EcoCharge

Towards a resilient design framework for
water scarcity issue in Pearl River Delta

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CONTENT

ABSTRACT

The Pearl River Delta region, where the author of this project grew up, has been a source of inspiration due to the devastating impacts of natural disasters such as flooding, hurricanes, and storms on the limited freshwater resources in the area. Water is a crucial necessity for the inhabitants of the PRD, but the complexity of the water system, characterized by its structure, dynamics, and human activities, presents a formidable challenge. Despite the region's abundant rainfall and hydrological conditions, six cities in the PRD experience water poverty as a result of limited resources.

Limited fresh water resources pose a threat to human life as the total renewable water resource available globally is around 54000 billion m3, which equates to less than 8000 m3 per person for all activities. This water is constantly in flux and moves through different stocks within the hydrological cycle, resulting in uneven distributions of water availability. Some climates, such as the wet tropics or temperate climates, experience fairly even rainfall, while others, such as monsoonal, Mediterranean or semi-arid climates, experience uneven rainfall. This unequal distribution of water resources can cause problems during periods of heavy rainfall or drought, making the availability of fresh water highly unpredictable and putting human activities at risk.

The existing centralized freshwater supply infrastructure, which relies on transporting water from rural areas to urban clusters, is unsustainable in the face of flooding, sea level rise, and salt tide intrusion. To address this issue, a landscape-based, decentralized freshwater supply system is necessary to promote sustainable ecosystem and urban growth. The landscape can serve as a foundation for such a system and provide a means of integrating design into contemporary urban development and transformation. By considering the landscape as a system, the freshwater supply system can act as a rechargeable battery, storing water in potential areas during wet seasons and during times of drought or salt intrusion.

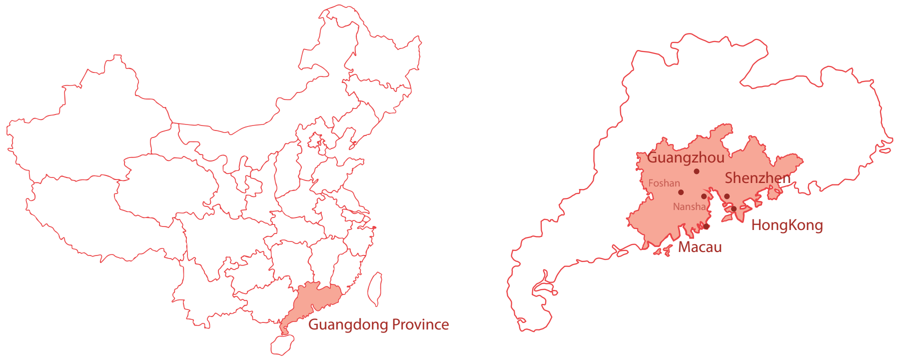
The densely populated Pearl River Delta offers a significant potential for freshwater storage through its urban landscape. This project aims to explore the role of design in incorporating current urban development and transformation activities through urban landscape infrastructure. Through field studies, mapping, historical analysis, and flowscape analysis, the author will design a sustainable landscape system that facilitates interaction among diverse subsystems and addresses the challenge of storing and utilizing freshwater resources in high-density cities.

CHAPTER 1 INTRODUCTION

1 INTRODUCTION

1.1 Fascination

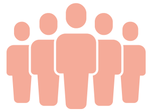
1.1.1
The Pearl River Delta Context
abundant hydrological condition
and limited freshwater resources



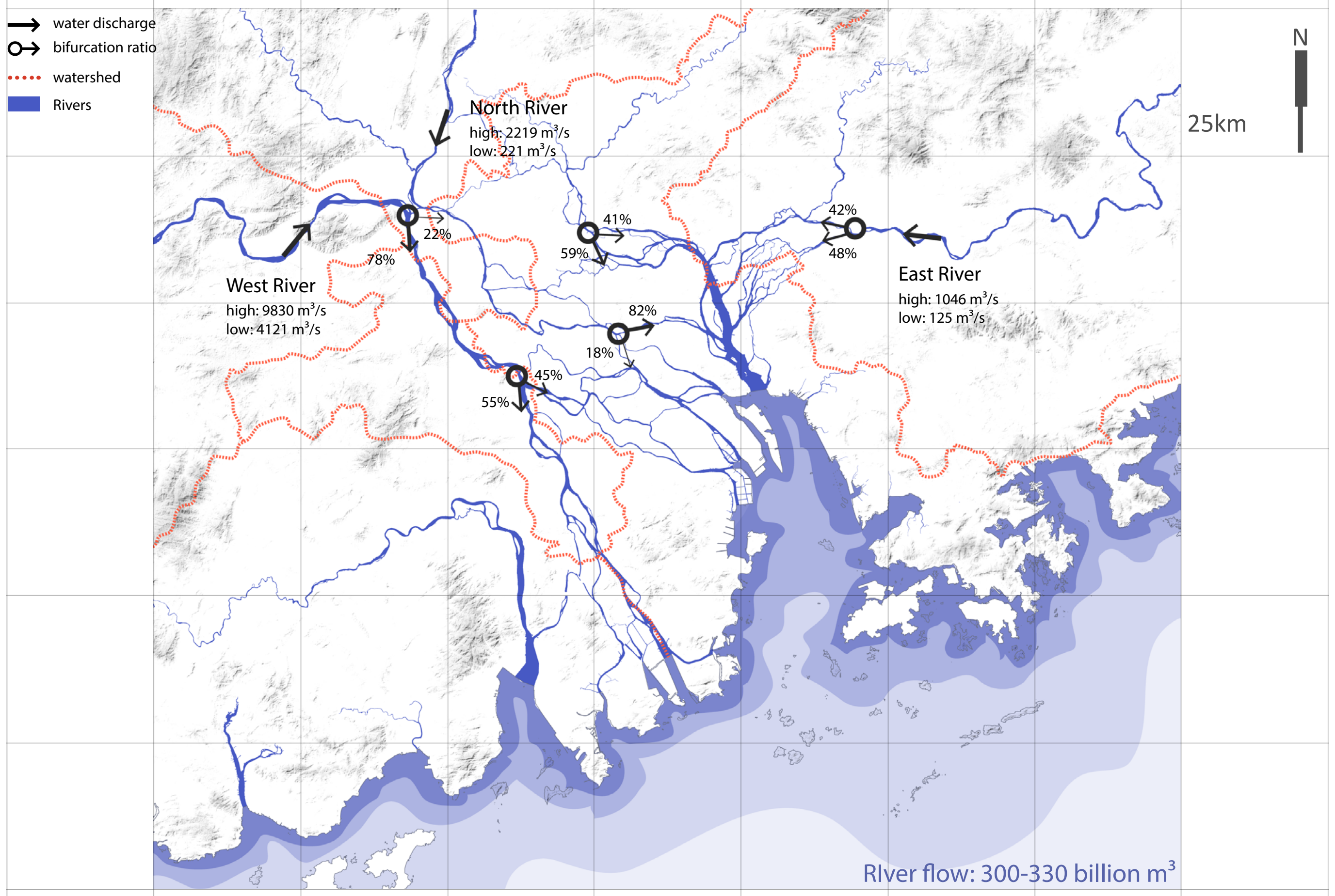
The Pearl River is a significant source of water for various purposes including agriculture, industrial production, and drinking water in southern China. It is the second largest river in China in terms of discharge and the third largest basin. The drainage area of the Pearl River Basin covers 4.54 x105 km2, with more than 330 billion cubic meters river flow(PRWRC, 2005).

Summer, between April and September, is the wet season in the PRB and receives the majority of its precipitation, which ranges from 1200mm to 2200mm annually (Zhang et al., 2012). However, the uneven distribution of rainfall and streamflow can result in seasonal water shortages in the basin.

The Pearl River Delta is the estuarial region of the Pearl River and includes nine major urban centers. The delta has experienced rapid urban expansion and is now the world's largest urban region in both population and area. The region has gone through a significant landscape transformation, with agriculture being expanded into nature areas. However, there is a difference in socio-economic development and water consumption across the Pearl River Basin, with the upstream being one of the poorest regions in China while the downstream delta region is a well-developed urban area.

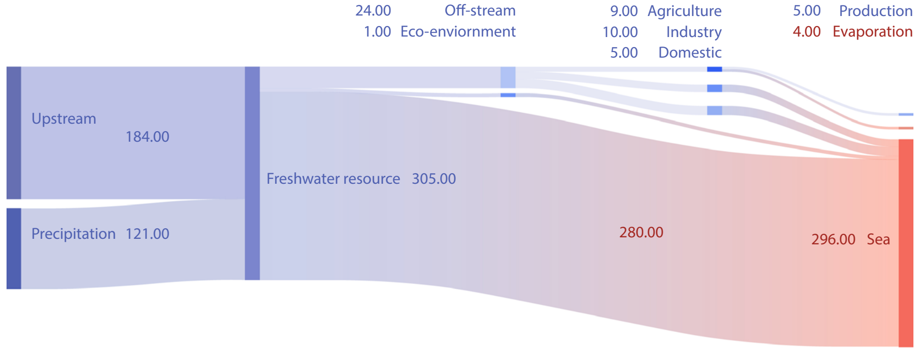


126.84 million people(2020)



drawing: by author
source: Dai, W. (2021). Spatial Planning and Design for Resilience: The Case of Pearl River Delta.

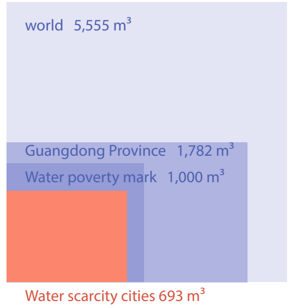
1.1.2
the existing freshwater supply situation in the PRD



drawing: by author
source: Mingtian Yao. et al, Sectorial Water Use Trends in the Urbanizing Pearl River Delta, China

the existing water resource and supply system of the PRD km³

Freshwater resource per capita



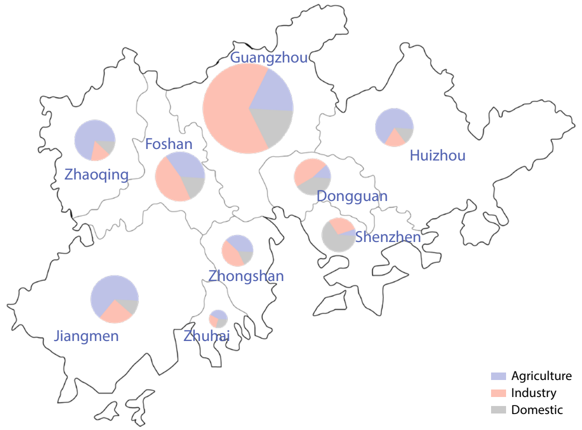
Freshwater is a crucial resource for human survival. However, the total renewable water resources, which represent the maximum amount of water that can be obtained, are limited to 54,000 billion cubic meters, resulting in an availability of less than 5,555 cubic meters per person for all activities, given the current global population (the World Bank, 2015).

With abundant water supplied by many of its rivers, however, there are 6 water scarce cities with 88% of PRD's GDP, which is over 60% less than the provincial standard level. The average freshwater resources per capita was 1,782 cubic meters of the Guangdong Province, while the main high-density cities located in the delta region presenting a very different picture: the average annual water resources per capita of this region was only 693 cubic meters. (China Water Risk Organization, 2017)

The freshwater resources are part of the hydrological cycle and the existing situation of the hydrological cycle presents a large amount of freshwater resources waste, and nearly 92% of the precipitation and surface run-off flow into the sea. However, the increasing demand of freshwater in agriculture, industry and domestic keep extracting underground freshwater resources, which make the hydrological cycle exhausted, and decrease the capacity on sustainable freshwater supply.

1.1.2
the existing freshwater supply situation in the PRD

Sectorial water use of different cities in the PRD



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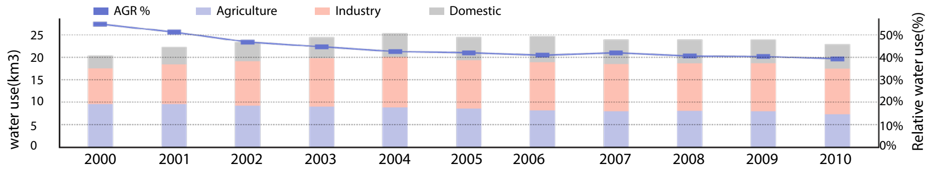
source: baesed on Mingtian Yao. et al, Sectorial Water Use Trends in the Urbanizing Pearl River Delta, China

The map shows how different cities in the PRD region use water in various sectors. Guangzhou, as the capital city of the region and home to over 20% of the PRD's population, counts one-third of the total water usage, especially for industry, urban and rural domestic purposes, accounting for an average of 51%, 29%, and 21% of the total. Dongguan's water usage increased significantly from 83 litres per person-day in 10 years. Foshan and Shenzhen no longer use rural domestic water since fully urbanized. Jiangmen was the largest agricultural water user, accounting for 22% of the total.



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source: Mingtian Yao, eg., Sectorial Water Use Trends in the Urbanizing Pearl River Delta, China

1 INTRODUCTION

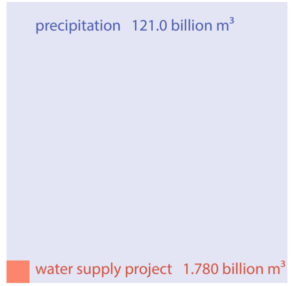
1.1 Fascination

1.1.3
Existing Planning Approach:
Centralized Freshwater Supply

The water supply accounts for only
2% of the total rainfall

But result permanent acquisition of
1733.33 ha of land

supply magnitude comparison

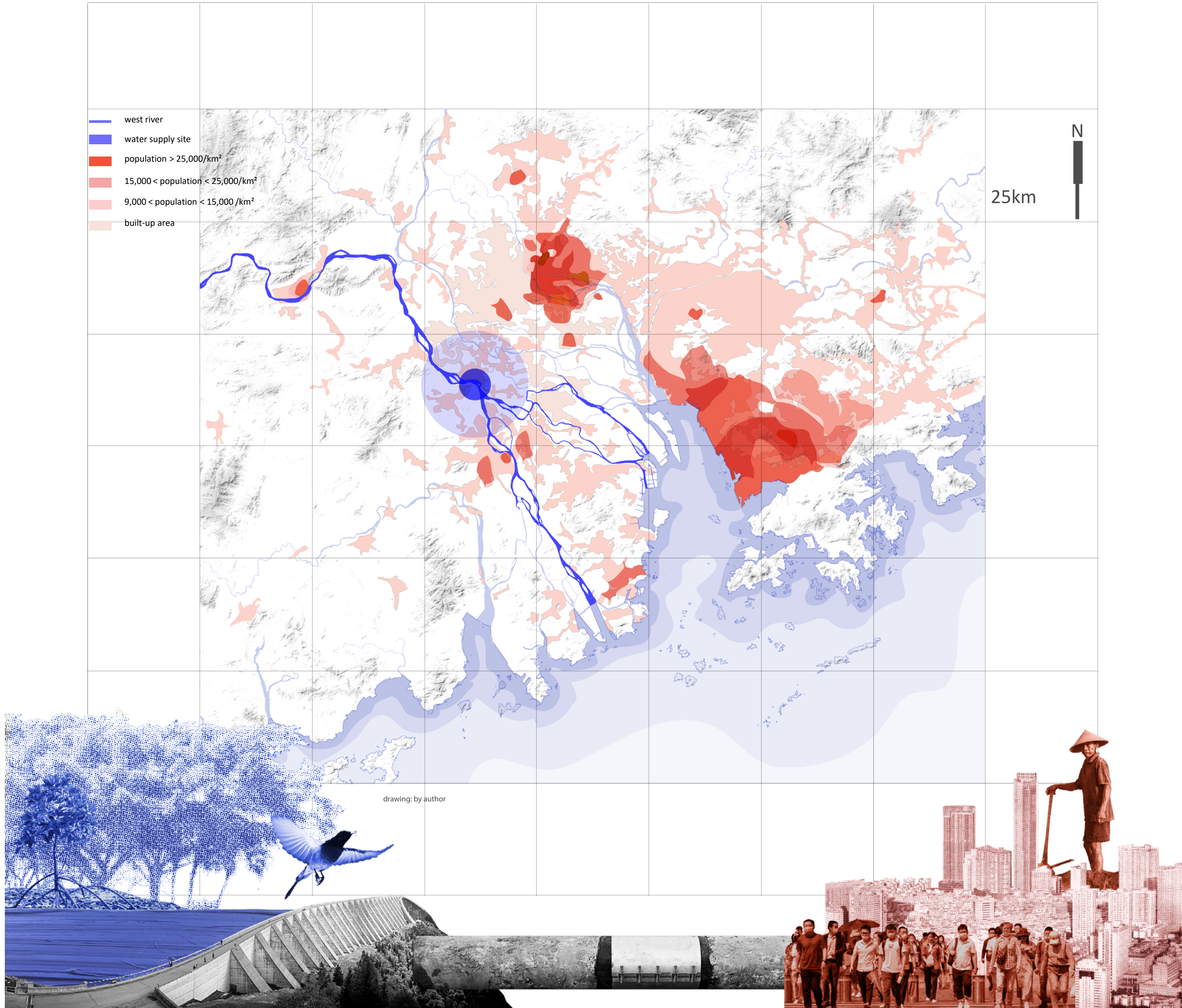


Is it a Suitable Solutions for Sustainable Freshwater Supply in the Pearl River Delta?

The western region of the Pearl River Delta has substantial river flow, with more than 330 billion cubic meters, particularly in the West River, which presents favorable conditions for the construction of large reservoirs. However, in contrast, the estuary of the Pearl River Delta is a high-density urban agglomeration, where the natural conditions for freshwater resource storage are limited due to intensive development and the demand for fresh water resources is rapidly increasing.

To address this challenge, the government has proposed a centralized freshwater supply system to transport water from the suburbs to the high-density urban areas. The project is 113 kilometers long, designed to supply 1.708 billion cubic meters of water annually, which is approximate 2% of the annual average precipitation(121.0 billion cubic meters) of the PRD. This engineering project for the centralized freshwater supply system, however, has an estimated cost of 35.4 billion yuan, almost 5 billion in euro.

However, this solution creates an unsustainable supply model. Climate change has led to a decrease in runoff in the West River in recent years, including autumn and winter drought events. It is imperative to restore the landscape ecosystem in the upstream of the West River instead of further overburdening the freshwater resources. Additionally, the project requires the construction of water pipelines at depths of 40-60 meters underground, resulting in the permanent acquisition of 1.733,33 ha of land. The geology of the Xijiang River is complex and diverse, and this method fails to fully develop the potential for freshwater resource storage in geological strata and may even cause damage.



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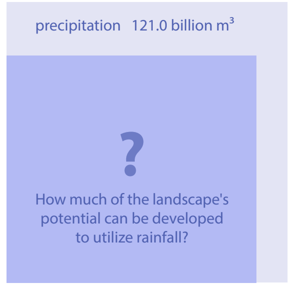
1 INTRODUCTION

1.1 Fascination

1.1.4
An Alternative Approach:
Spatial Decentralized Freshwater Supply

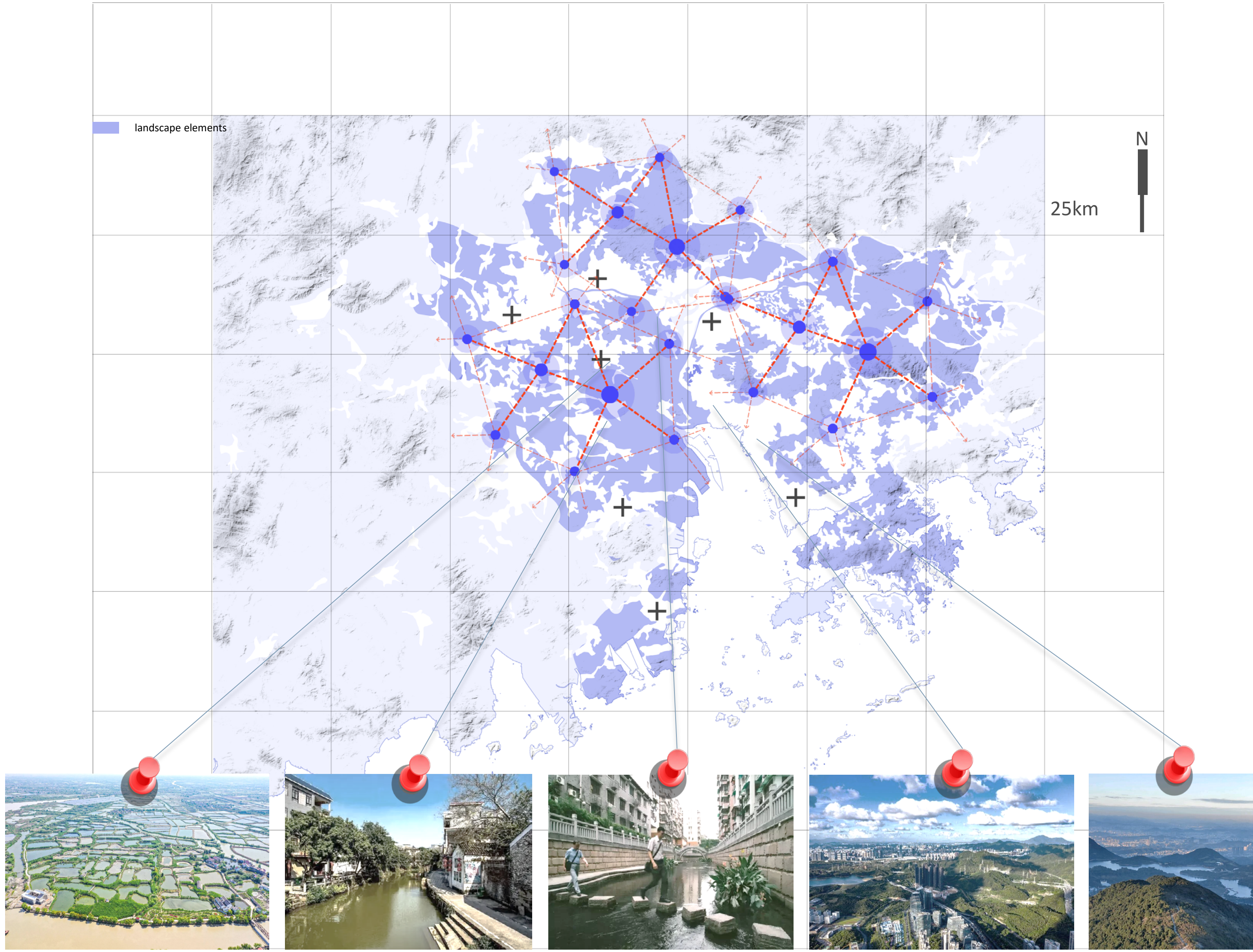


Exploring Sustainable Solutions for Freshwater Supply in the Pearl River Delta

For one thing, the Pearl River Delta region in southern China has a diverse landscape that holds great potential for freshwater conservation and recharge. This region is characterized by a variety of landscapes, including the West River Plain with its historical mulberry fishponds, the dense urban areas with man-made channels, hills and forests within the cities, sand dunes and dams along the coastline, among others. These landscapes have distinct functions and are distributed across various areas of the Pearl River Delta.

Moreover, the Pearl River Delta region consists of nine major urban centers and their suburbs, featuring dynamic land use such as agriculture, industry, urban built-up areas, and so on. Given the complexity of the region's spatial characteristics, a comprehensive understanding of various subsystems and their interactions is critical for exploring the potential of decentralized freshwater supply solutions. Therefore, the landscape of the Pearl River Delta can be viewed as a complex system composed of subsystems, such as the ecosystem, geo-hydrology system, and biological system (including flora and fauna), socio-cultural, and economic and so on, each with its unique dynamics and rate of change (Meyer and Nijhuis, 2013).

The impacts of climate change and the increasing urban expansion have made freshwater supply a pressing issue in the Pearl River Delta region. In this context, the region's diverse landscape types and their varied interactions with the hydrological cycle hold potential for freshwater conservation and recharge. To fully understand the relationship between these landscape types and the stocks and flux of the hydrological cycle, it is essential to optimize the use of precipitation and surface run-off while reducing evaporation and flow into the sea. Landscape-based solutions can provide a practical framework for defining and sustaining urban development and ecological processes, using landsape design principles as the operative field. In addition, the manage aquifer recharge as a technical guide, can enrich the potential space for freshwater conservation and recharge, providing a toolbox for strategic design.



-Water scarcity and the comprehensive effects of climate change and urbanization

The Pearl River Delta, located in Southern China with a subtropical climate, is currently facing a severe water scarcity issue due to the combined effects of climate change and urbanization. As the hydrological cycle is being impacted by climate change, it has led to an uneven distribution and limited availability of freshwater. The rise in temperatures has caused extended drought periods, and the extraction of groundwater has resulted in its depletion. Additionally, during the wet season, an increase in storm events exacerbates the uneven distribution of freshwater, leading to a loss of precipitation resources.

-The potential of the landscape are ignored

The government's proposed centralized freshwater supply system may not be sustainable for managing freshwater in the region, as it fails to tap into the potential of the local hydrological system. The landscape of the Pearl River Delta holds enormous potential for freshwater infiltration, retention, storage, and recharge. Natural systems such as mountain forests, traditional water systems, and the coastal mangrove ecosystem can be harnessed to create sustainable solutions for freshwater management. Utilizing these systems can help avoid damaging the water source area's ecosystem and promote a more efficient and effective approach to managing freshwater in the region.

-The existing landscape types not operate in the holistic system

A lack of understanding about the holistic hydrological system has led to insufficient implementation of landscape-based design principles for freshwater conservation and recharge. Freshwater conservation and recharge processes are dynamic and relate to various physical spaces, ranging from the atmosphere and ground surface land types to soil types and the hydro-geological aquifer layer. By reassessing landscape types based on the hydrological cycle, the freshwater supply landscape infrastructure can be an integral design approach, where objectives and means converge to promote a more sustainable and efficient approach to freshwater management.

In general, the Pearl River Delta faces severe water scarcity due to climate change and urbanization, resulting in an uneven distribution of freshwater. The proposed centralized freshwater system may not be sustainable, and optimizing the potential of natural systems can be harnessed for sustainable freshwater supply Understanding the holistic hydrological system and reassessing landscape types can promote a more sustainable landscape-based approach to freshwater conservation and recharge.

1.3 Research Objective

"

to identify and explore landscape-based design principles for spatial decentralized freshwater supply in the Pearl River Delta

"

1.3 Research Questions

Understanding

How to understand the landscape contexts in the PRD from the systemetic perspective and the upcoming challenges related to the freshwater supply issue?

· Context analysis
· Problem identity
· The role of the landscape

Potentials

What are the potentials of the landscape in terms of decentralized freshwater supply in response to the comprehensive effects of the PRD?

· Geo-hydrology
· Topsoil
· Landscape Type

Application

How is the decentralized freshwater supply infrastructure function as part of the landscape-based system?

· Design strategies
· Regional strategy
· Spatial Principles

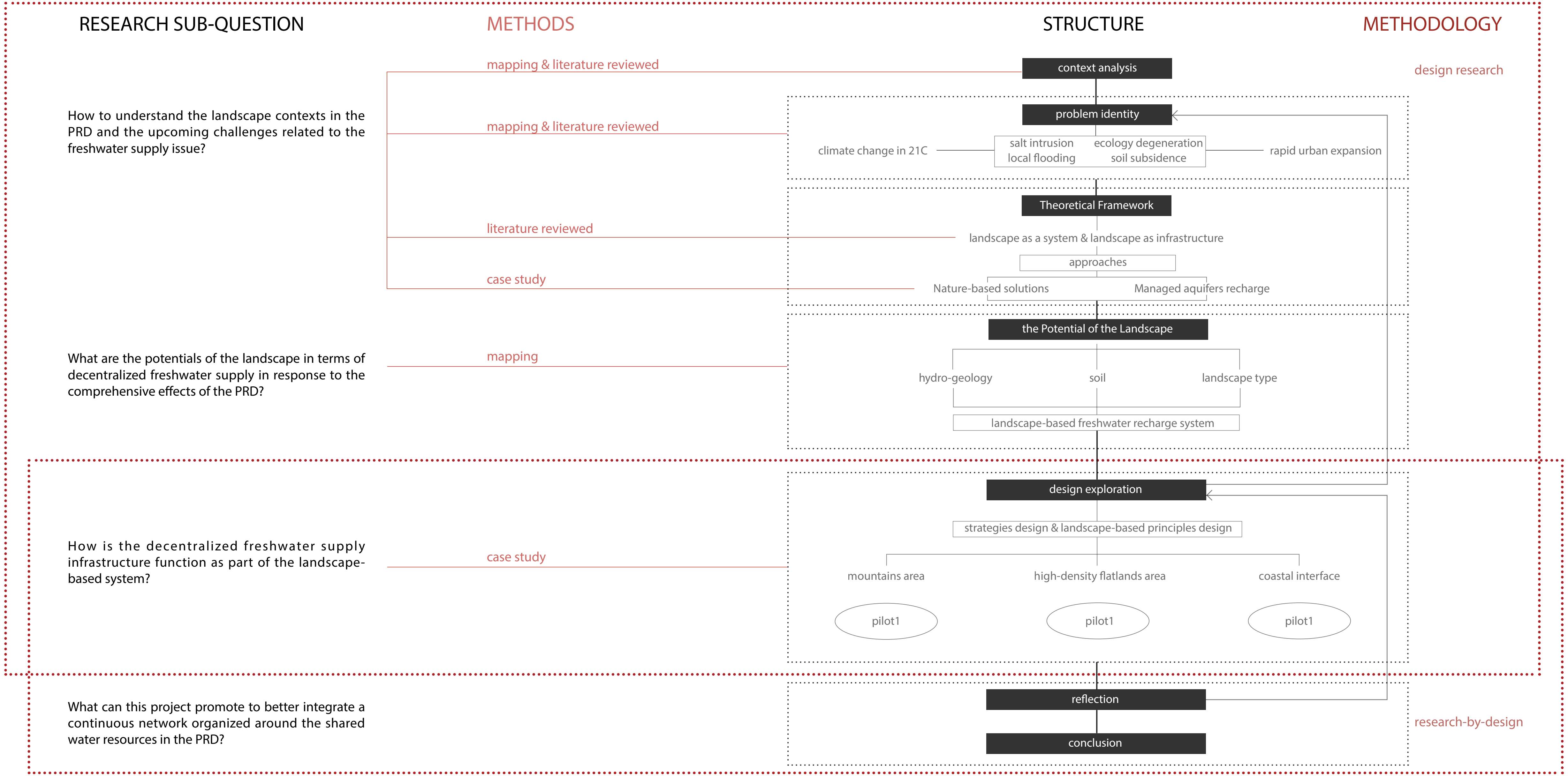
Lessons learned

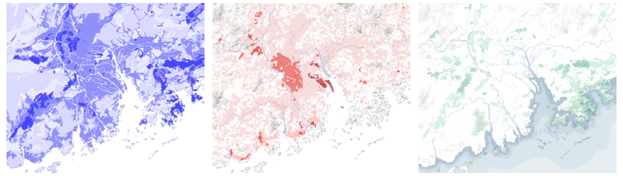
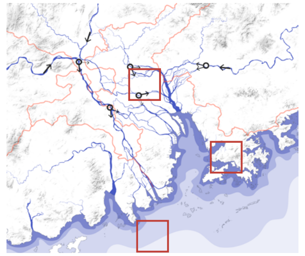
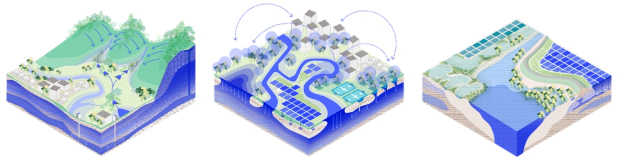
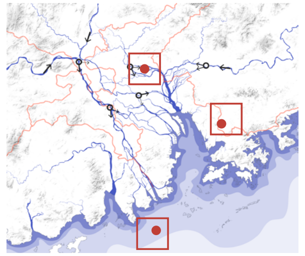
What can this project promote to better integrate a continuous network organized around the shared water resources in the PRD?

· Conclusion
· Reflection

1 INTRODUCTION

1.4 Research Structure



scales		challenges	goals
macro-scale PRD region 		1. A conflict between the rising demand for freshwater in densely populated urban areas and the decreasing availability of freshwater due to the combined effects of climate change and urbanization; 2. The PRD lacks an integrated system for freshwater supply due to its disjointed landscape types.	1. To explore the landsacpe potential in PRD based on the hydrological cycle for freshwater conservation and recharge 2. To construct a spatial decentralized green & blue system adapt to the climate change and the urbanization and enhance availability of freshwater.
meso-scale 5km x 5km 		Identify the typical landscape region and the corresponding strategy and spatial principles	To explain the phases of how the green & blue system build on 3 typical region, and how it function on the freshwater conservation and recharge
micro-scale 1km x 1km 		1. Site assessment: identity the precise hydrology, topography, vegetation information of a material site; 2. Freshwater-supply infrastructure integrated with other function & programme 3. Technical problems	To show intervention; explore integrated scheme with the local programme spatial quality for individual area;

1 INTRODUCTION

1.7 Scope and Relevance

Water scarcity is a pressing issue in high-density cities, especially those situated along coastal areas facing the effects of global climate change.

The project focuses on using landscape-based principles and methods to re-examine the relationship between freshwater resources in the Pearl River Delta, ecological systems, and the spatial development patterns of the hydrological cycle system. Because the freshwater resources cycle follows the regional climatic hydrological cycle system of the entire Pearl River Delta. Secondly, the rapid development of the Pearl River Delta has resulted in a transformation of its natural landscape into an urban system, transportation system, industrial facilities system, and so on, making the cityscape of the Pearl River Delta a complex system composed of multiple subsystems with varying rates of evolution.

In this context, considering the landscape as a system and viewing the landscape infrastructure as an operative field, can provide a landscape framework available to serve multiple purposes, and explores the potential of decentralized freshwater supply solutions.The resulting framework explores potential for freshwater conservation and recharge, urban ecological restoration on mountain forests, urban public spaces, coastal interface, and meanwhile it offers the new possibilities for the multi-layers interactive in the landscape infrastructure, like agroforestry, climate-adaptive community, and coastal aquaculture industries, entertainment, which promotes a sustainable and resilient approach to landscape design.

In a broader context, the project responds to how the landcsape-based solutions role as an operative sector of the hydrological system to prepare for freshwater coservation and recharge, and reach a sustainable way on the vulnerability and future climate challenges in a high-density area of the Delta.

CHAPTER 2 THEORETICAL FRAMEWORK

2.1.1
Landscape as a system

1. **Landscape as a system**

Urban landscapes can be known as complex systems that consist of interdependent subsystems, each with its own dynamics and rate of change(Otto, 2011; Portugali et al., 2012; Batty, 2013). This perspective acknowledges that the urban landscape is a system where different processes and systems influence one another and operate at different rates of change(Nijhuis, Daniel 2015& Braudel, 1966).
The spatial dimension of networks and locations is referred to as the space of flows and the space of places. Within this context, networks serve as crucial conduits for interactions, communication, and relationships, while locations emerge as a result of these interactions.(Castells, 2000)
In the Pearl River Delta (PRD), the urban landscape can be viewed as a complex system that consists of subsystems, each with its dynamics and velocity of change.

2 THEORETICAL FRAMEWORK

2.1 Theoretical Background

2.1.2
Landscape as infrastructure

2. **Landscape as Infrastructure**

Infrastructure is defined as the human impetus to alter the natural environment, while the landscape is described as the inadvertent result of natural and human factors(PERSI, 2006) (Council of Europe, 2000). However, their combination presents a chance to redefine both concepts as an integral design approach where objectives and means converge. This results in landscape structures that are operative and serve multiple purposes(steffen nijhuis & Daniel jauslin, 2015). Conceiving infrastructure as landscape generates architecture, constructing landscapes and living environments, and engaging social and imaginative dimensions as much as engineering(Shannon & Smets, 2010). This implies that infrastructures no longer belong to the realm of single disciplines, but to a crosscutting field that involves multiple disciplines and in which the role of designers is essential(Shannon & Smets, 2011; Bélanger, 2010).
Treating infrastructure as the landscape can be regarded as an object-oriented approach, where infrastructure is viewed as the object and is approached as an interdisciplinary landscape design concept with a focus on the various "scapes." (steffen nijhuis & Daniel jauslin, 2015).

2.2.1
Nature-based Solutions

3. the Natural-based Solutions:

"Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."

(IUCN definition, Cohen-Shacham, 2015)

Eight proposed NbS principles for providing a full understanding of NbS for IUCN:

1. embrace nature conservation norms (and principles);
2. can be implemented alone or in an integrated manner with other solutions to societal challenges (e.g. technological and engineering solutions);
3. are determined by site-specific natural and cultural contexts that include traditional, local and scientific knowledge;
4. produce societal benefits in a fair and equitable way, in a manner that promotes transparency and broad participation;
5. maintain biological and cultural diversity and the ability of ecosystems to evolve over time;
6. are applied at a landscape scale;
7. recognise and address the trade-offs between the production of a few immediate economic benefits for development, and future options for the production of the full range of ecosystems services; and
8. are an integral part of the overall design of policies, and measures or actions, to address a specific challenge.

(IUCN definition, Cohen-Shacham)

2 THEORETICAL FRAMEWORK

2.2 Approaches

Ecosystem-related approaches within the NbS: Green infrastructure Approaches and Nature infrastructure Approaches

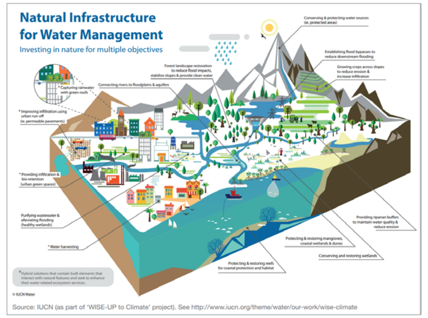
2.2.1
Nature-based Solutions

The European Commission in the context of the EU Green Infrastructure Strategy defines ***Green Infrastructure*** as:
"a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" .

(European Commission, 2013)

A ***Natural Infrastructure*** approach could be seen to be restoring structure, function and composition of ecosystems to deliver ecosystem services. In contrast, green infrastructure aims to improve these aspects of ecosystems in order to deliver these services. While green infrastructure is used in both urban and landscape settings, natural infrastructure is only used on a landscape scale. Nevertheless, both approaches share common principles and objectives, such as connectivity, multifunctionality, and intelligent conservation.

(European Environment Agency, 2011)

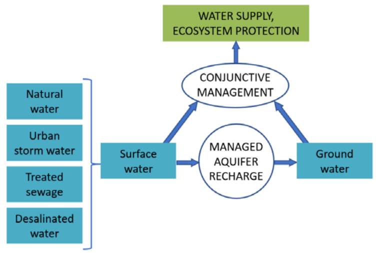


source: IUCN (as part of 'WISE-UP to Climate' project). http://www.iucn.org/theme/water/our-work/wise-climate

In both ***Green Infrastructure*** and ***Natural Infrastructure*** approaches, hybrid solutions are commonly used, mixing hard infrastructure with ecosystem-based infrastructure. Green infrastructure is used in the spheres of policy, practice and scientific research; its research applications tend to relate to urban settings

(IUCN definition, Cohen-Shacham, 2015&Tzoulas et al., 2007)

2.2.2
Managed Aquifer Recharged



Roles of managed aquifer recharge and conjunctive use in integrated water resources management

source: Dillon and Arshad, 2016

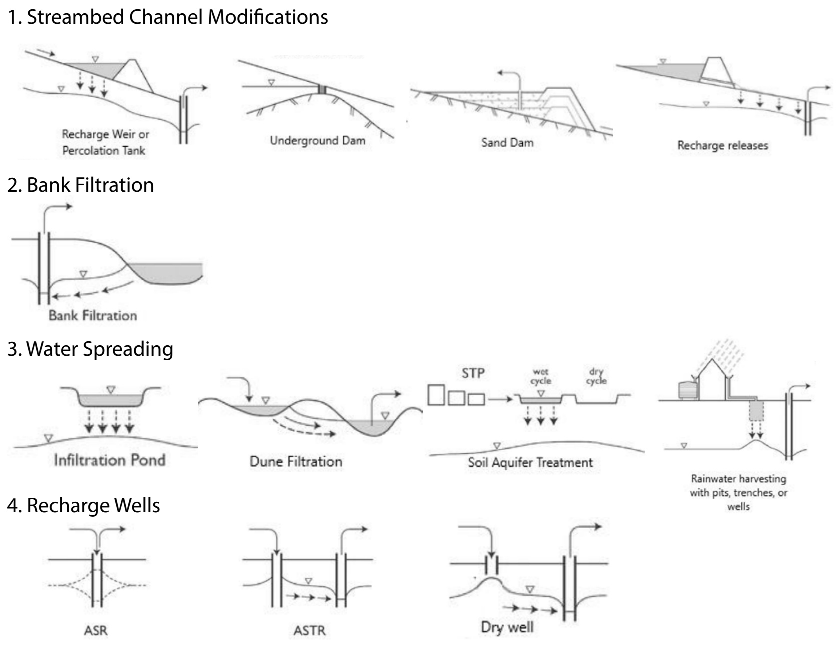
4. Managed Aquifer Recharged

Managed aquifer recharge (MAR) is defined as the purposeful recharge of water to aquifers for subsequent recovery or for environmental benefit (Dillon et al., 2009). This is typically done by directing surplus water, such as stormwater or treated wastewater, into the ground, where it can be stored in the aquifer for future use. This can help to increase the availability of fresh water for drinking and irrigation, and can also help to prevent water pollution by recharging the aquifer with clean water.

