

Coastal Resiliency

Port of Houston

WRITTEN BY
**Kayed I. Lakhia, AIA,
NCARB, LEED AP, CFM**
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**INSTITUTE FOR
HOMELAND SECURITY**
SAM HOUSTON STATE UNIVERSITY



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Kayed I. Lakhia, AIA, NCARB, LEED AP, CFM

Table of Contents

ABSTRACT	1
INTRODUCTION	2
PROBLEM STATEMENT	2
The Port of Houston in a Historical and National Context	2
What Disruption to the Port of Houston Means to Texas & the US	6
The Proposed Galveston Barrier System	9
What does the Dutch example teach us?	13
Opponents of the Galveston Barrier System	15
Ike Dike Alternatives	15
Secure by Design: What can other Gulf Port authorities learn from Houston?	16
CONCLUSION	20
ILLUSTRATION CREDITS	22
REFERENCES	23
AUTHOR BIOGRAPHY	27

ABSTRACT

The Port of Houston is one of the world's largest ports and the busiest in the US based on tonnage. The port includes major terminals along the Houston Ship Channel that link Houston's national transportation hubs to the Gulf of Mexico. The Port of Houston is the 5th largest container port in the US, and the shipping channel is the No. 1 waterway in the US by total tonnage. The petrochemical complex associated with the port is the largest in the world, with many petroleum refineries built in Galveston Bay to partially protect them from hurricanes in the Gulf of Mexico.

Any single hurricane or storm surge striking this 52-mile-long complex could devastate not just the Houston area and Texas, but the national economy. This impact was clear during Hurricane Ike in 2008, which caused over \$30B in economic damage. The storm shut down facilities that supply 27percent of US gasoline and resulted in half a million gallons of crude oil spilling into the Gulf and surrounding wetlands. Because Houston is a major transportation and logistics hub, supply chains were disrupted, devastating manufacturing, agriculture, food supply, trucking, and freight nationally.

To prevent such future disruptions and losses, a proposal was made shortly after Hurricane Ike to build a massive coastal protection system known as the Galveston Bay Barrier System. Informally called the "Ike Dike," it would be designed to withstand a 10,000-year storm. If built, the system, at a projected cost of \$35-\$57B, would be the single largest civil infrastructure project in the US and take over 20 years to build. The centerpiece of the project is a 2-mile operable gate between the Bolivar Peninsula and Galveston Island that, when swung closed during a hurricane, would protect Galveston Bay and the Port of Houston from storm surge.

While massive protection barriers are not uncommon in parts of the world facing similar challenges, notably the Delta Works in the Netherlands, the Ike-Dike faces notable challenges, among them funding shortfalls and environmental concerns. This paper provides an overview of the current state of the project, alternatives that have been proposed, and argues why long-term coastal resilience of the Port of Houston and Galveston Bay is vital to Texas and US interests.

Keywords: Coastal Resiliency, Port Infrastructure, Oil & Gas Infrastructure, Transportation and Logistics, Ensuring Continuous Operations, Mitigating Risks in Lifeline Sector

INTRODUCTION

The Port of Houston governs the 52-mile-long Houston Ship Channel and was established in 1914 to serve the region and the nation. The Port of Houston also owns, manages, and operates eight public terminals that handle three-quarters of all U.S. Gulf Coast container traffic.¹ The port is the 5th largest container port in the US, and the shipping channel is the No. 1 waterway in the US by total tonnage. In addition, the channel serves more than 200 private terminals in industries, from petrochemicals and heavy machinery to consumer goods and energy. The port's economic influence extends far beyond the port gates, supporting nearly 1.5 million jobs in Texas, 3.37 million jobs nationwide, economic activity totaling \$439 billion in Texas and \$906 billion in economic impact across the nation.²

PROBLEM STATEMENT

Shocks to the Port of Houston send ripples through Texas and across the country. Along Galveston Bay, some of the nation's most important oil and gas refineries sit directly in the path of Gulf hurricanes and storm surge, placing America's fuel supply at risk. Preserving the Bay, the Houston Ship Channel, and the broader Texas Gulf Coast through a combination of resilient grey infrastructure and restored natural systems is essential—not just for the region, but for the nation's economic and energy security.

The Port of Houston in a Historical and National Context

The Port of Houston began in 1837 at Allen's Landing on Buffalo Bayou, where the city was founded. In its early years, barges loaded with cargo navigated the bayou's shallow waters, traveling from the foot of Main Street along its winding route to the Gulf of Mexico. Once they reached Galveston Island, the freight was transferred to oceangoing vessels bound for markets across the nation and abroad. As Houston and the surrounding region expanded, this reliance on a shallow-draft waterway became a growing obstacle - especially as cargo volumes grew and the absence of a deep-water port limited the city's ability to compete with other ports in the country. By the late 19th century, Houston's civic and business leaders were regularly pressing Congress for a deep-water ship channel.

¹ "Port Houston | Gulf Coast Efficiency Driving International Trade," Port Houston, accessed July 28, 2026, <https://porthouston.com/>.

² "Port Statistics," *Port Houston*, n.d., accessed August 5, 2026, <https://porthouston.com/about/our-port/statistics/>.

The Port of Houston was formally established in 1842.³ The Houston Ship Channel was dredged in 1914, creating a 25-ft-deep and 150-ft-wide passageway allowing larger ships to navigate the waterway.⁴ The channel has been expanded several times since. In 2025, the Houston ship channel was ranked No. 1 in the US, handling approximately 12 percent of the nation's total waterborne tonnage. The Port of Houston is the 5th-ranked US container port; it is the largest Texas port, with a 97 percent market share of Texas container traffic and handles 75 percent of Gulf Coast container traffic.

The primary advantage that the Port of Houston presented over other ports in the nation was its unique landlocked, inland deep-water location. While most major American ports were built directly on exposed coastlines, Houston engineered a 52-mile inland waterway—the Houston Ship Channel—to bring ocean-going vessels directly to the Texas interior.⁵ This configuration provided two distinct advantages:

1. It offered some shelter from Hurricanes. Because the main terminals sit up to 50 miles inland along Buffalo Bayou, the Port of Houston is naturally shielded by Galveston Bay from the destructive winds and storm surges of the Gulf of Mexico, a lesson learnt from the 1900 Galveston Hurricane, which wiped out Texas' leading port. A protected interior port was a far safer alternative for international shipping and infrastructure investment.
2. The Port offered proximity to the inland supply chain. Before the ship channel opened in 1914, cargo arriving at coastal ports had to be unloaded, transferred to barges or trains, and shipped inland. Houston's location allowed massive ocean vessels to bypass the coast entirely and unload directly at a major rail and road hub. Being situated further inland placed the port significantly closer to the agricultural heartland of Texas, the Midwest, and Western consumer markets. This drastically reduced the land-based transit times and distribution costs for moving heavy goods like cotton, lumber, and grain.

