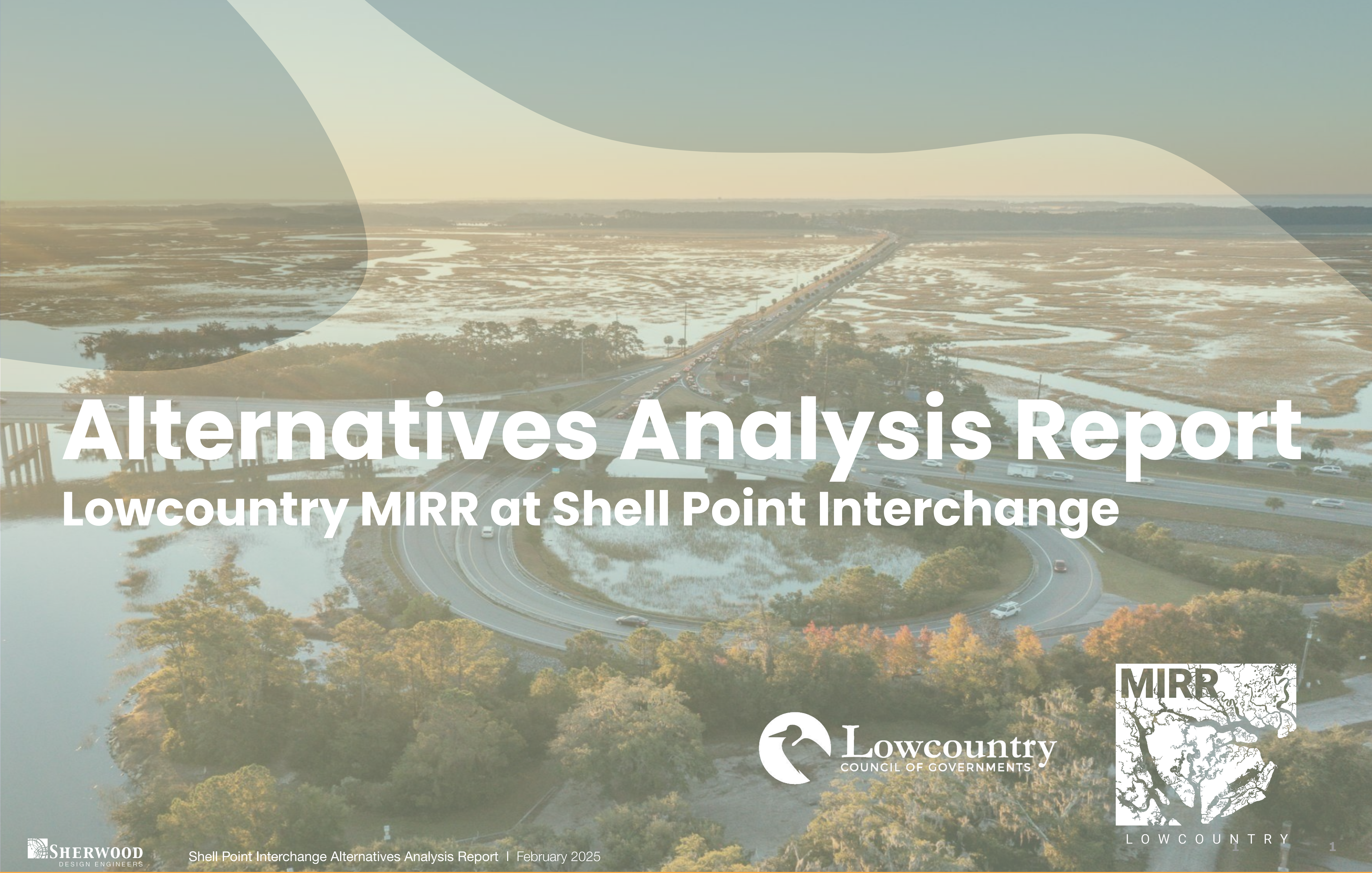

Alternatives Analysis Report

Lowcountry MIRR at Shell Point Interchange

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Executive Summary

Figure. Aerial Image of the Shell Point Interchange *Image Source: Paul Nurnberg*

Located in Port Royal, South Carolina, an Interchange between Hwy US-21 and General Pollock Causeway serves as the only vehicular access point to Marine Corps Recruit Depot (MCRD) Parris Island, a training-focused military installation with a civilian workforce of nearly 1,000 people and a population of 19,000 Marine Corps personnel. The installation is responsible for training 70% of all U.S. Marine recruits in any given year.

Hwy US-21 at the Interchange also serves as a critical access point for a primary evacuation route for surrounding communities, including the Town of Port Royal and St. Helena's Island, in addition to serving as an evacuation route for MCRD Parris Island.

This site, referred to as the Shell Point Interchange was first highlighted for study as a potential pilot project within the Lowcountry Military Installation Resilience Review (MIRR), an initiative led by the Lowcountry Council of Governments (LCOG) to evaluate the region's infrastructure for climate-related vulnerabilities.

The interchange was highlighted given both the frequency and severity of anticipated climate-related impacts to site operations and the infrastructure's criticality for both military and civilian operations. In 2023, LCOG secured additional funding for further study, with the goal of advancing engineering design for the Interchange to foster resilience against operational disruptions. This report provides a summary of the continued efforts for the interchange.

Section 1 contextualizes the site's existing conditions and findings from the MIRR study. Sections 2 and 3 outline a site-scale analysis of climate vulnerabilities that threaten the integrity of transportation infrastructure and the adjacent landscape's ecological health. Findings from analysis are coupled with takeaways gleaned from stakeholder engagement to establish design priorities and protection thresholds that must be met.

Section 4 outlines design considerations that serve as the basis of the mitigation concept presented in Section 5. Section 5 outlines a holistic mitigatory concept for the Interchange, presented in three phases, with each phase incorporating additional protection measures as conditions exacerbate.

Phase 1 aims to address coastal erosion and shoreline marsh deterioration that is already noted today, through measures including bank regrading and marsh restoration. Phase 2 aims to maximize the efficacy of stormwater infrastructure that is anticipated to be hindered by rising water levels in the future, causing acute flooding within one travel lane when system capacity is breached. Proposed measures include restoration of a disrupted drainage pattern to divert off-site runoff and retrofits of a existing stormwater outfall to include a muted tide gate. Phase 3 aims to address extreme coastal flooding anticipated in the long-term (2075) that could overtop the road and limit 2+ lanes of access, with a roadside-adjacent knee wall.

Section 5 also compares the logistical considerations, impacts of protection, and co-benefits of each phase to guide the decision of which phase will be advanced for engineering design. Ultimately, Phase 2 was selected to advance towards a 60% complete engineering design, which will be completed by the Summer of 2025.

ACKNOWLEDGMENTS

This Study was prepared under contract with Sherwood Design Engineers, initiated by the Lowcountry Council of Governments (LCOG) with financial support from the Office of Local Defense Community Cooperation Office, Department of Defense. The content reflects the views of Sherwood Design Engineers and its sub-consultants, Thomas & Hutton Engineering Services, Geoscience Consultants, Biohabitats, and Terracon. The input of the local stakeholders and does not necessarily reflect the views of the Office of Local Defense Community Cooperation Office, Department of Defense. The team would like to thank the stakeholders, the military installations, and community members for their close collaboration throughout this process.

DISCLAIMER

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COMMUNITY MEMBERS AND STAKEHOLDERS

- Beaufort County Council
- Beaufort County Engineering Department
- Beaufort County School Board
- Beaufort County Planning Department
- Beaufort County Public Works Dept.
- Beaufort Jasper Water Sewer Authority
- City of Beaufort
- Coastal Conservation League
- Lowcountry Council of Governments
- Marine Corps Recruit Depot Parris Island
- Marine Corps Air Station Beaufort
- Office of Local Defense Community Cooperation
- Open Land Trust
- SC Department of Environmental Services
- SC Department of Natural Resources
- SC Department of Transportation
- SC Lowcountry Sentinel Landscape
- The Nature Conservancy
- Town of Port Royal

Figure. Aerial Image of Shell Point Interchange *Image Source: Paul Nurnberg*

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Glossary

Annual Exceedance Frequency (AEF) - The probability of a data point exceeding a selected threshold of probability for occurring in a given year, given a range of data points (e.g., the probability of a water level occurring in a given year).

Adaptive Capacity - The ability of a person, asset, or system to adjust to disturbances for a threat or cope with change.

Coastal Flooding - Inundation of dry land as a result of an adjacent tidally-influenced water body given a climatic or environmental threat (e.g., storm surge, tidal flooding).

Climatic Threat - Events caused by atmospheric or environmental processes that pose a risk and can be adapted to, but not mitigated. Climate threats are often acute in scale and can be modeled based on frequency and spatial extents.

Compound Flooding - Flooding that is generated from multiple types of climatic threats occurring simultaneously, often referring to the interaction of pluvial flooding and coastal flooding.

Compound Coastal Flooding - Flooding that occurs from a combination of types of coastal climatic and environmental threats that yield multiple types of coastal flooding occurring concurrently (e.g., storm surge, tidal flooding, sea level rise).

Ecosystem Services - Benefits yielded to a community in the form of natural processes conducted by a healthy ecosystem. (e.g., water quality improvements, habitat provision, shoreline stabilization, aesthetic/placemaking benefit).

Empirical Data - Data originating through the recording of direct observations (e.g., water levels collected through a tidal gage).

Exposure - The presence of people, assets, and ecosystems in places where they could be adversely affected by threats.

Environmental Threat - Chronic threats caused by the natural environment that pose a risk, but can be mitigated (e.g., coastal erosion). Environmental threats are more appropriately represented with spatial extents and intensity.

Hydrologic & Hydraulic Model (H&H Model) - Modeling software that uses mathematical equations to simulate the behavior of water given rainfall patterns and local environmental conditions (e.g., topography, land cover) in order to evaluate projected impacts of stormwater runoff.

Marsh Accretion - The naturally occuring migration of marsh extents inland towards higher elevations in response to rising sea levels as excessive inundation causes marsh deterioration.

Mean High Water (MHW) - Average height of all high water heights (typically 2 per day) observed over a 19-year period.

Mean Higher High Water (MHHW) - Average height of a highest tide observed for each day over a 19-year period.

Nuisance Flooding - Threshold established by NOAA to characterize the water surface elevation that is anticipated to occur 30x per year, representing a higher tide that average that will likely cause high-tide flooding.

Pluvial Flooding (Inland Flooding) - Flooding that results from excessive rainfall that yields runoff at a volume or rate that exceeds capacity of drainage infrastructure.

Revetment - A retaining wall composed of stone or other material that supports stability of a wall, road, etc. In the context of this study, the stone retaining wall on the Battery-Creek side of Gen. Pollock causeway and along the Hwy. 21 bridge structures.

Sensitivity - The degree to which a system, population, or resource is or might be affected by threats. Measured by combination of frequency and intensity.

Shallow Coastal Flooding - Threshold established by NOAA to identify a water elevation higher than average, given the differences in elevation between high and low tide, which can be representative of high-tide flooding.

Statistical Models - Mathematical models that yield data points (e.g., water levels) that have a probable likelihood of occurring in an area given trends noted in a large dataset of theoretical storm events that could occur in any area given local environmental conditions.

Still Water Level (SWL) - A water surface elevation at any given time in the absence of wave height, regardless of what caused the water surface elevation - including mean sea level, sea level rise, tidal ranges, storm surge, etc.

Total Water Level (TWL) - A water surface elevation that considers Still Water Level (SWL), but including wave height.

Wave Action - Motion associated with waves breaking along the shoreline that results in the release of energy that may impact a shoreline.

Vulnerability - The propensity of assets to be adversely affected by climatic or environmental threats. Characterized by the culmination of an asset's exposure, sensitivity, and adaptive capacity to threat disturbances.

Figure. Aerial Image of Shell Point Interchange *Image Source: Paul Nurnberg*

1 INTRODUCTION

1.1 Project Context

This study is part of a larger effort to advance a pilot project of mitigatory measures for a critical transportation interchange first identified within the Lowcountry Military Installation Resilience Review (MIRR).[1]

Funded by the Department of Defense's Office of Local Defense Community Cooperation (OLDCC), the MIRR (**Figure 1.1**) is the result of a planning effort led by the Lowcountry Council of Governments (LCOG), completed in April 2022. Study efforts focused on evaluation of climate-related risks posed to communities surrounding the Marine Corps Air Station (MCAS) Beaufort and Marine Corps Recruit Depot (MCRD) Parris Island military installations.

The MIRR aimed to provide a thorough understanding of the climate-related vulnerabilities in the area and provide recommendations to mitigate disturbances yielded from threats that negatively impact the local infrastructure, including pilot projects to advance presented recommendations.

The interchange was identified as a priority pilot project after the site received one of the highest scores across all evaluated infrastructure across the region within a quantitative screening process that assigns points to each site given the likelihood of climate-related threats occurring near the site, the degree at which impacts from the threat would disrupt operation of the infrastructure, the importance of the interchange to serving local military installations, and the anticipated exacerbation of such threats in future (**Figures 1.2 and 1.3**).

Design objectives for mitigatory measures were identified for the pilot project and next steps were outlined to secure funding for the further design needed for eventual implementation. In 2023, LCOG secured additional funding through another OLDCC grant to advance efforts for the pilot project to a 60% complete engineering design.

LOWCOUNTRY MIRR

LOWCOUNTRY MIRR

Military Installation Resilience Review of MCAS Beaufort, MCRD Parris Island, and the Surrounding Areas

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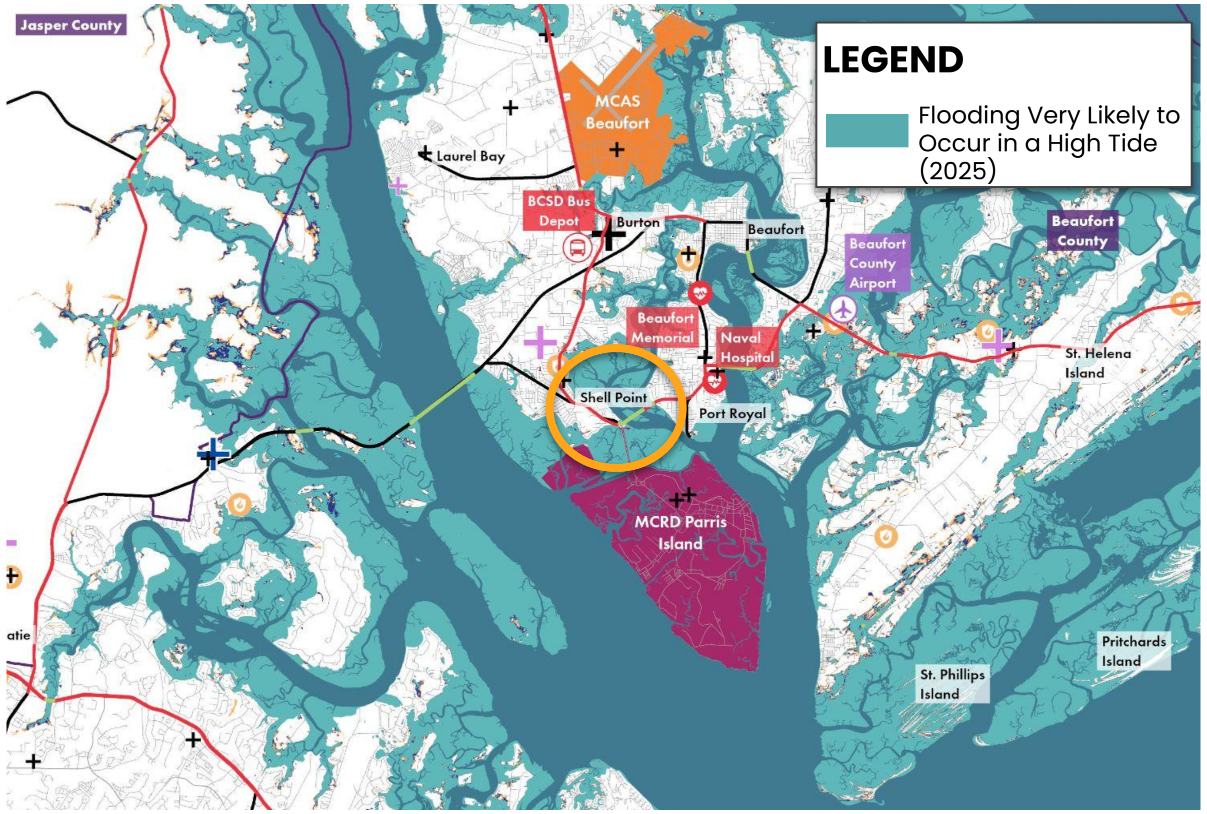

Figure 1.1 (Top Left). Report cover of Lowcountry Military Installation Resilience Review (MIRR), completed in 2022.[1]

Figure 1.2 (Top Right). MIRR study extents shown with anticipated flood extents during a high-tide event, shown with the Shell Point interchange highlighted.[1]

Figure 1.3 (Bottom). Typological transect of threats affecting urban land uses, taken from the MIRR study, shown with the Shell Point Interchange highlighted.[1]

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[1] Lowcountry Military Installation Resilience Review (2022)

1.2 Area of Interest

Study Extents

The Shell Point Interchange serves Hwy US-21 at the terminus of a bridge crossing over Battery Creek in Port Royal, South Carolina. The interchange serves an underpass under the bridge to the only vehicular entrance to MCRD Parris Island.

Study extents are bound to the East by the tidally-influenced Battery Creek and to the Southwest by a wetland marsh adjacent to an Archer Creek tributary. Study extents do not include the interchange's southern shoreline given a minimal risk of climate-related impacts noted in the MIRR. This study also does not include any infrastructure beyond the entrance sign to MCRD Parris Island or the public Parris Island Boat Ramp just North of the interchange, as shown in **Figure 1.4**.

Critical Infrastructure

This interchange serves as the only vehicular access point to Marine Corps Recruit Depot (MCRD) Parris Island via an underpass for the Hwy US-21 bridge over Battery Creek. The underpass has two lanes, an outer lane that provides access from the installation to Hwy US-21 west-bound and an inner lane that allows west-bound Hwy US-21 travellers to access the installation. Between the two lanes of the underpass is a concrete barrier in the median. For southbound arrivees and departees of installation, two additional ramps on either side of the underpass provide connection to Hwy US-21.

Along the shoreline of the underpass outer lane, a shoreline **revetment** is in place to armor the roadway against coastal erosion, and a guard rail follows the alignment of the outer lane for crash protection.

Marsh is present along all shorelines, and also present within two pockets inland of the roadway, henceforth referred to as the lower and upper inland marshes (see **Figure 1.4**).

Figure 1.4. Context map of the Shell Point Interchange with nomenclature of key critical infrastructure

1.2 Area of Interest

Both inland marshes are hydraulically connected to each other and Battery Creek via subsurface pipes, facilitating tidal flux for vegetation and use of the inland marshes as stormwater storage for road-generated stormwater runoff. All marshes on-site are considered wetlands according to the National Wetland Inventory.[2]

Within the interchange, stormwater generated on the road is collected via grate inlets within the road and piped towards outfall in either the lower inland marsh or the upper inland marsh. Both lanes of the interchange are also sloped slightly to drain surface runoff towards the inland marshes.

Housing for critical infrastructure serving the installation is located just West of the entrance sign and near the Southern shoreline, connecting the military installation with the mainland. These utilities are not considered in depth due to their relatively lower risk noted in the MIRR compared to the Eastern shoreline of the Interchange.

Ownership Framework

Land surrounding the interchange is primarily owned by MCRD Parris Island, with some portions of the land under an easement agreement with the South Carolina Dept. of Transportation (SCDOT) for road and associated utility infrastructure that serves Hwy US-21. The Northern portion of the interchange's shoreline is owned by Beaufort County.

Discussions between stakeholders during stakeholder engagement indicate opportunities for land swap agreements between MCRD Parris Island and Beaufort County in the future, although no current plans are in place as of February 2025.

Figure 1.5. Context map of the Shell Point Interchange highlighting property lines, deliberation of jurisdictional wetland extents, and existing utility infrastructure.

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[2] U.S. Fish & Wildlife Service, National Wetlands Inventory

1.3 Design Objectives

As previously shown in **Figure 1.3**, this site was selected as a pilot project within the MIRR study given the risk that climate-related hazards pose to the site's infrastructure operations, and the resultant impacts that climate conditions could have on operations of this infrastructure that is highly critical to regional community and military operations.

Threat considerations noted in the MIRR study for this area include high levels of erosion and **compound flooding**, or the coincidence of multiple types of flooding, including coastal flooding and flooding originating from rainfall-related events ("**pluvial flooding**"). Coastal flooding anticipated is expected both as a chronically occurring threat (e.g., high-tide flooding), an acutely occurring threat with high-intensity (e.g., storm surge), and a combination of multiple types (**"compound coastal flooding")**.

While the site's infrastructure and landscape is noted to already be vulnerable to climate-related risks, vulnerabilities are anticipated to exacerbate in the future due to trends of rising sea levels over time and exacerbating climatic threats.

Resultant vulnerabilities in the face of these threats include disrupted roadways, disrupted emergency response, loss of habitat, eroding shorelines, loss of tourism associated with MCRD Parris Island, and constrained liveability for both military personnel and civilian employees of the installation.

Figure 1.6. Spatial Extents of MIRR-Identified design objectives for the Shell Point Interchange across the site.

Design objectives for proposed mitigation measures were first identified for the interchange as part of the MIRR study, as shown in **Figure 1.6**, given the study's large-scale review of the interchange's vulnerabilities.

Design objectives are also described below. Building off the efforts first initiated with the MIRR, these design objectives will serve as a guide through contextualizing the site vulnerabilities, ultimately informing a resilient solution for the Interchange.

Shoreline Stabilization: Mitigate eroding of marsh edge and promote natural resilience of marsh to risks associated with tides, storms, and sea level rise.

Flood Management: Reduce impacts of pluvial flooding by capturing and storing stormwater. Balance storage with tidal fluxes and future scenarios of sea level rise.

Water Quality: Address water quality issues by 1) treating stormwater runoff before interaction with tidal waters and 2) improving the function of naturally occurring processes of the estuarine system ("**ecosystem services**").

Habitat Restoration: Preserve, enhance, and restore coastal habitat that will be resilient to future stressors associated with storms and sea level rise.

1.4 Project Overview

The MIRR at Shell Point Interchange (the Project) is a 14-month project to advance the design of resilient solutions for the Shell Point Interchange, a pilot project first identified in the MIRR study, to an 60% complete engineering design. Desired outputs of this project result in the production of a sufficiently completed design and associated documentation, readying LCOG to apply for funding for final design and implementation.

This project is considered in the following step, described below and visually summarized in **Figure 1.7** to the right.

- **Identify & Prioritize Site Vulnerabilities:** Conduct site-scale analysis of climatic threats and resultant impacts on present infrastructure to contextualize vulnerabilities, informing design priorities in future mitigation concepts.
- **Mitigation Concept Development & Evaluation:** Utilize identified design priorities to iterate upon mitigation measures to evaluate their suitability for implementation. Phase results in an adaptive capacity, considered from three phases of implementation to identify preferred phase of the alternative phases presented for implementation.
- **Concept Advancement and Implementation Plan:** Advance preferred phase to 60% complete engineering design. Document anticipated benefits and concept features to shepherd the project through implementation.

This report is intended to document approach, findings, and summary of effort through the second of the three steps listed above. The third phase of this work is expected to be completed by Summer 2025.

Project Goals

Goals of this project are to develop a mitigation design that will address near-term disturbances anticipated on-site and an accompanying adaptation framework to incorporate additional incremental protection in the future as threats exacerbate, maintaining performance services throughout the interchange lifecycle. Mitigation design development is intended to build upon previous work and curate a concept with three phases of intervention through a community-driven process to design nature-based solutions that address short-term disturbance and long-term adaptation.

The preferred phase to advance implementation for of the three phases presented for implementation will be advanced for engineering design as part of the project's final step.

Engineering design will aim to usher the project to implementation through permitting partnerships with regulatory agencies.Future phases beyond the identified phase for implementation will be considered as part of an adaptive implementation framework to guide future engineering decisions of design as the additional incremental protection measures become necessary in the future.

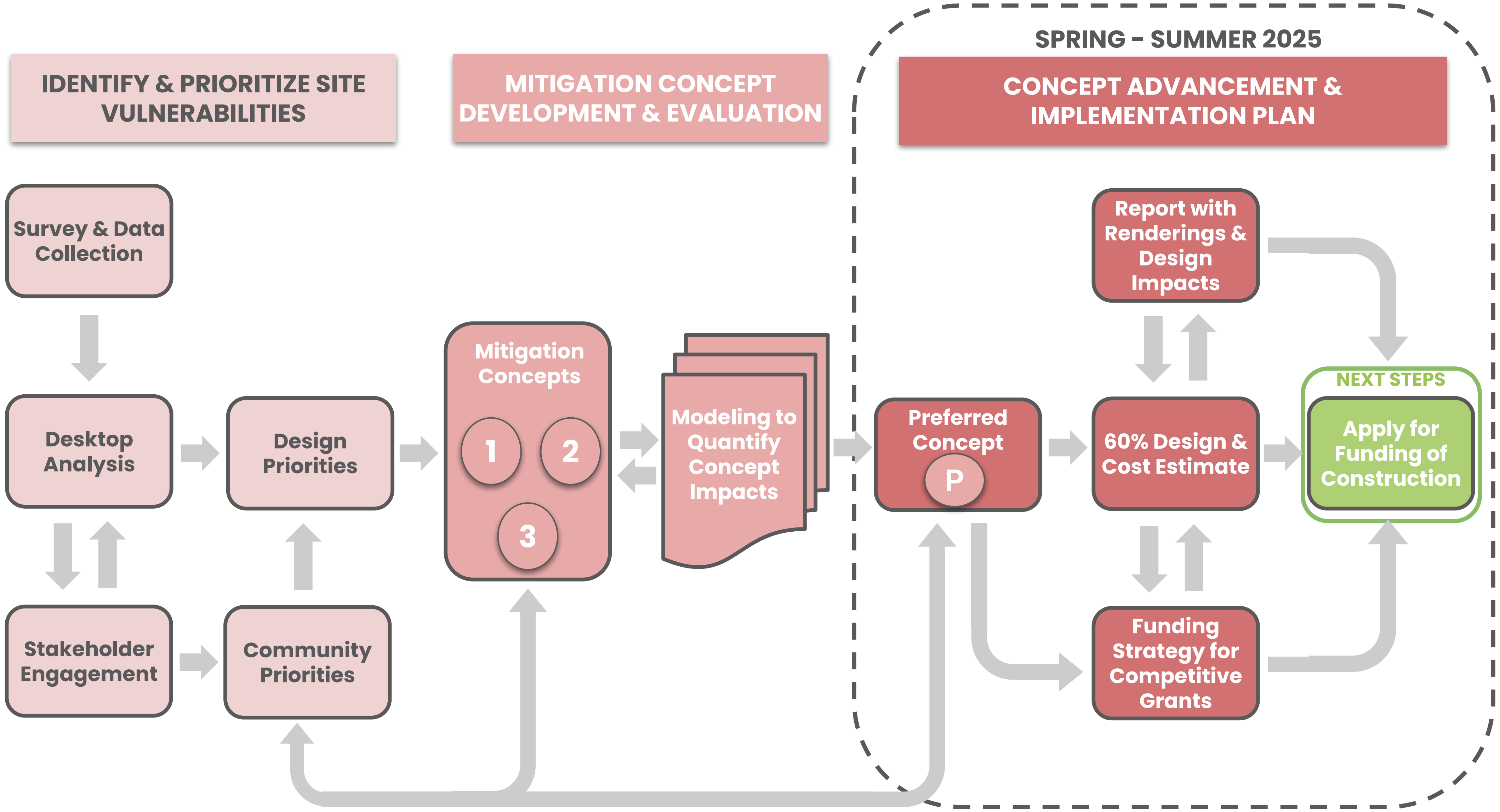


Figure 1.7. Visual diagram of the project's schedule to complete goals of advancing the MIRR pilot project to a design completion sufficient to apply for implementation funding.


