RECONNECT CITY & WATER

How can we turn the flooding threat into an opportunity to create new relationships between the city and water?

A Master's Thesis in Architecture
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   Common patters and solutions --- Tool kit/box
   Particular problems and actual situations --- Field application
2. Regionalism
   Features from the region or the nation.
   Local materials and construction techniques
3. Space design for guidance

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At last, I would like to express my gratitude to my parents and family, whose support, patience and love have provided me with strong confidence in my journey through this Master program.

Reading Instructions

Introduction

The first phase of the thesis introduces both historical and current relationship between Wuhan and water, while leading to the thesis question and main visions.

Background

The second phase describes certain background related to the cause of floods, as well as the curent mearsures that have been adopted in Wuhan, which contributes to search for more resilient stratagies.

Analysis

The third phase integrates the context in south of Huangpi district into the analysis, in order to determine the target environment for the final design after the research about dyke system.

Design

The last phase shows the process of newly-designed topography that merge into the context.

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Abstract

The context of the design proposal is Wuhan, China, which has a indivisible relationship with water(Yangze river). From historical and current perspectives, water shaped the city while the city also limited water.

Over the centuries, citizens in Wuhan have fought to resist flooding because of the weather conditions and low topography. A growing population and the scarcity of agricultural land led to the draining and reclamation of large bodies of water, which exacerbate the flooding risk.

Even though specific climate predictions remained in uncertainty, it is nevertheless a fact that we need comprehensive analysis and assessment for flood risk to better understand the elements that causing floods, while searching for further measures to guard against, and to take advantage of, flooding.

The oldest protective measures in Wuhan were to enclose land with dykes, these high dykes tend to get in the way of any direct relationship between the city and water, and just leave a rigid and inflexible impression to the kids and citizens, which indicates that these structures need to be better incorporated into the urban fabric.

The starting point for this Master's Thesis was to search more resilient and long-term measures for flooding mitigation from an architectural perspective, thereby promoting and reproducing the connection between the city and water. Conformable to more resilient solution, dynamic landscape design is introduced as a method to connect current context with stormwater as a flexible and variational element to promote urban resilience. Thereby, water management and dyke adaptation needs to be integrated into urban life, thus promoting outdoor activity and interaction between the city and water.

Research into the field of layer models and spatial qualities defined the target environment and strategies for promoting sustainability through design.

Adaptation to the existing flooding resistance and urban context

Since Hubei is called the "province of a thousand lakes", which means there are a lot of lakes located here in Wuhan, which could be a long-term and sustainable way for mitigating the floods as well as collecting and discharging rainwater. Current resistant measure is to build higher dykes, which should be also taken into consideration.

Stormwater management

Reconnecting stormwater management to the natural water cycle system could be more efficient and sustainable way to treat the rainwater, such as capturing and holding stormwater for transpiration, improving infiltration to decrease the runoff rainwater, as well as adding bio-filtration measures to filter stormwater.

Integration to public activities

For the surrounding school and residential buildings, lakes and other flooding resistant infrastructure such as dykes could be a great chance for the public and kids to have public activities and interactions with water, also provide great educational outcomes.

Introduction

City & Water

Wuhan & Water

Wuhan, composed of the three towns of **Wuchang, Hankou, and Hanyang**, is the capital of Hubei Province. Wuhan is also known as the "**River City**", which indicates the **close relationship between Wuhan and the Yangtze River**. The story of Wuhan must be told by the Yangtze River, starting from the origin to the process and development of the city.

More than a thousand years ago, as a result of the scour and siltation of the Yangtze river, the land and beaches were gradually formed, giving birth to Jianghan plain, and **Wuhan**. After the water flooded and receded, these beaches were so fertile that they were reclaimed and fortified by the citizens in order to develop agriculture, and it was on this basis that the prototypes of Hanyang and Wuchang were slowly formed. And then on the fertile soil irrigated by the Yangtze River, the Jianghan Plain became one of the world's largest breadbaskets.

More than a hundred years ago, Hankou, with the Yangtze river working as a golden waterway for transportation, was flourished as a trade hub for merchants and businessmen, which was also the first inland city to open a port in the late Qing Dynasty, becoming one of the birthplaces of modern industry.

In a sense, the Yangtze river has made Wuhan what it is, from both perspectives of agriculture and transportation.

"When the area around Dong Ting Lake (Hubei/Hunan Province) has a good harvest, the entire country has enough food."

" 湖广熟，天下足 "

--- Ancient Chinese Proverb

Wetlands in Wuhan (2021)

Floods in Wuhan (Historical)

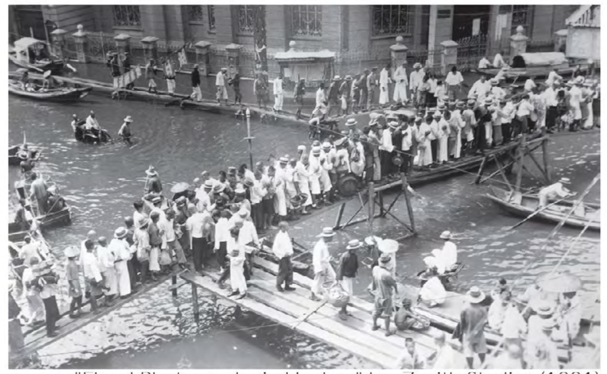
There is no other city like Wuhan, where the Yangtze River is a constant source of confrontation, where the "Great Water (floods)" visits Wuhan almost **every year**:

The book of "Wuhan Local Records" keeps really rich and detailed records on floods in Wuhan, where recorded several years of particularly detailed flooding, such as in June of 1931, "Under heavy raining, the river rose sharply, the water level of the Yangtze River reached 27.86 meters. The dikes collapsed." All three towns in Wuhan were flooded in this flood, with heavy losses, and the drowned and sick population was numerous.

The summer of 1954 was also a year well remembered by the people of Wuhan. From May to July of that year, 1634.7 mm of rainfall fell intensively in three months, and in mid-July, the the water level rose so high that reached 30.17 meters. It was the worst flood of the Yangtze River in the 20th century, but Wuhan had survived, and a flood control monument was erected on the riverbank to commemorate the fight.

People in Wuhan have become "experts" in observing the weathers, who have become accustomed to the perennial floods and have developed a way of dealing with them: such as waterspouts were prepared to be blocked, high ground was prepared for evacuation, local well-wishers would build temporary bridges over the city's thoroughfares, and poorer people ferried citizens with small boats. Importantly, the whole city contributes money and efforts to restore the city for the next year.

Flood in 1931 : 28.28m (water level)



"Flood Photography in Hankou" by Zenith Studios (1931)

Flood in 1954 : 29.73m (water level) & 1634.7mm (in 3 month)

Newspaper, Internet (1954)

Floods in Wuhan (Nowadays)

Nowadays, Wuhan has been protected by current dyke system, which was constructed and reinforced since 1954. Since then, floods in Wuhan are mostly represented by waterlogging.

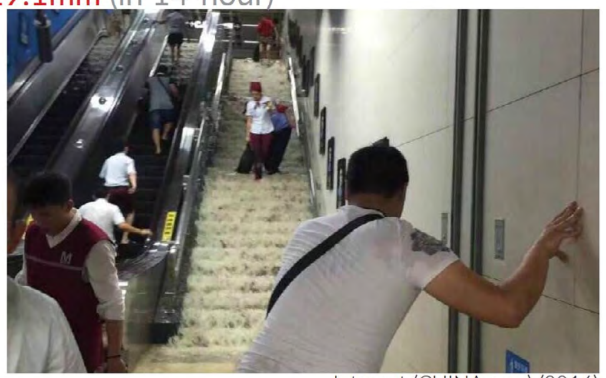
The heavy rainfall started from June 30 in 2016 was very rare in history, and the weekly sustained precipitation broke the highest value as the meteorological records showing. From the data recorded by the Wuhan National Basic Weather Station on July 6, the 14-hour rainfall in the main city of Wuhan reached 229.1 mm, which is defined as the events happened once in 50 years.

As of 12:00 on July 6, the rainstorm disaster caused 757,000 people to be affected in 12 districts of the city. There were 206 waterlogged sections in the city. Collapsed house included 2357 households and 5848 rooms. Direct economic losses were up to 2.265 billion yuan. 14 people died and 1 person was missing due to the disaster.

From June 28 to June 29 in 2020, heavy rainfall was widespread in Wuhan. With a maximum rainfall of 165.9mm in 24 hours, many sections of the city became waterlogged. On June 29, there were 13 waterlogged sections in Wuhan, and the waterlogging put pressure on some sections of traffic in the city as well as the surrounding residents.

However, thanks to the management and improvement of urban drainage, the embankments were unscathed and the number of waterlogged spots in the city was significantly reduced compared to four years ago.

Waterlogging in 2016 : 28.37m (water level) & 229.1mm (in 14-hour)



Internet (CHINA.com) (2016)

Waterlogging in 2020 : 28.77m (water level) & 165.9mm (in 24-hour)

Newspaper, Internet (2020)

Wuhan & Dykes & Water

Not only the rivers, the dyke system also has formed a significant part of the city's landscape.

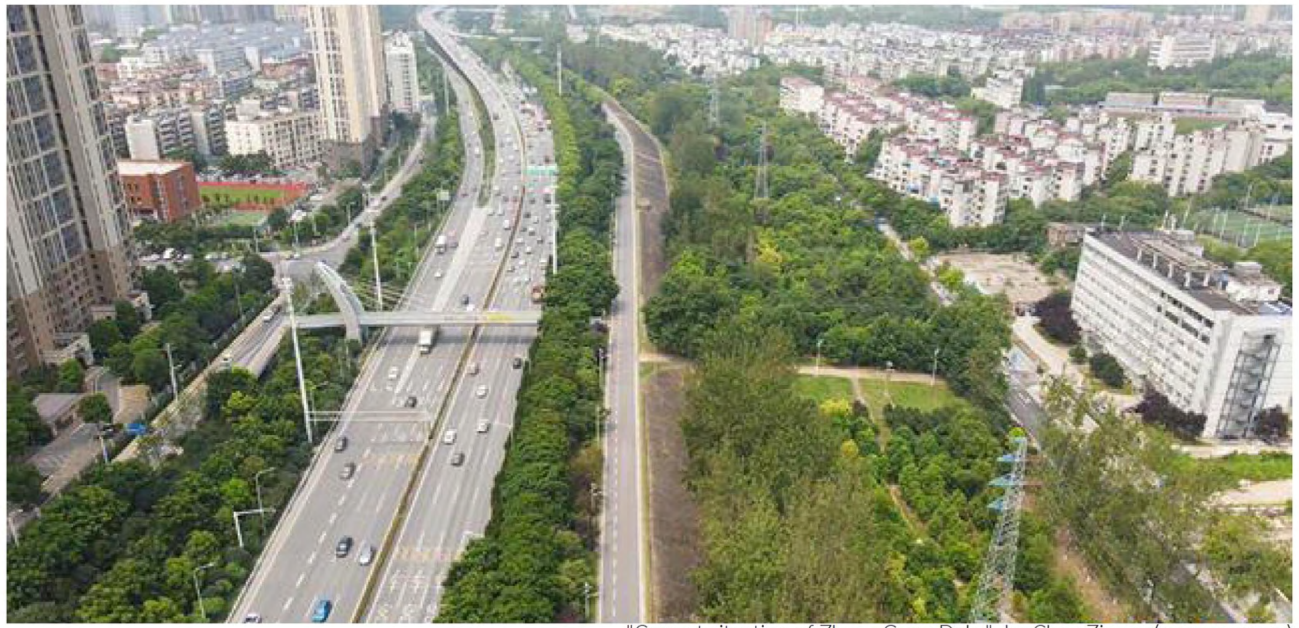
The Jianghan Plain has been defended by dykes since the Wei and Jin dynasties. In 1635 the first long dike was erected in Hankou and the main street was formed; in 1864 the local government built the Hankou Fort in the lakes outside the long dike to keep out incoming water, and the area of Hankou tripled; in 1905, Zhang Zhidong built the Zhang Gong Dyke, which really gave Hankou its modern city image.

On the other hand, the dyke system also shaped the rivers. Since the dykes acted as the barrier for waterflow, which actually changed and shaped the direction of river channels.

Therefore, the relationship between city, dyke system and water remained interdependent and interactive, which is why this relationship is exceptionally close and inseparable.

However, due to the enclosed prevention against unpredictable flooding hazard, as well as the requirement of urban construction, **the dyke system has virtually obstructed the connection between the city and water.**

"With the continuous improvement of the city's flooding control system, the Zhanggong dyke has long since ceased to face floods directly, but it remains an important part of Hankou's flood control protection. Since 2012, urban forest parks were built one after another around Zhang Gong Dyke for the recreation of the public "



"Current situation of Zhang Gong Dyke" by Chen Zixuan (www.news.cn)

Thesis Question

How can we turn the flooding threat into an opportunity to create *new relationships* between the city and water?

Purpose

With this thesis I wish to propose more sustainable and resilient measures to mitigate the flooding threats, while searching for opportunities for the city to better interact with water even under flooding situation. In addition, I attempt to raise awareness for the public to better understand the floods and live with them.

Aims and Visions

- Sustainable stormwater management
- New relationship between city and water

Aims

- more resilient design for flooding mitigation
- sustainable water management/ cycle
- public/ educational space for the kids and residents

Strategies

- dyke adaptation & divert runoff
- increase pervious area & water quality treatment
- resilient/ flexible utilization

Method

- infrastructural networks layer(over 50-100 years)
- sub-stratum (the natural layer over centuries)
- occupation layer(over 25-50 years)

Resilient Design / Nature Reconnection

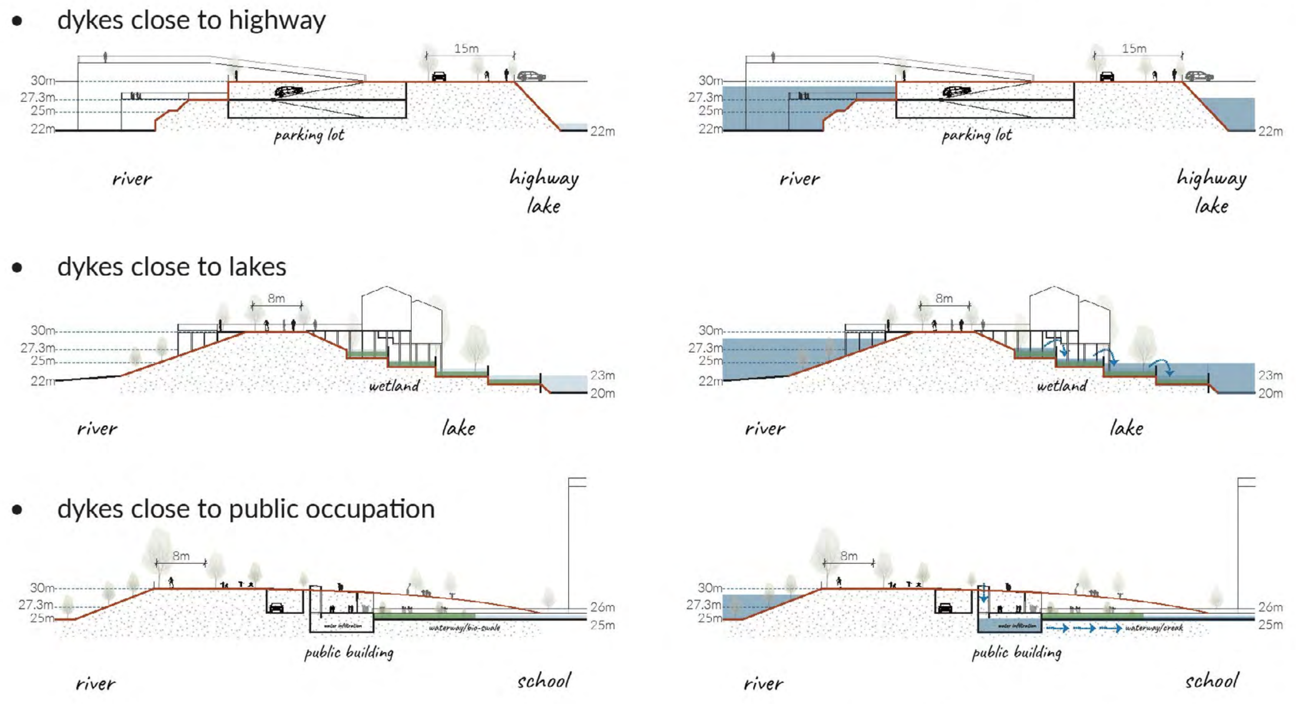


Figure 1: Section examples for dayke adaptation

Method

The layer model is used as a conceptual framework to describe and understand the essence behind the flood risk assignment in project Scheve-ningen(Nillesen, A, 2015), which could be a great method for my project to understand different characters of the measures.

Research-by-design

Different definitions of research-by-design exist. The research-by-design method used during this project assumes a definition in which a single parameter is systematically varied (the types of flood risk interventions) while fixing other parameters (such as the location, the existing construction and planned land use). The different flood risk interventions are used as a leading principle for an integrated design in which both the human participation and long-term flood risk protection are addressed. In this case this results in the specific design that close to a school, which would adopt different types of interventions in relation to their spatial potential and various forms of water management.

The aim of this research-by-design study is to develop and select the most favorable measure for public participation to adapt to existing flooding resistance, also to support a more resilient design regarding flood risk interventions related to water management by exploring different strategic opportunities for flood risk protection.

Layer analyses and complex systems

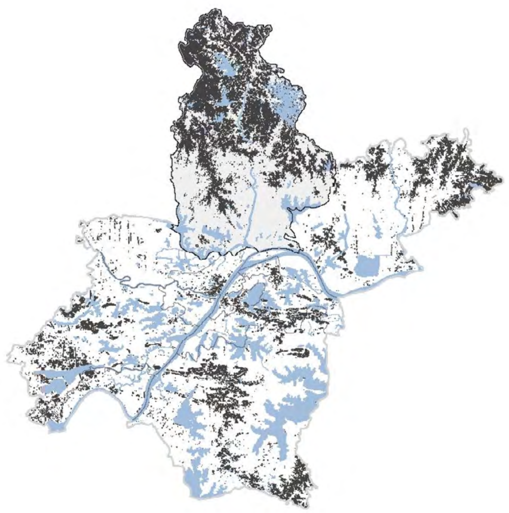
The layer model was documented by the Dutch Ministry of Infrastructure and Environment (VROM, 2001) and based on the triple layer model by Ian McHarg (1969). The layer model contains three conceptual layers:

- **The sub-stratum** (the natural layer of the subsoil in which changes take place over the course of centuries);
- **The network** (the layer of the infrastructural networks, changing over the course of 50-100 years);
- **The occupation layer** (the layer of the human occupation, changing over the course of 25-50 years) (Meyer & Nijhuis, 2013).

In the current researching context, these layers are interpreted as the three layers: water, flooding risk infrastructure (dyke system) and human occupation (construction/ city).

For this project, research about the relationship between three layers could provide various scenarios for comparison and analysis, which lead to different strategies related to different aims and visions.

In the end, this project aims to reconnect these three layers by different types of flood risk interventions, thus searching for the possibility of new connection between the city and water.



Background

Background

History about Hubei (lakes)

"What elements are exacerbating the flooding?"

Hubei --- the "province of a thousand lakes":

It is important to understand the geographical term of "Yunmengze", which is the only way to understand why flood control is so important in Wuhan,(Hankou and southern Huangpi), why there are still so many lakes, and why the cities were developed so late.

Between 10,000 and 2,000 years ago, the Yangtze River exited the Three Gorges, as well as the Han River exited the Danjiangkou, which rushed to meet each other in the present Jianghan Plain. At that time, the Jianghan Plain was a low-lying, uninhabited swampy wetland, known as the "Yunmengze". According to historical records, Yunmengze was connected to the Yangtze River in the south and the Han River in the north, with continuous lakes and swamps, covering a total area of more than 20,000 square kilometers. it was a place where rivers and lakes and were fully integrated in the middle reaches of the Yangtze River, where water flowed in and out freely.

During the flood seasons every year, the Yangtze and Han rivers suddenly became violent and flooding everywhere, so that the rivers and lakes were not separated in the entire Yunmengze, showing a large area of water connected land. At the same time, the river carried a lot of sediment, and as the flow of water slows down, the sediment was silted up. At first the smaller continental beaches were silting out, then gradually formed larger ones, the Yunmengze was continually divided, disintegrated and reduced in size, slowly forming the inland delta of Jianghan. After the floods had receded, these beaches became fertile, which were reclaimed and fortified by people. Based on these reasons, towns of Hanyang and Wuchang finally took shape.

Unfortunately, no one has accurately recorded the flood that occurred during the Chenghua period of the Ming Dynasty. That was the most friendly and valuable flood to Wuhan - it shaped Hankou. Wuchang and Hanyang had long existed because of their military value. But until 1465, Hankou was just a sandbar, crisscrossed by various currents, and certainly without any regular inhabitants.

Between 1465 and 1487, the Han River underwent a diversion, after which it had furiously and arbitrarily chosen its own route into the Yangtze river; thereafter it began to follow a fixed course, much as it does today. Afterwards, Hanyang and Hankou were thus clearly delineated, thus laying the geographical foundations for the formation of the three towns of Wuhan today.

The reason why Hubei is called the "province of a thousand lakes" is a gift of the Yunmengze, giving the very fertile land and survived lakes.

Lakes in Wuhan:

The topography of Wuhan is characterized by a plain in the central area, hilly terrain in the northern and southern parts, and low-lying terrain in urban areas. There are many lakes and ponds developed around the Yangtze and Han rivers in rural areas.

Based on LandSat series remote sensing data(MJW,2017), the water area of lakes under Wuhan's jurisdiction decreased significantly from 1973 to 2015 (Figure 1), with a decrease of 314.57 km2 in urban areas, and a decrease of 265.60 km2 in rural areas. The significantly decrease happened in the central urban areas, from 148.90 km2 to 99.94 km2 (MJW,2017).

Wuhan experienced rapid economic and urbanization development, in which a large number of lakes were encroached. "Enclosing lakes for farming", "enclosing lakes for waterproofing", and "building factories around lakes" began to occur frequently. Therefore, population growth and accelerated urbanization leading to increased pressure on human-water competition for land is one of the main reasons for the decrease of lakes in Wuhan, which has led to a reduction in storage capacity, thus exacerbating the flooding risk.

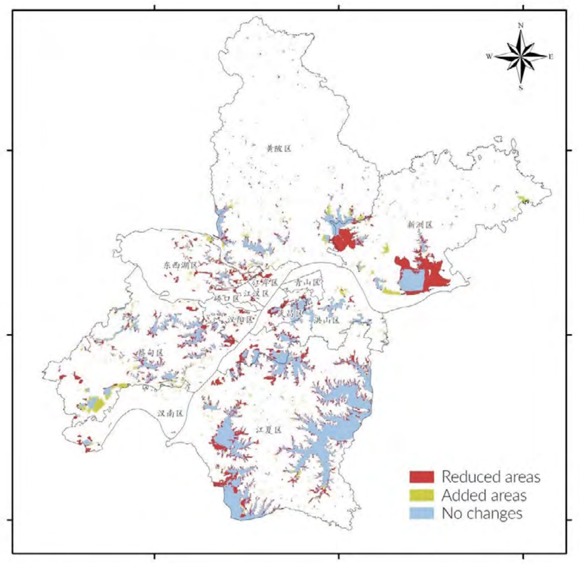


Figure 2: Distribution & changes of the lakes in Wuhan (MJW,2017)
1973-2015

In the past, Huangpi's lakes were mostly concentrated in the south, as this area belonged to the Yunmengze in ancient times. The Hanshui and Fu rivers regularly flooded every year, creating numerous lakes of various sizes in the south of Huangpi, which was dotted with rivers, lakes and mostly swampy lands (uninhabitable), only a few houses located on the high ground.

Later, as the sediment from the Han and Yangtze rivers pounded and settled, patches of land began to appear, and after thousands of years of reclamation, the Jianghan Plain, including the southern part of Huangpi and Hankou, has become home to a large number of human settlements.

The low-lying areas have survived to become lakes. However, rapid population growth required greater tracts of land for construction and urban development, which led to the significant decrease of water areas in South of Huangpi district.

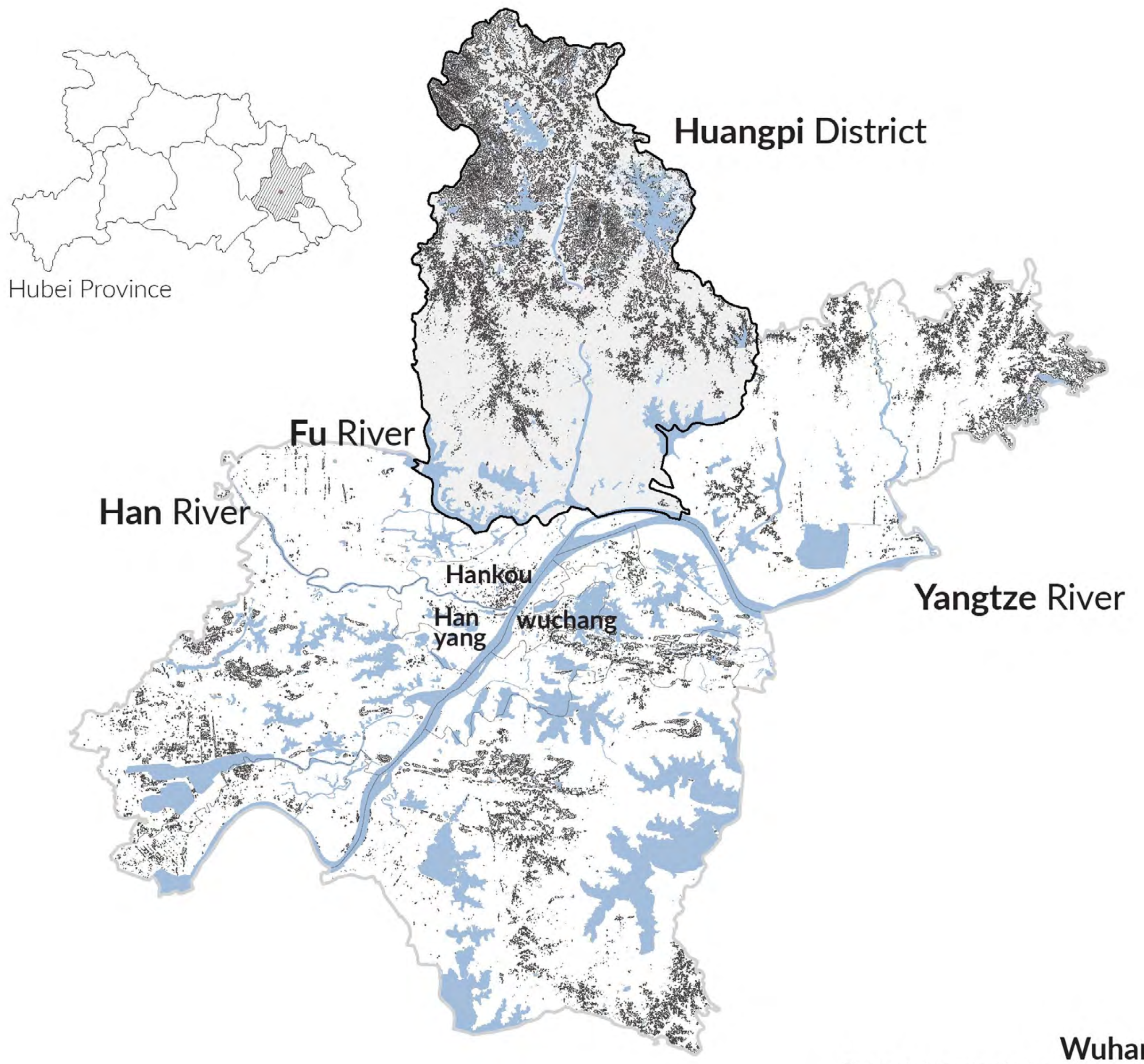


Figure 3: Map for Wuhan (Huangpi District)

Floods & Urbanization

Based on Li Z's research, maps of the flood sensitivity, vulnerability had been visualized, and comprehensive flood risk that corresponding spatial distribution in Wuhan had been developed. Based on these maps, the characteristics of their spatiotemporal variations were analyzed in the report (Li Z,2021).

The temporal variations in flood risk (Figure 4) showed that an increasing trend of risk was presented in most districts, and the year of 2010 was an obvious turning point for rapid risk increase, as flood risk increased rapidly since 2010, which was also the turning point when urbanization began to develop rapidly in Wuhan.

The results indicated that the central urban area, especially the area in the west bank of the Yangtze river, were mostly risk-prone due to its high flood sensitivity (S value) that was determined by land use type, and high vulnerability that was determined with the population concentration and economic development.

With the urbanization developing and land use changing, the area of harden surface and construction increased rapidly, which exacerbates the risk of waterlogging hazard; the prosperous population and economy will make the city face high post-disaster losses, especially in urban area.

Moreover, flooding risk of the new developed area such as Huangpi district turns out to be more obvious, since the area is newly planned, which could have great potential to adopt more sustainable and resilient measures for flooding resistance, such as better integration to the public activities, as well as better management for stormwater.

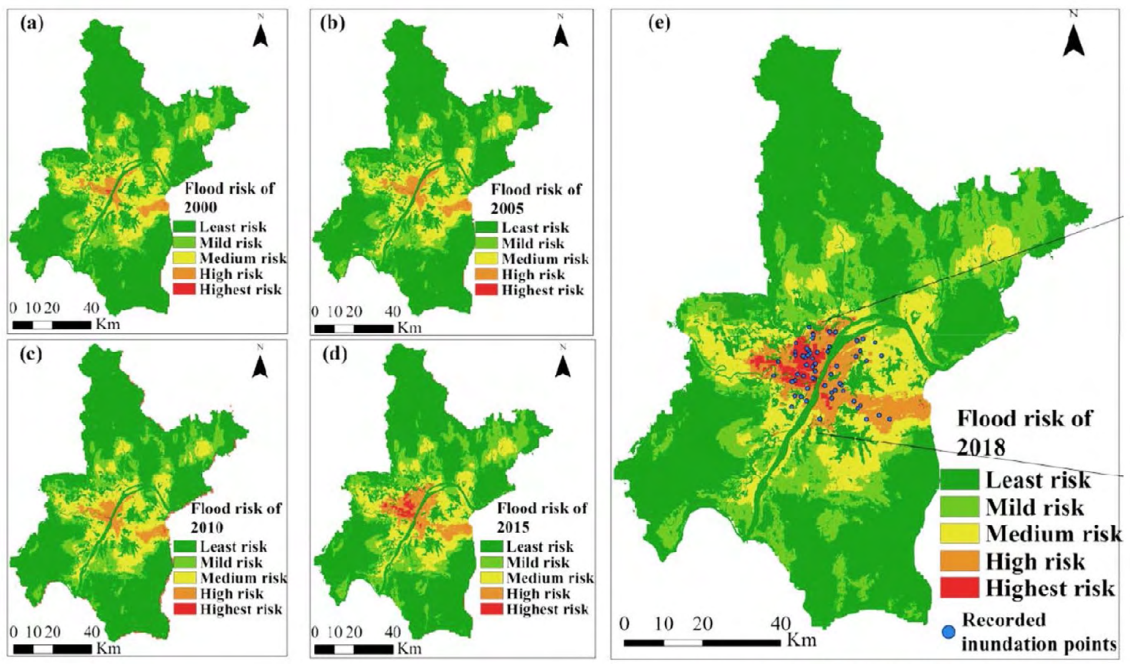


Figure 4: Spatial Distributions of Flood Risk (Li Z,2021)

- the high-flood-risk areas in the five years were mainly concentrated in the central urban area, extending in the southeast and northwest directions
- the flood risk of the areas close to the river network was higher than that of other flat lands.

