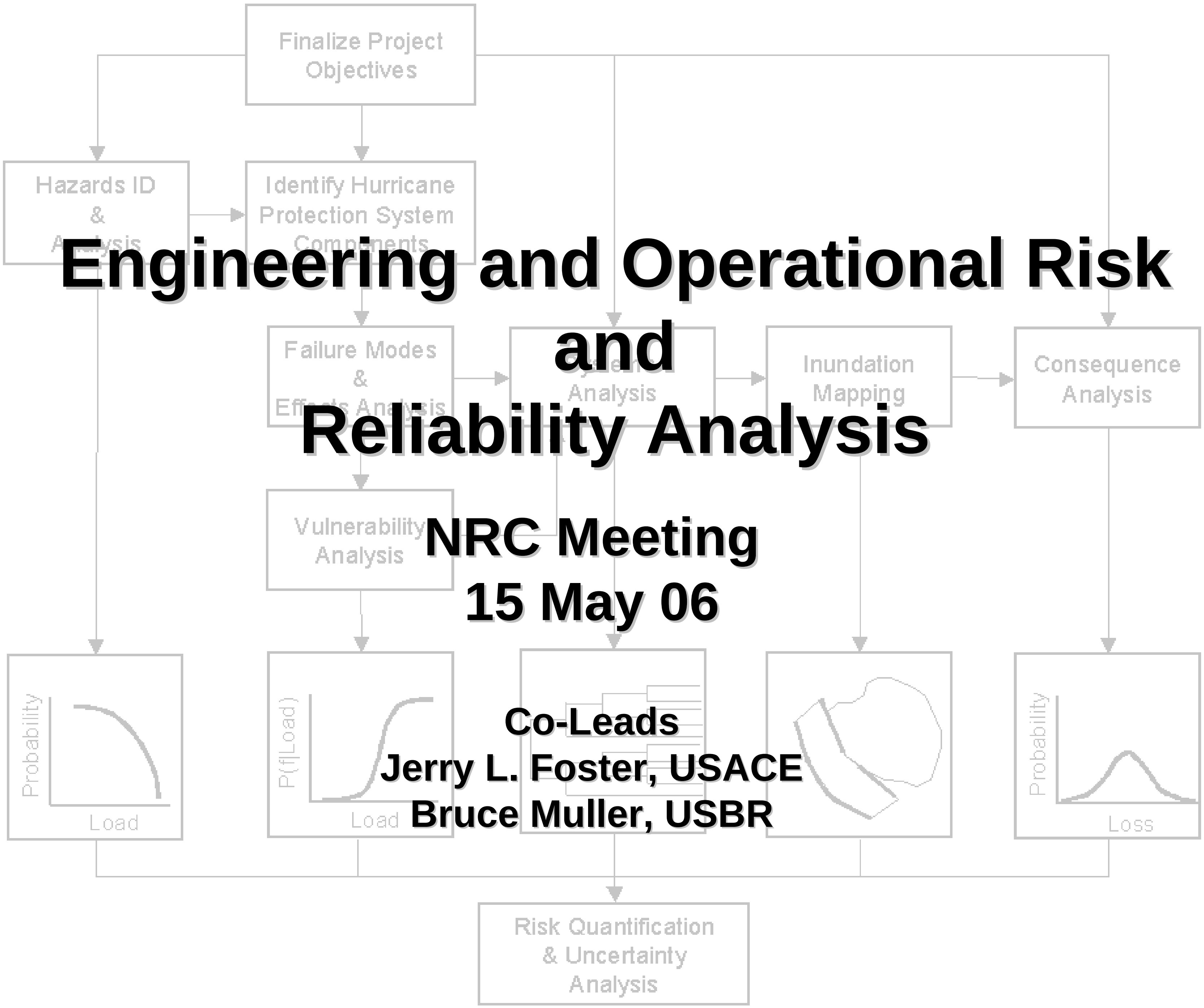
Engineering and Operational Risk and Reliability Analysis

NRC Meeting
15 May 06

Co-Leads
Jerry L. Foster, USACE
Bruce Muller, USBR



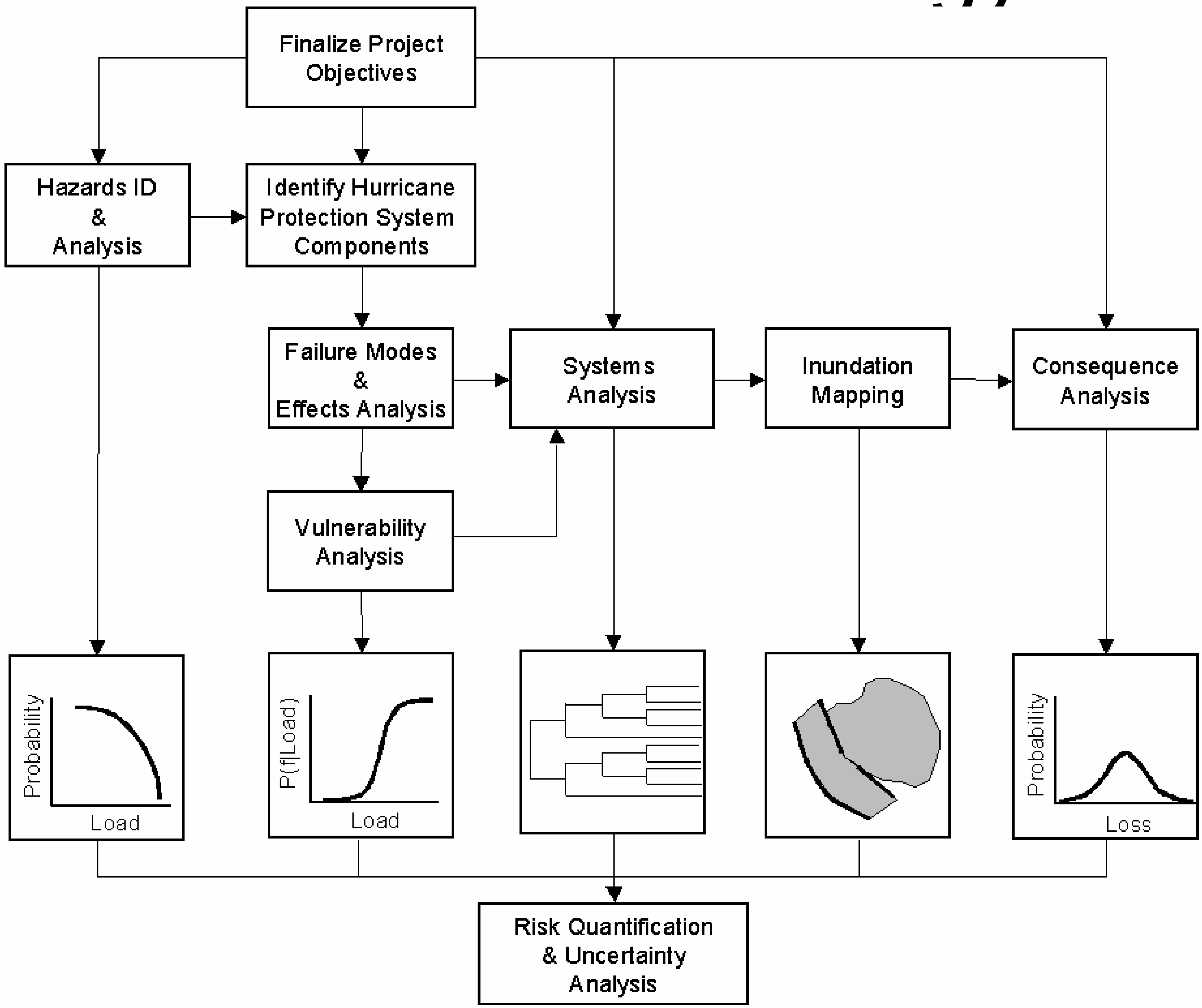
IPET Risk Model

- Risk analysis (RA) will identify areas of vulnerability for further investigation
- RA will provide estimated probabilities/rates of failure or flooding
  - Simplified analyses
  - Assumptions
  - Uncertainties
- Additional detailed engineering analyses would be required to confirm failure modes and to determine mitigation measures

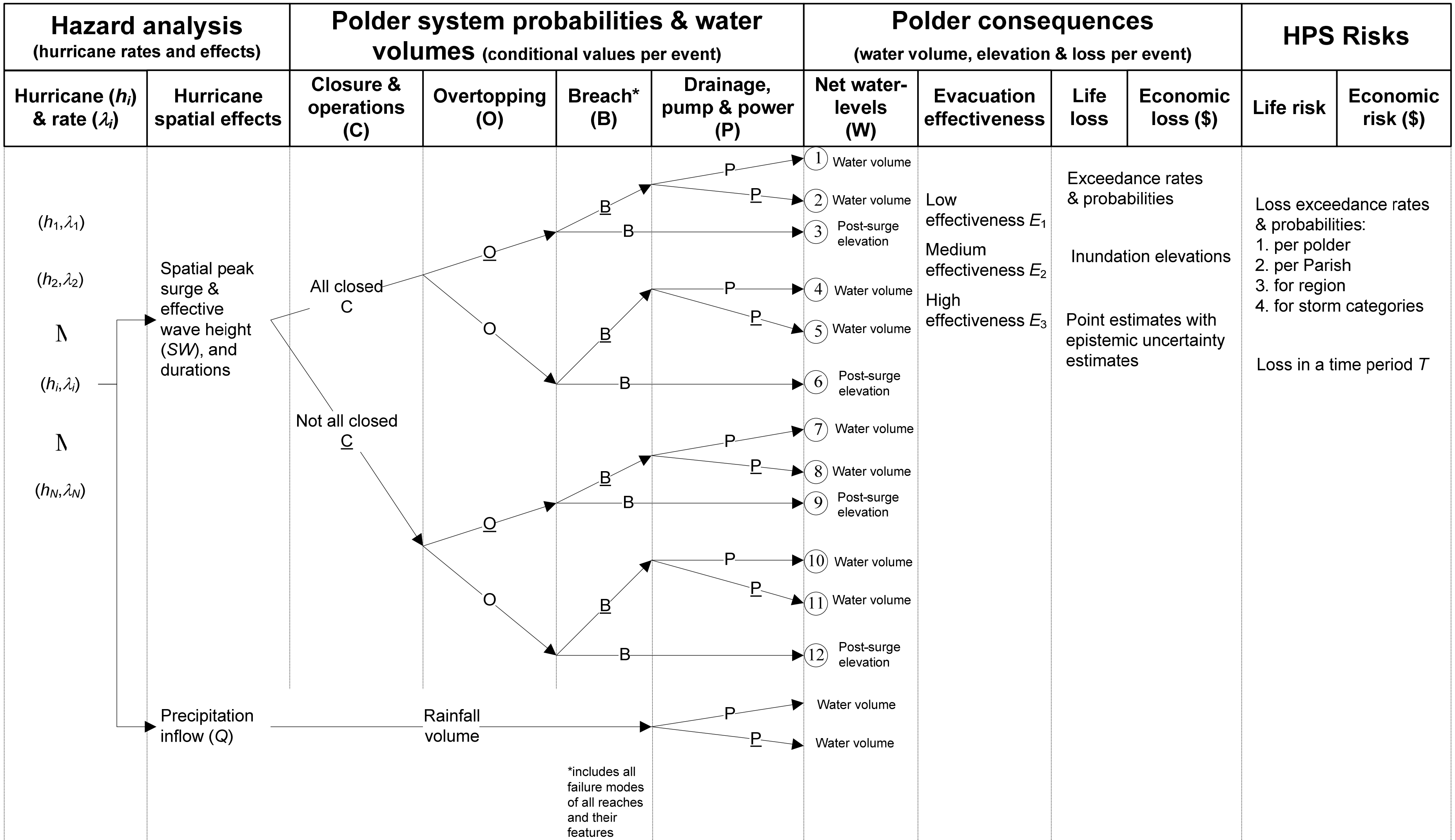
Expectations

- **RA will provide tools for USACE decision makers**
  - **Comprehensive HPS description**
  - **Full range of hurricane events**
  - **Incorporate component performance**
  - **Estimated probabilities of flooding and failure**
- **Transition to LaCPR**
- **System wide assessment capability**

Overall Methodology



Event Tree



Hazard analysis
(hurricane rates and effects)
Polder system probabilities & water volumes (conditional values per event)
Polder consequences
(water volume, elevation & loss per event)
HPS Risks
Hurricane (h_i) & rate (λ_i)
Hurricane spatial effects
Closure & operations (C)
Overtopping (O)
Breach* (B)
Drainage, pump & power (P)
Net water-levels (W)
Evacuation effectiveness
Life loss
Economic loss ($)
Life risk
Economic risk ($)
(h_1,λ_1)
(h_2,λ_2)
(h_i,λ_i)
(h_N,λ_N)
Spatial peak surge & effective wave height (SW), and durations
Precipitation inflow (Q)
All closed
C
Not all closed
C
Rainfall volume
O
B
P
1 Water volume
2 Water volume
3 Post-surge elevation
4 Water volume
5 Water volume
6 Post-surge elevation
7 Water volume
8 Water volume
9 Post-surge elevation
10 Water volume
11 Water volume
12 Post-surge elevation
Water volume
Water volume
Low effectiveness E_1
Medium effectiveness E_2
High effectiveness E_3
Exceedance rates & probabilities
Inundation elevations
Point estimates with epistemic uncertainty estimates
Loss exceedance rates & probabilities:
1. per polder
2. per Parish
3. for region
4. for storm categories
Loss in a time period T
*includes all failure modes of all reaches and their features

US Army Corps of Engineers

***FoRTE*: Flood Risk Analysis for Tropical Storm Environments**
Developed by BMA Engineering, Inc. for the US Army Corps of Engineers
Interagency Performance Evaluation Task Force (IPET)

BMA Engineering, Inc.

Input File Controls				
Time Increment	3.60E+03	Seconds		
Start Time	0.00E+00	Seconds		
Stratification Controls				
Number of Stratifications	10	☑ ON	Maximum Storms	574
Surge Deviation Log Mean	0.00	☑ ON	Total Deviation Log Mean	0.00
Surge Deviation StDev	0.20		Total Deviation StDev	0.25
Wave Deviation Log Mean	0.00	☑ ON		
Wave Deviation StDev	0.15			
Data File Output Controls				
Stratified Data Filename:	ProcessedData			☑ ON
Output Data Filename:	ElevationResults			☑ ON
Loss Output Filename:	LossOutput			☑ ON
Date-Time Tag:	38839.6562	38839		6561
Loss-Exceedence Output Controls				
Start Elevation (ft)	-1.400E+01	Number of Increments		51
Stop Elevation (ft)	3.600E+01	Elevation Increment		1.000E+00

Start Time	3:41:13 PM	Total Time	0:03:40
End Time	3:44:53 PM		

Version 0.3c, Updated 05/02/06

Instructions

Step 1. Input System Definition
Yellow-colored worksheets and cells are for inputting system definition information as:
- Subpolder definition in the "Subpolder Data" worksheet
- Interflow elevations in the "Interflow Mapping" worksheet
- Reach definition in the "Reach Data" worksheet
- Feature definition in the "Features" worksheet

Step 2. Specify Analysis Parameters
Blue-colored worksheets and cells are for inputting analysis parameters. This includes:
- Execution parameters in the "Control" worksheet (defaults provided)
- Annual rate of occurrence and precipitation for each storm in the "Storm Data" worksheet
- Aleatory uncertainty inputs in the "Reach Calculations" worksheet (defaults provided)

Step 3. Execute Analysis
Click on the "**Start Analysis**" button to load the hydrograph data and conduct risk analysis.

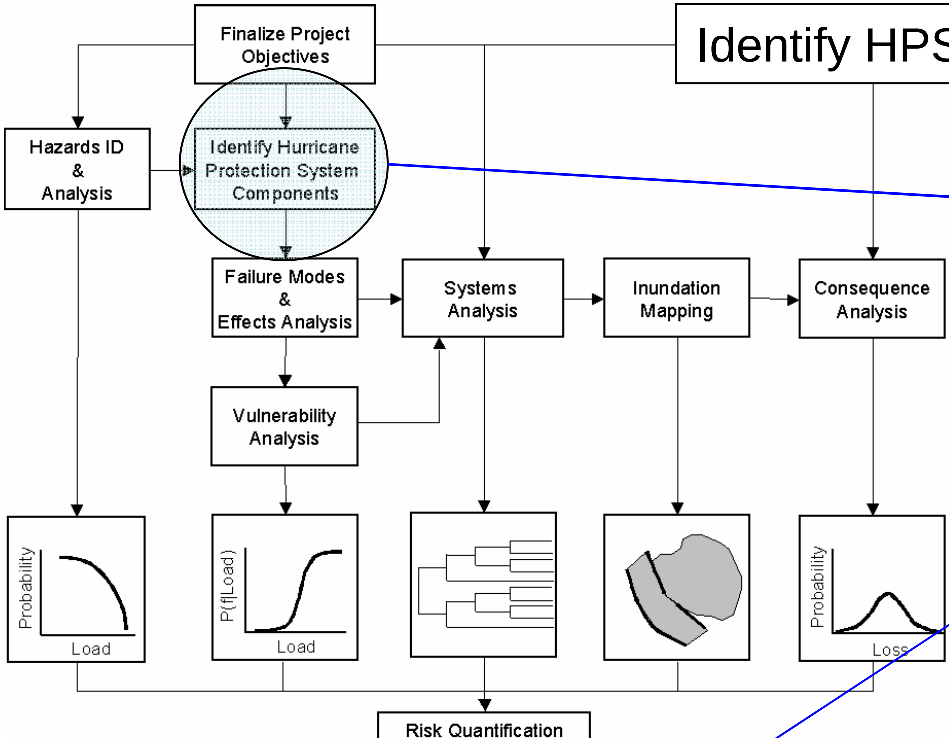
Step 4. View Results
Green-colored worksheets provide loss-exceedance curves.

