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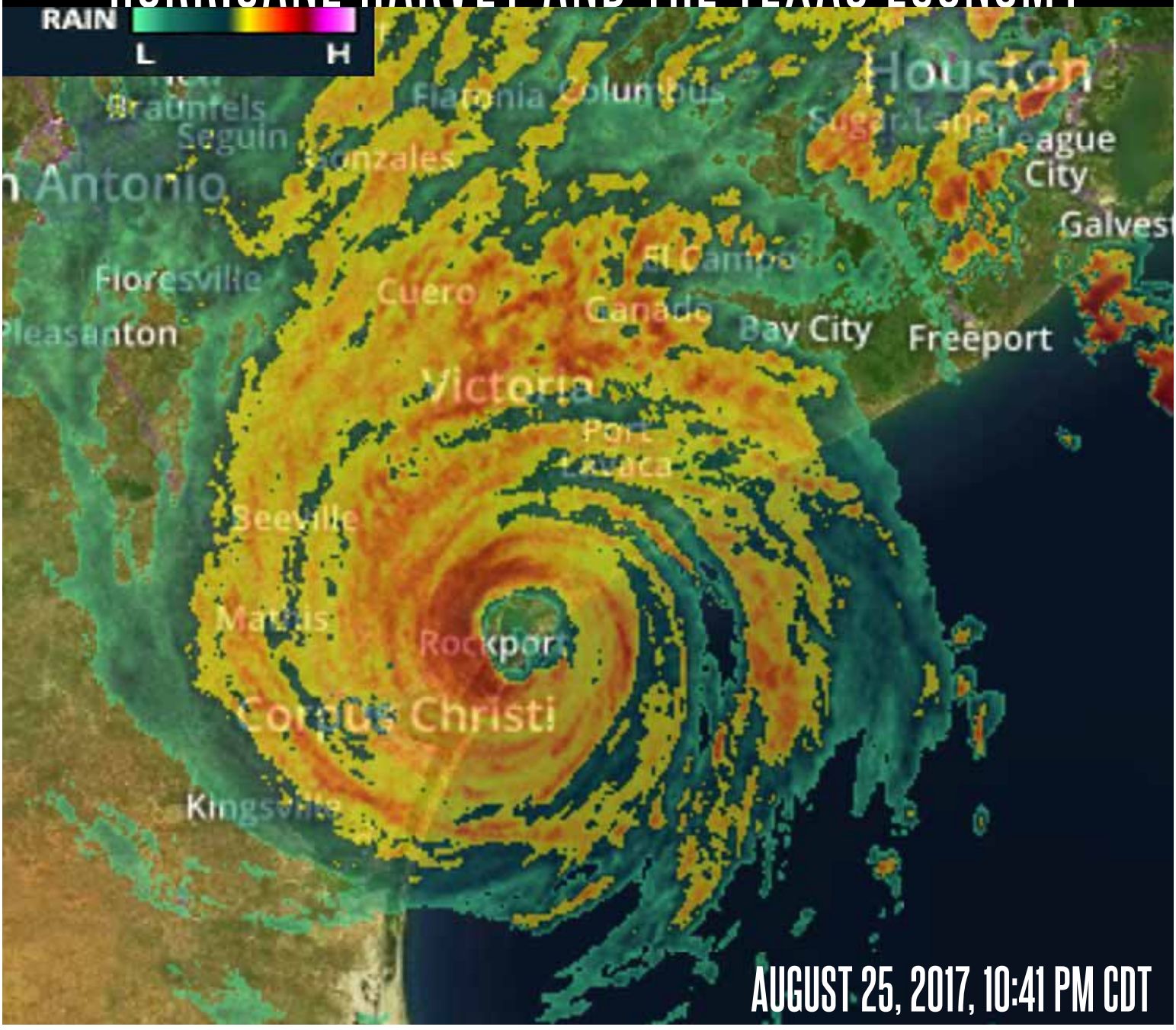
FISCAL NOTES

A REVIEW OF THE TEXAS ECONOMY FROM THE OFFICE OF **GLENN HEGAR**, TEXAS COMPTROLLER OF PUBLIC ACCOUNTS

A STORM TO REMEMBER:

HURRICANE HARVEY AND THE TEXAS ECONOMY



A Message from the Comptroller

In 2017, we saw massive destruction along U.S. coastlines from hurricanes Harvey, Irma and Maria. Texas, of course, was ground zero for Hurricane Harvey, one of the costliest storms in American history.

Harvey devastated much of southeast Texas in August, earning a page in the history books for its overwhelming winds and flooding. The storm brought unprecedented destruction to parts of our coast; dozens died and many more lost homes, automobiles and livelihoods. Many small communities may require years to recover, and some may not recover completely.

But Texans are resilient, and so is our state. While the initial impact of Harvey was severe, the Texas economy has already absorbed much of the damage from this record-breaking storm and should avoid long-term losses.

It may take years to tally Hurricane Harvey's toll on Texas, but we've been working hard to analyze the net impact of the storm based on the data we've seen so far.

Our analysis takes a wide-ranging view of the consequences, using a dynamic input-output model to measure the storm's economic impacts, both negative and positive, on our state. We estimate lost business productivity from the storm resulted in a $16.8 billion decrease in gross state product (GSP) — but that's only part of the equation, because gains to GSP stemming from recovery efforts and increased construction activity are likely to offset most of this loss.

As you'll see in this report, we estimate the *net* impact of Hurricane Harvey will be a loss of $3.8 billion in GSP during the first year following the storm, with a cumulative *gain* of approximately $800 million over three years.

