By Kathleen McCormick

LATE LAST AUGUST, HURRICANE HARVEY SWEPT THROUGH TEXAS, CAUSING WIDESPREAD FLOODING AND DESTRUCTION WHEN IT STALLED OVER THE HOUSTON METROPOLITAN REGION, dumping over 50 inches of rain in four days. Harvey paralyzed Houston, the nation's fourth-largest city and a global center for the oil industry, and it tested the resilience of a state that's home to nearly one in twelve U.S. workers. As Houston recovers and faces the next hurricane season, preparing for inevitable and potentially more devastating storms is highly stressful for urban planners, public officials, business leaders, and others who live and work there. Having been slammed with three 500-year floods in the past three years, the region is reconsidering its "build and let build" attitude. Harvey has occasioned a rethink—though not a complete redo—regarding urban planning and development.

Nicknamed the "Bayou City," Houston is naturally flood-prone. But critics say the region's longtime approach to urban planning (read: the lack of it) has resulted in zone-free development, low-density urban sprawl, and weak regulations that have led to or exacerbated destructive flooding. Many are calling for resilience planning that takes a regionwide, long-term, and greener approach to land planning, urban development, and storm water management.

Credit: Maribel Amador/SWA

Houston's city and county officials are pivoting to stricter regulations on building new homes in floodplains, and considering a wide range of flood mitigation strategies, infrastructure needs, and development changes. These include creating new flood barrier and detention facilities, rehabilitating urban drainage systems, buying out more homes in flood-prone areas, and creating green infrastructure. An important test of resilience-building will be how well the region can communicate and collaborate on these strategies.

"Harvey was a wake-up call that it might be time to revisit the sins of the past," said Houston director of planning and development Patrick Walsh, who presented a summary of Harvey's impacts at the Lincoln Institute's 2017 Big City Planning Directors Institute last October. Walsh has been involved in several aspects of post-Harvey planning. "There's a broad consensus from the community and from developers and builders that we need to do better, that we're all in this together. We need a resilient city." Houston has recovered reasonably well in the short term, said the Houston native, "but many people are still suffering." A new way of operating may be needed, he added, "if we want to continue to attract talented people and businesses to the city."

Many are calling for resilience planning that takes a regionwide, long-term, and greener approach.

(Not So) Equal Opportunity Disaster

Houston has a long history of flooding from tropical storms. Hurricanes in the 1920s and 1930s caused catastrophic floods that killed thousands. Tropical Storm Allison triggered mass flooding and caused 20 Texas deaths in 2001. Harvey came on the heels of the Memorial Day Flood of 2015 and the Tax Day Flood of April 2016. But Harvey was exponentially bigger, causing flooding in about one-third of the Houston metro region, including highways, waste-water treatment plants, and City Hall in downtown Houston. Half of the homes and businesses that were flooded by Harvey had not flooded previously, while many others flooded for the third time in three years. Harvey caused 68 deaths and $125 billion in damages in Texas, according to the National Hurricane Center's official report, which noted that it was the most significant tropical cyclone rainfall event in U.S. history, both in scope and peak rainfall amounts, since reliable rainfall records began in the 1880s. In the Houston area, Harvey damaged an estimated 300,000 housing units and displaced more than 1 million people, forcing some 42,000 of them to seek emergency shelter. The storm left 200 million cubic yards of debris.

With climate change, rising ocean temperatures have fueled more frequent and more intense storms and higher sea levels, increasing the risk of flooding. Harvey could have caused an even greater catastrophe. A storm surge from the Gulf of Mexico could have destroyed oil refineries and sent toxic floodwaters up the Houston Ship Channel to the Houston region. That threat remains, and many say Houston cannot rely on past data to predict future storms.

