Gulf Coast Study, Phase 2

Impacts of Climate Change and Variability on Transportation Systems & Infrastructure

Tools and Findings

U.S. Department of Transportation
Climate Adaptation and Mitigation Workshop

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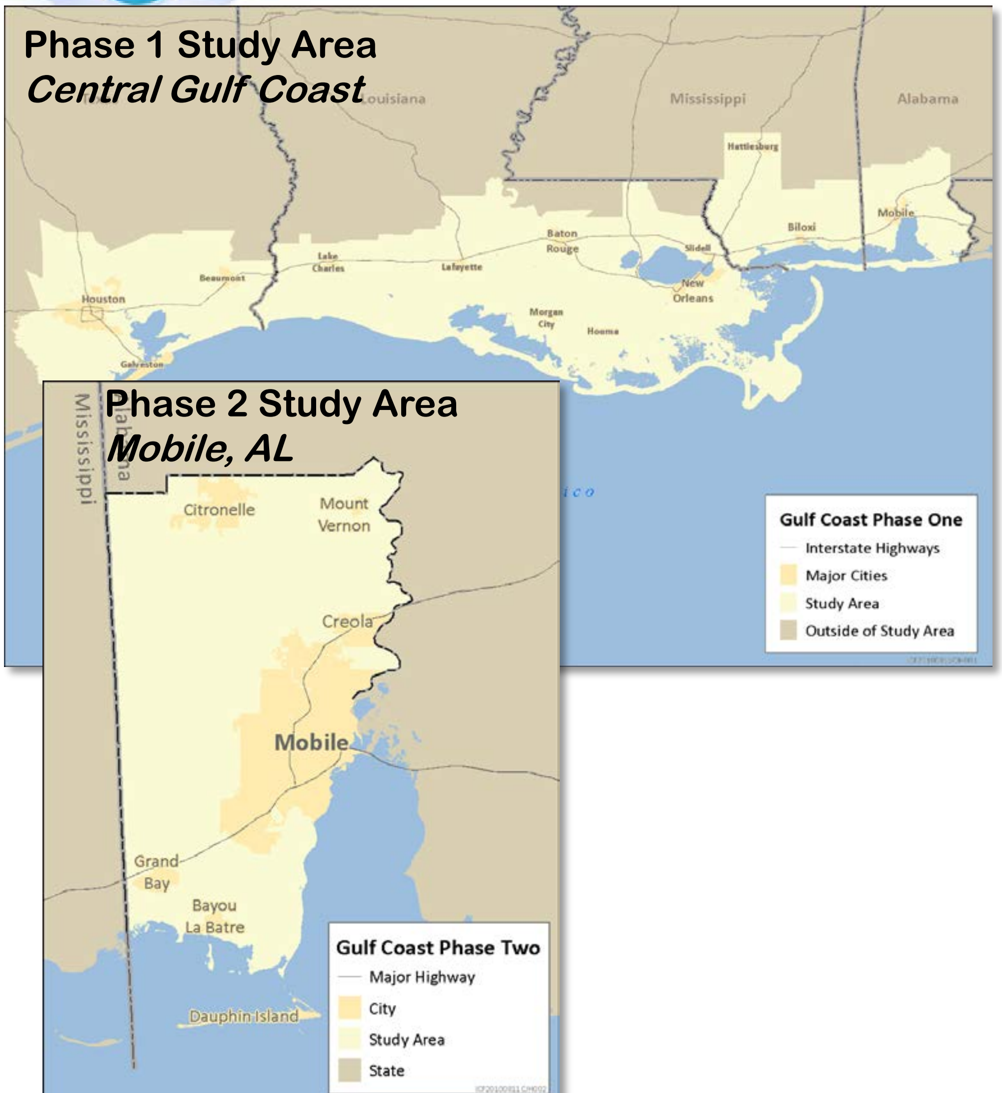
U.S. Department of Transportation
Federal Highway Administration

Comprehensive Assessment of Climate Impacts on Gulf Coast Transportation



- **DOT Climate Center study**
- **Managed by FHWA**
- **Key component of DOT effort to promote climate resilience at system and project levels**

Groundbreaking GC2 Processes

Addressed three of the main challenges facing climate adaptation in transportation:

1) **Developing climate projections for assessing transportation vulnerability in the future**
2) **Screening and assessing vulnerability of a large number of key assets**
3) **Applying engineering principles to develop adaptation options for vulnerable assets**

Projections: Challenges

Challenge:

Need data on future environmental conditions:

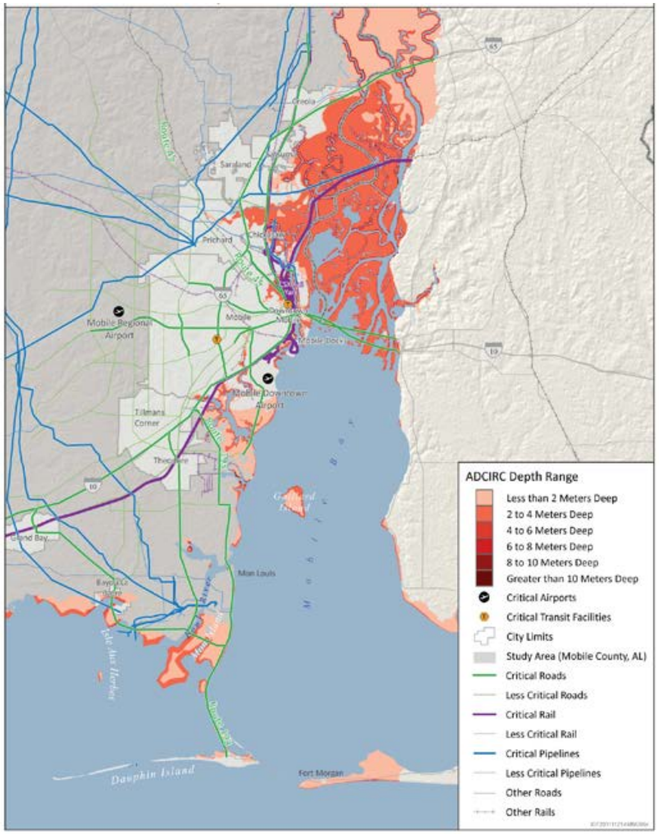
- Transportation assets have long service lives
- Historical data might not indicate future trends
- Projections from climate models may help inform future trends

