# Borrow Area Transformation Modeling Report

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# Borrow Area Wave Transformation Modeling

## Dauphin Island West End Beach & Dune Restoration Project

January 16, 2025

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# EXECUTIVE SUMMARY

The numerical model STWAVE was used to simulate changes in wave height and direction under existing and proposed bathymetry. The STWAVE model grid is approximately 25 miles in the alongshore direction and 13 miles in the cross-shore direction. The STWAVE model resolution is approximately 100 feet by 100 feet. Both the existing and proposed bathymetry data are informed by the results of the APTIM offshore geophysical investigations. The maximum cut depth in each borrow area is used to create the interpolated elevation surface for the proposed bathymetry. Data from WIS Station 73153 informed the forcing conditions along the offshore boundary of the STWAVE model. We performed simulations of the long-term average, 90$^{th}$ percentile, and maximum (i.e., 99.99$^{th}$ percentile) wave conditions for this assessment (as defined by the WIS data). For all conditions modeled, we found that changes in wave height and direction are relatively small and are confined to an area within 3 miles of the borrow areas (almost exclusively to the north). No significant changes in wave height or direction are noted along any part of the Alabama shoreline. Changes in the spectrally significant wave height ($H_{m0}$) are mostly less than ±10 percent, except for under the most extreme conditions when changes can exceed +20 percent near the borrow areas. The largest changes in wave heights are found within 3000 to 5000 feet of a borrow area. Changes in the wave direction associated with the borrow areas fall within the range of ±10 degrees, with most of the changes on the order of ±5 degrees (or smaller). The largest changes in wave direction are found adjacent to the borrow area boundary. Changes in wave period were insignificant.

The results of these model simulations indicate that the proposed borrow area extents and depths will not result in changes in the wave conditions along the Alabama coast.

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# List of Abbreviations

| Abbreviation | Description | Explanation or Units |
|---|---|---|
| CUDEM | Continuously Updated Digital Elevation Model | n/a |
| $H_{m0}$ | Significant Wave Height | feet or meters |
| NAD83 | North American Datum of 1983 | horizontal datum |
| NAVD88 | North American Vertical Datum of 1988 | vertical datum |
| NCEI | National Center for Environmental Information | n/a |
| NOAA | National Oceanic & Atmospheric Administration | n/a |
| STWAVE | Steady State Wave model | n/a |
| $T_p$ | Peak Wave Period | seconds |
| USACE | United States Army Corps of Engineers | n/a |
| WIS | Wave Information Studies | n/a |

# 1 Introduction

## 1.1 Purpose & Scope

The Dauphin Island West End Beach and Dune Restoration Project aims to restore critically eroding habitat along approximately 3.3 miles of Dauphin Island beginning near Ryan Court and ending west of the Town of Dauphin Island's West End Public Beach (near the east end of the rocks at what used to be Katrina Cut). The restoration of beach and dune habitats will require the addition of millions of cubic yards of new, clean, compatible beach sand. Currently, the project proposes to dredge and pump this material from borrow areas located on the southwest lobe of the Mobile Bay ebb tidal shoal, approximately 8 miles to the southeast of the project area. Dredging the borrow areas will lower the seabed elevation within the borrow area footprints. The subsequent change in depths on the ebb tidal shoal will lead to changes in the wave climate near the borrow areas, particularly during storm conditions when wave periods, and therefore wavelengths, are longer.

This report documents the results of wave transformation modeling to evaluate the potential impacts of the proposed borrow area extents and depths on the local wave climate. Of particular concern would be any non-negligible change in wave height, wave direction, and/or wave period along the shorelines of Dauphin Island or Fort Morgan. A two-dimensional, depth-integrated steady state wave model is used to investigate potential changes in wave characteristics as a result of the dredging. Proposed conditions are compared to existing conditions to document increases, or decreases, in wave height, period, and direction throughout the modeling domain.

