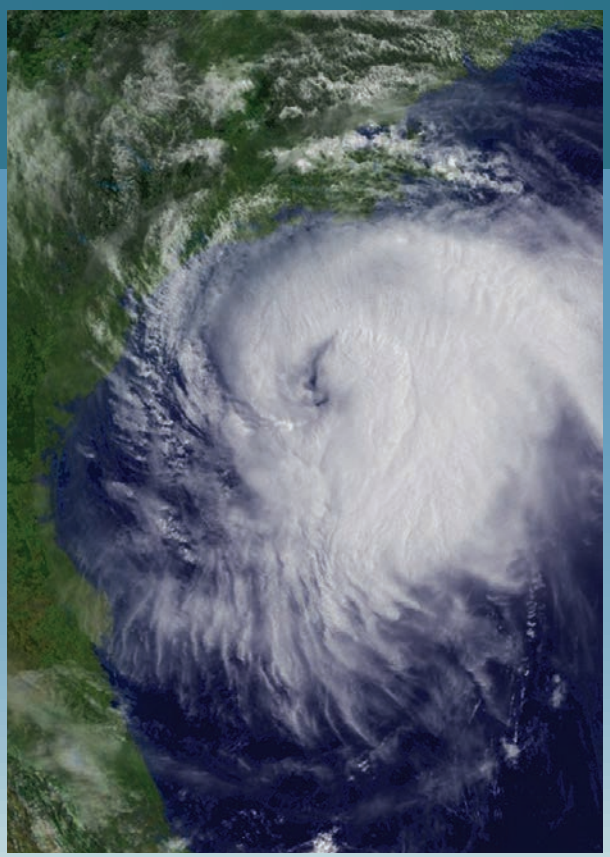
RE-ENGINEERING HOUSTON

A city built for the last century grapples with erecting defenses against the biggest storms of this one.

BY BRIDGET MINTZ TESTA



The Bolivar Peninsula (shown above in a satellite image) was virtually wiped clean by the storm surge of Hurricane Ike in 2008 (inset left). Engineers are now designing barriers that would protect Houston and other cities on Galveston Bay from future storms.
Image: U.S. Army Corps of Engineers

The Bolivar Peninsula stretches across the mouth of Galveston Bay like a forearm raised to ward off a blow. Indeed, that is more or less its function. The peninsula and Galveston Island to the south separate the bay and the low-lying land to the northwest from the warm waters of the Gulf of Mexico and the hurricanes that periodically blow up there.

As storm barriers go, it leaves a bit to be desired—the highest ground on the peninsula rarely breaks 10 feet above sea level—and in September 2008, it was tested. Hurricane Ike made its final landfall between Galveston Island and Bolivar Peninsula as a strong Category 2 storm, with a 15-foot-high surge to the east of the hurricane's center equal to that of a typical Category 3 hurricane. The Bolivar Peninsula, taking the brunt of the storm, was inundated with water between 12 and 16 feet high. Almost every structure on the Peninsula was destroyed by the storm surge; aerial photos in the storm's aftermath showed a landscape stripped down to the sand.

The City of Galveston's south side, which faces the Gulf and has a 17-foot-high, 10-mile-long seawall, suffered minor damage. Yet water surged around the seawall and flooded the north side, which fronts on Galveston Bay and has no seawall or other protection.

The winds from Ike were strong enough to blow out the windows of high-rises in Houston, about 50 miles inland, but the Bolivar Peninsula and Galveston Island blunted the

The Port of Houston is the second-largest in the U.S. and one piece of Houston's nationally important infrastructure. *Photo: Visit Houston*

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—Jim Blackburn, Rice University

storm surge enough to protect the city's low-lying infrastructure. Experts caution that it wouldn't have taken much in the way of bad luck—a somewhat stronger storm or one that hit slightly further to the west—to have inundated the 52-mile-long Houston Ship Channel (HSC) and several thousand cylindrical storage tanks along the HSC and at the Port of Houston.

Those tanks would be exposed to both lifting forces that could float them off their bases, spilling whatever they contain, and horizontal crushing forces that could split the tanks open.

"If you leave the Houston Ship Channel unprotected, 60 million to 90 million gallons of crude oil and/or hazardous materials could be released," said Jim Blackburn, co-director of the Severe Storm Prediction, Education, and Evacuation from Disasters (SSPEED) Center, located at the Rice University. It could be the worst environmental crisis in U.S. history, affecting Galveston Bay, other connecting bays in the area, and the Gulf. There's no telling how long recovery would take or if it would even be possible.