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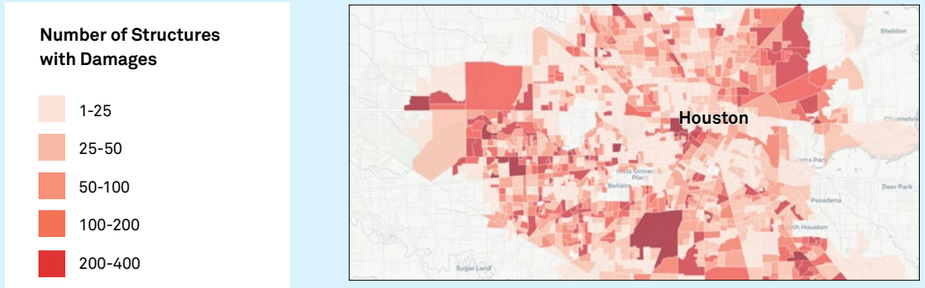
Harvey slammed the region's economy and quality of life. Before the storm—spurred by jobs in oil and gas, tech, healthcare, and other industries, as well as relatively cheap and plentiful housing—Houston was considered an affordable region. Its median July 2017 home price of $230,000 compared to a national median of $293,400, according to Redfin. Housing supply declined and costs jumped in the months following Harvey as residents competed to resettle in neighborhoods that weren't flooded. Roughly 80 percent of Harris County homeowners lacked flood insurance; many weren't located in areas designated as flood-prone. Prospects for renovating or rebuilding damaged homes, and the availability and cost of flood insurance, remain uncertain. Recipients of post-Harvey federal disaster assistance will have to purchase flood insurance, the *New York Times* reported.

While homes in the region's high-, middle-, and low-income neighborhoods alike were affected, many regional leaders note the impacts on middle- and lower-income households have been much greater, considering these households have fewer resources to rebound from flood damages, lost wages, lost jobs, and the lost fabric of community. National media reported on problems faced by renters in poorer neighborhoods near petrochemical plants and other industrial areas, including high levels of toxins in the floodwater and air, and lack of resources for storm preparedness, response, and recovery. Many renters could not pay for proper home clean-up or find alternative housing.

As of early December, the budget-strapped Federal Emergency Management Agency (FEMA), facing clean-ups from multiple climate-related disasters, had promised $160 billion in post-Harvey aid for Houston, in addition to funds for individual recovery assistance and debris pickup. The federal funds are only a fraction of what's needed to recover and plan for resilience. The *Houston Chronicle* noted the state legislature won't reconvene until 2019, but lawmakers will be asked to consider a range of proposals, such as increasing local governments' ability to bar development in certain areas, changing the operational guidelines of reservoirs,

Figure 1

City of Houston and FEMA Estimates of the Number of Structures Damaged During Harvey



Note: City Damage assessments are based on visual observation. This data should not be viewed as a comprehensive damage survey.

Credit: January Advisors. © OpenStreetMap © CartoDB

and mandating disclosure of flood risk for new home buyers or renters. Meanwhile, officials in Houston's Harris County are considering a bond referendum to finance more than $1 billion in flood control projects.

Magnified Flood Risks

Houston is often criticized for its lack of zoning: It's the only major U.S. city without a zoning code to help determine land-use planning and development rules. While urban planning alone can't prevent a disaster like Harvey, critics have said that zoning, along with careful land-use planning and stricter development regulations, could have prevented much of the destruction (figure 1).

Planning and Development Director Walsh maintains that zoning would not have made the city less flood-prone. "It's time that we dispel the myth of zoning," he said. "If we were a zoned city, we would have been a zoned, flooded city with Harvey. Any zoned city that is flat like ours would have flooded." He said the city's "tremendous amount" of development regulation such as setbacks, parking, and landscape requirements, plus a market-driven approach, determine how and where development occurs. "We look a lot like a zoned city. We have commercial development along major thoroughfares and neighborhoods tucked away on smaller streets," he said.

