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Committee on Homeland Security and Governmental Affairs
United States Senate

The Honorable Marco Rubio
Chairman
Committee on Small Business and Entrepreneurship
United States Senate

The Honorable Peter A. DeFazio
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The Honorable Sheila Jackson Lee
House of Representatives

Natural Disasters: Economic Effects of Hurricanes Katrina, Sandy, Harvey, and Irma

Between January 1980 and July 2020, the United States experienced 273 climate and weather disasters for which the National Oceanic and Atmospheric Administration (NOAA) estimated damages costing $1 billion or more each.[1] NOAA estimated that the total cost of damages from these disasters exceeded $1.79 trillion and attributed over 50 percent of these costs to hurricanes and tropical storms. The Congressional Budget Office (CBO) estimated that federal disaster assistance covered, on average, 62 percent of the costs across the regions affected by these hurricanes for calendar years 2005 through 2015.[2] GAO has reported that the rising number of natural disasters and reliance on federal disaster assistance is a key source of federal fiscal exposure.[3]

You asked us to review the costs of natural disasters and their effects on communities. This report examines (1) estimates of the costs of damages caused by hurricanes and hurricanes'

[1]NOAA adjusts their damage estimates for inflation, and these estimates are expressed in 2020 dollars. Dollar amounts for cost of damages are drawn from NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2020), accessed July 14, 2020, https://www.ncdc.noaa.gov/billions/, DOI: 10.25921/stkw-7w73.

[2]Congressional Budget Office, *Potential Increases in Hurricane Damage in the United States: Implications for the Federal Budget* (June 2016), 22.

[3]GAO, *The Nation's Fiscal Health: Action Is Needed to Address the Federal Government's Fiscal Future,* GAO-20-403SP (Washington, D.C.: Mar. 12, 2020), 34.

effects on overall economic activity and employment in the areas they affected, and (2) actions subsequently taken in those areas to improve resilience to future natural disasters.

To address these issues, we identified hurricanes that were declared a major disaster by the President under the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), which establishes key programs through which the federal government provides disaster assistance, primarily through the Department of Homeland Security's Federal Emergency Management Agency (FEMA).[4] We examined FEMA and NOAA data on hurricanes and selected as case studies the four hurricanes—Katrina (August 25-30, 2005), Sandy (October 30-31, 2012), Harvey (August 25-31, 2017), and Irma (September 6-12, 2017)—that caused the most damages in the 50 U.S. states and the District of Columbia from 2004 to 2018.[5]

To examine hurricanes' effects on overall economic activity and employment in the areas they affected, we first used FEMA data to identify counties (and parishes[6]) eligible for its Individual Assistance (IA) and/or Public Assistance (PA) programs after each selected hurricane (affected counties). Then, we used Census Bureau data to identify metropolitan areas that overlapped with affected counties (affected metropolitan areas). One limitation of this approach is that the severity of a hurricane and the damages it caused may have varied across affected counties even though they were all eligible for assistance. Similarly, the severity of a hurricane and the damages it caused may also have varied across affected metropolitan areas, even though they all overlapped with affected counties.

To describe overall economic activity in affected metropolitan areas, we used monthly indices of economic activity for the period from February 1990 through December 2019 created by researchers at the Federal Reserve Bank of St. Louis and Saint Louis University to reflect labor market, housing market, and credit market activity, as well as overall income and output.[7] These indices are only available for large metropolitan areas. For each selected hurricane, we therefore analyzed economic activity in each of the large metropolitan areas that was affected by the hurricane.[8] We examined whether economic activity in the month of the hurricane and

[4]Pub. L. No. 93-288, 88 Stat. 143 (1974), as amended, 42 U.S.C. §§ 5121-5207.

[5]For the purposes of this report, we did not consider the effects of hurricanes on U.S. territories. However, during the period from 2004 through 2018, American Samoa, Puerto Rico, and the U.S. Virgin Islands received major disaster declarations for hurricanes or tropical storms. We have recently reported on disaster response and recovery efforts in Puerto Rico and the U.S. Virgin Islands after Hurricanes Irma and Maria in 2017. GAO, *U.S. Virgin Islands Recovery: Status of FEMA Public Assistance Funding and Implementation*, GAO-19-253 (Washington, D.C.: Feb. 25, 2019); GAO, *Puerto Rico Hurricanes: Status of FEMA Funding, Oversight, and Recovery Challenges*, GAO-19-256 (Washington, D.C.: Mar. 14, 2019); GAO, *U.S. Virgin Islands Recovery: Additional Actions Could Strengthen FEMA's Key Disaster Recovery Efforts*, GAO-20-54 (Washington, D.C.: Nov. 19, 2019); and GAO, *Puerto Rico Disaster Recovery: FEMA Actions Needed to Strengthen Project Cost Estimation and Awareness of Program Guidance*, GAO-20-221 (Washington, D.C.: Feb. 5, 2020). We have also discussed certain economic effects of Tropical Storm Gita on American Samoa in 2018. GAO, *American Samoa: Economic Trends, Status of the Tuna Canning Industry, and Stakeholders' Views on Minimum Wage Increases*, GAO-20-467 (Washington, D.C.: Jun. 11, 2020).

[6]We also use the word counties to denote parishes in Louisiana.

[7]M. A. Arias, C. S. Gascon, and D. E. Rapach, "Metro Business Cycles," *Journal of Urban Economics*, vol. 94 (2016), 90-108.

[8]For each hurricane, we analyzed metropolitan areas that met two criteria: (1) an economic activity index for the metropolitan area is available because it was one of the 50 largest U.S. metropolitan areas by population in 2014, and (2) at least one county in the metropolitan area was eligible for FEMA IA, PA, or both after the hurricane. Based on this approach, we analyzed four metropolitan areas affected by Hurricane Katrina, 13 metropolitan areas affected

the subsequent three months was lower or higher than the average of economic activity over all months. We report that economic activity was lower or higher than expected in a given month when it was lower or higher than average economic activity and the difference is statistically significant at the five percent level. In metropolitan areas where economic activity was lower than expected in the month of the hurricane or in any of the subsequent three months, we also examined whether the average of economic activity over the first and second years after the hurricane was lower or higher than the average of economic activity over the year before the hurricane to describe how economic activity evolved after the initial shock. We calculated the average of economic activity over a year as the average of monthly economic activity for each of the 12 months of that year.

