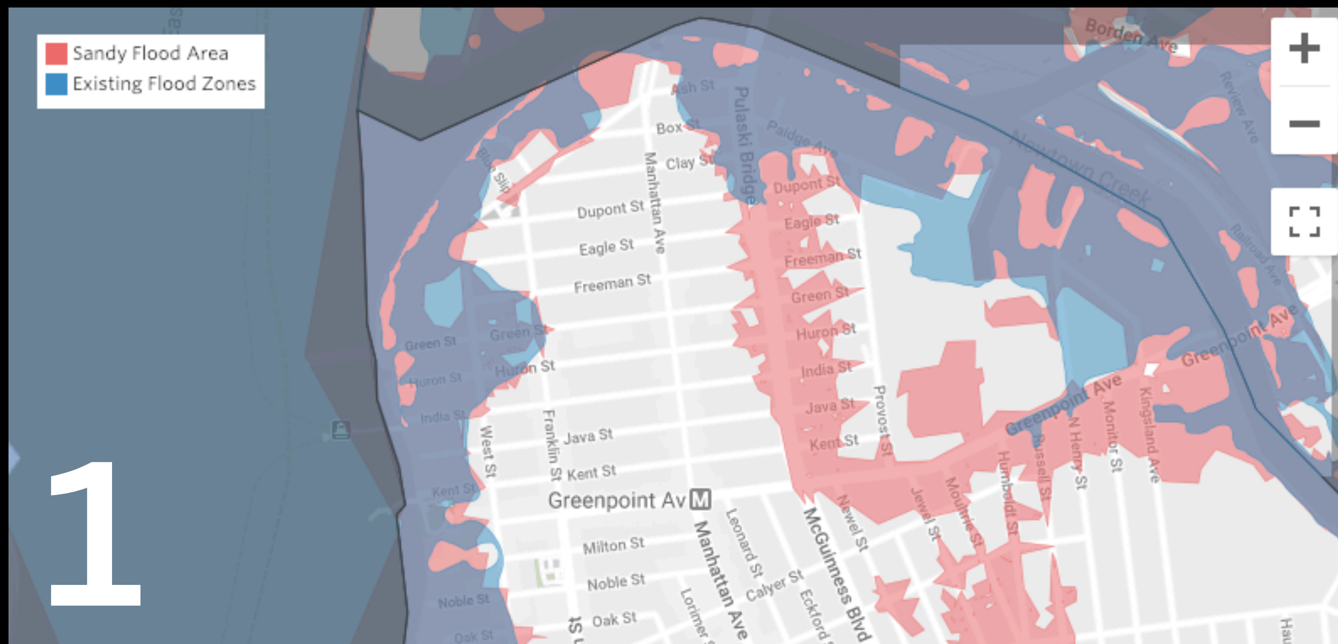
How visualizing flood data teaches us about our past—and our future

Cómo visualizar datos de inundación nos enseña sobre nuestro pasado y nuestro futuro

Al Shaw
al.shaw@propublica.org
@A_L


Sandy Flood Area
Existing Flood Zones
Greenpoint Av
Manhattan Ave
McGuinness Blvd
Pulaski Bridge
Newtown Creek
Greenpoint Ave
Dupont St
Eagle St
Freeman St
Green St
Huron St
India St
Java St
Kent St
Milton St
Noble St
Oak St
Box St
Clay St
Franklin St
West St
Provost St
Kingsland Ave
Monitor St
N Henry St
Humboldt St
Russell St
Jewel St
Newel St
Leonard St
Calyer St
Eckford St
Lorimer St
Borden Ave
1


2
RESTORING PRAIRIES- CARBON SEQUESTION


3

Me *Yo*

Sandy Flood Area
Existing Flood Zones
Borden Ave
Ash St
Box St
Clay St
Manhattan Ave
Dupont St
Eagle St
Freeman St
Green St
Huron St
India St
Java St
Kent St
Franklin St
West St
Greenpoint Av
Milton St
Noble St
Oak St
Leonard St
Calyer St
Eckford St
McGuinness Blvd
Provost St
Newel St
Jewel St
Moultrie St
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Russell St
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Monitor St
Kingsland Ave
Greenpoint Ave
Newtown Creek
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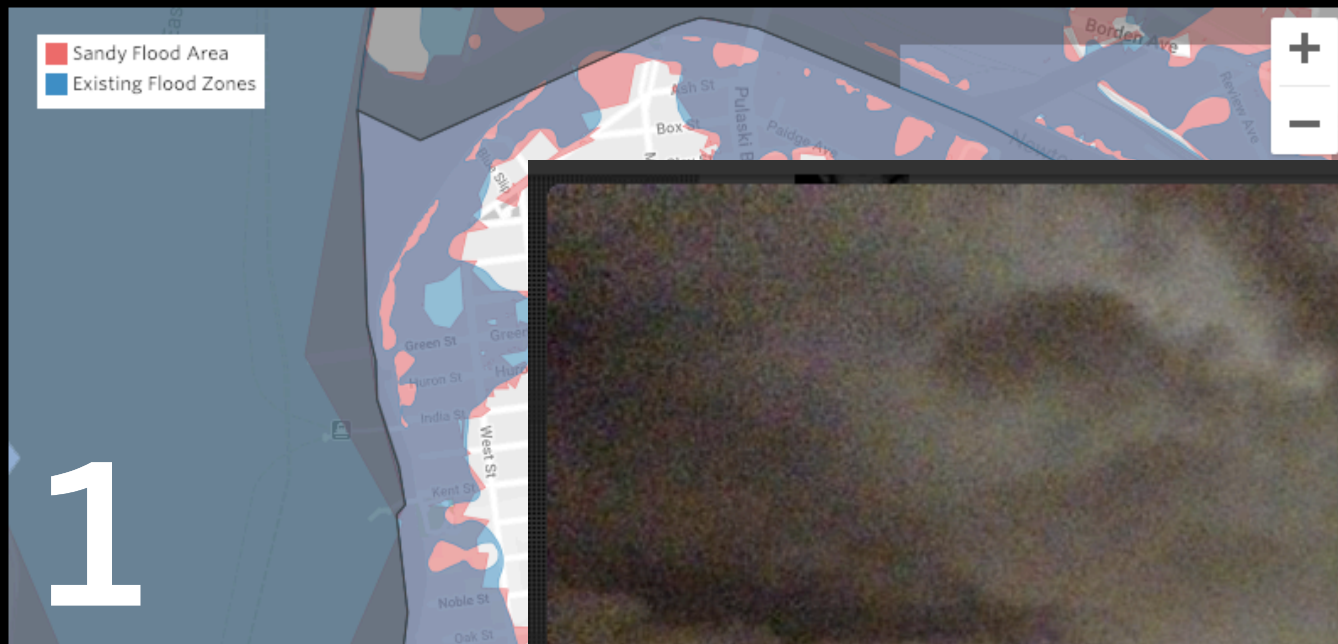
Review Ave
Railroad Ave
1

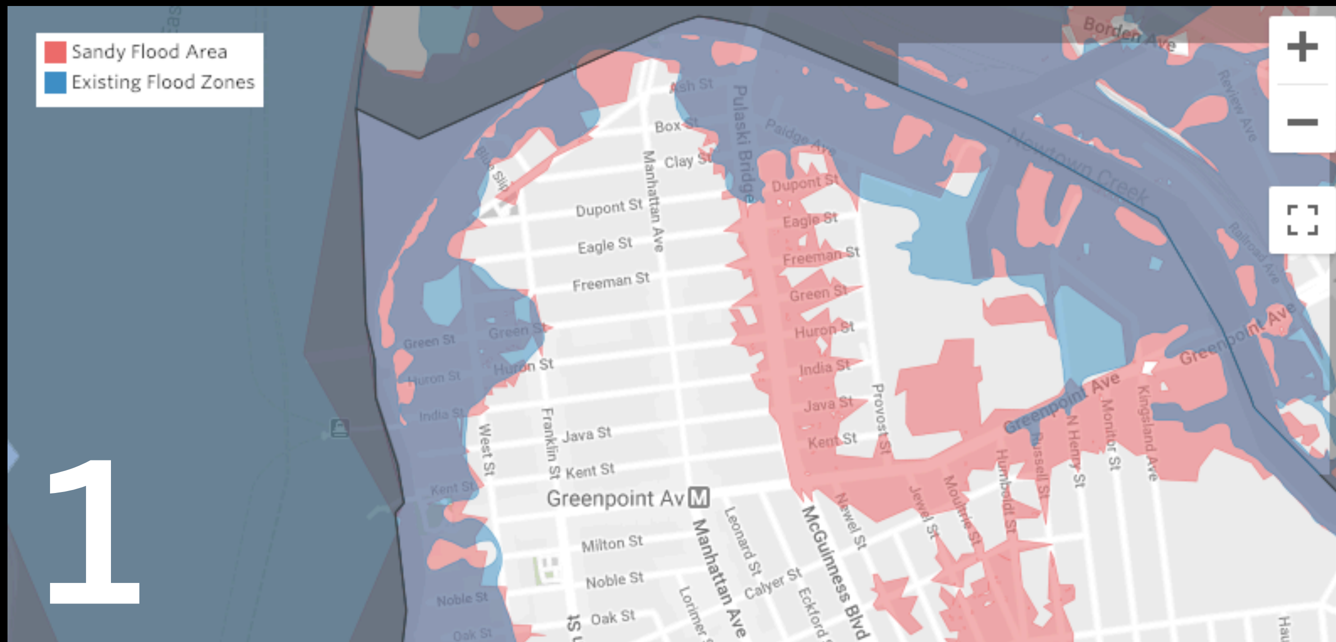

Sandy Flood Area
Existing Flood Zones
1
Green St
Huron St
India St
West St
Noble St
Oak St
Box St
Ash St


Al Shaw @A_L · 30 Oct 2012
Manhattan skyline from India St. pier pic.twitter.com/iRd03Dm8
Reply
Favorite
Flag media

2


3


National Great Rivers Museum
US Army Corps
of Engineers



Sandy Flood Area
Existing Flood Zones
Greenpoint Av
Manhattan Ave
McGuinness Blvd
Pulaski Bridge
Greenpoint Ave
1

2
RESTORING PRAIRIES- CARBON SEQUESTION

3

We know less than we think we do.

Sabemos menos de lo que creemos hacer.

We misrepresent the amount of uncertainty in flood data.

Tergiversamos la cantidad de incertidumbre en los datos de inundaciones.

We often don't know if or how the things we've built will make flooding worse.

A menudo no sabemos si o cómo las cosas que hemos construido empeorarán las inundaciones.

Even when we do know how vulnerable we are, we don't do anything about it.

Incluso cuando sabemos cuán vulnerables somos, no hacemos nada al respecto.

Flood data...

Los datos de inundaciones...

Flood data shows how bad humans are at comprehending probability

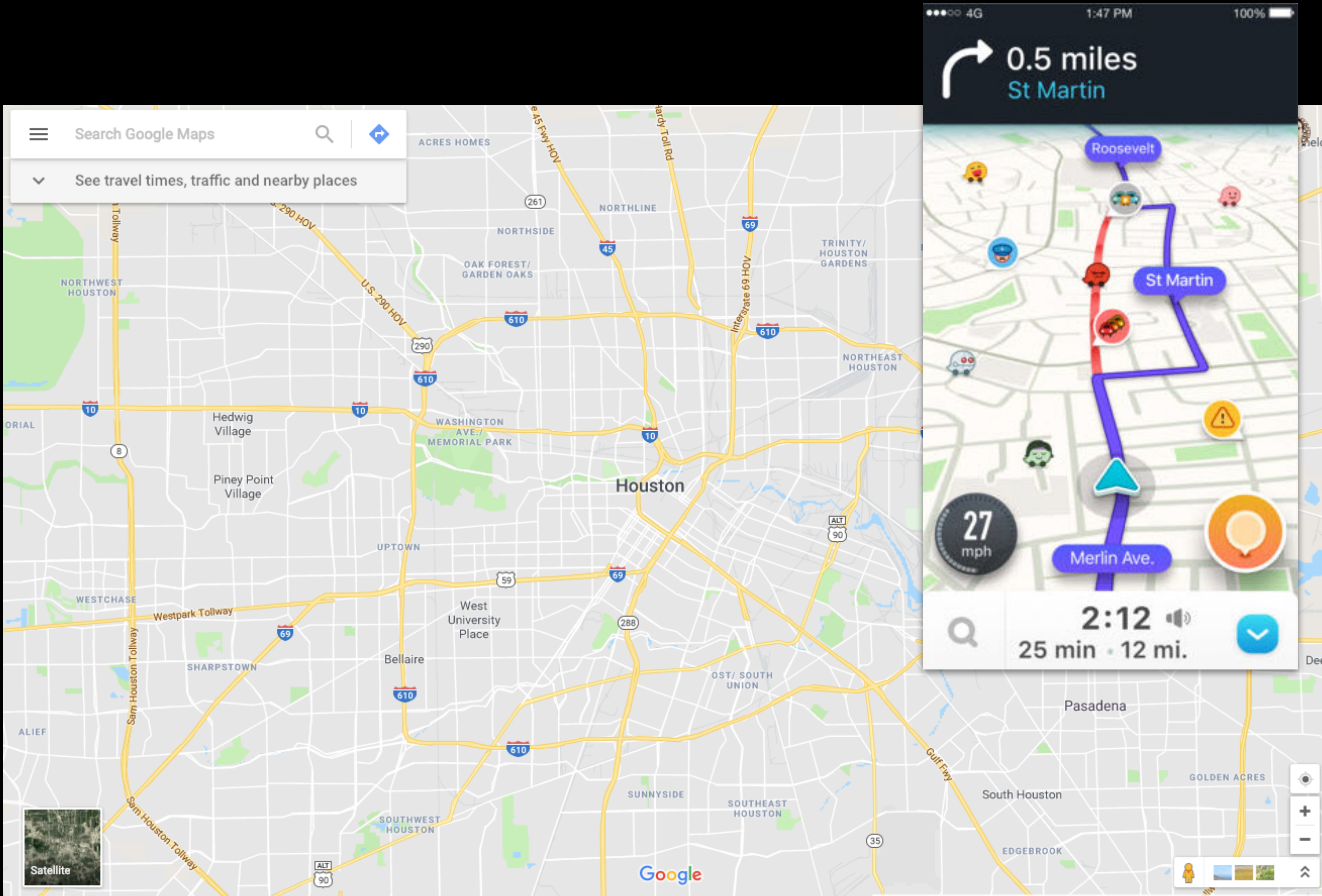
Los datos de las inundaciones muestran cuán malos son los humanos al comprender la probabilidad

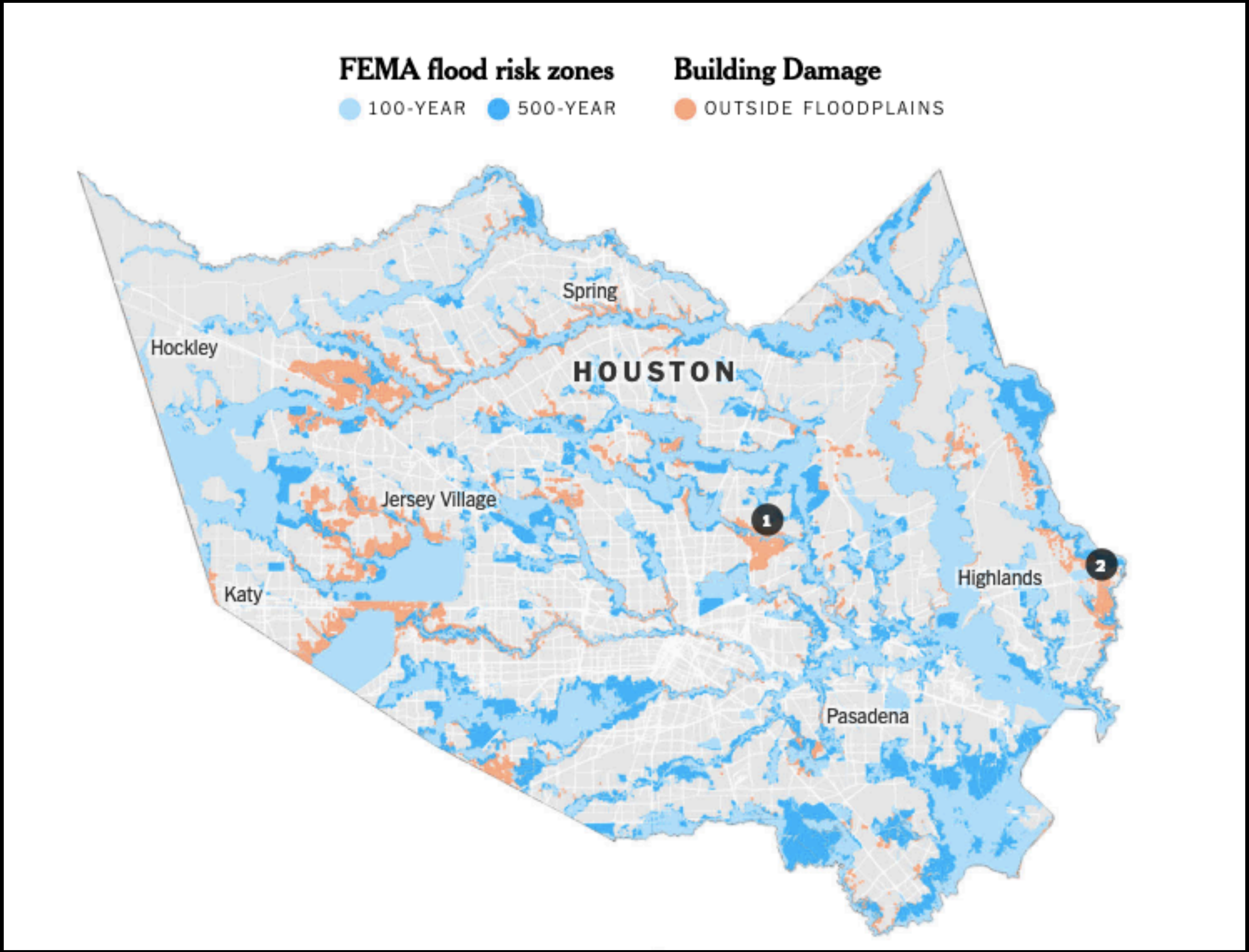
Flood data shows how we've irreparably altered our environment, and how disconnected we are from underlying ecosystems

Los datos de inundaciones muestran cómo hemos alterado irreparablemente nuestro entorno y cuán desconectados estamos de los ecosistemas subyacentes

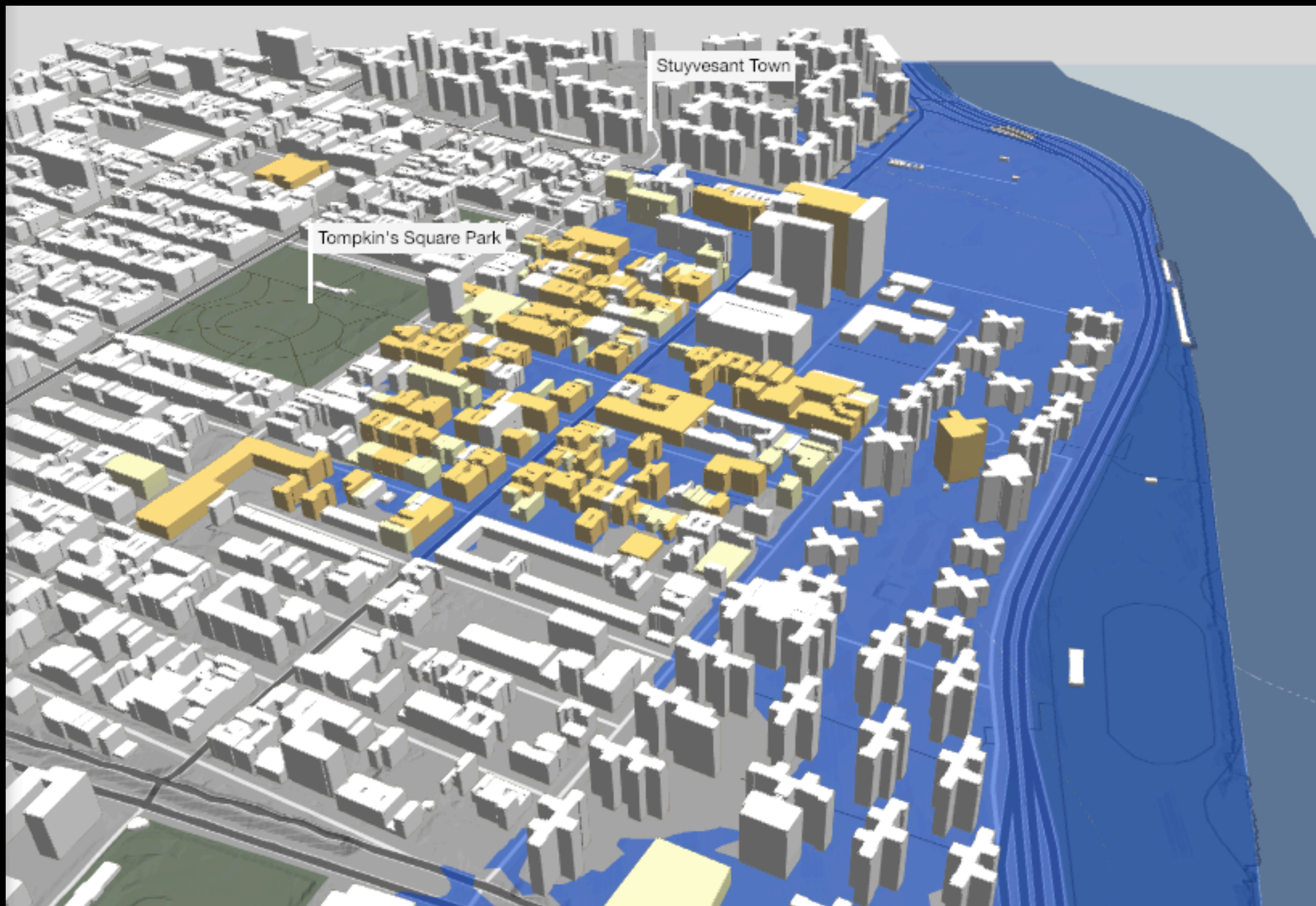
Flood data gives us a glimpse into our future, when waters will rise and our rivers and coastlines will look very different than they do today

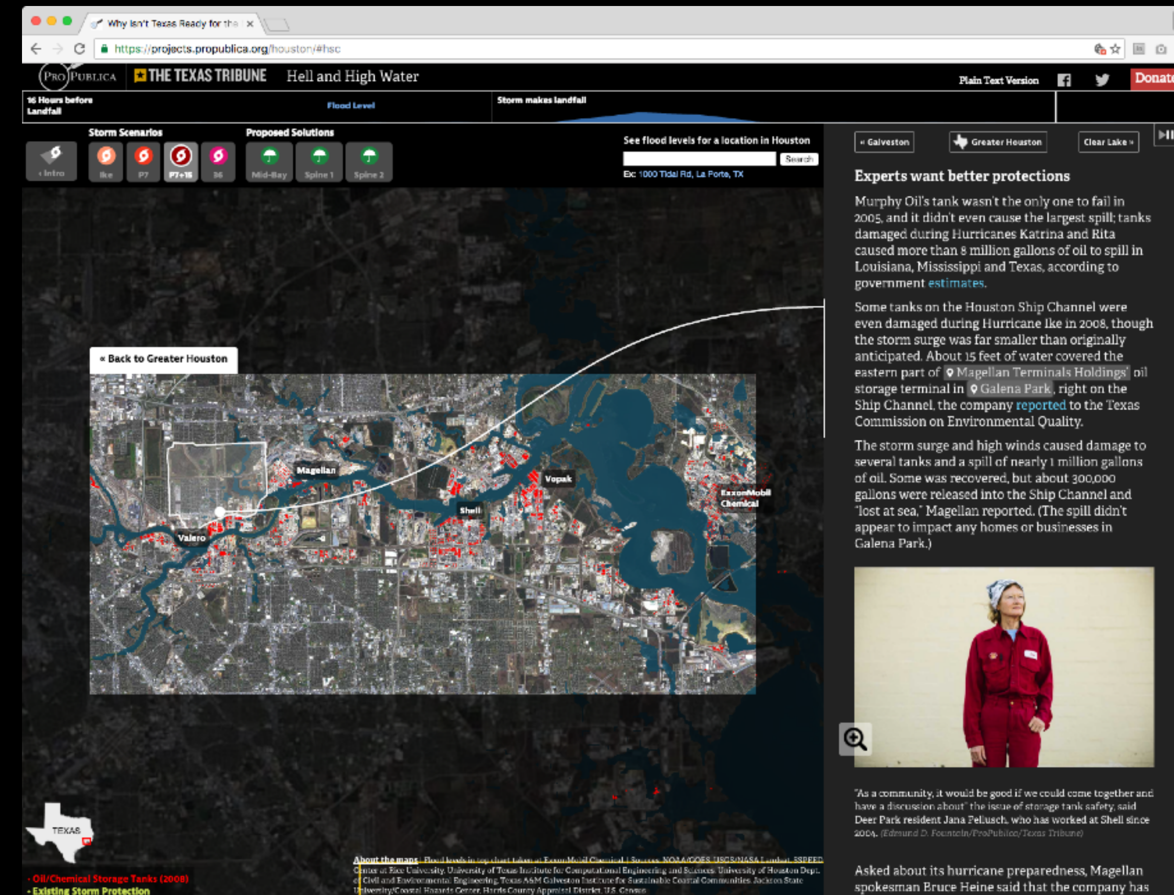
Los datos de las inundaciones nos permiten vislumbrar nuestro futuro, cuando las aguas suben y nuestros ríos y costas se ven muy diferentes a los de hoy.

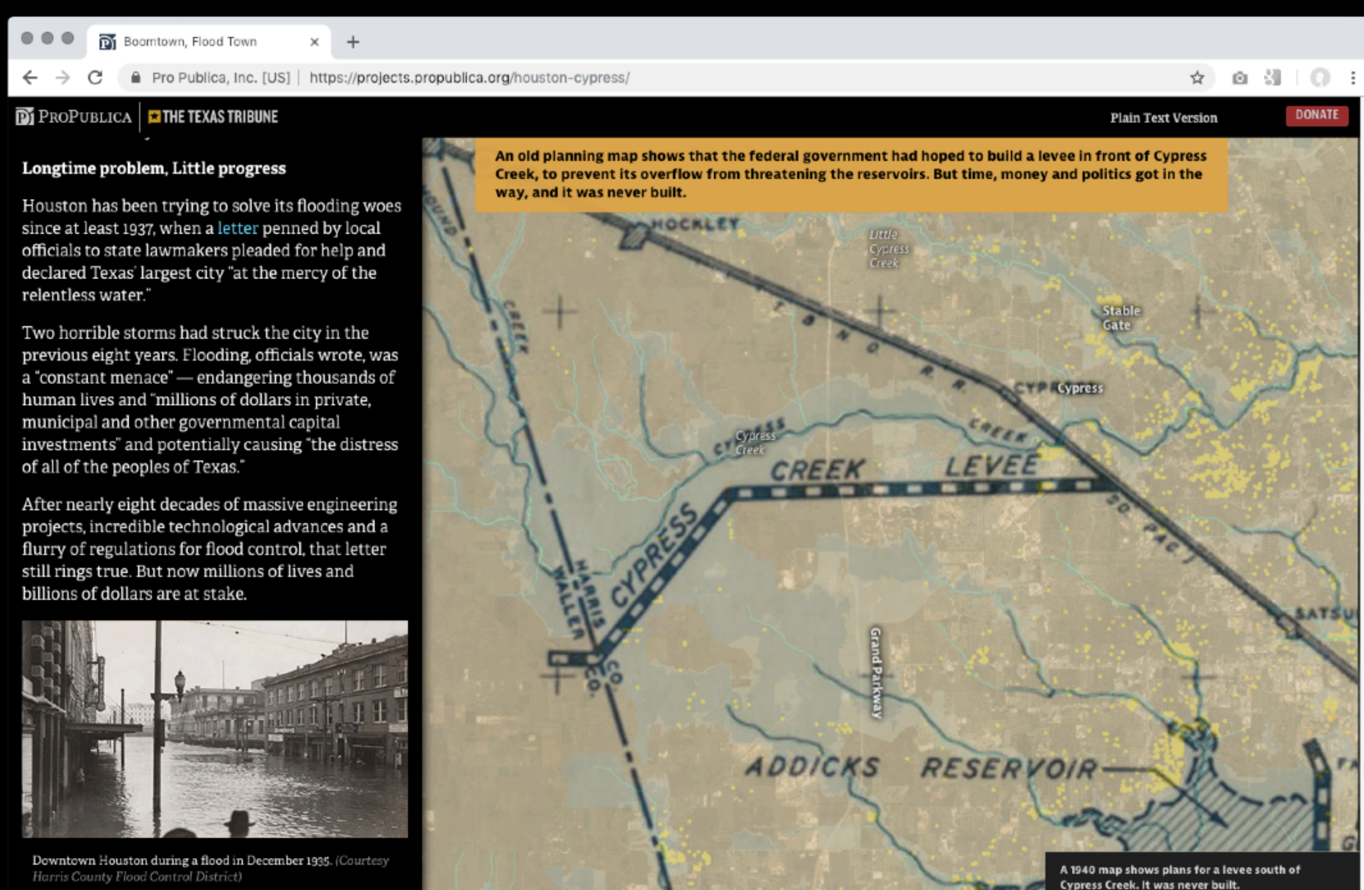

Search Google Maps
See travel times, traffic and nearby places
ACRES HOMES
NORTHLINE
NORTHSIDE
OAK FOREST/ GARDEN OAKS
TRINITY/ HOUSTON GARDENS
NORTHWEST HOUSTON
NORTHEAST HOUSTON
Hedwig Village
WASHINGTON AVE./ MEMORIAL PARK
Piney Point Village
Houston
UPTOWN
WESTCHASE
Westpark Tollway
West University Place
Bellaire
SHARPSTOWN
OST/ SOUTH UNION
ALIEF
Pasadena
SUNNYSIDE
SOUTHEAST HOUSTON
SOUTHWEST HOUSTON
South Houston
GOLDEN ACRES
EDGEBROOK
Sam Houston Tollway
Gulf Fwy
Satellite
Google
4G
1:47 PM
100%
0.5 miles
St Martin
Roosevelt
St Martin
27
mph
Merlin Ave.
2:12
25 min · 12 mi.

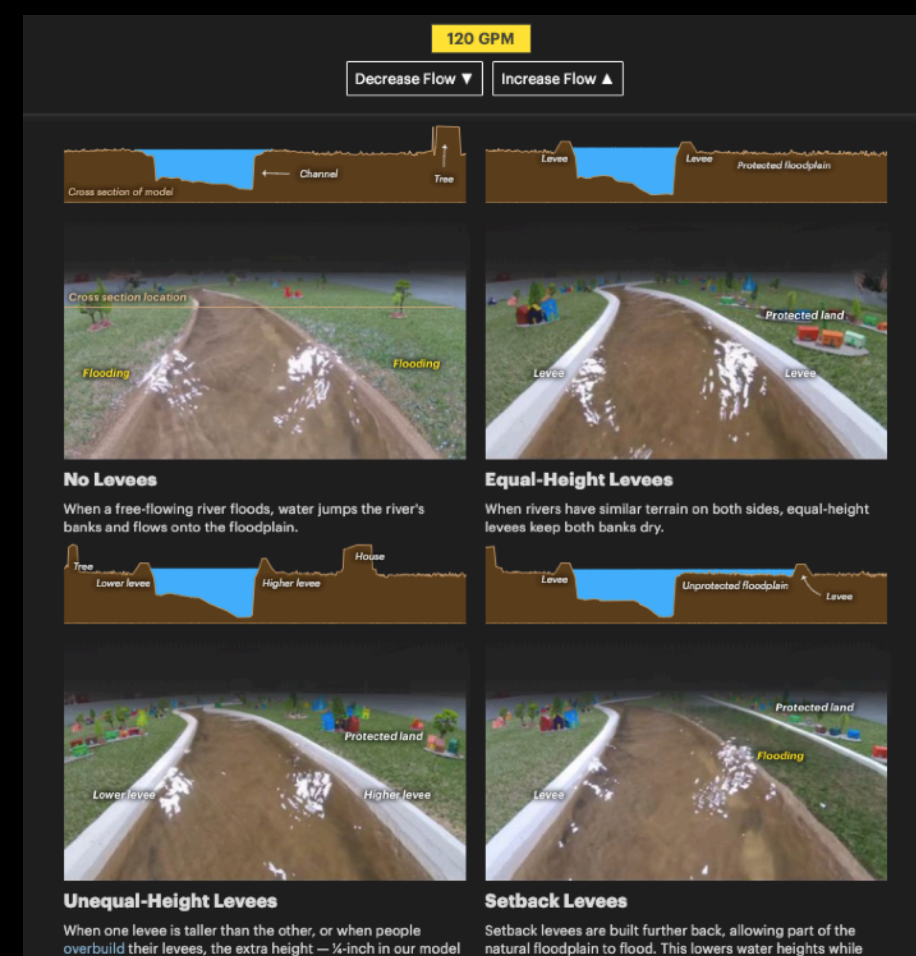


New York Times


Stuyvesant Town
Tompkin's Square Park

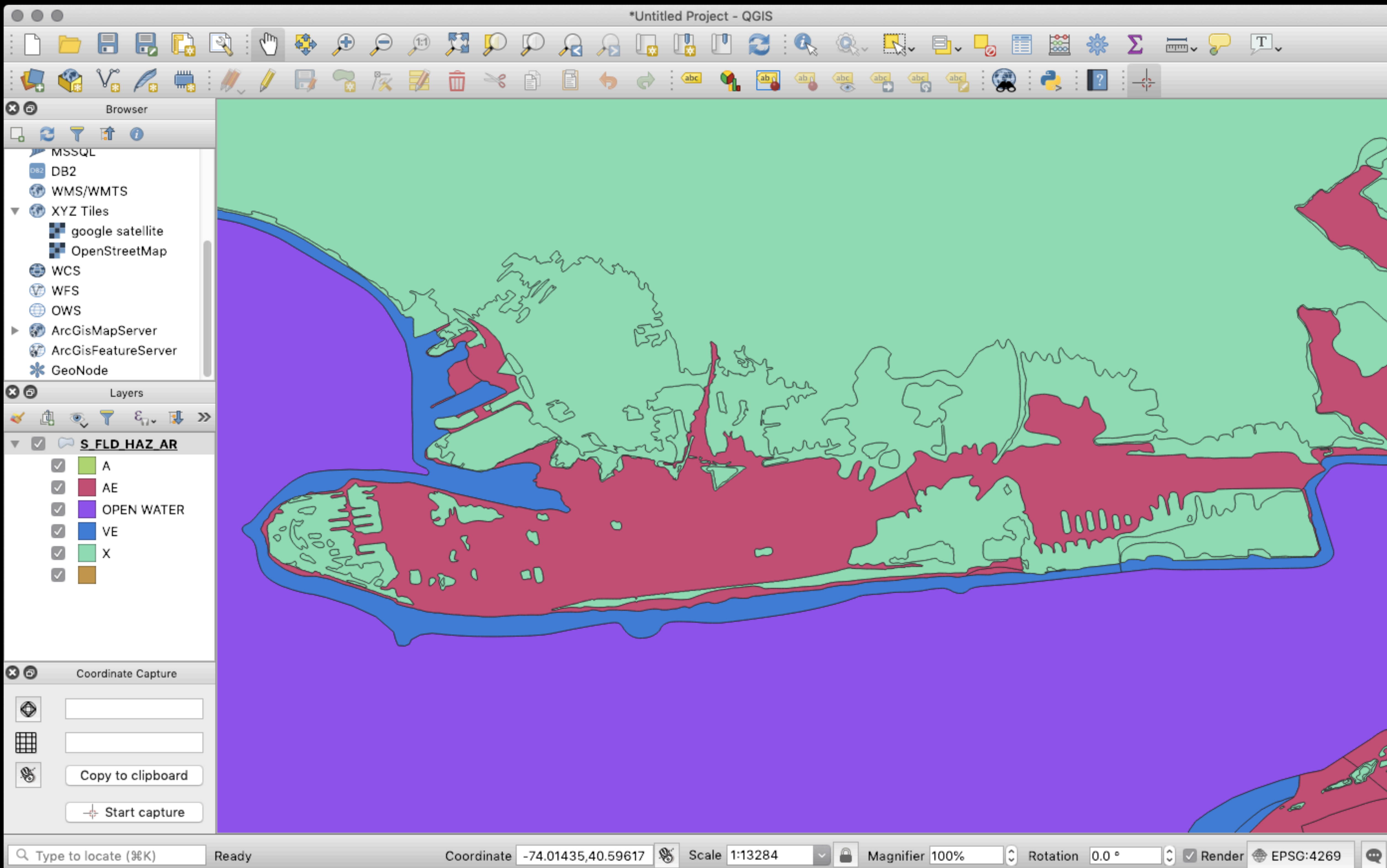

Why isn't Texas Ready for the
https://projects.propublica.org/houston/#hsc
ProPublica
THE TEXAS TRIBUNE
Hell and High Water
Plain Text Version
Donate
Flood Level
Storm makes landfall
Storm Scenarios
Proposed Solutions
See flood levels for a location in Houston
Search
« Back to Greater Houston
Magellan
Vopak
Shell
Valero
« Galveston
Greater Houston
Clear Lake »
Experts want better protections
Murphy Oil's tank wasn't the only one to fail in 2005, and it didn't even cause the largest spill; tanks damaged during Hurricanes Katrina and Rita caused more than 8 million gallons of oil to spill in Louisiana, Mississippi and Texas, according to government estimates.
Some tanks on the Houston Ship Channel were even damaged during Hurricane Ike in 2008, though the storm surge was far smaller than originally anticipated. About 15 feet of water covered the eastern part of Magellan Terminals Holdings' oil storage terminal in Galena Park, right on the Ship Channel, the company reported to the Texas Commission on Environmental Quality.
The storm surge and high winds caused damage to several tanks and a spill of nearly 1 million gallons of oil. Some was recovered, but about 300,000 gallons were released into the Ship Channel and "lost at sea," Magellan reported. (The spill didn't appear to impact any homes or businesses in Galena Park.)
"As a community, it would be good if we could come together and have a discussion about" the issue of storage tank safety, said Deer Park resident Jana Pellusch, who has worked at Shell since 2004. (Edmund D. Fountain/ProPublica/Texas Tribune)
Asked about its hurricane preparedness, Magellan spokesman Bruce Heine said that the company has
TEXAS
- Oil/Chemical Storage Tanks (2008)
- Existing Storm Protection

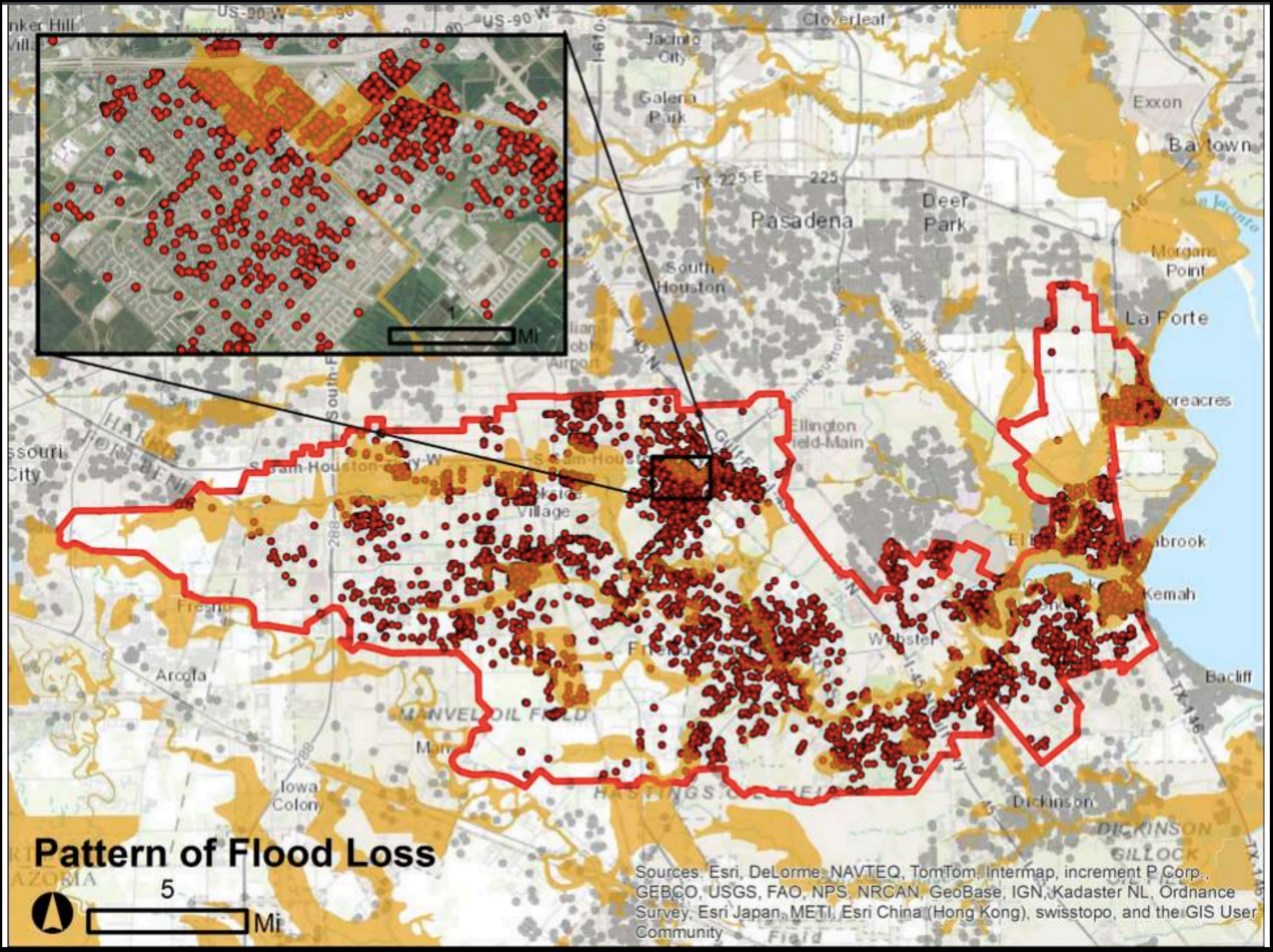

Boomtown, Flood Town
Pro Publica, Inc. [US] https://projects.propublica.org/houston-cypress/
ProPublica
THE TEXAS TRIBUNE
Plain Text Version
DONATE
Longtime problem, Little progress
Houston has been trying to solve its flooding woes since at least 1937, when a letter penned by local officials to state lawmakers pleaded for help and declared Texas' largest city "at the mercy of the relentless water."
Two horrible storms had struck the city in the previous eight years. Flooding, officials wrote, was a "constant menace" — endangering thousands of human lives and "millions of dollars in private, municipal and other governmental capital investments" and potentially causing "the distress of all of the peoples of Texas."
After nearly eight decades of massive engineering projects, incredible technological advances and a flurry of regulations for flood control, that letter still rings true. But now millions of lives and billions of dollars are at stake.
Downtown Houston during a flood in December 1935. (Courtesy Harris County Flood Control District)
An old planning map shows that the federal government had hoped to build a levee in front of Cypress Creek, to prevent its overflow from threatening the reservoirs. But time, money and politics got in the way, and it was never built.
HOCKLEY
Stable Gate
Cypress
CREEK LEVEE
CYPRESS
Grand Parkway
ADDICKS RESERVOIR
A 1940 map shows plans for a levee south of Cypress Creek. It was never built.