³ Texas State Historical Association, "The History and Significance of the Houston Ship Channel," Texas State Historical Association, accessed August 5, 2026, <https://www.tshaonline.org/handbook/entries/houston-ship-channel>.

⁴ "Ship Channel History - Port Houston: Houston Ship Channel Expansion," accessed August 5, 2026, <https://www.expandthehoustonshipchannel.com/ship-channel-history/>.

⁵ Debbie Harwell, *Vol. 12 No. 1 Houston Ship Channel Table of Contents | Houston History Magazine*, n.d., accessed August 5, 2026, <https://houstonhistorymagazine.org/2014/11/vol-12-no-2-houston-ship-channel-table-of-contents/>.

In most places, crude oil had to be piped long distances from the oil fields to a coast or unloaded from a ship and piped inland to a refinery. Houston's inland position allowed oil companies to pipe crude from the nearby Texas fields directly to the channel-side refineries. Once refined, the finished products were loaded directly onto tankers at the refinery's private docks, bypassing local transportation networks. The connection between Galveston Bay and Houston Ship Channel allowed massive tankers to move raw and refined products seamlessly across the globe.

Oil refineries, storage tanks, and chemical plants are incredibly expensive to build and highly vulnerable to weather. Because the channel sits inland, oil companies could invest billions of dollars into complex steel infrastructure with a drastically lower risk of it being destroyed by a hurricane and storm surge. The physical space along the channel allowed the region to pioneer the petrochemical industry, converting oil byproducts into synthetic rubber, plastics, and explosives. Because so many chemical plants are set up next to each other along the channel, one plant's waste product became the neighboring plant's raw material, creating a highly efficient, closed-loop industrial ecosystem.

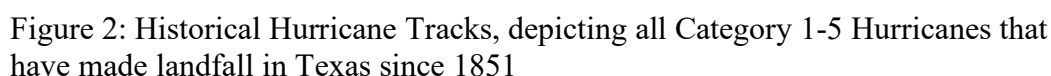
It is the petrochemical industrial complex that is most vulnerable to a hurricane. A study conducted by the Bulletin of Atomic Scientists and MIT found that more than 4,876 sites that handle toxic chemicals sit in storm- and flood-prone areas of Texas and Louisiana, of which the Houston area alone has about 900 facilities at risk of floods from storms.⁷ According to the report, thousands could be killed by the initial blast of wind and water, but the true catastrophe would unfold as the storm surge funnels into the Houston Ship Channel. The surge would tear ships from their moorings, rupture oil pipelines, and batter thousands of storage tanks filled with everything from paint thinners to jet fuel. A toxic mix of oil, chemicals, and debris would then pour into urban bayous, sweep through neighborhoods, and ultimately wash back into the bay.

Jim Blackburn, a professor at Rice University associated with its Severe Storm Prediction, Education and Evacuation from Disasters (SSPEED) Center, worries that the Ike Dike may be too little, too late, especially as the project may take two decades or more to complete. "It needs to be built for the bigger storms to come. It will be way outdated once it's constructed."⁸

⁷ Thomas Gaulkin, "Gathering Storm: The Industrial Infrastructure Catastrophe Looming over America's Gulf Coast," *Bulletin of the Atomic Scientists*, December 17, 2021, <https://thebulletin.org/2021/12/gathering-storm-the-industrial-infrastructure-catastrophe-looming-over-americas-gulf-coast/>.

⁸ Gaulkin, "Gathering Storm."

Since 1851, when NOAA started tracking hurricanes in the US, Texas has been affected by 66 hurricanes.⁹



9 “Historical Hurricane Tracks,” accessed August 6, 2026,

¹¹ “Texas Hurricane History: The Largest Storms to Hit Texas since 1851,” Texas Weather, *BKV Energy*, May 10,

The most devastating hurricane to strike the area was the 1900 Galveston Hurricane, and it stands as the deadliest natural disaster in US history. While the exact number of fatalities may never be known, the storm claimed more than 8,000 lives on Galveston Island and several thousand more on the mainland. In Galveston alone, it destroyed 2,636 homes and damaged thousands more. Property losses were estimated at \$28M – \$30M, a staggering toll for the era.¹² As part of the recovery, city leaders decided to raise 500 blocks of the city by between 8 and 17 ft, elevate 2,000 structures, and build a concrete seawall to protect the island.¹³

However, even before the 1900 Hurricane, the Port of Galveston had significant issues. Galveston's port had long struggled with a persistent sandbar issue first noted around 1843. The 1900 Hurricane served as an impetus to build up the Port of Houston as a safer alternative to Galveston. Fearing future coastal disruptions, major oil companies and private investors intentionally moved their shipping operations and terminals to Houston's inland port.

Although the Port of Houston was naturally protected by being inland and buffered by Galveston Bay, the impact of Hurricane Ike in 2008 was readily visible. Ike resulted in over \$30B in economic damage. Though it weakened from Category 4 to Category 2 before striking the Galveston area, it still became one of the state's most devastating storms. Forecasts warned that some coastal communities could face storm surges reaching 20 ft, underscoring how destructive Ike was despite its lower category at landfall.

Hurricane Ike heavily disrupted the U.S. oil and gas industry, causing widespread infrastructure shutdowns, physical destruction in the Gulf of Mexico, and a significant spike in national fuel prices. Coming just two weeks after Hurricane Gustav, Ike targeted the heart of the Texas and Louisiana energy corridors, crippling offshore production and onshore refining. Ike shut down facilities that supply 27 percent of US gasoline and resulted in half a million gallons of crude oil spilling into the Gulf and surrounding wetlands.

More than half of Texas' refineries were shut down by Ike, according to the U.S. Department of Energy.¹⁴ Operators shut down roughly 97 percent of crude oil production and 93 percent of natural gas output in the Gulf of Mexico as workers evacuated.¹⁵ Hurricanes Gustav and Ike

2024, <https://bkvenenergy.com/blog/texas-hurricane-history/>.

¹² "1900 Storm," Galveston & Texas History Center, accessed August 6, 2026, <https://www.galvestonhistorycenter.org/research/1900-storm>.

¹³ Danielle Lopez, "The Raising of Galveston After the 1900 Hurricane," *Texas Highways*, May 27, 2021, <https://texashighways.com/culture/history/the-raising-galveston-after-1900-hurricane/>.

