DEVELOPMENT OF THE COASTAL HAZARDS ANALYSIS AND RISK TOOLKIT (CHART)

Kevin Hodgens, P.E. and Rusty Permenter

U.S. Army Corps of Engineers, Coastal Hydraulics Laboratory, 3909 Halls Ferry Rd, Vicksburg, MS 39180
kevin.c.hodgens@usace.army.mil,
rusty.l.permenter@usace.army.mil

U.S. ARMY

US Army Corps of Engineers

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

COASTAL & HYDRAULICS LABORATORY

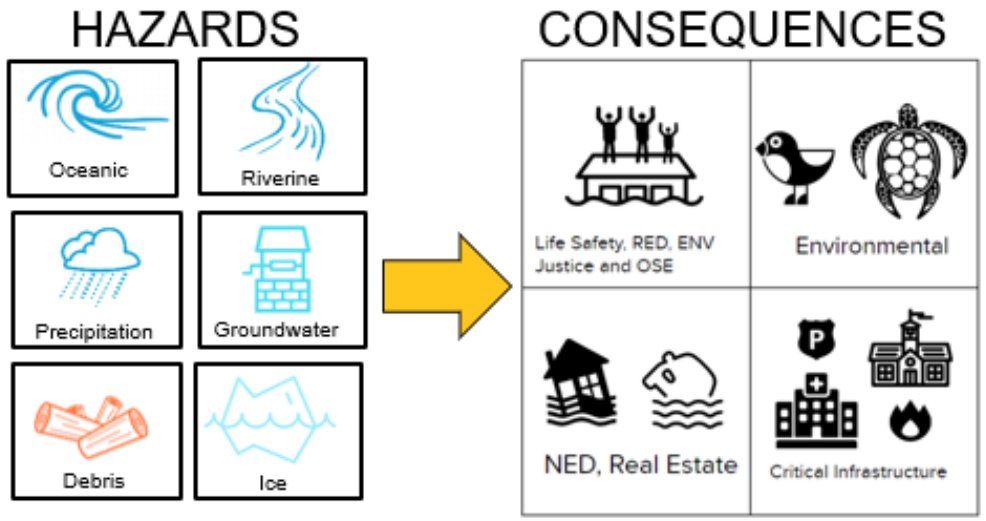
BOTTOM LINE UP FRONT

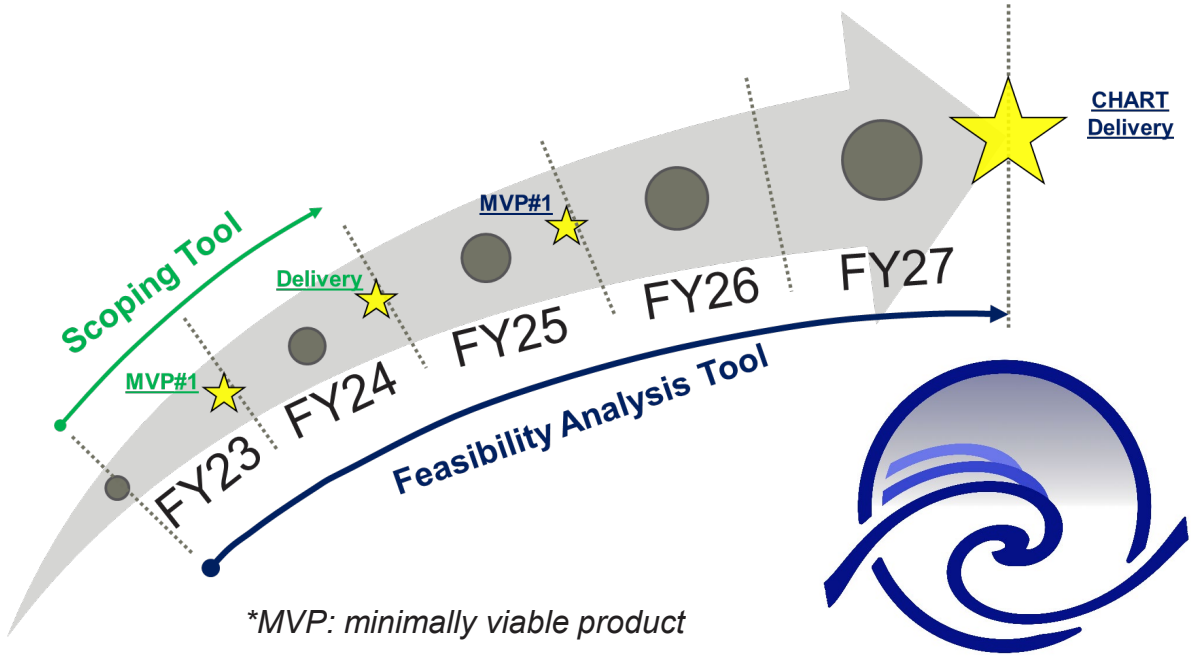
USACE districts require replacement of Beach-fx and Generation 2 Coastal Risk Model (G2CRM)

Coastal Hazards Analysis and Risk Toolkit (CHART) is a 5-yr, $5M development effort
Scheduled for FY27 completion

Two primary functions
- Study scope development and coordination
- Federal interest determination