Managed aquifer recharge is often connected with the concepts of sustainability, conjunctive use, and demand management (Dillon and Arshad, 2016).

> ***Groundwater sustainability*** can be defined as development and use of groundwater resources in a manner that can be maintained for an indefinite time without causing unacceptable environmental or socioeconomic consequences (Alley and Leake, 2004). For sustainable management of a groundwater resource, demand ultimately needs to be managed to balance the recharge, whether it be natural, managed or incidental.
>
> ***Conjunctive use*** means using both surface water and groundwater together to get the most benefit while minimizing negative effects. This involves using more surface water during wet years and more groundwater during dry years. Managed Aquifer Recharge (MAR) is often used alongside conjunctive use to add surface water to groundwater and help sustain water resources and protect ecosystems.
>
> (Dillon, P., W. Alley, Y. Zheng, and J. Vanderzalm (editors), 2022, Managed Aquifer Recharge: Overview and Governance)

Schematic of various types of MAR:



Source: Redrawn from Dillon et al, 2009

2.2.2
Managed Aquifer Recharged

Streambed Channel Modifications impoundments can be designed to capture or slow down runoff, which infiltrates through the bed to enhance storage in unconfined aquifers and is extracted down-valley.

Bank Filtration pumps water from underground aquifers connected to water body. The pumping induces seepage from the surface water body into the aquifer and provides filtration of the water as it flows to the water supply well.

Water spreading recharges an underground aquifer via ponds, basins or wetlands, and the recharged water is later extracted for use. Contaminants are attenuated faster through the unsaturated zone than through aquifers.

Recharge wells are used when the aquifer is deep, confined or has low permeability layers. Different methods like ASR, ASTR, and dry wells are used.

(Dillon, et al, 2022,)

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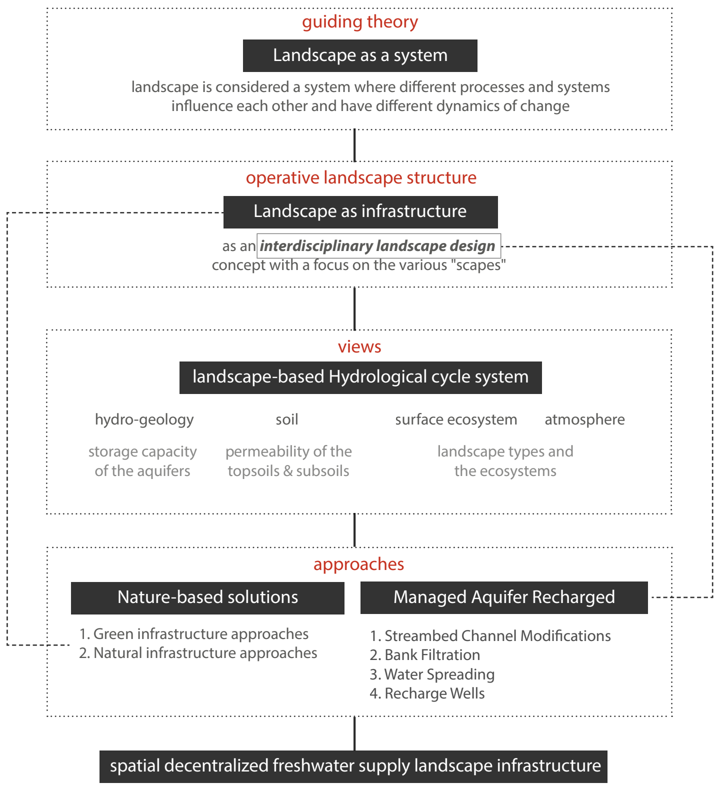


The project focuses on using landscape-based principles and methods to re-examine the relationship between freshwater resources in the Pearl River Delta, urban society, ecological systems, and the spatial development patterns of the hydrological cycle system. Firstly, the freshwater resources cycle follows the regional climatic hydrological cycle system of the entire Pearl River Delta. Secondly, the rapid development of the Pearl River Delta has resulted in a transformation of its natural landscape into an urban system, transportation system, industrial facilities system, and so on, making the cityscape of the Pearl River Delta a complex system composed of multiple subsystems with varying rates of evolution.

To address the freshwater resource issues in the Pearl River Delta, the project must take the entire landscape system of the region as the object of study. By using the concept of landscape as a system and landscape as infrastructure, the project will analyze the relationships among multiple levels and scales of systems, and integrate them to function together. The project will decompose the landscape into geo-hydrology infrastructure, ecology infrastructure, and urban-societal infrastructure to understand how freshwater resources operate within each infrastructure, and integrate the storage potential of all three levels to achieve an integrated, interactive freshwater resource storage system. By using design research and research by design, the project will explore methods that can effectively address the freshwater resource issues in the Pearl River Delta and further refine the theoretical framework.

CHAPTER 3 ANALYSIS & UNDERSTANDING

3 ANALYSIS & UNDERSTANDING
3.1 Background Information

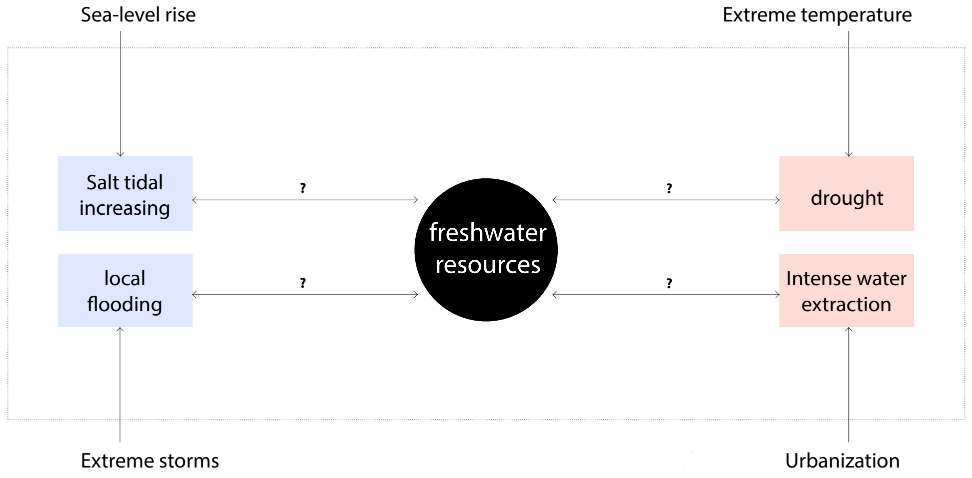
How does the hydrological cycle spatially respond to the processes of climate change and urbanization issue in the PRD?

The hydrological cycle is the fundamental pattern of freshwater, with the storage and movement of freshwater through different layers of the water system. Precipitation, surface runoff, evaporation, and groundwater flow all contribute to the flux and stocks in the hydrological cycle, allowing for adjustment of freshwater in the region.

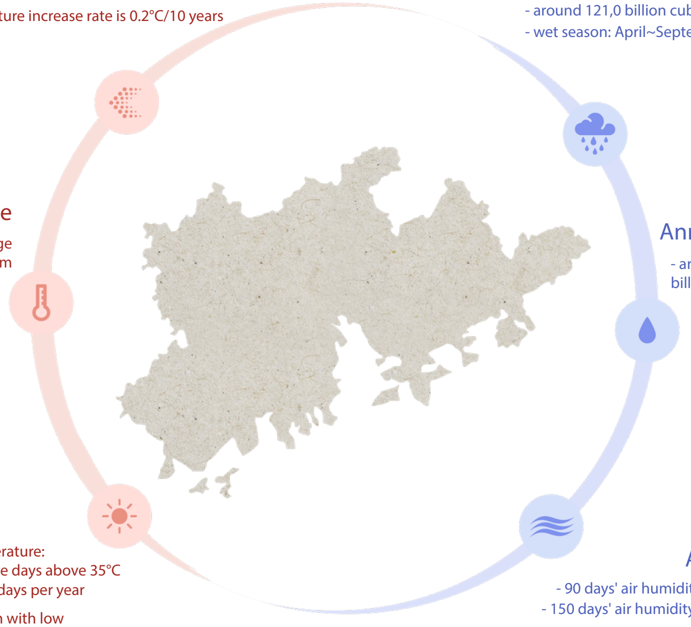
In the Pearl River Delta region, climate change and urbanization are putting pressure on the hydrological cycle. Increasing temperatures, extreme weather events, and the loss of natural landscapes and so on, are affecting the availability and quality of freshwater resources, with significant implications for human health, biodiversity, and economic development.

Understanding the relationship between different landscape types and the stocks and flux of the hydrological cycle is crucial. The landscape plays a vital role in optimizing the use of precipitation and surface runoff to recharge groundwater while minimizing evaporation and outflow into the sea.

Each landscape type has unique characteristics, and landscape-based solutions can provide a practical framework for sustaining urban development and ecological processes. By utilizing landscape design principles, it is possible to define and maintain a balance between the water cycle and the built environment, promoting sustainable water management and ecological health in the region.



3.1.1
Climate change as accerlerator for freshwater scarcity



drawing: by author
source: Guangdong Meteorological Service, Water Resources Department of Guangdong Province

3.1.1
Climate change as accerlerator for freshwater scarcity

Challenge and Opportunity

The 21st century has witnessed a significant increase in environmental issues and climate change, which have become a crucial factor affecting the hydrological cycle. The changing climate leads to alterations in precipitation, evaporation, and water flow dynamics, thereby impacting water resources. The freshwater resources are part of the hydrological cycle and undergo constant transfer through different stocks (such as lakes, soils, atmosphere, biomass, and reservoirs) and fluxes (such as rivers, rainfall, evapotranspiration, and urban drainage). The distribution of these resources is influenced by various factors, including the climate and social environment, leading to uneven distribution and disrupted circulation of freshwater. As a result, the limited amount of freshwater may not be available when and where it is required. In some cases, such as storm events or the extreme drought, the concentration or reduction of water flow can result in disastrous consequences.

On one hand, the Pearl River Delta has been experiencing severe drought due to rising temperatures in the past five years. This results in decreased precipitation, increased evaporation, and reduced availability of fresh water resources in the dry season. The region is also facing the challenge of rising demand for water for activities such as agriculture, manufacturing, and domestic use, as well as the threat of drinking water crisis due to saltwater intrusion from rising sea levels.

On the other hand, the increased frequency of storm events during the wet season due to climate change exacerbates the uneven distribution of freshwater resources.

However, climate changes in 21C present new opportunities as well. The altered hydrological cycle due to climate change can be utilized to re-evaluate the spatial structure of freshwater resources in the Pearl River Delta and tap into the landscape's potential to provide freshwater. By doing so, the challenges posed by climate change can be transformed into opportunities.

3 ANALYSIS & UNDERSTANDING

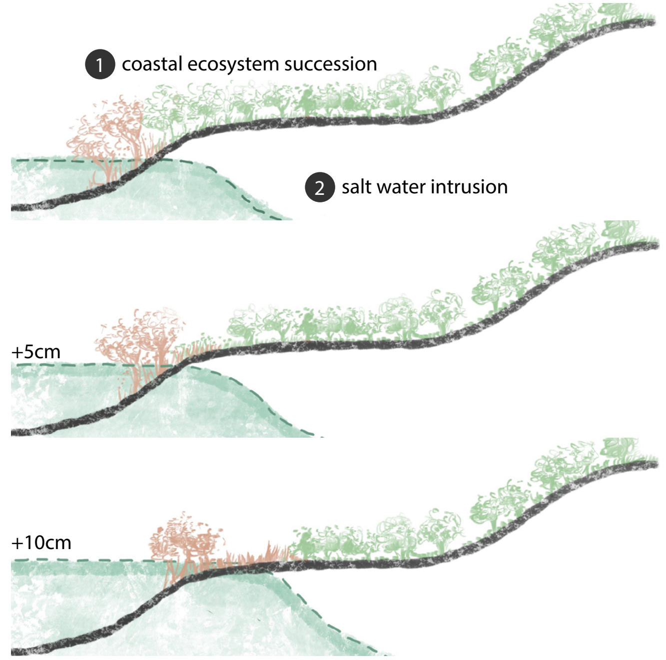
3.2 Layered Analysis

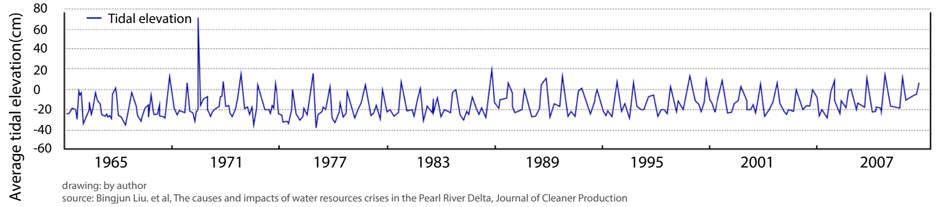
3.2.1
From Sea-level Rise
to ***Salt Intrusion***

The salt water intrusion in the Pearl River Delta, resulting from frequent dry seasons and low terrain, mainly affects the estuary and Xijiang Plain regions, where the river network is dense. The impacted land areas include coastal wetlands, a small amount of mangroves, river valleys, farmland on the river valley plains, and urban green spaces.

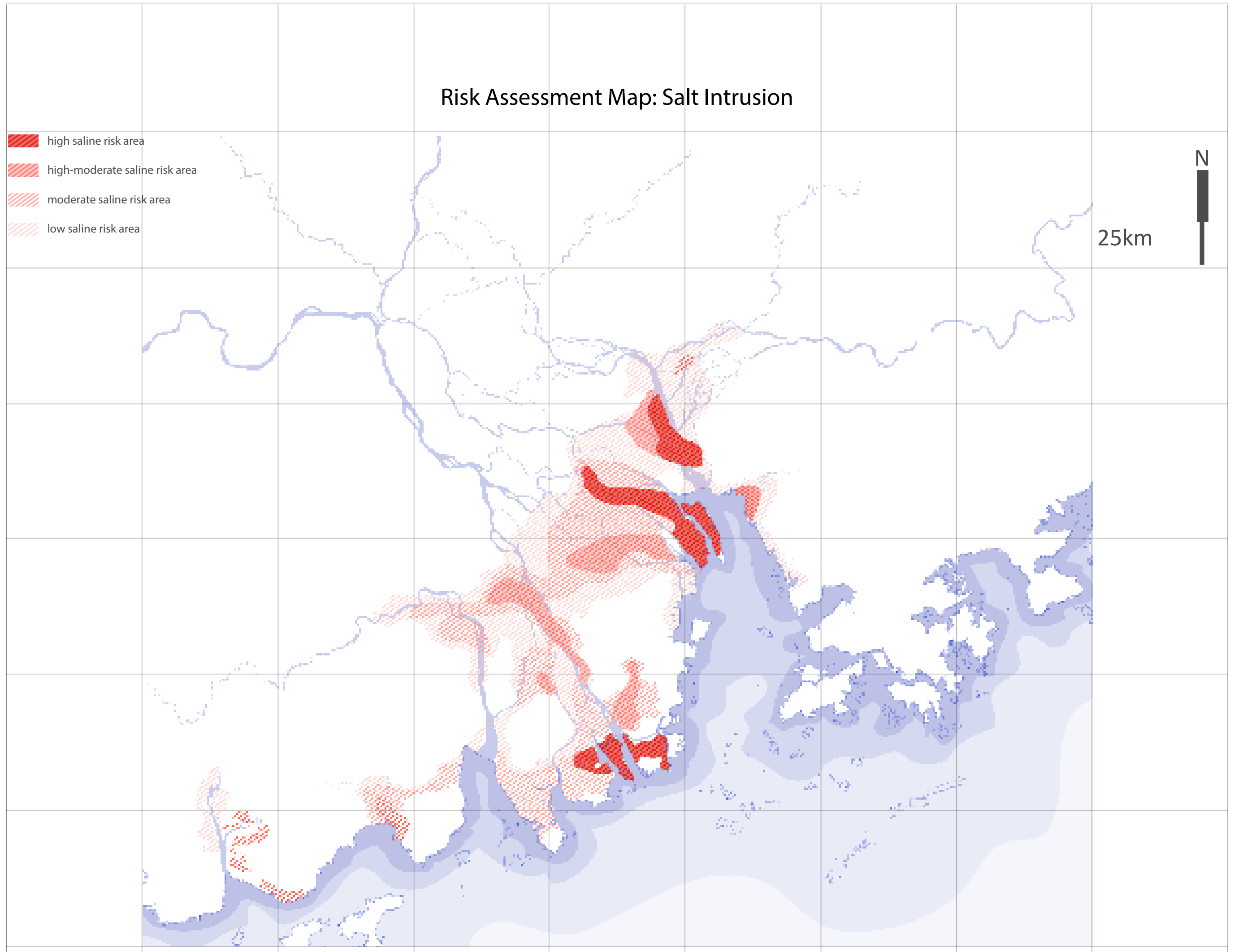
Currently, the landscape functions and land use patterns in the affected areas are fragmented and single-purpose, with agricultural lands focusing solely on planting, and the fragmentation of land use reducing the ecological value of wetlands and mangroves.

To address this issue, a more landscape-based approach that integrates multi-functional lands in the Pearl River Delta can help activate the potential of landscape-based infrastructures while also increasing resilience against saltwater intrusion. Such an approach can enhance the ecological value of wetlands and mangroves and promote sustainable land use.





drawing: by author
source: Bingjun Liu. et al, The causes and impacts of water resources crises in the Pearl River Delta, Journal of Cleaner Production



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source: baesed on Huang, P. et al, Assessment of groundwater sustainable development considering geo-environment stability and ecological environment: a case study in the Pearl River Delta, China.

As the sea level rises, saltwater intrusion into both surface and underground water sources becomes a concern. The denser saltwater moves downward, it intrudes into the lower layers of fresh groundwater, reducing its availability and gradually increasing its salinity. The process of saltwater intrusion can have devastating effects on freshwater ecosystems, making the water brackish and unsuitable for human consumption or agriculture.
Saltwater intrusion also alters the water conditions, changing the salinity and temperature, which can affect the distribution and abundance of aquatic species. Over time, this can have far-reaching consequences, including loss of biodiversity, altered food webs, and habitat loss.

3 ANALYSIS & UNDERSTANDING

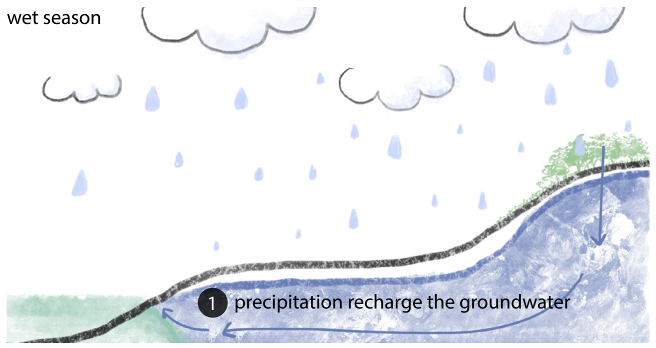
3.2 Layered Analysis

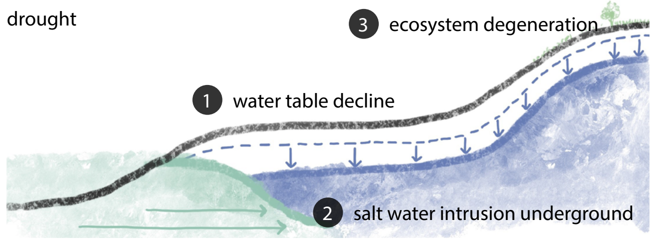
3.2.2
From drought
to ***ecology degeneration***

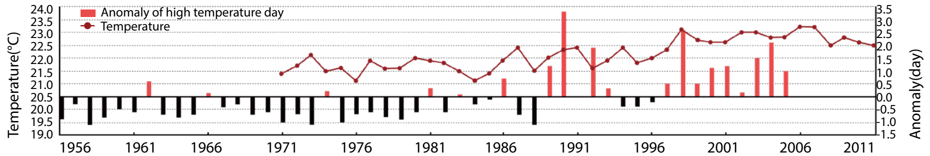
Climate change and extreme weather patterns are leading to more frequent and severe droughts in the Pearl River Delta region.

Urbanization and the loss of green spaces contribute to the problem by reducing the humidity in the atmosphere, exacerbating the effects of drought.

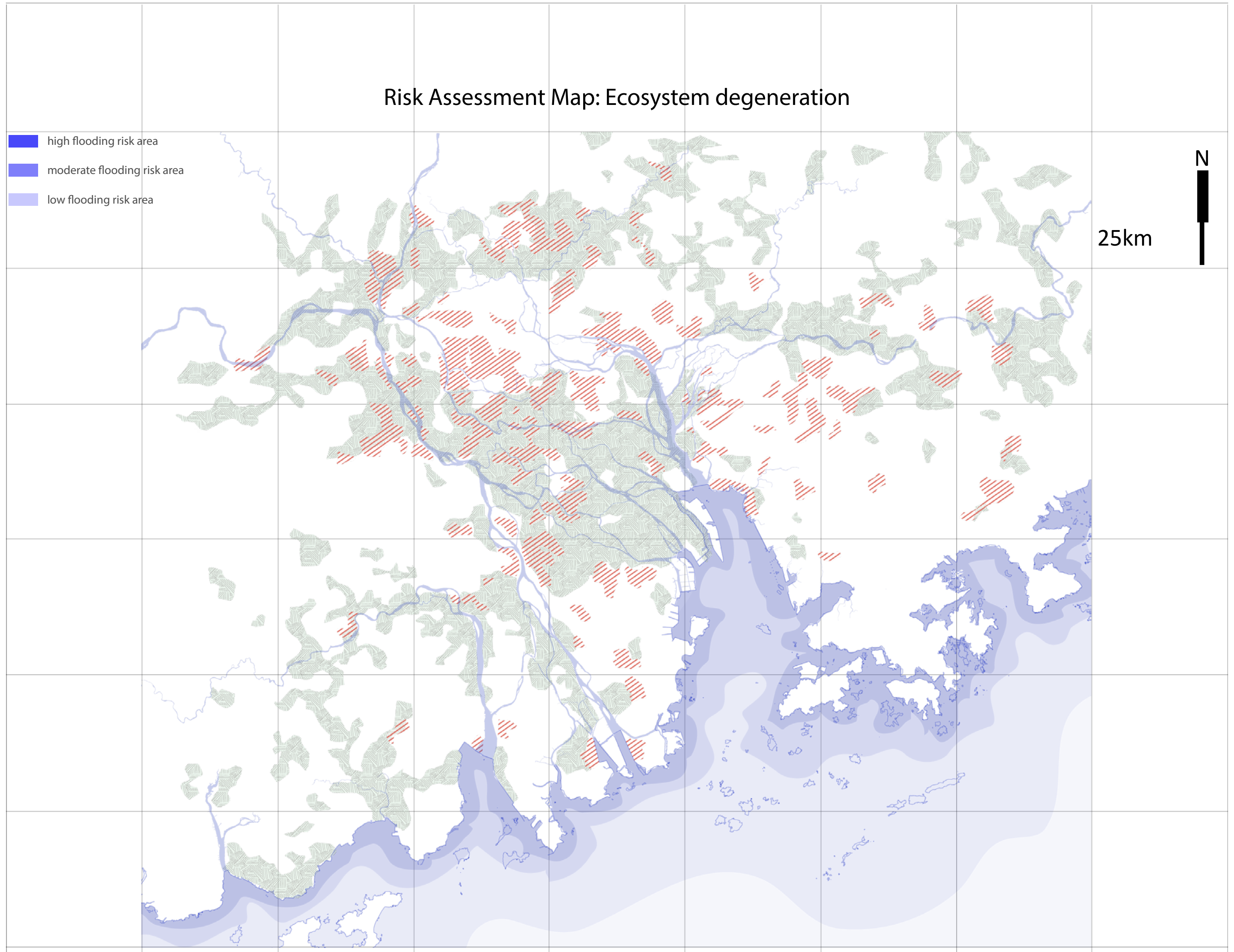
In addition, the underground freshwater reserves decrease during drought seasons, which exacerbates the problem of saltwater intrusion. This creates a vicious cycle where saltwater intrusion further reduces the availability of freshwater, making it increasingly challenging to conserve and manage freshwater resources in the region.







drawing: by author
source: Yang, L et al, Climate-related flood risks and urban responses in the Pearl River Delta, China



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The Pearl River Delta is prone to flooding, and the areas at the greatest risk are concentrated in the West River and Northe River basins, which are also densely populated with cities. The potential for flooding is especially high in agricultural lands, while moderate flood risk affects a vast expanse of territories, spanning nearly all the areas within the West River and Northe River basins. To mitigate the risk of flooding and optimize the utilization of rainfall as a valuable freshwater resource, comprehensive rainwater management strategies are implemented at the basin level. These strategies incorporate a wide range of landscape types to maximize water storage capacity, thus reducing the likelihood of flooding during periods of heavy rainfall.

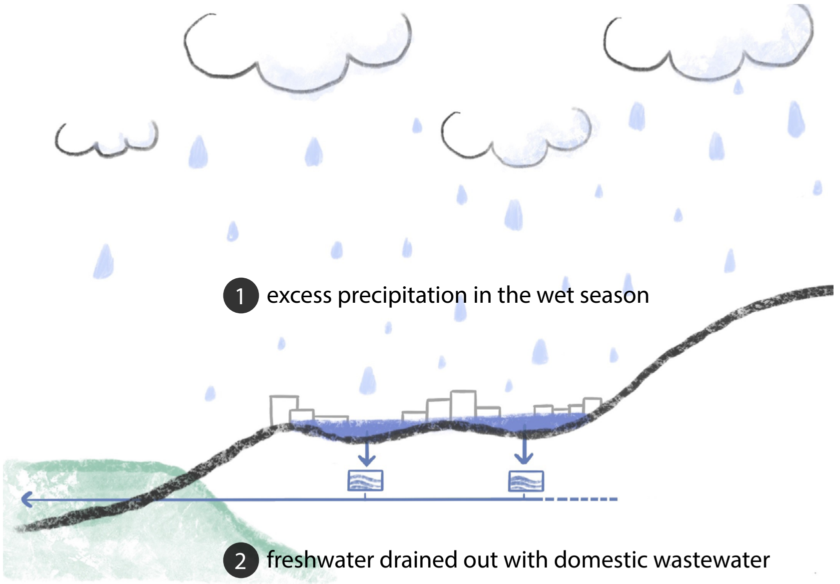
3 ANALYSIS & UNDERSTANDING

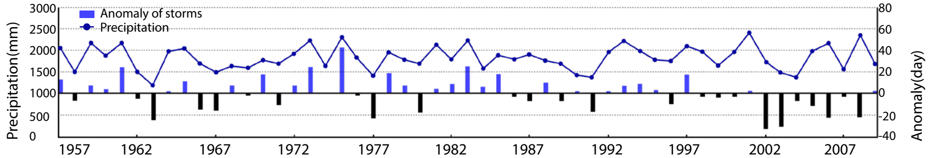
3.2 Layered Analysis

3.2.3
From storms
to ***local flooding***

The Pearl River Delta is prone to flooding, particularly in the estuary where cities and agricultural lands are located. This puts both human settlements and farmland at risk of damage and loss.

In high-density urban areas, the existing drainage system is not optimized for water conservation. Instead of capturing and using the abundant precipitation resources, the system collects the water and mixes it with wastewater, which is then directly drained into the sea. This results in the loss of valuable freshwater resources that could be used for a variety of purposes.





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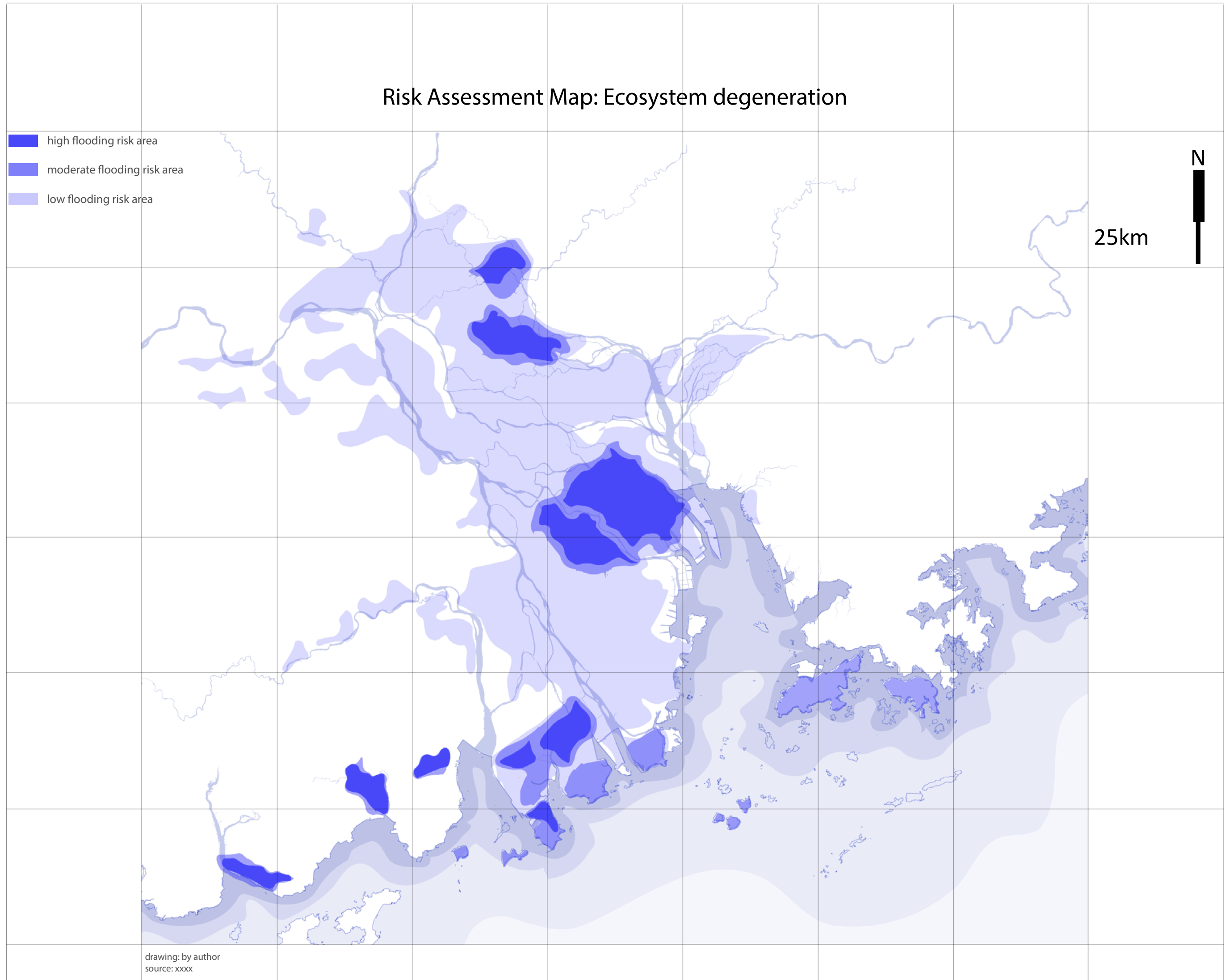
source: Yang, L et al, Climate-related flood risks and urban responses in the Pearl River Delta, China



The Pearl River Delta is prone to flooding, and the areas at the greatest risk are concentrated in the West River and Northe River basins, which are also densely populated with cities. The potential for flooding is especially high in agricultural lands, while moderate flood risk affects a vast expanse of territories, spanning nearly all the areas within the West River and Northe River basins. To mitigate the risk of flooding and optimize the utilization of rainfall as a valuable freshwater resource, comprehensive rainwater management strategies are implemented at the basin level. These strategies incorporate a wide range of landscape types to maximize water storage capacity, thus reducing the likelihood of flooding during periods of heavy rainfall.

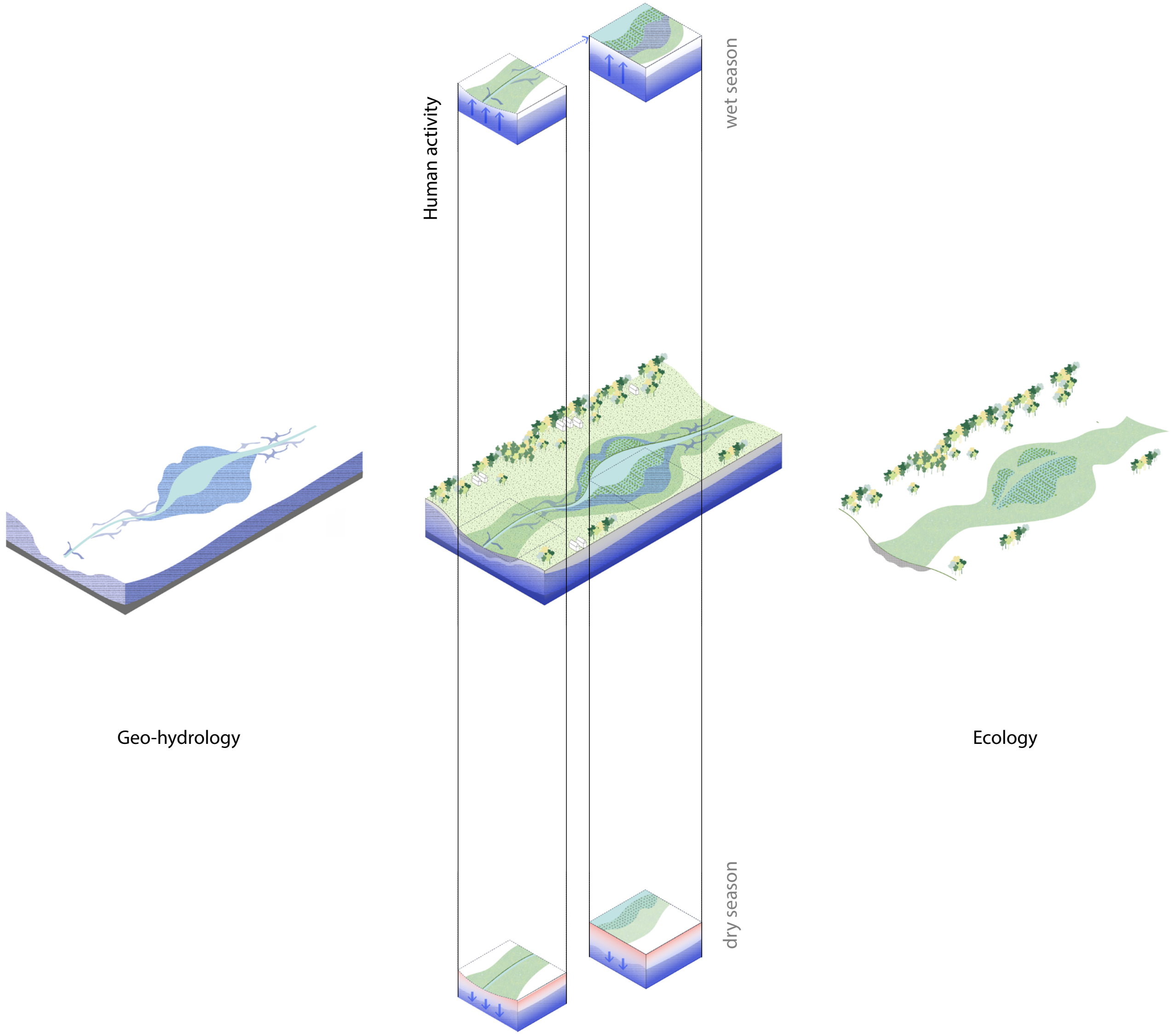
3 ANALYSIS & UNDERSTANDING

3.2 Layered Analysis

3.2.4
human-water relationship
phase1 (BC-1600s)

Natural forces dominant: rely on the groundwater spring and topsoil water

In the past, the PRD had a traditional water management system that relied on natural permeable soil to absorb and retain groundwater for agriculture purposes. This method was effective in ancient times, allowing agriculture activities to flourish along the river basin and valleys. So, the agriculture activities happened frequently along the river basin and the valleys.
However, urbanization have made this system inadequate for managing water, and it was unable to cope with heavy flooding during the wet season. As the system was limited by the availability of seasonal rainfall, resulting in constraints on agricultural activities.



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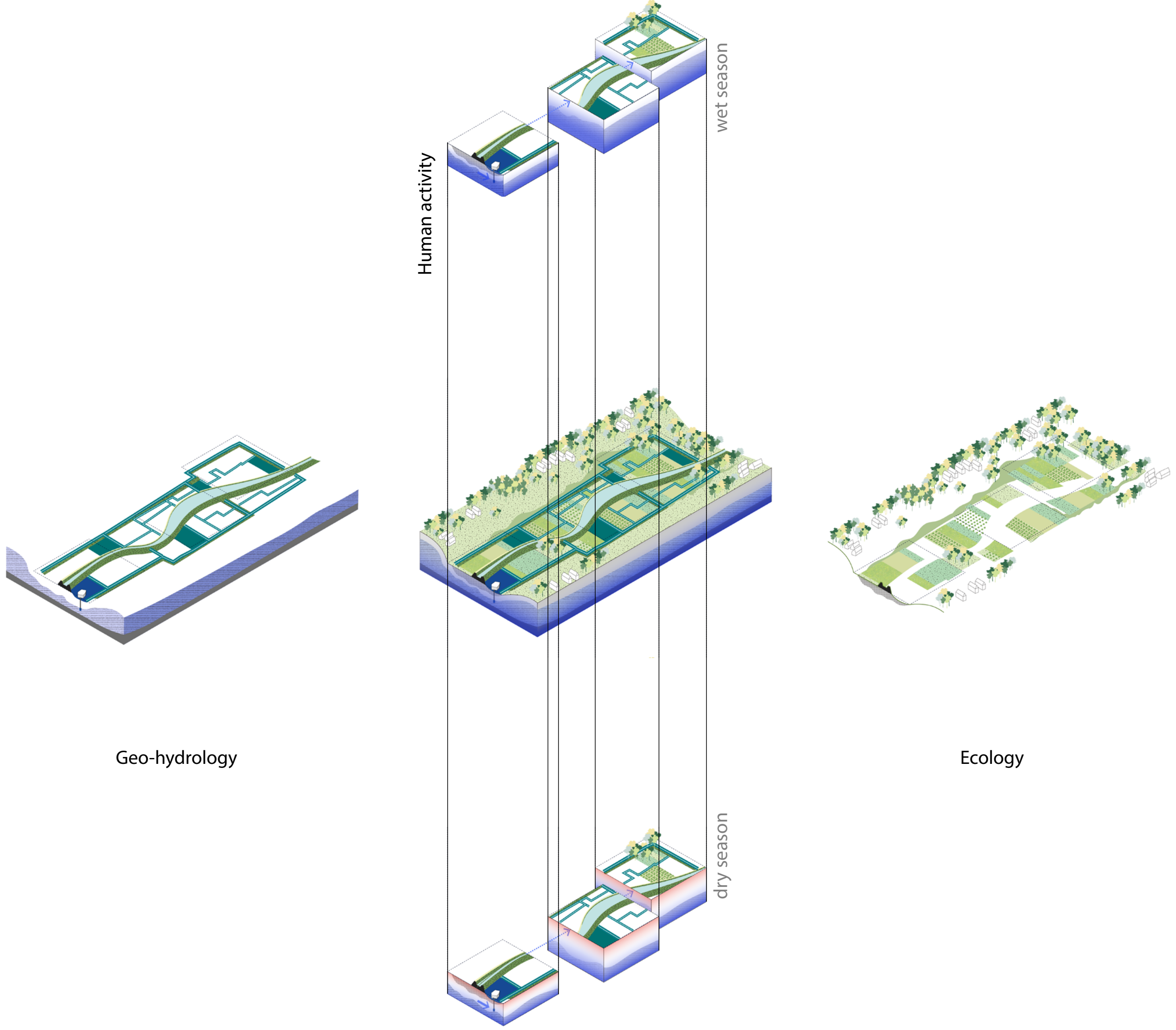
3.2.4
human-water relationship
phase2 (1600s-1950s)

Against the nature: rely on the water infrastructure networks

In the 1600s, people started constructing dams and dikes as a response to the limitations of the traditional water management system. These structures enabled better control over water flow, which increased agricultural productivity and facilitated land reclamation. It also led to changes in the hydrological cycle of the area, altering the natural balance of water resources.
During this period, private-owned dike pond systems were also in operation, such as the mulberry dike pond, which helped maintain a balance between freshwater resources and human demands through material recycling.