¹⁴ Comparing the Impacts of the 2005 and 2008 Hurricanes on U.S. Energy Infrastructure, U.S. Department of Energy, Feb 2009

<https://www.energy.gov/sites/prod/files/Comparingpercent20thepercent20Energypercent20Infrastructurepercent20Impactspercent20ofpercent20thepercent202005percent20andpercent202008percent20Hurricanespercent20percent20Februarypercent202009.pdf>

¹⁵ "Hurricane Ike News and Projections," accessed August 7, 2026,

destroyed 60 offshore production platforms and multiple drilling rigs.¹⁶ The severe underwater movement and storm surge damaged numerous transit pipelines, delaying the resumption of fuel transfers even after platforms reopened.¹⁷ At least 14 major oil refineries along the Texas and Louisiana Coasts completely ceased operations. The shutdowns instantly knocked out over 17 percent of total U.S. refining capacity, forcing nearly 150 oil tankers and cargo ships to stall offshore.¹⁸

Because Houston is a major transportation and logistics hub, supply chains were disrupted, devastating manufacturing, agriculture, food supply, trucking, and freight nationally. Millions of people were without power for more than a week. Because electricity was not fully restored, many gas stations couldn't sell gas even if they had it. The stations that did have power would sell out quickly after deliveries, which were reduced to once a week until electricity and normal supply lines were restored.

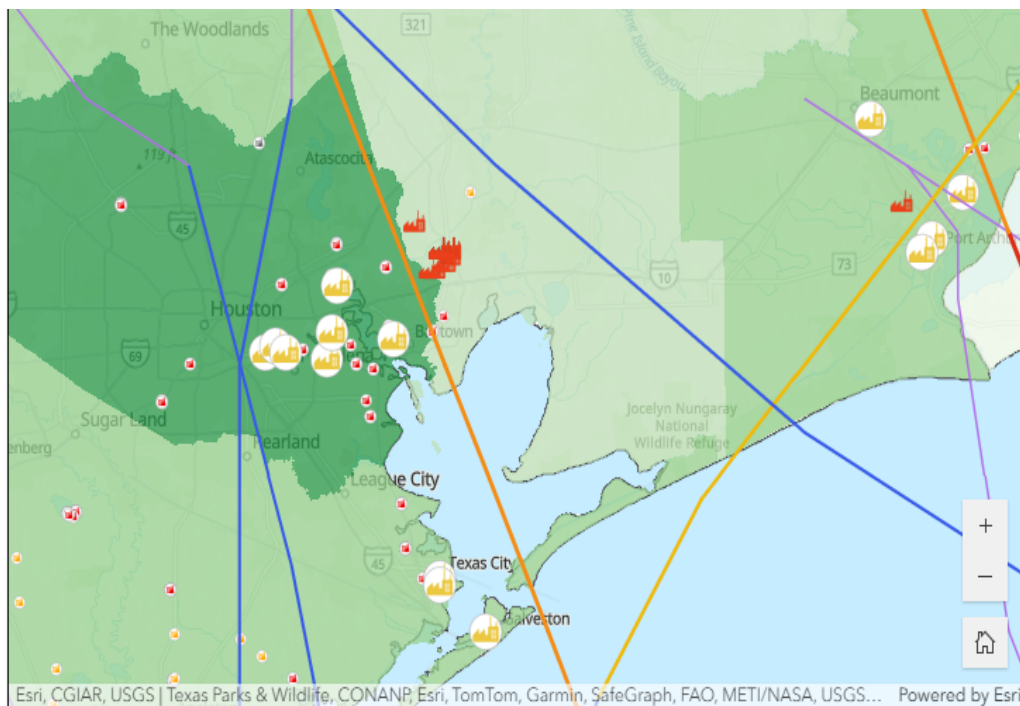


Figure 3: Path of Hurricane Ike (center yellow) and locations of Petroleum Refineries, Natural Gas Processing Plants, and Power Plants along Galveston Bay.

<https://www.rigzone.com/news/hurricanes/ike.asp>.

¹⁶ Mark J. Kaiser and Yunke Yu, "The Impact of Hurricanes Gustav and Ike on Offshore Oil and Gas Production in the Gulf of Mexico," *Applied Energy* 87, no. 1 (2010): 284–97, <https://doi.org/10.1016/j.apenergy.2009.07.014>.

¹⁷ "Ike Destroys Oil Facilities, Damages Pipelines," NBC News, September 14, 2008, <https://www.nbcnews.com/id/wbna26706452>.

¹⁸ SFS, "Hurricane Ike," *Specialty Fuel Services*, August 6, 2018, <https://specialtyfuelservices.com/hurricane-ike/>.

State and City leaders were prescient a Century ago; they decided to move the Port and Oil & Gas facilities inland to Galveston Bay and away from the open Gulf. This inland setback provides vast logistical and defensive advantages over offshore or open-coast setups. Ike could easily have struck as a Category 4 Hurricane, which a future storm may very well do. The narrow Houston Shipping Channel would concentrate the surge, intensifying its power, striking about 900 industrial facilities and more than 4,300 above-ground storage tanks.

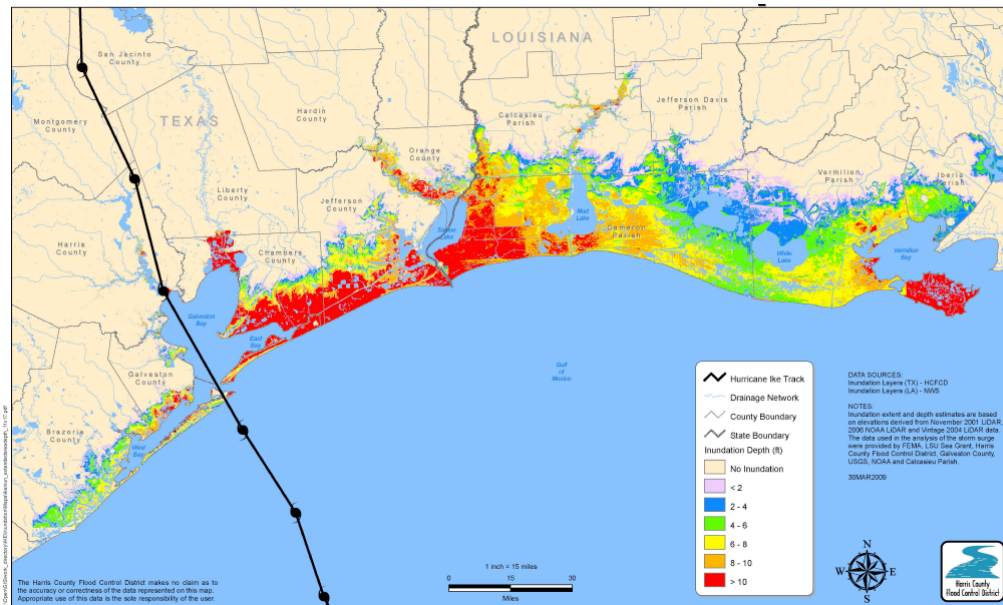


Figure 4: Hurricane Ike inundation, red indicating inundation over 10ft.