Need design thresholds for a range of variables

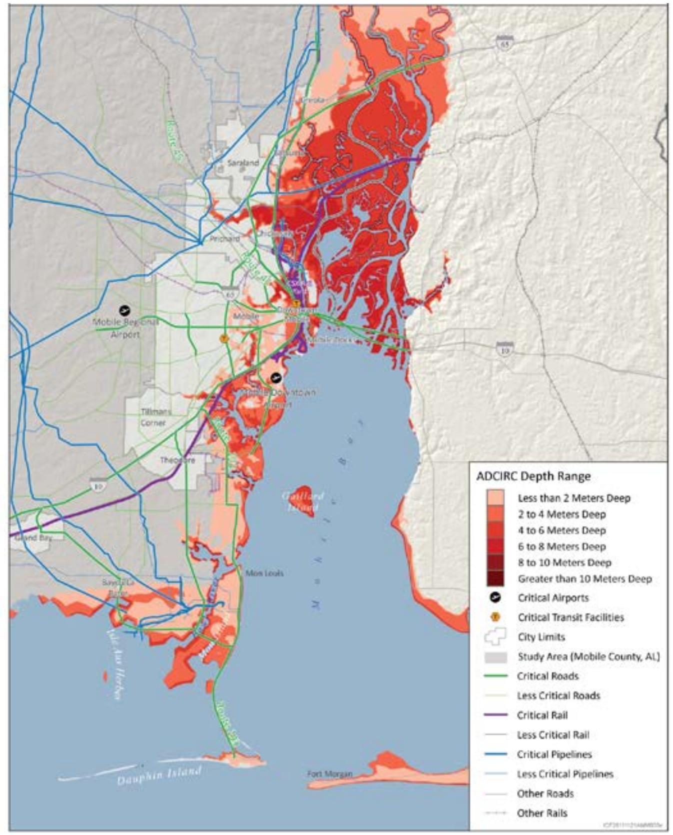
- Temperature (high temperature, # days per year above 95F)
- Precip (future 24-hr precip levels for 100-year events)
- Coastal conditions (future sea levels, storm surge inundation levels)

Projections: GC2 Solution
Temp, Precip; Storm Surge, Sea Level Rise

- Defined relevant climate variables
- Downscaled Temperature and Precipitation projections
- Storm scenarios based on historic hurricanes, with varying *track, intensity, sea level rise*
- Developed methods to bracket range of potential futures for vulnerability analysis



Hurricane Katrina, Natural Path Scenario



Hurricane Katrina, Shifted Path Scenario, 0.75 meter Sea-Level Rise

Projections: GC2 Products
CMIP Tool (Temp, Precip)

Transferable tool: CMIP Tool

Projected Changes in Temperature Conditions

e.g. Mobile, AL

Hide Details

Click to jump to derived variables related to...

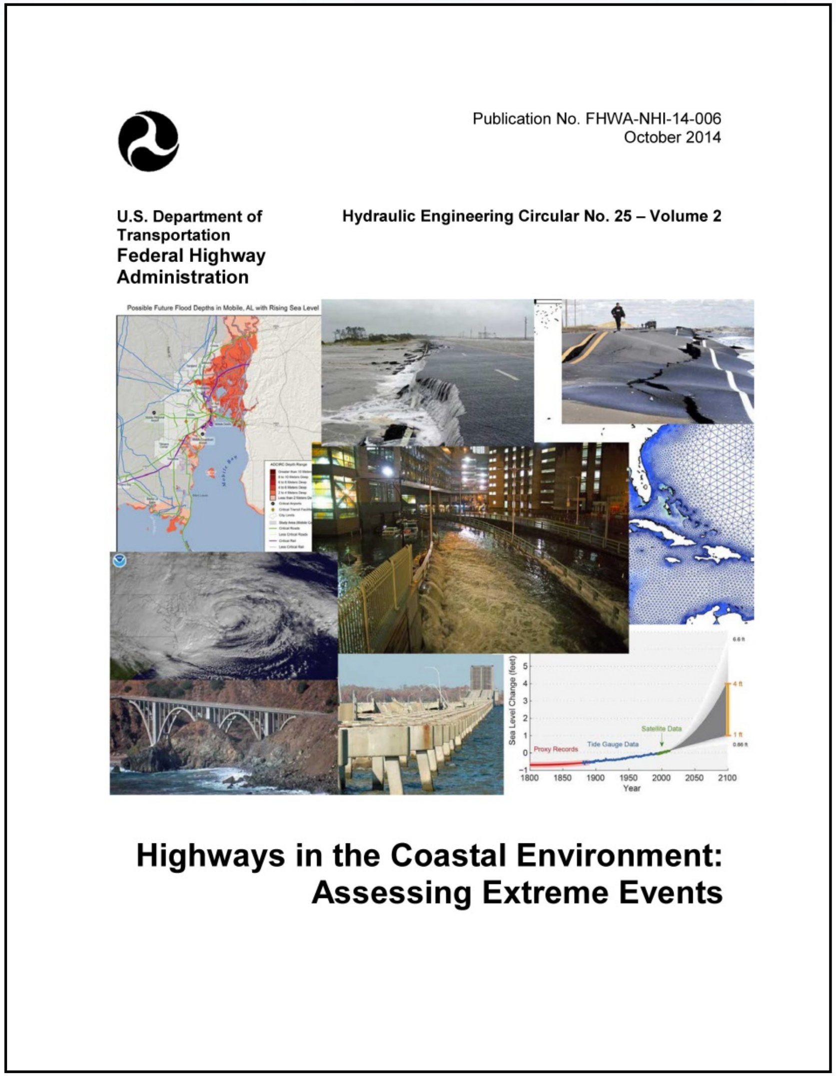
Annual Averages | Annual Extreme Heat | Seasonal Extreme Heat | Extreme Cold

