Move on

Research-through-drawing for flood resilience at the Galveston coast, TX

H. (Helena) Van Boxelaere
MSc Thesis Landscape Architecture
Wageningen, August 2016

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Colophon

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Fig 1: Zoom of the Galveston Bay-region and coast

Summary

Key words: hurricanes, flood resilience, research-through-drawing, Galveston, landscape-based-design approach, soft measures

In 2008, Hurricane Ike hit the Texas coast and despite 'only' being a category 2 storm Ike resulted in more than two dozen deaths and caused around $25 billion in damage. After Ike, concern was growing regarding the destructive storm surge and the flood risk at the barrier islands of the Galveston Bay, the petrochemical industries and the Port of Houston; the economic engine of the region. As a result, a coastal barrier (among others) with floodgates and a set of dikes lining the Galveston coast, was suggested to improve flood safety in the region.

However, the Galveston Bay is an important estuary, pressurized by economic activities and residential development and the barrier islands are confronted with more threats than storm surge flooding alone. The problem identified here is that a coastal barrier gives little concern to the integration and response of flood protective measures to preconditions set by the landscape system. However, an alternative approach for Galveston Island and Bolivar Peninsula that emerges from and responds to the landscape system has not been fully explored yet. The purpose of this MSc thesis is to propose a strategy for flood resilience at Galveston Island and Bolivar Peninsula based on a profound analysis of the landscape system by research-through-drawing.

Research-through-drawing is a newly explored method of regional landscape analysis by freehand drawing. Freehand drawing is an imaginative process of representation that encourages analysis and the establishment of new creative relationships. By tracing and drawing information, data is both internalized and coded into a visual simultaneous language. This allows handling and understanding large amounts of information for further strategic design. Eventually, the Galveston Bay region has been explored in more than 70 drawings based on literature, interviews and site visits. Connections within the landscape system and connection between the landscape system and flood protection have been explored by drawing and concept mapping. The research resulted in guidelines for flood resilience at the Galveston Coast in line with the landscape system of the Galveston Bay region.

As a result, the strategic design for the Galveston coast distinguishes between to 'hold on' and to 'let go'. For the city of Galveston [hold on], a dike ring around the city is suggested in combination with the improvement of the city's public space. Over time, the (industrial) area outside the dike ring is transformed into a protective natural edge and contributes towards long-term flood protection. For Galveston Island and Bolivar Peninsula [let go], it is accepted that the barrier islands become less suitable for living and more suited for recreational and natural use. A transformation is suggested to decrease development and to increase natural attraction. More time for the transformation is created by slowing down the negative effects of the landscape processes with soft measures such as sand nourishments, wetland restoration and dune protection.

The strategy for flood resilience at Galveston Island and Bolivar Peninsula based on a profound analysis of the landscape system initiates long-term thinking and balances between landscape preconditions or opportunities and between hard/structural or soft/mitigating. It is not a ready-made solution, but an invitation to reconsider flood protection in a wider frame from a different perspective.

“But man is a part of nature, and his war against nature is inevitably a war against himself”
(Carson & Darling, 1962)

Preface

This thesis report is part of the MSc program Landscape Architecture at Wageningen University and my final student project. The project specifically focuses on the coast and the barrier islands of the Galveston Bay near Houston, Texas and aims to propose a strategy for flood resilience based on a profound analysis of the landscape system.

As with more people, the Texas coast fascinates me. I was fortunate to spend 6 weeks full-time on Galveston Island, exploring the region: short enough to keep the overview, long enough to be touched by small experiences: the never-ending bay view, egrets and vultures, kayaking the bay, favourable company. The commitment to the place induced the aim for a moderate and balanced design approach. Between the extremes of diked isolation and total retreat, a compromise to keep enjoying these wonderful barrier islands had to be found.

The assignment is complex. Hurricanes are destructive phenomena, taking place at a different scale than everyday life, making it almost impossible to bridge the gap between the two. Subtle is impossible. As a generalist, it took me a long time to find out the real assignment and despite the dominant focus and the time-consuming activity, the landscape analysis was a much-needed step to get to the core of the assignment.

Move on is a call for future-oriented movement. Moving on requires acceptance and intentions to no longer do what has been done. Moving on looks straight ahead, beyond the next obstacle. In addition, move on directly refers to the barrier islands and the suggested approach to 'let go': let them move again and let us enjoy.

The report is organised in four larger parts. In part I, the background of the project, the problem and the research intentions are introduced. In part II, the research is addressed, focused on the landscape analysis by research-through-drawing, supported by outcomes for design. In part III, the strategic design approach for the Galveston coast is illustrated. Last, part IV reflects on the research and the entire project.

Finally, I would like to thank the people that guided me along the process. I would like to thank Baukje Kothuis, Nikki Brand and the TU Delft for involving me, for your hospitality and enthusiasm and for bringing me in contact with key persons in Texas. Many thank to Dr. Sam Brody and his team at Texas A&M for the hospitality and kindness. I would also like to thank all interviewees in Texas for your time, interest and enthusiasm. I would like to thank my supervisor Ingrid Duchhart and Kevin Raaphorst from Wageningen University and special thanks to H+N+S Landscape Architects for offering me an inspiring, energizing and productive working environment and for sharing your inspirational comments. Last but not least, I want to thank Rick, Mia, Anneriek, Chris, Jan, Marianne, Axelle, Paulien, Silke, Cathelijn and many more, for your patience and support. You are invaluable to me.

Helena Van Boxelaere

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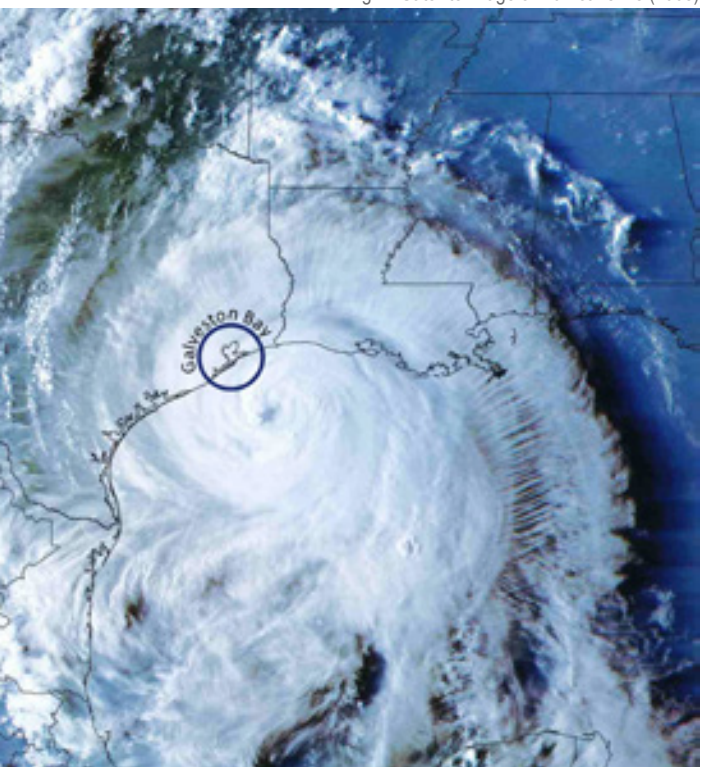

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Fig 4 : Flooded beach houses in Galveston

1 Introduction to the coast

1.1 Background

1.1.1 Hurricane Ike (2008) hit the Upper Texas Coast

On September 13, 2008 – three days before the stock market crash of 2008 – Hurricane Ike frightened away the Texas coast and the whole greater Houston region. Despite 'only' being a category 2 storm, Ike resulted in more than two dozen deaths and caused around $25 billion in damage. (J. B. Blackburn, Bedient, & Dunbar, 2014) It was one of the most destructive hurricanes to hit the United States, after Hurricane Katrina (2005), Hurricane Andrew (1992) and Hurricane Sandy (2012). Already 24hrs before the storm made landfall at Galveston, storm surge effects were felt along the Texas Coast and waves started crushing the Galveston seawall. At its peak intensity, Ike reached sustained winds of 230 km/hr with a field covering most of Texas and parts of Louisiana. In Houston, Hurricane Ike caused loss of power, broken glass from the tall skyscrapers, uprooting of trees, blocking of roads, and crushing of cars and homes. (Bedient & Sebastian, 2012) In addition, Ike brought a both deep and wide storm surge that caused significant flooding over 320 km of coastline. The land east of Galveston Bay has been covered with a 4,5m to 6,0m high surge. (J. Blackburn & Bedient, 2010) Bolivar Peninsula suffered most and was almost completely wiped out by Hurricane Ike. With some exceptions, beachfront developments were washed away and destroyed. Debris was piled up all over the island and found far inland. The city of Galveston had also much to endure. The existing seawall protected the city from the initial hurricane's storm surge from the Gulf of Mexico, but was not able to hold out a surge from the bay side. On Galveston Island, many homes were flooded. Beach sand was removed and redistributed, beaches eroded and the fragile dune systems were harmed. Aquatic life, wildlife and their habitats along the bay were affected as well during and after the hurricane. Thousands of redfish were found dead on the streets. Alligators died from saltwater intrusion and the lack of fresh, clean water. (Rifai, 2012) Characteristic live oak trees died from salt intrusion and oyster beds in Galveston Bay were seriously damaged and destroyed. (Bedient & Sebastian, 2012) In addition, environmental pollution was caused by release of chemicals into the atmosphere and the spilling of crude oil into the Gulf and Bay (approximately two million litre). (Rifai, 2012). Hurricane Ike *was a painful reminder of the vulnerability of the coastal regions* along the Gulf of Mexico.

1.1.2 Hurricanes and storm surges

Hurricane Ike was not the first storm to hit the Gulf of Mexico. "Each summer during the hurricane season between June 1st and November 30th, a number of severe storms enter the Gulf of Mexico and gain intensity as they hover over its warm waters." (Lindner, 2012) With over 15 million inhabitants, the coastal region along the Gulf of Mexico is among the most vulnerable areas to severe storms and hurricanes in the United States. (Bedient & Sebastian, 2012) Based on historical records, the Upper Texas coast has the third highest hurricane surge probability (J. B. Blackburn et al., 2014). Currently, the region is being hit by a major hurricane about every 15 years. Furthermore, it is likely that over the next century anthropogenic warming causes hurricanes to be more intense on average, implying a larger percentage increase in the destructive potential of the storms and in frequency, with likely higher rainfall rates than today. (Geophysical Fluid Dynamics Laboratory/NOAA, 2013) Therefore,

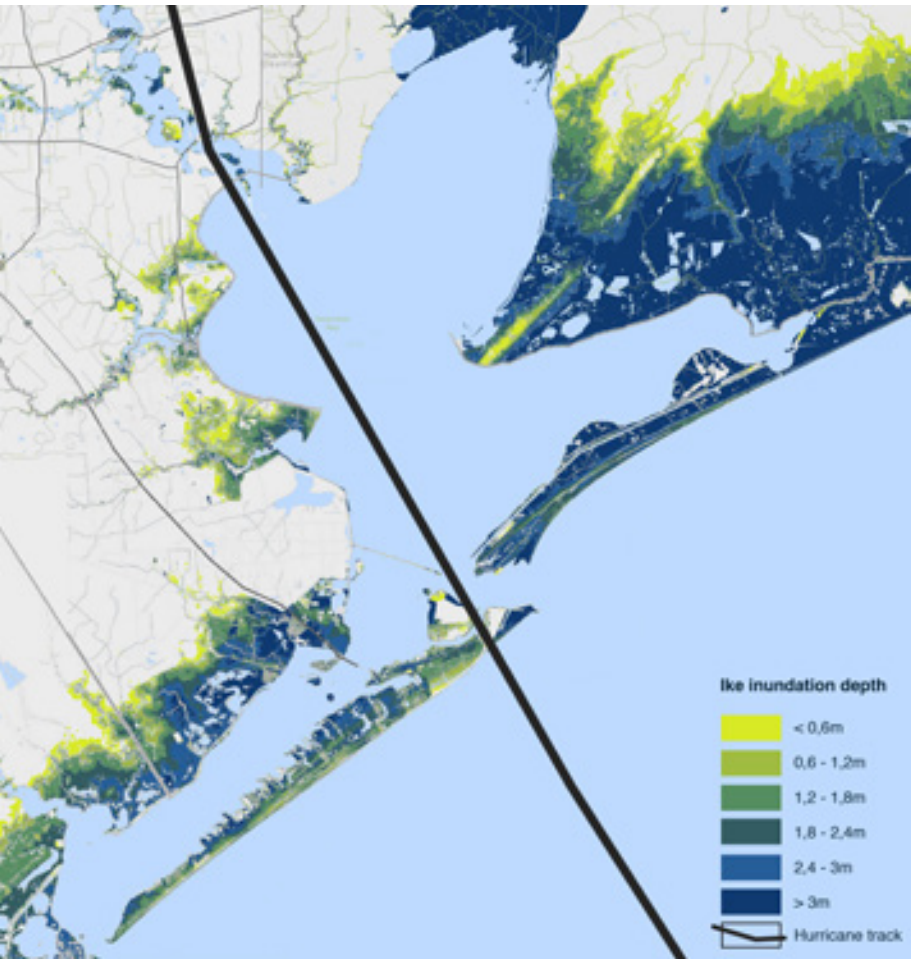
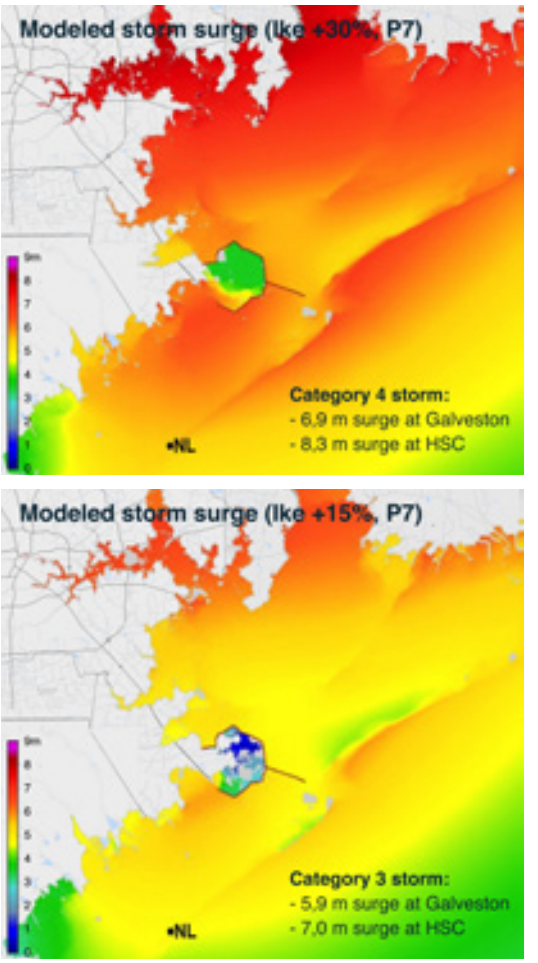


Fig 6: Hurricane Ike strom surge inundation depth



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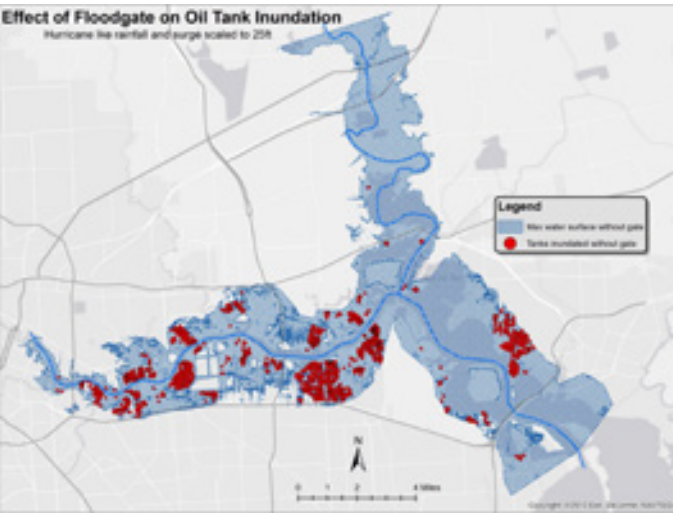


Fig 7: Oil tanks at risk of flooding with a +7.6m surge

Fig 9: Lifting of houses for flood-proofing

for the Upper Texas Coast, *the question is not whether or not, but rather when another destructive storm will hit the region.*

Tropical storms and hurricanes are destructive phenomena with their damaging winds, excessive rainfall, tornadoes and surges. (Dawson & Proft, 2012) They can inflict damage to very large areas along their track, causing inland flooding, storm surge flooding and increased wave action. The wind field of a hurricane plays an important role in the emergence of a storm surge. Hurricanes with large wind fields, such as Hurricane Ike, can generate greater storm surges with large quantities of water being move onto the coast, resulting in significant damage and inundation. (Lindner, 2012) Storm surges are a major concern because the *destructive flooding is the main cause of damage and casualties related to hurricanes.*

The Gulf Coasts are extremely vulnerable to flooding from hurricane surges. Storm surge has been responsible for the loss of thousands of lives and billions of dollars in damage along the Texas and Louisiana Gulf coasts. Unfortunately, more residents keep moving into these vulnerable coastal areas and the risk for significant loss continues to increase." (Dawson & Proft, 2012)

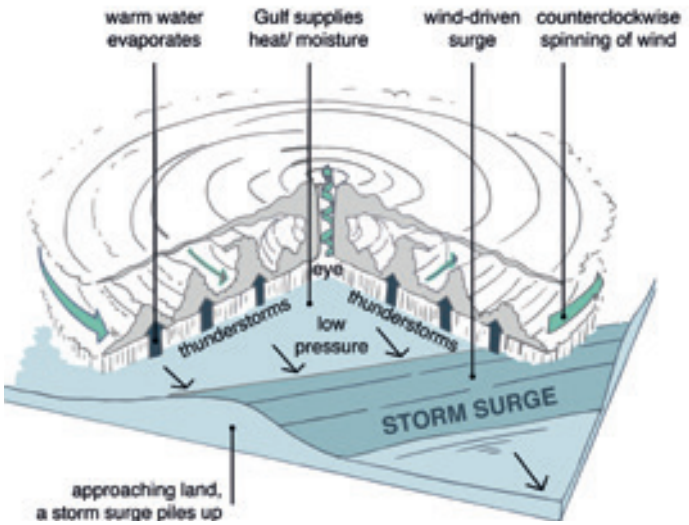
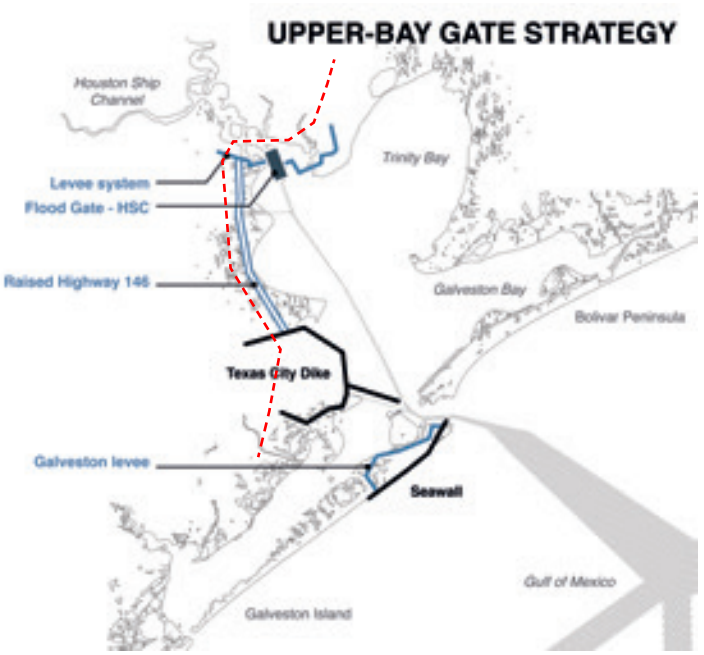


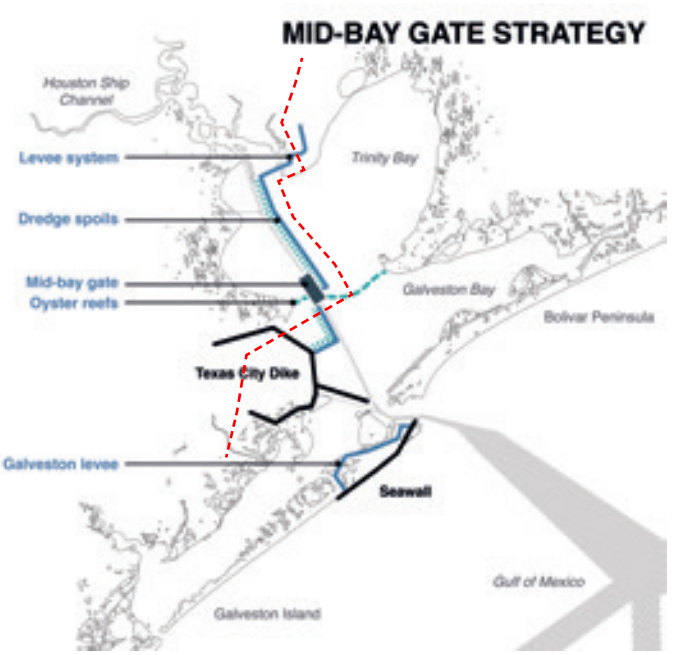
Fig 10: hurricane section with the generatation of a storm surge

At the Upper Texas Coast, the city of Galveston is located at the edge between land and sea. Developments along the shore on Galveston Island and Bolivar Peninsula are also located right at the forefront of a potential surge. Contrary to the coastal communities, the populated and economically important city of Houston is not directly situated at the Gulf of Mexico. However, the more inland location of the city at the upper side of the Galveston Bay does not exempt the area from a concerning flood risk. Research from the SSPEED Center (J. B. Blackburn et al., 2014) uncovered the reasonable potential of a 7 – 7,5m surge for the Houston Ship Channel in case of a 100-year surge. The Houston Ship Channel is the engine of the Houston economy, home to the world's second largest petrochemical complex. Flooding in this area would have catastrophic consequences for the Houston and Texan economy and spilling of oil and hazardous materials would possibly cause massive environmental damage. In addition, models suggest that a 100-year surge event would also severely affect the heavily populated and industrialized Clear Lake area west of Galveston Bay. (J. B. Blackburn et al., 2014) Therefore, besides the coastal communities on *Galveston Island and Bolivar Peninsula, the Houston Ship Channel and urbanized west side of Galveston Bay are also at high risk of severe flooding and damage.*

1.1.3 After the storm

After Hurricane Ike hit the coast in 2008, damage was assessed and rebuilding started. For those affected by flooding, it is a costly, emotional and enduring process. Besides buildings and infrastructure, lives and communities had to recover as well. In response to the lasting flood risk, dunes have been reconstructed, public facilities have been elevated and buildings on stilts have become slightly higher. Despite Bolivar Peninsula being hit the worst, only a few years later the coast was lined again with new beach developments. This approach seems to be common in other communities hit by a storm surge as well. But despite the new short-term outlook by rebuilding the same over again, *the long-term future of these highly vulnerable coastal areas is questionable*.





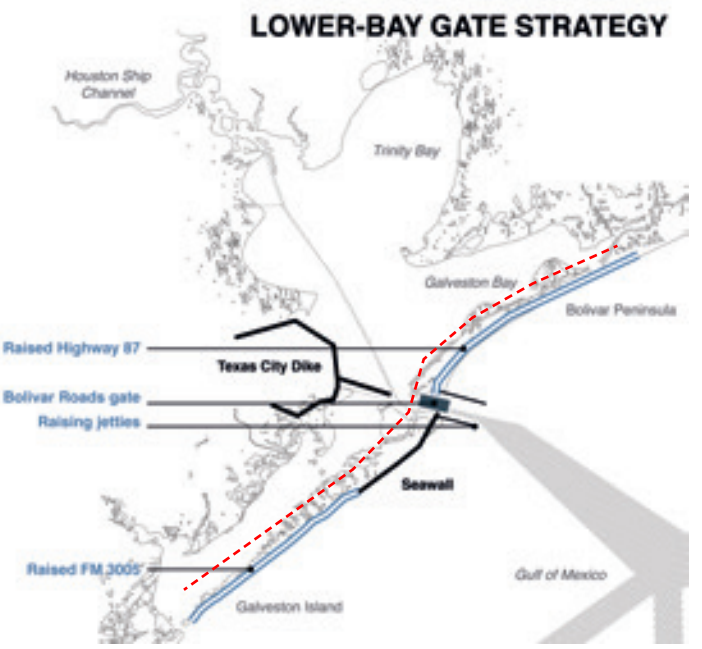


Fig 11: Proposed strategies and measures for flood protection

To assess the flood risk and decrease future damage and casualties from storm surge flooding, several institutions – involving private, governmental and academic parties – are researching the flood vulnerability and the potential of a regional protection system for the Houston-Galveston Bay region. Research institutions include the at Rice University located SSPEED Center (Severe Storm Prediction, Education and Evacuation from Disasters), Texas A&M University at Galveston, the six-country surge district (GCCPRD), the Texas General Land Office (GLO), the US Army Corps of Engineers (USACE), etc. (SSPEED, 2015) In addition, contributions have been made by TU Delft (various faculties), SWA Group Houston (landscape architecture, planning and urban design), the Dutch IV-Infra and RHDHV (engineering) and many more. The Houston-Galveston Bay region is also one of the study areas of the STW funded research program on the integral and sustainable design of multifunctional flood defences (MFFD), in collaboration with Delft University of Technology, Wageningen UR and the Technical University of Twente. In the course of this research, there has been much going on in the context of the collaboration between the Houston-Galveston Bay region and the TU Delft, including debates, publications, visits, symposia and workshops.

However, regional flood protection in the Galveston Bay region is a difficult challenge. Current flood protection systems in the region are limited (Galveston seawall and the Texas City dike), collective consciousness is humble and the public authority system is not configured to take up easily large-scale regional challenges such as flood protection or flood risk management. In addition, the assignment is divided between the coast and the bay. The entire coast is facing great exposure to potential flooding (as showed by history), but in the Galveston Bay the port and industrial facilities are decisive because of the unimaginable social, ecological and economic consequences of a potential disaster. In a risk-based approach to flood protection, the Houston Ship Channel and the urbanized and industrialized west side of Galveston Bay are the highest risk factor in the region.

However, in a regional flood protection approach, the exposure of Galveston and the barrier islands cannot be ignored either. *Therefore, it is expected that strategies for flood protection should complement each other*.

Research in the region already explored and identified several ways to deal with flooding. Protection techniques include hard measures such as dikes and flood barriers; soft measures such as dredge spoil islands and sand nourishments; or planning measures such as land use planning and land acquisition. However, the hard approach is dominant in current strategies for the region:

- *Upper-bay gate strategy:* compact combination of a storm surge barrier with a levee system near the Fred Hartman Bridge and the Houston Ship Channel. (HSC protected)
- *Mid-bay gate strategy:* larger combination of a storm surge barrier and dredge spoil islands in the Galveston Bay along the Houston ship Channel. (HSC and west side protected)
- *Lower-bay gate strategy:* extra large combination of a storm surge barrier and dikes along the coast and the barrier islands. (HSC, bay region and coast protected)

For Galveston Island and Bolivar Peninsula, a coastal barrier with floodgates and a set of dikes is the much debated protection system. The coastal barrier is suggesting a *hard approach* to the entire coastline. In the upper- and mid-bay strategy, the coast is excluded from hard protection measures and allocated to a *soft approach* or custom measures.

Fig 12: Downtown Houston

Fig 13: Petrochemical industries along the Houston Ship Channel near Baytown

Fig 14: Juvenile Fiddler Crab

Fig 15: Kayaking and bird watching at the backside of the barrier islands

1.2 Problem introduction

1.2.1 Contrast between culture and nature

Houston is the largest urbanized area near the Gulf of Mexico and with the Port of Houston, an important hub for oil trade and shipping. “Population projections place the Texas coast among the fastest growing regions in the nation over the next several decades”. (Brody, 2012) With over 2,1 million inhabitants, Houston is the largest city in the southern US and Texas, and the 4th most populous city in the entire United States (after New York, Los Angeles and Chicago). “The economic, the regional Gross Area Product of the Houston economy could be compared to other countries’ Gross Domestic Product, such as the Austrian and Polish GDP (Around $300 billion in 2006). Houston is also nicknamed the ‘Energy Capital of the World’ because of its position and innovation in the oil and gas industries. More than 5000 energy related firms are based in Houston and the gas and petrochemical industry delivers a significant production for the Texan and nation’s economy. The Port of Houston is home to the world’s second largest petrochemical complex and it is the busiest port in the US in terms of foreign tonnage. “Each year, more than 200 million tons of cargo move through the Port of Houston, carried by more than 8 000 vessel and 200.000 barge calls.” (The Port of Houston Authority). The Port of Houston is located at and connected to the Gulf of Mexico by the Houston Ship Channel: a 84km long dredged channel in the Galveston Bay. (The Port of Houston Authority) In addition to the energy industry, Houston is also significant in aeronautics, technology and medicine. Houston is home to the NASA Johnson Space Center and the Texas Medical Center, the largest medical centre in the world. (The City of Houston) Regarding population and economy, Houston is a high-ranking environment of national (and international) importance. Nevertheless, hurricanes and storm surges are a serious threat for the economy and productivity of this high-ranking environment. Current flood standards do not anticipate the actual risk of a catastrophic storm surge event in the economic core of the region.

Contrary to the urbanized industrial landscape, the Galveston Bay offers natural distraction. Galveston Bay is an important tidal estuary, enclosed by highly dynamic barrier islands. With about 1500 km^2, Galveston Bay is the largest bay in Texas and half of the population of Texas currently lives in the Galveston Bay watershed. Galveston Bay receives freshwater from the Trinity and San Jacinto Rivers and from the surrounding bayous and creeks. Fresh water, bringing in nutrients and sediments, mixes with salt water from the Gulf of Mexico and creates an immense productive estuarine ecosystem. (Galveston Bay Foundation) The large green and lush wetland systems surrounding the bay are a life-supporting environment offering food, nesting and shelter opportunities to a large variety of species: ‘shrimp, crabs, oysters, juvenile and adult finfish, redfish, flounder, speckled trout, and microscopic plants and animals upon which the whole system depends’. (J. Blackburn, 2004) The estuarine wetlands can be regarded as natural fish hatcheries and are among the most productive natural ecosystems on earth. However, the valuable natural resources are pressurized by the impact of human activities.