In this special edition of *Fiscal Notes*, we examine the effect of Harvey on the state economy through data modeling. We also look at recovery efforts and possible opportunities to prevent other flooding disasters in the future.

GLENN HEGAR
Texas Comptroller of Public Accounts

Cover: Radar image of Harvey on Aug. 25, 2017, 10:41 p.m.

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A STORM TO REMEMBER: Hurricane Harvey and the Texas Economy

Late last August, Texans watched and waited anxiously as Hurricane Harvey approached our state. Born in the Atlantic Ocean as a tropical storm, Harvey intensified rapidly to a Category 4 hurricane in the Gulf of Mexico and hurtled directly toward the Texas coast.

On Aug. 25, 2017, Harvey made landfall, devastating Port Aransas, Rockport and other nearby communities with 130 mph winds and a six-foot storm surge. Swinging north, the hurricane moved into the Houston area, bringing thunderstorms and tornadoes that caused extensive damage.

Although it downgraded to a tropical storm as it moved inland, Harvey wasn't through spreading havoc. The storm lingered in Texas for several days, bringing record-breaking rainfall and catastrophic flooding to the southeastern part of the state. Parts of the Houston metro area recorded more than 50 inches of rain in a four-day period, while inland communities such as La Grange, Bastrop and Smithville saw massive flooding as the Colorado River overflowed its banks.[1]

Aftermath of Harvey in Rockport, Texas.

The Saffir-Simpson Hurricane Wind Scale classifies hurricanes and tropical storms according to their maximum sustained wind speeds **(Exhibit 1**). A "major" hurricane is defined as one at Category 3 or higher.

Once the danger passed, it was clear the hurricane had caused dozens of deaths and billions of dollars' worth of physical damage to homes, buildings, vehicles and basic infrastructure in the affected areas.

Texans have weathered many major storms through the years, but Harvey — the strongest hurricane to hit Texas since Carla in 1961 — was particularly devastating.[2] According to data collected by the Texas Division of Emergency Management as of Nov. 30, 2017, Harvey damaged or destroyed more than 178,400 Texas homes and inflicted an estimated $669 million in damage to public property such as government buildings, roads, bridges, water facilities and electric utilities.[3] October estimates from the Texas Department of Motor Vehicles suggested flooding may have ruined from half a million to a million cars and trucks, although more recent estimates put the number at around a quarter-million vehicles.[4]

Harvey also exacted a high cost on many of the state's industries. According to the Texas A&M AgriLife Extension Service's most recent estimates, the storm caused more than $200 million in Texas crop and livestock losses.[5] The coastal tourism industry suffered crippling damages, especially in Rockport-Fulton, where the Chamber of Commerce estimates winter tourism was down by 50 percent. Other economic sectors — particularly

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HURRICANE CATEGORIES

EXHIBIT 1

THE SAFFIR-SIMPSON HURRICANE WIND SCALE

TYPE OF STORM	CATEGORY	SUSTAINED WIND SPEEDS (MPH)
Tropical Depression	TD	0-38
Tropical Storm	TS	39-73
Hurricane	1	74-95
Hurricane	2	96-110
Hurricane	3	111-129
Hurricane	4	130-156
Hurricane	5	157 or higher

Source: National Hurricane Center

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manufacturing, energy, chemical production and retail sales — suffered damage to structures and equipment and, in many cases, experienced significant and expensive downtime due to flooding, lost electrical power, employees' inability to get to work and other situations causing temporary disruptions to the flow of goods and services.

Most businesses in the affected areas had to close in the immediate aftermath of the storm, although the period of lost production varied. Many encountered structural damage, floodwater, debris and downed utilities.

This is a preliminary analysis. We may not know the full impact of Hurricane Harvey for years. But the National Center for Economic Information has predicted Harvey will prove to be one of the most expensive natural disasters in U.S. history, perhaps second only to 2008's Hurricane Katrina.[6] The most recent estimate from the National Oceanic and Atmospheric Administration estimates Harvey's total costs at $125 billion.[7] Once actual damages and repair costs are determined, the cost may be even higher.

Although the losses stemming from Hurricane Harvey are enormous, they will be counteracted, to some degree, by economic activity — primarily reconstruction and repair — following the storm. To estimate the full economic change resulting from the storm, we must consider not only losses but gains.

ECONOMIC IMPACTS

The extent and cost of Harvey's destruction were significant. But when balanced against the anticipated increase in business activity due to reconstruction and restoration efforts, combined with an influx of funding from federal aid and insurance payments, the effect on the state's economy may be much less severe than many expected. Gains from increased

A HISTORY OF HURRICANES

To put Harvey's costs in perspective, consider previous storms with similar characteristics. These storms shared many similarities with Harvey in their effects on lives, homes and infrastructure.

TROPICAL STORM ALLISON (June 2001): Like Harvey, Allison was responsible for severe flooding in the Houston area, dropping more than three feet of rain in four days and producing 23 tornadoes. Allison caused 43 deaths and damages estimated at $8.5 billion (or $11.9 billion in 2017 dollars), making it one of the most deadly and expensive weather events in Texas history.[8]

HURRICANE KATRINA (August 2005): Katrina made landfall on the Louisiana and Mississippi coasts as a Category 3 hurricane, bringing a 20- to 30-foot storm surge and strong winds that damaged many levees, flooding more than 80 percent of New Orleans and causing at least 1,833 deaths in five states.[9] With damage costs estimated at $125 billion ($161.3 billion in 2017 dollars), Katrina remains the costliest storm in U.S. history.[10]

