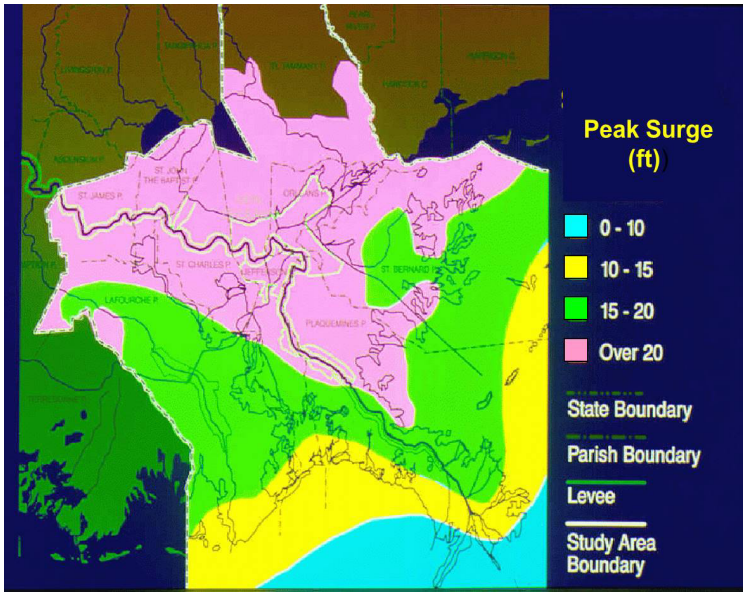
New Orleans
Hurricane Surge Risk Management

Part I. Pre-Katrina History



USACE 1998

Bob Jacobsen PE, LLC
Coastal Hydrologist

June 2015

Part I. Topics

- In the Beginning . . . Record Flood
- 1960s—Standard Project Hurricane
- 1970s—Surge Hazard Curve
- 1980s—Joint Probability Analysis & 2D Modeling
- 1990s—Extreme Storm Scenarios

In the Beginning . . . Record Flood

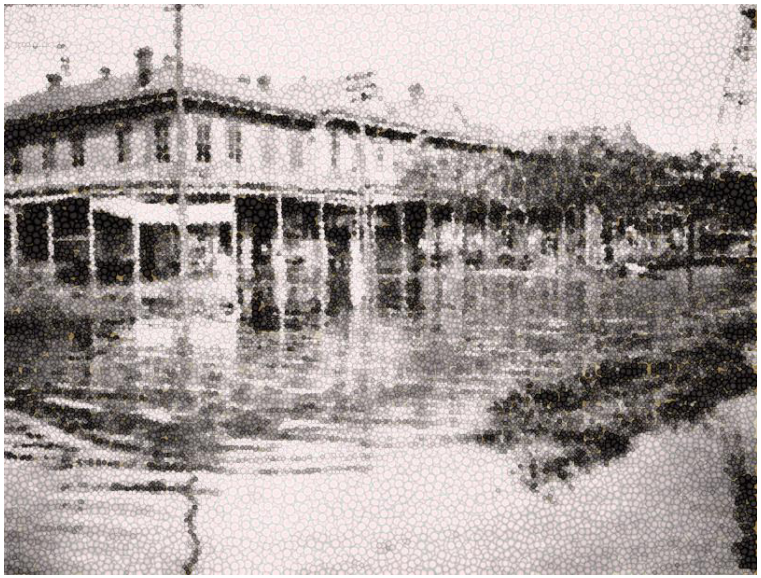
- Risks of river floods & "tidal surges" acknowledged in Bienville's letter to Company of West.
- Company needed location to fit many needs—military, regional navigation control, port, exploit local resources & cultivation of cash crops.
- He advocated for NO site: "fine crescent."
- But he had title to land!
- Conflicting interests & cost-benefit analysis, from moment of founding!

Earliest Flood Risk Management

- Elevating critical structures
  - Storage of food reserves
  - Temples
  - Leader dwellings
- Communities facing frequent floods also adopted the obvious measure of constructing perimeter levees.
  - Egypt
  - China
  - Mesopotamia

The Record Flood

- Earliest inhabitants of permanent floodplain settlements have always undertaken trade-off analyses.
- Survival placed a premium on more than relying on good luck.
- Maintained flood marks spanning generations to supplement their oral history.
- Use vast, flat, water surface during still periods to transfer major flood marks to outlying locations.
- Up until the latter half of the 20th Century, keeping track of the historic **Record Flood** continued to be the State-of-the-Practice (SOP) for defining flood hazard.



The Record Surge

- In 1722—after experiencing 1st hurricane surge—NO leaders required everyone to contribute to building "***back levee***."
- Behind the City, facing Lake Pontchartrain, initially constructed only a few feet above ground.
- Over ensuing 200 yrs NO experienced many record surges.
- Stimulating ever higher back levees & better material & construction.
- Particularly during 1st half of 20th Century—advances in geotechnical engineering.

1930s WPA Lakefront seawall construction

The Record Surge

- By early 1960s the City had upgraded its Lakefront levees several times.
- As had other River communities with their "40 Arpent" levees. (French colonial riverfront land grants had a rear limit of 40 Arpents, equivalent to about 1.5 miles.)
- The USACE had begun to assist bourgeoning Jefferson Parish with the design & construction of its back levee (USACE 1955).
- Latest levees response to September 1947 hurricane.
- Of course, relying on record flood to manage risk also proved unsustainable.

PICTURE PARADE TODAY

HURRICANE

NEW ORLEANS ITEM

Seventy-First Year—87 Friday, September 19, 1947 Price Five Cents

FINAL HOME

STORM BATTERS CITY

The Might Of A Hurricane

Hurricane Damage Is Heavy

Attended by winds above 90 miles an hour which raged through New Orleans, the center of the great hurricane passed over New Orleans today leaving in its wake heavy damage, scores of injured, but no dead.

Federal Involvement in LA Flood Protection

- Federal involvement on the nation's waterways grew during the 19th century with demands to enhance navigation in support of interstate commerce.
- After 1874 record multi-state Mississippi River flood Congress created Mississippi River Commission to takeover River levees.
- Ensure local flood control priorities didn't trump navigation.
- Protecting NO Port became a priority for MRC; thus beginning substantial & messy federal entanglement in NO flood protection.

Federal Involvement in LA Flood Protection

- 1890 & 1912 floods led to further levee upgrades.
- Great Flood of 1927 forced the MRC/USACE to rebalance River flood control & navigation priorities.
- Developed new policies & actions that better addressed balance—e.g., diversions.

- Led to greatly expanded flood control construction & operations & associated long-term funding.
- During 20th Century USACE increasingly authorized to lead regional & even local flood control projects—with state & local sponsors assuming a share of construction costs & O&M—including several in LA.
- Projects all involved balancing flood control vs competing interests, such as navigation, irrigation, power generation, recreation, and/or environmental preservation.

Hurricane Betsy—Sept 1965

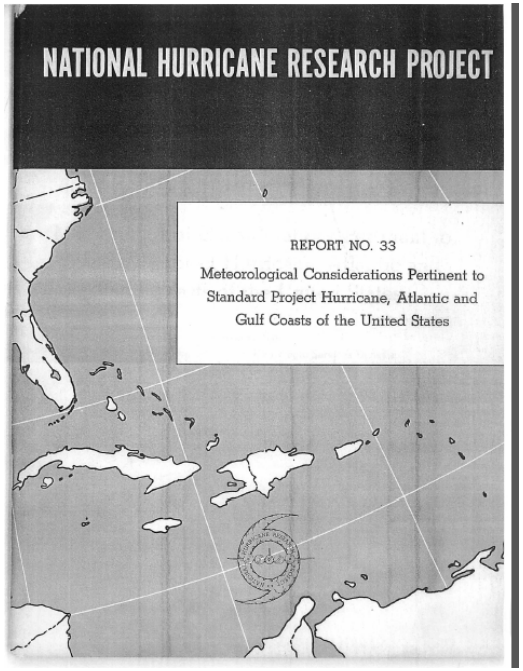
- Cat 4 at landfall; produced a new record surge—reaching up to 16 ft NAVD88 in places east of NO.
- Back levees failed; extensive flooding throughout the New Orleans Lower 9th Ward, St. Bernard Parish, as well as in Gentilly west of the IHNC.
- Regional damages of $1 billion, most expensive hurricane in the nation at the time.
- City faced a choice: massive, expensive perimeter protection vs economic stagnation.
- Sen. Long & Rep. Boggs persuaded a sympathetic Pres. Johnson & Congress to fund federal construction (70 percent) of Metro NO surge protection.

1960s
Standard Project Flood

- 20th Century scientific advances suggested that a practical extreme flood height reflecting the various physical factors could be directly calculated.
- US Weather Bureau (now NWS/NOAA) responsible for the SPF estimates.
- SPF used in riverine flood control since the 1940s.
  - Given regional hydrologic characteristics regional rainfall extremes, river basin topography, runoff, time of concentration to various tributaries, etc.
  - "***Close to Worst-Case***."
  - ***For design of flood controls intended to prevent <u>BOTH</u> the loss of life & destruction of property.***
  - A hazard more severe than any in the historical record.
  - Probable Maximum Flood (PMF) is "worst-case"—e.g., MRT design.

