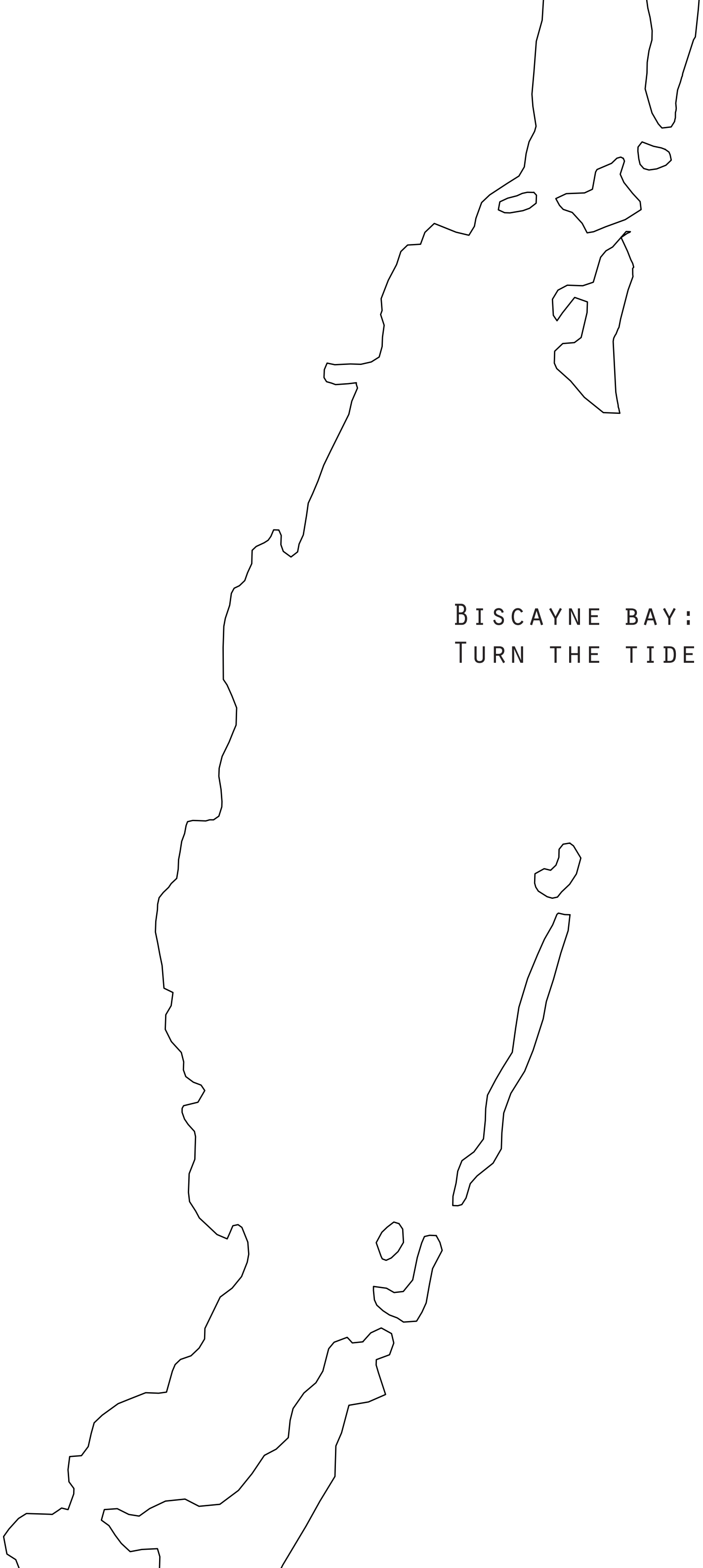

Biscayne bay:
Turn the tide

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Biscayne bay:
Turn the tide

An integrated landscape approach for coastal restoration in Biscayne Bay through spatial and ecological interventions

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Delft University of Technology - Faculty of the Built Environment - Landscape Architecture

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Abstract

The coastline of South Florida has undergone a drastic change in the last century and this has had a major impact on flood safety and natural resources of its inhabitants. Natural coastlines supporting mangrove and wetland have been transformed into seawalls with buildings. It is estimated that in the last 100 years, 40 percent of the mangrove coast and significant parts of wetland, pine forest and sea grass have disappeared. ("Florida's Mangroves | Florida Department of Environmental Protection", 2019).

Mangrove forests stand out to be a future-oriented way of natural coastal defense for South Florida. Although they mainly appear in calm tropical waters, they can withstand and recover from tropical storms. Their unique growth habit with a characteristic root system and branching forms a robust forest, that functions as a natural coastal defense. Also, marine life is dependent on the nursery grounds provided by the root system of the trees and maintaining a healthy fish stock (Sheppard, 2018).

We can learn from the past that this forest provides the land with a natural levee and protect against flooding. Also, this natural system has potential to adapt to the consequences of climate change that highly urbanized areas like Miami are already facing and which will increase rapidly in the future.

This research identifies and explores design strategies and principles for the mangrove landscape of Biscayne Bay in order to reduce the flood risk of Miami Metropolitan Area, as well as provides aesthetic, ecological and functional qualities that contributes to the identity and resilience of this coastal region. This is done through design-related-research, that divides this research in two domains. Design research, which consist of a system analysis and examination of best practices and research by design, which involves design experiments.

The result is a layered landscape strategy that contributes to the harmony of the natural coastal landscape of Biscayne Bay and thereby restores its functions. The systematic strategy is converted into a spatial design, applying principles gathered from best practices. This landscape architectural design adds an extra dimension to the mangrove landscape that will invite the residents of the Miami Metropolitan Area to experience through exposure to changes and value its aesthetic and ecological qualities and protective functions.

KEYWORDS: mangrove landscape, South Florida, Biscayne Bay, landscape architecture, spatial design, flood protection, ecological restoration, social reconnection, research by design, design with natural processes, user experience.

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Turn the tide:

"To completely change the direction of something"

Cambridge dictionary of American idioms (2003)

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Index

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I

Introduction to the mangrove landscape

I Introduction to the mangrove landscape

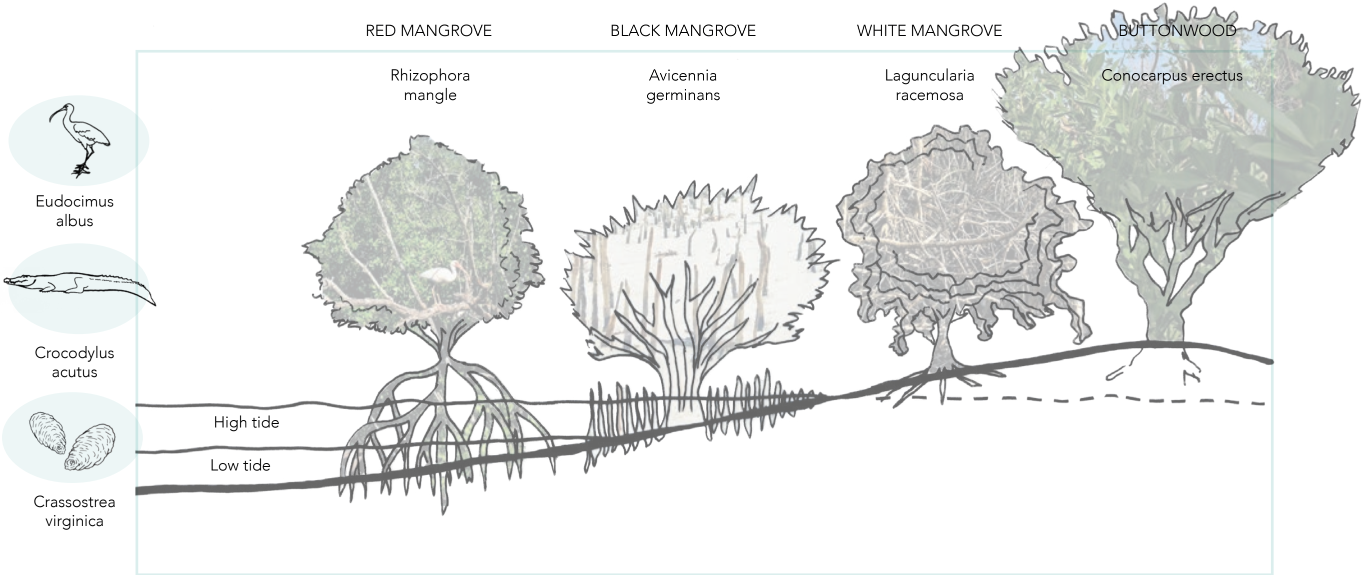
1 · Mangroves as a design assignment

In the moderate climate of the low-lying Netherlands, the coastline is surrounded by a layer of sand dunes stretching from the southwest to the upper north. There they transform into a flat and vast salt marsh, which in the past continued all the way to Germany and Denmark. Natural processes, such as sedimentation, erosion and tidal differences, created a dynamic landscape that protects the land from the North Sea. One natural landscape type, wrapped around the coastline to keep us safe for everyday tidal influences, but mainly for that one storm that will come in 10.000 years.

However, there are places on earth where this chance is significantly bigger. In the tropics, around the equator, tropical storms occur every year. One year they may be remote or weak, but the other year they can be devastating. Because the influence of tides is much smaller around the equator than in the Netherlands, there is little sediment deposition and therefore no dune formation or extensive salt marshes. The coastlines are characterized by a different intertidal area: the mangroves. This coastal forest allows a few decimeters of tidal differences to come in, but forms a barrier against spring tide and reduces tropical storms before they come ashore. Together with interdependent ecosystems, it forms the most important form of coastal defense of low-lying areas in this climate.

In addition to defending tropical coastlines, the mangrove forest has a number of other important roles that are indispensable for ourselves and our planet. Like any other forest, it functions as CO_2 storage, but with a much higher capacity. It is also the breeding ground for the residents of the neighboring coastal seas and coral reefs and offers a habitat for water-filtering shellfish such as oysters, which purify polluted terrestrial streams before they enter the sea (Sheppard, 2018). Because of these favorable characteristics, it is an attractive area for people to settle in and recreate.

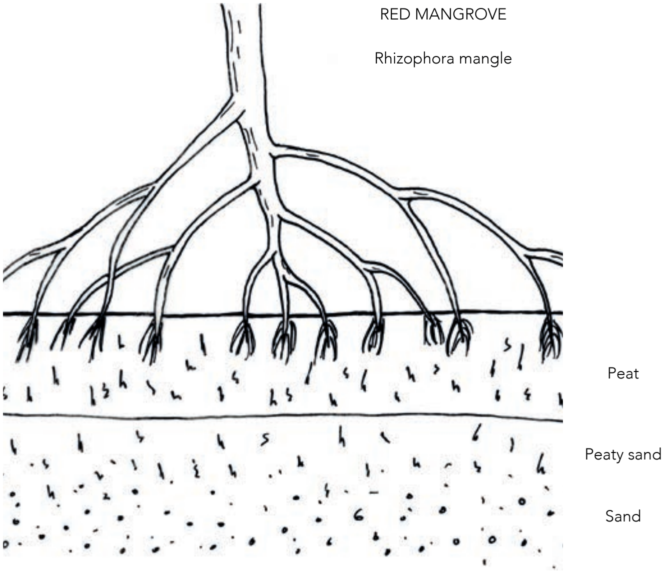
Like any other coastal area, it is a dynamic area due to its subjection to the influence of the sea. Every day it goes through a tidal transformation twice, every year the seasons change its physical appearance and over the years a different spatial language of creeks, tree formations and relation to its surroundings emerges. The mangroves have the great ability to adapt to all these natural changes and at the same time resist to cultural influences as well. Such as growing along with rising sea levels due to the rapid change in the climate that currently is taking place. This quality has significant potential for a landscape architectural design that works with natural processes to protect coastal areas now and making it climate-proof for the future, so people can live safely in tropical coastal zones and keep enjoying this beautiful landscape.

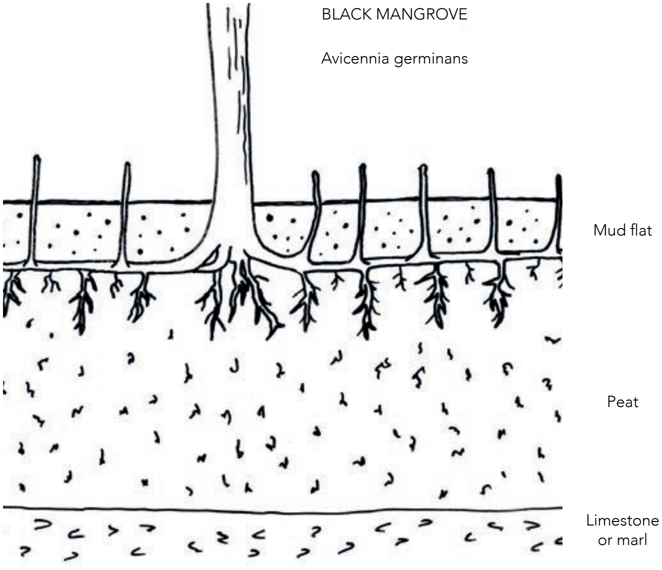


MANGROVE FOREST SECTION

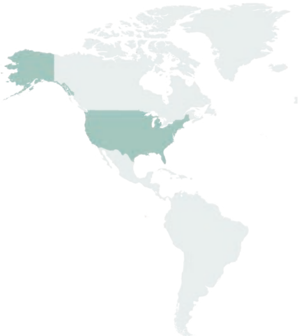
THE MANGROVE FAMILY
Mangroves grow between 29 degrees north and south latitude. These tropical forest grow in the intertidal zone of coastal areas and consist of three species: the red, black and white mangrove. They all have a unique way of dealing with salt water and therefore their own place is the coastal section. The image above shows the mangrove species in a typical tropical coastal section, with little tidal differences.

SPECIES
The Red Mangrove is found on the aquatic edge of the forest and is clearly recognizable by its impressive root system with a reddish color. The tree needs this firm anchoring to cope with currents and tropical currents and to prevent erosion through peat formation between the roots. The Black Mangrove is characterized by the “snorkels” that protrude above the mud from the underground root system. In contrast to the Red Mangrove, the roots of the tree become dry during low tide and as a result the peat formation takes place deeper in the soil. This spongy peat layer ensures that most of the salty groundwater from the sea is blocked and does not intrude in the fresh terrestrial groundwater. The White Mangrove is higher in the coastal section, where only brackish groundwater comes into contact with the tree via the roots. The peat layer blocks the last salt particles in the groundwater. The neighbouring species, Buttonwood, is not a mangrove, but is often seen as part of the mangrove coastline. This is not a salt-tolerant tree and thus marks the salt-intrusion line along the coast. (Woodroffe et al., 2016)

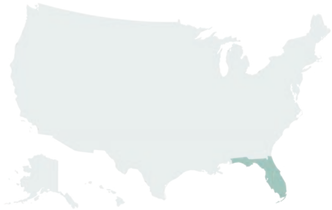




Drawings based on (Ezcurra et al., 2016)



United States of America



Florida

Biscayne Bay

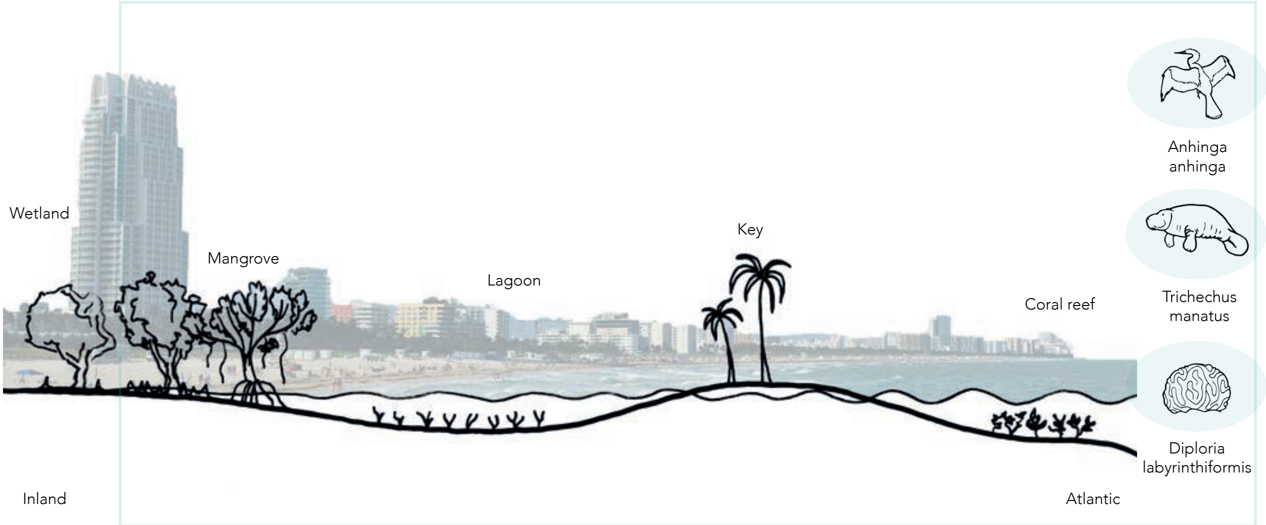
Impression of the natural landscape

Impression of the cultural landscape

STUDY AREA

The study area of this research is the Atlantic coastline of South Florida. The metropolitan area of Miami is one of the most densely populated areas on the southern east coast and also the only subtropical region of the United States. The area changed dramatically in the past century, in which the natural landscape had to make room for cities, industry and agriculture.

Nowadays, the city contrasts sharply with its natural surroundings, like the Everglades wetlands on the west side and the lagoon of Biscayne Bay on the east side. Once, this bay surrounded the city of Miami and its southern extension with a vast mangrove forest and wetlands in the south that were connected to the Everglades water system.



COASTLINE SECTION OF BISCAYNE BAY

Biscayne Bay is a shallow lagoon that covers 1110 km^2 (428 square miles) and extends from Miami downtown in the north to the power plant of Turkey Point in the south. On land, the coastline is a gradient from highly urban, to residential and eventually natural area. Offshore, the bay is semi enclosed, surrounded by characterizing islands, called keys. These natural barriers reduce the current, causing sedimentation and the deposit of nutrients. Therefore the bay accommodates relatively many different ecosystems and this diverse character attracts many visitors and permanent residents to settle along the water. On a larger scale, the bay plays an important role in the water management of South Florida and in the migration routes of various animal species.

Worldwide, the amount of mangrove forests has declined drastically over the last 100 years. One of the reasons is the decrease of habitat due to logging for the expansion of urban, agricultural and industrial areas. Also, the growing conditions of the trees are jeopardized and the consequences of climate change, such as sea level rise and temperature changes, seriously affect the mangroves and interdependent ecosystems, that are connected to the mangroves and thus contribute to natural coastal defense. Without these natural coastal zones, vast (sub)tropical coastal areas and its inhabitants are unprotected to flooding and erosion.

Florida greatly benefits from this natural form of coastal defense, which protects the state from the effects of the annual occurring tropical storms (Radabaugh et al, 2017). Up till 100 years ago this entire southern tip was surrounded by a vast layer of mangroves, which formed a natural levee through sedimentation, supplied by the adjacent ecosystems, together forming the mangrove landscape. When the region begun to develop in the beginning of the 20th century, this landscape and other natural areas started to transform into urban areas, agriculture and industry and people lost the connection with its origin.

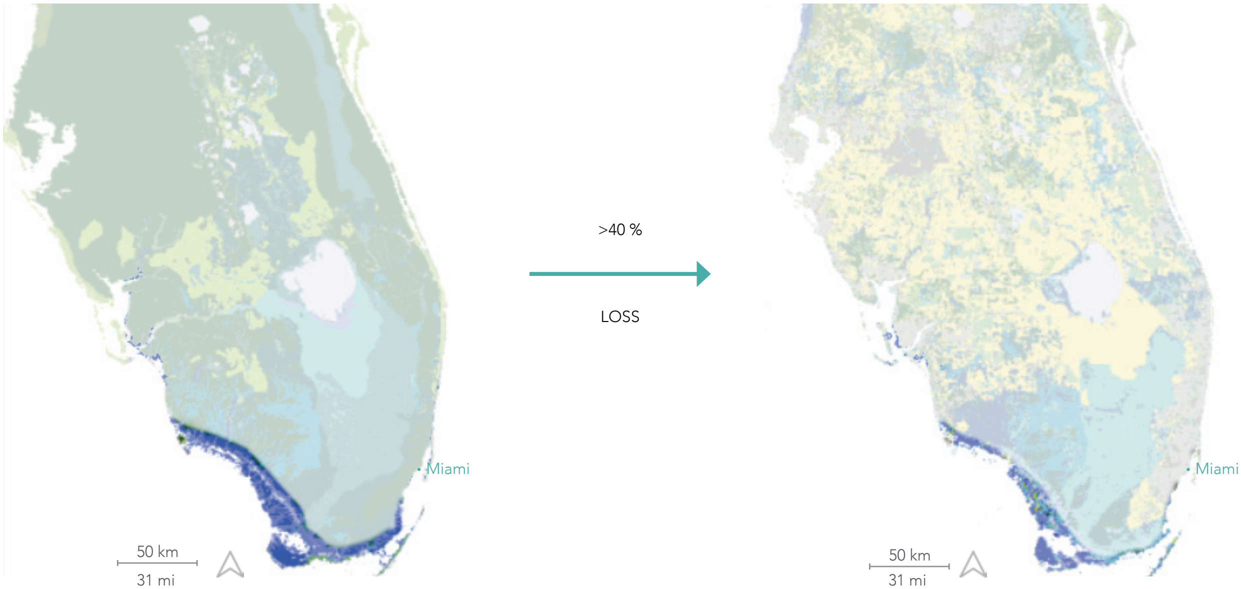
Nowadays, exactly on the critical point where the population density is highest and sea level is rising, a substantial part of the mangroves themselves have been replaced for a seawall. An artificial form of coastal defense that does not have the ability to adapt to the consequences of climate change. The 5.5 million inhabitant metropolitan region of Miami is already facing flooding and other water related problems and it is likely to increase in the near future.

MANGROVE LOSS

The coastline of South Florida has undergone a drastic change in the last century and that has had a major impact on the distribution of the mangrove. It is estimated that in 100 years 40 percent of the mangrove coast has disappeared, but also significant parts of wetland, pine forest and sea grass. The remaining 2000 km^2 (500.000 acre) has been protected by the Mangrove Trimming & Preservation Act since 1996 ("Florida's Mangroves | Florida Department of Environmental Protection", 2019). Within the National Park Service, the mangroves and important adjacent ecosystems, which are interdependent, are protected and maintained, but outside the park borders, they are often depleted.

According to the NPS, the disappearance of the mangrove in Biscayne Bay is due to threats such as: climate change, urban development and altered hydrology (Radabaugh et al., 2017). These threats all originate from the lack of awareness on the essential function of the mangrove forest along the shore of Biscayne Bay and all throughout South Florida.

MANGROVE DISTRIBUTION SOUTH FLORIDA



Mangrove distribution 1900

Mangrove distribution 1992

Maps and data obtained via NASA Retrieved on October 24 2018 from www.earthobservatory.nasa.gov

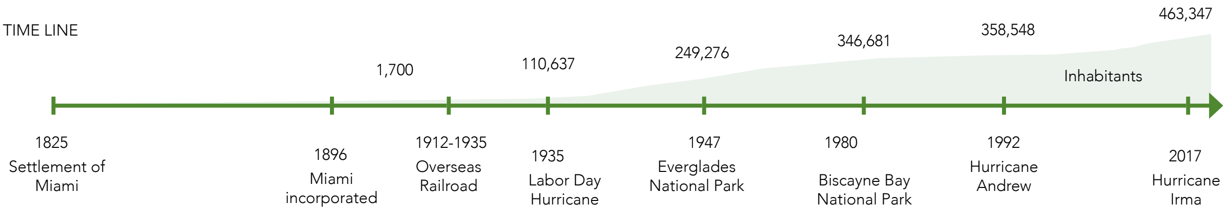
1800

1900

1960

2018

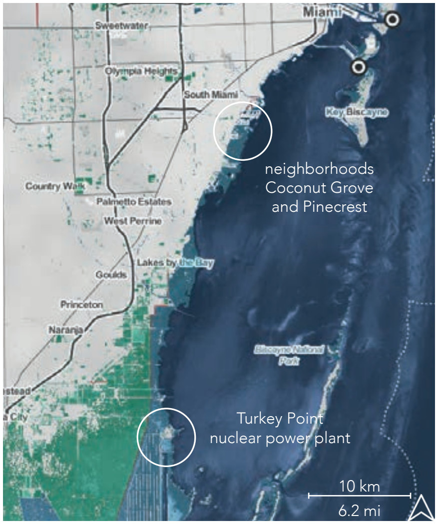
TIME LINE



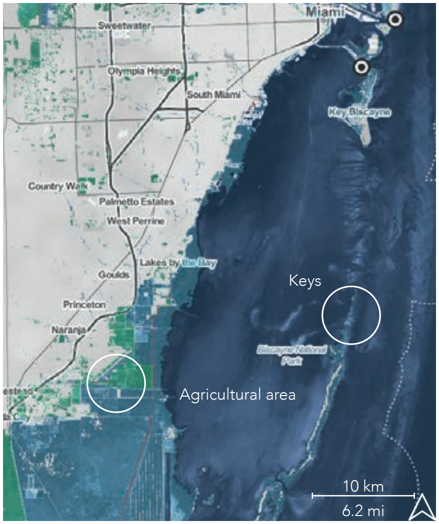
Data from World Population Review. Retrieved on November 28 2018 from www.worldpopulationreview.com

URBANIZATION

One of the reasons for the decline in mangrove in South Florida is urbanization and cultivation of the land. Since the beginning of the twentieth century, many natural areas had to make way for buildings, agriculture and industry. An artificial water system was essential for this development, but it has brought significant changes in the natural water system. Nowadays, this altered system still causes many problems in both urban and natural environment (Godfrey & Catton, 2012). The time line above shows the urban development around Biscayne Bay. The city of Miami has now more than 460.000 inhabitants, but the entire metropolitan region has 5.56 million.



1. Sea level rise of 0,5 meter / 1,6 ft



2. Sea level rise of 1 meter / 3,3 ft

3. Sea level rise of 3 meter / 9 ft

Source: Climate Central. Retrieved on December 12 2018 from http://sealevel.climatecentral.org

CLIMATE CHANGE

Since the incorporation of Miami in the late eighteen hundreds, sea level have risen 24 centimetres (9 inch). Since the late nineteen hundreds this rate is increasing exponentially due to global warming (Sweet et al., 2017). Sea level rise and other effects of climate change are a substantial threat to the coastline of South Florida. Studies have shown that mangroves can adapt sea level rise by peat formation in the root system (Woodroffe et al., 2016) But, when not given a retreat zone, they could drown. Also rising temperatures and increasing salinity levels are already a problem for the mangroves and interdependent ecosystems that the mangroves depend on. Sea level rise does not only cause flooding but also salt intrusion, which is a severe threat to agriculture and drinking water supply. Since mangroves can play an important role in coastal flood prevention, it is important to create retreat zones in higher areas that are slightly less exposed to flooding.

The images above show three sea level scenarios that illustrate the effects for important areas, such as residential and agricultural areas in the metropolitan area of Miami, the energy plant of Turkey Point and the keys. The image on the left shows an increase of 0,5 meter (1,6 ft) that is the inevitable prognosis for 2070 according to the US Army Corps of Engineers (2016). Vast areas along the shore of Biscayne bay will experience permanent flooding, including Turkey Point nuclear power plant, the most important electricity supply for the metropolitan area of Miami. The second image shows the average expected global sea level of 1 meter (3,3 ft) in 2100 (Keys et al., 2016). Wetlands in the south, agricultural area and the Keys will have major flooding problems. The third image is an extreme upper projection of 3 meters in 2100, whereby most of the metropolitan area is inundated and 75% of the inhabitants have to move (Sweet et al., 2017).

CONCLUSIONS

The disappearance of the mangrove landscape makes the Miami Metropolitan Area vulnerable to tropical storms and the consequences of climate change (Radabaugh et al, 2017). It can be concluded that one of the main reasons is the urbanization of the area, which is still ongoing. The replacement of mangroves by sea walls and buildings, and changing rivers and creeks into canals, is a direct effect of a absence of knowledge about the importance of the natural landscape in protecting this vulnerable coastal area. Also, economic interests were, and still are, placed above the conservation of the natural landscape outside of the boundaries of the Nation Park System. When the mangrove landscape began to disappear in the last century, their importance was underestimated. Nowadays, the essential value of this natural coastal landscape is known and is starting to be better understood by its users. A reason that has risen awareness is climate change, that poses a threat to the inhabitants of the metropolitan region of Miami and its natural resources. Now that it is clear that mangroves and adjacent ecosystems can contribute to mitigating the effects of tropical storms and flooding due to sea level rise, there is more support for the restoration of natural coastlines. However, despite the fact that the mangrove landscape can reduce the risk of flooding, it is itself threatened by climate change. The landscape is being caught between a rising sea and a densely built city, which cannot offer retreat zones.

Therefore, the mangrove problematique is a complex issue. On the one hand, there is a sea level rise that threatens the city, but also the mangrove landscape itself. On the other hand, the mangrove landscape can offer flood protection if it gets enough space in the ongoing urbanization. The design assignment is to find a strategy and principles to restore and develop the mangrove landscape in an urban environment that is under spatial pressure and is threatened by climate change.

While the sea level is rising, it is necessary for South Florida to turn the tide and start to make use of the existing natural systems, like mangrove forests and wetlands, that always have been protecting against flooding. In order to restore or create a natural coastline that can adapt to both a rising sea level and the pressure of ongoing urban expansion, it is required to understand the origin of the natural landscape and work with the characteristics of the existing landscape.

Biscayne Bay is a key location for the Miami Metropolitan Area when it comes to flood risk reduction. The 60 km (37 mile) low-lying coastline and its hinterland is exposed to current and future flooding, but its spacious character with some existing mangrove fragments has potential for ecological restoration in order to reduce flood risk and reconnect the users with the natural landscape.

It is essential to understand the use of the current landscape and how the residents and visitors of the area got disconnected to the natural landscape. In order to create support and to raise their awareness for the ecological restoration of the natural coastline it is required to integrate the experience of the user in a design.

GOAL
Identify and explore design strategies for the development of the mangrove landscape of Biscayne Bay, in order to reduce flood risk caused by tropical storms and sea level rise, as well as provide aesthetic, ecological and functional qualities that contribute to the identity and resilience of this coastal region.

RESEARCH QUESTIONS

Understanding: How does the mangrove landscape function in South Florida and how did it change in Biscayne Bay?

Tools: What spatial and ecological design principles can provide conditions to restore and improve the mangrove landscape in order to let it function as coastal defense and let users reconnect with the natural landscape.

Application: What are the spatial possibilities to create the needed conditions and reconnection in Biscayne Bay and how can they be made resistant to threats such as sea level rise and tropical storms?

Reflection: What lessons are learned from using the mangrove landscape in a landscape architectural design for Biscayne Bay, in order to reduce flood risk in the Miami Metropolitan Area and reconnecting inhabitants and visitors to its origin and function.

ACADEMIC
This research contributes to the complex issue of how to deal with coastal areas that are threatened by rising sea levels. As a landscape architect it is possible to connect technical, ecological and social objectives through a spatial landscape architectural design. This gives new perspectives on mangrove restoration and flood safety by connecting it to spatial quality and user experience. In South Florida there is a demand for a solution for flood related problems that can be found in the combination of these three types of issues. The coastline of Biscayne Bay is the key location because of its position in relation to the Metropolitan Area of Miami and connections with other ecosystems the community relies on.

SOCIAL
In South Florida, more than 2 million people live less than 1 meter (3 feet) above sea level. This is within the reach of inevitable sea level rise that will occur before the end of this century. This is not only a future perspective, but also a current problem. Extreme high water levels that occur during spring tide, king tide and tropical storms cause flooding, coastal erosion and salt intrusion that pose a threat to agriculture and drinking water supplies. In addition, it is a threat to local ecosystems and natural sites that are beneficial to the region, such as fresh water retention and purification, CO2 storage and fish stock.

Restoring the mangrove landscape along the coastline of the metropolitan area of Miami in Biscayne Bay will contribute to the current and future flood safety of the inhabitants, help to secure drinking water and agriculture and support vital ecosystems that are important for the community. In addition, restoring this natural landscape will contribute to the spatial quality of the area and that offers potential for the expansion of green economy services.

I Introduction to the mangrove landscape

This chapter introduces the mangrove landscape and explains its benefits and threatened status in a problem statement. It ends with the research objective, questions and relevance.

II Approach

This chapter contains the research approach, which is a theoretical background and a method that is applied throughout the research.

III Understanding the mangrove landscape

This chapter investigates the layers, dynamics and use of the mangrove landscape in South Florida and Biscayne Bay, which merge in the synthesis. The chapter ends with conclusions, by defining challenges and potentials.

IV Mangrove Design principles

This chapter defines the design principles that are needed to meet the research objective and goal. Best practices are used to explain the principles and to make a connection with the spatial design concept by the means of a strategy.

V New coastline for Biscayne Bay

This chapter shows the result of the research by means of a design. This is a strategic plan on a regional scale of Biscayne Bay and three focus area elaborations with a detailed design.

VI Discussion and conclusion

This chapter contains the conclusion of the research. This is an evaluation of the results, implications and recommendations.

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II

Approach

II Approach

1 · Theoretical framework

INTEGRATED APPROACH
Landscape architecture is about the landscape itself and how we perceive it. Doing research in this field, an integrated approach is necessary, because it includes more than physical elements. Besides natural processes, the landscape is rated by society in several ways, like social, cultural and economical values. Also, individual and subjective ways to value to landscape, such a memory, experience and attractiveness should be taken in account (Van den Brink et al, 2016).

According to Van den Brink et al (20i6), an integrated landscape architecture research consists out of three aspects that have 'mutual dependencies'. The first aspect is 'image', where the perception of the landscape is concerned. The second is 'structure', spatial features of the landscape. And third is 'action' that deals with the processes that take place in a landscape, including human interventions. The 'mutual dependencies' of this research can be found in the research objective and research questions.

Mangrove restoration through interventions with natural processes (action) and raising the awareness for the protective function of the forest amongst people (image) have 'mutual dependencies'. Designing is the 'structure' aspect and an answer to the main research question.

SCHEME

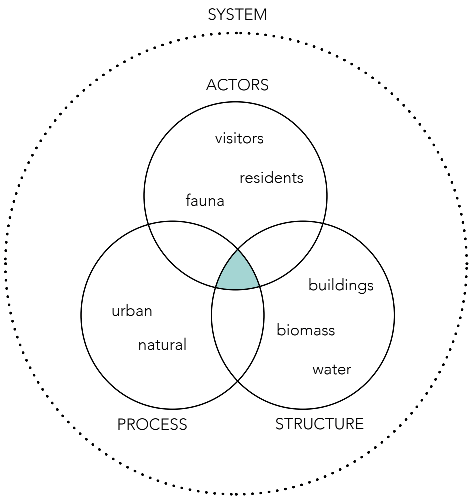
Domain	Method	Description
DESIGN RESEARCH	System analysis	A research on South Florida, according to the method considering the landscape as a system, it is divided in three parts: structures, processes and actors. A division is made between the historical situation and current. At different scales, both the terrestrial and aquatic part of the bay are being mapped and researched.
	Best practices	Best practices are used to explain and test the principles. Two types of comparable examples are used. First, 'research through design', to explore the possibilities of mangrove restoration methods. Second, 'research on design' to compare the principles to landscape architectural restoration projects..
RESEARCH BY DESIGN	Design experiments	Explore and experiment with the design principles derived from the 'design research' domain.
	Modelling and testing	Examine concepts through modeling and testing and adjust for the design.

DESIGN-RELATED RESEARCH

The three elements of integrated research Van den Berg can be applied in design-related research. This method is characterized by two domains with their own mode or research. The first domain is 'design research' and consists of analysis and orientating research. The second domain 'research-by-design' is experiment and research through design. (Nijhuis and Bobbink, 2012). Answering the understanding research question is done by examining the natural and urban processes in the study area. This is part of 'design research', like the answer to the tools research question, which can be found by doing case studies. To discover possibilities for restoring mangrove forests, a case study is done based on a 'research through design' method. To get design principles a case study is done based on the 'research on design' method. The answer to the application research question derives from the 'research-by-design' domain, through design experiments (experimental design study mode) and modeling and testing (design study mode). Design experiments derive from the challenges and opportunities synthesized from the analysis and the possibilities and principles found in the case studies. The experiments are followed up by modeling and tests, which will lead to the result: the design and the evaluation.

In order to apply an integrated approach, different methods are requisite for this research. On the one hand, the 'structure' and 'action' aspects can be measured by qualitative research methods, such as system analysis and case studies, to generate objective and generic data. On the other hand, the aspect 'image' requires a qualitative research method that provides specific and subjective information, because values like experience and awareness can only measured relatively. A mixed methods research combines qualitative and quantitative methods in order use and combine different types of data. (Johnson and Onwuegbuzie, 2004).

