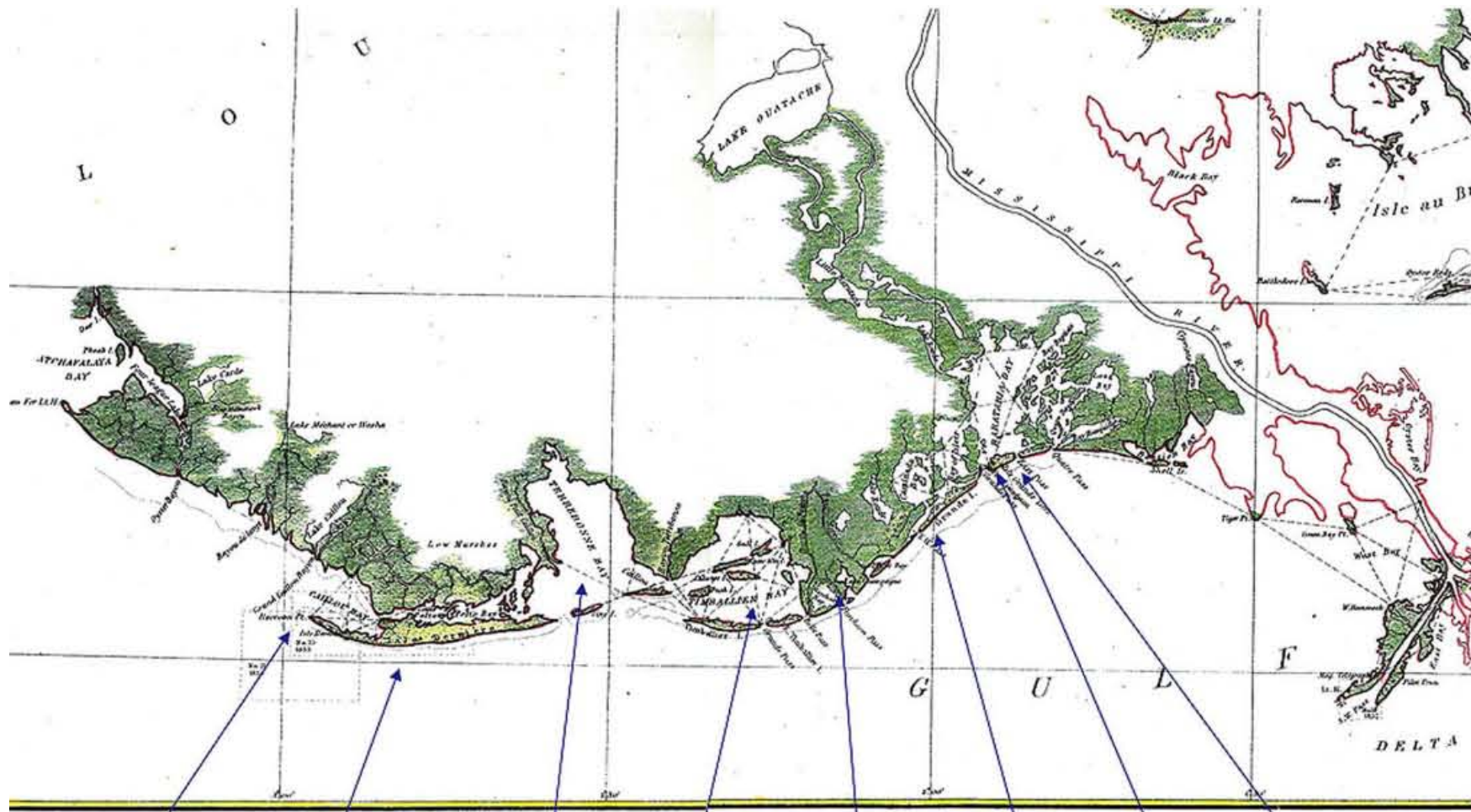


# Living on a Moving Coastal Landscape

Tim Osborn  
NOAA

Association of Levee Boards of Louisiana





Raccoon Point

Isle Derniere

Terrebonne Bay

Timbalier Bay

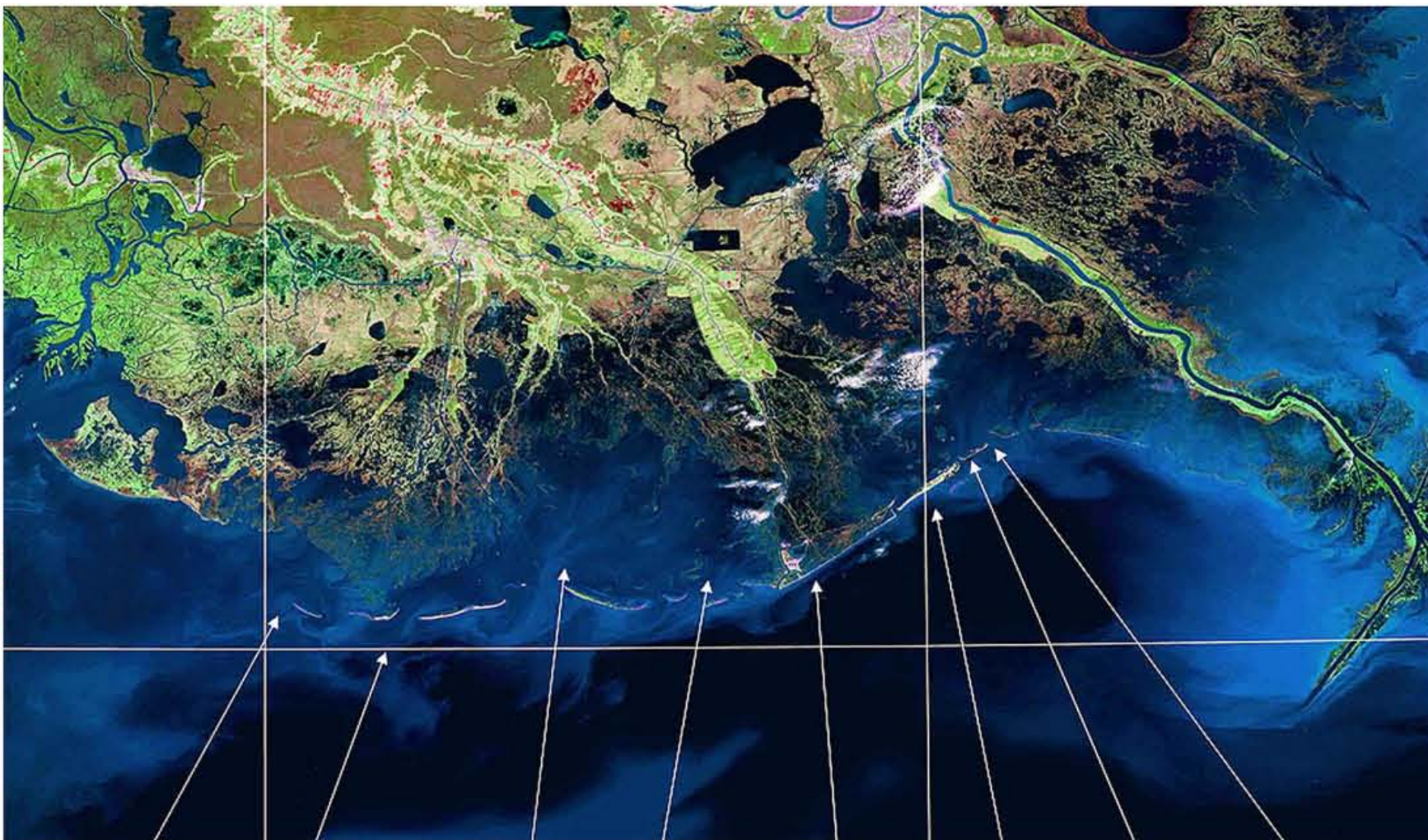
Fourchon

Grand Isle

Grand Terre

East Grand Terre





Raccoon  
Point

Isle Dernière

Terrebonne  
Bay

Timbalier  
Bay

Fourchon

Grand Isle

Grand Terre East Grand  
Terre



Standing on a Highway- Old Paris Road- St Bernard Parish





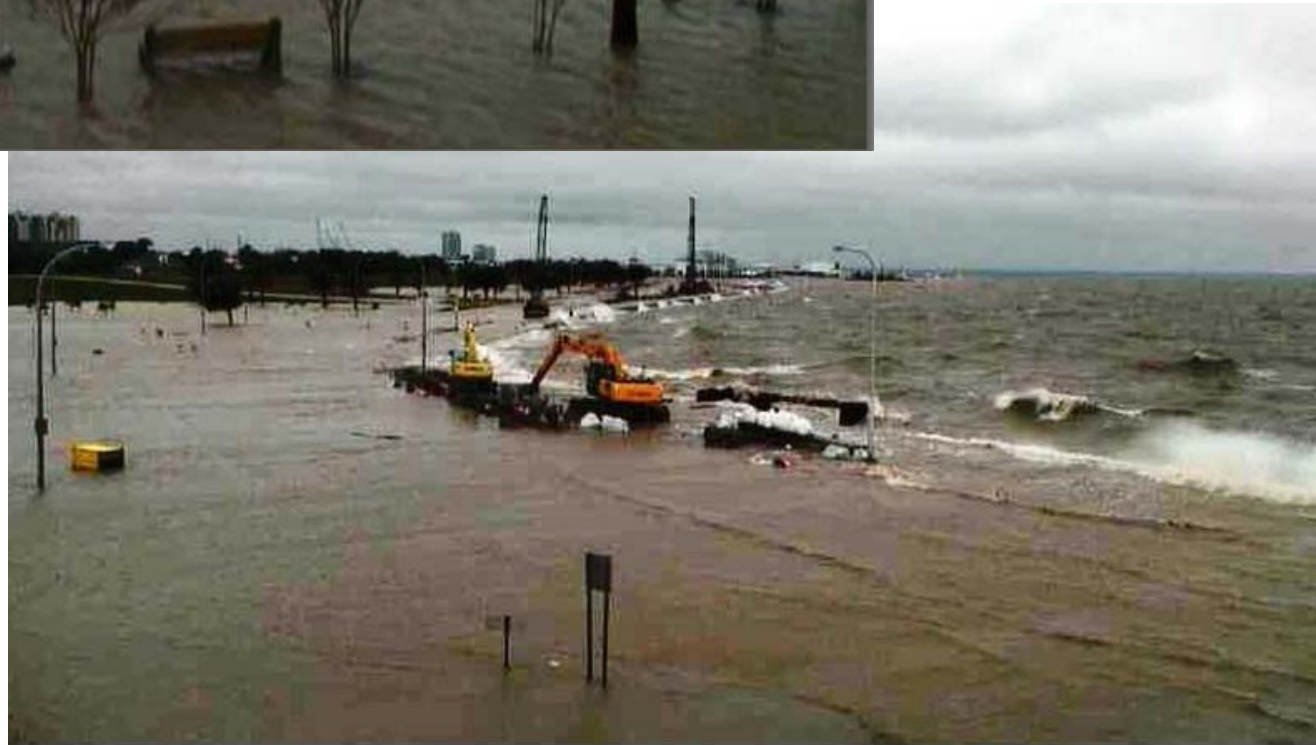
Abandoned Homes and  
Neighborhood in South  
Lafourche Parish from  
Sea Level Rise and  
Subsidence







Flooding of  
Lakeshore Drive  
here in New Orleans  
from a Cold Front  
early in 2014. The  
high tides and  
northerly winds of  
the Front overtopped  
and flooded the  
highway along the



# Annapolis, Baltimore lead nation for rise in flooding events

'Nuisance' events occurring 10 times more often than 50 years ago

Water rushes through a gate and onto South Caroline St. as water... (Al Drago, Baltimore Sun )

August 12, 2014|By Scott Dance, The Baltimore Sun

*Tuesday's flooding may have been extreme, but it wasn't unfamiliar for much of the region.*

*The low spots are well known: Compromise and Dock streets in Annapolis, Caroline and Thames streets in Fells Point. After a good rain and a high tide, they're under water.*

*For Maryland's two largest cities on the Chesapeake, flooding that once occurred just a day or two in any given year is increasingly common — more so than anywhere else in the country, according to a recent federal study.*




## Top ten U.S. areas with an increase nuisance flooding\*

	"Nuisance level": Meters above mean higher high water mark	Average nuisance flood days, 1957-1963	Average nuisance flood days, 2007-2013	Percent Increase
Annapolis, Md.	0.29	3.8	39.3	925
Baltimore, Md.	0.41	1.3	13.1	922
Atlantic City, N.J.	0.43	3.1	24.6	682
Philadelphia, Pa.	0.49	1.6	12.0	650
Sandy Hook, N.J.	0.45	3.3	23.9	626
Port Isabel, Texas	0.34	2.1	13.9	547
Charleston, S.C.	0.38	4.6	23.3	409
Washington, D.C.	0.31	6.3	29.7	373
San Francisco, Calif.	0.35	2.0	9.3	364
Norfolk, Va.	0.53	1.7	7.3	325

\* More than one flood on average between 1957-1963, and for nuisance levels above 0.25 meters.