As a single Category 2 Hurricane Ike demonstrated the kind of disruptions that could occur to the Region, the State, and the Country and why a long-term, comprehensive, resilient solution is necessary.

The Proposed Galveston Barrier System

Galveston Island and the Bolivar Peninsula sit a little over two miles apart at the mouth of Galveston Bay, each stretching roughly 27 miles in length and about three miles across at their widest point. Between them lies the entrance to the Houston Ship Channel, a corridor that, according to the Port of Houston, generates an estimated \$906 billion in economic value for the United States each year.¹⁹ Much of that value comes from the steady flow of oil and gas moving to and from the dense cluster of refineries surrounding Houston.

¹⁹ "Port Statistics."

Since Hurricane Ike in 2008, the west side of Galveston Bay has been heavily developed. Three major industrial complexes exist: Texas City, the Houston Ship Channel, and the Bayport Industrial District. This is the side that is extremely vulnerable to hurricane surge. Modeling indicates that today, a Hurricane Ike type storm, but with winds increased by 15percent to Category 3, would be classified as a 250-year event. “Land area that is home to about 800,000 people would be inundated to some extent, and a significant portion of the approximately 200,000 housing units would be destroyed.”²⁰ Given the Oil and Gas infrastructure and shipping that could be impacted, such an event would pose national security concerns.



Figure 5: Map showing major components of the Galveston Bay elements of the Coastal Texas Project.

With repeated storms and climate change that make intense storms more frequent, Texas has been searching for ways to protect Galveston Bay, the Houston Ship Channel, and the Port of Houston. The Coastal Texas Protection and Restoration Project, or the Coastal Texas Project, as it is officially called, was proposed after the devastation caused by Hurricane Ike. It is an ambitious project whose engineering centerpiece is a series of 36 concrete and steel sea gates, including two massive gates at the mouth of the Houston Ship Channel, that seal off Galveston Bay from devastating surge in the event of an incoming storm.

²⁰ “Surge Flooding - Houston,” ENERGY TODAY, accessed August 9, 2026, <https://energytoday.energysociety.org/surge-flooding---houston.html>.

The popular press dubbed the project the “Ike Dike,” although it is just one element in a system of protective measures. According to the Severe Storm Prediction, Education and Evacuation from Disaster (SSPEED) Center at Rice University, comparative modeling indicates that such a barrier would indeed be effective in shielding the Bay, the Shipping Channel, and the Port of Houston from storm surge and widespread flood inundation.²¹

Modeling shows a comparison of storm surge and flood inundation of a Cat 3 Hurricane without any barrier on the left and with a coastal protective spine on the right. Some of the red and purple areas indicate inundation over 20ft, which is reduced to 6ft to 12ft with the coastal protective spine.

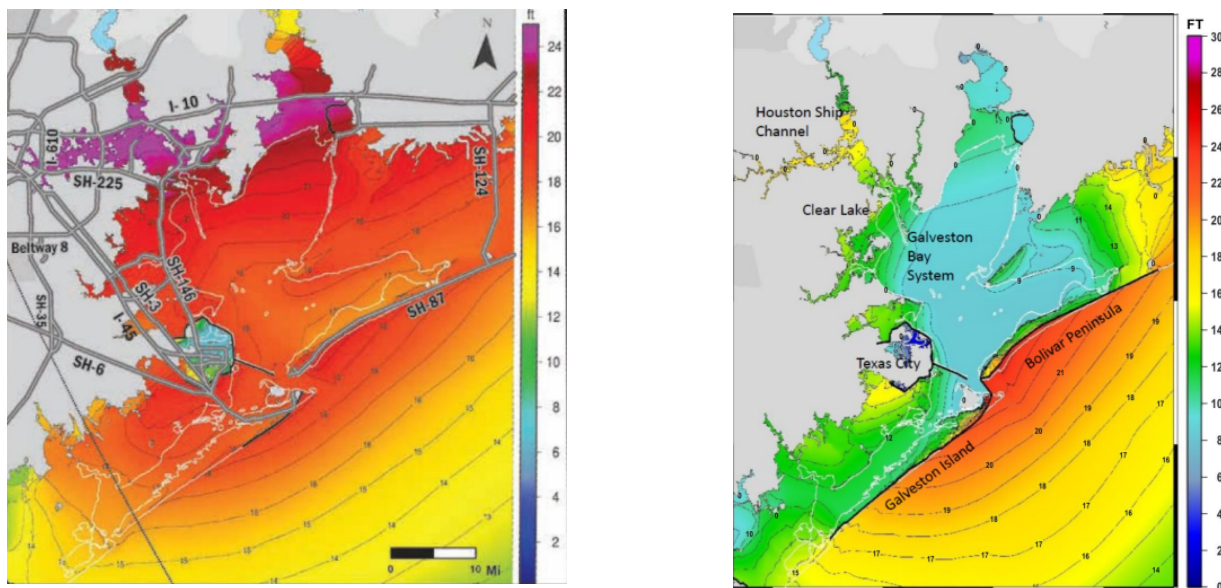


Figure 6: Models showing a comparison of storm surge and flood inundation of a Cat 3 Hurricane without any barrier on the left and with a protective spine on the right.

With the current level of protection, a Category 3 Hurricane would cause storm surge to reach 22 to 23 ft in the Bayport Industrial Complex and approximately 25 ft into the Houston Shipping Channel. The damage to Texas City refineries, chemical plants, and Bayport industrial district plastic plants would be extensive. Besides low-lying piping and electrical systems that would be flooded with salt water and need to be replaced, SSPEED estimates that a 24- foot surge could lead to the release of at least 90 million gallons of oil and hazardous substances into the Bay.

The proposed Galveston Barrier System, while not offering absolute protection, depending on the orientation of the storm, would reduce surge at the Bayport Industrial Complex to 12 to 14 ft

²¹ Storm Surge and the Future of the Houston Ship Channel, Jim Blackburn, SSPEED Center, Rice University, n.d. <https://reduceflooding.com/wp-content/uploads/2019/03/Storm-Surge-CFR-paper.pdf>

and to 18 to 20 ft at the Houston Shipping Channel.²²

The Ike Dike, initially proposed by Texas A&M University at Galveston as part of the larger Texas Coastal Spine, envisions a coastal levee system rising roughly 17 ft high and extending northward from San Luis Pass along the length of Galveston Island, where it ties into the existing Galveston Seawall. At the waterway separating Galveston from the Bolivar Peninsula, the



Figure 7: Conceptual rendering of the Galveston Bay Barrier System.

system incorporates two major gate structures - a navigation gate and a tidal-flow gate - spanning the two-mile-wide pass, where depths range from 30 to 60 ft.²³

The plan builds a protective dune system with shallow “swales” between the dunes to manage stormwater and create small wildlife habitats. In front of the dunes, the beach will be extended by 250 ft, adding new recreational and fishing areas. A similar 18-mile dune and beach extension will protect homes on western Galveston Island. Because dunes naturally erode, they must be rebuilt roughly every 6–7 years.

