CITY AS A SPONGE

EXPLORATORY AND INSPIRATIONAL RESEARCH ABOUT THE POTENTIAL OF ROTTERDAM AS A SPONGE CITY

FIRST PROGRESS REPORT - DECEMBER 2021

DE URBANISTEN

CONTENTS

CHAPTER 0

SPONGE INTRODUCTION

Motive

De Urbanisten has been involved in climate proofing the city of Rotterdam for over 15 years. In this period several policy documents have been set and implemented: the Waterplan (policy document 2007), the Rotterdam Adaptation Strategy (policy document 2011), Water Sensitive Rotterdam (implementation program from 2009 on) and the Rotterdam Weerwoord (Deltaplan on climate change, policy document 2019). In this period the emphasis has broadened from a focus on dealing with peak rainfall to wider climate issues like drought, heat stress and awareness. In our work we have worked alongside the municipality in designing on water safety (dikes of the city), watermanagement (water squares), climate proofing (Agniesebuurt and ZoHo), ecology (tidal parks), biodiversity (Hofbogen park) and awareness (all of the former mentioned projects). As a next step to take we have challenged ourselves to reflect on the concept of "The city as a sponge". Here we examine the hypothesis that a 100% local water collection and infiltration, without having to use a storm water sewage system (HWA) should be feasable within the city. And by doing so, climate goals on fightiong droughts, heat stress and storm water flooding should be tackled in combination with making our urban environments more attractive at the same time.

There is a growing interest in increasing knowledge about the potential of our subsoil. More and more there is an emerging awareness that our soil forms a fundamental basis of life on this planet and therefor also in our cities. If the city wants to be able to hold water for dry times, it will have to work like a sponge: sucking up the water in wet times and holding it for dry times. One way to deal with this is to soften and green the city. By placing more trees and replacing hard surfaces by more green, it is possible to retain water and to keep cool during heat waves. However, green solutions are currently not sufficiently capable of storing water quickly and coping with large volumes of water, in contrast to for example a water square where multifunctional urban use and effective rapid water storage are being combined. In "The city as a sponge" we want to come up with suitable forms of effective combinations for the concept of the sponge in terms of water management effectiveness and public usability. In this concept the urban soil plays a crucial role in its potential effectiveness.

Overall goal

This sponge research searches for a 'natural' solution to maximize water resources in the city. The core topic we have been examining is to discover methods and measures of design that deal with climate adaptation; to provide more 'natural systems' in the city that can deal with heavy rainfalls as well as periods of extreme drought while lowering heat stress along the way.

In order to be able to discover new methods and measures of design, the sponge research focusses on a different way of analysing the city of Rotterdam. The cities artificial drainage system is being discarded for a while, in order to rediscover and revalue its natural capabilities. This starts by analyzing the 'underground' of the city in order to redraw the map of an adaptive city based on natural sponge conditions and thus its subsoil. In the Sponge city, the falling rain can be collected fast, temporarily stored and then return to the natural context, like for instance the ground water table. Sponges can form local systems that contribute to a better water balance and place less burden on the conventional (existing) drainage systems. By locally retaining and returning water, the required capacity of sewer systems can be greatly reduced. This research therefore addresses the allocation of water management investments to more natural sponge systems as an important condition for a successful climate adaptation of the city.

Rotterdam

This research displays a detailed analysis of the city of Rotterdam mapping the relevant layers of the Draining city versus the relevant layers of the Sponge city. Concerning the draining city the relevant items to be mapped are clear. They consist of the technical system that keeps the city dry, such as dikes, polders, open waterways, pumps, inlets, outlets and overflows, an extensive network of sewage pipes and central cleaning facilities. Mapping the Sponge city is a less obvious exercise. For a better understanding of the potential of the Sponge city we selected relevant layers for dealing with the water, if the drainage system would be switched off. Then layers such as geological context, ground water variation, potential ground storing capacity, hidden historical water structures, all become relevant to map. The Sponge city does not only perform underground though. Also the availability of space above ground in public green areas, streets, private courtyards and urban roofs is vital to discover how much space we can make for water.

The outcome of comparing the Draining city to the Sponge city brings us two fundamental notions. The first notion is to underline and specify the most common paradox of cities located in Deltas and Estuaries. All over the world Draining cities have been built on top of geologies which are naturally meant to be wet. This has resulted in many economically prosperous cities enjoying the historical advantage of excellent accessibility. On the downside it is also bringing its societies a set of associated risks: floods, soil sinking, salinity, drinking water shortage, construction vulnerabilities and health risks. In most cases the end of technology as viable solution to these downsides, economically is in sight. They are simply becoming too expensive. The second notion concerns the need to explore and reinterpret the city map according to its sponge capabilities. Cities should be analysed, based on their adaptation potential in relation to their urban structures and specific risks to be solved.

In Rotterdam this reinterpretation leads to the (re)definition of four main urban sponge areas: 1. Urban Plateau, the higher outer dike area between Maas river and the flood protecting dike; 2. Peat City, the lower, very wet northern and eastern parts of the city; 3. Clay Island, the lower areas south of the Maas river; 4. Singel City, the layered, anthropogenically modified urban centre and its nineteenth century districts.

Implementation

This sponge research concludes with a double task to be addressed on the city agenda. The first task is the need for Rotterdam to continue working on its gradual shift from the Draining city towards the Sponge city, where natural water resources are being maximized within the city. Taking up this task has already started in 2007 with the cities ‘Waterplan’. It then was broadened in its ‘Water Sensitive’ programme (WSR) and is being taken further in the cities Delta plan 'Rotterdams Weerwoord’. The second task is to explore and upgrade the catalogue of possible measures for each of the four urban districts. Here technical and spatial solutions based on natural principles need to be explored and elaborated. We need to investigate, test and invest in naturally constructed sponges like soil compositions, planting schemes, ancient/innovative agricultural techniques and smart systems for reusing resources. We have literally taken up this challenge to realize our own Sponge Garden test-site. The design, set-up, construction, findings and lessons learned are being shared in the second part of this study report and will be a continuous agenda for years to come.

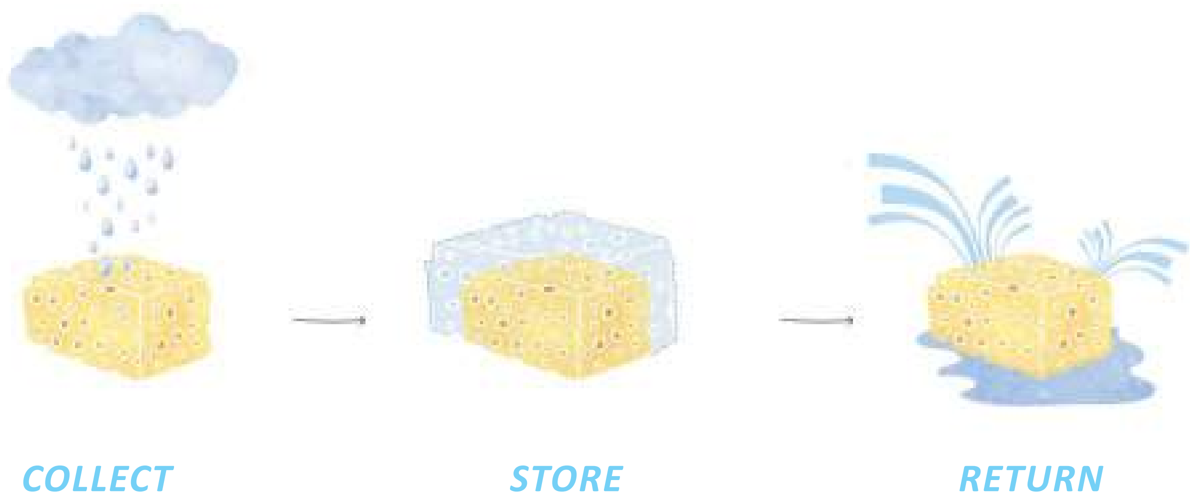
CHAPTER 1

EXPLORING THE DEFINITION OF A SPONGE

The city as a sponge is a generic concept which can have different meanings. Often it is used to express a strategy to increase space for water by reducing hard surfaces and replacing this by pervious surfaces, by building parks that can hold rain and by constructing new floodplains, river beds and even complete rivers. Instead of fighting water with higher flood walls, pumps and pipes, a more adaptive approach is being organized. This makes a lot of sense and should be supported. However, concerning the definition of the city as a sponge, we would like to start at a more fundamental level. We are interested in researching the basis of the city as a sponge: its natural characteristics, capabilities and meanings.

*This research process starts by exploring the fundamental function of a sponge which is summarized in three steps: **'Collect - Store - Return'**. This sequence implies that the concept of a sponge is in essence a system. 'Collect' deals with the range and speed of catchment of rain water. Primary functions consist of delaying and calming sudden cloudbursts. Next this water has to be stored, for which capacities have to be made available. This concerns volumes to be buffered over a longer period, depending on seasonal climatic characteristics. Finally the water can return into its natural context and become available to the cities ecosystem again. Also more artificial (directly human oriented) reuses of the stored water are part of the same potential.*

THE BASIC SPONGE PRINCIPLE

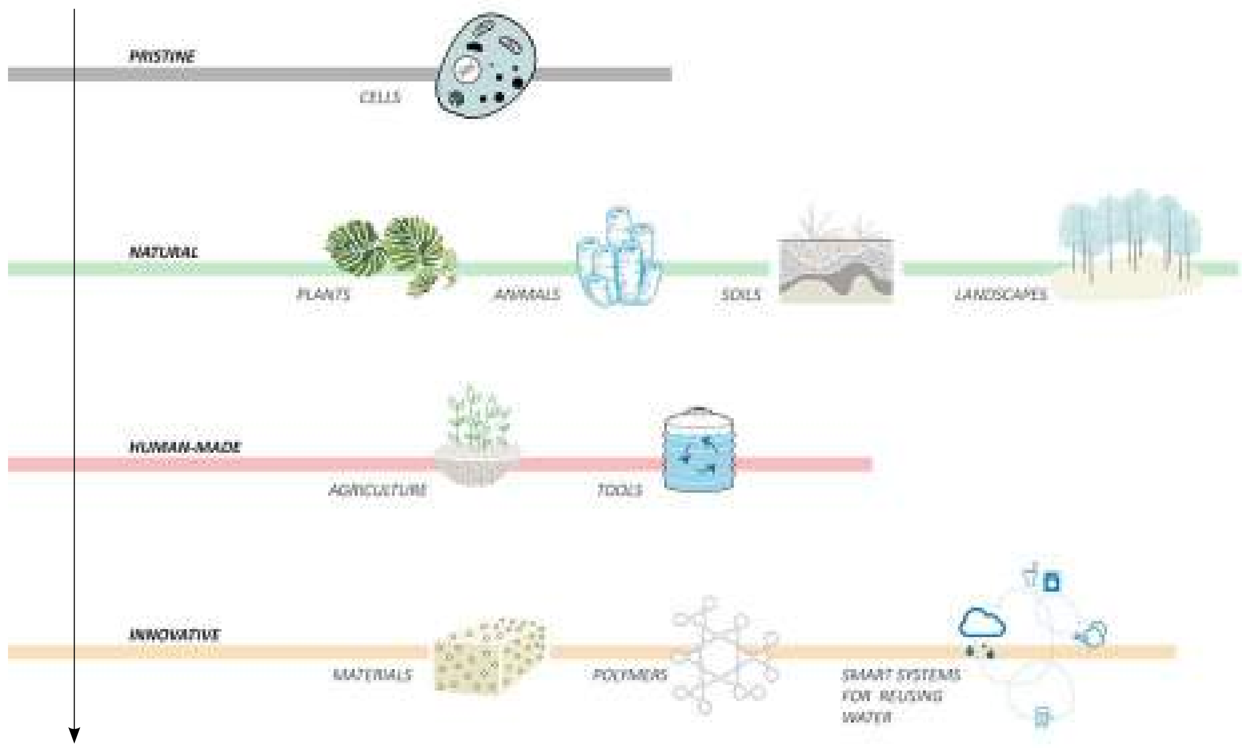


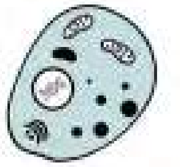
Scanning the multiple meanings and bibliographic references, we found that the principle of the sponge is a condition that is existing since the beginning of life and is widely embedded in natural systems and evolutionary disciplines. Many examples can be found that can inspire and help to expand the meaning of the sponge in a more holistic way and direct us towards solutions for application in urban environments.

The scheme shows an overall 'spongy family tree' organized in four categories:
*1. **Pristine** sponges are cells;*
*2. **Natural** and ecological sponges represent plant species, animals, soils and special landscapes;*
*3. **Cultural** manufactured sponges are applied in agricultural techniques, tools and objects ;*
*4. **Innovative** manufactured sponges mix nature and culture, materialized in special materials, artificial polymers and smart systems of reusing water.*

In this chapter we will go deeper into each one of these categories and show examples to illustrate them.

NATURAL PROPERTIES TO MAN-MADE DESIGNS



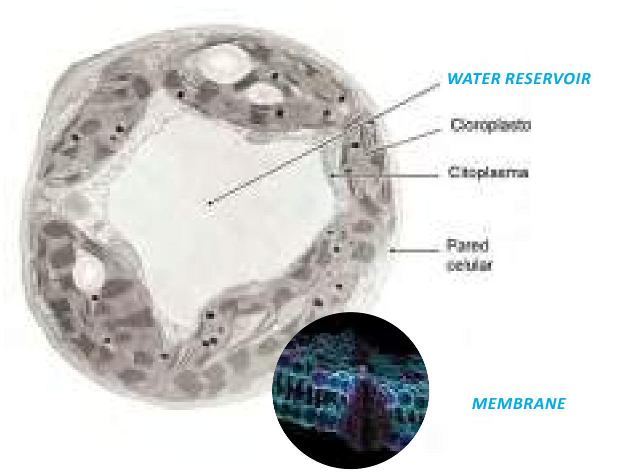


PRISTINE **CELLS**

One hypothesis to explain the beginning of life states that life started where 'something' developed strategies to regulate the exchange of water and substances with the outer environment. Cells are perfect small machines with highly sophisticated systems and components that control the mechanism of collecting, storing and releasing water for keeping the appropriate balance that allows vital functions to perform. Cell membranes, inner water reservoirs and special tissues like sponge parenchyma (groups of cells) are in charge of balancing the water exchange.

WATER EXCHANGE DEVICE

Microscopic image of cell structure



SPONGE PARENCHYMA (SP)

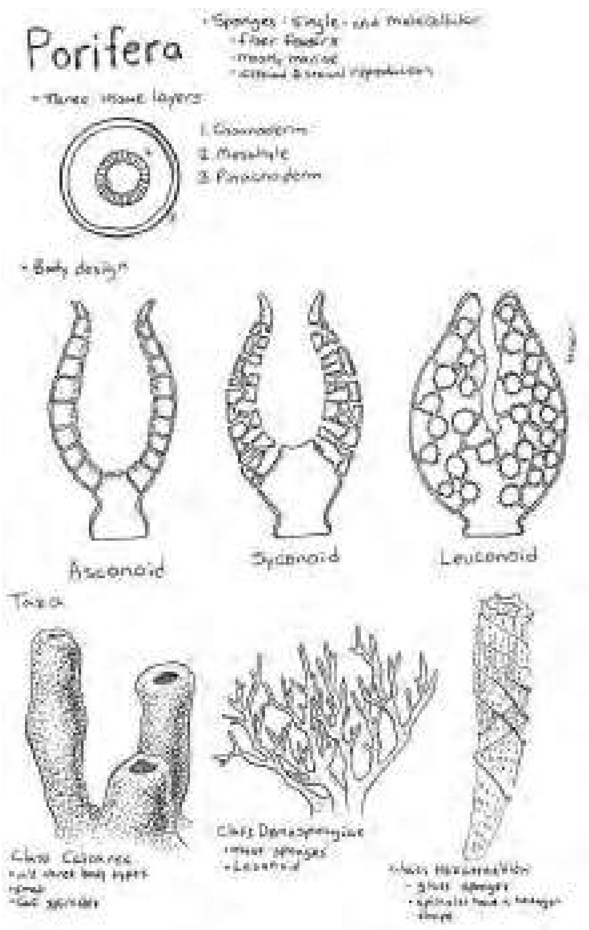
Microscopic section of a tree branch showing a special vegetal tissue in charge of storing water and controlling the exchange of water with the outer environment.

NATURAL **ANIMALS**

Sponges are the most simple animals and also very effective structures to develop more advanced life forms. Sponges are located at the base of the tree of life and although they are simple animal structures, they also appear to be adapted well enough to have remained longer on this planet than most other more complex creatures. The success of this phylum is based on the body design which is entirely dedicated to filter and modulate water exchange. These ancient inhabitants address the resilience of the simplicity and vital relevancy of the sponge principle.

SPONGE ANATOMY

Explanatory drawings about sponge morphology



North sea sponge_*Haliclona xena*

Commercial sponge sale

NATURAL ***PLANTS***

Certain species of plants have extraordinary capabilities to deal with the availability of water in their environments. These species are able to perform optimally with an abundance of water as well as with an absence of water. Well known is the response of certain types of cacti, being able to multiply several times their own water content after the rain to ensure their survival during the long dry season. In contrast to this arid extreme situation, we can find plants capable of ***bio-drainage*** *in latitudes with high groundwater levels. Their technique consists of a high transpiration capacity and with this these are able to absorb large quantities of soil moisture. Poplars, willows, tamarinds, alfalfa are the most common species using this technique.*

PLANTS WITH HIGHER RATES OF ABSORPTION AND SPECIES MOST USED IN BIO-DRAINAGE

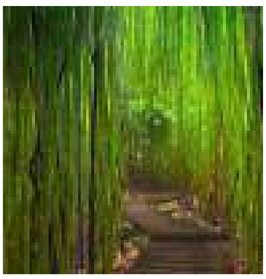
Cactus

*Salt cedar **

*Willows **

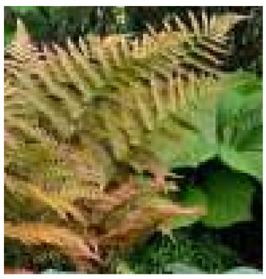
*Alfalfa (lucerne) **

*Black poplar **

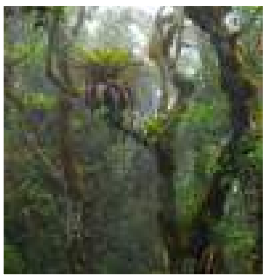


Bamboo

Sugar reed



Autumn fern
Dryopteris erythrosora



Drimys brasiliensis

** Main species used in Bio-drainage techniques.*

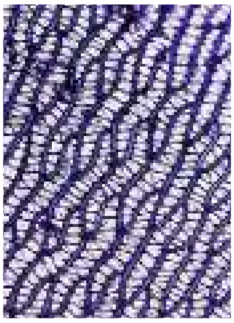
MOSS

Moss species deserve a special mention here. Mosses show higher water retention capacities than conventional plants having developed a smart adaptation on this function. Most plants lose dead leaves every season while mosses don't. They keep their dead leaves, known as hyaline cells, to use them as water reservoir and preserve the moisture level they need to keep growing. Certain mosses like Sphagnum commonly known as peat moss, may hold around twenty times as much water as their dry weight (depending on the species).

MOSS ANATOMY

Detail of moss leaves and microscopic image of hyaline cells.

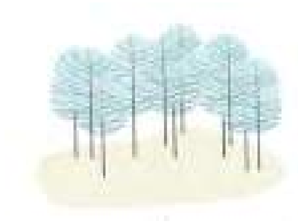
moss view



hyaline cells

ORGANIC SOILS / PEAT HORIZON

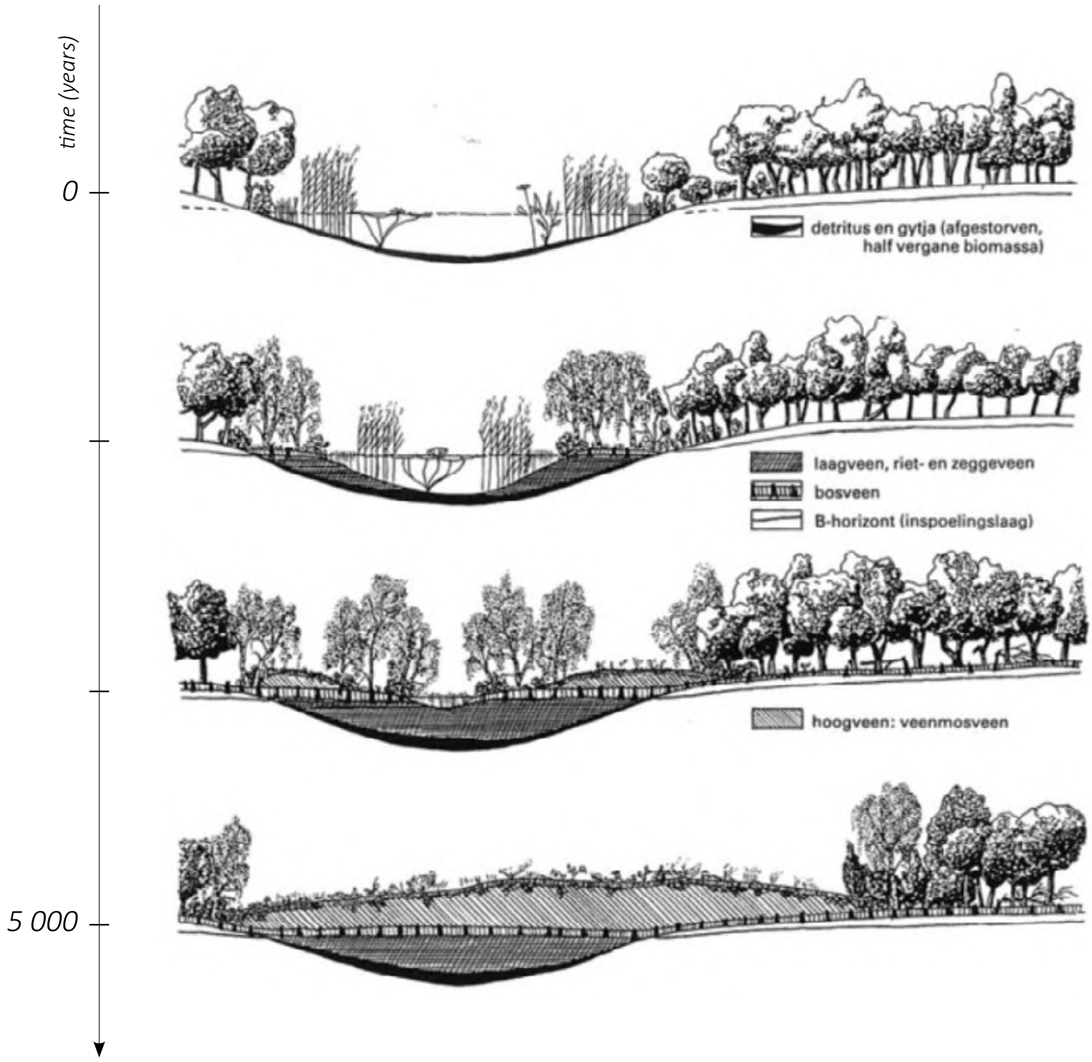
Section through a peat soil



natural LANDSCAPES

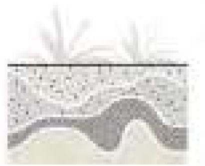
The peat landscapes of raised bog (hoogveen) and peat bog (laagveen) are special, representative pristine landscapes of the Dutch geography. Peat bogs are fens usually fed by mineral rich surface water or ground water, while raised bog is composed almost exclusively of the remains of peat moss (sphagnum) that cushions and holds rainwater. This peat moss grows on top of the lower peat surface and sucks up the rain water like a sponge. In these nutrient-poor environments sphagnum is one of the few plants that is able to settle. When saturated, they can consist for ninety percent out of water.

Raised bog development over time



Source: Stowa

Images of 'de Grote Peel' (Brabant and Limburg); This original raised bog, peat landscape has been largely dug out and used as fuel, some centuries ago and is now a wetland nature reserve.



NATURAL ***SOILS***

Soil and water are the two elements that in exchange with each other, support the majority of the life on Earth. Soil consists of a complex and precise mixture of organic matter, minerals, gasses, liquids and organisms. Differences in soil textures determine the capacities of the soil for water storage, conditions for plant growth and habitat for organisms. All of which in return modify the soil reciprocally in balance. There are extensive records of scientific bibliographies in which the potential of main soil types to store water, have been analysed. Peat soil stands out in its ability to hold water, even in comparison to a sponge made out of cellulose. The diagram shows the known measurable parameters on soil, regarding water mechanics.

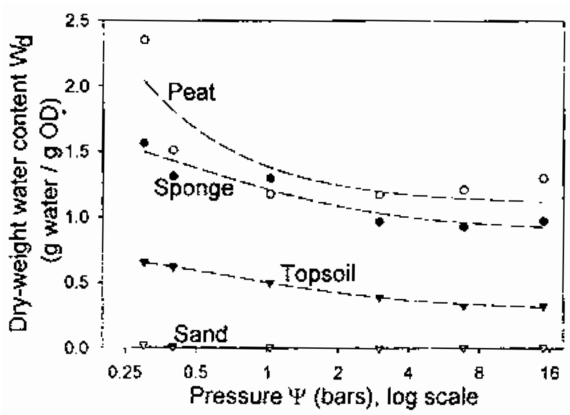
MEASURABLE VARIABLES REGARDING TO WATER

SOIL TYPES		PERMEABILITY	SATURATION POINT	RETENTION CAPACITY
INORGANIC	GRAVEL	↑↑↑↑↑		
	SAND	↑↑↑↑	41 %	6 %
	LOAM		39 %	24 %
	SILT	↑↑	36 %	28 %
	CLAY	↑	47 %	42 %
ORGANIC	PEAT	↑		

Sources: *Soil water characteristic estimates by texture and organic matter for hydrologic solutions. by K. E. Saxton and W. J. Rawls.*
SPAW software
Structure of peat soils and implications for water storage, flow and solute transport: A review update for geochemists.
http://www.geotechdata.info/parameter/soil-porosity.html
Constitutive models for practice in ZSoil v2014 Rafal OBRZUD

COMPARISON BETWEEN ARTIFICIAL SPONGES AND SOILS REGARDING RETENTION CAPACITY

PEAT ***SAND*** ***TOPSOIL***



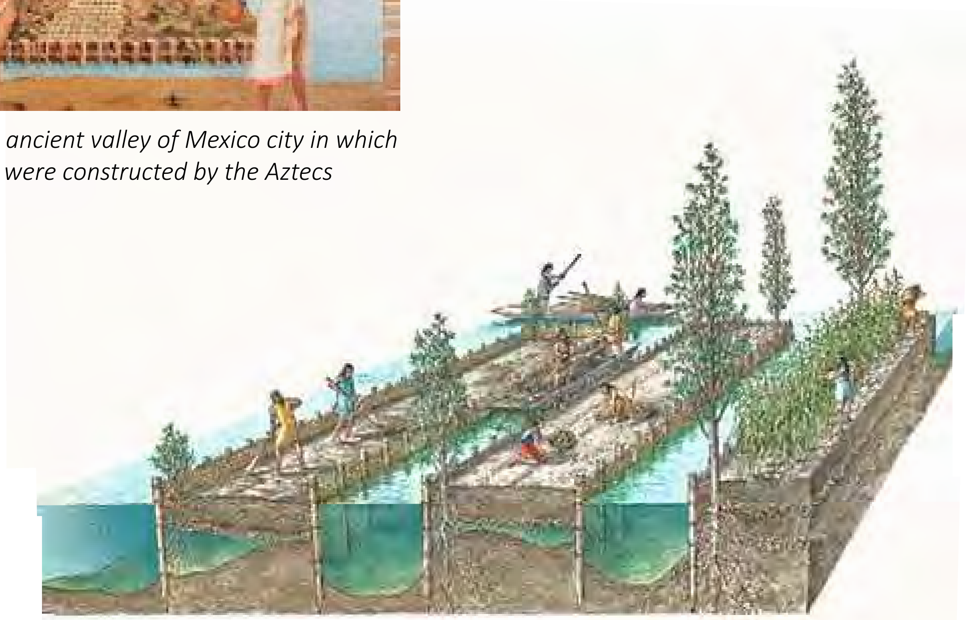
PLANT AVAILABILITY Readily available water	CAPILARITY	WILTING POINT	TEXTURE	POROSITY	SIZE
	↑			23-30 %	2-63 mm
5 %	↑	2 %		26-46 %	0,06-2 mm
13 %		11 %		XX	XX
23 %	↑↑	5 %		35-50 %	0,002-0,06 mm
12 %	↑↑↑↑↑↑↑	30 %		30-60 %	< 0,002 mm
50 %				71-95 %	0.1 - 4.6 mm

** Wilting point: minimal point of soil moisture the plant requires not to wilt.*
** Retention capacity: maximum amount of water that a given soil can retain.*

CULTURAL ***AGRICULTURE***

Agriculture had, has, and will have a primary task in dealing with available water resources in order to make profitable production. Agricultural knowledge and expertise has been developed since the beginning of settling civilizations and has many times played a crucial role in the success of certain cultures and societies. An interesting ancient example we have previously studied is the Chinampas system of Mexico City. This special method of semi-aquatic farming was developed by The Aztec empire some 800 years ago along the former lakes system that once covered the valley of Mexico city. This special technique permitted them to harvest six times a year thanks to the smart composition of soils and the continuous water supply to the roots of the different edible plant species. The ancient Aztec city of Tenochtitlan truly functioned as a sponge, successfully dealing with extreme seasonal fluctuations in climatic conditions and water availability.

Illustration of the ancient valley of Mexico city in which chinampas were constructed by the Aztecs



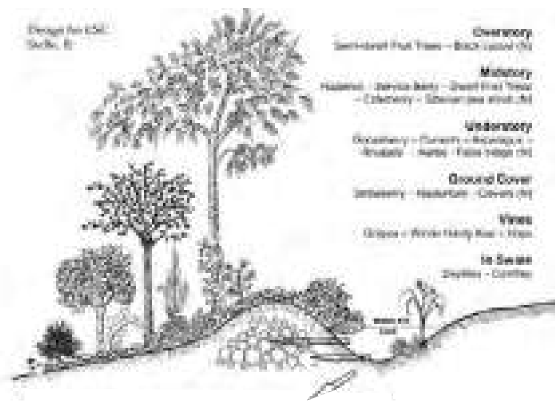
Section through a system of chinampas

Source: ***Towards a water sensitive Mexico City*** *research and strategy document_2016. De Urbanisten, Deltares, ORU, AEP & CAF*

Another special interest we have is directed towards the so called 'Hügelkultur': a traditional low-cost technique that originates in the Austrian agricultural tradition. The technique is based on a raised garden bed filled with logs and branches to store the humidity and to enhance plant growth and development on top. The decomposition of logs provides extra nutrients and a longer growing season due to the warmth generated by the internal breaking down of materials.


'Hügelkultur': using natural materials to maximize water storage and edible planting

In North America this technique has been further developed, where Hügelkultur is combined with measures to quickly collect the rain. The principle is to control and collect the water runoff, then slowly release the water into the mound and subsequently enhance plant absorption. Here a very interesting concept emerges regarding the direction of infiltration, being horizontal as well as vertical. Especially we want to focus on the phenomenon of capillary infiltration.

To be further explored: combination of Hügelkultur and swales

INNOVATION IMPROVEMENTS

Innovations on soil enhancements are closely linked to agriculture. Farmers, researchers and agricultural engineers have a long history on looking for sustainable combinations and how to maximize outcomes with limited resources. The sponge research is especially interested in various proven and non-proven techniques of soil amendments on improving water mechanics, nutrient availability and reduction of soil shrinkage.

Sand

Sand has been used traditionally as a soil amendment to increase the drainage capacity of soils. The use of sand should be accompanied by adding compost, bark or topsoil because it requires large volumes in order to be efficient in water absorption (up to 50% of the total volume).

Organic mulch

Mulch made out of bark and wood chips is a bioproduct from pruning of trees. Mulch contributes to conservation of soil moisture, improves fertility and health of the soil, reduces weed growth and enhances the visual appeal of an area.

Compost

Compost is organic matter that has been decomposed for a few months by recycling organic materials -some of which is regarded as waste- to produce soil amendments. Compost contains lots of nutrients and provides a rich growing medium, helping to hold soil moisture.

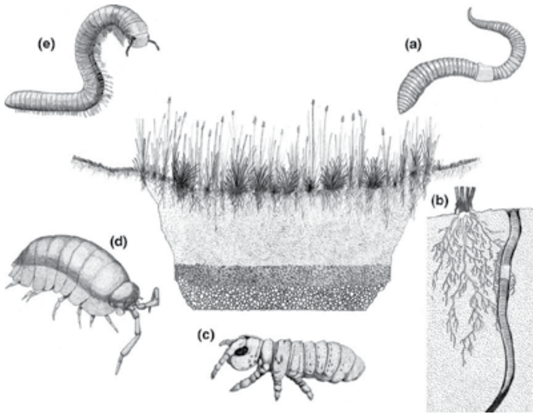
Peat moss

Peat moss is a type of soil amendment formed from dried moss species of Sphagnum. This special soil conditioner is widely used in landscaping and gardening, because it increases the capacity of soils to hold water and nutrients by improving its capillary characteristics.

Vermiculite

Vermiculite is an inorganic soil amendment mined from nature with an extraordinary water-retaining properties. Softer than perlite, vermiculite particles act as sponges soaking up water, while at the same time improve soil aeration by containing spaces within the particles that contain air so plant roots can receive oxygen.

Soil fauna

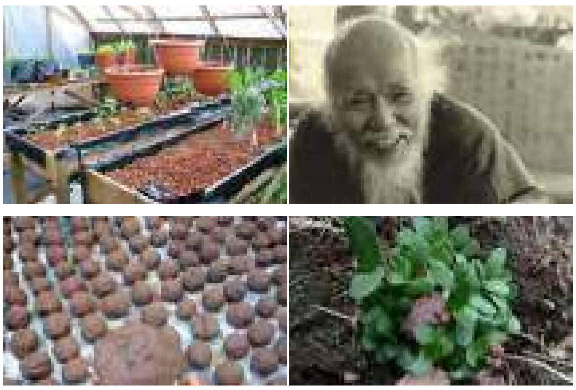


This drawing shows a cross section of a rain garden, displaying all dominant soil invertebrates. Earthworms, springtails and isopods are the best soil maintainers. They enhance denitrification, plant growth, build burrows, feed fungi, enhance organic matter breakdown and also help carbon mineralization.

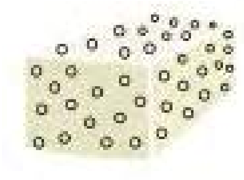
Mycorrhiza

Mycorrhiza is the symbiotic association between a green plant and a fungus. The plant captures the energy from the sun by means of its chlorophyll and supplies it to the fungus. In return, the fungus supplies water and mineral nutrients taken from the soil to the plant.

Expanded clay + Fukuoka method



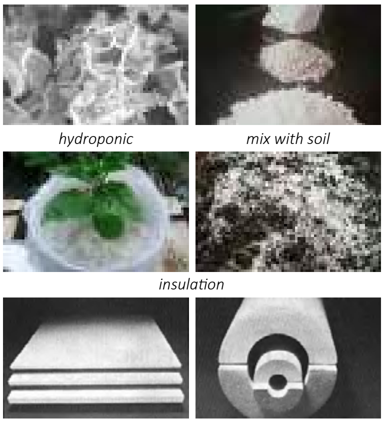
Masanobu Fukuoka was a Japanese farmer and philosopher who innovated in natural farming and revegetation of dry lands. Among his work he reinvented the use of clay seed balls in a smarter way to enhance plant growth as well as life cycle maintenance of soil without ploughing the land.



INNOVATION ***NEW MATERIALS***

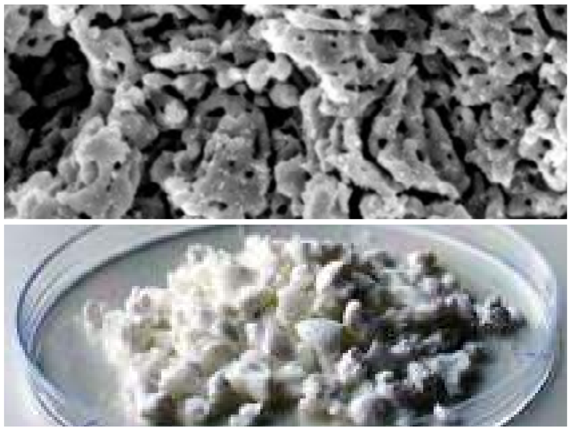
Many material innovations concerning the capability of fast and/or large water absorption, originate in the fields of water management and agricultural engineering. Here we highlight some interesting and noteworthy examples that vary from traditional techniques to recent material applications:

Perlite



Perlite is a glassy volcanic rock which consists mostly of silica with water molecules trapped within. Perlite is rated as having high air porosity which allows it to retain water by holding it in its bubbles. This offers the possibility to drain away water from these spaces quickly since they don't digest the water.

Upsalite



Upsalite is the most absorbent material discovered yet. The extraordinary properties of this new material were discovered by chance by a group of scientists in Uppsala (Sweden). The powerful absorbent capabilities are given by its three-dimensional structure with pore sizes of a nanometre(!), turning it into a stable and light material.

Biodegradable SAP

Superabsorbent polymers are artificially synthesized hydrogels with high water retention properties and high storage capacity for longer periods of time. There are many types of polymers and the most efficient ones are the biodegradable polymers based on cellulose, especially because they create small reservoirs of water to enhance water availability for plants.

Rockwool

Originated from building insulation techniques, rockwool also has high absorption qualities. Due to its substantial amount of hollow space (up to 95%) combined with considerable constructive strength, it can be very effective as an immediate storage facility underneath porous surfaces.It is available on the marker under a trademark of 'Lapinus'.

Porous asphalt

Porous asphalt pavements offer new tool for managing storm water. These pavements, used mostly for parking lots, allow water to drain through the surface into a stone recharge bed and infiltrate into the soil afterwards. The strength and resistance of porous asphalt pavements concerning traffic load, is claimed to be similar to conventional asphalt paving.

Porous concrete

Porous concrete is a special type of concrete with a high porosity that allows water from precipitation to flow through it. Thereby it reduces runoff/drainage and allows groundwater to recharge. It is mainly used in parking areas with light traffic, residential streets, pedestrian paths and bike trails.

Biochar

Biochar is a type of charcoal used in agriculture with some added benefits: it has potential to help mitigate climate change effects by capturing carbon; it has the ability to attract and retain water; and it has the ability to improve soil fertility of acidic soils and to increase agricultural productivity.

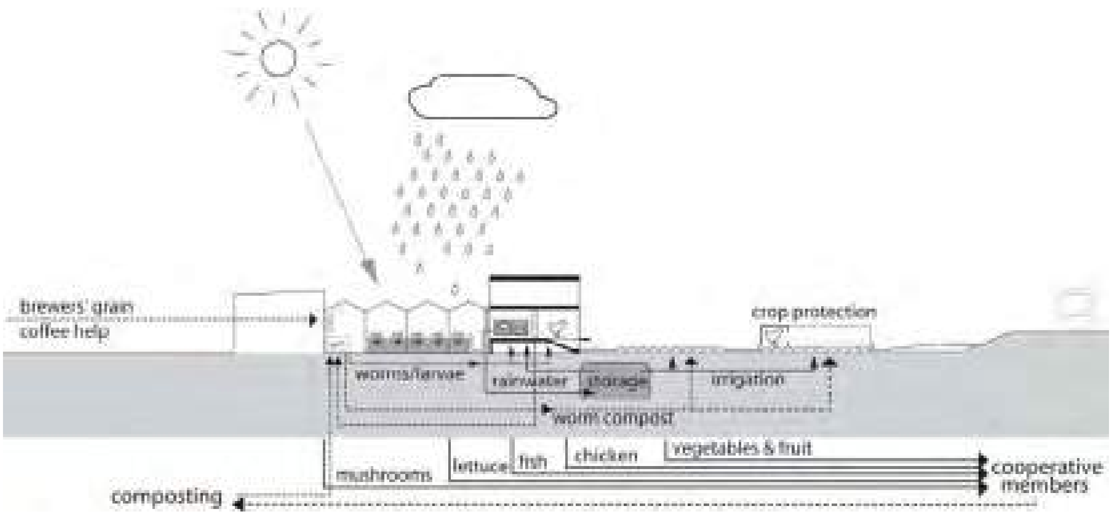
Cellulose

Most artificial sponges are made of cellulose. This material can provide the basic conditions of humidity, sunlight penetration rates and warmth for the germination of seeds. It is often used in greenhouses in the Netherlands.

INNOVATION ***WATER REUSE SYSTEMS***

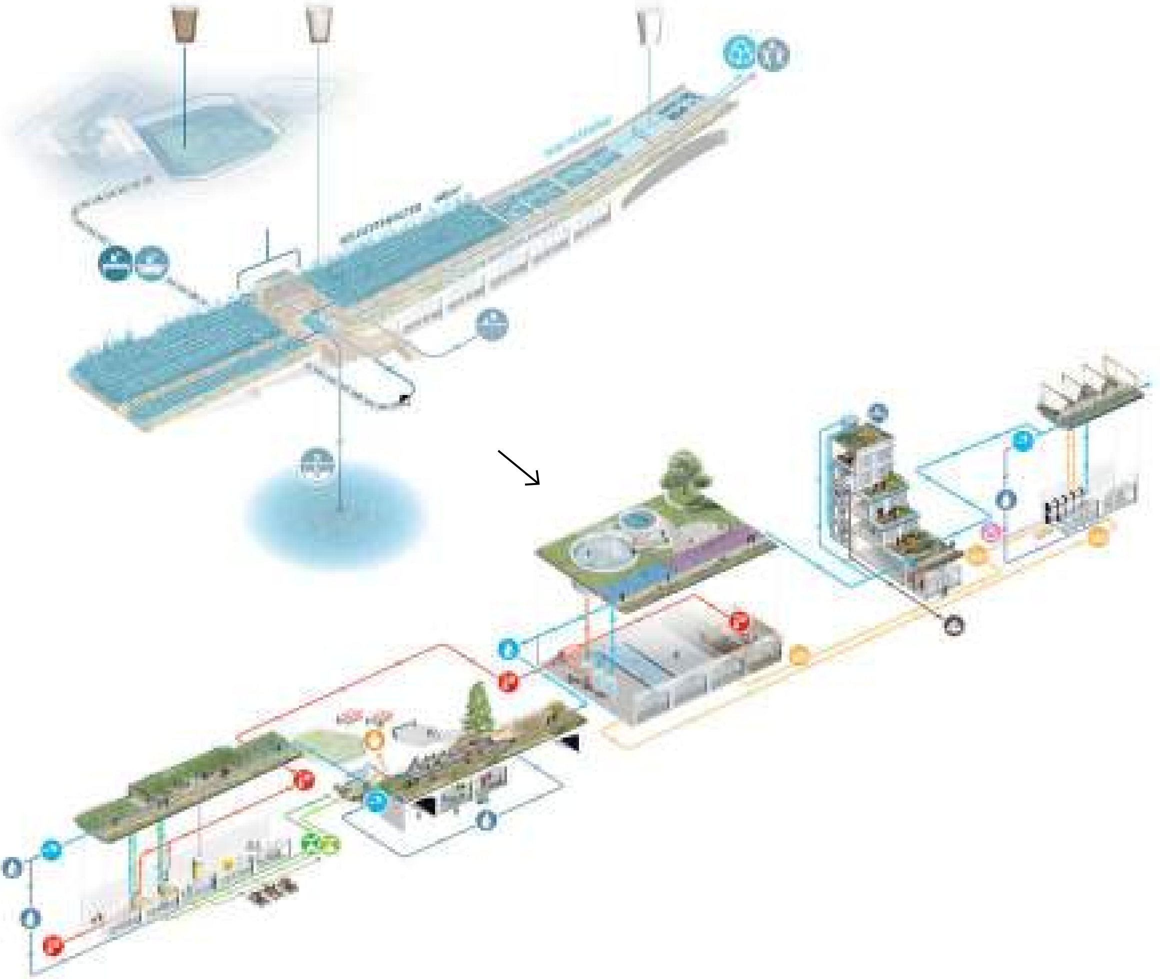
The Netherlands has a long tradition and experience in practising agriculture in an efficient way. In recent decades many of these innovations happen in greenhouses where the systemic approach of collecting, storing and reusing water is part of an efficient strategy to grow plants. The design of efficient circular systems of water reuse in greenhouses harbours specific 'sponge knowledge' that can be applied in urban contexts. Our research is not just interested in natural solutions, but also in translating innovation and engineering solutions as far they have an answer to collect, store and reuse water to the benefit of the 'natural system'.

GREENHOUSES



AQUADUCT 010 - A PROPOSAL FOR AN ELEVATED WATER CLEANING PARK

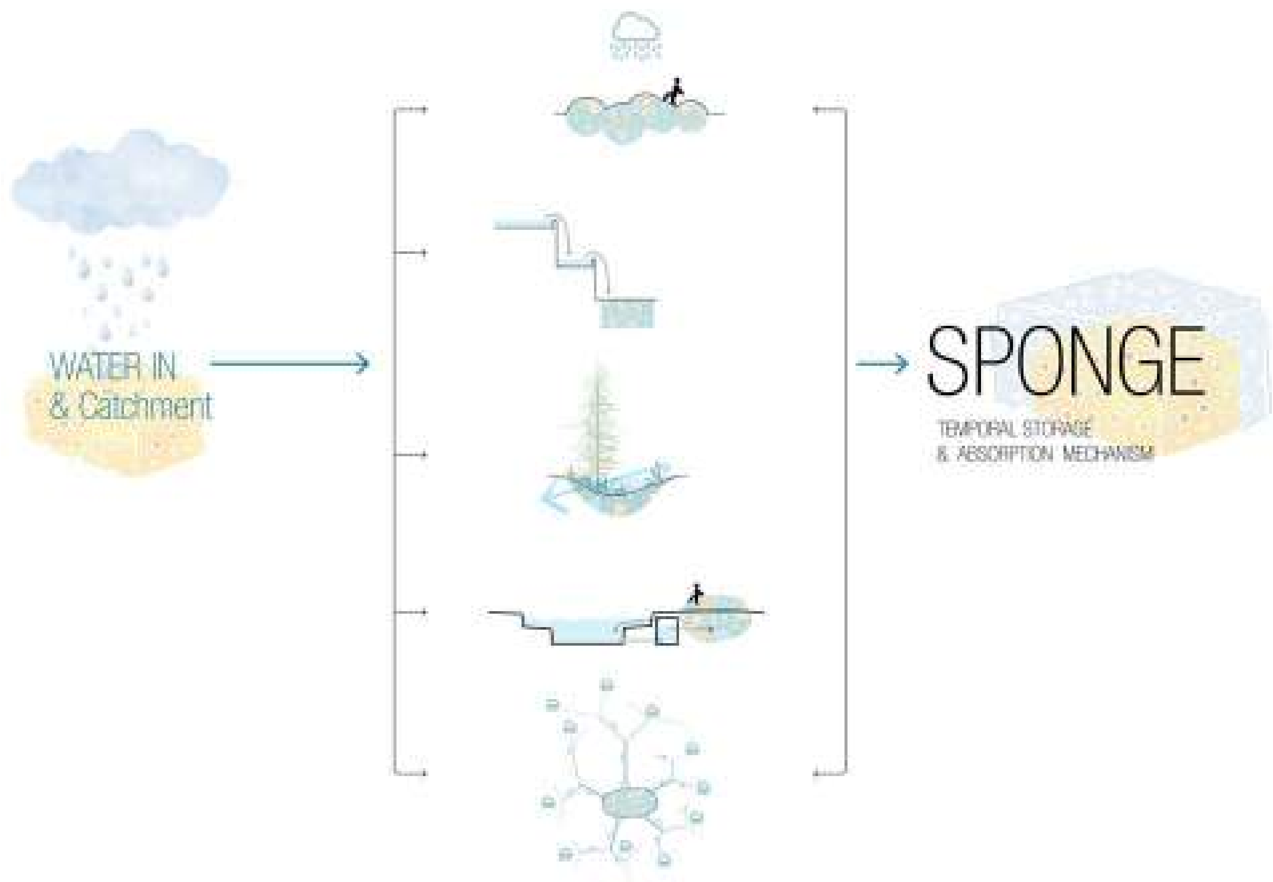
One of these 'translated innovative applications' could be the "Aquaduct 010". Here De Urbanisten explore the possibilities of transforming the roof of an abandoned railway line located in the inner city, into a stormwater cleaning park. This aqueduct combines water collection, purification, transportation and reuse to its surroundings for various uses. The water follows the logic of the sponge principle by firstly being collected in a nearby located water square, then transported and cleaned on the aqueduct and finally being reused for a water playground, a bath house and even for brewing beer. All for the benefit of the community around the railway line and the city as a whole. This stresses that the sponge principle is not just about balancing the urban water system, but it also has the ambition to create water amenities, raise awareness, stimulate water sensitive behaviour, enhance communities and contribute to a business case with ecosystem services. This concept is curently being worked out into a concrete design for an elevated park in the city of Rotterdam.