Figure. Aerial Image of Shell Point Interchange *Image Source: Paul Nurnberg*

2 IDENTIFY SITE VULNERABILITIES

2.1 Analysis Framework

Following the vulnerability analysis framework outlined in the MIRR study, initial efforts in this project intend to identify and improve characterization of the site infrastructure's climate-related vulnerabilities for infrastructure operation. Framework for this process evaluates infrastructure against the components that define vulnerability (exposure, sensitivity, and adaptive capacity). The framework first evaluates all infrastructure assets, but only further evaluates assets that pass through the subsequent screen, facilitating a thorough study across a regional study area.

Initial efforts in this project intend to identify and improve characterization of the site's climate-related **vulnerability**, defined by the site's **exposure** to anticipated threats, the infrastructure's **sensitivity** to disturbances yielded by these threats, and the **adaptive capacity** of the infrastructure and community to cope with change needed to mitigate such disturbances (**Figure 2.1.**).

Analysis of potential disturbances evaluated on-site include both ones that originate (A) from **climatic threats** that are acute in occurrence and can be adapted to but not mitigated (e.g., flooding), and (B) from **environmental threats** that occur chronically but can be mitigated (e.g., coastal erosion).

Technical analysis will build upon the preliminary analysis shown within the MIRR, offering a more site-scale analysis that provides a higher resolution of understanding given site-scale topography and infrastructure data.

Findings understood via desktop analysis are to be presented to stakeholders via a public engagement initiative to ground truth findings, bring forth knowledge of additional disturbances to community operations, and understand the **adaptive capacity** of infrastructure from a community lens.

At the conclusion of this analysis, once all facets of **vulnerability** are defined, findings will be synthesized for design criteria and priorities to consider in future design.

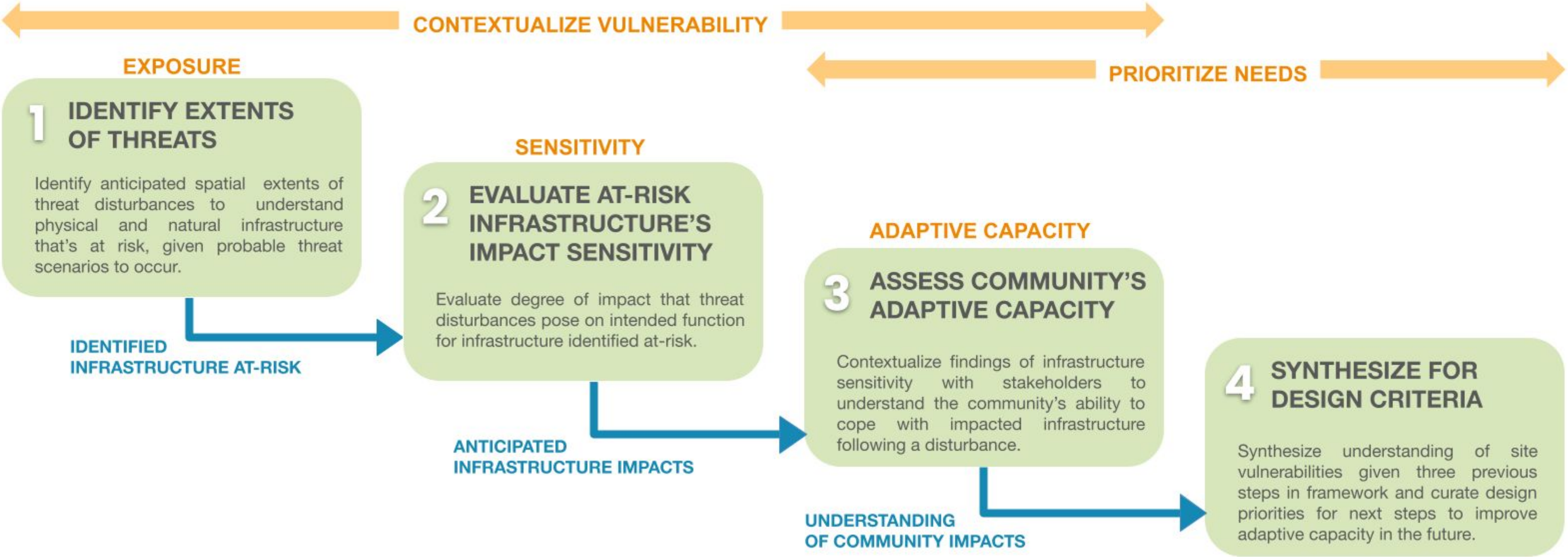


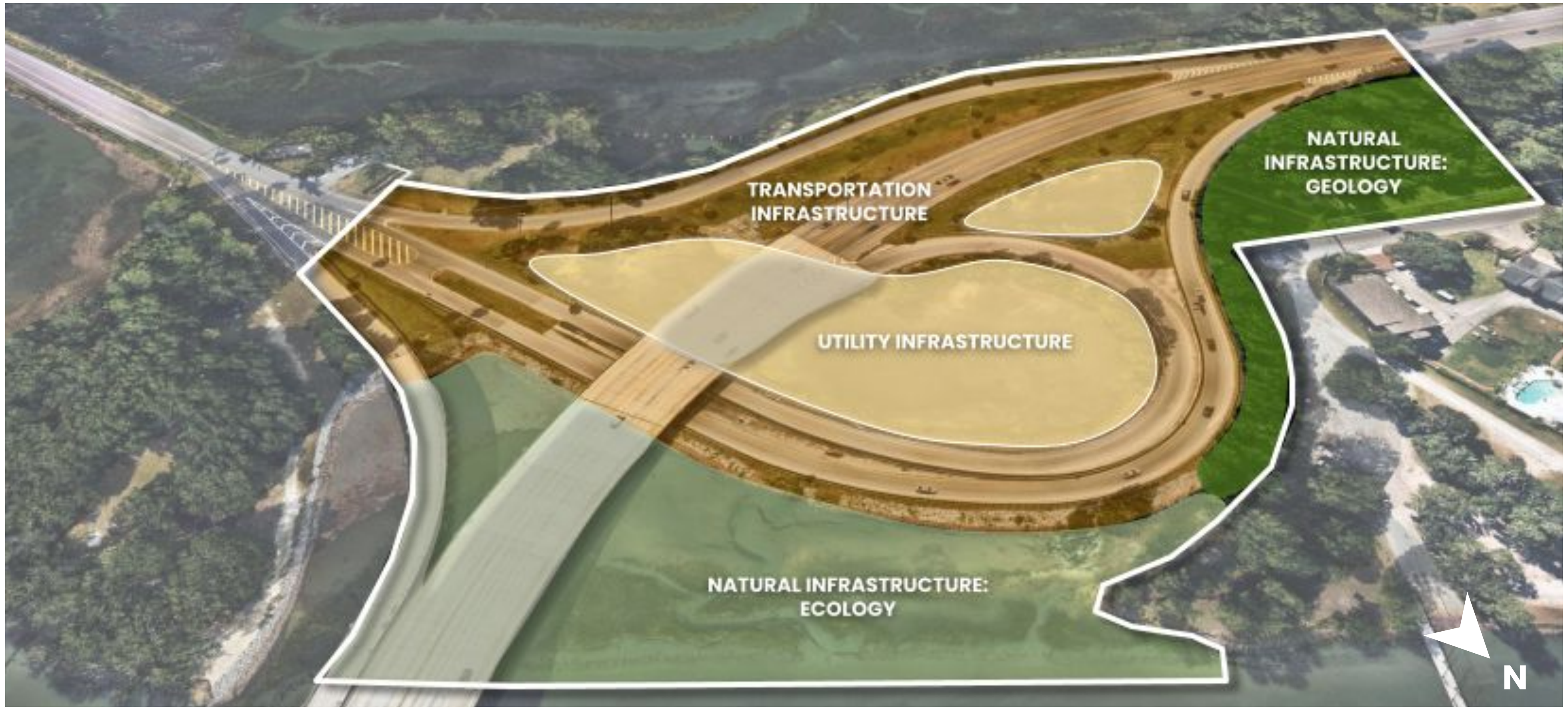
Figure 2.1. Framework for identifying and characterizing vulnerabilities to contextualize anticipated infrastructure impacts of climatic and environmental threats, ultimately informing future engineering design.

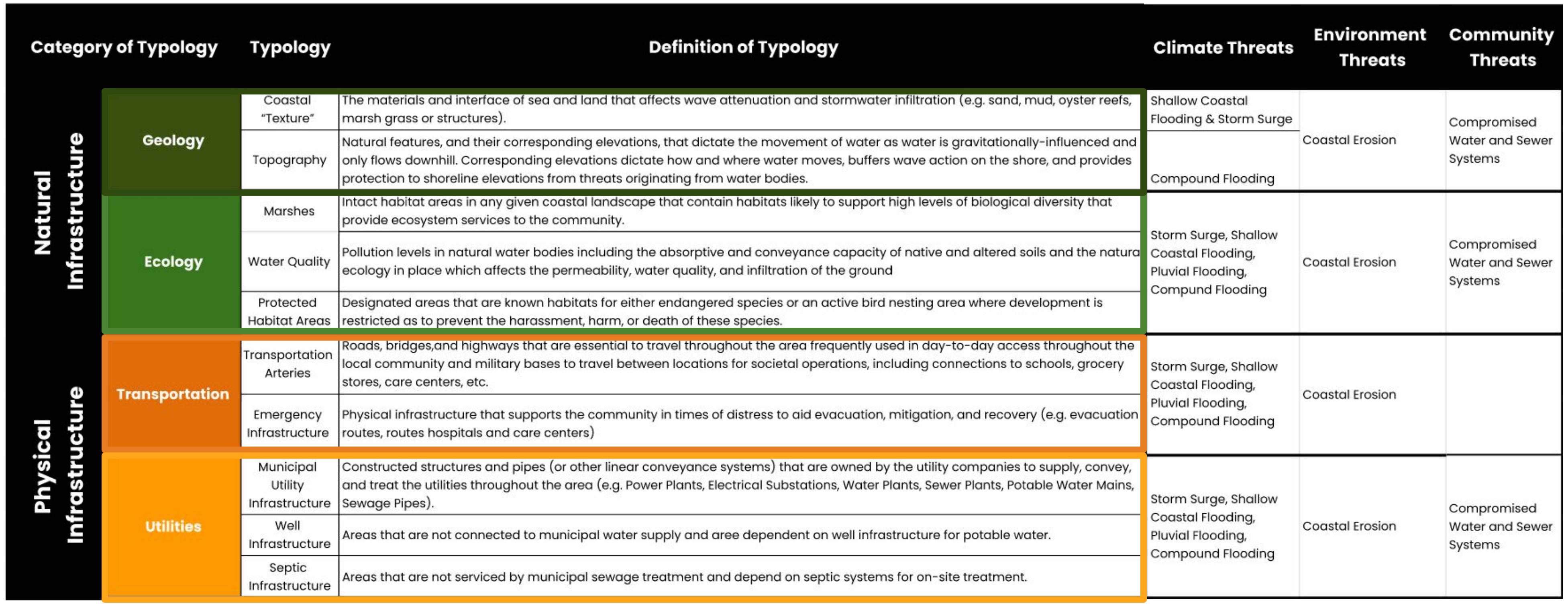
2.2 Climate Threats for Consideration

To contextualize the site's existing vulnerabilities, analysis must begin with identifying the extents across the site that current and future climatic threats are likely to impact as a result of occurrence, with the goal of overlaying these extents with aerial imagery to highlight areas within the interchange that exposed and at-risk to operational disturbances when these threats occur, requiring for further study. To identify the threats that should be considered in this extents-based exercise, referred to as the "Exposure Analysis", the vulnerability screening framework established as part of the MIRR study is referenced (**Figure 2.3**), given the infrastructure identified present on-site through aerial observation, as shown in **Figure 2.2** to the right.

Note compromised water and sewer systems, although listed as a threat for consideration given present infrastructure on-site, are not included in this analysis due to lack of civilian water and sewer systems present.

Evaluation of threat exposure within this analysis builds upon the preliminary analysis conducted in the MIRR study to provide a more granular understanding of conditions, using aerial-shot topographic data and infrastructure characteristics collected on-site in August 2024. See **Appendix A** for more detail on site survey data that was used in this analysis.





Category of Typology		Typology	Definition of Typology	Climate Threats	Environment Threats	Community Threats
Natural Infrastructure	Geology	Coastal "Texture"	The materials and interface of sea and land that affects wave attenuation and stormwater infiltration (e.g. sand, mud, oyster reefs, marsh grass or structures).	Shallow Coastal Flooding & Storm Surge	Coastal Erosion	Compromised Water and Sewer Systems
		Topography	Natural features, and their corresponding elevations, that dictate the movement of water as water is gravitationally-influenced and only flows downhill. Corresponding elevations dictate how and where water moves, buffers wave action on the shore, and provides protection to shoreline elevations from threats originating from water bodies.	Compound Flooding		
	Ecology	Marshes	Intact habitat areas in any given coastal landscape that contain habitats likely to support high levels of biological diversity that provide ecosystem services to the community.	Storm Surge, Shallow Coastal Flooding, Pluvial Flooding, Compund Flooding	Coastal Erosion	Compromised Water and Sewer Systems
		Water Quality	Pollution levels in natural water bodies including the absorptive and conveyance capacity of native and altered soils and the natura ecology in place which affects the permeability, water quality, and infiltration of the ground			
		Protected Habitat Areas	Designated areas that are known habitats for either endangered species or an active bird nesting area where development is restricted as to prevent the harassment, harm, or death of these species.			
Physical Infrastructure	Transportation	Transportation Arteries	Roads, bridges,and highways that are essential to travel throughout the area frequently used in day-to-day access throughout the local community and military bases to travel between locations for societal operations, including connections to schools, grocery stores, care centers, etc.	Storm Surge, Shallow Coastal Flooding, Pluvial Flooding, Compound Flooding	Coastal Erosion	
		Emergency Infrastructure	Physical infrastructure that supports the community in times of distress to aid evacuation, mitigation, and recovery (e.g. evacuation routes, routes hospitals and care centers)			
	Utilities	Municipal Utility Infrastructure	Constructed structures and pipes (or other linear conveyance systems) that are owned by the utility companies to supply, convey, and treat the utilities throughout the area (e.g. Power Plants, Electrical Substations, Water Plants, Sewer Plants, Potable Water Mains, Sewage Pipes).	Storm Surge, Shallow Coastal Flooding, Pluvial Flooding, Compound Flooding	Coastal Erosion	Compromised Water and Sewer Systems
		Well Infrastructure	Areas that are not connected to municipal water supply and aree dependent on well infrastructure for potable water.			
		Septic Infrastructure	Areas that are not serviced by municipal sewage treatment and depend on septic systems for on-site treatment.			

Figure 2.2 (Top). Infrastructure typologies identified on-site via observation of aerial imagery to inform threats considered in Exposure Analysis.

Figure 2.3 (Bottom). MIRR Vulnerability Assessment Framework, referenced in this study to identify threats for consideration in (three columns to right) given infrastructure typologies identified on-site

2.3 Anticipating Future Climate Conditions

This analysis considers a proactive approach to future climate scenarios with the intent of providing a mitigatory design that can meet performance expectations through the year 2075.

Typical climatic threats that occur in the area, and the associated disturbances that occur as a result, are anticipated to worsen due to impacts of climate change, necessitating the analysis of these threats in future scenarios to understand the anticipated evolution of infrastructure vulnerabilities.

By projecting the intensity, frequency, and spatial extents of these threats in future scenarios, this analysis framework identifies areas that are both vulnerable today and in the future in order to maximize proactive disaster management, thus minimizing the site's future vulnerability even as threats increase over time.

As flood-related disturbances are some of the greatest threats to the site, consideration of rising sea levels is paramount to understanding the site's future vulnerabilities. Rising sea levels will affect the frequency of marsh inundation that deteriorates the marsh's ecosystem services, the frequency at which the road may inundate due to coastal flooding, the height at which waves will break along the shoreline threatening shoreline stabilization, and the resultant capacity of stormwater infrastructure when coastal waters are able to fill the inland marshes.

Increases in rainfall intensity associated with climate change impacts are also considered, acknowledging that precipitation events are likely to increase in intensity, therefore increasing the amount of rainfall runoff that will reach stormwater infrastructure.

Threat Timelines Considered

In addition to evaluating today's climate conditions (2025), anticipated impacts of climate change on projected conditions are understood at three anticipated timeline events in the future, shown below in **Figure 2.4**. These timelines were selected to align with anticipated milestones for any implemented infrastructure, with the intent that mitigatory protection would need to be reconsidered by the year 2075, assuming that 50 years would be the end of life cycle for implemented infrastructure discussed in this report.

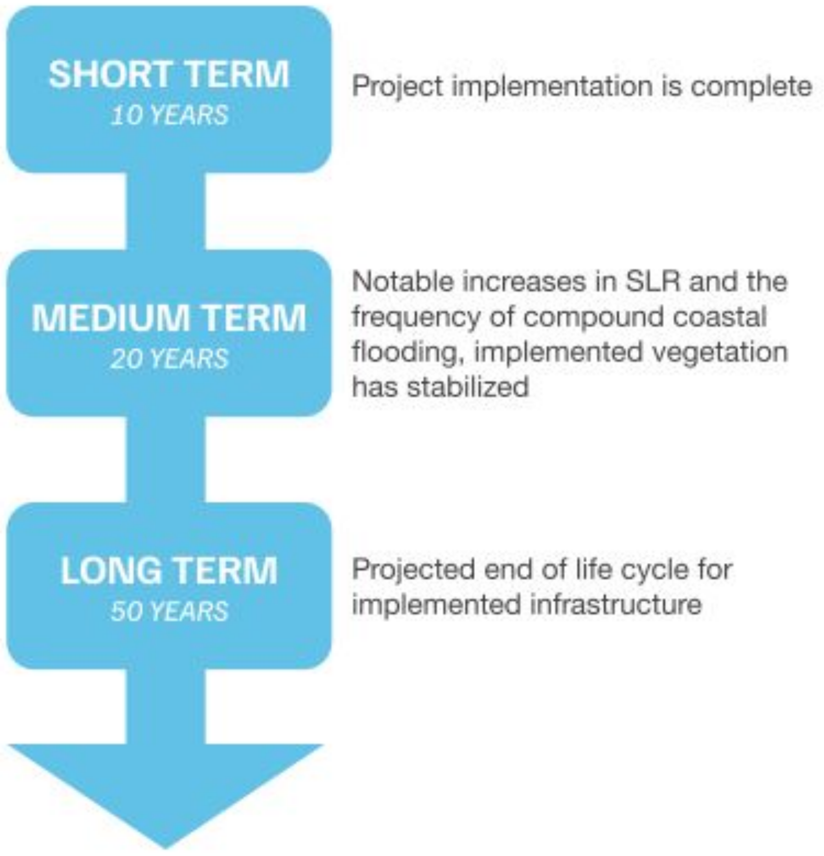


Figure 2.4. Threat timelines of future climate scenarios included in analysis to ensure consideration of future climate scenarios and the resultant evolution of impacts that may occur.

Sea Level Rise Scenarios

Analysis for future coastal-related threats account for sea level rise by appending projected increases to anticipated water levels yielded for threats occurring today (2025), with respect to the SLR increases anticipated at each threat timeline year.

Projected SLR increases are based on the National Oceanic and Atmospheric Administration (NOAA)'s SLR projection data, in alignment with guidance published in the Beaufort County Long-Term Resilience Strategy (2024).[3] Of NOAA's five established SLR scenarios that could plausibly characterize the rates of SLR increases (see **Figure 2.5**), this analysis utilizes projections from the Intermediate-High SLR scenario given the presence of critical infrastructure.

As NOAA SLR projections are based on national averages, projections were compared against rates of SLR observed between 1935-2024 at the nearest tide gage to the site to confirm alignment with local conditions (Ft. Pulaski, GA, ~17 mi. from site). Refer to **Appendix B** for detail on this analysis.

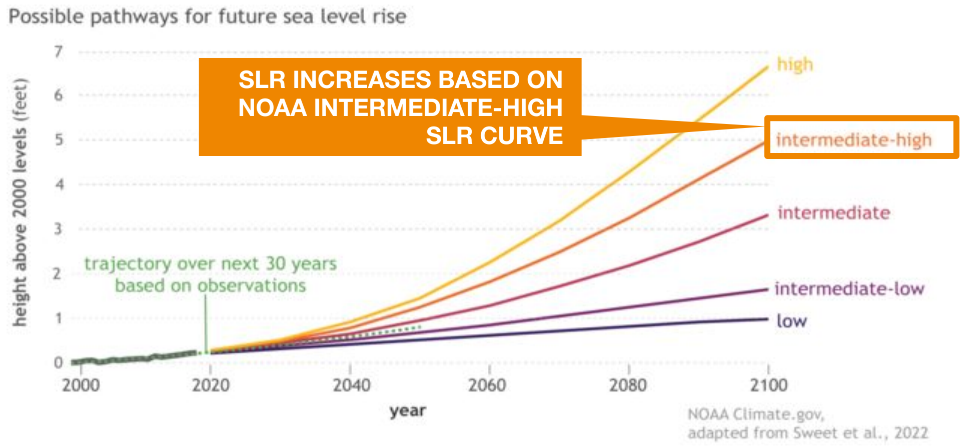


Figure 2.5. NOAA's published SLR projection curves to evaluate SLR in future climate scenarios.[4]

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[3] Beaufort County Long-Term Resilience Strategy (2024)

[4] NOAA Climate.gov, "Possible Pathways for Sea Level Rise"

2.4 Methodology

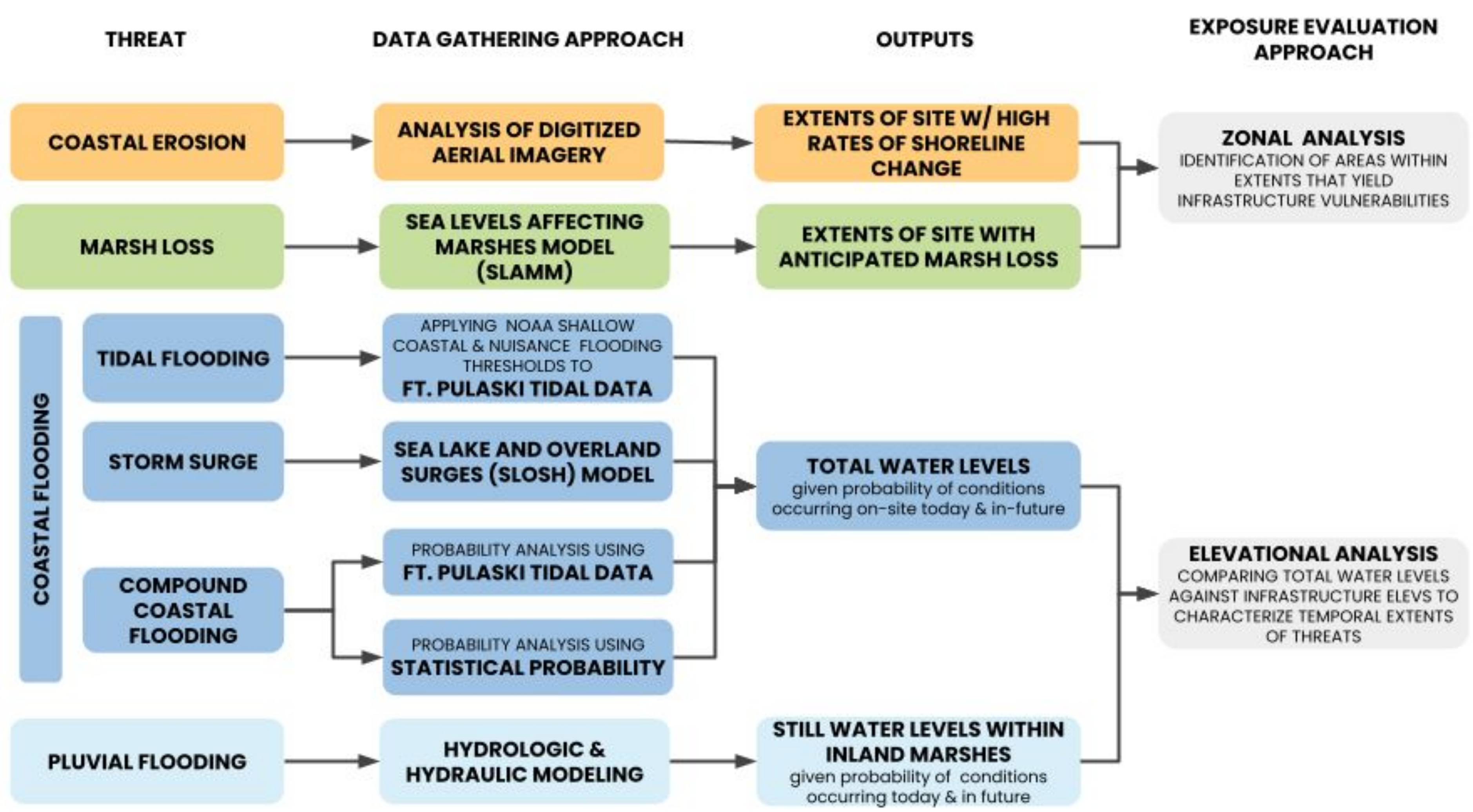


Figure 2.6 (Above). Summary of methodologies employed to conduct Exposure Analysis of climatic and environmental threats.

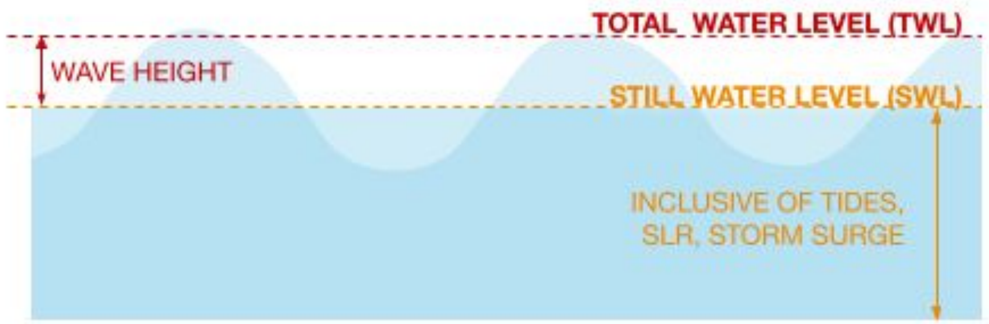


Figure 2.7 (Right). Diagram exhibiting differences between Still Water Level (SWL) and Total Water Level (TWL)

To evaluate the site's anticipated exposure to the prioritized threats identified, a collection of modeling and calculation techniques were used, shown in **Figure 2.6**.

Methodologies listed are intended to identify assets exposed to threats through either (A) the production of a spatially-referenced mapping output to apply in a qualitative analysis ("zonal analysis"), or (B) an anticipated water level resulting from threats that can be mapped against the site's topography to denote spatial extents and analyzed quantitatively compared to other anticipated water levels ("elevational analysis").