According to Walsh, other factors contributed to Harvey's impact, including the storm's extreme rainfall, the region's clay soils, which don't absorb water well, its aging and inadequate storm water infrastructure, and a "significant amount of low-density sprawl" in the surrounding county.

Walsh noted that Houston drains from west to east and that intensive growth on the western periphery has increased the volume of runoff flowing through the city. "Altering this growth pattern will be difficult, but we should be considering options like protecting the Katy Prairie," he said, referring to the shrinking remnant of the vast prairie and wetlands west of Houston.

About 20 miles west of downtown, thousands of homes that flooded for the first time had been developed decades ago inside the "dry" basins of the Addicks and Barker reservoirs. The U.S. Army Corps constructed the basins in the 1940s to control the flow of water along Buffalo Bayou and prevent downtown flooding. Because FEMA maps didn't place these basins in the 100-year floodplain, mortgage companies did not require flood insurance, and prospective home buyers had not been informed of the risks. Concerned that the reservoirs would fail during Harvey, the

Corps allowed a controlled release of water from the dams into the bayou, inundating downstream areas, including downtown.

Unchecked development has heightened flood risks regionwide, according to hydrologists, environmental engineers, and federal officials interviewed in 2016 by the *Texas Tribune* and *ProPublica*. At an elevation of about 50 feet above sea level, the region is drained by 22 watersheds in which storm water flows west to east in a network of bayous and drainage channels that empty into the Houston Ship Channel. Once a great expanse of prairie, wetlands, and woods that were better able to absorb rainwater, much of the area is now covered with low-density development.

A city of 2.2 million people, Houston spans 627 square miles. It lies within 1,777-square-mile Harris County, which has nearly 4.6 million residents, according to 2016 U.S. Census estimates. The vast metro region has a population of 6.8 million people and, at 9,000 square miles, is equivalent in size to New Jersey. Since 2000, over 80 percent of Harris County's nearly 1 million new residents have moved into unincorporated areas, connected by thousands of square miles of paved streets, parking lots, and over 360,000 new buildings, according to the *Houston Chronicle*. Development has increased storm water runoff, and during Harvey, the record amount of rainfall caused storm water, mixed with toxic chemicals and sewage, to rise to new heights and spread out, inundating areas previously not considered vulnerable to flooding.

"Cities that have a strong planning culture, including general plans and a tool kit of policies they use as part of everyday practice—with disaster plans, natural hazard mitigation plans, and zoning that reflects risk—tend to do better," said Laurie Johnson, a Bay Area planning consultant who specializes in catastrophe risk modeling, and coauthor of *After Great Disasters*, published by the Lincoln Institute. Johnson, lead author of a recovery plan for New Orleans after Hurricane Katrina, said that one of the biggest tests for Houston is whether the city and county can work together effectively.

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Resilience Efforts

In October 2017, Harris County officials released a 15-point plan calling for strategies such as a regional flood control organization to coordinate water management across county lines, and tougher regulations on development in flood-prone areas. The plan also proposed buying out all homes that are located in the 100-year floodplain or that have flooded repeatedly, an expansion of an existing county buyout program that could cost billions.

The City of Houston has begun to define its own strategies. "We're now focusing on recovery and looking at long-term resilience," said Stephen Costello, a former city council member and an engineer with 40 years of storm water management experience who was appointed the city's chief resilience officer in 2016 by Houston Mayor Sylvester Turner. Costello said Houston does not have a resiliency plan per se, and that his role is "to open the discussion, and hopefully the regulatory issues." He organized and led the city's redevelopment and drainage task force, which issued a report in February addressing rules on detention for redevelopment, placement of fill dirt in floodplains, and protection of the city's rights of way that obstruct drainage flow.

In September 2017, Mayor Turner appointed former Shell Oil Co. Chairman and President Marvin Odum as Houston's chief recovery officer. Odum led Shell's business recovery after Hurricane Katrina. He is charged with expediting disaster recovery and preparing the city for the next record-breaking storm. The resilience and recovery officers report to the mayor, who brings policy recommendations to the 16-member elected city council for a vote.