120 GPM
Decrease Flow ▼
Increase Flow ▲
Cross section of model
Channel
Tree
Levee
Protected floodplain
Cross section location
Flooding
Protected land
No Levees
When a free-flowing river floods, water jumps the river's banks and flows onto the floodplain.
Equal-Height Levees
When rivers have similar terrain on both sides, equal-height levees keep both banks dry.
Lower levee
Higher levee
House
Unprotected floodplain
Unequal-Height Levees
When one levee is taller than the other, or when people overbuild their levees, the extra height — ¼-inch in our model — is enough to shift some large floods to the other side of the
Setback Levees
Setback levees are built further back, allowing part of the natural floodplain to flood. This lowers water heights while still protecting areas behind the levees, and pushes less water

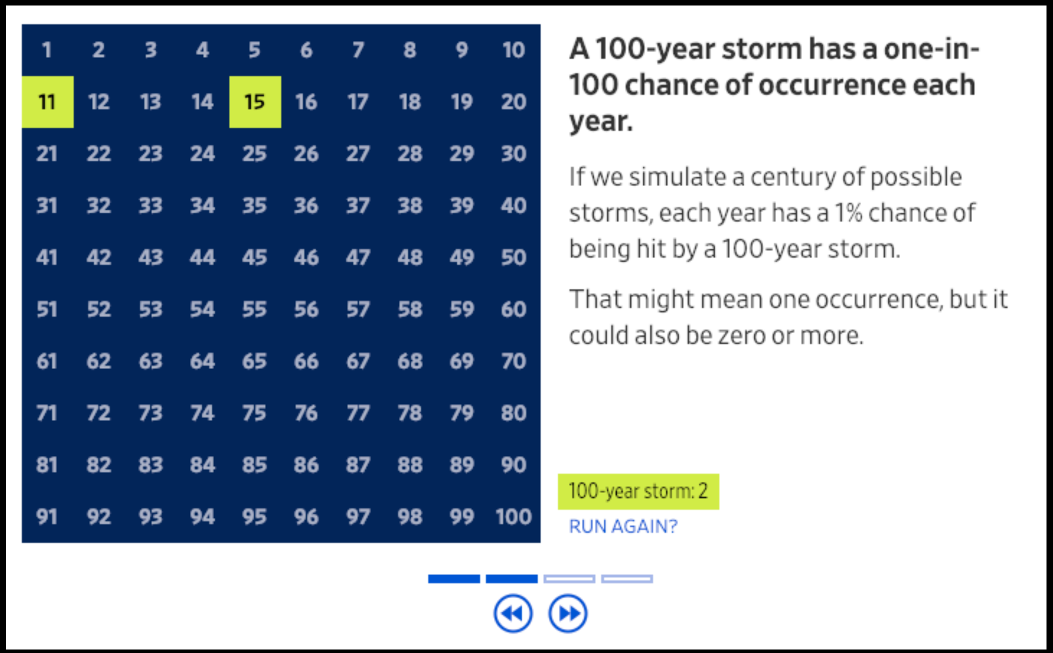

East River
City of New York 360497
Newtown Creek
QUEENS COUNTY
KINGS COUNTY
ZONE AE (EL 10)
ZONE X
Sea Wall
KU1050
KU1051
KU1054
KU1046
51ST AVENUE
54TH AVENUE
55TH AVENUE
53RD AVENUE
LONG ISLAND RAILROAD
BORDEN AVENUE
QUEENS MIDTOWN TUNNEL
JACKSON AVENUE
SKILLMAN AVENUE
DAVIS COURT
49TH AVENUE
50TH AVENUE
Dutch Kills
30TH STREET
27TH ST
25TH STREET
23RD STREET
2ND STREET
5TH ST
QUEENS MIDTOWN EXPRESSWAY
29TH STREET
REVIEW AVENUE
STARR AVENUE
PAIDGE AVENUE
BOX ST
CLAY STREET
COMMERCIAL ST
DUPONT STREET
EAGLE STREET
FREEMAN STREET
GREEN STREET
HURON STREET
INDIA STREET
JAVA STREET
KENT STREET
GREENPOINT AVENUE
MILTON STREET
NOBLE STREET
OAK STREET
CALYER STREET
QUAY STREET
MANHATTAN AVENUE
MC GUINNESS BOULEVARD
PROVOST STREET
Whale Creek
KINGSLAND AVENUE
N HENRY STREET
WEST ST
MESEROLE AVENUE
LORIMER STREET
LEONARD STREET
ECKFORD STREET
NEWEL STREET
DIAMOND STREET
JEWEL STREET
MOULTRIE STREET
HUMBOLDT STREET
RUSSELL STREET
MONITOR STREET
NORMAN AVENUE
SUTTON STREET
MORGAN AVENUE
HAUSMAN STREET
APOLLO STREET
NASSAU AVENUE
GUERNSEY STREET
DOBBINS
Jetty
Bushwick

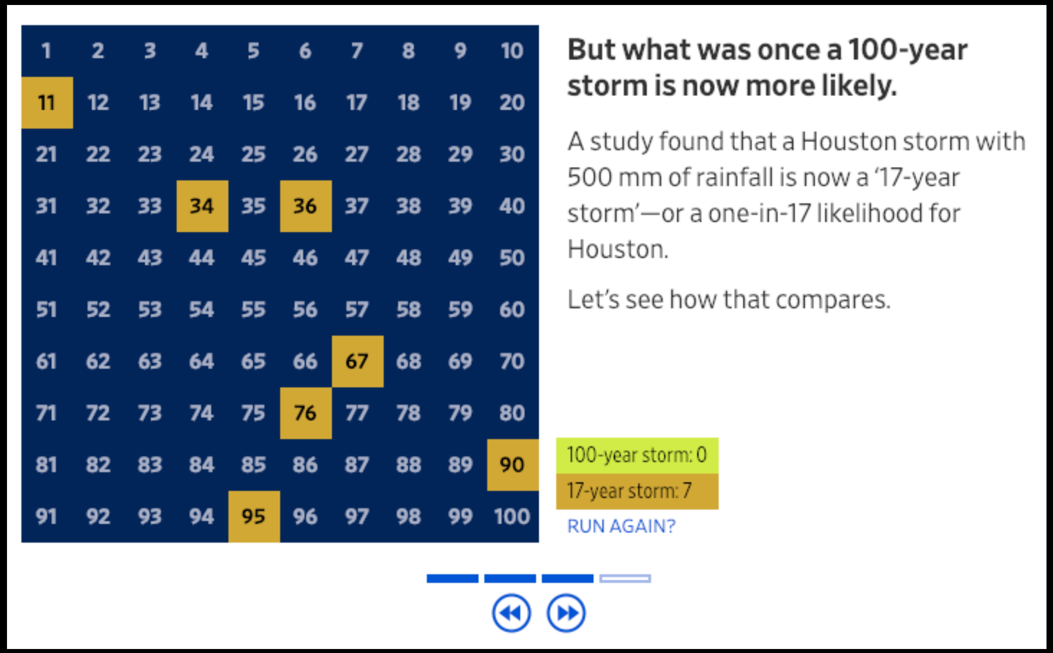
Product ID	Latest Study Effective Date	Latest LOMR Effective Date	Size	Download
NFHL_36_20181130	01/19/2018	02/16/2018	1044MB	DL

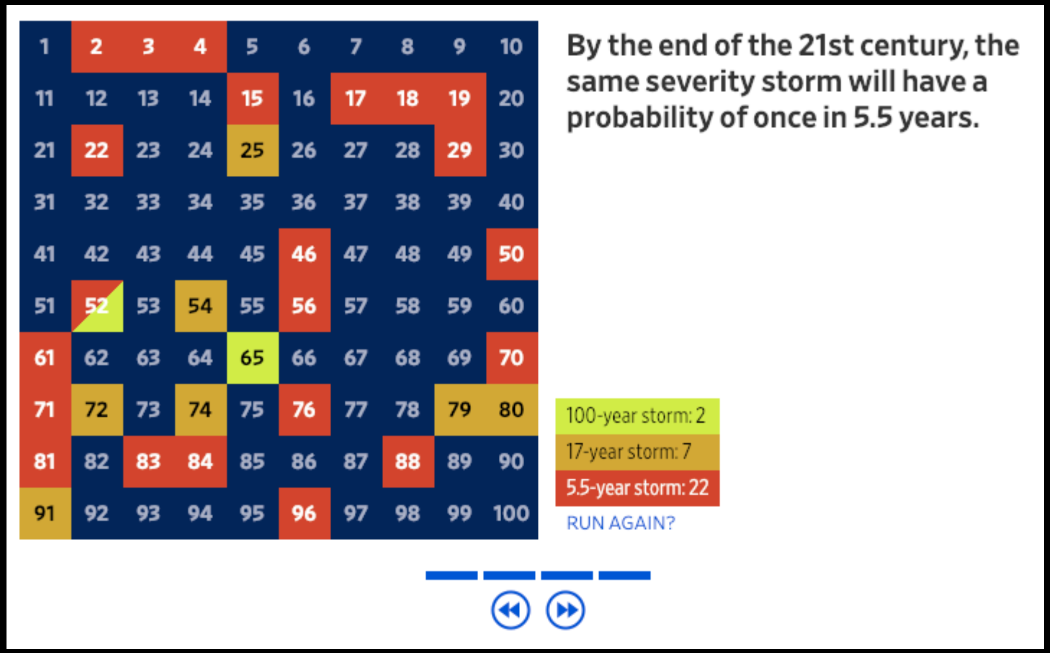




Blessing, Brody, Highfield







WSJ: Climate Change Is Forcing the Insurance Industry to Recalculate

FLOOD INSURANCE STUDY

VOLUME 1 of 4

ST. LOUIS COUNTY, MISSOURI
AND INCORPORATED AREAS

Flooding Source and Location	Drainage Area (sq. mi.)	Peak Discharges (cubic feet per second) 10-Percent-Annual Chance	2-Percent-Annual Chance	1-Percent-Annual Chance	0.2-Percent-Annual Chance
Maline Creek (continued)					
ther	4.1	4,900	6,700	7,400	8,300
)	2.77	3,365	4,546	5,068	6,300
te	1.9	2,000	3,000	3,500	4,800
o. 30	1.3	1,600	2,400	2,700	3,700
	3.98	2,950	4,650	5,450	7,600
rson	2.38	2,250	3,450	4,000	5,450
	1.39	1,650	2,500	2,850	3,800
oeur	2.54	2,100	3,300	3,850	5,300
	1.55	1,600	2,450	2,850	3,900
1,700 feet US of Conway Road	0.78	1,050	1,600	1,800	2,400
Mattese Creek					
New Baumgartner Road	9.65	4,950	8,100	9,700	14,000
Burlington Northern Railroad	8.39	4,550	7,450	8,900	12,500
Lemay Ferry Road	6.05	3,770	6,100	7,200	10,000
500 feet US of Lemay Ferry Road	3.89	2,900	4,600	5,400	7,600
425 feet DS of Du Bourg Lane	2.28	2,150	3,300	3,850	5,200
Tesson Ferry Road	1.86	1,900	2,900	3,400	4,600
Mehlville Creek					
Confluence with Gravois Creek	1.51	1,750	2,600	3,000	3,950
Meramec River					
At mouth	3,981	78,100	120,000	139,000	197,000
At State Highway 141	3,807	78,100	120,000	139,000	186,000
Confluence of Big River	2,816	61,000	109,000	133,000	186,000

FEMA

The estimated AEP corresponding to the December 2015 flood at the Meramec River near Eureka, Missouri, is 1.1 percent (recurrence interval of 91 years). A 66.7-percent confidence interval for the true annual exceedance probability of the flood extends from 0.7 (recurrence interval of 143 years) to 3.2 percent (recurrence interval of 31 years). The observed peak streamflow of 162,000 ft^3/s falls within the estimated 2-percent annual exceedance flow of 140,000 ft^3/s and the estimated 1-percent annual exceedance flow of 165,000 ft^3/s based on 99 years of peak record used in the analysis.

(100-year recurrence)		
	95-percent confidence limits	
Estimate	Lower	Upper
165,000	137,000	198,000

USGS

Flood Map Modernization

Mid-Course Adjustment

March 30, 2006

FEMA

At the end of the 5-year period of FEMA's Map Modernization initiative, with the course adjustment described above, the Nation can expect digital flood maps to cover 92 percent of the population of the United States and 65 percent of its land area. Overall, 75 percent of the mapped stream miles will meet the 2005 Floodplain Boundary Standard, meaning that the floodplain boundary on the maps is drawn using the best available topographic data. This covers 80 percent of the population. Of the stream miles mapped, 30 percent will be based on new, updated, or validated engineering analysis, covering 40 percent of the population.

FEMA will accomplish these final outcomes of the Map Modernization initiative provided that funding levels are maintained through FY 2008. No additional funding or schedule adjustments are required to meet FEMA's new targets as outlined in this report.

https://www.documentcloud.org/documents/803311-fema-2006-flood-map-modernization-mid-course.html

2005 Letter from NYS Flood Chief to FEMA

New York State Department of Environmental Conservation
Division of Water
Bureau of Program Resources & Flood Protection, 4th Floor
625 Broadway, Albany, New York 12233-3507
Phone: (518) 402-8151 • **FAX:** (518) 402-9029
Website: www.dec.state.ny.us

Erin M. Crotty

Mr. David I. Maurstad
Director, Mitigation Directorate
Federal Emergency Managemen
500 C. Street S.W.
Washington, DC 20472

Until recently, FEMA Region II supported our point of view. However, they have received their marching orders. This month, we were told in no uncertain terms that the task at hand is to produce digital flood maps nation-wide. This means that in much of New York, and I imagine in most of the rest of the nation, there will be sufficient funding to do little more than digitize existing maps with perhaps better quality approximate studies. This is insufficient and will result in poor quality, but really good looking maps that fail to provide the data needed to adequately manage development in floodplains. Many errors on existing maps will continue to appear on the new maps. Funds will not be available to connect disconnected studies at community boundaries, to correct inaccurate hydrology, or to update out of date hydraulic studies where needed. Out of date studies will continue to appear on newly issued maps. This will lead to higher than necessary flood damages and more expenses placed on individuals and on FEMA for LOMAs and LOMRs. It will also create public and political opposition to the Map Modernization Program.

Dear Mr. Maurstad:

Thank you for the opportunity to
(MHIP), which establishes the ou   p Modernization Program. As one of FEMA's first state-wide Cooperating Technical Partners (CTP), we are strongly committed to supporting and undertaking the most advanced flood mapping in history. We have enjoyed a long and fruitful relationship with FEMA in the areas of floodplain management and map modernization, and look

https://www.propublica.org/documents/item/808733-2005-mhip-ny-fema-letter

FLOOD INSURANCE STUDY

CITY OF NEW YORK, NEW YORK

BRONX COUNTY, RICHMOND COUNTY NEW YORK COUNTY, QUEENS COUNTY, KINGS COUNTY

REVISED:

SEPTEMBER 5, 2007

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
360497V000A

Queens

54%

Of Sandy flood area predicted by flood maps

Kings

47%

Of Sandy flood area predicted by flood maps

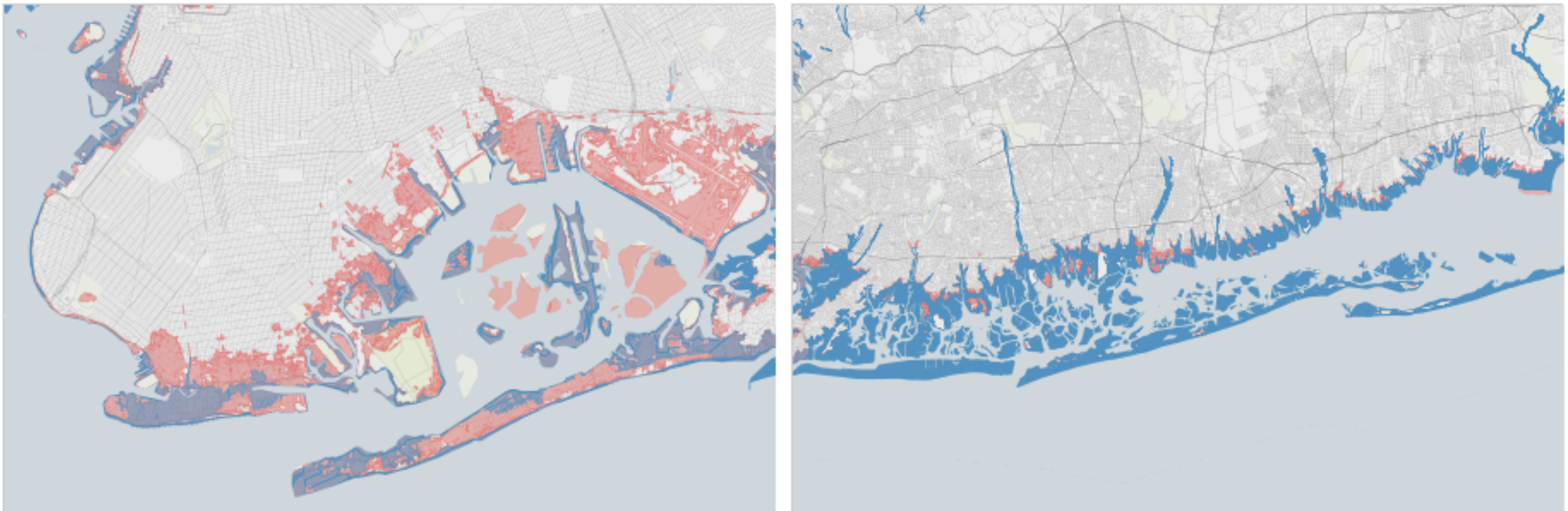
New York City's flood insurance maps, released by FEMA in 2007, are based on older technology and an older storm-surge model. ...

Nassau

89%

Of Sandy flood area predicted by flood maps

... Nassau County got new flood maps in 2009, using lidar data and a new storm surge analysis. These maps were better at predicting the area Sandy flooded than the New York City maps.



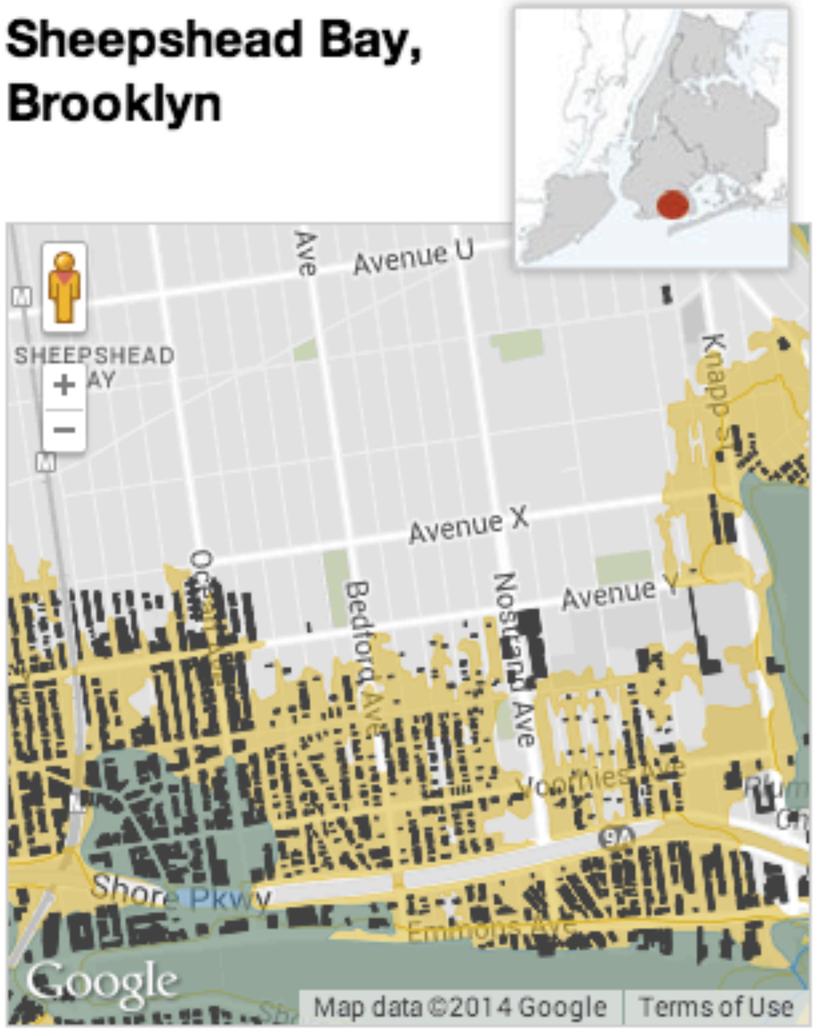
Sandy Flood Area

Existing Flood Hazard Zones

Source: FEMA

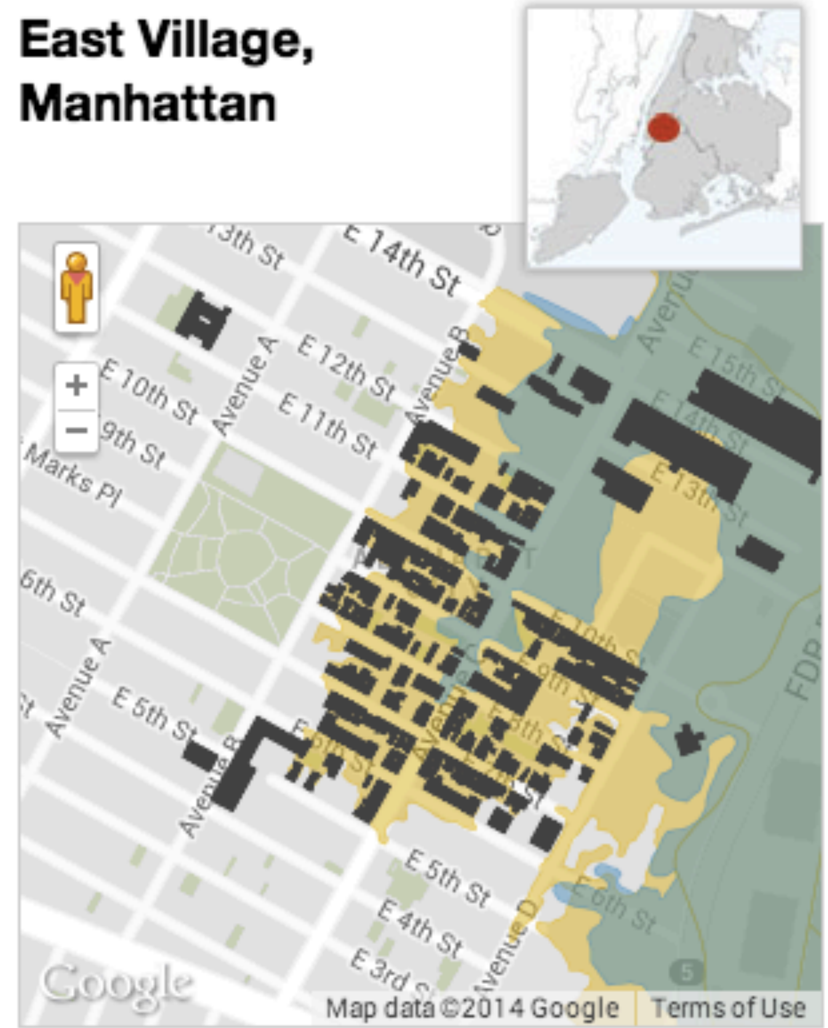
http://www.propublica.org/article/federal-flood-maps-left-new-york-unprepared-for-sandy-and-fema-knew-it

Sheepshead Bay, Brooklyn



Belle Harbor, Queens

East Village, Manhattan



2013 Preliminary Flood Zones
2007 Flood Hazard Zones
Buildings damaged in Superstorm Sandy
Source: FEMA

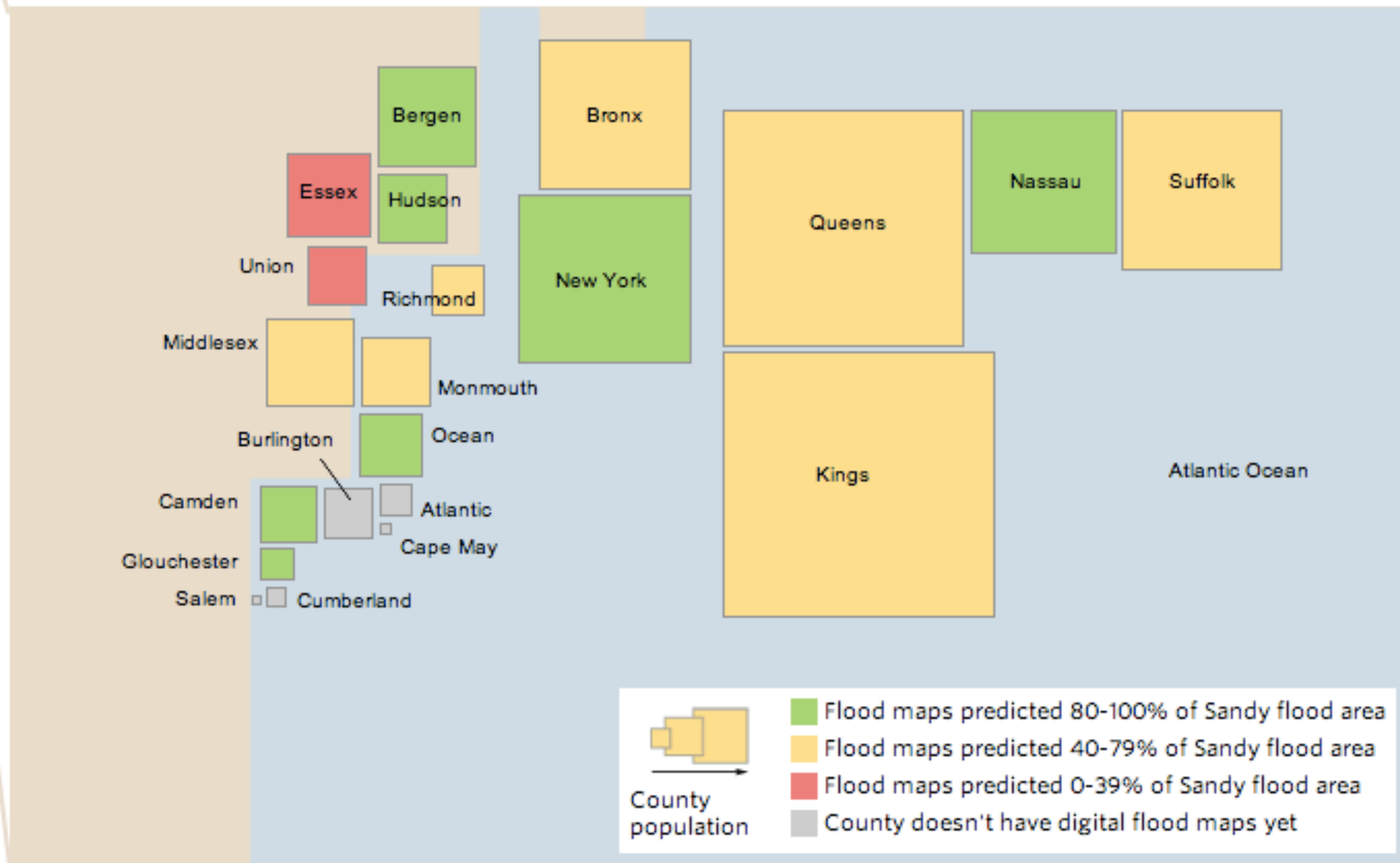
98	Gloucester, N.J.
98	Camden, N.J.
92	Ocean, N.J.
89	Nassau, N.Y.
83	Bergen, N.J.
80	Hudson, N.J.
80	New York, N.Y.
79	Middlesex, N.J.
76	Monmouth, N.J.
75	Suffolk, N.Y.
72	Bronx, N.Y.
67	Richmond, N.Y.
54	Queens, N.Y.
47	Kings, N.Y.
37	Essex, N.J.
33	Union, N.J.
N/A	Atlantic, N.J.
N/A	Salem, N.J.
N/A	Burlington, N.J.
N/A	Cape May, N.J.
N/A	Cumberland, N.J.

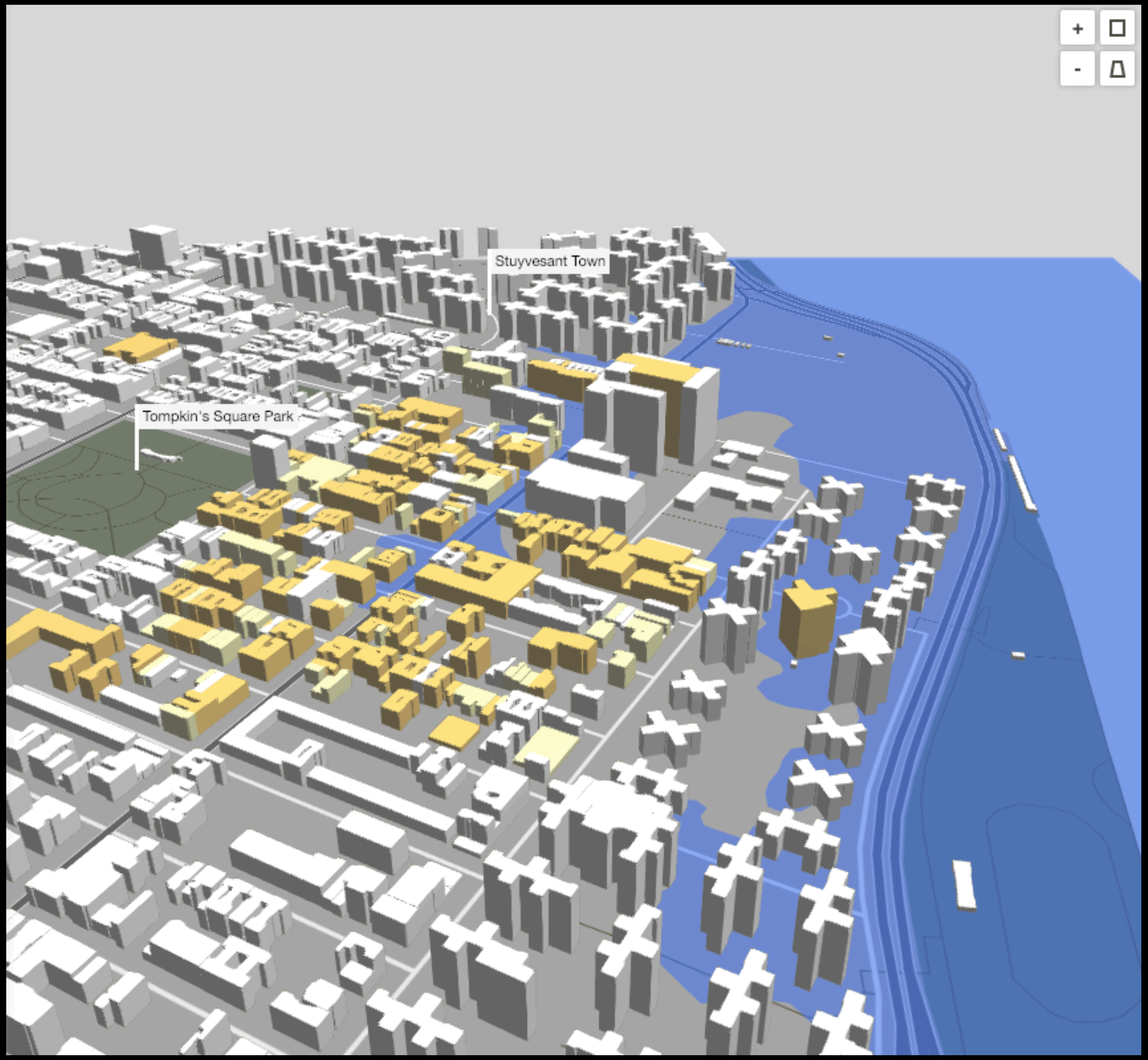
New York and New Jersey Coastline

Click a county to compare predicted flood risk to Sandy's real flood extent. Bigger boxes are more populous counties.

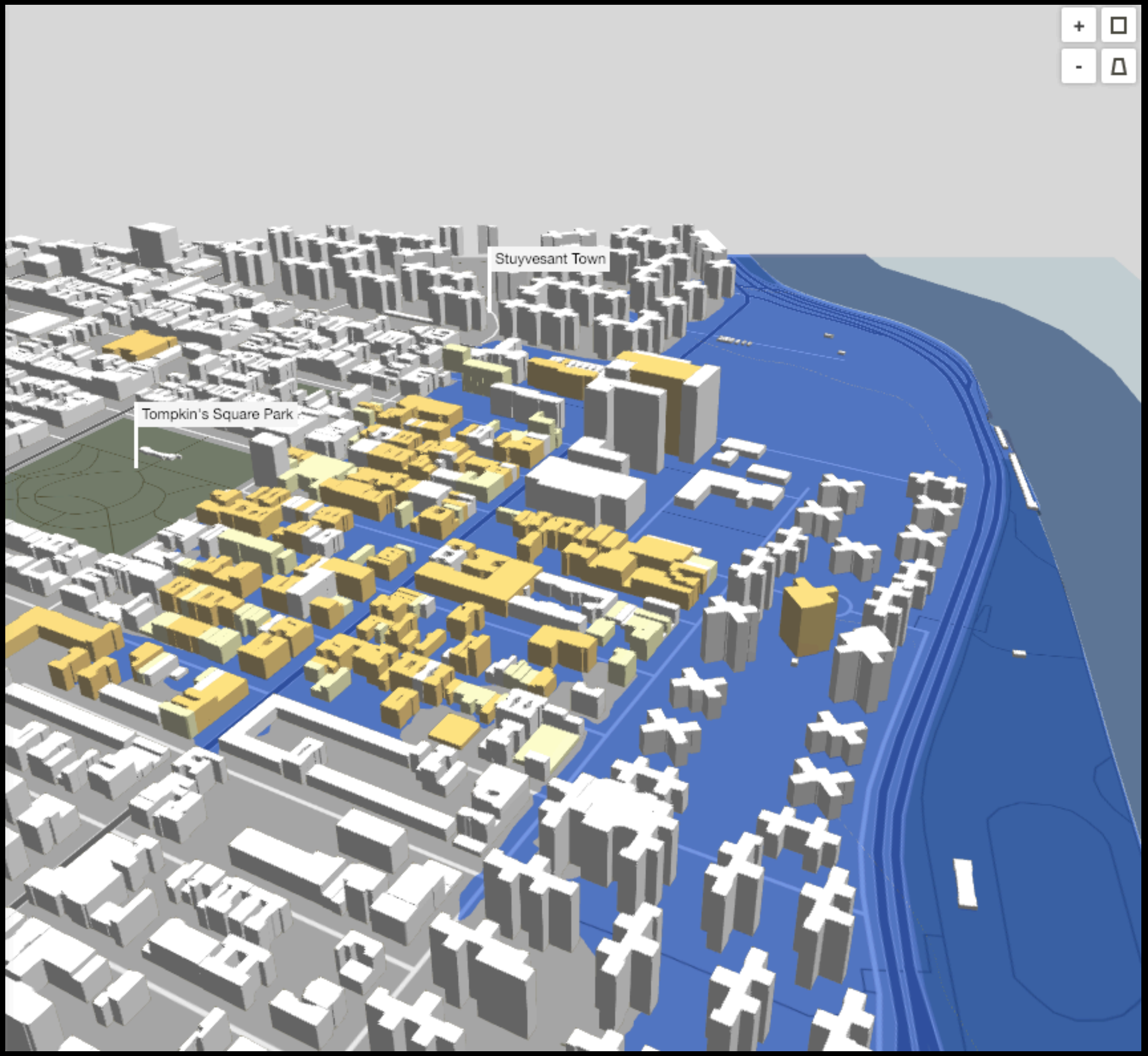
Search for an address or ZIP code in New York City, Long Island or New Jersey