FY25 development focus shifting from Scoping Tool (SCT) to Feasibility Tool (FEAT)





*MVP: minimally viable product

INTRODUCTION

USACE maintains a large, and growing, portfolio of Coastal Storm Risk Management (CSRM) projects

- 184 authorized and 28 in design
- 22 active feasibility studies

Coastal risk problems are increasing in complexity, frequency, and cost

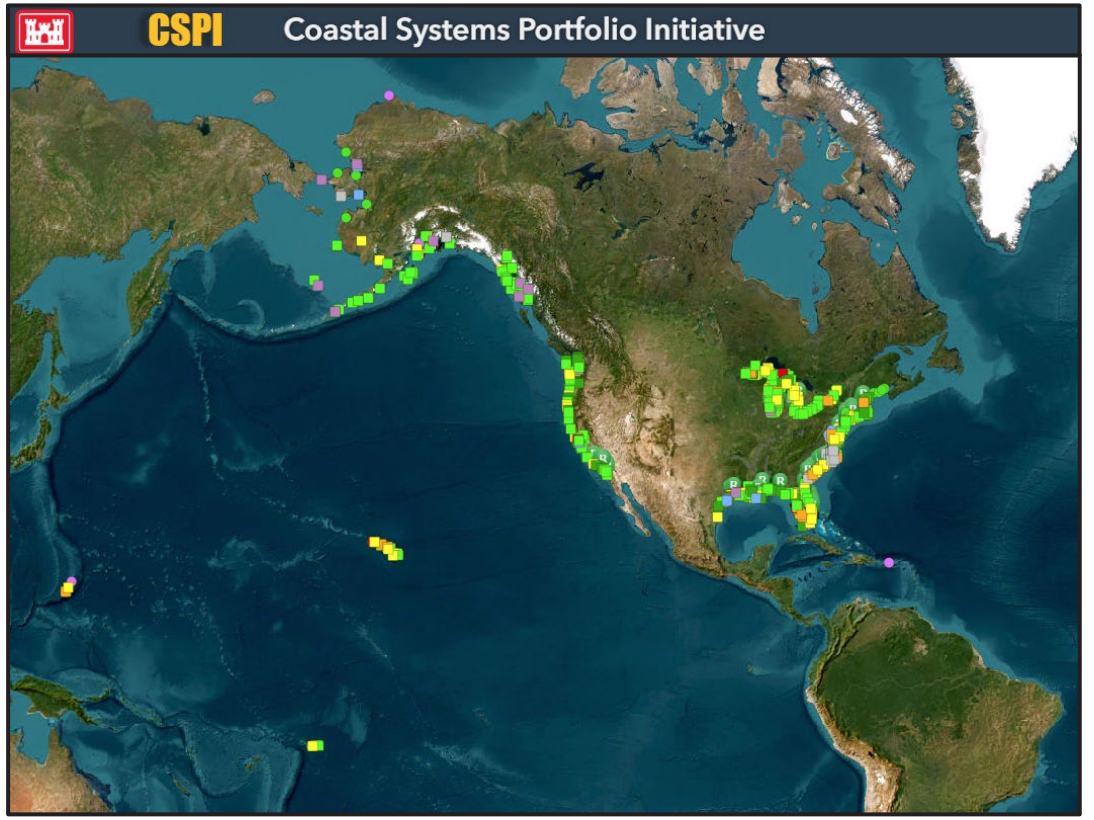
- Expanded exposure: relative sea level change and coastal floodplain development
- Estimated costs of tropical cyclones (TCs) over $3.7B/year in U.S.

Low-energy estuarine environments (i.e., 'back bay') garnering greater attention

- Additional considerations to quantify risk (fluvial, pluvial, groundwater; compounding effects)

Existing risk evaluation tools are dated and ill prepared to support agency federal interest determinations

- Multi-line protection and/or multiple flood sources



USACE CSRM Projects from Coastal Systems Portfolio Initiative (https://cspi.usace.army.mil/)

FIELD-DRIVEN MANDATE

Statement of Need #1498 (2019), "***Future Directions for CSRM Modeling for Probabilistic Lifecycle Studies***"
- Authors: C-PCX[1] and CPR CoP[2]

Prioritized for agency investment in SEP 2022
- $5M and five years
- FY23 project initiation, FY27 completion

Key Features
- Modular
- Transparent
- Scalable
- Automated data preparations, evaluations, visualizations
- Leverages agency investments and national datasets
- Study scoping support*

Functionality
- Probabilistic lifecycles > 50 years
- Computationally efficient
- Robust hazards and uncertainty
- Multiple protective features
- Identify risks from flooding, wave attack, and erosion

[1]C-PCX: Coastal Planning Center of Expertise
[2]CPR CoP: Climate, Preparedness, and Resiliency Community of Practice

PARTNERSHIPS

Horizontal and vertical agency integration

- Field participation
  - Subject matter experts and management
  - Districts, divisions, and headquarters

