENTIAL AREAS

There are six residential areas surrounding the chosen part of the flood plain, of which five are informal settlements.

Hanna Nassif - the narrow stretch of houses at the edge of Hanna Nassif is another informal settlement highly affected by floods. It is separated from the rest of the area by a steep slope, which keeps the upper parts safe when the water levels rise. Its structure resembles the one in Suna, from which it is separated only by the Sinza (Ng'ombe) River.

Upanga - the higher elevated district of Upanga is located on the south east side of the river, between Morogoro Road and Ali Hassan Mwinyi Road. It is a planned area situated on higher ground, hence not affected by the floods and separated from the flood plain by steep slopes and walls. Upanga houses the newly built Muhimbili Hospital which is one of the river pollutants in the area.

Suna - on the same side of the Msimbazi River, separated from Magomeni bondeni by Morogoro Road, is Suna. Suna is fairly large and situated on a slope, which leaves some parts of it flooded every year and some parts safe. There is an open sewage channel that discharges right by the Morogoro Road bridge and large amounts of garbage everywhere. In the lower part of Suna, the ground level has been largely elevated since the first residents settled here. The result is houses which seems submerged into the soil, with rooftops at eye level and lowered stairs and terraces in connection to the doors. A lot of the houses have their windows, which were originally about a meter above the ground, now at ground level, and have had to dig away huge amounts of sediment after each flood in order to empty their house. Several houses closest to the river are completely buried in sediment and have been abandoned.

There is also a drainage channel that runs through the lower Suna area, however, most of it is filled with sediment and houses have been built upon the channel. Some of the residents have tried to dig a new channel beside the original one. A large part of Suna is agricultural land upon which people grow vegetables both for their own use and for selling at the market.

Suna bondeni - is situated opposite of Suna, on the other side of the river. It sits right in the middle of the flood plain, beside Morogoro Road. This area is the smallest and has the lowest living standard of all the informal settlements in the flood plain. The houses here are less resilient, most of them are mainly made of metal sheets or pieces of wood. A large part of the area is agricultural land.

Magomeni bondeni - across from Jangwani and the BRT garage, on the other side of the Msimbazi River, is a residential area called Magomeni bondeni. It is a quite narrow stretch of houses squeezed in between the river and the rest of Magomeni, which sits on higher ground. The residents of the area says the floodings have gotten worse since the construction of the BRT and the wall on the other side of the river, it has pushed the water on to their side and the river has eroded the protecting ridge away. There is large amounts of garbage everywhere along the river and some of the residents actually use garbage dumping as a way to elevate the protecting ridge in low parts. Various animals, such as chickens, cats and birds, pick around for food in the floating garbage islands on the edge of the river. In Magomeni bondeni there are a few patches of agricultural land, which the residents use for growing vegetables.

Jangwani - the informal residential area of Jangwani is situated between the elevated planned district of Kariakoo and the lower areas of the playing field and the market place. Straight through the area runs a hard surfaced channel transporting waste water to the Msimbazi River. The water in the channel is mixed with garbage and stormwater which leaves it very polluted. Jangwani is very densely populated and houses are built on the absolute edge of the brewery channel, which makes them highly prone to flooding as well as spreading of waterborne diseases.

Children playing football in Suna.

Residents of Magomeni bondeni attempts to elevate the ridge along the Msimbazi River to protect from floods.

Rooster on top of a garbage pile along the river.

Open waste water outlet from Tanzania Breweries in Jangwani area.

Passage over the Msimbazi river between Magomeni bondeni and the Brownfield site.

Drainage channel in the lower parts of Hanna Nassif.

Blue line marks the flood limit on house in Suna.

Women and children gathered in Magomeni bondeni.

Abandoned house in Suna, submerged in the soil.

The informal settlement of Hanna Nassif bordering the Msimbasi flood plain.

Scattered houses of Suna bondeni, in the middle of the flood plain.

Steep slopes separates the informal flood prone housing of Hanna Nassif from the safe, upper parts of the area.

The informal settlement of Jangwani with the playing field and the BRT garage in the background.

SITE COMPLEXITY

The most striking aspect of the site is its complexity. The many structural issues of the city is blended together with environmental hazards and poverty, all while there is strong feeling of community and hope in the informal settlements. Children are playing everywhere in all of the residential areas; in the streets, along the river and adjacent channels and streams, in large piles of garbage. Animals graze the grasses as well as among the solid waste. Women are laughing, cooking and washing clothes together outside their houses. People harvest corn from patches of farm land. Many residents seem to enjoy life, but when asked about their problems with the river, they do not hold back their despair.

Several NGO's and university research reports state that it simply is not possible to have healthy living conditions in this area and that relocation of the residents is the only available sustainable solution. For example, Shemdoe (2010, p.4) writes in the article "Community based flood risk strategies – research summary"; "The researchers concluded that Msimbazi residents need to permanently relocate in order to protect their lives and property". Considering this, and also that the environmental situation is so severe, relocating the residents to a non-hazardous area where they would not have to evacuate every year, seems like a sustainable solution. However, the complexity in this question is that many of the residents do not think they have any reasonable housing alternatives, and some feel like the authorities only want to get rid of them. According to Jongo[1], there have been relocations of people from some of the areas, where the residents were given a plot with a house in an area a few miles outside the city centre, but many of these residents sold their new plots and moved back. The reason for this might be that the new location was too remote, which made it difficult for the residents to make their daily living as well as afford transport to the city.

Dialogues with the residents also showed that many like the life they have in their area and they simply do not want to move. Some residents have been living in their house for as long as 30 years and the neighbourhood is their home, it is where they have their family and friends. Many also believe that there is a solution to the problem with flooding if only the authorities took action, which also might be a contributing factor to them staying in the area despite the yearly evacuations. The residents generally display a feel of an unjust world, an anger towards the authorities who they feel abandoned by, yet a hope for change and a feeling of a right to be there. Above all, they try to protect their homes and the right they feel they have to live there. This is shown through a general superstition towards strangers and people taking photographs or notes while in the area.

In conclusion, relocation might, at least partly, be necessary in order to create a sustainable housing situation, but it must be remembered that this is not an all-desirable solution. The consequences for the relocated residents is not only a loss of a house, but also a loss of neighbourhood, friends and connections. However, as the environmental issues are so severe, not only posing a threat to the residents of the informal settlements, but also to the rest of Dar es Salaam, keeping things as they are today is not either a sustainable solution. As the situation is so complex, and involves daily life and health of both millions of people and the environment, all of these factors need to be considered in planning and design to create a sustainable future proposal.

[1] Jaffar Jongo, PhD fellow at AHO and lecturer at Ardhi University, Interview, 2015-09-25

CONCLUSION

SWOT ANALYSIS

STRENGHTS

- Large areas are not developed and remain natural

- Potential for well functioning wildlife and enhanced ecosystem functionality

- Farming activities

- Central location

- Poor people can afford to live here and already have an existing community

- Regularly used informal event ground, largest in the city

- Well used sportsfield and market space, brings people

- Potential for multifunctional areas during dry and wet season

- Potential for flood-adapted housing solutions

- Certain areas can help reducing the effects of floods by taking care of water

- Potential to make accessible for recreation

- Green area, green corridor

WEAKNESSES

- Floods, there is not enough space in the flood plain to take care of the water

- Non-functioning ecosystem and few ecosystem services due to human destruction

- Breeding ground for mosquitoes

- Solid waste is constantly being dumped in the river and flood plain

- Elevated areas causing even worse floods

- Polluted soil and water, not suitable for farming, wildlife or human consumption

- Industries discharge polluted waste water into the river

- Surrounding areas not adapted to river dynamics, causing destruction when the river moves and floods

- Lack of regulation of land, no constructions are permitted but there are no consequences for new development

- Non flood-adaptive housing, people need to be evacuated during floods and cannot afford to move elsewhere

- Certain areas are not accessible

- Drought, there is not enough water for farming during dry season

OPPORTUNITIES

- A functional solid waste management system leads to less waste being dumped in the flood plain

- Better bus connections with BRT

- Regulations for pollution discharge and development are implemented

- Residents in flood affected areas wants to move to safe areas

- Cleaning system for waste- and stormwater

- Improved infrastructure (sewage systems etc.)

THREATS

- New developments - new fill up's

- Higher flood levels

- Effects of poverty; diseases, violence etc

- Pollution destroys and kills everything living and growing in the flood plain

- Salt water colonisation rule out farming and aggravates floods

- Increased levels of solid waste and pollution dischargement

SELECTED WEAKNESSES

In order to finish this project within the limits of a master's thesis, the weaknesses to be solved had to be minimized to a few in focus. These selected weaknesses were defined by their relevance to the landscape architecture field of study and if the extent of them was suitable to this thesis. The chosen weaknesses to be solved in this project are:

- Floods, there is not enough space in the flood plain to take care of the water

- Non-functioning ecosystem and few ecosystem services due to human destruction

- Elevated areas causing even worse floods

- Polluted soil and water, not suitable for farming, wildlife or human consumption

- Surrounding areas not adapted to river dynamics, causing destruction when the river moves and floods

- Non flood-adaptive housing, people need to be evacuated during floods and cannot afford to move elsewhere

- Certain areas are not accessible

- Drought, there is not enough water for farming during dry season

ENHANCING STRENGHTS

For the design to be as sustainable and suited to the site as possible, a holistic approach is needed, as well as a focus on, and enhancing of, the strengths found in the SWOT analysis.

The large areal of non-developed land gives a vast opportunity for an overall restoration of the river system, improving the functionality of the ecosystem and by that, improving the water quality as well as the quality of life for plants, wildlife and humans alike.

The central location together with existing social gathering points, such as the Jangwani field and the future BRT bus stop, enhances the possibility for the project site to become a well used public space. Natural green spaces within the flood plain opens up the possibility to make the site multi-functional, letting the green space work as both retention area for flood water, as recreational space for the people of Dar es Salaam and at the same time work as a blue-green corridor between the city and the rural areas outside.

For the people living in the areas adjacent to the river, the farming possibilities provide a natural source of income, and if flood-adapted housing can be applied and the site designed to manage both dry and wet conditions, the Msimbazi flood plain might also be able to contain sustainable yet affordable residential areas.

RESEARCH THEMES

To address the found strengths and selected weaknesses, four main themes for the conceptual framework research was established:

- Restoration of urban river systems
- Flood water management
- Pollution reduction in urban water courses
- Turning flood plains into multiple-use spaces

PRESUMPTIONS

Not all of the identified weaknesses can be in focus for this thesis as they simply need to be addressed on a larger scale. In order to succeed with the solutions for the design anyway, presumptions have been made regarding these weaknesses:

- Solid waste is constantly being dumped in the river and flood plain
- Industries discharge polluted waste water into the river
- Lack of regulation of land, no constructions are permitted but there are no consequences for new development
- Breeding ground for mosquitoes

Solid waste

Dumping sites for solid waste next to the Msimbazi River need to be displaced to where discharge into Dar es Salaam water bodies is minimized. Illegal dumping of solid waste into the flood plain also needs to be stopped for the same occasion. This result can be achieved through a functional, efficient solid waste management system for the city of Dar es Salaam. According to Breeze (2012, p.8) there are existing collection points for solid waste in Dar es Salaam and operations for further transportation across the city, but this system needs to increase in efficiency and strictness.

To enable a sustainable environment that enhances ecological benefits and a functional ecosystem for humans and wildlife, the flood plain also needs to be cleaned from existing solid waste.

Pollution

In order to minimize polluted water in Msimbazi River, discharge from industries, hospitals and likely needs to be filtered before being discharged into the river. One solution could be development of restrictions for discharges into Msimbazi River and regulations regarding waste water purification for industries, on site or in closely situated water stabilisation ponds, before being allowed to let the water out to the river system.

