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HOUSTON AT THE CROSSROADS: RESILIENCE AND SUSTAINABILITY IN THE 21st CENTURY

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Introduction

Houston is at a crossroads, with one pathway leading to adaptation and long-term success in the 21st century, and the other leading to failure based on inability to compete in the 21st century. Robert Johnson, the great blues musician, is pictured below because of a story surrounding his music. As the legend goes, Johnson left his home not being able to play the guitar, made a deal with the devil at the crossroads, and came back as a genius guitar-playing blues musician, embellishing the mythology of the crossroads as a mystical place. Some of the ideas of this paper may seem like a deal with the devil to some of you, but in my opinion, we need to learn to play the guitar and don't really know how right now.

Figure 1. Blues Musician Robert Johnson

Source: Hooks Bros., Memphis, circa 1935, ©1989 Delta Haze Corporation

The paper is broken into five parts: Houston's past, current issues, ideas from others, our current assets for change, and ideas for adoption as future policy. The basic premise is that Houston's current financial position in the world is at risk if we don't change. And when you speak about money in Houston, people listen.

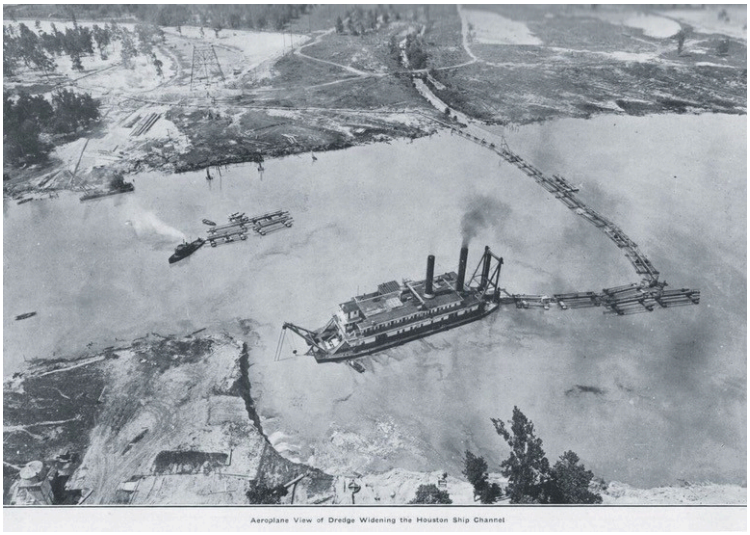
The Past

Houston's past is instructive of attitudes and difficulties. The city was founded after Texas gained independence from Mexico by entrepreneurial developers with a colorful, if not accurate, vision for Houston's future. Houston did not really flourish until two events occurred in 1900: the Great Galveston Hurricane destroyed Galveston and oil was

discovered at the Spindletop field on the Texas coast. This was about the same time that the horse and buggy was disappearing and being replaced by the internal combustion engine and the precursors to the modern-day car. Indeed, the horse-drawn buggy is relevant to this story of the crossroads—when the automobile came along, money went with it and away from the past, from the horse and buggy. As my business mentor Jake Hershey often reminded me, nothing changes faster than a company on the trail of money—something we all should keep in mind in the early 21st century.

Houston's port is not natural. It was dredged across Galveston Bay, through oyster reefs that cattle used to cross between Smith Point and Eagle Point, and up into the San Jacinto River and Buffalo Bayou. The Port of Houston opened in 1914 at about the same time the Panama Canal was completed, showing excellent planning and timing. These events set the course for significant growth in Houston and Harris County, whose respective populations went from about 45,000 and 65,000 in 1900 to about 940,000 and 1.2 million in 1960.

Figure 2. Man-made Port of Houston, 1914



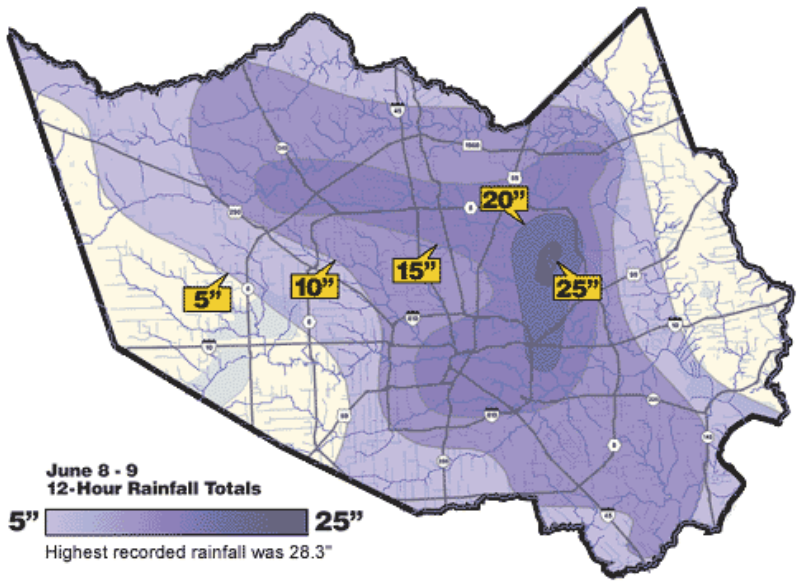
Source: Image courtesy of Port Houston, http://porthouston.com/about-us/background-and-history/

From 1960 until 2000, Houston's growth exploded. During this time, Houston became synonymous with technology. It became the oil center of the world at the height of the hydrocarbon era, hosting the Offshore Technology Conference and numerous other global events. It received the moniker "Space City" for its NASA Johnson Space Center and Mission Control Center, and it was home to the Astrodome, the self-proclaimed "Eighth Wonder of the World." But this period was also the beginning of the era of climate change, starting with the signing of the United Nations Framework Convention on Climate Change in 1992 and the founding of the Intergovernmental Panel on Climate Change (IPCC), setting in motion a collision of worldviews that will define the first half of the 21st century. By 2000, Houston grew to 1.95 million residents and Harris County exploded to about 3.4

million people, creating in the unincorporated areas of the county a suburban complex that, if incorporated, would have been the fourth- or fifth-largest city in Texas.

From 2000 to 2015, the complexion of growth and development in Houston began to change. Of greatest importance during this time was Tropical Storm Allison, a major rainfall event that caused widespread flooding across Houston, particularly in the northern and eastern parts of Harris County. From the vantage point of today, Allison was a forerunner event, a harbinger of big rainfalls yet to come. Houston was experiencing the first wave of a changing climate, but Allison was treated simply as an aberration, as indicated by the title of the Harris County Flood Control District's report, "Off The Charts." And while Houston's population began to level off to about 2 million persons by 2015, Harris County grew by another million to a total population of 4.4 million.

Figure 3. 12-hour Rainfall Intensity from Tropical Storm Allison, 2001

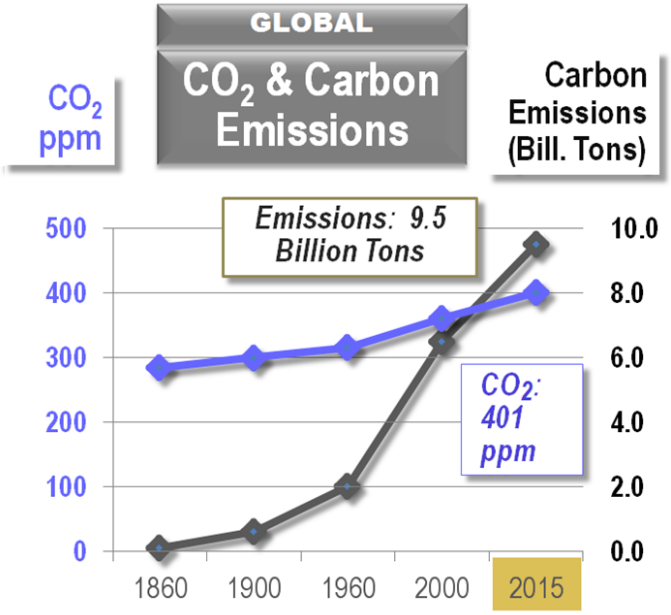


Source: "Off the Charts," Harris County Flood Control District

The period from 2015 to early 2018 has been a bit of a different story, leading to the opinion that Houston today is at a crossroads. 2015 marked the first time that the Earth's atmospheric concentration of carbon dioxide exceeded 400 parts per million (ppm), up from less than 300 ppm in 1900, an unprecedented change in that length of time (as far as can be discerned from the Earth's geologic record). This landmark helped fuel global concerns about climate change, leading to the Paris Agreement of 2015. Then, in August 2017, Hurricane Harvey pounded the Texas coast with an unprecedented amount of rain, inundating Houston and Southeast Texas, wiping out prior rainfall records, and causing record economic and social damage to nearly every corner of Harris County. On top of these two events, Amazon decided not to include Houston on its list of 25 finalists for the

site of its second U.S. headquarters. For many in Houston, it was hard to imagine that their city would not at least be among the top 25, yet it was not. Understanding why it was not, and what we need to do to change that reality, is what the crossroads analogy is all about: a 20th-century city trying to find the path to success in the 21st century.