HURRICANE RITA (September 2005): Rita made landfall near the Texas-Louisiana border as a Category 3 hurricane with sustained winds reaching 115 mph. Rita's 10- to 15-foot storm surge, combined with up to 15 inches of rain in some areas, caused extensive flooding and wind damage.[11] Rita caused 119 deaths and an estimated $18.5 billion in damages ($23.9 billion in 2017 dollars).[12]

HURRICANE IKE (September 2008): Ike, a Category 2 hurricane, hit Galveston with winds of up to 110 mph and a 20-foot storm surge. In addition to causing 112 deaths, Ike damaged oil platforms, storage tanks, pipelines and refineries, causing gasoline shortages in the southeastern U.S. The storm caused an estimated $30 billion in damages ($34.8 billion in 2017 dollars).[13]

POST-TROPICAL STORM SANDY (October 2012): Sandy, originally a Category 3 hurricane, hit the northeastern U.S. with a storm surge of up to 12 feet and about a foot of rain.[14] Sandy damaged or destroyed thousands of businesses and hundreds of thousands of homes.[15] Total damages were estimated at $65 billion ($70.2 billion in 2017 dollars), making Sandy the second-costliest storm in U.S. history after Katrina until Harvey.[16]

DIRECT AND INDIRECT DAMAGES

Weather events such as Harvey cause both direct and indirect damages. *Direct* damages include the destruction of buildings, possessions, vehicles and infrastructure, such as roads, water systems and power lines. *Indirect* damages refer to the interruption of business activity caused by the storm — disruptions caused by safety concerns, the loss of electrical power, damaged machinery or the temporary inability of employees to reach work. These affect the economy through lost business income as well as reduced employee earnings or, in some cases, lost jobs.[17]

While direct damages represent the most obvious and visible effects of the hurricane, they do not enter into our analysis because they represent what economists call retrospective or "sunk" costs — in essence, money already spent, economic activity that has already taken place. A home, for instance, affects economic output when it is *built*, but not if it is damaged or destroyed a decade later by a storm. Its repair or rebuilding, however, *will* affect the economy. ■

construction activity and associated spending undertaken to repair and rebuild should help offset losses in the months and years to come.

During and immediately following the storm, Texas communities in the affected areas faced costs associated with emergency response, evacuee shelters, debris removal and infrastructure repair. Many suffered damage to public buildings and vehicles that must be repaired or replaced. Many businesses, in addition to repairing damaged facilities, must replace some or all of their equipment and inventory.

Meanwhile, thousands of evacuees staying in hotels or rental units faced temporary housing costs and, upon returning to their flood-damaged homes, began replacing floors and sheetrock and purchasing furniture, household goods, electronics, clothes and vehicles.

Harvey disrupted a broad range of industries, but manufacturers represented a large share of them.[18] Although many were back in operation within five or so days, some experienced significant disruptions for two weeks or more.[19]

Based on information submitted to the Comptroller's office, federal, state and local governments, along with private insurers, had spent or committed about $31 billion for Harvey-related disaster relief and rebuilding as of Nov. 30, 2017. This number is likely to rise. Money for reconstruction efforts will come primarily from the Federal Emergency Management Agency (FEMA), state and local governments and private insurance (**Exhibit 2**).

EXHIBIT 2

FUNDING SOURCES FOR HURRICANE DISASTER RELIEF

FEDERAL EMERGENCY MANAGEMENT AGENCY
• National Flood Insurance Program: payments for flood claims
• Individual Assistance: payments to individuals and households
• Public Assistance: reimbursements to state and local governments and certain nonprofits
SMALL BUSINESS ADMINISTRATION
• Home loans
• Business loans
U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT – COMMUNITY DEVELOPMENT BLOCK GRANTS
STATE AND LOCAL FUNDS
PRIVATE INSURANCE COMPANIES
NONPROFIT ORGANIZATIONS

Sources: Congressional Research Service and the Texas Legislative Budget Board

All of this spending will spur economic growth.

Without the boost from rebuilding, Texas' gross state product (GSP) would have required four years to recover to pre-Harvey expectations; personal income would require five years. Single-family residential housing stock would take seven years to rebound to normally expected levels, while non-residential building stock in the affected areas would require four years for recovery.[20] With the help of federal, state and local government aid, however, all of these measures should recover in the second year after the storm, and Texas should gain about half as many jobs as it would have lost in the absence of government aid.

Exhibit 3 displays the estimated indirect losses and gains to Texas GSP resulting from Hurricane Harvey. In all, the total estimated net impact (losses plus gains) is a $3.8 billion loss in GSP in the first year following the storm. (To put this loss in perspective, Texas' GSP was $1.6 trillion in 2016.)[21]

Recovery will stimulate economic activity, producing an estimated $800 million cumulative

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gain in GSP over three years.[22]

It's also possible to assess economic costs on a local basis by examining the counties included in Texas' councils of government (COGs), multi-county regional planning bodies. Harvey affected eight COG regions — the Houston-Galveston, South East Texas, Golden Crescent, Coastal Bend, Brazos Valley, Deep East Texas, Capital and Alamo areas — and 41 counties within them were designated as disaster areas (**Exhibit 4**).

The storm hit the 13-county Houston-Galveston COG region hardest, causing an estimated $16 billion economic loss during the first year. FEMA designated all 13 counties in this region as disaster areas. The Coastal Bend, South East Texas and Golden Crescent COGs can expect first-year losses projected at $350 million to $800 million each. The Alamo Area, Capital Area and North Central Texas regions, by contrast, stand to gain in Harvey's wake, each with an estimated $1 billion to $2 billion in additional economic activity.