Regulation of land and housing

By acknowledging the flood plain of Msimbazi River, regulating the settlements and implementing and following set plans, future destruction can be prevented.
By upgrading existing informal settlements and prohibit new development of structures, there is a greater possibility to create a sustainable environment that can afford to minimize the destruction of floods. An important aspect of this is to make sure that there are consequences right away if the prohibitions are not followed.

Mosquitoes

The risk of mosquitoes spreading diseases such as malaria is always high in areas with stagnant water in Dar es Salaam. This is not possible to fully prevent in this project, but the risks can still be reduced by a few simple measures.

By regulating the water levels and managing the water to be stored in specified areas, the amount of stagnant water in clogged drains and channels in the residential areas can be decreased Recreational walkways can also be designed to avoid these spaces by elevation or redirection. The choice of plants can also help prevent mosquito presence, as some specific plant species work as mosquito repellent.

3 CONCEPTUAL FRAMEWORK

Part three includes strategies for addressing the weaknesses presented in the end of Part 2 and how these can be applied to the design.

PART 3 CONTENTS

Photo. *Flooded street in Dar es Salaam. Photo: Jaffar Jongo, 2011.*

RESTORATION OF URBAN RIVER SYSTEMS

As mentioned in the background, urban river systems are often ecologically degraded and restrained into small spaces in which the ecosystem cannot develop in a natural way and are hence less resilient to disturbances and future climate changes. These problems are highly acknowledged today and the subject of river restoration is gaining increasing importance worldwide.

There are a number of available strategies to improve the conditions of urban rivers which can prove beneficial to both people and wildlife in the surrounding environment, as well as the ecosystems connected to them, increasing the amount and quality of ecosystem services provided.

ADAPTING TO RIVER DYNAMICS

An understanding of natural river processes and integration of these into urban design and planning is crucial for obtaining positive change (Gurnell et al. 2007, p.1118). To achieve this, an adaption to river dynamics, flow regime and sedimentation processes is required.

In the article "Urban Rivers: Hydrology, Geomorphology, Ecology and Opportunities for Change" in *Geography Compass* 1/5 (2007), Gurnell, Lee and Souch (2007, pp.1118-1119) makes a compilation about the complex connection between river flow regime and ecological functionality. The authors stress that rivers and their floodplains in a natural state constitutes of a complex structure which changes constantly by sediment movements and natural disturbances in the river flow. These constantly changing flow regimes affect the connectivity, resilience and structure of surrounding habitats and are crucial for the biodiversity and functionality of river ecosystems. Adams & Watson (2011, p.88) also point out the variable nature of water courses and that they will change both in place and formation over time.

To adapt the design to these constant changes, Prominski (2012, p.30) suggests the use of "the Limit of self-dynamic river channel development". This limit signifies the border of the area in which erosion and sedimentation processes will occur, which may change the dynamic and position of the river. By defining this limit and leaving the area within it flexible enough to handle the possible change in river dynamics, the resilience of the river ecosystem, and design as a whole, can increase.

Other, more distinct, features of natural river systems are *pools* and *riffles*. Pools are the flatter, deeper areas where the water slows down, while riffles are their opposite; steeper and more shallow with faster water speed which makes the flow more turbulent (Adams & Watson 2011, p.88). If these features are not naturally present or have been removed in a watercourse, they can be artificially constructed to imitate natural features and by that, make the river flow more variable, create a more favorable environment for different species and increase biodiversity in the river ecosystem (Howe 1997, p.1).

Why natural adaption?

In many cities, solutions including canalization and dikes are common for controlling river flows. These allow for exploitation close to the rivers and prevent erosion. However, while they may increase control and protection from floods in specific areas, the restricted space leads to a change in the river flow, often an acceleration of water speed which affects upper parts of the river as well as raised water levels on the downstream site (Prominski 2012, p.32). It also has serious negative effects on the river ecology.

Besides from changing river flows, canalization and other river-restriction methods has also led to a great loss of natural retention areas in which the water can be delayed and infiltrated (Prominski 2012, p.32). Urban river systems that have lost these natural retention areas, have little buffering capacity and are hence less flexible and able to meet the demands of future climate change, such as more unpredictable and heavier rainfalls (Prominski 2012, pp.32, 339).

All of these factors points to the conclusion that adaption to river dynamics and restoration of natural processes, if possible, are more sustainable solutions for design of urban river systems.

RIPARIAN BUFFER ZONES

According to Adams & Watson (2011, pp.88-89) *riparian zones* - the vegetated areas around the edges of watercourses - are often the most biologically diverse areas of a river system and one of the two types of areas where the most biological and physical activity happens. The authors also mention that riparian zones offer important corridors for wildlife, providing cover, food and nesting space for animals, as well as filter sediments and damaging substances from waste- and stormwater runoff (Adams & Watson 2011, p.119).

Riparian zones also work as infiltration buffers during rain or periodically raised water tables, helping to reduce overflow in a river system and, at the same time, filtering sediments and nutrients in the water. The latter function can help reduce the levels of phosphorus in the water, a main source to excessive growth of algae in freshwater bodies (Adams & Watson 2011, p.89). The complexity of the relationship between the river flow regime and the surrounding environment suggests that the riparian buffer zone needs to be able to interact freely with the river and its dynamics to provide full positive effect (Gurnell et al. 2007, p.1125). It is also amiable that the riparian buffer zone includes large trees to prevent overgrowth of aquatic plants, such as water hyacinth, and provide stability to the river bank, reducing future erosion risk (Gurnell et al. 2007, pp.1125, 1129).

The width of the riparian buffer zones varies with specific site conditions, and is often defined by local rules and regulations. According to Adams & Watson (2011 p.119) a typical width used in the United States when constructing or protecting riparian buffer zones, is 100 feet (≈ 30 meters) on each side of the watercourse, creating a 200 feet (≈ 60 meters) wide riparian buffer surrounding the watercourse. However, the authors stress that this number is an estimation and every situation should be evaluated separately as the riparian buffers in many cases might have to be larger or smaller, depending on site conditions (Adams & Watson, 2011 p.121).

URBAN WETLANDS

Wetlands are a group of natural ecosystems that contain water often enough for the root systems of their vegetation to be short of oxygen either permanently or periodically, depending on what type of wetland it is. Permanent wetlands are always, at least partly, wet, while seasonal wetlands can be flooded during parts of the year but completely dry during the rest. Wetlands located in coastal areas, where rivers and other watercourses meet the ocean, normally contain brackish water as a result of freshwater mixing with the salt water of the sea (Adams & Watson 2011, p.38).

In urban areas, wetlands are often scarse, but construction of such areas can help improve urban ecological standards, such as habitats and water quality, and enable extended retention for flood water simultaneously (Adams & Watson 2011, p.122). Urban wetlands also provide a range of other ecosystem services such as microclimate control, carbon sequestration and biodiversity support while providing a valuable habitat for a range of wetland species (Davis & Macintosh 2013, pp.7, 13). They can also function as important tools for managing flood water, and urban wetlands which are accessible to the general public can also serve important aesthetical and recreational values (Davis & Macintosh 2013, p.13).

When designing urban wetland areas, it is crucial that there is a constant water motion to prevent the water from becoming stagnant, as well as for the wetland to have shallower areas for aquatic vegetation to grow in (Adams & Watson 2011, p.122).

ECOLOGICAL ENHANCEMENT

In general, adapting the design to natural river dynamics is preferable to restraining measures in terms of biodiversity and ecological connectivity (Gurnell et al. 2007, p.1130).

However, this is not always possible. In certain places where natural river channel development is hard to accomplish due to lack of space or other restrictions, it is amiable to combine the needed bank reinforcements with space for natural development and a meandering

river form in sections where this is possible, for example to reinforce one side of the river bank while leaving the other free, or to involve constructed wetlands, vegetated benches or other floating habitats into the design (Gurnell et al. 2007, pp.1130, 1131).

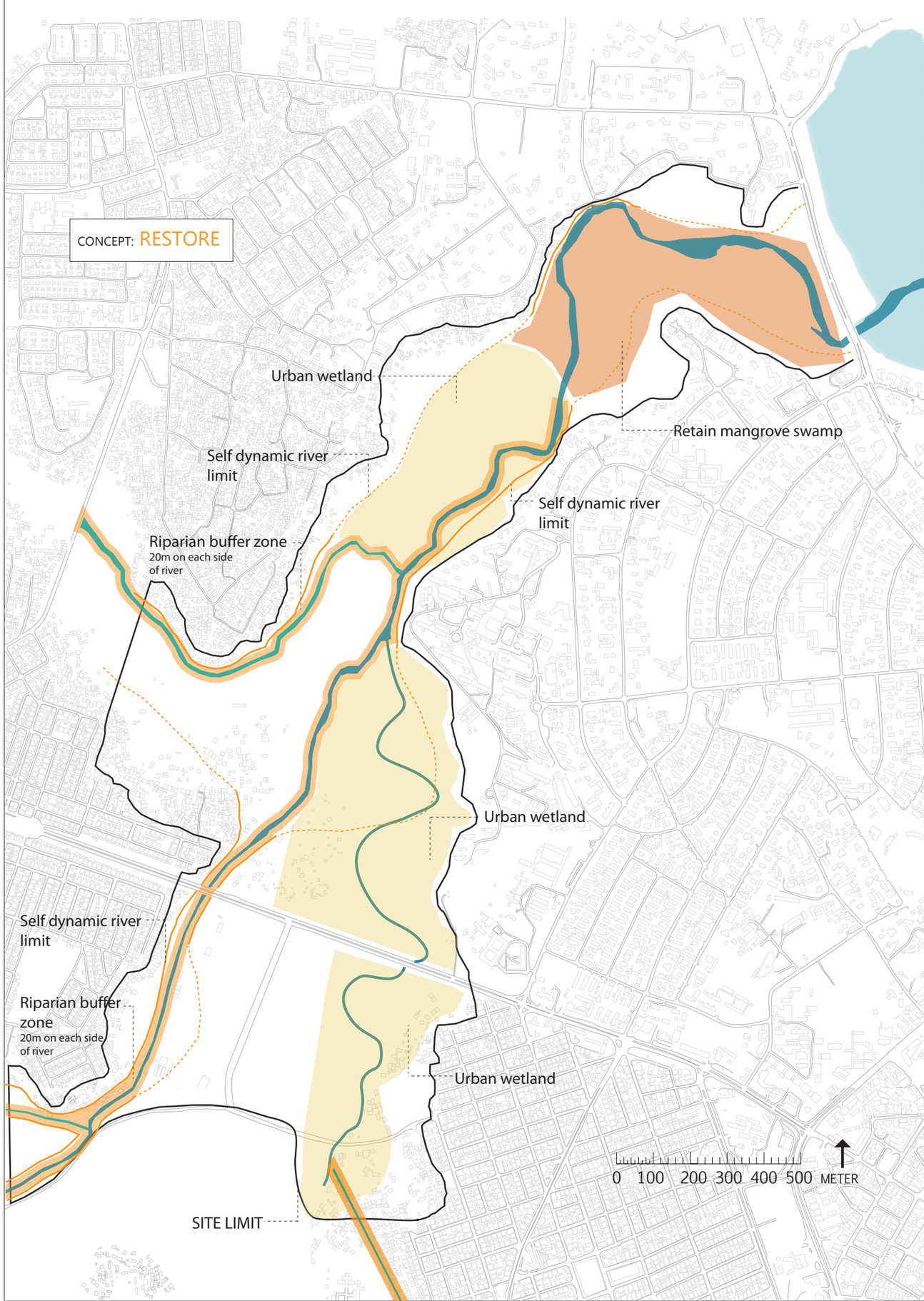
In order to improve river and wetland ecology, two important habitats mentioned in the book *Design for flooding* (Adams & Watson 2011, p.40) are swamps and salt marshes. A swamp is a wetland area where large parts are under water due to seasonal or permanent flooding or slow moving water, the water can be either fresh, salt or brackish. Swamps are suitable preservation areas for different animal and plant species since they seldom are accessible to the general public (Adams & Watson 2011, p.40). Salt marshes are normally situated in coastal areas where tidal water brings daily flooding sublime enough not to cause destructive erosion. The biodiversity in a healthy salt marsh is very high, and the species living there are highly salt tolerant (Adams & Watson 2011, p.40). Example of species in salt marshes are snails, mussels and different types of crabs (Adams and Watson 2011, p.42).