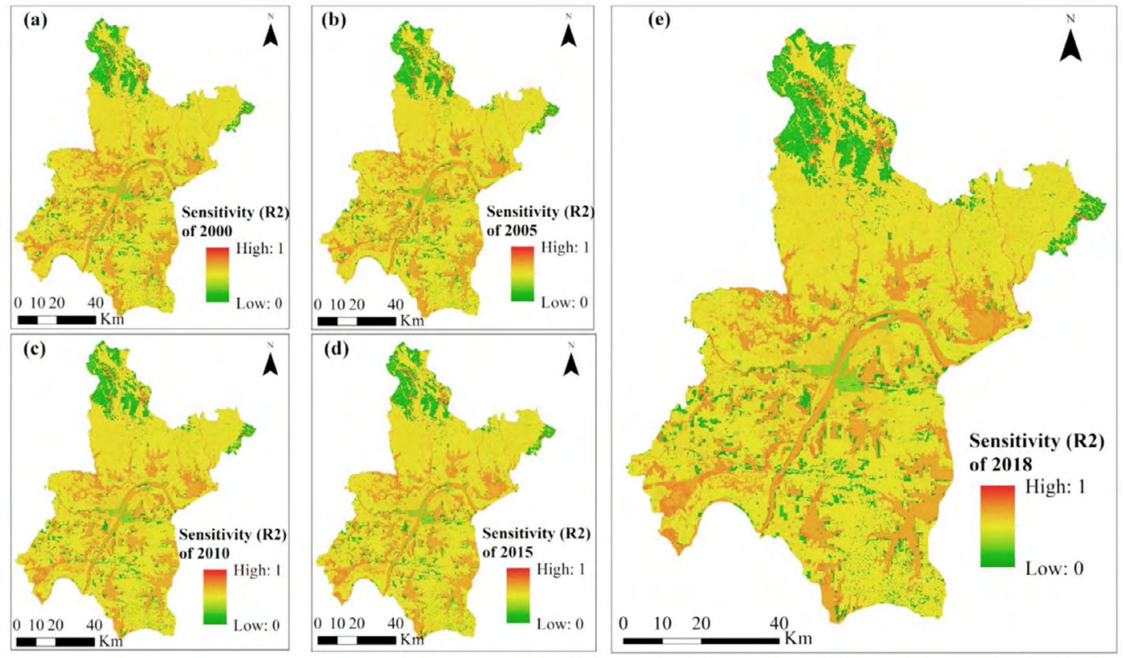


Figure 5: Spatiotemporal patterns of flood sensitivity in Wuhan (Li Z,2021)

- the sensitivity of the areas close to the water system was higher than that of other flat lands.
- the central urban area of Wuhan was of high sensitivity value.
- due to the expansion of urban land, the scope of highly sensitive areas was also expanding.

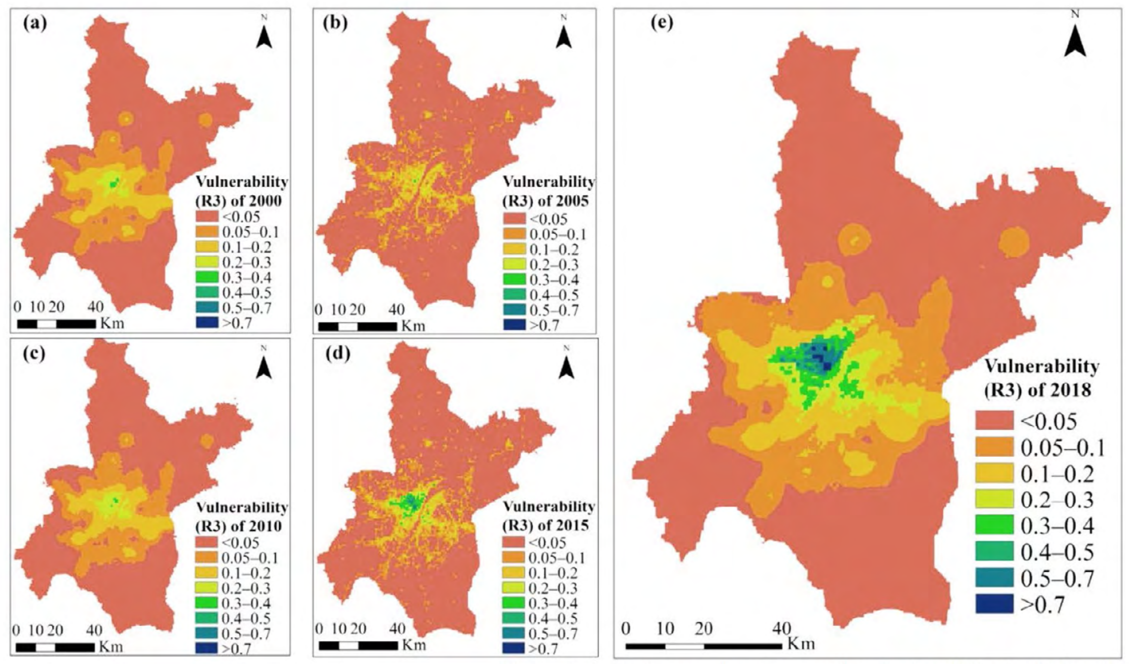


Figure 6: Spatiotemporal patterns of flood vulnerability in Wuhan (Li Z,2021)

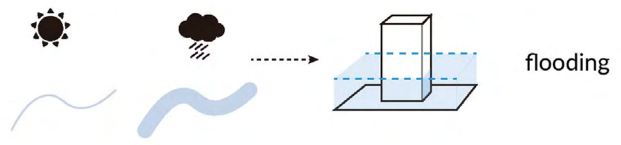
- the central part of the city has the highest vulnerability, and it decreased radially to the periphery

Description

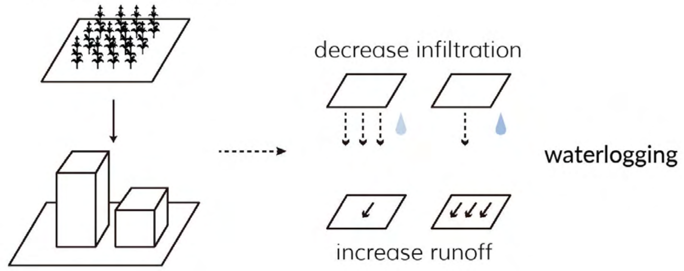
Relevance to Sustainability

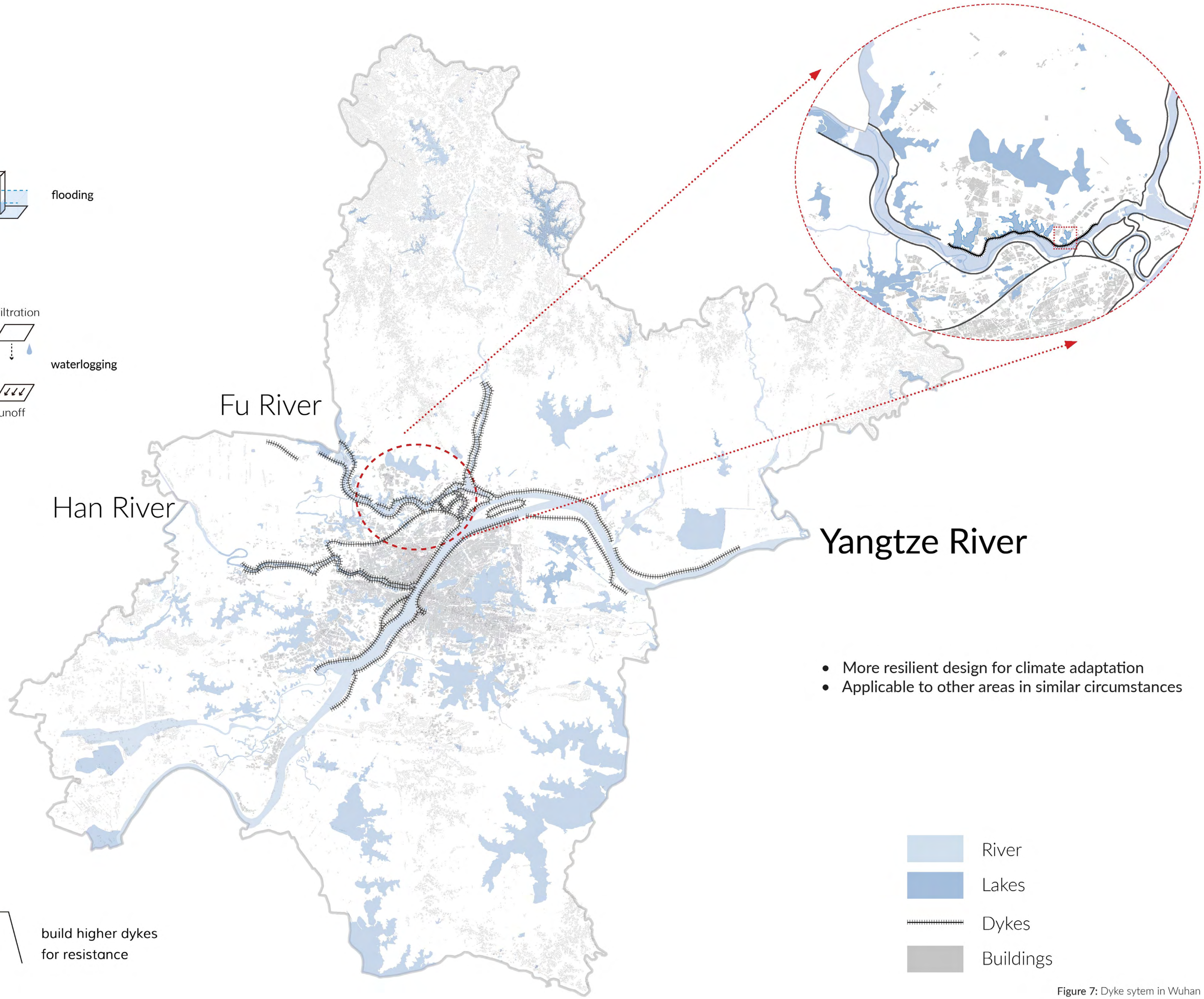
Cause of flooding hazard

climate



change of landuse





- More resilient design for climate adaptation
- Applicable to other areas in similar circumstances

Current measures 1

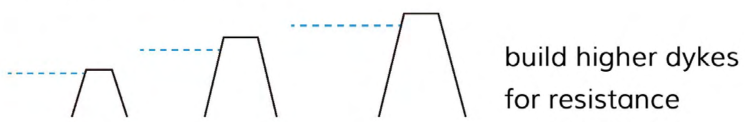


Figure 7: Dyke sytem in Wuhan

Current measure 2

Construction on water drainage and sewerage systems

Tremendous drainage pressure & Low design standard

• **Pressure on drainage system:** 90% of rainwater must be drained through sewers;

• **Unsuitable drainage system**: As an old city, the standard has not been able to adapt to the needs of urban development today;

• These networks are not easy to transform and increase;

• **Poor management of drainage facilities/ Lack of public awareness.** Some weak links in water management, the public's awareness of voluntary maintenance is also weak.

Construction of drainage facility (pump out and drainage)

• **Massive facility construction:** 55 external drainage pumping stations in the city, with a total pumping capacity of more than 1,960 m^3/s.

Pressure on lakes and river (Water treatment & storage capacity)

• **Pollutant entering water bodies:** The vast majority of untreated sewage will pollute the receiving water bodies and bring harm to urban production and people's lives.

• **Pressure on water storage.** Due to the topography, river levels will be higher than urban areas during heavy rainfall, and can even reach the peak of the levees, which means the capacity of river for receiving the pumped water decrease.

The lakes' storage capacity also has been reduced as a result of urban development and extensive land reclamation.

"The pipe network is basically designed for X year flood events."

"Underground pipes"
*Generally speaking, soil and ponds can store large amounts of water, but with the rapid development of construction in Wuhan, a large number of green areas, wetlands and ponds have disappeared and the city has become increasingly **"hard-bottomed"**, making it difficult for rainwater to drain itself during heavy raining. Thus putting tremendous pressure on the drainage system.*

"Interior of pumping stations"
*Since 2012, the city had lauched the construction for massive pumping stations. The drainage capacity has increased to **1,960m³/s** in 2020, almost triple that of eight years ago. The comprehensive assessment of Wuhan's central city drainage and flood control capacity is basically able to withstand **a heavy 24-hour rainfall of 150 mm**. That means, there will not be large area and long-term waterlogging in the central city.*

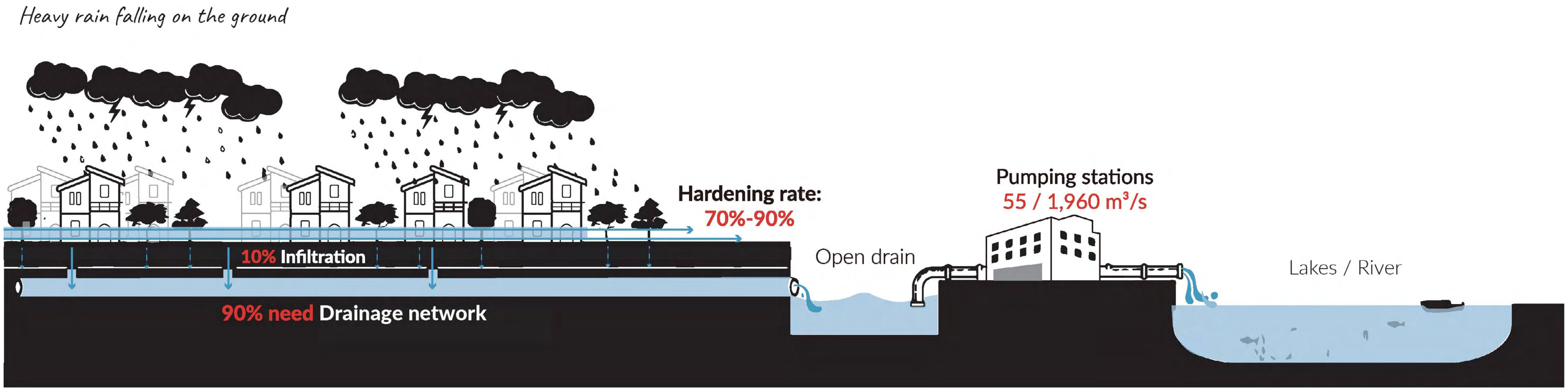


Figure 8: Water drainage and sewerage sytem in Wuhan

About Fu River

The Fu River was very powerful back then. Nowadays it is only during the summer months when the water rises that it looks like a big river (during the flood season, some sections of the river are as wide as the Yangtze River), and reminds people of how the river flooded the southern part of Huangpi district.

The river length of the Fu River in Wuhan is 38km from Chenjiaji into the Yangtze River, with a watershed area of 1093.9 km2. (Water Resources Bulletin of Wuhan in 2020).

Rainfall is abundant and concentrated in May to October, accounting for 73.6% of the year, with June to August accounting for 40% of the annual rainfall. The average rainfall over the years is 1,280.9mm (107 years average) and the maximum annual rainfall is 2,105.3mm (1889).

Long flood period: The Fu river is all recharged by rainwater, and the timing and regional distribution of floods is consistent with the distribution of heavy rainfall, generally earlier in the middle and lower reaches than in the upper reaches, and earlier in the south than in the north of the river. The flood season in Wuhan is about six months long.

Although the Fu river is not long, the water level is characterized by "steep rise and fall" every year, especially as the Yangtze River continues to rise, making flood control in the Fu River more difficult and more responsible. The total length of dyke system is 105.19km.

"What have caused the flooding in Huangpi district?"

Due to the low-lying topography and "S" shaped channel of the Zhujia River, (the southern branch of the Fu River, showed in the images), the water flow is limited, which cause the slow rate and difficulties in releasing flood water.

Dykes defended Zhujia river were gradually formed on the basis of the former soil dykes built by the citizens, with a vulnerable body and insufficient flood protection, thus the area is still plagued by floods. The pressure comes from upstream flooding and the influence of the high level of the Yangtze River. For the safety of residents, it must be freed from internal waterlogging and external flooding.

Google Earth *2016.02*

Google Earth *2016.07*

Dykes for Fu River:

Dyke system for Fu River (Huangpi district):

In 1931, 13 embankments in the southern part of Huangpi district breached, turning the southern part of the district into a swamp for over 60 miles. While in the summer of 2020, the water level at Wuhan Pass once exceeded 29 meters, but Huangpi was able to survive the flooding period without any danger thanks to the strong dykes.

Huangpi district underwent many periods of construction, culminating in the giant dyke system that today spreads across the northern bank of the Fu River.

There are four main dykes in the Huangpi area, named by West Dyke (built along the west side of the She River, defending the Qianchuan and Shekou streets), the Wuhu Dyke (built along the east side of the She River and north bank of the Yangtze River, enclosed the Lutai, Sanliqiao and Wuhu areas), the Minsheng Dyke (built along the north bank of the Fu River, defending the Shekou and Hankou North), and the West Lake Dyke (built along the north bank of Fu River, defending the Panlong Town).

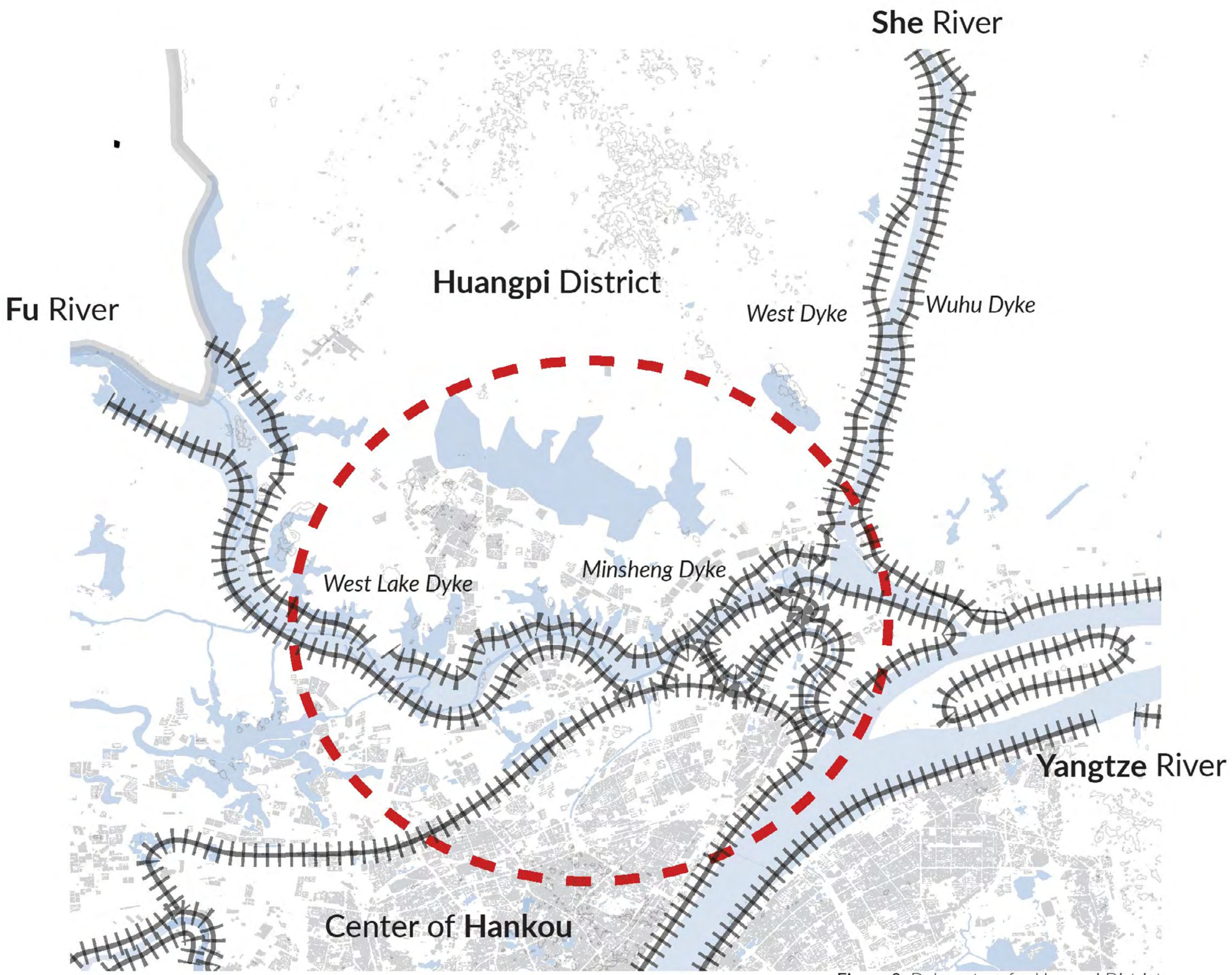


Figure 9: Dyke sytem for Huangpi District

Process of Building the West Lake Dyke:

The Minsheng and the West Lake dyke built along the north bank of the Fu River, aiming to prevent the Yangtze River from backing up into Huangpi district. From 1954 till 2000, these dykes finally had been reinforced and constructed.

In 1954, when the Yangtze River flooded and was about to pour into the Fu River, soil had to be taken from Pan Long Cheng to build a dike to prevent flooding, resulting in the discovery of the ruins of Pan Long Town .

In 1955, the construction of the West Lake dyke began. At first, only two small dikes of about 3 meters high were built near Panlong Lake and Tangrenhai, costing a spring and winter to pick up the soil. The dyke is very short and narrow which cannot withstand large floods at all, but only normal floods.

In 1972, Huangpi mobilised more than 5,000 laborers from five communes, to support the construction of the West Lake embankment, which was re inforced after a winter and spring. The top of the new West Lake embankment was 29 meters high and 2.5 meters wide, basically forming the basis of today's West Lake dyke, but the problem was that it was not strong enough and there was no drainage station, so there was no way to drain the stained water out of the embankment.

In 1983, the flood broke through several gaps in the West Lake embankment, and at the end of that year, the Ye Dian brigade organized the repair of the embankment, when the laborers hired from abroad were paid 5 yuan for a cubic meter of earth and stone.

In 1998, the West Lake embankment was again breached and the government arrange another investment of 80,000 yuan to repair the embankment.

In 2000, funds were allocated by the higher authorities to repair the West Lake embankment, using a variety of machinery (in the past, the people of Huangpi used to carry it by hand and shoulder), and after several months of construction, the height of the West Lake embankment was raised to 31 meters, and the surface of the embankment was widened to 6 meters.

Since then, the West Lake embankment has finally taken shape and has protected from many floods over the past 20 years, which has since turned 10,000 mu of swampy land into good land.

The history of dyke construction indicates that the main measure putting into practice for flooding resistance in Wuhan is to build and reinforce the large dykes. Even though the embankments had protected the city, it is infinite and unsustainable to raise the dykes under unpredictable climate changes.

Google Earth (2019)

Regulation of water level for flood control

According to the level of water and its threat to the safety of the embankment, the general regulation for water levels for flood control are divided into three levels, which works in order from low to high as follows:

Flood control/ Fortification level: This level indicates the river embankment starts to enter the flood control stage during the flood season, i.e. when the embankment begins to approach the water surface after the river floods over the mudflats.

Alert level: This level based on the quality of the embankment, protection priorities and the analysis of previous years' risk. It is also the level at which the embankment has been exposed to water at a certain depth, where there is a risk of danger and needs to be alerted.

Guaranteed water level: This flood level of the embankment is defined according to the flood prevention standard, or the highest flood level ever defended in history. When the water level reaches or is close to the guaranteed level, flood resistance enters a full state of emergency: the embankment has been soaking for a long time, which has a great possibility to reach the saturation, and face the danger of landslide even to be breached.

With the accelerated construction and reinforcement of the dyke system in Wuhan, the ability to resist floods has been increased compared to more than 20 years ago. So both the current regulation of water levels for fortification and alert are higher than before.

Minsheng Dyke from Baidu Map (2019)

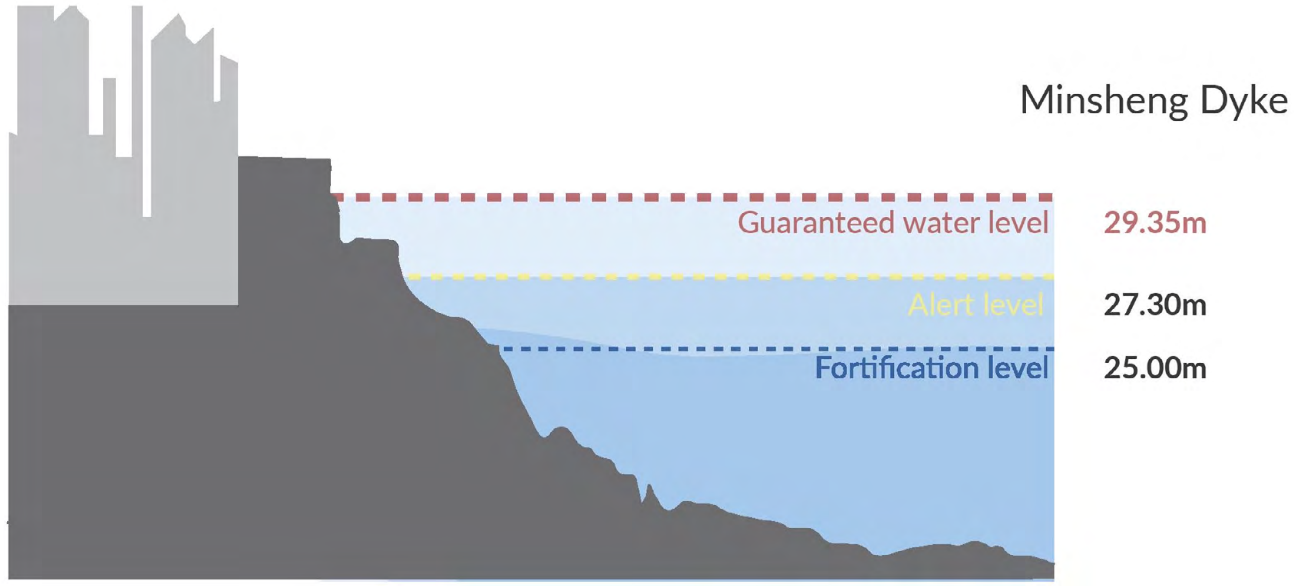


Figure 10: Regulation of water level for flood control

However, there are still relative problems among the flooding resistance with current dyke system:

- **vulnerable sections of dykes under long time of soaking;**

The soil embankments are most susceptible to hazards such as spreading soaking (wet or soft soil with water seeping out near the foot of the embankment) and piping disaster (seepage erosion activity occurs in the foundations of hydraulic structures under high water pressure, carrying away fine particles and soluble salts from the foundation and causing structural damage to the soil), which need supervision and observation during flooding seasons.

- **current heights of dykes are still difficult to meet the needs for the rise of river level under unpredictable raining volume;**

"Temporary construction of assembled floodwalls under extreme raining"

"Residents volunteered to reinforce the vulnerable section of dykes with sandbags"

Strategies

Green Stormwater Infrastructure

Green stormwater infrastructure systems are designed to convert surface area from impervious to permeable, and reduce the volume of runoff that reaches the sewer system or downstream water bodies, reducing the burden on gray infrastructure systems and infiltrating stormwater runoff directly back into the soil(NACTO, 2017).

VOLUME MANAGEMENT:

Since the volume of stormwater runoff increases as impervious surface area increases, the two major strategies related to volume management are to:

- increase pervious area
- to divert runoff into the green infrastructure system.

PEAK FLOW REDUCTION:

Green stormwater infrastructure programs aim to reduce peak flow rates and mitigate flooding(NACTO, 2017). Cities may design to accommodate the high runoff flows and flood risks of a given peak storm event, such as a ten-year storm (a storm that has a 10% chance of occurring in any given year).

WATER QUALITY IMPROVEMENT:

Stormwater runoff from streets carries sediment, debris, chemicals, and pollutants (such as heavy metals from brake pads, oil dripping from engines, and grit from tires). Green stormwater infrastructure projects are designed to capture pollutants in runoff and prevent them from reaching downstream water bodies(NACTO, 2017). Water quality treatment requirements vary based on the type of receiving water body (ocean, salt water bay, river, stream, wetland, or lake) as well as its existing condition.

Green infrastructure projects often set a specific water quality goal, such as removing 80% of total suspended solids(NACTO, 2017).

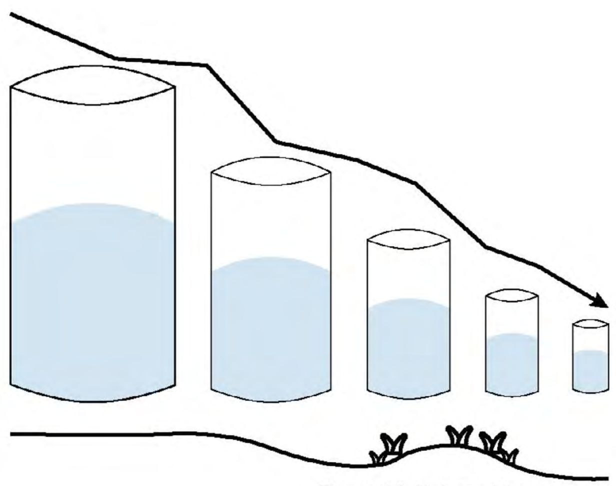
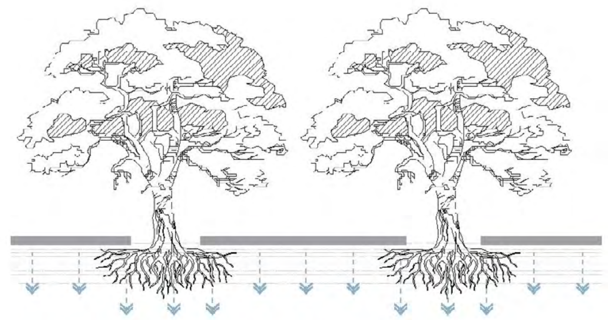


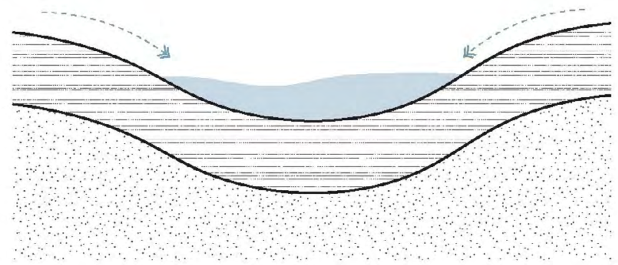
Figure 11: Volume Management

"How can flooding resistance become more resilient and long-term?"



