Evolution of Storm Surge and Rainfall Risk in the Galveston District to Target New Flood Risk Management (FRM) and Coastal Storm Risk Management (CSRM) Needs

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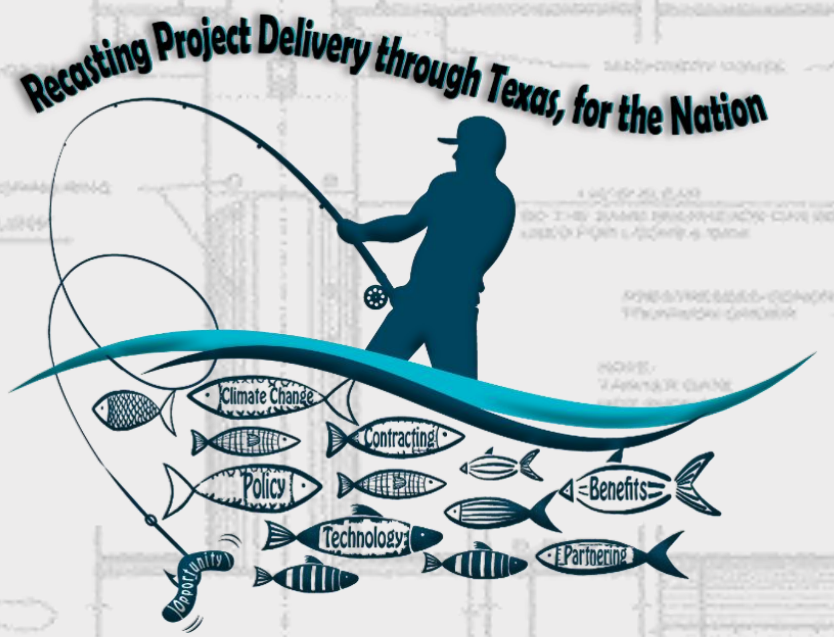

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Evolution Of Storm Surge And Rainfall Risk In The Galveston District To Target New FRM/CSRM Needs

USACE Galveston District
Stakeholder Partnering Forum
6 Oct 2022

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USACE, Galveston District

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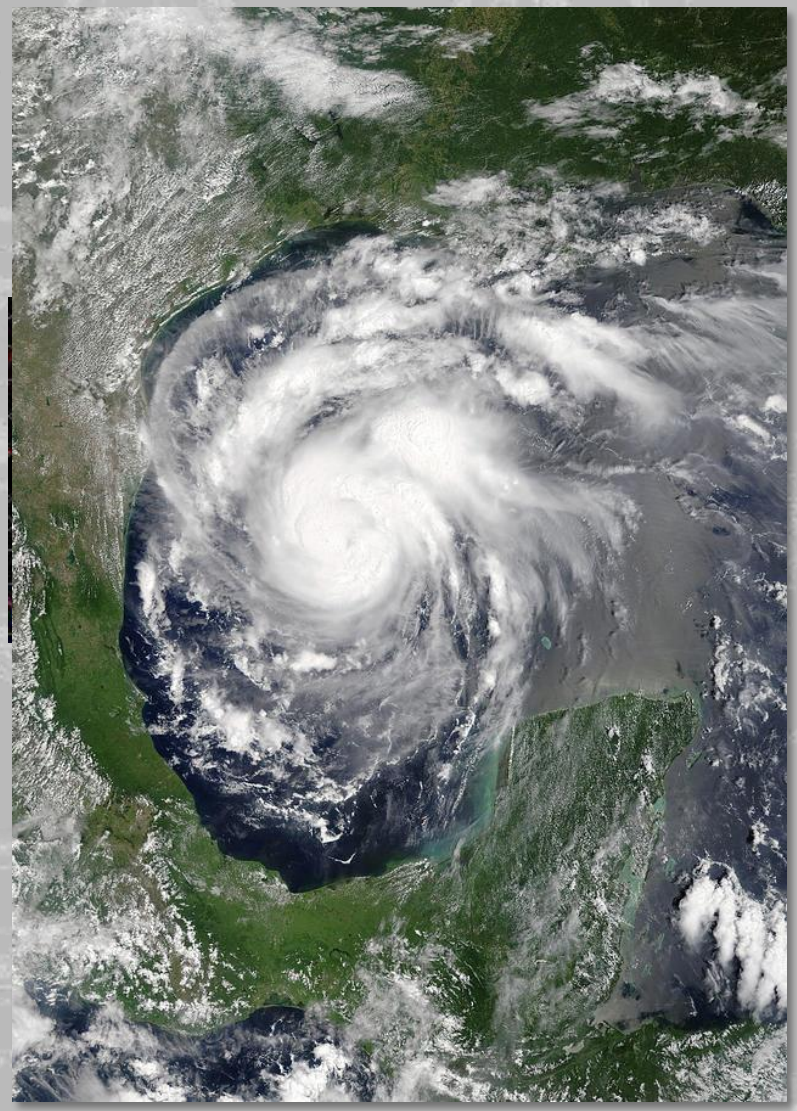
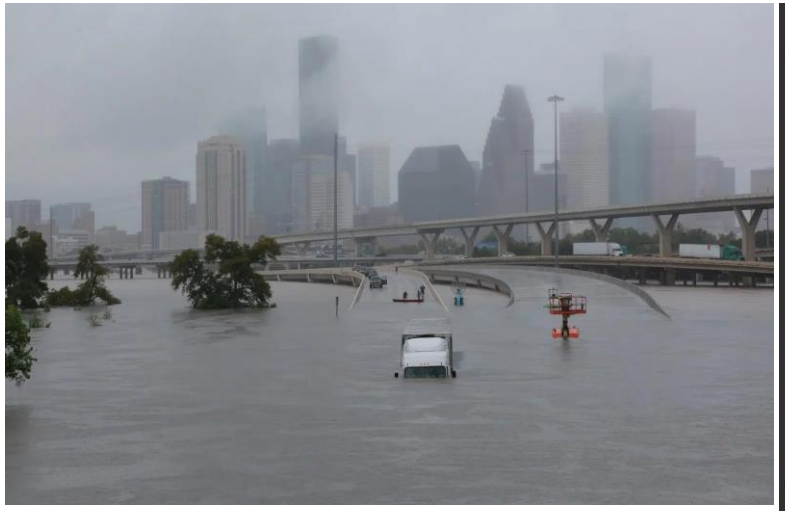


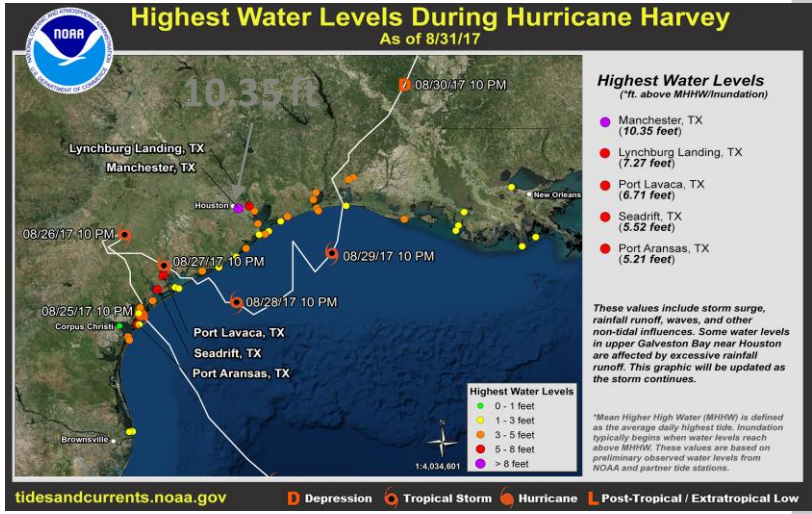
FLOODING PROBLEMS IN TEXAS

- Texas leads the nation in disaster declarations for the recent 2015, 2016, 2018 and 2019 floods
- Texas leads the nation in flood related deaths from 1960-1995 - National Climatic Data Center
- Hurricane Ike (2008) with 17.4 ft. storm surge in Galveston Bay ➔ $36.6 billion in damage
- Hurricane Harvey (2017) with a 7 ft. storm surge in Copano Bay, TX and ~60 inches of rainfall in Nederland, TX ➔ $130 billion

Hurricane Ike storm surge: Sept. 2008 (Photo: NOAA)



https://qz.com/1068625/hurricane-harvey-a-california-business-is-offering-free-data-recovery-for-wet-and-damaged-phones/



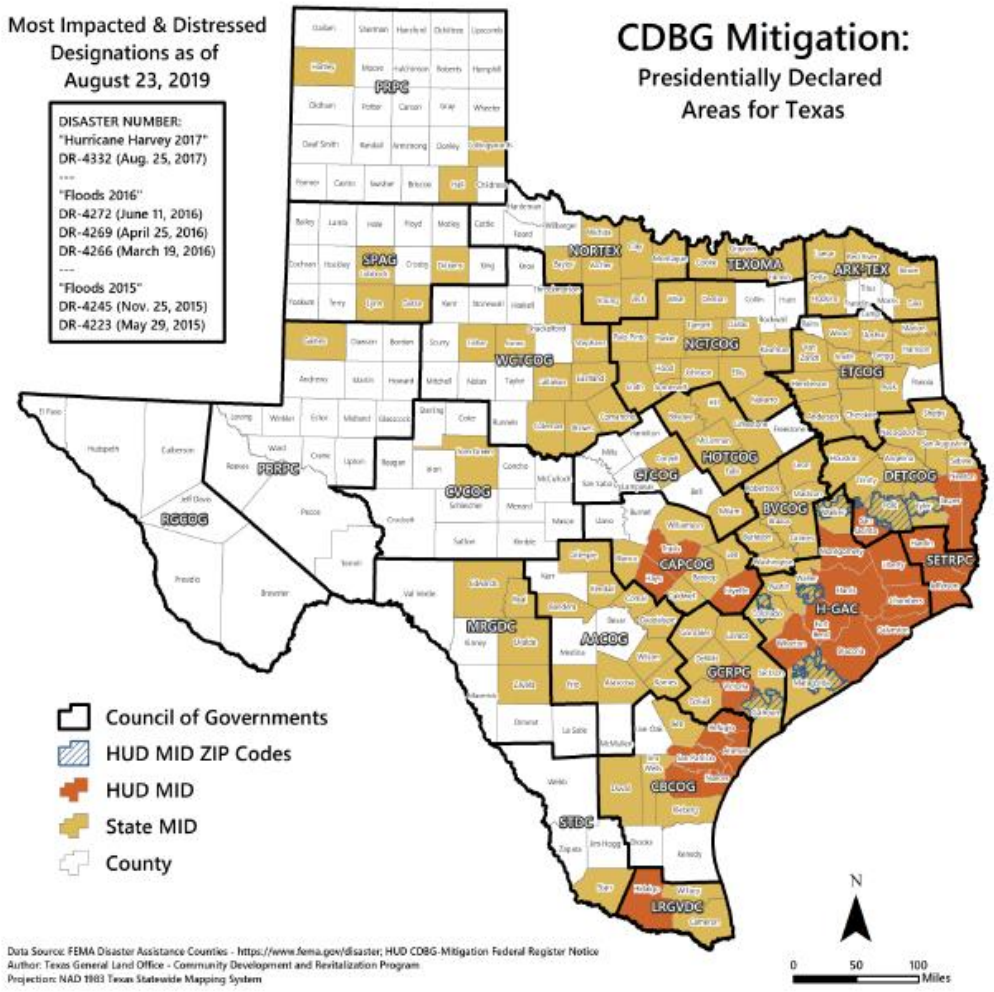
TEXAS DISASTER RECOVERY PLAN
U.S. DEPT OF HOUSING & URBAN DEVELOPMENT

CDBG Recovery Allocation

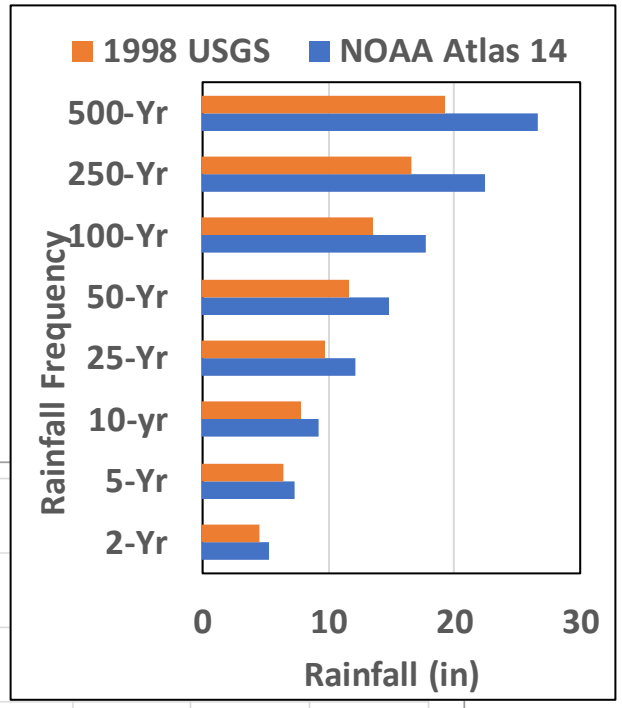
- $5.676B Allocation
  - Harris County - $1.221B
  - City of Houston - $1.265B
  - 48 eligible counties - $3.189B
- $137M Allocated for State Planning
- Funds must be expended by June 2024

