Planning to Exacerbate Flooding: Evaluating a Houston, Texas, Network of Plans in Place during Hurricane Harvey Using a Plan Integration for Resilience Scorecard

Matthew L. Malecha, Ph.D.[1]; Sierra C. Woodruff, Ph.D.[2]; and Philip R. Berke, Ph.D.[3]

Abstract: In August 2017, Hurricane Harvey inundated Houston, Texas, where flooding already was a persistent and growing challenge. Coordinated, proactive land-use planning has been shown to help mitigate flooding hazards, whereas conflicting guidance can exacerbate the problem. This study used the Plan Integration for Resilience Scorecard (PIRS) method to spatially evaluate a network of plans guiding land use and development in western Houston when Harvey struck, assessing their integration and effects on flood vulnerability. Despite generally positive results, we found important variations and conflicts across plans and across the study area. By encouraging development without sufficient attention to flood risk, some plans and policies increased vulnerability, especially in places outside the official 100-year (1% annual chance) floodplain but still in danger of flooding. A false sense of security provided by local flood control structures may have amplified the problem by enabling more intense development—an example of the safe development paradox—and making the area even more vulnerable to cascading effects from a massive and sustained precipitation event such as Harvey. **DOI: 10.1061/(ASCE)NH.1527-6996.0000470.**

Author keywords: Urban planning; Flooding; Land use; Spatial plan evaluation; Safe development paradox.

Introduction

On August 25, 2017, Hurricane Harvey made landfall along the Texas Coastal Bend. For the next 4 days the storm stalled over southeastern Texas, dropping historic amounts of rainfall—including over 1.2 m in the city of Houston (Blake and Zelinsky 2018; City of Houston 2018b). These rains caused catastrophic flooding. More than 8,500 calls were made to 911 to request water rescues, and over 37,000 families were displaced in Houston alone. Over 200,000 properties were damaged across southeastern Texas, including over 65,000 structures in Houston (Texas General Land Office 2019; Sebastian et al. 2017). Harvey is the second-costliest hurricane in United States history, behind only Hurricane Katrina in 2005 (Blake and Zelinsky 2018).

Although the Harvey event produced record amounts of rain, flooding has been a persistent and growing problem in the Houston area. The Houston Hazard Mitigation Plan (City of Houston 2018b) documented 57 flood events over 21 years. In 2015, the city experienced severe flooding on Memorial Day and on Halloween weekend; both events received a presidential disaster declaration (City of Houston 2018a). Again in 2016, two flood events were declared presidential disasters (City of Houston 2018a). More recently, Tropical Depression Imelda caused catastrophic flooding in parts of Houston and southeastern Texas, with precipitation totals of up to 1 m in some places. Since 1973, Harris County has received 28 federal disaster declarations related to floods and storms, and, as a result, has been classified as a repetitive loss community (Harris County 2013; FEMA 2019).

Rapid development in risky and greenfield locations throughout the Houston region exacerbates the flooding problem. In Harris County, over 100,000 homes and businesses currently are located in the 100-year floodplain (which has a 1% annual chance of flooding), designated by FEMA as the Special Flood Hazard Area (SFHA) (HCFCD 2018a). Across the region, poorly controlled development has replaced natural ecosystems such as wetlands and prairies with impervious surfaces, nullifying their ability to attenuate stormwater (Sebastian et al. 2017; Brody et al. 2011). Consequently, excessive rainfall frequently overwhelms drainage systems, resulting in overland and sheet flow flooding outside of mapped floodplains (Harris County 2013). The growing problem of flood damage occurring beyond the commonly acknowledged and comparatively well-managed SFHA has been documented in recent research (Blessing et al. 2017; Brody et al. 2014, 2013).

Land-use planning is a key factor in this equation, and can either mitigate or exacerbate flood risk (National Research Council 2014; Brody et al. 2011; Godschalk 2003). Planning for growth in a coordinated, proactive way has been shown to mitigate the effects of natural hazards such as flooding (Kim and Rowe 2013; Burby 1998). Unfortunately, planning efforts are increasingly fragmented in many US communities, leading to weak coordination between the various plans that guide development and land use (Hopkins and Knaap 2018; Berke et al. 2015, 2019b). As a result, hazard mitigation and land-use practices to reduce flooding often are poorly integrated across a community's network of plan documents. Disjointed planning increases vulnerability and the potential for loss, leaving many communities ill-prepared for the magnitude

[1]Postdoctoral Research Associate, Dept. of Landscape Architecture and Urban Planning, Texas A&M Univ., Scoates Hall, Room 125, 3137 TAMU, College Station, TX 77843-3137 (corresponding author). ORCID: https://orcid.org/0000-0003-4200-6593. Email: mmalecha@arch.tamu.edu

[2]Assistant Professor, Dept. of Landscape Architecture and Urban Planning, Texas A&M Univ., Scoates Hall, Room 125, 3137 TAMU, College Station, TX 77843-3137.

[3]Research Professor, Dept. of City and Regional Planning, Univ. of North Carolina–Chapel Hill, New East Bldg., CB# 3140, Chapel Hill, NC 27599.

Note. This manuscript was submitted on June 4, 2020; approved on December 30, 2020; published online on June 16, 2021. Discussion period open until November 16, 2021; separate discussions must be submitted for individual papers. This paper is part of the ***Natural Hazards Review***, © ASCE, ISSN 1527-6988.

and frequency of flood events with which they must contend (Burby et al. 1999; Macintosh 2013).

In this study, we spatially evaluated a network of plans with respect to its integration and responsiveness to flooding hazards, in the context of a large-scale flood event. Using the Plan Integration for Resilience Scorecard (PIRS) method (Berke et al. 2015, 2019a, b), we evaluated a network of 18 plans that were guiding land use and development in a section of western Houston that experienced dramatic flooding during Hurricane Harvey. We addressed the degree of integration of the network of plans in the study area, and how it affected flood vulnerability, by assessing (1) how plans at different administrative or geographic scales (e.g., regional, city, and neighborhood) affected flood vulnerability across the study area; (2) how different types of plans (e.g., transportation, parks and recreation, and small area master plans) affected flood vulnerability across the study area; and (3) how the network of plans affected flood vulnerability in the FEMA SFHA (100-year floodplain), the FEMA 500-year floodplain, and the parts of the study area that experienced flooding during Hurricane Harvey.

Our analysis revealed conflicts between different scales and types of plans, and uneven treatment of different flood-hazard zones. Findings, which include an illustrative case study of the Energy Corridor District, are discussed after a review of relevant literature and explanations of the study context and methods. Conclusions and potential implications—including for long-term flood mitigation in Houston, in light of climate change and increased frequency of extreme flood events—then are presented. The paper closes with an acknowledgement of study limitations and a look ahead to future research directions.

Literature Review

Land use in the US typically is guided by a network of local plans focused on transportation, housing, hazard mitigation, parks and recreation, or others aspects of the urban ecosystem, in addition to a comprehensive (or general) plan document (Hopkins and Knaap 2018; Hoch et al. 2000). The degree to which these plans are coordinated or in conflict can have a profound effect on a community's resilience—its capacity to cope with and effectively respond to hazardous events such as floods (Di Gregorio et al. 2017; Kim and Rowe 2013; IPCC 2014; Woltjer and Al 2007; Berke and Godschalk 2009; Burby et al. 1997). Emerging scholarship has suggested that policies and recommended actions found in plans not focused overtly on hazards still can influence resilience (Berke et al. 2015, 2019b; Kashem et al. 2016). Integrating hazard awareness and mitigation throughout a community's network of plans therefore is crucial for building and enhancing resilience (Fidelman et al. 2013).