NOAA HOME WEATHER OCEANS FISHERIES CHARTING SATELLITES CLIMATE RESEARCH COASTS CAREERS

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UNITED STATES DEPARTMENT OF COMMERCE

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## NOAA: 'Nuisance flooding' an increasing problem as coastal sea levels rise

Study looks at more than 60 years of coastal water level and local elevation data changes

July 28, 2014

Eight of the top 10 U.S. cities that have seen an increase in so-called "nuisance flooding"—which causes such public inconveniences as frequent road closures, overwhelmed storm drains and compromised infrastructure—are on the East Coast, according to a new NOAA technical report.

This nuisance flooding, caused by rising sea levels, has increased on all three U.S. coasts, between 300 and 925 percent since the 1960s.

The report, [Sea Level Rise and Nuisance Flood Frequency Changes around the United States](#), also finds Annapolis and Baltimore, Maryland, lead the list with an increase in number of flood days of more than 920 percent since 1960. Port Isabel, Texas, along the Gulf coast, showed an increase of 547 percent, and nuisance flood days in San Francisco, California increased 364 percent.

"Achieving resilience requires understanding environmental threats and vulnerabilities to combat issues like sea level rise," says Holly Bamford, Ph.D., NOAA assistant administrator of the National Ocean Service. "The nuisance flood study provides the kind of actionable environmental intelligence that can guide coastal resilience efforts."

"As relative sea level increases, it no longer takes a strong storm or a hurricane to cause flooding," said William Sweet, Ph.D., oceanographer at NOAA's [Center for Operational Oceanographic Products and Services \(CO-OPS\)](#) and the report's lead author. "Flooding now occurs with high tides in many locations due to climate-related sea level rise, land subsidence and the loss of natural barriers. The effects of rising sea levels along most of the continental U.S. coastline are only going to become more noticeable and much more severe in the coming decades, probably more so than any other climate-change related factor."

The study was conducted by scientists at CO-OPS, who looked at data from 45 [NOAA water level gauges](#) with long data records around the country and compared that to reports of number of days of nuisance floods.



Annapolis, Maryland, pictured here in 2012, saw the greatest increase in nuisance flooding in a recent NOAA study. (Credit: With permission from Amy McGovern.)

# New Orleans Area Map



Floodwall Along Mississippi River

A

23 FT

18 FT Project Flowline

Avg Annual Highwater 14 FT

Hurricane Protection Levee & Floodwall

B

17.5 FT

SPH Design Elevation 11.5 FT

Normal Lake 1.0 FT Level

Gentilly Ridge

Elevations in Feet NGVD

Mississippi River Bank

Canal St. at River

St. Louis Cathedral

Esplanade at St. Claude

Derbigny at I-10

Gentilly Blvd. at Allen

Dillard Univ. Campus

St. Anthony at Wildair Dr.

Wainright Dr. at L.C. Simon

UNO Side of Wainright Dr

Lake Pontchartrain Shoreline

## City of New Orleans Ground Elevations

From Canal St. at the Mississippi River to the Lakefront at U.N.O.



# The National Geographic Magazine

AN ILLUSTRATED MONTHLY



Editor: JOHN MYDE

Associate Editors:

A. W. GREELY

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C. HART MERRIAM

ELIZA HONAMAN GIDMORE

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WASHINGTON

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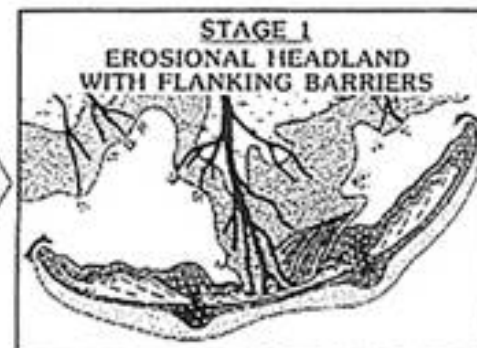
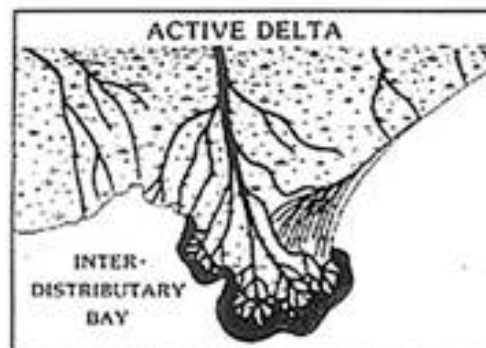
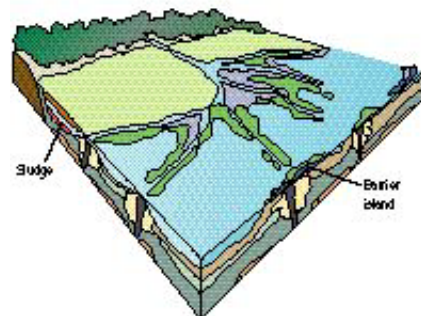
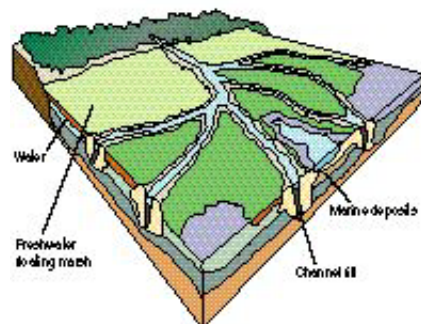
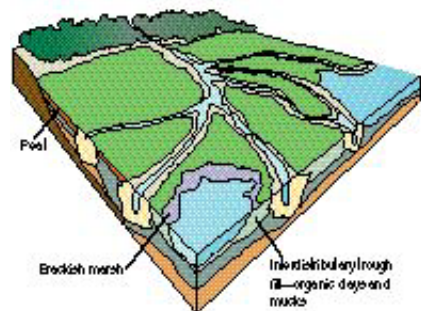
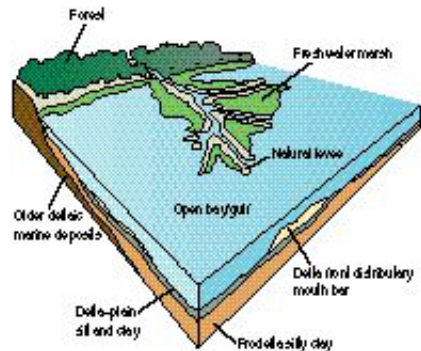
The geology of the delta of the Mississippi is an interesting local study. The effect of the withholding by the levees from the great areas of the delta of the annual contributions of sedimentary matters, and the steady, though slow, subsidence of these areas, is one which should be taken into account in deciding the important question of how to protect the people from the flood waters of the river. No doubt the great benefit to the present and two or three following generations accruing from a complete system of absolutely protective levees, excluding the flood waters entirely from the great areas of the lower delta country, far outweighs the disadvantages to future generations from the subsidence of the Gulf delta lands below the level of the sea and their gradual abandonment due to this cause. While it would be generally conceded that the present generation should not be selfish, yet it is safe to say that the development of the delta country during the twentieth century by a fully protective levee system, at whatever cost to the riparian states and the Federal Government, will be so remarkable that people of the whole United States can well afford, when the time comes, to build a protective levee against the Gulf waters, as the city of New Orleans has done on a small scale against the sea waters of Lake Pontchartrain, and as Holland has done for centuries and is now about to do on a still larger scale, in removing the sea waters themselves in the great projected reclamation of the lands submerged by the Zuyder Zee. Mr. Esch once said, in an eloquent speech on the subject of the imporation of the Mississippi river and its delta channels to the sea: "This giant stream, with its head shrouded in Arctic snows and embracing half a continent in the hundred thousand miles of its curious network, and coursing its majestic way to the southern Gulf through lands so fertile that human ingenuity is overtaken in harness their productiveness, has been given by its immortal Architect into the jealous keeping of this Republic."

## THE ANNEXATION FEVER

A curious and interesting example of the survival of inherited traits, on a large scale, is seen in the instinct for the acquisition of territory, which is manifested by all nations, savage or civilized, in greater or less degree.

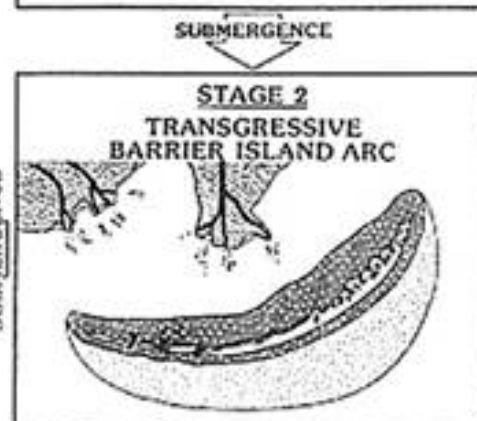
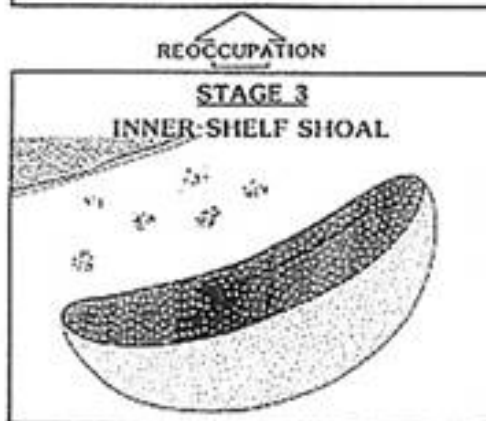
In the olden time, when the earth was peopled by savages, the acquisition of territory by conquest involved not alone the

1897—"The effects of the withholding by the levees from the great areas of the delta of the annual contribution of sedimentary matters and the steady, though slow, subsidence of the theses areas, is one which should be taken in account in deciding the important question of how to protect the people from the flood waters of the river....No doubt the great benefit to the present and two or three following generations accruing from a complete system of absolutely protective levees...*far outweighs the disadvantages to future generations from the subsidence of the Gulf delta lands below the level of the sea and their gradual abandonment due to this cause...*"



ABANDONMENT

SUBMERGENCE



SUBMERGENCE

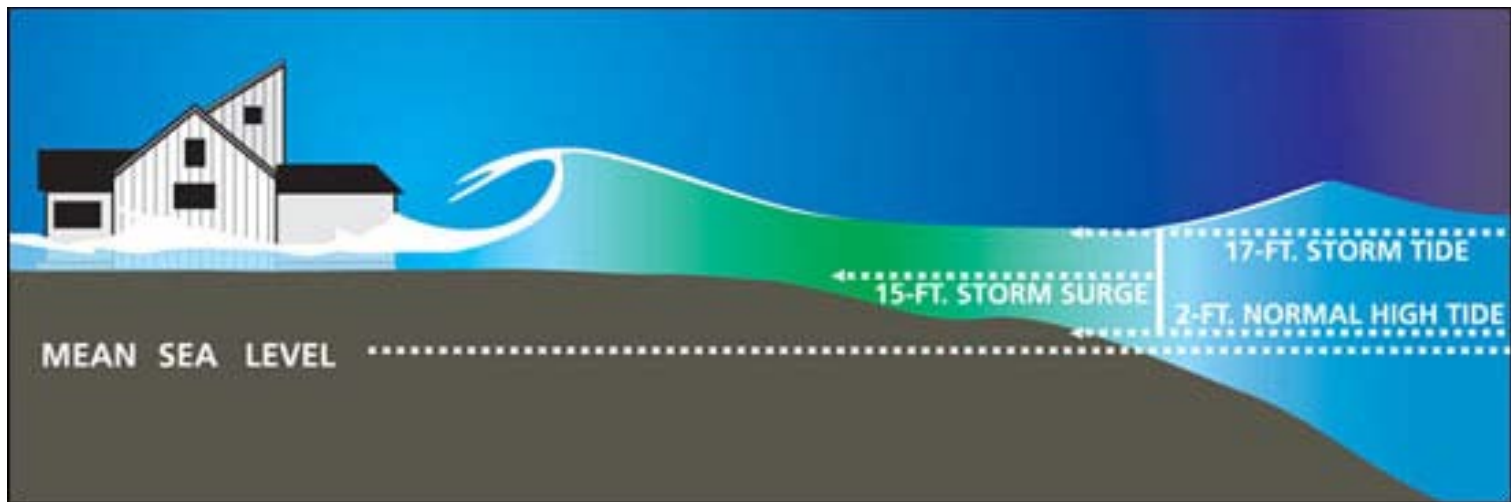
#### REGRESSIVE ENVIRONMENTS

- Distributary
- Fresh Marsh
- Beach Ridge

#### TRANSGRESSIVE ENVIRONMENTS

- Subaerial Barrier Sands
- Subaqueous Barrier Sands
- Sand Sheet
- Salt Marsh
- Recurved Spit
- Shell Reef
- Tidal Channel