Additional protection comes from a three-mile earthen levee, a concrete floodwall, and 15 vertical lift gates spanning 4,500 ft. The lift gates normally remain above the water. The two

²² “Galveston Bay Park: A Vision for Houston and Galveston Bay,” SSPEED, accessed August 9, 2026, https://sspeed.rice.edu/_files/ugd/d29356_89e3bbd23f4042a28d147e965ae0e9f2.pdf.

²³ “About Ike Dike,” accessed August 9, 2026, https://www.tamug.edu/ikedike/About_Ike_Dike.html.

main gates are supplemented by a three-mile earthen levee, a steel-reinforced concrete floodwall, and two other types of gates, including 15 vertical lift gates that rise from the bay's bottom. Spanning a total of 4,500 ft across, those 15 gates will be suspended above the water's surface year-round until they drop into the water to block a surge.²⁴

Since the Ike Dike was first proposed, the US Army Corps of Engineers, which oversees the Nation's waterways, with the Texas General Land Office as the local sponsor, has adopted the idea. In 2021, the Texas Legislature established the Gulf Coast Protection District, charged with safeguarding approximately 5,220 square miles along the upper Texas coast, including Galveston, Houston, and Harris County.²⁵ The special district is the largest coastal protection effort in U.S. history and is charged with carrying out projects including cost sharing, land acquisition, project design, construction, regulatory compliance, and long-term maintenance.

What does the Dutch example teach us?

The idea of a storm surge protective barrier is neither new nor unique. The Dutch Delta Works is a leading, successful program. Over a quarter of the Netherlands lies below sea level, and nearly 70 percent of its population lives in areas vulnerable to flooding.²⁶ In 1953, a massive North Sea Storm breached the ocean dike in more than 90 places, resulting in 1,800 fatalities.²⁷ In response, the Dutch Government proposed Delta Works, the world's largest flood protection system. The Works consists of dams, sluices, locks, dikes, levees, and barriers, the largest of which is the *Oosterscheldedam*, a huge storm surge barrier where the gates are closed to prevent intrusion of salt water in extreme weather conditions.²⁸

However, no physical barrier can offer total protection, something the Dutch realized when, in 1993 and again in 1995, meltwater and rainfall resulted in massive flooding requiring the evacuation of a quarter million people.²⁹ Part of this flooding was a result of greater

²⁴ Xander Peters, "Galveston's Texas-Size Plan to Stop the Next Big Storm," *Smithsonian Magazine*, accessed August 12, 2026, <https://www.smithsonianmag.com/science-nature/galveston-texas-plan-stop-next-big-storm-hurricane-ike-180984487/>.

²⁵ "About Us | GCPD," *Gulf Coast Protection District*, n.d., accessed August 9, 2026, <https://gcpdtexas.com/about-us/>.

²⁶ Science Blog Editorial Team, "About a Quarter of the Netherlands Now Sits below Sea Level, and the Obvious Explanation Is That the Sea Rose. However, Researchers Who Reconstructed the Past Thousand Years of the Dutch Coastal Plain Concluded the Opposite — Much of the Land Came down to Meet the Water," *ScienceBlog.Com*, August 11, 2026, <https://scienceblog.com/m-about-a-quarter-of-the-netherlands-now-sits-below-sea-level-and-the-obvious-explanation-is-that-the-sea-rose-however-researchers-who-reconstructed-the-past-thousand-years-of-the-dutch-coastal-plain/>.

²⁷ "Low Probabilities - Large Consequences," *Low Probabilities - Large Consequences*, accessed August 11, 2026, <https://themasites.pbl.nl/flood-risks/>.

²⁸ "Delta Works: Protecting the Netherlands from Flooding," *Institution of Civil Engineers (ICE)*, November 8, 2026, <https://www.ice.org.uk/what-is-civil-engineering/infrastructure-projects/delta-works>.

²⁹ Ministerie van Infrastructuur en Waterstaat, "Thirty Years Later: The 1995 High-Water Evacuation Remains

urbanization, but a larger factor was that water needed room for natural retention. Natural wetlands and marshes could act as natural sponges for the excess water. These events led to the realization that a comprehensive flood management strategy requires a multi-layered safety concept consisting of three components:

1. **Contingency Plans** that coordinate disaster and crisis management,
2. **Sustainable Spatial Adaptation** that reduces the consequences of flooding,
3. **Protection** that offers the backbone of flood risk management policy.³⁰

Houston and the Dutch city of Rotterdam share many similarities. They both feature deep inland shipping channels, massive petrochemical complexes, and heavy reliance on man-made or modified waterways. Both Houston and Rotterdam serve as massive global gateways for energy and industrial ecosystems tied closely to maritime logistics. Importantly, both regions sit on low-lying, vulnerable deltas and bays, requiring complex flood and storm surge defense strategies.³¹

But where the gates in Rotterdam span 1,185 ft, the channel between Bolivar Peninsula and Galveston Island is greater than two miles. Of course, it is not simply enough to protect the Bay and the entry to the shipping channel. If a hurricane hit the region, storm surge would simply bypass the gates and flood the land from adjacent flanking areas. The overall coastal spine in Texas requires a 17-foot-tall double-dune system stretching 60 miles.³² The dune will require regular nourishment every 3-7 years but is a far more cost-effective solution than barriers.

The Dutch realized that ever-larger coastal barriers may not be cost-effective or feasible, and this led to a program called Room for the Rivers, which gives rivers more room to flood.³³ The idea is simple: allow certain areas to flood during periods of particularly heavy rain. It marks a shift in mindset towards adapting to, rather than resisting, rising water levels. There are limits to how much control can be exerted over nature. The focus has shifted from fighting the water to living with it.³⁴

Unforgettable,” webpagina, accessed August 11, 2026, <https://www.rijkswaterstaat.nl/en/news/archive/2025/01/thirty-years-later-the-1995-high-water-evacuation-remains-unforgettable>.

³⁰ F. Klijn et al., “In Search of Robust Flood Risk Management Alternatives for the Netherlands,” *Natural Hazards and Earth System Sciences* 12, no. 5 (2012): 1469–79, <https://doi.org/10.5194/nhess-12-1469-2012>.

³¹ “Rotterdam and Houston Strengthen Economic Relationship during Digital Trade Forum - Rotterdam Maritime Capital of Europe,” Rotterdam. Maritime Capital of Europe, accessed August 11, 2026, <https://www.rotterdammaritimecapital.com/news/rotterdam-and-houston-strengthen-economic-relationship-during-digital-trade-forum>.

