



Systems of Systems Risk-Based Decisions for Critical Infrastructure under Climate Uncertainty

New Orleans Hurricane Protection System

System Performance

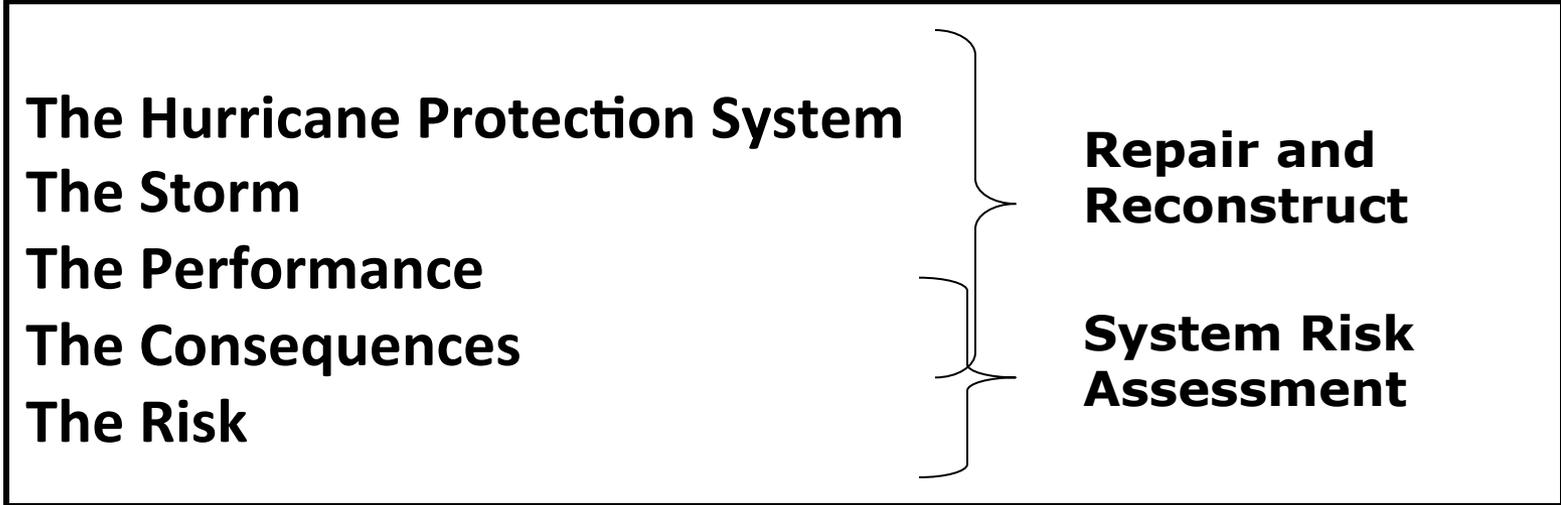


Lewis E Link, PhD
Director, IPET
University of Maryland



Interagency Performance Evaluation Task Force

...“to provide credible and objective scientific and engineering answers to fundamental questions about the performance of the hurricane protection and flood damage reduction system in the New Orleans metropolitan area.”
Chief of Engineers





US Army Corps
of Engineers

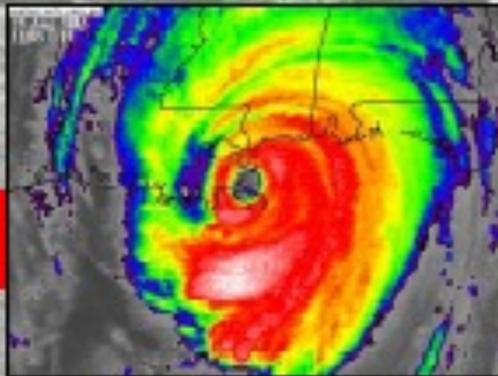
Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System

Final Report of the Interagency
Performance Evaluation Task Force

Volume III – The Hurricane Protection System

22 August 2007

FINAL



Volume I Executive Summary and
Overview

Volume II Geodetic Vertical and Water
Level Datum

Volume III The Hurricane Protection
System

Volume IV The Storm

Volume V The Performance - Levees
and Floodwalls

Volume VI The Performance – Interior
Drainage and Pumping

Volume VII the Consequences

Volume VIII Engineering and Operational
Risk and Reliability Analysis

Supplemental Report: A General
Description of Vulnerability to Flooding
and Risk for New Orleans and Vicinity:
Past, Present and Future

LAK E PONTCHARTRAIN

STREET DIRECTORY.

TO FIND THE LOCALITY OF ANY STREET
 TAKE THE DESIGNATION OPPOSITE THE NAME OF THE STREET HEREON AND THEY POINT TO THE BLOCK IN WHICH IT IS LOCATED BY THE LETTERS OF THE ALPHABET AND BY THE NUMBER OF THE STREET.

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B	ALBANY								
C	ALBANY								
D	ALBANY								
E	ALBANY								
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1878

DIRECTORY FOR PUBLIC BUILDINGS AND SQUARES

FOR SYMBOL LOCATIONS—SEE EXPLANATIONS ON STREET DIRECTORY.

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Metairie Ridge

Gentilly Ridge

17th St. Canal

Orleans Canal

London Canal

TOPOGRAPHICAL DRAINAGE MAP

NEW ORLEANS AND SURROUNDINGS

FROM RECENT SURVEYS AND INVESTIGATIONS

T. S. HARDEE, CIVIL ENGINEER.
 1878
 PRINCIPAL NOTES PUBLISHED BY U.S. COAST SURVEY DEPARTMENT
 SCALE

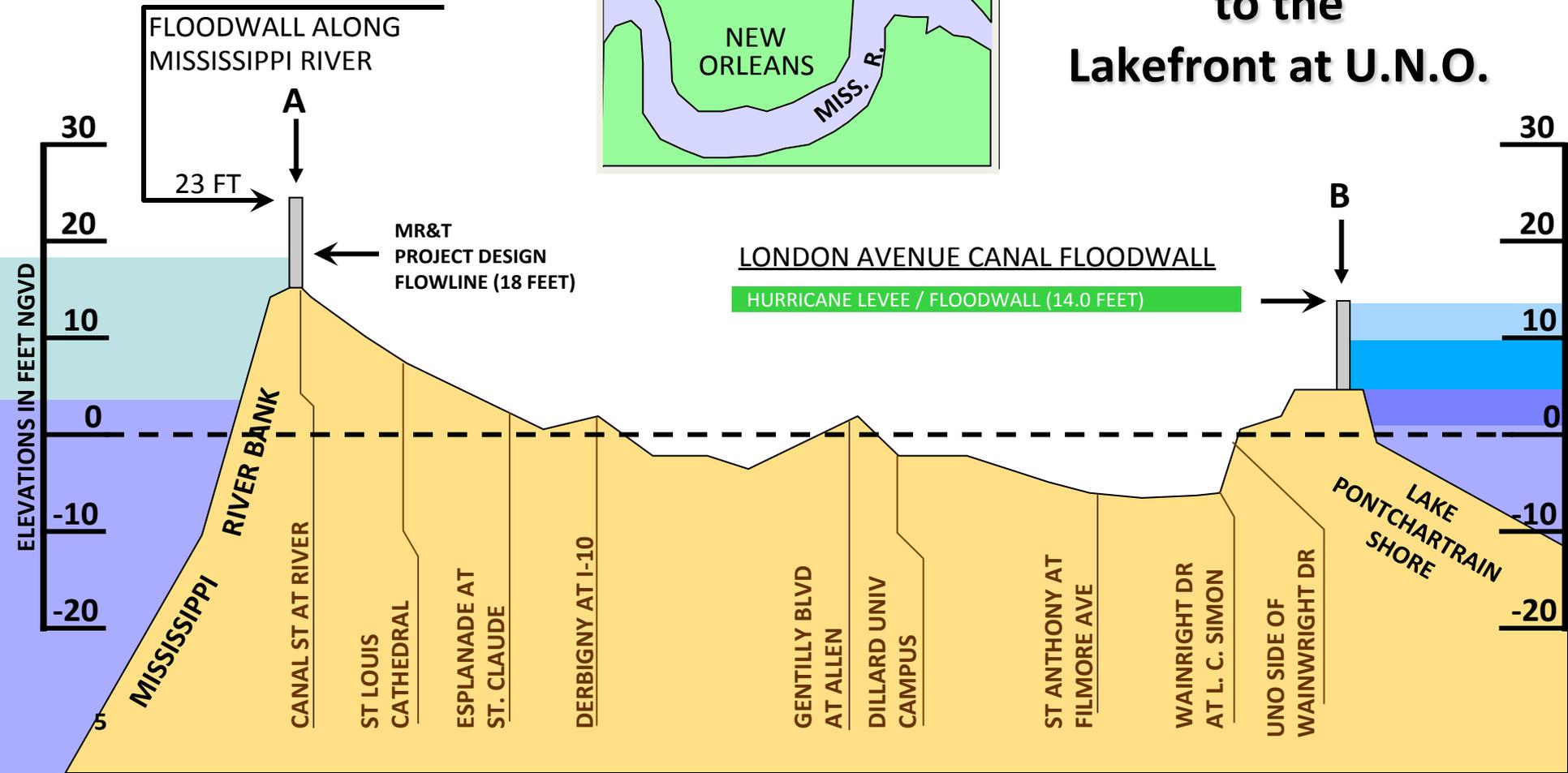
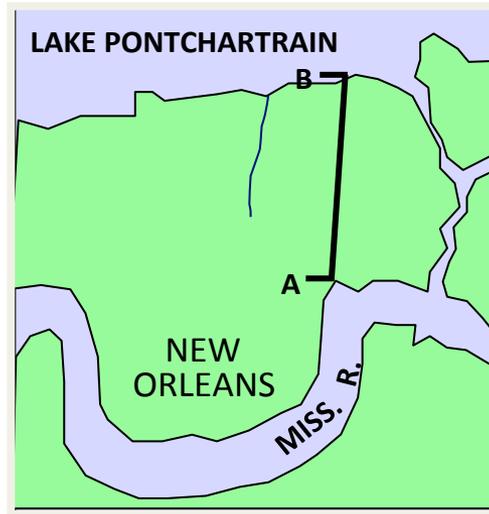
POPULATION OF THE CITY BY STATE CENSUS OF 1870
 WHITES 149,721 - COLORED 37,647 - INDIANS AND CHINESE 74
 TOTAL 187,442

ENTERED AS SECOND CLASS MATTER FOR POST OFFICE USE AT NEW ORLEANS, LA. BY POST OFFICE DEPARTMENT AT NEW ORLEANS, LA. MAY 1878.