Venice, LA, still with at least two to three feet of water two weeks after Hurricane Katrina's storm surge - 2005

# Another Very Large Impact Source





# Result of Cumulative Impact of Storm Tide and Waves

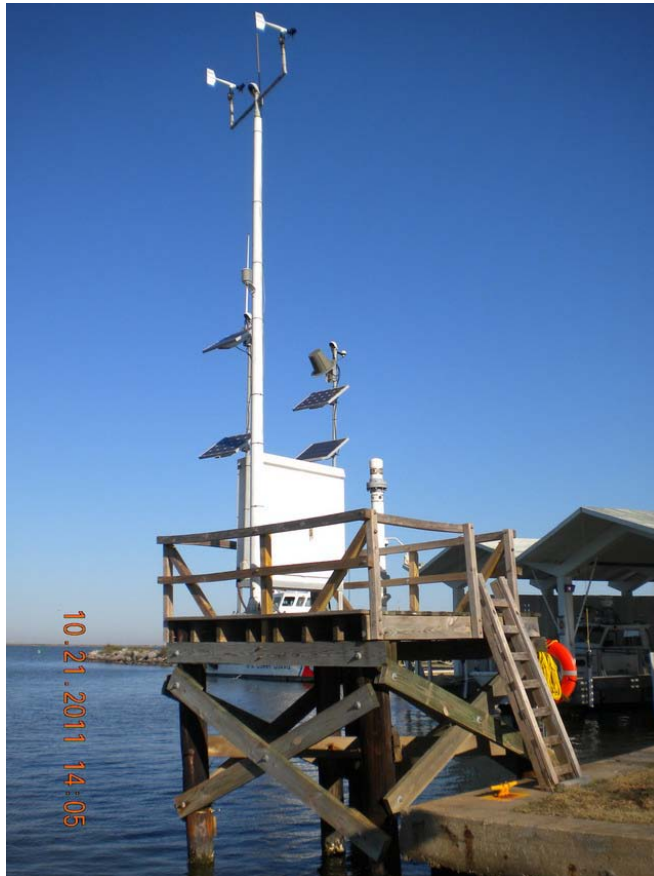


# Storm Tide and Waves Working Together and Separately

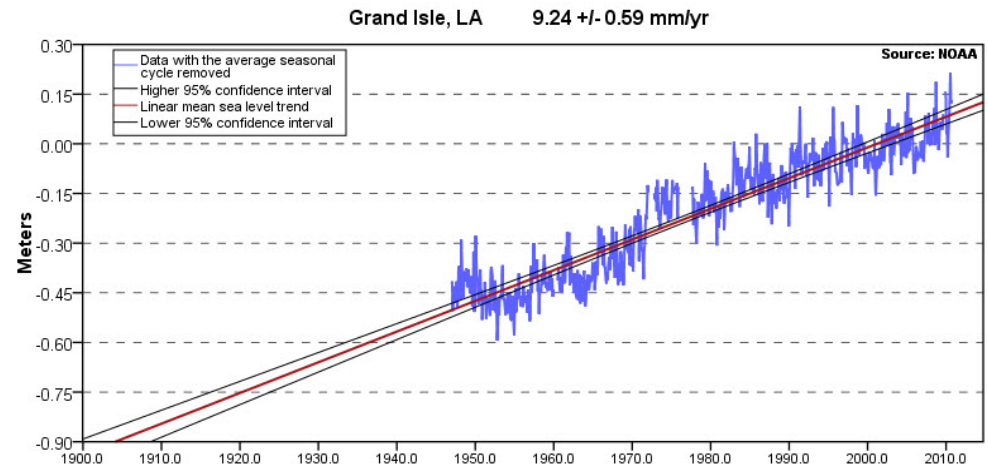




# Sea Level in Louisiana is Rising Relative to the Land at a Rapid Rate



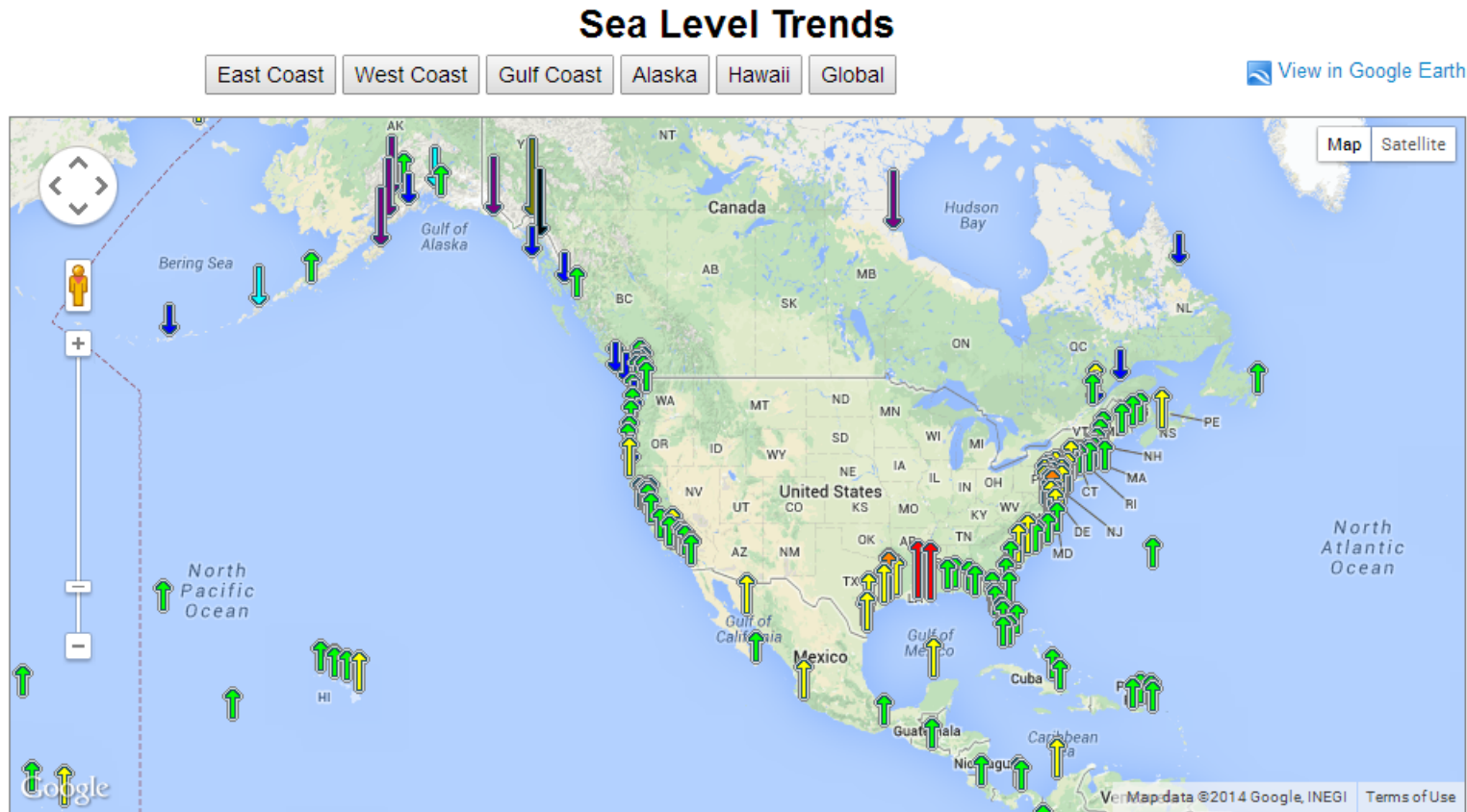
Mean Sea Level Trend  
8761724 Grand Isle, Louisiana



The mean sea level trend is 9.24 millimeters/year with a 95% confidence interval of +/- 0.59 mm/yr based on monthly mean sea level data from 1947 to 2006 which is equivalent to a change of 3.03 feet in 100 years.

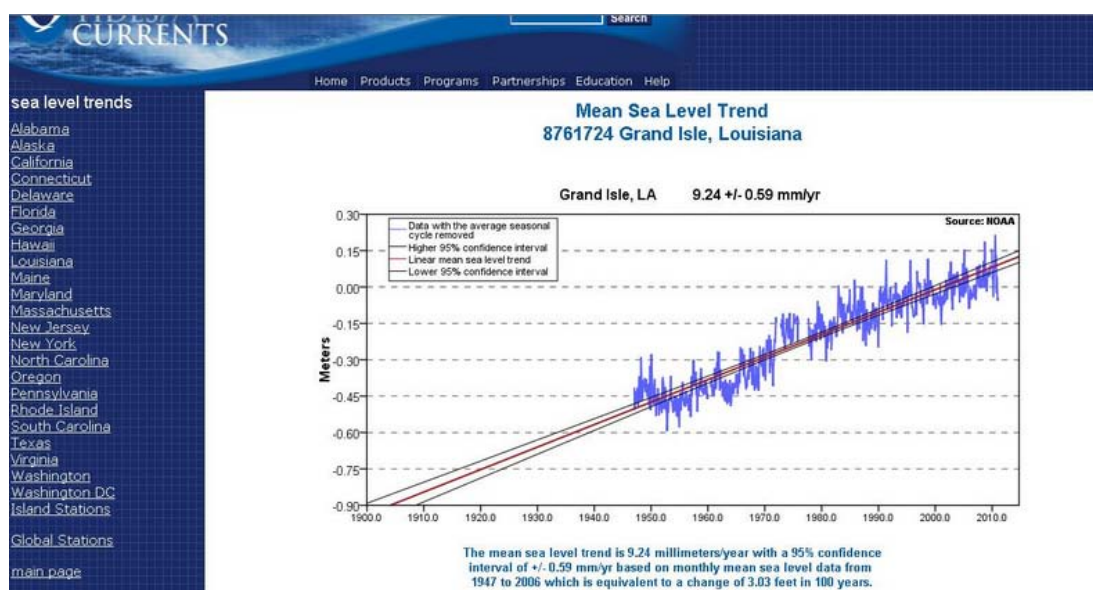
**Note: The tide gauge record at Grand Isle contains components of global sea level rise, regional oceanographic change, and regional local vertical land motion.**

# NOAA's Resources in the Measuring and Reporting of Sea Level Rise Trends is a National Effort Joined into an International Collaboration to Observe and Report on Sea Level Trends

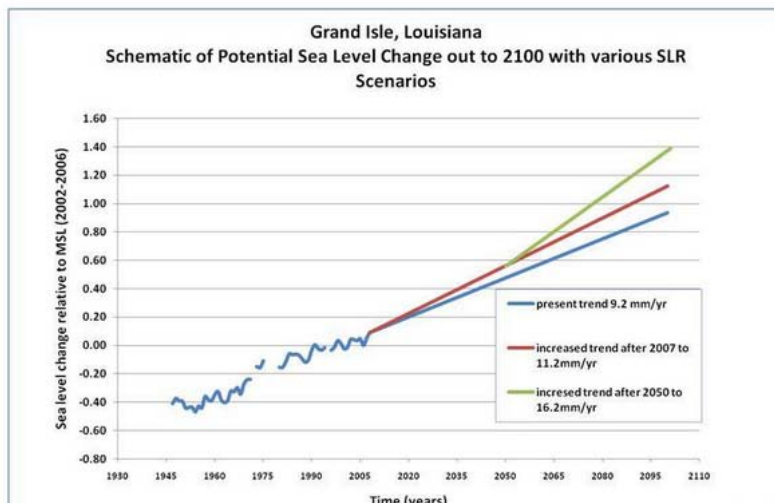


The map above illustrates regional trends in sea level, with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.