Figure 4. Unprecedented Rise of Global CO_2 Emissions, 1900–2015



Source: Prepared for Jim Blackburn by Christina Walsh

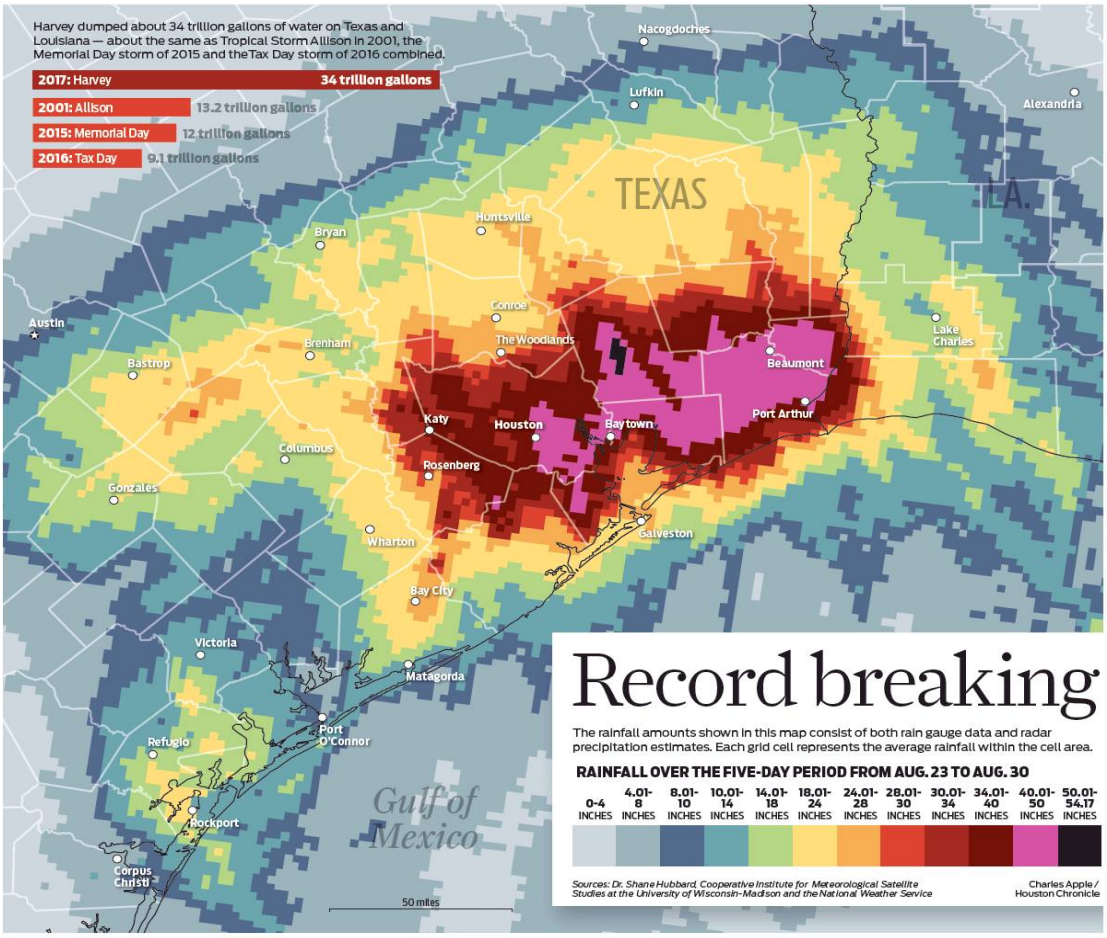
Current Issues

For the purposes of this paper, three key concepts for the future are considered: flooding, the climate and carbon, and food supply. There are certainly other issues that can and should be included on this list, but this is where I choose to start. Of these three issues, flooding is both an immediate and longer-term issue, and climate and carbon will become important in the next decade—as will issues of food supply resilience and integrity. These three issues underpin the economic realities of the future.

The collective psyche of today's Houstonians has been deeply affected by Tropical Storm Allison and the Memorial Day, Tax Day, and Halloween Day floods—all of which have occurred since 2000—events that seem to occur with increasing frequency, breaking past records, generating flooding beyond the so-called 100-year floodplain, and playing havoc with transportation, housing, and human security. And then came Harvey, a 4-day storm that dropped over 40 inches of rain across much of Harris County—a year's worth of rain in four days, a storm event more "off the charts" than Allison was. If nothing else,

Hurricane Harvey signaled that a "new norm" has been established, changing forever our view of rainfall and flood planning in Houston.

Figure 5. Record Rainfall from Hurricane Harvey, 2017



Source: Used with permission from the Houston Chronicle

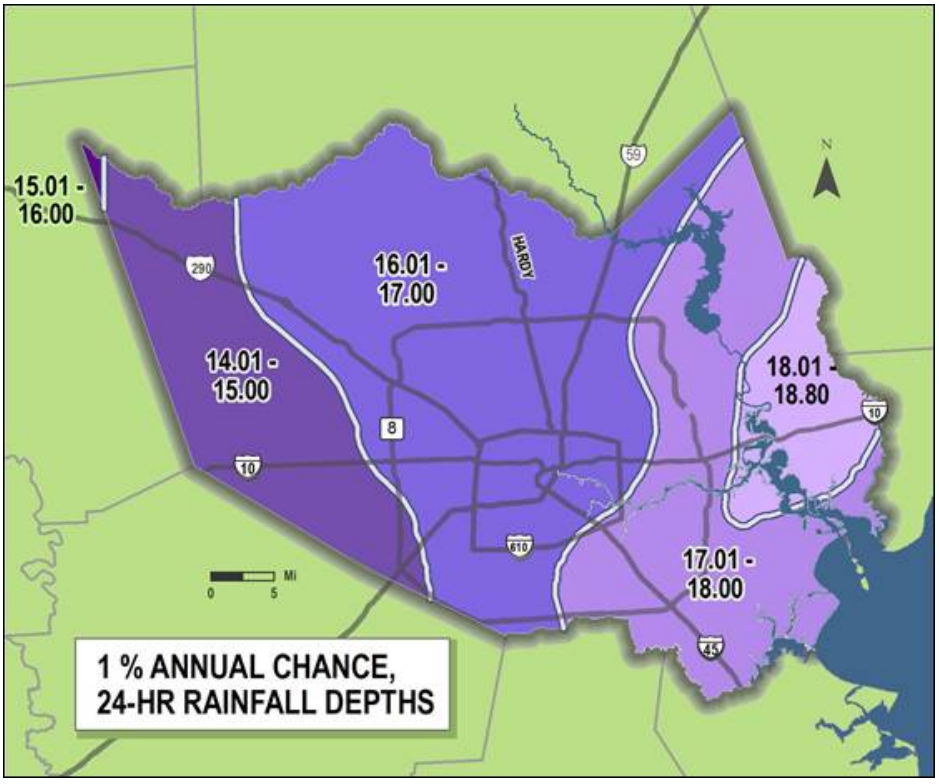
The issue that Houston is facing is rainfall of increasing intensity beyond the statistical norms of the past, creating what some call a "new norm," "weird weather," or climate change. Our climate is changing. We are experiencing extreme rainfall events more frequently than in the past, well beyond the norms of the past. The Gulf of Mexico is warming, providing more fuel for tropical storms and hurricanes. More moisture is evaporated with higher temperatures, hotter air can hold more moisture, and the jet stream is not always found today where it was in the past. Think of unanticipated weather events like Hurricane Sandy turning west rather than east, as almost every prior hurricane in history did, or Harvey coming ashore as a Category 4 storm and then stopping.

We are experiencing what climate scientists have been predicting: that we will see more and more events at the edge of the bell curve of normal distribution. Allison, Tax Day, and

Harvey were all extremely rare events, falling outside the 1 percent (100-year) or even 0.2 percent (500-year) points on the bell curve of distribution. The area at the edge of the bell curve was once described by a stock analyst as an area defined by "TBD." He asked the audience what TBD meant, and they were stumped because "to be determined" did not make sense. He then announced it meant "there be dragons"; indeed, there are dragons at the edge of the bell curve—a point to which those who suffered the whims of Harvey, Tax Day, and Allison will attest. We are victims of the "dragons" of climate change, and they are taking a toll.