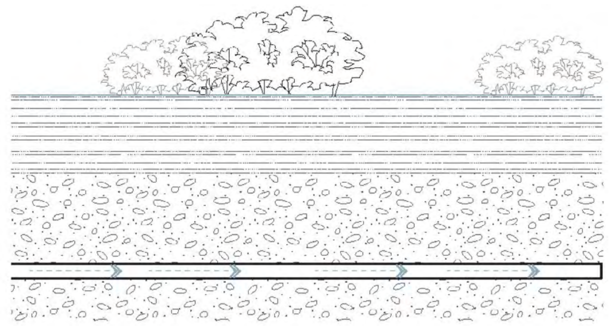
INFILTRATION:

Absorb stormwater through the ground surface and into the soil.



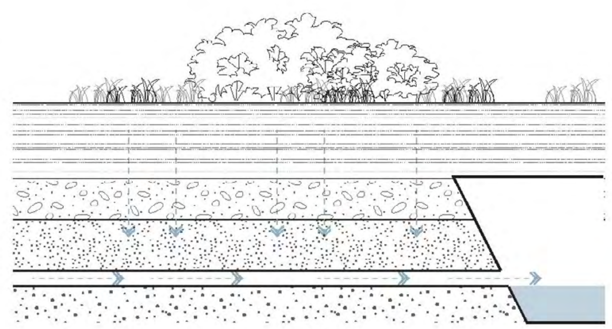
RETENTION:

Capture and hold stormwater on-site to reduce runoff to sewer systems. Water is then evaporated, transpired, or infiltrated through the soil.



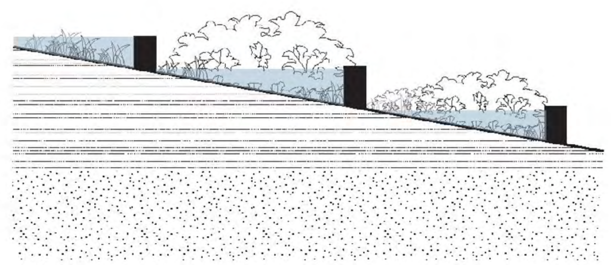
DETENTION:

Collect and hold runoff in temporary storage facilities or vegetated systems before slowly releasing the water into the downstream system.



(BIO)FILTRATION:

Remove particulate matter and other pollutants by filtering stormwater runoff through porous media such as sand, soil, or other filter.



PEAK FLOW REDUCTION:

Absorb stormwater through the ground surface and into the soil.

Figure 12: Green Stormwater Infrastructure

Delimitation

- more resilient design for flooding mitigation
- sustainable water management/ cycle
- public/ educational space for the kids and residents

Aims

- dyke adaptation & divert runoff
- increase pervious area & water quality treatment
- resilient/ flexible utilization

Strategies

- Sustainable stormwater management
- New relationship between city and water

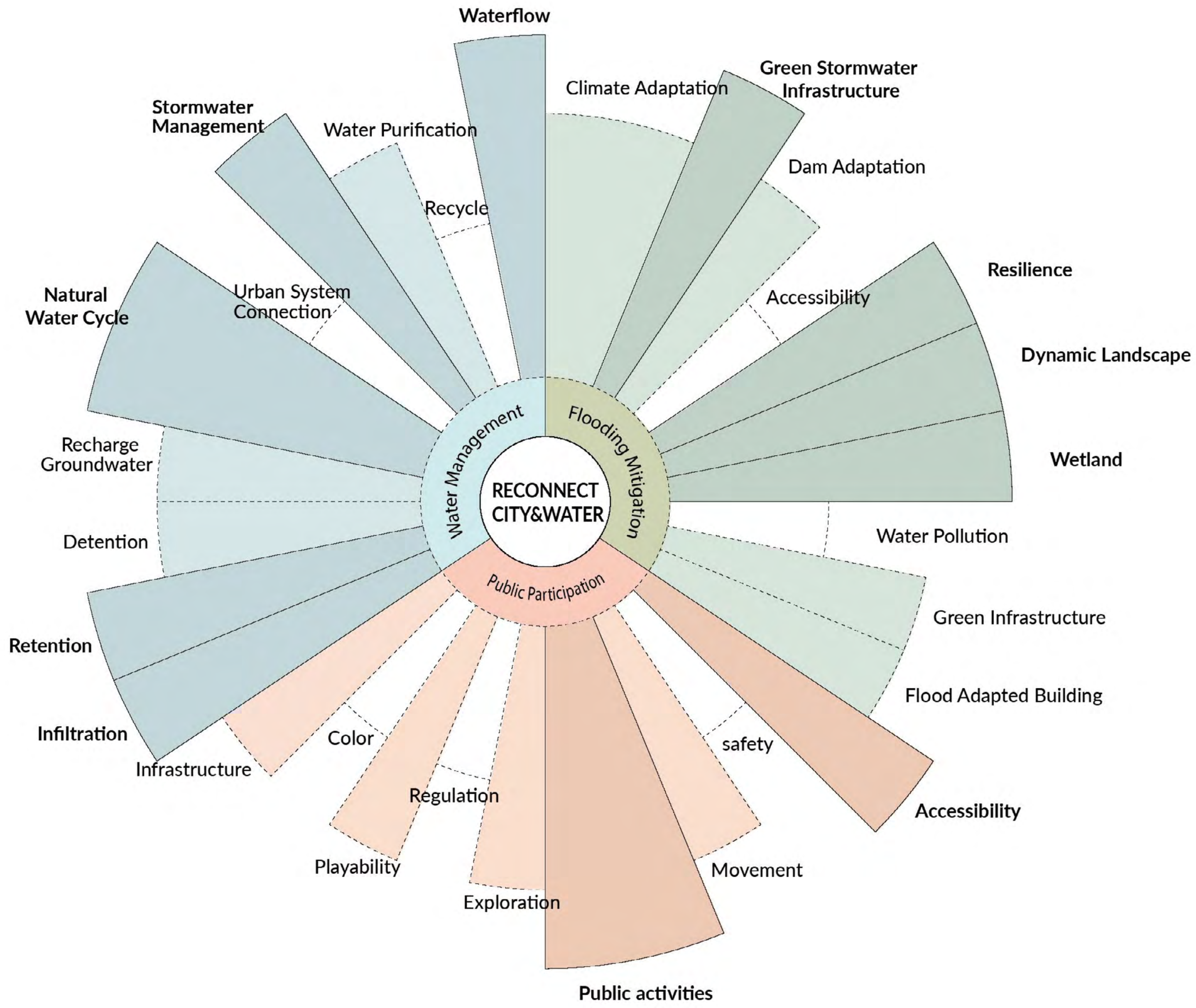
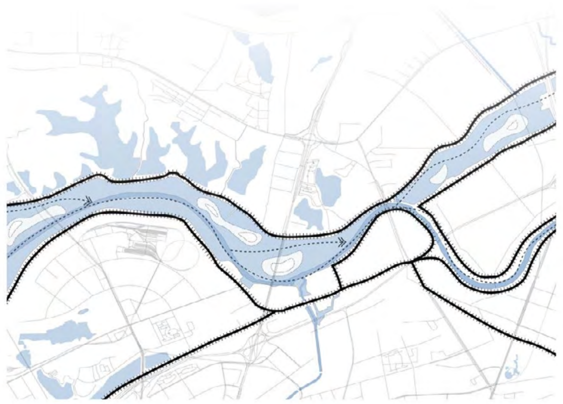


Figure 13: Delimitation Diagram



ANALYSIS

About Context

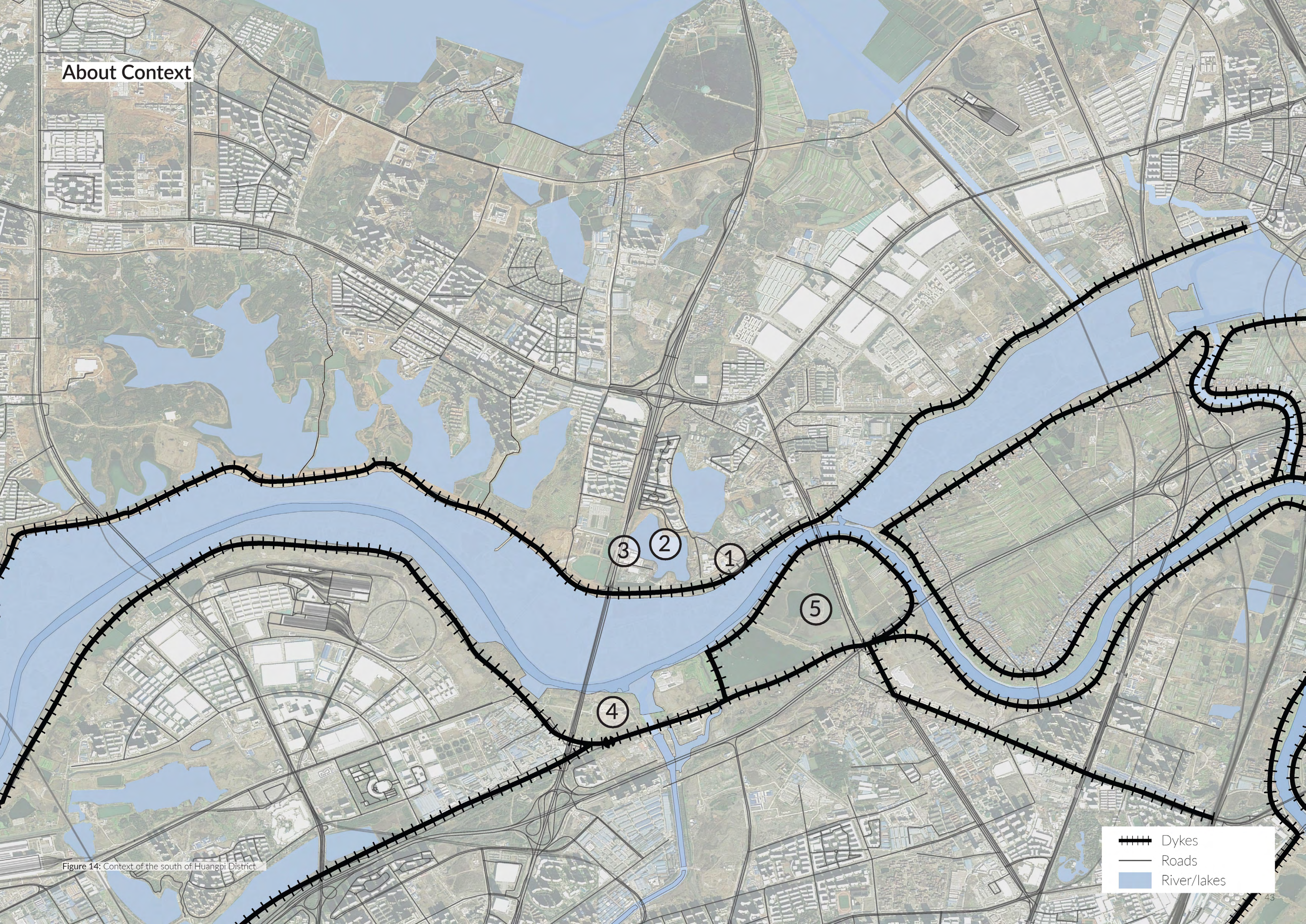


Figure 14: Context of the south of Huangpi District

Dykes as barriers (current)

For this area, the barrier of dykes should be reflected from both ecological and human perspectives.

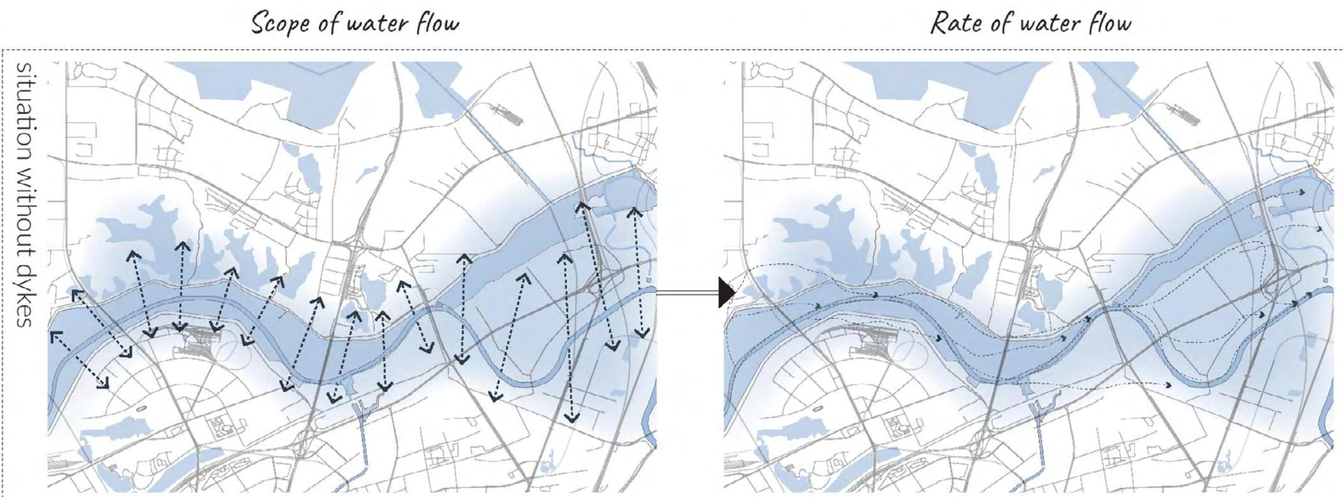


Figure 15: Ecological situation without dykes

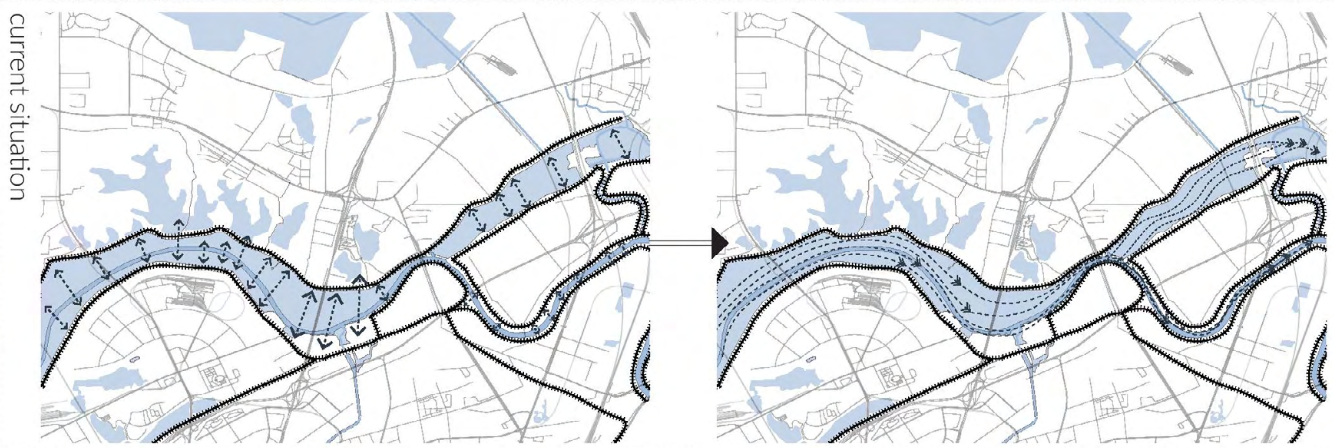
Restore & Reproduce

Process and outcome of construction of dykes (ecological impacts):

- Firstly, the construction of the dykes has led to a relatively regular and limited borderline of the river, which has also led to the reduction of scopes;
- Secondly, the construction has led to straighten the river channel, heights of the riverbeds become relatively onefold, the hardened banks also faster the flow rate;
- Finally, the limited scopes and faster water flow have led to a loss of natural habitats, which cause the loss of biodiversity.

Restore & reproduce natural habitats:

With the construction of current dyke system, we could still search for the possibilities to restore and reproduce certain natural habitats with the seasonal stormwater and varied water level of river.



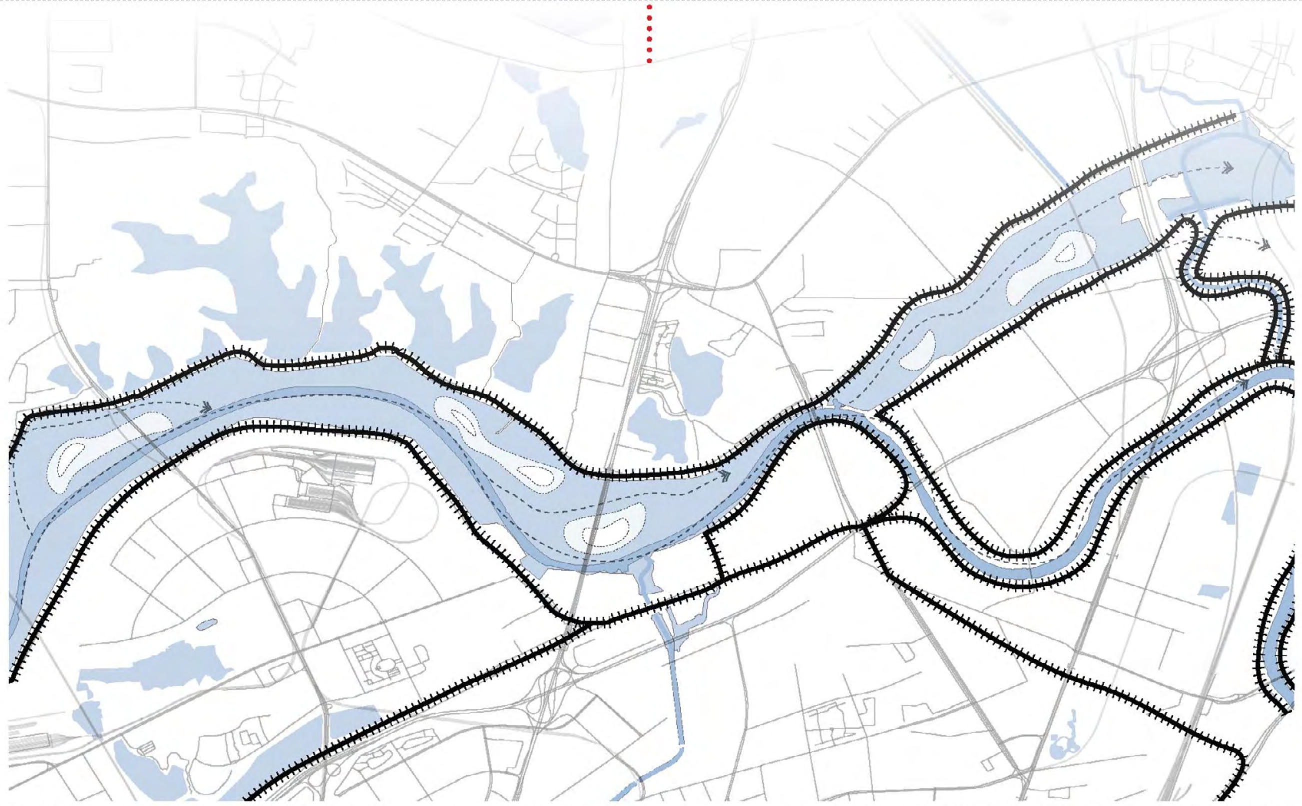
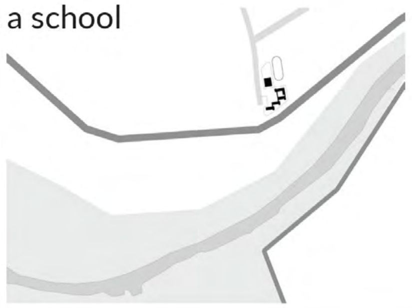
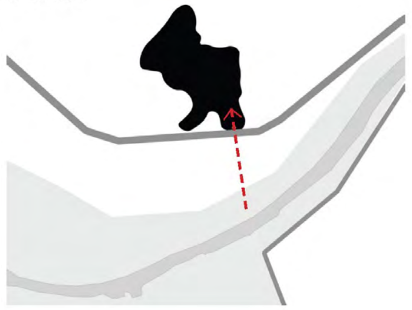
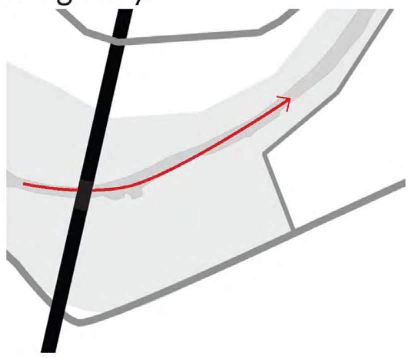
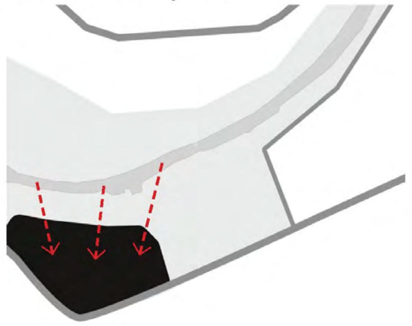
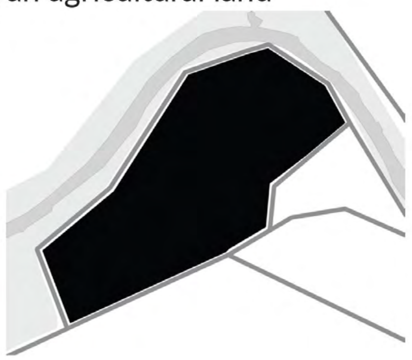


Figure 16: Ecological situation with enclosed dykes

Dykes with surroundings --- **barrier for the public & water**

	water accessibility	public activities	greenery	
① a school 	• enclosed fenses • no direct road to riverbanks • 6-meter height difference to the dyke ○○○○○	• playground • indoor playroom ●○○○○	• few green space • grass land around buildings ●○○○○	
② a lake 	• planned lake park • no direct road to riverbanks ●●●●○	• walking paths • water platforms ●●●○○	• diverse habitats • trees • swamp ●●●●○	
③ a highway 	• few exits to the riverbanks • 4-10 meters height difference to both sides ●○○○○	• 8 driving lanes • walking paths • no crossing on the highway ●●○○○	• Sidewalk trees on both sides of the road ○○○○○	
④ a suburban park 	• attached to one side of dykes • enclosed by dykes • flooded area under extreme raining • ponds ●●●●○	• public square • walking paths • water platforms ●●●●○	• diverse habitats • trees • ponds • swamp ●●●●○	
⑤ an agricultural land 	• enclosed by dykes • no direct road to riverbanks • 4-meter height difference to the dyke • flooded area under extreme raining ●●○○○	• walking paths • agricultural work • storage warehouses ●○○○○	• crops • fishponds • trees ●●●○○	

Related to the surroundings, dykes are not only the barriers for the water to enter the inland, but also the barriers for the public to reach the water and natural greenery. This survey gathered some current situation and simple evaluation for the surroundings that indicates the simple and rude blocking effects of current dyke system.

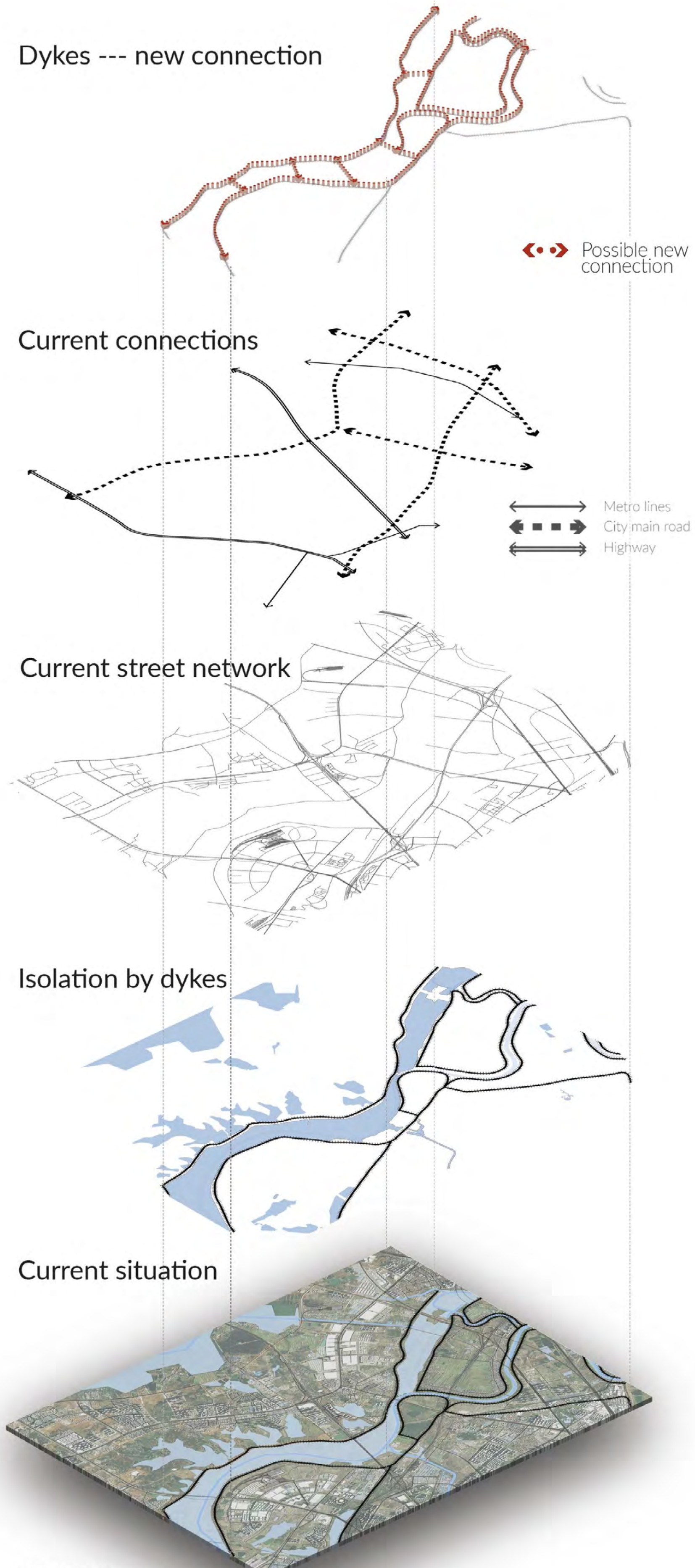
Even though some infrastructures that facing the river (suburban park & agricultural land) are enclosed by dykes, which were virtually flooded under extreme raining.

During the flood season in 2016, the water level of the Fu River rose to 28.2 meters. Under the bridge, a section of the dykes that protect the suburban park breached, measuring more than 20 meters in length, thus the park was severely flooded. The embankment was reinforced and repaired after the flood and the park was repaired and upgraded, then reopened to the public.

Most valuable ●●●●● ⟶ ○○○○○ Less valuable

Figure 17: Dykes with surroundings

Dykes as connector (potential)



- **The revetments of dikes and foundations of bridges** could work for sand retention, also work as habitats and shelters for small creatures and wildlife;
- The continual dykes could work as new connections for **public transportation;**

- The busy traffic of highway limit the possibility for the public to stop and reach the river;
- Current connections take the vehicles as first priority, which indicates the lack of public transportation for the public to reach the river;

- Currently, few metro lines are built across the river that enter the Huangpi district;
- The highway are wide and busy, which is a vital road for the citizens of Huangpi district and center of Hankou ;

- The construction of dykes has changed the original ecological composition of the river, which led to the discontinuity of river and the loss of biodiversity;
- The dykes become barriers for the public to reach the water .

- The process of building the dykes causes inevitably the consequences of discontinuous damage to rivers;
- There are large scopes of green areas on the site, which have great potential for the wildlife.

Figure 18: Connection diagram of context

Provide various ecosystem services

--- Dyke itself working as a new connection

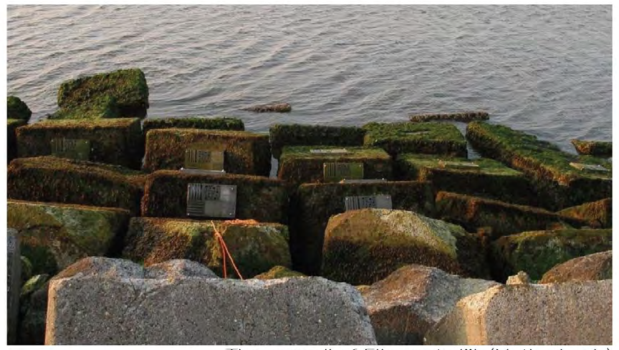
Creating rich revetments

Enriching revetments comprises small adaptations in texture, form, and material of hard structures in intertidal and underwater landscape that create habitat and support biodiversity (Ecoshape, 2020).

Designing and optimizing the dyke revetments are effective ways to make them more suitable as habitats for different plants and animal species. Examples include the use of varied kinds of rough gravel instead of smooth concrete and the construction of tidal ponds. Both provide additional habitat and/or shelter for algae, succulents, sponges, crabs, and juvenile fish. In addition, different concrete surfaces and combination of seawall blocks provide cracks and spaces that serve as protected habitats. Tidal pods could be complemented on the edge of dykes.

The concept is relatively easy to apply, which does not require much (extra) space, constructive techniques, or additional maintenance. Besides, enriching revetments with water-adapted vegetations can provide an extra service, such as water quality improvement.

Even though these spaces above revetments are narrow and limited, they can allow seaweed, seagrass, coral and other organisms to settle down and grow, which could become attractive food source for shellfish, fish and birds, thus promoting biodiversity and sustainability.



The seawall of Ellewoutsdijk (Netherlands)

Eco-concrete structures – IJmuiden (Netherlands)

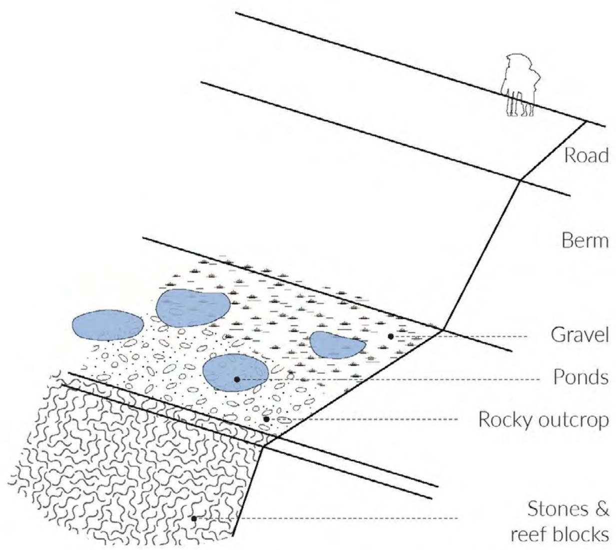


Figure 19: Example of enriching the dyke revetments

Rethink the Traditional Dykes

Creating multifunctional flood defences

Multifunctional Flood Defences (MFD) is a newly developed concept to optimize allocation of urban space rather than constructing stand-alone dikes. Multifunctional Flood Defences are flood defences that combine the function of flood protection with other functions. In addition to flood protection, multi-functional flood protection fulfils functions like housing, recreation, commercial buildings, ecology, mobility and transport, underground infrastructure and is a functional part of the urban or rural environment. There are various forms of multifunctionality included in the body of a dike or around it, to optimize allocation of space (Marlien, 2013).