Present Trends Shown with Two Possible Trend Increases that Both NOAA and USACE have Reported for the Grand Isle and SE Louisiana Area



ER 1100-2-8162  
31 Dec 13

USACE: Sea Level Trends and Analysis for Grand Isle and SE Coastal Louisiana. Rates Resulting in a to 8.9 Feet of Relative Sea Level Rise by 2112 for SE Coastal Louisiana including Terrebonne, Lafourche, Orleans, Plaquemine, Jefferson and others

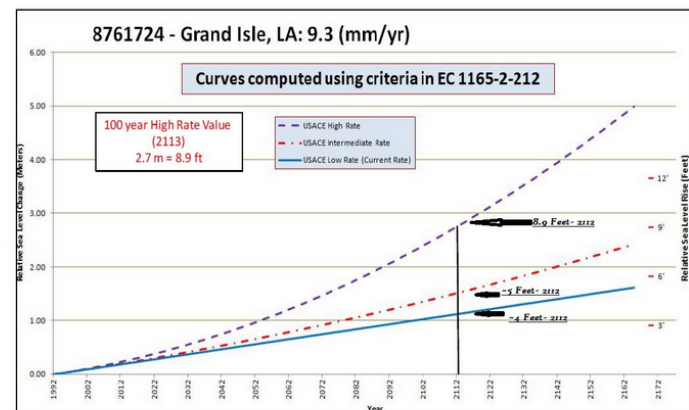
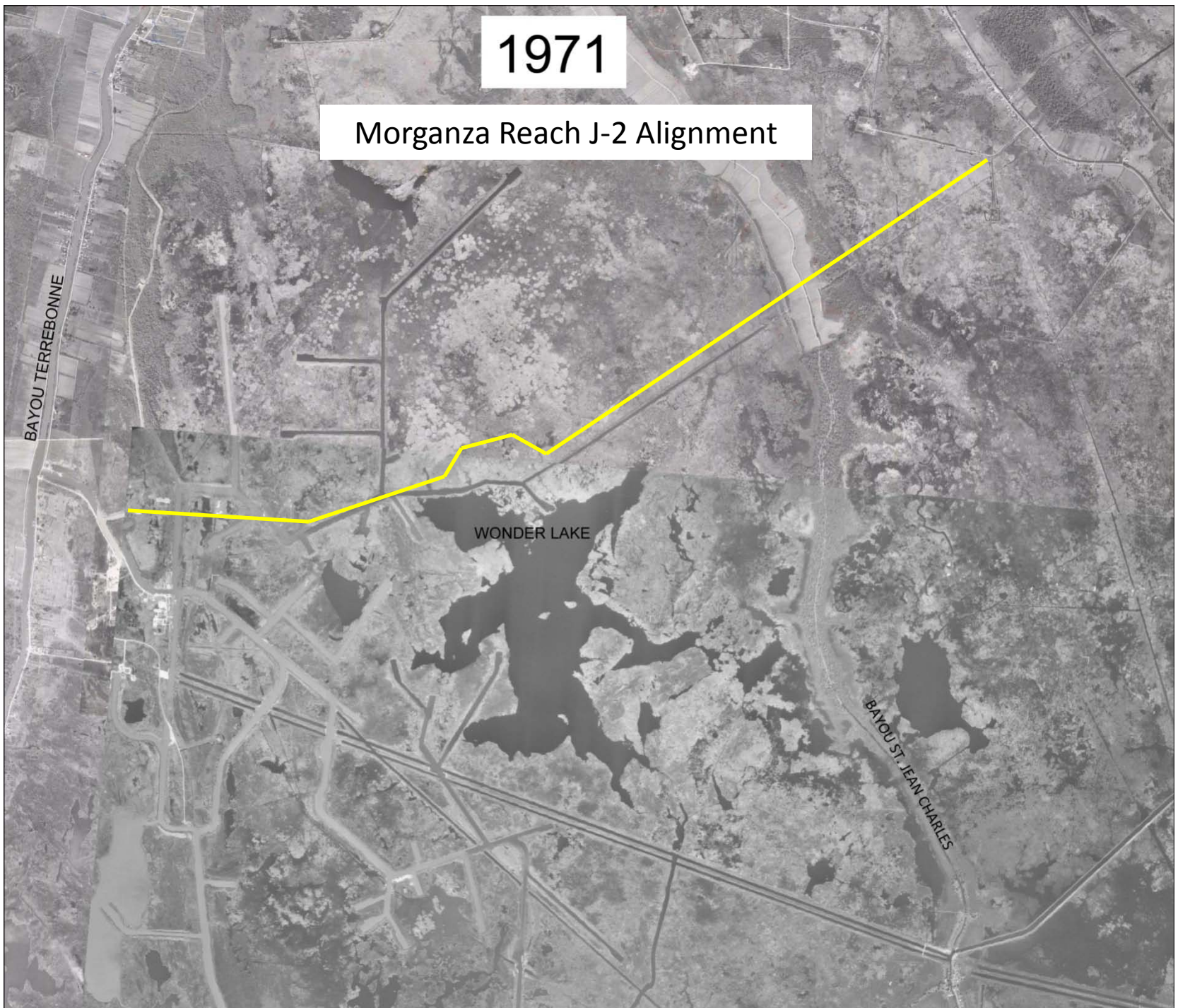


Figure B-10. Example USACE SLC curves for Grand Isle, Louisiana.