Risk Model Software

- **Excel Spreadsheet**
- **Data Input Template**
- **Output Graphics**

Reach	Length (ft)	Elevation (ft)	Design Water Elevation (ft)	Reach Type	Reach Weir Coefficient	Polder Reference	Subpolder Reference
1	5.000E+03	4.000E+00	1.000E+00	L	2.6	NOE	NOE1
2	5.000E+03	4.000E+00	1.000E+00	W	3.0	NOE	NOE1
3	5.000E+03	4.000E+00	1.000E+00	L	2.6	NOE	NOE2
4	5.000E+03	4.000E+00	1.000E+00	W	3.0	NOE	NOE2
5	5.000E+03	4.000E+00	1.000E+00	L	2.6	NOE	NOE3
6	5.000E+03	4.000E+00	1.000E+00	W	3.0	NOE	NOE3
7	5.000E+03	4.000E+00	1.000E+00	L	2.6	NOE	NOE4
8	5.000E+03	4.000E+00	1.000E+00	W	3.0	NOE	NOE4
9	5.000E+03	4.000E+00	1.000E+00	L	2.6	NOE	NOE5
10	5.000E+03	4.000E+00	1.000E+00	W	3.0	NOE	NOE5

Subpolder Number	Overtopping Volume (V|OT)		Precipitation Rainfall Volume		Closures Water Volume		Breach Volume Elevation		Breach Volume Volume	
	Mean (ft^3)	StD (ft^3)	Mean (ft^3)	StD (ft^3)	Mean (ft^3)	StD (ft^3)	Mean (ft)	StD (ft)	Mean (ft^3)	StD (ft^3)
OW1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	1.743E+08	4.571E+06
OW2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	4.858E+08	9.056E+06
NOE1	0.000E+00	0.000E+00	1.655E+04	3.310E+03	4.724E+02	7.162E+01	1.187E+00	5.937E-02	4.461E+08	3.157E+07
NOE2	0.000E+00	0.000E+00	3.775E+06	7.551E+05	4.977E+02	9.954E+01	1.187E+00	5.937E-02	1.109E+09	1.355E+07
NOE3	0.000E+00	0.000E+00	2.703E+06	5.406E+05	0.000E+00	0.000E+00	1.187E+00	5.937E-02	3.059E+08	5.171E+06
NOE4	0.000E+00	0.000E+00	1.550E+01	3.100E+00	5.972E+02	1.194E+02	1.187E+00	5.937E-02	8.688E+07	2.631E+06
NOE5	0.000E+00	0.000E+00	[illegible]	[illegible]	0.000E+00	0.000E+00	1.187E+00	5.937E-02	[illegible]	[illegible]

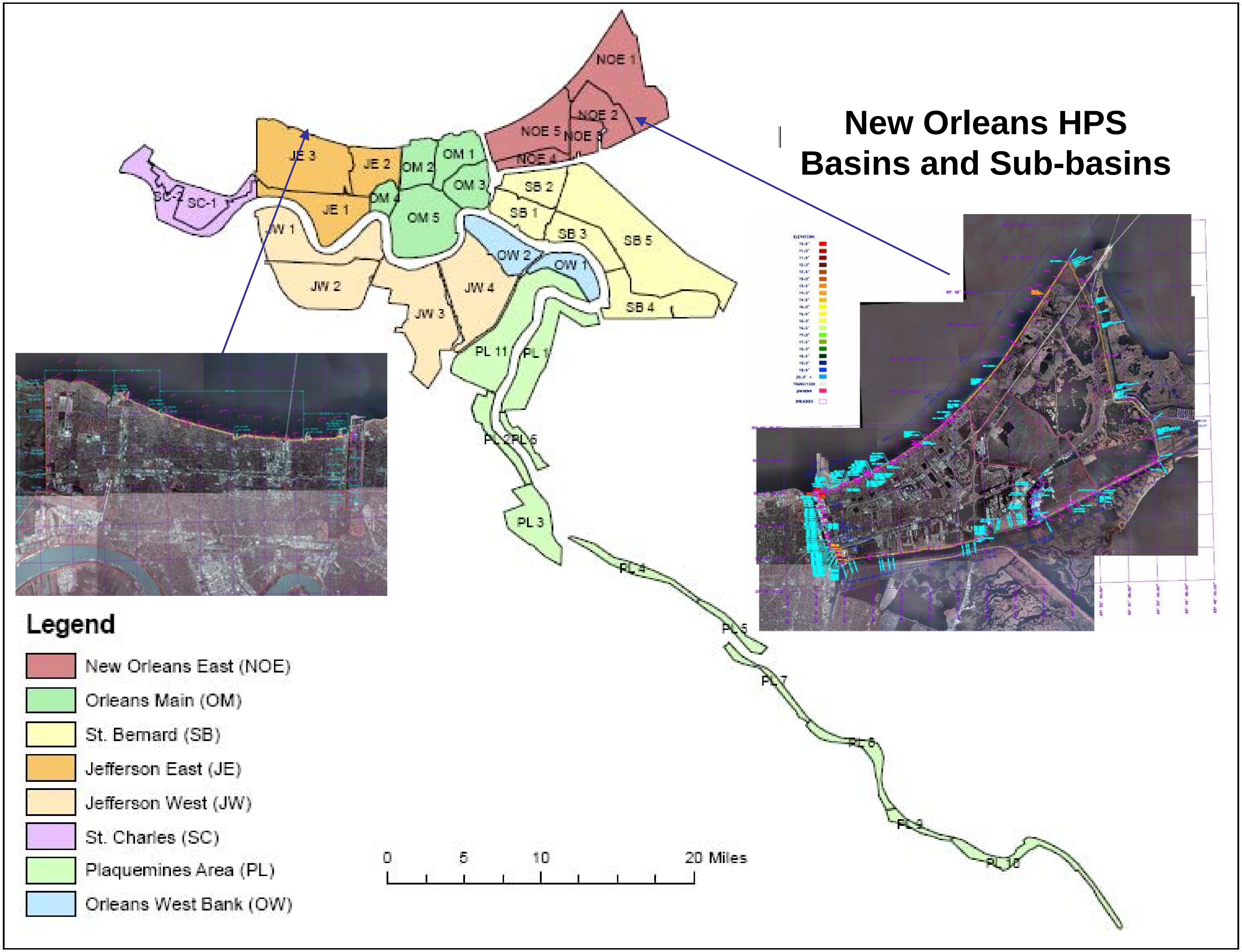


					Geometry						Reliability of Levee or Deep Failure Under I-Wall					
											Moments			Length-adjusted Pf		
Reach	Start STA	End STA	Subpolder Reference	GDM	Length (ft.)	Type	Design Elevation	Design Elev-3'	Length-wtd Elevation	Separate Wall Sections	E[FS] from GDM	COV	Beta	3/4 Water Height	Design Water Height	Design +3'
NOE01	04+02	27+28	NOE5	NOE Airport Floodw all	2,290	W	14.5	11.5	11.6		2.60	0.10	6.15	0.0000	0.0000	0.7955
NOE02	27+28	28+25	NOE5	Citrus Lakefront Levee	97	L	14.5	11.5	13.0		2.30	0.10	5.65	0.0000	0.0000	0.0650
NOE03	28+25	51+50	NOE5	Citrus Lakefront Levee	2,325	W	14.5	11.5	13.0		2.20	0.10	5.45	0.0000	0.0000	0.8004
NOE04	51+50	74+80	NOE5	Citrus Lakefront Levee	2,330	L	14.5	11.5	24.8	1	2.30	0.10	5.65	0.0000	0.0000	0.8011
NOE05	74+80	97+50	NOE5	Citrus Lakefront Levee	2,270	W	14.5	11.5	14.3		2.00	0.10	5.00	0.0000	0.0000	0.7927
NOE06	97+50	288+62	NOE5	Citrus Lakefront Levee	19,112	L	14.5	11.5	24.5	2	1.62	0.10	3.83	0.0000	0.0012	1.0000
NOE07	288+62	303+38	NOE5	Citrus Lakefront Levee	1,474	W	14.5	11.5	12.5		1.51	0.10	3.38	0.0000	0.0005	0.6400
NOE08	303+38	330+60	NOE5	Citrus Lakefront Levee	2,724	L	14.5	11.5	12.9		1.51	0.10	3.38	0.0001	0.0010	0.8486
NOE09	330+60	662+25	NOE1	NOE Lakefront Levee	33,165	L	16.5	13.5	37.1	1	1.30	0.10	2.31	0.0891	0.2956	1.0000
NOE10	662+25	938+90	NOE1	N.O. East Levee	27,665	L	13.5	10.5	15.1		1.44	0.10	3.06	0.0034	0.0306	1.0000
NOE11	938+90	1030+00	NOE1	N.O. East Levee	8,942	L	15.0	12.0	16.8		1.44	0.10	3.06	0.0011	0.0100	0.9980
NOE12	1030+00	1101+90	NOE1	N.O. East Levee	7,190	L	15.0	12.0	31.4	1	1.30	0.10	2.31	0.0200	0.0731	0.9924
NOE13	1101+90	879+33	NOE1	N.O. East Back Levee	22,257	L	17.5	14.5	15.5		1.31	0.10	1.60	0.4615	0.7147	0.9999
NOE14	879+33	874+40	NOE2	N.O. East Back Levee	493	W	17.0	14.0	19.9		1.34	0.10	2.54	0.0006	0.0028	0.2893
NOE15	874+40	772+30	NOE2	N.O. East Back Levee	10,210	L	5.0	2.0	16.8		1.30	0.10	2.31	0.0283	0.1022	0.9990
NOE16	772+30	664+73	NOE2	N.O. East Back Levee	10,757	L	19.0	16.0	17.9		1.50	0.10	3.33	0.0003	0.0046	0.9994
NOE17	664+73	571+55	NOE2	Citrus Back Levee	9,318	W	22.0	19.0	20.7		1.29	0.10	2.25	0.0321	0.1088	0.9981
NOE18	571+55	492+50	NOE3	Citrus Back Levee	7,905	L	18.0	15.0	17.4		1.31	0.10	2.37	0.0177	0.0688	0.9954
NOE19	492+50	430+95	NOE3	Citrus Back Levee	6,155	W	18.0	15.0	17.0		1.36	0.10	2.65	0.0046	0.0247	0.9857
NOE20	430+95	271+55	NOE4	Citrus Back Levee	15,940	L	14.0	11.0	14.6		1.31	0.10	2.37	0.0354	0.1339	1.0000
NOE21	271+55	253+35	NOE4	Citrus Back Levee	1,820	W	14.0	11.0	15.0		1.31	0.10	2.37	0.0041	0.0163	0.7153
NOE22	253+35	218+82	NOE4	Citrus Back Levee	3,453	L	14.0	11.0	14.0		1.31	0.10	2.37	0.0078	0.0307	0.9069
NOE23	218+82	202+95	NOE4	Citrus Back Levee	1,587	W	14.0	11.0	14.5		1.31	0.10	2.37	0.0036	0.0142	0.6658
NOE24	202+95	179+47	NOE4	Citrus Back Levee	2,348	L	14.0	11.0	13.6		1.31	0.10	2.37	0.0053	0.0210	0.8018
NOE25	179+47	141+44	NOE5	IHNC	3,803	L	14.0	11.0	12.0		1.34	0.10	2.54	0.0044	0.0211	0.9275
NOE26	141+44	136+07	NOE5	IHNC	537	W	14.0	11.0	12.5		1.31	0.10	2.37	0.0012	0.0048	0.3105
NOE27	136+07	130+81	NOE5	IHNC	526	L	14.0	11.0	12.5		1.96	0.10	4.90	0.0000	0.0000	0.3055
NOE28	130+81	112+03	NOE5	IHNC	1,876	W	14.0	11.0	13.3		1.56	0.10	3.59	0.0000	0.0003	0.7276
NOE29	112+03	105+60	NOE5	IHNC	643	W	14.0	11.0	13.5		1.44	0.10	3.06	0.0001	0.0007	0.3596
NOE30	105+60	10+13	NOE4	IHNC	8,168	W	14.0	11.0	12.4		1.33	0.10	2.48	0.0118	0.0522	0.9963
													At least one failure =	0.5919	0.9055	1.0000