Click column headings for additional info	Baseline (1961-2000) *Observed Value*	*Modeled Value*	Mid-Century (2046-2065) *Projected Value*	*Change from Baseline*	*% Change from Observed*	*Model Uncertainty Range (95% Confidence Interval)* *Low*	*High*	*Projected V*
Annual Averages								
Average Annual Mean Temperature	52.1 °F	51.7 °F	57.3 °F	5.2 °F	10%	56.6 °F	58.0 °F	59.5 °
Average Annual Maximum Temperature	62.2 °F	62.0 °F	67.5 °F	5.3 °F	8%	66.7 °F	68.2 °F	69.7 °
Average Annual Minimum Temperature								49.3 °
Annual Extreme Heat *(click + signs along left to v*								
Hottest Temperature of the Year								104.0 °
"Very Hot" Day Temperature (Very Hot defi 95th Percentile Temp)								97.1 °
"Extremely Hot" Day Temperature (Extremel defined as 99th Percentile Temp)								101.9 °
Average Number of Days per Year Above Baseline "Very Hot" Temperature (89.0°F)	18 days	18 days	64 days	45 days	248%	56 days	72 days	82
Average Number of Days per Year Above Baseline "Extremely Hot" Temperature (93.7°F)	4 days	4 days	33 days	29 days	795%	24 days	42 days	60

Excel Spreadsheet Tool
- Downloads Temperature and Precipitation projections
- Processes downscaled climate projections into T, P variables relevant to transportation projects
- Overcomes major need for easy access to climate data

Projections: GC2 Products
Storm Surge, Sea Level Rise

- ***Highways in the Coastal Environment: Assessing Extreme Events*** *(released 10.31.2014)*
- **How to incorporate extreme events and climate change into coastal highway designs**
- **Focus on sea level rise, storm surge, wave action**
- **3 levels of effort approaches, case studies**


Publication No. FHWA-NHI-14-006
October 2014

U.S. Department of Transportation
Federal Highway Administration

Hydraulic Engineering Circular No. 25 – Volume 2

Highways in the Coastal Environment: Assessing Extreme Events

Screening: Challenges

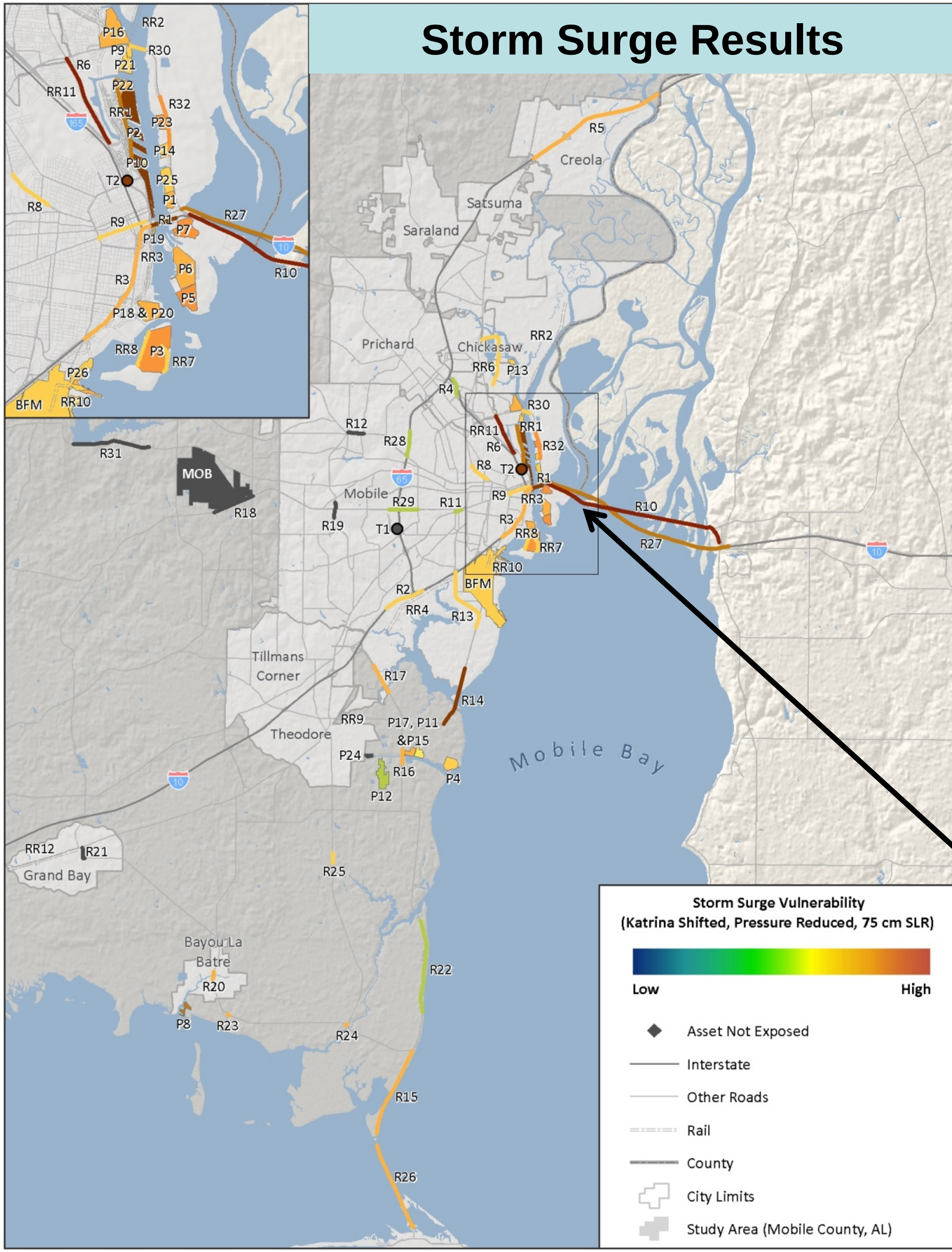
Challenges:

- **Need way to prioritize which assets to study for vulnerability**
- **Need method to quickly determine sensitivity of diverse set of assets to particular climate stressors**
- **Need procedure to efficiently develop vulnerability “scores” for large number of assets**

Using Indicators to Score Vulnerability

Exposure	Sensitivity	Adaptive Capacity
• **Temp**-Days above 95°F • 24-hour **precipitation** • **Storm surge** height • **Wind** speed exceeds threshold above which impacts may occur (yes/no) • Inundated by **sea level rise** (yes/no)	• **Temp** - Pavement binder, traffic (roads) • **Precip** - FEMA flood zones, ponding, surface permeability (all modes) • **Storm surge** – Height & condition (bridges), electric signaling & soil type (rail), access (transit) • **Wind** - Building height, materials, roof type; road sign or signal density (road and rail) • **Sea level rise** – Drainage (air), protection (transit, roads)	• **Speed to recover asset** – cost of improvement (bridges), identified as a priority in emergency planning (rail, air, transit) • **Redundancy** - detour length (bridges, air), number of terminals/ runways (air), ability to reroute (transit and rail), rail yard interchange utility (rail) • **System disruption duration** (climate variable-specific)

Screening: GC2 Results



- All modes except airports have assets highly vulnerable to sea level rise, storm surge
- Airports and rail vulnerable to extreme heat. Brownouts could affect ports
- Transit has low vulnerability due to flexibility of bus system; pipelines have low vulnerability as most are buried

Example: The Causeway (R10)

- 17-29 ft of storm surge/waves
- Damaged in past, unprotected, low approach, low embankment
- High replacement cost