To describe employment in affected counties, we used monthly employment data from the Bureau of Labor Statistics' (BLS) Quarterly Census of Employment and Wages for the period from August 2000 through September 2019. For each affected county we analyzed, we compared total employment the month of the hurricane and the subsequent three months to the average of total employment over all months after accounting for long-term trends and seasonal variation.[9] We report that total employment was lower or higher than expected in a given month when it was lower or higher than average total employment after accounting for long-term trends and seasonal variation and the difference is statistically significant at the five percent level. In counties where total employment was lower than expected in the month of the hurricane or in any of the subsequent three months, we also examined whether the average of total employment over the first and second years after the hurricane was lower or higher than the average of total employment over the year before the hurricane, in order to describe how total employment evolved after the initial shock. We calculated the average of total employment over a year as the average of monthly total employment for each of the 12 months of that year. Finally, we compared the distribution of employment across economic sectors for all affected counties one year after each hurricane to the distribution before the hurricane. Economic sectors in the BLS data we analyzed include construction; manufacturing; natural resources; education and health; finance; leisure and hospitality; professional and business services; trade, transportation, and utilities; information; and other private services.[10]

Our analyses of economic activity and employment have limitations and our results should be interpreted with caution. The patterns we observed in economic activity and employment may have occurred even in the absence of the hurricanes, and we cannot isolate the effects of the hurricanes from the effects of other events that occurred at the same time. In addition, hurricanes may have had effects on economic activity or employment that are not captured in the data we used or were significant only in certain parts of the metropolitan areas and counties we analyzed. Finally, our results do not generalize to other locations, hurricanes, or time periods.

To examine the actions taken to improve resilience to future natural disasters in the areas affected by the selected hurricanes, we examined data from FEMA's Hazard Mitigation Grant Program (HMGP), FEMA's PA program, the U.S. Department of Housing and Urban

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by Hurricane Sandy, five metropolitan areas affected by Hurricane Harvey, and nine metropolitan areas affected by Hurricane Irma. Enclosure I lists the metropolitan areas we analyzed.

[9]We analyzed 179 counties affected by Hurricane Katrina, 146 counties affected by Hurricane Sandy, 73 counties affected by Hurricane Harvey, and 272 counties affected by Hurricane Irma.

[10]Bureau of Labor Statistics, Quarterly Census of Employment and Wages, December 20, 2019, accessed July 7, 2020, https://www.bls.gov/cew/classifications/industry/industry-supersectors.htm.

Development's (HUD) Community Development Block Grant Disaster Recovery program (CDBG-DR), and the U.S. Army Corps of Engineers (USACE).

For both objectives, we interviewed federal, state, and local officials, and academic experts. We visited areas affected by each selected hurricane and met with federal, state, and local officials. We assessed the reliability of the data we used by interviewing agency officials, reviewing relevant documentation, and electronically testing the data. We determined the data were sufficiently reliable for our purposes. Enclosure I provides a more detailed description of our scope and methodology.

We conducted this performance audit from January 2019 to September 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Selected Hurricanes Caused Costly Damages and Challenges for Some Populations; Effects on Overall Economic Activity and Employment Varied Widely

In communities affected by the selected hurricanes, NOAA's damage estimates were $170 billion for Katrina, $74 billion for Sandy, $131 billion for Harvey, and $52 billion for Irma.[11] These estimates include the value of damages to residential, commercial, and government or municipal buildings; material assets within the buildings; business interruption; vehicles and boats; offshore energy platforms; public infrastructure; and agricultural assets.[12]

The selected hurricanes were also costly to the federal government, primarily as a result of federal disaster assistance and subsidized flood insurance payments.[13] In 2016, CBO estimated that federal spending exceeded $110 billion in response to Katrina and $53 billion in response to Sandy.[14] In 2018, we reported that Congress and the President have also provided federal agencies with at least $120 billion in supplemental appropriations for activities related to natural disasters in 2017, including Hurricanes Harvey and Irma.[15]

In addition to the costly damages they caused, we found that the selected hurricanes were associated with widely varying effects on overall economic activity in the affected metropolitan

[11]NOAA adjusts their damage estimates for inflation, and these estimates are expressed in 2020 dollars.

[12]NOAA's assessments include damages to military bases. However, they do not take into account values associated with loss of life, health care costs, or environmental damages and, as a result, the cost estimates should be considered conservative. A. B. Smith and R. W. Katz, "U.S. Billion-Dollar Weather and Climate Disasters: Data Sources, Trends, Accuracy and Biases," *Natural Hazards*, vol. 67 (2013): p. 387.

[13]To the extent that federal spending helps cover the costs of repairing or replacing damaged property, it does not represent an additional cost on top of NOAA's estimated costs.

[14]Dollar amounts are adjusted for inflation and measured in 2015 dollars. Federal spending includes spending by FEMA through the Disaster Relief Fund and the National Flood Insurance Program; HUD through CDBG-DR; U.S. Army Corps of Engineers civil works and disaster-response programs; the Small Business Administration for its disaster loans; the Department of Transportation; the Department of Education; and the Department of Defense, excluding the U.S. Army Corps of Engineers. Congressional Budget Office, *Potential Increases in Hurricane Damage in the United States: Implications for the Federal Budget* (June 2016), 19, 31. Federal spending in response to Hurricane Katrina and Hurricane Sandy was almost $120 billion and $59 billion, respectively, in 2020 dollars.

[15]GAO, *2017 Hurricanes and Wildfires: Initial Observations on the Federal Response and Key Recovery Challenges,* GAO-18-472 (Washington, D.C.: Sep. 4, 2018), 75.

areas we analyzed. Our analysis suggests that economic activity was lower than expected the month of the hurricane or in some of the first three months after the hurricane in New Orleans-Metairie, Louisiana, after Hurricane Katrina, as well as in Miami-Fort Lauderdale-West Palm Beach, Florida, and Columbia, South Carolina, after Hurricane Irma.[16] Within one year, average economic activity in these three metropolitan areas was similar to or greater than what it had been in the year before the hurricane.[17] Our analysis suggests that economic activity was not lower than expected in the month of the hurricane or any of the subsequent three months in the remaining affected metropolitan areas we analyzed.