Another aspect to be considered in design, is the importance of pervious surfaces. As established in the background chapter, large, connected areas with impervious ground cover has a negative impact on water quality of urban rivers. Gurnell et al. (2007, pp.1124-1125) adds another aspect of this when concluding that a short distance between the river and areas with connected impervious cover has greater negative effect on the river ecosystem than impervious areas located further away, stating the importance of a riparian buffer zone surrounding the river.

Gurnell et al. (2007, p.1126) also stresses the importance of a Sustainable Urban Drainage System (SUDS). Well implemented SUDS in combination with a functional riparian buffer zone and a disconnection of impervious surfaces in the surroundings, can seriously decrease the negative impacts of urban development on the river ecosystem. Gurnell et al. (2007, p.1126) also stresses the importance of a sustainable urban drainage system (SUDS). Well implemented SUDS in combination with a functional riparian buffer zone and a disconnection of impervious surfaces in the surroundings, can seriously decrease the negative impacts of urban development on the river ecosystem.

STRATEGIES FOR DESIGN

- Find and adapt the design to "The limit of self-dynamic river channel development" (henceforth shortened to the "Self-dynamic river limit")
- Diversify the river environment by creating pools and riffles
- Establish a riparian buffer zone along the river channel
- Restore and enlarge existing urban wetland areas
- Retain natural mangrove swamp



FLOOD WATER MANAGEMENT

Design of flood plains and features within them that can help to store, retain and infiltrate excess water during flood events are key points in flood water management work, as well as reducing both structural and personal damage during floods.
There are several available strategies regarding these topics available when working with seasonal flooding in an urban area.

FLOOD PLAIN DESIGN AND MANAGEMENT

Flood plains are naturally created for the purpose of managing flood water. They are also, together with wetlands, important elements for reducing damage done by floods (Adams & Watson 2011, p.119). The design of these, and strategies used to make them functional, are hence highly important in flood water management work. FEMA (2009), presents four main strategies for flood plain management:

> "1. Modify human susceptibility to flood damage - Reduce disruption by avoiding hazardous, uneconomic or unwise use of floodplains.
> 2. Modify the impact of flooding - Assist individuals and communities to prepare for, respond to and recover from a flood.
> 3. Modify flooding itself - Develop projects that control floodwater.
> 4. Preserve and restore natural resources - Re new the vitality and purpose of floodplains by re-establishing and maintaining floodplain environments in their natural state."
>
> (FEMA 2009, pp.(1-32)-(1-34))

According to Prominski (2012, p.30), the design needs to be considerate of "the flood limit", which is the outer border of the water level during floods; within that limit, changes in the water level will occur and the design should be adapted for it. This can be done through different strategies such as redirection and retention of flood water, using flood-tolerating elements or elements which are adaptive to changes in the water level. Adams & Watson (2011, p.99) promotes the natural landscape as a model for flood resilient design, as nature itself has several different techniques to handle rain water. During smaller rainfalls in a natural system, the water is infiltrated through the soil, absorbed by plants or stored in low-lying spots in the landscape (Adams & Watson 2011, p.99). An urban flood plain also needs to be able to offer these functions, handling the water as it emerges to reduce the amount and effects of flooding events.

To prevent further damage and restore natural functions of the floodplain, it is also important to avoid construction that in any way reduces its capacity to store and manage water during flooded periods. According to Adams & Watson (2011, p.129) new constructions should be strictly limited or prohibited in flood plain areas if flood management and design is to be sustainable. Another aspect of sustainable flood water management and design, is to be prepared for possible future flooding scenarios (Adams & Watson 2011, p.147). While previously measured water levels might give indications of upcoming flood events, it is important to be considerate of other factors, such as raised sea levels or upstream constructions, that might change site conditions in the future.

RETENTION WITHIN URBAN WETLANDS

Urban wetland ecosystems play an important role in flood water management work as they have a great ability to provide storage, retention and infiltration of water during rainfall and flooding events (Adams & Watson 2011, pp.38, 89)

Adams & Watson (2011) describes several water and wetland type habitats and elements that can prove important when managing flood water. One of them is *vernal pools*, which are lower lying dikes or smaller depressions which fills with water only for parts of the year during wet conditions, and then dry out again when the seasons changes (Adams & Watson 2011, p.38). Another is *freshwater ponds* – waterbodies that are shallow enough for the sunlight to reach the bottom of the pond and support the existence of rooted plants. Freshwater ponds usually contain aquatic species that are very flexible to water level changes due to developed strategies such as leaves floating on, and therefore also following, the water surface. These features, or other types of open retention basins or ponds can help reduce flooding by handling and storing excess water during wet periods (Adams & Watson 2011, p.39). The retention areas can then suitably be parts of larger wetland areas where the retaining function can be combined with natural purification of water, rainwater harvesting for agriculture and recreational purposes.

To enable a more intensive use of the flooded areas, retention basins can be constructed as several chambers that fills up in succession. By having a strongly reinforced retention pond to which the flood water flows first, a second retention basin which floods less does not need the same reinforcements and can be more flexibly designed, for example as a public park (Prominski 2012, p.96).

HOUSING IN FLOOD PRONE AREAS

According to Prominski (2012, p.89) we are now experiencing a rising interest in the integration of flood plains in the townscape as an increasing amount of flood-tolerant buildings appear in our cities. Adams & Watson (2011, pp.170-174) presents several strategies for flood-resistant design of buildings; relocation, elevation and flood-proofing.

Relocation involves moving residents or entire buildings to a safe area. This is, according to the authors, the most reasonable strategy when it comes to protecting both people and property, especially in areas prone to erosion (Adams & Watson 2011, p.170).

For situations when relocation is not desirable or possible, *elevation* of buildings is a suitable strategy to protect from flooding. The buildings can be raised either on some sort of piles or columns, on filled-up ground or on walls. However, filling the ground underneath the house is not recommended in all areas as it may cause flooding in adjacent places (Adams & Watson 2011, p.174). By building on piles, the flood water can flow underneath the houses and the area underneath the house can be used for other purposes, such as storage, during dry periods (Adams & Watson 2011, p.171).

To make it possible to leave and reach the houses during floods, additional escape routes can be constructed. (Prominski 2012, p.98). Pile dwellings are also popular in many places around the world which are affected by floods or located near the coast or in marshy areas.

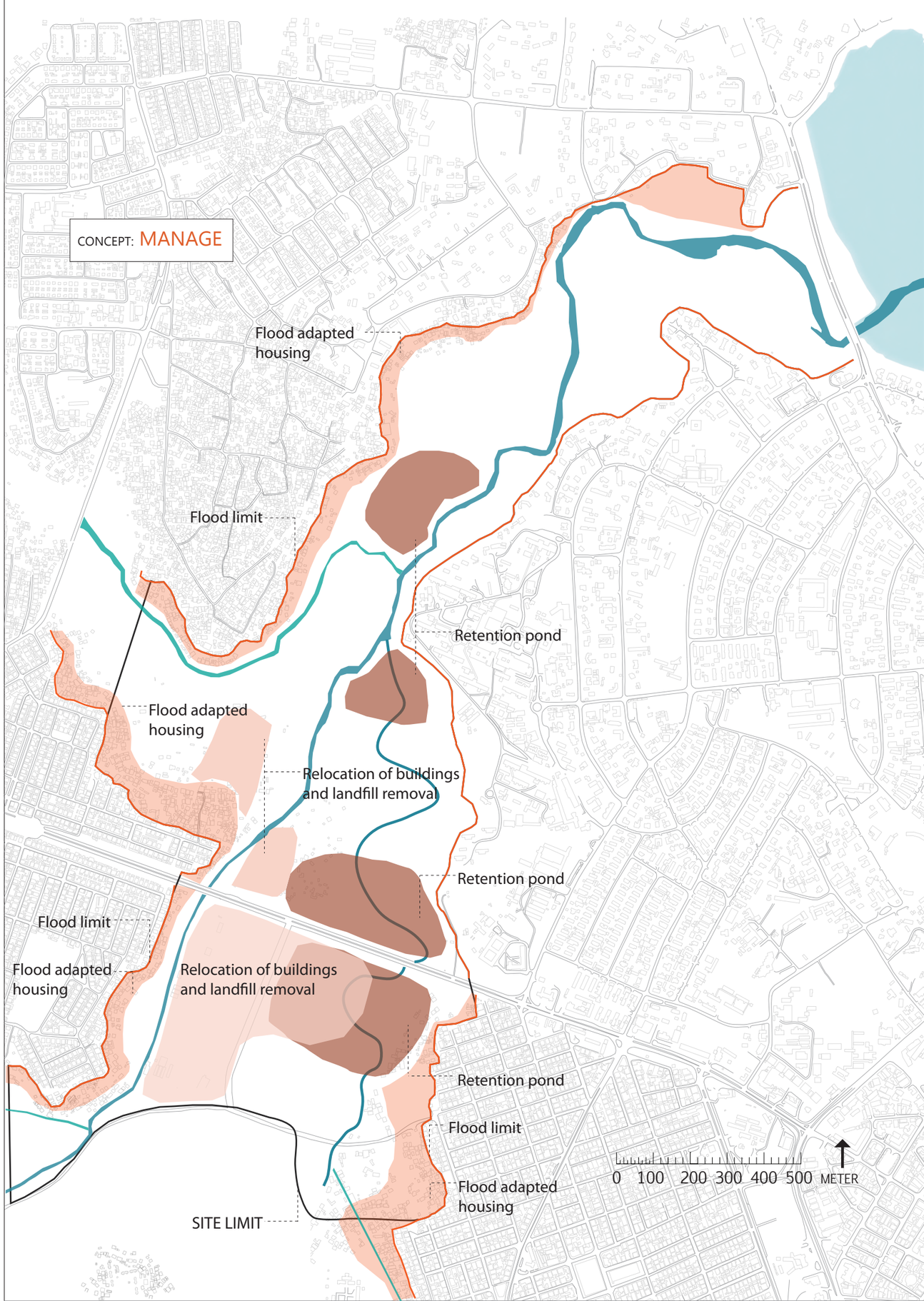
Another strategy presented is *flood-proof building*. There are two types of flood-proofing; wet and dry. Wet flood-proofing means securing parts of a building to tolerate water and then letting parts of it get flooded during wet periods. Dry flood-proofing means protecting a building from floods by securing the outer walls to withstand water. In the United States, the latter is only permitted for non-residential buildings (Adams & Watson 2011, p.174).

Floating housing solutions are also possible, as long as they remain fairly cheap.

What needs to be considered in both elevation, flood-proofing and floating housing, is access ways that works both during dry and flooded conditions, as well as a possible future ground level rise as an effect of sedimentation. In lowland delta areas, the speed of the river decreases, which allows sediment to settle and lead to a continuous raising of the ground level within the flood plain. This is a natural process of river dynamics and has to be taken into account while making a future plan for a flood plain (Prominski 2012, p.87).