CHAPTER 2

HOW THE SPONGE CAN WORK FOR THE CITY

Step 1 **COLLECT**

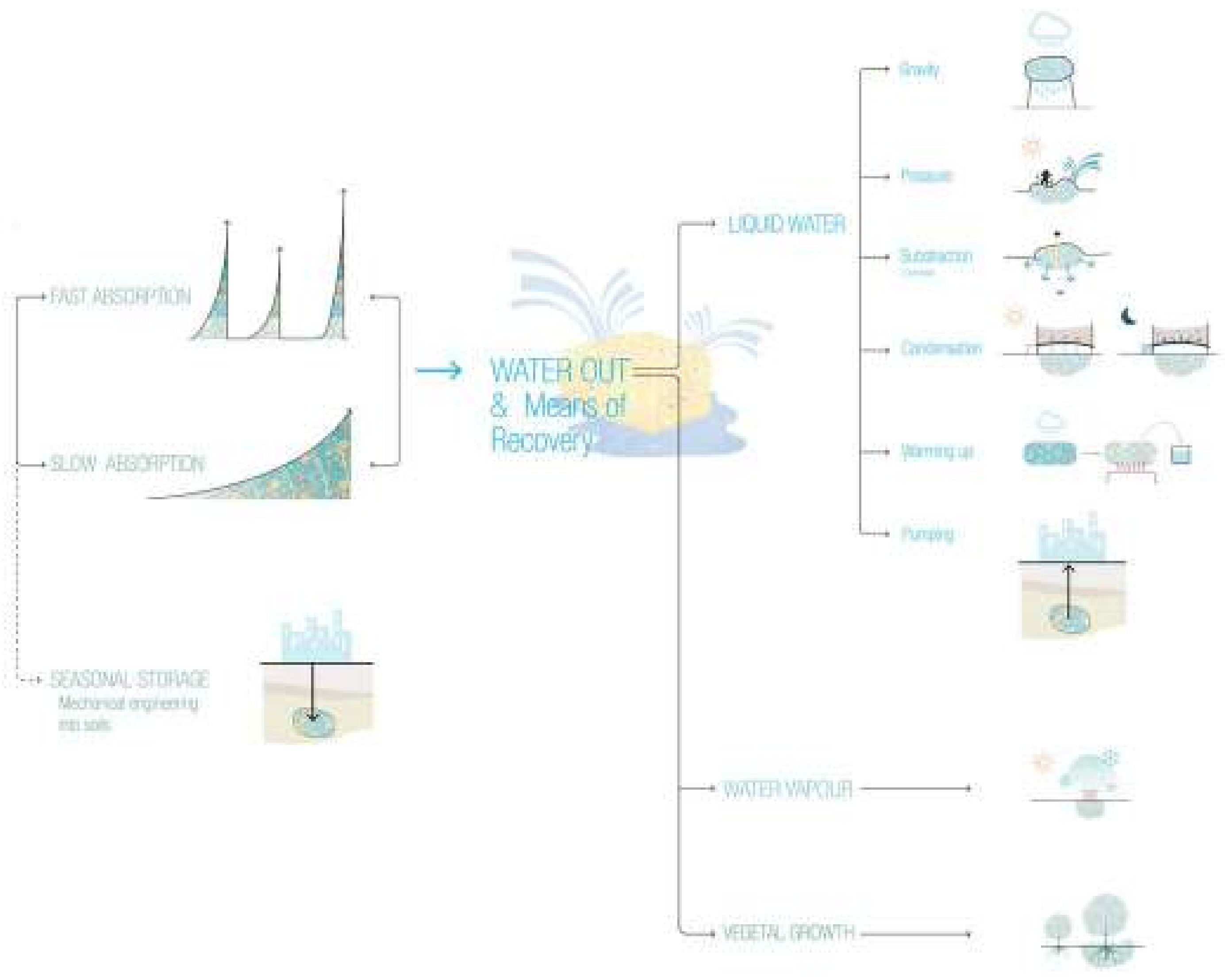


The mechanism of how a sponge can work, follows a threefold sequence of collecting water, storing it for a certain period and then returning the water into the ecosystem. This 'Collect - Store - Return' sequence implies that the concept of a sponge is in essence a system.

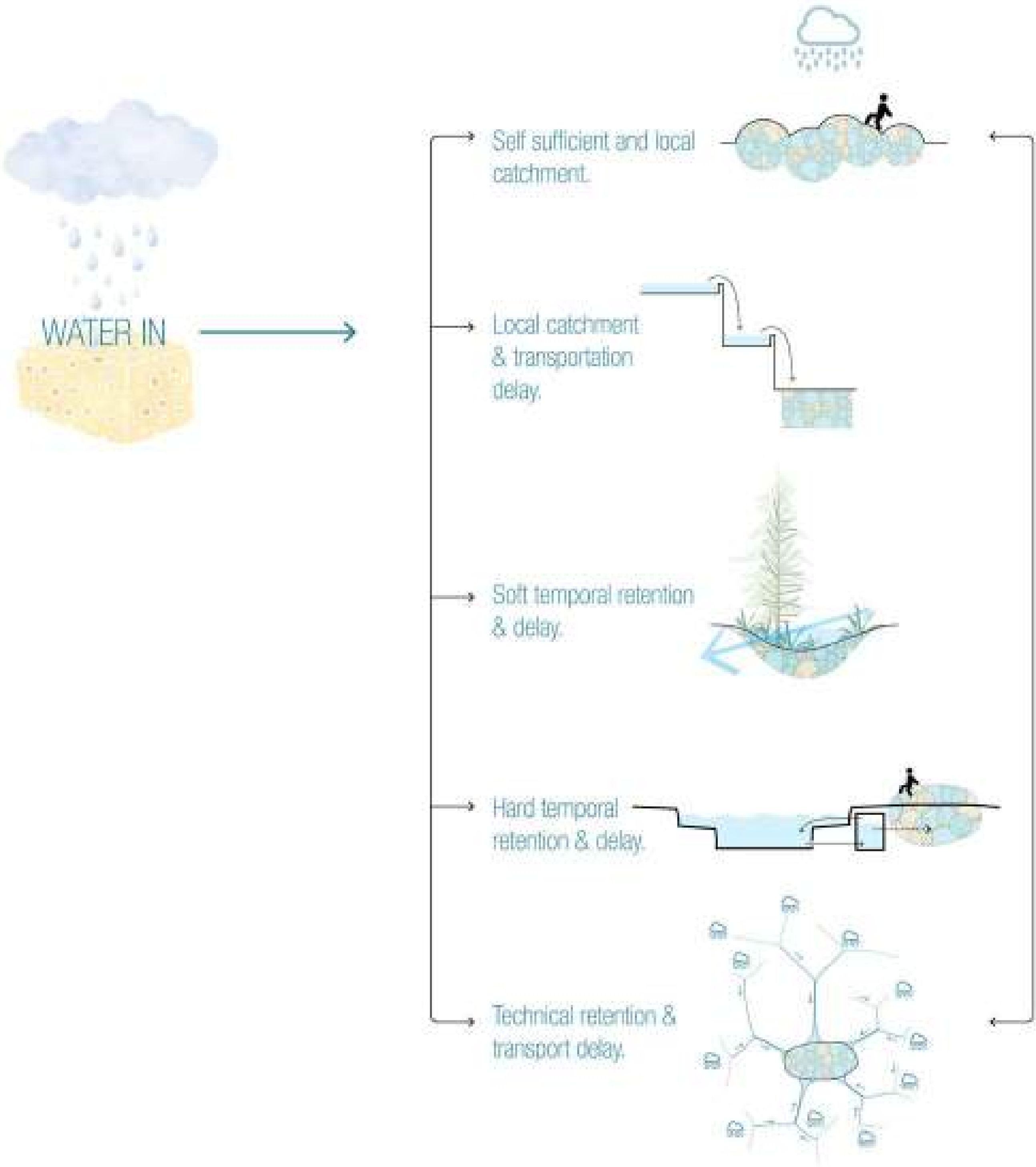
'Collect' deals with the range and speed of catchment of rain water. Primary functions consist of delaying and calming sudden cloudbursts and being able to digest them. Next this water has to be temporarily stored, for which capacities have to be made available. This concerns volumes to be buffered over a certain period, it's length depending on seasonal climatic characteristics of the context. Finally the water can return into its natural environment and become available to the cities ecosystem again. Also more artificial and human oriented reuses of the stored water are part of this step.

Step 2 **STORE**

Step 3 **RETURN**



STEP 1: COLLECT

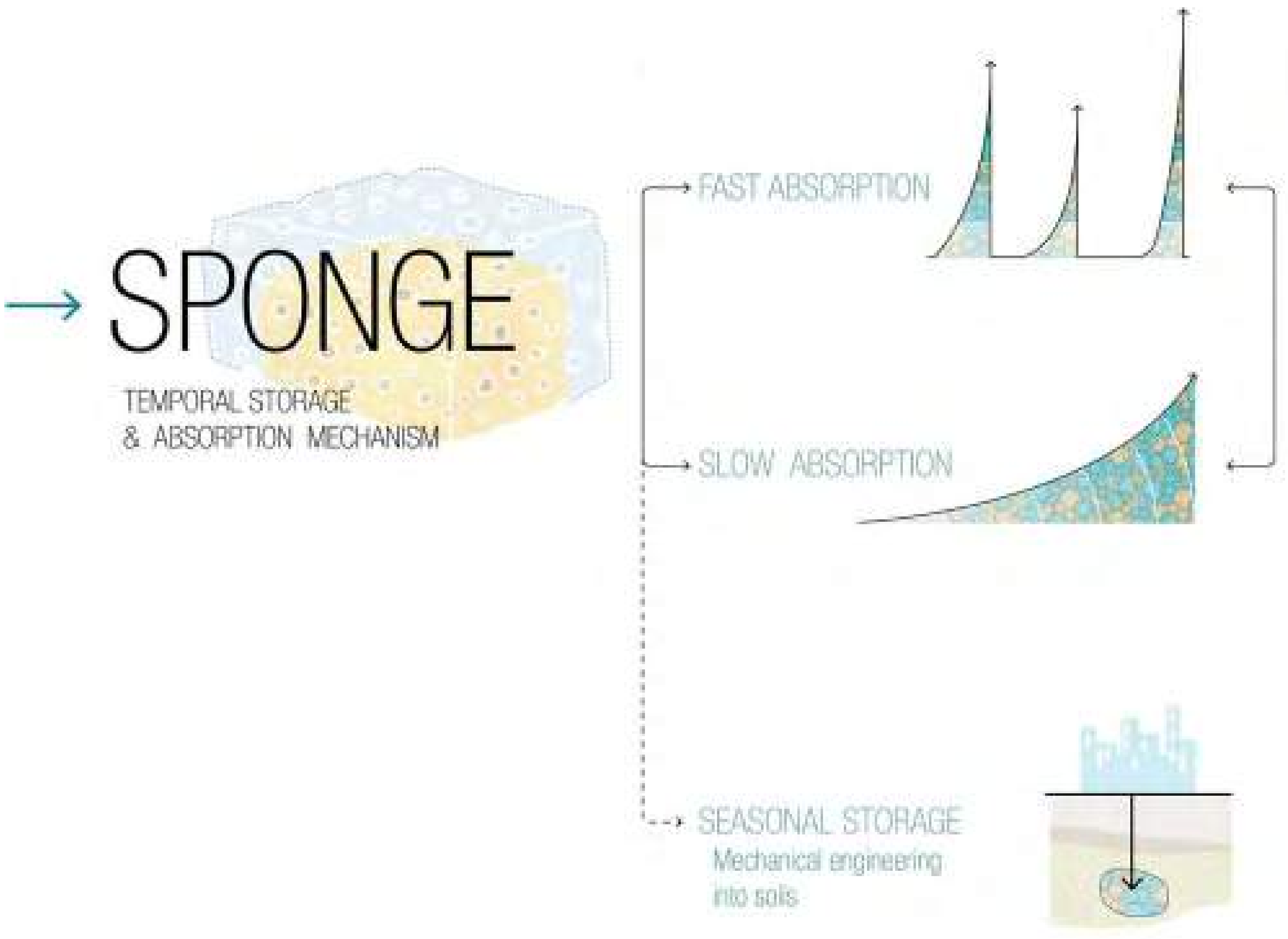


Collection focusses on how sponges receive their water. This can vary from very local to a more large scale context of an entire city quarter. The larger the scale, the more spacious or technical the water collection device needs to be.

We imagine self-sufficient sponges which locally deal with the rain that falls directly on it, being visually materialized in playgrounds, courtyards, front gardens and other similar types of small scale water sensitive solutions. Upscaling sponges as larger water retention entities, they can be connected to transportation and delay systems, located at within a water cascade. Devices like rain gardens or rain parks can be connected to temporal retention and transport delay systems like bioswales. They can also be connected to temporal storage in water squares, as a 'perfect partner' for very fast water collection and retention during the rain, emptying its storage unit at a slower pace into the sponge, to get ready for the next rain event.

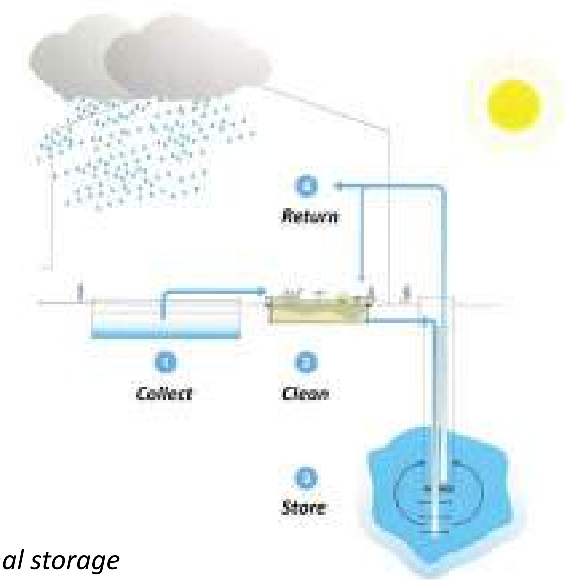
The mentioned solutions still have a somewhat limited water catchment volume (small and medium scale). However sponges can also be applied on larger areas by connecting them to extensively used green open areas or water bodies that allow a considerate fluctuation of water level. Big sponges can be combined with green blue corridors around the city collecting an extra supply of water for the longer term.

STEP 2: STORE


SPONGE
TEMPORAL STORAGE
& ABSORPTION MECHANISM
FAST ABSORPTION
SLOW ABSORPTION
SEASONAL STORAGE
Mechanical engineering
into soils

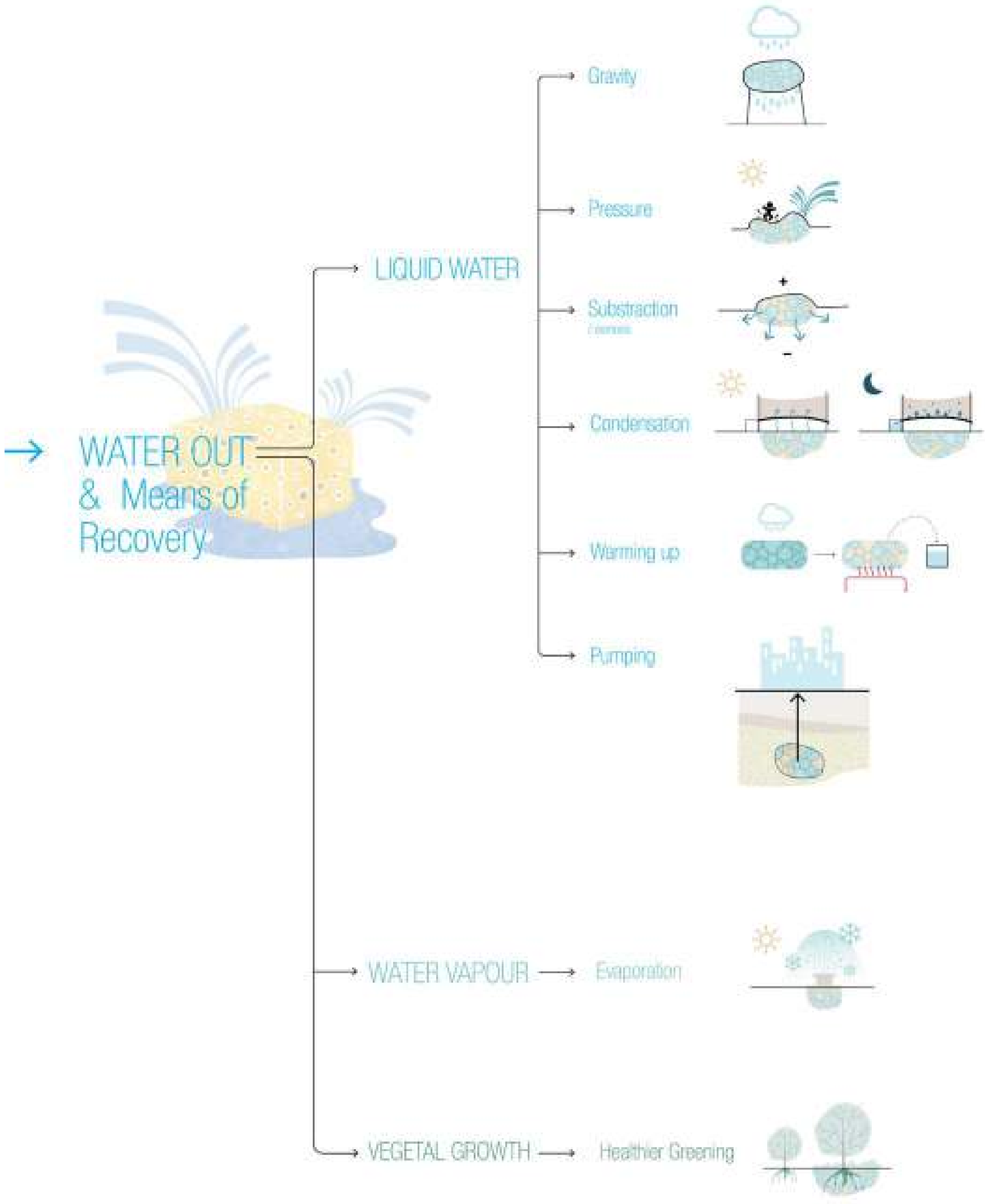
Concerning storage, the inner capability of keeping water is determined by the composition and material the sponge is made of. This will also be relevant in determining the speed of storage and recovery of the sponge. Green solutions are currently hardly sufficiently capable of storing water quickly and are neither coping with large volumes of water on the short term, in contrast to for example a water square. This fundamental characteristic of most sponges defines the role of the sponge as a suitable destination for the water after being collected by more appropriated and effective solutions for peak rain events. Within this relative slowness of storing water there still can be found a considerable variation in speed of absorption, which is highly determined by the composition of the topsoil in urban green areas. Natural solution like soils, planting and agricultural methods are most suitable for midterm to long term storage, while more innovative materials, polymers or technical systems seem to perform quicker.

An interesting long term storage option concerns deeper underground water storage. This technical system has been executed on a few spots in the city of Rotterdam and involves the injecting of filtered clean rainwater into the second aquifer for seasonal fresh water storage purposes.



Seasonal storage

STEP 3: **RETURN**



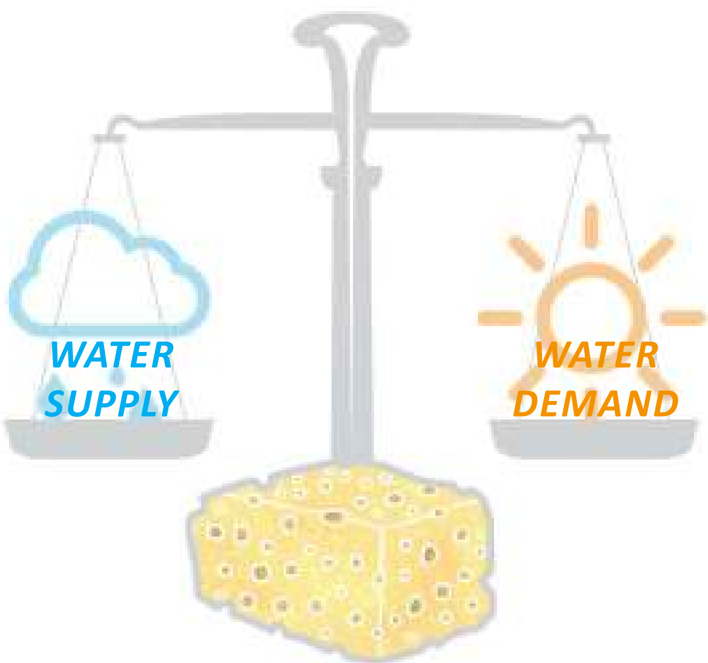
Returning concerns how we can release the water out of the sponge. The logics of this last step is based in the physical and chemical properties of water. Water can be recovered by gravity, by applying pressure, by subtraction, by condensation using the temperature difference between day and night or caused by a warmth source and by pumping it out or up. These physical mechanisms all deal with recovering water as a liquid source. Water can also be recovered in different ways. It can be released into the air as water vapour by active evaporation, to mitigate heat island effects. Also it can be recovered by the natural capabilities of trees and plants as nourishment. As such it improves the resiliency and health of the green structures in the city.

THE PARADIGM OF THE CLIMATIC AVERAGE

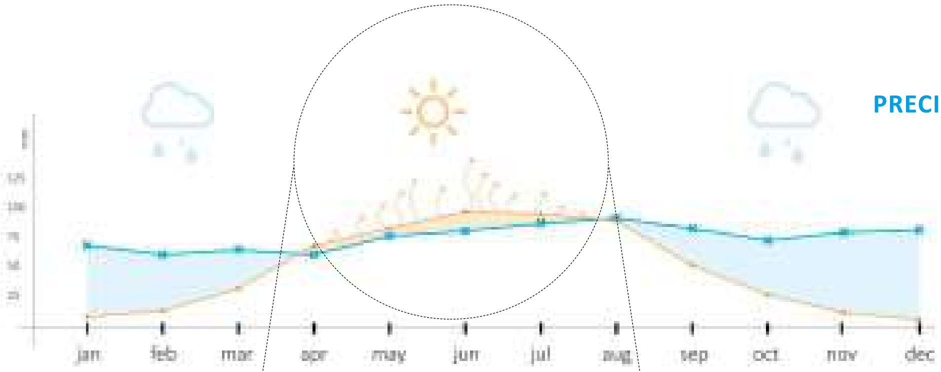
Primarily the Sponge aims at balancing the natural water cycle within the city. To do this we have to look beyond climate averages. Yearly averages on precipitation and evaporation show a pretty balanced situation with an abundant water supply in autumn and winter, and a shortage in late spring and summer. Overall there is a surplus of water which can be drained out without consequence for water demand. In reality this is not the case. Rain events are not equally distributed, but they are concentrated in several moments of intense rainfall. This is a trend that has been increasing over the past decades. At the same time longer periods of no rain at all occur, especially during the warm season. The consequences are short periods of cloudbursts in which the city has to digest a lot of water and longer periods of heat and drought, in which the city experiences a shortage of water.

If cities want to be able to deal with these climate phenomena they need to make space to quickly collect and digest the water, then keep it for longer periods, while simultaneously creating enough space to deal with unexpected cloudbursts again. Within our ever busy urban areas, this will be a true challenge to find the necessary extra space while at the same time being able to accommodate built programme for densification, infrastructures for energy transition and ever growing mobility and sufficient spaces for its inhabitants to meet, linger and recreate. Combining functions in an integral approach will be key.

In the Sponge city every drop counts, which means that we do not limit our objectives to a water management solution only. We have to understand sponges as urban ecologies that generate long term achievements in heat reduction, soil restoration, awareness and educational values, physical and mental public health, real estate values, geographical context expression of identity and emotional values. In general sponges aim for an overall improvement of our cities for future generations.



Monthly average of Precipitation / Evaporation in the Netherlands

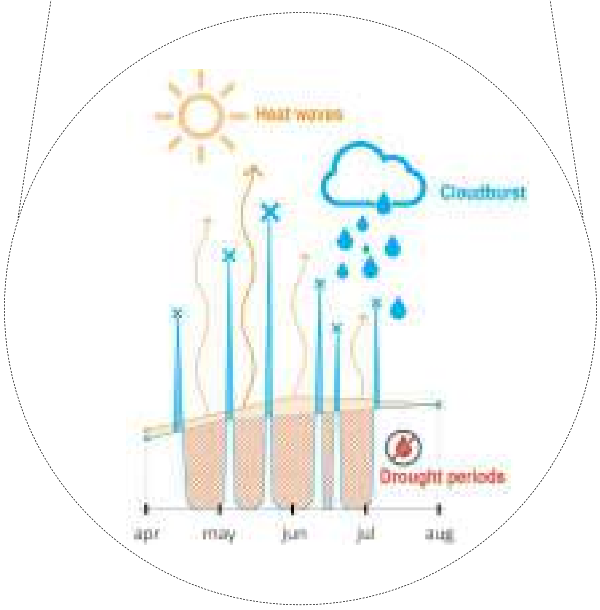


PRECIPITATION

EVAPORATION

Source: Interpolation of evaporation in the Netherlands Dr. Paul Hiemstra Dr. Raymond Sluiter December 15, 2011, Royal Netherlands Meteorological Institute

Educated guess for reality based on experience



CLOUDBURST

HEAT WAVES

DROUGHT PERIODS

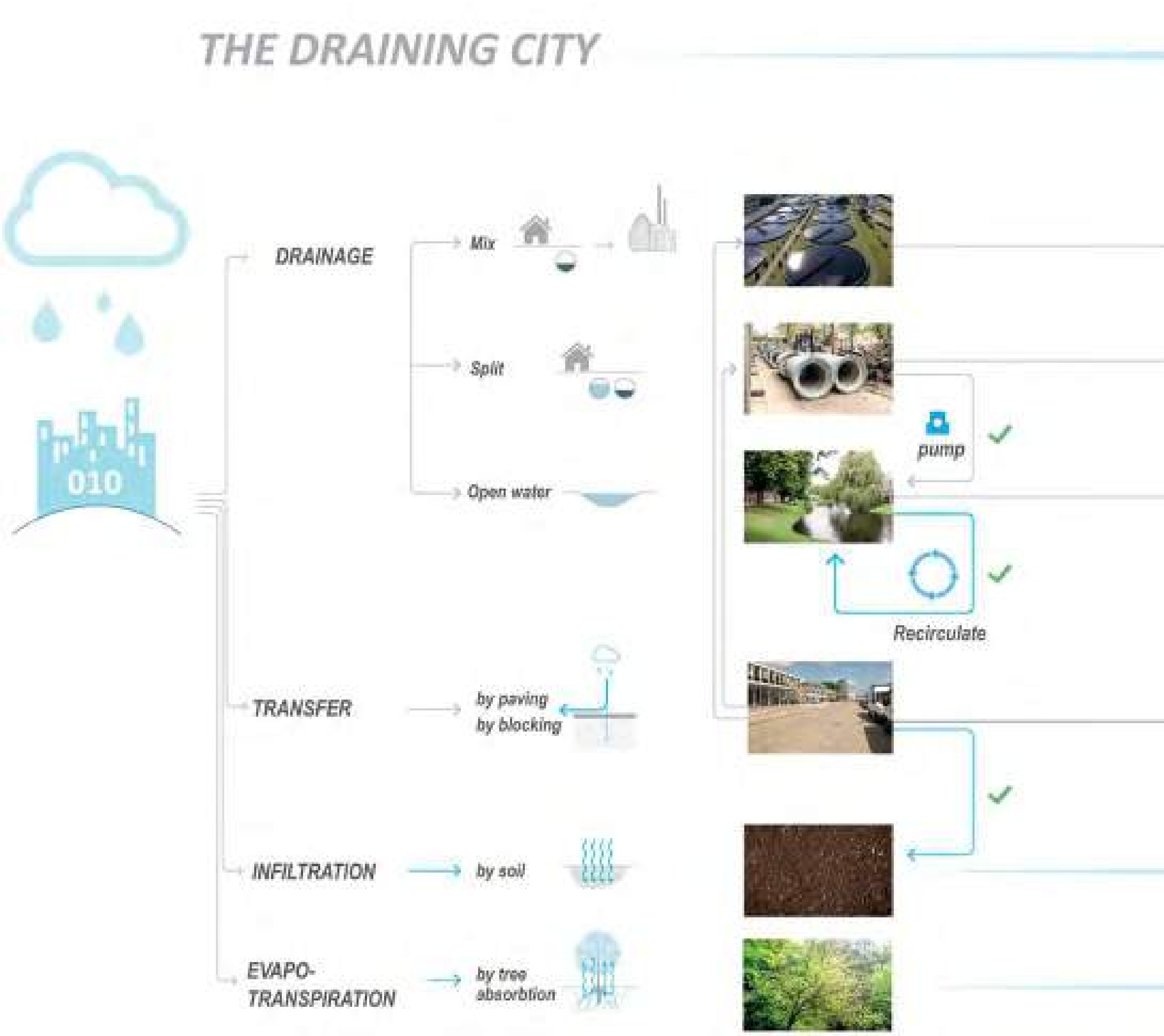
ROTTERDAM RAINFLOOD

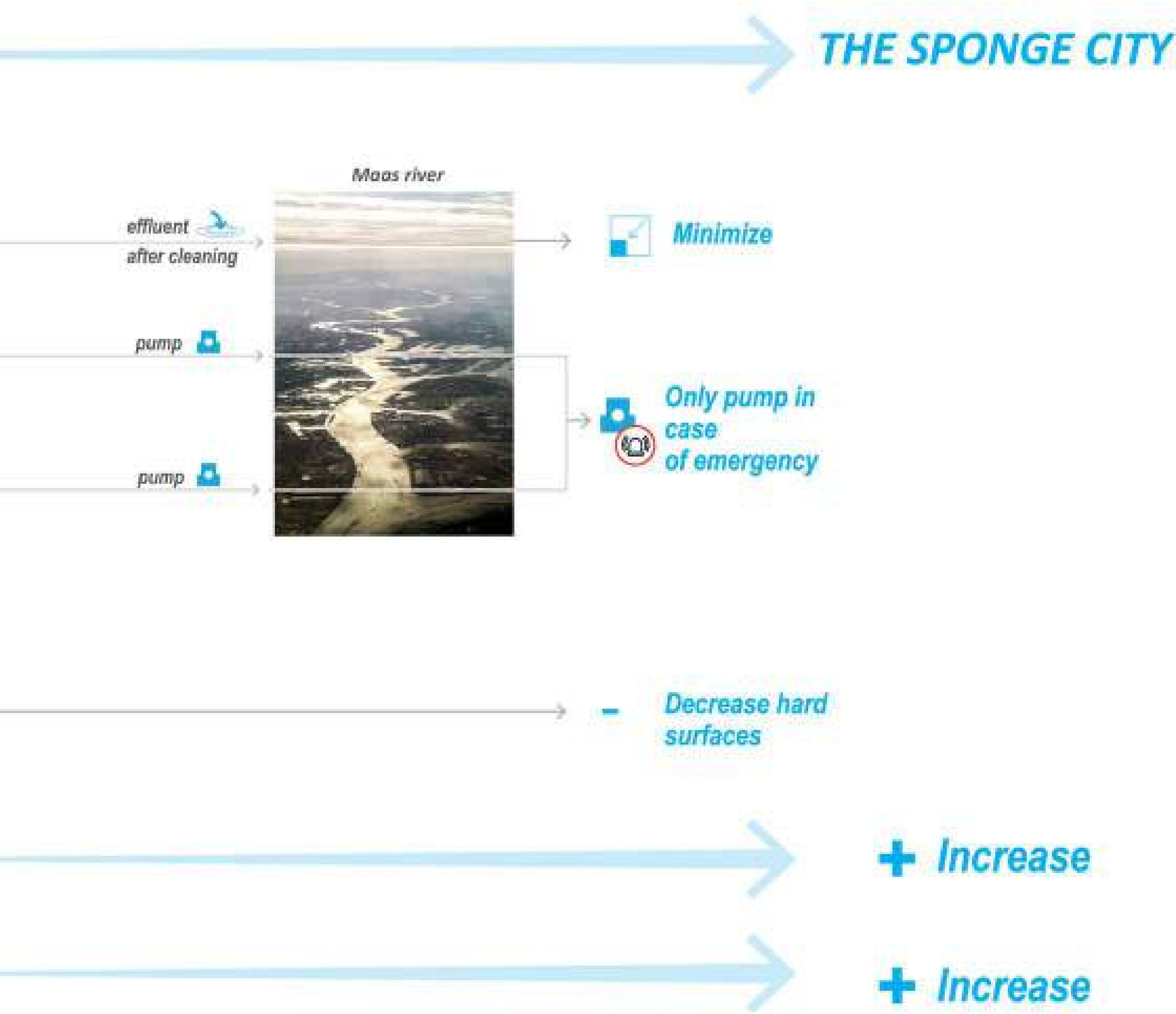
ROTTERDAM DROUGHT

FROM A DRAINING CITY TOWARDS A SPONGE CITY

The Sponge research asks for a transition from a draining city towards a Sponge city. In a Draining city, a small portion of rain is retained by infiltration and absorbed by plants, while most of the rainwater ends up in the river Maas (no matter whether it happens via mixed or split sewage or open water). In contrast, the guidelines of a sponge city are oriented to substantial increase in infiltration, reduction of evaporation, increase in absorption by plants and reuse and recirculation of the water.

This change is not expected to happen tomorrow or within a few years. It would rather be a gradual transition in time, trying to maximize the benefits of the sponge city. The draining system would need a reconsideration and would be used as an addition. The final goal is to help and enhance the capabilities of the city in an integrated model between sponge and draining systems.

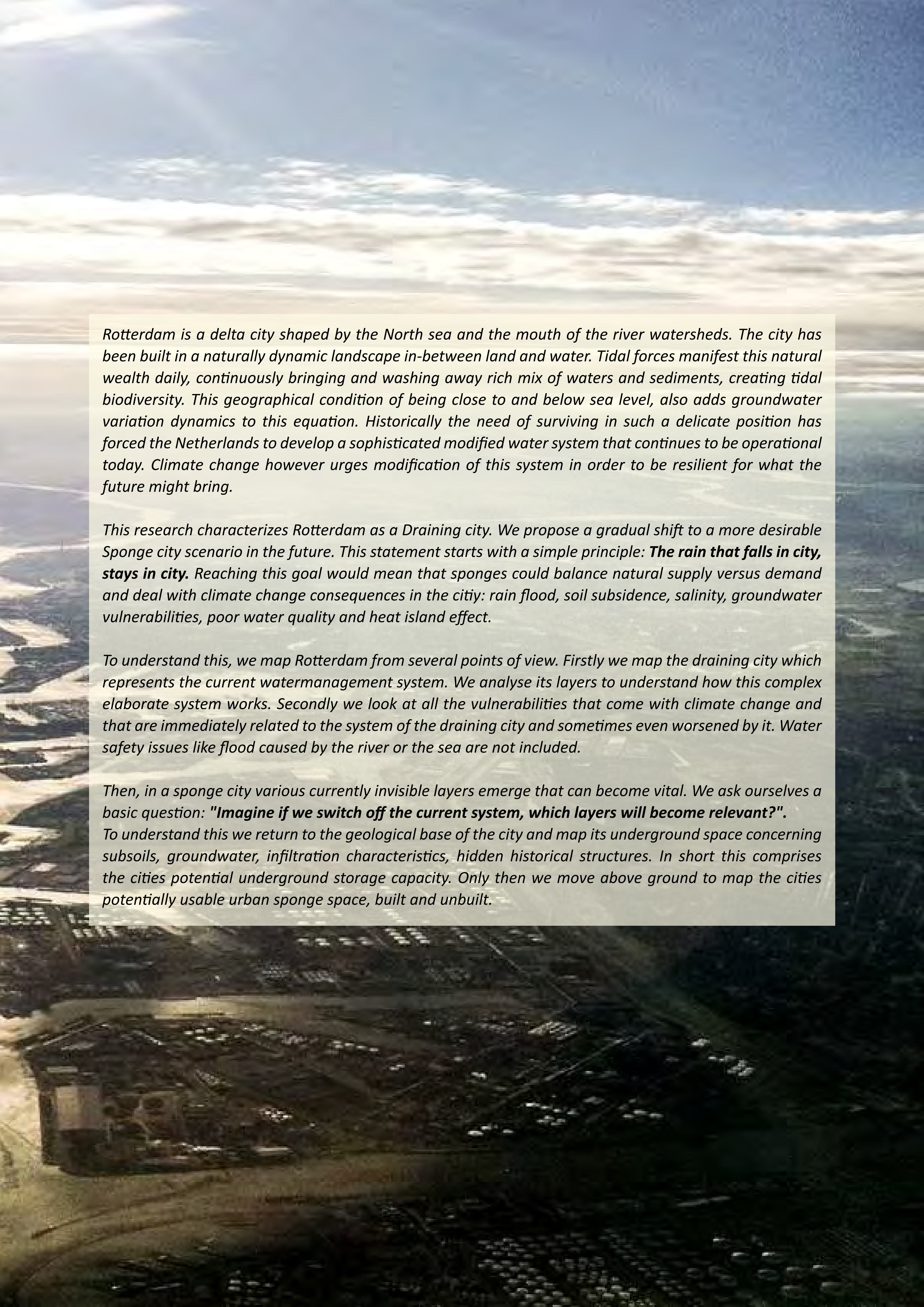




THE SPONGE CITY
Maas river
effluent
after cleaning
Minimize
pump
pump
Only pump in case of emergency
Decrease hard surfaces
Increase
Increase

CHAPTER 3

ANALYZING THE SPONGE AS AN ASSET FOR ROTTERDAM



Rotterdam is a delta city shaped by the North sea and the mouth of the river watersheds. The city has been built in a naturally dynamic landscape in-between land and water. Tidal forces manifest this natural wealth daily, continuously bringing and washing away rich mix of waters and sediments, creating tidal biodiversity. This geographical condition of being close to and below sea level, also adds groundwater variation dynamics to this equation. Historically the need of surviving in such a delicate position has forced the Netherlands to develop a sophisticated modified water system that continues to be operational today. Climate change however urges modification of this system in order to be resilient for what the future might bring.

This research characterizes Rotterdam as a Draining city. We propose a gradual shift to a more desirable Sponge city scenario in the future. This statement starts with a simple principle: ***The rain that falls in city, stays in city.*** *Reaching this goal would mean that sponges could balance natural supply versus demand and deal with climate change consequences in the citiy: rain flood, soil subsidence, salinity, groundwater vulnerabilities, poor water quality and heat island effect.*

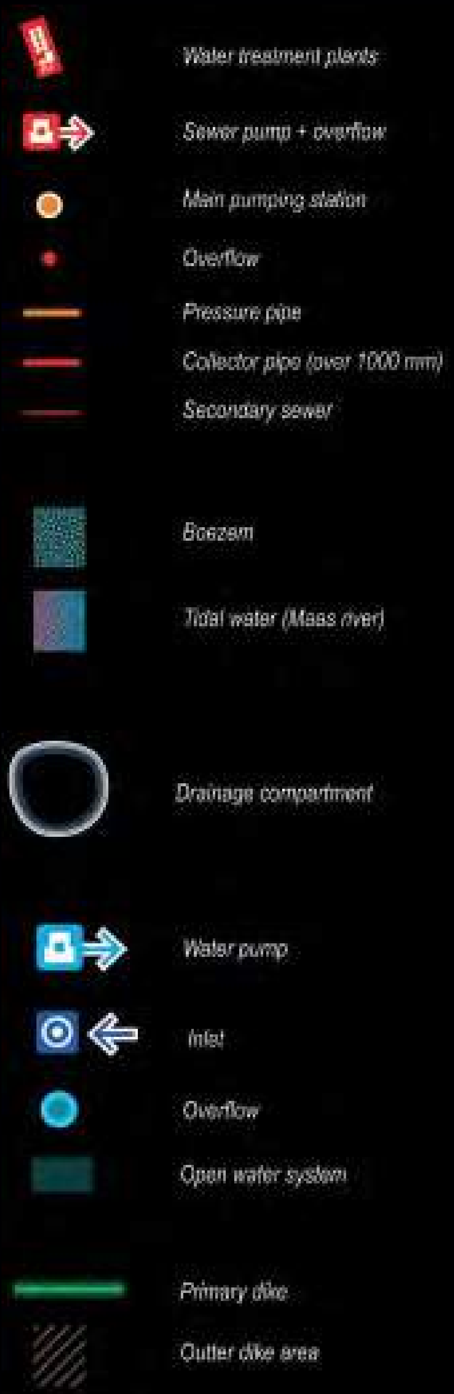
To understand this, we map Rotterdam from several points of view. Firstly we map the draining city which represents the current watermanagement system. We analyse its layers to understand how this complex elaborate system works. Secondly we look at all the vulnerabilities that come with climate change and that are immediately related to the system of the draining city and sometimes even worsened by it. Water safety issues like flood caused by the river or the sea are not included.

Then, in a sponge city various currently invisible layers emerge that can become vital. We ask ourselves a basic question: ***"Imagine if we switch off the current system, which layers will become relevant?".***
To understand this we return to the geological base of the city and map its underground space concerning subsoils, groundwater, infiltration characteristics, hidden historical structures. In short this comprises the cities potential underground storage capacity. Only then we move above ground to map the cities potentially usable urban sponge space, built and unbuilt.

The Draining city

THE COMPLETE DRAINING CITY

The current water system is a sophisticated and extensive network designed with a clear mission to drain all the water as soon as possible out of the city



Sources:
Rotterdam Municipality GIS
De Bosatlas van Nederland Waterland
Polders! Gedicht Nederland
AHN - Actueel Hoogtebestand Nederland

The Draining city

DIKES AND MAIN WATERWAYS

Primary dikes and the polder system represent the main national water safety protection (together with coastal dunes and delta works). The primary dikes protect the land from river floods and sea storm surges and shapes the polders. Culturally, the polder lines show the history and the growth of the city. The water system is a network of waterways with a goal to bring water out of the polders. It follows a certain hierarchy and transports water from lower to higher ground, from small ditches to big waterways. The destinations of this excess water are the rivers - Maas, and Oude Maas. Some of these historical structures function also as transportation routes.

Primary dike

Secondary dike

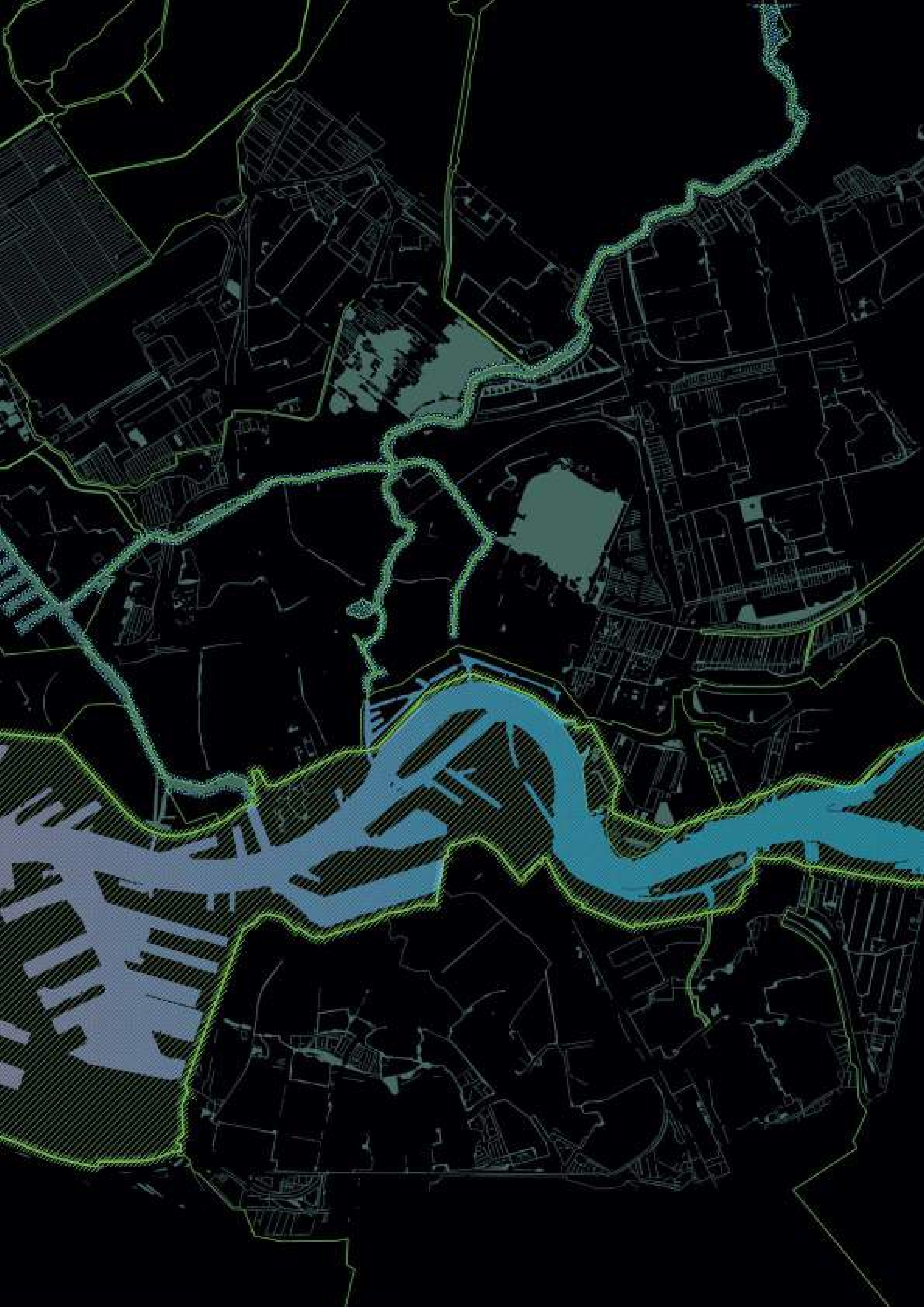
Open water system

Boezem

Tidal water (Maas river)

Outter dike area

Sources:
- De Bosatlas van Nederland Waterland
- Rotterdam Municipality GIS



The Draining city

OPEN WATER SYSTEM

The open water system is a complex engineering network of singels, canals, smaller rivers, ditches, lakes, waterways, pipes, pumps, overflow points, inlets, outlets. Its main function is to drain low lying lands of (urbanized) polders. They work as interconneted hydrological units, where water is ultimately pumped out into the Maas river.

Sources:
- De Bosatlas van Nederland Waterland
- Rotterdam Municipality GIS
- Rotterdam Waterplan

40 m3/ min
10 m3/ min
37 m3/ min
90 m3/ min
58 m3/ min
70 m3/ min
40 m3/ min
1 m3/ min
280 m3/ min
650 m3/ min
14 m3/ min
6 m3/ min
83 m3/ min
1.200 m3/ min

The Draining city

SEWAGE SYSTEM

The sewage system shows how the rainwater and black water is drained out of the city. The sewerage works were established in the past to enlarge the water capacity of the city and to ensure hygienic conditions. In 1854 the Rose plan marked a relevant moment in history with an affordable sewage plan that contributed to both the hygiene and spatial design of the city.
Today Rotterdam has to deal with different challenges brought on by climate change scenarios and extreme rain events. The sewage system is lacking the capacity to facilitate them.
In practice, rainwater is usually drained away via sewers. A way to accomodate the growing amount of water is to work with a split sewage system - separating black water from the relatively clean rainwater. Construction of such system will take decades and considerable financial means. A complete division throughout Rotterdam is rather unlikely to be feasable.

Water treatment plants
Sewage district border
Sewage district border
Sewer pump + overflow
Main pumping station
Overflow
Pressure pipe
Collector pipe (over 1000 mm)
Secondary sewer

Source:
- Rotterdam municipality

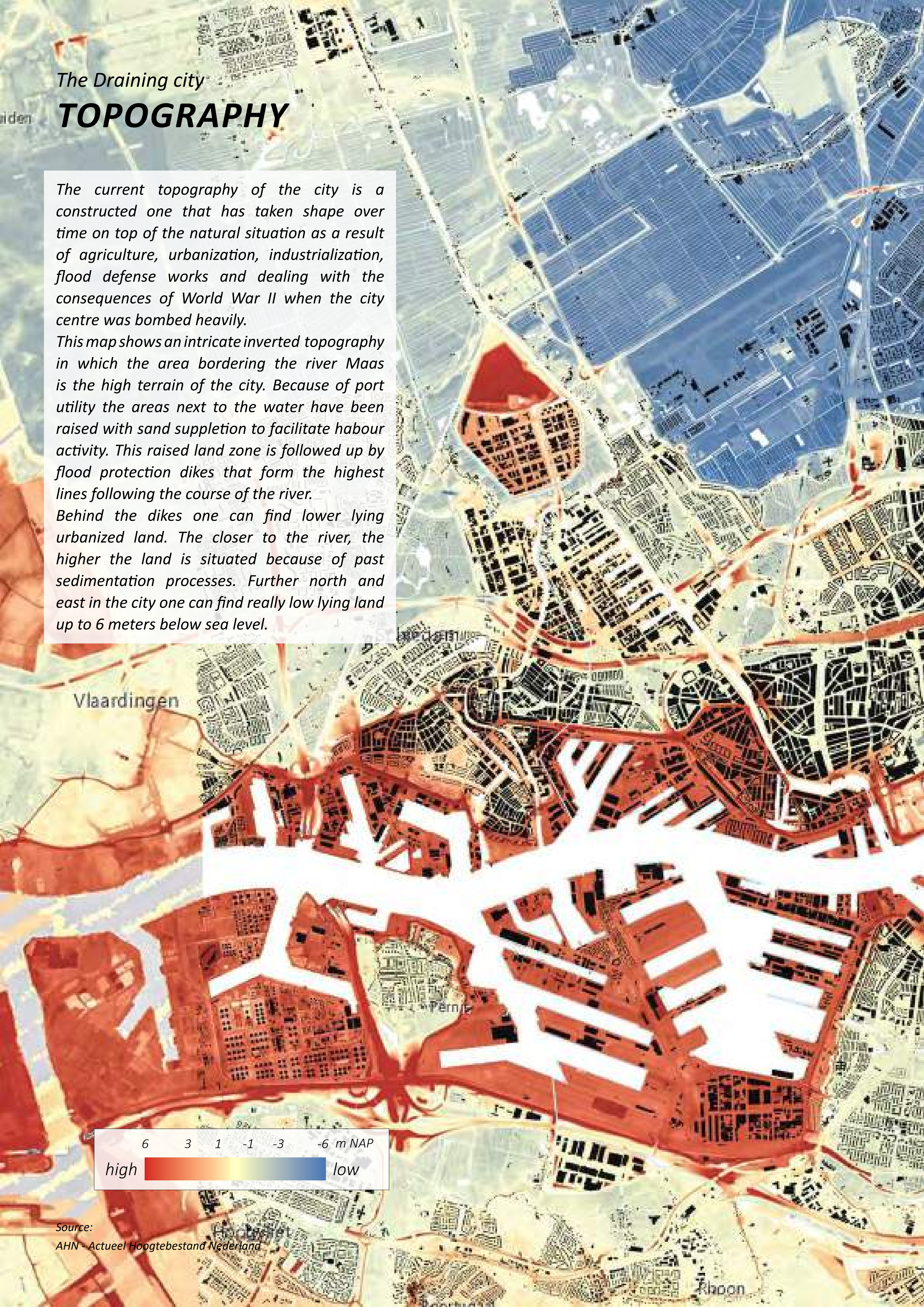
The Draining city

TOPOGRAPHY

The current topography of the city is a constructed one that has taken shape over time on top of the natural situation as a result of agriculture, urbanization, industrialization, flood defense works and dealing with the consequences of World War II when the city centre was bombed heavily.