Standard Project Hurricane

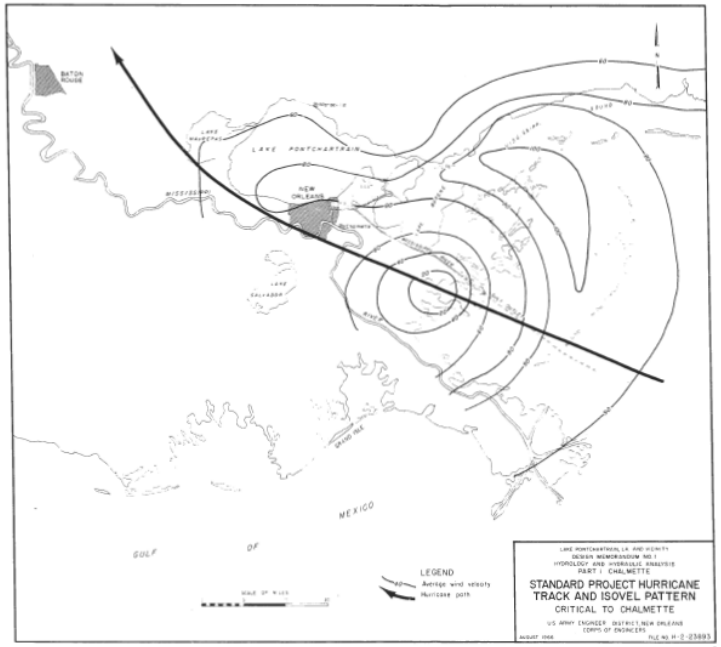
- For post-Betsy NO protection—***both*** lives & property—USACE turned to concept of SPH surge.
- 1959 Weather Bureau SELA SPH:
  - Core barometric pressure deficit: **ΔP = 80 mb** (P_P - P_C)
  - Core size, radius of maximum winds: **R_{MAX} = 30 n.mi**
  - Storm forward speed: **V_F = 11 knots**
  - Max sustained winds (1-min avg): **V_{MAX} = 112 mph**.
  - Modest decay as it moved overland.
  - Max sustained winds over Lakes Borgne & Pontchartrain: 100 mph.



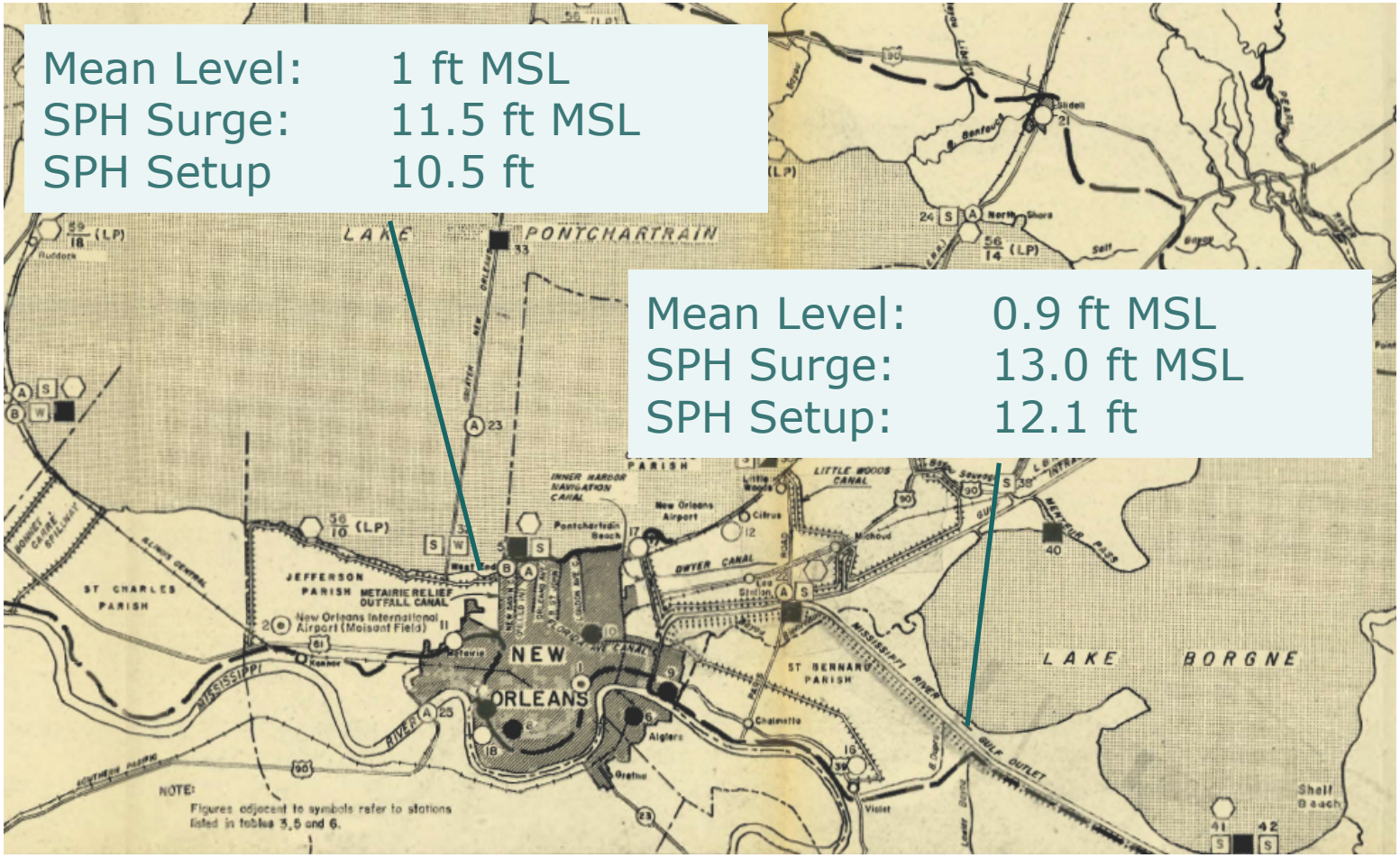
- 1978 SPH revision:
  - ΔP 84 mb; R_{MAX} of 29 n.mi; V_F 4 knots
  - Offshore max sustained winds: 104 mph
- Probable Maximum Hurricane: ΔP = 125 mb.

SPH Peak Surge

- Few selected landfall/track scenarios
- Late-1960s-era 1D ***steady-state*** empirical formula for wind setup.
  - Wind setup ∝ fetch, wind speed^2, 1/depth.
  - Wind speed is ***10-min wind*** ≈ 85-90% x 1 min wind
  - Loss coefficient.
  - ΔP effect also included.
  - Higher levees block raise calculation of steady-state setup.
  - Timing of tides was ignored.



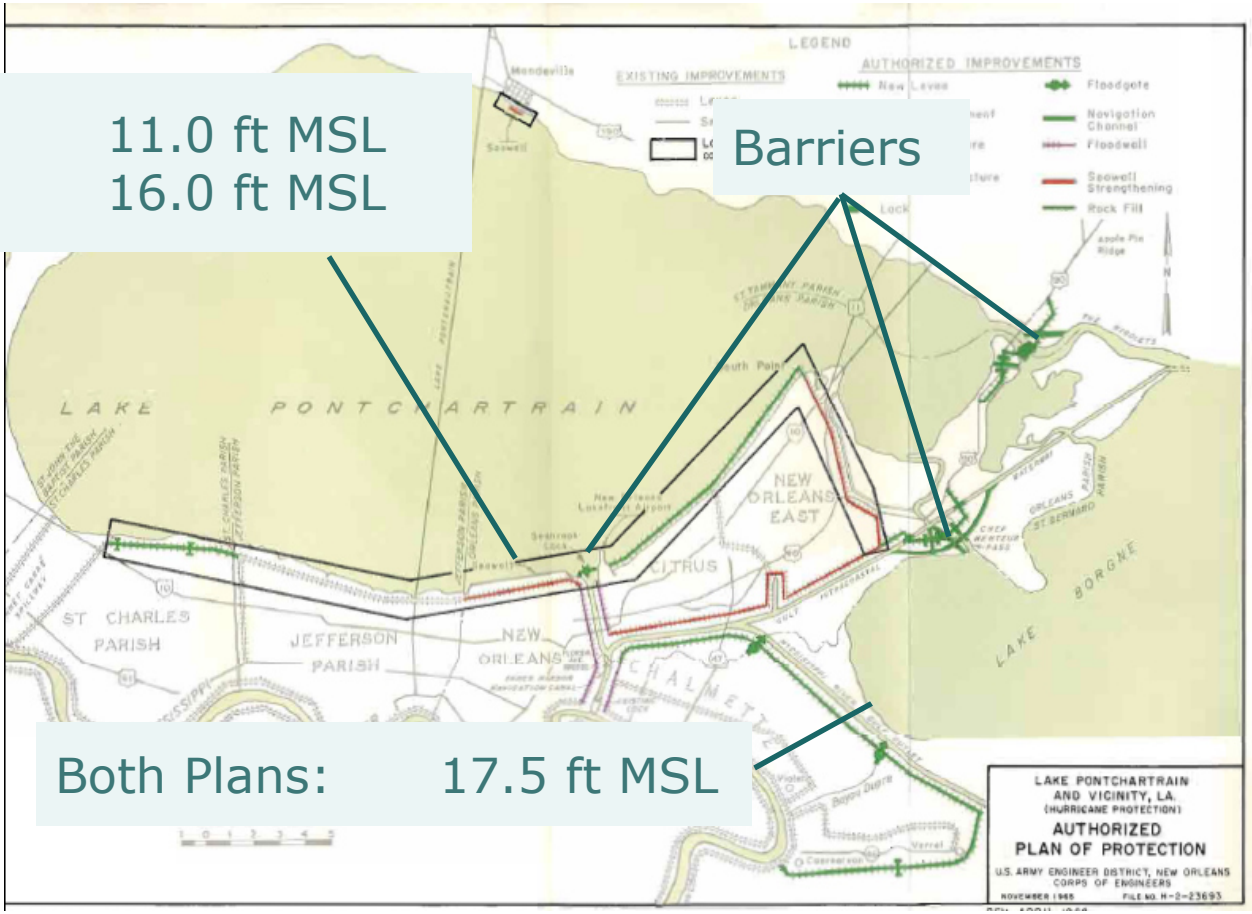
SPH Peak Surge



Barrier vs “High-Level” Plans

Levee heights 4.5 ft above SPH surge—account for peak waves & run-up height on levee slopes.