### 1.1.1 Study Area

The proposed beach and dune restoration project is located on the West End of Dauphin Island beginning near Ryan Court and ending just to the west of the Town of Dauphin Island's West End Public Beach. The proposed borrow areas are located approximately 8 miles to the southeast of the project area on the southwest lobe of the Mobile Bay ebb tidal shoal. The overall study area for this investigation is much broader, extending over 10 miles south of Dauphin Island into the Gulf of Mexico, and capturing all of Dauphin Island and the western 6+ miles of the Fort Morgan peninsula. The study area is broadly captured in Figure 1 below.

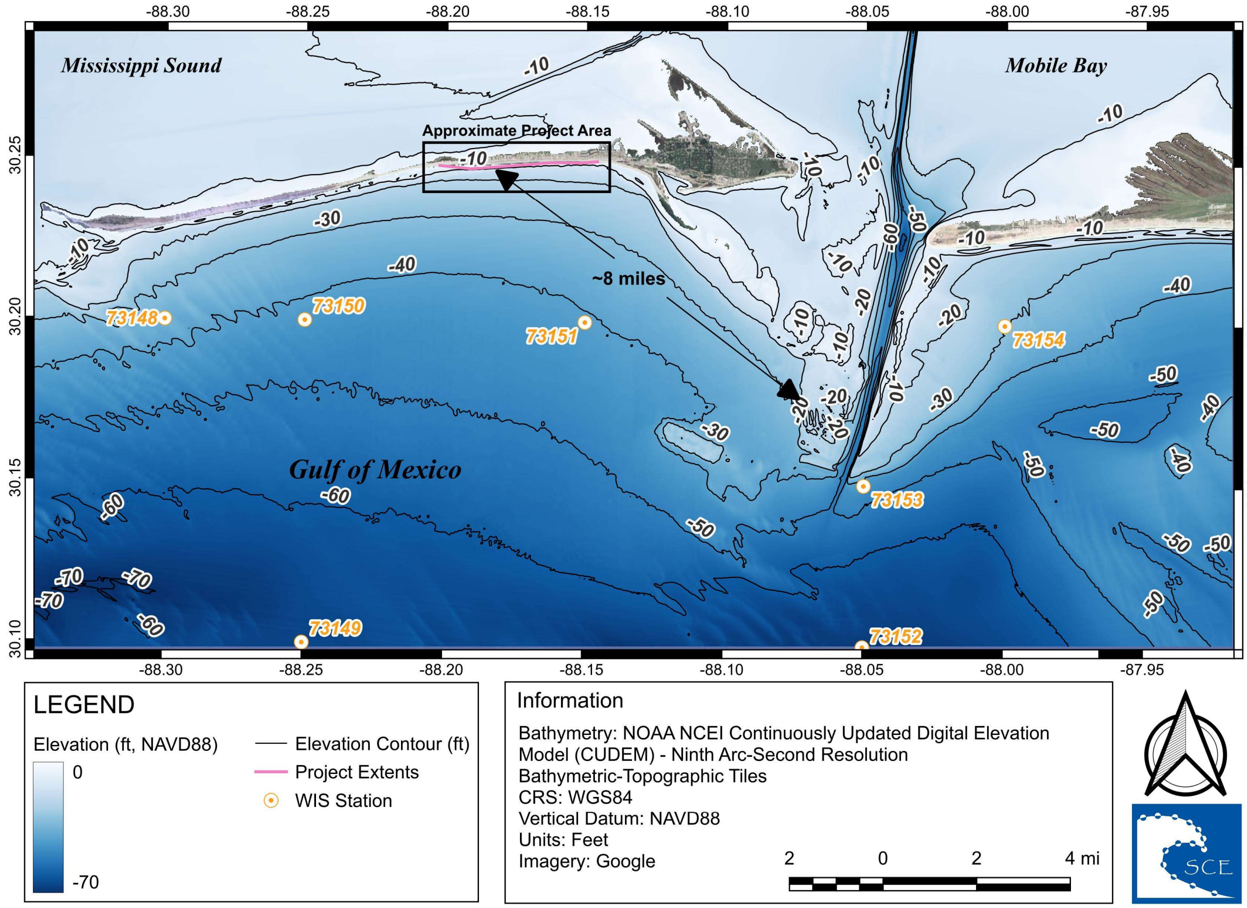


**Figure 1. Project and modeling area overview showing existing bathymetry, WIS station locations, and approximate project area.**