This leads to one clear conclusion: our current 100-year floodplain map—a map that guides urban development and protects our community—is no longer viable. It is *obsolete*, and the area within this mapped flood plain is *dangerous*. A new study, the "NOAA Atlas 14," has just been completed as a draft document, and it shows—based on statistical evidence that includes Harvey—that the 100-year (1 percent) chance storm for 24 hours in Harris County will need to be increased from the current level of about 13 inches to between over 15 to almost 19 inches, depending upon location within the county. This change does not predict future rainfall, which, according to our local climate experts, will increase. The bottom line is that our climate is changing, and it is affecting our flooding patterns, making them worse. This spells real trouble for Houston.

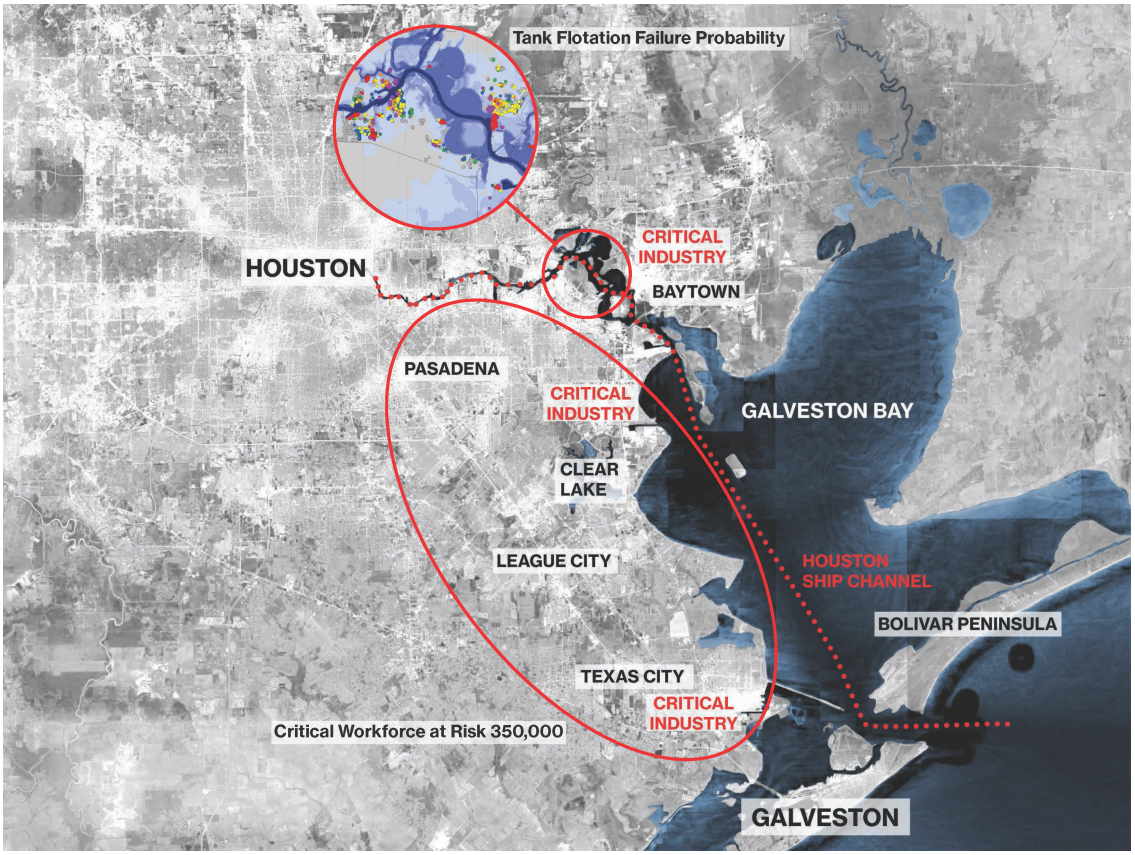
Figure 6. Proposed Increases to Houston's 100-year Rainfall



Note: Houston's 100-year rainfall is currently 13 inches in 24 hours.
Source: Based on National Oceanic and Atmospheric Administration data from NOAA Atlas 14.

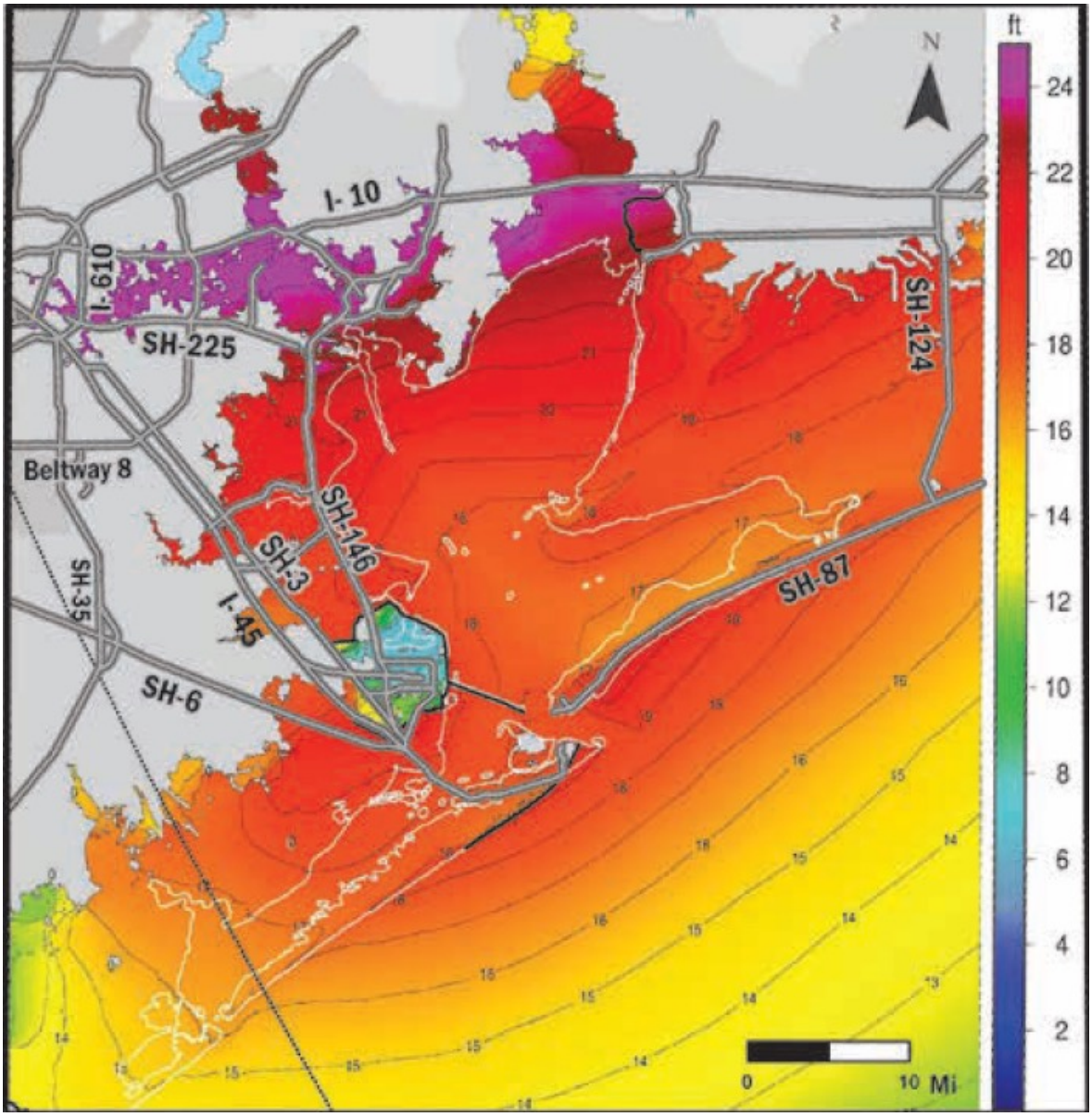
Key problem areas include the Addicks and Barker reservoir complex and the Houston Ship Channel. The Addicks and Barker reservoirs are two key flood protection storage areas in west Harris County that protect much of the urbanized area between Interstate 10 and 59 South into downtown Houston, including the Memorial area and the Energy Corridor. Addicks and Barker were evaluated in 2009 as two of the six most dangerous dams in the United States, a situation that remains today and one that exacerbated operational issues of these reservoirs during Harvey. The major concern is the integrity of the levees, which held during Harvey but portend huge damages far beyond anything suffered during Harvey if they were to fail. Second, the industrial area on the Houston Ship Channel is not protected from hurricane surge flooding beyond about 15 feet of above sea level. Fortunately, Harvey did not generate a significant surge in Galveston Bay, but a future storm could bring 25 feet of surge into the Houston Ship Channel, inundating up to seven refineries and over 100 chemical plants, flooding 2,200 storage tanks, and potentially releasing about 90 million gallons of oil and hazardous substances into the adjacent neighborhoods and then the bay—potentially representing one of the worst economic and environmental disasters in U.S. history. These two contingencies bookend the Houston area's flood fears.