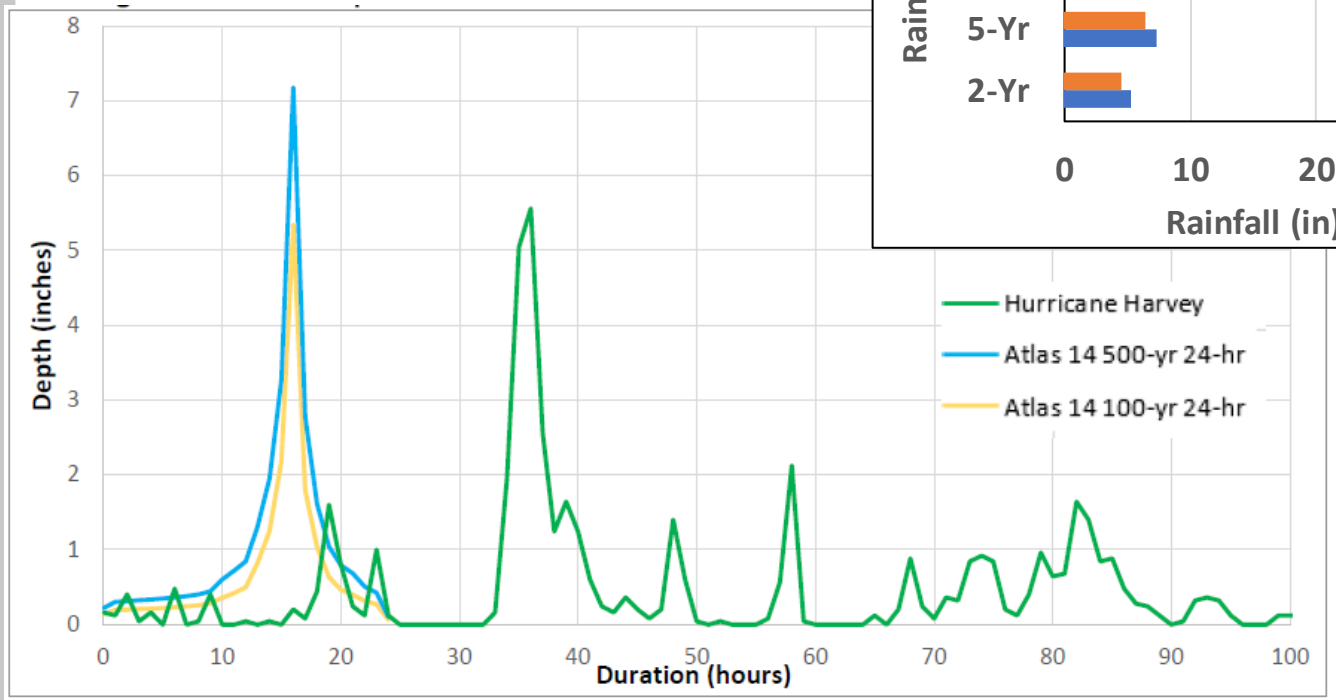
CDBG Mitigation Allocation

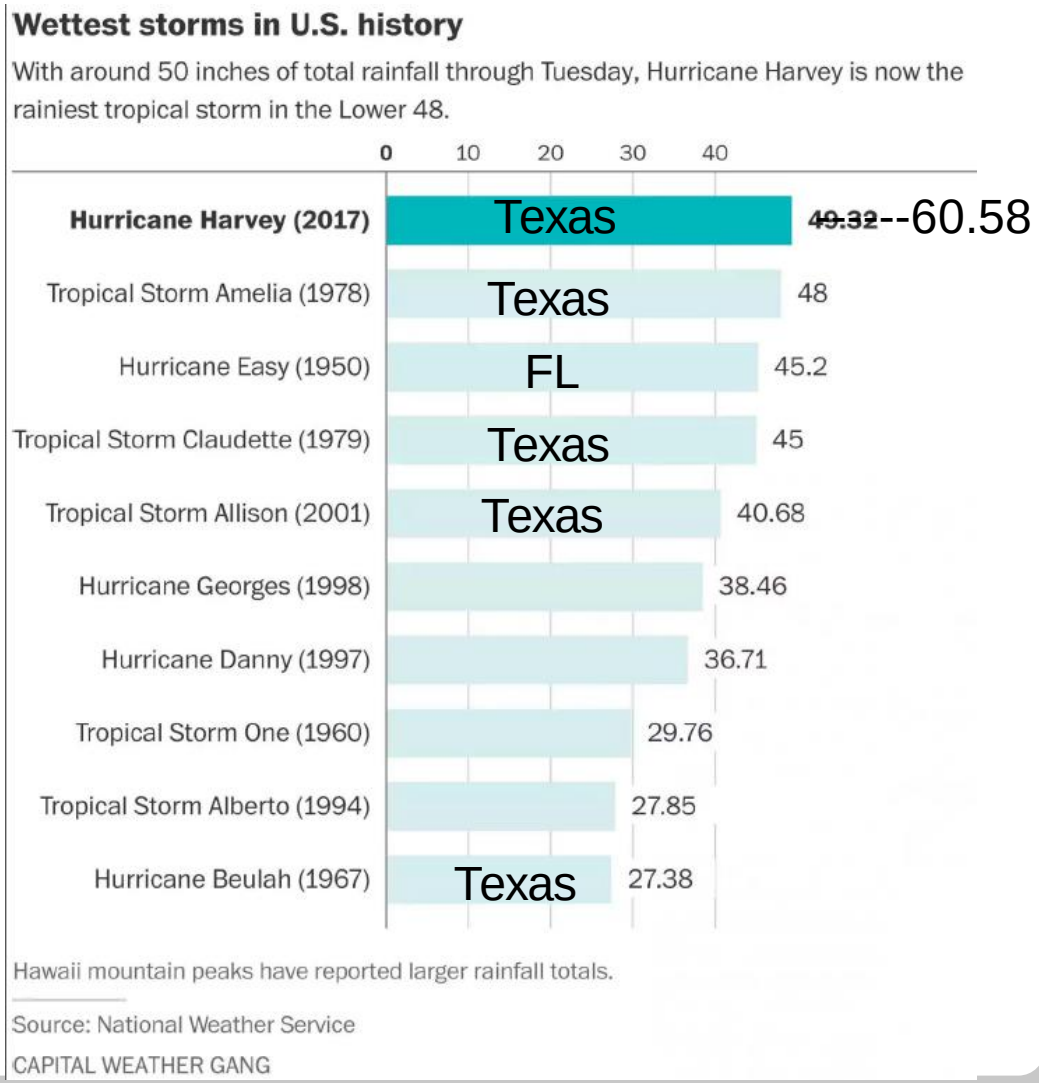
- $4.3B Allocation
- Federal register published August 30, 2019
- State run planning has a tentative budget of $200M
- Funding expires 2032



INCREASE RISK OF FLOOD HAZARD UNDER CHANGING CLIMATE CONDITIONS

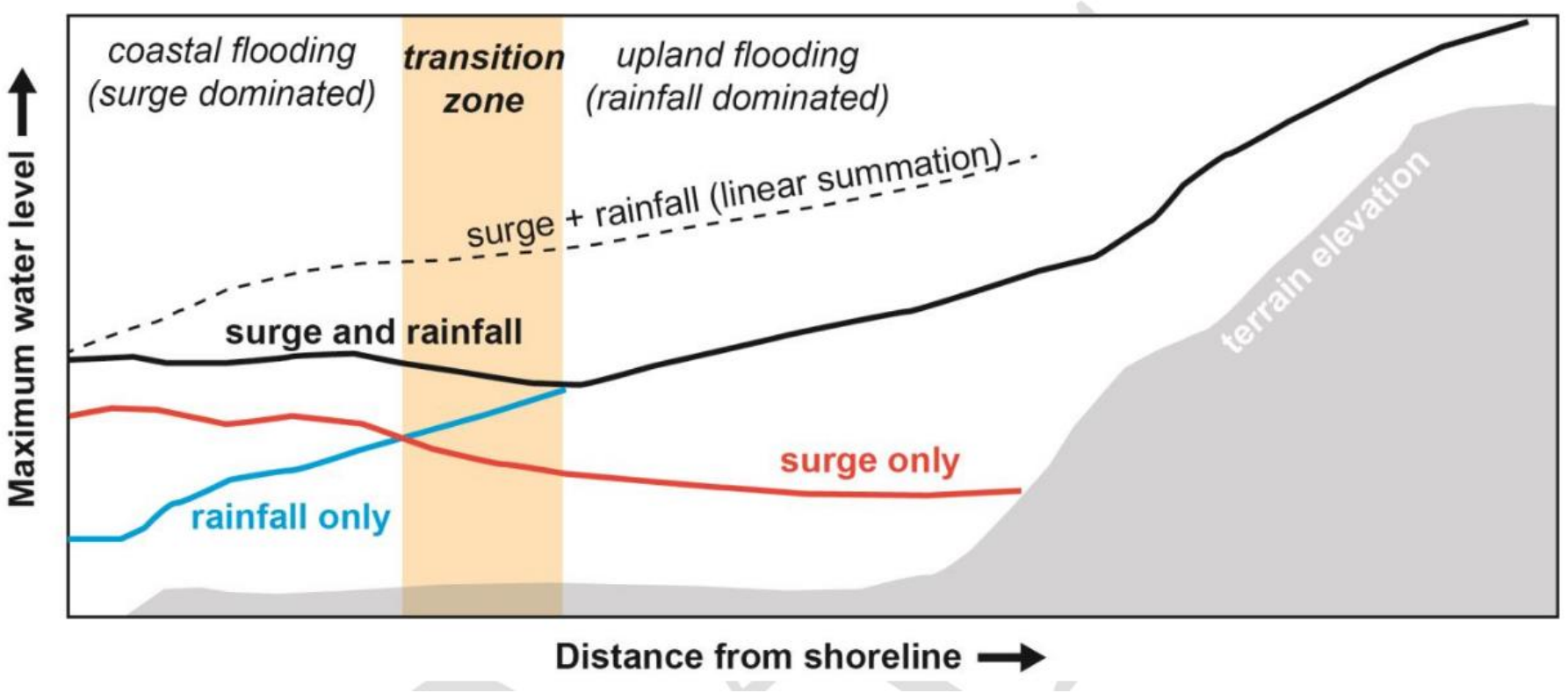






Lower Clear Creek & Dickinson Bayou Flood Mitigation plan (FNI, 2021)

COMPOUND FLOODING



- Compound flooding risk in the coastal watersheds
- Compound flooding depends on diverse flood driver interactions

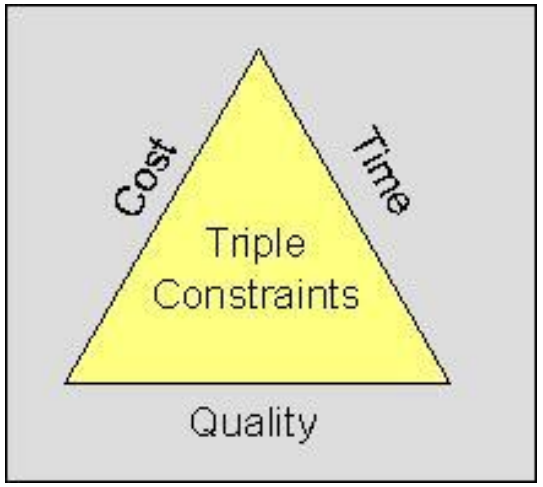
FRM / CSRM NEEDS

RESILIENCE means "the ability to **anticipate, prepare for,** and **adapt** to **changing conditions** and **withstand,** respond to, and **recover** rapidly from **disruptions.**"
Presidential Executive Order 13653, Preparing the U.S. for Impacts of Climate Change (NOV 2013)

USACE's Principles of Resilience

Factors requiring Consideration:

- Storm Surge
- Waves
- Rainfall
- Unknown Physics
- Data Gaps
- Old Data
- Bad Data
- Sea Level Rise and Subsidence
- Climate Change
- Erosion and Geomorphology
- Changing Statistics
- Urbanization
- Engineering With Nature (EWN)
- Water Control Structures
- Operational Guidance
- Drainage Infrastructure
- Transportation Systems



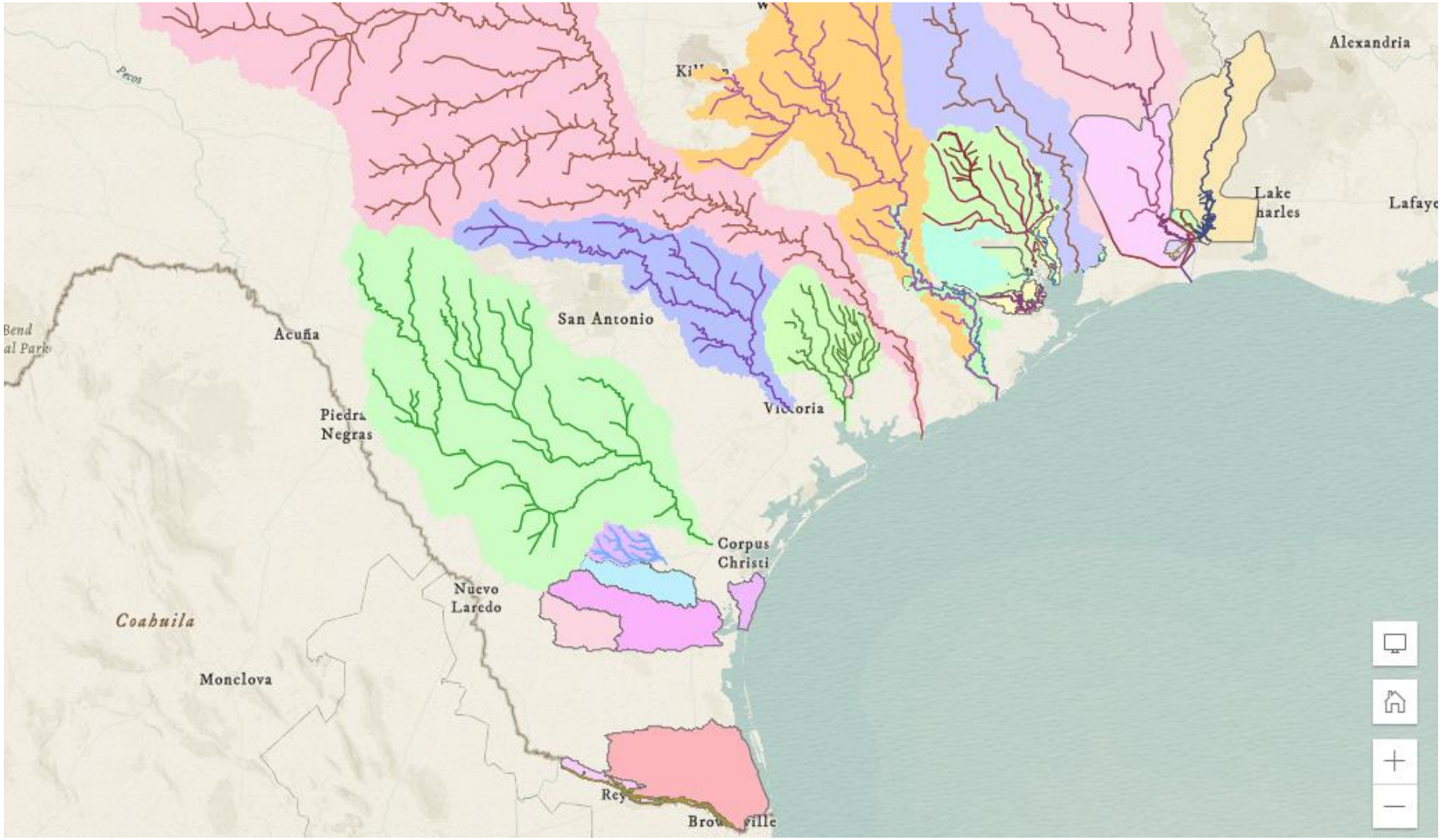
Cheaper and Faster

- Model Inventory
- Ready Data
- Approved Methods

Quality

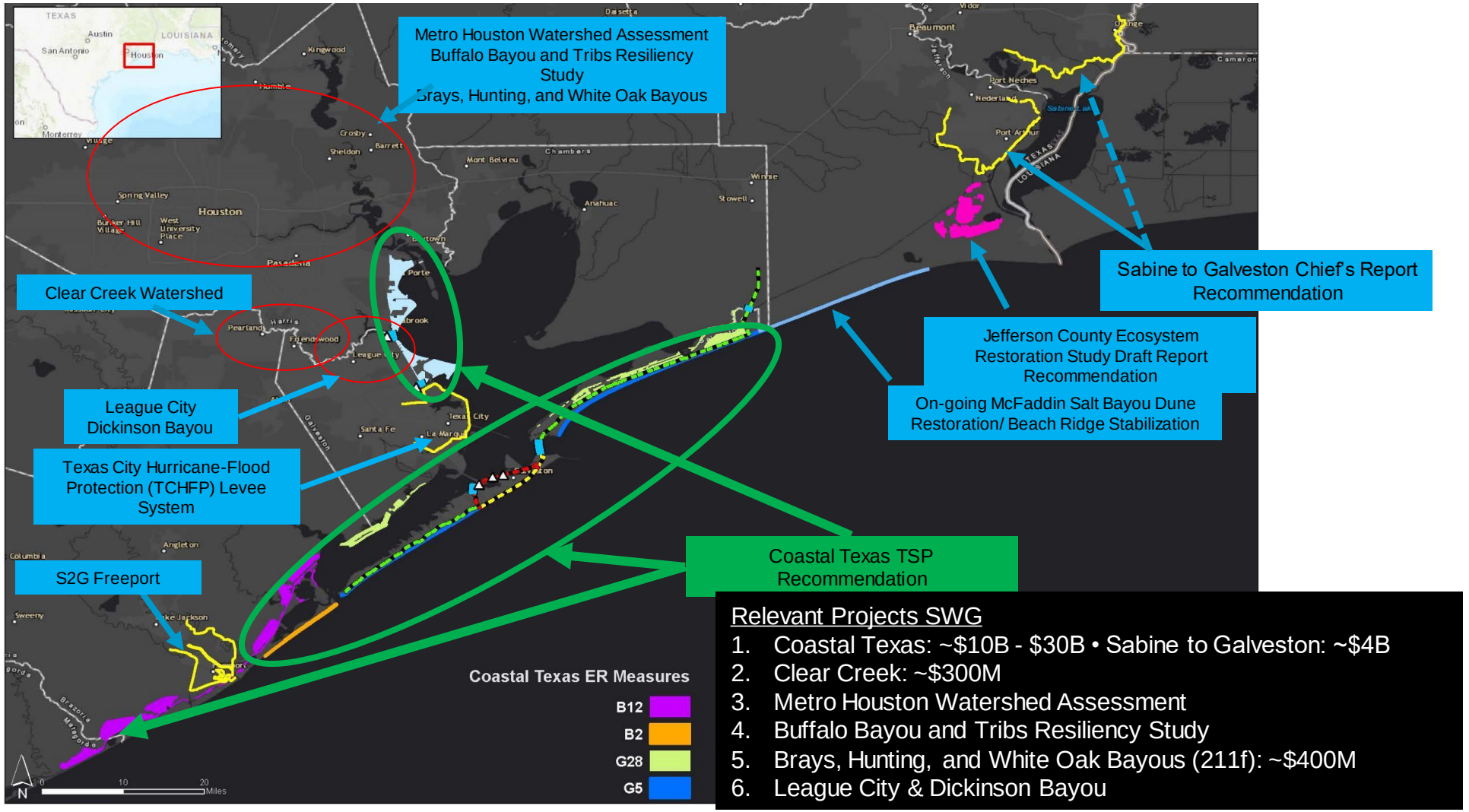
- Better/More Data
- Better Science

USACE/IBWC/FEMA/TWDB RAS MODEL COVERAGE



https://arcportal-ucop-corps.usace.army.mil/s0portal/apps/mapviewer/index.html?useExisting=1&layers=7721222c46b4494f807401ff0ddec52a