Methodologies to identify water levels associated with coastal flooding threats either estimate water levels given trends of historic data recorded in the local area using Ft. Pulaski tide gauge data ("**empirical data**") or through a statistical analysis given a large dataset of theoretical storms that could plausibly occur locally given environmental conditions ("**statistical models**"). Water levels associated with pluvial flooding are garnered using **hydrologic & hydraulic modeling** software that estimates stormwater runoff yielded from rainfall events.

Resultant water levels yielded through the presented methodologies are provided as a **still water level (SWL)**, which represents the water surface elevation at any given time, regardless of what caused the water surface elevation - including mean sea level, tidal ranges, storm surge, etc. Water levels are also considered as a **total water level (TWL)**, which includes the SWL with the additional height of waves anticipated for the conditions modeled. Inclusion of TWLs in analysis is recommended by the Beaufort County Long-Term Resilience Strategy given the erosive and inundation-exacerbating characteristics of wave action. Definitions of SWLs and TWLs are compared in **Figure 2.7**.

All water elevations and site topography elevations considered are relative to the NAVD88 vertical datum.

2.5 Coastal Erosion & Marsh Loss

Overview & Shoreline Context

This section provides an overview of the qualitative analysis that was conducted to evaluate the impacts of coastal erosion and marsh migration along the shoreline.

Outside of any climatic threat, marshes and shorelines are dynamic systems that migrate overtime due to sediment transport, human activities, and natural processes. As shown in **Figure 2.8**, a U.S. Army Corps of Engineers' (USACE) study of the shoreline indicates that the shoreline along the interchange has been consistently receding over time, with an accreting shoreline on the other side of Battery Creek.

Coastal erosion associated with marsh loss and **wave action** will exacerbate these naturally occurring processes, increasing the rate that the shoreline is destabilized resulting in deterioration of shoreline-adjacent infrastructure integrity.

Coastal Erosion

Aerial imagery of the shoreline taken at fourteen different times in history between 2006-2024 was digitized to understand both horizontal and vertical rates of change at a smaller time scale. Horizontal rates of change were studied by comparing shoreline profiles between the different images. Vertical rates of change were considered using elevational differences noted between federal-sourced aerial surveys conducted in 2013 and in 2019-2020.

Rates of horizontal change along the Battery Creek shoreline are shown in **Figure 2.9** below. Shoreline accretion noted to the North of the bridge is likely attributed to sediment deposition associated with a surface drainage path in the same location, and the highest rates of erosion noted to the South of the bridge is likely attributed to susceptibility to higher winds that exacerbate wave conditions. See **Appendix C** for more detail on the shoreline analysis.

Extents of Marsh Accretion

Preliminary analysis was conducted to identify areas experiencing marsh migration to higher elevations given rising sea levels ("**marsh accretion**") and understand projections for how marsh habitat is anticipated to change in the future using NOAA's Sea Levels Affecting Marsh Model (SLAMM). This model estimates changes based on accretion values, sea level trends, elevation, slopes, and existing marsh habitats. More detail on the modeling approach can be found in **Appendix D**.

As the biggest threat to the local marsh system is sea level rise, which results in marsh inundation frequencies and depths that are unsuitable for marsh habitat, the model identified areas that have ample sediment input to raise the elevation of the land that marsh exists on at a rate that can compensate for rising sea levels to preserve marsh health (shown in green in **Figure 2.10**) and areas where marsh cannot accrete at a similar rate to rising sea levels, indicating future marsh deterioration (shown in red).

Figure 2.8. Shoreline change along the sight that has occurred between 1880 - 2024. *Image Source: USACE South Atlantic Shoreline Regional Assessment National Shoreline Management Study*

Figure 2.9. Rates of horizontal shoreline change along Battery Creek denoted between 2006-2024

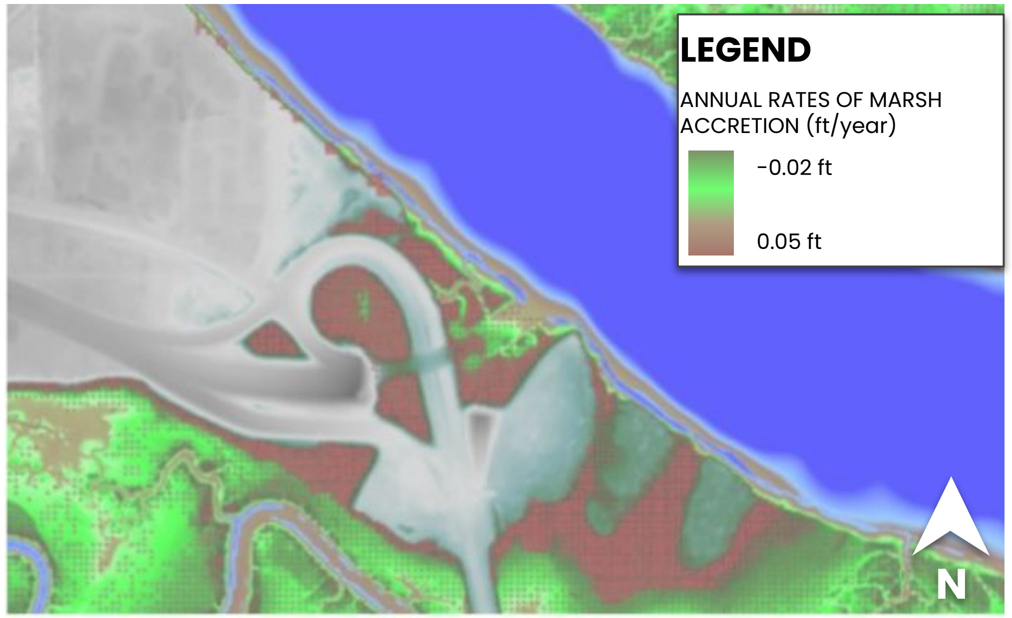


Figure 2.10. Areas of where marsh migration is occurring and anticipated to occur.

2.6 Coastal Flooding

Analysis was conducted to anticipate the severity and frequency of water levels within the tidally-influenced water bodies adjacent to the site. Goals, approach, and data inputs for each analysis technique are discussed below and shown in more detail in **Appendix B**.

Compound Coastal Flooding

Compound coastal flooding occurs due to some combination of coastal-originating threats that occur concurrently - including tidal ranges, storm surge, and sea level rise.

Extents of compound coastal flooding was evaluated by a numerical model created by the USACE, shown in **Figure 2.11**. The Coastal Hazards System (CHS) model, is a federally-sourced open database that estimates water levels for events of varying **Annual Exceedance Frequencies (AEF)**, which is the statistical probability of a water elevation occurring at any point over a given year, given a range of anticipated water levels.

Notable Historic Storms & Storm Surge

Anticipated water levels resulting from historical storms were also estimated using CHS. For historical storms analyzed, two water levels are provided - one representing water levels for storm conditions as they coincided with the experienced tide level, and one representing water levels if the storm were to coincide with the maximum tide plausible (worst case scenario). Inundation extents yielded by Hurricane Matthew (2016) storm surge shown in **Figure 2.12**.

Anticipated water levels associated with storm surge yielding from low-pressure systems (i.e., tropical storms and hurricanes) were modeled based on NOAA's Sea Lake and Overland Surges from Hurricanes Model (SLOSH). SLOSH is a statistical model used to estimate water levels associated with storm surge resulting from tropical storms and hurricanes ranging from Categories 1-5. The SLOSH model anticipates water levels given topography and hypothetical hurricanes that could occur in the area given characteristics of past hurricanes.

Tidal Flooding

The site's exposure to high-tide flooding (i.e., "sunny day flooding") was analyzed both in severity and frequency. Anticipated high-tide flooding was defined using two thresholds: Shallow Coastal Flooding and Nuisance Flooding.

Thresholds to define **Shallow Coastal Flooding**, as established by NOAA, characterize tidal flooding as a factor of the local tidal range (i.e., vertical height between high tide and low tide). As a result, rising sea levels will increase the frequency of which this threshold is met (6x per year in 2025, 47x per year in 2045), but not increase the threshold itself.

Nuisance Flooding is defined as the anticipated water level that is anticipated to occur 30 times in any given year. Unlike the aforementioned threshold, water levels associated with the threshold increase in future threat timeline scenarios due to sea level rise increasing the mean sea level that all tidal elevations are based upon, as shown in **Figure 2.13**.

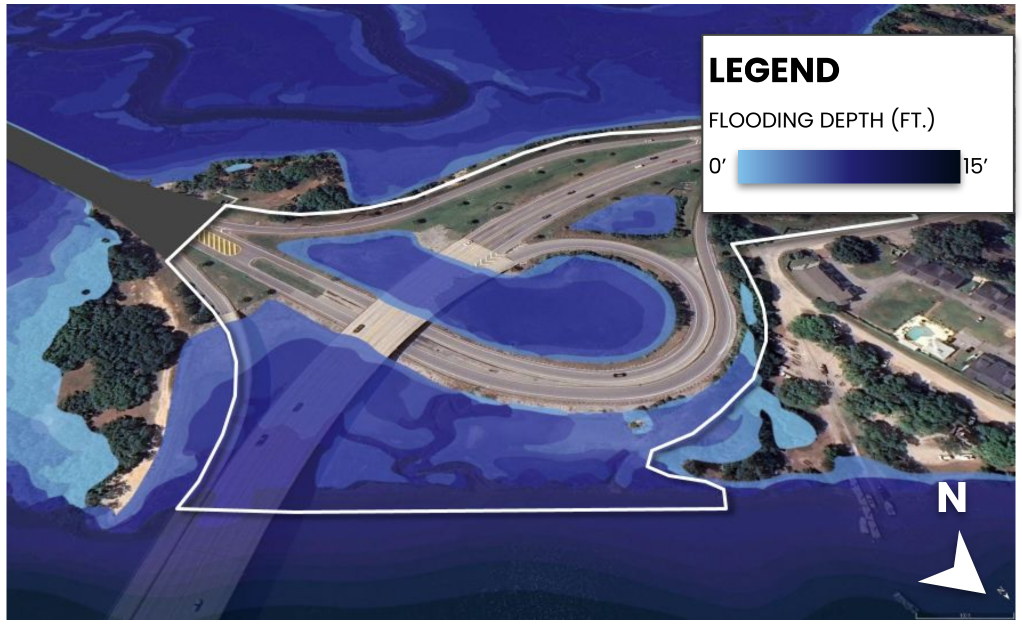


Figure 2.11. Inundation extents of 10-yr AEF in 2025 (i.e., storm with 10% statistical probability of occurring at site in any given year)

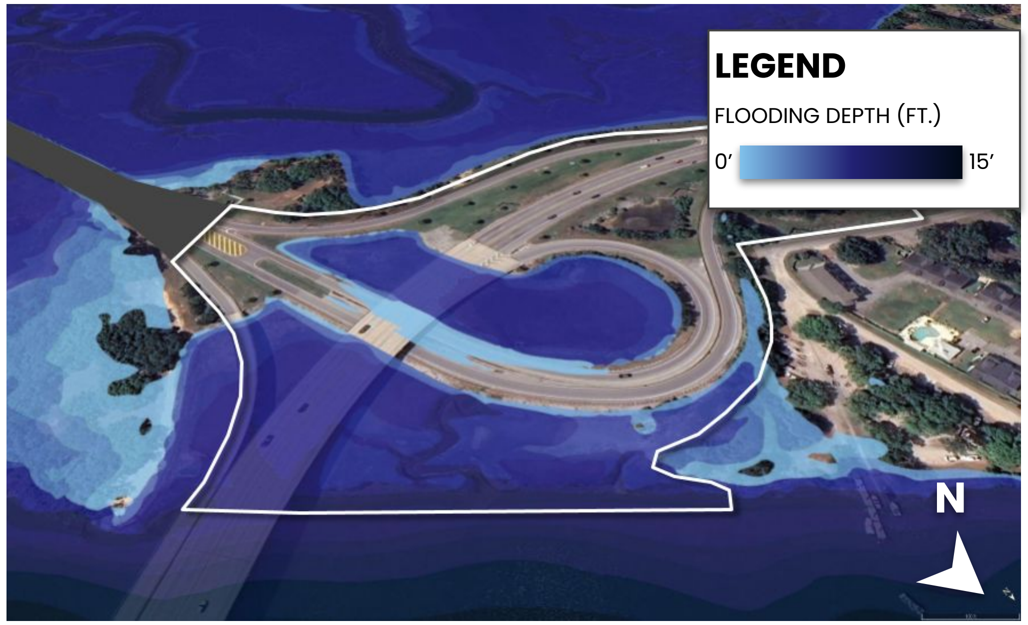


Figure 2.12. Inundation extents of Hurricane Matthew (2016), assuming experienced tide conditions.

Figure 2.13. Extents of inundation related to Nuisance Flooding in 2025 vs. 2045

2.7 Pluvial & Compound Flooding

Pluvial flooding, or the flooding that occurs from excessive runoff generated from intense rainfall, was analyzed using hydrologic and hydraulic modeling software to evaluate the capacity of existing stormwater infrastructure and anticipated water surface elevations of the inland marshes, which the majority of site stormwater drains towards and utilizes to meet stormwater storage requirements. More detail on analysis can be referenced in **Appendix E** and associated regulatory requirements are included in **Appendix F**.

Stormwater storage capacity considers the total volume of water that can fit within the basins before the basins reach capacity and breach their banks, spilling into the adjacent roadway. As the inland marshes are hydraulically connected to the tidally influenced Battery Creek, elevated tidal waters fill up the inland marshes to an elevation equal to the coastal water elevation within the creek. This influx of coastal waters reduce the overall capacity of these inland marshes to store additional volumes of stormwater runoff, inhibiting the efficacy of drainage infrastructure to convey runoff away from the road that would otherwise cause road inundation during heavy rainfall events.

To evaluate the impact that rising sea levels will have on stormwater infrastructure capacity, **Figure 2.14** identifies anticipated reduction in stormwater capacity within the lower inland marsh, during a high-tide scenario for the future threat timelines. Elevated water levels are considered as the anticipated **Mean Higher High Water (MHHW)** in each scenario, which is the average height of the highest daily tide recorded at the Ft. Pulaski tide gauge each day throughout a 19-year period. The lower inland marsh (as first indicated in **Figure 1.4**) is highlighted in this section, rather than the upper inland marsh, due to the lower inland marsh's proximity to the lowest road elevations, where spillover is most likely to occur.

Storage Capacity of Lower Inland Marsh - 2035

MHHW: 3.78 ft
Reduced Stormwater Capacity in Lower Inland Marsh: 15%
Max. Rainfall Depth Before Spillover into Lane: 2.67”

Storage Capacity of Lower Inland Marsh - 2045

MHHW: 4.11 ft
Reduced Stormwater Capacity in Lower Inland Marsh: 28%
Max. Rainfall Depth Before Spillover into Lane: 2.27”

Storage Capacity of Lower Inland Marsh - 2075

MHHW: 5.88 ft
Reduced Stormwater Capacity in Lower Inland Marsh: 46%
Max. Rainfall Depth Before Spillover into Lane: 1.71”

As shown, stormwater storage capacities are anticipated to continually decrease in efficacy due to rising tidal water levels feeding the marsh, increasing the frequency at which Gen. Pollock Causeway may flood during a rain event due to water within the lower inland marsh exceeding capacity. More detail on this analysis can be referenced in **Appendix E**.

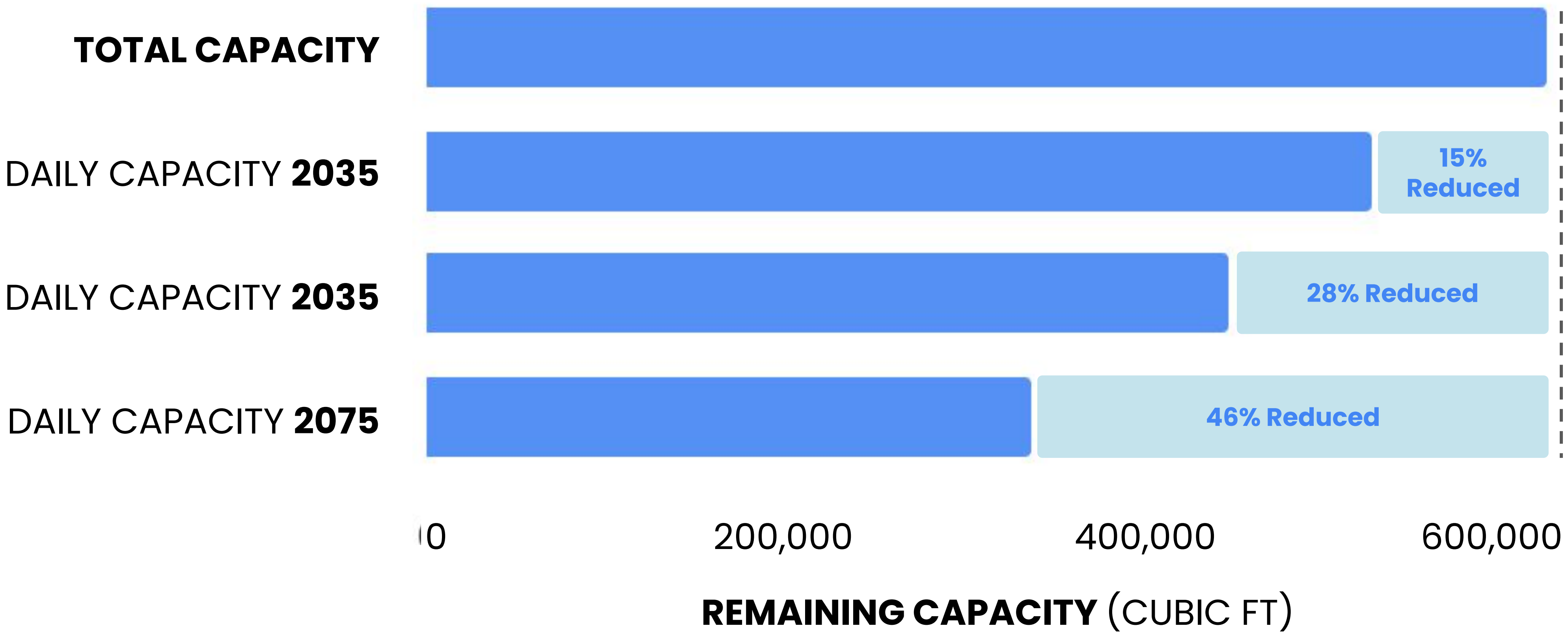


Figure 2.14. Available stormwater storage capacity within the lower inland marsh during MHHW tides in 2035, 2045, and 2075.

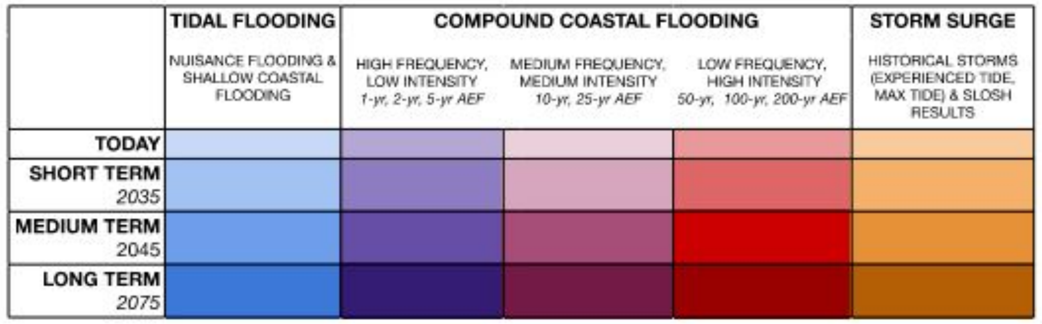
2.8 Exposure Analysis Takeaways

Elevation Analysis

All water levels generated as part of the "Exposure Analysis" were compiled into one table (see **Appendix G**), color categorized by both the type of threat and timeline considered, and sequentially ordered based on the resultant water elevation (**Figure 2.16**). All water levels considered are provided as total water levels, with the exception of tidal flooding elevations, which are represented as still water levels. All water levels provided are shown relative to the NAVD88 vertical datum.

Listed in **Figure 2.15** (below) is the color categorization applied to water levels to represent the types of events (see column header) and the corresponding threat timeline scenario (see row header) that yielded the water level determined.

For compound coastal flooding threats shown within **Figure 2.15**, threats are either categorized as high frequency, low intensity; medium frequency, medium intensity; or low frequency, high intensity. Hypothetical storms associated with these categorizations can be referenced in the row header.



	TIDAL FLOODING	COMPOUND COASTAL FLOODING			STORM SURGE
	NUISANCE FLOODING & SHALLOW COASTAL FLOODING	HIGH FREQUENCY, LOW INTENSITY *1-yr, 2-yr, 5-yr AEF*	MEDIUM FREQUENCY, MEDIUM INTENSITY *10-yr, 25-yr AEF*	LOW FREQUENCY, HIGH INTENSITY *50-yr, 100-yr, 200-yr AEF*	HISTORICAL STORMS (EXPERIENCED TIDE, MAX TIDE) & SLOSH RESULTS
TODAY	🟦	🟪	🟪	🟥	🟧
SHORT TERM *2035*	🟦	🟪	🟪	🟥	🟧
MEDIUM TERM *2045*	🟦	🟪	🟪	🟥	🟧
LONG TERM *2075*	🟦	🟪	🟪	🟥	🟧

Figure 2.15. Color Categorization Structure for Resultant Water Levels Obtained through "Exposure Analysis"

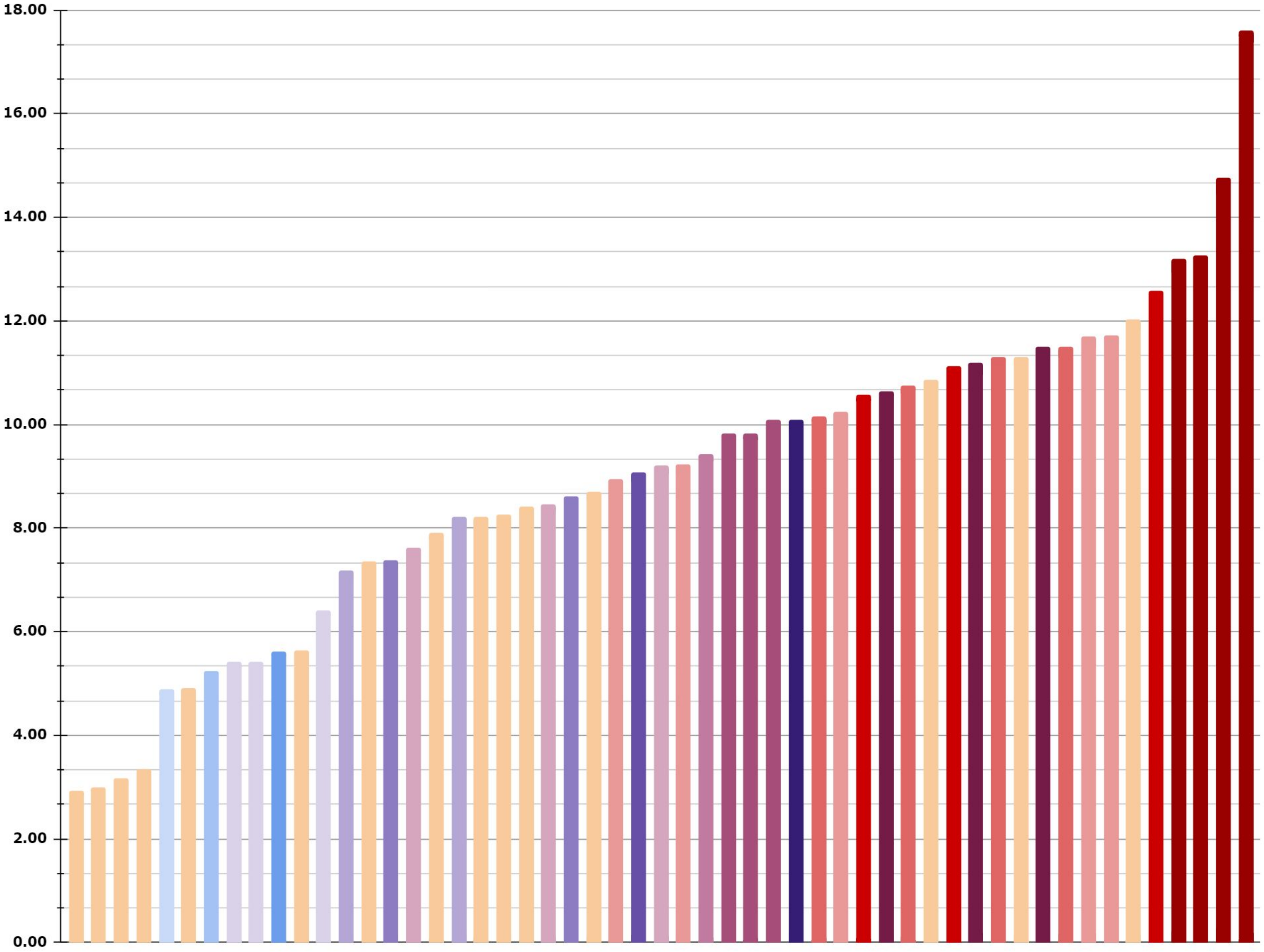


Figure 2.16. Resultant water levels yielded from analysis, sequentially ordered and color categorized given threat and timeline considered.

Note: Critical water levels associated with storm surge shown as lowest water elevations in Figure are associated with historic storms whose storm path did not directly impact study area, yielding only fringe impacts.

2.8 Exposure Analysis Takeaways

Trends of Exposure

Anticipated water levels resulting from the elevational analysis were grouped together based on trends of threats that resulted in similar anticipated water levels to evaluate types of threats anticipated to affect relative across the site.

0-5.87 ft | Tidal Flooding in the Short- and Medium-Term

Threats associated with tidal flooding today and in the short-term (2035) and medium-term (2045), resulting in coastal erosion and marsh loss.

5.88-7.40 ft | High-Frequency Coastal Flooding Today and Long-Term Tidal Flooding

Flooding associated with high frequency, low intensity compound coastal flooding today and in the near-term (2035, 2045) and tidal flooding anticipated in the long-term (2075), yielding similar disturbances to the first elevation band, but at these higher elevations in the future. Compound flooding is anticipated if tidal waters fill inland marshes during medium frequency, medium intensity rainfall events.

7.41-9.85 ft | Hurricanes & High Intensity Storms in the Short-Term, Medium-Term Compound Flooding, and Long-Term Coastal Flooding

Compound flooding anticipated if elevated coastal waters reduce storage capacity within inland marshes and coincide with a high frequency, low intensity rainfall event in the medium-term (2045). Compound coastal flooding that is characterized as either low frequency, high intensity in the medium-term (2045) and medium frequency, medium intensity in the long-term (2075).

9.85+ ft | Hurricanes & Low Frequency, High Intensity Storms in the Medium- and Long-Term

Catastrophic storms (i.e., Hurricanes) resulting from storm surge, or low frequency, high intensity storm events to occur in the medium- (2045) and long-term (2075.)