In the US, local and regional planning rarely achieves the integration required to mitigate hazards effectively. Poor coordination of a community's multiple plans—which often are developed by disparate, siloed departments and organizations, each pursuing its own goals (Hopkins and Knaap 2018)—may result in ineffective guidance, conflicting policies, and increased hazard vulnerability (Berke et al. 2019b; Finn et al. 2007). Recognizing this challenge, planning researchers developed new concepts and tools to analyze and coordinate plans. Finn, Hopkins, and Wempe (2007) geocoded a community's projects and spatially explicit policies in a GIS-linked online database, enabling more-effective comparisons and detection of conflicts between policies and actions in various plans.

Focusing more directly on the problem of integrating hazard mitigation, Berke et al. (2015, 2019a, b) developed the PIRS methodology to spatially evaluate plans and policies at the subjurisdictional scale. They scored applicable plan policies based on their geographic focus and effects on hazard vulnerability, facilitating the indexing and comparison of scores across a network of plans and across a community. By revealing policy conflicts and gaps, and highlighting places where policies may increase vulnerability to hazards, the PIRS allows planners and decision makers to better understand their communities and more effectively focus their efforts on strengthening integration across the network of plans.

Although it increasingly is established in theory and practice (Berke et al. 2015, 2019a, b; Malecha et al. 2018, 2019; Woodruff 2018; Yu et al. 2020), this type of analysis has yet to be conducted against the backdrop of an actual hazard event. It is unknown what may be learned from spatially evaluating plans that were in place at the time of a major flood event. This study fills that knowledge gap by assessing a network of 18 plans that were guiding development and land-use decisions in a section of western Houston when Hurricane Harvey inundated the area in August 2017. We investigated the coordination and effects on flood vulnerability of plans from different administrative scales (e.g., regional, city, and neighborhood) and with different foci (e.g., transportation, development, and conservation). We also incorporated into the analysis varying degrees of flood-hazard risk (e.g., 1% chance of flooding) to discern patterns in their differential treatment by plans and policies. The new perspective and empirical data offered by this research have broad implications for understanding the relationship between plan coordination and flood risk management, not only in Houston but more broadly—complicating and perhaps complementing arguments about the critical role of land use in mitigating (or exacerbating) flooding.

Context

Our analysis focused on a cluster of four super neighborhoods—Briar Forest, Eldridge / West Oaks, Memorial, and Westchase—and three municipal management districts—Energy Corridor, Memorial, and Westchase—in western Houston (Fig. 1). The former denotes an administrative and planning division unique to the city (Neuman 2004), whereas the latter comprises special districts created by the Texas Legislature to coordinate and promote development and the public welfare [State of Texas Local Government Code § 375.001 (2005)]. The 122.5-km^2 study area is home to approximately 200,000 residents (City of Houston 2019). These neighborhoods have higher than average median household incomes and percentages of white residents compared to the city as a whole (City of Houston 2019). The study area also is home to headquarters or regional offices of numerous energy companies, including Shell and BP, helping make it the second largest employment center in the region (Energy Corridor District 2015).

Despite its relative affluence, this part of the city suffered extensive damage during Hurricane Harvey (Fig. 2). Located immediately downstream from the Addicks and Barker Reservoirs, the area was inundated not only by the unprecedented rainfall accumulation, but also as a result of controlled releases from the reservoirs to prevent catastrophic dam failure (Blake and Zelinsky 2018). Releases began August 28 and continued until September 20; only then did floodwaters begin to recede from the area (HCFCD 2018b).

Following catastrophic flooding in the 1930s, the Addicks and Barker Reservoirs were built to protect downtown Houston from flooding (USACE 2009). The reservoirs are designed to collect excessive rainfall and release water into Buffalo Bayou at a controlled rate. Although releases from the reservoir devastated downstream neighborhoods during Harvey, the dams successfully protected

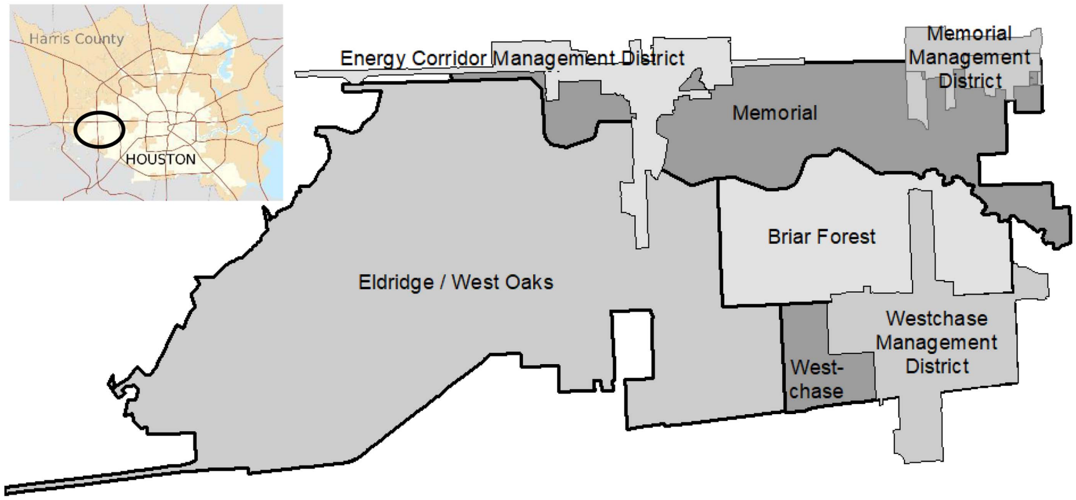

Fig. 1. Study area: a cluster of four super neighborhoods and three municipal management districts in western Houston, Texas. The Barker Reservoir (including George Bush Park) comprises the western half of the Eldridge / West Oaks super neighborhood. The Addicks Reservoir is located just north of the Energy Corridor Management District.

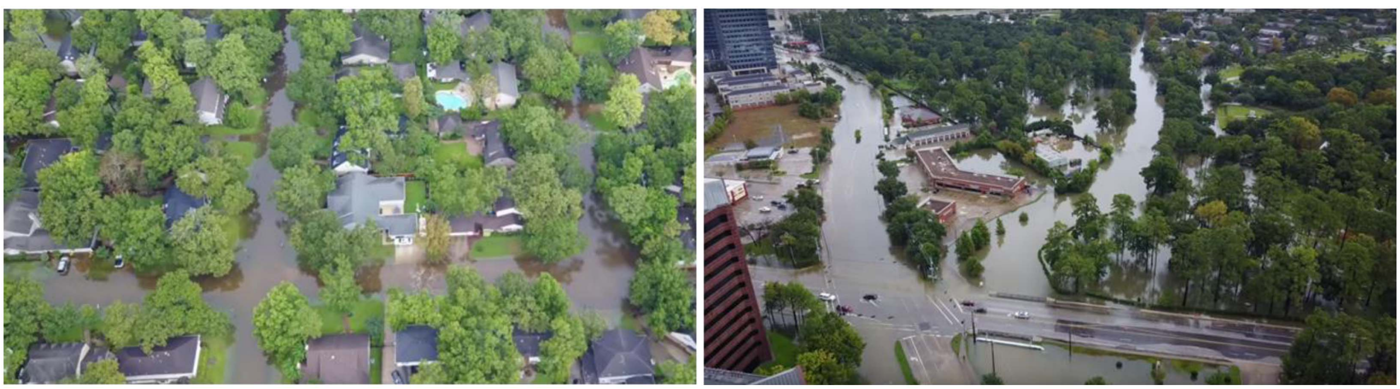

Fig. 2. Flooding in the Energy Corridor District, Houston, Texas, on August 27, 2017. (Images reprinted from Gipson 2017, with permission from Travis Gipson/Jukin Media.)

downtown Houston, the Houston Ship Channel, and Port Houston (HCFCD 2018d).