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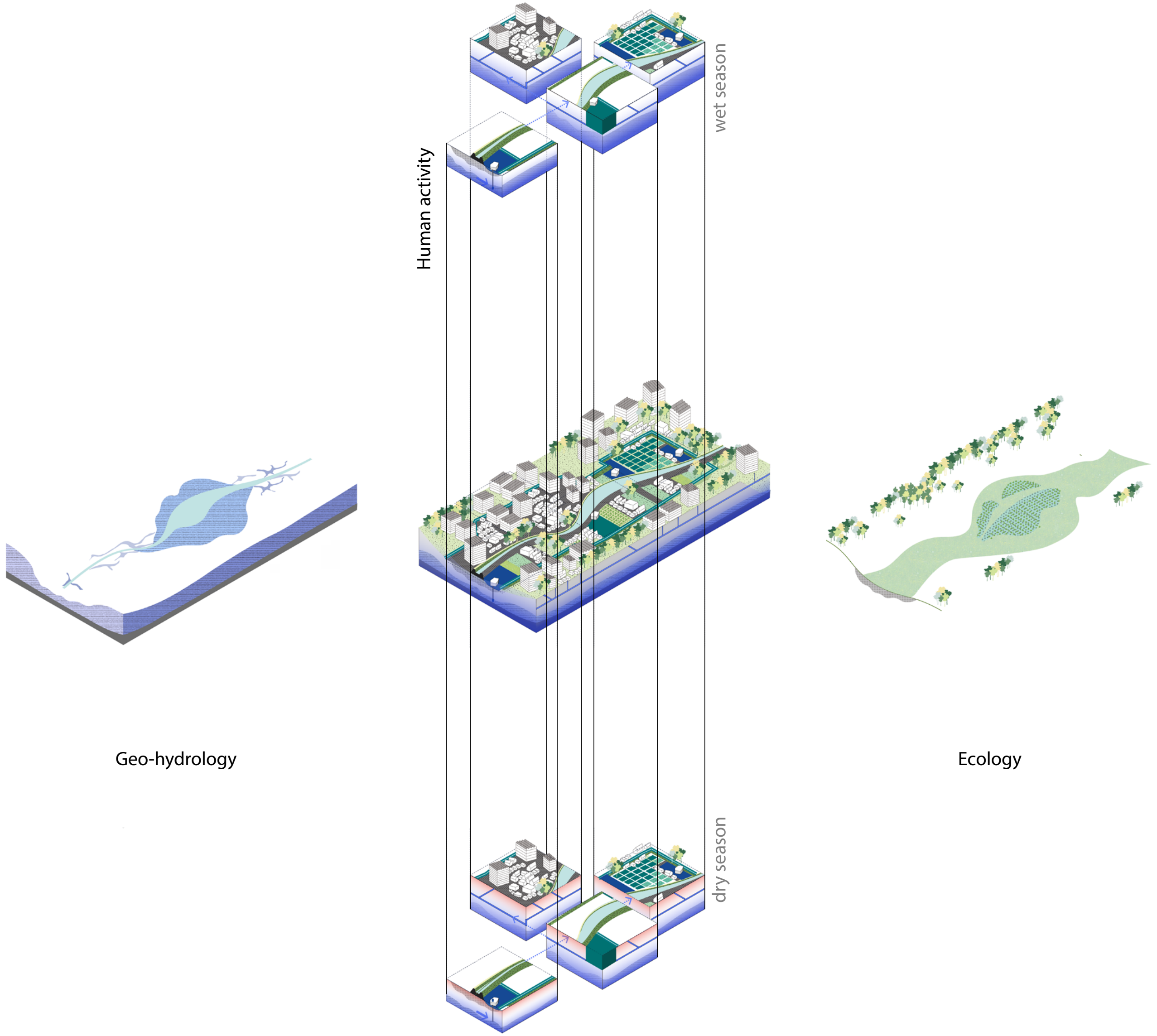
3 ANALYSIS & UNDERSTANDING

3.2 Layered Analysis

3.2.4
human-water relationship
phase3 (1950s-present)

Faces new crisis: rely too much on the large-scale dike system

The implementation of state-owned infrastructures in the 1950s marked a new phase in water management in PRD. Small dikes were combined into larger ones, and new water management technologies were introduced. This led to changes in the delta pattern, which created new opportunities for economic development but also increased flood risk.
However, the benefits of these changes were not distributed equally, and some regions experienced water shortages and ecosystem degradation. Overall, these were a larger trend towards centralized water management and urbanization, which have had significant impacts on the hydrological cycle and the relationship between people and water in the region.



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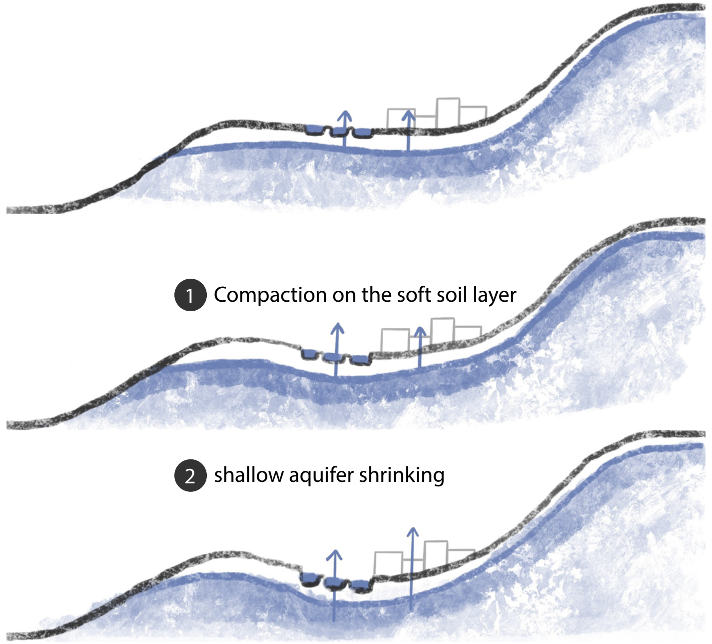
3 ANALYSIS & UNDERSTANDING

3.2 Layered Analysis

3.2.4
From urban expansion
to ***soil subsidence***

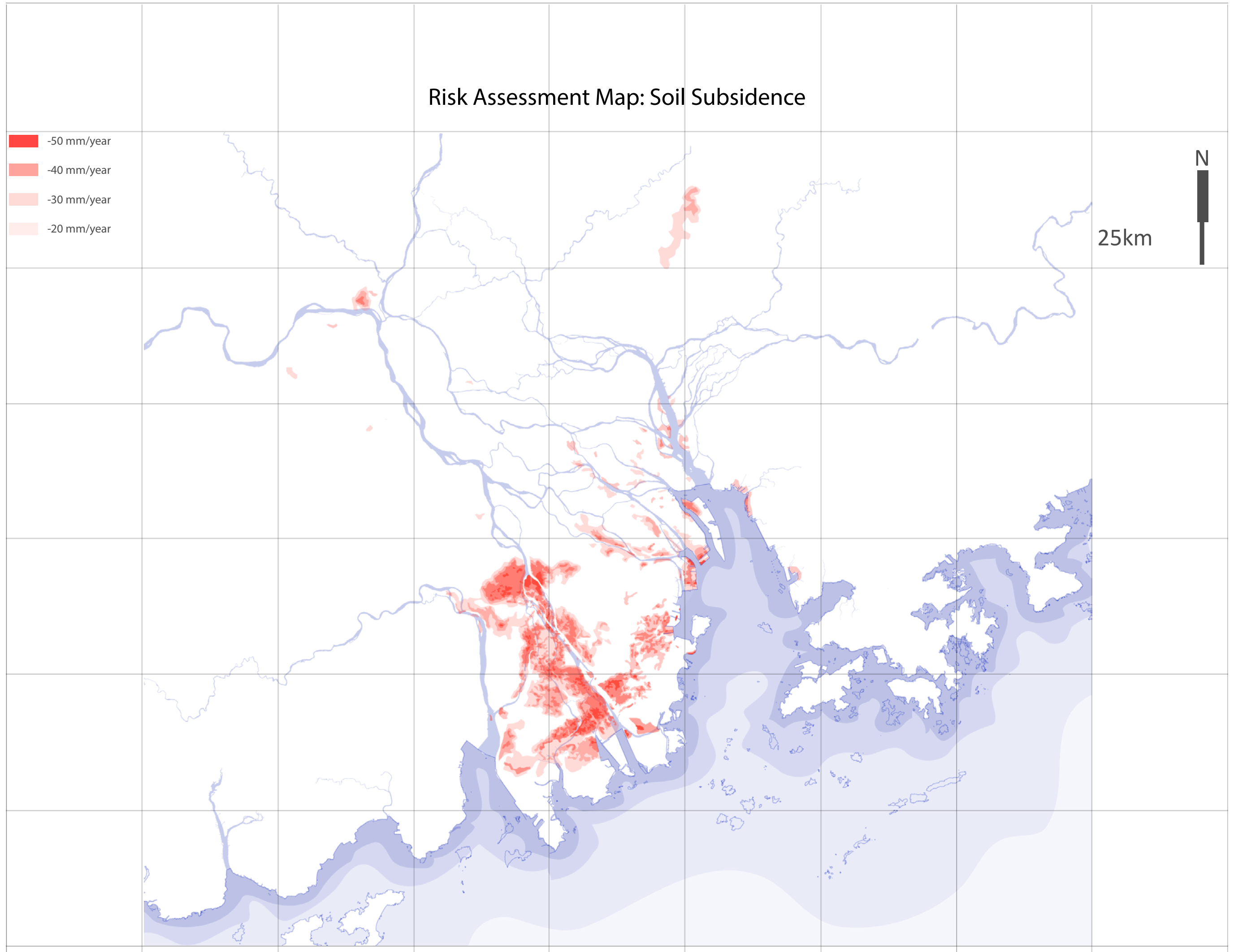
One of the main cause of soil subsidence in the PRD is excessive underground water extraction for agriculture. The topsoil and shallow aquifer layers rely on sufficient moisture to maintain the soil structure, and when water is not adequately retained in the soil or infiltrates into the underground, soil subsidence can occur. This can lead to a shrinking of the shallow aquifer space and a reduction in its capacity.

The impact of soil subsidence is far-reaching, affecting both the environment and human infrastructure. In coastal areas, subsidence can cause changes in the water system and coastal flooding, damaging habitats and forcing local species out of their homes. Additionally, subsidence increases the risk of inland flooding, which can damage foundations and other infrastructure.



Soil Subsidence

Surface deformation in the PRD is usually caused by the joint force of natural geological evolution and human activities. Natural factors include soft sediment consolidation, tectonic activity, sea-level rise, and tidal load (Hu et al., 2018), while human activities include land reclamation, groundwater extraction, and engineering construction (Wu et al., 2016; Wang et al., 2017). For example, fish ponds are widely distributed in the coastal area, where large area land subsidence occurred. Aquaculture needs great amount of freshwater. Aggressive extraction of groundwater leads to the rapid drop of the groundwater level and causes subsidence, even settlement cones.

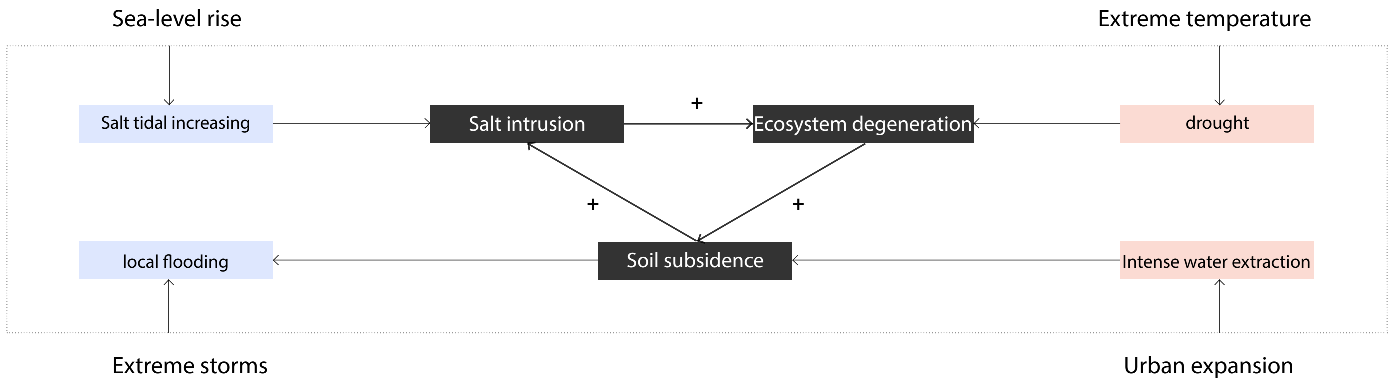


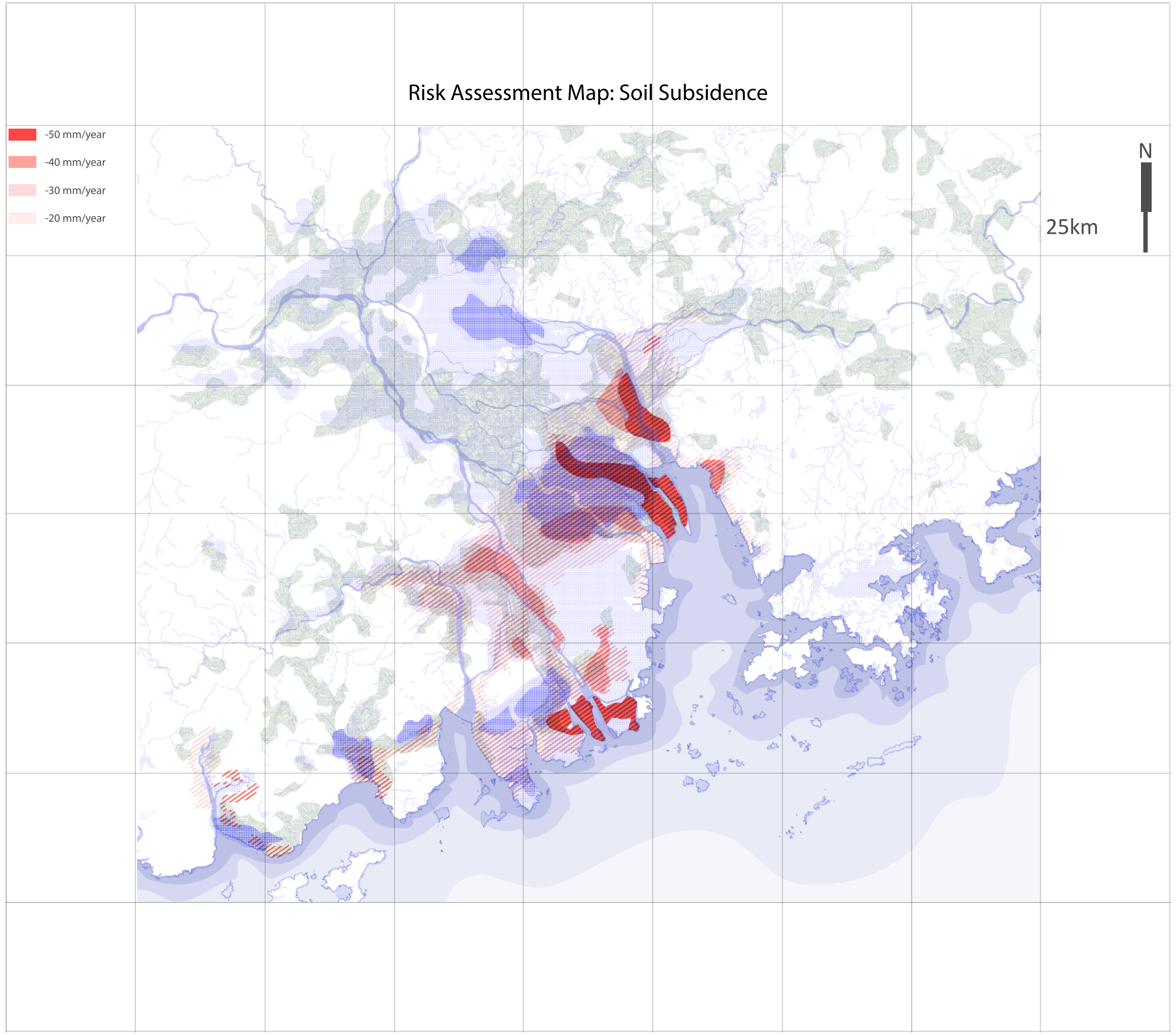
drawing: by author
source: baesed on Genger Li. et al, Surface deformation evolution in the Pearl River Delta between 2006 and 2011 derived from the ALOS1/PALSAR images

In the PRD region, subsidence is a common occurrence near rivers, particularly in areas with dense farmlands. This is mainly due to the unstable and compressible nature of the soft soil layers in the region, which can deform the surface, especially during human activities and engineering projects.
The subsidence rates in reclaimed areas, such as the coastal regions of Zhuhai, Guangzhou, Dongguan, and Shenzhen, are particularly high, exceeding 50 mm/year. Similarly, the coastal areas of Zhongshan and Foshan, where fish ponds are widespread, experience significant land subsidence due to excessive groundwater extraction for aquaculture.
To address this issue, a regional integrated landscape-based infrastructure focused on freshwater recharge could be implemented. This infrastructure could help to infiltrate, retain, and restore freshwater resources, such as precipitation and surface runoffs, into the groundwater. By doing so, it can prevent soil subsidence and ensure sustainable use of the region's abundant freshwater resources.

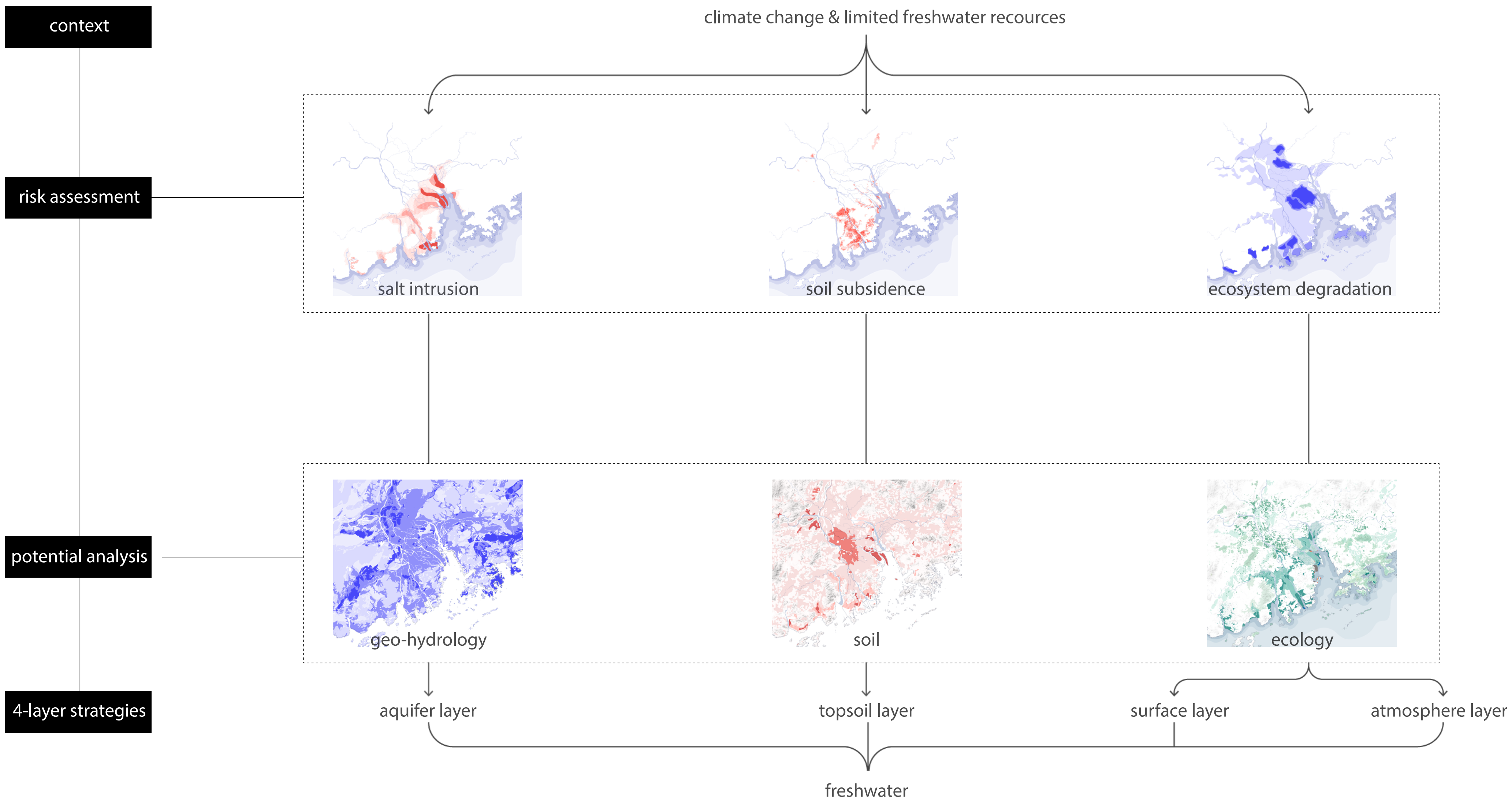
3 ANALYSIS & UNDERSTANDING

3.3 Understanding





3.5.1
Analytical Framework

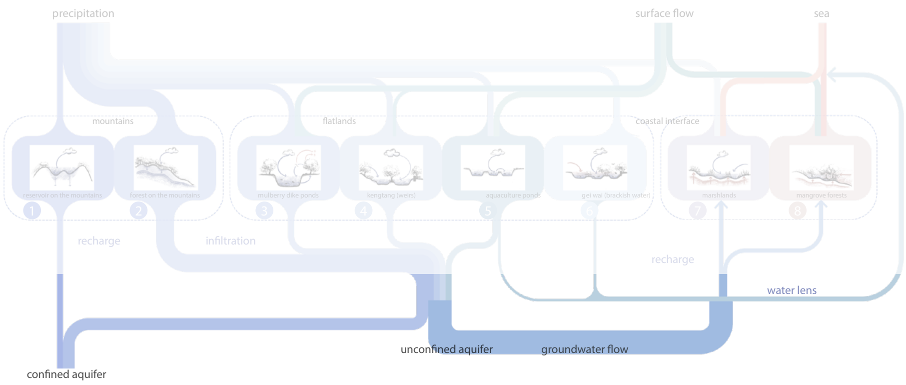


3.5.1
Analytical Framework

3 ANALYSIS & UNDERSTANDING

3.5 Potential

3.5.2 Hydro-geology



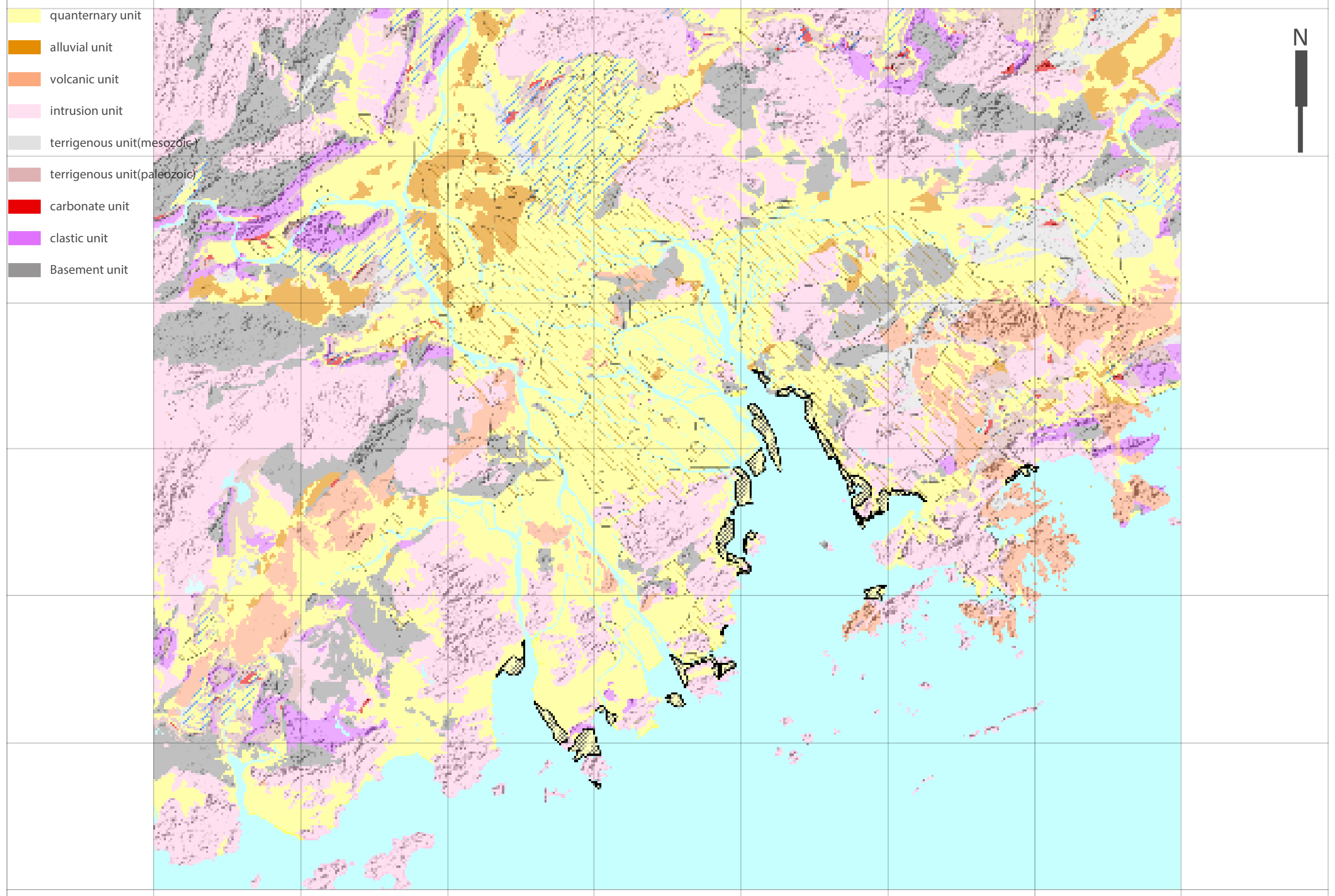
Aquifers as Inter-Annual Water Stocks for Sustainable Freshwater Supply

Studying the distribution and characteristics of aquifers in the PRD through the lens of landscape as a system thinking can provide a more comprehensive understanding of underground water resources and the hydrological cycle. Aquifers are integral components of the landscape-based water cycle, and their conservation and recharge are crucial for sustainable water management.

In addition to serving as sources of freshwater for agriculture, industry, and domestic use, aquifers also play a critical role in maintaining the ecological health of the landscape. By supporting vegetation and wildlife habitats, they contribute to a healthy and resilient ecosystem.

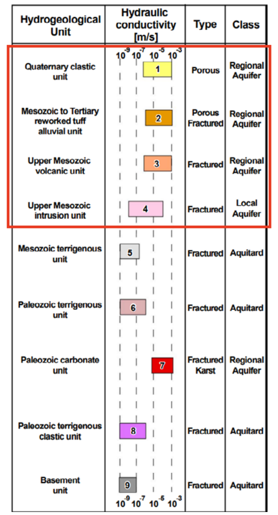
A landscape-based solution approach considers the interconnectedness of various elements of the landscape, including aquifers, in developing sustainable water management strategies. This approach recognizes the importance of aquifers as part of a larger system and prioritizes their conservation and recharge for the benefit of both humans and the natural environment.

Hydrogeology map of Pearl River Delta

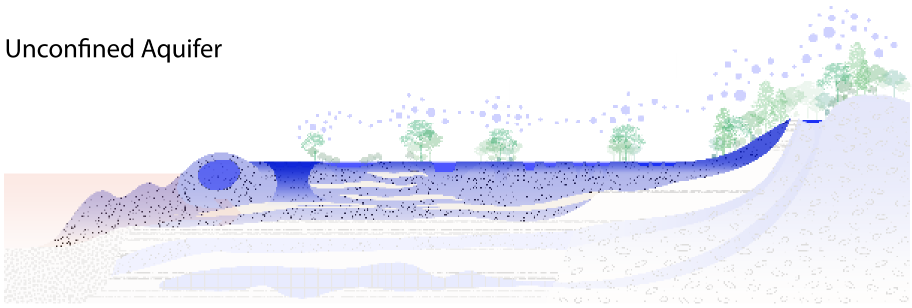


source: Taylor & Francis. et al, Hydrogeology of the Pearl River Delta, southern China.

3.5.2
Hydro-geology



Unconfined Aquifer

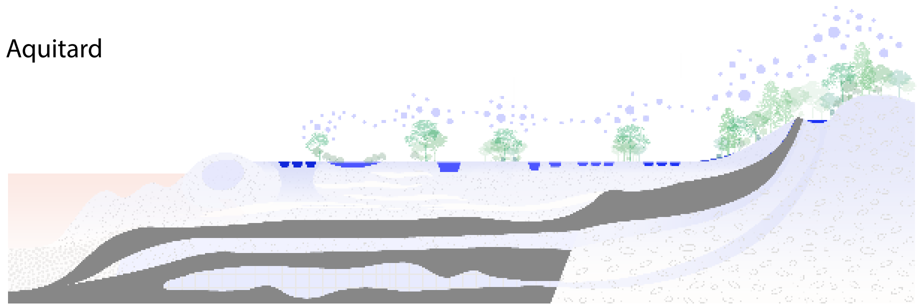


An unconfined aquifer is a type of aquifer that contains free water surface, known as the water table. Unconfined aquifers can be recharged when rainfall infiltrates the ground, which percolates through the soil and into the aquifer, augmenting its water supply. This type of aquifer not only has high water storage capability but is sensitive to human activities, such as over-extraction and land use changes, which can alter the water balance and cause depletion of the aquifer.

Therefore, landscape as the crucial sector in the hydrological cycle can help manage unconfined aquifers in a sustainable way and ensure the availability of groundwater for future generations.

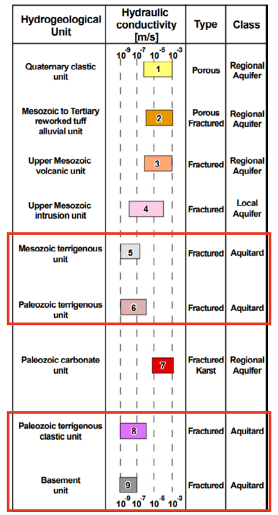
3.5.2
Hydro-geology

Aquitard



An aquitard does not transmit water as readily as an aquifer due to its low permeability, so it restricts the flow of water between adjacent aquifers or aquicludes. Aquitards can be crucial in controlling the flow and distribution of groundwater within a hydrogeological system. They act as barriers, slowing down or preventing the vertical movement of water and preventing the mixing of water between different aquifers or aquicludes.

Thus, understanding the properties and characteristics of aquitards is essential for the proper management and protection of groundwater resources.



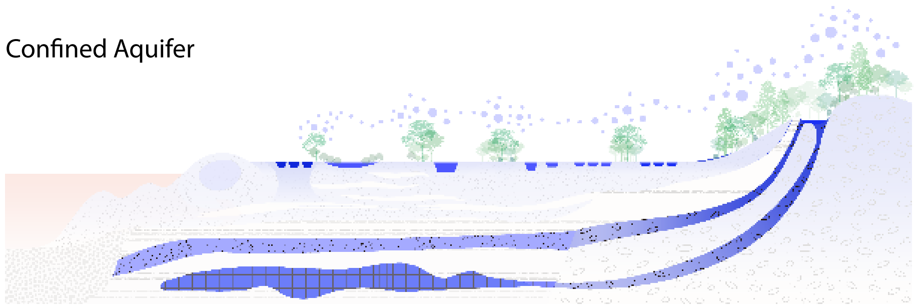
3 ANALYSIS & UNDERSTANDING

3.5 Potential

3.5.2
Hydro-geology

Hydrogeological Unit	Hydraulic conductivity [m/s] (10^{-9} 10^{-7} 10^{-5} 10^{-3})	Type	Class
Quaternary clastic unit	1	Porous	Regional Aquifer
Mesozoic to Tertiary reworked tuff alluvial unit	2	Porous Fractured	Regional Aquifer
Upper Mesozoic volcanic unit	3	Fractured	Regional Aquifer
Upper Mesozoic intrusion unit	4	Fractured	Local Aquifer
Mesozoic terrigenous unit	5	Fractured	Aquitard
Paleozoic terrigenous unit	6	Fractured	Aquitard
Paleozoic carbonate unit	7	Fractured Karst	Regional Aquifer
Paleozoic terrigenous clastic unit	8	Fractured	Aquitard
Basement unit	9	Fractured	Aquitard

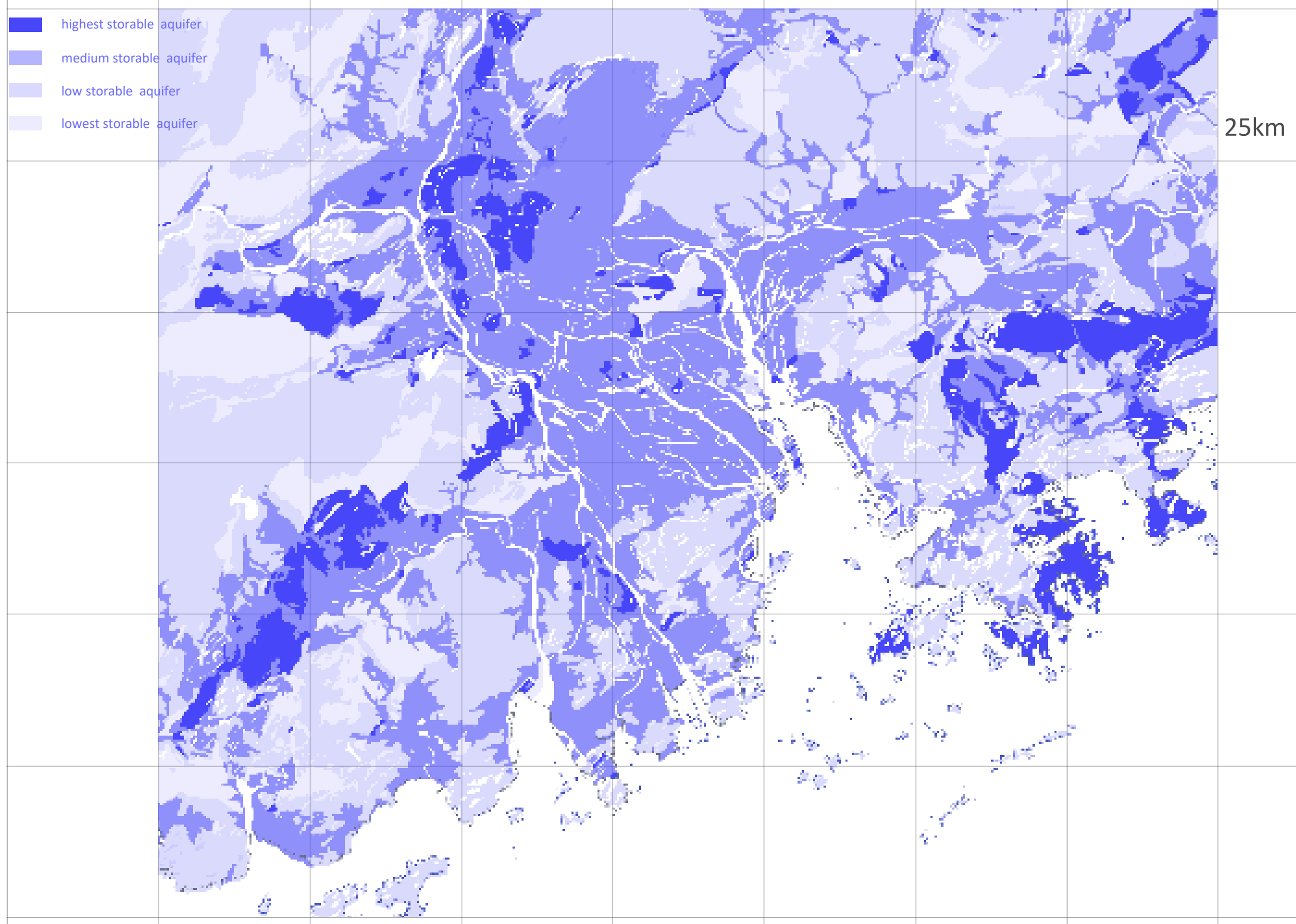
Confined Aquifer



A confined aquifer is a type of groundwater storage that is sandwiched between two impermeable layers such as aquifuge or aquiclude. The recharge of the confined aquifer occurs when it is exposed to the ground surface, which allows rainwater to seep through the overlying soil and replenish the aquifer. This process may take a long time due to the slow rate of water flow through the surrounding rock formations, and thus, confined aquifers are generally considered to be non-renewable resources.

Therefore, the role of the Landscape -based solution is a pre-treatment sector in the process of precipitation and surface runoff recharge to the confined aquifer.

Potential map of Aquifer: storage capacity



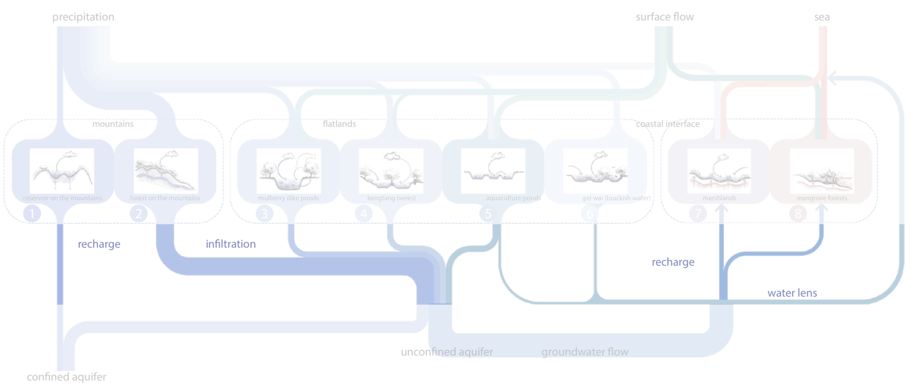
drawing: by author
source: Taylor & Francis. et al, Hydrogeology of the Pearl River Delta, southern China.

Creating a map based on aquifer types reveals potential of aquifers on storage capacity, helping to plan conservation and recharge efforts. Understanding the characteristics of different aquifers helps identify the most suitable places to store and recharge groundwater, creating sustainable water management strategies that optimize the use of underground water resources.

3 ANALYSIS & UNDERSTANDING

3.5 Potential

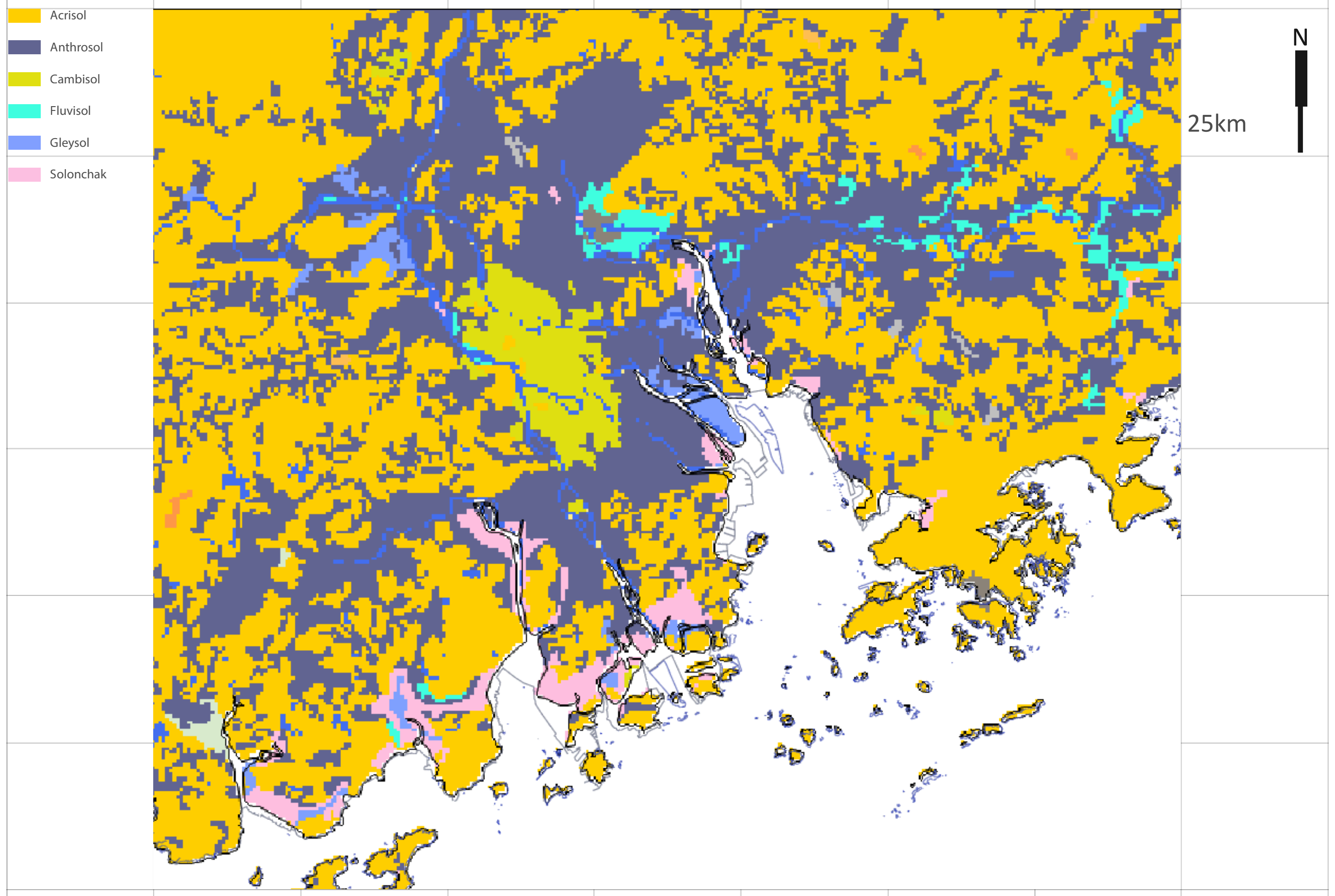
3.5.3
Soil



Soil Permeability as Key Condition of Sustainable Freshwater Supply by NbS

Soil permeability, or its ability to allow water to pass through, is crucial in freshwater conservation and recharge efforts in the hydrological cycle. Soils with high permeability allow water to penetrate deep into the ground, where it can be stored in aquifers and used as a reliable source of freshwater. In contrast, soils with low permeability limit the amount of water that can be conserved and recharged, resulting in reduced availability of freshwater.
Landscape-based solutions on maintaining and improving soil permeability is essential for successful freshwater conservation and recharge efforts. This can be achieved by reducing soil compaction, implementing conservation tillage practices, and promoting the use of cover crops to improve soil structure and permeability.
In summary, improving soil permeability is critical in ensuring the availability and sustainability of freshwater resources.