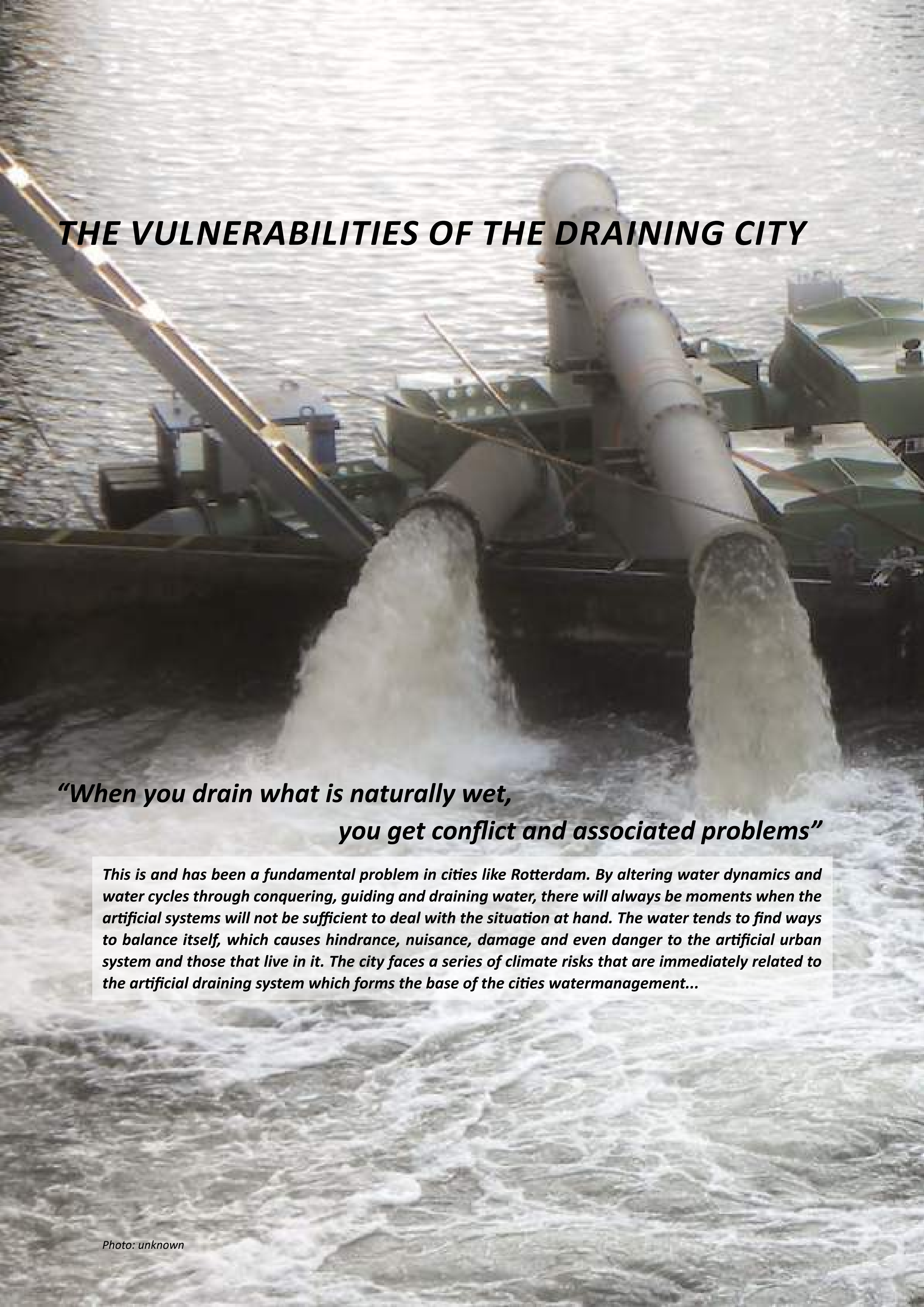
This map shows an intricate inverted topography in which the area bordering the river Maas is the high terrain of the city. Because of port utility the areas next to the water have been raised with sand suppletion to facilitate habour activity. This raised land zone is followed up by flood protection dikes that form the highest lines following the course of the river.

Behind the dikes one can find lower lying urbanized land. The closer to the river, the higher the land is situated because of past sedimentation processes. Further north and east in the city one can find really low lying land up to 6 meters below sea level.



Source:
AHN - Actueel Hoogtebestand Nederland

Nieuwerkerk aan den
Krimpen aan den IJssel
Slikkerveer
Ridderkerk



THE VULNERABILITIES OF THE DRAINING CITY

"When you drain what is naturally wet,

you get conflict and associated problems"

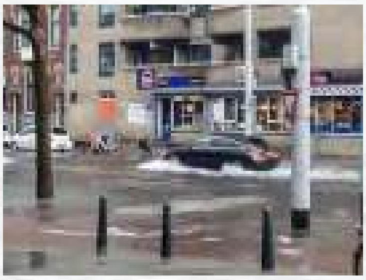
This is and has been a fundamental problem in cities like Rotterdam. By altering water dynamics and water cycles through conquering, guiding and draining water, there will always be moments when the artificial systems will not be sufficient to deal with the situation at hand. The water tends to find ways to balance itself, which causes hindrance, nuisance, damage and even danger to the artificial urban system and those that live in it. The city faces a series of climate risks that are immediately related to the artificial draining system which forms the base of the cities watermanagement...

Photo: unknown

TOO WET

FLOODING INFRASTRUCTURE

FLOODING PUBLIC SPACE



FLOODING PRIVATE PROPERTY

TOO DRY

WOODEN PILE ROT

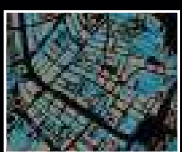
SOIL SUBSIDENCE

POOR WATER QUALITY

The Draining city vulnerabilities

RAIN WATER FLOODING

The city is experiencing heavy cloudbursts and due to climate change these downpours will become more frequent and stronger in size. Not all the areas are being affected equally. Densly built as well as low lying areas are most vulnerable in Rotterdam. The map shows the potential inundation depth of rain flooding and those areas where water can accumulate most under extreme rainfall. The model is based on topography and the available water storage space on the ground level. Insufficient sewage capacity, largely paved surfaces and insufficient infiltration capacity are the main causes of flooding on street level.



Areas with flood risk above 10 cm inundation
** Based on topographical conditions*

Sources:
- Climate adapatation services Rotterdam
- De Bosatlas van Nederland Waterland

The Draining city vulnerabilities

SOIL SUBSIDENCE

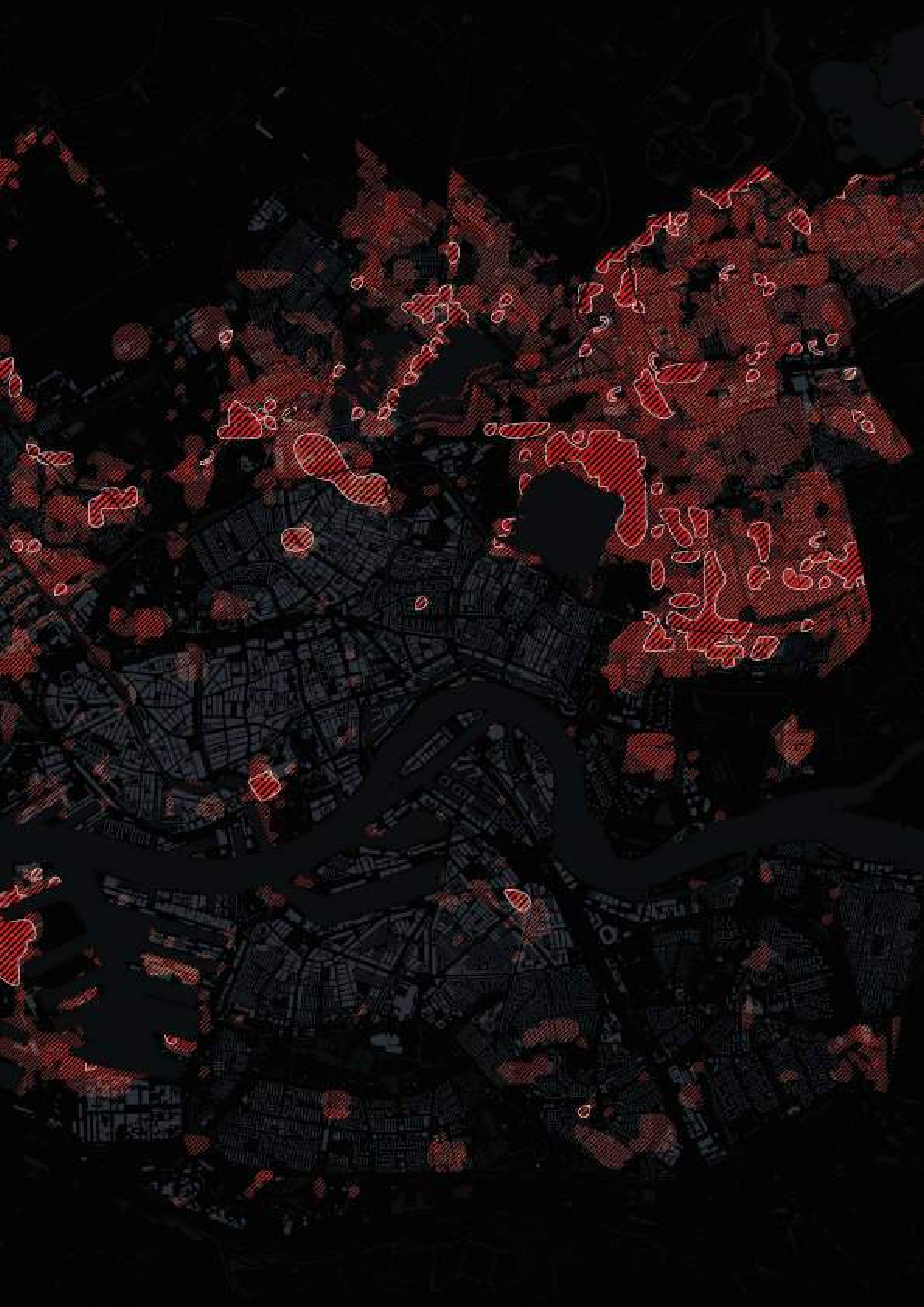
Subsidence is a natural process of soil sinking due to the collapse of soil stratum. The Rotterdam situation is a typical case of risks caused by soil disturbance. The problem is mainly located in the part of the city that has been built on peat soils. Outside the city boundaries the problem extends towards the adjacent polders of Krimpenerwaard and Alblasserwaard, both raised on peat. Peat soil is a stable base when appropriated moisture level is preserved. The issues start when these soils get drier due to lower groundwater levels and/or exposure directly to the air (oxygen). The reaction causes the collapsing and subsequent settling of the peat package. Long periods of drought, as a result of climate change, will probably negatively influence and accelerate the subsidence.

Sinking area > 1 cm

Sinking area 0.5 - 1 cm

Sinking area 0.1 - 0.5 cm

Sources:
- Climate adapatation services Rotterdam
- RAS (Rotterdam adaptation strategy)



The Draining city vulnerabilities

LOW GROUNDWATER LEVELS

Wooden pile foundation

*Low groundwater level and soil subsidence are a threat to buildings on **wooden pile foundations.** When the piles dry out, they can start to rot, partly collapse and cause structural damage to properties. The map shows those areas with wooden pile foundation at a high risk and moderate risks.*

Urban flora and fauna

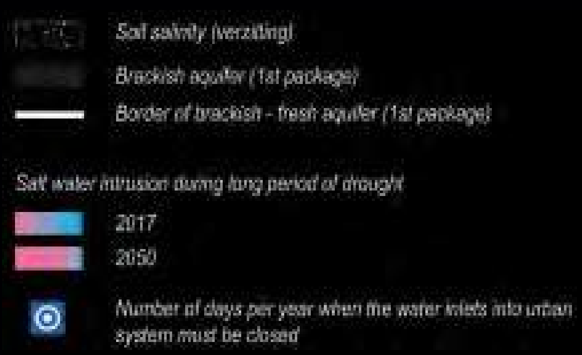
*Furthermore, insufficient groundwater and lower water table represent a negative impact on the **urban flora** in Rotterdam. It is specially endangering the species whose preferred environment allows them to have roots submerged in groundwater. Long periods of drought are the principle reason for groundwater deficit and unfortunately summer rainfall doesn't help due to its high concentration in a short period. In summer rainpours the excess of rainwater drains away through the sewers and surface water, leaving too short periods of infiltration time.*

Sources:
- Climate adapatation services Rotterdam
- De Bosatlas van Nederland Waterland
- RAS (Rotterdam adaptation strategy)

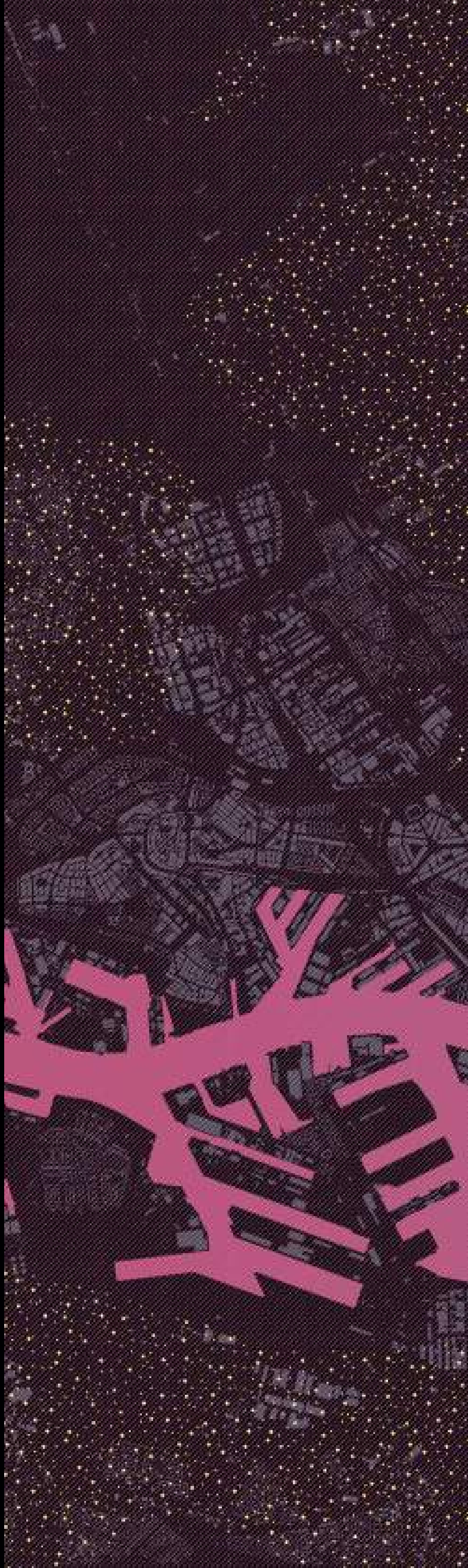
The Draining city vulnerabilities

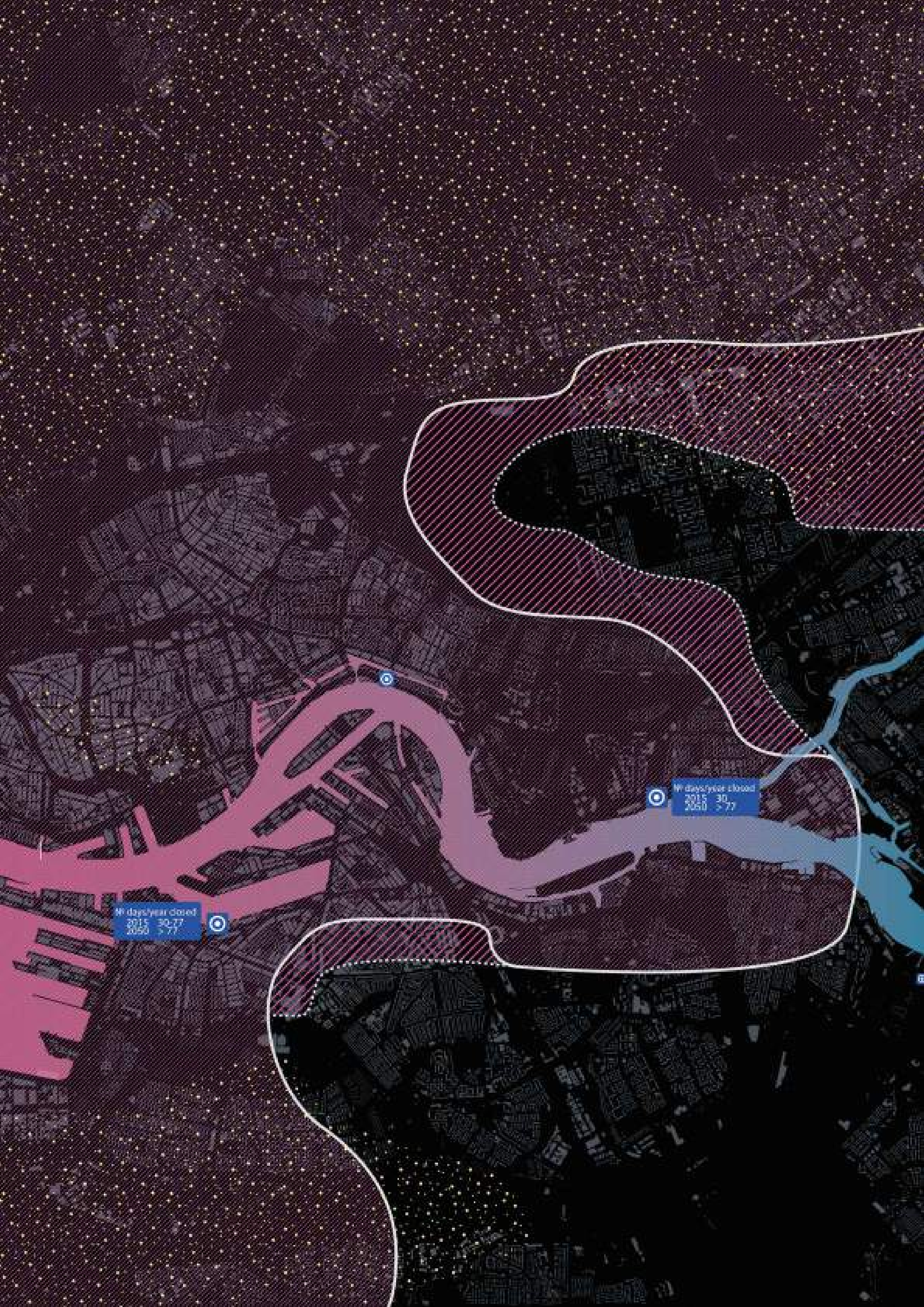
SALTWATER INTRUSION

Every day the tide brings water with high concentrations of salt in and out of Rotterdam. Long periods of drought cause low river levels which combined with high sea levels have as a consequence that salty water travels further inland and negatively effects the inner dike open water of the city, its groundwater quality and subsequently its soil and dependent flora and fauna.
River water currently flows into the inner dike urban water system at three places through inlets. The availability of fresh water is declining and in order to maintain a certain water level in canals and singels, the river water has to be let in. Even when the salt concentration is higher than desirable. If the water would not be replenished then canal levels will become too low, leading to the risk of subsidence and extremely low water tables. The alternative is to use fresh water from the cities drinking water supply. Non of these 'solutions' are desirable.



Sources:
- Interactieve atlassen en kaarten
- RAS (Rotterdam adaptation strategy)



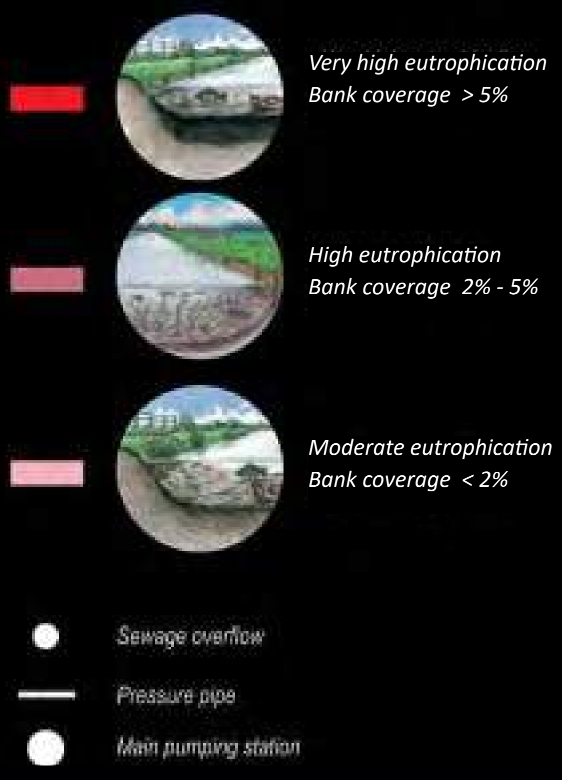

Nº days/year closed
2015 30
2050 > 77
Nº days/year closed
2015 30-77
2050 > 77

The Draining city vulnerabilities

POOR WATER QUALITY

*Open water quality in Rotterdam tends to be poor. The reasons are associated with less rainfall infiltration and periods of drought, resulting in a detriment of the ecological quality of open water. The lack of available fresh water, too little flow and the increment in salt concentration lead to higher nutrient concentrations, especially nitrogen and phosphorus. This enhances an uncontrollable algae growth, drastically reducing the oxygen level in the water. Furthermore, sewerage overflow into open water, due to extreme downpours, accelerate the negative situation. This problem is commonly known as **eutrophication** of open water. It requires special attention as it brings problems in public health, reduces navigability of waterways for fish and increases the growth of undesirable bacteria in the sludge, producing lethal toxins in birds and mammals.*

Poor water quality due to the high amount of organic matter (Eutrophication) and the lack of vegetation along the banks



Source:
- Interactieve atlassen en kaarten
- Herijking Waterplan Rotterdam 2. Werken aan water voor een aantrekkelijke en klimaatbestendige stad
- RAS (Rotterdam adaptation strategy)

The Draining city vulnerabilities

HEAT STRESS AND DROUGHT

Global warming is and will continue to affect Rotterdam in the future. It manifests itself in longer and warmer periods with an increase of a number of summer days (>20°C) and a number of tropical days (>30°C). In addition to the periods of warmth, the city will face urban heat island effect caused by daily excess heat absorption of paving and a lack of planting in the city centres, harbours and industrial areas.

The raising temperature has a direct effect on public health, liveability of flora and fauna and the functionality of the city. Elderly people with respiratory diseases are particularly vulnerable; office workers become less productive due to the loss of thermal comfort; flora and fauna are negatively affected, specially species depending on water and the proliferation of non-desirable species like mosquitoes and ticks. Finally the bridges, major roads and railways are prone to damage in extreme temperatures, thereby causing negative effects on the cities accessibility.

Urban areas affected by heat island effect by 2050 (number of days with minimum temperature >20C)

Sources:
- Climate adapatation services Rotterdam
- RAS (Rotterdam adaptation strategy)

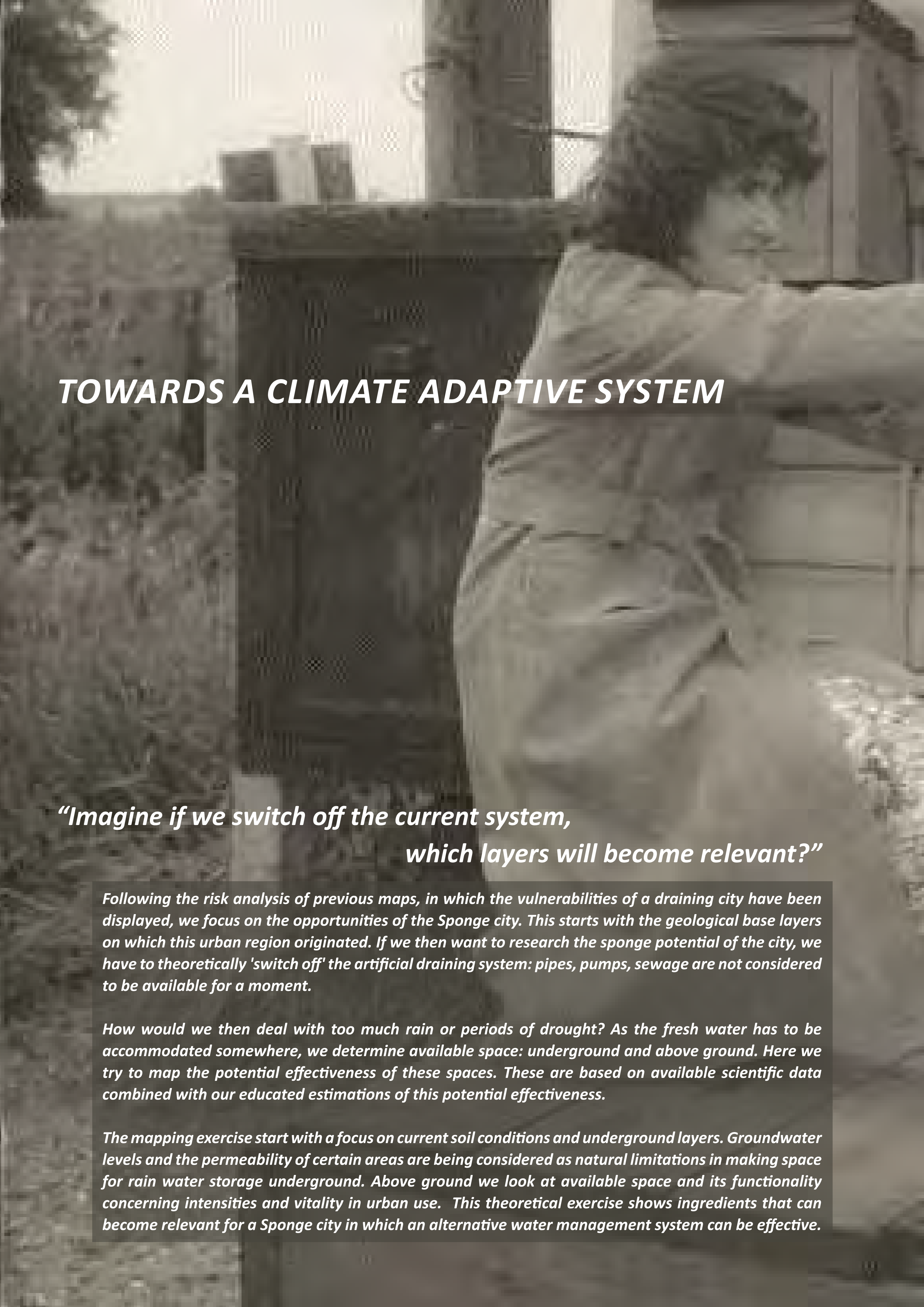
The Draining city vulnerabilities

ACCUMULATION OF DISTURBED WATER BALANCE

*This map indicates all c**limate vulnerabilities in Rotterdam regarding the loss of water balance in the Draining city.** Subsidence, rain flood, wooden pile rotting, poor water quality, saltwater intrusion and heat island effect are shown together to visualize the magnitude of the risks.*

We can distinguish various risk zones according to underlaying landscape and built structure: subsidence in the districts built on peat (Prins Alexander); groundwater vulnerability and wooden pile foundation rot in the north and the south of Rotterdam (19th century neighborhoods); poor water quality in low laying areas and rain flood in the most densely built districts.

Sources:
- Rotterdam Municipality GIS
- De Bosatlas van Nederland Waterland
- AHN (Actueel Hoogtebestand Nederland - Interactieve atlassen en kaarten)
- Herijking Waterplan Rotterdam 2 // Werken aan water voor een aantrekkelijke en klimaatbestendige stad
- Climate adapatation services Rotterdam
- RAS (Rotterdam adaptation strategy)



TOWARDS A CLIMATE ADAPTIVE SYSTEM

"Imagine if we switch off the current system, which layers will become relevant?"

Following the risk analysis of previous maps, in which the vulnerabilities of a draining city have been displayed, we focus on the opportunities of the Sponge city. This starts with the geological base layers on which this urban region originated. If we then want to research the sponge potential of the city, we have to theoretically 'switch off' the artificial draining system: pipes, pumps, sewage are not considered to be available for a moment.

How would we then deal with too much rain or periods of drought? As the fresh water has to be accommodated somewhere, we determine available space: underground and above ground. Here we try to map the potential effectiveness of these spaces. These are based on available scientific data combined with our educated estimations of this potential effectiveness.

The mapping exercise start with a focus on current soil conditions and underground layers. Groundwater levels and the permeability of certain areas are being considered as natural limitations in making space for rain water storage underground. Above ground we look at available space and its functionality concerning intensities and vitality in urban use. This theoretical exercise shows ingredients that can become relevant for a Sponge city in which an alternative water management system can be effective.

The base layers

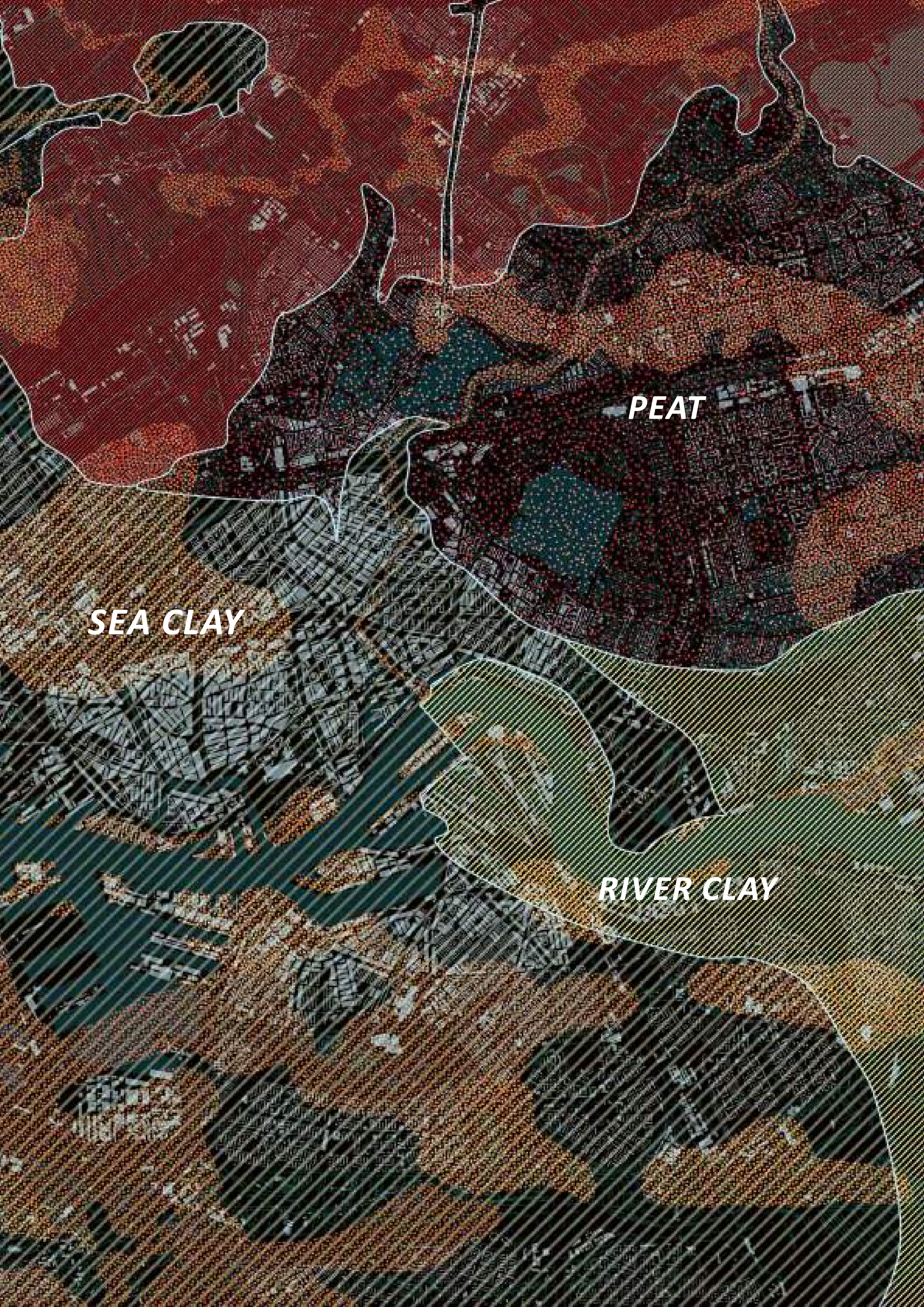
GEOLOGY

The map shows the foundation of Rotterdam and the underlying natural landscape forming processes. We can distinguish two main geological divisions:

- *river delta complex, composed of clay sediments and brackish waters;*
- *peat complex on the Netherlands, formed by wet peat soils and fresh water.*

Clays have been brought over centuries from the sea by tide and from the hinterland through river discharge. While peat soils have been formed in the wetlands probably fed by rain, and moulded by partially decomposed semi-aquatic plants. Currently in South Holland, there are hardly any completely natural landscapes left. However, the differences between both its geological complexes are still clearly recognizable. Moreover, a system of sediment belts (stroomgordels) runs intertwined through the clay and peat soils mixing with subsoils. It is characterized by sandy berms that follow the traces of former rivers and creeks. Closely along these river beds coarser sediments (sand) and further away finer ones (clay) were deposited during peak discharges. Historically these river courses and their sandy levees were present until the time of dike construction in the Late Middle Ages and they still have a major influence on the current landscape.

Sources:
- Interactieve atlassen en kaarten // Provincie Zuid-Holland - Kwaliteitskaart ondergrond
- TNO (de Bos atlas)


PEAT
SEA CLAY
RIVER CLAY

The base layers

GEOLOGY

THE BASE OF ROTTERDAM IS WET

There are three main soil typologies in Rotterdam and their corresponding landscapes have a common characteristic: ***wet geology.*** *Although in reality they are far away from being natural, we can still find some areas where their inherent natural condition is expressed.*

River clay

Large quantities of sediments come with river waters. Usually most of the clay travels to the sea by river discharge. However, floods occure in the autumn due to heavy rainfalls and in the late spring when the snow melts up in the mountains. Then rivers exceed their banks, overflow into the floodplains and clay sediments settle as the speed of water decreases.

The floodplains historically have been used for multiple purposes: cultivation of fast-growing crops such as corn and sugar beets; pastures -grass can easily withstand river flooding-; as a resource of clay for manufacturing bricks and roof tiles.

THE ORIGINS OF ROTTERDAM

Rotterdam in the 13th century

RIVER CLAY

Sea clay

The formation of sea clay grounds started in the Early Holocene (10,000 years ago) after the melting of the ice sheets. The sea level rose to a higher level than today and large part of the Netherlands was flooded. Behind the sandy front, a vast volume of water came to rest and promoted the sinking and deposition of small particles. This resulted in thick packages of sea clay that still form the largest part of the soil along the entire coastline.

Sea clay has been widely used due to the high fertility and it provides suitable growing conditions for salt-loving plants like glasswort (zeekraal), potatoes, beets, corn and grain.

Peat soil

Peat areas are formed by partial decomposition of swampy plants. In the absence of oxygen they decompose very little and accumulate in thick layers that eventually form a peat soil. There are two types of peat soil:

- *peat bog (laagveen) from wetlands where groundwater reaches the surface and where reeds, alders and willows grow;*
- *raised bog (hoogveen) from wetlands where rain is the only water supply and only moss species grows.*

Peat soils are not very suitable for agriculture as they are often too acidic and too wet. Historically, peat soils have been used for salt extraction, mining and fuel (it contains loads of carbon).

SEA CLAY

PEAT

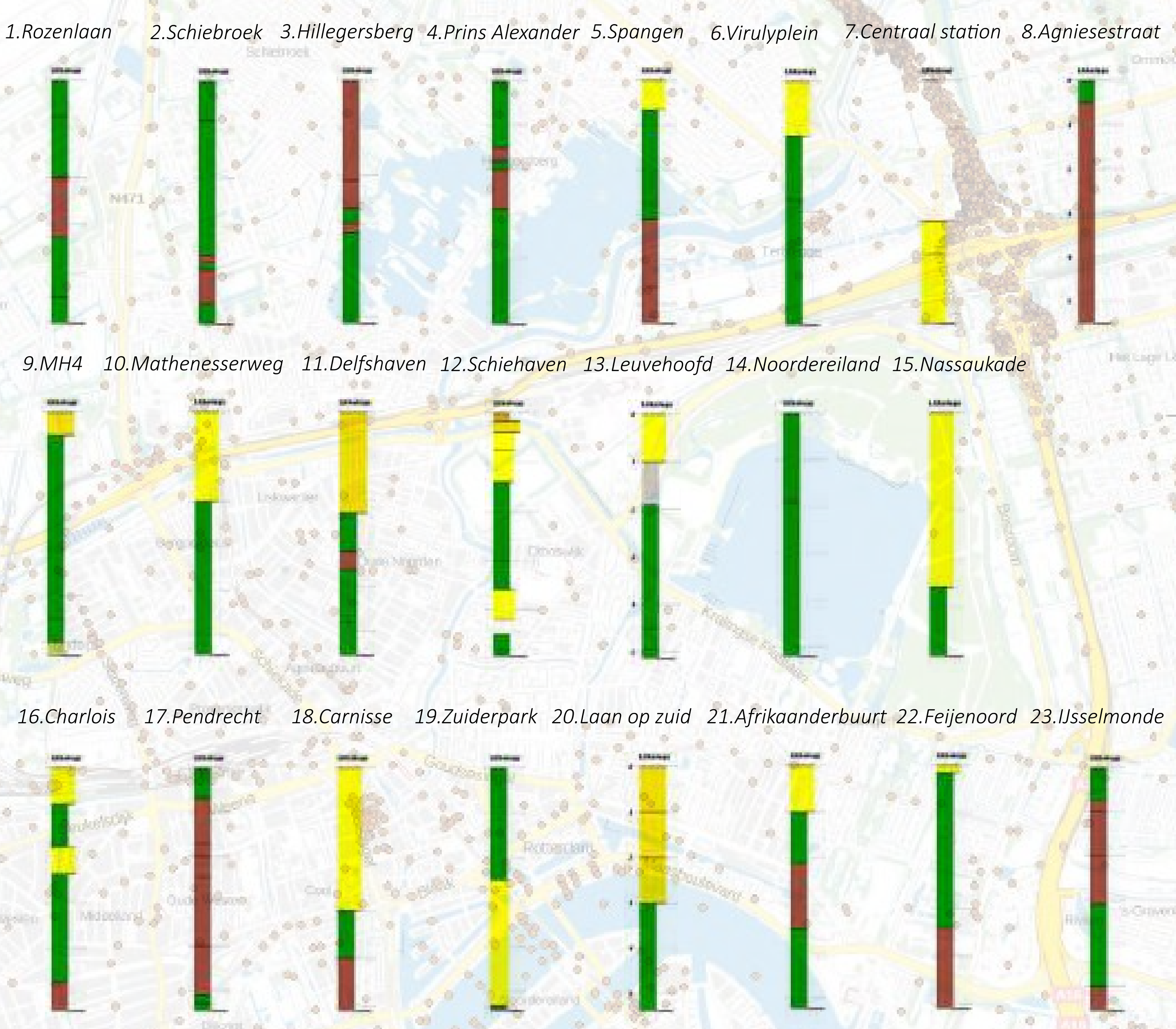
The base layers
ROTTERDAM SOIL SAMPLES

In basis we try to understand the role of the subsoil in storing water by mapping its relevant aspects. Most of these aspects are related to soil types and the rainwater behaviour within these soils - from the surface level till the groundwater level. Soil is a complex element to study and also a much ignored element in climate measures. There are many references in bibliographies on soil problems like subsidence of peat soils or the lack of permeability in clay soils but there is little to be found on integrating the existing geology in climate issues in the urban context.

Most of the current climates pressures (rain flood, subsidence, wooden pile foundation rot etc) derive from the fact that the natural relation of water between its aerial phase and subterranean phase has been altered in urban environments. It has been done by changing the logics of water movement towards the soil and by introducing non-local soil compositions under paved areas. Soil analysis requires a multi-scale approach. On one hand it requires analysis on the city scale on zoning and historical formation. On the other hand it requires a close up investigation of boreholes that show soil characteristic of specific locations. The adjacent page shows results of 23 borehole extractions of different urban areas in Rotterdam. Each of the diagrams shows soil composition of the upper 5 meters where green and brown colours indicate the original soils (clay and peat) while yellow and grey indicate the anthropogenic and artificial layers due to city construction (sand and rubble). The layers of sand from paving the streets and raising the land, as well as debris from the post-war reconstruction are relevant and we classify them as a part of the typical Rotterdam soils - these 4 soil types reoccur in our test site setup, explained from chapter 5 on.

In order to gain deeper knowledge of how water and soil relate to each other, it is important to highlight the fact that accommodating water in the soil will be affected by certain factors. The first one is the available surface area for receive the falling rainwater in itself. Planted and permeable spaces are suitable to hold water in a greater or lesser extent, while impervious surfaces do not contribute as the water is drained elsewhere. Secondly, is the available space for water storage in the ground. This depends on the depth of groundwater level in relation to the surface level. In low laying Dutch geography, like Rotterdam, groundwater is quite high as a consequence of the position of the land being close to sea level. Historical polder areas tend to have a very high groundwater level, while it can be relatively low in artificially raised land in (former) port areas. The capacity to hold water can be calculated by this available space, however it does not indicate that this space is also 100% effective. The third factor is soil effectiveness, meaning each soil type has an infiltration rate and ability to hold water for a certain period after the rain. Generally speaking, coarse soils (sand based soils and soils with high content of rubble) are very permeable as they allow quick water circulation. However, they are incapable of holding water for a longer period of time as the retention capacity is low. On the other hand, fine particle soils and organic soils (clay and peat based soils) are quite effective in keeping the moisture level through time, but their infiltration rates are relatively slow. Thus they do not perform well during heavy rainfalls.

In this research we are aware of the complexity of the soil, at the same time we want to look optimistically at elaborating on a series of techniques to maximize their natural potential and limit disadvantages. When we know about locations with space for infiltration, we can strive to maximize this as much as possible. If we know peat soils have very good long-term water retention qualities, we can elaborate on this natural property. Even in restricting situations of high groundwater, we can search for using this small play-space in a smart way. When adressing climate change, any action of keeping rainwater out of the sewer, is a contribution. Moreover, a Sponge city aims at actively using soil improvements to recover its vital functions and to address the extraordinary source of wealth that it can provide to the city.



Sand and debris

Clay (sea and river)

Peat

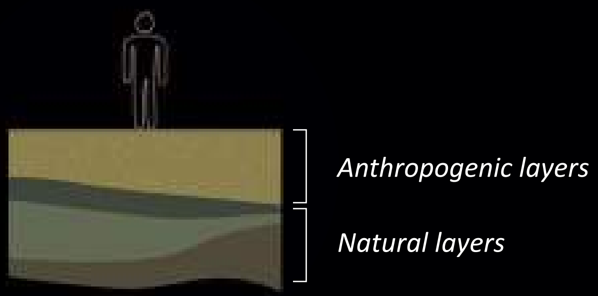
Source:
- Dinoloket.nl

The Sponge city_Underground available space

NATURAL + ANTHROPOGENIC GEOLOGIES

The map shows the current situation regarding the underlying geology of Rotterdam, in which also the anthropogenic layer of infrastructure and raised land along the river (outer dike area) has been added. This layer is highly variable in soil composition, but in majority it consists of sand or similar permeable material.

** Building construction materials here are not considered as a part of anthropogenic geology and thus not shown in the map.*



Sources:

- Interactieve atlassen en kaarten // Provincie Zuid-Holland: Kwaliteitskaart ondergrond

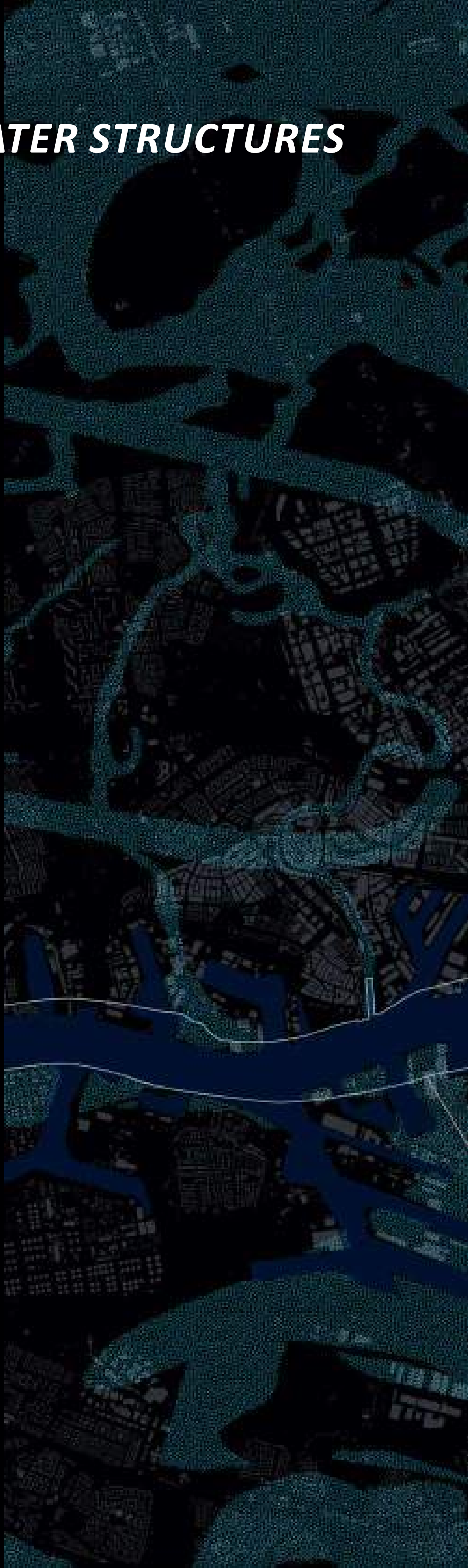
- TNO (de Bos Atlas)

The Sponge city_Underground available space

HIDDEN AND HISTORICAL WATER STRUCTURES

Rotterdam water structure has changed substantially over time, specially in the period after World War II. Before that, the city was an archetypical Dutch city where canals and waterways defined the urban structure. The devastation during the war and later reconstruction changed this historical identity. This followed modernist urbanism principles in which open water structures were replaced by road infrastructures. Rubble and debris were used to fill the canal beds and gullys. Despite these visible spatial changes, they still kept working hydrologically, specially in cases when the covering material allowed the water to flow through. Some studies and experts express that these historical watercourses probably still work as underground water channels. This is interesting for further research, especially for a potential use as underground water circulation.

Filling the Rotterdamse Schie with WWII rubble



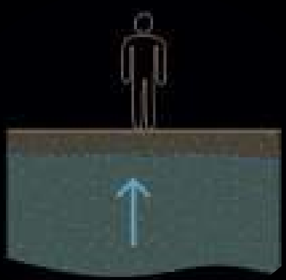
Source:
Open sources and historical maps of Rotterdam

The Sponge city_Underground available space

HIGHEST GROUNDWATER LEVELS

Rotterdam has overall, relatively high groundwater levels meaning that a large part of the city has a water table within the upper 1 meter from ground level. High groundwater levels usually occur during the rainy season when recharge from precipitation exceeds the discharge.

This water logged situation leaves little space for extra water storage when there is a lot of rainfall. The places in the city with potentially most underground space available on the basis of dewatering depth, are the raised areas next to the river Maas and a large part of the city centre.