EXHIBIT 3

NET ECONOMIC IMPACT OF HURRICANE HARVEY ON TEXAS GROSS STATE PRODUCT

(IN BILLIONS OF DOLLARS)

	YEAR 1	YEAR 2	YEAR 3	YEARS 1-3
Estimated Losses	($16.8)	($2.0)	($1.0)	($19.8)
Estimated Gains	$13.0	$4.1	$3.5	$20.6
Net Economic Impact	($3.8)	$2.1	$2.5	$0.8

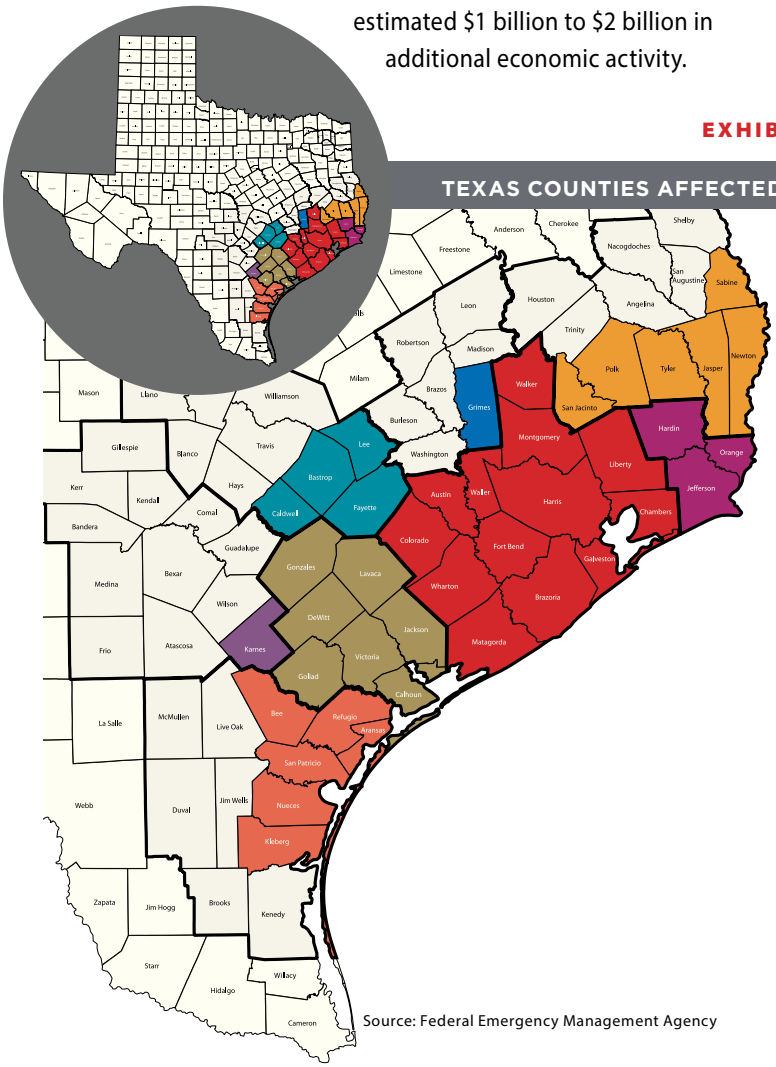
Source: Texas Comptroller of Public Accounts

Our estimate of first-year effects on real GSP by sector show the hardest-hit industries include memberships (to clubs, sports centers, parks, theaters and museums), telecommunication services and entertainment, while those faring the best include health services, food and beverages and, for obvious reasons, rental housing, motor vehicles, furniture and clothing.

The auto industry in particular should see increased demand as consumers seek to replace the cars and trucks damaged or destroyed by flooding.

EXHIBIT 4

TEXAS COUNTIES AFFECTED BY HURRICANE HARVEY



Source: Federal Emergency Management Agency

Counties declared by FEMA as disaster areas and boundaries showing the eight Councils of Governments affected.

DETCOG — **Deep East Texas Council of Governments**
Jasper, Newton, Polk, Tyler, Sabine, San Jacinto

SETRPC — **South East Texas Regional Planning Commission**
Hardin, Jefferson, Orange

H-GAC — **Houston-Galveston Area Council**
Austin, Brazoria, Chambers, Colorado, Fort Bend, Galveston, Harris, Liberty, Matagorda, Montgomery, Walker, Waller, Wharton

BVCOG — **Brazos Valley Council of Governments**
Grimes

CAPCOG — **Capital Area Council of Governments**
Bastrop, Caldwell, Fayette, Lee

GCRPC — **Golden Crescent Regional Planning Commission**
Calhoun, DeWitt, Goliad, Gonzales, Jackson, Lavaca, Victoria

AACOG — **Alamo Area Council of Governments**
Karnes

CBCOG — **Coastal Bend Council of Governments**
Aransas, Bee, Kleberg, Nueces, Refugio, San Patricio

Although this increase in demand is expected to spike during the first year after the storm, it should return to pre-Harvey levels within five years.

As expected, the Texas economy as a whole appears to have bounced back to pre-Harvey levels as of the end of the fourth quarter of 2017.[23]

DATA AND ASSUMPTIONS

For this analysis, Comptroller economists used a Regional Economic Models Inc. (REMI) model based on Texas' 24 COG regions to examine economic activity. Eight of the 24 include the 41 counties that bore the brunt of the damage inflicted by Harvey, as determined by FEMA's disaster designation.

The methodology used to estimate losses and gains in economic activity as a result of Harvey relied on a combination of data, assumptions and estimates. REMI calculates the effect of losses and gains on projected GSP for the duration of the time period used in this analysis. (**Appendix 2** provides a detailed description of the methodology used in this analysis.)