Soil type map of Pearl River Delta



source: Food and Agriculture Organization of the United Nations, Harmonized World Soil Database v 1.2

3 ANALYSIS & UNDERSTANDING

3.5 Potential

3.5.3
Soil

Soil type and the characteristics

Cambisol

high permeability

Anthrosol

Acrisol

moderate permeability

Fluvisol

low permeability

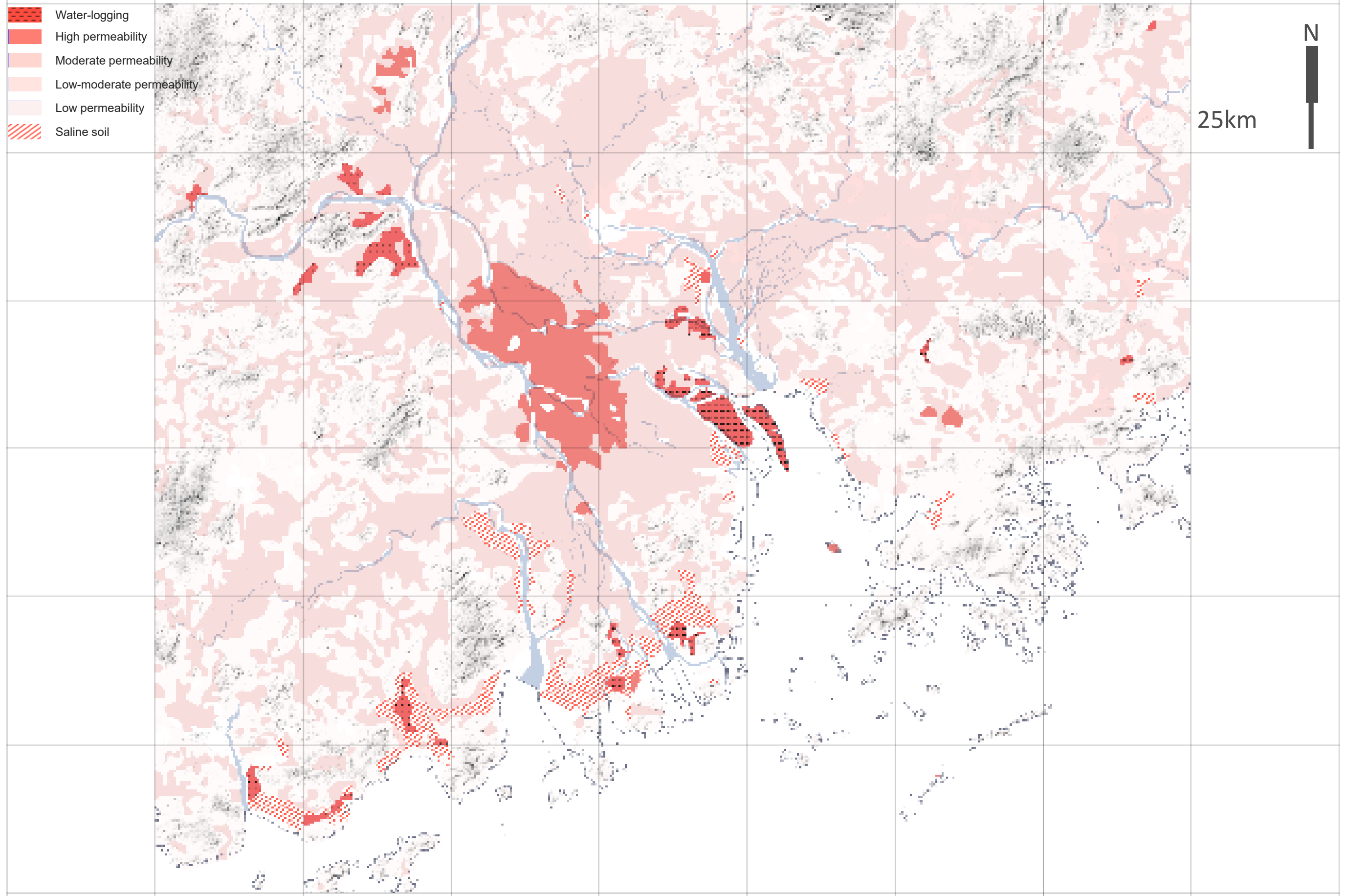
Gleysol

water-logging

Solonchak

saline soil

Potential map of topsoil: permeability



drawing: by author
source: Food and Agriculture Organization of the United Nations, Harmonized World Soil Database v 1.2

The permeability of topsoil determines whether freshwater will flow towards underground aquifers or remain on the surface. By understanding the storage capacity of underground aquifers and the permeability of topsoil layers, it is possible to develop effective strategies for managing water flows towards different destinations. This knowledge is essential for creating water management plans that conserve and recharge freshwater resources.

3 ANALYSIS & UNDERSTANDING

3.5 Potential

3.5.6
Landscape type mapping:
mountain area

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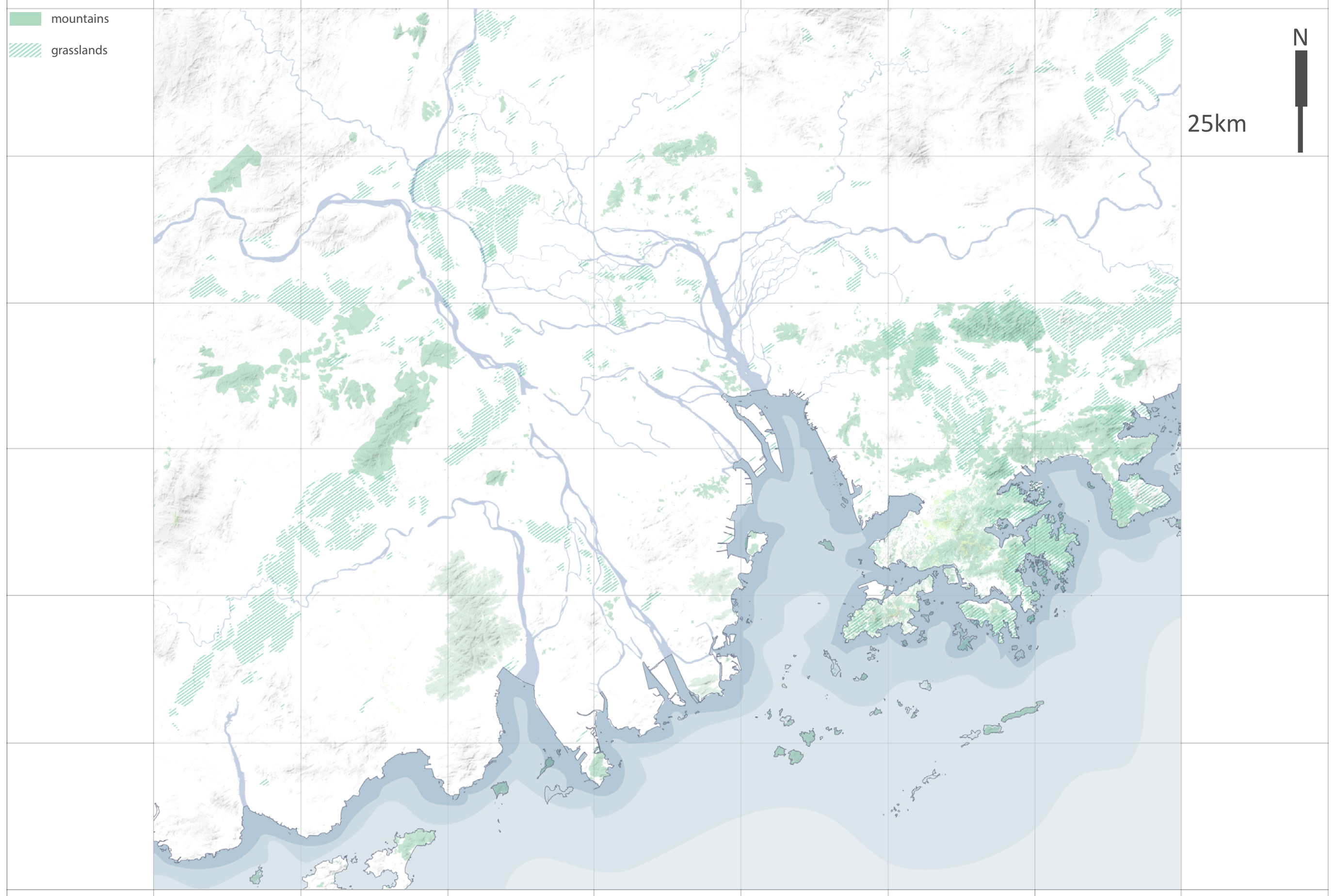
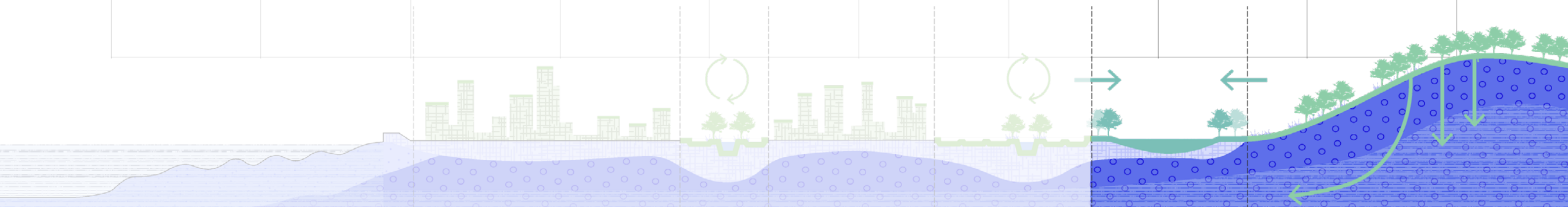
Landscape type: the Distribution of Mountain area



drawing: by author
source: Minstry of Natural Resouces of the People's Republic of China



3 ANALYSIS & UNDERSTANDING

3.5 Potential

3.5.6
Landscape type mapping:
water body
——dike pond, Kengtang

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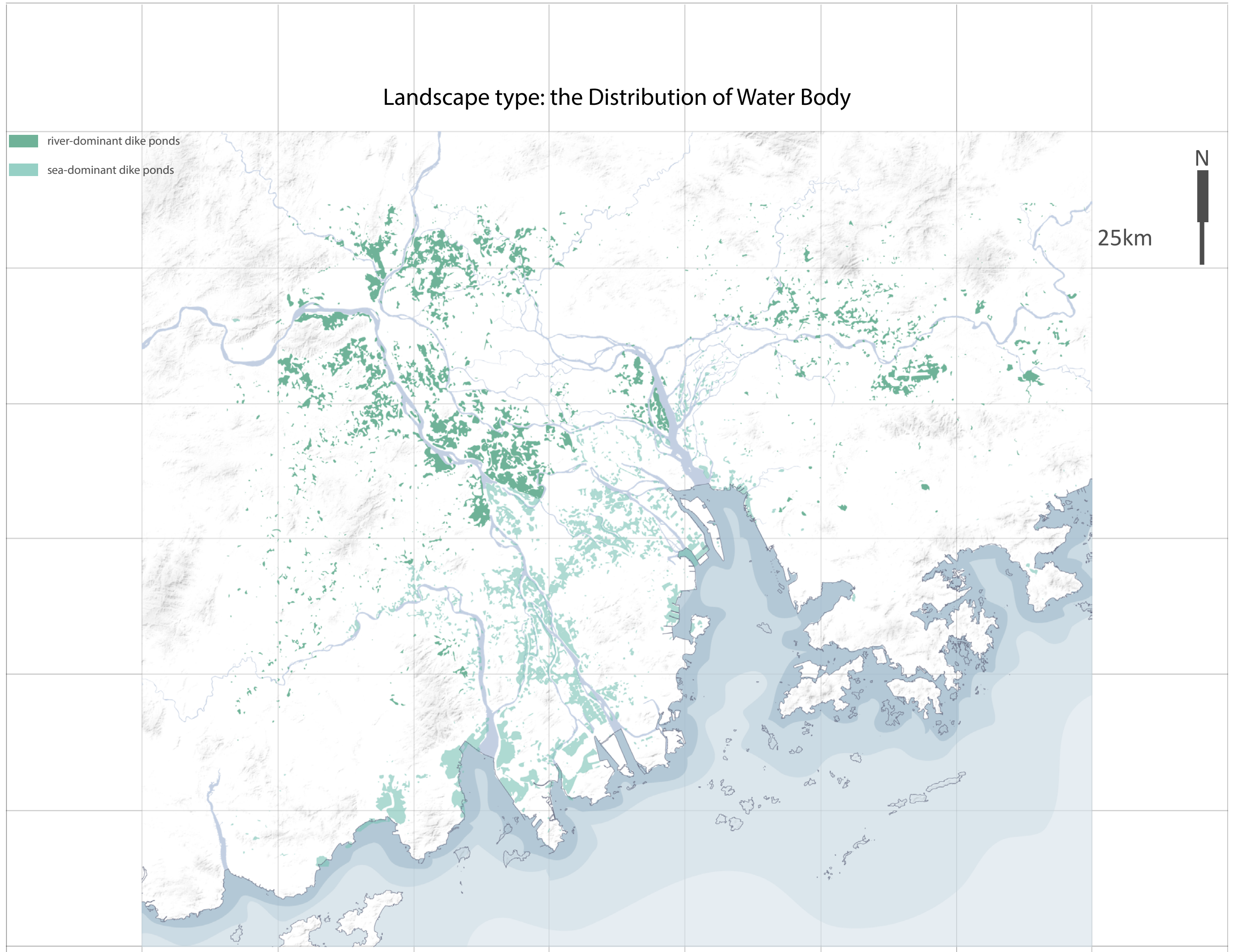

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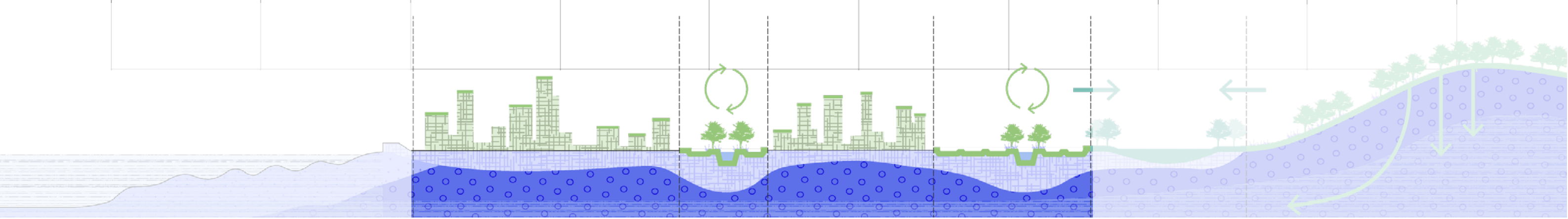

3 ANALYSIS & UNDERSTANDING

3.5 Potential

3.5.6
Landscape type mapping:
Coastal interface

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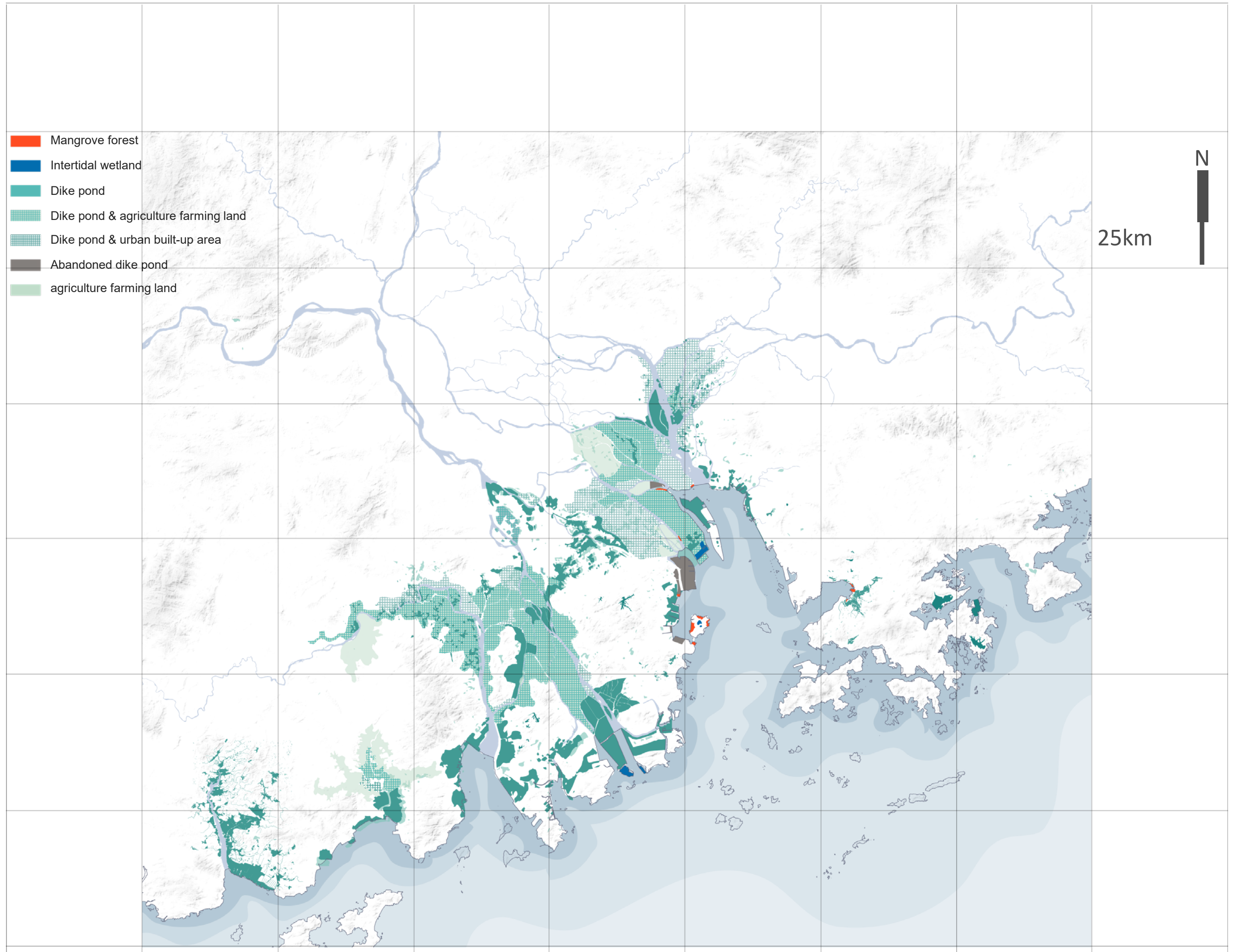

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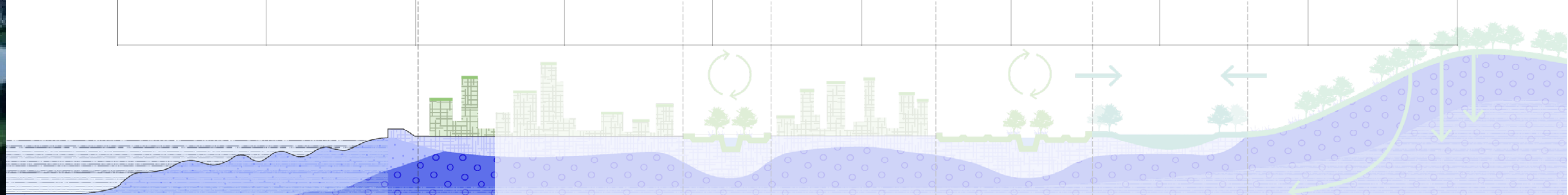
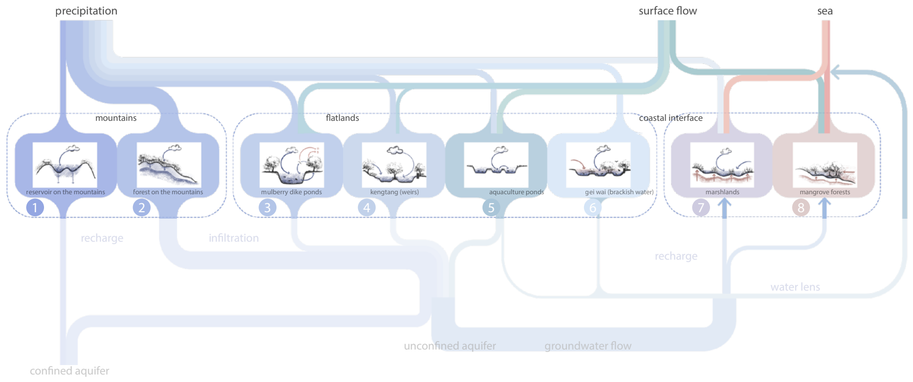


3 ANALYSIS & UNDERSTANDING

3.5 Potential

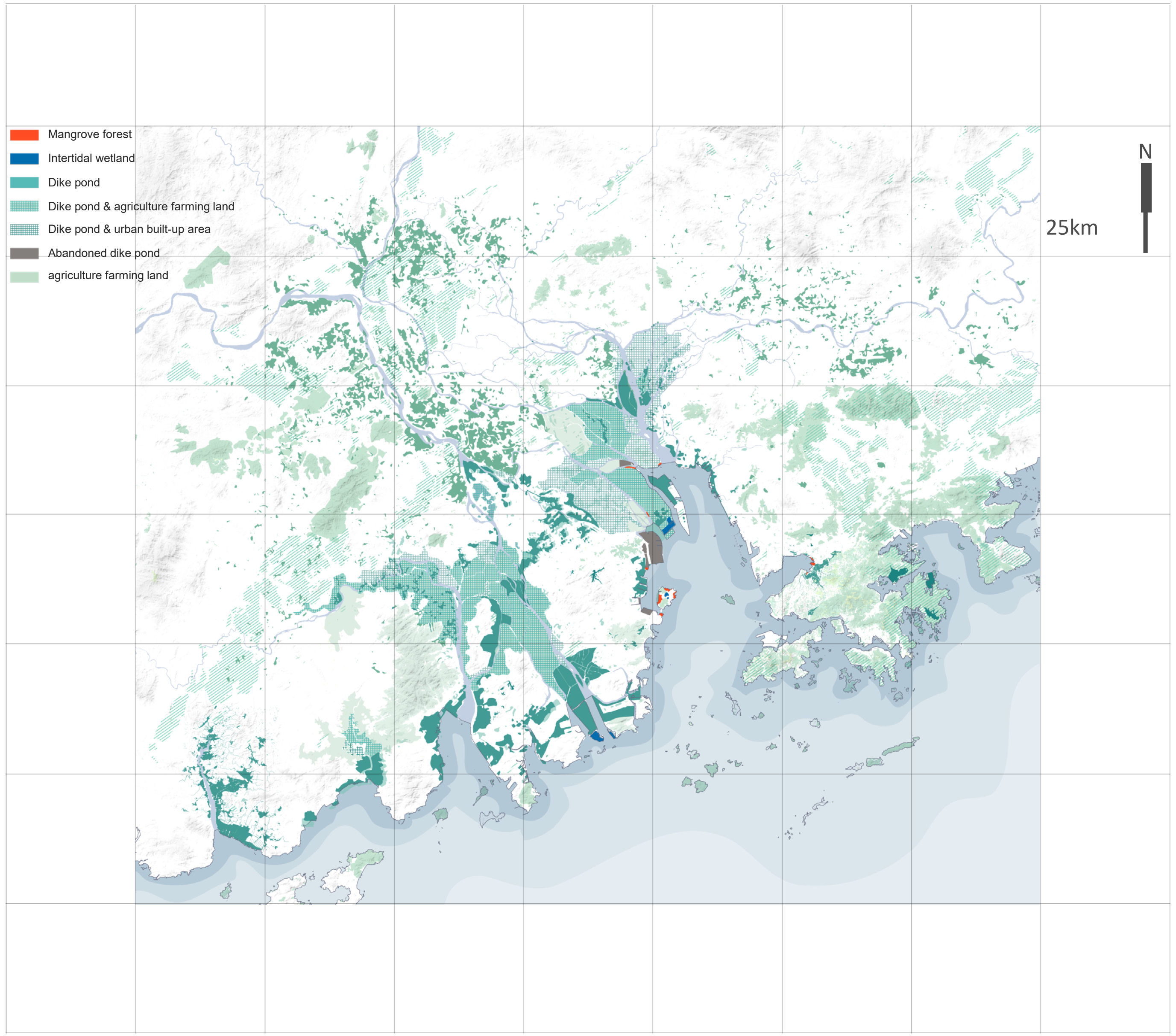
3.5.4
Landscape Type

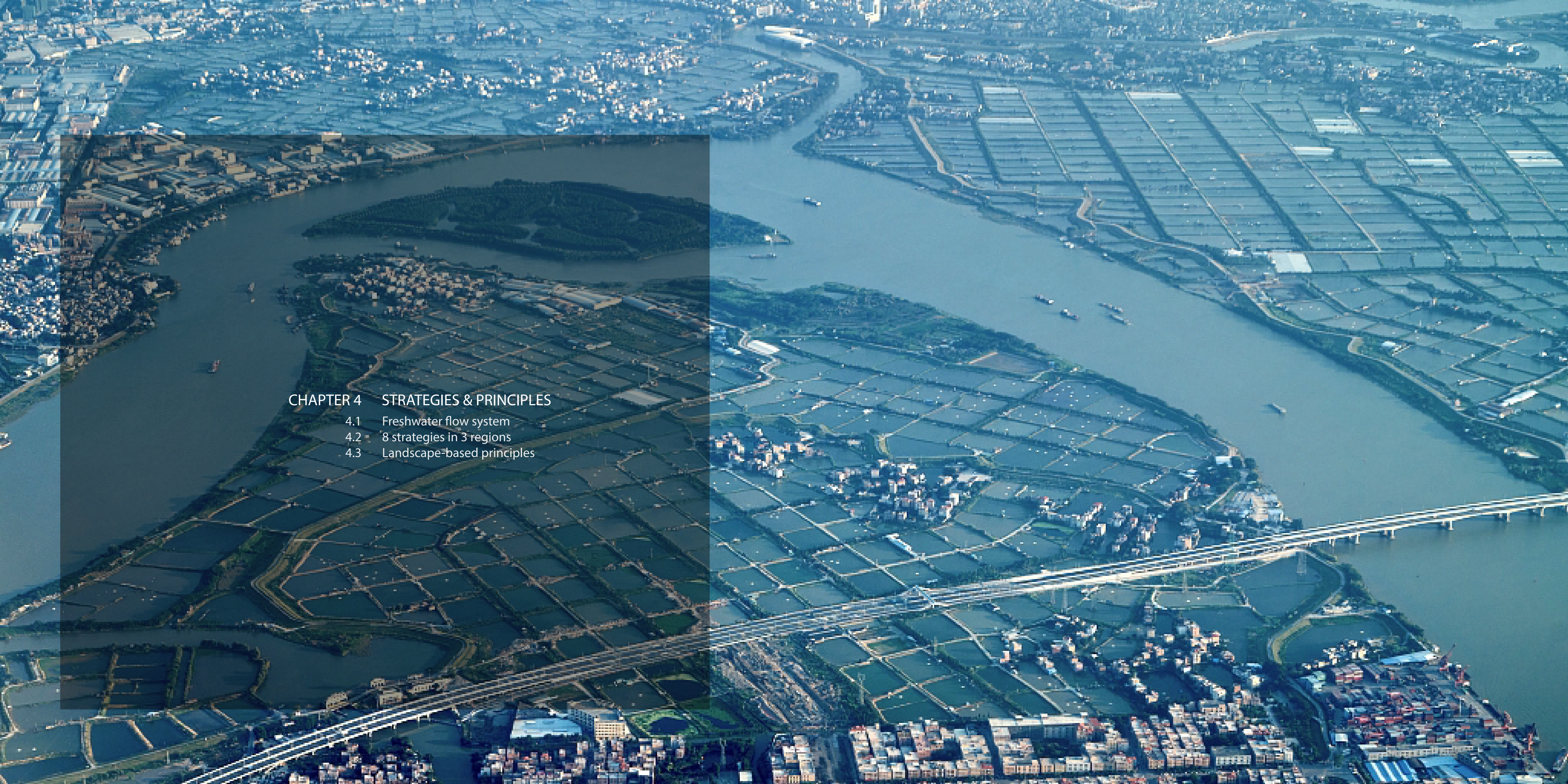


Landscape Type as a Operative Field for the Sustainable Freshwater Supply

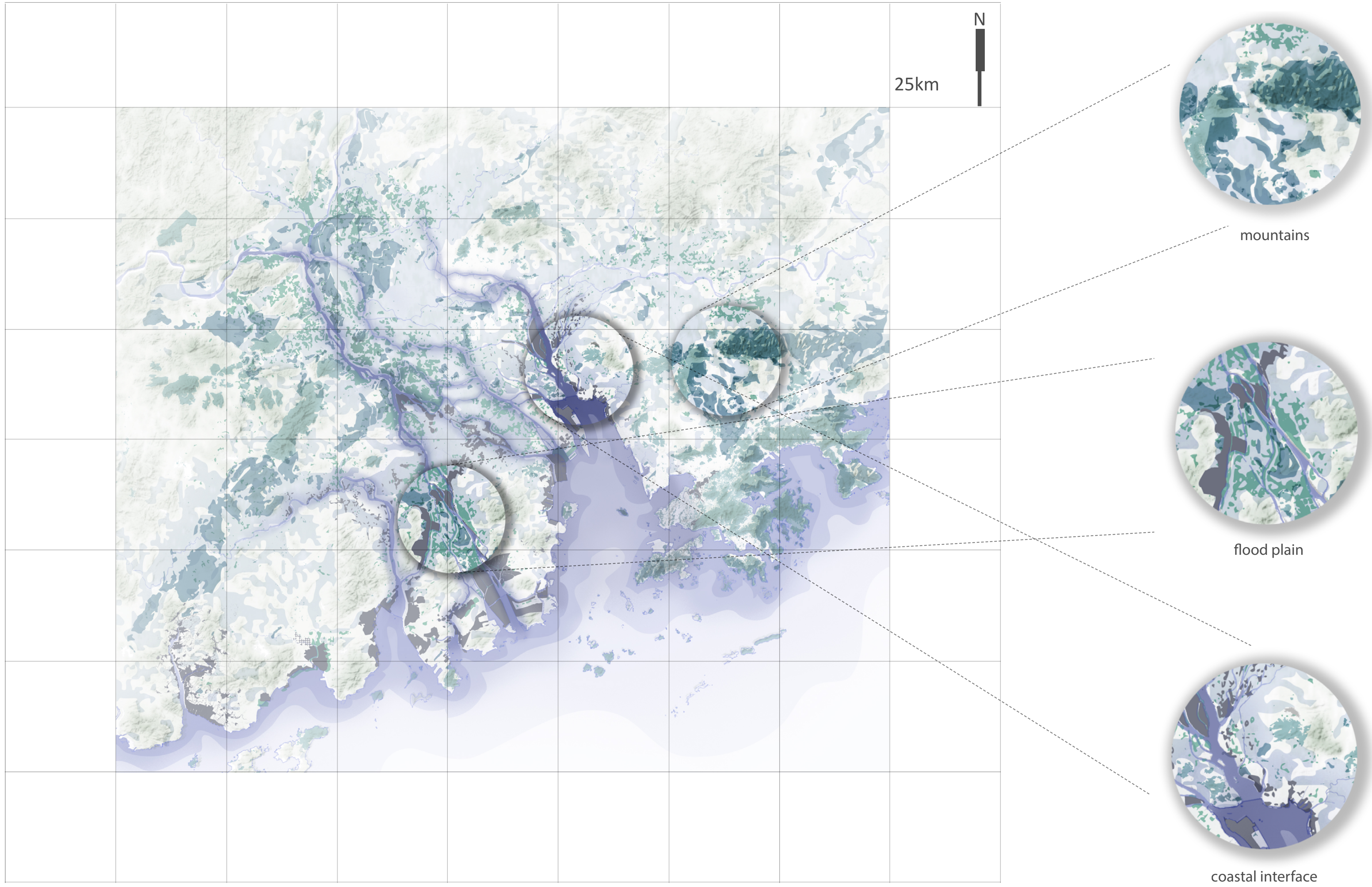
The hydrological cycle is a fundamental and essential pattern of freshwater, with different landscape types impacting the cycle's stocks and flux. comprehending the relationship between the different landscape types and the stocks and flux of the hydrological cycle is vital since it enables the optimization of precipitation and surface runoff to replenish groundwater while reducing evaporation and surface flow into the sea.

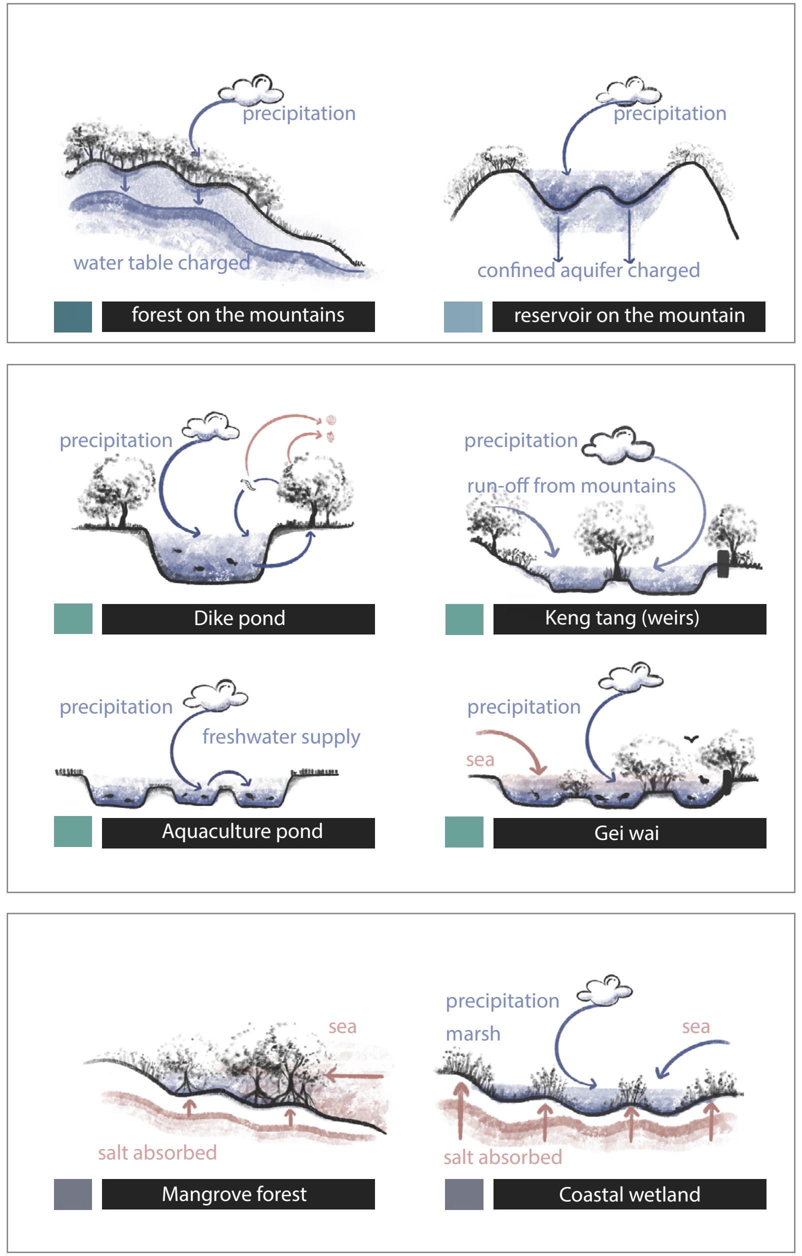
Landscape-based solutions, which focus on the distinctive characteristics of each landscape type, provide a practical framework for sustainable urban development and ecological processes. Through the use of landscape spatial design principles and managed aquifer recharge schemes, it becomes possible to develop and maintain a sustainable environment that caters to the needs of both humans and the ecosystem. These solutions can contribute to sustainable freshwater supply, and reduce the risk of drought and water scarcity.