Groundwater highest levels

0.0 → -0.8 m

-0.8 → -1.2 m

> - 1.2 m

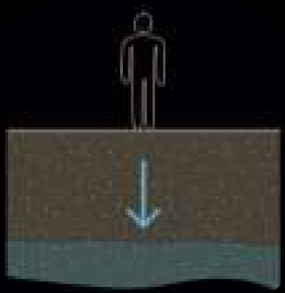
Source:
- De Bosatlas van Nederland Waterland

The Sponge city_Underground available space

LOWEST GROUNDWATER LEVELS

Rotterdam can also experience relative low groundwater levels in the dry season during summer and late spring. This is when discharge by pumping, evapotranspiration and drainage to streams, exceeds the recharge of groundwater. The fact that peak rainfalls in this period are mainly drained out of the city, doesnot help to recharge when it is so much needed.

The availability of underground space, based on the dewatering depth, is covering a very large part of the city. Interestingly enough also large parts of the water logged areas in the wet season. Slowing down peak rain events in order to keep this fresh water within the city is key to fight the consequences of drought, which have been shown at the beginning of this chapter - see the maps on draining city vulnerabilities.



Groundwater lowest levels

- -1.0 m → -1.2 m
- -1.2 m → -1.5 m
- -1.5 m → -2.0 m
- deeper -2.0 m

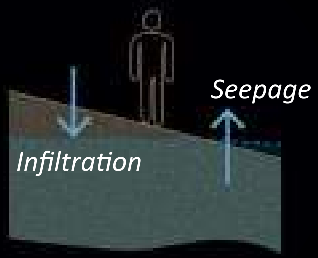
Source:
- De Bosatlas van Nederland Waterland

The Sponge city_Underground available space

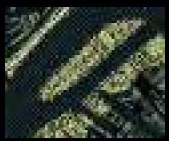
INFILTRATION AND SEEPAGE

Each soil has an infiltration capacity determined by soil texture and structure, its compactness and grain, vegetation cover types, water saturation, soil temperature. The more sandy the higher the rate in which water can be digested and can be dealt with high rainfall intensities. Therefore close to the river on higher (and raised) grounds the city of Rotterdam has the highest potential infiltration rates.

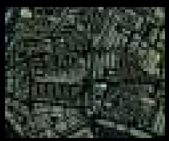
In the clay and deep peat polder areas, a different phenomenon is present: seepage (kwel). Here the groundwater shows an upward movement to the surface. Seepage derives from an underground water flow from higher to lower areas. In the Netherlands this is mostly coming from high water levels in the river towards low lying polders. This water can travel long distances before it reaches the surface and first appears in bodies of open water.



Infiltration rates



> 1mm / day



0.1 - 1mm / day

Seepage rates

> 1mm / day

0.1 - 1mm / day

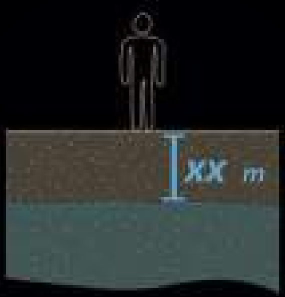
Source:
- Rotterdam municipality

The Sponge city_Underground available space

POTENTIAL WATER STORAGE CAPACITY IN SUBSOIL

The potential ground storage capacity expresses how much water (mm) can be stored in the Rotterdam subsoil. Water storage is possible in an unsaturated zone between the surface (ground level) and the groundwater level. In this map we speculate on this potential by making a simple geometric measurement, which should be read as an indication of proportion and not be taken literally.

The shown values of the potential storage capacity indicate certain zones that have space for water storage, but due to current soil conditions might need adjustments to become truly effective. There are three relevant soil storage parameters for effectiveness that are needed for uninterrupted city functions but have not been included in the calculation: porosity, soil capillarity and minimum dewatering depth for groundlevel stability (> 0.7m).



Potential water storage capacity

Source:
- Atlas natuurlijk kapitaal

The Sponge city_Underground available space

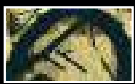
SUMMARY OF THE POTENTIAL EFFECTIVENESS OF UNDERGROUND STORAGE CAPACITY

This map represents the overlap of all previously mentioned layers: groundwater levels, geometric ground storage capacity, soil types, vertical water flows (infiltration and seepage) and special geological entities (old dunes and stream sediment belts). The goal is to have a clearer view where the subsoil could be effective to what extent, for water storage purposes. It also helps deciding which type of sponge intervention is are most suitable.

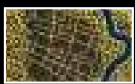
POTENTIAL EFFECTIVENESS

ANTHROPOGENIC LAND

Raised land *- mixed composition, mainly sand*

A-1  ***HIGH***
**Very high GSC + infiltration*

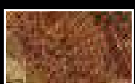
Streetscape *- mainly sand and gravel*

A-2  ***MODERATE***
**Variable GSC*

CLAY SOILS

C-1  ***MODERATE***
**High GSC + infiltration*

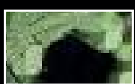
C-2  ***LOW***
**High GW + seepage*

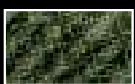
C-3  ***LOW***
**Very high GW + seepage*

CLAY SOILS + stream sediment belts above old river dunes

C-4  ***DEBATABLE***
**Very high GW + seepage*

PEAT SOILS

P-1  ***HIGH***
**Very high GSC + infiltration*

P-2  ***DEBATABLE***
**High GW + seepage*

PEAT SOILS above old river dunes

P-3  ***DEBATABLE***
**Very high GW + seepage*

Sources:
- Interactieve atlassen en kaarten
- TNO (de Bos Atlas)
- Gwz
- Atlas natuurlijk kapitaal
- Dinoloket
- Rotterdam municipality

**GW - groundwater*
**GSC - ground storage capacity*


C-3
P-3
P-1
P-2
A-2
C-1
C-1
C-1
A-1
C-2
A-1
A-1
C-4
C-2
C-3
A-1
C-3

The Sponge city_Above ground available space

PUBLIC LARGE GREEN AREAS

After analyzing the potential of the subsoil, it is time to move to groundlevel and above. We start by mapping large green areas in the city such as: parks, public gardens, medians, tree canopies, playgrounds, allotment gardens. All these spaces can be used for rainwater catchment.

What would be needed is to improve their sponge potential, so that they can accommodate rain showers in a smart and integrated way and offer greater biodiversity. Especially for the green areas the goal should be to take the areas around them into consideration in order to create a network; an urban watershed system with the green spaces as the final destination for water storage and reuse. Elaboration on this system would imply exploring ways of transporting rainwater to the green areas, determining specific suitable spaces for water collection and technicalities of long-term rainwater storage. In addition, maintaining attractiveness and/or function for the public use.

The Sponge city_Above ground available space

SMALL SCALE SOFT SPACES (PRIVATE AND PUBLIC)

This map includes the potential use of all available unbuilt smal scale soft spaces within built environment: private courtyards, front and back gardens and green space around the blocks. The challenge is similar to the one for the large public green areas with differences in: less rainwater catchment volume; typically located within the reach of direct roof runoff and involvement of mostly private owners and entrepreneurs instead of public institutions.

COURTYARDS

Courtyards and green spaces within building blocks

The Sponge city_Above ground available space

STREETSCAPE

Streetscape refers to all the infrastructure spaces: local streets up to major roads, harbour, industrial and logistic areas. Here the available space differs with its function. Major roads and main network infrastructures remain as they are, while many local streets offer possibilities to create space for rainwater collection and storage.

This can be done through measures as bioswales, pervious pavements, porous asphalt among others. The water sensitive interventions can be easily combined with planting new trees to absorb summer heat and excess water. This will also increase the liveability of the streets for those who live in them.

Also logistics zones in harbours and industrials areas have a potential water sensitive typology. Here replacing impervious surfaces for more permeable options like pervious pavements and green edges for water catchment, are welcome.

STREETSCAPE POTENTIAL

Main infrastructure - unsuitable

Local streets - suitable

Harbour, industrial, commercial areas - moderately suitable

The Sponge city_Above ground available space

ROOFSCAPE

Rotterdam has abundance of flat roofs in comparison with many other Dutch cities. Its post war reconstruction formed a built environment where modern and bigger buildings are dominant. A total area of 14.5 km^2 of flat roofs is estimated to be part of the cities roofscape. In a high density city, the roof landscape should offer a multifunctional use where water storage can be combined with cooling, planting and sustainable energy production.

The map shows the sponge potential of the urban roofs:

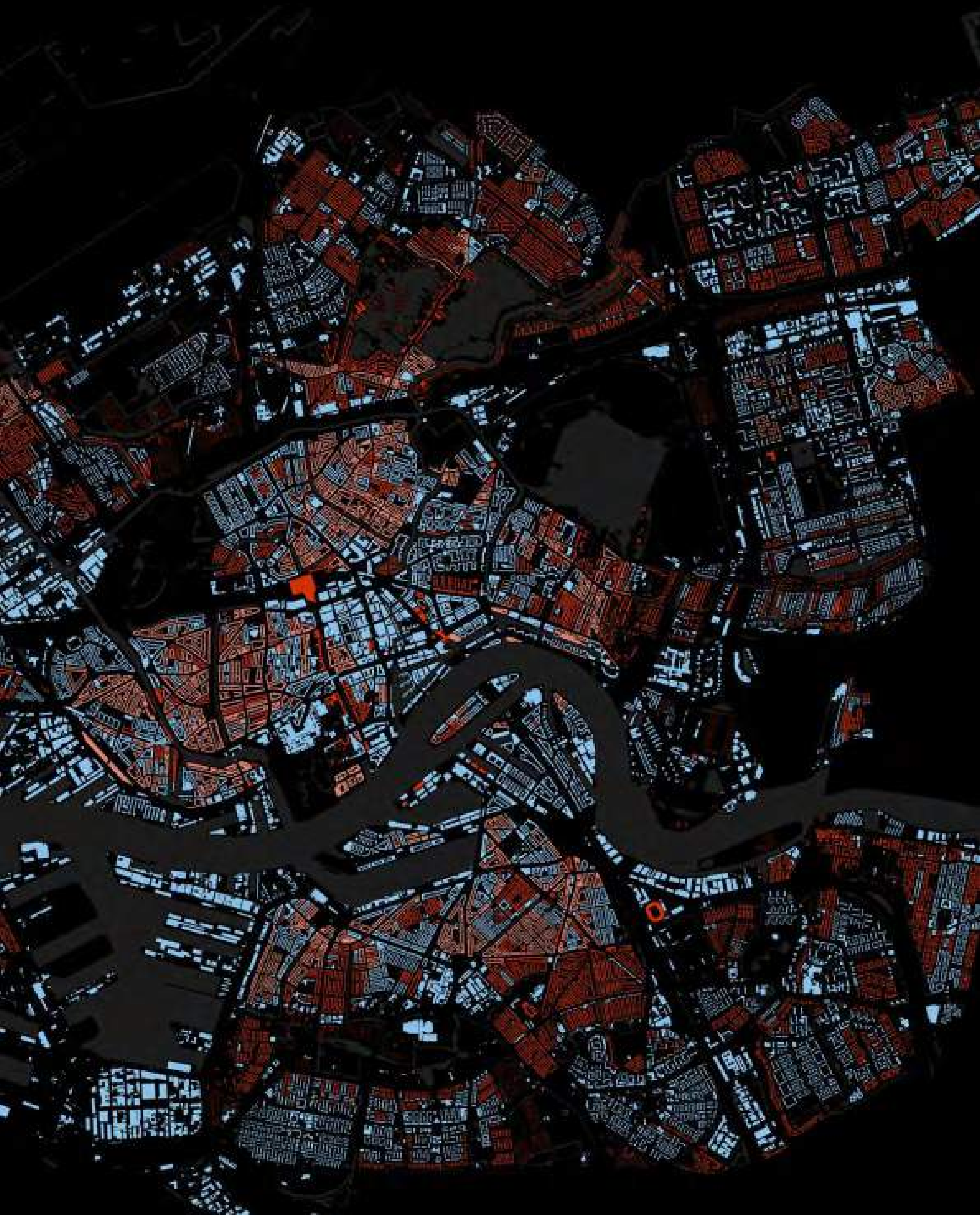
- *blue roofs refer to suitable roofs (mainly flat roofs);*
- *red roofs are not suitable (pitched roofs);*
- *the pinkish ones are partial suitability (when we calculated around 50% flat and 50% pitched within one urban plot).*

ROOFSCAPE POTENTIAL

Highly suitable for rainwater collection: plots with flat roofs

Partly suitable for rainwater collection: plots with flat and pitched roofs

Not suitable for rainwater collection: plots with pitched roofs



The Sponge city_Above ground non-available space

VITAL INFRASTRUCTURES

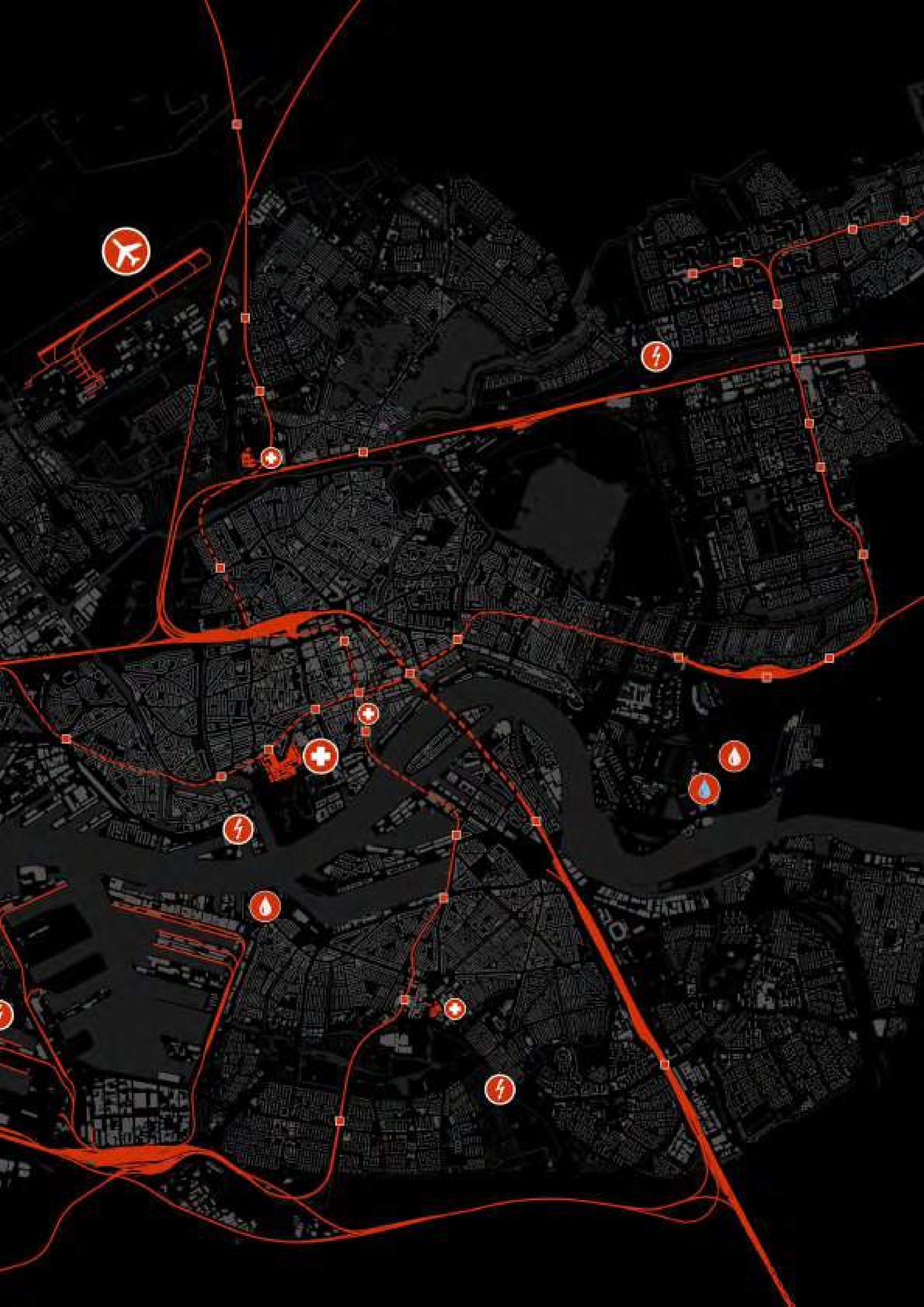
Vital infrastructures are the urban services that should remain functioning under any circumstance, because without them our public health is immediately is under threat. These include: airports, hospitals, drinking water plants, water treatment plants, energy transfer stations, metro lines and railways. These areas have very limited availability to hold rainwater.

Hospital

Sewage treatment plant

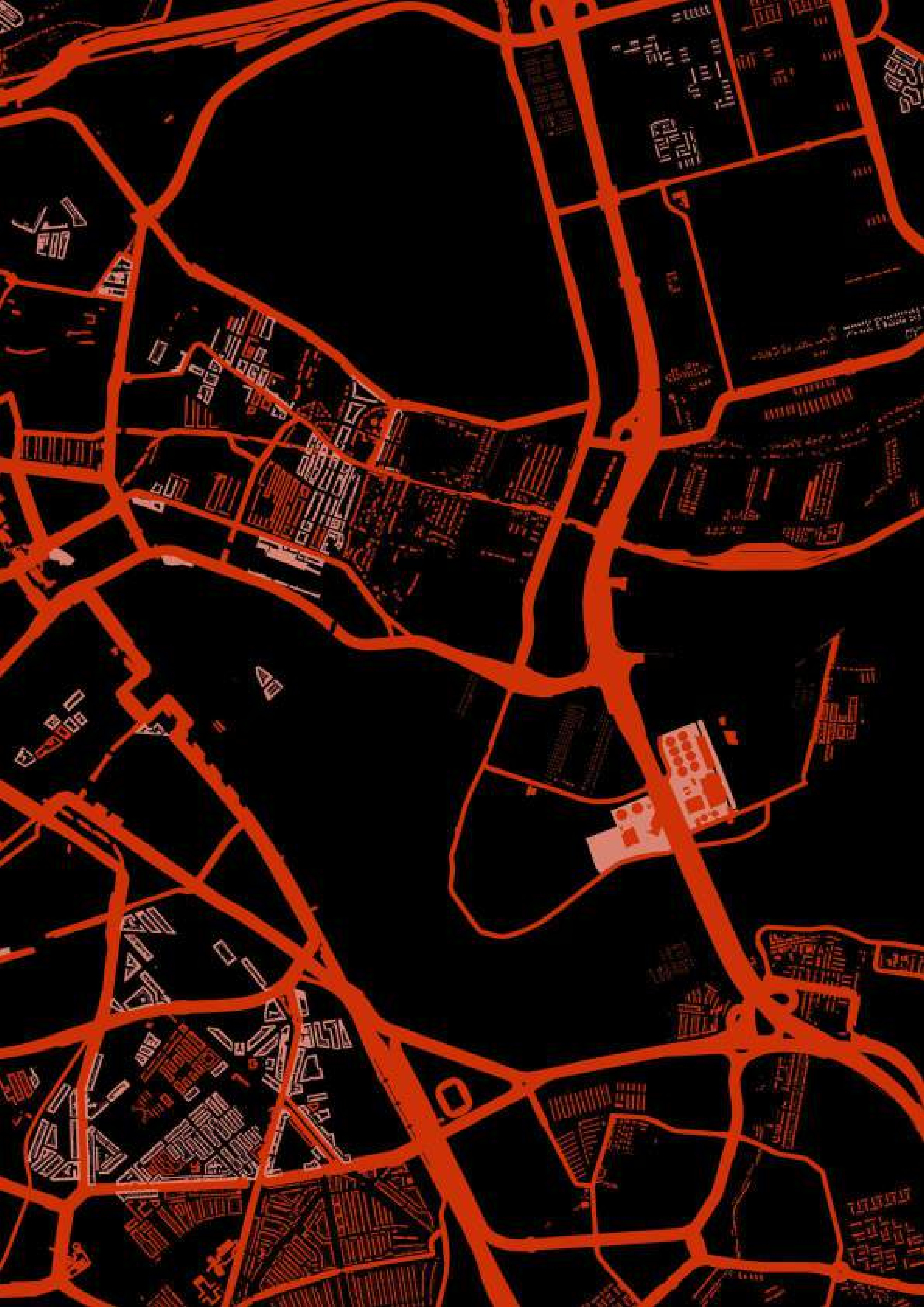
VITAL INFRASTRUCTURES

Sources:
- www.tennet.eu
- Deltaprogramma / Rijnmond-Drechtsteden



The Sponge city_Above ground non-available space

TOTAL NON-AVAILABLE SPACE ABOVE GROUND OVERVIEW



The Sponge city_Above ground available space

TOTAL AVAILABLE SPACE ABOVE GROUND OVERVIEW

CHAPTER 4

APPLYING THE SPONGE ON ROTTERDAM

This chapter will focus on envisioning solutions that can be drawn up for the city of Rotterdam based on the analysis and illustrated potentials shown in the previous chapter. This starts by drawing up a strategic map of Rotterdam as a Sponge city, where the city is redefined in four distinctive Sponge districts:
1. Urban plateau; 2. Singel city; 3. Peat city; 4. Clay island. Each of these four have their own specific natural and contextual conditions, specific water management challenges and sponge capabilities.

The Rotterdam Sponge map (plus conceptual section) represents our attempt to use the soil and the underlying landscape as guidelines for defining urban identity. It would be as if the natural context can become the main engine for creating urban typologies and therefor a main driver for the functioning of the city. Maybe this is what the city ultimately needs to truly become climate adaptive and resilient for the changes that the future will bring.

Subsequently this chapter will focus on possibilities for concrete application. If the aim is to shift from the draining city towards a sponge city, this will take time and therefor it needs a stepwise approach to be able to work on a small scale as well. There is already a rich set of climate tools available that can be directly applied to different problems and situations.

These tools have been developed by municipalities, design and engineering firms. We collected and completed them into a toolbox that is still being prefected and extended in several running projects. This collection of climate adaptive tools deal with rainflood, drought, heat stress and aim at improving the quality of living by creating a healthier city where public space is inviting, reduces stress and raises awareness. The tools are organized on a gliding scale from technical solutions to more natural measures. These latter ones have our preference, because they can contribute more effectively to awareness goals while they also enrichen the urban environment with multiple ecosystem services.

Next the toolbox has been confronted with the four distinguished Sponge districts. For each of them we suggest the most appropriate selection of measures to be able to tackle the risks that are applicable in the specific district.

Lastly we focus on one specific measure that we consider to be especially effective: the swale. Here we explore the possibilities to apply the swale on each of the four districts and what specific modifications it needs to be an effective tool in each of them. This exploration leads us to do a real-life experiment on site which will be explained in subsequent chapters.

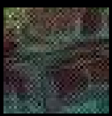
Photo: Jonker photography

SPONGE CITY MAP ROTTERDAM

We can identify four districts characterized by water:
*1. **Urban plateau** - the raised landscapes along the river Maas and the elevated waterways (so called "boezem")*
*2. **Peat city** - the peat polder area located in the north and east along Prins Alexander*
*3. **Clay island** - on top of the raised clay polders situated in the south part of the city*
*4. **Singel city** - the central urban area and 19th century city structures with their historical green canals.*

PEAT CITY

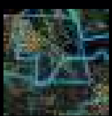
Peat polder areas



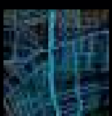
Low GSC (except specific areas)
Seepage
Potentially high water retention capacity due to peat soils
Stream sediment belts and old river dunes in deep layers

SINGEL CITY

Cental city and 19th century districts



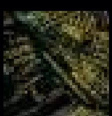
Moderate GSC
Infiltration
Variable water retention capacity due variety of soils
Stream sediment belts and old river dunes in deep layers



Low GSC
Seepage
Variable water retention capacity due variety of soils
Stream sediment belts and old river dunes in deep layers

URBAN PLATEAU

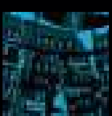
Anthropogenic raised land



Very high GSC
Infiltration
Low water retention capacity in sandy areas
Variable water retention capacity in areas with variety of soils

CLAY ISLAND

Sea clay polders

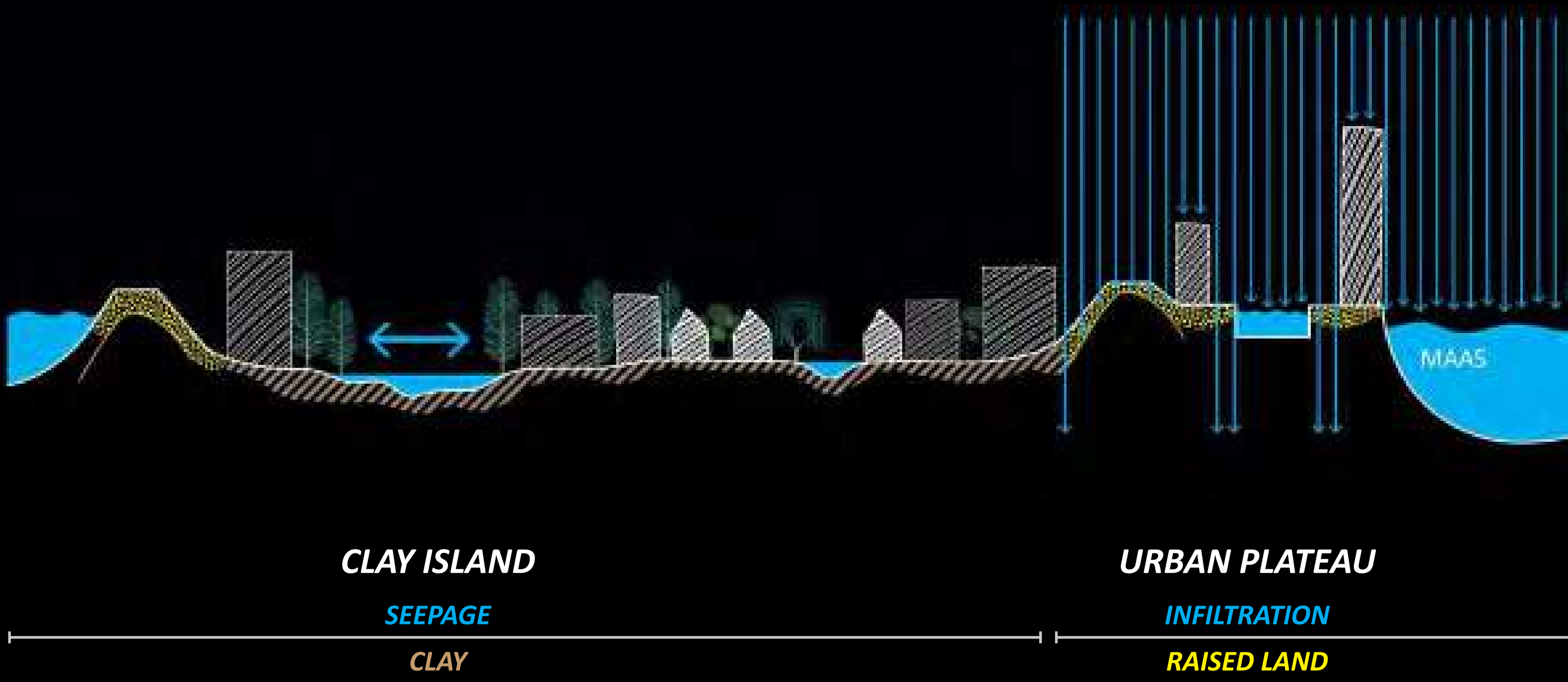


Low GSC (except specific areas)
Seepage
Limited - moderate water retention capacity due to clay soils
Stream sediment belts and old river dunes in deep layers

gw - groundwater
GSC - ground storage capacity

SPONGE CITY PRINCIPLE SECTION

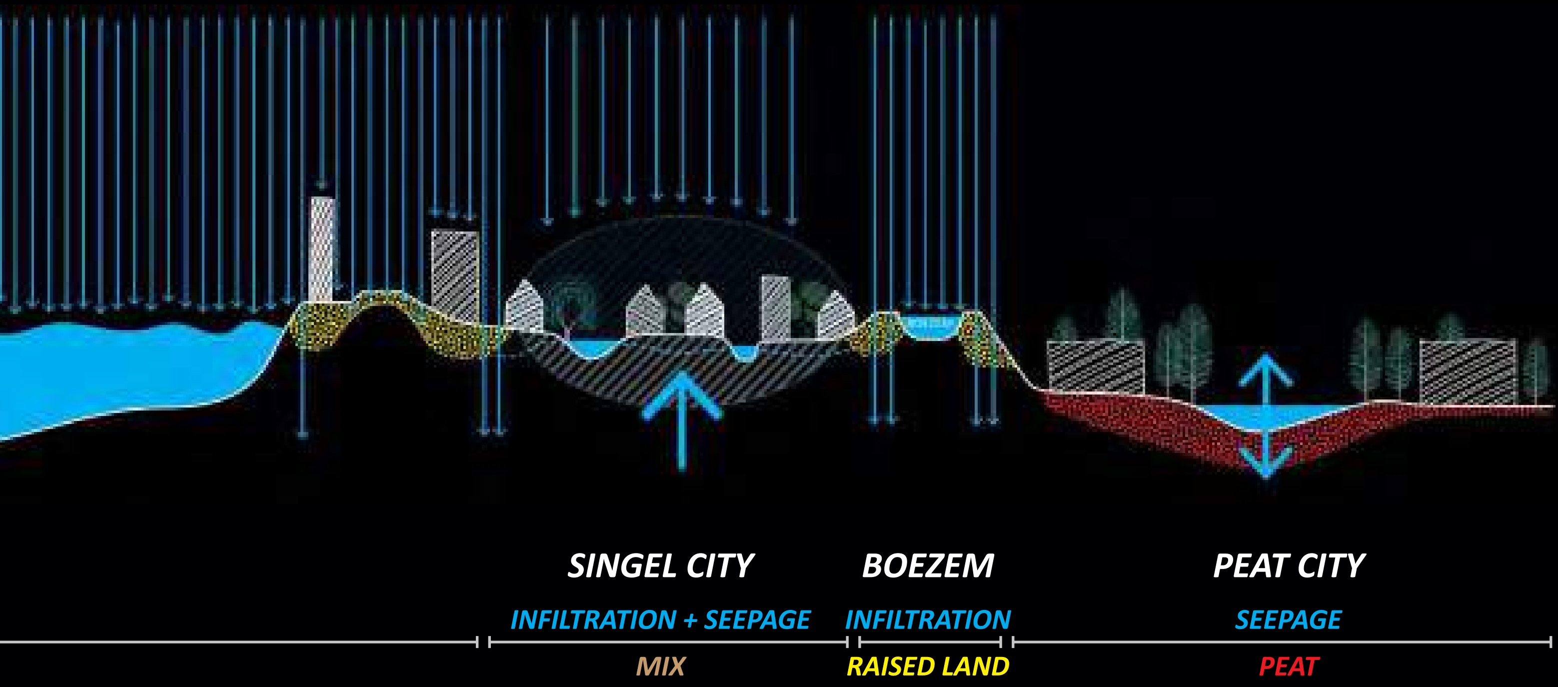
The sponge districts can be seen as inspirational guidelines with their own distinct characteristics and measures that can be chosen to maximize water resource management in the city and not to waste a drop. The water functions and the subsequent tools are different in each of the districts, as water and soils perform differently. The main principles are layed out in the diagram below and can be summarized as follows:



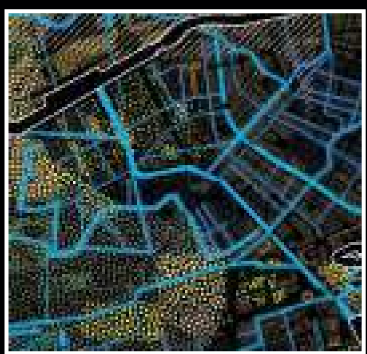
CREATE SPACE FOR OPEN WATER

MAXIMIZE SPACE FOR INFILTRATION

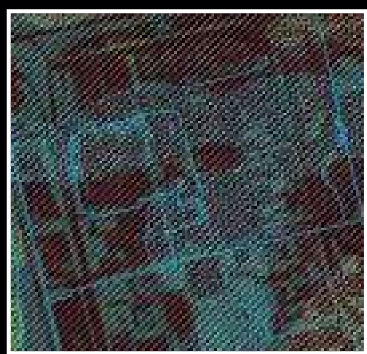
- *Maximize the space for infiltration along the* ***Urban plateau*** *by adapting soils and materials;*
- *Balance the combination soil-and-water above and below ground in the* ***Singel city*** *by smartly adapting the available space to maximize water collection, retention and reuse locally;*
- *Create extra space for open water in the* ***Clay island*** *to buffer and recirculate water resources*
- *Create space for groundwater exchange in the* ***Peat city****, by controlling moisture levels in specific areas to limit subsidence and aiming for long-term re-adaptation of the district in its natural context.*



BALANCE BETWEEN ABOVE AND BELOW GROUND



CREATE SPACE FOR GROUNDWATER EXCHANGE

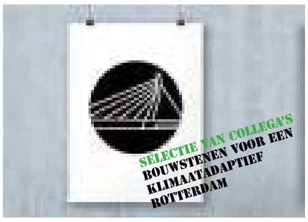


SPONGE APPLICATION

To explore concrete possibilities to create a sponge city we follow four steps. This starts by gathering a complete toolbox, then organizing it ranging from technical to natural measures and then applying them to each of the four sponge districts. Lastly we elaborate on the specifically effective tool of 'the swale' that is being tested out in real-life and will be explained in the next chapters.

1 *GATHER AVAILABLE MEASURES*

The starting point is to organize an overview of plausible measures in a toolbox. We look -amongst others- into the following sources: Water sensitive Zomerhof / Agniese district (de Urbanisten); De straatD (Bosch Slabbers), Towards a water sensitive Mexico city (de Urbanisten); Bouwstenen voor een klimaatadaptief Rotterdam (Ingenieursbureau of municipality of Rotterdam); Deltaplan Ruimtelijke adaptatie; Rainproof Amsterdam (Waternet and Amsterdam municipality); Climate app (Deltares); Klimaatadaptieve maatregelen (HAS Hogeschool); Waterplan of Antwerpen (De Urbanisten). And this list is growing ever since it is to be updated regularly.*



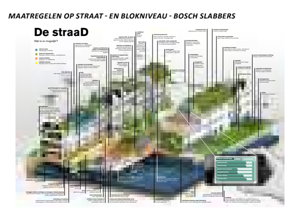
Ingenieursbureau,
Gemeente Rotterdam

Amsterdam rainproof
Waternet

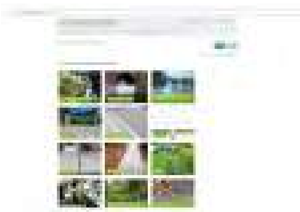
Climate app
Deltares

Watersensitive Zomerhof
De Urbanisten

Deltaplan Ruimtelijke Adaptatie



De StraaD
Bosch and Sabbers



Groenblauwe netwerken
HAS Amsterdam

Waterplan Antwerpen
De Urbanisten

Selection of consulted toolboxes

2 *ORGANIZE FROM TECHNICAL SOLUTIONS TO NATURAL MEASURES*

The next step is to organize the measures, ranging from technical measures to solutions based on natural principles. This sequence follows the categories of: robust system interventions, building related interventions, underground space for water, space for water in buildings, aboveground space for water, space for water outdoors that also helps raising awareness, space for infiltration, space for water and planting, space for planting, space for infiltration and planting. This diagram is on display on the next pages.

** The most recent development of climate adaptive tools is being made for the city of Antwerp to be applied on the level of city quarters. These so called "Wijkinrichtingsplannen water en groen" are currently in development by De Urbanisten and Witteveen+Bos*

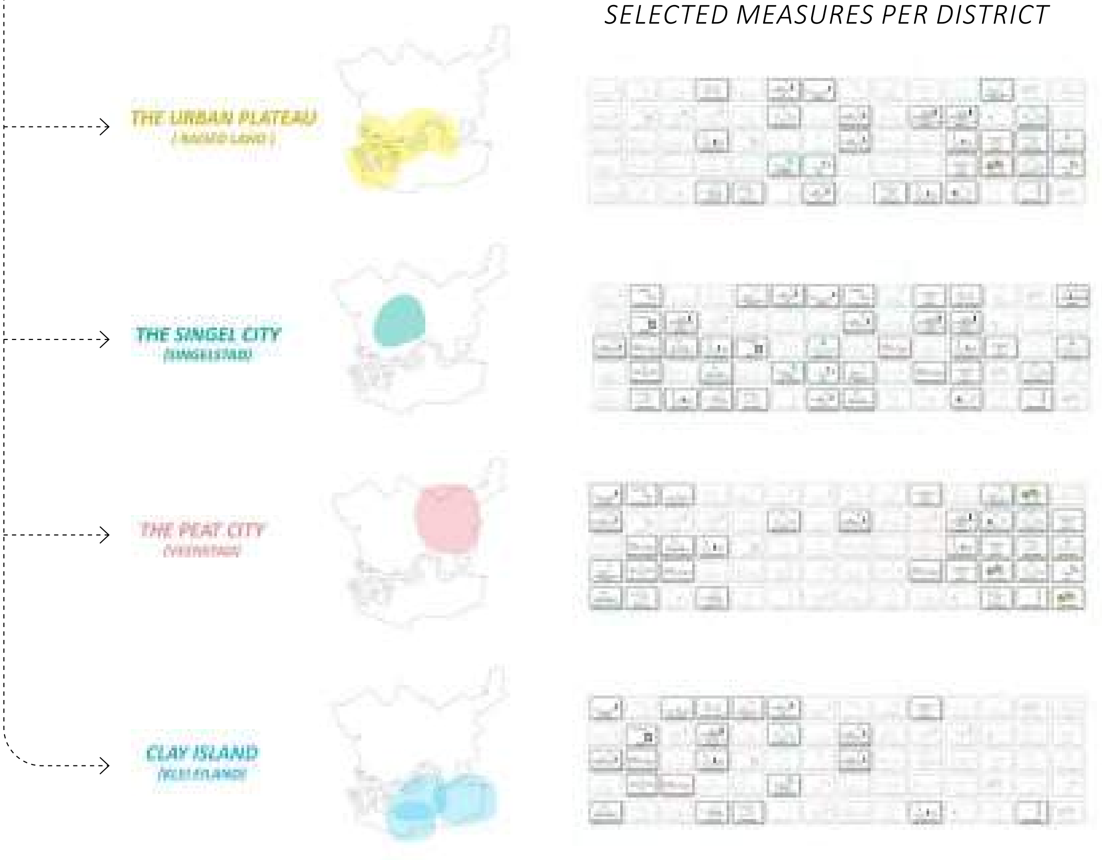
3 *CONNECT APPROPRIATE TOOLS TO CONTEXTUAL ZONING*

The third step is to select climate measures that are appropriate per Sponge District that have been identified on the previous pages. Here we will mainly focus on green, more natural measures and a brief selection of technical measures. On the following pages these will be worked out further.

RISKS

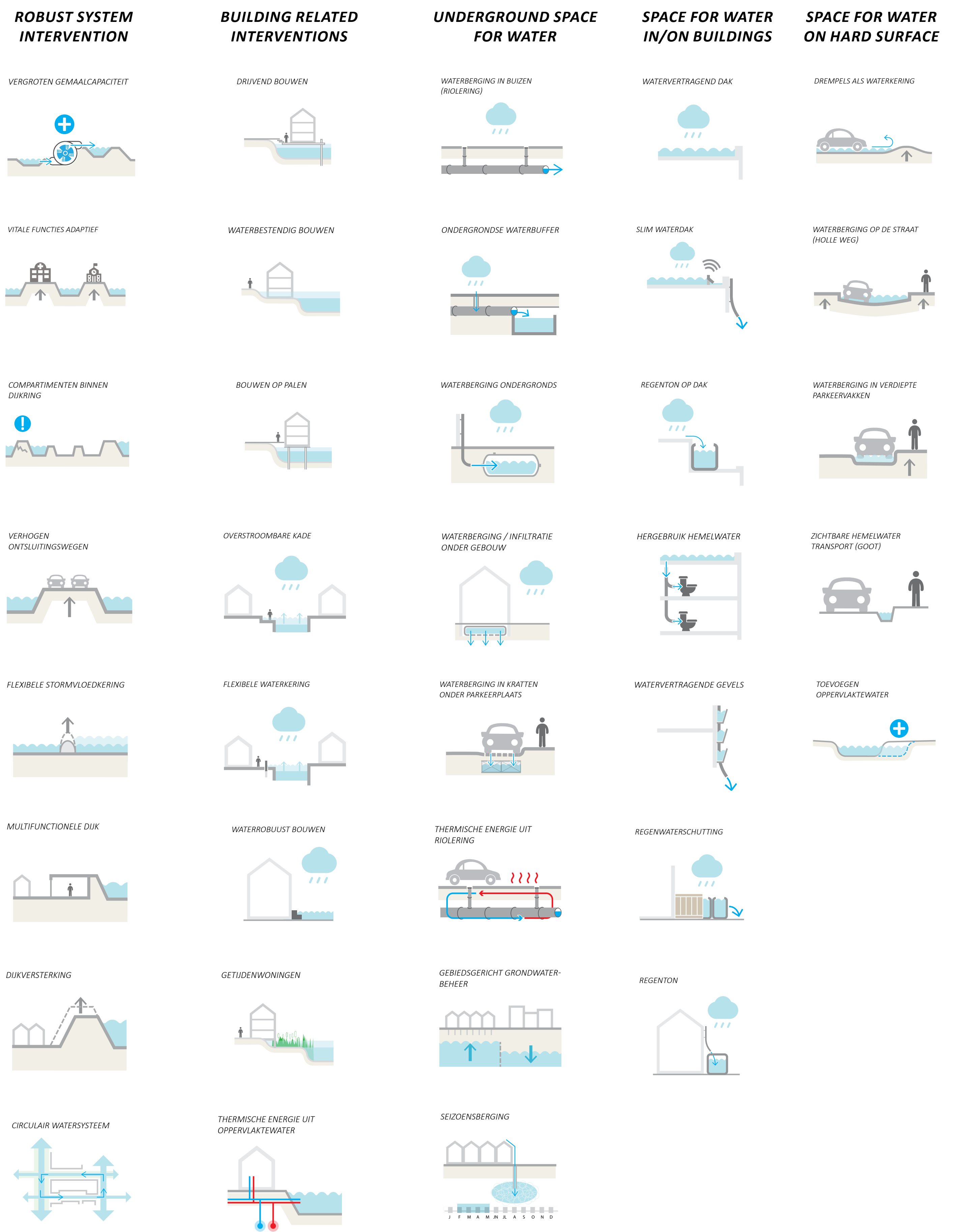
SPONGE DISTRICTS

SELECTED MEASURES PER DISTRICT



Overview of climate adaptation measures organized from technical solutions to nature based solutions

TECHNICAL

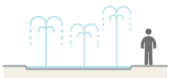


NATURAL

SPACE FOR WATER ON HARD SURFACE

WATERPLEIN

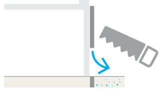
ACTIEVE EVAPORATIE / FONTEIN



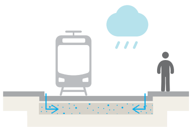
WATERSPEELPLAATS

WATER STORAGE AND INFILTRATION

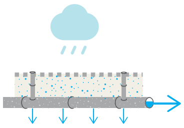
AFKOPPELEN REGENPIJP



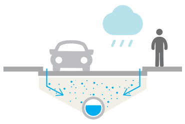
WATERBERGENDE STRAATFUNDERING (GRANULAAT)



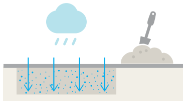
INFILTRATIE EN TRANSPORTRIOOL



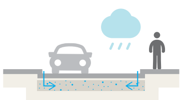
WATERBERGEND WEGCUNET



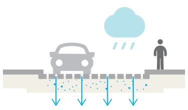
VERBETERD GRONDPAKKET VOOR INFILTRATIE



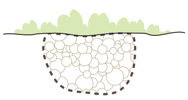
WATERBERGENDE STRAATFUNDERING (GRANULAAT)



WATERPASSERENDE VERHARDING

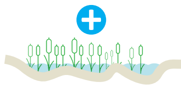


POROUS SOIL

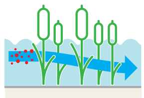


EXTRA GREEN SPACE FOR WATER

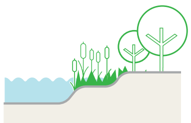
STADSUITERWAARD (OVERSTROOMBAAR GEBIED)



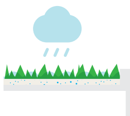
LOKALE WATERZUIVERING



NATUURLIJKE OEVERS



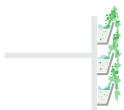
WATERBERGEND SEDUMDAK



POLDERDAKEN / DAKAKKERS

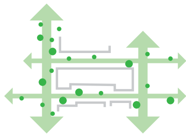
COLLECTIEF GROEN DAK

GROENE GEVELS



EXTRA GREEN SPACES

VERBONDEN GROEN NETWERK

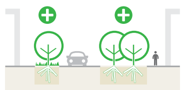


LOKALE VOEDSELPRODUCTIE

GROENE ERFAFSCHEIDING

VERBETERDE TOEGANG TOT GROEN

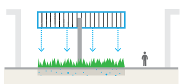
TOEVOEGEN GROENOPPERVLAK / BOMEN



BUURTPARK / POCKETPARK

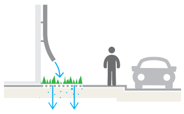
GEZOENDER GROEN

HUMIDITY COLLECTOR

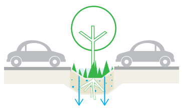


EXTRA GREEN SPACE FOR WATER + INFILTRATION

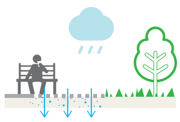
GROENE GEVELTUINEN



INFILTREREND PARKEERVELD



WATERPASSEREND TERRAS

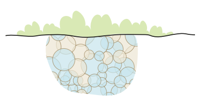


BIOSWALE

INFILTRATIEVELD / WADI

REGENTUIN

SPONGY SOIL



SPONGY PLANTING

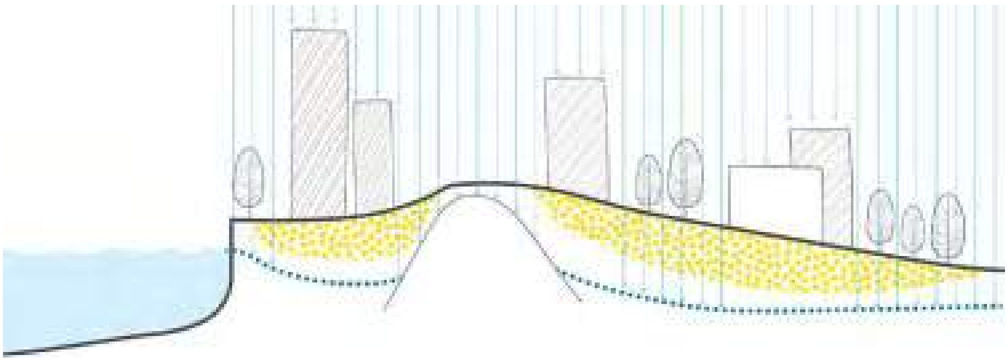
URBAN PLATEAU

FOCUS: *MAXIMIZE SPACE FOR INFILTRATION*

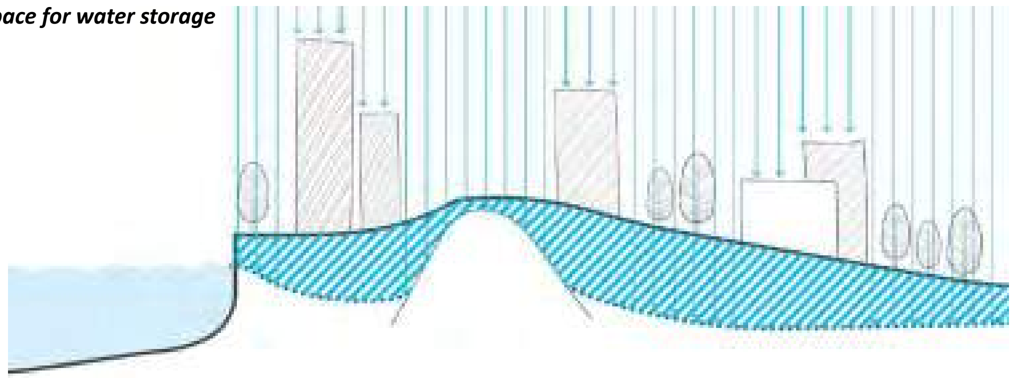
The Sponge strategy for the Urban plateau aims at performing as a large infiltration device. All rainwater is collected and guided towards areas that are adjusted to this function in order to recharge groundwater without wasting water into the sewer or into the river. The Urban plateau can be understood as a strategy for water sensitivity which does not just solve risks, but rather contributes to the overall water cycle in the city. The entire area can perform as a catchment area where all rain follows its natural gravitational flows and before reaching groundwater level, it can feed green roofs and bioswales, rocky gardens, pervious parks and greener waterfronts along the river. Hard surfaces like pavements or asphalt can be actively included into the groundwater recharge system by replacing conventional elements by permeable materials or by using special sub-layers, reusing rubble or debris into a cycle of reusing waste materials locally.

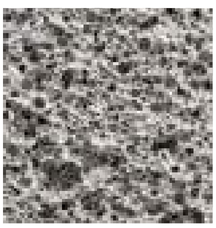
A climate risk that cannot be dealt with by local sponge interventions is river flooding. Here system interventions are needed which can be complemented by local flood protections.These measures are being mentioned, but they ly outside the scope of this research.