### 1.1.2 Borrow Area Information

APTIM performed geophysical investigations on the Mobile Bay ebb tidal shoal in the fall of 2004. The results of those investigations were used along with magnetometer data to define the lateral extents and cut depths of potential borrow areas. Four contiguous areas were targeted for investigation, which were subsequently subdivided into seven potential borrow areas (Table 1). The borrow area locations are shown in Figure 2.

**Table 1. Borrow Area Cut Depths and Volumes**

| Final Cuts | | | | BA Total | Total |
|---|---|---|---|---|---|
| **BA** | **Cut Depth (ft, NAVD88)** | **Volume (cf)** | **Volume (cy)** | **Volume (cy)** | **Volume (cy)** |
| BAIIIa | -30 | 20044594 | 742392 | 2707970 | 8435099 |
| BAIIIb | -33 | 53070604 | 1965578 | | |
| BAIV | -33 | 16361440 | 605979 | 605979 | |
| BAVa | -36.5 | 27608637 | 1022542 | 4026807 | |
| BAVb | -34.5 | 35773281 | 1324936 | | |
| BAVc | -35 | 45341860 | 1679328 | | |
| BAVI | -36 | 29547252 | 1094343 | 1094343 | |

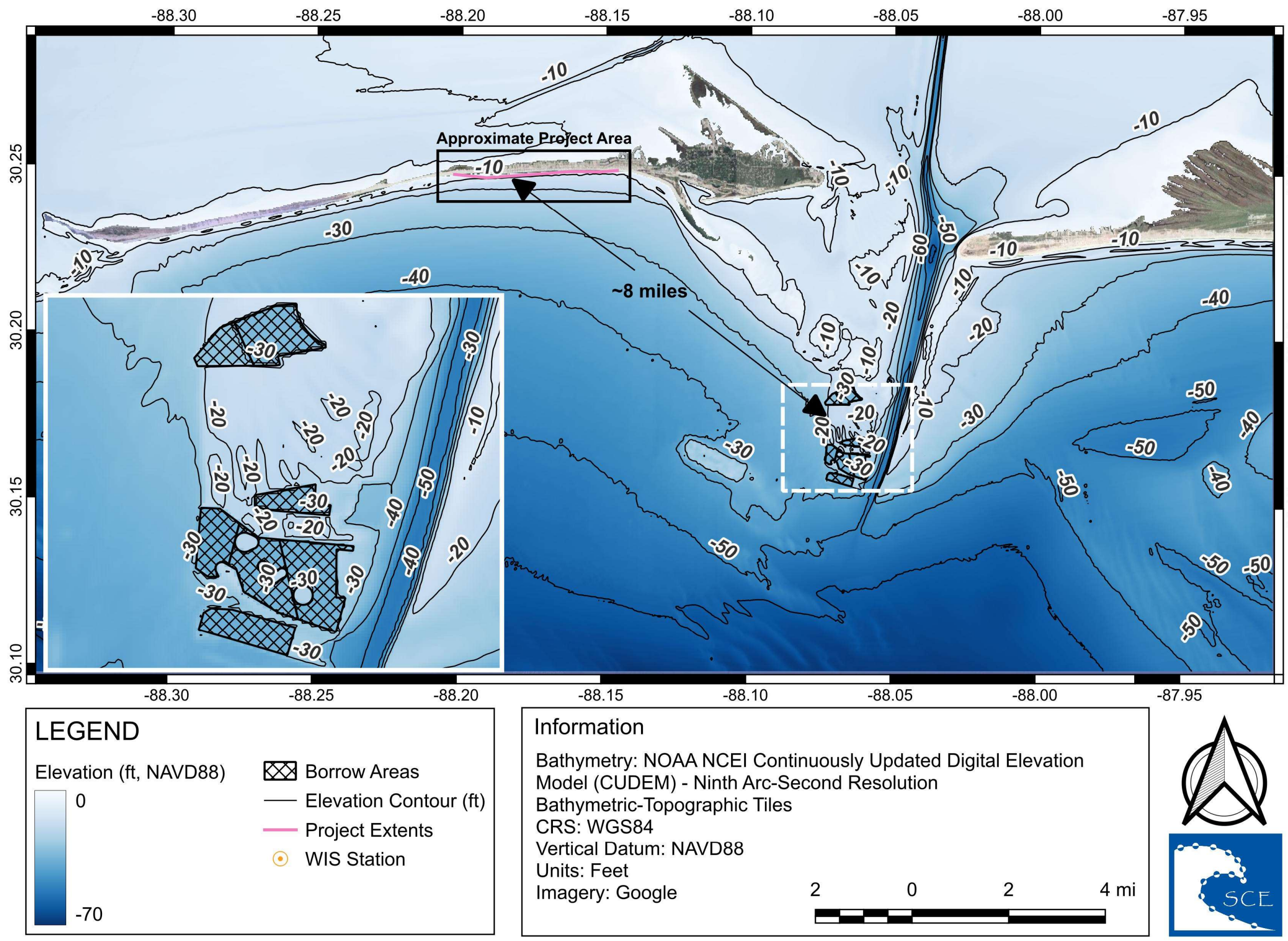


**Figure 2. Location and extent of proposed borrow areas.**

# 2 Methodology

## 2.1 Wave Model

The two-dimensional, depth-integrated steady state wave model STWAVE was selected for this investigation. The STWAVE model is capable of wave generation and propagation over spatially varying bathymetry, water levels, currents, and frictional features. The Aquaveo Surfacewater Modeling System (SMS) was used to prepare, run, and export the STWAVE model data. For this study, we applied the half-plane version of STWAVE since we were only concerned with waves originating from the Gulf of Mexico and propagating to the north. We also limited the simulations to wave propagation only, with boundary conditions derived from the WIS data summarized previously.

## 2.2 Numerical Grid

The uniform Cartesian grid prepared for the STWAVE modeling is shown in Figure 3. The grid is approximately 25 miles in the alongshore direction and 13 miles in the cross-shore direction. The grid resolution is approximately 100 feet by 100 feet (30 meters by 30 meters). The offshore boundary location was selected to approximately coincide with the 65-ft depth contour (20 meters). This decision ensured proper wave generation along the boundary, and clean wave transformations across the ebb tidal shoal. The grid extents were chosen to capture all of Dauphin Island and portions of Fort Morgan, Mobile Bay, and Mississippi Sound. The extents also captured a number of USACE WIS stations to better define the wave climate for this investigation.