We found that the selected hurricanes were also associated with widely varying effects on total employment in affected counties. Our analysis suggests that in 80 affected counties, total employment was lower than expected the month of the hurricane or in some of the first three months after the hurricane (see table 1). In 47 of these 80 counties, total employment was at least as high as pre-hurricane employment on average within one year, but in the other 33 counties, total employment was lower on average than pre-hurricane employment for at least one year.[18] Our analysis suggests that in the remaining affected counties, the selected hurricanes were not associated with total employment that was lower than expected the month of the hurricane or any of the subsequent three months.

Table 1: Number of Affected Counties with Low Total Employment after Selected Hurricanes

Hurricane	Affected Counties	Employment Lower than Expected in the Month of the Hurricane or in Some of the Subsequent Three Months	Average Employment in First Year After Hurricane Lower than Average Employment the Year Before the Hurricane	Average Employment in First and Second Years After Hurricane Lower than Average Employment the Year Before the Hurricane
Katrina	179	26	17	13
Sandy	146	19	9	6
Harvey	73	7	4	3
Irma	272	28	3	2
Total	670	80	33	24

Source: GAO analysis of data from the Bureau of Labor Statistics and the Federal Emergency Management Agency. | GAO-20-633R

Notes: Affected counties are counties and parishes that were eligible for FEMA Individual Assistance, Public Assistance, or both after a hurricane. We estimated that total employment in an affected county was lower than expected if it was less than average total employment in the county for the period from August 2000 through September 2019 after taking into account long-term trends and seasonal variation and the difference was statistically significant at the five percent level. We estimated that total employment one and two years after the hurricane was lower than total employment before the hurricane if the average of total employment for the first and second 12 month periods after the hurricane was less than the average of total employment for the 12 month period before the hurricane. See enclosure I for more information on our methodology.

[16]We estimated that economic activity in an affected metropolitan area was lower than expected if it was lower than average economic activity in the metropolitan area and the difference was statistically significant at the five percent level.

[17]We calculated average economic activity over a year as the average of monthly economic activity for each of the 12 months of that year.

[18]We calculated average employment over a year as the average of monthly employment for each of the 12 months of that year.

Finally, we found that the selected hurricanes were not associated with noticeable changes in the distribution of employment across economic sectors.[19] Construction employment increased temporarily after each hurricane across all affected counties, but the year after each hurricane, the distribution of employment across economic sectors was similar to that the year before.

In addition to their effects on overall economic activity and total employment, the selected hurricanes created challenges for certain populations within the communities they affected. State and local government officials told us that the selected hurricanes had significant impacts on communities, local governments, households, and businesses with fewer resources and less expertise, and that challenges faced by households may have impacted local businesses.

- Local officials in Louisiana told us that New Orleans' weak economy after Katrina was in part associated with the decline in the city's population and reduction in the local oil and gas industry, a major employer, before the storm.

- State officials in Texas noted that the size of a community and its overall capacity to provide public services are important factors influencing how quickly it can recover after a disaster. They told us that recovery is faster in larger communities, such as Houston, where local governments have staff who specialize and have experience in disaster management, and that recovery is slower in smaller communities where the local government may not have staff solely dedicated to or specializing in disaster management. They also told us that, because of the size of their tax bases, larger communities have more money to invest in emergency services with significant fixed or upfront costs.

- Local officials in Texas explained that a large part of a household's recovery is either entirely self-funded or partially funded by insurance. Accordingly, local officials in Texas and Louisiana told us that households with low income and wealth may struggle because they have fewer resources to draw on and are less likely to be insured. Local officials in Louisiana noted that seniors, in particular, struggled after Hurricane Katrina because they lacked insurance and the resources to relocate. State officials in Florida indicated that low income households tend to live in older homes and thus were more likely to be displaced after Hurricane Irma. Local officials in Florida and Texas informed us that low income households have more difficulty taking the steps required to obtain federal disaster assistance, such as producing documentation, finding transportation to places to fill out applications, and taking time off to attend meetings or interviews.[20]

- Local officials in Florida explained that smaller business that have less access to capital struggle to cover operating expenses, including salaries and inventories, while they wait for disaster assistance or the economy to recover. Similarly, local officials in Louisiana

[19]Economic sectors in the BLS data we analyzed include construction; manufacturing; natural resources; education and health; finance; leisure and hospitality; professional and business services; trade, transportation, and utilities; information; and other private services.

[20]The U.S. Department of Homeland Security (DHS) found that financial disruptions from disasters disproportionately affect lower-income communities. U.S. Department of Homeland Security, *2018 National Preparedness Report* (Washington, D.C.: 2018), 44.

said that many small businesses without insurance, capital, or continuity plans prior to Katrina closed because of Katrina.[21]

- State officials in Florida and local officials in Texas told us that even businesses that rebuilt and reopened their establishments quickly may have had difficulty recovering if their employees were displaced after Hurricane Harvey and Hurricane Irma. Similarly, state officials in Florida indicated that some businesses reopened quickly but had difficulty recovering from Hurricane Irma because their customers had relocated to a different area after the storm.

Affected Communities Are Taking Actions to Improve Resilience but Multiple Factors Can Affect Decision-making and Vulnerabilities Remain

We found that communities affected by the selected hurricanes have been taking actions to improve resilience to future hurricanes and similar natural disasters (hereafter resilience actions). As we have previously reported, resilience actions encompass hazard mitigation—actions taken to lessen the impact of future disasters.[22] We found that affected communities in selected states have been using post-disaster federal financial assistance from FEMA and HUD to implement hazard mitigation projects, as well as recovery projects with a hazard mitigation component (see table 2). Affected communities have also implemented such projects in collaboration with USACE.