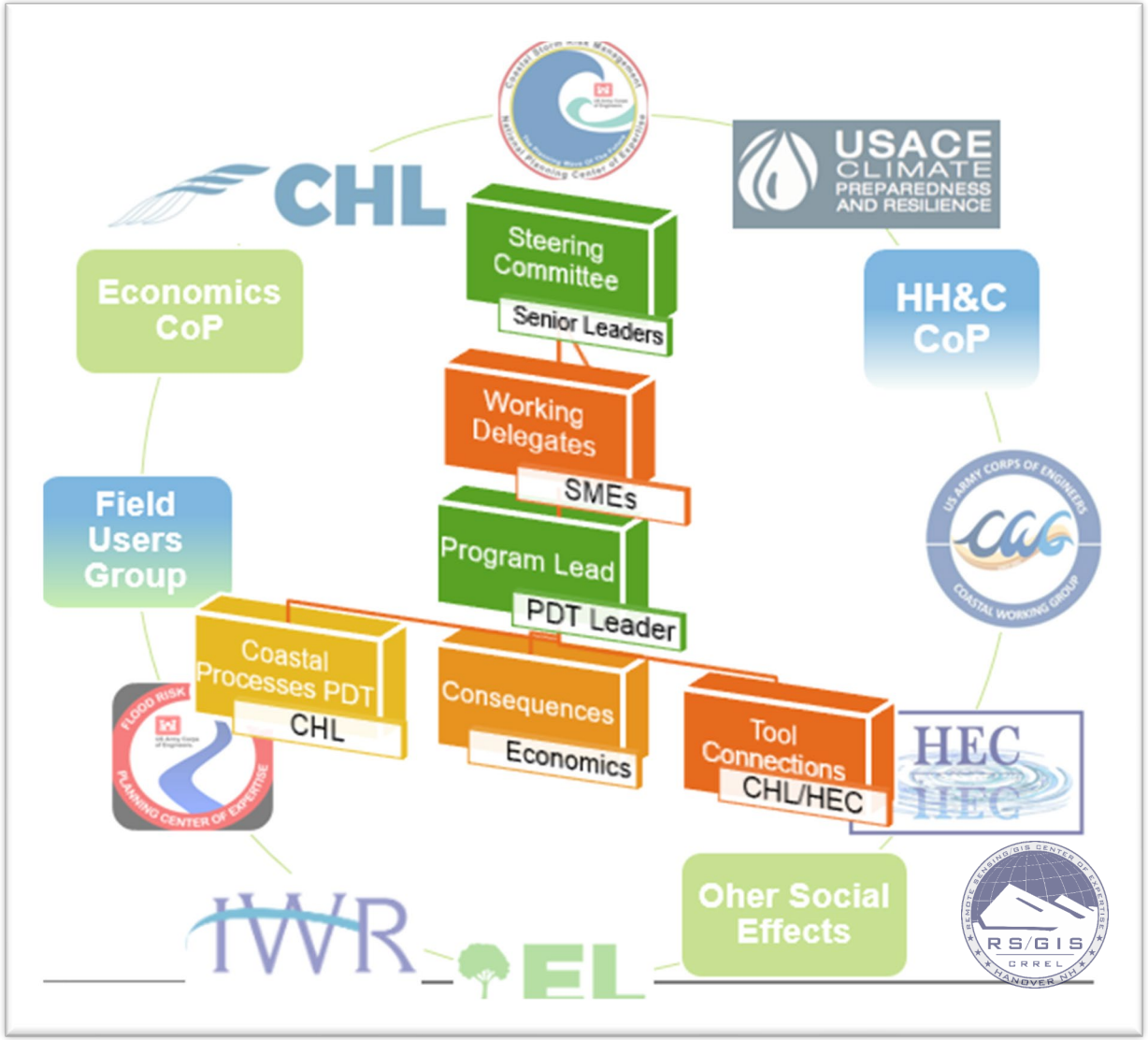
- Communities of practice

- Planning centers of expertise

- Research labs and centers

External collaborations

- A/E contractors
- Academia



THE CONCEPTUAL RISK EQUATION

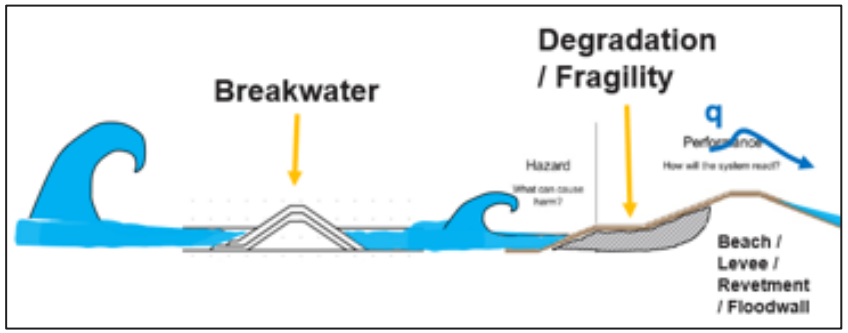
Risk = *f* (Hazards, Physical System Response, Exposure, Vulnerability)

National Economic Development

Life Loss

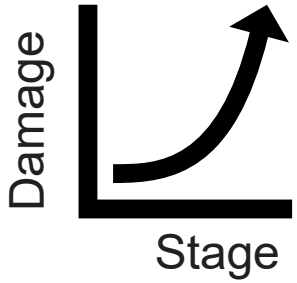
Environmental Consequences

(i.e., Performance)



Affected, Yes/No?

How much harm?



