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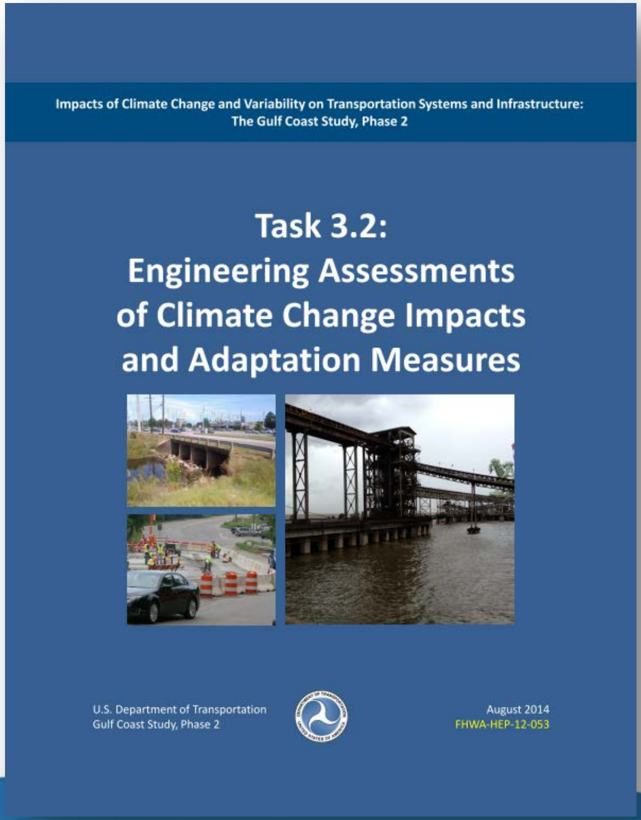
Changing Climate and Our Infrastructure

The Gulf Coast Phase 2 Case Studies on Transportation Infrastructure Impacts

Gulf Coast Study

- Goal of the Study was to develop a better understanding of potential climate change impacts of transportation infrastructure and identify adaptation strategies.
- Phase 1 (completed in 2008) focused on the central gulf coast region
  - General trends and potential infrastructure vulnerabilities
- Phase 2 (completed in 2014) focused specifically on the Mobile region
  - Task 1: Assessed Criticality of Infrastructure
  - Task 2: Development of Climate Projections
  - Task 3: Vulnerability Study