Table 2: Recovery and Mitigation Project Amounts in Selected States Associated with Selected Hurricanes

Dollars in millions

Hurricane and State	FEMA Hazard Mitigation Grant Program[a]		FEMA Public Assistance[b]			HUD Community Development Block Grant Disaster Recovery[c]		U.S. Army Corps of Engineers[d]	
	Total Estimated Project Amount	Total Federal Amount Obligated	Total Project Amount	Total Federal Amount Obligated	Total Mitigation Amount	Total Project Amount	Total Budget Amount	Total Project Amount	Total Federal Amount
Hurricane Katrina in Louisiana	1,692.6	1,577.6	9,943.6	9,943.5	386.7	16,595.9	13,567.0	14,738.4	12,964.6
Hurricane Sandy in New York	1,060.3	867.6	12,935.0	11,641.6	5,024.5	8,175.0	8,175.0	3,545.8	3,320.4
Hurricane Harvey in Texas	338.0	253.4	701.1	631.0	102.4	5,391.5	5,391.5	5,109.6	3,724.6

[21]DHS found that small businesses tend to lack continuity plans. U.S. Department of Homeland Security, *2018 National Preparedness Report* (Washington, D.C.: 2018), 39-40.

[22]Disaster resilience refers to the ability to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions. Hazard mitigation—actions taken to lessen the impact of disasters—is a kind of action that enhances disaster resilience by reducing disaster risk. GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters,* GAO-20-100SP (Washington, D.C.: Oct. 23, 2019), 1.

Hurricane and State	FEMA Hazard Mitigation Grant Program[a]		FEMA Public Assistance[b]			HUD Community Development Block Grant Disaster Recovery[c]		U.S. Army Corps of Engineers[d]	
	Total Estimated Project Amount	Total Federal Amount Obligated	Total Project Amount	Total Federal Amount Obligated	Total Mitigation Amount	Total Project Amount	Total Budget Amount	Total Project Amount	Total Federal Amount
Hurricane Irma in Florida	279.5	197.0	401.0	360.9	9.8	615.3	615.3	1,042.8	955.6

Source: GAO analysis of data from the Federal Emergency Management Agency (FEMA), the U.S. Department of Housing and Urban Development (HUD), and the U.S. Army Corps of Engineers. | GAO-20-633R

Notes: Recovery generally refers to actions taken to address damages caused by a disaster that occurred in the past, while mitigation refers to actions taken to lessen the impact of future disasters. Hurricane Katrina occurred in August 2005, Hurricane Sandy occurred in October 2012, and Hurricanes Harvey and Irma occurred in August-September 2017.

[a]Analysis of FEMA Hazard Mitigation Grant Program (HMGP) projects used data as of May 2020 on projects funded in selected states after the selected hurricanes. HMGP is designed to improve communities' resilience to future disasters during recovery and funds a wide range of projects for this purpose. Federal amounts are the actual amounts that FEMA has obligated for a project. These amounts may change over time because funds are awarded up front and additional obligations or de-obligations may occur when projects are completed. We estimated project amounts by dividing the federal amount for each project by the federal cost share for that project.

[b]Analysis of FEMA Public Assistance (PA) projects used data as of February 2020 on permanent works projects funded in selected states after the selected hurricanes. PA provides funding to state, territorial, local, and tribal governments to assist them in responding to and recovering from major disasters or emergencies, as well as funding for hazard mitigation. Permanent works projects involve permanent restoration of damaged facilities, including hazard mitigation to protect the facilities from future damage. Project amount is the estimated total cost of the PA grant projects, without administrative costs. Federal amount obligated is the PA grant funding available to the grantees (states) for sub-grantees' approved project worksheets. Mitigation amount is the part of project amount that is mitigation instead of repair and restoration to pre-disaster capacity.

[c]Analysis of HUD Community Development Block Grant Disaster Recovery (CDBG-DR) projects used data as of January 2020 for projects funded in Louisiana after Hurricane Katrina and as of October 2019 for projects funded in New York, Texas, and Florida after Hurricane Sandy, Hurricane Harvey, and Hurricane Irma, respectively. CDBG-DR grants can be used to address a wide range of unmet recovery needs after a disaster related to housing, infrastructure, and economic revitalization, and mitigation actions that are part of rebuilding efforts may be eligible as CDBG-DR recovery activities. Projected amount reflects the total costs of projects and can include amounts that will be funded by sources other than CDBG-DR, such as FEMA Hazard Mitigation Grant Program funds. Budget amount includes CDBG-DR funds and any income generated by those funds. Amounts reflect the largest grantees only.

[d]Analysis of U.S. Army Corps of Engineers projects used data as of October-November 2019 for projects in Florida and New York funded at least in part with supplemental appropriations associated with Hurricane Irma and Hurricane Sandy, respectively, and data as of May 2020 for projects in Louisiana and Texas funded at least in part with supplemental appropriations associated with Hurricane Katrina and Hurricane Harvey, respectively. Amounts reflect project funding from supplemental appropriations associated with selected hurricanes.

Affected communities have been using FEMA HMGP grants primarily to (1) elevate, relocate, flood-proof, retrofit, and add safe rooms to public and private structures in Louisiana after Hurricane Katrina; (2) improve the resilience of critical facilities and infrastructure in New York after Hurricane Sandy; (3) acquire private real property for flood plain management in Texas after Hurricane Harvey; and (4) elevate, relocate, flood-proof, retrofit, and add safe rooms to public and private structures, as well as improve the resilience of critical facilities and infrastructure, in Florida after Hurricane Irma (see table 3 for examples of specific projects).

Table 3: Largest FEMA Hazard Mitigation Grant Program Projects by Estimated Project Amount in Selected States Associated with Selected Hurricanes as of May 2020

Hurricane and State	Sub-grantee	Type and Description	Estimated Project Amount (dollars in millions)	Federal Amount Obligated (dollars in millions)
Hurricane Katrina in Louisiana	State of Louisiana Office of Community Development	Elevations, Relocations, Floodproofing, Retrofits, and Safe Rooms This project provides assistance to eligible homeowners to elevate or reconstruct their homes and for individual mitigation measures to make homes stronger and safer in future natural disasters.	678.3	678.3
Hurricane Sandy in New York	State of New York Department of Transportation	Critical Facilities and Infrastructure This project provides upgrades and retrofits of 105 bridges in New York State vulnerable to erosion of foundation materials during floods.	518.0	518.0
Hurricane Harvey in Texas	Harris County Flood Control District	Acquisitions This project involves the acquisition of 502 flood-prone homes damaged by Hurricane Harvey. Once the structures are removed, the land will be dedicated and maintained as open space to conserve natural floodplain functions.	215.8	161.8
Hurricane Irma in Florida	North Bay Village	Critical Facilities & Infrastructure This project involves removing utility poles and burying overhead power lines. Severe winds can cause poles and/or overhead lines to fall, damaging property and causing both power outages and a risk of electric shock. Burying these lines can increase the resilience of the power grid and reduce effects on people and property.	19.3	11.0