CHS

STORMSIM

Nonstationary:	Sea Levels Hazards*	Morphology Armor construction Future with project features	Rebuilding Condemnation Elevation

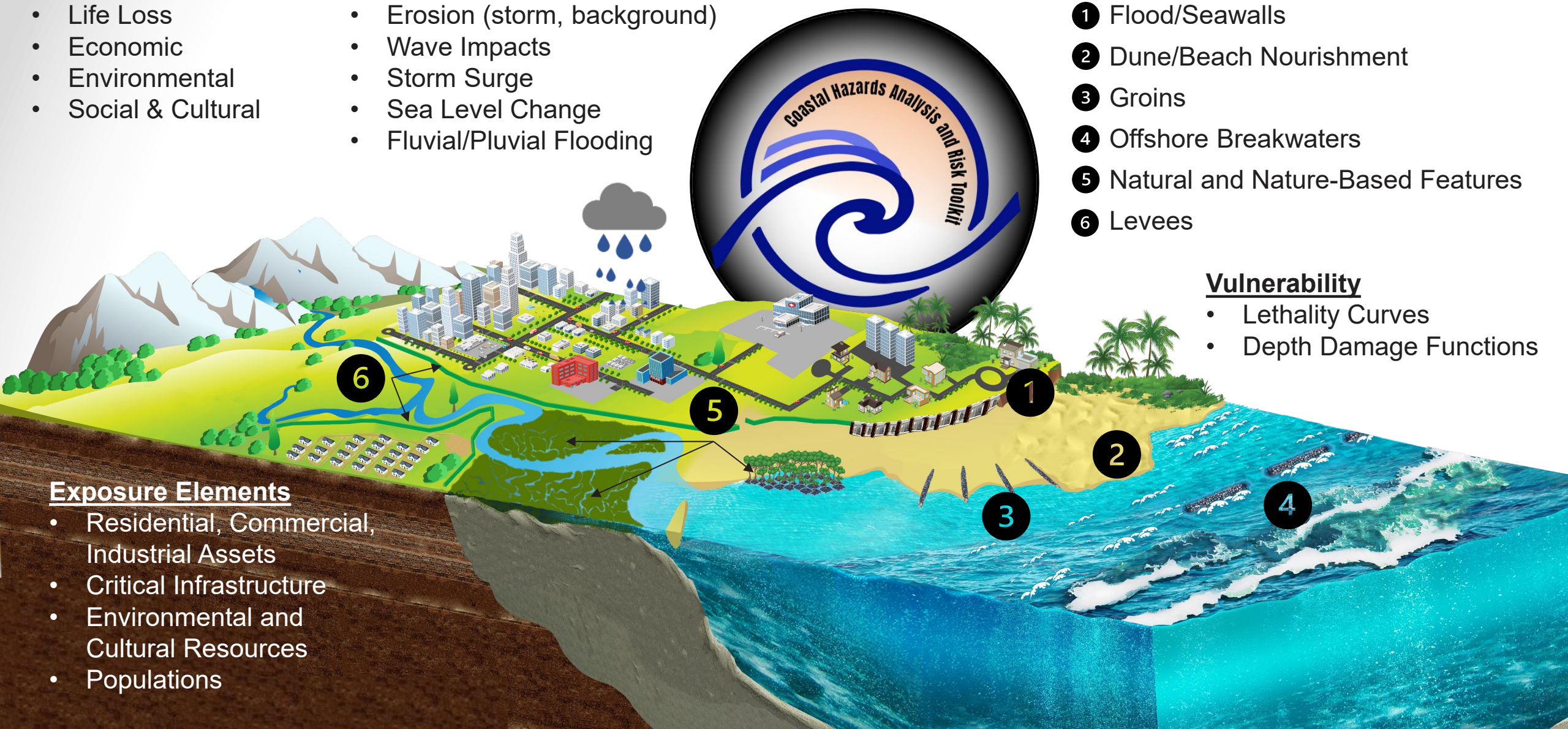
Risk = *f* (Hazards, Physical System Response, Exposure, Vulnerability)

Risk / Consequences
- Life Loss
- Economic
- Environmental
- Social & Cultural

Hazards
- Erosion (storm, background)
- Wave Impacts
- Storm Surge
- Sea Level Change
- Fluvial/Pluvial Flooding