1971

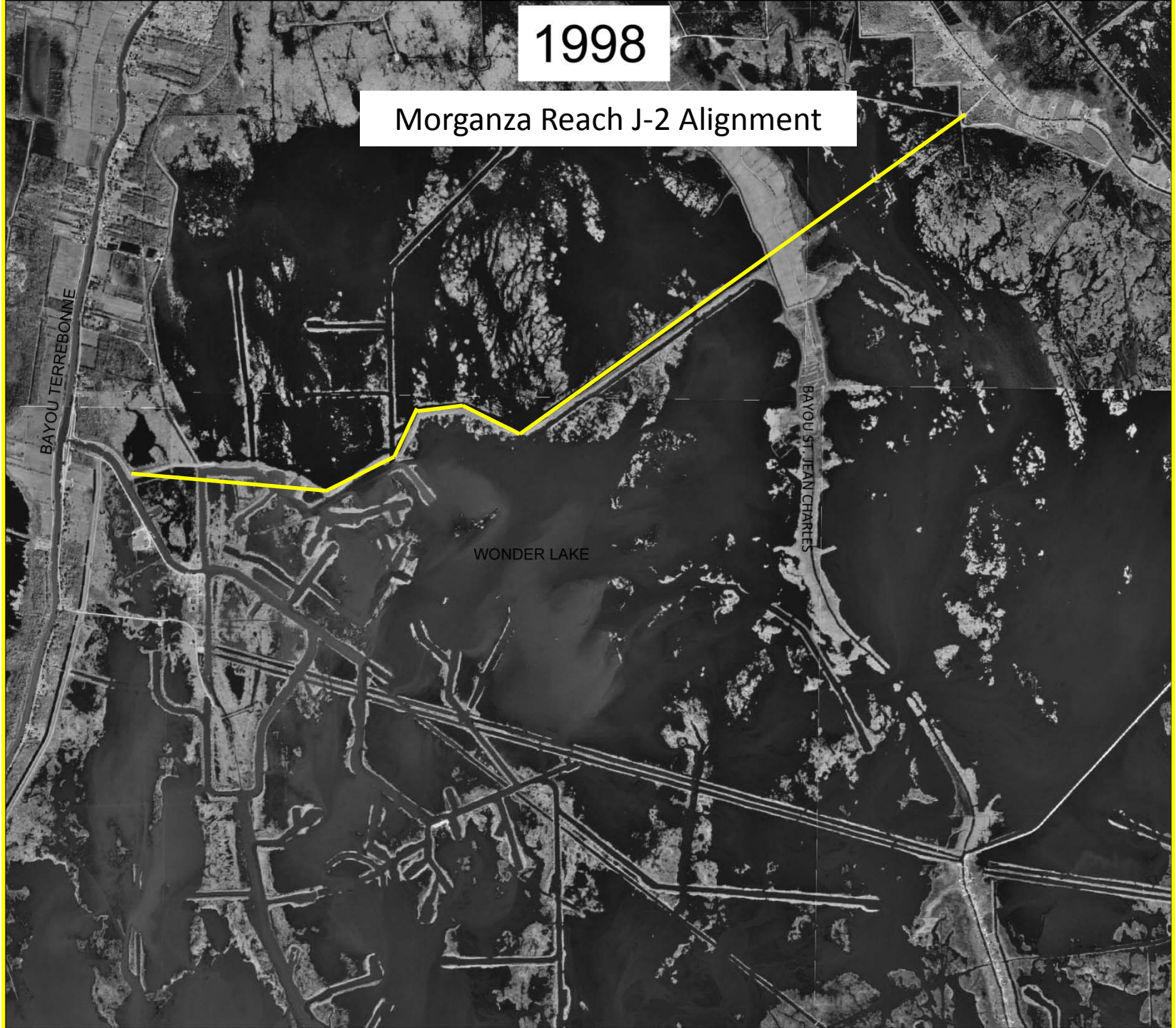
Morganza Reach J-2 Alignment





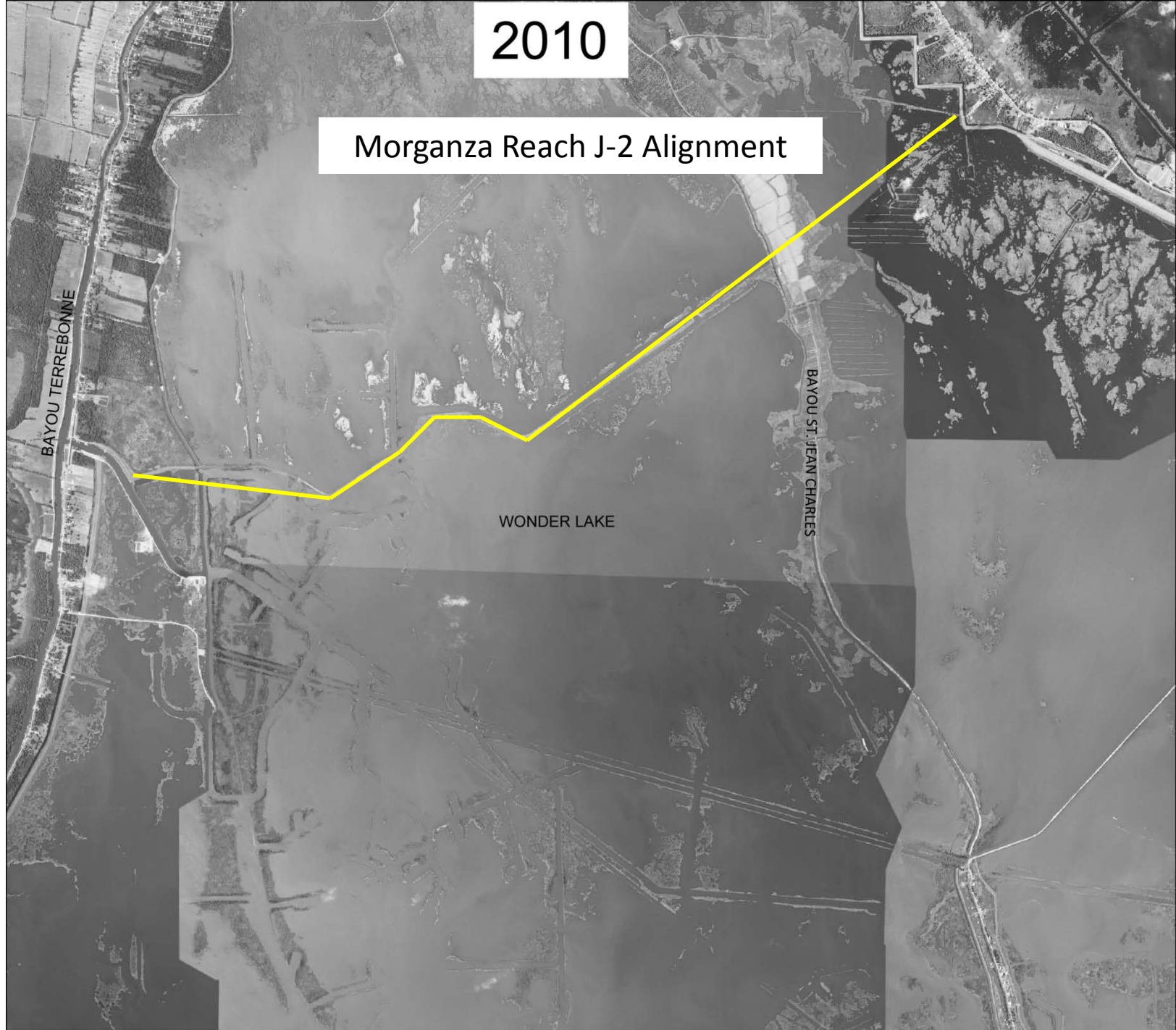
1998

Morganza Reach J-2 Alignment



2010

Morganza Reach J-2 Alignment







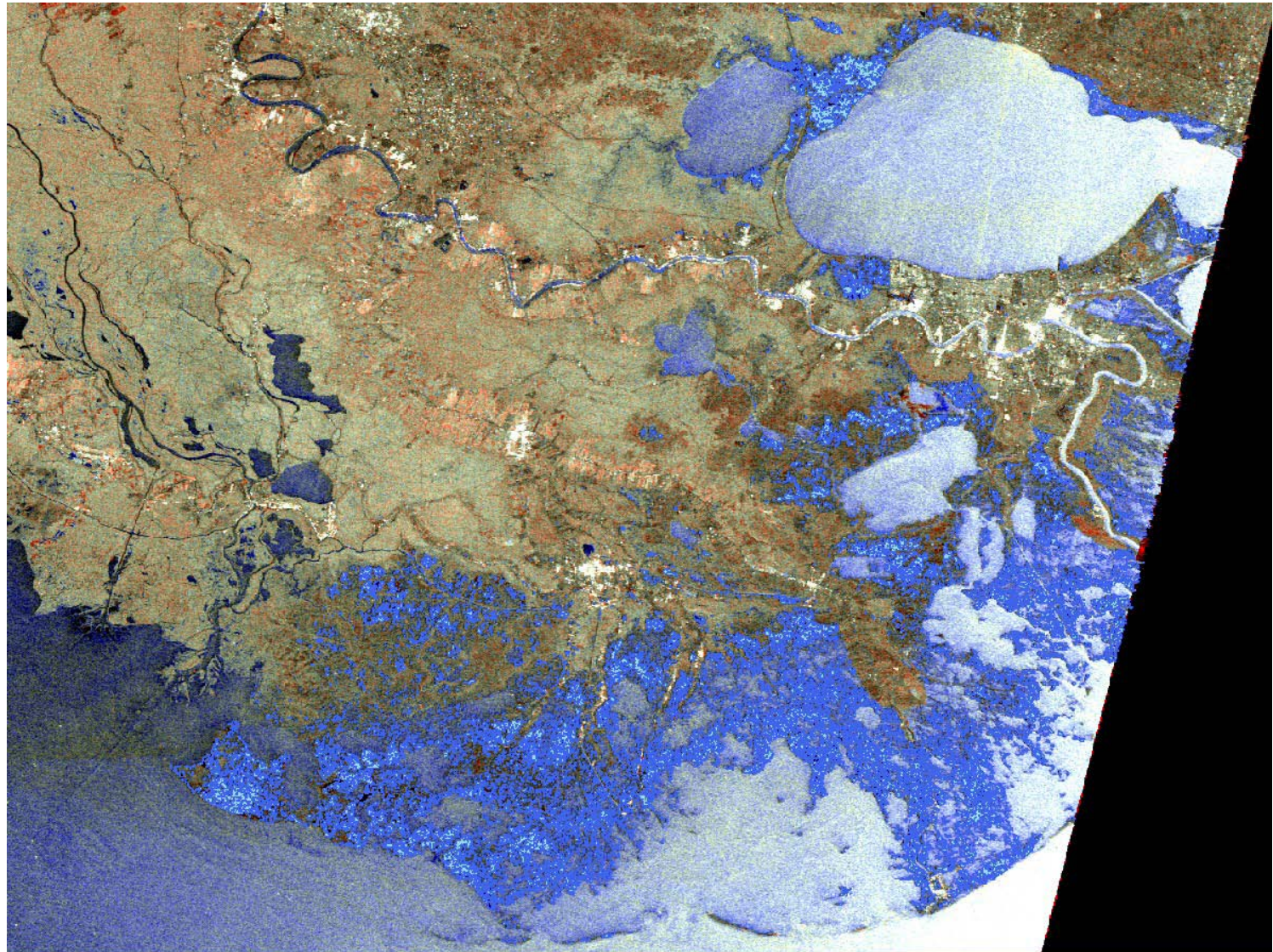
Interior of Caminada  
Headland and Open  
Water



Caminada Headland Inundated by  
Tropical System, July 2010



# Hurricane Ike Flooding Eastern Louisiana

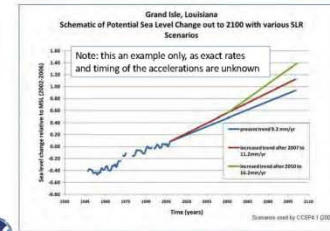




St Charles Parish— Bayou Gauche Area— Flooding of the Main Road and Home Areas by High Tides. With 9.24mm of Relative SLR Yearly— Submergence of this Area is Rapid



Climate models project acceleration in Sea Level Rise starting before 2100 due to climate change- Many Areas through SE Coastal Louisiana See High Rates Now In Excess of 10mm





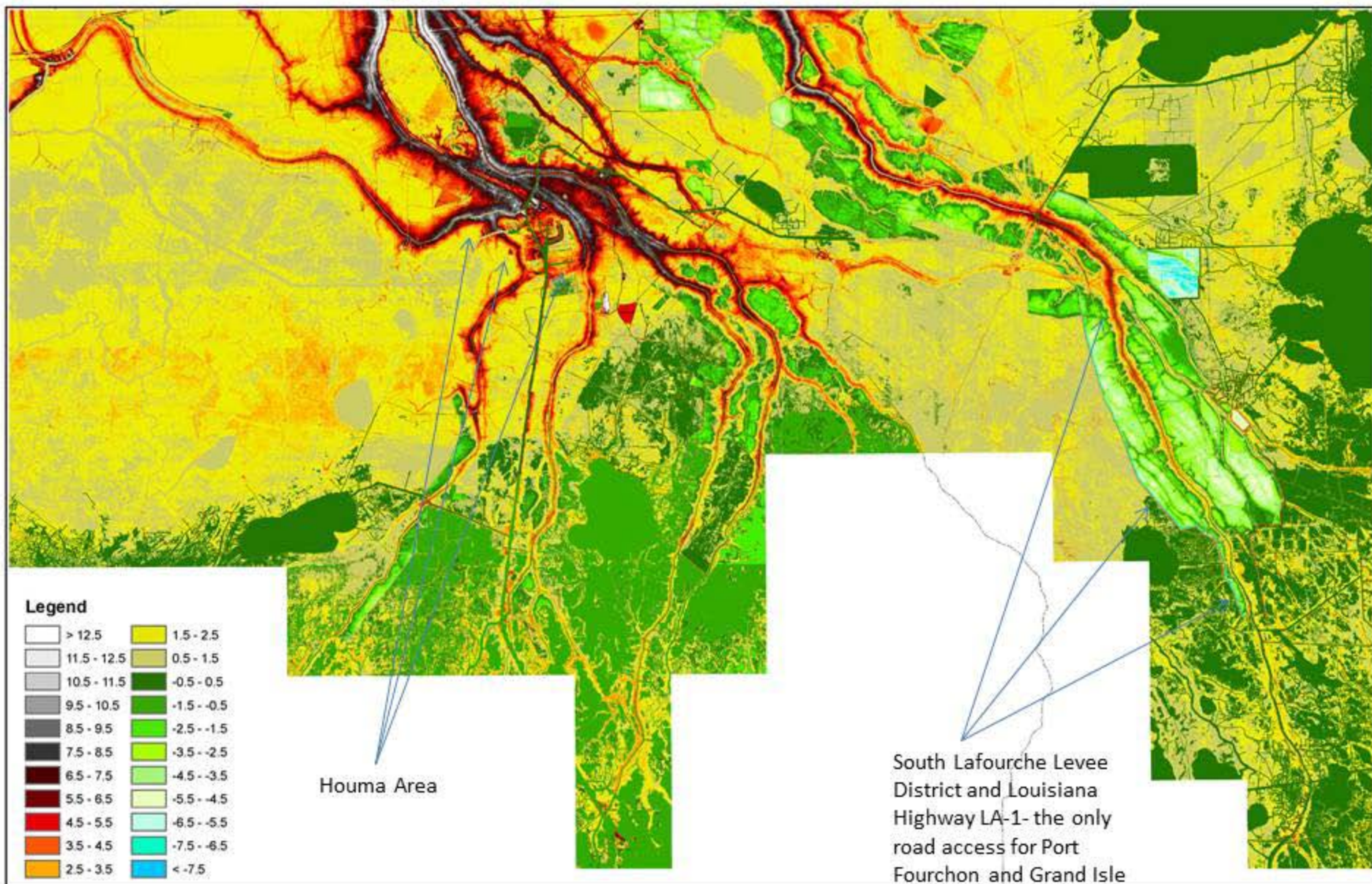
## Living in a Basin

*Adaptation will be second nature, as the region, the place which President Jefferson referred to as the "Island of New Orleans," becomes a true delta city.*





# LIDAR Elevation Imagery over Terrebonne and South Lafourche Parishes, Louisiana

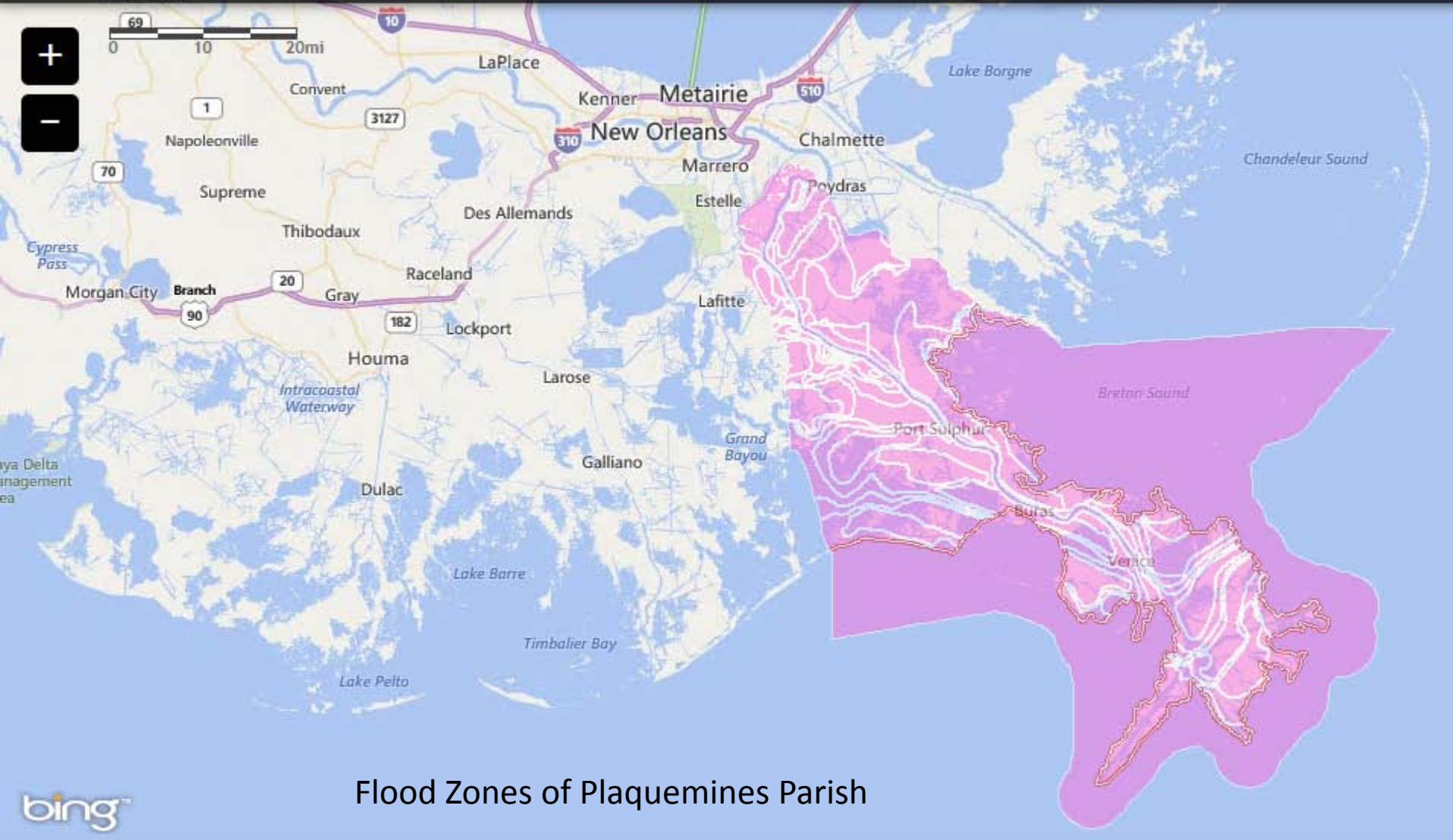
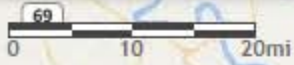