1.2.2 Problem statement

Currently, “more than 1,6 million people live within the designated hurricane evacuation zones surrounding Galveston Bay.” (Sebastian, 2015) Damage from hurricane Ike in 2008 exceeded $24.9 billion and as more people move into the low-lying coastal areas, the risk and vulnerability only increase. However, damage and flood risk is directly related to human activity in relation to the environment. Hurricanes are referred to as natural disasters, but damage from hurricanes “results from the interaction between biophysical systems and human systems with their built environments. Communities in the United States and much of the world continue to develop and expand into high hazard areas.” (Peacock, Zandt, Henry, Grover, & Highfield, 2012) This contributes to

increased hazard exposure and frequently results in the destruction of protective environmental resources such as wetlands and dune systems.

Galveston Island and Bolivar Peninsula are highly vulnerable to storm surge flooding due to their location at the frontline of the coast. Despite the imminent risk, the islands have been attracting people throughout history for diverse economic, ecological and aesthetic reasons. In 2008, Hurricane Ike reinforced the wish for flood safety and a *coastal barrier with dikes and floodgates* was proposed.

The coastal barrier for the Galveston coast is a hard, traditional approach to flood protection. *The problem identified is that a hard approach gives little concern to the integration and response of flood protective measures to* ***preconditions set by the physical and biological landscape system.*** *However, a soft approach for Galveston Island and Bolivar Peninsula that emerges from and responds to the landscape system, has not been fully explored yet.*

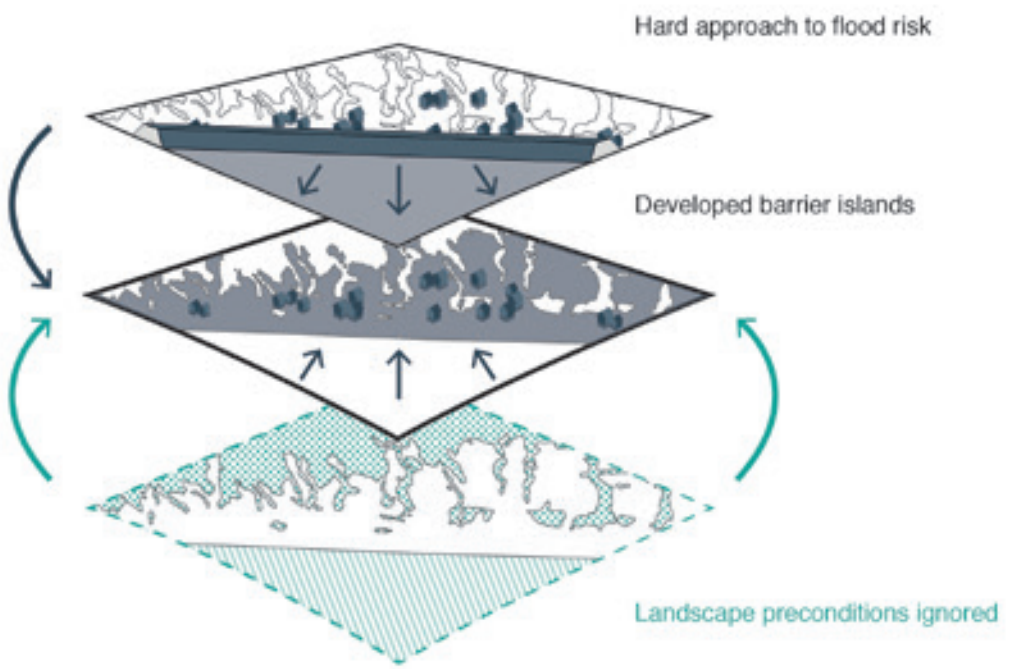


Fig 16: A hard approach to flood protection gives little concern to precondition set by the landcape system

1.3 Research introduction

1.3.1 Research purpose

The aim of the master thesis is to research a soft approach to flood protection on Galveston Island and Bolivar Peninsula that responds to the preconditions of the landscape system. The strategy has to tune human actions in with natural processes and therefore, the aim is to search for protective measures that emerge from understanding the landscape system.

The aim of the MSc thesis can be divided in a design and research purpose:

- *Design purpose:* propose a strategy for flood resilience at Galveston Island and Bolivar Peninsula in line with the landscape system.

- *Research purpose:* analyse the landscape system of the Galveston Bay region to provide guidelines for flood resilience.

The approach to research and design can be described as 'research for design' and 'evidence based design'. In the overall design process, research is used to find out what the context demands in order to inform the main design question on flood protection. Meredith Davis (Davis, 2015) mentions in the 'Routledge Companion to Design Research' that this type of design research often addresses 'grand challenges' in which solutions are in the public interest. The research in this case is specifically focused on the generation and internalization of knowledge on the existing landscape system. In order to do so, scholarly research and scientific data have been used to research the existing landscape system. The data and the outcome of the research inform the design.

1.3.2 Significance

The combination of research and design for flood protection is significant for Galveston Island and Bolivar Peninsula as an alternative to the existing hard approach (coastal barrier) for the region. A custom regional design approach to the coast can reveal new location-specific opportunities. A general strategy in line with the landscape system can complement other (bay-focused) solutions as well. As such, a system-wide approach is advocated.

II. Research

2 Research Framework

2.1 Theoretical lens

2.1.1 Ecology and a landscape-based design approach

In essence, ecology is the holistic study of interacting organisms with their environment. Literally meaning, 'the study of the household', ecology deals with plants, animals, microbes and people and the interconnectedness of humans and nature. "Ecology is by definition, the mutual relationships among all organisms and their biological and physical environments." (Steiner, 2002) Streams, rivers, marshes, plants, animals, etc. are affected by our actions, and at the same time human activity is impacted by these aspects.

Already in the 1960's, Ian McHarg pointed to the significance of ecology for landscape architecture. He reminded landscape architects of the balance between art and science, between nature and culture, and between the local and the regional. His aim was to discipline human purpose and growth through a profound understanding of natural processes. (Margulis, Corner, & Hawthorne, 2007) McHarg warned that 'to ignore natural processes is to be ignorant and to exclude life-threatening hazards such as floods and pervasive environmental destruction is either idiocy or criminal negligence.' (McHarg, 1997) Therefore, McHarg - among others – advocated a planning and design approach that draws on the fundamentals of ecology as a way of directing or managing change in the landscape to bring human actions in tune with natural processes. Ecological planning provides methods to reveal the most fit locations and processes for particular human use and to prevent terrible (common) mistakes and abuses in planning and design. (Olin, 1997) Even today his well-known layer-cake model is a common tool for landscape architects for acquiring substantive knowledge about the landscape.

Theory on ecological planning and design has greatly evolved over time with remarkable engagement and development among Dutch and American academia. Similar to the shift from the traditional closed and balanced ecosystem approach to a new more complex and dynamic view on ecology, ecological planning and design also adopted new assumptions and developed new approaches. At Wageningen UR in the Netherlands, ecological design and regional design converge and characterize the traditional approach of the landscape architecture school. Kerkstra, Struik, & Vrijlandt (Kerkstra, Struik, & Vrijlandt, 1976) developed a framework ['Denkraam'] using a simple layer-cake model, known as the triplex landscape, to aid in understanding concepts and interactions between man and nature in a specific observable landscape. A division is made between three general groups of landscape shaping factors that steer diversification in the landscape: the physical factors, the biological factors and the cultural factors. The observable landscape can be regarded as the expression of complex interactions between these factors (further referred to as 'landscape processes'). Interactions are in constant motion and subjected to change over time. (Kerkstra et al., 1976) Human activity is not exactly determined by the natural system, but activities are intrinsically connected and part of the natural system: in the past and future. It is the future-oriented change in the landscape where humans can intervene consciously and thoughtful to create their optimized living environment. In her dissertation on 'Designing Sustainable Landscapes'

with extensive case-study projects in Kenya, Duchhart (Duchhart, 2007) further developed the ecological and site-specific approach to landscape architecture of Prof. Kerkstra and Vrijlandt, by 'combining the sociophysical-organisation model of Kleefmann and the triplex-landscape model of Kerkstra.' In this model, the natural organisation principle similar to the landscape triplex is intertwined with a social organisation principle consisting of a cultural, political and economic subsystem to allow better understanding of the driving forces underlying the visual landscape. (Duchhart, 2007)

Alongside the development of a greater social involvement, Koh (Koh, 2008) rather emphasized the importance of aesthetic values and experience in the ecological design approach. The great emphasize on the rational understanding the driving forces in the landscape, contains the risk of inventories and analyses unaware the true design goal. In his 'landscape approach', Koh (Koh, 2008) advocates both a scientific and an aesthetic approach to landscape design, which is integrative and dynamic. More than being ecological alone, the landscape approach seeks to reveal landscape and ecological processes to enable people to see and experience them in daily life and learn what these processes do for people. Design in the landscape approach, becomes not just form-making but contextualizing and process-ordering and a landscape approach to design is not only about process design but also about experience design. It is definitely not about form alone but about form in landscape. (Koh, 2008)

The research and design approach in this thesis is closely related to and building on the ecological design framework. Despite being inspired and influenced by different perceptions, views and approaches within the larger ecological approach, there is no commitment to one specific claim and therefore the theoretical approach of this thesis is described as *a 'landscape-based design approach*.'

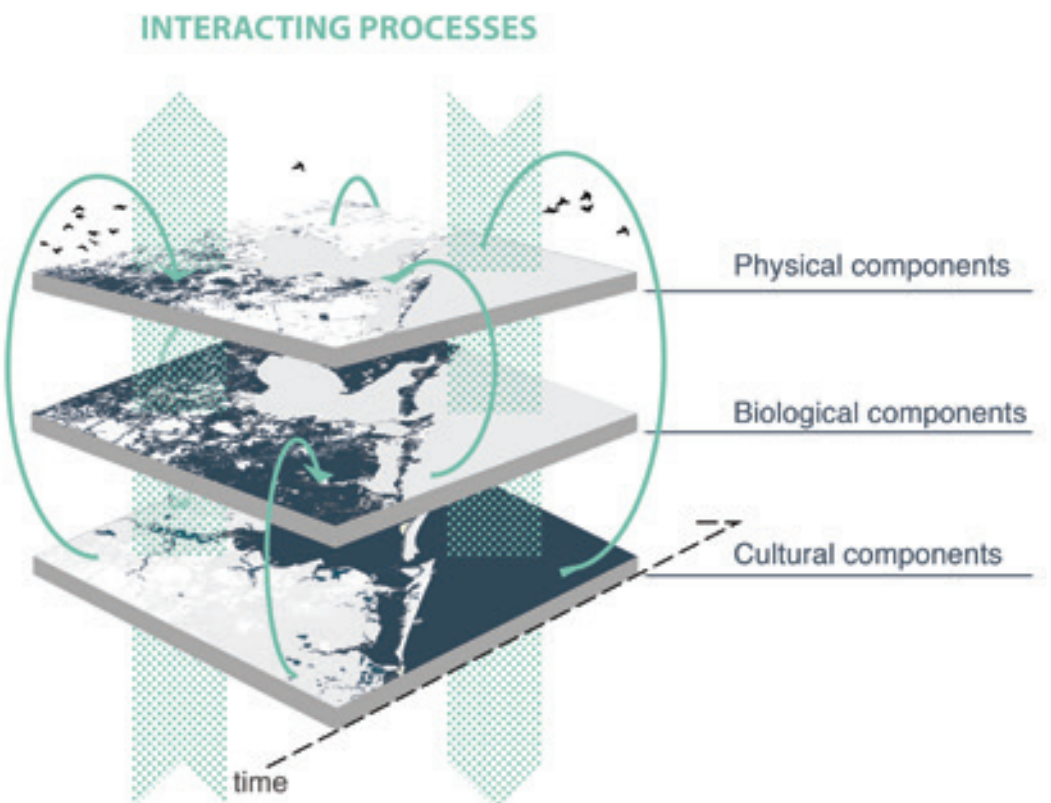


Fig 17: A landscape-based-design approach, looking at connections between the landscape layers

2.1.2 Flood risk reduction approach

When water goes temporary beyond its normal confines, we speak about floods. Floods are part of the natural hydrological cycle and the sediments left behind result in fertile land attracting human use and settlement. However, as more social and economic assets develop into flood prone areas, the flood risk increases. Therefore, flood risk is entirely a human issue. (Schanze, Zeman, & Marsalek, 2006) Flood risk can be defined as the probability of a damaging flood event and the vulnerability of a community to flooding. 'Vulnerability may be defined as the characteristics of a group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard' (Schultz van Haegen & Wieriks, 2015) Vulnerability can range from social to economic and ecological vulnerability, referring to loss of life, health impacts, stress and psychological damage, social impacts, loss of personal belongings, loss of cultural heritage, financial losses by property damage, loss of materials and goods, loss and damage due to pollution, etc. (Schanze et al., 2006) In the Netherlands, flood protection is a matter of survival and throughout history the Dutch have become experts in flood control and water management. New challenges and societal change required on-going innovation and development. Over the course of time, new techniques have been implemented and the general water management approach has changed. In the nineties', the paradigm shifted from flood defence to flood risk management.

Flood risk management can be defined as 'a holistic and continuous societal analysis, assessment and reduction of flood risk.' (Schanze et al., 2006).' A societal and political discussion defines the acceptable levels of risk and the desired safety level. Because absolute protection is considered unachievable and unsustainable due to high costs and inherent uncertainties, flood risk management received growing attention. (Schanze et al., 2006)' Flood risk management is focused on risk analysis, risk assessment and risk reduction. Risk levels are calculated and optimal protection standards are reached when the total costs are equal to investment costs and the expected damage costs. As such, a risk-based protection approach is not aiming to avoid damage at all stakes, but rather seeks for the optimal protection between costs and benefits.

In the Dutch context, spatial planning and design are important aspects in the flood risk reduction approach. In recent years, the hard engineering approach to flood protection characterized by the prevention of flooding with hydraulic structures and brute force, shifted towards a soft approach, characterized by the reduction of flood impact with the use of natural resources in line with the landscape. The shift resulted from the realization that the closure of the estuaries by the Delta Works initiated a process of large scale changes in the morphological balance, tidal currents and water quality of the tidal landscape" (Hooghart & Posthumus, 1989) A soft dynamic approach is ecosystem-based and is being applied where appropriate. Safety is typically no longer the only criteria for intervention, but ecology, integration and multi-functionality pulled ahead in the flood protection program, for example in combination with spatial quality and nature development. (Eijsbergen & Geer, 2008) The large-scale reinforcement of the Dutch 'Afsluitdijk' (Enclosing dike) for example is besides a technical protection assignment, also formulated as a challenge for sustainability, innovation and ecology (among others). The plans now include improvements of the spatial quality and the realization of a large fish passage with a gradual transition from fresh to salt water to allow fish to migrate more easily. (Gerkes, 2011) The *flood risk reduction approach* moved beyond control and stability towards flexibility and long-term resilience and is usually characterized by a multidisciplinary approach.

In the case of flood protection in the Galveston Bay region, a hard approach with combinations of levees and floodgates is being studied. For the barrier islands, a custom strategy including soft measures is publicly not being discussed.

2.1.3 Knowledge Gap

The landscape of the Galveston Bay region is studied well in all its aspects. Abundant (scientific) information is available on the coastal ecosystem, geologic formation, history, development, culture, economy, water quality, etc. However, the current approach to flood protection at Galveston Island and Bolivar Peninsula gives little concern to these aspects and the proposed protection measures only limited include the landscape system. Despite all information being available to fuel a landscape-based approach, the landscape is poorly included in the current flood protection approach. A gap exists between flood protection on Galveston Island and Bolivar Peninsula and the inclusion of the landscape system of the Galveston Bay region. In particular, a method lacks to connect to the landscape as a system with connected parts and whole, informed by available information.

2.2 Research questions

The research is subdivided in one main design question and two research questions that contribute to the overall understanding of the main question.

Main design question:
What strategic approach for Galveston Island and Bolivar Peninsula moves to flood resilience in line with the landscape system of the Galveston Bay region?

Research questions:

- What embodies the landscape system of the Galveston Bay region?

- What principles guide an approach to flood resilience in line with the landscape system of the Galveston Bay region?

2.3 Research approach

2.3.1 Research steps

I. Scoping
During the IABR_2014 symposium 'Urbanized Deltas in Transition', the complex flood mitigation debate in the Houston-Galveston Bay region in Texas, USA was presented. As a result of this presentation, I started exploring the Texan context and the topic of hurricane flood risk reduction. Contact with the TU Delft improved the perception of and involvement with the current project context. This first phase served to explore the subject and to narrow down to define the right scope of interest for research and design. The problem definition and focus was the result of this phase.

II. Preliminary research
In the ambition to connect the local landscape system to flood risk reduction, the main focus was the coastal and estuarine landscape of the Galveston Bay. The landscape is considered both the object of study and the source of information for the research. Therefore, it was necessary to go on site early in the research process. Prior to the fieldwork, an initial desk study on hurricanes, flood protection and the sensitivity of the region was carried out. In addition, map studies helped to explore the area and initial connections between the landscape and flood risk reduction strategies.

III. Data collection: field work in Texas
The field trip lasted for six weeks in Texas, mainly in Galveston but also in Houston and even in College Station. Besides data collection, the trip was intended to get physically and mentally well acquainted with the area, the scale, the subject, the people and the culture. Aiming for more than just a visitor experience, travelling alone helped to root down fast and to participate in daily life. During the fieldwork in Texas, data was collected by interviews with experts, by field

observations and (guided) field trips and by literature reviews. The data collection provided the basis for the landscape system research.

- DESIGN intermezzo-

IV. Data processing: research-through-drawing
Literature reviews, interviews sheets and excursion sheets were analysed and scanned on key words and concepts regarding the landscape system. The result was a general overview of the landscape system characteristics, grouped and ordered in a physical, biological, cultural category. Triangulation, intuition and snowballing helped to reach a saturation point at this stage. Next, all characteristics were explored in depth and translated to similar freehand drawings. Drawing requires selecting, omitting and adding new information in a steered way. New data is added and combined in representation. Therefore, freehand drawing can be regarded the method of 'coding' and analysing data. All together more than 70 drawings resulted in a visual overview of the landscape system of the Galveston Bay region.

- DESIGN intermezzo -

V. Data analysis: landscape system understanding
The data, coded into freehand drawings, has been further analysed by exploring connections and coherence to reach full understanding. By concept mapping, drawings have been moved around by trial and error based on their content until the best hierarchy was reached. Understanding interactions between the individual concepts helped to get grip on the landscape system as a whole. The result of the analysis is a concept map with the best-organised hierarchy to reflect the analysed coherence.

- DESIGN intermezzo-

VI. Research conclusions for flood risk reduction:
Understanding the landscape system and the connections between individual concepts resulted in different ideas about flood protection. Understanding the landscape system, also regarded as the bigger picture, reveals other connections than initially identified. The final concept map has been used as a sub layer to identify and express these observations. Tracing paper is again the platform for exploration, in words and arrows. On the tracing paper, the link between the landscape system and flood protection is established, with several guidelines in line with the system as a result.

VII. Design for flood risk reduction
Several design principles indicate possible interventions in line with the landscape system, but are not spatial and specific yet. In this last phase, the principles have been used to establish a strategic custom approach for the Galveston coast. The combination of explicit guiding principles and implicit knowledge from researching the landscape system in earlier stages has been used as an inspiration and knowledge base for design. The result is a strategic design to move to flood resilience at the Galveston Coast, TX.

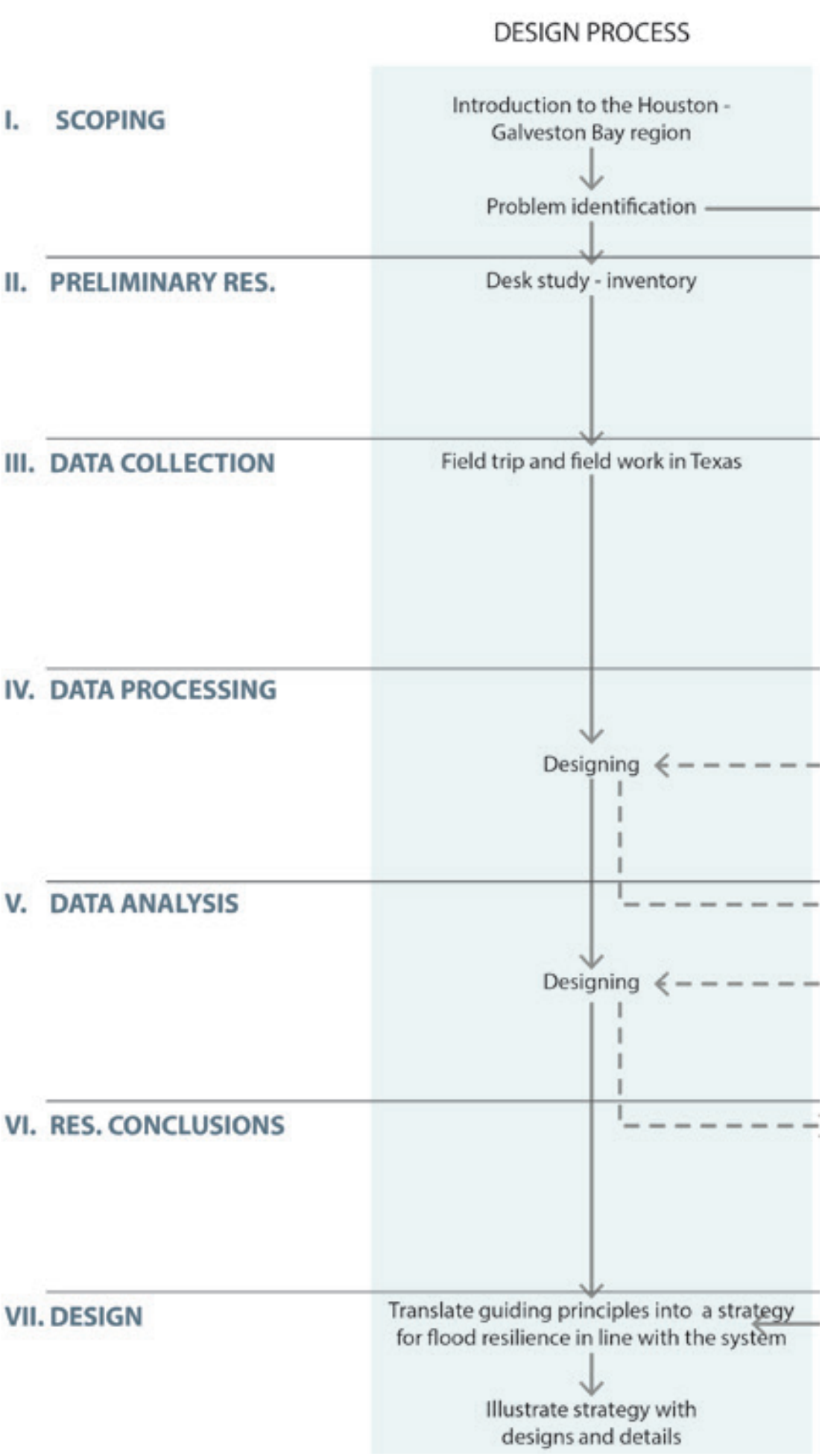


 Fig 18: Research flow-chart

RESEARCH PROCESS

Prepare research scope
and research approach

Construct
theoretical framework

MDQ: What strategic approach for Galveston Island and Bolivar Peninsula moves to flood resilience in line with the landscape system of the Galveston Bay region?

= Collect landscape elements
[data: locals, experts, books, guides]

Ecology

RQ1: What embodies the landscape system of the Galveston Bay region?

Expert interviews | Literature reviews | Field observations | (Guided) field walks

OUT: overview of landscape characteristics

= Translate landscape elements info
[data: literature, maps, secondary data]

– Freehand drawing
[maps, sections, schemes, diagrams, icons, interpretations]

OUT: visual overview of the landscape in 70 drawings

= Analyse drawings for internalization/ understanding
[data: drawings of landscape elements]

– Freehand drawing | Model building | Concept-mapping

OUT: concept map reflection landscape system coherence

RESEARCH-THROUGH-DRAWING

= Examine landscape system with flood mitigation
[data: concept map]

Flood R. M.

RQ2: What principles guide an approach to flood resilience in line with the landscape system of the Galveston Bay region?

Designing ← – – → Freehand drawing

OUT: guidelines for flood resilience in line with the system

2.3.2 Methodological overview

Field observations and (guided) field trips
Living in the study area and field trips in the greater Houston-Galveston Bay area helped to research the observable landscape. The field trips were crucial in grasping the environment and scale of the bay area. Field trips were usually done by car, sometimes by boat, kayak or by foot. Individual trips helped to wonder and to closely observe and question features of interest. Guided trips helped to clarify previous observations and to fill in gaps. Every field trip was captured in an excursion sheet with time indications, a precise route map, pictures, written observations and remarks.

Literature reviews
Contrary to field observations, literature reviews provided information on processes behind the observable landscape. "Literature reviews help to distill information and catch the essence from published credible sources." (Martin & Hanington, 2012) The reviews summarized the literature and captured relevant information with an exploratory purpose in mind. A selection of peer-reviewed and non-reviewed articles and books on Galveston Bay and the Galveston coastal area were used as a data source. The text was reviewed by highlighting key words related to the landscape system.

(Expert) interviews
Interviews were done in Texas with academics, professionals, landscape architects and environmentalists. Interviews were used to collect first-hand personal opinions and experiences. (Martin & Hanington, 2012) All interviews were exploratory to discover the landscape system and to name processes related to the coastal area, the barrier islands and the bay. The interviews were crucial in determining the degree of information and the relevance for the research. The aim of these interviews was to get a general overview of the system, not to get in-depth data about one specific topic. All interviews were done in person, mostly semi-structured and open-ended. Key words were collected in personal notes of the conversations and later processed into interview sheets for each interview.

Freehand drawing
Freehand drawing is an imaginative process of representation that encourages analysis and the establishment of new creative relationships. Drawing demands the adding, selection, processing and omission of information for visualisation, supported by GIS-data, literature and secondary data sources. For this research, freehand drawing is a method of coding the landscape characteristics for exploring their spatial connections with the landscape. By coding, data is processed and prepared for further analysis. Map studies, tracing, diagrams and schemes require to use information about the individual characteristics considered and to represent the whole thoughtfully for the next step. In fact, freehand drawing is a form of designing, on a conceptual level.

Concept mapping
Concept mapping is used as a sense-making tool to study connections between drawings and concepts. Instead of words, each drawing is considered to express a concept and to hold implicit knowledge. As such, large amounts of information can be connected in a visual framework that allows designers to absorb new concepts into an existing understanding of a domain so that new meaning can be made." (Martin & Hanington, 2012)

Designing
Throughout the entire research process, designing has been a method to keep focused on the main goal and to strengthen the link between research and design. Designing helps to focus, narrow down and provide new knowledge and new questions on the problem. At several stages, designing has been exercised as an activity, not a product, to explore and develop the approach to flood protection and to redefine the assignment. While freehand drawing is a creative method to research past and present conditions, designing seamlessly connects in a similar way to research the future conditions. Throughout the process, the result of the designing transformed from abstract conceptual sketches at a large scale to detailed sketches at a lower scale.

3 Research

3.1 Research-through-drawing

Drawings are core to the design discipline for internal and external communication of ideas and plans. Problems, beliefs, processes and products need to be expressed and represented from more abstract to very precise levels. Drawings are not only suitable for representation of plans and products for communication, but also the act of drawing itself plays a major role throughout the stages of the design process. (Cross, 2007) However, as Frits Palmboom mentions in 'Inspiration and Process in Architecture' (Fosso, Andreotti, & Colombo, 2014), "talking about drawing is a delicate matter. Each drawing can evoke different words; each word can evoke different drawings. The relationship between words and images is not ruled by laws, but by conventions. These are 'relationships of possibility'."

Freehand drawing is a quick method that allows expression of character and personal style. Moreover, freehand drawing stimulates creativity and imagination and therefore, it is a perfect tool for design. (Laseau, 2001) The speed and flexibility of drawing and the different levels of abstraction that can be handled stimulate a dynamic thinking process. This process is the result of the link between the eye, the mind and the hand, where reality is grasped and represented on paper. (Treib, 2006) Juhani Pallasmaa describes 'the pencil in the architect's hand as a bridge between the imagining mind and the image that appears on the sheet of paper: the image emerges as an automatic projection of the imagining mind.' (Pallasmaa, 2009) Sketches are graphic representations of thoughts and opportunities for new thoughts, offering feedback to the mind. By watching, combining and focussing on different elements, new ideas and combinations emerge. (Levens, 1962) At the same time, abstract sketches help the designer to form a visual memory of important considerations. Tracing lines of information in particular, is an important aspect in memorizing and internalizing information. As such, sketching can stimulate visual-spatial thinking and the inner dialogue.