USACE PROJECTS- COMPOUND FLOODING CONSIDERATIONS



Relevant Projects SWG

1. Coastal Texas: ~$10B - $30B • Sabine to Galveston: ~$4B
2. Clear Creek: ~$300M
3. Metro Houston Watershed Assessment
4. Buffalo Bayou and Tribs Resiliency Study
5. Brays, Hunting, and White Oak Bayous (211f): ~$400M
6. League City & Dickinson Bayou

REGIONAL FLOOD STUDIES – SWF LEADING TECHNICAL OVERSIGHT WITH SWG SUPPORT

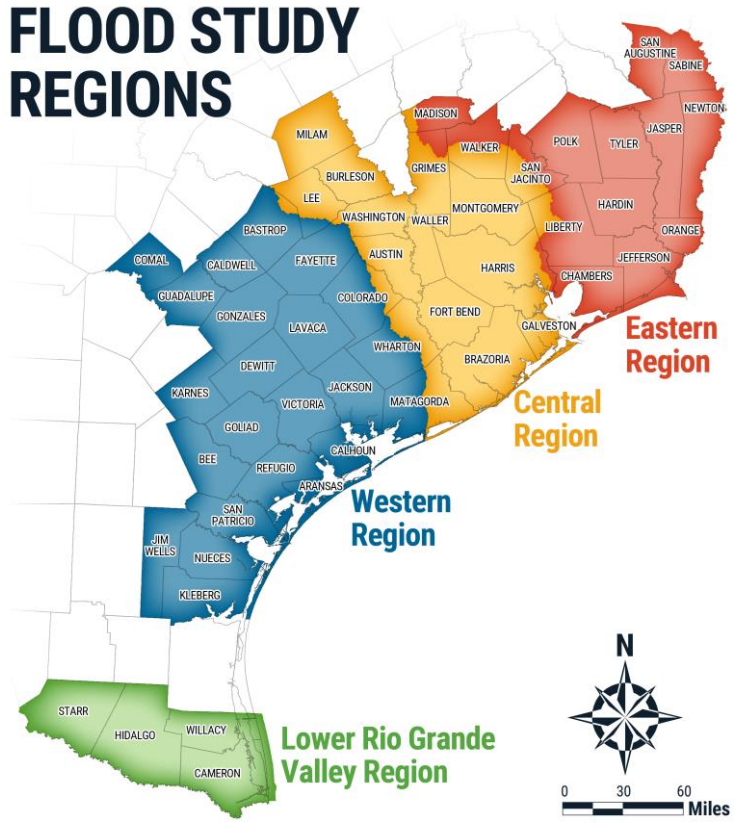
Mission Statement:

GLO Planning Team designs and oversees planning studies to collect, analyze, and communicate disaster-related data to assist decision makers to better protect Texans from future disasters.

Study Goals

- Evaluation of flood risks within the study area
- Development of cost-effective flood mitigation projects
- Determination of funding sources for identified mitigation projects

Five-phase Study



Budget- $85M Total – by June 2024 (contract expires)

- $25M per East, Central, West Regions (HUD CDBG-DR)
- $10M for Lower Rio Grande Valley Region (CDBG-MIT)

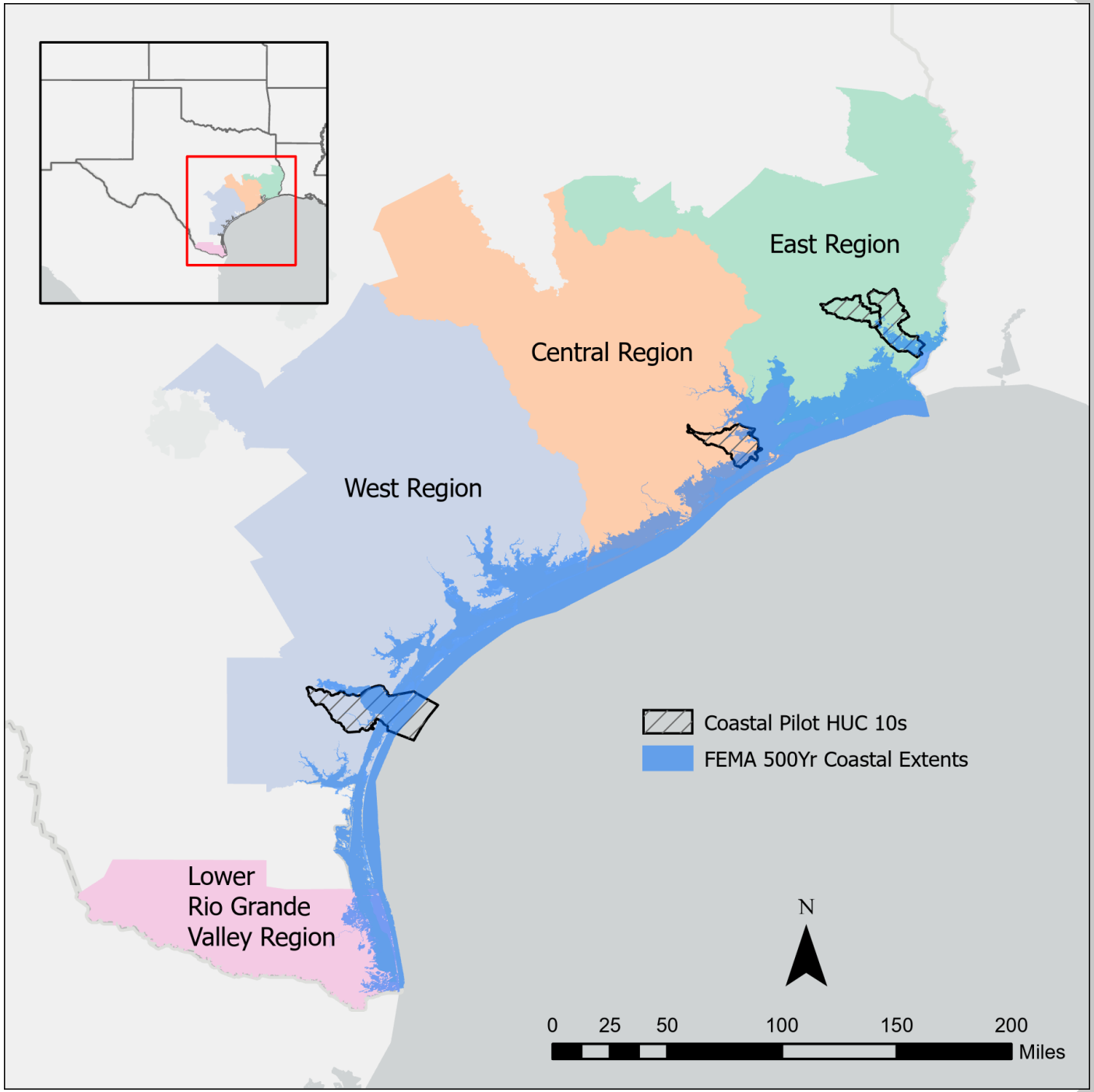
COASTAL PILOT WATERSHED SELECTION

East Region
– Dannenbaum Engineering and The Water Institute of the Gulf
– Lower Neches, Village Creek, and Pine Island Bayou

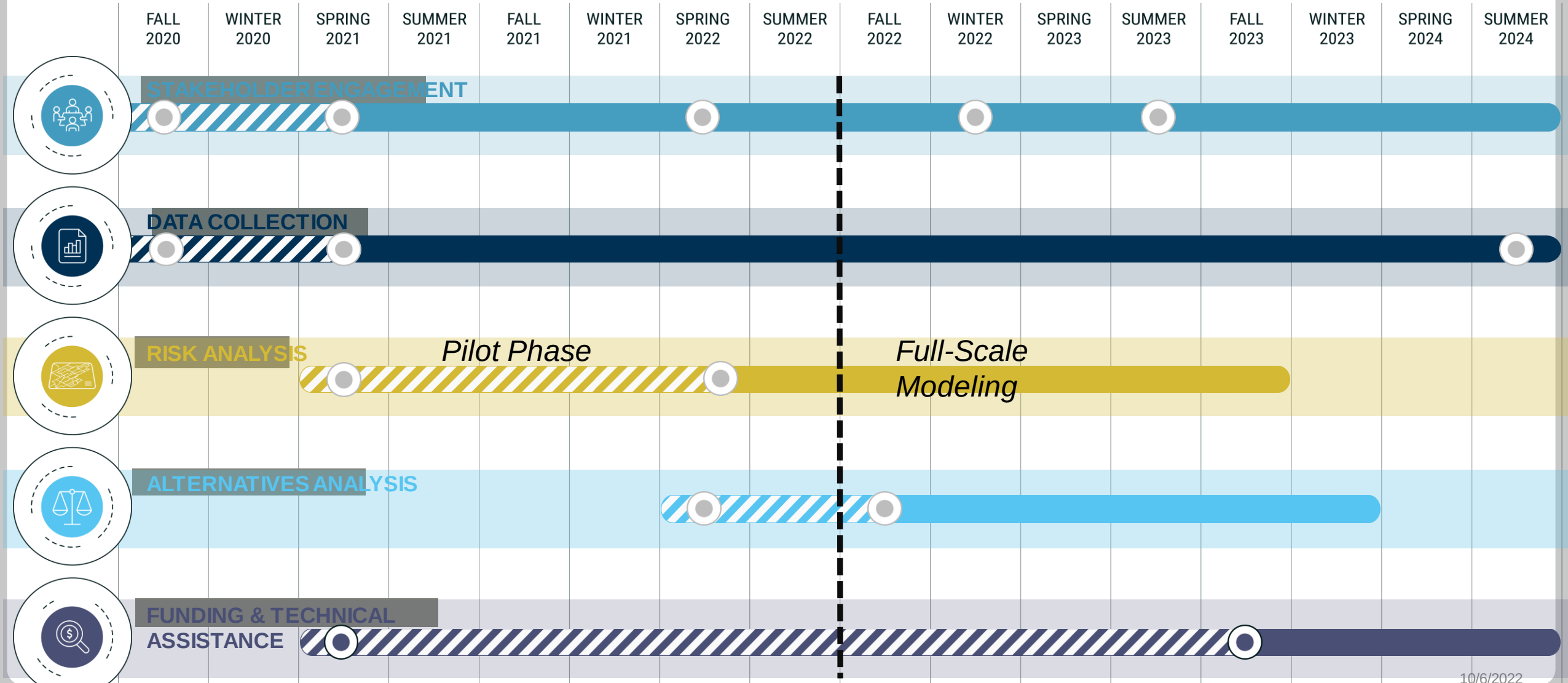
Central Region
– FNI and Taylor
– Dickinson Bayou

West Region
– AECOM and Arcadis
– Oso Creek

Lower Rio Grande Valley
– Halff
– No COASTAL PILOT



SCHEDULE AND ROADMAP



TEXAS DRIVING TECHNICAL ADVANCEMENT

Software Investments ($$)

HEC-RAS 2D - HEC-RAS (6.0 -> 6.3) improvements

- Spatial infiltration (losses)
- Spatial precipitation
- 1-D bridge hydraulics inside of 2D Flow Areas
- Wind forcing
- Coupling Coastal and Riverine Models through spatially variable downstream Boundary Conditions

Future Improvements HEC-RAS

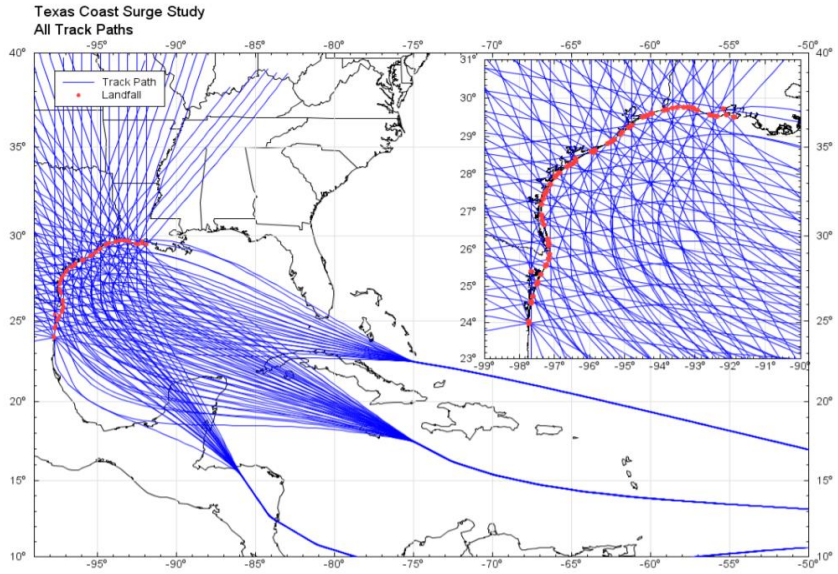
- Atmospheric pressure
- Parallelization (if funded)

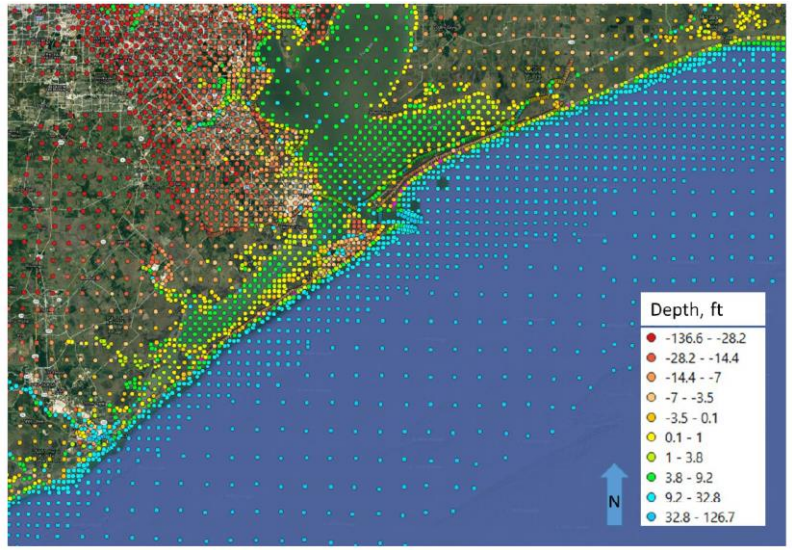
HMS Enhancements
- Storm Shifting

Model Development ($$)

- SWG – developing improved SWAN-ADCIRC Coastal Surge model for Texas
- ERDC - Developing improved surge hazard stats and compound flooding analysis
- SWG, ERDC and others – JPM Compound Flood Hazard Improvements

STORM SURGE MODELING FOR COASTAL TEXAS REGION





- **Coastal Texas Protection and Restoration Feasibility Study (USACE,2018).**
- **Sabine Pass to Galveston Bay (S2G), TX Pre-Construction, Engineering and Design** : Coastal Storm Surge and Wave Hazard Assessment study (Melby et al,2020).

