



# Addressing Resilience in Project Development

## Barrier Island Roadway Overwashing from Sea Level Rise and Storm Surge

This study focused on the vulnerability of a Florida barrier island roadway to overwashing from sea level rise and storm surge.<sup>1</sup>

### Site Context and Facility Overview

This study covered a 3.5 mile stretch of US Highway 98 (US 98) that runs along a narrow barrier island between the Gulf of Mexico and Choctawhatchee Bay on the Panhandle of Florida. It is a four-lane divided highway that serves a US Coast Guard facility and regional traffic between two communities. Because of the value of the beach tourism and the military connection, Florida Department of Transportation (FDOT) considers this road to be a critical asset.



Figure 1: Map of the project area with the US 98 highway segment in blue.

With elevations of only +6 to +7 feet, this stretch of US 98 occasionally overwashes and has been significantly damaged in major storms. Historically, the primary damage mechanism has been weir flow<sup>2</sup> damage on the landward (north) shoulder as the storm surge and waves overwash the pavement. This damage may occur more frequently with sea level rise.



Image Source: South Coast Engineers

Figure 2: Photograph of the north side of the US 98 eastbound travel lanes along Choctawhatchee Bay.

### Environmental Stressors and Scenarios

The main environmental stressors affecting US 98 are storm surge and sea level rise. Potential future increases in the frequency and intensity of hurricanes were not considered in this assessment.

The research team evaluated historic and projected future rates of relative sea level rise at the study location. Relative sea level rise accounts for the effects of local vertical land movement. Historical rates of relative sea level rise were obtained from a nearby NOAA tide gage. Future projections of relative sea level rise were evaluated using the US Army Corps of Engineers' (USACE) Sea-Level Change Curve Calculator.<sup>3</sup> This study considered the intermediate (1.6 feet [0.5 m]) and high (4.9 feet [1.5 m]) global sea level rise scenarios for 2100 developed by the National Research Council.

<sup>1</sup> This snapshot summarizes one of nine engineering-informed adaptation studies conducted under the Transportation Engineering Approaches to Climate Resiliency (TEACR) Project. See <https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/> for more about this study and *Synthesis of Approaches for Addressing Resilience in Project Development*.

<sup>2</sup> A weir is a low dam or wall across a stream. See Section 8.2 –The Coastal Weir-Flow-Damage Mechanism of HEC-25 (2nd ed.) *Highways in the Coastal Environment*, for a detailed explanation of the coastal weir-flow-damage mechanism.

<sup>3</sup> The USACE Sea-Level Change Curve Calculator is accessible at: <http://www.corpsclimate.us/ccaceslcurves.cfm>.

The rise in storm surge elevation was assumed to be directly proportional to the rise in sea level. Although this approximation neglects the non-linear nature of the relationship between sea level rise and storm surge, it is a reasonable first approach to understand if adaptation measures will remain effective with sea level rise.

Existing storm surge inundation data from the Florida Department of Environmental Protection was combined with the USACE sea level rise projections to develop future storm surge elevations (Figure 3).

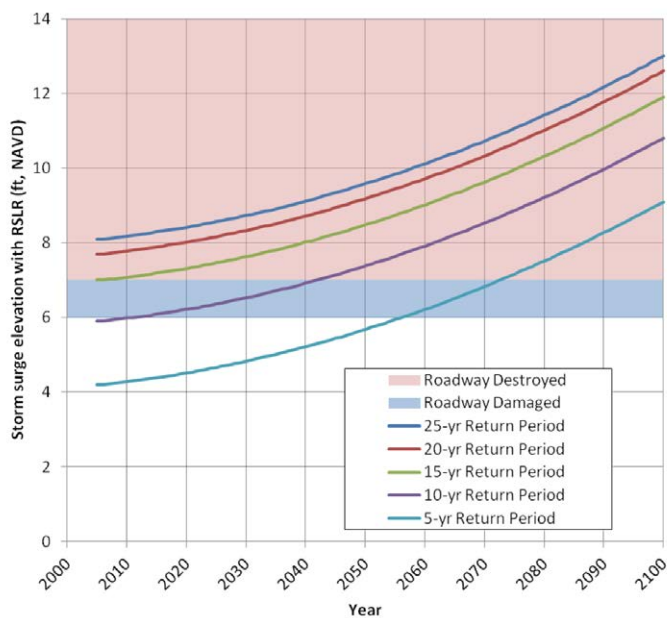


Figure 3: Storm surge elevations over time under a high (4.9 feet by 2100) relative sea level rise scenario.

## Analytical Approach

### Overview

The research team analyzed the performance of US 98 using the general methods described in HEC-25 (2nd ed.) for a “Level of Effort 1” analysis.<sup>4</sup> This level of effort is appropriate for US 98 because:

- This is the initial assessment of this asset for this vulnerability.
- It can be used to inform the need for more sophisticated assessments including storm surge modeling.
- The damage and failure mechanism is relatively well understood.

To assess the asset performance the research team used the specific principles outlined in HEC-25 (2nd ed.), Section 8.2: The Coastal Weir-Flow Damage Mechanism.<sup>5</sup> The research team assumed that any significant level of flow across the pavement surface would damage the roadway.