STRATEGIES FOR DESIGN

- Find and adapt the design to "The flood limit"
- Create retention ponds within wetlands
- Relocation of landfill, housing and other constructions on hazardous land
- Flood-adaption of existing housing in possible areas



POLLUTION REDUCTION IN URBAN WATER COURSES

Reducing pollution and improving water quality in severely degraded water courses, are important parts of restoring urban river ecosystems and their ability to manage water.

Natural elements and cycles in the landscape can decrease river system pollution in themselves if left to develop properly, but only to a certain extent. If pollution levels are too high, additional water and soil remediation might be needed for plants and wildlife to have a chance to establish and for ecosystem functionality to be fully restored.

WASTE- AND STORMWATER RUNOFF

A large part of the pollution reaching urban rivers originates from waste- and stormwater. Strategies for decreasing both the amounts of waste- and stormwater that reaches the urban river systems, and the pollution levels in the water that actually reaches the rivers, are key factors in the overall success of pollution reduction in urban river systems.

One method to decrease the amounts of stormwater is to collect the rainwater before it falls to the ground, for example from rooftops (U.S. EPA 2010, p.4). This water can then be stored in barrels or larger cisterns, and used for other purposes such as agriculture. The use of porous pavements in parking lots and other large, hard-surfaced areas, can also help reduce the amounts of stormwater reaching the drains (U.S. EPA 2010, p.4).

DECREASING POLLUTION BY THE USE OF PLANTS - PHYTOREMEDIATION

Phytoremediation means a removal of harmful substances from soil or water by the use of plants. Pilon-Smits (2005, p.16) defines the term as "the use of plants and their associated microbes for environmental cleanup". Phytoremediation can then be divided into several different methods that can be chosen depending on the site specifics and types of pollutions (Andersson & Svensson 2007, p.1).

In the processes of phytoremediation, the plants extract heavy metals, antibiotics and other man-made chemicals from the ground or water via its roots. These substances are then dealt with in a number of different ways depending on the plant and situation. Some plants store heavy metal in its cells in the roots or leaves, others volatilize or metabolize metals to degrade them to non-toxic substances which is then either extracted back out into the environment or even used by the plant itself as a source of nutrition (Saier Jr. & Trevors, 2008). There are also hyperaccumulate species of plants which have abilities to store large concentrations of metals and use them in their own defence against animals or other insects or pests (Saier Jr. & Trevors, 2008). Depending on the situation and conditions of the surroundings on a chosen site, a specific method of phytoremediation and a variety of plants with different characters can be chosen.

The specific phytoremediation process of using plants to purify polluted water is known as *Rhizofiltration* (Andersson & Svensson 2007, p.35). Rhizofiltration can be done both by the use of terrestrial and aquatic plants. The terrestrial plants usually have a greater capacity to absorb metals than aquatic plants, however, they may require floating devices if used in ponds or other sites with deep water (Andersson & Svensson 2007, p.35), for example constructed as floating islands.

In the Singapore based *Bishan Park* project by *Atelier Dreiseitl*, cleaning plants have been used in retention ponds as an effective water treatment to clean the biotopes (PUB, 2010-09-21). No wildlife was introduced to Bishan Park during the construction of the upgrading project, but biodiversity still increased with 30 per cent afterwards (World Landscape Architecture, 2012-03-28).

Since phytoremediation is implemented directly on site there is no need for transport of material, which lowers the costs as well as the impact on the environment compared to conventional methods of remediating soil (Andersson & Svensson 2007, p.1), As of this, and the easy implementation of the method, the specific use of phytoremediation as a tool for cleaning polluted soil and water is a suitable choice for low-income countries (Pilon-Smits 2005, p.17).

Plant selection, implementation and maintenance

Several different projects with tests and trial growths has been done around the world, and numerous plant species have been identified as useful for uptake and accumulation of different contaminants. However, to ensure that certain plants are effective on the site in focus, site specific trials might be needed. Lone et al. (2008 p. 213) writes that the ability for plant species to accumulate heavy metals varies extensively between different plant species, climate and biotope. Andersson & Svensson (2007, p.20) also argues for the fact that depending on substance, climate and method, different species accumulates different amounts of contaminants. As the existing species at site usually accumulate some of the contaminants it is also important to include them in trial growing to see if they are useful.

Both Lone et al. (2008) and Andersson & Svensson (2007) presents some genus of species and also some specific species that can be used. According to Andersson & Svensson (2007, pp. 20-24) the genus *Salix* is useful to store several different contaminants while *cabbage species* are useful to accumulate for example lead and cadmium. Species such as *corn* and *sunflower* can extract lead from heavily polluted soils, and *sugar cane* can increase the amount of contaminants which microorganisms are able to break down. Lone et al. (2008, p. 216) presents several grass species which are useful for rhizofiltration.

In most cases, the plants will need to be removed from the site by a certain time interval, and sometimes, the remnants also needs to be dried and burned. If aquatic plants or floating terrestrial plants are used, the whole plant might be taken away with its roots and all, which makes sure all of the absorbed substances are removed from the water as well (Andersson & Svensson 2007, p.37).

Larger plants used, means longer time until it has to be removed. If maintenance cost are to remain as low as possible, it is preferable to use larger terrestrial plants, like the genus *Populus*, if possible. These can grow for several years before they need to be harvested, and by that point, the wood can be used for fuel, lumber or paper production (Saier Jr. & Trevors 2008). Populus are also favourable for phytoremediation because of their extensive root systems which rapidly can absorb water and a wide range of different contaminants (Saier Jr. & Trevors 2008).

OTHER METHODS OF RIVER POLLUTION REDUCTION

Liu et al. (2011) presents several possible pollution prevention strategies for urban rivers in their article "Urban River Pollution Control and Remediation". One of these methods is *bioretention*, which works similar to Phytoremediation, but instead of plants uses microbes, which converts the harmful substances in the water to non-toxic material (2011, p.1858). Bioretention can be done directly in the river at site, and there is no transport or removal of material needed which makes it a cost-efficient method. Since it does not leave any secondary pollution, it also has a low impact on the river ecosystem. Liu et al. (2011, p.1858) mentions bioretention technology as the most promising remediation strategy. Gurnell et al. (2007, p.1126) also points out treatment of waste- and stormwater through the use of bioretention as an important part of a sustainable urban drainage system.

Other available methods include water remediation through *aquatic animals*, such as the silver carp, and *bio-film technology*. The latter purifies the water through the use of a biomembrane attached to the river bank, removing pollutants from the water by adsorption, degradation and filtration (Liu et al. 2011, p.1858). The bio-film technology can be done in several different ways, for example underground or through indirect purification, where the water is led into a purification facility placed beside the river where it is cleaned before being discharged back into the river (Liu et al. 2011, p.1858).

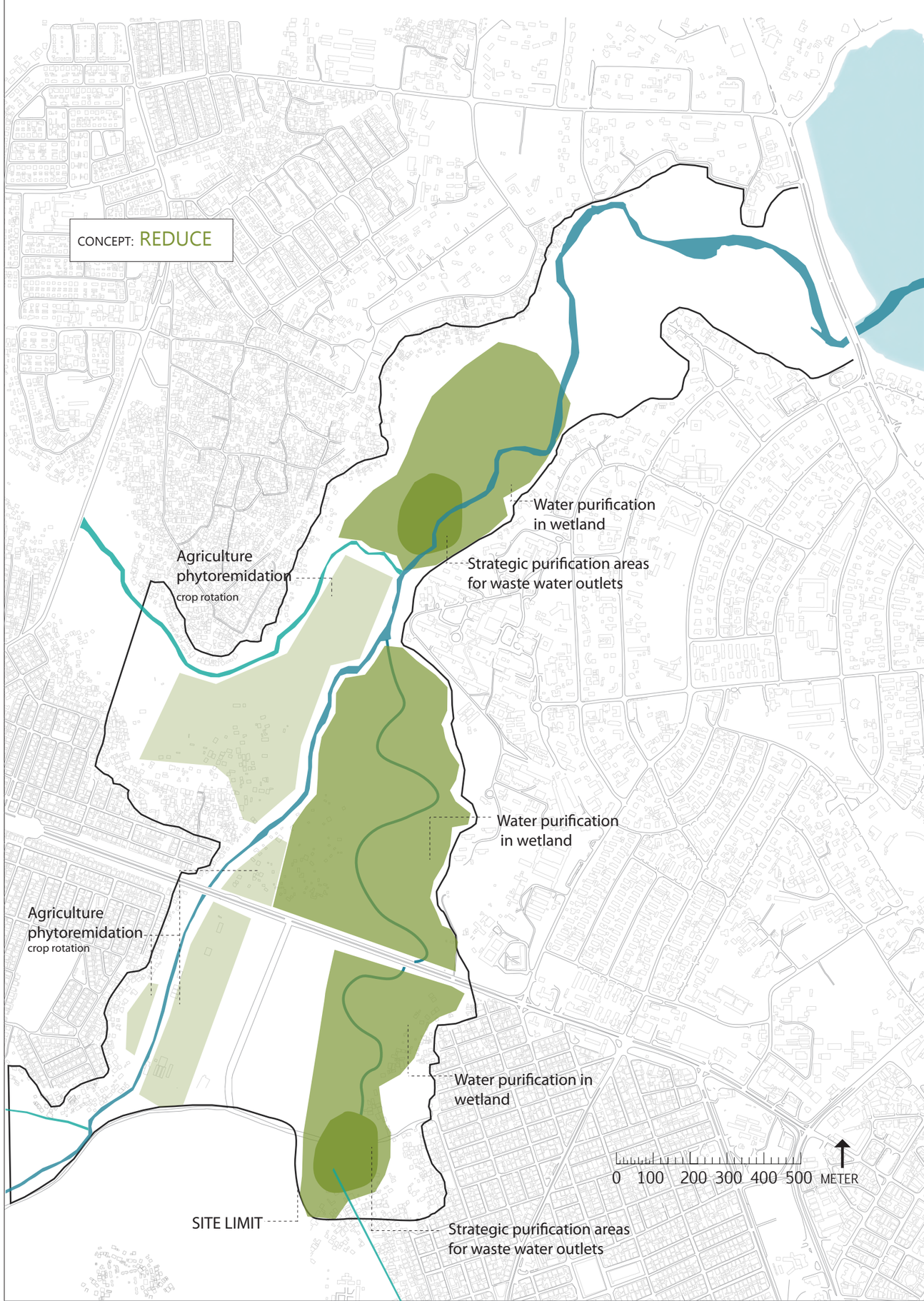
According to U.S. EPA (2010, p.2) there are also a number of other available strategies to minimize stormwater pollution. These include for example public education, collection of hazardous materials and prevention of pollutant discharge (U.S. EPA 2012, p.3). Reduction of erosion and sedimentation, other common effects of stormwater runoff, can be realized through planting of fast-growing vegetation to stabilize the topsoil (U.S. EPA 2010, p.3).

STRATEGIES FOR DESIGN

• Agricultural phytoremediation

• Purification in wetland - for example bio-retention, rhizofiltration by aquatic plants or floating islands

• Strategic purification areas for waste water outlets



TURNING FLOOD PLAINS INTO MULTIPLE-USE SPACES

Many flood plains have low water levels most of the time, but can be flooded quickly during storms or seasonal heavy rains. Due to this, flood plain design needs to be flexible enough to provide functions that tolerates both high and low water tables or temporary uses that can work during specific climate scenarios.

The flood plain can offer space for several activities during periods without floods, such as event grounds, sports facilities, playgrounds, barbeques or natural areas with riparian vegetation that can withstand high water levels (Prominski 2012, p.90).