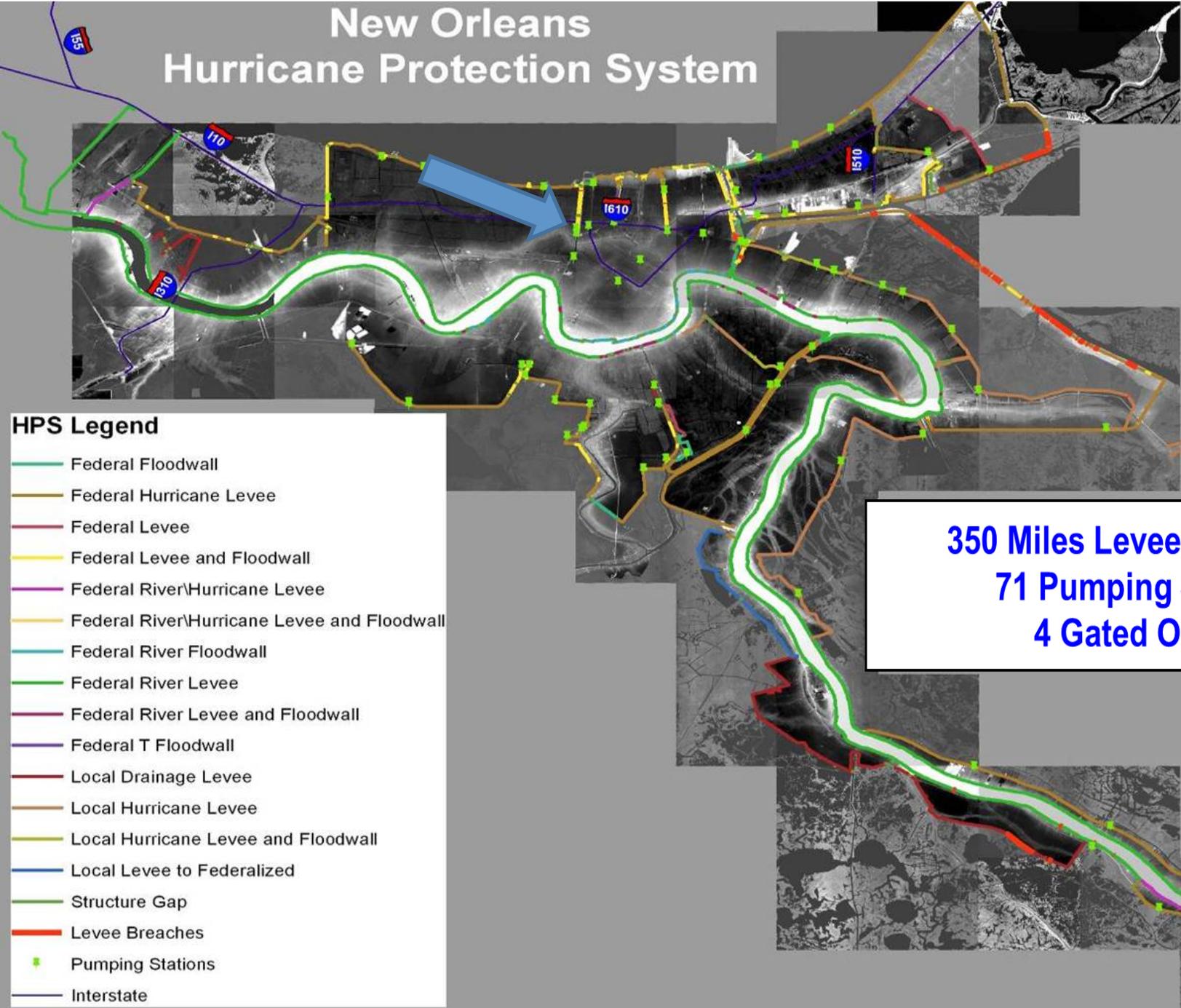
New Orleans Topography

City of New Orleans Ground Elevations

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



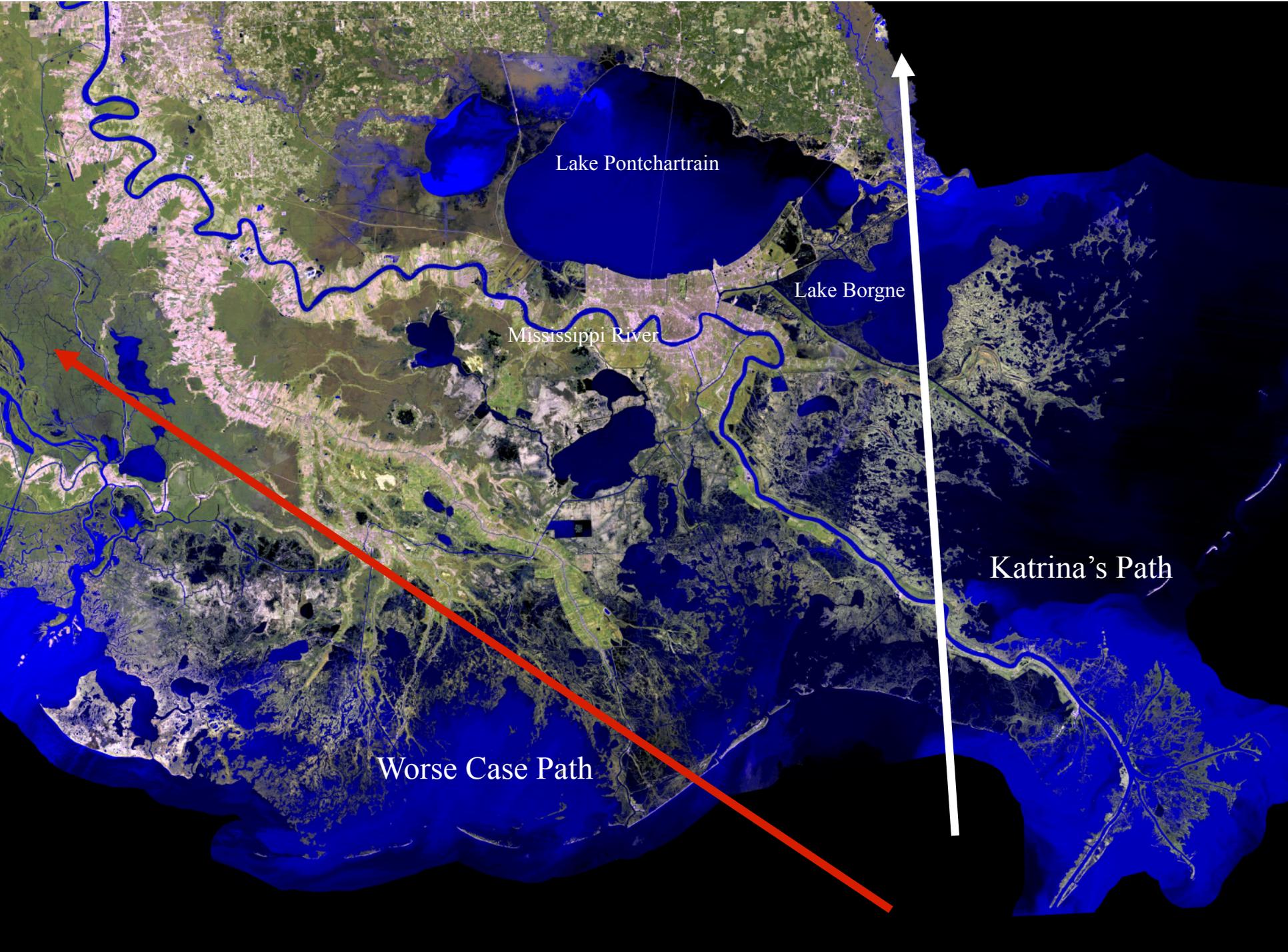
New Orleans Hurricane Protection System



HPS Legend

- Federal Floodwall
- Federal Hurricane Levee
- Federal Levee
- Federal Levee and Floodwall
- Federal River\Hurricane Levee
- Federal River\Hurricane Levee and Floodwall
- Federal River Floodwall
- Federal River Levee
- Federal River Levee and Floodwall
- Federal T Floodwall
- Local Drainage Levee
- Local Hurricane Levee
- Local Hurricane Levee and Floodwall
- Local Levee to Federalized
- Structure Gap
- Levee Breaches
- Pumping Stations
- Interstate

