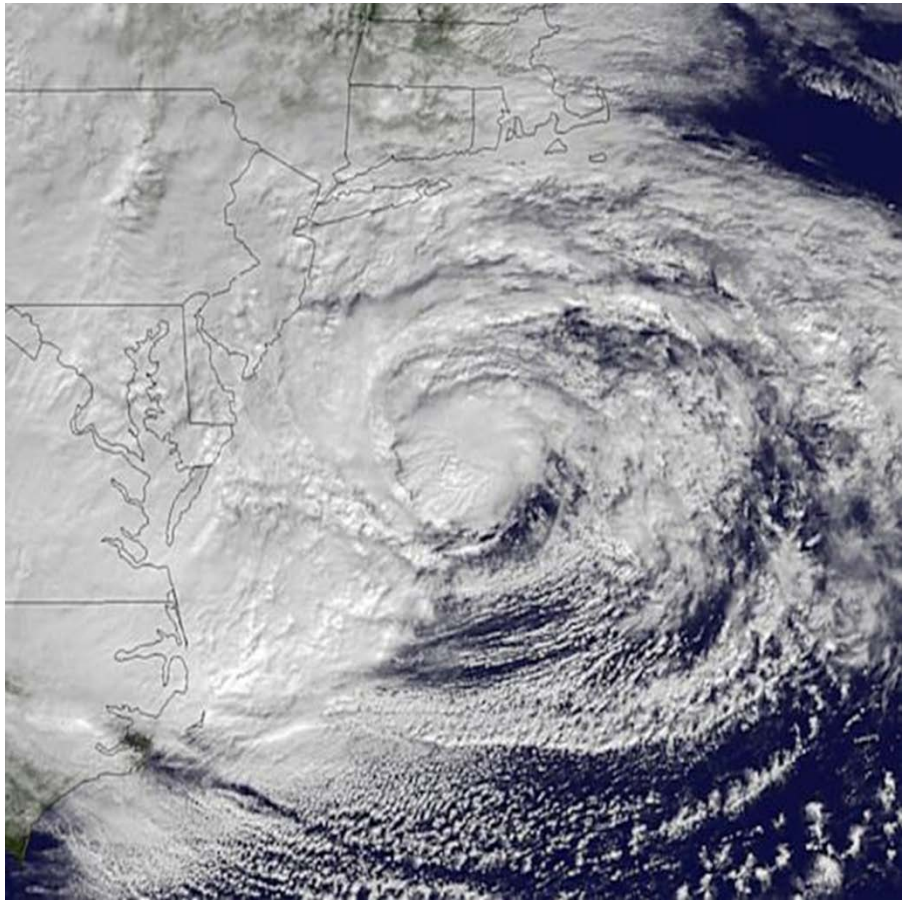
Infrastructure Design in the Age of Climate Change: Lesson Drawing from Natural Hazards and Disasters

COASTAL HAZARDS CENTER

Geo3 T2 Conference & Exposition
Exploring the challenges and advances in Geotechnical, Geophysical, and Geoenvironmental Engineering Technology Transfer



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Executive Director
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http://hazardscenter.unc.edu

Research Lead: The University of North Carolina at Chapel Hill

Education Lead: Jackson State University, Mississippi

Overview

- **Coastal Hazards Center**
- **Natural Hazards and Disasters**
- **Climate Change Adaptation Challenges and Opportunities**
- **Dynamism of Natural Hazards**
- **Case Studies (Vermont, Mississippi, Galveston Bay)**
- **Role of Engineers**

Coastal Hazards Center Overview

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COE Description

- **Need**: Hurricane Katrina showed gaps in the Nation's natural disaster preparedness, planning and response capabilities
- **Scope**: CHC conducts basic and transformational university-based R&D and develops expertise in related disciplines (through education programs) to improve coastal hazard planning, preparedness, response and recovery

Research Activities

CHC strengthens coastal area resilience to natural disasters through advancements in:

- Coastal Hazards Modeling
- Engineering of Built and Natural Coastal Infrastructures
- Disaster Response and Social Resilience
- Planning for Resilience

Customers

- Science and Technology Directorate (FRG and IDD)
- U.S. Coast Guard
- Federal Emergency Management Agency
- US Army Corps of Engineers
- National Oceanic and Atmospheric Administration
- State and Local Emergency Management Agencies
- Infrastructure Managers
- First Responders

Evolving and Engineered Landforms

PI: Margery Overton, NCSU

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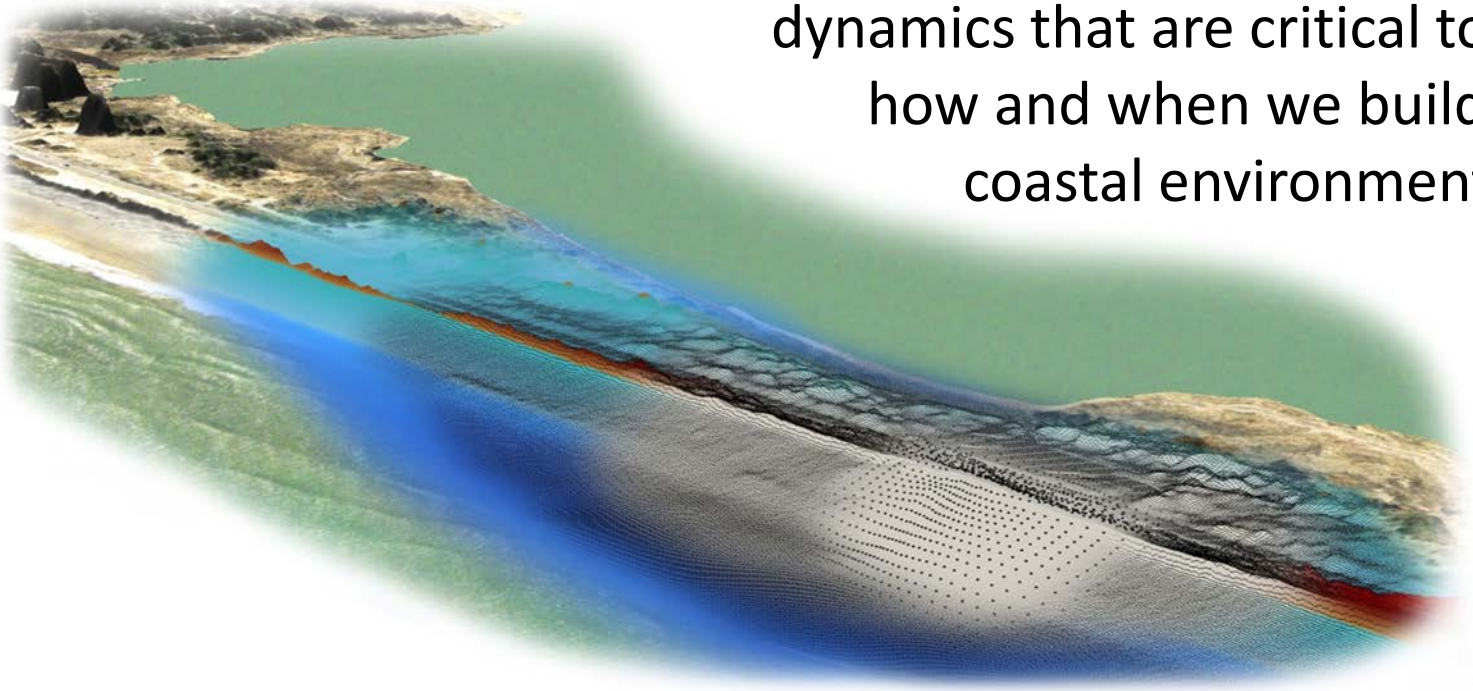
- High resolution and multi-temporal geospatial modeling of geomorphic evolution
- Improving the understanding and communication of landform dynamics that are critical to where, how and when we build in coastal environments



