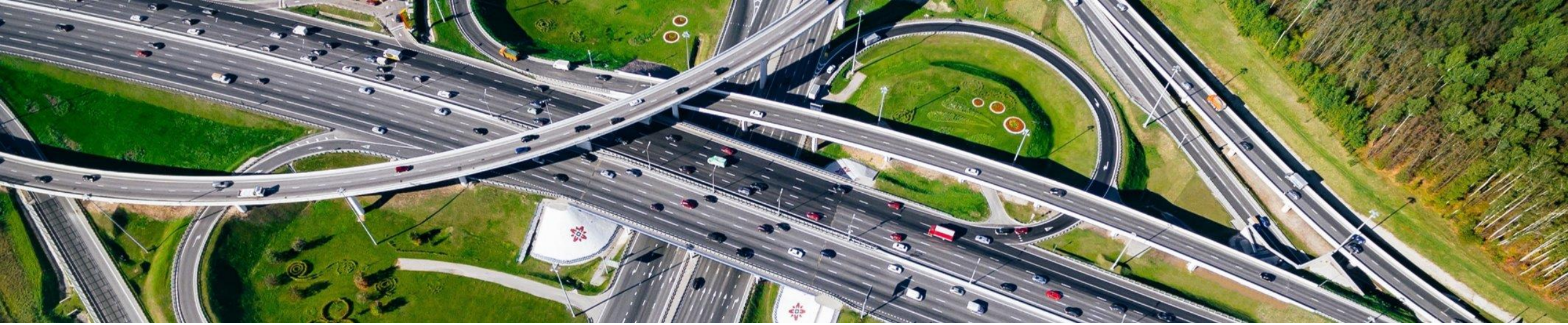


Coastal Texas Study & Coastal Resiliency

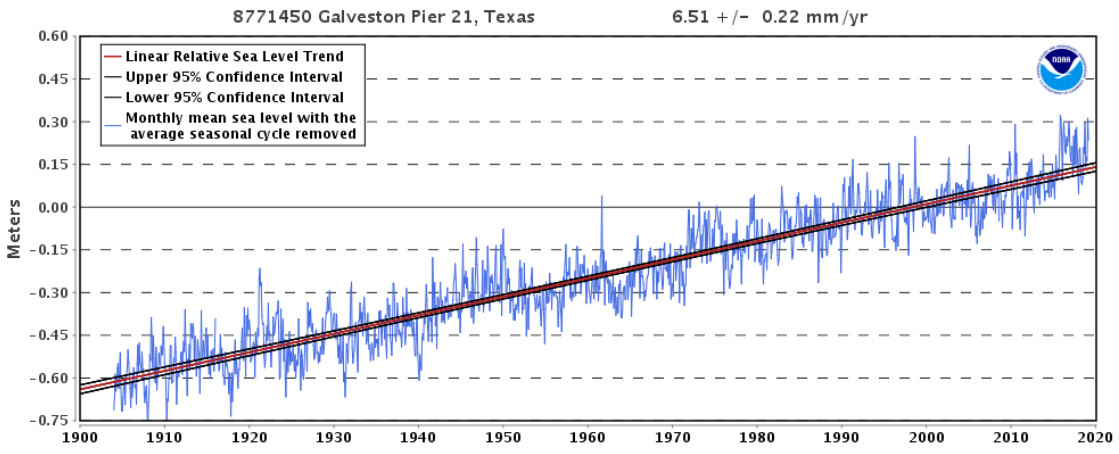
JUNE 2023

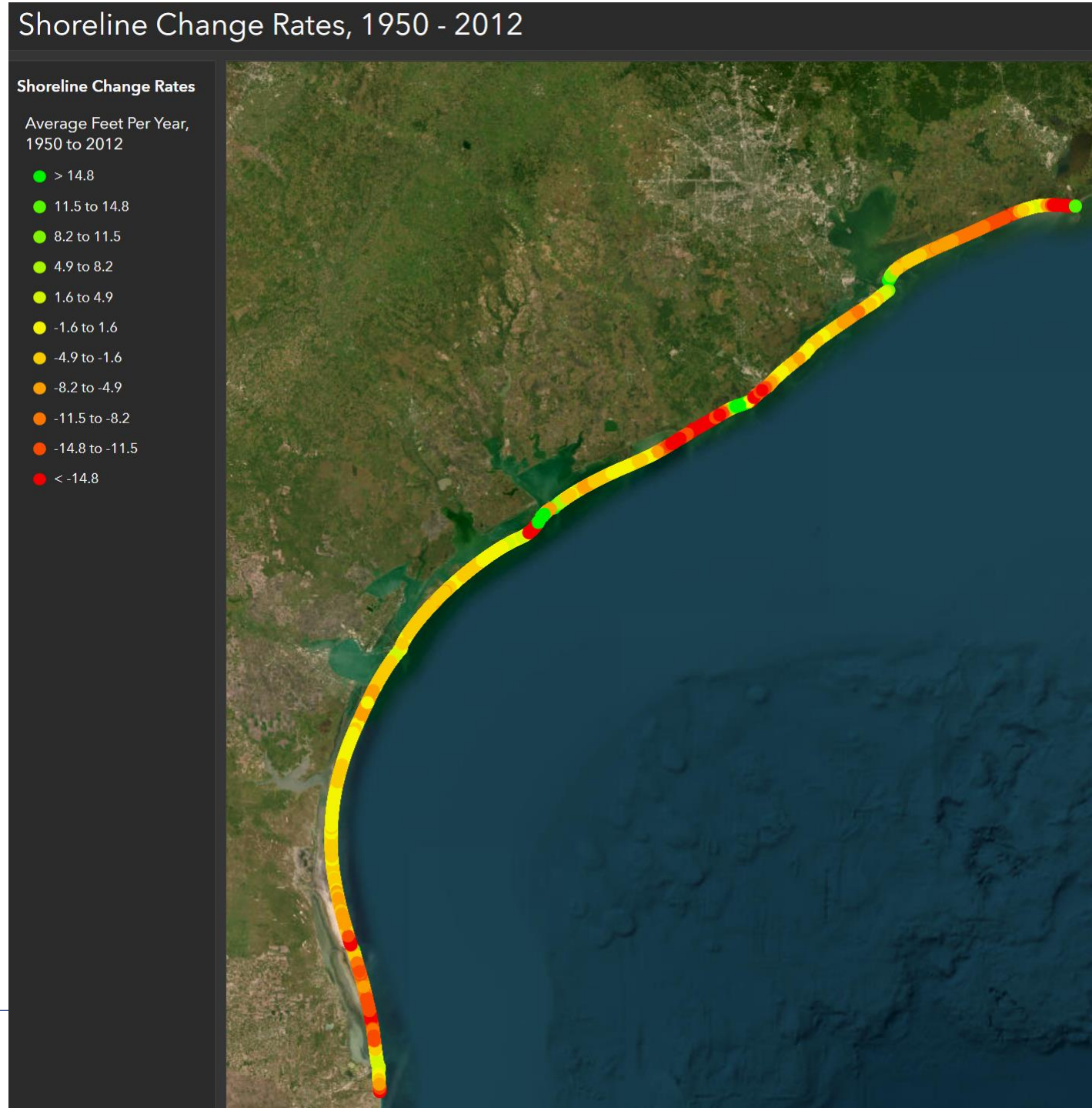
Innovative strategies to design, develop, and grow

The Problems

Land Loss

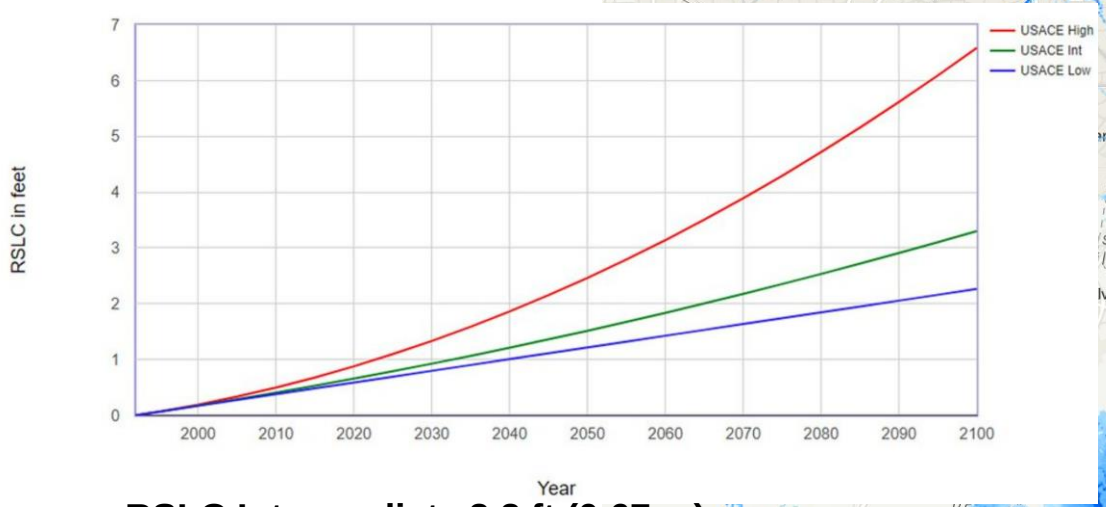
- Coast and bay shorelines are eroding
- Sea level rise & subsidence
- Loss of sediment inputs
- Littoral transport





Coastal Texas Study Area and Regions

Surge - 500 Year Annual Exceedance Probability – Still Water Level



- **RSLC Intermediate 2.2 ft (0.67 m)**
- **2030 to 2100**

https://www.coastalstudy.texas.gov/

Water Depth
30 ft
0 ft

Esri, CGIAR, USGS | Texas Parks & Wildlife, CONANP, Esri, HERE, Ga

1900 Hurricane

- Hurricane winds
- Storm surge ~ 15 ft (4.6 m)
- Damages $25 m
- 6,000 to 12,000 deaths
- 1,500 ac (607 ha) flattened
- 2,600 houses destroyed
- 300 ft (90 m) of beach erosion

- Science at the time…
  broad flat continental shelf
  reduces surge

- Dead wrong…
  allows for increased surge!

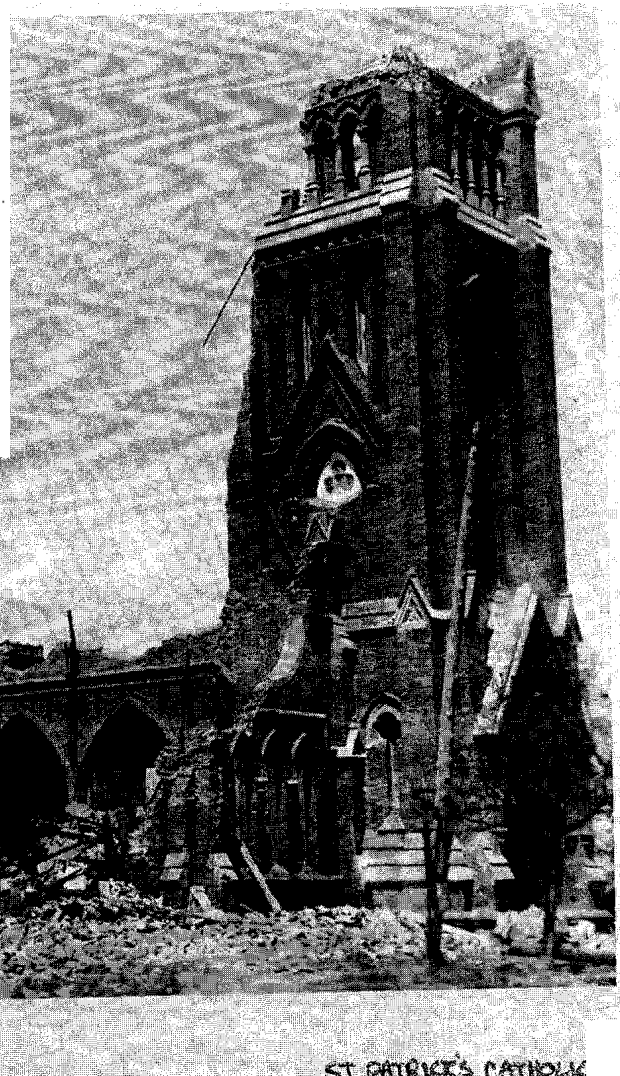
2008

1915

1900

1961

1983



1900 Hurricane

LOCAL RESPONSE:

- **About one year post storm City & County Commission's of Galveston appointed a board of engineers to report on means for protecting the city.**

CHARGE:

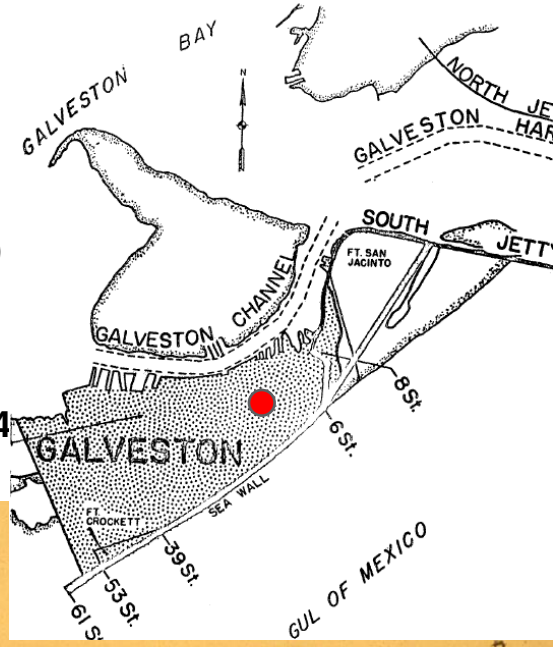
- **Safest and most efficient way for protecting the city against overflows**
- **Elevating, filling, and grading the avenue, streets, alleys, and lots… to secure sufficient drainage and sewerage**
- **A breakwater of seawall of sufficient strength and height to prevent overflow**