Barrier: 11.0 ft MSL
High Level: 16.0 ft MSL



Both Plans: 17.5 ft MSL

Design & Construction Challenges

Given the USACE's experience with Mississippi River & other flood protection projects, **not that unusual**.

- Alignment details
- Adequate buffers
- Pipeline, utility, & other relocations
- Suitable material & proper compaction
- Foundation & subsurface variability (affecting levee geometry, soil compaction procedures, & settlement both during & after construction)
- Elevation survey control
- Turf establishment.

But 3 would become significant!

Floodwalls substituted for levees

- Limited rights-of-way
- Requires extensive subsurface information to specify appropriate sheet pile depth.

Competing Interests

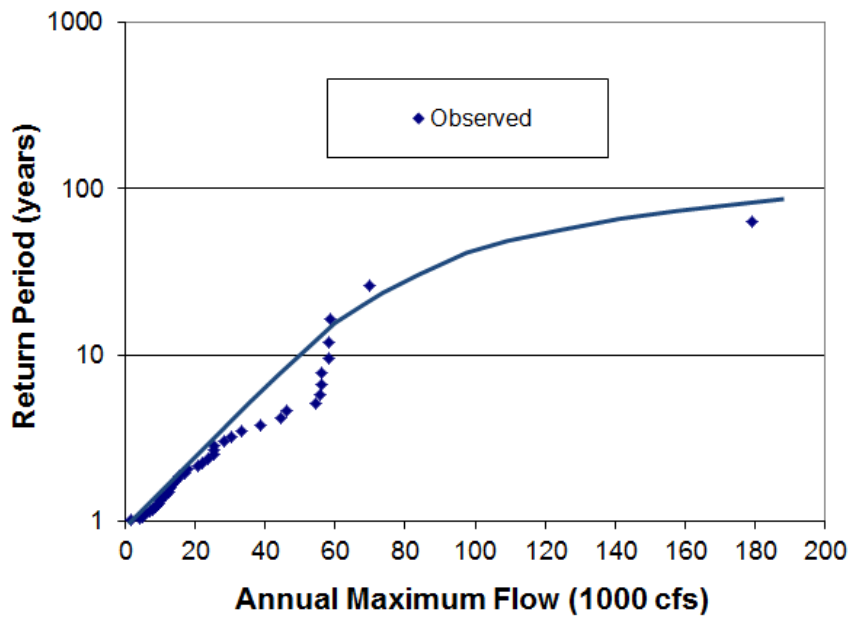
- 1969 Hurricane Camille >20 ft surge Waveland MS reinforced sense of urgency.
- Barrier Plan confronted serious competing interests & new programmatic hurdles.
  - Opposition over changes to Lake water quality & fisheries.
  - Opposition to St. Charles Parish levee along the Lakefront, preferring to move it further south & impound much less of the LaBranche Wetlands.
  - Addressing challenges involved new & evolving—time consuming—requirements for environmental impact assessments & economic cost-benefit analysis.
- A final resolution switching to High-Level Plan was not reached until the ***mid-1980s*** & St. Charles south alignment was not adopted until the ***1990s***.
- Through 70s & 80s region entered an extended period of low hurricane activity, which began to undermine the urgency to complete the SPH surge protection project.

Quantifying Flood Hazard

- By mid-20th Century, flood protection projects had begun to routinely apply statistical techniques for estimating the probability of extreme events.
- ***Flood hazard* quantified in terms of the annual probability of a particular flood stage being exceeded.**
- Each stage has its own discrete *mass probability* so the probability of exceedance is a *cumulative probability* encompassing the mass probabilities of all higher stages.
- In theory:
  - Objective, uniform criteria.
  - Gauge cost-effectiveness of incremental protection alternatives.
  - Avoid suboptimal over- & under-designs.
- Subsequent planning developments would incorporate the probability for flood consequences—damages, loss of life, etc.—and seek to compare projects on the basis of quantified *flood risk*.

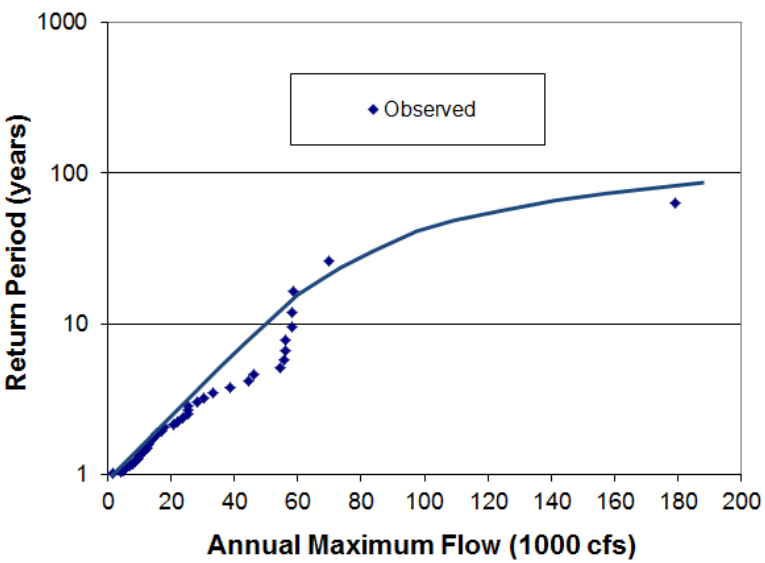
1970s
Flood Hazard *Curve*

- Quantified flood hazard is depicted with a *location-specific* curve.
- Stage (or discharge for rivers) on one axis & cumulative annual probability, aka annual return frequency, on the other.
- The annual return frequency has a finite range—from 0 to 100%.
- Instead of annual return frequency the average annual return period is often used—the latter is simply the inverse of the former—e.g., an annual return frequency of 0.01 equals an *average* return period of 100 years.



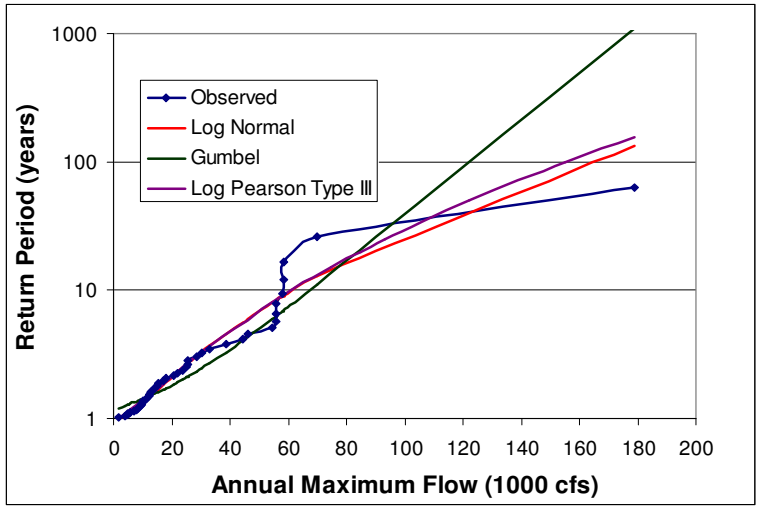
Early SOP for Flood Hazard Curve

- Plot series of max stages from local river gauge (or tide gauge for surge) vs each observed stage's rank in the record (sometimes slightly adjusted).
- If river gauge information was limited, additional stage-frequency "data" could be synthesized by estimating the stages associated with regional rainfall events (using the probability of the rainfall event together with hydrologic & hydraulic modeling).
- Hand draw a smooth curve to generally fit points.
- Not a parametric equation.
- Given very limited data sets, extrapolation of the hazard curve by hand was very subjective—e.g., to return periods of 100- & 500 years.



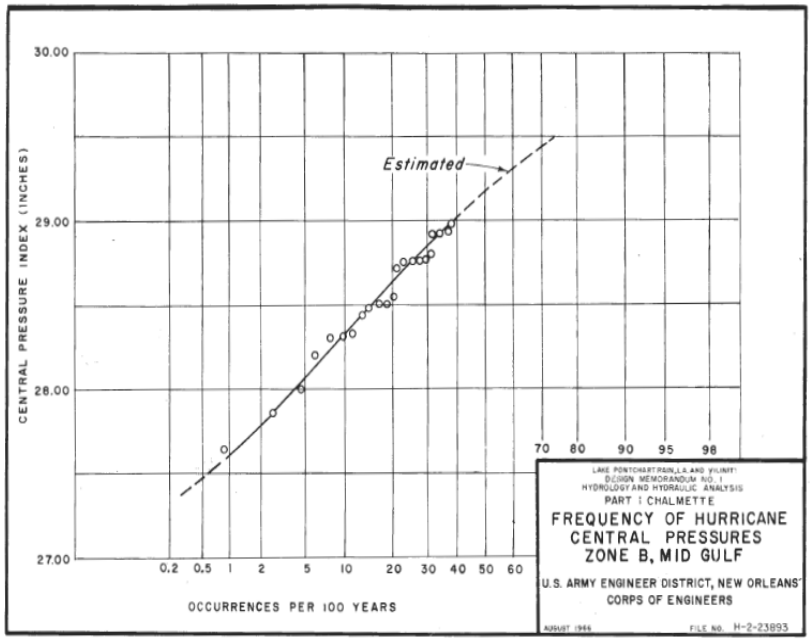
Extreme Value Functions (EVFs)

- Later (by 1980s) hydrologists used parametric equations—EVFs—to reduce interpolation/extrapolation subjectivity.
- Example EVF Types:
  - Log-Normal
  - Log-Pearson Type III
  - Generalized Extreme Value (GEV)—Gumbel, Weibull, & Frechet.
- EVF Type selected for general shape agreement (asymmetry) & suitable tailing properties. Agencies tend to use a particular EVF Type after extensive evaluation:
  - USGS/Rivers—Log-Pearson Type III.
  - NOAA/Tides—GEV.
- Still some subjectivity in choice of EVF Type.
- EVF equation coefficients selected with regression analysis—minimize RMSE.