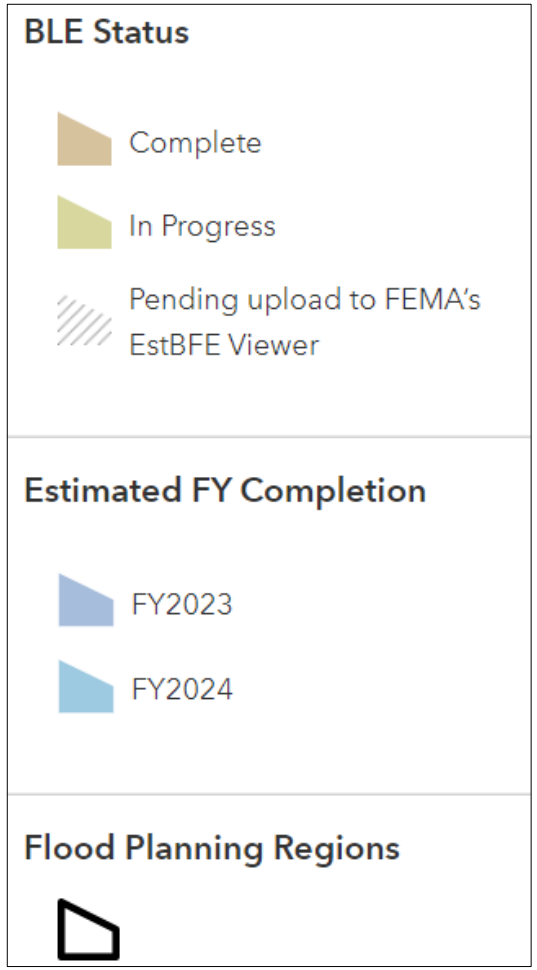
✓ 660 and 189 synthetic tropical cyclones (TCs) along with historical storms were simulated for Coastal Texas and S2G study, respectively.

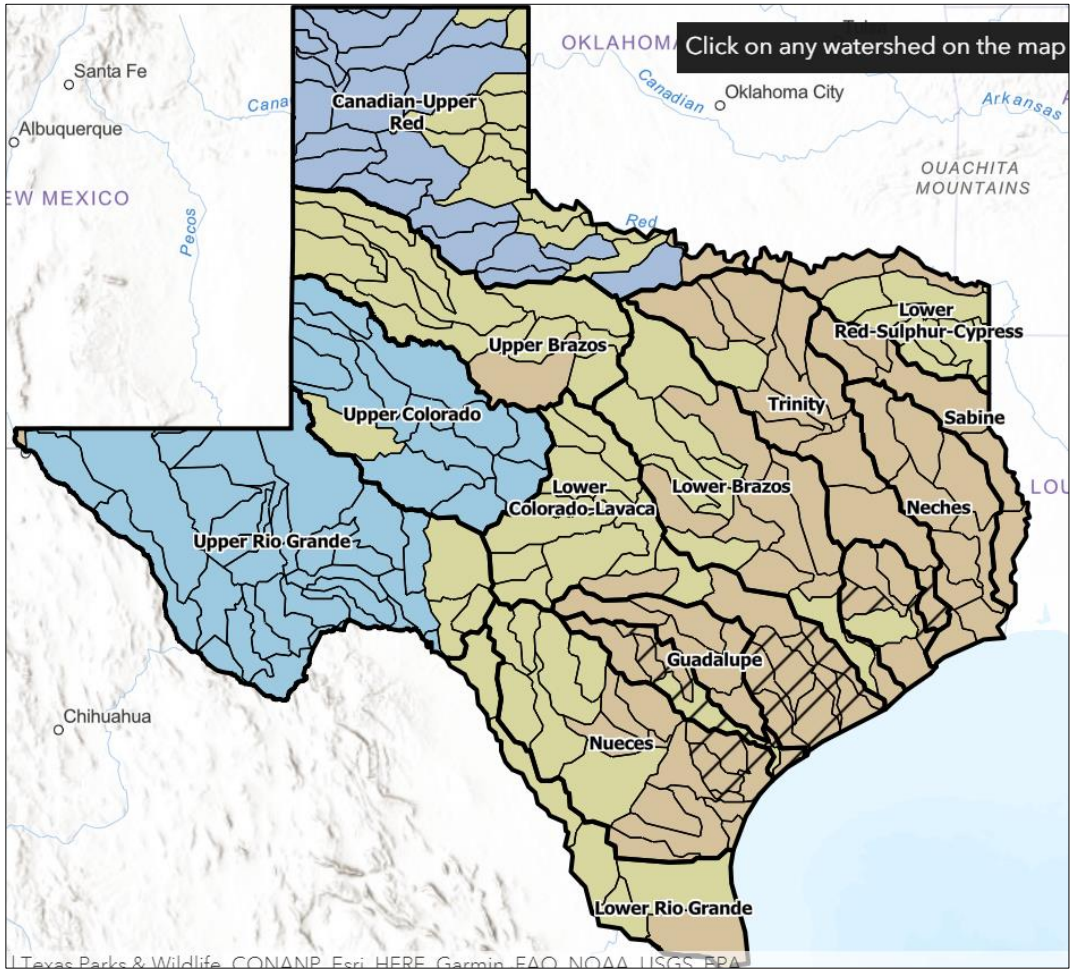
✓ All model outputs are stored in over 18000 savepoint locations covering the entire Texas coastal region.

✓ Time series model outputs along with peak water surface elevation and wave height for different frequency (1-yr to 10,000-yr) storm surge events are stored in the savepoint locations.

× Did not consider **rainfall-runoff** processes

MAPPING -BASE LEVEL ENGINEERING (BLE)





2024 – approximate flood mapping complete for all of Texas

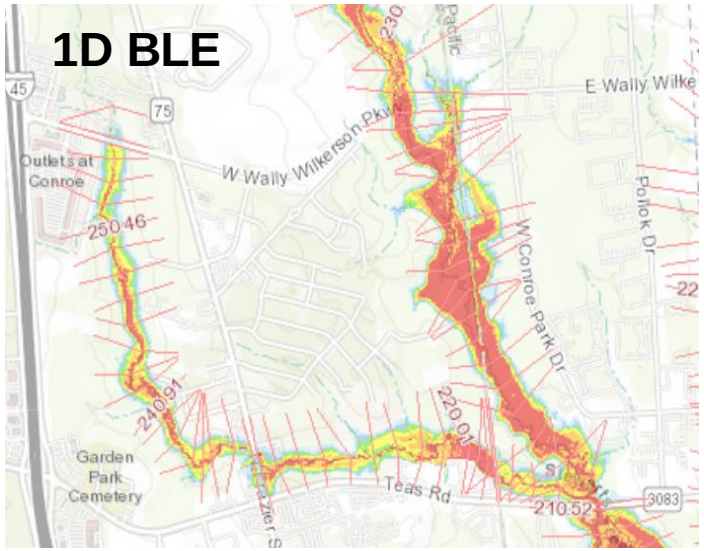
https://www.twdb.texas.gov/flood/mapping/ble-status-viewer.html

Texas Water Development Board

TX BASE LEVEL ENGINEERING: OVERVIEW

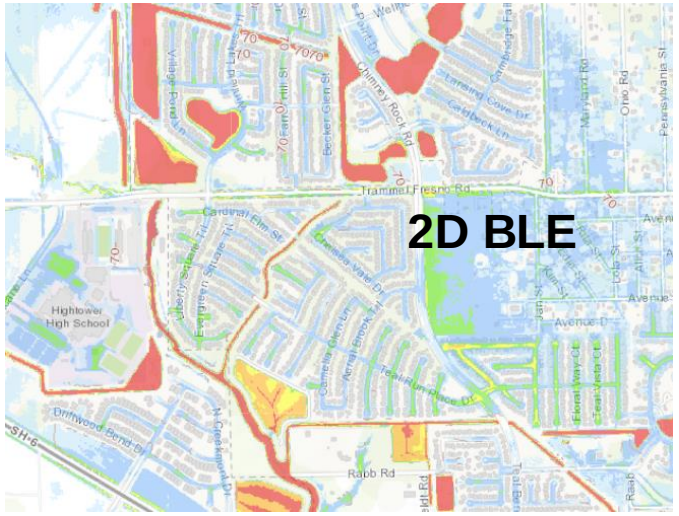
❖ 1D BLE:

- ✓ Riverine Flood Risk mainly
- ✓ Older BLE studies
- ✓ About 10-20% of the HUCs



❖ 2D BLE:

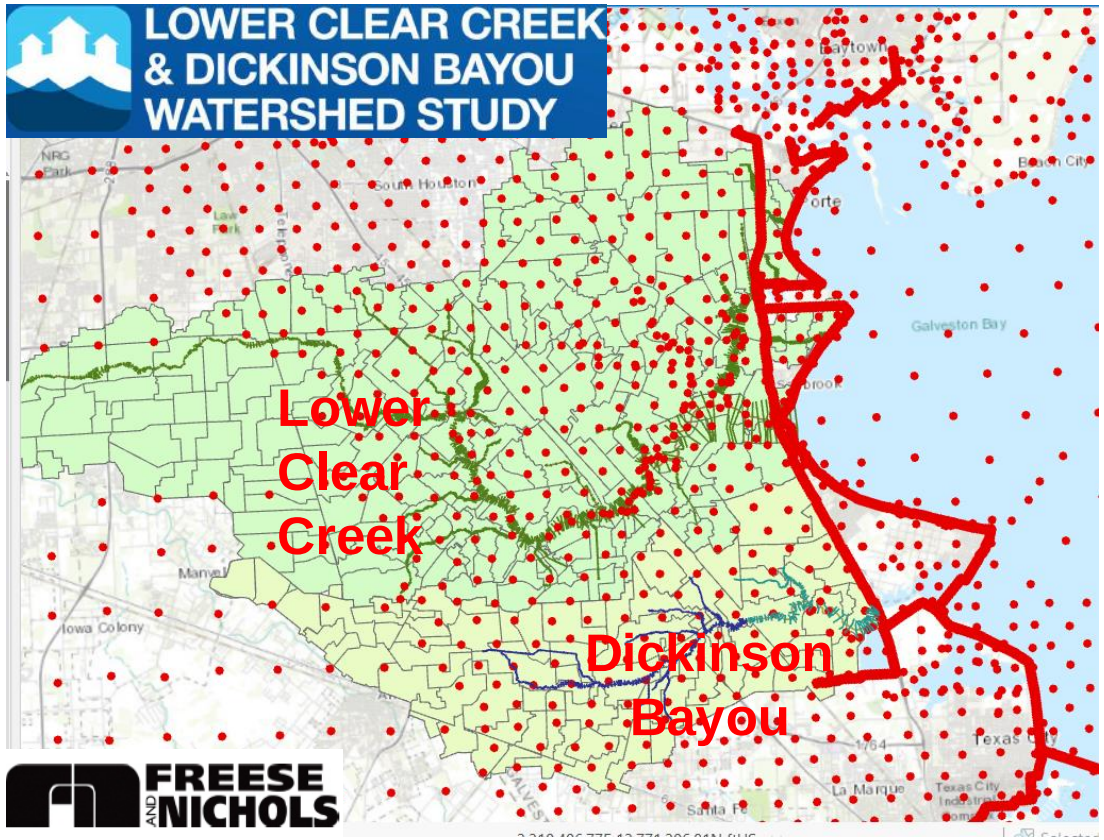
- ✓ Riverine and Localized Flood Risk
- ✓ Recent/new studies – 80-90% of HUCs
- ✓ Rain-on-mesh Approach
- ✓ Terrain
  - ✓ Latest LiDAR DEMs at 1-3m resolution



- ❖ **Storm surge effect omissions**
- ❖ **Limited model calibrations/validations**

× Not Detailed (i.e. Missing structures)

(LCCDB) FLOOD MITIGATION PLAN DEVELOPMENT- PAS STUDY



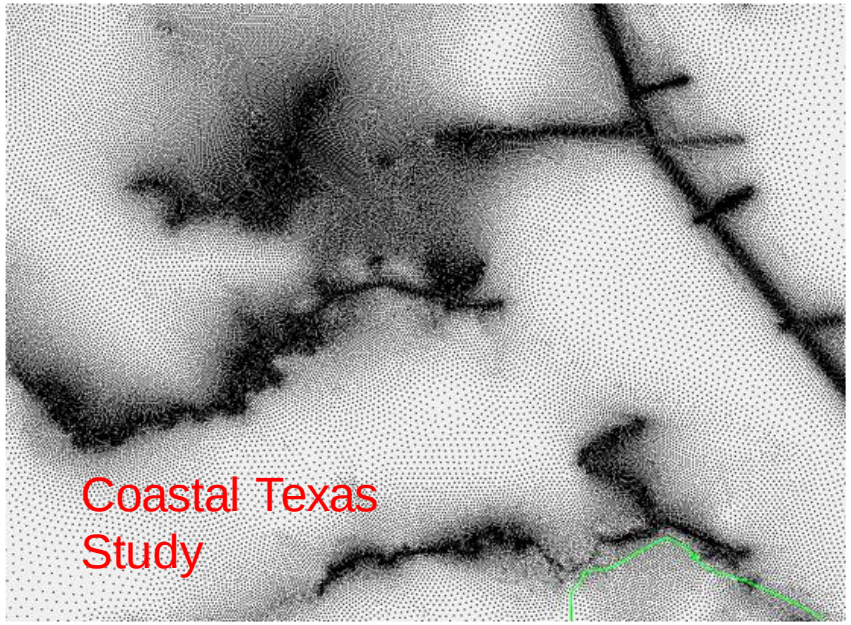
Lower Clear Creek & Dickinson Bayou (LCCDB)

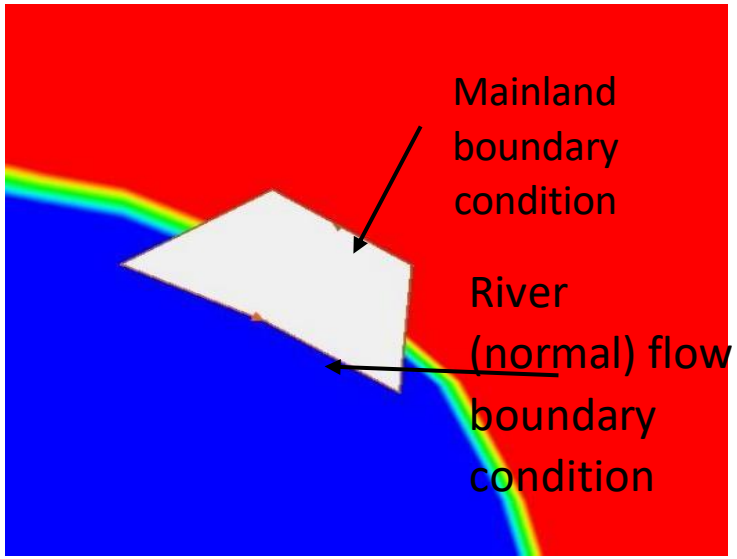
Alternatives Evaluation

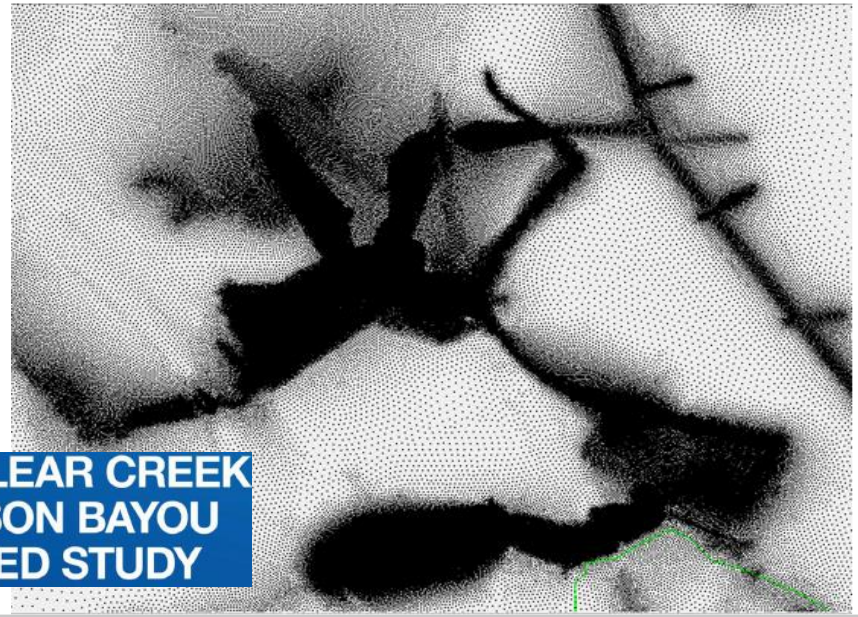
- **Detention**
- **Bypass**
- **Channel**
- **Tunnel**
- **Non-Structural**