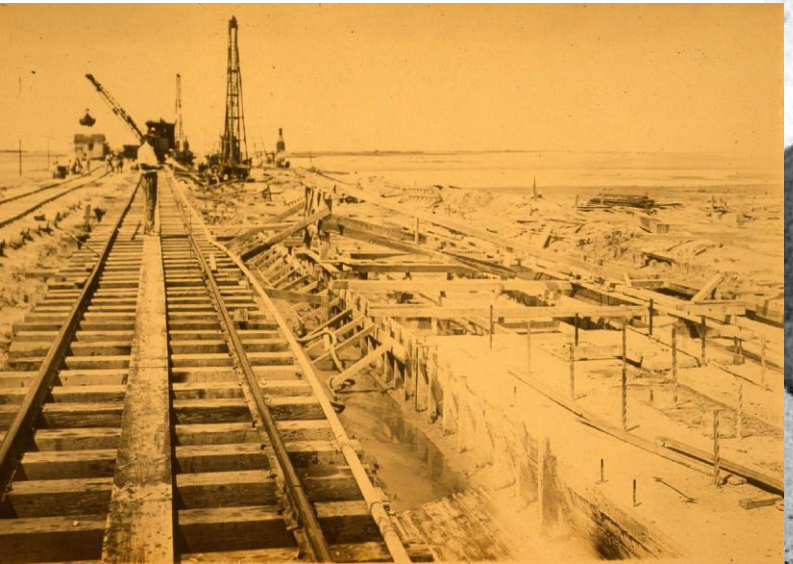
ENGINEERS REPORT:

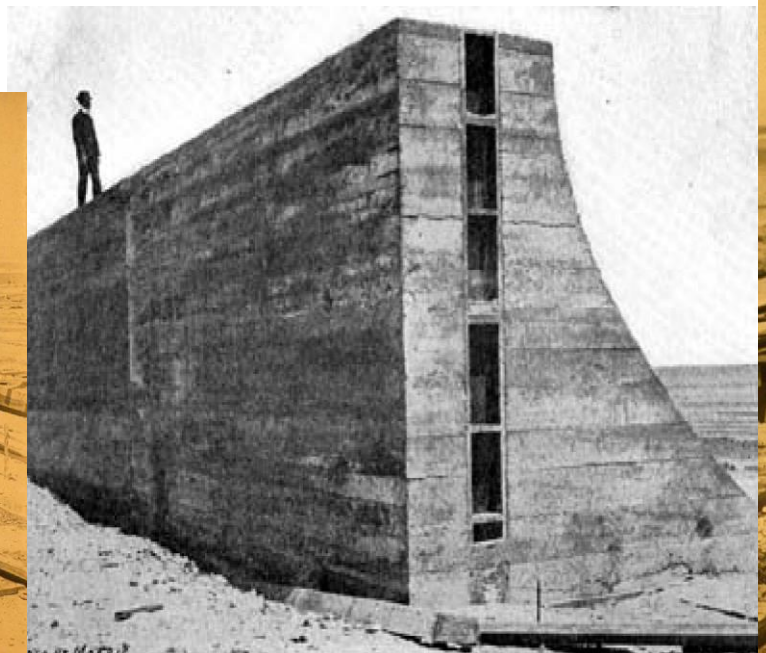
- **January 25, 1902**
- **Solid concrete gravity wall 3 miles long jetty to 39th St. 17 ft above MLLW**
- **Raising of the city's grade to 8 ft (2.4 m) at bay to 18 ft (5.5 m) near seawall**

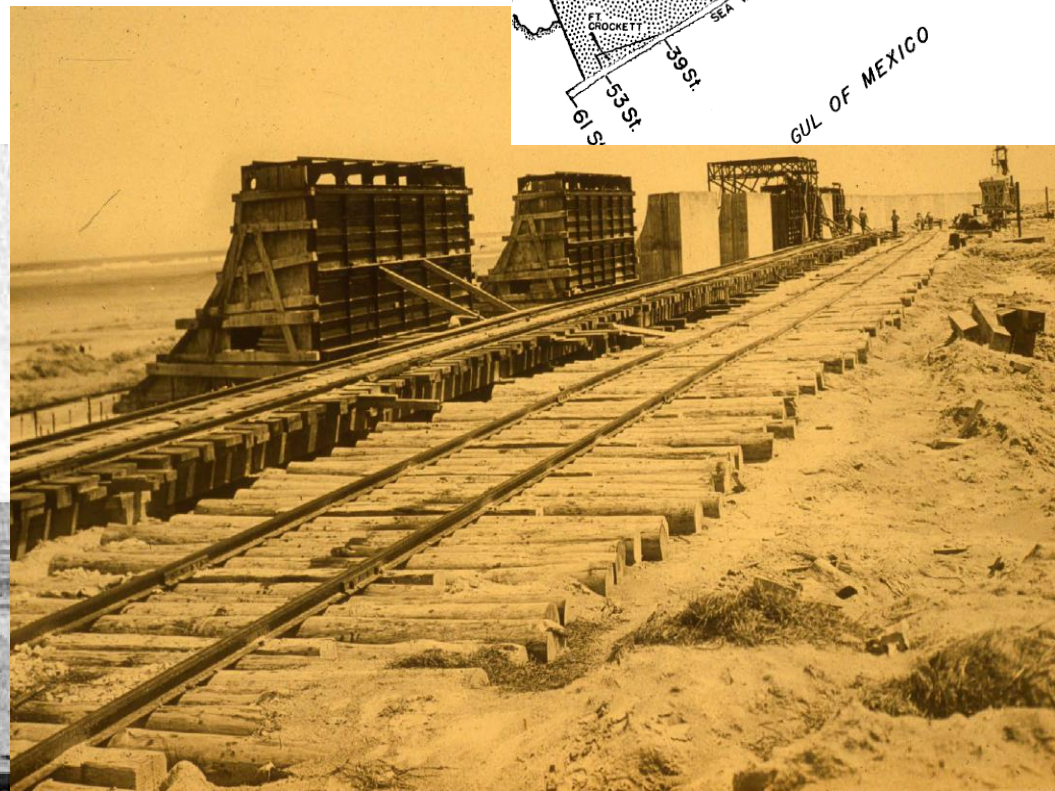
CONSTRUCTION: Cost $1,581,673.30

- **Start October 1902 - Complete July 1904**

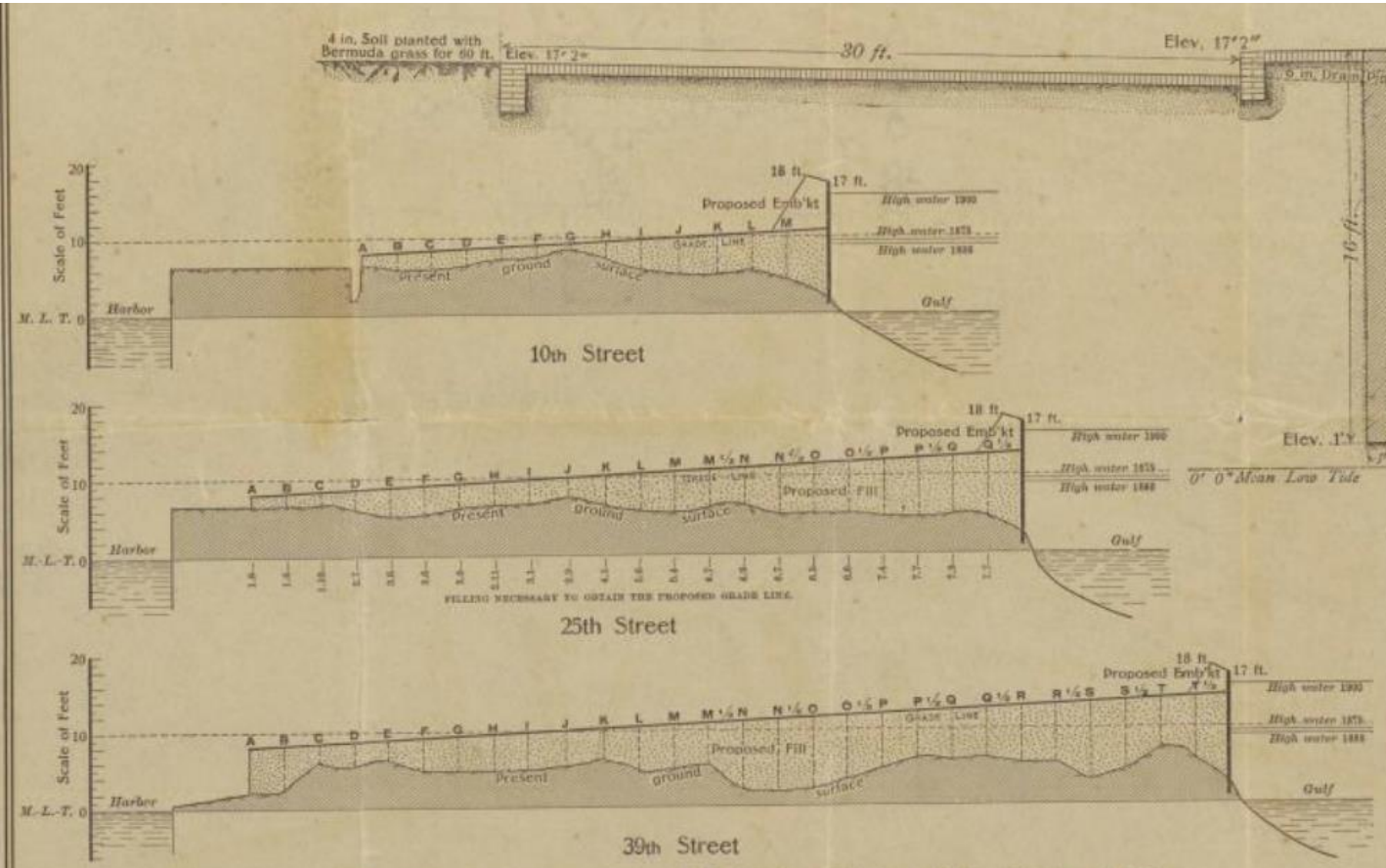


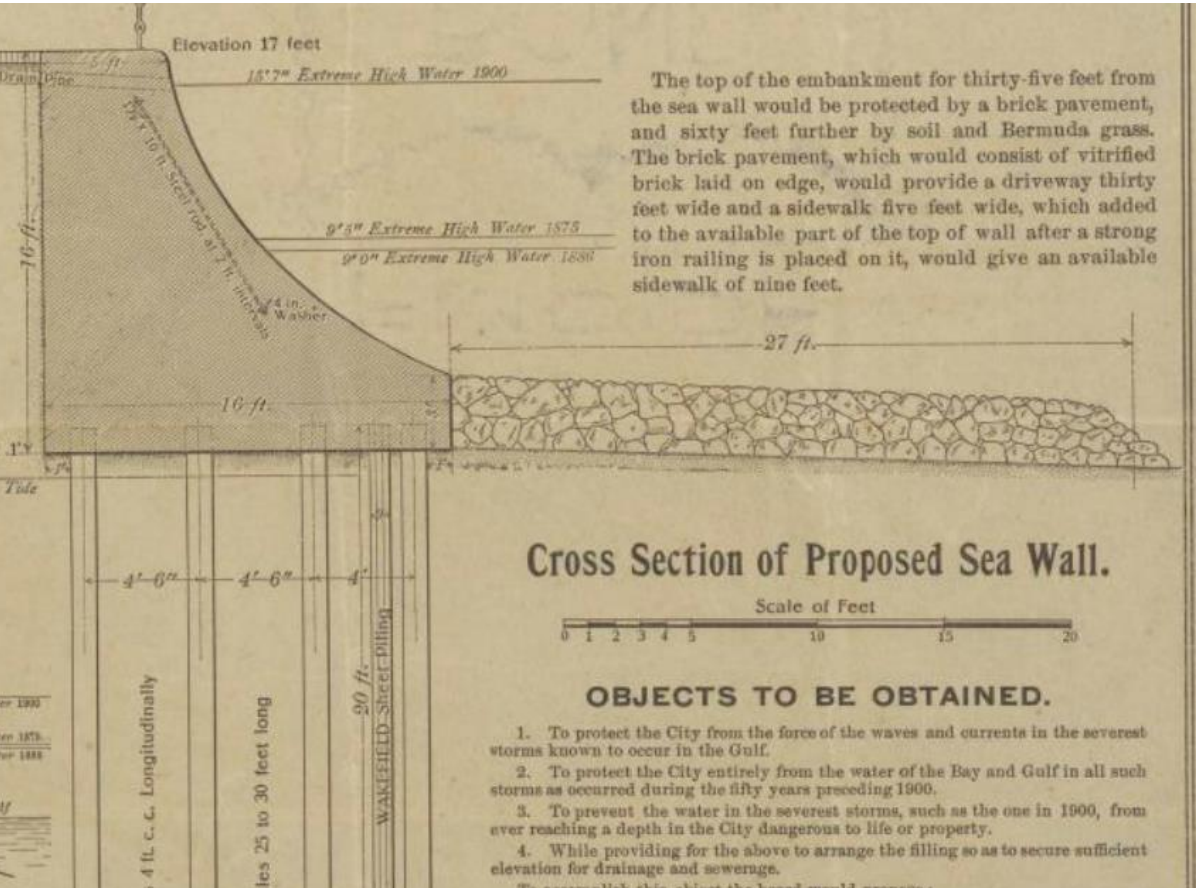






Galveston Seawall





The top of the embankment for thirty-five feet from the sea wall would be protected by a brick pavement, and sixty feet further by soil and Bermuda grass. The brick pavement, which would consist of vitrified brick laid on edge, would provide a driveway thirty feet wide and a sidewalk five feet wide, which added to the available part of the top of wall after a strong iron railing is placed on it, would give an available sidewalk of nine feet.

Cross Section of Proposed Sea Wall.

Scale of Feet

0 1 2 3 4 5 10 15 20

CROSS SECTIONS OF ISLAND AT 10th, 25th AND 39th STS.

ESTIMATED COST OF ENTIRE PROJECT.

1.	Sea Wall		$1,294,755
2.	Filling east of west line of 13th street, and south of Market street	$ 206,553	
3.	Filling west of 13th street and south of north line of Broadway	1,433,520	1,640,073
4.	Filling east of west line of 13th street and north of south line of Market street		31,982
5.	Filling streets, avenue and alleys west of 13th street and north of Broadway	229,185	
6.	Filling lots west of 13th and north of Broadway	309,045	538,230
	Total cost of entire project		$3,505,040

OBJECTS TO BE OBTAINED.

1. To protect the City from the force of the waves and currents in the severest storms known to occur in the Gulf.

2. To protect the City entirely from the water of the Bay and Gulf in all such storms as occurred during the fifty years preceding 1900.