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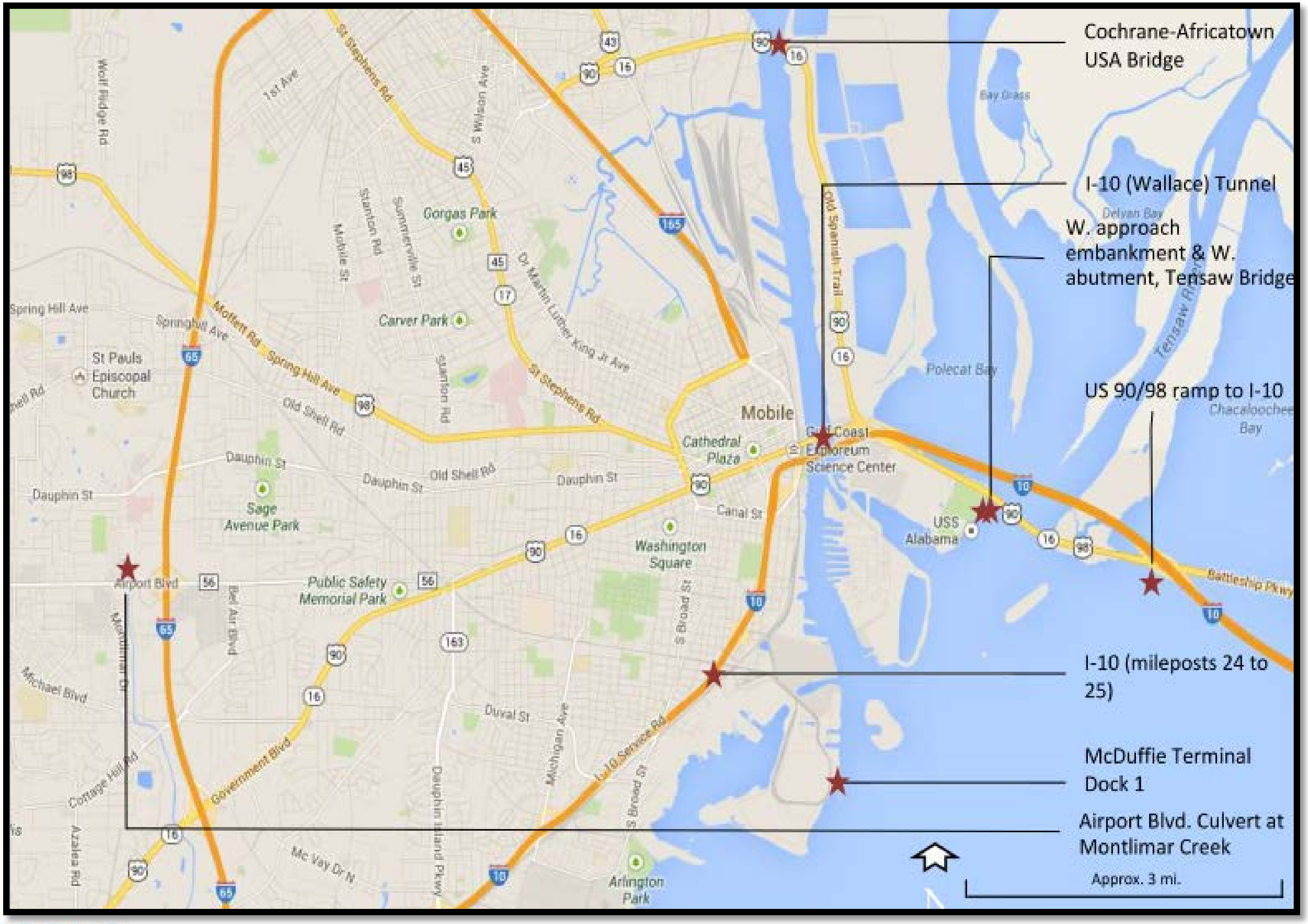
Gulf Coast Phase 2 Study

- Study focused on Mobile, AL
- Funded by USDOT Center for Climate Change and Environmental Forecasting
- Managed by FHWA
- Project Partners:
  - Mobile Metropolitan Planning Organization
  - South Alabama Regional Planning Commission
  - Alabama DOT
  - City and County of Mobile
- Report Authors:
  - Parsons Brinckerhoff
  - ICF International
  - South Coast Engineers
- Independent Reviewers

Vulnerability Study

- Development of a process for evaluation of current asset vulnerability to climate change and develop adaptation options and measures for selection
- 11 case studies performed
  - Precip. impacts on a culvert
  - Sea level rise on a bridge
  - Wave impact on an approach roadway
  - Storm surge overtopping of a roadway
  - Storm surge impact on a port
  - Storm surge impact on a bridge
  - Storm surge impacts on tunnels
  - Storm surge impacts on an abutment
  - Temperature impacts on pavements
  - Temperature impacts on rail
  - Impacts on operations and maintenance activities

Vulnerability Case Studies



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Study / Adaptation Process

- General Process for Transportation Facility Adaptation Assessments
  - Flexible for use across an array of changing climate conditions
    - Study considered Precipitation, Sea Level Rise, Storm Surge, and Temperature
- Process as developed is intended to weight multiple future climate conditions, design and evaluate adaptation options, and weight the options through a cost-benefit analysis