LANDSCAPE AS A SYSTEM



DESIGN RESEARCH

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III

Understanding the mangrove landscape

1·Landscape system of South Florida and Biscayne bay

Structures
Processes
Actors
Conclusions

2·Challenges and Potentials for Biscayne Bay

III Understanding the mangrove landscape

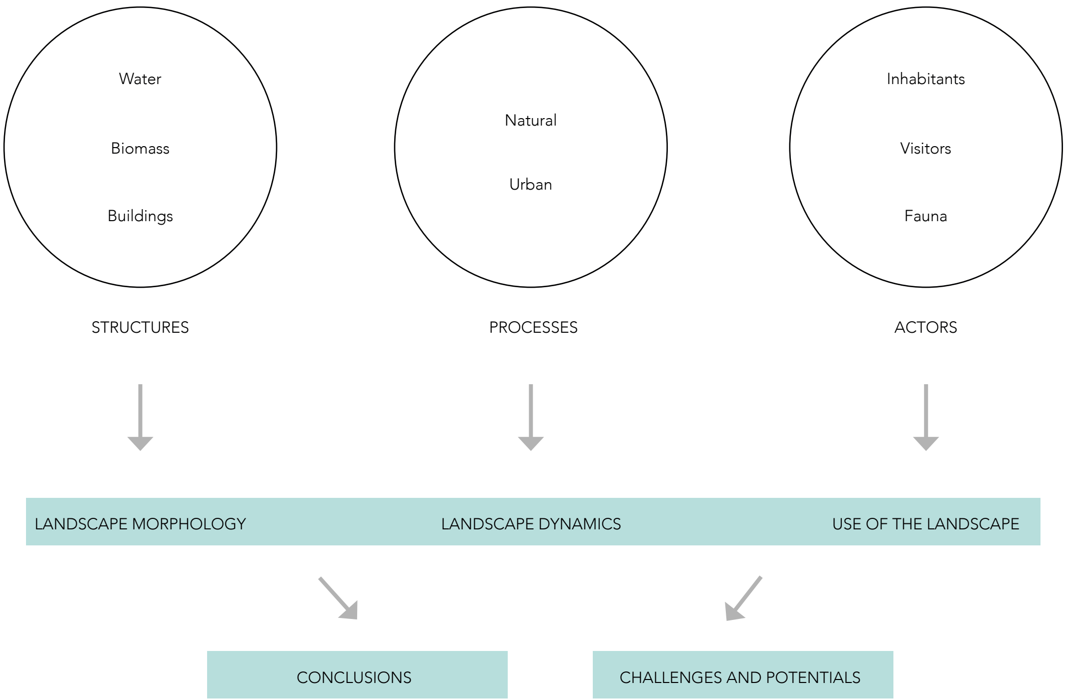
1 · Landscape system of South Florida and Biscayne Bay

In order to understand how Biscayne Bay functions, this chapter researches the current and historical situation, according to a system analysis. This is divided into three parts to reveal the elements of the landscape as a system method. The first part looks into **structures**, which are the physical elements of the landscape, though a morphological analysis.

The second part examines landscape dynamics which are the natural and urban **processes** that occur in the landscape. The third part explores the use of the landscape by the **actors**. From these three elements, the most important changes are identified in a synthesis and the corresponding challenges and potential are addressed.

This chapter addresses the first research question:

How does the mangrove landscape function in South Florida and how did it change in Biscayne Bay?

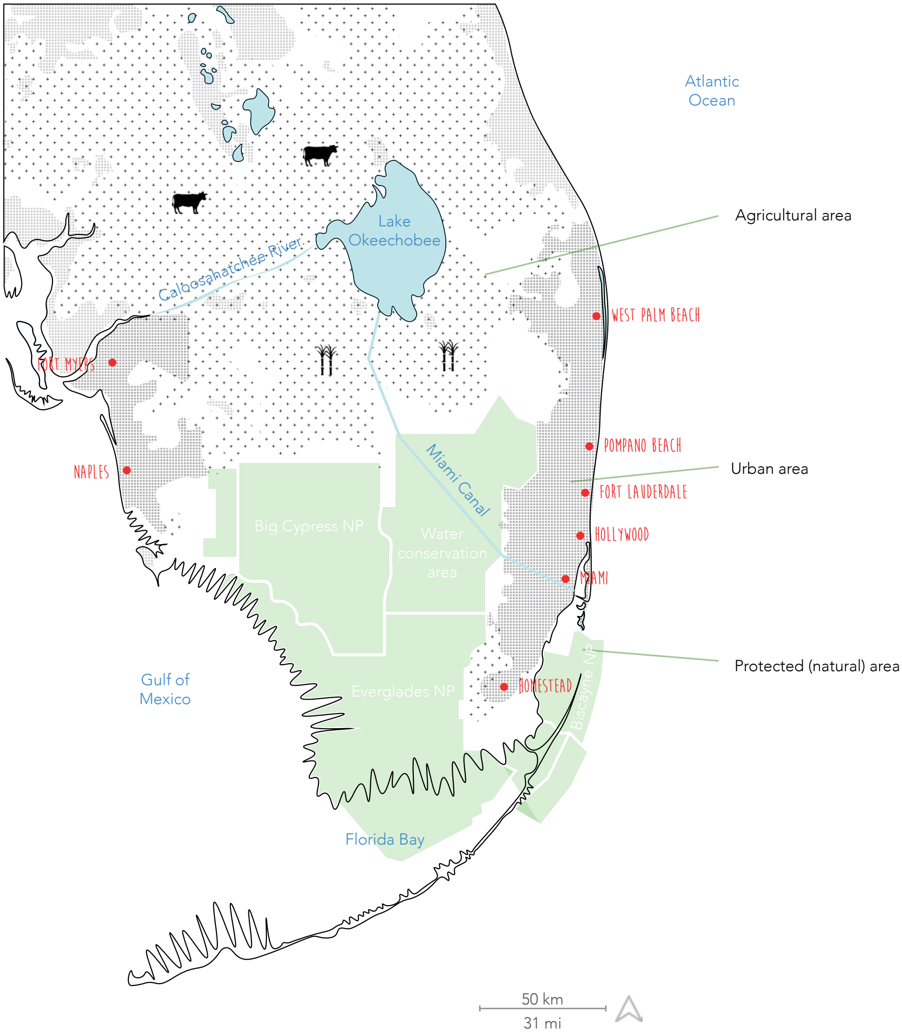


STRUCTURAL ELEMENTS

South Florida can be divided into four structural elements: urban area, agriculture, natural area and surface water. The urban areas with large cities, such as Fort Myers, Naples and Miami are mainly located along the Atlantic coast and the gulf of Mexico. The Miami Metropolitan Area is the largest and extends from West Palm Beach in the north to Homestead in the south. In the centre of the state, there are mainly natural areas and agricultural land. Most of the natural areas are protected and are under federal, state or county supervision. North of these areas, there is mainly agricultural land. South of Lake Okeechobee, sugar cane is grown and to the north is cattle breeding.

DIVISION

The structural elements of South Florida are divided. This originates from the cultivation of the country since people settled there. Urban development began along the coast at estuaries and the largest cities can still be found here. Miami along the Miami River which is now mainly canalized into the Miami Canal and Fort Myers along the Caloosahatchee River. Agriculture is mainly settles in the centre around Lake Okeechobee, which provides crop land and pastures with fresh water all year round. The natural areas are mostly found where is was hard to settle, such as in the constantly inundated Everglades. This "River of grass" originally stretches from lake Okeechobee all the way down south to the Florida Bay. The northern part of it was drained and cultivated into crop land in 1948, whereby more then a quarter of this swamp disappeared. Nowadays there is less than a third of this structure intact. (Godfrey & Catton, 2012)



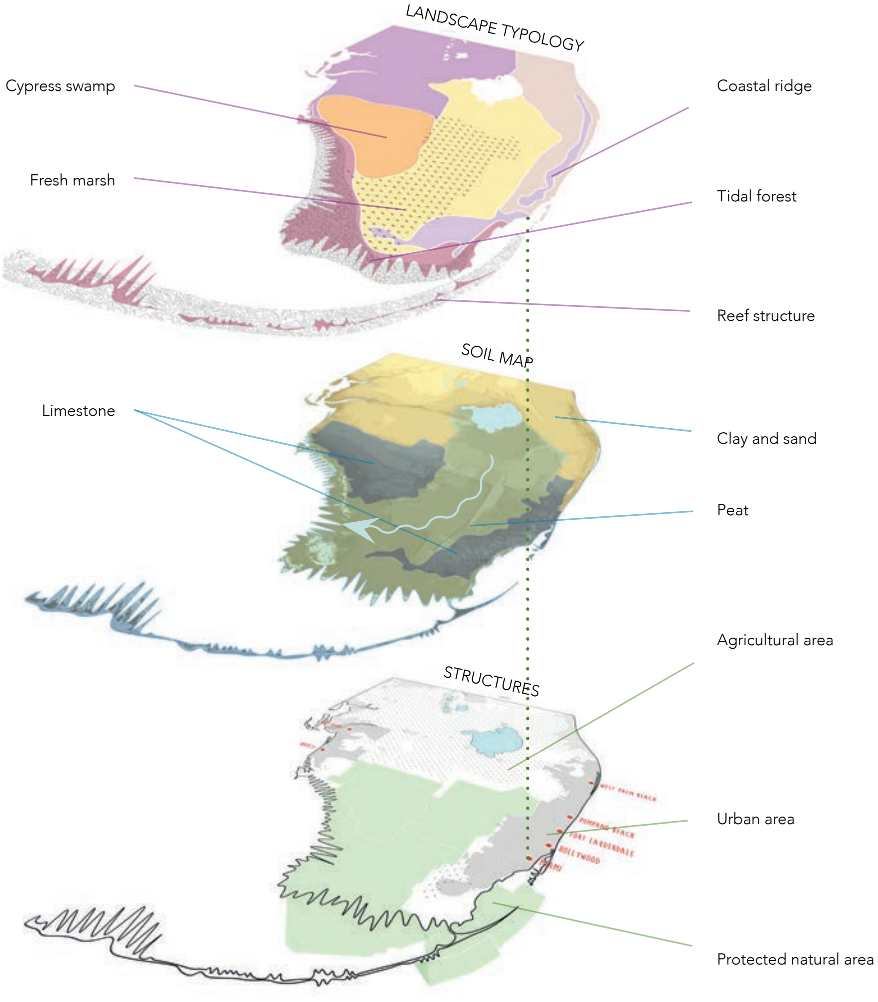
STRUCTURE MAP OF SOUTH FLORIDA

Map based on data provided by Delft University of Technology

MORPHOLOGY
The structure of South Florida is also related to the landscape types and soil. When these morphological layers are superimposed, it becomes clear that there had been another reason to settle along the coastlines. The swamp area of the Everglades is wedged between two limestone areas. The metropolitan region of Miami is located exactly on the Atlantic Coastal Ridge. This higher-lying porous rock reaches up to 12 meters (40 feet) above sea level. On the other side is a limestone plateau that encloses the Everglades and its water flow on the west coast (Lodge, 2016).

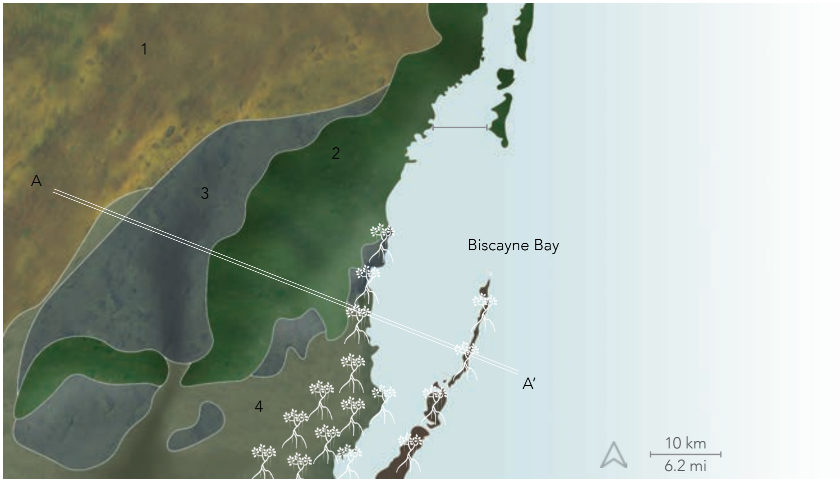
SALT INTRUSION
When people first settled, the limestone ridges were safe above sea level and deep-lying aquifers provided the residents above with fresh water. Due to the porous characteristic of limestone and the rising sea level, salt groundwater from the ocean flows inside the op rock structure and reaches the aquifer. Therefore, Building sea walls on top of the rock is not effective, because it does not stop sea water from intruding inland.

BAYS
South of Florida, there is a long chain of narrow islands. This archipelago is called the Florida Keys and they consist of biologically shaped islands on fossilized coral reefs. The outside of the island chain, on the border of the Gulf of Mexico and the Atlantic Ocean, is surrounded by a barrier reef. The keys and the barrier reef enclose the Florida Bay in the south and Biscayne Bay in the southeast. Both bays are shallow and, originally, coastal forest is located on the edges to form a natural barrier against the sea.



EXPLODED VIEW OF STRUCTURAL ELEMENTS

Data provided by Delft University of Technology



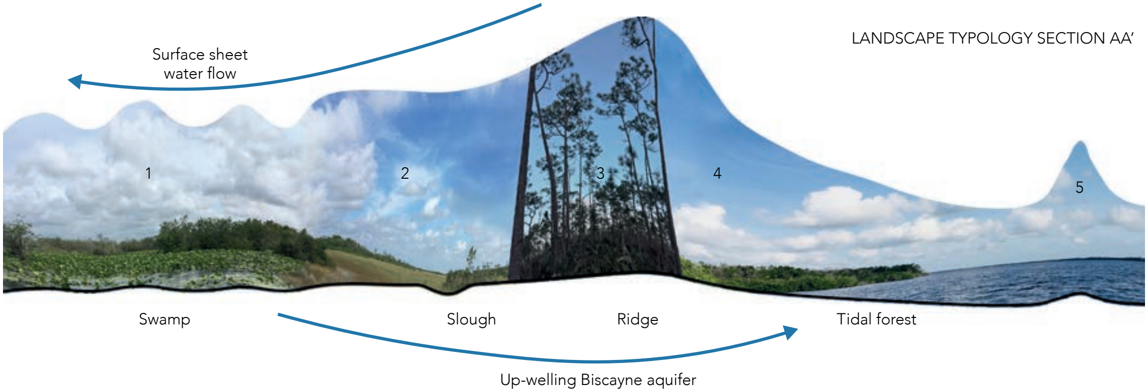
1. EVERGLADES SWAMP

2. ROCKY PINE LANDS

3. ROCKLAND MARSH

4. TIDAL FOREST

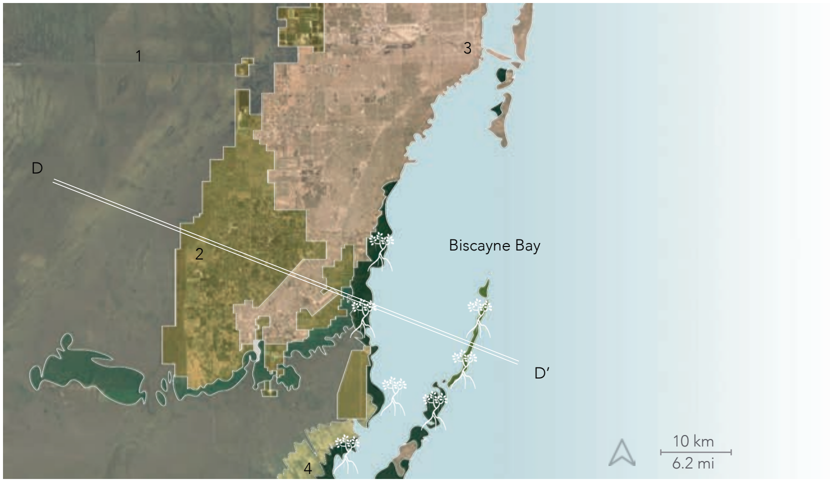
RECONSTRUCTION OF HISTORICAL LANDSCAPE OF BISCAYNE BAY   Map based on Google Earth historical satellite data

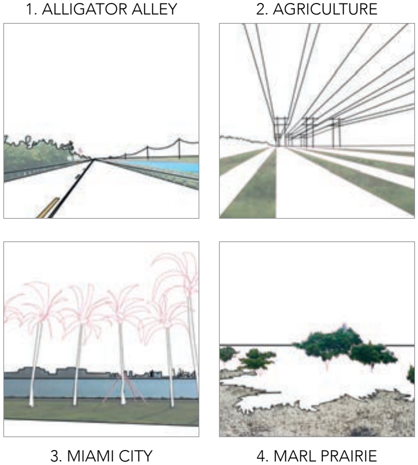


LANDSCAPE TYPOLOGY SECTION AA'

HISTORICAL LANDSCAPE

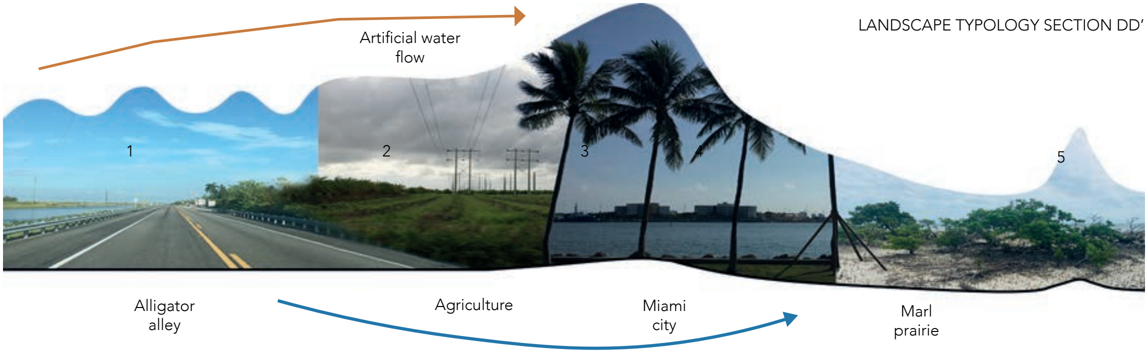
Biscayne Bay is located at the northern end of the Florida Keys archipelago. Along with the coral reef, the southern part of the lagoon is being sheltered. The northern part is enclosed by barrier islands. In the historical situation, which is outlined in the images above, Biscayne bay is connected to the Everglades. The ribbed topography of the landscape with sloughs and ridges let surface sheet water flow from the Atlantic Coastal Ridge towards the Everglades. This results in a varied landscape with marshes and forests. The mangroves grow to the point where the ridge meets the lagoon. Here, the tidal forest becomes narrower and eventually stops, because it has not enough space and receives fewer sediments and fresh water from the adjacent fresh marsh, which also decreases in width due to the presence of the ridge (Radabaugh et al, 2017).





CURRENT MAP OF LANDSCAPE OF BISCAYNE BAY

Map based on Google Earth satellite data and (Whelan, 2013)

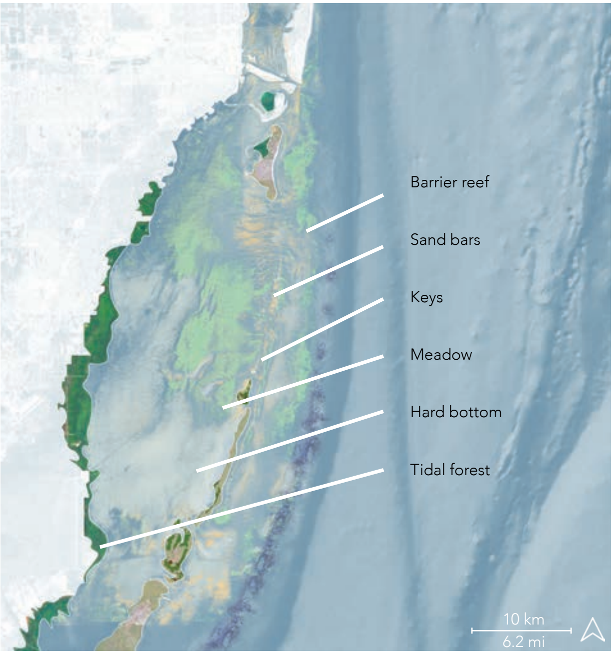


LANDSCAPE TYPOLOGY SECTION DD'

CURRENT LANDSCAPE

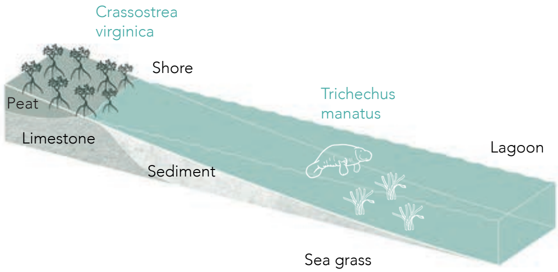
Many landscape typologies have changed in the current situation. The images above show that the rocky pine lands and rock land marsh disappeared almost completely in this area. The higher limestone ridge turned out to be a good foundation for urbanization and the fertile and well-irrigated soil of the rock land is now used for agriculture. In fact, these new landscape typologies precisely follow the contours of the historical ones. This is due to the inundated character of the Everglades, which strongly defines city and agricultural boundaries. In addition, the Everglades have been part of the National Park Service since 1947 and is therefore a protected area, where no urban expansion or agriculture can take place (Godfrey, 2012).

Another natural typology is the marl prairie. Due to the damming of the Everglades in 1968 during the construction of Alligator Alley, the connecting road between the east and west of South Florida, the water flow in the river of grass has partially stagnated. In addition, due to canalization of the sloughs on the ridge, the water flow redirected. Because of these two interventions, the south of the Everglades has to deal with drought dries out the marl soil. It also adversely affects the mangrove distribution along the entire south coast (Radabaugh et al, 2017).

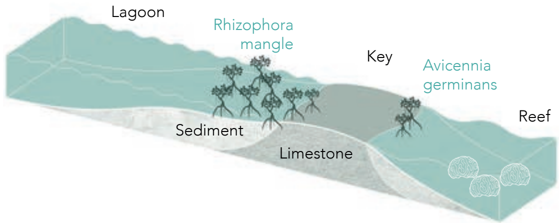


STRUCTURES IN THE LAGOON

Map based on Google Earth satellite data



3D SECTION OF TIDAL FOREST ON SHORE



3D SECTION OF TIDAL FOREST ON KEY

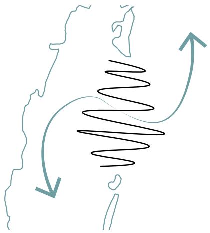
AQUATIC STRUCTURES

Six aquatic structures can be distinguished in the lagoon of Biscayne Bay. Four of them are submerged: barrier reefs, sandbanks, meadows and hard bottom. About 64% of the soil is covered by a soft sedimentation layer, on which grows sea grass. The rest is mainly hard bottom and reef (National Park Service, 2006). The other two structures are keys and tidal forest which is partly submerged and consists of mangroves. The mangroves can be found both in the intertidal area of the mainland and on the keys. There, they mainly grow on the leeward side, but the more salt tolerant Black Mangrove is also found on the windward side. Between the keys, they are shaped the a system of creeks, carving in the sea floor. Mangrove tree roots support oysters, that are indispensable in their food chain and for water filtration

CHANGE

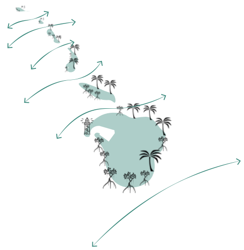
The conditions in the bay changed drastically in the last 50 years and that affected the aquatic landscape structures. Both tidal forest and the barrier reef became fragmented, respectively caused by an altered water system and rising sea temperatures. This change of an individual typology does not only affect the ecosystem settled there, but also the symbiosis with interrelated ecosystems. On the one hand, these changes have a negative effect on the vital functions of the bay, such as coastal protection and fish stock. But, on the other hand, the altered water system generated new fresh water flow that resulted in an habitat expansion of the soft bottom sea grass and an extension of the mangrove distribution zone towards the north. (Radabaugh et al, 2017)

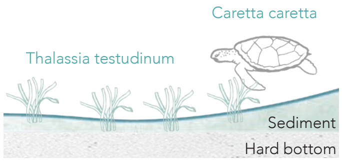
BARRIER REEF
The Florida reef is an elongated structure of coral groups on the border of the deep ocean and the shallow sea, functioning as natural offshore breakwaters. The reef is shaped by coral, an animal species that consists of colonies of polyps that live in a lime skeleton, forming the hard structure of the reef.



SAND BAR
Sand based areas evolved from sedimentation and shaped by erosion. Most of the sandbars appear in between the most northern key and the southern barrier island. This area is called the Safety Valve, because it allows large amounts of water to enter and exit the lagoon during storm events.

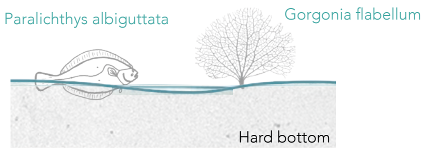
KEY
Biologically shaped islands on a limestone subsoil of an ancient coral reef, extending over the entire south coast of the state and parallel to the current Florida Reef. The ocean side of the keys are characterized by white beaches with alternating Black Mangrove trees. The windward lagoon side is completely covered with mangrove forests.

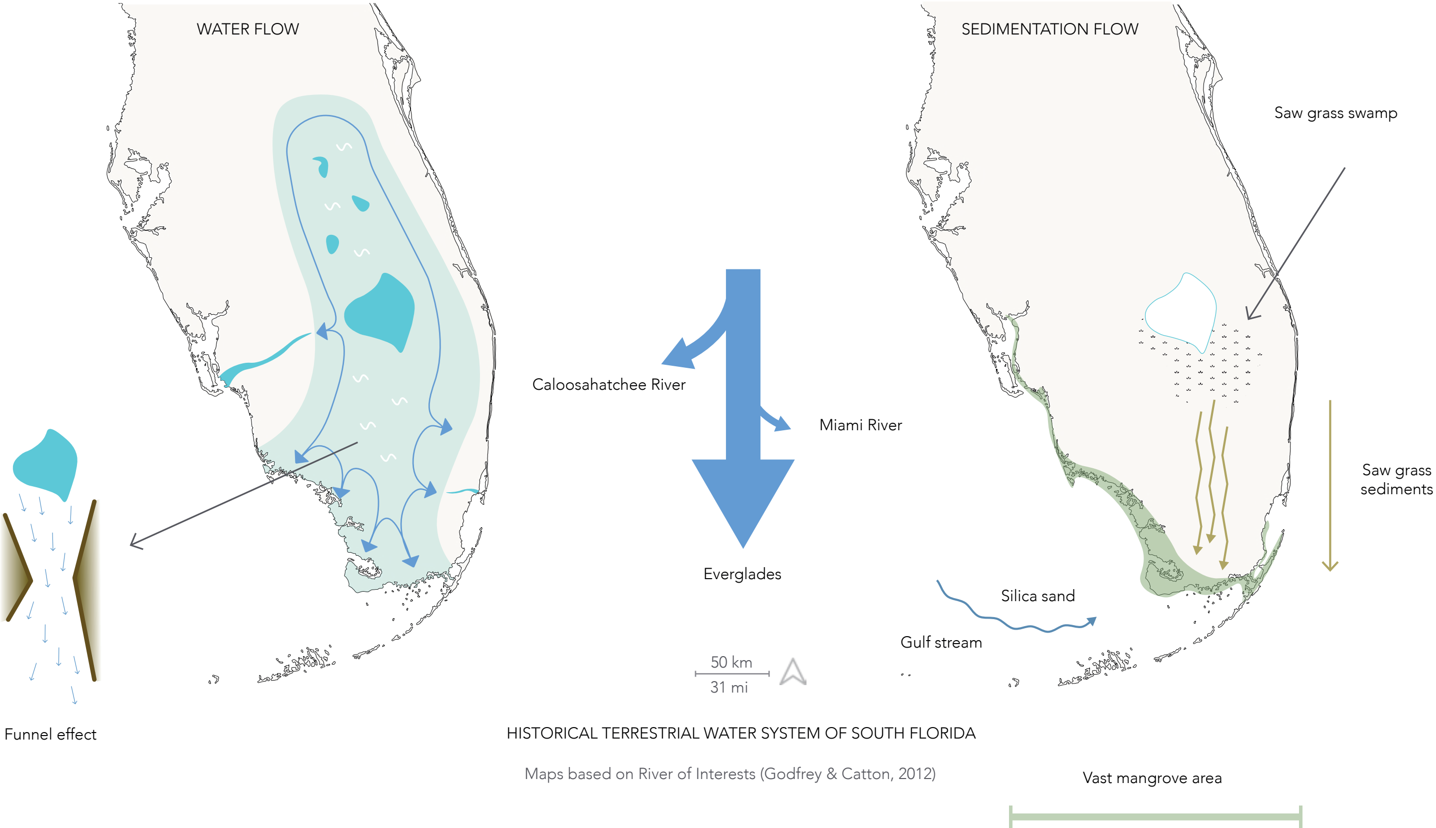




MEADOW
Submerged fields of sea grass species growing on a thin sedimentation layer that lies on the limestone hard bottom lagoon floor. It supports marine grazers, crabs and different types of fish that are popular for commercial fishing. The vegetation causes more sedimentation, flowing in the direction of the mangrove forest, where it contributes to the natural coastal levee.

HARD BOTTOM
Sea floor with an exposed limestone substrate with few to no sediments. It is habitat to hard and soft coral species and , like the meadow, fish that are popular for commercial fishing





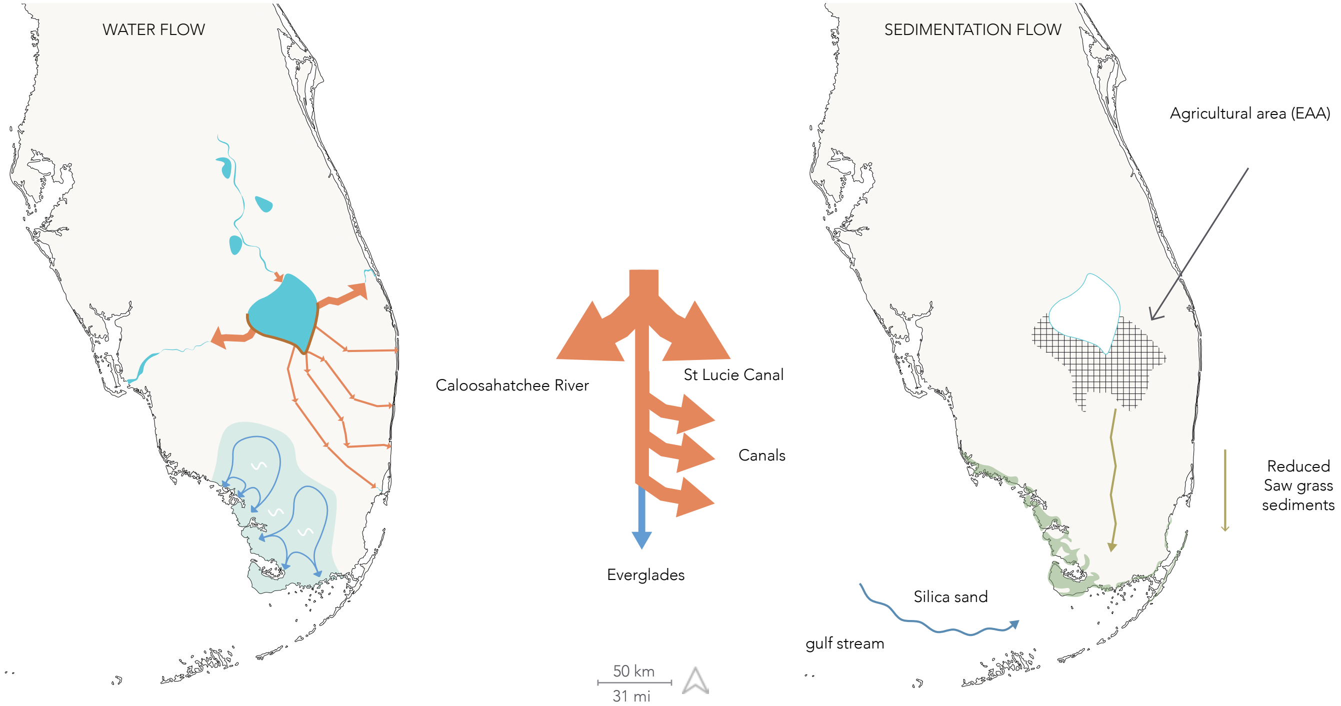
HISTORICAL TERRESTRIAL WATER SYSTEM OF SOUTH FLORIDA

Maps based on River of Interests (Godfrey & Catton, 2012)

HISTORICAL SITUATION

The Everglades are the beating heart of the South Florida water system. Water comes from the states of Georgia and Alabama and flows, both above and under ground, through countless lakes towards Lake Okeechobee. This is the third largest lake in the country and a huge water retention area. From here, most of water flows slowly down south, through the Everglades, guided by the two higher lime stone ridges that function as a funnel. Eventually the water reaches the mangrove forest in the south and discharges in the Florida Bay. Along the way the water carries important sediments, which are essential for the mangroves. The sediments contribute to the formation of the levee, which keeps the mangroves at the right water level. Saw grass (Cladium jamaicense) plays an important role in generating these sediments. In the historical situation this grass species was mainly found south of Lake Okeechobee and to a lesser extent further south (Lodge, 2016).

Also, a smaller amount of water flowed east and west through smaller rivers. The Caloosahatchee River directed water into an estuary in the Gulf of Mexico and the Miami River to the north Biscayne Bay.

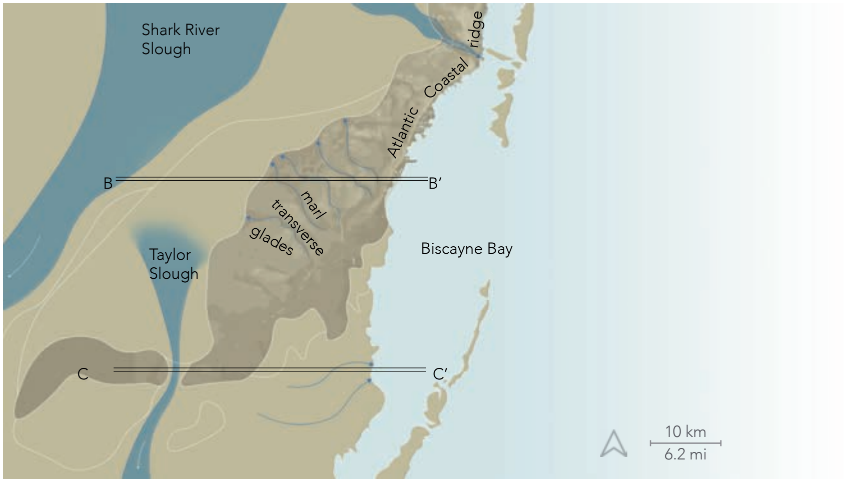


CURRENT TERRESTRIAL WATER SYSTEM OF SOUTH FLORIDA

Maps based on River of Interests (Godfrey & Catton, 2012)

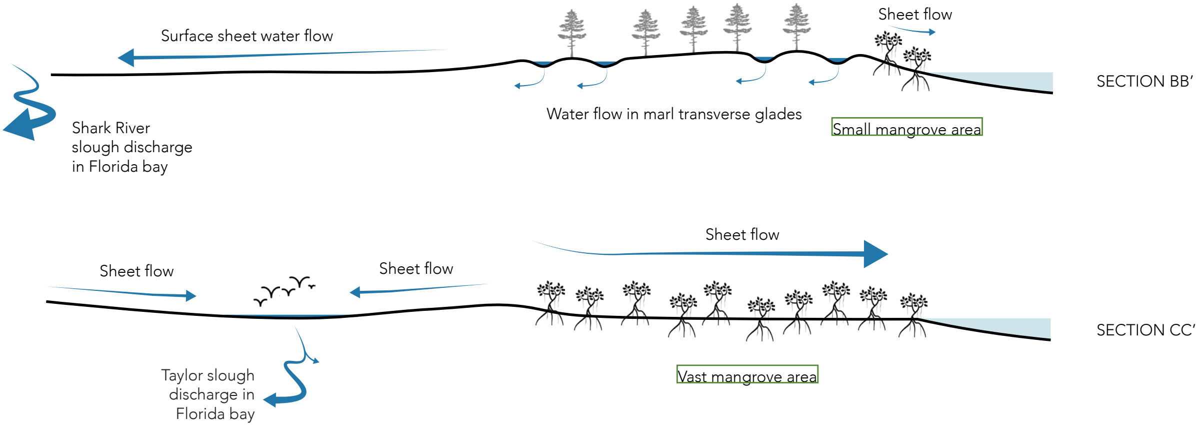
CURRENT SITUATION
By cultivating the land for the development of cities and agriculture in the last century, the dynamics of the water system changed radically. The embankment of Lake Okeechobee has by far the most influence on the natural systems of South Florida. The dam around the southern part of the lake, the Herbert Hoover Dike, was gradually constructed in the first half of the twentieth century. A large part of the water is diverted by the dyke through the partly canalized Caloosahatchee River, the Miami Canal and a series of other channels that lead to the east (Godfrey & Catton, 2012). This altered water flow has ensured that the Everglades receive much less water, the sheet flow has decreased and the water sheds are greatly reduced. In the dry season this causes droughts that pose a major threat to flora and fauna. In addition, when the water level drops below the ground level, peat soil is exposed to the air and released CO^2. As a result, the swamp changes into a greenhouse gas producer instead of storage.

The mangroves now receive less fresh water, but also less sediments. This is due to the transformation of the Saw grass area directly below Lake Okeechobee. The embankment of the lake ensured that a large agricultural area was be realized south of the lake, the Everglades Agricultural Area. Besides being an additional blockage for the water flow through the Everglades and causing groundwater pollution, a large part of the essential sediment flow has also disappeared. The distribution area and the total surface area have therefore decreased substantially (Lodge, 2016).