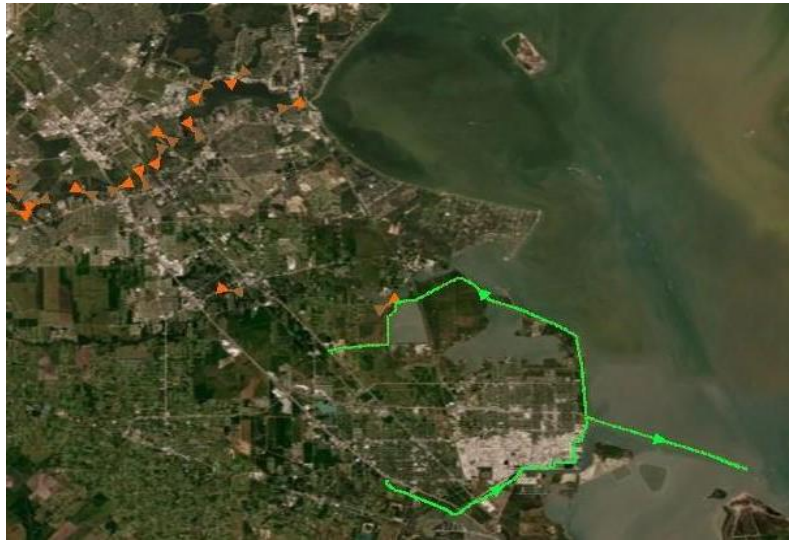
- High Resolution Hydrologic and Hydraulic Models
- Downstream boundary condition assignment using surge model (ADCIRC+STWAVE) results

DOWNSTREAM BOUNDARY LOCATION SELECTION





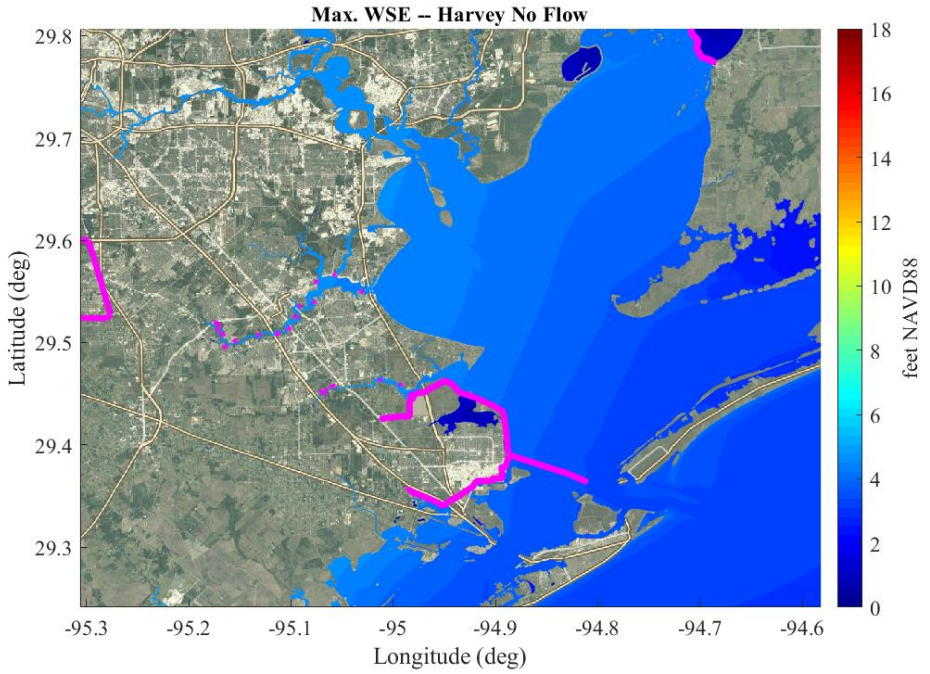




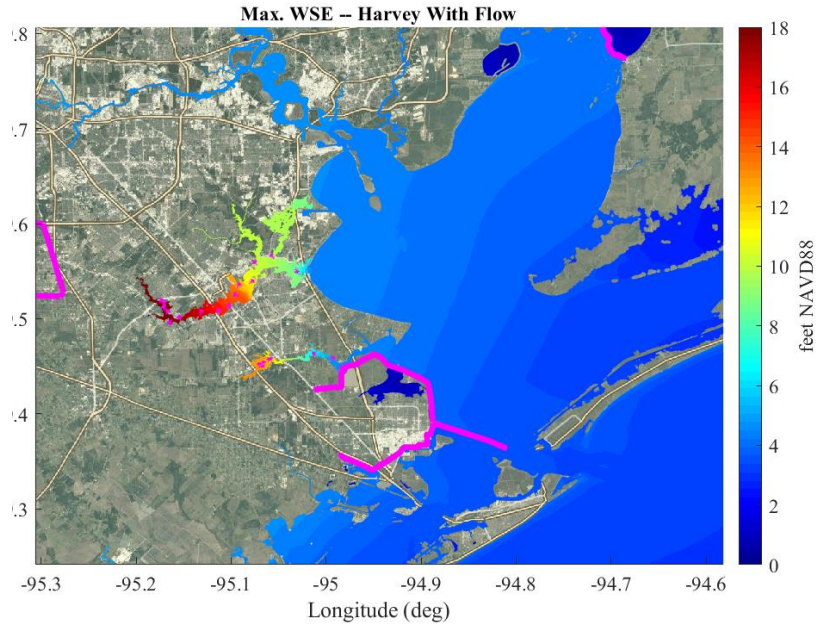
LOWER CLEAR CREEK & DICKINSON BAYOU WATERSHED STUDY

DOWNSTREAM BOUNDARY LOCATION SELECTION

MAXIMUM WSE – HURRICANE HARVEY



No Flows

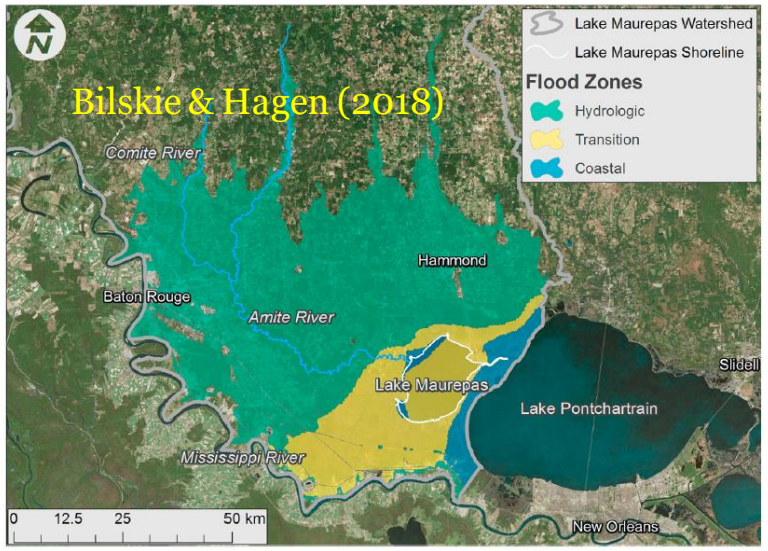


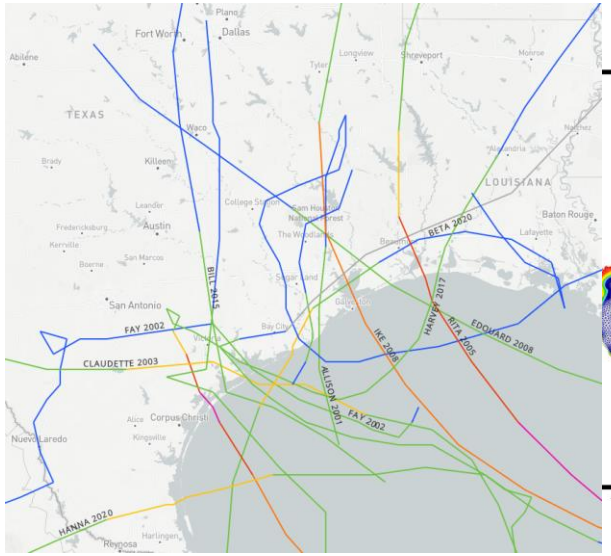
Flows Included

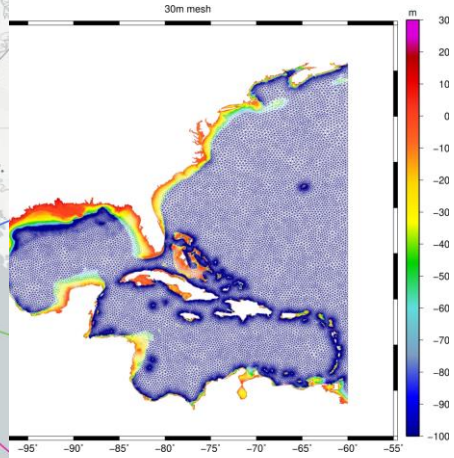
LOWER CLEAR CREEK & DICKINSON BAYOU WATERSHED STUDY

TRANSITIONAL FLOODING ZONE IDENTIFICATIONS ALONG THE TEXAS COAST

- Collaboration between TWDB & the University of Texas at Austin
- Simulate surge model (ADCIRC) with flows
- Run ADCIRC Model: 1) surge + flow, 2) surge only, and 3) flow only
- Calculate WSE differences to estimate transition areas







GLO REGIONAL BASIN FLOOD STUDY (RBFS)

❖ Loosely-coupled hydrologic-hydraulic and storm surge models

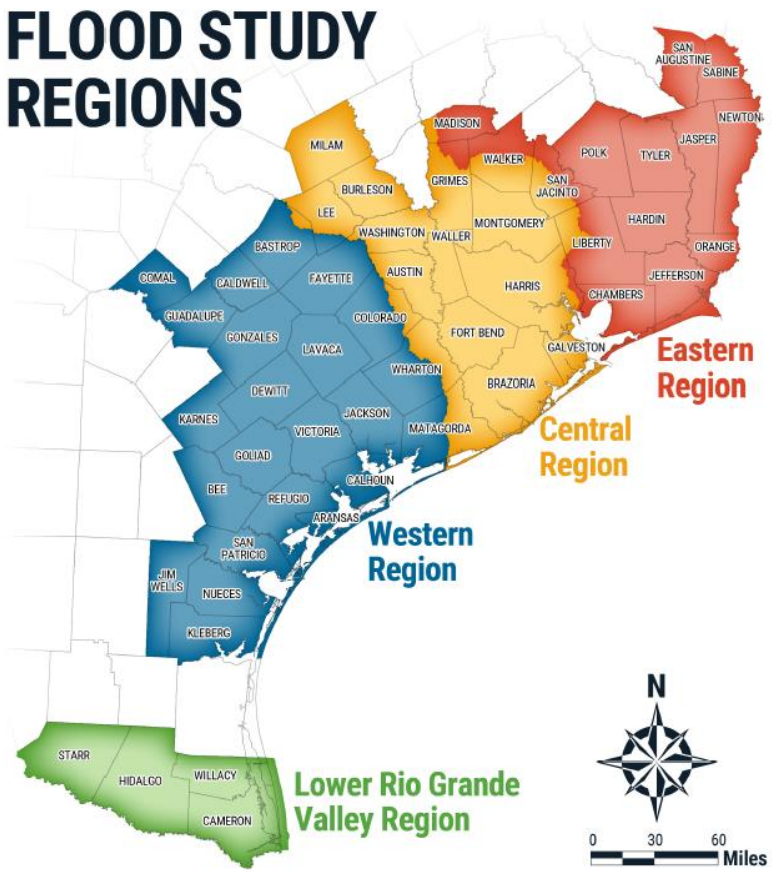
❖ Rain on Mesh (ROM) Hydrology for Low-lying Flat Topography OR HEC-HMS Inflows

✓ 2D ROM for coastally-impacted areas

❖ Carefully Consider Interbasin Transfers / Levees and Control Structures

❖ Model Calibration/Validation events: Compound flooding, surge-dominated and rainfall-runoff-dominated coastal flooding