Several factors influenced the inputs used to generate this estimate, including the number and population of counties affected by Hurricane Harvey as well as the extent and duration of the damage.

Because the affected areas do not match up neatly with COG boundary lines, this estimate assumes only the affected counties experienced productivity loss and reduces nonfarm productivity by the proportion of people in affected counties to the total population of each region.

Our estimate also addresses reconstruction and repairs in the first three years, although no actual timeline for reconstruction has been determined.

The estimate also assumes the duration of business closures or reduced revenue as follows:

- medical care facilities: four days
- manufacturing and oil- and gas-related production: two weeks
- all other industries: one week

RECOVERY AND BEYOND

Despite the transitory nature of Harvey's impact on employment and business activity, the damage to property and infrastructure has been severe. Moreover, insured losses are expected to be a smaller share of the total damages compared with other major U.S. hurricanes because a larger-than-usual share of the property damage was caused by flooding rather than wind damage, and flooding generally is not covered under homeowner policies.

The negative economic impact of lost productivity and damage to structures, however, is expected to be counterbalanced largely by businesses' quick recovery as well as the money communities and businesses spend to rebuild.

Texas' diverse and resilient economy will help buoy the state from Harvey's impact. While some industries continue to struggle, most businesses are recovering and moving ahead. In all, our analysis indicates that Hurricane Harvey will have minimal long-term effects on the Texas economy, which — with time — will recover and be stronger than ever.

HURRICANE HARVEY AND THE STATE BUDGET

The damages wrought by Harvey will affect the state budget as well. While the federal government, local authorities and private insurance are providing much of the funding needed for cleanup and rebuilding, the state may have further expenses.

Determining funding sources and storm-related expenses is an ongoing task, and the picture is changing rapidly as information is shared among state, federal and local entities. The Comptroller, Legislative Budget Board and the Governor's office are working together to identify and track Harvey-related revenues and expenditures.

FUTURE MITIGATION OPPORTUNITIES

A storm as devastating as Hurricane Harvey inevitably is followed by efforts to mitigate the effects of future storms. *Hazard mitigation* is any sustained action taken to reduce or eliminate the risks and impacts of natural hazards, such as floods, tornadoes and severe winter storms.[24]

Recovery efforts are more expensive than mitigation efforts, but many believe the nation hasn't adequately funded the latter. According to Larry Larson, a senior policy adviser at the Association of State Flood Plain Managers, the U.S. has spent about

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Hurricane Harvey and the Texas Economy

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HARVEY AND TEXAS TASK FORCE 1

Amid the chaos of Hurricane Harvey, Texas Task Force 1 (TX-TF1) deployed to Texas coastal communities to coordinate and perform search and rescue missions. More than 250 TX-TF1 personnel participated, as did teams from Texas state agencies, two federal agencies and more than a dozen other states. In all, the effort completed 841 rescues by air, 19,050 rescues by ground or water and nearly 38,000 evacuations.

TX-TF 1, comprising more than 600 volunteers representing 60 organizations throughout Texas, is one of 28 federal teams within FEMA's National Search and Rescue System. TX-TF1 is based in College Station and sponsored by the Texas A&M Engineering Extension Service (TEEX).

Under the direction of the Texas Department of Public Safety's Texas Division of Emergency Management, TX-TF1 also serves as a statewide urban search and rescue team. In partnership with the Texas Military Department (TMD), the task force coordinates the state's swift-water rescue program and helicopter search and rescue team.

TX-TF1 maintains its readiness for rapid response through training classes and exercises held throughout the year at a 52-acre training facility in College Station called Disaster City, a mock community outfitted with full-scale, collapsible structures that simulate disaster and wreckage.

"Texas A&M System and TEEX support includes Disaster City, originally built to train TX-TF1, a 40,000-square-foot headquarters facility, a large vehicle fleet and equipment cache and 18 TEEX staff to provide constant and well-trained support of the team and its equipment," says Chuck Jones, TX-TF1 operations chief.

"Our mission is to always be ready to respond at a moment's notice, to do the most good for the most people in the least amount of time," says Jeff Saunders, TX-TF1 director. "The support the Texas A&M University System and TEEX give to TX-TF1 is incredible, and a critical part of what keeps this team always ready to respond."

TX-TF1 members include firefighters, doctors, nurses, structural engineers, canine handlers, professors, police officers and other professionals from many different fields. TX-TF1 also has 10 trained and FEMA-certified dogs for locating survivors and human remains.

TX-TF1 has been deployed more than 100 times in its 20-year history, assisting with a wide range of emergency and disaster recovery operations around the state and across the nation. From the team's first deployment in response to the 1997 tornado in Jarrell, Texas, to 2017's Hurricane Harvey, TX-TF1 has provided on-site emergency services under the most severe and challenging circumstances. ■

Photo courtesy of Texas Task Force 1.

$300 billion responding to various natural disasters, but only $600 million on mitigation. Yet mitigation spending has a four-to-one payback ratio.[25]

Mitigation actions fall into two categories, structural and non-structural.

STRUCTURAL MEASURES

Structural measures attempt to "disaster-proof" physical infrastructure through repair, replacement or additions.

RESERVOIRS

Houston has two reservoirs, Addicks and Barker, created by earthen dams in the 1940s to address downtown flooding. Neither was designed to contain the volume of water they've received in the last three

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EXTRA HELP IN TOUGH TIMES: COMPTROLLER'S OFFICE SUPPORTS TAXPAYERS AND EMPLOYEES

State agencies serve Texas residents in good times and bad. During the devastating hurricane of August 2017, the Comptroller's office took this commitment to heart.