Adaptation

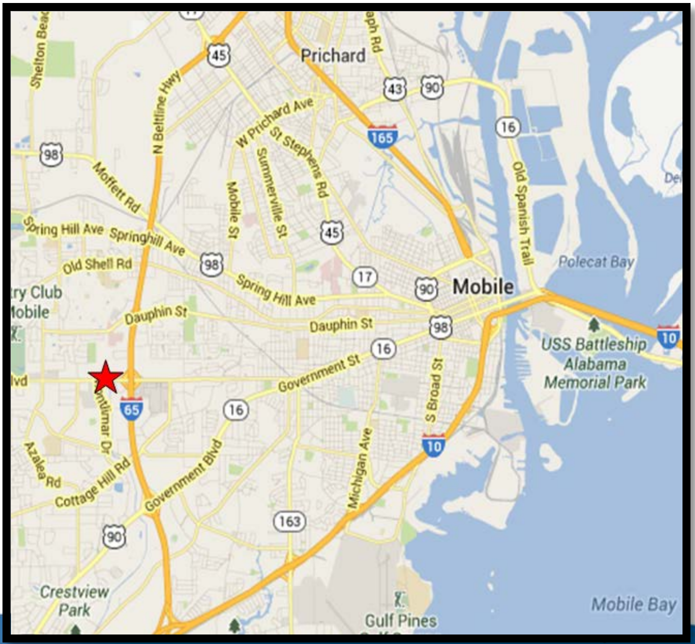
- Actions taken to reduce the vulnerability of natural and human systems to increase system resiliency in light of expected climate change.

The Process

1. Describe the Site Context
2. Define the Existing / Proposed Facility
3. Identify Climate Stressors of Concern
4. Decide on Climate Scenarios and Magnitude of Change
5. Assess Performance of Existing / Proposed Facility
6. Identify Adaptation Options
7. Assess Performance of Adaptation Options
8. Conduct an Economic Analysis
9. Evaluate Additional Decision-Making Conditions
10. Select a Course of Action
11. Plan and Conduct Ongoing Activities

Airport Boulevard Culvert Study

- Goal of study is to determine the impacts of projected precipitation changes on system hydrology
- Four precipitation scenarios:
  - Observed precipitation values
  - The NOAA Atlas 14 90% Upper Confidence Limit
  - “Wetter” narrative (projected climate data)
  - “Drier” narrative (projected climate data)
- 24-hr. precipitation depths used in all scenarios



Precipitation in the Gulf Coast

24-hour Storm Event Return Period	Observed (Model Baseline) 1980–2009 (inches)	NOAA Average Baseline (inches)	NOAA 90% Upper Conf. Limit	"Wetter" Narrative			"Drier" Narrative		
				2010–2039 (inches)	2040–2069 (inches)	2070–2099 (inches)	2010–2039 (inches)	2040–2069 (inches)	2070–2099 (inches)
100-yr storm	13.5	14.9	18.9	21.0	20.4	22.3	12.6	14.2	13.4
50-yr storm	12.5	12.8	15.9	19.1	18.5	20.2	11.7	13.1	12.5
25-yr storm	10.1*	10.9	13.4	15.7*	15.2*	16.7*	9.3*	10.4*	9.9*
20-yr storm	9.5	Unavailable	Unavailable	14.8	14.4	15.8	8.8	9.9	9.4
10-yr storm	8.5	8.6	10.1	12.9	12.5	13.7	7.9	8.8	8.4
5-yr storm	7.1	7.1	8.3	10.5	10.3	11.1	6.6	7.3	7.0
2-yr storm	4.8	5.3	6.2	6.7	6.7	7.1	4.4	4.8	4.6

* Asterisks denote interpolated values

Equivalent Present Day Return Periods for Projected Future Precipitation Values

Existing NOAA 24-hour Storm Event Return Period	Wetter Narrative			Drier Narrative		
	2010–2039 (year storm)	2040–2069 (year storm)	2070–2099 (year storm)	2010–2039 (year storm)	2040–2069 (year storm)	2070–2099 (year storm)
100-yr storm	325	292	408	47	74	59
50-yr storm	227	201	281	36	55	46
25-yr storm	108	96	137	15	23	19
20-yr storm	87	78	111	12	19	16
10-yr storm	52	46	65	8	12	10
5-yr storm	24	22	29	4	6	5
2-yr storm	4	4	5	1	1	1