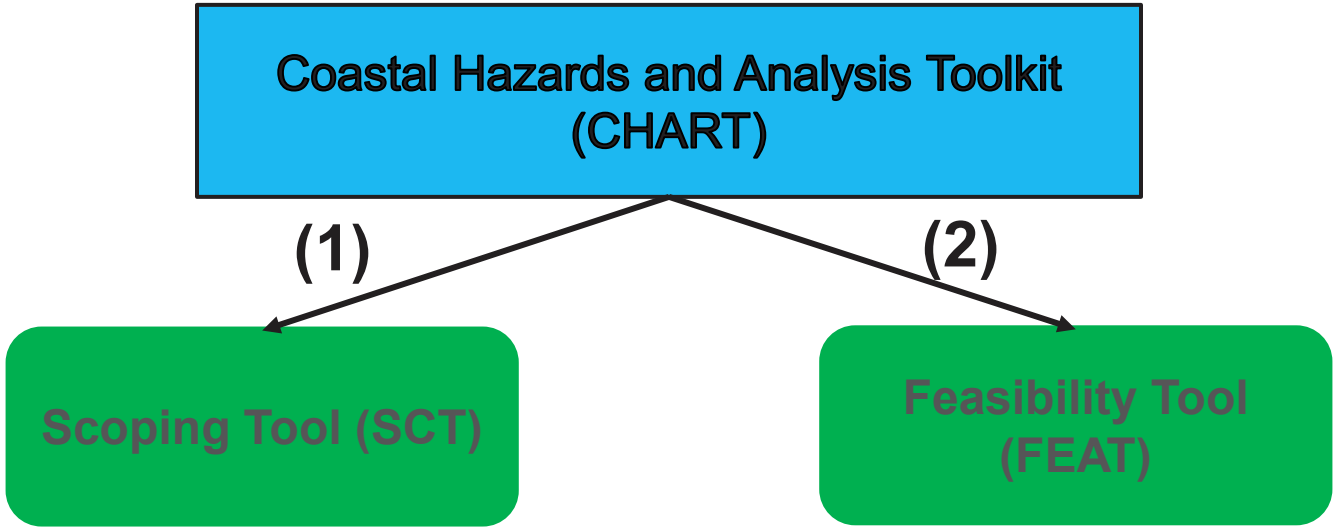
Physical System Measures
1. Flood/Seawalls
2. Dune/Beach Nourishment
3. Groins
4. Offshore Breakwaters
5. Natural and Nature-Based Features
6. Levees

Vulnerability
- Lethality Curves
- Depth Damage Functions



Exposure Elements
- Residential, Commercial, Industrial Assets
- Critical Infrastructure
- Environmental and Cultural Resources
- Populations

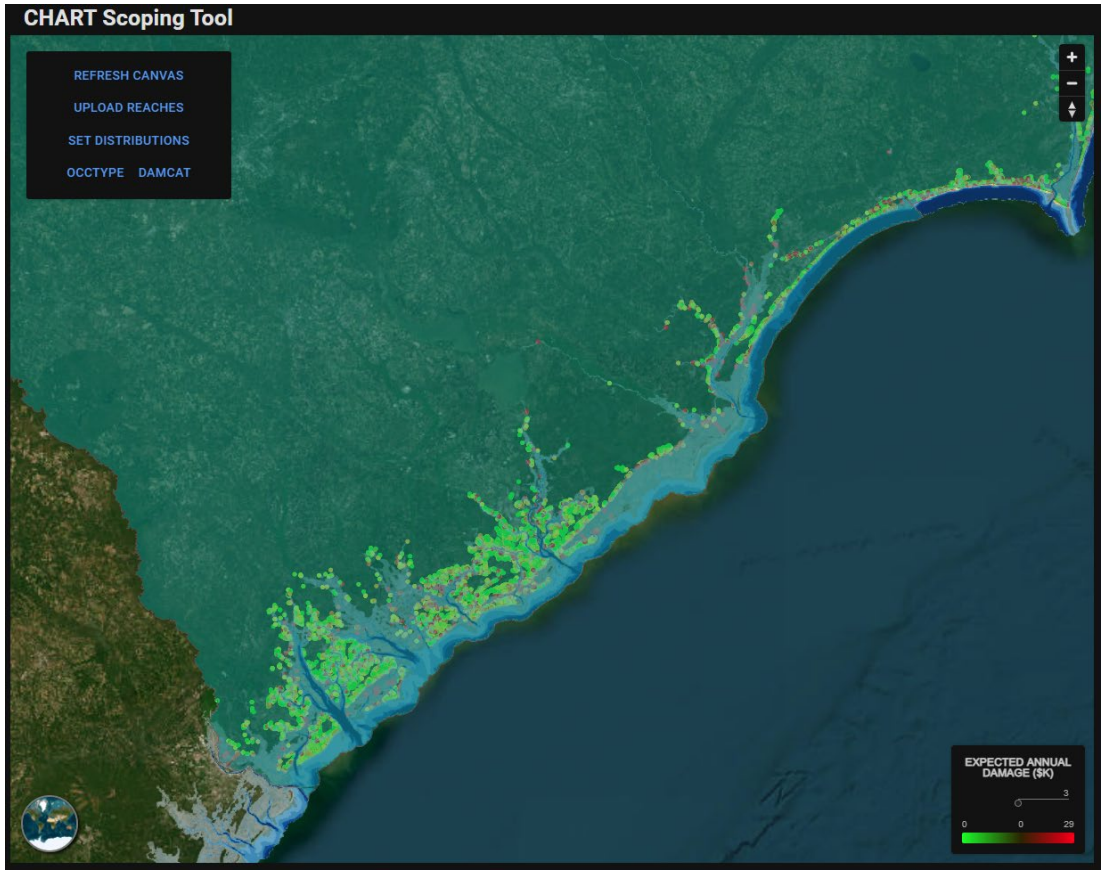
CHART FUNCTIONALITY



Risk Component	Scoping Tool	Feasibility Tool
Hazards	Probabilistic peak storm values with uncertainty	Lifecycles of response-based timeseries
Physical System	Regional hazards study topography	Existing topography, modified system elements (armoring, fragility, failure)
Exposure	National Structure Inventory assets	Refined and verified asset inventory with parameter uncertainty
Consequences	Expected annual impacts	Lifecycle impacts with aggregation