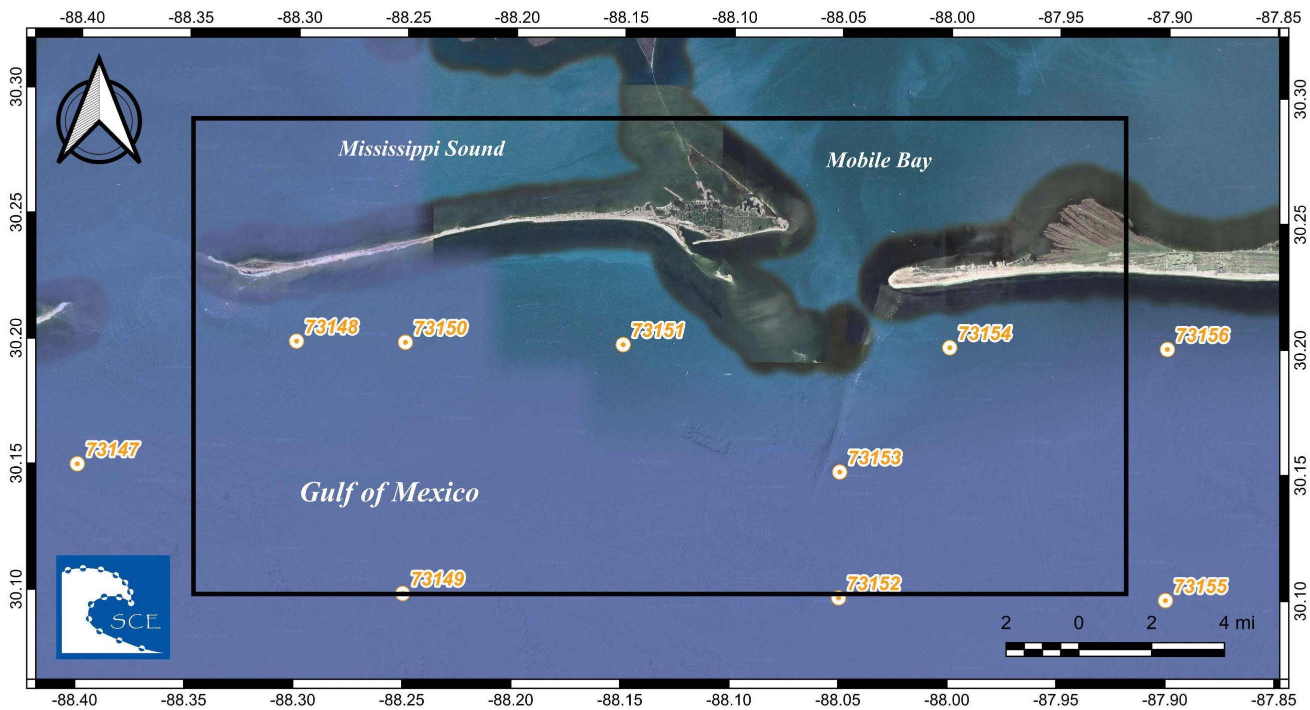


**Figure 3. STWAVE numerical grid extents.**

## 2.3 Bathymetry Data

The STWAVE model grid elevations are a composite of two or three sources of data in the case of the existing and proposed conditions, respectively. The background bathymetric elevations are based on the NOAA NCEI Continuously Updated Digital Elevation Model (CUDEM) – Ninth Arc-Second Resolution Bathymetric-Topographic Tiles. The CUDEM data were merged with more recent survey data collected by APTIM in 2024 as part of their cultural resources and geophysical data collection campaigns. The APTIM data coverage included all proposed borrow areas as well as the proposed pipeline corridor to Dauphin Island (see Figure 4). The combination of the CUDEM and APTIM elevations served as the topobathymetric elevation dataset for the existing conditions simulations. The proposed borrow area extents and cut depths were then incorporated and a new elevation dataset was created to serve as the elevations for the proposed conditions simulations. Borrow area locations and cut depths are as described earlier in this report.