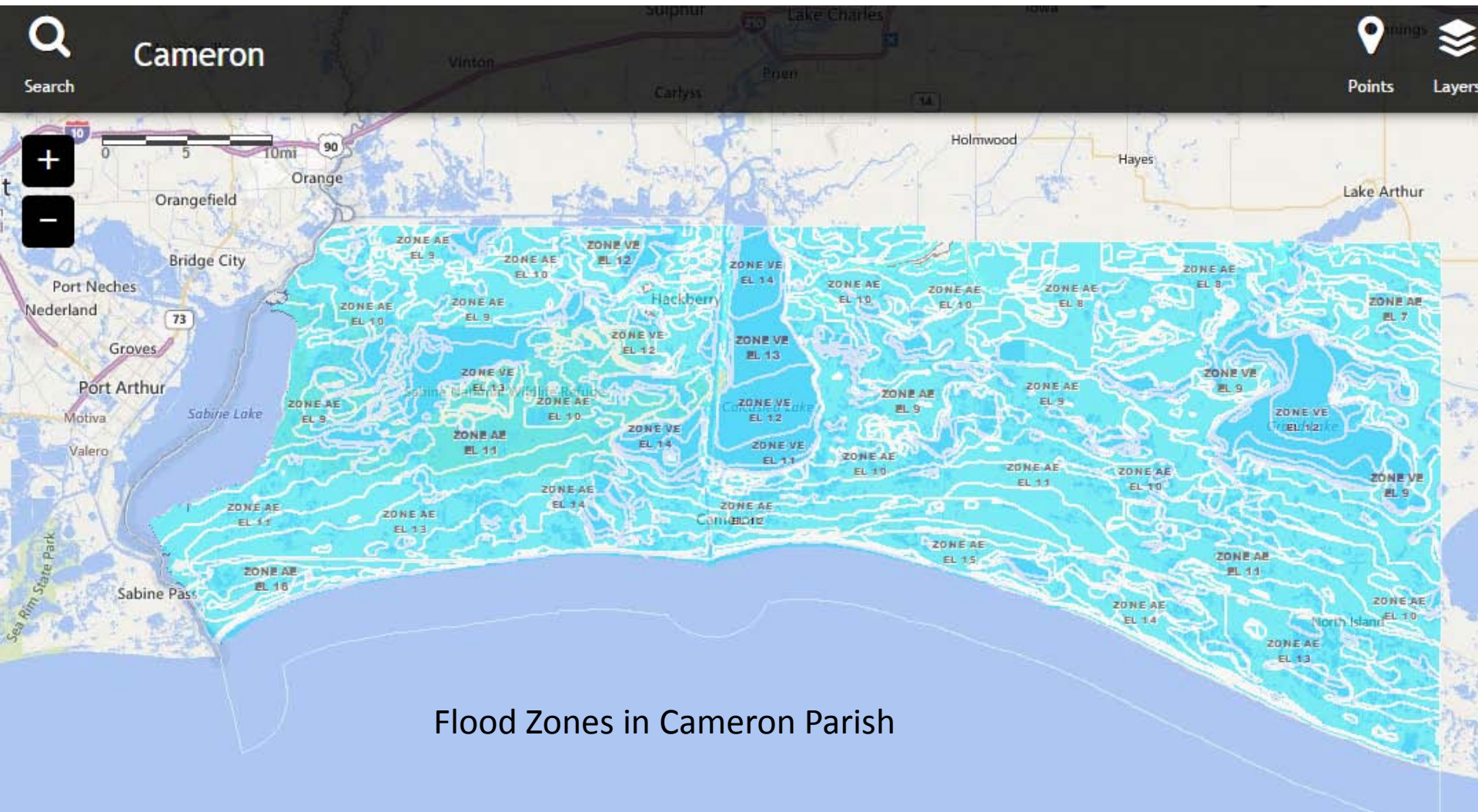


Plaquemines

Search



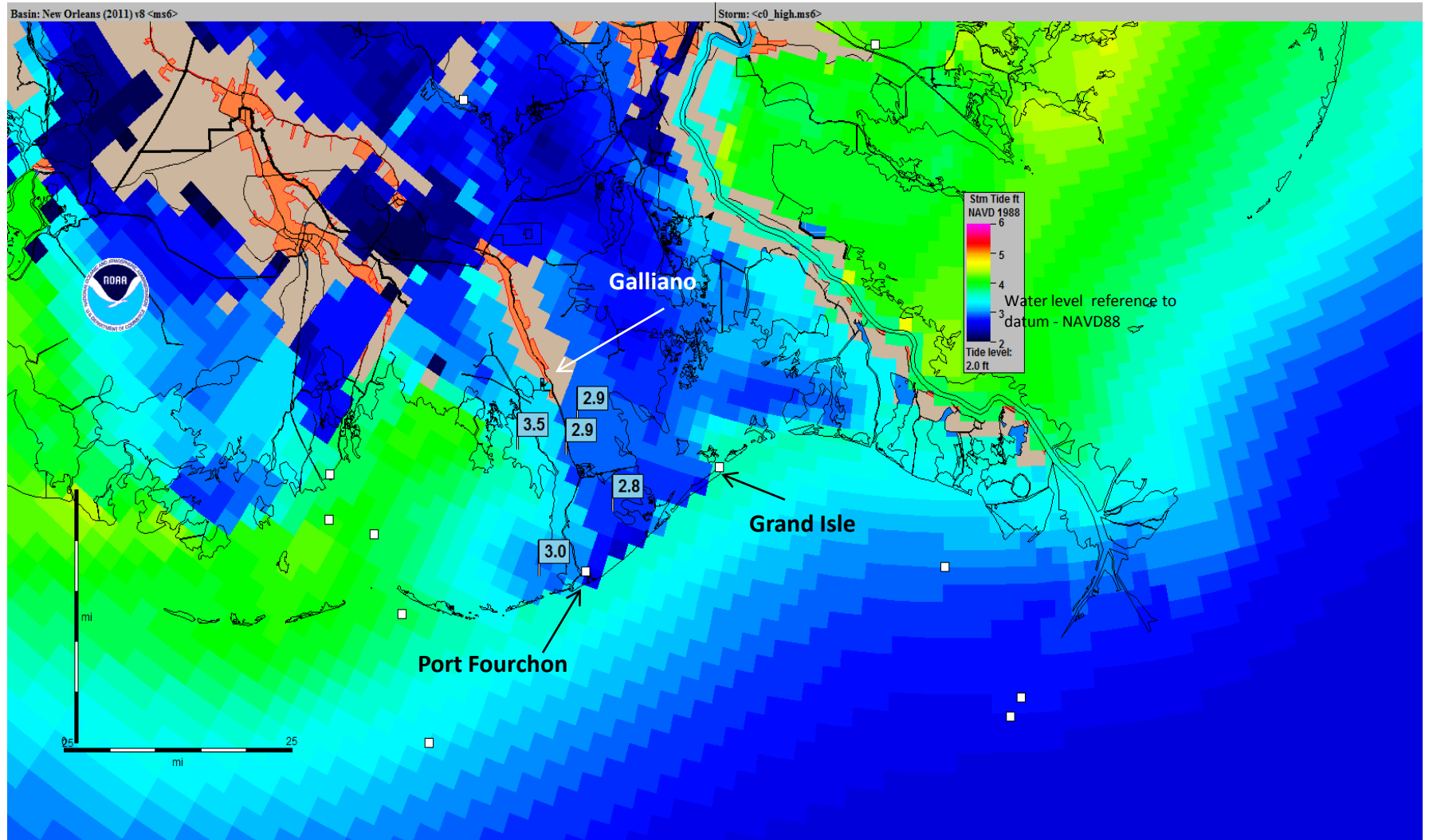
Flood Zones of Plaquemines Parish



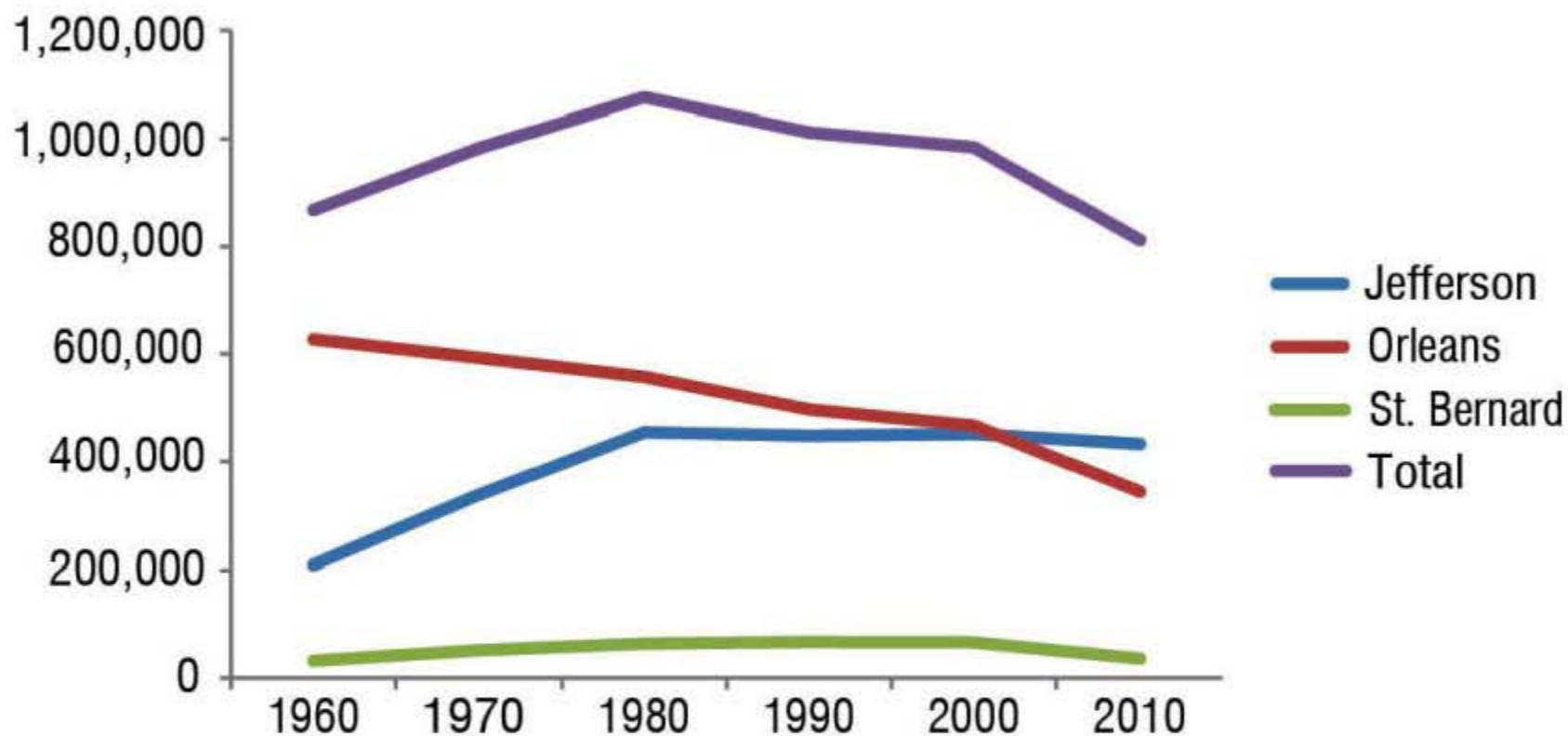
Flood Zones in Cameron Parish



# Weak Tropical Storms at Port Fourchon Will Inundate LA 1 to the Point of Closure- Source NWS New Orleans Baton Rouge – Category 0 Storm Surge SLOSH Output