CHART FUNCTIONALITY

Scoping Tool (SCT)



Scoping Tool Output for SC and Portions of NC
0.01 AEF (100-yr) SWL and Base SLC

Primary Intent

Identify study resources

Reduce study completion risk

Study Timeline

Zero to six months

Functions

1. Risk exploration in study area (economic, social, environmental) w/ sea level change and uncertainty
   - Expected Annual Damages (EAD) and Hazards
   - Critical Infrastructure (CI)
   - Environmental Justice (EJ)
   - Life loss (LL)
2. Risk statements and study courses of action (COAs)
3. Future consideration: dynamic computations (e.g., 'what if…' analyses)

SCOPING TOOL PROGRESSION

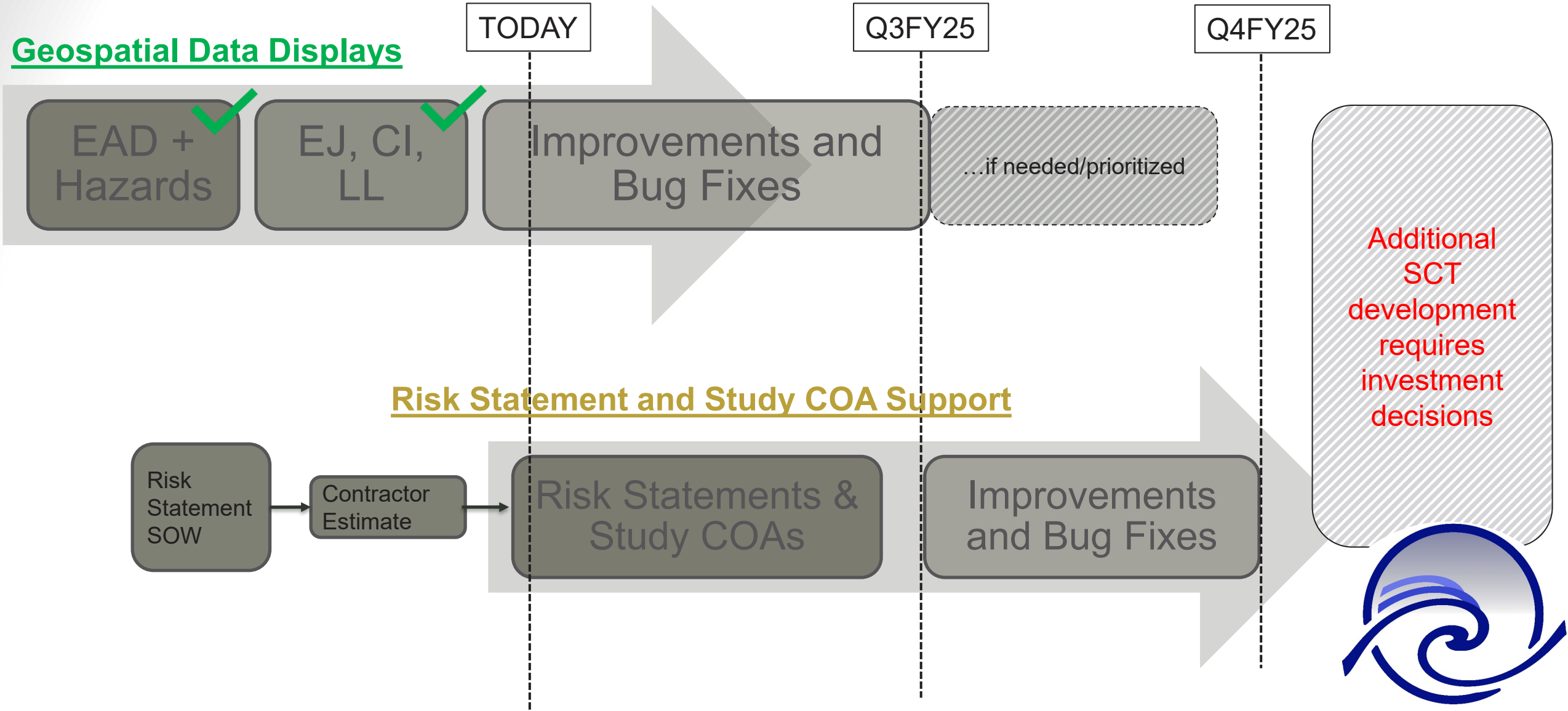
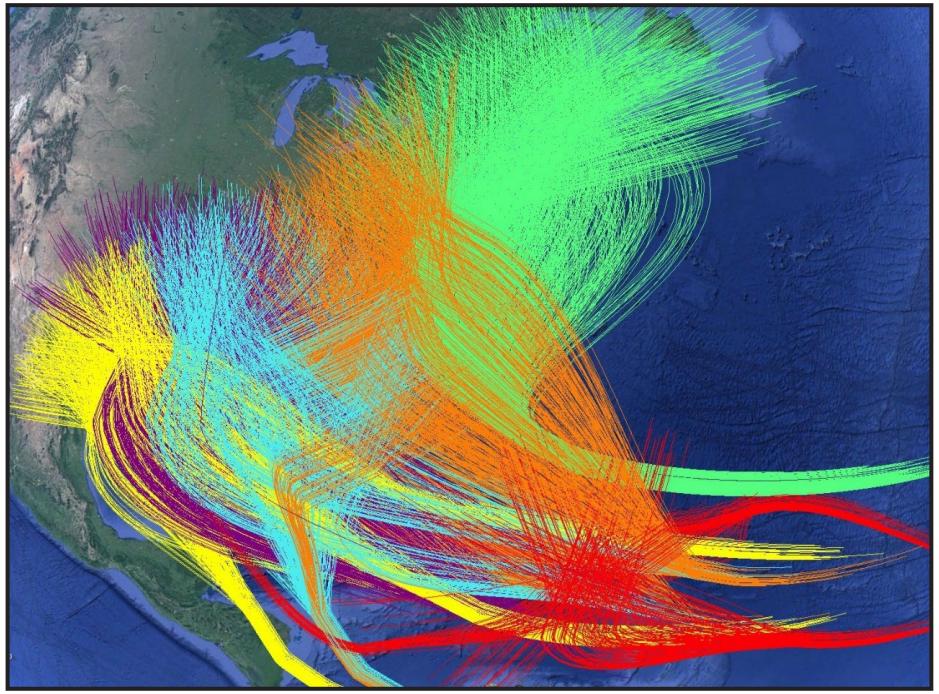