MAX INFILTRATION INTO GROUND



Effective space for water storage



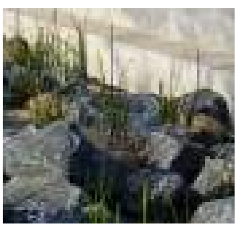


porous materials

pervious sublayers

swales

gardens

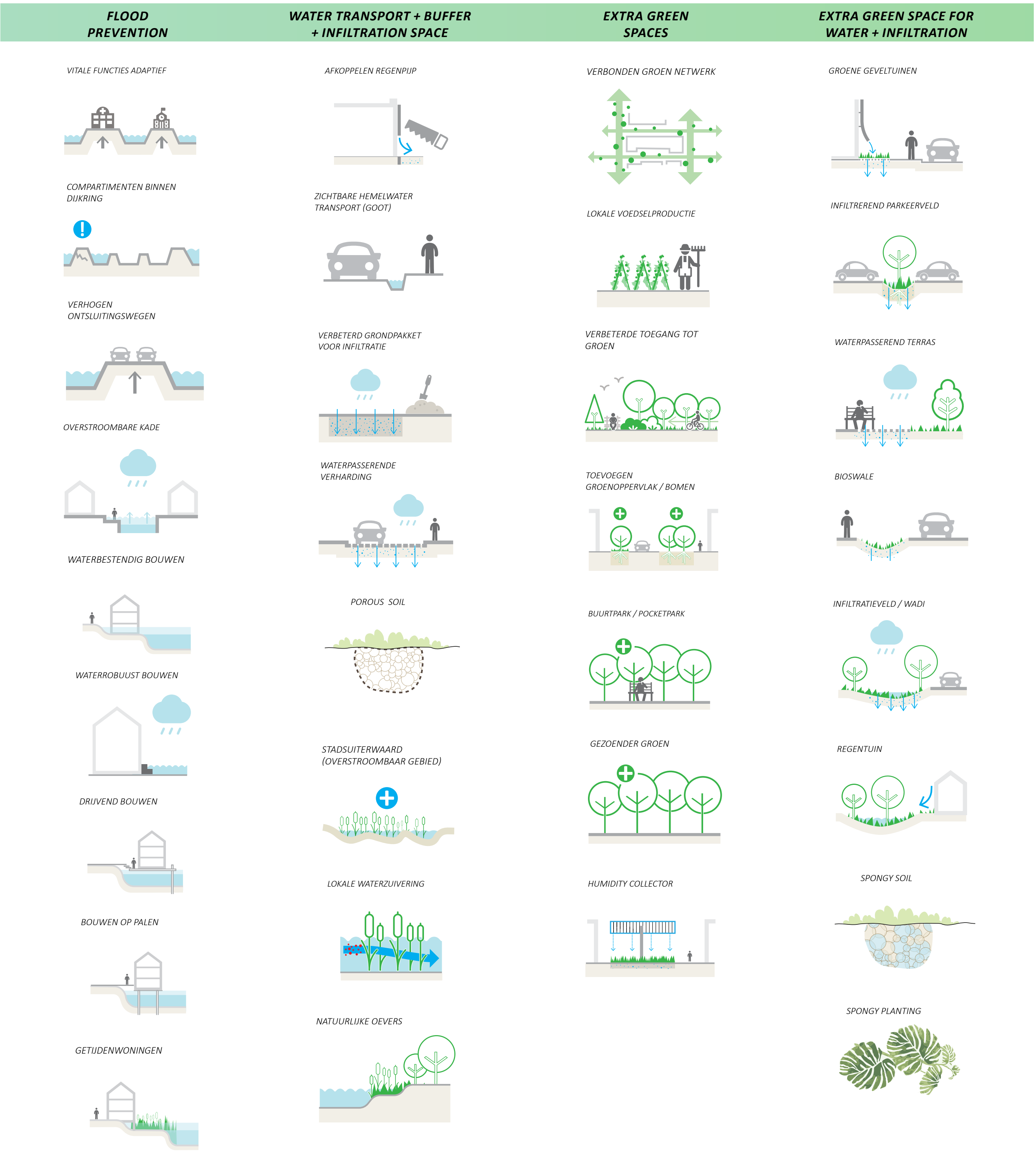


rocky planting

open, pervious pavement

Exemplary zoom

Risks



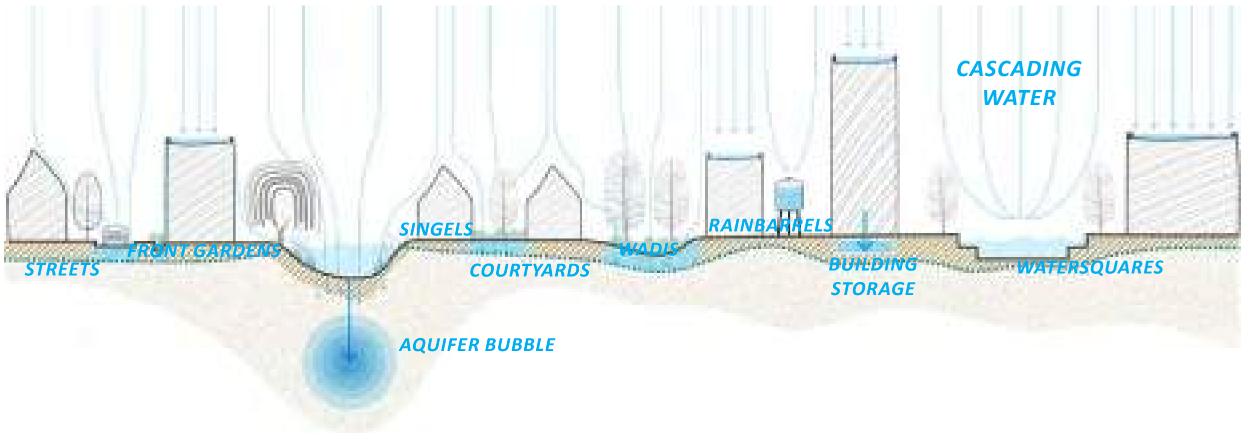
SINGEL CITY

FOCUS: BALANCE BETWEEN SURFACE LEVEL AND UNDERGROUND

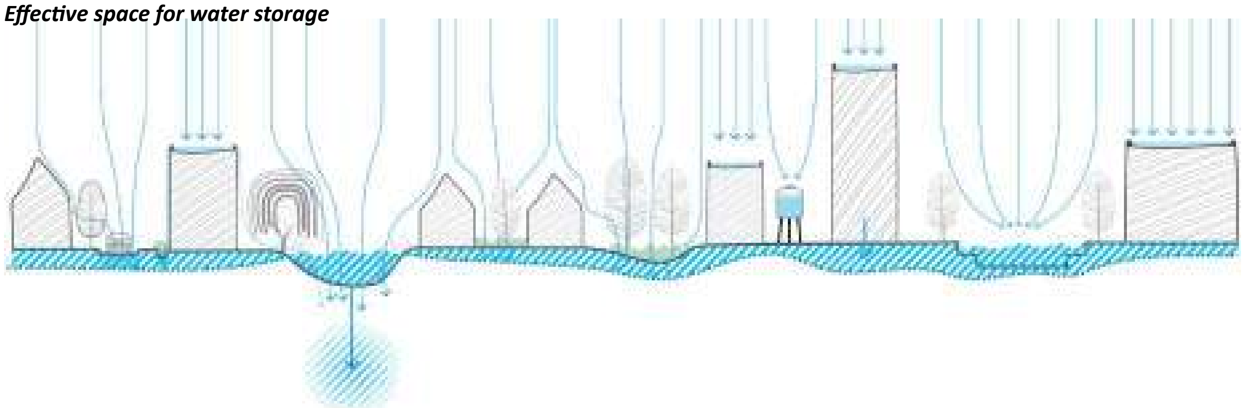
The Sponge strategy for the Singel city aims at balancing its water content by applying smart measures that take a maximum advantage of the available space between groundlevel and groundwater level. Along the singel city is where we find major risks of rainwater flooding and of weakening wooden pile foundations. Both these problems exemplify the paradox that insufficient capacity to deal with excess rain water causes flooding and at the same time an insufficient level of humidity in the soil is causing 19th century buildings to sink. The ambition here is to equalize the water content throughout the year by applying measures to maximize fast water collection and at the same time to ensure that soils have capacity enough to hold water for the longest possible period.

The singel city is probably the area where innovative measures and designs will have to be applied to smartly use available 'play space' without disrupting daily urban functions. Many innovations have already been developed and applied here. Their level of performance can and should be taken into 'common practice', as well as the set of options can be ever expanded and made more integral. One can think of complete cascading systems which drain water into green streets, rain gardens, water squares, swales etc., need smart soils, appropriated planting and innovative materials to maximize the collection, storage and reuse, locally balancing moisture levels.

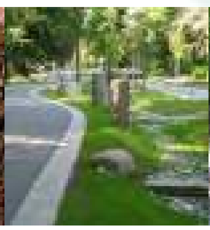
MAX COLLECTION / DELAY ABOVE GROUND



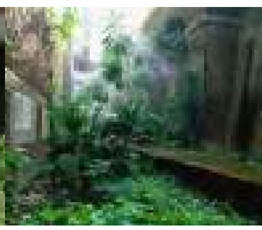
Effective space for water storage



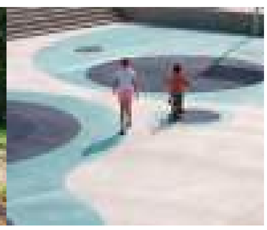

spongy soil


swales to collect and retain


spongy frontgardens


rain gardens / courtyards


spongy tram lines

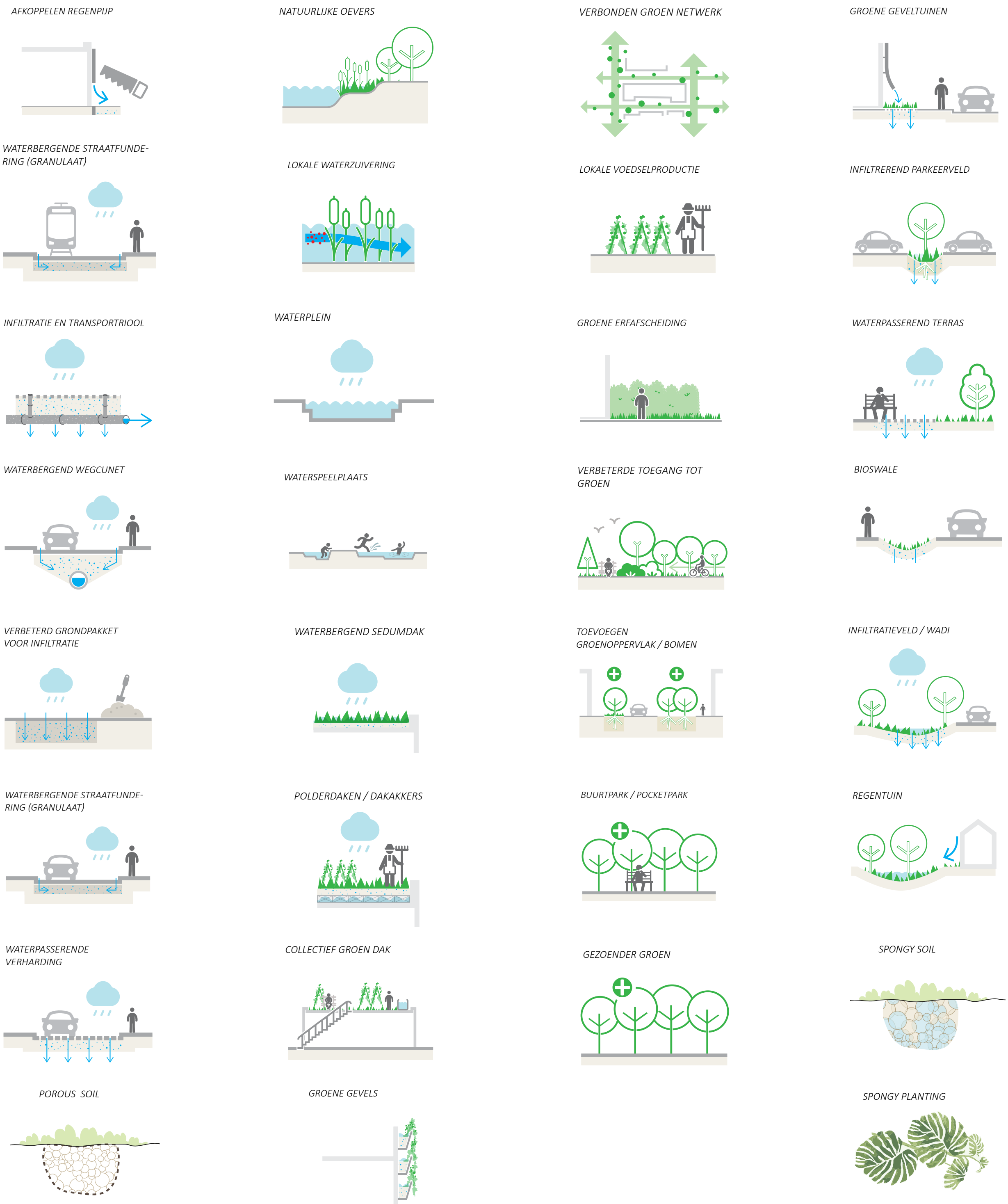

watersquares

Exemplary zoom

Risks

- Subsidence
- Seepage
- Flood
- Vulnerable flora
- Poor water quality
- Foundation pole rot

WATER TRANSPORT + BUFFER + INFILTRATION SPACE	WATER BUFFERS	EXTRA GREEN SPACES	EXTRA GREEN SPACE FOR WATER + INFILTRATION

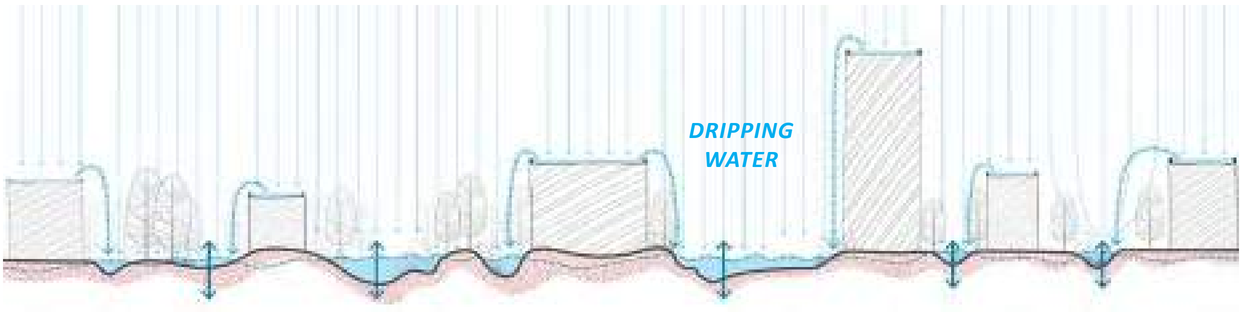


PEAT CITY

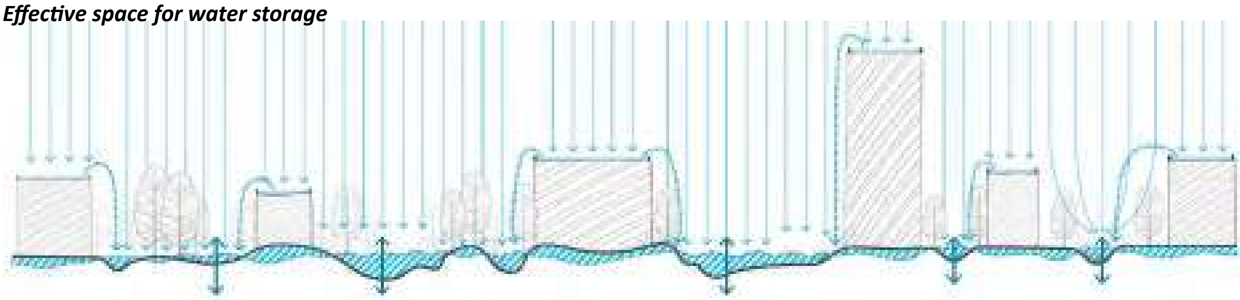
FOCUS: CREATE SPACE FOR GROUNDWATER EXCHANGE / WETLANDS

The area defined as the Peat city is facing a paradox between its natural context and human occupation. On one side, peat areas are the most efficient natural sponges, as illustrated by exemplary landscapes shown in the first chapter of this research. On the other side this area is experiencing subsidence, because urban occupation asks for a continuous draining to allow urban infrastructures to keep on running and to stay dry. The paradox underlies in the fact that if draining continues, subsidence will continue as well. The question where and when the limit of this 'business as usual' lies, will have to be addressed sooner or later. For this reason we think that a sponge strategy for Peat city has to go beyond a display of measures and rather focus on a gradual and integral shift to adapt all urban functions to a wetter environment: urban planning, mobility, real estate, public space, energy infrastructure, ecology, social interaction, local economy, etc.

The future perspective for urban peat areas could be made out of districts where a high level of moisture is accepted and integrated as an asset into all aspects of urban life, in order to stop soil sinking, to rediscover its natural context and to extend the biodiversity of the entire city. Although this landscape type has been traditionally present throughout the entire cultural history and development of the 'lowlands', a future fruitfull integration with our current urban systems will need a fundamental rethinking of basically everything.



Effective space for water storage



moss

space for water

moist landscape
controlled areas with higher groundwater levels

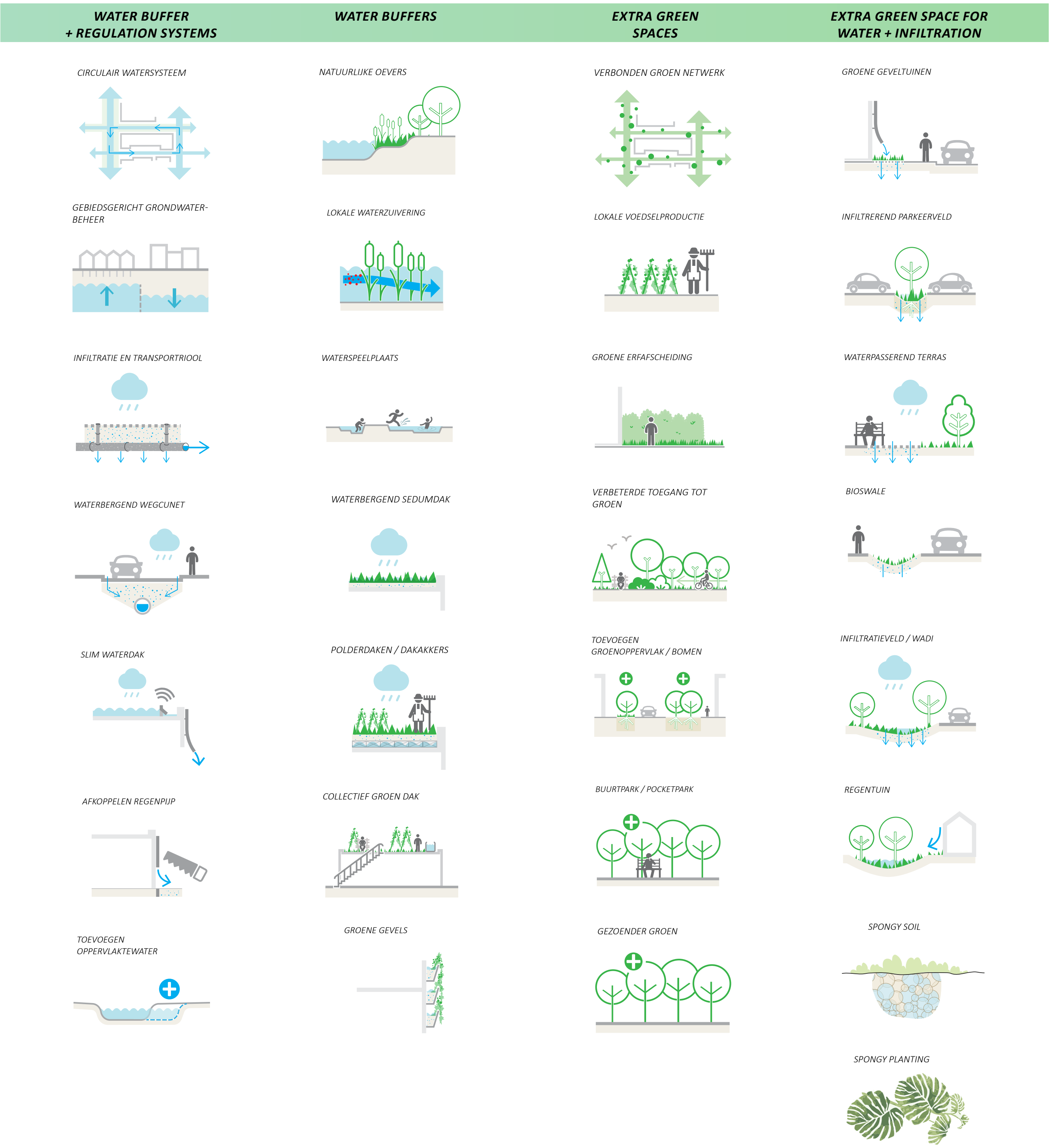
spongy public spaces

moist wild playground

Exemplary zoom

Risks

- Subsidence
- Seepage
- Flood
- Vulnerable flora
- Poor water quality
- Foundation pole rot



DE URBANISTEN

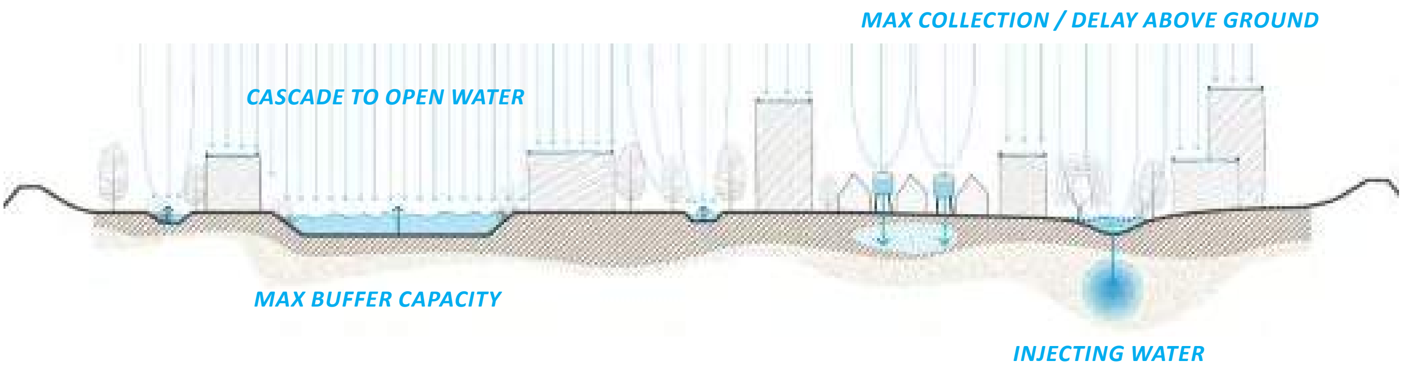
CLAY ISLAND

FOCUS: CREATE SPACE FOR OPEN WATER

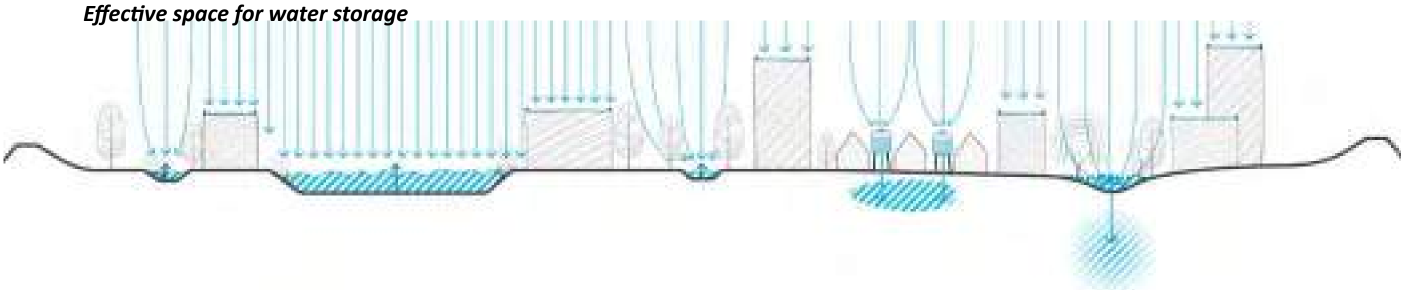
The Sponge strategy for the Clay island has a clear direction given the fact that the entire area is dominated by high groundwater levels and low rates of infiltration. These conditions ask for creating as much as possible space for water within the urban fabric. Making room for the water should be understood not just by creating new open water structures like canals and ponds, but also by actively including roofscapes, public space and even the available space in deeper underground layers. Such a comprehensive water system should perform as one entity capable of holding cloudbursts, recirculating the water after the rain and redistributing the water when drought happens.

Water dynamics should therefor be organized in a hydrological cycle where it moves horizontally from one place to the other, as well as vertically from the top layers to deep underground layers in a smart three-dimensional scheme. If available space is limited, like in the northern part of this urban area, the potential of private local solutions can be explored such blue-green roofs, rain barrels and water tanks. If a more generous open space is available, like in the southern part of this urban area, the introduction of more open water is appropriate; not as isolated spots but as blue-green structures that provide recreational opportunities and new identity. A recently realized, good example is "de Blauwe verbinding".

The sponge strategy implies a fundamental and gradual shift in which water is treated as an asset for urbanism, for real estate value, for mobility, for typologies of social amenities like floating sports areas, for regional recreational structures as green-blue corridors, and in general as a sustainable way of inhabiting the delta. Although the impact of this strategy is touching upon every aspect of city life, like in the previous Peat city, its integration requires less radical change and can be implemented in a much more gradual way.



Effective space for water storage



blue roofscapes

space for open water and green-blue networks

living next to and on open water as an asset

mobility on water

floating public space

Exemplary zoom

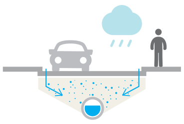
Risks

- Subsidence
- Seepage
- Flood
- Vulnerable flora
- Poor water quality
- Foundation pole rot

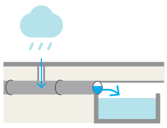
WATER BUFFER + REGULATION SYSTEMS

WATERBERGING OP DE STRAAT (HOLLE WEG)

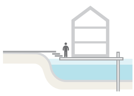
WATERBERGEND WEGCUNET



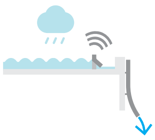
ONDERGRONDSE WATERBUFFER



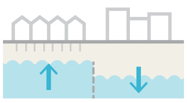
DRIJVEND BOUWEN



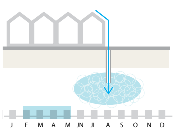
SLIM WATERDAK



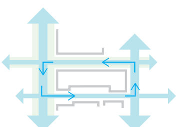
GEBIEDSGERICHT GRONDWATER-BEHEER



SEIZOENSBERGING

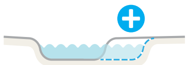


CIRCULAIR WATERSYSTEEM

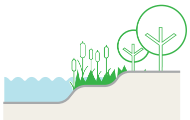


WATER BUFFERS

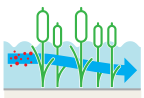
TOEVOEGEN OPPERVLAKTEWATER



NATUURLIJKE OEVERS



LOKALE WATERZUIVERING



WATERSPEELPLAATS

WATERBERGEND SEDUMDAK

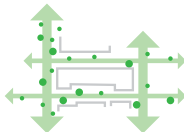
POLDERDAKEN / DAKAKKERS

COLLECTIEF GROEN DAK

GROENE GEVELS

EXTRA GREEN SPACES

VERBONDEN GROEN NETWERK

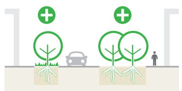


LOKALE VOEDSELPRODUCTIE

GROENE ERFAFSCHEIDING

VERBETERDE TOEGANG TOT GROEN

TOEVOEGEN GROENOPPERVLAK / BOMEN



BUURTPARK / POCKETPARK

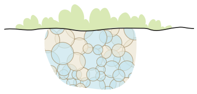
GEZOENDER GROEN

EXTRA GREEN SPACE FOR WATER

INFILTRATIEVELD / WADI

REGENTUIN

SPONGY SOIL



SPONGY PLANTING

4 THE SWALE: THE EXPLORATION OF CONTEXTUALIZING A GENERIC SPONGE TOOL

The next step in understanding sponge applicability is motivated by developing new knowledge: to explore and to discover. As mentioned, we see the need to contextualize generic tools spatially and to reach a maximum effectiveness in climate adaptation. The best measure to focus on would be "the swale", which we interpret as a generic tool that can be applied anywhere and always serves multiple climate adaptation purposes. The swale connects the use of subsoil and planting in a slightly deepened planter or even a wadi. Mostly this is being accompanied with technical features for optimal watermanagement purposes.

The diagram shows the differentiation in main in sponge functions a swale should have, to be effective in each of the four distinguished city districts. They vary from maximizing infiltration (1), to balancing water above and below groundlevel (2), to creating space for vertical groundwater exchange (3), to creating temporal space for open water (4). To reach these goals the swale will vary in appearance and function determined by combinations of different subsoils, additives, planting schemes and technical enhancements.

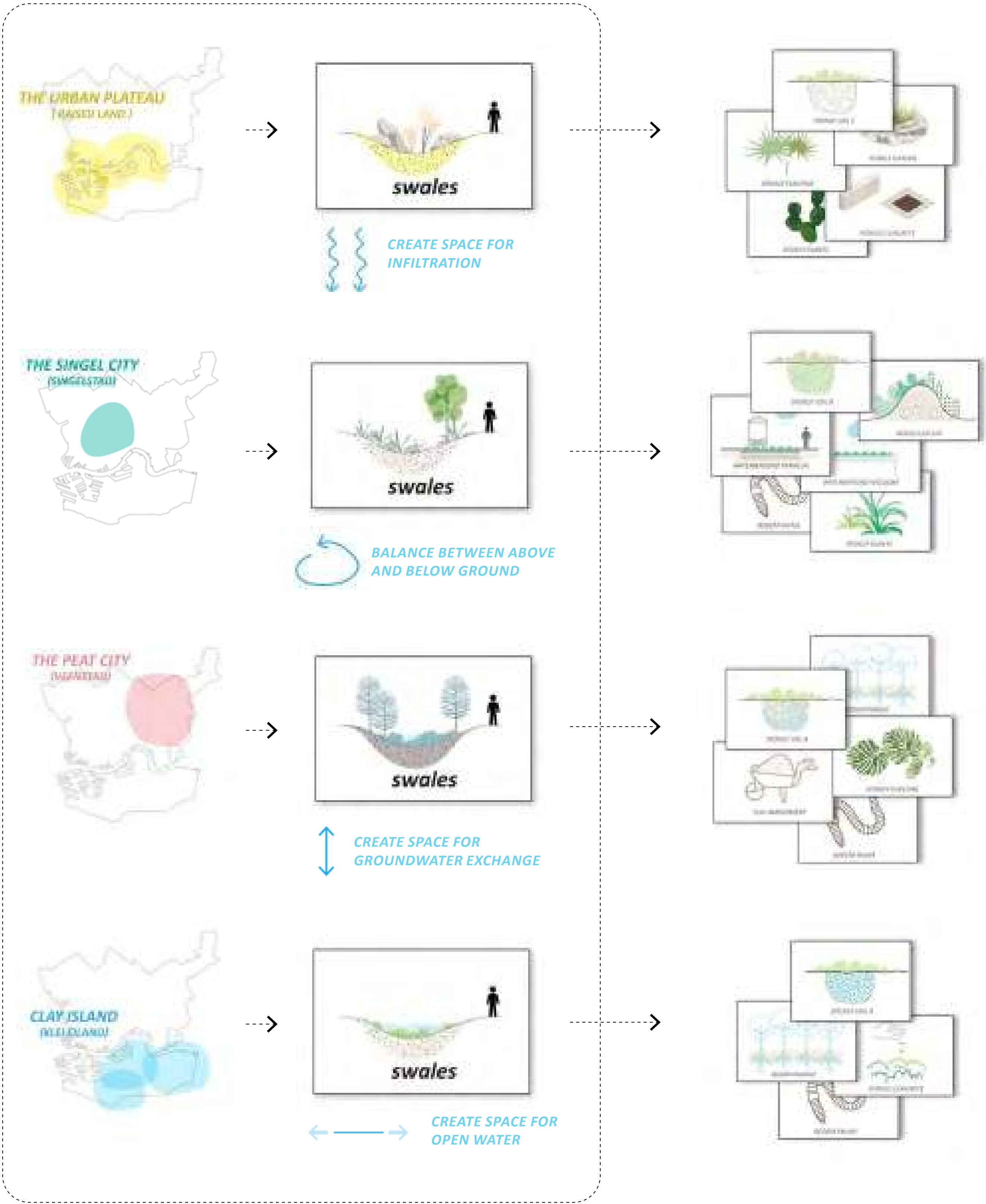
The continuation of our research comprises the examination of pure combinations of soil + plants, joining natural additives to it and applying technical enhancements in search of optimized wadi typologies. This research 'leaves the paper' to be translated into a test-site we name "Sponge Garden". It will be explained from the next chapter on and looks to find answers to following questions:

- How to amplify the swale in both 'climate performance' as well as pleasing aesthetics ?
- How to design a representative swale per different type of district (as defined in this chapter) ?
- Which effects we get from variations in soil composition, soil additives and specific planting ?

The swale or wadi: a base typology that can be further explored and enriched

CHARACTERISTICS OF A SWALE IN DIFFERENT CONTEXTS

DETAILED MEASURES BASED ON NATURAL SOLUTIONS



CHAPTER 5

INTRODUCING THE SPONGE GARDEN TEST SITE


SPONSTUIN

SPONGE GOALS - LOCATION - PARTNERS

In order to test out our research in practice, the Sponge garden has been designed and constructed. Here we have realized a test-site for simple and practical 'natural' solutions to maximize water resources in the city during heavy rainfalls and periods of extreme drought while creating a context for enhancing biodiversity.

One of the key components established earlier in the research, is to design with site specific conditions in mind and in this case - Rotterdam characteristics. This immediately relates to a variation in soil conditions as described earlier. Also the need for climate effective use of space is crucial, as the available space in the city is limited due to multiple and intense urban uses and moreover also underground space is limited due to geological conditions and/or high groundwater levels. The potentially available space has to be found both in public and private realms. Although from a technical perspective, methods can be the same disregarding the ownership, but there are differences in installation, costs and maintenance that set them apart.In order for climate measure to be atrractive for private individuals, they have to be cost effective and easy to implement. Another focus lies on natural ways of handling heavy rainfall within urban spaces of limited sizes. Therefor we look into ways of increasing a (fast) water absorption volume as well as the possibilities for slow return of the retained water volumes.

In the Sponge garden three methods are being tested:

- *Improving water retention within the four districts of Peat city, Clay island, Urban plateau and Singel city. Low maintenance planting and effective soil enhancements for small areas like private gardens to encourage owners to contribute to climate measures and increase the overall amount of green spaces. This is the concept of* ***Soil cubicles****.*
- *Using public space to collect rainwater from a local catchment area of 4 to 5 times their size and to return their water slowly. These spaces can be effective for immediate buffering of heavy rainfalls. They subsequently retain the water for longer periods in order to be usable in extended periods of drought. This is worked out in the concept of the* ***Waving Wadi****;*
- *Immediate and simple ways to enlarge planted spaces and reduce the area of paved spaces by implementing the concept of the* ***Depave garden****.*

The Sponge garden is located in "de Voedseltuin" (Food garden) just outside the office of De Urbanisten in the M4H district in Rotterdam. This allows us to closely and intensively monitor the progress in our research test-site

The Sponge garden is realised in close collaboration with the municipality of Rotterdam, Binder green projects, Kim Kogelman advies and de Voedseltuin. It's realization has been financially supported by WSR Rotterdam (watersensitive), the Waterboard of Delfland (Hoogheemraadschap), the Provincie of South Holland, the EFL Foundation and Lapinus by Rockflow.

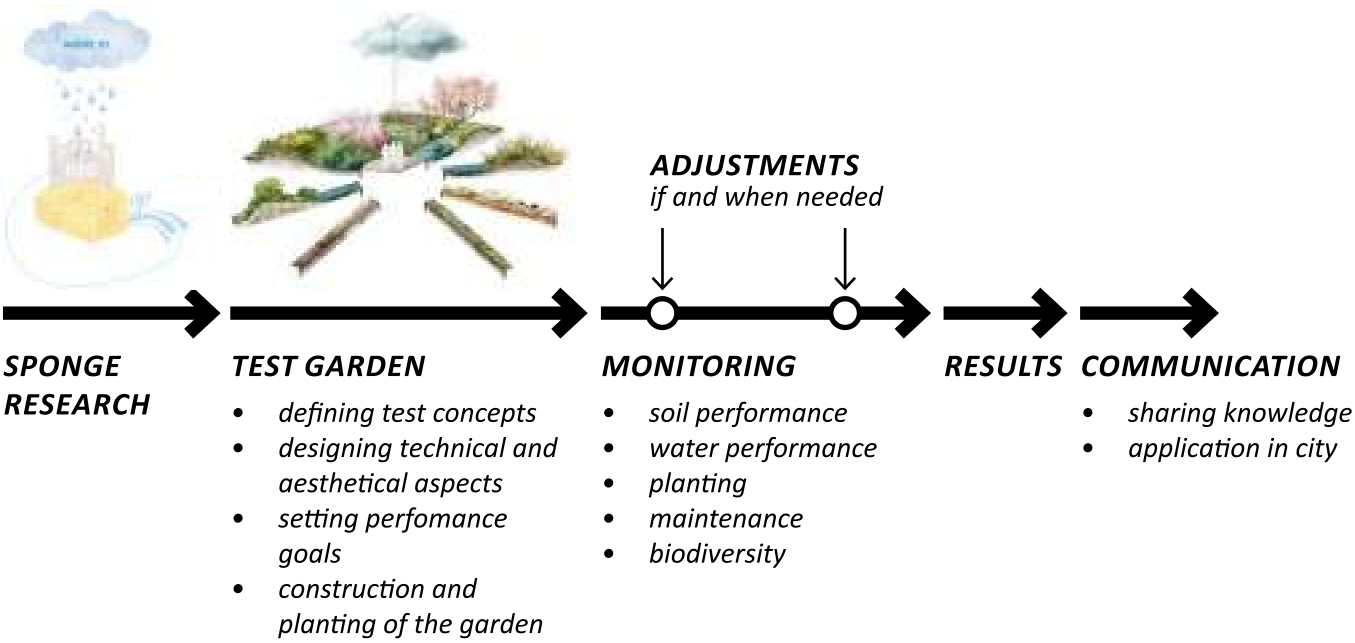
The location of the Sponge garden in the Food garden / Voedseltuin in the M4H-district in Rotterdam

SETUP OF TEST-SITE PROCESS

The setup of the test-site is as follows:

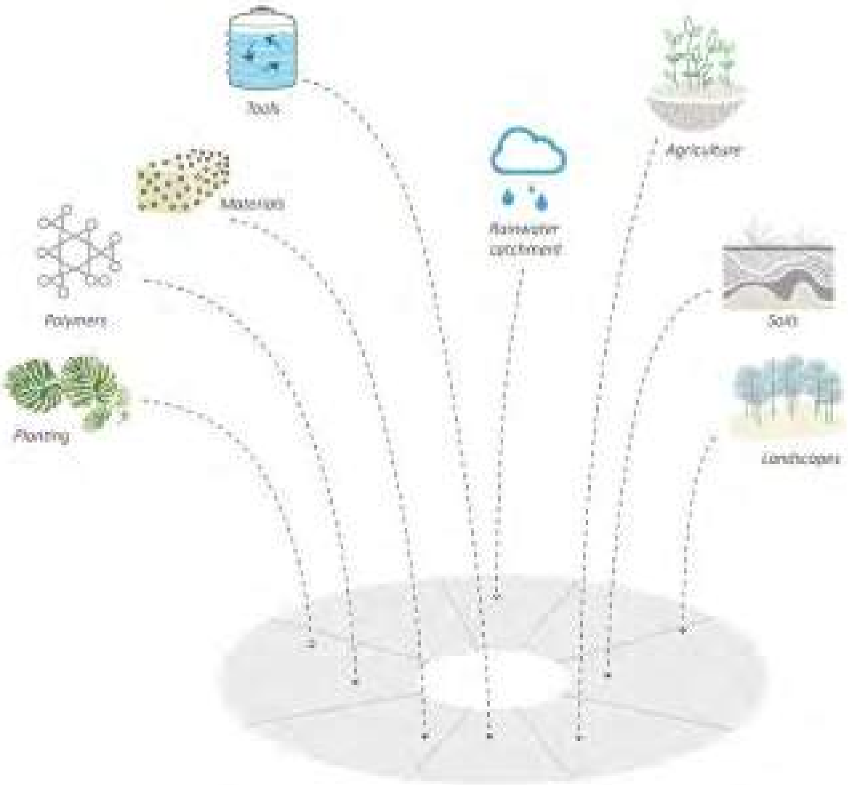
- *Arrange financial support and partners to help constructing the Sponge garden. Arrange a place within the food garden and make agreements with the owner of the land (Rotterdam Port Authority).*
- *Design of the experimental garden together with municipal experts to figure out soil mix and planting. Design and engineering of technical framework to be able to monitor groundwater and humidity together with municipal field experts (veldmeetdienst).*
- *Arrange materials and transport; planning of the construction with parties such as: Rotterdam soil bank, Rotterdam engineering department, Binder Green projects, Lapinus Rockflow. Inform the community around the site concerning possible hindrance.*
- *Communicate progress to financial supporters and partners. Organize celebrations at start plus finish of the construction of the Sponge garden.*
- *Recording zero situation. Allowing the plants to establish in the first year. Performing the necessary maintenance of weeding, replanting if needed.*
- *Monitoring during the two years or possibly/preferably longer to acquire more objective results. Simulate heavy rainfall event on site, in order to test the performance of Waving wadi.*
- *Record results on performance of soil, water, planting, biodiversity and maintenance.*
- *Find appropriate and efficient means of sharing the results with public and private parties, professionals and residents. Possibly find ways to implement the sponge tools within project(s) in the city.*

These steps have often been taken simultaniously.
Some of them are also reoccuring as a cycle during the ongoing process.

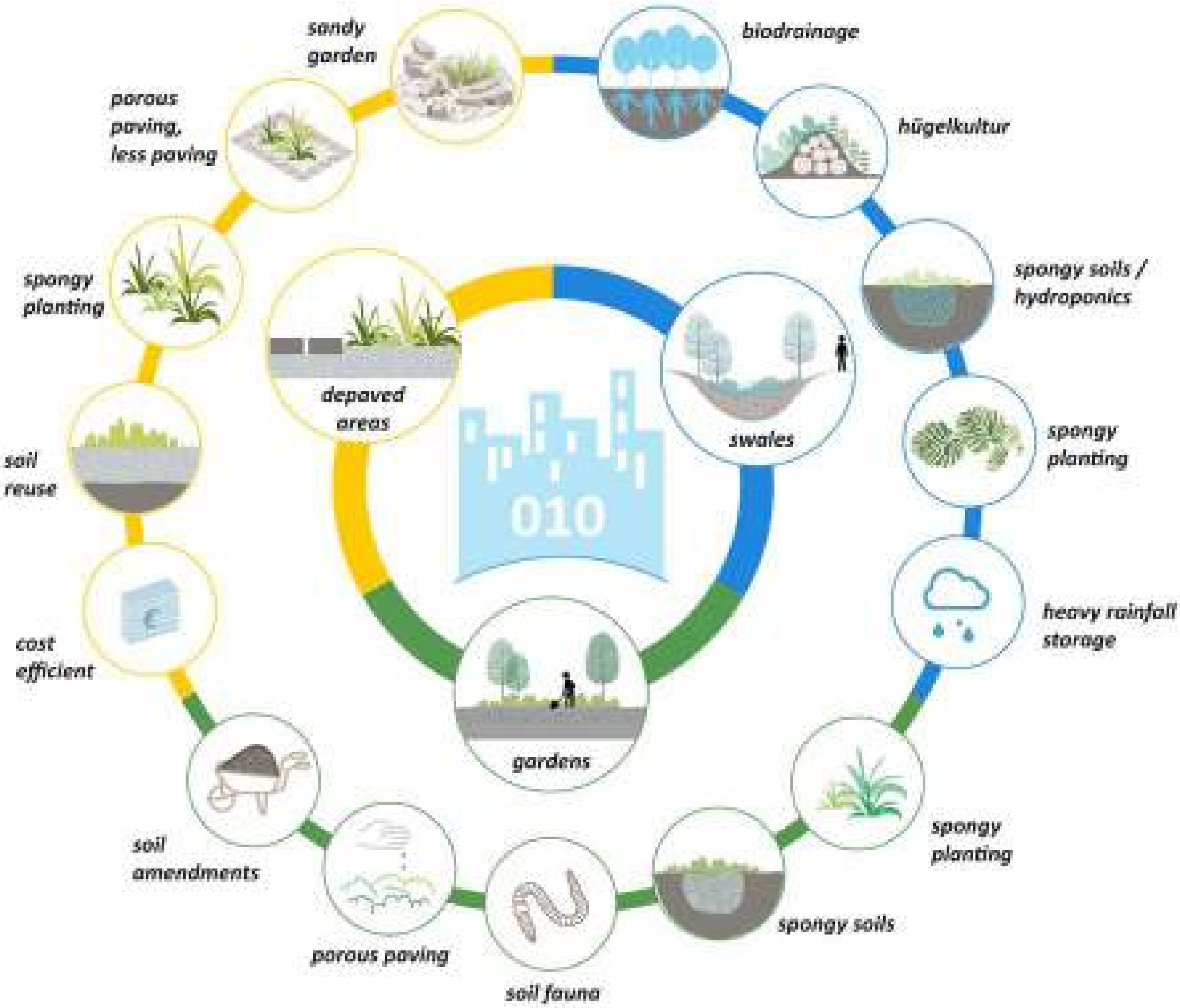


Schematic overview of the process setup of the test-site Sponge garden

PILOT PROJECT AS A SOURCE OF KNOWLEDGE DEVELOPMENT



NEW KNOWLEDGE FOR URBAN APPLICATION



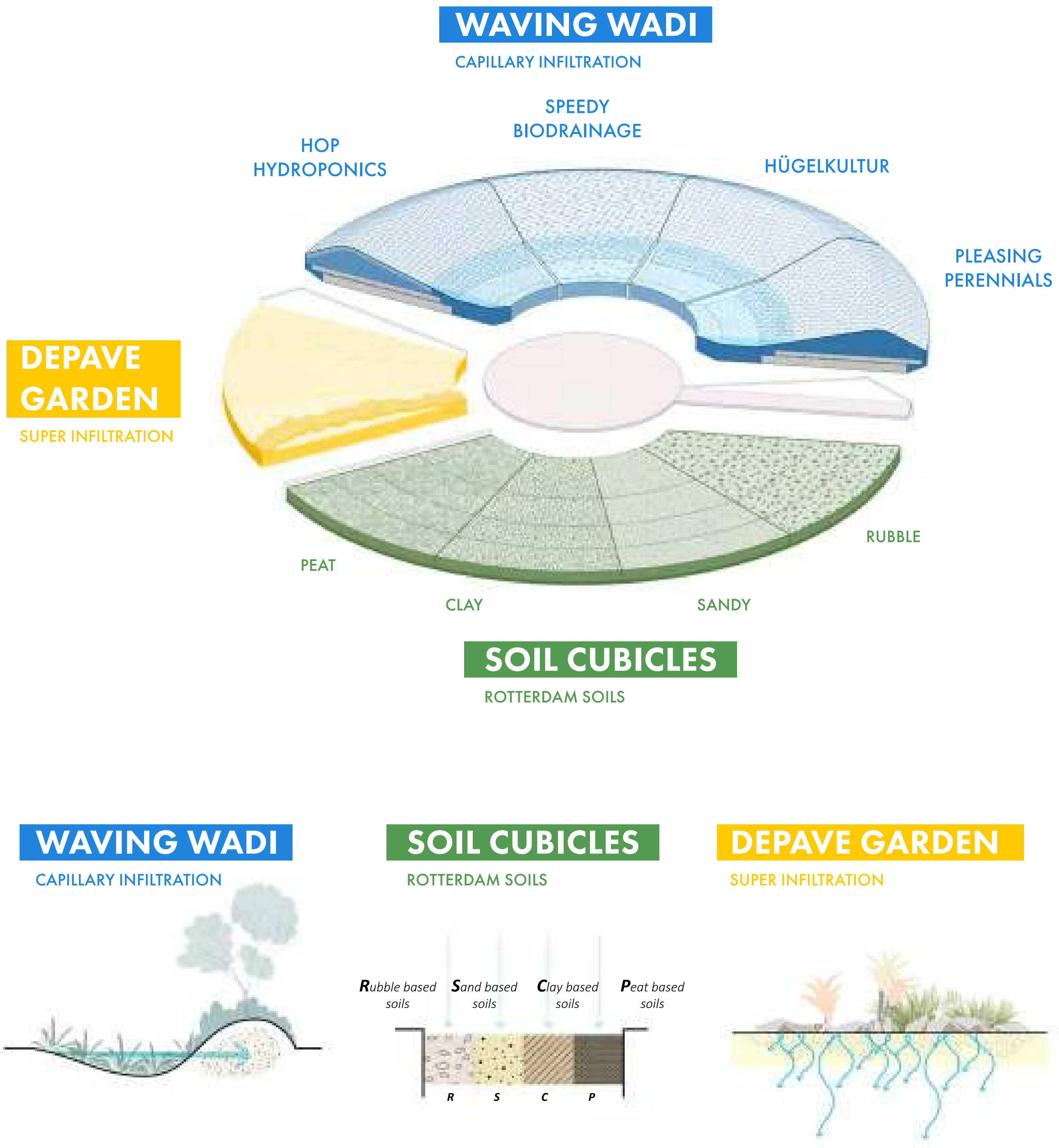
SPONGE GARDEN TEST-SITE LAYOUT

The test-site layout follows the design of the Food garden / Voedseltuin in which all planting is organised in circles (design by LOLA landscape architects). The Sponge garden has a central meeting space in the very middle and the outer doughnut is split in three parts, each dedicated to a different experiment:

- *Waving wadi - capillary infiltration. This wadi plus small mount garden catches, stores and reuses water and is divided in four subconcepts to offer diverse public use and aesthetics in urban contexts*
- *Soil cubicles - Rotterdam soils. The cubicle garden is divided into four slices based on characteristics of typical Rotterdam soils and each slice is further subdivided, differentiated by additives added to enhance local soil qualities. Each of the subconcepts are hydrologically isolated to offer objective water measurements as far as possible in the given situation.*
- *Depave garden - super infiltration. The most low-key intervention to depave hard infrastructure is being tested on its potential to function as a planter or even as a small garden.*

The soil used in the test site is local and comes from Rotterdam soil bank. Additionally, we use materials of vegetal, mineral, organic nature - both traditional and innovative. A complete list of soils and additives can be found on page 170.