Figure 7. Galveston Bay Area Critical Facilities and Suburban Areas at Risk from Catastrophic Flooding



Source: Prepared for the SSPEED Center at Rice University by Rogers Partners Architects

Figure 8. Potential Surge Tide Coming Ashore on Galveston Island



Note: This projected surge tide could result from a hurricane with 15 percent stronger winds than Hurricane Ike. The path of the hurricane is indicated by the dotted line.

Source: *A Texan Plan for the Texas Coast* by Jim Blackburn; map prepared by Christina Walsh based on data supplied by the SSPEED Center at Rice University

A longer-term issue is represented by Houston's dependence on a hydrocarbon-fueled economy. Despite discussions about Houston's economy becoming more diversified, this is still an oil and gas town, with hundreds of thousands of jobs dependent on oil and gas production, transport, and refining, as well as on chemicals and associated support jobs. Around the world and within the United States, scientific consensus exists that the climate is changing, and that hydrocarbon-related emissions are a major factor causing this change.

This has led to widespread concern about the increasing level of carbon dioxide in the atmosphere and the need to take action to prevent worst-case scenarios of carbon dioxide concentrations from being realized. In fact, the Paris climate talks (COP 21) led to general agreement among global leaders to focus on stabilizing these atmospheric levels at 450 ppm or lower.

In order for such levels to be maintained, change will need to occur in the economy to reduce reliance on hydrocarbon combustion. This will be achieved in three ways: by avoiding hydrocarbons, by reducing hydrocarbon consumption, and by removing carbon dioxide from the atmosphere. Avoidance is achieved by switching to renewables—e.g., wind and solar. Minimization is achieved by greater efficiency in the use of hydrocarbons. And removal can be achieved either by technology or by natural processes such as photosynthesis. Avoidance and minimization have led to, among many other things, the electric car, and the market is rapidly responding to this new technology.

In fact, market pressure on the oil and gas industries is mounting from several directions, pushing them to address their carbon emissions. The current status of the movement to curtail carbon dioxide and greenhouse gas emissions is reminiscent of other large-scale social movements such as the anti-apartheid, the anti-tobacco, and the anti-colonization movements, to name a few. Moral pressure is being exerted by Pope Francis's encyclical on climate change titled "*Laudato sí*," perhaps the most revolutionary environmental or faith-based document of the early 21st century. Financial pressure is coming from divestment action and efforts, and from investors questioning the long-term economics of fossil fuel development projects. Legal pressure is coming from issues related to stock offerings and the difference between public releases and private analyses within corporations, as well as from evolving concepts of fiduciary duty.

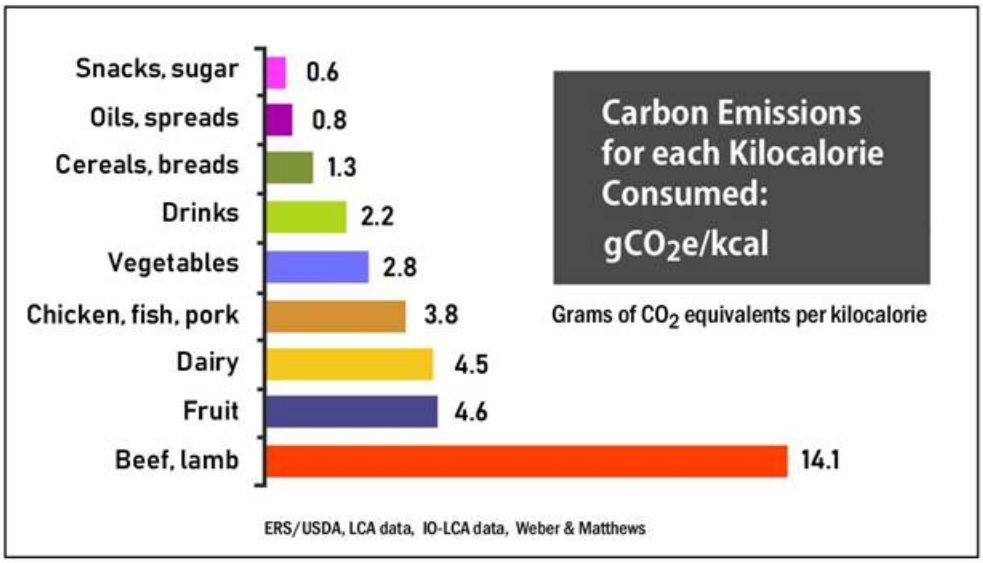
Change is afoot globally. The market is changing, and will continue to change. In the midst of this shift, Harris County finds itself at the center of carbon dioxide emissions in the United States, leading the nation at 68 million tons per year. We are ground zero for the hydrocarbon economy. And if that economy begins to disappear, if the money goes in a different direction, we will find ourselves in a situation analogous to that of the Rust Belt in the mid-to-late 20th century—a time of population movement, growth for Houston, and decline in the upper Midwest. We need to face the reality that Houston's current economic model will need to change in order to succeed. One key for that change and success is for the Houston region as a community to secure storage capacity for the carbon dioxide we emit.

At the current time, technology that is cost-effective and capable of capturing significant portions of U.S. and global carbon dioxide emissions has not emerged. Surprisingly, nature-based solutions are the only viable option for the foreseeable future. The capacity of nature—while substantial—is not sufficient to capture all of the carbon dioxide currently being emitted, a situation that ultimately will lead to limits on the future availability of carbon storage capacity.

While perhaps a bit more remote than either flooding or carbon issues, food supply is of emerging concern from a long-term health and welfare standpoint, as well as from a carbon footprint perspective. Food is a basic need, along with water, shelter, and clothing. Houston currently enjoys excellent local resources for food, mainly community gardens and farmers markets maintained by Urban Harvest and others, yet we import over 17,000 tons of food daily. During Harvey, transportation into and around Houston was disrupted for at least three days across the region, and for weeks in certain areas. With a surge event, that disruption could be much more severe. We also have many areas of town that are simply underserved from a food standpoint—the so-called "food deserts"—which raise any number of social equity and health issues.

But in the longer term, food and carbon will be inextricably tied together, and we should pay attention to that issue now. The 17,000 tons of food that are imported daily to the Houston area come from all over the United States and the world. The food is produced by hydrocarbon-intensive processes—varying from lows of certain vegetables to highs of corn-fed beef and lamb—and travels thousands of miles. And in the future, when a price will be attached to carbon dioxide emissions, the carbon intensity of food will translate into a higher price.

Figure 9. Carbon Intensity of Consuming Food



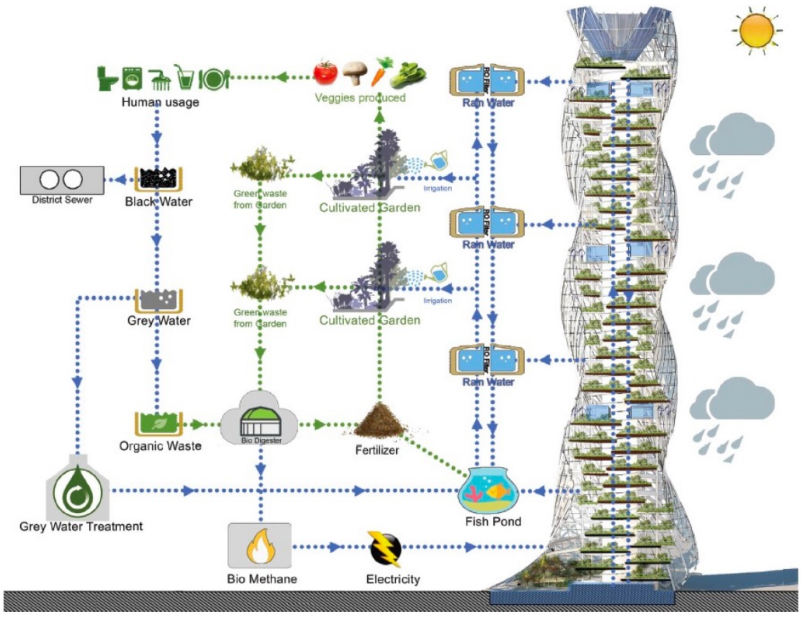
Source: Modified from Shrink That Footprint; http://shrinkthatfootprint.com/food-carbon-footprint-diet.