In the study of the landscape on a regional scale, a method is needed to handle large amounts of information. GIS is a common tool to manage, organize and represent data, but does not support the personal internalization of the information. Reading literature and seeing maps not necessarily results in profound understanding of the matter. As freehand drawing requires a more active approach, it could be a suitable method for regional research and design. Kempenaar says that 'drawings and visualizing information is regarded a content-related contribution to the design process. The visualisation of information is considered valuable to understand interactions and relationships between different spatial issues. The mapping, exploring and visualising of spatial information and issues is seen as a tool of research.' (Kempenaar, Westerink, Lierop, Brinkhuijsen, & Brink, 2016) As an aid in visual thinking, freehand drawing is considered to h**elp designers for understanding**. Drawing helps to **internalize** large amounts of information, to **translate** information to the same format, to **get grip** on the assignment, to **jump scales** flexibly, to **reduce complexity**, to **explore** implicit connections, etc. Drawing takes time and requires to look carefully. In addition, drawings are beneficial because they embody implicit knowledge

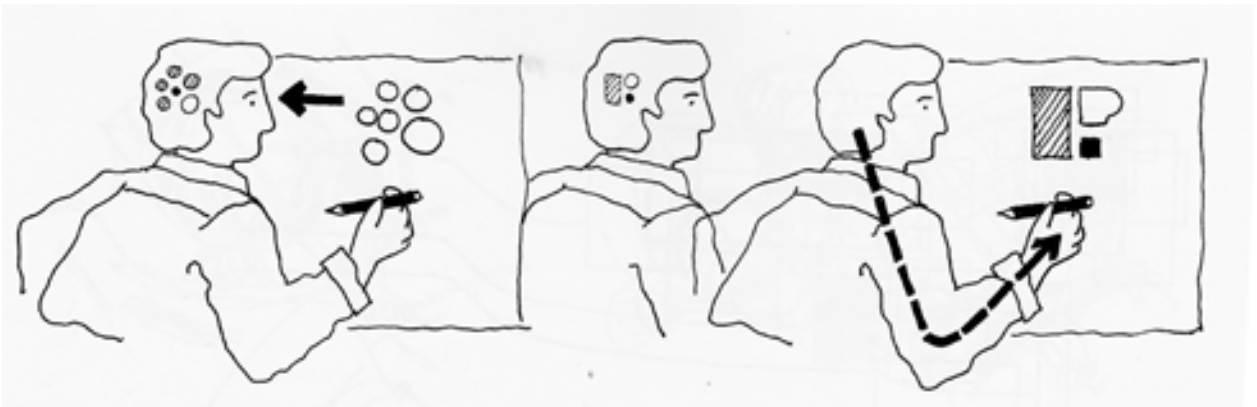


Fig 19: Connections between the paper, the mind and the hand

and present information simultaneous. (Laseau, 2001) Robert McKim points out (Laseau, 2001) that 'contrary to sequential verbal language, graphic language is simultaneous. All symbols and their relationships are considered at the same time and are transmitted and received on several levels simultaneously. The simultaneity and complex interrelationship of reality accounts for the special strength of graphic language in addressing complex problems.'

In architecture, freehand drawing is often used as a method for internalization of project data. 'In the physical site analysis, site features such as macro- and micro-climates, topography, natural circulation, views, trees, rocks, or water must be considered in order to place and design a house. Abstract sketches of these features can uncover problems and opportunities by showing the site features simultaneously'. ' The use of abstract diagrams is to help the designer commit to memory large amounts of project information. These diagrams can also be used directly as a record of design variables. The main advantage of diagrams as a graphic record is their immediately accessible information when all the diagrams are arranged in a large group. Creative designers fill sheets upon sheets of paper with diagrams and sketches of all types to record what they know and think about a design problem.' (Laseau, 2001)

Despite the difference in scale and matter, a similar approach is followed for the regional case of the Galveston Bay region. Freehand drawing is specifically used as a research method to internalize information and as a visual simultaneous language that helps to explore relationships between different spatial issues. As a design method, sketches and diagrams help to make information spatial and to record project information, providing direct access to features in the landscape. Therefore, freehand drawing is an important method of bridging the gap between research and design.

3.2 Research Steps

3.2.1 Overview of landscape elements

In the landscape system of the Galveston Bay and the Galveston coast both the metropolitan area and the estuarine landscape come together and interact. Besides the vulnerability to hurricane surges, the landscape is facing more issues and challenges. It is the aim to not only identify system characteristics related to this flood vulnerability, but also to move beyond the flood risk and to research other landscape features as well. To intervene in line with the system, it is necessary to understand interactions and to assess connections and opportunities. Challenges such as land subsidence, landward retreat and the rising sea level cannot be ignored when proposing a significant change. The initial step for understanding is to find out *what characteristics define the landscape of the Galveston Bay region.*

METHOD:
To research the landscape system, observations, (guided) field trips, literature and interviews with local experts provided the necessary information base. Information has been gathered during the fieldwork in Texas and later keywords have been identified in personal notes and texts to create an overview of important characteristics of this particular system. An initial selection was done among key words based on their relevance for the research. Following the layers approach of Kerkstra and Vrijlandt (Kerkstra et al., 1976), identified characteristics have been organised in three categories: physical characteristics (abiotische factoren), biological characteristics (biotische factoren) and cultural characteristics (antropogene factoren). Together the characteristics provide a general overview of the landscape system of the Galveston Bay and Coast, aiming to inform a strategic approach to flood protection in line with the landscape system.

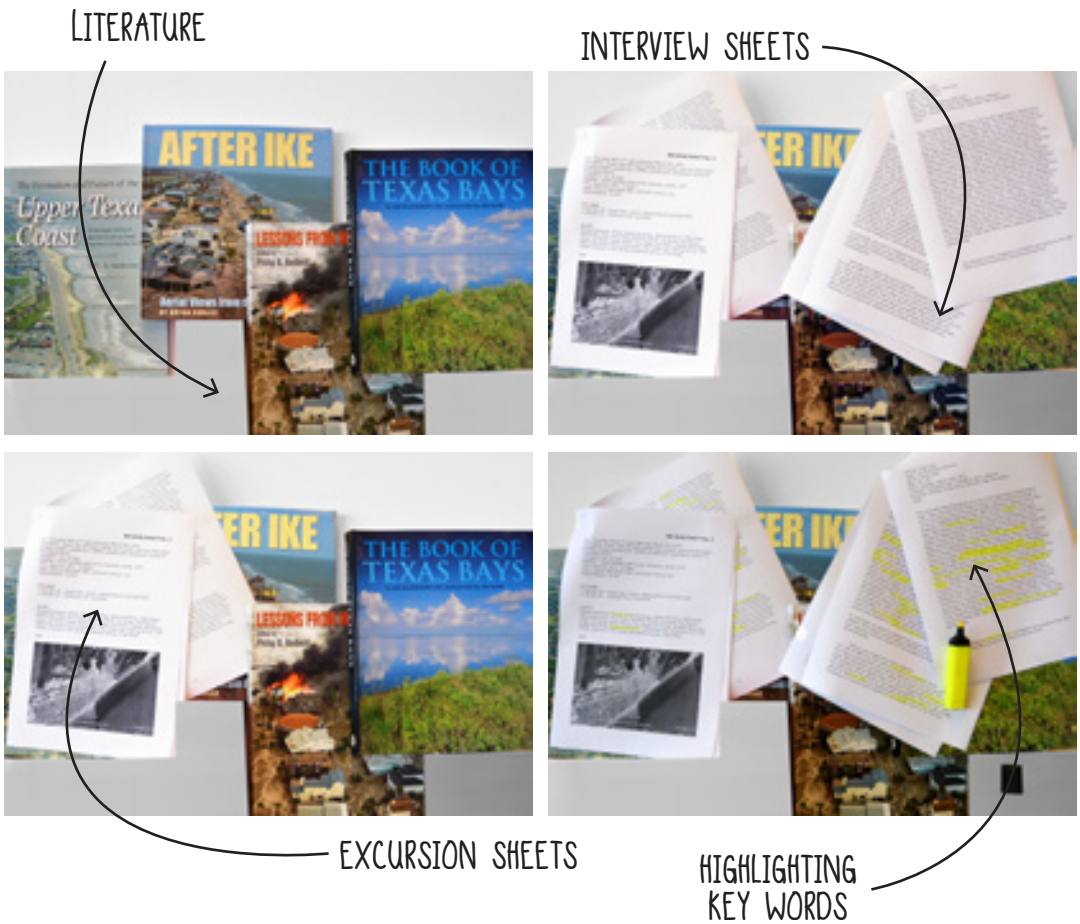


Fig 20: Step-by-step approach to indentify landscape characteristics

RESULT

The data collection of landscape elements resulted in a large amount of key words and characteristics. Per category, several main characteristics can be identified among the different key words.

Physical characteristics:

- Beach and dune systems
- Sediments
- Estuarine conditions
- Climate and storms
- Water circulation and salinity

Biological characteristics:

- Bird migration
- Fish hatchery and marine life
- Wetlands and marshes
- Coastal vegetation

Cultural characteristics:

- Galveston history and heritage
- National flood insurance program
- Economy of Galveston and the region
- Coastal population
- Hydraulic interventions

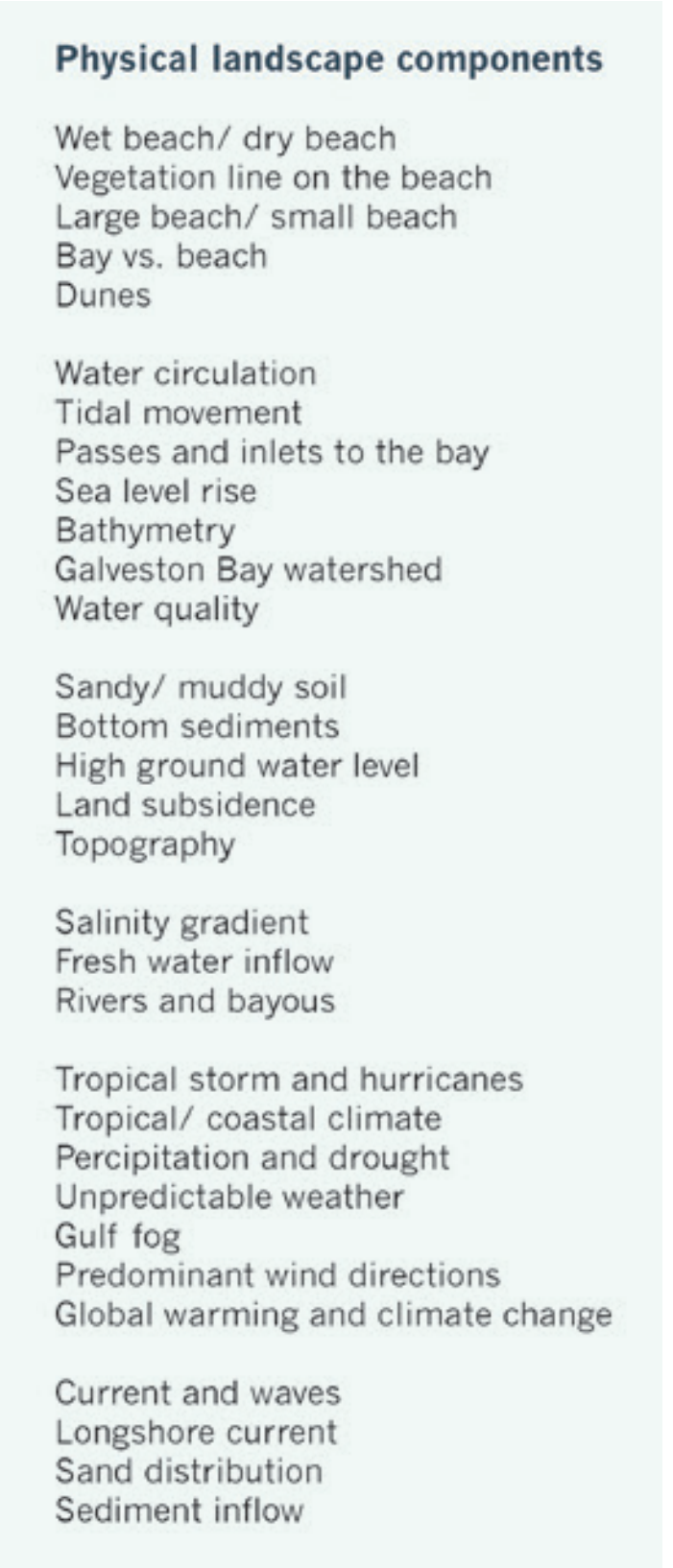


Fig 21: Overview of landscape characteristics

Biological landscape components

Bird migration flyways
Bird mugration rest places
Bird watching destination

Natural fish hatchery
Estuarine productive ecosystem
Deepwater unproductive ecosystem

Coastal marshes
Cordgrass marsh
Seagrass beds
Oyster beds
Water purification
Salt tolerant species

Wildlife species (birds, fish, etc.)
Vegetation species
Exotic and invasive species
Protected species
Ecological indicators

Tall crass prairie
Wet coastal prairie
Bottomlands
Forested wetlands
Freshwater marshes
Brackish marshees
Salt marshes
Saltflats/ mudflats
Tidal marshes
Riparian forest

Ecosytem services of wetlands
Disappearing wetlands
Sargassum washes ashore

Cultural landscape components

Galveston history
Victorian architectural heritage
Building characteristics

Karankawa tribes living at the coast
Pirates and early trade
European immigration via Galveston
Early port and banking activities
Discovery and use of oil
Opening of the Houston Ship Channel
Economical shift from Galv. to Houston
Population increase

FEMA Flood control
Building houses on stilts
Flood insurance
Flood maps

Port of Galveston
Houston Ship Channel
UTMB
Univesities and education
Recreation on the coast
Cruiseships at Galveston
Fresh water withdrawal
Oil spills and contamination

Open Beach Act
Rolling easement
Environmental laws and legislation

Dredging of ship channels
Dikes and jetties
Breakwaters
Sand suplementation
Texas culture

3.2.2 Investigating landscape elements

The overview of landscape elements gives a good impression of the different forces in the Galveston Bay region. However, new concepts and unfamiliar characteristics are encountered and need more explanation. In addition, most elements need a spatial context and additional information to be best understood. Therefore, the second step is to *learn more in detail about the individual characteristics of the landscape system.*

METHOD

After the fieldwork, each characteristic in the overview of the landscape system is researched more into detail and represented in a drawing. Drawing allows translating different forms and sources of information to the same comparable kind. Information available in literature, online and in GIS is gathered to expand the personal knowledge about one topic of interest. Data sources are checked on their reliability and triangulation with different sources allows validating information. Next, a specific purpose and message for each drawing is chosen and new information is selected, added, combined, interpreted and omitted. A geographic map serves as a sub-layer and allows to make information spatial. Then the drawing process starts, where information is represented and processed by the hand, the eye and the mind. Sometimes drawings are made from scratch by heart, but more often maps and diagrams are traced. Tracing is a quick and accurate method to combine information and tracing by hand in addition stimulates awareness and attention. It is even believed that tracing amplifies the visual memory in the mind. Besides the content related decisions, freehand drawings also require to think about representation and make choices on size, type, view, colour, line type, text, etc. In this MSc thesis however, this specific domain is not further discussed.

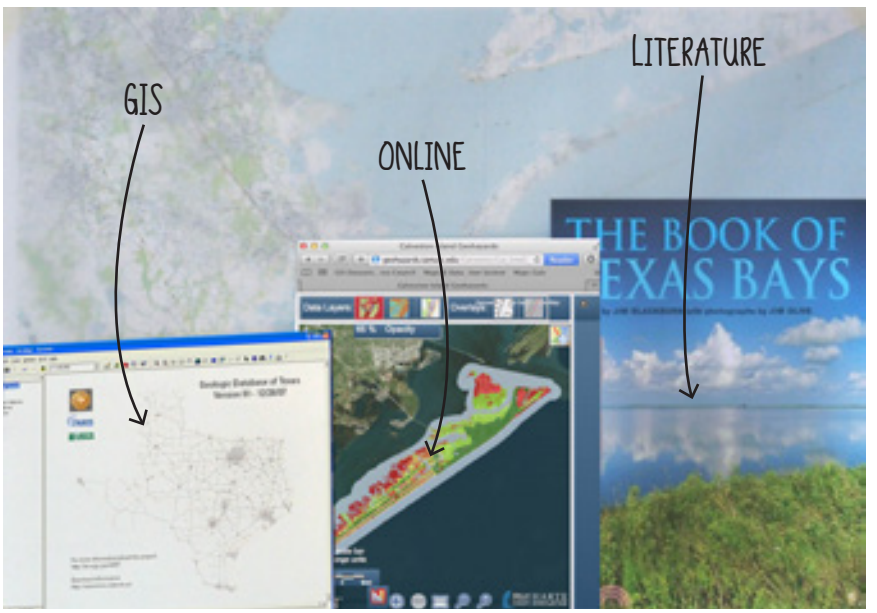


Fig 22: Data sources for investigating landscape elements

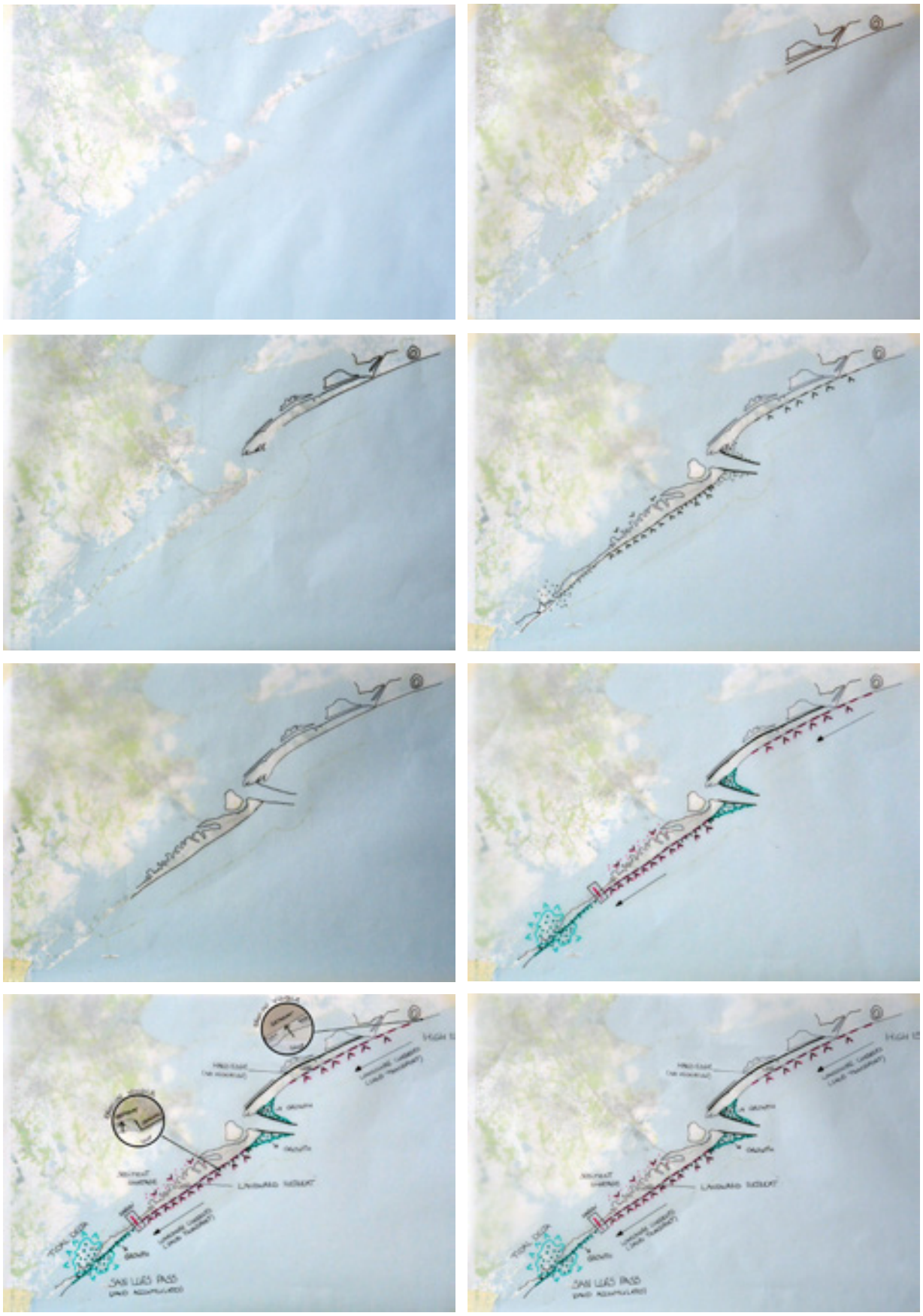


Fig 23:Step-by-step drawing approach: tracing, selecting, adding, omitting, etc.

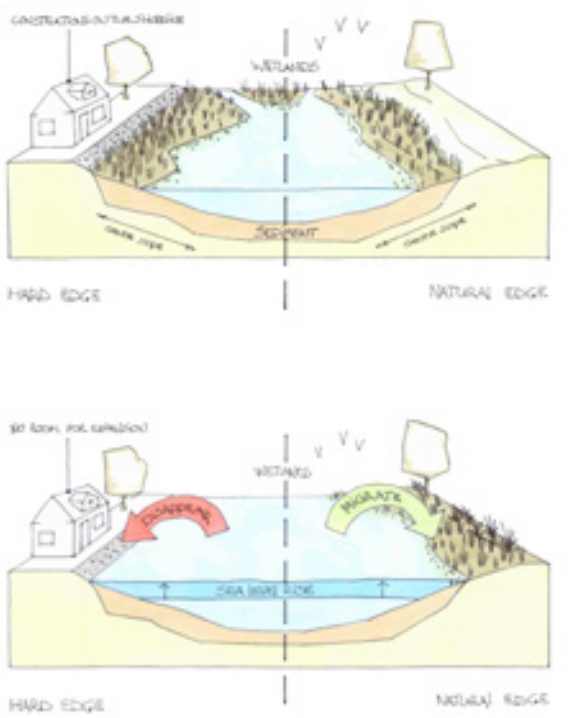
Step-by-step drawing:

- select information on a subject
- validate sources
- add/combine/ interpret/ omit layers of information for the specific subject
- use spatial sub-layer/ tracing material
- consider scale/type/ view/ colour/ line/ text etc.
- combine layers of info into one drawing

RESULT

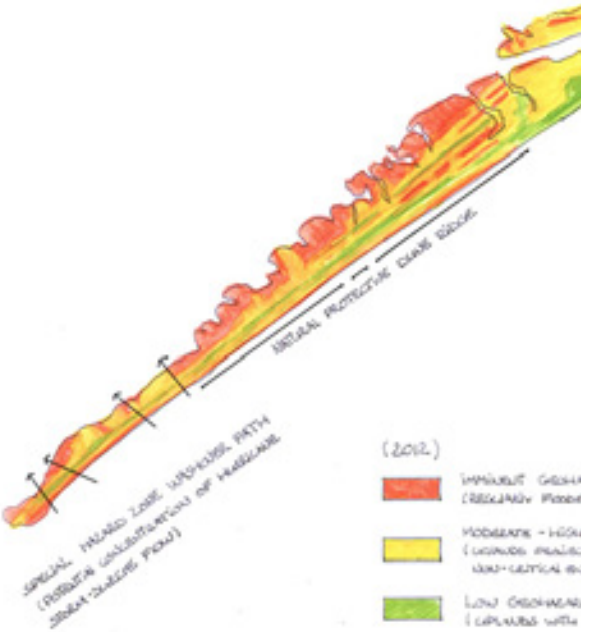
The drawing approach resulted in more than 70 freehand drawings explaining the characteristics in the landscape system of the Galveston Bay and Coast. Each drawing is the result of research and encloses more knowledge than directly expressed. Therefore, the total of drawings is the expression of an even wider knowledge base on the landscape system, which can be invoked later on in the research process.

NON-TRACED DRAWING



Development prevents wetland migration

TRACED DRAWING



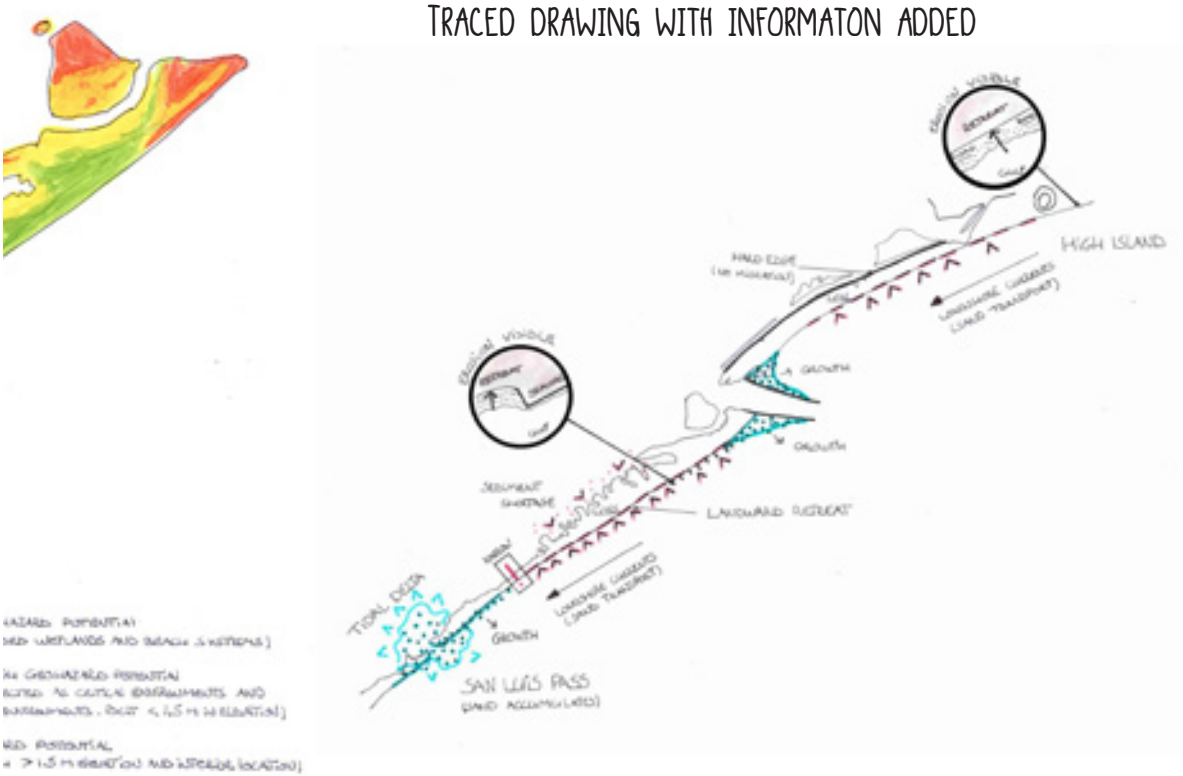
Geohazard map of Galveston Island

Fig 24:Different types of drawings for research-through-drawing

MIXED DRAWING

Architectural heritage and the Galveston historical district

TRACED DRAWING WITH INFORMATON ADDED



Landward retreat of the barrier islands

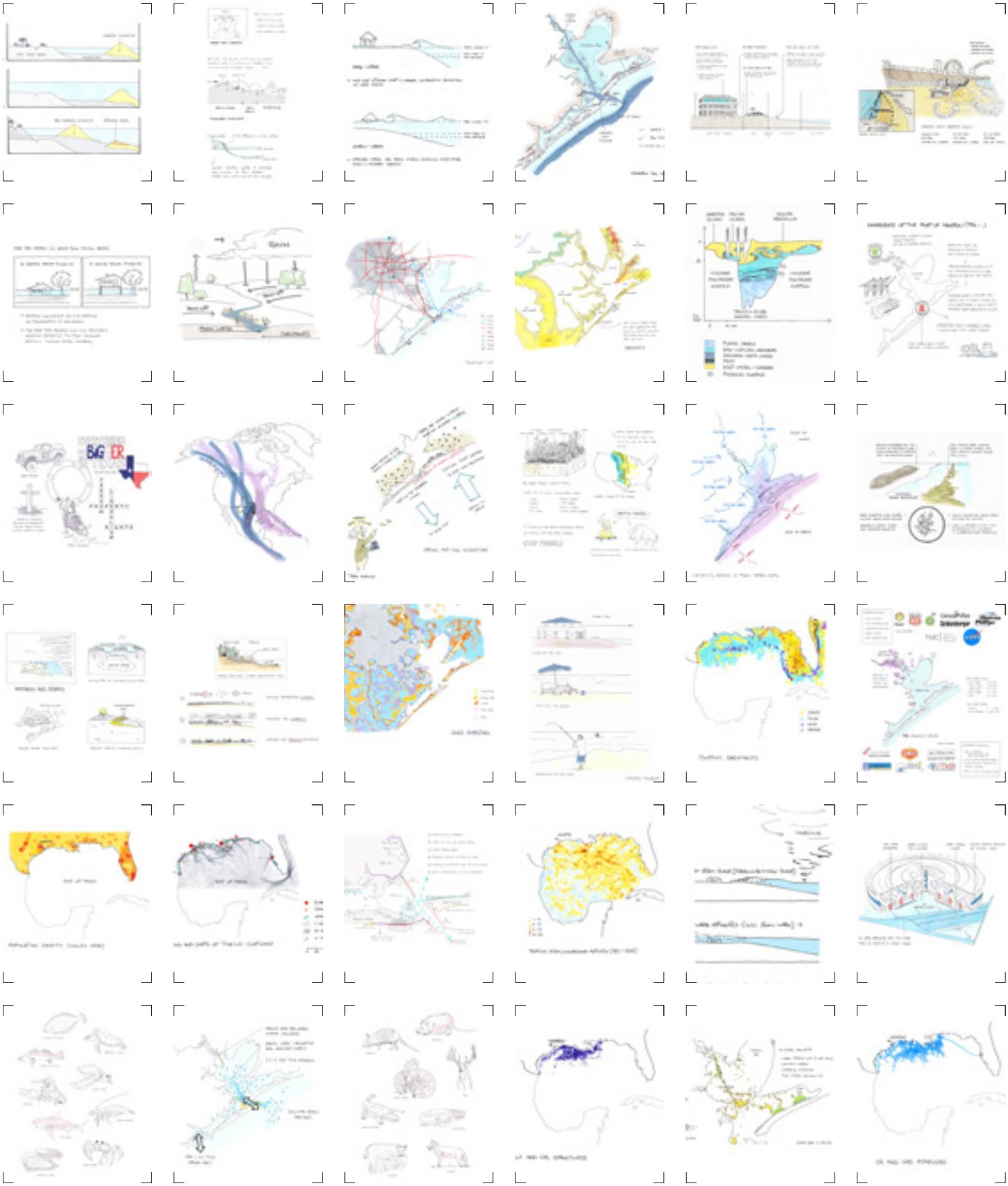
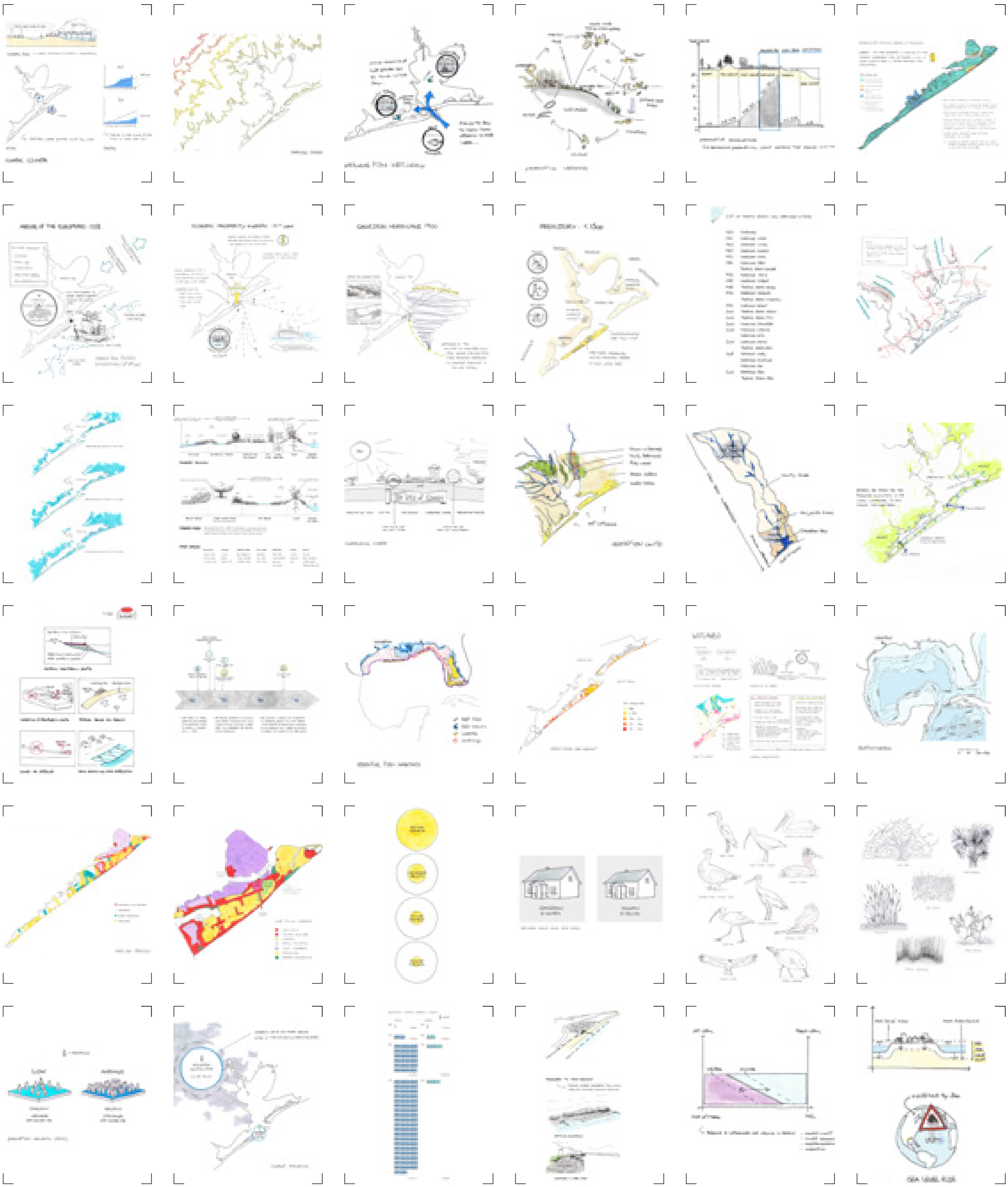