1966 NO Surge Hazard Curves

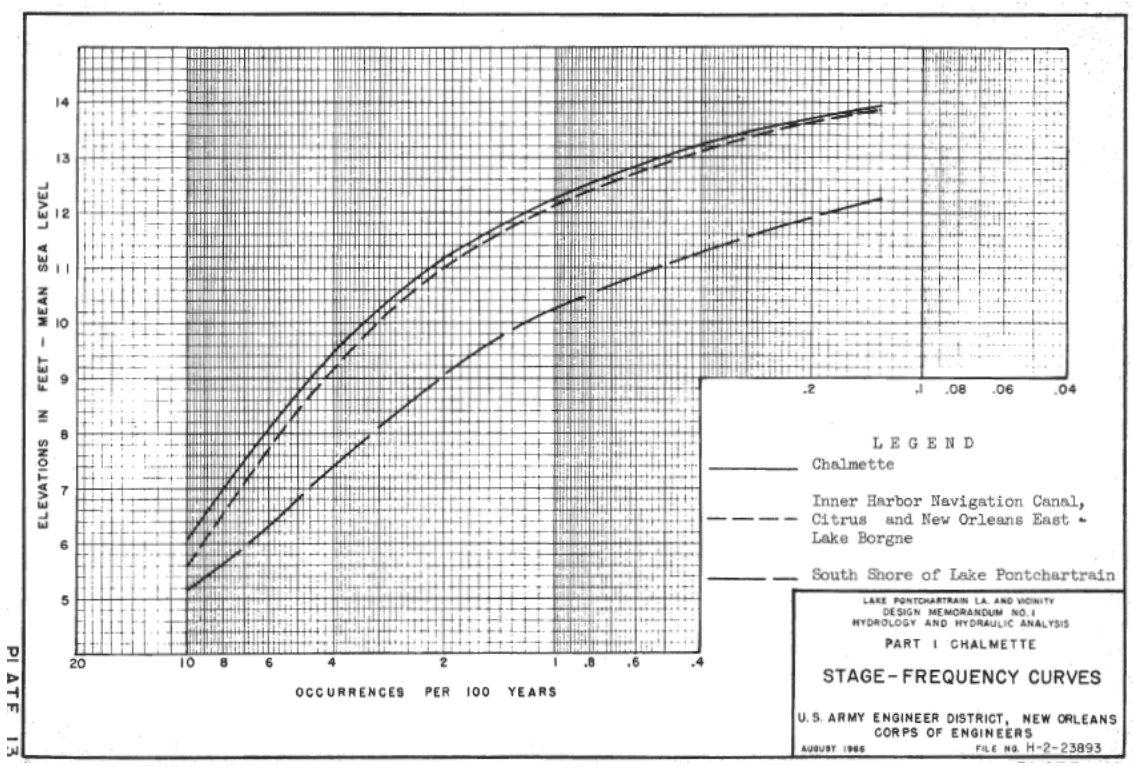
- Regional surge return data for nine storms
  1893, 1901, 1909, 1915, 1926, 1947, 1956, 1964, 1965
- Weather Bureau regional hurricane intensity (P_C) return frequency curve.
- USACE used hurricane intensity returns—plus basic track scenarios & the simple 1D steady-state empirical wind setup formula described—to synthesize some limited surge-return data.



1966 NO Surge Hazard Curves

Hand-drawn curves; 3 main sub-regions:

- Lakefront of Jefferson & Metro New Orleans
- New Orleans East & the IHNC
- St. Bernard Parish (referred to as Chalmette Loop).



NFIP/FIS 100-yr Surge Hazard

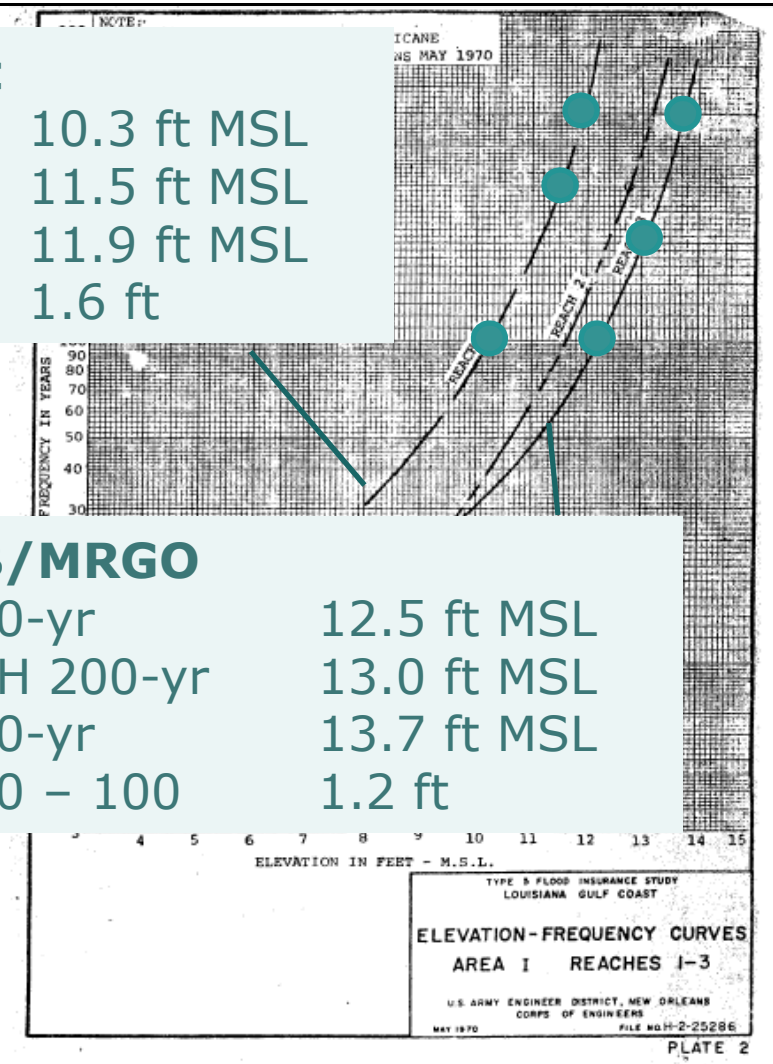
- 1970, FEM predecess USACE to NO region hazard an
  - Reach 1, South Shore of Lake Pontchartrain.
  - Reach 2, North Shore of Lake Pontchartrain.
  - Reach 3, Lake Borgne (St. Bernard Parish).
- 1966 and 1970 curves identical at return period > 50 yrs
- Excluded Barrier Plan

NO Lakefront

100-yr	10.3 ft MSL
SPH 300-yr	11.5 ft MSL
500-yr	11.9 ft MSL
500 – 100	1.6 ft

SB/MRGO

100-yr	12.5 ft MSL
SPH 200-yr	13.0 ft MSL
500-yr	13.7 ft MSL
500 – 100	1.2 ft



NFIP Consequences for NO

- Interior home mortgagors in good drainage areas were not required to purchase flood insurance—optional flood insurance was very affordable.
- Areas with100-yr drainage problems—property values declined, economic hardship for whole neighborhoods.
- NO officials (similar to other flood-prone cities) wanted drainage improvements to remove larger/populated/ potentially more valuable areas from 100-yr flood zone.
- In 90s NO leaders sought & obtained federal interior drainage construction project: **USACE SELA Project**.

NFIP ironically had inevitable & perverse effect of spurring local officials to prioritize USACE funding for SELA over SPH surge protection!

The Beginning of Decades of Delay

- Environmental and programmatic delays were compounded by budget issues.
- Steep inflation of construction costs during 70s & 80s meant that annual appropriations covered less & less work, exacerbating delays.
- Annual appropriations for SPH surge protection projects were restricted—as Congress spread USACE funds across many competing demands from across the nation—forcing construction schedules to be greatly extended.
- NO officials often placed navigation & SELA priorities above surge protection for annual funding.
- Declining sense of urgency due to lull period.

Review & Re-Evaluation

The official estimated cost (millions) & schedule for East-Bank SPH surge project ***mushroomed***:

Year	During	Cost (millions)	Estimated Completion
1965	Authorization	$85 (rev 1968 to $98)	1978
1976	GAO Review	$352	1992
1982	Re-Evaluation & Adoption of High-Level Plan	$760	2008

9X 3 Decades

Design Concessions

As SPH Surge Protection Project dragged on there was an inevitable increasing emphasis on cost control & construction speed-up.

This in turn contributed to ***engineering concessions***—

- levee materials
- elevation control
- floodwall support conditions

What was the rationale? Acceptability of lower FOSs?

And to deferring supplemental lifts for segments which had undergone significant post-construction settlement.

Saffir-Simpson Scale

- 150 yrs of coastal/marine barometric pressure observations, P_C has long been used to represent hurricane intensity.
- $P_C \propto (V_{MAX})^2$ & *all other factors being equal* surge $\propto (V_{MAX})^2$.
- P_C convenient short-hand predictor of surge severity.
- From 1970s on:
  - Routine aircraft reconnaissance of hurricane eyewalls
  - Measurement of maximum sustained winds
  - Saffir-Simpson Scale (1 to 5 V_{MAX}) popularized.
  - Track & SSS ingrained in the minds of officials & the public as the overriding factors in surge hazard.
- NO offshore SPH V_{MAX} of 112 mph is minimal Cat 3.
- SPH ΔP of >80 mb more indicative of Cat 4.