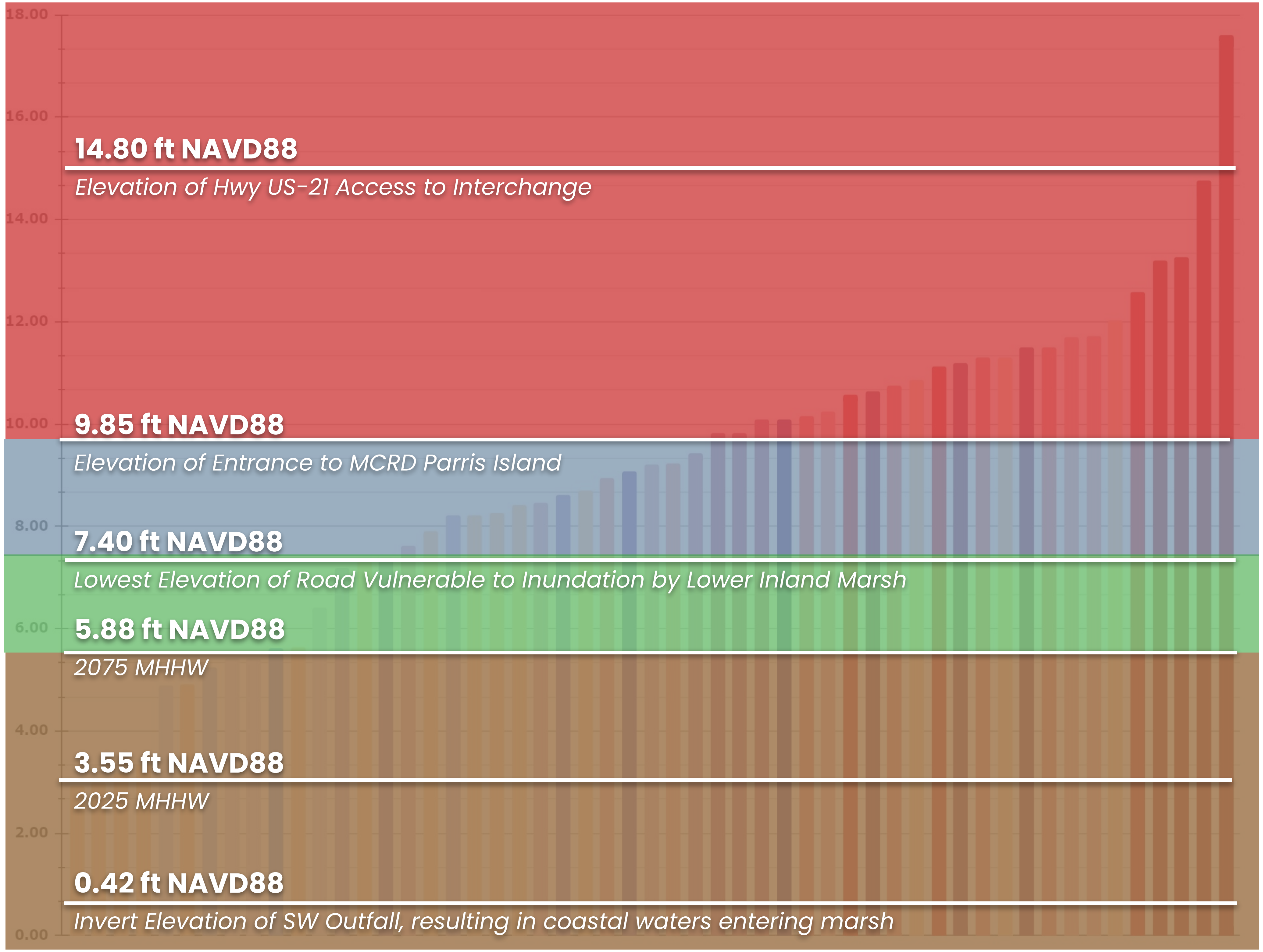


Figure 2.17. Elevational bands identified based on trends of critical water levels anticipated on-site and the associated types of threats that cause them.

Figure. Aerial Image of Shell Point Interchange *Image Source: Paul Nurnberg*

3 PRIORITIZE SITE VULNERABILITIES

3.1 Impact Assessment

Elevation bands described on the previous page are shown as they relate to site topography in **Figure 3.1** to the right, and understood infrastructure impacts as a result are listed below.

0-7.40 ft | Coastal Erosion & Marsh Loss Today & In Future

Disturbances corresponding with threat trends identified include marsh loss and coastal erosion, due to wave action and deterioration of marsh that stabilizes shoreline soil due to excessive inundation of marsh. Although the shoreline shows healthy low marsh vegetation, the density and health of this vegetation rapidly declines moving inland from the shoreline due to high tides and increased wave energy, yielding large mudflat areas where vegetated space would normally be. Wave energy deteriorates the structural integrity of the road-adjacent revetment and dissipated wave energy results in downstream turbulence, further disrupting marsh vegetation.

7.41-9.85 ft | Road Inundation

Disturbances anticipated to temporarily inundate the southbound travel lane of the underpass due to the lower inland marsh reaching capacity and overflowing into the road. The Hwy US-21 westbound lane of the underpass closest to Battery Creek may be subjected to a few inches of inundation during compound coastal flooding threats due to waves breaking onto the road.

9.86+ ft | Large-Scale Infrastructure Disruption

Multiple feet on inundation are anticipated across all travel lanes along the causeway, disrupting all vehicular access across the interchange. Road infrastructure and revetments are anticipated to have sufficient damage due to the extreme depth of inundation.

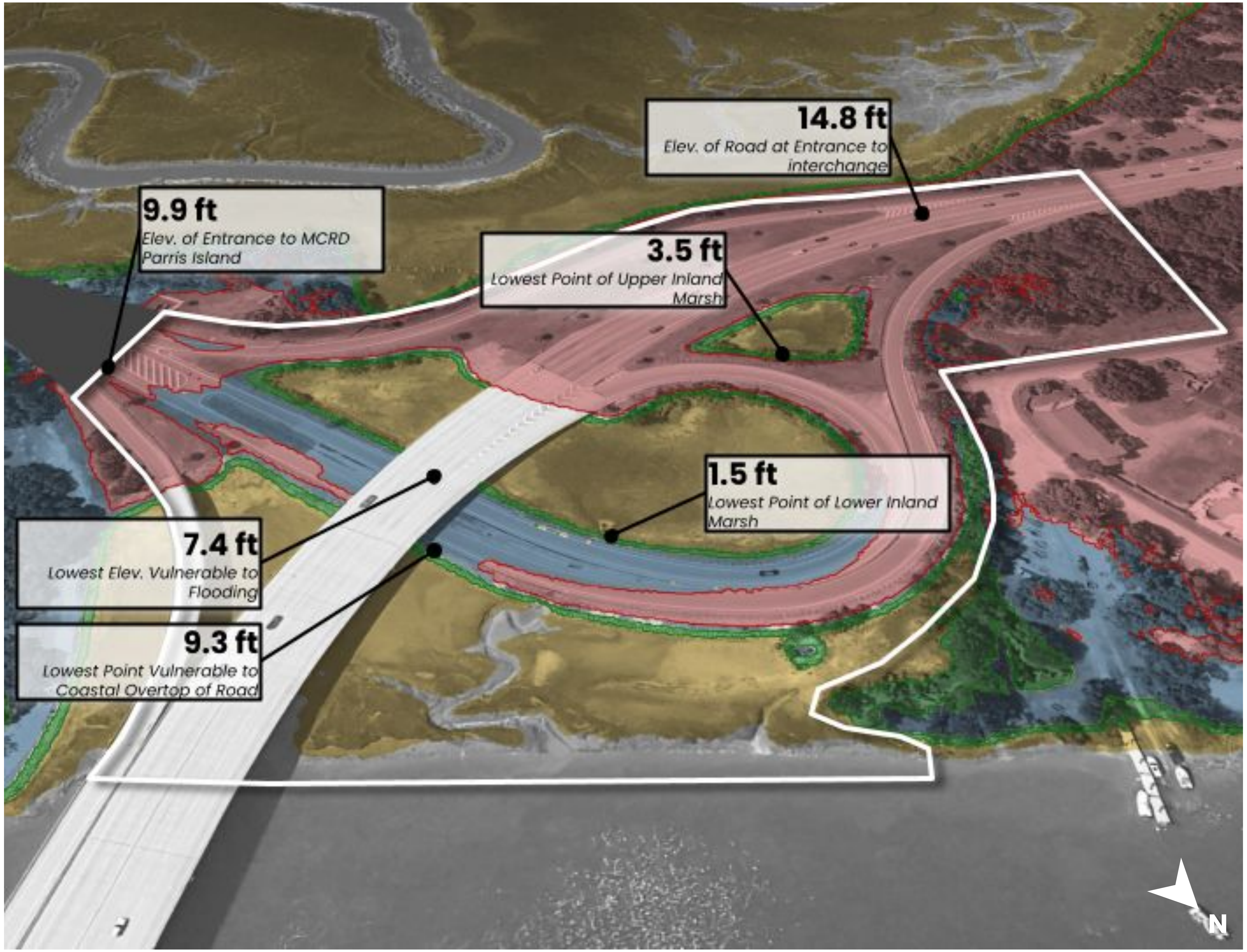


Figure 3.1. Elevational bands shown as they apply to site topography to understand where trends of disturbance are anticipated.

3.2 Impacts of Coinciding Threats

To gauge infrastructure sensitivity of when threats occur simultaneously, three hypothetical compound threat scenarios were curated and mapped for analysis. Scenarios were derived given threats that typically compound in the area, as first identified in the MIRR study, and result in typological disturbances that are representative of a variety of disturbances anticipated to occur.

Each scenario presented corresponds to a successive future threat timeline scenario and aligns with one of the three elevation bands identified on the previous page. Due to the likelihood that the majority of disturbances occur when threats compound, these scenarios will serve as design storms that design efforts are intended to protect against, in addition to meeting regulatory requirements.

Short Term: Chronic Tidal Flooding in 2035

In 2035, a high-tide flooding occurs at an elevation (5.25 feet) that occurs at least 30 times a year (2-3 times a month). Mean sea level has risen nearly 4 inches since 2025, thus increasing the water elevation of high-tide flooding, as shown in **Figure 3.2**. As a result, larger extents of marsh in upper elevations are degraded due to the increased frequency of marsh and impacts of wave action on the shoreline increase in spatial extent and frequency. Even in the absence of storm-like conditions, wave heights are still close to exceeding allowable thresholds for marsh vegetation.

Medium Term: Compound Flooding in 2045

In 2045, mean sea level is anticipated to be eight inches higher than in 2025, resulting in a high-tide flooding elevation of 5.61 feet, given the same frequency of the first presented scenario. Tidal waters fill up inland marshes, reducing stormwater storage capacity by ~50%. This high-tide occurs at the same time that rainfall patterns similar to that of Hurricane Debby (2024, 10.8 inches over 24 hours).

Given both the coastal waters and stormwater runoff contributing to the inland marshes simultaneously, stormwater storage capacity is reached and water from the lower inland marsh spills into the underpass's southbound lane just North of the bridge, resulting in several inches of flooding, threatening safe travel within the lane, but with no impacts to the outer lane (**Figure 3.3**).

Long Term: Hurricane Matthew in 2075

In 2075, a storm with similar characteristics to Hurricane Matthew is anticipated to make landfall in the area. Mean sea level is anticipated to have risen nearly 2 feet since 2025, exacerbating the compound coastal flooding experienced when the storm occurred in 2016. Nearly two feet of inundation is anticipated within the lane adjacent to the lower inland marsh, and over one foot of inundation is anticipated within the underpass's outer lane due to waves overtopping (**Figure 3.4**). Large-scale infrastructure damage after the storm is anticipated after the storm due to excessive wave energy and depths of inundation across the road infrastructure.

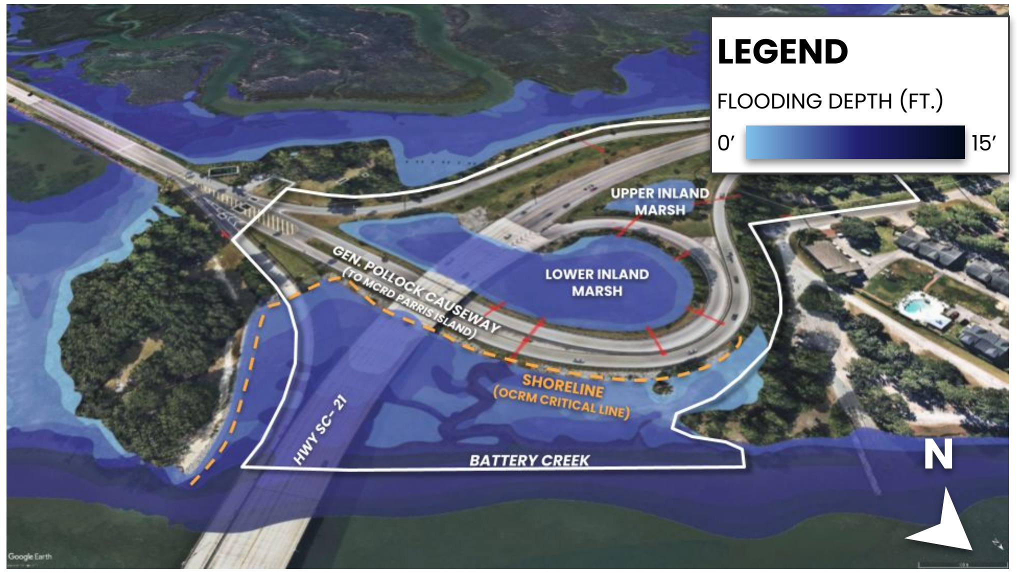


Figure 3.2. Inundation depths anticipated across the site resulting from a high-tide flood that occurs 30x per year in 2035.

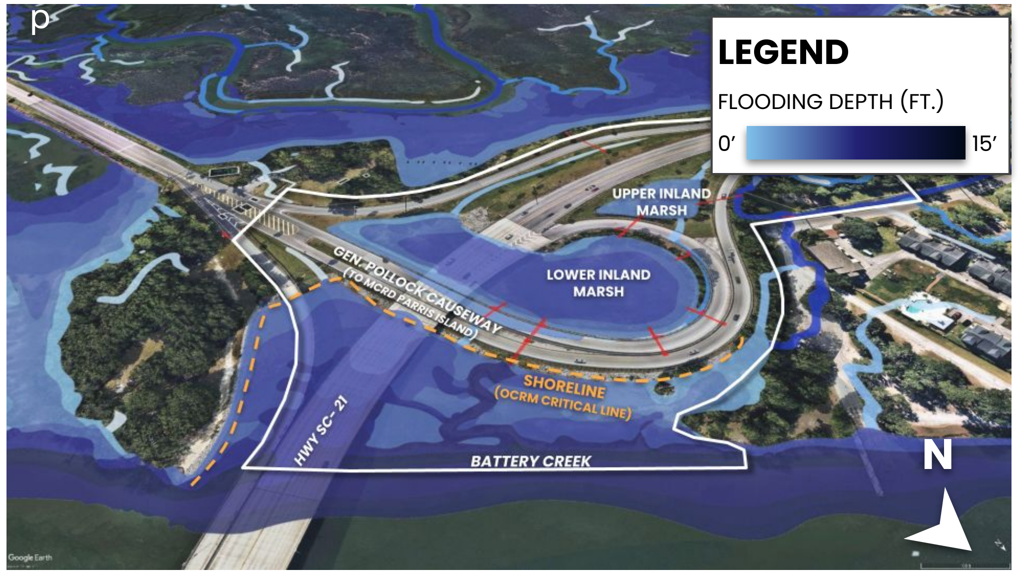


Figure 3.3. Anticipated inundation extents result from a 2045 high-tide flood coinciding with rainfall patterns experienced during Hurricane Debby (2024). Surface drainage patterns also shown to indicate how water accumulates in the absence of pipes.

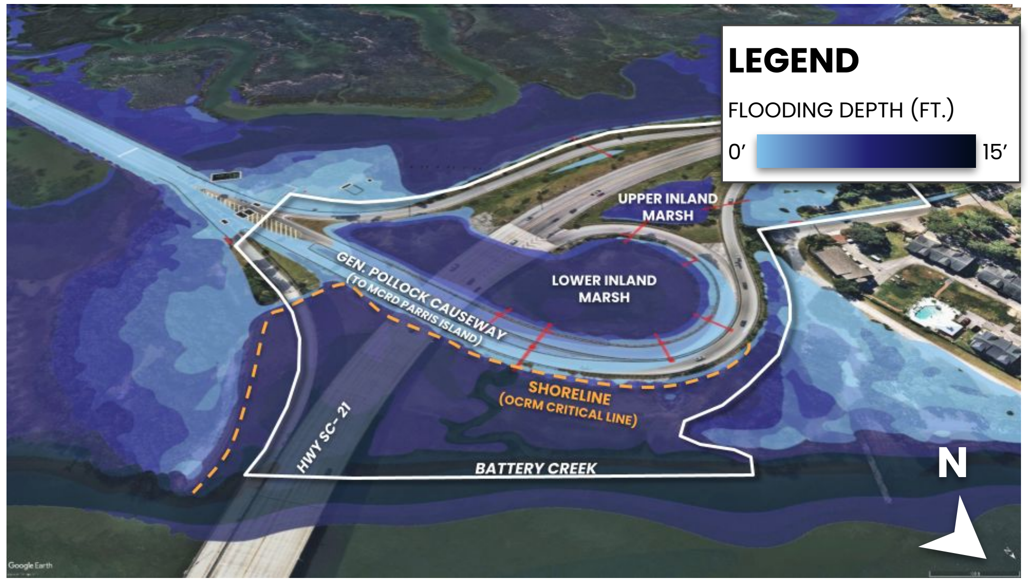


Figure 3.4. Inundation depths anticipated across the site if a hurricane identical to Hurricane Matthew (2016) was to occur in 2075, given 50-yrs of SLR.

3.3 Sensitivity to Community Threats

In addition to the technical review of impacts resulting from coinciding threats described in Section 3.2, operational disturbances yielded from the three compound threats were also considered from the perspective of local stakeholders through an interactive tabletop exercise conducted in September 2024.

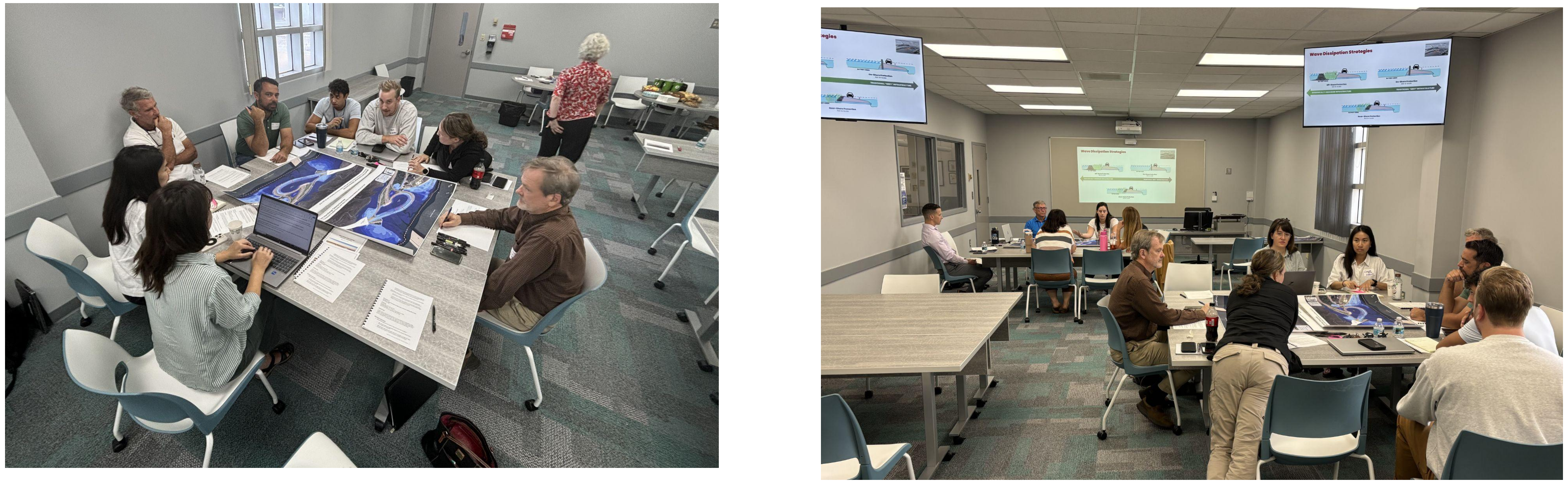
Stakeholder Tabletop Exercise

The interactive exercise utilized the three hypothetical compound threat scenarios to prompt discussion amongst the invited stakeholders regarding initial reactions, planned responses, and concerns with understood disturbances for the future condition. Conversations were held with the following goals in mind:

- Groundtruth findings from desktop analysis against lived experiences to identify potential gaps in desktop analysis;
- Understand how community operations respond to threat impacts presented in scenarios to gage disturbances to community operations;
- Understand potential constraints or community considerations for potential mitigation measures to inform design priorities.

Stakeholder engagement was emphasized to leverage previous partnerships amongst local agencies that has been fostered through the MIRR study, among other local resilience initiatives. Agencies represented at this event ranged in expertise and purview, including representatives from MCRD Parris Island, Beaufort Jasper Water Sewer Authority, Beaufort County Engineering, Town of Port Royal, and the South Carolina Lowcountry Sentinel Landscape.

Images taken during the exercise are shown in **Figures 3.5 -3.6** and resultant design priorities gleaned from discussions conducted in **Figure 3.7**.



	Priorities	Strategies
01	Minimize operations + maintenance requirements of design solutions	• Prioritize use of nature-based solutions • Maintain or retrofit infrastructure where feasible
02	Marsh habitat should be protected and augmented where feasible	• Maximize marsh migration potential • Integrate with SCDNR living shoreline project
03	Continue facilitating collaboration and dialogue among stakeholders to stay ahead of permitting	• Continue consistent engagement with local agencies
04	Design for and communicate varied risk tolerances across stakeholder groups	• Prioritize resilience in non-evacuation mandated events • Maintain travel access in one lane in large storm events
05	Integrate long-term resilience of the interchange to stakeholder visions and planning efforts	• Identify for synergies with existing planning efforts for long-term resilience • Educate on long-term resilience strategies

Figure 3.5-3.6 (Top Left, Top Right). Photos taken of Stakeholder Tabletop Exercise, conducted in September 2024

Figure 3.7 (Bottom). Resultant design priorities for site gleaned from community input via Stakeholder Tabletop Exercise

3.4 Improving Adaptive Capacity

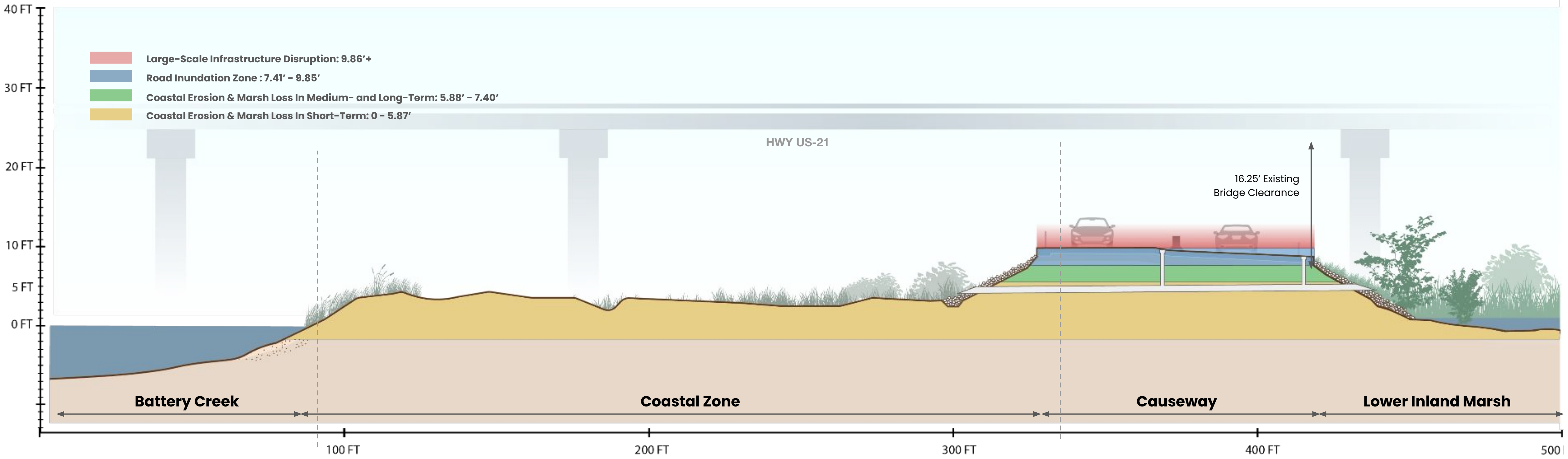


Figure 3.8.
Cross section of site in Existing Conditions
(Vertical Exaggeration 5:2)

Evaluating infrastructure's **adaptive capacity** is crucial to understand how infrastructure and community operations can withstand impacts from climatic threats, informing existing assets to preserve and identifying gaps where additional measures must be implemented during design.

① Gaps in Existing Adaptive Capacity

Gaps are organized below by the three elevation based categories, given takeaways from regulatory requirements and performance specifications for infrastructure.

Coastal Erosion & Marsh Loss

Even in the day-to-day condition, average wave heights along the shoreline nearly exceed the thresholds of tolerable wave heights for a natural marsh system. Turbulence created by wave energy reflecting against the revetments, along with the shoreline soil's soft and silty characteristics that yield low soil stability, exacerbate this condition, resulting in unsuitable conditions for marsh re-establishment without intervention. The shoreline is relatively flat with small changes in elevation and bound by the underpass's concrete infrastructure, both contributors to limited marsh migration feasibility on-site without intervention. Results are anticipated to cause marsh die-off to happen relatively quickly across the entire shoreline, causing erosion exacerbation and loss of revered habitat in the Lowcountry.

Road Inundation

As tidal levels anticipate increases in the future, increasing tidal influx within the inland marshes are anticipated in both frequency and severity, prohibiting the efficacy of stormwater management infrastructure. As a result, inundation of the underpass's southbound lane has a likelihood of occurring by 2045 and frequently is to occur without intervention by 2075. In the instance of restricted access, the military does maintain access to and from the installation via the alternative entrance and exit ramps for Hwy US-21 just south of the underpass, both several feet higher in elevation. The alternative access points will maintain critical travel, but still yield disruptions. For example, passengers driving westbound from the Hwy US-21 bridge will require prior notice (e.g., signage) to continue westbound for a u-turn to access the installation rather than taking the exit ramp for the underpass, as drivers will have no reroute option upon reaching the inaccessible road portions given the concrete vertical barriers between travel lanes.

There are no existing plans in place for operations if the underpass were to flood during a non-evacuatory event. Operational impacts would be heavily exacerbated if this was to coincide with a peak travel day for the installation, which occurs every few weeks for recruit graduation ceremonies that families attend. In the event of coincidence Hwy US-21 is not sized to handle the increased number of vehicles, potentially resulting in traffic jams that may delay emergency access to the installation, constrain livability for employees and visitors accessing the installation, and cause excessive reliance on one asset.

Military operations rely on trucks delivering supplies via the underpass, so road raising capabilities are limited to maintain minimum vertical clearances needed for truck passage.

3.4 Improving Adaptive Capacity

Large-Scale Infrastructure Disruption

For large storm events that warrant evacuation, evacuation plans and warning systems exist for both the military installation and surrounding community. Access of the installation is typically not needed within 12 hours of an event that requires evacuated, which is sufficient time for a tidal cycle to recede flooding waters that cause widespread inaccessibility. Drainage infrastructure will not have sufficient capacity to drain floodwaters from road until tides recede. There are no adaptive operations plans in place for if this infrastructure (e.g., outer lanes of the underpass and direct entrance/exit ramps from installation to Hwy US-21) is heavily damaged during an event.