CHAPTER 4 STRATEGIES & PRINCIPLES


N
25km
mountains
flood plain
coastal interface


precipitation
water table charged
forest on the mountains
precipitation
confined aquifer charged
reservoir on the mountain
precipitation
Dike pond
precipitation
run-off from mountains
Keng tang (weirs)
precipitation
freshwater supply
Aquaculture pond
precipitation
sea
Gei wai
sea
salt absorbed
Mangrove forest
precipitation
marsh
sea
salt absorbed
Coastal wetland

4 STRATEGIES & PRINCIPLES

4.1 Freshwater flow system

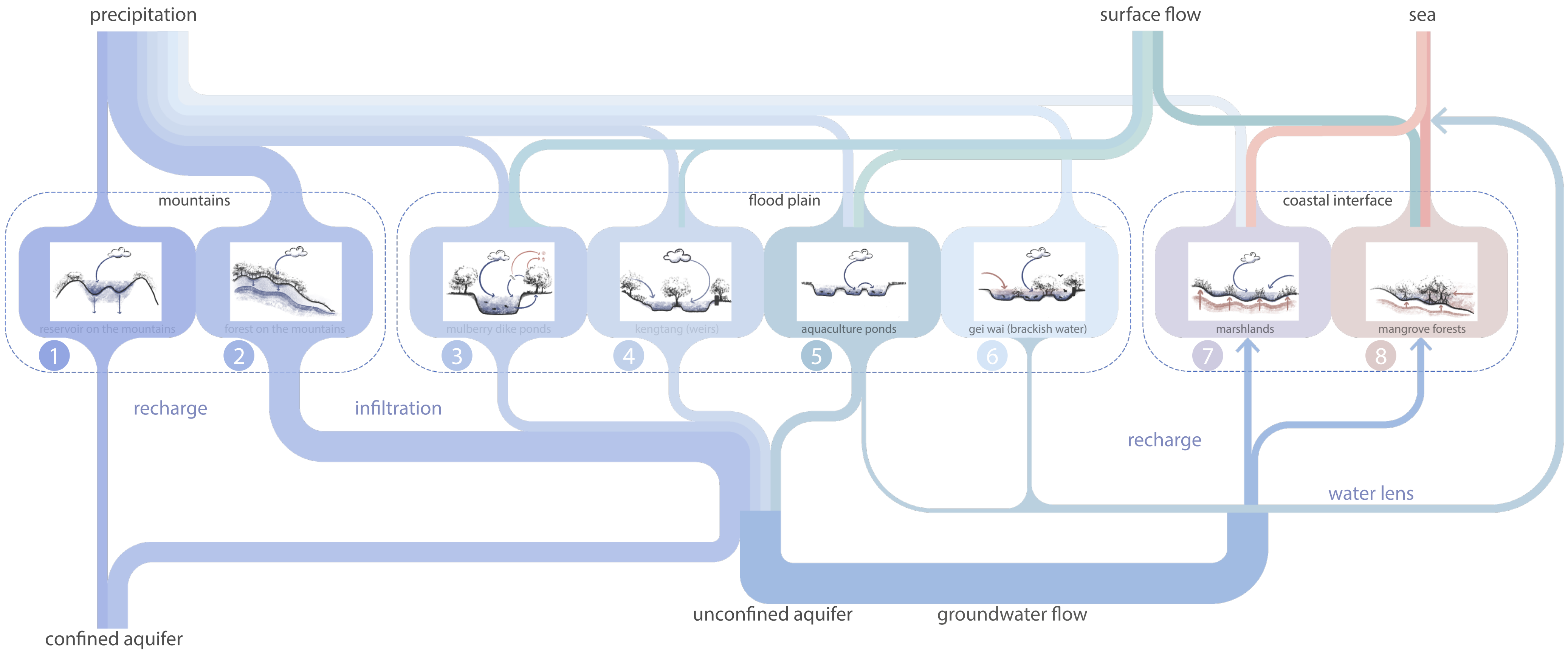
1.
precipitation - recharged to the confined aquifers

2.
precipitation - infiltrated - groundwater flow - recharged to brackish land

3.
precipitation - retained in the pond (- infiltrated - recharged to brackish land)

4.
surface runoff - retained in the pond (- infiltrated - recharged to brackish land)

drawing: by author



5.
precipitation - retained in the pond - soil lens

6.
precipitation - retained in the geiwai - adatpting to the flactuated saltwater

7.
precipitation - retained in the marshland - absorbing the saltwater

8.
surface runoff - retained in the pond (- infiltrated - recharged to brackish land)

4 STRATEGIES & PRINCIPLES

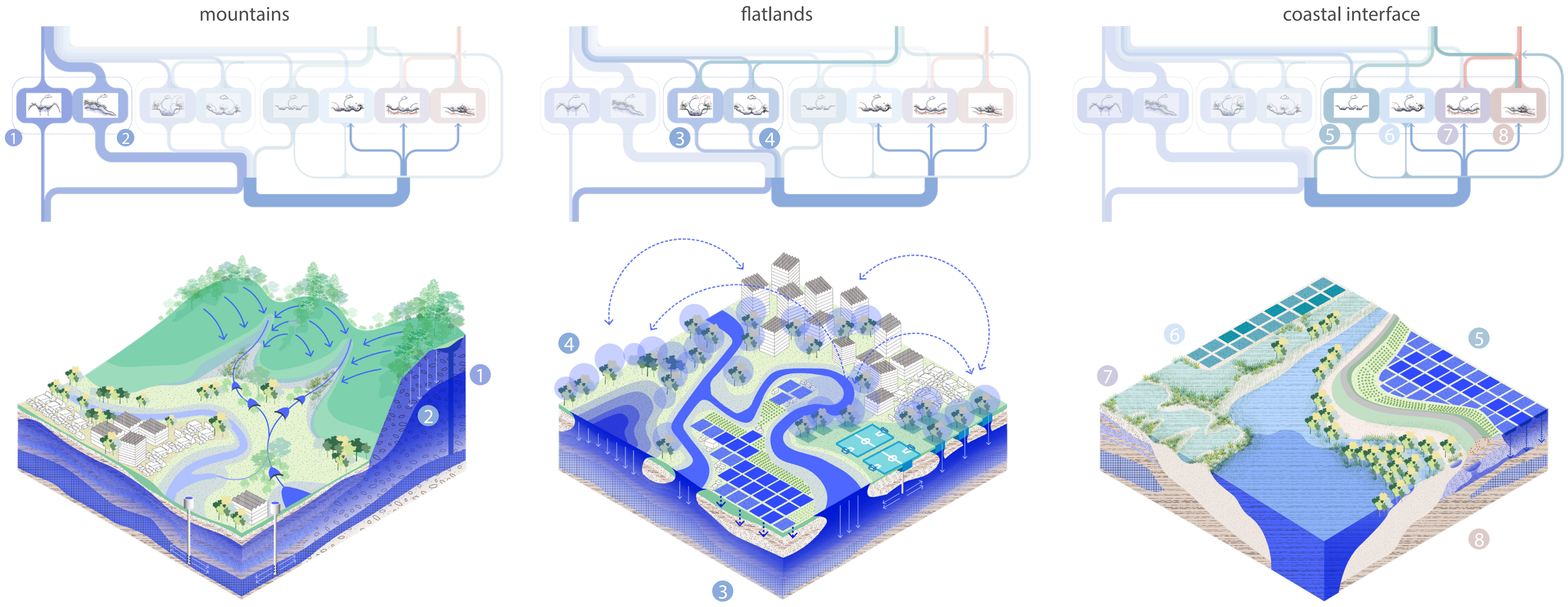
4.2 8 strategies in 3 regions

1.
precipitation - recharged to the confined aquifers

2.
precipitation - infiltrated - groundwater flow - recharged to brackish land

3.
precipitation - retained in the pond (- infiltrated - recharged to brackish land)

4.
surface runoff - retained in the pond (- infiltrated - recharged to brackish land)



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precipitation - retained in the marshland - absorbing the saltwater

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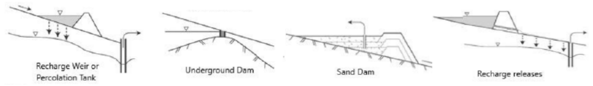
surface runoff - retained in the pond (- infiltrated - recharged to brackish land)

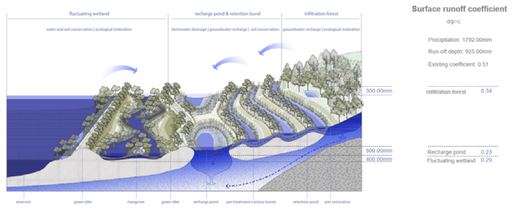
CHAPTER 5 DESIGN EXPLORATION

Schematic of various types of MAR:

1. Streambed Channel Modifications



case study



Interdisciplinary study

ASSESSMENT

layering analysis

1. Ecosystem challenges
2. Hydrological challenges
3. Geological challenges

DESIGN

3 layers strategies

1. Ecology
2. Hydrology
3. Geology

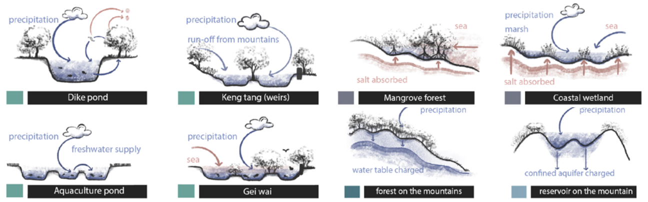
spatial principles

1. Ecological succession
2. Water management
3. Landforming

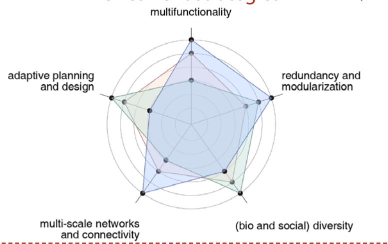
ASSESSMENT

1. capacity on freshwater conservation and recharge
2. landscape benefits

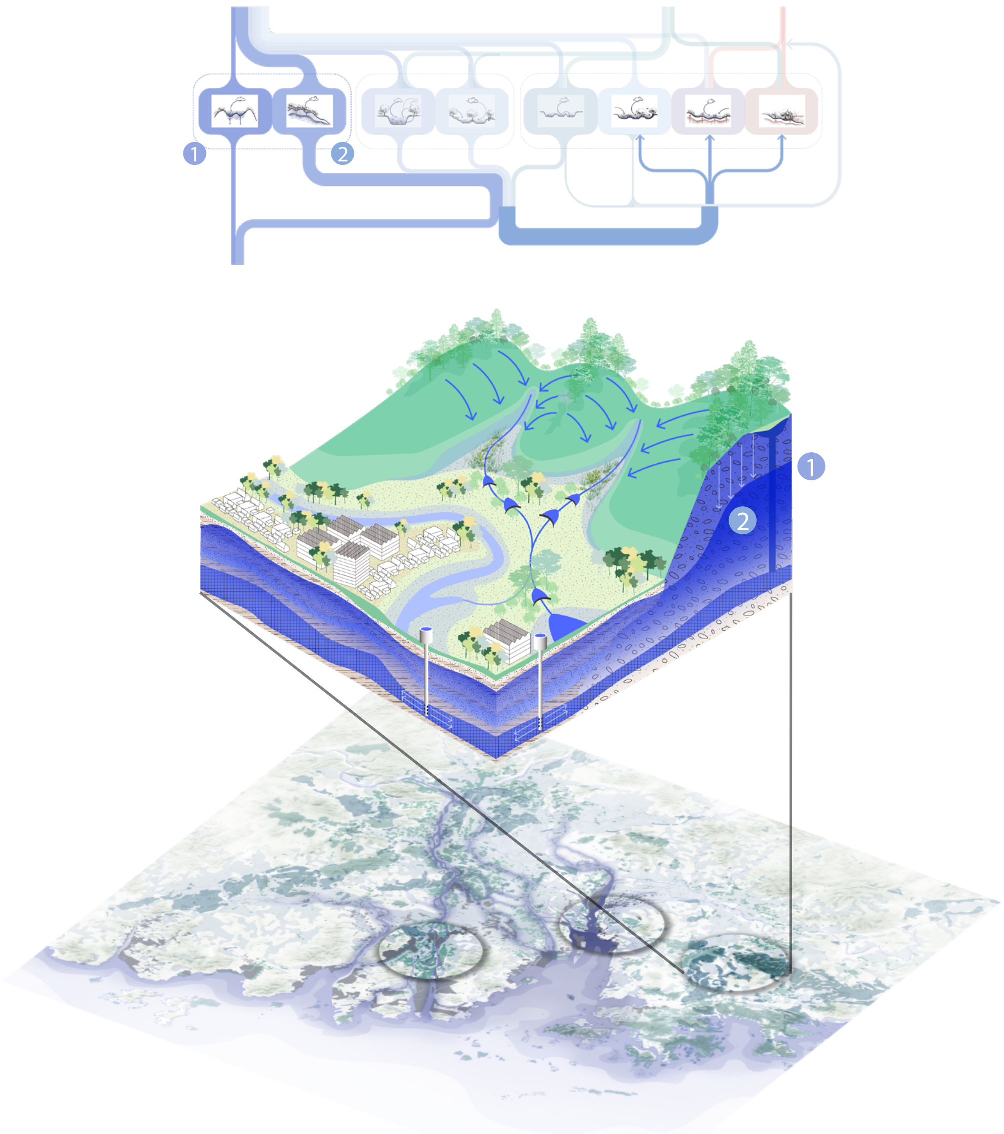
learning from history

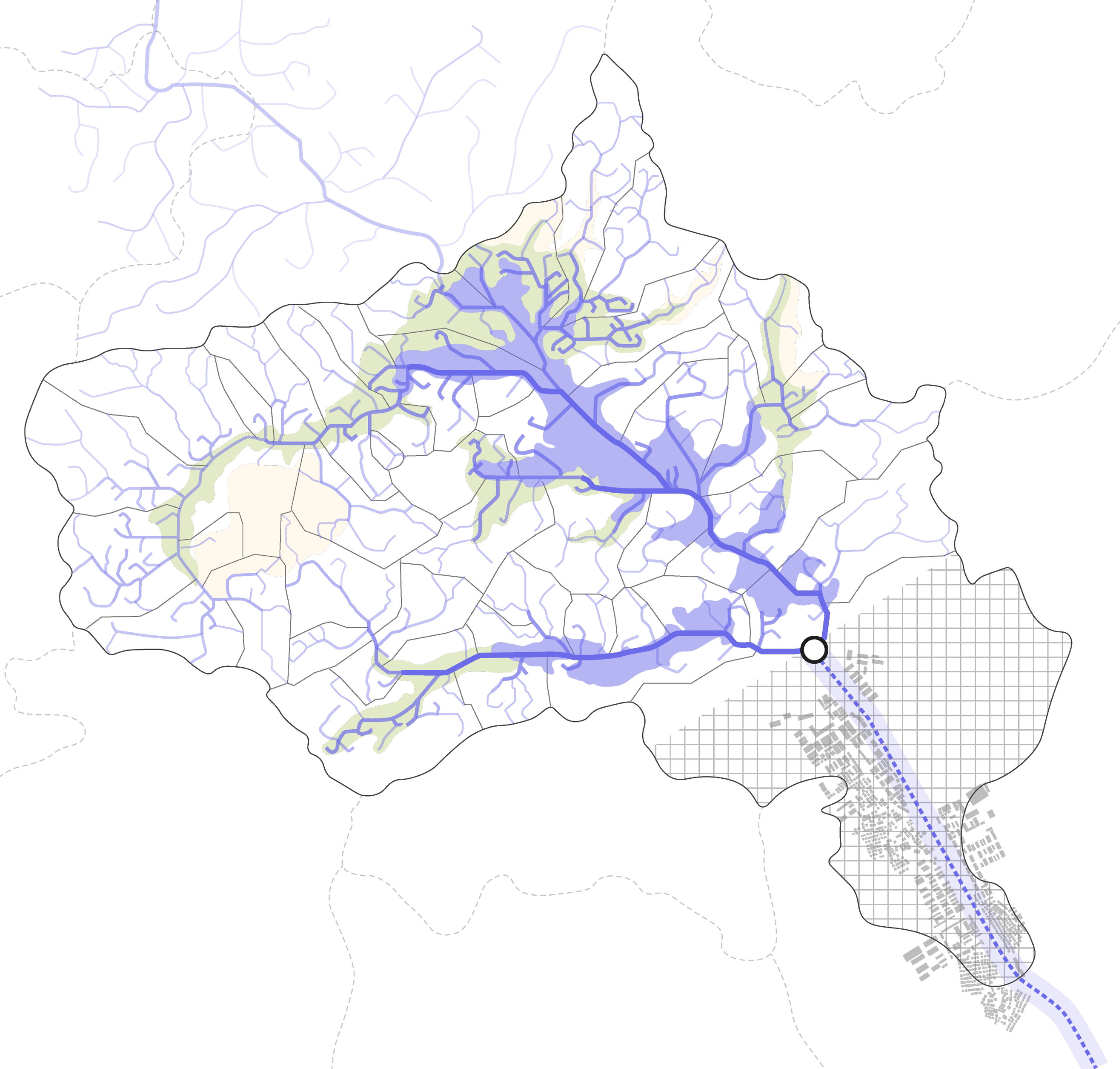


5 resilient strategies



MOUNTAINS





5 DESIGN EXPLORATION

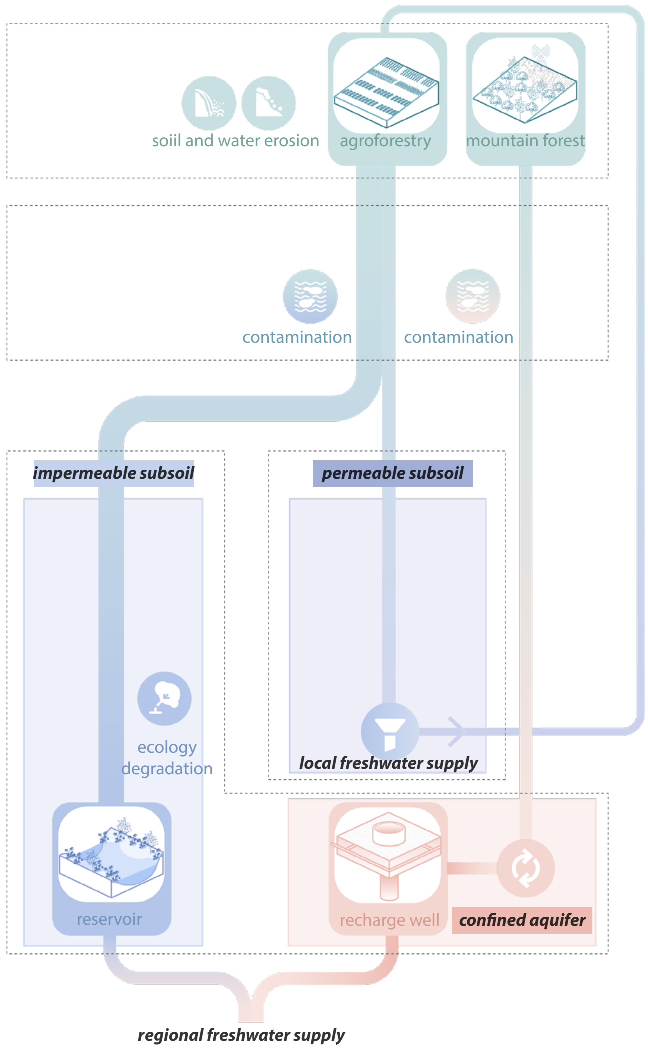
5.1 mountain as the water tower of the PRD

The site is in the southeastern part of Shenzhen, specifically within the mountainous watershed of the densely populated urban area of Longgang District.

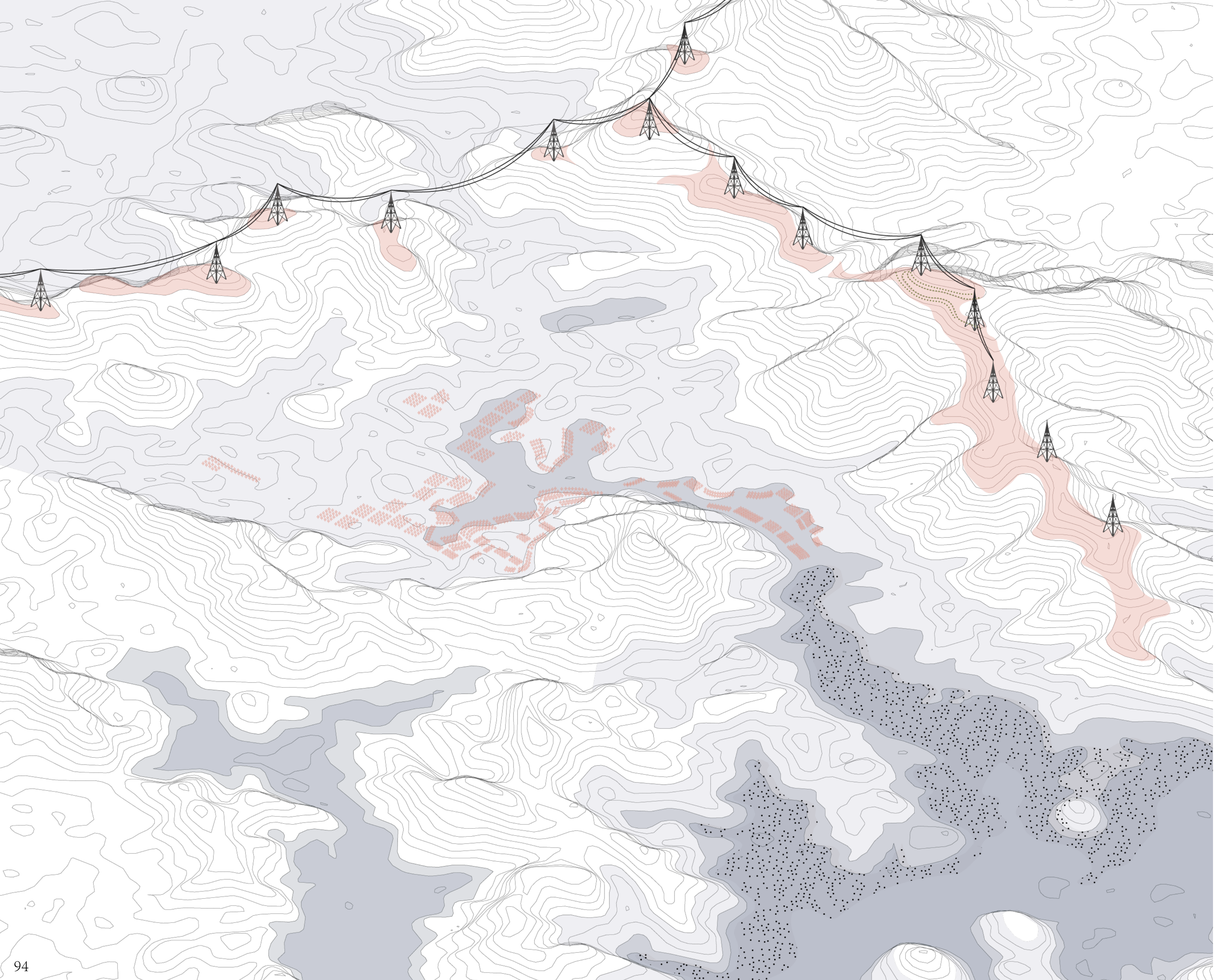
Longgang, being a densely populated region, faces a significant water challenge. The annual water consumption is around 230 million cubic meters, while the available water supply is limited to 150 million cubic meters per year. The ongoing urbanization process worsens this water resource gap, emphasizing the need to explore potential solutions. Shenzhen has hilly terrain, and by effectively utilizing the water storage capacity of these hills, a significant portion of the water resource deficit can be addressed.

Spanning an area of 23 square kilometers, this site exhibits excellent rainfall conditions, with an average annual precipitation of 1726.2mm. However, the average annual runoff depth within the watershed stands at 925.1mm, resulting in current surface runoff coefficients of approximately 0.54. By capitalizing on favorable hydrological conditions and implementing prudent mountain development strategies, surface runoff coefficients can be adjusted according to established guidelines. Specifically, on gentle slopes (<7 degrees) with clay soil, the recommended adjustment range for surface runoff coefficients is 0.25-0.35. Similarly, for gentle slopes (<7 degrees) with sandy loam soil, the recommended range is also 0.25-0.35. Such adjustments, ideally within the range of 0.15-0.2, have the potential to significantly mitigate the loss and pollution of rainwater resources while fostering groundwater storage in the region.

In the existing mountain water flow pattern, over half of the rainfall is currently washed down to the mountain's foothills through runoff, leading to extensive mountain erosion and further degradation of the mountain ecosystem. Only a fraction of the rainfall infiltrates the ground and contributes to groundwater storage.



Water flow in the proposed mountain freshwater conservation and recharge system



5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD

Hydrological conditions

1. **Precipitation**: The area experiences relatively abundant rainfall, with the rainy season occurring from April to September, averaging about 1726.20mm annually and reaching a maximum of 2467.00mm. There is a possibility of extreme heavy rainfall in June and July.
2. **Runoff**: Due to ample rainfall, the average annual runoff depth is 925.1mm, and the average annual runoff volume can reach approximately 22,790,000.0 cubic meters, or up to 24,410,000.0 cubic meters in years of high water. However, in recent years, unreasonable development has led to water resource problems, due to the vulnerability of the mountain's ecosystem, the average annual soil erosion has also reached a maximum of about 18000t/a.

Ecological environment conditions:

The watershed has a drainage area of about 23 square kilometers and features hilly erosion landforms. The dominant ground vegetation consists of Acacia and Eucalyptus trees. The original tropical vegetation of South Asia no longer exists. The vegetation coverage is around 70% (calculated based on an international standard of 0.2 canopy closure).
In particular, Eucalyptus trees have high water absorption and evaporation rates. According to data from the Guangdong Soil and Water Conservation Experimental Station in 1987, a comparison between pure Eucalyptus forests and bare land shows a 20% reduction in soil moisture content in the 0-1m layer. Additionally, Eucalyptus leaves contain a significant amount of acidic substances, and the resulting acidity from the decomposition of dead branches and fallen leaves does not benefit the growth of understory shrubs and grasses.
Overall, the forest structure of the ecosystem is single, with small tree trunks and a limited amount of dead branches and fallen leaves provided each year, which is unfavorable for conserving the mountain's water

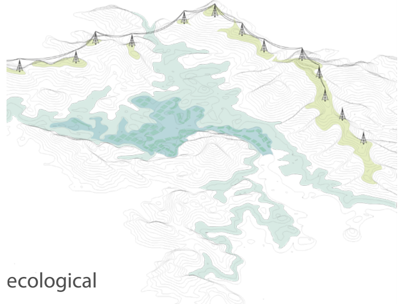
Topographical and geological conditions:

1. **Slope:** The mountain slopes are mainly gentle and suitable for development. However, steep slopes are exceeding 15 degrees in the northwest direction, forming concentrated artificial or drainage channels within the mountain range.
2. Soil permeability: The soil consists of clay in the lower part of the mountain and weathered sandy loam in the upper part. As a result, some slopes have almost no permeability, causing most of the runoff to quickly erode and carry away the soil to the reservoir at the foot of the mountain.
3. **Soil acidity:** Due to the predominance of Eucalyptus trees, their fallen leaves contribute to soil acidity. Therefore, the surface soil is acidic.

5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD

challenges

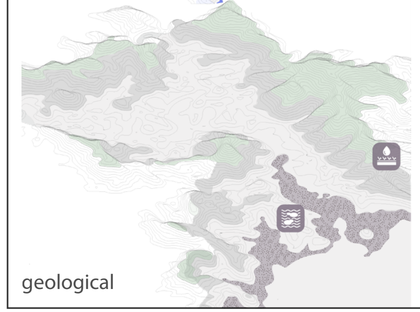


ecological

The dominance of a single plant species, particularly fast-growing eucalyptus trees, on the slopes exacerbates the issue of dry topsoil due to their substantial water absorption capacity. Furthermore, the lack of diversity in the forest structure limits the vertical richness of the ecosystem.

hydrological

The dominance of a single plant species, particularly fast-growing eucalyptus trees, on the slopes exacerbates the issue of dry topsoil due to their substantial water absorption capacity. Furthermore, the lack of diversity in the forest structure limits the vertical richness of the ecosystem.



geological

The erosion caused by runoff has resulted in fragmented topsoil layers, preventing the formation of a continuous water table on the mountain. As a consequence, the topsoil becomes dry, impeding the rise of groundwater levels.

3 layers Strategies

tree stories diversify ecological succession

It is essential to enhance the overall ground cover rate in acidic topsoil conditions by employing low-impact approaches. This will facilitate the establishment of initial conditions for a sustainable and healthy ecosystem, minimizing human disturbance.

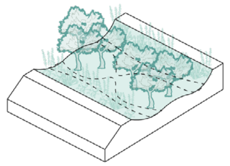
catch the water (infiltration, retention, recharge)

Maximizing retention and infiltration should be achieved by combining diverse forest vertical layers with highly permeable soil layers. Slowing down runoff erosion on saturated clay layers, utilizing gentle slopes to retain water sources, and leveraging acidic and anaerobic conditions for the restoration of peat topsoil are key strategies to be considered.

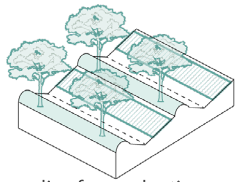
stabilize the soil structure peat restoration

Implementing peat restoration techniques can help conserve the topsoil layer, creating a moist environment and promoting the elevation of groundwater levels. In areas with high permeability, efforts can be focused on concentrated groundwater recharge.

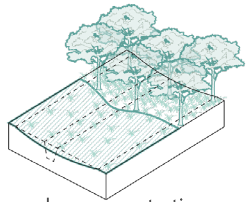
Principles



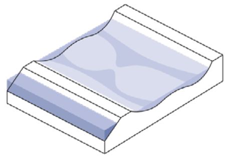
habitat restoration



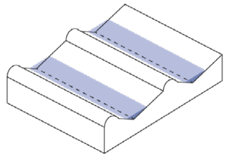
live fence planting
pre-treatment



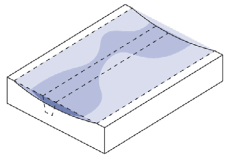
carbon sequestration
no planting on shallow peat



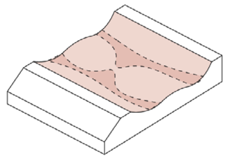
water retention



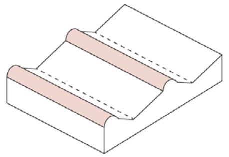
retention bunds
recharge pond



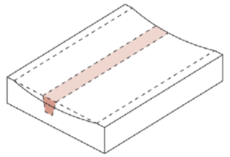
rewetting the shallow peat
water infiltration



double dike landforming



contour bunds landforming



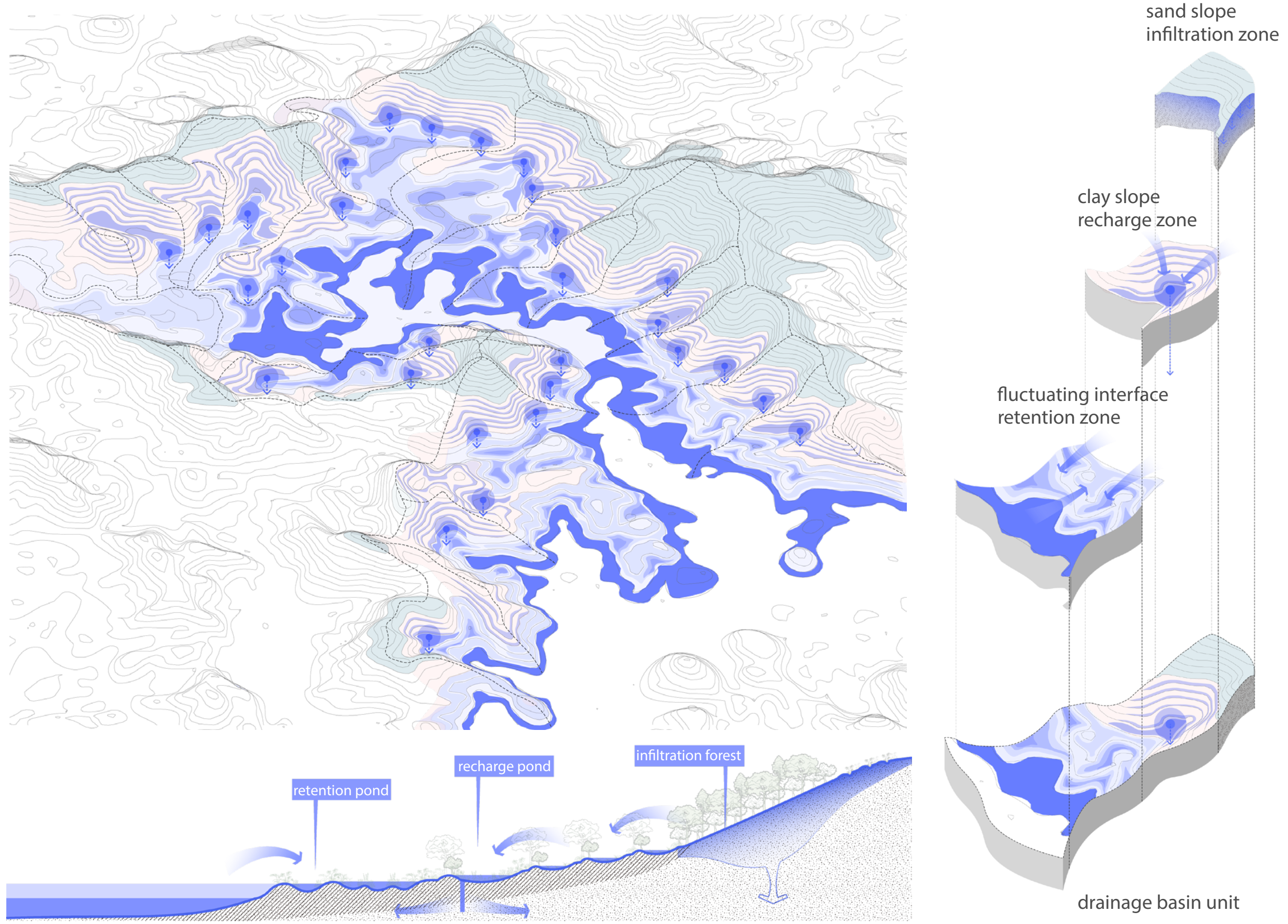
canal blocking

fluctuating interface
50: mangrove habitats succession

clay slope
50: peatland forest

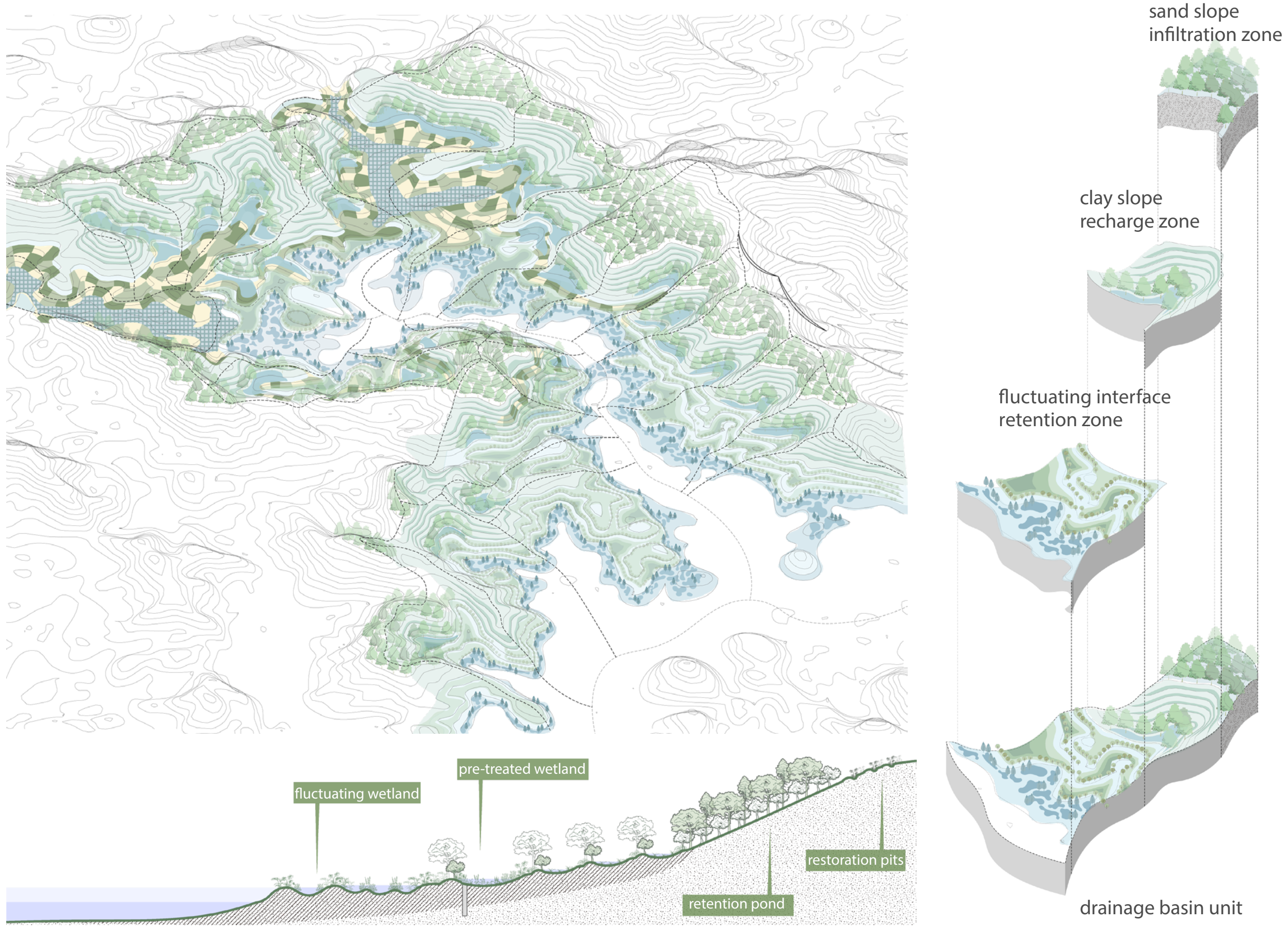
sand slope
50: tree stories diversify forest

5.1 mountain as the water tower of the PRD



The initial design intervention divided the mountain into three distinct zones, each characterized by unique soil and water conditions. The first zone encompasses the weathered sand slope at the mountain's summit, primarily consisting of forests that facilitate rainwater infiltration. The second zone comprises the clay slope on the lower hillside, where gentle slope swamps and recharge ponds play a dominant role in retaining runoff. Lastly, the third zone corresponds to the interface area along the reservoir shore, forming a fluctuating wetland characterized by water stagnation and the restoration of denuded landforms.

5.1 mountain as the water tower of the PRD



Considering the varying water and soil conditions across these zones, intervention strategies and vegetation approaches differ accordingly. As a result, the transformed landscapes within the next 10-50 years will exhibit a rich and diverse array of features. These include forests with abundant vertical layers, wetlands serving as pre-purification zones, recharge ponds that accumulate and release clean water, and thriving aquatic plants. Additionally, the shore area will feature a double dike mangrove ecosystem, contributing to a multifaceted and dynamic landscape.

5 DESIGN EXPLORATION

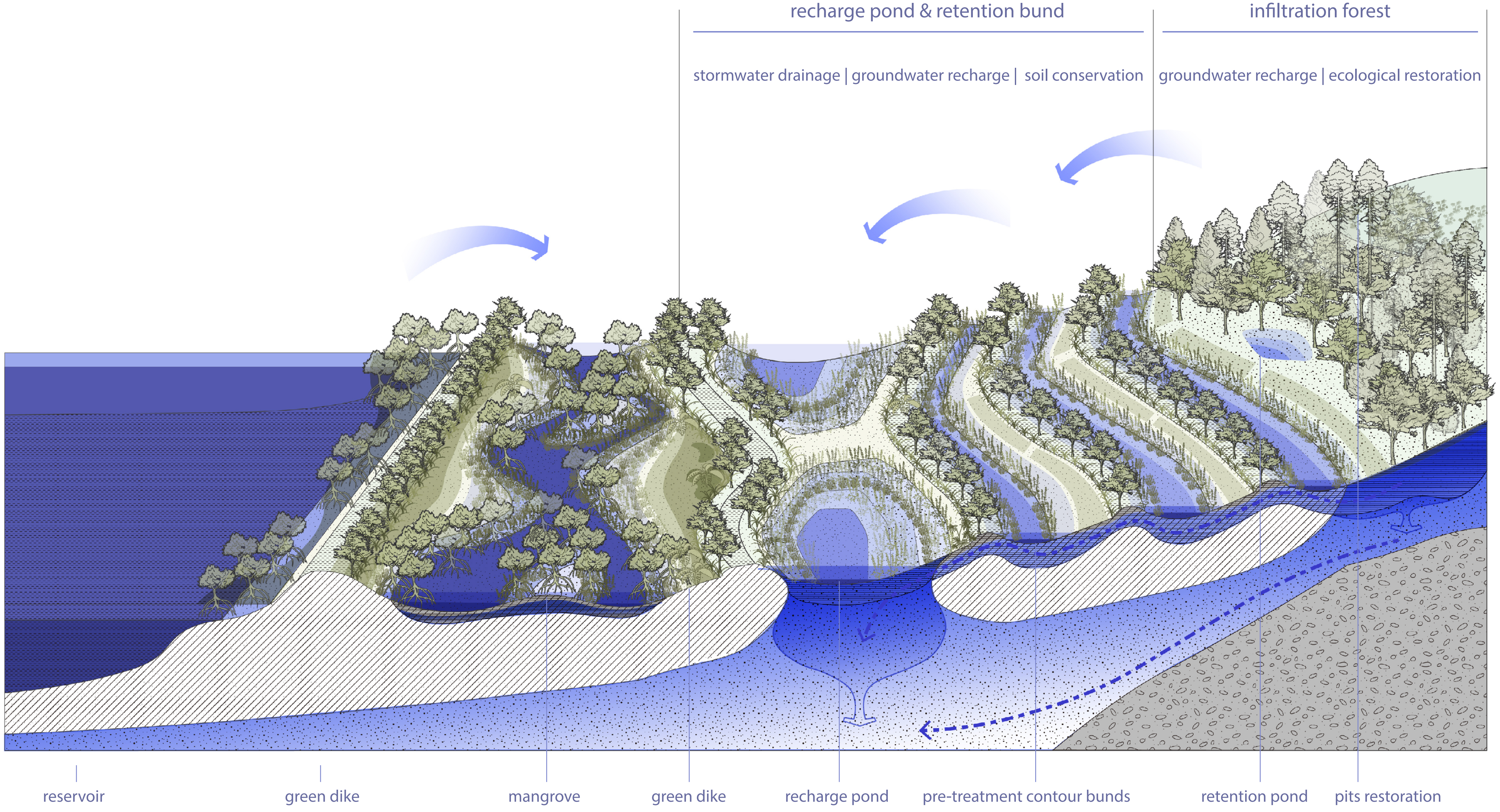
5.1 mountain as the water tower of the PRD

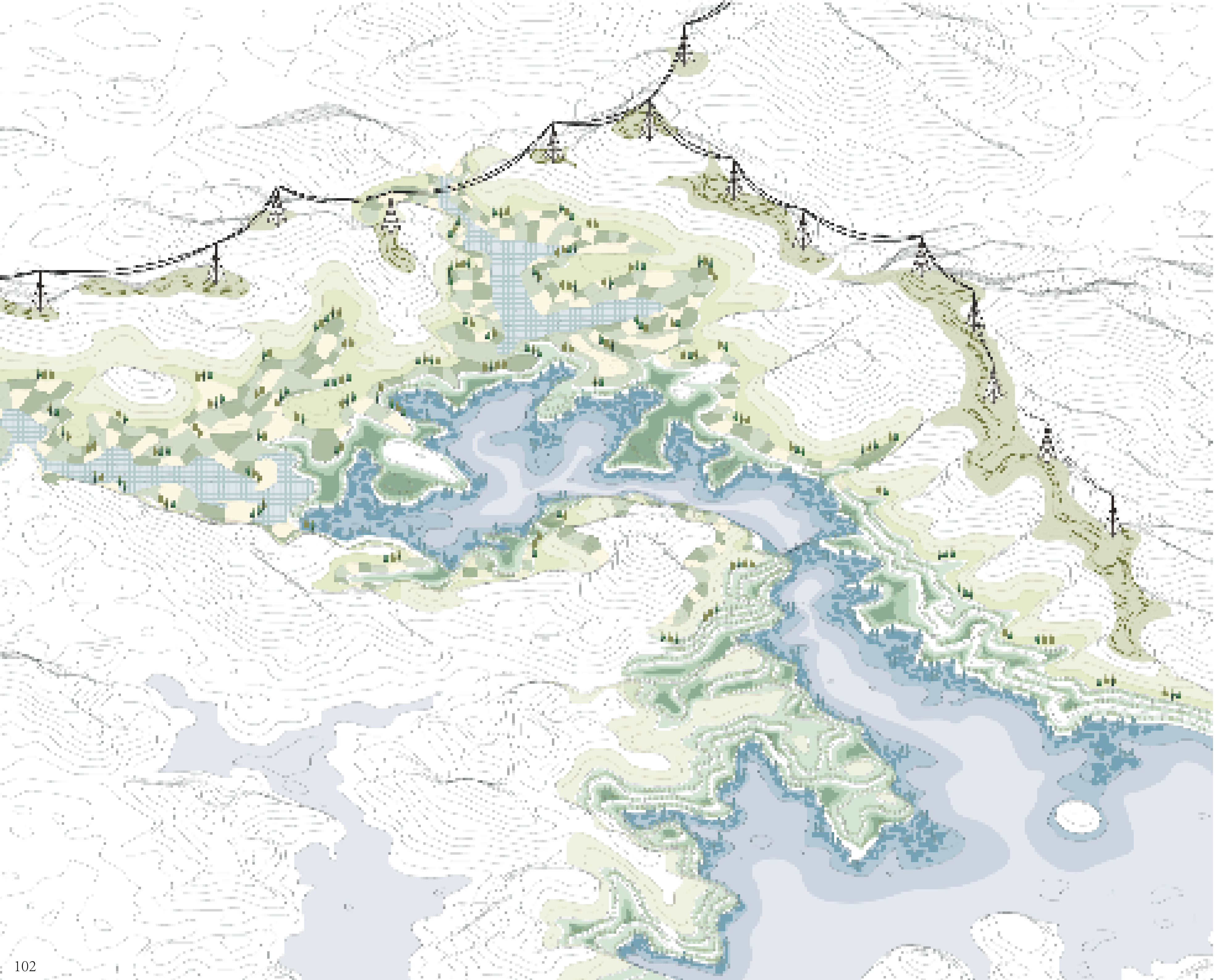
The research objective of the pilot site is to explore the potential and application of a landscape-based approach for freshwater conservation and recharge in urban mountain areas. To achieve this, the analysis and design process of the mountain landscape are centered around the watershed as the fundamental research element and the drainage basin as the basic research unit. An operable experimental basin is selected to demonstrate the distinct landscape characteristics of various regions, their freshwater storage functions, and the integrated system's functionality.