Source: GAO analysis of data from the Federal Emergency Management Agency (FEMA). | GAO-20-633R

Notes: Analysis FEMA Hazard Mitigation Grant Program projects used data as of May 2020. Federal amounts are the actual amounts that FEMA has obligated for a project. These amounts may change over time because funds are awarded up front and additional obligations or de-obligations may occur when projects completed. We estimated project amounts by dividing the federal amount for each project by the federal cost share for that project.

Affected communities have been using FEMA PA grants primarily to improve resilience of public buildings in all four selected states after selected hurricanes, as well as to improve resilience of roads and bridges, public utilities, and recreational and other facilities in Florida after Hurricane Irma (see table 4 for examples of specific projects).

Table 4: Largest FEMA Public Assistance Program Mitigation Projects by Mitigation Amount in Selected States Associated with Selected Hurricanes as of February 2020

Hurricane and State	Sub-grantee	Type and Description	Project Amount (dollars in millions)	Federal Amount Obligated (dollars in millions)	Mitigation Amount (dollars in millions)
Hurricane Katrina in Louisiana	State of Louisiana, Facility Planning and Control	Public Buildings Restore damaged architectural, mechanical, and electrical components; elevate mechanical, electrical, plumbing, and other equipment; install generators.	102.9	102.9	89.2
Hurricane Sandy in New York	Long Island Power Authority	Public Utilities Long Island Power Authority is a power company serving 1.2 million customers with 12,000 miles of lines that experienced downed power lines. Mitigation entails strengthening lines for wind, burying lines, installing Automatic Sectionalizing Units, elevating substations, and storm hardening.	1,409.7	1,268.7	729.7
Hurricane Harvey in Texas	Humble Independent School District	Public Buildings Restore and floodproof the school. Floodproofing will involve installing floodgates at the entrances to the school building that will be underground during normal conditions, but will rise as the water table rises during storms. The floodgates will be 8 feet high when fully deployed.	78.7	70.8	28.2
Hurricane Irma in Florida	Tampa	Public Utilities Defray the costs of wastewater infrastructure repairs taken for Hurricane Irma.	1.4	1.2	0.6

Source: GAO analysis of data from the Federal Emergency Management Agency (FEMA). | GAO-20-633R

Notes: Analysis of FEMA Public Assistance (PA) projects used data as of February 2020. Project amount is the estimated total cost of the PA grant projects, without administrative costs. Federal amount obligated is the PA grant funding available to the grantees (states) for sub-grantees' approved project worksheets. Mitigation amount is the part of project amount intended to mitigate future damages instead of repair and restoration to pre-disaster capacity.

Recipients of HUD CDBG-DR grants have allocated most of the funds to (1) compensation and incentive payments to eligible homeowners in Louisiana, after Hurricane Katrina, under the Road Home Homeowner Program,[23] and (2) rehabilitation and reconstruction of residential

[23]The Louisiana Road Home Homeowner Program was designed to provide a one-time compensation grant payment, up to a maximum of $150,000, to eligible homeowners whose primary residence was damaged by Hurricane Katrina or Hurricane Rita in 2005 and who wished to (1) repair or rebuild their home, (2) purchase another home in Louisiana, or (3) sell their home and relocate outside of the state.

structures in New York after Hurricane Sandy, Texas after Hurricane Harvey, and Florida after Hurricane Irma.

In collaboration with nonfederal community partners, USACE has rehabilitated and constructed flood barriers (e.g. levees, floodwalls, floodgates) and water diversion projects (e.g. retention basins, waterways enlargements) in Louisiana after Hurricane Katrina, and they are taking similar actions in New York after Hurricane Sandy, Texas after Hurricane Harvey, and Florida after Hurricane Irma. For example, in collaboration with the Coastal Protection and Restoration Authority Board of Louisiana, USACE spent billions of dollars replacing, rebuilding, and raising levees and floodwalls along Lake Pontchartrain bordering New Orleans after Hurricane Katrina.

Community officials we spoke with also reported taking resilience actions outside of federal programs. For instance, state officials in Louisiana and local officials in Texas told us that Louisiana and Harris County, Texas, approved new building code regulations after Hurricanes Katrina and Harvey, respectively. In addition, local officials in Florida constructed a storm water park to collect and store water that could otherwise flood nearby homes during storms.

A community's decision to take a resilience action can depend on the costs and benefits of that action to the community. If the community decides to take the action, then the community incurs the cost of taking the action and forgoes other uses of the funds. Under certain circumstances, federal financial assistance is available to a community to help fund a resilience action and thereby lower its costs to the community.

The community's primary benefit from a resilience action is improved resilience to future natural disasters. For example, a 2019 report by the National Institute of Building Sciences suggests that the benefits of several types of resilience actions may exceed their construction and maintenance costs by protecting lives and property and preventing other losses.[24] However, the benefits from a resilience action are uncertain and depend on the likelihood, severity, and location of future disasters. The benefit also depends on the extent to which the community bears the cost of damages from a future disaster. If the community expects that federal assistance will be available post-disaster to cover damages that the resilience action could have prevented, then the expected benefit of that action could be reduced. The community's tolerance for incurring damages can factor into this assessment. Indeed, the resilience action may prevent costly damages from occurring, whereas post-disaster federal assistance does not.

When evaluating the costs and benefits of an action, the standard criterion to decide whether the action can be justified on economic principles is net present value—the discounted monetized value of expected net benefits (i.e., benefits minus costs). Net present value is computed by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits. An action with a positive net present value is generally preferred, and the sensitivity of the net present value to important sources of uncertainty should be considered. GAO has outlined in its Disaster Resilience Framework how the federal government can contribute information and integrated analysis that enhance a community's understanding of the costs and benefits associated with resilience actions.[25]

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[24]Multihazard Mitigation Council, National Institute of Building Sciences, *Natural Hazard Mitigation Saves: 2019 Report* (Washington, D.C.: December 2019).