3. To prevent the water in the severest storms, such as the one in 1900, from ever reaching a depth in the City dangerous to life or property.

4. While providing for the above to arrange the filling so as to secure sufficient elevation for drainage and sewerage.

To accomplish this object the board would propose:

1. The building of a solid concrete wall, over three miles long, connecting with the South Jetty at Eighth street; thence to Sixth and D; thence across the island and down the beach as far as Thirty-ninth street. The top of the wall to be 17 feet above mean low tide, or 1.3 feet higher than the highest point reached by the water in the storm of 1900.

2. The raising of the city grade to 8 feet at Avenue A, 10 feet at Broadway, 12 feet at Avenue P, and continue this slope to the sea wall. This corresponds to a rise of one foot in 1500 from the Bay toward Gulf.

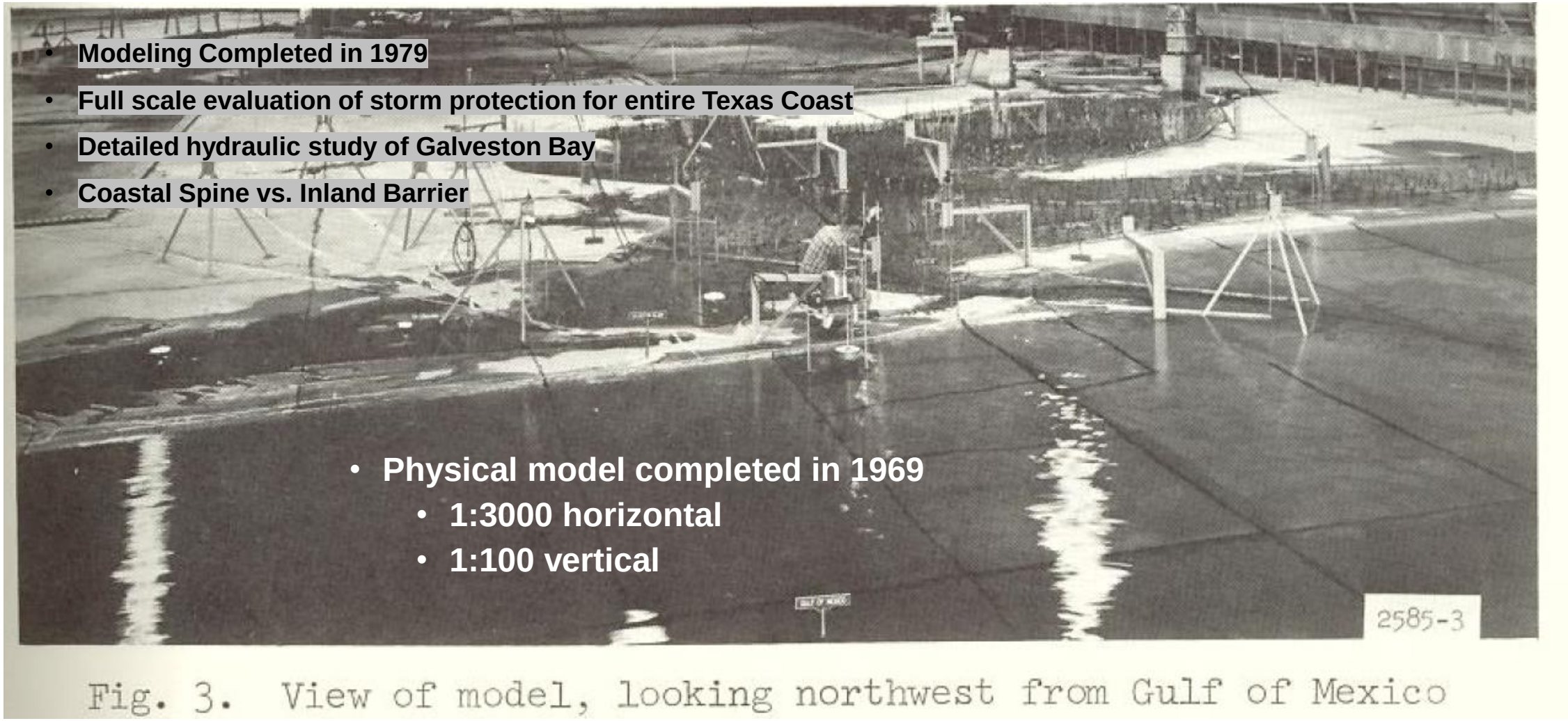
3. The making of an embankment on top of this fill adjacent to the wall and rising to a height of eighteen feet above low water at a distance of 200 feet from the wall, and thence sloping down on a grade of one foot in fifty feet to the surface of the fill.

The raising of the city grade is necessary to get the streets and lots sufficiently high for safety to life and property in severe storms.

Galveston Grade raising

The Studies & Projects

USACE Galveston Bay surge modeling 1969-1979



- Modeling Completed in 1979
- Full scale evaluation of storm protection for entire Texas Coast
- Detailed hydraulic study of Galveston Bay
- Coastal Spine vs. Inland Barrier

- Physical model completed in 1969
  - 1:3000 horizontal
  - 1:100 vertical

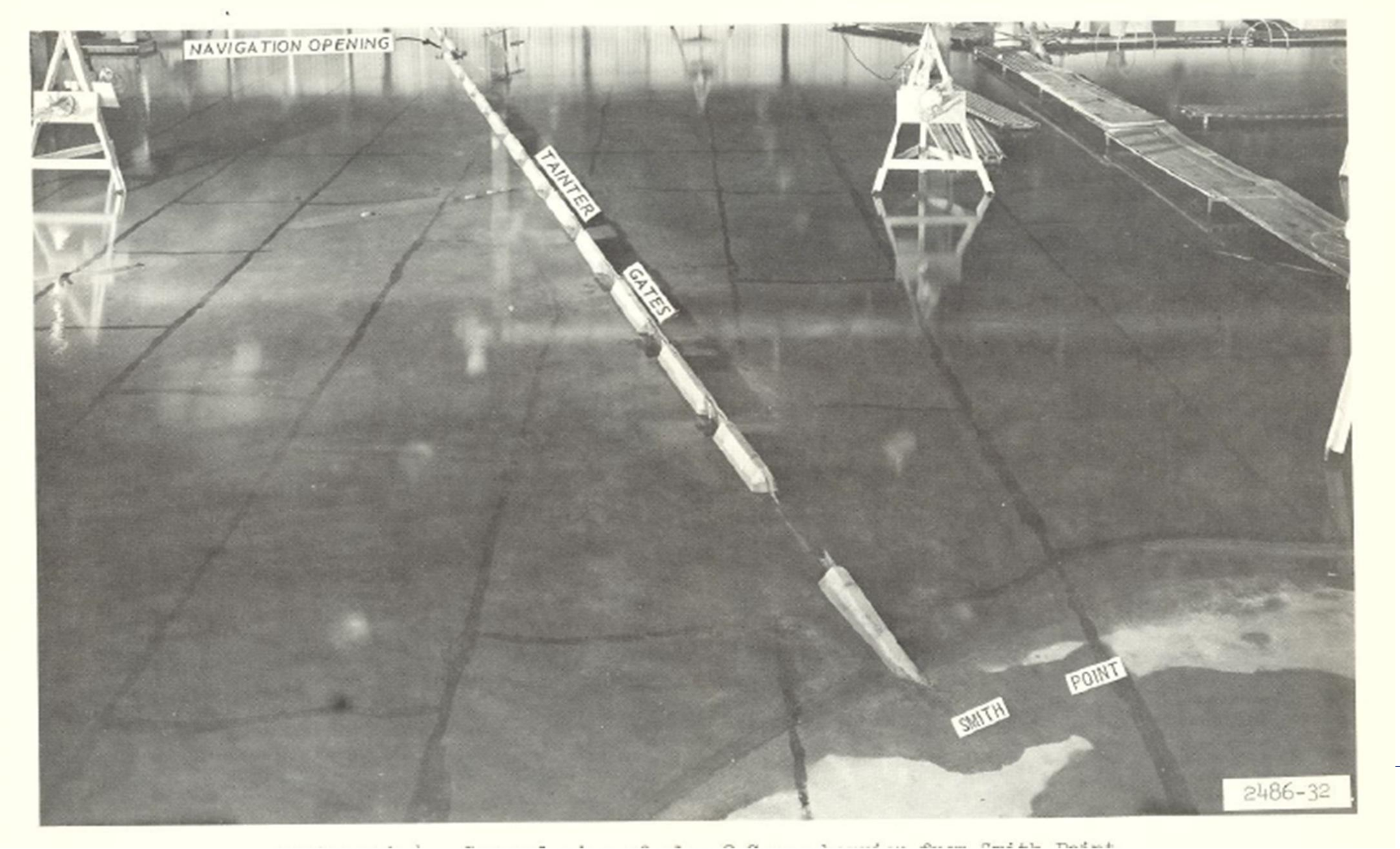
Fig. 3. View of model, looking northwest from Gulf of Mexico


Houston
University Place
Deer Park
Baytown
Peggy Lake
Pasadena
La Porte
LA PORTE MUNI AIRPORT
WILLIAM P HOBBY AIRPORT
ELLINGTON FLD
ELLINGTON AIR FORCE BASE
GULF OF MEXICO
Pearland
Seabrook
Friendswood
League City
Alvin
6
75
Santa Fe
La Marque
Texas City
Galveston
SCHOLES INTL AT GALVESTON AIRPORT
Gamma
Alpha

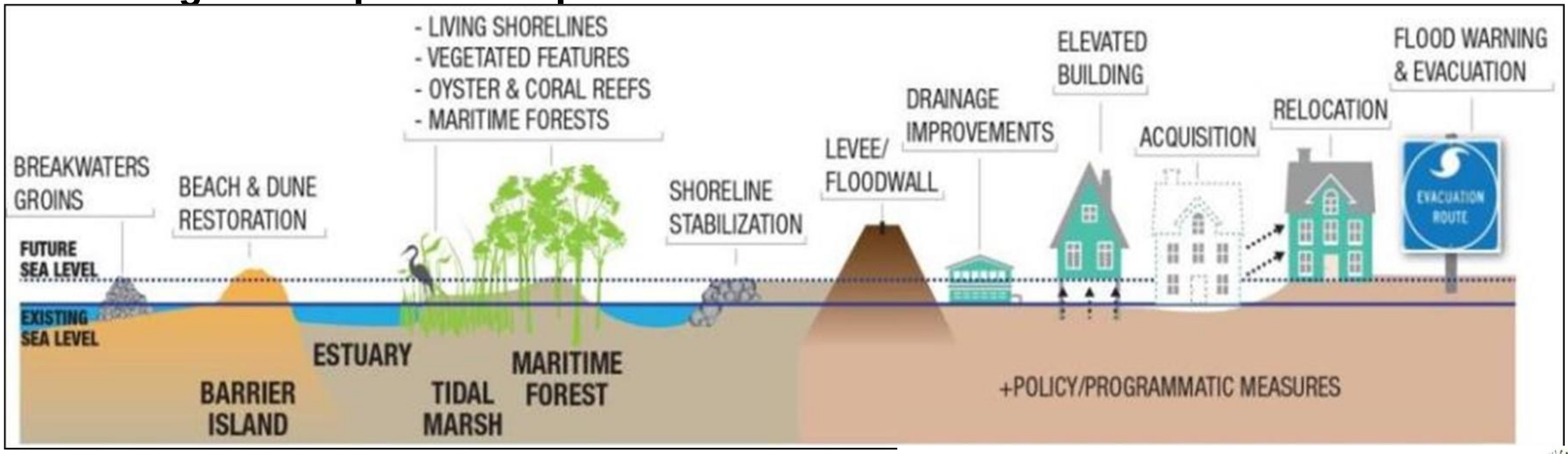
Alpha Plan- Ungated

Photograph 1. General view of plan 2 Alpha barrier from Galveston Island

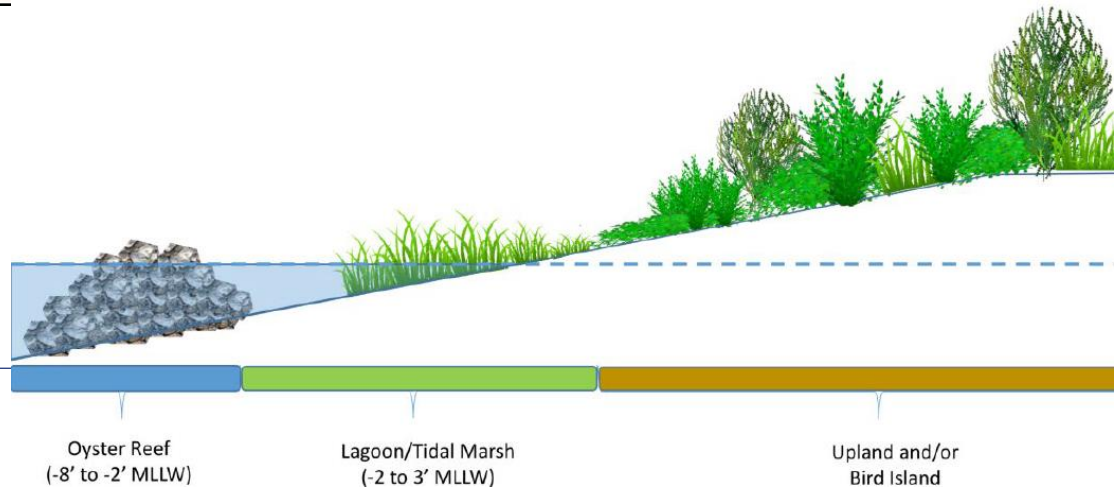
Gamma Plan- Gated



Design Principles- Multiple lines of Defense



- **Combination of structural, non-structural, and NNBF:**
- **Coastal storm damage risk reduction**
- **Coastal ecosystem restoration and management**
- **Supporting coastal sustainability and resilience - redundancy**
- **Uses an integrated systems approach**



Strategic Efforts – Massive Investment

Coastal Texas - $34B USD construction est.