Flooding below the dams in this part of Houston has become a greater threat as urban development has intensified (USACE 2009). Continued development downstream has placed more people and property in risky locations, whereas development upland, near the western edges of the rarely filled reservoirs (USACE 2009), has resulted in additional pressure and less room for the reservoir to function. Thus, it is critical that the plans guiding this development are coordinated and that hazard awareness is integrated throughout the entire network of plans.

Unlike many parts of this notoriously planning-averse city [although that perhaps is an unfair characterization (cf. Neuman 2004)], this prominent section of Houston has received a great deal of policy attention from plans at multiple administrative scales. Development in the western Houston super neighborhood cluster study area is guided by 18 separate plans, developed by regional, city, and neighborhood entities (and combinations thereof). Municipal management districts, which are empowered to promote economic development and public welfare, also have developed numerous plans to guide future development. This enables a robust exploration of the relationships between plans, including at different administrative scales (Woodruff 2018; Yu, Brand, and Berke 2020), as well as of the potential effects of policies that apply to one area but affect another—e.g., policies that encourage new development in an upland location increasing flood risk in downstream areas (Brody et al. 2011).

Method

Our examination of the network of plans in the western Houston super neighborhood cluster generally followed the standard PIRS evaluation methodology (Berke et al. 2015), detailed in the most current version of the *Plan Integration for Resilience Scorecard Guidebook* (Malecha et al. 2019). The study proceeded in two steps: (1) delineation of planning districts and hazard zones, and (2) evaluation of the study area's plans regarding their integration and effects on flood vulnerability.

Step 1: Delineate Planning Districts and Hazard Zones

The western Houston study area first was subdivided to facilitate spatial analysis of plans and improved understanding of the heterogeneity of policy effects across the community. For this analysis,

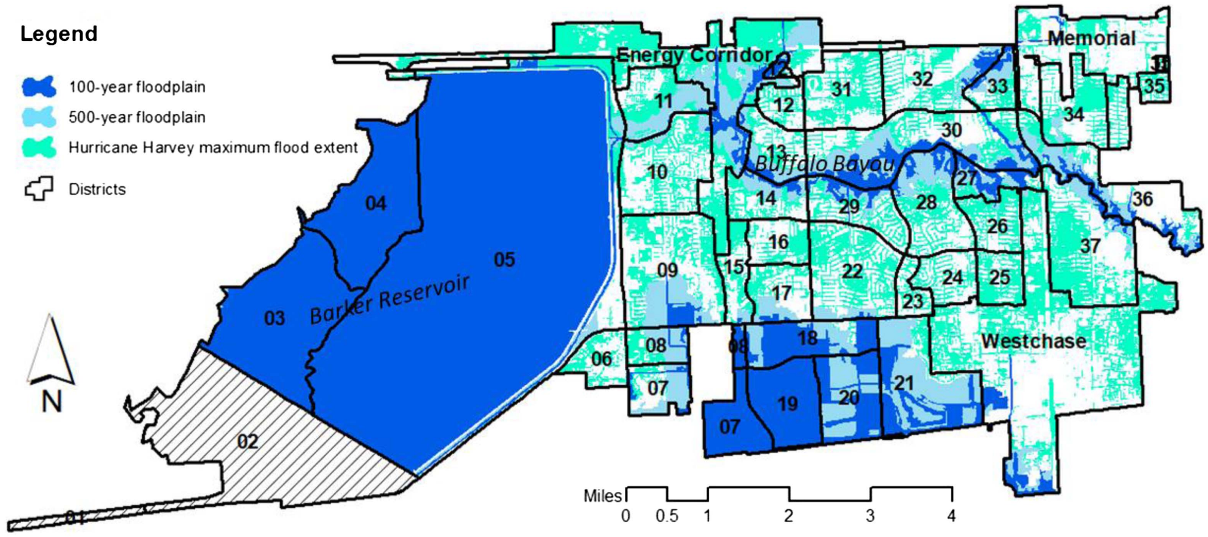

Fig. 3. Map of the western Houston super neighborhood cluster study area, showing numbered/labeled planning districts (38 total, excluding Districts 01 and 02, which contain no population and are outside Harris County) and hazard zones (3 total). These were combined to subdivide the study area into 97 mutually exclusive district-hazard zones. To enable more useful comparisons, the Hurricane Harvey maximum flood extent hazard zone covered only areas that flooded outside the other hazard zones, despite significant overlap.

planning districts consisted primarily of US Census tracts—statistical and geographic units of roughly 4,000 inhabitants which are "designed to be relatively homogeneous ... with respect to population characteristics, economic status, and living conditions" (US Census 2019). Census tracts were preferred to super neighborhoods as a scale of analysis because they are significantly smaller, which enhanced the quality of the spatial plan and policy analysis that could be performed. Moreover, despite official recognition by the city, super neighborhoods generally play a relatively minor role in local planning. To the US Census tracts were added the three legislatively established municipal management districts (Fig. 1), which were included because of their significance to planning in the region; many plans and policies reference management districts as their specific areas of geographic focus. Together, the US Census tracts and management districts yielded a set of 38 total planning districts (Fig. 3).

Three separate hazard zones were used in the analysis, each of which is significant for planning and policy in the Houston region. First, given its central role in driving flood-related land-use policy over many decades (National Research Council 2014), we included the current FEMA SFHA (100-year floodplain). Its spatial extent, which corresponds to the part of the study area ostensibly subject to a 1% chance of flooding in a given year, is indicated in Fig. 3.

The 500-year floodplain (the area with a 0.2% chance of flooding in a given year) also was included (Fig. 3). The 500-year floodplain is particularly suitable as an analytical frame in the study area due to its prominence in the post-Hurricane Harvey planning and policy-making discourse. Authoritative voices in Houston and Harris County (Puckett 2018; Houston Business Journal 2019; Bennet 2019) have suggested replacing the current 100-year-floodplain-based development standards in Houston and Harris County with similar standards based on the 500-year floodplain. Even before Hurricane Harvey, the recent spate of large floods had suggested that the current 100-year floodplain was an inadequate measure of flood risk.

A third hazard zone was created based on the maximum extent of flood waters during Hurricane Harvey. This was an especially salient hazard zone given the geographic and temporal context of the study. It is the most extensive of the three zones, affecting every planning district in the study area. It overlaps large portions of the SFHA and 500-year floodplain hazard zones and extends beyond them to include much of the land located outside the FEMA-recognized flood hazard areas. For the purpose of this evaluation, however, the parts of the layer outside the other hazard zones (Fig. 3) were isolated and analyzed as a third mutually exclusive hazard zone, representing the parts of the community thought to be quite safe but which nevertheless flooded during the hurricane—and which may be at increased risk in the future due to climate change and continued development.

Spatial data for the 100-year and 500-year floodplain hazard zones were retrieved from the Harris County Flood Control District (HCFCD 2019). The Hurricane Harvey maximum flood water extent was derived from a 3-m^2 continuous flood depth raster grid for the entire Harvey-impacted area (FEMA 2018). Geoprocessing was performed to collapse all depths into a single polygon layer, such that standing water of any depth constituted flooding (Jenkins et al. 2018), an outcome paralleling the depth-related aspects of FEMA floodplains.

The planning districts and hazard zones were combined using GIS to form district-hazard zones, the unit of analysis for this study. In total, the 38 planning districts and 3 hazard zones combined to form 97 mutually exclusive district-hazard zones (some districts do not include all 3 hazard zones) that may be differentially affected by policies in the network of plans.