Ike showed Houston just how vulnerable it is to a large storm. Leaders of the city and the surrounding area realized they needed to re-engineer the storm defenses, a far-ranging infrastructure project that will ultimately cost billions of dollars. Now, nine years later, they are still debating, exactly, will be done and who, exactly, will pay the bill.

Where to Draw the Line

Houston is the fifth-largest metropolitan area in the United States and has an outsized impact on the U.S. economy. More than 90 percent of U.S. offshore oil and gas production takes place in the Texas Gulf Coast area, and the Houston region contains the largest concentration of energy, petrochemical, and refining industries in the United States. Houston is home to 25 percent of the country's petroleum refining capability, 40 percent of the nation's capacity for downstream chemical production, and the fastest-growing liquefied natural gas industry in the nation.

The region is important beyond energy, too. One-third of the United States seafood harvest is taken from the Texas coast, and the NASA Johnson Space Center—the home of Space Station Mission Control—is located there. The area includes the Port of Houston, which ranks second in the nation, Beaumont's port, which ranks fourth, and Texas City's port, which ranks tenth.

With so much activity in Houston—and with so much of that activity vulnerable to storm surges—regional planners and government officials wanted to know exactly how much of an upgrade the region's coastal defenses needed. That required advanced fluid dynamics models and time on state-of-the-art supercomputers.

"The model utilizes the latitude, longitude, and the elevation of the ground, both above and below the water," said SSPEED Center project manager Larry Dunbar. The model encompasses thousands of square miles of the Gulf of Mexico, Dunbar said, and "there are a couple of million points in the model to represent all the ground."

The model can simulate normal tides based on the phase of the moon and wind direction, showing how the water flows in and out of the complex geography of the bay, both above the surface and below. But when the modelers want to run a storm surge scenario, they start by placing a hurricane-force wind field in the model, along with a storm track, the air pressure in the storm's eye, and the

hurricane's overall size. "The model calculates how high the water gets as a result of a wall of water pushed by the wind and the movement of the storm," Dunbar said.

It just takes a couple of hours to run SSPEED's model on the supercomputer at the University of Texas in Austin, but because there's a queue for supercomputer time, it takes about 24 hours to get results back. Other groups studying Houston's vulnerability to storms are using other models on different supercomputers, and comparing calculation results with each other to ensure they get the same answers from the same data from their respective models.

For each set of starting parameters, the models calculate how high the water gets in Galveston Bay and other locations. When you know how high the water rises, then you know how high a barrier must be built to protect against it. The so-called 100-year storm, which has a 1 percent chance of occurring in any given year, would require barriers as high as 15 feet. Rarer storms would overtop that, however, and expected sea level rise throughout this century would make storm surges relatively higher decades from now.

With those simulation results and the fresh memories of Ike, as well as such storms as Katrina and Sandy, engineers and architects started planning out what would be needed to protect the Houston area from inundation.

The first proposal that attempted to address storm surge, put forth in 2014 by the SSPEED Center, was a levee system with a floodgate at the point where the Houston Ship Channel meets Galveston Bay. This upper-bay gate concept was designed with the sole intent of protecting the HSC, and it quickly became obvious to everyone that while any town inside the project's levees would be protected from storm surge when its floodgate closed, anyone outside the gate would be utterly exposed.

That did not sit well in the many small towns dotting the coast around Galveston Bay. The SSPEED Center still considers the Upper-Bay Gate concept to be feasible for protecting the HSC, but it would be a hard project to build by itself, considering the opposition to it. Estimates of its cost are about $2.8 billion.

The SSPEED Center began expanding its storm surge study and came up with other concepts that would protect more of the region. One would place a barrier and gate across the middle of Galveston Bay—a mid-bay gate concept—and connect to some existing levees. That would protect the northwest part of the bay but still leave many towns exposed. Another concept would build a floodgate across Bolivar Roads, the two-mile gap between Galveston and the Bolivar Peninsula, connecting coastal barriers facing the Gulf itself and protecting the lower bay. The mid-bay gate, like the upper-bay gate, would cost about $2.8 billion, whereas the lower-bay gate's preliminary cost estimate is about $7.6 billion.