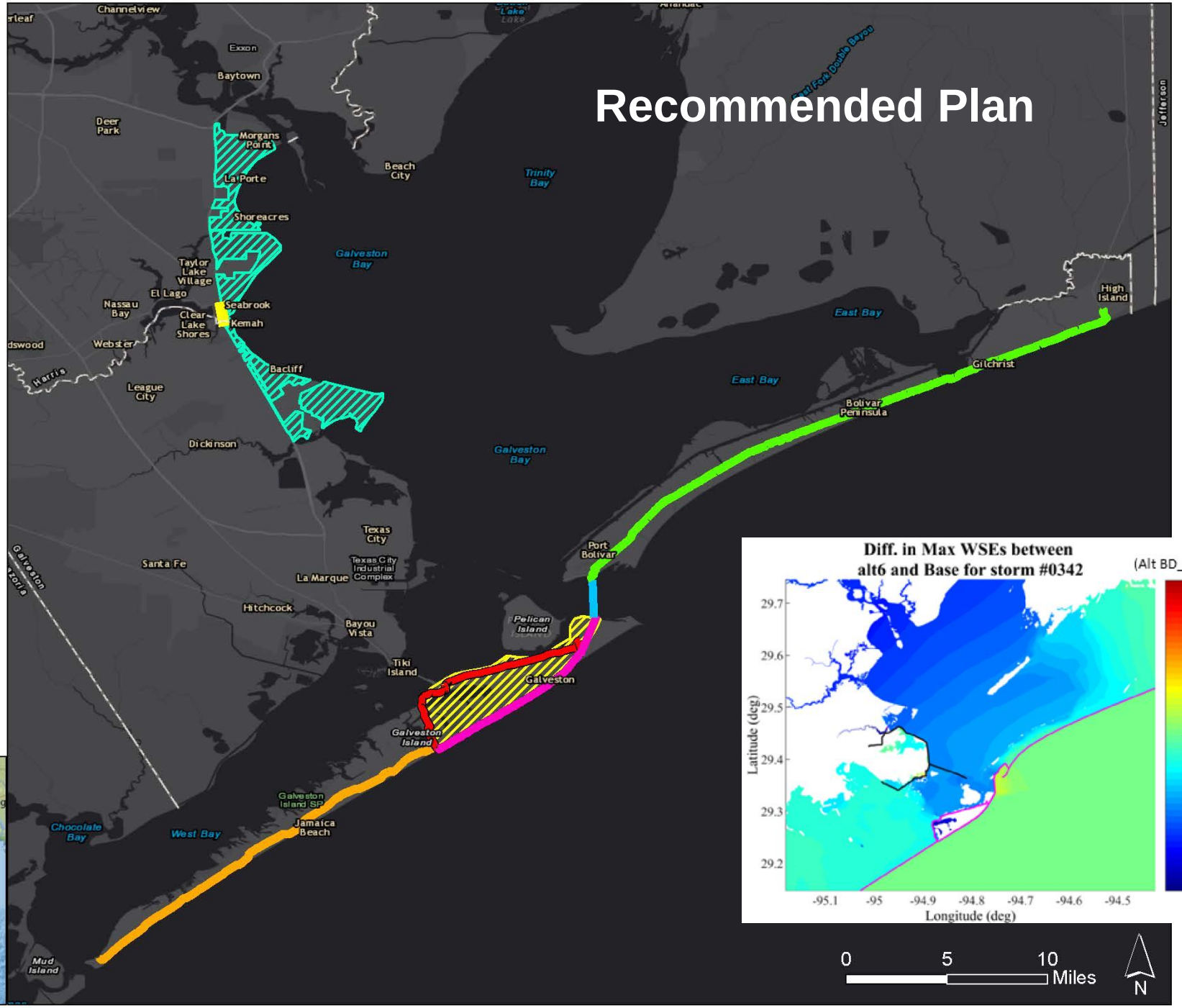
- +$21M USD, +5 yr study
- $5 to $10B – Galveston Entrance channel Gate
- 62.8 miles (101 km) of dune/beach restoration
  - $300M – Beach and dune 44 mi (71 km) Galveston and Bolivar – 50Mcy (38Mm3)
  - $10M - Follets Island - 800k cy (612k m3)
  - $60M – Beach and dune 10 mi (16 km) – lower coast
- 15.33 miles (25 km) of oyster reef creation
- 105 miles (169 km) of breakwaters
- 837.9 acres (339 ha) of island restoration
- 1,985 acres (803 ha) of initial estuarine marsh restoration
- 33,342 ac (13,500 ha) of future marsh nourishment
- 112,864 acres (45,700 ha) of Hydrologic Restoration

Coastal Texas Protection and Restoration Study

Alternative A

- High Island to Bolivar Peninsula
- Bolivar Roads and Houston Ship Channel Gates
- Galveston Seawall
- Galveston Ring Levee*
- Seawall to San Luis Pass
- Clear Lake Gates
- West Side of Galveston Bay Nonstructural Improvements
- Galveston Island Nonstructural Improvements*

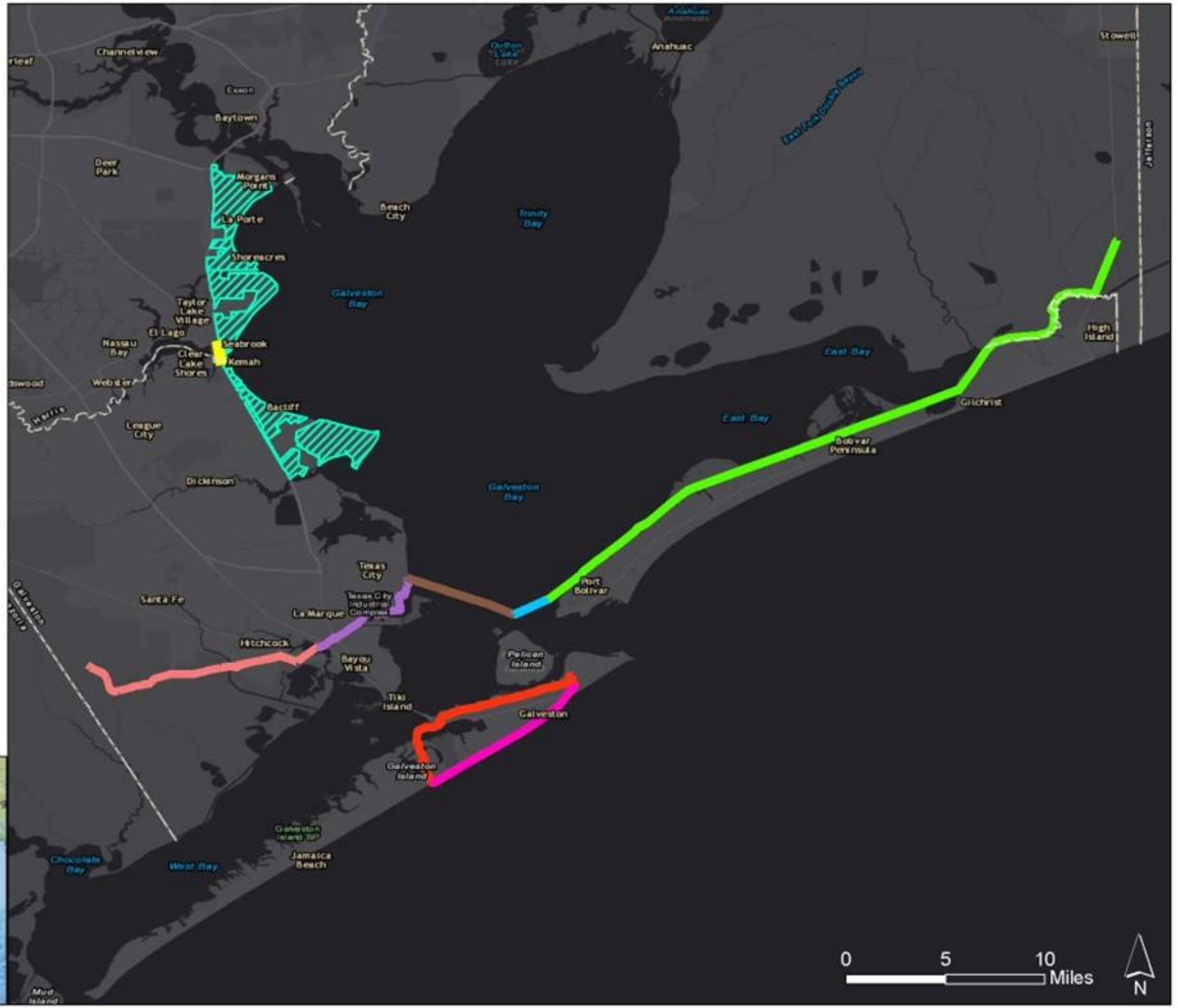
* Galveston Back Bay Risk Reduction will select one of these measures.



Coastal Texas Protection and Restoration Study

Alternative B

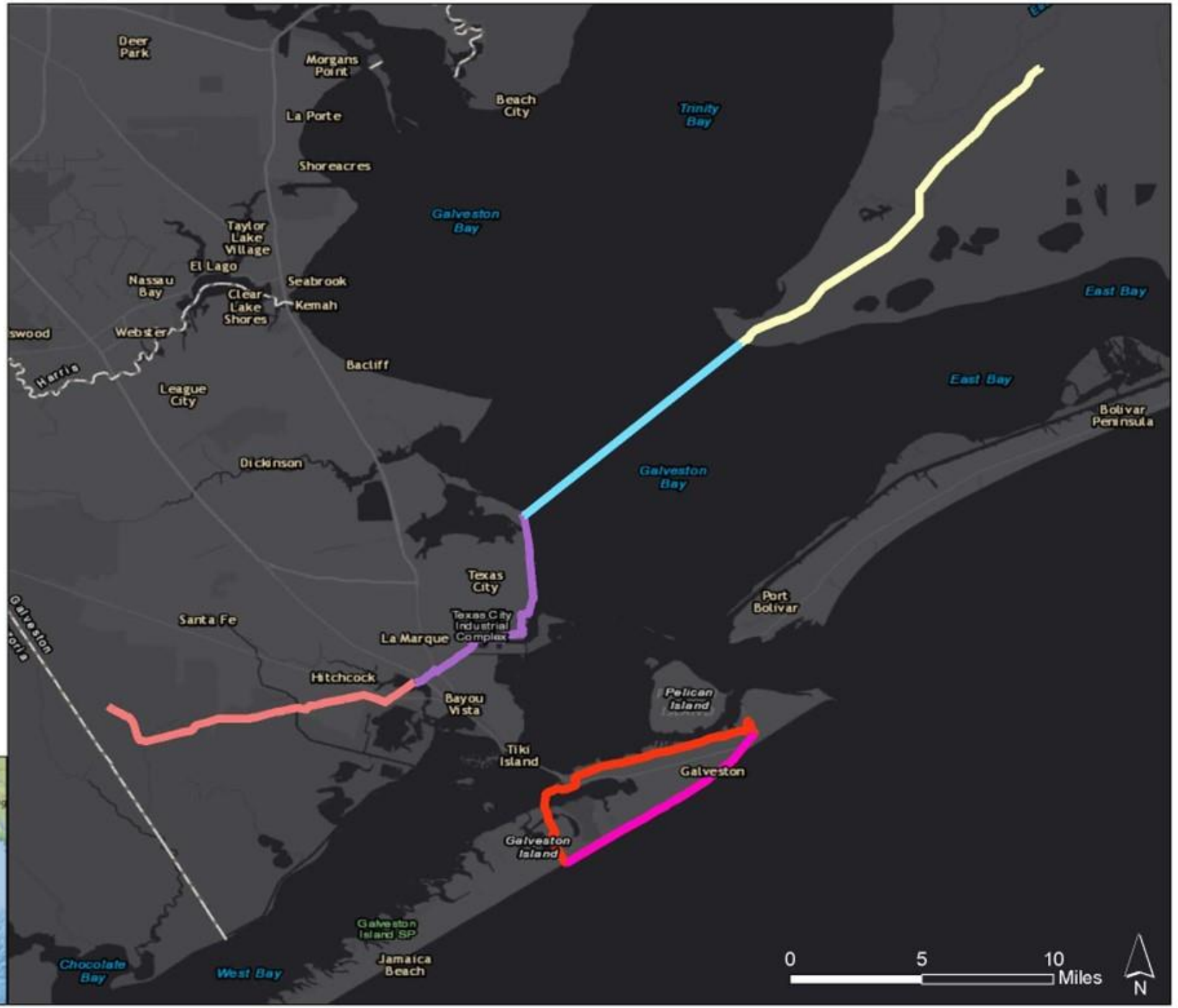
- High Island to Port Bolivar
- Bolivar Roads and Houston Ship Channel Gates
- Existing Texas City Dike
- Existing Texas City Hurricane Flood Protection Levee (HFPL)
- West Extension of Texas City HFPL
- Galveston Seawall
- Galveston Ring Levee
- Clear Lake Gates
- West Side of Galveston Bay Nonstructural Improvements



Coastal Texas Protection and Restoration Study

Alternative C

- Double Bayou to Smith Point
- MidBay Navigation and Environmental Gates
- Existing Texas City Hurricane Flood Protection Levee (HFPL)
- West Extension of Existing Texas City HFPL
- Galveston Seawall
- Galveston Ring Levee