Fig 25: More than 70 freehand drawings on the landscape system of the Galveston Bay region



3.2.3 Investigating landscape connections

The collection of freehand drawings on the landscape characteristics provides overview and insight on the nature of the landscape system. Nevertheless, the drawings remain individual elements. Despite the grouping of physical, biological and cultural characteristics, profound understanding is lacking at this stage. As Foster Ndubisi mentions (Thompson & Steiner, 1997), 'a comprehensive understanding of the inner workings of the landscape requires us to look at it in terms of structure, location and processes (implying the movement of energy, materials and organisms).' Comprehensive understanding goes beyond structures alone and requires new attention. Therefore, the next step is to *explore connections and relationships between freehand drawings of the landscape system.*

METHOD

To explore connections and relationships, the drawings have been printed on small cards to allow easy shuffling. Concept mapping of the drawings – with an explicit and implicit knowledge base – steers the arrangement of the concepts based on multiple criteria and intuition. Each drawing has been moved around by trial and error to explore connections until the best hierarchy was reached. Each attempt resulted in the exploration of new relations and new connections for (re)arranging. Research steps included:

I. Arrangement according to physical, biological, cultural characteristics (= proved insufficient)
II. Arrangement in two groups: components (structure/ pattern) vs. processes (movement/ time)
III. Linear arrangement with core concepts (comp. only)
IV. Circular arrangement with core concepts (components only)
V. Paper model with components around core concepts and interacting processes

The different motives for shuffling the drawings resulted in the internalization of the landscape system with new discoveries about the nature of the connections. Ultimately, several core concepts within the representation of the system emerged. Core concepts refer to the most defining concepts in terms of connections with other drawings. Other, less decisive concepts have been organised around this core subversively.

RESULT

The result of the investigation resulted in a concept map of the landscape system of the Galveston Bay and Coast according to the intuitive best arrangement. The best arrangement is pictured in an A0 poster with indication of relations and connections between the drawings by coloured bands:

Components/ processes: A division is made between component drawings (structures/patterns) and process drawings (movement/ time). Codes in the caption of the drawings indicate connections between the two groups.

Layers: Process drawings are categorized according to physical, biological and cultural processes. (Similar to the division of landscape characteristics in chapter *3.2.2 Landscape elements*) Processes are crucial aspects in the landscape system as they cause change over a longer period of time. It is important to understand the influence of processes on components.

Core concepts: The component drawings are ordered around the core concepts in the landscape system. Core concepts refer to the most defining concepts in terms of connections with other drawings. The further away from the core concept, the more subordinate the drawing is. In the case of the Galveston Bay region, we talk about following core concepts:

- Sediments
- Bathymetry/ topography
- Ports and shipping
- Wetlands
- Hydrology
- Climate
- Hurricanes
- Coastal population

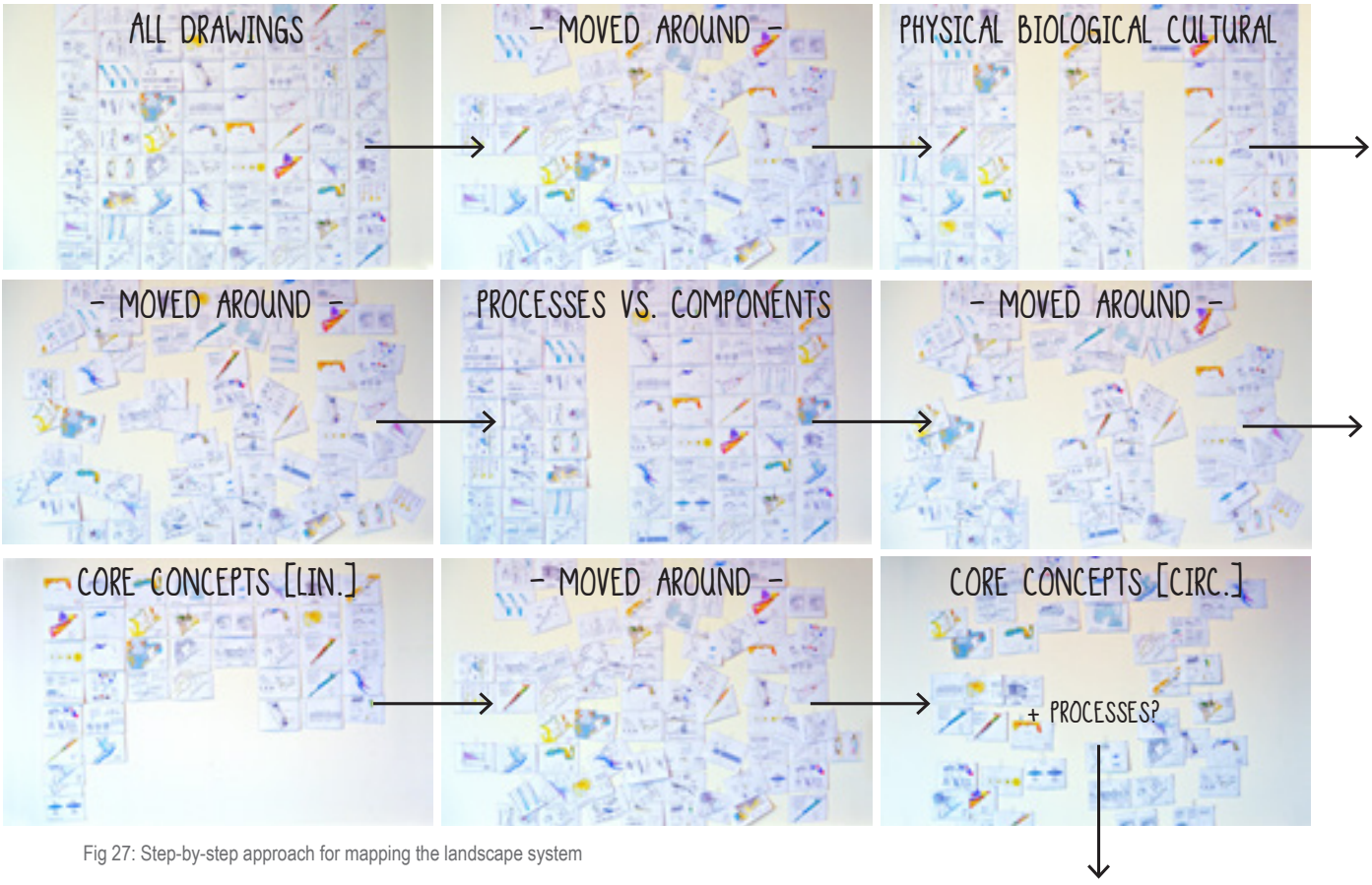


Fig 27: Step-by-step approach for mapping the landscape system

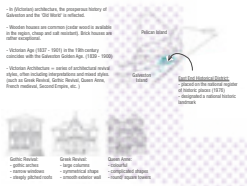
Fig 28: Simplified paper model to express complexity of interconnections

The Landscape System

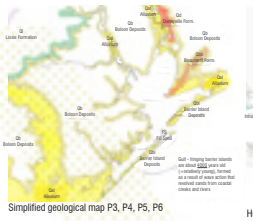
...OF THE GALVESTON BAY AND COAST, TEXAS (USA)

Helena Van Boxelaere - MSc thesis Landscape Architecture - 2015/2016 - Wageningen University

Landscape components

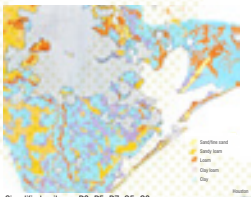


Architectural heritage and the Galveston historical district C1

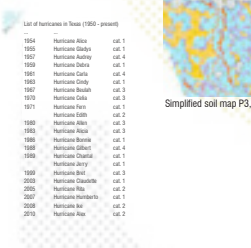


Simplified geological map P3, P4, P5, P6

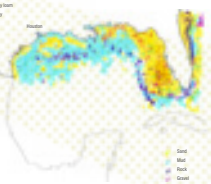
Human interventions and structures P2, P3, P4, P7, C1, C8, C9



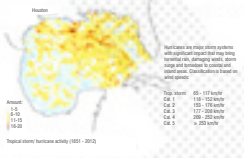
Simplified soil map P3, P5, P7, C5, C8



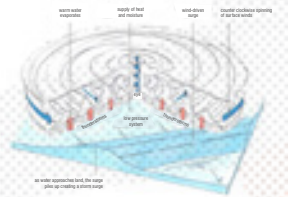
Historical overview of hurricanes P8, C1



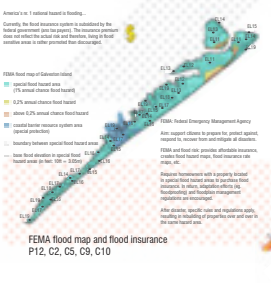
Bottom sediments in the Gulf of Mexico P3



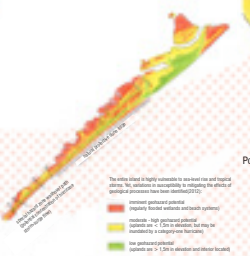
Hurricane activity in the Gulf of Mexico P8, C1



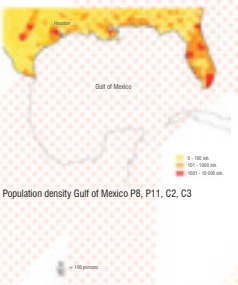
Hurricane characteristics and storm surge P10, P11, P12, B4, C5, C6



FEMA flood map and flood insurance P12, C2, C5, C9, C10

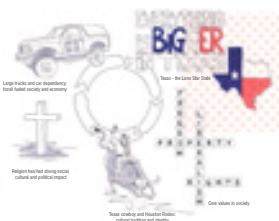


Geohazard map of Galveston Island P4, P7, P8, P11, B4, C5, C6, C9, C10



Population density Gulf of Mexico P8, P11, C2, C3

Population density Houston vs. Galveston C2, C3, C4

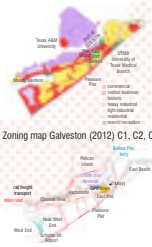


Texan culture and tradition P8, C1, C2, C9

Population USA vs. Houston C2, C3

Median house value C2, C4

Regional transport network C2, C4

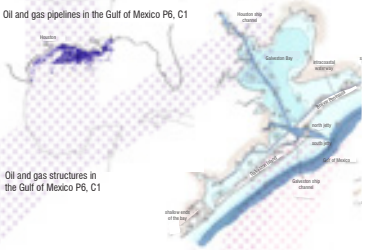


Zoning map Galveston (2012) C1, C2, C4, C8, C10

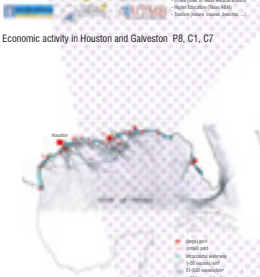
Transport network Galveston C2, C4

Land use Galveston Island P4, P7, P11, C2, C3, C4, C5, C6, C10

Oil and gas pipelines in the Gulf of Mexico P6, C1



Oil and gas structures in the Gulf of Mexico P6, C1



Economic activity in Houston and Galveston P8, C1, C7

Bathymetry of the Gulf of Mexico P1, P2, P10, B1

Ports and shipping in the Gulf of Mexico C1

Galveston Bay bathymetry and shipping lanes P3, P6, C

Simplified elevation (contours) P7, P9, B1, B4, C6, C10

Ports and shipping

Topography/Bathymetry

Sediments

Wetlands

Hydrology

Coastal population

Alleviating climate

Hurricanes

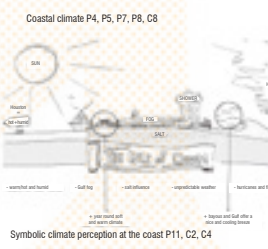
THE LANDSCAPE SYSTEM OF THE GALVESTON BAY AND COAST IN 75 SKETCHES

Coastal wetlands P2, P9 B1, B3, B4, B5, B6, C7,

Salinity gradient in the estuary P1, B1

Coastal climate P4, P5, P7, P8, C8

Hy

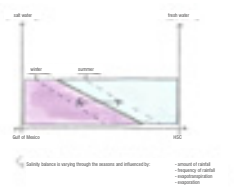


Symbolic climate perception at the coast P11, C2, C4

Beach recreation and tourism P11, C2, C4, C8, C9

Sargassum washing ashore P8

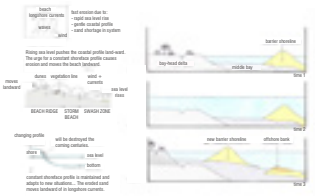
Physical processes



P1/ Changing salinity

P2/ Water circulation during high tide

P3/ Fresh water and sediment supply

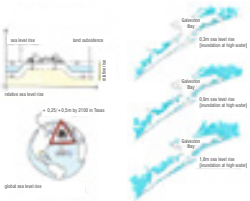


P4/ Coastline dynamics

P5/ Barrier island formation

P6/ Geologic cross-section of the old Trinity River valley

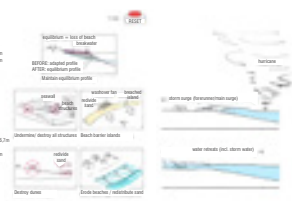
P7/ Landward retreat of the barrier islands



P8/ Global sea level rise

P9/ Local sea level rise

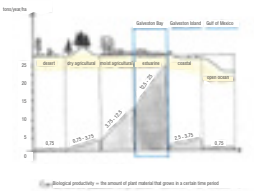
P10/ Bathymetry and storm surges



P11/ Hurricane effects on the coastline

P12/ Storm surge flooding

Biological processes

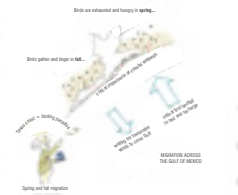


B1/ Ecosystem productivity

B2/ Wetland simplified life cycle

B3/ Wetlands are natural fish hatcheries

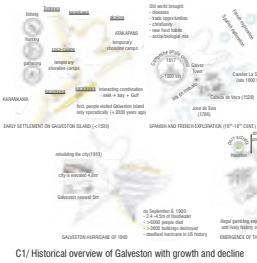
B4/ Wetland ecosystem services



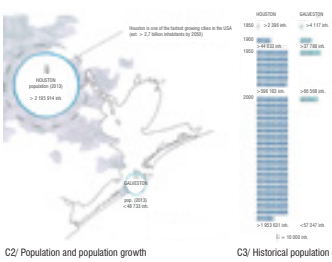
B5/ Crucial wetlands along bird migration flyways

B6/ Wetlands and birds

Cultural processes



C1/ Historical overview of Galveston with growth and decline

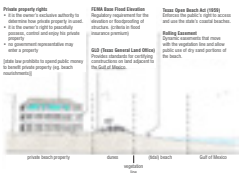


C2/ Population and population growth

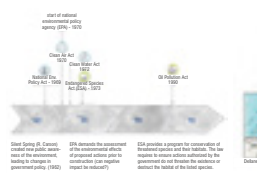
C3/ Historical population growth

C4/ Development on Galveston Island

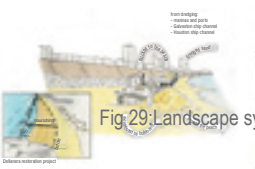
C5/ Base flood elevation and floodproofing



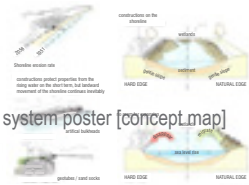
C6/ Rules and regulations applying to the coastline



C7/ Environmental law development



C8/ Beach nourishments at Galveston



C9/ Fighting erosion individually

C10/ Developm. prevents wetland migration

Fig 29:Landscape system poster [concept map]

3.2.4 Investigating the landscape system and flood risk reduction

Understanding the landscape system of the Galveston Bay region is necessary to be able to intervene in line with the system. The landscape system and the working of the landscape system has been studied extensively in earlier stages, however the aspect of interventions for flood resilience has not been addressed yet. Therefore, the last step is to connect the landscape system with flood protection. More specific, the aim is to redefine the assignment and to *explore guiding principles that increase flood safety and also work (in line) with the system.*

METHOD

The A0 poster with the final concept map from the previous step is used as a sub layer to physically explore the connections between the landscape system and flood protection. Theory and experiences with flood protection and the internalized landscape system are combined in a cognitive exercise. Tracing paper on top of the poster registers the lines of thought, expressed with notes, arrows and other symbols. Despite the different style and purpose, visual expression and freehand drawing is again bridging the gap between implicit and explicit, between internal thinking and external expression, between research and design.

RESULT

During this research step, distinction emerged in the relation between the freehand drawings and flood protection. Investigating the landscape system and flood risk reduction not only helped defining guiding principles for design, but also helped to reveal additional problems and boundary preconditions of the landscape system. The result is divided between new observations: problem related, context related or opportunity related.

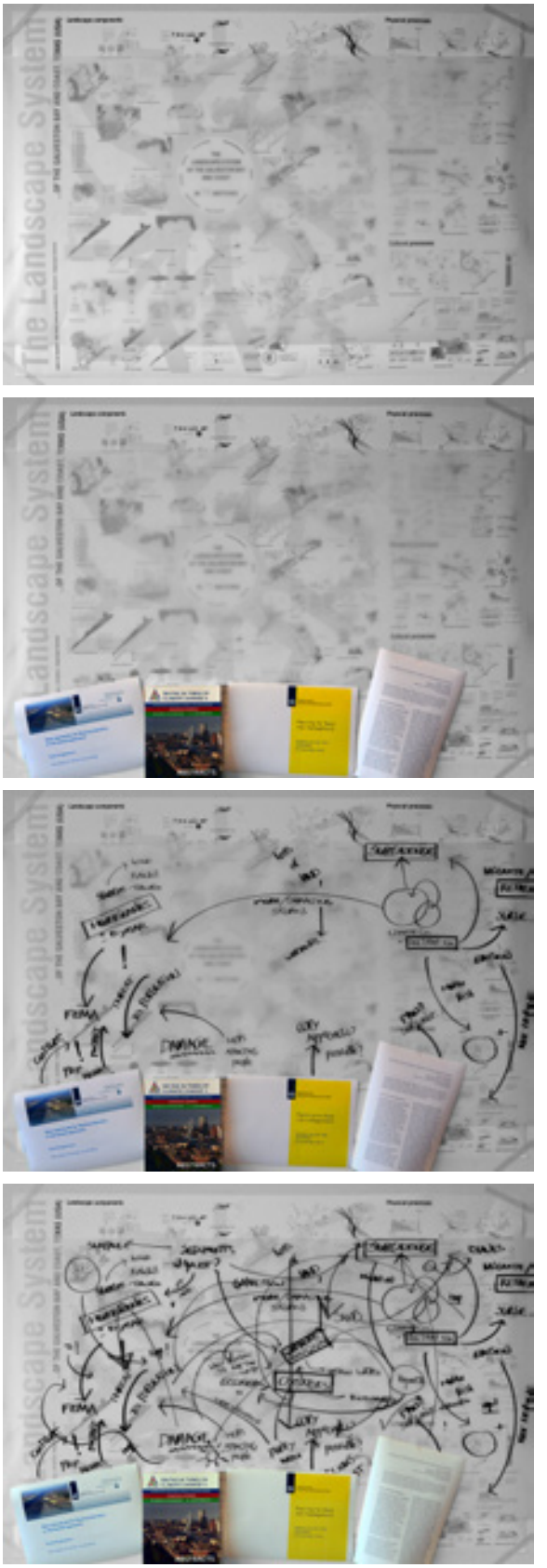


Fig 30: step-by-step investigating landscape and flood risk

Problem related:

The Galveston Bay region and coast are **facing more flood-related problems and issues** than the hazard of storm surges. Among others:

- Climate change and sea level rise
- Irreversible land subsidence due to pumping
- Declining water quality in Galveston Bay
- Loss and degradation of natural ecosystems such as wetlands, prairies and oyster reefs
- On-going development in the coastal plain
- Funded flood insurances concealing actual flood risks
- Limited flood risk and environmental awareness
- Limited collective consciousness and government steering

Context related:

The Galveston Bay region and the coast in particular, are highly sensitive:

The barrier islands are young and dynamic. The spectacular location between the bay and the beach attracts humans to settle, but the vulnerability of the islands results in a harsh and risky living environment. The **living conditions are decreasing** over time and physical processes such as sea level rise and landward retreat question the future suitability of these islands for living. The gulf side and the bay side of the islands are facing different challenges and have little cross-connections over land.

- **Gulf side:** While the sensitive dune system protects the inner islands, natural elements such as wind, waves or tides affect the coastline. In addition, the activities of public beach users and beach developments pressurize the protective capacity of beaches and dunes.

- **Bay side:** The land on the backside of the barriers is low-lying and highly vulnerable to flooding. The bay side is shielded by protective wetlands and offers natural and recreational opportunities. However, wetlands are slowly drowning and the accessibility is low due to private developments and subordinate interest for the bay side (compared to the beach).

The city of **Galveston** is located at the confluence of the bay waters and the tides of the Gulf of Mexico. Despite facing similar risks as the rest of the barrier islands, Galveston is large, developed, historic, attractive and better protected. Galveston has potential for development, but the flood safety level is currently insufficient.

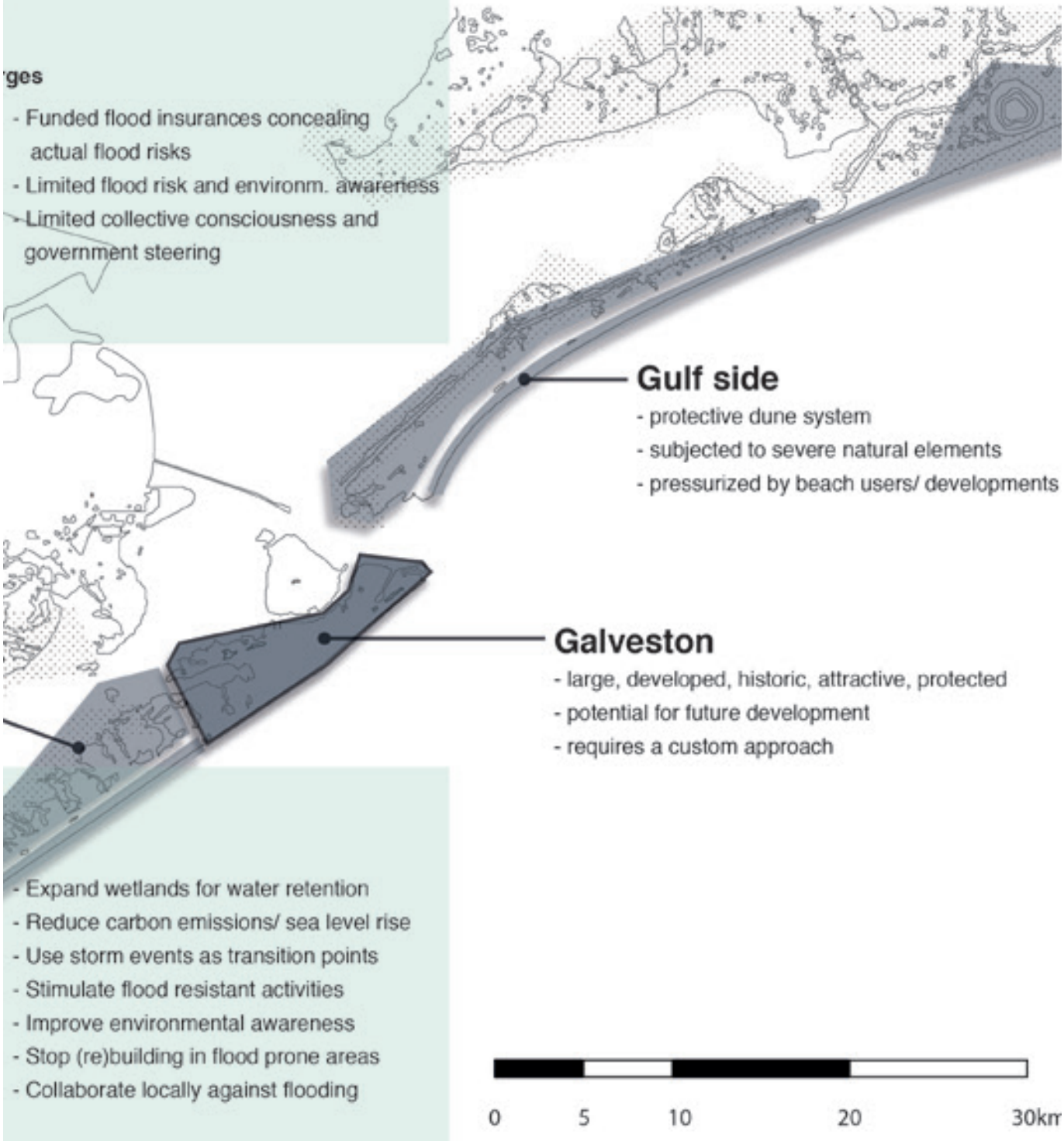
Opportunity related:

The landscape system of the Galveston Bay region and coast offers direct and indirect opportunities for flood protection. Possible opportunities suggest general alternations, connections with existing natural forms of protection and interventions on a strategic level. Following principles guide interventions to improve flood safety in line with the landscape system of the region:

- Reuse dredge spoil for building
- Re-establish oyster reefs
- Supply and catch sediments in the system
- Make room for sea level rise and landward retreat
- Protect locally, affect regionally
- *Balance groundwater withdrawal and supply*
- Raise land for direct protection
- Expand wetlands for water retention
- *Reduce carbon emissions and sea level rise*
- Use storm events as transition points
- Stimulate flood resistant activities
- *Improve environmental awareness*
- Stop (re)building in flood prone areas
- *Collaborate locally against flooding*

Possible connections are listed as guiding principles. However, not all guiding principles have been used for the strategic design. (Italic principles have been omitted)

Fig 31: landscape system in combination with flood risk reduction


ges
- Funded flood insurances concealing actual flood risks
- Limited flood risk and environm. awareness
- Limited collective consciousness and government steering
Gulf side
- protective dune system
- subjected to severe natural elements
- pressurized by beach users/ developments
Galveston
- large, developed, historic, attractive, protected
- potential for future development
- requires a custom approach
- Expand wetlands for water retention
- Reduce carbon emissions/ sea level rise
- Use storm events as transition points
- Stimulate flood resistant activities
- Improve environmental awareness
- Stop (re)building in flood prone areas
- Collaborate locally against flooding
0
5
10
20
30km

3.3 Outcomes for a landscape-based design approach

Research on the landscape system resulted in a great amount of background information and understanding of the landscape system of the region. This is particularly important for proposing a **conceptual** and **spatial** approach in the design process. The research both questions how to move in line with the system, but also offers clues about **where to intervene.**

Along the research process, the most important discovery was the importance of the landscape processes for a landscape-based approach. The **landscape processes** (for more information see chapter *3.2.3 Investigating landscape elements*) give indications about time, movement and change. The physical, biological and cultural landscape processes are the steering forces of the system that shape the landscape over time. Moving in line with the landscape system means responding to these particular shaping processes, with great awareness of their effects on the landscape components (structures/ patterns). Softening or reinforcing particular processes such as sedimentation, sea level rise or coastal development, proves an approach in line with rather than against the system. As such, change is reached by intervening on the level of the processes and a new way of bringing about change is open for exploration.