GO

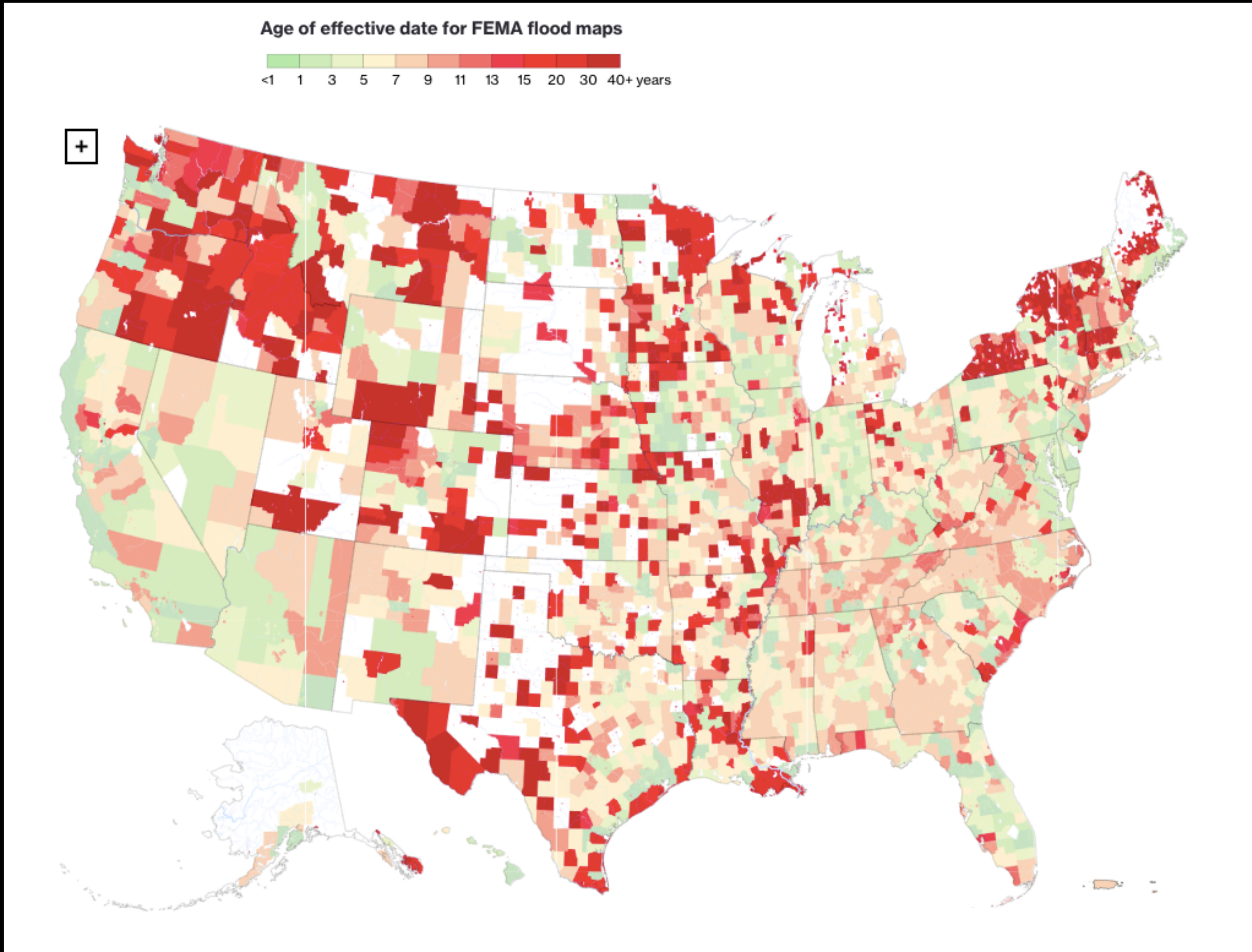




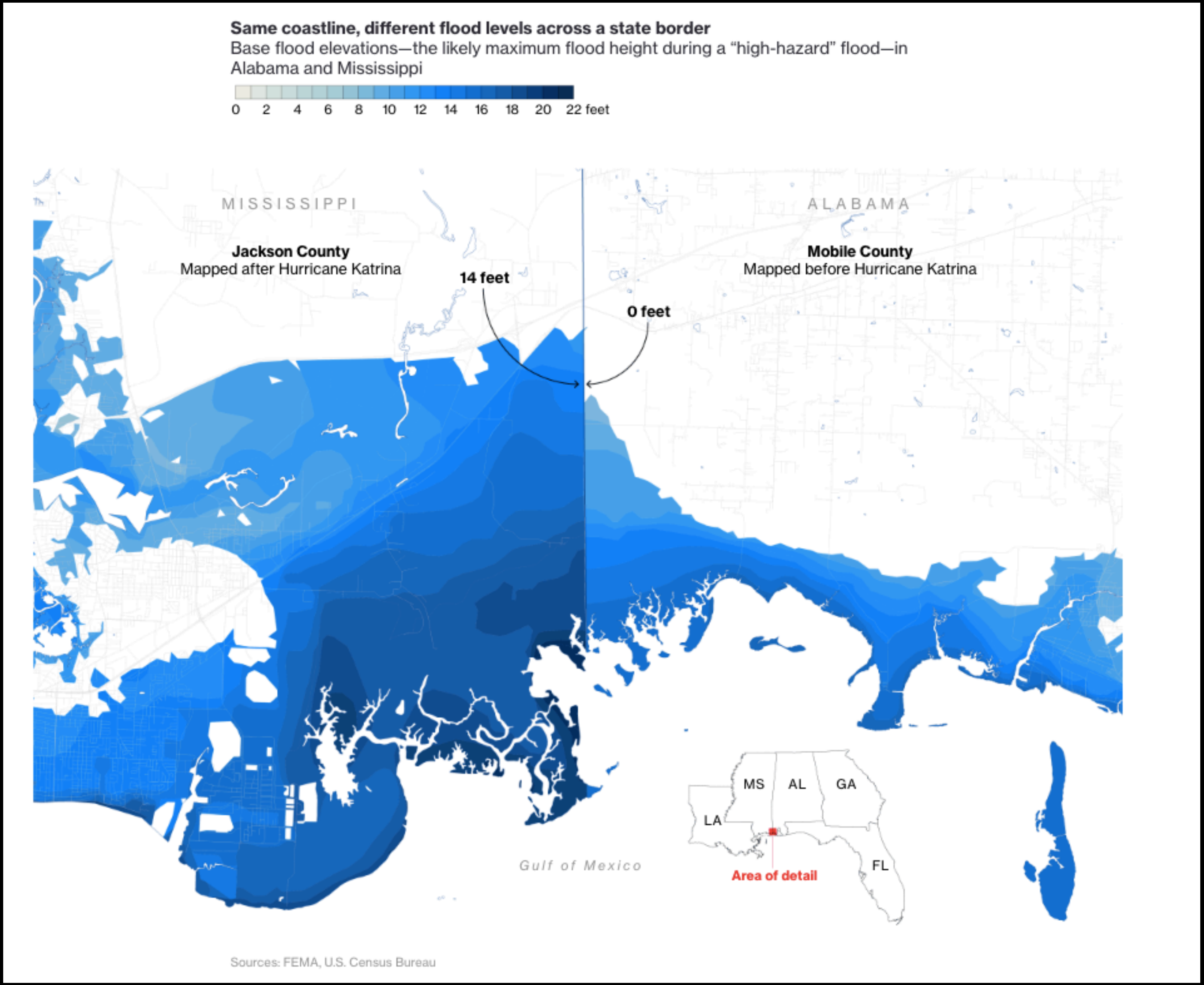
Stuyvesant Town
Tompkin's Square Park



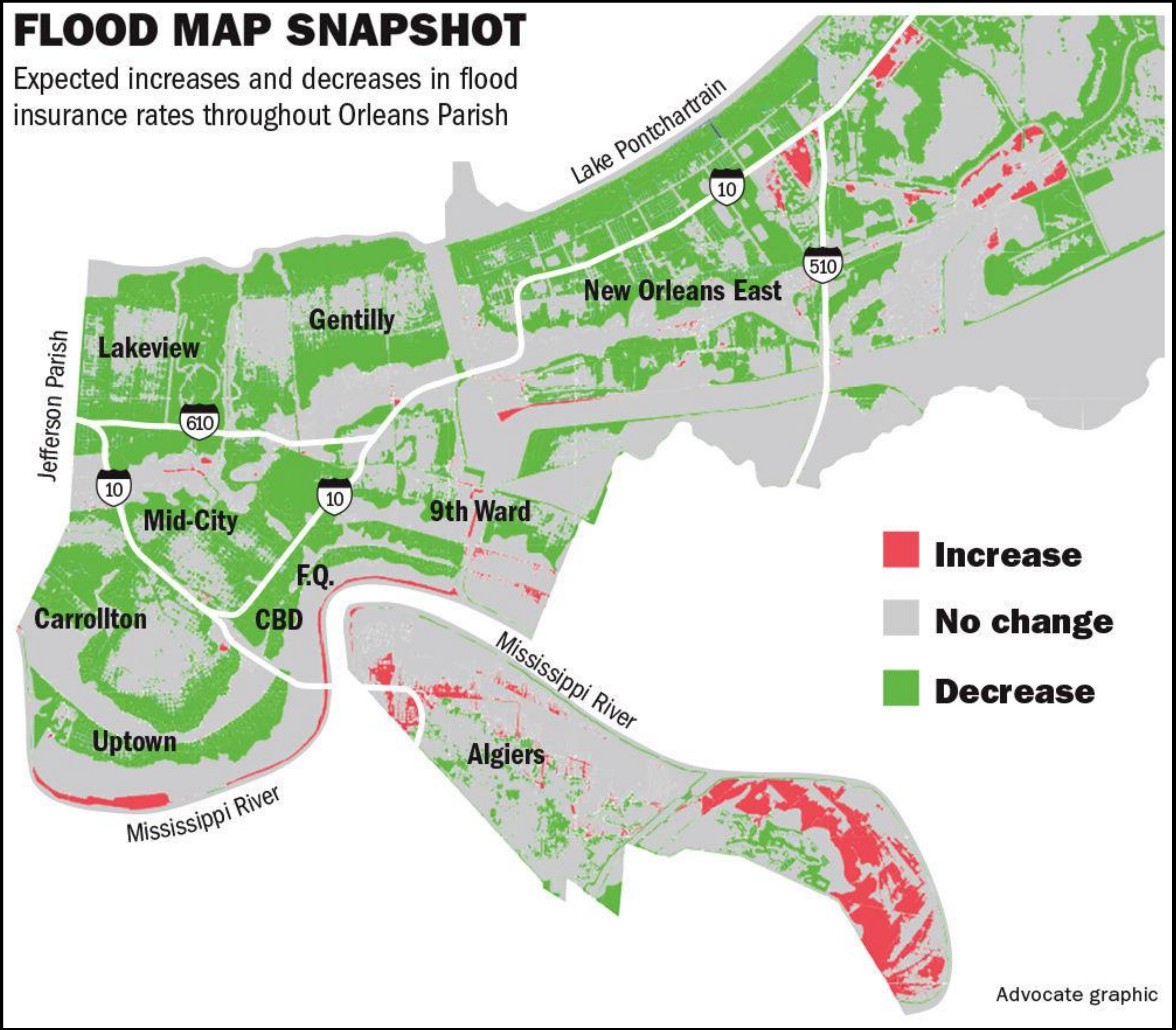
Stuyvesant Town
Tompkin's Square Park



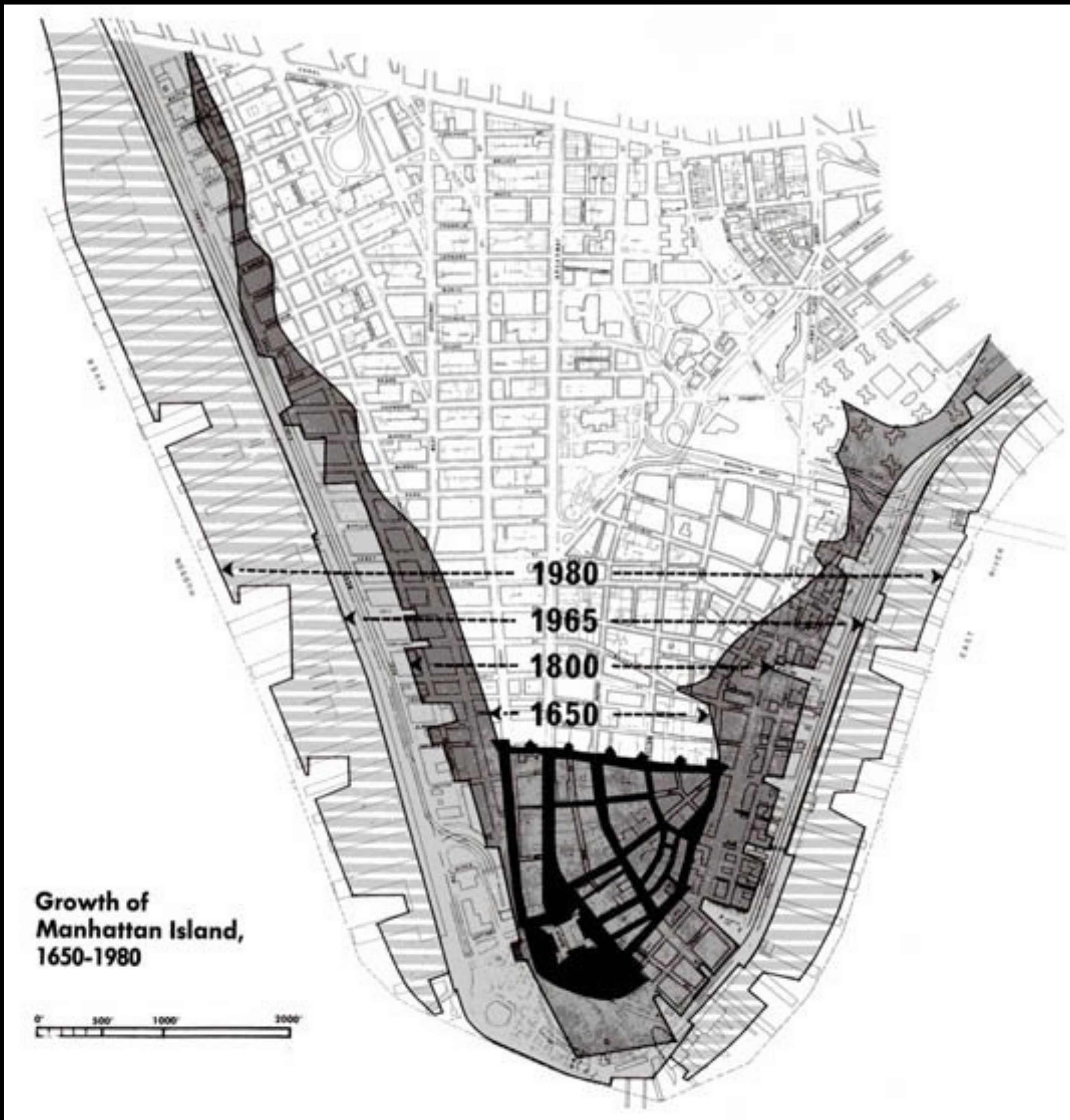
Bloomberg: Outdated and Unreliable: FEMA's Faulty Flood Maps Put Homeowners at Risk



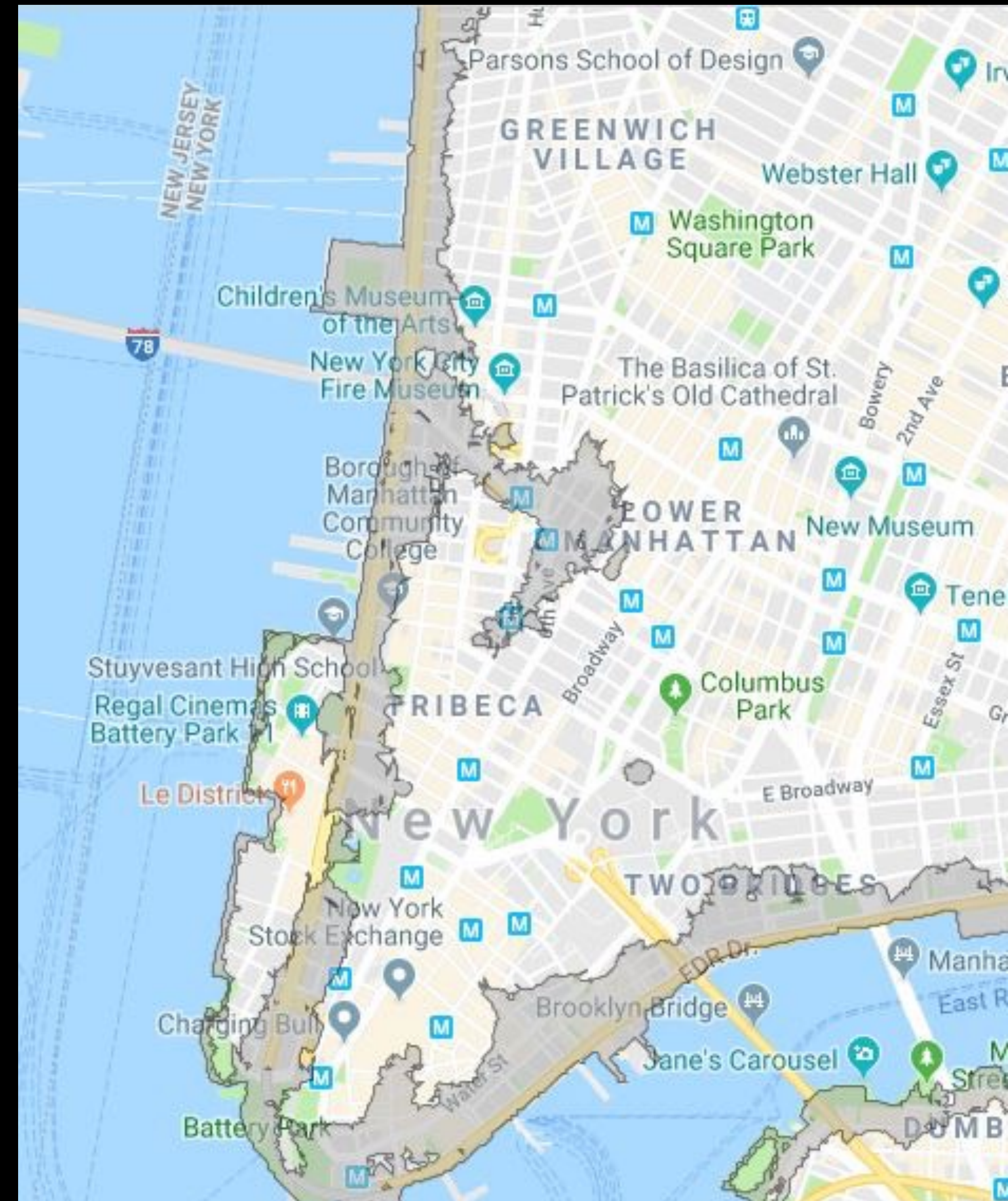
Bloomberg: Outdated and Unreliable: FEMA's Faulty Flood Maps Put Homeowners at Risk



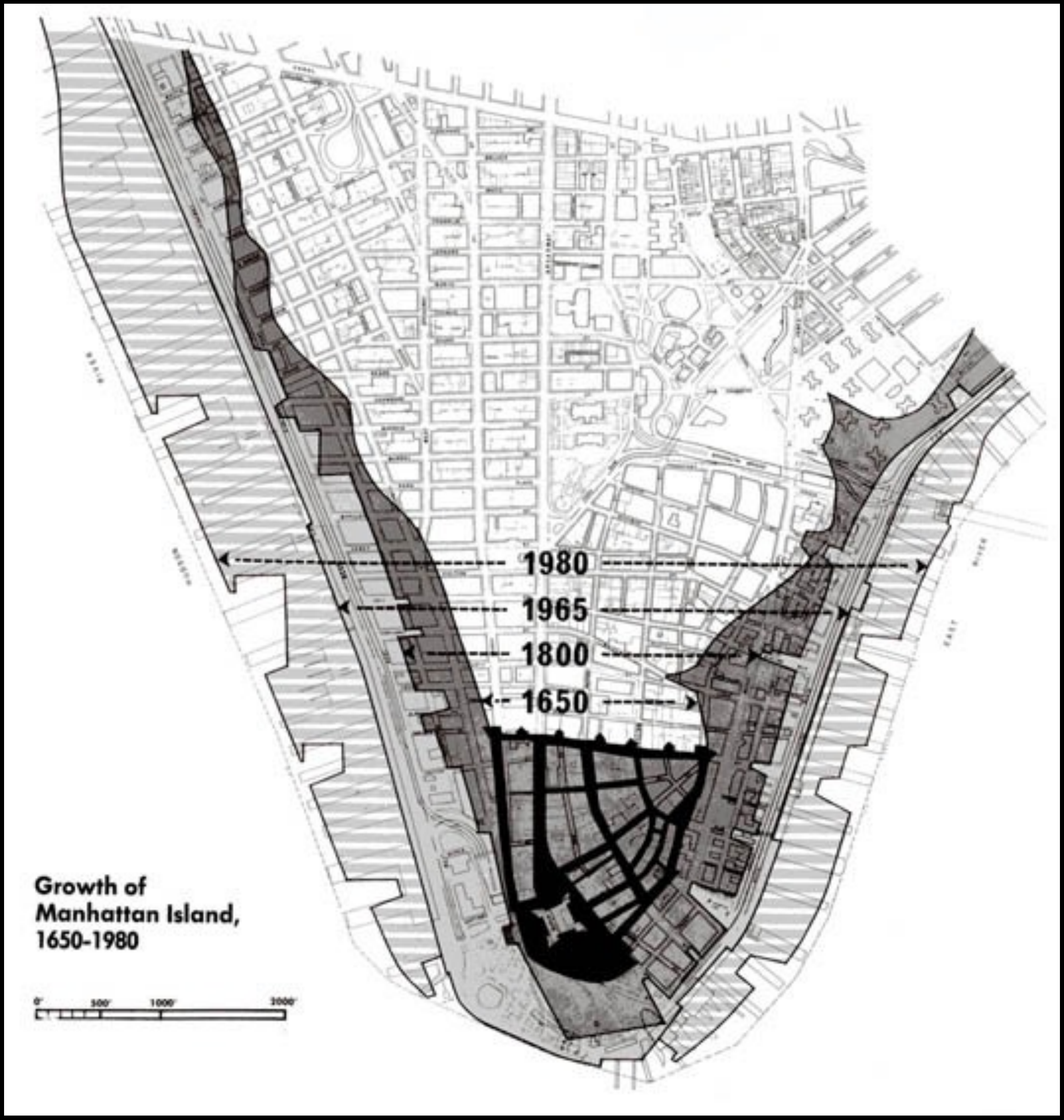
Dan Swenson/The Advocate



1980
1965
1800
1650
Growth of Manhattan Island, 1650-1980



Parsons School of Design
GREENWICH VILLAGE
Webster Hall
Washington Square Park
NEW JERSEY
NEW YORK
Children's Museum of the Arts
New York City Fire Museum
The Basilica of St. Patrick's Old Cathedral
Borough of Manhattan Community College
LOWER MANHATTAN
New Museum
Stuyvesant High School
Regal Cinemas Battery Park
TRIBECA
Columbus Park
Le District
New York
E Broadway
TWO BRIDGES
New York Stock Exchange
Charging Bull
Brooklyn Bridge
Jane's Carousel
Battery Park



NOAA

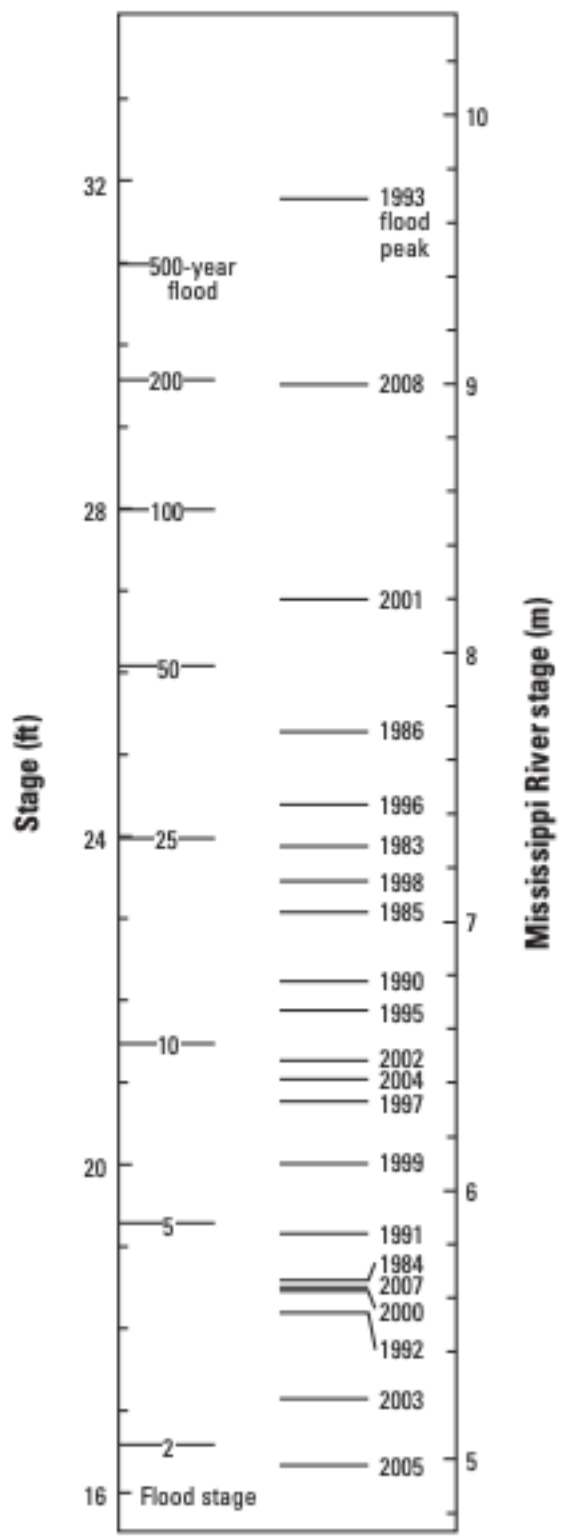


Figure 1. Mississippi River flood levels recorded at Hannibal over the last 25 years [right (NWS 2008; USACE 2008b)] compared with the theoretical stages for 2-year to 500-year floods [left (USACE 2004, 2008a)].

Criss, Winston, 2008

Nat Hazards (2015) 77:1183–1203
DOI 10.1007/s11069-015-1652-7

ORIGINAL PAPER

Vulnerability of an industrial corridor in Texas to storm surge

Daniel W. Burleson · Hanadi S. Rifai · Jennifer K. Proft · Clint N. Dawson · Philip B. Bedient

Delineating the Reality of Flood Risk and Loss in Southeast Texas

Samuel D. Brody[1]; Russell Blessing[2]; Antonia Sebastian, M.ASCE[3]; and Philip Bedient, F.ASCE[4]

Urban Studies at 50

Urban Studies
50(4) 789–806, March 2013

Examining the Impacts of Development Patterns on Flooding on the Gulf of Mexico Coast

Samuel Brody, Heeju Kim and Joshua Gunn

[Paper first received, November 2011; in final form, April 2012]

Hindcast and validation of Hurricane Ike (2008) waves, forerunner, and storm surge

M. E. Hope,[1] J. J. Westerink,[1] A. B. Kennedy,[1] P. C. Kerr,[1] J. C. Dietrich,[1,2] C. Dawson,[3] C. J. Bender,[4] J. M. Smith,[5] R. E. Jensen,[5] M. Zijlema,[6] L. H. Holthuijsen,[6] R. A. Luettich Jr.,[7] M. D. Powell,[8] V. J. Cardone,[9] A. T. Cox,[9] H. Pourtaheri,[10] H. J. Roberts,[11] J. H. Atkinson,[11] S. Tanaka,[1,12] H. J. Westerink,[1] and L. G. Westerink[1]

Structural Integrity of Storage Tanks

Jamie E. Padgett, Ph.D.
Assistant Professor

Risk Analysis

DOI: 10.1111/j.1539-6924.2012.01840.x

Perspective

Examining the 100-Year Floodplain as a Metric of Risk, Loss, and Household Adjustment

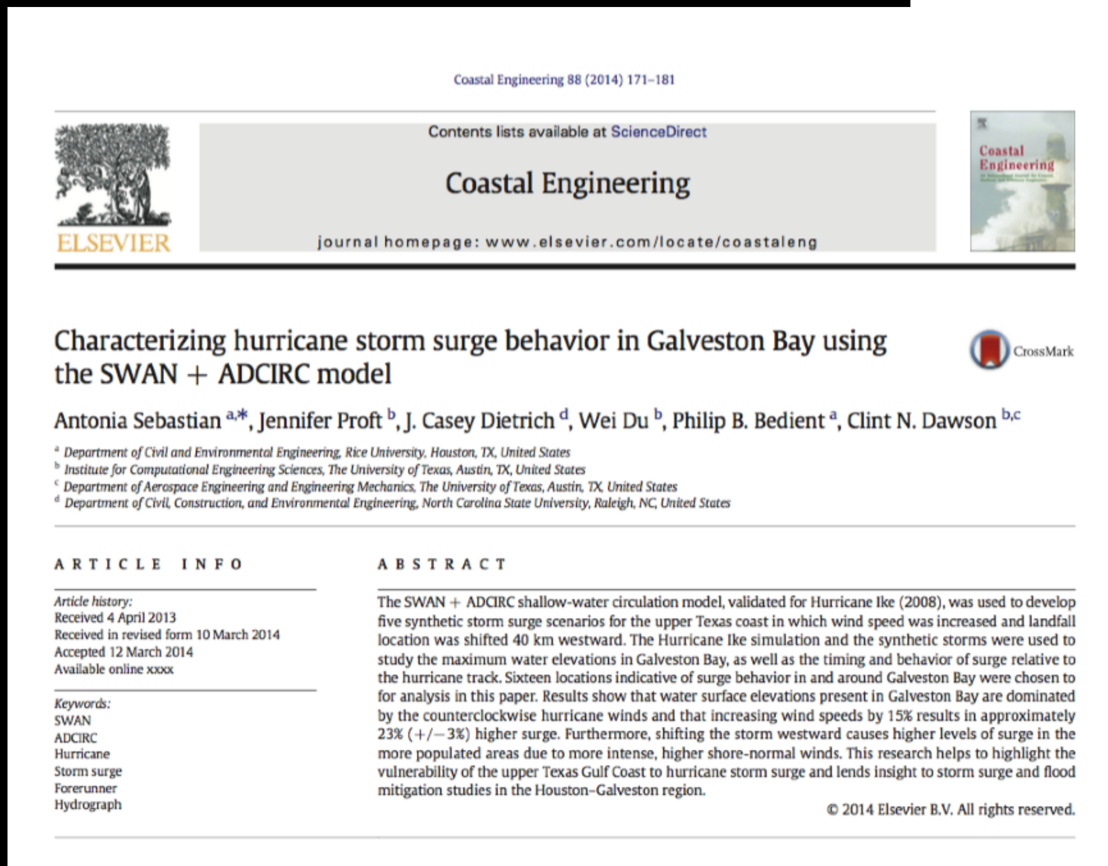
Wesley E. Highfield,* Sarah A. Norman, and Samuel D. Brody

Hurricane Katrina and Rita

RICE UNIVERSITY

2

10/1/2013


Coastal Engineering 88 (2014) 171–181

Contents lists available at ScienceDirect

Coastal Engineering

journal homepage: www.elsevier.com/locate/coastaleng

Characterizing hurricane storm surge behavior in Galveston Bay using the SWAN + ADCIRC model

Antonia Sebastian [a,*], Jennifer Proft [b], J. Casey Dietrich [d], Wei Du [b], Philip B. Bedient [a], Clint N. Dawson [b,c]

[a] Department of Civil and Environmental Engineering, Rice University, Houston, TX, United States
[b] Institute for Computational Engineering Sciences, The University of Texas, Austin, TX, United States
[c] Department of Aerospace Engineering and Engineering Mechanics, The University of Texas, Austin, TX, United States
[d] Department of Civil, Construction, and Environmental Engineering, North Carolina State University, Raleigh, NC, United States

A R T I C L E I N F O

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Keywords:
SWAN
ADCIRC
Hurricane
Storm surge
Forerunner
Hydrograph

A B S T R A C T

The SWAN + ADCIRC shallow-water circulation model, validated for Hurricane Ike (2008), was used to develop five synthetic storm surge scenarios for the upper Texas coast in which wind speed was increased and landfall location was shifted 40 km westward. The Hurricane Ike simulation and the synthetic storms were used to study the maximum water elevations in Galveston Bay, as well as the timing and behavior of surge relative to the hurricane track. Sixteen locations indicative of surge behavior in and around Galveston Bay were chosen to for analysis in this paper. Results show that water surface elevations present in Galveston Bay are dominated by the counterclockwise hurricane winds and that increasing wind speeds by 15% results in approximately 23% (+/−3%) higher surge. Furthermore, shifting the storm westward causes higher levels of surge in the more populated areas due to more intense, higher shore-normal winds. This research helps to highlight the vulnerability of the upper Texas Gulf Coast to hurricane storm surge and lends insight to storm surge and flood mitigation studies in the Houston–Galveston region.

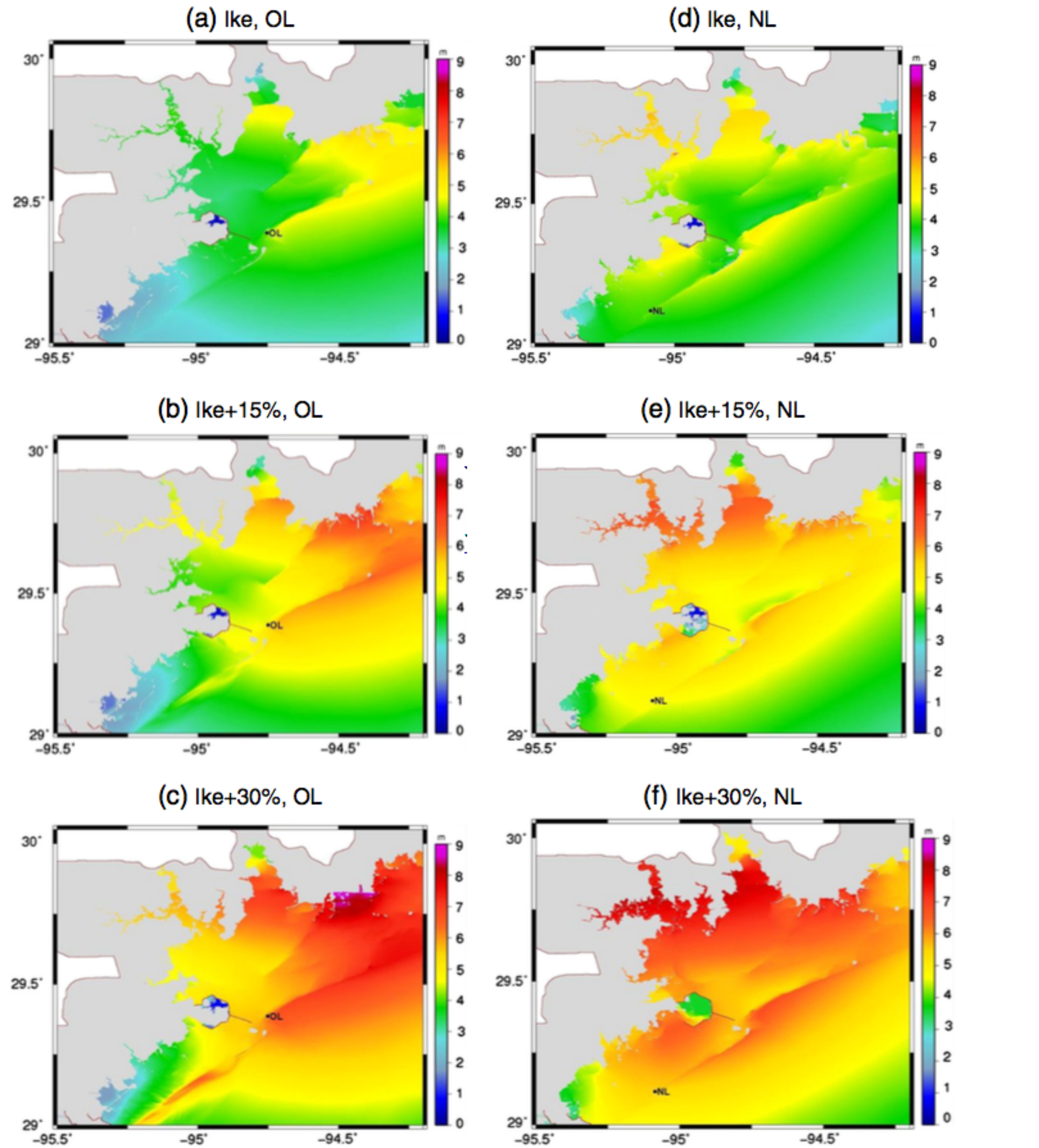
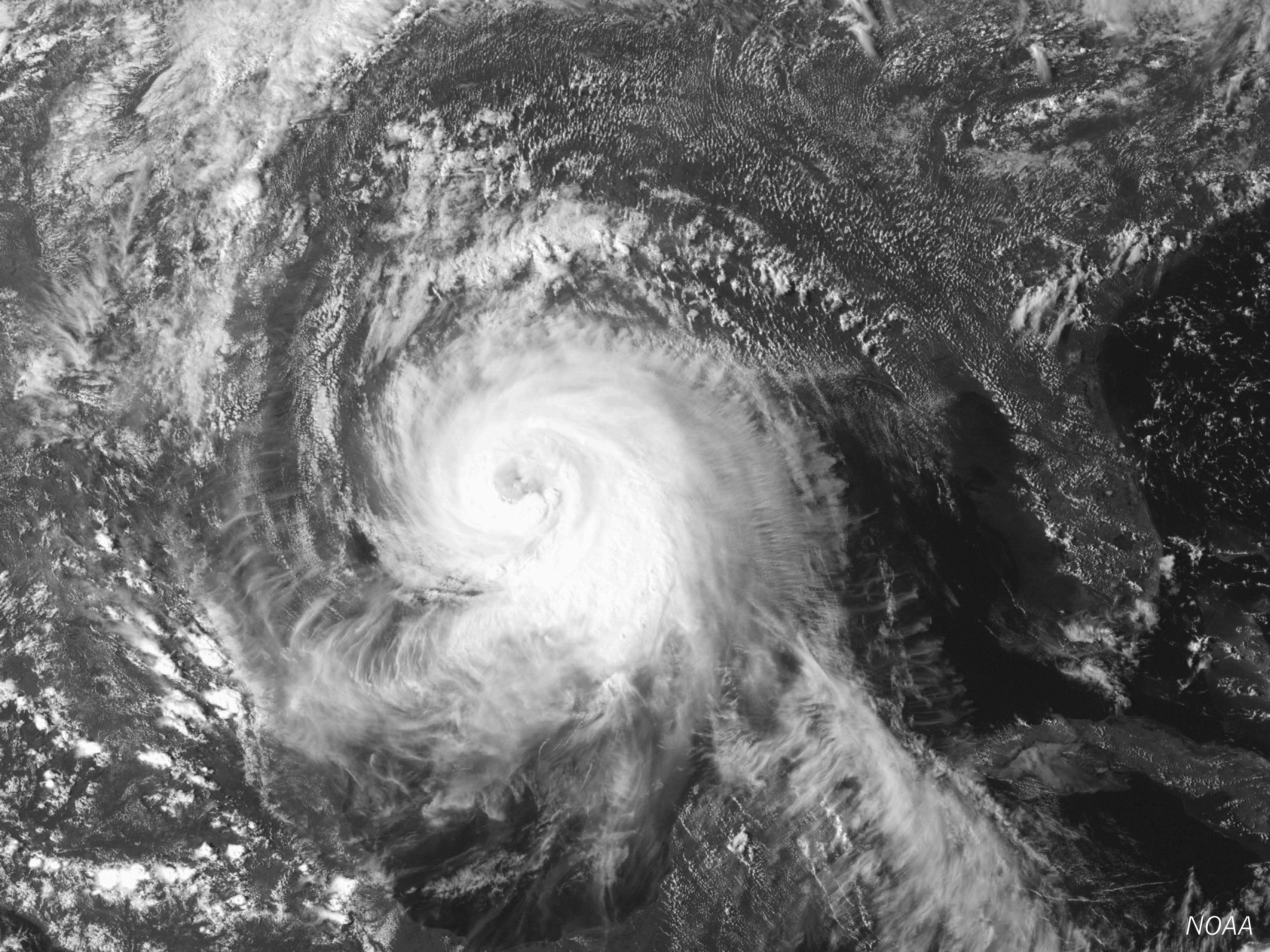


Fig. 9. Maximum water surface elevations from ADCIRC + SWAN for the Hurricane Ike original, +15%, and +30% wind scenarios at the original landfall (OL) and new landfall (NL) locations. a. Ike, OL. b. Ike + 15%, OL. c. Ike + 30%, OL. d. Ike, NL. e. Ike + 15% NL. f. Ike + 30%, NL.


NOAA

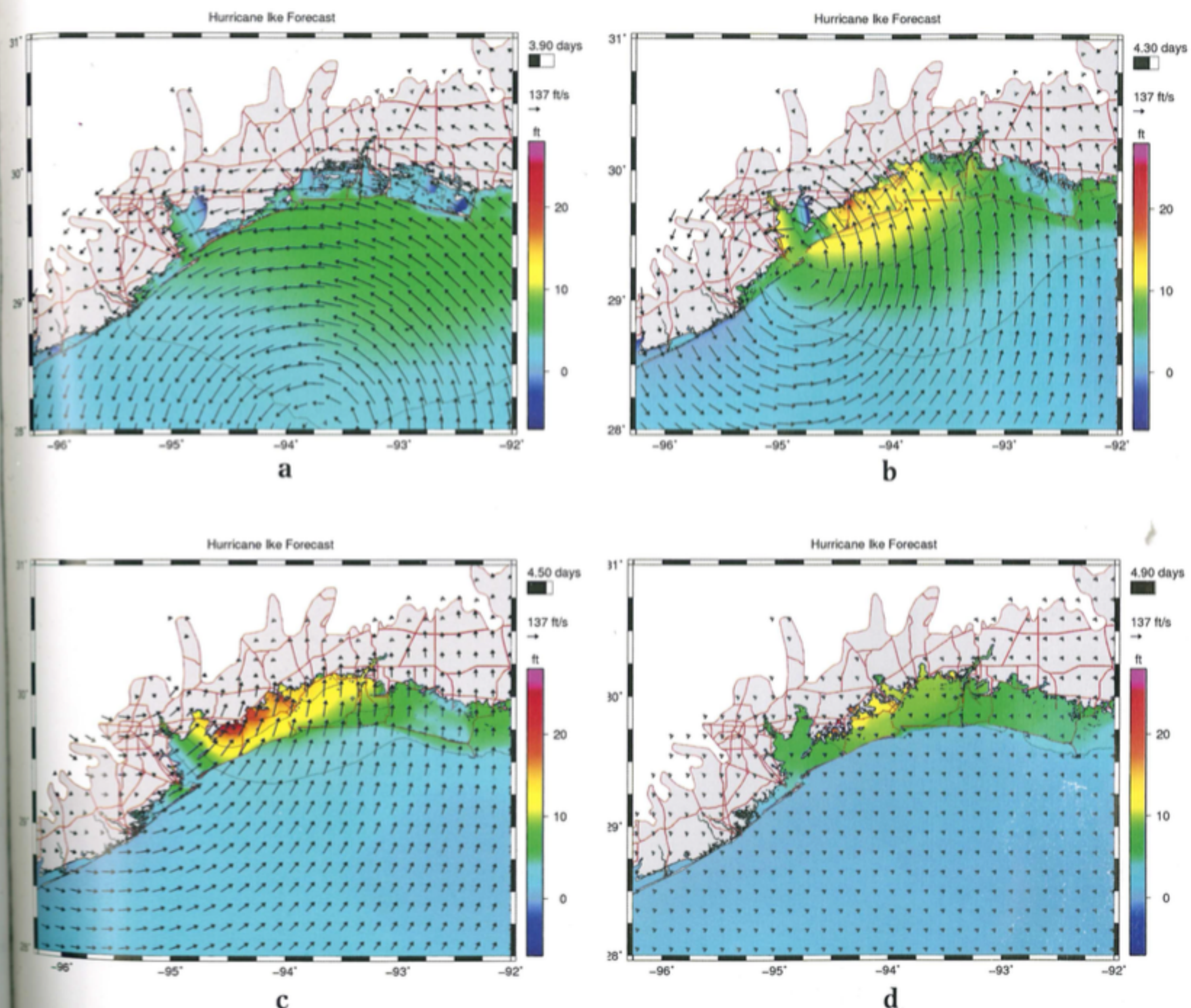


Figure 5.6a–d. The ADCIRC model maps the progression of Hurricane Ike as it makes landfall, showing wind vectors and inundation levels along the Texas coast.

