Baukje Kothuis, Sebastiaan Jonkman, Antonia Sebastian

DELTA PLANNING AND DESIGN IN THE HOUSTON GALVESTON BAY REGION, TEXAS

INTRODUCTION

During the past decade, a major hurricane and multiple rain-induced flash floods have devastated parts of the Houston Galveston Bay Region in Texas. This forcefully directed attention to the extensive planning and design challenges that the region faces in order to mitigate flood risk, including the complex hydraulic system, lack of zoning, and urban sprawl. Although the occasion is regrettable, these challenges make this area an interesting case study location for the Delta Interventions Studio.

On September 13, 2008, Hurricane Ike made landfall near Galveston Island. The hurricane claimed over a hundred lives in the United States. Many communities along the Texas Coast experienced major damage to residences, personal property, infrastructure, local economy, and the environment. Storm surge was measured as high as 17.5 feet (5.3 m) just east of Galveston Bay in Chambers County and much of the region received more than 10 inches (25 cm) of rainfall in 24 hours (Berg, 2009). Hurricane Ike's total direct damages are estimated to be as high as $29 billion (NOAA, 2011), the indirect economic effects being many times this amount (TEEX, 2010). At the time, Hurricane Ike was one of the costliest storms in US history, second only to Hurricane Katrina.

The region is also prone to severe rain-induced flooding. For example, in 2001 Tropical Storm Allison caused severe inland flooding in Texas when up to 37 inches (94 cm) of rain fell, but there was relatively little associated storm surge (USDC, 2001). Still it is the costliest tropical storm in US history ($5 billion). While not as damaging as a hurricane like Ike, these extreme rainfall events occur much more frequently than surge events and have the potential to extensively disrupt social and economic life, as well as cause people - seemingly unaware of flood risks - to be at risk in flash floods.

The flood risk issues in the Houston Galveston Region are complex, stemming from different sources (e.g., ocean, bay, river environments), encompassing different hazards (e.g., rain, runoff, surge), and having to deal with the effects of climate change and sea level rise. For example, storm surge inundation risk is a function of several interrelated components including the physical hazard, a combination of the surge in the Gulf of Mexico and local (residual) surge within the Bay, and the extent of the damage, governed by urban and economic development patterns in inundated areas. Therefore, several strategic alternatives for surge risk reduction have been studied over the past few years, ranging from a coastal protection system, dubbed the 'Coastal Spine' (see Figure 110) to inner or mid-bay protection system alternatives (see Figure 109). Eventually, given the complexity of the system, it is expected that a regional intervention strategy and system-wide approach, including multiple elements ('multiple lines of defense') that incorporate both grey and green interventions, will be necessary to mitigate flooding in the region.

After each of the major floods, substantial reconstruction projects have been initiated. However, the new or repaired structures often resemble the previous structures to a large extent. While some outliers exist (e.g., Texas Medical Center [TMC] post Allison), more flood- and water-conscious planning and design can create a safer and more attractive living environment in the Houston Galveston Bay Area, at the same time building resilience and public awareness of flood risk. Unfortunately, this is not a simple task in a region which consists of different areas with diverging and locally-specific spatial, socio-economic, and water related characteristics. This introduction discusses these characteristics, specifically addressing flood related issues, to explain the specific planning and design challenges for spatial interventions in this extremely rapidly urbanizing delta.

The City of Houston
Houston is the fourth largest city in the US, situated on the northwestern tip of Galveston Bay. The city boomed after the Great Hurricane of 1900 and the construction of the Ship Channel in 1915 and is still expanding. The current population of 2.2 million people is expected to double by 2050 (OSD, 2014). The city is extremely vulnerable to flooding and Harris County has one of the highest rates of repetetive flood losses in the US. Not only are residential plots situated in flood-prone areas, these areas also host major industries and businesses of national and global importance. These include large petrochemical plants in the Port of Houston, as well as the Texas Medical Center downtown, both of which are built on the banks of bayous.

The areas around Galveston Bay are drained by numerous of these bayous, slow-moving, tidal-influenced, coastal 'rivers'. These small rivers can be quickly overwhelmed by intense precipitation events and the resulting floodplains are extremely wide, often hundreds of feet across. Houston was originally built on the banks of two of these bayous (Buffalo and Brays Bayous) and has experienced frequent rainfall-induced flooding during its history. Since many of the bayous have been channelized over the years, the normally slow moving water can quickly turn into a raging river during extreme storms (Sebastian 2015). On several occasions, the region has received more than 6 inches (15 cm) of rain in a few hours, causing rainwater to fill the bayous, freeway underpasses and low lying areas. As far as flooding, rain-induced floods are the major issue here; hurricane surge does not directly impact downtown Houston. It was the wind damage that was most devastating during Ike, causing widespread, and lengthy, power outrages across the city.