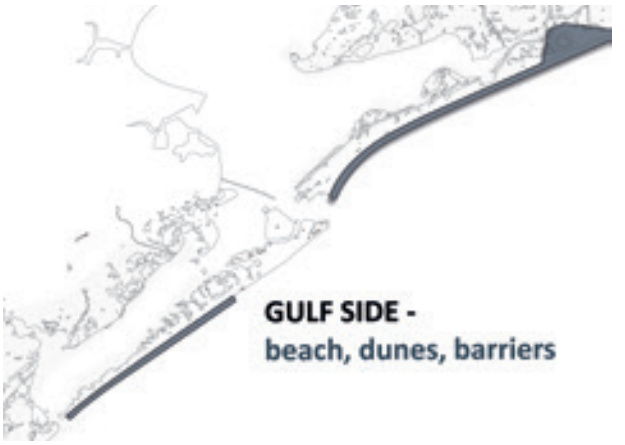


Fig 32: Overview map

3.3.1 Outcomes for beach, dunes and barriers

+ Introduction to the landscape processes:
Barrier islands such as Galveston Island and Bolivar Peninsula are sandbars aligning the coast. Geomorphological, barrier islands are recently shaped young, dynamic phenomena. Their movement is visible in the traces of former dune ridges along the islands. The shoreface of the sandbars stretches into the Gulf of Mexico. A **shoreface profile equilibrium** is strived for by nature and maintained by **erosion** or **sedimentation**. For example, when the sea level rises, the islands **migrate landward** resulting in loss of land. Human linear structures along the coast such as seawalls and sand socks are designed to slow down erosion, but actually result in an unattainable steeper shoreface profile.

Sand bars are usually low and flat, but together with their **small dunes** they protect and shield the bay. Despite their importance, the dune systems are relatively small and highly sensitive. Dunes are shaped from sand in the coastal water system. Rivers carry sediments to the coast and deposit in the slow running waters. Short rivers, such as the San Jacinto and Trinity Rivers, supply less sand than long rivers (e.g. Colorado River) and therefore the available amount of sand at the Galveston coast is limited. Along the coast, **longshore currents** move sand from northeast to southwest. Waves, wind and currents further move the sand on the shoreface and beach and aid in building dunes. On the land, **dune vegetation** captures sand with plant roots and

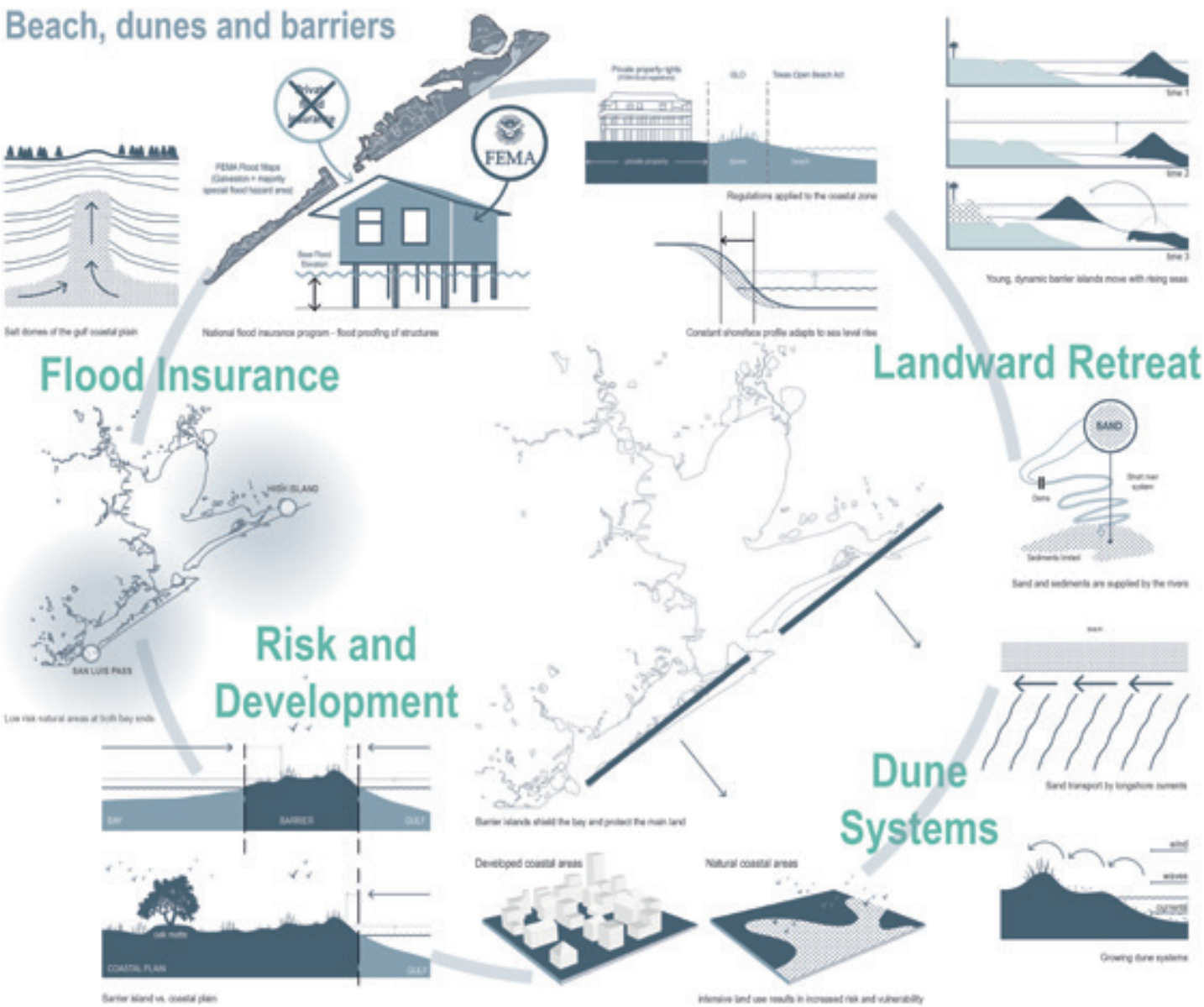


Fig 33: System overview of the gulf side of the barrier islands

establishes growth. However, hydraulic interventions along the coast such as jetties and breakwaters interfere with the sediment supply. The structures capture sand, while erosion occurs behind the dams. Also human activities on the beach disturb the dune formation.

Salt domes are geomorphological phenomena found at the Gulf Coast. Because of their higher elevation, communities on salt domes are relatively resistant to surge flooding. **High Island**, in the east end of Galveston Bay, is a salt dome with elevations up to 11,6m high. The dome is covered with trees and in the surroundings, large areas of wetlands and marshes can be found. . The **natural land cover** and the **lack of development** and the elevation results in a highly resilient coast from flooding. In addition, sandy dunes protect these natural and uninhabited areas. Two large state parks are located on this side of the coast: The Anahuac and McFaddin National Wildlife Refuges. Due to the combination of large wetland systems and elevated forests, High Islands is a top-destination for bird watching

The combination of a wonderful sea view, the bay and the beach offer **major attraction** on people. The coastal climate and the soft sea breeze as well offer alleviation in the subtropical humid climate, especially for the main land. Therefore, the coast is a beloved place, proved by the (million dollar) beach houses aligning the beaches of Galveston Island and Bolivar Peninsula. Because of the interest, landowners are eager to develop their properties on the barrier islands and **private property rights** give them the freedom and the right to develop their property as they like. However, most buildings on the barrier islands are situated in the FEMA's **Special Flood Hazard Areas** with 1% annual chance flood hazard. Flood insurance is complementary and houses are built on stilts for flood proofing according to the Base Flood Elevation requirements. The national flood insurance program is a federal government subsidized system created because private insurances were no longer available.

+ Problems to align with the system:

Landward retreat:

- Nothing, but adding sand to the water system helps to slow down landward retreat.
- Qualitative sand is limited available in the system and needs to be imported from outside the local system (e.g. sandbars in the Gulf of Mexico). Or local sand captured in dune ridges needs to be released where protection levels allow more dynamics.

Dune systems:

- The dunes at Galveston Island and Bolivar Peninsula are small and highly sensitive.
- The landward movement of the shoreface is prevented by the edge of beach developments in the dunes and causes the beach and dunes to narrow and eventually disappear.
- The dunes are only limited protected from human influence and destruction. Car access is still allowed on many beaches.

Risk and development:

- Flooding from storm surges is an emotional and traumatic experience. Especially when communities get disrupted and personal belongings are damaged.
- Governmental influence on development at the coast is limited due to private property rights.
- The collective memory after a storm is limited and does not prevent redevelopment. In addition, the effects of each hurricane differ and influence the risk perception.
- On the individual barrier islands, density and multi-layered stakes are missing for a large-scale flood control project. (Cost-benefit-wise the islands are very different from Galveston or Houston)

Flood insurance:

- Storm surges are only one aspect of hurricanes. Damaging winds, rainfall and the battering of debris are other associated threats. Ike shows that regular

houses on stilts are only limited effective to face a hurricane surge.
- Flood proofing of buildings offers only limited protection. Infrastructure and facilities such as roads and bridges are damaged as well and result in high community costs for repair.
- Flood insurance premiums do not entirely reflect the actual risk and living in flood sensitive areas.
- When flood premiums increase, beach houses become more and more exclusive.
- Flood maps do not anticipate the changing environment fast enough (e.g. climate change)

Goals for beach, dunes and barriers:

1. Protect dunes and stimulate plant growth to increase local and regional flood protection
2. Cut through the dunes and increase dynamics around High Island for extra sand supply
3. Decrease island development to avoid physical, financial and emotional loss
4. Design recreational public access points to the beach without harming the dunes

Fig 34: Overview map

3.3.2 Outcomes for the bay and the backside of the barriers

+ Introduction to the landscape processes:
Away from the beaches and the protective dunes at the Gulf side, the barrier islands are flat and at some points narrow, with irregular banks at the bay side covered with tidal wetlands. On the bay side, the islands move gently from land into water: a gradient between high and low, between fresh, brackish and salt. Shielded by the barrier islands, the intertidal areas around the bay are covered with wetlands. The soft gradient leaves you **clueless where the land starts and the bay ends**, with nothing but far-away buildings at the horizon. Wetlands are among the most **productive ecosystems** on earth and their **value for the environment** is priceless. Wetlands help to infiltrate fresh water and recharge groundwater levels. They help to purify water, stabilize the shores and lessen erosion. After hurricane Ike, the tidal wetlands survived and appeared green and lush, demonstrating their ability to **withstand surges**. In addition, wetlands are **adaptive** (e.g. sea level rise) as long as the right conditions for growth are met. Sufficient sediment and space for migration needs to be available.

Wetlands are productive and attractive. The edges provide shelter, nesting cover and food for many wildlife species, including birds. Located near two continental **migration flyways**, the Texas coast is a hotspot for **birding and nature tourism**. Birds gather and linger in fall at the coastal wetlands, waiting for favourable winds to cross the Gulf of Mexico. In spring, the Texas coast is their critical first landfall to rest and recharge. Also for fish and marine species, the estuary is invaluable and the wetlands could be regarded a **natural fish hatchery**. Providing food and cover, fish from the Gulf of Mexico enter the Galveston Bay to hatch their offspring and most juvenile fish spend their first year in the bay. Enjoying the Gulf and the beaches makes the barrier islands popular, but bird watching, boating or kayaking the wetlands, fishing or photographing are **attractive recreational activities** as well**.**

Similar to the east end, the west end of Galveston Bay is covered by wetlands and wildlife refuges. **San Luis Pass** is the second, smaller (**natural) tidal inlet** between the bay and the Gulf of Mexico. Remarkably is the lack of hydraulic structures or interventions such as breakwaters or jetties, except for the pillars of the toll bridge in the direction of Freeport. Behind the Pass, the estuary is relatively undisturbed with the large Brazoria **wildlife refuge** and the Christmas Bay, Bastrop Bay and Chocolate Bay. Located between the service area of Galveston and Freeport, San Luis Pass is the separation between the island and the mainland. The natural land surrounding San Luis Pass and the presence of large wetlands areas results in a **lower vulnerability** to flooding.

Home to the intertidal and shallow bay areas, **oysters** are a **delicacy** from the bay and the coastal region. Oysters prefer circulating warm waters with a moderate salinity. Oysters from the Galveston Bay are **commercially** exported throughout the southern US and are important for local oyster farmers. In addition, oysters can **purify** large amounts of water and help to improve the water quality of the bay. In soft-sedimentary environments, oysters tend to gather together to form hard **reefs** to create optimized growing conditions. These reefs can aid in stabilization and (shore) protection by **reducing wave** energy during storms.

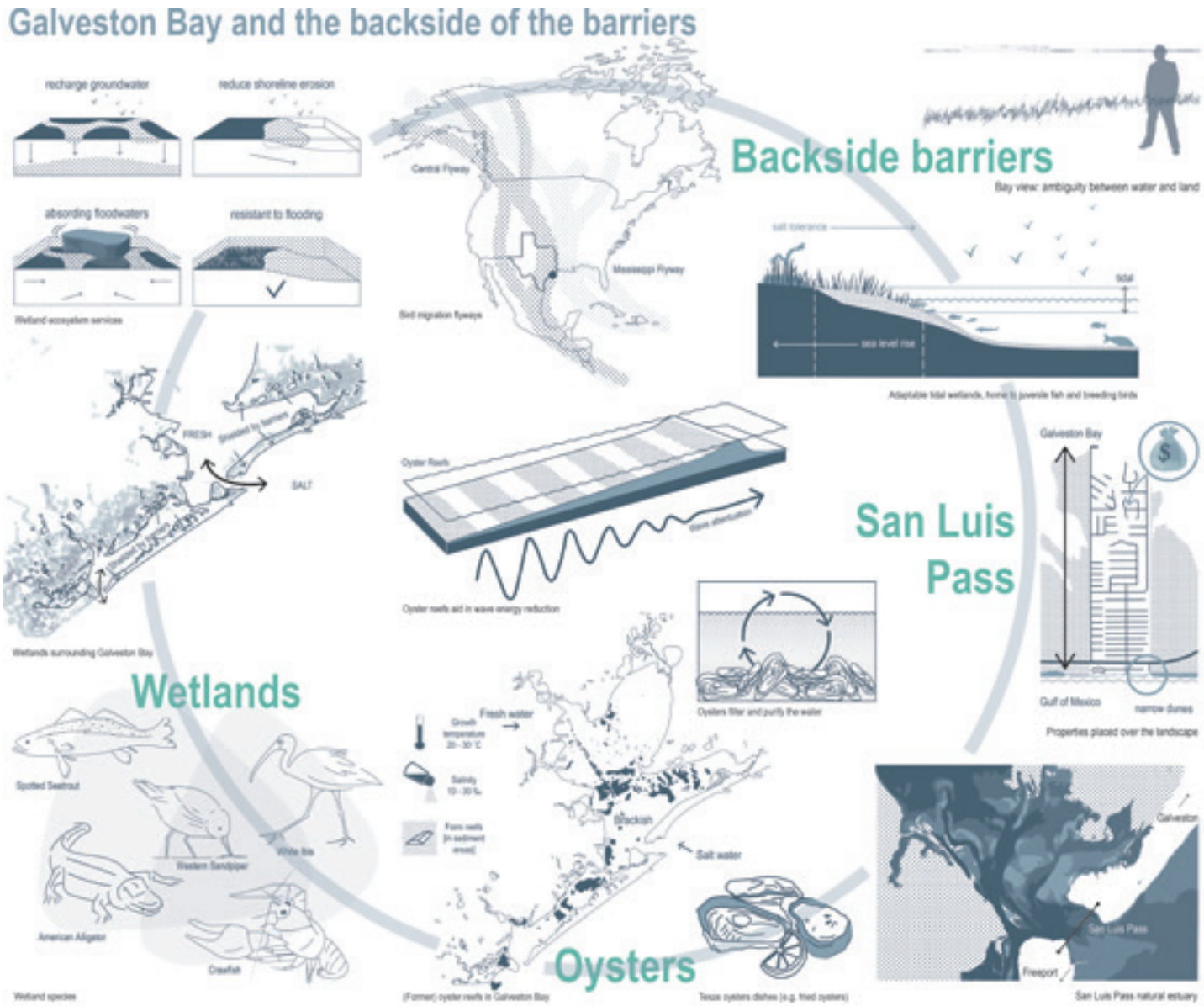


Fig 35: System overview of the bay side of the barrier islands

+ Problems to align with the system:

Backside barriers:

- Wetlands are at risk of drowning by the rising sea if their growth cannot keep up
- The effect of sea level rise is increased by irreversible land subsidence due to groundwater withdrawal and pumping of gas and oil in the coastal region.
- In theory, wetlands are able to expand horizontally. In practice, space for migration lacks due to developments on the barrier islands and due to lack of sediments as a base for plants to grow.
- The decrease of sediments is problematic for the wetlands in the West Bay, because the Texas City Dike blocks sediment supply from the bay.
- In addition, only current wetland areas are protected by the EPA. (US Environmental Protection Agency).
- The wetlands at the Texas coast are a top-destination for bird watching and nature tourism. Right now, tourism is based on day-tourists and commercial recreational activities. Despite the possibilities, nature tourism seems not very fashionable. Facilities are to some extent available, though not very visible or attractive.

San Luis Pass:

- The barrier islands are flat, low and highly vulnerable to sea-level rise and tropical storms.
- The island becomes narrower towards the west. The west end is vulnerable for washover pathways from hurricanes (concentrated cross-islands storm-surge flows).
- Development at the west end often stretches from beach to bay, without protective wetlands.
- Several large and relatively new developments from recent years are located at the west end. Developments are at odds with the natural character and the vulnerability of the area around San Luis Pass.
- Due to sea level rise, the groundwater table is also expected to rise, not in favour of the islands' living conditions.

Oysters:

- Water in the north- and east side of Galveston Bay suffers most from contamination and poor water quality.
- Too much contamination results in constraints for the consumption of oysters and seafood
- The amount of oyster reefs has decreased dramatically over the years due to drought, overfishing and unstable growing conditions
- Many oyster reefs have disappeared after being covered with sand by Hurricane Ike in 2008.

Goals for the bay and the backside of the barriers:

1. Compensate loss and expand wetlands to increase water retention capacity
2. Reuse dredge spoil for sediment supply for wetland restoration
3. Improve nature recreational facilities, in particular on the bay side
4. Restore surge reducing oyster reefs in Galveston Bay

Fig 36: Overview map

3.3.3 Outcomes for the city of Galveston

+ Introduction to the landscape processes:

The city of Galveston has **a history of disastrous hurricanes and optimistic rebuilding**. Each time, the city proved valuable enough to restart over again: mostly because the strategic trade position at the mouth of the Galveston Bay (the entrance to the main land). Galveston was once wealthy and advanced. It was once one of the busiest ports in the south and regarded the **greatest finance centre** between New Orleans and San Francisco, also nicknamed 'the Wall Street of the southwest'. Galveston even possessed the first post office, the first opera house, the first golf course, etc. In the East End Historical District Victorian architecture is a reminder of this time.

However, in 1900 a large hurricane swept away the entire island community by surprise. With over 6000 deceased, the Galveston Hurricane is to this day the **deadliest storm** in the US history. After the hurricane, engineers were called in to construct the 5m high concave Galveston **seawall** and to **raise the grade** of the entire city with a few meters to protect the city from future hurricane surges. (SSPEED, 2015) Nevertheless, the city and its port never fully recovered after the hurricane and the opening of the Houston Ship Channel, the deepwater port of Houston.

Today, the Galveston economy is less dependent on the port activities alone and is complemented by different forms of recreation (e.g. the beaches and cruise terminal), the university campus of Texas A&M University and the medical centre of the University of Texas Medical Branch (UTMB). Following a risk-based approach to flood protection, the flood risk at Galveston is high due to potentially high consequences of a new disaster.

+ Problems to align with the system:

Flood protection:

- After the 1900 hurricane and opening of the HSC, Galveston came to be under the shadow of Houston.
- Galveston has more potential for growth and development, but has inadequate flood protection and flood risk management.
- Aspects such as sea level rise and long term flood protection are rather ignored and insufficiently taken into account today.
- During Hurricane Ike, the seawall could withstand the surge, but Galveston flooded from the bay side.

Recreational focus:

- The sandy beaches are the major recreational attraction, but fast eroding due to sea level rise.
- Interventions in the constant shoreface profile such as the seawall will eventually be undermined and destroyed
- Despite the historical architectural heritage, the city lacks appearance and attractiveness in its public space (especially around the old centre and harbour area)

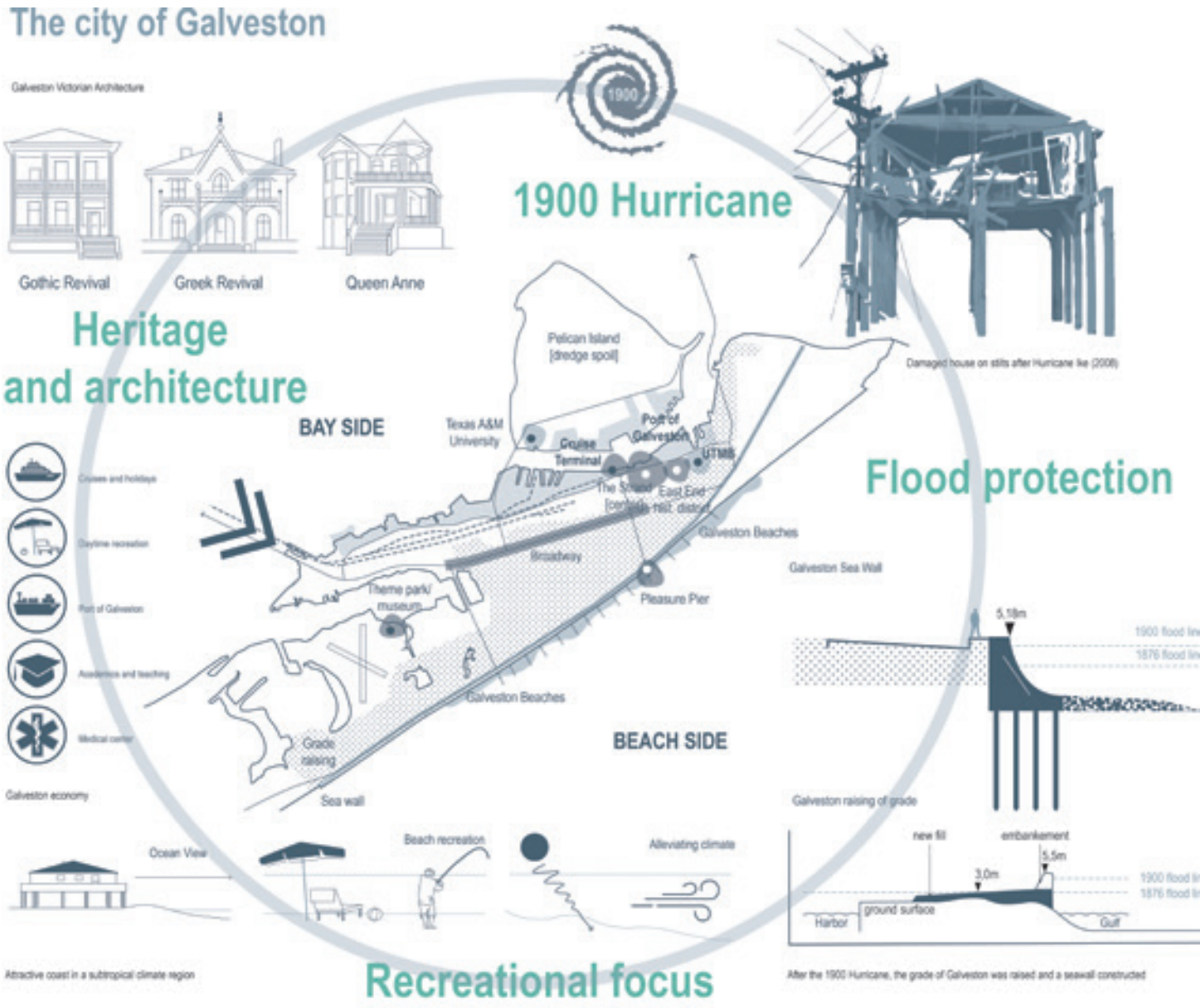
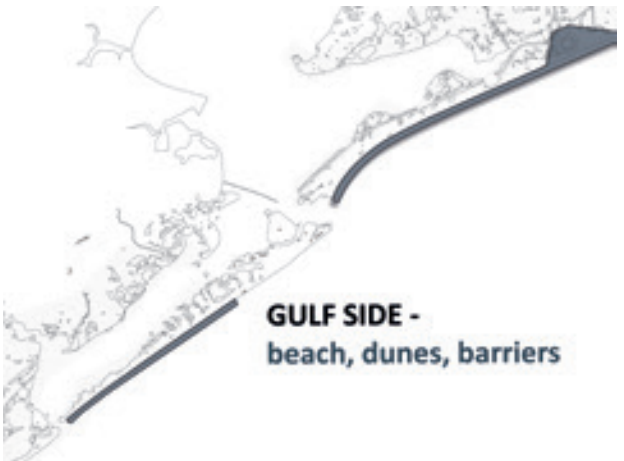


Fig 37: System overview of the city of Galveston

Goals for the city of Galveston:

1. Sand nourishments of Galveston beaches in front of the sea wall
2. Closure of the flood defense system around the centre with interventions on the backside
3. Adaptive flood defense system addressing both short and long term resilience
4. Combination with urban regeneration of the harbour side (between the centre and bay)



Goals for beach, dunes and barriers:

1. Protect dunes and stimulate plant growth to increase local and regional flood protection
2. Cut through the dunes and increase dynamics around High Island for extra sand supply
3. Decrease island development to avoid physical, financial and emotional loss
4. Design recreational public access points to the beach without harming the dunes

Goals for the bay and the backside:

1. Compensate loss and expand wetlands to increase water retention capacity
2. Reuse dredge spoil for sediment supply for wetland restoration
3. Improve nature recreational facilities, in particular on the bay side
4. Restore surge reducing oyster reefs in Galveston Bay

Fig 38: Overview of guiding principles for flood resilience in line with the landscape system

Goals for the city of Galveston:

1. Sand nourishments of Galveston beaches in front of the sea wall

2. Closure of the flood defense system around the centre with interventions on the backside

3. Adaptive flood defense system addressing both short and long term resilience

4. Combination with urban regeneration of the harbour side (between the centre and bay)

III. Design

Fig 43: Aerial view of the Galveston seawall

Fig 44: Galveston seawall with the pleasure pier

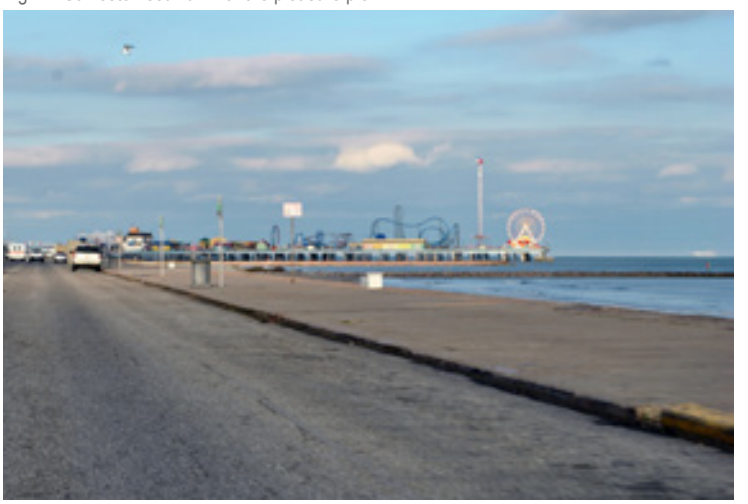


Fig 45: The Strand - Galveston historic centre

Fig 46: Area between the centre and the harbour

4 Design

4.1 Introduction: Focus on the coast

After the analysis of the entire Houston-Galveston Bay region, the design narrows down to the Galveston coast from San Luis Pass in the west to High Island in the east. Galveston Island, Bolivar Peninsula and the city of Galveston are the larger entities of focus. Galveston Island and Bolivar Peninsula are highly vulnerable to storm surge flooding due to their low topography and their location at the frontline of the coast. The focus origins from the missing of a specific strategy for flood protection at the coastal areas that emerges from and responds to the greater landscape system.

The city of Galveston

In the city of Galveston, the old Victorian architecture and the Strand bear witness of prosperous times in the past when Galveston was the largest city in Texas and the largest port west of New Orleans with an important banking and finance centre: the Wall Street of the South. The flourishing period of Galveston ended abruptly when the 1900 Hurricane hit the city. The Galveston Hurricane of 1900 was the deadliest storm in history. More than 8000 people died and a storm surge of 2,5 – 4,5m covered the island. After the hurricane, the Houston Ship Channel was constructed and most of the shipping activity was moved to the Port of Houston, further inland. (Bedient & Sebastian, 2012) The city lost its status and economic position. Today, Galveston is a beacon at the coast between the mainland and the Gulf of Mexico. The city is a tourist destination, in particular because of the sandy beaches and the alleviating summer breeze. The location between the bay and sea is attractive for port- and water-related activities and for the marine and maritime studies of Texas A&M University. In addition to

Fig 39: Beach house with high stilts on Bolivar Peninsula

Fig 40: Small and sensitive dunes at Bolivar Peninsula protect the coast

Fig 41: Beach houses on the gulf-side, endsless horizon on the bay-side

Fig 42: Wetlands protect the barrier islands from the backside

recreation and the port of Galveston, the University of Texas Medical Branch is another major employer and important institute in Galveston.

The barrier islands

Galveston Island and Bolivar Peninsula are fascinating landscapes where people and nature come together. The barrier islands are young and dynamic geomorphological phenomena, located between the Galveston Bay and the Gulf of Mexico. The wetlands of the bay are located on one side, the sandy beaches on the other side of the island. The soft sea breeze of the coast attracts people in the otherwise subtropical and humid climate. Million-dollar beach developments line the coast on the barrier islands, offering wonderful views on the ocean and the bay. The wetlands on the backside of the islands are productive ecosystems, attractive to wildlife, birds and many aquatic species. Because of the wetlands and marshes, the coast is a top destination for camping, fishing, bird watching and kayaking. Nevertheless, the islands are dynamic and sensitive. Galveston Island and Bolivar Peninsula in particular suffered major damage from hurricane Ike in 2008. Yet, after the storm, rebuilding started and new oceanfront properties were constructed again: newer, larger and on higher stilts. As the attraction of the coast seems to outweigh the risk of a hurricane surge, people continue to settle down.