³² Heather, “What Is Ike Dike? The Galveston Bay Barrier System Explained,” *Gulf Coast Protection District*, June 9, 2026, <https://gcpdtexas.com/publications/what-is-ike-dike-the-galveston-bay-barrier-system-explained/>.

³³ Ministerie van Infrastructuur en Waterstaat, “Room for the River,” webpagina, accessed August 11, 2026, <https://www.rijkswaterstaat.nl/en/projects/iconic-structures/room-for-the-river>.

³⁴ Caroline M. Kraan et al., “Expert Perspectives on Living with Water (Meebewegen) as Climate Adaptation in the Netherlands,” *Environmental Research: Climate* 4, no. 1 (2025): 015009, <https://doi.org/10.1088/2752-5295/adafd5>.

Opponents of the Galveston Barrier System

Just as in the Netherlands, the Galveston Barrier System is not without its opponents. The proposed coastal spine was the focus of a Draft Environmental Impact Statement released by the US Army Corps in late 2018. Environmental groups argue that the plan reflects a flawed attempt to engineer natural systems. They warn that Ike Dike would degrade the ecosystem by eliminating critical bird habitat and constrain the exchange of water between Galveston Bay and the Gulf, with potential consequences for wetlands, water quality, and marine species that rely on that movement at different stages of their life cycles.³⁵ Environmental groups caution that the massive gate structures—designed with numerous tide-gate openings to reduce ecological harm—could still alter circulation and salinity patterns in the Bay over the long term.³⁶

Ike Dike Alternatives

The alternative Galveston Bay Park Plan, developed by the SSPEED Center, is located entirely within Galveston Bay. The proposed protection system would extend down Galveston Bay alongside the Houston Ship Channel and then tie into the existing Texas City levee system. Along the Ship Channel, the flood-protection levee would be built to an elevation of 25 ft—potentially integrated with the channel-widening project—combining improved navigation with storm-surge defense.³⁷

The levee system and associated dredged-material placement areas would ultimately be transformed into wetlands, parkland, and open space. The plan includes a navigation gate approximately 1,100 ft wide, along with at least five smaller navigation and circulation gates to maintain connectivity between Galveston Bay and Trinity Bay. In addition, the SSPEED Center proposes raising the Texas City levee from its current 17-foot height to 25 ft, elevating major evacuation routes on the Bolivar Peninsula and West Galveston Island, and constructing a bayside levee around the City of Galveston.³⁸

Besides environmental concerns raised above, there is the question of funding. The Corps estimated the project to cost \$34B, the largest it has ever undertaken. But with a 20-year anticipated completion date (7 years to design, 13 years to build), and factoring in inflation, the project cost could escalate to \$57B. Although Congress has authorized the project, it has not

³⁵ Erin Douglas Foxhall Emily, “Texas ‘Ike Dike’ Coastal Barrier Could Cost \$57 Billion with Inflation,” *The Texas Tribune*, September 28, 2023, <https://www.texastribune.org/2023/09/28/texas-ike-dike-coastal-barrier-army-corps/>.

³⁶ “Ike Dike: A Hazard to Galveston Bay | Sierra Club,” accessed August 11, 2026, <https://www.sierraclub.org/texas/houston/blog/2016/07/ike-dike-hazard-galveston-bay>.

³⁷ “GALVESTON BAY PARK PLAN,” SSPEED Center, accessed August 9, 2026, <https://sspeed.rice.edu/gbpp>.

³⁸ “Surge Flooding - Houston,” ENERGY TODAY, accessed August 9, 2026, <https://energytoday.energysociety.org/surge-flooding---houston.html>.

appropriated much money for it, and given that the Corps has over a \$109B project backlog, it is unclear whether Congress ever will.³⁹

As the Federal Government will only foot 65 percent of the total cost, the question of the local match will come down to the will of local governments, the Port of Houston, and the private sector, who have a significant stake in protecting their assets on Galveston Bay. As of 2024, the Texas Legislature has appropriated \$950M to the Gulf Coast Protection District to advance its projects. As of 2026, Congress has authorized the appropriation of \$5M to the Coastal Texas Project.⁴⁰ Given that Ike caused \$30B in damages, and Harvey across Texas and Louisiana caused damages of \$125B, a single disaster can justify the cost of the Ike Dike.⁴¹

Fundamentally, the debate comes down to two philosophical differences in how to deal with Nature. Control floodwaters with ever-bigger defenses via barriers and gates through grey infrastructure, or live with floods by allowing room for them through a combination of grey and green infrastructure. The other big concern is whether Houston can wait twenty years. Six million people call the Houston area home, and the Metro is expected to surpass Chicago and become the third largest US metro by 2035.⁴² With the likelihood of another Hurricane of greater severity striking the Houston area, and rising waters in the Gulf, the question is whether a project such as Ike Dike, if completed, would be too late.

Secure by Design: What can other Gulf Port authorities learn from Houston?

In terms of economic impact, the Port of Houston is by far the largest seaport in Texas, but it is not the only one. Collectively, Texas seaports contribute \$713.9B annually to the state's economy – that is 28percent of its economy – handle 746.4M tons of cargo, and directly and indirectly support 2.5M jobs. The Texas coastline has 13 shallow draft ports and 15 deep draft ports.⁴³ Of these, the five biggest each have their own unique characteristics. The first four of these make the list of the ten largest ports in the US.⁴⁴

³⁹ Foxhall, "Texas 'Ike Dike' Coastal Barrier Could Cost \$57 Billion with Inflation."

⁴⁰ "Galveston Bay Barrier System | GCPD," *Gulf Coast Protection District*, n.d., accessed August 11, 2026, <https://gcpdtexas.com/our-projects/coastal-texas-project/galveston-bay-barrier-system/>.

⁴¹ "Hurricane Costs," accessed August 12, 2026, <https://coast.noaa.gov/states/fast-facts/hurricane-costs.html>.

⁴² "Houston's 15-Year Growth in Three Charts | Kinder Institute for Urban Research," Kinder Institute for Urban Research | Rice University, accessed August 11, 2026, <https://kinder.rice.edu/urbanedge/houstons-15-year-growth-three-charts>.

⁴³ *Texas Port Mission Plan*, n.d.

⁴⁴ "Southwestern Division > About > Texas Ports and Coastal," accessed August 11, 2026, <https://www.swd.usace.army.mil/About/Texas-Ports-and-Coastal/>.

- **Port Houston** is the largest and most economically impactful, dominating U.S. waterborne tonnage and container traffic.
- **Port of Corpus Christi** is the nation's leading energy export gateway, with massive crude and LNG volumes.
- **Port of Beaumont** is strategically critical for military logistics and ranks among the top U.S. ports by tonnage.
- **Port of Brownsville** is uniquely positioned on the U.S.–Mexico border and is rapidly rising in national rankings.
- **Port of Freeport** is a fast-growing mid-sized port with strong energy and chemical export performance.