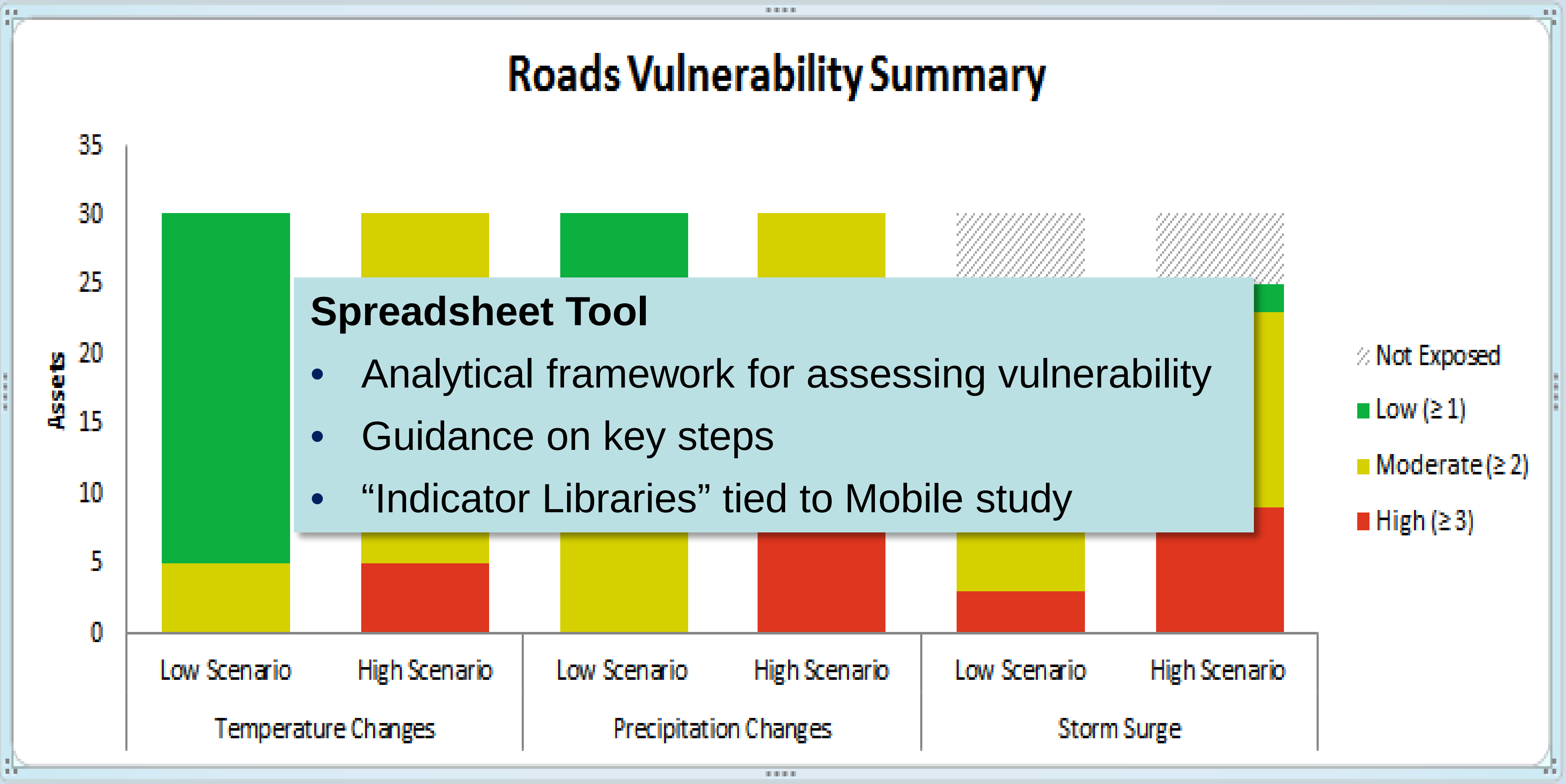
Screening: GC2 Products

Vulnerability Assessment Scoring Tool (VAST)

View results for...

Roads

Generate PDF



Spreadsheet Tool

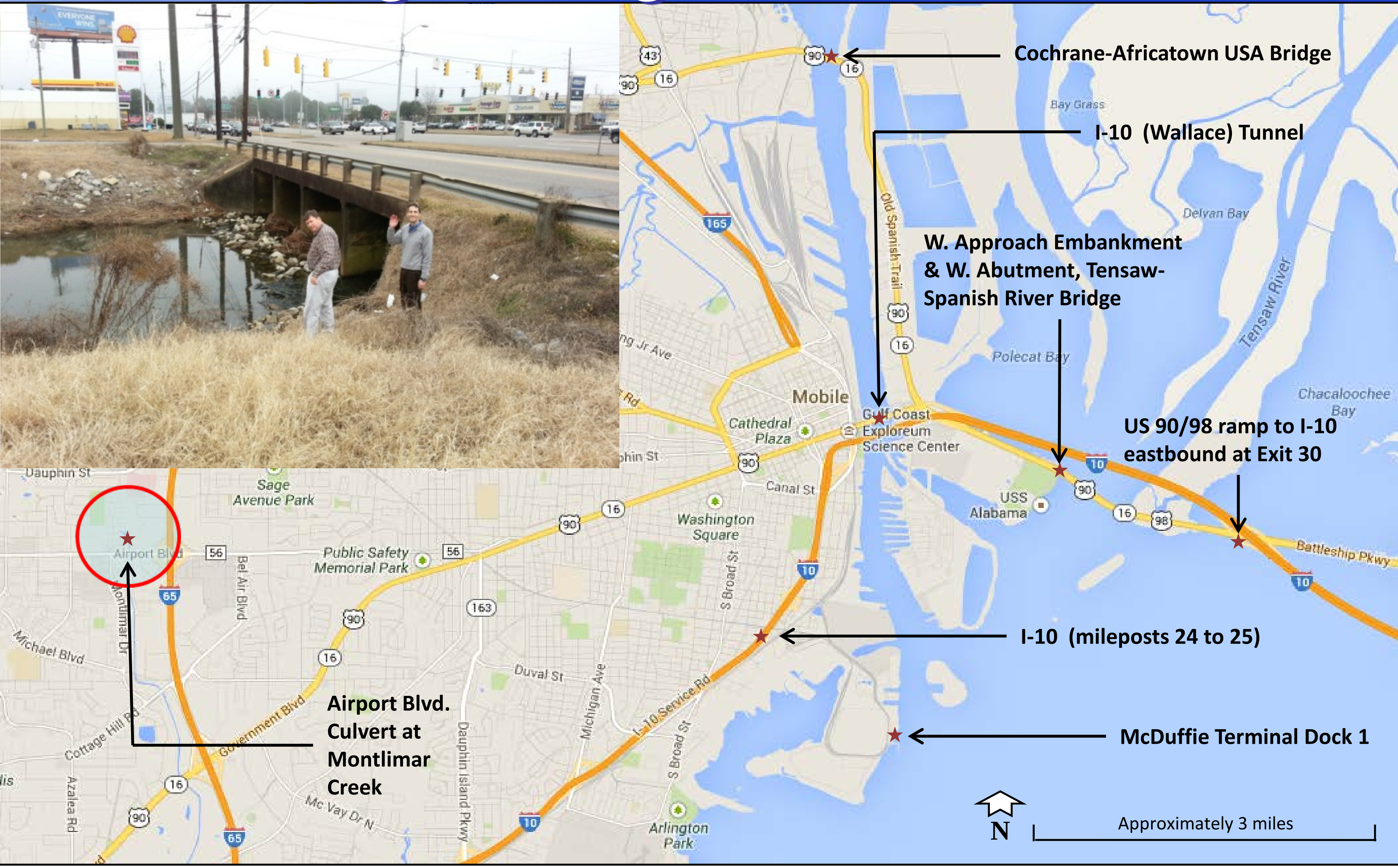
- Analytical framework for assessing vulnerability
- Guidance on key steps
- “Indicator Libraries” tied to Mobile study

Engineering: Challenges

Problems:

- **Need analytical process for assessing vulnerability of assets and developing solutions**
- **Need method for using climate projections to inform traditional engineering design processes**