Step 2: Evaluate Network of Plans

After deriving the district-hazard zones, the study area's network of plans was acquired from the online outlets of relevant local governments, management districts, and nonprofit stakeholder groups, and then spatially evaluated using the PIRS method (Malecha et al. 2019; Berke et al. 2015). Plans were perused to identify policies affecting physical vulnerability to flooding. Relevant policies were assigned to appropriate district-hazard zones and scored according to their effects on flood vulnerability. Policies likely to increase vulnerability received a score of −1 (negative), whereas those likely to reduce it received a score of +1 (positive). Scores were totaled to create policy score indexes for every district-hazard

Table 1. Network of plans in the western Houston super neighborhood cluster study area

Administrative scale	Plan title
Regional plans	Our Great Region 2040 (including the 'Strategy Playbook') (2014)
	Houston Stronger (no date)
	Gulf-Houston Regional Conservation Plan (2017)
	2040 Houston-Galveston Regional Transportation Plan (RTP) + 2017–2020 Transportation Improvement Plan (TIP)
County plans	Harris County Flood Control District 2017 Federal Briefing
City plans	City of Houston Hazard Mitigation Plan Update (2017)
	Plan Houston (2015)
	Houston Parks & Recreation Department Master Plan (2015)
District and small area plans	The Energy Corridor District Unified Transportation Plan, 2016–2020
	The Energy Corridor District 2015 Master Plan
	Energy Corridor Livable Centers Plan (2010)
	Energy Corridor Bicycle Master Plan (2010)
	Memorial City Management District 2014–2024 Service and Improvement Plan and Assessment Plan
	Westchase District Long Range Plan (2006)
	West Houston Plan 2050: Envisioning Greater West Houston at Mid-Century
	West Houston Trails Master Plan (2011)
	West Houston Mobility Plan (2015)
	2009 Master Plan, Addicks and Barker Reservoirs, Buffalo Bayou and Tributaries, Fort Bend and Harris Counties, Texas

zone. The resulting scorecard was analyzed to determine how and where plan policies aligned and conflicted with respect to flood vulnerability in the study area. Following the precedent set in prior PIRS studies (Berke et al. 2015, 2019a, b; Malecha et al. 2018; Woodruff 2018; Yu et al. 2020), the deliberately straightforward scoring system was maintained to avoid overcomplicating the analysis. This is discussed in greater detail in the "Next Steps and Future Applications" section.

The large network of plans evaluated for the western Houston study area is listed in Table 1. It includes 18 plans across 4 administrative scales which were in place and directing land use and development when Hurricane Harvey made landfall in August 2017. Regional plans are the broadest in scope, generally focusing on the Greater Houston metropolitan area. Given the size of Harris County and Houston proper, the county- and city-scale plans also had relatively broad geographic scopes, whereas the district and small area plans were much more narrowly focused. Along with differences in the purpose(s) for which plans are produced, variations in scope can influence the focus of their policies, including the attention they pay to flooding hazards.

Well-established content analysis procedures were followed (Stevens et al. 2014). Two trained researchers worked independently to code and score policies across the entire network of plans, resolving instances of disagreement to produce a final consensus scorecard. The intercoder agreement score (0.88) was above the acceptable plan evaluation coefficient threshold.

Findings and Discussion

Overview (Study Area–Wide Findings)

Results from the spatial plan evaluation indicated that the network of 18 plans guiding development and land use in western Houston when Hurricane Harvey struck generally supported a reduction in flood vulnerability. Of the 152 land-use policies and actions across the network of plans that were likely to influence physical vulnerability to flooding, many more were focused on reducing it (90) than were likely to increase it (62) (Table 2). Across the entire study area (Fig. 4), not a single district-hazard zone received a negative overall policy score, which would have indicated that the mix of policies affecting that part of the city were, on the whole, guiding it in a more vulnerable direction. This positive overall picture, however, belies hidden patterns within the network of plans and across hazard zones, including apparent conflicts between policies in some areas, which are discussed in greater detail subsequently and illustrated in an in-depth case study of the Energy Corridor District.

Results by Administrative Scale

Analysis of policy scores for the western Houston network of plans by administrative scale revealed stark differences between larger-scale and smaller-scale plans (Table 2). Policies in the 8 regional-, county-, and city-scale plans more frequently were positive and wider ranging (affecting more district-hazard zones) than were those found in the 10 neighborhood and small area plans, though the latter included more total policies likely to affect vulnerability. Of the policies in the larger-scale plans, 91% (51 of 56) supported a reduction of flood vulnerability, whereas only 41% (39 of 96) of the neighborhood and small area plan policies guided the community in a less vulnerable direction. However, the broader geographic scope of many vulnerability-reducing policies—e.g., protecting natural riparian areas along bayous—resulted in positive overall policy score averages (calculated by summing the scores across all district-hazard zones in a plan). The smaller-scale plans had an average of 26.8 per plan, whereas the larger-scale plans averaged 229.3.

These trends are influenced heavily by the prominence of development and transportation policies in the smaller-scale plans, whereas the city, county, and regional plans are focused mainly on environmental, safety, and connectivity issues. Being closer to the action, neighborhood and small area plans also frequently are required to balance many competing needs—including the classic development-versus-preservation challenge—whereas larger-scale plans generally avoid such issues. Houston's city-scale plans are less affected by these competing drivers than might be expected. This may be an artifact of the city's recent re-embracing of citywide planning, and the preliminary, largely visionary nature of the Plan Houston document (Table S1 in the Supplemental Materials).

This pattern between plan scale and focus suggests key jurisdictional relationships in the Houston region, including a preference

Table 2. Scorecard results: policy counts and overall policy score statistics by administrative scale, plan type, and hazard zone

Categories	Policy counts			Overall policy score statistics[a]		
	Likely to reduce vulnerability	Likely to increase vulnerability	Total	Composite policy score	Average	Standard deviation
Administrative scale[b]						
Larger (regional, county, and city plans)	51	5	56	1,834	229.3	163.3
Smaller (district and small area plans)	39	57	96	268	26.8	66.9
Total	90	62	152	2,102	—	—
Plan type						
Environmental	35	1	36	853	213.3	176.3
Hazard mitigation	22	0	22	841	210.3	160.1
Transportation	3	14	17	−84	−28.0	11.5
Comprehensive	30	47	77	492	70.3	96.0
Total	90	62	152	2,102	—	—
Hazard zone						
100-year floodplain (1% annual chance)	81	22	103	956	53.1	72.0
500-year floodplain (0.2% annual chance)	69	24	93	629	34.9	47.7
Hurricane Harvey maximum flood extent	69	57	126	517	28.7	44.5
Total	90	62	152	2,102	—	—

[a]Overall policy score statistics are calculated slightly differently for each subgroup. Inputs for administrative scale statistics include total policy scores by plan (all hazard zones combined), regardless of plan type. Inputs for plan type statistics include total policy scores by plan (all hazard zones combined), regardless of administrative scale. Hazard zone statistics were calculated by totaling policy scores by hazard zone for each plan, resulting in averages that are lower than in the other subgroups. Composite policy scores reflect the total number of policies in an administrative scale, plan type, or hazard zone; their likely direction of influence (reducing or increasing vulnerability); and their geographic range.

[b]Administrative scale groupings are based on geographic scope (larger than study area versus smaller than study area).