Awareness of flooding and when it is going to occur is a major issue in Houston; therefore several warning systems have been built or proposed. For example, the Harris County Flood Warning System measures rainfall amounts and monitors water levels in bayous and major streams on a real-time basis to inform residents. The Rice University/TMC Flood Alert System is an integrated system issuing flood warnings and forecasts for the TMC Complex. This complex also features 25 automatic floodgates, installed at all of the entrances and drives, and built into a granite clad concrete wall that surrounds the entire facility.

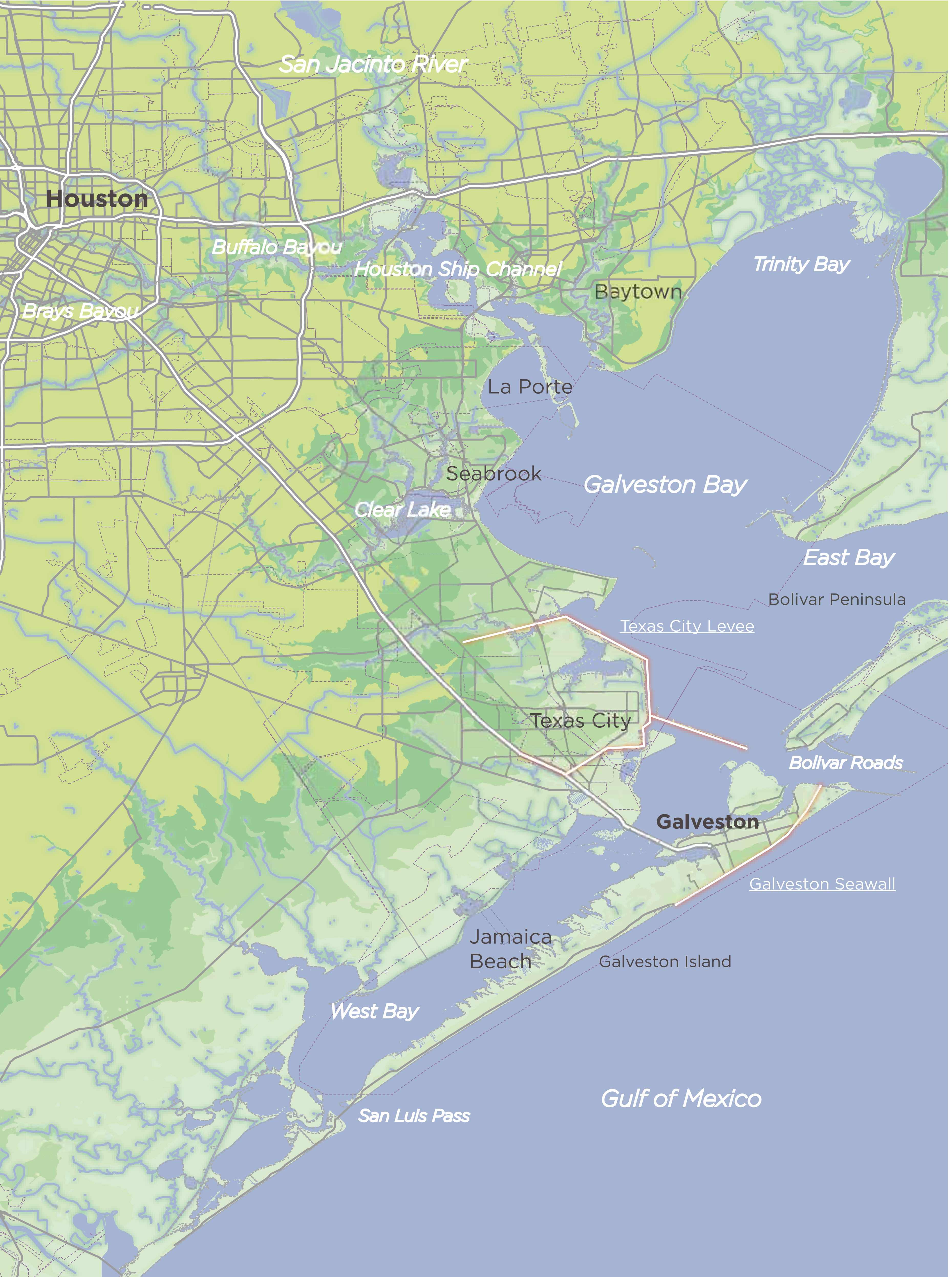
Galveston Bay shores
The west shore of Galveston Bay runs from Morgan's Point to Eagle Point. More than 1 million people live within the low-lying evacuation zones, and this number is expected to double by 2035 (Bedient 2012). It is an area of primarily suburban communities, characterized by sprawl and interspersed with some industrial activity. There are lots of local businesses and schools located here, but also the NASA Johnson Space Center, a major economic impetus. In the past two decades, the Clear Creek watershed area has repeatedly been subjected to floods, caused by rainfall as well as storm surge, both causing extensive property damage.