[25]GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters,* GAO-20-100SP (Washington, D.C.: Oct. 23, 2019), 8.

Even as communities are taking resilience actions, state and local officials we spoke with indicated that vulnerabilities remain. Local officials in Louisiana and Texas told us that numerous older homes in their communities remain vulnerable and do not meet current building codes. Texas officials also reported that flood losses covered by insurance are growing in areas outside FEMA's identified base flood areas.[26] For example, Harris County Flood Control District in Texas reported that of the 154,170 homes flooded in Harris County during Hurricane Harvey, 68 percent were located outside the FEMA base flood areas.[27] Further, in reports to FEMA, states indicate they anticipate that the scope of damages via exposure to weather hazards, such as hurricanes, will likely remain high and could expand across regions affected by the selected hurricanes, and some local governments have projected that population will grow in the regions affected by the selected hurricanes.[28] GAO has reported that population growth in hazard prone regions is increasing the nation's vulnerability to losses from natural hazards.[29] To help address this vulnerability, GAO has identified key principles for the federal government to facilitate and promote resilience to natural disasters in its Disaster Resilience Framework.[30]

Agency Comments

We provided drafts of this report to the Department of Commerce, the Department of Defense, the Department of Homeland Security, and the Department of Housing and Urban Development for their review and comment. The National Oceanic and Atmospheric Administration within the Department of Commerce provided technical comments, which we incorporated as appropriate. The other agencies told us that they had no comments on the draft report.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Defense, the Secretary of Commerce, the Secretary of Homeland Security, the Secretary of Housing and Urban Development, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have any questions about this report, please contact me at (202) 512-8424 or richardo@gao.gov. Contact points for our offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report were Courtney LaFountain (Assistant Director), Lorraine Ettaro (Analyst-in-Charge), Pille Anvelt, Namita Bhatia Sabharwal, Ben Bolitzer, Carol Bray, Colleen Candrl, Jehan Chase, Lacey Coppage, Jaci Evans, Kathryn Godfrey, Dani Greene, Tim Guinane, Susan Irving, Christine

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[26]FEMA identifies a flood hazard area on the Flood Insurance Rate Map as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the *base flood* or 100-year flood.

[27]Harris County Flood Control District, Immediate Report Final Hurricane Harvey Storm and Flood Information (Houston, Texas: June 4, 2018), 13.

[28]Florida Division of Emergency Management, *Enhanced State Hazard Mitigation Plan* (2018), 133, 179, and 201; Louisiana Governor's Office of Homeland Security and Emergency Preparedness, *2019 State Hazard Mitigation Plan Update* (Baton Rouge, Louisiana: 2019), 162-163; Texas Department of Public Safety, Division of Emergency Management, *State of Texas Hazard Mitigation Plan* (October 17, 2018), 105; Miami-Dade County, *Local Mitigation Strategy* (January 2018), 15 and 19; City of Houston, *Hazard Mitigation Plan Update 2018* (March 2018), 25; and New York City Emergency Management, *NYC's Risk Landscape: A Guide to Hazard Mitigation* (May 2019), 18.

[29]GAO, *Natural Hazard Mitigation: Various Mitigation Efforts Exist, but Federal Efforts Do Not Provide a Comprehensive Strategic Framework,* GAO-07-403 (Washington, D.C.: Aug. 22, 2007), 24.

[30]GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters,* GAO-20-100SP (Washington, D.C.: Oct. 23, 2019).

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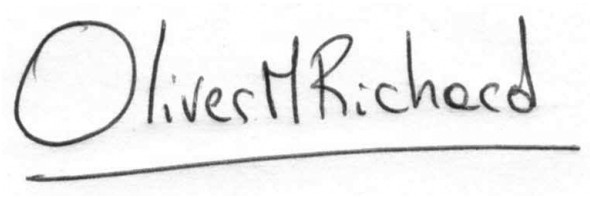

Oliver Richard
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Enclosure(s) – 1

Enclosure I: Objectives, Scope, and Methodology

This report examines (1) estimates of the costs of damages caused by hurricanes and hurricanes' effects on overall economic activity and employment in the areas they affected, and (2) actions subsequently taken in those areas to improve resilience to future natural disasters.

To address these objectives, we selected four hurricanes (selected hurricanes) as case studies that had sizable effects on the 50 U.S. states and the District of Columbia during the period from 2004 through 2018. We used Federal Emergency Management Agency (FEMA) data to identify hurricanes that received major disaster declarations in one or more of the 50 states and the District of Columbia during this time period. We used FEMA data and National Oceanic and Atmospheric Administration (NOAA) data to construct indicators of the effects of those hurricanes. FEMA data included numbers of approved Individual Assistance (IA) applications, amounts of approved Individual and Households Program (IHP) assistance, and amounts of obligated Public Assistance (PA) grants associated with each hurricane. NOAA data included estimated costs and estimated deaths associated with each hurricane. We assessed the reliability of these data by interviewing FEMA and NOAA officials, reviewing relevant documentation, and electronically testing the data, and we determined that the data were sufficiently reliable for our purpose.

Based on our indicators, we identified the hurricane that had the largest effect in each of three time periods: 2004 through 2008, 2009 through 2013, and 2014 through 2018. The selected hurricanes are Hurricanes Katrina, Sandy, Harvey, and Irma (see table 5).[31] We selected both Hurricanes Harvey and Irma because some indicators suggested that Hurricane Harvey had the largest effect in the period from 2014 through 2018 and other indicators suggest that Hurricane Irma did. A limitation of this approach is that our findings are not generalizable to other hurricanes or other types of natural disasters.