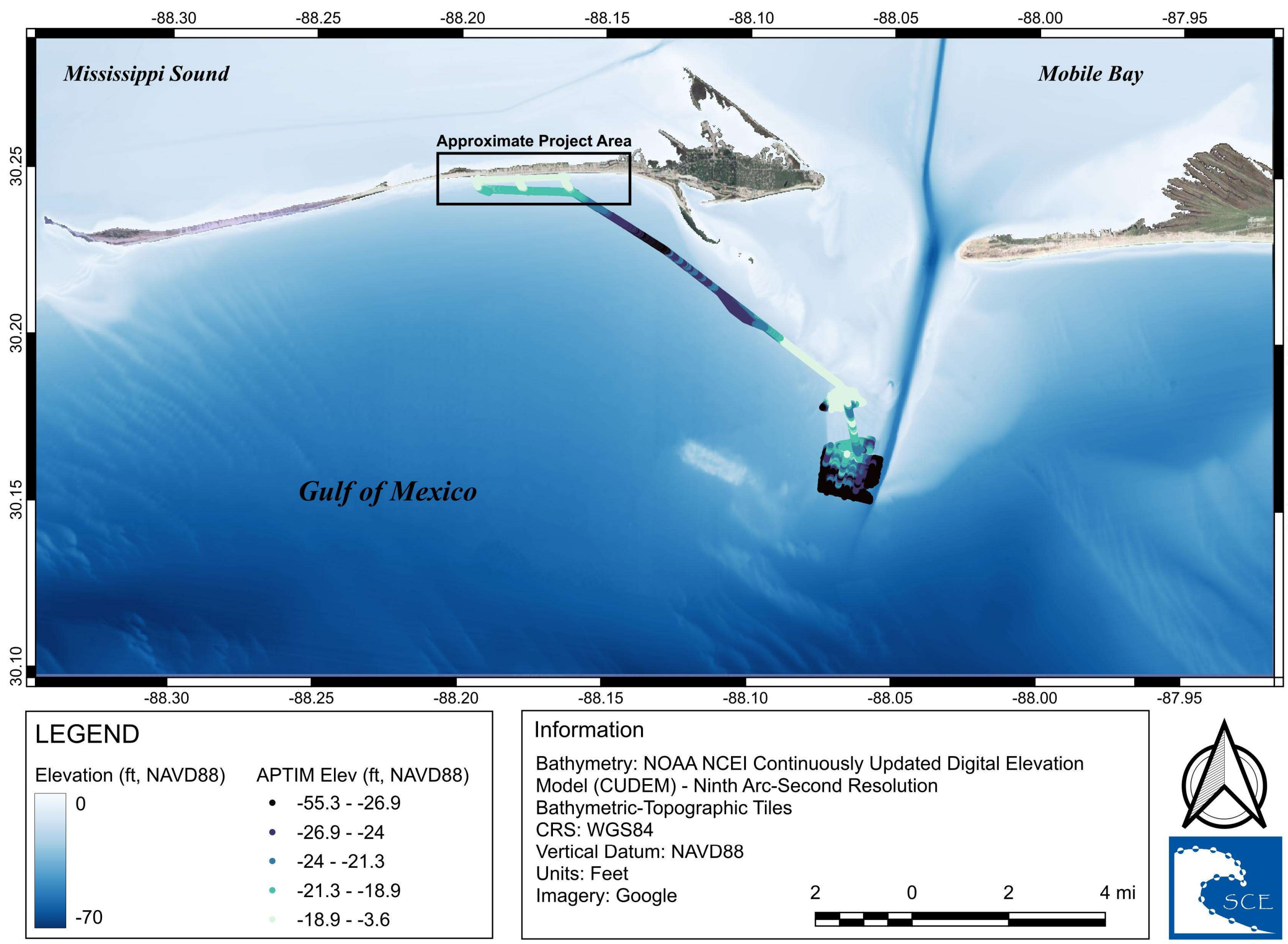


**Figure 4. Existing bathymetric data and the extent of 2004 APTIM bathymetric survey data.**

## 2.4 Forcing Conditions

The hindcast wave conditions from USACE WIS Station 73153 (30.15ºN, 88.05ºW) were selected to describe the forcing conditions under existing and proposed conditions. Though WIS Station 73152 is located on the offshore boundary of the STWAVE grid, the wave conditions at 73153 are more reflective of conditions that may occur near the borrow areas. Thus, the wave characteristics at 73153 were transformed to the offshore boundary for the purpose of generating the two-dimensional TMA spectrum.

The STWAVE forcing conditions are summarized in Table 2. Three forcing scenarios were selected to investigate the potential impact of the borrow areas on wave heights, wave directions, and wave periods: the long-term average conditions (1980-2023 inclusive); the 90th percentile conditions; and the maximum hindcasted wave condition for WIS Station 73153. For each of these scenarios, the wave height was chosen as the defining characteristic. The corresponding peak wave period and dominant wave direction that most closely matched that wave height condition were then selected to complete the definition of forcing conditions for a particular scenario. As expected, the wave periods increase with wave height. The largest wave heights "observed" at WIS Station 73153 tend to occur from the south-southwest(SSW), whereas milder waves tend to come from directions that are more due south (S), south-southeast (SSE), or southeast (SE). The long-term average conditions were extracted from the file "ST73153-wave_percent_occurrence-20241130T21_39" whereas the extreme event conditions were extracted from the file labeled "ST73153-extremes_analysis_table-20241130T21_51" in the WIS output. The normal and cumulative distributions of wave height are shown in **Figure 5**.