"At Bolivar Roads, there is a 2-mile section of open water between the Peninsula and Galveston Island," Dunbar said. "There we would have a navigation gate that is about 850 feet wide—the width of the Ship Channel—and about 60 feet deep that could close off the navigation channel. In addition, there would be a series of vertical environmental gates that can lift up out of the water. When a hurricane comes, you would close all of the gates."

SSPEED now leans toward a multiple barrier system combining the mid-bay and lower-bay gate concepts. The combination plan would provide some protection to the towns along Galveston Bay's coast, while providing additional protection to the HSC and its critical infrastructure, as well

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The storm surge from Hurricane Ike destroyed almost every structure on the Bolivar Peninsula.
Photo: Jocelyn Augustino/FEMA

as to the heavily developed west side of the bay.

That sort of staged defense system leaves a bad taste in some people's mouths. "If the storm surge gets into Galveston Bay, you'll have winners and losers," said Bill Merrell, professor of marine sciences at the Texas A&M University at Galveston, director of the Center for Texas Beaches and Shores, and chairman and principal scientist of the Institute for Oceans and Coasts.

Merrell has instead proposed a 60-mile barrier system along the entire stretch of the Bolivar Peninsula and Galveston Island. This system would cost $6 billion to $10 billion.

The beaches in the area could be used as foundations, and the barriers that make up the levee system would have hard cores covered with beach sand. The result would be a series of fortified sand dunes—a coastal spine 17-feet high—that keeps the storm surge out of Galveston Bay, protecting not only the high-value infrastructure along the Houston Ship Channel but also the small towns along the bay shore.

The coastal spine would place a swing-type navigation gate across Bolivar Roads, and it would also place environmental gates—smaller, vertical-lift devices—at the smaller San Luis Pass (which is at the southwest tip of Galveston Island). Both the navigation gate and the environmental gates would remain open most of the time to allow water to flow throughout the bay, thus protecting the bay's delicate ecology. When all are closed, the gates would provide a continuous barrier against storm surge getting into the bay. Merrell says that the barrier system could be built using existing, proven technology developed in the Netherlands.

"It shortens and strengthens the coast, and it allows storm surge to be stopped at the coast," Merrell said.

As a nod toward the Dutch, who have built similar extensive coastal barriers, Merrell calls his proposal the "Ike Dike."

Another group, the sprawling Gulf Coast Community Protection and Recovery District, which grew out of a commission studying the aftermath of Hurricane Ike, released a report in June 2016 recommending a coastal spine similar to the Ike Dike protecting Houston and the counties on either side of Galveston Bay, plus a new levee encircling the city of Galveston. For counties further out, the GCCPRD endorsed building new conventional levees.

"We would rework the ends of the new levees to seamlessly join the ends of existing levees," said GCCPRD's Chris Sallese, who was formerly Commander of the U.S. Army Corps of Engineers in Galveston. "When you build a levee, you're keeping water in, but then you have rain that falls from the sky and can't get out, so you have to have pump stations to pump that water out and keep the levees from flooding." The costs, according to Sallese, would be about $111 million for the pump station, and around $816 million for the levees.

How High is High Enough?

While it's hoped that the federal government would help provide funds for Houston's storm surge protection, much as it did for Louisiana after Katrina, it's also expected that local sales taxes would pay for much of the construction. "If you took storm surge protection construction from Houston down to Galveston, that could be five billion to eight billion dollars, and it could be funded by a one-penny sales tax," said Stephen Costello, an expert in Houston's need for storm surge protection. He works for the Houston Mayor's Office. "The only entities in Texas that can levy sales taxes are cities, towns, and the state," Costello said. "Houston's sales tax is already spoken for. We could let the voters decide—we can fund the work with a one-cent state sales tax or let local cities and towns increase their sales taxes by one cent," he added.

Other flood prevention methods put the onus on individual property owners. For instance, buildings on or near the coast in the Houston-Galveston area must be elevated to keep them safe from flooding. No new construction can occur near the coast that doesn't include elevation.

WE CAN FUND THE WORK WITH A ONE-CENT STATE SALES TAX.

—Stephen Costello,
Houston Mayor's Office

In addition to its various floodgate concepts, the SSPEED Center at Rice also has proposed a nonstructural alternative or supplement. The Texas Coastal Exchange would involve restoring the native coastal prairie and marsh to withstand hurricane storm surge. The rising water simply remains in the prairie or marsh, and after the storm has passed, the water flows back into Galveston Bay.