Earlier, the research-through-drawing approach on the landscape system of the Galveston Bay region provided guidelines for flood resilience [see 3.3 Outcomes for a landscape-based design approach]. Specific guidelines are formulated for the barrier islands (subdivided in Gulf-side and bay-side guidelines) and for the city of Galveston.

- Gulf-side guidelines are engaged with the dunes along the coast and seek to protect and encourage growth of these natural protective systems. Decreasing dune development to allow migration space is identified as a critical guideline.

- Bay-side guidelines are engaged with wave-reducing natural features such as wetlands and oyster reefs. The guidelines seek to restore wetlands and reefs in combination with the improvement of recreational opportunities. Similar to the gulf-side, reducing development is identified essential to allow migration space.

- Guidelines for the city of Galveston are engaged with the provision of proper flood protection in combination with urban renewal and redevelopment. In addition, the guidelines seek to include opportunities for long-term safety from the start to allow for future adaptation.

In the next chapter, the guidelines from the research will be further applied to the different areas of the Galveston coast to propose a strategy for flood resilience. During the design phase, a landscape-based design approach was used to explore the use of soft measures for flood protection aligned with the system, but yet responding to the flood risk of the barrier islands.

Fig 47:Strategic plan for the coast

4.2 Strategic approach

The landscape system requires a different strategy for flood protection at the regional scale. The first key consideration to move in line with the system is whether to close off the tidal inlets or not. Because interfering the tidal inlets could have major influence on the estuarine environment, closing off the bay with a (moveable) surge barrier is not considered desirable from a landscape system perspective. Therefore, other ways of improving flood safety at the coast have been suggested. The strategic approach in combination with a mid-bay gate or upper-bay gate strategy, together result in a regional flood protection system.

The Galveston Coast calls for a custom approach. The barrier islands contrast with the city of Galveston in topography, productivity and density. Therefore, the strategy suggests to **'hold on'** and to **'let go'.** Galveston as an urban centre with the port, the medical branch, the beaches and the recreational attraction has potential for more development and is recommended to HOLD ON. In contrary, the barrier islands are facing major challenges from physical processes the following decades in addition to storm surges. Living conditions are decreasing, while vulnerability keeps rising. Therefore the barrier islands are advised to slowly LET GO.

HOLD ON

This approach is characterized by **building towards flood resilience**. Structural measures improve flood safety step-by-step in the long term, but as a result also contribute in the short term by offering new development prospects. In the city of Galveston, a custom design approach helps to improve flood protection and spatial quality in public space at the same time. In particular, the harborside areas could benefit from redevelopment in combination with flood protection. However, safety is not considered a static goal. Flood safety is an adaptive process that requires re-evaluation and improvement over time. Therefore, from the start the need for future adaptations is recognized and included at several levels in the custom design.

LET GO

This approach is characterized by **directing towards flood resilience**. Measures are not directly focused on spatial adaptation or design, but rather on directing in law, regulations, policy and public perception for indirect spatial impact. Turning knobs regarding building codes for example can help to transform the landscape slowly from a residential to a more natural and recreational use. This complex transformation can be supported by soft interventions that slow down the negative effects of the physical system (such as erosion, landward retreat, hurricanes, etc.) and generate more time for the transformation process.

The strategic approach is characterized by interventions with **both a short and long-term focus**. In essence it is put forward that actions today, have benefits today but should be considered to steer outcomes tomorrow as well. Long-term thinking allows anticipating future challenges long before they become problems or even damaging hazards.

4.3 Masterplan

To support the two strategic approaches, several interventions have been introduced in line with the landscape system. Interventions are based on the research in general and originate from the 'outcomes for a landscape-based design approach' (chapter 3.3). Interventions include activities that respond to processes in the landscape system, identified for their flood protective potential. Interventions are listed, but work in combination and collaboration to eachother. Together, they provide a coherent response in line with the landscape system from San Luis Pass via Galveston to High Island.

Fig 48: Masterplan for the coast


Galveston Bay
East Bay
High Island
Gulf of Mexico
SAND
Bolivar Peninsula
City
Bolivar Roads
Galveston
Barrier islands - LET GO
1 Release sand from dune ridges
2 Catch sand and let dunes grow
3 Restore wetlands (with dredge)
4 Reestablish oyster reefs
5 Decrease development
0
5
10
15
20 km

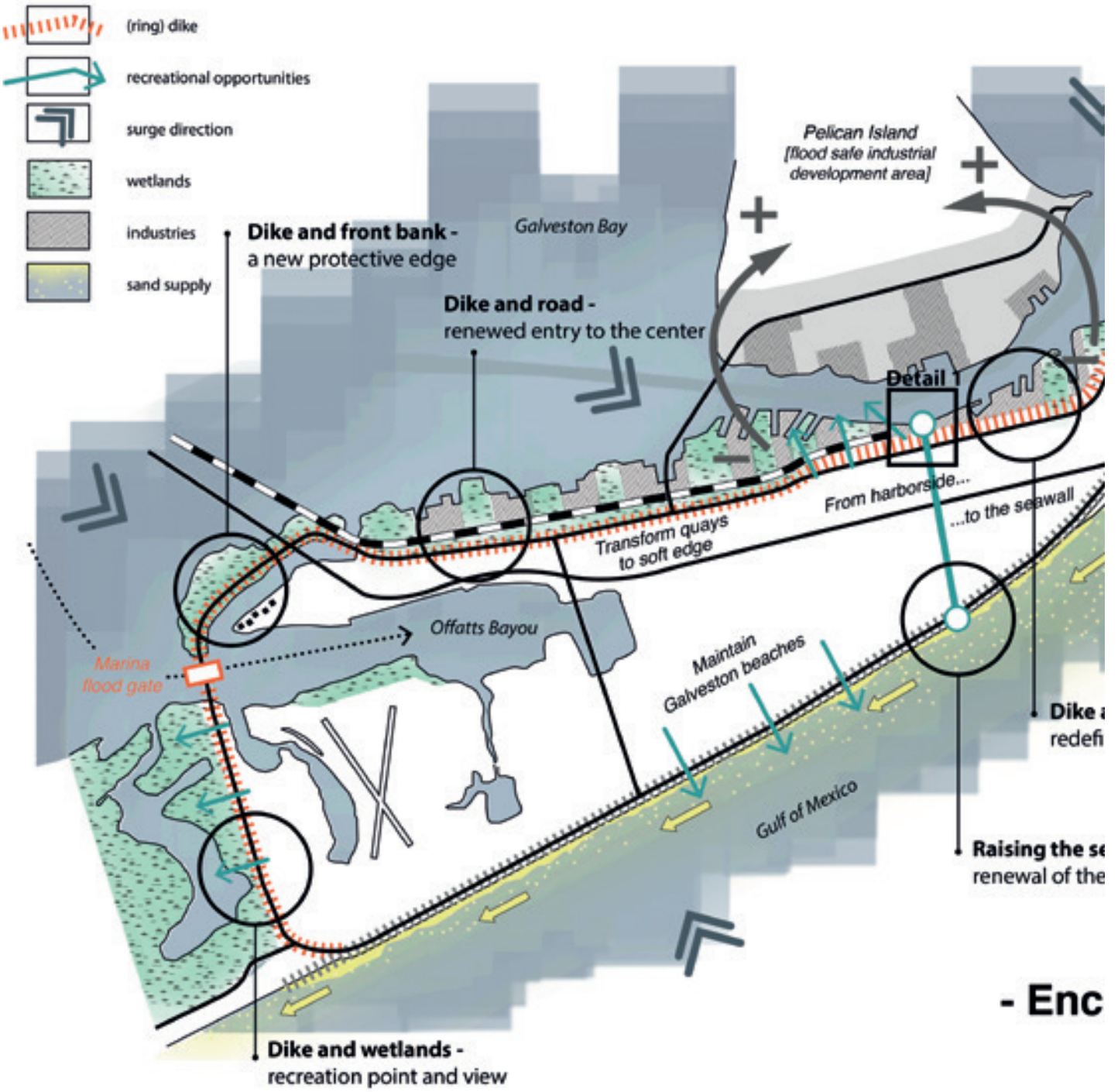
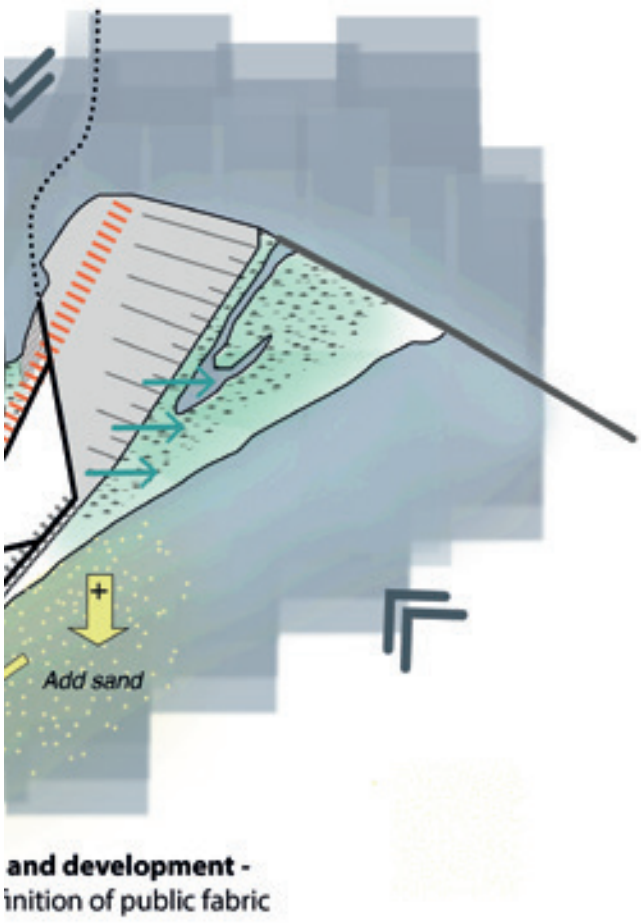


Fig 50: Galveston masterplan: Hold on



and development -
inition of public fabric

eawall -
e promenade

losing Galveston -
levee + soft edge

0 1 5km

4.3.1 Galveston - Hold on

For the city of Galveston, structural measures are suggested to improve flood safety in the short and long term. Galveston is currently protected by a 5m-high seawall and the structural grade raising from the early 1900s. However, the harbour on the bay side seems to be the weak link as the city flooded from the back during Hurricane Ike. In addition, the seawall was able to withstand Ike's storm surge, but according to surge models it is insufficient to withstand other surge scenarios. It is therefore suggested to create a dike ring around Galveston, with inclusion of possibilities for future adaptation.

A dike ring around the city significantly improves the flood safety inside and the chances for development. At the same time, the redesign of the outer boundary of the city is a great opportunity to improve the city's public space. The dike ring connects to the current seawall in the south and to higher ground in the east. On the north and west side, a new structure needs to be built. To fit in, the dike profile can be combined with a new front bank near Offatts Bayou, with the 'Harborside Drive' access road and with new embanked housing development along the port area. At other places, the structure offers opportunities for improvement by renewal of the seawall street profile, by providing access to the wetlands in the west and by reconnecting the harbour with the city center and the seawall. In addition, a dike road improves circulation for the west side of the city.

It is important to realize that building a dike alone is not sufficient to reach flood safety in Galveston. Over time the flood risk is increasing and current standards surely have to be reviewed at some point. Acknowledging the need for adaptation from the start, allows including future extension possibilities and making future proof design choices. The suggested extension approach for Galveston is twofold. The new dike construction takes the future crest level and slope width into account. In addition, the (industrialised) areas outside the dike are designated to transform in time into natural protective areas with recreational opportunities. At the seawall,

sand is being added to stop the beaches from eroding, but frequent large-scale nourishments can also help to create a broader strip for flood protection. However, each year, new sand has to be added. Fortunately the sand does not disappear, but helps to reinforce the dune systems further down the islands. On the bay side of the city, areas outside the dike are mainly used by industrial companies today. However, undeveloped land at Pelican Island could be convincingly more attractive for new companies. The vacant status of Pelican Island is a precious opportunity, because it allows to include and design flood protection prior to construction. As such, Pelican Island becomes a highly attractive safe environment for future industrial development. As a result, the current industrial areas might move on and transform in time to become a protective edge.

The approach is short- and long term oriented:

1. *Close the dike ring on the west and north and pay attention to the improvement of spatial quality.*
2. *Redesign the seawall profile, including a higher water retaining capacity.*
3. *Transform the outer ring into a protective and productive natural edge for improved protection*

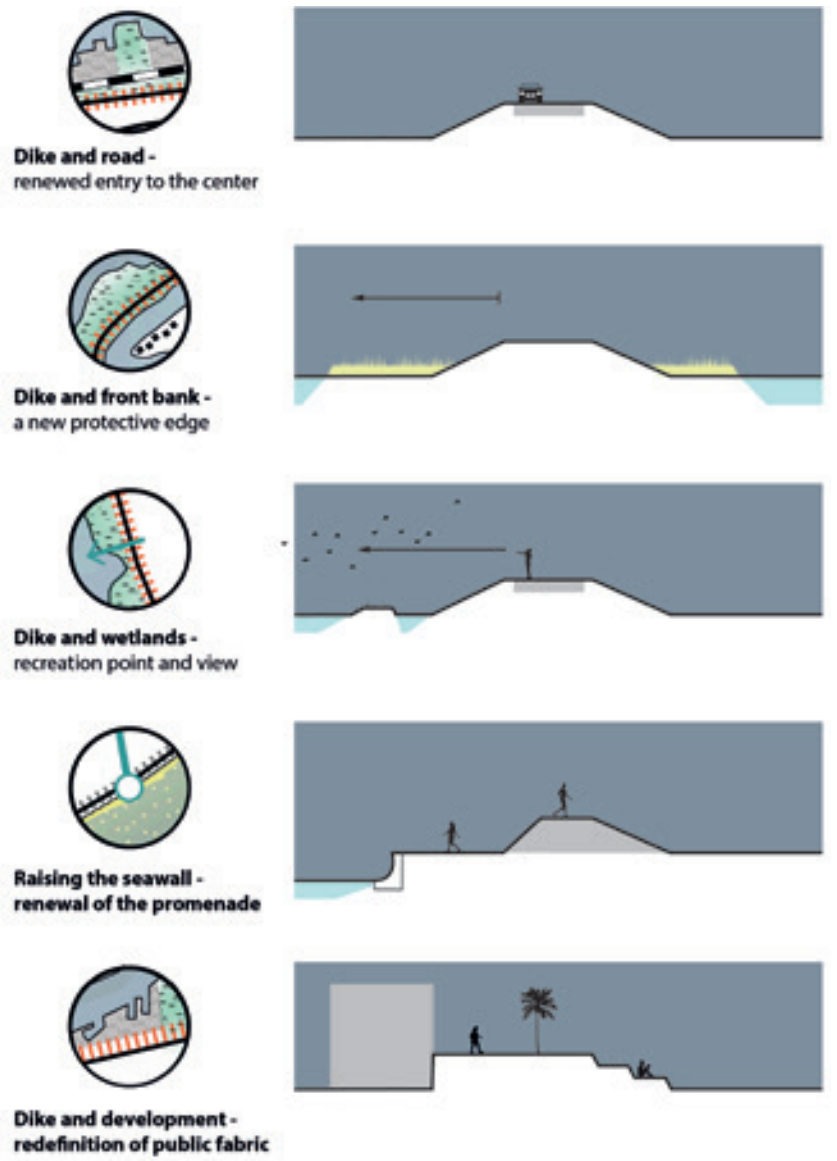


Fig 49: Dike typologies around Galveston

Fig 51:Stormy impression of the seawall with a wider beach and improved connections with the harbour

4.3.2 Barrier islands - Let go

For Bolivar Peninsula and Galveston Island, proposed measures rely more on rules and regulations than on structural interventions. Instructions are provided to direct the barrier islands towards flood resilience based on a soft approach. At the barrier islands, landscape processes are at work and come together on each side of the islands (bay side/ beach side). Processes are dynamic in time and space and therefore require a response at the same level.

For the barrier islands it is suggested to 'let go' referring to the line of defence against floodwater: let go, let it move. The barrier islands are dynamic by nature and landscape processes such as sea level rise, landward retreat and land subsidence are expected to increase vulnerability and decrease liveability in the long term. As such, the suggested soft approach responds in two ways. On the one hand, it is accepted that the barrier islands become less suitable for living and more suited for recreational and natural use. Over time, a transformation is desirable, initiated by regulations in the national flood insurance program. On the other hand, slowing down the negative effects of the landscape processes with soft measures such as sand nourishments, wetland restoration and dune protection generates more time and new assets for the transformation.

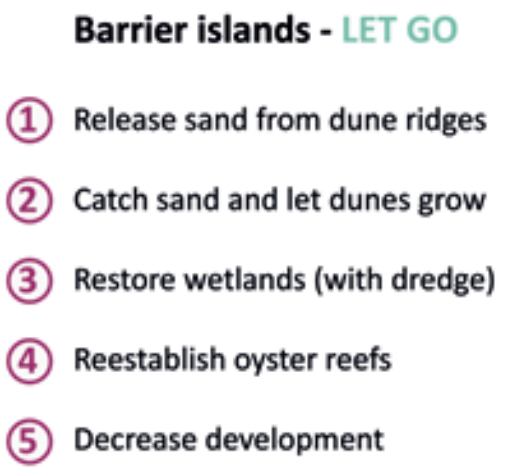
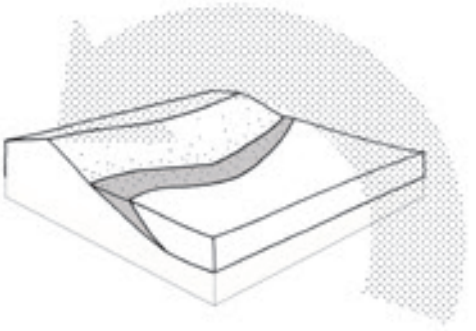
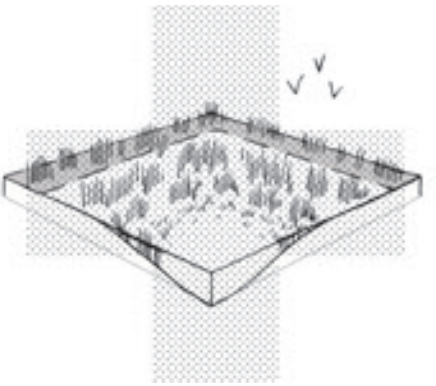


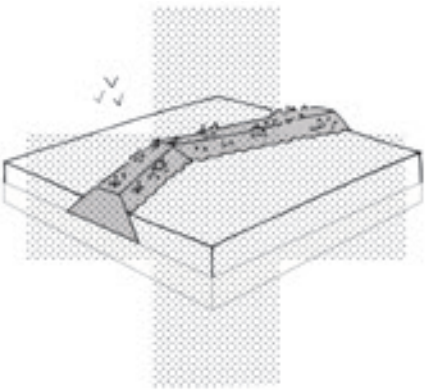
Fig 52: Masterplan for Bolivar Peninsula and Galveston Island



1. Release and catch sand from dunes ridges



3. Restore wetlands (with dredge)



4. Reestablish oyster reefs

5. Decrease development


High Island
1
East Bay
4
5
2
Gulf of Mexico
SAND
Bolivar Peninsula
Intracoastal Waterway
DREDGE
3
2
SAND
West Bay
Gulf of Mexico
5
San Luis Pass
0
5
10 km

Generating more time allows having a gradual transition. Avoiding new buildings on the islands is essential and restricting reconstruction of damaged buildings after flooding is crucial. Instead of the insured rebuilding, homeowners are bought out and land is acquired. As such, future hurricanes become tipping points and accelerate the process of the transformation. In addition, current homeowners have not to worry, because current buildings are not affected as long as damage stays away. Current homeowners however can choose to transform their property from residential to recreational use themselves to avoid emotional damage. In each approach, the flood insurance plays a key role in laying down conditions to steer change. After a while, more land becomes vacant and new recreational opportunities emerge. The area near San Luis Pass [and the existing wildlife refuges] could be just one hurricane away of becoming an estuarine Walhalla for migratory birds and bird watching.

Other natural recreational opportunities emerge when soft measures slow down the effects of natural processes. On the side of the Gulf of Mexico, the sensitive dune system is the natural flood protection of the barriers. Dunes are reinforced by supplying more sand in the system and by restricting access to the dune areas, including the activities surrounding dune developments. Public access points allow steered beach access and allow artificial reinforcement when needed. Public access points also improve the recreational use of the islands and compensate the decrease of private access points. On Galveston Island, more sand is added to the system by sand nourishments at the seawall and currents transport the sand towards San Luis Pass while it helps to strengthen the dunes. On Bolivar Peninsula, sand has to be added differently. Because sand is limited available in the system, sand captured in dune ridges around the natural High Island area is mined and made available in the system. High Island is less dependent on the dunes because it is located on higher ground and surrounded by wetlands. Mining sand can help to increase dynamics in the area and make it even more attractive for wildlife and bird watchers. As a result,

Fig 54: Approach to current development: recreational transformation or land aquisition

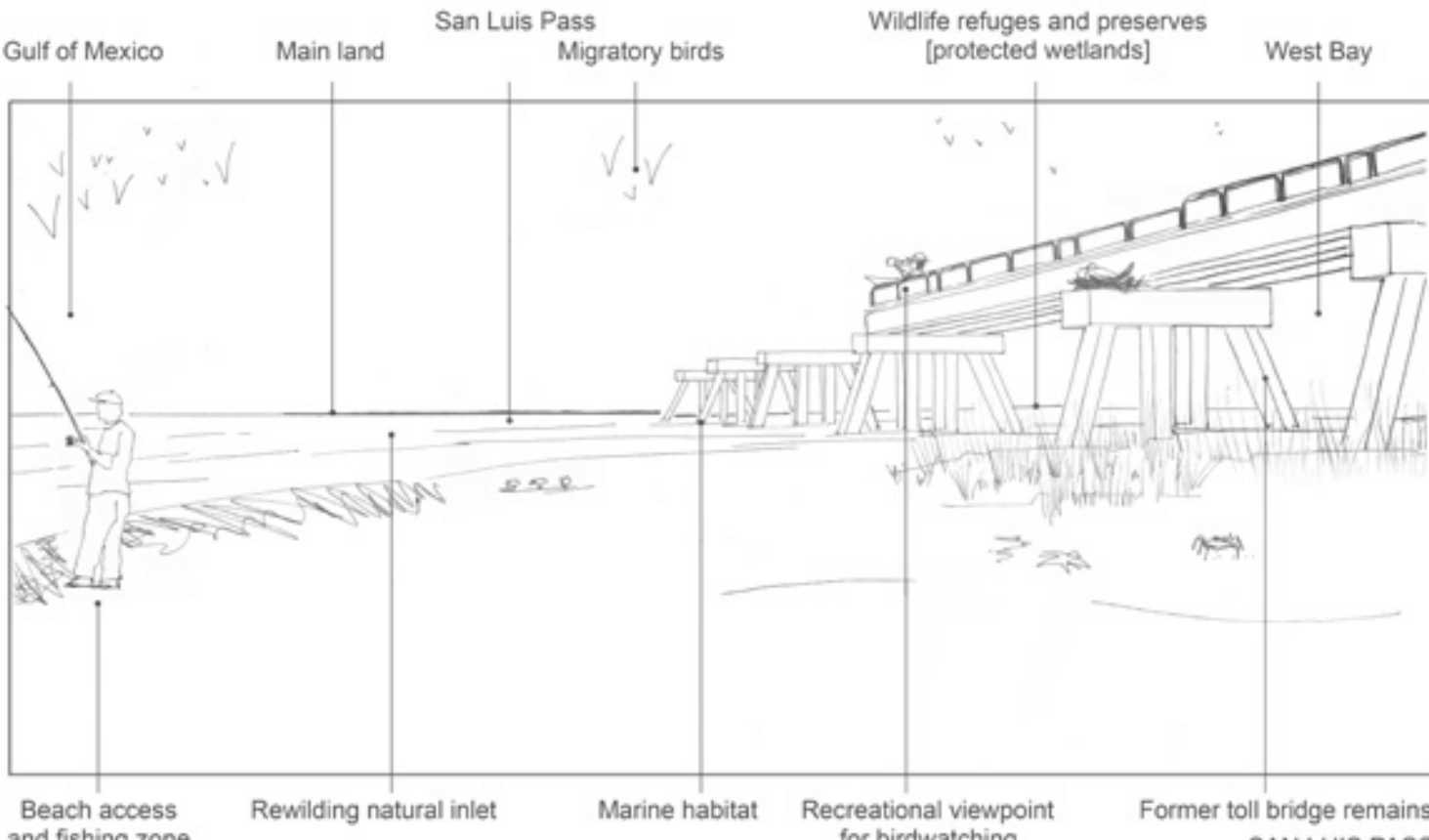


Fig 53: Sketch and impression of a transformed San Luis Pass bridge after development decreased

High Island becomes an even more important habitat for migratory birds and top destination for bird watching.

On the side of Galveston Bay, sea level rise threatens the surge protective wetlands that align the backside of the barriers. Using dredge spoil from dredging activities in the bay's shipping lanes, wetlands are helped to overcome drowning. Marshes are reconstructed by providing sediment [dredge] and capturing sediment in artificial structures. Small dams are used to capture sediment, but at the same time, dams have a water retaining impact as well and offer new ways of accessing and experiencing the bay-side marshes. Restoration projects in combination with camping lodges increase the benefits at multiple levels. A similar approach is used to oyster reefs in East Bay near Bolivar Peninsula. Oyster reefs reduce wave energy in storms and improve the water quality of the bay by filtering. In addition, oysters are a local delicacy. Over the years however, reefs have disappeared for various reasons. Reconstruction of oyster reefs in combination with recreational access creates new attractions in the bay area that contribute to safety as well.

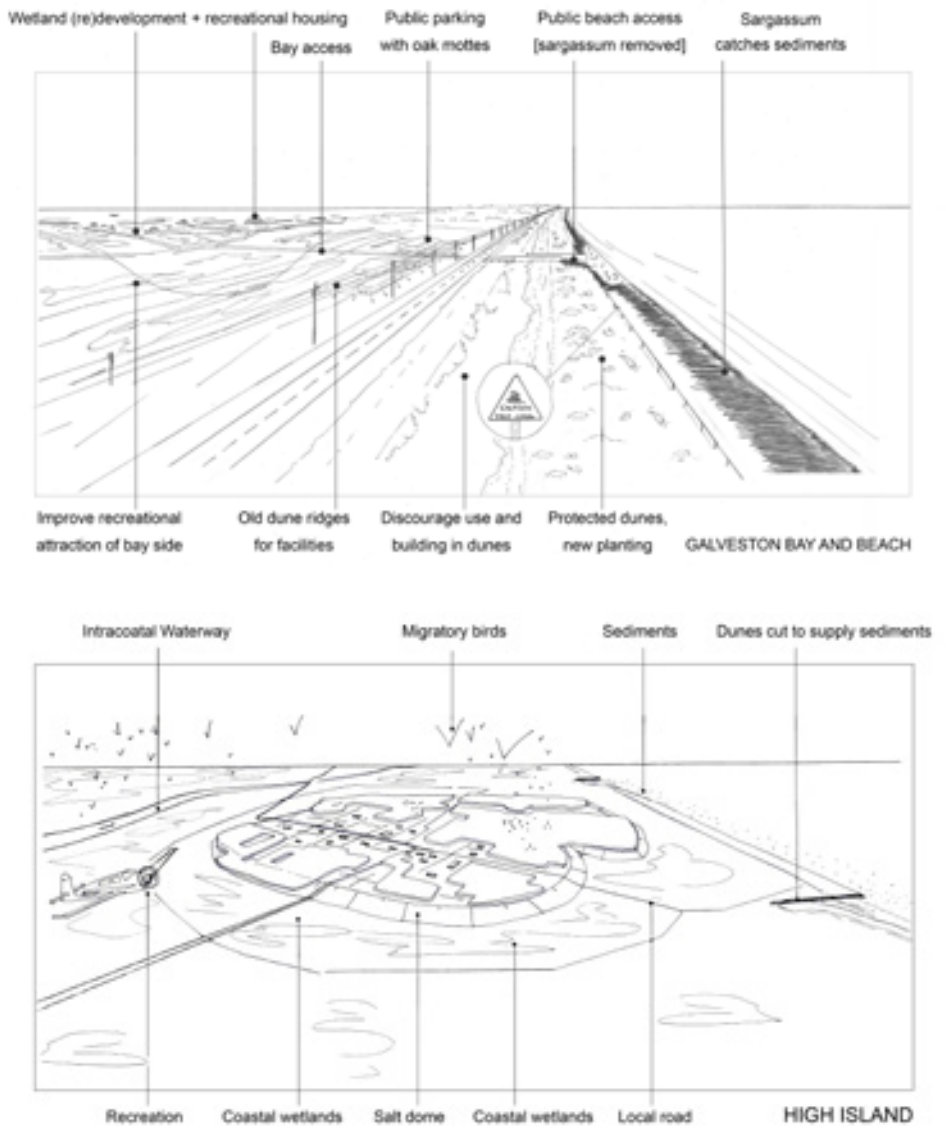


Fig 55: Impression of soft measures on the beach [public access/ dune protection] and bay [wetland restoration/recreational lodges]

Fig 56: Impression of High Island and the mining of sand dunes along the coast [increased dynamics]

4.4 Details

4.4.1 Harborside redevelopment

The Galveston Harborside goes back to the origin of Galveston where merchants brought in overseas goods and the city flourished between the Strand and the Harbour. Today the quays are relatively disconnected from the historic centre, separated by a 4-lane access road and many parking lots. The profile is too wide to experience connection and as a result, the harbour, the centre and the seawall seem to be separate entities. In addition, cars dominate the quays and public space for other users is subordinate and undefined.

Besides flood safety, the proposed new dike in combination with embanked housing can help address these issues. Designed as a boulevard near town, new qualitative public space is created with attention for views points and experience. Connection with the historic centre is realised by densification of the urban fabric in the extension of the current floor plan. The former trolley is reintroduced and operates between the seawall, the centre and the harbour.