Innovative Component Design and Retrofit of Critical Civil Infrastructure

PI: Mo Gabr, NCSU

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- Platform for assessing failure potential of protective earth structures
- Investigates deformation-based limit states associated with coastal storms as well as advanced materials to minimize damage

In Situ Erosion Evaluation Probe (ISEEP)

PI: Mo Gabr, NCSU

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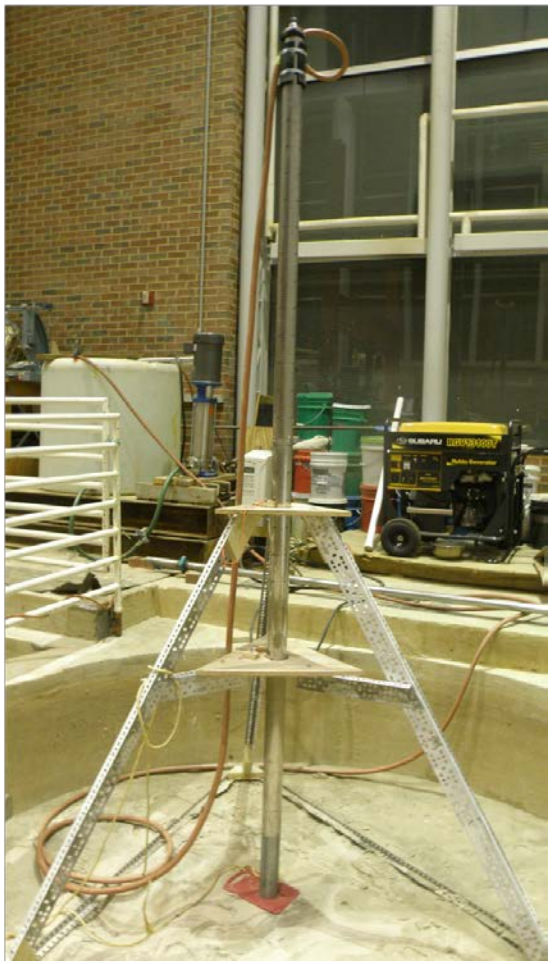

- Developing a process to assess critical erosion / scour without needing to remove and test soil samples in a lab
- The probe will help estimate the stability of hydraulic structures, including levees and bridges, before and after storm events

Natural Hazards and Disasters

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Adaptation Challenges and Opportunities

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- **Adaptation to Existing Climate/Weather is Poor**
- **Slow-Onset and Episodic Events**
  - **Differing timescales**
  - **Differing spatial scales (global-local)**
  - **Differing camps of researchers and practitioners**
    - **Knowledge base and terminology (physical science/engineering, social sciences, planning); hazard mitigation/adaptation**
    - **Policy frameworks (while different, both emphasize sustainability and resilience)**
  - **Differing analytical tools**
    - **Risk assessment and risk communication**
    - **Linking global assessments and local impacts**
  - **Funding and implementation mechanisms**
  - **Shared Governance / Adaptive Governance**

Adaptation Challenges and Opportunities

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- **Political Impediments**
  - **“Competing with mitigation of greenhouse gas”**
  - **Exceeding political timescales/election cycles**

- **Institutional and Resource Limitations**
  - **Limited mandate (e.g. FEMA, NOAA)**
  - **Need for new institutions/maximization of boundary spanning organizations/Underutilization of existing hazards management institutions**
  - **Limited funding for climate change adaptation**
  - **Costs of adaptation uncertain**
    - **Protecting coastal infrastructure to 3 foot sea level rise (estimate 100 billion (New Orleans Levee 14 billion-100 year event)**

Adaptation Challenges and Opportunities

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- **Designing and Implementing Pre- and Post-Disaster Adaptation Strategies**
  - **Risk Reduction Options**
    - **Natural resource protection**
    - **Education and Outreach**
    - **Land use**
    - **Retrofitting critical public facilities and infrastructure**
    - **Relocation and resettlement**
    - **Insurance**
    - **Protective measures (levees, sea walls, beach nourishment)**

- **Social Vulnerability**


OFFICE OF THE PRESIDENT
METROPOLITAN MANILA DEVELOPMENT AUTHORITY
METRO GWAPO
TAO-GANADO
FIRST EAST METRO MANILA FLOOD CONTROL OPERATION DISTRICT