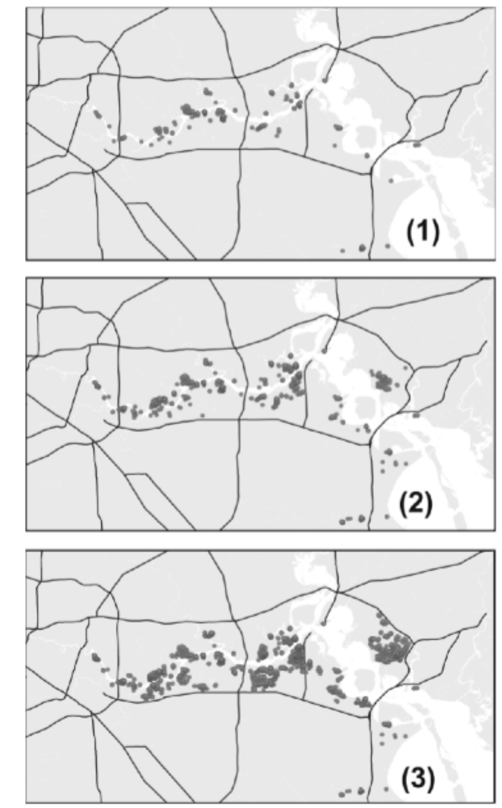
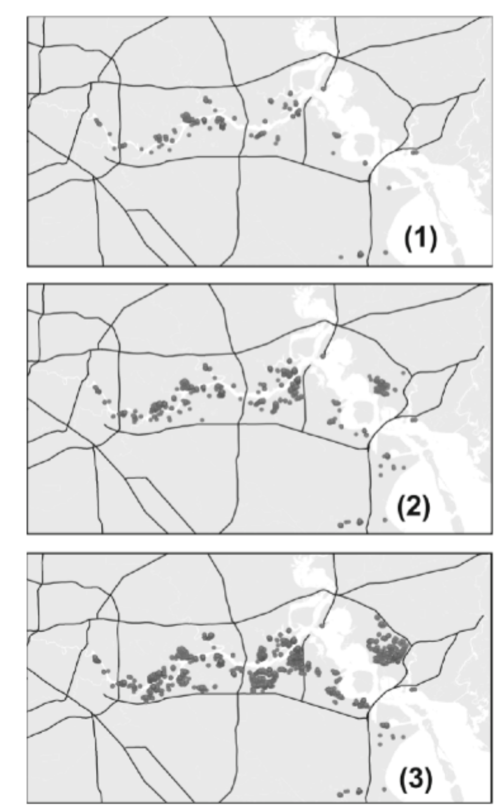


Fig. 7 Inundated tanks for the modeled scenarios. The dots represent tanks that would be inundated based on their elevation and storm surge level—Hurricane Ike (*panel 1*), Hurricane Ike at point 7 (*panel 2*), and Hurricane Ike at point 7 with 30 % increase in wind speed (*panel 3*)

1196 Nat Hazards (2015) 77:1183–1203



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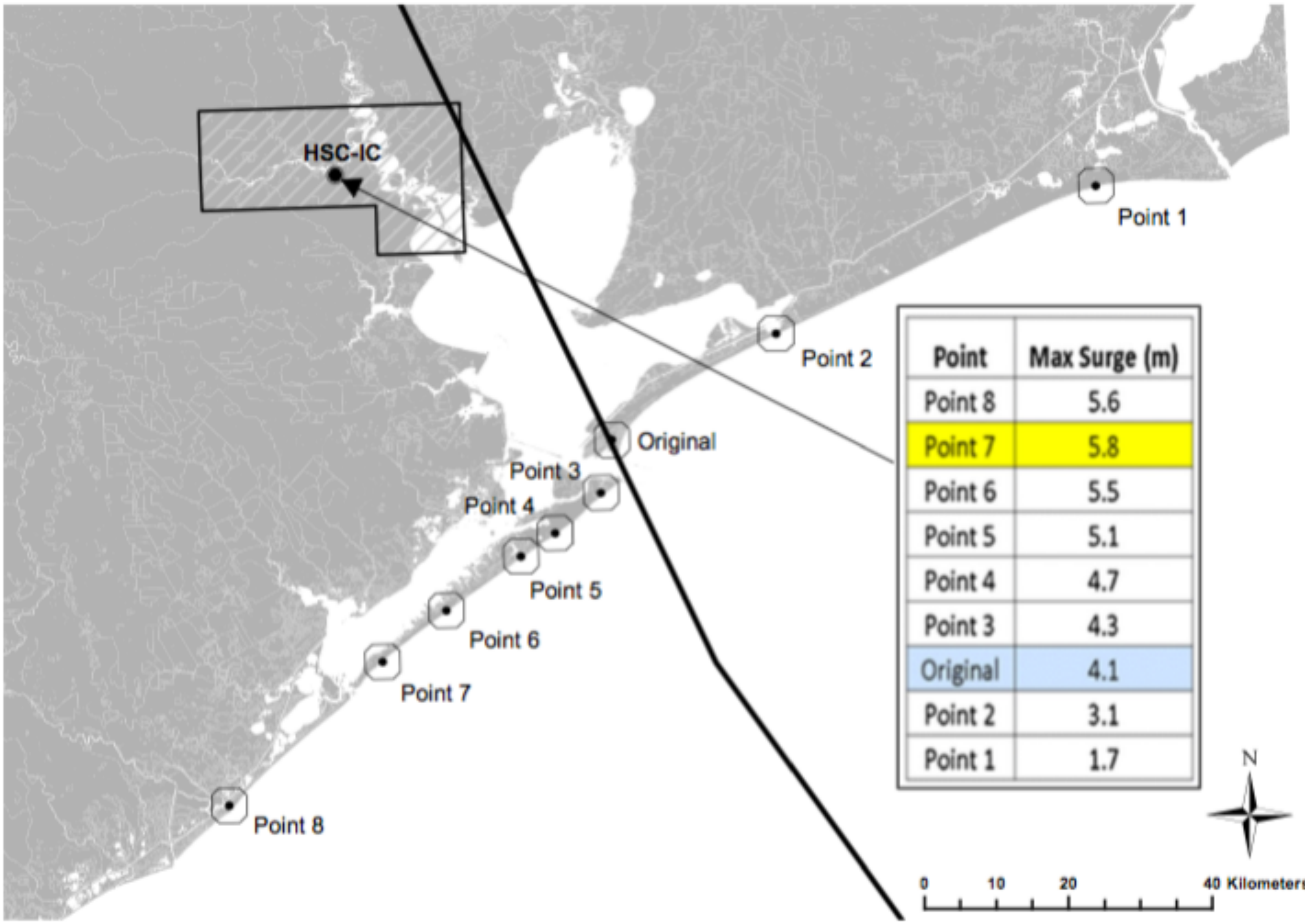


Point	Max Surge (m)
Point 8	5.6
Point 7	5.8
Point 6	5.5
Point 5	5.1
Point 4	4.7
Point 3	4.3
Original	4.1
Point 2	3.1
Point 1	1.7

Fig. 3 Landfall locations for SWAN + ADCIRC modeling of Hurricane Ike. The *solid black line* represents the original track of Hurricane Ike. The *table* shows the change in storm surge for the simulated landfall locations of Hurricane Ike at the indicated point in the HSC-IC

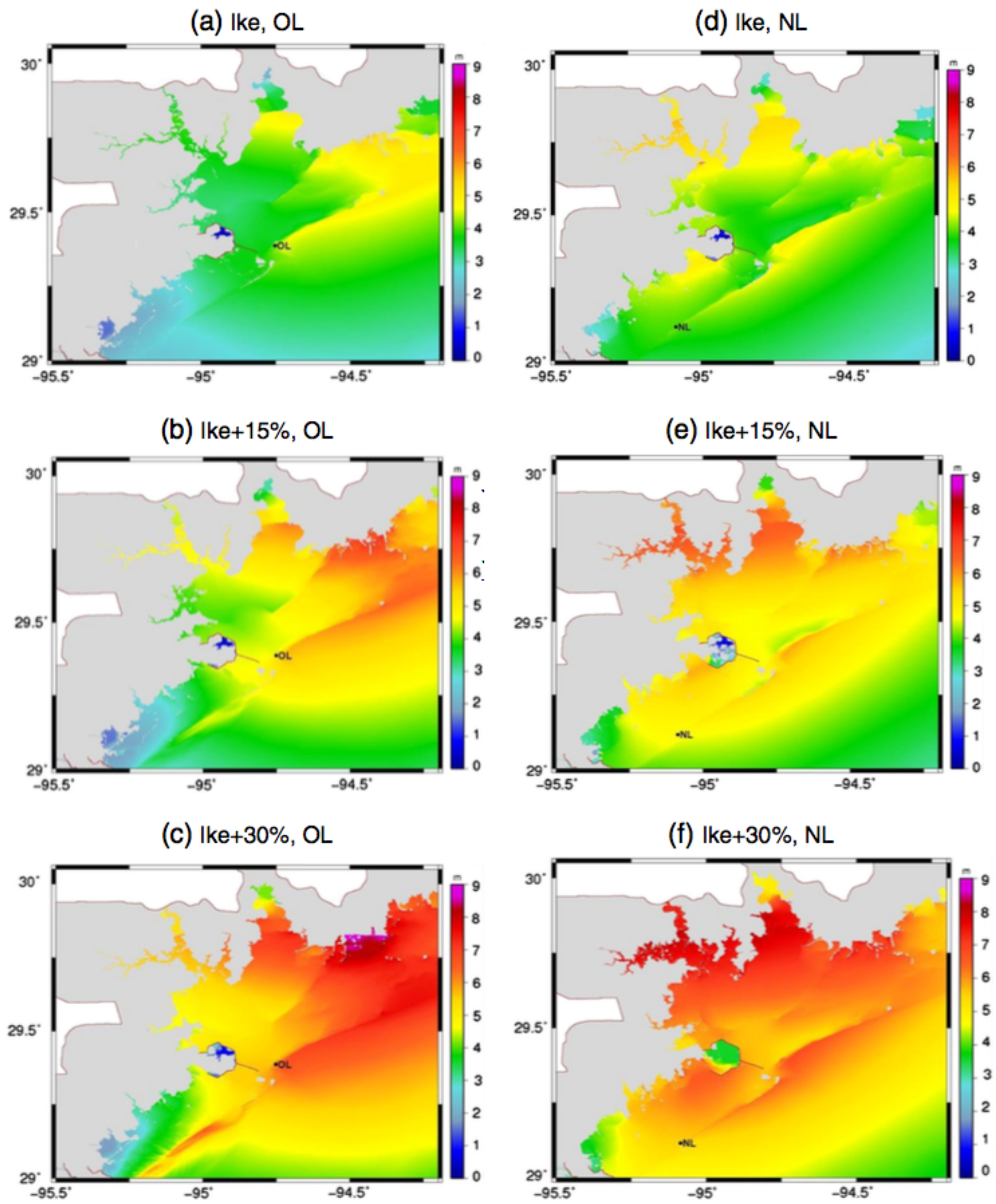
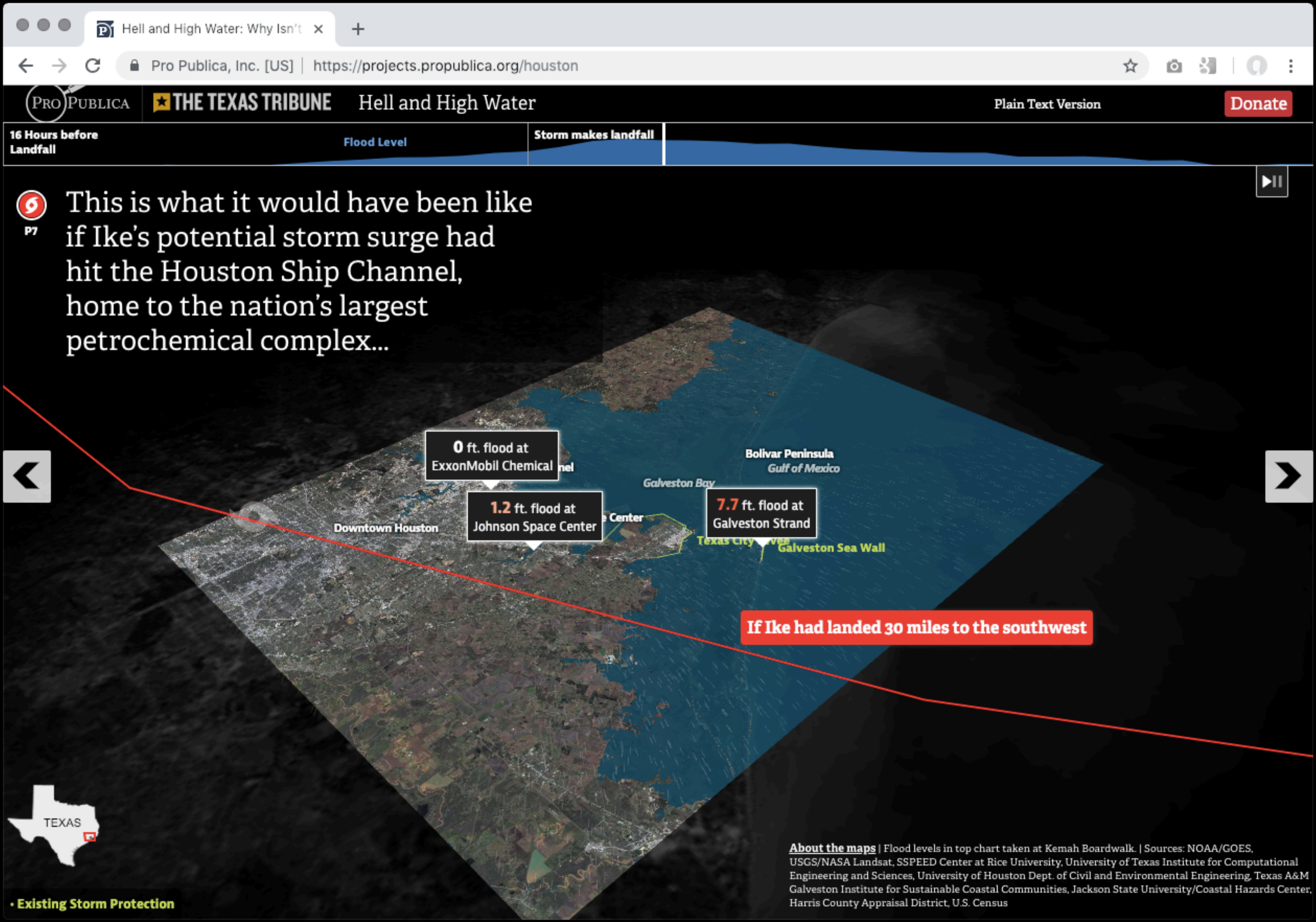
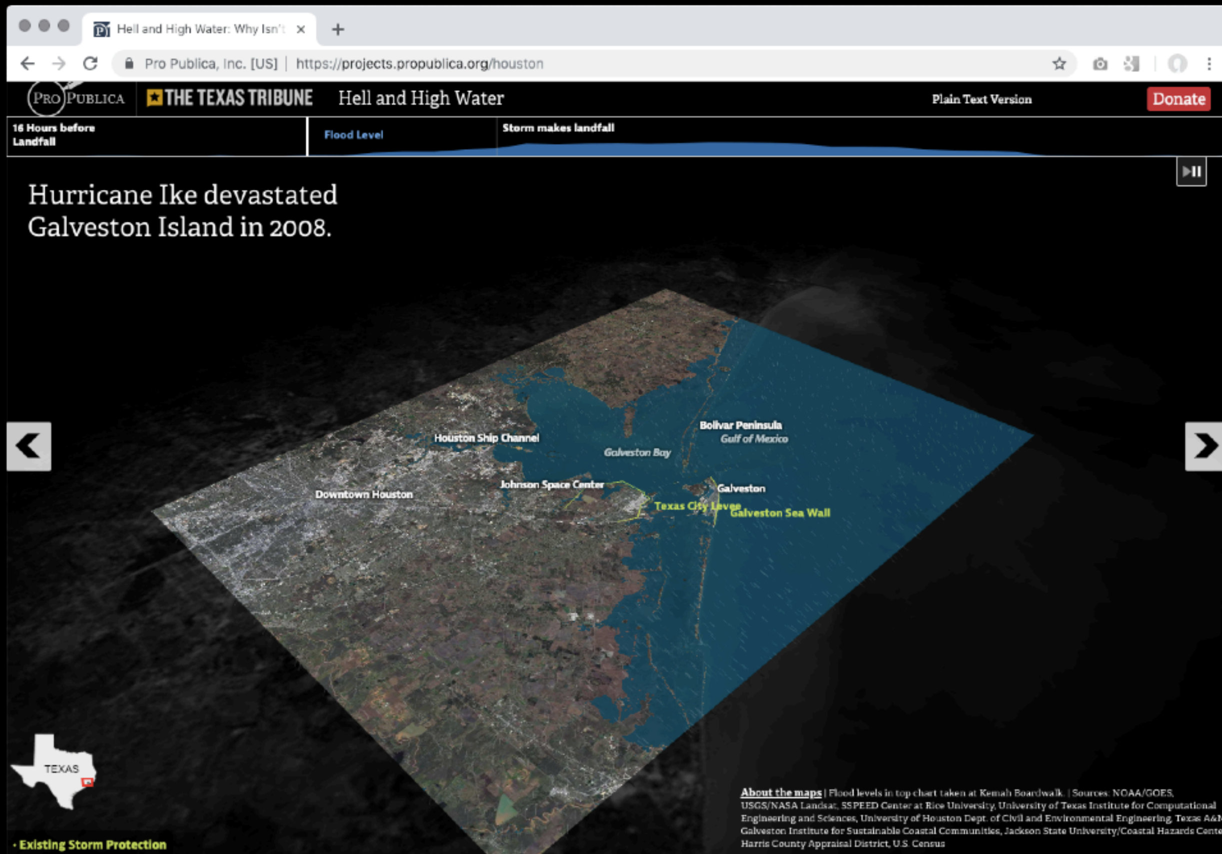


Fig. 9. Maximum water surface elevations from ADCIRC + SWAN for the Hurricane Ike original, +15%, and +30% wind scenarios at the original landfall (OL) and new landfall (NL) locations. a. Ike, OL. b. Ike + 15%, OL. c. Ike + 30%, OL. d. Ike, NL. e. Ike + 15% NL. f. Ike + 30%, NL.


Hell and High Water: Why Isn't
Pro Publica, Inc. [US] | https://projects.propublica.org/houston
ProPublica
THE TEXAS TRIBUNE
Hell and High Water
Plain Text Version
Donate
16 Hours before Landfall
Flood Level
Storm makes landfall
P7
This is what it would have been like if Ike's potential storm surge had hit the Houston Ship Channel, home to the nation's largest petrochemical complex...
0 ft. flood at ExxonMobil Chemical
1.2 ft. flood at Johnson Space Center
7.7 ft. flood at Galveston Strand
Downtown Houston
Bolivar Peninsula
Gulf of Mexico
Galveston Bay
Galveston Sea Wall
If Ike had landed 30 miles to the southwest
TEXAS
• Existing Storm Protection
About the maps | Flood levels in top chart taken at Kemah Boardwalk. | Sources: NOAA/GOES, USGS/NASA Landsat, SSPEED Center at Rice University, University of Texas Institute for Computational Engineering and Sciences, University of Houston Dept. of Civil and Environmental Engineering, Texas A&M Galveston Institute for Sustainable Coastal Communities, Jackson State University/Coastal Hazards Center, Harris County Appraisal District, U.S. Census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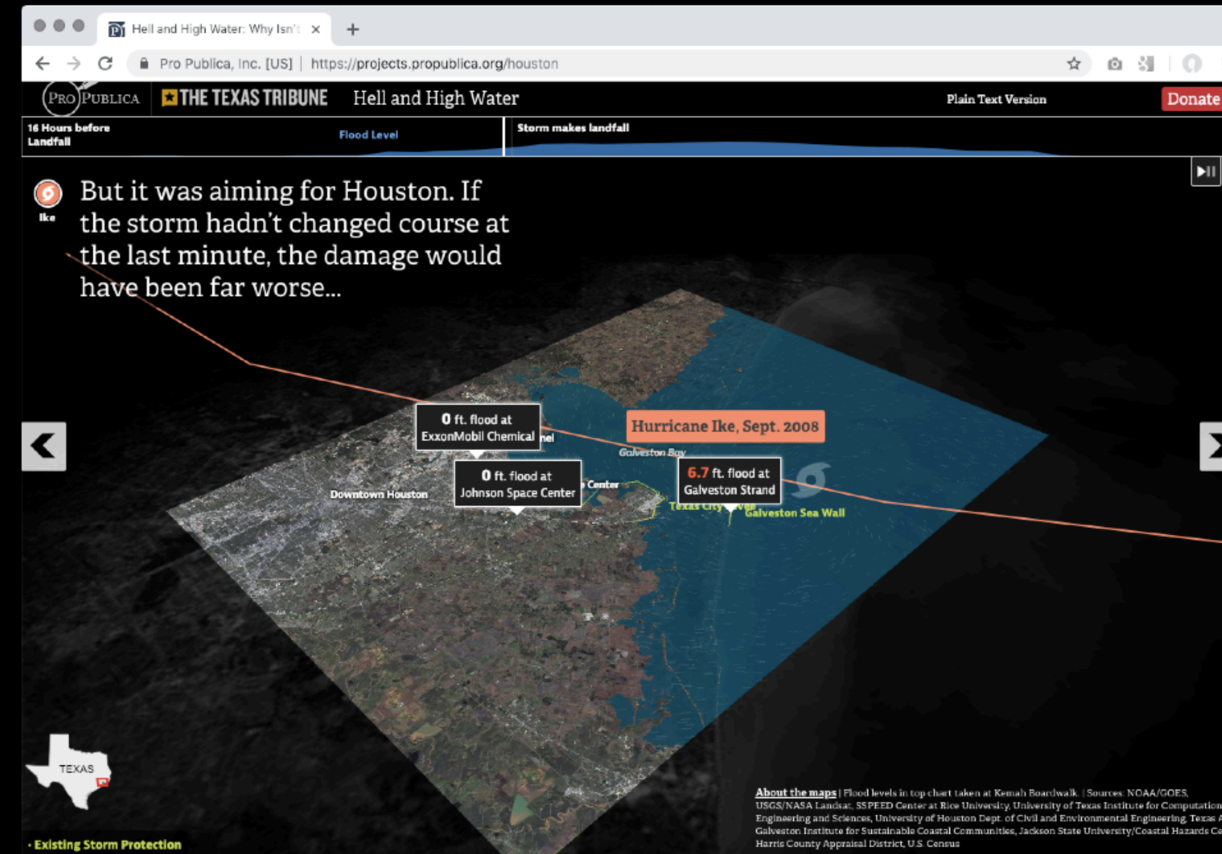
Donate
16 Hours before Landfall
Flood Level
Storm makes landfall
Hurricane Ike devastated Galveston Island in 2008.
Houston Ship Channel
Bolivar Peninsula
Gulf of Mexico
Galveston Bay
Downtown Houston
Johnson Space Center
Galveston
Texas City Levee
Galveston Sea Wall
TEXAS
Existing Storm Protection
About the maps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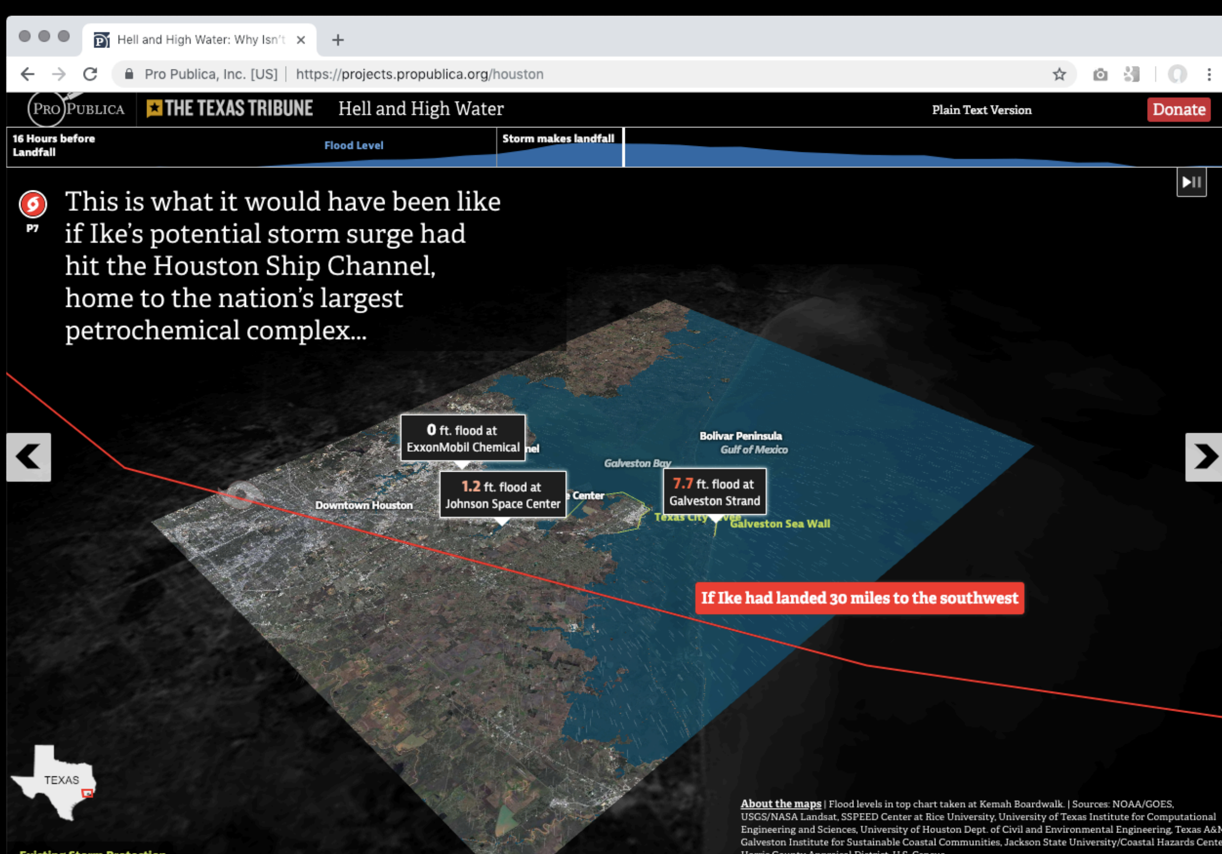
Hell and High Water
Plain Text Version
Donate
16 Hours before Landfall
Flood Level
Storm makes landfall
Ike
But it was aiming for Houston. If the storm hadn't changed course at the last minute, the damage would have been far worse...
0 ft. flood at ExxonMobil Chemical
Hurricane Ike, Sept. 2008
0 ft. flood at Johnson Space Center
6.7 ft. flood at Galveston Strand
Downtown Houston
Galveston Sea Wall
TEXAS
Existing Storm Protection
About the maps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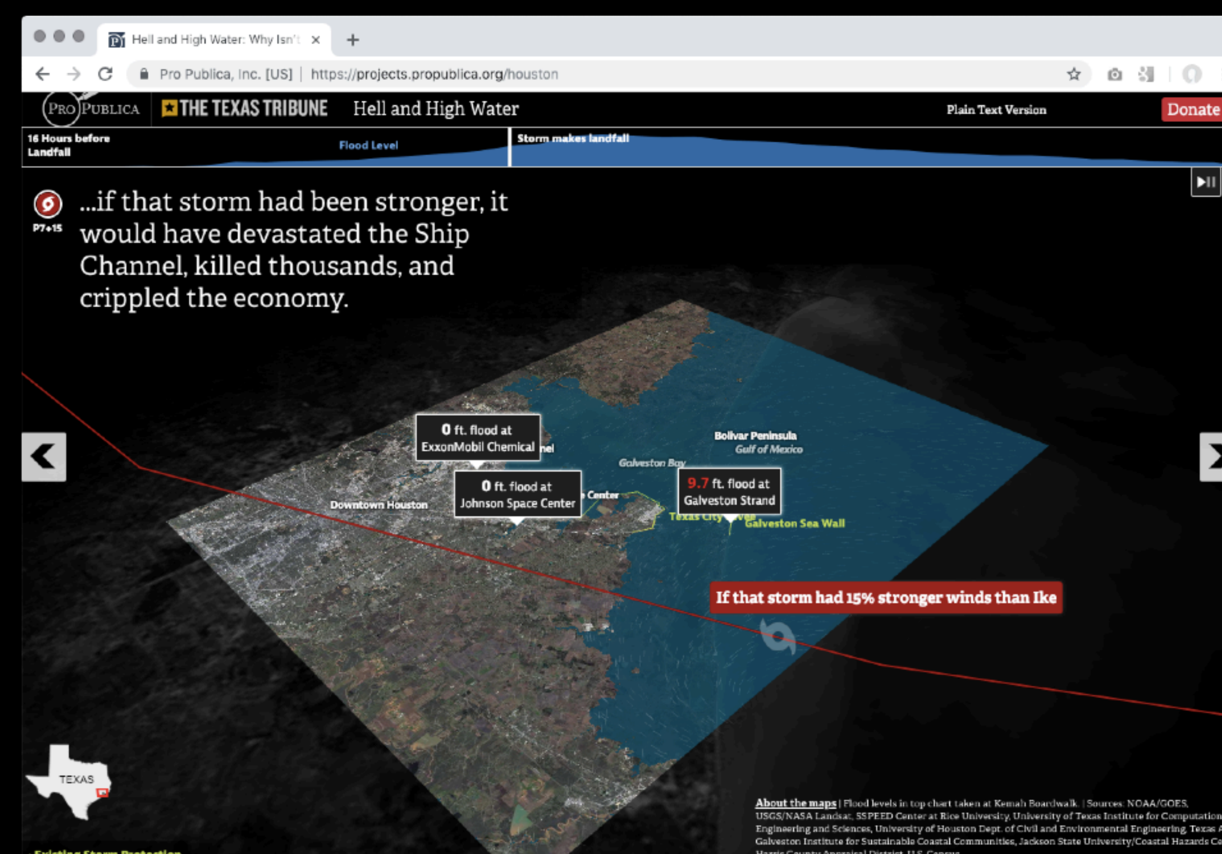
Hell and High Water
Plain Text Version
Donate
16 Hours before Landfall
Flood Level
Storm makes landfall
P7
This is what it would have been like if Ike's potential storm surge had hit the Houston Ship Channel, home to the nation's largest petrochemical complex...
0 ft. flood at ExxonMobil Chemical
1.2 ft. flood at Johnson Space Center
7.7 ft. flood at Galveston Strand
Bolivar Peninsula
Gulf of Mexico
Galveston Bay
Downtown Houston
Galveston Sea Wall
If Ike had landed 30 miles to the southwest
TEXAS
Existing Storm Protection
About the maps


Hell and High Water: Why Isn't
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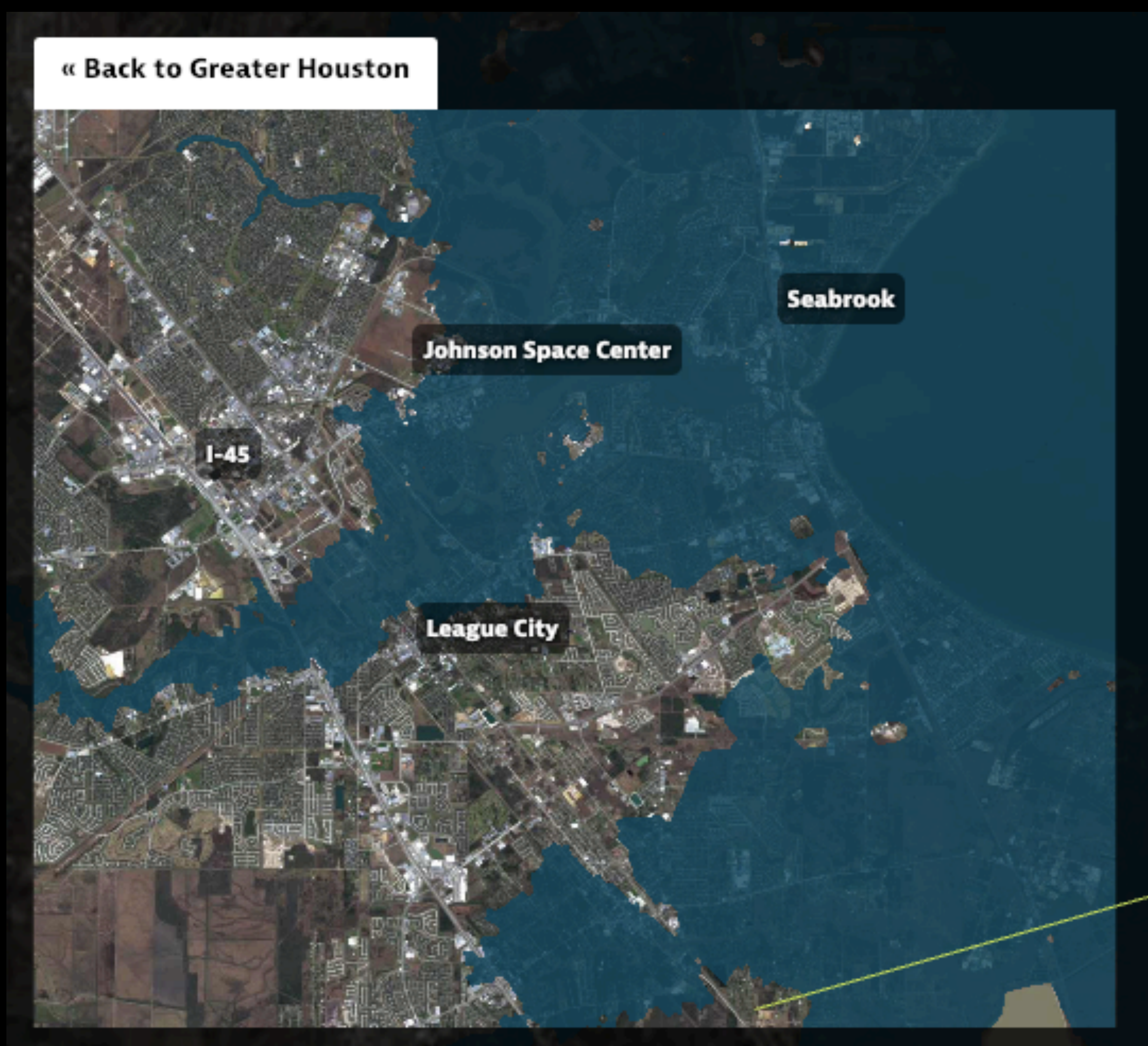
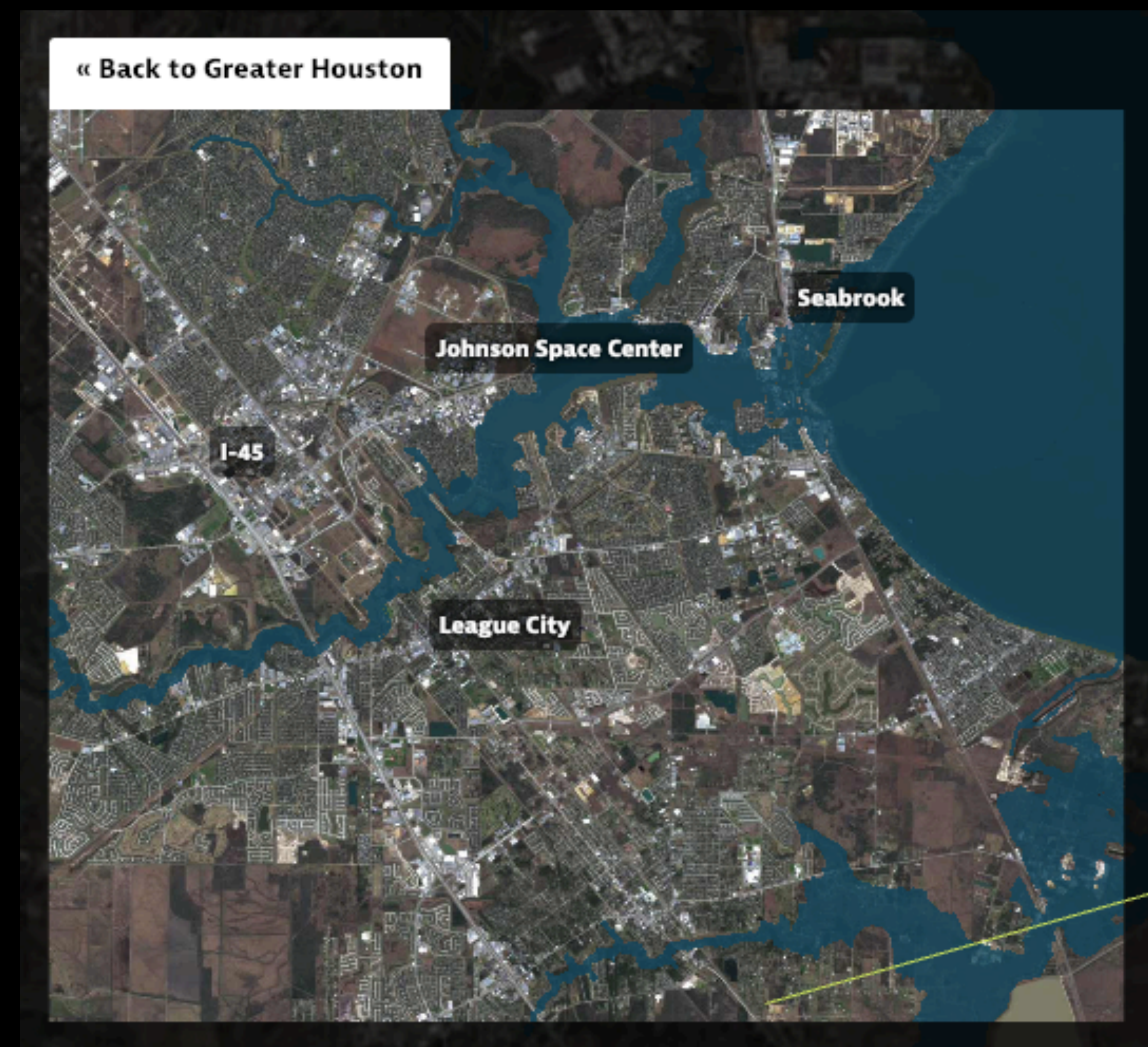
ProPublica
The Texas Tribune
Hell and High Water
Plain Text Version
Donate
16 Hours before Landfall
Flood Level
Storm makes landfall
P7+15
...if that storm had been stronger, it would have devastated the Ship Channel, killed thousands, and crippled the economy.
0 ft. flood at ExxonMobil Chemical
0 ft. flood at Johnson Space Center
9.7 ft. flood at Galveston Strand
Bolivar Peninsula
Gulf of Mexico
Galveston Bay
Downtown Houston
Galveston Sea Wall
If that storm had 15% stronger winds than Ike
TEXAS
Existing Storm Protection
About the maps

16 Hours before Landfall
Flood Level
Storm makes landfall

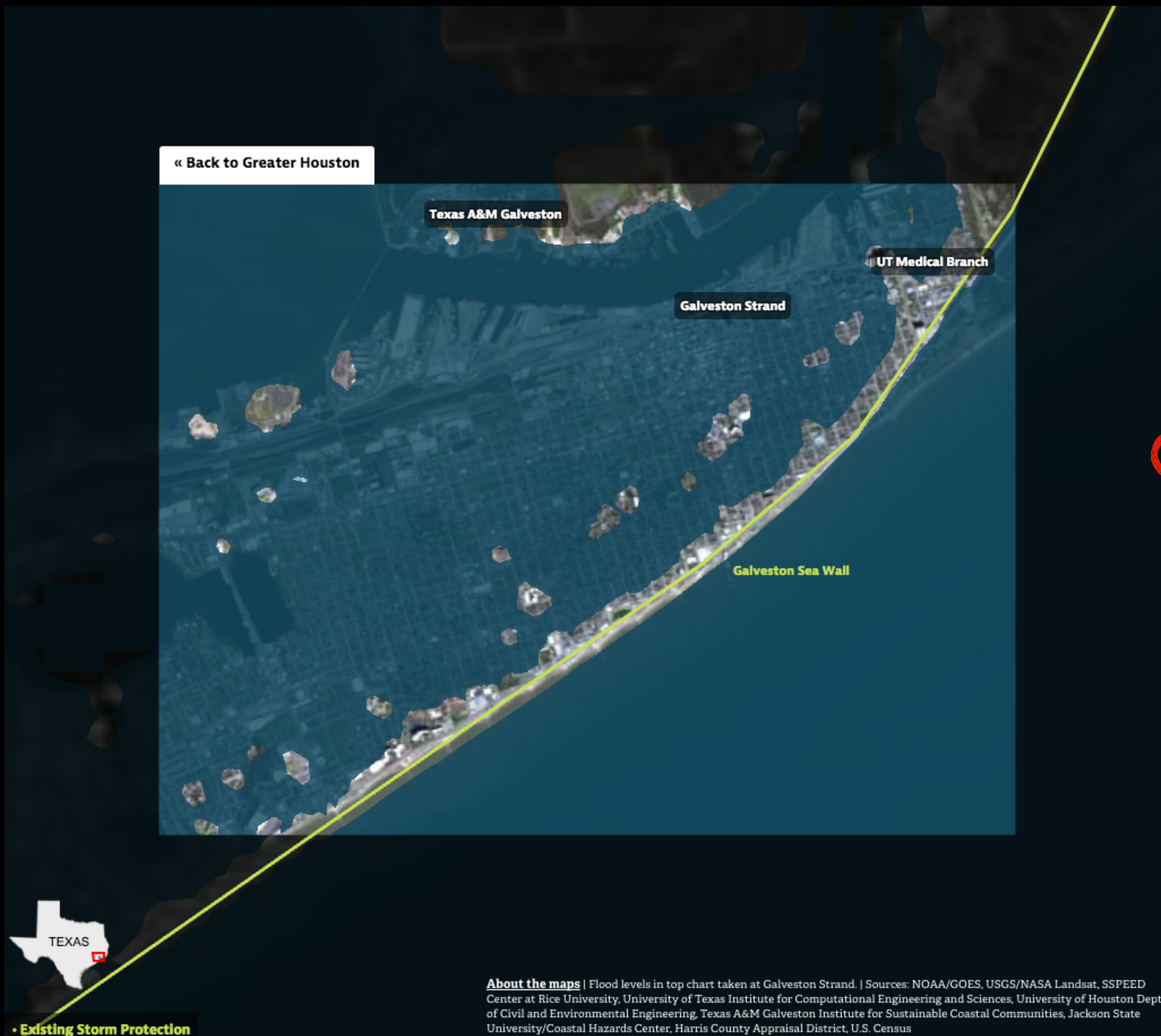
16 Hours before Landfall
Flood Level
(Without Solution)
Storm makes landfall



« Back to Greater Houston
Seabrook
Johnson Space Center
I-45
League City



« Back to Greater Houston
Seabrook
Johnson Space Center
I-45
League City



About the maps | Flood levels in top chart taken at Galveston Strand. | Sources: NOAA/GOES, USGS/NASA Landsat, SSPEED Center at Rice University, University of Texas Institute for Computational Engineering and Sciences, University of Houston Dept. of Civil and Environmental Engineering, Texas A&M Galveston Institute for Sustainable Coastal Communities, Jackson State University/Coastal Hazards Center, Harris County Appraisal District, U.S. Census

some storm protection to ships, tankers, barges and the facilities they serve. Shipping experts describe the geography as a big advantage over other ports that sit directly on the coast.

With its own deepwater port, Houston quickly gobbled up Galveston's shipping activity, and its population boomed. Today, the city has nearly 50 times more people than it did 100 years ago.

Meanwhile, Galveston's population is scarcely larger than it was back then, with less than 50,000 full-time residents today.

In the century since the Great Storm, the island has been walloped by eight more hurricanes that have killed hundreds of people, forcing Galveston into an almost constant state of repairing and rebuilding. The last time was in 2008, when Hurricane Ike nearly destroyed the city all over again.

Play Hurricane Ike

Outsiders — even insiders — often talk about it as a city that shouldn't exist. Of the 10 barrier islands and peninsulas on the Texas coast, it is the only one with a sizable population of permanent residents.

More than 23 percent of Galveston's residents live at or below the poverty line. That is notably higher than the state's overall poverty rate of 17.6 percent, though not much worse than Houston's (22.9 percent).

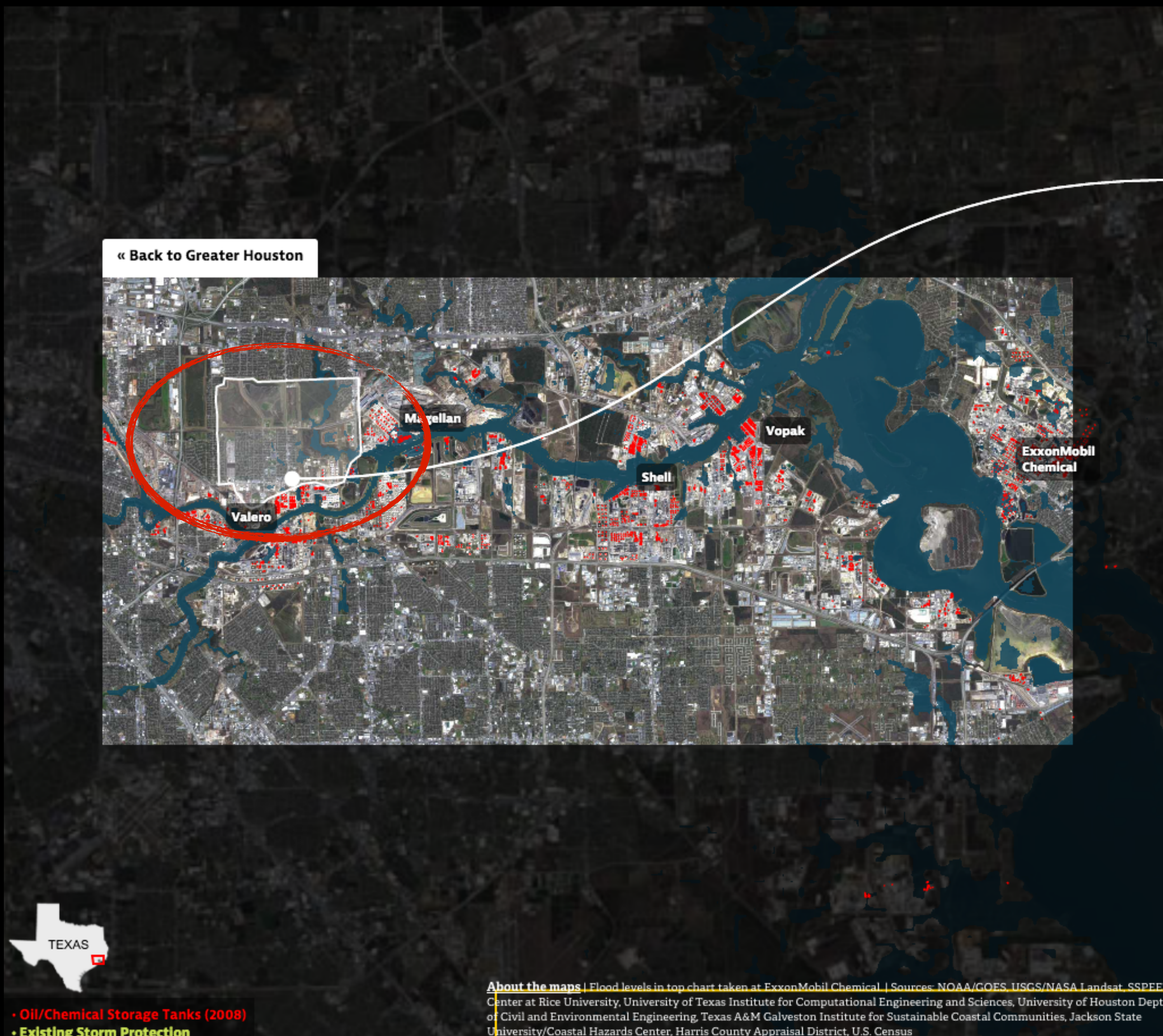
While Galveston has slipped from prominence, it has become the state's go-to summer getaway spot, and tourism is key to its economy.

16 Hours before Landfall | Flood Level | Storm makes landfall

Storm Scenarios: ‹ Intro | Ike | P7 | P7+15 | 36

Proposed Solutions: Mid-Bay | Spine 1 | Spine 2

See flood levels for a location in Houston
Search
Ex: 1000 Tidal Rd, La Porte, TX



About the maps | Flood levels in top chart taken at ExxonMobil Chemical | Sources: NOAA/GOES, USGS/NASA Landsat, SSPEED Center at Rice University, University of Texas Institute for Computational Engineering and Sciences, University of Houston Dept. of Civil and Environmental Engineering, Texas A&M Galveston Institute for Sustainable Coastal Communities, Jackson State University/Coastal Hazards Center, Harris County Appraisal District, U.S. Census

« Galveston | Greater Houston | Clear Lake »

Experts want better protections

Murphy Oil's tank wasn't the only one to fail in 2005, and it didn't even cause the largest spill; tanks damaged during Hurricanes Katrina and Rita caused more than 8 million gallons of oil to spill in Louisiana, Mississippi and Texas, according to government estimates.