TRANSFORMATION OF FLOOD PLAINS

Prominski writes, about transforming flooded areas:

> "From monofunctional flood plains to submersible landscapes with multiple uses. The area between the flood limit and the river is so designed that, despite naturally occurring periodic flooding, it can be used as open space for recreation while serving as a natural habitat for many riparian species at the same time"
>
> (Prominski 2012, p.86).

The river restoration project for Bishan Park in Singapore shows how an urban flood plain can be turned into a well used recreational park combined with structures that tolerate floods. The concept for Bishan Park was to naturalize the river, today the flood plain works as a recreational park where green spaces complement the ecological restored river. The park provides generous spaces for recreational activities and planted river banks enable people to come in close contact with the water. The restoration has also created a variety of micro-habitats which supports the long-term survival of different species (World Landscape Architecture, 2012-03-28).

In an other example, Vattenparken in Enköping, Sweden, the major purpose was to purify water through biological processes. Meanwhile, the park also serve as an appealing recreational area offering a variety of biotopes and activities (Enköpings kommun, 2010).

AGRICULTURE

According to (UN n.d., p.31) flood plains can be used for agricultural purposes, as they are essential for production of food. Specially in countries with a limited amount of agricultural land and were the possibility to grow and sell crops is very important to many inhabitants for making a living. According to Adams & Watson (2011, p.122) urban farming provides extended security regarding availability of food and water for the urban population and can also be beneficial by raising interest for sustainable water-use.

Prominski (2012, p.97) suggest the use of 'the mound principle', in which parts of the farmland is submerged. This enables the area to be used for farming during dry periods and helps releasing the water pressure during floods. By surrounding the submerged parts with dikes, the areas can remain accessible even in wet periods. However, it is important that supporting buildings and houses are flood proofed or located in higher areas, so that stored crops and machinery can be evacuated during floods (UN n.d., p.31).

PUBLIC SPACE

In general, urban rivers and flood plains are highly desirable to use for recreational purposes as well as flood protection. Rather than trying to ensure that further development is flood proofed, it is better to use flood prone land for purposes such as parks, nature areas or ecological reserves (UN n.d., p.28).

Martin Prominski (2012, p.86) also argues for the opportunity to use flood plains as recreational green spaces along with the flood protection and retention areas. Prominski writes further (2012, p.87) that the challenge for urban river design is to find the best combination for the flood plain to function for water retention and for nature and recreation. Access to the water, in combination with functional cycle- and footpath systems, can create an appreciated environment for recreation, while connecting the city to rural areas further out along the river. Adams & Watson (2011, p.121) also states the possibility of combining green infrastructure with restoration and connecting of riparian buffer zones, creating wildlife corridors and recreation simultaneously.

Flood adapted material

To enable the flood plain to withstand floods, the furniture and vegetation has to be designed for tolerating several days of floods, for example by using heavy stone benches and trees that tolerate lots of water. Drainage pipes under a park also enables the green areas within it to be used shortly after flooding. To provide safe easy access to flood prone areas during floods, elevated boardwalks or pathways can be constructed, which also can add new views and perspectives (Prominski 2012, p.97).

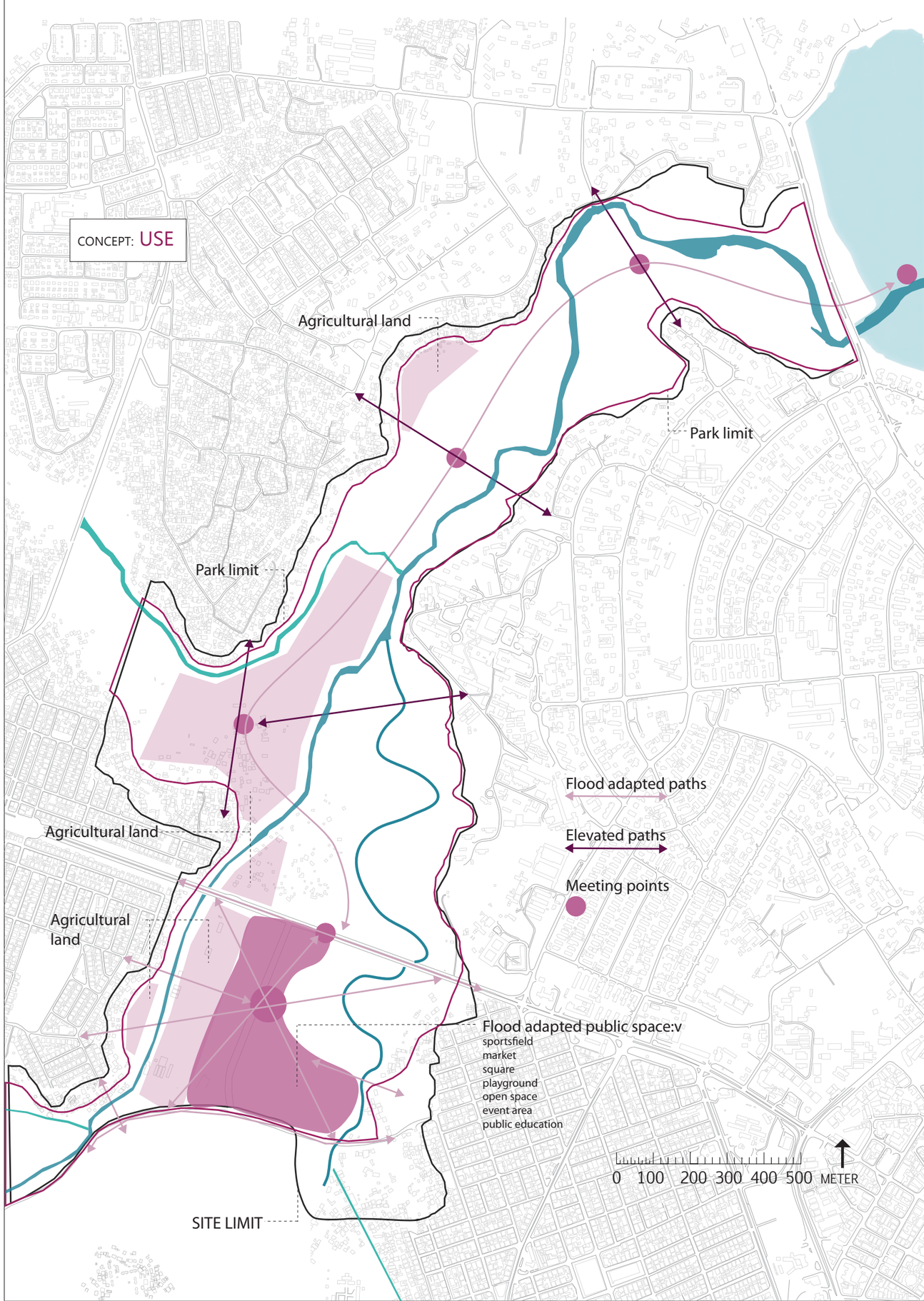
Public education

Vattenparken in Enköping, Sweden, offers, beside water purification, a pedagogical resource as it is possible for children to get an insight to the process of nature and the cycle of water. The park contains several areas for different activities such as playgrounds, open areas, areas for frisbee and boule and also an activity centre with a gathering point (Enköpings kommun, 2010).

In general, public education in different ways can be key factors for informing people about the ways of water and the problems that comes with not managing the environment in a sustainable way. Increase public knowledge by informing about local watershed situations and the importance of design and management of them can be of great importance (Adams & Watson 2011, p.125), both in river system restoration projects and flood water management work .

STRATEGIES FOR DESIGN

- Flood adapted infrastructure (elevated or flood managing pedestrian walkways)
- Flood adapted public space
- Agriculture



4 DESIGN

The fourth part of the thesis gives an insight to the main ideas of the design. The full design proposal is presented on separate sheets in: "Appendix to Master thesis: Msimbazi Wetland Park".

PART 4 CONTENTS

Photo. *House in Suna rebuilt to withstand flooding.*

MSIMBAZI WETLAND PARK

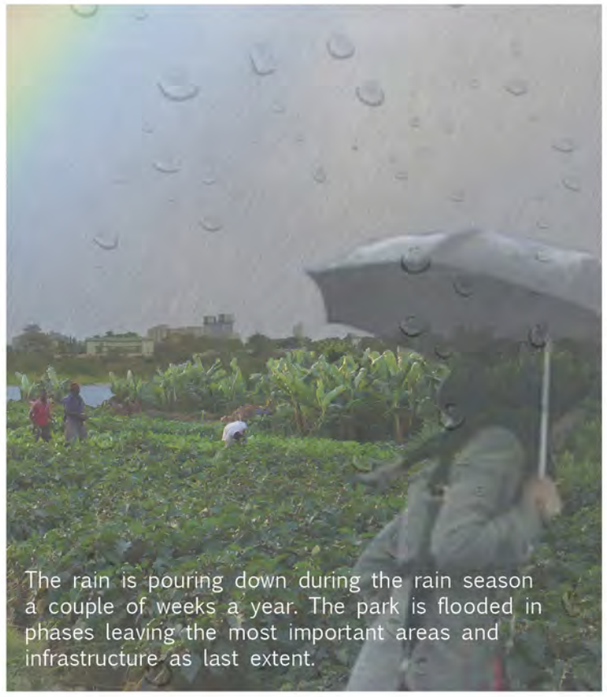
RESTORATION OF AN URBAN FLOOD PLAIN

The Recreational path brings the visitor from Jangwani Field to the Indian Ocean. Along the way the vistor gets close to the Wetlands, Agricultural land and deep Mangrove forest.

MSIMBAZI FLOOD PLAIN today is a natural retention area for flood water that is important for housing, social gatherings, agriculture and provides Dar es Salaam with much needed vegetated space.
However, the flood plain environment is heavily polluted, the area struggles with infrastructural problems, is more a barrier than well-used public space and the whole area is flooded every year during the rain seasons.

Due to its central location and the fact that the river still has not been channelized or restrained by walls, it provides valuable opportunities for improving both environmental, social and
recreational factors.

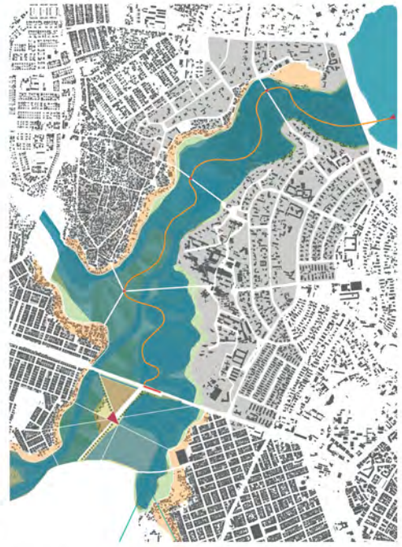
MSIMBAZI WETLAND PARK is a reconstruction of the flood plain that restore its function as a retention area for floods, enhance the ecological functions and make it a better environment both for wildlife, vegetation and humans. At the same time, the park creates a link between the different areas in the city and a sustainable public green space for the citizens of Dar es Salaam.



The rain is pouring down during the rain season a couple of weeks a year. The park is flooded in phases leaving the most important areas and infrastructure as last extent.