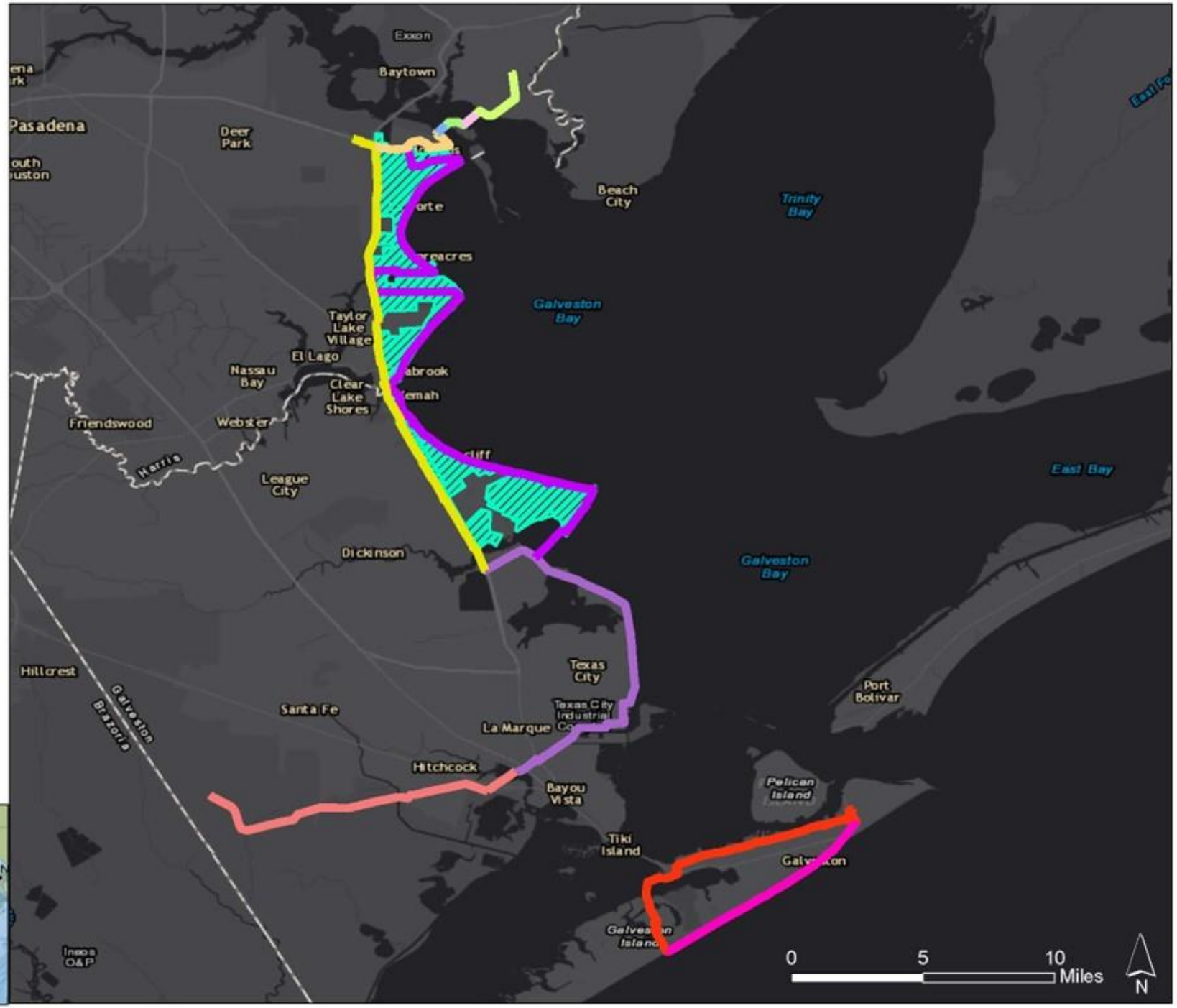


Coastal Texas Protection and Restoration Study

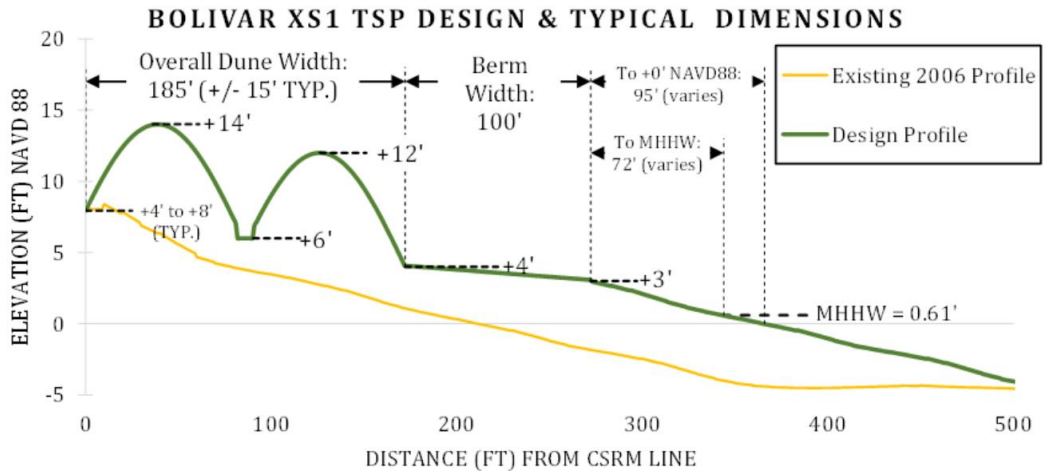
Alternative D

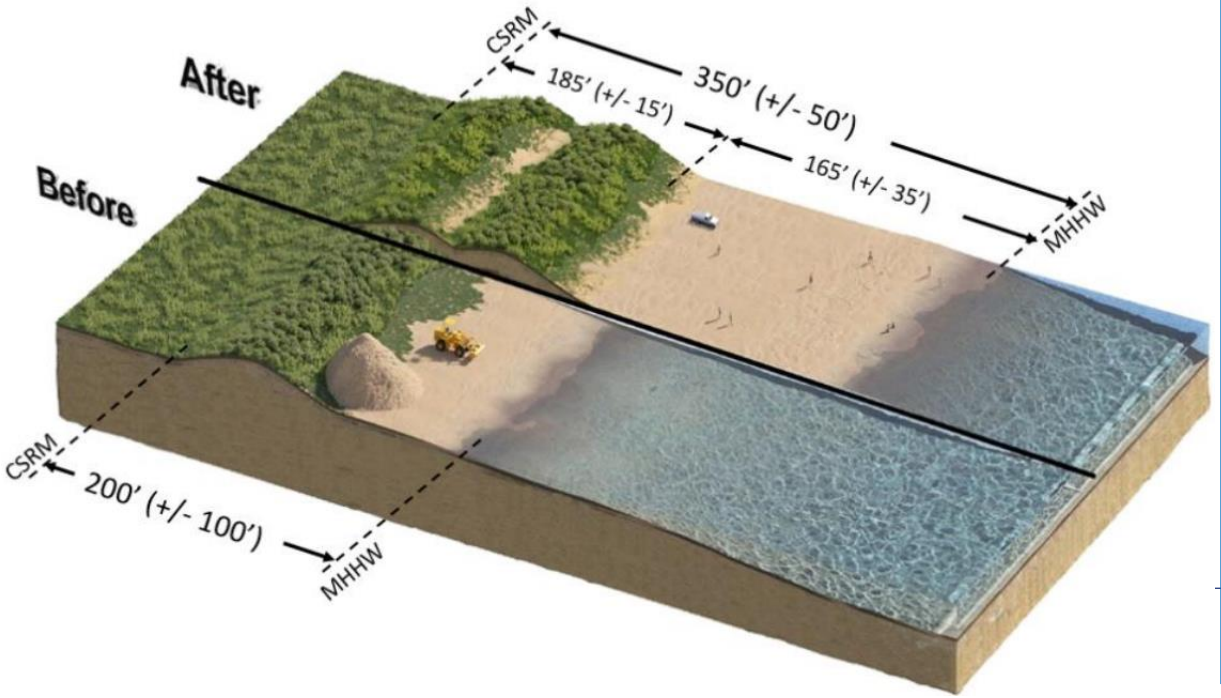
- Baytown to Tabbs Bay
- Tabbs Bay Environmental Gates
- Hog Island
- Houston Ship Channel Gates
- Spillman Island
- Highway 146 Alignment*
- Bay Perimeter Alignment *
- Existing Texas City Hurricane Flood Protection Levee (HFPL)
- Extension of Texas City HFPL
- Galveston Seawall
- Galveston Ring Levee
- West Side of Galveston Bay Nonstructural Improvements *

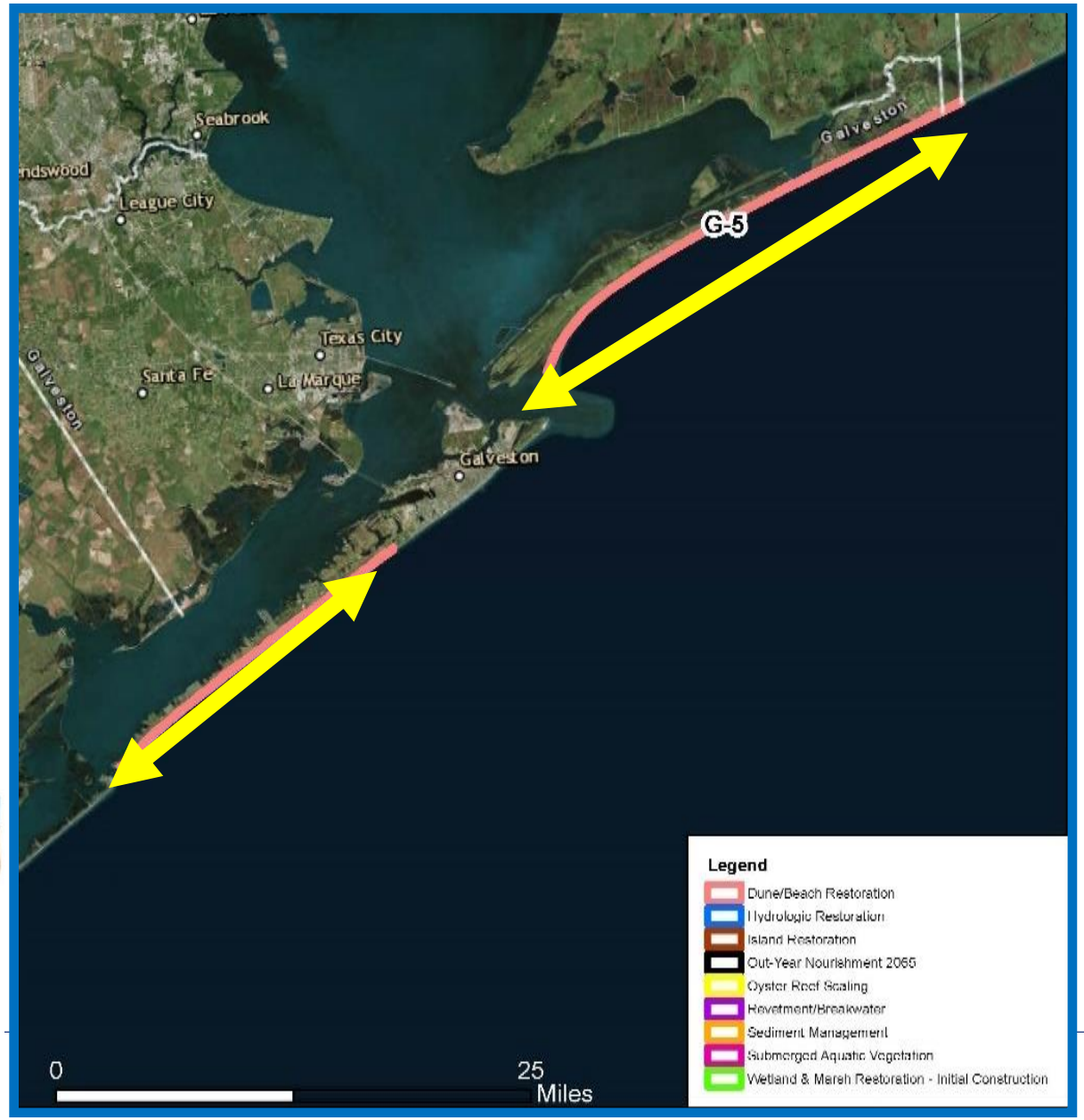
* Alternative D will select one of these measures.