Table 5: Selected Hurricanes, States, Counties or Parishes, and Metropolitan Areas

Selected Hurricane	Dates	Selected State Affected by Hurricane	Selected County or Parish Affected by Hurricane	Selected Metropolitan Area Affected by Hurricane
Hurricane Katrina	August 25-30, 2005	Louisiana	Orleans	New Orleans-Metairie
Hurricane Sandy	October 22-29, 2012	New York	New York	New York-Newark-Jersey City
Hurricane Harvey	August 17-September 1, 2017	Texas	Harris	Houston-The Woodlands-Sugarland
Hurricane Irma	August 30-September 12, 2017	Florida	Miami-Dade	Miami-Fort Lauderdale-West Palm Beach

Source: GAO analysis of data from the Census Bureau (Census), the Federal Emergency Management Agency (FEMA), and the National Oceanic and Atmospheric Administration (NOAA). | GAO-20-633R

Notes: Selected hurricanes are those that that had sizeable effects on the 50 U.S. states and the District of Columbia during the period from 2004 through 2018 as indicated by data from FEMA and NOAA. The selected state and county or parish associated with each hurricane is the state and county or parish on which the hurricane had the largest effect as indicated by Census and FEMA data. The selected metropolitan area associated with each hurricane is the metropolitan area containing the selected county.

[31]Sandy has been referred to as both a hurricane and a superstorm. The National Hurricane Center declared Sandy a hurricane, but changed that designation to "post-tropical" storm just before it made landfall. In this report, we refer to the event as "Hurricane Sandy."

For each selected hurricane, we identified a state and metropolitan area affected by the hurricane from which to obtain the views of state and local government officials, to tour sites of selected recovery and mitigation projects, and to describe actions taken to reduce the costs of future disasters. We used Census Bureau (Census) and FEMA data to construct indicators of the effects of the hurricane by state and county. Census data included population. FEMA data included numbers and costs of PA projects; numbers of valid IHP registrations, numbers of approved IHP applicants, and amounts of approved IHP assistance for homeowners and renters; and amounts of IHP damages for homeowners. We assessed the reliability of these data by reviewing relevant documentation, interviewing FEMA officials, and electronically testing the FEMA data, and we determined that the data were sufficiently reliable for our purpose. We selected the state that the hurricane affected most according to those indicators and, within that state, the metropolitan area containing the county that the hurricane affected most according to those indicators. A limitation of this approach is that our findings may not generalize to other areas affected by the same hurricane.

For both objectives, we obtained the views of officials from federal agencies, state and local governments, and academic experts. We focused on gathering information from three federal agencies that, according to the Congressional Budget Office (CBO), accounted for the majority of discretionary federal spending associated with large-scale hurricanes in recent years—FEMA, the Department of Housing and Urban Development (HUD), and the U.S. Army Corps of Engineers (USACE).[32] We also interviewed state government officials from Florida, Louisiana, New York, and Texas, as well as local government officials from the Houston, Miami, New Orleans, and New York City metropolitan areas. We focused on gathering information from state and local government officials associated with agencies involved in disaster response, recovery, or mitigation.

To examine selected hurricanes' costs, we reviewed NOAA estimates of damages associated with selected hurricanes. We assessed the reliability of these data by reviewing relevant documentation and interviewing NOAA officials, and we determined that the data were sufficiently reliable for our purpose.

To examine selected hurricanes' effects on the economy in the areas that they affected, we focused on economic activity and employment as our indicators. We analyzed data from the Bureau of Labor Statistics (BLS), Census, FEMA, and the Federal Reserve Bank of St. Louis (St. Louis Fed). We assessed the reliability of the data we used for our analysis by reviewing relevant documentation and electronically testing the data. We also spoke with knowledgeable officials from FEMA and with the researchers who developed the data from the St. Louis Fed. We determined that the data were sufficiently reliable for our purpose.

To analyze overall economic activity and employment in areas affected by the selected hurricanes, we first used FEMA data to identify counties and parishes (counties) eligible for IA, PA, or both after the selected hurricanes (affected counties). Then, we used data from Census to identify metropolitan areas that overlapped with affected counties (affected metropolitan areas). A limitation of this approach is that the severity of a hurricane and the damages it caused may have varied across affected counties even though they were all eligible for

[32]CBO estimates suggest that FEMA, HUD, and USACE accounted for about 75 percent of discretionary federal spending associated with the 16 hurricanes that caused over $1 billion in damages over the period from 2000 through 2015. Congressional Budget Office, *Potential Increases in Hurricane Damage in the United States: Implications for the Federal Budget* (June 2016), 18. In general, discretionary spending refers to the outlay of appropriated funds to fulfill a federal commitment that creates a legal liability to pay for goods or services.

assistance. Similarly, the severity of a hurricane and the damages it caused may also have varied across affected metropolitan areas, even though they all overlapped with affected counties.

To analyze overall economic activity in affected metropolitan areas, we used monthly indices of economic activity created by researchers at the St. Louis Fed and Saint Louis University and obtained from the St. Louis Fed. Each index is derived from a dynamic factor model based on 12 underlying variables capturing various aspects of metropolitan area economic activity, including labor markets, housing markets, and credit markets, as well as overall income and output. These indices reflect an unobserved common factor underlying the co-movements in these variables. Each index is calibrated to Gross Metropolitan Product (GMP) growth and variance to allow for comparison across metropolitan areas. Increases in the value of each index correspond to stronger economic growth.

An economic activity index is available for each the 50 largest metropolitan areas by population in 2014. We compared the list of these large metropolitan areas to the list metropolitan areas affected by selected hurricanes and analyzed economic activity in the metropolitan areas that are on both lists (see table 6).