② Themes to Improve Adaptive Capacity

Opportunities to improve adaptive capacity are listed below and summarized in **Figure 3.9**. These opportunities, which will serve as design priorities in subsequent efforts, were identified via community priorities synthesized from stakeholder engagement and gaps identified in existing adaptive capacity.

Shoreline Stabilization

To allow for marsh re-establishment, wave dissipation strategies along the shoreline edge could minimize everyday wave energy before interaction with marsh vegetation or the roadside adjacent revetment, allowing for more suitable conditions for the re-establishment of marsh vegetation in the short-term, providing additional stabilization to the shoreline.

If the upper shoreline marsh nearest to the revetment were to be elevated, conditions could be suitable for establishment of upper-marsh vegetation, expanding marsh migration capabilities and furthering stabilization. Elevating would also reduce the frequency at which waves break against the revetment, further limiting the turbulent energy identified.

	GAPS IN ADAPTIVE CAPACITY	✚	COMMUNITY PRIORITIES	⇨	DESIGN PRIORITIES
SHORELINE STABILIZATION	Average wave height nearly exceeds marsh suitability thresholds Flat shoreline bank limits marsh migration capabilities	✚	Minimize Need for Operations & Maintenance Protect & Enhance Marshes	⇨	Mitigate wave height seaward of marshes to allowable thresholds Facilitate marsh migration through the medium-term
OPTIMIZE STORMWATER MANAGEMENT	Stormwater storage capacity limited by tidal influx, causing spillovers into lanes No restricted access plans in non-evacuation events	✚	Maintain 2- lane travel access in non-catastrophic events	⇨	Maximize Inland Marsh's storage capacity to maintain 2-lane access through medium-term
EXTREME COASTAL FLOOD PROTECTION	Drainage capacity limited if waves overtop outer lane Road raising not feasible due to bridge vertical clearance	✚	2-lane access not necessary in direct aftermath given in-place evacuation processes	⇨	Mitigate coastal overtopping of outer lane to maintain 1-lane access through long-term

Figure 3.9. Design priorities for mitigation given identified gaps in adaptive capacity and community priorities

Optimize Stormwater Management

Roadway inundation impacts could be mitigated in frequency and severity through drainage improvement strategies that improve the efficacy of the inland marshes as stormwater infrastructure. Design strategies for the inland marshes that controlled the influx of coastal water volumes into the inland marshes could both maintain stormwater storage capacity to reduce frequency and intensity of spillovers during rain events and also limit marsh die-off within the inland marshes in the future as rising water levels would exceed inundation thresholds suitable for the inland marsh.

Regardless of mitigatory measures to be implemented, the military and civilian communities should initiate operational plans for instances of underpass inaccessibility in the future.

Extreme Coastal Flood Protection

Opportunities to maintain at least one lane of access to the installation can be achieved through either wave dissipation or overtopping protection measures to mitigate flooding in the outer, Hwy US-21 westbound lane of the underpass. As a result, operations would maintain emergency access in all instances.

Figure. Aerial Image of Shell Point Interchange *Image Source: Paul Nurnberg*

4 CONCEPT DEVELOPMENT

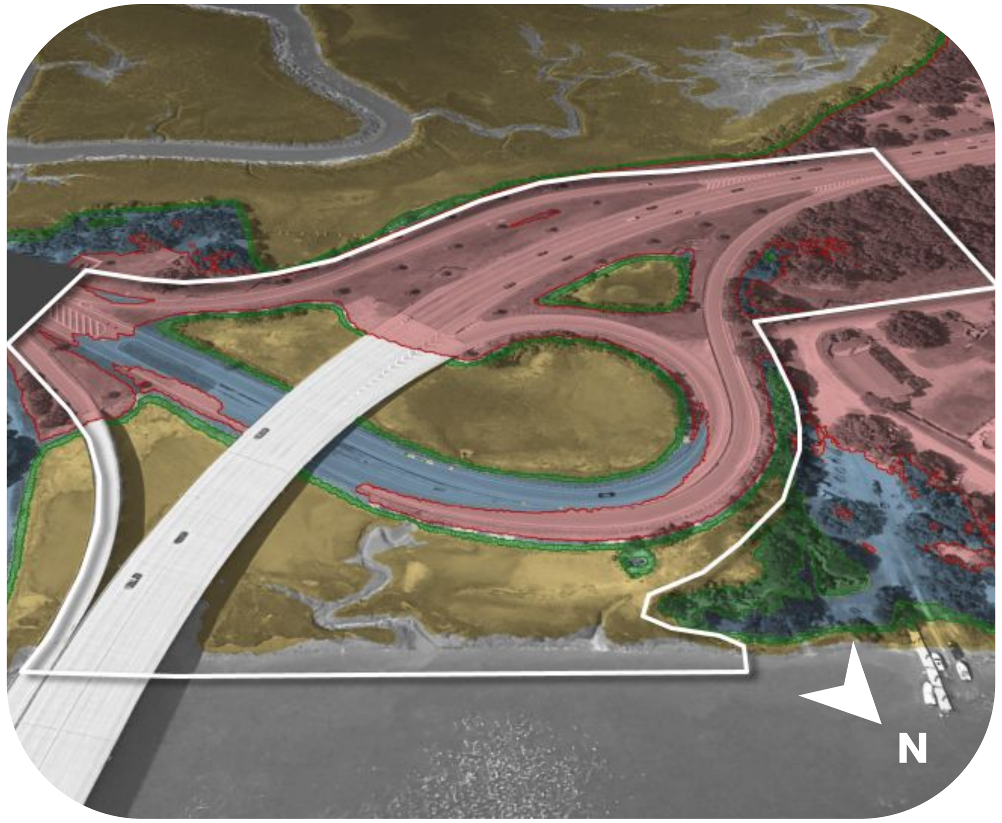
4.1 Concept Development Overview

Section 4 will outline the development of proposed concept measures for mitigation. The design priorities established in the previous section are ground in local conditions through the detailing of opportunities, constraints, design studies, and regulations, informing the mitigation measures proposed in the following section.

Throughout concept development proposed design strategies were evaluated for the site via iterative design team workshops; studies, simulations, and climate models to evaluate physical feasibility and effectiveness; regulatory frameworks and research; and stakeholder feedback.

As key vulnerabilities are anticipated to change across the planning timelines, concept development embraced a phased implementation methodology that can apply incremental protection measures as conditions change. As Shown in **Figure 4.1**, threat and sensitivity events were paired with design priorities and their phases of implementation. Details on key themes for each phase are shown to the right.

EXTENTS IMPACTED BY THREAT



SENSITIVITY		DESIGN PRIORITIES BY IMPLEMENTATION PHASE
🟫🟩 COASTAL EROSION & MARSH LOSS	⇨	**PHASE 1** SHORELINE STABILIZATION
🟦 SOUTHBOUND LANE ACCESS DISRUPTED	⇨	**PHASE 1 + 2** OPTIMIZE STORMWATER MANAGEMENT
🟥 ALL ACCESS DISRUPTED	⇨	**PHASE 1 + 2+ 3** EXTREME COASTAL FLOOD PROTECTION

Figure 4.1. Proposed phasing of implementation by design priorities

Phase ① : Shoreline Stabilization

The site's natural infrastructure located at lower elevations along the shoreline has already experienced observable disruptions. Excessive wave action and increasing inundation frequency from rising sea levels, are expected to result in marsh deterioration and the significant exacerbation of these disruptions in the short-tem (2035).

Phase ② : Optimize Stormwater Management

As sea level continues to rise through the medium-term, sensitivities from compound flooding will begin to worsen in the medium term. Coastal water levels will rise enough to notably reduce the storage capacity within the inland marshes, resulting in spillovers if high tide coincides with a medium-intensity rain event. Mitigation measures must focus on optimizing the functionality of the interchange's stormwater management infrastructure to prevent overflows that would impact the lowest road infrastructure elevations, namely the southbound travel lane of the underpass.

Phase ③ : Extreme Coastal Flood Protection

In the long-term scenario (2075), sea levels have risen significantly exacerbating extreme water levels associated with high-intensity coastal storms (e.g., hurricanes), potentially at an elevation that may overtop the outer Hwy US-21 westbound lane of the underpass. An additional level of coastal protection is needed to protect the outer lane from overtopping to maintain at least one lane of access within the interchange at all times. Water levels do not have a likelihood of rising sufficiently to cause overtopping until the long-term scenario.

4.2 Design Thresholds

Design thresholds are shown below in accordance with meeting both the stated design priorities, compliance with regulatory requirements, and adherence to infrastructure performance specifications.

Shoreline Stabilization

Wave action attenuation is critical for marsh survival inland of any shoreline protection. Literature indicates that the threshold wave height for marsh vegetation establishment is between 0.5 and 1.1 feet.[5] Any wave action exceeding this range must be mitigated to ensure the long-term persistence of marsh habitat.

Any proposed measures to preserve marsh habitat via marsh migration should aim to facilitate marsh migration through at least the short- and medium-term given increases in water levels. It's assumed that due to coastal squeeze, designing for maintenance of shoreline marsh in the long-term condition (2075) is infeasible while maintaining slopes suitable for marsh vegetation today.

Optimize Stormwater Management

Stormwater management infrastructure must be optimized to comply with Beaufort County and SCDOT regulations for stormwater performance, as described further in Section 3.4, and maintain accessibility of all lanes during all climatic threats considered through the medium-term. In absence of any regulatory requirements, and to maintain accessibility within within both lanes road inundation is assumed to be limited to a maximum depth of to 2”, to align with industry-standard performance specifications.

Extreme Coastal Flood Protection

Maintenance of accessibility within the underpass's outer Hwy US-21 westbound lane assumes a maximum of 2” of road inundation in all climatic threats studied.

Design Storms

Each of the compound threat scenarios presented in Section 3.2 aligns with one of the three elevation bands identified and corresponds to both a successive future threat timeline. As threats compound, the majority of potential disturbances all become more likely to occur. These threat scenarios will serve as design storms that design efforts are intended to protect against in addition to meeting regulatory requirements. Inclusion of these scenarios as goalposts for what must be addressed by protective measures is due to the fact regulatory requirements have not established thresholds of performance needed for future conditions. By designing to each of the presented scenarios within the three implementation phases, mitigation designs will be holistic in nature and address coincident threats, ensuring that “worst case scenarios” are properly addressed to maintain infrastructure operations. A summary of the scenario's resultant water levels resulting from the design storms are shown in **Figure 4.2**.

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[5] Roland, Rebecca M and Scott L Douglass. Estimating Wave Tolerance of Spartina alterniflora in Coastal Alabama (2005). Journal of Coastal Research, West Palm Beach, Florida.

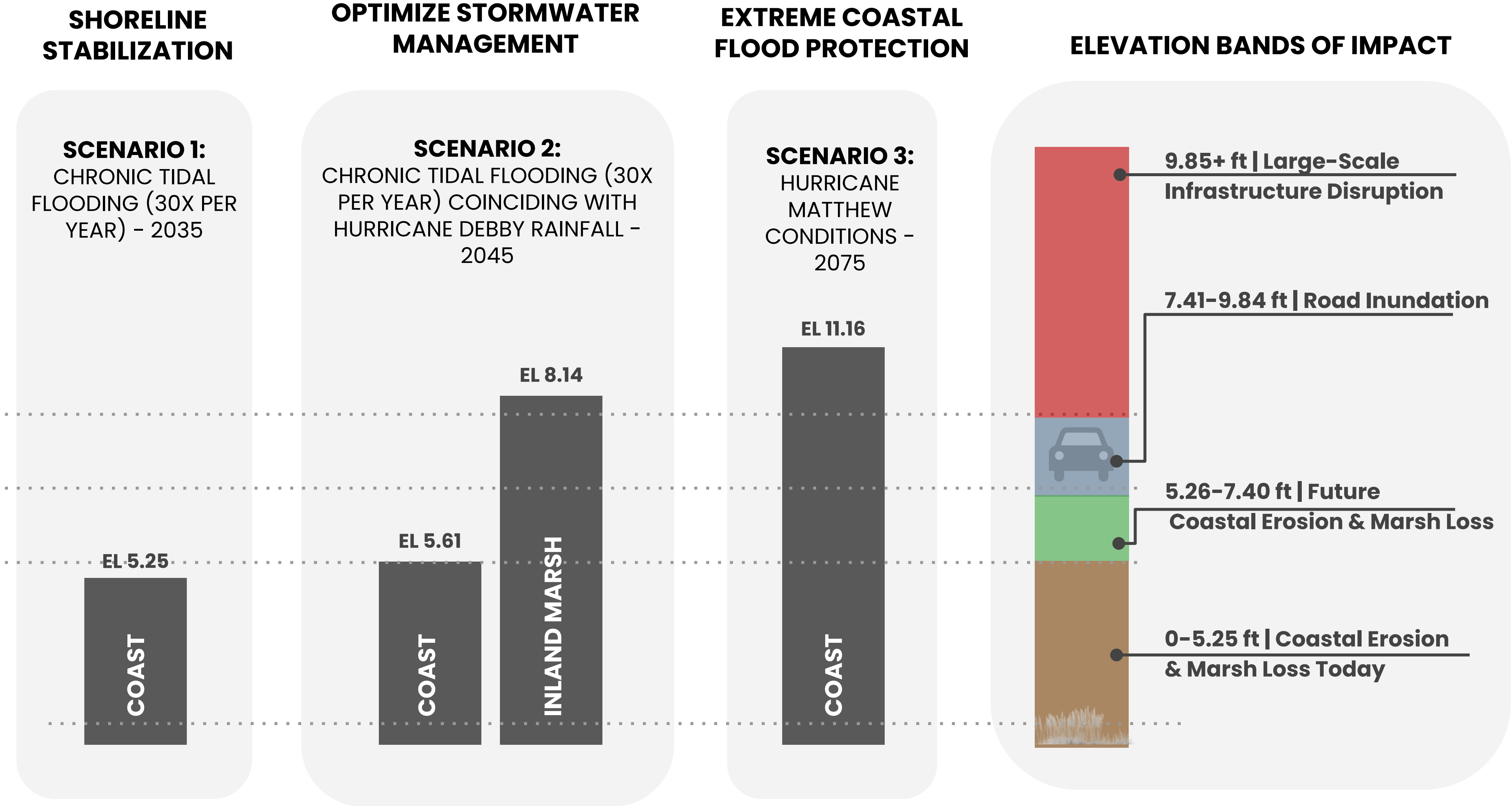


Figure 4.2. Anticipated water levels associated with compound threat scenarios to serve as design storms for protective measures.

4.3 Shoreline Stabilization Considerations

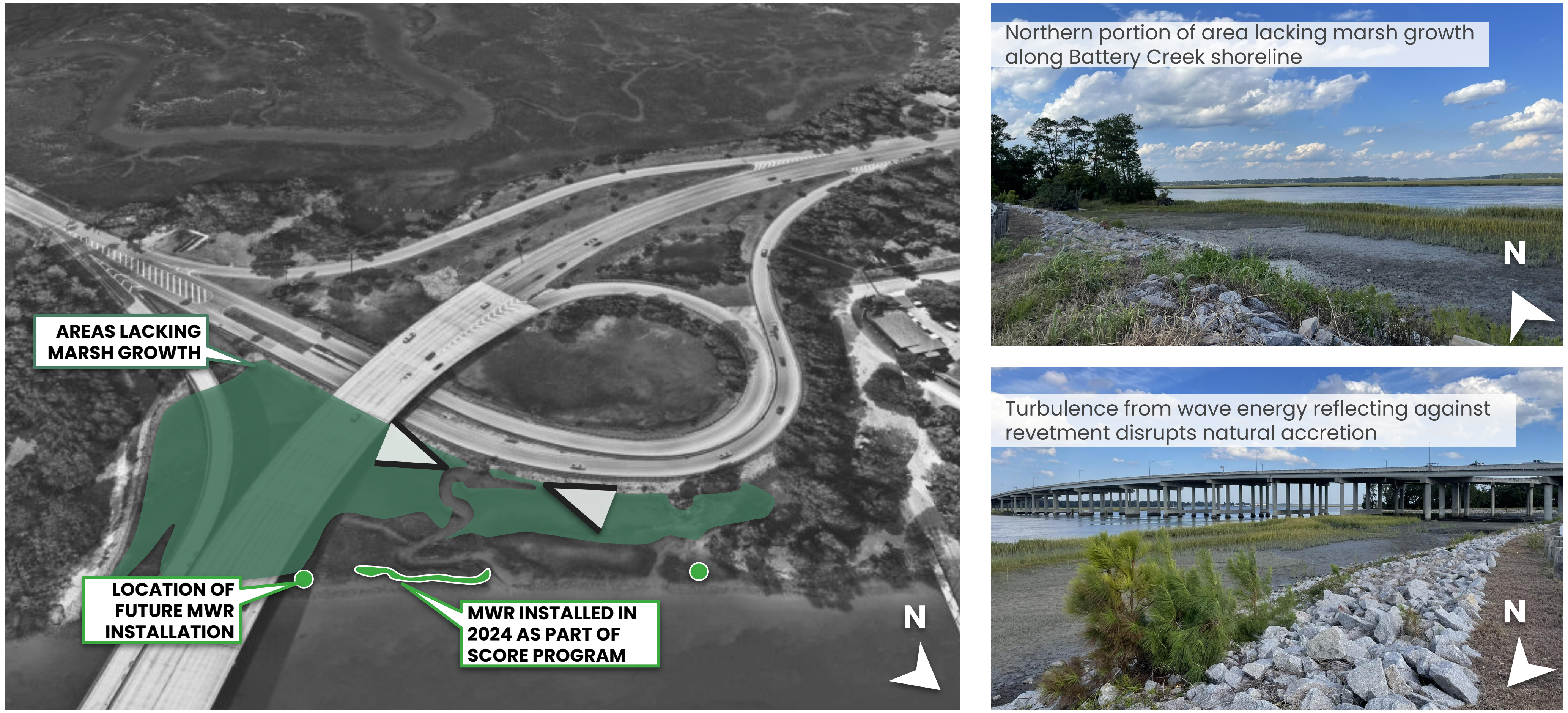
Constraints & Opportunities

Evaluation of constraints and opportunities for shoreline stabilization only consider the interchange's shoreline along Battery Creek, as coastal erosion or marsh degradation are not noted on the interchange's southern shoreline.

The Battery Creek shoreline of the interchange is subject to high-energy wave action influenced by boat wake traffic, tidal currents, wind, and storm events. These forces, combined with other indirect impacts, contribute to persistent erosion that affects both marsh stability and the resilience of the roadway. Continuous exposure to wave energy and reflected wave energy off the revetment limits sediment deposition and plant establishment, making it difficult for marsh grasses to maintain long-term stability. High-frequency wave heights are near the threshold for sustaining marsh vegetation, which will further exacerbate erosion and habitat loss.

The shoreline revetment, originally designed to provide structural reinforcement along the road-adjacent shoreline, plays a complex role in shoreline dynamics. When waves interact with the revetment, the energy is redirected downward and outward, intensifying turbulence and scouring sediment at the base of the structure. Continuous exposure to wave energy and reflected wave energy off the revetment limits sediment deposition and plant establishment, making it difficult for marsh grasses to maintain long-term stability. As a result, portions of shoreline lack marsh growth and has destabilized the soil (**Figure 4.3**). The current condition of the revetment is noted to be "fair" with visible signs of erosive forces. Other contributing factors to lack of growth may include sun shading from the Hwy US-21 bridge and pollution deposition, among others.

Excessive turbulence at the base of roadway revetment uproots young plants and prevents marsh from naturally replenishing itself, leading to ongoing sediment displacement and instability. Without dense plant root systems to anchor the sediment, the exposed marsh substrate becomes increasingly vulnerable to erosion, compromising the ability of the marsh to buffer wave energy and protect adjacent infrastructure.



Northern portion of area lacking marsh growth along Battery Creek shoreline

Turbulence from wave energy reflecting against revetment disrupts natural accretion

Figure 4.3. Extents of areas lacking marsh growth with corresponding site photos; Planned extents of Manufactured Wire Reefs to be installed

As water levels rise in the future, the Interchange underpass's location being so close to the shoreline is anticipated to yield a phenomenon called coastal squeeze, the restriction of natural marsh migration landward by infrastructure. Given the marsh has nowhere to retreat, as sea levels rise coastal squeeze will occur resulting in habitat loss, decreased shoreline stability, and accelerated degradation of remaining marsh. The marsh will be unable to provide its ecosystem services and functions over time, further compounding erosion and ecological decline.

As part of a grant-funded initiative sponsored by the U.S. National Fish and Wildlife Service (NFWF), the South Carolina Department of Natural Resources (SC DNR) and the Coastal Conservation League have begun implementation of manufactured wire reefs (MWR) in selected segments of shoreline along both the Interchange and MCRD Parris Island to mitigate wave action. Implementation, which is part of the SC DNR's South Carolina Oyster Recycling and Enhancement (SCORE) program, is to be completed in 2025 and preliminary reports have indicated successful implementation. The concept proposed will assume implementation of these measures and consider their impact on site conditions.

4.3 Shoreline Stabilization Considerations

Design Goals

The following goals guide the selection and implementation of stabilization strategies to address site-specific challenges:

1. **Erosion Control:** Minimize land loss by buffering wave action and enhancing marsh growth to reduce sediment displacement. Maximize marsh migration potential with incorporation of a more gradual, continuous slope that will allow for natural migration in response to changing inundation regimes.
2. **Habitat Preservation & Enhancement:** Provide gradients of elevations, slopes, vegetation species, and materials to increase habitat viability.
3. **Improve Water Quality:** Enhance local ecosystem services through the re-establishment of marsh vegetation and oyster recruitment to capture and filter nutrients, sediments, and contaminants before they reach open water
4. **Integrate with existing infrastructure and future plans:** Implement protection measures that blend in with existing shoreline features; complement ongoing regional efforts, including the SCORE program, to ensure consistency across initiatives.

Design Criteria

Given that marsh sediment accretion is unlikely to keep pace with sea level rise, a re-graded shoreline slope will be needed to meet design goals, offering progressively higher ground for marsh expansion. A range of slopes will be needed to accommodate variable conditions across the site, but the minimum slope should not exceed 5:1 slopes.

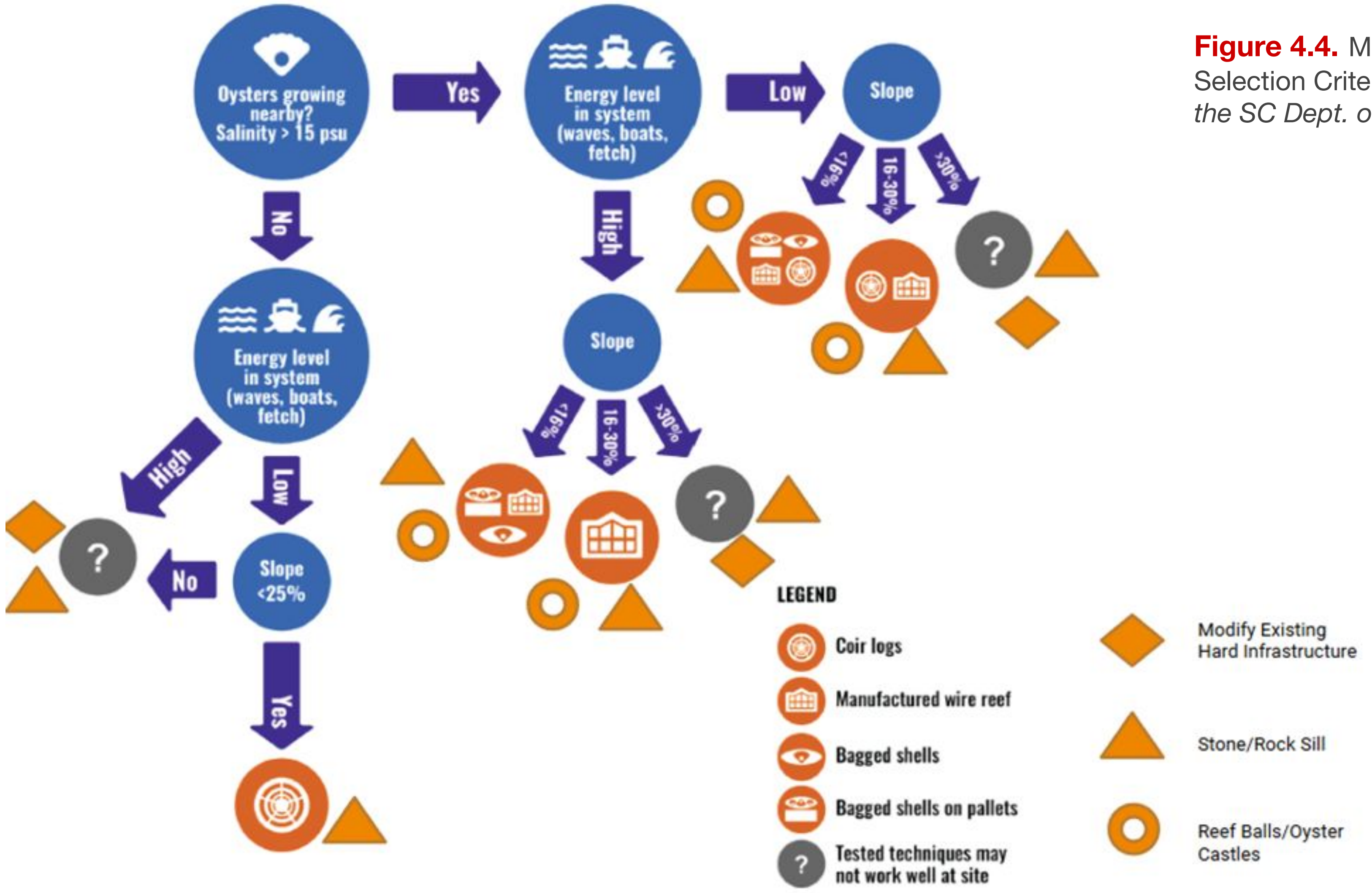
Even with intervention, the combination of increasing inundation at higher elevations and the presence of hard infrastructure constricting marsh migration means that coastal squeeze will remain a long-term concern as sea levels rise.

Due to the inevitability of coastal squeeze, mitigation measures must prioritize benefits of the short- and medium-term, but not the long-term. In designing for the medium-term (i.e., 2045), the highest elevation of the shoreline near the revetment should be set to the maximum daily high tide of the planning year to fully encapsulate the tidal prism within the marsh; reducing the frequency and intensity of turbulent energy from wave energy reflecting against the revetment.

Modified Living Shoreline Selection Criteria Tool

Consideration of appropriate living shoreline measures in alignment with design goals and criteria is considered as part of concept development was determined using a project-modified version of the Living Shoreline Selection Criteria Tool published by the SC DNR.[6] Modifications expanded upon the baseline criteria, to explore other methodologies initially considered as part of the Lowcountry MIRR for the region (**Figure 4.4**). A full discussion of how the tool was expanded and utilized can be found in **Appendix H**.

Given the modified tool, the preferred living shoreline measure was indicated to be manufactured wire reefs (MWRs). This preference aligns with the SCORE program's independent design decision to incorporate MWRs along the shoreline.



Modified from South Carolina Department of Natural Resources, 2019

Figure 4.4. Modified Living Shoreline Selection Criteria Tool *(originally published by the SC Dept. of Natural Resources [6])*

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[6] South Carolina Department of Natural Resources. Summary of Living Shoreline Research to Inform Regulatory Decision-Making in South Carolina (2019).