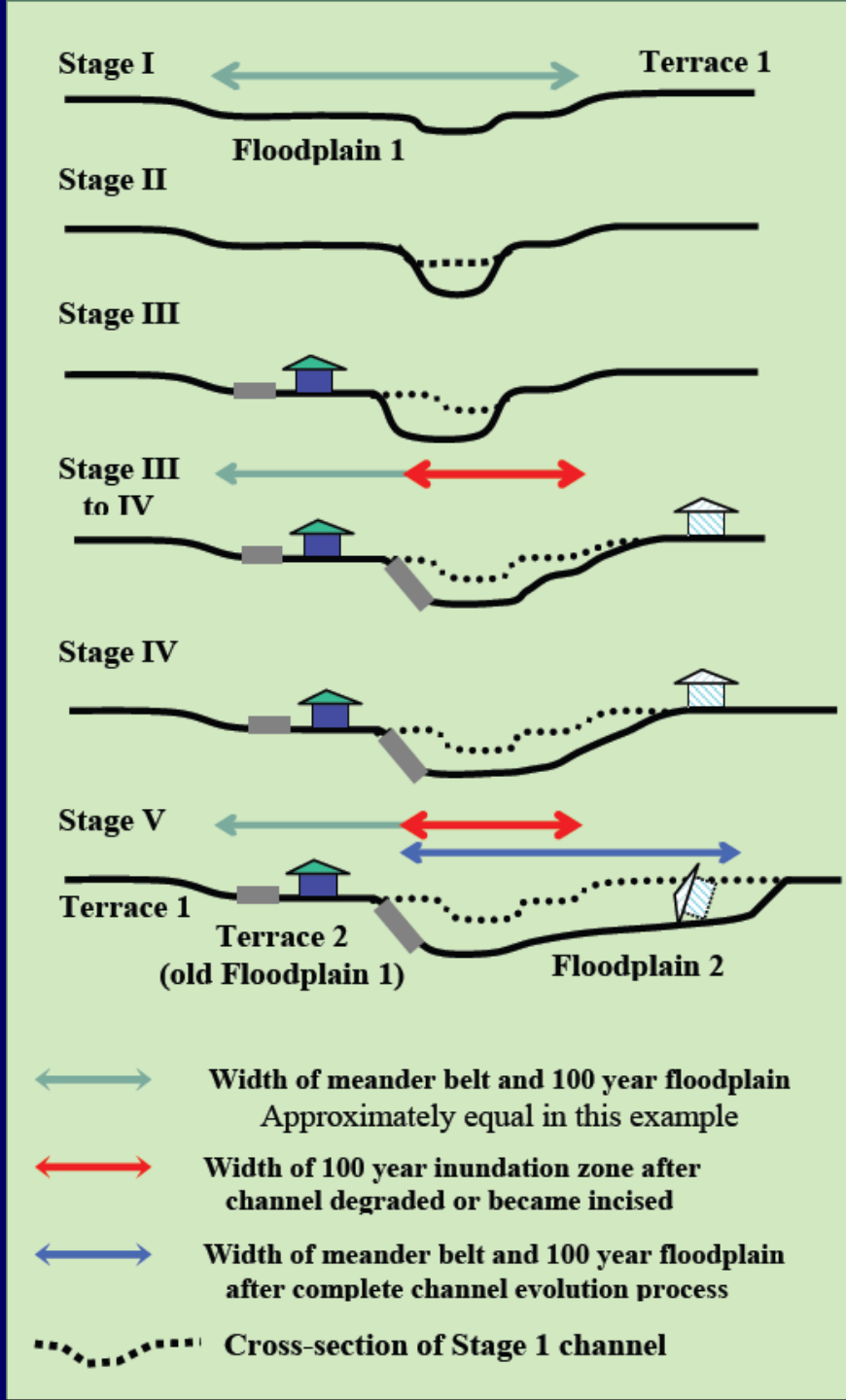
Irene


COVERED BRIDGE RD.
MILL RD.
PVT.

200+ years of Channel, Floodplain and Watershed Modifications:

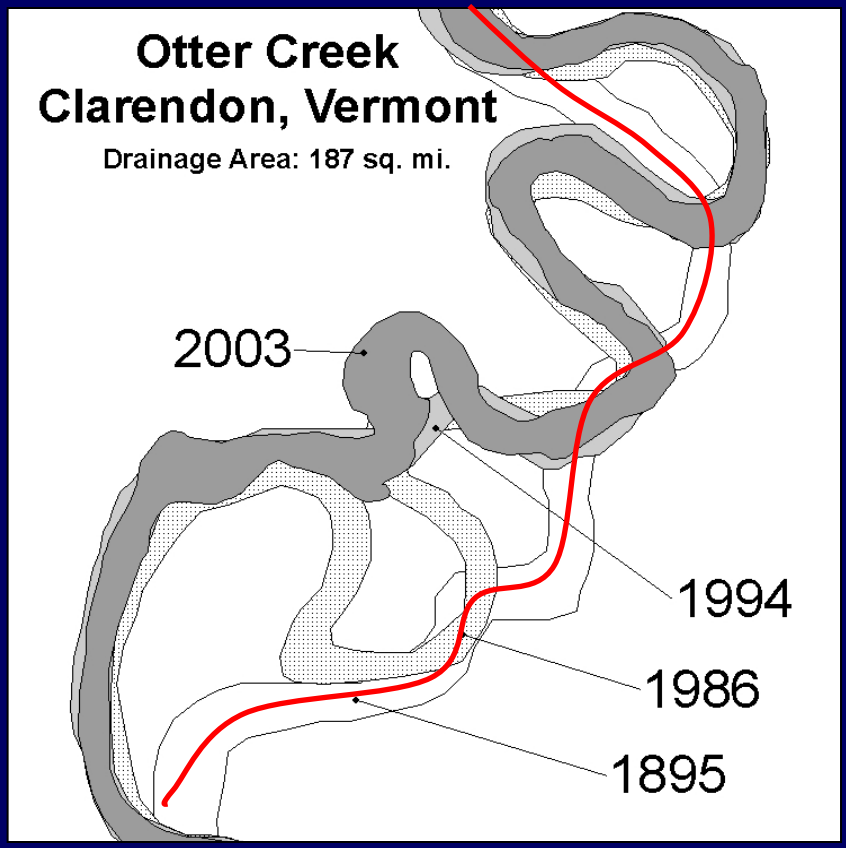
- Deforestation
- Snagging and ditching
- Encroachments, i.e., villages, farms, roads and rails
- Dams and diversions
- Gravel removal
- Straightening - berming
- Undersized Culverts
- Stormwater

These activities have contributed to channel incision and adjustments (Stages I-V on right) that confound flood mapping and the under-estimation of risk in Vermont.