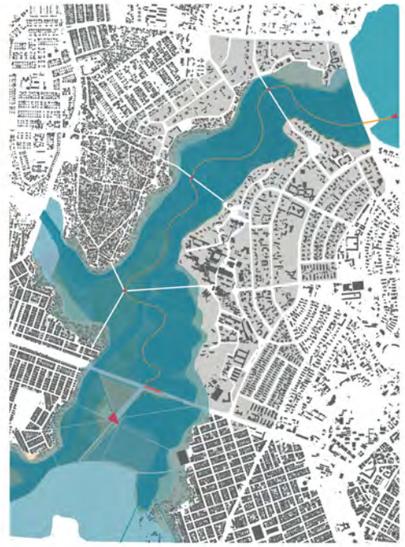
SHORT RAIN SEASON

The flood water fills the riparian buffer zones and wetlands, which are constructed to manage flood water frequently. All infrastructure is accessible as well as all public areas.



ANNUAL FLOOD

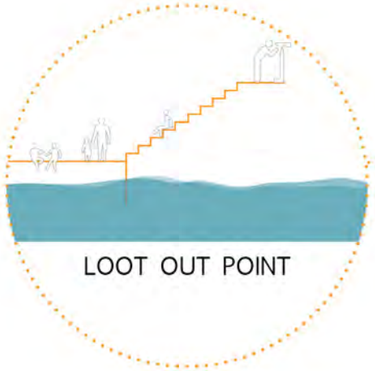
During the Annual Floods, much of the flood plain is flooded, but leaving some elevated areas accesible for market activities and small gatherings. Elevated paths are still accessible.



EXTREME FLOOD

During the Extreme Floods the whole flood plain is filled with water, including the flood adapted housing areas, during a few weeks. Only the flood adapted infrastructure on bridges is accessible.

There is full activity in the Agricultural land where many crops are grown and sold at site and at the market. When the extreme floods arrives, the only way to cross the area is to use the elevated walk- and bicycle paths.



LOOT OUT POINT

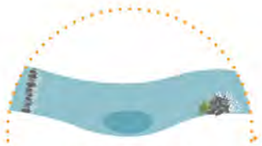
REINFORCED RIVER BANK

FLOATING ISLANDS

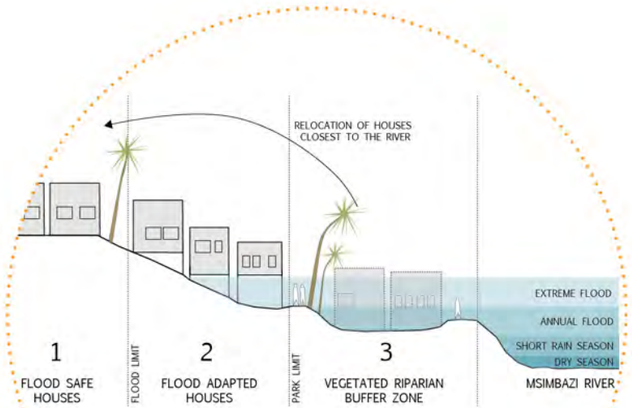
WATER PURIFICATION

AGRICULTURE PHYTOREMIDATION

MARKET AND EVENT AREA



RIFFLES AND POOLS



HOUSING PRINCIPLE
1 Safe housing
2 Flood adapted housing
3 No housing

MEETING POINT WITH SPEAKERS CORNER & EVENT AREA

STRATEGIC SITE PLAN, SCALE 1:12000 (A4)

5 AUTRO

The fifth part of the thesis includes a discussion about different aspects of the project and the references for those who may be interested in gaining further information about the subject.

PART 5 CONTENTS

Photo. *Morogoro Road in front of Magomeni area in Dar es Salaam.*

DISCUSSION

The discussion includes the project results, the design proposal and strategies, methods and sources used, along with the limitations and presumptions made. Further development of the subject is also proposed.

THE PROJECT RESULTS

The objective of this study was to present strategies for design and to make a design proposal for a specific part of the the flood plain surrounding the Msimbazi River in Dar es Salaam. The aim for the thesis was to focus on managing flood water, decreasing pollution levels in the water and soil, and restoring the riverine ecosystem. The aim for the design proposal was to create a multi-use green space which combines all of these aspects as well as important social and recreational functions.

The project was meant to work as a strategic intervention to a part of the river, that in the future might be implemented and replicated at sites with similar conditions and challenges. Within this thesis, a combination of theoretical and practical knowledge was used in order to achieve a sustainable design. To help answer the main research question, two complementary questions were used.

Research question:

How can an urban watercourse, such as a part of the Msimbazi flood plain, be transformed into a blue-green space that prevents damages of floods and enhances ecological and social functions?

- *How can an area surrounding an urban river be designed to minimize the effects of floods?*
- *How can damage from pollution in water and soil be reduced?*

Was the objective of study met?

The research question, along with the site survey and other information we found about Msimbazi River Valley, led us to four main themes that laid the basis for the conceptual framework research which later became strategies and concept for the design proposal. We also wanted to ensure that these themes were reflected in the objective of study, which we consider them to be. These four themes were:

- Restoration of urban river systems
- Flood water management
- Pollution reduction in urban water courses
- Turning flood plains into multiple-use spaces

By doing research on the site, identifying these themes and then applying the found strategies to the design, we believe that we managed to meet the objective of the thesis.

Does the design proposal for Msimbazi flood plain transform the area into a blue-green space that prevents damage of floods and enhances ecological and social functions?

Designing to prevent damage from floods - the main purpose of creating a sustainable design that manages flood water, was to prevent as much damage to people, property and nature as possible. To succeed in this, we combined several design strategies, working on different stages, that will make the space adaptable to changes in the water level.

Enhancing ecological functions - The fact that Msimbazi river still is flowing in its natural environment presented a great opportunity of restoring large parts of its flood plain in a natural way, thus creating a sustainable and resilient urban river system. One of the main purposes of the design proposal was therefore to ensure that the river could develop naturally and to restore the natural environment with wetlands, which we think we have succeeded with.

The pollution prevention strategies are a bit more uncertain. The methods of phytoremediation, bioretention and biofiltration have been empirically tested before, but not exactly in the environment of Msimbazi flood plain, therefore, small scale trials of the different methods might be necessary to ensure their functionality. The tropical climate is generally a positive factor for pollution prevention, since the plants and microbes can function for remediation all year round instead of being restricted to summer season. The river and wetland conditions also secure an access of water which severely reduces the risks of drought for the plants growing on land. As mentioned before, the biological purification strategies adapted in the design proposal can not solemnly take care of all pollution in the Msimbazi area. In order to ensure a decrease to sustainable pollution levels in the river, waste- and sewage water also need to be treated on site before being discharged into the river.

Enhancing social functions - By enabling the flood plain to be used all year round, some new social functions can be introduced and existing ones can be used to a larger extent. The introduction of recreational possibilities in the wetland areas is something that we hope can be beneficial for the whole population of Dar es Salaam. An uncertainty about the recreational idea, is the assumption that people actually will use the area for recreation. Since there are so few formal public spaces in Dar es Salaam, people do not have a habit of using such places which makes it hard to predict whether they will be used. That said, we have considered this scenario during the development of the design and tried to make the place useful in many ways. By providing everyday functions, such as farming, playground, places to gather and sit and wait for the bus, football field and market, people have other reasons to visit the area than purely for the recreational purpose. Central location, bus station and elevated pedestrian walkways makes the area easy to access and cross over as a shortcut to the other side of town, even during floods. The recreational walkway can also work as an attraction in itself, bringing people out to discover the park, wetlands and even tempt the occasional tourist to visit.

What does the design proposal do to the site?

The proposal is quite low-key and focuses on restoration and ecology rather than spectacular design. A lot of the existing structure is used and regarding the appearance of the design proposal, there is no large transformation of the site. Although some might find this a bit dull, it was a choice we made. The site has a great complexity with problems and opportunities concerning the ecological environment, and for us, these issues were too urgent to be overlooked and too complicated to end up in the periphery. There are also realistic aspects to this choice since Tanzania is a low-income country and we wanted the proposal to be implementable without huge investments.

The largest interference to the site, might be the long elevated pathways which are crossing the flood plain in a few places. These will transform the spatiality and change how people experience the site. While these pathways will increase the connectivity across the flood plain, they might be seen as barriers from ground level and along the flood plain. The width of the flood plain and the high water level during floods has also enforced the pathways to be large. The size of them might therefore be experienced as disproportionate.

Regarding the design expression, the proposal has a combination of organic shapes and strict angular shapes. The reason behind this is a division between ecological and social aspects where the ecological areas have been given more natural, organic shapes whereas the infrastructure and areas made for people to meet and gather has strict and straight shapes. These two shapes of design meet in the recreational path which winds through the site. This variation of shapes creates a distinction between people and nature, but they are also fitted together side by side to demonstrate the close relationship between humans and their environment. Hopefully, this information can be combined with public education on impacts of waste and pollution on natural ecosystems and help to spread awareness about environmental issues among the visitors.

As the design proposal is a strategic plan, the actual design and shaping of specific areas within the site need to be developed further.

Design strategies evaluation

RESTORE

These are strategies for restoration of the flood plain environment and ecosystem.

Self dynamic river limit - With identification of the self dynamic river limit, the design was adapted to manage river movements and erosion within the found limit. Where there is enough space to let the river change freely, the area is mainly vegetated in order to let erosion occur in a natural way. In areas where there

is not enough space to let this happen, river movements are restrained and reinforcements of the river banks are needed to protect bordering areas from erosion. This might make the ecosystems in the reinforced areas more vulnerable and decrease the connectivity within the area as a whole. The use of the self dynamic river limit should make the design more resilient towards future climate change and river movements. One flaw in this strategy though, is that there are many ideas about how large this area generally should be. The placement of the limit is therefore made through our own combination of these ideas and not by previously tested guidelines.

Pools and Riffles - This strategy includes features which creates a variation of waterflow. The features were useful in order to form a diverse river environment and design, and also hopefully to enhance the ecological aspect as a whole as it creates varying depths and helps the river to develop naturally.

Riparian Buffer zone- Creating riparian buffer zones is a well used method that mimics the function of riparian zones that exists in naturally developed river systems, and should if constructed correctly be able to work on the Msimbazi flood plain as well. One issue might be the early phase, before the plants have established themselves fully. If there is an extreme, or unpredicted change in the water level during this period, the plants might not be able to withstand the water pressure. Protective reinforcements of the ground cover might therefore be needed in the riparian buffer zones until the plants have established a steady root system.

Urban wetlands - Establishment of urban wetlands is a key part to enhance the ecological environment. As the site already has wetlands, the strategy should be easy to implement. The condition of the existing wetlands could become much better and also designed so they can be a part of the pollution reduction strategy. As wetlands are a biotope that is declining around the world, the restoration of the wetlands in Msimbazi flood plain definitely feels motivated.

Retain Mangrove Swamp - The existing mangrove forest is ecologically degraded, but still a natural, unexploited area. To restore and protect this forest from future development should not be a problem, especially since the area is wet all year round and building there would therefore be uncertain and demand complex constructions. The question is if the ecosystem would manage to restore its natural functions even though the pollution and solid waste levels are high. The pollution levels should be lowered by the purification processes further up on the flood plain, but the solid waste might have to be manually removed in order to allow animals and plants to develop naturally.

MANAGE

These are the strategies for managing flood water.

Flood limit - The use of a known flood limit helps to protect the design from damage by future floods if applied and followed correctly. One uncertainty about this though, is the lack of data recorded about the actual flood levels. To set the flood limit in the design we had to rely on our own judgement compiled in the Flood levels inventory map, which ultimately leaves the result a bit dubious. Future climate change and rapidly rising flood levels are other factors that might threaten the safe areas outside this border. To address this, the flood limit is placed a little bit higher than what might be necessary today, in that way the park will be able to adapt to fluctuations in the water table to a reasonable level. By identifying the flood limit there is a great possibility to minimize damage of floods as it becomes useful as tool of understanding the flood levels.