350 Miles Levee / Floodwall
71 Pumping Stations
4 Gated Outlets



Lake Pontchartrain

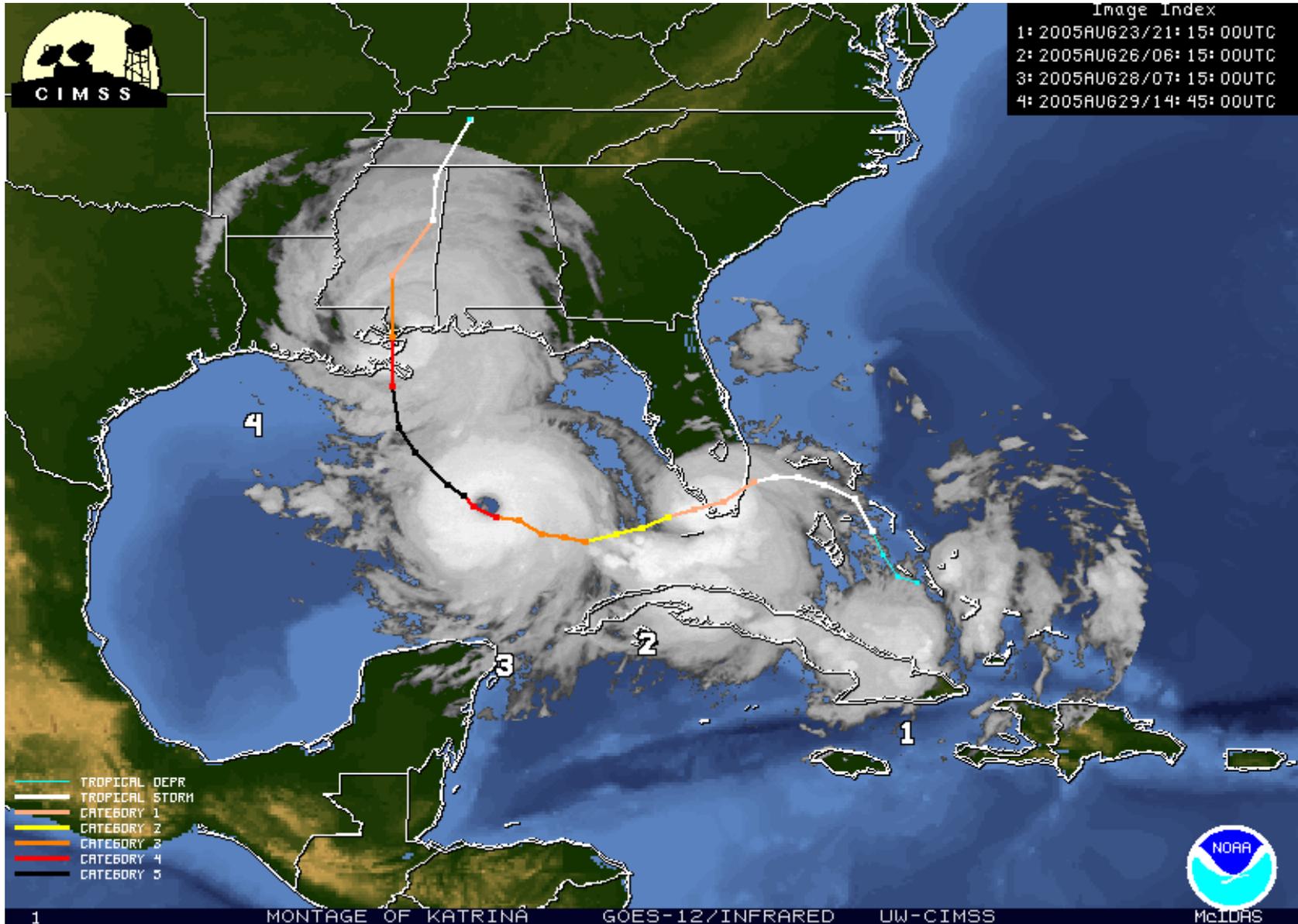
Lake Borgne

Mississippi River

Katrina's Path

Worse Case Path

Hurricane Katrina

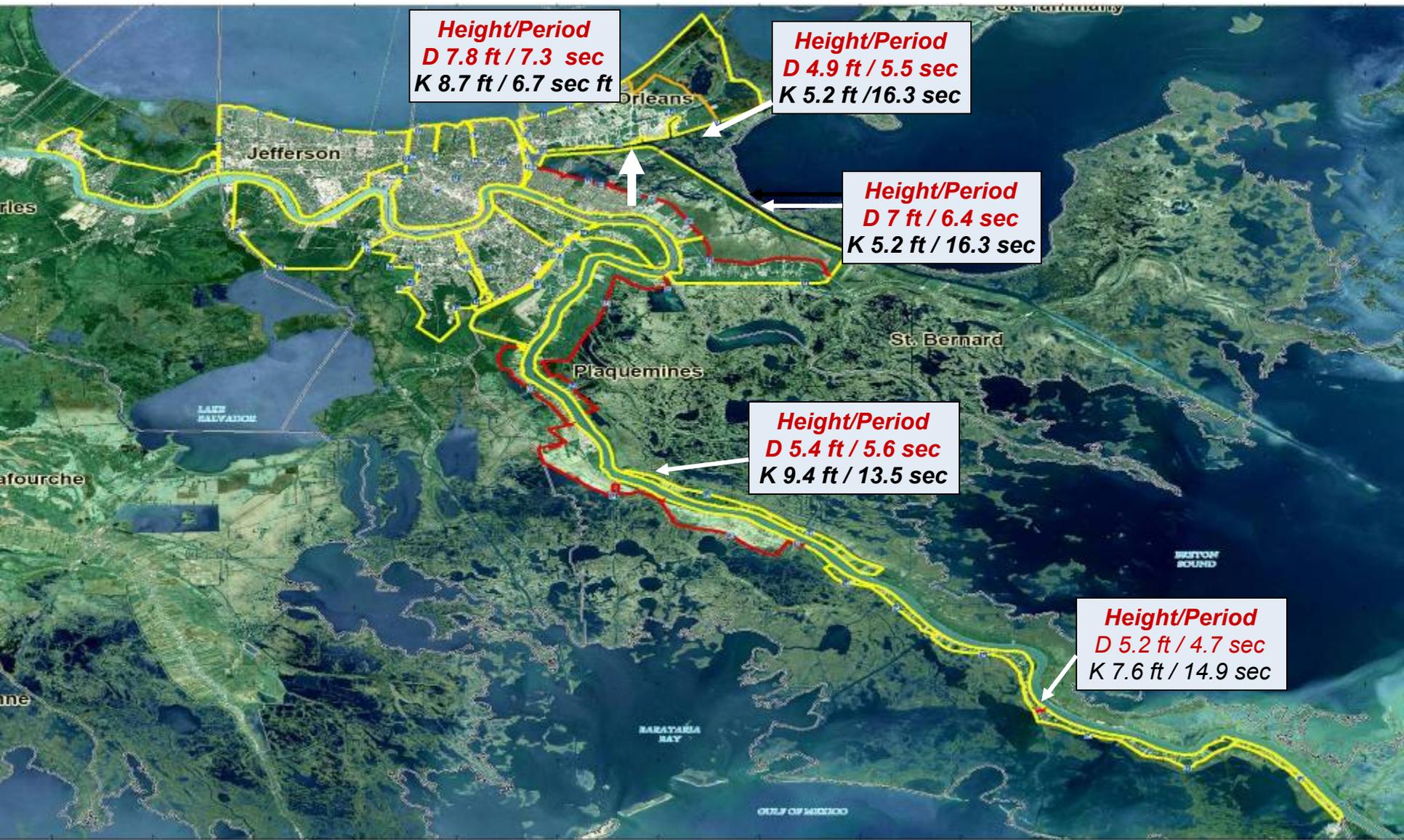


IPET Reports - biotech.law.lsu.edu/Katrina/ipet/ipet.html

Comparison of Design and Katrina Surge Levels



Comparison of Design and Katrina Waves



Consequences

Total Fatalities up to 1600

Direct Property Losses - \$ 30 B

Indirect Economic Losses - up to \$ 200 B



“A System in Name Only”

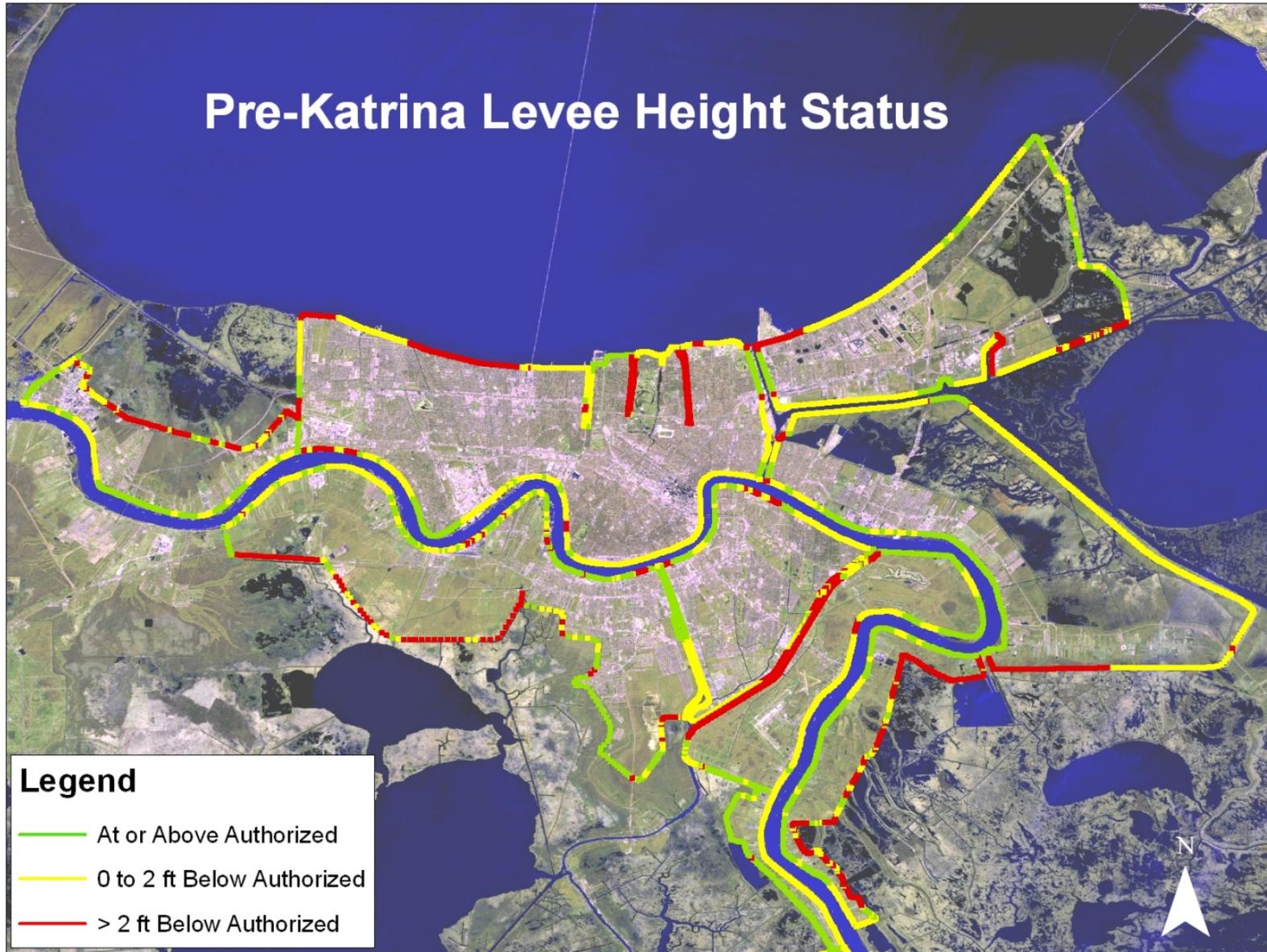
- **System Incomplete**
- **Datum/Elevations deficient**
- **Components not integrated**
- **Outdated Hazard and Design Criteria = Outdated System**
- **Lack of Infrastructure Robustness/Resilience**
- **Lack of Emergency Preparedness and Response**

Post-Katrina Levee Height Status



Figure 7-1. Comparison of repaired structure elevations (post-Katrina) to authorized elevations for northern portion of the hurricane protection system. (Source, New Orleans District.)