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Montlimar Creek Watershed

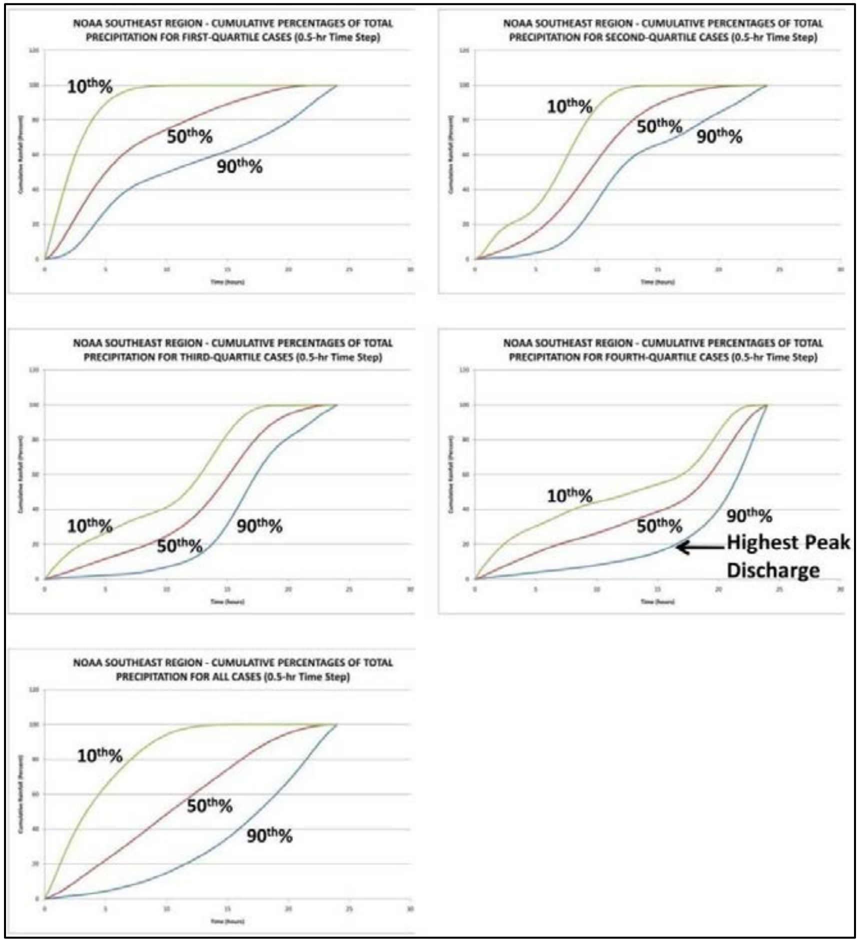
- Montlimar Creek is a man-made stream channel that drains Wragg Swamp
- 3.3 square mile DA
- Tc of 1.5 hours

24-hour Storm Event Return Period	Observed 1980–2009 w/ Current LU (cfs)	Observed 1980–2009 w/ Future LU (cfs)	NOAA 90% Upper Conf. Limit w/ Future LU (cfs)	"Wetter" Narrative w/ Future LU			"Drier" Narrative w/ Future LU		
				2010–2039 (cfs)	2040–2069 (cfs)	2070–2099 (cfs)	2010–2039 (cfs)	2040–2069 (cfs)	2070–2099 (cfs)
100-yr storm	4,361.8	4,484.6	6,553.8	7,347.1	7,122.3	7,844.8	4,137.9	4,754.8	4,445.1
50-yr storm	3,975.0	4,097.9	5,404.3	6,626.9	6,396.8	7,047.2	3,789.3	4,330.8	4,097.9
25-yr storm	3,045.1*	3,170.4*	4,445.1	5,328.1*	5,138.7*	5,712.9*	2,899.1*	3,325.2*	3,131.6*
20-yr storm	2,813.4	2,938.1	Unavailable	4,984.9	4,831.7	5,369.3	2,664.8	3,092.6	2,899.1
10-yr storm	2,424.8	2,549.4	3,170.4	4,253.3	4,097.9	4,560.1	2,316.6	2,664.8	2,510.5
5-yr storm	1,889.0	2,008.1	2,467.1	3,325.2	3,247.6	3,557.5	1,817.4	2,086.9	1,968.4
2-yr storm	1,030.8	1,134.6	1,665.5	1,855.0	1,855.0	2,008.1	987.7	1,134.6	1,061.0