**Table 2. STWAVE Forcing Conditions**

| *Condition* | *$H_{m0}$ (ft)* | *$T_p$ (s)* | *Direction (deg)* | *Exceedance (%)* |
|---|---|---|---|---|
| *Long-term Average* | 2.0 | 5.0 | 160 | 50 |
| *90th Percentile* | 9.2 | 7.7 | 193 | 10 |
| *Maximum* | 16.1 | 14.1 | 190 | 0.01 |

**a)** **b)**

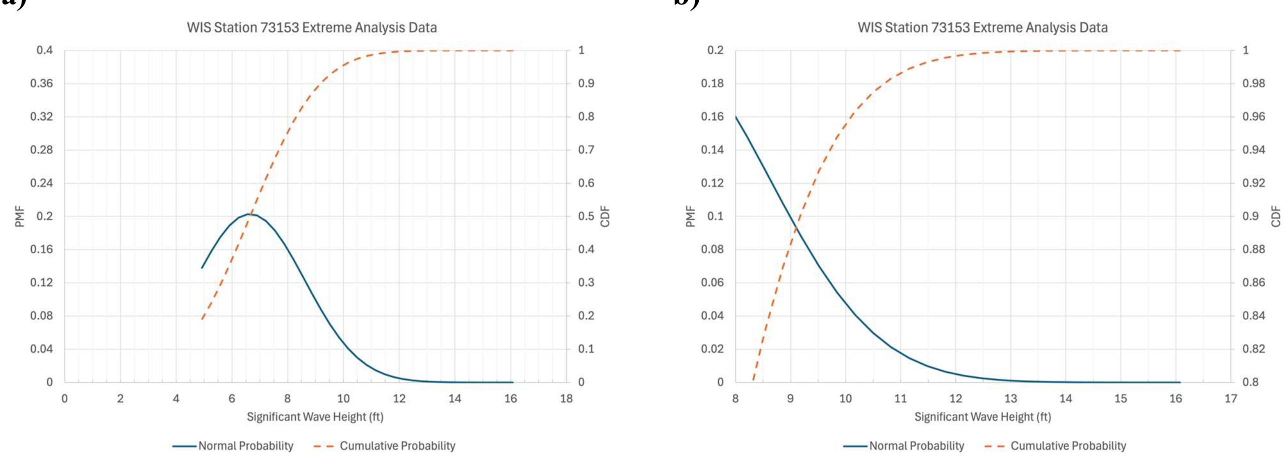


**Figure 5. The a) normal probability and cumulative distributions of extreme wave heights at Station 73153; and b) detailed probabilities over the top 20 percent of wave heights.**

# 3 Results & Discussion

## 3.1 Average Conditions

Simulations of the long-term average wave conditions resulted in minimal change near and around the borrow areas. Given the relatively short wave periods associated with the synoptic wave conditions in this part of the Gulf of Mexico, local changes in depth do not have a major impact on wave characteristics. Increases and decreases in wave height as a result of the proposed borrow areas are shown in Figure 6. Changes in the significant wave height are limited to ±0.5 feet and are limited to areas adjacent to the borrow areas. The percent change in wave height from existing to proposed conditions is shown in Figure 7. As shown, changes generally fall within ±10 percent. Changes in wave direction are shown in Figure 8 and demonstrate an expected pattern associated with refraction of the waves as they travel over the increased depths of the borrow areas (i.e., waves turning to the east on the east side of the borrow area; wave turning to the west on the west side of the borrow area). Changes in wave period (Figure 9) are negligible.