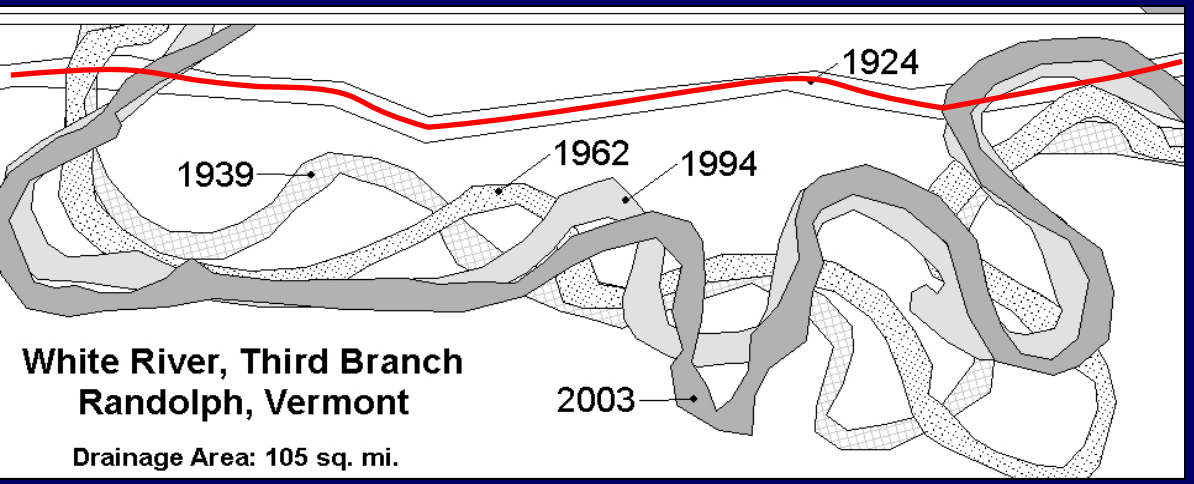


Straightened rivers immediately begin to re-meander, lowering the energy gradient of the river.

When we stop this process to protect new encroachments, we increase hazards to downstream property, and the recovery costs after each major flood.



Otter Creek after 1895



White River after 1924

Dissipate Flood Energy, Sediment, and Debris

Create and Maintain Roughness and Places for Sediment and Debris to Deposit

Vermont River Management:

Moving away from the concept that rivers are static systems.

Repeated and costly efforts to control long lengths of rivers as static channels is proof that channelization with structural measures at a large scale is an unsustainable public policy.

Vermont River Corridor Planning

Public Safety and Property Protection

Very High Water Quality

Healthy Riparian Ecosystems

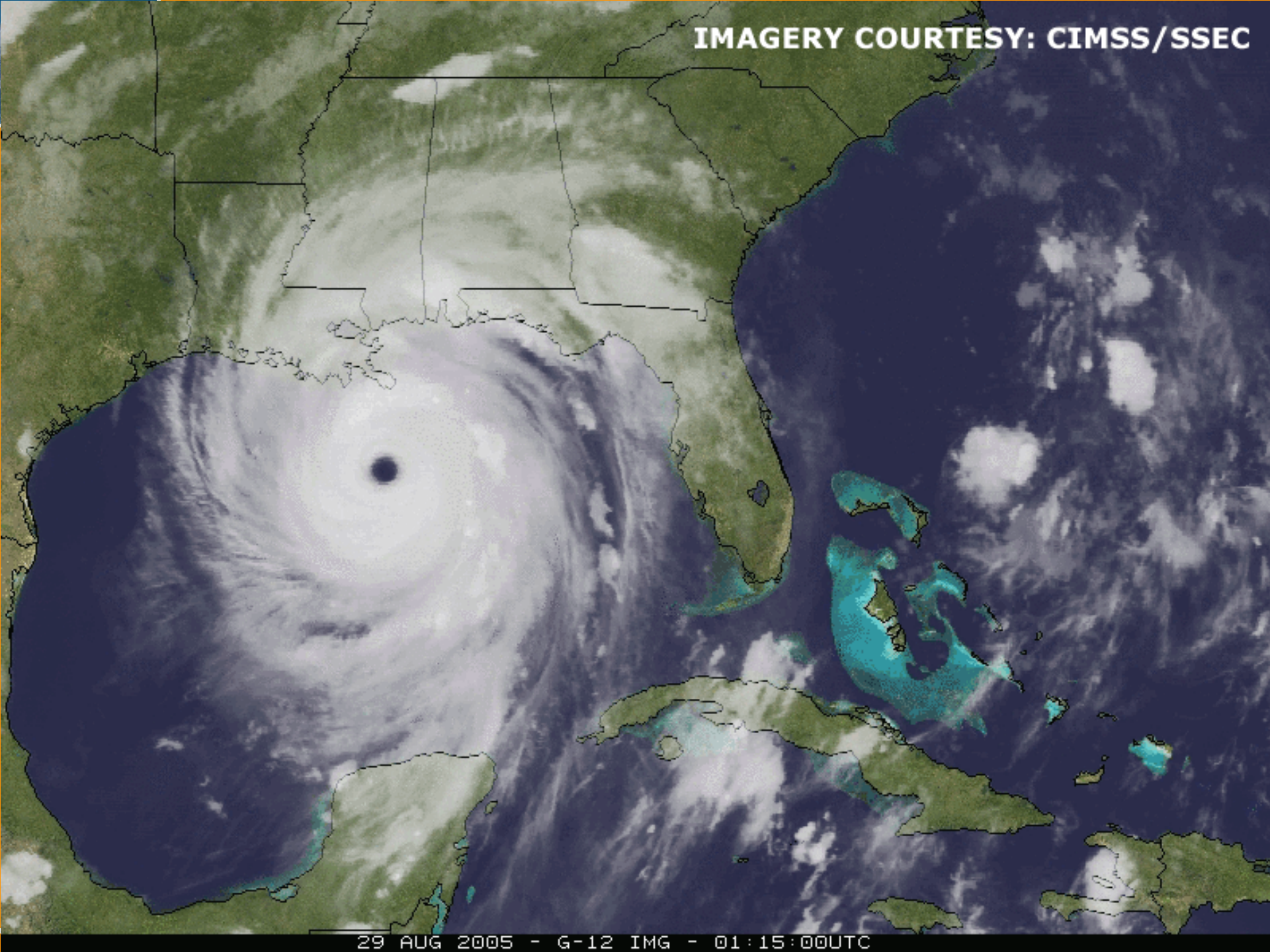
Economically and ecologically sustainable relationship with rivers by managing toward *dynamic equilibrium*