First and foremost, this study highlights the synergistic processes within the three zones. In the initial design intervention of the mountain landscape system, rainwater and runoff on the sandy slope are dispersed and infiltrated within the existing forest due to the obstruction of drainage channels. In areas with steeper slopes and severe erosion, restoration ponds retain and infiltrate rainwater and runoff. Consequently, a significant volume of clean water resources can be discharged into the subsurface aquifer through infiltration, while the height difference transports abundant water resources to the plain area at the mountain's base.

On the clay slope, the restoration of the topsoil layer gradually establishes a wet surface retention pond and an underground perched water table. This transformation improves the fractured topsoil layer, ensuring the sustainability of the ecosystem in the clay soil succession. The retained runoff is slowly released along the slope towards the recharge pond located on permeable soil, replenishing the groundwater.

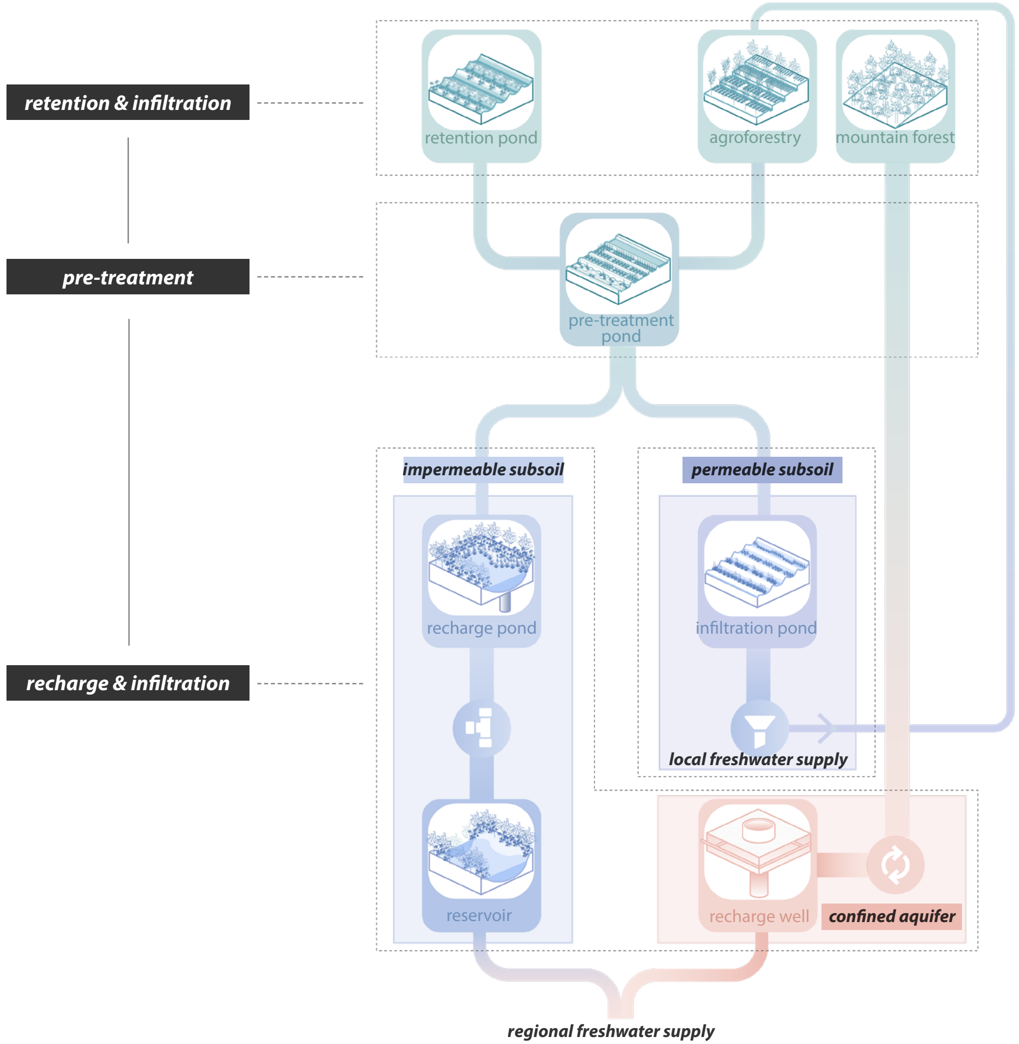
Lastly, at the fluctuating interface, the implementation of a double dike system composed of mangrove ecosystems creates stable water conditions and a dense canopy cover. This approach mitigates silt accumulation and water pollution resulting from soil erosion.





5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD



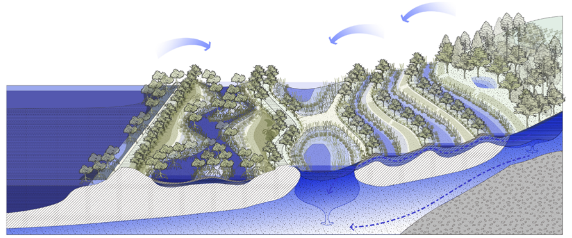
Water flow in the proposed mountain freshwater conservation and recharge system

5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD

3.5.6
infiltration forest

Implementing block canals to disperse runoff for infiltration and repairing extensively damaged topsoil are crucial for sandy slope hillsides. To prevent the proliferation of dominant plant species like Eucalyptus, which can have deep roots, retaining runoff and creating an acidic, oxygen-deprived environment aids in rehabilitating peat soil. These principles establish favorable conditions for the initial stage of ecological succession, fostering a multi-species forest system with a moist, slightly acidic, and partially anaerobic topsoil layer. This approach discourages the dominance of a single species and provides ongoing nutritional support for the ecological succession process over the next 10-50 years. The resulting forest system with diverse vertical layers facilitates rainwater infiltration and groundwater recharge.

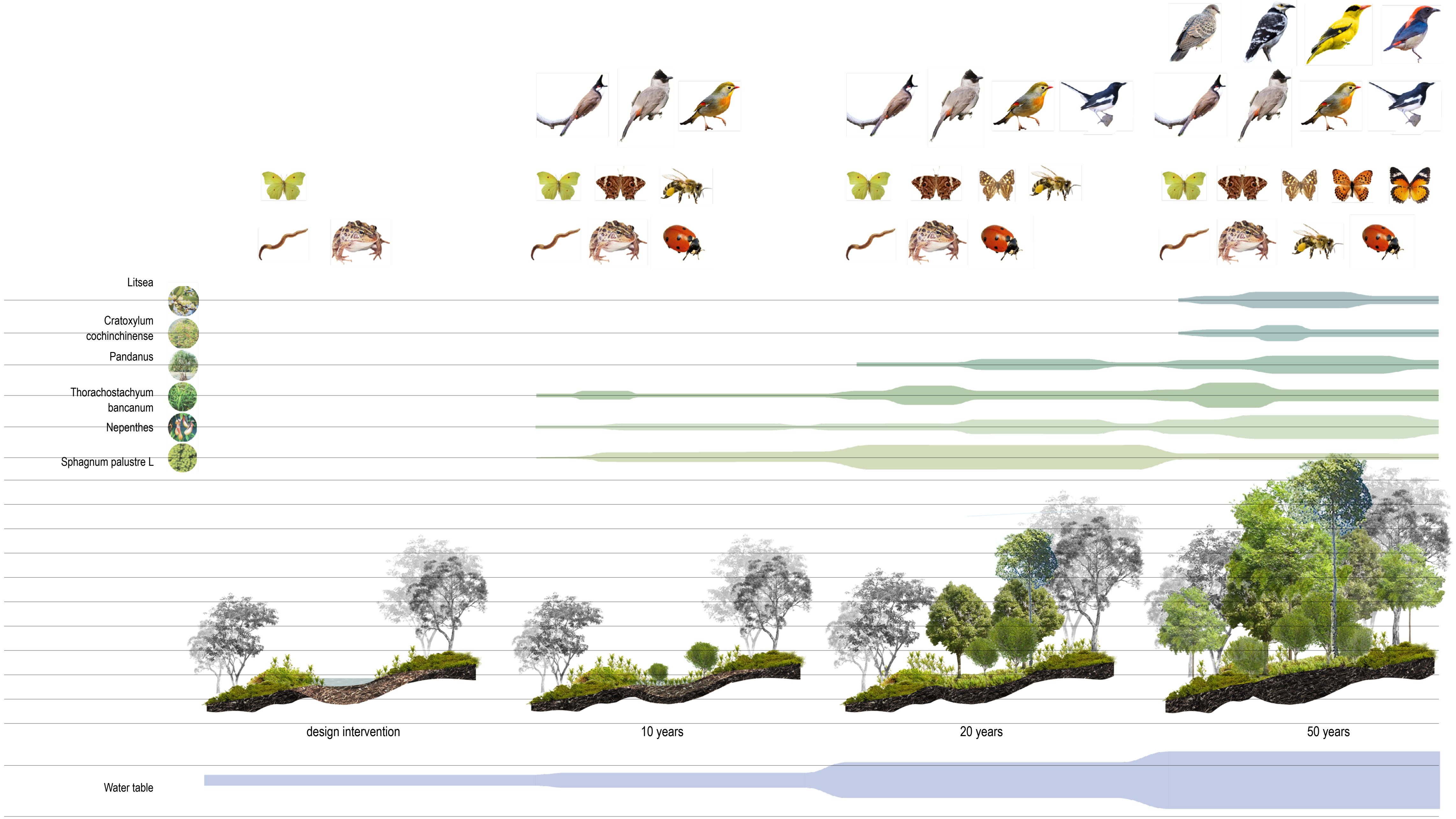


5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD

3.5.6
infiltration forest: ecological succession

In the sand slope, despite a tree canopy density of 70%, the ground coverage is less than 50%, consisting mainly of subtropical natural grassland with an average height of approximately 20 cm. Within the grass gaps, scattered organic matter composed of dead branches and leaves from trees, as well as a small amount of decomposed grass, can be found. To implement the strategy, the initial design intervention utilizes dead branches as interceptors, creating sunken pits of around 20 cm depth in denuded areas with significant gaps. The dead branches and naturally formed leaves are then accumulated to create an organic matter layer of approximately 10-20 cm thickness. These specific conditions, characterized by slight acidity, oxygen deficiency, moisture, and organic matter richness, serve as the foundation. This approach not only protects the denuded areas from the encroachment of dominant tree species but also facilitates peat soil restoration and prepares the terrain for a diverse forest ecosystem with hierarchical species composition. During this stage, three plant species revegetate the site, with Sphagnum palustre L (70%), Nepenthes, and Thoracostachyum bancanum being prominent, present throughout the seasons in the soil. Overall, the forest water table fluctuates between 0 and 30 cm below the tussock soil interface, depending on weather conditions, while soil moisture remains saturated due to the initial design interventions.
Over the next 10 years, as organic matter accumulates, the denuded topsoil layer undergoes initial repair, resulting in an increased ground cover layer, enhanced species richness, and the emergence of a shrub layer dominated by Pandanus tree species. After 50 years, with an increase in forest tree species diversity, organic matter accumulation accelerates, leading to the formation of an initial layer of peat soil, approximately 5-10 cm in thickness. A peat ecosystem dominated by Cratoxylum cochinchinense and Litsea as the main tree species begins to emerge.

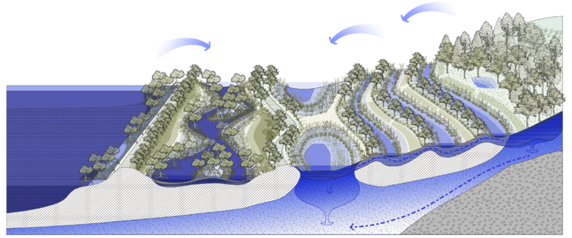


5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD

3.5.6
Contour bunds

On clay hillsides, where the topsoil layer is severely fragmented, has low permeability, and suffers from significant soil erosion, employing shrubs as live fences and constructing contour bunds are necessary for stabilizing the soil structure. These principles create undulating terrain that effectively retains runoff. Additionally, water-resistant and wet-purifying plants are planted to purify runoff descending from the ridges. The retention bunds formed by contour bunds provide a partially anaerobic and moist environment, establishing the foundational conditions for peat soil restoration. Over time, continuous accumulation of peat soil enhances the development of a continuous and stable topsoil layer. With improved moisture content and permeability, the groundwater table's height can be raised. Moreover, runoff trapped at the bottom of a series of contour bunds gradually seeps into the subsurface aquifer through a recharge pond established on slowly settled, permeable soil at the base.



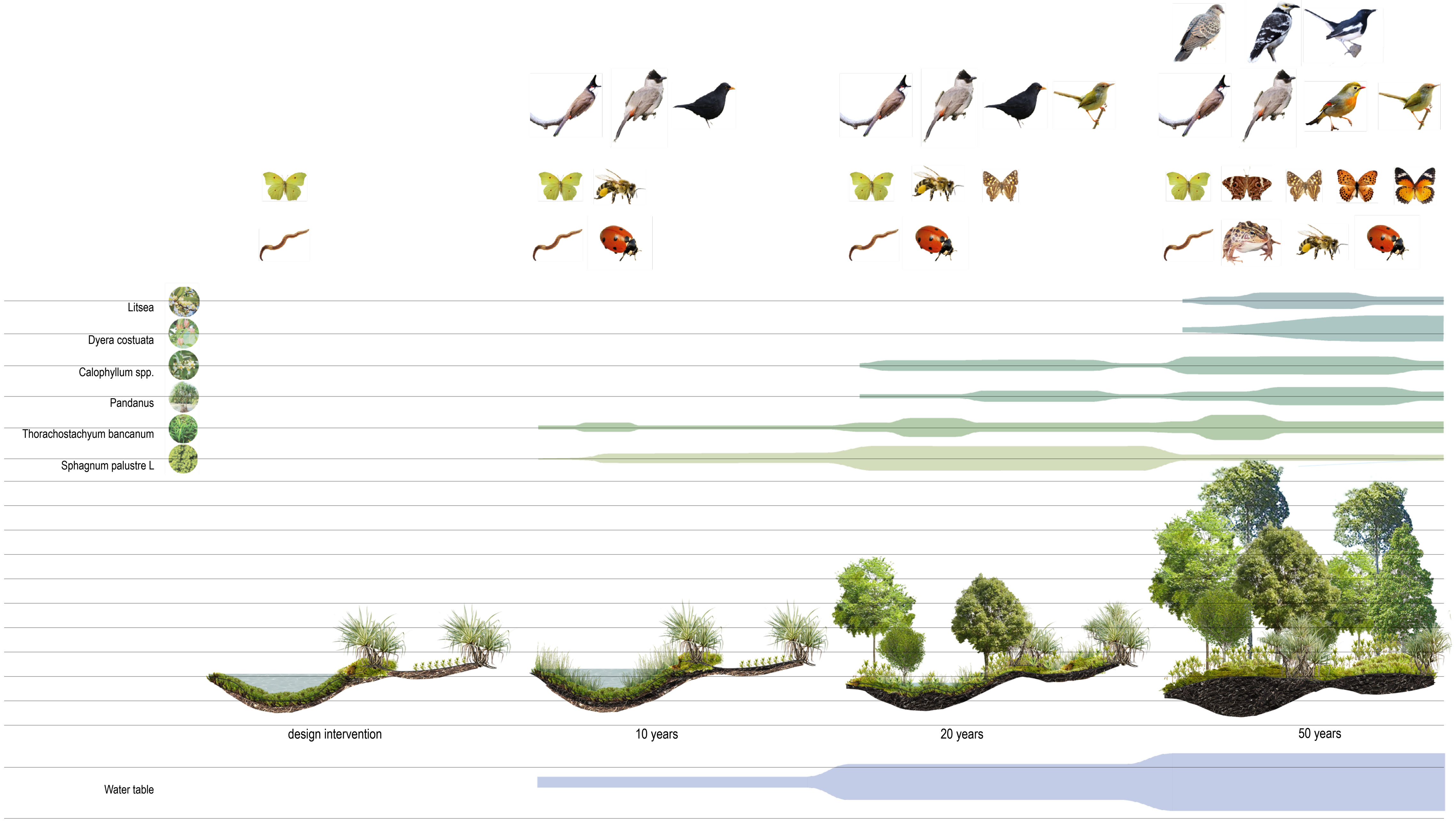
5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD

5.1.2
Contour bunds: ecological succession

In the clay slope, where the canopy closure and ground coverage are generally below 45%, the initial design intervention applies the planting of Calophyllum inophyllum L along the contour line. This tree species is adaptable to various soil conditions, possesses a well-developed root system, and exhibits strong erosion resistance, effectively consolidating the uplifted terrain of the bunds to prevent further runoff erosion. The well-developed root system aids in maintaining soil moisture. Additionally, the bunds are designed with depressed topography in each layer unit, allowing for runoff retention on the denuded clay, thereby creating an initial environment that is slightly acidic, oxygen-free, moist, and rich in organic matter, thus promoting the restoration of peat soil. During this stage, the dominant plant species include Sphagnum palustre L (70%) and Thoracostachyum bancanum, both of which are present throughout the seasons. Overall, the forest groundwater table tends to be higher at this stage, facilitating the formation of a perched water table on clay soil and ensuring saturated soil moisture. During periods of heavy rain and flooding, this area effectively decelerates and collects a substantial amount of runoff, which can then be directed to the recharge pond on permeable soil, ultimately replenishing the groundwater layer.

Over the following 10 years, with the accumulation of organic matter, the initial restoration of the denuded topsoil layer takes place, leading to an increase in ground cover layer coverage and species richness. Subsequently, the shrub layer, dominated by pandanus species, begins to thrive. After 50 years, as the forest tree species diversity expands and the organic matter continues to accumulate, an initial peat soil layer of approximately 5-10 cm forms, giving rise to a peat ecosystem where Dyera costuata and Litsea serve as the main tree species.



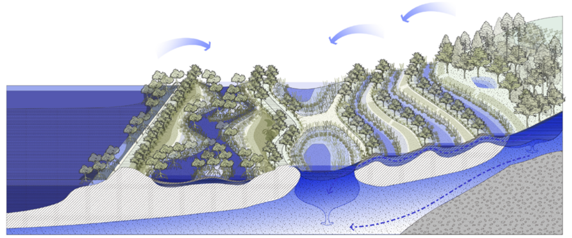
5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD

3.5.6
fluctuating wetlands

Regarding fluctuating interfaces, where the water level in the reservoir collecting runoff does not exhibit seasonal variation, a double dike system is necessary based on the range of water levels. This system ensures sufficient water retention during high water levels and relatively stable water conditions during low water levels and dry seasons. The stable water conditions facilitate the restoration of the original mangrove habitat along the shore while maintaining soil moisture and increasing the groundwater level.

The establishment of the double dike long the fluctuating interface provide athe depth variations, slowing waterflow and expanding space for the sedimentation. Meanwhile, it also increase the flood conveyance cpacity and support habitat development. This fluactutating wetlands offer opportunities to enhance the natural and recreational values.



5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD

5.1.3
fluctuating wetlands: ecological succession

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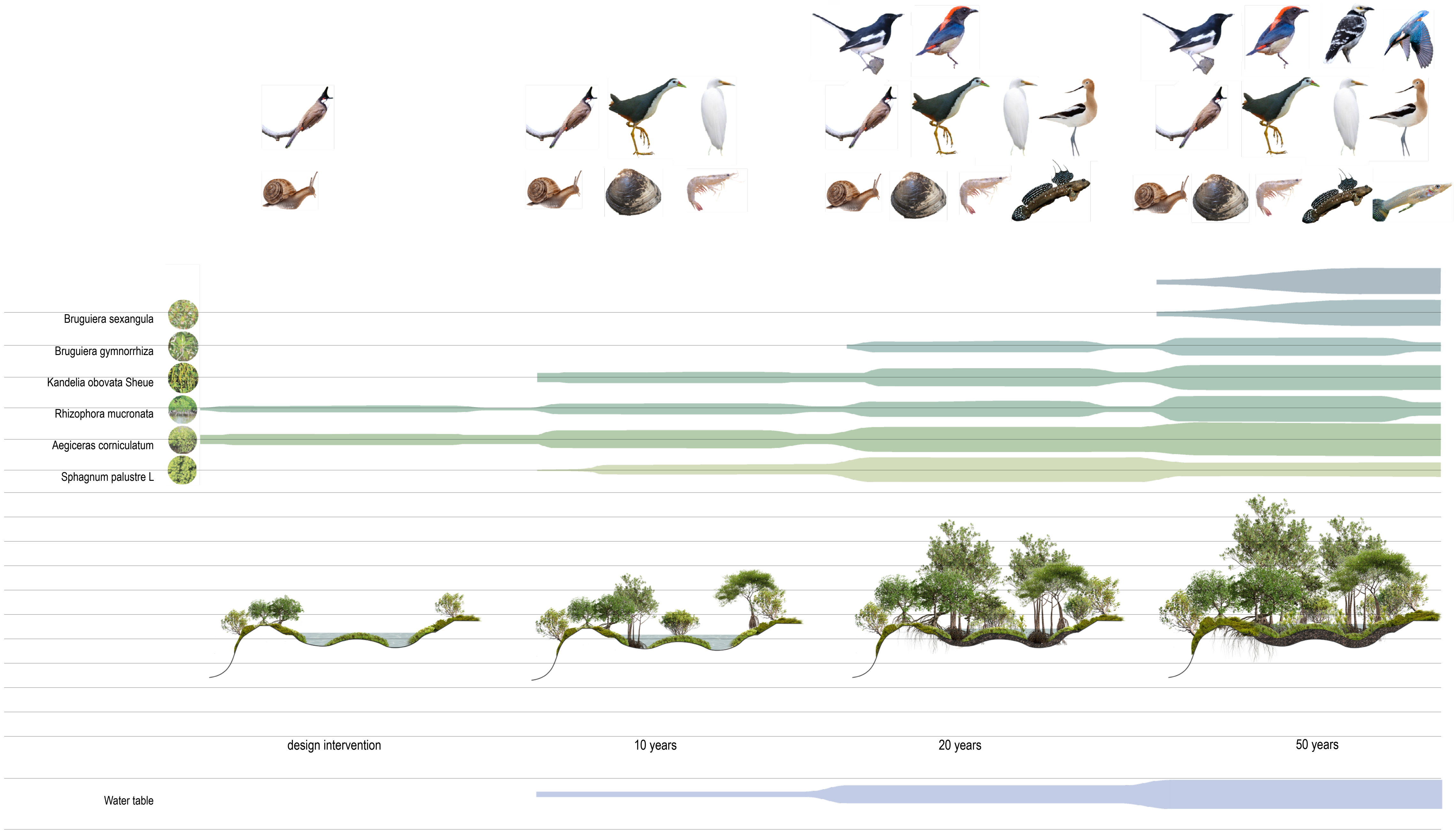
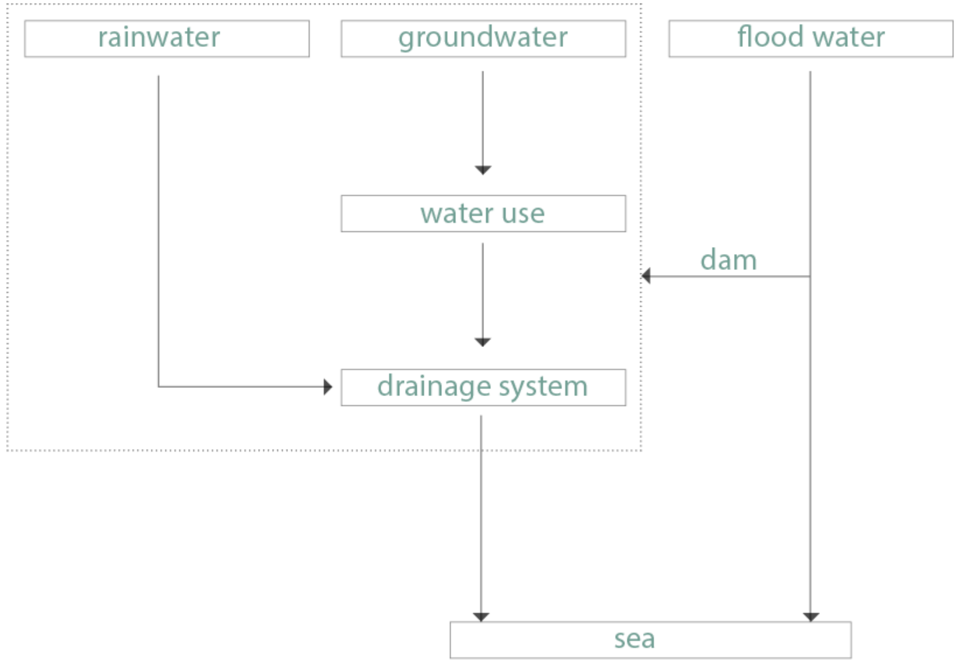


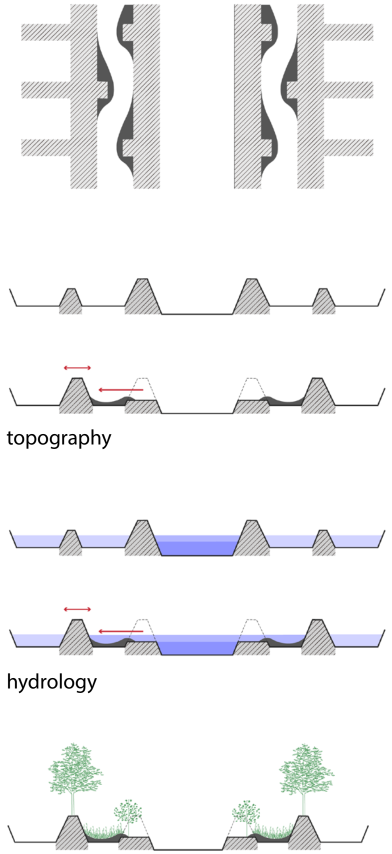
FLOOD PLAIN

5 DESIGN EXPLORATION

5.1 mountain as the water tower of the PRD

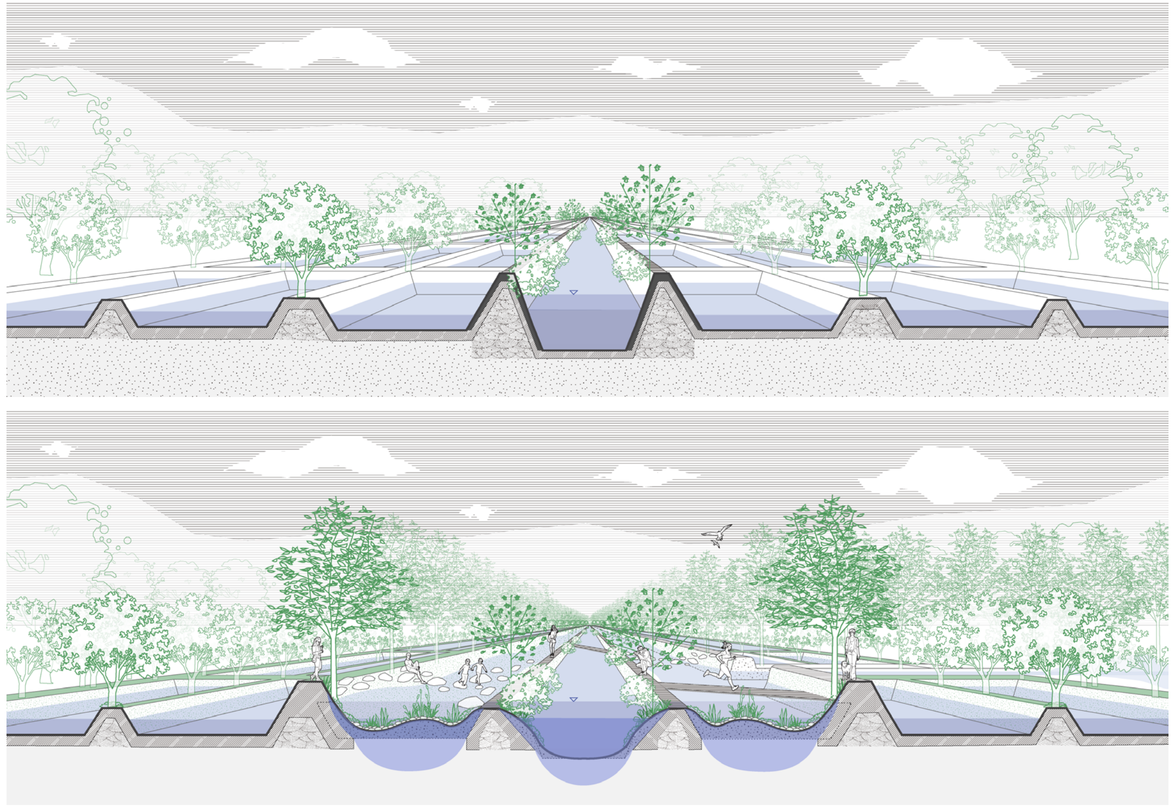


Water flow in the existing flood plain freshwater conservation and recharge system



5 DESIGN EXPLORATION

5.2 flood plain as the sponge of the PRD

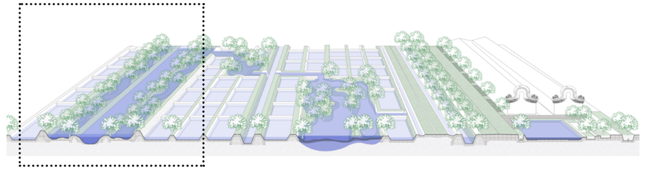


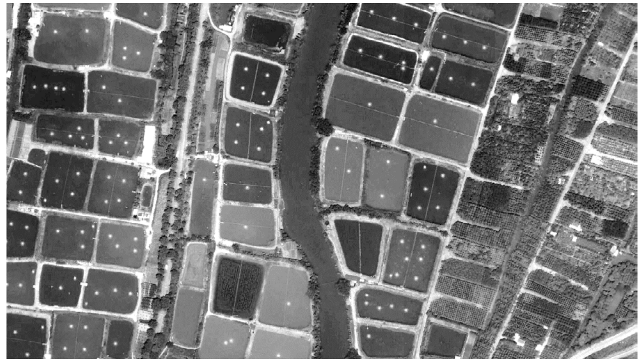
The main flood corridor is identified for river flood and stormwater during peak times. By demolishing and relocating the current dike inland, a new floodplain can be formed along the canalized border, which creates room for floodwater. Some parts of the dike pattern can be retained, allowing sedimentation and promoting the aquatic plants, gradually forming an ecological edge.

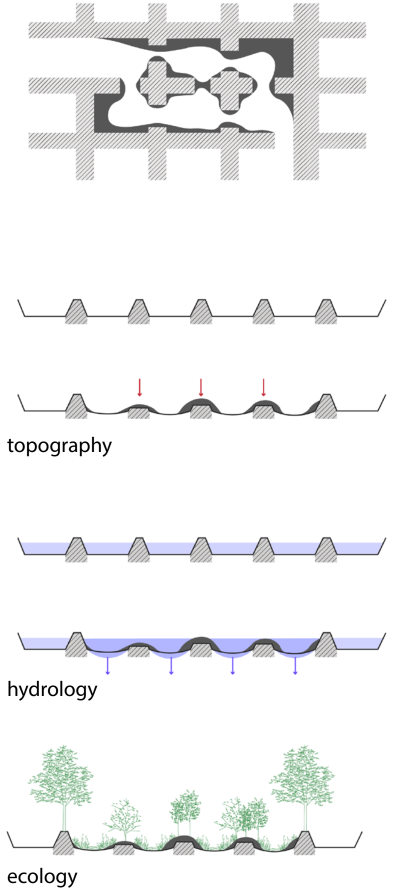
5 DESIGN EXPLORATION

5.2 flood plain as the sponge of the PRD

5.2
Flood Corridors

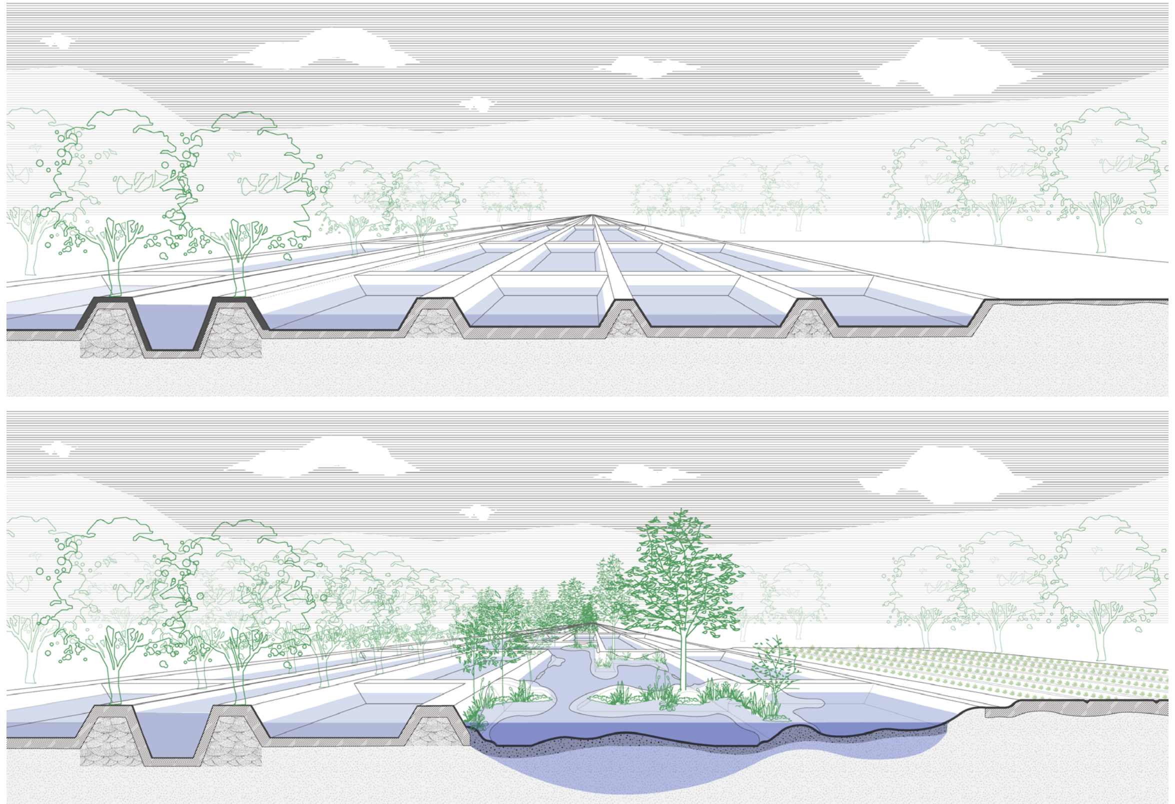






5 DESIGN EXPLORATION

5.2 flood plain as the sponge of the PRD

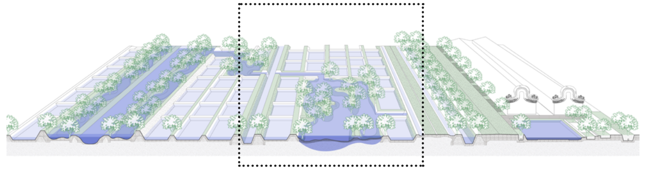


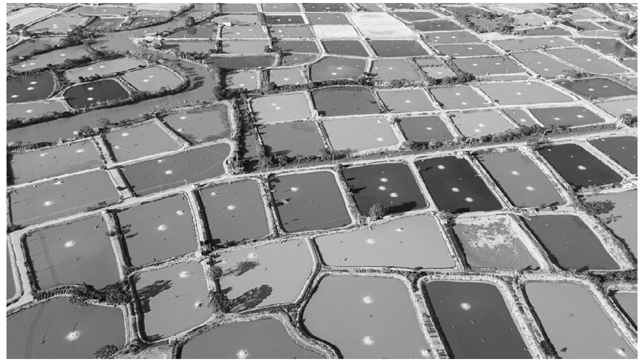
To make better use of the precipitation, in the dike pond, the strategy aims to recharge excess water from flood-prone areas to lower natural terrain. So low-lying wetlands collect and infiltrate excess water, while clay soil dig out can be used for urban development and agriculture.