Engineering: GC2 Solution
Engineering Case Studies



Engineering: GC2 Solution
Case Studies Covered Multiple Modes

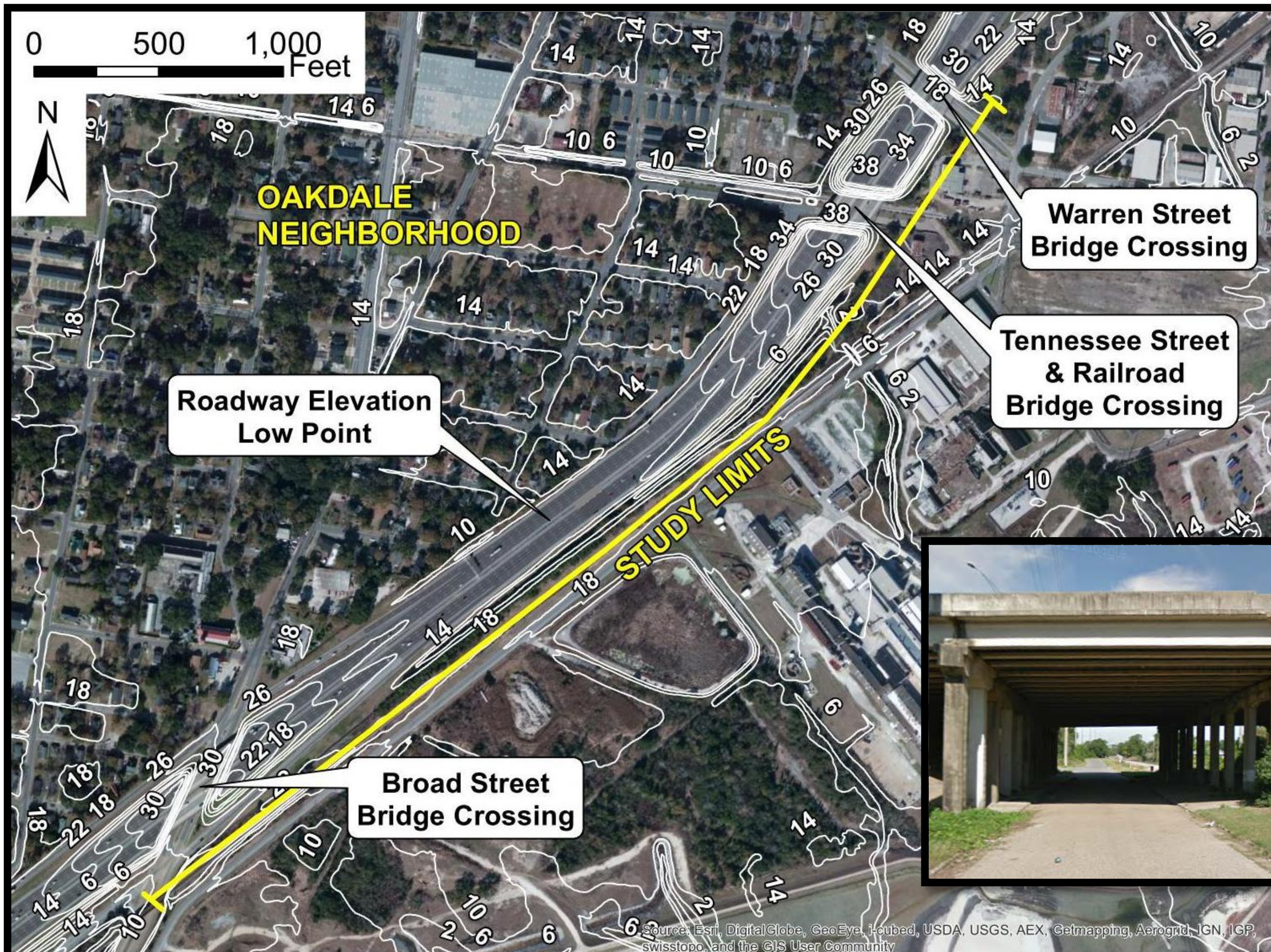
Climate Stressor	Asset Type	Damage Mechanism	Asset Location
Precipitation	Culvert	Overtopping	Airport Blvd @ Montlimar Creek
Sea Level Rise	Bridge	Clearance	Cochrane Africatown USA Bridge
Sea Level Rise	Slope	Slope erosion	US 90/98 Tensaw Bridge
Storm Surge	Pier	Waves	McDuffie Coal Terminal, Dock 1
Storm Surge	Bridge	Waves/Scour	US 90/98 Tensaw Bridge
Storm Surge	Bridge	Wave forces	Exit 30, EB Ramp I-10 Bayway Brdg
Storm Surge	Roadway	Flood/erosion	I-10, Between Mileposts 24 and 25
Storm Surge	Tunnel	Flood	Wallace Tunnel
Temperature	Pavement	Ruts, Heaves	Generic
Temperature	Rail	Buckling	Generic
All	O&M	Wear/tear	Generic

Engineering: GC2 Products
11 Step "Process"