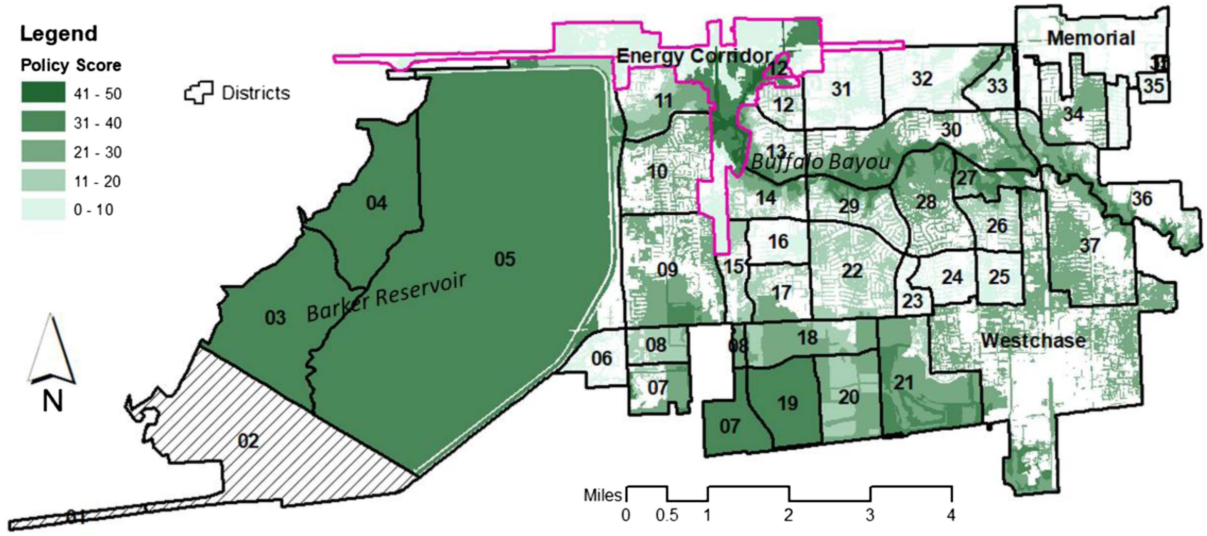

Fig. 4. Resilience scorecard results: policy scores by district-hazard zone in the western Houston study area. Darker shades indicate stronger and more positive policy attention, whereas lighter shades suggest less attention (and potentially more policy conflict). Districts 03, 04, and 05, located inside the Barker Reservoir, were affected positively by policies aimed at preserving and enhancing it as a parkland and water detention facility.

among city and county administrations to leave most land-use and development guidance to local actors, focusing their planning and resources on regional issues such as parklands, waterways, and transportation routes. Without sufficient cross-agency communication, however, this approach can lead to policies at larger scales conflicting with those in smaller-scale plans. For example, policies in large-scale parks or hazard mitigation plans aimed at preserving natural areas sometimes clash with those in local master plans aimed at intensifying development in some of the same areas.

A well-defined process that mandates a degree of interadministrative consistency and promotes consensus would reduce many such conflicts. Successful examples of this include the Minneapolis–St. Paul Metropolitan Council's requirements for municipal plans in the region (Metropolitan Council 2020), Florida's statutory mandate for planning consistency [Florida Statute §163.3177 (2020)], and the modern Dutch planning system (Needham 2005; Malecha et al. 2018). For the western Houston study area, the most planning and regulatory legitimacy rests with the municipal government (counties have relatively little authority in Texas), and thus the City of Houston is best placed to assume this authority, identifying and reconciling instances of plan inconsistency.

Results by Plan Type

Regardless of administrative scale, plan type had a major influence on policy guidance with respect to flood resilience. Table 2 indicates that plans with an environmental emphasis (*Gulf-Houston Regional Conservation Plan*, *Houston Parks & Recreation Department Master Plan*, *West Houston Trails Master Plan*, and *Energy Corridor Bicycle Master Plan*) or a focus on hazard mitigation (*Houston Stronger*, *Harris County Flood Control District Federal Briefing*, *City of Houston Hazard Mitigation Plan Update*, and *Addicks and Barker Reservoirs Master Plan*) contained many policies aimed at reducing flood vulnerability (35 and 22, respectively). Overall policy scores also were very high for these plans, on average (213.3 and 210.3, respectively). Policies in transportation plans (*Houston-Galveston Regional Transportation Plan/Transportation Improvement Plan*, *Energy Corridor District Unified Transportation Plan*, and *West Houston Mobility Plan*) increased vulnerability (14 of 17) more often than they reduced it (3 of 17), typically by guiding development toward hazard-prone locations. Overall policy score averages per plan were negative (−28.0) for transportation plans. Results were mixed for comprehensive-style multipurpose plans (*Our Great Region*, *Plan Houston*, *Energy Corridor District Master Plan*, *Energy Corridor Livable Centers Plan*, *Memorial City Management District Service & Improvement Plan*, *Westchase District Long Range Plan*, and *West Houston Plan 2050*), reflecting the diversity of policies often contained in such documents—from increasing development intensity on the one hand, to preserving critical habitat or scenic areas on the other.

Results by Hazard Zone

Table 2 compares total policy scores for the three hazard zones examined in this study. It reveals that the strongest and most positive policy attention was paid to the 100-year floodplain (the FEMA SFHA). The floodplain surrounding Buffalo Bayou, in particular, was the focus of significant attention aimed at reducing vulnerability (Fig. 4). The total policy score for the 100-year floodplain averaged 53.1/plan across the network of plans. Scores were significantly lower for the 500-year floodplain (34.9/plan, on average), and lower still for the Hurricane Harvey maximum extent hazard zone (28.7/plan).

This suggests that the network of plans was focused heavily on mitigating flooding in the FEMA SFHA, the flood-hazard zone that was most familiar, most strongly regulated, and for which proactive planning was best incentivized (for example, meeting national floodplain development standards enables subsidized flood insurance under FEMA's National Flood Insurance Program). At the time of Harvey's impact, such institutional drivers were far weaker with respect to the 500-year floodplain, although this may be changing. Strong federal attention on the SFHA also may have provided some cover to local plan makers, enabling greater land-use restrictions, and thus strengthening resilience, compared with the other hazard zones.

The lowest policy scores by plan—as well as many of the lowest policy scores by district-hazard zone [e.g., Districts 6, 16, 18, 24, 25, 31, 33, 35, and Energy Corridor (Fig. 4)]—were found in the Hurricane Harvey maximum-extent hazard zone, reinforcing the notion that policy attention is contingent in large part on perceived hazard risk and on the institutionalization of hazard awareness. Policies that increase vulnerability were more likely to target such areas, given their location outside the FEMA-designated flood zones. However, as Hurricane Harvey and other recent flood events have shown, and research has documented (Blessing et al. 2017), flooding does not always respect hazard zones.

Case Study: Energy Corridor District

An in-depth discussion of Houston's Energy Corridor District (Fig. 4) is presented to help illustrate the broader patterns described previously—many of which it reflects in microcosm. The Energy Corridor also is the most heavily planned part of the western Houston study area, with more than 100 policies across 14 plans likely to affect flood vulnerability in some part of the district (Supplemental Materials). This abundance of flood-vulnerability-related policies enabled an in-depth investigation of some of the drivers behind the resilience scorecard results, including examples of how polices across the network of plans aligned, conflicted, and affected different parts of the community in different ways.

Established in 2001 by the Texas Legislature to "promote, develop, encourage, and maintain employment, commerce, economic development, and the public welfare" [Energy Corridor District 2015; State of Texas Local Government Code § 375.001 (2005)], the Energy Corridor District has been the focus of significant planning and policy attention from the city, region, and state. Straddling Interstate 10 and Buffalo Bayou and bordering the Addicks and Barker Reservoirs (which double as regionally significant parks), the Energy Corridor is a leading employment center in Houston, with designs for continued growth as a high-amenity mixed-use destination (Energy Corridor District 2015).

Findings from the PIRS analysis generally reflected those observed for the wider study area: more policies affecting the Energy Corridor District were working to strengthen resilience (65) than to increase vulnerability (52); scores generally were better for plans at higher administrative scales and for those that focused on environmental or hazard issues; and more positive policy attention was given to the parts of the district in the 100-year floodplain (policy score: +44) than to those in the 500-year floodplain (+30) or Hurricane Harvey maximum flood extent hazard zone (+1). A closer examination of the policies behind these scores revealed patterns, including conflicts between plan documents, that often were relevant to the broader study area, and perhaps even to Houston and the wider region. They help tell the story of how the existing network of plans influenced flood vulnerability in this part of Houston at the time of Hurricane Harvey's impact in August 2017.