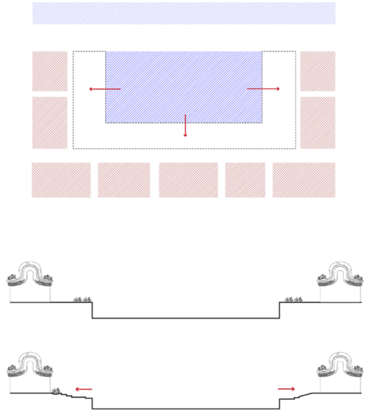
5 DESIGN EXPLORATION

5.2 flood plain as the sponge of the PRD

5.2
infiltration wetland







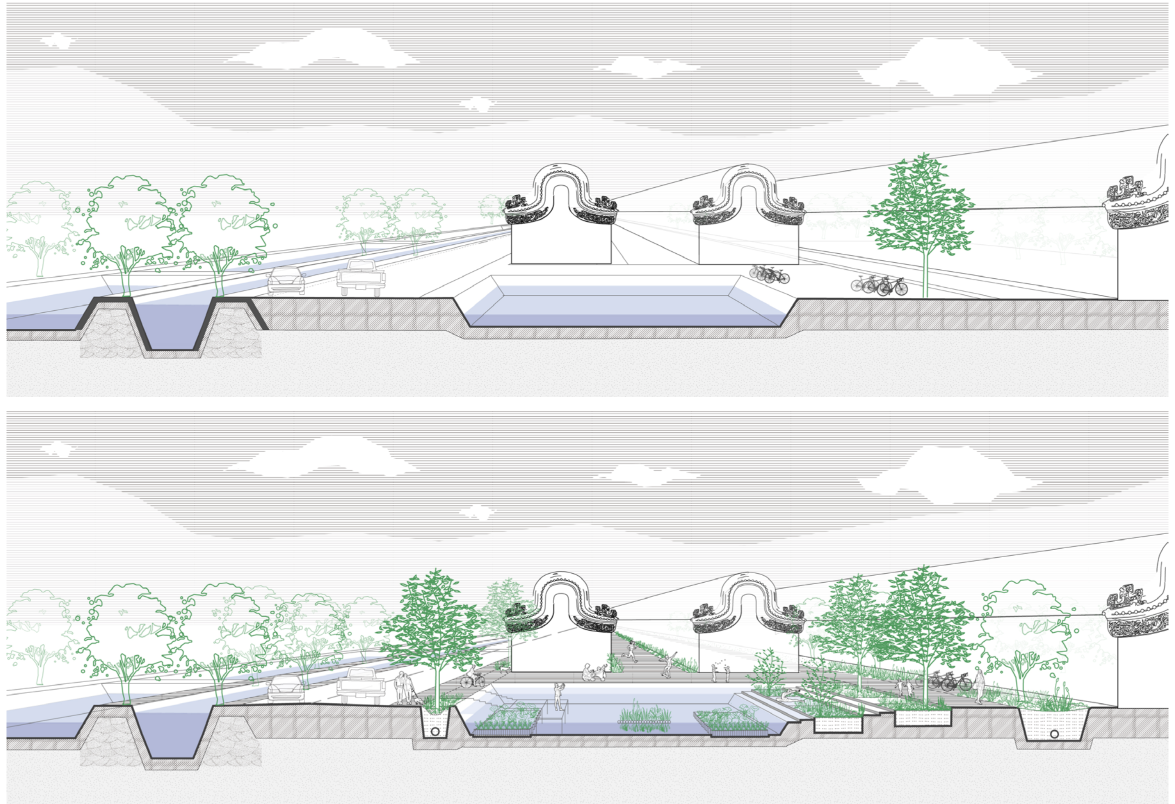
topography

hydrology

ecology

5 DESIGN EXPLORATION

5.2 flood plain as the sponge of the PRD

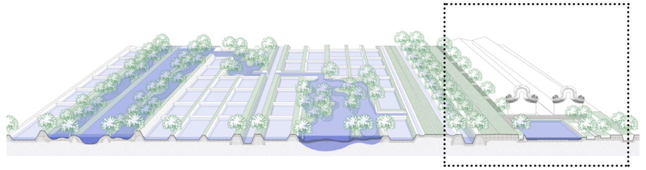


This infiltration buffer with wetland will connect the village physically and spiritually, by the fengshui pond at the entrance square of echa village. These ponds serve as a place for praying for happiness and also collect excess precipitation. The strategy is to extend the boundary of the Fengshui pond. By using the public squares around it. so more room for water storage is created.

5 DESIGN EXPLORATION

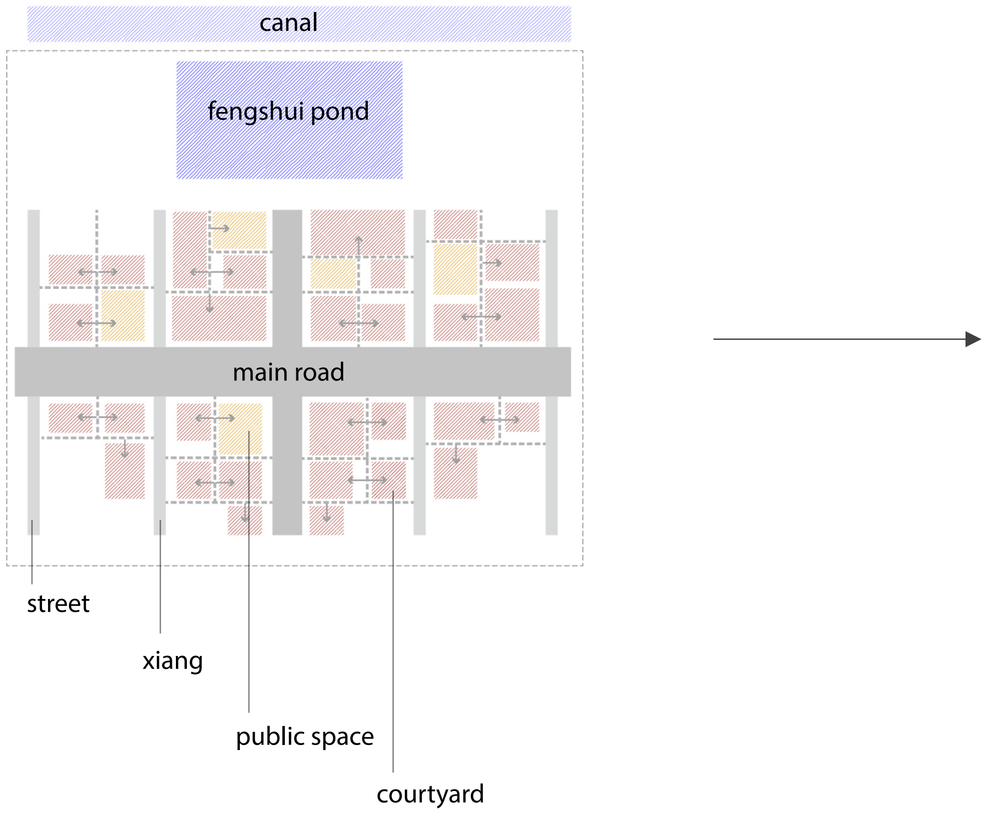
5.2 flood plain as the sponge of the PRD

5.2
Fengshui pond



5.2
the old pattern of the Lingnan Village

By studying the spatial structure of the village, it is found out that the ancient village was originally set up from fengshui ponds near the canal. Based on their position, the main street structure was formed, and in turn, created a hierarchy from the main road to streets and further to alleys, connecting the public spaces and private courtyards. So these ancient hierarchy patterns have the potential to come up with a proposed hierarchy system for freshwater collection and recharge.

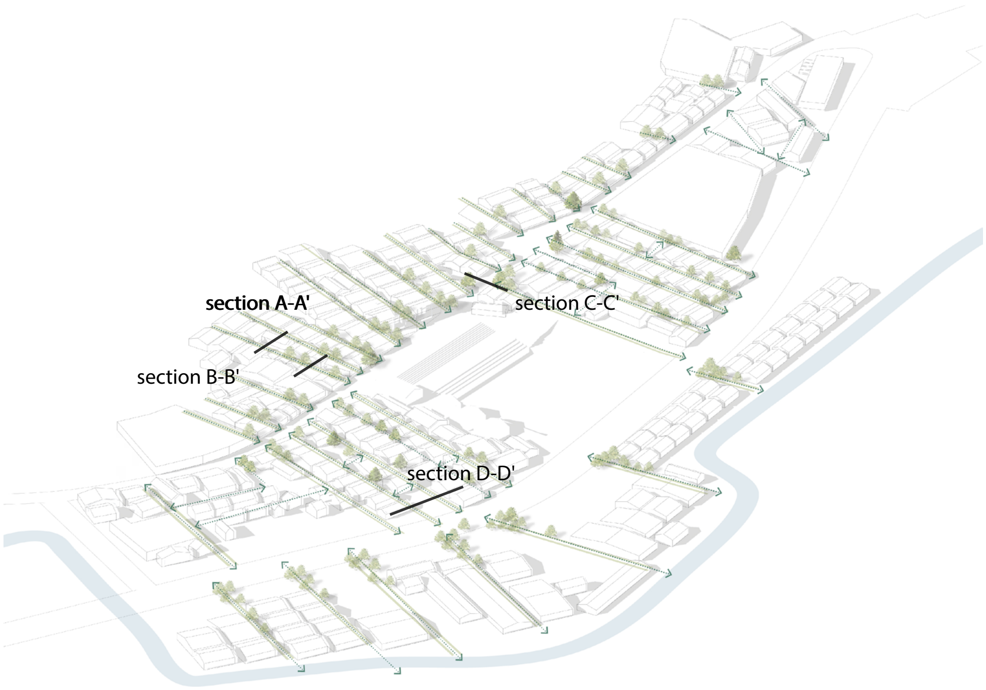


Proposed hierarchy
for freshwater managed recharge

5.2

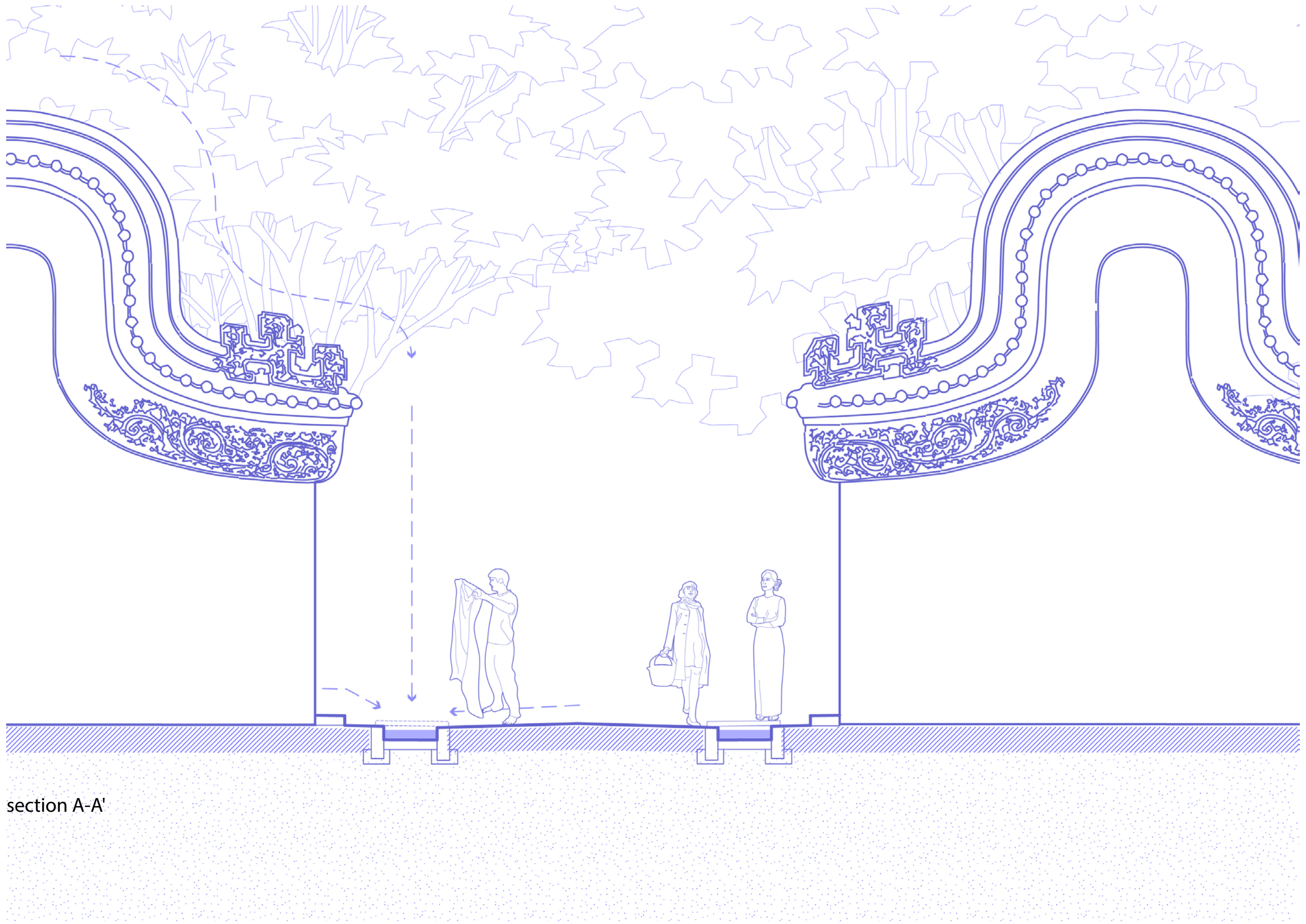
the old pattern of the Lingnan Village

the non-motorized alley role as the starting point. because the rainwater firstly accumulates from roofs and is collected through ancient alley ditches into the streets.



5 **DESIGN EXPLORATION**

5.2 flood plain as the sponge of the PRD

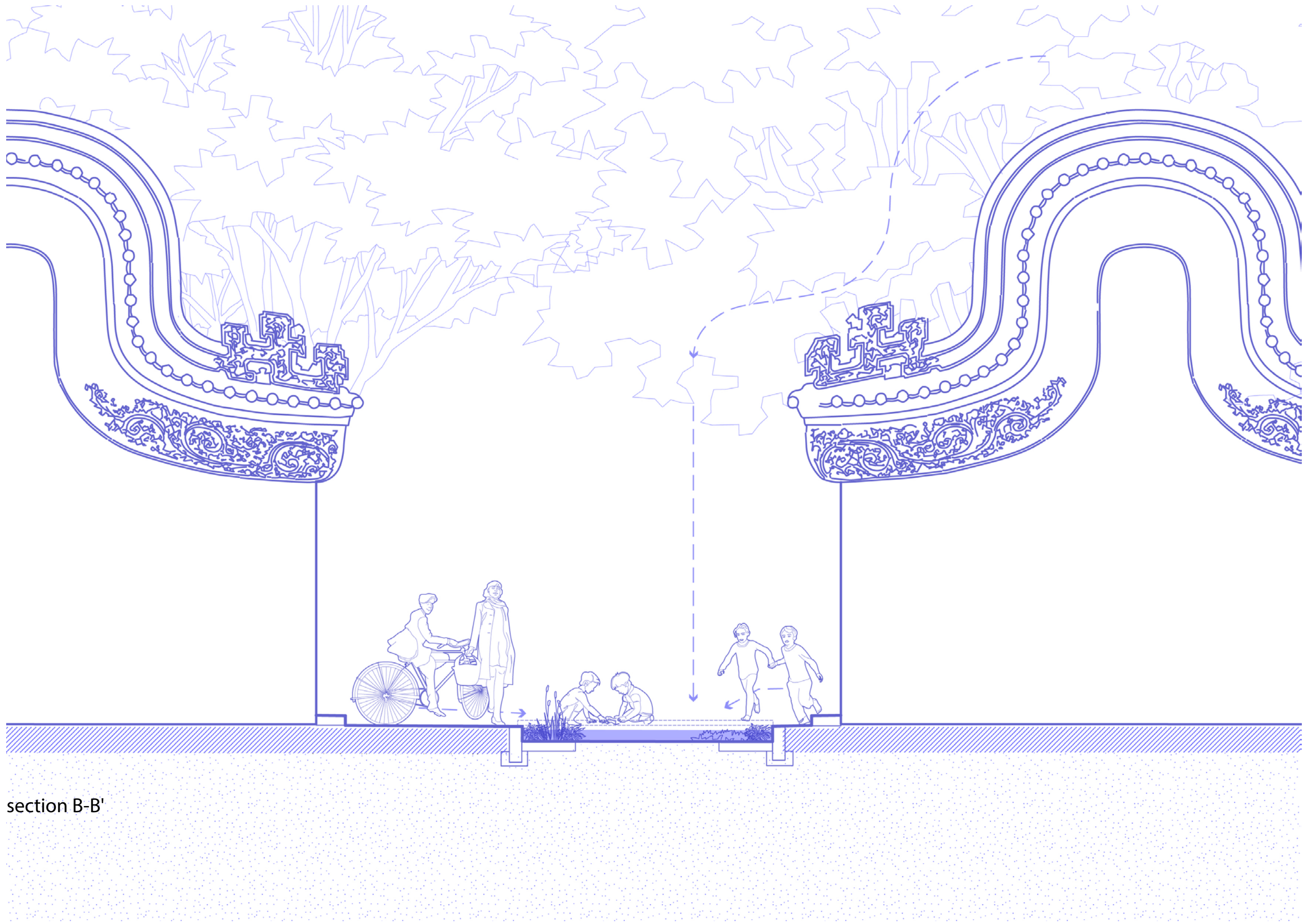


section A-A'

5.2
the old pattern of the Lingnan Village

5 DESIGN EXPLORATION

5.2 flood plain as the sponge of the PRD

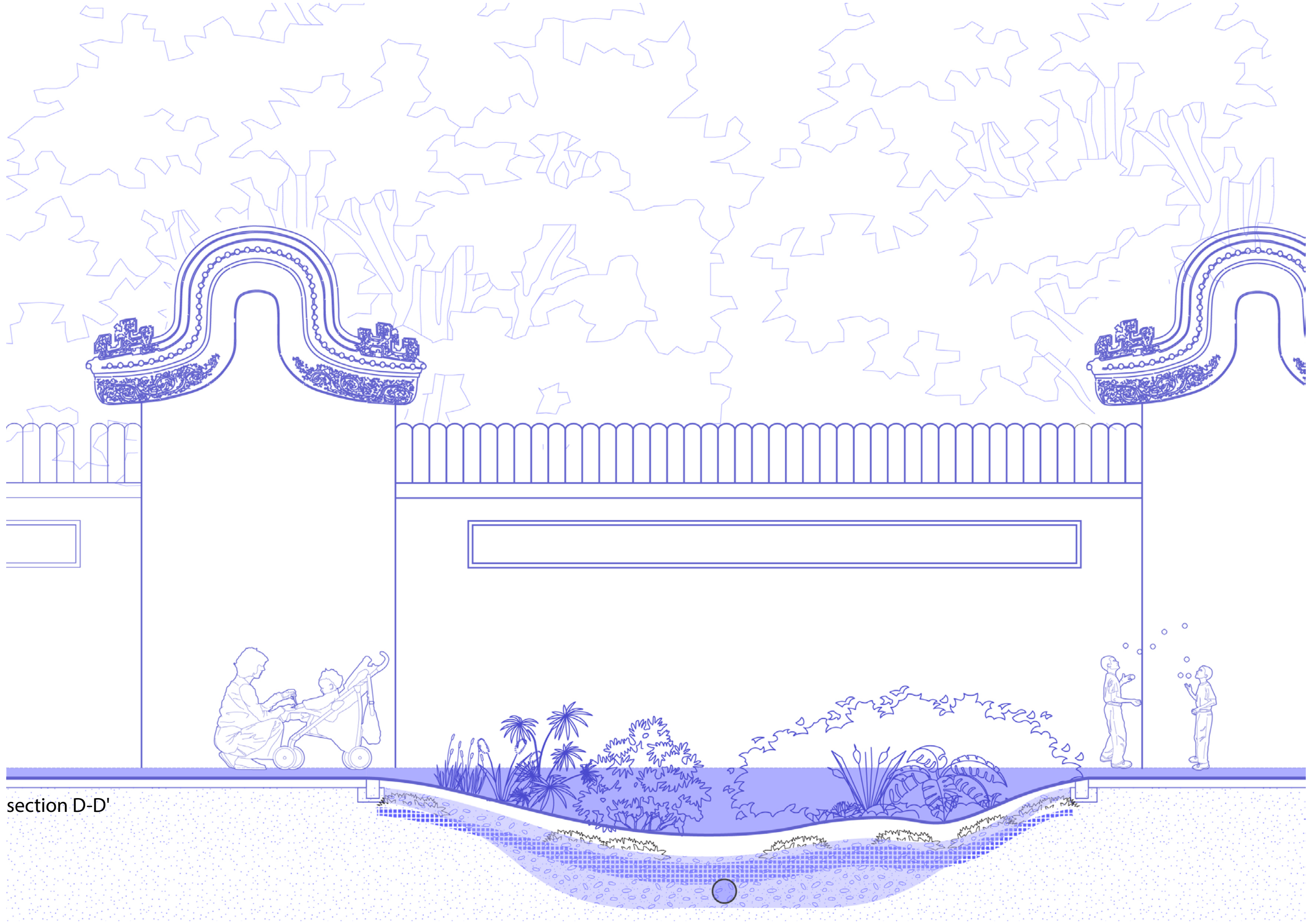


5.2
the old pattern of the Lingnan Village

These ditches built towards the street connect some public spaces, which have great potential to retain the water, and provide space for planting and primary sedimentation and purification .

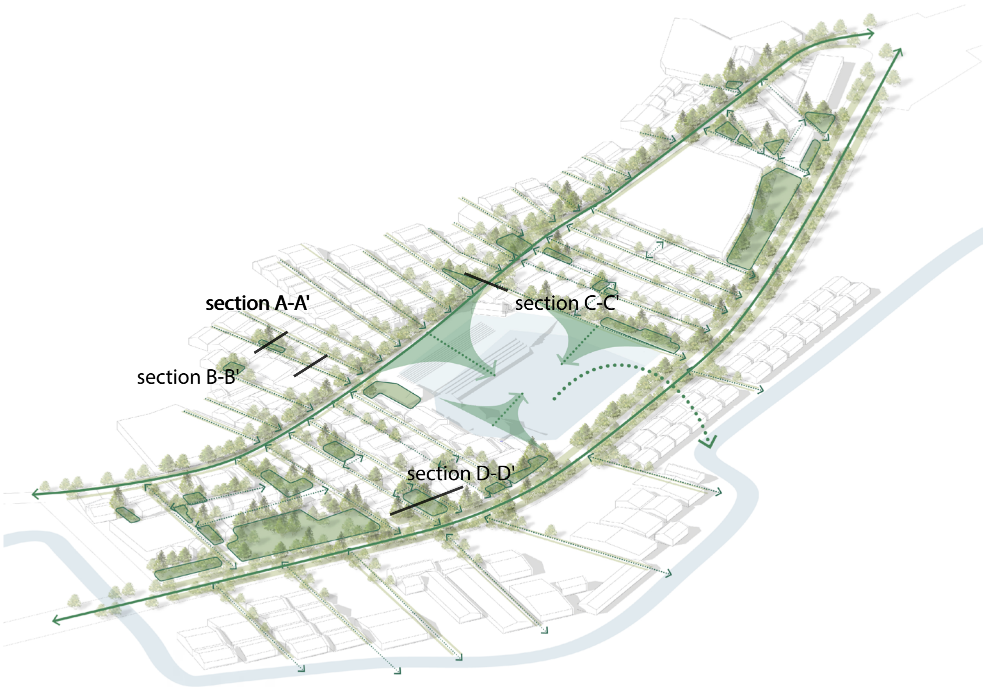
5 DESIGN EXPLORATION

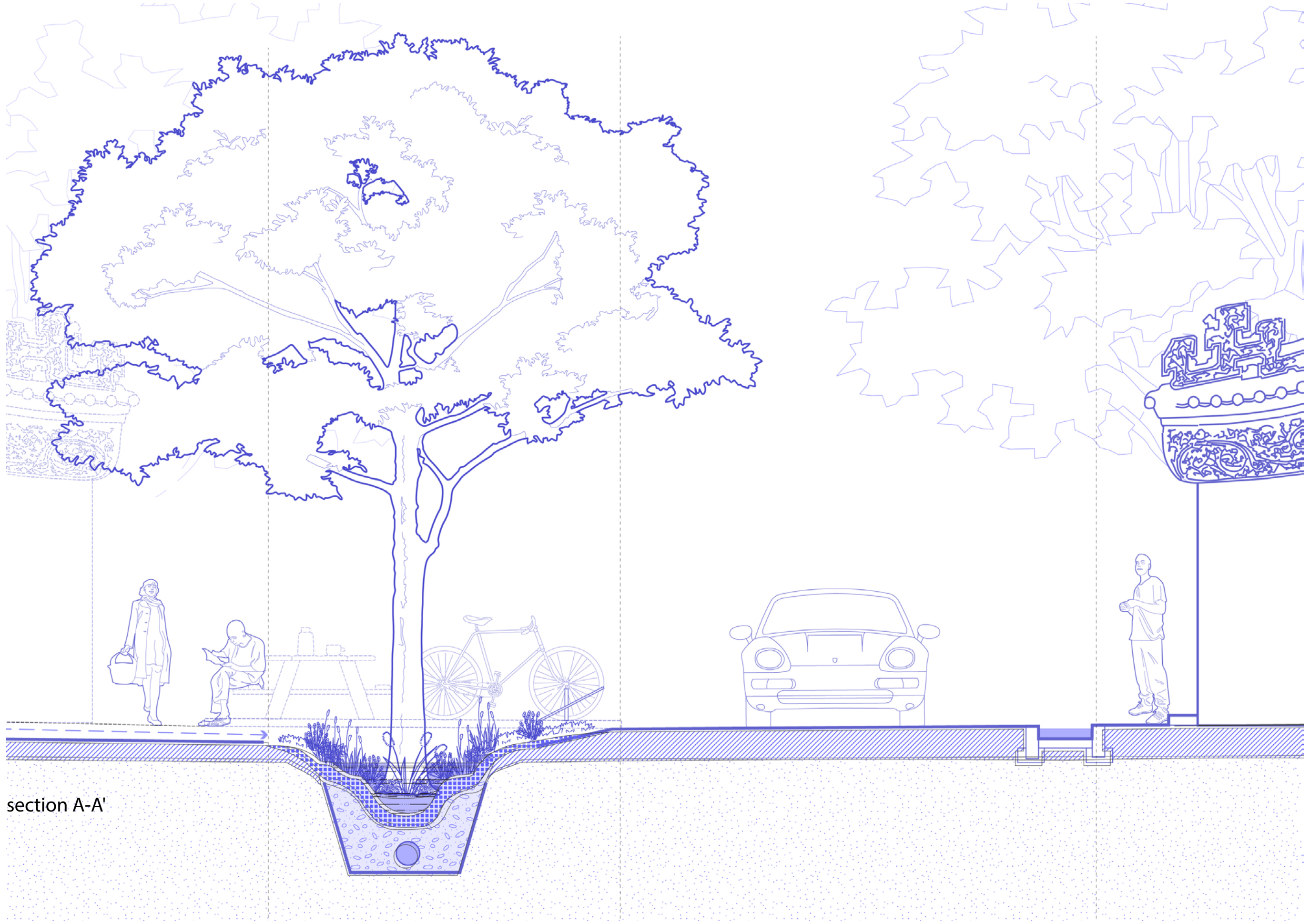
5.2 flood plain as the sponge of the PRD



5.2
the old pattern of the Lingnan Village

Following the water will be recharged to the swales along the motorized main road, which role as the infiltration gallery of the village.

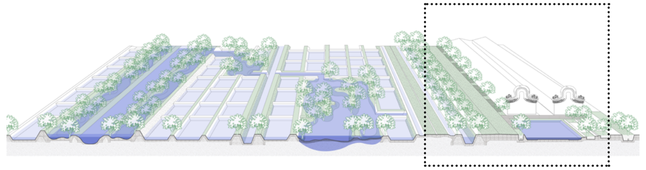


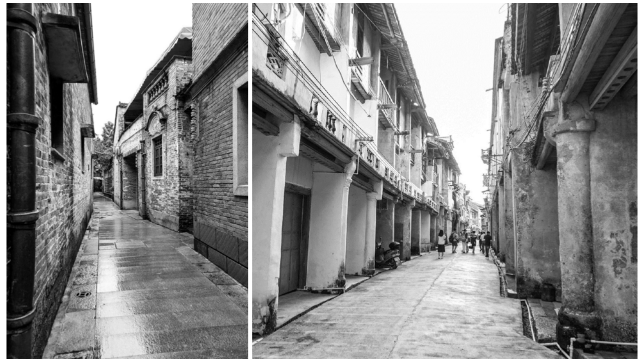


5 DESIGN EXPLORATION

5.2 flood plain as the sponge of the PRD

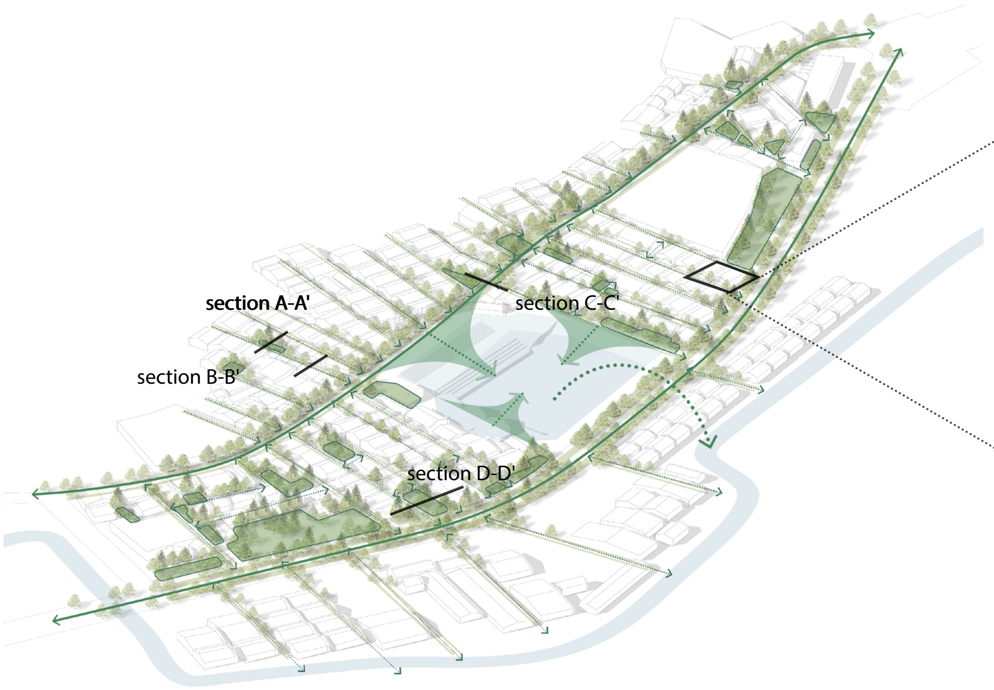
5.2
swales in the old street

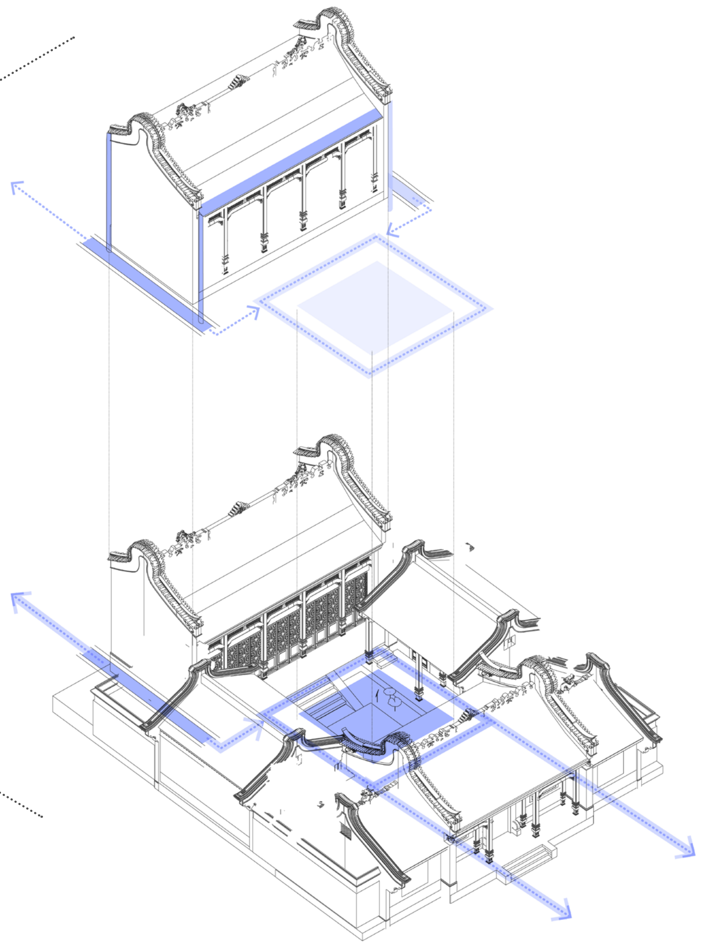


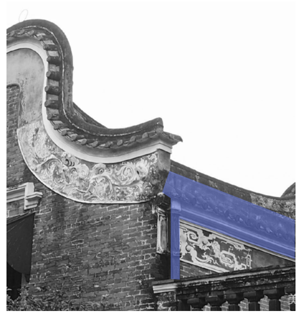


5.2
the old pattern of the Lingnan Village

In short, the above hierarchy recharges the freshwater from the village to the infiltration buffer and recharges freshwater underground. Meanwhile, this water flow system also has a direction that is towards the smaller scale of private courtyards.
By studying the water management system of Lingnan traditional buildings and courtyards could provide clues about it.





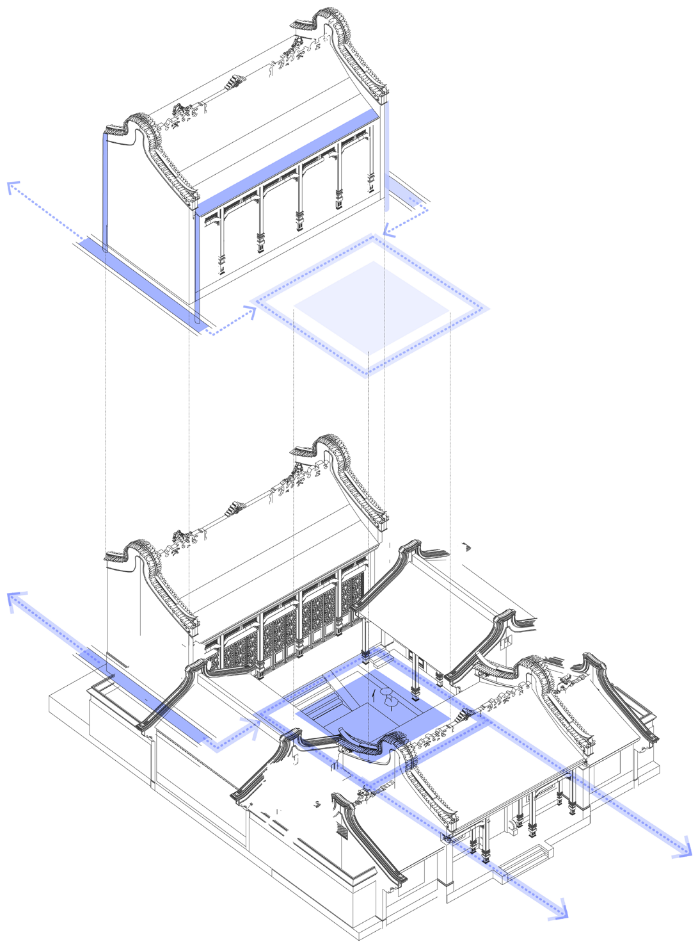


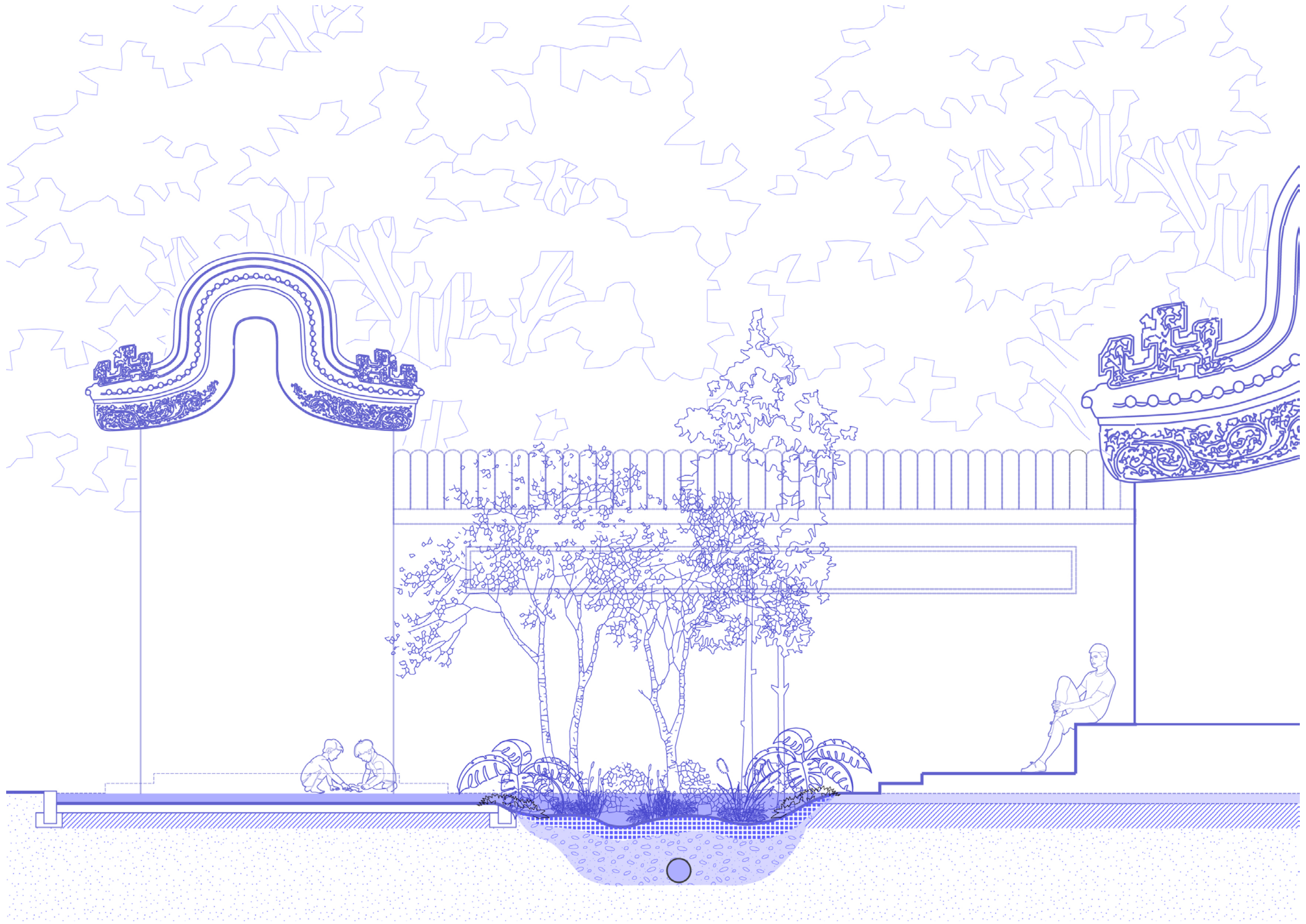
5 DESIGN EXPLORATION

5.2 flood plain as the sponge of the PRD

5.2
the old pattern of the Lingnan Village

First, rainwater is collected by the ditches at the lower end of the sloping roof. Then the precipitation will be quickly drained with this kind of bamboo shape pipe. Finally to the private courtyard. That provides an opportunity to connect the courtyard landscape to the original drainage system.