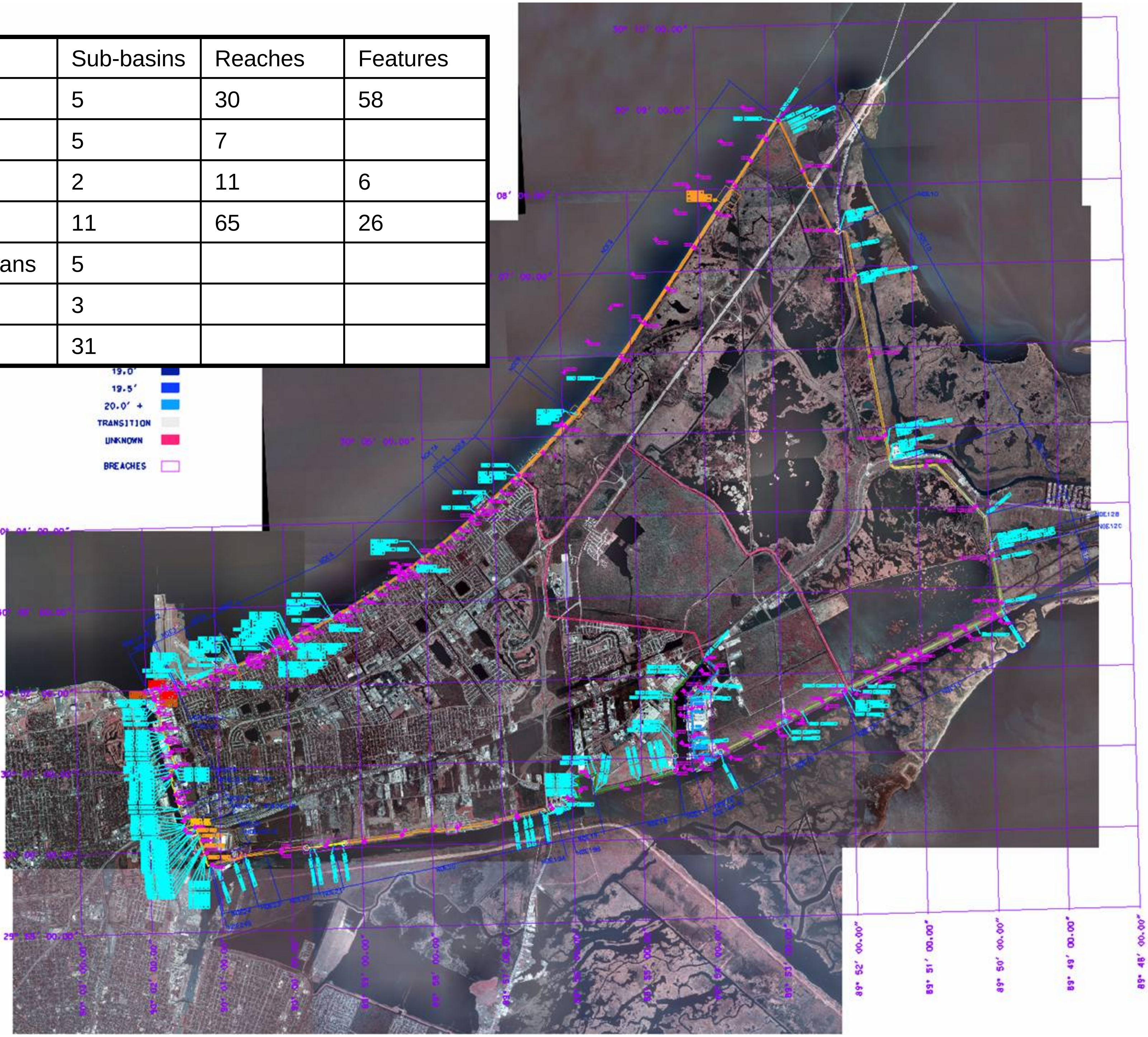
Define System

- DM's, As-Builts, etc
- Field Surveys
- IPET Teams
- TFG
- Elevation Maps

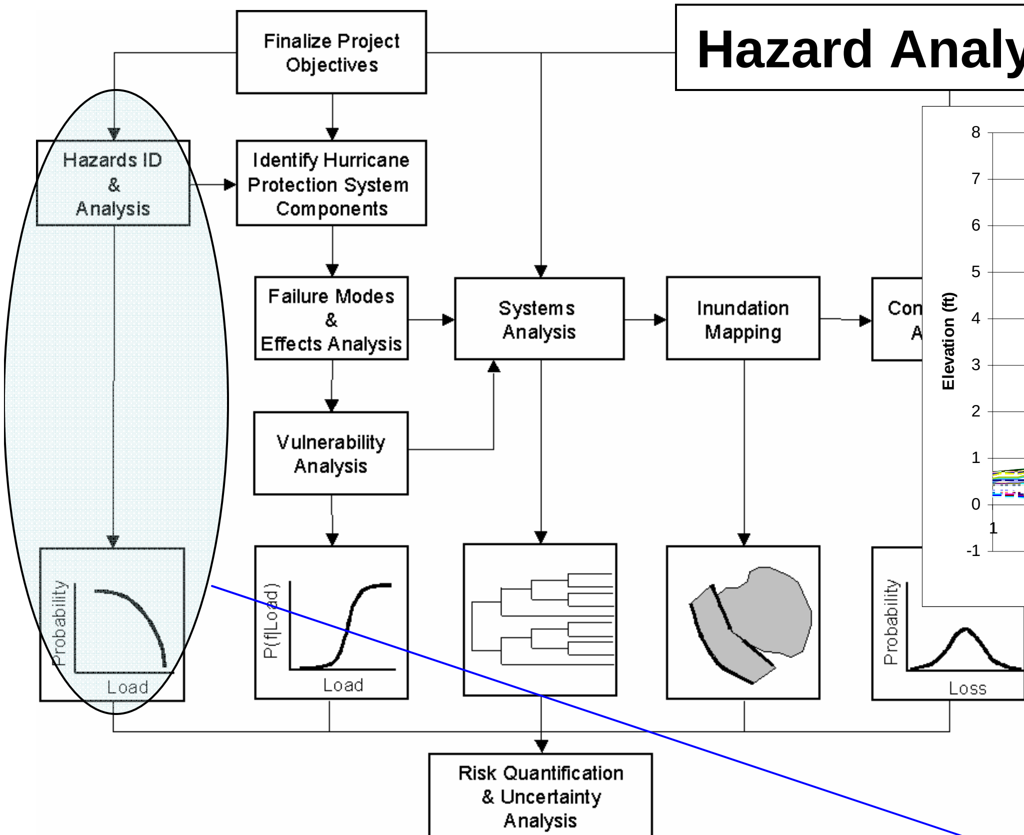
New Orleans HPS Basins and Sub-basins

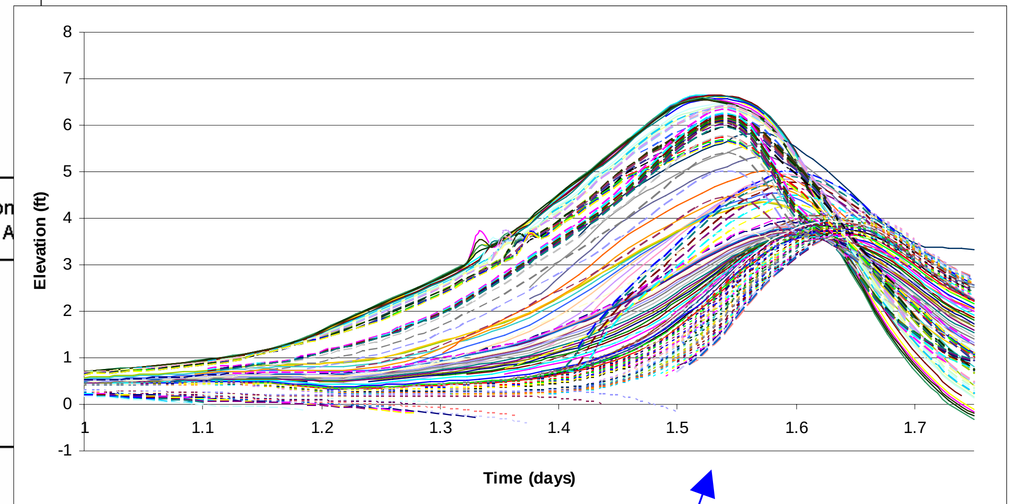


Basin	Sub-basins	Reaches	Features
NOE	5	30	58
St. B	5	7	
St. C	2	11	6
Plaq.	11	65	26
E. Orleans	5		
E. Jeff	3		
Totals	31		



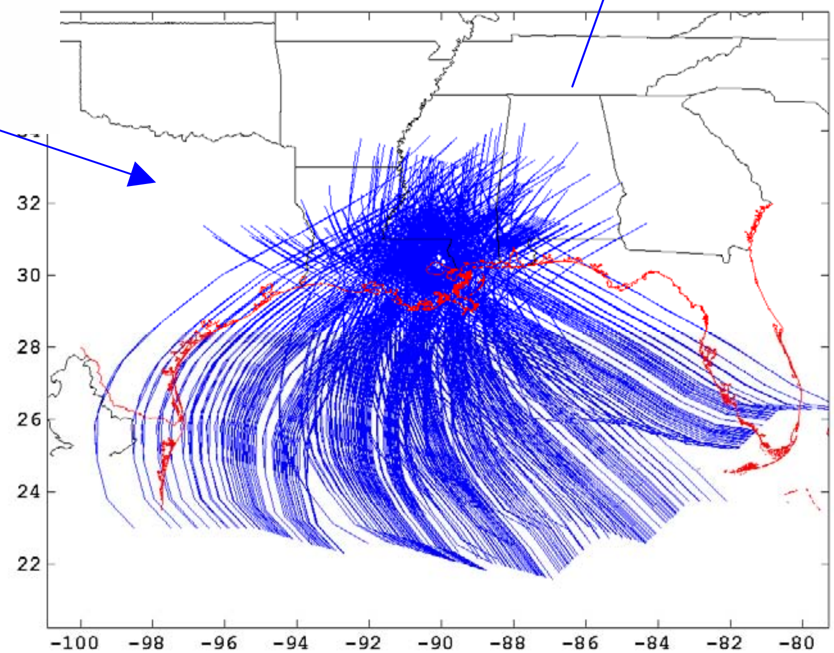
Hazard Analysis



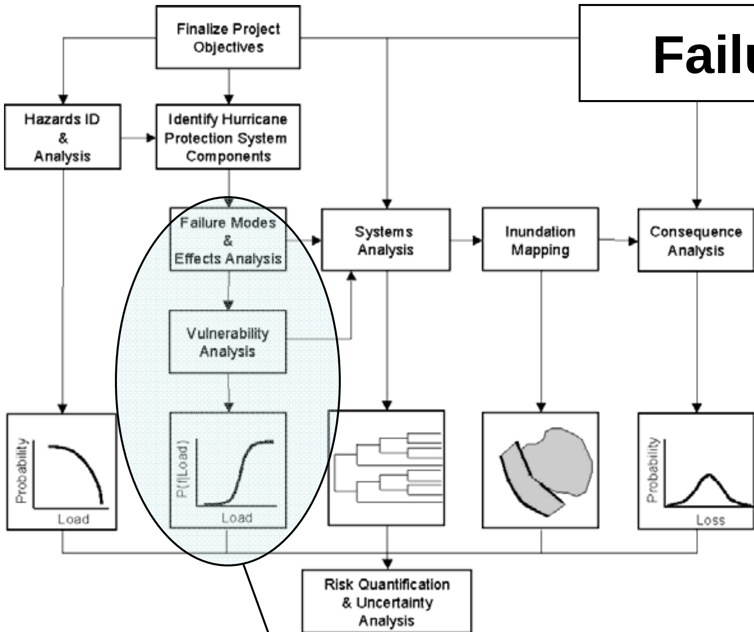


Storm Modeling

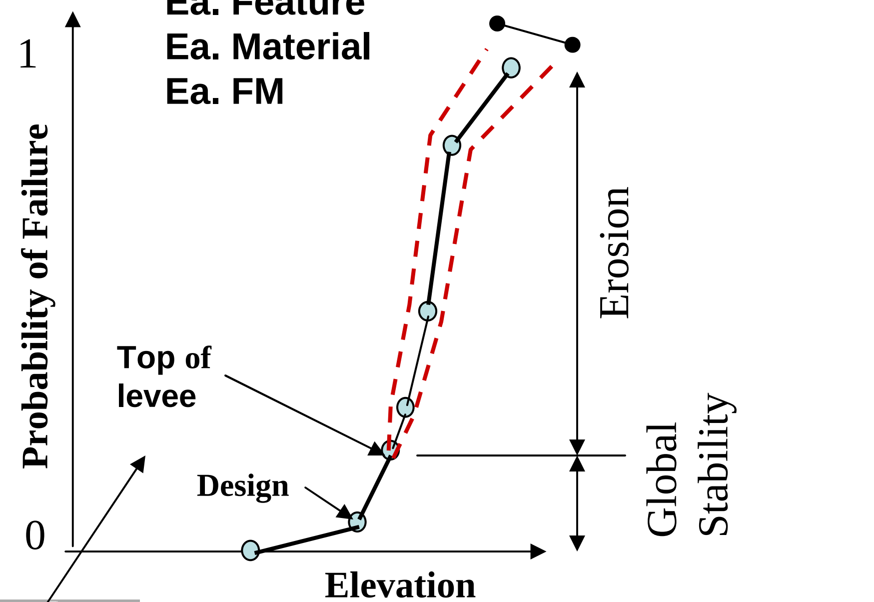
- ADCIRC
- Historic storms in parameter set
- 100+ Low Res Runs
- 1800+ Med Res Runs
- 60+ High Res Runs
- Frequency Analysis
- Calibrate (HWM & Storm Team Results)
- Add Waves

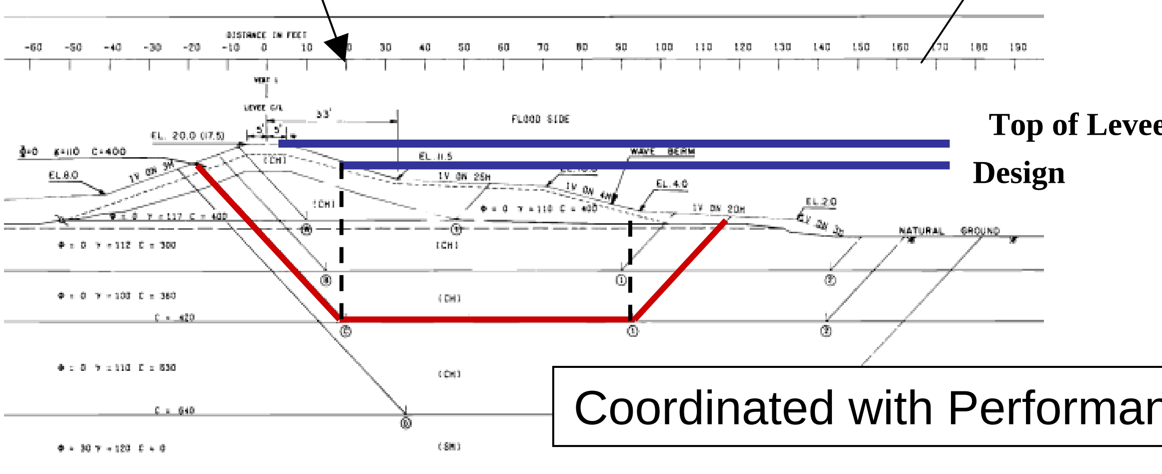


Failure Modes/Vulnerability Analysis



Fragilities Developed For:
Ea. Reach
Ea. Feature
Ea. Material
Ea. FM

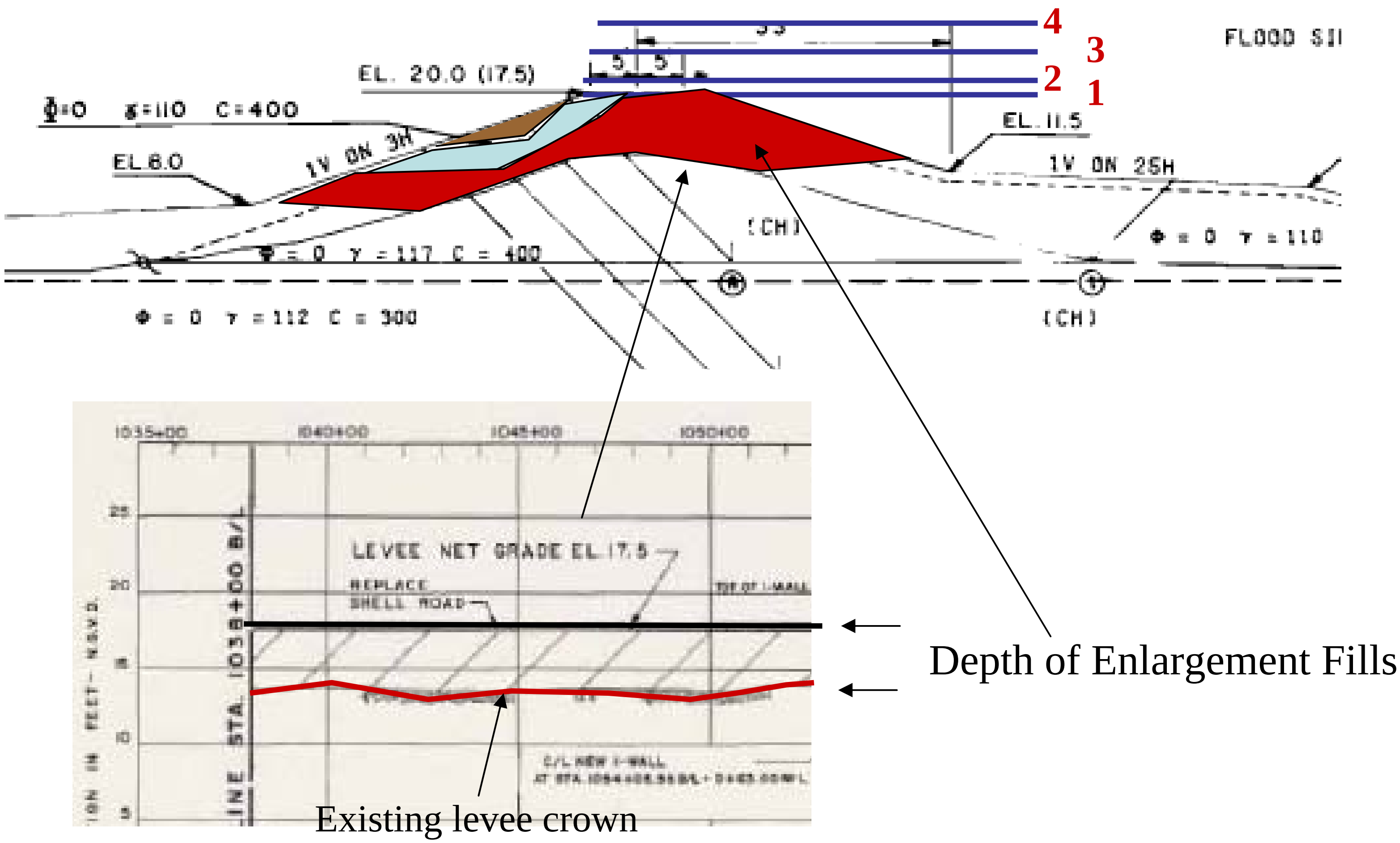


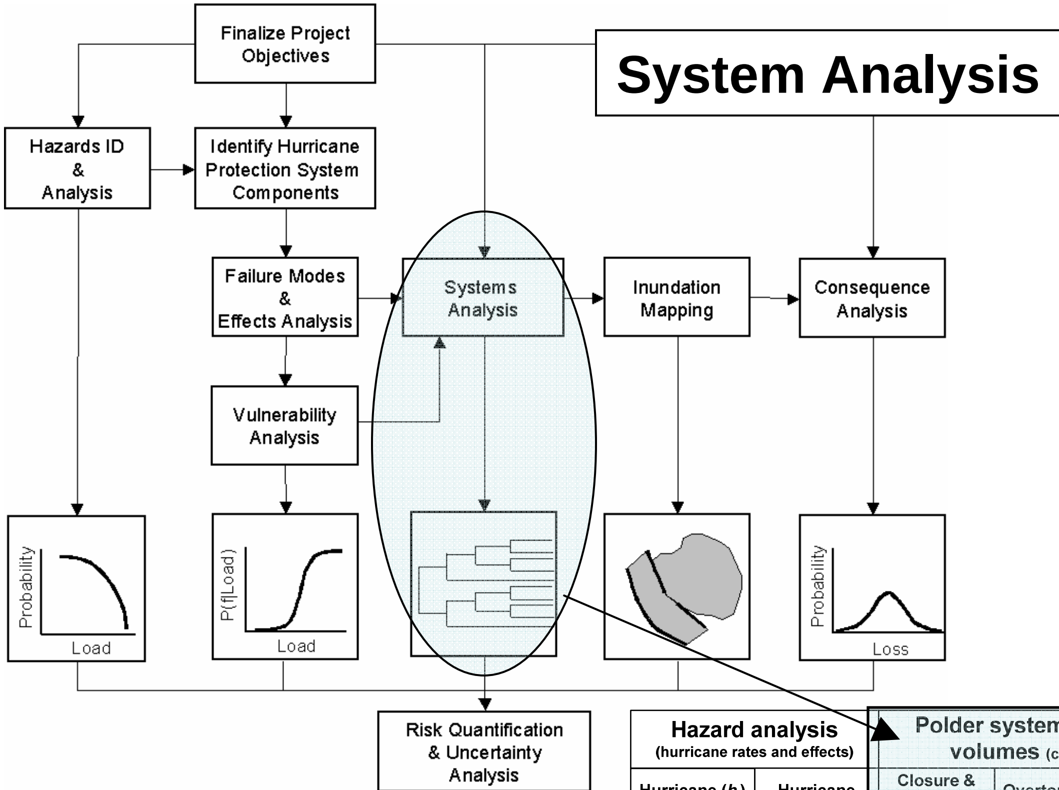


Coordinated with Performance Team results

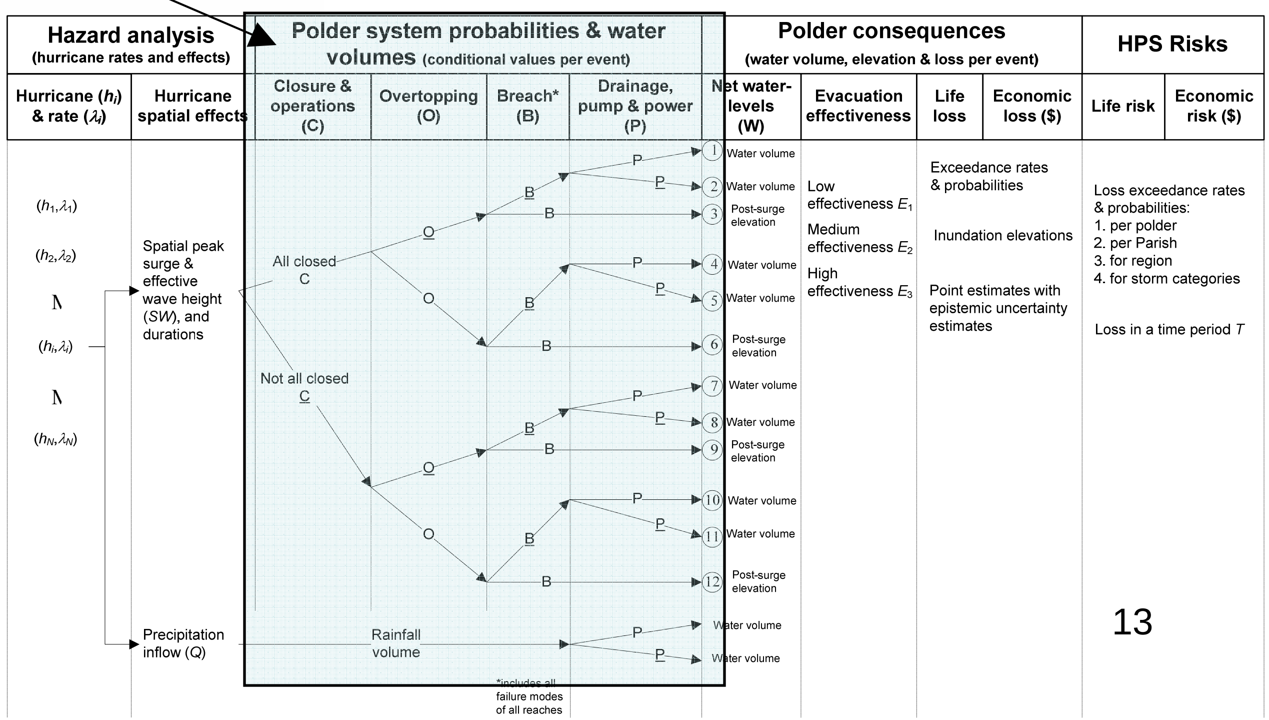
Fragility Curves for Levees
NOE Reach 13, Levee Erosion FM