CHART FUNCTIONALITY

Feasibility Tool (FEAT)



CHS Atlantic basin synthetic tropical cyclone tracks (4,355 unique TCs; https://chs.erdc.dren.mil/)

Primary Intent

ID risk across lifecycles
Support federal interest determination
Support Chief's Report

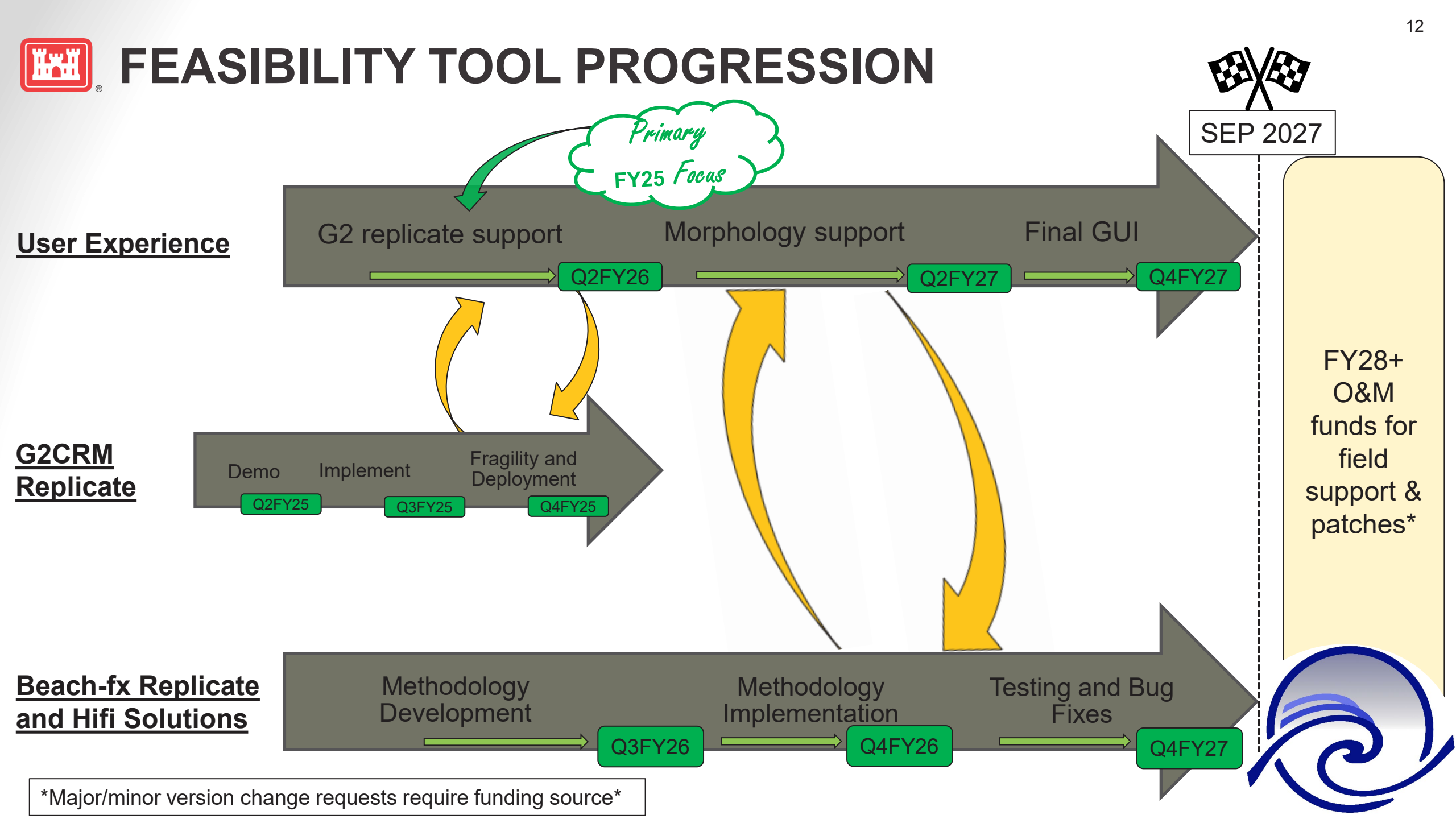
Study Timeline

Three months to completion (e.g., three years)