## Population Trends



	1960	1970	1980	1990	2000	2010
Jefferson Parish	208,769	337,568	454,592	448,306	451,109	432,552
Orleans Parish	627,525	593,471	557,515	496,938	467,033	343,829
St. Bernard Parish	32,186	51,185	64,097	66,631	66,441	35,897
Total	870,440	982,224	1,076,204	1,011,875	984,583	812,278



# An Effort was Implemented by NOAA CO-OPS to Update the Posted Water Levels of Various Coastal Areas on a Shorter- 5 Year Cycle

## Datums for 8761724, Grand Isle LA

Certain geographic areas are experiencing rapid land movement due to uplift or subsidence, which results in anomalous relative sea level trends compared to most other coastal regions in the United States (see <http://tidesandcurrents.noaa.gov/sltrends/>). In these areas, NOAA has adopted a modified procedure for computing accepted tidal datums for the National Water Level Observation Network (NWLON). The long-term control stations in these areas have tidal datums updated approximately every 5 years using the modified procedure, with the most recent update being the 2007-2011 Modified Procedure. The adoption of this procedure was necessary to ensure that these tidal datums accurately represent the existing stand of sea level relative to the land. A detailed report explaining this modified procedure can be found in the publications section of the CO-OPS Tides & Currents website at <http://tidesandcurrents.noaa.gov/pub.html>.

### Elevations on Station Datum

Station: 8761724, Grand Isle, LA

T.M.: 90 W

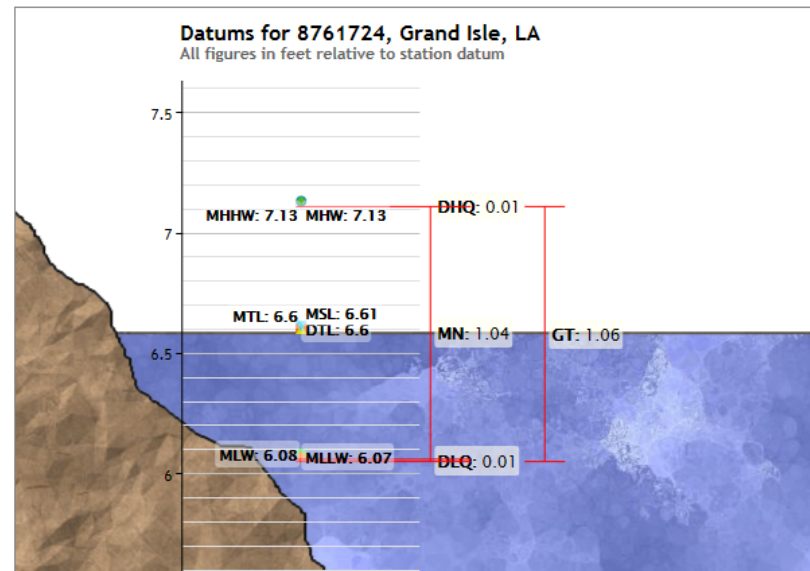
Status: Accepted (Apr 29 2014)

Epoch: 2007-2011

Units: Feet

Datum: STND

Datum	Value	Description
MHHW	7.13	Mean Higher-High Water
MHW	7.13	Mean High Water
MTL	6.60	Mean Tide Level
MSL	6.61	Mean Sea Level
DTL	6.60	Mean Diurnal Tide Level
MLW	6.08	Mean Low Water
MLLW	6.07	Mean Lower-Low Water
NAVD88		North American Vertical Datum of 1988
STND	0.00	Station Datum
GT	1.06	Great Diurnal Range
MN	1.04	Mean Range of Tide



## Notification Of Updated Tidal Datums

### Using The 2007-2011 Modified Procedure For Computing Accepted Tidal Datums For Areas With Anomalous Sea Level Trends

**SUMMARY:** NOAA's National Ocean Service (NOS), Center for Operational Oceanographic Products and Services (CO-OPS), last updated the Nation's tidal datums to a new National Tidal Datum Epoch (NTDE) in April 2003 to adjust for changes in mean sea level that have occurred along the Nation's coast over the past 25 years. The NTDE was updated from the 1960-1978 to the 1983-2001 time period effective on May 28, 2003 (Federal Register, volume 68, Number 102). The NTDE is a specific 19-year period over which tide observations are taken to determine Mean Sea Level and other tidal datums such as Mean Lower Low Water and Mean High Water. This period includes an 18.6 year astronomical cycle that accounts for all significant variations in the distances to the moon and sun that cause slowly varying changes in the range of tide. It is the policy of NOS to consider a revised NTDE every 20-25 years in order to take into account relative sea level changes caused by global sea level rise and the effects of long term land movement on local sea level due to subsidence or glacial rebound. The NTDE of 1983-2001 has been adopted so that all tidal datums throughout the United States will be based on one specific common reference period.

In 1998, NOS recognized the need for a modified procedure for computing accepted tidal datums for regions with anomalously high rates of relative sea level change, and has adopted a 5 year computational period to better reflect the current mean sea level datum. Consequently, tidal datums at stations exhibiting anomalous trends are computed from MSL observations for the most recent 5 year time period, and tidal ranges based on the most recent 19 year NTDE observations at that station. Anomalous relative sea level trends are seen along the western Gulf Coast, southeast Alaska, and southern Cook Inlet, AK (Figure 1). The magnitudes of the sea level trends in these areas are so large, (+9.24 mm/yr in Grand Isle, LA; -12.92 mm/yr in Juneau, AK; and -9.45 mm/yr in Seldovia, AK), that computation of a 19-year epoch value for mean sea level has little practical meaning.

The modified procedure is necessary at selected stations to ensure that the tidal datums accurately represent the existing stand of sea level. Sea level analyses in these anomalous regions are conducted approximately every five years to determine if the sea level trend exceeds the established 9.0mm/yr threshold tolerance in order to qualify for a 5-yr modified procedure datum update. A detailed report explaining this modified procedure can be found in the publications section of the CO-OPS Tides & Currents website at <http://tidesandcurrents.noaa.gov/pub.html>.

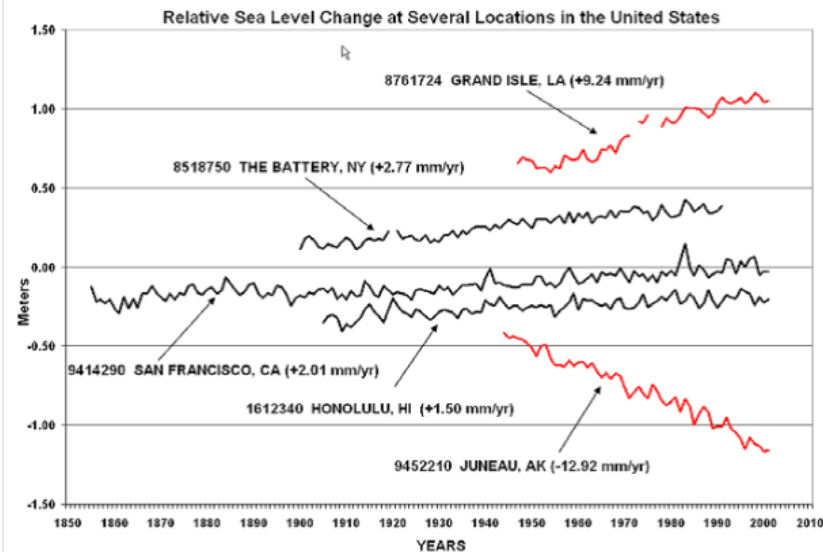


Figure 1: Plots of relative sea level change for several locations around the U.S. highlights the anomalous trends in Louisiana and Alaska.

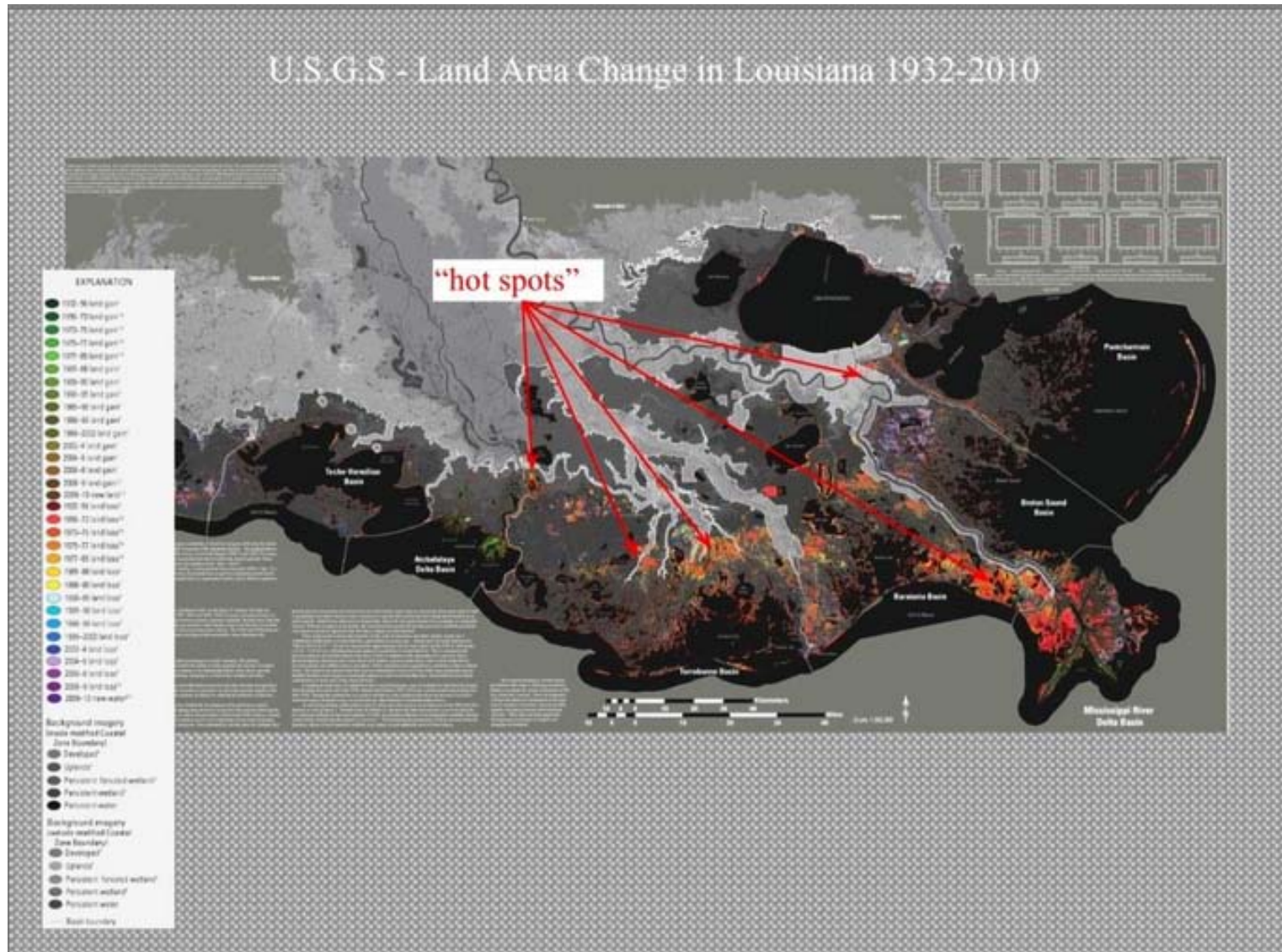


# Posting of Adjusted Values to Mean Sea Level Occurred Last Week by NOAA CO-OPS for the Time Period 2007-2011

- The Adjustment was 1.32 inches for the Station and a Listing of Subordinate Stations with Coverage across SE Coastal Louisiana
- This Adjustment in just a Five Year Period is in Response to the Large Shifts in Such a Short Timeframe for a Coastal Area that has Such Low Coastal Elevation Profiles
- Continued Updates on a Five Year Cycle is Planned in the Future

Our Coast Today--Interior of the Caminada Headland and Open Water that is Growing Yearly Threatening Infrastructure as Port Fourchon and Grand Isle

Indeed, A Lot of Discussion Around this High Rate of Relative Change is Very Common





# Use of these Trends and the Analysis of Coastal Elevations has assisted the State and Lafourche Parish and Port Fourchon Assess the Flooding Outlook of Louisiana LA-1 for the Unelevated Section below Golden Meadow



## HIGHWAY AT RISK

*Flooded LA Highway 1*

Two recent tidal inundation studies completed in cooperation with the LA 1 Coalition estimate that the existing LA Highway 1 between Golden Meadow and Leeville has less than 40 years of life left before being covered in water and impassible for more than 300 days per year, threatening America's energy and economic security. Additionally, the highway could experience a total wash-out before that time as a result of a tropical storm or hurricane in the area, cutting off access to Port Fourchon indefinitely.