Table 6: Large Metropolitan Areas Affected by Selected Hurricanes

Hurricane	Metropolitan Areas
Katrina	Birmingham-Hoover, AL
	Memphis, TN-MS-AR
	Miami-Fort Lauderdale-West Palm Beach, FL
	New Orleans-Metairie, LA
Sandy	Allentown-Bethlehem-Easton, PA-NJ
	Baltimore-Towson, MD
	Boston-Cambridge-Quincy, MA-NH
	Bridgeport-Stamford-Norwalk, CT
	Hartford-West Hartford-East Hartford, CT
	New Haven-Milford, CT
	New York-Newark-Jersey City, NY-NJ-PA
	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD
	Providence-Warwick, RI-MA
	Richmond, VA
	Virginia Beach-Norfolk-Newport News, VA-NC
	Washington-Arlington-Alexandria, DC-VA-MD-WV
	Worcester, MA-CT
Harvey	Austin-Round Rock, TX
	Dallas-Fort Worth-Arlington, TX
	Houston-The Woodlands-Sugar Land, TX
	New Orleans-Metairie, LA
	San Antonio-New Braunfels, TX

Hurricane	Metropolitan Areas
Irma	Atlanta-Sandy Springs-Marietta, GA
	Charlotte-Concord-Gastonia, NC-SC
	Columbia, SC
	Greenville-Anderson-Mauldin, SC
	Jacksonville, FL
	Miami-Fort Lauderdale-West Palm Beach, FL
	North Port-Sarasota-Bradenton, FL
	Orlando-Kissimmee-Sanford, FL
	Tampa-St. Petersburg-Clearwater, FL

Source: GAO analysis of data from the Census Bureau, the Federal Emergency Management Agency (FEMA), and the Federal Reserve Bank of St. Louis. | GAO-20-633R

Notes: Large metropolitan areas are those that were among the 50 largest metropolitan areas by population in 2014. Metropolitan areas affected by selected hurricanes are those that overlapped with at least one county eligible for FEMA Individual Assistance, Public Assistance, or both after a hurricane. The metropolitan areas in this table are those that meet both criteria.

The economic activity indices are updated regularly as new information becomes available. The earliest update that measured economic activity was released in September 2015 and the most recent update at the time of our analysis was released in April 2020. The April 2020 update spans the period from February 1990 through December 2019. Each earlier update spans the time period from February 1990 through a few months prior to the release date. We analyzed all available updates with a sufficient number of months after the hurricane that affected the metropolitan area.

To describe the initial effect of the selected hurricanes on economic activity, we estimated whether economic activity was higher or lower than expected within the first three months after the hurricane. First, we estimated regressions of economic activity on a constant term. Then, we calculated the Studentized residuals from these regressions. Studentized residuals are in the family of residuals adjusted by dividing by their standard errors. These residuals are adjusted using the root mean squared error of a regression omitting the observation in question. In general, they are preferred for purposes of outlier identification and can be interpreted as the t-statistic for testing the significance of a dummy variable equal to one on the observation in question and zero elsewhere. Finally, we used the Studentized residuals to identify months when economic activity was higher or lower than expected: economic activity was higher than expected when the Studentized residual is greater than or equal to two and lower than expected when the Studentized residual is less than or equal to -2. Our choice of two as the threshold is motivated by the interpretation of the Studentized residual as a t-statistic and combined with the common rule of thumb that t-statistics of two or more in absolute value indicate statistical significance at the five percent level.

For metropolitan areas affected by Hurricane Katrina and Hurricane Sandy, we analyzed all updates released in September 2015 and later. For metropolitan areas affected by Hurricane Harvey and Hurricane Irma, we analyzed updates released in April 2018 and later. The April 2018 release is the first one that included data for December 2017, the third month after Hurricane Harvey and Hurricane Irma. To assess the robustness of our results, we repeated the analysis using seasonally differenced economic activity—economic activity minus economic activity 12 months before.

To describe longer-term economic activity patterns in places where economic activity was lower than expected within 3 months after a hurricane, we compared economic activity one and two years after the hurricane to economic activity the year before the hurricane. We made this comparison using a 12-month moving average of economic activity to smooth within-year

variation. For metropolitan areas affected by Hurricane Katrina and Hurricane Sandy, we analyzed all available updates. For metropolitan areas affected by Hurricane Harvey and Hurricane Irma, we analyzed updates released in January 2020 and later. The January 2020 release is the first one that included data for September 2019, the second year after Hurricane Harvey and Hurricane Irma.

To analyze employment in affected counties, we used monthly data on employment from BLS's Quarterly Census of Employment and Wages (QCEW) for the period from August 2000 through September 2019. We analyzed 179 counties affected by Hurricane Katrina, 146 counties affected by Hurricane Sandy, 73 counties affected by Hurricane Harvey, and 272 counties affected by Hurricane Irma.[33] For each affected county, we analyzed total employment in all industries. To describe the initial effect of the selected hurricanes on total employment, we estimated whether total employment was higher or lower than expected within the first three months after the hurricane. We first adjusted total employment to account for typical seasonal variation and long term trends and then used the same approach we used to describe the initial effect of selected hurricanes on economic activity.

To describe longer-term total employment patterns in places where total employment was lower than expected within 3 months after a hurricane, we compared total employment one and two years after the hurricane to total employment the year before the hurricane. We made this comparison using a 12-month moving average of total employment to smooth within-year variation.

Finally, we compared the distribution of employment across economic sectors at one and at two years after the hurricane to the distribution the month before the hurricane. Economic sectors in the BLS data we analyzed include construction; manufacturing; natural resources; education and health; finance; leisure and hospitality; professional and business services; trade, transportation, and utilities; information; and other private services.

Our analyses of economic activity and employment have limitations and our results should be interpreted with caution. The patterns we observed in economic activity and employment may have occurred even in the absence of the hurricanes, and we cannot isolate the effects of the hurricanes from the effects of other events that occurred at the same time. In addition, hurricanes may have had effects on economic activity or employment that are not captured in the data we used or were significant only in certain parts of the metropolitan areas and counties we analyzed. Furthermore, we cannot isolate the effects of the hurricanes from the effects of other events that occurred at the same time. Finally, our results do not generalize to other locations, hurricanes, or time periods.

To examine the actions taken after a hurricane in affected areas to address the costs of future hurricanes, we analyzed FEMA data on Hazard Mitigation Grant Program (HMGP) and PA projects, HUD data on Community Development Block Grant Disaster Recovery projects, and USACE projects associated with the selected hurricanes. We assessed the reliability of these data by interviewing agency officials, reviewing relevant documentation, and electronically testing the data, and we determined that the data were sufficiently reliable for our purpose. In addition, we reviewed selected state and local hazard mitigation plans and other reports. We also visited the selected metropolitan areas associated with our selected hurricanes to tour sites

[33]Six counties affected by Hurricane Sandy did not match with counties in the BLS QCEW data we used.

of completed, ongoing, and planned recovery and mitigation projects and discussed those projects with federal, state, and local government officials.

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