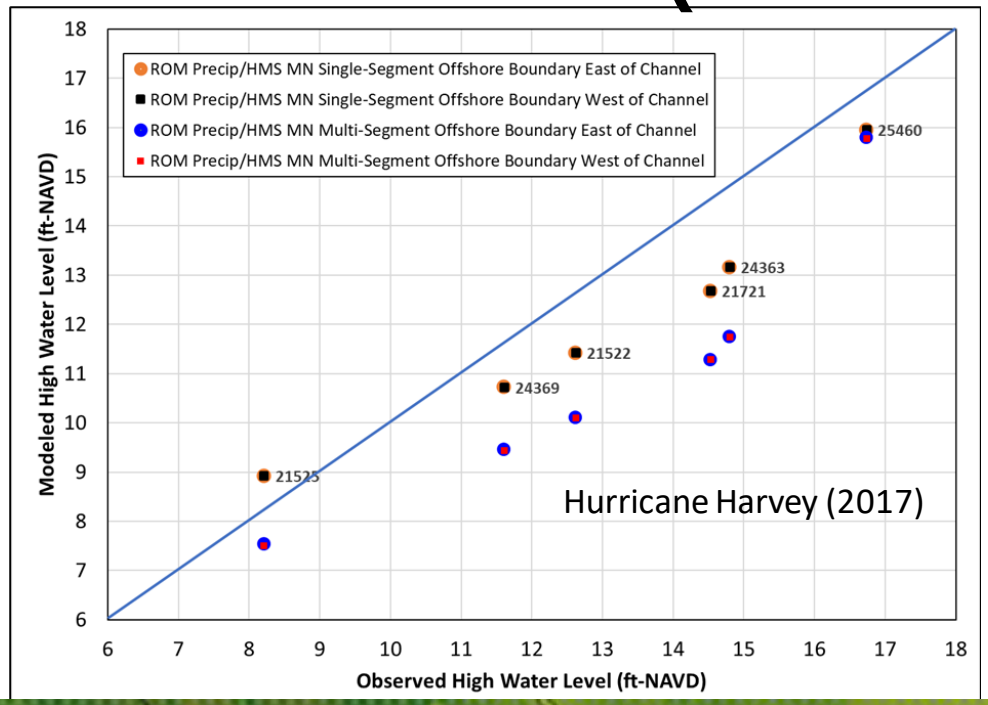
❖ Level of Details: Low, Medium & High

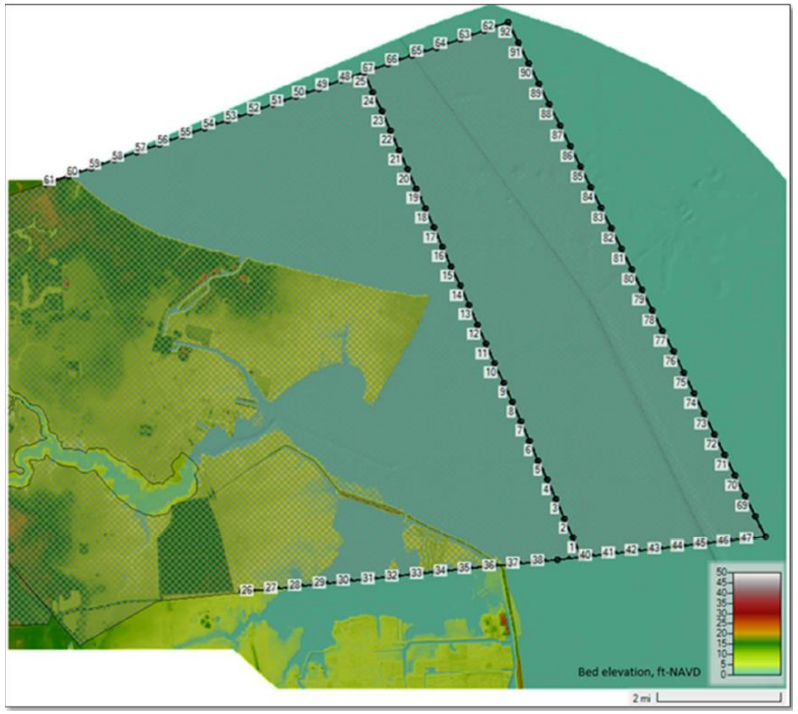


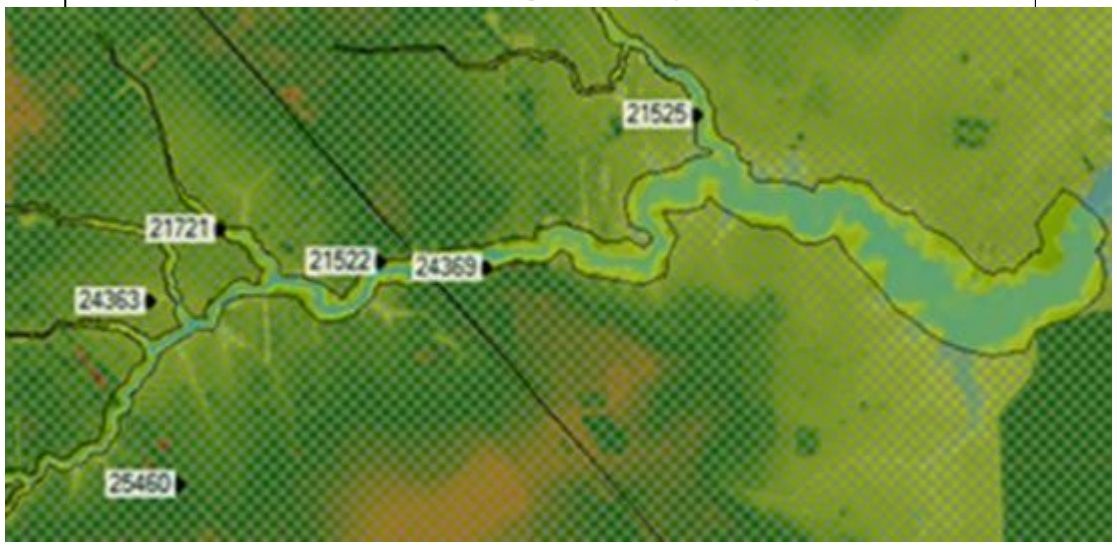
GLO REGIONAL BASIN FLOOD STUDY (CONT'D)

SENSITIVITY/UNCERTAINTY ANALYSIS

- Boundary placement
- Boundary discretization
- Wind forcing
- Time Lag



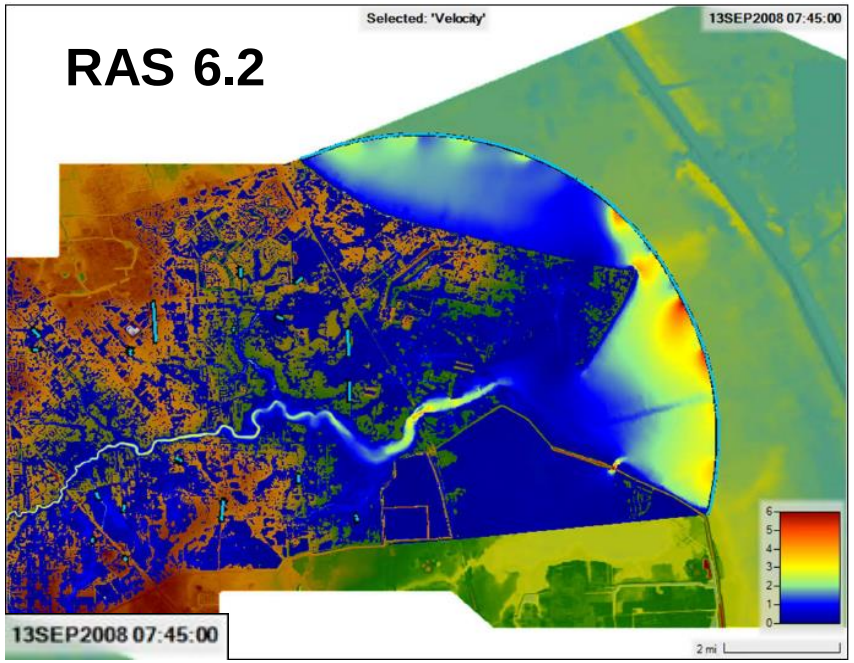


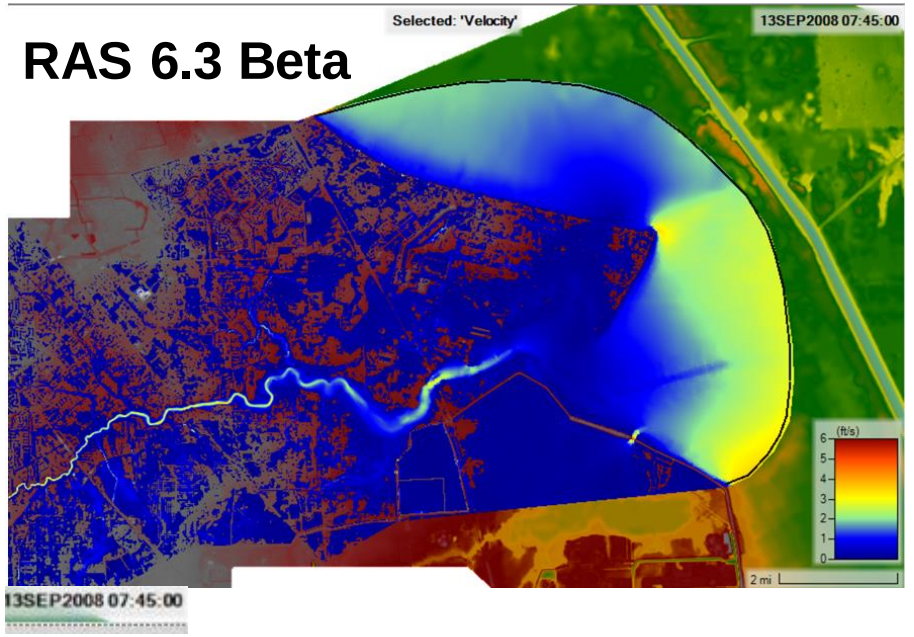


RAS ENHANCEMENT FOR COASTAL MODEL INTEGRATION

Funded by Texas General Land office

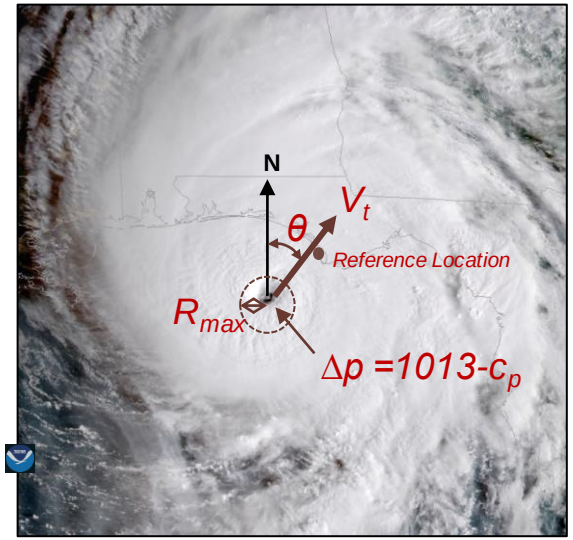
- ✓ Spatially Variable Downstream Boundary Conditions
- ✓ Atmospheric Pressure Inclusion

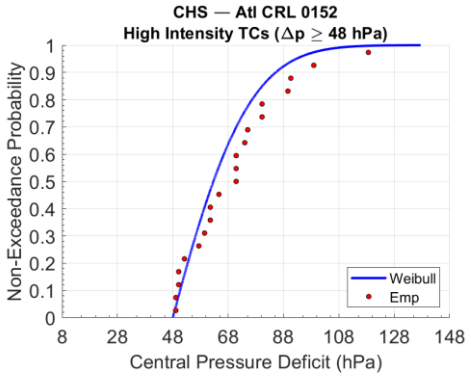


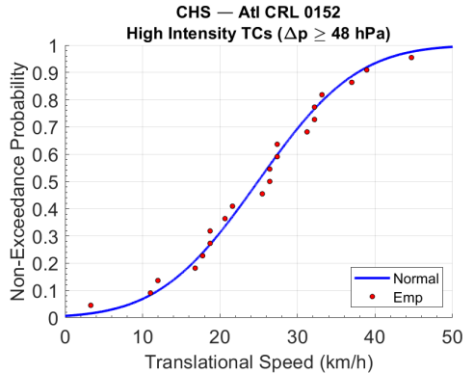


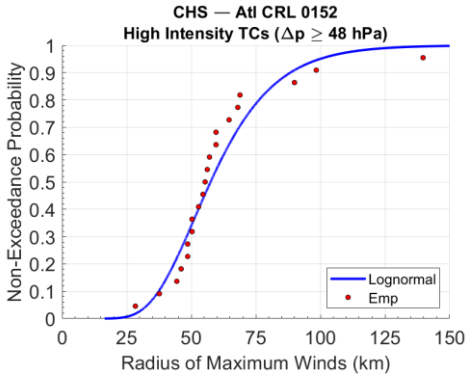
PROBABILISTIC STORM SURGE HAZARD ANALYSIS

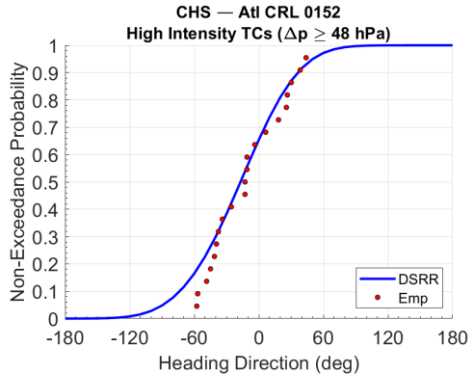
- Why use synthetic tropical cyclones?
  - Underrepresented in historical record
- JPM is the standard JPA model approach for TCs.
- Standard TC forcing parameters in JPM











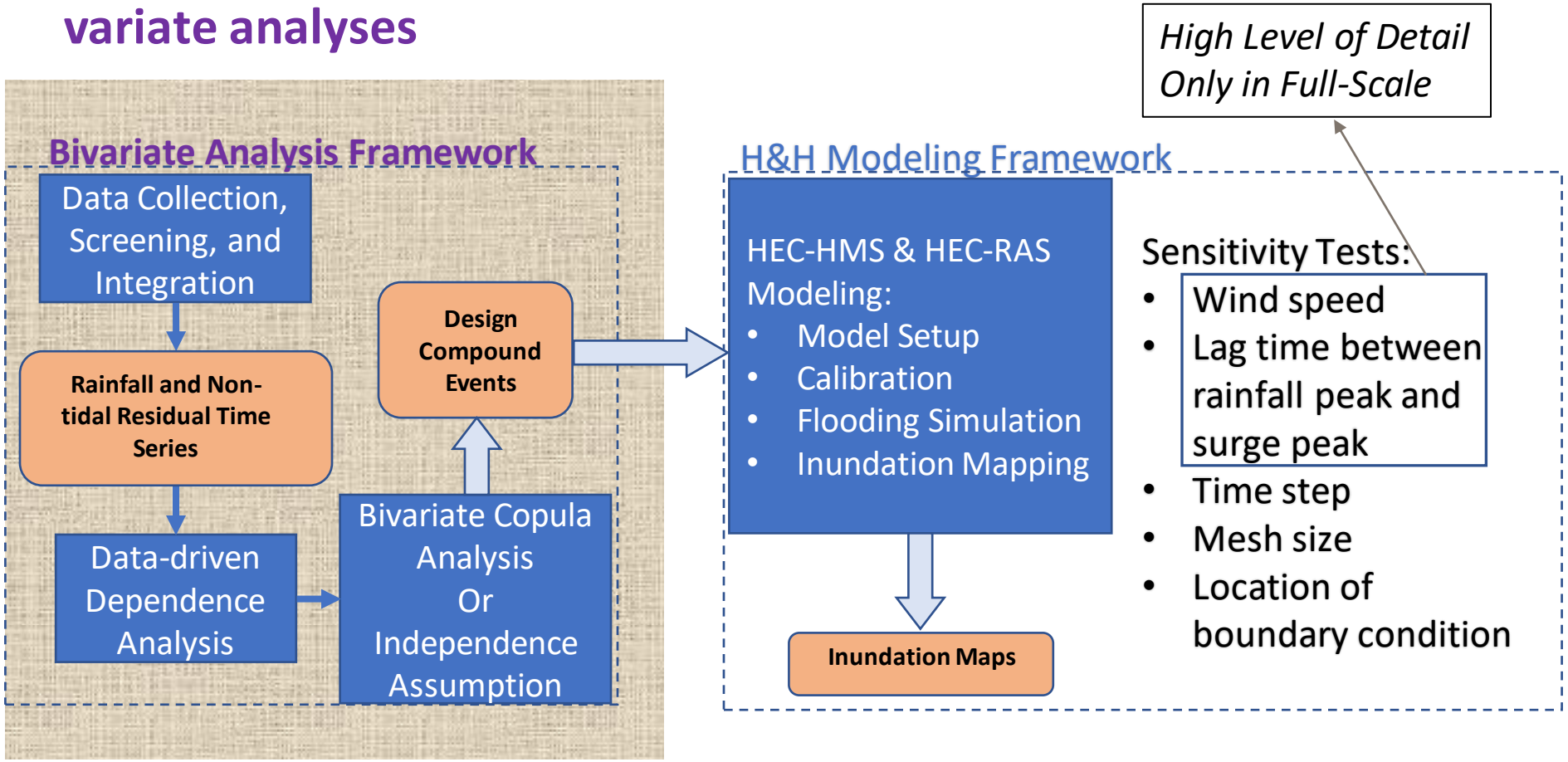
Δp = central pressure deficit **V_t = translational speed**

R_{max} = radius of maximum winds **Θ = heading**

- **Do not take into considerations of rainfall-runoff processes.**

GLO REGIONAL BASIN FLOOD STUDY (RBFS)- PROBABILISTIC ANALYSIS

- Surge and rainfall coincidence evaluation using **bi-variate analyses**



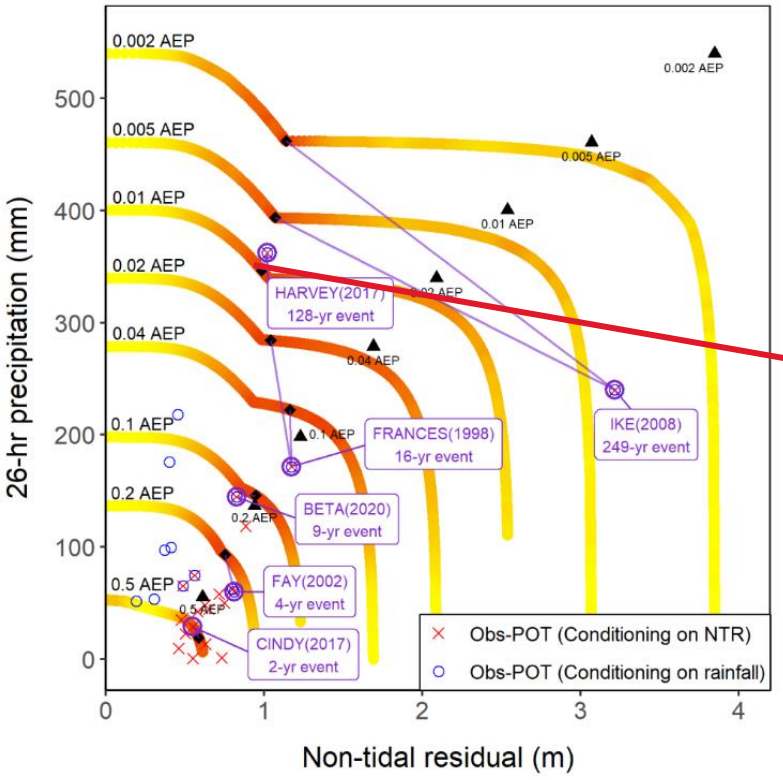
BI-VARIATE ANALYSIS FRAMEWORK

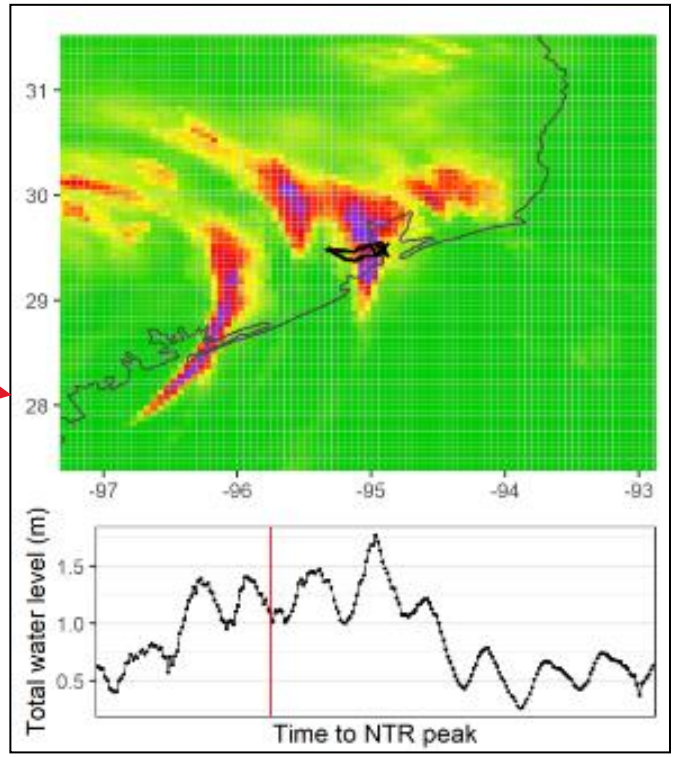
Bi-variate Copula Modeling

- ✓ Copula modeling to obtain the bivariate joint distribution conditioning on rainfall