Mitigate Flood and Fluvial Erosion Hazard

Reduce Sediment and Nutrient Loading

Restore / Protect Meandering, Connectivity, Flows & Wood

Limit Encroachments / Remove Constraints / Manage Stormwater
Restore Floodplain Function / Maintain Woody Buffers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"Planning" for Post-Disaster Recovery/Risk Communication

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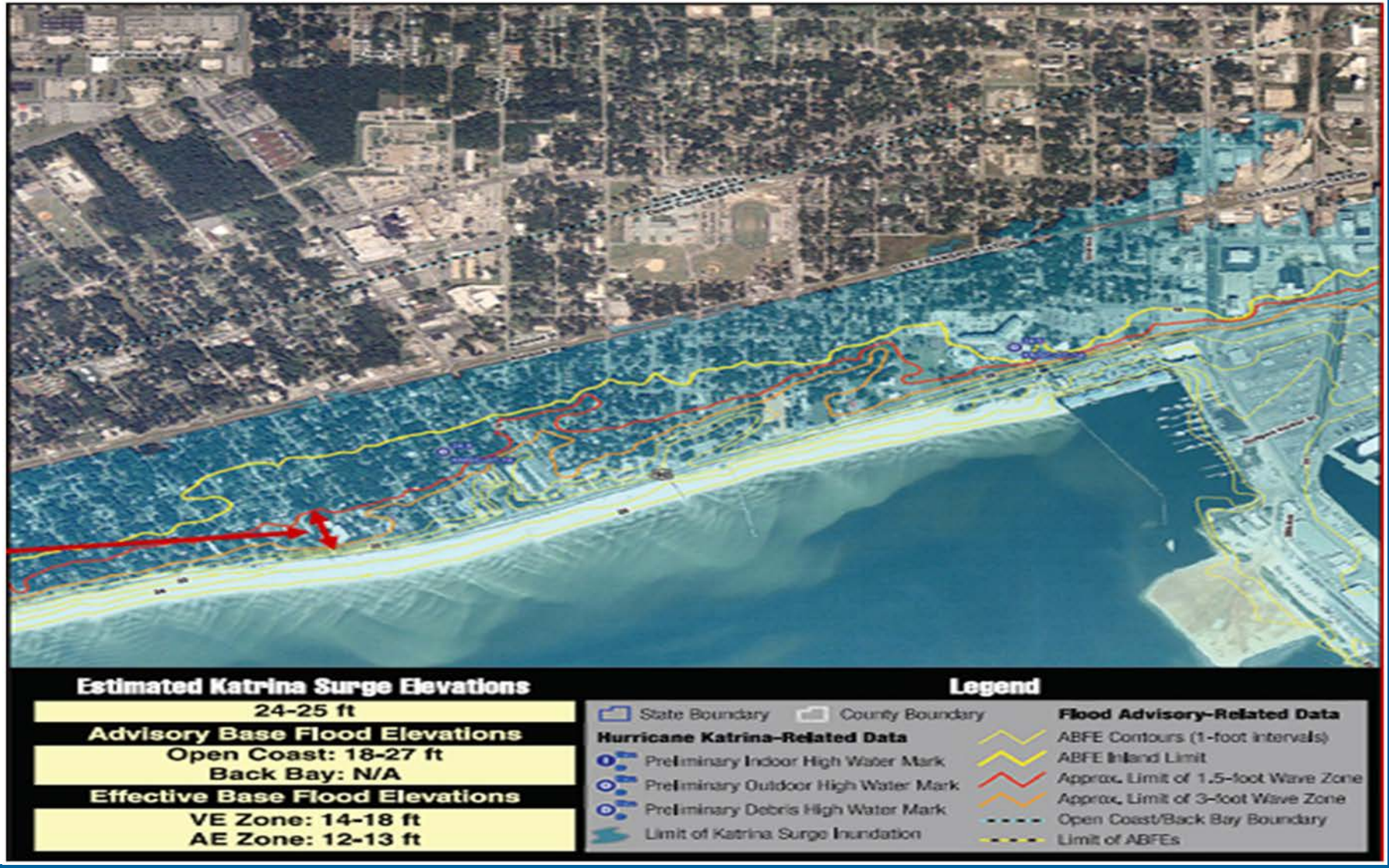

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Post-Disaster Recovery, Reconstruction and Resettlement? (Recovery as "Opportunity" -- Hazard Mitigation)

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Building Codes and Land Use: What is the Appropriate Design Standard?

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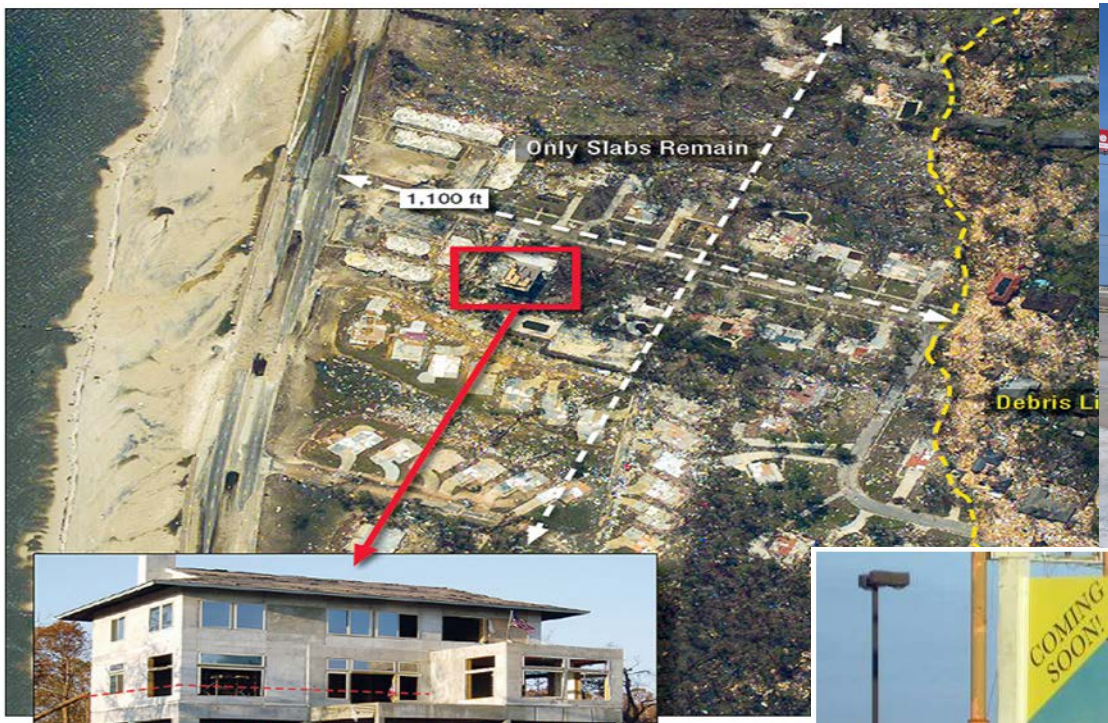