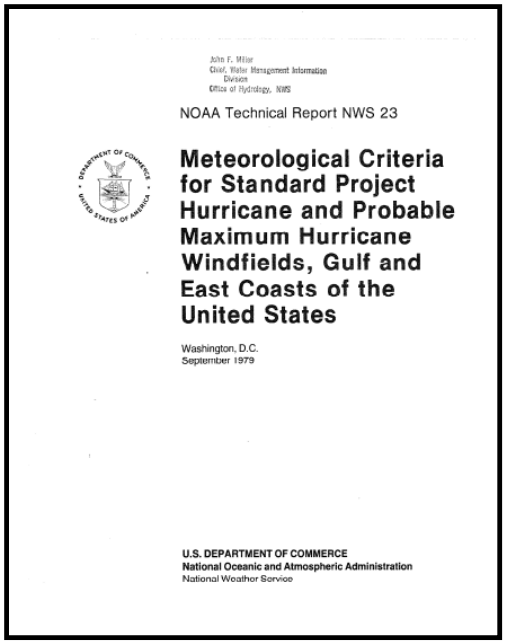
Lowest recorded overland pressure in the United States is 892 mb (ΔP of >110 mb) on September 2, 1935 in Florida during the Labor Day Hurricane.

1980s
Hurricane Joint Probability Analysis

- Other factors not equal; significance to local wind & surge hazard long known to hurricane meteorologists.
- 1980s NOAA began re-examining influence of variations in

R_{MAX} V_F Landfall θ Landfall X Landfall Decay

- Surge hazard analysis requires a large array of synthetic storms representing the combined joint probabilities.
- 2 approaches to JPA:
  - Empirical
  - Joint Probability Method


John F. Miller
Chief, Water Management Information Division
Office of Hydrology, NWS

NOAA Technical Report NWS 23

Meteorological Criteria for Standard Project Hurricane and Probable Maximum Hurricane Windfields, Gulf and East Coasts of the United States

Washington, D.C.
September 1979

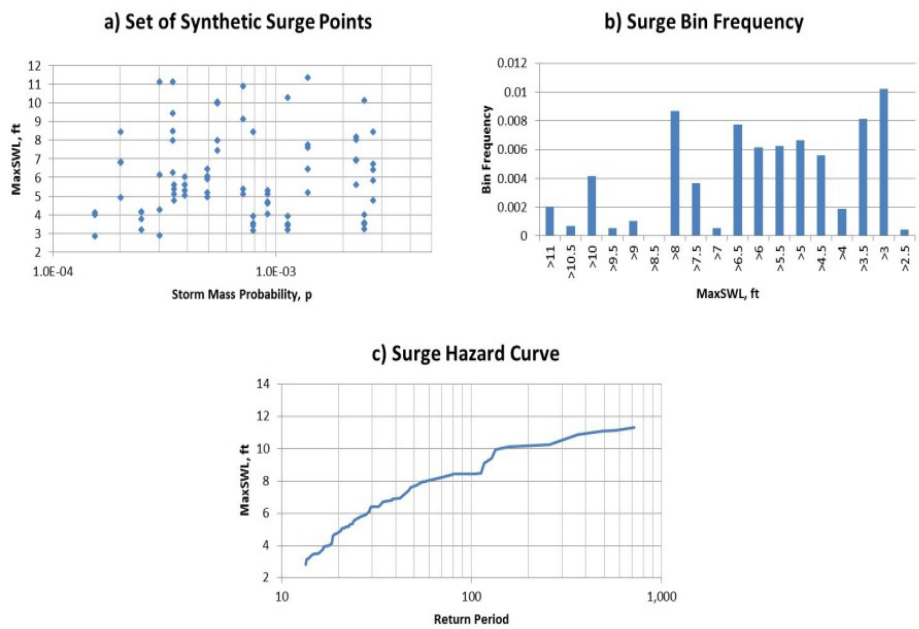
U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

JPA Empirical Approach

1. Expanding on historical observations to create an artificial hurricane record:
   - ***5X to 10X longer than the longest return period of interest.***
   - Variability in the combination of hurricane attributes that is consistent with the generally observed return frequencies, trends, & variance in the regional climatology.
   - After 2000, coastal ***wind hazard analysts*** developed an artificial 100,000-yr hurricane record—with tens of thousands of storms (Vickery et al 2009).
   - ***Not practical for surge hazard analysis***—too many surge simulations.

JPA JPM Approach

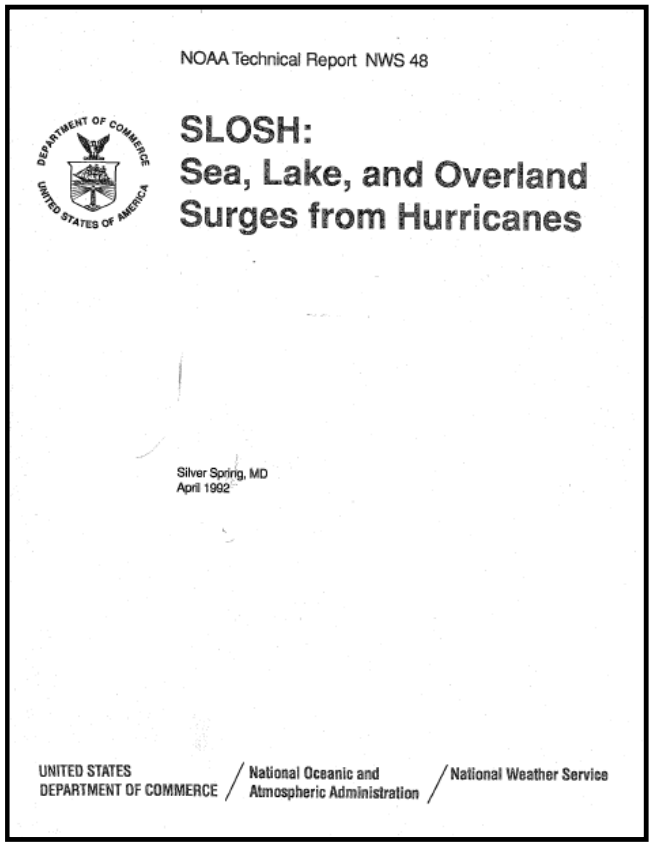
- Tries to provide a ***reasonable sample*** of the joint-probabilities—not a full artificial record.
- What's reasonable? 2, 3, 4 per characteristic?
- 3 values for 6 characteristics yields a set of 729 storms.



Set of 76 storms with their respective mass probabilities; a histogram of the combined mass probability by 1-ft bins; & the numerically integrated cumulative hazard curve.

Advent of 2D Hydro*dynamic* Models

- FEMA Coastal Flooding Storm Surge Model; SLOSH; RMA2 .
- Began to capture some of the complex ***time-varying*** physical interactions between
  - The shoreward-driven forerunner & main surge.
  - The rapidly shifting local setup driven by passing wind-field.
  - The impact of coastal landscape features.
- Still coarse resolution.
- Tides, wave setup not included.
- Debate: 2D model vs 1D steady-state equations.



NOAA Technical Report NWS 48

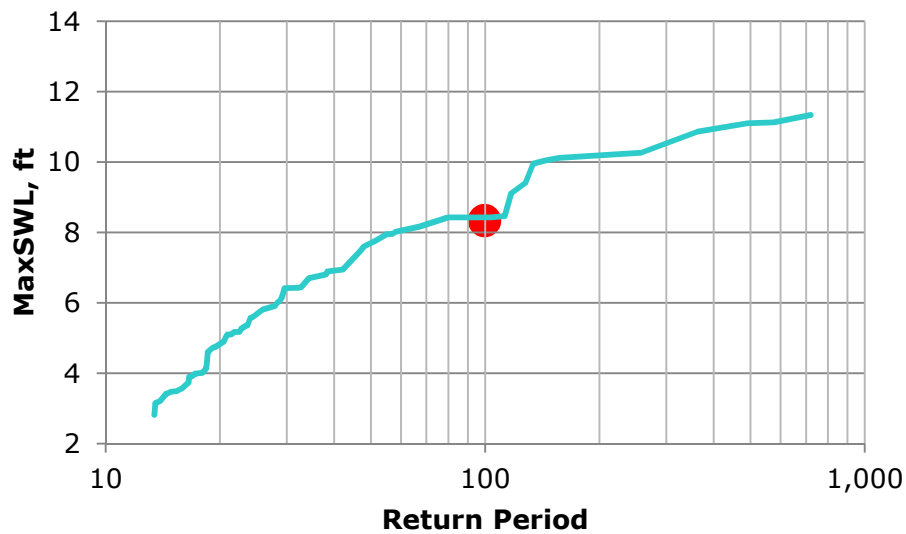
SLOSH:
Sea, Lake, and Overland Surges from Hurricanes

Silver Spring, MD
April 1992

UNITED STATES DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

Combining JPM & 2D Modeling

- Joseph N. Suhayda (LSU) 1989 Cameron Parish LA FIS; JPM set used 685 storms.
- 1990s—continued advances had made JPM & 2D modeling the SOP in surge hazard analysis.
- Surge hazard curve presented as a non-parametric function covering the wide range of return periods generated by the analysis (perhaps smoothed using an algorithm) & there was no need for extrapolation.