The economic concept behind the Exchange is "ecological service," which puts a dollar value on the natural benefits of the land. "We would restore the coastal prairie and develop income for the land owners," said SSPEED's co-director Jim Blackburn. "We must provide enough income to landowners so they don't build on the land."

One concept being looked at is creating a carbon market that would pay landowners for the carbon dioxide that a marsh pulls out of the air and locks in the soil. "It's a partial solution to climate change," Blackburn said. "It's also the commodity most likely to generate significant income for landowners. The projected value of carbon dioxide is $40 to $60 per ton."

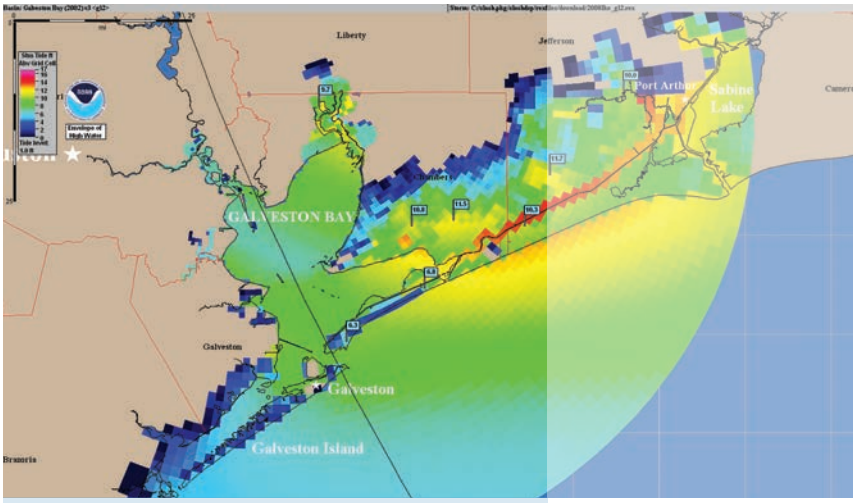
Up to three tons per acre can be removed by landowners, integrating ecology and economy. "We use ecosystems and economics instead of building technological systems for removing carbon. The natural systems do it naturally," Blackburn said.

Using natural ecological systems that pay the landowners addresses several issues: sea level rise, carbon reduction, and climate change. "We would not use regulations; instead, we'd use a market system," Blackburn said. "In many parts of the world, they use regulations. That won't work in Texas. The market system is a much better fit for Texas."

Of course, getting people to pay for soft defenses rather than high walls may be difficult, too. The wall-builders don't even agree among themselves as to how high is high enough.

"The federal government will typically cost-share up to the 100-year point," Sallese said. "It will cost-share for more than the 100-year storm, even up to the 500-year storm, but you have to prove the benefits."

That extra protection is worth it, others say, given the critical infrastructure built along the Houston Ship Channel. "We don't want nuclear plants to flood, so they are designed to be protected from a one in a million event," Dunbar said.



The maximum storm surge of Hurricane Ike. Houston and its critical infrastructure are at the top left of the map. A bigger storm tracking a bit to the west would have inundated the Port of Houston.

Image: NOAA

WATER SURGED AROUND THE SEAWALL AND FLOODED THE NORTH SIDE, WHICH FRONTS ON GALVESTON BAY.

"The industrial complexes at the HSC are generally protected to about 15 feet, which is equivalent to a 100-year storm. But 200-year or 500-year events are not protected by the 15-foot barrier."

SSPEED's mid-bay barrier would place a 25-foot-high barrier and gate across Galveston Bay to protect against the 200-year or even 500-year events.

"It would be ludicrous to build a $10 billion barrier and then have a Category 3 or 4 storm come and destroy the HSC," Dunbar said.

Figuring out which approach is the right one may not even be the right question to ask. "When you include sea level rise, it gets more complicated," Dunbar said. "Think dual barrier system—multiple lines of defense."

That's what the Netherlands does to protect itself from sea level rise and storm surge. Multiple lines of defense would work for Houston and Galveston Bay, too. The hard part is reaching an agreement on where to draw those lines of defense and then finding the money to build them.

The clock is ticking. It's been nine years since Ike, and Houston could face another hurricane at any time. **ME**

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