FMs Experienced
Materials of Construction
Water Elevation
Protected Side Velocities

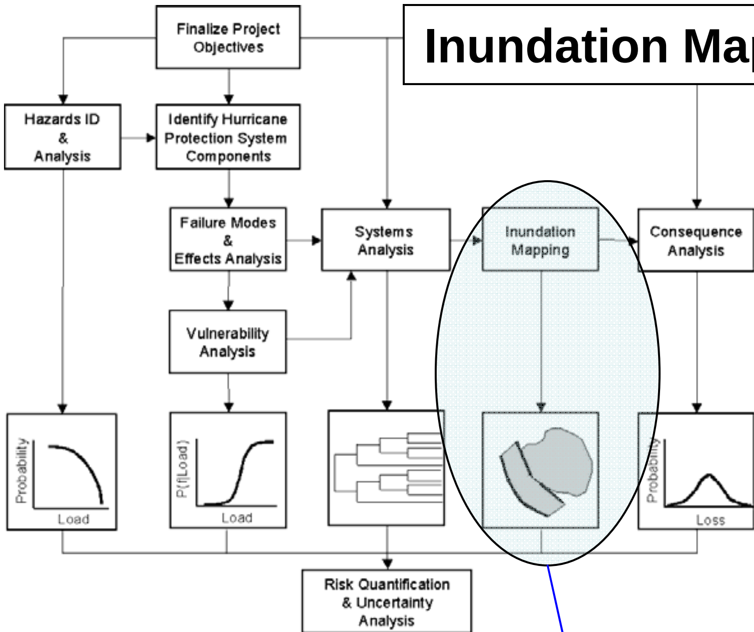


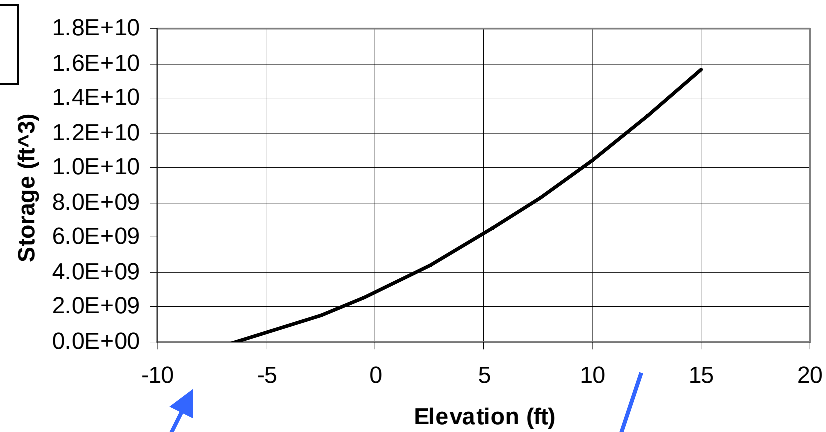


- •Event Trees
- •Scenarios
    - •Closure Structures
    - •Overtopping
    - •Breaching
    - •Interior Drainage
- •Every Hurricane
- •Every Reach & Feature
- •Basins
    - •Sub-basins

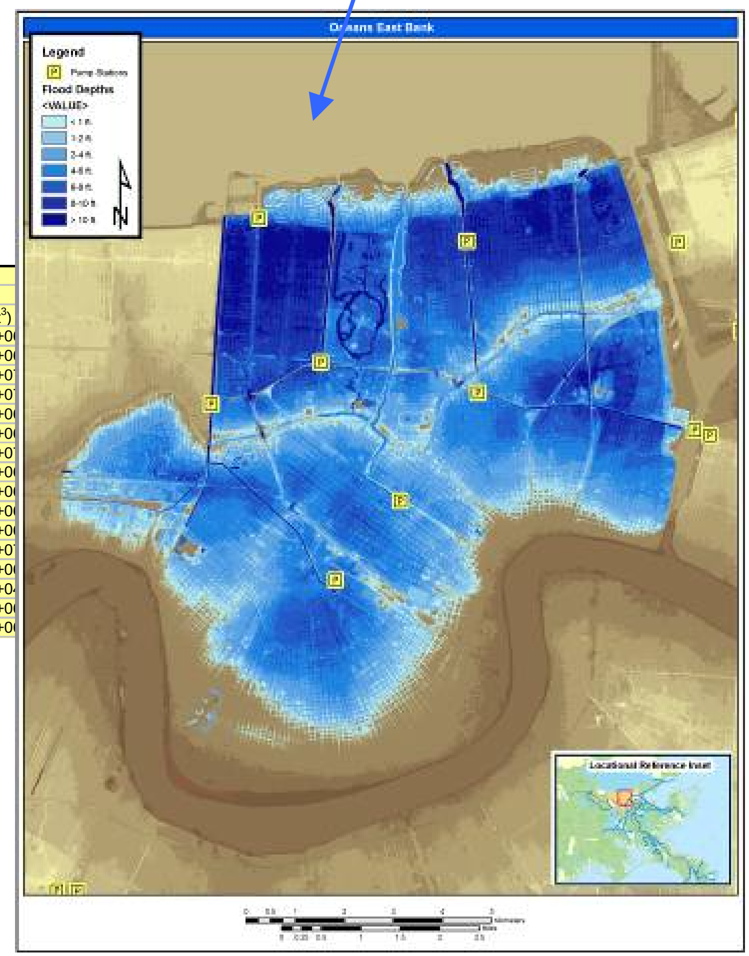


Inundation Mapping



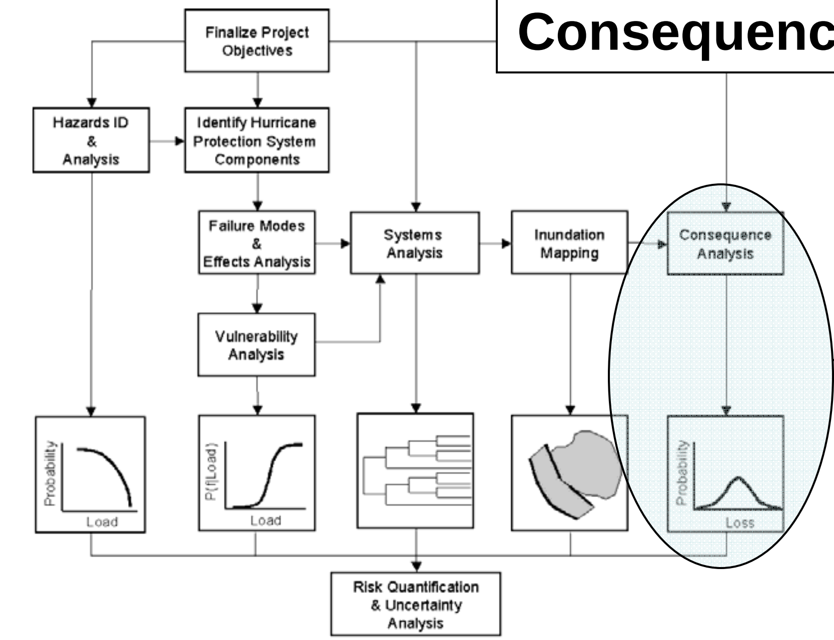


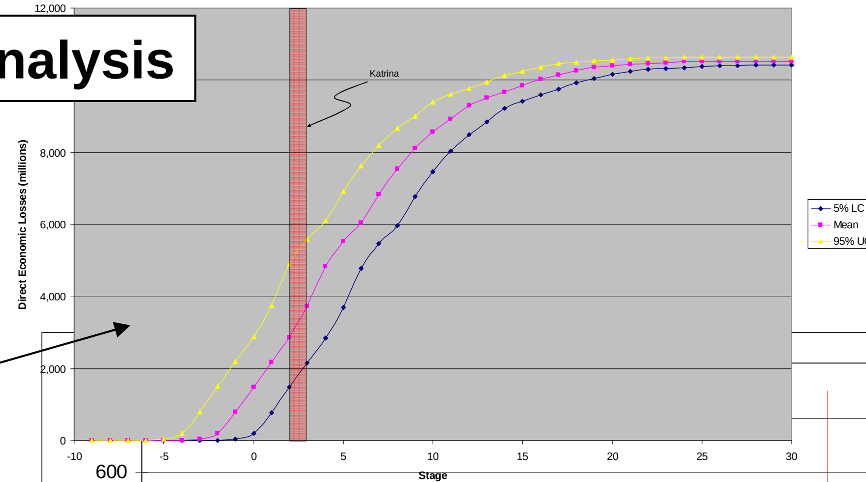
Subpolder Number	Overtopping Volume (V|OT)		Precipitation Rainfall Volume		Closures Water Volume		Breach Volume Elevation		Breach Volume Volume	
	Mean (ft^3)	StD (ft^3)	Mean (ft^3)	StD (ft^3)	Mean (ft^3)	StD (ft^3)	Mean (ft)	StD (ft)	Mean (ft^3)	StD (ft^3)
OW1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	1.743E+08	4.571E+0
OW2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	4.858E+08	9.056E+0
NOE1	0.000E+00	0.000E+00	1.655E+04	3.310E+03	4.724E+02	7.162E+01	1.187E+00	5.937E-02	4.461E+08	3.157E+0
NOE2	0.000E+00	0.000E+00	3.775E+06	7.551E+05	4.977E+02	9.954E+01	1.187E+00	5.937E-02	1.109E+09	1.355E+0
NOE3	0.000E+00	0.000E+00	2.703E+06	5.406E+05	0.000E+00	0.000E+00	1.187E+00	5.937E-02	3.059E+08	5.171E+0
NOE4	0.000E+00	0.000E+00	1.550E+01	3.100E+00	5.972E+02	1.194E+02	1.187E+00	5.937E-02	8.688E+07	2.631E+0
NOE5	0.000E+00	0.000E+00	9.367E+07	1.873E+07	0.000E+00	0.000E+00	1.187E+00	5.937E-02	2.463E+09	2.281E+0
OM1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	7.075E+08	9.807E+0
OM2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	6.399E+08	8.787E+0
OM3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	2.480E+08	6.962E+0
OM4	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	7.016E+07	2.248E+0
OM5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	4.371E+08	1.257E+0
SB1	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	1.753E+08	5.671E+0
SB2	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	1.367E+06	4.737E+0
SB3	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	1.491E+08	4.839E+0
SB4	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.187E+00	5.937E-02	1.581E+07	2.990E+0

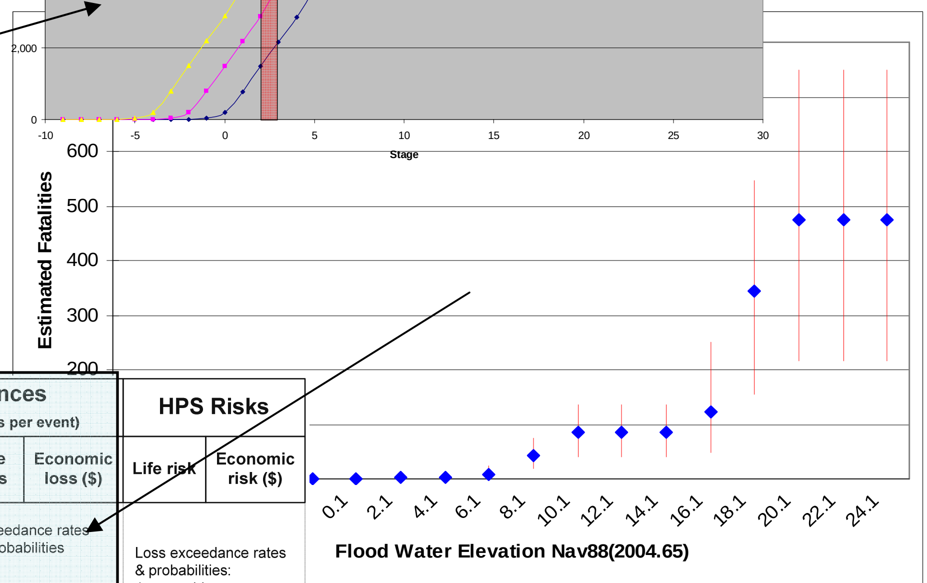


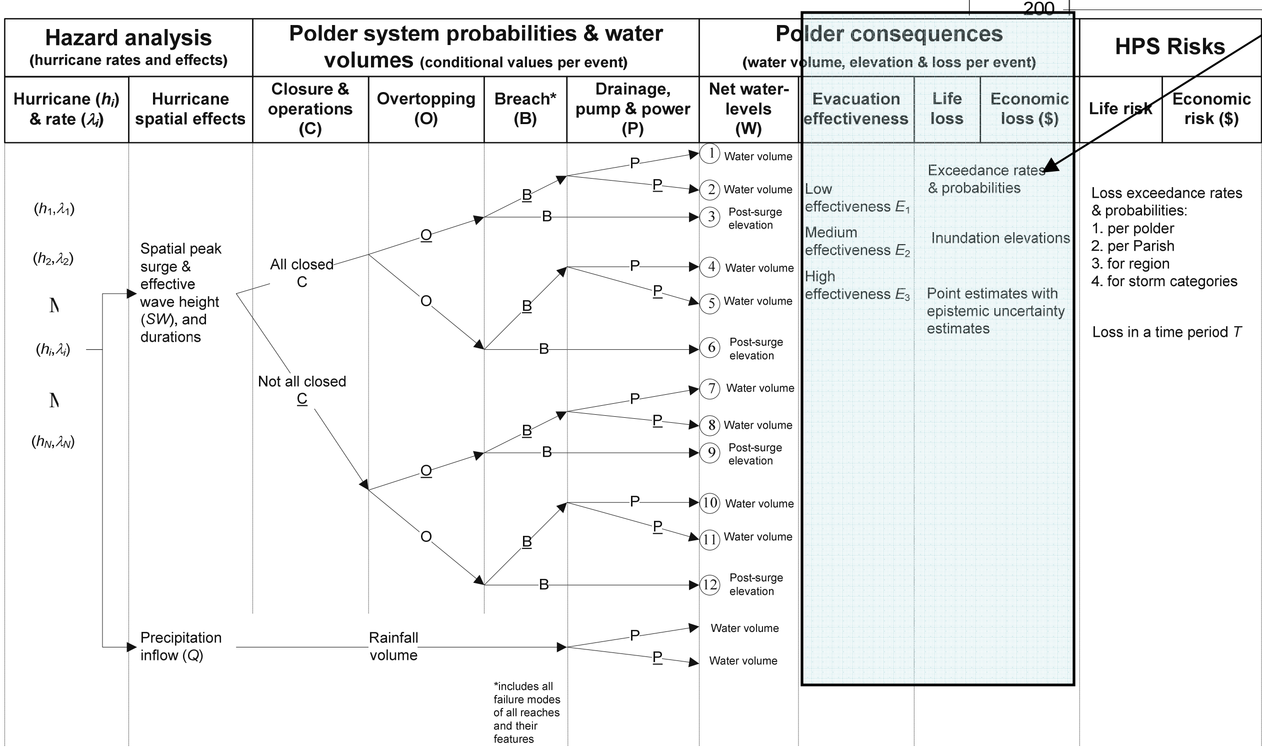
- Inflow Volumes
- Sub-basin Interflow
- Stage-Storage (Interior Drainage Team Input)
- Plot Contours