Design events selection

- ✓ Spatial-temporal precipitation
- ✓ Water surface elevation at the model boundary





- ❖ Results could be affected by small sample size
- ❖ Inundation map discontinuities

ADVANCE JOINT PROBABILITY METHOD (JPM) FOR COMPOUND FLOOD HAZARD ESTIMATION

Received: 22 February 2021 | Revised: 24 June 2021 | Accepted: 3 August 2021
DOI: 10.1002/joc.7335

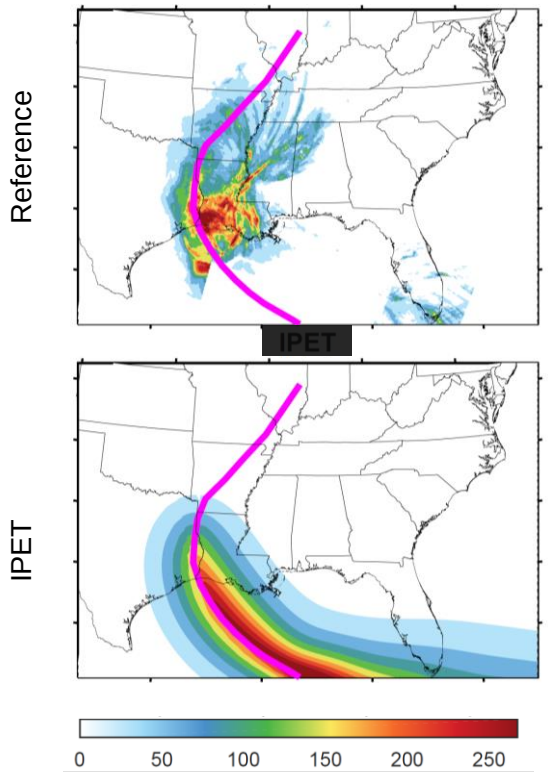
RESEARCH ARTICLE

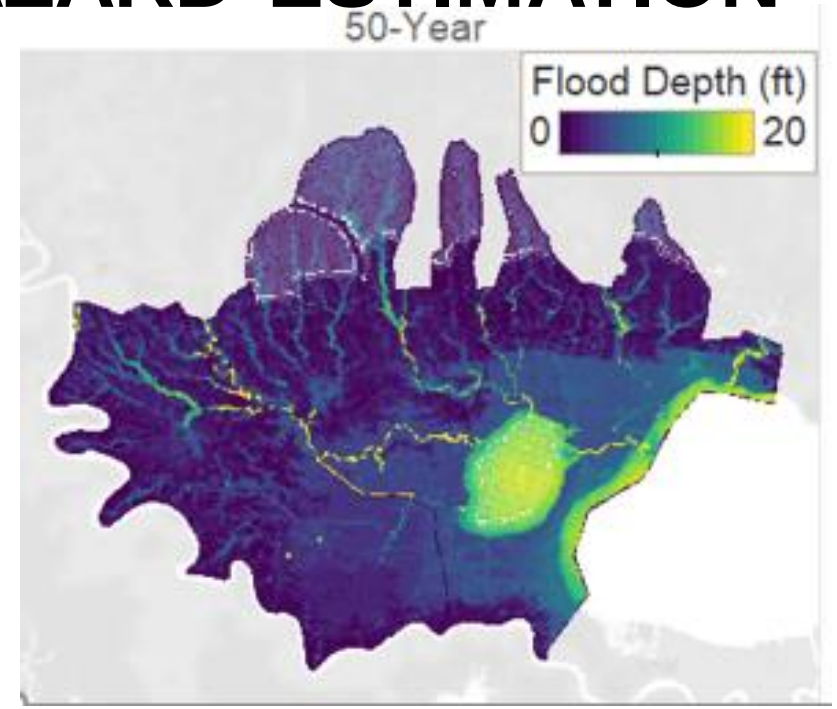
International Journal of Climatology | RMetS

Probabilistic rainfall generator for tropical cyclones affecting Louisiana

Gabriele Villarini[1] | Wei Zhang[1,2] | Paul Miller[3] | David R. Johnson[4] | Lauren E. Grimley[5,6] | Hugh J. Roberts[5]

Hurricane Rita (2005)





PURDUE UNIVERSITY

IIHR Hydroscience & Engineering

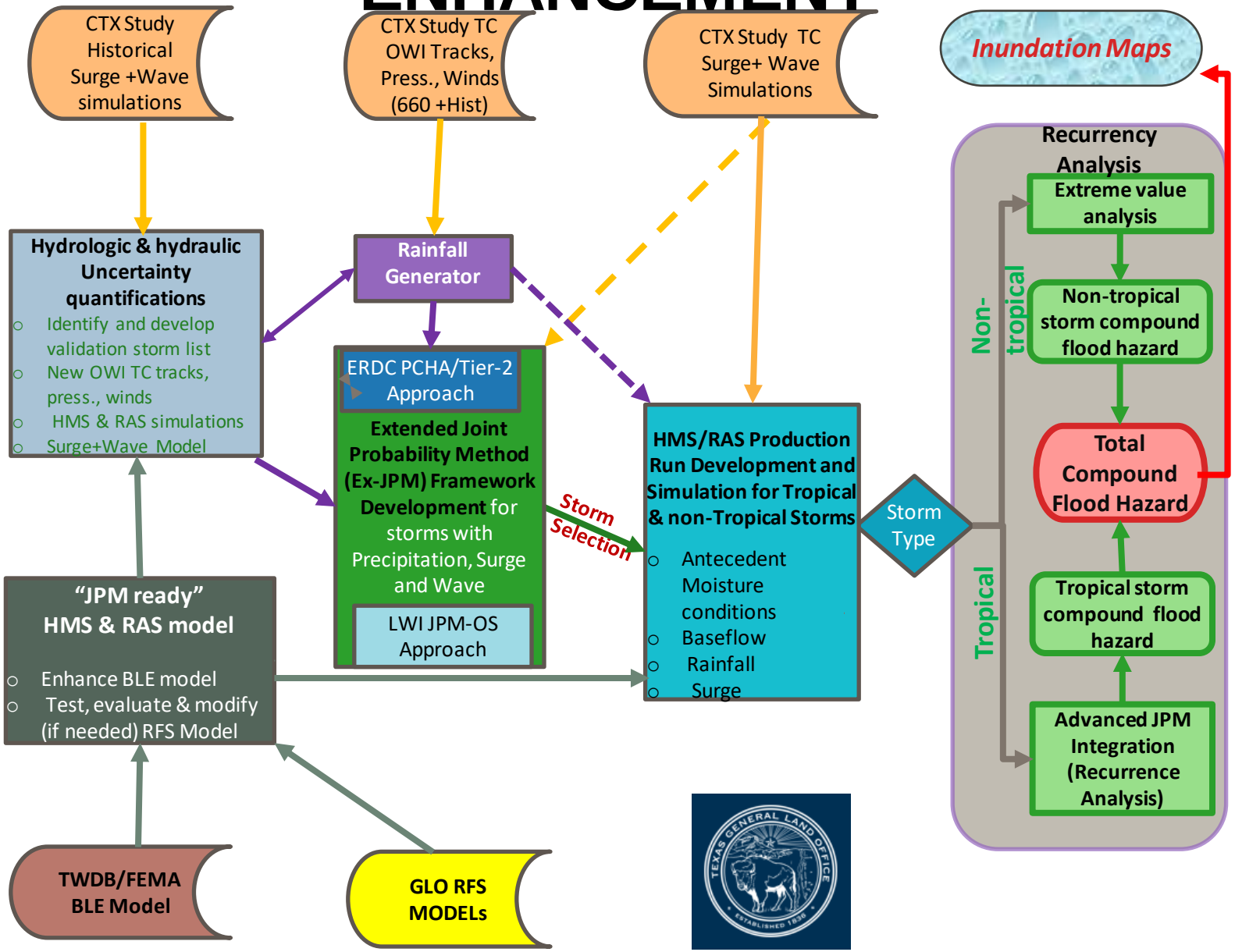
IOWA

THE WATER INSTITUTE OF THE GULF

LSU

LOUISIANA WATERSHED INITIATIVE

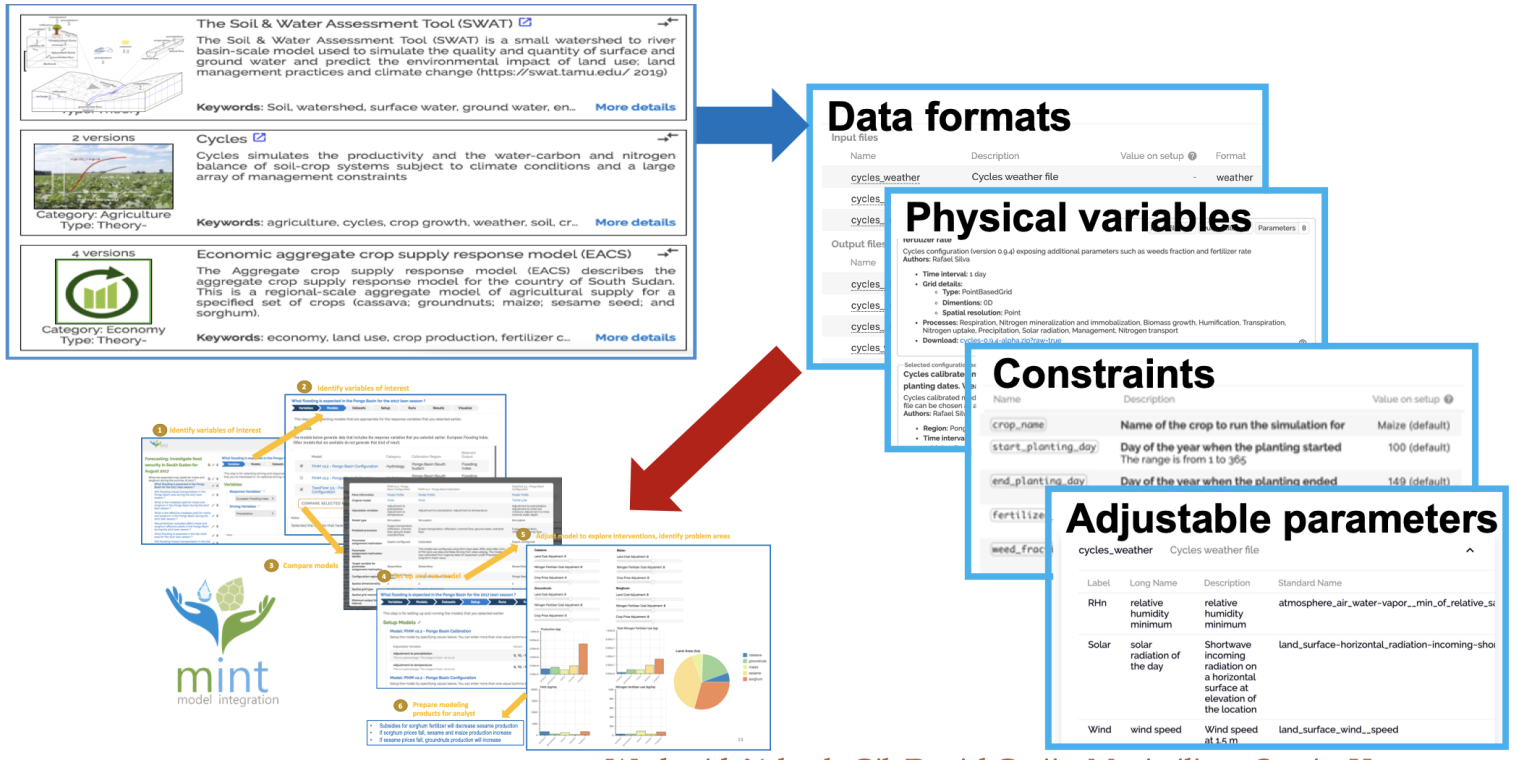
CONCEPTUAL DIAGRAM FOR JPM FRAMEWORK ENHANCEMENT



DATA MANAGEMENT AND SHARING - TDIS

Texas Disaster Information System will provide shared spaces to compose workflows, execute models, and share collections of outputs to support partners

Orchestrating and Curating Workflows with Advanced Computing Resources

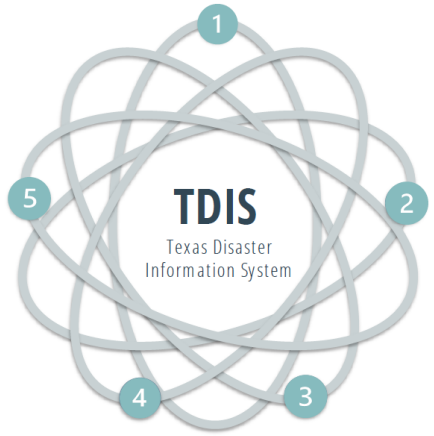


INSTITUTE FOR A DISASTER RESILIENT TEXAS

The cornerstone project for IDRT is the Texas Disaster Information System (TDIS).