Eleven-Step Adaptation Process

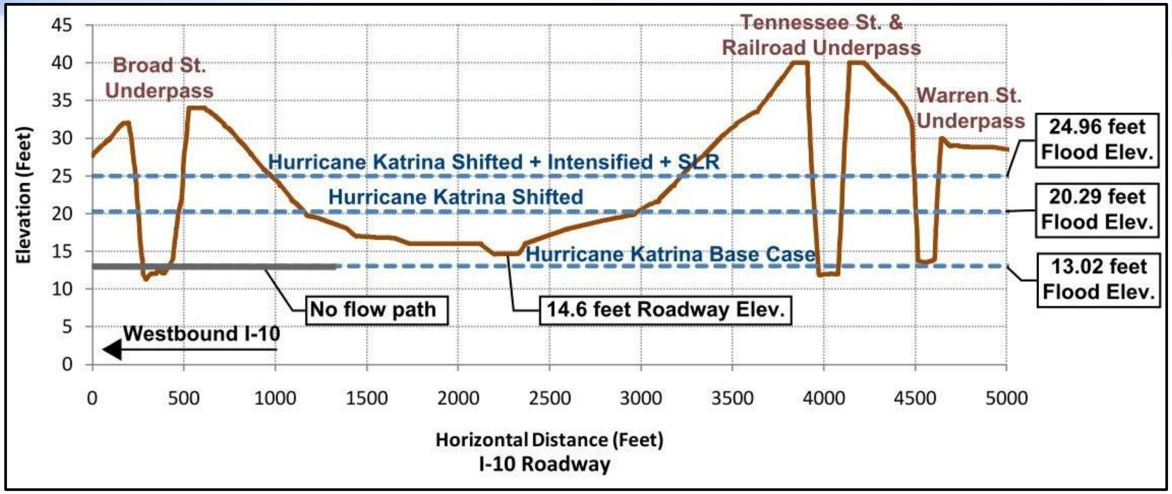
1. Describe the site context
2. Describe the existing or proposed facility
3. Identify environmental factors that may impact infrastructure components
4. Decide on climate scenarios and determine magnitude of changes
5. Assess performance of the existing or proposed facility
6. Develop adaptation option(s)
7. Assess performance of the adaptation options
8. Conduct an economic analysis
9. Evaluate additional decision-making considerations
10. Select a course of action
11. Plan and conduct on-going activities

I-10 – Mileposts 24 to 25
Road Alignment Exposure to Storm Surge



I-10 – Mileposts 24 to 25
Road Alignment Exposure to Storm Surge

Step 4: Climate scenario – Coastal storm surge with sea level rise added to most extreme scenario

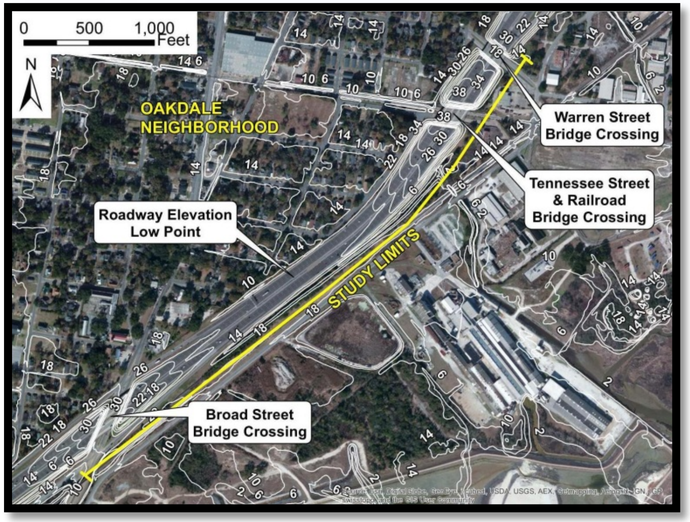


Step 5: Assess Facility Performance

Surge Scenario	Overtop I-10?	Inland Flooding Acre-Feet (Cu.Meters)	Flow Velocities at Tenn. St. &Rail Underpass fps (m/s)
Hurricane Katrina Base Case Scenario	NO	40 (51,700)	3.4 (1.0)
Hurricane Katrina Shifted Scenario	YES	1,300 (1,581,000)	6.6 (2.0)
Hurricane Katrina Shifted + Intensified + Sea Level Rise (SLR) Scenario	YES	2,800 (3,412,000)	6.8 (2.1)

Permissible velocities: Grass: 2 to 4 fps; RR ballast: 3 to 6 fps; Concrete: 18 fps

I-10 – Mileposts 24 to 25
Road Alignment Exposure to Storm Surge



Step 6: Develop Adaptation Options

- Harden one or more of the underpasses
- Armor I-10 roadway embankment
- Raise the roadway

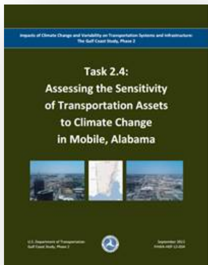
Lessons Learned

- Roadway embankment breaching is an area with little research data on prediction methods.
- Additional erosion protection should be considered when designing roadway crossings that could be subjected to reverse flow from storm surges.

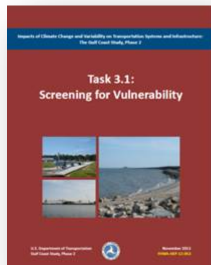
Gulf Coast Phase 2 Project Products

2010 — 2011 — 2012 — 2013 — 2014

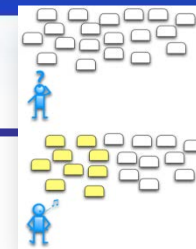
Assessing the Sensitivity of Transportation Assets to Climate Change



Screening for Vulnerability

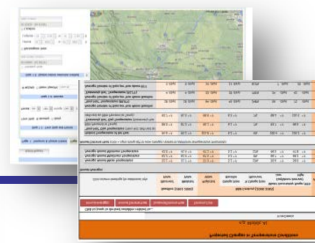


7 videos

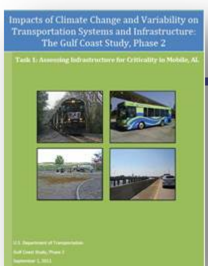


Assessing Criticality in Transportation Adaptation Planning

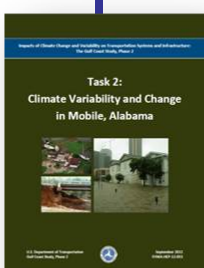
Transportation Climate Change Sensitivity Matrix