Some tanks on the Houston Ship Channel were even damaged during Hurricane Ike in 2008, though the storm surge was far smaller than originally anticipated. About 15 feet of water covered the eastern part of Magellan Terminals Holdings' oil storage terminal in Galena Park, right on the Ship Channel, the company reported to the Texas Commission on Environmental Quality.

The storm surge and high winds caused damage to several tanks and a spill of nearly 1 million gallons of oil. Some was recovered, but about 300,000 gallons were released into the Ship Channel and "lost at sea," Magellan reported. (The spill didn't appear to impact any homes or businesses in Galena Park.)

"As a community, it would be good if we could come together and have a discussion about" the issue of storage tank safety, said Deer Park resident Jana Pellusch, who has worked at Shell since 2004. *(Edmund D. Fountain/ProPublica/Texas Tribune)*

Asked about its hurricane preparedness, Magellan spokesman Bruce Heine said that the company has

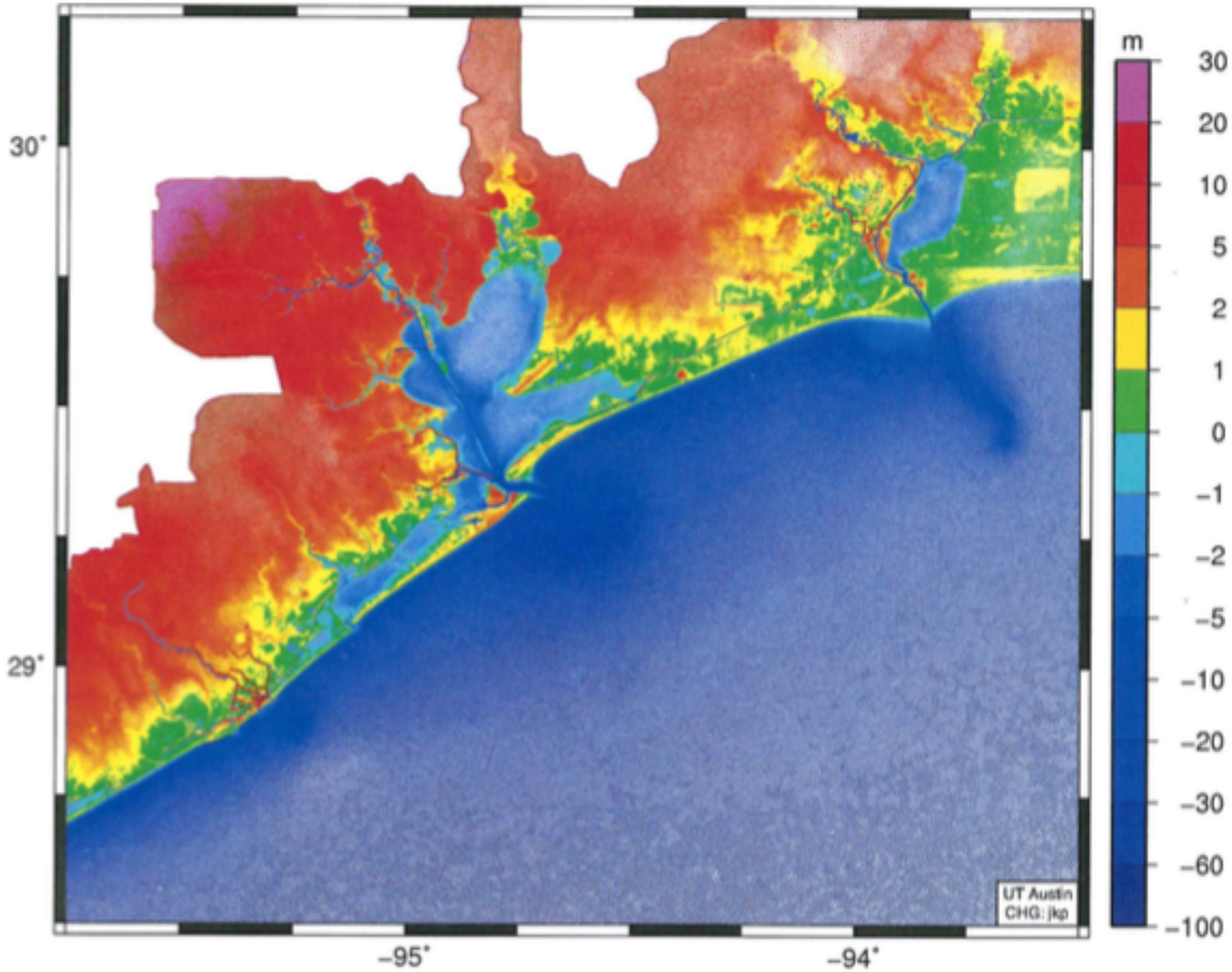


Figure 5.4. The ADCIRC Model Texas Grid.