The test site is experiment based and open to adjustments throughout the process, in order to further elaborate and fine-tune the tools. Therefor this is a growing document and this is the first progress report.



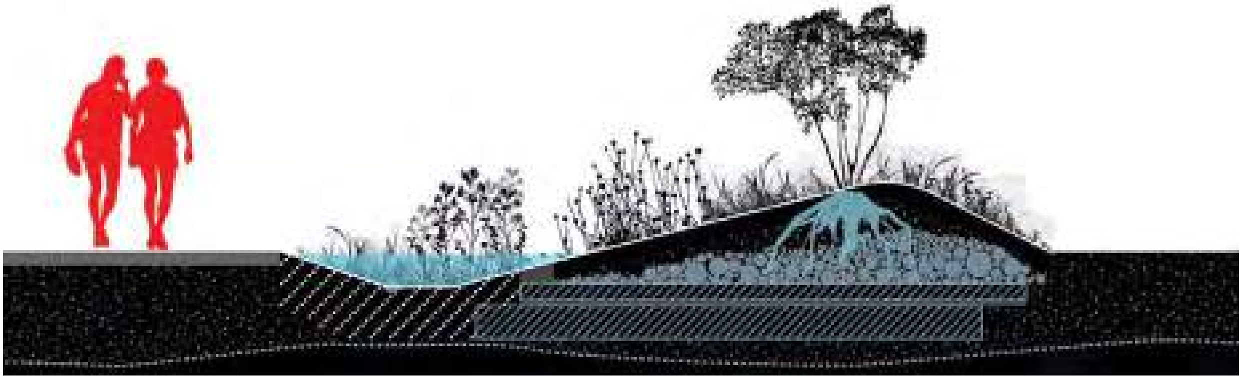
Schematic overview of the Sponge garden test-site layout and conceptual characteristics

WAVING WADI

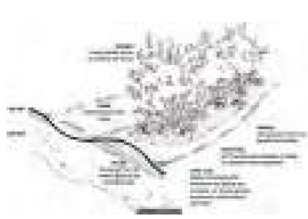
CAPILLARY INFILTRATION

A Wadi is a type of swale, originating from the Arabic word meaning dry stream bed except when its rains. It stores water, retaining it in its recess, letting it slowly soak away. The waving wadi improves on this, testing how the water can be absorbed in the berm that makes up one of the wadi's sides. The idea is to gather rainwater into the swale, then lead it within 24h into the immediate storage under the berm. Later water is drawn higher into the berm by capillary action, increasing water storage capacity and behaving like a sponge. The soil composition and planting is chosen to facilitate the water flow. The total waving wadi construction reaches no deeper than 70 cm below ground level, making it ideal for use in areas with high groundwater levels or in clay soil areas where water infiltration is very slow or limited. In the garden we are testing four variations that offer different spatial, aesthetic and maintenance qualities:

A. ***Pleasing perennials:*** *an elegant ornamental addition that brings nature into our public spaces;*
B. ***Hügelkultur:*** *a collective food garden on a wood log and soil mound;*
C. **Speedy biodrainage:** *robust, water loving planting along road and other infrastructure;*
D. **Hop garden:** *a taller planting on a hydroponic mound, creating a natural boundary.*



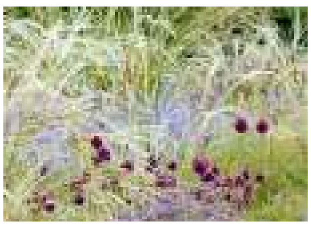
Schematic setup of the waving wadi

Swale

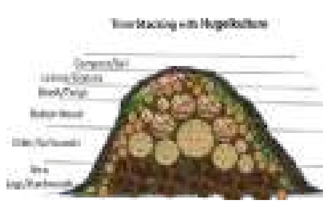
Swale with a rocky bottom

Rock wool



Ornamental planting

Hügelkultur + wadi



Hügelkultur

Edible planting

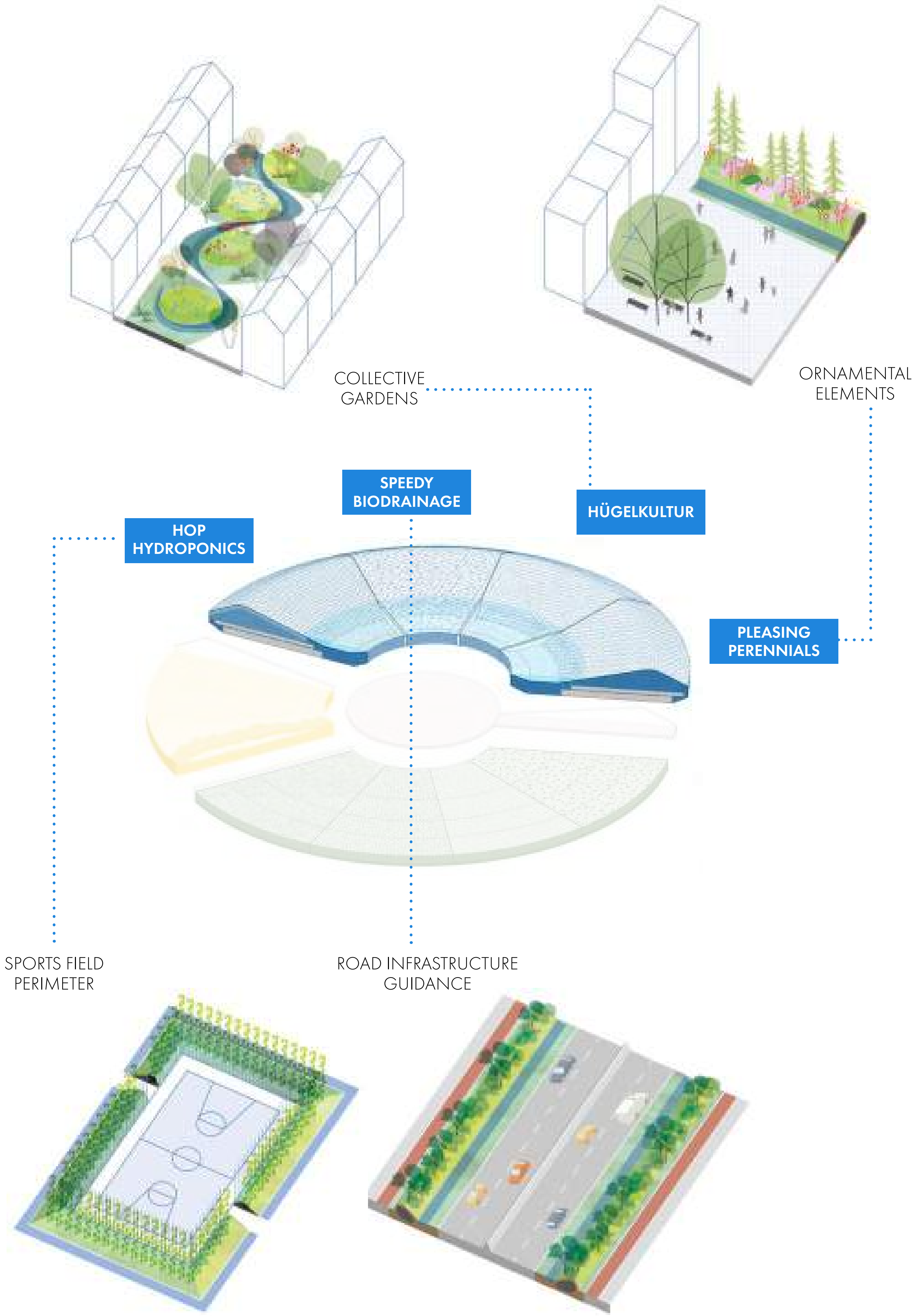
Salt cedar

Creeping willow

Purple willow

Hydroponics

Hop planting

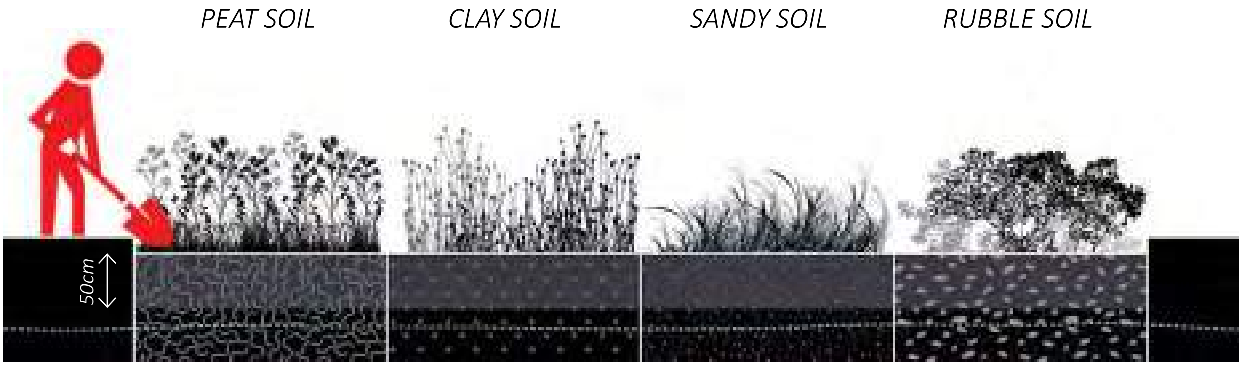

COLLECTIVE GARDENS
ORNAMENTAL ELEMENTS
SPEEDY BIODRAINAGE
HÜGELKULTUR
HOP HYDROPONICS
PLEASING PERENNIALS
SPORTS FIELD PERIMETER
ROAD INFRASTRUCTURE GUIDANCE

SOIL CUBICLES

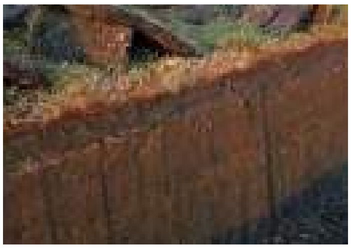
ROTTERDAM SOILS

Here we are looking for optimal planting and soil additives that are most suitable for local Rotterdam soils. The aim is to find simple installation, low maintenance, cost efficient solutions for use particularly in the private realm. The focus is to improve rainwater storage within the local soil, healthy development of plants and trees and using the local resources in the most profitable way possible. Our question is how can we improve the water absorbing performance of city's subsurface? Water struggles to permeate into peat and clay whilst it runs straight through sand and rubble without being absorbed.

In the test garden we have collected four local soil compositions: peat, clay, sand and a rubble mix. The depth of the soil mixtures are only 50 cm, making this test easily applicable in small-scale environments such as private gardens and that can be done with basic gardening tools. The planting is selected according to the different soil types.



Schematic setup of the soil cubicles



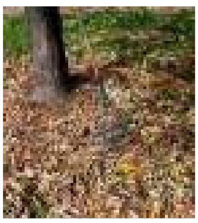
Peat soil

Clay soil

Sandy soil

Rubble soil

Rotterdam soils



Leaves, grass

Woodchips

Compost

Perlite

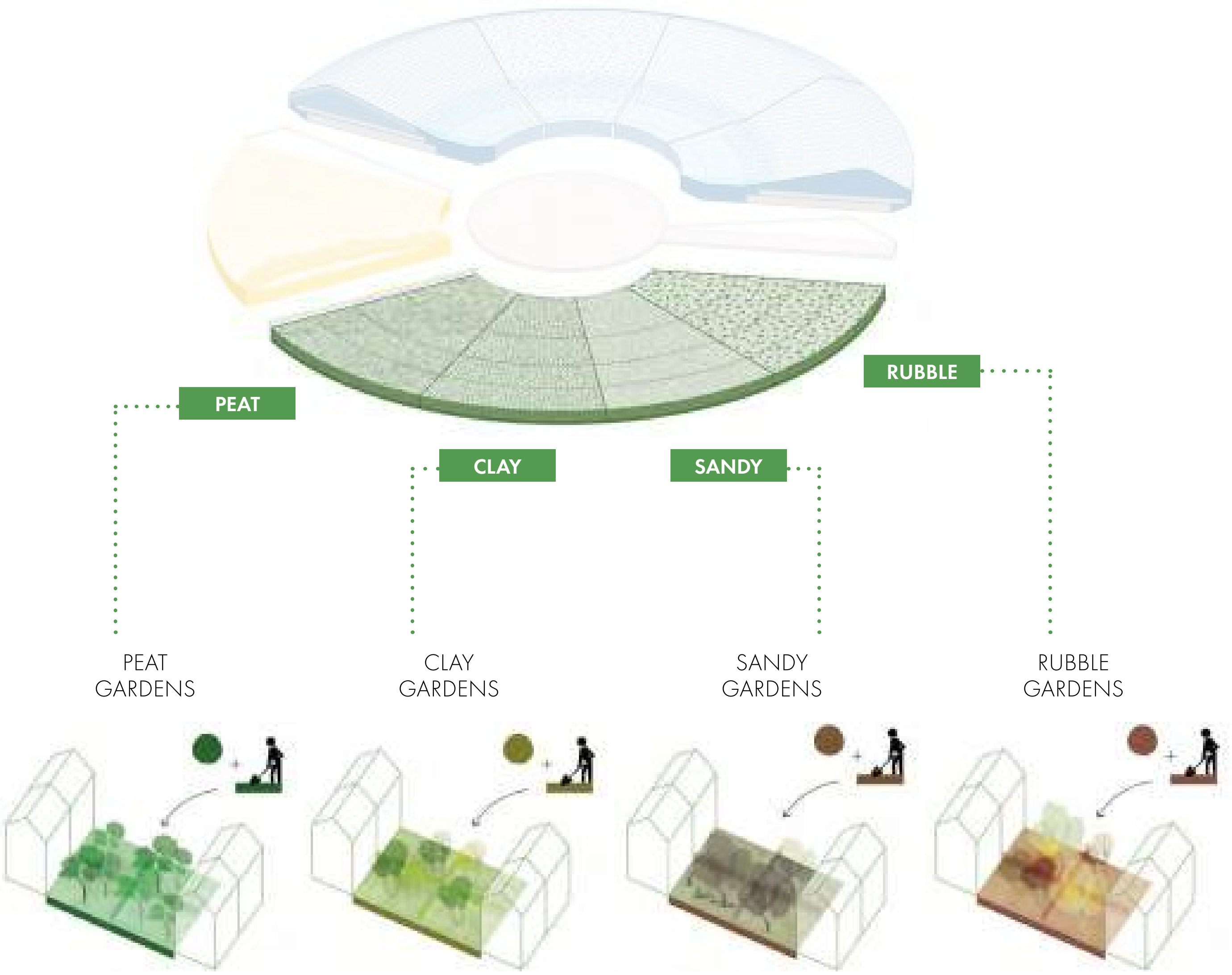
Vermiculite

Super absorbent polymer

Lapinus fibers

Soil amendments


PRIMARY GOAL FOR EASY
USAGE IN PRIVATE GARDENS

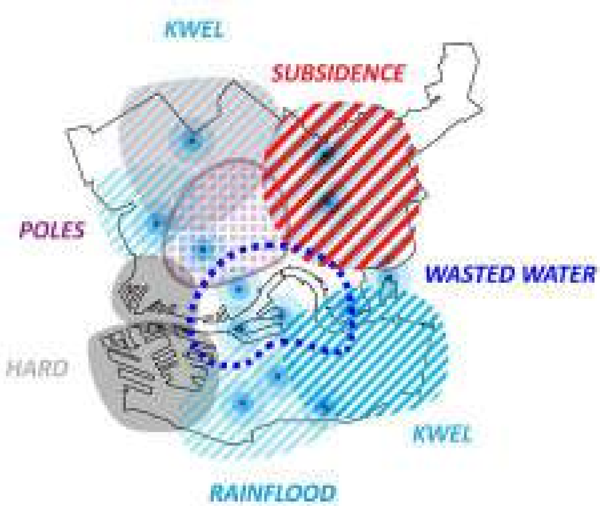

PEAT
CLAY
SANDY
RUBBLE
PEAT
GARDENS
CLAY
GARDENS
SANDY
GARDENS
RUBBLE
GARDENS

SOIL CUBICLES

ROTTERDAM SOILS

In the test-site we have chosen four local soil compositions according to the sponge-city districts that have been distinguished in chapter 4: peat (Peat city), clay (Clay island), sand (The urban plateau) and a rubble mix (The singel city). Each of the soils have different characteristics and imply certain risks (seepage, subsidence, rotting building foundation poles etc) within the urban environment. On the site we are experimenting with a variety of amendments, in order to improve the characteristics and reduce those risks.

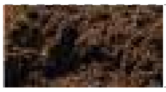
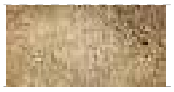
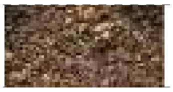
All the soils are brought from the Rotterdam Soil Bank and are arranged per soil type in a slice. Each of these slices is split into four cubicles where one is control (soil as found) and the other three have organic, inorganic and innovative additives mixed in. On the opposite page the soil characteristics and additives are being specified.



Risks in Rotterdam, simplified scheme

Main urban Sponge districts

PARAMETERS

	PEAT SOIL min 80% m.o	CLAY SOIL 50% clay + 30% sand	SANDY SOIL 5% clay + 92% sand	RUBBLE SOIL
POROSITY	71-95%	30-60%	26-46%	23-38%
SIZE	0.1-4.6mm	<0.002mm	0.06 - 2mm	2 - 63mm
TEXTURE				
PERMEABILITY	↑	↑	↑↑↑↑	↑↑↑↑↑
SATURATION POINT	HIGH	47%	41%	HIGH
RETENTION CAPACITY	HIGH	42%	6%	LOW
PLANT AVAILABILITY Readily available water	50%	12%	5%	LOW
WILTING POINT	??	30%	2%	< 2%
SHRINKAGE	HIGH 8-48mm (100mm)			
CAPILARITY	↑↑↑↑↑↑↑	↑↑↑↑↑↑↑	↑	↑

* In red are shown limiting parameters

GOALS

	PEAT SOIL	CLAY SOIL	SANDY SOIL	RUBBLE SOIL
INCREASE ↑	* DRAINAGE CAPACITY * WATER RETENTION * MOISTURE LEVEL AVAILABLE FOR PLANTS & ROOTS	* DRAINAGE CAPACITY * LONG TERM WATER STORAGE * MOISTURE LEVEL AVAILABLE FOR PLANTS & ROOTS * NUTRIENT LEVEL * OXYGEN LEVEL	* LONG TERM WATER STORAGE * MOISTURE LEVEL AVAILABLE FOR PLANTS & ROOTS * NUTRIENT LEVEL	* LONG TERM WATER STORAGE * MOISTURE LEVEL AVAILABLE FOR PLANTS & ROOTS * NUTRIENT LEVEL
REDUCE ↓	* SUBSIDENCE			

SOIL AMENDMENTS

/ REFERENCE SITUATION	PEAT SOIL	CLAY SOIL	SANDY SOIL	RUBBLE SOIL
ORGANIC	WOODCHIPS	COMPOST	MULCH, LEAVES, GRASS	COMPOST
INORGANIC	PERLITE VERMICULITE	PERLITE VERMICULITE	MULCH, LEAVES, GRASS VERMICULITE	COMPOST VERMICULITE
NEW PRODUCTS	LAPINUS FIBERS Rockwool	LAPINUS FIBERS Rockwool	MULCH, LEAVES, GRASS SAP	COMPOST SAP

*SAP = super absorbent polymer

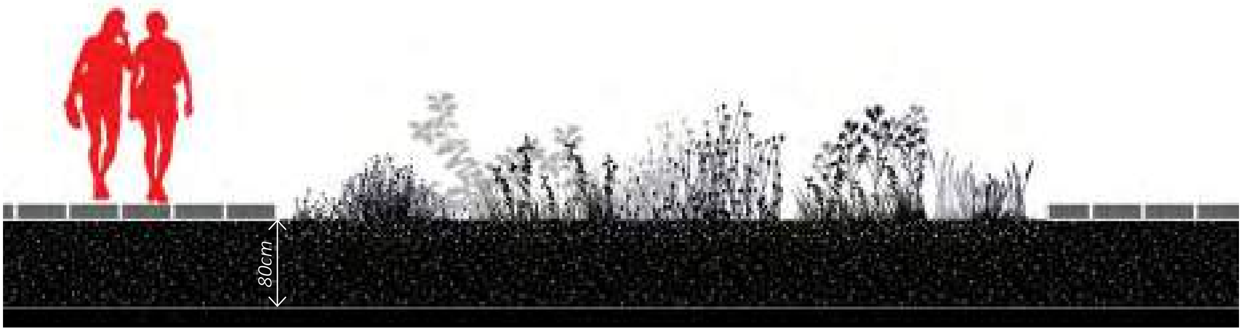
DEPAVE GARDEN

SUPER INFILTRATION

The idea behind this arrangement is to look for a simple way to enlarge green spaces in the city. The focus here is on low cost, simple installation and maintenance that could work both in the long-term as well as a temporary intervention. It is suitable for softening the sides of roads and sidewalks and paved private gardens, frontgardens (geveltuin), where the soil consists of a sand foundation.

The paved surface would be removed and a small amount of soil is mixed into the top layer of sandy foundation, making good conditions for drought-resistant plants. Meanwhile the deeper layer of sand is left as found. Due to the subsoil composition these depaved gardens can absorb lots of water, and the 70cm deep foundation used in the garden, is the standard for road construction across the city. The test garden has three zones with different top layer materials:

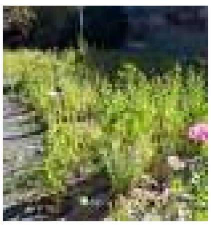
- *regular fine sand;*
- *extra absorbent 'flow sand' (sand with basalt grit, an innovation from Aquaflow);*
- *a mix with crushed asphalt to partly recycle the road surface.*



Schematic setup of the depave garden

Reused materials

Depaving

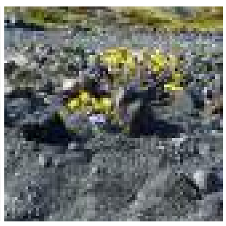


Planting in road construction sand reusing existing materials

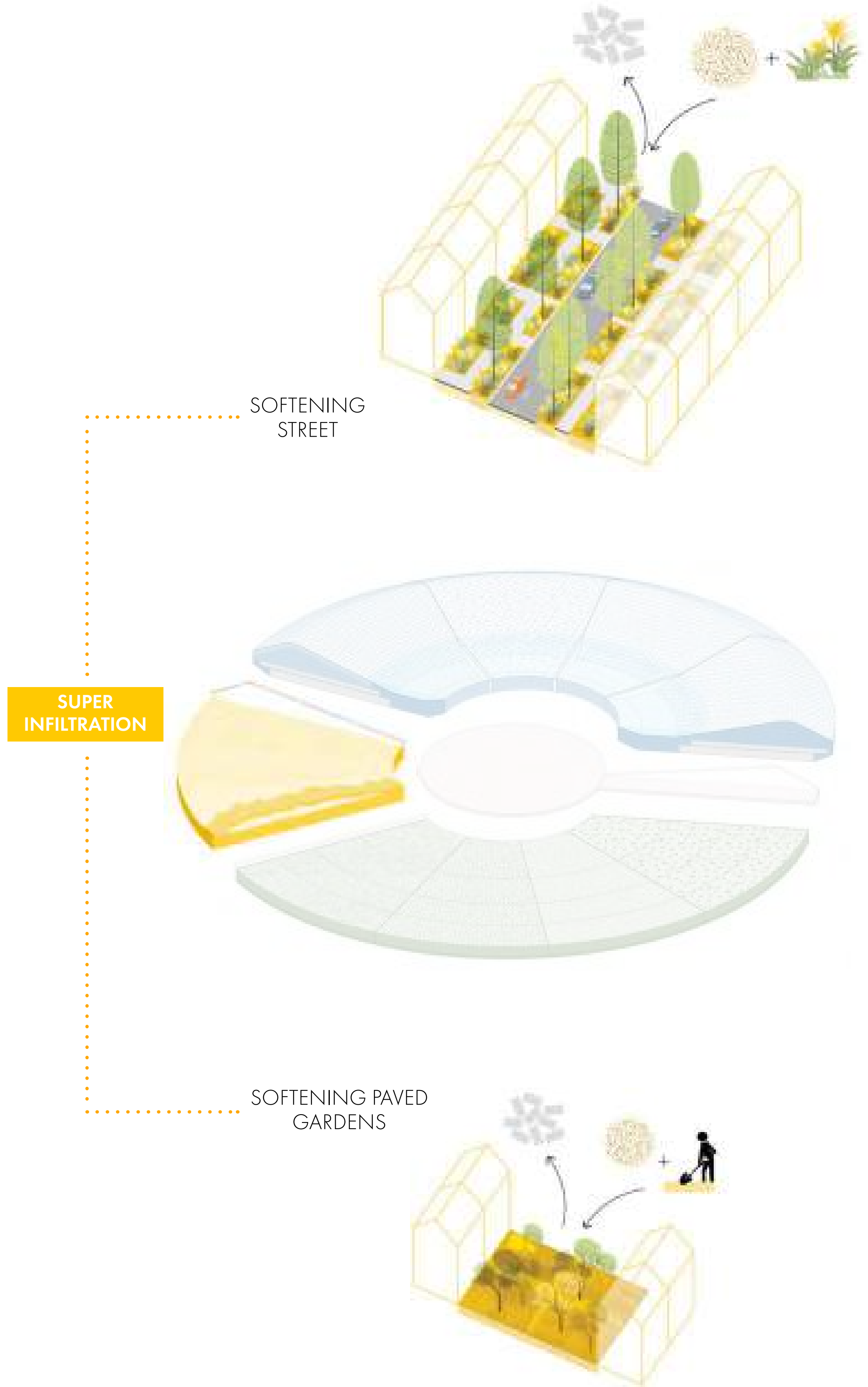
Asphalt gardens

Prairie planting

Dune planting



Rock planting


SOFTENING
STREET
SUPER
INFILTRATION
SOFTENING PAVED
GARDENS

SPONGE SOILS

All the soils are sourced locally and supplied by the Rotterdam soil bank that collects and distributes soils within the municipal boundaries.

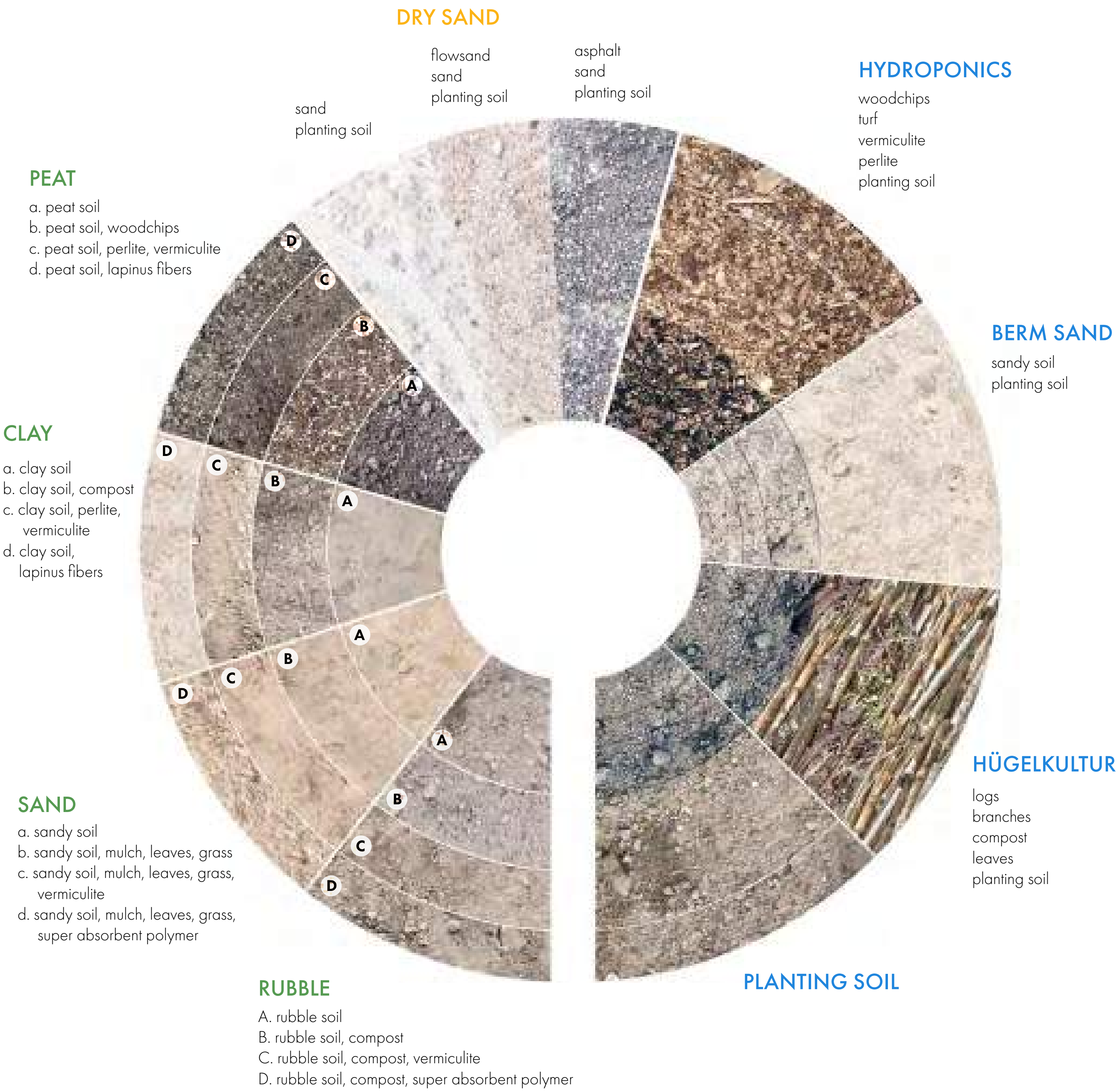
Waving wadi
The swales are made of good planting soil, except for the speedy biodrainage plot where sandy soil is used. The mounds have different soil compositions:

- *Pleasing perennials: good planting soil*
- *Hügelkultur: soft wood branches, leaves and compost, covered with a good planting soil*
- *Speedy biodrainage: sandy soil with top layer of good planting soil*
- *Hop garden: mix of peat moss, vermiculite and perlite, and topped with a layer of mulch*

Depave garden
Compressed construction sand with some good planting soil added in the top layer. There are three different top finishes: crushed asphalt, flowsand and none.

Soil cubicles
Each slice houses a different soil type. The inner cubicles are pure soil as found - the control cubicle. Going outwards the rings have organic, inorganic or new materials added to the soils to improve certain parameters. There's a impermeable layer underneath the cubicles to simulate high groundwater level that is typical for the situation in Rotterdam.

Soil samples



Organization of the soils and additives in the Sponge garden

SPONGE PLANTING

The planting is chosen based on the concepts, soil types performance and desired maintenance. Most plants are perennials with some exceptions of annuals. We have chosen to plant only a couple of trees and higher shrubs due to the temporary nature of the garden. It is highly recommended to have trees in a permanent situation.

Waving wadi

Planting is arranged according to water - wet loving, floodable planting in the swales; dry loving plants with deeper root system in the mounds.

The mounds and swales have different planting concepts:

- *Pleasing perennials: ornamental planting*
- *Hügelkultur: edible garden*
- *Speedy biodrainage: planting that absorbs large amounts of water*
- *Hop garden: taller planting that can grow in hydroponics*

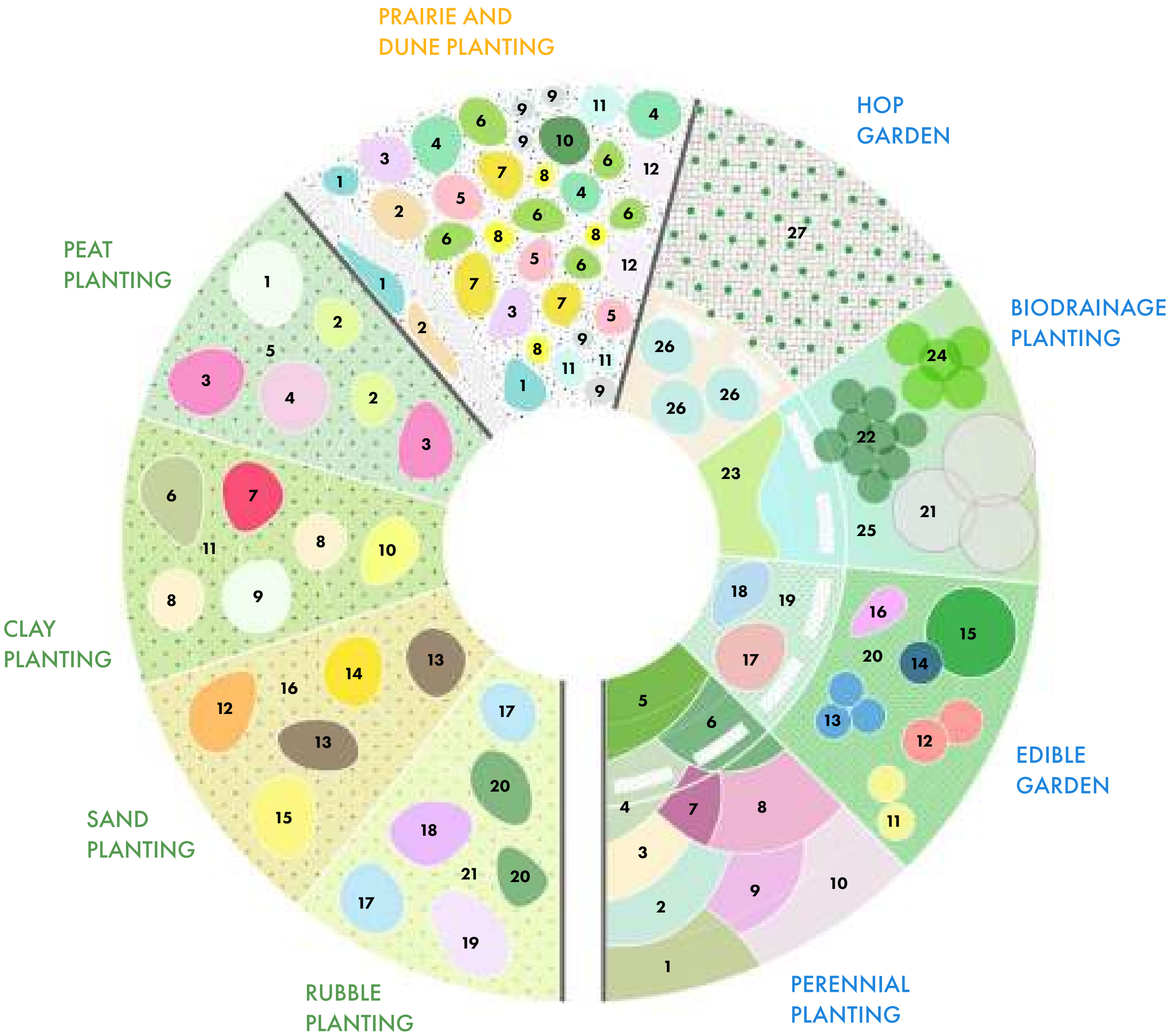
Depave garden

Prairie and dune planting whose natural habitat is sand.

Soil cubicles

Perennials and ornamental grasses suitable for each soil type. The planting plan features a groundcover layer with accent planting. The selection is based to keep good planting structure throughout the seasons and is easy to maintain.

Plants arriving...



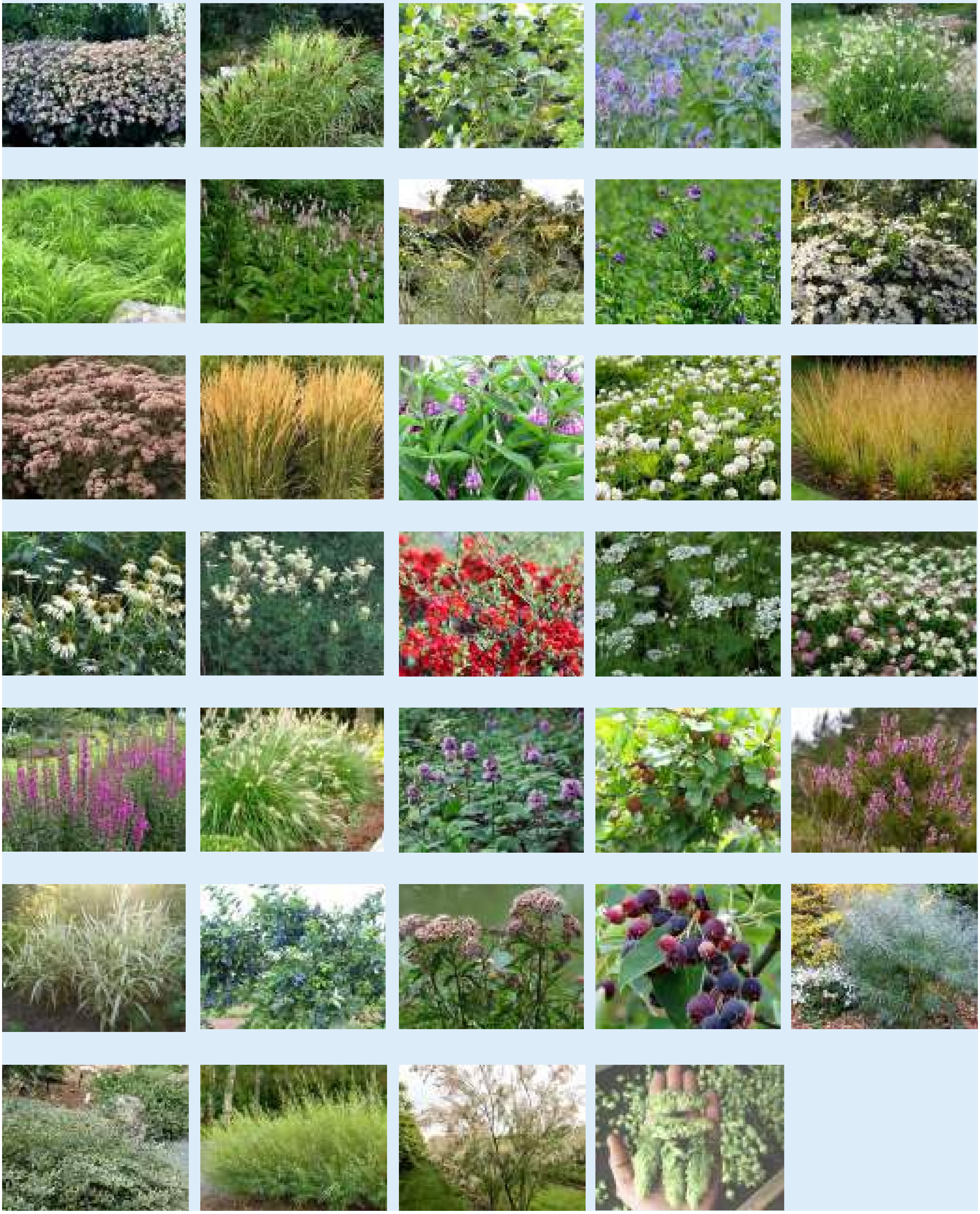
1. Sea lyme-grass 'Blue dune'
2. European beach grass
3. Lupin
4. Pearly everlasting
5. Red valerian
6. Mexican feather grass
7. Tickseed
8. Great mullein
9. Umbelata yarrow
10. Dwarf mountain pine
11. Hairy hawkweed
12. Russian sage

1. Aster 'Starshine'
2. Purple moor-grass 'Heidebraut'
3. Heather
4. Japanese spiraea 'Genpei'
5. Snow rush
6. Chinese fountaingrass 'Hameln'
7. Red bistort
8. Feather reed-grass 'Karl Foerster'
9. White bistort
10. Coneflower 'Early Bird Gold'
11. Lady's mantle
12. Butterfly flower
13. Stonecrop 'Chocolate'
14. Yarrow
15. Tickseed
16. Mexican feather grass + Silver feather grass
17. White sage 'Valerie finnis'
18. Sea aster
19. Russian sage
20. Prairie dropseed
21. Lavander cotton + Green lavander cotton

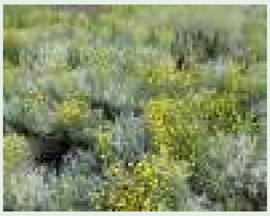
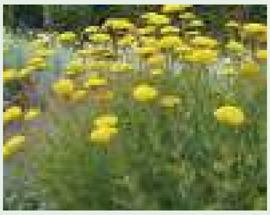
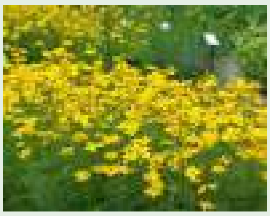
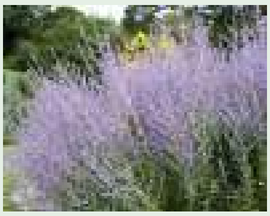
1. Chinese fountaingrass 'Hameln'
2. Purple coneflower 'Alba'
3. Feather reed-grass 'Karl Foerster'
4. Meadowsweet
5. Palm sedge
6. Japanese forest grass
7. Purple loosestrife 'Robin'
8. Common bistort
9. Stonecrop 'Matrona'
10. Aster 'Asran'
11. Gooseberry
12. Japanese quince
13. Blueberry
14. Purple chokeberry
15. Juneberry
16. Bronze fennel
17. Common valerian
18. Common comfrey
19. Water mint
20. Borage + Coriander + Lucerne + White clover
21. Tamarisk 'Pink cascade'
22. Purple willow 'Nana'
23. Silvery creeping willow
24. Narrow-leaved rosemary willow
25. Native grassland flowers
26. Northern sea oats 'River mist'
27. Common hop

Planting plan of the Sponge garden

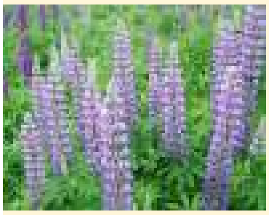
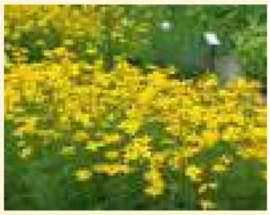
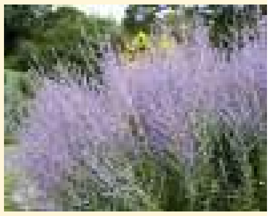
WAVING WADI



SOIL CUBICLES

DEPAVE GARDEN

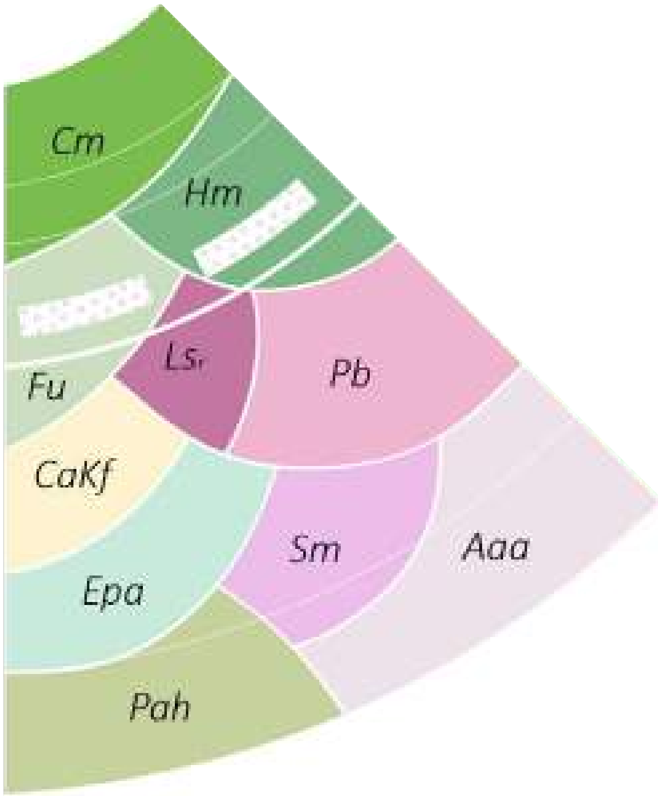
 
 
 
 
 
 

Waving wadi

1 PERENNIAL PLANTING

Aesthetically pleasing planting for an urban space:

- *a mix of ornamental grasses and perennials with seasonal flowers;*
- *plants arranged according to water conditions from wet (swale) to dry (mound);*
- *focus on evergreen species or species with good winter structure;*
- *relatively high estimated maintenance level to ensure the quality - regular weeding, cutting back in early spring and replenishing planting if necessary*



Aaa

Aster 'Asran'
Aster ageratoides Asran

CaKf

Feather reed-grass 'Karl Foerster'
Calamagrostis acutiflora Karl Foerster

Cm

Palm sedge
Carex muskingumensis

Epa

Purple coneflower 'Alba'
Echinacea purpurea alba

Fu

Meadowsweet
Filipendula ulmaria

Hm

Japanese forest grass
Hakonechloa macra

Lsr

Purple loosestrife 'Robin'
Lythrum salicaria robin

Pah

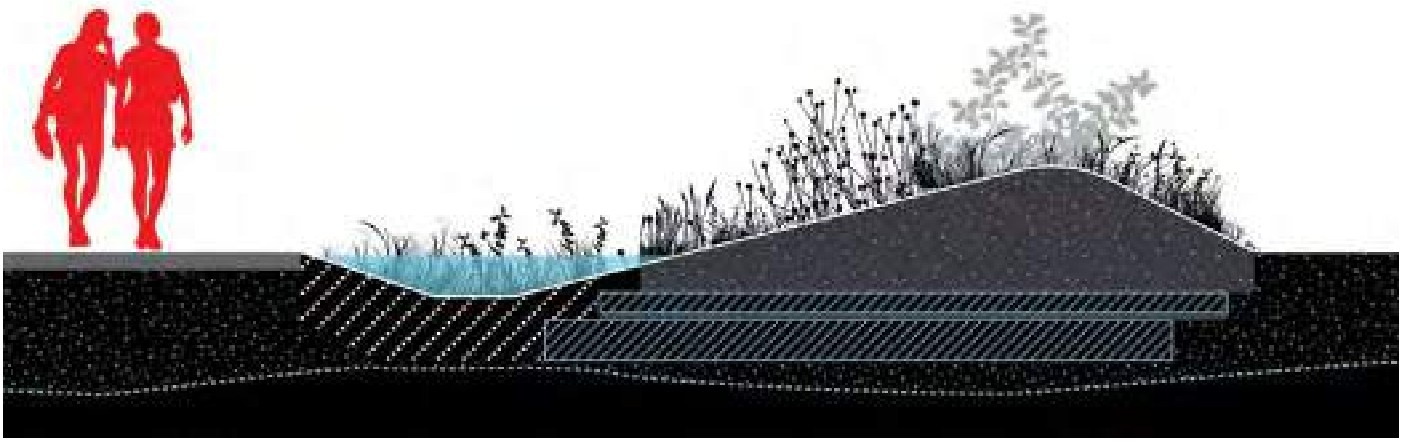
Chinese fountaingrass 'Hameln'
Pennisetum alopecuroides 'Hameln'