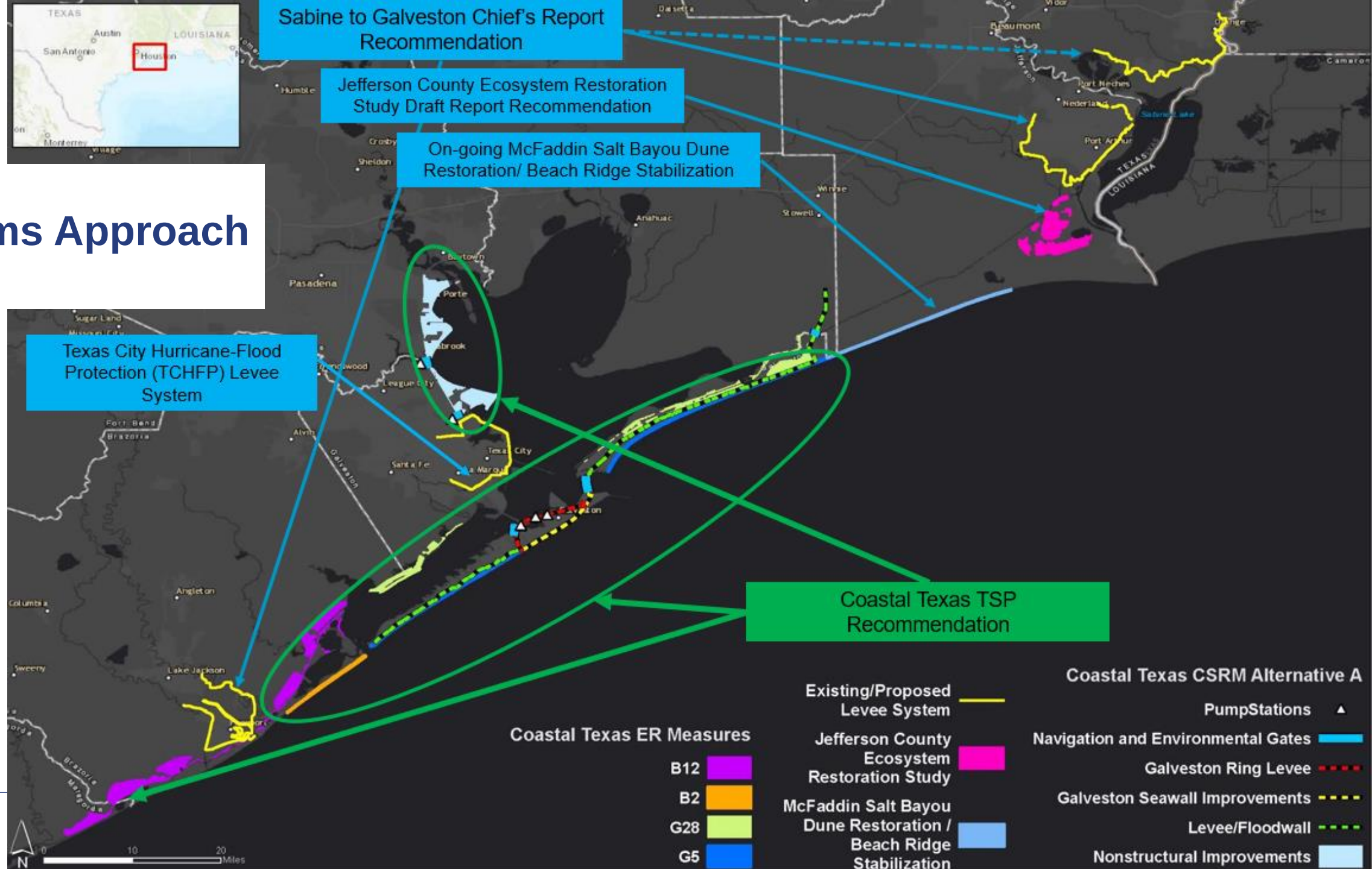
Recommended Plan Dual Dunes





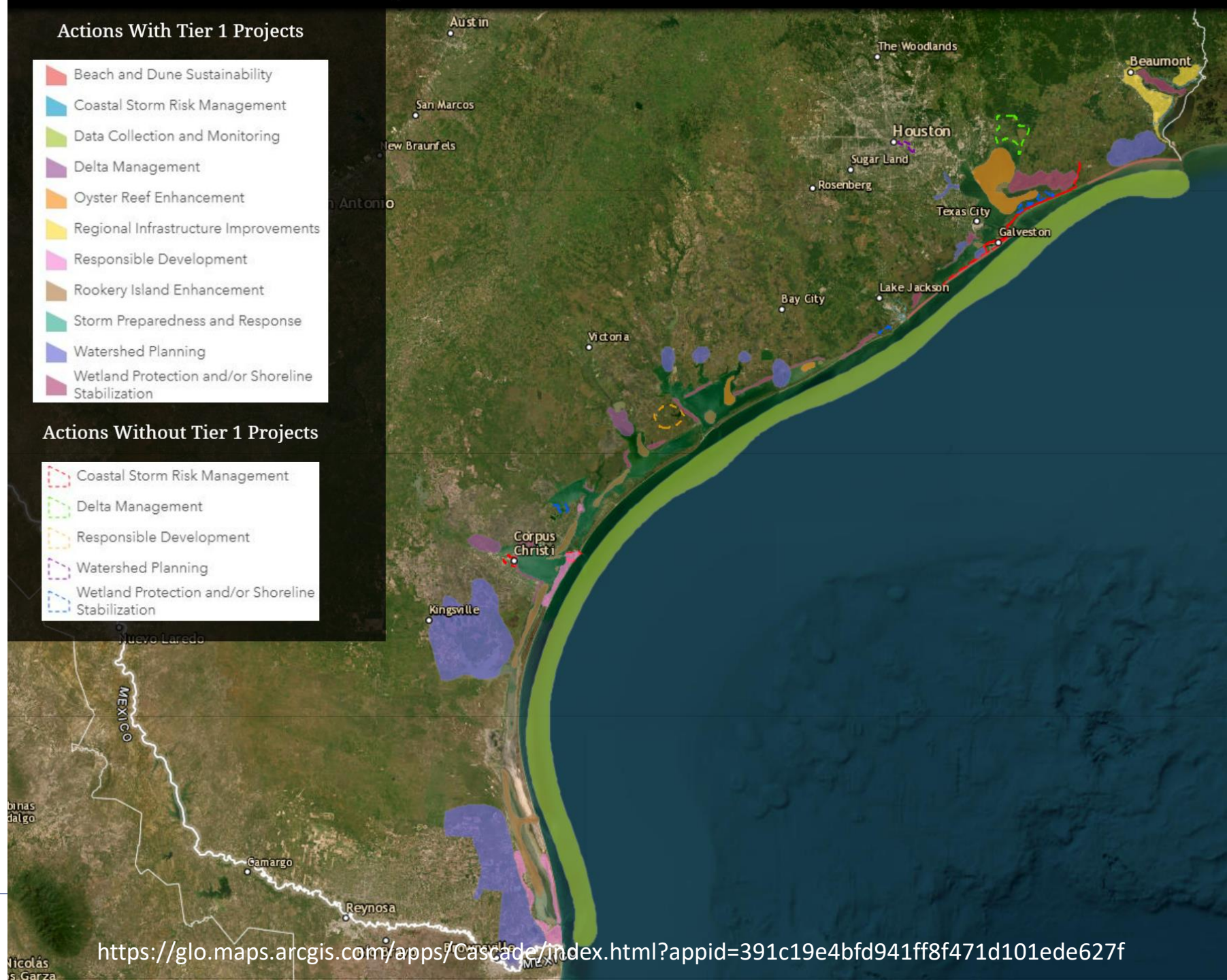


Systems Approach



TxGLO 2019 Texas Coastal Resiliency Master Plan

- The 2019 Texas Coastal Resiliency Master Plan recommends **123 Tier 1** projects for a cumulative Resiliency Plan cost of **$5.4B USD**.
- The Plan aims to reduce or alleviate coastal hazards such as:
  - Altered, Degraded or Lost Habitat
  - Gulf Beach Erosion and Dune Degradation
  - Bay Shoreline Erosion
  - Existing and Future Coastal Storm Surge Damage
  - Coastal Flood Damage
  - Impact on Water Quality and Quantity
  - Impact on Coastal Resources
  - Abandoned or Derelict Vessels, Structures and Debris

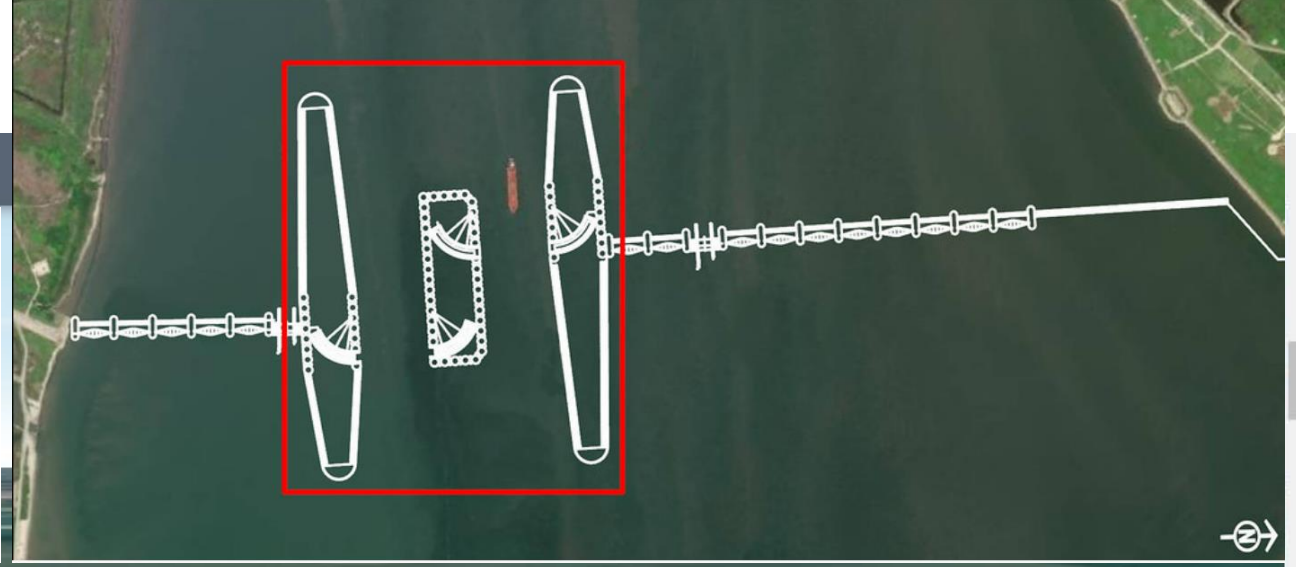


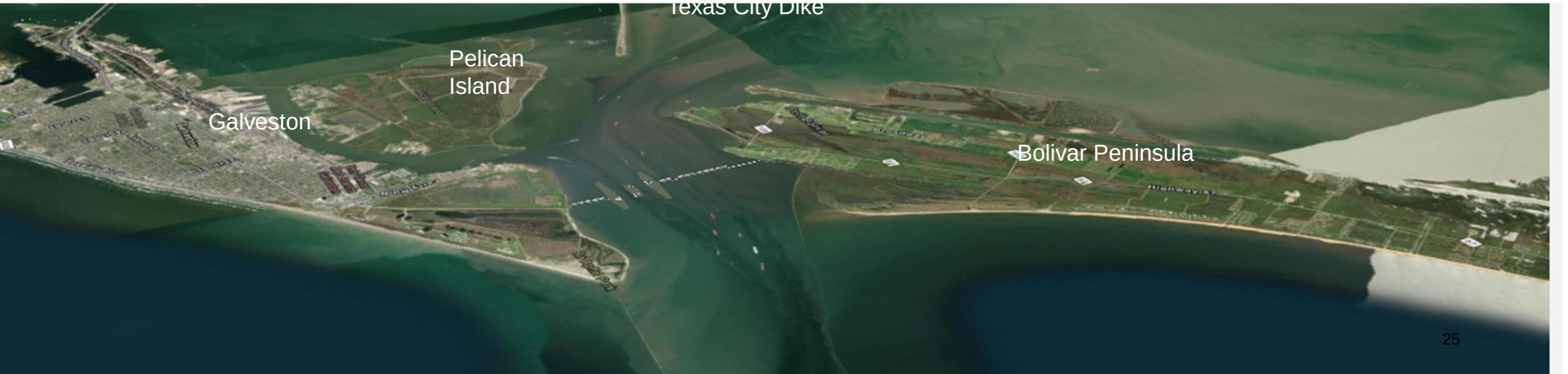
https://glo.maps.arcgis.com/apps/Cascade/index.html?appid=391c19e4bfd941ff8f471d101ede627f