Retention ponds - The strategy of directing water to retention ponds is commonly used in flood water management solutions. However, this is usually done in places located on a safe distance from residential houses. This is not the case of the Msimbazi flood plain, simply because there is no such space. The consequences might be that the retention ponds not will be able to hold very large amounts of water and still risk being flooded on a yearly basis. Another uncertainty about the retention ponds is the lack of information regarding the groundwater levels in the flood plain. The lower parts are almost down at sea level and in the higher situated areas it is still a lowland area, therefore the retention ponds will most likely need to be relatively shallow due to ground water, which ultimately affects their ability to store water. However, if constructed and working well, the retention ponds will help to manage floodwater, store big amounts of water and increase the infiltration, thus minimizing the damages of floods.

Landfill removal - Landfill removal will be done on the parts of Jangwani field that were filled up during the construction of the BRT. All of the flood plain is needed for flood water management, and every new landmass put on it only pushes the flood water further out. For the landfill removal to work properly, a location of the excess soil would have to be decided. It might even be possible to use a part of it on site, for example to construct the pedestrian/bicycle lanes at the park limit. Even though this is a great amount of landfill, the positive effects of removing it seems to outweigh the cost. By reducing the ground level back to how it used to be, the space which can manage flood water will increase and minimize the effects of flooding in critical places.

Flood adapted housing - Several housing strategies presented have actually been built and are proved to work in a real setting. There are really clever solutions for housing, however, the problem with the housing solutions in this projects is money. Most of the people living in the flood prone areas of Msimbazi cannot afford special housing solutions, unless they can build the houses themselves with cheap materials. But then the problem is; who is going to implement these ideas and control the process? The authorities might need to step in for this to have a chance of working. On the other hand, by adapting some of the houses to withstand floods, fewer residents will have to be relocated in order to obtain a sustainable housing situation.

Relocation of buildings - The relocation strategies might also stand and fall with the cooperation of the authorities as someone would have to organize the new houses as well as help people to actually move from one place to the other. It also important to bear in mind that this highly affect people's lives, and it must be done with caution and respect towards the concerned residents. The relocation area should also be somewhere close to the flood plain so that people can continue living their lives without difficulties. The design proposal also suggests to remove the newly built BRT garage as a part of the environmental enhancement and reducement of floods. This is not going to be easy, but our opinion about this is that; if we suggest that people who live in the area will have to move from their homes, a bus garage, which really has no need to be so centrally located, definitely has no place on the flood plain.

REDUCE

These are the strategies for reducing pollution in the river and flood plain.

Purification in wetlands - As a strategy, purification in wetlands provides a great possibility to minimize the pollution levels as the vegetation and microbes will help take care of the contaminants biologically. Before establishing biological purification systems, trial growing needs to be conducted in order to find out which species to be used in this specific site. But as it works for example in Bishan Park in Singapore, which has a similar climate, there are great possibilities for it to work in Msimbazi flood plain as well.

Agricultural phytoremediation - The agricultural purification would work as crop rotation, where all the farmers have a part of their plot for phytoremediation plants, and then rotate every year. Eventually, the whole of the agricultural land would have been purified. How long that will take is hard to predict, but it is definitely a long-term solution. For it to work, there also has to be some kind of regulation of the agricultural production, division of plots and access of phytoremediation plant material for the farmers. Trial growings with specific species will be needed in order to ensure functionality.

Strategic purification areas for waste water outlets - This strategy was used to do selective purification at important close to waste water outlets with specifically contaminated water. By being aware about these outlets, the pollution reduction can be more effective. But, the biological processes can not purify all of the water completely and hence needs to be complemented by on-site water purification before being let out into the river.

USE
These are the strategies for multiple-use of the flood plain.
Park limit - This strategy was used to clarify what is in the park and what is outside, hence where public and private space meets. Establishing this limit will make it easier for people to see the extent of the park space and also to understand where constructions are allowed or not allowed.

Flood adapted infrastructure - As people need to move around, get to work and sell their things even during floods, it is important that some of the infrastructure works even during flooded conditions. The rest need to handle being submerged for shorter periods of the year. Some paths are therefore suggested to be elevated and hence accessible even during extreme floods. Even though this is an expensive suggestion, we think it is necessary in order to create a sustainable flooding situation for the city of Dar es Salaam. Today, all traffic from the north to the city centre relies on one road during flooding and it is simply not sustainable with the current urbanization rate and the already problematic traffic situation.

Flood adapted public space - This strategy is about creating public spaces which are multifunctional and can manage flooded conditions and still be places for people the rest of the time. The idea in the design proposal is that these areas are designed with permeable cover and includes furniture and vegetation which can handle being submerged for periods of time. The areas are also intended to flood in phases, which allows the most important public spaces, such as the market, to remain dry for all but the most extreme flooding events. For this to work, detailed measurements of actual flood levels and water movements will have to be conducted, and the ground levels very precisely engineered.

Along the network of infrastructure are several meeting points located in natural path crossings, which should indicate good possibilities for social interaction. Since most of them are located a few metres off the ground, it is still a bit hard to predict the outcome of their functionality. Putting seating, lights, information and other features in these points might however raise possibilities of people wanting to stop for a while, and the view that the elevation gives should also draw people's interest. These places also function as connections between paths and enables to the visitors and residents to reach the different areas.

Agriculture - As agriculture is currently being done in the area, maintaining this practice is only natural as it is also the main way to make a living for many residents in the surrounding areas. The agricultural land is also purposed for growing of crops that can help decrease the amount of pollutants, thus having another objective.

LIMITATIONS AND PRESUMPTIONS MADE

The limitations were made both geographically, as the limits for the study site, and theoretically, as in the amount of information that was used in the study.

The geographical limits were partly decided by the shape of the Msimbazi flood plain, which was a natural choice as that limits the flood affected area. The size of the chosen stretch of the site was more uncertain, and we had originally chosen a smaller part. However, when we had concluded the SWOT-analysis and decided we wanted to make a proposal on a more strategic scale, this larger size was more suitable as many of the strategies used require large spaces to function.

The content of the conceptual framework and the design proposal is a result of the selection of aspects we wanted to work with after the SWOT analysis. In this selection, we had to make many presumptions regarding the problems we could not choose to work with. Naturally, relying on presumptions in any way somewhat decreases the credibility of the project. But on the other hand, we do not feel like we had much of a choice, if we were to work with this site.

In the end, we wanted to make the proposal a part of something bigger that can easily be combined with other solutions, for example regarding the presumptions, or replicated to other parts of the flood plain further upstream.

METHODS

In this thesis, the aim was to connect theory with practice by adapting design strategies to a design for a specific site. Therefore, a mixture of different methods was used in order to enable combinations of theory and practice, and different ways of gathering information, both regarding the strategies and the specific site. The combination of methods were inspired by similar theses, in a way that enabled the object of the thesis to be fulfilled.

Were the chosen methods operable?

In summary, the combination of methods was useful and sufficient for this project and created a helpful framework for the information gathering and development of the design proposal.
Literature studies was useful for gaining information about Msimbazi River Valley and to develop the conceptual framework.

Semi-structured interviews formed a good start for the information gathering about Msimbazi River Valley, as Jaffar Jongo have a great insight in the subject. However, as the information from one person always is, at least partly, subjective, we were not able to use all of it in the thesis.

The **Site visits** were compulsory as the objective of the thesis was to develop a design proposal for a specific site. Therefore, proper site visits and inventory was very useful to understand the site, its complexity and different areas.

Mapping and analysing enabled us to get a deeper understanding and identify the different characteristics and and complexity and also to identify and limit the focus for the conceptual framework and design proposal. The specific use of SWOT as a method for analysis can be discussed as the outcome of it in many ways steered the direction of the rest of the project. This issue is discussed further under the next headline.

For the **Design process,** it sometimes was a bit difficult in the meaning of how and where to implement the found strategies, but as it was an ongoing process during the whole project, we had a lot of time to develop the ideas.

Was the site study, mapping and analysis sufficient?

As the site study took place during several days walking around the whole site and documenting by photography, experiencing and taking notes accompanied by a guide and translator, we would say that it was sufficient enough. It would have been even better if we also could have visited the site during flooded conditions, but with the limited time we had in Dar es Salaam, that was simply not possible. In general, the site visits went smoothly, but in some informal areas we were a bit restricted regarding photographing and interacting with people due to the suspicion of the residents. However, as there are a lot of restraints concerning access and safety in Tanzania, the site visits could have been much more difficult. It would have been interesting to have had contact with the municipality, but as we could not reach them we had to go on without their interaction.

Directly after the site visits we started writing down everything we had experienced and map the site according to different aspects. This was a really useful way to structurize all information and proceed to the analysis.

The SWOT analysis method was a suitable way to structure and value the complexity at the whole of the site at the same time. At first, we tried several analysis methods, among them LCA (Landscape Character Assessement) which focuses more on a division of the site into smaller areas with different characteristics. However, as there are so many aspects to consider and most of them are general for the whole site, we considered the SWOT to be most useful. As we decided to stay with the SWOT analysis, it laid the way for the chosen themes and the conceptual framework. Since this was very influential to the rest of the thesis, we are aware that another method for analysis might have given a different outcome of the conceptual framework and design proposal.

LITERATURE AND OTHER SOURCES

As little has been published about Msimbazi, it was difficult to find information and we spent a lot of time on research to understand the site. The semi-structured interviews with Jaffar Jongo were useful as an in-

troduction, but as we wanted to widen the perception of Msimbazi, we complemented with written sources. Sometimes the reliability of the found information felt doubtful or outdated, hence we had to read and combine several written sources to make sure the information was correct.

To establish a map over water levels in the flood plain was not easy, mostly because no measurements have been taken concerning the actual flood levels. Instead, our source was a great number of photos taken by Jaffar Jongo and bloggers, residents descriptions and assumptions. Due to this, the accuracy of the predicted flood levels is uncertain and they should be seen rather as approximate guides than facts. If the proposal was to be realized, exact measurements of the flood levels would have to be taken.

The conceptual framework is based on several sources, but mainly *River.Space.Design* by Martin Prominski and *Design for flooding* by Donald Adams and Michele Watson. These two books contributed a lot to the project since they present a great selection of strategies and ideas for design that we found adaptable to the site in focus. However, these books focus on American and European situations which, to a certain extent, made it difficult to predict whether the proposed strategies would work in an East African setting as well. It might have strengthened the project if we would have had a more specialized source, but it was very difficult to find information and examples linked to flood water management and urban river systems in low-income countries with tropical climate.

By adapting the found strategies to the site and making concept maps for where they could be implemented in the design proposal, we enabled a use of the conceptual framework in practice.

FURTHER DEVELOPMENT OF THE SUBJECT

As mentioned in *Part 2 - Msimbazi* and also discussed in this part, there is a great complexity to the case of Msimbazi flood plain. A lot of presumptions has also been made in this project, which means there are a range of issues that could be of interest for further development of the subject.

Concerning the design proposal presented in this thesis, there are several issues which could be developed further to facilitate an implementation. For example, the project could be divided into different stages, which would enable local organizations, NGO's and other groups to take smaller initiatives and start improving the site conditions one measure at the time. This might make the proposal easier to implement than to try to build the whole project at once, and it would also present a vast opportunity to involve the local residents into the process. Having a working collaboration and dialogue between planning and people, might make the process both smoother and better suited for its purpose, as all sides of the case can be presented and taken into account. It could also prove beneficial in terms of gaining understanding about the severity and complexity of the situation for all involved parties.