For example, a dyke with a road on the top is a multifunctional flood protection facility (current situation of dykes in Wuhan). Houses with water retaining walls and parking lots are other examples. In order to be functional and working as flood protection, these structures must be part of a whole flood protection system, with strict requirements of construction.

A research program of the Dutch Technology Foundation STW investigated the integrated and sustainable design of multifunctional flood protection facilities. New principles for risk assessment methods were developed and multifunctional and flexible flood protection techniques were integrated into the development of urban and rural landscapes.

"We rethink the traditional Dutch dike and come up with a method to score and value different dike configurations based on six parameters: level of safety; ability to control; extendibility; space occupation; barrier effect; possibilities for multifunctional use." These parameters represent technical and spatial criteria that, which also indicates that there is no common best solution. We need to take different parameters into consideration for each situation.

Combining flood protection with other functions is an interesting option, especially the existing flood protection facilities conflict with other functions. Such as the dykes in Wuhan, road in top makes it hard to add housing as new function.

In addition, multifunctional flood protection facilities can be a relevant option in ongoing urbanization where more space is needed.

" One dyke, One road, Two forests "

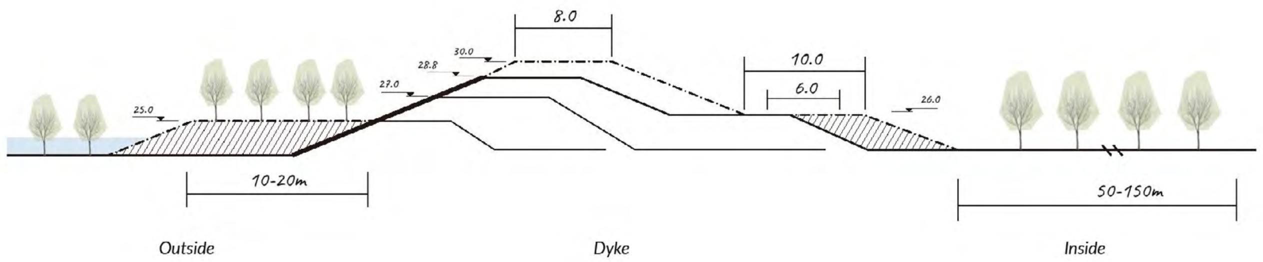


Figure 20: Section of dykes in Wuhan

New dyke system --- examples of new connections

Continual dyke system

- **public transportation**

current dyke systems with possible new connections could form a continual and circular route for public transportation, such as bus lines and metro lines;

- **bike lanes**

possible new connections aim to connect major roads in both riverbanks, which could create a attractive and interesting bike route for the public and residents.

- **devices for water retention (habitats)**

The revetments of dikes and foundations of bridges could work for sand retention, also work as habitats and shelters for algae, polyps, sponges, crabs and juvenile fish;

Adding devices to foundations of bridges could work as new habitats for the wildlife.

Multi-functional dykes

- parking lots
- recreation
- water filtration
- underground infrastructures
- passage of vehicle
- public buildings

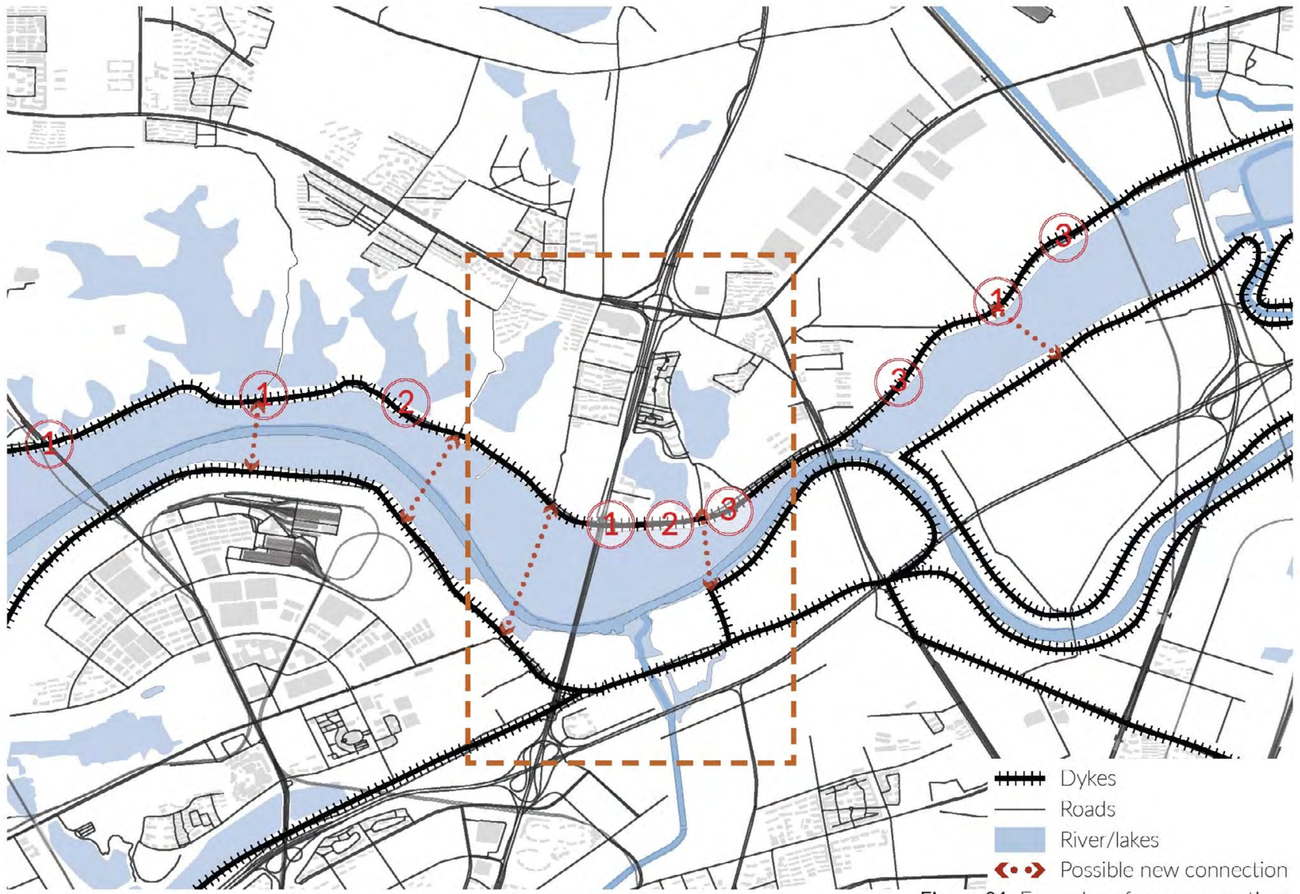
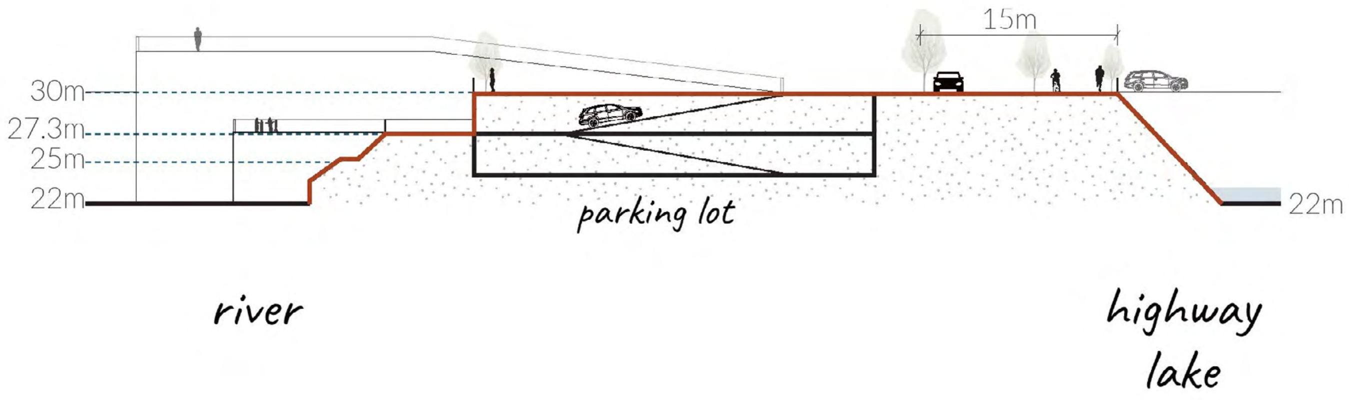
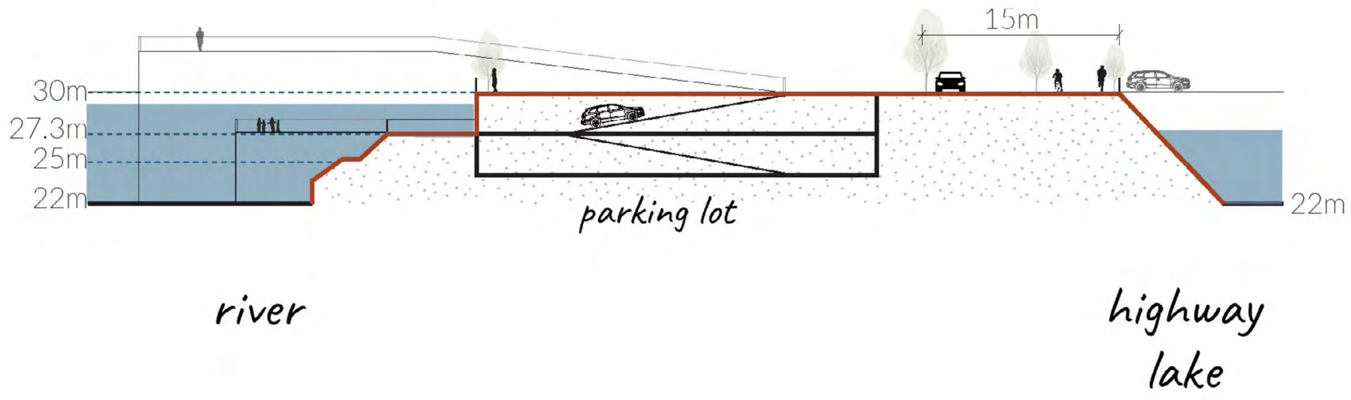


Figure 21: Examples of new connections

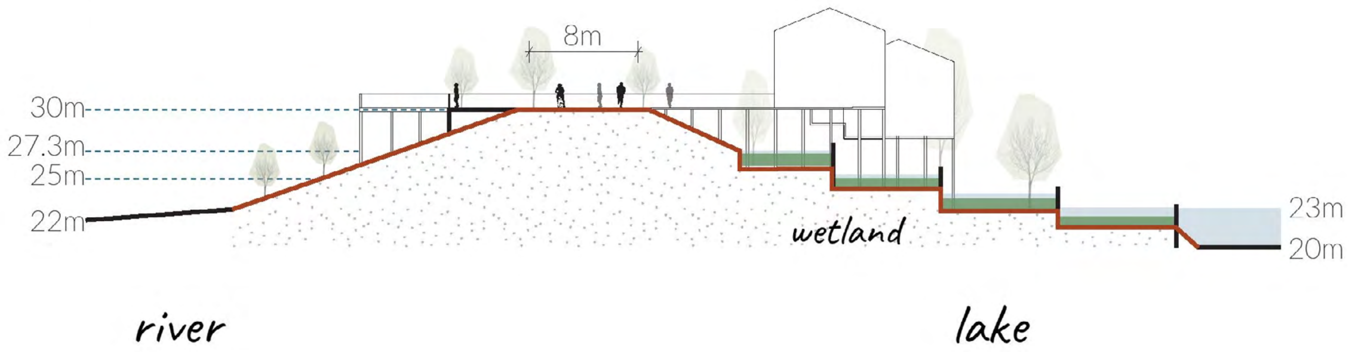
Section types of connection

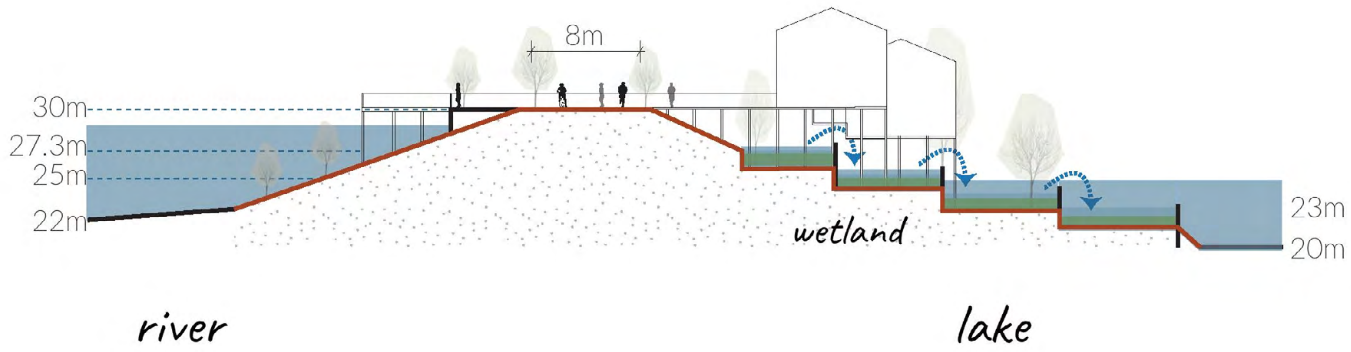
1 • Dykes close to highway



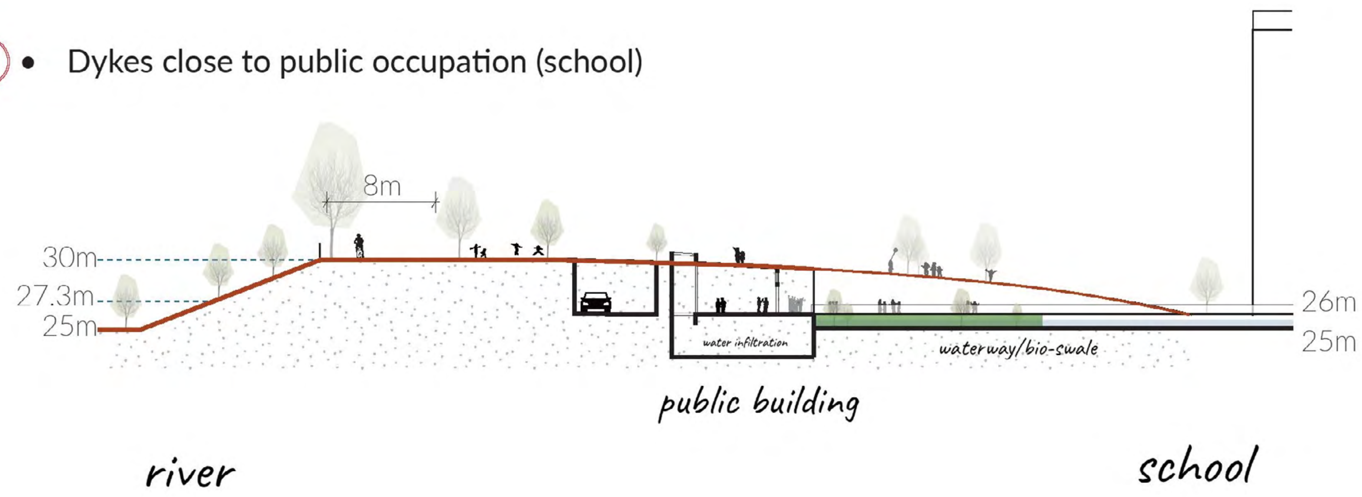


2 • Dykes close to lakes





3 • Dykes close to public occupation (school)



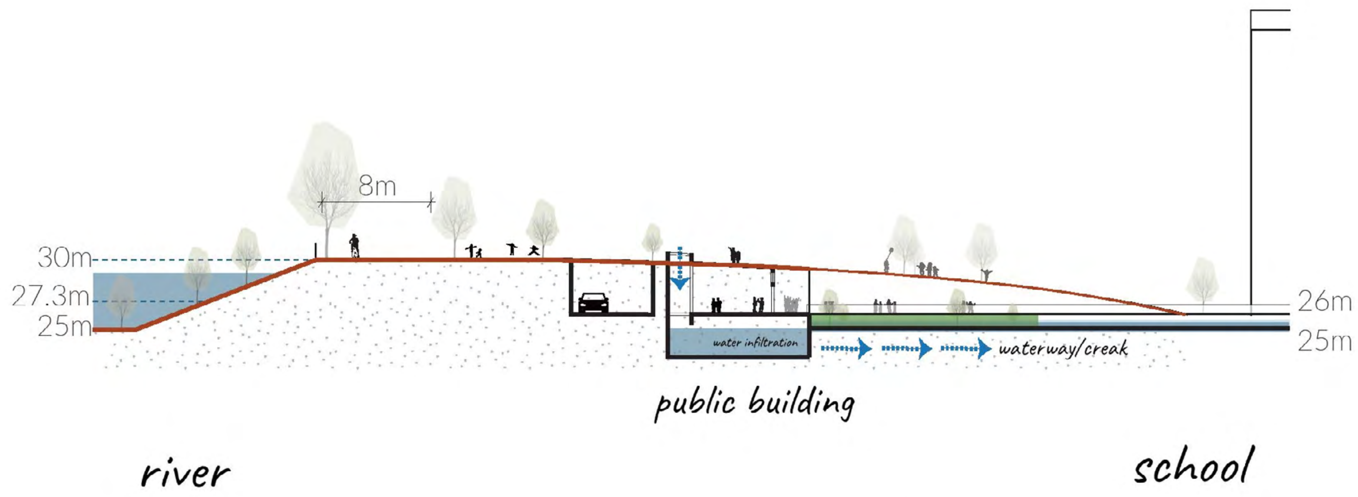


Figure 1: Section examples for dayke adaptation

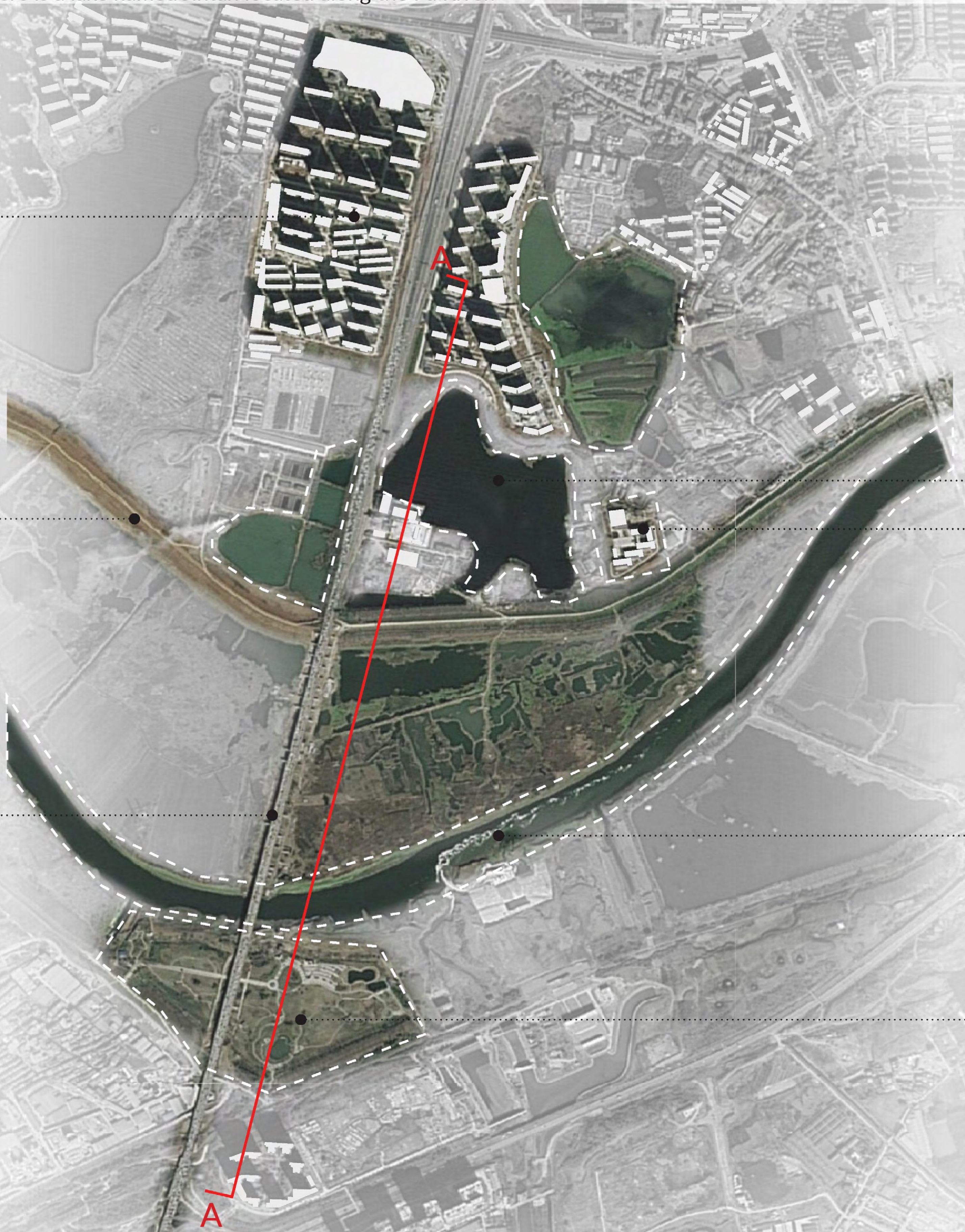
Site Situation

The project is located in the north of Hankou by the Fu River, adjacent to the Dai Huang Expressway to the west, residential areas to the north, the Fu River and Minsheng Dyke to the south and Dao Guanquan West Road (planned road) to the east. There is a lake named Jintan located along the Fu River.

Residential buildings 18F

Minsheng Dyke

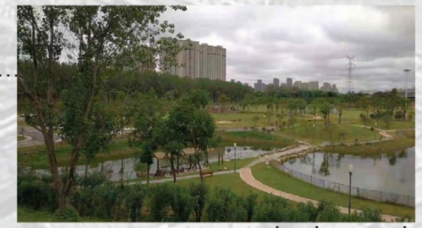
Daihuang Expressway
Bridge of Fu River



Preserved lakes

Jintan Primary school

Fu River



suburban park

Figure 22: Context for the south of Huangpi district

Current section of levees

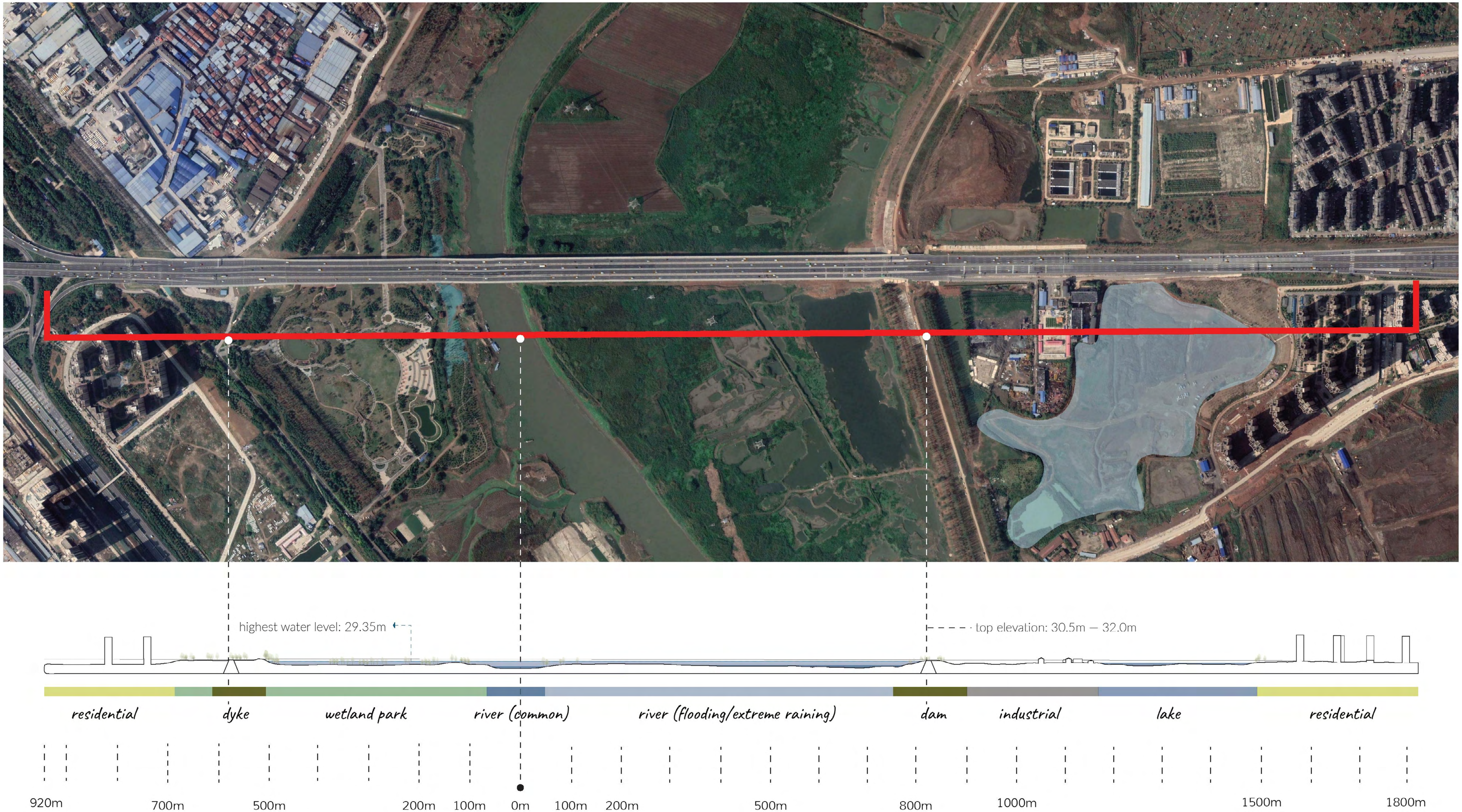


Figure 23: Current section of levees

Scenarios of the relationship between city & water

Levees as main parameter

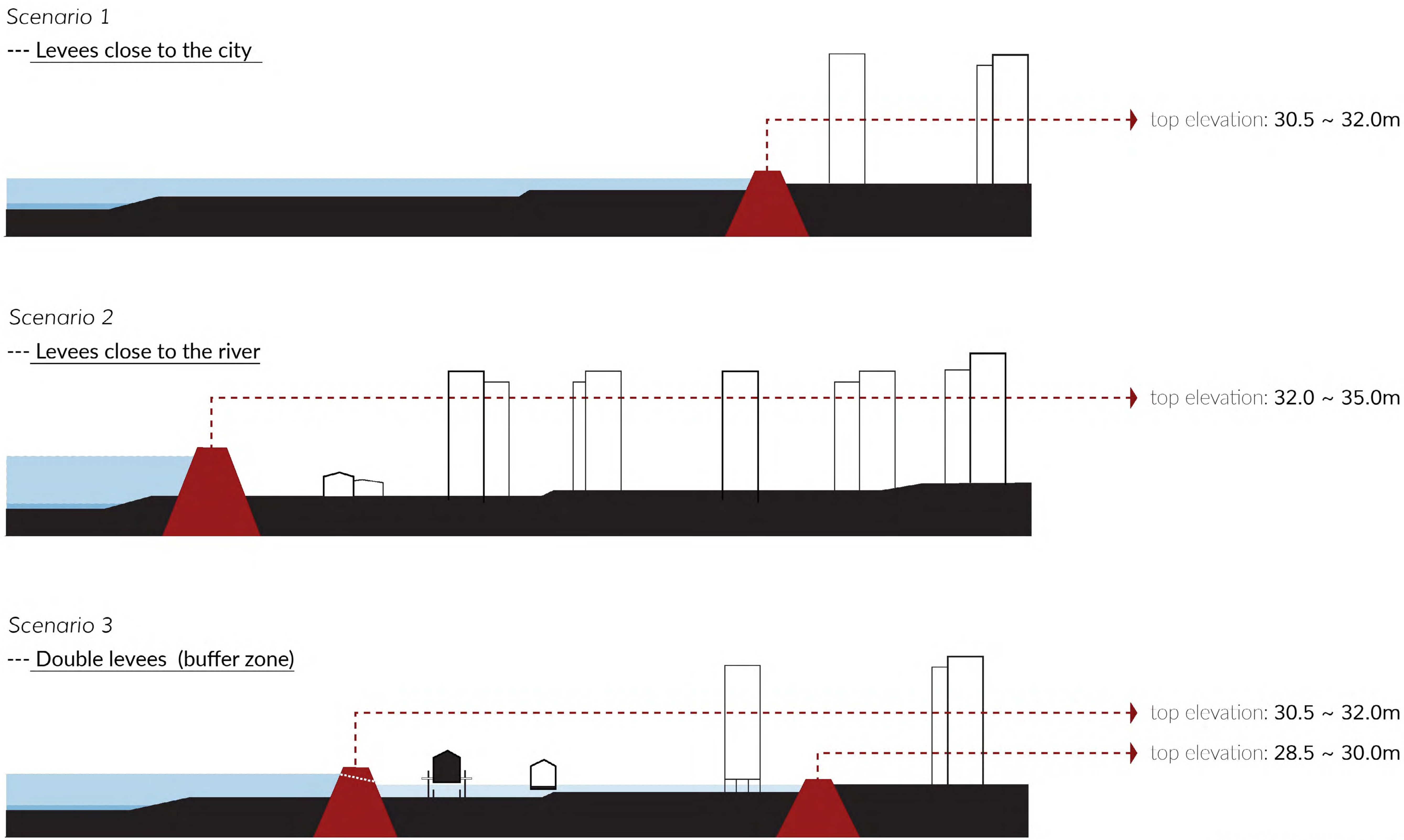


Figure 24: Scenarios for varied location of levees

Scenario 1 --- Levees close to the city

Strength

- more riverbed areas reamin natural conditions
- lower the rate of water rising
- lower the water level under extreme raining
- relieve certain pressure on the dykes

Weakness

- more riverbed areas suffer from the considerable fluctuation of water level
- less area could be constructed for urban devel-opment
- the city and water still remain unconnected