* Asterisks denote flows derived from interpolated precipitation values

Airport Boulevard Culvert Study

- TR-20 was used for runoff predictions
- Temporal distributions considered included:
  - SCS Type II and Type III storms
  - NOAA distributions developed from actual gauge data for a range of storm types
- Regression equations were used to calibrate ex. cond. TR-20 model
- HY-8 used for hydraulics



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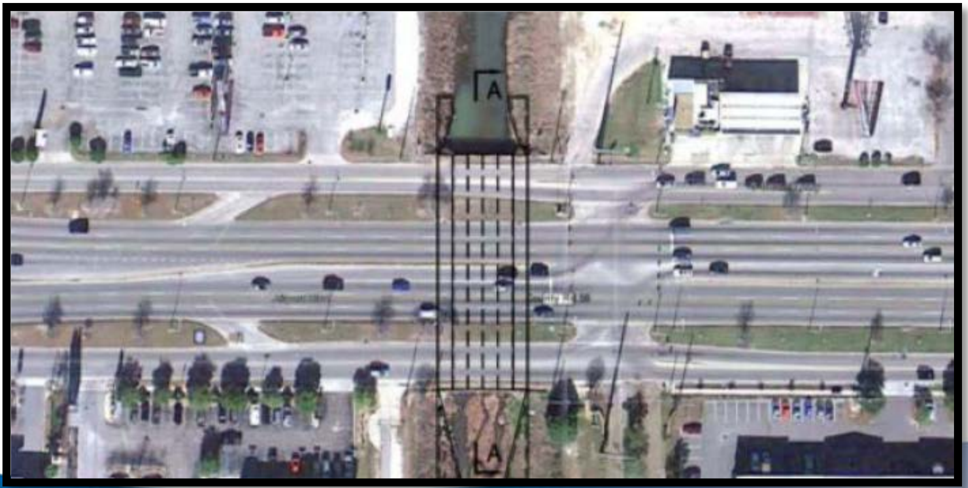
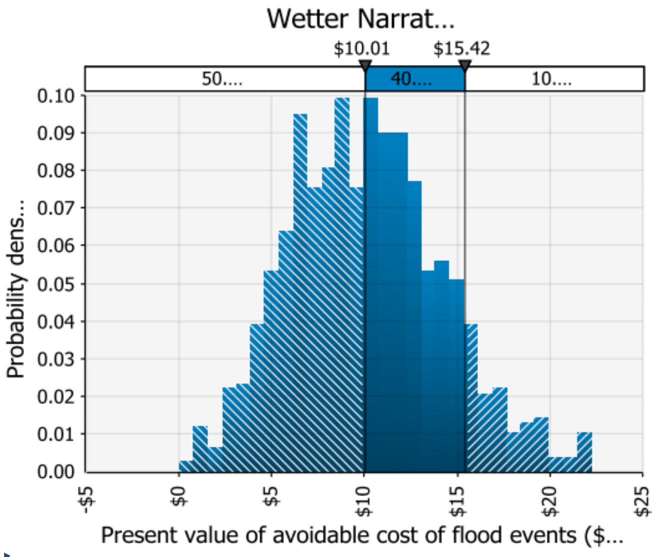
Facility Performance / Adaptation Options

- 4 Cell 12’ x 8’ box culverts
- Minimal cover
- Meets current 25-year storm performance
- Does not meet performance criteria for either of the projected climate conditions
- Primary evaluation criteria was roadway overtopping



- Adaptation Option #1
  - Expansion of culvert system with 2 supplemental cells
  - Improved overtopping performance to meet low climate condition
- Adaptation Option #2
  - Replacement of system with triple cell 21’ x 9’ box culverts
  - Meets all overtopping performance criteria

Economic Analysis



- Monte Carlo approach
  - Thousands of simulated outcomes over a 30-year evaluation period
- Benefits defined as flood costs avoided
  - Loss of Service Costs
  - Damage to Private Properties due to Backwater
  - Clean-up Maintenance Costs
  - Repair and Replacement Costs
- Cost avoided determined based upon costs incurred at the base case – costs incurred at each adaptation option
- Probabilistic distribution of results generated from analysis