Learning From Others

We are not the only the city to face these issues. We can and should learn from others, and there is much to learn if we will just look and be open. Take food, for example. The Living Building Challenge—the 21st-century version of the best green building practices for a city—includes urban agriculture as a required element for certification, stating that "no truly sustainable city can rely on globally sourced food production." On top of that strong statement of principle comes the Milan Urban Food Policy Pact (MUFPP), which was set out in 2015 and currently has 163 participating cities. The goal of the MUFPP is to develop food sources that are inclusive, resilient, safe, and diverse by working on issues such as food production, food supply and distribution, social and economic equity, sustainable diet and nutrition, food waste, and governance.

Geographic aspects of urban agriculture are represented by examples such as Melbourne, Australia; New York City; and Singapore. The concept of a "food bowl" is illustrated in Melbourne, where the focus of food production is both within and outside the city, integrating regional production into the food footprint. In contrast, New York City is highly focused on urban agricultural production, concentrating on mapping and understanding both existing food production and potential food production within the city, including details such as the relationship of urban roof farming to floor area ratio. Then at the far end of the spectrum is Singapore, with its proposed 100-story urban agricultural high-rise, the end point of the search for food security for a city with little available land area.

Figure 10. 100-story High-Rise for Growing Food Proposed in Singapore



Source: Surbana Jurong, http://www.eco-business.com/opinion/the-food-tower-looking-up-to-solve-the-global-food-crisis/

Other cities in the world are seriously pursuing climate planning and carbon-neutral options. The C40 Cities Climate Leadership Group has been in existence for some time and Houston is a member, although we do not hear much about this program locally. Its work was featured more prominently during the mayoral administration of Annise Parker than seems to be case currently in Mayor Sylvester Turner's administration, even as many other cities are moving forward on climate issues. The leaders on climate are those cities seeking to be carbon neutral, with the North American members of the Carbon Neutral Cities Alliance including Vancouver, Seattle, Portland, San Francisco, Boulder, Minneapolis, Toronto, Boston, New York City, and Washington, D.C.

Figure 11. Cities Participating in the C40 Cities Climate Leadership Group

Source: http://www.c40.org/cities

In fact, carbon neutrality has become the first major emblem of the 21st century. Numerous corporations have pledged to become carbon neutral or have made significant commitments to renewable energy, as have over 600 universities, including Rice University, in addition to Norway and the province of British Columbia. Carbon-neutral thinking requires an understanding of the carbon dioxide represented by different types of building materials, with wood being very carbon efficient (and, in fact, a carbon sink), while concrete and brick are carbon intensive.

Then there is the more general movement toward resilience—toward being able to withstand and recover from various types of impacts. 100 Resilient Cities is a nonprofit funded by the Rockefeller Foundation that designs communities focused on being reflective (using past experience to inform future decisions), resourceful (recognizing alternative ways to use resources), robust (having well-conceived, constructed, and managed systems), redundant (sparing capacity purposively created to accommodate disruption), flexible (willing and able to adopt alternative strategies in response to changing

circumstances), inclusive (prioritizing broad consultation to create a sense of shared ownership in decision-making), and integrated (bringing together a range of distinct systems and institutions). And then there are places such as Amsterdam that pull it all together under the heading of sustainability—emphasizing renewable energy, clean and healthy air, a circular economy that makes resources out of waste, a climate-resilient and, ultimately, sustainable city that makes improvements across all focal points.

The Dutch also have much to offer on the subject of flooding—if we will listen to them—as they have been addressing sea and riverine flooding for over 1,300 years. When many think of the Dutch, they think of engineering solutions like levees and dikes, or massive mechanical structures such as the Maeslant Barrier at the Port of Rotterdam. But there is much more to Dutch thinking than simply armoring against the water. In fact, their thinking has been evolving and changing in modern times as they learn more about impacts of past actions and pursue better means of management flooding.

For example, the concept of "Room for the River"—giving land back to the riverine system to restore functions lost over decades and centuries of confinement—is a major new concept, culminating in projects such as "Room for the Waal," the river running through Nijmegen. There, the levee along the Waal was moved back to allow a secondary channel to be constructed, resulting in the removal of housing and other structures protected by the prior levee. In other circumstances, farmers have been removed from their land so that the river could again flood certain areas, adding to the ecological wealth of the soil and the system.

Figure 12. The Netherlands Provides "Room for the River" on the River Waal

Source: Anna Loes Nilleson, Defacto Architecture and Urbanism, Rotterdam

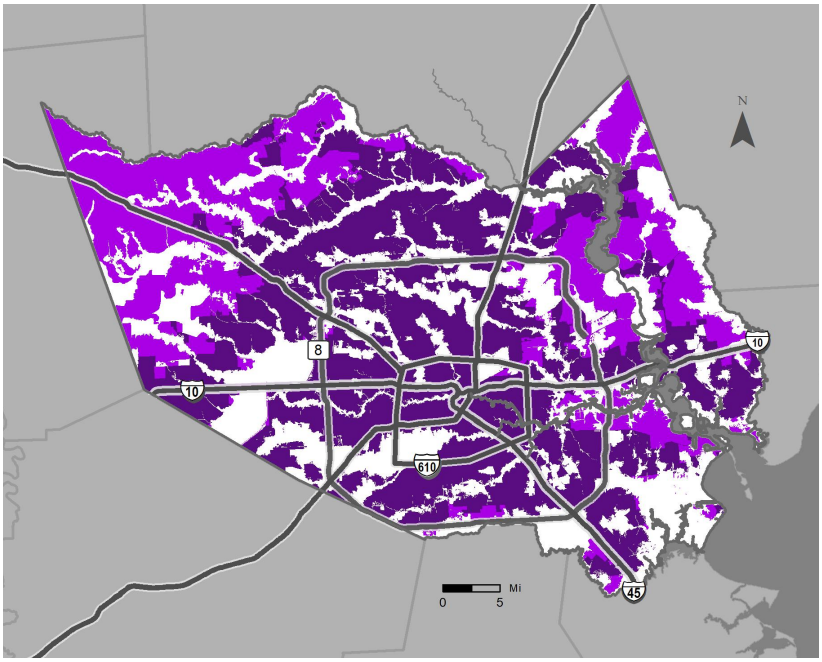
Dutch ingenuity extends to the built environment, where they have learned to live with water. They have perfected the art of flood-proofing buildings to the point where a man can stand in front of his window and watch the water flow by above the windowsill. That concept of living with water is shared by Germany, where numerous examples exist of designs where flooding is simply part of the built environment.

As can be seen, these and many more ideas exist in the world today. We should pick and choose the solutions that work best for us while understanding what direction the world is heading in, as well as the long-term changes this new direction portends.

Houston's Assets

Houston does not face this challenging future without assets. Indeed, we have substantial resources, including some we have not relied upon in the past. Our citizens who are so willing to rise to help one another must be considered one of our strongest assets, for we are a diverse and strong community. We showed our best in the Harvey rescue, but we need to be correctly focused to realize the potential of our wonderful people. Further, on a scale that compares both revenues and GDP, Houston today with a GDP of almost $500 billion ranks above Belgium and Switzerland, and above Walmart and Royal Dutch Shell. The city's economic engine is strong right now, and, if correctly utilized, it can power us to success in the 21st century. But we need to be smart and not squander this current wealth, a trait sometimes missing from our boomtown mentality.