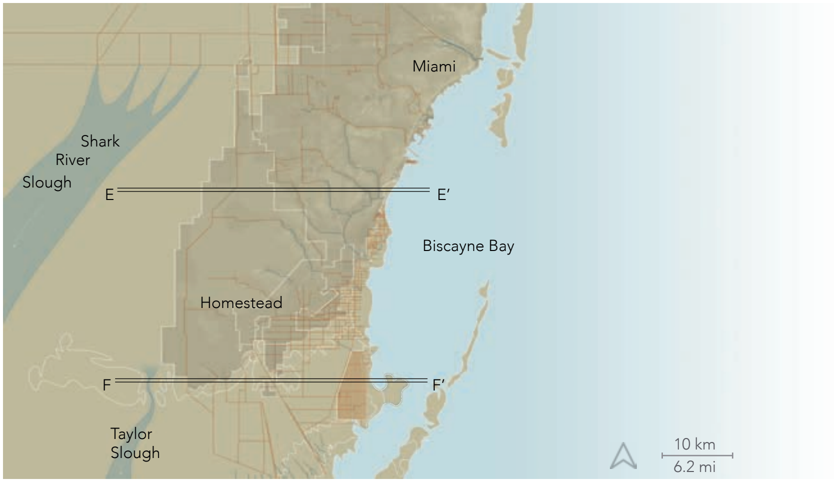
RECONSTRUCTION MAP OF THE HISTORICAL WATER SYSTEM OF BISCAYNE BAY

Map based on The Everglades Handbook (Lodge, 2016)

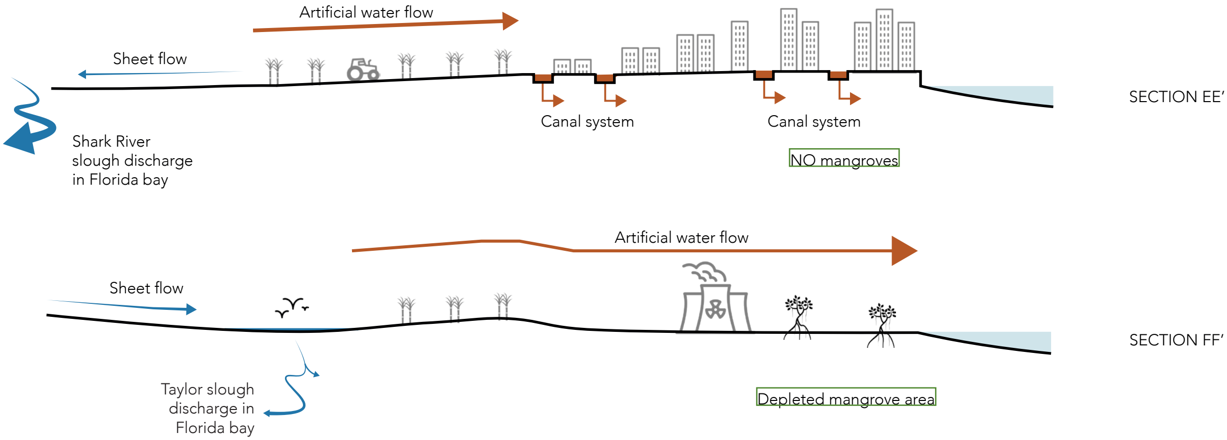


HISTORICAL WATER SYSTEM

Before the urbanization of Miami and cultivation of the landscape and water system, Biscayne Bay depended on the Miami river and the Everglades swamp for fresh water. The discharge of fresh water in the bay prevented intruding salt ground water from the ocean. Mangroves grew along the coastline to form an additional barrier against this salt intrusion by building up a peat layer with fresh groundwater. The most storm water from land did not flow towards the bay, but in the direction of the Everglades. Via the Marl Transverse Glades system it flowed through countless sloughs towards the swamp of the Everglades. Here, it was further guided as sheet flow by larger sloughs towards the south. The large Shark River Slough ends in the Florida Bay, but the smaller Taylor Slough is redirected between a opening in the Atlantic Coastal Ridge. A part of the sheet flow bends towards Biscayne Bay. This water flow was essential for the supply of nutrients and sediments to wetlands in the hinterland of the bay and the adjacent mangroves (Lodge, 2016).

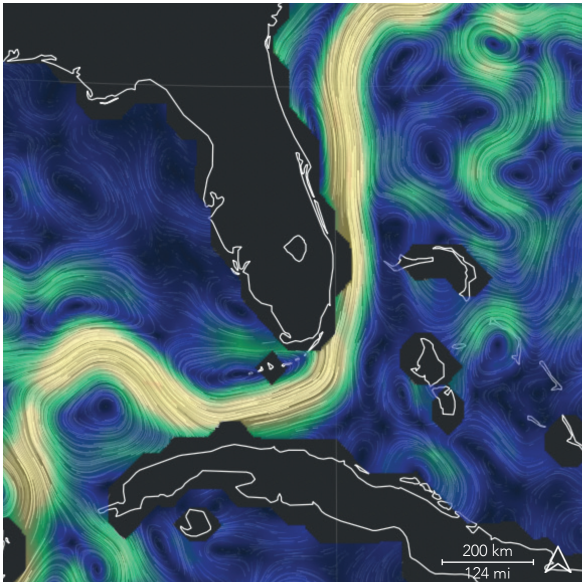


MAP OF THE CURRENT WATER SYSTEM OF BISCAYNE BAY Map based on The Everglades Handbook (Lodge, 2016)



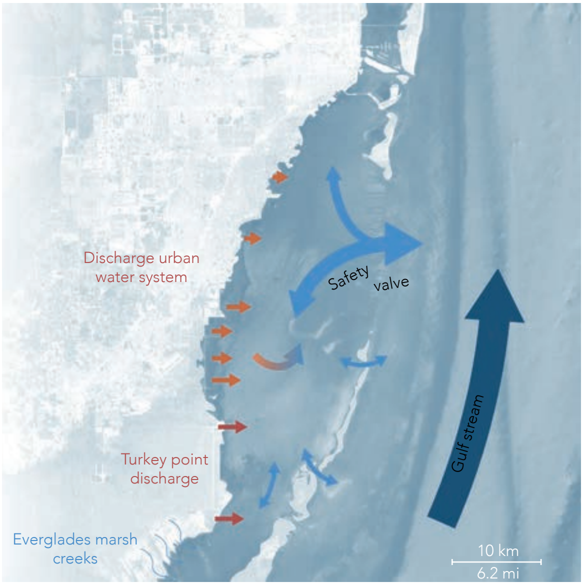
CURRENT WATER SYSTEM

Nowadays, almost all terrestrial water flows around Biscayne Bay are canalized. The watershed of the Everglades has been reduced by the embankment at Lake Okeechobee, but also because storm water runoff from the Atlantic Coastal Ridge no longer flows naturally westwards. All water flows are canalized in both residential and agricultural areas. As a result, the water is now directed to the east and discharges artificially in Biscayne Bay. Because of this reversal, the Taylor Slough also contains less water which, in the historical situation, provided the wetlands and mangroves along the bay with fresh water (Lodge, 2016). Thus, the same amount of water still ends up in the bay, but brings little or no nutrients and sediments. In addition, the water connections between canals and bay are often blocked by a lock and further closed off from the surrounding land. This collected way of discharge is the opposite of gradual sheet flow and causes depletion of mangrove areas.



WARM GULF STREAM ALONG FLORIDA

Image from Nullschool Retrieved on December 18th 2018



WATER SOURCES AND CIRCULATION IN BB

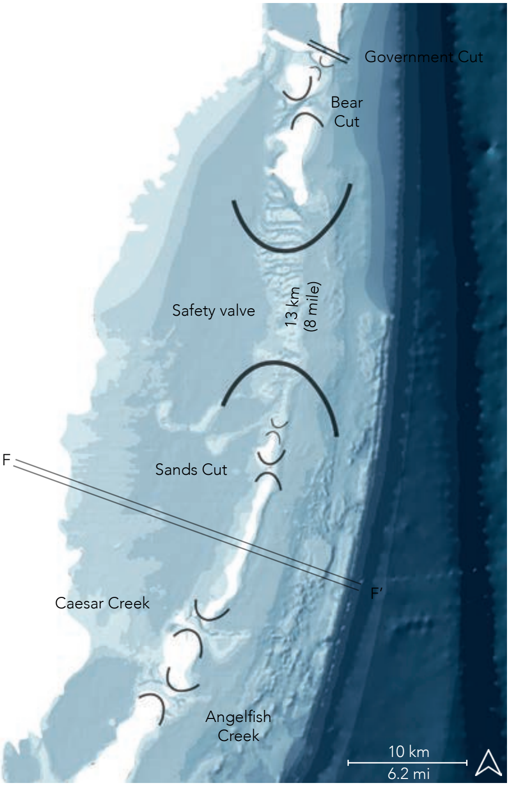
Map based on data provided by the National park Service

GULF STREAM

Biscayne Bay is subject to the Gulf Stream, which is simulated in the image above. This sea current is part of the North Atlantic Drift and transports warm water from the Gulf of Mexico along the southern tip of Florida via the Atlantic Ocean to the far north. This current carries silica sediments, which deposit on the way at Biscayne Bay and in the tidal forests. The Gulf Stream follows the contours of South Florida, but at Safety Valve Biscayne Bay it enters the bay. Here it changes direction and flows in a diagonal way towards shore and back to the valve.

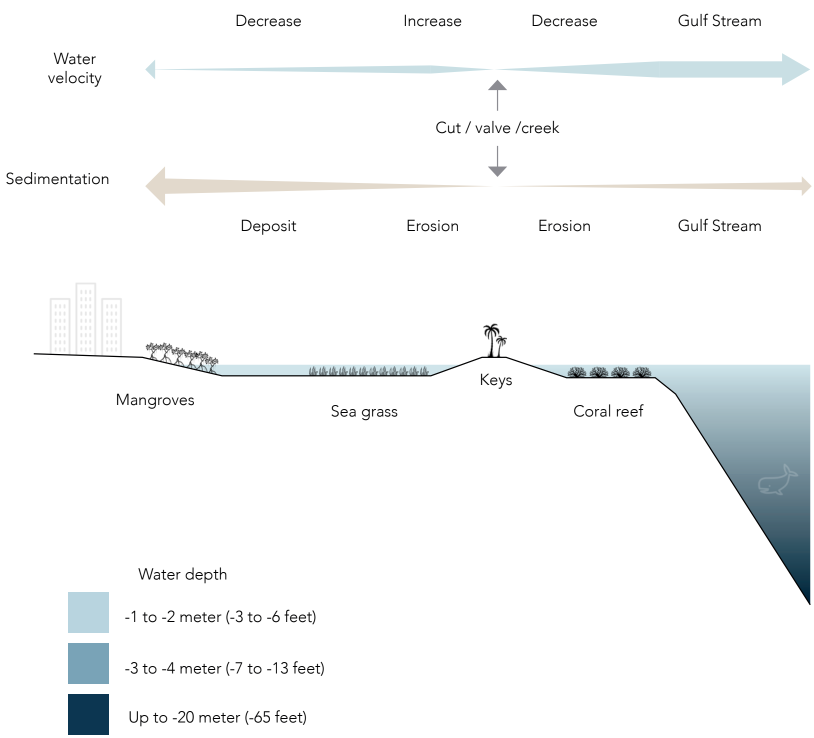
ALTERED FLOWS

The natural water flows in the bay are influenced by the discharge of urban water systems and the cooling water of the nuclear power plant at Turkey Point. The water is fresh and relatively warm, therefore it creates different flow patterns in the bay. In addition, rising water temperatures due to climate change are enhanced by the relatively warm water from the channels. This increases salinity levels and has an impact on surrounding flora and fauna in the bay. As a result, the less salt-resistant Red Mangrove reduces in some areas, while the more salt-resistant Black Mangrove occurs more frequently (National Park Service, 2006).



TOPOGRAPHY MAP OF BISCAYNE BAY

TOPOGRAPHIC SECTION FF'

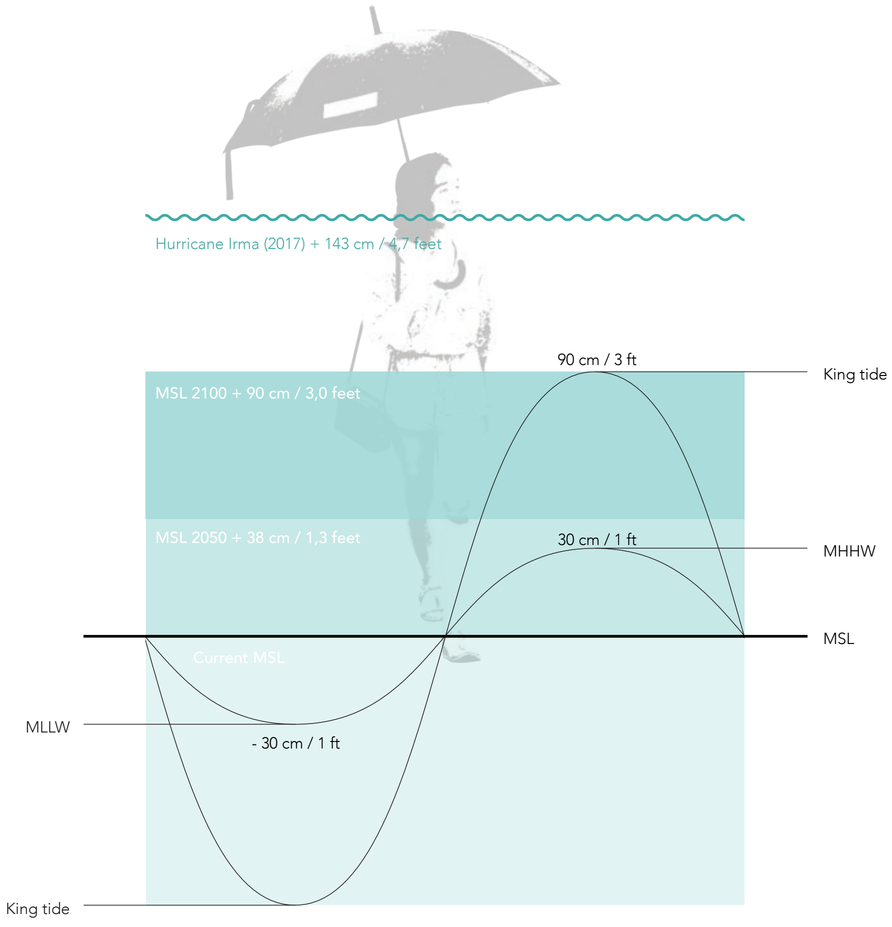


AQUATIC WATER SYSTEM
Atlantic seawater also enters in the bay via openings between the Keys, called cuts. Because these cuts are relatively small, but are the only openings in the entire southern part of the bay, the current here is very strong. The water velocity changes because of the funnel effect of the cuts and causes erosion an sedimentation deposit. This effect is illustrated in the section above.

SEDIMENTATION PATTERNS
When the Atlantic water with silica sediment hits the barrier reef, its slowed down and drops a part of the sediment. Then, the water flows towards an opening between two Keys and is slowed down more. Once it passes beyond the narrowest point of the cut, it rapidly increases speed. This acceleration causes erosion on the bottom of the cut, but mangroves prevent erosion of the banks of the Keys. Without mangroves, the keys would erode quickly and the cuts would get bigger. Next, the water enters the lagoon and its speed decreases, which causes sedimentation. As a result, a large part of the hard bottom is covered with a layer of white mud which supports turtle grass. This grass slows down the water more, until it reaches the tidal forest on the shore of the mainland. Here, it deposits almost all of its sediment between the roots of the mangroves. This chain reaction is essential for all ecosystems in the bay, including the mangroves.

ALTERED WATER LEVELS
The diagram to the left shows the average water levels in Biscayne Bay, compared to extremes. This area is vulnerable to flooding due to its geographical location and topography. The hurricane season is from beginning of June to end of November. During this period, the climate and sea level are influenced by tropical storms. Such a cyclone has high wind speeds, heavy rainfall and causes storm surges. In the past, layered natural coastal defense contributed to mitigating the influences of hurricanes, but due to the depletion and disappearance of these areas, Florida is more exposed to flooding. In 2017, Hurricane Irma rushed from the Caribbean towards Florida and came ashore here. Water levels reached up till 134 cm (4,7 ft) above sea level (MSL) and flooded vast areas. This devastating cyclone killed 134 people, 72 of them in the state of Florida. The water level of Irma was over 3,5 times higher than normal high water level (MHHW) in South Florida (Cangialosi et al., 2018).

KING TIDE
Besides hurricanes, every year, Florida is also subjected to another phenomenon that causes exceptional high water levels. An unusual case of spring tide occurs in the fall, called King Tide. The water level rises to almost one meter (3 ft) above MSL. This water level is comparable to the prognosis of the average sea level rise towards the end of this century (Keys et al., 2016). During King Tide, seawater flows into the land both above and below ground. The seawater is up welling through the porous limestone all around the bay and vast low-lying areas flood. But, also sewerage, cannot stop these high water levels. So, for Miami, sea level rise is not a future perspective, but due to King Tide it is already a current problem.

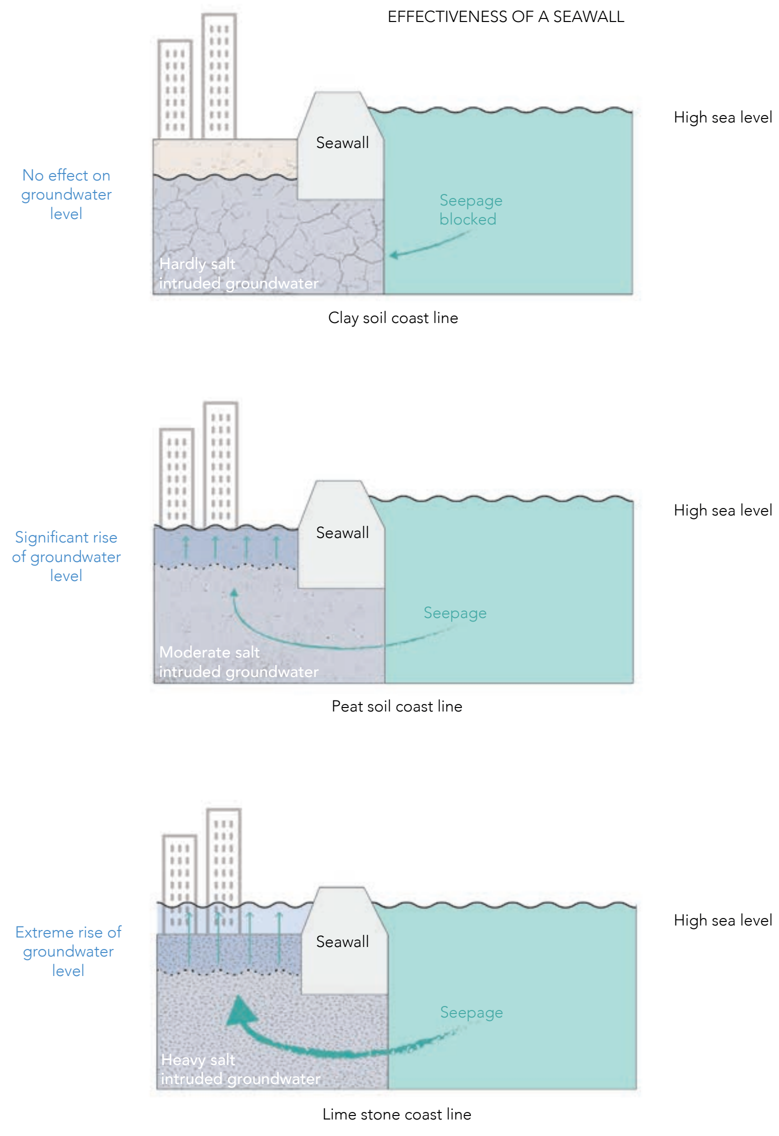


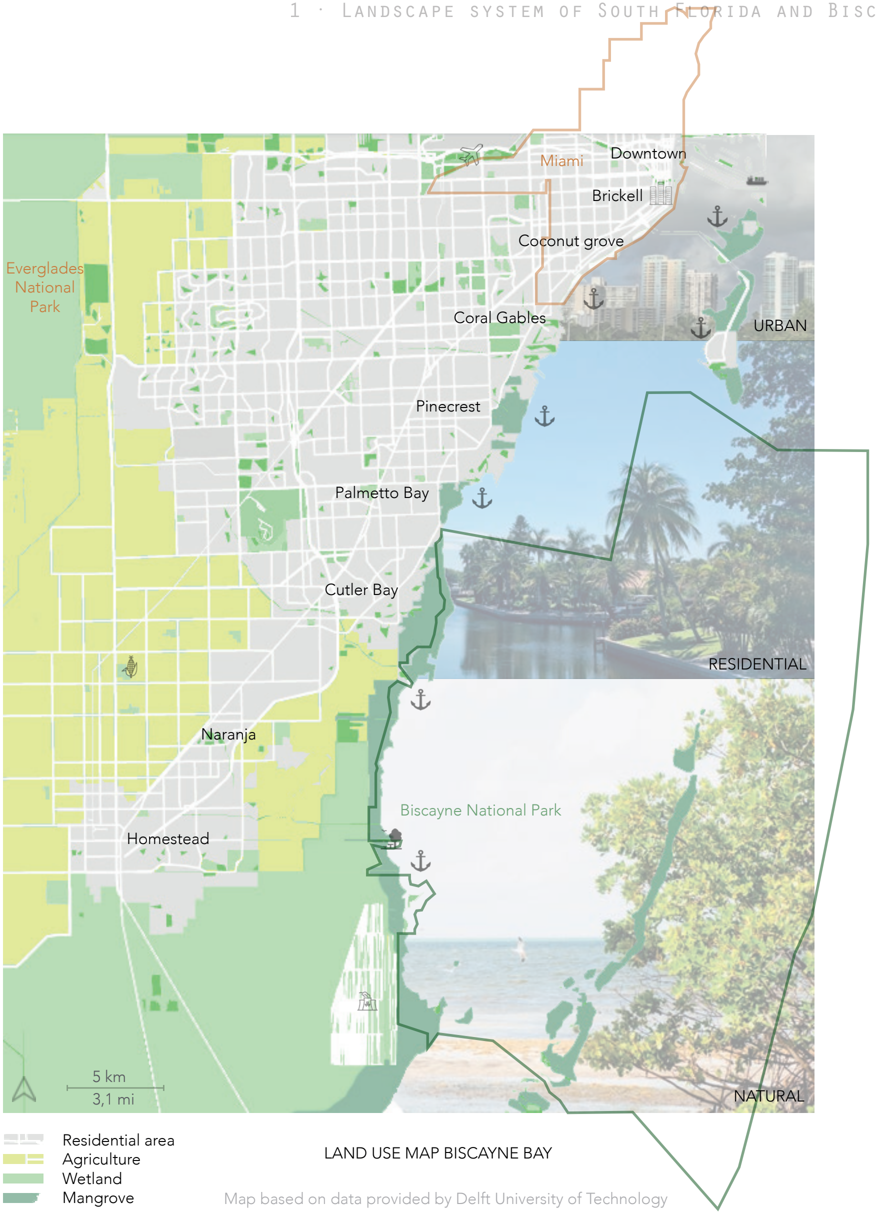
WATER LEVELS BISCAYNE BAY

Data based on the National Hurricane Center

SEAWALLS
A method to protect the land against high water levels during storm surge or because of sea level rise, is the construction of a seawall. The effectiveness of this embankment in relation to soil type is shown in the images on the right. Compact soil types like clay, blocks the salty seawater so that it can hardly enter the soil. This means that even lower-lying areas with this soil type can remain protected against sea level rise. In the case of peat soil, which contains a lot of water, the situation changes. When sea level rises, part of the seawater penetrates the groundwater and causes the groundwater to salinize. Also, due to the upward pressure of the seawater, the groundwater rises significantly. This causes water management problems in coastal regions, such as in the west of the Netherlands. Here, the water level is kept artificially low by pumps, to prevent inundation. The third image represents Florida, with its limestone soil. Due to the porous property of this rock, seawater easily enters and mixes it with groundwater. As a result, the Biscayne aquifer, which is the largest fresh water source for the 5.5 million inhabitants of the Metropolitan Area of Miami, is salinizing. The salinized groundwater has the same level as the sea, due to the upward pressure of the seeping water. This causes flooding without the need for extreme weather conditions.

Coastal wetland and mangrove forest form peat underground and in the root system. When these vegetation types grow in a coastal area with limestone soil, the effects of seepage can mitigate. With a continuous system of this vegetation, like a seawall, a situation arises that is a combination of the two lower images.





LAND USE MAP BISCAYNE BAY

Map based on data provided by Delft University of Technology

USE OF BISCAYNE BAY

The coastline of Biscayne Bay is a diverse gradient from high-rise in the north to natural areas in the south. At the top of the map on the left, there are densely built-up areas of Miami: Down Town and Brickell. This is the economic heart of the region, but covers relatively little coastline of the bay. The waterfront is primarily public space and has also port functions. To the south lies a series of residential areas such as the cities Coral Gables, Coconut Grove and Pinecrest. These cities consist mainly of gated communities, which means that most of the coastline is not accessible here. The neighborhoods decrease in density as you go further south. Palmetto Bay and Cutler Bay are spacious and primarily accessible to the public. There are a few exceptions that are semi-accessible, closer to the coastline. This degree of accessibility determines accessibility to Biscayne Bay, which is currently very fragmented. The water system of canals mainly determines where you can enter the bay, because there is often a marina there. They are mainly used for recreational boating and fishing. Also, some artificially laid out beaches can be found here. Further south, the Atlantic Coastal Ridge bends inland, including the built-up areas. Between the ridge and the bay, there are tree nurseries, wetland and a mangrove area. At this point, the Biscayne National Park begins, this is a wildlife and recreation area which covers 5% of land and the remaining 95% is water. So it is only a thin coastal strip with mangroves that is protected by the National Park Service.

USER TYPOLOGY EXPLAINED

The users of Biscayne Bay can be divided into three groups, described below. The use of the bay and the protection offered to the Metropolitan Area of Miami is worth 6 billion US Dollar annually (Miami-Dade, 2019).

WILDLIFE

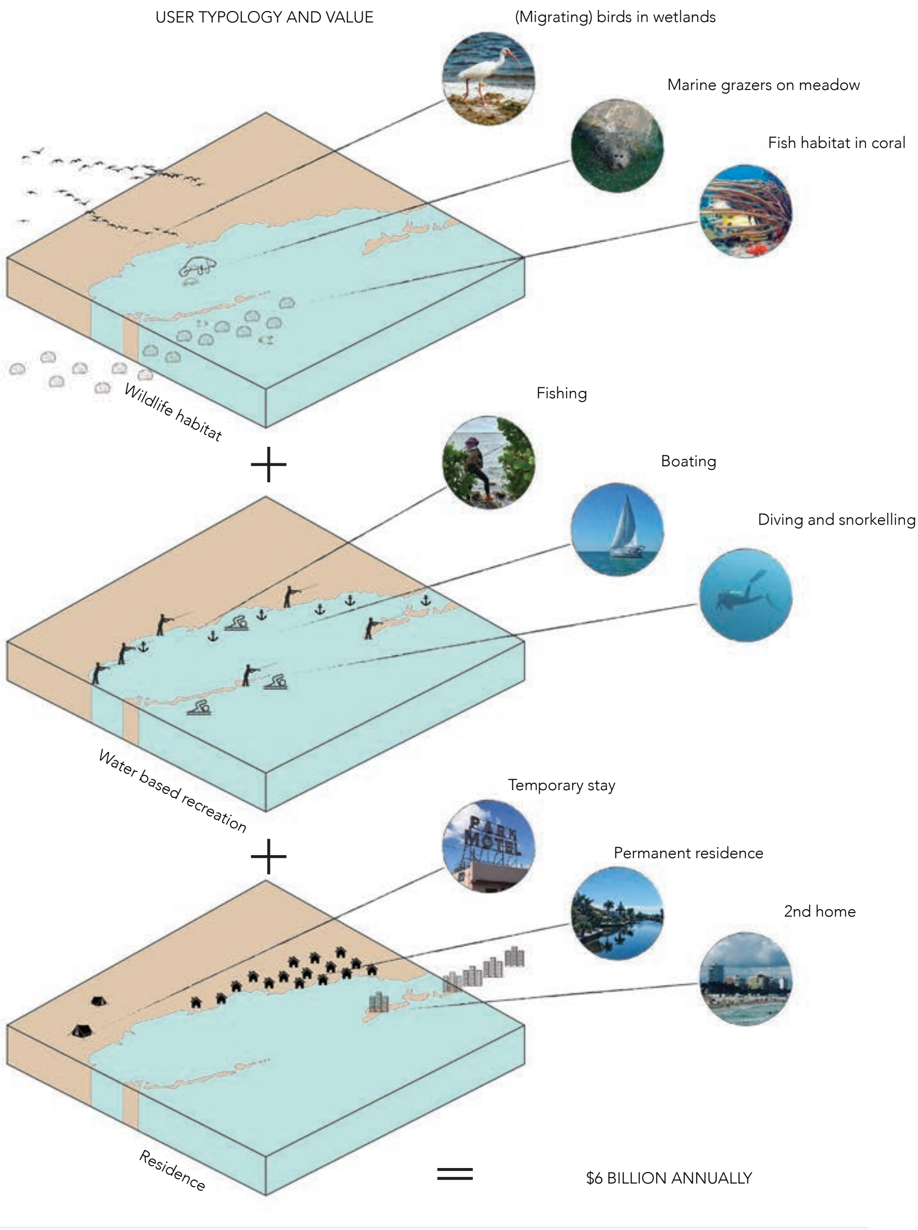
Biscayne bay accommodates relatively many different ecosystems and therefore it has a great number and diversity in wildlife. Wildlife is important for a healthy balance in the bay, but also for recreation. The mangrove forest and the coral reef are popular places for recreation.

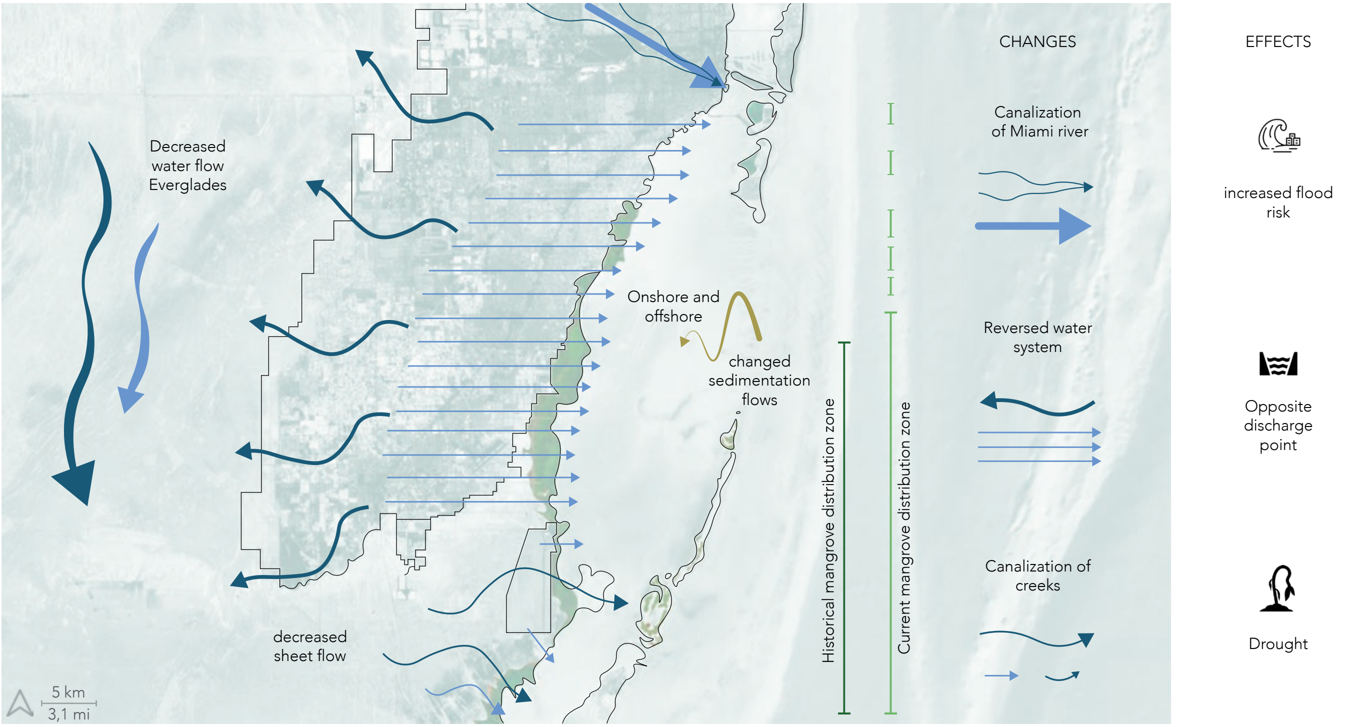
RECREATION

The most important forms of recreation are fishing and boating. The countless marinas along the coastline form the basis for recreation in the bay. In addition, kayaking, snorkelling and scuba diving is also a popular, because it is a good way to spot wildlife.

RESIDENCE

Users who live around the bay can be divided into temporary and permanent residents. Temporary residents mainly come to bay for recreational opportunities in the south or around Miami Down Town. Permanent residents are located all over the area, but mainly use bay at the residential shore line.



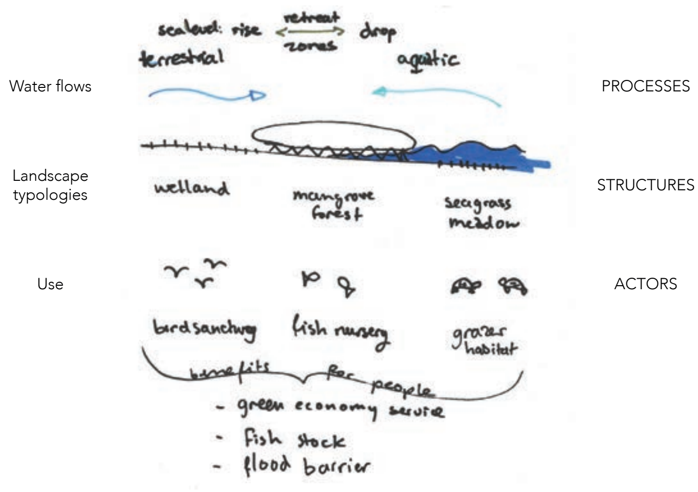


STRUCTURE MAP

FINDINGS

The image above shows a synthesis of the most important elements that have changed compared to the historical situation. From the analysis it can be concluded that these changes have had an impact on the structure, processes and users of South Florida and therefore a strong effect on the coastline of Biscayne Bay. There is one element that almost all changes have in common, and that is water. The construction of canals, dams and locks transformed the natural water system into an artificial system. Due to that change, the water flow through the Everglades has decreased significantly, so also the sediment rich sheet flow in the southern part of the bay. Together with the sheet flow blocking canal structure of the hinterland, the mangroves are being depleted. In addition, many of the mangroves and wetland have disappeared due to the urbanization of the Metropolitan Area of Miami. While this area is still expanding, the risk of flooding is increasing due to rising sea levels, seepage and coastal erosion. A remarkable change in the water system on the ridge is the reversal of the water flows. In the past, storm water flowed towards the Everglades, but now it goes directly through channels towards the bay. On the one hand, this influences the salinity in the bay, which partly has a positive influence on the development of submerged ecosystems. On the other hand, this is one of the reasons that the sheet flow in the southern part of the bay decreases.

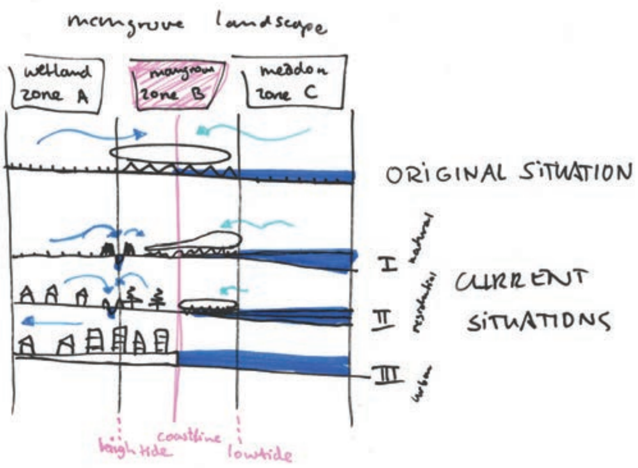
Finally, it can be concluded that the altered water system influences the structures, processes and actors of Biscayne Bay and this increases water related problems as flooding, salinization and erosion. The mangroves are depleted and fragmented, but the distribution area has increased because of the new growth opportunities due to reversing water flows on the ridge.



ELEMENTS OF THE BISCAYNE BAY COASTLINE

THREE LAYERS

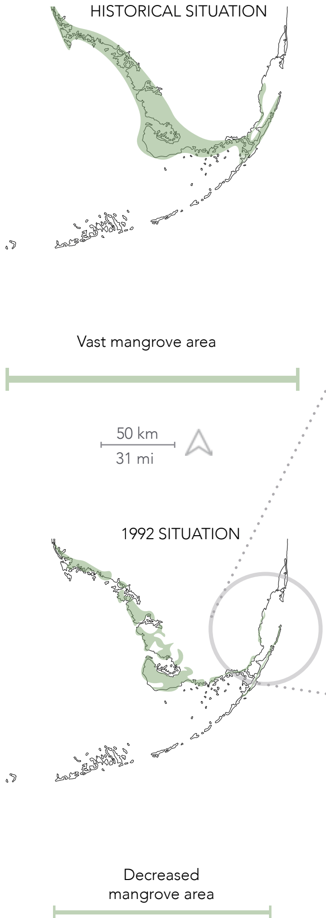
The coastline of Biscayne Bay was originally a mangrove landscape that consisted of three layers, that are defined by the topology of the landscape. The middle layer is the tidal forest consisting three types of mangrove species. The mangroves border on the inland side to a wetland that carries terrestrial sediment via sheet flow and on the seaward side it lies adjacent to a submerged meadow of sea grass that supplies aquatic sediments. The three structures are connected by water, both above and below ground, but also by the actors of the landscape. Fauna makes an important contribution to the maintenance and food supply of the mangrove landscape. Man benefits from this landscape in the form of coastal defense, recreational facilities and fish stock.

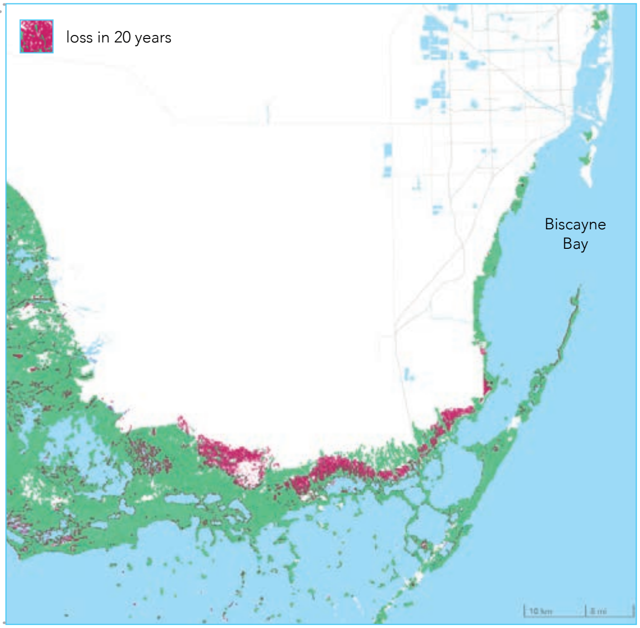


THREE ZONES

THREE ZONES

The mangrove landscape has been changed by coastal transformations. These can be divided into three zones: natural, residential and urban. The natural zone is most similar to the original situation due to the presence of all three parts of the mangrove landscape, but has a blocked terrestrial water flow. The residential zone has a fragmented mangrove forest and, in some places, sea grass meadow. The terrestrial water flow has changed too and the aquatic flow has decreased at the places with less sea grass. The urban zone is a complete replacement of the original landscape by built-up area. Little or no elements of the mangrove landscape can be found here.