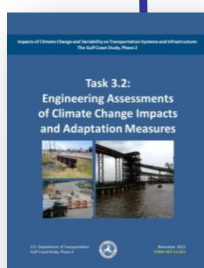
CMIP Climate Data Processing Tool



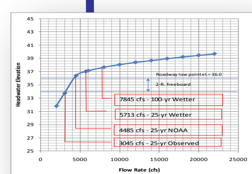
Assessing Infrastructure Criticality in Mobile, AL

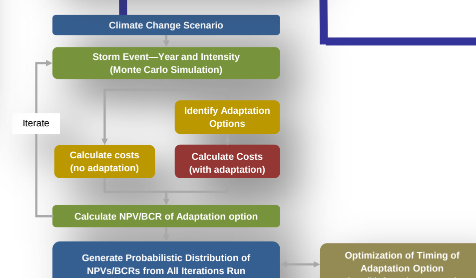


Climate Variability and Change in Mobile, AL

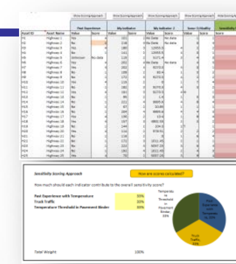


Engineering Assessments of Climate Change Impacts and Adaptation Measures





Engineering Analysis and Assessment



Vulnerability Assessment Scoring Tool (VAST)

GC2 Products: Where Do I Start?

Feedback

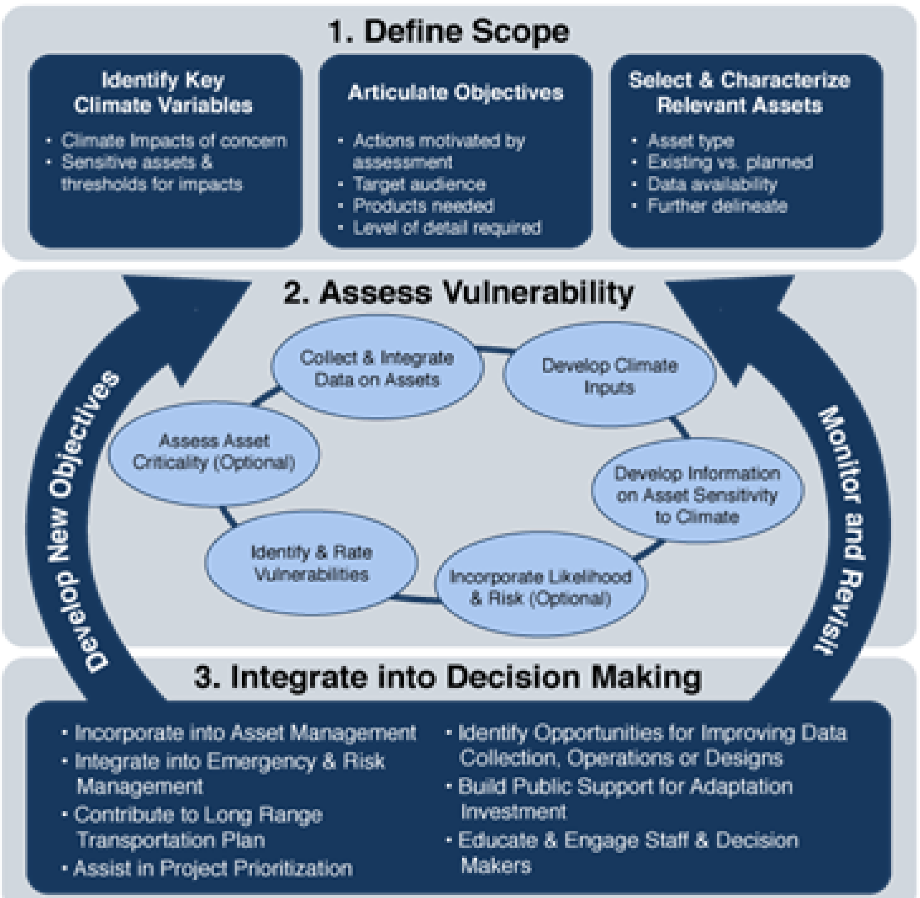
For more information, please contact:

- Robert Kafalenos
- Robert Hyman
- Rebecca Lupes
- Heather Holsinger
- Tina Hodges

Virtual Framework for Vulnerability Assessment

This section of FHWA's Climate Change Adaptation website provides resources, tools, and guidance to help local and regional transportation agencies implement the Federal Highway Administration's (FHWA's) Climate Change and Extreme Weather Vulnerability Assessment Framework, a guide to assessing the vulnerability of transportation assets to climate change and extreme weather events.

The section's structure follows that of the framework as shown in the graphic below. *Click on any area of the graphic to go to its corresponding module in the Virtual Framework site, or use the page list in the navigation bar at left to navigate through the modules.* Each module includes an overview, a summary of key steps, an introductory video, and links to case studies, tools, and other resources. Several of the modules include tools developed by FHWA to help transportation agencies implement their assessments.



For More Information

Webinar Series

Building a Climate Resilient Transportation System

Tuesdays starting February 10th

fhwa.dot.gov/environment/climate_change/adaptation/webinars/

Virtual Adaptation Framework

fhwa.dot.gov/environment/adaptationframework

fhwa.dot.gov/environment/climate_change/adaptation/