Figure 13. Harris County: The developed area (shown in dark purple) outside the 100-year and 500-year floodplain

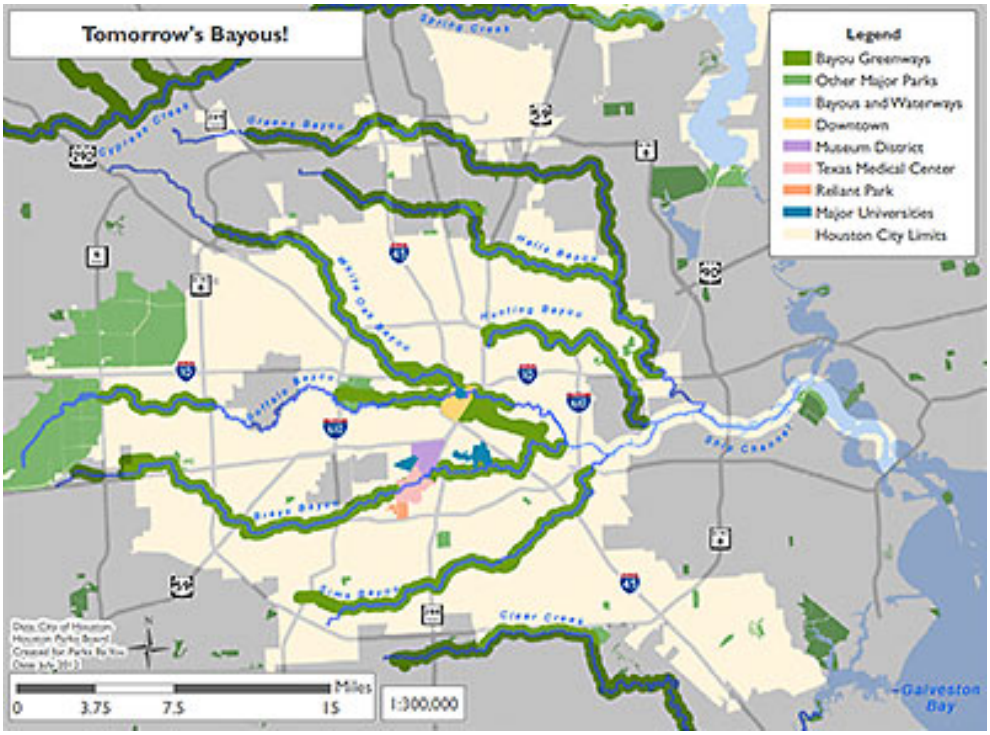


Source: Prepared for Jim Blackburn by Christina Walsh

Our key assets for 21st-century success, however, come from concepts of strength that may seem foreign to many in Houston. A starting point is the developed areas of Houston and Harris County that are outside of the mapped 100-year floodplains. This area is a building block for the future, representing areas with higher elevations away from the bayous and their floodplains. Although there has certainly been flooding in portions of this area in the past, there is a better chance that this part of Houston can be successfully drained in the future, whereas there are areas within the 100-year floodplain that cannot be made safe within the next several decades of planned flood control work. Those areas that we cannot protect need to be identified and also treated as an asset, but not as a place for human habitation.

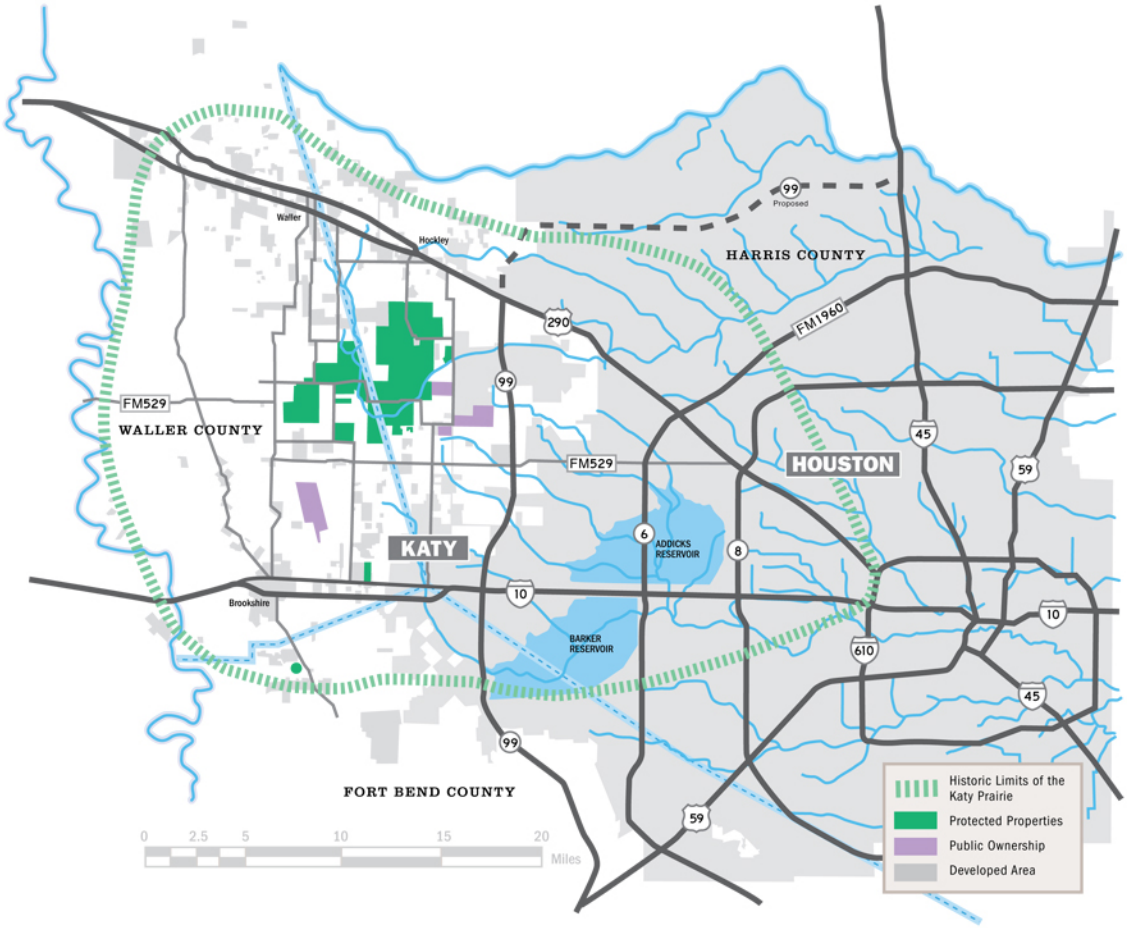
From a flood protection standpoint, three assets stand out for special attention: First, the Katy Prairie is a flood storage resource. It has substantial capacity to store floodwaters both within the soils and on the surface, particularly with the assistance of small check dams and levees. Additionally, the Addicks and Barker reservoirs are the best flood-control investments ever made in Harris County; they have protected the west side of Houston and Downtown since the early 1950s. Today, they need to be and should be repaired and perhaps excavated, but they are excellent resources that need to be fully and safely utilized. And third, the Bayou Greenways project provides the underpinnings for a water management system that could include structural flood control features such as swales and detention, as well as trails and open spaces that would provide the spine for a "Room for the Bayou" concept for Harris County and beyond.