3.6 million points
20 sq. meter resolution near shore

```
ashaw@iMac-22 ike  $ head -10 fort.14.reduced2
tx2008_r35h
3666307  1846542      lon                 lat                 depth
              1  -95.2348460000    29.8469070000   -12.6699990000
              2  -95.2344780000    29.8445710000   -12.0169990000
              3  -95.2350320000    29.8485990000   -12.8539980000
              4  -95.2354060000    29.8477430000   -12.7420000000
              5  -95.2356890000    29.8466290000   -12.6150000000
              6  -95.2349510000    29.8436950000   -11.6780000000
              7  -95.2354200000    29.8446890000   -12.0449990000
              8  -95.2347630000    29.8457650000   -12.3539980000
```

```
ashaw@iMac-22 ike  $ head -100 fort.63
  BTK NOAA Ike Track - Holland      padcirc 50.71             tx2008_r35h
         72    1846542  0.3600000E+004     7200     1 FileFmtVersion:    1050624
    5.2200000000E+005        1044000
         1     -9.9999000000E+004
         2     -9.9999000000E+004
         3     -9.9999000000E+004
         4     -9.9999000000E+004
         5     -9.9999000000E+004
         6     -9.9999000000E+004
         7     -9.9999000000E+004
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        11     -9.9999000000E+004
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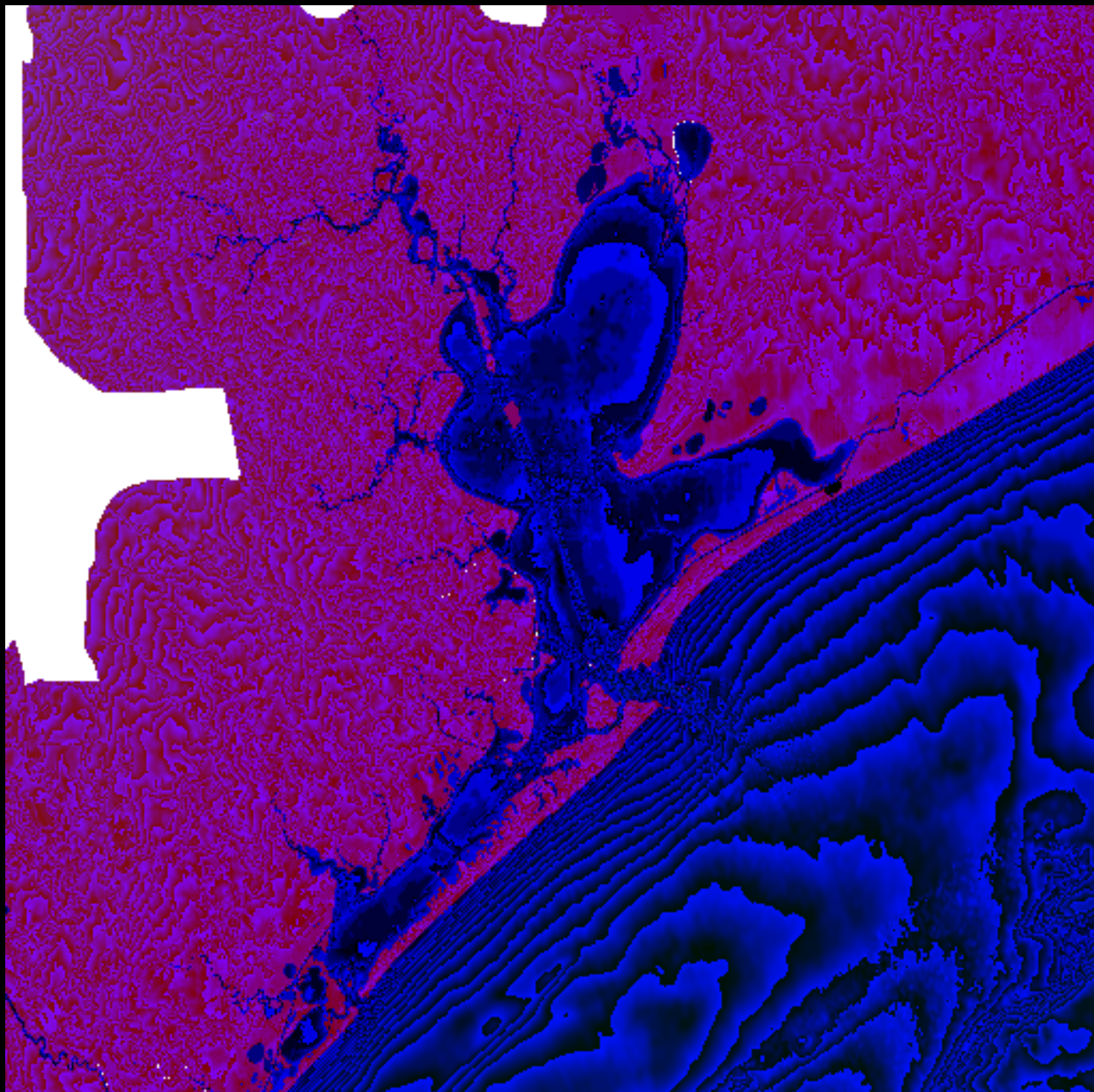


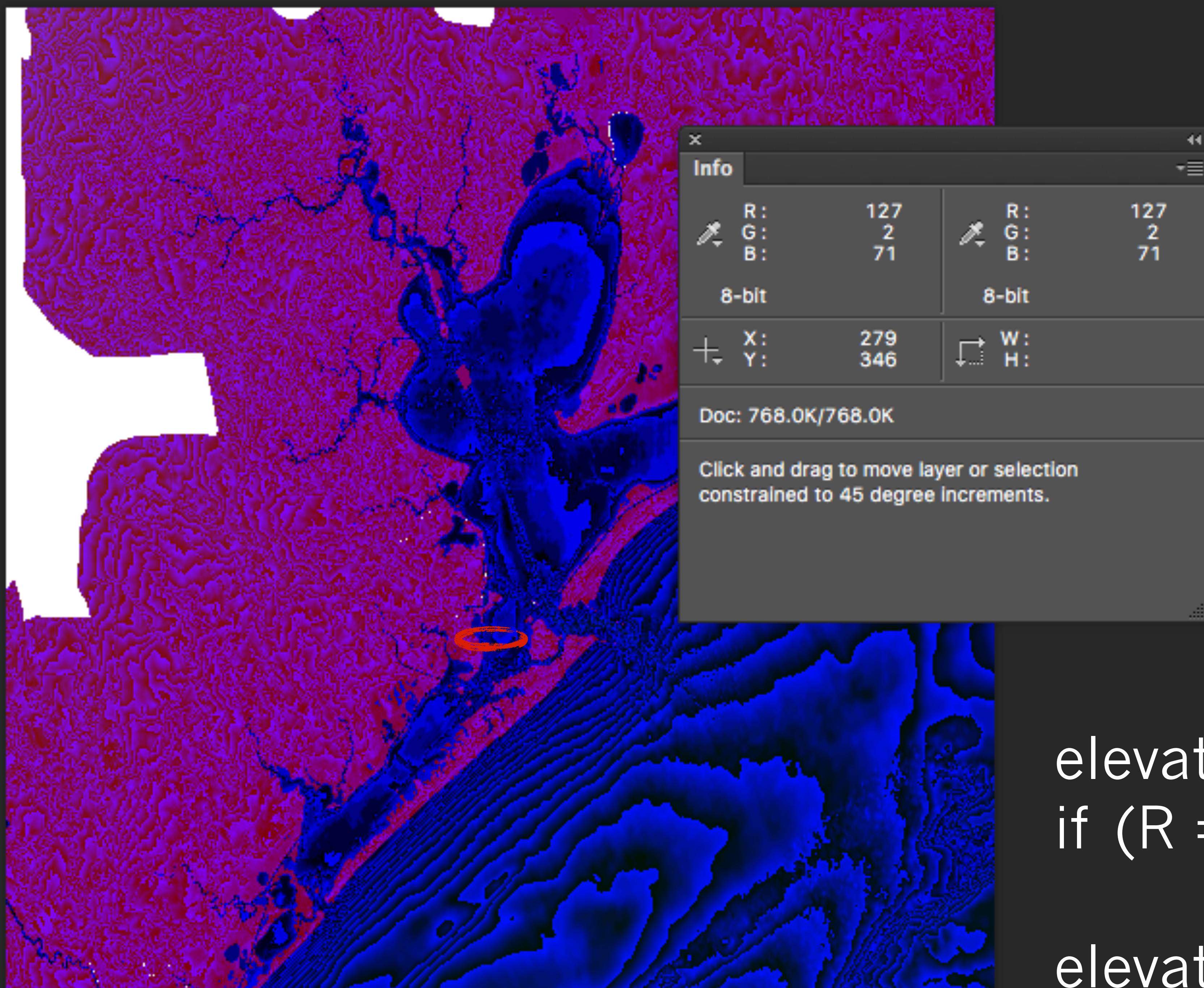
R = above/below sea level flag
G = depth (before decimal)
B = depth (after decimal)

R = Wind X

A = Wind Y

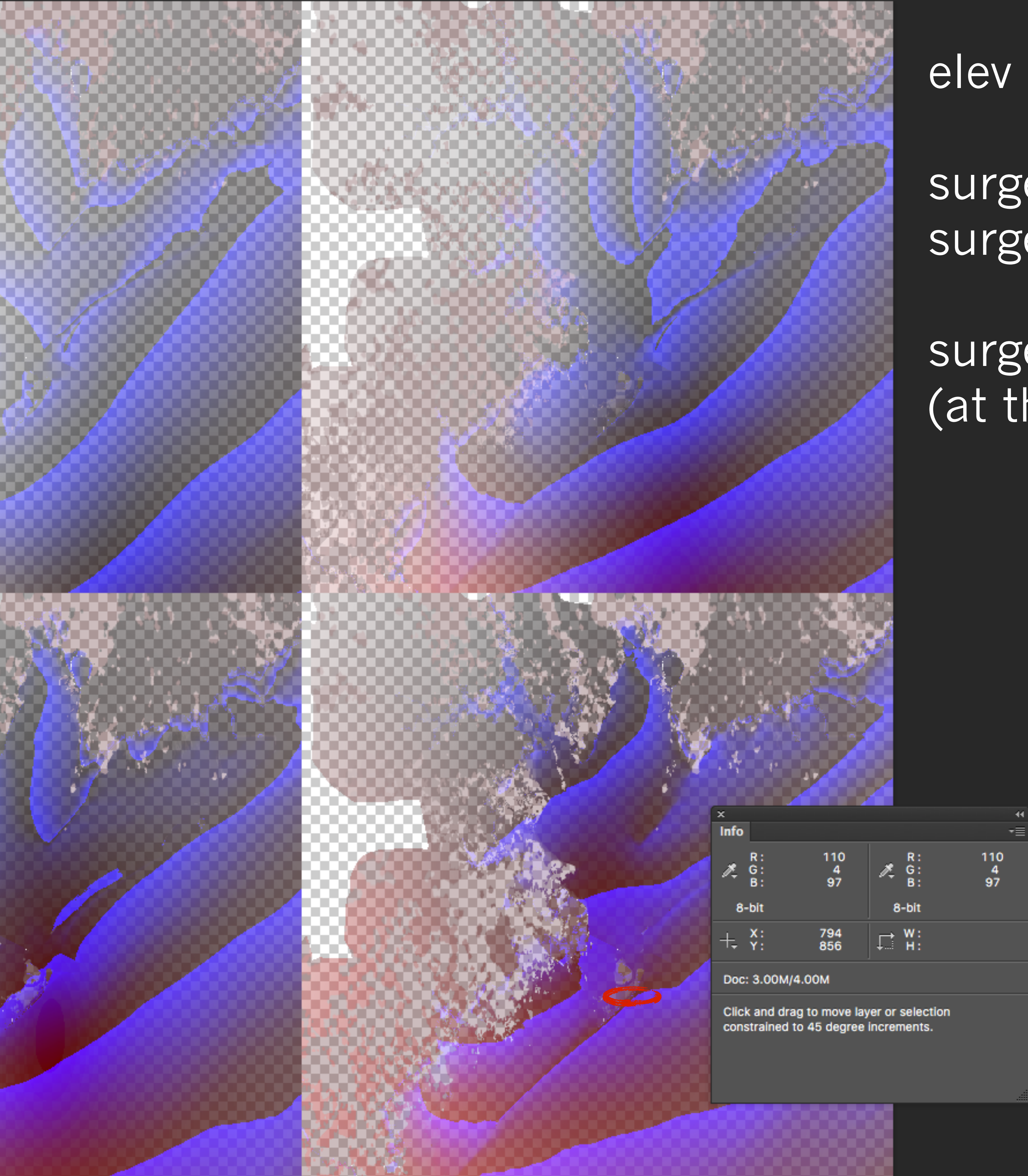
G = Depth (before decimal)

B = Depth (after decimal)



elevation = G + B / 255
if (R == 0) depth *= -1

elevation = 2.27 meters above sea level



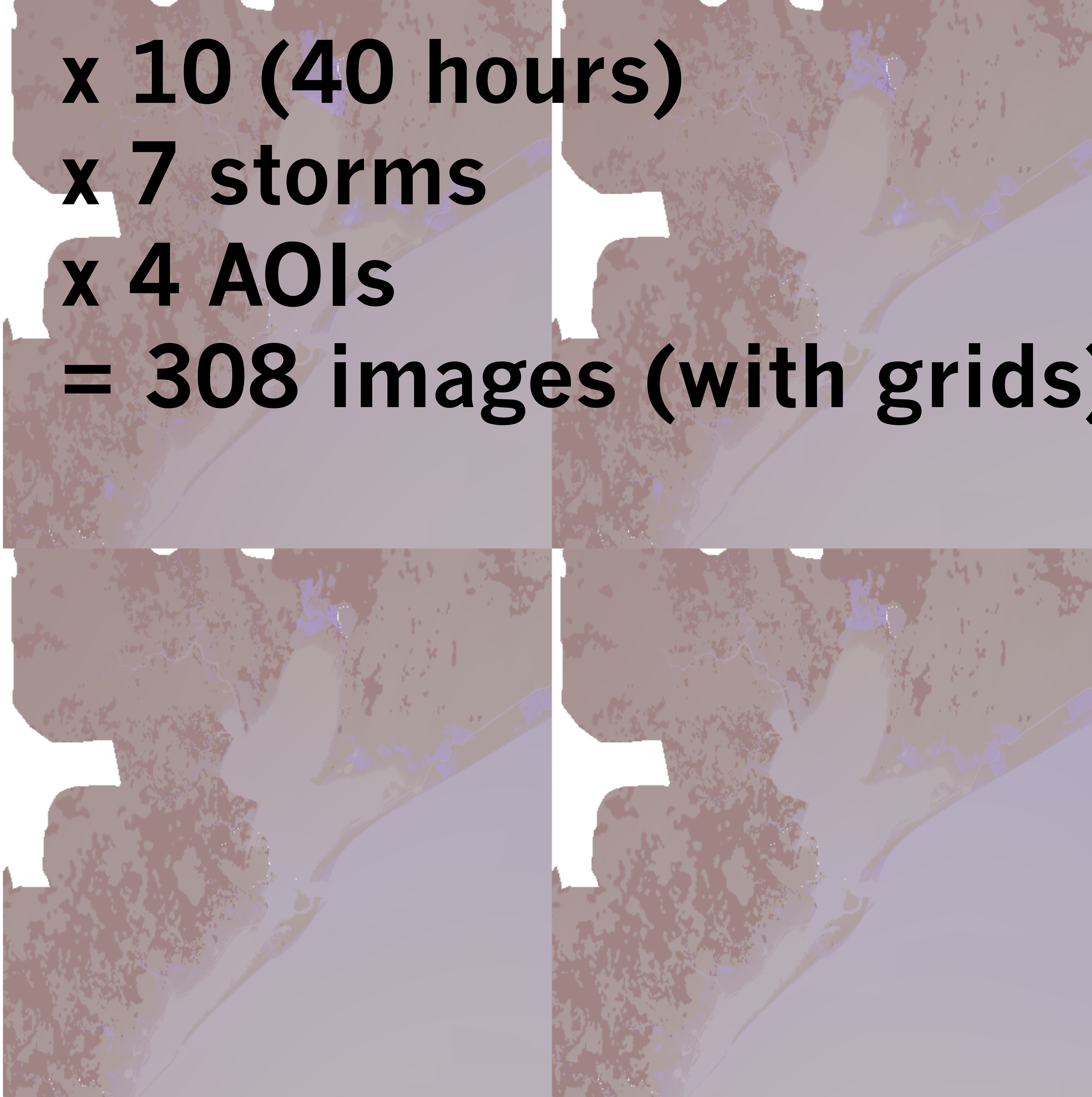
elev = 2.43 MASL

$$\text{surge} = (G + B / 255) - \text{elev}$$

surge = 4.38 meters

surge = 1.95 MASL
(at this point in the storm)

x 10 (40 hours)
x 7 storms
x 4 AOIs
= 308 images (with grids)



HELL AND HIGH WATER

Sen. Cornyn Files Bill to Speed Texas Hurricane Study

The Texas senator has proposed a bill to speed up the process of protecting Houston from a devastating hurricane.

by **ProPublica**, April 28, 2016, 2:30 p.m. EDT

HELL AND HIGH WATER

U.S. Rep. Weber Says He'll Work on Bill to Speed Hurricane Protection Plan

The Texas Republican will introduce a companion to a Senate bill filed this week seeking to expedite a hurricane protection plan for Houston.

by **ProPublica**, April 29, 2016, 4:20 p.m. EDT


RESTORING PRAIRIES: CARBON SEQUESTION
The Land Institute

Michael Stravato for The Texas Tribune/ProPublica

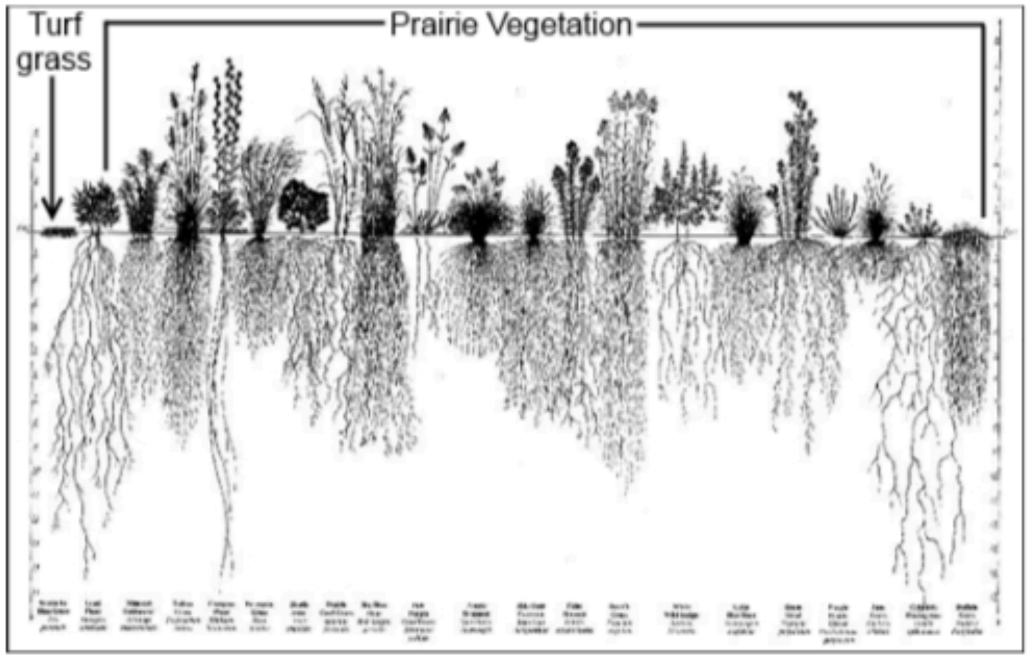
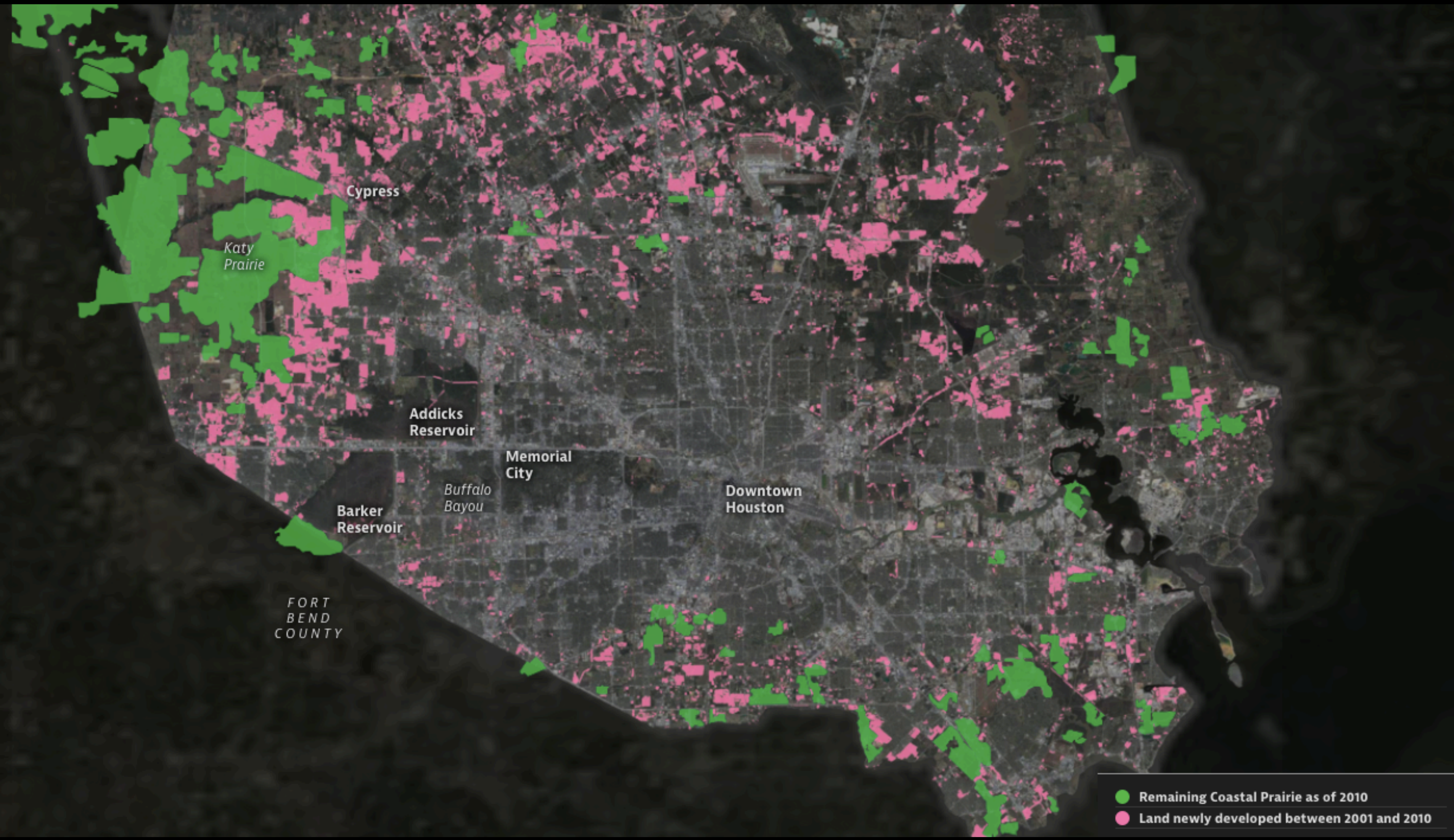


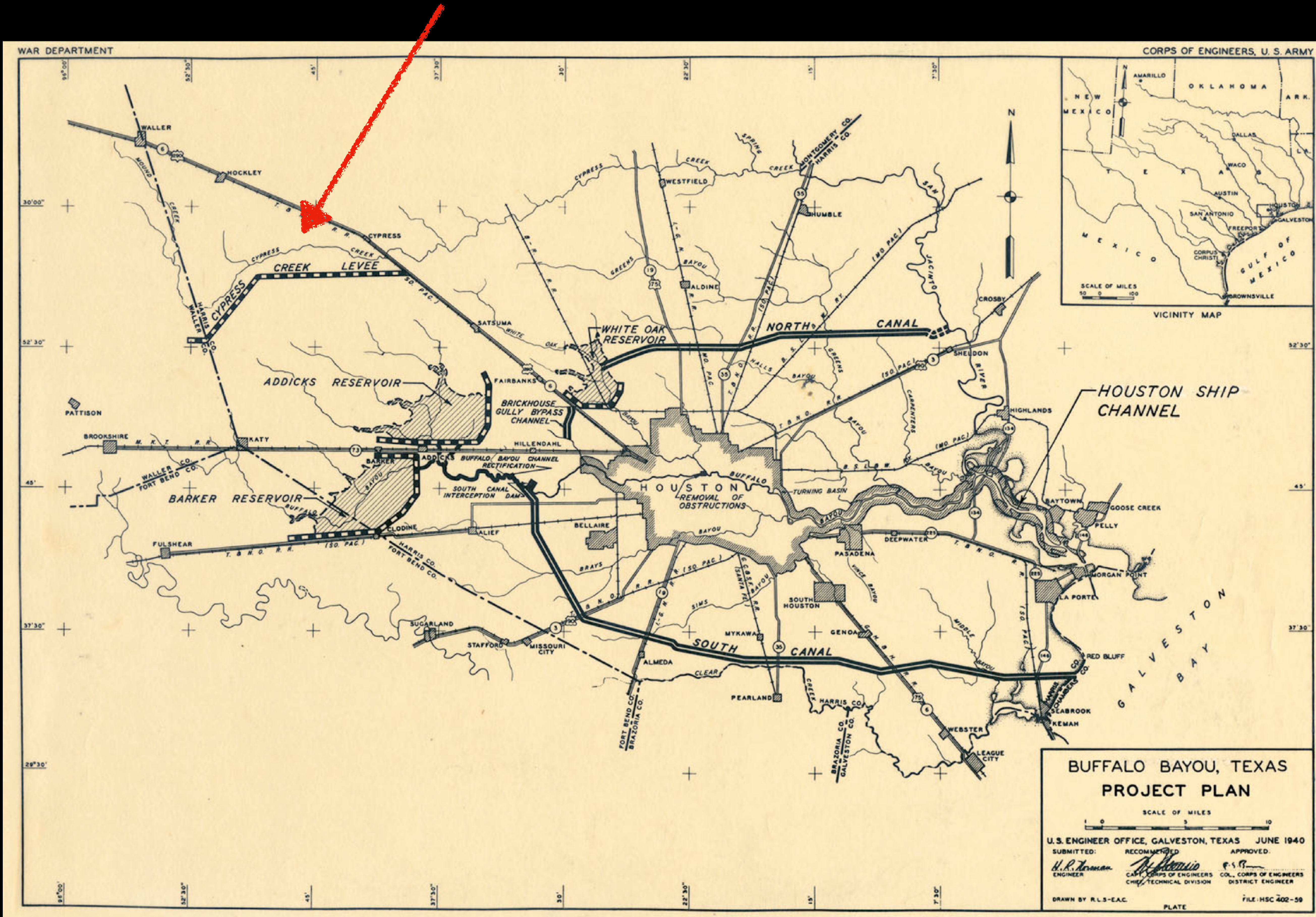
Figure 5.1 Root structure of turf grasses versus prairie vegetation (Source: Heidi Natura for the Conservation Research Institute)

undeveloped land by 3.52 inches in a 100-year flood event (Table 5.3). The restoration of one acre of prairie would offset the volume impact of about two acres of a single-family subdivision, or about one acre of commercial or retail development. These changes in hydrology appear to be

Michael Stravato for The Texas Tribune/ProPublica



Cypress
Katy Prairie
Addicks Reservoir
Memorial City
Buffalo Bayou
Barker Reservoir
Downtown Houston
FORT BEND COUNTY
Remaining Coastal Prairie as of 2010
Land newly developed between 2001 and 2010



WAR DEPARTMENT
CORPS OF ENGINEERS, U. S. ARMY
BUFFALO BAYOU, TEXAS
PROJECT PLAN
SCALE OF MILES
U. S. ENGINEER OFFICE, GALVESTON, TEXAS JUNE 1940
SUBMITTED:
RECOMMENDED:
APPROVED:
ENGINEER
CAPT., CORPS OF ENGINEERS CHIEF, TECHNICAL DIVISION
COL., CORPS OF ENGINEERS DISTRICT ENGINEER
DRAWN BY R.L.S.-E.A.C.
PLATE
FILE: HSC 402-59
VICINITY MAP
NEW MEXICO
OKLAHOMA
ARK.
TEXAS
MEXICO
GULF OF MEXICO
AMARILLO
DALLAS
WACO
AUSTIN
SAN ANTONIO
HOUSTON
GALVESTON
FREEPORT
CORPUS CHRISTI
BROWNSVILLE
CYPRESS CREEK LEVEE
ADDICKS RESERVOIR
BARKER RESERVOIR
WHITE OAK RESERVOIR
BRICKHOUSE GULLY BYPASS CHANNEL
BUFFALO BAYOU CHANNEL RECTIFICATION
SOUTH CANAL INTERCEPTION DAM
NORTH CANAL
SOUTH CANAL
HOUSTON SHIP CHANNEL
HOUSTON
REMOVAL OF OBSTRUCTIONS
TURNING BASIN
GALVESTON BAY
WALLER
HOCKLEY
CYPRESS
SATSUMA
FAIRBANKS
KATY
BROOKSHIRE
PATTISON
FULSHEAR
BARKER
ADDICKS
HILLENDAHL
CLODINE
ALIEF
BELLAIRE
SUGARLAND
STAFFORD
MISSOURI CITY
ALMEDA
PEARLAND
SOUTH HOUSTON
PASADENA
DEEPWATER
MYKAWA
GENOA
WEBSTER
LEAGUE CITY
SEABROOK
KEMAH
RED BLUFF
LA PORTE
MORGAN POINT
BAYTOWN
GOOSE CREEK
PELLY
HIGHLANDS
SHELDON
CROSBY
HUMBLE
WESTFIELD
ALDINE

Boomtown, Flood Town

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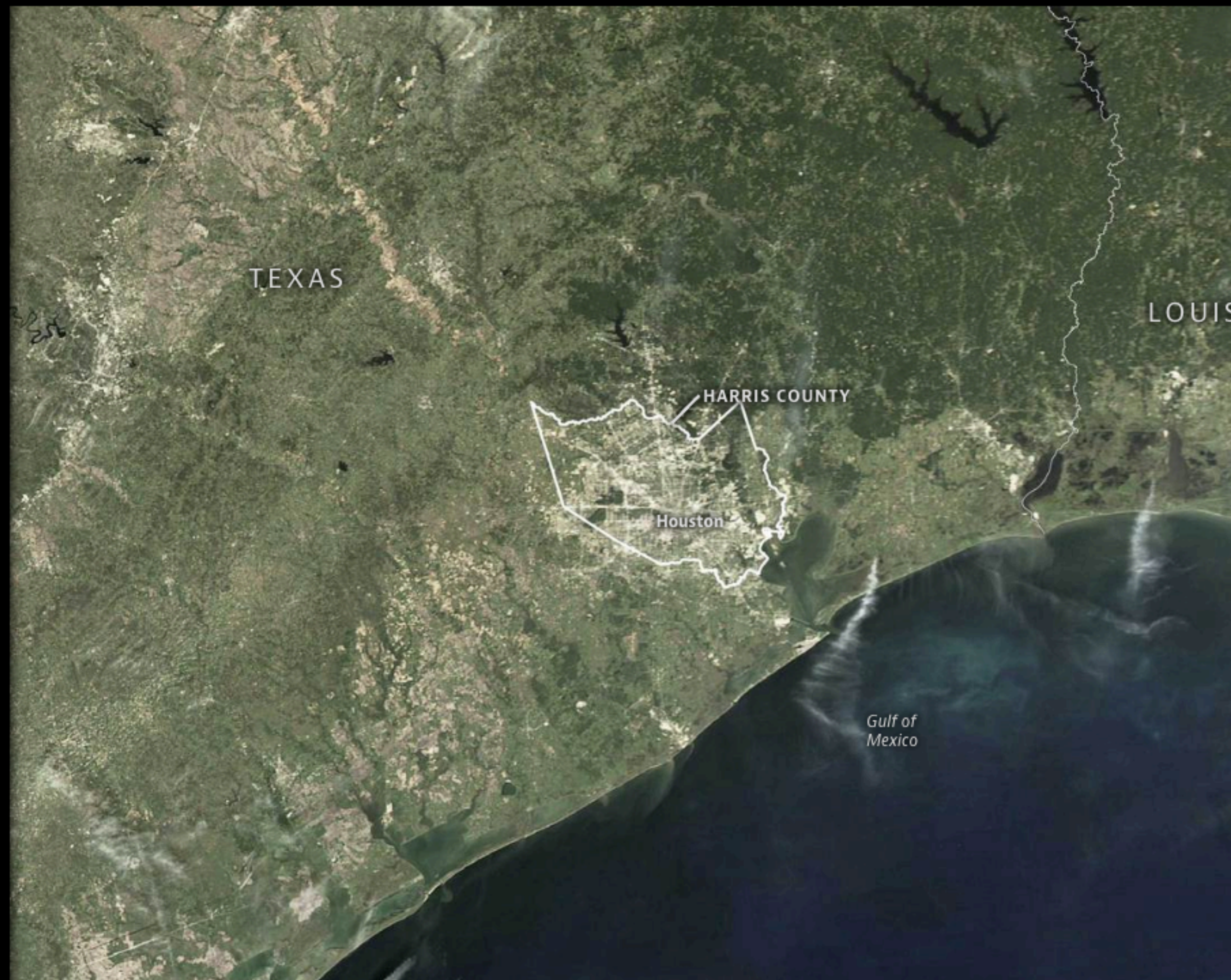
Boomtown, Flood Town

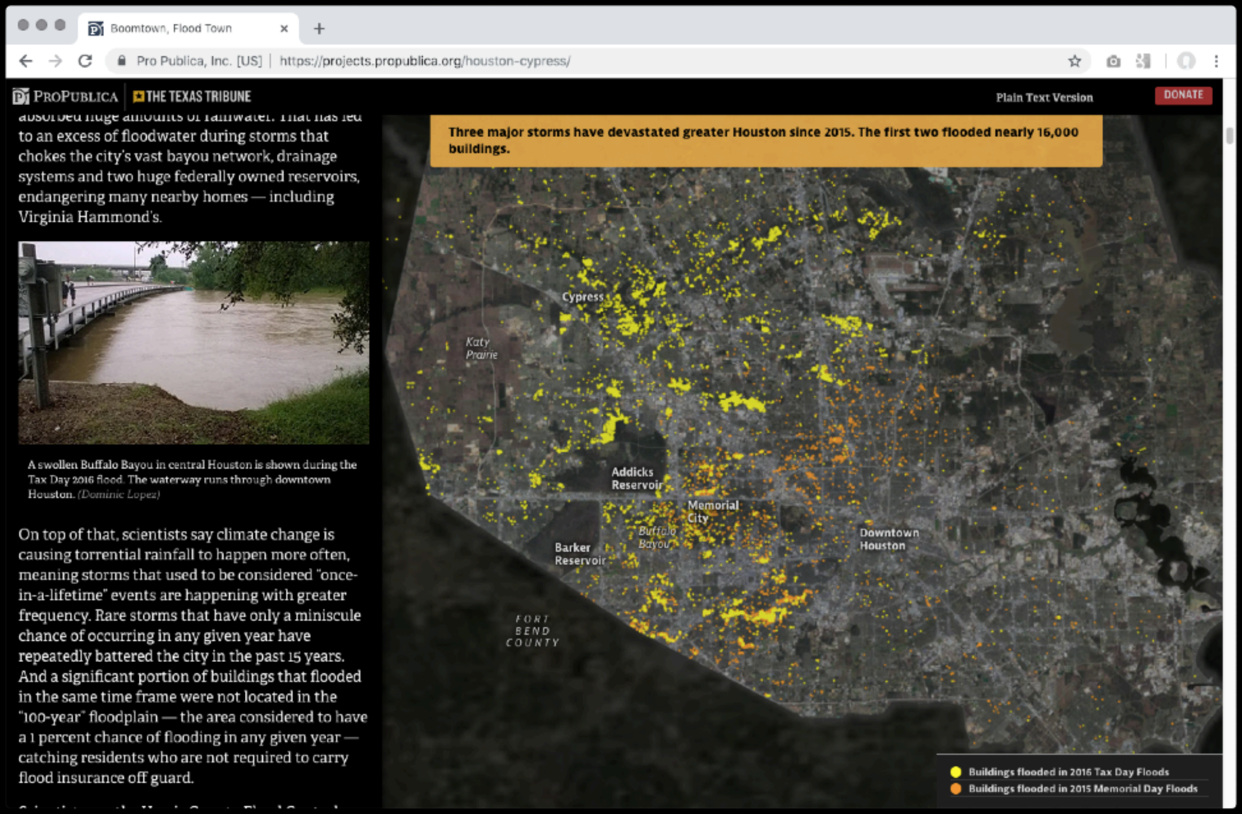
Climate change will bring more frequent and fierce rainstorms to cities like Houston. But unchecked development remains a priority in the famously un-zoned city, creating short-term economic gains for some while increasing flood risks for everyone.

by Neena Satija for The Texas Tribune and Reveal; Kiah Collier for The Texas Tribune; and Al Shaw for ProPublica, December 7, 2016

An aerial shot of downtown Houston during the "Tax Day Flood" in April. *(Jordan Anderson/DoubleHorn Photography)*

This is part of a series on Houston's flood risk. Read about why Texas isn't ready for the next big

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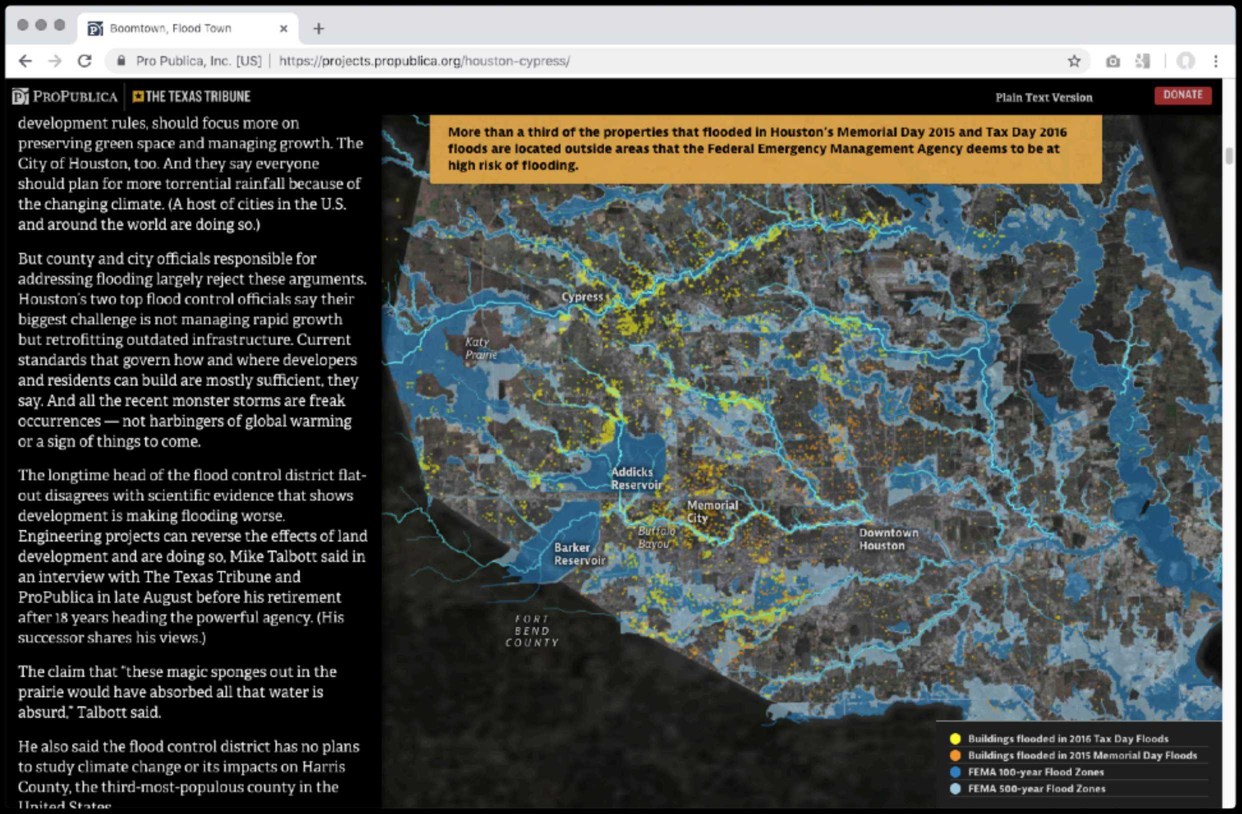
to an excess of floodwater during storms that chokes the city's vast bayou network, drainage systems and two huge federally owned reservoirs, endangering many nearby homes — including Virginia Hammond's.

A swollen Buffalo Bayou in central Houston is shown during the Tax Day 2016 flood. The waterway runs through downtown Houston. *(Dominic Lopez)*

On top of that, scientists say climate change is causing torrential rainfall to happen more often, meaning storms that used to be considered "once-in-a-lifetime" events are happening with greater frequency. Rare storms that have only a miniscule chance of occurring in any given year have repeatedly battered the city in the past 15 years. And a significant portion of buildings that flooded in the same time frame were not located in the "100-year" floodplain — the area considered to have a 1 percent chance of flooding in any given year — catching residents who are not required to carry flood insurance off guard.

Three major storms have devastated greater Houston since 2015. The first two flooded nearly 16,000 buildings.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development rules, should focus more on preserving green space and managing growth. The City of Houston, too. And they say everyone should plan for more torrential rainfall because of the changing climate. (A host of cities in the U.S. and around the world are doing so.)

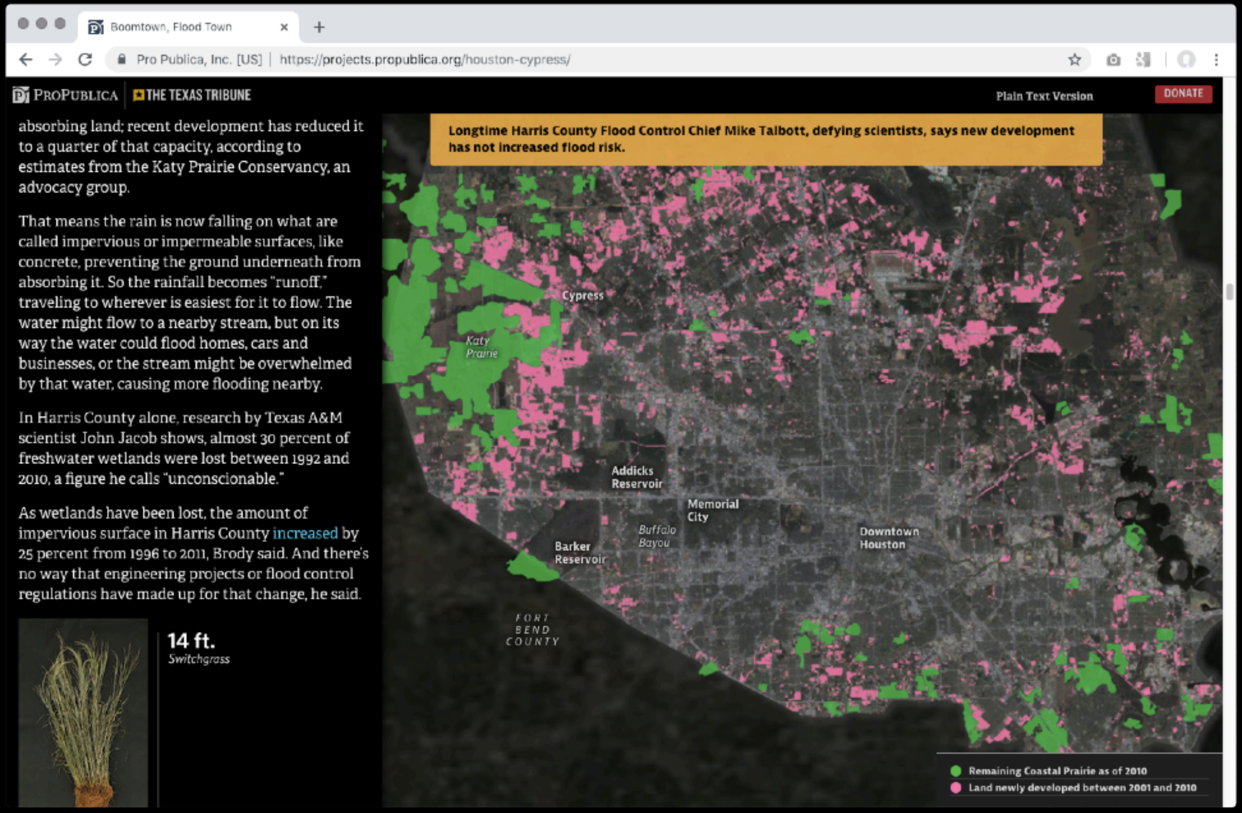
But county and city officials responsible for addressing flooding largely reject these arguments. Houston's two top flood control officials say their biggest challenge is not managing rapid growth but retrofitting outdated infrastructure. Current standards that govern how and where developers and residents can build are mostly sufficient, they say. And all the recent monster storms are freak occurrences — not harbingers of global warming or a sign of things to come.

The longtime head of the flood control district flat-out disagrees with scientific evidence that shows development is making flooding worse. Engineering projects can reverse the effects of land development and are doing so, Mike Talbott said in an interview with The Texas Tribune and ProPublica in late August before his retirement after 18 years heading the powerful agency. (His successor shares his views.)

The claim that "these magic sponges out in the prairie would have absorbed all that water is absurd," Talbott said.

He also said the flood control district has no plans to study climate change or its impacts on Harris County, the third-most-populous county in the

More than a third of the properties that flooded in Houston's Memorial Day 2015 and Tax Day 2016 floods are located outside areas that the Federal Emergency Management Agency deems to be at high risk of flooding.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absorbing land; recent development has reduced it to a quarter of that capacity, according to estimates from the Katy Prairie Conservancy, an advocacy group.

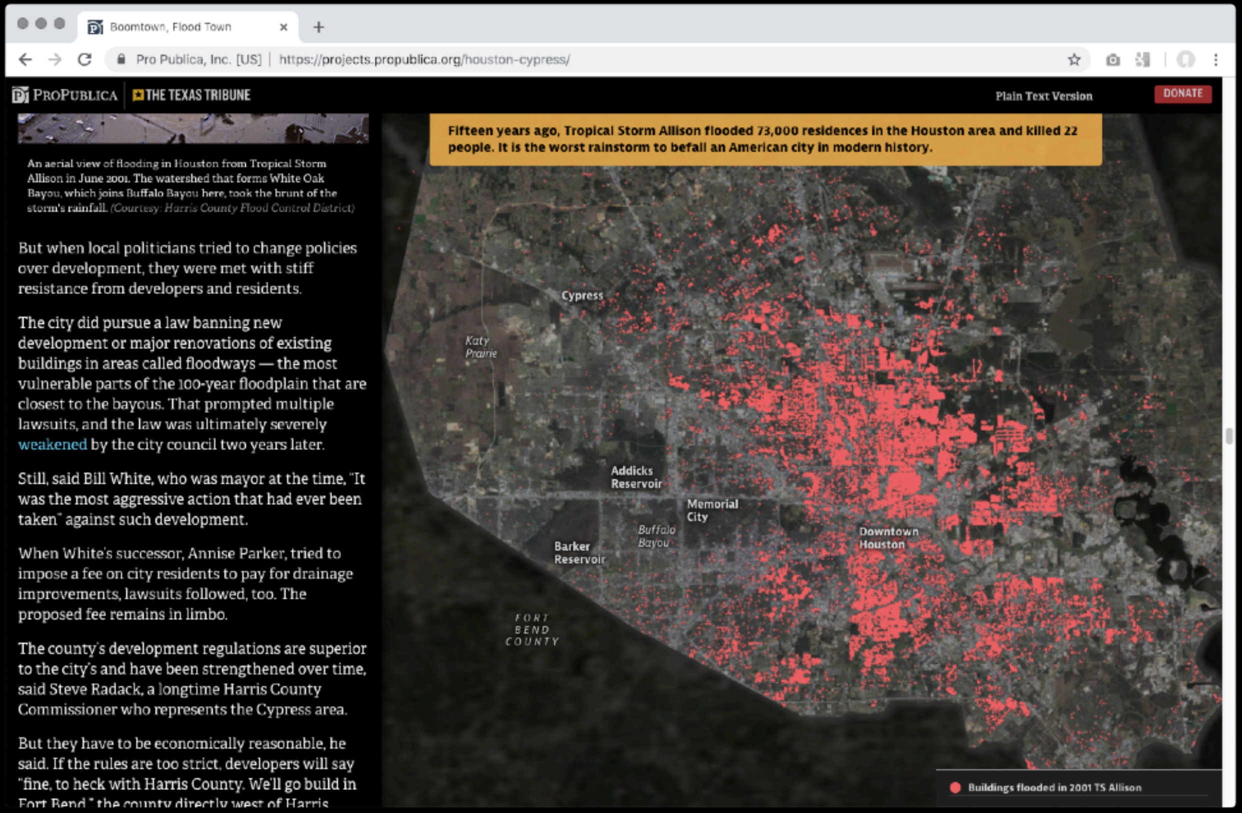
That means the rain is now falling on what are called impervious or impermeable surfaces, like concrete, preventing the ground underneath from absorbing it. So the rainfall becomes "runoff," traveling to wherever is easiest for it to flow. The water might flow to a nearby stream, but on its way the water could flood homes, cars and businesses, or the stream might be overwhelmed by that water, causing more flooding nearby.

In Harris County alone, research by Texas A&M scientist John Jacob shows, almost 30 percent of freshwater wetlands were lost between 1992 and 2010, a figure he calls "unconscionable."

As wetlands have been lost, the amount of impervious surface in Harris County increased by 25 percent from 1996 to 2011, Brody said. And there's no way that engineering projects or flood control regulations have made up for that change, he said.

14 ft.
Switchgrass

Longtime Harris County Flood Control Chief Mike Talbott, defying scientists, says new development has not increased flood risk.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An aerial view of flooding in Houston from Tropical Storm Allison in June 2001. The watershed that forms White Oak Bayou, which joins Buffalo Bayou here, took the brunt of the storm's rainfall. *(Courtesy: Harris County Flood Control District)*

But when local politicians tried to change policies over development, they were met with stiff resistance from developers and residents.

The city did pursue a law banning new development or major renovations of existing buildings in areas called floodways — the most vulnerable parts of the 100-year floodplain that are closest to the bayous. That prompted multiple lawsuits, and the law was ultimately severely weakened by the city council two years later.

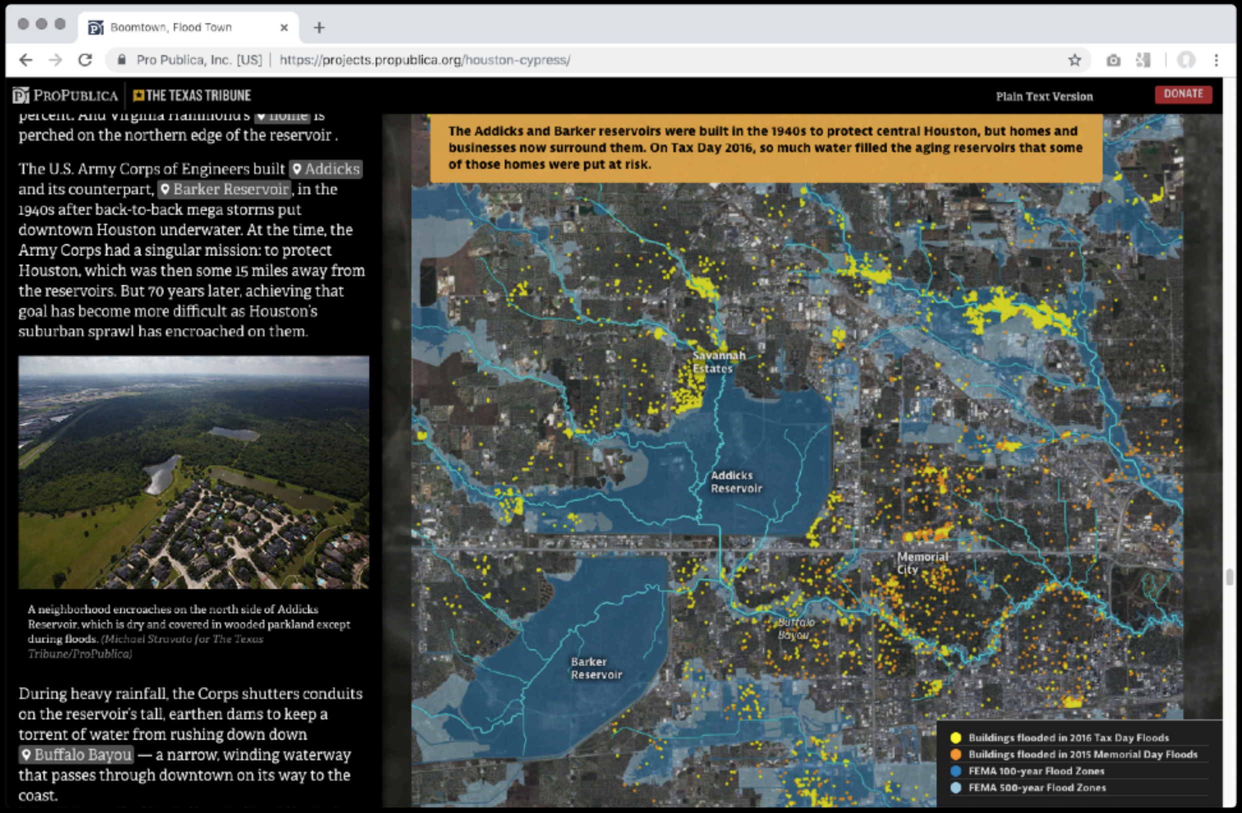
Still, said Bill White, who was mayor at the time, "It was the most aggressive action that had ever been taken" against such development.

When White's successor, Annise Parker, tried to impose a fee on city residents to pay for drainage improvements, lawsuits followed, too. The proposed fee remains in limbo.

The county's development regulations are superior to the city's and have been strengthened over time, said Steve Radack, a longtime Harris County Commissioner who represents the Cypress area.