MANGROVE LOSS IN SOUTH FLORIDA 1996 - 2016

Source: GFW. Retrieved on January 12 2019 from www.globalforestwatch.org

THE MANGROVE POTENTIAL

The disappearance of the mangroves is not a constant event. The largest part has disappeared before the foundation of Everglades NP (1947) and Biscayne NP (1980) and the logging law that from 1996 also protected the mangroves outside the borders of the National Park Service. Since then, the area of mangroves still decreased by around 1% per year (Sheppard, 2018). The map above shows that this mainly happened within the borders of the Everglades National Park. This is mainly due to recurring drought. Although a restoration plan (CERP) has been initiated, the mangroves still cannot recover from the embankment of lake Okeechobee in the first half of the last century. Unlike the Everglades, few mangroves have disappeared in Biscayne Bay in the last 20 years. This indicates that the conditions for the mangroves are stable and a potential for restoration and expansion.

CHALLENGES AND POTENTIALS IN THREE ZONES
Resulting from the analysis, challenges and potentials for Biscayne Bay are listed in the scheme below. Illustrated by sections of each zone of the bay, they are assigned to the current and desired situation. The current situation is linked to the challenges and the desired situation is linked to the potentials. Overall can be concluded that the main challenges are the restoration of the mangrove landscape and its ecological and social connections in an area with a lack of space. The main potentials are the favorable conditions of the reversed artificial water system and the existing elements of the mangrove landscape that can be used as points of application.

CHALLENGES

Wetland: Not accessible and disconnected from water system, causing drought.

Mangrove: Not accessible and little depleted with a lack of inland retreat zone.

Meadow: Threatened by boating, erosion and by high salinity levels.

Wetland: No wetland.

Mangrove: Poor accessibility and depleted or decreased size with lack of inland retreat zone.

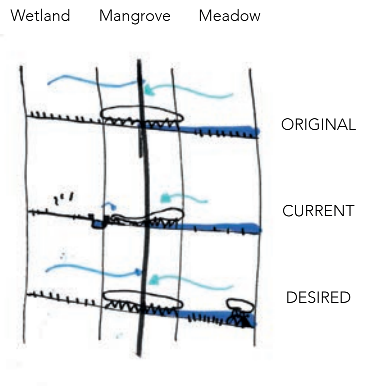
Meadow: Partially increased and decreased, also threatened by boating, erosion and by high salinity levels.

Wetland: No wetland.

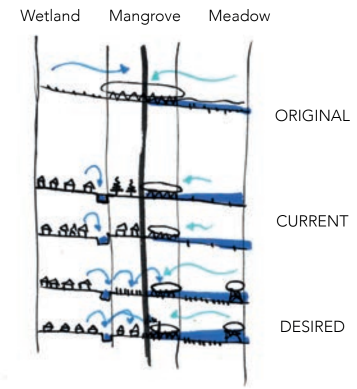
Mangrove: No mangroves.

Meadow: Depleted and damaged meadow due to by boating, erosion and high salinity levels.

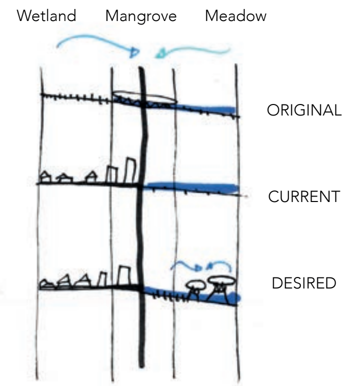
NATURAL



RESIDENTIAL



URBAN



POTENTIALS

Wetland: Restore sheet flow en connect to mangrove with Public access.

Mangrove: Restore existing mangroves and create retreat zone.

Meadow: Offshore expansion of mangroves and meadow on shallow seabed.

Wetland: Reintroduce wetland area with public access.

Mangrove: Restore existing mangroves and create retreat zone, inland /offshore, with connection to bay.

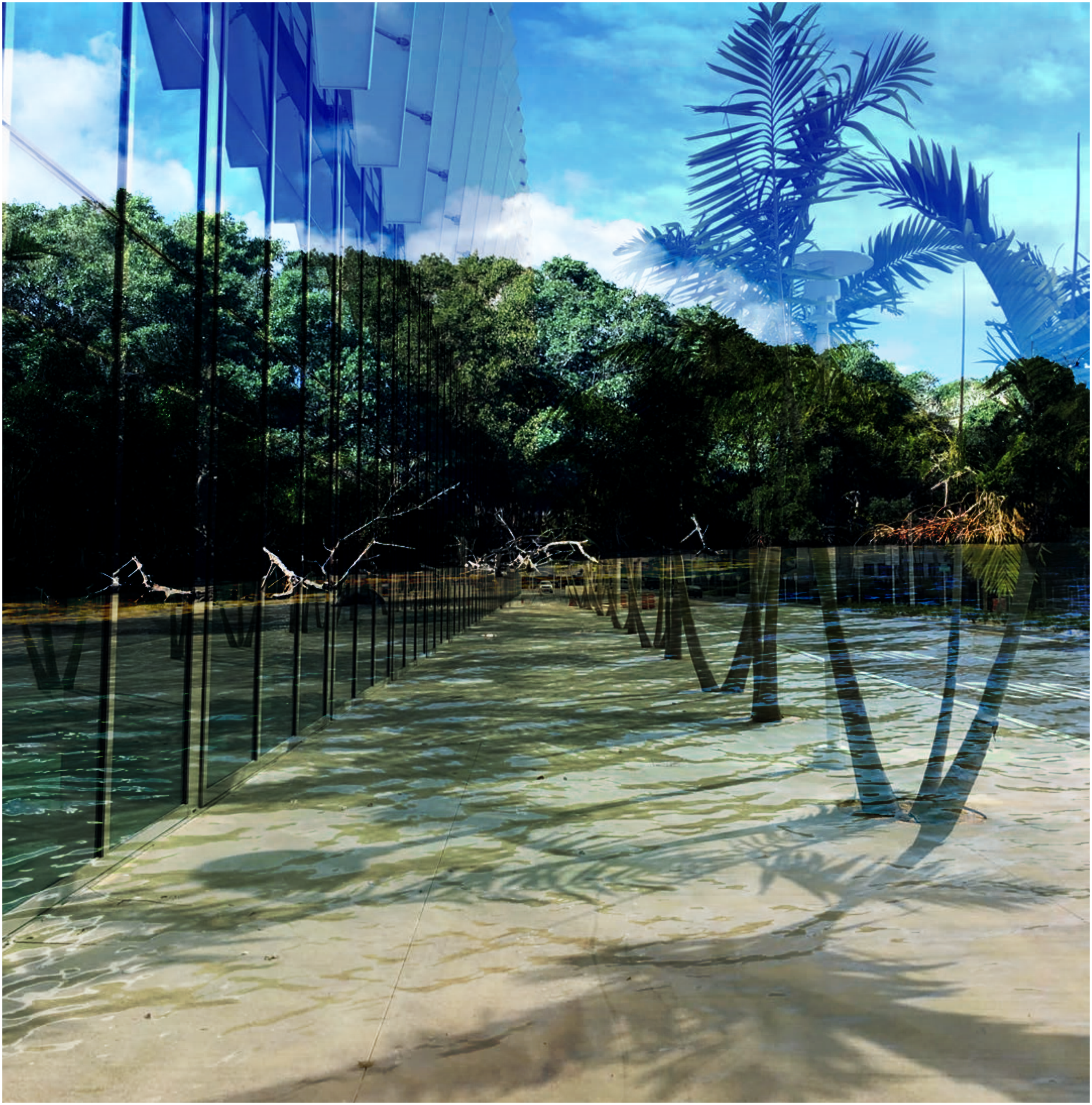
Meadow: Offshore expansion of mangroves and meadow on shallow seabed.

Mangrove: Offshore mangrove introduction with public access.

Meadow: Offshore expansion of mangroves and meadow on shallow seabed.

IV

Mangrove design principles



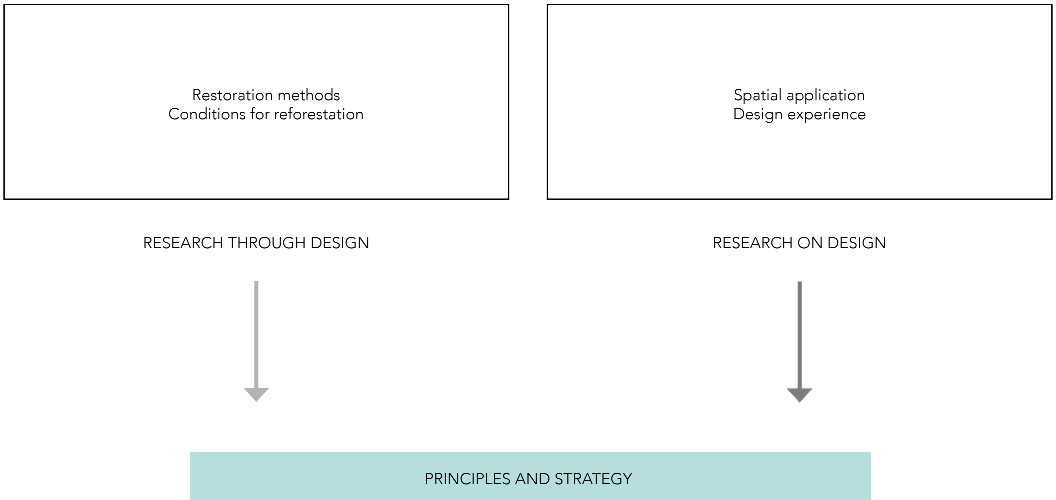
IV Mangrove design principles

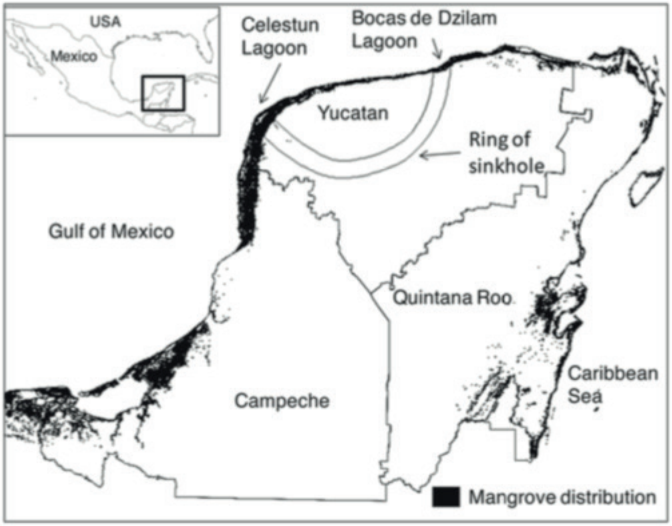
1 · Best practices

This chapter explores possibilities and looks for principles that can tackle the challenges of Biscayne Bay and work with its potentials. In order to explore the possibilities for the challenge of the restoration of depleted mangrove area, an ecological restoration method on the Yucatan peninsula in Mexico is reviewed. Also, two landscape architectural projects are examined that provide principles for the design of coastline that works with natural processes and deals with an dense urban area, and that gives users a place to connect them with the landscape. This addresses the challenges of space issues and accessibility of the lagoon and the mangrove landscape itself. Eventually, design principles will be formulated that are necessary for a strategic plan for Biscayne Bay and the elaboration of a landscape architectural design.

This chapter addresses the second research question:

What spatial and ecological design principles can provide conditions to restore and improve the mangrove landscape in order to let it function as coastal defense and let users reconnect with the natural landscape?





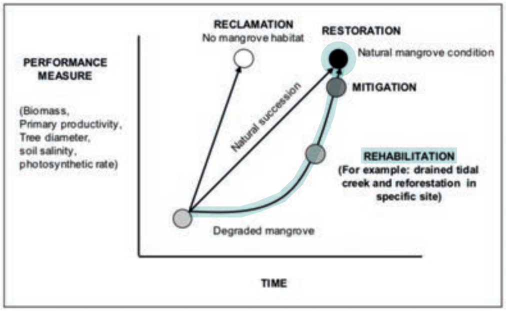
Source: Zaldívar-Jiménez et al, 2010

Name: Conceptual framework for mangrove restoration in the Yucatan peninsula
Location: Yucatán, Mexico
When: 2010
Authors: Zaldívar-Jiménez et al (2010)

This research explores the possibilities of the restoration of degraded mangrove forest in the Yucatán Peninsula. The conditions for restoring degraded mangroves are discussed and different types of approaches. A conceptual framework is developed that focusses on the recovery of mangroves as a whole ecosystem and not only the physical forest. It is tested in a case with technical and systematic interventions to improve the growing conditions in order to restore mangroves. The framework is based on the processes and functions of mangroves and the external conditions of the ecosystem (Zaldívar-Jiménez et al, 2010).

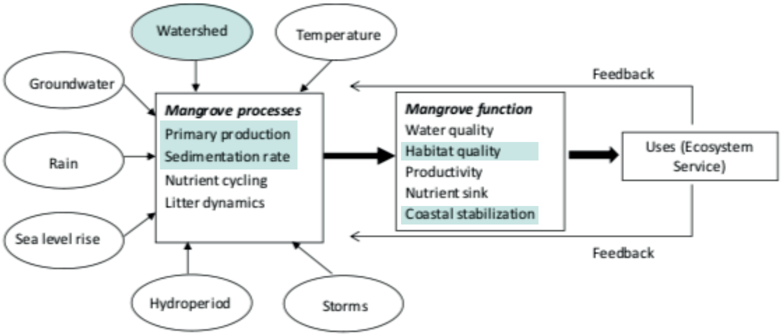
RELEVANCE FOR BISCAYNE BAY

We can learn from this study that there are different types of mangrove restoration, in terms of bringing back the physical forest and that the mangroves must be considered as an ecosystem that is interrelated to others and therefore functions in a larger whole. Although the study area is not an urban area like Biscayne Bay, it shows that the structure of the mangroves landscape and the growing conditions of the trees are the similar. Also, the geographical location of the peninsula, the tree species and conditions such as and ocean currents, are comparable.



Approaches for degraded mangrove forest

Source: Zaldívar-Jiménez et al, 2010



Interaction between conditions, processes, functions and use

Source: Zaldívar-Jiménez et al, 2010

CREATING CONDITIONS

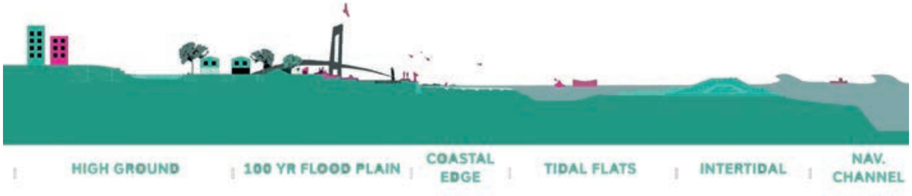
The recovery of a mangrove area can be divided into two strategies, which are illustrated in the image above: reclamation and restoration. Restoration gives the possibility to achieve the same result as natural succession, but is not always applicable. Mangrove reclamation is the forestation of an area, by means of planting trees where they did not exist before. This gives the possibility to introduce mangroves in other landscapes and is done through planting seedlings or young trees. Because mangroves only grow in areas that are subjected to the tidal differences and currents, seedlings are vulnerable to be drowned or being swept away by the current. Restoration on the other hand, is a way of reforestation and defined as reintroduction of mangroves in an area where they have existed before. This is done through the act of rehabilitation, which is the recovery of processes that are depleted or disappeared, on which mangroves depend and therefore improve the their growth conditions. The scheme above shows the processes, functions and affecting conditions which are used for rehabilitation (Zaldívar-Jiménez et al, 2010). The blue highlight shows the focus for this exploration of principles for Biscayne Bay, which will be discussed in the summary of principles.

Source: Toward an urban ecology (Orff, 2016)

Name: Living Breakwaters
Location: Staten Island (NY), USA
Completion: Under construction since 2016
Landscape Architect: Scape

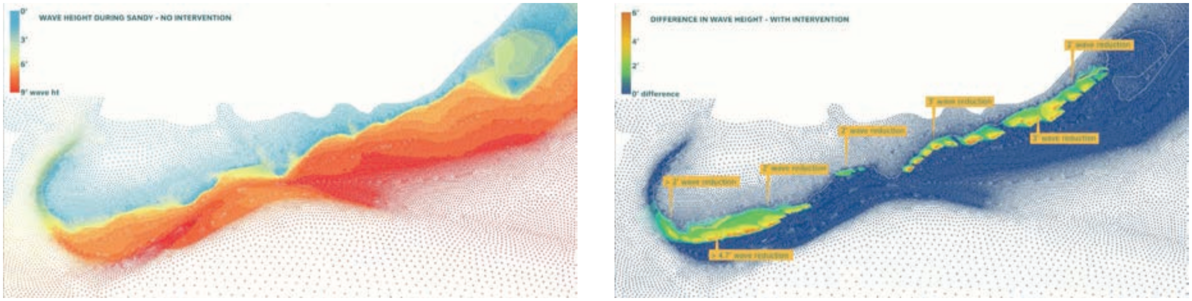
This is a landscape architectural design proposal by Scape for the coastal area of Staten Island (NY).The area is subjected to coastal erosion and storm surge, but also has social issues. The strategy for the design consists out of three objectives: flood risk reduction, ecological regeneration and improving social resilience (Orff, 2016). These objectives are similar to the ones for this research and therefore posed design principles could give insight how to deal with the challenges and potentials of Biscayne Bay.

RELEVANCE FOR BISCAYNE BAY
The design consists of a strategic regional plan for an urban area with a coastline that is comparable in length to the urban zone of Biscayne Bay. The coastline of Staten Island is characterized by beaches and shallow sand dunes, which have different growing conditions as mangroves, wetlands and submerged meadows, but similarities in sedimentation processes. The design is based on improving these existing landscape typologies and introducing new ones, in order to create a layered coastal defense system and reduce flood risk. The concept is that multiple layers offer multiple protection, so if one fails, another layer takes over function. Also, more layers, means more habitats for different ecosystems and possibilities for ecological regeneration. The social resilience increased by reconnecting the community to the waterfront and with educational projects (Orff, 2016).



LAYERED COASTAL DEFENSE SYSTEM

Source: Toward an urban ecology (Orff, 2016)



HYDRODYNAMIC SIMULATION

Source: Toward an urban ecology (Orff, 2016)

OFFSHORE BARRIERS

To reduce the flood risk of Staten Island, a layered coastal defense system is introduced, which is illustrated in the top image. Existing layers as wetlands and dunes are reducing the flood and other layers like levees, can block the flood. The newly introduced layer of offshore barriers functions as a breakwater and reduces floods. The simulation above, shows the effectiveness of this ecological infrastructure and shows that waves are can be reduced up to 1,2 meter (4 ft) . The elongated barriers are constructed from stones and the shape is optimized for the sedimentation on land, which provides the beach and the dunes with sand. In addition, these artificial islands are also habitat for various marine animals, including oysters. These fulfill an important task in the ecosystem by means of filtering water, but also for reconnecting the community with the waterfront through the reintroduction of oyster fishing (SCAPE, 2016).

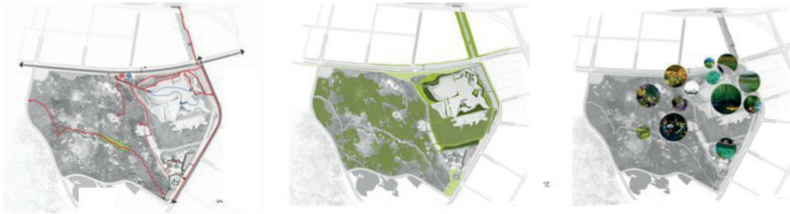
Source: Shantou Mangrove Forest (Loh, 2015)

Name: Shantou Mangrove Forest
Location: Shantou City, China
Completion: 2017
Landscape Architect: AECOM Shanghai

This is a landscape architectural design for the mangrove landscape of Shantou City in China. It is a fragmented mangrove area that is threatened by uncontrolled and irresponsible use, aquaculture, urbanization and adjustments in the water system that block tidal and fresh water flows. Through an ecological landscape design these challenges are addressed by increasing the forest and raise public awareness. This particular landscape architectural design approach focusses on the experience and regeneration of ecological processes in relation to the aesthetically value of the landscape itself. This brings the two objectives from a different domain of the project together in one design. The cultural domain is static assembly of human interventions and the ecological domain represents change of natural processes. The designers used this contrast as a tool emphasizes theses domains and make change and process visible (Loh, 2015).

RELEVANCE FOR BISCAYNE BAY
The design of Shantou Mangrove Forest shows how the challenges of Biscayne Bay are similar and can be addresses with an ecological landscape approach. Natural processes can be restored for the restoration of the mangrove landscape, but also for the experience of the users at the same time, in order to reconnect them to the landscape and learn how it functions.

CIRCULATIONS HABITATS PROGRAM



Ecological and cultural infrastructure. Variety of landscape typologies. Different kinds of activities.

FRAMEWORK ELEMENTS

Source: Shantou Mangrove Forest (Loh, 2015)

DIACHRONIC CHANGE SYNCHRONIC CHANGE

Development through processes Phenomena that occur through change

DEFINING CHANGE

Source: Shantou Mangrove Forest (Loh, 2015)

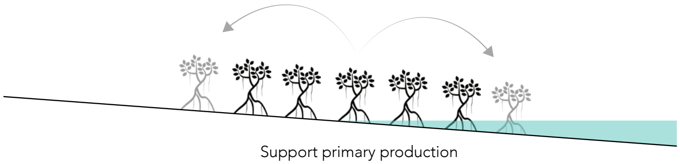
FRAMEWORK

The design framework is based on three systems which are illustrated in the image above. These systems are necessary to support the ecological dynamics and their experience by people. The circulations contain infrastructure for natural processes and routing on land and on water that connects different habitats of the park. Habitats accommodate space for ecosystems, such as mangrove swamp, mudflats and lagoons. Activities take place in the different habitats kayaking, fishing and hiking.

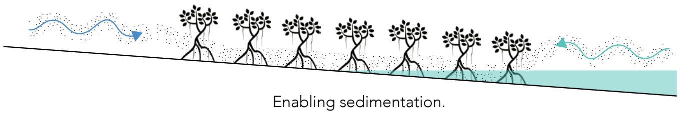
PROCESSES AND EXPERIENCE

In the design, processes and experience and interrelated in order to connect people to the landscape. It is stated that when you observe a landscape, you see the aesthetic value, but only by experiencing the landscape you can grasp the ecological value. Ecological processes are experienced by making change in the landscape. Two types of change are defined in order to implement them in the design. First, diachronic change, which is the development of a structure or landscape through processes. For example, submerged concrete objects are used to construct a reef. Oysters attach and while they grow, they form a reef structure together. In the meantime the concrete decays and eventually an independent oyster reef remains. Second is synchronic change, which is are reoccurring phenomena driven by changing biotic or abiotic factors of the landscape. An example of this are the influences of tides and seasons. Both types of change can be experienced in a different way and used to experience, and thereby value, the landscape (Loh, 2015).

After studying the best practices, the findings are summed up below, in a list of spatial and ecological principles that can provide conditions to restore and improve the mangrove landscape. On the follow pages they will be merged into a strategy for a spatial design for the coastline of Biscayne Bay.



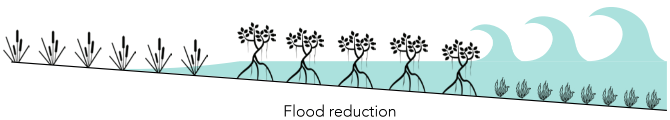
Support primary production



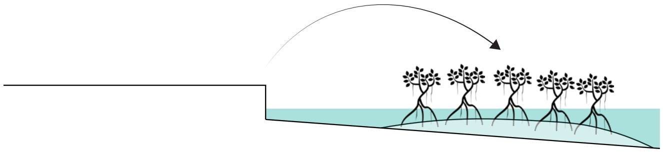
Enabling sedimentation.

RECOVERY CONDITIONS
As discussed in the Yucatan study, both reclamation and restoration, could be applied as recovery strategies for the mangrove landscape. In Biscayne Bay, reclamation can be used in the northern part of the bay, where no mangroves are found and their original habitat is taken over by urban development. Restoration can be implemented in all places where there is still place for new mangrove habitat and for the regeneration of existing depleted forest. Both strategies require conditions to support the recovery. Implementing these conditions in a design can be based on the principles of supporting processes that determine the spatial characteristics of the landscape, such as primary production of the forest and enabling sedimentation.

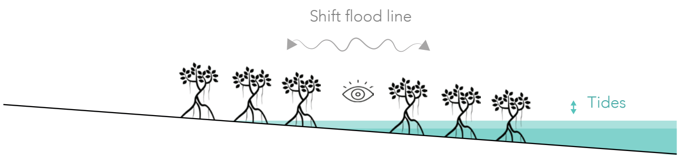
LAYERS AND BARRIERS
The mangrove landscape is a layered landscape, and by restoring the three layers, it can reduce flood risk of the Miami Metropolitan Area. In the design of Living Breakwaters, the meadow and the wetland are used to reduce flood and the mangrove levee to block flood. Because there is a lack of space onshore for the mangrove landscape in the urban zone, the principle of offshore barriers can be used to create new space for one or more of the layers and to benefit from its sedimentation processes.



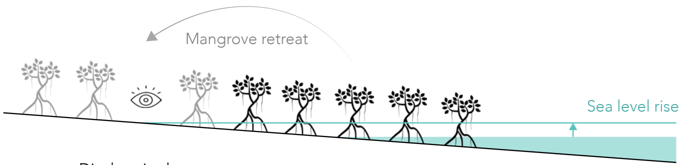
Flood reduction



Offshore mangrove barrier



Sychronic change



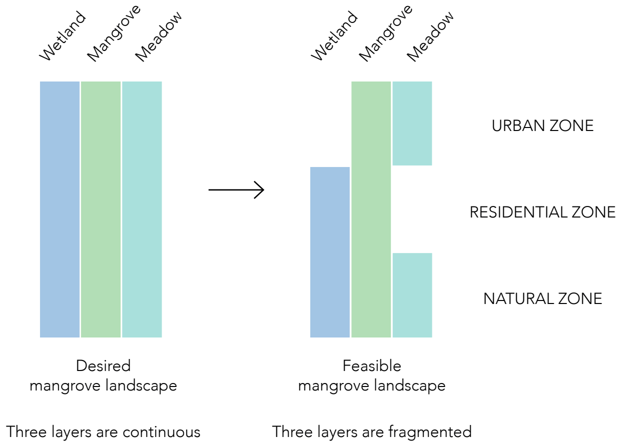
Diachronic change

VISUALIZATION OF CHANGE
In order to reconnect people to the mangrove landscape to raise their awareness for its function, the principle of visible ecological processes can be used, like in The Shantou Mangrove Forest. A social connection between user and ecological value of the landscape is established, by showing different forms of change to the visitors. Synchronic change for reoccurring phenomena, such as tidal difference, and diachronic change for single processes with a longer duration, like mangrove retreat as a result of sea level rise.

THE LAYERED LANDSCAPE
The challenge for Biscayne Bay is to restore the mangrove landscape, in order to reduce the flood risk of Miami Metropolitan Area, as well as provides aesthetic, ecological and functional qualities that contributes to the identity and resilience of this coastal region. Corresponding to this objective, the desired situation is illustrated below. It is a vertically continuous mangrove landscape, consisting out of the three layers, like the original mangrove landscape. As concluded in the analysis, these thee individual layers depend on each other and are interrelated through the water system. Also, the study of Yucatan leans that these layers are essential to rehabilitate the conditions for mangrove restoration, with principles such as fresh water flow connection and sedimentation supply (Zaldívar-Jiménez et al, 2010).
In Biscayne Bay, the desired situation of a continuous layered landscape and the interrelation between the layers is interrupted by the spatial limitations of the built environment and the current water system of each zone. Therefore, a feasible situation has been outlined, in the adjacent image. This is a fragmented but continuous mangrove landscape, which contains at least one of the three layers. These existing layers and fragments offer the opportunity to restore the desired landscape. The strategy is therefore to preserve, restore and reintroduce the layers in a design for a continuous mangrove landscape.

SHIFTING TYPOLOGIES AND BARRIERS
If there is no space for one of the typologies in the original zone, which is defined by the topography of the landscape, it can be shifted to an adjacent zone, such as illustrated in the image below on the left. This limits the space of one typology, but it enables adding a layer which makes the mangrove landscape more complete and resilient to storms according

The original mangrove landscape

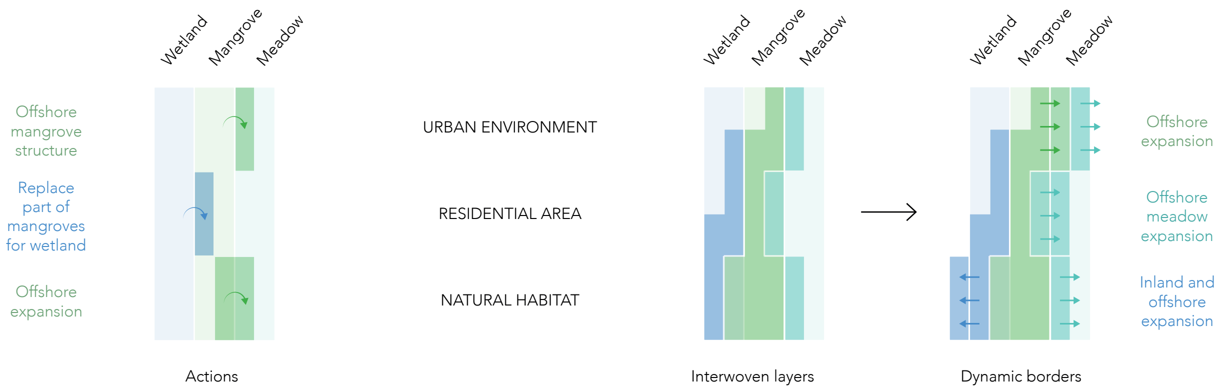


LAYERED STRATEGY

to the principle of Living Breakwaters (Orff, 2016). The application will be a mangrove landscape with interwoven typologies. However, the landscape is built up of three layers and therefore two layers are always on the outside and therefore have the possibility expand layers and create a dynamical landscape, as shown in the image on the right page. However, the direction depends on the space limitations of the zone, north in the urban environment, only offshore expansion is possible. South, both inland and offshore expansion are possible. Offshore expansion could be compared to the barriers placed along the coastline of Staten Island in the Living Breakwaters project. This principle would enable the mangrove landscape to expand outside the borders or its original habitat. This principle can also be applied to shift barriers to a zone where they can fulfill a more efficient role in coastal protection. In the current situation of Biscayne Bay, the coastline exist of barriers against flooding which are also barriers that block vital natural processes for the mangrove landscape and the connection between its users. The barriers of Living Breakwater were placed offshore, so that the dunes and the beach still can continue to exist for protection and for people to make use of these habitats.

EXPERIENCE OF THE LANDSCAPE

On the one hand, the aesthetic quality of Biscayne Bay can be displayed by guiding the user through the landscape and let them experience the different atmospheres. The ecological quality and flood protection function on the other hand, can only be valued by exposing the user to change. This principle can be applied through experiencing the tidal difference, sedimentations processes and mangrove movement because of changing sea levels. Synchronic change, such as tidal differences will make the user aware of the daily transformation of the landscape and the influence on its use. Diachronic change will learn the user what is going to happen in the future, such as rising sea levels that push mangroves further inland.



SHIFTING TYPOLOGIES

SPATIAL APPLICATION

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V

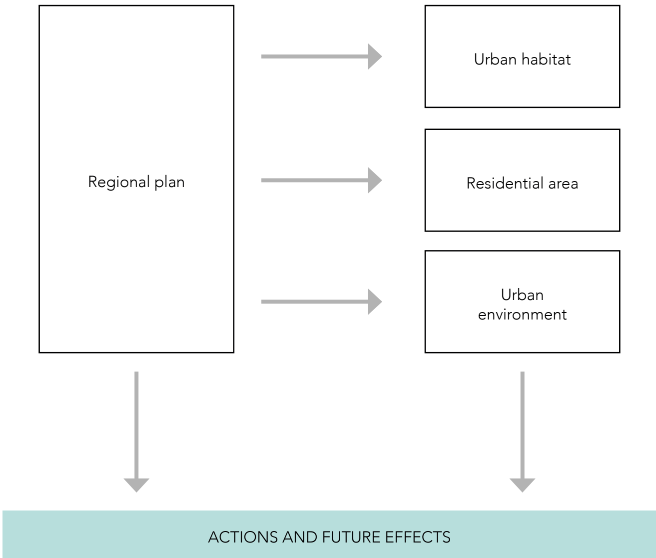
A new coastline for Biscayne Bay

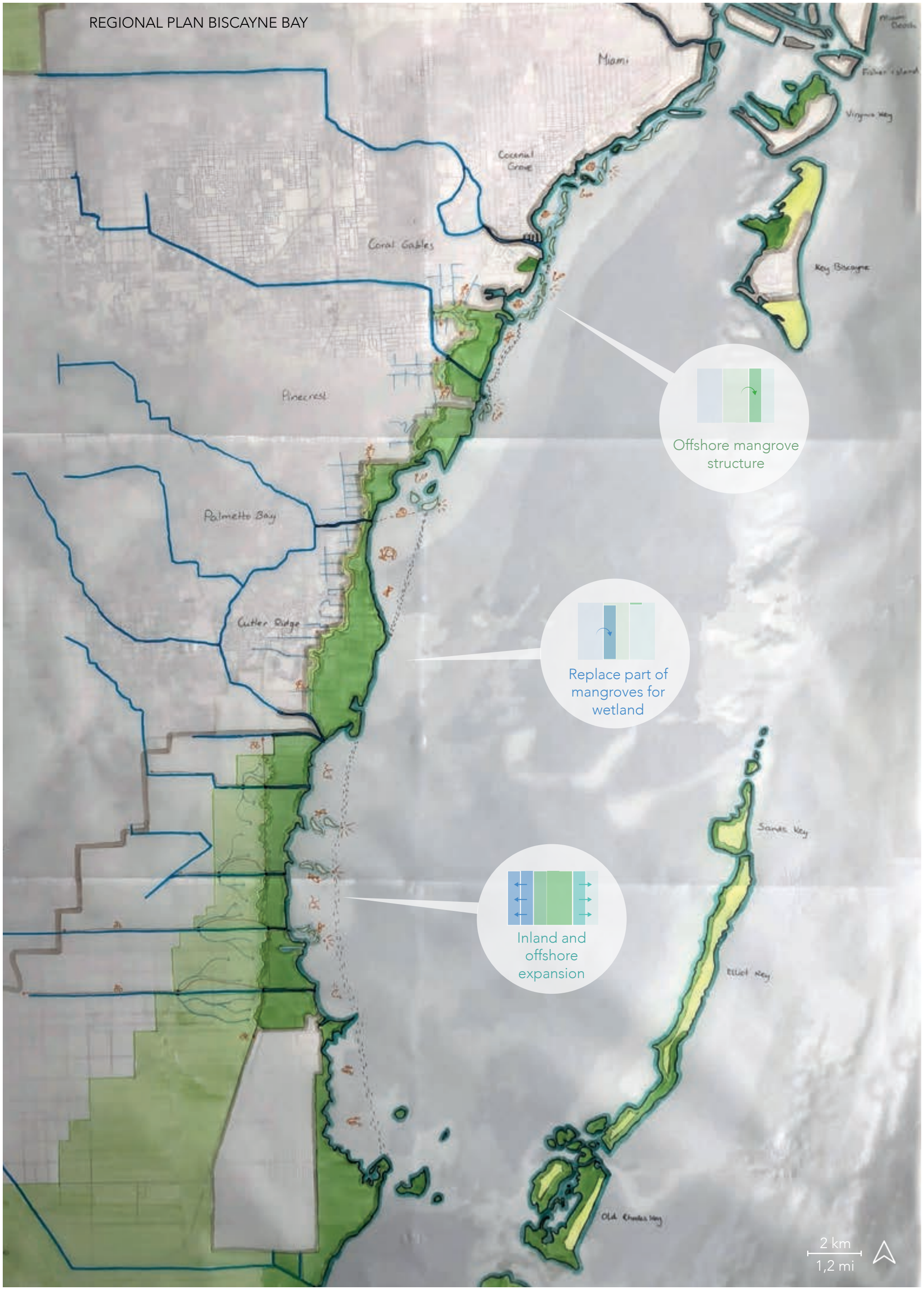
V A new coastline for Biscayne Bay

This chapter contains the application of the principles, found in the previous chapter, in a landscape architectural design for Biscayne Bay. This design consist of a region plan, three different elaborations in each of the predefined zones and conclusions. The regional plan covers the whole bay and works mainly with the principle of the layered landscape and shifting typologies to restores the mangrove landscape. For each of the elaborations, the site is analysed in detail and design concept is made according to the principles of the layered landscape, shifting typologies and barriers and visible change. The conclusions discuss a time line and the actions that need to be taken in order to successfully implement this plan.

This chapter addresses the third research question:

What are the spatial possibilities to create the needed conditions and reconnection in Biscayne Bay and how can they be made resistant to threats such as sea level rise and tropical storms?




REGIONAL PLAN BISCAYNE BAY
Miami
Coral Gables
Pinecrest
Palmetto Bay
Cutler Ridge
Key Biscayne
Offshore mangrove structure
Replace part of mangroves for wetland
Inland and offshore expansion
2 km
1,2 mi

MANGROVE RESTORATION LINE

The regional concept is based on the objective of restoring the mangrove landscape along the coastline of Biscayne Bay. In order to define the design area, a coastal zone is selected for interventions to take place. This zone is corresponding with the original mangrove distribution, found in the analysis. In the image on the right, the turquoise area marked for mangrove forest restoration and wetland and sea grass meadow (re) introduction. The shallow topography of the bay marks the outer borders of the landscape and is shown with a bold restoration line.