4.4 Optimizing Stormwater Management

Constraints & Opportunities

Critical areas within inland marshes serve as the stormwater management infrastructure for the interchange and the Hwy US-21 road corridor just west of the interchange. These critical areas contain existing marsh that was once an extension of the shoreline marsh which was bisected by the development of the interchange. The stormwater outfall within the lower inland marsh provides tidal influx necessary to maintain marsh health. The two inland marsh areas are connected by a subsurface stormwater pipe, and water can freely flow between the two marshes so that the elevation of water is equal in both cells.

Within the interchange, road-generated stormwater runoff via grate inlets towards either the lower inland marsh or the upper inland marsh. Both lanes are sloped slightly to drain runoff towards the inland marshes. Given the vertical crash barrier between travel lanes of the underpass, inlets lie in both travel lanes to convey surface runoff towards the lower inland marsh. Inlets and pipes throughout the interchange are noted to have some sediment buildup, typical of slow-moving water. These conditions can impact performance efficacy of infrastructure.

A historic drainage pattern that once conveyed runoff originating from eight acres worth of land west of the Site towards an outfall at Battery Creek was impounded by the construction of Marina Boulevard just north of the interchange. This disruption causes water to accumulate from eight acres of the Hwy US-21 road corridor within the Hwy US-21 median now just West of the upper inland marsh. Accumulated water is anticipated to be polluted with sediment, debris, grease, fertilizers, and other vehicular-related chemicals that were suspended in the runoff as water drained across the road infrastructure. Accumulated off-site drainage is diverted to the upper inland marsh via a subsurface pipe connection with the median, where water is temporarily stored before outfall to Battery Creek. Although the supply for this drainage pattern has minimized due to conveyance to the inland marshes, the ditch carved by water that once fed the drainage pathway is still present. Furthermore, the outfall of the ditch is still designated as a stormwater outfall according to Beaufort County GIS data,

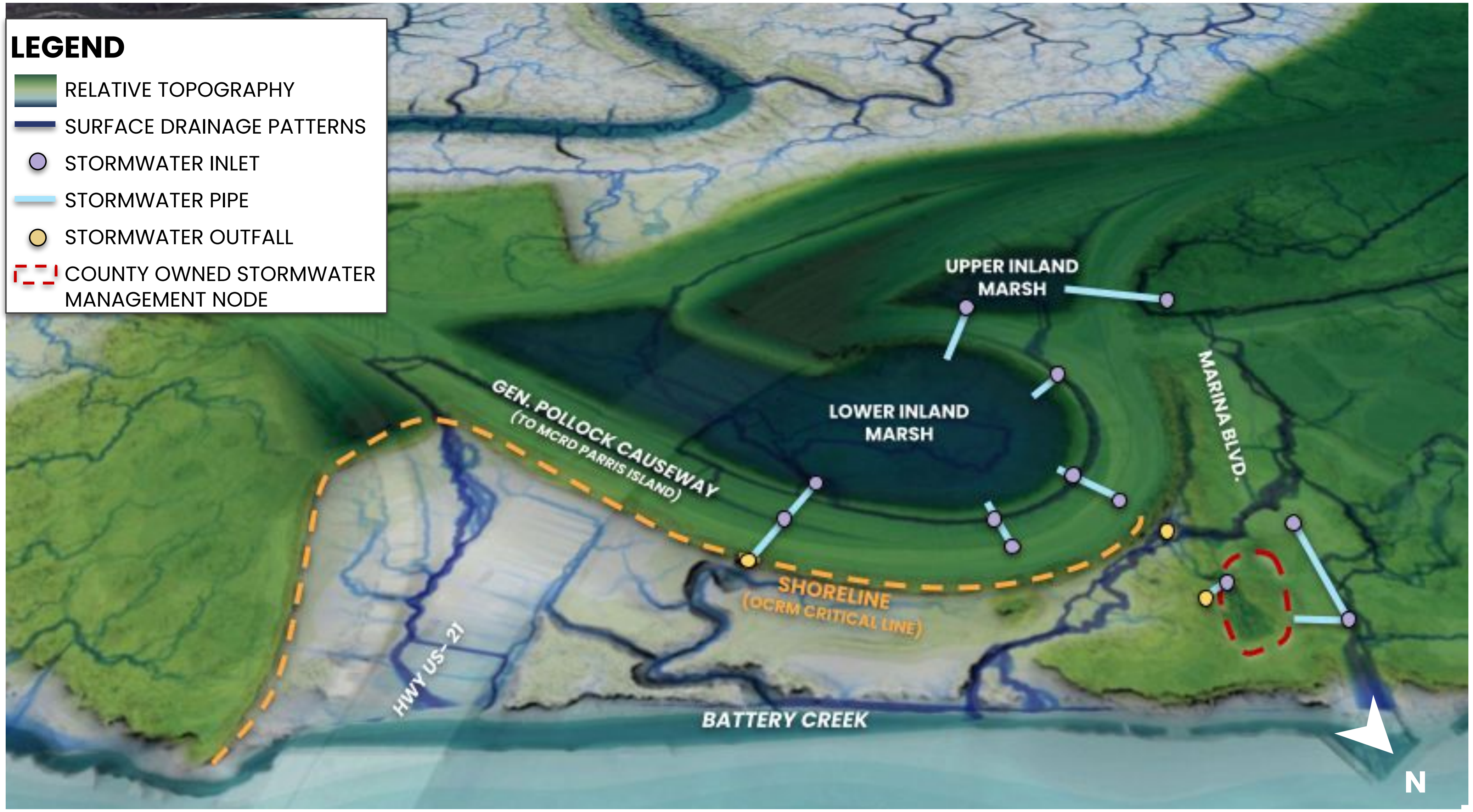


Figure 4.5. Visualization of relative topography patterns across site, with relation to existing stormwater infrastructure.

County-owned infrastructure is noted just north of the interchange to accommodate the disrupted drainage pattern and convey runoff towards the marsh along the Battery Creek shoreline, as shown in **Figure 4.5**.

As mentioned in the vulnerability analysis, tidal influx into the lower marshes via the stormwater outfall pipe can reduce available storage capacity for stormwater runoff. In instances where a high tide coincides with a high-intensity rainfall event, an excess in generated runoff reaches the inland marshes and they become at risk of exceeding capacity. The result is stormwater spilling over into the underpass's inner travel lane, inhibiting access. Spillovers reaching the outer lane of access are not a concern as the outer late is nearly 1.5' higher in elevation than the inner lane. By 2045, tidal influx into the inland marshes could be sufficiently high enough to cause spillover into the road 50 times a year if coincident with an intense rainfall event.

4.4 Optimizing Stormwater Management

Design Goals

The priority of optimization is to mitigate flooding impacts by improving the efficacy of existing stormwater management infrastructure. Design strategies should aim to balance storage, tidal fluxes, and future scenarios of sea level rise. Water quality is addressed by treating stormwater runoff before interaction with tidal waters and improving the function of naturally occurring processes of the estuarine system ("ecosystem services"), thereby preserving, enhancing, and restoring coastal habitat. Design goals for optimization include:

- **Optimize stormwater runoff storage capacity** within inland marshes to mitigate instances of marshes exceeding capacity and spilling into inner lane, threatening access.
- **Reduce storage demands of inland marsh** through restoration of disrupted drainage patterns to repair connection that was diverted to inland marsh.
- **Maintain marsh health within critical areas** through control of excessive inundation with rising sea levels in face of constricted marsh migration along shoreline.
- **Employ nature-based solutions** for stormwater management that contribute towards provision of ecosystem services, including: habitat provision, water quality improvements, and placemaking capabilities.
- **Meet treatment and detention regulatory requirements** for proposed infrastructure.

Design Criteria

Restoration of historic drainage pattern to restore flows for diversion would require infrastructure on land owned by MCRD Parris Island and Beaufort County under Marina Boulevard, on the upstream and downstream ends of the connection respectively. Both landowners have indicated a preliminary willingness to comply given stakeholder engagement.

Stormwater management should be optimized to mitigate the overflow of the lower inland marsh, in alignment with the conditions set by the second compound threat design storm The design must also align with Beaufort County Stormwater Code, which defers to the more stringent Southern Lowcountry Stormwater Design Manual due to the Site's designation within a Bacteria and Shellfish Protection Area. Infrastructure should be sized to accommodate the contributing drainage basin that once fed the disrupted drainage pattern, highlighted in **Figure 4.6** below.

The Southern Lowcountry Stormwater Design Manual requires proposed stormwater infrastructure to employ one of their approved best management practices to retain 95% percentile storm (1.95") on-site, meet minimum treatment standards, and provide sufficient storage capacity to maintain control of the rate of stormwater discharging off-site as to what's currently discharging in current conditions. Best management practices are to be approved measures outlined in the Southern Lowcountry Stormwater Design Manual.

Refer to **Appendix F** for more detail on the applicable code requirements required. SCDOT regulations require peak flow rate mitigation, also referenced in **Appendix F**, but are less stringent than the Stormwater Design Manual.

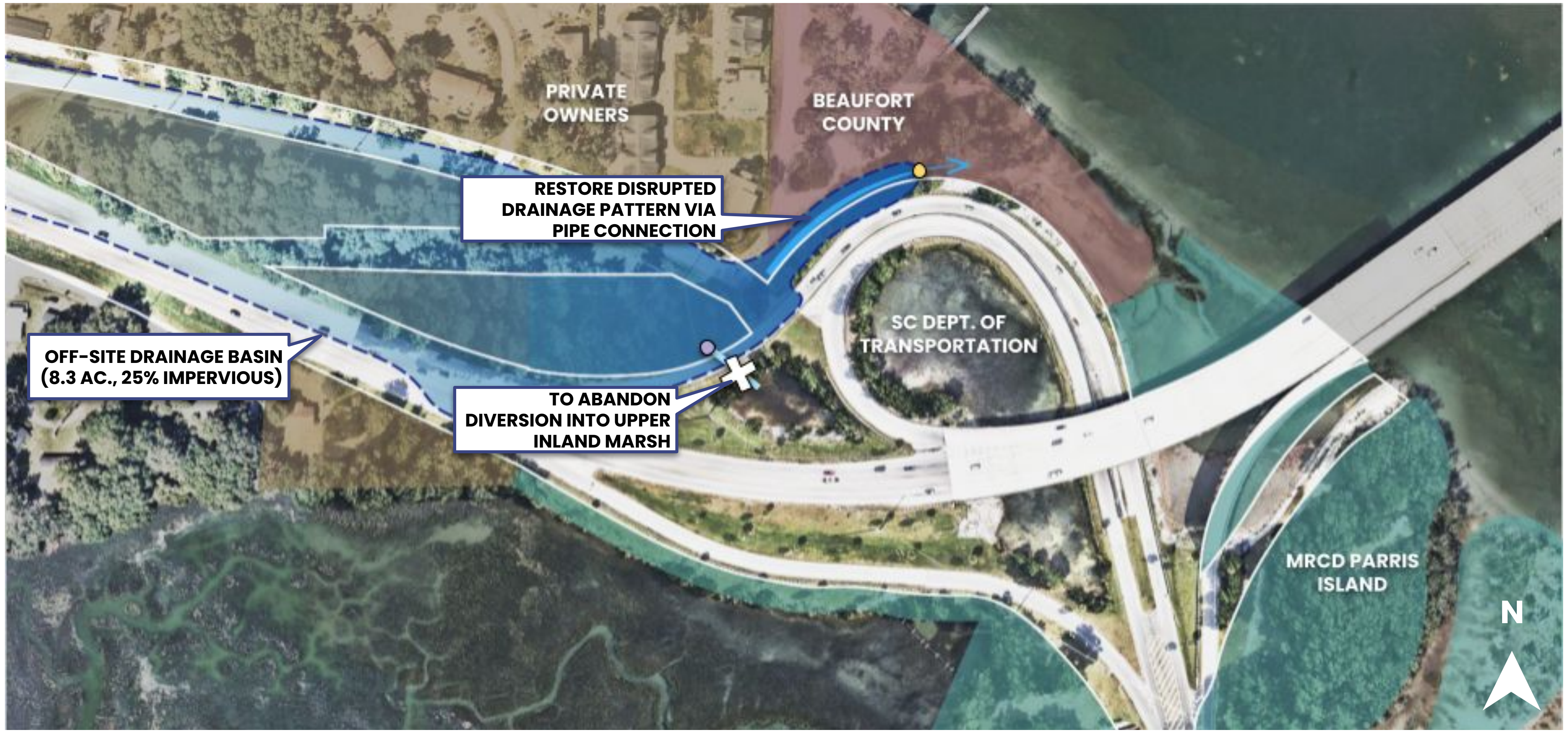


Figure 4.6. Contributing drainage area of off-site runoff that would be diverted from the upper inland marsh to the restored drainage pattern.

4.5 Designing for Extreme Coastal Flood Protection

Constraints and Opportunities

Although susceptible to erosion of the adjacent revetment, the outer lane closest to Battery Creek is at a relatively high enough elevation that it is not susceptible to inundation-based vulnerabilities until after the year 2050. By this time mean sea level will have risen several feet above where it currently is. After the year 2050 either standing water levels in Battery Creek, or the height of waves above the standing water level may reach an elevation higher than the lowest point of the outer lane, around elevation 9.30'. This would cause water to overtop the revetment and spill into the outer lane (**Figure 4.8**).

In existing conditions, only a guardrail exists between the shoreline revetment and the outer lane, allowing water to spill into the lane in the gaps between the posts of the guardrail (**Figure 4.7**). The guardrail is noted to be in fine condition.

In an instance where water would spill into the lane, it's assumed that the lower inland marsh is filled to a capacity so high that it can't effectively drain stormwater from the outer lane via the grate inlet, resulting in stormwater ponding in the lane given the median barrier wall would prohibit surface drainage. This would heavily restrict access in both lanes within the underpass.

The other entrance ramp to Parris Island from eastbound Hwy US-21 is at a similar elevation to that of the outer lane, indicating restricted access in a similar manner. This disrupted access would result from a high-intensity storm (e.g., Hurricane Matthew) that may warrant an emergency response. If inundation did occur, it would be only periodic in nature even if severe as drainage infrastructure would regain efficacy upon another low tide.

Design Goals

The design concept should provide protection against overtopping of the outer lane in extreme coastal events that would restrict both lanes of access. Integration of the design concept with existing infrastructure noted to be in good condition should be maximized, and they should provide resilient protection against anticipated wave action.

Stakeholder feedback revealed a desire to maintain views to the marsh and river. Additionally, since protection is not needed until after 2050, there is a preference for measures that facilitate adaptation of the scenario if implemented after the Phase 2: Optimized Stormwater Management.

Figure 4.7. Site photo of guardrail and road-adjacent revetment along the Hwy US-21 westbound lane of the underpass

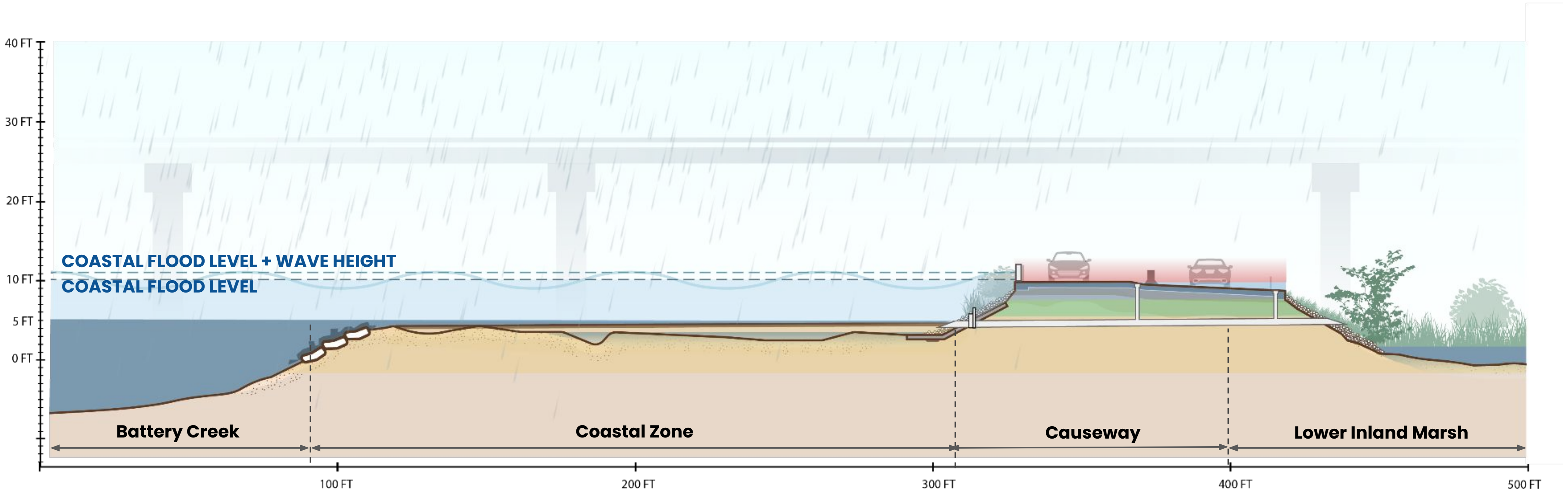


Figure 4.8. Visualization of design goal to protect against coastal overtopping in high intensity coastal flood events.

4.5 Designing for Extreme Coastal Flood Protection

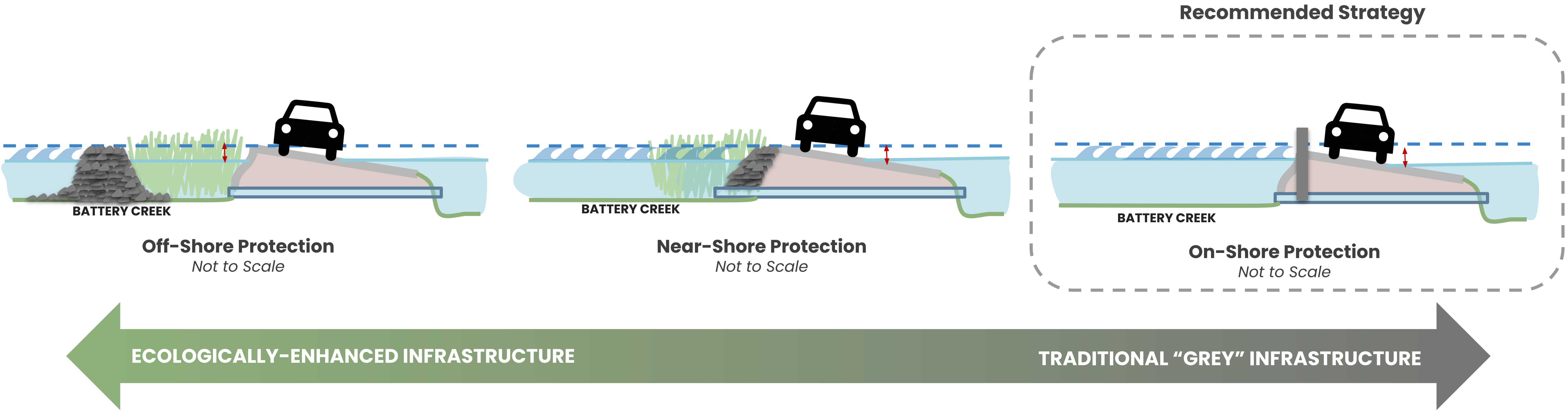


Figure 4.9. Overview of protection measure types available for considerations to meet design priorities.

Design Studies

Design studies were conducted to evaluate what types of infrastructure should be implemented to meet design goals, ranging from off-shore protection to on-shore protection (**Figure 4.9**).

For off-shore protection the feasibility of a breakwater was evaluated to understand its potential efficacy in mitigating wave height and dissipating wave energy to reduce the total water level reaching the outer lane. Suitability was evaluated through modeling simulations that considered the inclusion of a breakwater in the site's topography to understand how relative wave heights anticipated on the shoreline changed. Takeaways noted due to the unique location of the site within a bend, referred to as an "outside straight" within the waterway, local wave conditions are not suitable for notable benefits of wave dissipation benefits offered by a breakwater. The proposed breakwater would need to be designed to an elevation of 11' to meet desired protection, resulting in a 15' tall structure from base to top of wall, which would both prohibit viewsheds and raise concerns of the shoreline soil stability. More detail on the breakwater suitability studies conducted can be found in **Appendix I**. Preliminary permitting research also indicated complexities with implementation due to its location within tidally influenced waters.

For near-shore protection, an earthen berm was discounted due to the limited space along the outside of the road.

Given space allowances, it was determined that the proposed barrier would be best suited as an on-shore protection that could be co-located with the existing guardrail system alignment. To accomplish this, the proposed barrier (wall) would double as a crash system and a flood barrier.

Design Criteria

Given this is a phased adaptation that would only be activated in conditions after 2050, regulations are limited in how to address future conditions exacerbated by climate change. In this absence, design criteria established for the Scenario 3 design storm are referenced. Protection in this event must address the total water level (including still water and wave height) to maintain two-lane accessibility if a Hurricane Matthew-level event were to occur in 2075 (11.15').

Minimum vertical clearances outlined in the SCDOT Roadway Design Manual prohibit road raising given current vertical clearances between the underpass and the Hwy US-21 bridge, which is in fine condition with no imminent plans for replacement. Flood infrastructure that is co-located within roadway infrastructure must align with SCDOT standard details and regulations outlined in the SCDOT Roadway Design Manual for any requirements to replace existing guard rails.

Figure. Aerial Image of Shell Point Interchange *Image Source: Paul Nurnberg*

5 CONCEPT EVALUATION

5.1 Phased Concept Overview

This section of the report will review the phasing concept for implementation measures given elements outlined in the previous section. Phases are compared in detail for the level of protection provided, implementation considerations, provision of benefits associated with each phase compared to its cost, and inclusion of ecological co-benefits. In-Depth exploration of these factors informed the eventual selection of a preferred phase to advance for 60% design at the conclusion of the section. Subsequent phases beyond the preferred phase for implementation will have outlined next steps for further examination in the future as part of the final report.

Each phase alternative proposed was derived to meet the outlined design criteria and design thresholds established by the three design storms, and address the anticipated vulnerabilities resulting from them. Each phase provides a successive level of protection, including the measures presented in the preceding phases.

Phase 1

Phase 1 is aimed at addressing disruptions to the natural infrastructure occurring in the relative lower elevations of the site starting in the short-term (2035). As these disruptions result from the existing marsh's deterioration from excessive wave energy and inundation in high-tide events, this phase's measures are concentrated along the shoreline of Battery Creek. Included in these measures is integration with the Manufactured Wire Reefs planned for implementation through the grant-sponsored SCORE initiative led in partnership by the South Carolina Department of Natural Resources and the Coastal Conservation League.

Phase 2

In addition to measures proposed in Phase 1, this phase prioritizes optimization of stormwater infrastructure within the inland marshes to mitigate flooding anticipated in the underpass's inner southbound lane. Optimization is proposed through both maximizing available storage capacity within the inland marshes and reducing anticipated storage demands from off-site drainage that's piped to the inland marshes against natural drainage patterns. Infrastructure improvements are to be sized and placed to maintain accessibility of both travel lanes during compound flood events of an intensity similar to what was experienced locally during Hurricane Debby, but if it were to occur in the medium-term (2045).

Phase 3

Phase 3 includes the measures presented in the first two phases, plus additional measures to protect against wave overtopping of the Hwy US-21 underpass's westbound outer lane in extreme coastal events, maintaining at least one lane of access at all times to MCRD Parris Island. This measure is a level of protection not necessary until the long-term condition (2075) when multiple feet of sea level rise is anticipated.

Figure 5.1. Approximate extents of intervention for Phase 1

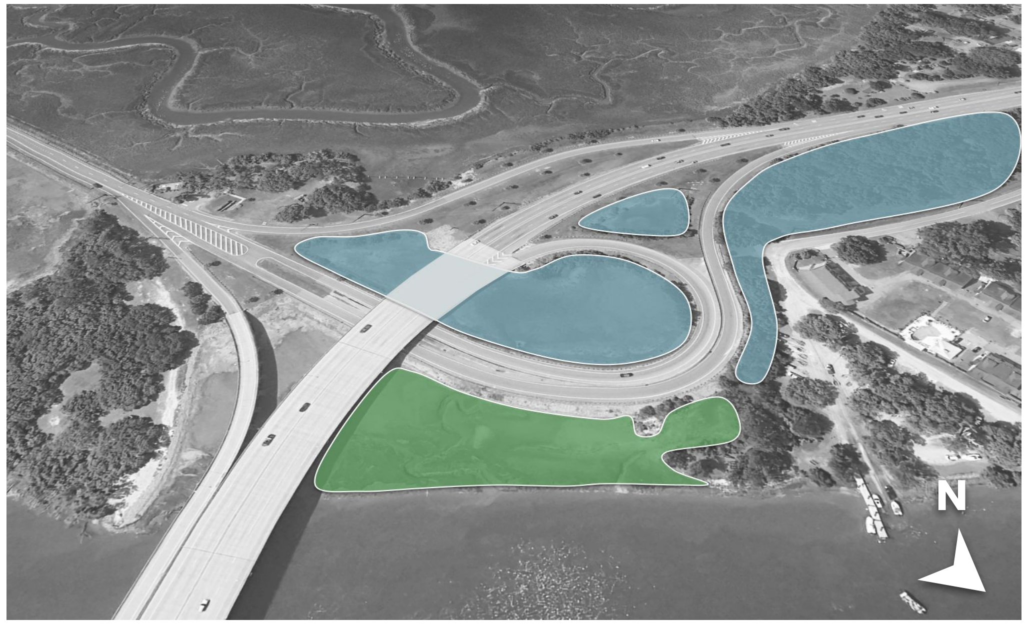


Figure 5.2. Approximate extents of intervention for Phase 2

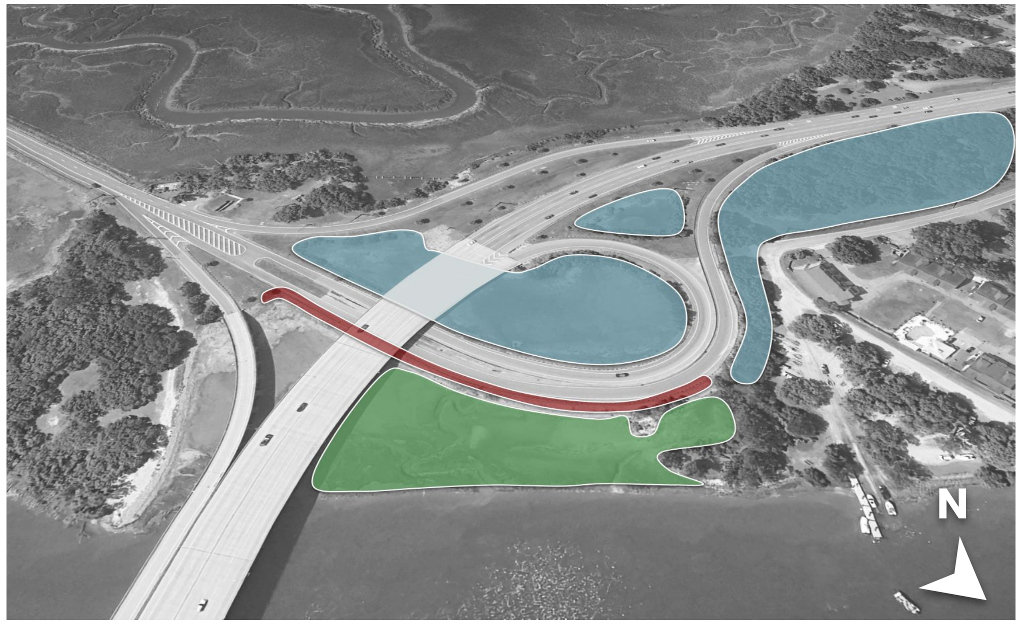


Figure 5.3. Approximate extents of intervention for Phase 3

5.2 Phase 1 Summary

Concept Components

1. **Manufactured Wire Reef Integration**
SC DNR SCORE's installation of 140 linear feet of manufactured wire reefs (MWR) along the interchange's shoreline and plans to install another 400 linear feet of MWRs along the shoreline in 2025 will play a crucial role in mitigating wave energy and enhancing water quality. By dissipating wave energy before it reaches the marsh, MWRs will create calmer conditions more conducive to marsh expansion.