A majority of policies affecting flood vulnerability in the Energy Corridor District were aimed at increasing flood-resilience—from promoting conservation subdivision design, preserving wetlands and riparian zones, and developing an integrated regional storm defense system (*Our Great Region 2040* and *West Houston Plan 2050*); to land acquisition and conservation easements (*Gulf-Houston Regional Conservation Plan*); to buyouts of flood-prone homes (*Houston Stronger*), regulatory measures that ensure safety in future development (*City of Houston Hazard Mitigation Plan Update*), and improvement of reservoir outlet structures (*Harris County Flood Control District Federal Briefing*). Extensions and enhancements of park and trail networks, especially along drainageways, also were suggested in multiple plans (*Houston Parks & Recreation Department Master Plan*, *Energy Corridor District Bicycle Master Plan*, and *West Houston Trails Master Plan*).

However, many policies directed at the same part of the city encouraged intensification of development near transit (*Plan Houston*), large-scale redevelopment and infill (*Energy Corridor District Master Plan*, *Energy Corridor Livable Centers Plan*, and *Energy Corridor District Unified Transportation Plan*), and new transportation corridors to induce development (*West Houston Plan 2050* and *West Houston Mobility Plan*), even suggesting financial incentives to help accomplish the goal (*Our Great Region 2040*). Although appropriate in less hazardous places, such density- and development-focused policies increase vulnerability if implemented in flood-hazard areas without sufficient attention to mitigation. They also conflict with the direction of much of the other guidance (aimed at reducing flood vulnerability) and make no mention of this potential discord or how it should be resolved, such as by asserting the primacy of hazard mitigation rules/actions in flood-hazard areas. Also notable is the distribution of these policy examples among plan scales and types: following broader trends seen throughout the study area, policies aimed at reducing vulnerability were found most often in plans at higher administrative scales and focusing on environmental or hazard issues, whereas policies increasing vulnerability were found in the local plans and those focused on transportation or development.

The Energy Corridor District also exemplifies the disparity in policy attention with respect to the three hazard zones. A higher policy score for the district's 100-year floodplain (SFHA) is the result of many policies focused on protecting riparian and other flood-prone areas from development (*City of Houston Hazard Mitigation Plan Update* and *Our Great Region 2040*), as well as conserving or expanding existing parkland (*West Houston Trails Master Plan* and *Houston Parks & Recreation Department Master Plan*), much of which coincides with the SFHA. Fewer such policies applied in the 500-year floodplain, which also was the focus of policies aimed at increased development (*Energy Corridor District Unified Transportation Plan*, *Energy Corridor District Master Plan*). Policy conflict was even more apparent in the Hurricane Harvey maximum flood extent hazard zone; many parts of the district that flooded during the storm but are located outside the acknowledged floodplains were the focus of intense development pressure and related policies (*Energy Corridor Livable Centers Plan* and *West Houston Mobility Plan*). Results of the spatial plan evaluation therefore suggest that planning in the Energy Corridor District at the time of the impact of Hurricane Harvey was proceeding with some awareness of flood risk, but that this was directed much more toward the established, regulatory SFHA.

This may go some way toward explaining the massive destruction that occurred in this otherwise relatively well-planned and prosperous part of the city. A much stronger focus on the known floodplain—almost as if it were the only hazard area worth worrying about, despite the recent trend toward larger-than-expected flood events—appears to have exacerbated the consequences from Hurricane Harvey. In many ways, this is a stark example of the safe development paradox (Burby 2006): focusing on large structural interventions to safeguard new development from disasters inadvertently increases the human and economic costs of disasters when those systems fail or are exceeded. In the Energy Corridor District, which is located immediately downstream from the Addicks and Barker Reservoirs (which flow into Buffalo Bayou), planners and decision makers appear to have recognized the need to restrict development in the most flood-prone area (100-year floodplain), but they also were guiding new and/or intensified development toward proximate parts of the city, many of which are at only slightly higher elevation. Thus, when Hurricane Harvey's relentless rainfall necessitated the opening of the Addicks and Barker Reservoirs—to prevent additional flooding and their potential rupture and collapse—much of the community was inundated, leading to more catastrophic damage than would have occurred had the area not been deemed safe and thus intensely developed without adequate mitigation measures.

Plan conflict also was observed in the case of several regional plans with policies spatially focused on upstream areas, which nevertheless are likely to affect flood vulnerability along Buffalo Bayou and in the Energy Corridor District. The *Gulf-Houston Regional Conservation Plan* aims to preserve upland Katy Prairie as part of a broader Prairie Conservation Initiative, likely reducing pressure on the Addicks and Barker Reservoirs and retaining or enhancing resilience along Buffalo Bayou. However, the *West Houston Plan 2050* discusses the need for a new Prairie Parkway in the same area to accommodate future growth. Unless the development induced by such a major roadway addition proceeds extremely cautiously, the likely result will be reduced storage area for storm water, thereby increasing downstream vulnerability to flooding.

Conclusions and Implications

The spatial plan evaluation in this study showed that the existing network of plans generally was guiding the western Houston neighborhood cluster in a more resilient direction leading up to Hurricane Harvey. However, greater and more consistently positive policy attention was paid to the 100-year floodplain (SFHA) than to other parts of the study area. Policies likely to reduce vulnerability also more often were located in the plans farther removed from neighborhood-scale decision-making. That is, plans focused on small areas often contained development- or density-focused policies likely to increase vulnerability, whereas those at higher administrative scales more consistently emphasized reducing flood vulnerability.

A close examination of the scorecard results revealed that, despite positive overall scores and many instances of sound planning, policies in many plans were guiding the community toward increased vulnerability—especially in areas outside the SFHA but still at some risk for flooding. In the drive to accommodate and encourage new development, some plans and policies paid insufficient attention to actual flood risk. This suggests that the plans had trouble keeping up with a rapidly changing reality; they indicated an awareness of the need for flood mitigation, although this was aimed primarily at the SFHA. Given the recent increase in large flood events in Houston, and the mounting evidence of the SFHA's inadequacy as an accurate and up-to-date indicator of flood risk (Blessing et al. 2017; National Research Council 2014; Brody et al. 2013, 2014), some of the plan guidance at the time of Hurricane Harvey's impact appears to have been outdated. The problem may have been amplified by the false sense of security provided by ostensibly strong flood control measures, including the massive Addicks and Barker Dams. Intensifying development in locations just below a dam is a classic example of the safe development paradox, and appears to have had the predictable effect of making the area even more vulnerable to cascading effects from a massive and sustained precipitation event such as Harvey.

If Houston is to reverse the worrying trend of annual (or even more frequent) flooding catastrophe—with Hurricane Harvey as a massive exclamation point—a concerted effort must be made to build resilience across the city, and especially in the city's expanding flood-hazard zones. Much of this begins with sound planning, underlain by an acknowledgement of the new paradigm of frequent and extensive flooding. Plans and policies must be adjusted to reflect this reality, and the City of Houston should, at minimum, embrace stronger land-use restrictions and building requirements in the current 500-year floodplain. Recent local efforts to implement transit-oriented development (TOD), New Urbanism, and smart growth (City of Houston 2020) are commendable for their contribution to larger-scale climate change mitigation, but they must be paired with wise, flood-hazard-aware land-use decisions.

The empirical evidence provided by a PIRS evaluation can help decision makers identify policy gaps and conflicts, more effectively focus attention and resources, and strengthen resilience through better-integrated and more-hazard-aware plan guidance. For the western Houston study area, the focus on the SFHA must be broadened to include other parts of the community that are at risk for flooding. Policies aimed at intensifying development also should be reconsidered or designed to minimize flood vulnerability through methods such as elevating buildings, wet-proofing, or dry-proofing. A more unified and resilient policy direction across the network of plans not only will help prepare the area for the inevitable next flood event, but also likely will make it more attractive to development in the long run.