IDRT Program Areas

1. Hazard Analytics
2. Risk Communication & Perception
3. Policy & Decision Support
4. Education
5. Coastal Risk Reduction



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CURRENT PHASE (Flood)

KEY TDIS STAKEHOLDERS & ROLES

Federal
FEMA
USACE

State
TDEM
GLO
TWDB

Elected Officials

Local
Counties, special districts, councils of governments, public works

Government Institutions
Decision Making, Response, Planning, Regulation, Grantmaking, Accountability

Academia
Research; Innovation; Evaluation; Testing; Implementation; Education

Key TDIS Partners
Texas A&M University (IDRT)
University of Texas (TACC)

Other Partners
Rice University
University of Iowa
University of Texas-Arlington

ALL ARE TDIS CONSUMERS, CONTRIBUTORS, & COMPLEMENTORS

TDIS

Private Sector

Application; Services; Products
- Vendors/contractors
- Engineering Cos
- Technology Cos
- Other Consultants

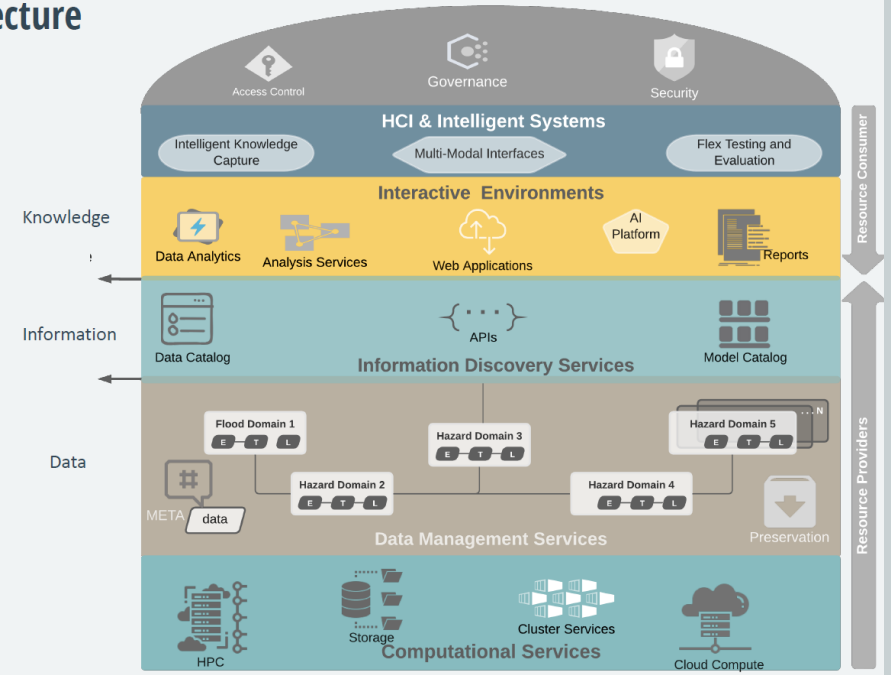
Awareness; Advocacy
- Nonprofits
- General Public

TDIS Conceptual Architecture

Defines data domains by hazard type

Distinguishes Thresholds
- Data-to-Information
- Information-to-Knowledge

Design will consider multiple strategies to manage
- Data-proximate computing
- Hybrid compute services
- Processes to define data models
- Data registration tiers
- Reusable workflows & algorithms
- Usability and flex test protocols
- Cross-organizational security



TDIS Federated Data Governance Structure

TDIS Users can be consumers, contributors, and complementors at every phase of TDIS development.

Contributors
Authoritative Sources

TDIS will directly ingest some types of data.

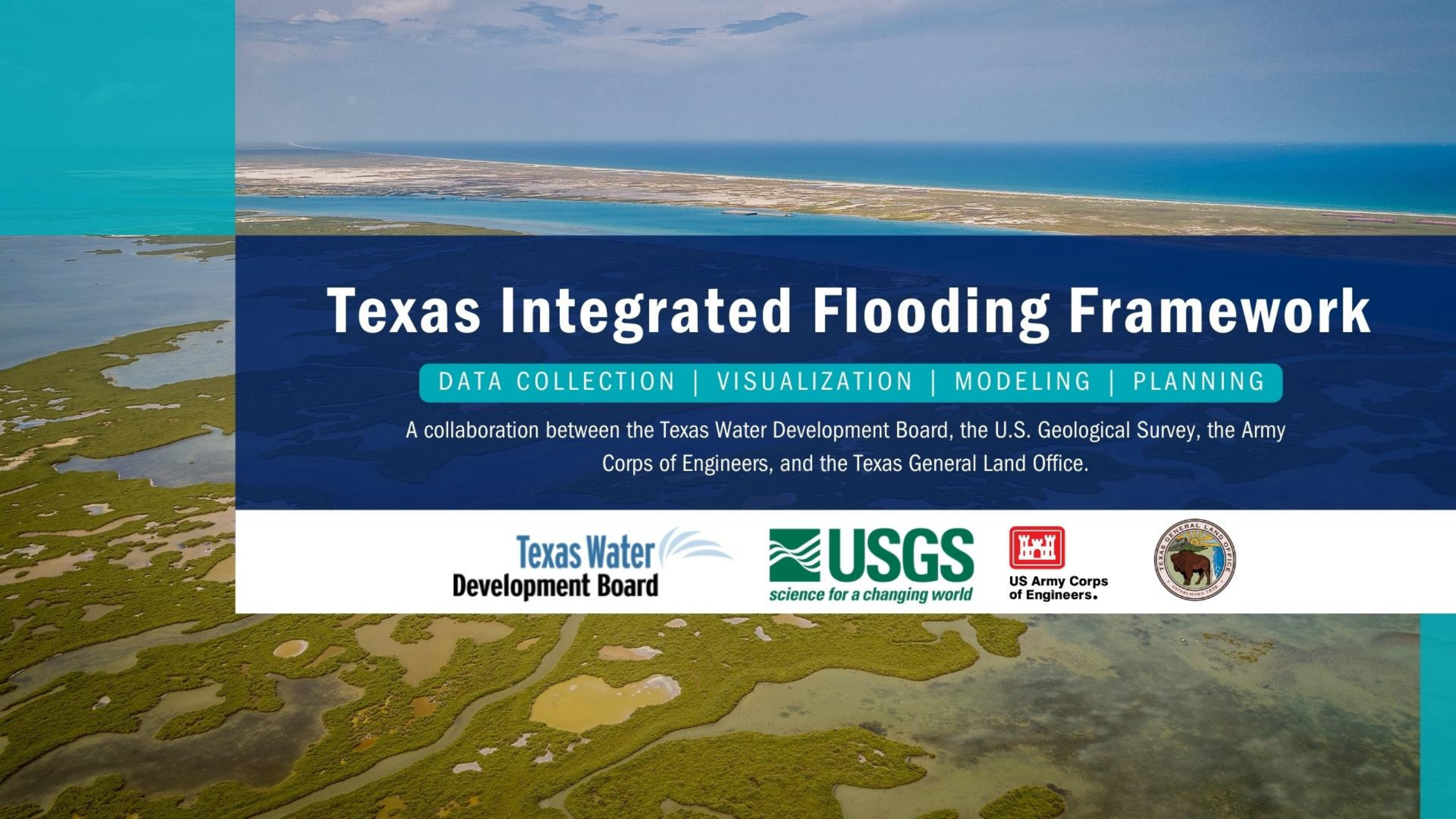
- IDRT Project Data
- FEMA (BLE/ Redacted)
- FEMA PII
- PII
- Critical Infra.
- Non-PII

Consumer Access Levels
- Dev Group
- Priority Users / Policy-makers
- State Agencies / Academic Research
- Local Governments
- General Public

Complementors
Authoritative Sources

TDIS will identify, catalog, and link to external data sources maintained by other entities.

- TNRIS
- TWDB
- TDEM
- GLO
- USACE



Texas Integrated Flooding Framework

DATA COLLECTION | VISUALIZATION | MODELING | PLANNING

A collaboration between the Texas Water Development Board, the U.S. Geological Survey, the Army Corps of Engineers, and the Texas General Land Office.

Texas Water Development Board

USGS science for a changing world

US Army Corps of Engineers.

TIFF - PLAN

MISSION:

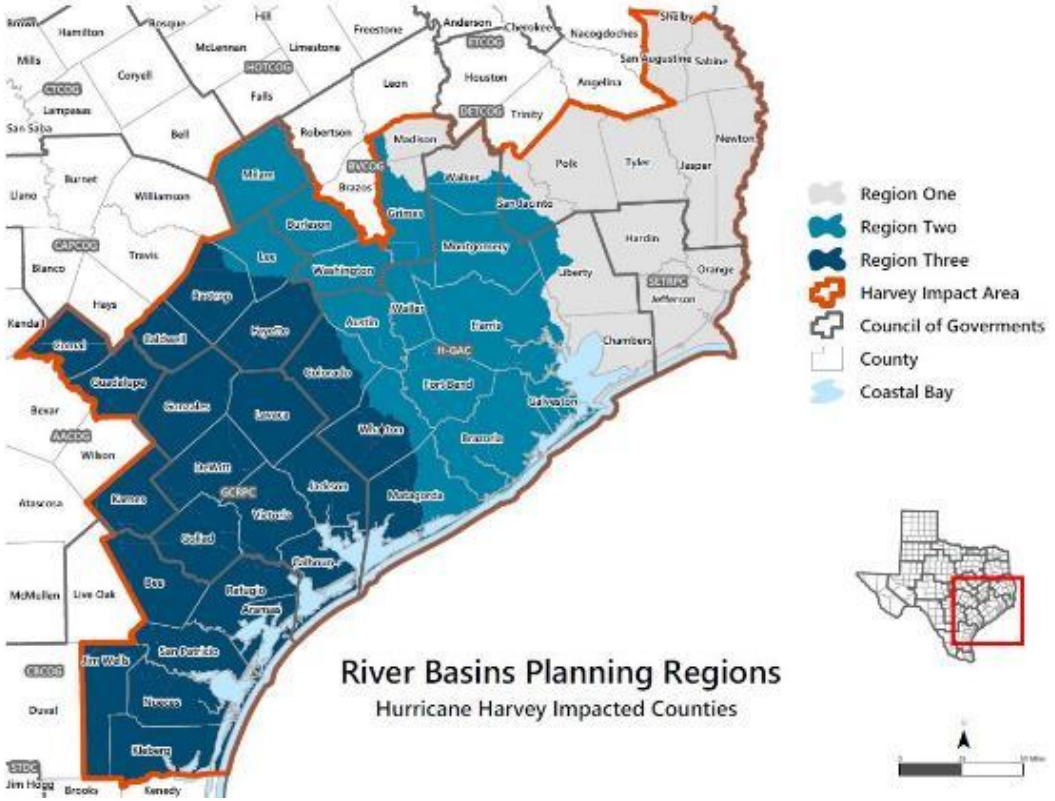
Texas Integrated Flooding Framework leverages expertise and resources to bring about the best information to enhance coastal flood risk planning and mitigation.

- Develop guidelines and processes for implementing an integrated framework to model, visualize, and plan coastal floods
- Compliment the many ongoing efforts
- The future of the science

Timeframe: November 2020 – December 2024

Four-component study

1. Data and Monitoring Gap Analysis
2. Data Management and Visualization
3. Integrated Flood Modeling Framework
4. Planning and Outreach



TIFF - ORGANIZATION

STEERING COMMITTEE (SC)

Facilitates access to accurate and reliable compound flood-related information for decision-makers at all levels through a collaborative planning approach and by utilizing quality data, robust models, and sound science.

FACILITATION TEAM

Provide pre- and post-meeting facilitation, support offline collaboration, and stakeholder engagement.

The Meadows Center for Water and the Environment
Texas State University

TECHNICAL ADVISORY TEAMS (TATS)

Groups of technical experts serve as the source of expertise guiding the TIFF project from vision to execution.

Texas Water Development Board

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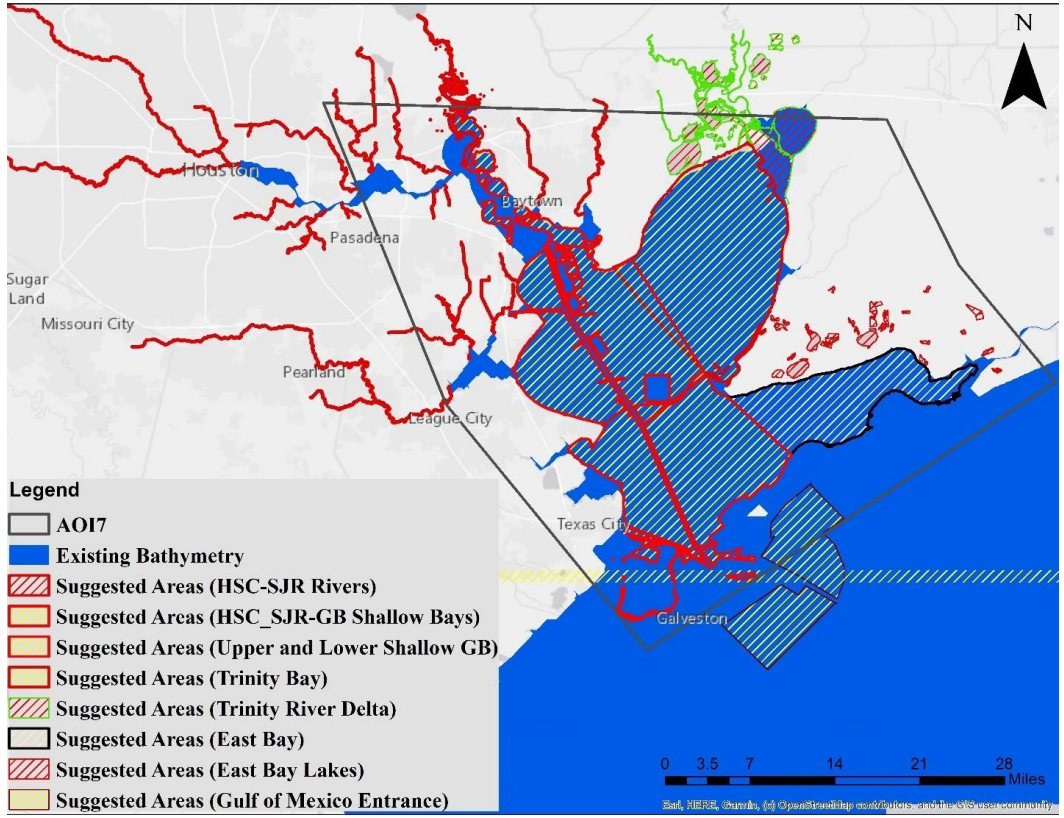
TIFF - TECHNICAL ADVISORY TEAMS

Adaptation International	NOAA/National Ocean Service, Center for Operational Oceanographic Products and Services	Texas Division of Emergency Management	University of Notre Dame
AQUAVEO LLC	Princeton University	Texas Floodplain Management Association	University of Texas - Arlington
Center for Space Research - UT Austin	Region 5 Flood Planning Group (Neches River), Lamar University	Texas General Land Office	University of Texas at Austin
Coastal Bend Bays & Estuaries Program	Seahorse Coastal Consulting	Texas Natural Resources Information System	University of Texas Rio Grande Valley
Coastal Emergency Risks Assessment - Louisiana State University	Southwestern Division Office	Texas Spatial Reference Center, TAMU Corpus	US Army Corps of Engineers - Engineer Research and Development Center
DSI LLC	Texas A&M - Institute for a Disaster Resilient Texas	Texas Water Development Board	US Army Corps of Engineers - Fort Worth District
Federal Emergency Management Agency	Texas A&M AgriLife/Community Health and Resource Management (CHARM)	The University of Iowa	US Army Corps of Engineers – Galveston District
Harris Country Flood Control District	Texas A&M- College Station	The University of Texas at Austin	US Army Corps of Engineers - Hydrologic Engineering Center
Harte Research Institute	Texas A&M- Corpus Christi	The University of Texas Rio Grande Valley	US Geological Survey
Institute for a Disaster Resilient Texas, Texas A&M University-Galveston	Texas A&M University- Kingsville	The Water Institute of the Gulf	Utah Water Research Laboratory - Utah State University
Iowa Flood Center	Texas Advanced Computing Center	United States Geological Survey	Virginia Institute of Marine Science
January Advisors	Texas Commission on Environmental Quality	United States Naval Academy	Virginia Tech
National Oceanic and Atmospheric Administration	Texas Department of Transportation	University of Central Florida	West Consultants
National Weather Service	Texas Disaster Information System	University of Georgia	
National Weather Service - West Gulf River Forecast Center		University of Houston	
		University of North Carolina at Chapel Hill	
		University of North Florida	

TIFF - BATHYMETRY WORKSHOP

- One of the most important datasets if not the most important one when it comes to modeling
- Highly dynamic
- Some datasets are very old
- Expensive to collect data
- Communication could be improved
- Bottom classification in water



https://www.georgefyoung.com/hydrographic-surveying/

ACKNOWLEDGMENTS

- Tyler Payne & Corragio Maglio
- GLO, TWDB, USGS
- GLO Regional Flood Study vendors
- TWDB BLE vendors
- Lower Clear Creek and Dickinson Bayou Study A/E Contractors
- The Water Institute of the Gulf
- Purdue University
- University of Iowa
- University of Texas at Austin
- Engineer Research and Development Center
- Other local stakeholders and partners