2. **Shoreline Re-Establishment**
Regrading the shoreline bank at allowable slopes is essential for facilitating marsh migration, reducing wave energy impacts, and ensuring long-term stabilization. The grading process will create a continuous slope, allowing marsh vegetation to migrate and adapt to changing inundation conditions while minimizing erosive forces along the shoreline.

Manufactured Wire Reef Integration

MWRs will function as offshore energy dissipation structures, reducing wave intensity before it reaches the shoreline. By breaking up wave action at the shoreline, MWRs help maintain calmer water conditions along the marsh edge, fostering an environment where vegetation can take root and persist.

Additionally, MWRs address the issue of wave energy reflecting off of the shoreline revetment. The current revetment structure amplifies wave turbulence, redirecting energy downward and outward, which scours sediment at its base and prevents natural accretion processes. By intercepting wave energy offshore, MWRs will limit the force of waves that reach the revetment, reducing erosion at its base and minimizing the destabilization of adjacent marsh areas.

The MWRs also promote oyster recruitment, which improves water quality and fosters a more resilient nearshore ecosystem.

Figure 5.4 (Top). Spatial extents of Phase 1 mitigation measures

Figure 5.5, 5.6 (Bottom, Left to Right). Precedent imagery of Manufactured Wire Reefs and a re-established bank project

Figure 5.5 Image Credit: SC DNR

5.2 Phase 1 Summary

Bank Re-Establishment

Re-grading the shoreline to create a more gradual, continuous slope will provide marsh species with an adaptive gradient, allowing for natural migration in response to changing inundation regimes. The proposed grading will create a gradual, greater than 14:1, slope landward to an elevation of 5’. This will allow marsh vegetation to adapt to changing inundation conditions while minimizing erosive forces along the shoreline, as shown in **Figure 5.7** to the right.

Local finished slopes will vary across the site in an effort to ease the transition between the water's edge and the revetment while staying out of the established marsh vegetation. Ranges of slopes throughout allow for site-specific flexibility, ensuring that the marsh can effectively dissipate wave energy while maintaining conditions suitable for plant establishment.

The fill material required for regrading should be pluff mud, a mix of clay, sand, and organic matter that closely matches the existing substrate composition. A more detailed fill distribution plan will be provided in later design phases to ensure compatibility with natural sediment processes.

Revegetation efforts will focus on native marsh species that support long-term resilience and habitat stability. Species selection will be tiered based on elevation, ensuring a gradual transition from low to high marsh species. The plant palette will include:

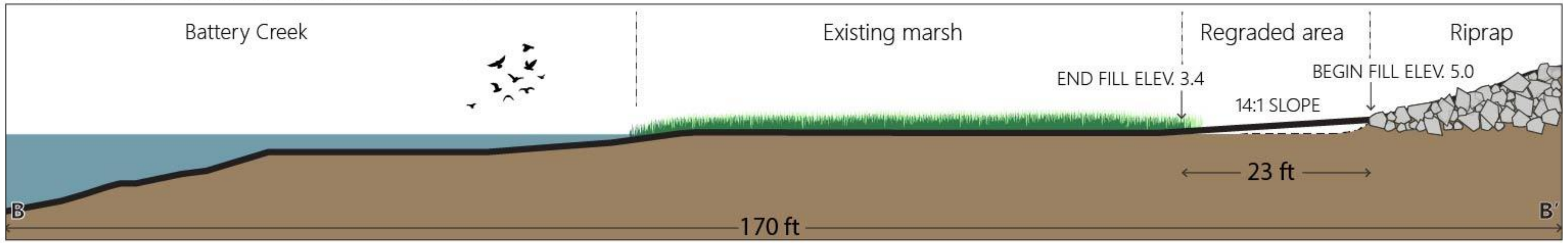
- **Low marsh:** *Sporobulus alterniflora* (smooth cordgrass)
- **High marsh:** *Juncus roemerianus* (black needlerush)
- **Marsh edge:** *Distichlis spicata* (saltgrass), *Baccharis halimifolia* (groundsel bush), and *Borrichia frutescens* (sea oxeye daisy).

Marsh establishment is a gradual process, typically requiring one to three growing seasons for vegetation to become well-rooted and function effectively as a stabilizing element.

Additionally, large root wads, anchored woody debris, and standing snags will be incorporated into the marsh to enhance habitat complexity, provide shelter for aquatic species, improve sediment retention, and support overall ecosystem function.

It should be noted that even with intervention, the combination of increasing inundation at higher elevations and the presence of road infrastructure at the landward boundary means that coastal squeeze will still remain a long-term concern as sea levels rise, and the marsh is unable to move inland.

Figure 5.7 (Below).
Conceptual Cross Section of Bank Re-Grading Schematic



Precedent: Living Shoreline at MCAS Beaufort

A similar living shoreline project implemented by The Nature Conservancy (TNC) near MCAS Beaufort serves as a valuable precedent for this design. That project successfully integrated oyster castles and bank regrading, demonstrating measurable shoreline stabilization and marsh expansion. The successes and lessons learned from that implementation were discussed in stakeholder engagement, with attendees noting its effectiveness as a model for this site. By incorporating best practices from this project, this design aims to achieve long-term stabilization while maximizing ecological uplift.

Figure 5.8-5.9 (Below). Shoreline before and after implementation
Image Credit: Cara Chancellor / The Nature Conservancy

5.2 Phase 1 Summary

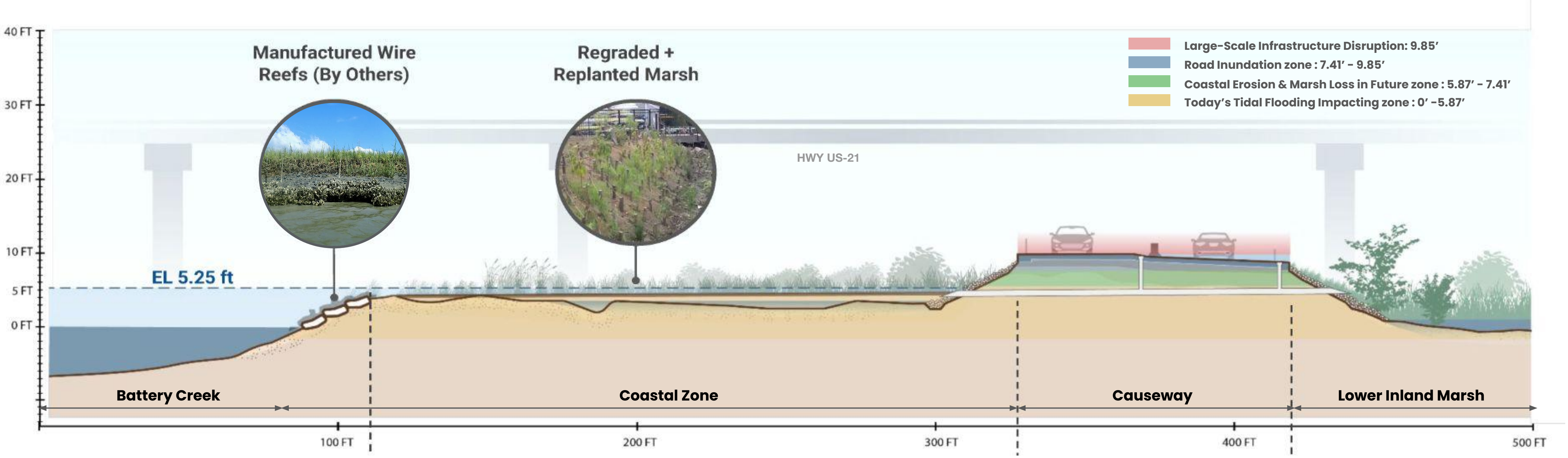


Figure 5.10.
Phase 1 Cross Section
(Vertical Exaggeration 5:2)
*** Image credits for example photographs listed on page 39*

Additional Recommendations

While MWRs will provide some habitat value and promote marsh growth, additional nearshore habitat enhancements can be employed to complement MWRs. Examples of these habitat enhancements include submerged aquatic vegetation beds, submerged reef structures to attract fish, and shellfish enhancement zones.

Coir logs or anchored toe logs could also be installed at the base of the revetment to provide added protection against erosion, particularly where wave turbulence is highest. These measures would help retain sediment and buffer the toe of the revetment from scouring forces.

As the site is revisited over time, the success of the design will be evaluated using key performance metrics such as:

- Changes in marsh elevation & vegetative coverage
- Wave attenuation effectiveness
- Sediment stability & accretion rates
- Oyster recruitment & habitat functionality

If monitoring reveals unexpected erosion patterns or vegetation stress, design adaptations may include additional sediment reinforcement through coir matting or thin layer placement, habitat adjustments, or further shoreline stabilization elements.

Concept Benefits

MWRs will provide wave dampening capabilities and recent observations from SCORE shared in January 2025 confirm the oyster recruitment has been successful on recently installed MWRs in 2024. This suggests that MWRs could serve as an effective multi-purpose strategy, stabilizing the shoreline while also promoting habitat restoration and improving water quality.

Regrading of the shoreline slope also mitigates excessive wave energy and facilitates marsh migration. Proposed changes to the shoreline will minimize the frequency at which waves are at a sufficient elevation to break against the revetment, minimizing the destructive feedback loops that accelerate erosion and habitat loss. Regrading the shoreline to create a more gradual, continuous slope will allow for natural migration in response to changing conditions of marsh inundation frequency and depth.

In addition to shoreline stabilization, healthy saltmarsh ecosystems support a variety of wildlife and is widely considered one of the most bio-dense ecosystems in the world.

Implementation Considerations

Cost: $200-300k

Permitting Requirements: 3-6 months
Individual permits needed from US Army Corps of Engineers, SC Bureau of Coastal Management

Anticipated Construction Disturbances: Minimal disruption to infrastructure operations and existing healthy marsh

Operation & Maintenance Requirements:

- Post-Storm Inspection for first 2 years
- Monitoring of invasive species, vegetation coverage, sediment control and water quality at outfalls for first 3 growing seasons
- Remove excess debris and replant as needed

5.3 Phase 2 Summary

Proposed components for Phase 2 operate in tandem to mitigate compound flooding by both maximizing stormwater storage capacity within the inland marshes and reducing the volume of water draining to the inland marshes and taking up stormwater capacity by restoring natural drainage patterns that redivert off-site flows to Battery Creek. More detail on each component of infrastructure and how they contribute to holistic mitigation is outlined on the following page.

Concept Components

1. **Manufactured Wire Reef Integration**

2. **Shoreline Re-Establishment**

3. **Stormwater Wetland**
An upstream stormwater wetland will intercept stormwater runoff generated off-site along the Hwy US-21 corridor and which currently drains towards the inland marshes via existing subsurface pipes. Nature-based mechanisms and additional temporary storage will be provided to manage runoff from large storm events, and treat pollutants in the intercepted water.

4. **Flow Diversion Swale**
Stormwater runoff intercepted by the proposed wetland will be diverted from draining towards inland marshes, and instead drain to a wet enhanced swale between the Interchange embankment and Marina Boulevard. This will restore the historic drainage pattern conveying this runoff towards Battery Creek and reduce storage demands on the inland marshes, expanding the volume of stormwater they can hold before spilling over into the interchange's travel lanes.

5. **Muted Tide Gate**
The existing stormwater outfall will be retrofitted to include a muted tide gate that limits excessive inundation of the inland marshes by coastal waters, preserving their storage capacity for effective stormwater management.

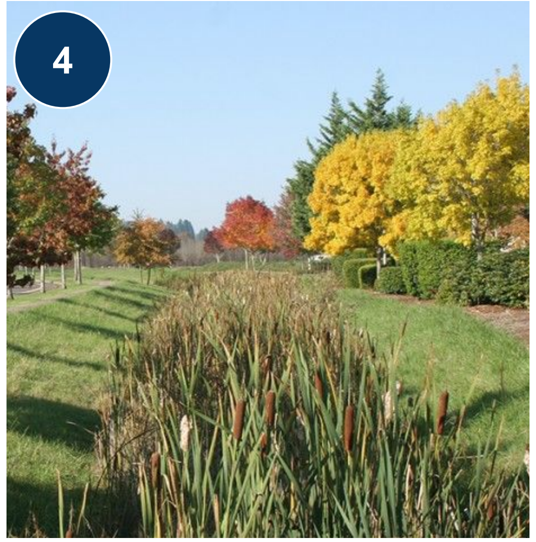


Figure 5.11 (Top). Spatial extents of Phase 2 mitigation measures

Figure 5.12 - 5.14 Bottom, Left to Right). Precedent imagery of stormwater wetlands, wet enhanced swales , and muted tide gate.

Figure 5.12 Image Credit: Hanover Engineering, Figure 5.13 Image Credit: Living Concepts

5.3 Phase 2 Summary

Muted Tide Gate

The muted tide gate is proposed to limit tidal waters entering the inland marshes via the lower inland marsh's outfall connection pipe to Battery Creek, maximizing available storage capacity for road-generated stormwater runoff. The muted tide gate would be implemented through a retrofit of the existing stormwater outfall, embedded within a headwall and installed with concrete-lined riprap surrounding the headwall base to armor the shoreline surrounding the outfall from erosion.

Unlike conventional tide gates that completely block influx of tidal waters, muted tide gates have a mechanism (often a float) that allows them to function passively through changes in specific tidal heights to regulate how much water enters or exits. Incorporation of a muted tide gate will allow the continual ebb and flow of tidal waters within the existing marsh vegetation landward of the gate needed to preserve critical areas.

The specific tidal elevations which would activate the muted tide gate to limit flows was established to be that of the existing vegetation within the landward critical areas, as this protection elevation will effectively serve as the "daily high tide" for the vegetation. Elevations were set in accordance to the anticipated bottom elevations of critical areas in 2045, given survey data of existing elevations and annual rates of accretion noted in **Figure 2.10**, resulting in a protection elevation of 4.26'; all further inundation will be limited by the tide gate.

This elevation is the most conservative elevation that maximizes storage while still ensuring full-inundation of the both critical areas. Inundation of the lower inland marsh is anticipated approximately 70% of days, and full-inundation of both inland marshes approximately 25% of days in 2045. More detail on the approach for establishing this elevation threshold and an example construction detail are shown in **Appendix J** and **Appendix K**.

Precedent: Muted Tide Gate in the Mossy Oaks Neighborhood | Beaufort, SC

In Beaufort, South Carolina, within the Mossy Oaks neighborhood, two muted tide gates were recently installed to help reduce flooding during heavy rains, elevated tides, and storm surges. The project kicked off in 2017 to address the issue of repeated flooding in the neighborhood that was identified due to inefficient drainage structures and poor drainage patterns. Project efforts resulted in the installation of two tidal flap gates on Battery Creek along the Spanish Moss Trail to control the flow of water into and out of the marsh during heavy rains.

Figure 5.15. Example of Muted Tide Gate installed in Beaufort, SC

Stormwater Wetland & Diversion Swale

The stormwater wetland and diversion swale are proposed in tandem to reduce demands on the storage capacity within the inland marshes by the diversion of off-site flows generated West of the Interchange as shown in **Figure 5.16**. Stormwater wetlands are constructed wetlands that employ nature-based mechanisms to treat stormwater pollutants and provide temporary detention storage in large storm events; both necessary to meet local regulations. The stormwater wetland is proposed within the topographic low point of the drainage area where runoff naturally accumulates. The wetland is divided into several sub-cells, each with at least 4:1 slopes, and separated by sand berms which water can filter through between cells.

Stormwater is first intercepted by three sediment forebays, located at intersections of surface drainage paths draining flows towards the lowlands, for initial settlement of pollutants ("pretreatment"), before spilling over into the high marsh and deep pool cells. The high marsh provides primary treatment by nature-based mechanisms including gravitational settling, biological uptake through vegetation, and microbial activity. Inundation within the high marsh vegetation zone can be in excess or restraint of 6 inches for normal water levels to maintain suitable inundation for marsh health.

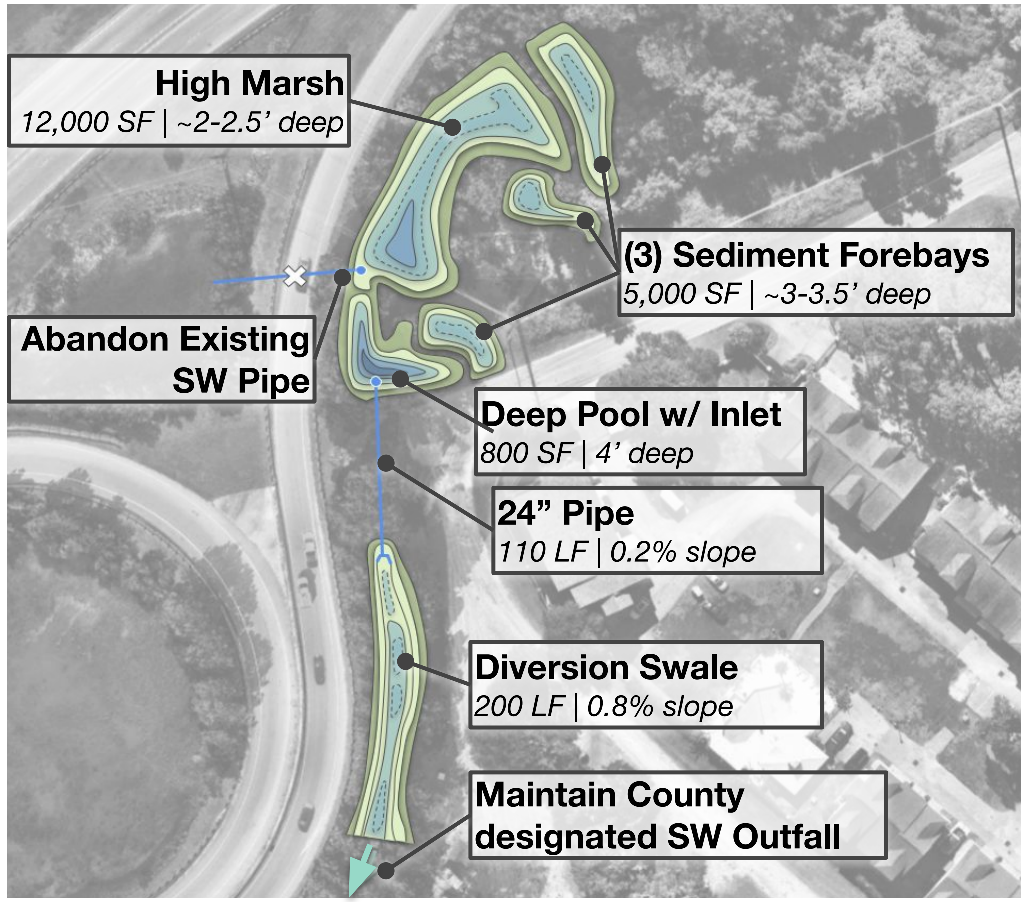


Figure 5.16. Detailed concept for Stormwater Wetland & Diversion Swale

5.3 Phase 2 Summary

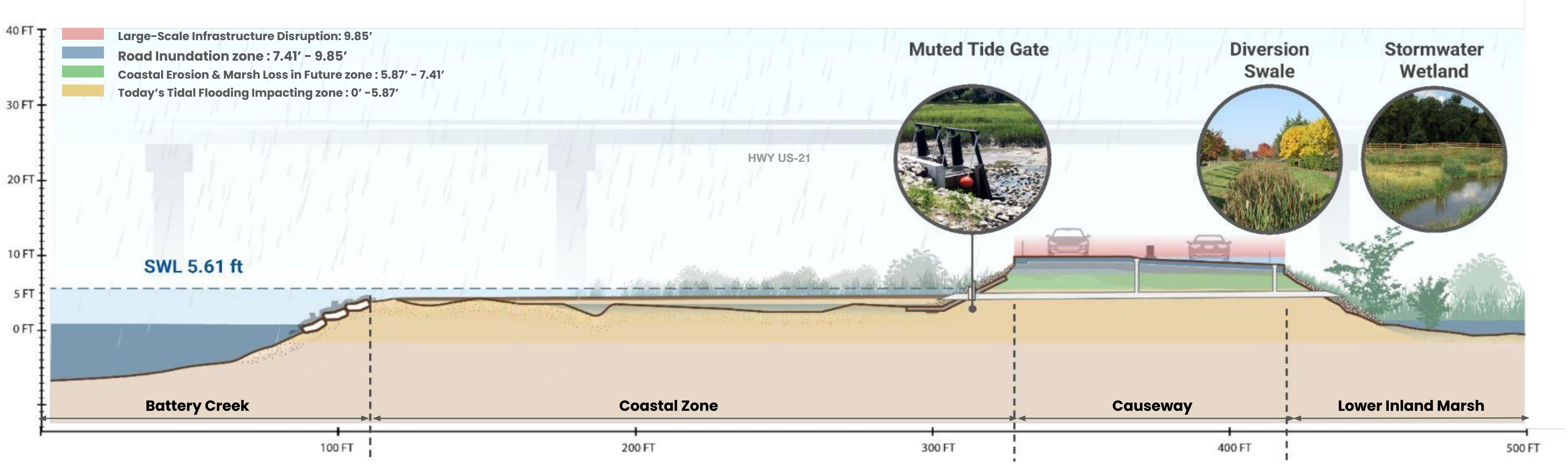


Figure 5.17.
Phase 2 Cross Section
(Vertical Exaggeration 5:2)
*** Image credits for example photographs listed on page 42*

The last cell, the outlet cell, is the deepest and provides additional temporary detention. When volumes exceed 2' in depth within this cell stormwater is drained from the wetland to the diversion swale via a 24" pipe. The proposed diversion swale largely mimics the existing ditch that once conveyed these flows towards Battery Creek, with minor earth work adjustments to stabilize slopes. The swale is recommended to have a bottom width of 3', 3:1 slopes, and pockets of ponding throughout its length for additional slowing of flows before outfalling to the shoreline marsh at the same County-designated SW outfall identified in **Figure 4.5**.

Both the stormwater wetland and diversion swale concept are presented in alignment with design specifications outlined in the Southern Lowcountry Stormwater Design Manual. Both measures operate in tandem to meet retention, treatment, and detention requirements. The sizing and placement of these components is subject to change given future groundwater studies, additional modeling, and coordination.

Concept Benefits

When operating in tandem, this phase's measures are anticipated to mitigate spillovers into the inner travel lane in high-intensity storm events similar in intensity to Hurricane Debby rainfall if experienced in 2045 (10.4" in 24 hours). Spillover mitigation is achieved as the muted tide gate maintains more than 90% of the total storage capacity within the inland marshes, while the wetland and diversion swale reduce typical demands needed of the inland marshes' storage capacity by 40-50%.

Ecologically, in addition to the benefits presented in Phase 1, this phase maintains the health of the existing marsh vegetation within the inland marshes. By limiting future excessive inundation of the inland marshes to preserve marsh health in the future, and providing additional habitat for high marsh vegetation within the stormwater wetland, this measure compensates for marsh lost along the shoreline due to coastal squeeze.

Implementation Considerations

Cost: $700K - $1m (including Phase 1)

Permitting Requirements: 18-24 months
Individual permits needed from US Army Corps of Engineers, SC Bureau of Coastal Management, SC Bureau of Water, Beaufort County

Anticipated Construction Disturbances: Minor disruption to existing shoreline with installation of work access platforms for tide gate installation. No construction impacts anticipated for private land owners on land adjacent to project site work.

Operation & Maintenance Requirements:

- Routine clearing of wetland and moving of diversion swale every 2 years;
- Non-routine maintenance every 5-10 years;
- Post-storm inspection of tide gate for debris;
- Phase 1 requirements

5.4 Phase 3 Summary

Concept Components

1. **Manufactured Wire Reef Integration**
2. **Shoreline Re-Establishment**
3. **Stormwater Wetland**
4. **Flow Diversion Swale**
5. **Muted Tide Gate**
6. **Knee Wall**
Three-foot high knee wall to protect against wave overtopping of outer lane in extreme coastal events, with an additional storm inlet and pipe to maintain positive drainage.

Knee Wall

The proposed knee wall is a concrete flood barrier wall that protects against coastal waters overtopping the road and inundating the outer interchange lane. The proposed barrier is to be co-located with existing guardrail system alignment due to the limited space along the outside of the road. To do this, the proposed barrier (wall) would double as a crash system and a flood barrier. The proposed design is to replace the existing guardrail with a standard barrier wall, aligning with standard details provided by the SC Dept. of Transportation (SCDOT), made watertight so that it can serve as a flood barrier.

It is anticipated that the wall will be secured via a SCDOT typical vertical face rigid barrier with a moment slab to anchor the barrier to a suitable degree that satisfies the current guardrail alignment. Protection measures will require the wall to be a minimum height of 3-feet above adjacent grade, preventing inundation up to elevation 11.35'. The proposed knee wall would tie into the existing embankment on the Southern side and tie into the existing guardrail on the Northern side.