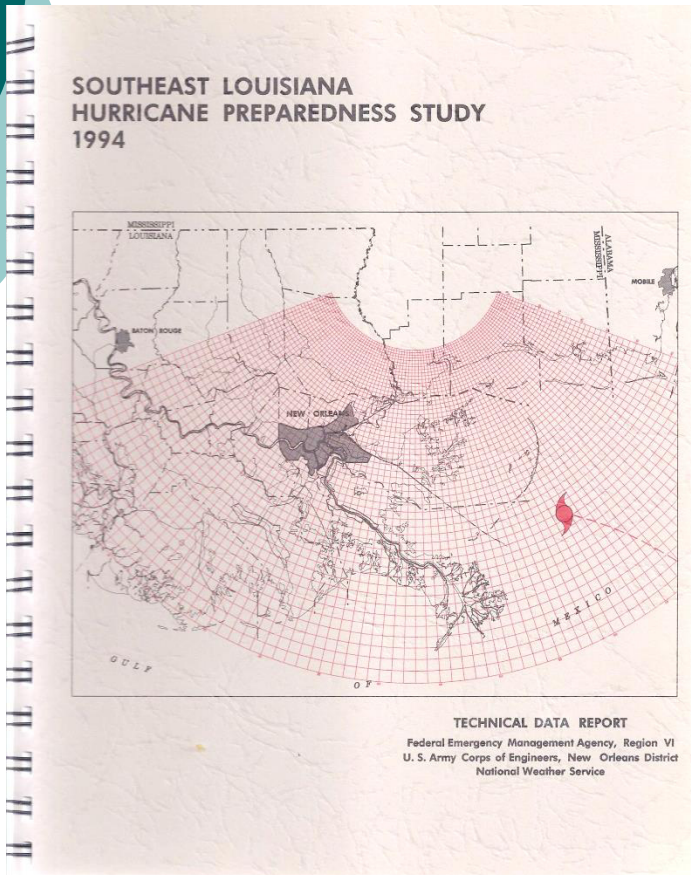
Continued Reliance on SPH

Despite advances in JPA & 2D modeling and even as High-Level Plan was only then being finalized & a surge protection project was being added for West-Bank.

5 factors:

1. NOAA didn't change SPH.
2. FEMA didn't revise regional surge hazard analysis; might have indicated higher surges at 200- /300-yr; big FIS backlog.
3. 1966 SPH surge estimates still thought reasonable in light of relative newness of the JPM/2D approach; some considered 1D steady-state surge estimates more conservative.
4. 30 yrs of project momentum; natural reluctance to re-open the specification of design surge height; desire to expedite completion of regional SPH protection.
5. Expert team could have been assembled to re-evaluate design surge—***BUT*** change in the design surge likely would have delayed the High Level Plan adoption by many more years.

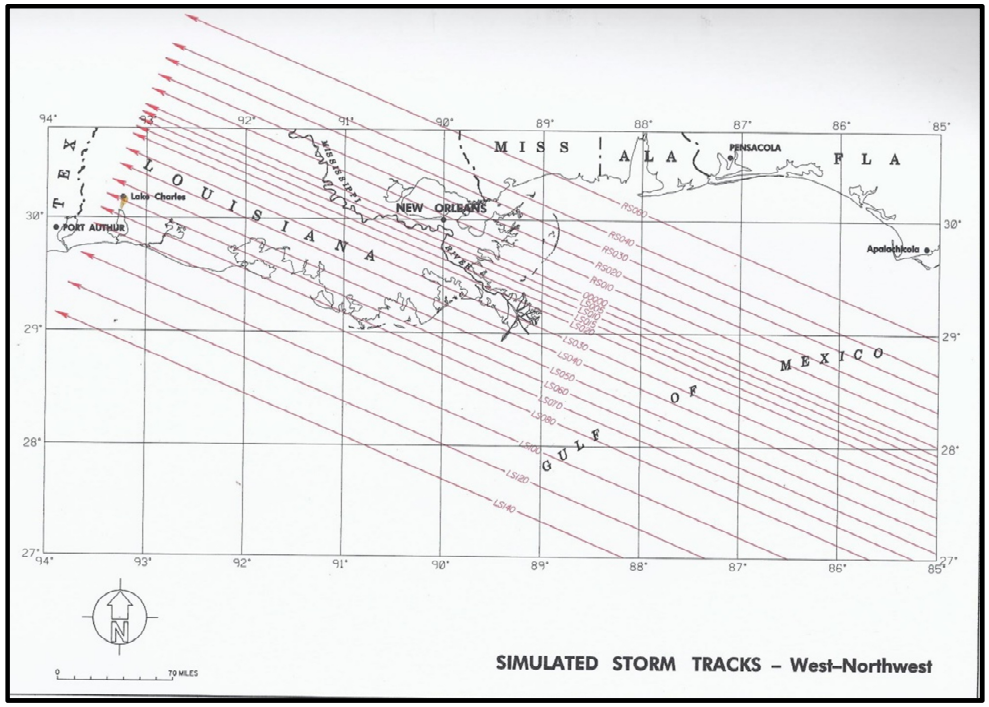
1990s
Extreme Storm Scenarios



- Stimulated by Hurricane Andrew—wind and surge hazard.
- Mid-90s, fed/state/local emergency ops & storm forecasters concerned that available analyses not sufficient about potential severe surge events.
- If a major hurricane approached SE LA officials needed information about surge scenarios associated with that hurricane.
- Wanted to enhance annual preparedness drills & "table-top exercises."
- Increasingly aware that surge scenarios based on track & SSS alone were not sufficient.
- Wanted effects of coastal landscape on surge—topo barriers—better accounted for in the scenarios.

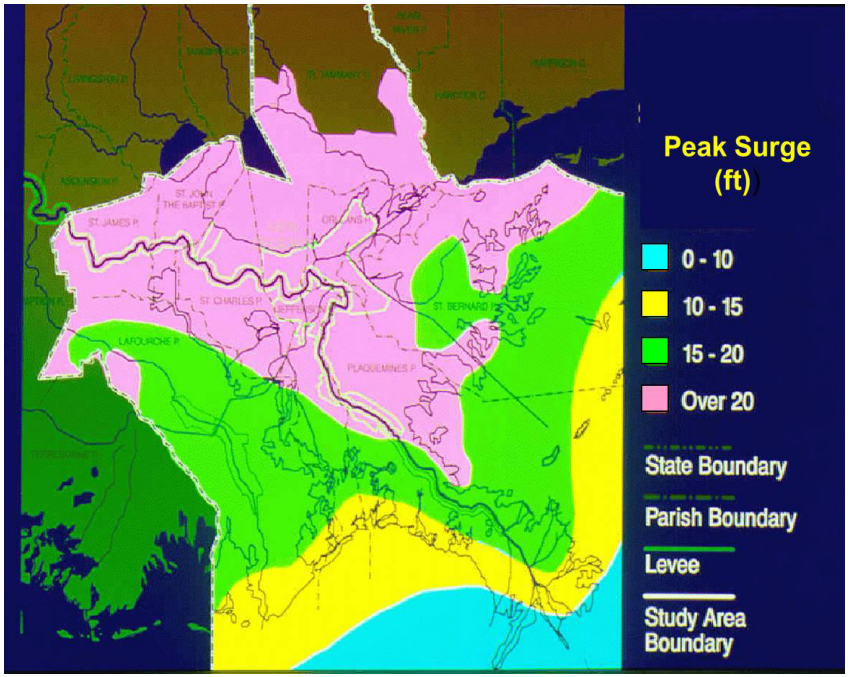
1994 Southeast Louisiana Hurricane Preparedness Study

- SLOSH—much coarser than the FEMA's model—but simulations more efficient allowing more storm variations to be considered.
- 328 variations for each SSS Cat 1 – 5.
- 9 variations in θ.
- Each with 2 V_F.
- 15 to 20 landfall locations.
- A single R_{MAX} of 25 miles.
- No tides.



MEOWs and MOMs

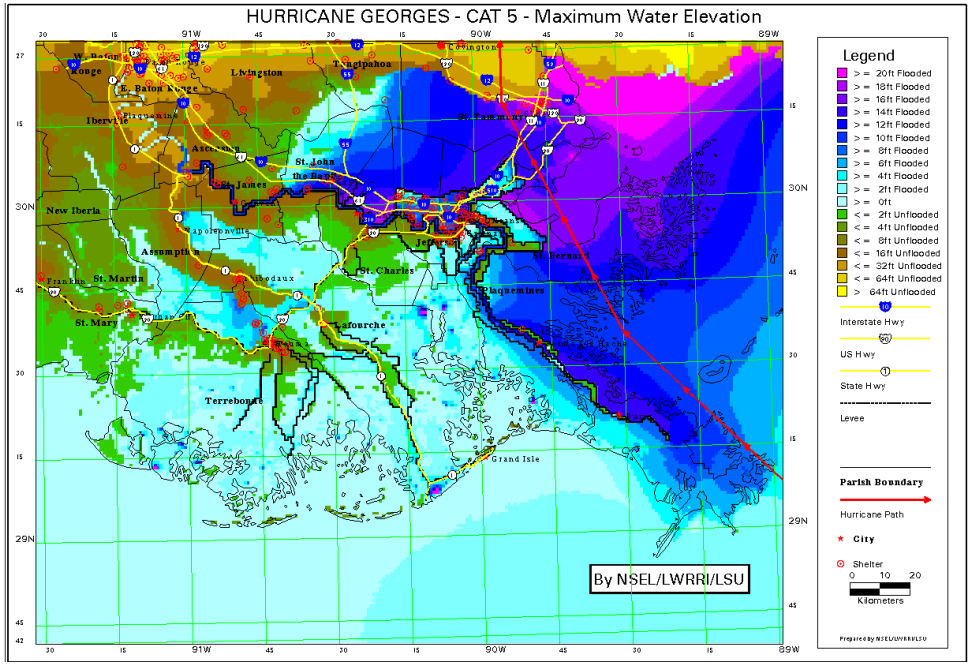
- Maximum Envelope Of Water (MEOW): composite map illustrating the maximum surge exposure for a hurricane of given category & general heading.
- MEOWs indicated surge exposure throughout the region—given less predictable landfall and V_F—for emergency response.
- Maximum of Maximums (MOM)—overall composite for each category—for general planning.