Next Steps and Future Applications

This study represents a first attempt at applying the concept of spatial plan evaluation (using the PIRS method) in the context of an actual flood event. As such, it deliberately was limited in scope. Time and resource constraints prompted a decision to focus the evaluation on a portion of the city rather than on the entire municipality or an even larger area. Prior studies (Malecha et al. 2018) have shown that such limitations do not negatively impact the efficacy of a PIRS evaluation as long as the geographic parameters are acknowledged and remain clear throughout the process.

Still, a broader examination would surely provide additional insight, particularly if focused on actual flood events, which often are regional in nature. Given the right circumstances, such as a municipal or regional organization using it to systematically evaluate its network of plans and policies to improve resilience (Malecha et al. 2019), such an undertaking would be warranted. An analysis of the entire city, or even of Greater Houston, could be informative with respect to the differential effect of plans and policies on flood vulnerability and impacts. Alternatively, a direct comparison of the western Houston study area examined in this article and another part of the city—one that shares some characteristics (e.g., level of damage from the flood event) but not others (e.g., socioeconomics, plan/policy attention)—might present a compelling contrast in planning and hazard integration within the same governance structure.

Finally, we address the straightforward scoring process (i.e., +1, 0, and −1) used in this analysis. We considered modifying the scoring system by, for example, differentially scoring or weighting policies according to their relative strength or potential impact, but ultimately chose to maintain the dichotomous (trichotomous, if 0 is included) system preferred in all prior PIRS-related studies (Berke et al. 2015, 2019a, b; Malecha et al. 2018; Woodruff 2018; Yu et al. 2020). Although the resulting index policy scores were somewhat limited in their explanatory power, we believe the PIRS methodology is meant to provide a single step forward (albeit a useful one), raising potential issues related to policy conflict, providing a new perspective and way to organize plan data, and setting the stage for further scrutiny of policies and their relationships (Malecha et al. 2019). We employed it as such, using the results to probe apparent policy discrepancies at the district-hazard-zone scale, as in the case study of the Energy Corridor District. Evaluating the relative quality of policies, or their likelihood to be implemented, and incorporating such differences in the scoring system was deemed beyond the scope of this study. We leave it to future research to explore these intriguing new dimensions and to discover what they can add to the PIRS methodology and the spatial evaluation of plans and policies.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request, including final Plan Integration for Resilience Scorecard (PIRS) results for the study network of plans.

Acknowledgments

This work was supported by the National Science Foundation (NSF), Award No. 1760258. The findings and conclusions are those of the authors and do not necessarily represent the official position of the NSF. The authors thank Dr. Ali Mostafavi for his leadership, support, and encouragement of this and other research endeavors as part of the NSF-RAPID award, as well as Drs. Dawn Jourdan, Sam Brody, and Kent Portney for their helpful critiques of early drafts. We also are grateful for the thoughtful evaluations of three anonymous reviewers and the guidance of the editorial staff at Natural Hazards Review.

Supplemental Materials

Table S1 is available online in the ASCE Library (www.ascelibrary.org).

References

Bennet, A. 2019. "Harris County approves tougher interim floodplain development rules." Accessed April 5, 2019. https://www.bizjournals.com/houston/news/2019/07/10/harris-county-approves-tougher-interim-floodplain.html.

Berke, P., and D. Godschalk. 2009. "Searching for the good plan: A meta-analysis of plan quality studies." *J. Plann. Lit.* 23 (3): 227–240. https://doi.org/10.1177/0885412208327014.

Berke, P., G. Newman, J. Lee, T. Combs, C. Kolosna, and D. Salvesen. 2015. "Evaluation of networks of plans and vulnerability to hazards and climate change: A resilience scorecard." *J. Am. Plann. Assoc.* 81 (4): 287–302. https://doi.org/10.1080/01944363.2015.1093954.

Berke, P., S. Yu, M. Malecha, and J. Cooper. 2019a. "Plans that disrupt development: Equity policies and social vulnerability in six coastal cities." *J. Plann. Educ. Res.* https://doi.org/10.1177/0739456X19861144.

Berke, P. R., M. L. Malecha, S. Yu, J. Lee, and J. H. Masterson. 2019b. "Plan integration for resilience scorecard: Evaluating networks of plans in six US coastal cities." *J. Environ. Plann. Manage.* 62 (5): 901–920. https://doi.org/10.1080/09640568.2018.1453354.

Blake, E. S., and D. A. Zelinsky. 2018. "National Hurricane Center tropical cyclone report: Hurricane Harvey." Accessed February 20, 2019. https://www.nhc.noaa.gov/data/tcr/AL092017_Harvey.pdf.

Blessing, R., A. Sebastian, and S. D. Brody. 2017. "Flood risk delineation in the United States: How much loss are we capturing?" *Nat. Hazards Rev.* 18 (3): 04017002. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000242.

Brody, S., R. Blessing, A. Sebastian, and P. Bedient. 2014. "Examining the impact of land use/land cover characteristics on flood losses." *J. Environ. Plann. Manage.* 57 (8): 1252–1265. https://doi.org/10.1080/09640568.2013.802228.

Brody, S. D., R. Blessing, A. Sebastian, and P. Bedient. 2013. "Delineating the reality of flood risk and loss in Southeast Texas." *Nat. Hazards Rev.* 14 (2): 89–97. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000091.

Brody, S. D., W. E. Highfield, and J. E. Kang. 2011. *Rising waters: The causes and consequences of flooding in the United States*. Cambridge, UK: Cambridge University Press.

Burby, R., P. May, P. R. Berke, L. C. Dalton, S. P. French, and E. J. Kaiser. 1997. *Making governments plan*. Baltimore: Johns Hopkins University Press.

Burby, R. J. 1998. *Cooperating with nature: Confronting natural hazards with land-use planning for sustainable communities*. Washington, DC: Joseph Henry.

Burby, R. J., et al. 1999. "Unleashing the power of planning to create disaster-resistant communities." *J. Am. Plann. Assoc.* 65 (3): 247–258. https://doi.org/10.1080/01944369908976055.

Burby, R. J. 2006. "Hurricane Katrina and the paradoxes of government disaster policy: Bringing about wise governmental decisions for hazardous areas." *Ann. Am. Acad. Political Social Sci.* 604 (1): 171–191. https://doi.org/10.1177/0002716205284676.

City of Houston. 2018a. "Draft local action plan hurricane Harvey housing recovery." Accessed November 7, 2018. https://recovery.texas.gov/public-notices/files/5b-sap-amend8-english.pdf.

City of Houston. 2018b. "Hazard mitigation plan update 2018." Accessed June 28, 2018. https://s3-us-west-2.amazonaws.com/uasi-jtti/wp-content/uploads/sites/29/2018/05/16202024/City-of-Houston-HMAP-Update-3.13.18-3.12.23-PUBLIC-COPY_compressed.pdf.

City of Houston. 2019. "Demographic data." Accessed September 2, 2019. https://www.houstontx.gov/planning/Demographics.

City of Houston. 2020. "Transit-oriented development standards." Accessed August 27, 2020. https://houstontx.gov/planning/tod-standards.html.

Di Gregorio, M., D. R. Nurrochmat, J. Paavola, I. M. Sari, L. Fatorelli, E. Pramova, B. Locatelli, M. Brockhaus, and S. D. Kusumadewi. 2017. "Climate policy integration in the land use sector: Mitigation, adaptation and sustainable development linkages." *Environ. Sci. Policy* 67 (Jan): 35–43. https://doi.org/10.1016/j.envsci.2016.11.004.