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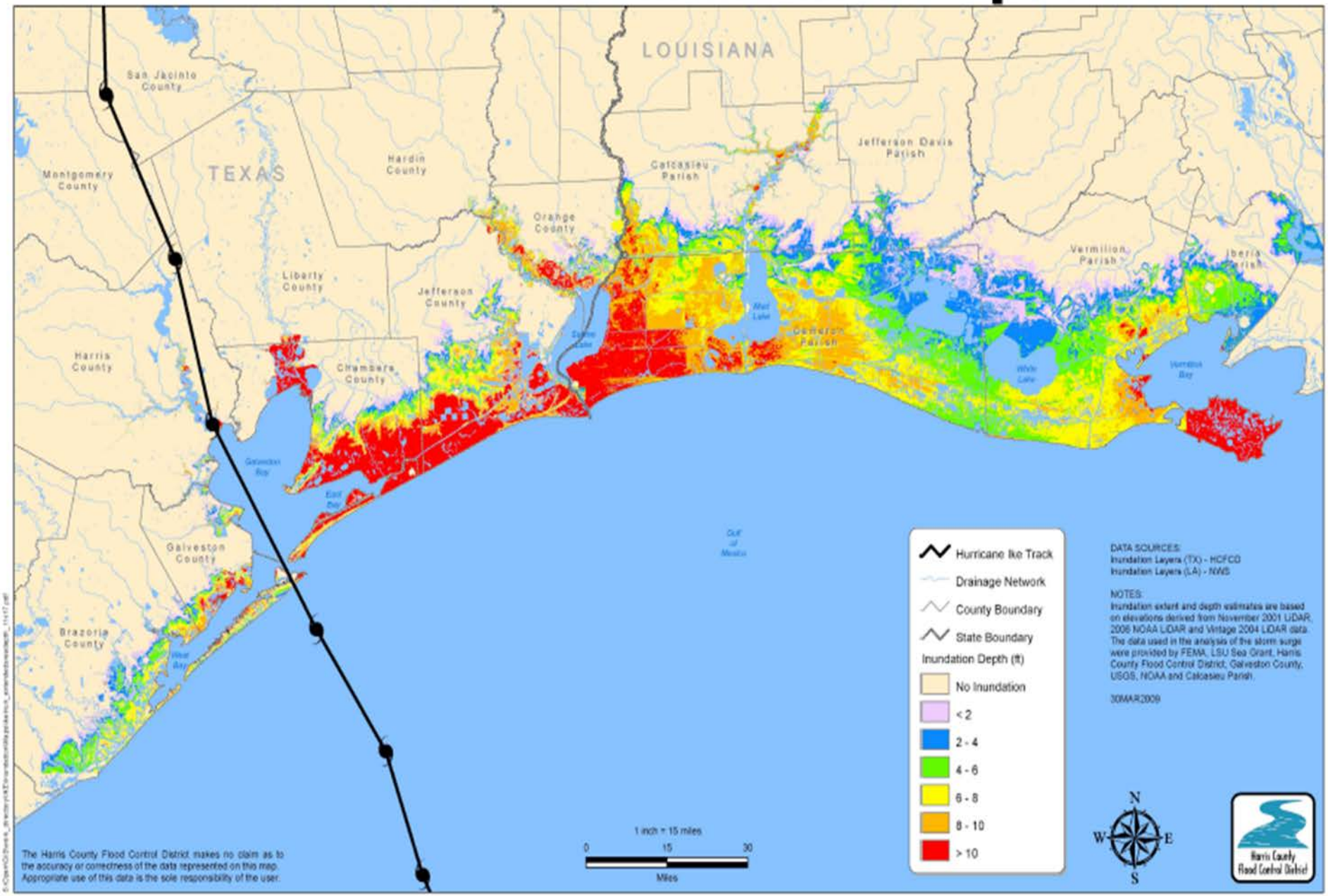
TORNADO SHELTER
A
B
C