Further south is Texas City. The Texas City Levee has protected the city - and a large cluster of petrochemical industries within its boundaries - from storm surge since its construction in 1962. Texas City Levee remained structurally intact after Hurricane Ike, and was not overtopped, although debris was found on top of the levee and it required repairs for two years.

The flood issues are different along the east bay shore than along the west bay. The region is not heavily populated; in addition, it does not get a lot of surge during hurricanes because these spin counter clockwise. On the other hand, the coastline is severely inundated from the ocean side; in fact, this was wherethe highest surge during Ike occurred. The parks, rice fields and grazing pastures in this area took several years to recover from the saltwater intrusion.

The industrialized north end of the bay, including the Houston Ship Channel, has very different characteristics again. The area is heavily industrialized, and houses a low-income population. From a flooding standpoint, it also faces a different threat; the Ship Channel could potentially experience much higher surges than the west bay shore because of the 'funneling effect' that happens when surge enters the San Jacinto River. Since it is constricted to a smaller area (channel), the surge water level becomes much higher in the industrial portion of the ship channel than at other locations around the bay.

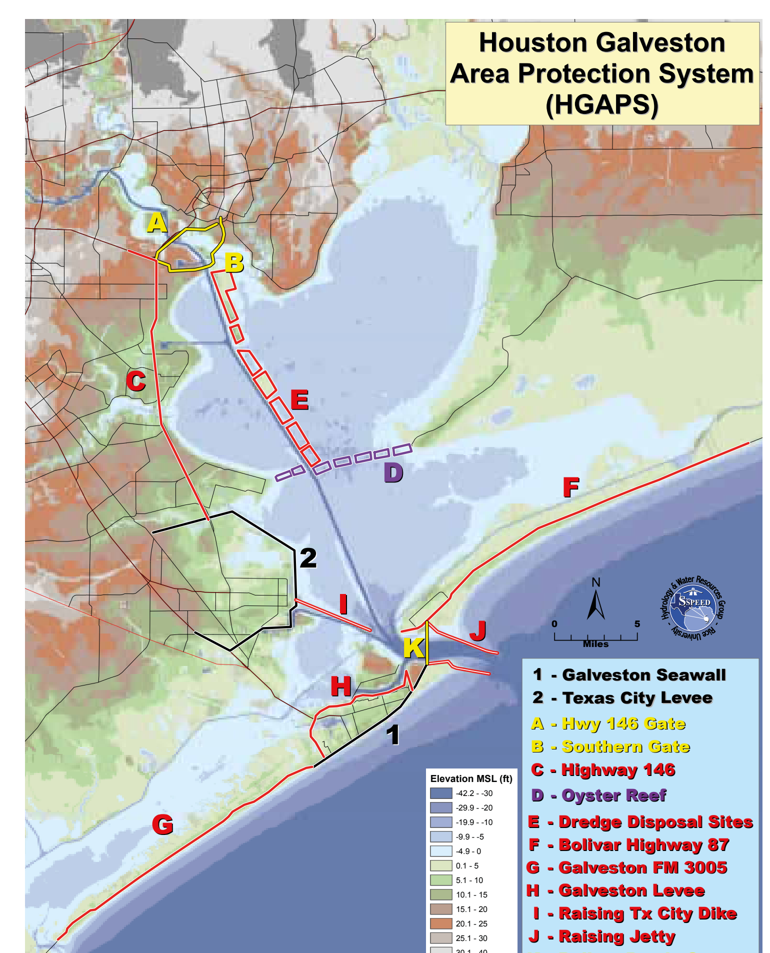
The Barrier Islands
Galveston Island and Bolivar Peninsula, two barrier islands separated by the Houston Ship Channel, form the southern edge of Galveston Bay. Galveston Island is about 27 miles (43.5 km) long and no more than 3 miles (4.8 km) wide, and has a population of about 50,000 people, mostly residents living in Galveston City. The city has a famous historical district, which attracts many visitors from around the globe. The western side of the island is occupied by beach houses, mostly second homes of Texas residents.



In the year 1900, the Great Hurricane killed more than 8000 people in and around Galveston, inundated the complete island and destroyed much of the city. To date, this remains the costliest tropical cyclone in history and is the storm of record for the Galveston Bay Region. Afterwards, a 10-mile (17 km) long seawall was constructed along the beach of Galveston. To the east, the island was backfilled to meet the height of the seawall, in order to raise properties. Since 1900, more than five major hurricanes have made landfall near the City of Galveston, but the seawall has largely protected the City from storm surge. During Hurricane Ike, the greatest damage to the city was caused by storm surge ebb that hit the back of the island as the hurricane crossed the Bay.