Energy Corridor District. 2015. The energy corridor district 2015 master plan." Accessed January 28, 2019. https://www.energycorridor.org/sites/ecd/media/about/master-plan/20150625_ECD_MasterPlanReport_WEB.pdf.

FEMA. 2018. "3 m^2 continuous flood depth raster grid for Hurricane Harvey." Accessed April 18, 2019. https://doi.org/10.4211/hs.165e2c3e335d40949dbf501c97827837.

FEMA. 2019. "Disaster declarations for states and counties." Accessed July 3, 2019. https://www.fema.gov/data-visualization-disaster-declarations-states-and-counties.

Fidelman, P. I., A. M. Leitch, and D. R. Nelson. 2013. "Unpacking multilevel adaptation to climate change in the Great Barrier Reef, Australia." *Global Environ. Change* 23 (4): 800–812. https://doi.org/10.1016/j.gloenvcha.2013.02.016.

Finn, D., L. D. Hopkins, and M. Wempe. 2007. "The information system of plans approach: Using and making plans for landscape protection." *Landscape Urban Plann.* 81 (1–2): 132–145. https://doi.org/10.1016/j.landurbplan.2006.11.006.

Florida Statute §163.3177. 2020. "Florida statute." Accessed August 25, 2020. https://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&ULR=0100-0199/0163/Sections/0163.3177.html.

Gipson, T. 2017. "Hurricane Harvey—Houston, TX (Energy Corridor)." YouTube. Accessed October 3, 2019. https://www.youtube.com/watch?app=desktop&v=9LE_zYH6CEk.

Godschalk, D. 2003. "Urban hazard mitigation: Creating resilient cities." *Nat. Hazards Rev.* 4 (3): 136–143. https://doi.org/10.1061/(ASCE)1527-6988(2003)4:3(136).

Harris County. 2013. "Harris County all hazard mitigation plan." Accessed July 7, 2018. http://mitigationguide.org/wp-content/uploads/2013/05/TXHarris.pdf.

HCFCD (Harris County Flood Control District). 2018a. "Harris County flood control district federal briefing 2018." Accessed July 7, 2018. https://assets.documentcloud.org/documents/4578465/hcfcdfederalbriefing2018.pdf.

HCFCD (Harris County Flood Control District). 2018b. "Hurricane Harvey impact and response in Harris County." Accessed April 30, 2019. https://www.hcfcd.org/Portals/62/Harvey/harvey-impact-and-response-book-final-re.pdf.

HCFCD (Harris County Flood Control District). 2019. "Interactive mapping tools." Accessed February 25, 2019. https://www.hcfcd.org/interactive-mapping-tools/.

Hoch, C., L. C. Dalton, and F. S. So. 2000. *The practice of local government planning*. Washington, DC: International City/County Management Association.

Hopkins, L. D., and G.-J. Knaap. 2018. "Autonomous planning: Using plans as signals." *Plann. Theory* 17 (2): 274–295. https://doi.org/10.1177/1473095216669868.

Houston Business Journal. 2019. Harris County approves tougher interim floodplain development rules." Accessed August 5, 2019. https://www.bizjournals.com/houston/news/2019/07/10/harris-county-approves-tougher-interim-floodplain.html.

IPCC (Intergovernmental Panel on Climate Change). 2014. "Summary for policy makers." In *Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects: Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change*, edited by C. B. Field and V. R. Barros. New York: Cambridge University Press.

Jenkins, K., J. Hall, V. Glenis, and C. Kilsby. 2018. "A probabilistic analysis of surface water flood risk in London." *Risk Anal.* 38 (6): 1169–1182. https://doi.org/10.1111/risa.12930.

Kashem, S. B., B. Wilson, and S. Van Zandt. 2016. "Planning for climate adaptation: Evaluating the changing patterns of social vulnerability and adaptation challenges in three coastal cities." *J. Plann. Educ. Res.* 36 (3): 304–318. https://doi.org/10.1177/0739456X16645167.

Kim, S., and P. G. Rowe. 2013. "Are master plans effective in limiting development in China's disaster-prone areas?" *Landscape Urban Plann.* 111 (Mar): 79–90. https://doi.org/10.1016/j.landurbplan.2012.12.001.

Macintosh, A. 2013. "Coastal climate hazards and urban planning: how planning responses can lead to maladaptation." *Mitigation Adapt. Strategies Global Change* 18 (7): 1035–1055. https://doi.org/10.1007/s11027-012-9406-2.

Malecha, M., J. H. Masterson, S. Yu, and P. Berke. 2019. *Plan integration for resilience scorecard guidebook: Spatially evaluating networks of plans to reduce hazard vulnerability—Version 2.0*. College Station, TX: Institute for Sustainable Communities, College of Architecture, Texas A&M Univ.

Malecha, M. L., A. D. Brand, and P. R. Berke. 2018. "Spatially evaluating a network of plans and flood vulnerability using a Plan Integration for Resilience Scorecard: A case study in Feijenoord District, Rotterdam, the Netherlands." *Land Use Policy* 78 (Nov): 147–157. https://doi.org/10.1016/j.landusepol.2018.06.029.

Metropolitan Council. 2020. "Local planning handbook." Accessed August 25, 2020. https://metrocouncil.org/Handbook.aspx.

National Research Council. 2014. *Reducing coastal risk on the east and gulf coasts*. Washington, DC: The National Academies Press.

Needham, B. 2005. "The new Dutch spatial planning act: Continuity and change in the way which the Dutch regulate the practice of spatial planning." *Plann. Pract. Res.* 20 (3): 327–340. https://doi.org/10.1080/02697450600568662.

Neuman, M. 2004. "Planning Houston: A city without a planning culture." In *Proc., 11th Conf. of the Int. Planning History Society*. Barcelona, Spain: Universitat Politécnica de Catalunya.

Puckett, M. 2018. "New City of Houston floodplain regulations post-Harvey." Accessed April 5, 2019. https://www.freese.com/blog/new-city-houston-floodplain-regulations-post-harvey.

Sebastian, T., et al. 2017. *Hurricane Harvey Report: A fact-finding effort in the direct aftermath of Hurricane Harvey in the Greater Houston Region*. Delft: Delft University Publishers.

State of Texas Local Government Code § 375.001. 2005. "Chap. 375. Municipal management districts in general." Accessed July 10, 2019. https://law.justia.com/codes/texas/2005/lg/012.00.000375.00.html.

Stevens, M. R., W. Lyles, and P. R. Berke. 2014. "Measuring and reporting intercoder reliability in plan quality evaluation research." *J. Plann. Educ. Res.* 34 (1): 77–93. https://doi.org/10.1177/0739456X13513614.

Texas General Land Office. 2019. Texas coastal resiliency master plan." Accessed April 2, 2019. https://coastalstudy.texas.gov/resources/files/2019-coastal-master-plan.pdf.

USACE (United States Army Corps of Engineers). 2009. *Master plan, Addicks and Barker reservoirs, Buffalo Bayou and tributaries*. Fort Bend and Harris Counties, TX: USACE.

US Census. 2019. "Definition of 'Census tract'." Accessed June 21, 2019. https://www.census.gov/programs-surveys/geography/about/glossary.html#par_textimage_13.

Woltjer, J., and N. Al. 2007. "Integrating water management and spatial planning: Strategies based on the Dutch Experience." *J. Am. Plann. Assoc.* 73 (2): 211–222. https://doi.org/10.1080/01944360708976154.

Woodruff, S. C. 2018. "Coordinating plans for climate adaptation." *J. Plann. Educ. Res.* https://doi.org/10.1177/0739456X18810131.

Yu, S., A. D. Brand, and P. Berke. 2020. "Making room for the river: Applying a plan integration for resilience scorecard to a network of plans in Nijmegen, the Netherlands." *J. Am. Plann. Assoc.* 86 (4): 417–430. https://doi.org/10.1080/01944363.2020.1752776.