Figure 8: Ports in Texas

The Texas Port Mission Plan (PMP) outlines \$9.16 billion in total port system needs across its three major components:

- Maritime Infrastructure: \$3,110,000,000
- Seaport Connectivity: \$585,000,000
- Ship Channels: \$5,460,000,000

These investments are essential to maintain competitiveness, support Texas's rapidly expanding population, strengthen supply chain resilience, and accommodate the next generation of global vessels.

The Port Mission Plan makes clear that Texas ports face urgent challenges, among them aging infrastructure, congested roadways, insufficient channel depths, and environmental and resilience needs. In addition, the industry is placing demands with rapid growth in LNG and petrochemical exports and increasing vessel sizes (Megamax-24, New Panamax). A \$1.1B investment recommended by the Texas legislature in its last legislative session would accelerate critical projects, support statewide economic growth, and maintain Texas's leadership in global trade.⁴⁵

⁴⁵ *Texas Port Mission Plan.*

This paper focuses on environmental and resilience needs that ensure long-term growth, prosperity for the Texas Coast, and how to make Texas communities Secure by Design. Various studies have shown that mitigation measures to prepare and prevent are far more cost-effective than measures to respond and recover. A 2019 National Institute of Building Sciences report found that for every \$1 invested in resilience can save up to \$13 in future losses and, depending on the mitigation measure, may result in national average savings of \$4 to \$11.⁴⁶ The US Chamber of Commerce and Allstate Insurance reached a similar conclusion in its 2024 study: every \$1 invested in hazard preparedness, \$6 is saved in damage costs, and another \$7 is saved in community economic recovery costs, for a total savings of \$13.⁴⁷ In other words, resilience pays for itself.

The Port of Houston, and by extension, Galveston Bay and the Houston Shipping Channel, have been our focus. Prompted by ambitious projects such as Ike Dike, the opposition surrounding it, and the fatalistic view that it may be “too little, too late,” inform the debate surrounding the Texas Coast. Lessons about climate adaptation can inform this topic in a non-partisan manner. Flood defenses like dams, levees, and dikes have long enabled communities to prosper alongside rivers, coasts, and other waterways. But as climate change drives more frequent and severe flooding, many regions may need to complement—or rethink—these traditional structures with strategies that embrace living with water. Such approaches aim not only to reduce long-term flood risk but also to advance broader societal priorities. Constructing hard defenses to limit flooding—or to push development deeper into high-risk areas—often brings substantial upfront costs and environmental consequences.⁴⁸

Given the profound uncertainties surrounding future flood behavior and long-term societal change, traditional approaches to keep the water out may not always be the most suitable path. Alternative “living with water” strategies offer different adaptation strategies to manage risk. These approaches can be thought of as a matrix of activities ranging from “do nothing” to “resistance,” with various hybrid scenarios in between. They can be characterized thus:

- **Advance**, which involves moving further out into the sea to accommodate areas that can be flooded.
- **Resist**, which includes building physical barriers such as sea walls, levees, gates, etc.
- **Avoidance**, which restricts or prevents development in areas most prone to flooding.

⁴⁶ “Natural Hazard Mitigation Saves: 2019 Report,” *National Institute of Building Sciences*, n.d., accessed August 12, 2026, <http://nibs.org/projects/natural-hazard-mitigation-saves-2019-report/>.

⁴⁷ “The Economic Benefits of Investing in Climate Resilience,” June 25, 2024, <https://www.uschamber.com/security/the-preparedness-payoff-the-economic-benefits-of-investing-in-climate-resilience>.

⁴⁸ Kraan et al., “Expert Perspectives on Living with Water (Meebewegen) as Climate Adaptation in the Netherlands.”

- **Accommodation**, which enables communities to remain in place by adopting more resilient land-use practices and construction methods.
- **Retreat**, which involves relocating people and critical assets away from high-risk zones to safer ground.

There is no single ‘right’ pathway to adaptation. Local characteristics, not least of local politics, influence the choice made at each Texas Port. In some situations, depending on the value of the asset to be protected, to resist may be the right approach. But such an approach comes with a high up-front cost, environmental consequences, and public buy-in. What may be the right adaptation strategy for Houston may not be for Brownsville.

Texas faces ongoing challenges in “Accommodation,” which helps communities remain in place by encouraging resilient land-use practices and stronger construction methods. The Federal Emergency Management Agency (FEMA) monitors state-by-state building code adoption through its Building Code Adoption Tracking (BCAT) System, and buildings constructed under modern hazard-resistant codes consistently perform better during disasters. Texas currently uses the 2012 edition of its building codes for municipalities.⁴⁹ As a “home rule” state, Texas does not require uniform statewide adoption or enforcement of these codes, and local jurisdictions have broad discretion to modify them. As a result, only 30.4 percent of residents and 18.8 percent of buildings in Texas are covered by the most up-to-date hazard-resistant standards.⁵⁰

Likewise, when it comes to land-use planning and zoning, Texas relies on a decentralized, pro-development framework for land use. Cities hold exclusive zoning authority, while counties have no general zoning powers. This dynamic allows for rapid expansion and flexible commercial or residential growth.⁵¹ Texas does not have a state-level environmental review act for development, and typically quick permitting (2-4 weeks as opposed to 12-18 months in California) means the State ranks 18th from the bottom for building and land-use regulations.⁵²

The Greater Houston Metropolitan Area has lost between 38,000 and 54,000 acres of natural wetlands over recent decades due to rapid, low-density suburban sprawl. Land-use studies by Texas A&M University show that rapid urbanization and the expansion of impermeable surfaces have severely degraded the region's natural stormwater infrastructure and the soil's ability to absorb precipitation. Between 1992 and 2010 alone, Harris County suffered a catastrophic 29

⁴⁹ Building codes are updated every 3 years. The latest published code is 2024.

⁵⁰ FEMA, “FEMA FY25 BCAT Region 6 Report,” Annual Fact Sheets: BCAT & Mutual Aid for Building Departments, accessed August 13, 2026, https://www.fema.gov/sites/default/files/documents/fema_fy25-bcat-region-6-report.pdf.

⁵¹ “What You Need to Know About Land-Use Restrictions in Texas,” *Texas Real Estate Research Center*, n.d., accessed August 13, 2026, <https://trerc.tamu.edu/article/what-you-need-to-know-about-land-use-restrictions/>.

⁵² Emily Hamilton, *Ranking State Land Use Regulations – Market Urbanism*, March 29, 2013, <https://marketurbanism.com/2013/03/29/ranking-state-land-use-regulations/>.

percent to 30 percent loss of its freshwater wetlands, which accounts for nearly 80 percent of all wetland destruction in the lower Galveston Bay Watershed. This lost sponge capacity of 25,000 acres paved over once provided roughly 4 billion gallons of natural stormwater detention.