Consequence Analysis





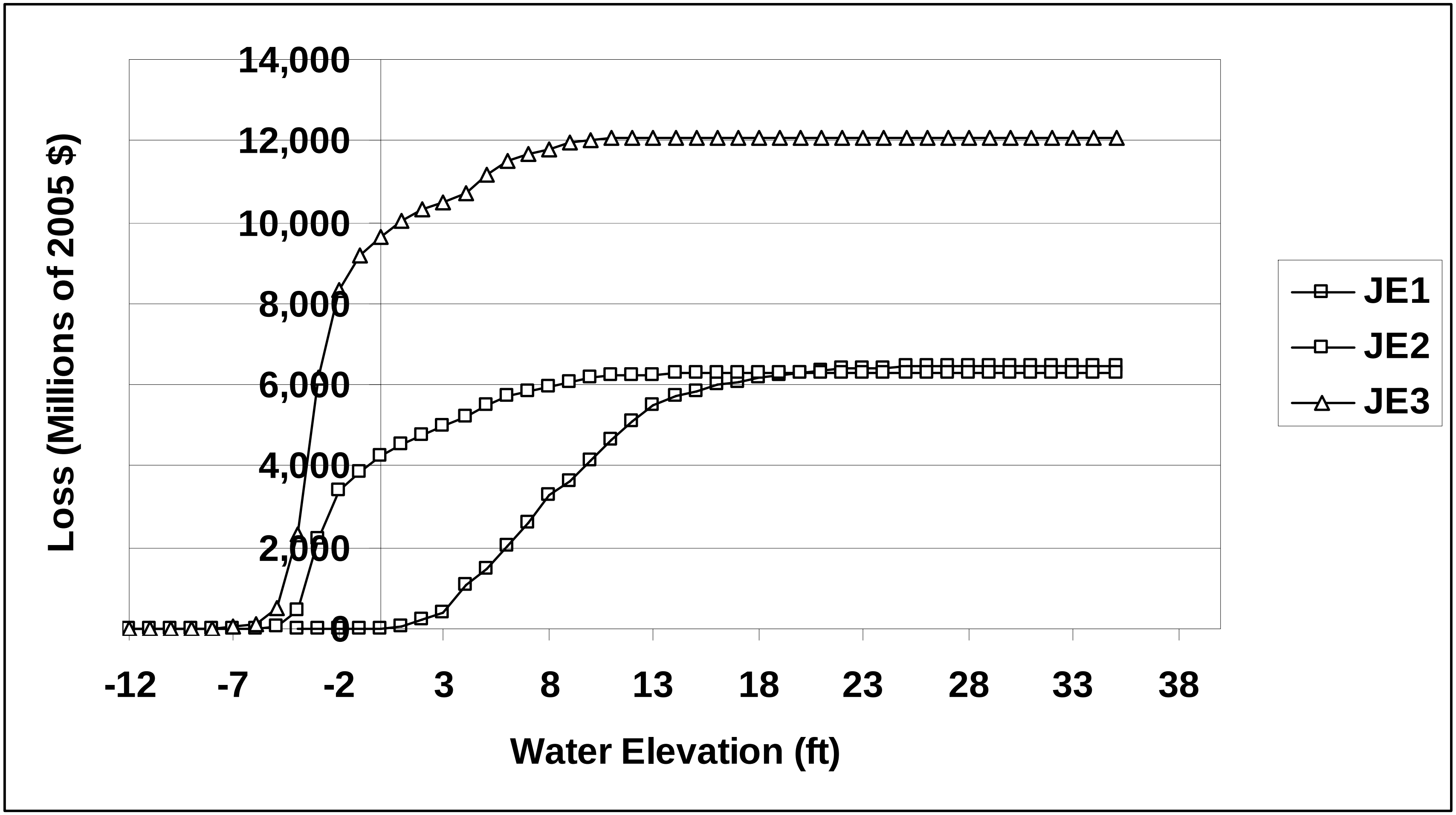




Consequence Team Input

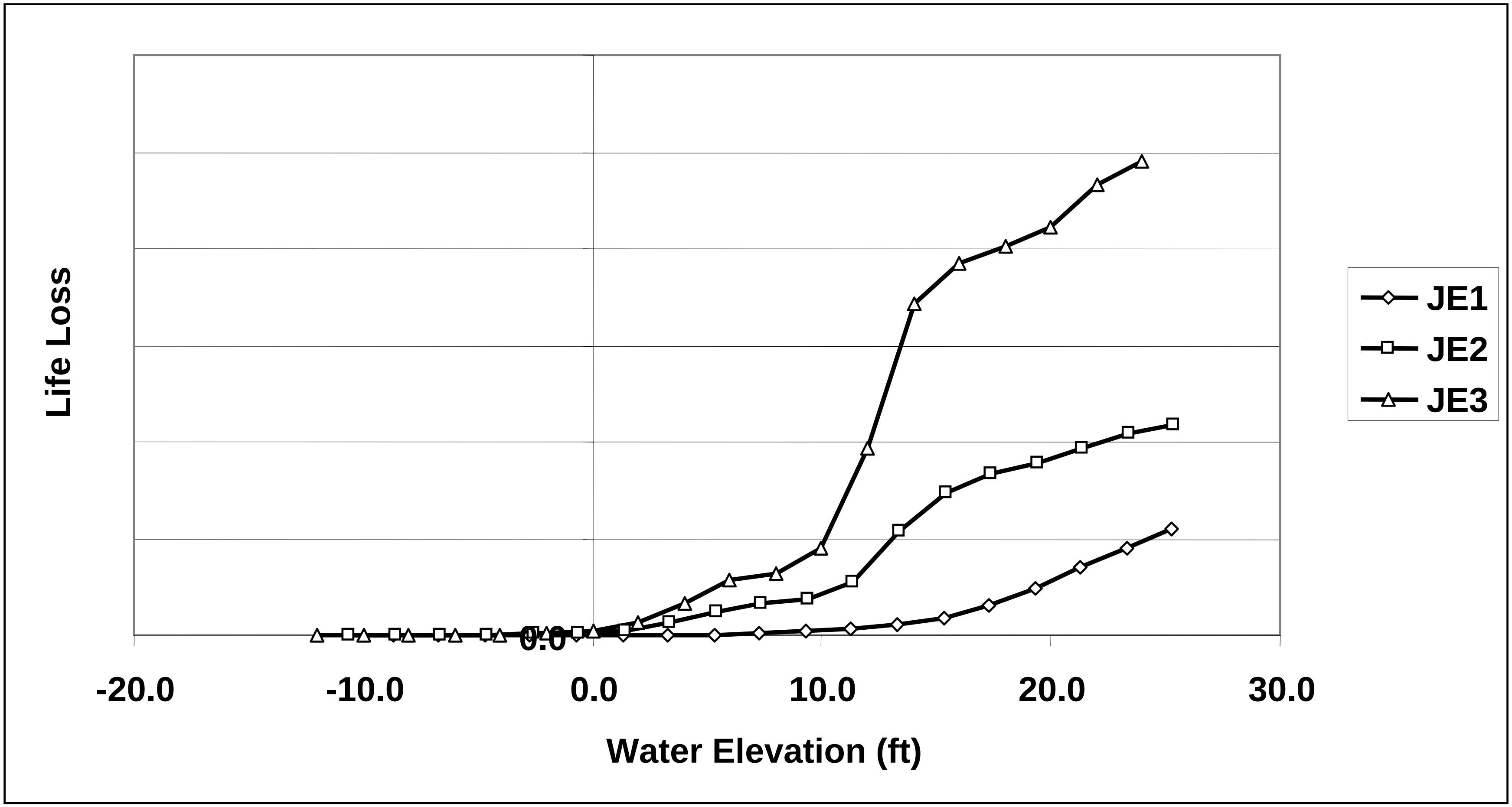
- **Stage-Damage Curves**
- **Stage-Fatality Curves**