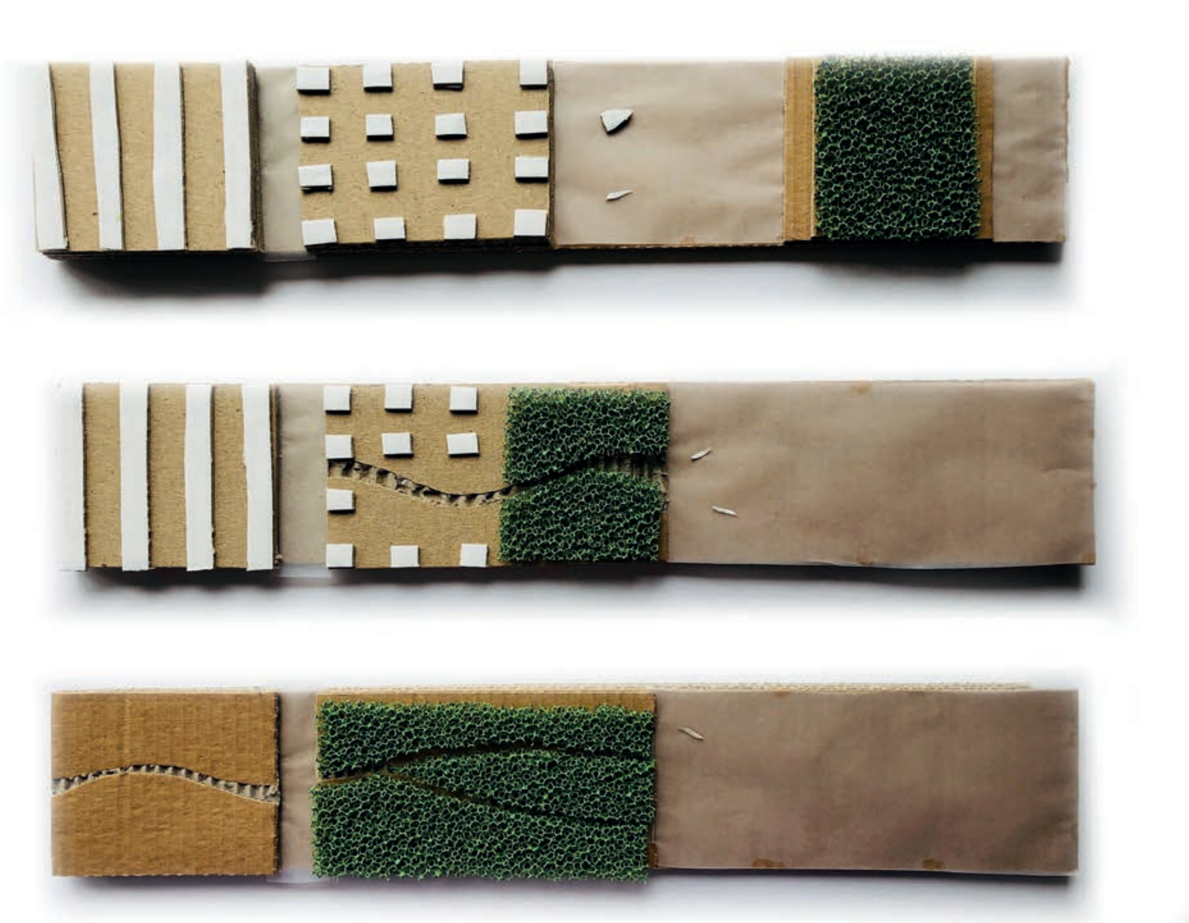
REGIONAL PLAN

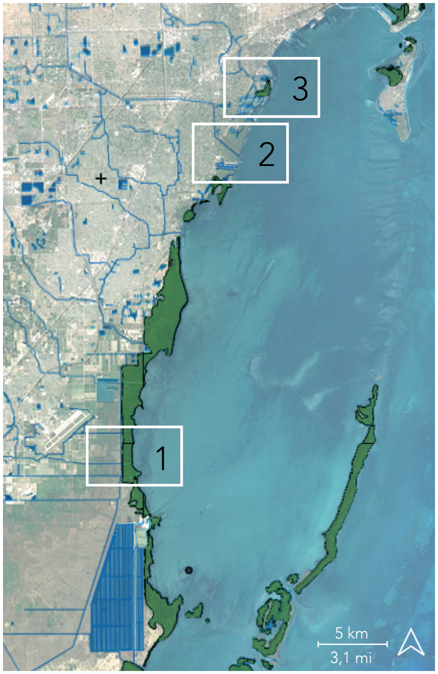
In the regional plan on the left page, the layered landscape principle is applied on the coastal area of Biscayne Bay. The restoration line is used to define the outer barrier of the mangrove landscape and the design interventions. In the northern urban zone, offshore mangrove structures are placed on the restoration line, in the parts without substantial mangrove forest. This elongated structure of islands creates new small lagoon in between the coastline of the main land, which can be used for local recreational purposes for the residents of the adjacent neighborhoods. In the residential middle zone, a part of the mangroves are replaced for wetland, according to the shifting typologies principle. Another elongated structure, that creates a new zone in between the mangroves and the residential area. The wetland offers opportunities for recreation and water storage, and is a soft border between the mangrove and residential areas. In the southern natural zone, wetland and meadow are connected to the mangroves by implementing the shifting barrier principle. Removing vertical water structures that are disturbing the interaction between the three layers of the landscape, rehabilitates the conditions for the mangroves and allows them to retreat and expand.

ONE SYSTEM

Considering the mangrove landscape as a system, process, structure and actor find their place in the design. By the means of detailed elaborations of each zone, the elements of the system are explained. These focus areas prove that regional plan for the mangrove landscape as a whole, can function as one system in order to reduce flood risk, restore its ecological value en reconnect its users.

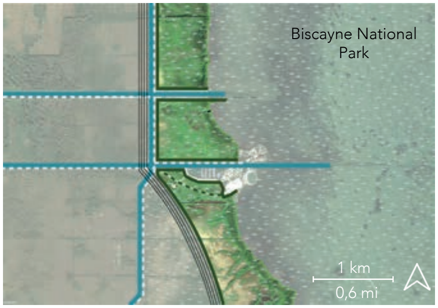
EXPERIMENTING WITH PRINCIPLES
In order to implement the principles on a local scale, they were tested in a model experiment. The image below shows the three zones of Biscayne Bay with possible interventions, that are based on the design principles that are defined in the previous chapter. These experiments provide insight into the relationship between the interventions and the existing environment. These experiments provide insight into the spatial language of the interventions. Such as the possibility of implementing the three layers of the mangrove landscape and the relationship between the interventions and the existing environment. The order of the models below is: Urban, residential and natural.



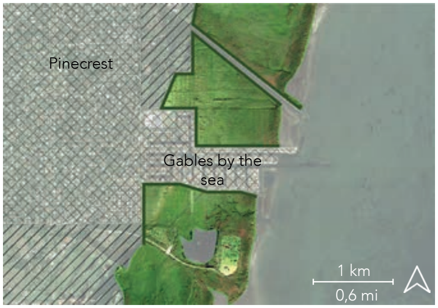


LOCATION FOCUS AREAS

1 NATURAL FOCUS AREA



2 RESIDENTIAL FOCUS AREA



3 URBAN FOCUS AREA

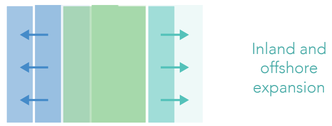
FOCUS AREA

In the analysis the coastline is divided in three zones: natural, residential and urban. A focus area, that best represent the diversity of Biscayne Bay, is assigned to each of these zones, to elaborate the design and prove the approach of restoring the mangrove landscape. The areas are marked on the map above and local scale maps shown on the right. The natural focus area (1) contains the three landscape types of the mangrove landscape around the visitors centre of Biscayne NP. The residential focus area (2) is defines by fragmented mangroves and gated neighborhoods around Snapper Creek Canal. The urban focus area (3) is located around the northernmost mangrove fragments and the Coral Gables Waterway. This area has a high urban density and lack of space for mangrove landscape. The next sub chapters will elaborate on each of these areas.

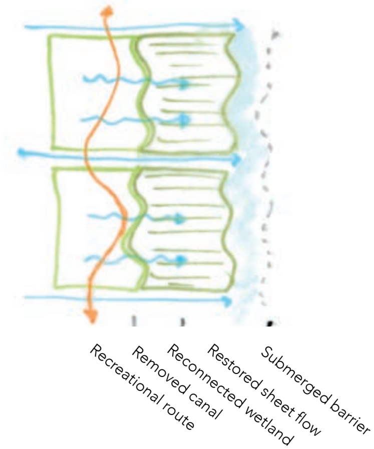
BREAKING BARRIERS

The natural area is characterized by the presence of all three layers of the mangrove landscape. The cross section on the next page shows the current situation with a depleted and dried-out wetland, mediocre mangrove forest and mediocre sea grass meadow. The wetland and the forest are disconnected from the water system by the construction of a water system as a superimposed grid of canals. According to the principle for the rehabilitation of mangroves, barriers are broken so that the natural water flow can recover, as illustrated in the drawing below. The north-south channel L31E is cut off from the water system and the adjacent levee is partly removed. This channel is part of a water system constructed to drain a completely cultivated the landscape, but this was never realised. Therefore, this channel can be considered as unnecessary and switched to natural drainage of the land, through the processes in the mangrove landscape. As a result, the mangroves and wetland will merge into a transition area and the border will fade, like in the drawing on the right. According to the layered principle, a vital mangrove landscape with layers functioning as flood mitigators and barriers, and therefore contribute to reduce flood risk. The sea level of a storm surge will reduce and thereby the inland flood line.

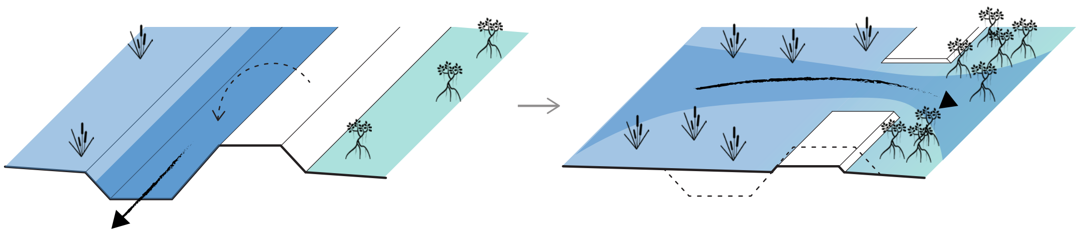
PRINCIPLE



CONCEPT MAP

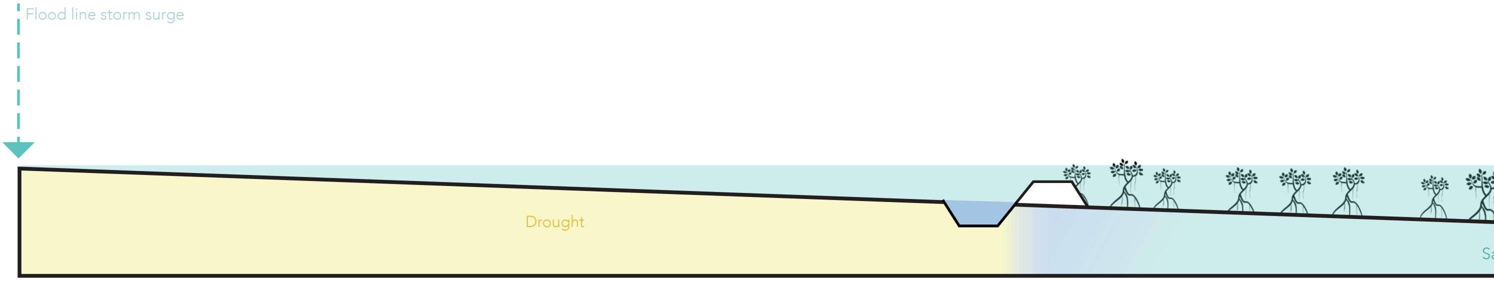


RECONNECTING WETLANDS TO MANGROVE

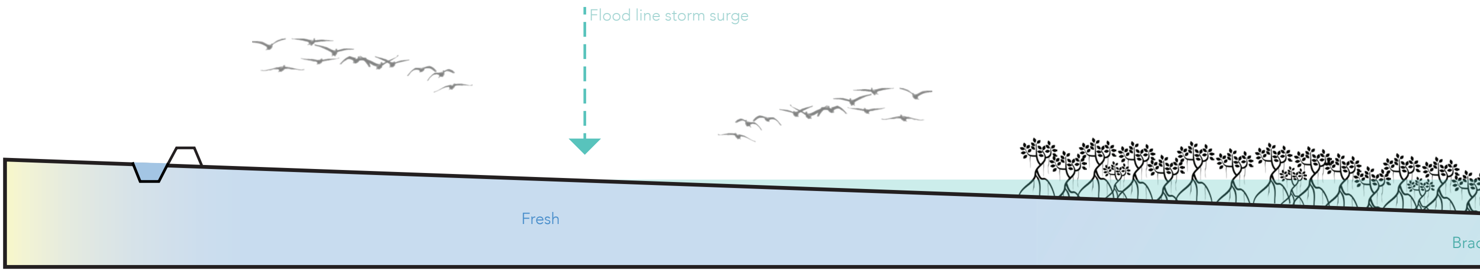


FILLING UP CANAL

RESTORED SHEET FLOW

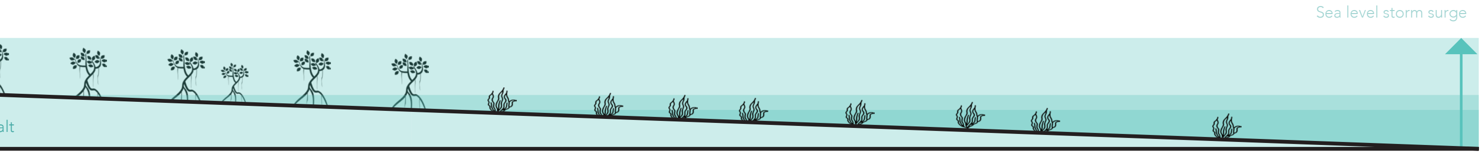


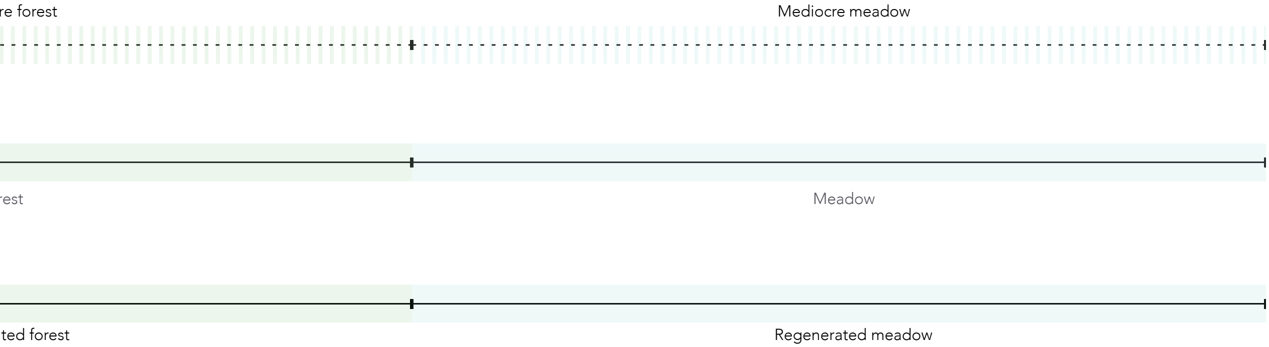
SECTION OF THE CURRENT NATURAL LANDSCAPE

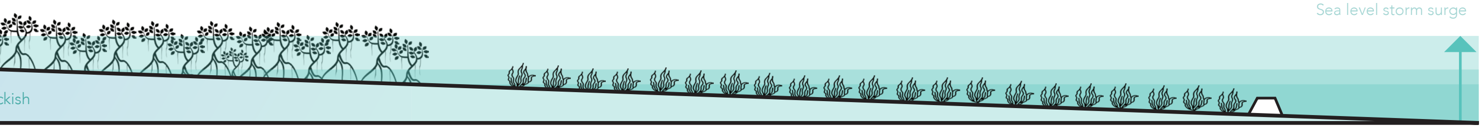


SECTION OF THE DESIGNED NATURAL LANDSCAPE

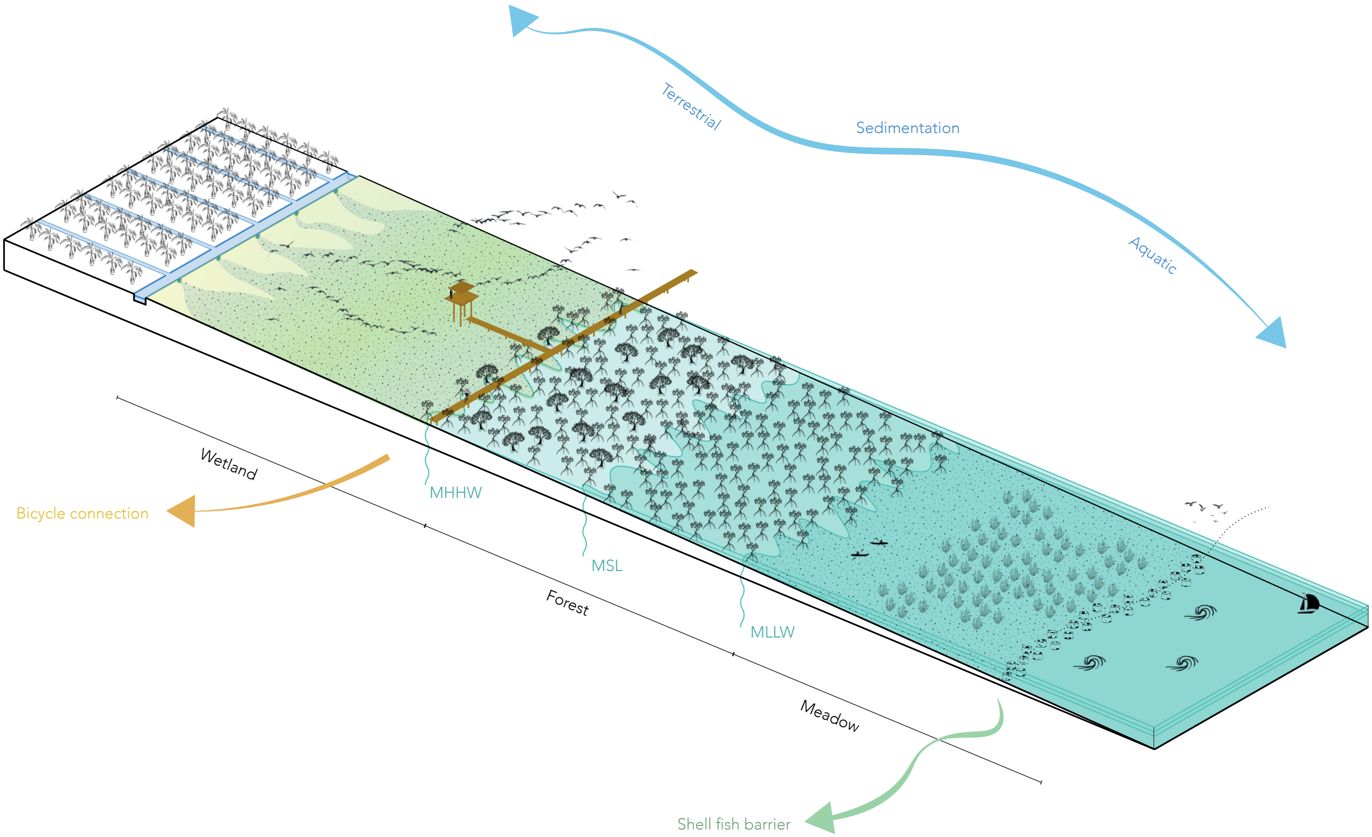
IMPLEMENTATION







OF THE PRINCIPLES

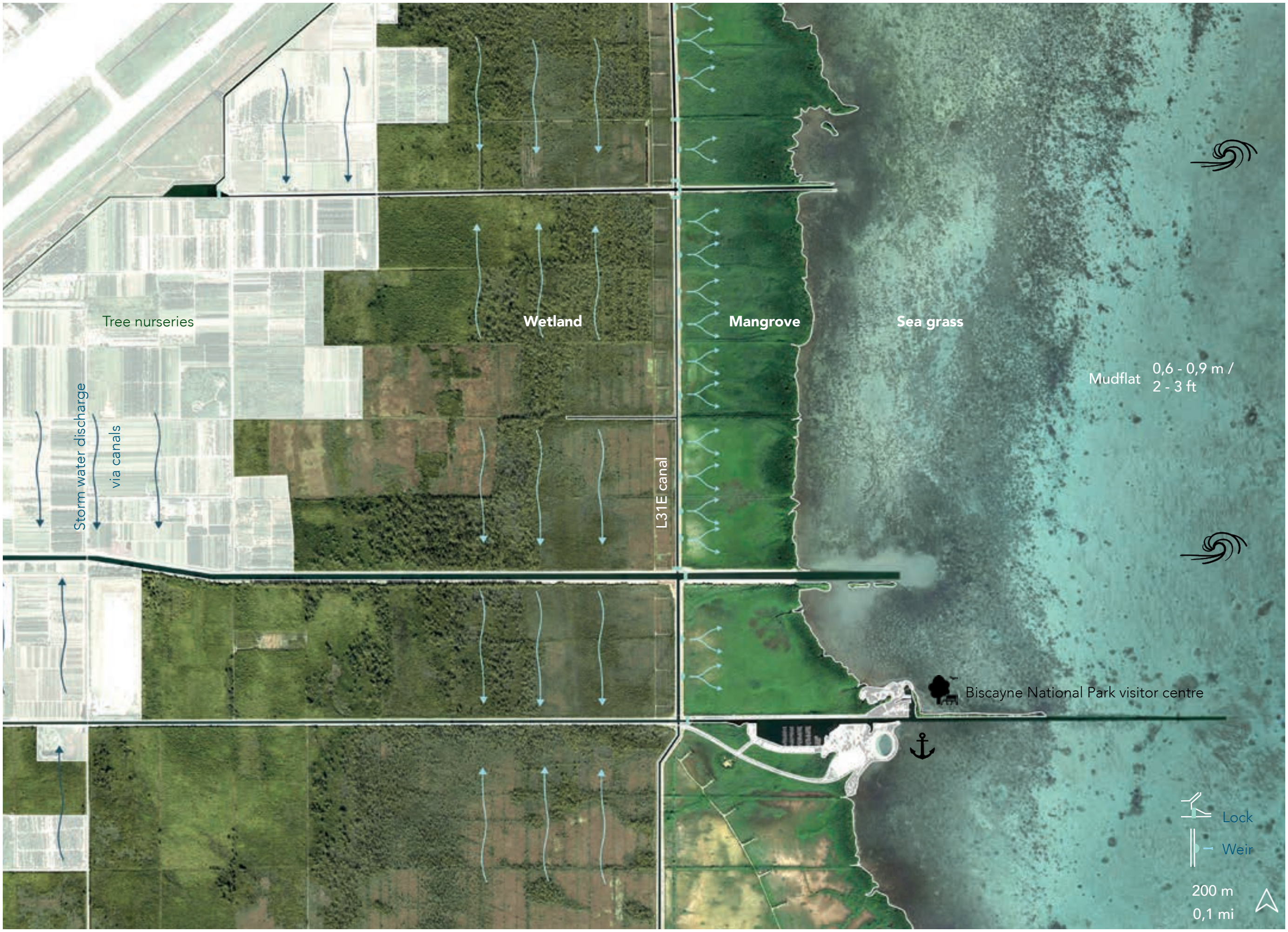


ISOMETRIC PROJECTION OF THE DESIGN FOR THE NATURAL ZONE

LANDSCAPE SYSTEM OF THE NATURAL ZONE

Breaking barriers changes the landscape system. The sedimentation process (blue arrow) is given free rein, whereby on the one hand tidal influence can infiltrate further into the land, but on the other hand gets resistance from the sheet flow. To get this sheet flow going, a fresh water source is needed. Through openings in the levee between the water system of the tree nurseries in the west and the wetland, the water flows slowly towards the bay through the slight difference in height. These weirs contain a threshold, which means that the water is gradually let through and does not discharge in one go during the dry season. A new barrier is introduced offshore (green arrow). This is a submerged construction of minimal material, that supports the growth of shellfish. Firstly, this will contribute to the sedimentation process that benefits the sea grass meadow and therefore the levee formation in the forest. Secondly, shellfish like eastern oyster filter the water, which is important for the health of the ecosystem. Thirdly, the oyster reef absorbs wave energy which means flood risk reduction. Right in the flood line of high tide (MHHW) lies a connective route for pedestrians and cyclists (yellow arrow). In this transitional and dynamic zone between wetland and mangrove, the user can experience the landscape by seeing different types of change. During water levels above MHHW, the whole route can be flooded, which learns the user the function of the landscape layers. The image on the right gives a birds eye impression of the interventions.

BIRDS EYE IMPRESSION



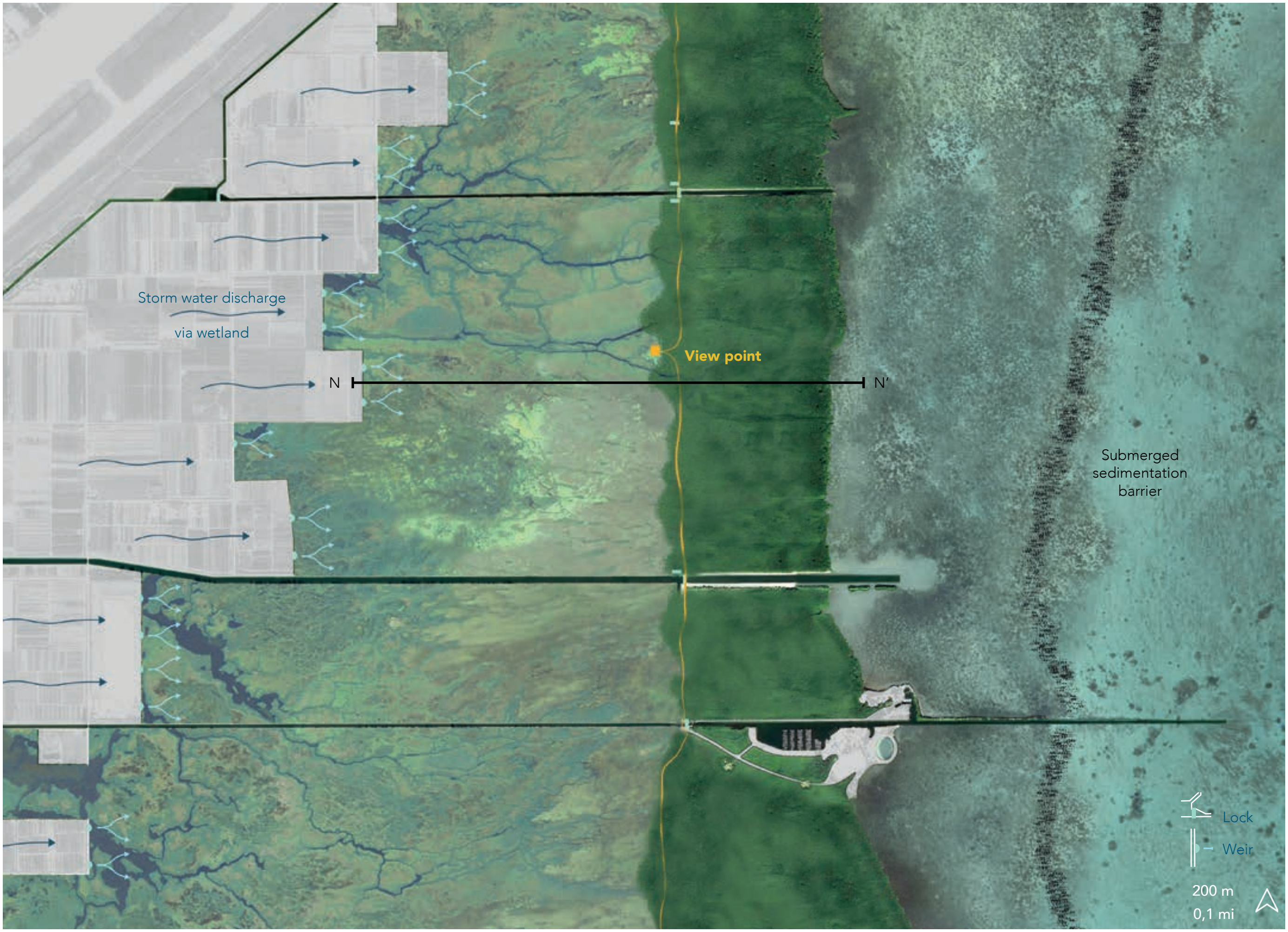
CURRENT SITUATION OF FOCUS AREA ON LOCAL SCALE

Map based on USGS The National Map (2019) and Google Earth

CURRENT SITUATION

The range of the focus area, shown in the map above, represents the entire natural zone of Biscayne Bay. The L31E channel runs parallel to the coastline until the residential zone begins. This canal does not only block inland retreat of the mangrove forest, but also disconnects the degraded wetland from mangroves.

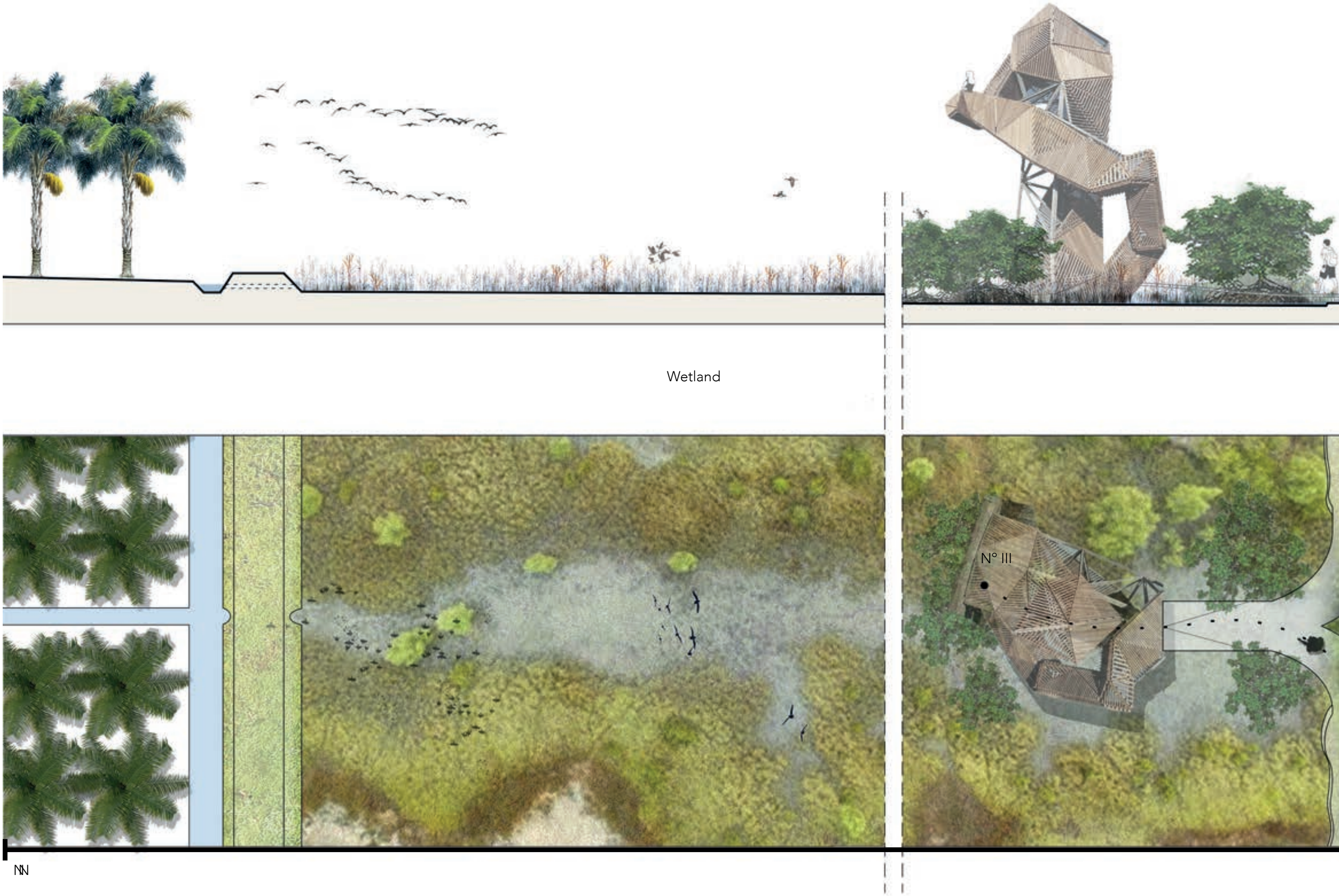
Storm water from both the tree nurseries and the wetland is discharged via the canal system towards the bay. Though, some water from the L31E canal is flowing gradually into the mangroves by a series of weirs. However this is not sufficient for the tidal forest to thrive and to control the salinity levels of the soil.

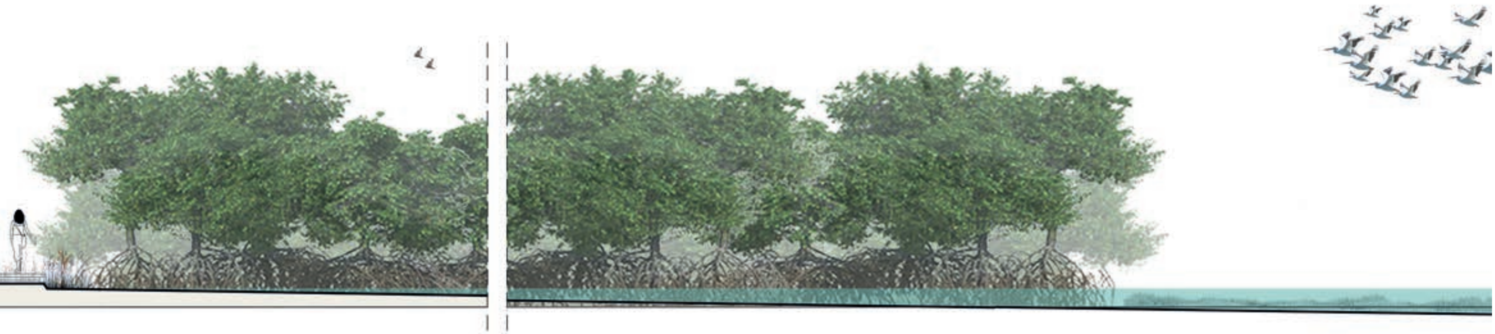


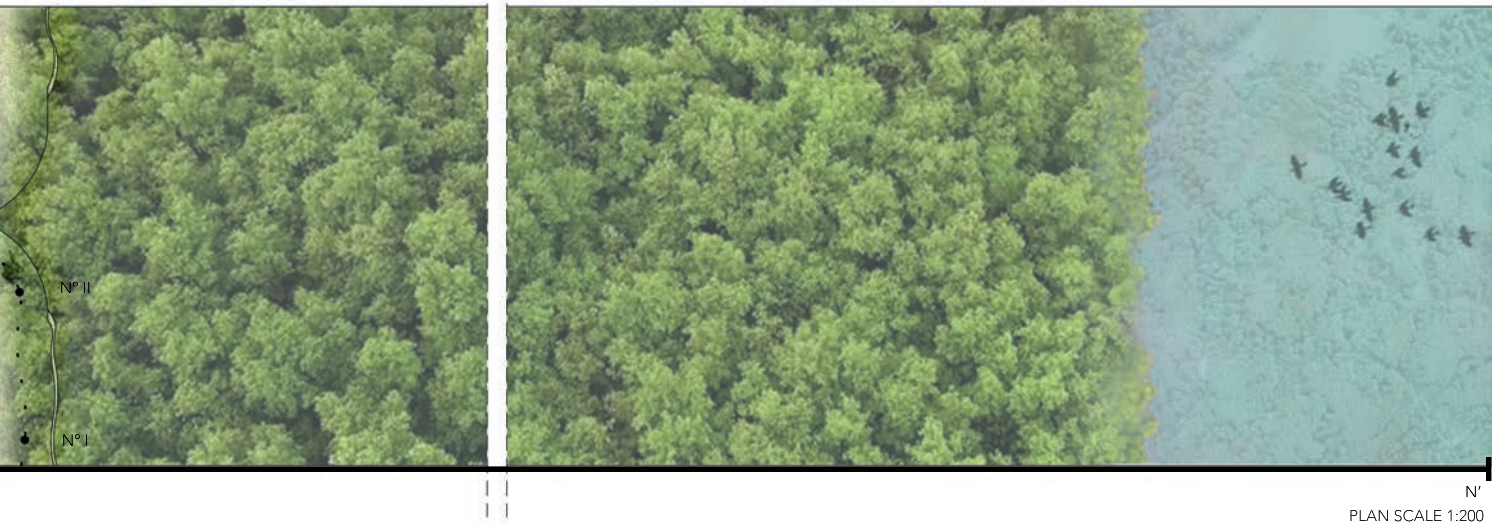
DESIGN OF FOCUS AREA ON LOCAL SCALE

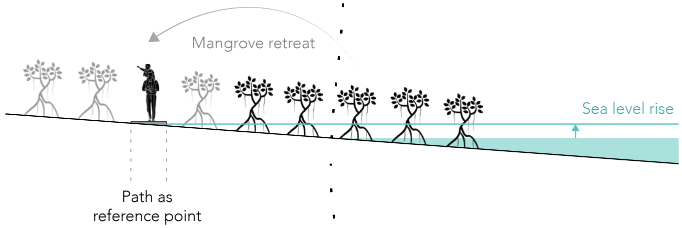
NEW SITUATION

The map above shows the design of the focus area. The L31E canal is removed and the wetland is reconnected to the mangrove forest in a dynamical transition zone. Also the wetland is restored by placing weirs between the water system of the tree nurseries and the wetland itself. The storm water is now discharged via the wetland and the original sheet flow is restored. The little height differences of the landscape determine the direction of the sheet flow and daily tidal influences. The bicycle and hiking route through the transition zone connects the Everglades with the residential area. The submerged sedimentation barrier offshore enables more sedimentation and seaward mangrove expansion, but also generates a calm water based recreation area at the visitors centre and marina.