The upscale Meyerland neighborhood is among the areas under consideration for a buyout program. Rice University's Baker Institute for Public Policy recommended such a program in its post-Harvey report. Credit: Citysqwirl, via iStock/Getty

The city and county collaborate through a storm water management joint task force and with the Harris County Flood Control District (HCFCD), a nonregulatory special district that develops storm water management plans and builds and maintains flood control infrastructure. The county's five elected officials determine regulations for unincorporated areas. Each of the county's 34 municipalities has its own criteria for drainage systems, including storm water detention storage. HCFCD, among others, has asked for a "big-picture regional planning effort," said Rob Lazaro, communications officer. Costello said he doesn't favor a regional flood mitigation authority. "Rather than creating an overlapping entity, we need intergovernmental agreements."

Houston is considering building a coastal barrier of dunes and gates to provide storm-surge protection for the region's vulnerable oil refineries and shipping channel. Construction of the system could cost $10 billion. Harris County has supported the concept, which was also included in a request for FEMA funding.

Development Regulations

David Hightower, executive vice president of Midway Companies, a Houston-based developer, is a member of the city's redevelopment and drainage task force. He said solutions may "require some out-of-the-box thinking, which is a challenge when you're dealing with bureaucrats managing over 600 square miles." Developers would consider "reasonable, equitable, fairly applied" rules, but they object when people blame development such as strip malls for flooding, "when factors like aging and inadequate drainage infrastructure" are really to blame, Hightower asserted.

Hightower, also a member of a Harris County flood mitigation committee, said 2009 county drainage regulations proved effective. The county analyzed where and how Harvey flooded homes in its unincorporated areas, he said, and found that only 467 built after 2009 were flooded.

"It's the areas that are much older, like Meyerland, developed in the 1960s and located mostly within the city limits, that got hit really hard," said Hightower. In Meyerland, an upscale enclave of 2,000 homes located west of downtown Houston along Brays Bayou, some homes have flooded three years in a row. Many homeowners say these older homes have flooded because of newer upstream development, and they want buyouts.

Planning consultant Johnson said risk modeling can show scenarios that link development with flooding risk. "You can show if you put a house here, that impervious surface will affect the system in a certain way." Three years of 500-year storms in Houston "shows that the past is no longer a good indicator of the future," she said. "What is lacking is a common understanding of the future risk, and that's the challenge right now with a changing climate. As modelers, we have to add in the range of possibilities, the uncertainty."

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Houston *is* using climate modeling to predict future flooding impacts, according to Walsh. Post-Harvey, Harris County is requiring that all new buildings on unincorporated land be raised at least 24 inches above the flood plain. The first finished floor of new construction must be at least as high as the 500-year flood level. New houses in the floodplain must be built on piers and cannot use fill dirt to elevate construction. The regulations received wide support from the Greater Houston Builders Association, Houston Real Estate Council, American Council of Engineering Companies of Houston, Houston Apartment Association, and the Houston chapter of the American Institute of Architects.

"These regulations apply in 100-year, 500-year, and outside of 500-year floodplains," said Christof Speiler, vice president and director of planning for Houston's Huitt-Zollars architecture and urban planning firm and project manager for the Greater Houston Flood Mitigation Consortium. "These are very fundamental changes that have a very real impact on new development."

The regulations apply only in unincorporated areas of the county, however, and Houston and other municipalities make their own regulations, Speiler noted. It is unlikley that new regulations will stop homes from flooding in older developed areas, however, because "a very large portion of the city is legacy building stock, which preceded any flood regulations at all."