Pre-Katrina Actual vs Authorized Elevations



London Avenue Outfall Canal

Design v Constructed Floodwall Elevations

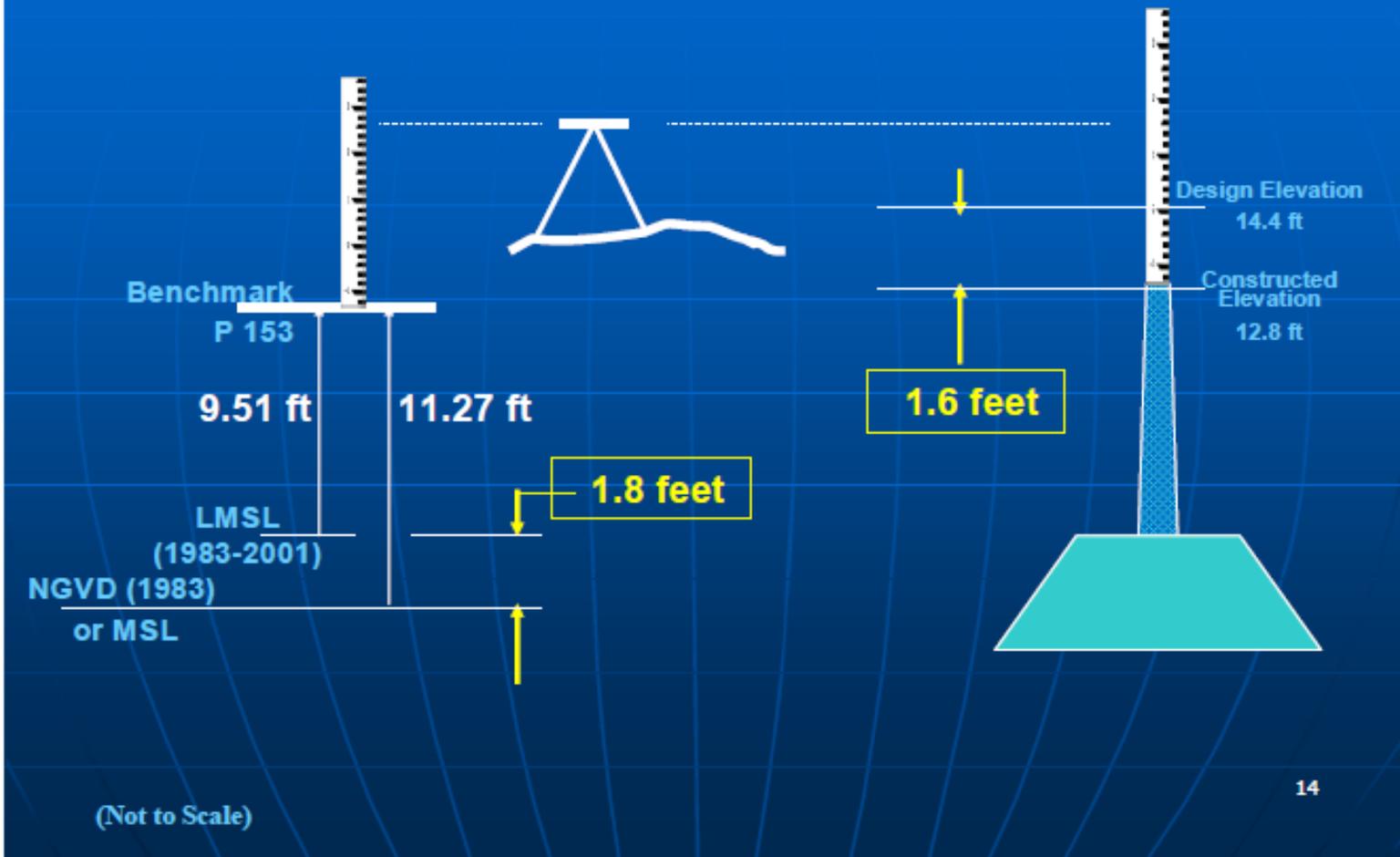
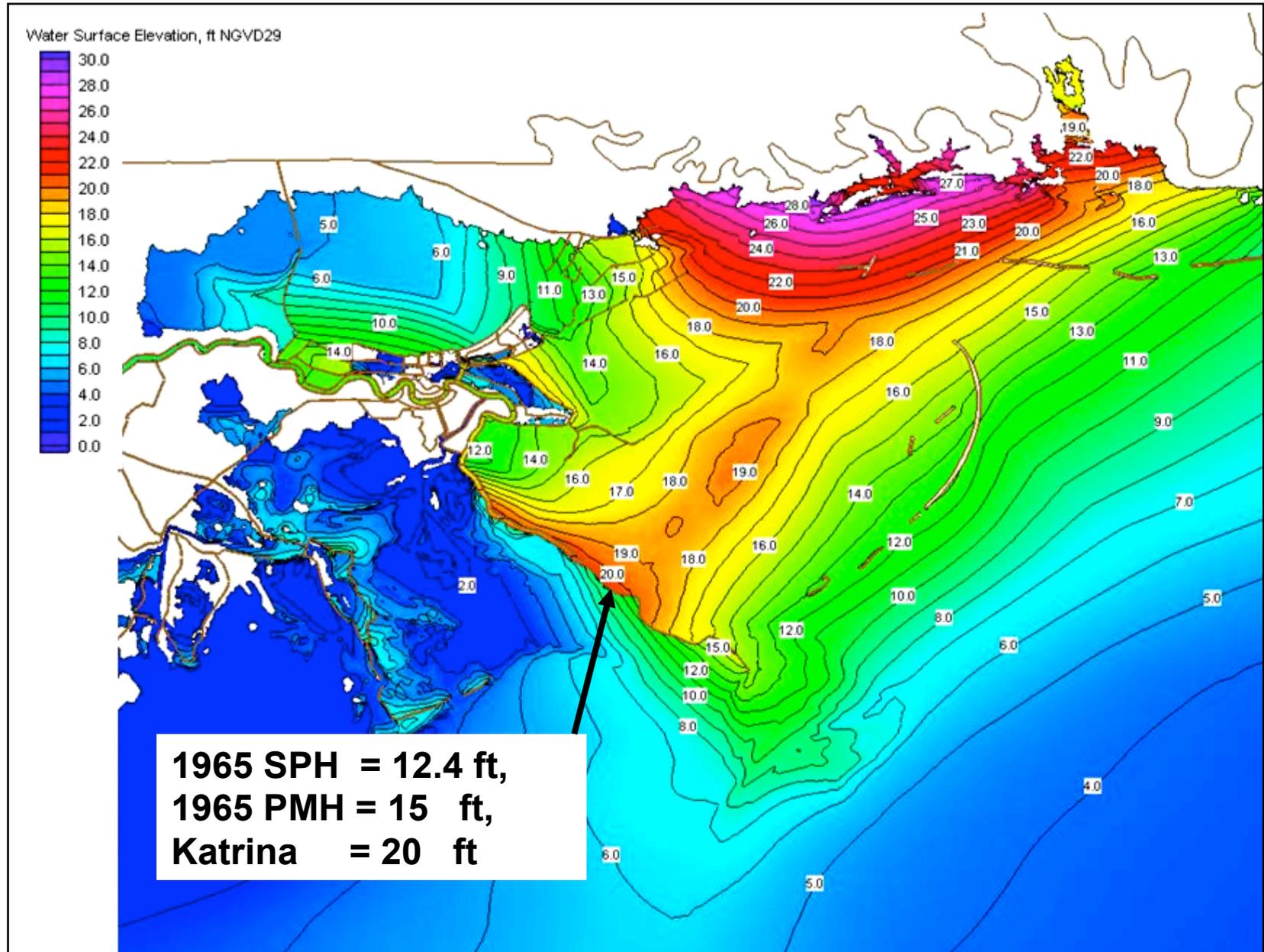


Figure 42. Impact of using NGVD elevation instead of LMSL elevation for construction stakeout of London Ave. Outfall Canal floodwall construction.

Pumping Station, 17th Street Canal



ADCIRC Modeled Katrina Peak Surge



Katrina Return Period ?

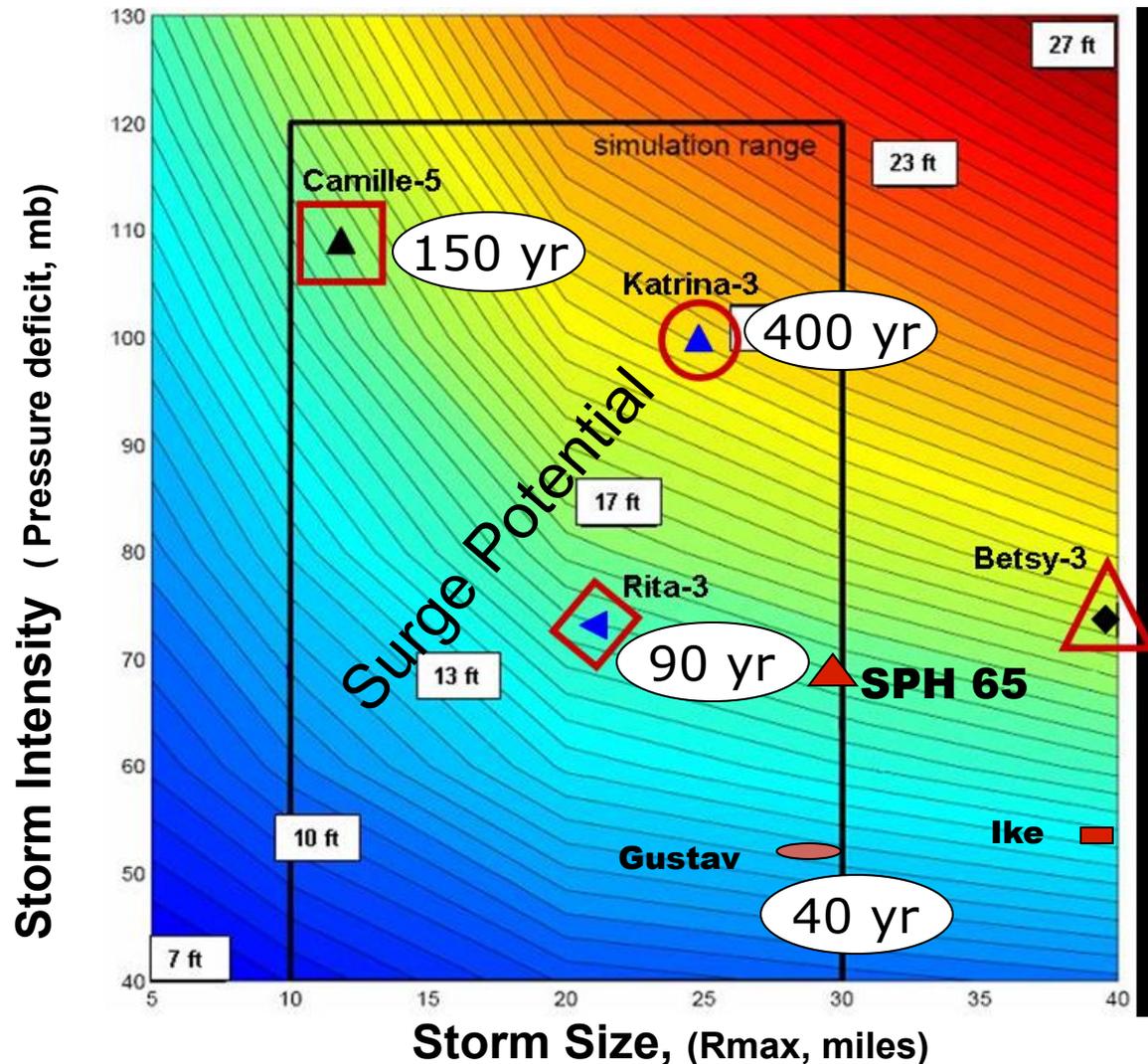
Publication (Year) Period of Record	USWB Tech Report #33 (1959) 1900-1956	NWS Tech Report #23 (1979) 1900-1975	NOAA/NCDC Prelim Analysis (2006) 1900-2005
Meteorological Parameter			
100-year Central Pressure Index (millibars)	934.6 mb	926.2 mb	901.7 mb
100-year Peripheral Pressure (millibars)	1013.2 mb	1008.1 mb	1007.9 mb
Return Period for a Hurricane Katrina intensity storm** (905 mb)	900 years	285 years	98 years