Pb

Common bistot
Persicaria bistorta

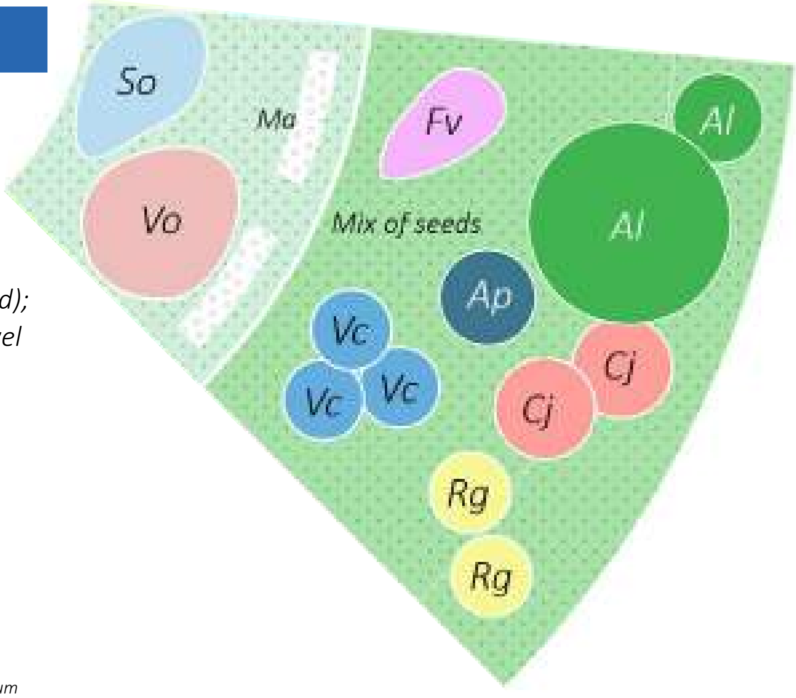
Sm

Stonecrop 'Matrona'
Sedum matrona



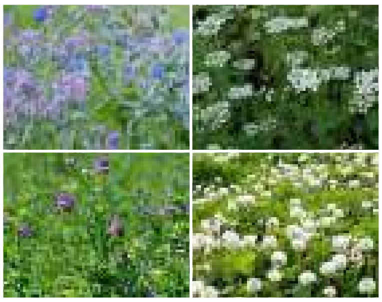
Waving wadi

2 EDIBLE GARDEN



Edible planting for a local community:

- *a mix of edible and herbal plants;*
- *plants arranged according to water conditions from wet (swale) to dry (mound);*
- *relatively high estimated maintenance level to have a good harvest and community bonds*



Borage / Borago officinalis
Coriander / Coriandrum sativum
Lucerne / Medicago sativa
White clover / Trifolium repens

Al

June berry
Amelanchier lamarckii

Ap

Purple chokeberry
Aronia prunifolia

Cj

Japanese quince
Chaenomeles japonica

Fv

Bronze fennel
Foeniculum vulgare 'Purpureum'

Ma

Water mint
Mentha aquatica

Rg

Gooseberry
Ribes grossularia

So

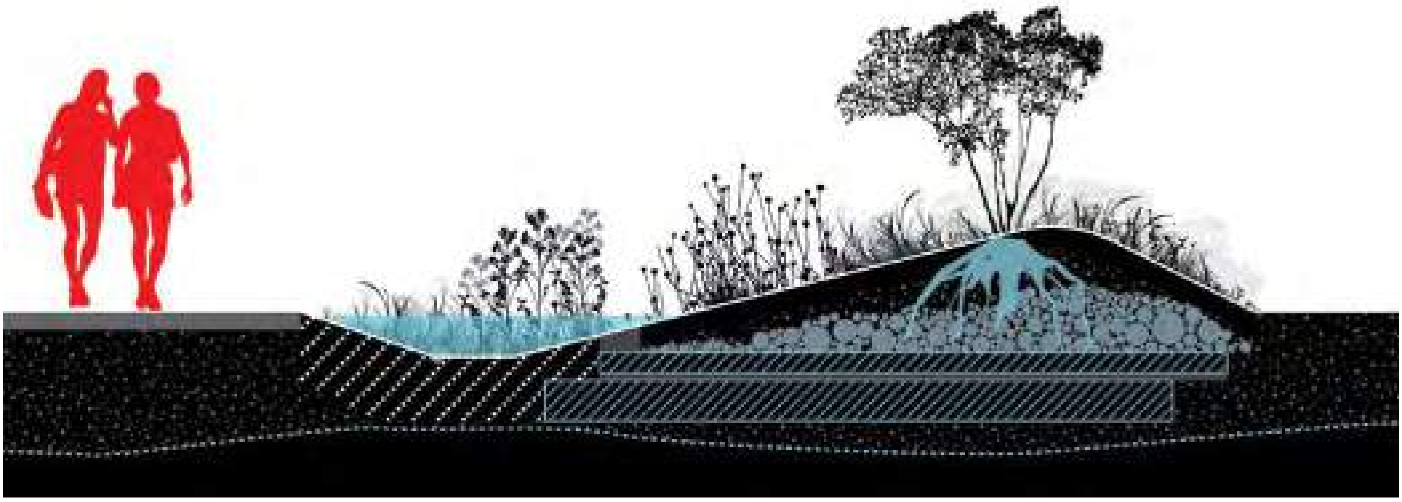
Common comfrey
Symphytum officinale

Vc

Blueberry
Vaccinium

Vo

Common valerian
Valeriana officinalis

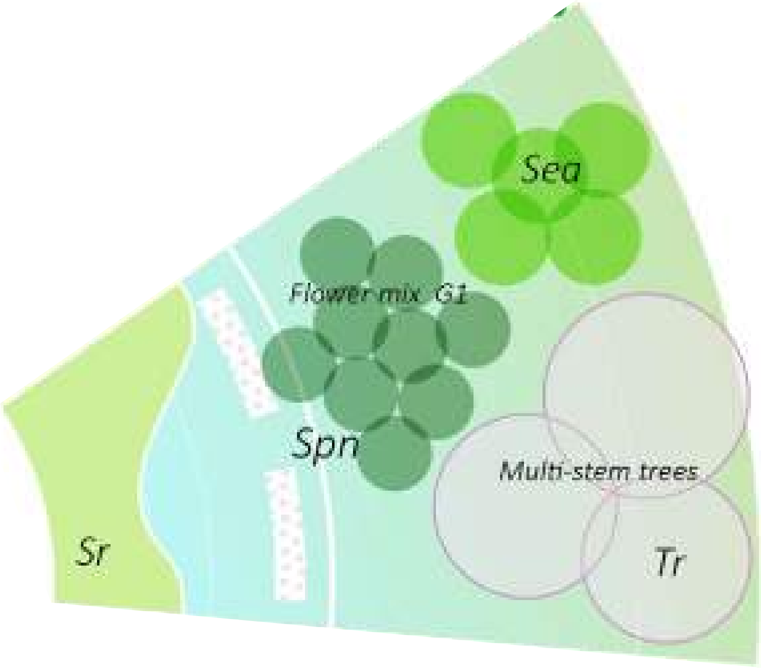


Waving wadi

3 BIODRAINAGE PLANTING

Biodrainage planting along infrastructure:

- *biodrainage species that can absorb large amounts of water when available;*
- *plants arranged according to water conditions from wet (swale) to dry (mound);*
- *meadow grasses and flowers as undergrowth;*
- *low estimated maintenance level, except the first couple of years when plants need extra help to be well established*



Sea

Narrow-leaved rosemary willow
Salix eleagnus angustifolia

Spn

Purple willow 'Nana'
Salix purpurea nana

Sr

Silvery creeping willow
Salix repens agentea

Tr

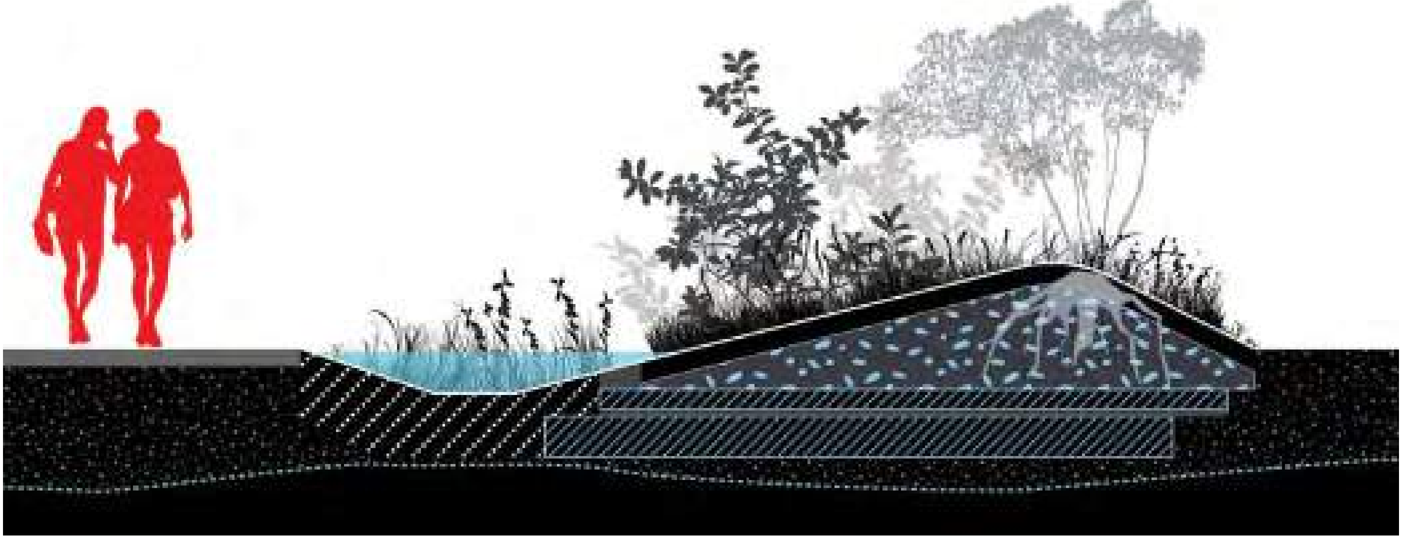
Salt cedar 'Pink cascade'
Tamarix ramosissima 'Pink cascade'

G1

Flower seed mix G1 by Cruydthoeck

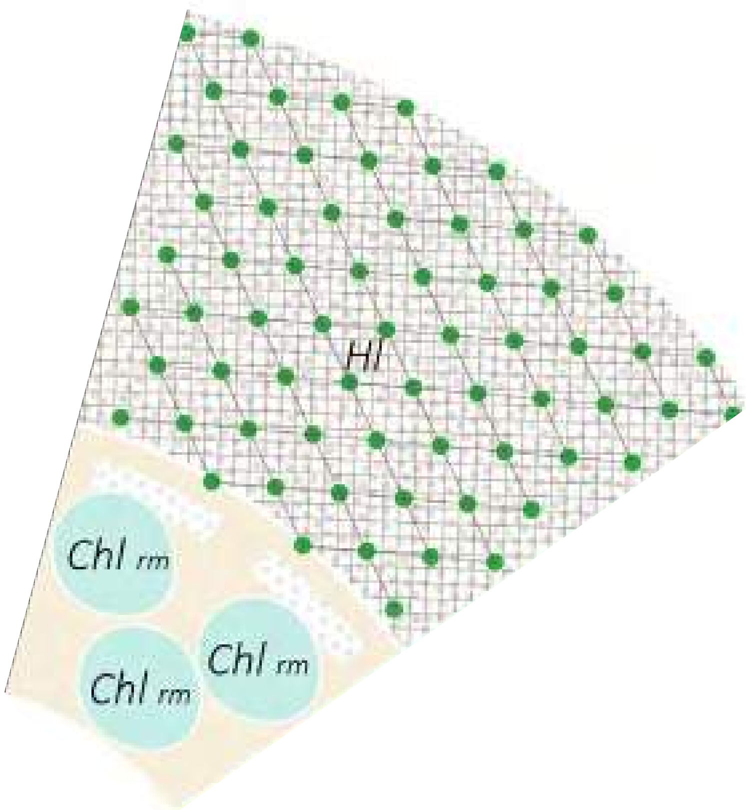
Achillea millefolium - Duizendblad
Barbarea vulgaris - Gewoon barbarakruid
Centaurea jacea - Knoopkruid
Crepis biennis - Groot streepzaad
Daucus carota - Peen
Echium vulgare - Slangenkruid
Erodium cicutarium - Gewone reigersbek
Galium mollugo - Glad walstro
Hieracium laevigatum - Stijf havikskruid
Hieracium umbellatum - Schermhavikskruid
Hypericum perforatum - Sint Janskruid
Hypochaeris radicata - Gewoon biggenkruid
Jasione montana - Zandblauwtje

Leontodon autumnalis - Vertakte leeuwentand
Leucanthemum vulgare - Gewone margriet
Luzula campestris - Gewone veldbies
Malva moschata - Muskuskaasjeskruid
Oenothera biennis - Middelste teunisbloem
Plantago lanceolata - Smalle weegbree
Prunella vulgaris - Gewone brunel
Ranunculus acris - Scherpe boterbloem
Rhinanthus minor - Kleine ratelaar
Silene dioica - Dagkoekoeksbloem
Tragopogon pratensis subsp. pratensis - Gele m
Trifolium arvense - Hazenpootje



Waving wadi

4 HOP GARDEN



Taller planting to create visual boundary (i.e. around sports pitches) suitable for hydroponic soil:

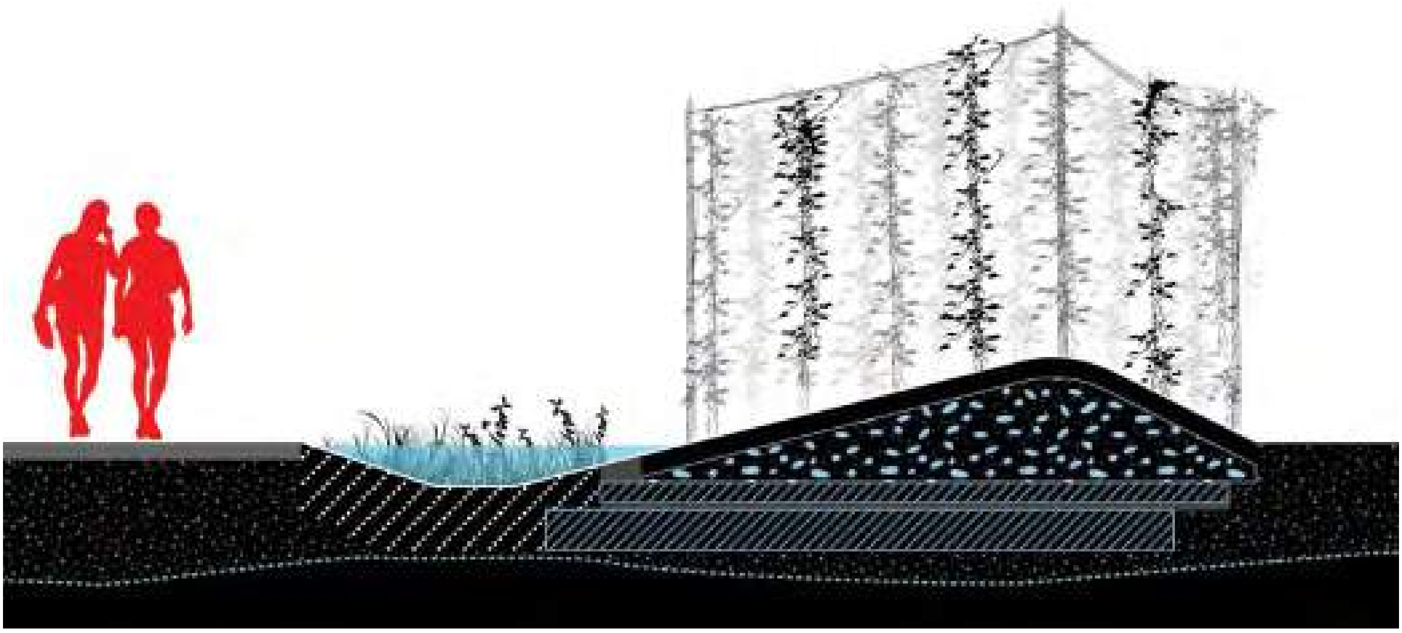
- *hop planting;*
- *wet-loving ornamental grasses in the swale;*
- *low estimated maintenance level*

Chl rm

Northern sea oats 'River mist'
Chasmanthium latifolium 'River mist'

Hl

Common hop
Humulus lupulus

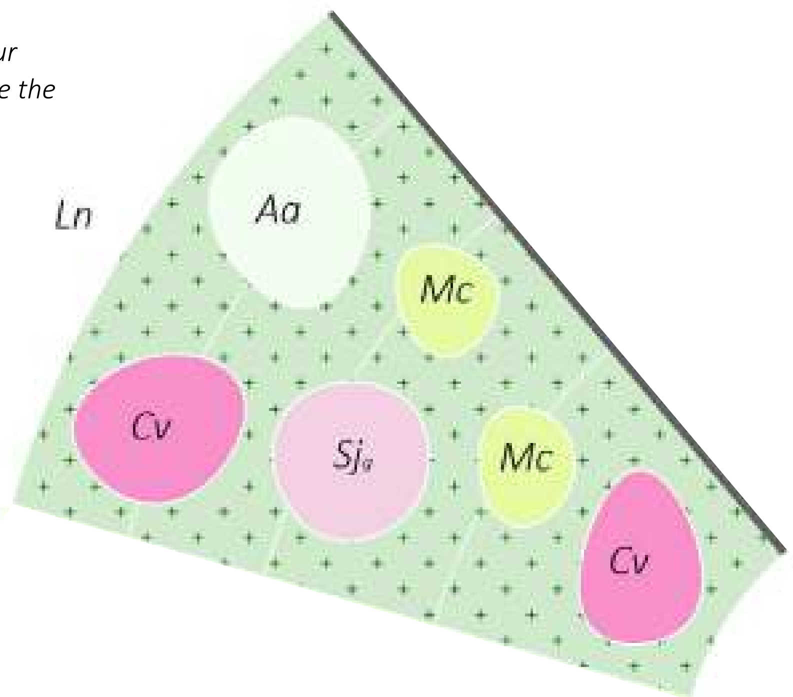


Soil cubicles

5 PEAT GARDEN

Ornamental planting for private gardens in the Peat city:

- *a mix of groundcovers, grasses, shrubs and perennials with seasonal flowers;*
- *focus on species with good winter structure and seasonal accents;*
- *relatively low estimated maintenance level with little weeding due to soil type;*
- *same plants are planted across the four different soil mixes in order to compare the growth*



GROUNDCOVER

Ln

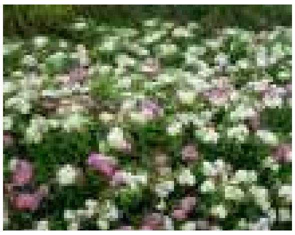
Snow rush
Luzula nivea

ACCENTS

Aa

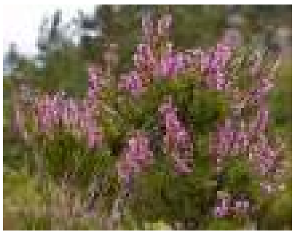
Aster 'Sunshine'
Aster ageratoides 'Starshine'

Sjg



Japanese spiraea 'Genpei'
Spiraea japonica 'Genpei'

Cv



Heather
Calluna vulgaris

Mc

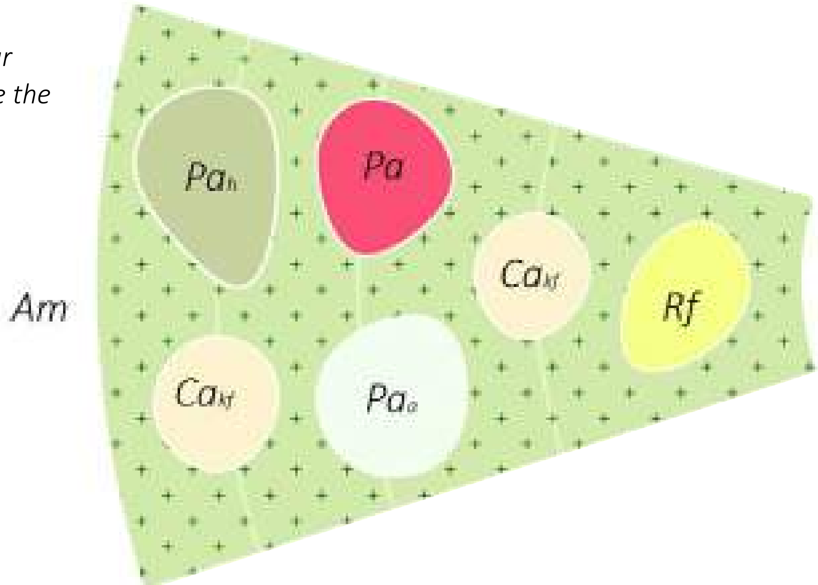
Purple moor-grass 'Heidebraut'
Molinia caerulea 'Heidebraut'

Soil cubicles

6 CLAY GARDEN

Ornamental planting for private gardens in the Clay city:

- *a mix of groundcovers, grasses and perennials with seasonal flowers;*
- *focus on species with good winter structure and seasonal accents;*
- *relatively low estimated maintenance level with little weeding due to soil type;*
- *same plants are planted across the four different soil mixes in order to compare the growth*



GROUNDCOVER

Am

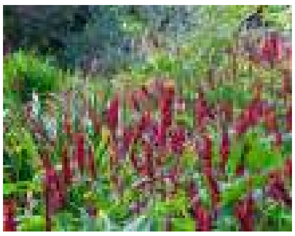
Lady's mantle
Alchemilla mollis

ACCENTS

Cakf

Feather reed-grass 'Karl Foerster'
Calamagrostis acutiflora 'Karl Foerster'

Pa



Red bistort
Persicaria amplexicaulis

Pah

Chinese fountaingrass 'Hameln'
Pennisetum alopecuroides 'Hameln'

Paa

White bistort
Persicaria amplexicaulis 'Alba'

Rf

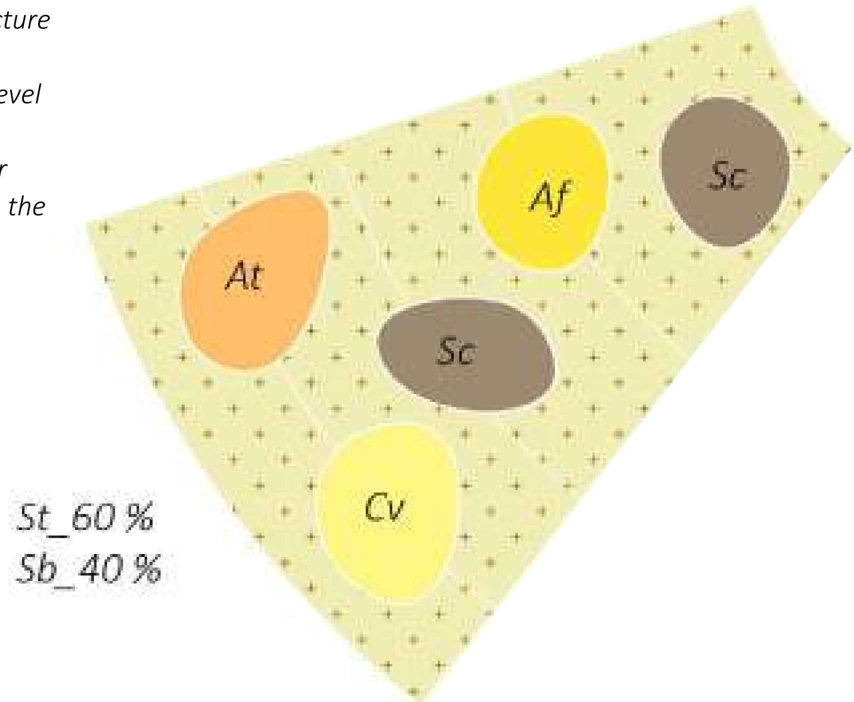
Coneflower 'Early bird gold'
Rudbeckia fulgida var 'Early bird gold'

Soil cubicles

7 SAND GARDEN

Ornamental planting for private gardens in the Urban plateau:

- *a mix of groundcovers, grasses and perennials with seasonal flowers;*
- *focus on species with good winter structure and seasonal accents;*
- *relatively low estimated maintenance level with little weeding due to soil type;*
- *same plants are planted across the four different soil mixes in order to compare the growth*



GROUNDCOVER

St **60 %**

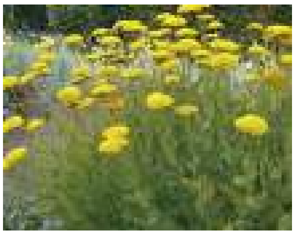
Mexican feather grass
Stipa tenuissima

Sb **40 %**

Silver feather grass
Stipa barbata

ACCENTS

Af



Yarrow
Achillea filipendulina

At

Butterfly flower
Asclepias tuberosa

Cv

Tickseed
Coreopsis verticillata

Sc

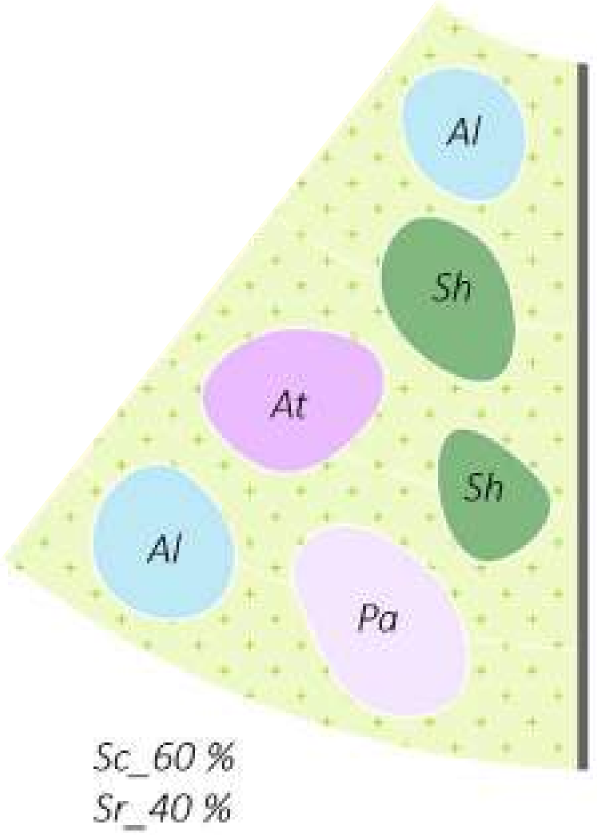
Stonecrop 'Chocolate'
Sedum 'Chocolate'

Soil cubicles

8 RUBBLE GARDEN

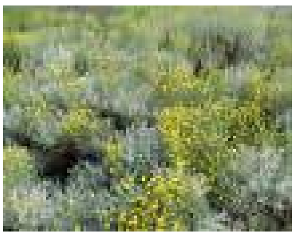
Ornamental planting for private gardens in the Singel city:

- *a mix of groundcovers, grasses and perennials with seasonal flowers;*
- *focus on species with good winter structure and seasonal accents;*
- *relatively low estimated maintenance level with little weeding due to soil type;*
- *same plants are planted across the four different soil mixes in order to compare the growth*



GROUNDCOVER

Sc **60 %**



Lavander cotton
Santolina chamaecyparissus

Sr **40 %**

Green lavander cotton
Santolina rosmarinifolia

ACCENTS

At

Sea aster
Aster Tripolium

Al

White sage 'Valerie finnis'
Artemisisa ludoviciana 'Valerie finnis'

Pa

Russian sage
Perovskia atriplicifolia

Sh

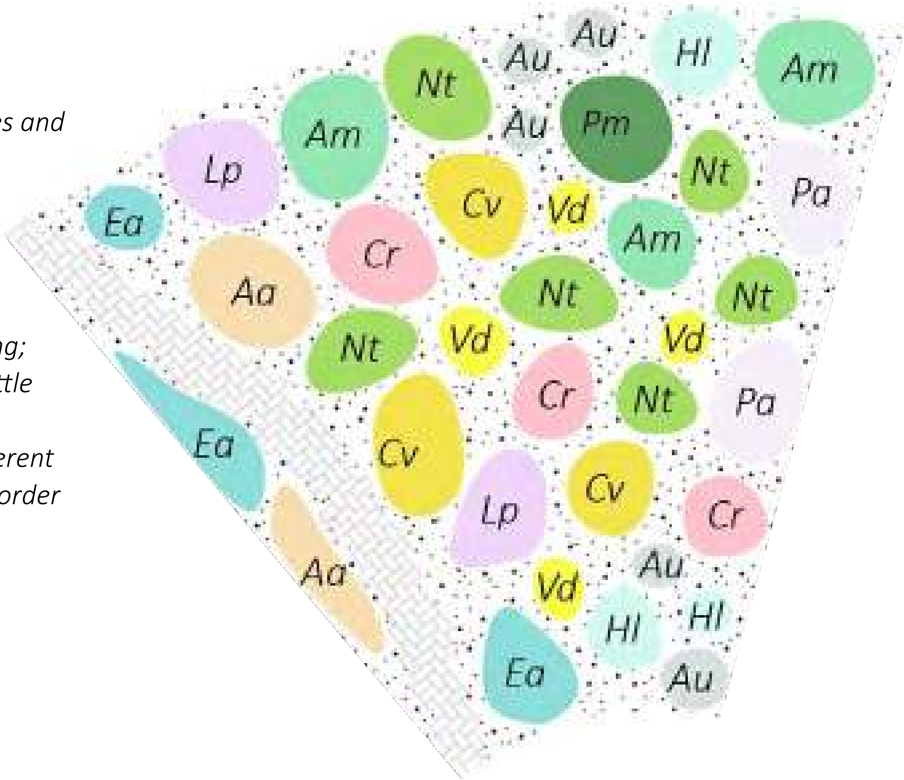
Prairie dropseed
Sporobolus heterolepsis

Depave garden

9 PRAIRIE AND DUNE PLANTING

Ornamental planting for temporary and permanent situations on the streets, squares and private gardens:

- *perennials and biennials suitable for growing in sand;*
- *also evergreens and plants with good winter structure;*
- *focus on prairie and native dune planting;*
- *low estimated maintenance level and little weeding*
- *same plants are planted across the different top layers (sand, flow sand, asphalt) in order to compare the growth*



Aa

European beach grass
Ammophila arenaria

Am

Pearly everlasting
Anaphalis margariticea

Au

Umbelata yarow
Achillea umbelata

Ea

Sea lyme-grass 'Blue dune'
Elymus arenarius 'Blue dune'

Lp

Lupin
Lupinus perennis

Vd

Great mullein
Verbascum densiflora

Cr

Red valerian
Centranthus ruber

Cv

Tickseed
Coreopsis verticillata

Hl

Hairy hawkweed
Hieracium lanatum

Nt

Mexican feather grass
Stipa tenuissima

Pa

Russian sage
Perovskia atriplicifolia

Pm

Dwarf mountain pine
Pinus mugo

CHAPTER 6

CONSTRUCTING THE SPONGE GARDEN


KEILEWERF

THE MAKING OF... A PHOTO IMPRESSION

Digging a donut - Preparing the site by removing existing soil

Start of the construction ceremony with our sponsors in the 'centre of the donut' - October 2018

Flags and bags....

Heavy equipment rolling in for placing hydrological compartments and for 325 m3 of new soils

Festive ceremony inaugurating the Sponge garden - June 2019

WAVING WADI

Placing Lapinus rockwool for substantial water storage

Placing soil in-between the Lapinus and gravel layer for infiltration and ventilation

Shaping lower parts of bioswale and bringing diverse soil mixtures for mounds

1 Pleasing perennials

2 Hügelkultur

3 Biodrainage planting

4 Hop garden

Shaping the mounds

DEPAVE GARDEN

Construction sand base layer

Compacting the clean sand as if it were a road foundation layer

Placing a brick path

Clean sand

Aquaflow sand

Broken asphalt layer

Overall view with different finish layers of asphalt, aquaflow sand and construction sand

SOIL CUBICLES

Placing an impermeable layer to simulate high groundwater level on top

Separating various soils to allow monitoring - installing root shields, drainage pipes and a gravel layer

Preparing various soils mixtures off site

Placing soil mixtures in the right places

Peat soils

Clay soils

Sandy soils

Rubble soils

Overview of all soil cubicles - ready for planting

INSECT WALL

Casting lightweight concrete wall layer by layer

Inserting wood, bamboo and balloons to create voids for organic matter

Casting concrete with a very porous structure to allow weathering

The aesthetics of a hand casted concrete weathering wall

PLANTING

Sorting, arranging and planting the plants

Group activity by volunteers of the Food Garden, Binder professionals and Urbanisten enthusiasts

Perrennial planting

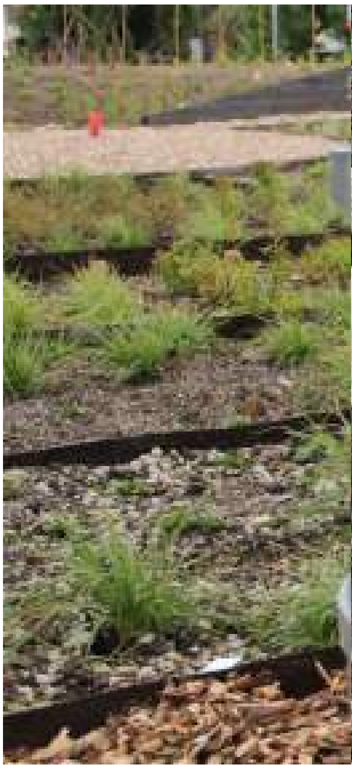
Edible garden

Biodrainage planting

Hop garden

Prairie and dune planting

Peat planting



Clay planting

Sand planting

Rubble planting

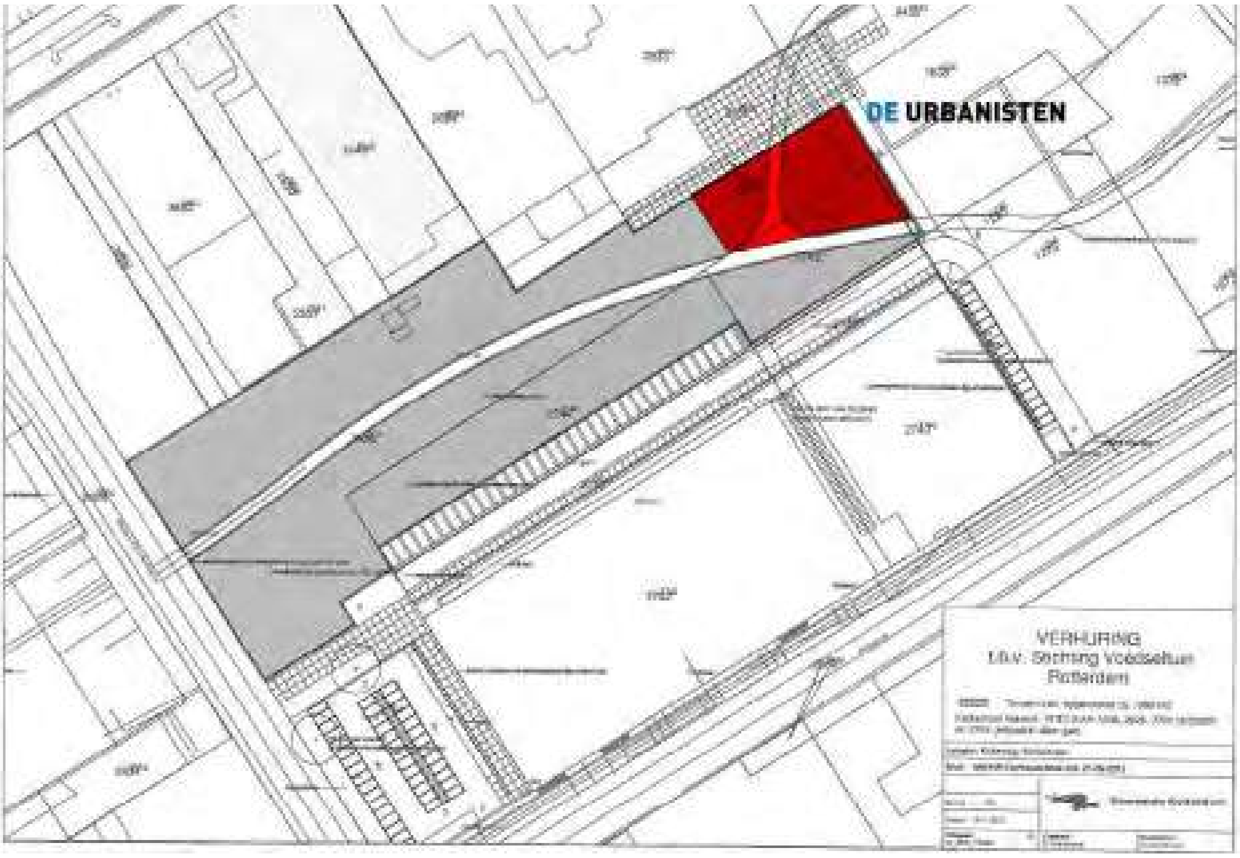
MISCELLANEOUS PAPERWORK

FINANCIAL OVERVIEW

KOSTEN		FINANCIËLE BIJDRAGEN	
Aanleg door Binder Groenprojecten:	€ 57.000,--	Korting Binder:	€ 11.000,--
Incl. materialen + beplanting / zie bijlage			
Extra beplanting / aanvullingen	€ 500,--		
Grondbank – levering + transport	-->		In kind
Gemeentewerf – levering + transport	-->		In kind
Rockflow – Lapinus panelen	€ 6.250,--	Korting Rockflow:	€ 5.000,--
Coördinatie en ontwerp De Urbanisten	-->		In kind
Technisch ontwerp gemeentewerken	-->		In kind
Voorbereidingen Voedseltuin	-->		In Kind
Bouwbegeleiding De Urbanisten	-->		In kind
Beplanting De Urbanisten + Voedseltuin	-->		In Kind
Huur ruimte in Voedseltuin	€ 5.000,--	Korting Voedseltuin	€ 5.000,--
Grafisch Materiaal	€ 3.500,--	Provincie Zuid-Holland	€ 10.000,-
Startceremonie	€ 500,--	Delfland	€ 8.250,--
Openingsceremonie	€ 1.500,--	EFL-stichting	€ 10.000,--
Reserve / onvoorzien (ca. 5%)	€ 3.500,--	Gemeente Rotterdam	€ 28.500,--
	+		+
TOTAAL	**€ 77.750,--**		**€ 77.750,--**

Ir. F.W. Boer
DE URBANISTEN

A brief cost calculation + overview of financial support.
Invisible behind the "in kind" ly countless unpaid Urbanisten hours...

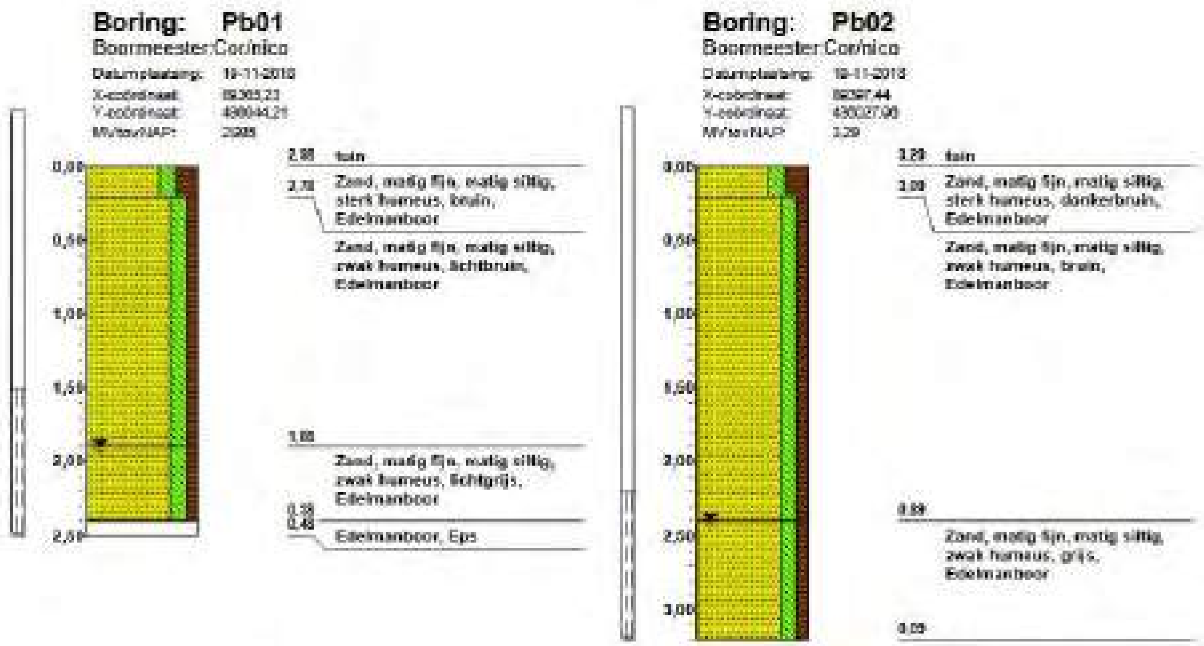


"Alonge" with Rotterdam Port Authority - A formal agreement that allows an exeptional use of the Sponge garden location within the Food garden

CONSTRUCTION MATERIALS - SOILS - LIST OF PLANTS

SPONGE GARDEN – BASE CONTENT LIST

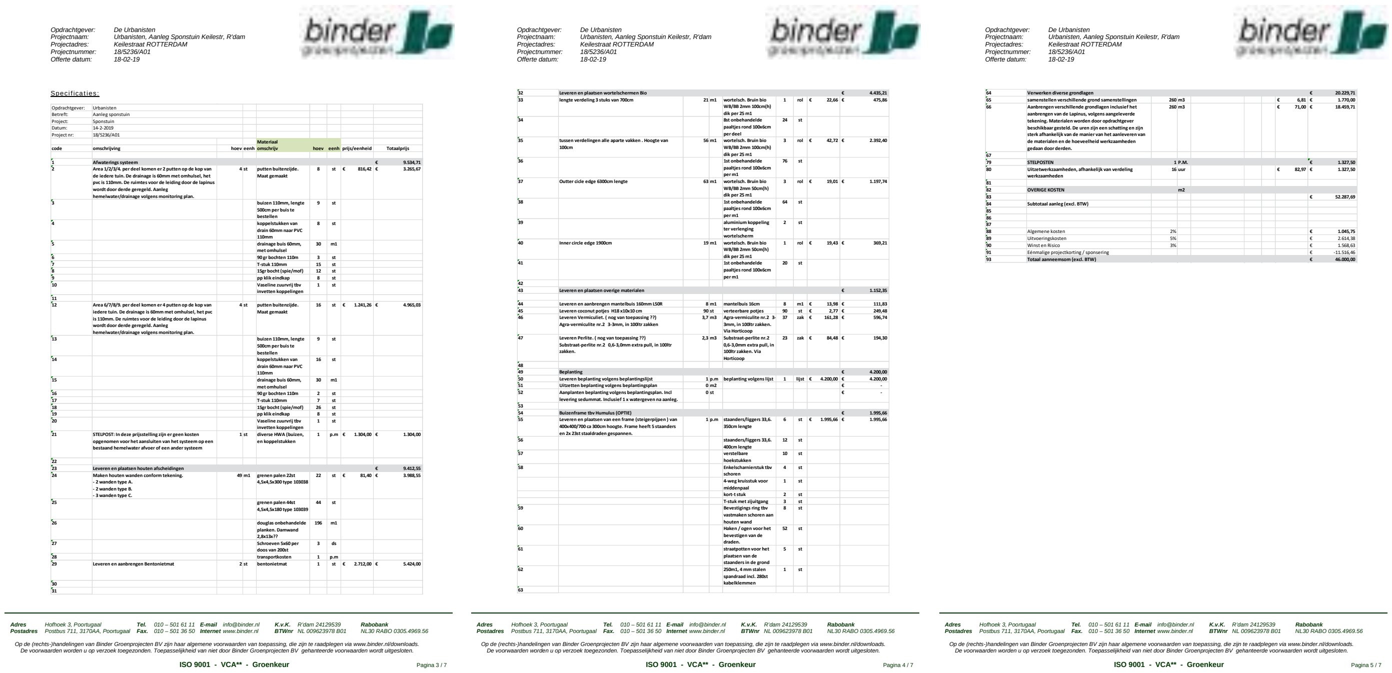
Clean sand	50 m3	Betoniet carpet	100 m2
Peaty soil	25 m3	Root screens	150 m
Clayish soil	25 m2	Drainage pipes	140 m
Rubble mixed soil	25 m3	Hydrology cilinders	24 pieces
Berm sand	50 m3	Wooden division walls	50 m
Turf soil	15 m3	Rockflow particles	3,0 m3
Wooden logs	15 m3	Perlite	2,5 m3
Gravel	30 m3	Vermiculite	3,5 m3
Mulch	25 m3	SAP packs	0,1 m3
Natural compost	35 m3	Leftover bricks	undisclosed
Crushed shells	30 m3	Asphalt rubble	undisclosed
Rockflow plates	36 m3	Bamboo sticks	45 pieces
	_______+		
Total base volume	*361 m3*		



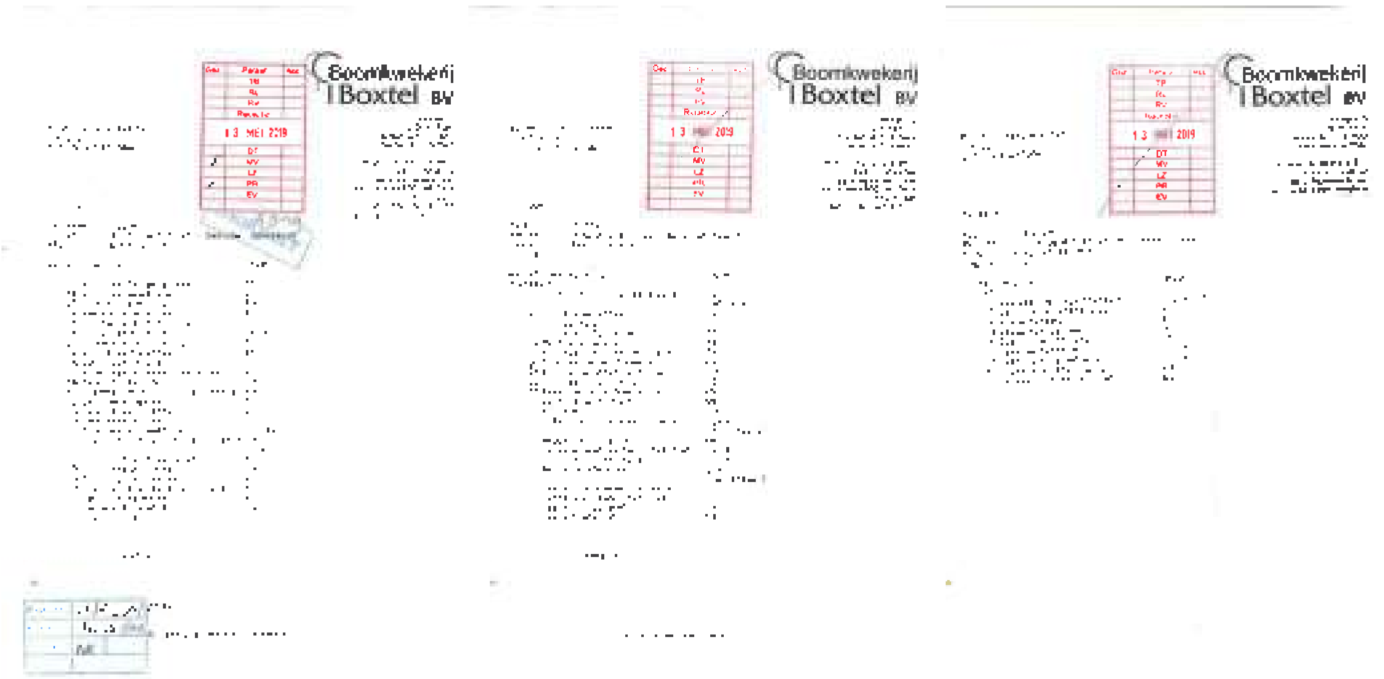
Site soil examination by the Rotterdam Engineering bureau

WERF	Description	Location	Where it's used		
1. Grind 20/40		Gemeente / roadworks	in all wadi's and under all soil cubicles	Dit heb ik niet	26 m³
2. Zand	construction sand	Gemeente / roadworks	depave garden	Kan ik leveren	15 m³
3. Steenmengsel		Gemeente / roadworks	depave garden	Kan ik leveren	13 m³
4. Gebroken asfalt		Gemeente / roadworks	depave garden	Kan ik leveren	1 m³
5. Klinkers	m2	Gemeente / roadworks	depave garden	Kan ik leveren	7 m2
6. Schelpen		Gemeente / roadworks	path and middle of circle	Dit heb ik niet	5 m³

Informal note from the Rotterdam Warf confirming available free materials



construction work break down by Binder



List of plants as delivered

CHAPTER 7

SPONGE GARDEN MONITORING AND FIRST RESULTS

Opening ceremony on June 2019

MONITORING SET-UP + PROGRESS

In this chapter the first results of two years of monitoring the Sponge garden will be shown. Within the test-site, the different concepts of the Waving wadi, the Depave garden and the Soil cubicles focus on various goals as explained in chapter 5, thus also the monitoring goals differ. The Sponge garden is being monitored on the following different aspects:

Water

The monitoring plan is set and is carried out by the Rotterdam engineering bureau. This is focused on groundwater fluctiation and soil moisture. Unfortunately a lot of data is not delivering a reliable outcome yet. And due to the Covid-19 crisis no action could be taken in examining the cause and fixing the problem.

Soils

The soil composition has been set in close collaboration with the municipality of Rotterdam and was partly dependent on availability in the soil banks of the city. On site monitoring is carried out by De Urbanisten.

Planting

The planting plan as well as monitoring is done by De Urbanisten. An evaluation by the municipality of Rotterdam is planned, yet not scheduled.