Study Conclusion

- Results of Monte Carlo Economic Analysis

	Option One	Option Two
Scope of improvement	Six cell, 12’ span x 8’ rise culvert	4 cell, 21’ span x 9’ rise culvert
Present value of costs	$1.7m	$2.5m
Present value of benefits [avoided traffic congestion costs]	$6.0m *($3m to $12.7m)*	$6.5m *($3.2m to $14.4m)*
Net present value	$4.3m *($1.3m to $11.0m)*	$4m *($0.7m to $11.9m)*
Benefit-cost ratio	3.5 *(1.7 to 7.3)*	2.6 *(1.3 to 5.8)*

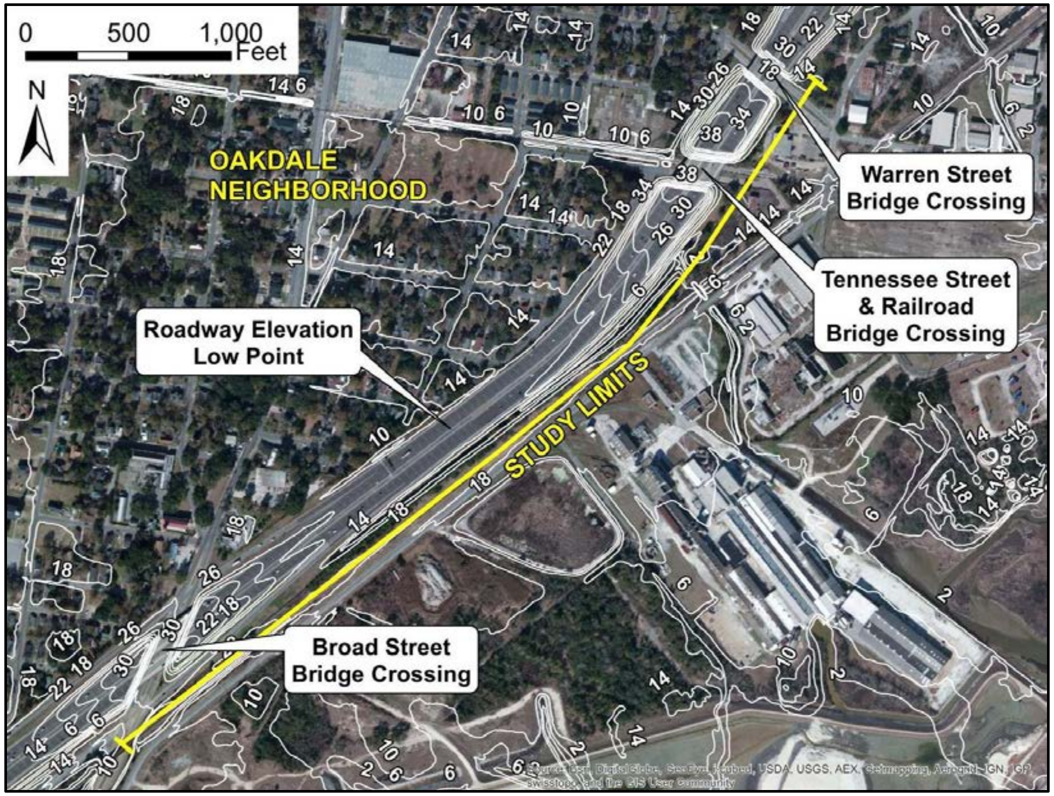
Airport Boulevard Culvert Study

Lessons learned:

- Greatest challenge is coordination with climate science & models
  - Availability of climate data in engineering formats
    - CMIP Climate Processing Tool
    - SimCLIM
  - Drainage area limited to moderate sized catchments for which TR-20 and 24-hour storm modeling is appropriate
  - Temporal distributions relied on current / historical observations
- Development of methods to project or scale IDF curves for study of smaller catchments and temporal distributions

The I-10 overtopping study

- Goal of study is to determine the potential for and impacts of storm surge overtopping of I-10
  - Study impacts to existing infrastructure
  - Develop adaptation options for improvement
- Storm surge results from ADCIRC modeling