Loss Risk Profiles

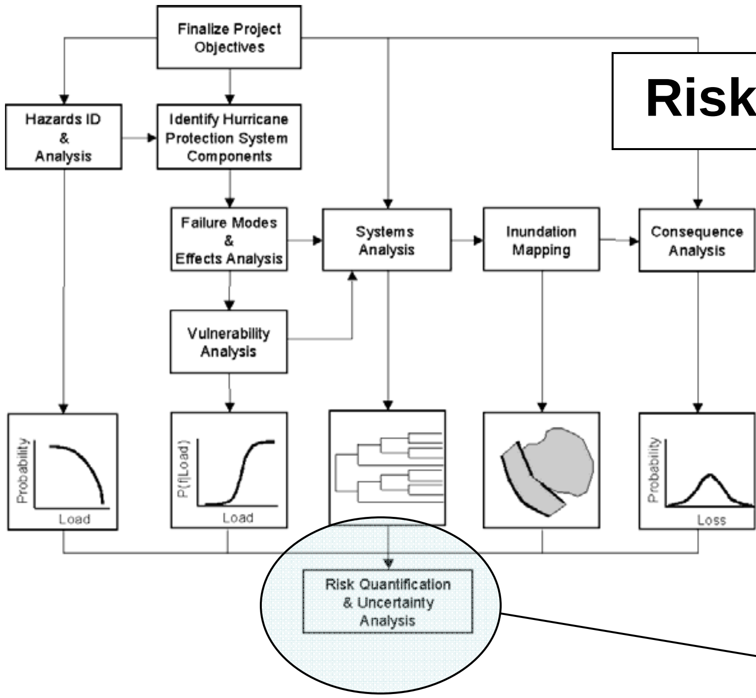


Note: Chart shows testing results

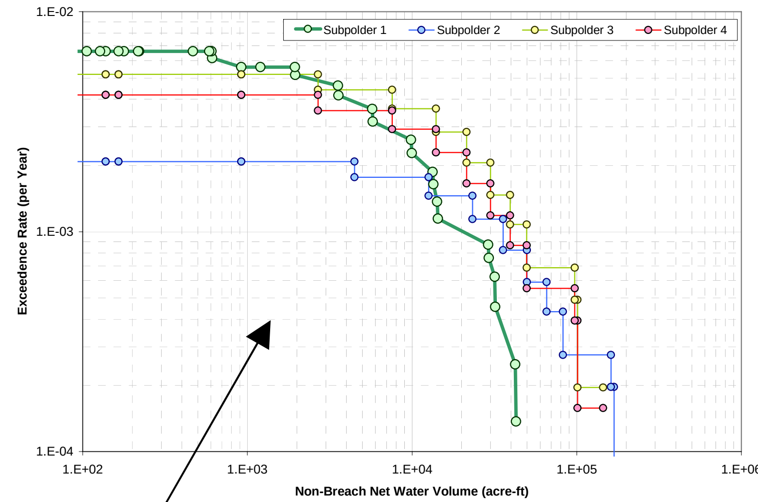
Loss Risk Profiles

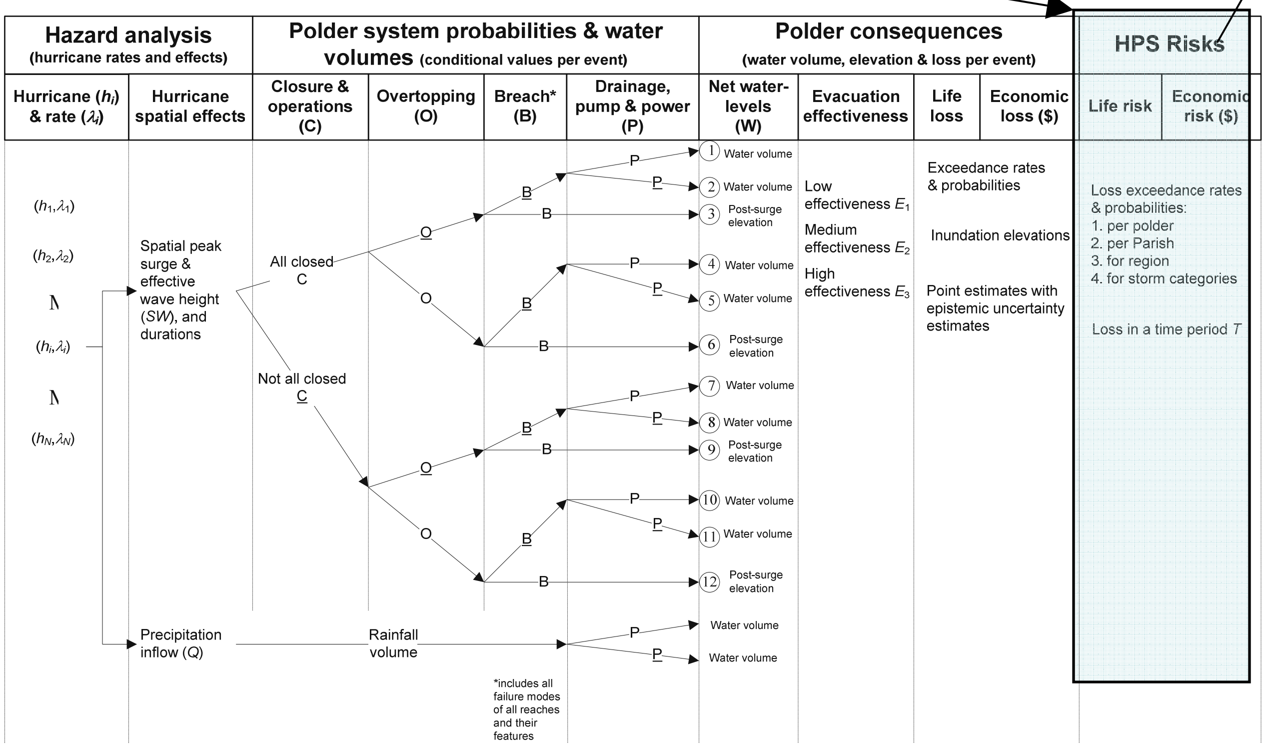


Note: Chart shows testing results



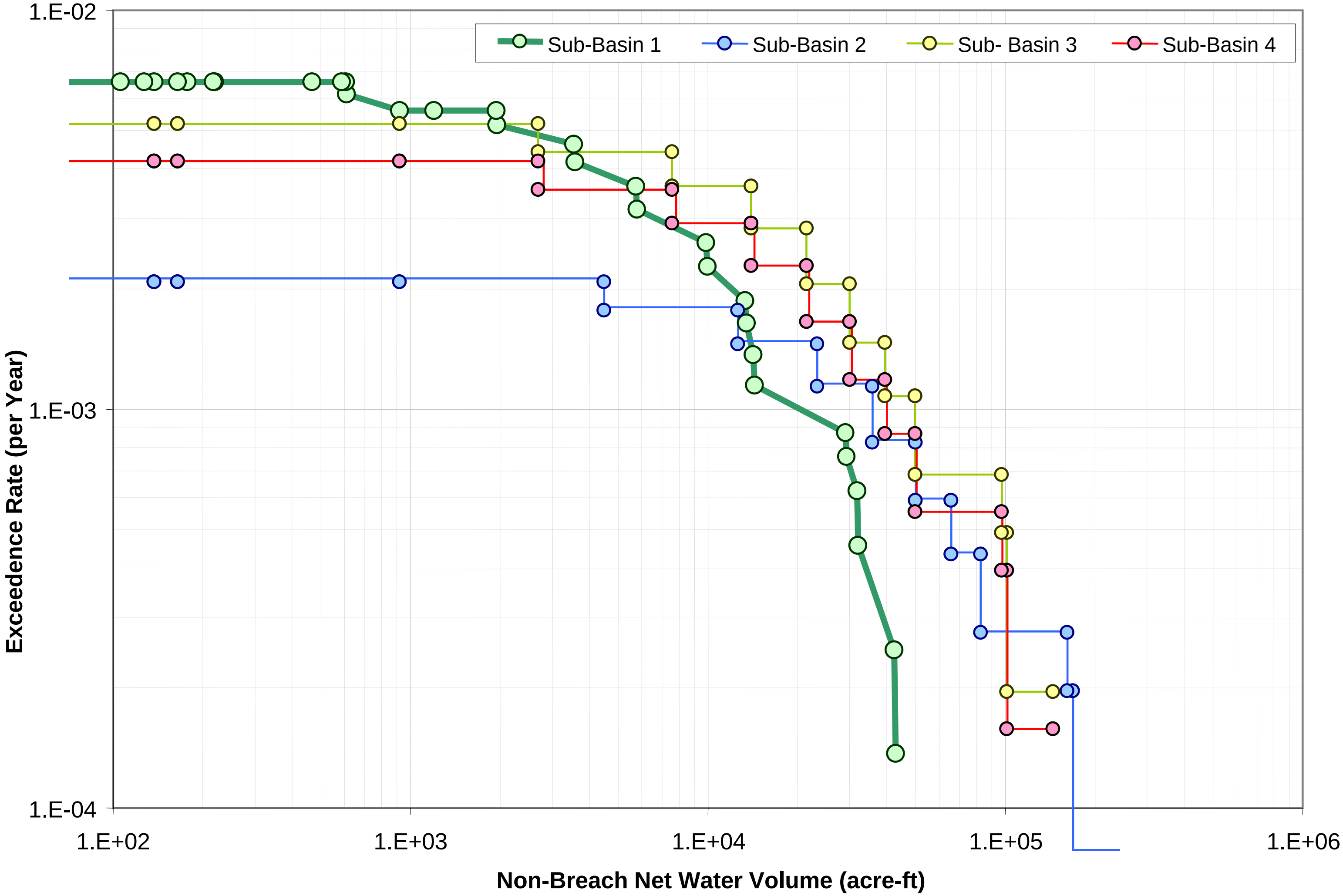
Risk Quantification Analysis

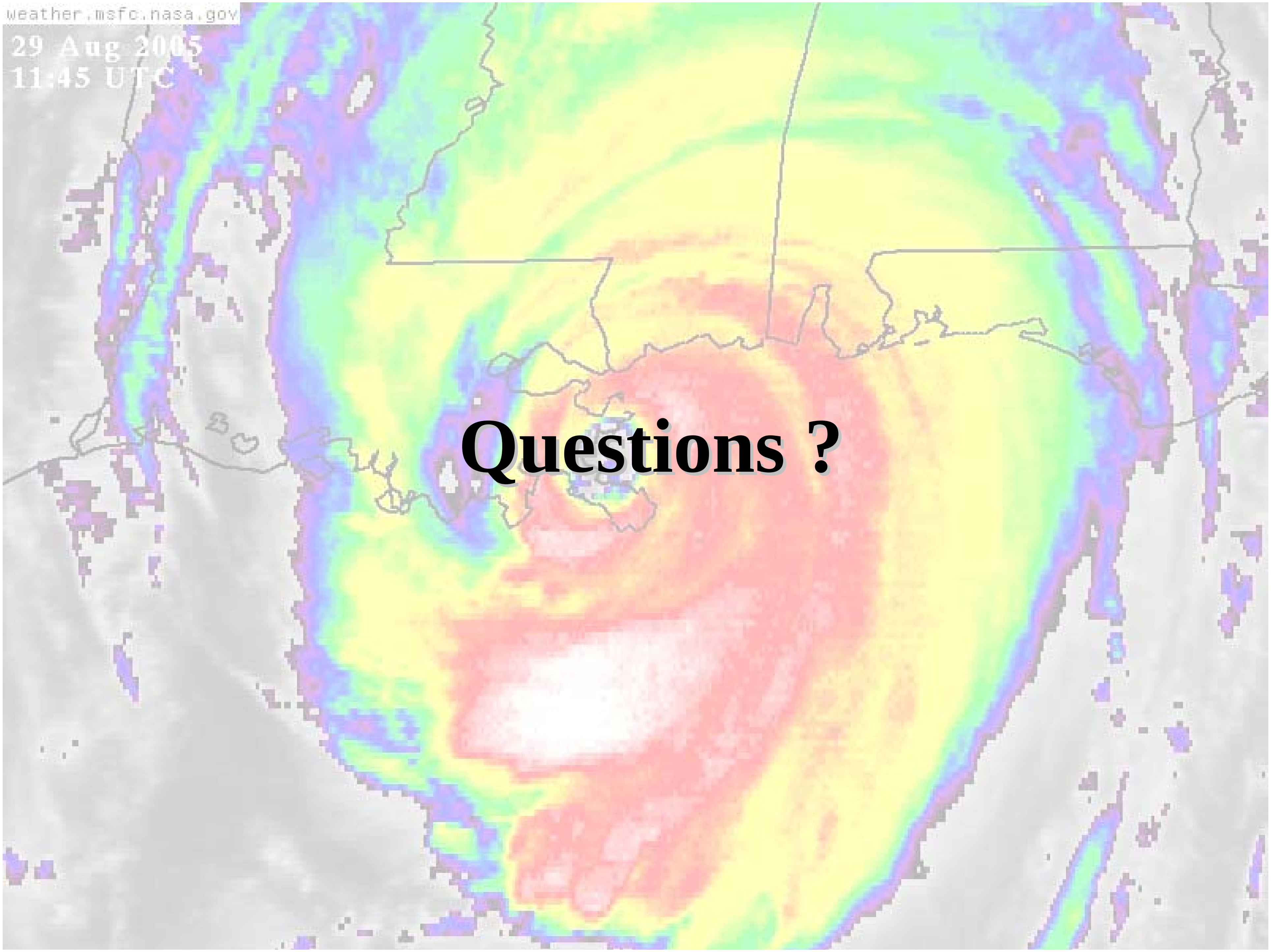




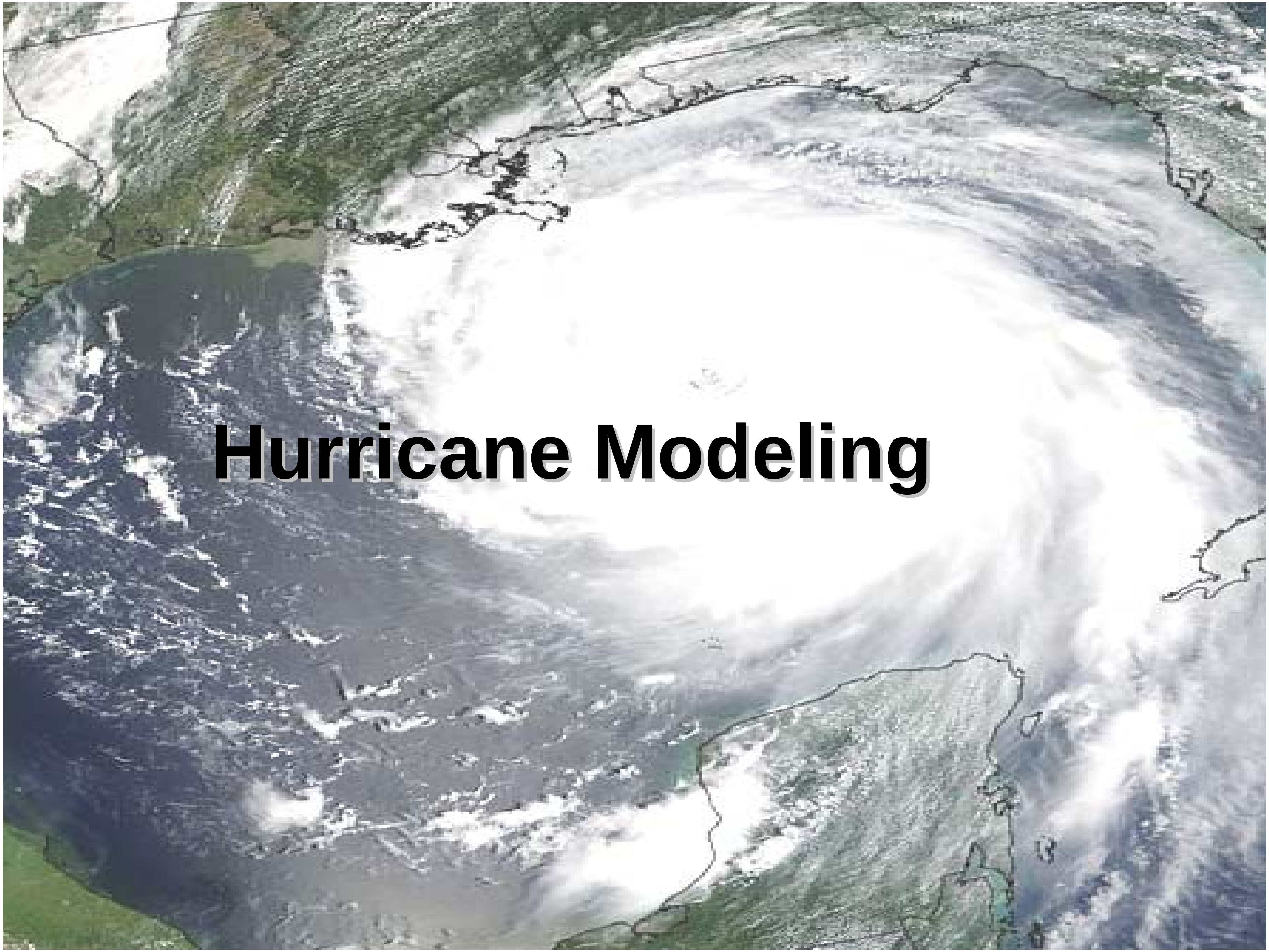
Branch Losses
Elevation Frequency Curves
Damage Frequency Curves
Fatality Frequency Curves
Annual Losses

Elevation Risk Profiles




weather.msfc.nasa.gov
29 Aug 2005
11:45 UTC
Questions ?

Hurricane Modeling



Approach

- The approach generally follows the plan of Appendix J to Report 2
- Joint Probability Method with 6 storm parameters:
  - – Central pressure, ΔP
  - – Radius to maximum winds, R_{max}
  - – Forward speed, V_f
  - – Track direction, θ
  - – Track position, X
  - – Pressure profile parameter, B

Number of Simulations

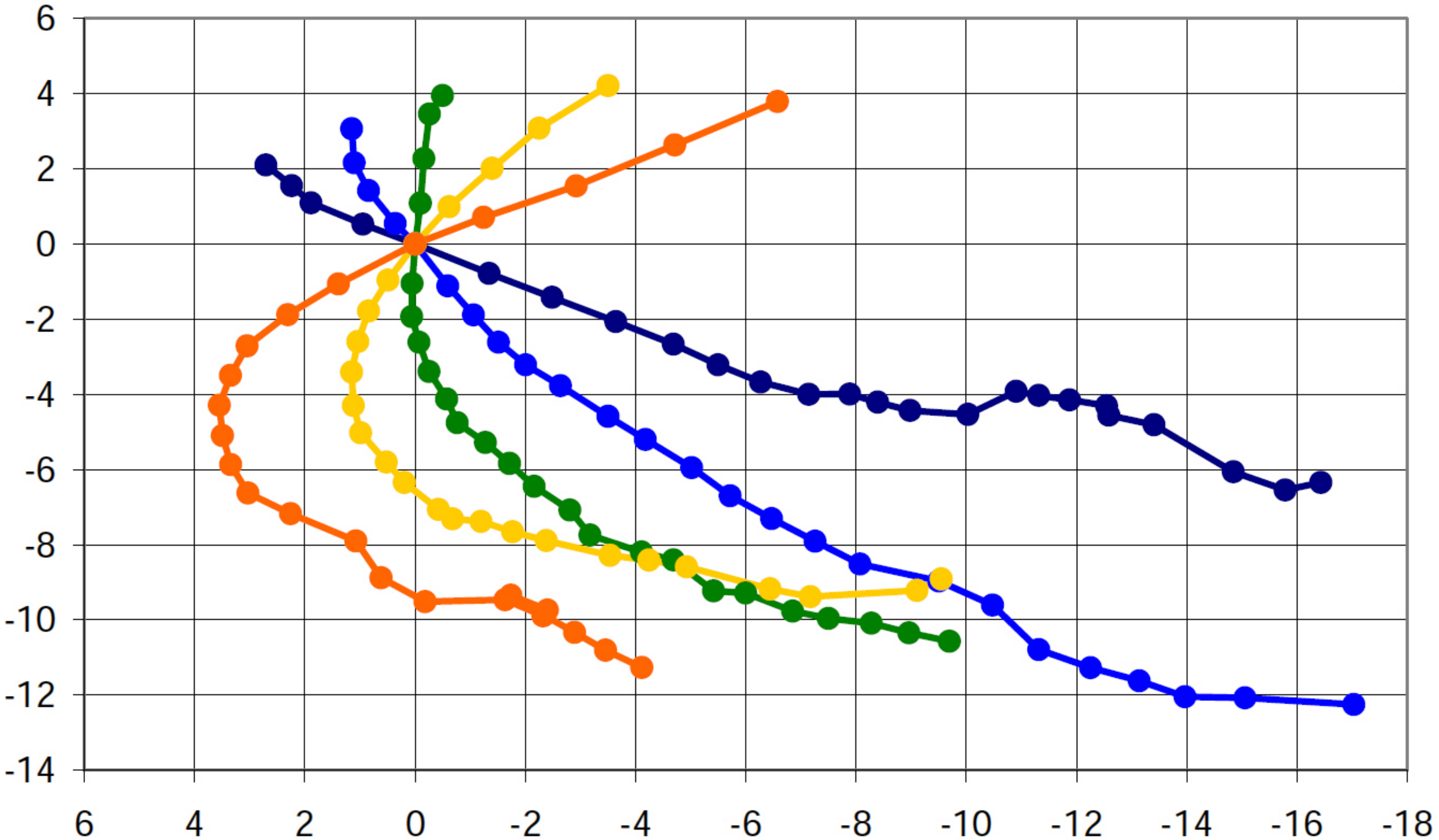
- **ΔP 6 values simulated**
- **R_{max} 3 values simulated**
- **V_f 5 values simulated**
- **θ 5 values simulated**
- **X 8 values simulated (4 to left, 3 to right)**
- **B 5 values simulated (partial)**
- **TOTAL ≈ 1600 simulated; ≈ 1800 extended**

Storm Characteristics

- Tracks are curvilinear, rather than straight
- Parameters are time varying, both before and after landfall
- Landfall is reckoned from a piece-wise linear approximation to the north Gulf shoreline

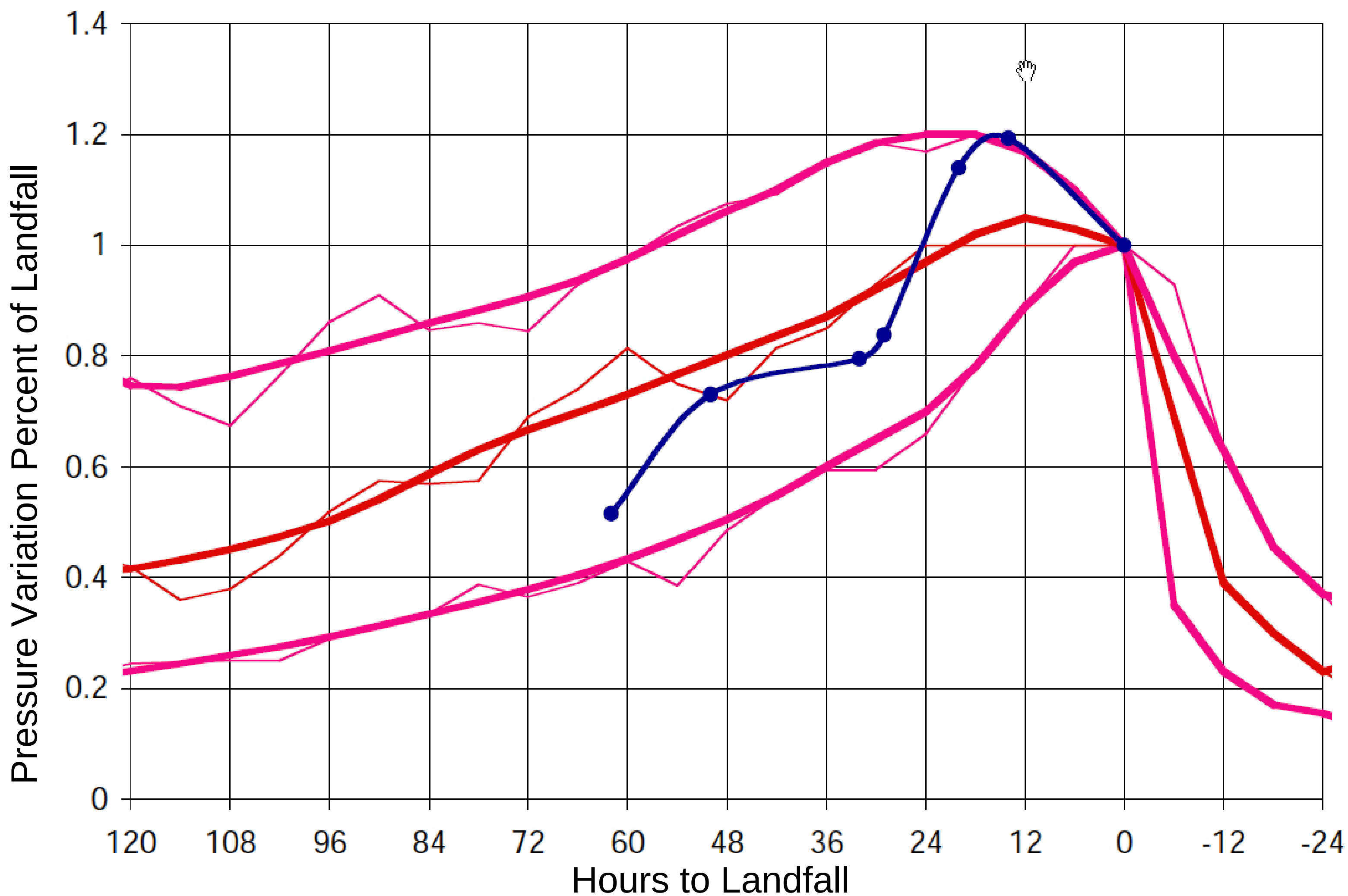
Storm Paths

Degrees offset from landfall for 5 crossing angles (Volume 8, Figure 8-20)