Figure 14. Houston Bayou Greenways



Source: The Houston Parks Board

Figure 15. The Katy Prairie Reserve and Addicks and Barker Reservoirs



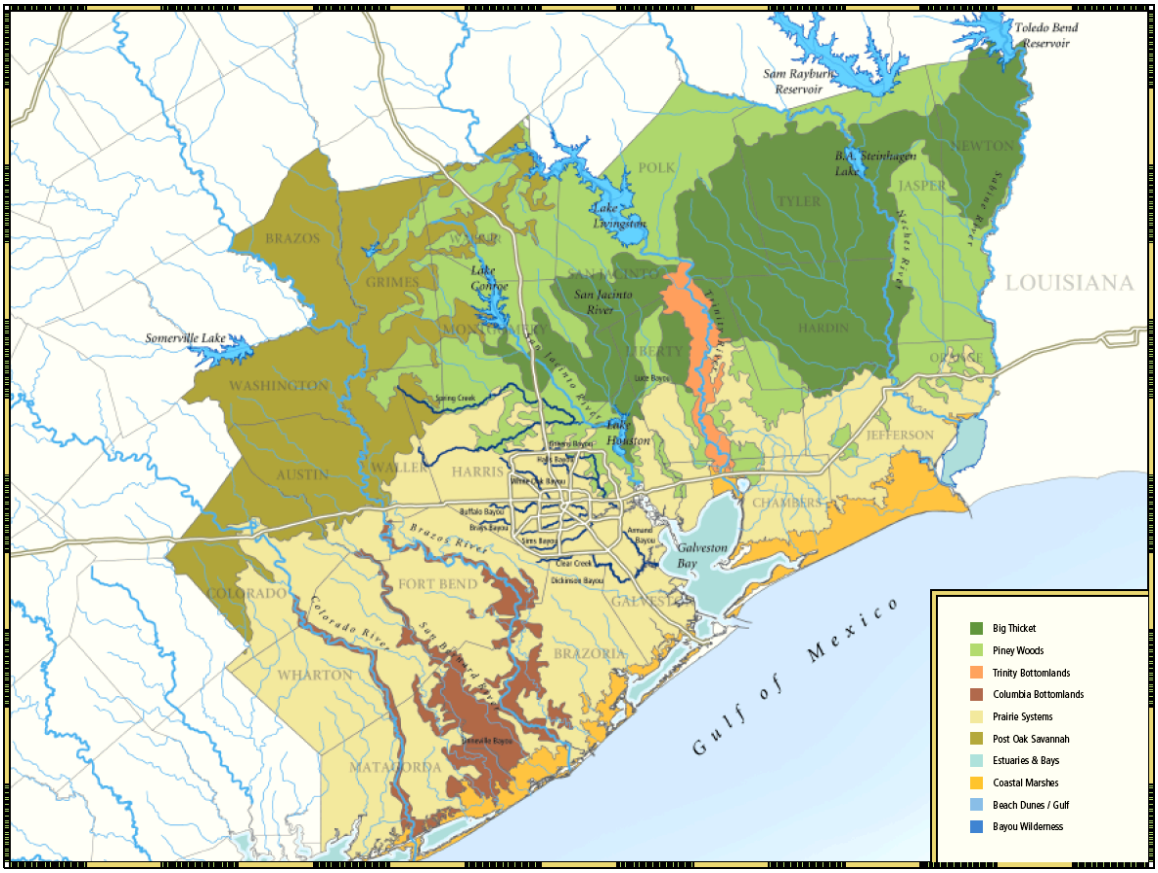
Source: Katy Prairie Conservancy, http://www.katyprairie.org/about-us/

From a food standpoint, Bob Randall and Urban Harvest have provided us with numerous gifts that can be used as starting points for the food-resilient Houston of the future. Randall's masterwork, *Year-Round Vegetables, Fruits and Flowers for Metro Houston*, sets out how and when to grow almost any foodstuff, and more. Houston enjoys a year-round growing season, balanced rainfall, and abundant cropland, all critical ingredients for food independence. Additionally, Urban Harvest and other groups and growers have more than 100 community gardens and support farmers markets throughout the metro area, which are supplied by farmers enjoying the prime farmland that surrounds Harris County. We have more ingredients for food independence than most areas of the United States and the world; we just need to tap them.

And then consider the climate. Surprisingly, the most important key to climate resilience for Houston may be the maintenance and restoration of natural ecological systems with which the Houston region is endowed. We have forests to the north that vary from the more arid

Post Oak Savannah to the northwest, to the pine forest of the northern counties, to the dark and mysterious hardwoods of the Big Thicket to the northeast. We have wet bottomlands along the Trinity River to the east and dry bottomlands along the Brazos, San Bernard, and Colorado rivers to the west. We developed most of Houston on the prairie system that extends from east to west parallel to the coast, and we have extensive marshlands along Galveston Bay. These bays are also ecosystems where fresh and salt water combine to produce a highly productive estuary that is bounded by barrier islands and the Gulf of Mexico. This ecological diversity is unmatched among U.S. cities, yet we are unaware of this value and have not begun to understand how to appropriately value, and create an economy around, these incredible natural systems—a situation that will change.

Figure 16. Houston's Ecological Capital



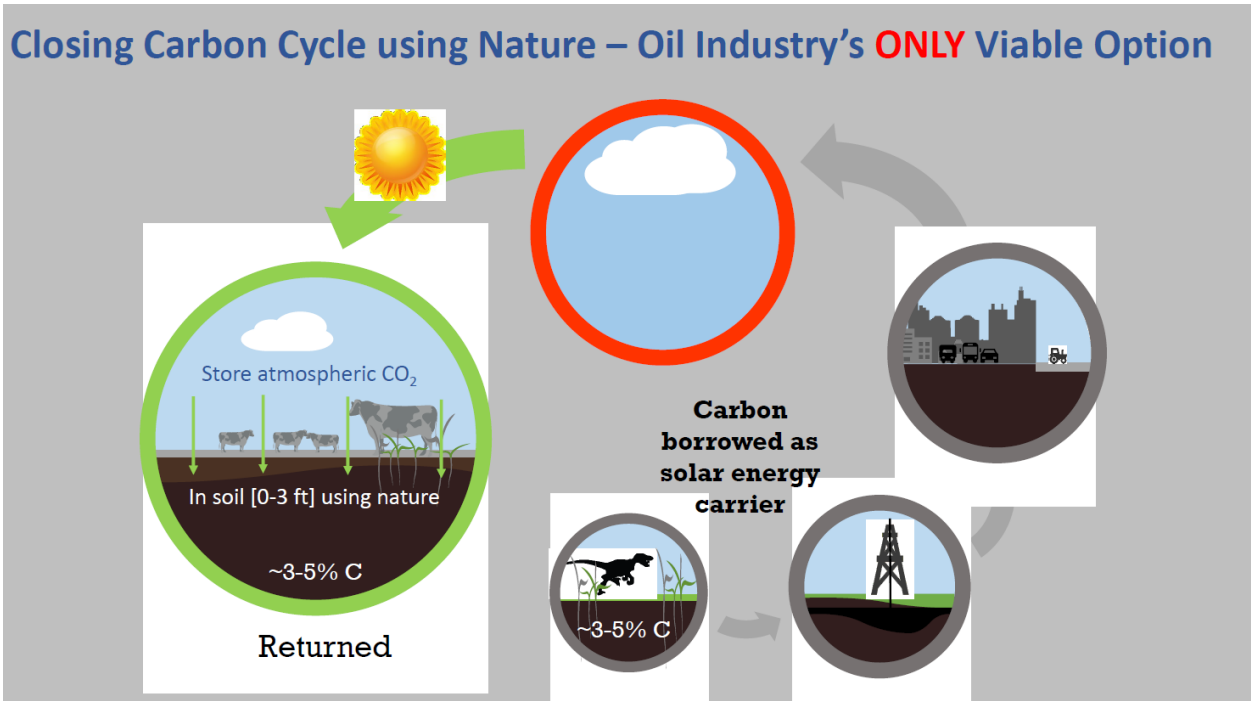
Source: Houston Wilderness, http://houstonwilderness.org/about-ecoregions/

Generally, the functions performed by these ecological systems have not been fully valued, although some ecological values such as grazing cattle on native prairies and leasing land for dove, deer, and quail hunting generate value for landowners, as does harvesting timber from private forests. Our bays produce tons of shrimp, oysters, and fish, offering value to the public rather than to a landowner per se. Importantly, these ecosystems provide other

services for humans that are not yet valued by society, such as the ability to remove carbon dioxide from the atmosphere. Trees can remove 4 to 5 tons of carbon dioxide per acre per year from the atmosphere—or more, depending upon the species—and some marshes can remove up 25 tons of carbon dioxide per acre per year, although Texas coastal marshes are more likely to remove about 5 tons per acre per year. And restored prairies, with the right type of grazing, can also achieve comparable removal rates. Together, these systems offer a tremendous value to Houston's future if this potential can be captured.

The key to capturing this value is to develop a trading system that allows landowners to be paid for storing carbon. Storing carbon in the ground is just like growing potatoes—it is a crop, a commodity. In the case of carbon farming, however, the goal is to restore the natural carbon cycle by returning the mined carbon back to the soil, creating a circular economy similar to that identified as a goal for Amsterdam. In turn, this stored carbon allows gasoline refiners to market "carbon-neutral gasoline," e.g., gasoline for which the emitted carbon dioxide has already been stored in advance and paid for by the company.