Combined MOM
Slow Cat 4 & All Cat 5 Hurricanes
USACE 1998

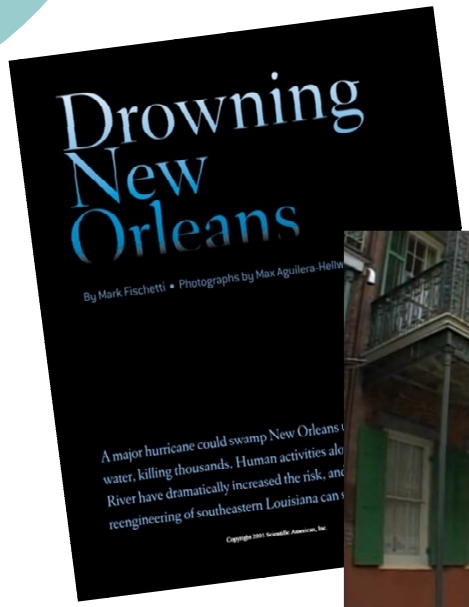
1998 Hurricane Georges Near Miss

- Further amplified interest in extreme surge scenarios.
- NOAA subsequently undertook minor refinements of the SLOSH model & updates to the MEOWs & MOMs with additional variations for tide.
- Joseph N. Suhayda (LSU) examined hurricane scenarios (Cat 5) with higher resolution FEMA model for LA OEP.



Media Reaction—Early 2000s

- Conditions far exceeding Betsy, SPH, 1966 500-yr estimate.
- Local and national news media increasingly attentive to stories on extreme surge hazard.
- Broad dissemination of the extreme surge scenarios among state & local officials & the public.



INSIDE

Special Report: Washing Away

- Part 1 - In Harm's Way
- Part 2 - The Big One
- Part 3 - Exposure's Cost
- Part 4 - Tempting Fate
- Part 5 - Cost of Survival
- Hurricane Center

Washing away

- SPECIAL REPORT from THE TIMES-PICAYUNE -

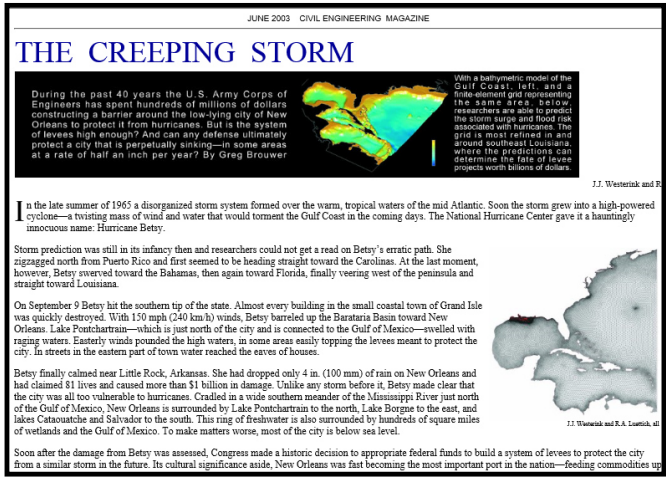
It's only a matter of time before South Louisiana takes a direct hit from a major hurricane. Billions have been spent to protect us, but we grow more vulnerable every day.

Five-Part Series published June 23-27, 2002

Response to Extreme Scenarios:

1. SPH Surge Protection

- USACE undertook a serious but limited response—within authorization & budget constraints:
  - Development of an advanced, "Supercomputer"-based, regional 2D surge model (ADCIRC).
  - Preparations with FEMA for new FIS.
  - Assessment of settlement with GPS-enhanced surveying.
  - Preliminary studies for higher protection.
  - Interior "unwatering plan" in the event of catastrophic surge inundation.
  - However, comprehensive review of structural vulnerabilities—given that reaching or exceeding the SPH surge could be more likely than previously thought—was not initiated.



JUNE 2003 CIVIL ENGINEERING MAGAZINE

THE CREEPING STORM

During the past 40 years the U.S. Army Corps of Engineers has spent hundreds of millions of dollars constructing a barrier around the low-lying city of New Orleans to protect it from hurricanes. But is the system of levees high enough? And can any defense ultimately protect a city that is perpetually sinking—in some areas at a rate of half an inch per year? By Greg Brouwer

With a bathymetric model of the Gulf Coast, left, and a finite-element grid representing the same area below, researchers are able to predict the storm surge and flood risk associated with hurricanes. The grid is most refined in and around southeast Louisiana, where the predictions can determine the fate of levee projects worth billions of dollars.

J.J. Westerink and R.

In the late summer of 1965 a disorganized storm system formed over the warm, tropical waters of the mid Atlantic. Soon the storm grew into a high-powered cyclone—a twisting mass of wind and water that would torment the Gulf Coast in the coming days. The National Hurricane Center gave it a hauntingly innocuous name: Hurricane Betsy.

Storm prediction was still in its infancy then and researchers could not get a read on Betsy's erratic path. She zigzagged north from Puerto Rico and first seemed to be heading straight toward the Carolinas. At the last moment, however, Betsy swerved toward the Bahamas, then again toward Florida, finally veering west of the peninsula and straight toward Louisiana.

On September 9 Betsy hit the southern tip of the state. Almost every building in the small coastal town of Grand Isle was quickly destroyed. With 150 mph (240 km/h) winds, Betsy barreled up the Barataria Basin toward New Orleans. Lake Pontchartrain—which is just north of the city and is connected to the Gulf of Mexico—swelled with raging waters. Easterly winds pounded the high waters, in some areas easily topping the levees meant to protect the city. In streets in the eastern part of town water reached the eaves of houses.

Betsy finally calmed near Little Rock, Arkansas. She had dropped only 4 in. (100 mm) of rain on New Orleans and had claimed 81 lives and caused more than $1 billion in damage. Unlike any storm before it, Betsy made clear that the city was all too vulnerable to hurricanes. Cradled in a wide southern meander of the Mississippi River just north of the Gulf of Mexico, New Orleans is surrounded by Lake Pontchartrain to the north, Lake Borgne to the east, and lakes Cataouatche and Salvador to the south. This ring of freshwater is also surrounded by hundreds of square miles of wetlands and the Gulf of Mexico. To make matters worse, most of the city is below sea level.

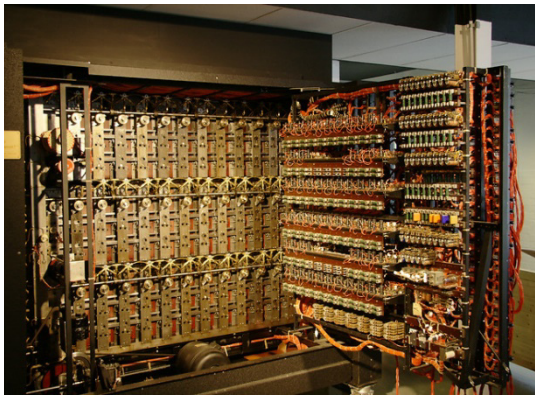
J.J. Westerink and R.A. Luettich, et

Soon after the damage from Betsy was assessed, Congress made a historic decision to appropriate federal funds to build a system of levees to protect the city from a similar storm in the future. Its cultural significance aside, New Orleans was fast becoming the most important port in the nation—feeding commodities up

USACE & local levee boards routinely underscored need for funding to complete/maintain/enhance SPH surge protection.

Supercomputing

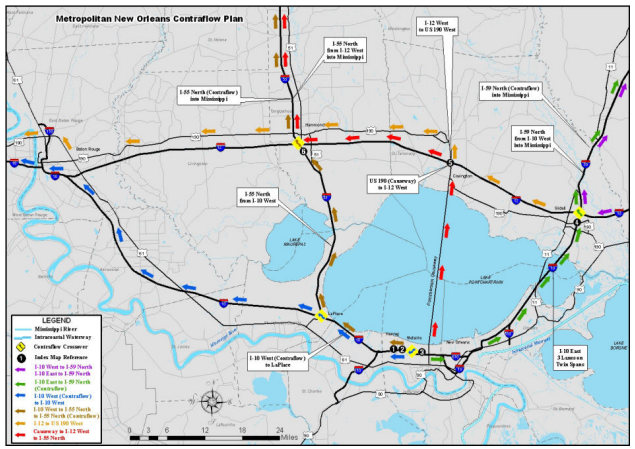
- High Performance Computer—***HPC***.
- Distributes ***parallel*** steps among X00s - X0,000s of microprocessors.
- Accelerating microprocessor speeds enabled development & adoption of HPC ***clusters*** for a vast number of computing needs.
- Large-Scale/High-Resolution models of natural systems.
- Research : "SuperMike" & "Queen Bee" at LSU.
- Commercial: WorldWinds, Inc. at Slidell, Louisiana.



Response to Extreme Scenarios:

2. Emphasis on Evacuation

- Leaders stressed critical importance of evacuation.
- Significant improvements in quality & communication of hurricane warnings & recommendations for evacuation of low-lying areas.
- Evacuation more practical to increasing numbers of residents in potentially affected areas.
- 1998 Hurricane Georges—substantial NO evacuation.
- 2004 Cat 4 Hurricane Ivan appeared headed for SE LA
  - Authorities urged NO residents to evacuate.
  - Mass evacuation of ensued, 1st "ContraFlow" (Wolshon).
  - ContraFlow Plan tweaked.
- Red Cross decided against shelters in NO.



Evacuation and Levees

For communities with flood levees, ***an increasing emphasis on evacuation reduces the priority of levees as a life-saving measure***.

- Leads to levees designed and maintained strictly for mitigating property damage risk (e.g., NFIP purposes).
- Fuels greater commitment on the part of leaders to evacuation.
- Reasonable if higher levees are not feasible.
- When evacuation becomes essential communities must provide for those who have medical, logistical, or financial problems with self-evacuating.