Katrina Surge Level at Landfall = 20.0 ft
1965 Standard Project Hurricane = 12.4 ft
1965 Probable Maximum Hurricane = 15.0 ft

Katrina Return Period

Katrina was a 400-year event Based on “Surge Generation Potential”

Actual Katrina Surge varied from <40- year to >400-year Depending on Location



Source: Irish and Resio

I-Wall Foundation Failures



Floodwall Overtop/Scour

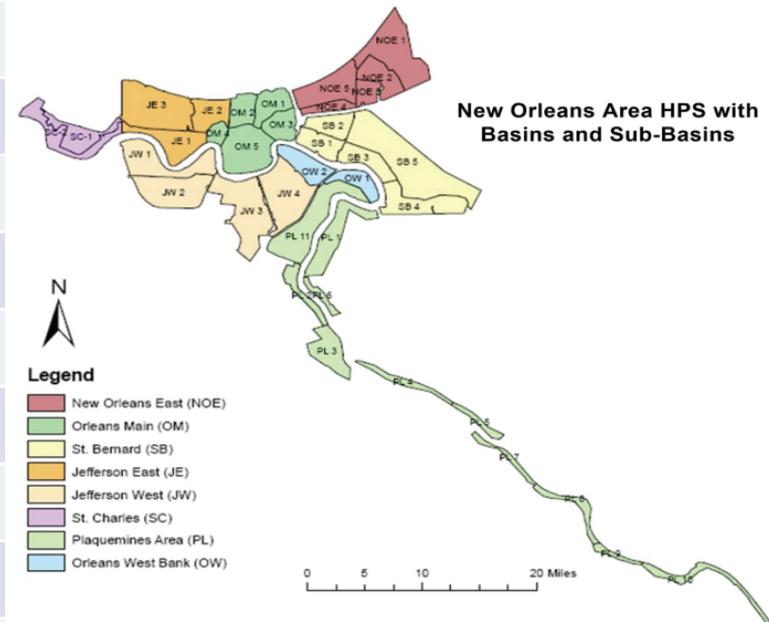


Levee Overtop/Scour



Mean Failure Frequency By Polder/Basin for New Orleans

Polder	2005 (Pre-Katrina) Years
New Orleans East	29
Jefferson	68
St Charles	54
Orleans Main	30
St Bernard	30
Plaquemines North	18
Plaquemines South	18
Jefferson West	22
Orleans West	32
Average	33



The Risk Process

Chance of Hazard

X

System Performance

=

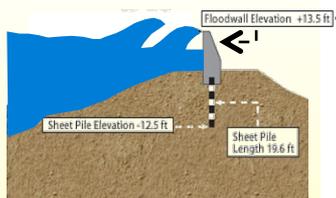
Vulnerability to Flooding

X

Consequences

=

Risk



Surge & Wave levels estimated at 138 locations from

76 possible hurricanes

30 to 3000-Year storm events

Performance of entire 350-mile system

- 1) Pre-Katrina
- 2) 2007
- 3) 2011

Reaches, Features and Transitions

Volume of Flooding and Flood Depth

By location and HPS Scenario

With / Without Pumping

Potential Loss of Life vs Flood depth**

Potential Property Damage vs Flood depth**

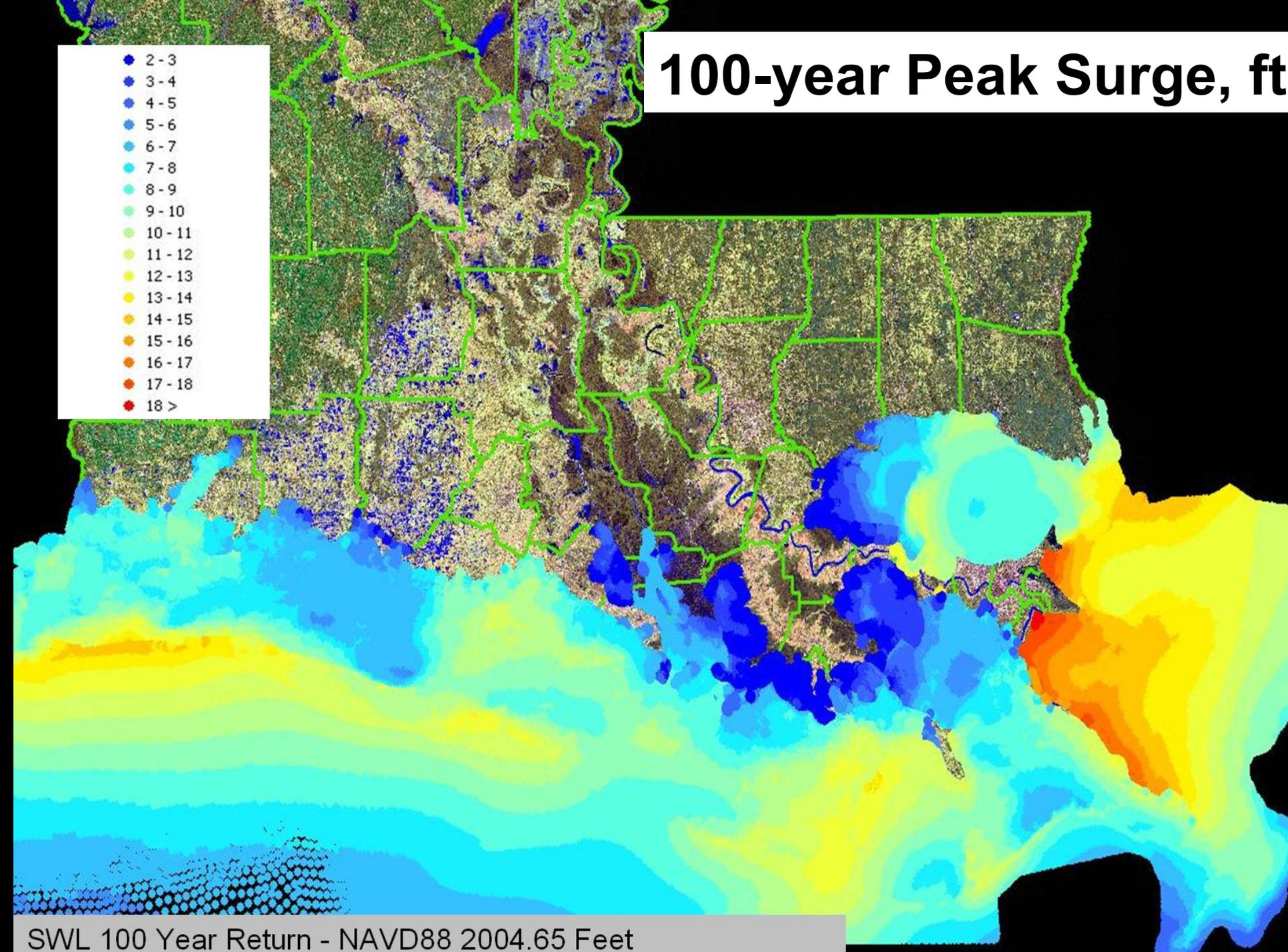
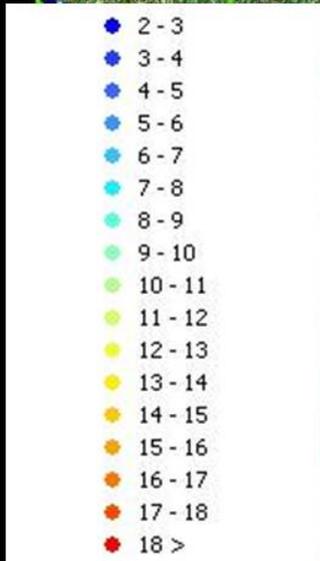
**Based on Pre-Katrina population and property values