Fig 57: overview map

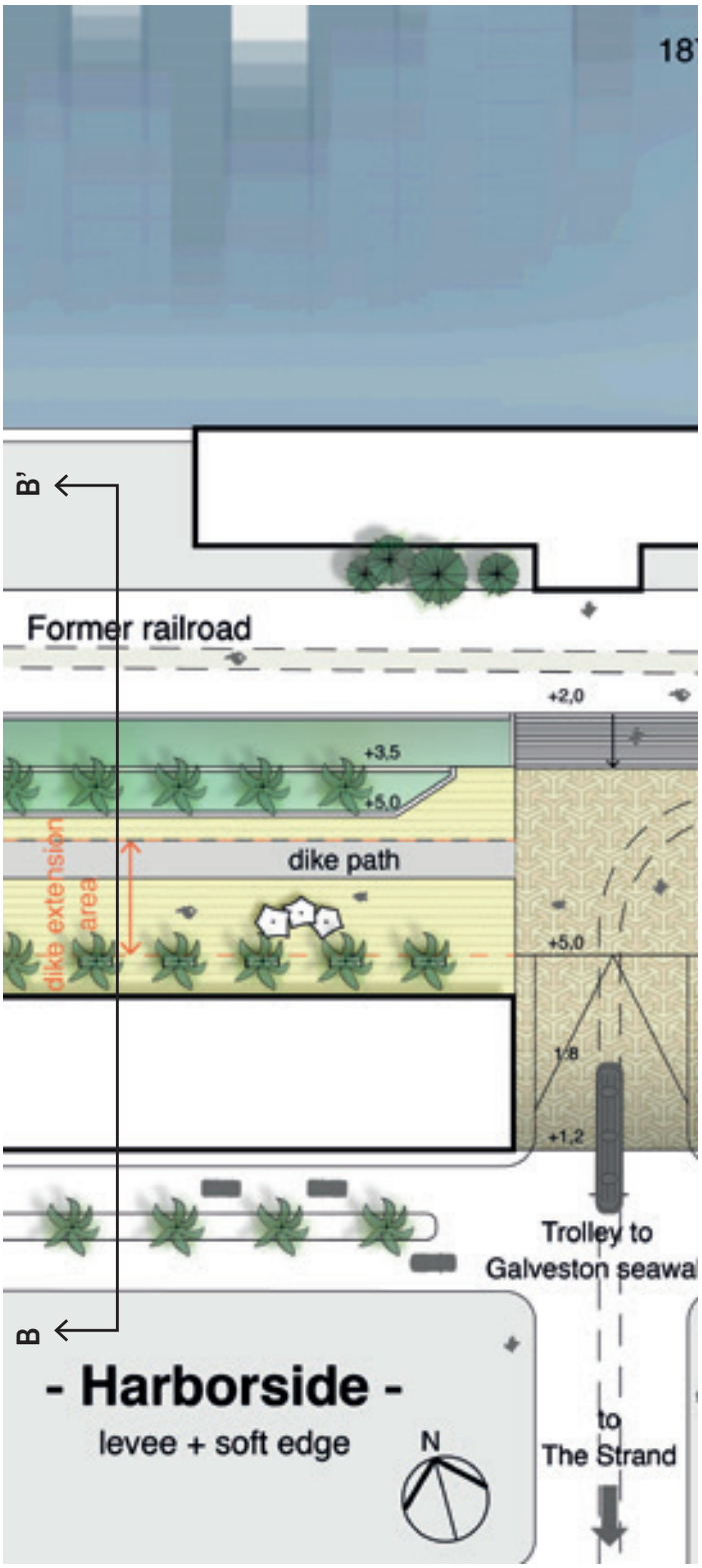
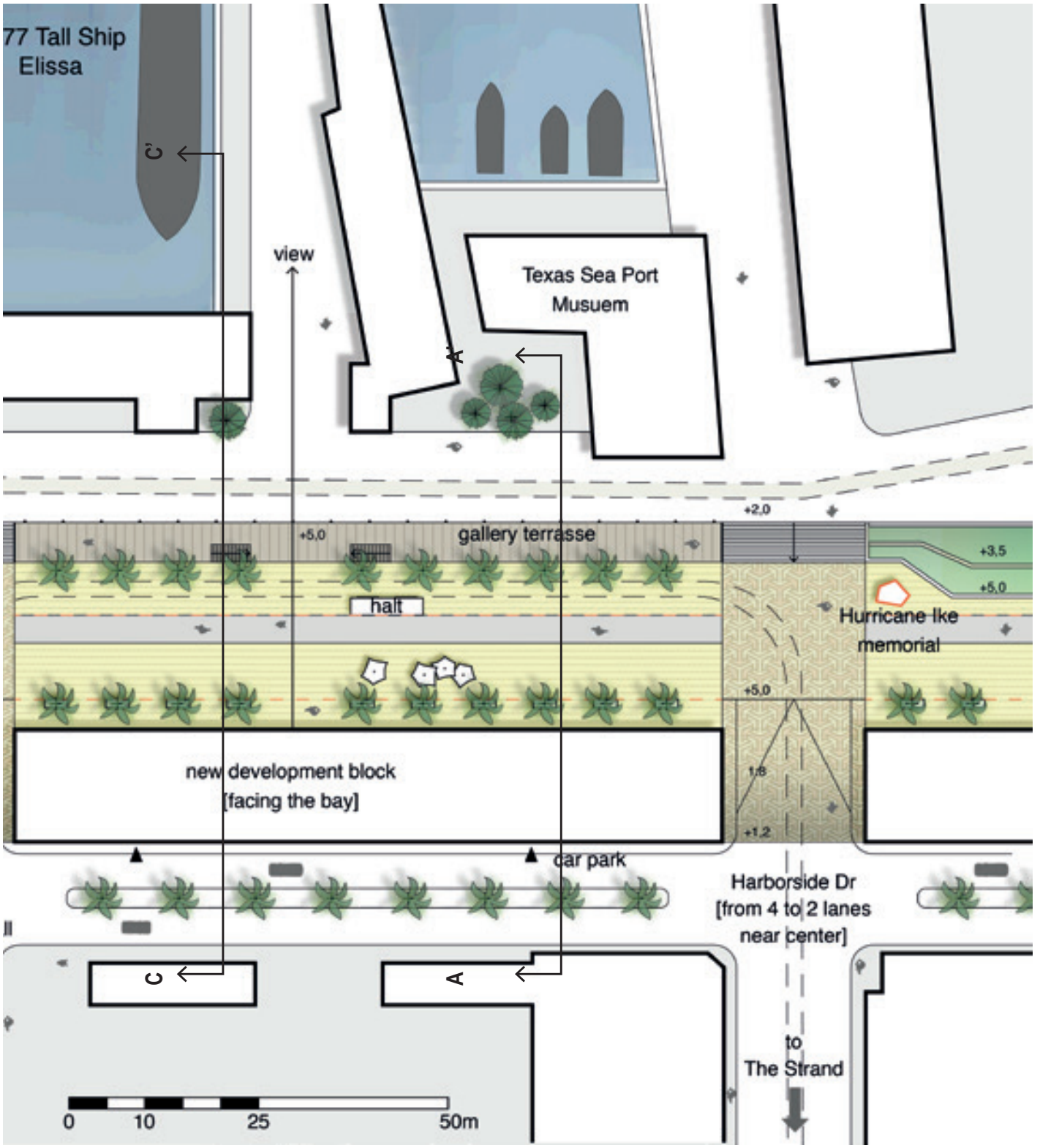


Fig 59: Harborside plan


77 Tall Ship
Elissa
C'
view
Texas Sea Port
Musuem
A'
+2.0
+5.0
gallery terrasse
+3.5
+5.0
halt
Hurricane Ike
memorial
+5.0
new development block
[facing the bay]
1.8
+1.2
car park
Harborside Dr
[from 4 to 2 lanes
near center]
C
A
to
The Strand
0
10
25
50m

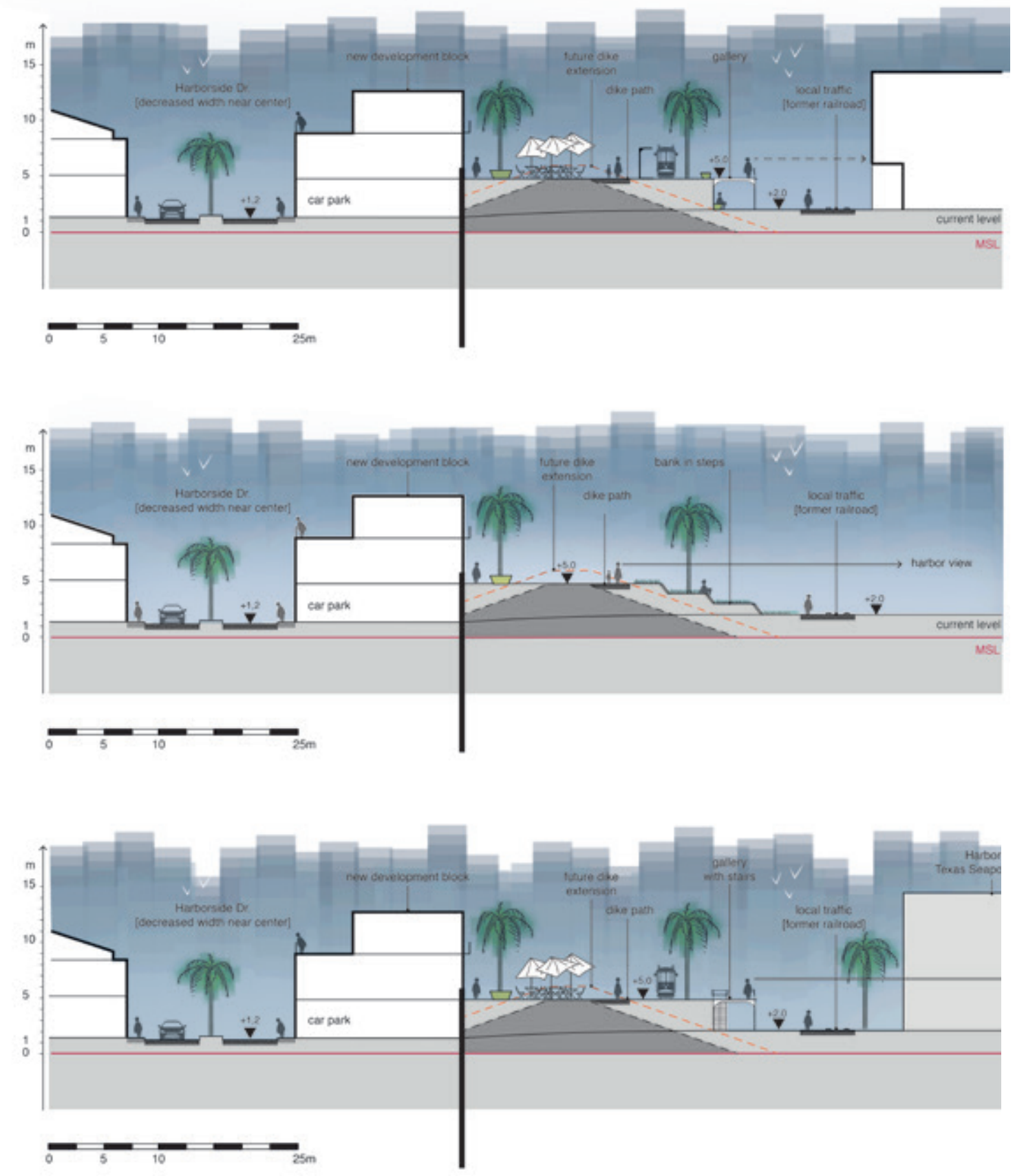


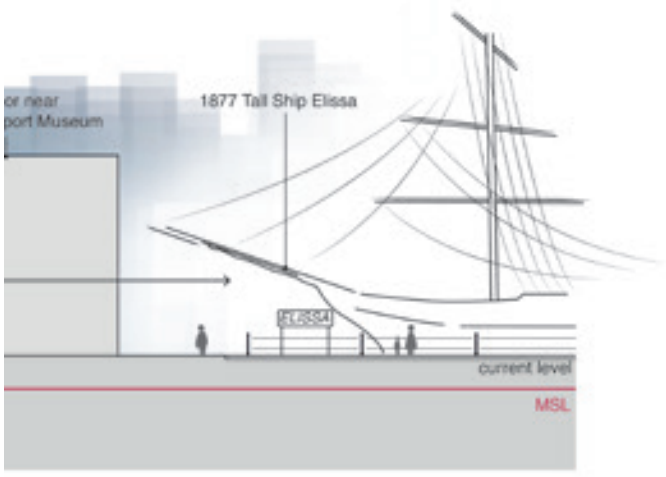
Fig 60: Harborside sections with indication of the dike extension

Section A -A’

Fig 58: Harbourside parking area with on the right side the access to the center

Section B-B’

Section C-C’



The harbourside road near the centre decreases from four lanes to two lanes to reduce speed and emphasize the presence of the centre. In addition, the two-lane road is easy to cross and brings the harbourside closer to the centre. Palm trees in the middle of the profile are an extra accent to mark the special area.

The need for an adaptive dike has been explained previously. In the design the embankment is combined with one row of houses. A retaining wall supports the dike and protects the new buildings. However, the wall already includes the future extension of the dike body. When the proposed crest height of +5,0m (MSL) is considered insufficient, the dike can be easily adapted (+1m) due to the oversized dimension. The extra space also offers design opportunities to include palm trees outside the theoretical profile of the functional dike.

4.4.2 East Bay oysters

New oysters reefs have been suggested on the location where former reefs used to be located. The reefs are developed alongside new breakwaters in the bay that increase surge reducing potential and provide access to the reefs. Therefore the utility of the reefs is multifunctional and the oysters rise beyond their functional-ecological character.

The breakwaters are located diagonal in the bay, with an extra hook to increase the surge retention capacity. The reefs are located east of the breakwater, in front according to the surge direction of hurricanes.

For construction, concrete rubble and dredge spoil is being reused. Bags with oyster shells provide growing conditions for new oysters.

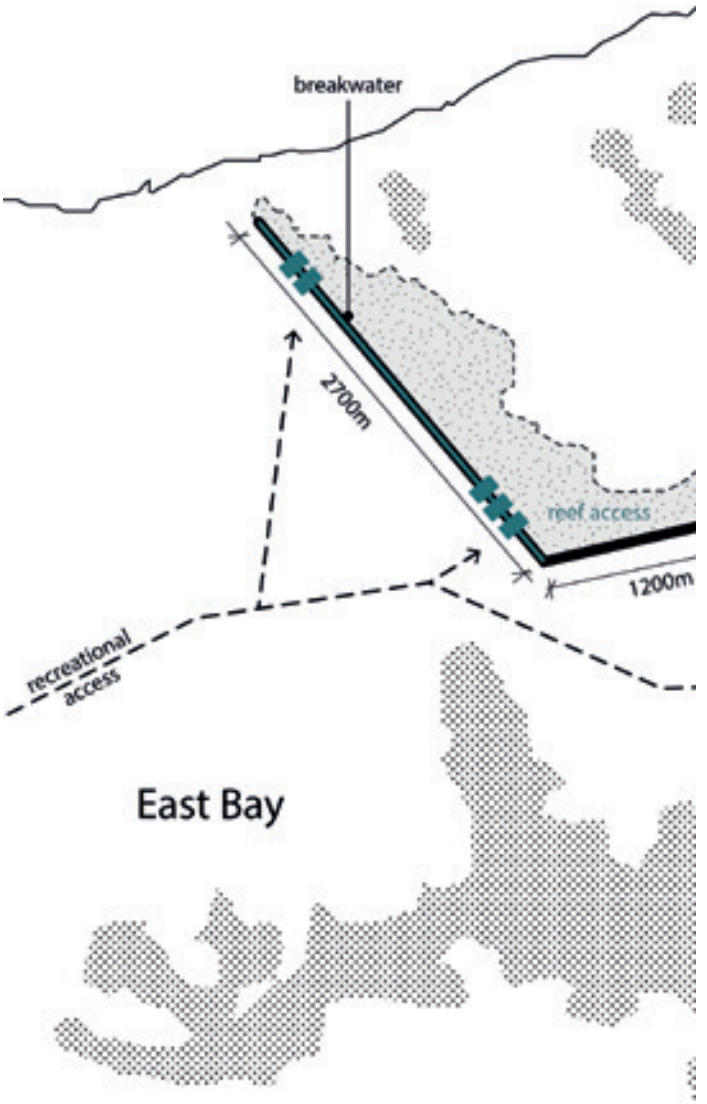
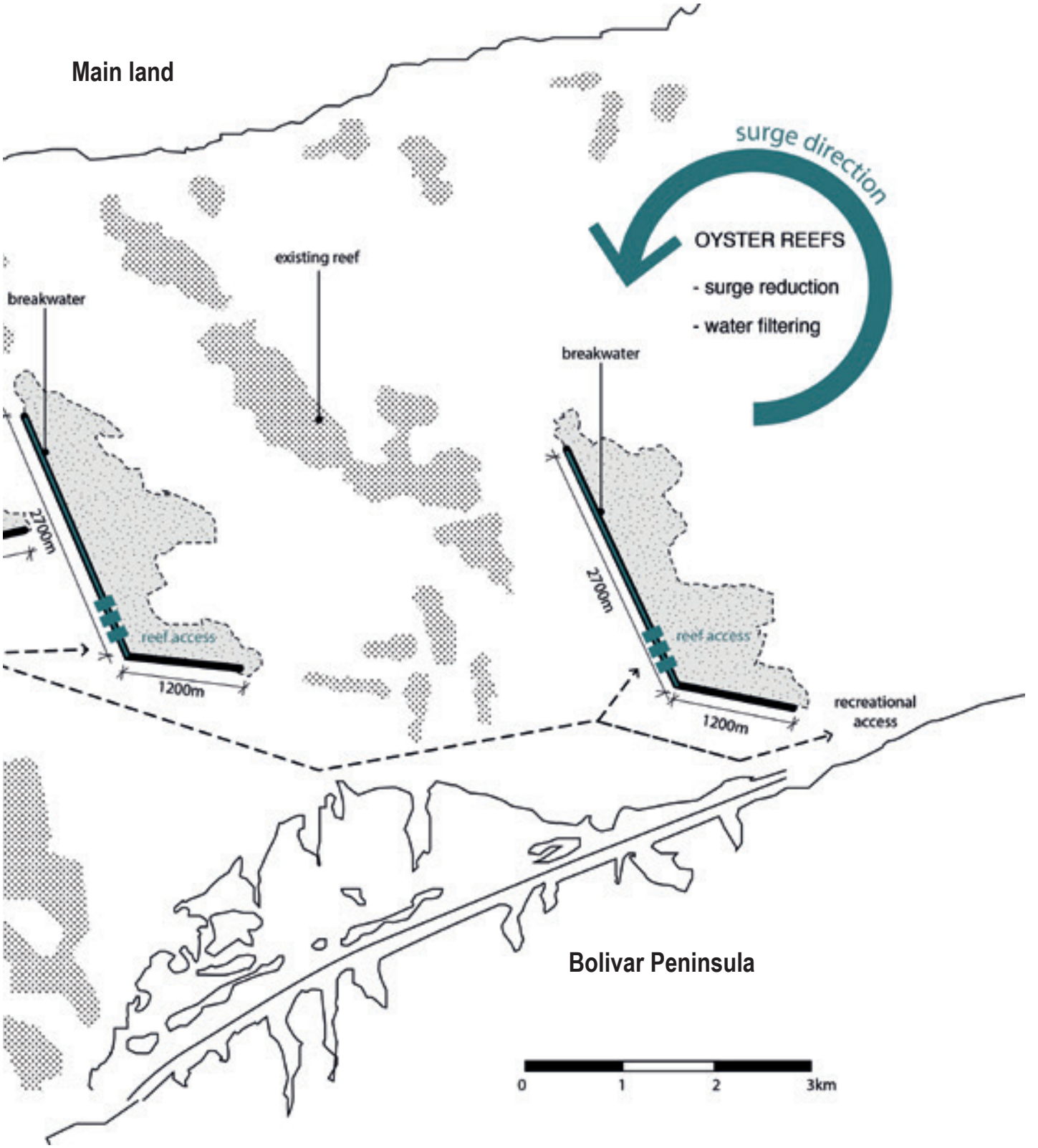


Fig 61: Plan oyster reef reconstruction in East Bay


Main land
surge direction
OYSTER REEFS
- surge reduction
- water filtering
existing reef
breakwater
breakwater
2700m
2700m
reef access
reef access
1200m
1200m
recreational access
Bolivar Peninsula
0
1
2
3km

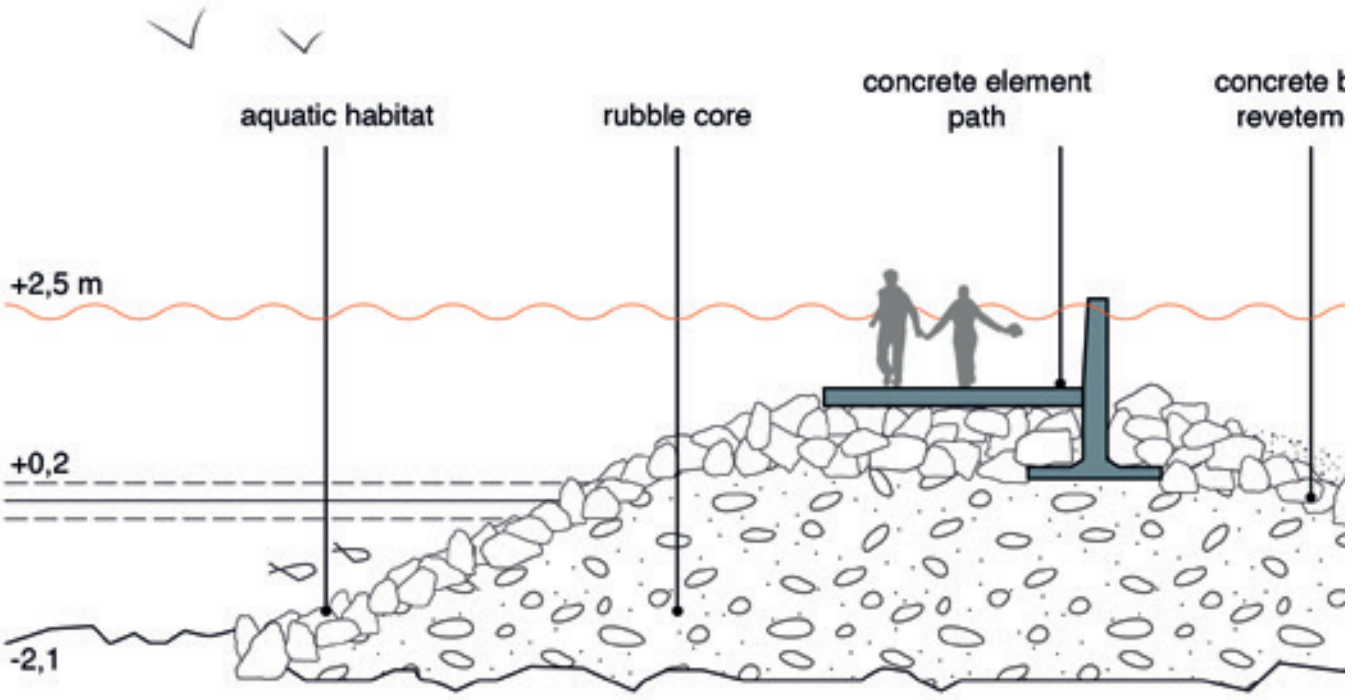


Fig 62: Section breakwater and oyster reef

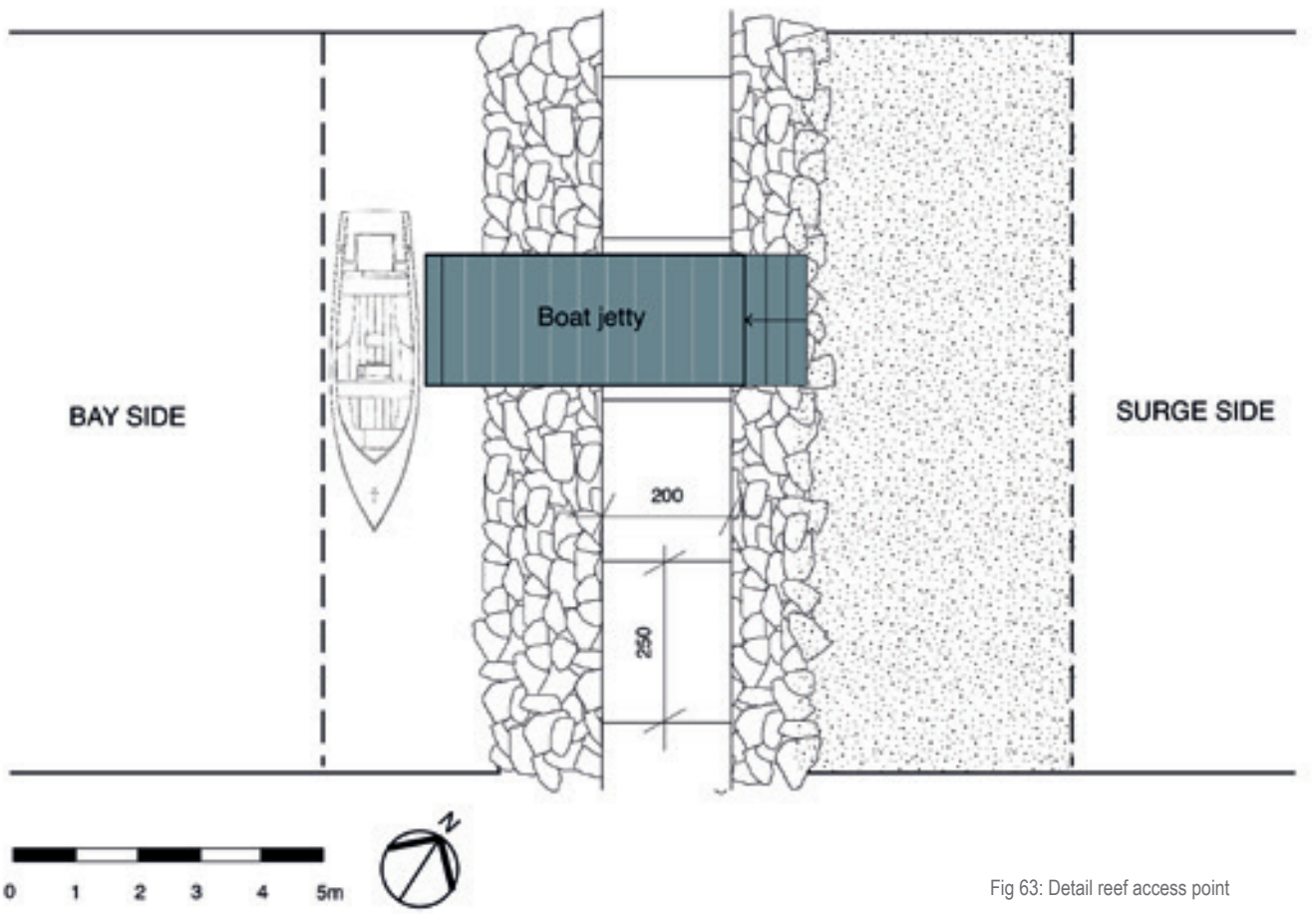
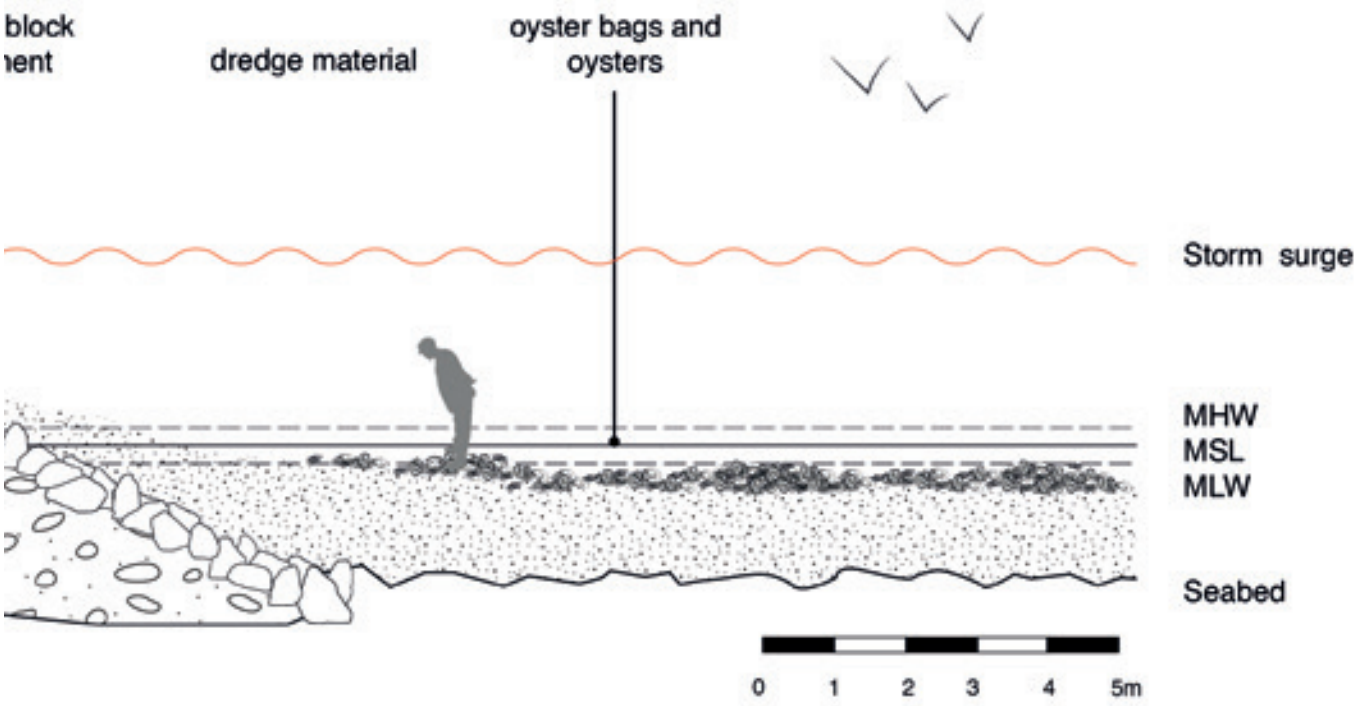