Coastal Texas Recommended Plan

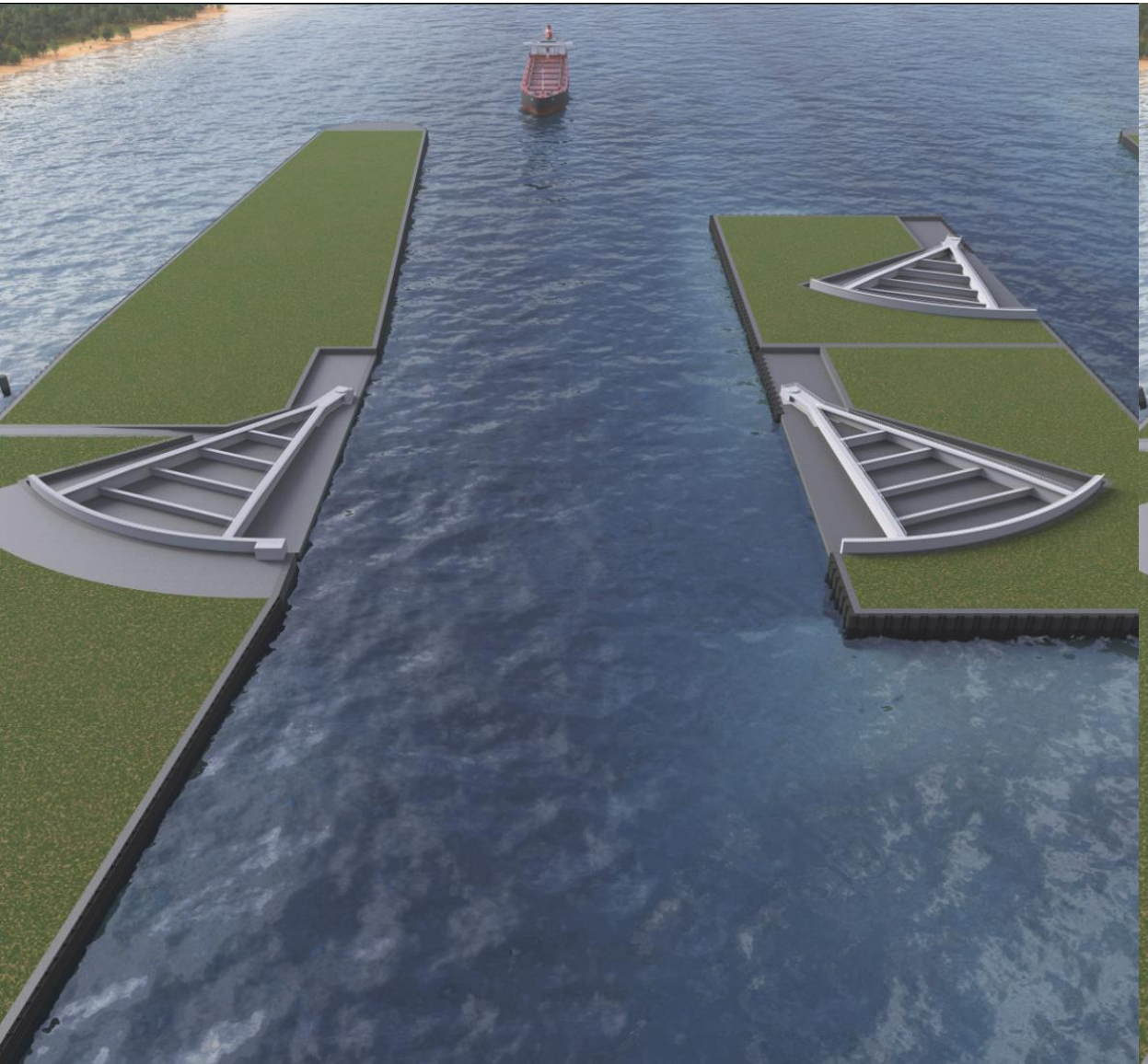
Bolivar Roads Navigation Gate System

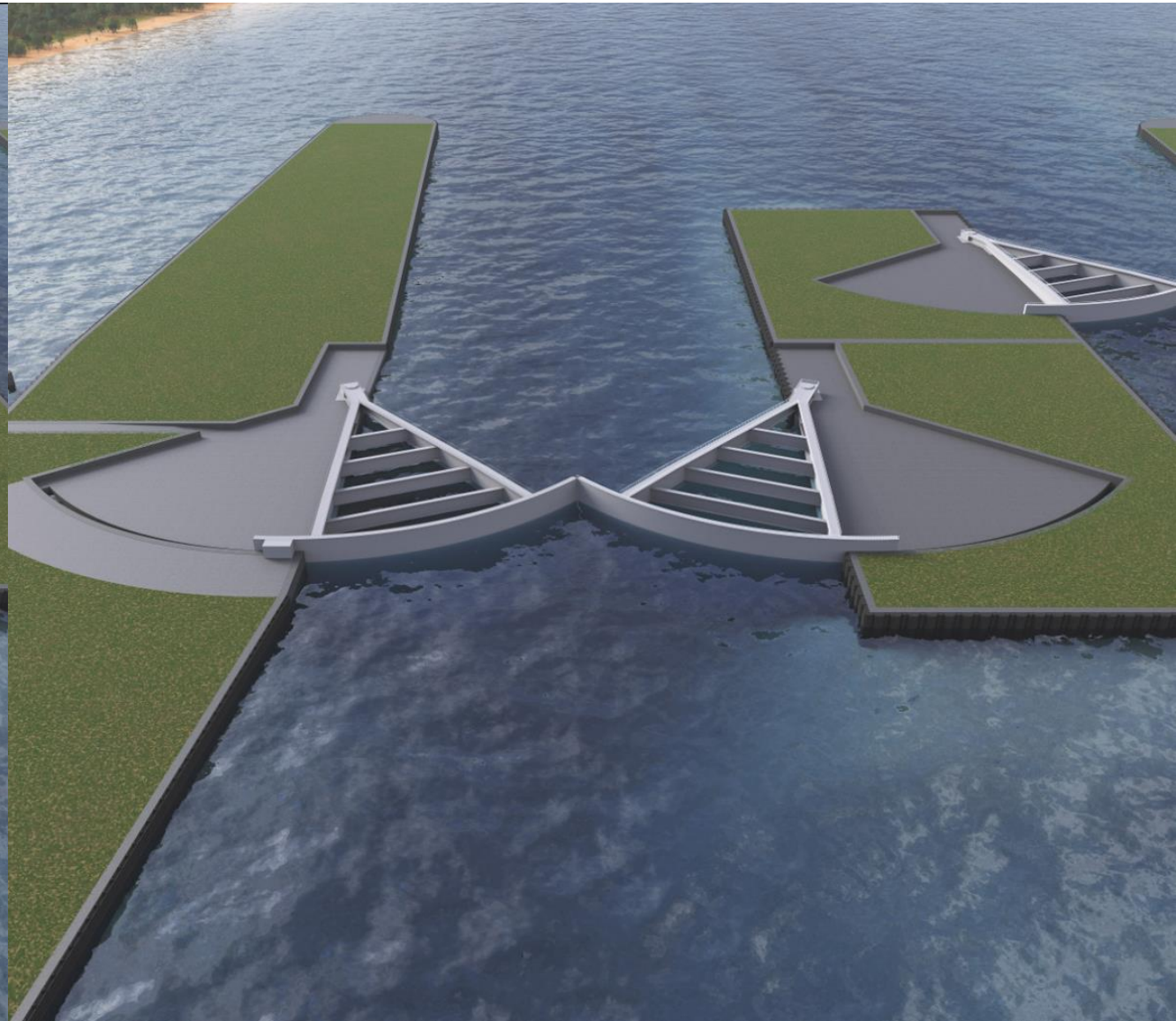
- **Dual Navigation floating Sector Gates 650 ft wide, 82 ft tall**
- **Dual Small Boat Sector Gates 125 ft wide, 62 ft tall**
- **15 Vertical Lift Gates 300 ft wide, spanning 4,500**
- **Box Culverts 16 ft wide and 16 ft tall, spanning 1500 ft**



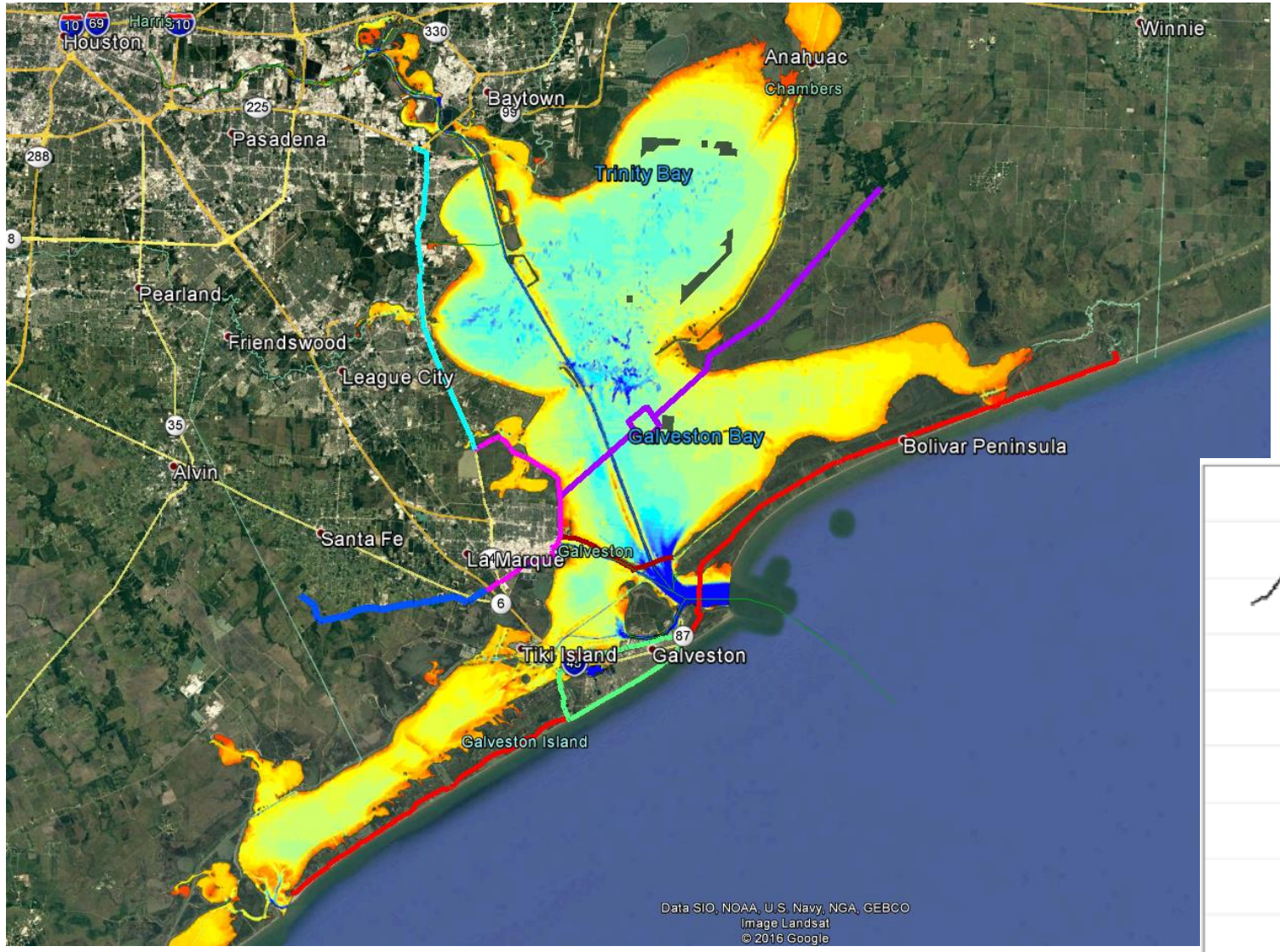


Coastal Texas Recommended Plan Bolivar Roads Navigation Gate System

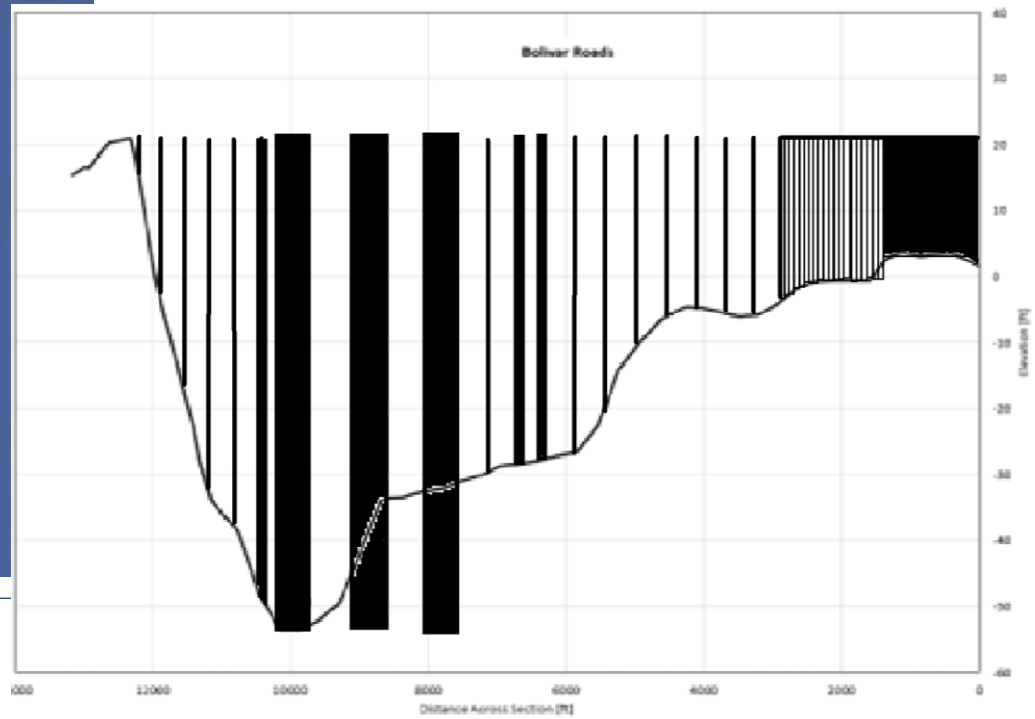




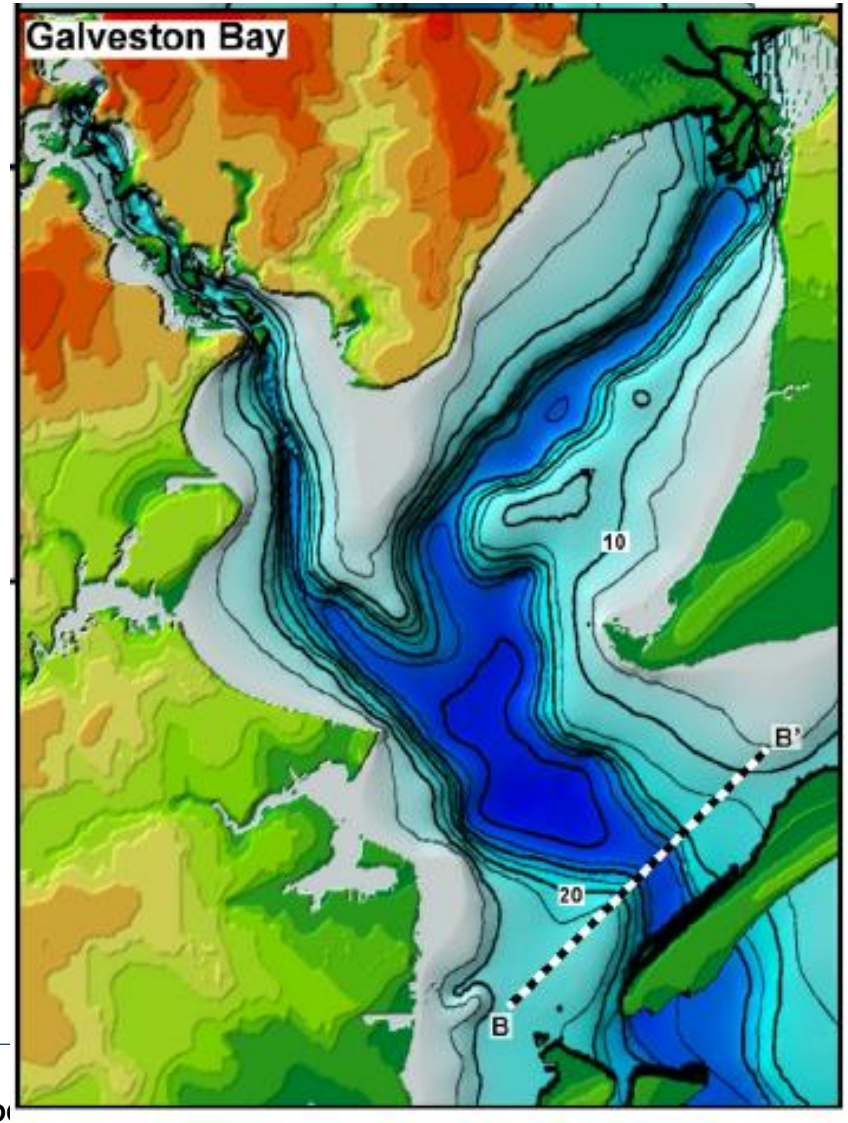
Coastal Texas Recommended Plan Bolivar Roads Gate



- **Cross section**
  - **8,000 ft (2,440 m) wide opening Bolivar Roads**
  - **Approximately 60 ft (18 m) depth**
  - **Navigation gate width 840 to 2,000 ft (256 m – 610 m)**
- **Environmental considerations**
  - **Reduction in tidal prism – 0% up to 40%?**
  - **No net change in exchange?**
  - **Navigation, Tidal exchange, Intertidal enviro gates**