Wetland
N° III
NN


Mangrove forest
Sea grass meadow
SECTION NN' SCALE 1:200


N° II
N° I
N'
PLAN SCALE 1:200

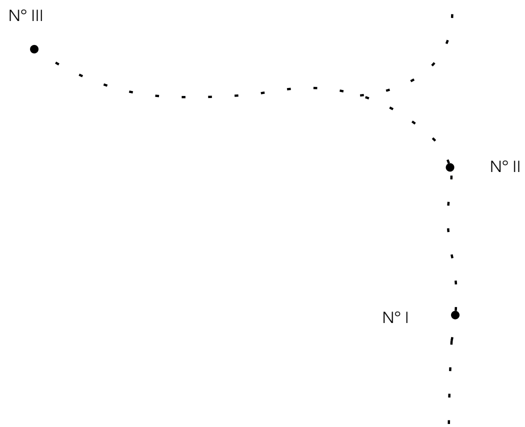


FROM THE EVERGLADES TO CUTLER RIDGE

The proposed route in the design goes through Biscayne NP, from the Everglades in the south towards the residential zone of Cutler ridge in the north. It connects the residential area with the natural mangrove landscape. The experience of the route is illustrated by means of a spatial sequence with three eye level impressions. The numbers of the route are corresponding to the detailed 1:200 map and the eye level impressions. Protruding elements represent the interventions.

MANGROVE MOVEMENT EXPERIENCE

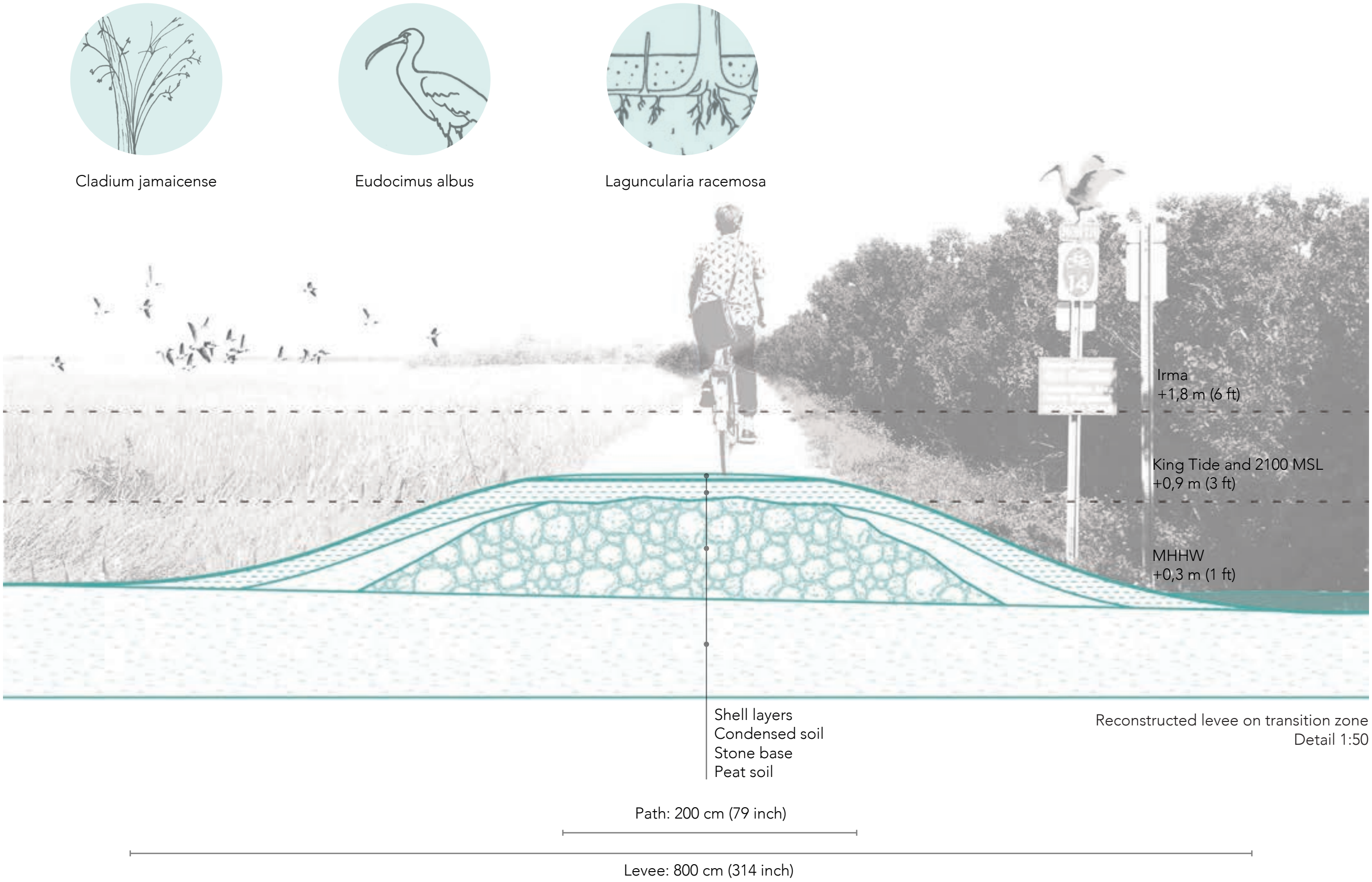
The linear route through this area has a double function. On the one hand creating accessibility in this mainly wet area and on the other hand functioning as a reference point. The path is a static element in a dynamic landscape, which gives the user a reference to observe change to experience and value the landscape. The route marks the borders of the wetland and the forest on the current MHHW line, but over time, sea level rise will push this line will inland. This form of diachronic change can be observed as mangroves retreating inland and MHHW passing the raised path.



SPATIAL SEQUENCE N° I

SPATIAL SEQUENCE N° II

SPATIAL SEQUENCE N° III



Reconstructed levee on transition zone
Detail 1:50

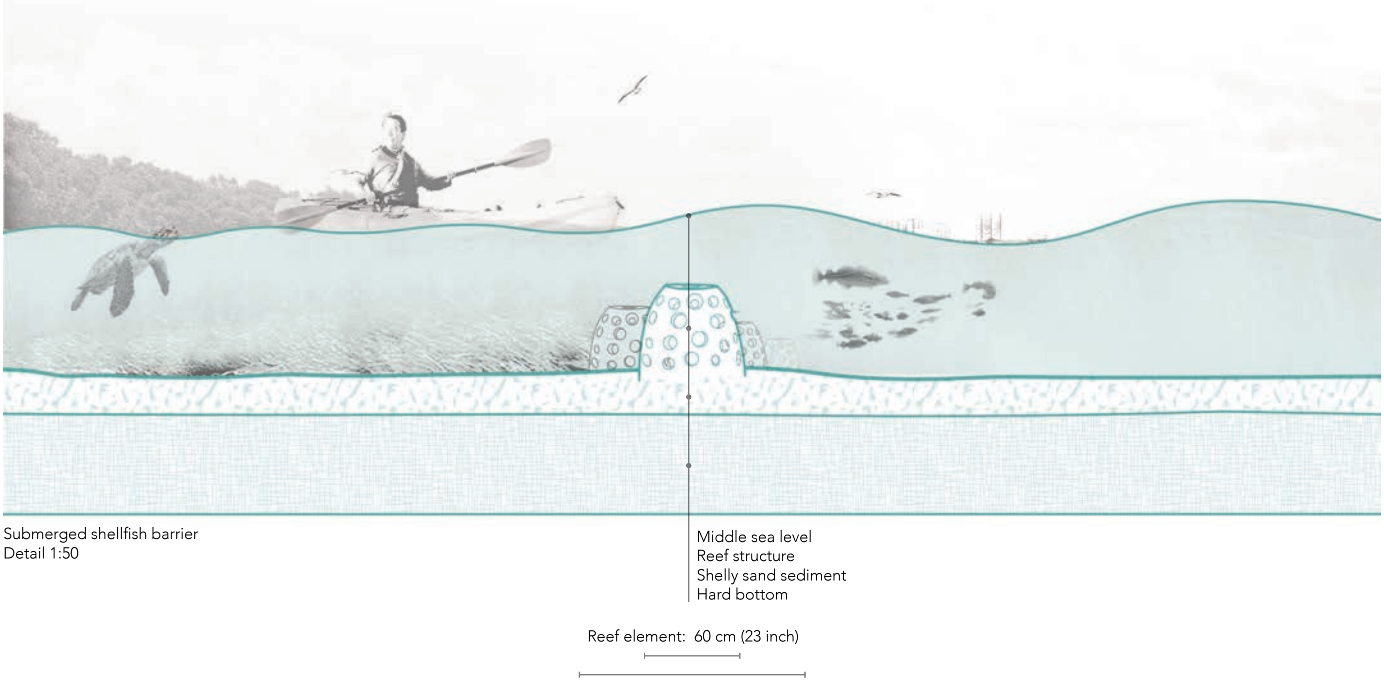
DETAIL OF THE RAISED ROUTE

An important intervention in the natural zone is removing the barrier between the wetland and mangrove forest. However, part of this barrier will remain to make the landscape accessible for its users. In this zone, only the high tide (MHHW) and altering high water levels will enter, which is an ideal habitat for the black mangrove (Laguncularia racemosa). In the adjacent wetland, saw grass (Cladium jamaicense) grows, which is an indispensable source for sediments and habitat to variety of wading birds like the white ibis (Eudocimus albus). In the 1:50 detail above, the reconstructed levee is shown in an initial stage of the plan. At this point the levee blocks both the terrestrial and aquatic water flow. However, a little further there is a board walk, which allow water to flow freely. The whole route is a combination of alternately levee and board walk. As the sea level rises further, the water can flow over the entire length of the route and the transitional zone will move further inland. The levee is reinforced with stones and condensed soil, so that it can withstand the influence of the tides and rainy seasons.


Caretta caretta


Thalassia testudinum


Crassostrea virginica

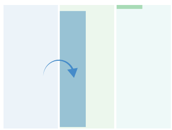


DETAIL OF THE SHELLFISH BARRIER
The submerged reef is a shifted barrier in the mangrove landscape. It functions as a breakwater that decreases the water speed by the absorption of wave and current energy. This results in the deposit of shelly sand sediments, which are essential for the sea grass meadow. This meadow consists mainly of turtle grass (Thalassia testudinum) and the loggerhead sea turtle (Caretta caretta) is the most important maintainer of his layer. The reef also acts as a threshold, in order to keep the sediments in place. This speeds up the silting process in the meadow layer of the landscape and will make the seabed shallow enough for mangrove expansion seaward. Shellfish, crustaceans and fish will live on and around the reef that play an essential role in the circular footpath of this landscape. For example the eastern oyster (Crassostrea virginica) which filters the turbid water and allows other fish to thrive here. Both of these residents have a commercial and recreational value and calm water between the mangroves and the reef is safe for fishermen, divers and kayaking

WETLAND BYPASS

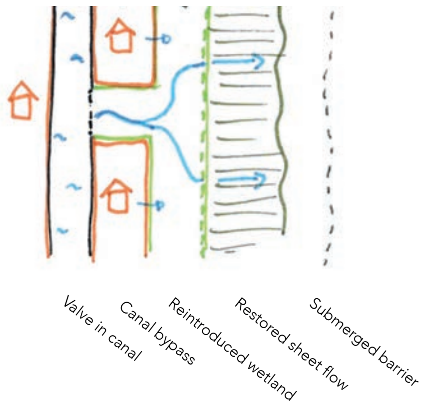
In a residential environment, the mangrove landscape is enclosed between buildings and the bay. The low-rise neighborhoods have taken the place of the wetland and are located right next to the mangrove forest. In the sections on the next page you can see that this forest, but also the meadow, is in mediocre. This is because there is no natural supply of sediments through sheet flow. To rehabilitate the conditions of the forest, the principle of moving layers is applied. Part of the mangrove forest is cleared for wetland and forms a transition zone between buildings and mangrove, but also a bypass between the artificial and the natural terrestrial water system. To provide this wetland with a fresh water stream, a new passage has been made between the Snapper Creek Canal. A valve ensures that the water gradually enters the passage and spreads across the wetland towards the mangrove, as shown in the concept map on the right. A continuous submerged barrier offshore accelerates sedimentation, which allows the forest to expand seaward and create dynamic borders.

PRINCIPLE

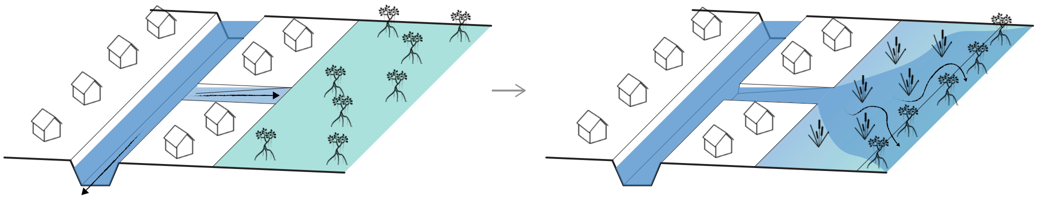


Replace part of mangroves for wetland

CONCEPT MAP

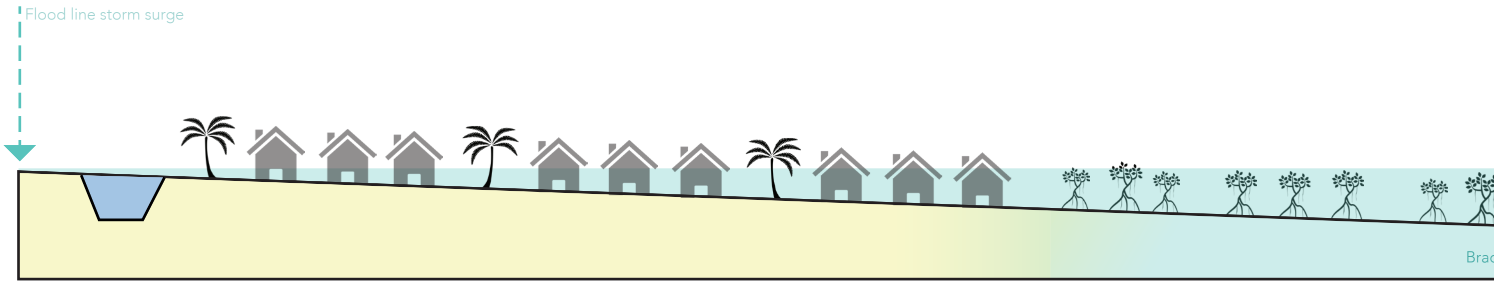


CANAL BYPASS FOR WETLAND INTRODUCTION

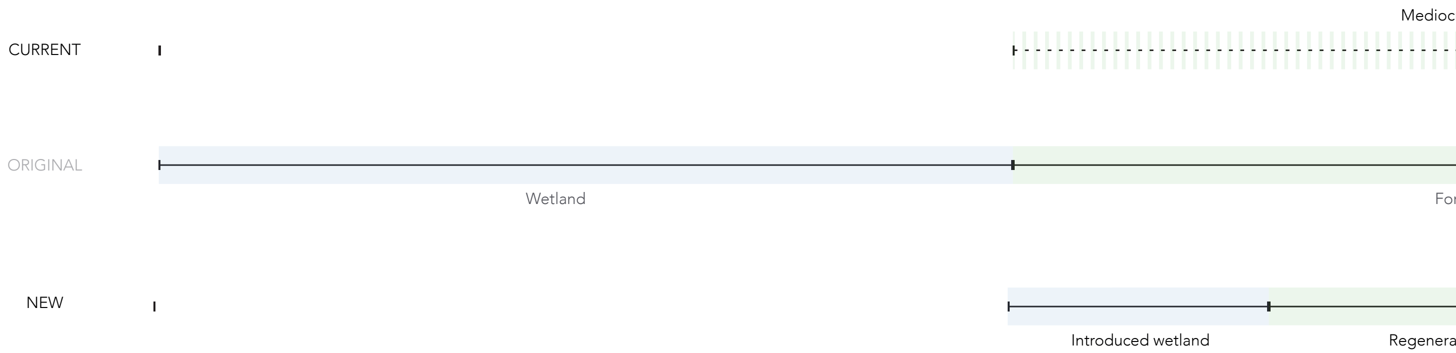


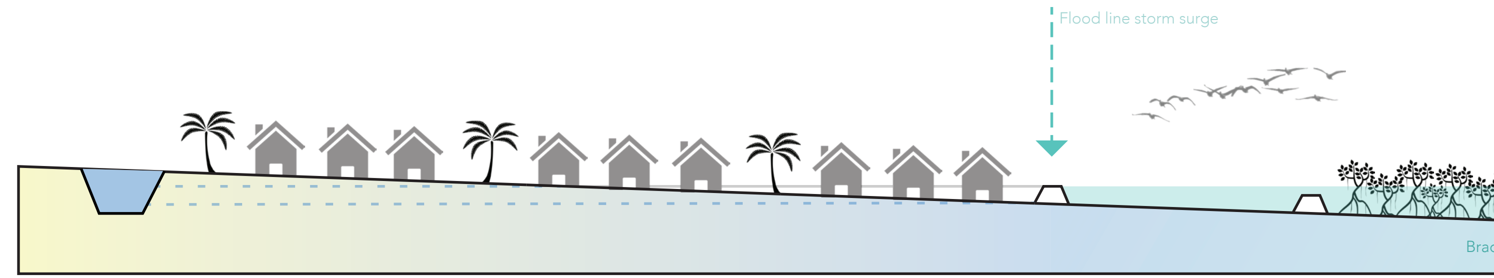
NEW CANAL PASSAGE

FRESH WATER ENABLES WETLAND AND SHEET FLOW



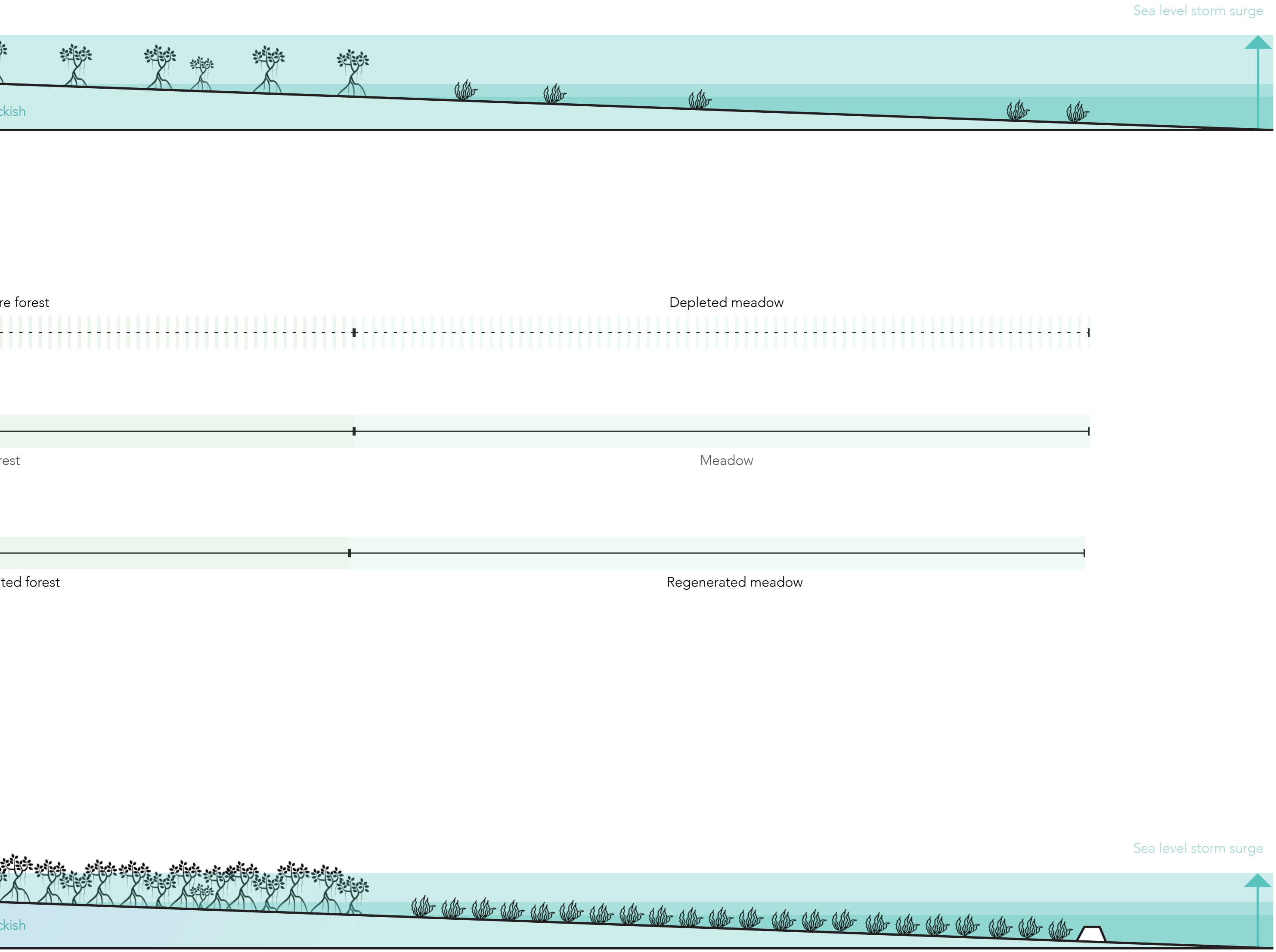
SECTION OF THE CURRENT RESIDENTIAL LANDSCAPE



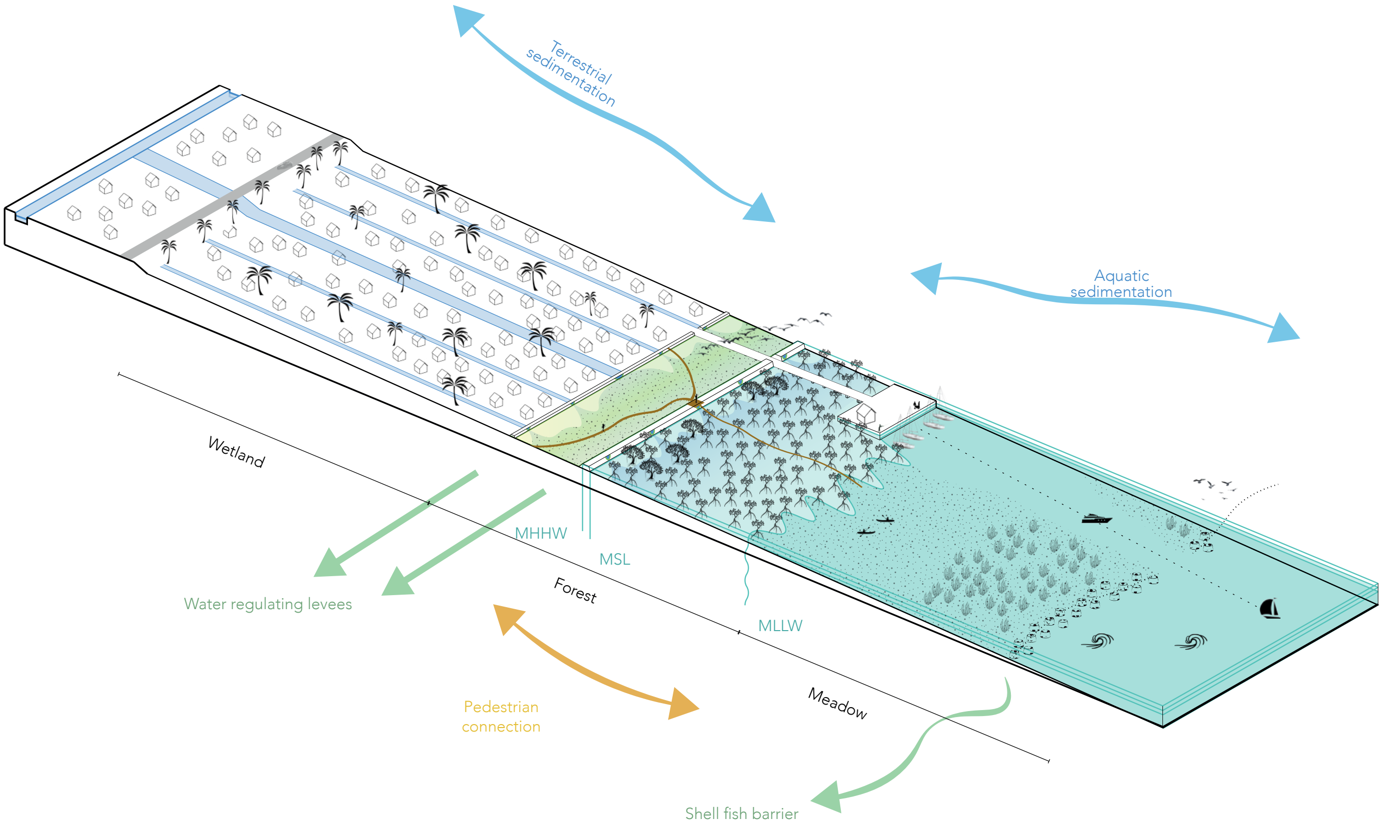


SECTION OF THE DESIGNED RESIDENTIAL LANDSCAPE

IMPLEMENTATION



OF THE PRINCIPLES



ISOMETRIC PROJECTION OF THE DESIGN FOR THE RESIDENTIAL ZONE

LANDSCAPE SYSTEM OF THE RESIDENTIAL ZONE

The construction of a canal bypass and the reintroduction of wetlands is changing the landscape system. The bypass releases fresh water gradually and a new sedimentation flow has emerged (upper blue arrow) that carries terrestrial sediments to the mangroves. Aquatic water flows (lower blue arrow) are blocked at the border of forest and wetland, to prevent flooding at high water level (MHHW). A second lower barrier between the wetland and the neighborhood blocks deviating water levels above MHHW. In addition to the wetland, a new structure can also be found in the landscape. This is a submerged barrier reef (green arrow) such as in the natural zone, for sedimentation and wave breaking. A hiker's route (yellow arrow) runs through the mangrove landscape, so that the different layers can be experienced. During water levels above MHHW, the forest part of the route could be flooded, which learns the user the function of the extra barriers. The image on the right gives an birds eye impression of the interventions.

BIRDS EYE IMPRESSION

CURRENT SITUATION OF FOCUS AREA ON LOCAL SCALE

Map based on USGS The National Map (2019) and Google Earth

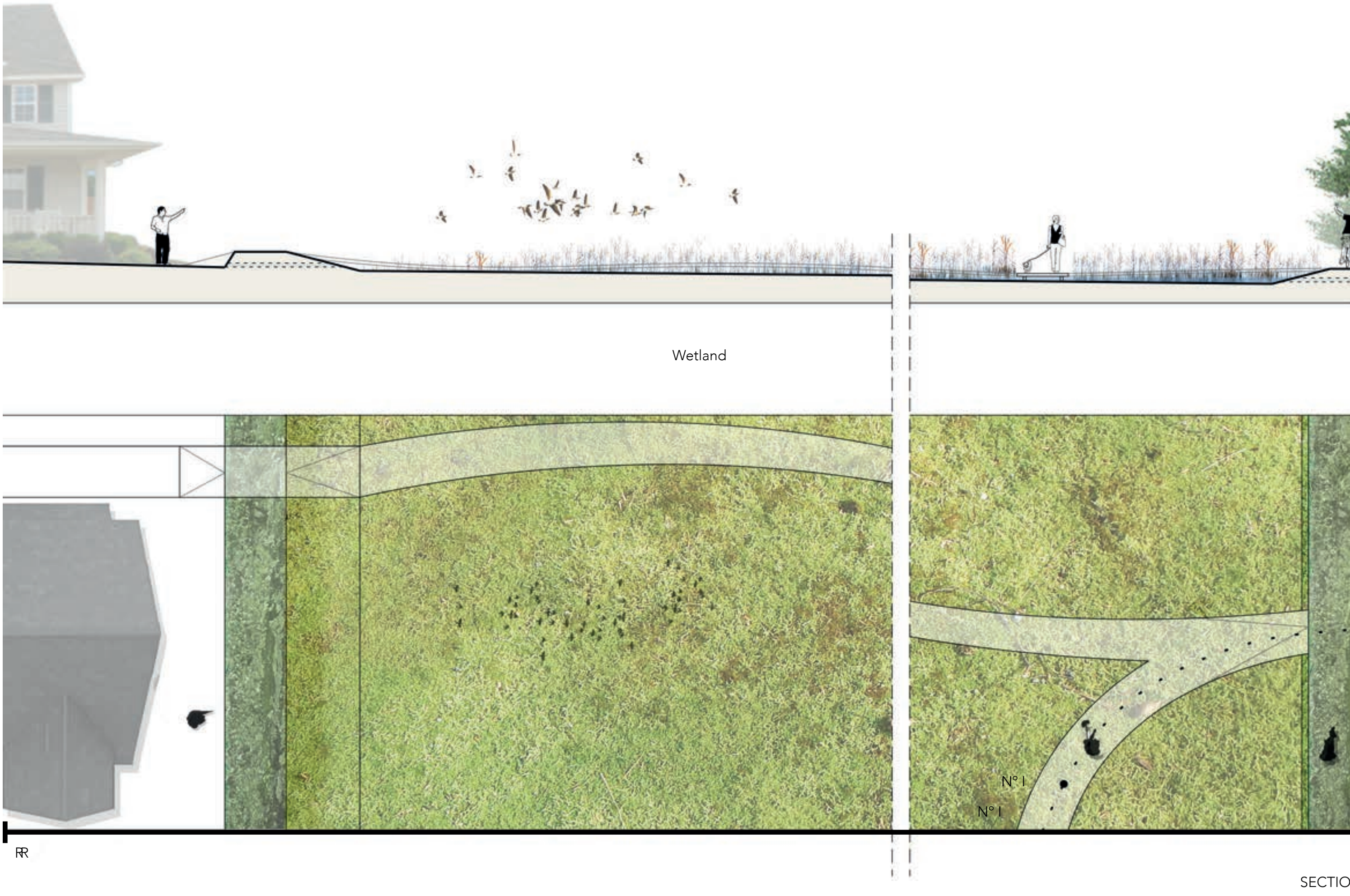
CURRENT SITUATION

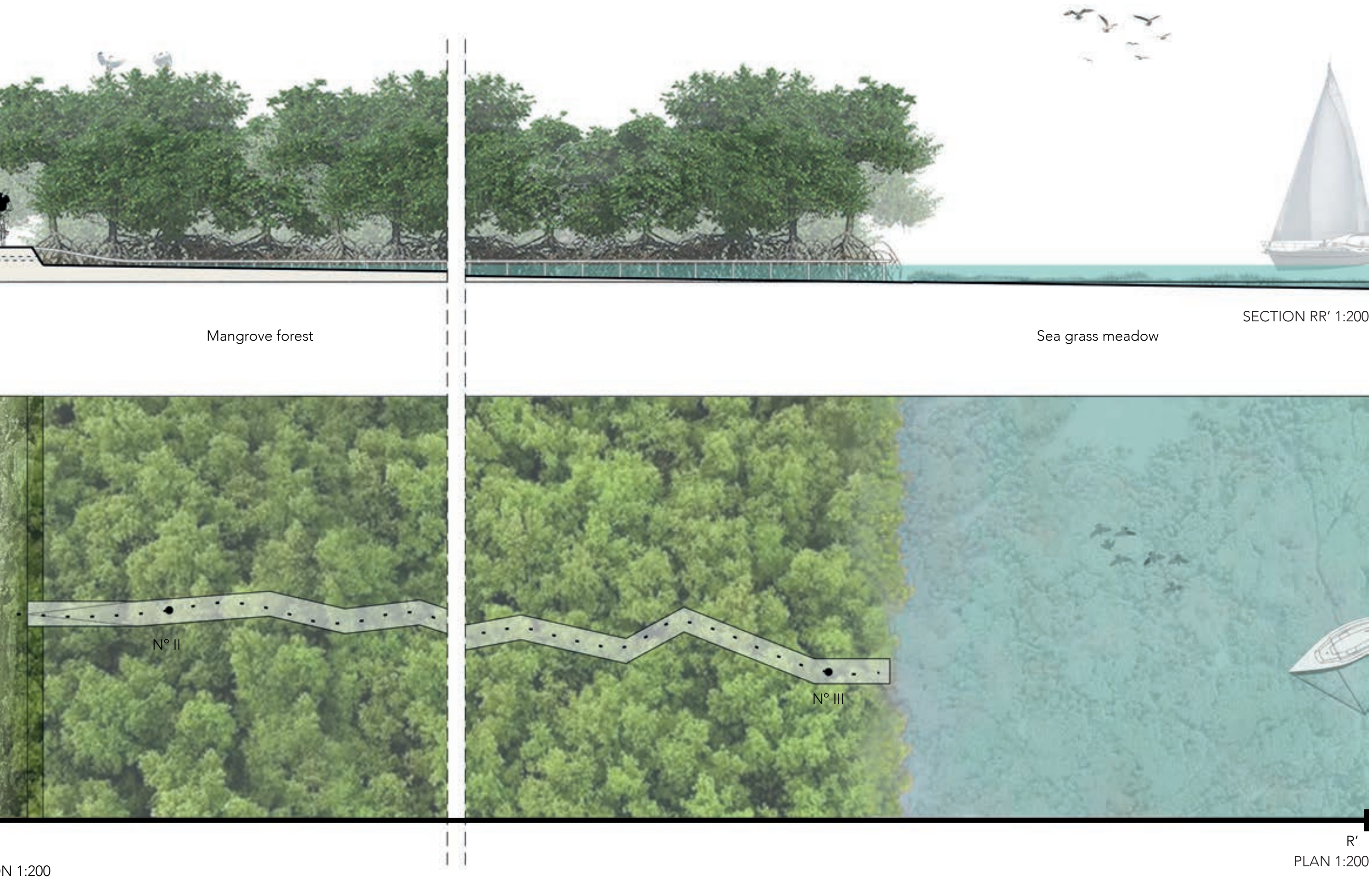
The range of the focus area, shown in the map above, represents the entire residential zone of Biscayne Bay. Open canals without a lock like Snapper Creek Canal and mangroves fragments like the one between the neighborhoods Gables by the Sea and Old Cutler, appear all along the coast in this zone. Storm water from the surrounding neighborhoods is discharged in the canal and directed towards the bay. The mangroves cannot fulfill their protective function because of a lack of fresh water flow. This results in a barren intertidal strip which is vulnerable for erosion and flooding.

DESIGN OF FOCUS AREA ON LOCAL SCALE

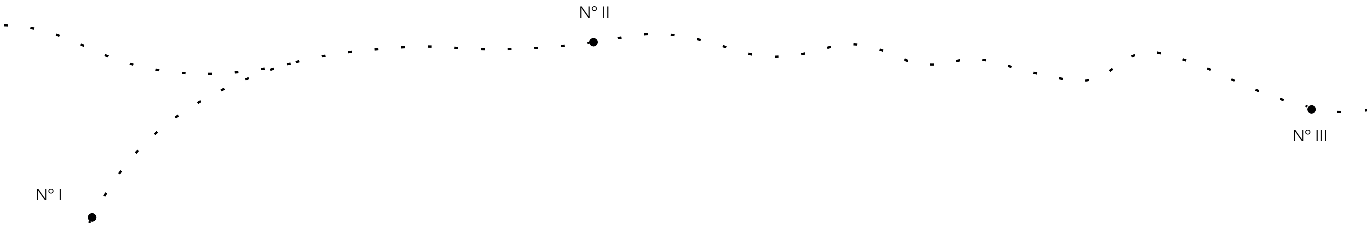
NEW SITUATION

The map above shows the design of the focus area. In order to create fresh water flow through the mangrove forest to control salinity levels, weirs are introduced along the Snapper Creek Canal. The northern most weir is connected to a green space that is transformed into a wetland park. The new water flow supplies the mangroves with sediment, that will support the expansion of the forest. Also, a strip of wetland is introduced around the neighborhood that are next to the mangroves. Flowing water through the wetland increases its quality and generates sheet flow for the mangroves. This sheet flow is supplied by the storm water from the surrounding neighborhoods. Besides, the strip is bordered by low levees and can function as a flood plain in the rain season. The wetland creates a new spatial experience for the residents, by generating a pleasant open space between the houses and the mangrove forest.


Wetland
N° I
N° I
RR
SECTIO



SECTION 1:200

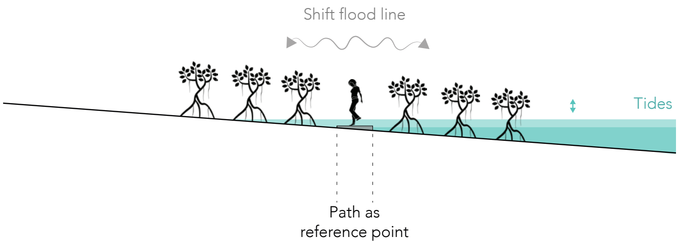


FROM PINECREST TO THE LAGOON

The route of this zone connects the neighborhoods with the bay in a new way and creates extra access points. Existing roads are meant for transport by car, with the goal to access the marinas and not to experience the cross section of the landscape in particular. The experience of the route is illustrated by means of a spatial sequence with three eye level impressions. The numbers of the route are corresponding to the detailed 1:200 map and the eye level impressions. Protruding elements represent the interventions.