Storm Surge in the Gulf Coast

- **Design storms and modeled future storms**
  - GC2 involved selecting an historic weather event (Hurricanes Katrina & George) and altering its characteristics to produce permutations (scenarios) that local stakeholders can relate to

- **The GC scenarios**
  - Katrina’s observed path
  - Georges observed path
  - Katrina’s path shifted to the east (worst case path for Mobile)
  - Katrina’s path shifted with higher sustained winds and a lower central pressure

Storm Surge in the Gulf Coast

Storm Surge Scenario	Storm Surge Model Results			Wave Model Results		
	Water Surface Elevation Feet (Meters)	Sustained Wind Speed MPH (KPH)	Depth Averaged Current Knots (KPH)	Wave Height Feet (Meters)	Peak Wave Period Seconds	Wave Direction Compass Degrees
Hurricane Katrina Base Case	12.8 (3.9)	74 (119)	2.6 (4.8)	6.2 (1.9)	7.7	7
Hurricane Katrina Shifted	20.0 (6.10)	104 (167.3)	4.3 (8.0)	8.9 (2.7)	8.3	7
Hurricane Katrina Shifted + Intensified + SLR	24.9 (7.59)	110 (177.0)	4.4 (8.1)	4.4 (1.3)	8.3	7
FEMA Base Flood Elevation (100-yr Flood Level)	17.0 (5.2)	-	-	-	-	-

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ADCIRC Modeling Results

- Study was focused on impacts to I-10, damage potential to underpasses, and breaching of embankment
- Neighborhood flooding was considered as economic impact

Katrina Shifted

Katrina Base Case

Katrina Shifted + SLR + Intensification

Evaluation Results / Adaptation Options

- Overtopping of I-10 and slower release of flows through underpasses inundated community for longer than would have occurred with natural drainage pathways
- Study concluded that the I-10 embankment was prone to breaching under the Katrina Shifted and the Katrina Shifted + Intensified + SLR storm scenario
- Study concluded that underpasses were prone to scouring due to open grass medians where piers were located
- Adaptations Evaluated:
  - Raising of I-10 roadway to prevent breaching and lessen neighborhood flooding
  - Hardening of I-10 roadway with rock riprap
  - Hardening of median areas for pier protection

The I-10 overtopping study

- **Issues with this approach**
  - Approach as utilized does not correlate storm events to return period probabilities
  - Approach does not directly correlate changes in storm intensity to climate projection scenarios
- **Possible solutions**
  - Increasing storm sample size and perform EST or Monte Carlo simulation to determine return periods.
    - Replication of the FEMA methodology with altered conditions
  - Methods for correlating surge changes to climate scenarios is a knowledge gap

http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/gulf_coast_study/

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Adaptation

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Feedback

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- **Tina Hodges**

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Gulf Coast Study

PDF files can be viewed with the Acrobat® Reader®

To better understand potential climate change impacts on transportation infrastructure and identify adaptation strategies, the U.S. Department of Transportation (U.S. DOT) is conducting a comprehensive, multi-phase study of climate change impacts in the Central Gulf Coast region. This region is home to a complex multimodal network of transportation infrastructure and several large population centers, and it plays a critical national economic role in the import and export of oil and gas, agricultural products, and other goods. The study is sponsored by the U.S. DOT's Center for Climate Change and Environmental Forecasting in partnership with the U.S. Geological Survey (USGS) and is managed by FHWA.

Phase 1

Phase 1 (completed in 2008) examined the impacts of climate change on transportation infrastructure at a regional scale, investigating risks and impacts on coastal ports, road, air, rail, and public transit systems in the central Gulf Coast, with a study area stretching from Houston/Galveston, Texas, to Mobile, Alabama. The study assessed likely changes in temperature and precipitation patterns, sea level rise, and increasing severity and frequency of tropical storms. Phase 1 then explored how these changes could impact transportation systems. The final report can be found here.

Phase 2

Phase 2 focuses on the Mobile, Alabama region, with the goal of enhancing regional decision makers' ability to understand potential

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