Regarding the stages, we would suggest the first measures to be done should be to try to diminish the most destructive effects of flooding in the area. For smaller actors, this could include organizing a clean-up for all the solid waste that is clogging drains and disturbing the ecosystem in the flood plain. For larger actors, it could include construction of retention ponds to lower the water levels, building one of the pedestrian bridges from Suna/Hanna Nassif to Upanga in order to enable movement across the flood plain during rain season, and construction of flood-adapted housing in suggested areas. For the authorities, this stage could include; removing the BRT garage and excess soil that has been dumped in Jangwani field, developing strategies for relocation of residents to nearby areas and plans for prevention of illegal waste dumping and new constructions on the flood plain.

Secondly, measures to improve the ecological state of the flood plain and securing the area could be done. This could include aspects like; implementing the park limit, starting off agricultural phytoremediation, restore the wetland areas around the retention ponds and begin to try different purifying plant species.

Furthermore; increased movability through the flood-adapted infrastructure, important social meeting points and recreational factors could then be taken into account.

More long-term ideas for developing the subject further, is to look at flood water management, pollution prevention and river system restoration practices on the greater scale in Dar es Salaam city and the whole of the Msimbazi River watershed. Strategies for stormwater runoff reduction from impervious surfaces, waste water cleaning stations and rainwater harvesting could be interesting for the city scale, while ecosystem health and improvement measures, protection of upstream waterbodies and construction of retention areas, buffer zones and biological water remediation stations in upstream areas could be interesting on the watershed scale. Both of these issues would most likely serve to assist the measures done in this project to manage flood water in a sustainable way and protect the environment surrounding the Msimbazi river and flood plain. Another issue to develop is a plan for solid waste management for Dar es Salaam, or a specific part of Dar es Salaam.

Furthermore, replications of the design ideas through new proposals for sites further upstream in the Msimbazi River Valley could be developed since the whole river needs to be involved in order to restore the riverine system.

OUR PROJECT IN THE LARGER CONTEXT

As mentioned in the background, degradation of urban river systems poses a great challenge in many parts of the world, not least as a result of rapid urbanization and inadequate water management systems. Urban river systems are polluted in almost all urban areas of the world and extreme weather events has made floods a serious issue even in areas not naturally prone to seasonal flooding. Our design is applied to Msimbazi flood plain in Tanzania, but the ideas of how to design for flooding, pollution reduction and natural river development, might be applied to sites with similar problems in other contexts as well.

One argument against the thought of replicating our ideas in other settings, might be that the general strategies already are known, and when applied, they are too adapted to their context and may therefore not contribute much to anywhere but sites with very similar conditions. However, while the general strategies are well known, they are still not often implemented in design and this project can show examples of how that might be done. It is also important to remember that the use of strategies and design shown in this project always must be adapted to the specific site in focus in order to work properly.

There is also a socio-economic aspect of this as the people who are most affected by the degradation of urban rivers, are usually people with low income and minimal social influence, which is also the case in the Msimbazi flood plain. It is thus evident, that addressing these problems in a sustainable way also can provide great social benefits, along with ecological and structural ones.

Last but not least, even if this project only may work as an example of how all of these factors can be used in design, it can hopefully inspire other people to work with the same topics in the future.

REFERENCES

Adams, M. & Watson, D. (2011). *Design for flooding: architecture, landscape and urban design for resilience to flooding and climate change.* Hoboken, N.J.: John Wiley & Sons, Inc.

Andersson, Å. & Svensson, M. (2007). *Fytoremediering - Att rena mark och vatten med växter.* Lunds Universitet. Ekologiska Institutionen/Ekosystemteknik. (Master thesis 2007).

Blacksmith Institute (2015). *Msimbazi River Action Network.* Available: http://blacksmithinstitute.org/projects/display/173 [2015-09-23].

Boverket (2006). *Lär känna din ort! - metoder att analysera orter och stadsdelar (Get to know your neighbourhood! - Methods to analyse neighbourhoods and districts).* Available: http://www.boverket.se/sv/om-boverket/publicerat-av-boverket/publikationer/2006/lar-kanna-din-ort/ [2015-11-13].

Breeze, R. (2012). *Municipal Solid Waste Management in Dar es Salaam. Draft Baseline Analysis.* Toronto. Available: http://siteresources.worldbank.org/INTUSWM/Resources/463617-1202332338898/MSWM_Dar-es-Salaam.pdf [2015-10-09].

Bryman, A. (2011). *Samhällsvetenskapliga metoder.* 2. ed. Malmö: Liber.

Cluva (2013). *Green infrastructure: An essential foundation for sustainable urban futures in Africa.* Available: http://www.researchgate.net/publication/260192147_Green_Infrastructure_An_essential_foundation_for_sustainable_urban_futures_in_Africa [2015-11-31].

Davis, J. & Macintosh, T. (2013). 1.1 The importance of urban wetlands. In Paul, S. (ed.) *Workbook for Managing Urban Wetlands in Australia.* Sydney: Sydney Olympic Park Authority, pp. 2 - 17. Available: http://www.sopa.nsw.gov.au/__data/assets/pdf_file/0003/804522/1.01_The_importance_of_urban_wetlands.pdf [2016-01-12]

Enköpings kommun. (2010). *Vattenparken: Naturlig rening i Enköping.* Available: http://www.enkoping.se/files/pdf/bygga%20o%20bo/va/Vattenparken_2010.pdf [2016-01-12].

FEMA. (2009). Unit 1: Floods and floodplain management. *Managing Floodplain Development through the NFIP*, pp. (1-32) - (1-34). Available: http://www.fema.gov/media-library-data/20130726-1535-20490-8858/is_9_complete.pdf [2016-01-05].

Global Climate Adaptation Partnership (2011). *The Economics of Climate Change in the United Republic of Tanzania.* Available: http://economics-of-cc-in-tanzania.org/images/Final_report_launch_vs_3.pdf [2015-10-08].

Gurnell, A., Lee, M., Souch, C. (2007). Urban Rivers: Hydrology, Geomorphology, Ecology and Opportunities for Change. *Geography Compass*, 1/5 (2007), pp. 1118–1137, DOI: 10.1111/j.1749-8198.2007.00058.x

GIZ water programme. (2014). *Mlalakua Our River Our Health. - Mlalakua river restoration project* [fact sheet]. Available: http://www.swsd.or.tz/fileadmin/downloads/2014/Mlalakua_River_Restoration_Project_eng.pdf [2016-01-16].

Howe, K. (1997). Construction of Artificial Riffles and Pools for Freshwater Habitat Restoration. *Restoration and Reclamation Review*, vol:2, issue:1 (1997), pp. 1-5. (Student on-line journal). Department of Horticultural Science. MN: University of Minnesota. Available: http://conservancy.umn.edu/bitstream/handle/11299/58739/2.1.Howe.pdf?sequence=1

Landguiden. (2015). *Tanzania.* Landguiden: Utrikespolitiska institutionen. Available: http://www.landguiden.se/Lander/Afrika/Tanzania?p=1

Liu, X.D., Lu, J., Wang, J. (2011). Urban River Pollution Control and Remediation. *Procedia Environmental Sciences*, vol:13 (2012), pp. 1856-1862.

Lone et al. (2008). Phytoremediation of heavy metal polluted soils and water: Progresses and perspectives. *Journal of Zhejiang University* SCIENCE B, vol:9 issue:3 (2008), pp. 210-220, DOI:10.1631/jzus.B0710633

Monoghan, M. M. (1987). *Dar es Salaam Masterplan.* Toronto.

Moss D., Happold B., Arch A., Q-consult (n.d.). *Dar es Salaam Master Plan* 2012-2032. [Unpublished]

Olorunfemi, F.B. (2010). Disaster risk and climate change in Africa. *Joto Africa*, (3), p.1.

Oxford Dictionaries (2015). 'flood plain', 'waste water'. *Oxford University Press.* [Online version] http://www.oxforddictionaries.com/ [2015-11-14].

Pan-African START Secretariat, International START Secretariat, Tanzania Meteorological Agency & Ardhi University Tanzania (2011). *Final Report. Urban Poverty & Climate Change in Dar es Salaam, Tanzania; A Case Study.* Available: http://start.org/download/2011/dar-case-study.pdf [2015-10-08].

Pilon-Smits, E. (2005). Phytoremediation. *Annual Review of Plant Biology*, vol 56, pp.15-39. DOI: 10.1146/annurev.arplant.56.032604.144214.

Prominski, M. (2012). *River.Space.Design. Planning Strategies, Methods and Projects for Urban Rivers*. Birkhauser: Basel.

PUB (2010-09-21). *Kallang River-Bishan Park ABC Waters Project*. Available: http://www.pub.gov.sg/abcwaters/Publications/Pages/KallangRiver.aspx [2015-10-28].

Saier Jr., M. H. & Trevors, J. T. (2008). Phytoremediation. *Journal: Water, Air and Soil Pollution* (2010), vol.205 (Suppl 1), pp.61-63. DOI: 10.1007/s11270-008-9673-4.

Shemdoe, R.S. (2010). Community based flood risk strategies in Tanzania - research summary. *Joto Africa*, (3), p.4.

Sida (2014-06-27). *Our mission*. Available: http://www.sida.se/English/About-us/Our-mission/ [2015-11-14].

Sida (2014-06-30). *Sida-sponsored scholarships*. Available: http://www.sida.se/English/get-involved/Sida-sponsored-scholarships/
[2015-11-14].

UN (n.d). *Guidelines for Reducing Flood Losses*. Available: https://sustainabledevelopment.un.org/content/documents/flood_guidelines.pdf [2015-11-31].

UN-Habitat (2003). *The Challenge of Slums – global report on human settlements 2003*. UK: UN-habitat (United Nations Human Settlements Program). Available: http://www.aq.upm.es/habitabilidadbasica/docs/recursos/monografias/the_challenge_of_slums-%282003%29.pdf [2015-02-16].

UN-Habitat (2009). *Tanzania: Dar Es Salaam City Profile*. Available: http://unhabitat.org/books/tanzania-dar-es-salaam-urban-profile/ [2015-11-14].

UN-Habitat (2010). *Citywide Action Plan for Upgrading Unplanned and Unserviced Settlements in Dar es Salaam*. Kenya, Nairobi: Publishing Services Section. Available: http://www.unhabitat.org/publications [2015-11-14].

UN-Habitat (2015-11-14). *UN-Habitat at a glance*. Available: http://unhabitat.org/about-us/un-habitat-at-a-glance/ [2015-11-14].

U.S. EPA (2010). *Source Water Protection Practices Bulletin. Managing Stormwater Runoff to Prevent Contamination of Drinking Water* [Facts sheet].

WGA (2015). *Water Resilient Green Cities For Africa*. Available: http://ign.ku.dk/english/research/landscape-architecture-planning/landscape-technology/water-green-africa/cities-cases/ [2015-09-21].

World Bank (2002). *Upgrading low income urban settlements - Country Assessment Report, Tanzania*. Available: http://web.mit.edu/urbanupgrading/upgrading/case-examples/overview-africa/country-assessments/download/TANZANIA.pdf [2015-10-28].

World Bank (n.d.). *Dar es Salaam Case Study Overview. Climate change, Disaster risk and the Urban poor: Cities Building Resilience for a Changing World*. Available: http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1306291319853/CS_Dar_Es_Salaam.pdf [2015-12-10].

World Care (n.d.). *Dar es Salaam Marine Ecology Conservation PROJECT. Concept Paper*. Tanzania: World Care. Available: http://www.reefball.org/album/tanzania/worldcareproject/dar_es_salaam_marine_ecology_conservation_project.pdf [2015-09-27].

World Landscape Architecture (2012-03-28). *Kallang River Bishan Park. Singapore. Atelier Dreiseitl*. Available: http://worldlandscapearchitect.com/kallang-river-bishan-park-singapore-atelier-dreiseitl/ [2015-10-28].