But they have to be economically reasonable, he said. If the rules are too strict, developers will say "fine, to heck with Harris County. We'll go build in

Fifteen years ago, Tropical Storm Allison flooded 73,000 residences in the Houston area and killed 22 people. It is the worst rainstorm to befall an American city in modern history.



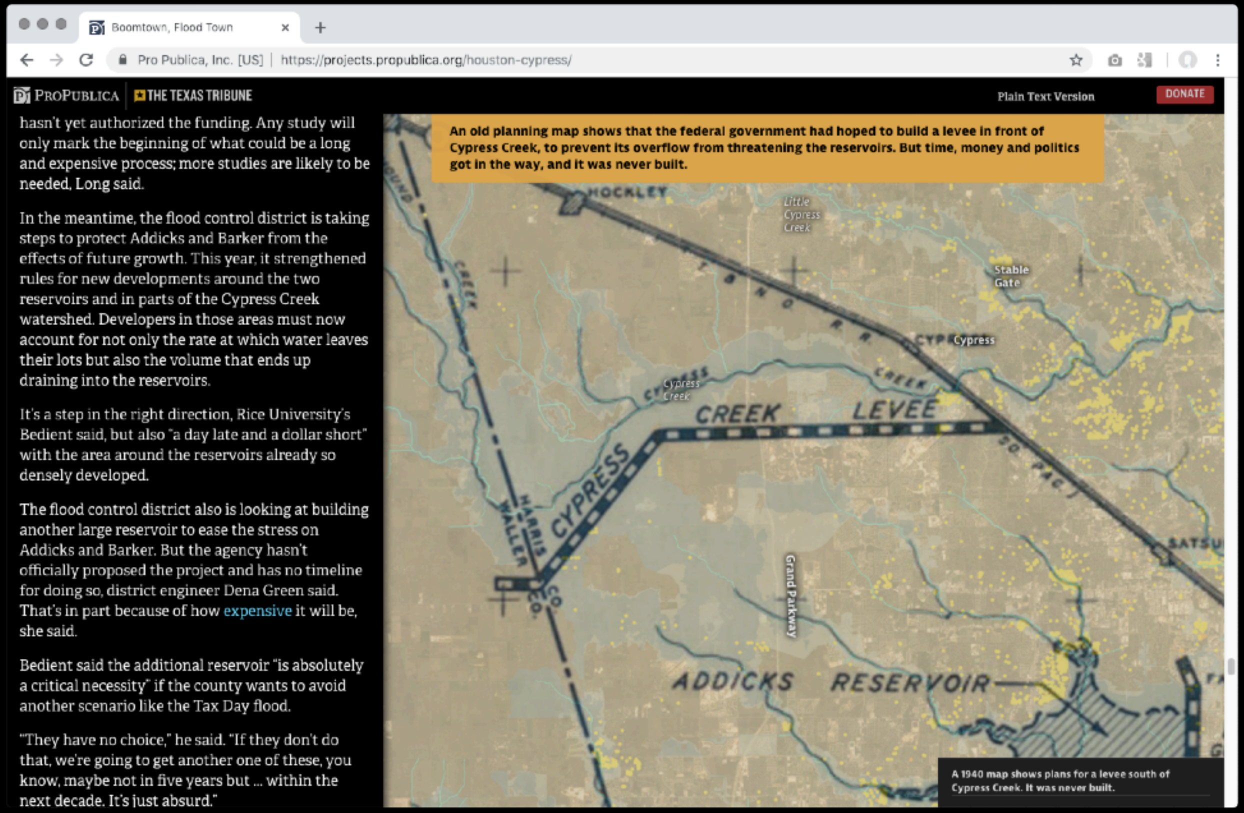
perched on the northern edge of the reservoir .

The U.S. Army Corps of Engineers built Addicks and its counterpart, Barker Reservoir, in the 1940s after back-to-back mega storms put downtown Houston underwater. At the time, the Army Corps had a singular mission: to protect Houston, which was then some 15 miles away from the reservoirs. But 70 years later, achieving that goal has become more difficult as Houston's suburban sprawl has encroached on them.

A neighborhood encroaches on the north side of Addicks Reservoir, which is dry and covered in wooded parkland except during floods. *(Michael Stravato for The Texas Tribune/ProPublica)*

During heavy rainfall, the Corps shutters conduits on the reservoir's tall, earthen dams to keep a torrent of water from rushing down down Buffalo Bayou — a narrow, winding waterway that passes through downtown on its way to the coast.

The Addicks and Barker reservoirs were built in the 1940s to protect central Houston, but homes and businesses now surround them. On Tax Day 2016, so much water filled the aging reservoirs that some of those homes were put at risk.



hasn't yet authorized the funding. Any study will only mark the beginning of what could be a long and expensive process; more studies are likely to be needed, Long said.

In the meantime, the flood control district is taking steps to protect Addicks and Barker from the effects of future growth. This year, it strengthened rules for new developments around the two reservoirs and in parts of the Cypress Creek watershed. Developers in those areas must now account for not only the rate at which water leaves their lots but also the volume that ends up draining into the reservoirs.

It's a step in the right direction, Rice University's Bedient said, but also "a day late and a dollar short" with the area around the reservoirs already so densely developed.

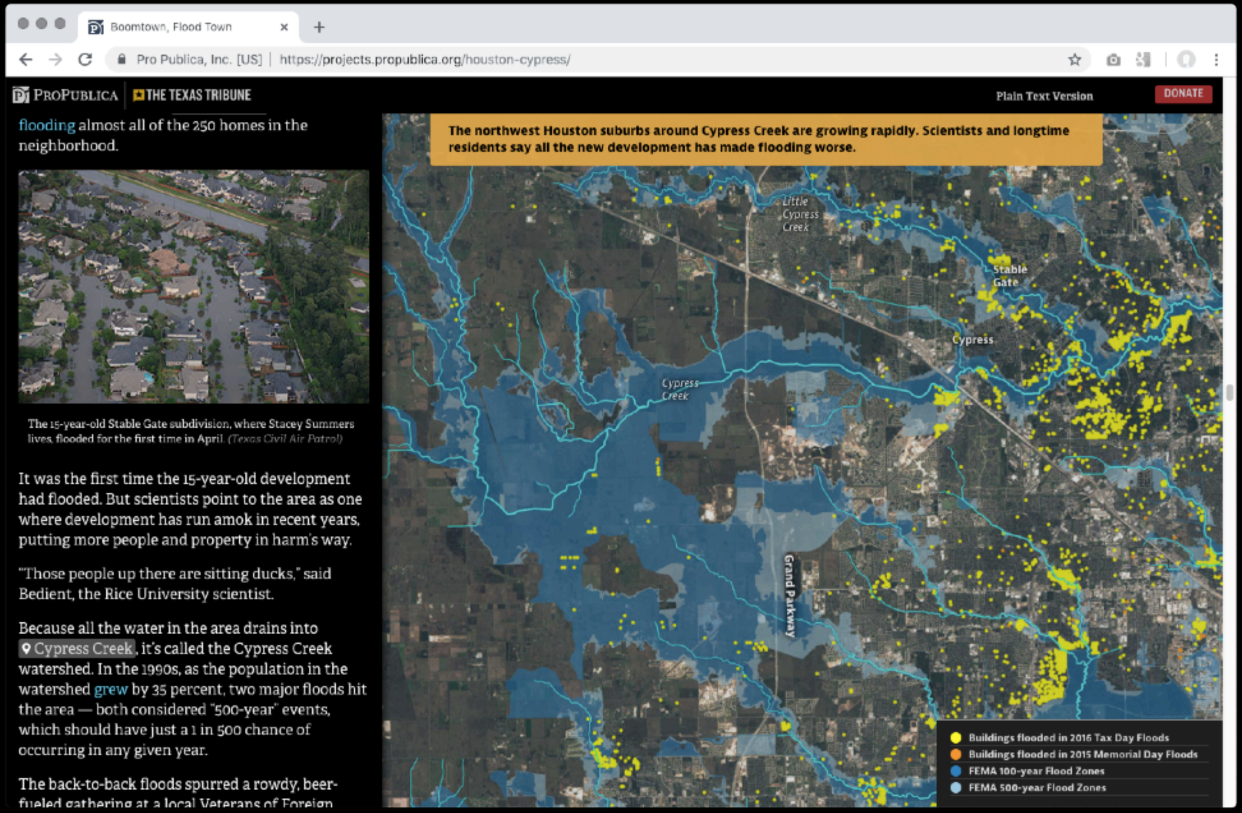
The flood control district also is looking at building another large reservoir to ease the stress on Addicks and Barker. But the agency hasn't officially proposed the project and has no timeline for doing so, district engineer Dena Green said. That's in part because of how expensive it will be, she said.

Bedient said the additional reservoir "is absolutely a critical necessity" if the county wants to avoid another scenario like the Tax Day flood.

"They have no choice," he said. "If they don't do that, we're going to get another one of these, you know, maybe not in five years but … within the next decade. It's just absurd."

An old planning map shows that the federal government had hoped to build a levee in front of Cypress Creek, to prevent its overflow from threatening the reservoirs. But time, money and politics got in the way, and it was never built.

A 1940 map shows plans for a levee south of Cypress Creek. It was never built.



flooding almost all of the 250 homes in the neighborhood.

The 15-year-old Stable Gate subdivision, where Stacey Summers lives, flooded for the first time in April. *(Texas Civil Air Patrol)*

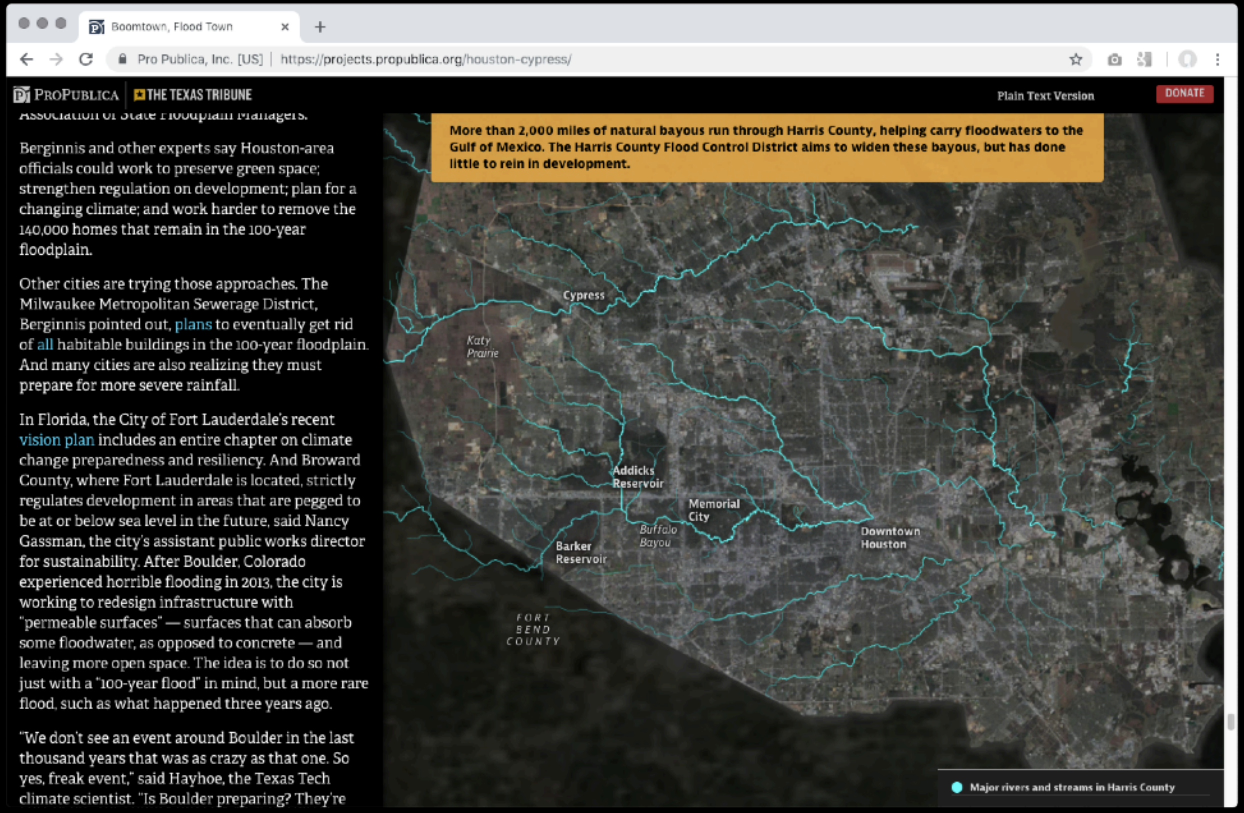
It was the first time the 15-year-old development had flooded. But scientists point to the area as one where development has run amok in recent years, putting more people and property in harm's way.

"Those people up there are sitting ducks," said Bedient, the Rice University scientist.

Because all the water in the area drains into Cypress Creek, it's called the Cypress Creek watershed. In the 1990s, as the population in the watershed grew by 35 percent, two major floods hit the area — both considered "500-year" events, which should have just a 1 in 500 chance of occurring in any given year.

The back-to-back floods spurred a rowdy, beer-

The northwest Houston suburbs around Cypress Creek are growing rapidly. Scientists and longtime residents say all the new development has made flooding worse.



Berginnis and other experts say Houston-area officials could work to preserve green space; strengthen regulation on development; plan for a changing climate; and work harder to remove the 140,000 homes that remain in the 100-year floodplain.

Other cities are trying those approaches. The Milwaukee Metropolitan Sewerage District, Berginnis pointed out, plans to eventually get rid of all habitable buildings in the 100-year floodplain. And many cities are also realizing they must prepare for more severe rainfall.

In Florida, the City of Fort Lauderdale's recent vision plan includes an entire chapter on climate change preparedness and resiliency. And Broward County, where Fort Lauderdale is located, strictly regulates development in areas that are pegged to be at or below sea level in the future, said Nancy Gassman, the city's assistant public works director for sustainability. After Boulder, Colorado experienced horrible flooding in 2013, the city is working to redesign infrastructure with "permeable surfaces" — surfaces that can absorb some floodwater, as opposed to concrete — and leaving more open space. The idea is to do so not just with a "100-year flood" in mind, but a more rare flood, such as what happened three years ago.

"We don't see an event around Boulder in the last thousand years that was as crazy as that one. So yes, freak event," said Hayhoe, the Texas Tech climate scientist. "Is Boulder preparing? They're

More than 2,000 miles of natural bayous run through Harris County, helping carry floodwaters to the Gulf of Mexico. The Harris County Flood Control District aims to widen these bayous, but has done little to rein in development.

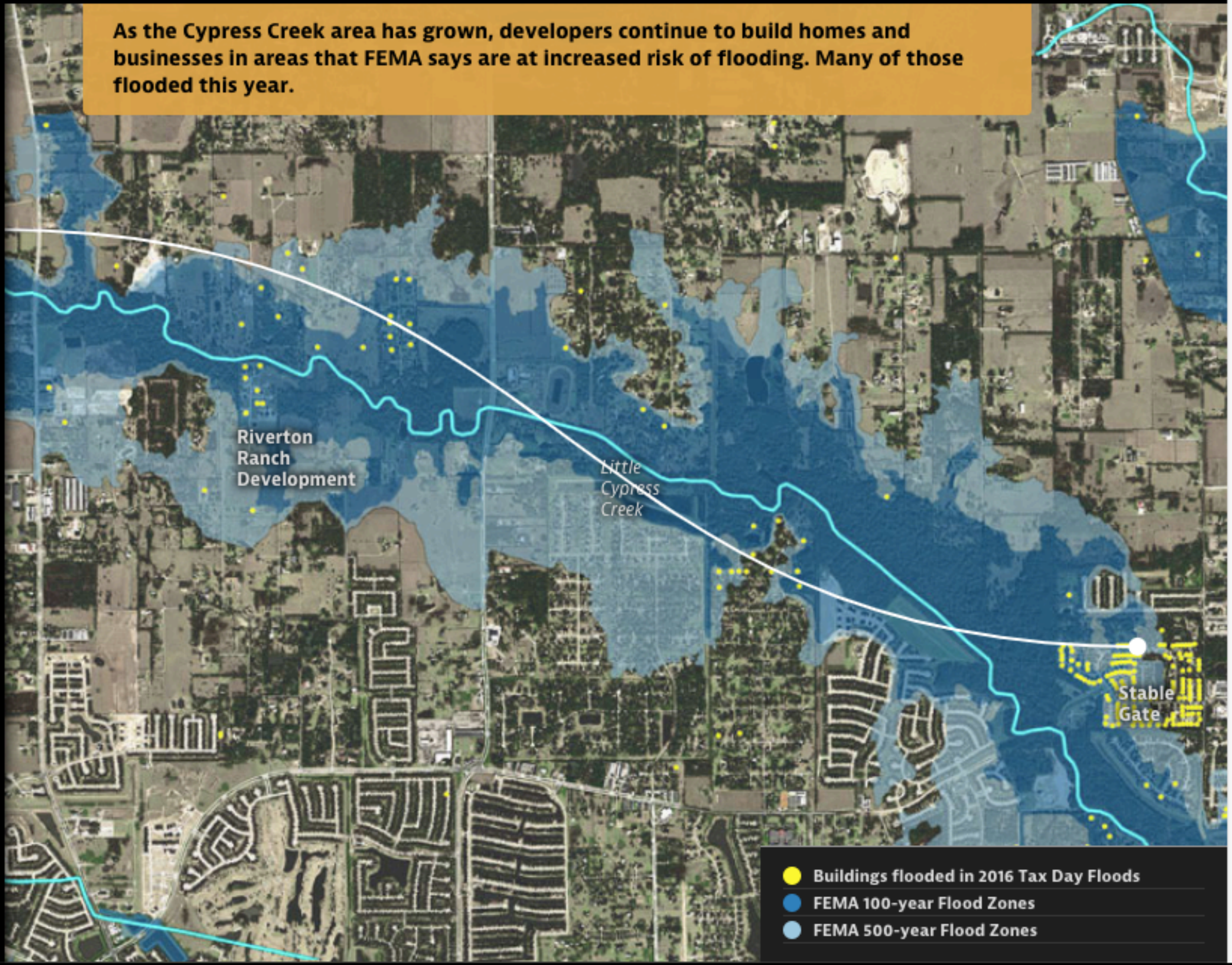
swath of the subdivision in the 100-year floodplain, triggering flood insurance requirements for many residents. Parts of the neighborhood were also placed in a newly expanded 500-year floodplain — an area with a smaller but still notable chance of flooding each year.

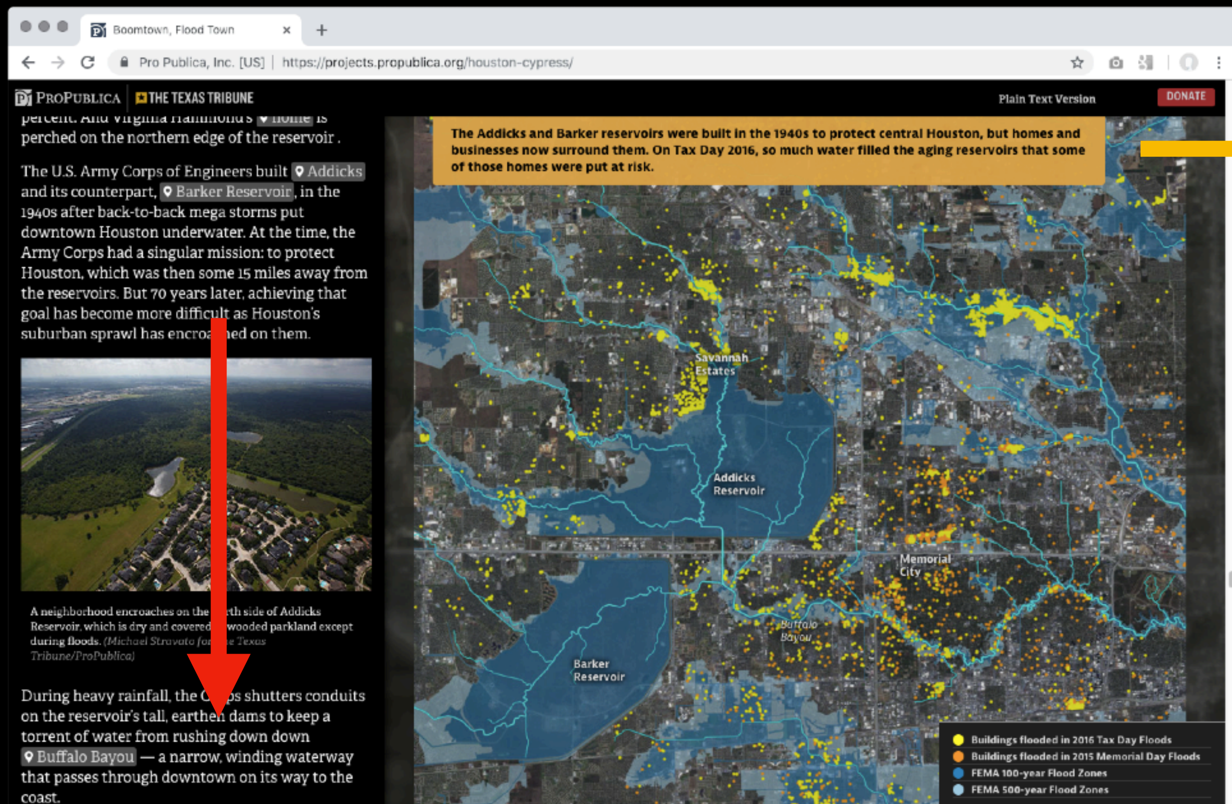
Summers' home ended up in a 500-year floodplain after the new maps took effect. She doesn't need to buy flood insurance, but she still carries it for about $400 a year. Greg Bowen, president of the Stable Gate Homeowners Association, said the neighborhood "was built on the best data they had at the time."

But even with the new flood maps, development has continued in the 100-year floodplains. Since 2010, more than 7,000 residential buildings have been built in these risky areas in Harris County, according to a Tribune/ProPublica analysis of local appraisal data, along with more than 1,600 nonresidential buildings.

Bowen said the county and developers are not installing enough flood control measures or ensuring developers follow the rules for building in a floodplain.

"The bottom line is there needs to be more done to keep up with the growth out in Cypress," he said.

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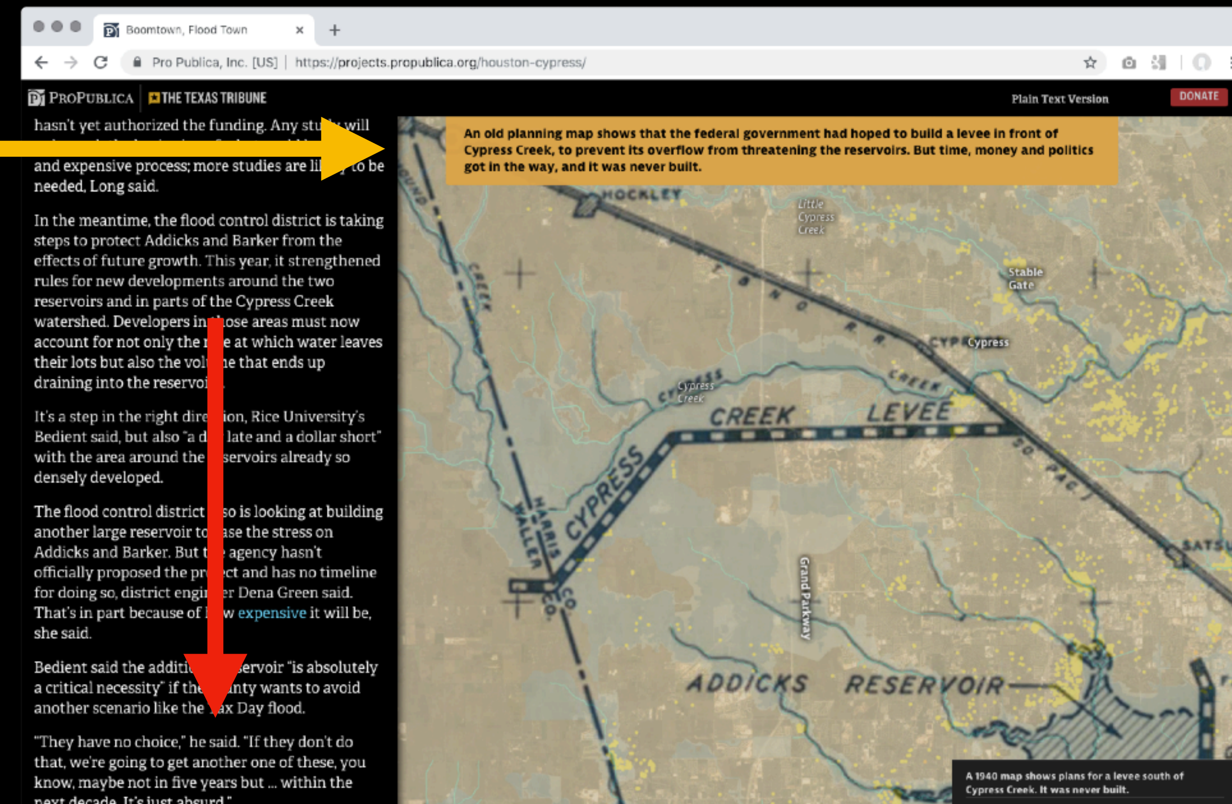
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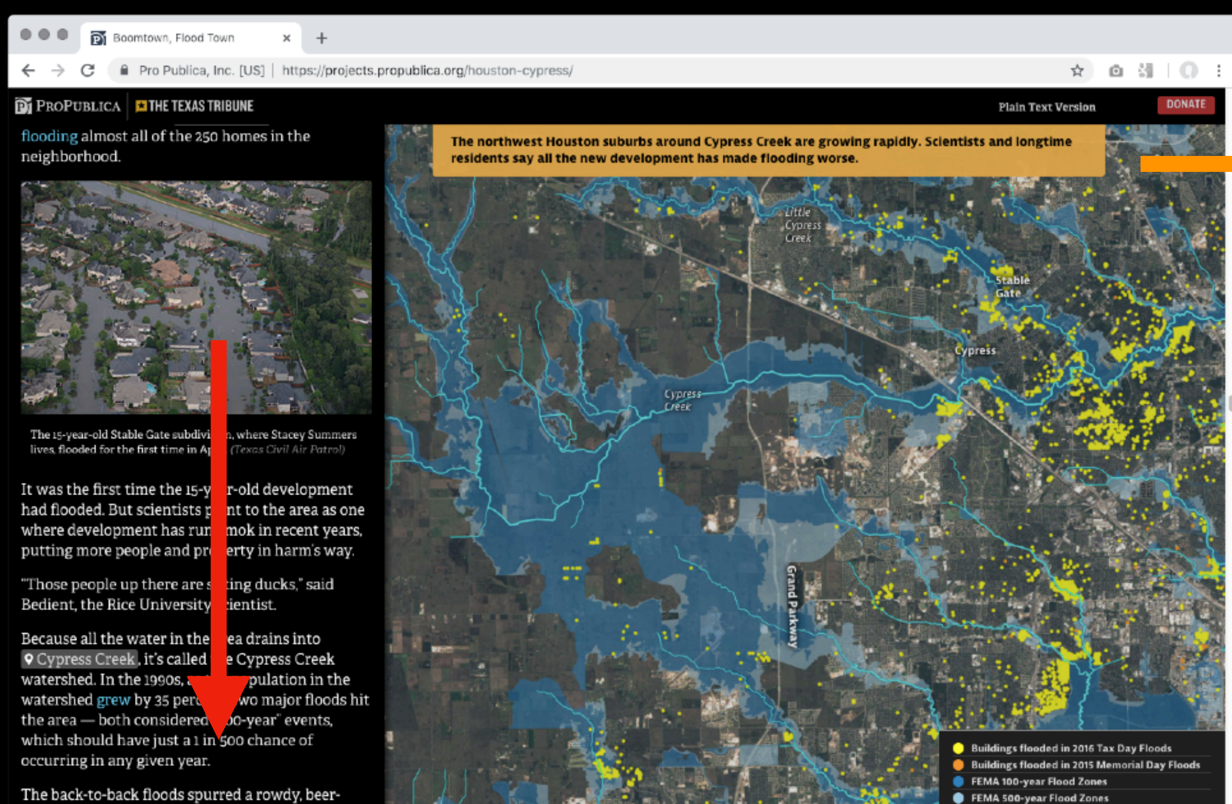
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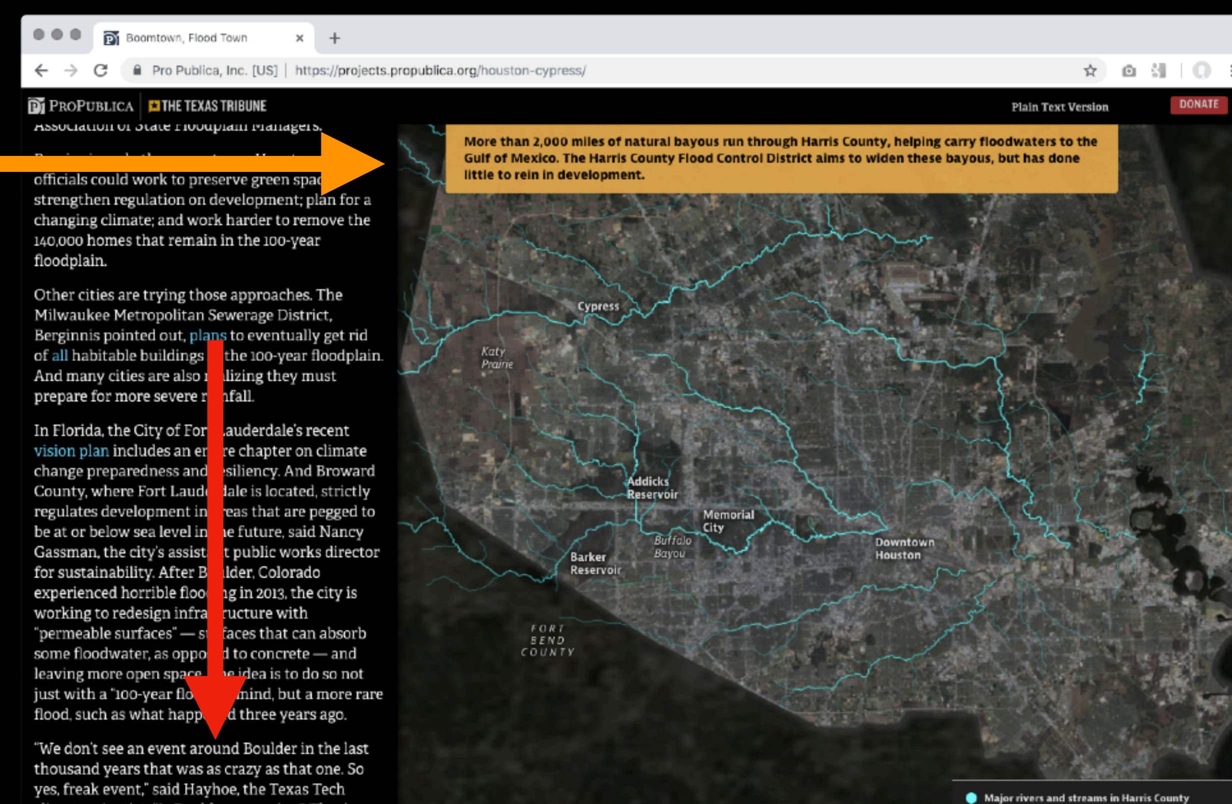
The back-to-back floods spurred a rowdy, beer-fueled gathering at a local Veterans of Foreign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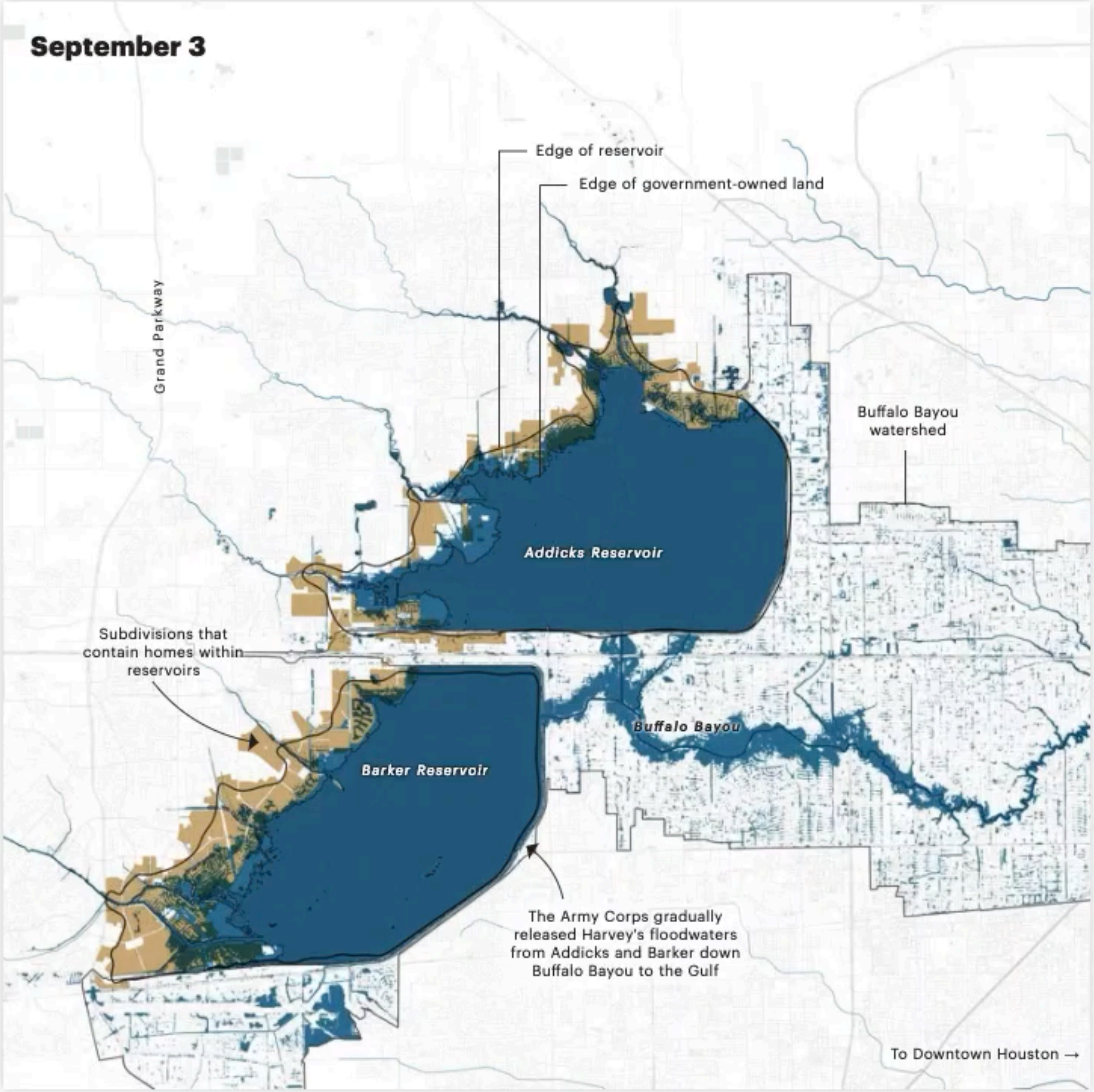
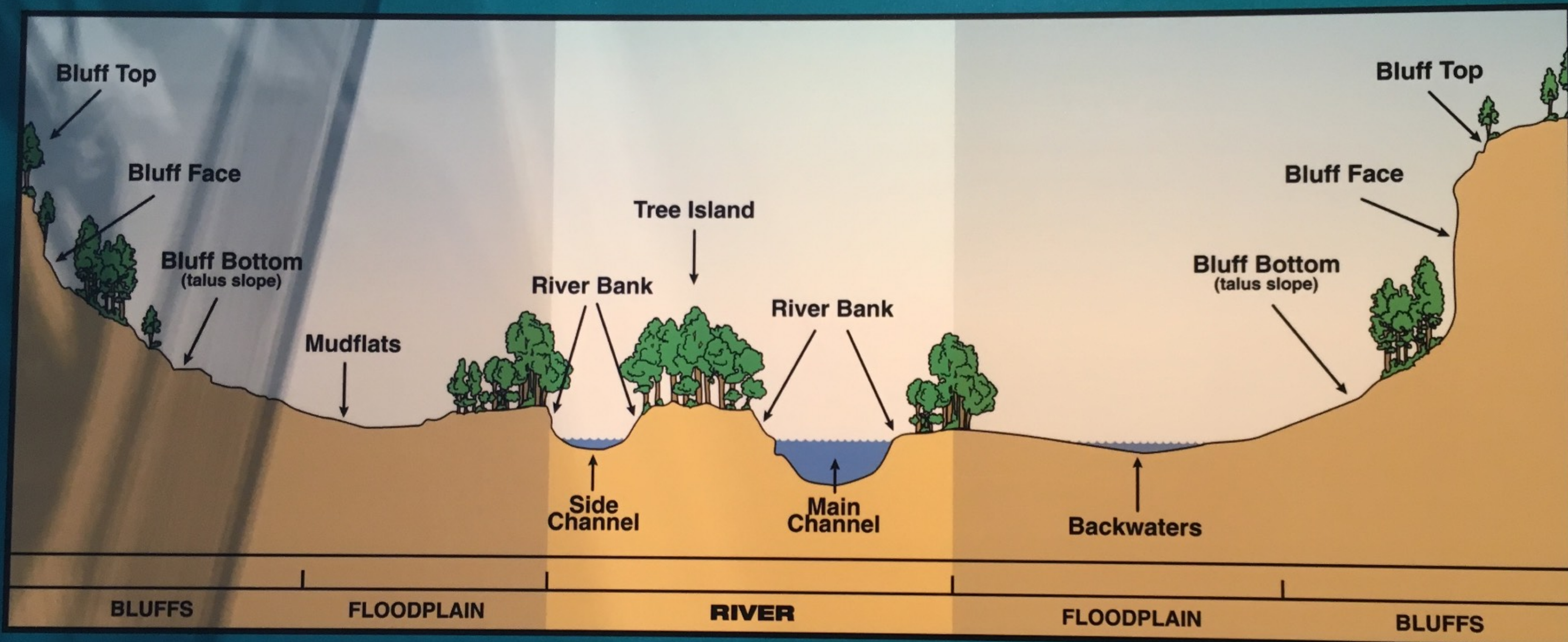
Absorbent prairie grasses such as switchgrass can grow roots up to 15 feet long. Researchers say the developed landscapes that replace it — such as suburban lawns — can't compare with its ability to absorb water and protect against floods. *(photo: Steve Renich, courtesy of The Land Institute, illustration: Alberto Cairo)*


September 3
Edge of reservoir
Edge of government-owned land
Grand Parkway
Buffalo Bayou watershed
Addicks Reservoir
Subdivisions that contain homes within reservoirs
Buffalo Bayou
Barker Reservoir
The Army Corps gradually released Harvey's floodwaters from Addicks and Barker down Buffalo Bayou to the Gulf
To Downtown Houston →


National Great Rivers Museum
US Army Corps
of Engineers



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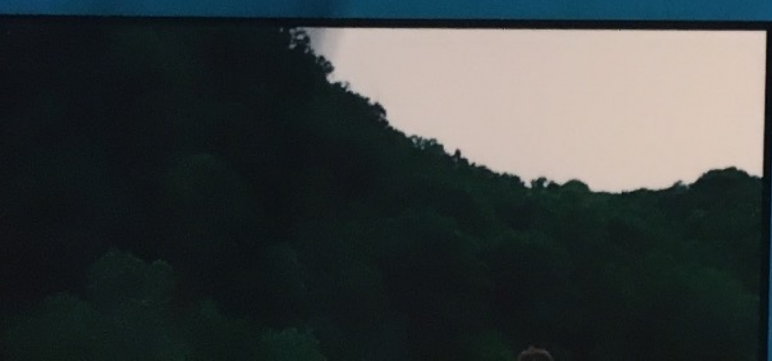
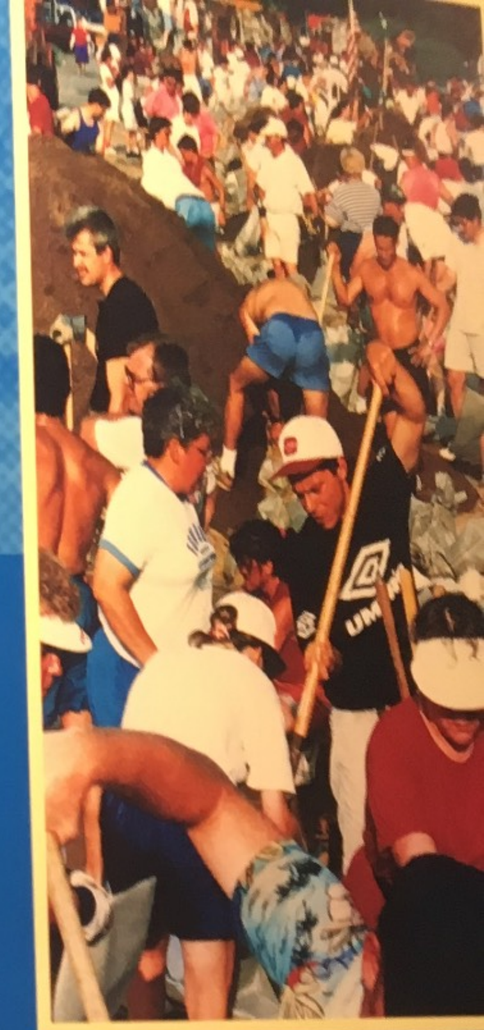


The Flood of 1993

During the summer of endless rains, the Missouri and Mississippi Rivers swelled to their greatest heights in recorded history. The flood inundated much of mid-America. From Iowa to Illinois to Missouri, over 8 million acres were under water – an area bigger than Lake Erie. Over 55,000 homes were damaged or destroyed and 52 people drowned. Damage was estimated at over $15 billion.

BUT it could have been worse—in fact, over twice as bad. The system of flood protection structures prevented over $19 billion dollars of additional flood damage.



Courtesy of St. Louis Post Dispatch

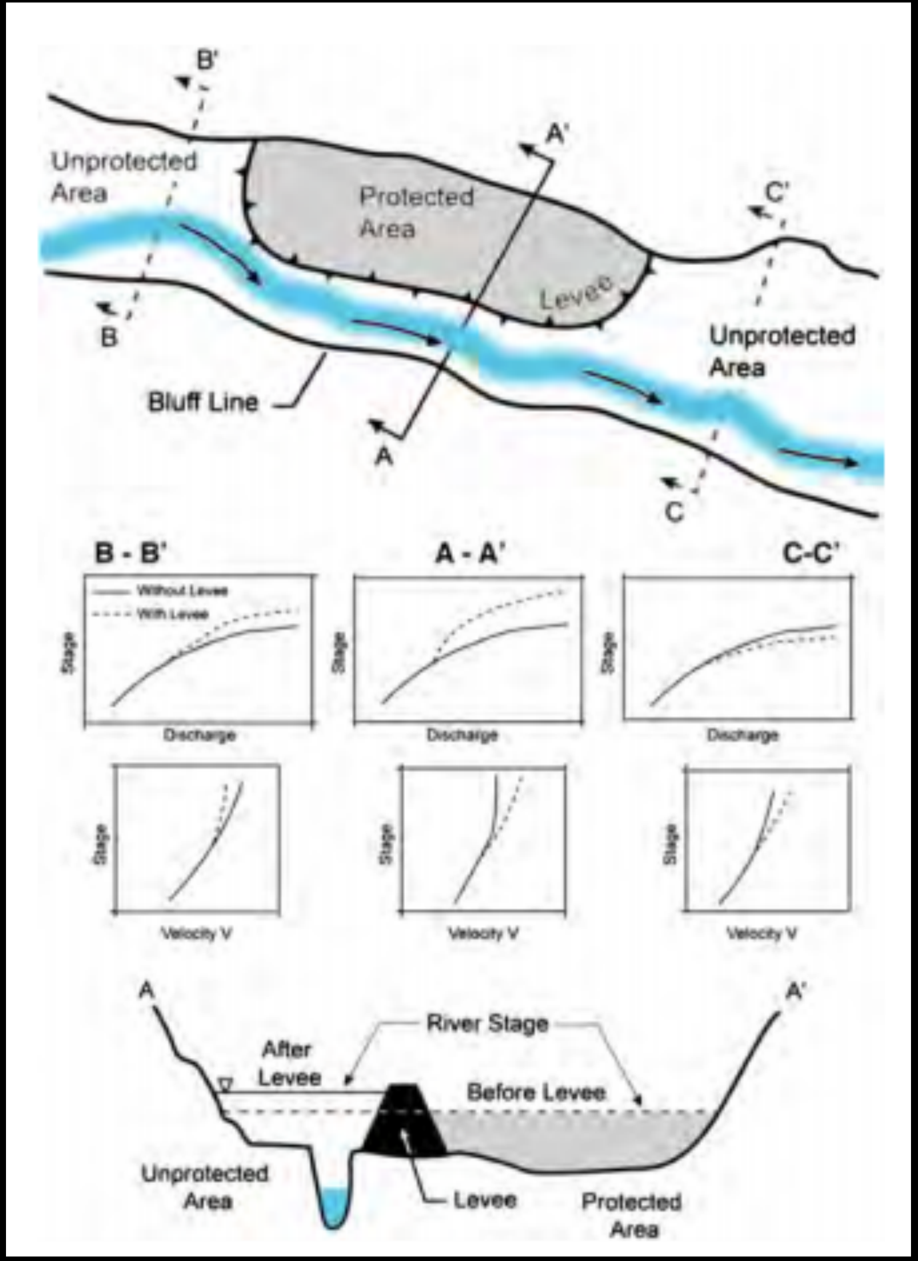
overtops Melvin Price Locks

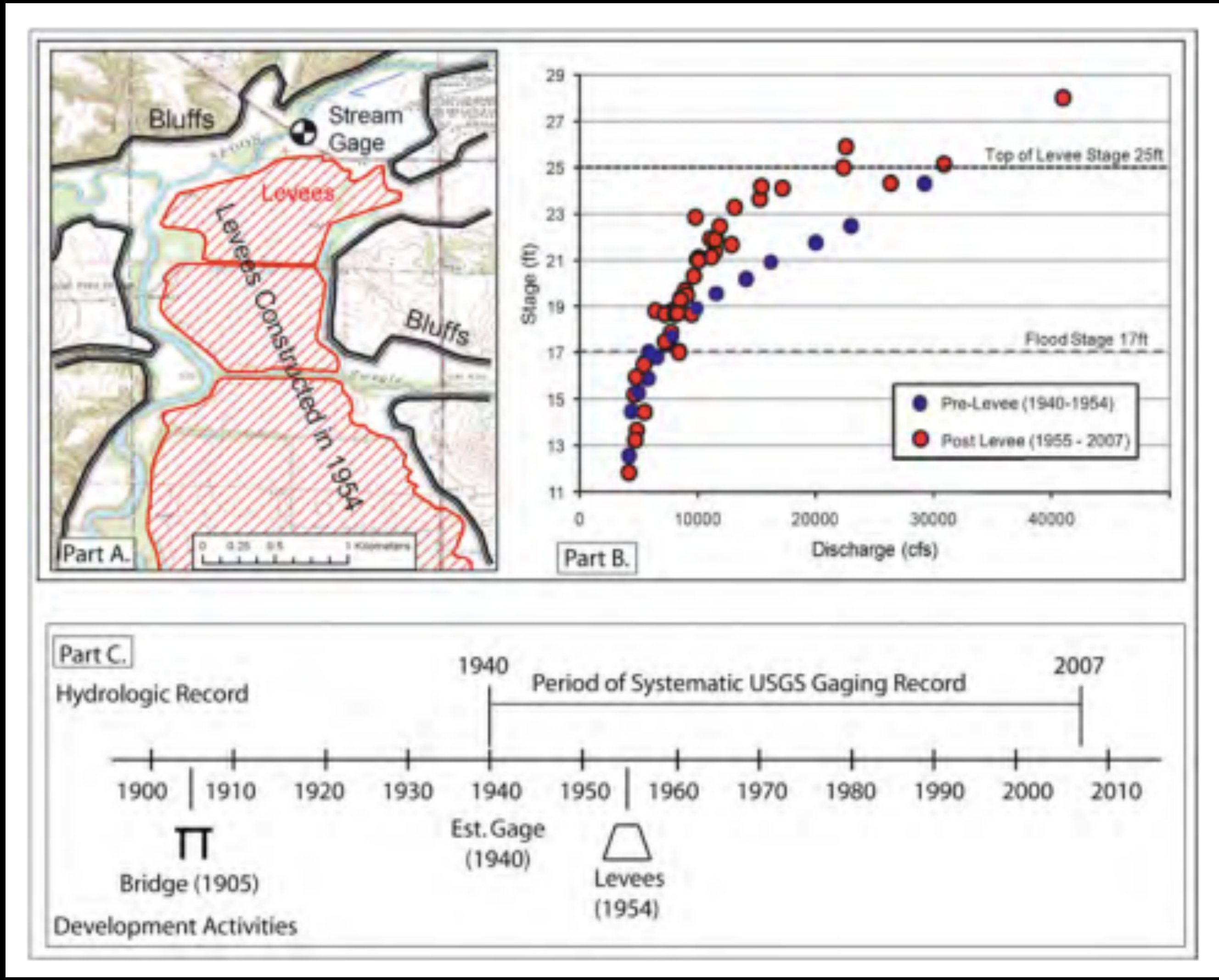

Martin Luther Ki
Eads Bridge
WEIR NO. 179.9L
WEIR NO. 179.8L
Mile 181
180

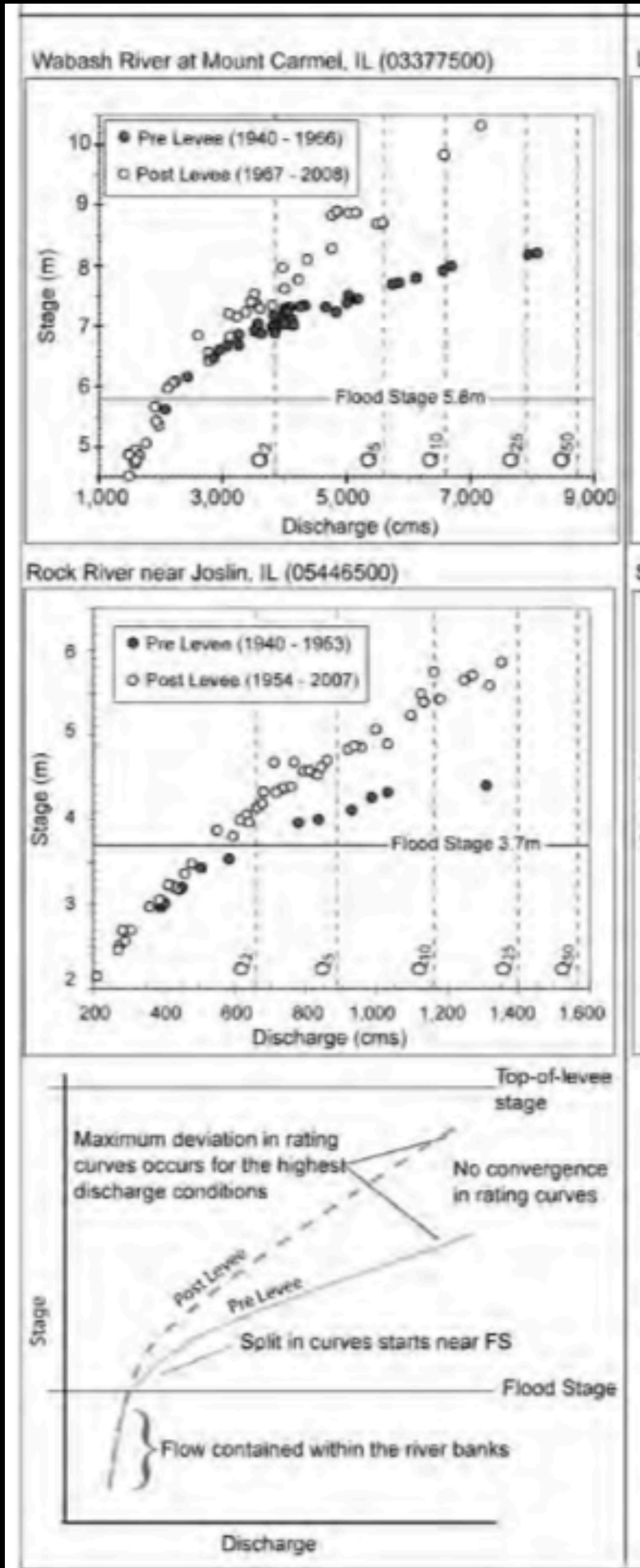
HYDROLOGICAL PROCESSES
Hydrol. Process. (2011)
Published online in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/hyp.8261

Levee effects upon flood levels: an empirical assessment

Reuben A. Heine[1]* and Nicholas Pinter[2]
[1] *Geography department, Augustana College, Rock Island, IL, USA*
[2] *Geology department, Southern Illinois University, Carbondale, IL, USA*



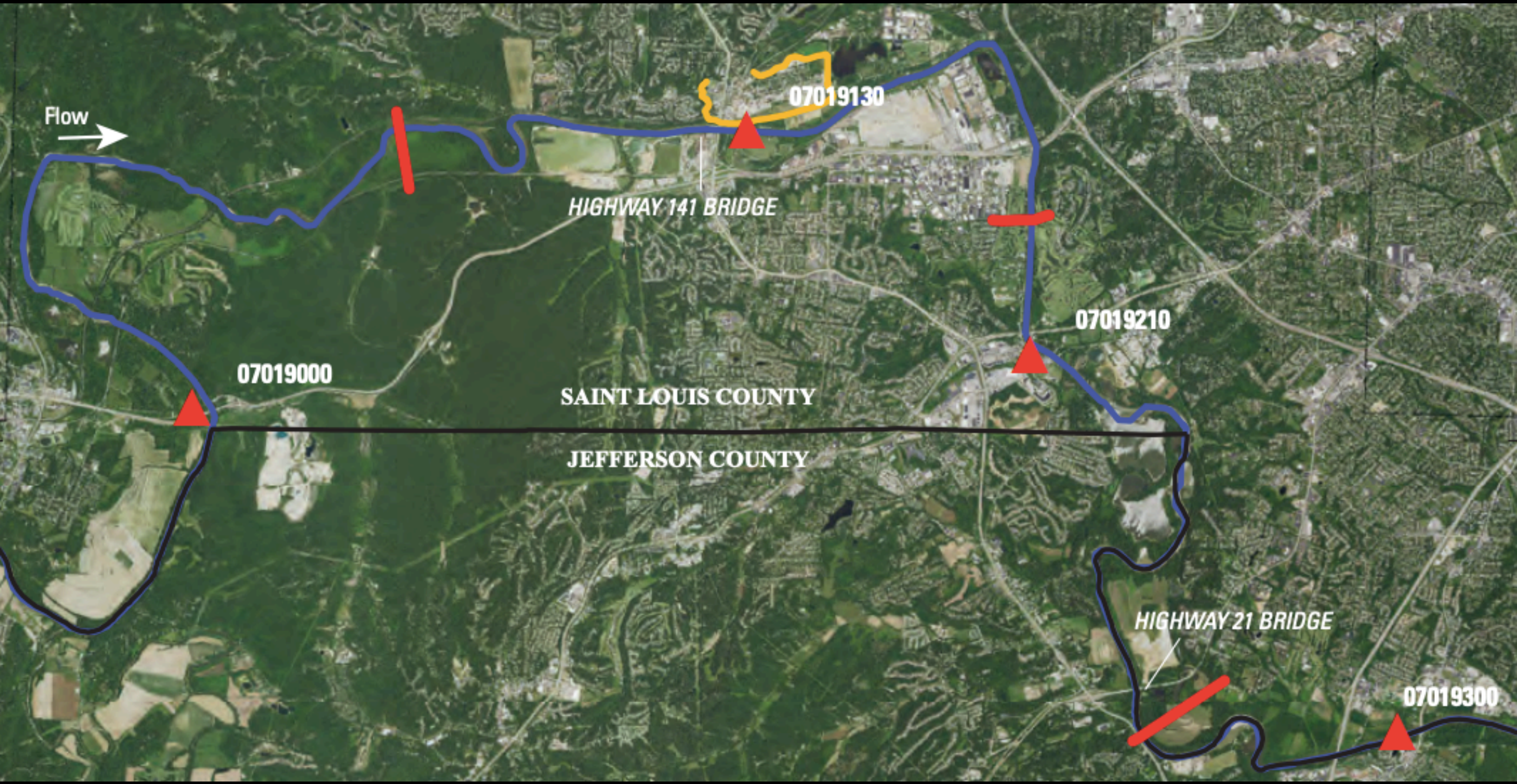




Heine/Pinter

	Available Parameters	Available Period	
☐	All 3 Available Parameters for this site		
☑	00045 Precipitation	2018-10-06	2019-02-03
☑	00060 Discharge	2004-10-01	2006-09-30
☑	00065 Gage height	2007-10-01	2019-02-03

NWS


Flow
07019130
HIGHWAY 141 BRIDGE
07019210
07019000
SAINT LOUIS COUNTY
JEFFERSON COUNTY
HIGHWAY 21 BRIDGE
07019300

USGS

07019000 MERAMEC RIVER NEAR EUREKA, MO

LOCATION - Lat 38°30'16.85", long 90°35'26.69" referenced to North American Datum of 1927, in SE 1/4 sec.32, T.44 N., R.4 E., St. Louis County, MO, Hydrologic Unit 07140102, on right bank, 44 ft upstream from bridge on north access roadway of I-44, 2.0 mi east of Eureka, 3.0 mi downstream from Big River, and at mile 34.1.

DRAINAGE AREA - 3,788 mi².