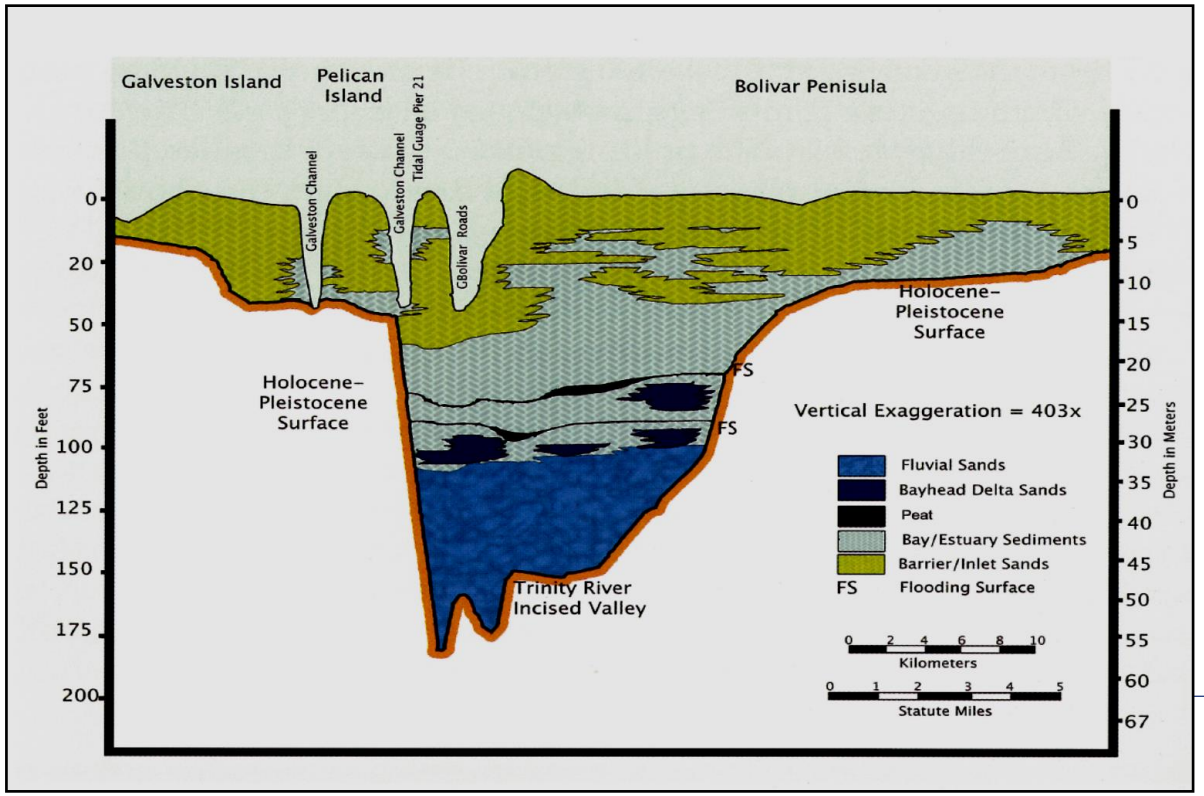


Coastal Texas Recommended Plan Bolivar Roads Gate



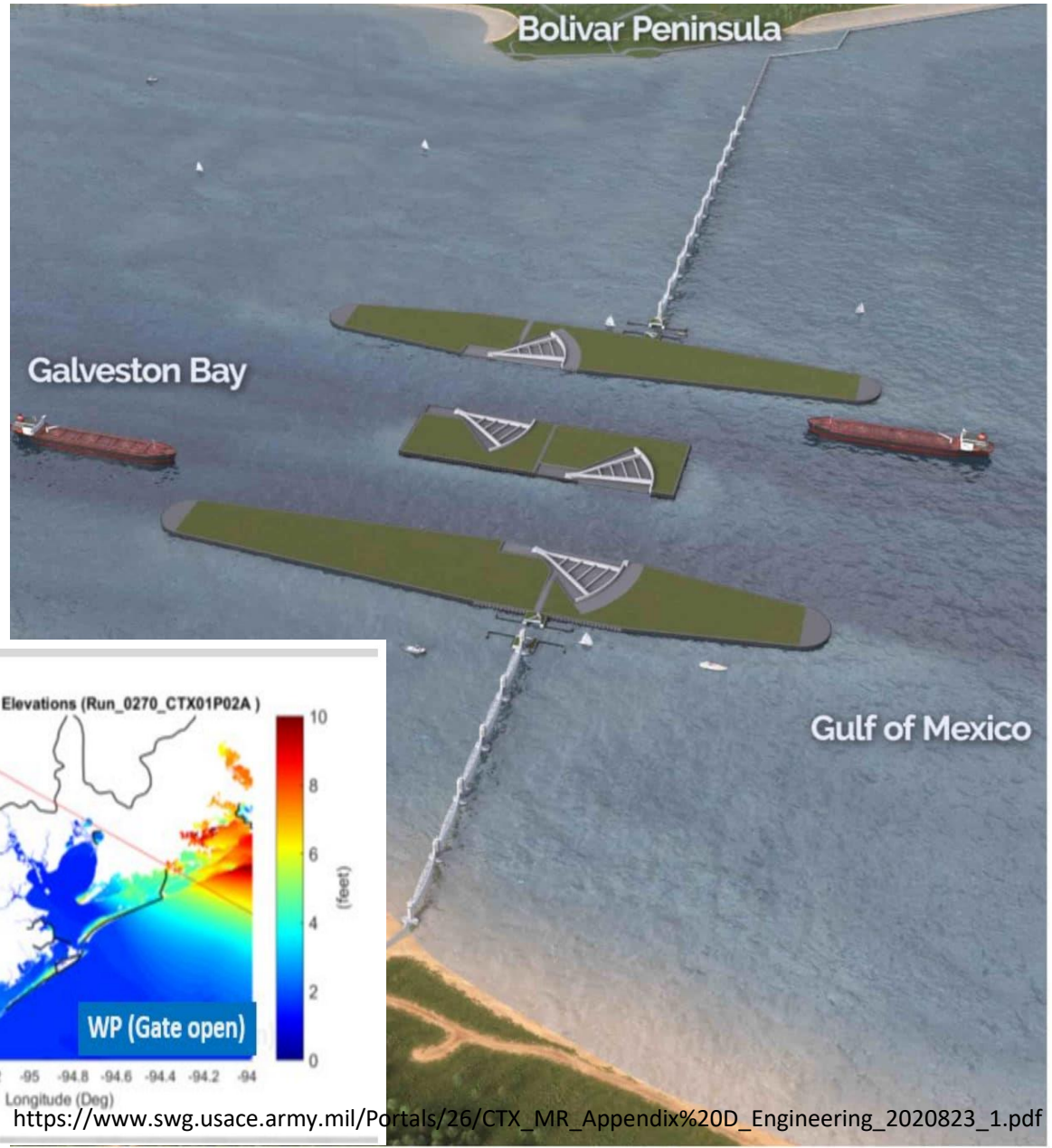
- **Paleo Geomorphology of the former Trinity River Valley 17,000 years ago**
- **Very poor subsoils at current channel location**

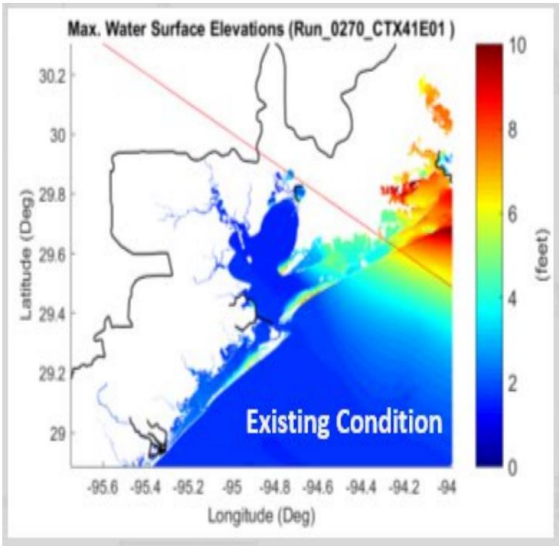
Anderson, et al. 2016.

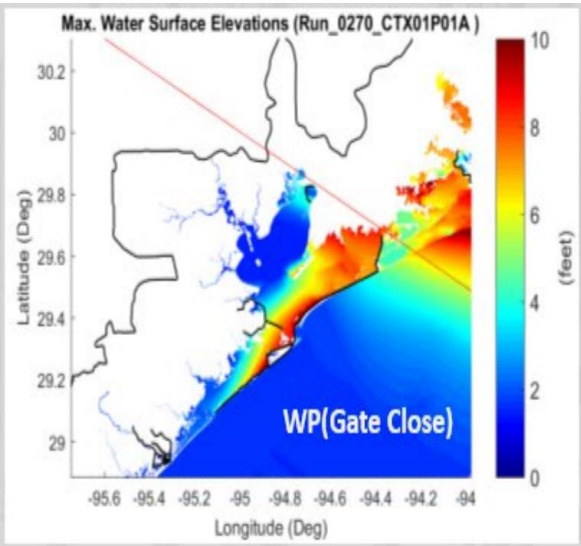


Criteria - Drives the Gate Design

1. Tidal Prism – reduction inducing mitigation for 10% requirements ~$1.1B to $0.9B (G-28 or B-2, respectively)
   - Islands - restrict flow
   - Vertical Structures - impacts flow
2. Geotechnical Conditions – paleochannel of the Trinity River beneath Bolivar Roads
   - Piles vs. spread foundation
   - Consolidate sediment (vibratory)
3. Navigation Gate Closure Criteria – must be able to be opened quickly during hurricane
   - Rapid opening prevent - reverse head
   - Sedimentation







https://www.swg.usace.army.mil/Portals/26/CTX_MR_Appendix%20D_Engineering_2020823_1.pdf


Ike Dike Coastal Spine Alignment
Ike Dike - Plan
Eastern Section
High Island
Middle Section
Western Section

DCCM

SSPEED – Galveston Bay Park Plan

The main component of Rice University's proposed Galveston Bay Park Plan is a 25-foot-tall levee along the Houston Ship Channel that would be constructed out of clay dredged from the shipping lane. Additional dredged material would be piled behind it to form parkland. Connie Hanzhang Jin

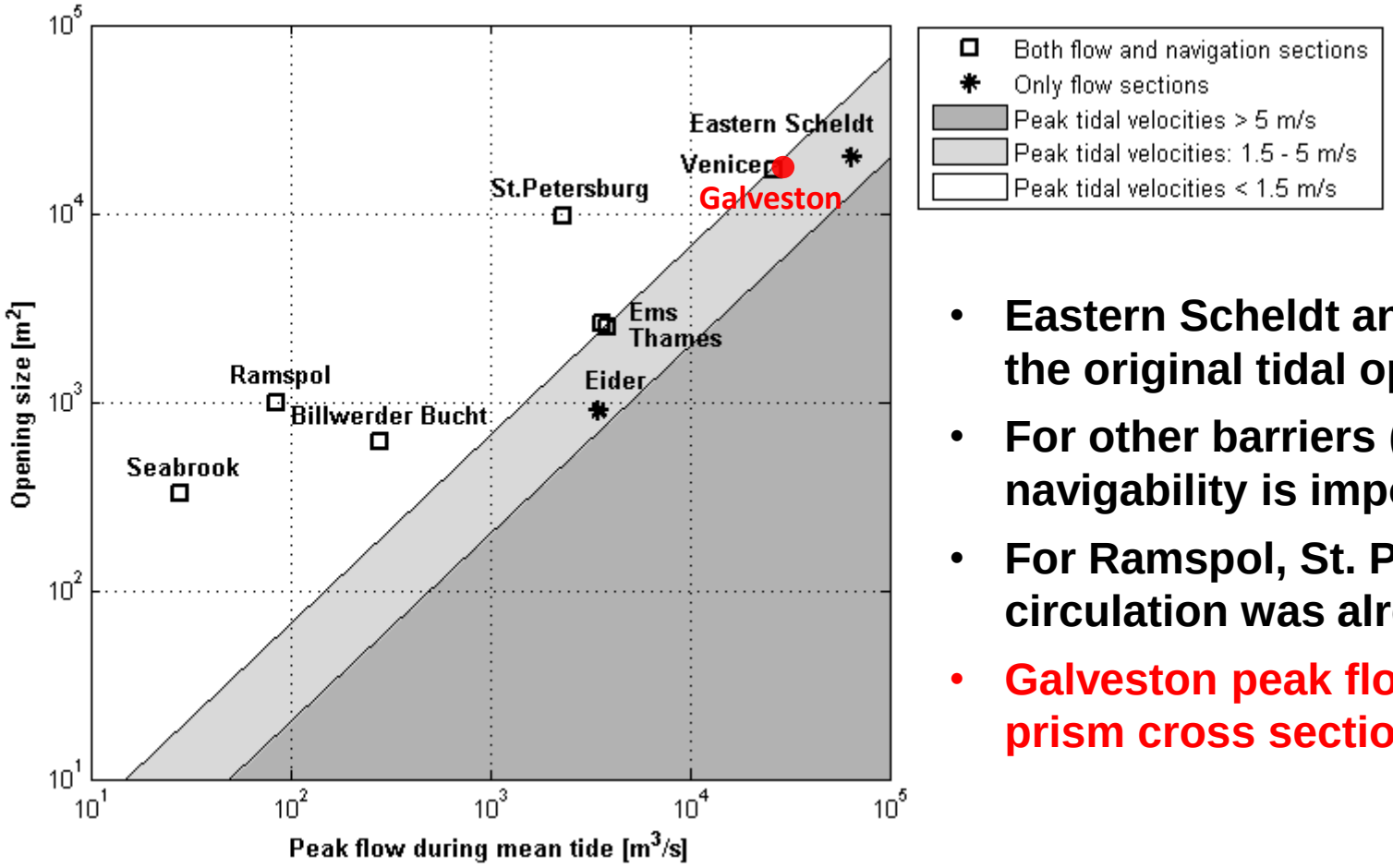
Multiple Lines of Defense – Strategy

- **Develop shared understanding among local stakeholders, agencies, and allies**
  - **TAMU, SSPEED, UH, PoH, TxDOT, TxGLO, USACE, Galveston Bay Foundation, etc.**
  - **Galveston Bay – Resiliency Master Plan development**

- **Science and Technology**
  - **Surge and circulation modeling - with and without combo of features**
  - **CFD modeling of gates – w/o and selected plan**
  - **Bridge gate combo design concept**
  - **Navigation gate design optimization**

- **Align priorities - multiple lines of defense – to increase impact**
  - **Strategic communication**
  - **Political education and alliance building**
  - **Perform detailed resiliency studies**
  - **Secure design and construction funding – by component**

Our Similarities - Navigation vs. Environmental flows



- **Eastern Scheldt and Eider barrier have reduced the original tidal opening**
- **For other barriers (e.g. Maeslant, Venice, Ems) navigability is important**
- **For Ramspol, St. Petersburg, the water circulation was already low before construction.**
- **Galveston peak flow of approx. 2 m/s and tidal prism cross sectional area of 23,000 m2**

Slide from: Prof. dr. ir. S.N. (Bas) Jonkman - TU Delft Professor of Hydraulic Engineering

QUESTIONS?

cmaglio@dccm.com