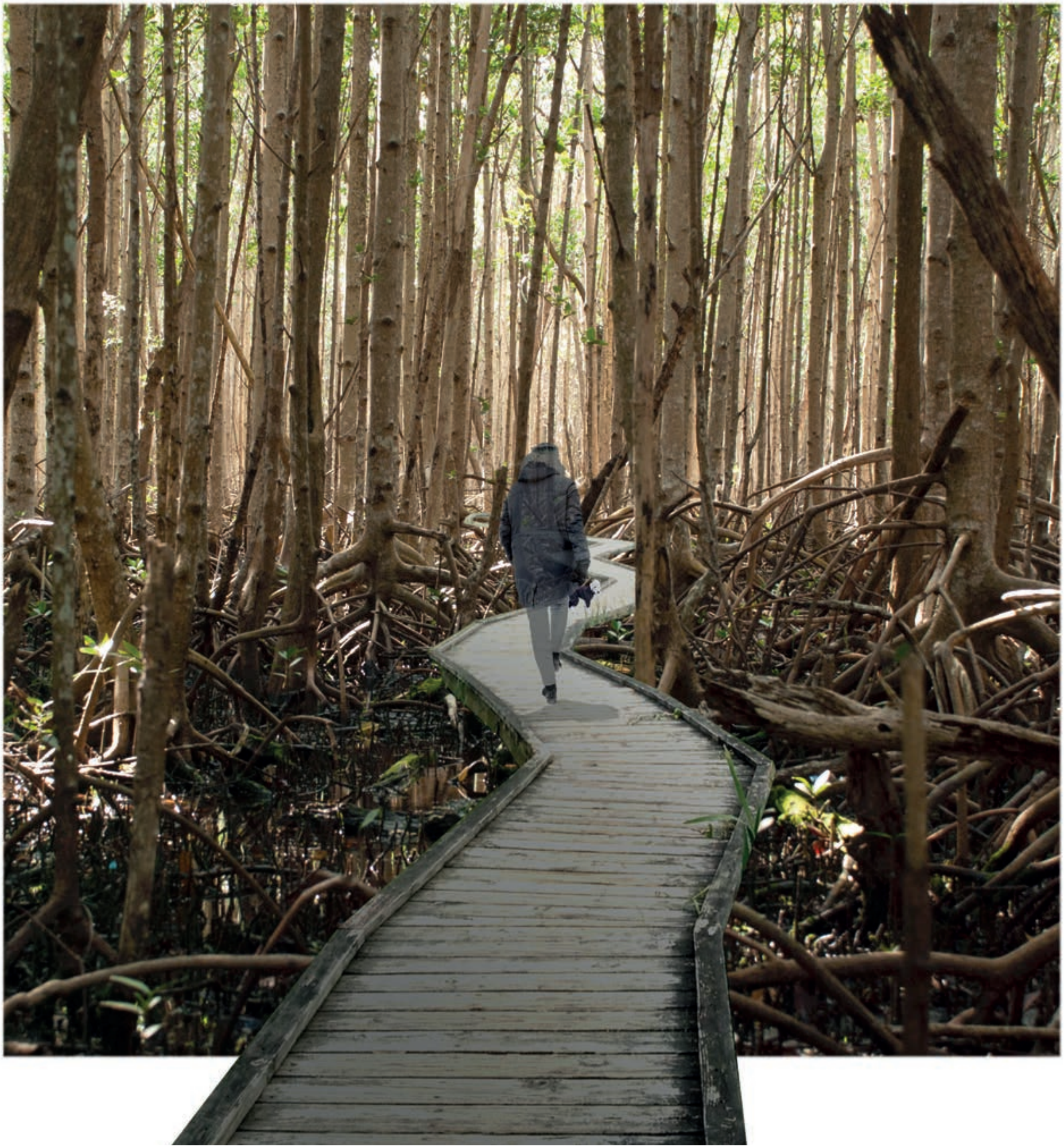
TIDAL EXPERIENCE

This route goes through the mangrove landscape like a cross section and explains the user its structure in atmospheres, that represent the different layers. The route also functions as a reference point, to observe changes so the user can experience and value the landscape. Both in the wetland and in the forest, synchronic change is perceptible from the path. In the forest, tidal difference influences the water level and therefore the height difference between the path and the water. In case of deviating high water levels it can even determines the accessibility by flooding the path.

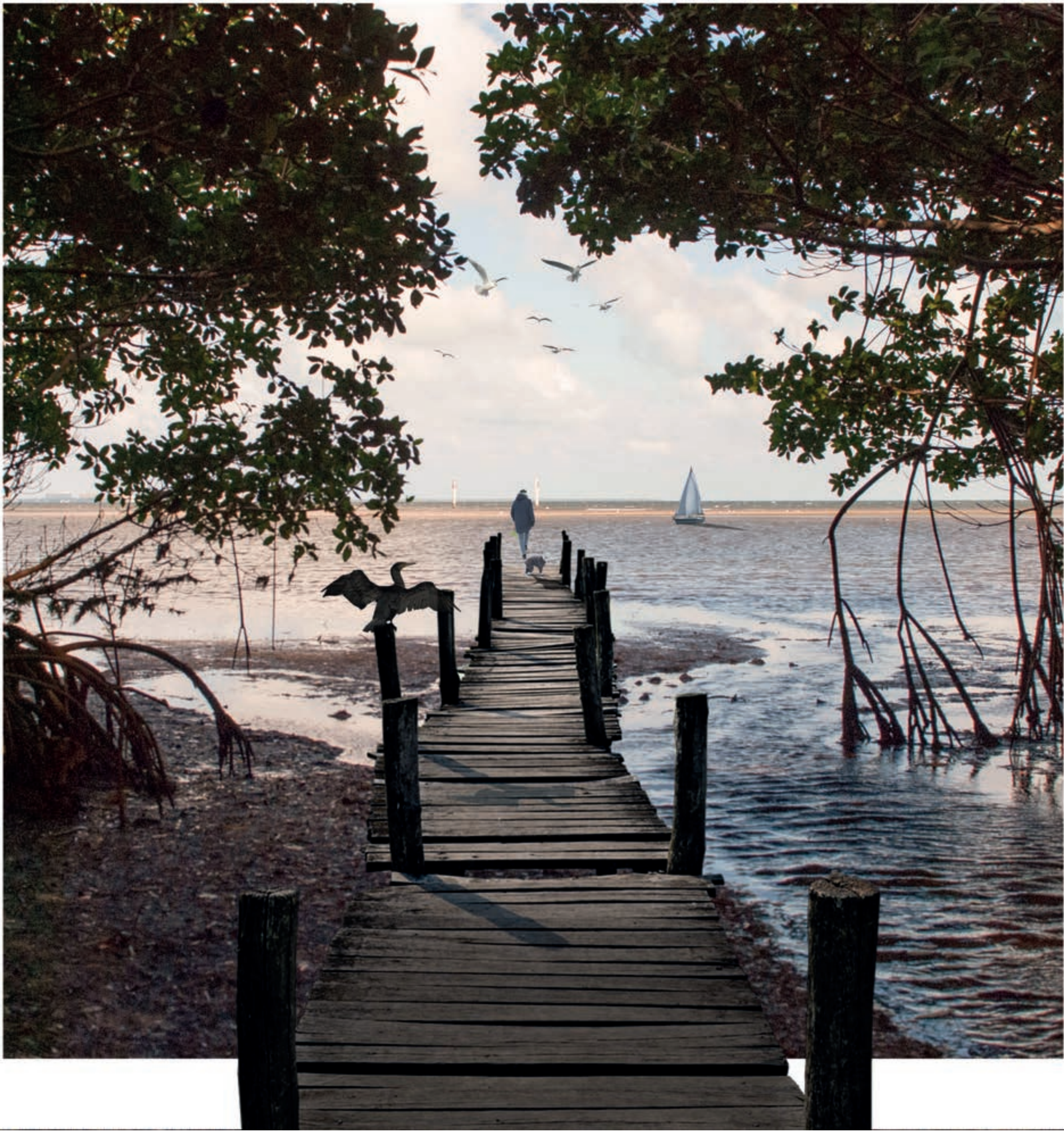


SPATIAL SEQUENCE N° I

SPATIAL SEQUENCE N° II



SPATIAL SEQUENCE N° III



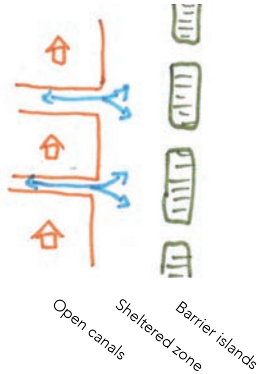

SEÑOR

MANGROVE ISLANDS

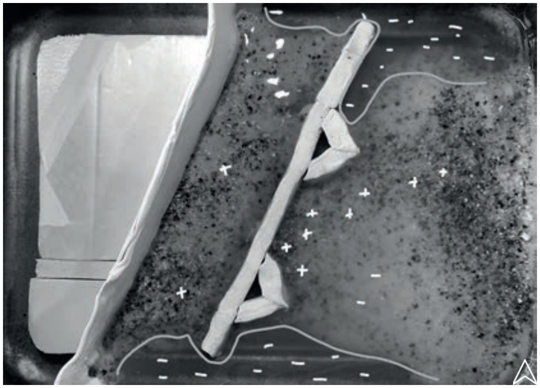
In the most northern part of the bay does the mangrove landscape barely exist anymore. Apart from a few small mangrove fragments and depleted meadow, there is no place for this landscape in this urban area, as shown in the cross section on the next page. The principle of shifting typologies, forms the basis for the concept of this focus area. Barrier island off the coast of Coral Gables offer space for the mangrove forest. The images below illustrate the formation of the island with its core construction and the sedimentations processes which determine its actual shape. This process and the influence of the shape of the core construction has been studied in an experiment that can be found in the appendix. As learned from the best practices, a barrier structure such as this can substantially lower the water level of storm surges. They reduce the impact by functioning as a breakwater. The mangroves improve and hold sedimentation, but also add spatial quality and aesthetic value to the area. On the leeward side of the islands, between the coastline, a sheltered recreation zone arises.

PRINCIPLE

CONCEPT

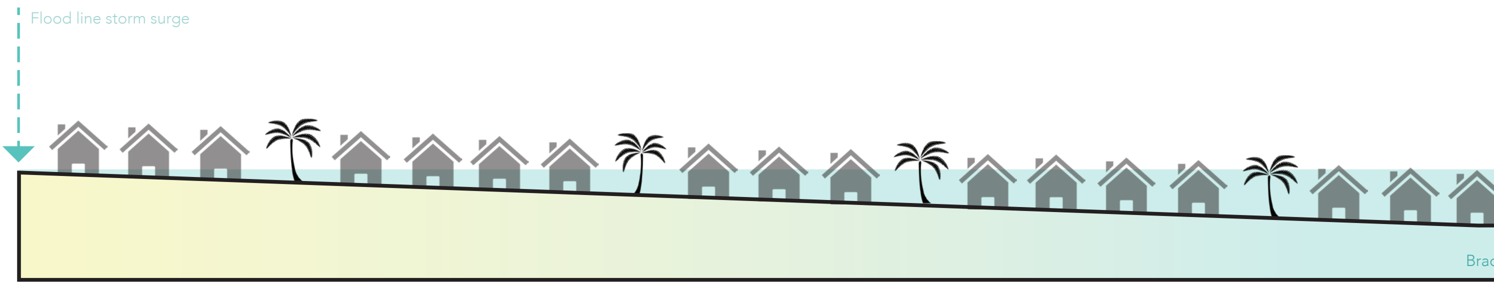


BARRIER ISLAND

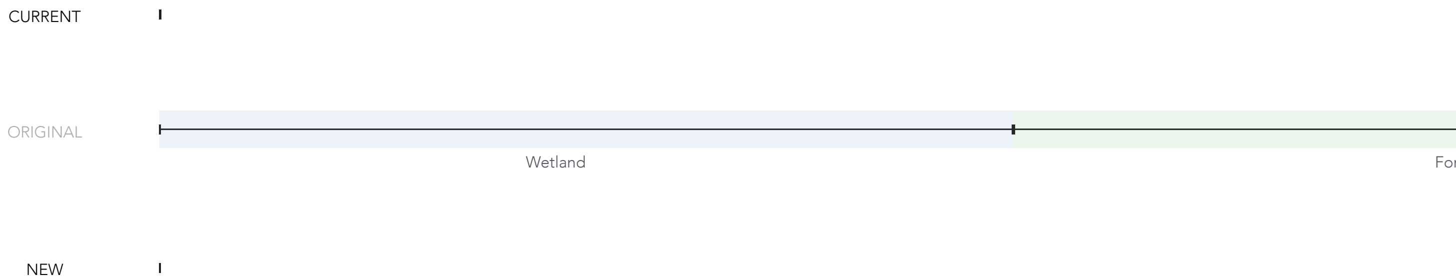


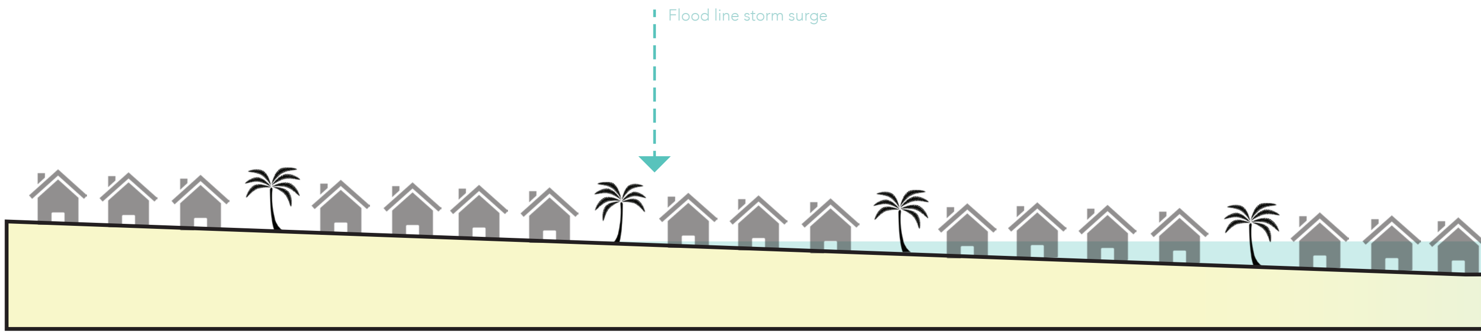
SEDIMENTATION DEVELOPMENT

MANGROVE DEVELOPMENT



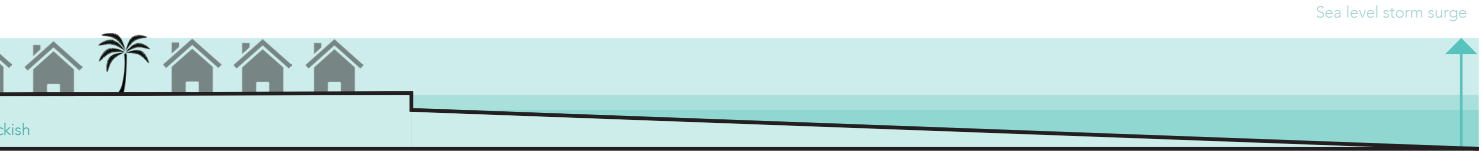
SECTION OF THE CURRENT URBAN LANDSCAPE

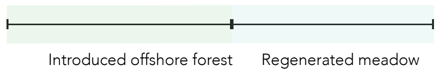


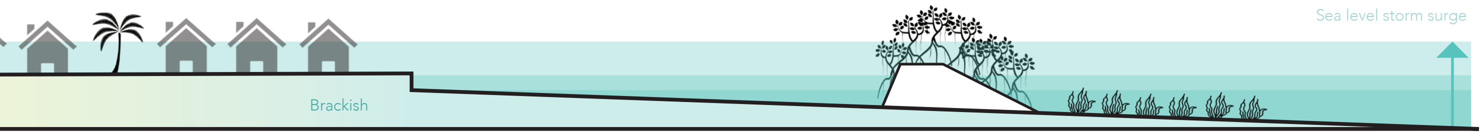


SECTION OF THE DESIGNED URBAN LANDSCAPE

IMPLEMENTATION







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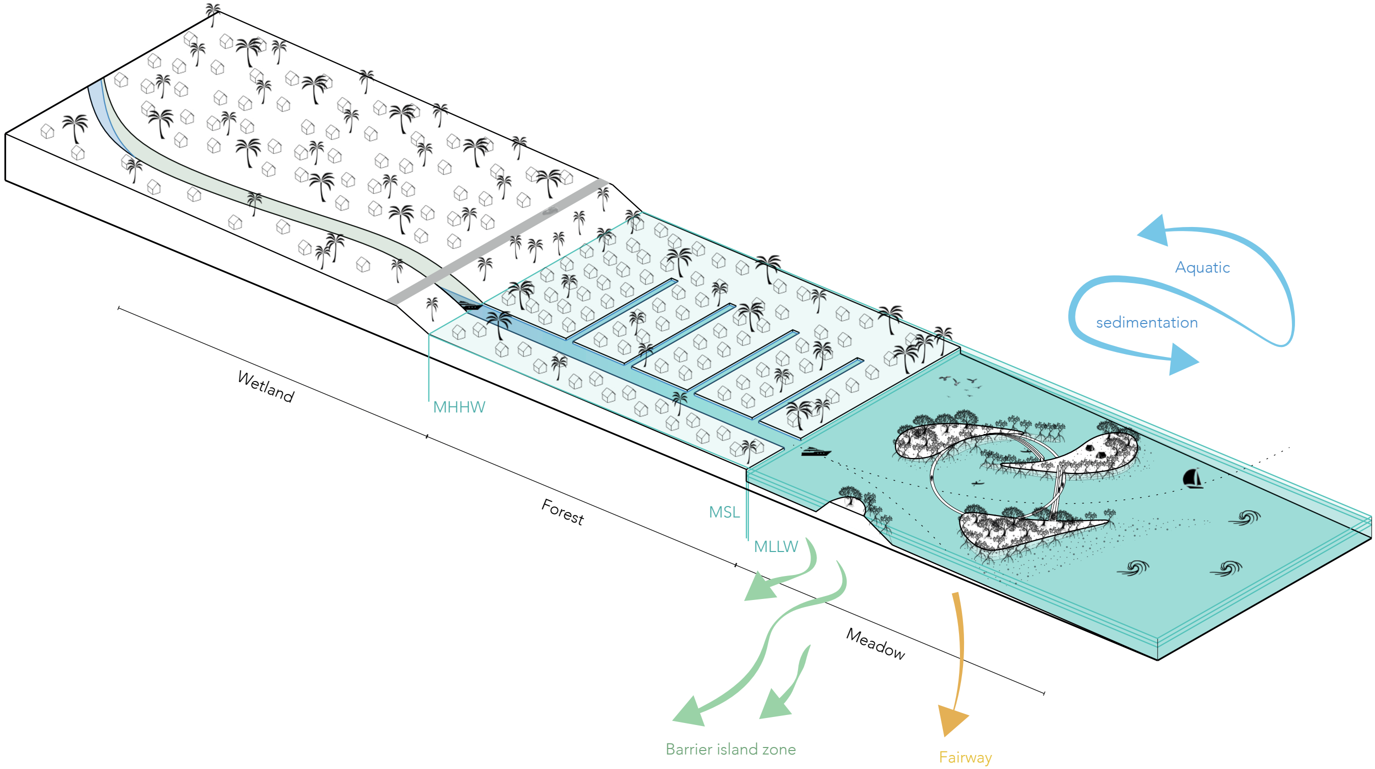
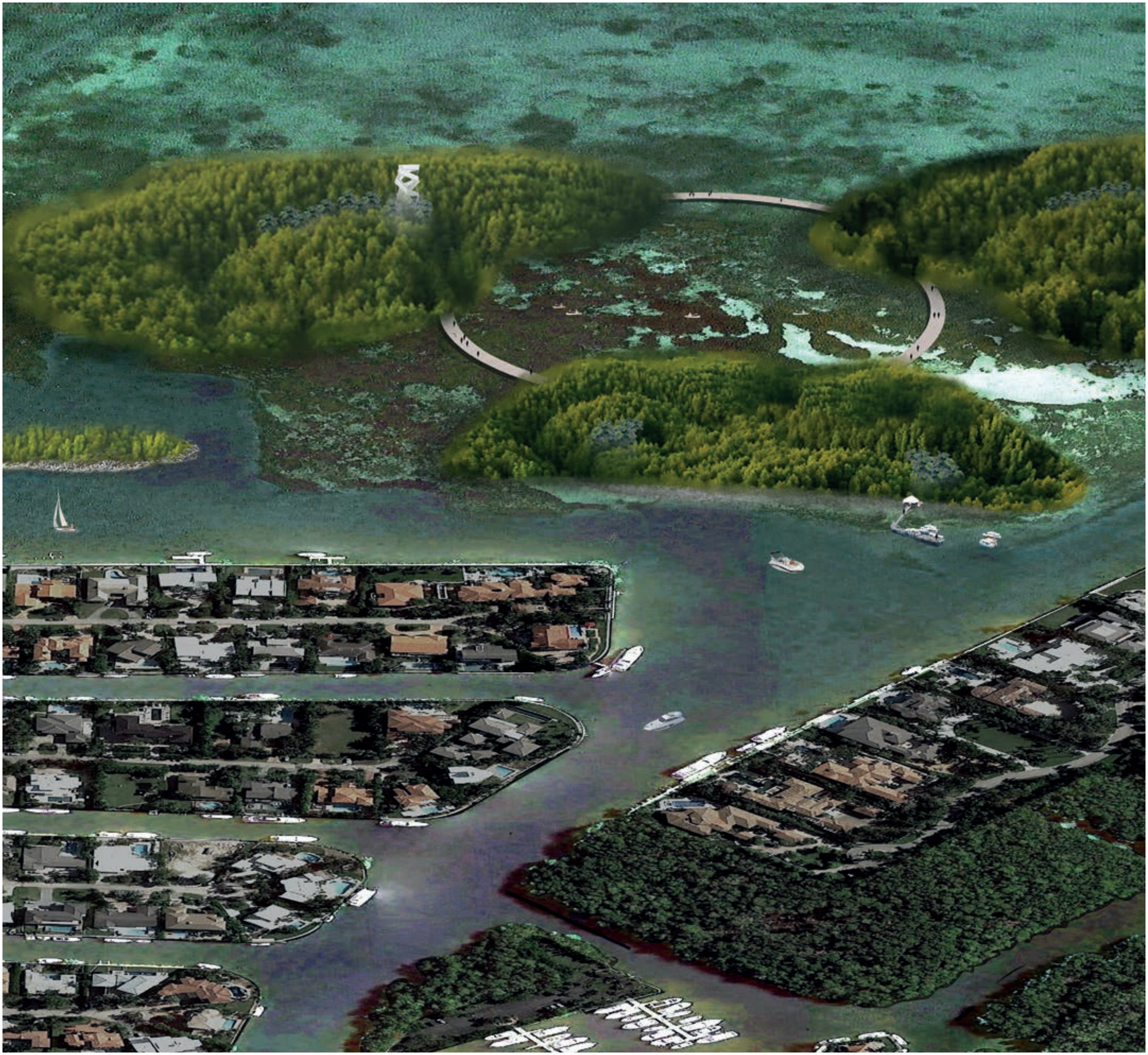


ISOMETRIC PROJECTION OF THE DESIGN FOR THE URBAN ZONE

LANDSCAPE SYSTEM OF THE URBAN ZONE

The mangrove islands extend the mangrove landscape all the way to Miami Downtown. Therefore, the current mangrove landscape does not change in this zone, but finds its origin here as an elongated barrier structure (green arrows). It is connected to existing islands off the coast of Coconut Grove, which protect the Dinner Key Marina against currents and flooding. Existing out of smaller islands, this permeable structure allows currents and carried sediments to flow through (blue arrow). Also, large amounts of discharged storm water during rainy season can flow through without accumulating and causing flood problems on shore of the mainland. The existing fairways can remain and some are connected to bigger, accessible islands. The image on the right gives an birds eye impression of the interventions.



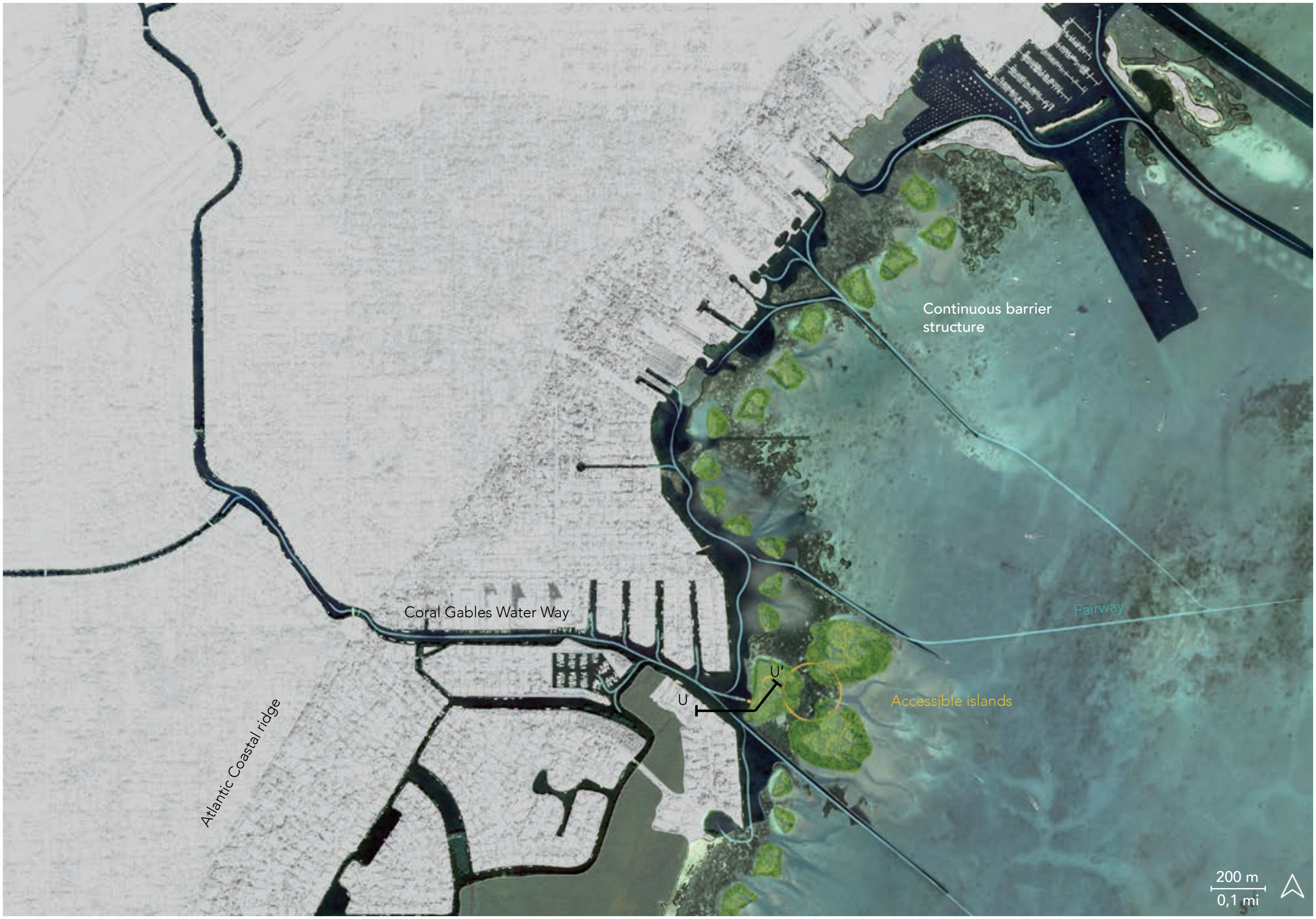
BIRDS EYE IMPRESSION

CURRENT SITUATION OF FOCUS AREA ON LOCAL SCALE

Map based on USGS The National Map (2019) and Google Earth

CURRENT SITUATION

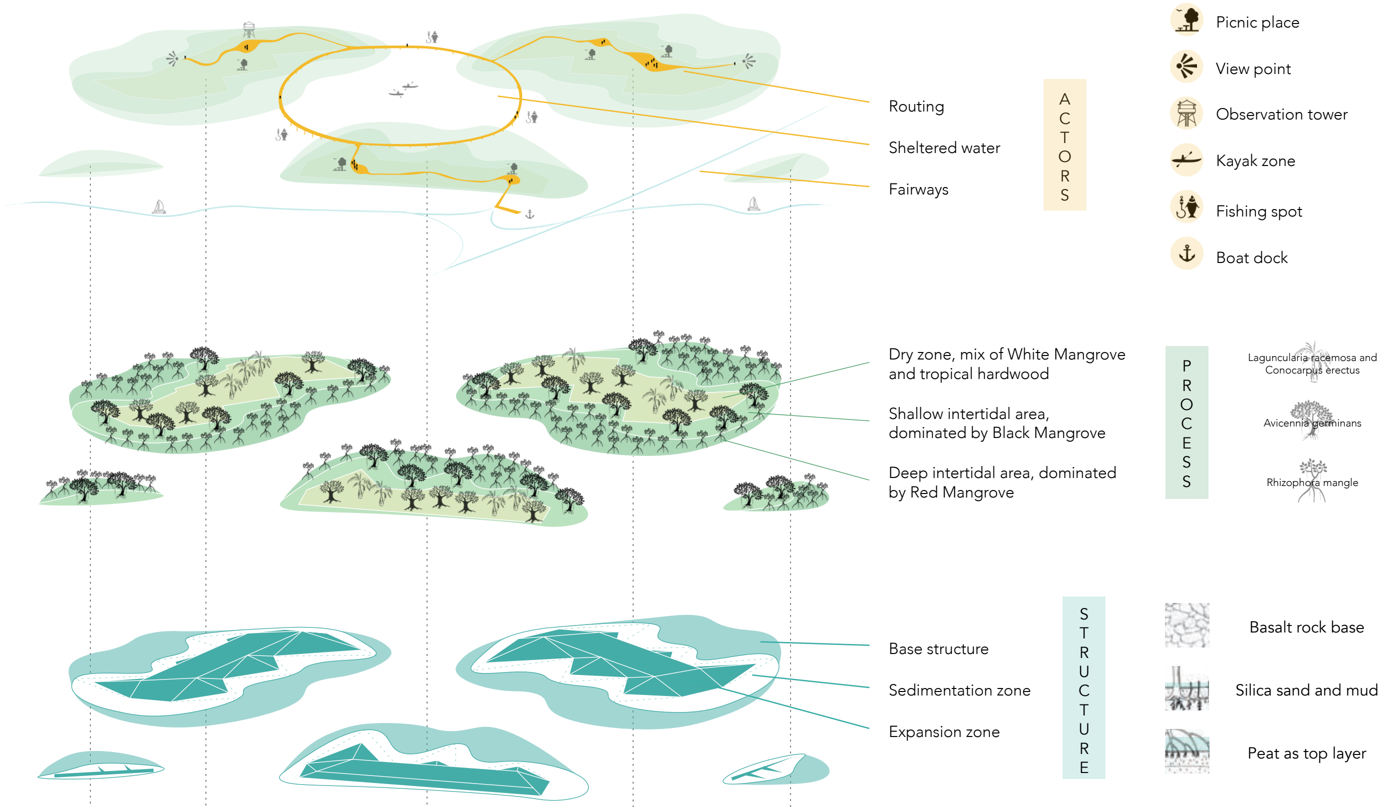
The range of the focus area, shown in the map above, represents the urban zone of Biscayne Bay. Vast parts of neighborhoods can be found off the coastal ridge and are therefore vulnerable to coastal erosion, seasonal flooding and sea level rise. The Coral Gables Waterway is an open connection to the bay and the only canal in this zone. Because there is no other from of water discharge, the potential for wetland introduction is low. Also, the hard edge shores makes introducing mangroves difficult. Therefore, the area of interventions is completely offshore and is marked by the neighborhoods the left side and by the topography of the seabed on the right, which consist of deeper boating zone and shallow sea grass meadow and mud flats.

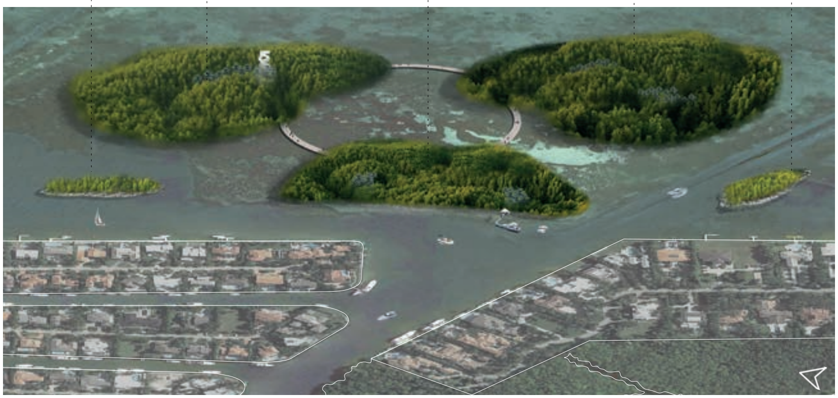


DESIGN OF FOCUS AREA ON LOCAL SCALE

NEW SITUATION

The map above shows the design of the focus area. The shape and pattern of the islands are defined by the bay's current and the topography and topology of the sea floor. The islands are situated in existing fairways or on the mudflat, to spare the sea grass meadow that supplies the islands with sediments so they can expand. Some of the island in front of the Coral Gables Waterway are bigger and accessible by boat. They mark and protect this historical waterway and are interconnected by a circular bridge which forms a calm zone for kayaking and fishing. The area between the shore is sheltered by the barriers islands and supports larger water based recreation.

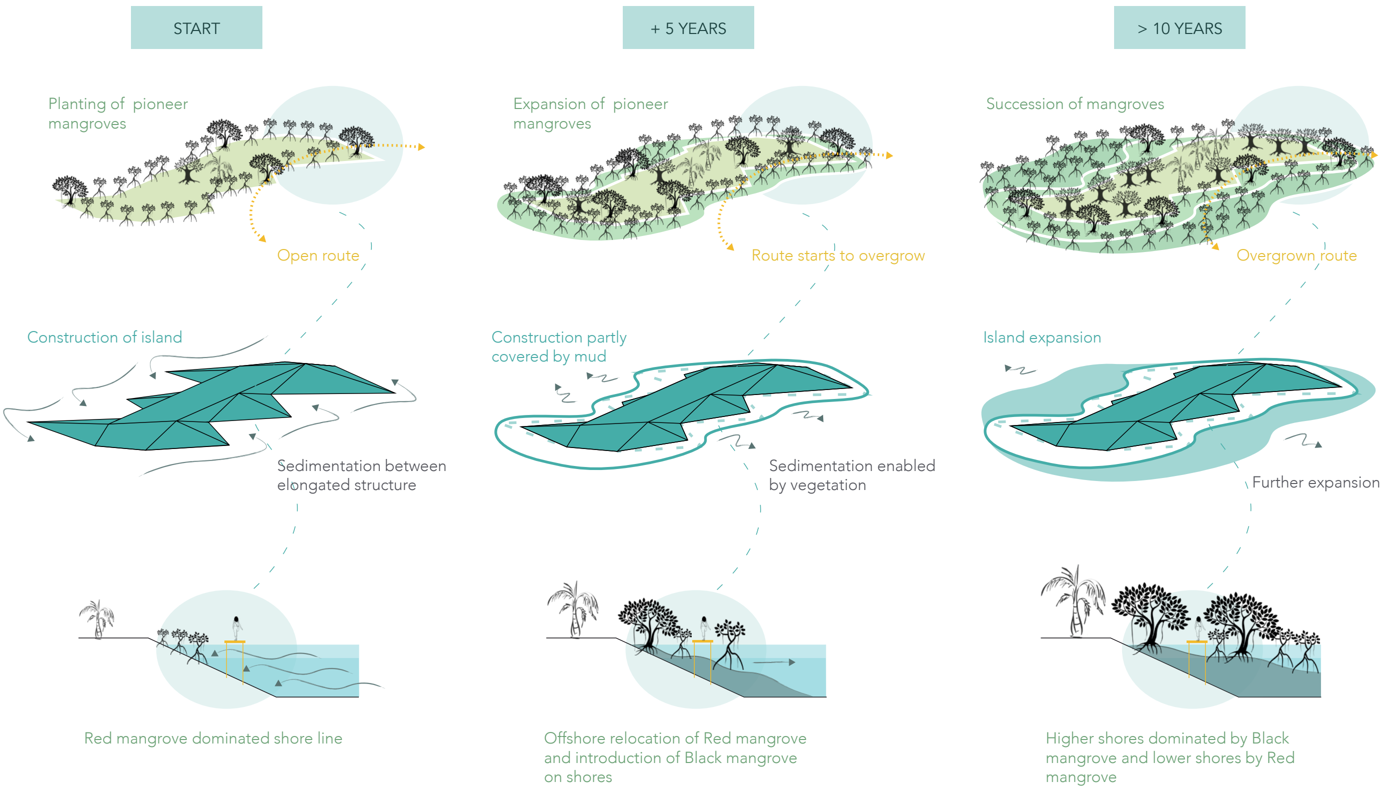




EXPLODED VIEW ACCESSIBLE BARRIER ISLANDS

THE ACCESSIBLE ISLANDS

All islands are built up from a basalt rock structure. Their specific shape enables sedimentation and supports mangrove expansion. Not only sedimentation, but also peat formation between the mangroves root system will cause growth of the islands. The bigger accessible islands have a wider base that allows elements of the program, such as the routing, picnic places and a observation tower. This higher middle zone is mostly dry and vegetated by native tropical hardwood. Around it is a intertidal zone that, dependent on the water depth, dominated by different mangrove types.