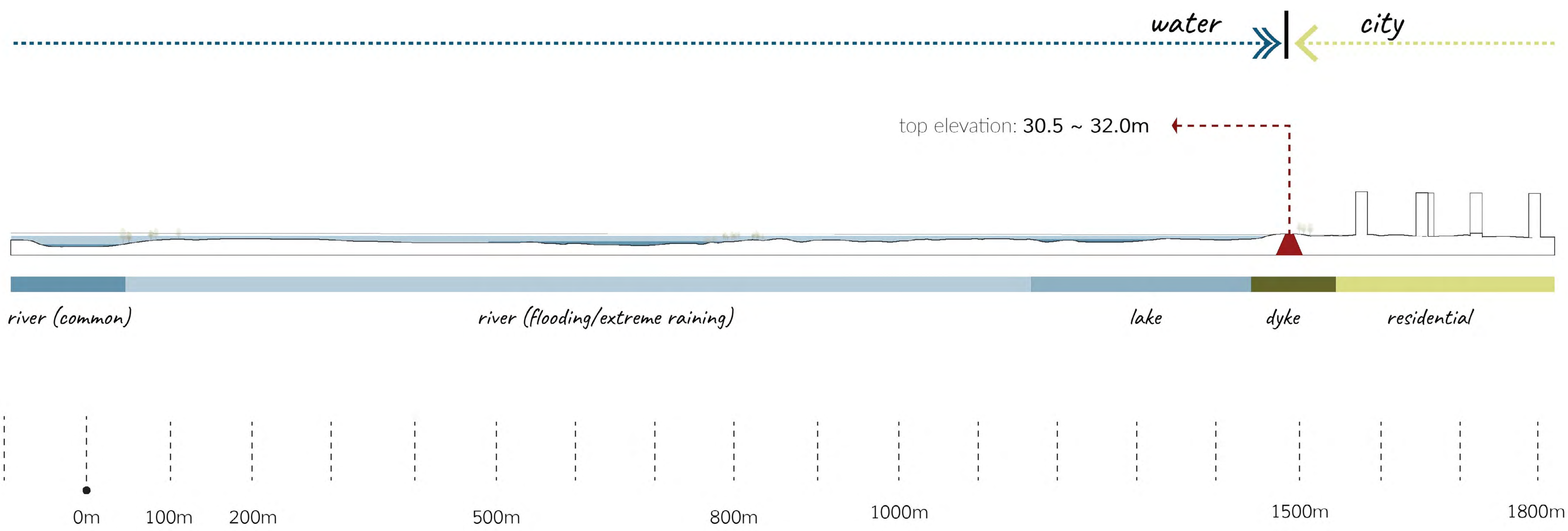


Figure 25: Section of scenario 1

Scenario 2 --- levees close to the river

Strength

- less riverbed areas suffer from the considerable fluctuation of water level
- more area could be constructed for urban development

Weakness

- less riverbed areas reamin natural conditions
- the rate of water rising will increase
- the water level under extreme raining will increase
- bring more pressure on the dykes
- higher dykes need to be constructed and reinforced
- the city and water still remain unconnected

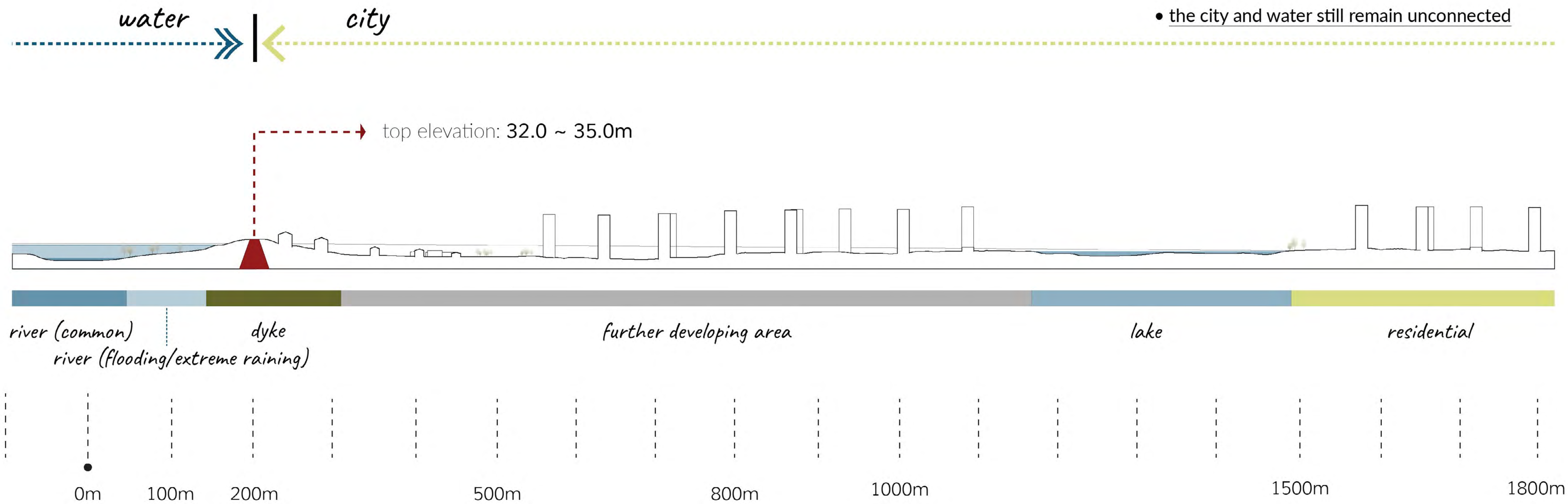


Figure 26: Section of scenario 2

Scenario 3 --- Double levees (buffer zone)

Strength

- add certain areas for water storage
- less riverbed areas suffer from the considerable fluctuation of water level
- relieve certain pressure on the dykes
- more area could be constructed for urban development
- experiencing water is possible in urban areas
- connect the city and water in a resilient way

Weakness

- cost more on construction and maintenance of flood-proof buildings

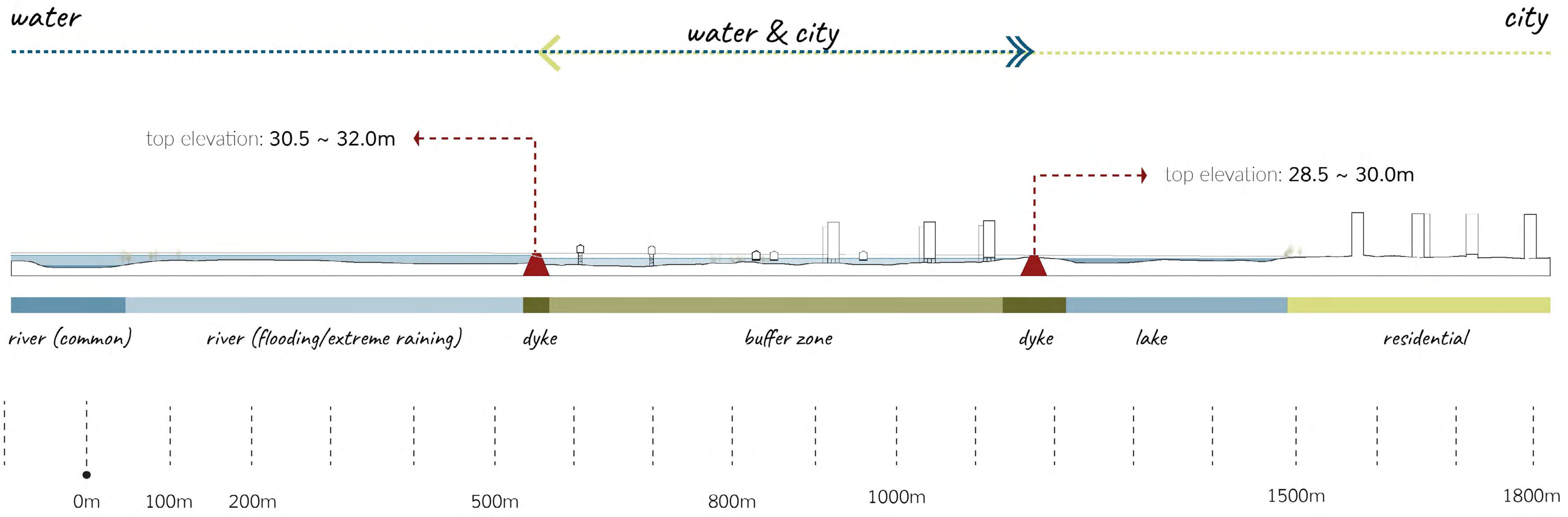


Figure 27: Section of scenario 3

Develop double-levee systems

Flooding Mitigation

Double-levee systems

Double-levee systems provide ecosystem benefits while resisting water surge. The frontal dyke/levee is designed for periodic over washing, while the inner dyke/levee provides an additional barrier to prevent inland flooding. The expanded foreshore condition slows seepage between water and land and creates new and differentiated habitats in the widened shore landscape that in turn can deliver various ecosystem services. (Ecoshape, 2020).

Due to the construction of secondary dykes, the primary defense can meet lower safety standards, which indicates that the main dyke does not have to be raised endlessly. In addition, under extreme high level of water conditions, the double levee system allows certain zones to be flooded, as the secondary dykes will prevent water from flooding the land behind the secondary dykes, which is profitable to save the cost of construction and maintenance for dykes, especially under unpredictable climate changes. Moreover, a limited overflow can be allowed, which could form dynamic landscape in different seasons. Depending on the levels of rising water, the area between the dykes could occasionally be flooded, which determines the variation of land us, as well as the diverse vegetation.

The area between the dykes may not be suitable for high quality land use for housing, but could be used for nature and recreation.

The water retention area with shallow ponds provides valuable places for birds to feed, roost and nest. Particularly at times of high water level, birds will seek out their food here. This natural environment enclosed by dykes also provides opportunities for recreation, such as walking and cycling along the dykes, as well as observing many different types of birds for bird watchers.

Buffer zones

A zone along the banks in between dykes/levees is called as a buffer zone. Historically these areas arose when people built a spare inner dyke parallel to the defense when there was a threat of dyke failure (Ecoshape, 2020).

Buffer zones and retention areas create capacity to hold stormwater surpluses in cities (Ecoshape, 2020). Buffer zones on large scales could serve as an alternative to pumping and drainage systems, small-scale buffers can provide valuable ecosystem services to the surrounding communities as well as the wildlife.

Large fluctuations in water levels on the buffer zones should be taken into consideration in advance. Connected to regional water systems, the buffer zones could act as a climate buffer, water levels would be managed in such a way that the area can letting water in when there is excess water and releasing water when lacking of water supply, thus forming a more dynamic water system. Moreover, certain area with permanent water (retention ponds) should always be maintained to prevent the loss of biodiversity and living conditions.

Surface water required to be clean and in good ecological condition could provide suitable habitats for the creatures. Good water quality is also important to allow recreational use of the water and form a great living environment (Ecoshape, 2020). Therefore, the design for buffer zones should consider the possibility of acting as a bio-filter to improve water quality (such as the wetlands and bio-swales), which is considered necessary for multiple land use.

In addition to the ecological benefits of natural habitats, buffer zones could provide more opportunities for the citizens through recreational services, such as open space (squares), fishing, swimming, floating development and terp structures, which depends on the desires of stakeholders.

Creating secondary channels & Bioswales

Secondary channels are constructed by profiling the channels through the land and by inserting specific flow or ecological enhancing structures (Ecoshape, 2020).

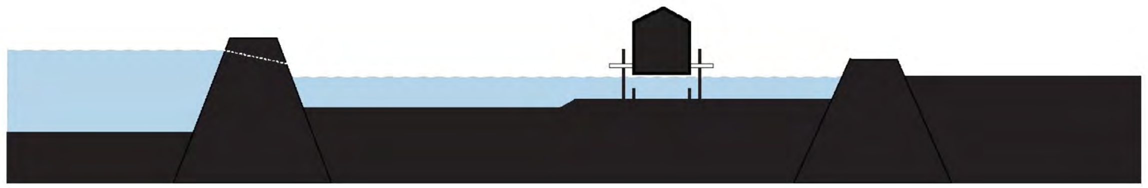
Secondary channels could increase the flood conveyance capacity of rivers and support habitat development, while offering opportunities to enhance the natural, recreational, and cultural value of the river landscape. Combined with the strategy of bioswales, the channels could also serve as bio-filters for the water flow. (Bioswales are landscape elements designed to remove silt and pollution from surface run-off water. They consist of a swaled drainage course with gently sloped sides (less than six percent) and filled with vegetation, compost and/or riprap.)

The water's flow path, along with the wide and shallow ditch, could be designed to maximize the time water spends in the swale, which aids the trapping of pollutants and silt. Depending upon the geometry of land available, a bioswale may have a meandering or almost straight channel alignment. Biological factors also contribute to the breakdown of certain pollutants.

Toolbox

Water-adaptable Structure --- *large degree of human intervention*

Amphibious structure



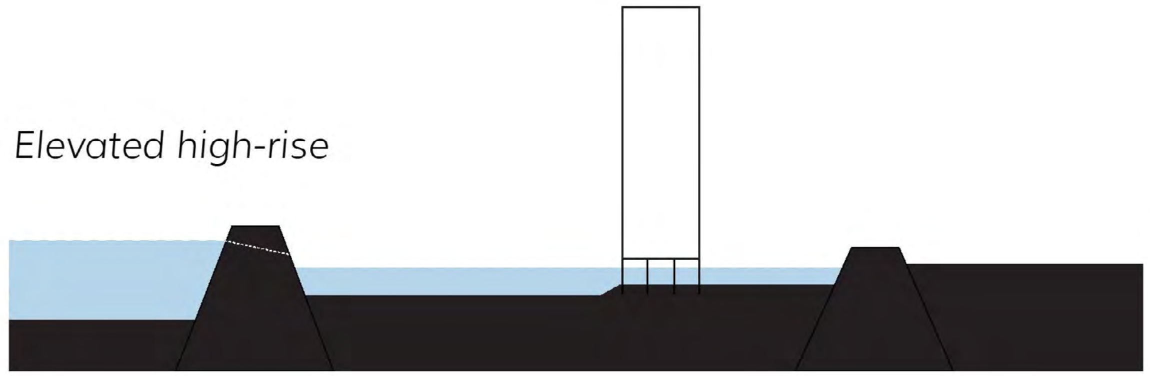
Waterside structure

Dyke structure

Pile structure

Floating structure

Elevated high-rise



Terp structure

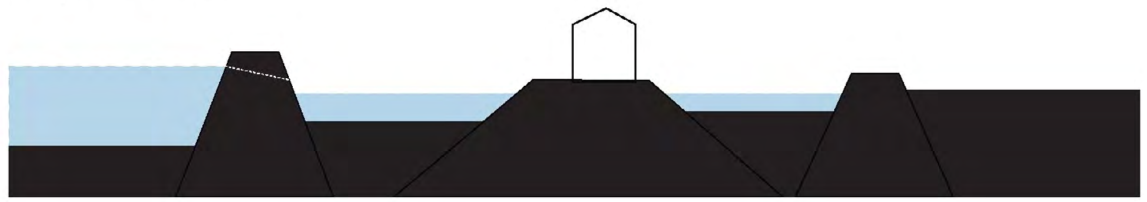
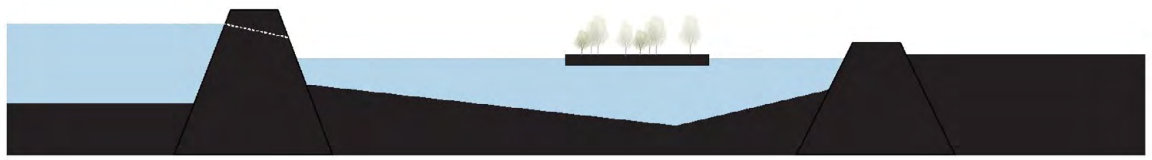


Figure 28: Toolbox of hard construction on buffer zones

Water-adaptable Structure --- *less degree of human intervention*

Riverside platforms

Lake



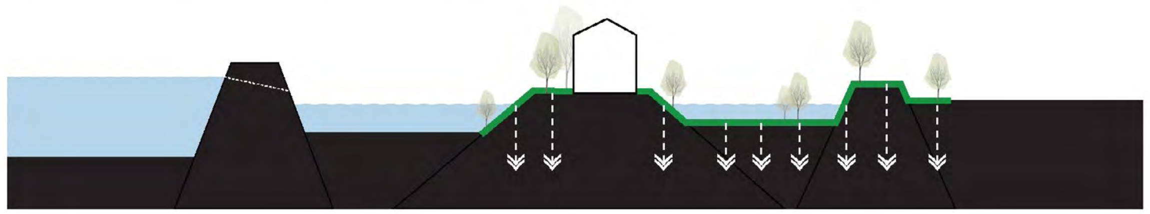
Bridge

Wetland

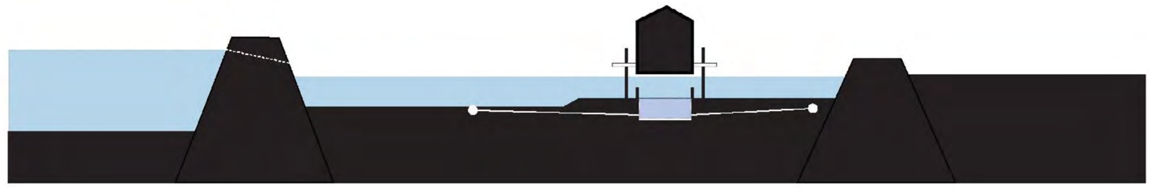
Figure 29: Toolbox of light construction on buffer zones

Water management

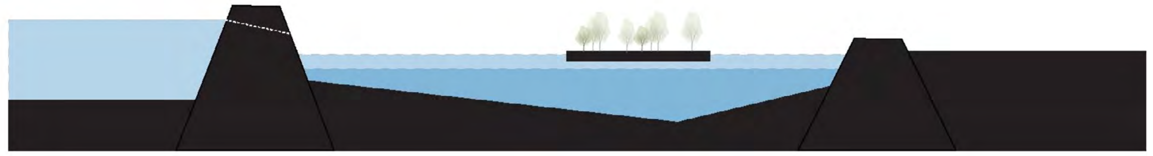
Green surface - water infiltration



underground storage - water detention

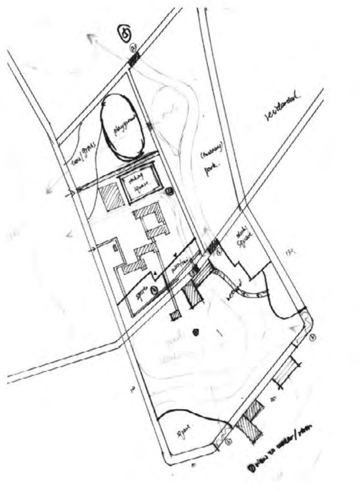


Lake - water retention



Wetland - water filtration

Figure 30: Toolbox of water management on buffer zones



DESIGN

Water Flow

--- Guidance for the design

Current Situation

- No direct connection between the city and water;
- the river and lakes working for water storage under flooding situation;

- the waterflow remains onefold and same direction under different seasons;
- single system working for flooding resistance (dyke & pumping station).

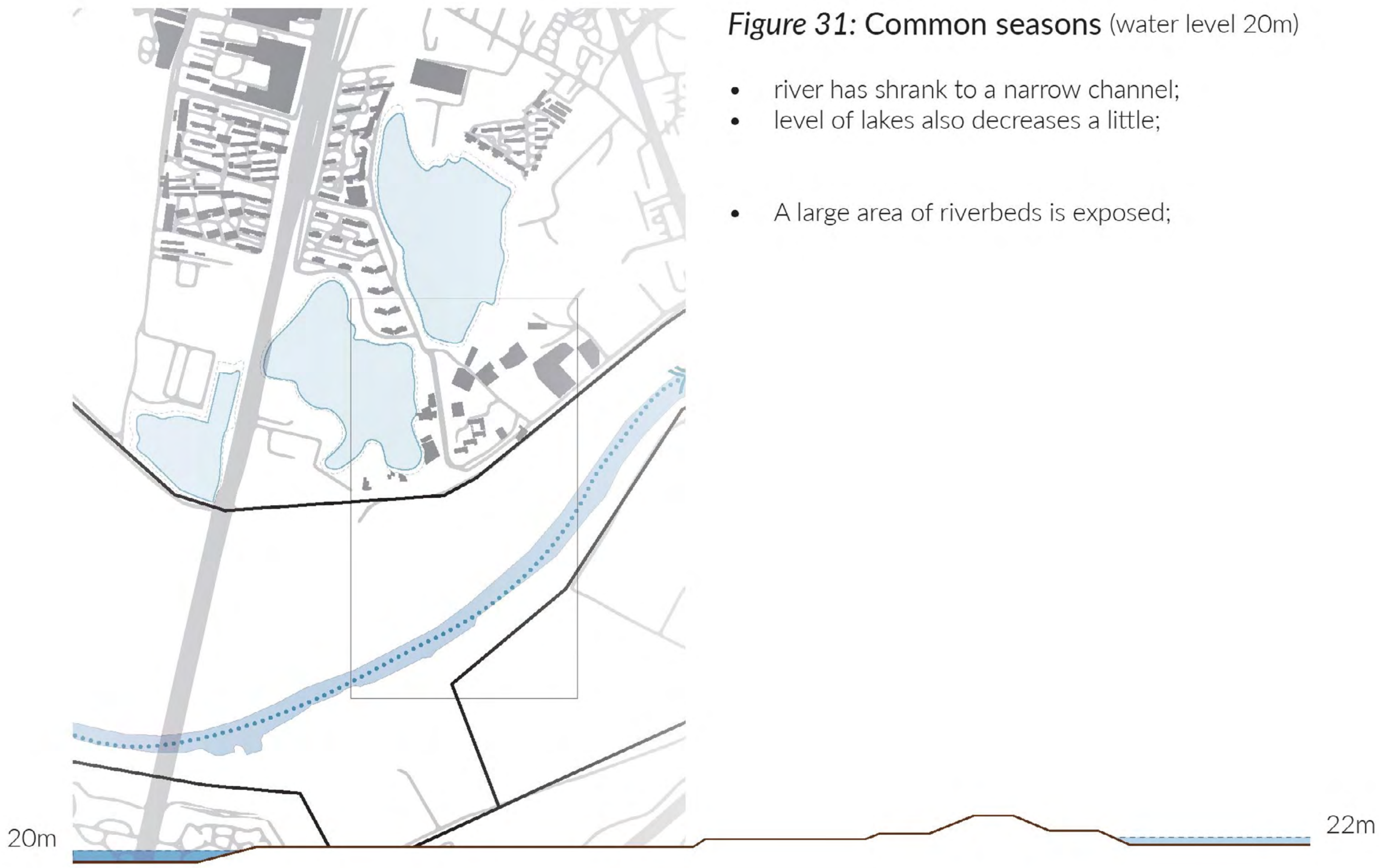


Figure 31: Common seasons (water level 20m)

- river has shrank to a narrow channel;
- level of lakes also decreases a little;

- A large area of riverbeds is exposed;

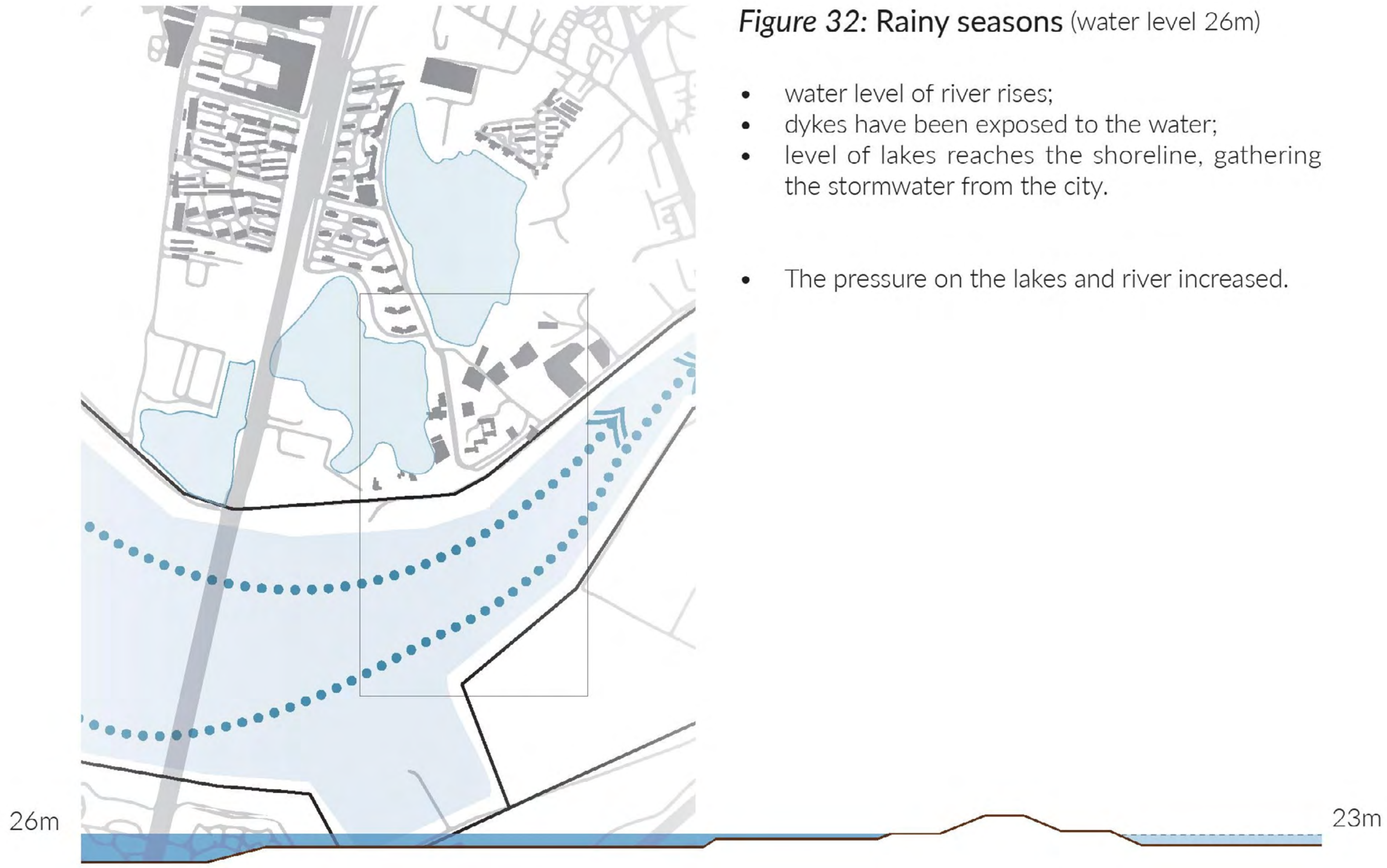


Figure 32: Rainy seasons (water level 26m)

- water level of river rises;
- dykes have been exposed to the water;
- level of lakes reaches the shoreline, gathering the stormwater from the city.

- The pressure on the lakes and river increased.

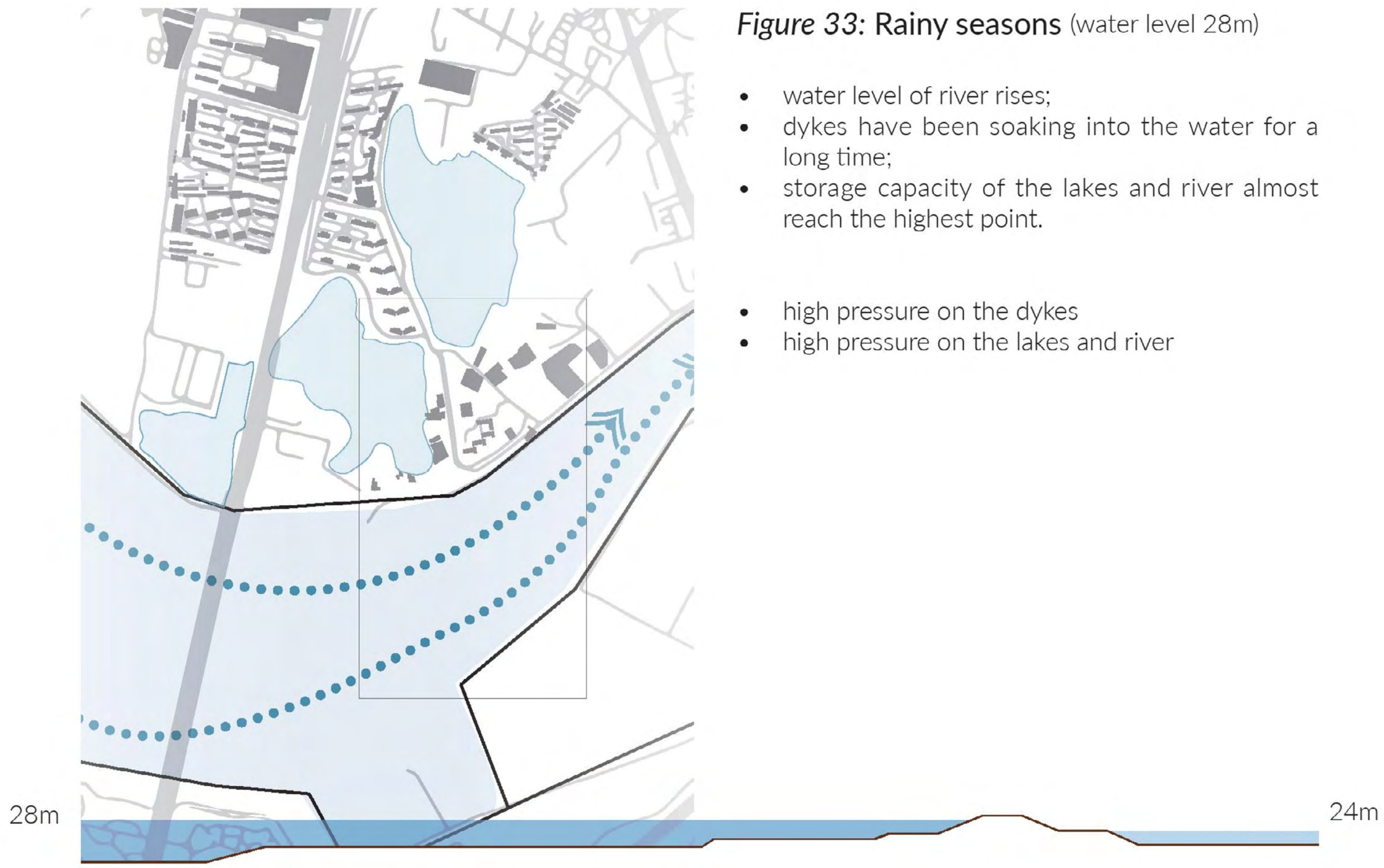


Figure 33: Rainy seasons (water level 28m)

- water level of river rises;
- dykes have been soaking into the water for a long time;
- storage capacity of the lakes and river almost reach the highest point.

- high pressure on the dykes
- high pressure on the lakes and river

Proposal

- New channels for connections to inland lakes;
- connecting the river and buffer zones to reproduce the natural water spreading;

- management, control, and guidance of the waterflow
- complex system working for water storage and release.