While the seawall provides a first protection for properties on the east end of Galveston City, flood risk on the island still poses many flood risk challenges for planners, architects, and engineers. Major issues that need to be addressed promptly include protecting the Galveston historical district, reconnecting the city to the ocean, and reducing coastal erosion. First, the existing seawall forms a hard boundary between the city and the sea, and its height is likely no longer sufficient to protect the city from future storm surge. The 1% annual chance surge calculated by FEMA in 2012 is now higher than the existing seawall: 18 feet (5.5 meters) instead of 17 feet (5.2 meters). Second, the backside of the city needs protection, as it is threatened by flooding due to storm surge ebb (wind set-up as the hurricane crosses the bay). Finally, the homes on the west side of the island need more protection: although they are on stilts and might be high enough to withstand sea level rise and storm surge, they still suffer damage from waves and erosion. On top of this, the consequences of climate change and sea level rise are likely to aggravate these issues at some point. Questions that are raised are whether protection on the west end should be at the individual/parcel level (e.g., more and higher stilts) or community level/island level (e.g., nourishments, extra sea wall). Erosion is one of the premier issues for the barrier islands, since the loss of beachfront also causes loss of property.

The second barrier island is Bolivar Peninsula. This island suffered heavy damage from Hurricane Ike. With fewer than 3000 permanent residents and about 5000 housing units, many of which are tourist-related, it might seem that major flood risk reduction plans are not a high priority. However, nothing is less true. Although the island is only a narrow strip of very low-lying land - 27 miles (43.2 km) long and only half a mile (0.8 km) wide at its narrowest point, it provided considerable protection for Galveston Bay by holding back high volumes of Gulf water during the hurricane; and thus should not be neglected.



Both barrier islands are critical to surge reduction in the overall Bay system. Maintaining the location and height of these islands (potentially even raising them) is critical for the system as a whole. Addressing erosion is therefore essential. Furthermore, the historical and recreational value of these islands, and their ecological habitat value (especially the west end of Galveston and Bolivar) need to be protected. These varied functions mean that we should consider designing a multifunctional flood reduction system that considers all functions of the system, is resilient, and adaptable. If a coastal spine concept is preferred, both islands need a so-called 'land barrier' in the system. To help provide the essential overall quality of the composition, technical, architectural, and spatial planning and design inputs are necessary, as well as an understanding of the local ecology and governance system.

Delta Interventions Studios Texas Design

Taking climate change into account, and with the frequency of compound flood events (rainfall and surge) shown to be increasing in the Gulf Coast (Wahl et al. 2015), a number of urban delta planning interventions are necessary: addressing water storage capacity, reducing the impact of river and coastal flood events, enhancing risk awareness of Houstonians, and improving the livability and spatial quality of the urban zone (e.g., Nillesen 2015). On a systems scale, adaptable flood mitigation is necessary to respond to the rapid developments in land use and urban sprawl, as well as to address the effects of sea level rise and climate change. On a smaller scale, preparedness for changing water levels must become the leading design principle for individual buildings and public spaces: flood-proofing these structures and areas must be one of the design conditions. Adopting new building codes and using improved building materials and methods, smart planning and design of public spaces to enlarge water storage capacity, and a policy to restrict development in flood prone areas, will make communities more resilient (GHF 2011).

These diverse planning and design challenges appeal to students of the Delta Interventions Studios. The studio offers them the opportunity to develop skills in a multidisciplinary environment with civil engineers, planners and policy analysts, the opportunity for international exchange and local collaboration, and the opportunity to apply and adapt concepts to an area with a different flood regime from the Netherlands. This stimulates the researchers to find answers to new problems at different scales, incorporating water-related aspects in their designs, and thus offering many opportunities to learn. The challenging design environment encouraged students to come up with a wide range of engaged and attractive designs. These vary from flood and hurricane resilient recreational complexes that reconnect Texans with their water environment (Ho, p. 94; Liu, p. 85) to the redevelopment of a watershed to address urban sprawl (Huang, p. 91); an elevated cultural building protected against a 500-year flood (Cao, p. 90); and a framework to help professionals to communicate flood risks more effectively to the public (Yam, p. 92). These projects have facilitated discussions about flood risk mitigation alternatives and are an inspiring contribution to decision-making on flood-related planning and design in the Houston Galveston Bay Region.

Figure 109. Houston Galveston Area Protection System (HGAPS). .

Figure 110. Coastal Spine. design including proposed flood defences.