Figure 17. Illustration of the Closing of the Carbon Cycle Implicit In Using Nature To Remove and Store Carbon Dioxide Emissions

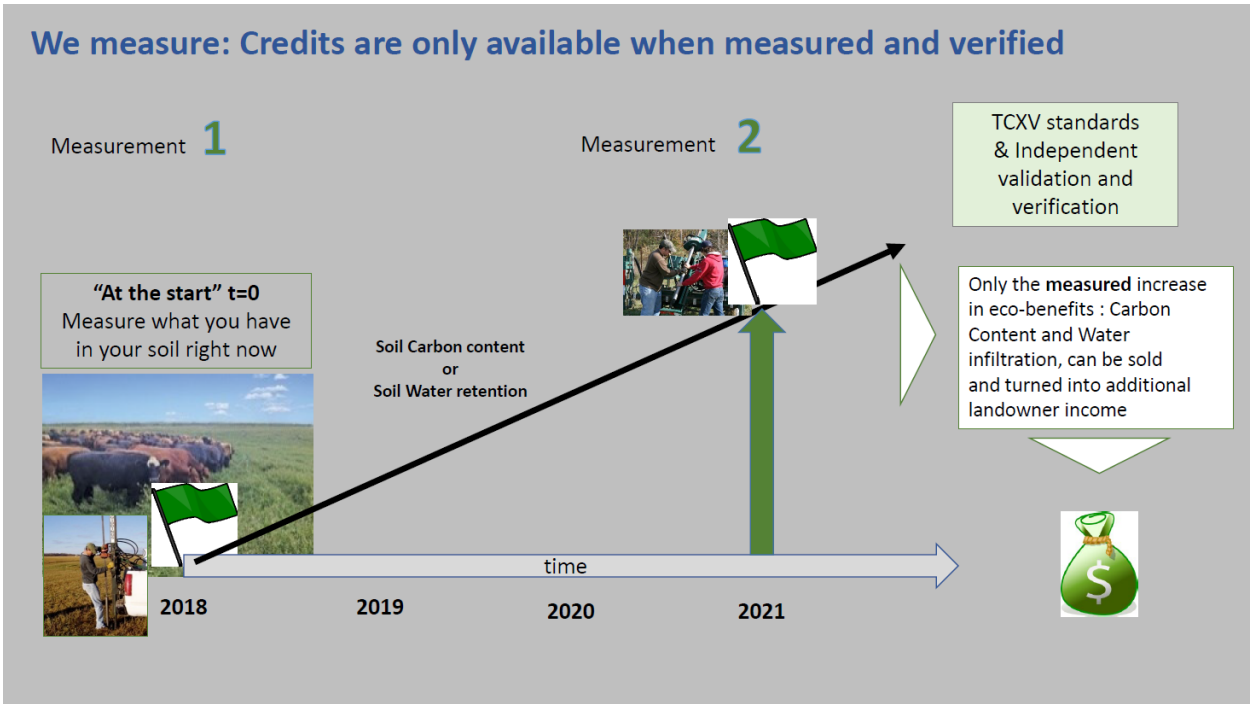


Source: Henk Mooiweer for the Soil Value Exchange (SVX)

According to research from the SSPEED Center at Rice, it takes about a football field of prairie to offset an average car's carbon footprint for a year. If a refinery that produces 150,000 barrels per day wished to be carbon neutral, it would take about one million acres of prairie to offset its footprint and another four million to offset the footprint of its customers, representing in total about 3 percent of the land area of Texas. And if you want to offset the global footprint for a major oil company such as Exxon, as well as its customers, as determined from publicly available records, about 600 million acres would be needed—25 percent of the pasture lands of the United States. Now that is a large goal, but as one oil company employee was heard to say, "it's doable."

A system to unlock this potential of nature has been developed by the SSPEED Center at Rice. Originally called the Texas Coastal Exchange, the concept has evolved beyond the Texas coast and is now called the Soil Value Exchange (SVX). The basic concept is that a landowner must measure the starting carbon content of their land and then measure the increase at a later point in time in order to sell the commodity of "stored carbon." The "sweet spot" for carbon sequestration is the middle part of the United States, where a willing buyer-willing seller approach to addressing climate change by storing up to one-third of the United States' 7-billion-ton carbon dioxide emission footprint in the nation's prairie grasslands and marshes would likely be welcomed.

Figure 18. Illustration of the Testing Protocol under the Soil Value Exchange Concept of Selling Only Measured Carbon Storage



Source: Henk Mooiweer for SVX

Houston's Path to Success

Each of the concepts set out in the ideas from others section are worthy of inclusion in a long-range strategy. But where possible, the premium policies will be those that address all three goals—climate, flood, and food resilience. There are certainly policy options that meet these criteria.

The first policy that encompasses all three objectives is utilizing adaptive multi-paddock (AMP) grazing to raise grass-fed beef and store carbon and water in the restored ecological system. Harris County is the leading carbon-emitting county in the United States and needs about 15 million acres of land to offset its carbon footprint. That land area exists under private ownership in all of the counties surrounding Houston. It is estimated that lands supporting AMP grazing will store about 4 tons of carbon dioxide per acre per year. These same lands will also store water and recover in the case of coastal surge flooding, or will knock the peak off of riverine flooding along the Brazos River, for example. By working with private landowners (carbon farmers), SVX proposes to establish a trading system that will benefit both landowners and carbon dioxide emitters. If the carbon market proposed by SVX or other entities can be initiated, then landowners will be able to be paid for carbon and water storage, in addition to being able to sell grass-fed beef.

Related to new economic opportunities, the recreational potential of these protected and restored lands is huge and totally underutilized, representing a fourth potential overlap with food, flooding, and climate on these key coastal lands. A proposal has been developed to combine existing protected lands owned by the federal, state, and local governments and nongovernmental organizations of our coastal region into a national park unit called the Lone Star Coastal National Recreation Area (LSCNRA). Initiated at the SSPEED Center following Ike and carried forward by National Parks Conservation Association and the Lone Star Coastal Alliance, this proposal represents a new model for economic development in low-lying coastal areas. It is a model that leverages our region's world-class nature-based resources, requires little or no additional infrastructure, and recovers quickly following storms, enhancing coastal resilience. More information can be found at www.lonestarcoastal.org.

Another example of the three goals coming together is in the Katy Prairie west of Houston. A large amount of water was stored on the Katy Prairie during the Tax Day flood. These same lands are useful for both AMP grazing for beef and increased carbon storage (depending upon soil type), and could be managed to protect the Addicks and Barker reservoirs.

Similarly, if we focus on development in the developed areas of the city and county outside of the floodplains, we can address flooding and carbon by increasing development and population within the urban core, thereby reducing commuting distance. This "Room For the Bayou" approach also offers the further potential for community gardens to be developed in the green space, along with major recreational opportunities with hiking and biking trails, representing another intersection of the four policy goals.

Drawing from a Netherlands concept, all properties in Houston and Harris County should become responsible for their own runoff—meaning we all must intercept, slow down, and store our rainfall runoff. This can be done by rethinking landscape design of every home and commercial structure in Houston. Among other solutions, vegetable gardens can retain and store rainfall in addition to producing food. And if this is done at scale across the city, we will have a significant reduction in our food supply's carbon footprint.

In a more general approach to food, we could establish urban and regional food bowls much like in Melbourne. In this way, we could expand the area within which we grow food. Depending on farming techniques (e.g., permaculture), these areas can also store significant amounts of water. And if they are successful at increasing regional food supply, our food supply's carbon footprint will continue to decline. Additionally, with production concepts such as no-till farming, it will certainly be possible to sequester carbon along with agricultural production.

Finally, a structural flood-control alternative needs to be initiated soon to protect the western shoreline of Galveston Bay and the Houston Ship Channel industrial complex. Although much attention has been focused on the so-called "Ike Dike," it would cost over $10 billion and likely take 20 or more years to build. While we should pursue that alternative, we also should start permit applications to build the less expensive mid-bay solution, which would offer 95 percent of the protection of the Ike Dike and could be constructed in a shorter time frame for about $3 billion. Ultimately, we will need both.

The mid-bay alternative has been termed the "Archipelago of Access" by Rob Rogers, an architect working with the SSPEED Center. This name emphasizes that this flood control device offers much more than protection from a 25-foot surge. It also offers significant access to Galveston Bay, a recreational venue that suffers from poor public accessibility. Such a solution will ultimately protect Galveston Bay from a major environmental disaster, preserving this ecological system and source of seafood for decades to come. Done correctly, this Archipelago of Access could become a landmark, a destination, and a statement about resilience and design. And it will help protect a massive carbon investment in tens of thousands of homes and the world's largest manufacturing complex.

This paper begins with blues musician Robert Johnson who, as the story goes, was at a crossroads in his career—but he became a brilliant guitar player after making a deal with the devil. The proposals in this paper—though certainly different from Houston's thinking today—are hardly deals with the devil, although some may beg to differ. The important point, however, is that Houston today is at a crossroads, and, to borrow from the Robert Johnson metaphor, Houston needs to learn to play the guitar.

Author's Note

This paper is adapted from a presentation made on February 27, 2018, before an audience assembled at the Houston Museum of Natural Science on behalf of Urban Harvest and the Houston Museum of Natural Science. However, the author is solely responsible for the content. The PowerPoint for the original presentation is available at http://urbanharvest.org/blackburn-lecture.

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