Besides wetlands, prairies, which also act as freshwater sponges, have been decimated.⁵³

Texas is widely recognized for its light regulatory framework that emphasizes economic growth and development. As the state considers future adaptation strategies, it may need to balance continued development with approaches that incorporate natural systems, which can provide sustainable and cost-effective pathways to resilience. In practice, an effective strategy will likely involve a combination of methods. Given the long-term horizons associated with most adaptation efforts, any approach should also retain flexibility to adjust as climatic conditions evolve, communities change, and perceptions of risk shift.

CONCLUSION

The Gulf Coast Protection District is moving ahead with a US Army Corps version of the coastal resilience plan that is comprehensive, addresses many environmental concerns, and includes the Ike Dike. However, climate change fundamentally reshapes the question of what magnitude of storm we must plan for in our regulations, design standards, and operating procedures. We are already experiencing events of unprecedented scale - storms that exceed historical records and are not yet reflected in FEMA floodplain maps. Since Hurricane Ike in 2008, which prompted the current debate, we have had Hurricane Harvey in 2017, which dumped over 50 inches of rain over 4 days in parts of Houston and Harris County.⁵⁴

Events once classified as “100-year” storms—those with only a one-percent chance of occurring in any given year—are now appearing every few years. Deep Sky, a climate infrastructure company’s model, found that severe hurricane rainfall that used to occur only once every 100 years will now happen every 25 years. The volume of rainfall that fell in one day over the Houston area was previously seen only once every 7 years, but it will now occur on average every 3 years, and Gulf Coast states, including Texas, face the greatest rainfall increases.⁵⁵ Even the so-called “500-year” storms are emerging far more frequently instead of once in a lifetime.

⁵³ “Houston’s Flooding Shows What Happens When You Ignore Science and Let Developers Run Rampant,” Quartz, August 29, 2017, <https://qz.com/1064364/hurricane-harvey-houstons-flooding-made-worse-by-unchecked-urban-development-and-wetland-destruction>.

⁵⁴ “Reviewing Hurricane Harvey’s Catastrophic Rain and Flooding | NOAA Climate.Gov,” September 18, 2017, <https://www.climate.gov/news-features/event-tracker/reviewing-hurricane-harveys-catastrophic-rain-and-flooding>.

⁵⁵ “Frequency of Deadly Hurricane Weather Has Jumped 300percent,” accessed August 10, 2026, <https://www.deepskyclimate.com/blog/frequency-of-deadly-hurricane-weather-has-jumped-300>.

Hurricane Harvey in 2017 was Houston's third "500-year flood" since 2015.⁵⁶

The past is not always a good predictor of the future. Emerging risks from climate change and rising seas are not widely accounted for in our regulatory flood maps, and the engineering community still lacks robust tools to fully account for them. Yet the storms continue to strike with greater intensity and increasing frequency. Addressing the gap between perceived risk and actual risk is essential to prevent catastrophic failure along the Coast of Texas and the Port of Houston.

⁵⁶ Ariel Wittenberg, "The Myth of the 100-Year Flood," *E&E News* by *POLITICO*, August 30, 2017, <https://www.eenews.net/articles/the-myth-of-the-100-year-flood/>.

ILLUSTRATION CREDITS

Figure 1: Port of Houston Industrial District Map, Image courtesy of the University of Houston⁵⁷

Figure 2: Historical Hurricane Tracks, Image Courtesy of NOAA⁵⁸

Figure 3: Path of Hurricane Ike and locations of Petroleum Refineries, Natural Gas Processing Plants, and Power Plants along Galveston Bay, Image courtesy of Rice University, Baker Institute, Texas Natural Disaster Resilience Dashboard⁵⁹

Figure 4: Hurricane Ike Inundation, Image Courtesy of Harris County Flood Control District⁶⁰

Figure 5: Map showing major components of the Galveston Bay elements of the Coastal Texas Project. Image courtesy of the Gulf Coast Protection District⁶¹

Figure 6: Models showing a comparison of storm surge and flood inundation. Maps courtesy of the SSPEED Center, Rice University⁶²

Figure 7: Conceptual rendering of the Galveston Bay Barrier System. Image courtesy of the Gulf Coast Protection District⁶³

Figure 8: Ports in Texas. Image courtesy of the Texas Department of Transportation, Port Authority Advisory Committee, Texas Port Mission Plan, 2023⁶⁴

⁵⁷ <https://id.lib.uh.edu/ark:/84475/do9112m8776>

⁵⁸ <https://coast.noaa.gov/hurricanes/>

⁵⁹ <https://www.bakerinstitute.org/dashboard-natural-disaster-resilience>

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⁶¹ <https://gcpdtexas.com/our-projects/coastal-texas-project/galveston-bay-shoreline-and-island-protection/>

⁶² <https://reduceflooding.com/wp-content/uploads/2019/03/Storm-Surge-CFR-paper.pdf>

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⁶⁴ <https://www.txdot.gov/content/dam/docs/division/mrd/port-profiles/maritime-pmp-book.pdf>

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AUTHOR BIOGRAPHY

Kayed Lakhia, until his retirement in 2025, was the Director of FEMA’s Hazard Mitigation Assistance program, which included disaster and non-disaster grants, and managed a national portfolio of over \$10B. He was also the National Director of Dam Safety for FEMA. His leadership saw the creation of FEMA’s new BRIC-Building Resilient Infrastructure and Communities grant program. He has also acted as FEMA’s Deputy Assistant Administrator for Recovery.

Before his Federal Service, Mr. Lakhia was a principal at a global engineering firm. He holds a Master of Science degree from MIT and a Master's in Homeland Security from the Naval Postgraduate School. He has also completed post-graduate studies at Harvard’s National Preparedness Leadership Institute and the University of Virginia’s Darden School of Business. He is a Registered Architect, a Certified Floodplain Manager, and a LEED Accredited Professional. Mr. Lakhia is an OPM-certified member of the Senior Executive Service (SES).

The opinions expressed in this paper are those of a private citizen and not the official position of a former official of the U.S. Federal Government.

The Institute for Homeland Security at Sam Houston State University is focused on building strategic partnerships between public and private organizations through education and applied research ventures in the critical infrastructure sectors of Transportation, Energy, Chemical, Healthcare, and Public Health.

The Institute is a center for strategic thought with the goal of contributing to the security, resilience, and business continuity of these sectors from a Texas Homeland Security perspective. This is accomplished by facilitating collaboration activities, offering education programs, and conducting research to enhance the skills of practitioners specific to natural and human caused Homeland Security events.

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