The Comptroller's office has locations across Texas. Some field offices in Houston, Beaumont, Corpus Christi and elsewhere experienced brief, storm-related closures, but the Comptroller's Taxpayer Services staff in Austin fielded hundreds of calls and emails about tax payments. The agency granted businesses in affected counties temporary extensions to file taxes.

But the Comptroller's hurricane relief efforts extended well beyond taxes. The Comptroller's Statewide Procurement Division (SPD) plays a lead role in the State of Texas Emergency Management Plan and the state's Emergency Management Council. During disasters, the governor can suspend state purchasing laws with the issuance of a disaster proclamation, allowing SPD to get emergency supplies and equipment to first responders and Texans in need as quickly and efficiently as possible.

In a single weekend, SPD staff initiated purchases of more than $15 million for mobile fueling stations, a fleet of 650 evacuation buses, bottled water and ice, showering stations, portable toilets, heavy equipment for recovery efforts and other items for emergency shelters and rescue efforts.

It wasn't the first time. SPD worked with the Department of Public Safety's Texas Division of Emergency Management to support recovery efforts during hurricanes in 2005, 2007 and 2008; the Bastrop fires in 2011; the West fertilizer plant explosion in 2013; and many other disasters.

Our own Comptroller family also was affected by Harvey. About 20 employees experienced flood damage; at least one of our Houston-area employees lost his home. In response, agency employees hosted fundraisers to purchase supplies for fellow workers affected by the hurricane and took food, bottled water, clothes, cleanup supplies and gift cards to storm-ravaged areas.

"It was a very pleasant surprise when employees from Austin walked into our office with care packages wearing 'Houston Strong' T-shirts," says Houston Northwest Enforcement Office Manager Jesse Vela. "We had office staff who had property damage, had to be rescued and even had to be evacuated. But thankfully, considering all the damage that occurred throughout the Houston area, we didn't have a loss of life."

The Comptroller's office is here to help Texans, from expedited purchasing of emergency equipment and supplies, special licenses for motor fuel imports, tax deadline extensions and more. We'll continue to assist in this situation and any other that arises. ■

Comptroller volunteers delivered care packages and water to fellow employees in the Houston office.

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years, and both need repairs. In 2009, the U.S. Army Corps of Engineers classified both as "unsafe" and called for more than $100 million in dam repairs and maintenance, but to date the repairs have not been completed.[26]

FLOOD ABATEMENT

Perhaps the best-known proposal for hurricane mitigation along the upper Texas coast is the "coastal spine," also known as the "Ike Dike" — a concept, borrowed from the Dutch, which would involve a line of coast barriers, levees and gates to protect Galveston Bay and the Bolivar Peninsula. The Gulf Coast Community Protection and Recovery District has recommended the construction of a 277-mile line of these features at a cost of $11.6 billion.[27] The U.S. Corps of Engineers, however, must recommend a similar plan before Congress will fund its construction; the Corps' recommendation is expected by June 2018.[28]

Mike Talbott, a former executive director of the Harris County Flood Control District, says another solution is to widen some of Houston's thousands of miles of bayous, allowing them to carry more water to the Gulf of Mexico. According to Talbott, this would cost about $25 billion. At the district's current funding levels, however, protecting this stretch of coast to 100-year-flood protection levels would require *400 years*.[29] Governmental partnerships would be needed to fund such large-scale projects, but the 2011 ban on Congressional earmarks, which discourages federal legislators from devoting funds to home-state "pet" projects, has made such funding difficult to obtain.[30]

Yet another idea concerns repairing Houston's outdated drainage system. According to Texas A&M Professor Sam Brody, a specialist in natural hazard mitigation, the city's drains and pipes are old and inadequate, able to handle only one to one-and-a-half inches of rain per hour.[31] The city of Houston estimates 60 percent of its drainage infrastructure needs repairs that would cost about $650 million annually.[32]

"GREEN STORMWATER INFRASTRUCTURE"

Civil and structural engineering experts contend Hurricane Harvey shows a need for "green stormwater infrastructure," also known as low-impact development. Rebuilding damaged areas with features such as "green" roofs covered with vegetation, permeable pavements and rain cisterns would reduce runoff and thus lower the chances of flooding.[33]

NON-STRUCTURAL MEASURES

Non-structural measures include those that do not involve massive changes to existing infrastructure.

CITY/REGIONAL PLANNING

One contentiously debated issue affecting Houston is the city's rapid rate of growth and development. More than 166,000 acres in the area have been

paved in the last 10 years, greatly increasing the flow of floodwater into bayous, reservoirs and drainage systems.[34]

The temporary accumulation of water after heavy rains, as in the Addicks and Barker reservoirs, is called a "flood pool." Of the 10 largest U.S. flood pools accumulated after storms, six occurred since 2000. Richard Long with the U.S. Army Corps of Engineers says new growth and development, with concrete replacing prairie lands, directly causes flooding in previously vegetated areas.[35] City planners must take such factors into account when approving new development.

UPDATED FLOOD PLAIN MAPS

FEMA, in cooperation with state and local officials, creates Flood Insurance Rate Maps (FIRMs) for every community in the U.S. These maps delineate special flood hazard areas — those judged to have a 1 percent chance of flooding in any year, sometimes called the 100-year flood plain — and "risk premium zones," areas in which insurance companies may charge higher premiums due to an increased risk of flooding. Depending on the classification of the zone, these premiums may be considerably higher than in nearby areas.

It typically takes three to five years to complete the study for a FIRM, which form the basis for National Flood Insurance Program (NFIP) regulations (see next section) and the insurance requirements that accompany mortgages. FEMA periodically revises these maps to reflect population growth and development or changing conditions that may lead to increased risk of flooding. Due to funding constraints, however, FEMA can update only a limited number of flood plain maps each year, and many researchers contend flood maps often fail to reflect current conditions.