Hurricane Ike Inundation Depth



Galveston Hurricane of 1900: Recovery and Hazard Mitigation

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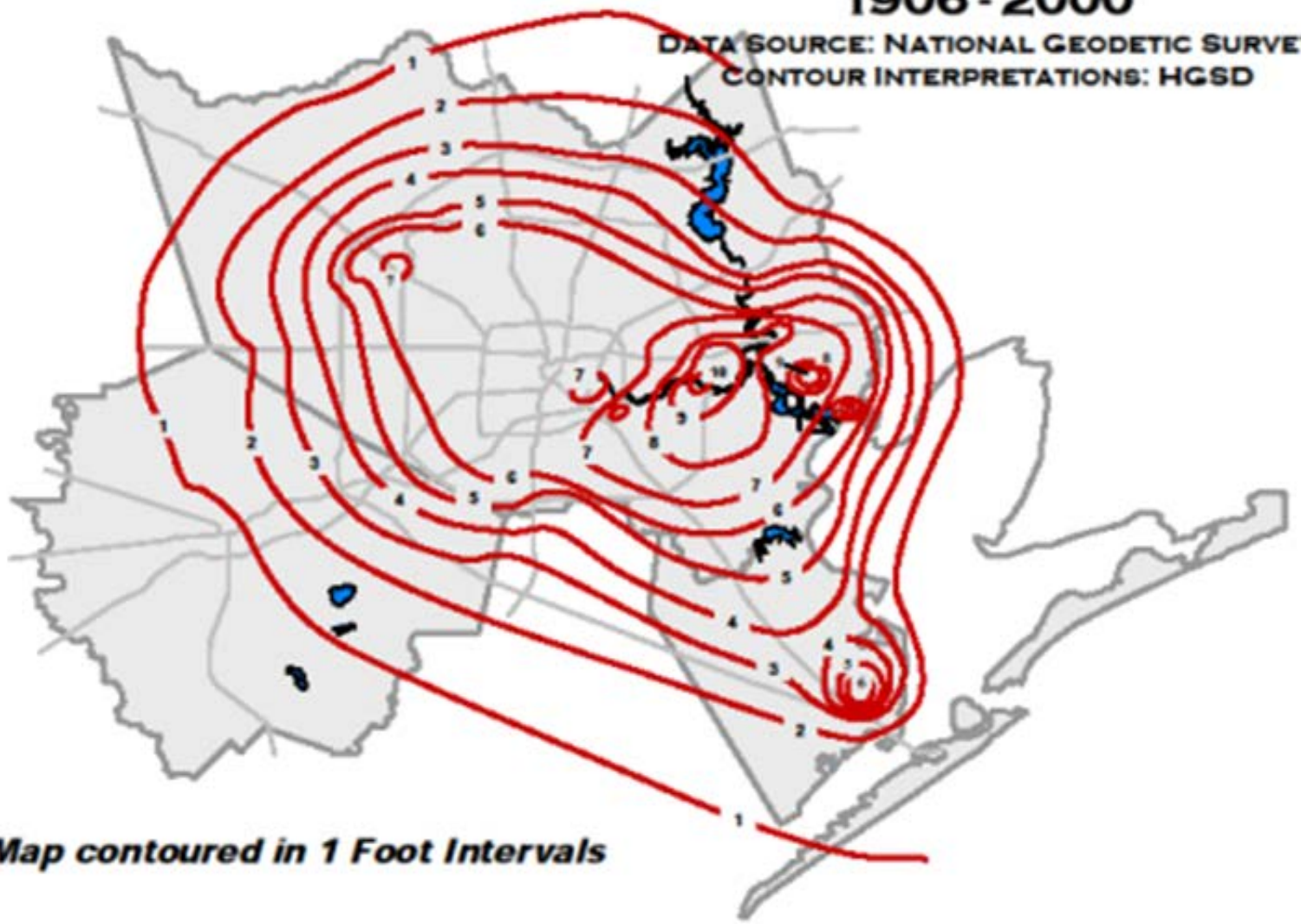
Research Lead: The University of North Carolina at Chapel Hill

Education Lead: Jackson State University, Mississippi

SUBSIDENCE

1906 - 2000

DATA SOURCE: NATIONAL GEODETIC SURVEY
CONTOUR INTERPRETATIONS: HGSD



Map contoured in 1 Foot Intervals

Vulnerability of the Houston Ship Channel

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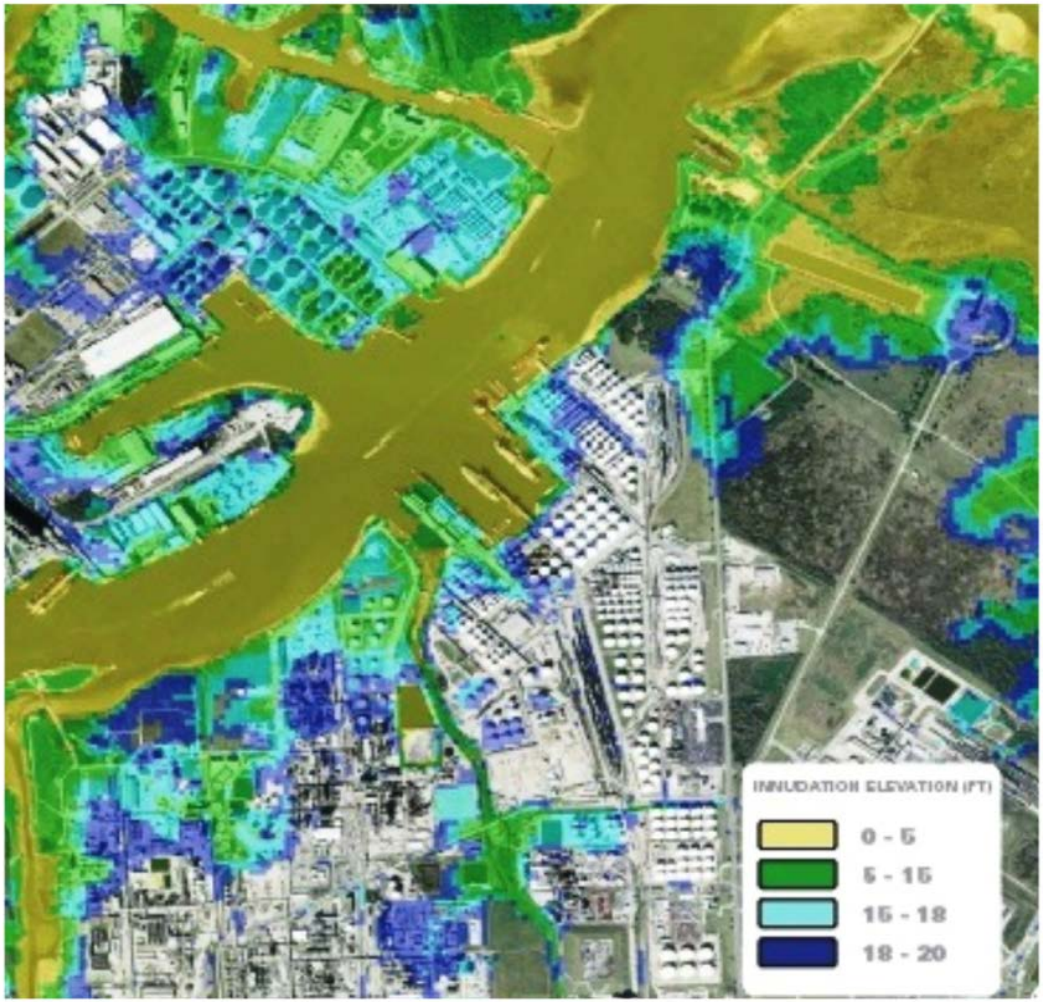
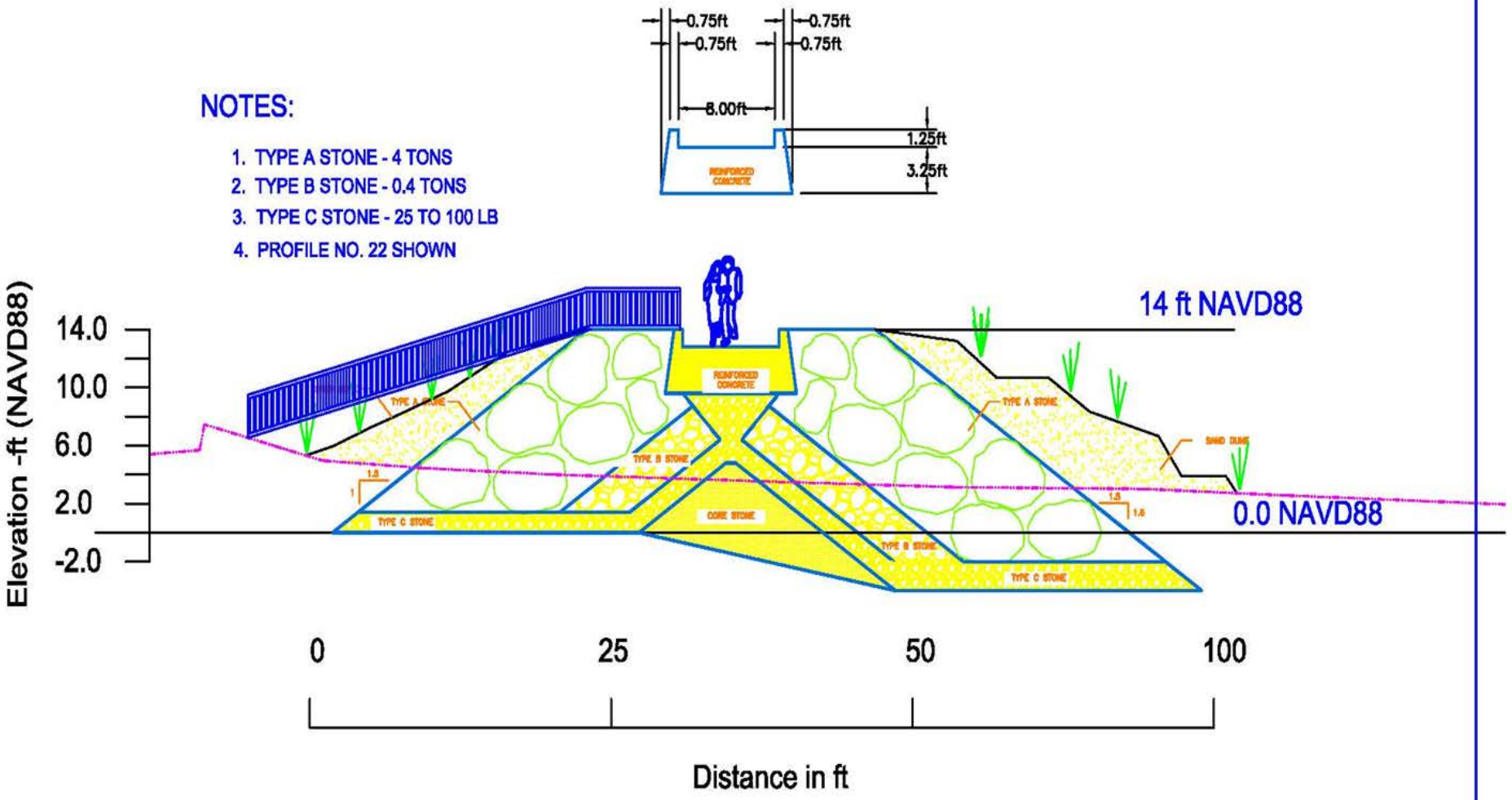