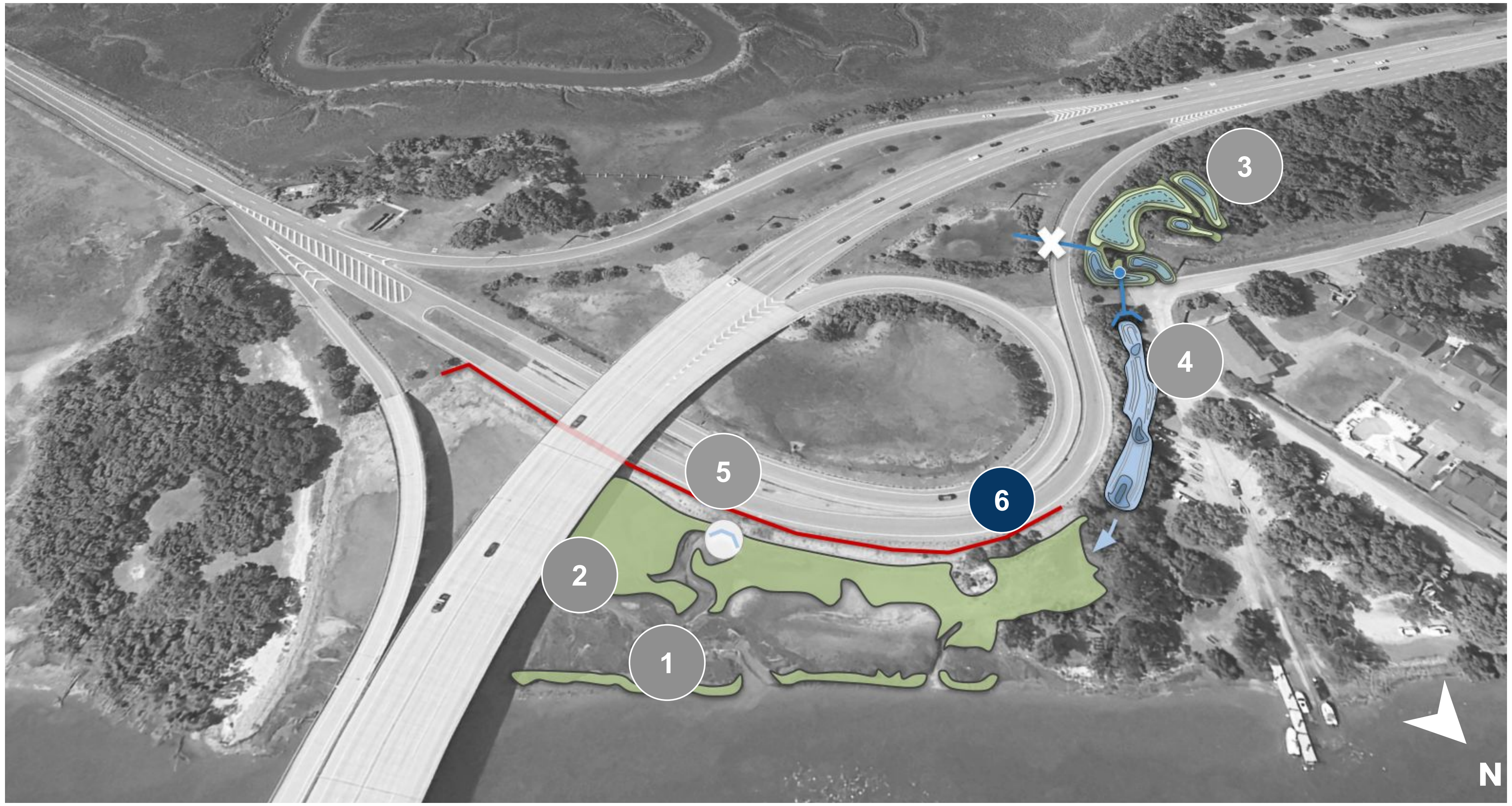


Figure 5.18 (Top). Spatial extents of Phase 3 mitigation measures

Figure 5.19 - 5.20 (Bottom, Left to Right). Precedent Imagery of Knee Wall

Figure 5.19 Image Credit: Texas Transportation Institute Roadside Safety Research Program Pooled Fund Study (2011), Figure 5.20 Image Credit: USACE NY District

5.4 Phase 3 Summary

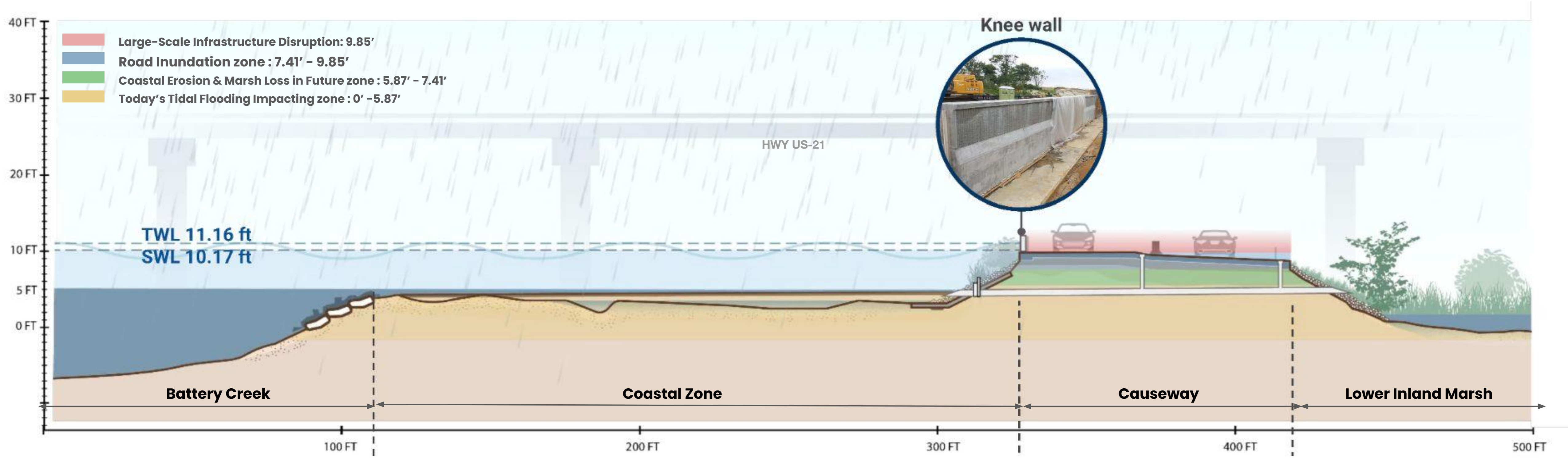


Figure 5.21.
Phase 2 Cross Section
(Vertical Exaggeration 5:2)
*** Image credits for example photograph listed on page 45*

Additional Considerations

To maintain positive drainage the knee wall would require the implementation of one stormwater inlet and a connecting 18" pipe that is approximately 20 LF on its southern edge of the alignment to accommodate the flow of stormwater runoff that once drained from the road surface towards Battery Creek but will now be impeded by the wall alignment. Riprap would surround the outfall of the 18" pipe to mitigate any erosive forces of the stormwater connection.

The outfall of the pipe is anticipated to be set at an elevation along the shoreline that is higher than daily high tides in 2045, therefore not requiring a tide gate like the existing stormwater outfall. Long-Term however, retrofits to incorporate a backflow preventer within the pipe may be necessary to limit tidal waters spilling out the stormwater inlet via the pipe.

Concept Benefits

In addition to the benefits provided by Phases 1 and 2, the proposed knee wall will provide a level of protection to the outer interchange lane to an elevation beyond 11.35', maintaining at least one lane of access even if a catastrophic event (e.g., Hurricane Matthew) were to occur in the long-term planning scenario (2075). Implementation of this knee wall would ensure at least one lane of access to the entrance to MCRD Parris Island is maintained in all studied scenarios, facilitating emergency access to and from the base.

No additional ecological co-benefits beyond those provided in Phases 1 and 2 are anticipated with this phase.

Implementation Considerations

Cost: $1.5 - $2 million (including Phase 1 & 2)

Permitting Requirements: 18-24 months permitting timeline Individual permits needed from US Army Corps of Engineers, SC Bureau of Coastal Management, SC Bureau of Water, Beaufort County, and SC Dept. of Transportation

Anticipated Disturbances: Implementation will require continuous traffic control to be implemented along the length of the proposed wall during construction, causing temporary road closures. Construction is anticipated to last 3-6 months.

Operation & Maintenance Requirements:

- Post Storm & Post-Crash Inspection of Knee Wall;
- Routine Maintenance every 5 years;
- Phase 1 & 2 O&M

5.5 Comparison of Phase Costs and Benefits

The associated costs and benefits of each phase prepared are compared in **Figure 5.22** to inform selection between the three alternative phases. For each category listed per row, a relative value between 1-3 is assigned per phase to indicate a low-high applicability.

Benefits are considered both in terms of the degree of protection provided against disruptions in infrastructure operations and additional co-benefits gained. Protection provided considers both the efficacy of measures to maintain routine operations and the frequency at which the measure is used to provide protective benefit. By characterizing both efficacy and frequency of mitigation, comparisons are meant to capture the value of balanced protection for both chronic, low-impact events and high-intensity events that occur rarely but with much more severe impact. Efficacy of maintaining operations is considered for both day-to-day access and emergency access to reflect criticality of infrastructure across multiple use scenarios.

Ancillary benefits are considered in alignment with stated design objectives, including provision of ecosystem services (e.g. habitat provision, water quality improvements) and regional flood management.

Assuming all categories are weighted equally, the difference between total assigned points for project needs and points awarded for benefits is considered as the "net value" for which phases are compared to each other. **As shown in the Figure, Phase 2 provides the greatest net value given both the value of protection provided to maintaining operations and the frequency at which this protection is utilized. Phase 3 provides a great scale of impact when mitigation is to occur, but mitigation is not anticipated necessary until the long-term scenario (2075), and even then is anticipated to be relied upon relatively infrequently.**

	Phase 1	Phase 2	Phase 3
Project Needs			
Implementation Cost	●○○	●●○	●●●
Frequency of Operations & Maintenance	●○○	●●○	●●●
Permitting & Implementation Complexity	●●○	●●○	●●●
Protection Provided			
Efficacy of Maintaining Day to Day Access to MCRD Parris Island			
2035	●●●	●●●	●●●
2045	●●●	●●●	●●●
2075	●●○	●●●	●●●
Efficacy of Maintaining Emergency Access to MCRD Parris Island			
2035	●●●	●●●	●●●
2045	●○○	●●●	●●●
2075	●○○	●●○	●●●
Frequency of Protection Measures Anticipated to Activate			
2035	●●○	●○○	●○○
2045	●●●	●●○	●○○
2075	●●●	●●●	●●○
Additional Benefits			
Improvements in Local Water Quality	●●○	●●●	●●●
Provision of Habitat	●●○	●●●	●●●
Regional Flooding Improvements	●○○	●●○	●●○
Difference of Total Assigned Points (Protection + Benefits - Needs)	**22**	**26**	**22**

Figure 5.22. Comparison of project costs and benefits by Phase

5.6 Engaging Stakeholders on Alternative Phases

A stakeholder meeting was conducted on January 17, 2025 to gather input on the three proposed design phases. This meeting was a critical point to gather feedback that would guide selection and refinement of the preferred phase and inform advancement of the pilot project towards a 60% engineering design. Throughout the meeting, stakeholders had the opportunity to ask questions and provide feedback. Four major themes emerged over the course of the conversation that serve as a basis for evaluating the preferred phase:

Minimize Disruption and Disturbance
Stakeholders were curious about the constructability and environmental impact of proposed strategies. There was an apparent desire from multiple participants to minimize environmental disturbance at critical areas and understand disruptions to vehicular traffic flow during construction. Strategies that required a larger disturbance footprint such as the wetland and diversion swale should be evaluated for their impact and interactions with existing conditions.

Consider the Adaptability of Solutions
Storm and erosion monitoring of design strategies should be tailored to regional weather patterns. Participants appreciated the option to pursue a phased implementation to allow for flexibilities for long-term design priorities and timelines to secure funding. Implementation of environmental enhancements should utilize native plantings where possible and be ecologically appropriate to allow for self-adapting vegetation pallets in the long-term scenario.

Identify Opportunities for Stakeholder Collaboration
Stakeholders discussed points of collaboration that would aid in successful execution of the project, requiring cooperation between multiple stakeholder groups and the need to navigate ownership agreements. Participants also identified opportunities to align with existing plans and initiatives such as the Boat Landing Master Plan.

Coordination of Ownership Structures
Proposed measures in the mitigation concept exist on land primarily owned by MCRD Parris Island, with some portions of the land under an easement agreement with the South Carolina Dept. of Transportation (SCDOT) for road and associated utility infrastructure serving Hwy US-21, and some portions of the Northern shoreline owned by Beaufort County.

Engagement confirmed opportunities for land swap agreements between MCRD Parris Island and Beaufort County, in which representatives from both parties confirmed preliminary interest in the appropriation of installation-owned land where proposed mitigation measures would be implemented. Land under consideration for appropriation is all outside the installation's entrance sign and signifies a likely opportunity to streamline contiguous shoreline rehabilitation and unify maintenance requirements under a single entity (Beaufort County).

Takeaways gleaned that detailed coordination of logistical considerations for the land transfer must be prioritized early in the engineering design process and further development of maintenance regimes must coincide with the timelines and terms of the agreement.

Preferred Phase for Stakeholders

Stakeholders noted a preference for advancing engineering design for Phase 2, given the frequency at which the provided level of protection is needed by the medium-term, the criticality of the infrastructure that is protected by the phase's measures, and the flexibility that the phase allows for addressing long-term vulnerabilities at a time closer to when the impacts are to occur.

STAKEHOLDER TYPE	IN-PERSON	VIRTUAL
Design Team	5	1
Lowcountry Council of Governments (LCOG)	2	0
State Agency Reps	0	2
County Agency Reps	3	1
U.S. Military Representatives	1	5
Representatives from Local Environmental Non-Profits	2	1
TOTAL	**13**	**10**

Figure 5.23 (Top). In-person attendees during presentation

Figure 5.24 (Bottom). Composition of attendees at Event

5.7 Preferred Phase

Confirmed by both stakeholders during engagement initiatives and LCOG, Phase 2 (**Figure 5.25**) is the preferred phase to advance for implementation as part of the project's final step.

In Line with Project Goals

Goals of this project are to develop a mitigation design that will address near-term disturbances anticipated on-site in order to maintain performance services throughout the interchange lifecycle. Phase 2 of the concept recommendation addresses vulnerabilities anticipated to exacerbate through the in the next 30 years, while allowing for flexibility to include Phase 3 for long-term protection at a later point as protection is needed in the long-term. Phase 2 also aligns with stated design objectives by providing shoreline stabilization and flood management capacities, while also improving local water quality and providing habitat as co-benefits of the concept.

Critical Benefits in Both Scenarios

When considering the value of balanced protection between both chronic, low-impact events and high-intensity events that occur rarely but with much more severe impact, Phase 2 provides the greatest net value given both the value of protection provided to maintaining operations and the frequency at which this protection is utilized (**Figure 5.26**). Phase 3 provides a greater scale of impact to maintaining access when protection is necessary, but mitigation is not anticipated necessary until the long-term scenario (2075), and even then is anticipated to be relied upon relatively infrequently.

Next Steps

Engineering design will aim to usher the project to implementation through detailed design and establishing permitting partnerships with regulatory agencies that will be strengthened through the conclusion of the project via preliminary permitting-focused coordination.

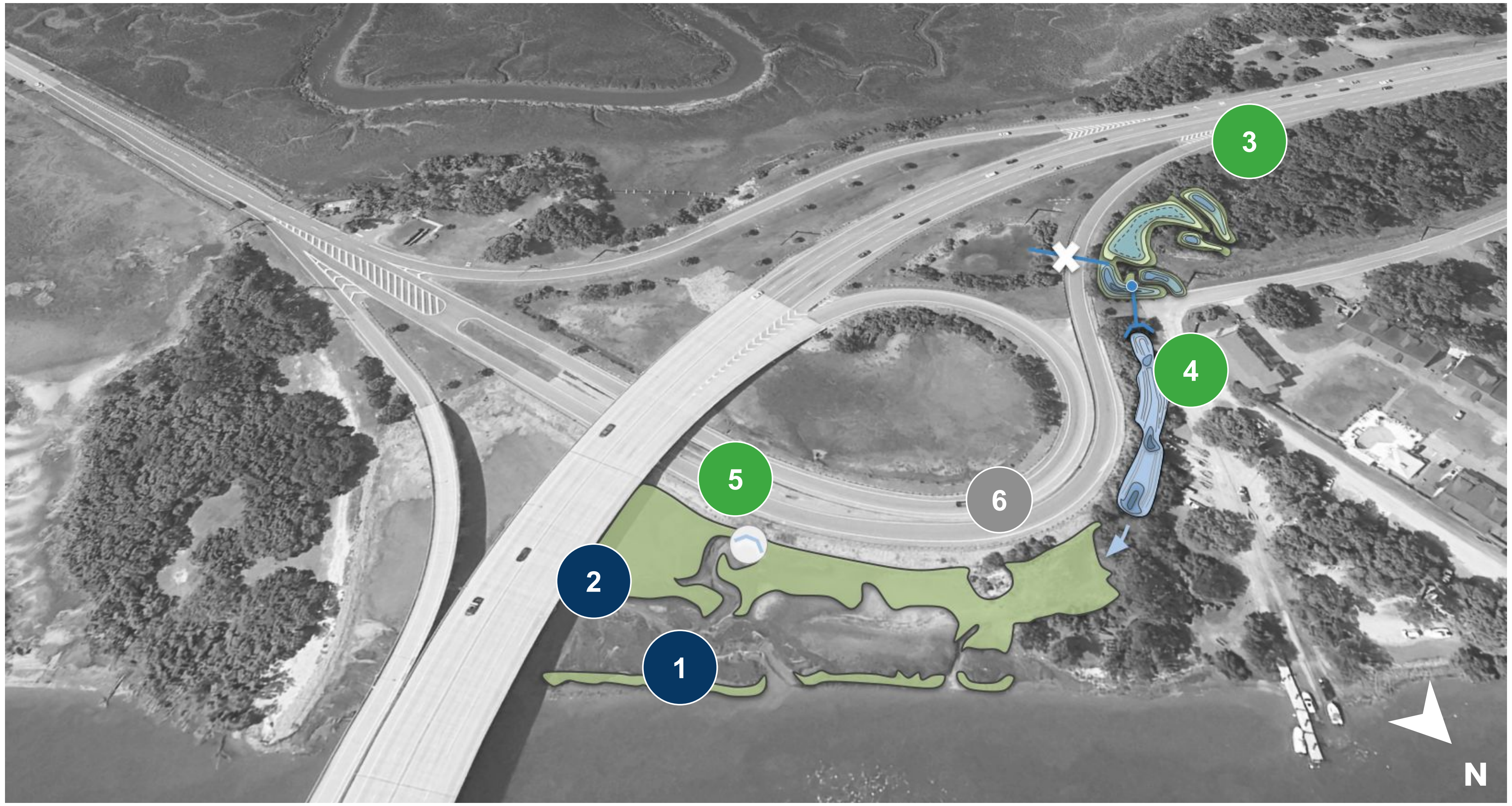


Figure 5.25. Phase 2 as Preferred Phase for Implementation

Funding opportunities to sponsor 100% design and eventual implementation of Phase 2 are also to be advanced in remaining efforts of this scope, as outlined in the following section. For Phase 2, funding needs are estimated to range between $825,000 and $1.1 million to finalize engineering design and conduct implementation, assuming the phase's preliminary cost estimate and an additional 10% of estimate to cover remaining design and permitting fees.

Phase 3 will be considered as part of an adaptive implementation framework to guide future engineering design decisions as additional protection becomes necessary in the future, to be outlined in the project's final report.

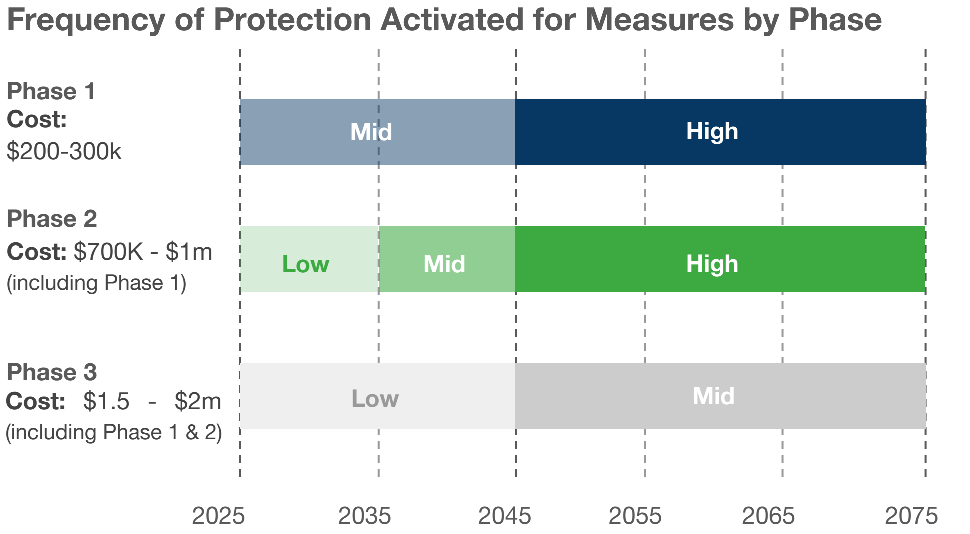


Figure 5.26. Comparing Phases by Frequency of Protection Provided

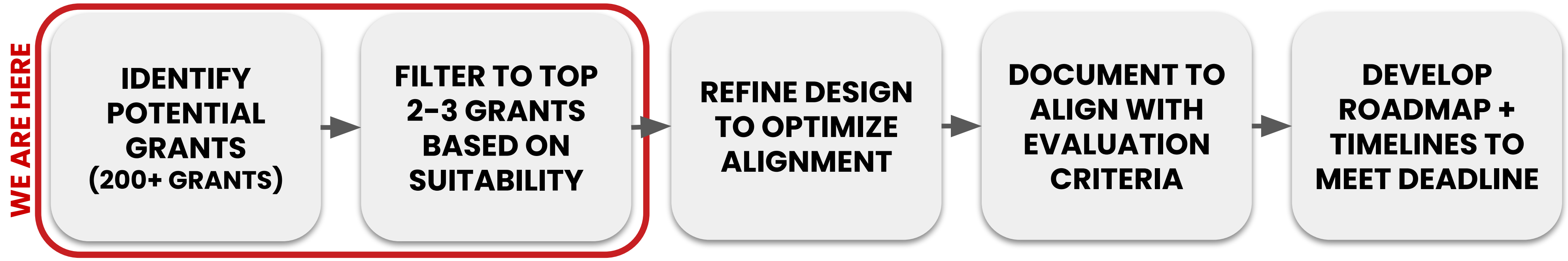
5.8 Funding Mechanisms

Given the decision to advance Phase 2 for engineering design and eventual implementation, the project's funding needs are now sufficiently clear to advance the preliminary identification of suitable funding mechanisms to sponsor remaining design efforts beyond this study's scope (e.g. 100% complete engineering design and implementation). Early consideration of funding opportunities allows for refinement of the current project schedule and design features to optimize alignment with prioritized funding opportunities, in addition to allowing ample time for coordination with local agencies on match requirements and other supporting documents.

The remainder of this section prioritizes the first two steps of the funding pursuit process outlined in **Figure 5.27**, in which grant opportunities are screened for suitability against the project's funding needs given the filtering considerations outlined in **Figure 5.28**. Opportunities are screened against these considerations to allow for filtering of low-priority grants to generate a short list of opportunities for which the project is not only eligible, but is also at least somewhat competitive for success given initial review of the grant's funding principles and project trends across the aggregate of the grant's previously awarded applications (e.g. project location, average fee, phase in project design).

Shortlisted grant opportunities are then further considered with a more detailed review of both projects previously funded by the grant and the grant's application requirements. Detailed review is intended to result in three priority opportunities amongst the shortlist for which the project can produce a highly competitive application without significant additional efforts beyond what's already to be completed in this study's scope. Future documentation will be tailored to align with key application requirements and guiding principles of the prioritized opportunities to streamline both design and development of applications.

Approach Overview for Funding Pursuit



WE ARE HERE

IDENTIFY POTENTIAL GRANTS (200+ GRANTS) → **FILTER TO TOP 2–3 GRANTS BASED ON SUITABILITY** → **REFINE DESIGN TO OPTIMIZE ALIGNMENT** → **DOCUMENT TO ALIGN WITH EVALUATION CRITERIA** → **DEVELOP ROADMAP + TIMELINES TO MEET DEADLINE**

Filtering Considerations

GRANT ELIGIBILITY	**Does the project meet logistical prerequisites to be eligible for grant?** *Match requirements*, eligible project types & funding available, project completion timelines* *** Match Requirements: Amount of Money that Applicant must self-provide to supplement funder's award for project*
GIVING HISTORY	**Is the funder's giving history indicative of meeting project funding needs?** *Indicated by the grant's funding history for awarded projects. Considerations evaluated include: geographic location, scale of impact, size of project, average award, project phase funded*
COALIGNMENT WITH FUNDER MISSION	**Does the outcome of project align with the mission of the grant & funder?** *Includes both primary benefits and co-benefits of the project (e.g., ecological restoration)*
LOGISTICAL LEVEL OF RISK	**What level of risk is the applicant willing to take when applying for grants?** *Includes decisions to pursue one grant that addresses all portions of project vs. several grants for each infrastructure type, allowable timelines for application development.*

Figure 5.27 (Top). Overview of process recommended to identify and advance grant opportunities that could sponsor implementation.

Figure 5.28 (Bottom). Filtering considerations used in preliminary screening of available grants to identify opportunities for which the project meets at least a "moderate" level of competitiveness for the application.

5.8 Funding Mechanisms

Identified Funding Opportunities

The opportunities highlighted in **Figure 5.29** indicate the shortlisted funding opportunities for which the project is eligible and at least mildly competitive for award. Identified opportunities primarily include grants focused on transportation resilience and ecosystem restoration, as the former category defines the project's primary design goal but the latter defines the means of how transportation resilience is fostered given Phase 2's reliance on nature-based solutions. Both types of grants were considered equitably within the filtering process as the study will yield strong documentation required for narrative in both types. All opportunities presented below can provide sufficient funding to sponsor all portions of remaining scope needed for Phase 2, including design and implementation.

Prioritized Opportunities for Pursuance

Of the larger list shown below, three opportunities were selected as priority opportunities given noted similarities in scope, scale, and design intent between each grant's previously funded projects and this project, in addition to aligning timelines and documentation requirements for applications.

Funding Agency	Grant Program	Type of Infrastructure Funded	Funding Priorities	Match Requirements (% of Project Cost)	Application Deadline (Annual)
Office of Local Defense Community Cooperation (Department of Defense)	Defense Community Infrastructure Program (DCIP)	Community Infrastructure (transportation, utilities)	Assist state and local governments, and not-for-profit, member-owned utilities in addressing deficiencies in community infrastructure supportive of a military installation.	30% min.	June 2024
Federal Emergency Management Agency	Building Resilient Infrastructure and Communities (BRIC)	At-risk infrastructure in need of climate adaptation	Support hazard mitigation projects, reducing the risks they face from disasters and natural hazards as a research-supported proactive investment in community resilience.	25% min.	April 2025
National Fish and Wildlife Foundation	America's Ecosystem Restoration Initiative (AERI)	Conservation + Restoration projects	Support locally led projects that invest in fish and wildlife habitat restoration, ecosystem and community resilience, habitat corridors and connectivity, and collaborative, partnership-driven conservation.	10% min.	July 2025
National Fish and Wildlife Foundation	National Coastal Resilience Fund (NCRF)	Critical infrastructure vulnerable to flooding	Provide for small municipalities to fund nature-based solutions that protect critical infrastructure vulnerable to flooding, including emergency routes.	50% min.	July 2025
National Oceanic and Atmospheric Administration	Coastal Zone Management Habitat Protection and Restoration Competition	Coastal resilience/ restoration projects	Protect ecologically fragile coastal habitat vulnerable to degradation through restoration, including conserving lands that play a critical role in helping coastal communities build resilience to flooding, erosion, SLR, and other climate hazards.	N/A	August 2025
U.S. Department of Transportation	PROTECT Discretionary Grants	Transportation infrastructure	Provide grants to increase resilience of transportation infrastructure to natural hazards, including climate change and other natural disasters through resilience improvement for at-risk coastal infrastructure.	20% min.	Feb 2026
U.S. Department of Transportation	RAISE Discretionary Grants	Transportation infrastructure	Sponsor transportation projects that create high-quality jobs, improve safety, protect our environment, and generate equitable economic opportunity for all Americans. Projects evaluated on safety, economic competitiveness, quality of life.	20% min.	Dec 2025

Figure 5.29 Shortlisted opportunities to consider pursuing via grant application to fund final design and implementation of this project's Phase 2 concept.

Figure. Aerial Image of Shell Point Interchange *Image Source: Paul Nurnberg*

APPENDIX