Expected Annual Loss of Life

Expected Annual Economic Loss

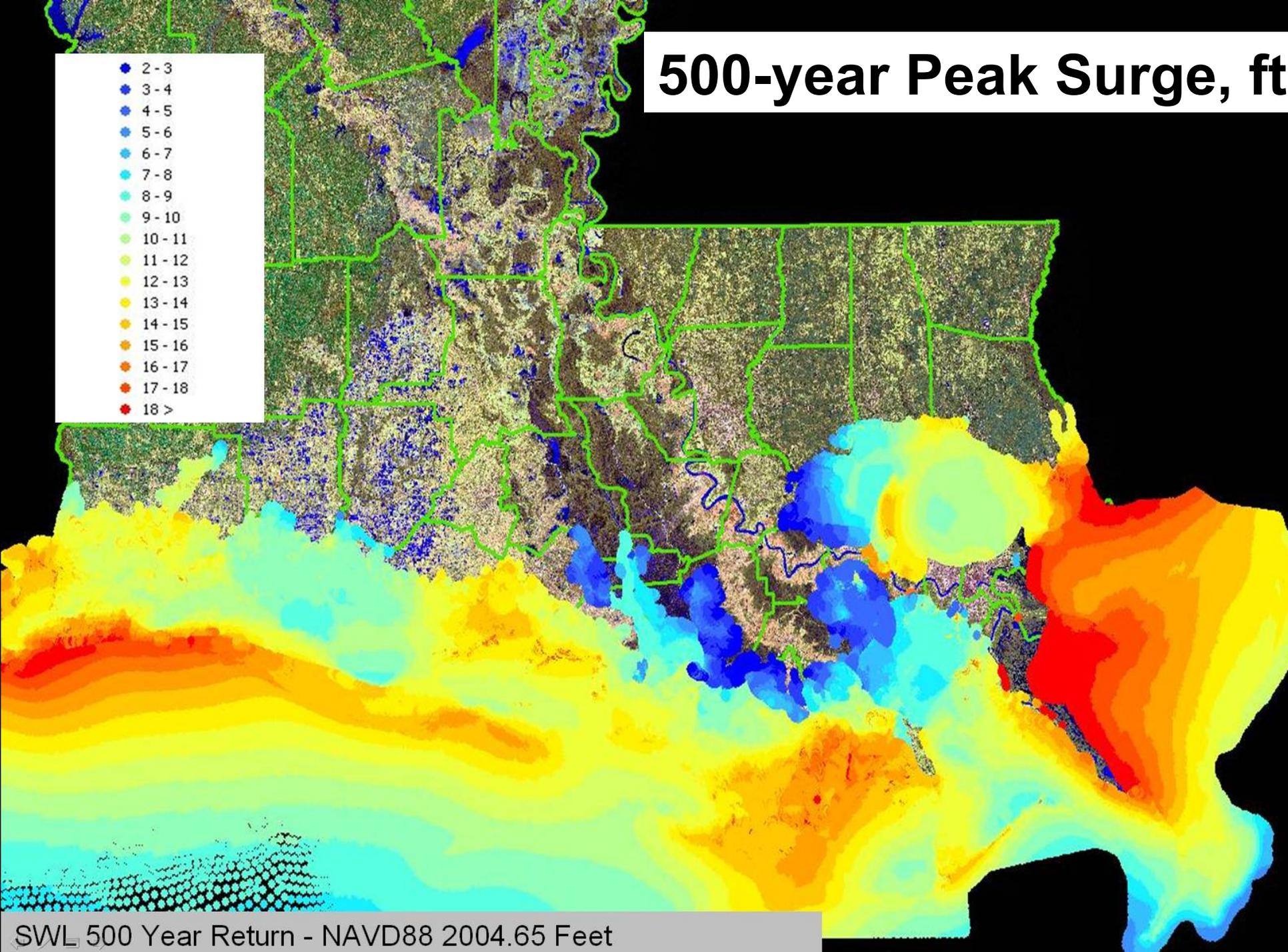
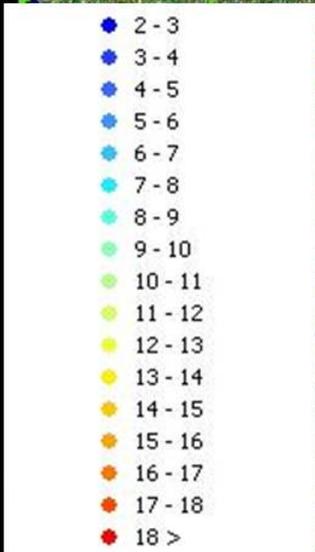
Based on Pre-Katrina population and property values

100-year Peak Surge, ft



SWL 100 Year Return - NAVD88 2004.65 Feet

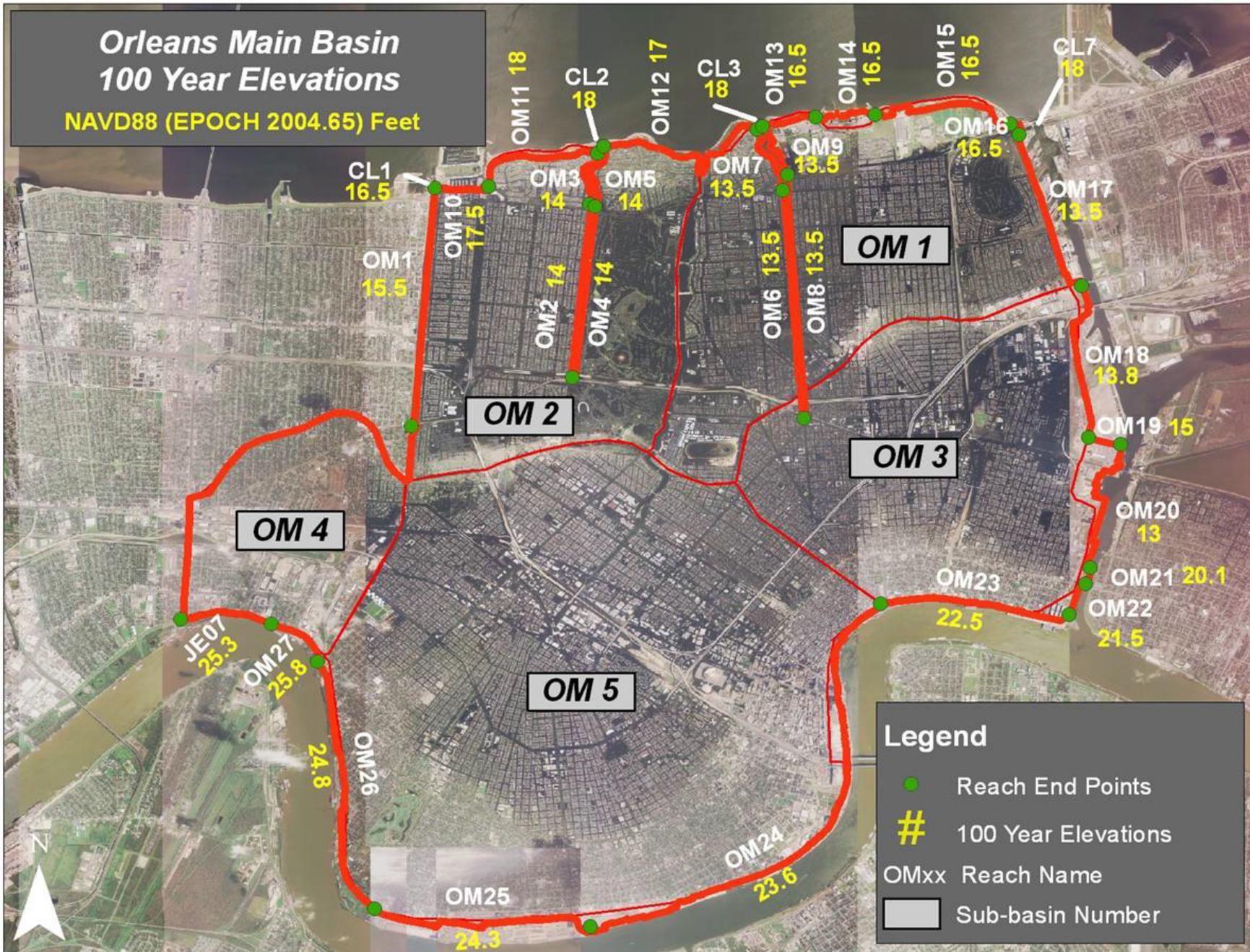
500-year Peak Surge, ft



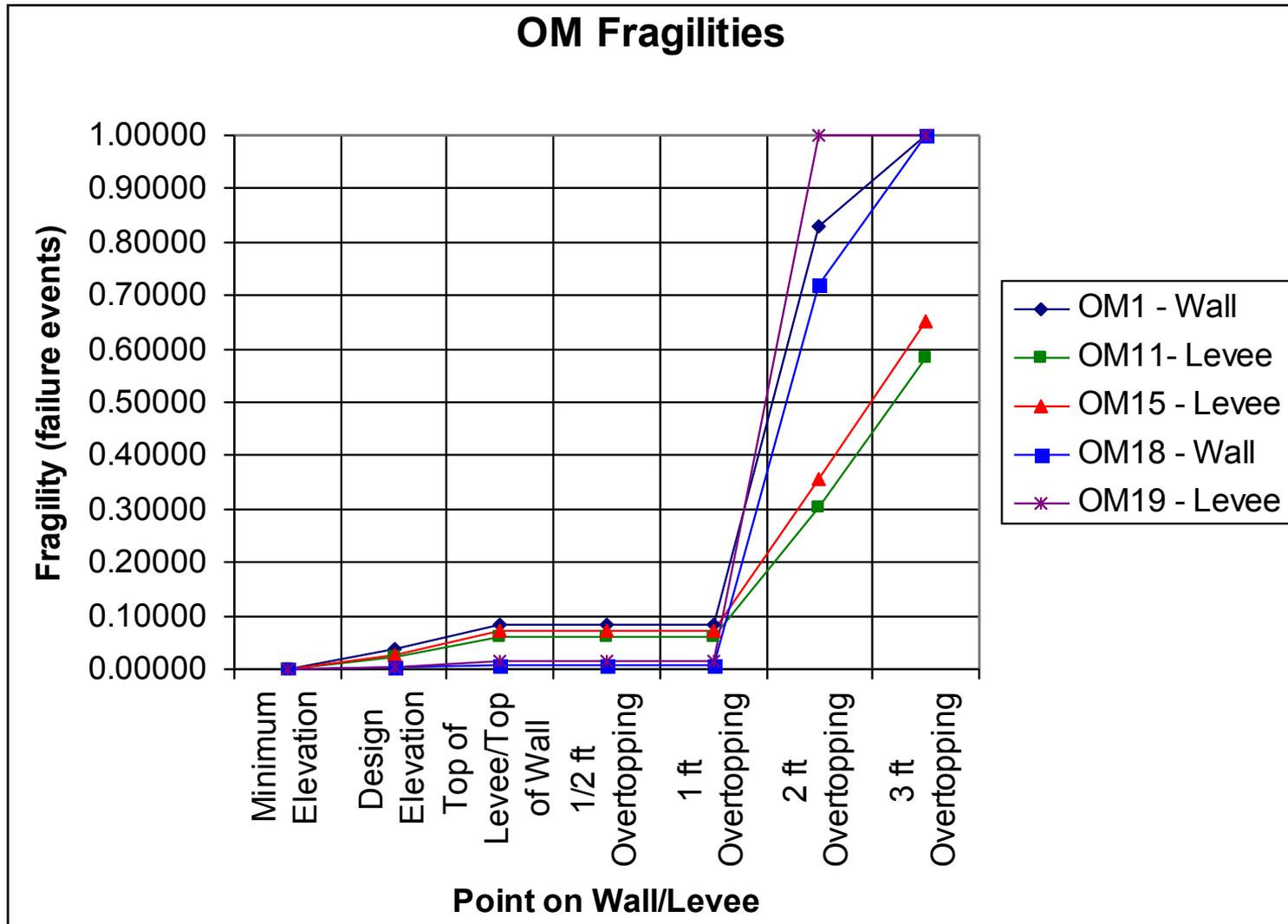
SWL 500 Year Return - NAVD88 2004.65 Feet