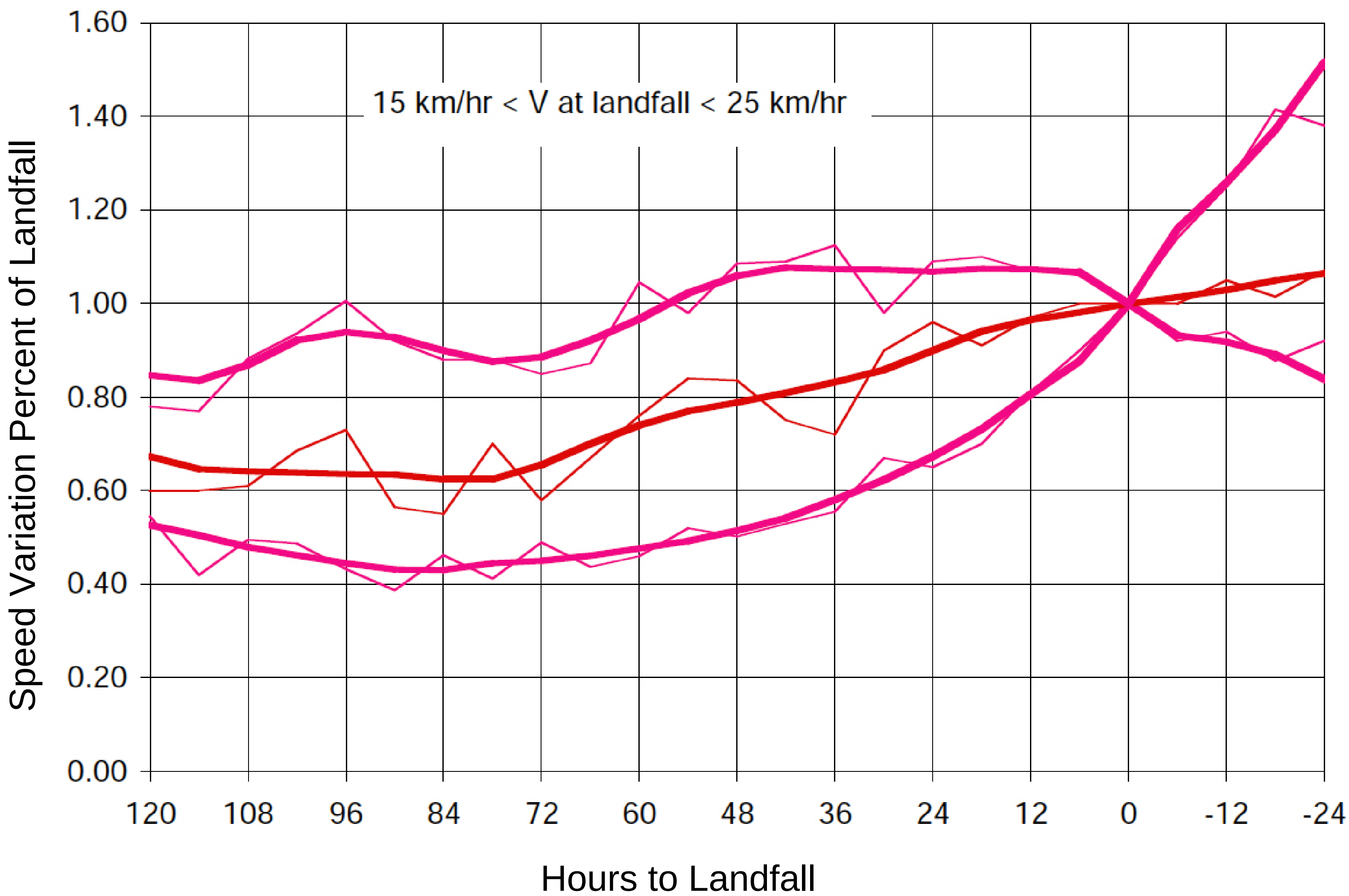
Pressure Variation

Relative to landfall pressure, vs hours before landfall (App. 8, Figure 8-21)
25%, 50% (Orange), 75%; Katrina in Blue



Typical Speed Variation

Relative to landfall speed, vs hours before landfall (App. 8, Figure 8-22b)



Track Design Considerations

- Tracks must begin far enough offshore to allow model ramp-up and time for surge to develop
- Tracks must extend far enough onshore to ensure that the hydrograph peaks have been reached
- Tracks must extend far enough to the left and right of the central track through NO to capture all large events
- Tracks must be spaced closely enough to minimize spurious alongshore surge variation

Track Design Considerations

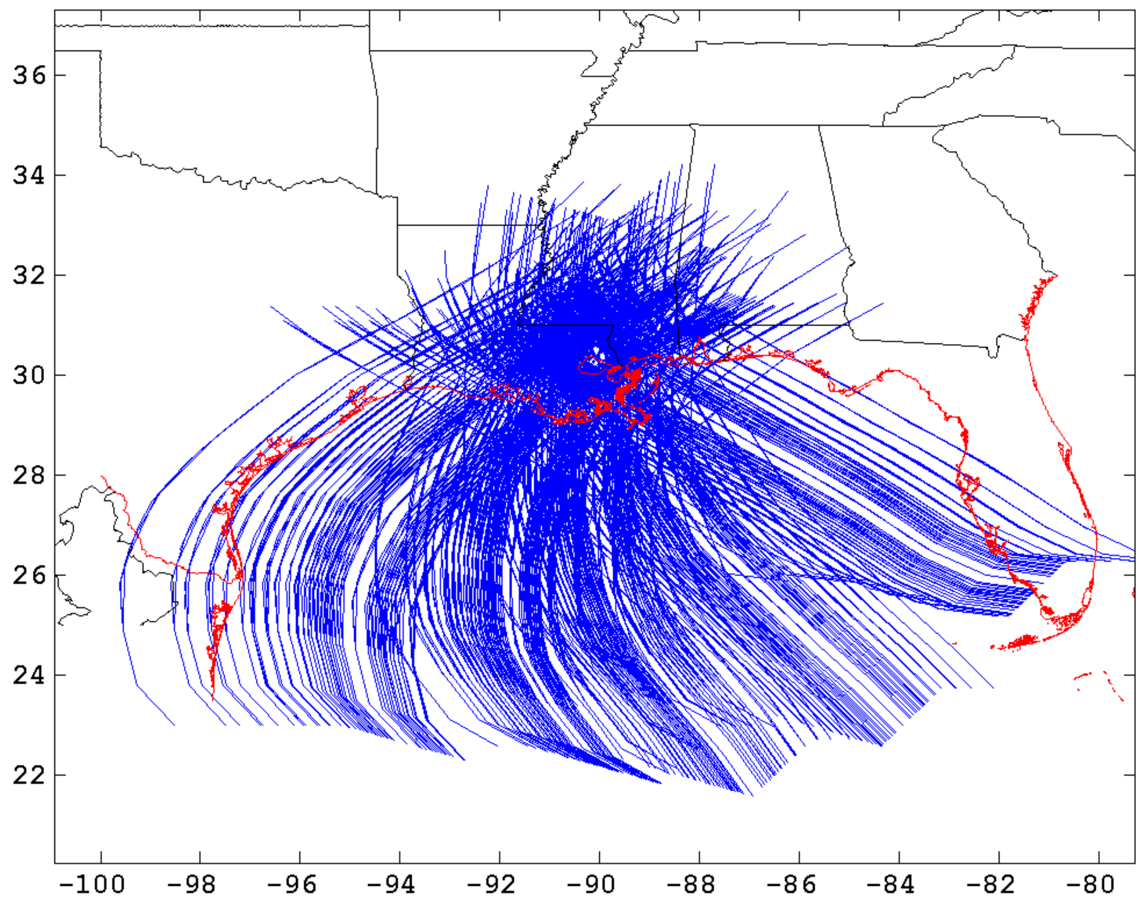
- However, it is essential to minimize the number of tracks and their lengths, in order to obtain a tolerable run time with the extremely large ADCIRC grids being used
- The final plan is based on a compromise set of tracks to achieve reasonable accuracy within acceptable run time requirements
- The primary difference between the current plan and the prior plan is in track spacing: spacing is set equal to R_{max} requiring more tracks than previously planned

High Resolution Simulations

- The fundamental simulations are being made on a medium resolution grid (MR)
- A small set of additional simulations (60) were made on a higher resolution grid (HR), requiring longer run times
- The results of the HR simulations are used to provide (small to moderate) corrections to the basic MR simulations
- Historic Storms (Katrina, Isidore, Betsy)

Simulated Tracks

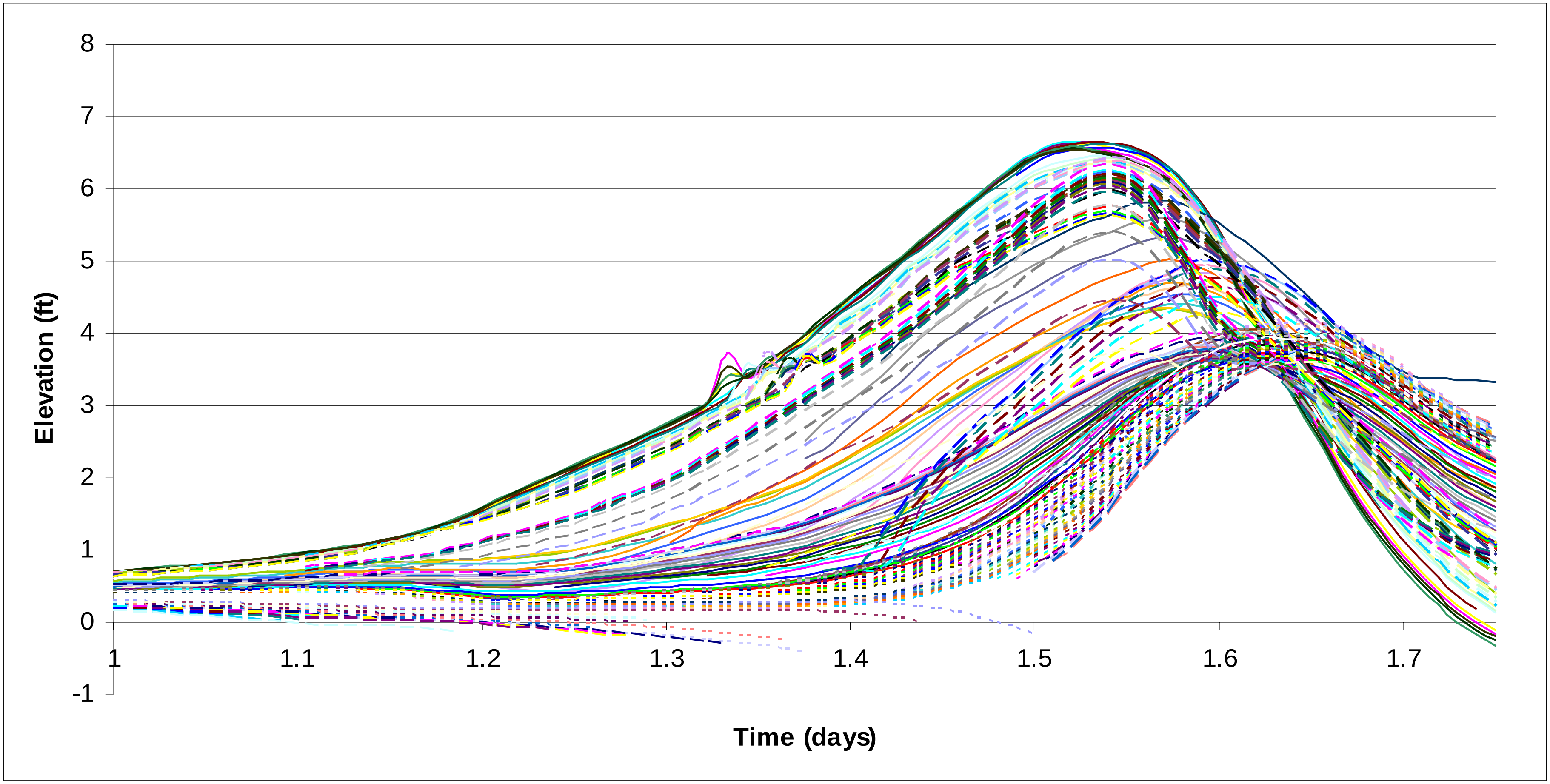
The outer envelope is determined by storm radius and forward speed. Pattern irregularity is a consequence of the irregular shoreline shape, to which the tracks are referenced.



Additional Highwater Components

- Two significant additions to the total high water level are:
  - The contribution of wave setup, dependent upon wave generation by each storm and bathymetry. Special methods were developed by Risk Team for this purpose.
  - The contribution of astronomic tide. Since tide is small, approximate methods suffice.

Hurricanes and Hydrographs



The time was extended to fully develop the hydrographs.

WAVE SETUP COMPONENT OF STORM SURGE

As Applied for Risk and Reliability

Methodology

- Parametric Method of Predicting Wave Setup That is Added to the Wind Induced and Other Storm Surge Components
- Method Depends on: (1) Central Pressure Deficit, (2) Radius to Maximum Winds, (3) Translational Speed, (4) Hurricane Track Characteristics

Outline

1. Describe Underlying Physics
2. Examples from Lab and Field
3. Describe Risk and Reliability Criteria and Methodology
4. Illustrate With an Example

Four Components of Storm Surge

1. **Wind Stress Component**
2. **Barometric Pressure Component**
3. **Coriolis Force Component**
4. **Wave Set-up Component**

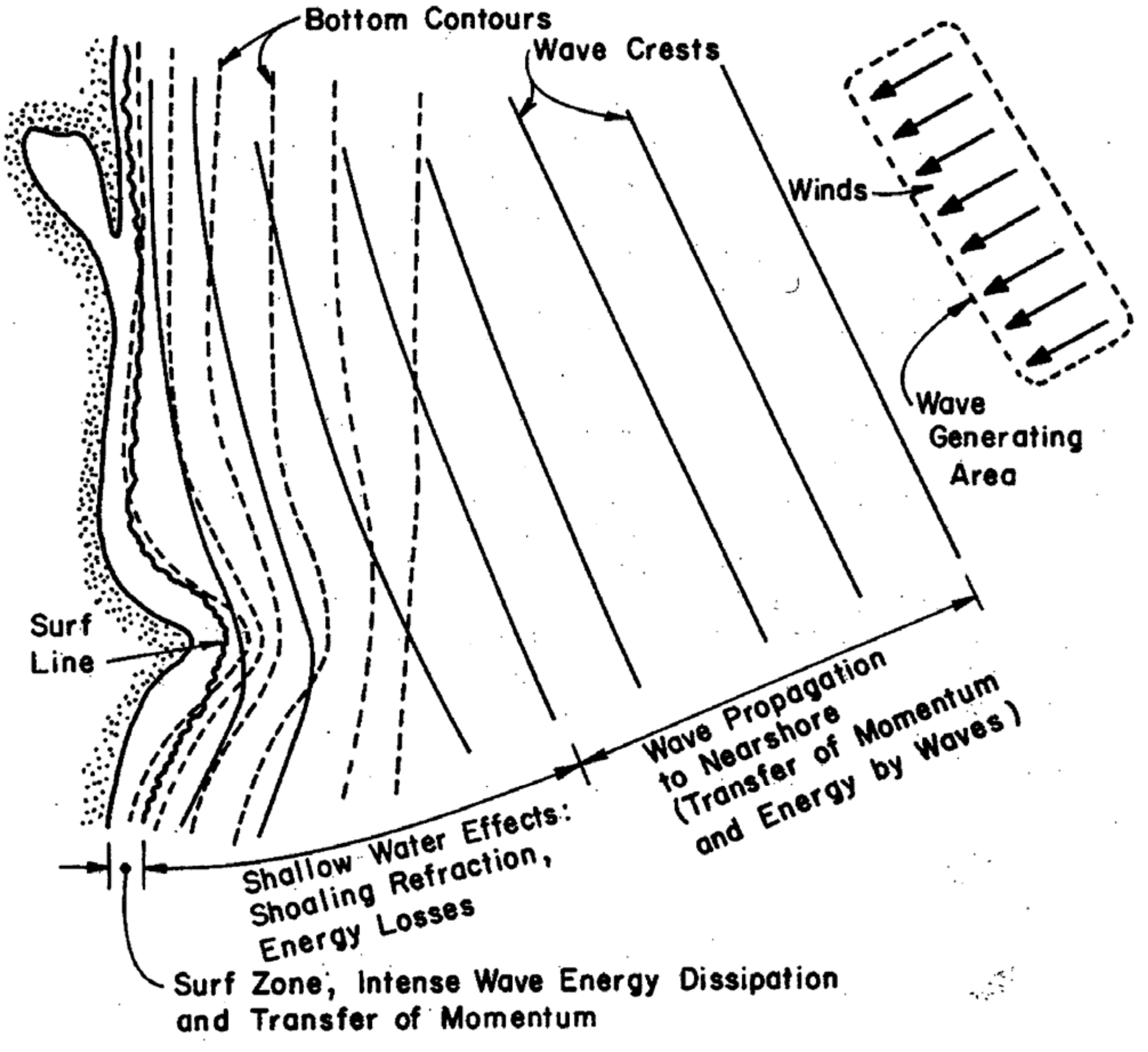
Criteria for Incorporating Wave Setup in Risk and Reliability

- **Time and Resource Constraints – Insufficient For Full Wave Modeling**
- **Must be Compatible With ADCIRC Modeling Which Uses Parameterized Hurricanes**
- **Applicable to Open Coasts and Levees**