Walsh agrees that many homes were built in places where they never should have been, such as along the bayous. Four out of five structures in the city's official floodplain areas were built before stricter regulations were adopted in 1981, he said. "For decades, we have allowed development in the floodplain, but we've had to build it higher." Current city regulations require new or rebuilt homes to be raised one foot above the 100-year FEMA floodplain elevation; as a result, in some neighborhoods, ground-level homes that were flooded by Harvey sit side-by-side with elevated homes that were not.

In January, Mayor Turner proposed new development regulations that would require all new buildings to be raised two feet above the projected flood level, noting that Houston could not call for more state and federal flood and resilience funding "without showing that we are moving urgently at the local level to find solutions for ourselves."

Roughly 80 percent of the city's buildings located in mapped floodplains were constructed before the maps were drawn. Harvey inundated some areas that had flood control measures in place. Credit: Karl Spencer, via iStock/Getty

Houston, with its limited and aging storm water management infrastructure, faces the daunting task of preparing for more of the severe storms experts attribute to climate change. Credit: (left) Houston First Corporation; (right) Geoffrey Lyon/SWA

Floodplain and Detention Mitigation

Detention is Houston's main method of flood control, but lack of available land limits the city's ability to build large detention infrastructure that could handle Harvey-like flooding. HCFCD manages about 15,700 acres of storm water reservoirs across a 1.1 million-acre area. In the past year, HCFCD invested over $100 million in capital improvement projects to repair detention basins and widen and deepen channels along the county's major bayous. The state plans to pay for a third reservoir to better protect areas west of Houston and to avoid the kinds of releases from Addicks and Barker dams that swamped Houston during Harvey. A systemwide upgrade to protect the region fully from a 100-year storm would require an estimated 52,000 additional detention acres, but the cost of acquiring that land exceeds HCFCD's annual budget several times over.

Mayor Turner in January proposed new detention rules based on the recommendations of the redevelopment and detention task force. Under current measures, only new development is required to manage storm water runoff from rooftops, parking lots, and other impervious surfaces by means of detention. The task force advised closing this loophole, so that a developer intending to build a skyscraper on a parking lot would now have to provide detention to support effective drainage. Another new rule would require those redeveloping lots under 15,000 square feet to pay a fee in lieu of providing detention. Proposed changes also would provide detention credit for low-impact development options like green swales—typically planted, shallow basins designed to absorb and filter runoff.

Much of the city's detention and drainage infrastructure dates from the 1940s and '50s. A January 2017 report from Houston's Storm Water Maintenance Branch said certain areas developed before 1985 were prone to flooding because of "inadequate and undersized infrastructure." The city spends over $250 million per year on street and drainage infrastructure, and its public works department estimated it would cost $650 million annually to rebuild and maintain decaying storm water infrastructure to reduce flood threats along the city's bayous, remove properties from the floodplain, replace storm sewer and outfall pipes, regrade ditches, and accomplish other upgrades.

The city faces other big decisions. Harvey flooded 18 of the city's 39 waste water treatment plants, eight of which were completely inundated, said Costello. Does the city retrofit and design protection for inundated plants, or does it relocate them to other sites? Does it consolidate the waste water treatment system at an estimated cost of $10 billion?

New Mapping Needed

Walsh said the city adopted more stringent floodplain mitigation regulations after FEMA reissued maps for Harris County in 2007. Homes built after 2007 are generally elevated and protected from floods. In neighborhoods that were flooded by Harvey, many homes that were not elevated had their first floor flooded. New maps would help regulate floodplain development and facilitate other resilience efforts, he said.

FEMA maps floodplains and flood levels by modeling how water spills out of creeks, bayous, and ditches during storms and by projecting where and how high the water would rise. In Harris County, a "100-year event" equates to between 12 and 14 inches of rainfall within 24 hours, and a "500-year event" produces between 17 and 20 inches of rainfall within 24 hours. Initial post-Harvey National Oceanic and Atmospheric Administration estimates for Houston increased the 100-year-event level to 18 inches of rainfall within a 24-hour period. Data show that Harvey was at least a 500-year event across the county and in some areas rose above a 1,000-year storm level.