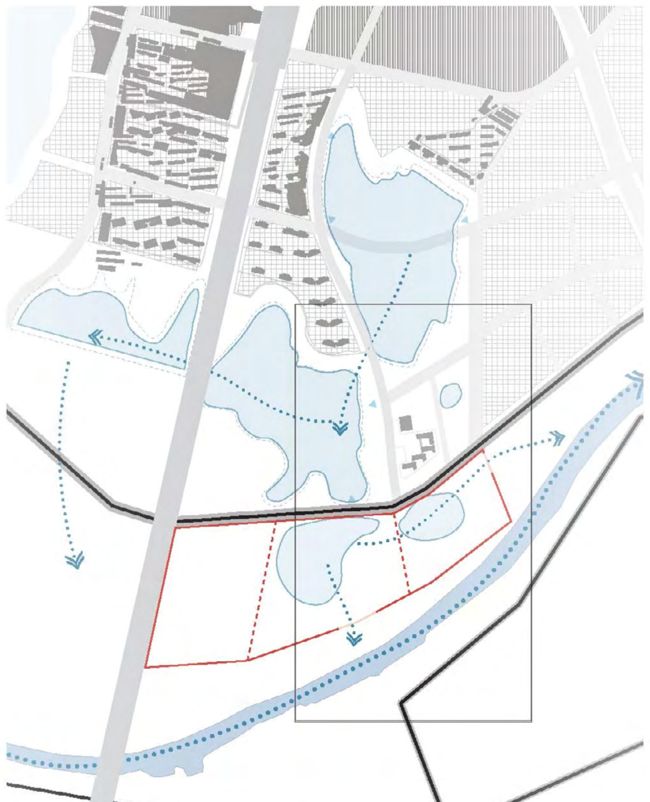



Figure 34: Common seasons (water level 20m)

- lakes could storage common rainfall;
- rainwater could be gathered and filtrated by the wetlands on buffer zones;
- river could be complemented by the inland lakes and ponds;

- Create more habitats on the former riverbeds;
- Improve water retention.

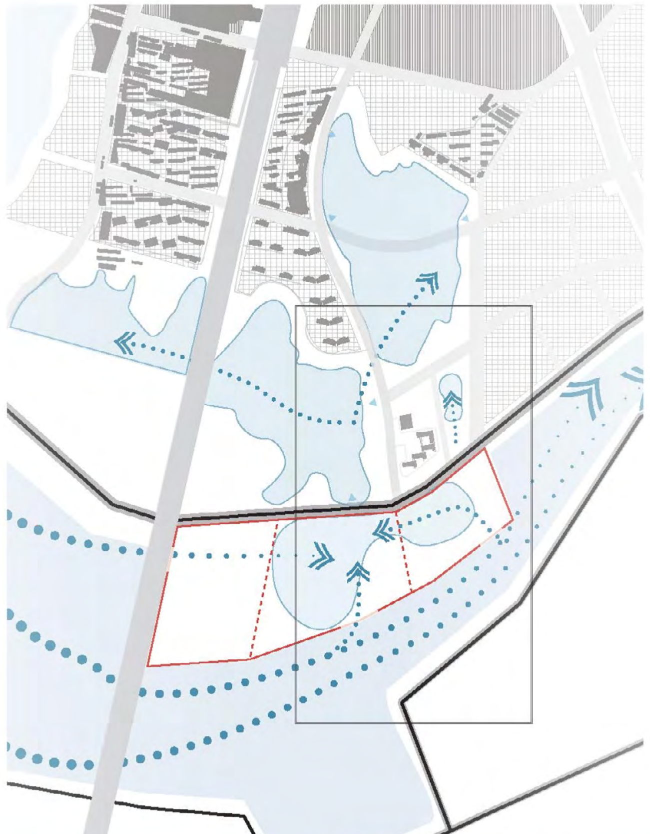



Figure 35: Rainy seasons (water level 26m)

- water start to enter the buffer zones through several breaches of the dykes;
- more channels appear with the ingoing water;
- vegetation and ponds could decrease the peak flow while filtrating the water.

- water level of river rises slower than before;
- buffer zones work as a calm room for the storm water to ensure certain public accessibility;
- lakes, buffer zones and river work together for flooding mitigation.

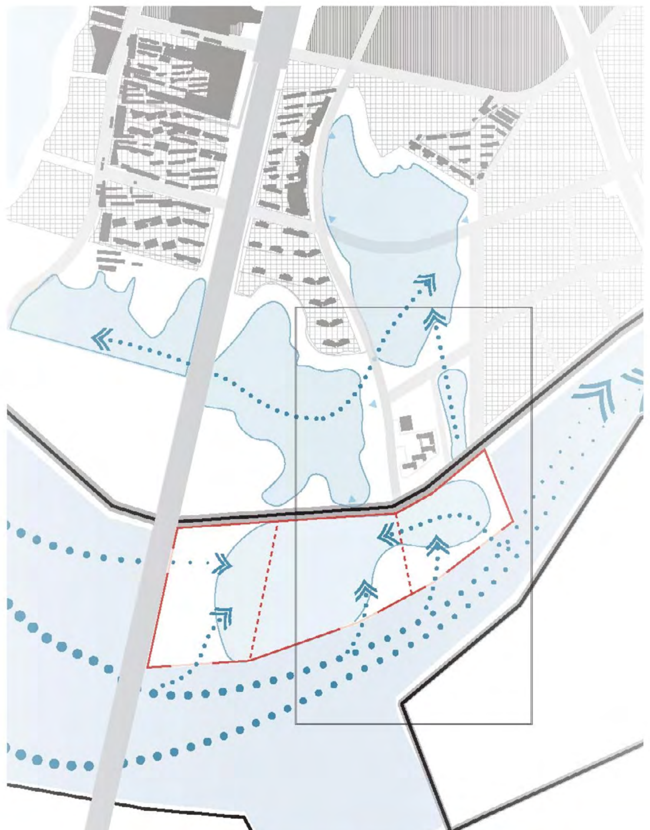



Figure 36: Rainy seasons (water level 28m)

- more higher breaches start to work for the ingoing water;
- more channels appear to transit the water;

- buffer zones work as another large water storage facility while remaining certain accessibility for the public;

Current Situation & Planned Landuse

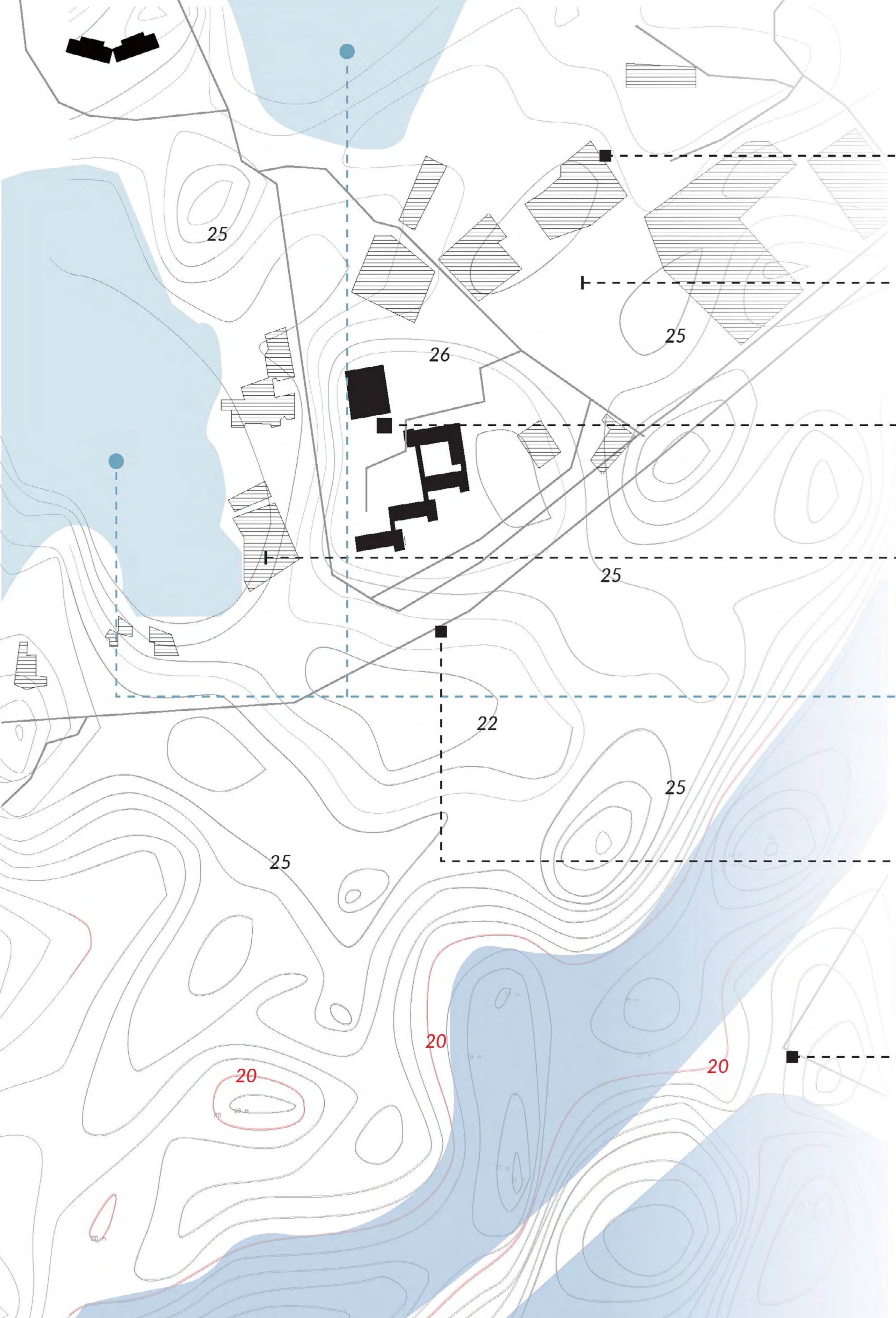


Figure 37: Current situation

Figure 38: Planned landuse

Soil Management

Move & Reuse

Renovation Project of Lakes

The "Urban Area Lakes Protection Plan in Wuhan (2004–2020)" was approved in March 2005 to protect the 38 urban lakes, both Jintan and Xisai lakes are involved in this project.

The program aims to protect the lake and control further deterioration of the water quality and ecology of the lakes, so that the morphology of the lakes is largely controlled, and the water area does not continue to be eroded.

The main function now is farming and storage (collecting and discharging rainwater), after the renovation the storage function will remain and become a recreational park for the surrounding residents.

The transformation process is similar for both Jintan Lake and Xisai Lake, which are divided into two phases. First construction includes lake dredging, shoreline redefinition, landscape works and ecological drainage system. The second phase of construction will focus on the demolition area along lakes. Jintan Lake would be renovated antecedently, the Xisai Lake would start after clearing the silt in Jintan Lake.

The basic process of renovation is as follows:

- Dredging (water is pumped into Xisai Lake and the Fu River, and then transported the silt away when the lake is dry, which is why Jintan Lake was renovated before Xisai Lake)
- Renovation of the lake shoreline (total length of 2,432m, most of the area is natural grass slope)
- Landscape construction

Reuse of the Silt

The renovation process for Jintan lake started since 2019. As seen in the December 2019 satellite image above, the lake has been pumped clean and dredging, work for lakeshore remediation is underway, which actually left a large pile of silt.

While dredging the lakes, the silt could be dehydrated and solidified to be conducive for later resource utilization. After certain process, the silt could be the main source for the foundation of new dykes in this project, which could reduce the cost of soil and transportation. In addition, reusing the silt could promote recycling for sustainable development.

As the project develops, digging process of the deep ponds for water retention could also provide certain amount of soil for the construction.

Children's Participation

Water & Children

--- Relate to Jintan Primary School

- Nature could influence adults and children in a good way. For children, it has better influence than adults. Trees and flowers could attract insects followed by birds. This would never happen in a garden with artificial lawn. Children could interact with the plants, insects, and birds which they have seen on the books.

- Related to the floods, close observation during the development and process of flooding could provide great educational outcomes. In addition, it is a direct and clear way for the children to see the process and reuse of the water filtration.

Playability

--- outdoors/nature

- blurred boundary could entice the children to go outside and increase their time of outdoor activities.

Education

--- participation/immersiveness

- natural elements would change constantly through days that children will never be fed up with them.

Activities Related to Children

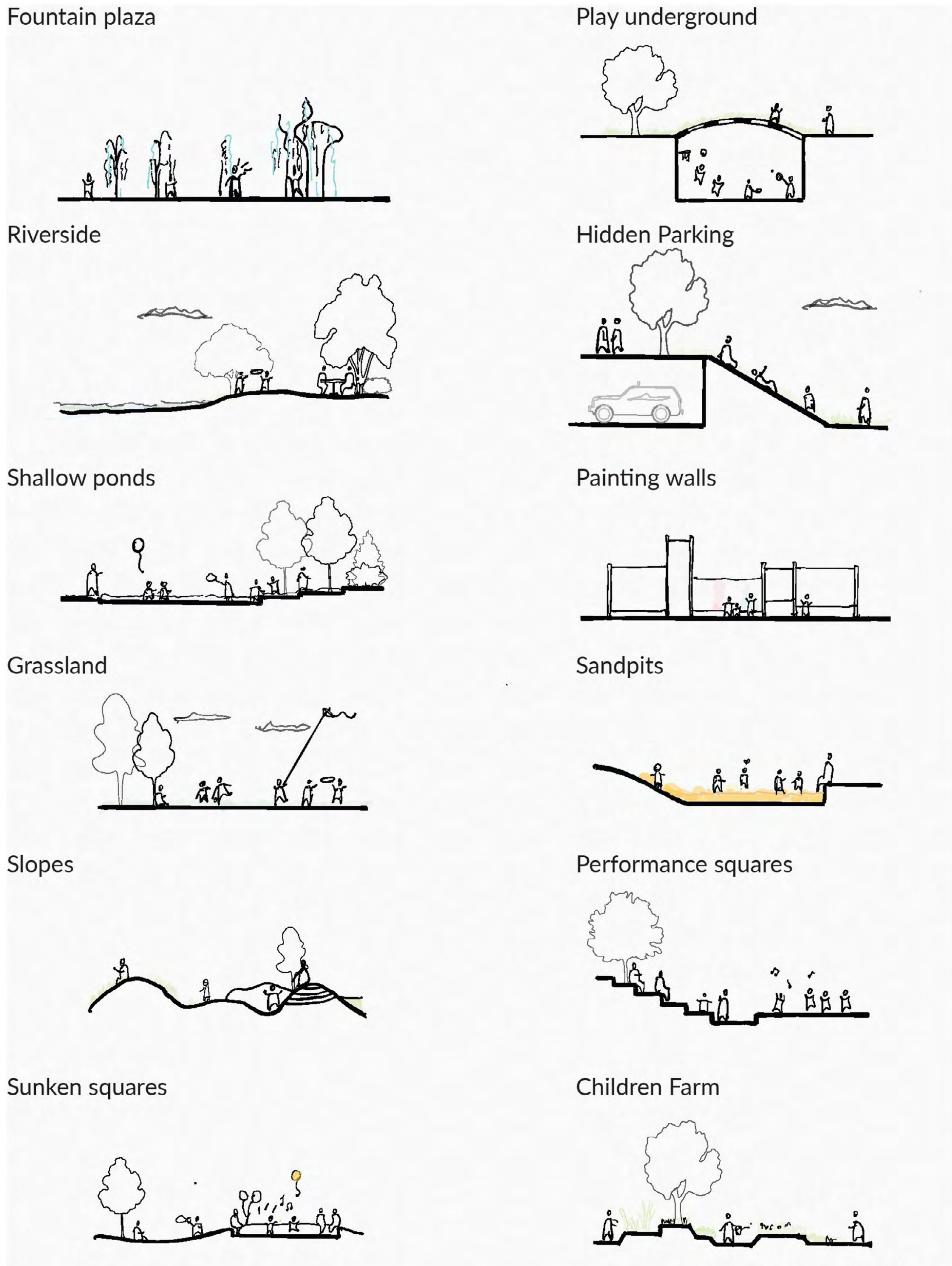


Figure 40: Activities related to children

Function

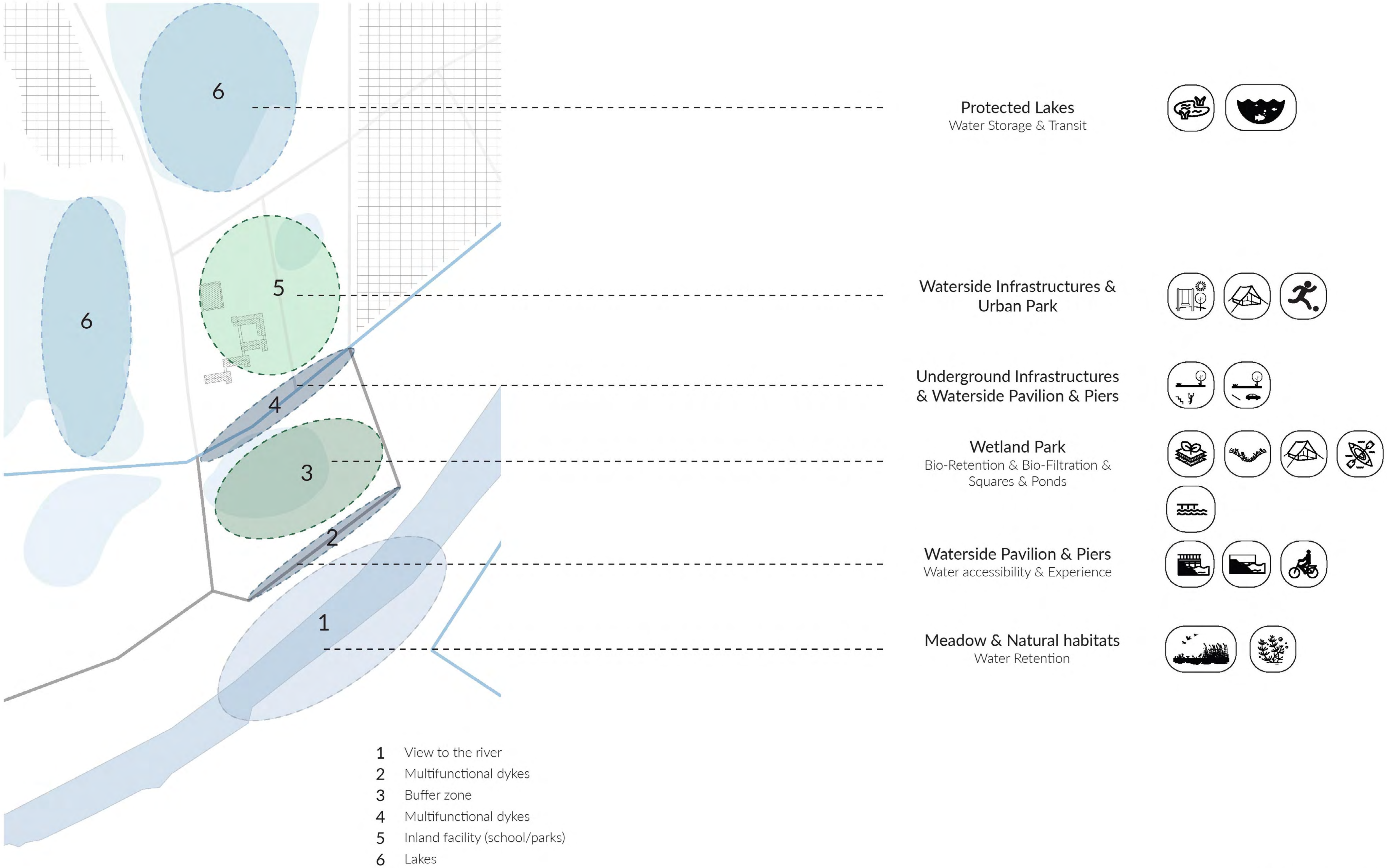


Figure 41: Function diagrams

Dyke Adaptation

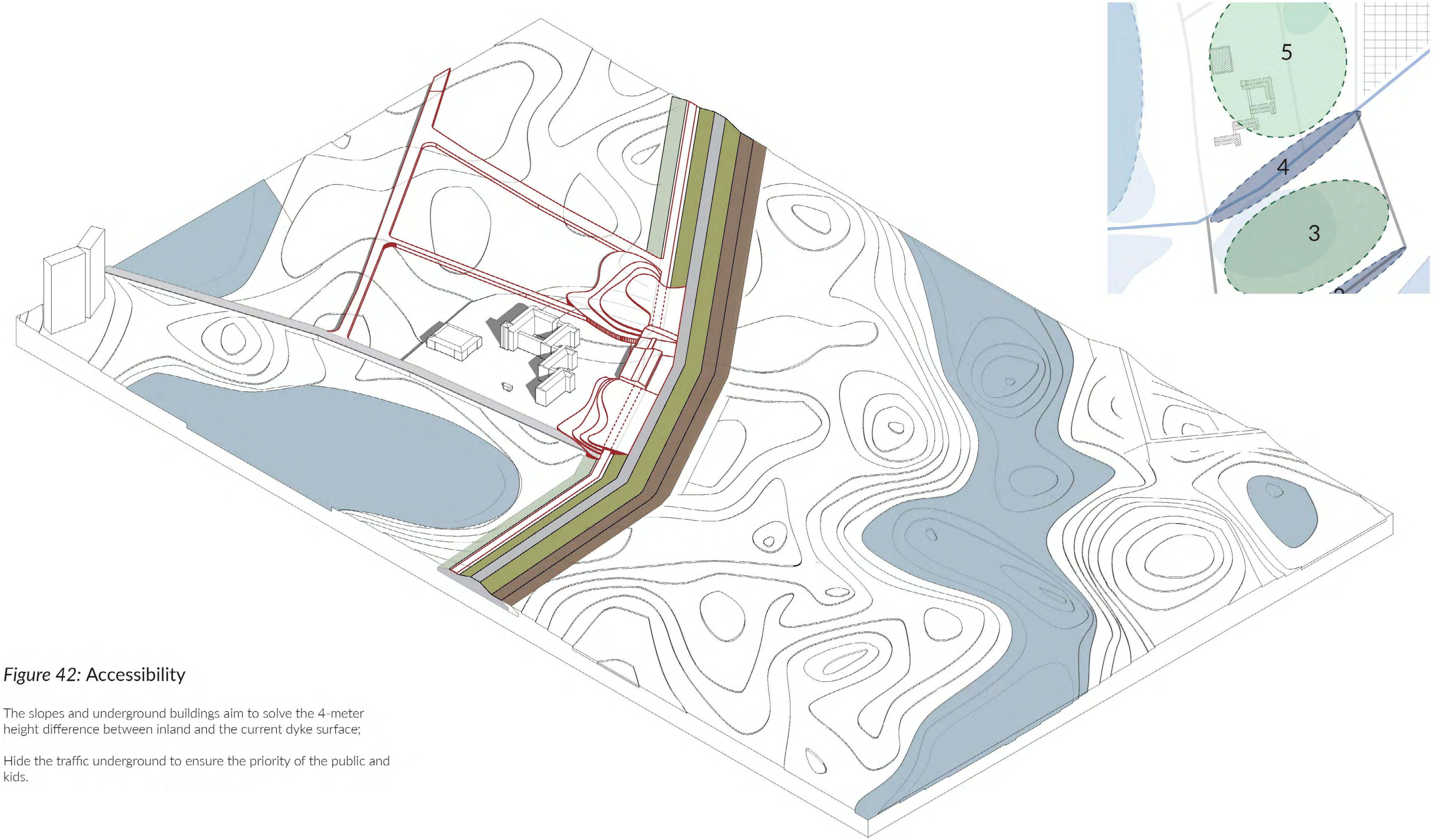


Figure 42: Accessibility

The slopes and underground buildings aim to solve the 4-meter height difference between inland and the current dyke surface;

Hide the traffic underground to ensure the priority of the public and kids.

Connection of city & dykes

"One dyke, one road, two forests"

According to the hydrogeological conditions in Wuhan, the section of the embankments is 8-meter width with the internal and external slopes of 1:3 and 1:2.5. If the height of the dyke exceeds 5 meters, the front and rear earthen slopes are generally added to reinforce the embankment and provide pressure. In order to facilitate flood control communication and transport of emergency supplies, a road is built on the top of the dykes.

For this project, the front slopes could be integrated to the new topography, while remaining the function for flooding resistance; Since the backside area is planned for urban development, it is important to solve and take advantage of the height difference.

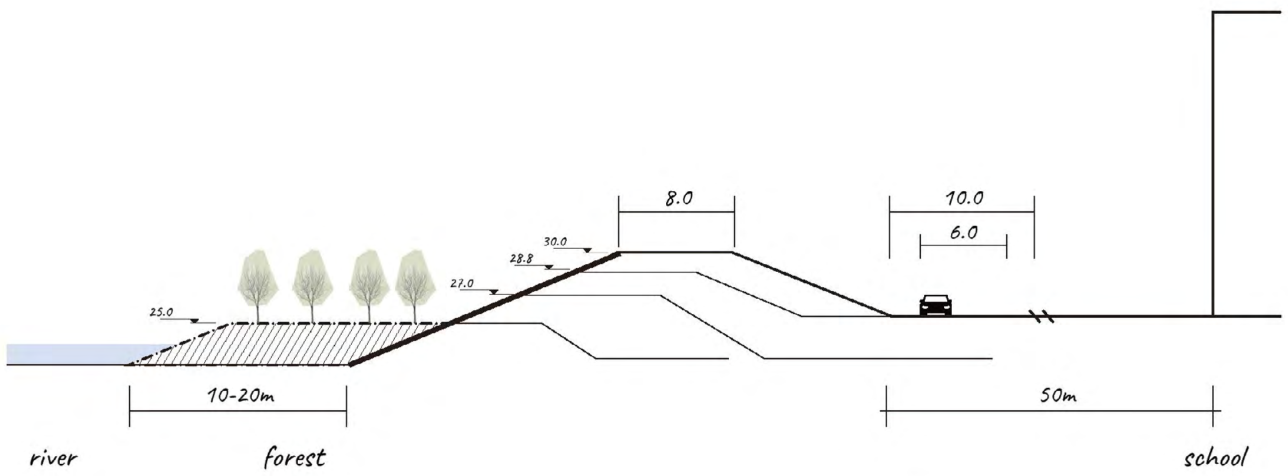
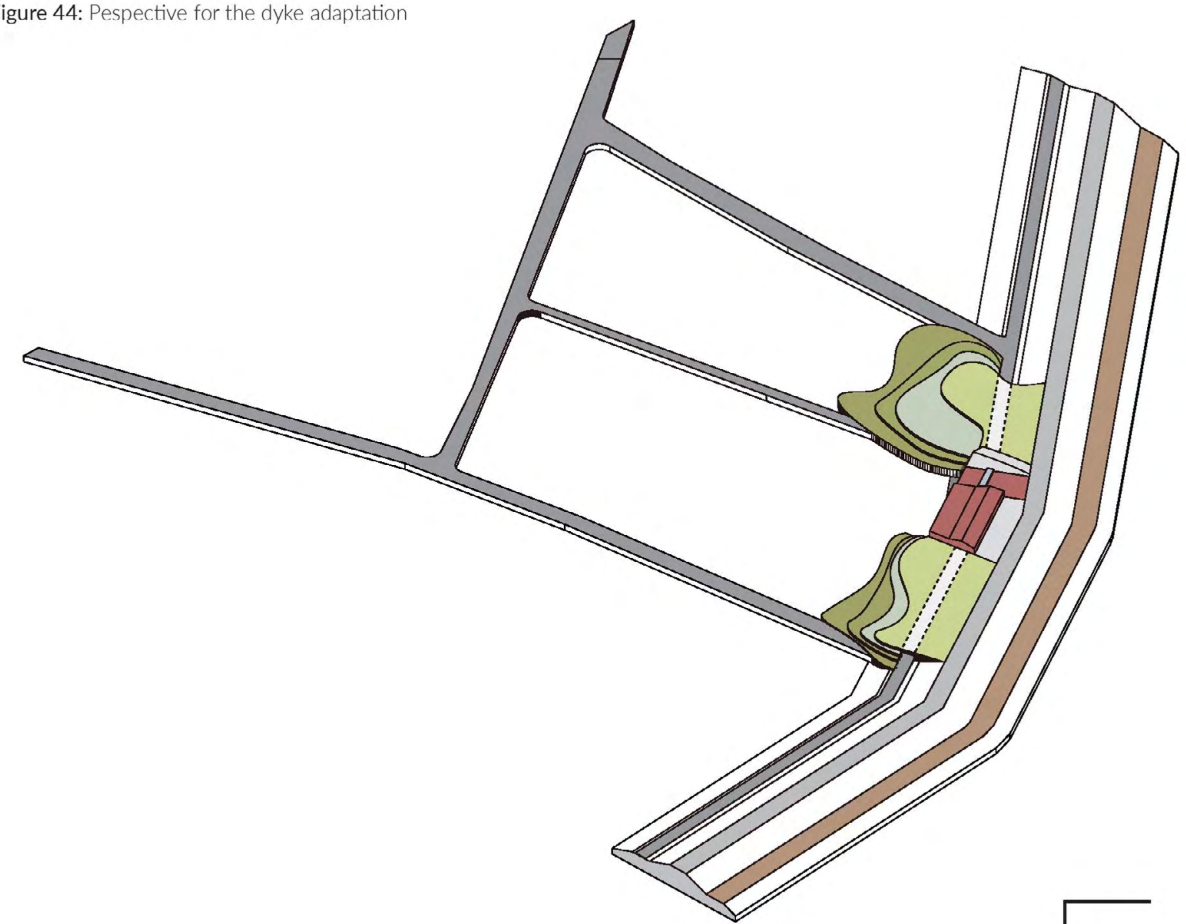


Figure 43: Current section of the school and dykes

Figure 44: Pespective for the dyke adaptation



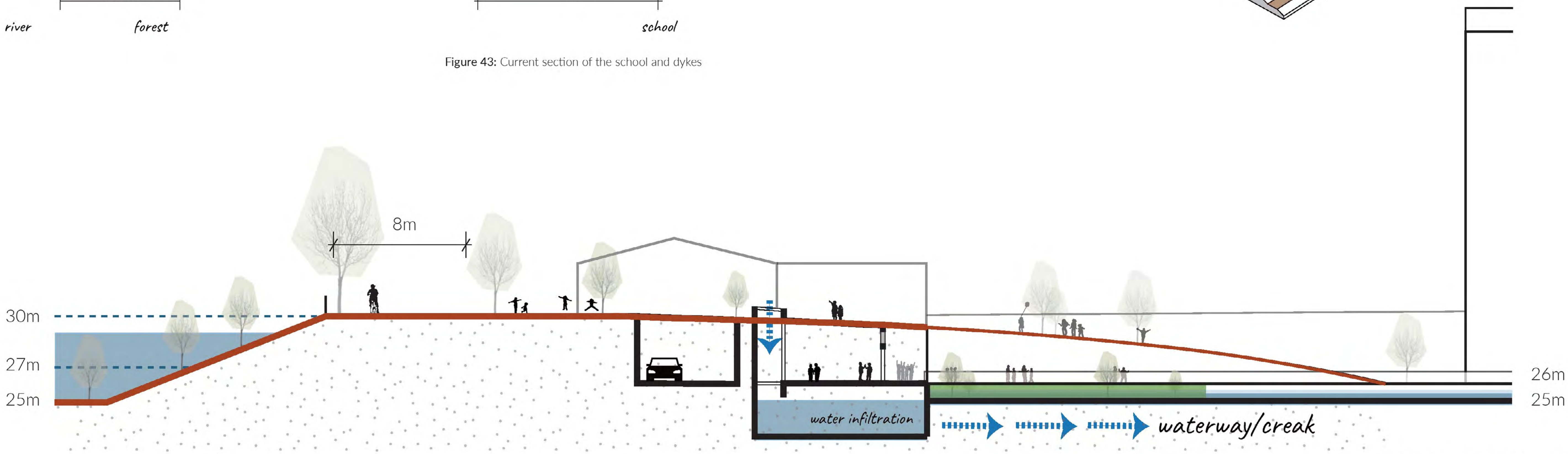
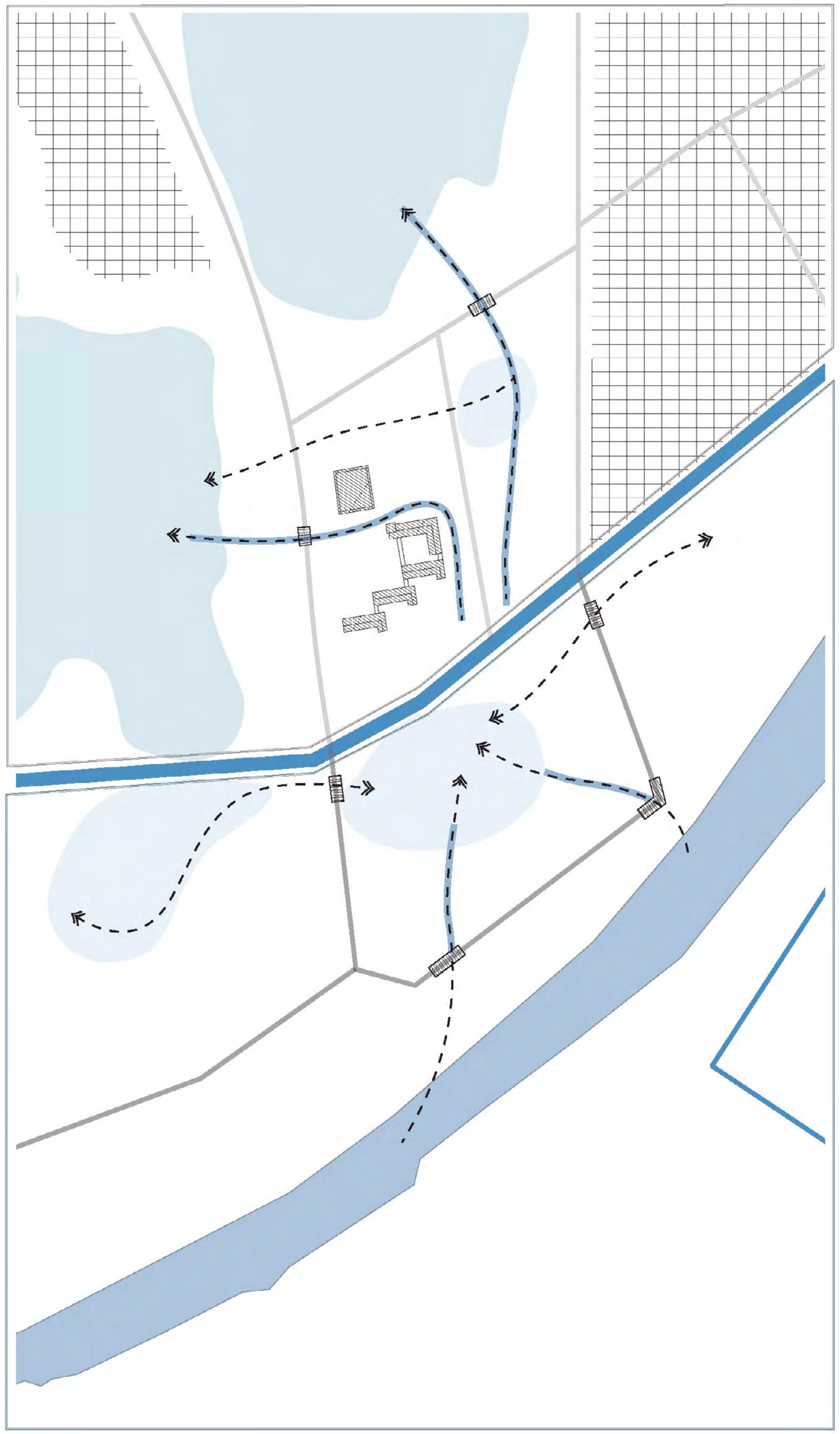


Figure 45: Design section for the school

Water Management



Rearside of dykes

This area is fully protected by the current dykes, where has high rate of harden surfaces.
The design aims to guide the water with lower topography to flow into the lakes, while promoting water infiltration, thus achieving the water management.