Functions

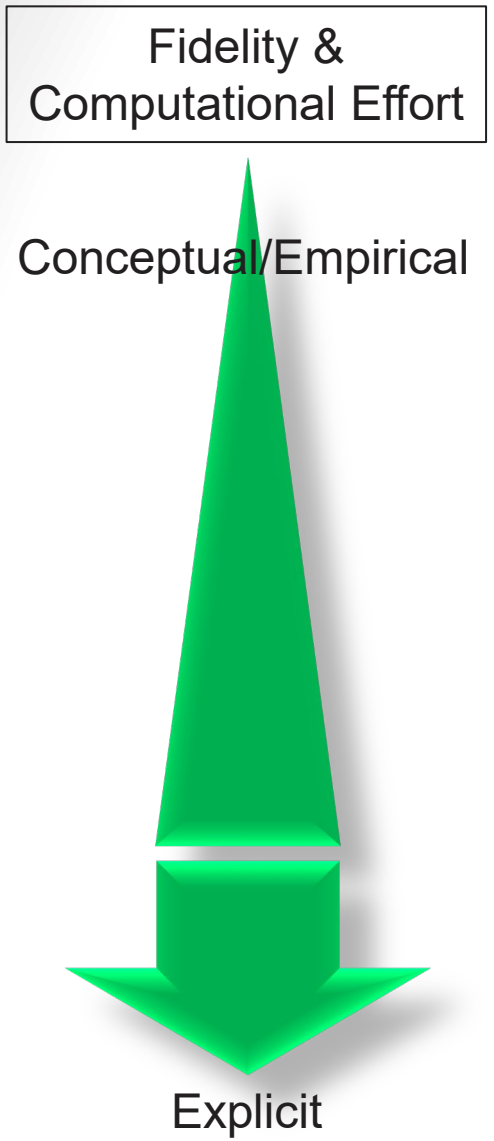
1. Input development and visualization
   - Hazards (Storm selection, lifecycle generation, hydrograph manipulations, 'sunny day' floods)
   - System performance (protective system and geometry, storage volume, structure responses, fragility)
   - Exposure elements and characteristics
2. Preproduction inputs and run checks
3. Production runs, consequence calculations, and output storage
4. Graphics and results reporting
5. Project archival

FEASIBILITY TOOL PROGRESSION



Major/minor version change requests require funding source

CHART FEAT APPROACHES

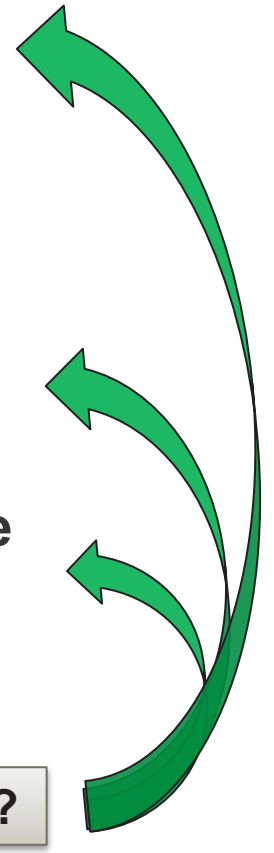


Simple Upland Flooding
- 1-d transect approach (e.g., G2CRM)
- Beta milestone, Sep 2025

Simple Upland Flooding with Morphology Change
- 1-d transect approach (e.g., Beach-fx)
- Seeking improved flooding response over Beach-fx

Complex Upland Flooding
- 2-d grid approach (e.g., Adcirc+STWAVE, Delft3d)

Complex Upland Flooding with Morphology Change
- 2-d grid approach (e.g., Delft3d, CMS)
- Computation challenges



Machine Learning Approaches?

REMAINING CHALLENGES

Software architecture to support broad application of CHART
- Transect-based simple flooding -> 2d coupled wave & hydrodynamics

Computational efficiency vs. fidelity, decision support needs, and user experience
- Scalable solutions to represent damage drivers and consequences
- Incorporation of additional damage drivers (e.g., infragravity waves, pluvial inputs, compound flooding characterization)

Morphology change implementation
- Temporal and spatial scales
- Beach recovery
- Built environment interactions
- Upland hydrodynamics under morphology change

CONCLUSIONS

Existing planning models are ill prepared to address contemporary coastal storm risk problems

- Districts require tools to address multiple hazards, protection systems, and risks

CHART will be a cloud-based software replacing G2CRM and Beach-fx and delivered in FY27

- Facilitated data handling and input development to improve efficiency
- Modular components to allow for scaled solutions and simple upgrades
- Analysis and visualization tools enhance transparency and understanding

Scoping Tool provides

- Enhanced alignment across the study team (risks to address)
- Improved likelihood of study success (Chief's Report to Congress)

Implementation and testing of the Feasibility Tool functionality underway this year

QUESTIONS

Image credit: FDEP, 2023