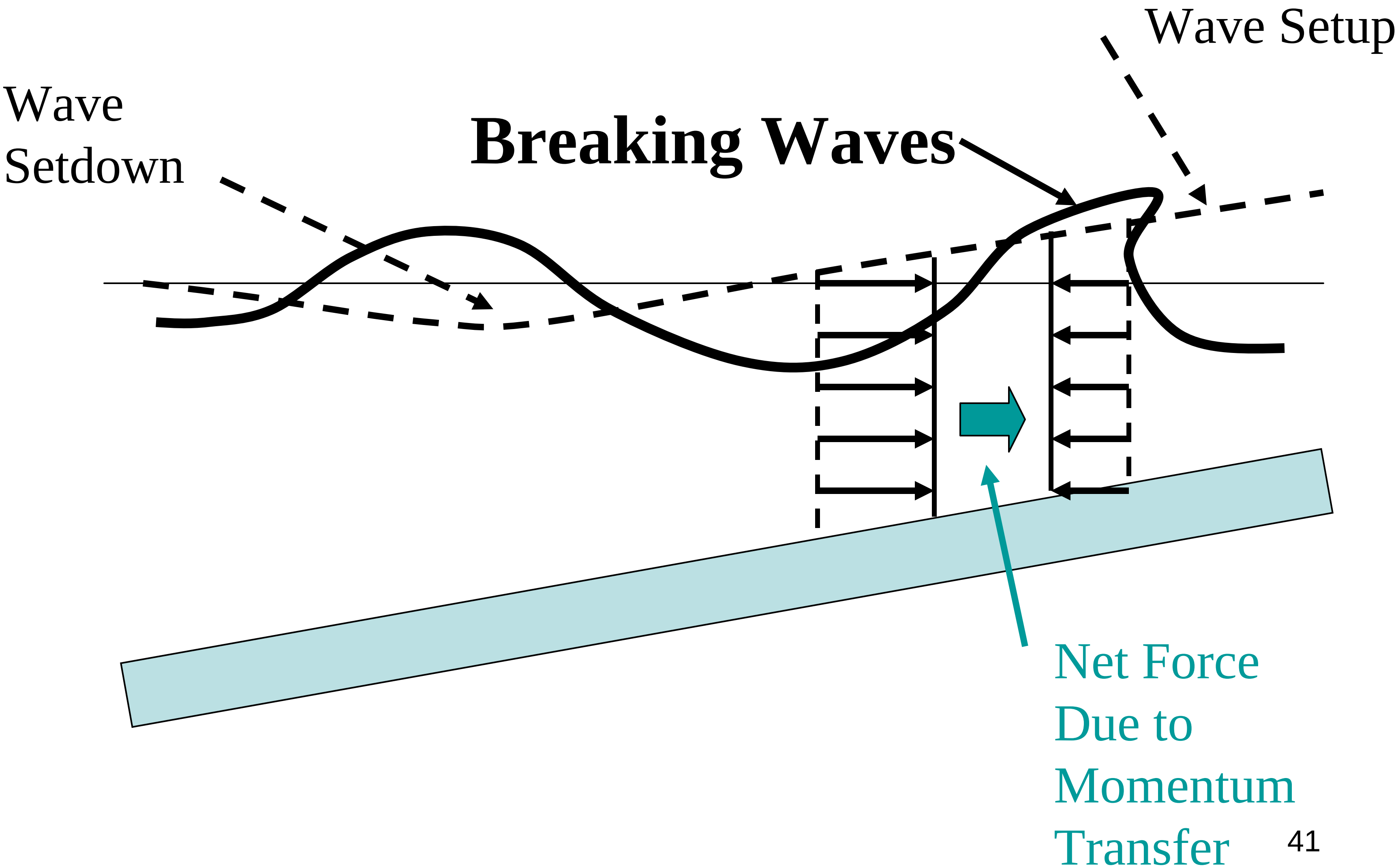
Wave Setup

- **Due to the Transfer of Wave Related Momentum to the Water in the Surf Zone As the Waves Break.**
- **Similar in Effect to Wind Stress Setup.**

The Process in Nature



Wave Setup Component



Theoretical Wave Setup

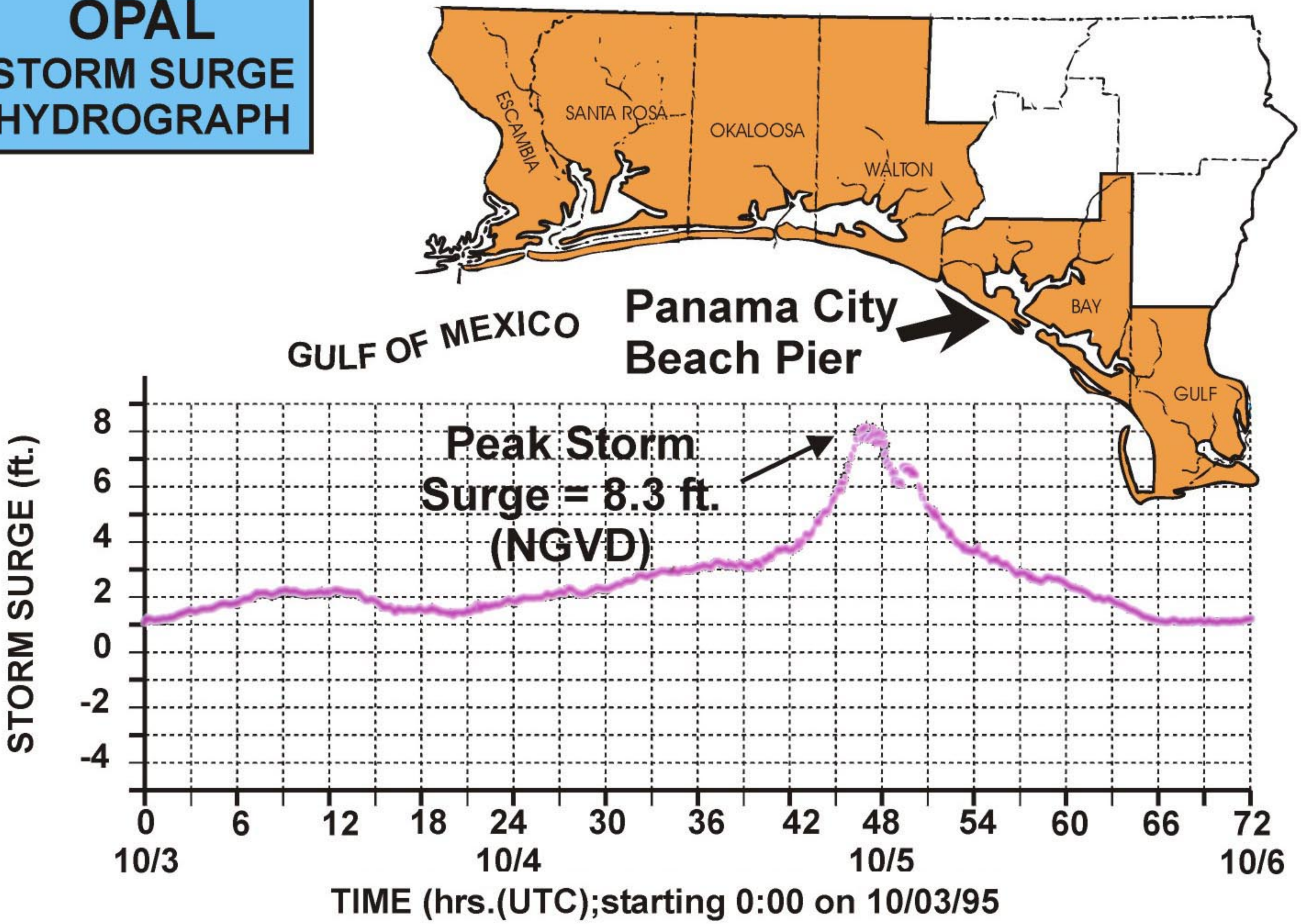
- **The Maximum Wave Setup Magnitude (at the Shoreline) is Approximately 20% of the Breaking Wave Height (Based on Simple Wave Theory for Breaking Waves on a Relatively Steep Slope)**

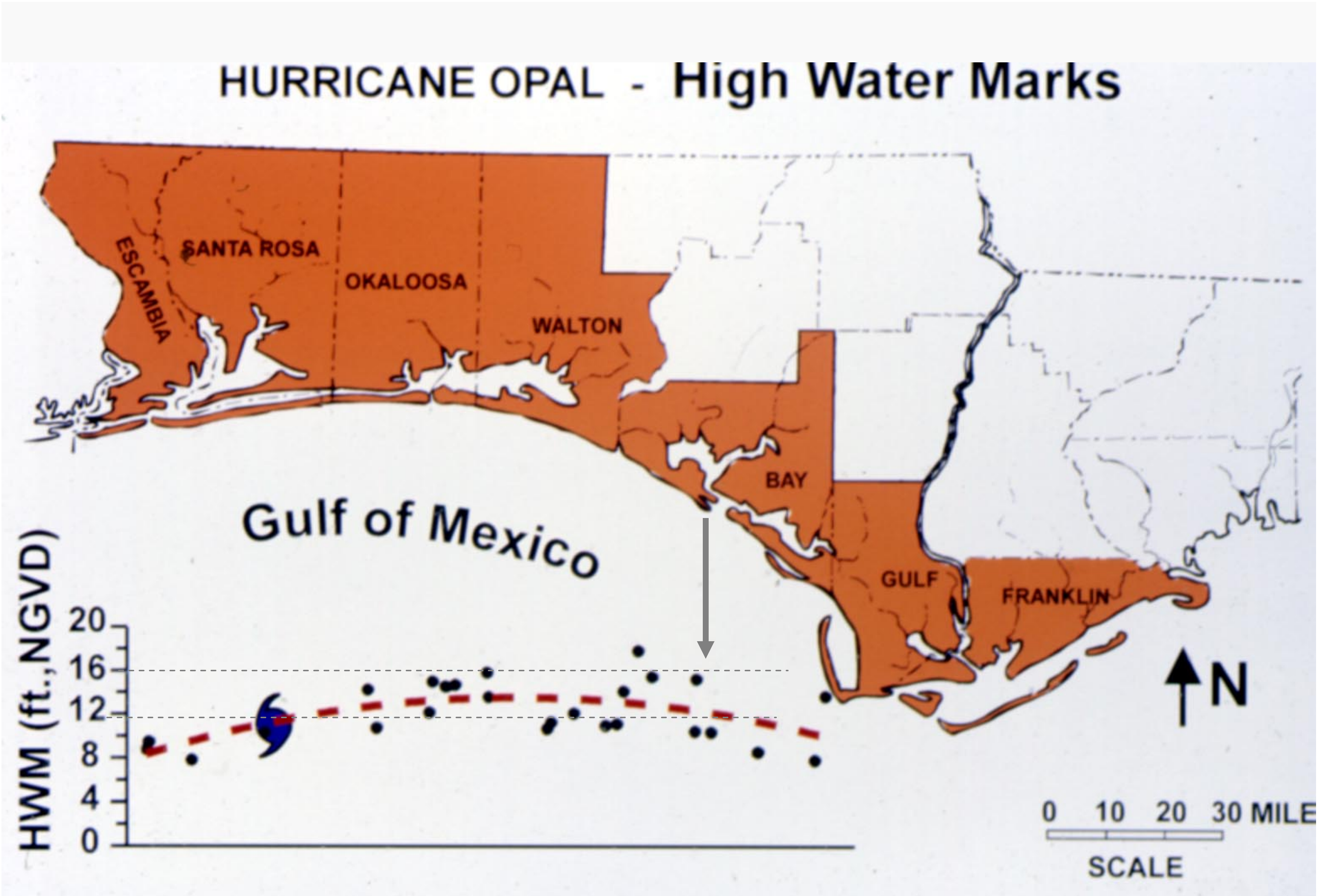
Field Evidence of Wave Setup

Hurricane Opal, 1995


Hurricane Opal Storm Track
GULF OF MEXICO
OPAL

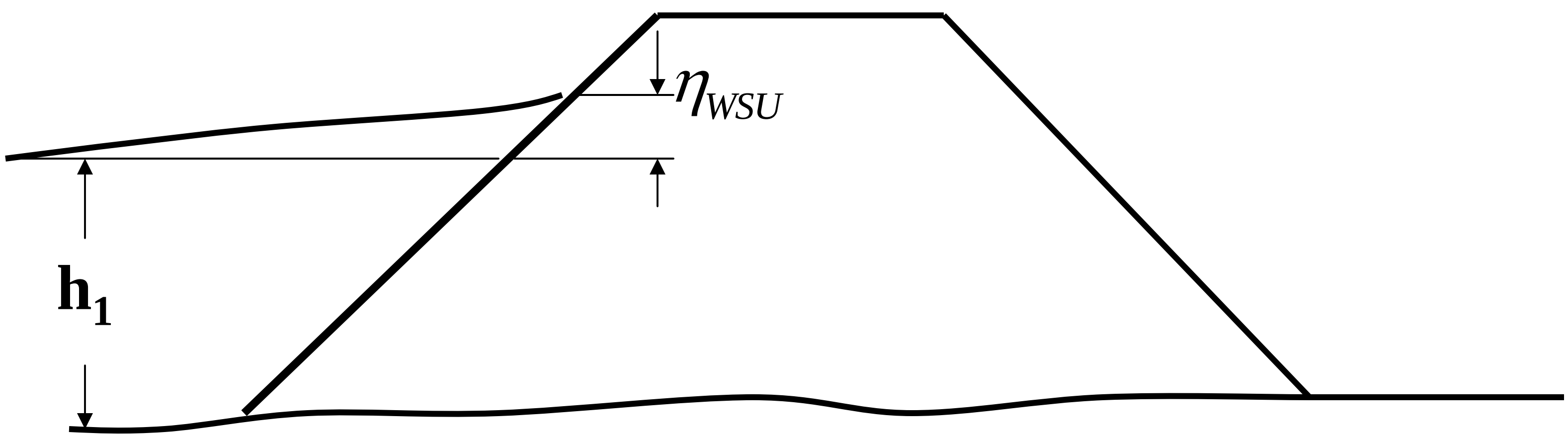
OPAL STORM SURGE HYDROGRAPH





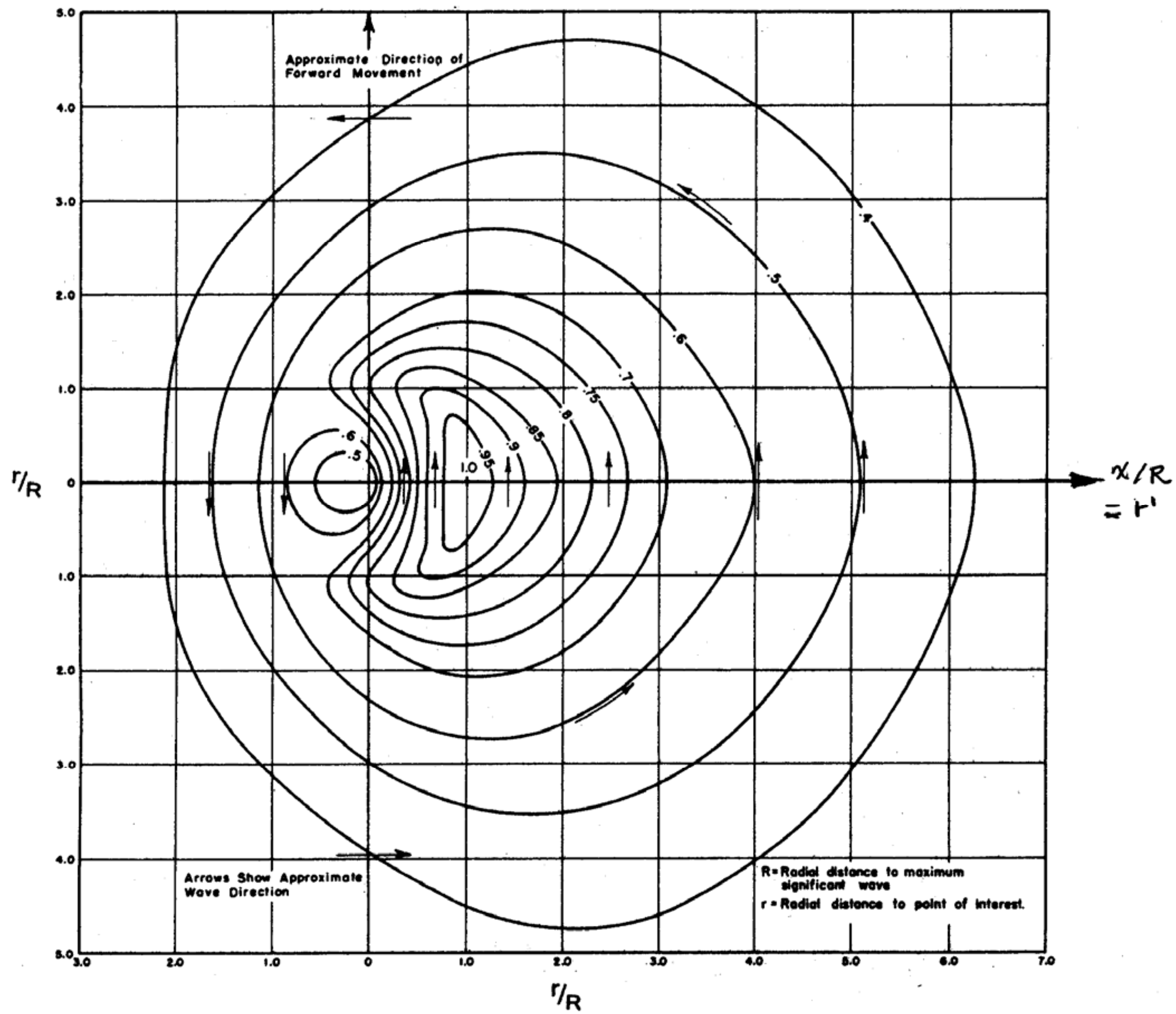
HURRICANE OPAL - High Water Marks
ESCAMBIA
SANTA ROSA
OKALOOSA
WALTON
BAY
GULF
FRANKLIN
Gulf of Mexico
HWM (ft., NGVD)
20
16
12
8
4
0
N
0 10 20 30 MILE
SCALE

Wave Setup on Levee



h_1 Includes All Surge Components Exclusive of Wave Setup

Bretschneider Relationship for H_{max}



Bretschneider Relationship for H_{max} and Associated Period, Ts

$$H_{o,\max} = 16.5 e^{\frac{R\Delta p}{100}} \left[1 + \frac{0.208 \alpha V_F}{\sqrt{U_R}} \right]$$

$$T_s = 8.6 e^{\frac{R\Delta p}{200}} \left[1 + \frac{0.104 \alpha V_F}{\sqrt{U_R}} \right]$$

For "Katrina Like" Hurricane at Landfall (Actually Slightly Less Intense but Larger)

$$\Delta p = 2.5\, in.\, Hg\ vs\ 2.75\, in.\, Hg,\ R = 40\ n\ mi, V_F = 12\ kts$$

- **Method Predicts the Following:**
  - **Maximum Setup on the Open Coast: 6.4 feet**
  - **Maximum Significant Wave Height: 56.8 ft**
  - **Associated Wave Period: 16.1 sec.**