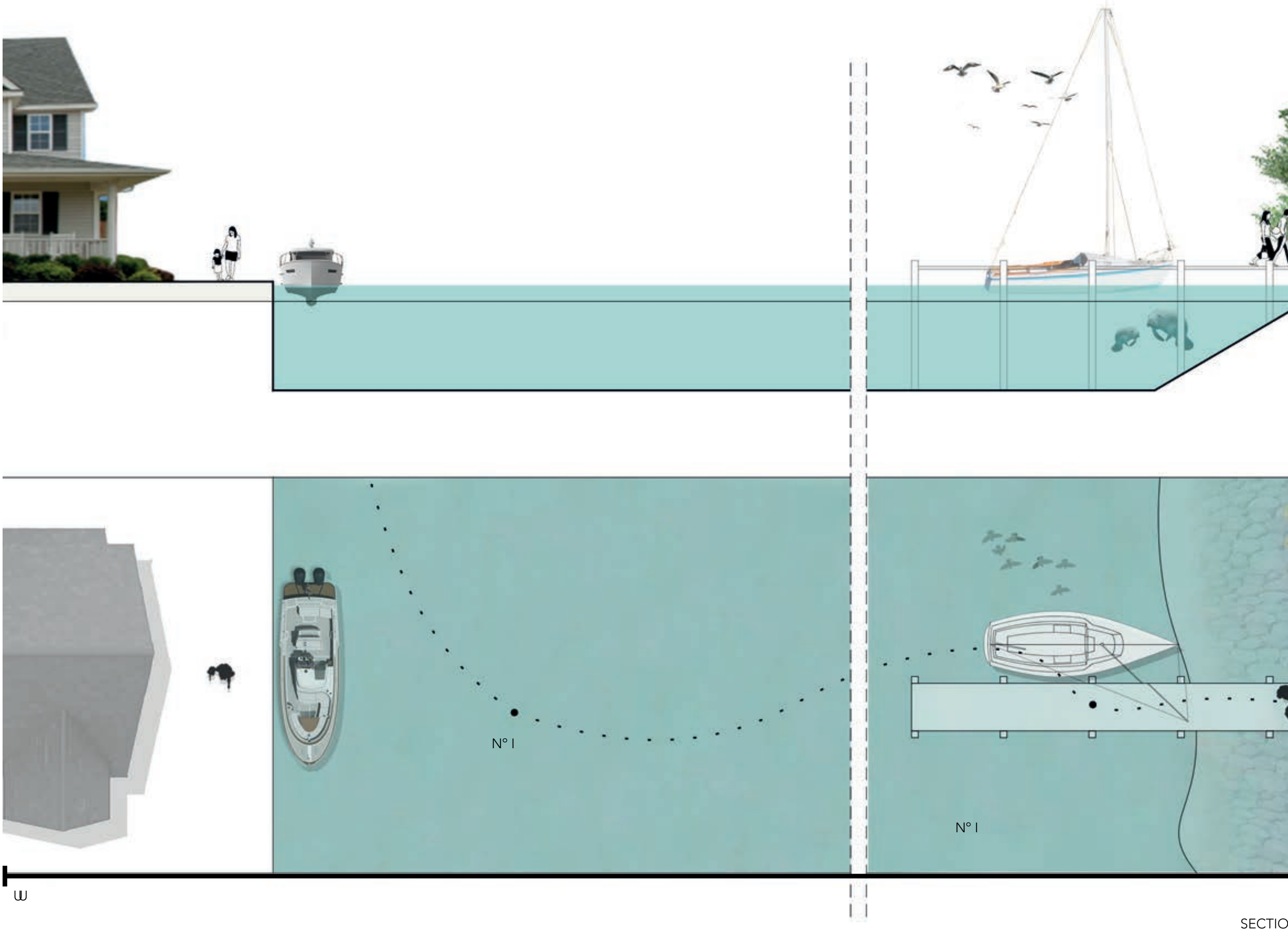
DEVELOPMENT OF BARRIER ISLANDS

DEVELOPMENT AROUND THE RING

The scheme above illustrates the development of an accessible island. In the beginning, the base is constructed in the water and planted with different mangrove types. The ring shaped route goes mainly through the open water and along the island, but at one point is goes ashore on one of the elongated shapes, to allow users to enter the island.

In the following years sedimentation will occur and the mangrove trees start to expand. Red Mangroves move seaward and the Black Mangrove strip increases on the higher shores. The relocation of the forest changes the experience of the route, which will partly overgrow close to the slopes of the islands.

After a decade, the slopes of the islands will be more elongated by sedimentation and peat formation. The circular route will become mainly overgrown and only in the middle between two islands be open to the bay. Eventually, several islands can expand towards each other and form one bigger islands. Though, the expansion is not based on stable rock or solid ground and could be washed away during a heavy storm. The base of the island would continue to exist and the process of expansion can start again from the beginning.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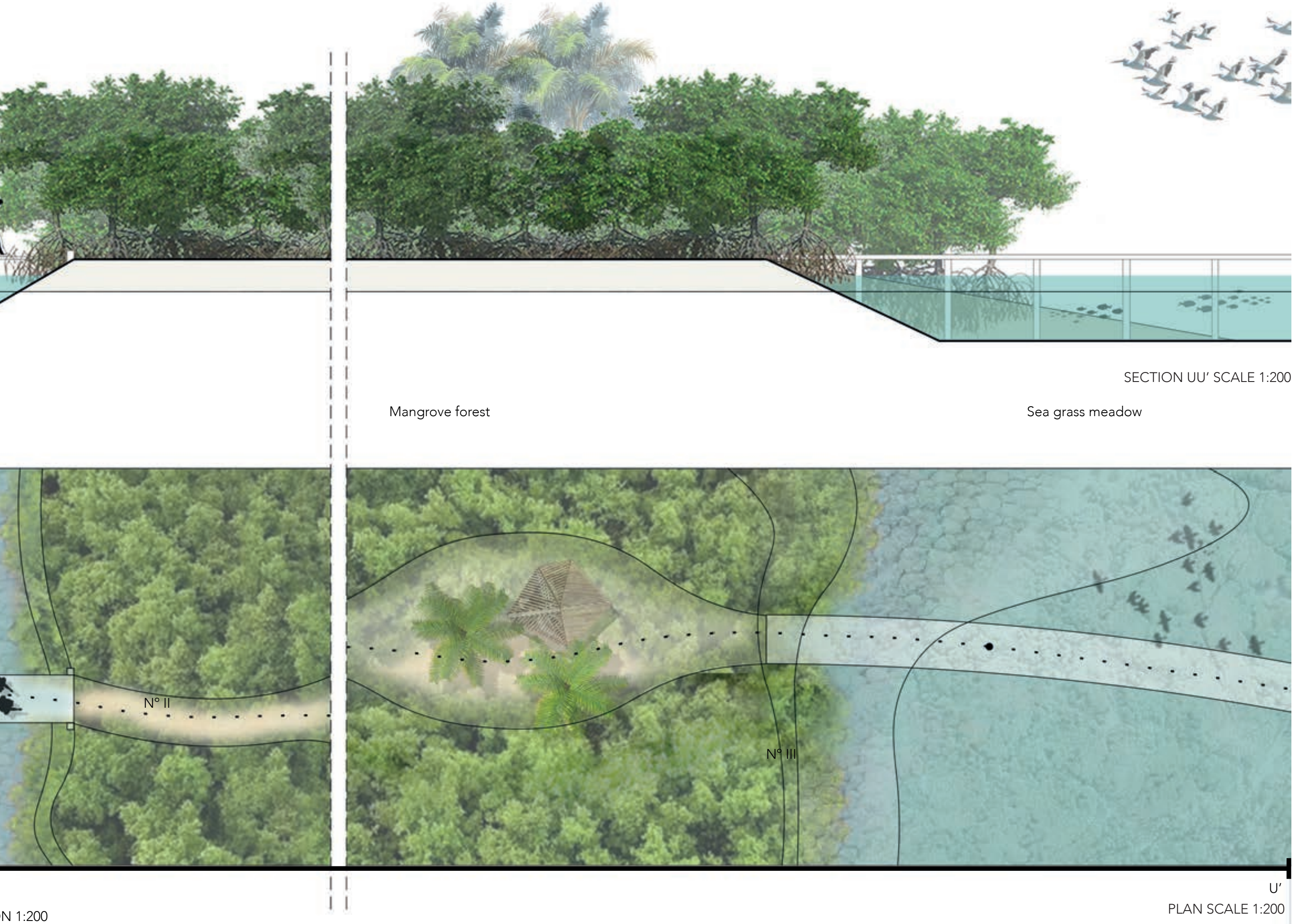
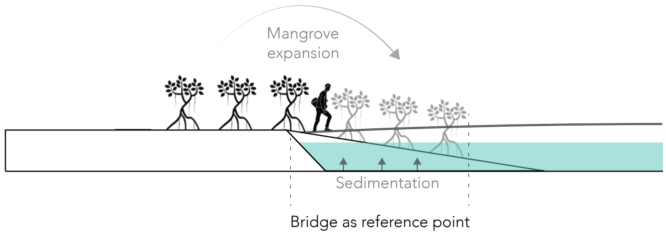


SECTION UU' SCALE 1:200

PLAN SCALE 1:200

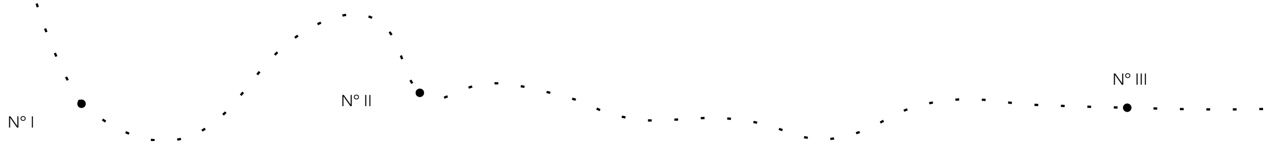


FROM CORAL GABLES TO THE ISLANDS

The route through the mangrove landscape of the urban area connects the neighborhood Coral Gables with the mangrove islands. Because of the offshore location, they are only accessible by boat of kayak. Details are shown in the 1:200 section and map. The experience of the route is illustrated by means of a spatial sequence with three eye level impressions. The numbers of the route are corresponding to the detailed 1:200 map and the eye level impressions. Protruding elements represent the interventions.

MANGROVE ISLAND EXPERIENCE

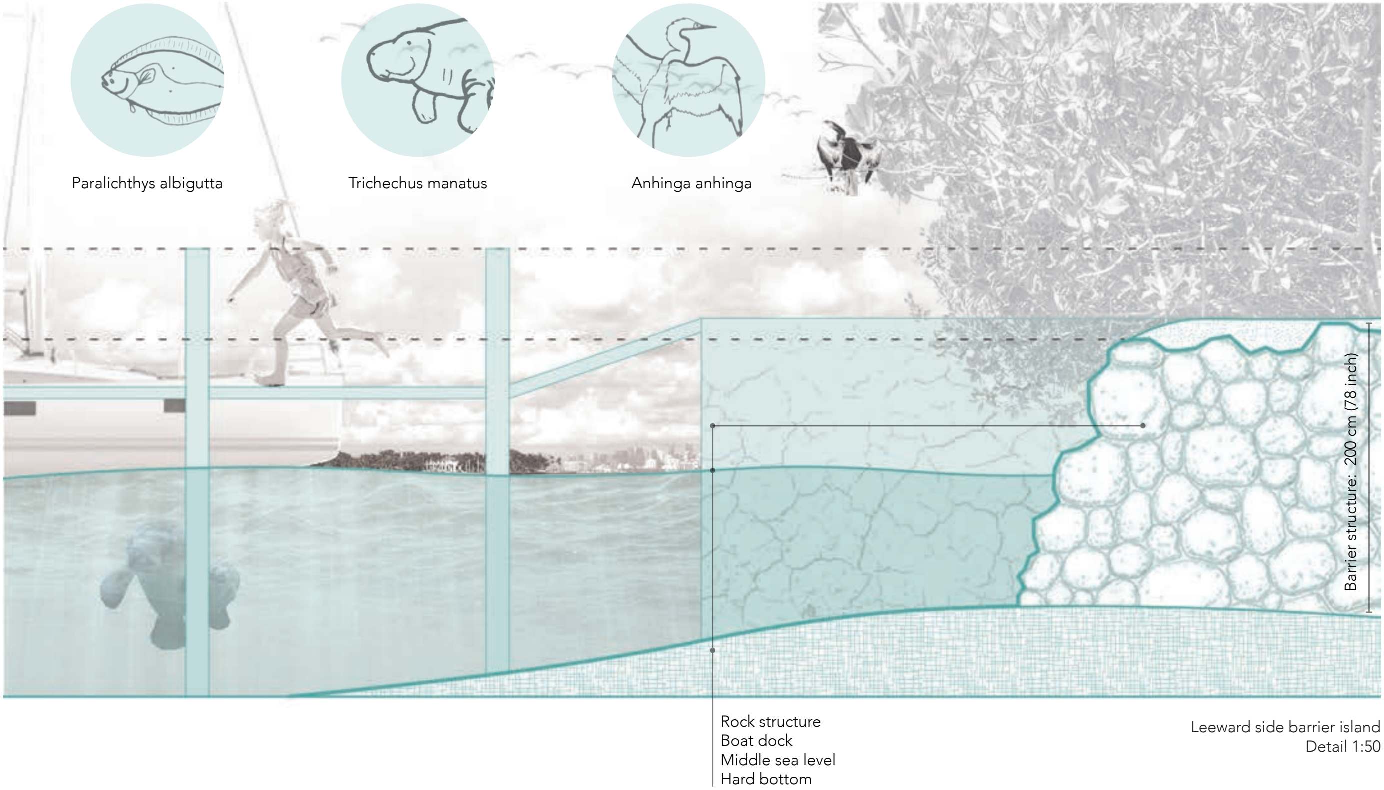
The islands offer a new experience in this zone and in the mangrove landscape. The shape of the islands and their vegetation is constantly changing due to sedimentation and erosion. This is a form of diachronic change allows the user to experience the most important processes of the mangrove landscape. The bridge is a reference point to observe mangrove expansion over time. Deviating high water levels can flood islands and therefore determine the degree of accessibility that makes the visitor aware of events like King Tide.



SPATIAL SEQUENCE N° I

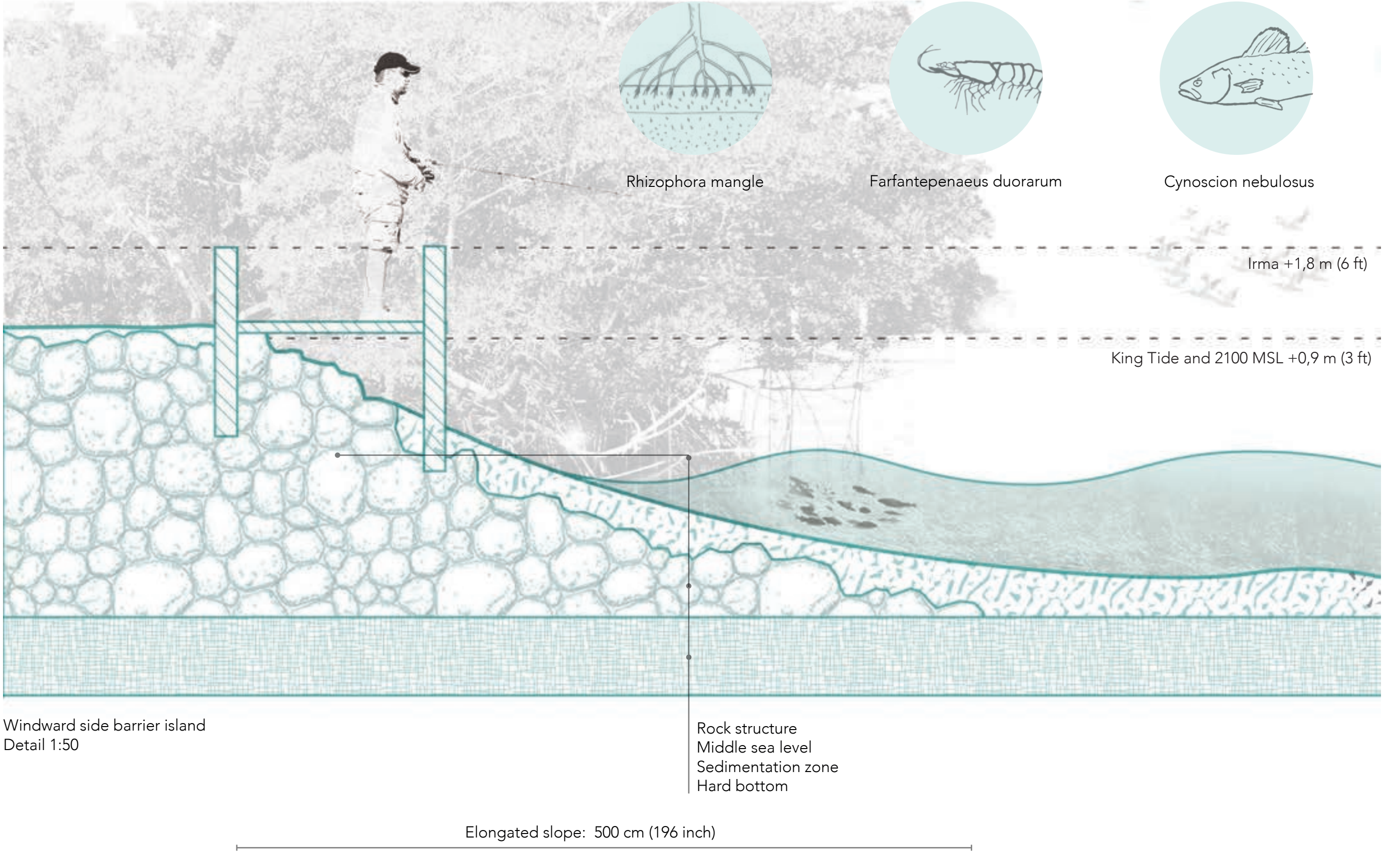
SPATIAL SEQUENCE N° II

SPATIAL SEQUENCE N° III



Leeward side barrier island
Detail 1:50

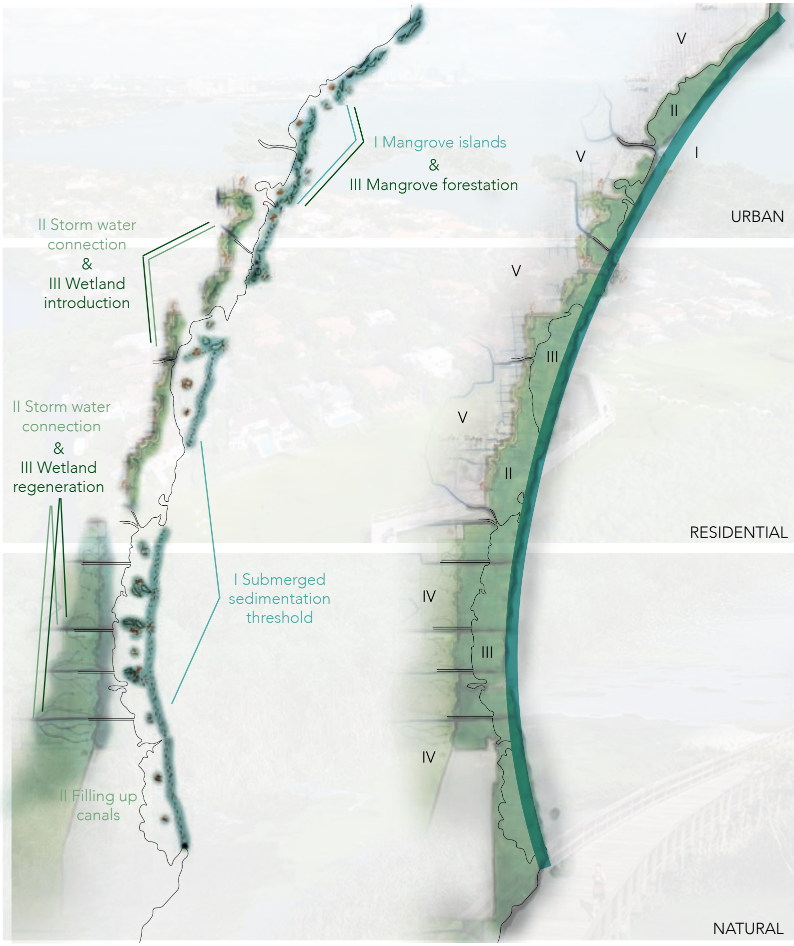
DETAIL OF THE LEEWARD SIDE
The leeward side of the mangrove island offers calm waters, suitable for recreation such as boating and swimming. The islands are made out of large rock of different sizes, which are ideal for the mangrove to root in and allows water and sediments to enter. The shores of the island are steep, to limit sedimentation in the lagoon between the barrier and the mainland. The 1:50 detail above shows an example of an island that has a boat dock and is accessible for people. The seabed below is subjected to the current caused by shape of the islands and therefore has little to no vegetation. Nevertheless, the manatee (Trichechus manatus) likes to come to this sheltered spot in the calm lagoon. Just like different types of flatfishes, such as the gulf flounder (Paralichthys albigutta) which are liked by recreational fishermen and that make the islands an attractive fishing spot.



DETAIL OF THE WINDWARD SIDE

On the windward side of the mangrove island, the slope is constructed differently. As described earlier in the concept, the islands have regularly long foothills on the windward side. This elongated slope causes deposit of shelly sand and speeds up the sedimentation process in order to enable mangrove expansion. The islands are made out of large rock of different sizes, which are ideal for the red mangrove (Rhizophora mangle) to root and offer a sheltered habitat for its residents.

Various crustaceans live between the stones and the roots of the mangroves. Just like oysters, they make an important contribution to the food chain of the mangrove landscape. The pink shrimp (Farfantepenaeus duorarum) converts plant residues from the mangrove into particulate organic material that the trees absorb through the water and the soil as food. In addition, these and other shrimp species have a commercial value because they are food for recreational fish such as the spotted trout (Cynoscion nebulosus).



PLANNING

CURRENT SITUATION

DESIGN ACTIONS

I Creating barriers

II Making connections

III Ecological restoration

FUTURE EFFECTS

I Closed continuous barrier
II Continuous mangrove forest layer
III Silting up area and seaward mangrove expansion
IV Restored sheet flow
V Built-up areas protected by the mangrove landscape

ACTIONS
Designs are made of the focus area of each zone. The concept of this design can be applied to the entire zone, according to the regional plan. Eventually, this will result in the restoration of the mangrove landscape of Biscayne Bay and contribute to the flood safety of the Miami Metropolitan Area and creates social reconnection with the natural coastline. In order to implement the designs, a list of action is made. Some of these actions apply to multiple designs, others are zone specific.

URBAN ZONE
In the northern part of the bay, where no mangrove landscape existed, barrier islands have been designed to protect the coastline and create an new recreational area on the water. The most important action is the construction of the barrier structure in the water. It has the highest priority because this intervention is needed to start the sedimentation process. This allows the islands to be raised and extended, so that mangroves can be planted. Unlike the rest of the interventions in the bay, this is forestation, because mangroves have never grown in this place. This implies that a combination is made of creating the right conditions for the new forest and planting trees. Once the islands are established, further design interventions can be done, such as the construction of boat docks, paths and bridges, so that the user can access them.

RESIDENTIAL ZONE
The introduction of wetland in the middle part of the bay is designed to add an extra layer to the mangrove landscape, so that it can offer more protection against storm surge and floods. In addition, the new layer also functions as a water retention area. The action with the highest priority is to transform a strip of mangroves into wetland, surrounded with a levee with weirs in it. Subsequently, a bypass is made between the Snapper Creek Canal and the new wetland, in order to provide it with fresh water. Next, infrastructure for the connecting route between the neighborhoods and the bay can be created.

NATURAL ZONE
In the southern part, wetland and mangrove forest are reconnected. Together with the regeneration of the sea grass meadow, these interventions ensure that the mangrove landscape can be restored to its original state in this part of the bay. The first action that needs to be taken is breaking barriers. The L31E canal and its levee, which separates the mangroves from the wetland in the current situation, must be removed. The remains of the levee can be used to partially raise the route that will show its users the old border. Subsequently, weirs are placed in the levee between the wetland and the tree nurseries, so that these water systems can be connected to each other and sheet flow is enabled. At the same time, the submerged barrier reef can be constructed by applying hard structures in the water to which shellfish can attach such as oysters.

FUTURE EFFECTS
Besides the main design actions, the map on the left page also shows future effects. This is a prediction of what can happen after the completion of the interventions and is summarized in five effects. First, a continuous mangrove landscape will emerge that follows the restoration line from the regional plan. Second, all the fragments of the forest layer will be connected and form the continuous core of the mangrove landscape. Third, areas between the current coastline and the submerged barrier will silt up and support offshore mangrove expansion. Fourth, the sheet flow will be restored and embedded in the landscape, so it can carry sediments and supply the mangrove forest. And last but not least, the built up area of the Miami Metropolitan Area will be protected against flooding by the restored mangrove landscape.

It can be concluded that the actions that need to be taken and their effects need to be placed in a long term time line and need an elaborated planning in order to achieve the desired effects and goals. The first stage of the implementation of the design actions will already result in a functioning mangrove landscape, but only the expected future effects can prove its functioning. However, the implementation of the designs should be seen as an open-ended development, because the performance of this dynamic landscape is subjected to a constant change and it will never be completed.

VI

Discussion and conclusion

1·Research findings

2·Lessons learned

3·Implications and Recommendations

VI Discussion and conclusion

1 · Research findings

The disappearance of the mangrove landscape makes the Miami Metropolitan Area vulnerable to tropical storms and the consequences of climate change. The remaining fragments of the landscape are being caught between a rising sea and a densely built city, which cannot offer retreat zones. This research has searched for a landscape architectural approach to this complex challenge. The predetermined goal was identify and explore design strategies and principles for the mangrove landscape of Biscayne Bay in order to reduce the flood risk of Miami Metropolitan Area, as well as provides aesthetic, ecological and functional qualities that contribute to the identity and resilience of this coastal region. Several research questions have been answered to investigate how this goal can be achieved and these are answered below.

UNDERSTANDING
The mangrove landscape of South Florida originally existed out of three layers: wetland, intertidal forest and submerged meadow. These layers depend on each other and are interrelated by their processes and actors. It functions most optimally when all layers are thriving and present. The lack of layers obstructs processes and therefore the functioning of the landscape. In Biscayne Bay, the mangrove landscape changed drastically by obstructing factors like an altered water system that increased water related problems as flooding, salinization and erosion. The reversion of the water system, however has increased the mangrove distribution zone and allows for new growth opportunities.

TOOLS
From the best practices we learned that restoration through rehabilitation is the only way to restore the landscape in a way that it can grow independently like natural succession. To create the right conditions for rehabilitation, the three layers of the mangrove landscape are needed, without any obstruction of the processes and natural actors. When there is not enough space for the restoration of one or more of the layers, typologies can shift. The same applies to barriers in the landscape that cause blockages. Levees that block natural water flows and thereby the sedimentation process can be moved to a place outside the mangrove landscape. This makes the flood reducing and protective function of the landscape stronger and could actually replace the levee. In order to reconnect people to the mangrove landscape and raise their awareness for its protective function, they need to experience it by seeing the changes of the landscape, such as the tidal difference, sedimentation processes and mangrove movement because of changing sea levels.

APPLICATION
The regional plan shows how the Biscayne Bay coast can be restored and the layered mangrove landscape can be applied to it. Following the topography of the landscape, a zone is created for applying the principles. The elaboration of the three focus areas, shows in a landscape architectural design how each zone with its own characteristics can function in the big picture. First, restoring wetland and its connection with the mangrove landscape, through breaking barriers in the southern natural zone. Second, Reintroducing wetland in the middle residential zone by means of a bypass between the canal and the mangrove landscape. And third, Introducing the mangrove landscape in the northern urban zone, by creating offshore barrier islands with mangrove and sea grass meadow development.

REFLECTING
A landscape architectural design can contribute to the restoration of the harmony of the natural coastal landscape of Biscayne Bay and thereby restore its function. The spatial aspect of design tells that in some areas of the bay there is simply not enough space for a complete mangrove landscape, but by studying best practices one learns that there are principles to find a solution for this. The systematic layer approach is then converted into a spatial design, transforming a scheme into a tangible landscape. The landscape architectural design is needed to add an extra dimension to the mangrove landscape that will invite the residents of the Miami Metropolitan Area to experience it. On the one hand, by seeing the special flora and fauna and the spatial quality of the three different landscape types, the user will give the landscape aesthetic value. And on the other hand, exposing the user to change, such as tides, sea level rise and mangrove retreat, will let them assign the ecological value, which will form the basis for awareness of the indispensable function of this landscape in the coastal protection of this area.

2 · Lessons learned

BEYOND THE BAY

The result of this research is a regional plan for Biscayne Bay and three partial elaborations that represent a landscape architectural design for the entire bay. This is a specific result for that area, but this research is also relevant for other places where the risk of flooding has increased due to a lack of mangroves. The used 'landscape as system' method make the research findings also applicable to other regions. This is because the mangrove coasts have many similarities throughout its distribution area. Considering the mangroves as landscape with layers, instead of only a forest, is an generic approach that can be used as a tool for designing vulnerable (sub)tropical coastal regions.

RESEARCH AND DESIGN

In this research, design is on the one hand a method for conducting research and on the other hand a way to arrive at the result of the research itself, by testing and demonstrating the design. The analysis of the mangrove landscape in South Florida and Biscayne bay, using the landscape as a system method, is a form of design research. The landscape mangrove is explored and understood by making and combining maps and sections. When searching for the right tools for dealing with the challenges of the bay, existing designs are examined to find design principles. Subsequently, design is used as a method to apply the principles and to display the result. This form of research by design shows in a theoretical way how the outcome would function in practice.

3 · Implications & recommendations

IMPLICATIONS

The application of the research results will largely surround the coastline of Biscayne Bay with a natural landscape. This has implications for both the natural and the urban environment. In the south of the bay, the restoration of the wetlands can shift the boundaries of the national park and thereby expand, to protect this landscape and its function as coastal defense. In the north of the bay, the spatial experience of the border area between neighborhood and mangrove, and the waterfront through the barrier islands, changes. This will affect the current and future residents of these places and how they use the landscape.

RECOMMENDATIONS

Recommendations to improve this research and the design result are to conduct further multidisciplinary research into the undiscovered parts of the aspects (structure, process and actor) of the used method. Ecological research on the different types in the mangrove landscape and their interrelation and dependence, hydrological research into sedimentation processes and barrier island development offshore and a social study on the behavior of the user towards the landscape. This allows a more detailed design to be made for Biscayne Bay. Furthermore it is important to take into account that the projections of the effects of climate change, such as sea level rise and increasing storm surges, deviate in future studies and that has consequences for the functions of the mangrove landscape and its spatial design.

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2 · Images

All Images without a source are made by the author

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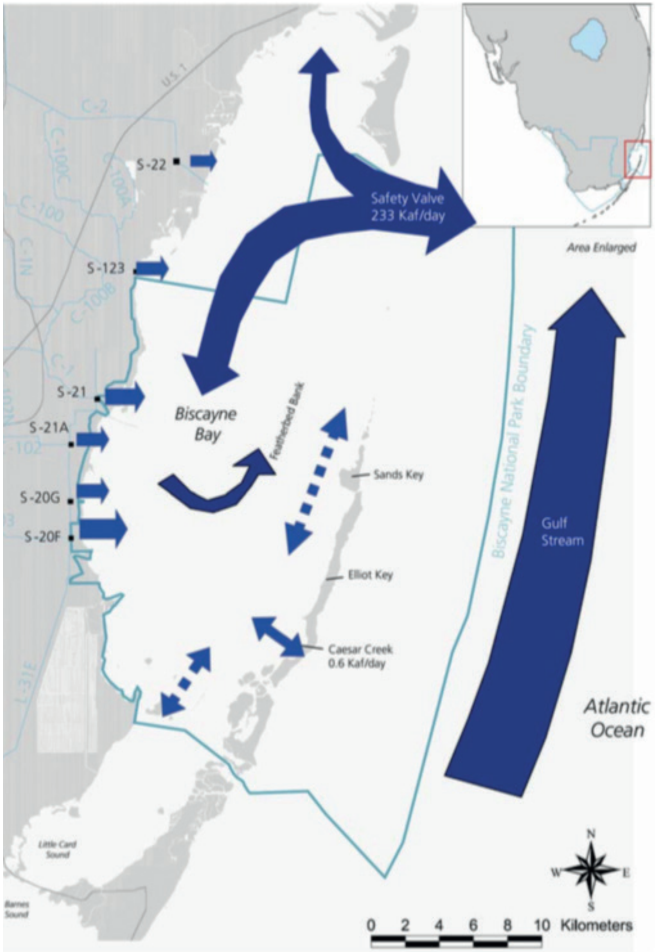
Appendix

1·Glossary
2·Abbreviation list
3·Sedimentation experiment

Actor (landscape)	User of the landscape.
Atlantic Coastal Ridge	Elongated limestone structure along the Atlantic coast of SF.
Biodiversity	Variety in flora and fauna.
Climate change	Drastic change in natural processes due to global warming.
Comprehensive Everglades Restoration Plan	Environmental restoration project of the Everglades
Biscayne Bay	Semi enclosed lagoon at the Atlantic coast of SF.
Breakwater	Physical element along the coast that decreases currents and waves.
Ecosystem	Interactive group of organisms in a defined physical environment.
Ecosystems, interrelated	Mutual dependence between two ecosystems.
Hard bottom	Stony seabed free of sand or mud.
Hurricane	Cyclone wind as a result of a tropical storm.
Key	Biologically formed island, on remains of old coral reefs.
Leeward side	Downwind side of an object.
Levee	Natural or artificial elevation in the landscape to stop water.
Limestone	Hard soil type consisting of carbonate sedimentary rock.
Marl	Soft soil type consisting of limestone mud.
Miami Metropolitan Area	Region of 5.5 million inhabitants including the city of Miami.
National Park	Protected natural area under the supervision of the NPS
National Park Service	Federally agency that manages national parks.
Peat	Soft soil type consisting of composted plant material.
Process (landscape)	Dynamic feature of a landscape.
Sea level rise	Exponential and ongoing rise of the sea level due to climate change.
Structure (landscape)	Physical feature of the landscape.
Symbiosis	Cooperation between two or more organisms.
Wetland	Permanently flooded area, home to aquatic vegetation and marsh birds.
Windward side	Upwind side of an object.

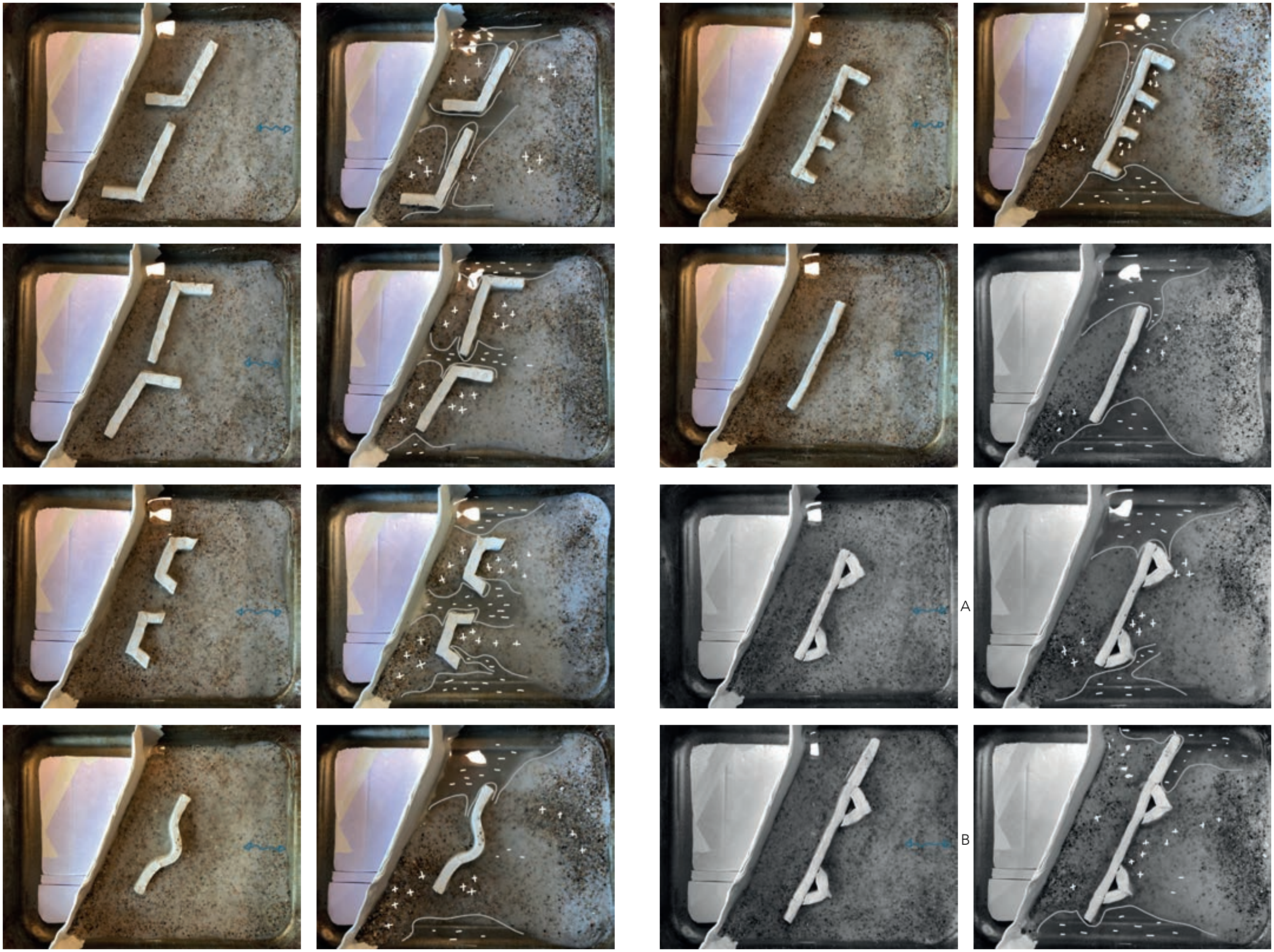
BB	Biscayne Bay
CERP	Comprehensive Everglades Restoration Plan
cm	centimeter (unit)
FL	Florida (state)
ft	feet (unit)
km	kilometer (unit)
m	meter (unit)
mi	mile (unit)
MMA	Miami Metropolitan Area
MSL	Middle Sea Level
MLLW	Mean Lower Low Water
MHHW	Mean Higher High Water
NP	National Park
NPS	National Park Service
SF	South Florida
USACE	Army Corps of Engineers



BB GENERAL WATER CIRCULATION AND SOURCES

Source: National Park Service (2006)

This experiment was done to determine the shape and position of the barrier islands. In the image above the flow directions in Biscayne Bay can be seen. There is a combination of a tidal current diagonal on the coastline and various discharge points with fresh water from channels. The experiment focuses on the tidal current in relation to one or more islands.



The position and shape of the island must ensure that sedimentation takes place in the right places. Sedimentation is desired on the seaward side of the islands, in the images above that is the right-hand side. This allows the mangrove forest on the island to expand and thus make the island more resistant to storms. In addition, sea grass will also grow on this side, which in itself increases sedimentation. On the other side, between the island and the mainland, as little sedimentation as possible is wanted in order that this zone remains accessible for boats and water based recreation. The result is that images A and B are the most suitable shapes and these are used in the design.