Orleans Main Basin 100 Year Elevations

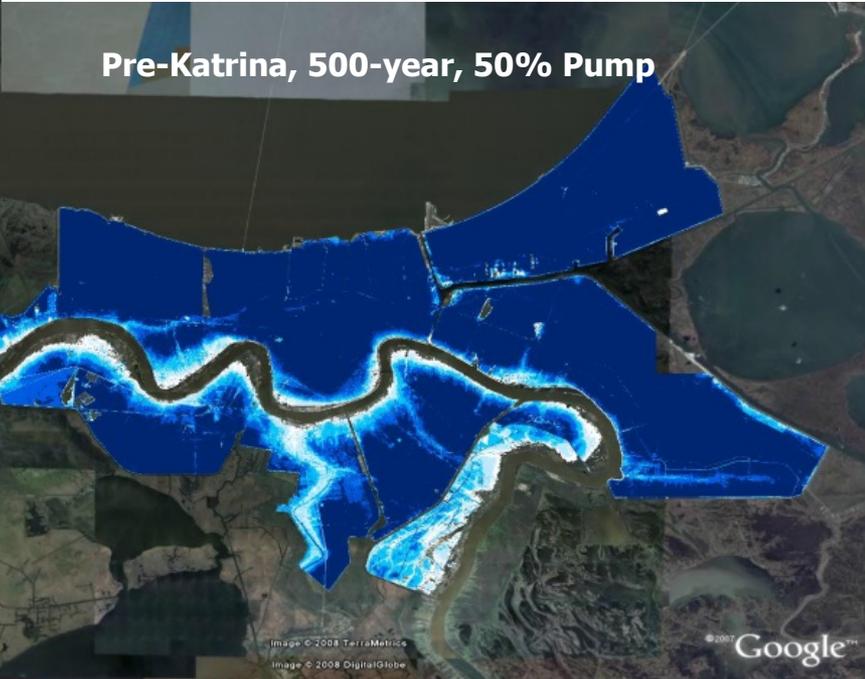
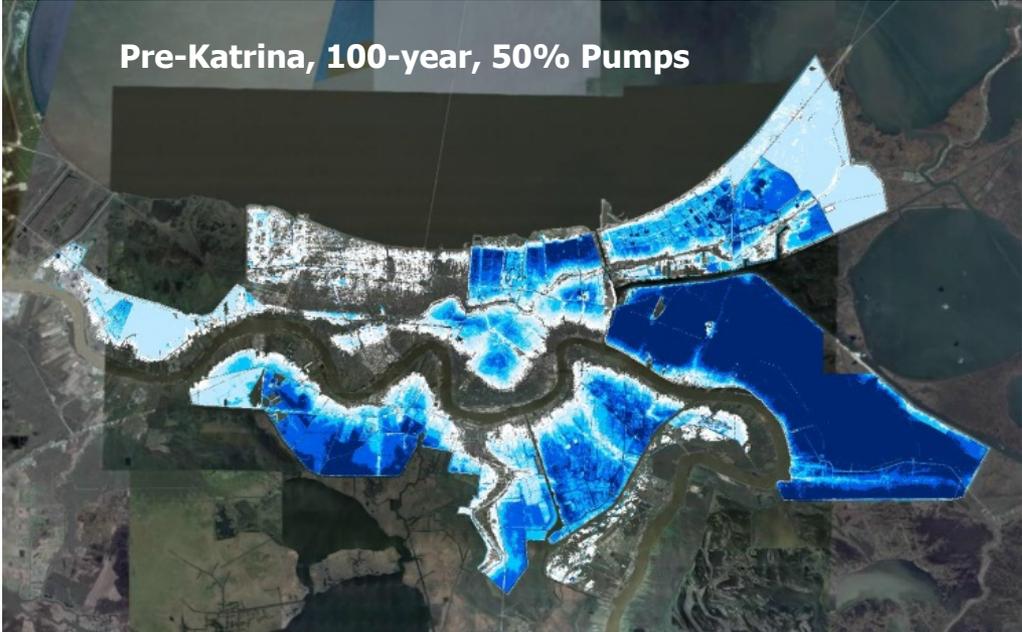
NAVD88 (EPOCH 2004.65) Feet

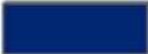


Sample Fragility Curves for Orleans Main



100-year vs 500-year Flood Depth Maps

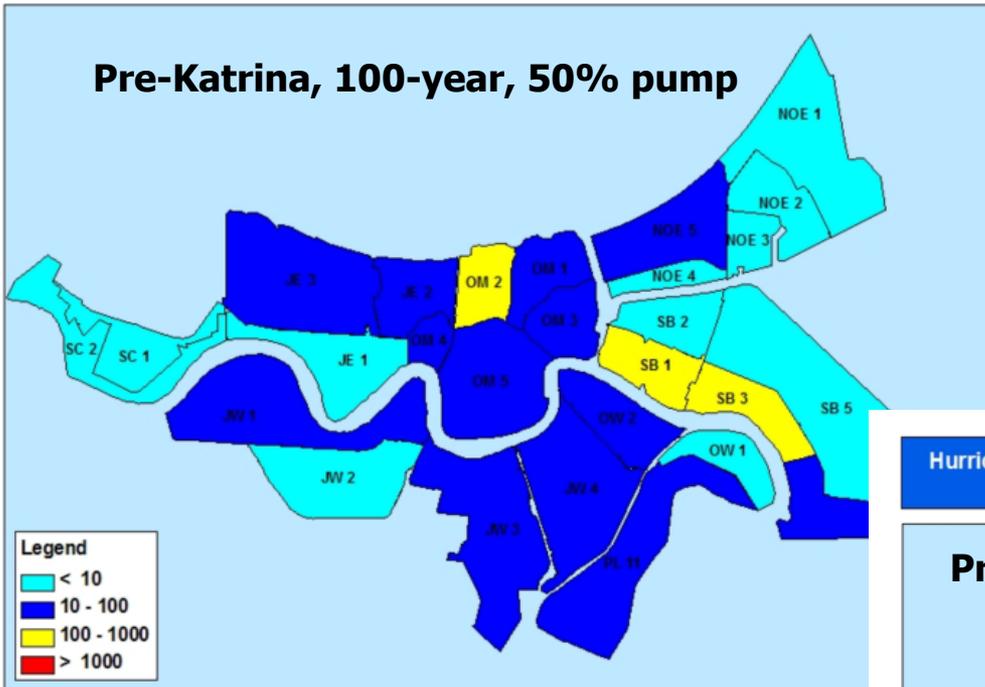


Feet of Flooding	
	>8
	6 - 8
	4 - 6
	2 - 4
	0 - 2

Loss of Life Risk Map

Hurricane Protection System in place before Katrina with pumping at 50% of capacity
There was a 1% (1 in 100) chance for this number of fatalities