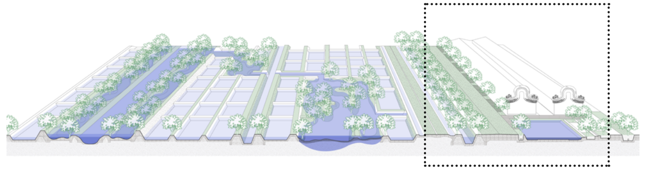


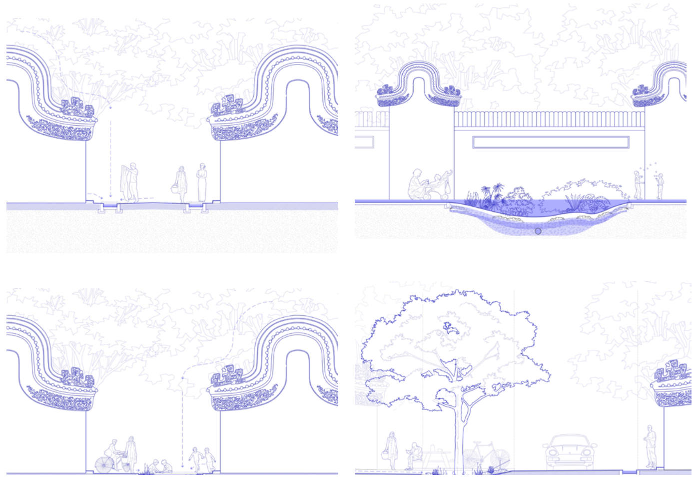


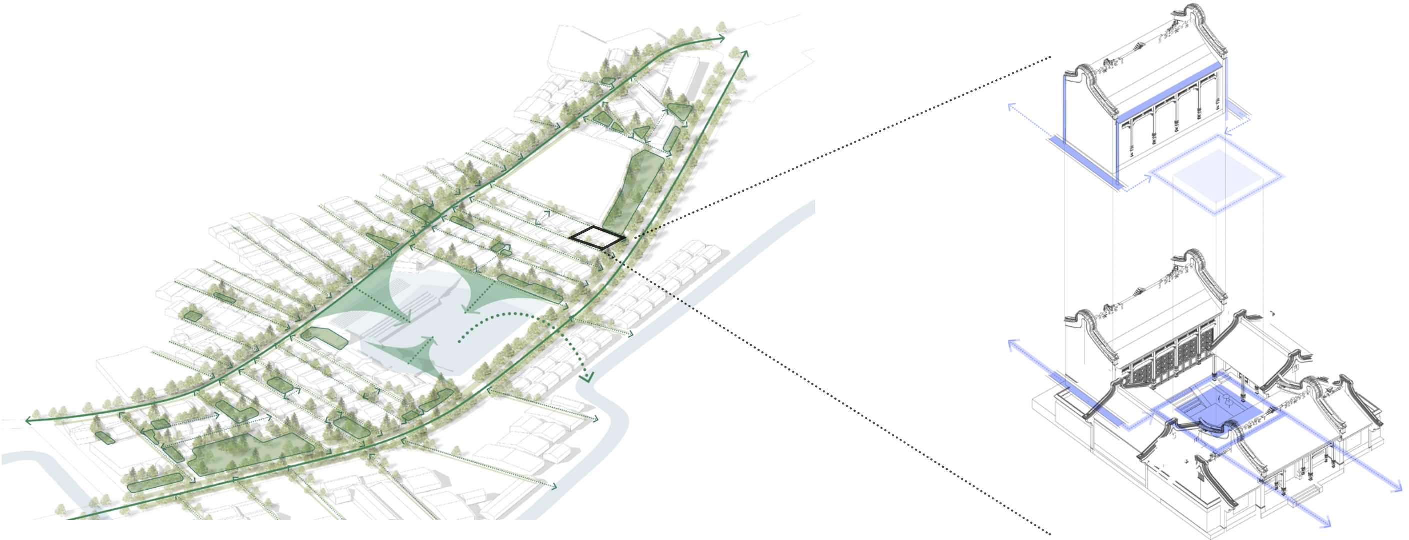
5 DESIGN EXPLORATION

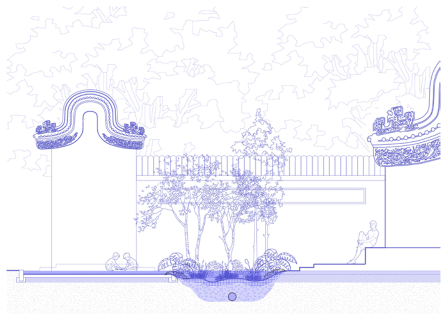
5.2 flood plain as the sponge of the PRD

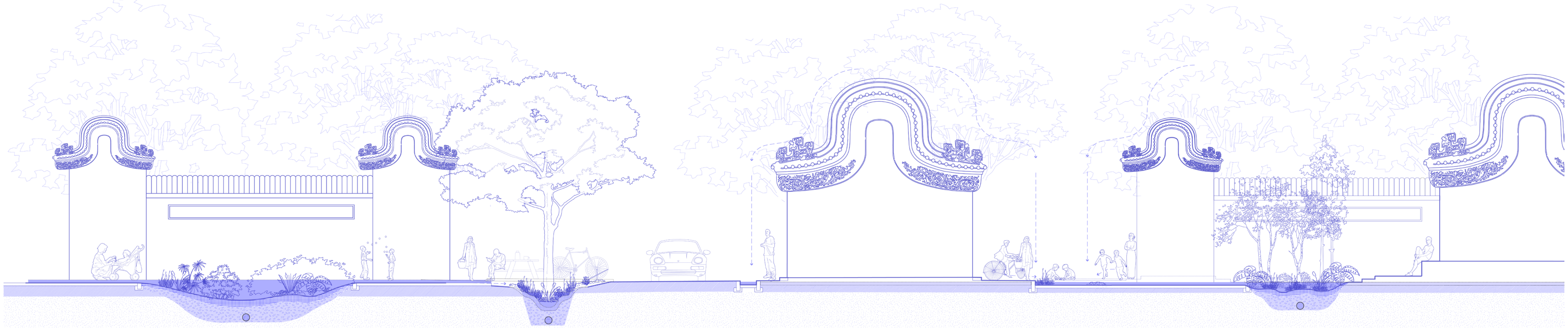
5.2
courtyard





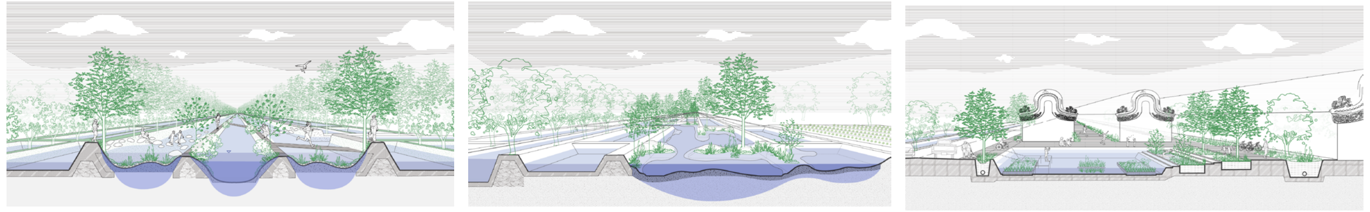


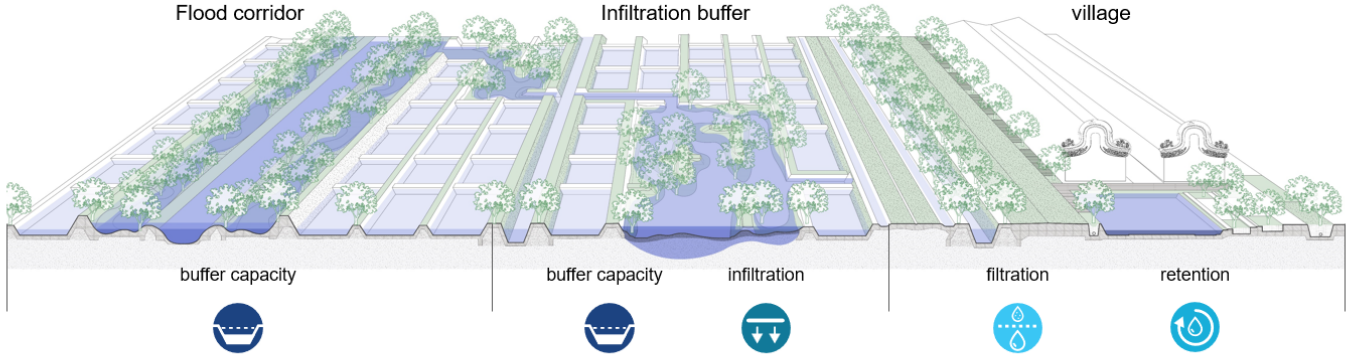




5 DESIGN EXPLORATION

5.2 flood plain as the sponge of the PRD





5 DESIGN EXPLORATION

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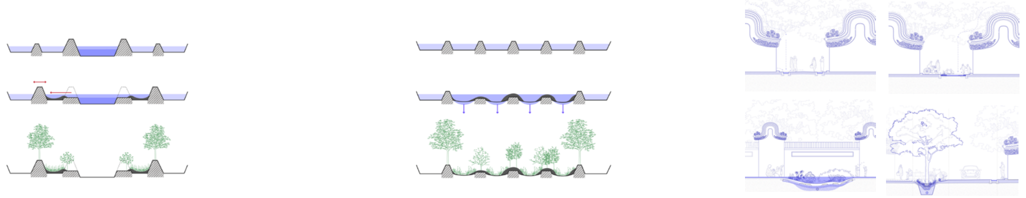
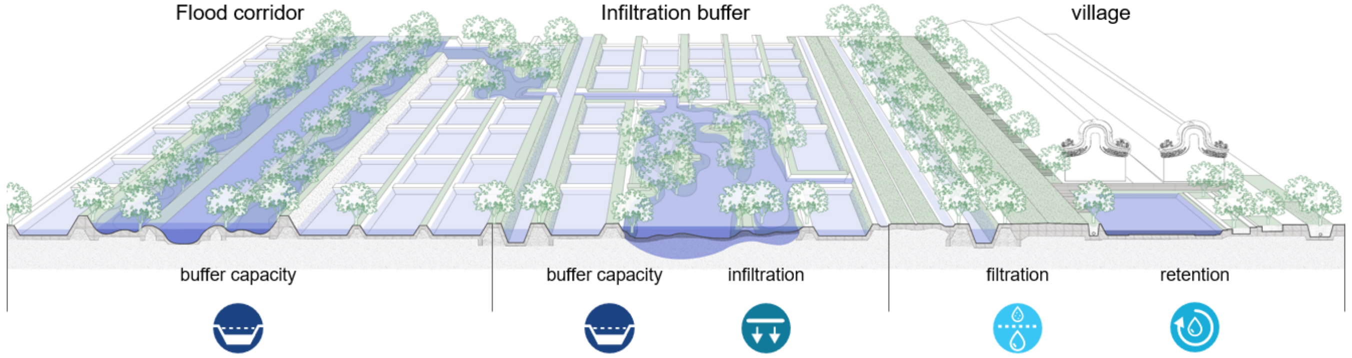




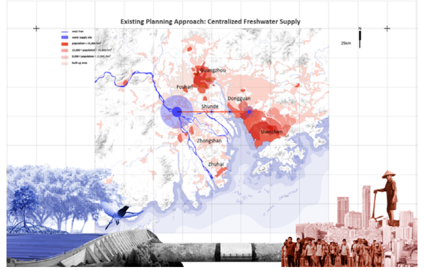
6 REFELCTION

6.1 Reflection for the Research Questions

Understanding

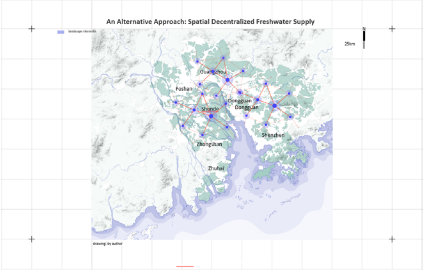
RQ1:How to understand the landscape contexts in the PRD from the perspective of landscape as a system and what lessons could be learned to respond to the upcoming challenges related to the freshwater conservation and recharge issue?

" landscape as an operative and complex living system "



"When a major urban function or service is provided by a centralized entity or infrastructure, it is more vulnerable to failure."

(Ahern,2011)



"In order to understand the coherence and heterogeneity of landscape in space and time, it is important to study the chronological (horizontal) and topological (vertical) relationships."

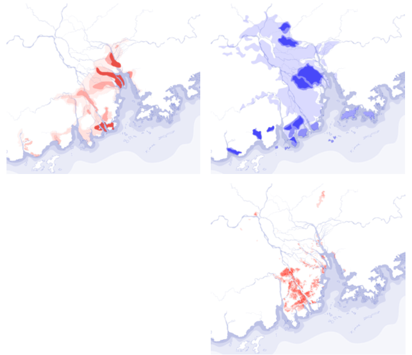
(Zonneveld 1995)

Single-Goal-Oriented iInfrastructure

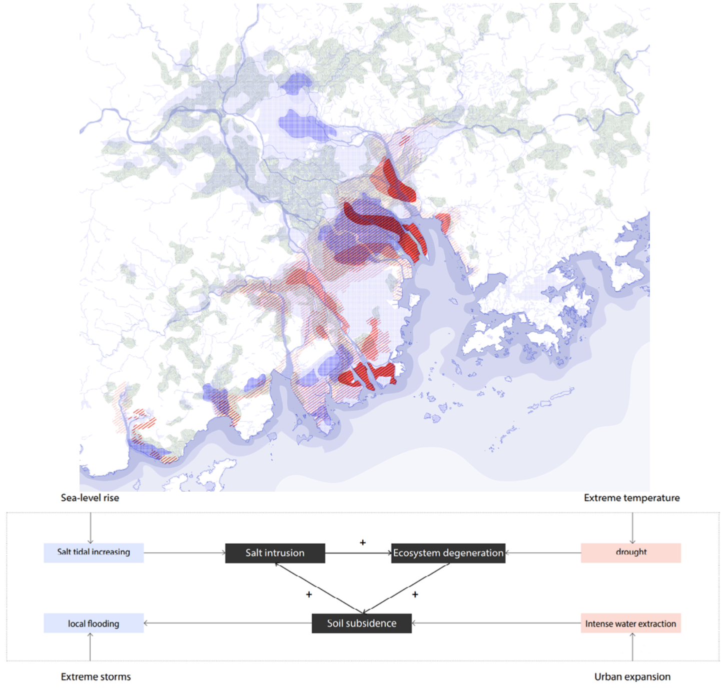
Systematic Thinking

By regarding the landscape as an operative and complex living system, this project explores the interactive processes of different subsystems, as well as their contributions to freshwater conservation and recharge solutions amidst the challenges caused by climate change and urbanization processes.
When facing extreme events or constantly changing environments that complex systems cannot cope with, a new equilibrium point must be found. This implies that different subsystems not only need to redefine themselves but also establish new relationships with each other. Thus, to solve the freshwater scarcity issue by systematic thinking, the landscape system can be systematically dissected into the hydro-geology system, the ecosystem, and the spatial experiential system, facilitating layered analysis.
Systematic thinking allows for the integration of the decomposed subsystems to conduct a comprehensive evaluation of their ability to address the crises faced by the region. Through this analysis, three primary freshwater-related issues are identified: saltwater intrusion, ecological degradation, and land subsidence resulting from excessive urbanization and water demands. By conducting the hydro-geological analysis of the Pearl River Delta, the potential for groundwater recharge can be identified, enabling the utilization of abundant groundwater recharge to adapt to saltwater intrusion. Additionally, by assessing the ecological conditions of different landscape types in the Pearl River Delta, their capacity to manage precipitation and runoff and facilitate the continuous succession of ecosystems can be determined, thereby providing the possibilities for long-term freshwater storage. In general, this process showcases the potential of diverse subsystems through a layered approach, fostering collective efforts to address the threats posed to freshwater storage.

Landscape Type



Subsystem Layers Analysis



a comprehensive evaluation on addressing the crises

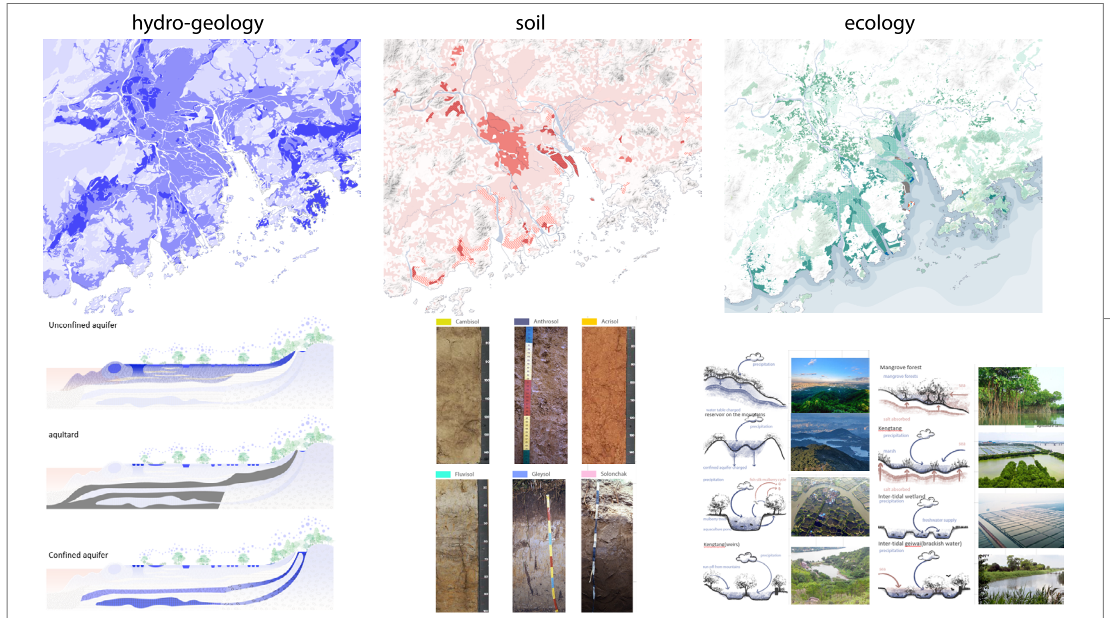
6 REFELCTION

6.1 Reflection for the Research Questions

Potentials

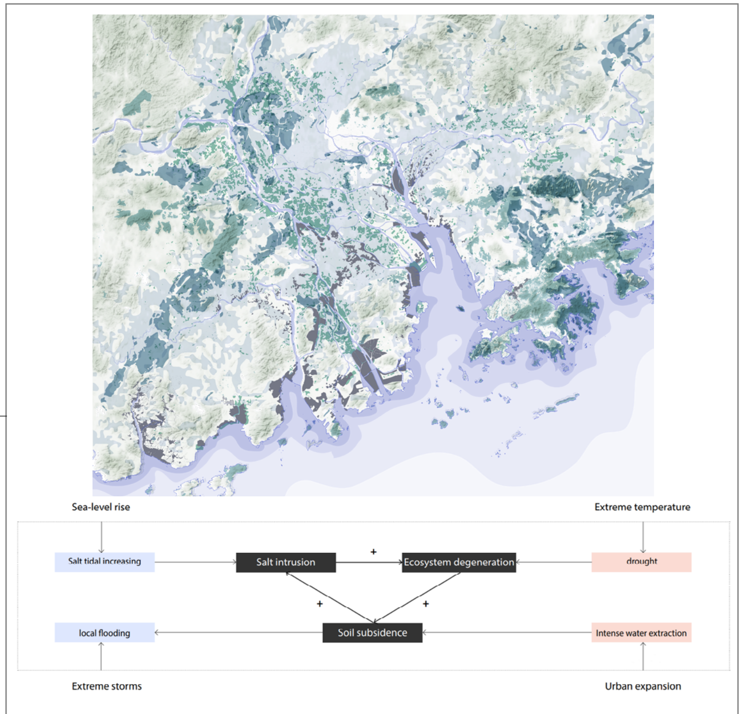
SQ2: What are the potentials of the landscape as a system to develop a resilient landscape framework and What does resilience mean for freshwater conservation and recharge issues in the PRD?

" multifunctionality, redundancy and modularization, (bio and social) diversity, multi-scale networks and connectivity, and adaptive planning and design. "
(Ahern,2011)



Resilient Design Framework for Freshwater Conservation and Recharge

Resilient means each element is safe to fail in one system. To achieve this requirement, the following strategies need to be followed in the design: multifunctionality, redundancy and modularization, (bio and social) diversity, multi-scale networks and connectivity, and adaptive planning and design(Ahern,2011).
Firstly, relying on the 113km water supply pipeline projects for freshwater supply lacks resilience because urban freshwater supply should not be driven by a single-goal-oriented infrastructure. When a major urban function or service is provided by a centralized entity or infrastructure, it becomes more susceptible to failure. Therefore, in my design project, I aim to provide multifunctional landscape infrastructure in high-density cities. Multifunctionality can be achieved through interweaving/combing functions, stacking, or temporal shifting(Ahern,2011). For example, combining rainwater storage in mountain forests with long-term ecological restoration processes to create a natural park with diverse spatial experiences, or integrating the needs of mountain agriculture during the restoration process. Furthermore, considering different levels of flood resistance and combining rainwater discharge with the recreational function of urban public green spaces in floodplains, collecting, discharging, or recycling urban water, etc.



a comprehensive evaluation on addressing the crises

Secondly, the solution is to disperse risks through redundancy and modularization across time, geographical areas, and multiple systems(Ahern,2011). Taking advantage of the decentralized landscape features in the Pearl River Delta, distributed systems are dispersed throughout diverse landscapes such as mountains, floodplains, urban dike ponds, etc., offering similar functionalities and enhancing the landscape system's resilience to disturbances. By understanding the entire process of freshwater storage, release, supply, and circulation, the potential of elements within the landscape system to participate in different steps of this process is explored.
Furthermore, a resilient framework must be connected by networked systems that support mutual interactions. Although the landscapes for coping with rainfall and runoff are decentralized and dispersed, the connection of blue and green infrastructure networks can be achieved at three levels: understanding and designing groundwater aquifers, surface ecosystems, and microclimates. This enriches the hydrological cycle system of the Pearl River Delta and reduces the probability of failure in freshwater storage and release systems.
In the following design exploration part, applying landscape-based design methods can achieve the vision of adaptive planning and design. Ecologically beneficial landscape infrastructure can promote biodiversity that compact cities currently cannot provide, and in turn, biodiversity can facilitate more species to perform similar functions, thereby increasing the resilience of the landscape system.

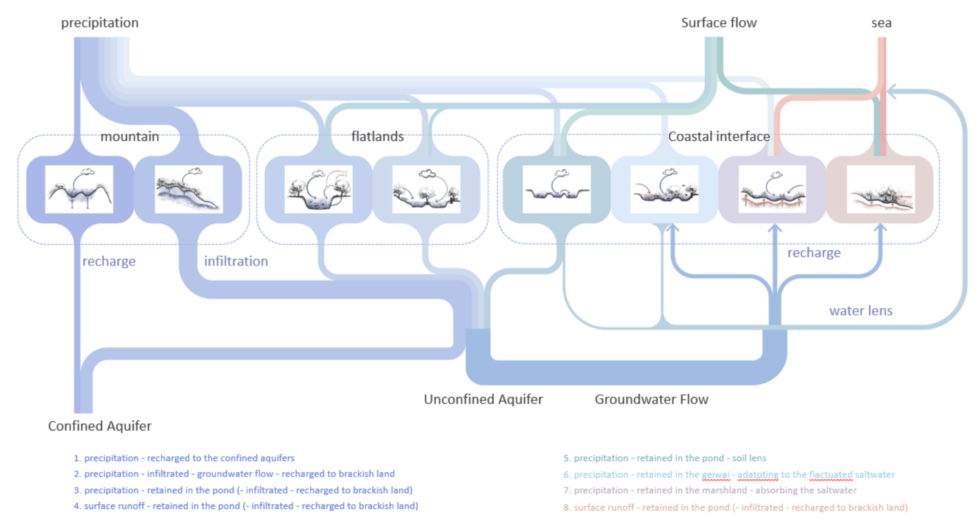
6 REFELCTION

6.1 Reflection for the Research Questions

Application

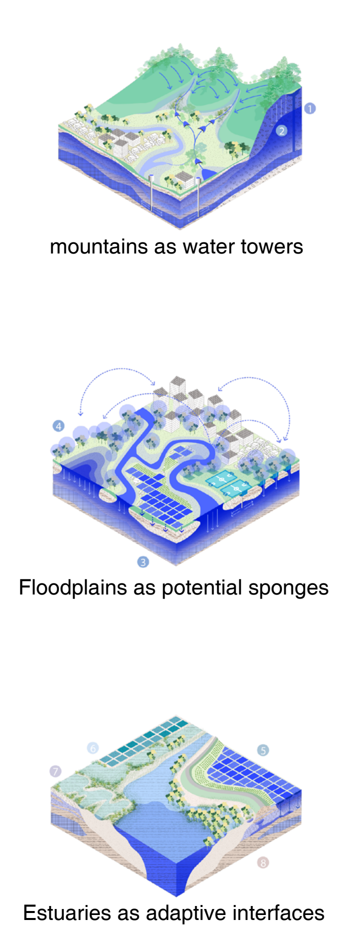
SQ3: What landscape-based principles be applied in different landscape contexts (including mountains, and foodplains) to optimize the potential for freshwater conservation and recharge, and How to generate principles in different landscape scales of the 3 contexts?

It is important to recognize the characteristics of the water flow system in different landscape types.
1)mountains, as water towers in the region, allow rainwater to infiltrate and recharge groundwater due to their elevation advantage.
2)Floodplains, as potential water-absorbing sponges, not only adapt to rainstorm disasters in compact cities but also create new possibilities for urban living, agricultural land, landscape development, and economic activities.
3)Estuaries, as adaptive interfaces, not only adapt to saltwater intrusion but also store freshwater through ecosystem functions.
Based on this understanding, I propose eight water flow components and corresponding principles for three land parcels, collectively forming a regional landscape framework dedicated to the vision of resilient freshwater conservation and recharge in the compact Pearl River Delta urban area.

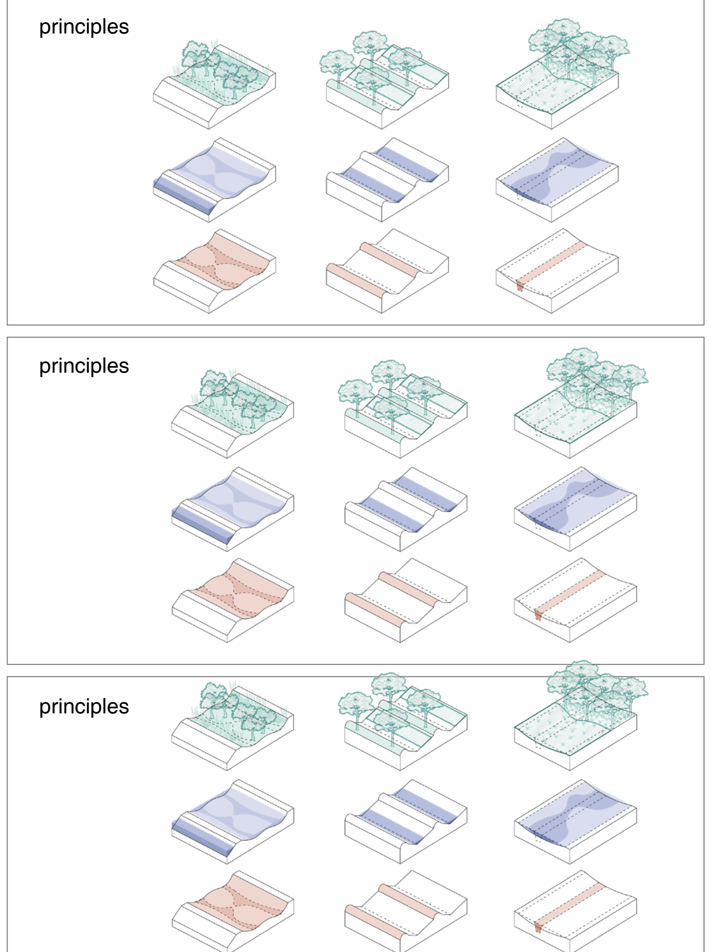


Resilient Design Framework for Freshwater Conservation and Recharge

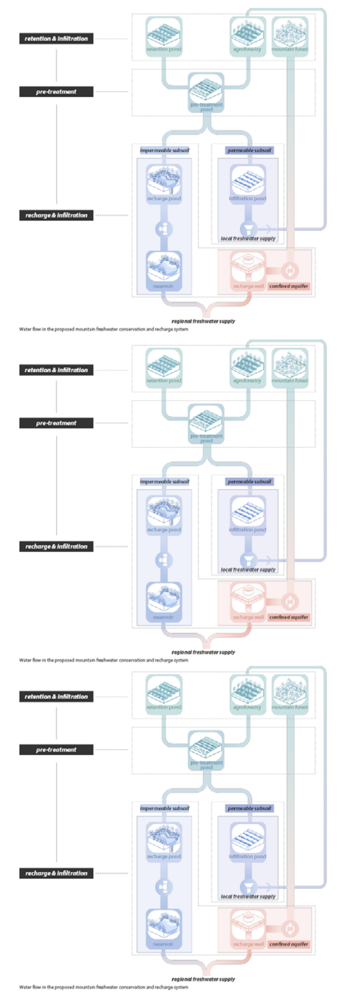
The different landscape types in the Pearl River Delta are complex. Therefore, there are three selected different sites and their respective scales to test and apply the principles under specific conditions, allowing for adjustments based on local circumstances. The specific approach involves analyzing the current conditions of the sites. In this process, historical knowledge and case studies are combined with cutting-edge water storage strategies to incorporate the achievements of historical wisdom in the Pearl River Delta and address challenges such as mountain ecological restoration and succession, floodplain flood control and water storage, and the restoration of mangrove habitats and dune water storage in estuaries.



landscape-based strategies



landscape-based principles

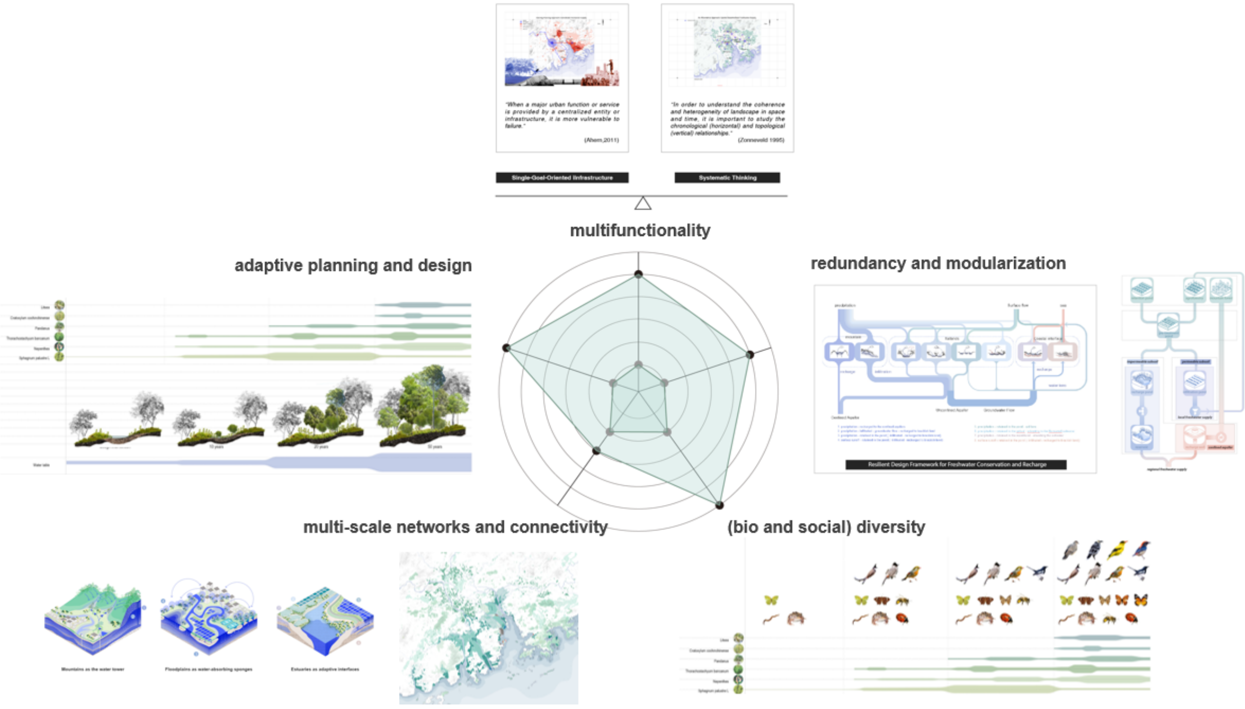


6 REFELCTION

6.1 Reflection for the Research Questions

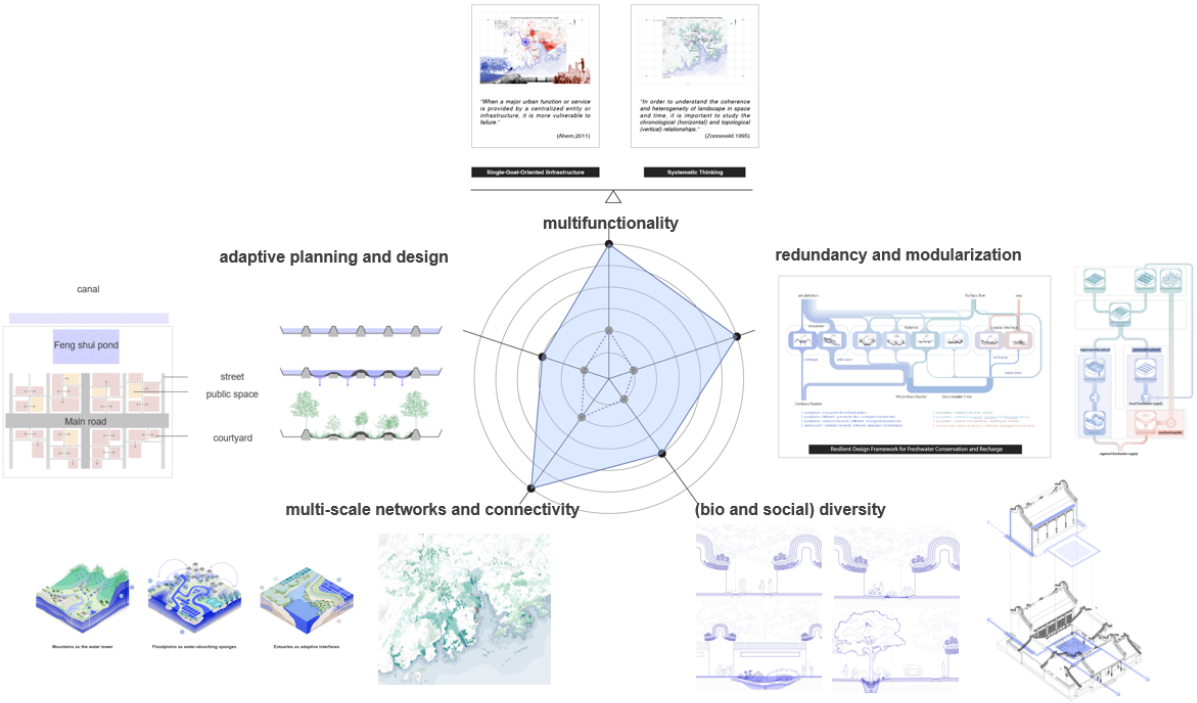
Lessons Learned

SQ4: What lessons could be learned in this project to foster a resilient landscape system on different scales?



Lessons Learned

SQ4: What lessons could be learned in this project to foster a resilient landscape system on different scales?



6 REFELCTION

6.1 Reflection for the Research Questions

Lessons Learned

SQ4: What lessons could be learned in this project to foster a resilient landscape system on different scales?

The project presents a resilient framework that incorporates Chinese traditional experiences and landscape characteristics, making valuable contributions to the development of resilient urban delta projects in China.
On a macro scale, there are two key points to achieve the concept of resilience:

1. The project presents the integration of the historical experiences of the PRD, emphasizing the importance of learning from history. Through research on the evolution of the water management system in the Pearl River Delta, the project shows the transformation process from a landscape dominantly shaped by nature to one heavily influenced by human activities. This exploration revealed various landscape types that foster sustainable coexistence between humans and nature, such as the dike pond system, Chinese contour-line land forming, agroforestry, and gei wei brackish water ponds. These landscape experiences fit in the water system management under different environmental conditions, guiding the development of a resilient framework for addressing freshwater scarcity in the future.

2. The second aspect involves analyzing, applying, and testing the resilient landscape framework in an interdisciplinary way. Learning from civil engineering and geoscience, the perspective to consider the hydrological cycle is expanded during the analysis stage by facilitating the exploration of elements related to freshwater storage systems. In the application phase, by case studies from managed aquifer recharge, the relevant techniques are incorporated into the landscape-based approaches. Finally, in the evaluation stage, the experiences from civil engineering conduct a preliminary quantification of the design outcome.

On the small scale, there are two key points to achieve the concept of resilience:

1. Creating conditions for the natural ecological succession:
I approach landscape design as a dynamic process, where design interventions are integrated with nature. Taking mountain design as an example, as a landscape architect, I extensively studied the characteristics of plant communities during various stages of peat soil restoration, as well as the corresponding water and topographical conditions. These studies guided me in proposing the initial stage of design interventions. Subsequently, considering the site's climatic conditions, the resulting flora from the initial intervention forms a successional community capable of adapting to natural conditions.

2. Incorporating spatial qualities for both nature and people:
The resilience of the system should consider human activities and spatial experiences from social and cultural perspectives. In my small-scale designs, I emphasize the role of resilience in facilitating landscape systems as intersections, rather than treating them as separate entities. For example, in the process of ecological succession, the varying topography and soil conditions formed during different periods can create diverse spatial experiences at eye level. Additionally, the plant seasons associated with these conditions differ, enriching the scenery and enhancing opportunities for recreational and viewing experiences. The value of these diverse landscapes also promotes economic benefits in tourism and related industries.

6 REFELCTION

6.2 Reflection on Aspects

What is the relation between your graduation project topic, your master track (LA), and your master programme (MSc AUBS)?

Firstly, the Resilient Coastal Landscape Lab is guided by the concept of "Flowscape" in shaping my thinking on resilient landscape design. It reveals that landscapes are not static and fixed images but rather allows systems to adapt to new circumstances and accommodate changes. Therefore, the project is based on the Landscape as System as a guiding theory for research and design, responding to the overarching concept of "Flowscape".

To effectively implement the "Flowscape" concept, in the Resilient Landscape Lab, the project focuses on the explore the potential of the landscape and using the landscape-based principles to diverse landscape types in the Pearl River Delta, aiming to establish a regional framework for resilient freshwater storage and release landscapes.

For the master programme of AUBS (Architecture, Urbanism, and Building Sciences), this project provides a resilient freshwater conservation and recharge framework with Chinese traditional experiences and landscape characteristics, which contribute to the construction of Chinese resilient urban delta projects. Due to historical development and policy factors, there are still numerous high-density urban clusters, like Shanghai in the Yangtze River Delta, and Tianjin in the Bohai River Delta, situated on estuaries and deltas along the southeastern coast of China. All of these urban deltas face water scarcity crises due to climate change and accelerated urbanization. In this context, this project offers a resilient framework for freshwater resources that incorporates historical landscape experiences and the characteristic features of Chinese landscapes, providing valuable references for future Chinese cities.

Furthermore, by incorporating the concept of resilience, the framework promotes interdisciplinary knowledge integration. For instance, during the problem identification and analysis phase, an understanding of the hydrogeological analysis logic is gained, which expanded the analytical levels of landscapes, and ultimately combined them within a water flow system framework. This framework also guided the design practice during the design exploration phase to take experiments and strengthen the arguments of the framework.

How did your research influence your design/ recommendations and how did the design/ recommendations influence your research?

Research and design are two synergistic approaches in this project.

The research methodology enabled me to identify the problems related to freshwater scarcity in the Pearl River Delta by literature review and site research. This process helped determine the core challenges I needed to address: replenishing

Research and design are two synergistic approaches in this project.

The research methodology enabled me to identify the problems related to freshwater scarcity in the Pearl River Delta by literature review and site research. This process helped determine the core challenges I needed to address: replenishing groundwater, enhancing urban resilience in water storage and flood control, and improving the adaptability to saltwater intrusion in estuaries. What is more, based on theoretical studies and literature reviews, I clarified the Landscape as System theory as a guiding principle and established a resilient landscape framework in response to the core challenges. This process allowed me to decompose the analysis into multiple layers, including hydrology, geology, soil, and ecology.

During the design exploration part, case studies and learned from historical examples help establish principles for realizing the vision within the elastic landscape framework. Meanwhile, I used design to refine the project's research scope and conducted design testing in two typical landscape types in the Pearl River Delta.

In general, research and design were conducted, with interactive feedback shaping and continuously adjusting my design proposals. Therefore, I will reintegrate the design outcomes into the theoretical framework to compare and analyze the relationship between theory and results, as well as among different sites. Throughout this process, research and design will help me reflect on the strengths and limitations of various design strategies, enriching my theoretical framework.

Limitations

The engagement of stakeholders should be enhanced. This includes mountain and forest management authorities, farmers from the agricultural and fishing industries, as well as relevant users in small-scale site design. Therefore, the current design outcomes represent an optimized vision for addressing freshwater storage in the Pearl River Delta through the resilient landscape framework. However, the specific implementation still requires the involvement of individuals from different fields and social identities, and this process needs time for evaluation and implementation.

6.2 Reflection on Future Outlook

The project provides an alternative solution to address the water scarcity in the Pearl River Delta. In contrast to a 113km pipeline project, it focuses on exploring a landscape-based approach within a resilient framework. The project proposes locally oriented guidelines for hydrological cycle systems, aiming to stimulate the long-term sustainable response of the Pearl River Delta's landscape system to future freshwater-related crises.

The resilient landscape framework holds great promise as it implies multiple functions, multi-layer participation, and room to adapt fail. The operation of the landscape system within this design framework follows the specific development speed of elements in different subsystems. While benefiting a broader scope, it also means a wider range of considerations and evaluations. Therefore, within this project, it is crucial to determine which aspects are qualitative, which are quantifiable, and which have the potential to be quantified and put into practice in collaboration with other disciplines.

In this project, water is the core element, therefore, there are analyses of the connections between water and other elements at different layers like biotic (relief, water, soil), biotic (flora and fauna), and anthropogenic (human activity) layers(Nijhuis,2020). The culmination of this process is a resilient water flow system capable of adapting to future water scarcity. To validate its feasibility in design, I have also considered interdisciplinary collaboration and quantification methods to strengthen the water management strategies within the resilient landscape framework. For example, in the project, I integrated concepts of managed aquifer recharge through interdisciplinary engagement with civil engineering. Additionally, in mountainous areas, I quantified the extent of precipitation storage and erosion prevention through runoff coefficients to evaluate the benefits.

In summary, these efforts involve the analysis and application of the operational logic of the water system. The project primarily focuses on qualitative work, preliminary quantitative evaluations, and reflections on the water system. However, due to the richness of elements encompassed within the resilient landscape framework, a comprehensive assessment of its actual effectiveness will require future practical implementation and the collaborative participation of multiple fields and disciplines.

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