Waterfront side of dykes

This area is natural riverbeds, where suffers severe fluctuation of river levels.
The design aims to create a buffer zone for the public to interact with water under different flooding phases.

Figure 46: Water flow diagram

Topography

Process of formation

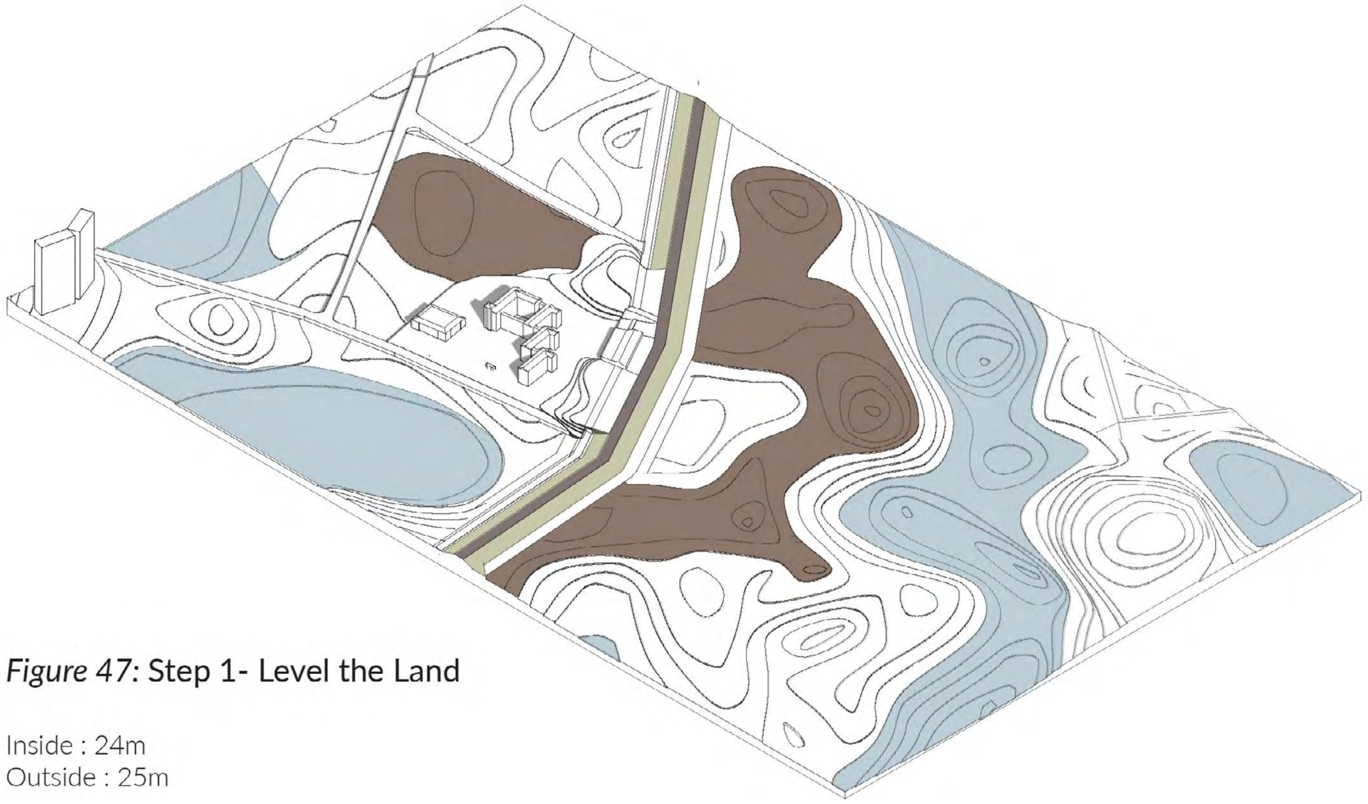


Figure 47: Step 1- Level the Land

Inside : 24m
Outside : 25m

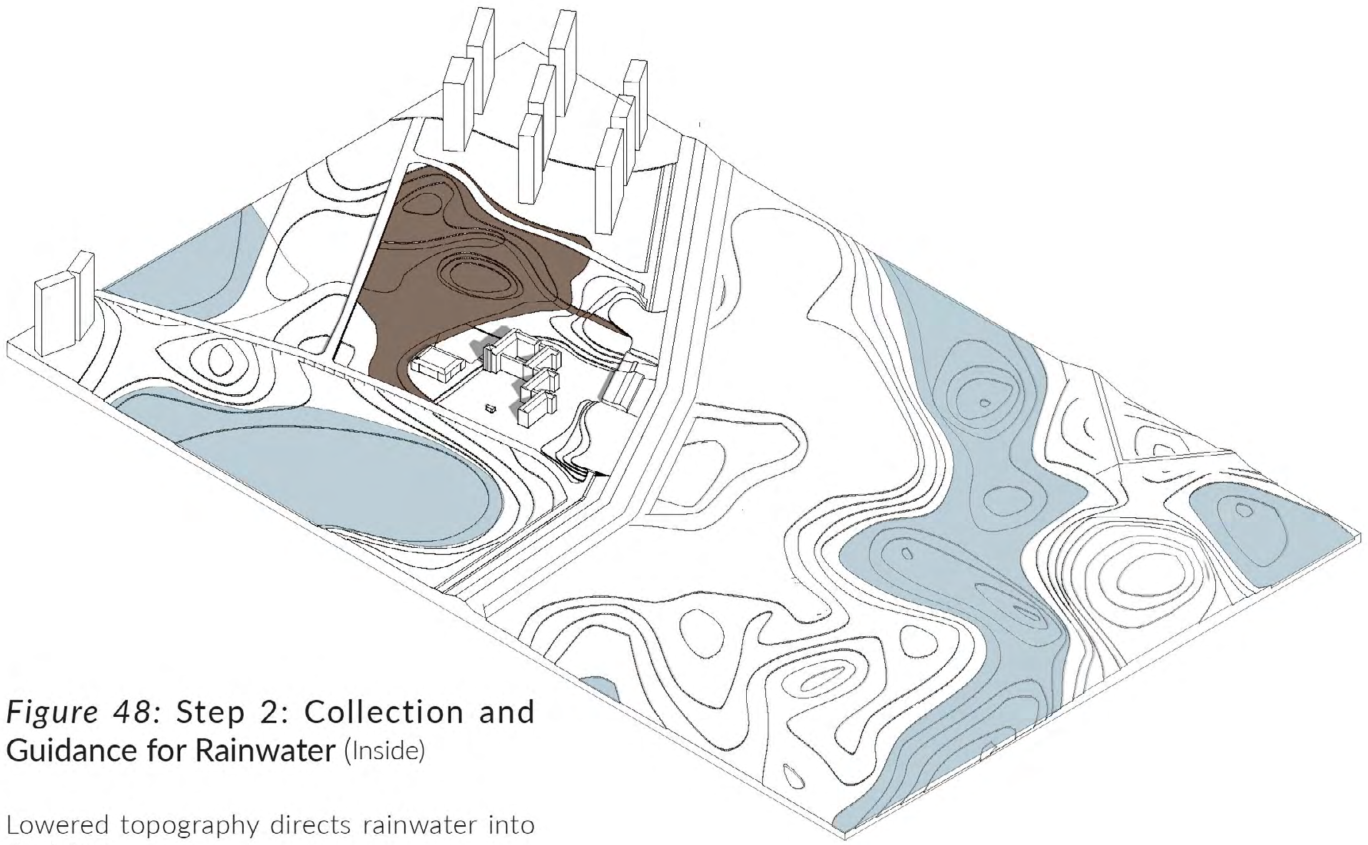


Figure 48: Step 2: Collection and Guidance for Rainwater (Inside)

Lowered topography directs rainwater into the lakes;

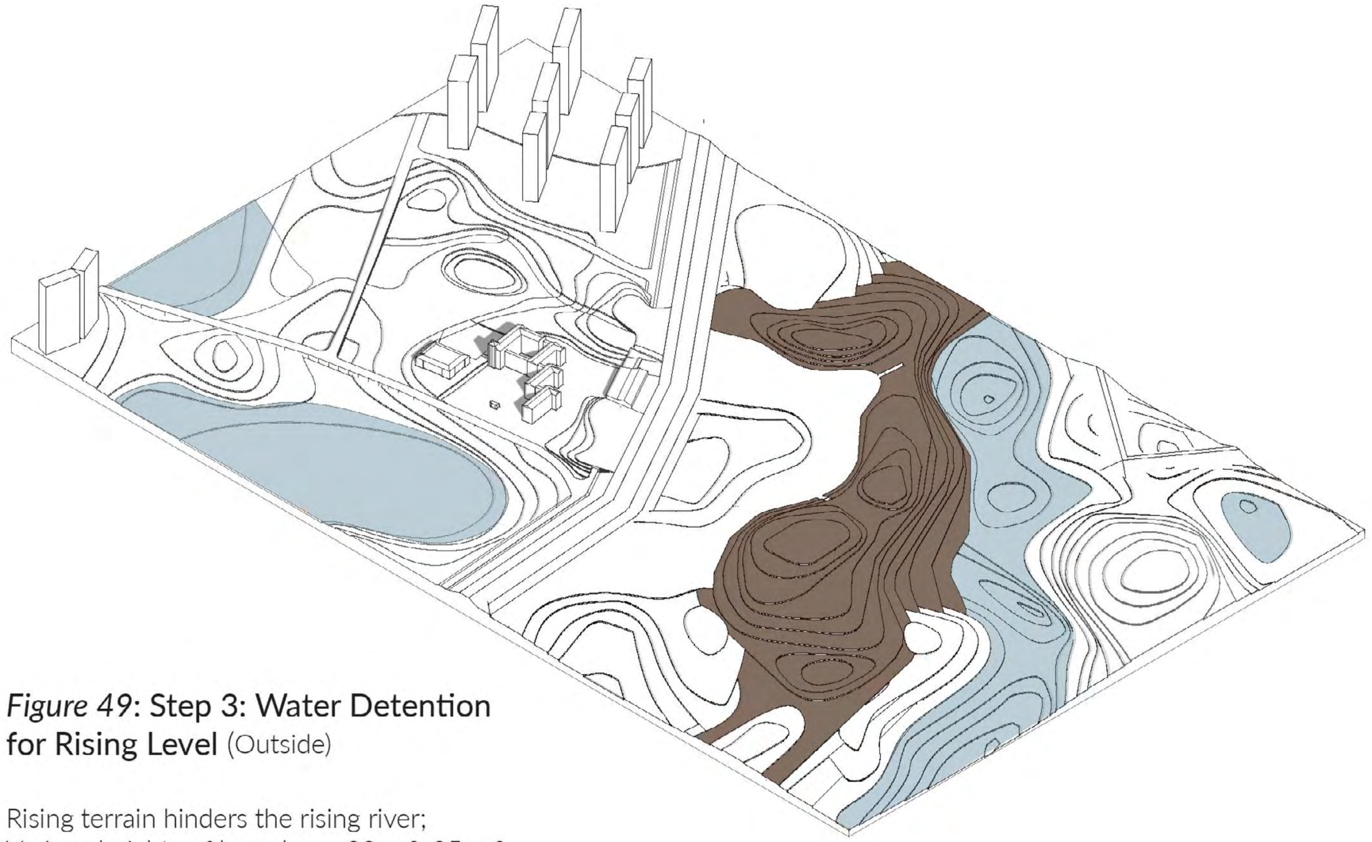


Figure 49: Step 3: Water Detention for Rising Level (Outside)

Rising terrain hinders the rising river;
Various heights of breaches - 22m & 25m & 27m

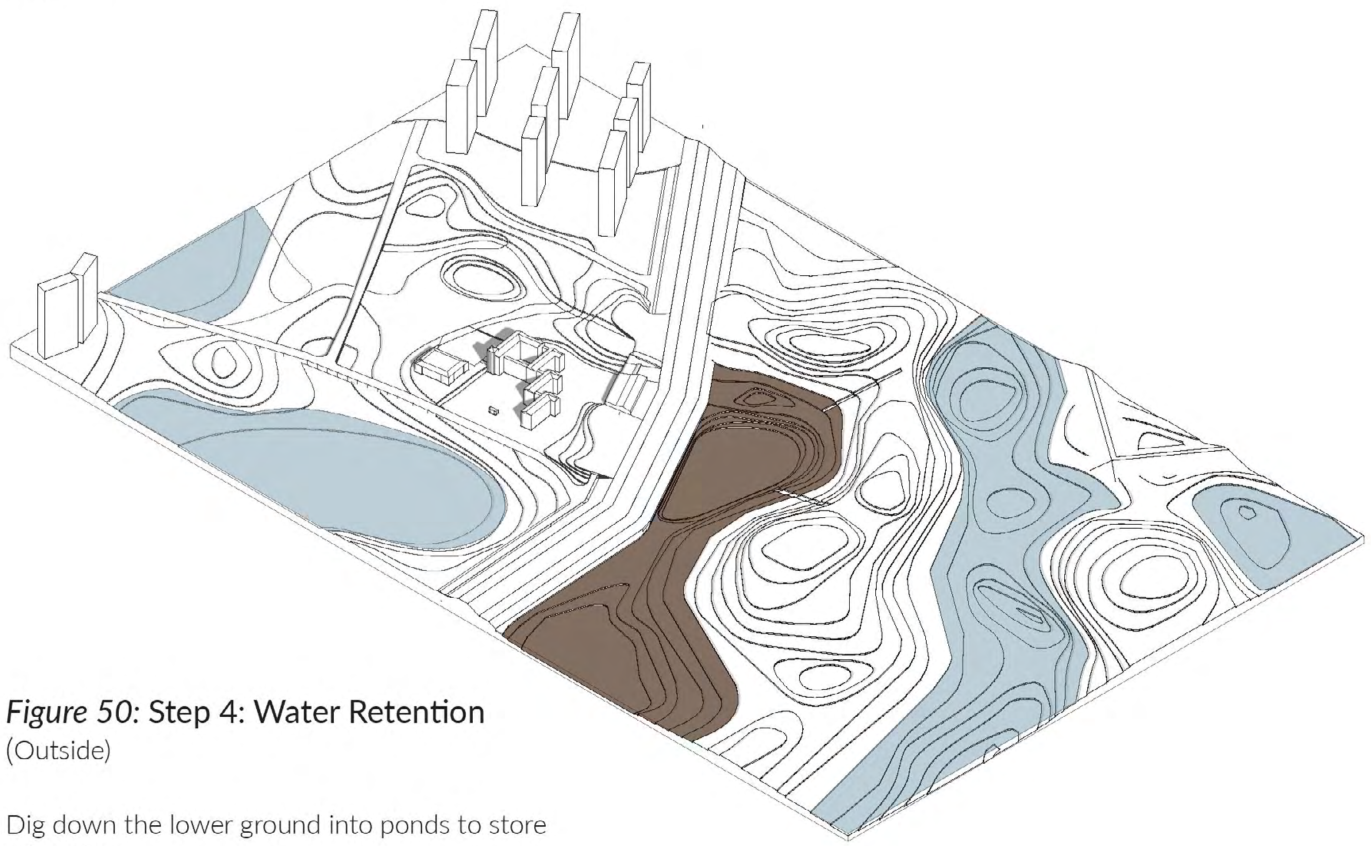


Figure 50: Step 4: Water Retention (Outside)

Dig down the lower ground into ponds to store rainwater;

Sections for breaches

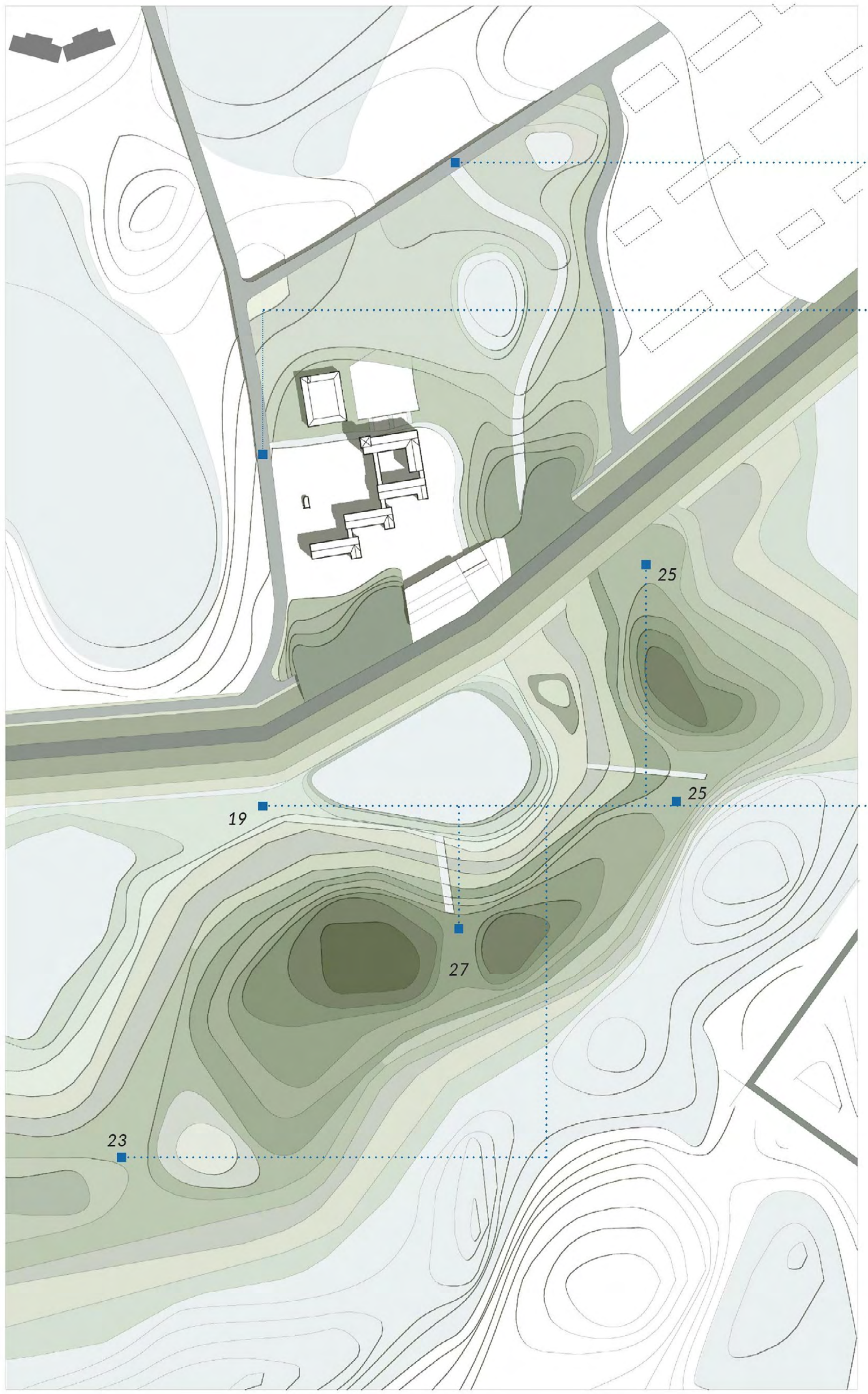


Figure 51: Topography

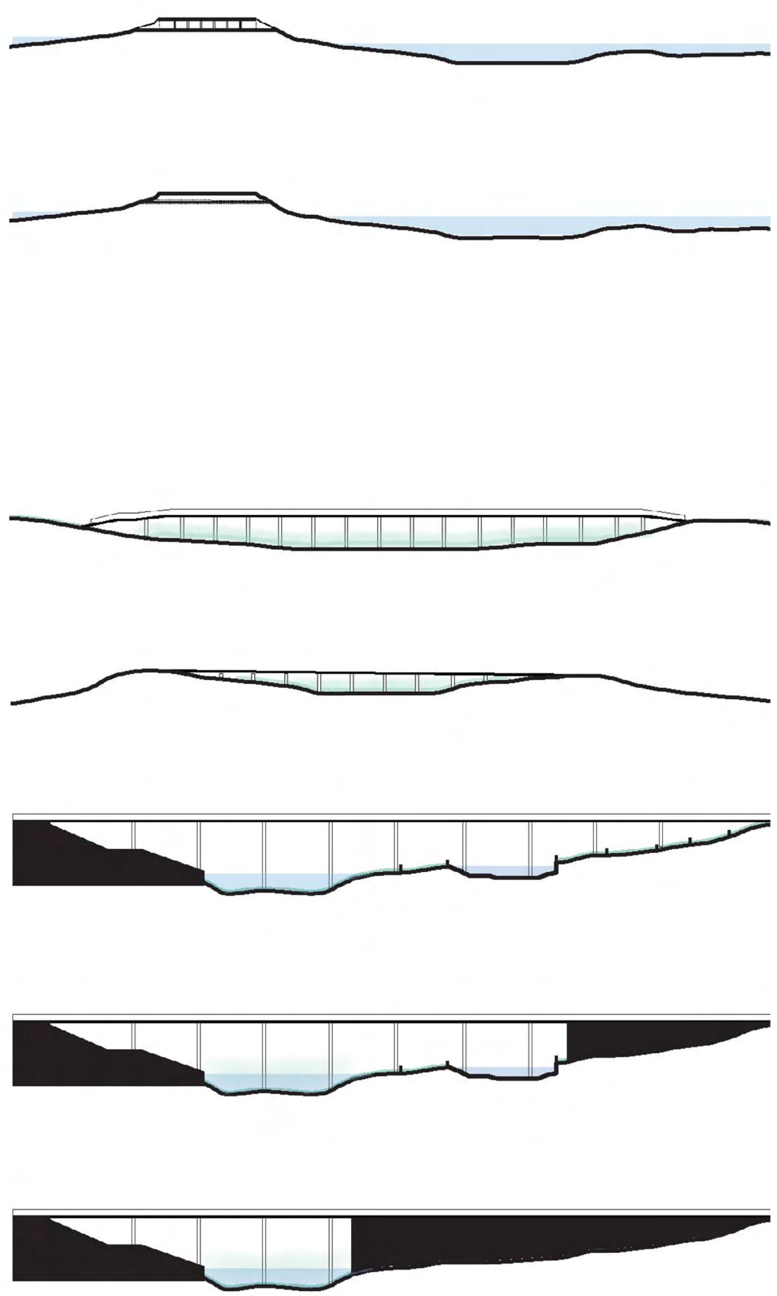


Figure 52: Sections for breaches

Strategies for Water Management with Vegetation

Partition of Zones

Depending on the flooding condition of the different areas, the site can be roughly divided into three zones: retention, buffer and top zones, with decreasing flooding conditions. In these three zones, plants and constructive materials are allocated in a coordinated manner, taking full account of their water and drought tolerant properties, as well as the needs for public activities.

- Zone A - Retention area

The area is often below water level, so the selection for vegetation and building materials should take strong resistance to flooding water as priority. Examples could be concrete and aquatic plants with well-developed root systems. Submerged, floating and water-supporting elements are desirable.

- Zone B - Buffer area

This area is a land-water zone, with wetter soil and periodic flooding. Concrete-based and amphibious elements are suitable for this area.

- Zone C - Top area

The area is relatively flat and generally dry. It might be inundated by rain when heavy rainfall is encountered, so plants in this area need to be tolerant of prolonged drought and short-term flooding. The choice of plants is not greatly affected by rainfall inundation, which can be selected based on local conditions and needs for landscape shaping. Constructive material should be pervious and meet general needs for public movement and activities.

Selection for plants

Selection for plants should give preference to native species to ensure community stability, while allowing people to fully appreciate the beauty of nature. In addition, it is beneficial to moderate the stereotypical impression of rigid rainwater engineering measures.

- Selecting native plants

The original native plants need to be well preserved and protected, which can assure the water demand period of the plants to meet local rainfall period, thus reducing the cost of garden planting and maintenance costs. At the same time, the landscape created by native plants is more compatible with the local environment, which also makes the urban landscape unique. In addition, the development of local wild plant resources can also promote the recycle and reuse of stormwater: wild species have great resistance, which have a high capacity for water and soil.

- Selecting plants with high tolerance

Tolerance here mainly refers to the resistance of plant species to water and humidity, drought and pollution. Water and moisture tolerance means that plants are resistant to certain water soaking, while having a low water requirement that can grow healthily despite low humidity and low rainfall. Drought tolerance refers to the ability of plants not only to tolerate drought well, but also to recover quickly after drought stress is lifted. Pollution tolerance means that plants are resistant to pollution from stormwater runoff.

- Choose plants with strong purification capacity

The process of stormwater runoff dissolves a large amount of acidic gases, car exhaust and other polluting gases, which also contains a large amount of organic matter, heavy metals, pathogens, suspended solids, grease and other pollutants due to the washing of asphalt concrete roads and construction sites, so plants with strong purification capacity need to be selected to filter and decontaminate stormwater. Rainwater in the project is mainly purified by aquatic and herbaceous plants, and the choice of plants requires a high degree of purification capacity.