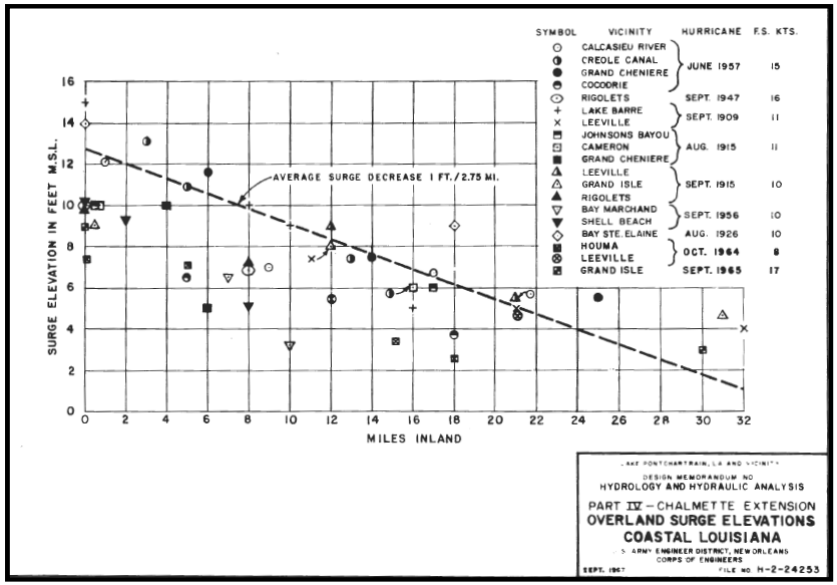
"A couple of days ago we actually had an exercise where we brought a fictitious Cat 5 hurricane [...] into the metropolitan area. Well, when the exercise was completed it was evident that we were going to lose a lot of people. We changed the name of the storm from Delaney to K-Y-A-G-B —kiss your ass goodbye—because anybody who was here as that Cat 5 storm came across was gone."

—Walter Maestri in 2002, then Director of Emergency Management for Jefferson Parish LA

Response to Extreme Scenarios:

3. Coastal Restoration & Protection

- History of studying impacts of hurricane surge on coastal
  marsh swamps cheniers channels bays barrier islands dunes
- 1990s recognition of rapid coastal land loss + Hurricanes Andrew/Georges spurred more investigations of impacts.
- Increasing attention on extreme surge scenarios & inland risks ***also encouraged studying counterpart effect of various features on surge hazard***.
  - Prior to 2000 simplistic e.g., 2.7 miles of wetlands reduce surge 1 ft.
  - After 2000 rigorous inquiries.
  - Nuanced influences of features on surges yet to be well-defined.
  - Nevertheless, advocates stressed what seemed an obvious link: more coastal wetlands & less surge hazard.

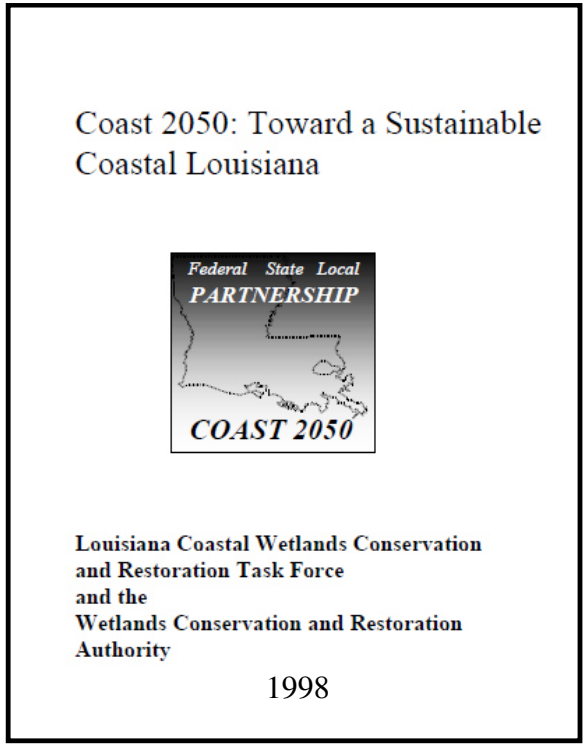


Response to Extreme Scenarios:

3. Coastal Restoration & Protection

State, local, academic, and private officials lobbied for federally sponsored (USACE) coastal protection & restoration program.

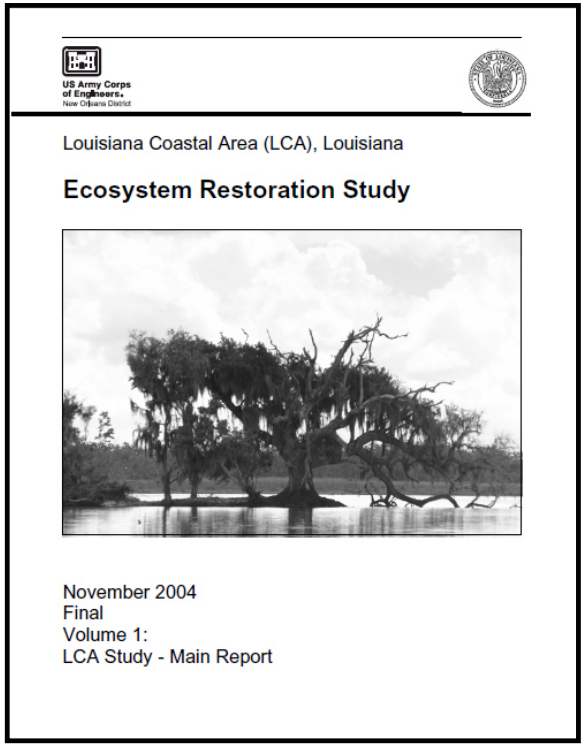
Not only for ecosystem benefits, but to reduce inland surge risk.


Coast 2050: Toward a Sustainable Coastal Louisiana

Federal State Local
PARTNERSHIP
COAST 2050

Louisiana Coastal Wetlands Conservation and Restoration Task Force
and the
Wetlands Conservation and Restoration Authority

1998


US Army Corps of Engineers
New Orleans District

Louisiana Coastal Area (LCA), Louisiana

Ecosystem Restoration Study

November 2004
Final
Volume 1:
LCA Study - Main Report

As of 2004

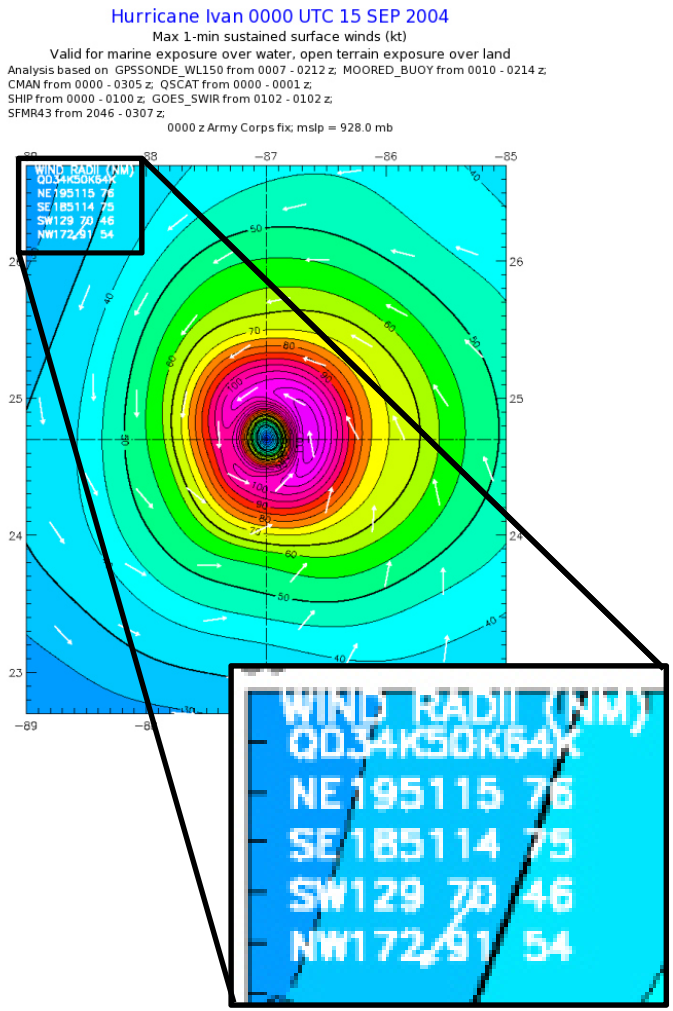
- Most East-Bank protection segments still incomplete or had inadequate heights (due either to settlement or vertical control issues).
- USACE-NOD proposed FY2005 budget <$4 million for work on SPH surge protection
  - Substantially less than previous years
  - Small fraction of $70 million needed for completion.
  - $30 million for SELA Drainage budget
  - >$200 million for navigation & other civil works.

Summer 2004 (awaiting FY2005 appropriation) USACE forced for first time in 40 years to temporarily halt work on the SPH surge project.

Another Important Hurricane Attribute Emerges

- By the mid-2000s hurricane climatologists noted that the Western Atlantic seemed to be returning to a period of high hurricane activity.
- At the same time they began urging surge hazard planners to be mindful of the effects of storm size.
- Not just R_{MAX}

  Extent & strength of full wind-field.
- Characterized with radial span of tropical storm & hurricane force winds and shape parameter, Holland B.



Hurricane Pam

- July 2004 8-day response exercise; >300 representatives of various federal, state, & local agencies.
- LSU Hurricane Center researchers collaborated with ADCIRC developers on supercomputer simulation of "Hurricane Pam"—very large Cat 3 storm passing on critical path just west of NO.
- After Ivan near-miss a month later, Hurricane Pam received greater attention.
- 3 follow-up workshops, 2 in NO.
- The last, ironically, in late July 2005, 1 month before Hurricane Katrina struck NO.