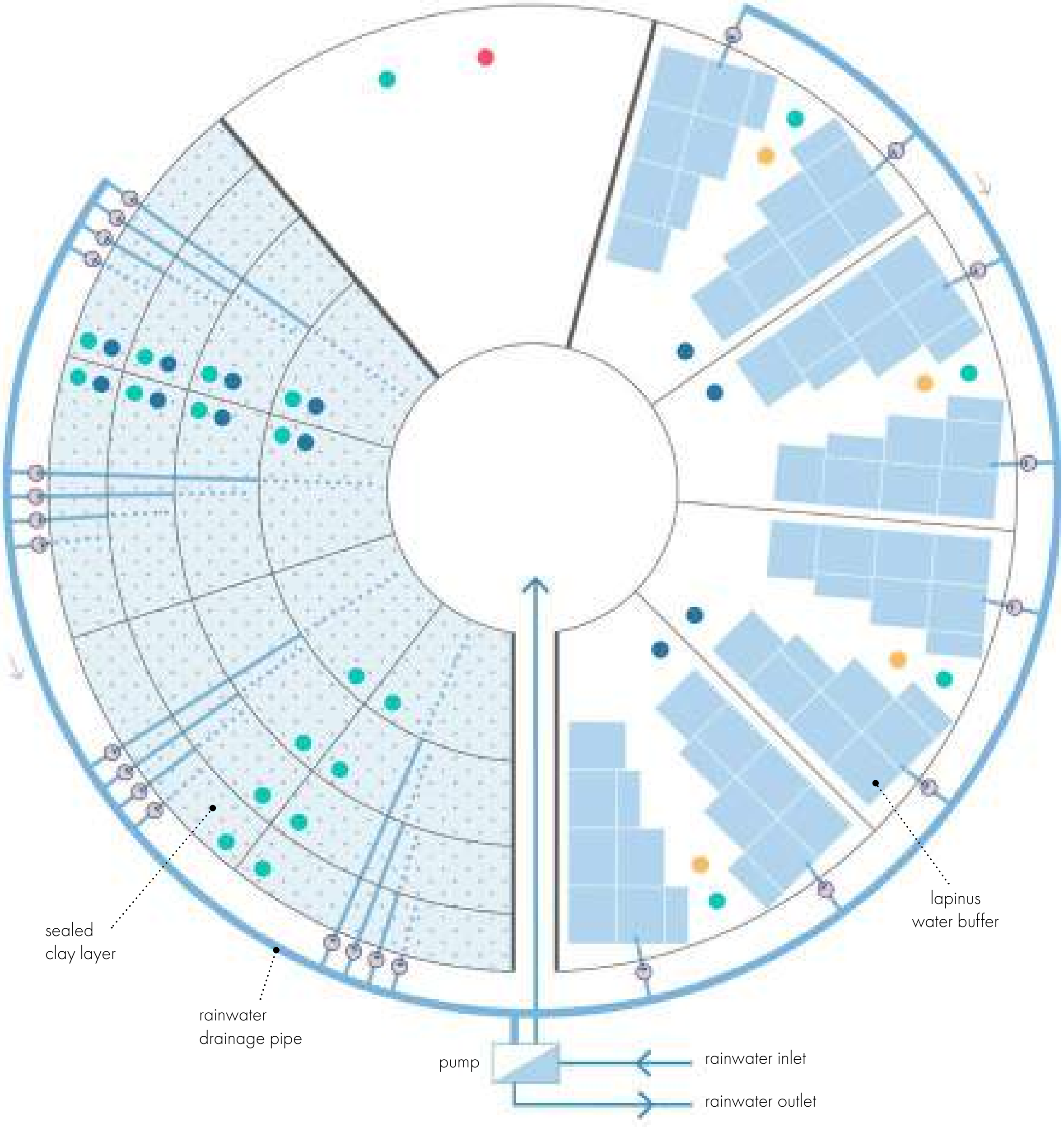
Maintenance

The garden is maintained by De Urbanisten. Within the first year also the Binder groenprojecten team helped out with the maintenance.

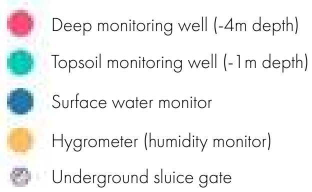
Biodiversity

Monitoring is done by De Urbanisten. Evaluation by the municipality of Rotterdam was planned in 2021, but postponed due to the Covid-19 crisis.


Installation of the hydrological monitoring pipes and the digital water loggers



Setup of the hydrological monitoring infrastructure of the test-site



MONITORING HYDROLOGY

What is being measured:

Waving wadi
The aim of the waving wadi is to provide a complete water cycle: immediate collection of a lot of rainwater in the open ditch, fast drainage into the bottom of the mound and storage for a longer period through capillary infiltration up the mound, while providing space for immediate collection as well.

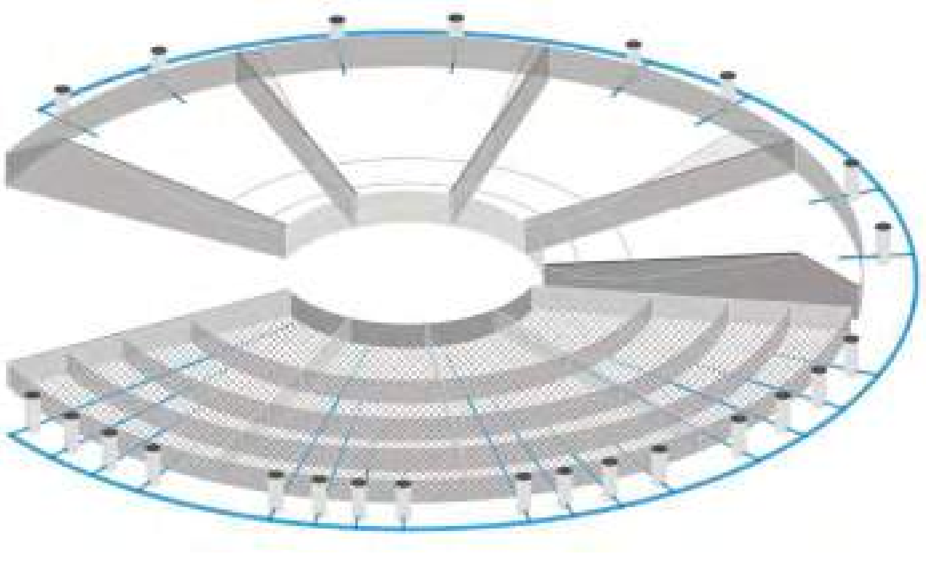
There are two main questions te be answered here:
- *Can the wadi digest a '70mm in one hour' rainfall of a local catchment area that is 4 times larger than area of the waving wadi itself?*
- *How well does the storage and capillary infiltration into the mound work?*

Depave garden
This functions as an easy infiltration place and is not being monitored on hydrological performance.

Soil cubicles
Here the goal is to improve the spongy qualities of the local Rotterdam soils, by adding different additives. For peat and clay that is to improve infiltration speed, while for sandy and rubble soils it is about holding the water, measured by soil humidity level.

The questions for the Soil cubicles are as follow:
- *How much and for how long can the different soil compositions retain the water? - measuring moisture levels.*
- *How quickly can the water be absorbed by infiltration in the different compositions? - measuring permeability levels.*

As mentioned in the introduction of this chapter, many of the monitoring actions have not been able to be carried out because of the Covid-19 situation. The aim is to carry out some of the missing trials in 2022, as well as to test out why the digital monitoring didnot deliver stable results yet.



Scheme of the design for the hydrological monitoring sytem.

SOIL CUBICLES

<u>INFILTRATION SPEED</u>
Goal: to improve infiltration capacities in peat and clay soils.
How quickly can the water be absorbed?

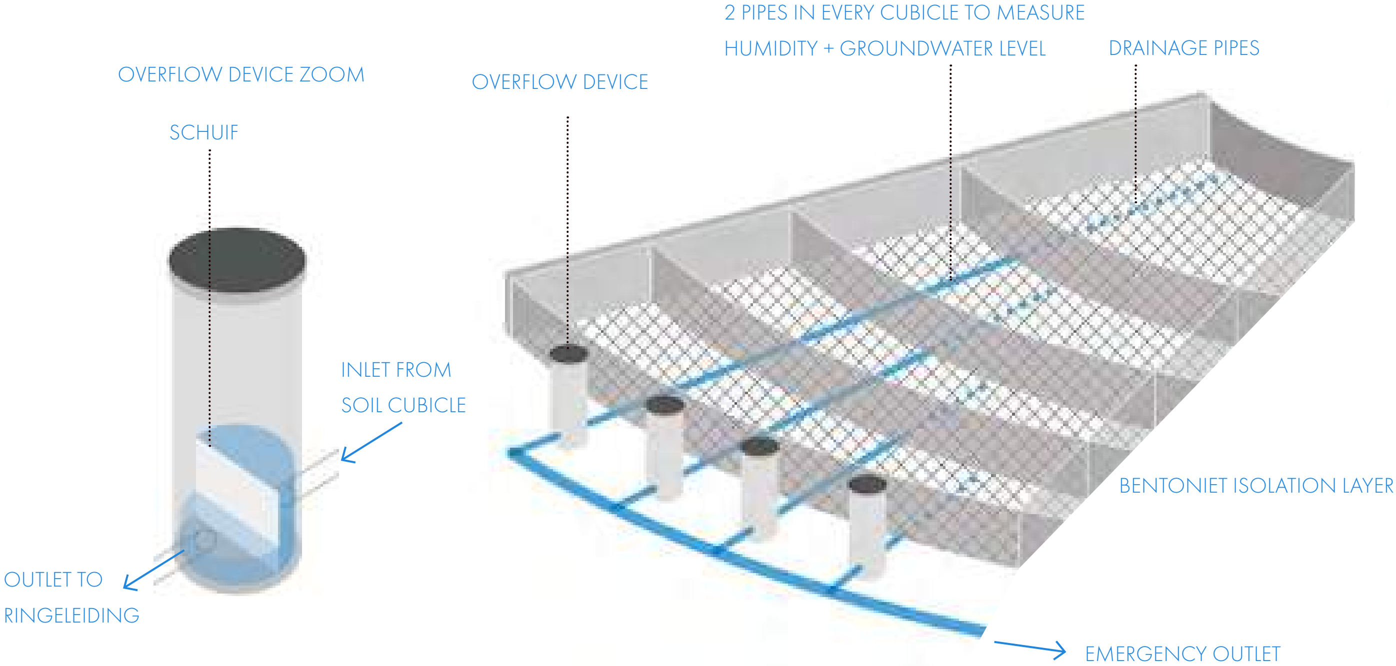
<u>WATER RETENTION</u>
Goal: to improve soil moisture in sandy and rubble soils.
How much humidity is in the soil and in the rock wool? (moisture measurements, pF curve)
How much and for how long can the different soil compositions retain the water (capillary action)?

<u>GROUND WATER LEVEL</u>
The groundwater level is simulated and forced by an imprenetrable layer of bentonite clay under the cubicles. A set of drainage pipes in a gravel bed assure that the water level can be controlled if needed

There's no data available from the installed devices.

Necessary steps:

- *Check manually why groundwater level isn't read by loggers. DRI-tests as alternative*
- *Soil analysis in lab (van der Genuchten parameters) for creating pF curves (water retention)*
- *Manual moisture measuring*



Scheme detail of the design for hydrological monitoring in the Soil cubicles.

WAVING WADI

PERFORMANCE IN HEAVY RAINFALL
Can the wadi digest a '70mm in one hour' rainfall of a local catchment area that is 4 times larger than area of the waving wadi itself? And then empty the rockflow storage within 48 hours?

This can only be tested by simulating a rainfall of such a magnitude, while multiplying the surface of the wadi times four. This would need a 9000 liter tank per 'wadi slice'. Because of Covid-19 this test has not taken place but is still planned for 2022.

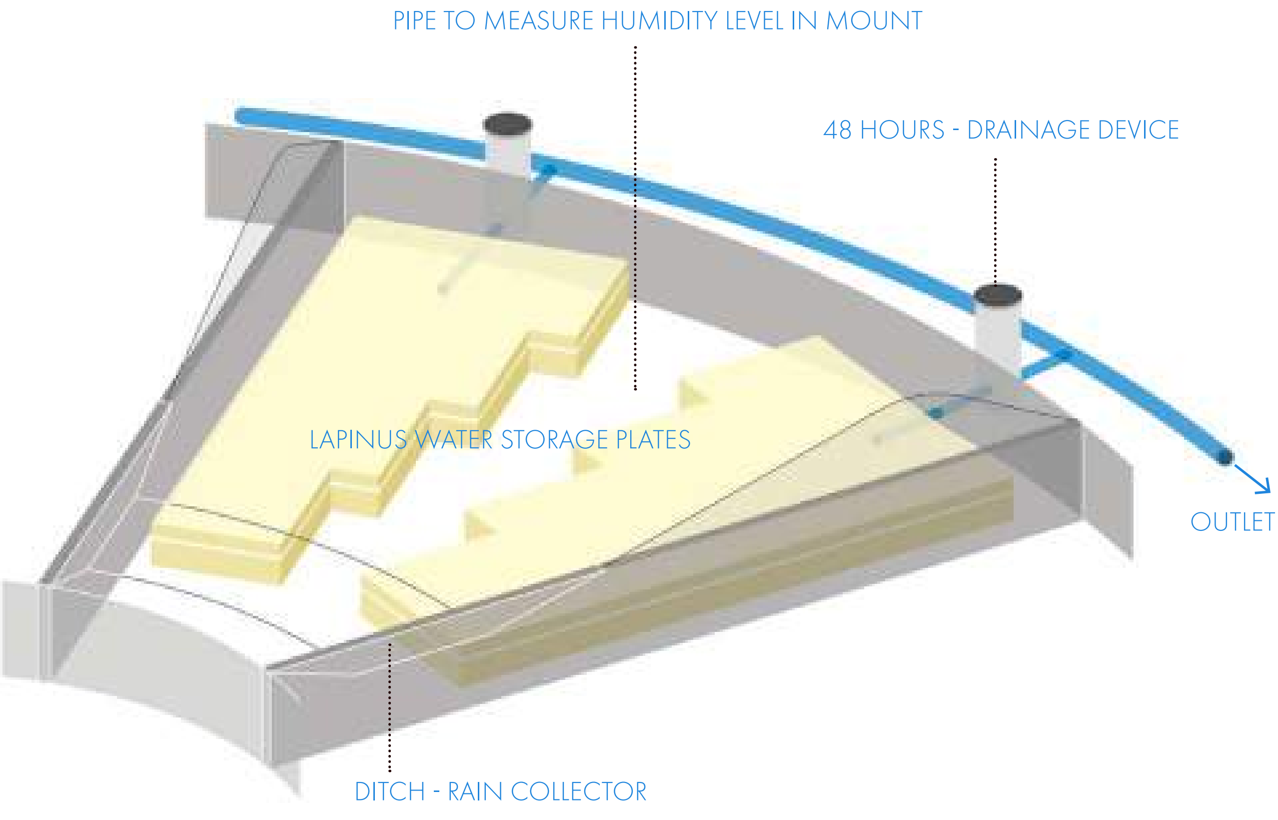
CAPILLARY INFILTRATION
How much capillary infiltration takes place in the mound? (infiltration speed)

WATER RETENTION
How much humidity is in the soil and in the rock wool? (moisture measurements, pF curve).
One brief first conclusion is that the 'Hop hydroponics' wadi retains by far the most water.

Overall there's insufficient data available from the installed devices.

Necessary steps:

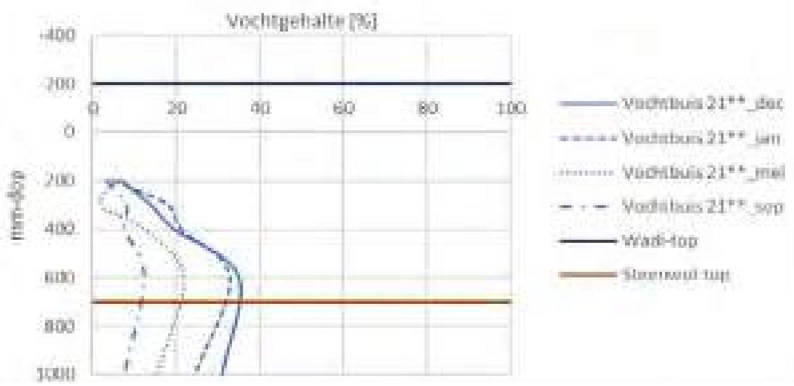
- *Simulation of heavy rainfall - planned in 2022*
- *Soil analysis in lab (van der Genuchten parameters) for creating pF curves (water retention).*
- *Moisture measurements*
- *Soil moisture measurements of* Hügelkultur



Scheme detail of the design for hydrological monitoring in the Waving wadi

Soil moisture measurements - graphs

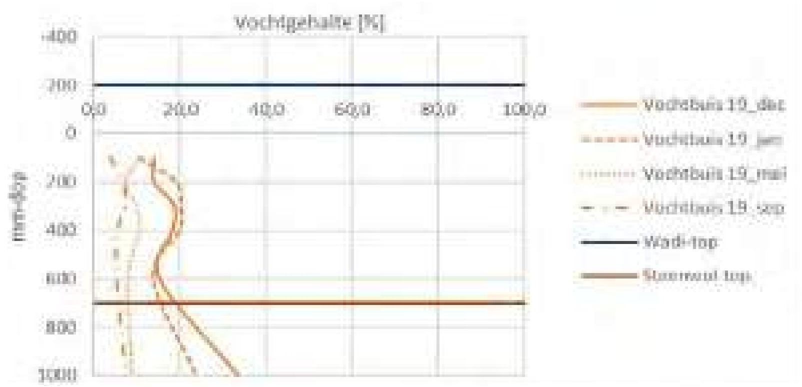
Pleasing perennials
NR.5



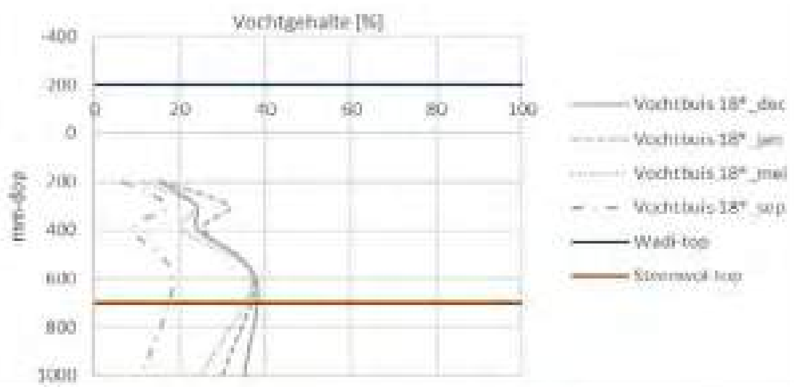
Hügelkultur
NR.6

No data available - no pipe installed, no measurements taken

Speedy biodrainage
NR.7



Hop hydroponics
NR.8



MONITORING SOIL

What is being measured:

Waving wadi
The main focus here is on water infiltration, retention and capillary action properties of the soil.
- *What is the soil composition?*
- *What are the pH levels?*

Depave garden
The goal is to use existing construction sand found underneath pavement.
- *There are different top layers of crushed asphalt, flowsand and sand/soil mix. How do they affect the growing conditions for plants?*

Soil cubicles
Here the goal is to improve the certain qualities of the local Rotterdam soils, by adding different additives. The following questions can help to compare various additives.

Peat soil:
- *How to reduce soil shrinkage (oxidation) while also maintaining capabilities for extra water capture?*

Clay soil:
- *How to improve nutrient and oxygen levels?*

Sandy and rubble soils:
- *How to improve nutrient levels?*

Soil monitoring plan

Following activities have been analysed in spring 2021:
- *Determine soil composition for all the fields*

Still to be determined:
- *pH level*
- *nutrient content*
- *oxygen level*

In summer a measuring of the temperature in the soil layers of the Depave garden should be carried out, in order to determine the influence of different soil toppings.

WAVING WADI

Soil composition
pH levels
nutrient level
oxygen level

PLEASING PERENNIALS	HÜGELKULTUR	BIODRAINAGE	HOP HYDROPONICS

good planting soil

soft wood branches, leaves, compost, covered with good planting soil

sandy soil, covered with good planting soil

mix of peat moss, vermiculite and perlite, covered with a layer of mulch

DEPAVE GARDEN

Soil composition = 100% clean sand
Temperature above the surface, on the surface and in various depths. Data to be measured, but not yet scheduled.

SOIL CUBICLES: PEAT SOIL

- *How to reduce soil shrinkage?*

pure

47% sand
21% silt
14% clay
18% organic
Peat heavily clay

+ woodchips

49% sand
9% silt
7% clay
35% organic
Peat lightly clay

+ perlite
+ vermiculite

73% sand
8% silt
8% clay
11% organic
Peat heavily sandy

+ lapinus fibers

62% sand
14% silt
3% clay
21% organic
Peat heavily sandy

SOIL CUBICLES: CLAY SOIL

- *How to improve nutrient and oxygen levels?*

pure

51% sand
30% silt
14% clay
5% organic
Loam

+ compost

60% sand
26% silt
8% clay
6% organic
Sandy loam

+ perlite
+ vermiculite

65% sand
14% silt
19% clay
2% organic
Sandy clay loam

+ lapinus fibers

81% sand
4% silt
14% clay
1% organic
Sandy loam

SOIL CUBICLES: SANDY SOIL

- *How to improve nutrient levels?*

pure

76% sand
5% silt
14% clay
5% organic
Sandy loam

+ mulch, leaves, grass

72% sand
8% silt
17% clay
3% organic
Sandy loam

+ mulch, leaves, grass
+ vermiculite

79% sand
6% silt
10% clay
5% organic
Loamy sand

+ mulch, leaves, grass
+ SAP

83% sand
2% silt
11% clay
4% organic
Loamy sand

SOIL CUBICLES: RUBBLE SOIL

pure

65% sand
12% silt
21% clay
2% organic
Sandy clay loam

+ compost

69% sand
9% silt
21% clay
1% organic
Sandy clay loam

+ compost
+ vermiculite

70% sand
11% silt
17% clay
2% organic
Sandy loam

+ compost
+ SAP

73% sand
12% silt
12% clay
3% organic
Sandy loam

MONITORING PLANTING

The goal is to create a catalogue of plants that are suitable for various soils and conditions. The sponge concept focuses on planting that does well both during heavy rainfalls as well as during drought. Thus the growth of the plants is evaluated in this context.

Due to various external factors, the plants were planted in June 2019. Additional plants were planted in November 2019, as some of the selected plants were not delivered or different plants had been delivered instead. As the summer of 2019 was exceptionally hot and freshly planted plants vulnerable, we decided to intensively water all the plants, to make sure they could get established well. This wouldn't be necessary when choosing the right planting season would have been possible. Since this start it has not been necessary to water the garden.

Waving wadi
The focus here is on evaluating plant growth in the wet area of the swale and in the dryer area on the hill. The plants are growing well under current conditions. However a simulation of heavy rainfall is necessary, in order to properly evaluate plant growth in the swale and on the mound. We presume that in that case the soil would be more moist and some plants that are now struggling, would actually be able to grow better.

Soil cubicles
Plants have been selected so that they suit the soil type. The focus here is on comparison between plant growth in various cubicles of the same soil type and different amendments.

Depave garden
The concept of this garden is focusing on plants in scarce soil conditions and the possibly temporary nature in the urban context. Thus the main criteria are - how quickly do the plants establish and how well they grow in these harsh conditions.

For evaluation, we distinguish several categories:

- *plants that grow well*
- *plants that were planted after june 2019 and still need time to grow before a proper evaluation*
- *plants that struggle*
- *plants that are too competitive and require more attention and maintenance*
- *plants that were in the initial planting plan but were not delivered by the nursery. Thus not planted.*

The overall appearance of the Sponge garden planting after two years of establishment is quite lush

Waving wadi

1 PERENNIAL PLANTING

Plants that grow well

The most of these established quickly and keep growing well. Stonecrop (sedum matrona) was struggling at first, presumably cause of snails or bugs, but recovered in 2020.

Aaa

Aster 'Asran'
Aster ageratoides Asran

CaKf

Feather reed-grass 'Karl Foerster'
Calamagrostis acutiflora Karl Foerster

Cm

Palm sedge
Carex muskingumensis

Epa

Purple coneflower 'Alba'
Echinacea purpurea alba

Sm

Stonecrop 'Matrona'
Sedum matrona

Pah

Chinese fountaingrass 'Hameln'
Pennisetum alopecuroides 'Hameln'

Pb

Common bistot
Persicaria bistorta

Fu

Meadowsweet
Filipendula ulmaria

Planted late, too early to evaluate

These plants were planted in November 2019 and still need some time to be properly established.

Fv

Dropwort
Filipendula vulgaris

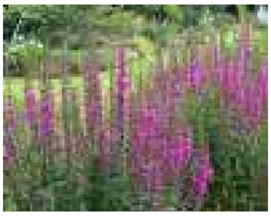
Hm

Japanese forest grass
Hakonechloa macra

Plant that struggles (due to lack of water in the wadi)

Loosestrife was doing well in the first year. In the second year it's still growing but not flourishing. That could be due to lack of water in the wadi. The plant prefers moist areas and would be doing well during rainfalls.

Lsr



Purple loosestrife 'Robin'
Lythrum salicaria robin

July 2019

September 2019

October 2019

April 2020

May 2020

May 2020

June 2020

November 2020

November 2020

2 EDIBLE GARDEN - HÜGELKULTUR

Plants that grow well

These established quickly and grow well.

Fv

Fennel
Foeniculum vulgare

So

Common comfrey
Symphytum officinale

Vo

Common valerian
Valeriana officinalis

Competition issues

Water mint, borago and lucerne are quite aggressive in growth and are taking over the garden. Coriander and white clover were growing well in the first year but dissappeared in the second year under the competition of borago and lucerne.

Ma

Water mint
Mentha aquatica

Bo

Borage
Borago officinalis

Ms

Lucerne / alfalfa
Medicago sativa

Cs

Coriander
Coriandrum sativum

Tr

White clover
Trifolium repens

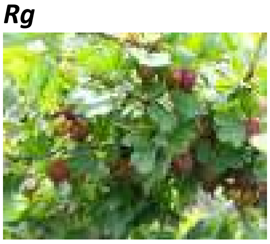
Plants too early to evaluate

The small trees and bushes need more time to get established. Gooseberry and blueberry was cut in the spring of 2020 by accident during pruning. These plants shouldn't be pruned and it caused set back in growth. June berry was planted as a larger tree and needs time and more care to adjust.

Al

June berry
Amelanchier lamarckii

Rg



Gooseberry
Ribes grossularia

Cj

Japanese quince
Chaenomeles japonica

Ap

Purple chokeberry
Aronia prunifolia

Vc

Blueberry
Vaccinium

July 2019

August 2019

September 2019

October 2019

March 2020

April 2020

May 2020

May 2020

November 2020

Waving wadi

3 BIODRAINAGE PLANTING

Plants that grow well

These established quickly and grow well. The larger salt cedar shrubs might need more time before they flourish but they're growing well.

Sea

Narrow-leaved rosemary willow
Salix eleagnus angustifolia

Spn

Purple willow 'Nana'
Salix purpurea nana

Sr

Silvery creeping willow
Salix repens agentea

Tr

Salt cedar 'Pink cascade'
Tamarix ramosissima 'Pink cascade'

G1

Flower seed mix G1 by Cruydthoeck

Achillea millefolium - Duizendblad
Barbarea vulgaris - Gewoon barbarakruid
Centaurea jacea - Knoopkruid
Crepis biennis - Groot streepzaad
Daucus carota - Peen
Echium vulgare - Slangenkruid
Erodium cicutarium - Gewone reigersbek
Galium mollugo - Glad walstro
Hieracium laevigatum - Stijf havikskruid
Hieracium umbellatum - Schermhavikskruid
Hypericum perforatum - Sint Janskruid
Hypochaeris radicata - Gewoon biggenkruid
Jasione montana - Zandblauwtje

Leontodon autumnalis - Vertakte leeuwentand
Leucanthemum vulgare - Gewone margriet
Luzula campestris - Gewone veldbies
Malva moschata - Muskuskaasjeskruid
Oenothera biennis - Middelste teunisbloem
Plantago lanceolata - Smalle weegbree
Prunella vulgaris - Gewone brunel
Ranunculus acris - Scherpe boterbloem
Rhinanthus minor - Kleine ratelaar
Silene dioica - Dagkoekoeksbloem
Tragopogon pratensis subsp. pratensis - Gele m
Trifolium arvense - Hazenpootje

June 2019

September 2019

April 2020

April 2020

April 2020

May 2020

June 2020

November 2020

November 2020

Waving wadi

4 HOP GARDEN

Plants that grow well

These established quickly and grow well. Japanese forest grass was delivered wrongly by the nursery and is thriving. However it might not be suitable as a plant in the lower part of the swale.

Hm

Japanese forest grass
Hakonechloa macra

Hl

Common hop
Humulus lupulus

Appeared by itself

Red valerian travelled from nearby depave garden by seed and is growing well.

Cr

Red valerian
Centranthus ruber

Not planted

Northern sea oats were not delivered by mistake but would be interesting to evaluate. It's very suitable for wet areas of the swale.

Chl rm

Northern sea oats 'River mist'
Chasmanthium latifolium 'River mist'

June 2019

August 2019

September2019

March 2020

April 2020

May 2020

June 2020

November 2020

November 2020

Soil cubicles

5 PEAT GARDEN

Plants that grow well

All the plants established quickly and in overall grow well.

Ln

Snow rush
Luzula nivea

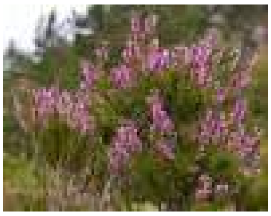
Aa

Aster 'Sunshine'
Aster ageratoides 'Starshine'

Sjg

Japanese spiraea 'Genpei'
Spiraea japonica 'Genpei'

Cv



Heather
Calluna vulgaris

Mc

Purple moor-grass 'Heidebraut'
Molinia caerulea 'Heidebraut'

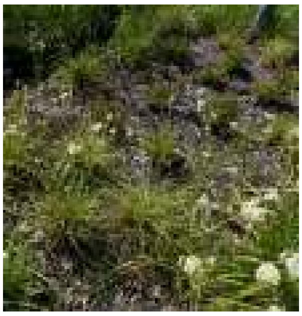
Comparison between cubicles

May 2020

pure

Plants grow well.

+ woodchip

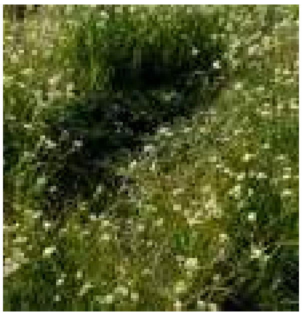


Plants are growing poorly in this cubicle. They are much smaller in size and yellow.

+ perlite + vermiculite

Plants grow well.

+ lapinus fibers



Plants grow well.

Conclusion

Snowrush dominates the garden and the accents are poorly visible as they are smaller in size. Combining taller plants could bring some balance to the appearance. ***Woodchip is not a suitable additive to the peat soil.***

June 2019

July 2019

September 2019

October 2019

November 2019

March 2020

April 2020

May 2020

November 2020

Soil cubicles

6 CLAY GARDEN

Plants that grow well

These plants established quickly and are growing well.

Cakf

Feather reed-grass 'Karl Foerster'
Calamagrostis acutiflora 'Karl Foerster'

Pah

Chinese fountaingrass 'Hameln'
Pennisetum alopecuroides 'Hameln'

Rf

Coneflower 'Early bird gold'
Rudbeckia fulgida var 'Early bird gold'

Pp

White fleece flower
Persicaria polymorpha

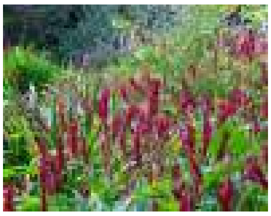
Am

Lady's mantle
Alchemilla mollis

Planted late, too early to evaluate

Red bistort was planted in November 2019 and still need some time to be properly established.

Pa



Red bistort
Persicaria amplexicaulis

Not planted

By mistake white fleece flower was delivered instead of white bistort.

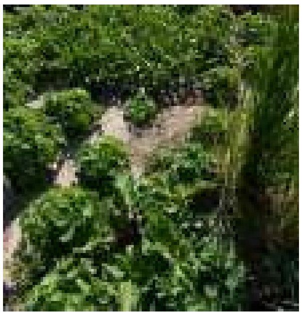
Paa

White bistort
Persicaria amplexicaulis 'Alba'

Comparison between cubicles

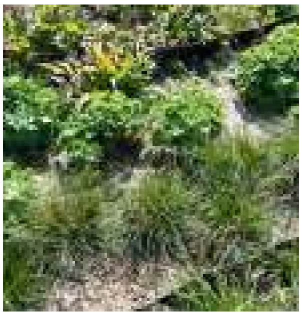
May 2020

pure



+ compost

+ perlite + vermiculite



+ rockwool

Conclusion

Plants are growing well in all of the soil compositions. The feather reed-grass could be replaced by a less visually dominant altenative.

June 2019

September 2019

September 2019

October 2019

March 2020

April 2020

June 2020

July 2020

November 2020

Soil cubicles

7 SAND GARDEN

Plants that grow well

These plants established quickly and growing well. The aster was delivered by accident instead of butterfly flower and was growing well. It was decided to remove it.

St

Mexican feather grass
Stipa tenuissima

Af

Yarrow
Achillea filipendulina

Cv

Tickseed
Coreopsis verticillata

A

Aster
Aster

Plants that struggle

Stonecrop took time to establish, seemingly due to snails, bugs or illness. The grass was either not delivered or dissappeared.

Sc

Stonecrop 'Chocolate'
Sedum 'Chocolate'

Sb

Silver feather grass
Stipa barbata

Not planted

Butterfly flower was not delivered.

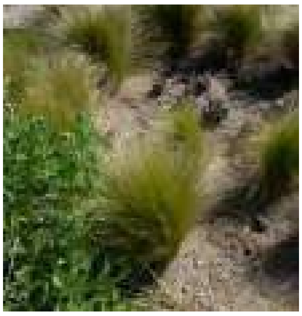
At

Butterfly flower
Asclepias tuberosa

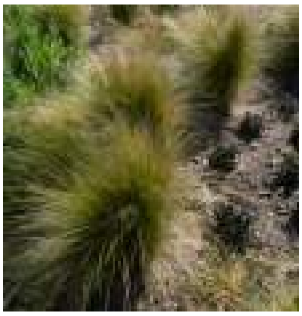
Comparison between cubicles

May 2020

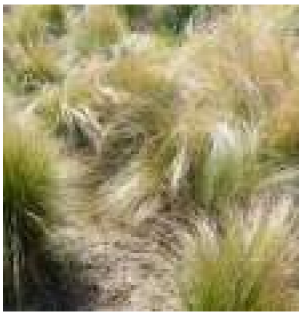
pure



+ mulch, leaves, grass



+ mulch, leaves, grass
+ vermiculite



+ mulch, leaves, grass
+ SAP

Conclusion

Plants are growing well in all of the soil compositions. The grasses are dominating the aesthetics.

June 2019

September 2019

September 2019

October 2019

March 2020

April 2020

May 2020

June 2020

November 2020

Soil cubicles

8 RUBBLE GARDEN

Plants that grow well

These plants established quickly and are growing well. Some of the cotton plants didn't survive the first summer presumably due to planting in the wrong season. Additional ones were planted in november 2019 and they are growing well. Poppies seeded themselves and are growing well. Prairie dropseed doesn't stand out well yet.

Sc

Lavander cotton
Santolina chamaecyparissus

Sr

Green lavander cotton
Santolina rosmarinifolia

Pa

Russian sage
Perovskia atriplicifolia

Sh

Prairie dropseed
Sporobolus heterolepsis

At

Aster species
Aster

Aggressive growth

This plant grows very vigorously and needs to pruned extensively.

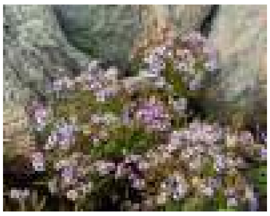
Aab

Tree wormwood 'Powis castle'
Artemisia arborescens 'Powis castle'

Not planted

Sea aster was not delivered and a different species of artemisia was delivered instead.

At



Sea aster
Aster Tripolium

Al

White sage 'Valerie finnis'
Artemisia ludoviciana 'Valerie finnis'

Comparison between cubicles

May 2020

pure

+ compost

+ compost + vermiculite

+ compost + SAP

Conclusion

Plants are growing well in all of the soil compositions. Tree wormwood needs excessive pruning to keep the garden in balance.

June 2019

July 2019

September 2019

September 2019

October 2019

May 2020

May 2020

June 2020

November 2020

Depave garden

9 PRAIRIE AND DUNE PLANTING

Plants that grow well

These established quickly and grow well. The different toppings of asphalt, flow sand don't seem to have any influence on growth.

Aa

European beach grass
Ammophila arenaria

Am

Pearly everlasting
Anaphalis margariticea

Au

Umbelata yarrow
Achillea umbelata

Cr

Red valerian
Centranthus ruber

Cv

Tickseed
Coreopsis verticillata

Hl

Fox-and-cubs
Hieracium aurantiacum

Lp

Lupin
Lupinus perennis

Mexican feather grass
Stipa tenuissima

Pa

Russian sage
Perovskia atriplicifolia

Pm

Dwarf mountain pine
Pinus mugo

Vm

Moth mullein
Verbascum blattaria

Competition issues

This grass grows well and spreads vigorously with its roots through brick path. A root container would be needed to limit the spread. It might cause trouble in urban environment.

Ea

Sea lyme-grass 'Blue dune'
Elymus arenarius 'Blue dune'

Not planted

The great mullein was not delivered but could be a tall vertical accent. A different type of Hieracium was planted and is growing well.

Vd

Great mullein
Verbascum densiflora

Hl

Hairy hawkweed
Hieracium lanatum

July 2019

September2019

September 2019

April 2020

May 2020

July 2020

July 2020

July 2020

July 2020

MONITORING MAINTENANCE

Planting

2019: June - planting the whole garden

November - planting additional plants and moving some plants around within the garden

2020: No plants planted

2021: Spring - planting vegetables, edible flowers and herbs in the edible garden (waving wadi) + planting additional perennials in the rubble soil cubicle.

Weeding

There's more weeding needed in the first year while the plants are small and weeds can easily take over. In the following years the plants are larger, overgrow the weeds and thus less weeding is needed.

Weeding schedule:

2019	***2020***	***2021***
June 6, 17	*March 4*	*May 14*
July 1, 19, 25	*May 19*	*June 2, 8*
September 3	*September 15*	*September 17*
October 16		
November 15		
December 12		

Pruning

Cutting back grasses and dead flowers yearly in the winter is necessary.

2019: none

2020: March 4 - cutting back all the grasses (except Mexican feather grass) and the dead flowers

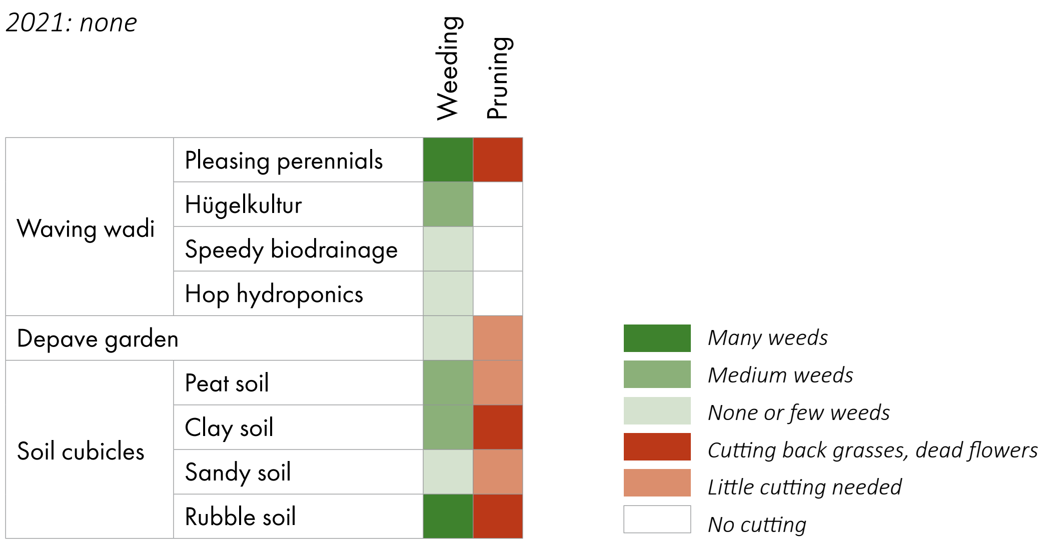
2021: February 25 - pruning extensively throughout the entire Sponge garden

Watering

2019: As the summer was exceptionally hot and freshly planted plants vulnerable, we decide to intensively water the whole garden (throughout June until end of August) to make sure the plants establish well. After this initial help to start0up we expect no more watering to be needed; the Sponge garden should sustain itself.

2020: none

2021: none



Regular weeding has become an Urbanisten office activity

Cutting back in early spring

Planting missing plants and adding some extra

MONITORING BIODIVERSITY

Pollinators and insects

Plants in the sponge garden are often visited by pollinators during the flowering season - several species of bees, bumble bees and butterflies. From our accounts, it seems that the most visited section of the sponge garden are the Waving wadi - Pleasing perennials, Hügelkultuur, Biodrainage, the Depave garden and Sandy soils in the Soil cubicles. These areas have nectar rich flowers that attract the pollinators.

Honey bees (Apis mellifera)
Found on tickseed flowers in sandy soils and the Depave garden (may, july 2020).

Solitary bees
Found in bamboo in the insect wall (june 2019 and may 2020). In the summer of 2020 they were nesting in the open ground of the Pleasing perennials.

Earth bumblebees (Bombus terrestris)
Found feeding on the flowers in Pleasing perrennials, Hügelkultur, Biodrainage planting throughout the summer 2020.

Common brimstone (Gonepteryx rhamni)
Spotted ... (july 2019)

Ladybugs (Coccinella magnifica)
The larvae was spotted ... (june 2019)

Stinkbug (Pentatomidae)
Spotted ... (may 2020)

European firebug (Pyrrhocoris apterus)
Spotted in groups on seedheads of asters in Pleasing perennials (november 2020).

Ants (???)
Spotted in Hop hydroponics (summer 2019 and 2020).

Pigeons (???)
Spotted eating berries on juneberry tree (june 2019) - and chased away...

	2019							2020												2021												2022											
	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Honey bee												■																															
Solitary bee	■											■																															
Bumble bee												■	■	■																													
Common brimstone		■																																									
Stinkbug												■																															
European firebug																		■																									
Ants				■										■																													
Ladybugs	■																																										
Pigeons	■																																										

Bumblebee
Bombus terrestris

Honeybee
Apis mellifera

European firebug
Pyrrhocoris apterus

Insect wall

From the very first days after the construction there have been observations (6 June 2019) of solitary bees visiting the bamboo sticks and the holes in the wood. Small holes have been occupied much more than bigger holes (sizes to be specified). The holes have been closed with either green leaves or soil. These are probably the making of bees in the genera Megachile and Osmia. Thicker bamboo stalks are sometimes occupied by spiders and isopods. Further investigation is needed to quantify occupancy and categorize species.

According to several instructional websites on insect hotels, the hotel should be facing S/SE and shielded from dominant wind and rain. The insect hotel in the sponge garden faces West and is exposed to the predominant wind and rain in the area. This does not seem to affect occupancy, but we do not know what are the effects of this orientation on the health and reproductive success of the bees. It could be possible, for instance, that the rain and moisture favour moulds and disease that have an effect on the larvae or on future population. On the other hand, since the wall receives direct sunlight on the black backside, this might be enough to provide sufficient warmth and dryness.

In november 2020 we transplanted mosses on the wall - both in full pieces and cut and painted in a mixture with yoghurt. Similarly, in the holes we placed also wall plants, maidenhair spleenwort (Asplenium trichomares) among others.

June 2019
Observations of occupation

Spider ?

Hole stuffed with a green leaf

Holes blocked with pieces of wood

September 2019

May 2020

November 2020

Soil fauna

During the excavation of soil samples in may 2020, we found only one earthworm. No other soil macrofauna was noticed. When digging for soil samples, the soil was quite dry and it had not rained for a few weeks. This might have induced the present worms to move to moister areas deeper in the ground. On other days we saw snails, ants, ground nesting bees, and isopods, which suggests that more macrofauna might be present.

A focused investigation on soil macrofauna when the ground is at least 12° C could reveal more insights. When digging soil samples, we did not spend much time looking for macrofauna. One simple experiment is to create a pitfall in the ground, checking it at regular intervals.

Additionally, the biodegradation of the organic matter in some soils, especially the mulch in the peat soils and in the hop hydroponics, makes us believe that composting bacteria and fungi are probably present. But no mushrooms or other fruit bodies have been observed. An expert would be able to assess better the presence of soil bacteria and fungi.

Next steps

- *Conduct an accurate inventory of species (both plants and animals)*
- *Replace some of the bigger bamboo stalks with reeds, diversifying the brooding possibilities and therewith possibly attracting different species*

Plants that attract pollinators, insects and birds

Aaa

Aster 'Asran'
Aster ageratoides Asran

Epa

Purple coneflower 'Alba'
Echinacea purpurea alba

Pb

Common bistot
Persicaria bistorta

Al

June berry
Amelanchier lamarckii

Cv

Tickseed
Coreopsis verticillata

Bo

Borage
Borago officinalis

Ev

Viper's bugloss
Echium vulgare

CHAPTER 8

NEXT STEPS

COMMUNICATE + ENHANCE + APPLY

Practical activities in the Sponge garden: 2022 and onwards

Sponge garden

<u>Adjustments to the site</u>

In spring 2021 new edible plants have been added in the Waving wadi. These need monitoring, care and possible some more additions. In the Soil cubicles missing plants and some replacements can be done. In the Hop hydroponics some wadi planting adjustments can be made.

<u>Heavy rainfall simulation</u>

Look into possibilities of simulating heavy rainfall in Waving wadi area:

- *a truck with water - one time event. Preferably organised in rain periods in early spring or in autumn.*
- *detaching local roof - long-term, more complex planning and construction. In co-operation with Keilepand, Keilewerf 2 or Soundport is needed.*

Sharing knowledge / how to

<u>Research book</u>

Continue recording monitoring, conclusions and findings in this research book - update versions.

- *Continue monitoring water performance. Carry out additional tests manually (municipality Rotterdam)*
- *Prepare soil monitoring plan and carry out various tests*
- *Continue monitoring planting and biodiversity*
- *Further maintenance - weeding and pruning*

<u>Brochures</u>

Findings can be shared with city residents. Extra funding is needed for this and could be related to subsidies for climate adaptation (i.e. through websites of Rotterdams Weerwoord, Operatie Steenbreek etc.)*

- *On gardens >> Soil cubicles about knowledge of soil additives and planting choices to encourage greening by showing low maintanance possibilities*
- *On facade gardens (geveltuinen*) and simple actions for greening streets >> Depave garden about knowledge of suitable planting and depaving*
- *straaDkrant Sponge edition*

<u>Site visits</u>

There have been already many visits from other municipalities within the Netherlands and from abroad, also from students, journalists and interested Rotterdam citizens. The Sponge garden was also part of the tours during Stadsmakerscongres 2019 and Havendagen in 2020. Site visits will be continued following Covid-19 regulations..

*.*References:*

https://www.rotterdam.nl/wonen-leven/subsidie-klimaatadaptatie/
https://www.groenemorgen.org/1000geveltuinen

Expand various 1:1 test-sites in the city

To end this first progress report we want to scale up from the Sponge garden to the Sponge city again. The city of Rotterdam has ambition of creating extra 20 hectare green planted spaces within the coming years. The municipality aims to encourage residents and schools to make their gardens and school squares greener. Furthermore, the aim is to have greener work locations, specifically business premises (bedrijventerreinen), office locations and port areas.

The Sponge garden can help in applying an effective greening strategy within different urban contexts and the various subsoils Rotterdam has. More spongy test-sites in the city can help to achieve the 'greening goal' in an effective way, offering several ecosystem services and expanding the knowledge wider and deeper into the city. On the next (last) spread we briefly showcase some interesting options for application of the Sponge garden findings to build a Sponge city...

https://www.rotterdam.nl/wonen-leven/meer-groen-in-de-stad/

Examples of possible future Sponge test-sites

Some visual explorations in Rotterdam to be expanded and enriched.

Climate adaptive street (berm, sidewalk, parking) with diverse planting

WAVING WADI

SPEEDY BIODRAINAGE

DEPAVE GARDEN

Green school square with edible garden (can be complemented with soft paving)

WAVING WADI

EDIBLE GARDEN

HOP HYDROPONICS

DEPAVE GARDEN

Sandy facade garden (can be extended into the sidewalk easily)

DEPAVE GARDEN

Climate adaptive and greener square (pervious paving can be added)

WAVING WADI

PLEASING PERENNIALS
HOP HYDROPONICS

Climate adaptive, greener work locations (pervious paving should be added) (bussiness areas, office locations, port areas)

WAVING WADI

SPEEDY BIODRAINAGE
HOP HYDROPONICS

DEPAVE GARDEN

Edible community garden in public space (soft paving can be added)

WAVING WADI

EDIBLE GARDEN

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- *Tjerron Boxem (Hoogheemraadschap Delfland)*
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- *Rob Luyk (Binder Groenprojecten)*
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- *Fransje Hooijmeijer (TU Delft)*
- *Kim Kogelman (Kim Kogelman ruimtelijk advies)*

SPONGE GARDEN TEST SITE

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- *Tom Lorier (coördinator tuin)*
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The Sponge Research and Test-site is an initiative of De Urbanisten

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