### Results

Figure 3 shows the projected increase in the 5-year through 25-year surge elevations over time under the USACE high sea level rise scenario. Also shown is a blue horizontal elevation band between +6 and +7 feet that corresponds to the likely surge elevation where the road would be inundated by storm surge and damage would begin to occur. Surge above that elevation can destroy the road (see Figure 4). Today, a 10-year return period event and above would be expected to damage an undefended roadway. Under the high sea level rise scenario, by around 2055, roadway damage would be caused by a 5-year storm. However, FDOT has already taken measures to protect the roadway from damage during overwashing events, as discussed in subsequent sections.



Image Source: FDOT

Figure 4: US 98 damage to the north pavement edge during a 2005 tropical storm (prior to the 2006 installation of protection measures).

<sup>4</sup> FHWA “Highways in the Coastal Environment.”

<sup>5</sup> FHWA “Highways in the Coastal Environment.”



## Adaptation Options

Although the prior analysis assumed no protection measures, FDOT actually modified US 98 in 2006 after a storm event. The 2006 FDOT design included the installation of buried gabion mats (stainless steel cages filled with rocks) along the shoulders and in the median of the roadway, and the installation of a sheet pile wall along the northern edge of the roadway. The purpose of these structures is to prevent undermining of the roadway foundation during overwashing.

One of the advantages of gabions is that they use smaller rocks than revetments since the rocks are constrained by the wire cage. The gabions act more as a large unit mat than as individual rocks in a revetment. Another advantage is that gabions have a track-record of performance in uni-directional streamflow (i.e., not waves) such as the primary situation that US 98 experiences in storm surges.

Although not analyzed, several other possible adaptation options are presented in HEC-25 (2nd ed.), Section 8.3, Strategies for Roads that Overwash.<sup>6</sup> These include considerations of:

- Road location,
- Road elevation,
- Construction of sand dunes, and
- Other forms of armoring of the shoulders.

## Economic Analysis

The research team conducted an economic analysis using the Equivalent Uniform Annual Costs (EUAC) approach to determine whether the 2006 FDOT strategy is cost effective. The EUAC method<sup>7</sup> is simply a direct comparison of the total expected average annual costs for two or more scenarios.

The methodology requires knowledge of three specific items:

1. The annual hazard probability considering future sea level rise (e.g., 10% annual chance, 20% annual chance);
2. The damage costs assuming the hazard occurs; and
3. The cost of the adaptation.

The cost of damages is assumed to be equivalent to the cost of construction of a 4-lane divided highway with paved shoulders,<sup>8</sup> approximately \$4M in 2015 dollars. After the installation of the adaptation strategy, it is assumed that storm damages would only require minor repairs, costing approximately \$30 per running foot of highway.

The total expected EUAC values in Table 1 indicate that the original FDOT decision to construct the countermeasure was economically justified even without consideration of the social costs (e.g., lost business) and without consideration of sea level rise. Between 2006 and 2056 the total expected EUAC of the standard roadway is expected to increase from 1.7 to 7.2 times that of the adaptation, meaning the strategy becomes more cost effective as sea levels rise.

Year	Adapt?	Damage if Event Occurs		Annual Hazard Probability		Expected Annual Damages		EUAC of First Cost		Total Expected EUAC
2006	Without	\$3 M	x	0.1	=	\$0.3 M	+	\$0	=	\$0.3 M
	With	\$0.2 M	x	0.1	=	\$0.02 M	+	\$0.2 M	=	\$0.2 M
2056	Without	\$14 M	x	0.2	=	\$3 M	+	\$0	=	\$3 M
	With	\$0.7 M	x	0.2	=	\$0.1 M	+	\$0.2 M	=	\$0.3 M

Table 1: Summary of EUAC costs with and without adaptation.

<sup>6</sup> FHWA "Highways in the Coastal Environment."

<sup>7</sup> The EUAC method is equivalent to a Net Present Value analysis that is normalized by the present value of annuity factor to achieve the equivalent annual value or cost.

<sup>8</sup> According to the FDOT Long Range Estimate tool. Accessible at: <http://www2.dot.state.fl.us/ProgramManagement/costpermile.aspx>.

## Recommended Course of Action

If the 2006 strategy, as described above, were not in place today, the recommended course of action would be to construct it as a sea level rise adaptation and maintain it following the existing FDOT procedures. This recommendation is based on the economic assessment findings that it is much more cost effective to build the adaptation than to not build it.

## Lessons Learned

- The FDOT design built in 2006 on this stretch of US 98 is a good example of a sound adaptation option for managing current weir-flow risks and future sea level rise impacts.
- Post-storm damage assessments focused on understanding coastal storm damage mechanisms can provide excellent information for informing the engineering design of protection strategies.
- The implementation of the 2006 strategies to protect US 98 is economically justified with the EUAC analysis and the economic benefits of this adaptation will increase as sea levels rise. The implication is that similar techniques could be applicable for other low-lying coastal roadways with little dune protection.
- As sea levels rise, coast parallel roads can be exposed to and damaged by overwashing storm surges more frequently.
- Some adaptations to sea level rise will be similar to strategies required for improving infrastructure resilience to extreme events with today's sea levels. However, consideration of sea level rise can significantly alter the economics of the decisions.
- Qualified coastal engineers should be included in the design/assessment team for any transportation engineering design and analysis along the coast.

## For More Information

### Resources:

**Transportation Engineering Approaches to Climate Resiliency (TEACR) project website**  
<https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/>

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