Figure 53: Table for vegitation & materials

Programs

Connection of rearside & waterfront side

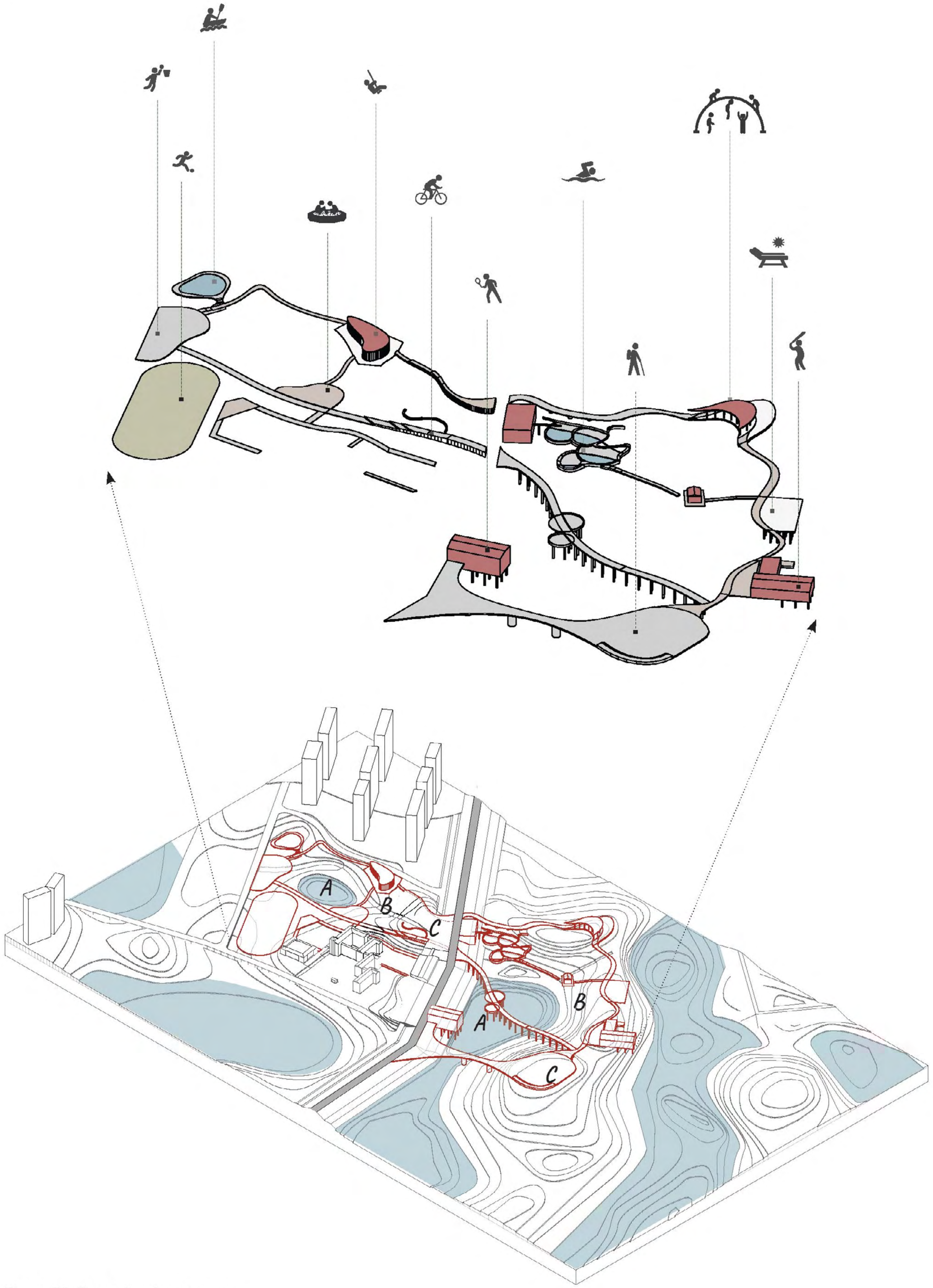


Figure 54: Pespective for programs

Figure 55: Plan

Scenarios

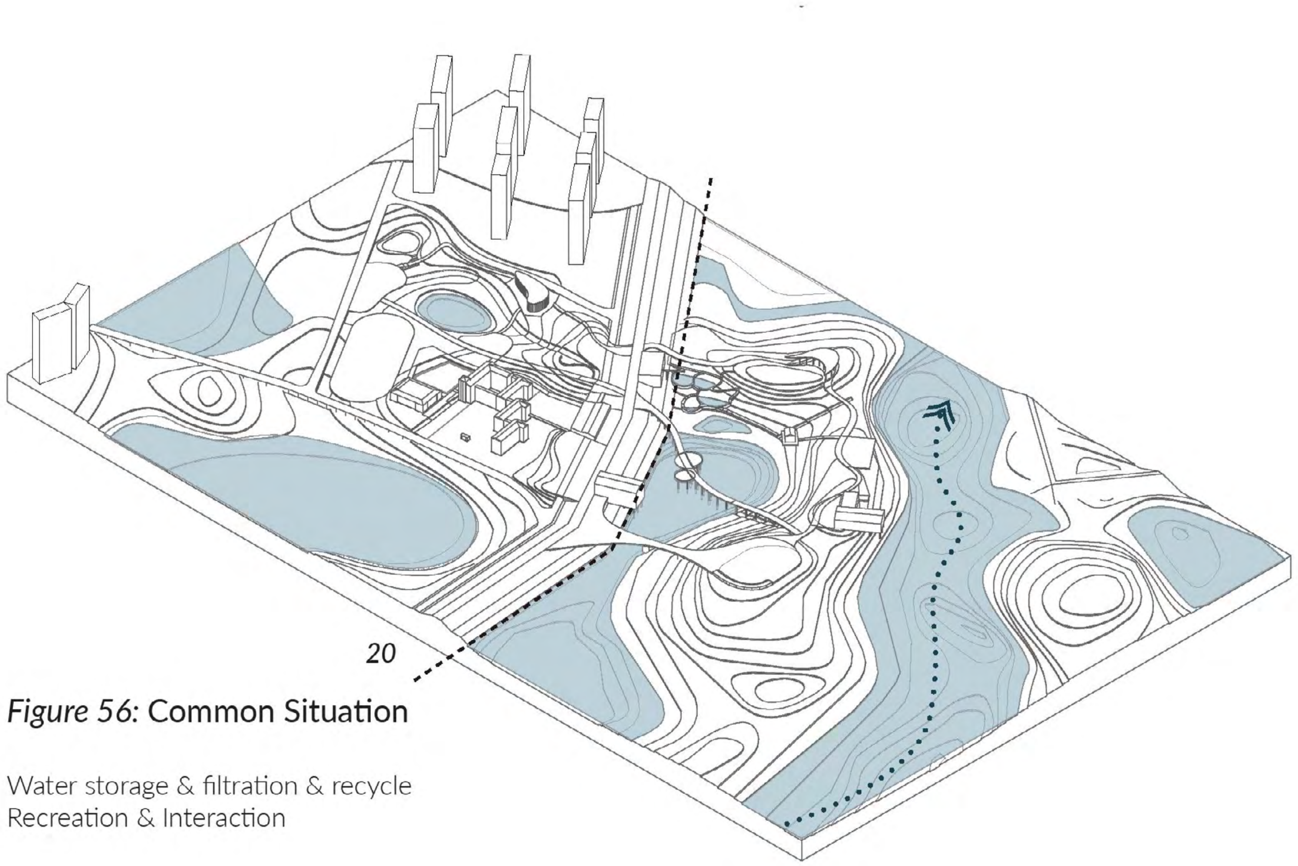


Figure 56: Common Situation

Water storage & filtration & recycle
Recreation & Interaction

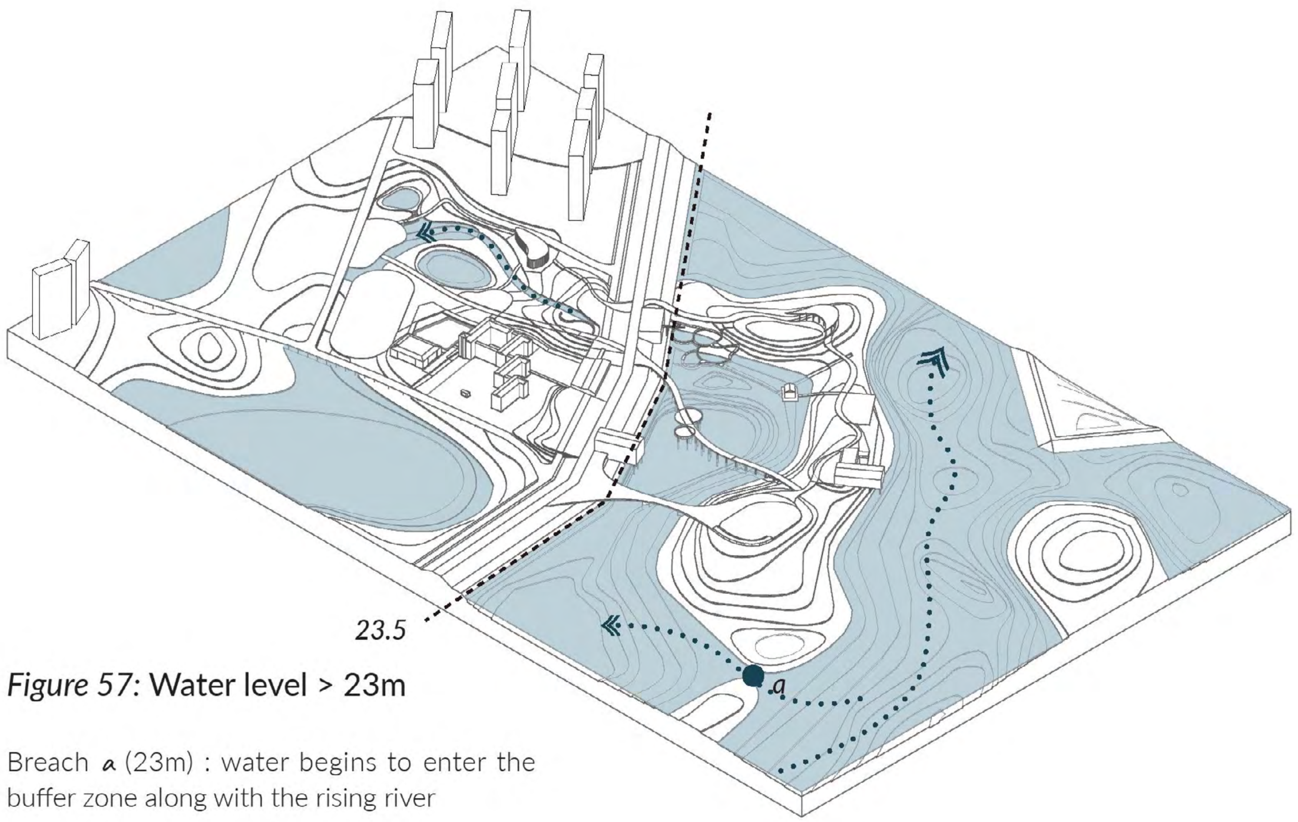


Figure 57: Water level > 23m

Breach *a* (23m) : water begins to enter the buffer zone along with the rising river

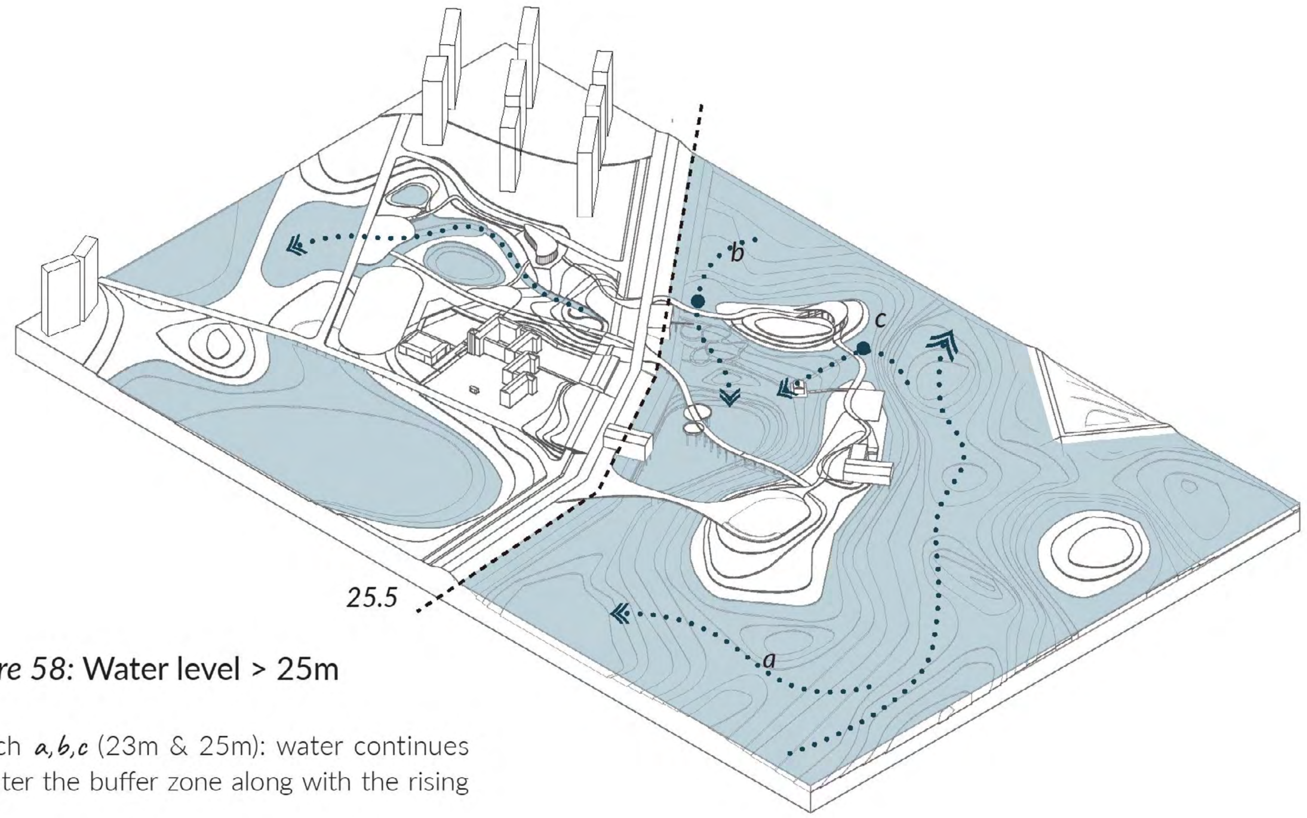


Figure 58: Water level > 25m

Breach *a,b,c* (23m & 25m): water continues to enter the buffer zone along with the rising river

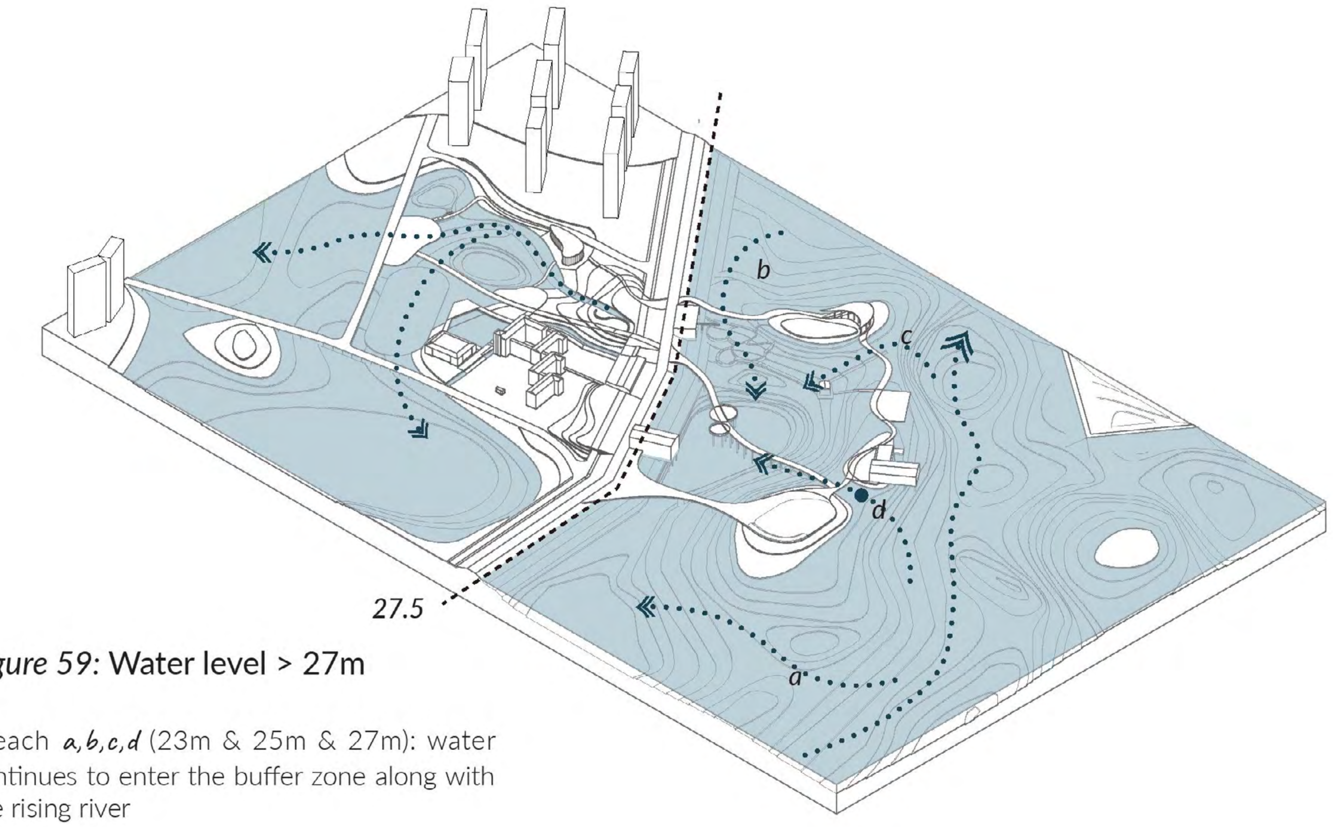


Figure 59: Water level > 27m

Breach *a,b,c,d* (23m & 25m & 27m): water continues to enter the buffer zone along with the rising river

Site Plan

Figure 60: Site plan

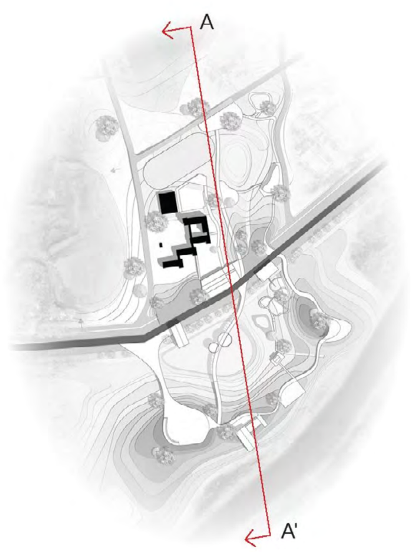
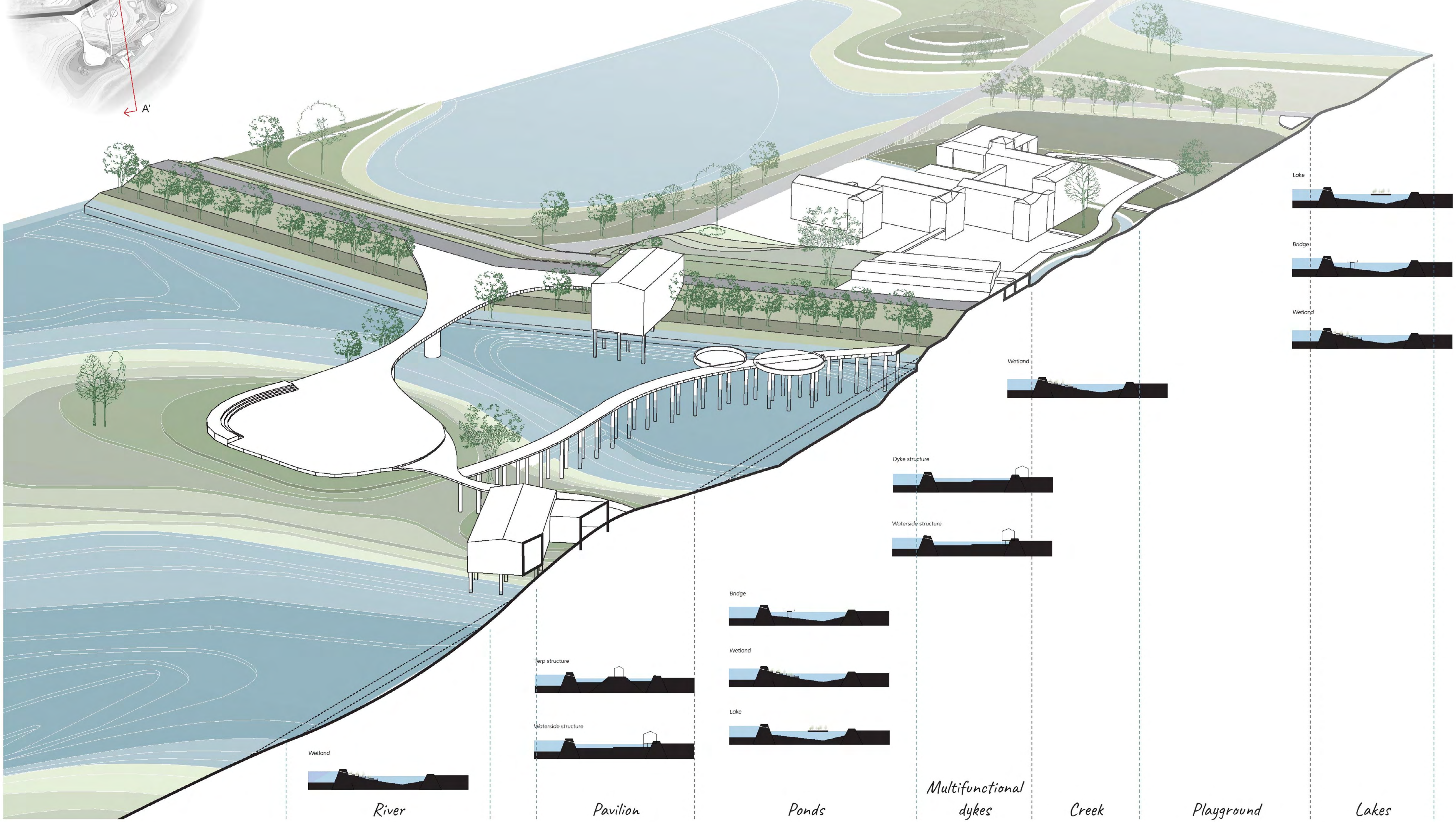


Figure 61: Pespective section A-A'

Connection of the lake & school & dyke & buffer zone & river



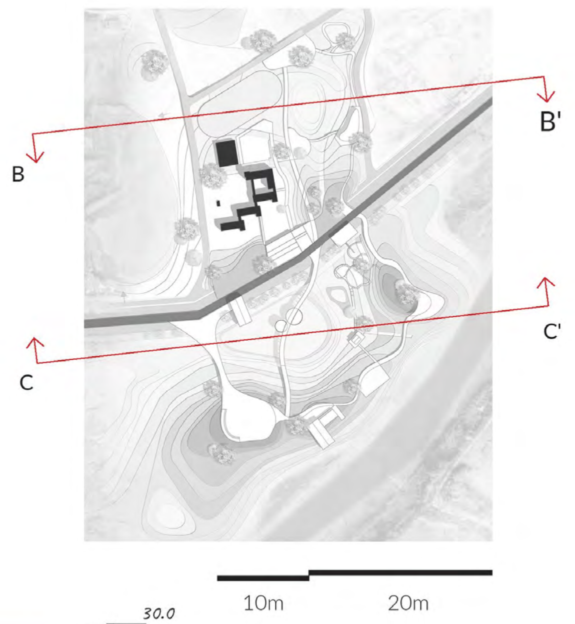


Figure 62: Urban section B-B'
Rearside of dyke

Figure 63: Urban section C-C'
Waterside of dyke

Figure 64:
"The School"
Creek & Sunken square

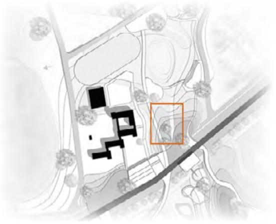


Figure 65:
"The Urban Park"
Scenario 1 - normal condition

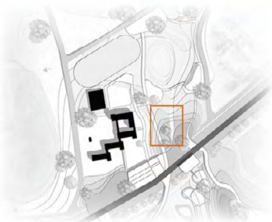


Figure 66:
"The "
Scenario 2 - flooded condition

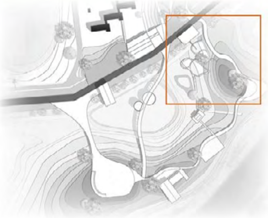


Figure 67
"The Waterfall Playground"
Scenario 1 - normal condition

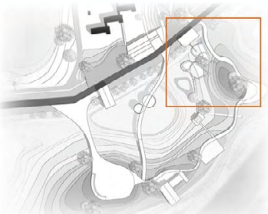


Figure 68:
"The Waterfall Playground"
Scenario 2 - flooded condition

Discussion

The design proposal is an urban design project for the south of Huangpi district in Wuhan. Knowledge about the floods in Wuhan has been acquired to understand why flood control so important for the city, and the dyke system is such a crucial element in urban development and context. While floods are the mainly seasonal challenges in Wuhan, the dyke system also developed into a context-based urban challenge as barriers for the city and water. The method has been research-by-design focusing on the adaptation of current dyke system, and layer models about how to integrate flooding water management into urban planning to reconnect the city with water.

This thesis aims to propose more sustainable and resilient measures to mitigate the flooding threats, while searching for opportunities for the city to better interact with water even under flooding situation. Green stormwater infrastructures and buffer zones were added into current flooding resistance as they provide more sustainable and resilient solutions. Based on current context, these solutions can restore and reproduce certain areas of natural habitats along the dykes, which can serve as a source of inspiration to apply to other areas with similar challenges.

The project aims to reconnect the city and the water, while telling a story about how the challenges about floods can turn into exploitable opportunities. By embracing the fluctuation of water levels, the dynamic landscape comes alive in different weather conditions, thus facilitating public events outside the dykes.

The design has not yet been finalized and many elements of the buffer zone scheme still need to be refined and specified. Aspects such as the technical part of the waterproofing structure built on buffer zones, as well as the different types of vegetation for the dynamic landscape have not yet been mentioned due to time constraints. In addition, planning for stormwater management is a complex system, which requires a more broad and interdisciplinary perspective to design. The solution should not be alone and onefold, the surrounding environment and local water system need to be taken into consideration when dealing with water treatment. Therefore, in order to develop the project further, the next step is to investigate more on practical construction for different degrees of intervention on buffer zones, while connecting the design for the specific site with the local context.

In addition, potential safety issues that occur when the public face great height difference or expose to water have not been fully solved. Related to the construction of bridges and platforms on buffer zones, more investigation about the safe movement needs to be done. The design of the connection between both sides of dykes still needs to be further developed and concreted. Thus, together with the dynamic landscape, these services could be integrated into a practically flexible space for the citizens to face the floods.

Returning to the thesis question, whether the flooding threats can be turned into an opportunity to reconnect the city and water, the results of research and the application of the design strategies suggest the answer to be positive. The idea of a dynamic landscape integrated into the rigid dyke system can be applied into any other similar context, since the dykes are wide spread in Wuhan, even other cities close to water.

Reflection

Before starting my Master's thesis in January 2022, I had been quite decisive in the design focus during preparation course. Mainly because I have already thought about the thesis for a long time, as well as my previously impressive experience about floods in Wuhan. This is, of course, a very convenient and strong foundation of this thesis work, but it also hinders the extension of topics and normal progress for my work. As a matter of fact, the journey has gone back and forth for a long time, which gave me an intense but enriching experience. I appreciated the opportunity to experience the process of the method of research-by-design, which helped me to better understand the logics and development of design, while remaining the enthusiasm and curiosity during the research phase.

The design has been carried out by a student major in architecture. Although I did acquire sufficient knowledge base about the flooding resistance and current dyke system, I cannot quantify how successful I have been integrating the flooding mitigation into the design, since I am not familiar with the engineer parts. Moreover, I could not carry out the design as detailed and developed as I had imagined in the beginning due to the conflict between self-awareness and accurate expression for the audience. However, the unpredictable process of design kept me feel curious and excited. In addition, I have learned a lot not only about the subjects but also about how to better explain and illustrate my idea with proper drawings.

During the process of master's thesis, I gradually understood what a Master's Thesis in architecture want us to achieve. It is not about outputting the perfect design that solves the challenges. Instead, it is more important to experience the process of research, and explain the process explicitly and well-understood.

Before starting my career, this thesis work gives a relatively complete, independent, and disengaged experience from the topic till the design part, which is beneficial for me to be better planned and organized about work, while allowing me to follow both architectural and urban planning perspectives for urban resilience on public space in regard to the connection between city and water.

While urban development has provided much convenience and support for our urban life, it has also been accompanied by new challenges. Resilience is an interesting and complex field that attracts me to search in the future, which is a great solution in the face of changes.

Bibliography

Literature Sources

Li Z, Song K, Peng L.(2021) *Flood Risk Assessment under Land Use and Climate Change in Wuhan City of the Yangtze River Basin, China. Land.* (https://doi.org/10.3390/land10080878)

"Wuhan Wastewater and Stormwater Management Project". (ADB)

Chris Courtney. (2018) *Picturing disaster: The 1931 Wuhan flood.* (https://chinadialogue.net/en/2/10811-picturing-disaster-the-1931-wuhan-flood/)

MJW, HSF, XZN.(2017) *Satellite remote sensing of lake area in Wuhan from 1973 to 2015*

Xiang J, Liu Q, Wang L(2012) "*A Preliminary Study on the Management of Drainage and Flood Control in the Central City of Wuhan*". (Wuhan Municipal Water Affairs Bureau)

NACTO, (2017) *Urban Street Stormwater Guide.*

van Veelen, P., Voorendt, M., & van der Zwet, C. (2015). *Design challenges of multifunctional flood defences. A comparative approach to assess spatial and structural integration.* Research In Urbanism Series.

Marlien Oderker. (2013) *Design concepts of multifunctional flood defence structures.*

Nillesen, A. (2015). *The synergy between flood risk protection and spatial quality in coastal cities.* Research In Urbanism Series.

Ecoshape. (2020). *Building with Nature – Creating, implementing and upscaling Nature-based Solutions.*

Nillesen, A.L., Singelenberg, J. (2011). *Amphibious Housing in The Netherlands.* Architecture and Urbanism on the Water.

Li H. (2015). *Study on The Design of Comprehensive Park in Wuhan Bsaed on Rainwater Utilization.*

Liu R, Feng X, Chen L. (2016). *Typical Plant Communities at Urban Parks and Their Species Diversity in Wuhan City.*

Wang W. (2012). *Studies on the Characteristics and Landscape Evaluation of Artificial Plant Communities of Park Green Space in Wuhan.*

Yang Z. (2017). Research on Designing Plant Community with Plants Life Characters of Wuhan Parks.

Dai X, Xiong T. (2013). Resources Investigation and Current Situation of Application of Aquatic Plant in Wuhan City.

Yu Z. (2013). Study on Construction of the Plant Landscape of Urban Wetland Park in Wuhan.

Lou J. (2005). Construction of the Plant Landscape in Wuhan Urban Wetland.

Lou J. (2016). Wetland Plant Resource in Wuhan and their Application.

Wuhan Municipal Bureau of Ecology and Environment. *Wetland Biological Map for Fu River.* URL (http://hbj.wuhan.gov.cn/hjsj/ztzl/xjldnkfh/swtjzwp/index.shtml#book7/page1)

Photography Sources

Self media "JINJINYOUWEI" (2021). URL (https://baijiahao.baidu.com/s?id=1718836990105247441&wfr=spider&for=pc)

Chris Courtney. (2018) *Picturing disaster: The 1931 Wuhan flood* (https://chinadialogue.net/en/2/10811-picturing-disaster-the-1931-wuhan-flood/)

NEWS Focus. (2018). Three sets of rare and shocking old photographs of the floods: 1931/1954/1998 (http://k.sina.com.cn/article_6410803751_17e1d1a270010027uw.html#/)

News.cn. (2020). URL (http://m.xinhuanet.com/hb/2020-07/29/c_1126294948.htm)

Wuhan Water Bureau (2019). URL (http://swj.wuhan.gov.cn/ssgz/fhs/202004/t20200426_1127663.html)

Huangpi Rong Media. (2020). URL (https://www.sohu.com/a/407431524_120065450)

Ecoshapes. (https://www.ecoshape.org/en/concepts/creating-rich-revetments/practical-applications/)

KEFA Landscape Architecture. (2016). URL (http://www.whkfyl.com/product/17.html)

Wuhan Municipal Bureau of Ecology and Environment URL (http://hbj.wuhan.gov.cn/hjsj/ztzl/xjldnkfh/swtjzwp/index.shtml#book7/page1)

Wikipedia, Photographs on p97.

Shandong Weifang Yongjia Building Material Co., Ltd. (2021) URL (http://www.yjsncz.com/product187609.html)

Photophoto.cn. (2019). (https://www.photophoto.cn/pic/36184630.html)

Google Earth Pro, Photographs on p31, 33, 55, 57, 81.

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RECONNECT CITY & WATER
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