Fig 63: Detail reef access point



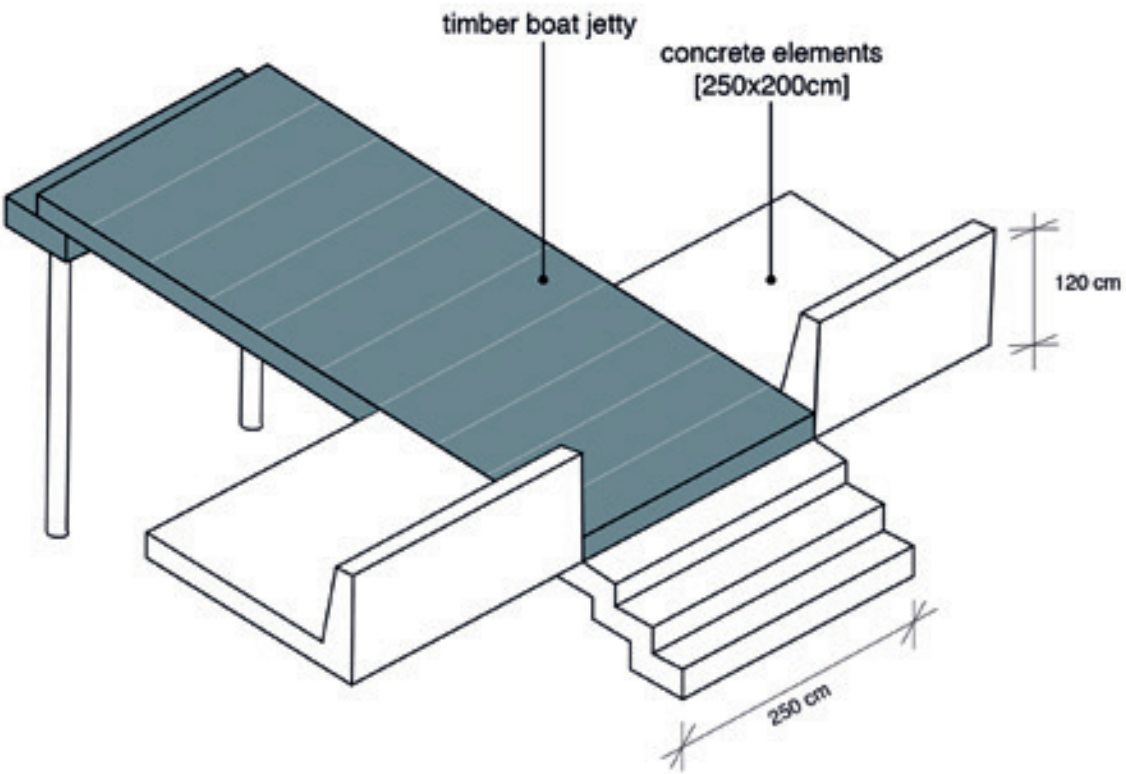
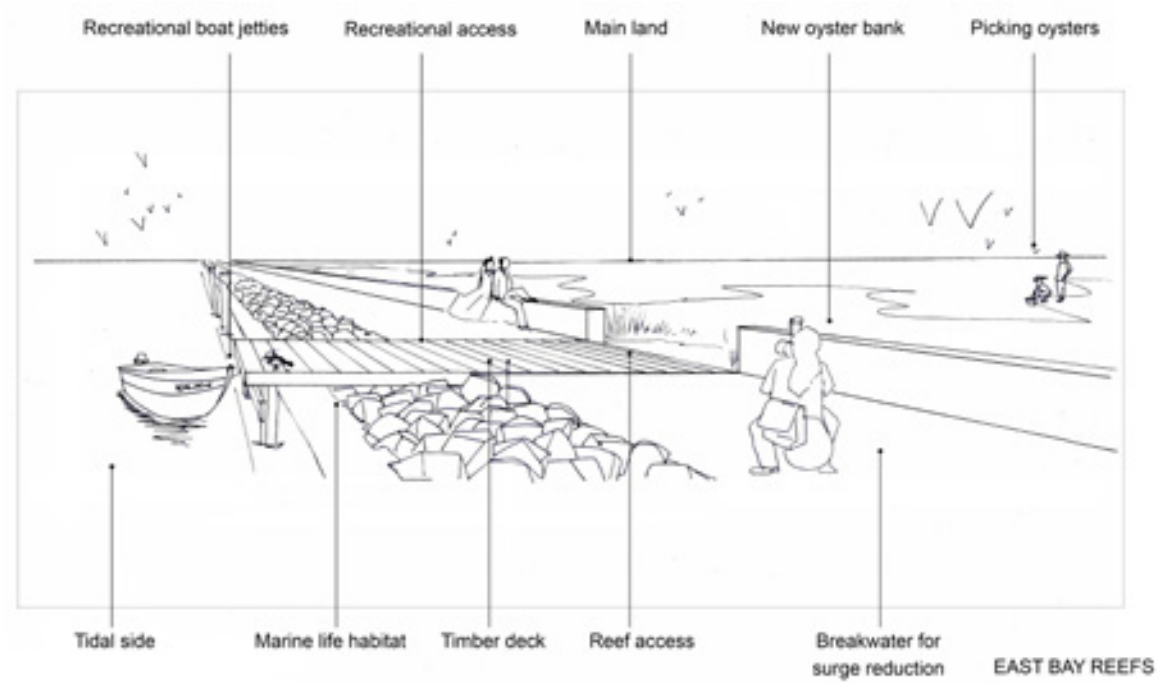


Fig 64:Detail flood retaining wall and boat jetty

Fig 65: Impression of the oyster reef recreational access


Recreational boat jetties
Recreational access
Main land
New oyster bank
Picking oysters
Tidal side
Marine life habitat
Timber deck
Reef access
Breakwater for surge reduction
EAST BAY REEFS

IV. Reflection

5 Discussion

5.1 Flood protection: US/NL

Throughout the research process, governmental and societal contrast between the USA and the Netherlands was encountered. Despite shared vulnerability of the coastal regions, there is no comparable tradition in flood protection in the United States. The Dutch approach is very much focused on prevention of flooding by infrastructure and spatial planning restrictions, while in the US the approach is much more focused on emergency management and disaster recovery. Characteristics in the US such as the public attitude towards government interference, low taxation, different building codes, private property rights and the national flood insurance program also add to the contrasting approaches of the two countries. Therefore, one specific approach cannot be disconnected from its context and applied somewhere else. Proclaiming a long-term, ecosystem based approach to flood resilience after the Dutch example is therefore questionable and daring. Nevertheless, the approach can be inspirational and valuable in both directions. Partnerships and collaborations in flood risk management and governance, such as the Dutch Dialogues, Rebuild by Design or the collaboration on the Houston - Galveston Bay region, testify the acknowledgment of the mutual value of exchange.

In this MSc thesis, a strategy for the Galveston Bay and Coast was suggested, inspired by Dutch practice in flood risk reduction, but with the acknowledgement of the need for a custom approach, connected to the local system. Nevertheless, aiming for an inspirational approach, further research, collaboration and elaboration is required to validate the suggested strategy.

Fig 66: Hurricane evacuation route sign

5.2 Climate change in a region running on fossil fuels

In the Houston-Galveston Bay region, the Port of Houston and the industrial complex along the Houston Ship Channel is a major risk, because of the catastrophic consequences a potential event would cause. Therefore, flooding in these areas should be prevented at all costs and structural solutions are being researched. Simultaneously, a changing climate due to anthropogenic warming is likely to result in heavier storms with more destructive potential. In the low-lying coastal areas, sea level rise due to climate change and land subsidence are adding to the vulnerability of the coast and the entire region. Therefore, flood protection is not only about avoiding the flood, but also about addressing the cause of flooding. Effective solutions combat both symptoms and causes.

In the discussion on climate change, carbon gasses are regarded one of the main causes of anthropogenic warming. The Houston – Galveston Bay region, also nicknamed the energy capital of the world, is running on fossil fuels – pumping, processing, trading and using - and therefore linked to global warming, climate change and sea level rise. In a landscape-based approach to storm surge protection, causes and consequences are both to be taken into account because a sustainable solution is regarded more than treating symptoms alone. For this MSc thesis however, the share of the regional activities in sea level rise and climate change has not been addressed any further as it moves beyond my possibilities and surpasses the purpose of my work. Nevertheless, I firmly believe spending equal (or greater) attention to causes than symptoms would definitely increase our chances in this global challenge.

5.3 Research – through – drawing

Freehand drawing is an established method in design practice. In landscape architecture, we usually see freehand drawings being used for observations and design and not so much for analysis and inventory. However, in the work of Palmbout Urban Landscapes drawings and sketches have a vital role early on in the design process. 'Evocative sketches dissect the layers inherent in a landscape to make them intelligible and to extrapolate those elements into possible future forms. As such, a clear tool of analytic planning is established, connecting large issues to the eye and the hand through drawing.' (Fosso et al., 2014). The method calls for effective observation and simultaneously, large amounts of (visual) information can be internalized in the drawing process.

Other than this analytical method (mostly depending on tacit knowledge and visual observations), the research-through-drawing approach in this research is using static information in texts, maps and documents as an input source. This requires a different approach and is rather involved with the **visual expression and translation of information to more workable forms for understanding**. The process is stimulated by the urge for visual information demanded by a visual-spatial thinking and learning style. The specific approach arises from the intuitive requirement for a suitable method to deal with large amounts of information for interpretation. The availability of abundant written information, data and numbers requires a framework for selection and a method for internalization and understanding. In addition, with the excessive load of information, freehand drawing helps to close the gap between the analysis of the current state and moving towards the imagination of a new form.

Immersed in the process, a new **step-by-step approach emerged by doing**. However, exploration is a time-consuming activity and this research-through-drawing approach requires further development and reflection to become more effective for design. Drawing the region also takes time itself, because of the size of region, the distance, complexity and language. I strongly believe there is room for improvement in order to get a new

efficient analytic design method, but more experience and experiments are needed. I recommend further research-through-drawing practice in order to identify the essence of the approach. After all, practice makes perfect.

Drawing refers to both the verb 'to draw' and the product 'the drawing'. In a similar way, drawing refers both to the act of representation and the representation itself. The act of representation is considered crucial for the internalization of information. Internalization means that information is truly acquainted in the drawing process by searching, selecting, tracing, sketching, etc. However, it is important to recognize that more information is acquainted than explicitly represented in the drawing. The represented product embodies more knowledge for the researcher than for an outsider and therefore, it is an **intimate subjective process of communication between the drawing and the drawer**. As a result, the approach is personal and limited in communication. The same research by a different person is likely to result in different drawings, different interpretations and different motives for design, but building on the same knowledge base. This limitation however, is very beneficial for design as it leaves room for creativity, inspiration and interpretation.

Throughout the research the duality between the act of representation and the representation itself, became stronger. Initially, drawing was nothing but a research method and a form of expression for personal reflection. It started as a personal experiment, but eventually the research had to be shared with others. The emergent research approach eventually required clarification. As a result, **the drawings became in addition to the activity, a product of representation as well**. Consequently, the style of drawing slightly changed and intuitively greater attention was paid to style, appearance and distinctness. Because drawing as an activity was the main goal, the change in representation was not entirely desirable and therefore no further attention is paid to discussing appearance of drawings (type, colour, size, etc.). Even though it could bring an interesting discussion, this subject is beyond the scope of the research.

Research-through-drawing as a new tool for the regional design analysis based on emergent research, proved to be worth exploring. As mentioned, improvements are needed to increase effectiveness and to find more balance between analysis and design. Last but not least, the question remains if research-through-drawing can be considered an effective approach. Is there added value created by drawing? During the research process, interim moments of designing helped to keep the focus on design. These moments however, demonstrate the change in the viewpoint and considerations regarding the problem. What started out with the softening of a dike along the coast, ended up with a strategy without a dike. During the drawing process, it became clear that closing of the barrier islands with hard measures would not be appropriate from a long-term landscape-based perspective. **Drawing helped to truly acquaint the landscape system knowledge and to change my point of view**. This allowed to move beyond the hard approach and to proclaim a soft, long-term approach with reasoned arguments. As a result, for this regional design challenge research-through-drawing proved to be an effective approach with added value. However, I can imagine the approach is not suitable for every assignment or researcher. I recommend additional research and reflection to identify the suitability of research-through-drawing for other research assignments.

5.4 Drawing and designing

In the perspective essay 'Design makes you understand—Mapping the contributions of designing to regional planning and development', Kempenaar et al. (Kempenaar et al., 2016) discuss the contributions of designing to Dutch regional planning and development. In the Dutch context, 'regional design is characterized by strategic designs that cover a large area and

seek to accommodate change over a long period of time by providing a framework for smaller scale decisions. Regional designers typically shape, create and envision regional futures, order information and search for coherence and connections.' (Kempenaar et al., 2016) The article concludes that design makes you understand and describes a number of ways designing contributes to regional planning: 'Designing enables a better understanding: of the area, of the viewpoints of various stakeholders, of the possible futures and options, of the actions that can be taken, of who should be involved.' (Kempenaar et al., 2016)

Reading the article, similarities between drawing and designing have been observed. First, drawing and designing argue both to create understanding. In both cases, understanding is fundamental for creating a counterweight to another approach. Looking at the origin of the methods, research-through-drawing emerged to explore a long-term soft responsive approach to flood protection as an alternative against the hard engineering practice. Designing in regional planning was explored as a reaction to the Dutch rational planning approach in the 1980's. (Kempenaar et al., 2016) Second, drawing and designing share the same difference in meaning between the activity and the product. Drawing refers to both the activity of making a drawing and its result as a physical representation. In the same way, designing refers to the activity of making a design and the result of the process.

However, differences between drawing and designing have been identified either. First, the result of the designing process ('the design') is usually a drawing, while the result of the drawing process ('the drawing') is not necessarily a design. In the article 'Drawing as a means to design reasoning' designing is described as a problem-solving activity with drawing as an expression of designing and a means to support reasoning in designing. (Do & Gross, 1996) As such, drawing and designing share common ground.

However, in this MSc thesis, drawing has been used to nourish reasoning in designing, but drawing is not the expression of designing. Drawing is running ahead of designing and bridges the gap between research and design. Second, differences have been identified between collaboration in drawing and designing. Kempenaar et al. (Kempenaar et al., 2016) mention the participation and engagement of stakeholders in the regional design process. Collaborative design and co-creation have proved valuable for regional design. In the drawing process, stakeholders have been involved at the start to provide information, but without collaboration or co-creation of the drawings themselves. However, the inclusion of stakeholders in the drawing process might work faster and spark substantial discussions. Regarding limitations of scope and time, I recommend this collaborative approach to research-through-drawing for further research.

6 Conclusions

6.1 Research conclusion

In this MSc thesis, the outcome of the research is the input for design. In the overall design process, research is used to find out what the context demands in order to inform the main design question on flood resilience. The research is subdivided in one main design question and two research questions that contribute to the overall understanding of the main question. The research conclusions are organized following to the research questions.

RQ1: What embodies the landscape system of the Galveston Bay region?

The first question builds on the theoretical framework of ecology and the landscape-based design approach. The landscape is perceived as a system. Organisms interact with their environment and mankind is mutually connected with nature and with the physical, biological and cultural environment. Actions have reactions in the system and cause change over time. To understand interconnections is the start to succeed in tuning human purpose in line with the system. However, systems are complex in essence and understanding them in reality proves to be more difficult than expected.

What embodies the landscape system starts with the exploration of elements in the landscape. Physical, biological and cultural elements have been identified to provide overview. Later, individual elements have been further studied to understand their behaviour and exterior connections. The individual elements have been grasped in drawings, as parts of the system together defining the whole. In the drawing process, tracing information and maps proved to be valuable for the internalization and memorization of information. In the next step, the whole system was explored by identifying the connections between the drawings and the whole. Drawings have been distinguished and received value in relation to each other. Shuffling cards by trial and error helped to internalize the landscape system and provide new clues. The physical, biological and cultural categories for example were not sufficient and called for new reasoning for arrangement. Finally, the landscape system was represented in an arrangement with expression of different paths and groups. The representation of the landscape system is the product of this research question and expresses the aspects that embody the landscape system of the Galveston Bay.

Representation demands to make choices about selection and omission. To represent is also to differentiate and to attach value to certain elements, enabling an endless number of possibilities. Despite endless ways to grasp the landscape system, it is not the aim to create the most truthful representation. The landscape system is by nature utmost complex and the aim of the research is the **internalization of this complexity**. Actively dealing with complexity helps to acquire understanding about the nature of the system and the representation aims to express that complex nature. Therefore, if the product is too complex to understand at first sight, it is a great success. However, it is also an invitation for a second glance to dive in.

RQ2: What principles guide an approach to flood resilience in line with the landscape system of the Galveston Bay region?

The second research question builds on the theoretical framework of flood risk reduction. A risk-based approach to the Houston-Galveston Bay region indicated a difference between the risk in the upper bay near the port and the developed barrier islands at the coast. Flood risk is the combination of consequences x probability and despite imminent risk, the nature of the risk is very different for both areas. As a consequence, the corresponding approaches were expected to differ as well. At this stage, the focus turned to the coastal barrier islands: Galveston Island and Bolivar Peninsula.

The exploration of guiding principles for flood resilience started with the combination of the landscape system and flood risk reduction. Focussing on the coastal barrier islands, a risk-based approach was reflected to the landscape system. During the explorations of the system in previous stages, connections with flood protection and ideas already emerged naturally. In combination with new insights and observations, **opportunities for flood resilience** have emerged. An overview of principles and insights was the product of this question and helped to guide an approach to flood resilience at the coastal barriers in line with the landscape.

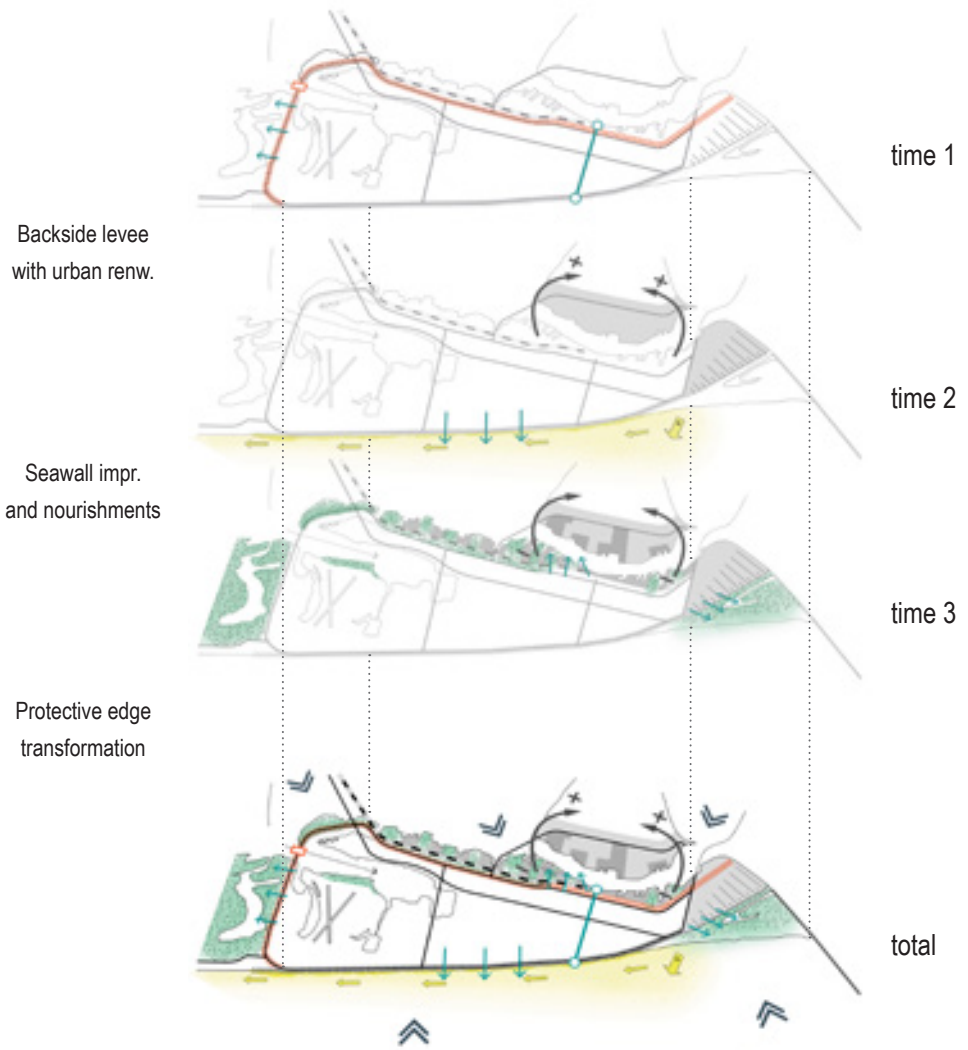
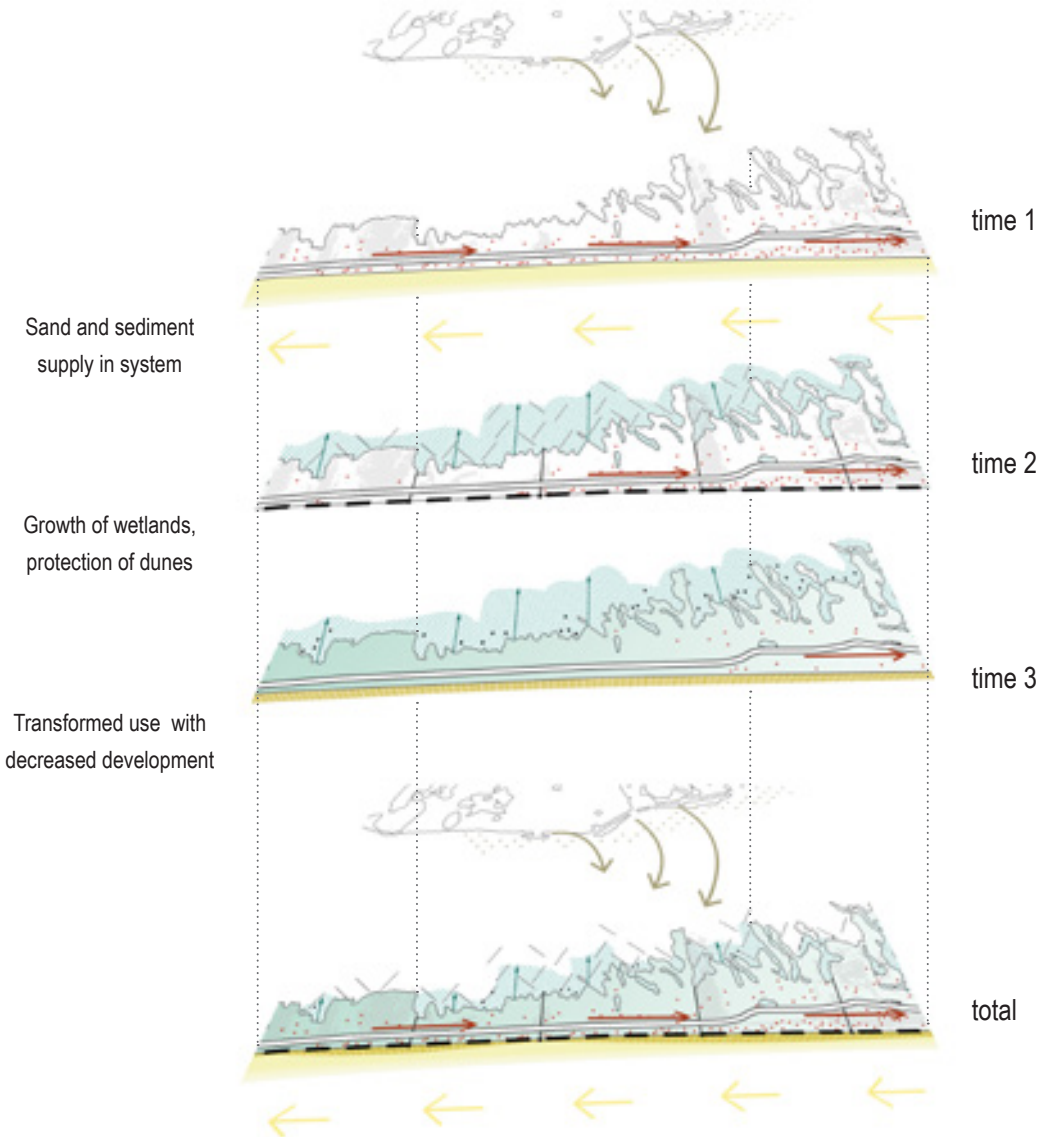


Fig 67: Long-term strategic approach for Galveston and the barrier islands

During the exercise, the method with tracing paper and markers helped to visualise thoughts and connections. It is a pleasant tool for exploration as it allows messy records of thoughts and at the same time, offers feedback to the mind. As a result, the mind was allowed to deviate with new findings as a result. Remarkable was the **redefinition of the problem** and the extension of the list of flood risk related problems in addition to the storm surge hazard. The exercise also demanded to reinterpret the **context of the landscape** and revealed major differences between the city of Galveston, the Gulf side and the bay side of the barrier islands.



DQ: What strategic approach for Galveston Island and Bolivar Peninsula moves to flood resilience in line with the landscape system of the Galveston Bay region?

The research outcomes from previous stages have been used to answer this design question. Landscape system knowledge and guiding principles helped to explore an alternative approach to flood resilience specifically applied to the case of the Galveston coast. The alternative approach in this case refers to a soft approach that emerges from and responds to (the preconditions of) the landscape system (as described in the problem statement), contrary to the hard approach with structural dikes and gates.

The result of the design phase is a strategy balancing between to hold on and to let go. A custom design approach to Galveston calls for new multifunctional structural measures with long-term considerations. A directive approach to the barrier islands proclaims the slow transformation of the islands' use from residential to natural and recreational, supported by measures to slow down the negative impact of inevitable physical processes. As such, **the strategy is a manifest to include long-term thinking now**, before time has passed and more flood events leave nothing but a few drastic/ costly options. (fig 67: long-term strategic app.)

The first key consideration in line with the system is whether to close of the tidal inlets or not. Taking into account the dynamic, protective nature of 'barrier islands' it could be considered that **the landscape system reasons against the protection of 'protection'.** However, keeping the tidal bay inlets open results in the need for alternative measures to reduce the high risk industrial areas of Houston elsewhere. In practice, to be considered an alternative to the lower-bay gate strategy, the upper-bay gate or mid-bay gate strategies have to complement the proposed approach for the barrier islands to be effective. The second key consideration is **the balance between hard/structural and soft/ mitigating measures**. Risk levels and spatial conditions determine the possibilities for the one or the other. In highly urbanized/ high-risk environments, hard measures could be inevitable. In contrary, in tiny populated/ low risk environments, soft measures could be desirable. At the Galveston Coast, the contrast between the islands and the city of Galveston demands a **custom approach.** After all, the suggested strategy balances between preconditions and opportunities in the landscape system, between hard/structural and soft/mitigating. It is not a ready-made solution, but an invitation to reconsider flood protection in a wider frame from a different perspective.

6.2 Extended layers approach

The theoretical framework for the landscape system analysis builds on theory of ecology and ecological design. The layer-cake model of Ian McHarg and the 'landscape triplex' of Kerkstra and Vrijlandt (Kerkstra et al., 1976) are both introduced (under 2.1.1. Ecology and a landscape-based design approach) as frameworks for acquiring knowledge about the landscape. Characteristic is the pattern study of the landscape, layer after layer.

In this research **the importance of landscape processes over patterns was the greatest discovery** of the research process. By taking a distance from the systematic analysis of patterns (scale dependent) more freedom was granted in the way of depicting landscape elements and more variety among the different drawings emerged. Nevertheless, two general categories stand out: component drawings' depicting patterns or structures; and process drawings, depicting change, movement or time. It became clear that the landscape processes are the power buttons of change and operate between the components of the system. Landscape processes proved to be very important, because they induce change and responding to these processes appeared to help to move in line with the system.

While layer-based approaches such as the layer-cake model or the triplex landscape, mainly study patterns and structures on thematic landscape layers, this research

suggests that processes between the layers deserve more attention instead. The research argues that the internalization and understanding of the processes between the layers supports understanding and provides opportunities for change, following a reasoned and sustainable approach. Nevertheless, further research is needed to confirm this assumption and to further explore the value of this claim.

6.3 General conclusion

Coastal regions all over the world are facing conflict between men and nature in challenging their flood risk. It seems that for many regions small and fast measures are no longer sufficient. Despite endless possibilities in hydraulic engineering, expensive complex solutions might not fit all situations and parallel problems in ecology and society are simultaneously demanding our increasing attention. There is still a long way to go for adaptation and there is the need to find out how we have to respond to the growing flood risk, in particular for less populous but vulnerable areas.

Galveston Island and Bolivar Peninsula are dealing with a growing conflict between men and nature. Realisation has to grow that current decisions and regulations in spatial planning set the course for the next decades and determine where we stand in 25 – 50 years. Currently, it is noticed that on the one hand, the research strategies for flood protection in the Houston-Galveston Bay region have opened the debate and general awareness is increasing. For example, sea level rise and flood risk are publicly addressed by various local organisations such as the Galveston Bay Foundation or the Galveston Historical Foundation. On the other hand, it is questionable whether change and awareness have gone through the local politics and policy making yet. Today, it is undecided how these barrier islands at the edge are going to respond to the growing conflict and the current approach seems to allow the future to tell.

The 'Geohazards Map' of Galveston Island is a good example of this undecided approach. The map shows varying areas of the island (imminent to low-hazard potential) based on their susceptibility to the effects of geological processes. These processes include sea-level rise, land subsidence, erosion, storm-surge flooding and (potential) washover paths. The caption of the map mentions 'the entire 48-km long portion of Galveston Island depicted in the map is highly vulnerable to sea-level rise and tropical storms, but simply categorizing the entire island as a risky place to live would not help guide the on-going development.' (Gibeaut et al., 2007) As such, the geohazards map acknowledges the vulnerability of the barrier islands, but advises in the light of the indisputable concept of on-going development.

However, what happens if we do challenge on-going development on the highly vulnerable barrier islands? At what expense do we want to try to avoid the surge, but also decrease the risk of pain, damage and loss of property and belongings? What if we look for a strategy in line with the geological processes, taking advantage of the qualities of the barrier islands as a mediator between men and nature? At this point, current standards and values might not be receptive yet to such suggestions, because they strongly question the current existence of the barrier islands. However, it could be an interesting experiment and I strongly believe representation, imagination and design can serve to clarify the problem, to persuade the necessity of change and to trigger action to start to move on…

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List of figures

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