The effects of sea level rise and subsidence on LA 1 traffic and national commerce, however, will begin to be experienced even sooner, according to modelings conducted by the National Oceanic and Atmospheric Administration (NOAA) and environmental researchers at Stratus Consulting.

By 2027, NOAA predicts inundation levels that will obligate local officials to close a seven-mile section of the existing highway between Golden Meadow and Leeville for more than 30 days per year, restricting access to Port Fourchon and impacting hurricane evacuation.

# Impact of Rising Water Level Values Being Updated by NOAA on Critical Infrastructure- Louisiana Highway LA-1 – The Only Road Access to Port Fourchon and Grand Isle

Increasing Rate of Flooding and Closures of Louisiana LA-1 South of Golden Meadow as Water Levels Rise



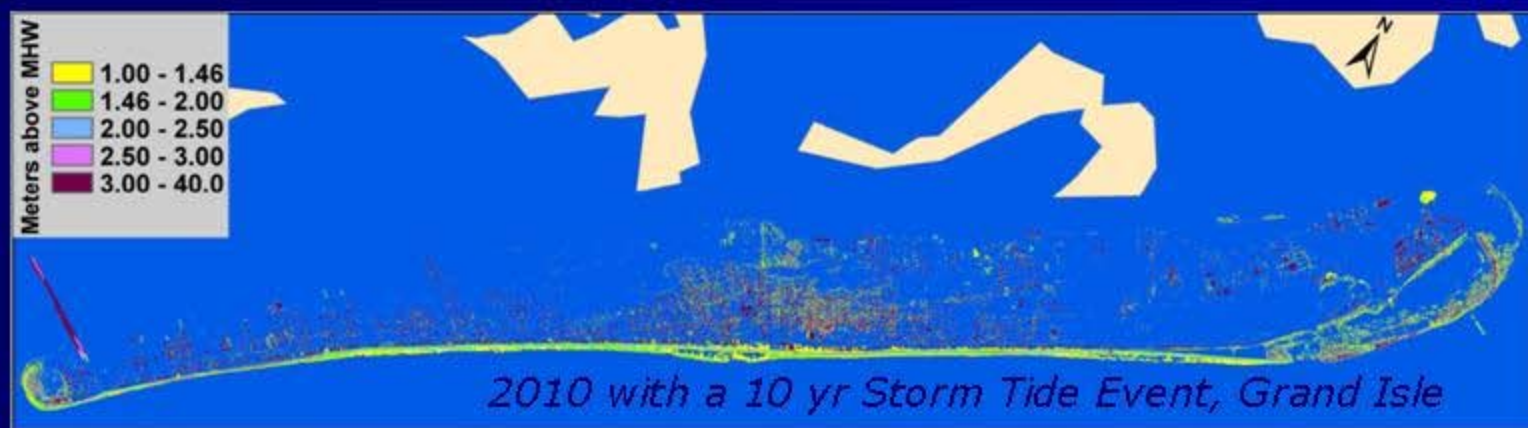
**Figure 2–12: Consecutive Days of LA-1 Submergence, using 9.24mm/yr**

In fact, the slower increase in the curve of this graph after about the year 2044 will likely be an artifact of the estimation model. Further investigation will probably show this model reaching 365 days of submergence significantly earlier than 2065, perhaps as early as 2050.

### 2.1.1.4 A Worse Case

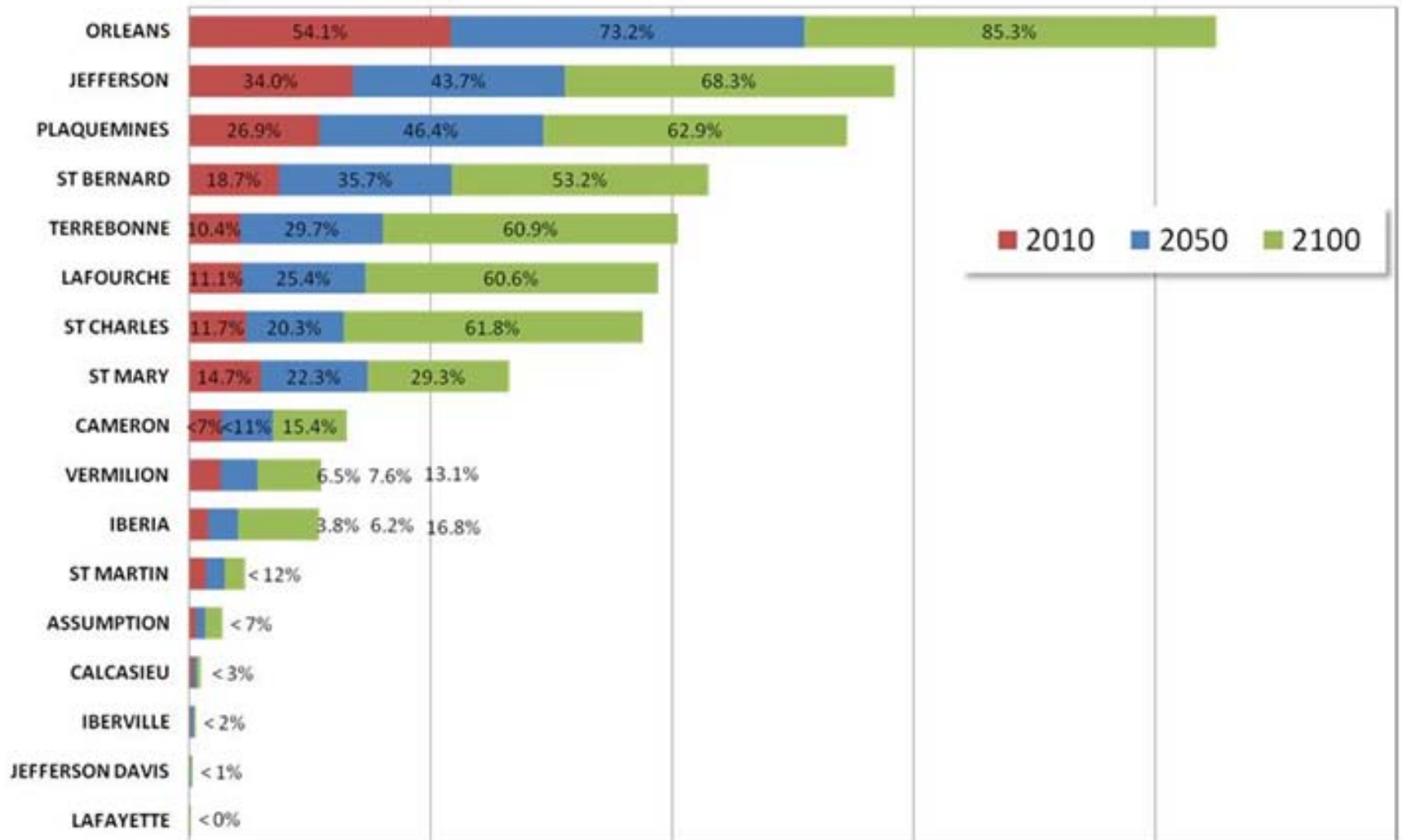
As mentioned during the discussion of Figure 2–2, NOAA estimated that the rate of Mean Sea Level rise in this geographic area is increasing. Using their predicted rate of 11.2mm/yr from 2007 through 2050, a 90 consecutive day outage could be reached by 2030 or 2031, 8 or 9 years earlier than when using 9.24mm/yr. See Figure 2–13.



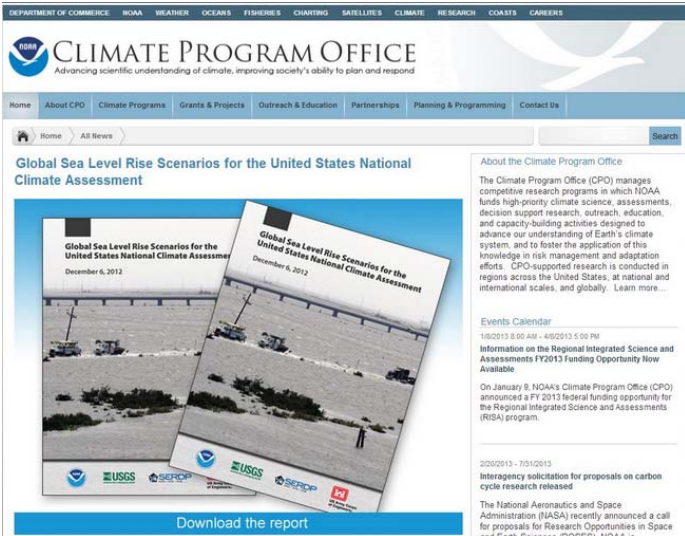


*Grand Isle Louisiana, Sea Level Rise 2010-2060 and Growing Inundation by the same 10 year storm tide event*

## Percent Land Below Sea Level by Parish Through 2100





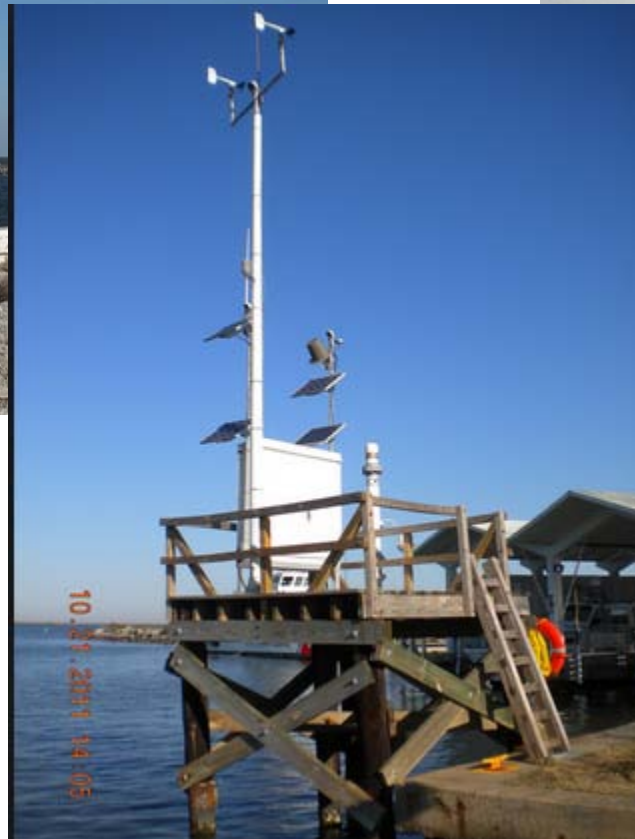


- Reports as ‘Global Sea Level Rise Scenarios for the United States National Climate Assessment Provide Reasonable Support that Increases in the Rate of Relative Sea Level Rise May be Seen in Coastal Louisiana

# Trends of Relative Sea Levels



Installation and Operation  
and Observation by Storm  
Hardened Water Level and  
Surge Stations— ***With Tidal  
Datums Established at  
Each Station!***





# The Take Home

- We must be very focused on our priorities
- These landscape changes are rooted in a natural process though we have made decisions our land use and the development of the Mississippi River that have exacerbated this process
- ‘What do you want to keep– Fight for?’ – is a very key question. The Communities and Economy of our