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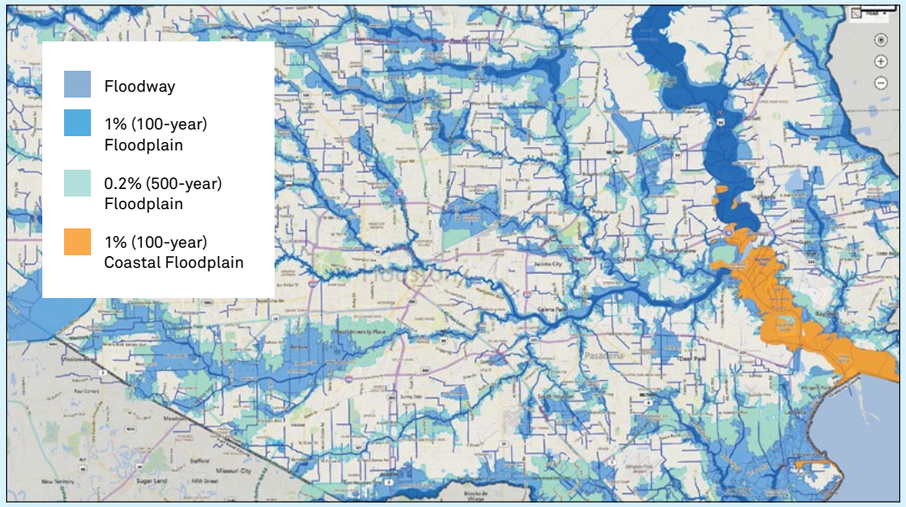
Costello noted, however, that remapping might come too late, at too high a cost, and with too little effect. "Even if we were to decide to remap, it would take a couple years for regulations to change," he said.

Figure 2
Houston Floodplains Credit: Federal Emergency Management Agency.



– A floodway is defined as a waterway and adjacent land, kept free of obstruction, that can carry flood water downstream and keep water levels from rising above a certain height.
– A 100-year flood has a 1 percent chance of occurring in any given year.
– A 500-year flood has a 0.2 percent chance of occurring in any given year.

Harvey's record rains dispersed waves of floodwater mixed with toxic chemicals and sewage throughout the city, depositing tons of debris and silt, and raising questions about the residue's composition. Credit: Jonnu Singleton/SWA

Buyouts

A post-Harvey report from Rice University's Baker Institute of Public Policy, recommended a home buyout and removal program, noting that many homes had flooded three or more times since Tropical Storm Allison.

Although buyouts involve an initial public investment and remove properties from tax rolls, they mitigate flood-risk and reduce the cost of repeated damage to property and infrastructure while bolstering communities' resilience (Freudenberg et al. 2016).

Since 1985, the HCFCD's voluntary buyout program has purchased more than 3,000 properties; over 1,060 acres have been restored as natural floodplain. By November 2017, the county had received over 3,000 requests for buyouts related just to Harvey, and in February HCFCD notified the state it would request $180 million for home buyouts. Countywide, over 100,000 homes and other buildings currently sit within 100-year floodplains along 2,500 miles of waterways, said HCFCD.

Advocates say more buyouts would have a host of resiliency benefits: They would relocate people out of harm's way and eliminate future flood damages and health and safety risks, reduce repetitive subsidized flood insurance payments and federal disaster assistance, and allow for restoration of the floodplain to its natural function for storm water storage and release.

On the other hand, a larger scale buyout program could cost billions and have other downsides. "In a lot of very established subdivisions, people like their homes and schools, and you'd damage the fabric of the community," said Walsh. "How aggressive should a buyout program be? Do you take the first row of houses backing up from the bayou? Do you take the first three rows? We have limited resources. It's a difficult policy question."