Houston provides a case in point; FEMA estimated about 40 percent of all buildings flooded in Harris County were in areas considered to be "of minimal flood hazard." Similarly, researchers at the University of California at Davis determined half of the flooded land in Harris County was outside the boundaries of official flood maps. As a result, many buildings and homes lacked flood insurance.[36]

According to the Harris County Flood Control District, more than 140,000 Houston-area homes are in flood plains, and thousands of them should be purchased by the city, county, state or federal governments to remove them from future floods.[37] Updated flood plain maps may require thousands more homes to be removed in this way.

FLOOD INSURANCE POLICIES

The federal National Flood Insurance Program, established in 1968, subsidizes flood insurance on homes in special flood hazard areas, which may encourage developers to build more homes in flood plains. The program has outgrown its scope, however, and is currently $24 billion in debt.[38] Scaling back the subsidies offered through NFIP would make the cost of insurance prohibitive for some homeowners and deter them from buying homes in flood-prone areas.[39] **FN**

APPENDIX 1: Major Hurricanes in Texas and the U.S.: A Historical Perspective

In a typical year, about 100 storms and tropical disturbances develop in the Atlantic Ocean, Caribbean Sea and Gulf of Mexico. Some of these turn into tropical storms, and on average, two each year become hurricanes that make landfall in the U.S.[40] Between 1851 and 2016, 289 hurricanes affected the continental U.S. Of these, 63 made landfall in Texas.[41]

Hurricane season runs from June 1 to Nov. 30, with most storms making landfall during August and September.[42] In Texas, these storms make landfall on the Gulf Coast, generally moving north or northeast through the state.

MAJOR TEXAS HURRICANES

The Galveston hurricane of 1900, a Category 4 storm, was the deadliest natural disaster in U.S. history, bringing a 15-foot storm surge and winds of more than 135 mph. The hurricane killed between 6,000 and 12,000 and brought damages totaling about $881 million in 2017 dollars.[43]

Since then, Texas has been affected by 20 more major hurricanes (classified as Category 3 or higher).[44] **Exhibit 5** lists major hurricanes that have made landfall in Texas since the early 1950s, when the U.S. National Hurricane Center began naming each storm.

COSTLIEST U.S. STORMS

Of course, hurricanes and other major storms affect the entire country, not just the Gulf Coast. **Exhibit 6** lists the most destructive storms affecting the U.S. in the last half-century.

Hurricane Katrina, which caused $161.3 billion in damages, still ranks as the costliest storm in American history; Hurricane Harvey is expected to rank second, with total estimated damages of about $125 billion.[45] ■

EXHIBIT 5

MAJOR HURRICANES AFFECTING TEXAS SINCE 1957*

STORM NAME	YEAR	CATEGORY AT LANDFALL
Audrey	1957	4
Carla	1961	4
Beulah	1967	3
Celia	1970	3
Allen	1980	3
Alicia	1983	3
Bret	1999	3
Rita	2005	3
Harvey	2017	4

*Category 3 or higher
Source: National Oceanic and Atmospheric Administration

EXHIBIT 6

TOP 15 COSTLIEST STORMS IN THE U.S. SINCE 1980

STORM NAME	CATEGORY AT LANDFALL	YEAR	DAMAGE* (BILLIONS)
Katrina	3	2005	$161.3
Harvey	4	2017	125.0
Maria	4	2017	90.0
Sandy	Tropical Storm	2012	70.9
Irma	4	2017	50.0
Andrew	5	1992	48.3
Ike	2	2008	35.1
Ivan	3	2004	27.3
Wilma	3	2005	24.5
Rita	3	2005	23.9
Charley	4	2004	21.3
Hugo	4	1989	18.4
Irene	1	2011	15.1
Frances	2	2004	13.0
Allison	Tropical Storm	2001	12.0

*Dollar amounts represent the 2017 Consumer Price Index cost-adjusted value.
Source: National Oceanic and Atmospheric Administration

APPENDIX 2: Detailed Methodology of Net Economic Impact Analysis

Economists use various modeling techniques to estimate the effect of economic trends and government policy options over time. For this report, the Comptroller's office developed an approach to analyze the cost of a disruptive event on the Texas economy as well as the subsequent economic activity generated as a result of the shock. Our economic impact analysis thus estimates the net effect of Hurricane Harvey on the Texas economy.

To estimate the cost of the storm on Texas, productivity loss is approximated by discounting the expected economic forecast for three years by the amount of time businesses were closed or out of production, varying in length by industry.

To estimate the gain from rebuilding, reported and anticipated expenditures are introduced that offset the negative effects of production loss.

The forecast employs a 70-sector, 24 Council of Government (COG) region version of Regional Economic Models Inc. (REMI) Policy Insight+ for Texas, Version 2.0, an economic software application that generates realistic annual estimates of the total regional effects of policy or other market changes, based on an approach that combines and builds on input-output, general equilibrium, computable econometric and economic geography modeling techniques. The software calculates differences between the baseline (a regional control forecast) and the shock forecast.[46]

The COG regions affected by the storm are assumed to be those containing counties that received FEMA assistance due to the storm.[47] All counties in the Houston-Galveston, South East Texas and Golden Crescent COGs were affected by the storm. The Brazos Valley, Coastal Bend, Deep East Texas, Alamo Area and Capital Area COGs were only partly affected and were discounted by the share of population in the affected counties in each COG to the total population of each (a "population discount"). The estimate assumes all of the businesses in affected counties were affected.