REVISIONS HISTORY - WSP 877: 1938(M). WSP 977: 1942. WSP 1007: Drainage area. WSP 1281: 1924-25.

SURFACE-WATER RECORDS

PERIOD OF RECORD - Aug 1903 to Jul 1906, Oct 1921 to current year. Monthly discharge only for Jan, Feb, and Mar 1904, published in WSP 1311.

GAGE - Water-stage recorder. Datum of gage is 404.18 ft above National Geodetic Vertical Datum of 1929. Prior to Jan 17, 1933, nonrecording gage at site 200 ft upstream at different datum; Jan 17, 1933, to Sep 22, 1937, nonrecording gage; Sep 23, 1937, to Sep 30, 1971, water-stage recorder at present site at datum 2.00 ft higher. July 16, 2015, gage moved 450 ft upstream to Interstate-44 bridge and different gage pool, approximately 1 ft higher stage, same datum.

REMARKS - Accuracy of records is discussed in the annual Station ... Science Center.

EXTREMES OUTSIDE PERIOD OF RECORD - Flood of Aug 22, 1915, ... fr ... ea measure...

NWS

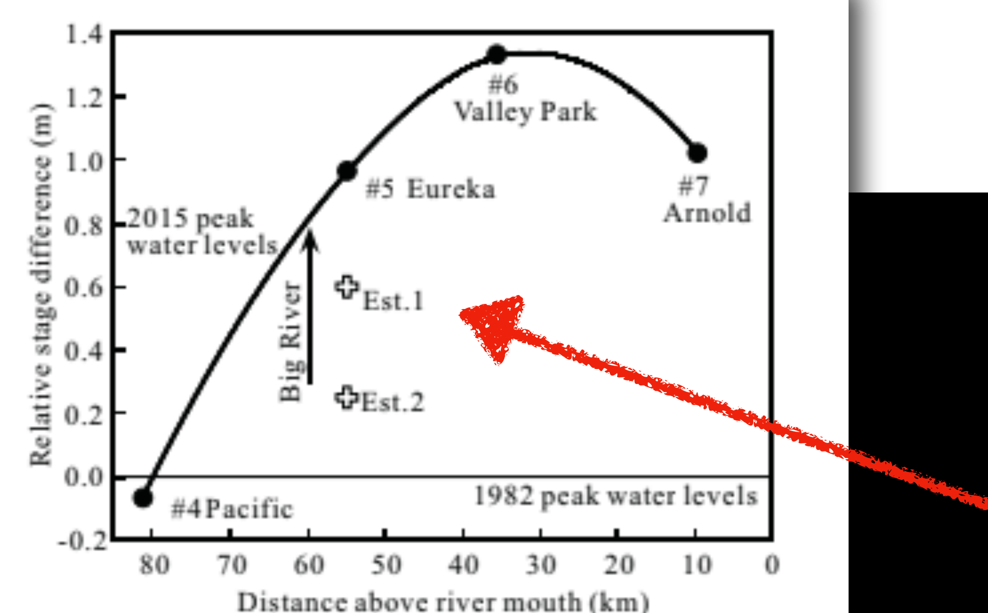
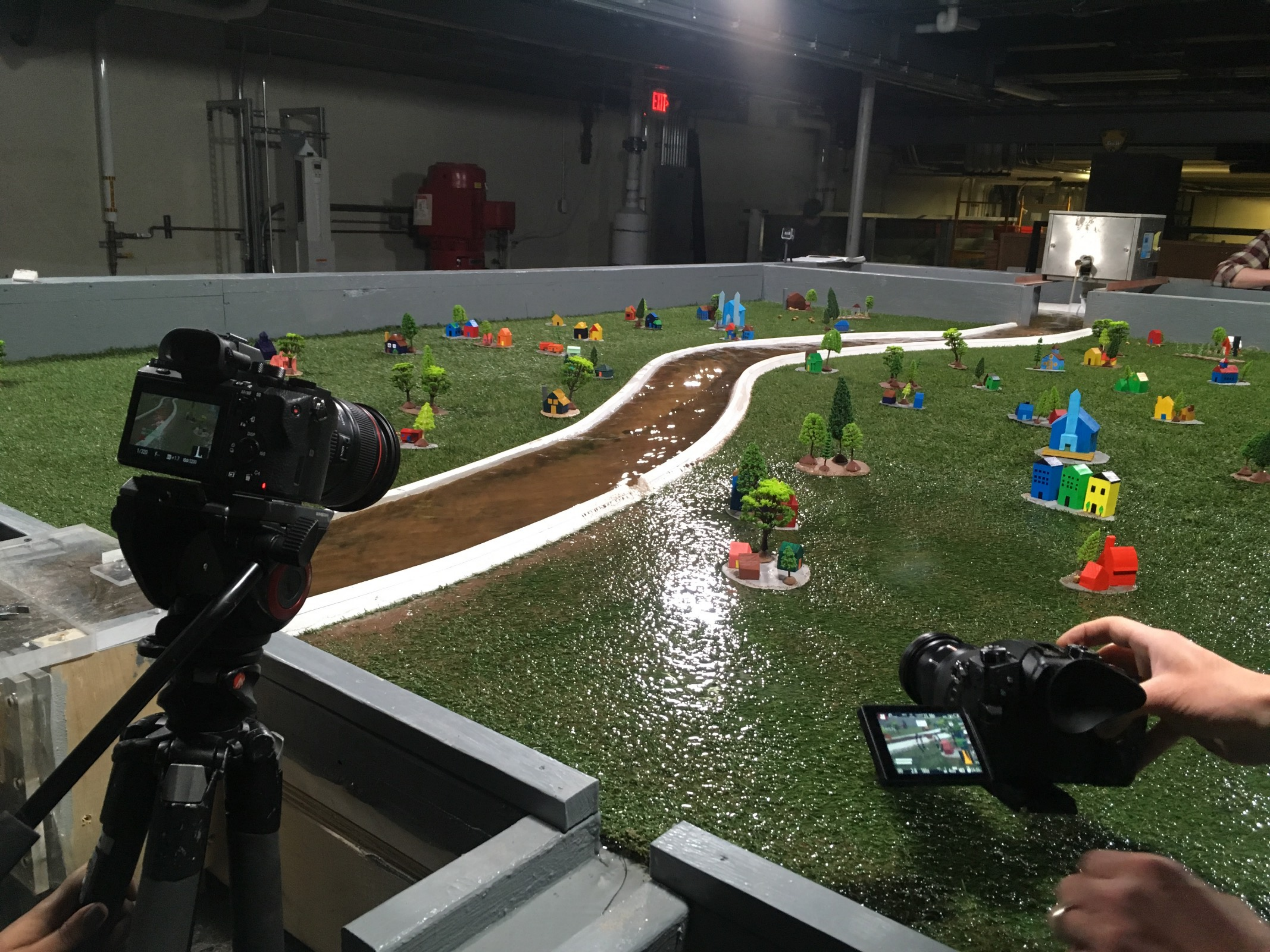


Figure 4. Relative difference between the peak water levels of December 30–31, 2015 and those of December 6, 1982 at different sites in the lower Meramec Basin (cf. Fig. 2). This difference was greatest close to Valley Park, where a large levee was built in 2005; this and other changes appear to have increased stages at Valley Park as well as upstream and downstream. Two estimates (crosses) suggest what the stage difference between these floods should have been at Eureka, had the 2015 flood occurred under the 1982 landscape condition (see text). Big River (arrow) enters the Meramec River from the south, 4.8 km upstream of Eureka.

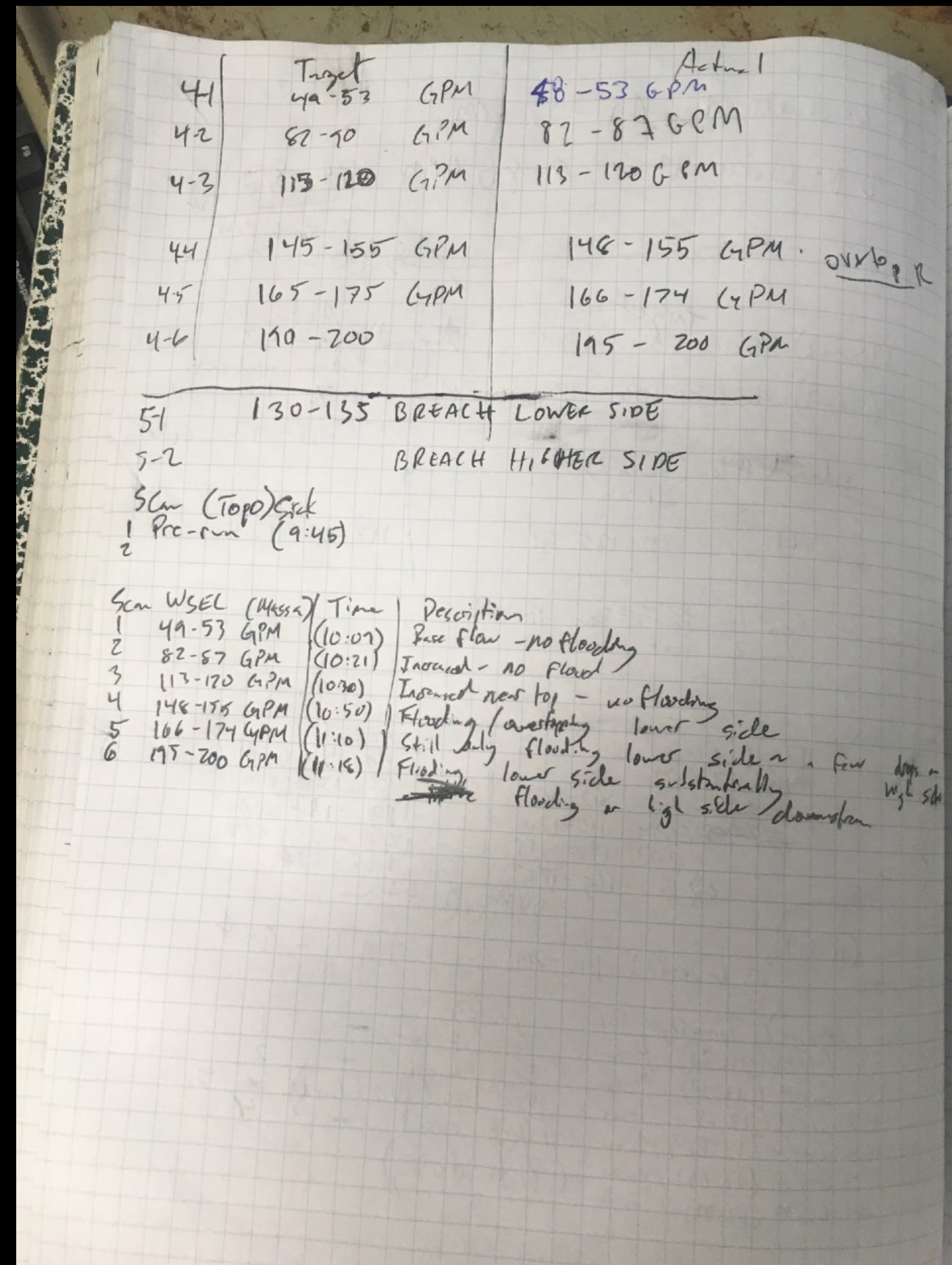
Criss/Luo


This box deposited a constant rate of sediment into the channel
We piped Mississippi River water in from here
Artificial turf floodplain
PVC levees
Extra levees
Houses painted by ProPublica staff
Water exited through a slot here

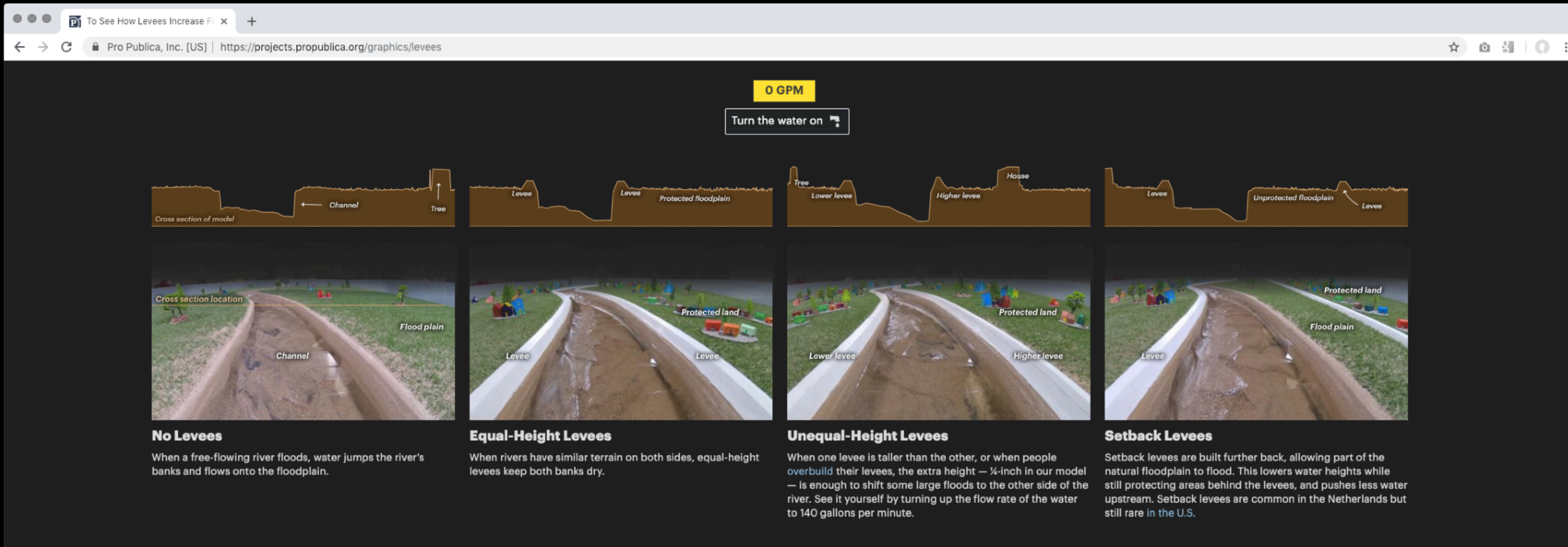

EXIT

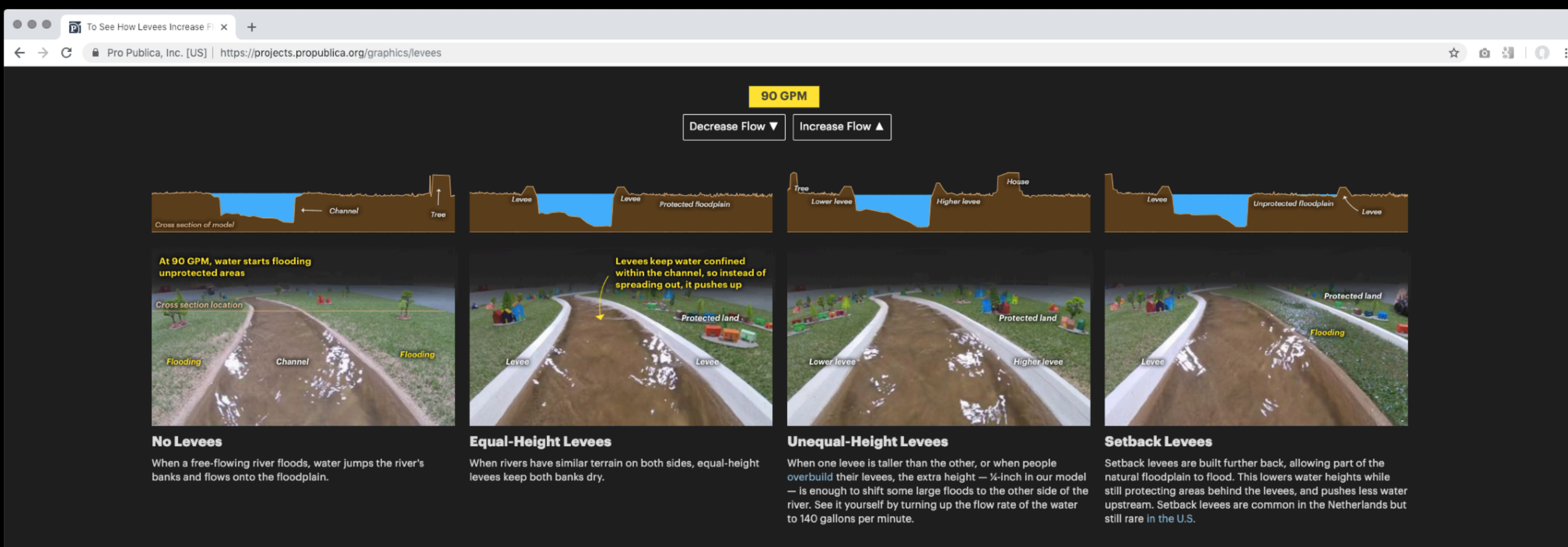

+GF+
Signet Flow Transmitter
ENTER

GoPro


Target
Actual
4-1 49-53 GPM 48-53 GPM
4-2 82-90 GPM 82-87 GPM
4-3 115-120 GPM 113-120 GPM
4-4 145-155 GPM 148-155 GPM · overtop R
4-5 165-175 GPM 166-174 GPM
4-6 190-200 195-200 GPM
5-1 130-135 BREACH LOWER SIDE
5-2 BREACH HIGHER SIDE
Scan (Topo) Sick
1 Pre-run (9:45)
2
Scan WSEL (Meas.) Time Description
1 49-53 GPM (10:07) Base flow - no flooding
2 82-87 GPM (10:21) Increased - no flood
3 113-120 GPM (10:30) Increased near top - no flooding
4 148-155 GPM (10:50) Flooding / overtopping lower side
5 166-174 GPM (11:10) Still only flooding lower side ~ a few drops on [illegible] side
6 195-200 GPM (11:15) Flooding lower side substantially
flooding on high side / downstream


Reduce


To See How Levees Increase F
Pro Publica, Inc. [US] | https://projects.propublica.org/graphics/levees
0 GPM
Turn the water on
Cross section of model
Channel
Tree
Levee
Protected floodplain
Lower levee
Higher levee
House
Unprotected floodplain
Cross section location
Flood plain
Protected land
No Levees
When a free-flowing river floods, water jumps the river's banks and flows onto the floodplain.
Equal-Height Levees
When rivers have similar terrain on both sides, equal-height levees keep both banks dry.
Unequal-Height Levees
When one levee is taller than the other, or when people overbuild their levees, the extra height — ¼-inch in our model — is enough to shift some large floods to the other side of the river. See it yourself by turning up the flow rate of the water to 140 gallons per minute.
Setback Levees
Setback levees are built further back, allowing part of the natural floodplain to flood. This lowers water heights while still protecting areas behind the levees, and pushes less water upstream. Setback levees are common in the Netherlands but still rare in the U.S.


To See How Levees Increase F
Pro Publica, Inc. [US] | https://projects.propublica.org/graphics/levees
90 GPM
Decrease Flow ▼
Increase Flow ▲
Cross section of model
Channel
Tree
Levee
Protected floodplain
Lower levee
Higher levee
House
Unprotected floodplain
At 90 GPM, water starts flooding unprotected areas
Levees keep water confined within the channel, so instead of spreading out, it pushes up
Cross section location
Flooding
Protected land
No Levees
When a free-flowing river floods, water jumps the river's banks and flows onto the floodplain.
Equal-Height Levees
When rivers have similar terrain on both sides, equal-height levees keep both banks dry.
Unequal-Height Levees
When one levee is taller than the other, or when people overbuild their levees, the extra height — ¼-inch in our model — is enough to shift some large floods to the other side of the river. See it yourself by turning up the flow rate of the water to 140 gallons per minute.
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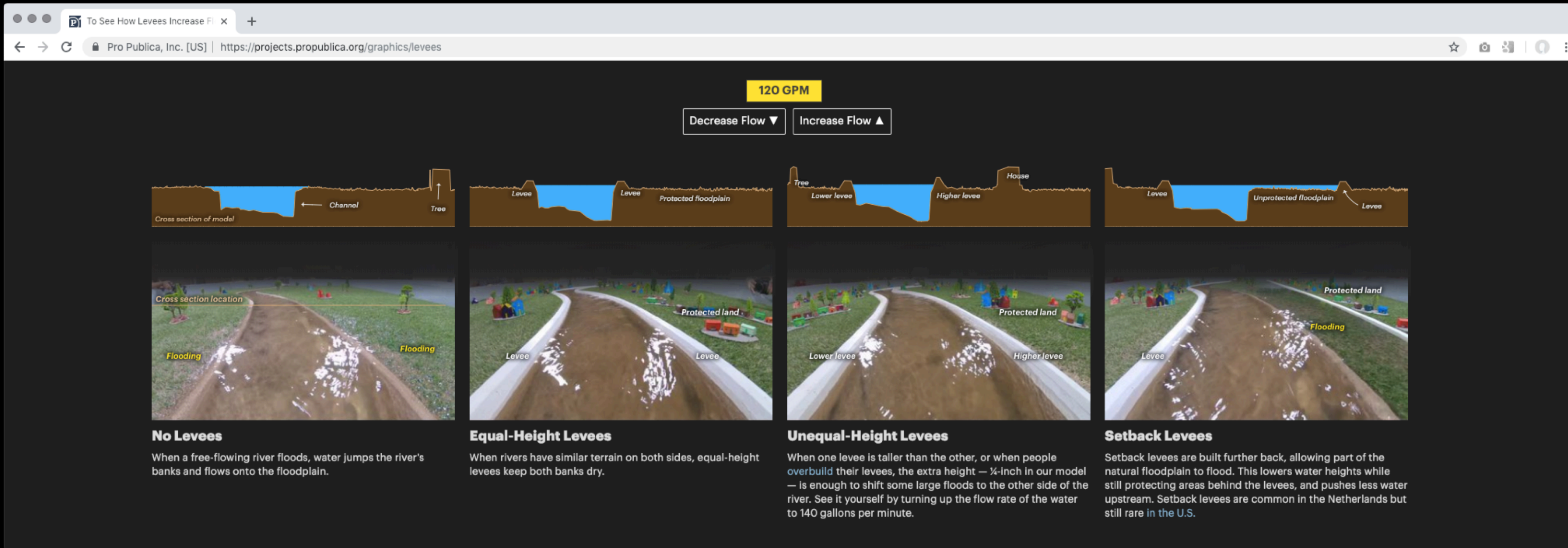

To See How Levees Increase F
Pro Publica, Inc. [US] | https://projects.propublica.org/graphics/levees
120 GPM
Decrease Flow ▼
Increase Flow ▲
Channel
Tree
Cross section of model
Levee
Levee
Protected floodplain
Tree
Lower levee
Higher levee
House
Levee
Unprotected floodplain
Levee
Cross section location
Flooding
Flooding
Protected land
Levee
Levee
Protected land
Lower levee
Higher levee
Protected land
Flooding
Levee
No Levees
When a free-flowing river floods, water jumps the river's banks and flows onto the floodplain.
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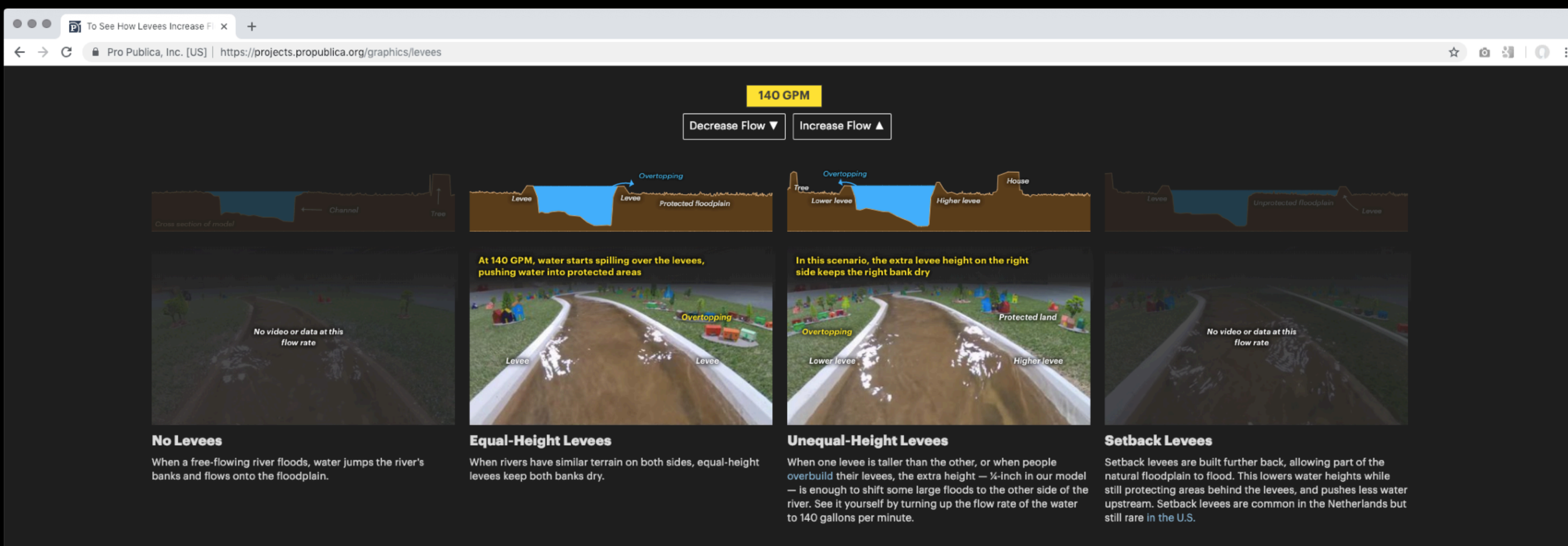

To See How Levees Increase F
Pro Publica, Inc. [US] | https://projects.propublica.org/graphics/levees
140 GPM
Decrease Flow ▼
Increase Flow ▲
Overtopping
Levee
Levee
Protected floodplain
Overtopping
Tree
Lower levee
Higher levee
House
No video or data at this flow rate
At 140 GPM, water starts spilling over the levees, pushing water into protected areas
Overtopping
Levee
Levee
In this scenario, the extra levee height on the right side keeps the right bank dry
Protected land
Overtopping
Lower levee
Higher levee
No video or data at this flow rate
No Levees
When a free-flowing river floods, water jumps the river's banks and flows onto the floodplain.
Equal-Height Levees
When rivers have similar terrain on both sides, equal-height levees keep both banks dry.
Unequal-Height Levees
When one levee is taller than the other, or when people overbuild their levees, the extra height — ¼-inch in our model — is enough to shift some large floods to the other side of the river. See it yourself by turning up the flow rate of the water to 140 gallons per minute.
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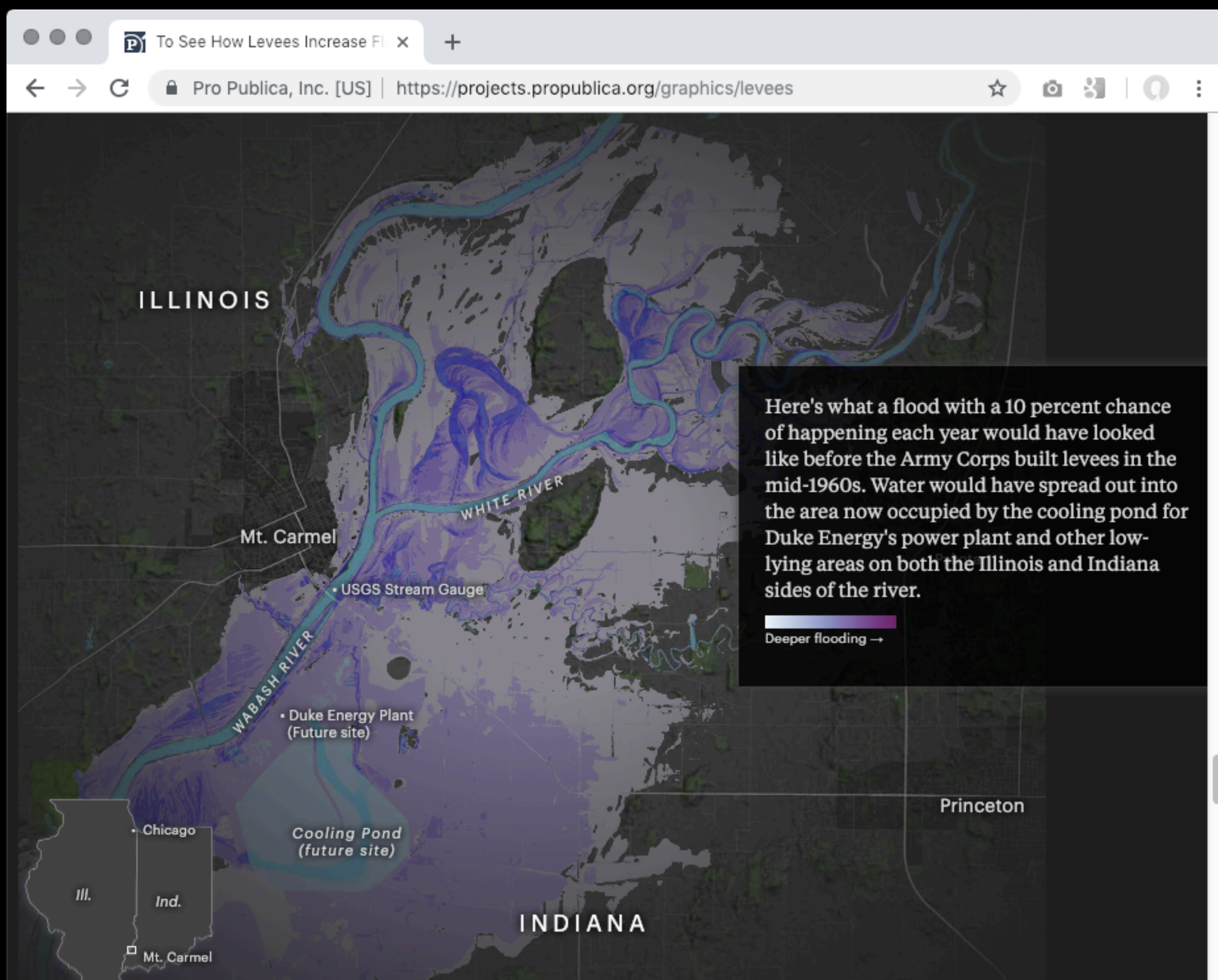
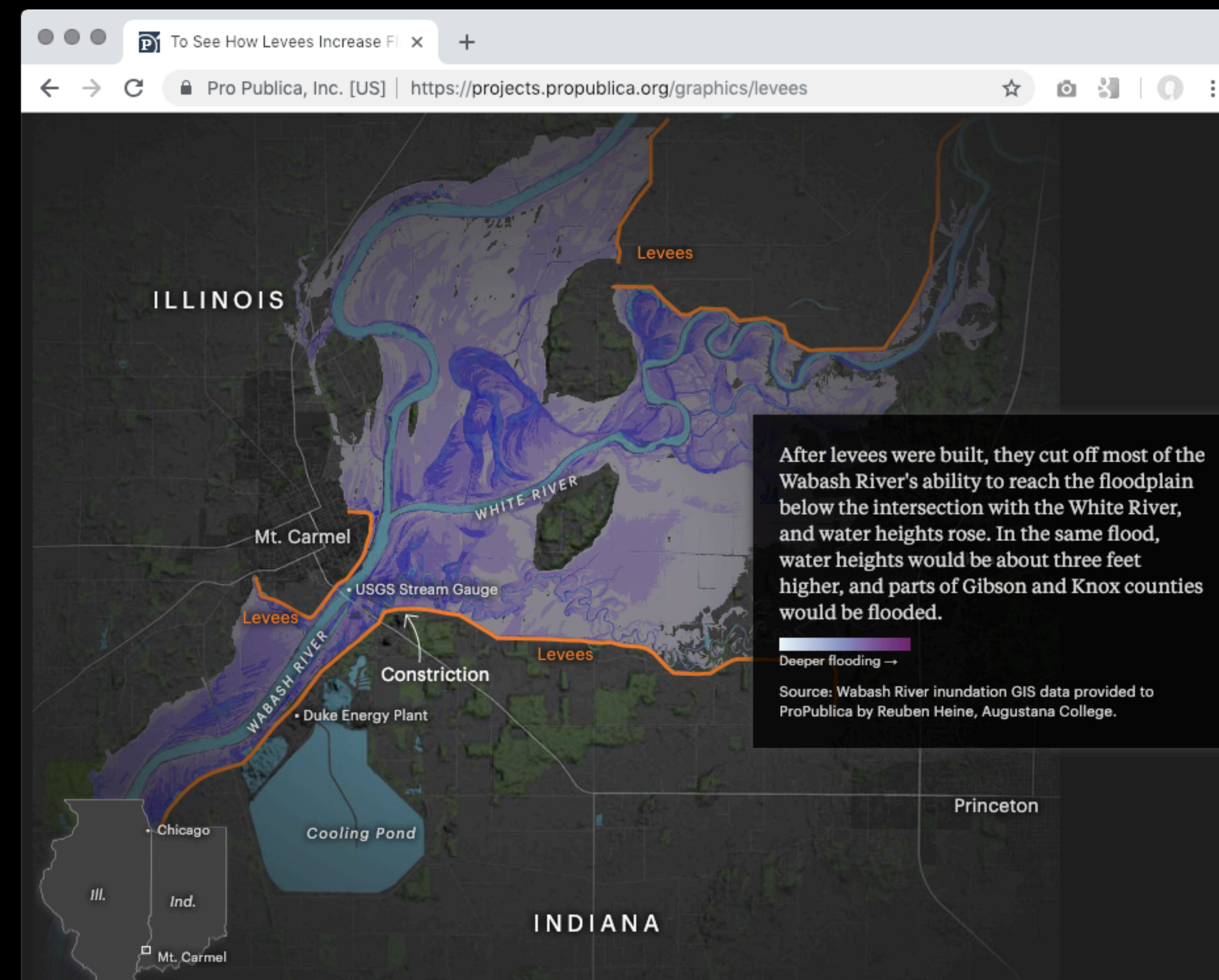
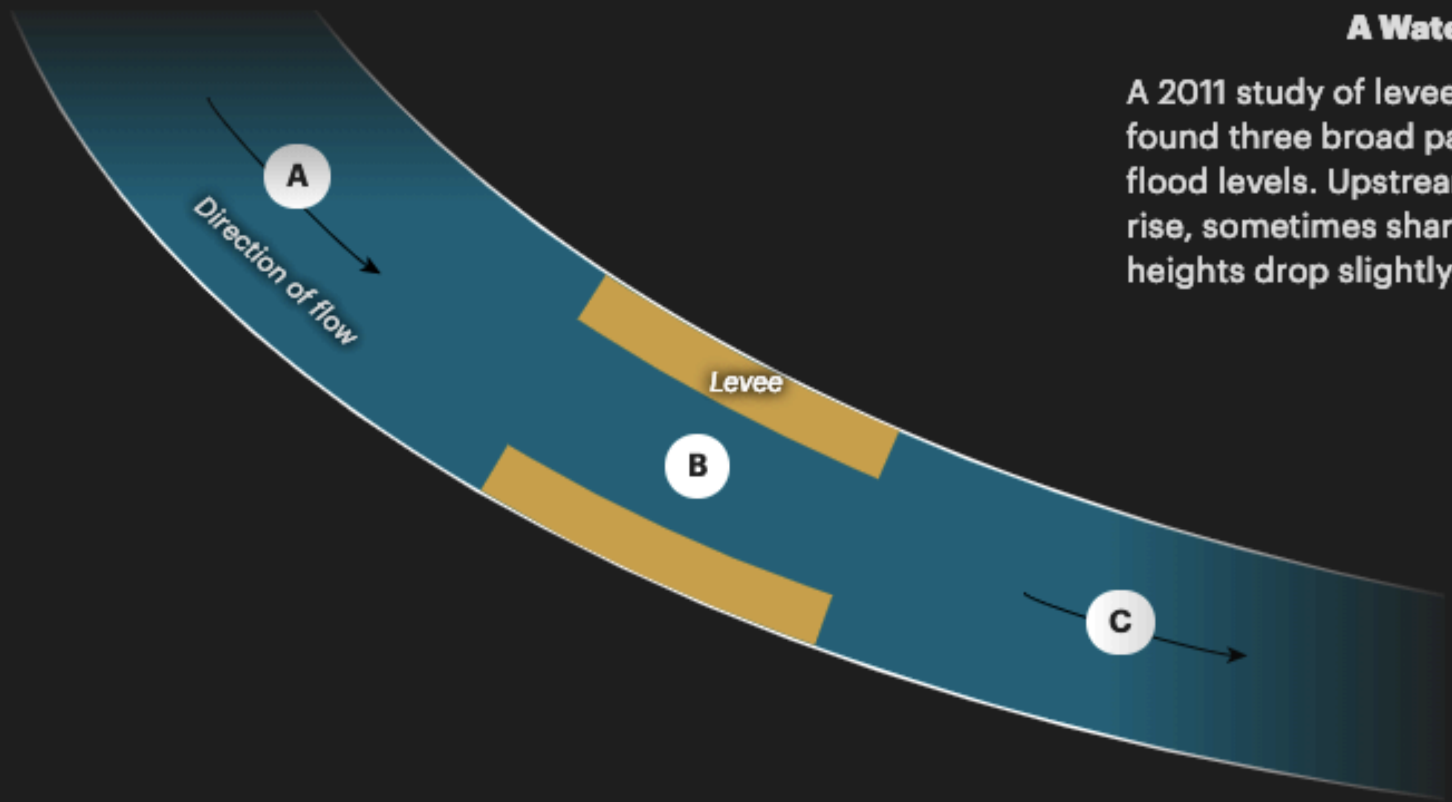


To See How Levees Increase F
Pro Publica, Inc. [US] | https://projects.propublica.org/graphics/levees
ILLINOIS
WHITE RIVER
Mt. Carmel
USGS Stream Gauge
WABASH RIVER
Duke Energy Plant
(Future site)
Cooling Pond
(future site)
Princeton
INDIANA
Chicago
Ill.
Ind.
Mt. Carmel
Here's what a flood with a 10 percent chance of happening each year would have looked like before the Army Corps built levees in the mid-1960s. Water would have spread out into the area now occupied by the cooling pond for Duke Energy's power plant and other low-lying areas on both the Illinois and Indiana sides of the river.
Deeper flooding →



To See How Levees Increase F
Pro Publica, Inc. [US] | https://projects.propublica.org/graphics/levees
ILLINOIS
Levees
WHITE RIVER
Mt. Carmel
USGS Stream Gauge
Levees
Levees
Constriction
WABASH RIVER
Duke Energy Plant
Cooling Pond
Princeton
INDIANA
Chicago
Ill.
Ind.
Mt. Carmel
After levees were built, they cut off most of the Wabash River's ability to reach the floodplain below the intersection with the White River, and water heights rose. In the same flood, water heights would be about three feet higher, and parts of Gibson and Knox counties would be flooded.
Deeper flooding →
Source: Wabash River inundation GIS data provided to ProPublica by Reuben Heine, Augustana College.

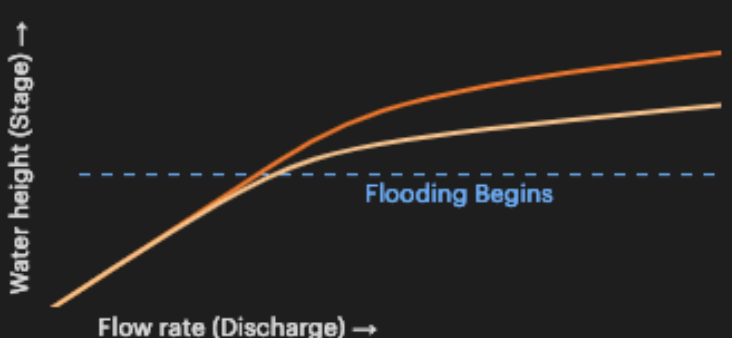


A Watery Traffic Jam

A 2011 study of levee systems in Iowa and Illinois found three broad patterns in how levees affect flood levels. Upstream from levees, water levels rise, sometimes sharply, while downstream, heights drop slightly.

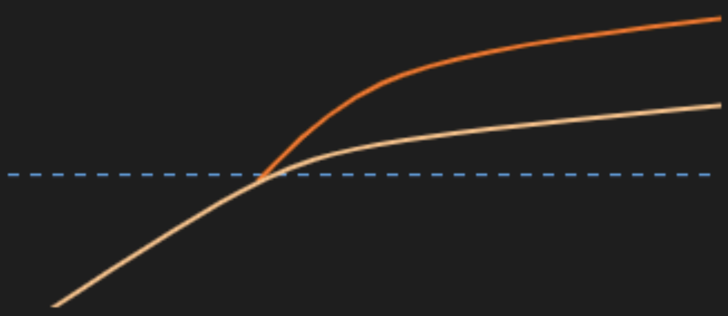
A Upstream of Levee

Because levees constrain rivers, water heights upstream of levees rise higher than they would without levees. One engineer compared it to a traffic jam.



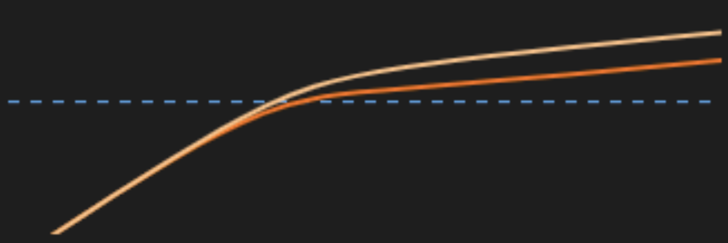
B Alongside the Levee

When the river floods, water heights alongside levees are pushed even higher than those upstream.

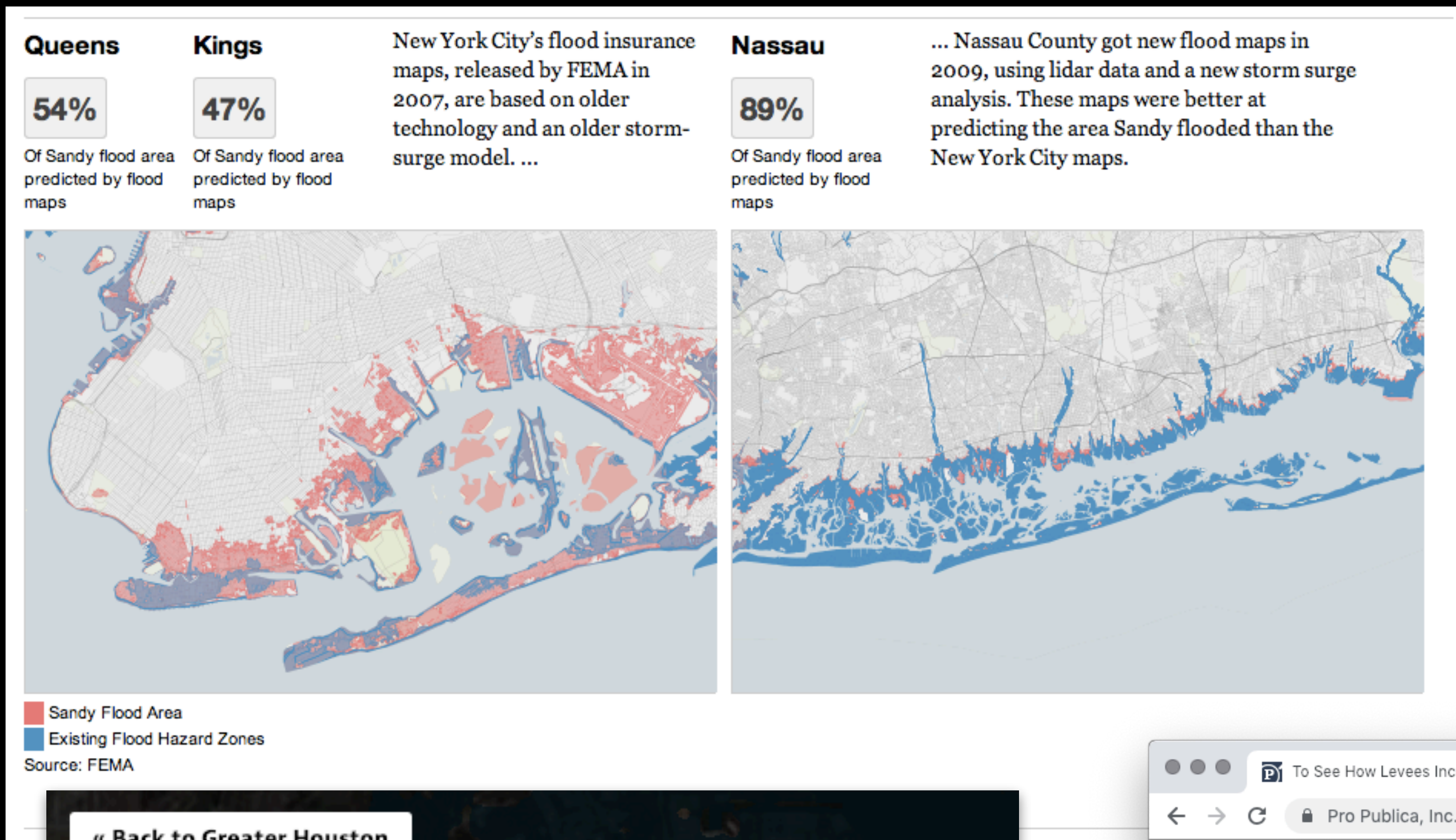


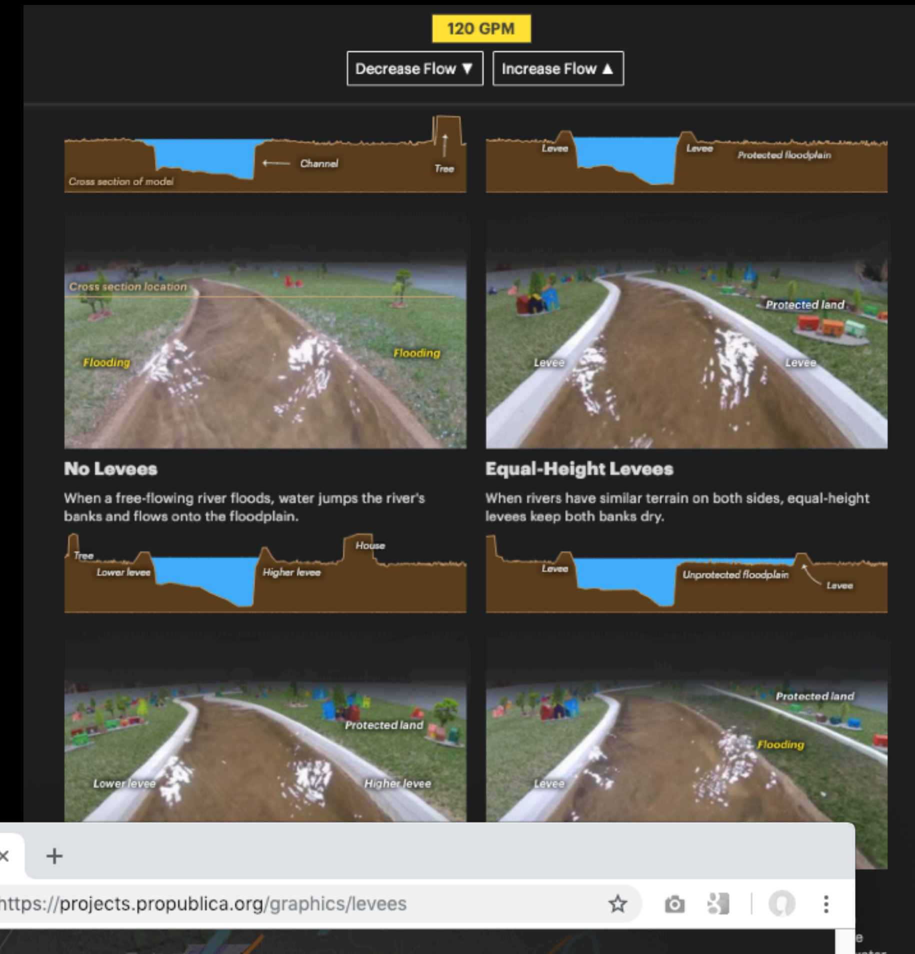
C Downstream of Levee

Downstream of a levee, water heights are a little lower because the water moves faster after being squeezed through levees.

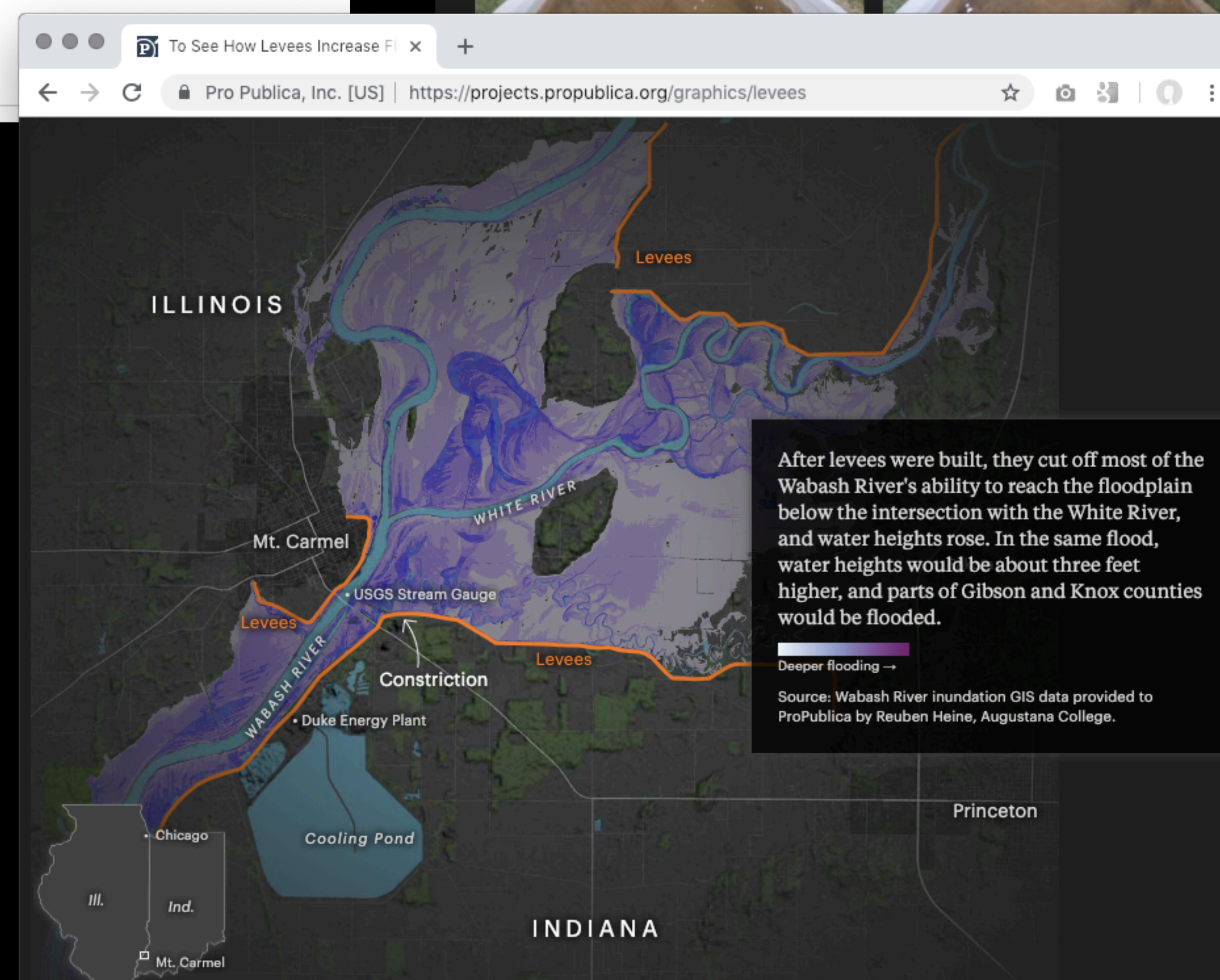


Source: Heine/Pinter, 2011


Queens
54%
Of Sandy flood area predicted by flood maps
Kings
47%
Of Sandy flood area predicted by flood maps
New York City's flood insurance maps, released by FEMA in 2007, are based on older technology and an older storm-surge model. ...
Nassau
89%
Of Sandy flood area predicted by flood maps
... Nassau County got new flood maps in 2009, using lidar data and a new storm surge analysis. These maps were better at predicting the area Sandy flooded than the New York City maps.
Sandy Flood Area
Existing Flood Hazard Zones
Source: FEMA


120 GPM
Decrease Flow ▼
Increase Flow ▲
Channel
Tree
Cross section of model
Levee
Protected floodplain
Cross section location
Flooding
Protected land
No Levees
When a free-flowing river floods, water jumps the river's banks and flows onto the floodplain.
Equal-Height Levees
When rivers have similar terrain on both sides, equal-height levees keep both banks dry.
House
Lower levee
Higher levee
Unprotected floodplain


« Back to Greater Houston
Seabrook
Johnson Space Center
I-45
League City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ILLINOIS
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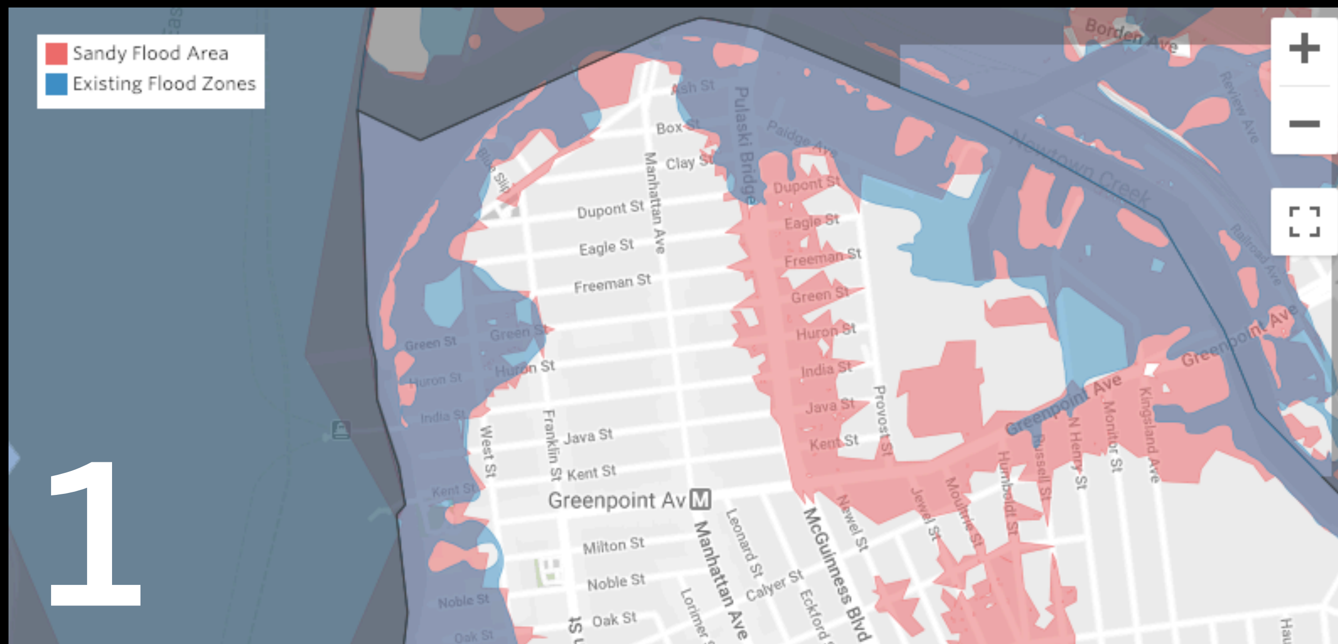
Sandy Flood Area
Existing Flood Zones
Box St
Clay St
Dupont St
Eagle St
Freeman St
Green St
Huron St
India St
Java St
Kent St
Greenpoint Av
Milton St
Noble St
Oak St
West St
Franklin St
Manhattan Ave
Pulaski Bridge
McGuinness Blvd
Provost St
Greenpoint Ave
Newtown Creek
Kingsland Ave
Monitor St
N Henry St
Russell St
Humboldt St
Leonard St
Calyer St
Eckford St
Lorimer St
Newel St
Jewel St
Moultrie St
Borden Ave
1


2
RESTORING PRAIRIES- CARBON SEQUESTION


3

Thank you!

¡Gracias!

al.shaw@propublica.org @A_L