- **Typical floodplain elevations along the HSC range from 14-15 ft. above sea level. This is significantly lower than what is needed to protect the projected 20-25 ft. surge tide in a 100 year event.**
- **Environmental regulations for hazardous waste, oil spill contingency planning and wastewater plants require protection to the one-hundred year flood plain.**

The overall strategy is to keep the ocean surge out of Galveston Bay by using a coastal barrier (the Ike Dike) similar to the Dutch Delta Works

Revetment Shown on Pre-Ike Topography



Department of Civil Engineering, Texas A&M University

- **How do you balance the issues of large-scale infrastructure and human settlements in known high hazard areas with hazard mitigation/risk reduction and climate change adaptation efforts?**
  - **Houston Galveston Bay**
  - **New Orleans**
  - **Charleston**
  - **Barrier island communities (intensive high-rise development)**
  - **Arctic communities (e.g. Shishmaref Alaska)**
  - **Other deltaic cities (e.g. Rotterdam)**
  - **Developing nations (e.g. Maldives, Bangladesh)**
- **Biggert-Waters Act**

BOLIVAR PENINSULA

Previous Storm Damage

- 1996, Tropical Storm Josephine
- 1998, Tropical Storm Frances
- 2001, Tropical Storm Allison
- 2002, Tropical Storm Fay
- 2003, Hurricane Claudette
- 2005, Hurricane Rita
- 2007, Hurricane Humberto

The Role of Engineering in Climate Change Adaptation and Disaster Management

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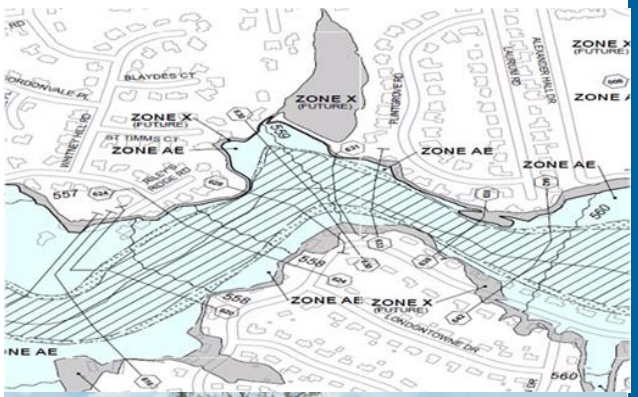
- **Type and Location of Infrastructure**
- **Hazard Modeling/Risk Communication**
- **Design Standards (new return periods)**
- **Integration of Engineering and Land Use Planning**
  - **Infrastructure Design and Placement**
  - **Green Infrastructure**
  - **Resettlement of Hazard-Prone Communities**
  - **Scenario-Based Planning**
- **Resilience versus Resistance**
  - **Redundancy**
  - **Compartmentalization**
  - **Flexibility**



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Nice view, HUH?
SETBACK REGS FOR RENOURISHED BEACHES
COASTAL RESOURCES COMMISSION
Powell 4/1/07
DEVELOPMENT PRESSURES


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