Pre-Katrina, 100-year, 50% pump



Mean Expected Annual Losses

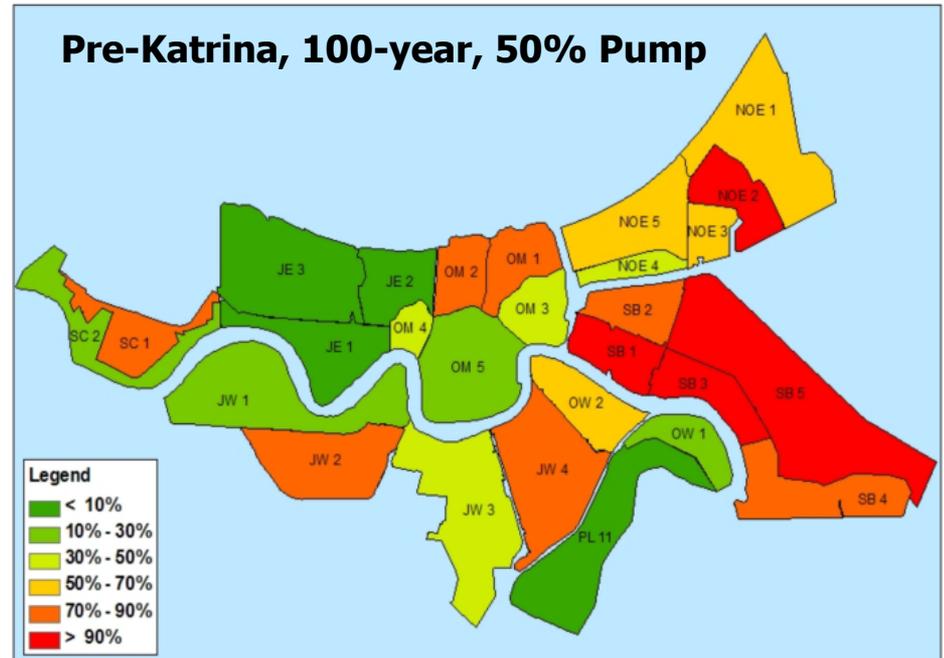
44 Lives

\$250M

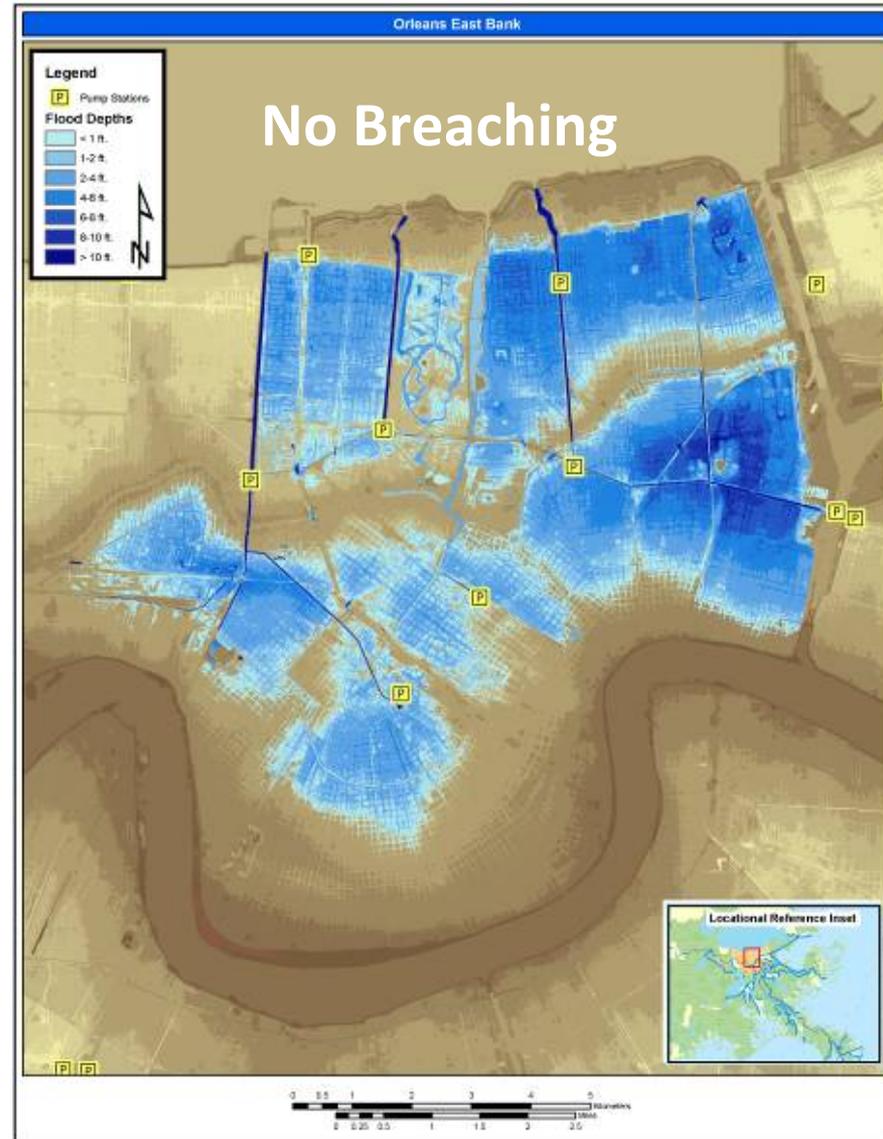
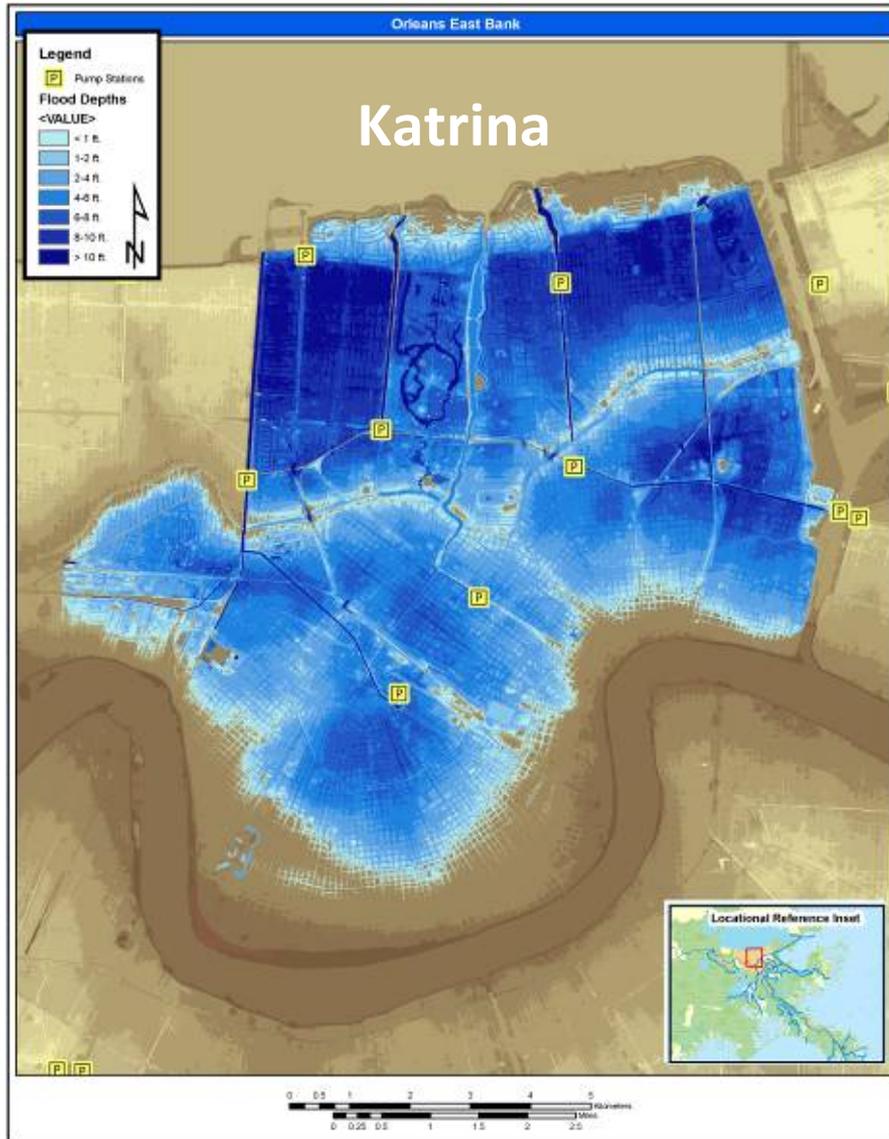
Property Loss Risk Map

Hurricane Protection System in place before Katrina with pumping at 50% of capacity
There was a 1% (1 in 100) chance of this percentage property loss

Pre-Katrina, 100-year, 50% Pump

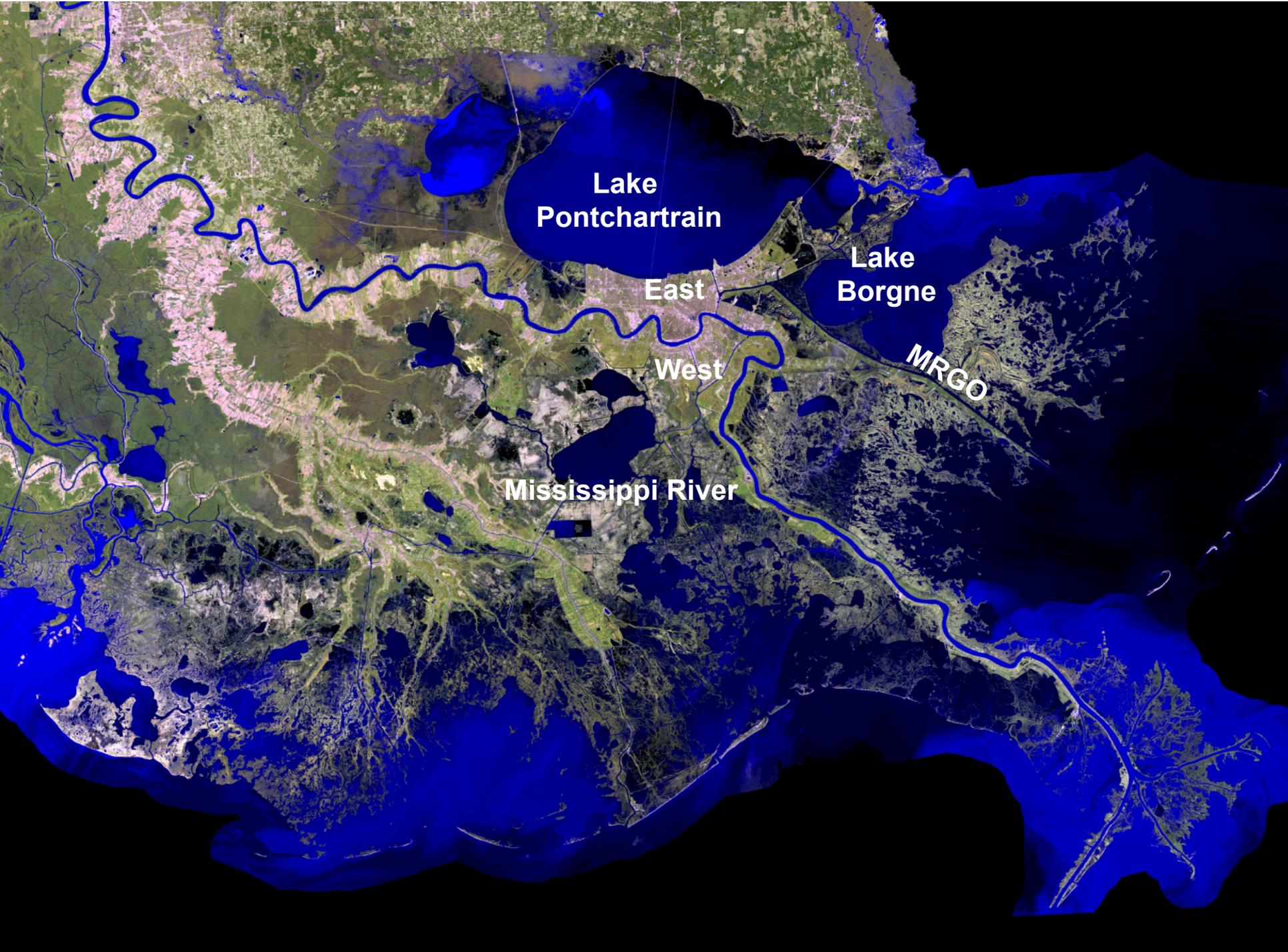


Infrastructure Resilience



Fatalities - Orleans Parish (LifeSim)

Sub-Basin	Katrina Flooding	No Breaching
OM1	11	7
OM2	751	394
OM3	84	63
OM4	13	9
OM5	53	23
Total	912	496



Lake
Pontchartrain

Lake
Borgne

MRGO

Mississippi River

East

West