The estimate's timeframe is the initial shock year and two forecast years. Determining the cost share among federal, state and local governments is ongoing, even as more costs are being recorded. Because we do not yet know who will ultimately bear the burden of some Harvey-related costs, the scope of this analysis is limited to a relatively short time period.

The estimate uses nominal dollars (unadjusted for inflation).

PRODUCTIVITY LOSS

The productivity-loss component of the estimate assumes business days lost due to the storm, whether from power outages, damaged structures or temporary labor shortages, result in lower output (a "time discount"). The estimate assumes most industries were offline or experienced reduced revenue for one week, from landfall on Friday, Aug. 25, followed by five days of rain and subsequent dam overflows in Houston until it dissipated in Louisiana on Aug. 30.[48] Industries are discounted differently depending on the amount of time they were estimated to be offline, their level of competition and their place in the supply chain:

- manufacturing and mining were assumed to be offline or experiencing reduced revenue for 15.4 days.[49]
- hospitals were assumed to be offline or experiencing reduced revenue for four days.[50]
- firm-level competition is assumed for all industries except those with a high location quotient (LQ > 4) such as oil and gas extraction, which are considered exogenous.[51]
- retail and wholesale trade are further discounted to account only for the markup of cost of goods sold, to avoid double-counting.[52]
- accommodation is assumed to be unaffected by productivity losses as the decrease in tourism from the storm could be counterbalanced by the increase in hotel occupancy by evacuees.

The standard regional control is reduced by a percentage of sales derived from a combination of the time discount and population discount. The results show the reduction in GSP due to this reduction in output.

A similar reduction in labor productivity was considered; however, it is assumed the negative effects on wages in August would be counterbalanced by increases in the fourth quarter. It is also assumed that salaried employees were largely unaffected by the storm and would either telework or make up lost time in September, while non-salaried employees would experience a dip in productivity and income in August but would have more work opportunities and higher wages in the recovery months following the storm.

Because the model treats labor productivity differently based on regional and industry variation, the effects of the storm on labor productivity could have counterintuitive effects; nevertheless, change in labor productivity is left outside the scope of this estimate.

GAINS FROM REBUILDING

Following economic shocks, institutions begin to respond to the community's needs, both immediate and ongoing. Gains from the rebuilding component of the estimate account for increases in spending from government, businesses and nonprofits on timely disaster relief, shelter and food for displaced people, debris removal, medical attention and reconstruction.

For this estimate, current and expected expenditures were collected — via either news sources or self-reporting — from federal and state agencies as well as private insurance companies and large nonprofits; these are non-exhaustive. Each organization's expenditures are categorized by expected use over a three-year period, divided 40/20/20, and assuming the remaining 20 percent will be spent in future years beyond the three-year scope of this analysis.

Funds flowing from and through state agencies are allocated by individual industry and weighted by output in construction, housing, health care and social services.[53] The estimate weights funds categorized as government administration or equipment by population. It excludes agency expenditures reallocated from a similar use, such as medical costs expected to be covered by Medicaid funds.

Funds from the National Flood Insurance Program,[54] Small Business Administration (SBA) loans,[55] private insurance companies[56] and nonprofits[57] are allocated by individual industry in the proportion by which funds were released for SBA loans following Superstorm Sandy: roughly 64 percent on construction for real estate damages, weighted by output; 10 percent on equipment for business content, weighted by population; and 26 percent on relevant consumer spending for home content (such as motor vehicles, furnishings, housewares and health services), weighted by consumer spending.[58]

LIMITATIONS

This estimate is intended to depict Texas' economy as a whole and the net effects of Hurricane Harvey based on currently available data. Figures for government spending may change as agencies report expenditures and more people submit claims.[59] It is a *projection*, and does not account for:

- damage to commercial, government or personal property, including real estate, contents, equipment, vehicles, inventory, etc. Instead, it accounts for the funds likely

CONTINUED ON PAGE 14

APPENDIX 2: CONTINUED FROM PAGE 13

Detailed Methodology of Net Economic Impact Analysis

be spent in the next three years to rebuild and replace these items.

- expenditures from smaller nonprofit organizations.
- change in tax burden on Texans at the local and state levels due to increased costs from Harvey recovery or state budgetary actions that may be taken.
- change in government services provided due to resource reallocation.
- income to insurance companies from deductibles or potential changes in insurance premiums.
- productivity loss and gains from agricultural insurance; this study focused on the nonfarm portion of the economy. The REMI model does not include an agriculture sector.
- non-pecuniary losses due to fatalities or decreased desirability of living in an area. The estimate assumes people who do not receive a buyout will rebuild — especially property owners along the coast in hurricane-prone areas, who are likely to understand the risk of property ownership in their location.
- the long-term costs of flooding, including buyout programs, new reservoirs, bayou dredging or seawall construction. These flood mitigation efforts will cost billions of dollars over a number of years and are beyond the scope of this study.

The model available divides Texas into COG regions and depicts dynamic relationships between industries and market forces; future studies may benefit from a more granular model to show county-level damage to housing stock, which would eliminate the need for the population discount.

This estimate intends to depict the order of magnitude of the net effects of Hurricane Harvey on the Texas economy as a whole. The economic losses and gains may not be known in their entirety, but our approach aims to provide a high-level perspective of the possible damage by a severe weather event such as Harvey as well as the strength of the Texas economy to withstand such events. Individual Texans and communities may continue to bear a heavy burden rebuilding their lives in the wake of the storm, but the assistance provided by government, business and nonprofit resources and the diversity of Texas' economy protect the state from the level of devastation experienced by smaller, less robust economies after an economic shock. ■

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