Green Infrastructure

A regional planning strategy focused on natural infrastructure like wetlands would provide "shock protection" from climate-related floods and store and slowly release floodwaters, said Forster Ndubisi, professor of landscape architecture and urban planning at Texas A&M, senior fellow with its Hazard Reduction Recovery Center, and contributor to Lincoln Institute's *Nature and Cities*. The city and county could provide flood protection and amenities like parks and trails by buying and removing homes in certain neighborhoods and redeveloping bayou riparian zones with detention ponds and native vegetation, he said. "It's a proactive plan, and it's so much cheaper" than engineered solutions.

The Houston region has already begun to create detention basins and bayous that double as parks. On the Sims Bayou, HCFCD and the Army Corps built two regional storm water detention basins and planted trees and shrubs along the channel banks. "Sims was the only bayou that didn't overflow its banks during Harvey," noted HCFCD's Lazaro. In a $480 million project with the Corps, HCFCD is building four detention ponds and widening and deepening a 21-mile stretch of the Bray's Bayou channel, which they will plant with native vegetation. The Houston Parks Board and the city's Parks and Recreation Department, collaborating with HCFCD, are developing the Bayou Greenways 2020 project, a 150-mile greenways trail system that provides drainage, transportation, and recreation along eight bayous. A voter-approved bond referendum is funding $100 million of the $220 million project.

Advocates of an extensive network of "green infrastructure"—including parks and golf courses running along Houston's bayous—point to the success of such landscaped buffers as Buffalo Bayou Park (below) in detaining and slowly releasing Harvey's floodwaters. Credit: SWA

In downtown Houston, a 2.3-mile stretch of Buffalo Bayou Park—part of a $58 million public-private project led by the Buffalo Bayou Partnership, the city, and HCFCD—included restoration of the banks with reinforced infrastructure and a riparian landscape, walking trails, boat launches, and picnic areas. During Harvey, when water from the Addicks and Barker dams was released into the bayou, the flood level reached as high as 25 vertical feet, said Scott McCready, senior project designer and principal of SWA Group in Houston. The deluge left 8-foot piles of sand, but compared to engineered bayou channels, he said, the park worked as intended, detaining and slowly releasing floodwaters.

Houston region officials may also use golf courses as storm water detention basins. The metro area has more than 200 golf courses, which are generally easier and cheaper to redevelop for flood control purposes than areas with construction. Clear Lake City, a master-planned community 23 miles southeast of downtown Houston, had a history of flooding, and in 2011 the city's water authority acquired a former golf course for detention purposes. A nonprofit organization is now developing a detention and open-space park, Exploration Green, with contoured basins, wetland preserves, and miles of trails that can survive flooding. It passed its first trial during Harvey by saving 150 homes from flooding. When completed, it will manage up to one-half-billion gallons of storm water and protect up to 3,000 homes, according to the *Texas Tribune*.

Focus and Accelerate

"There is a larger conversation that needs to happen," said Speiler. "What is resiliency for the region?" He said many local efforts "seem to be the right things, but we just haven't done enough of them." Some changes may be required to retrofit infrastructure for older developed sections of Houston and protect natural habitat upstream. But generally, he said, "it isn't so much that we need to change, but rather that we need to focus and accelerate what we're doing."

Many say Houston is not likely to enact a zoning code as a resilience measure, nor is a prohibition or even a moratorium on development in floodplains likely. But Walsh said Houston is taking a more thoughtful approach. He said city and county officials are considering a resilience plan and making decisions with resilience in mind. City council, for example, is looking more carefully at infrastructure and development-related decisions they used to approve routinely. "They've shown they're concerned about development in flood-prone areas," he said, "even something like a MUD [municipal utility district]."

Ultimately, Walsh said, Houston's long-term concern is "keeping the focus on resiliency—that's the political challenge when the skies are blue."

Kathleen McCormick, principal of Fountainhead Communications in Boulder, Colorado, writes frequently about healthy, sustainable, and resilient communities.

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