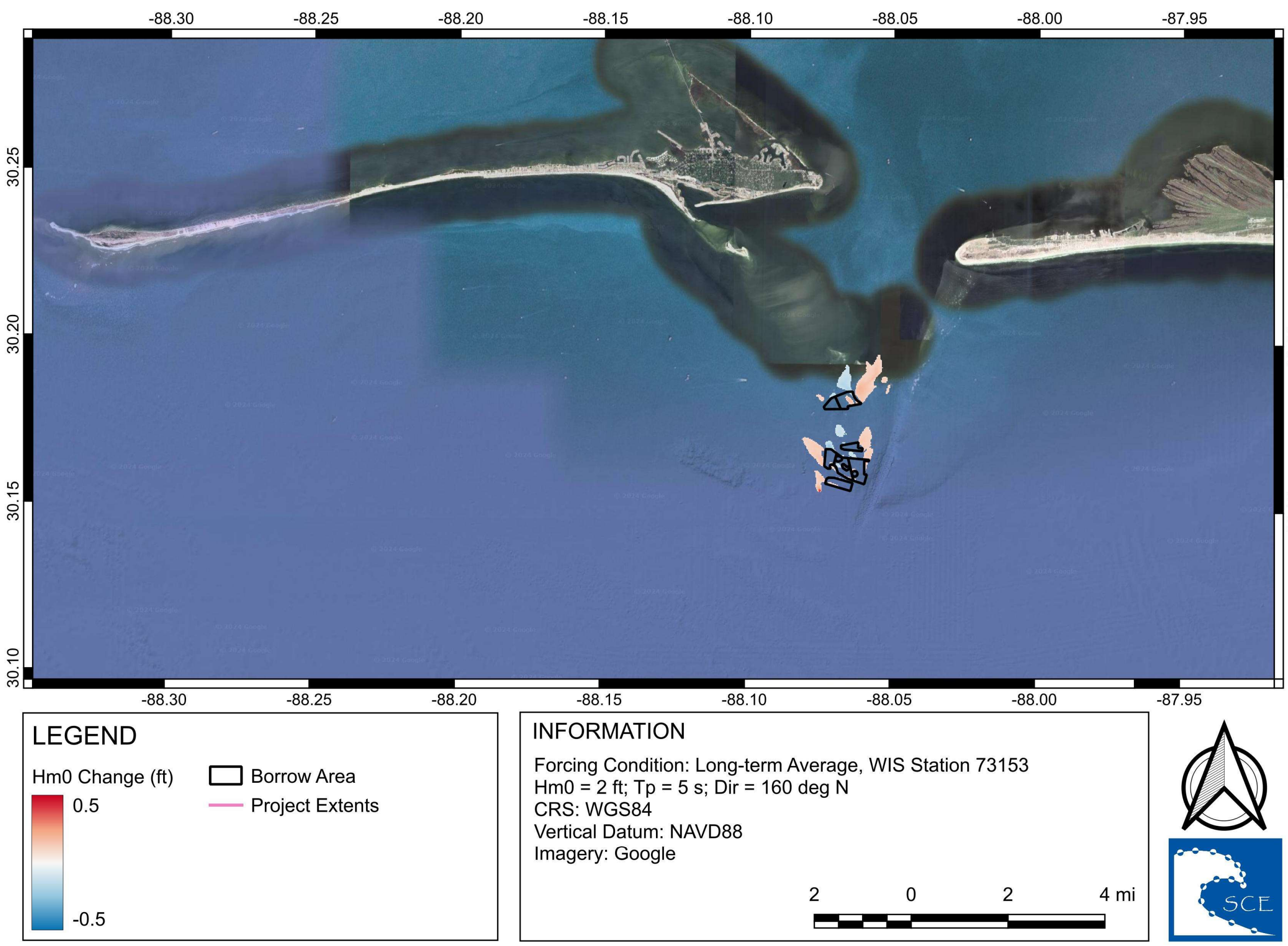


**Figure 6. Change in the long-term average spectrally significant wave height (proposed – existing). Values between -0.1 and +0.1 feet are set transparent. Changes are represented as "proposed" – "existing" such that positive values indicate increases in wave height as a result of the borrow areas.**

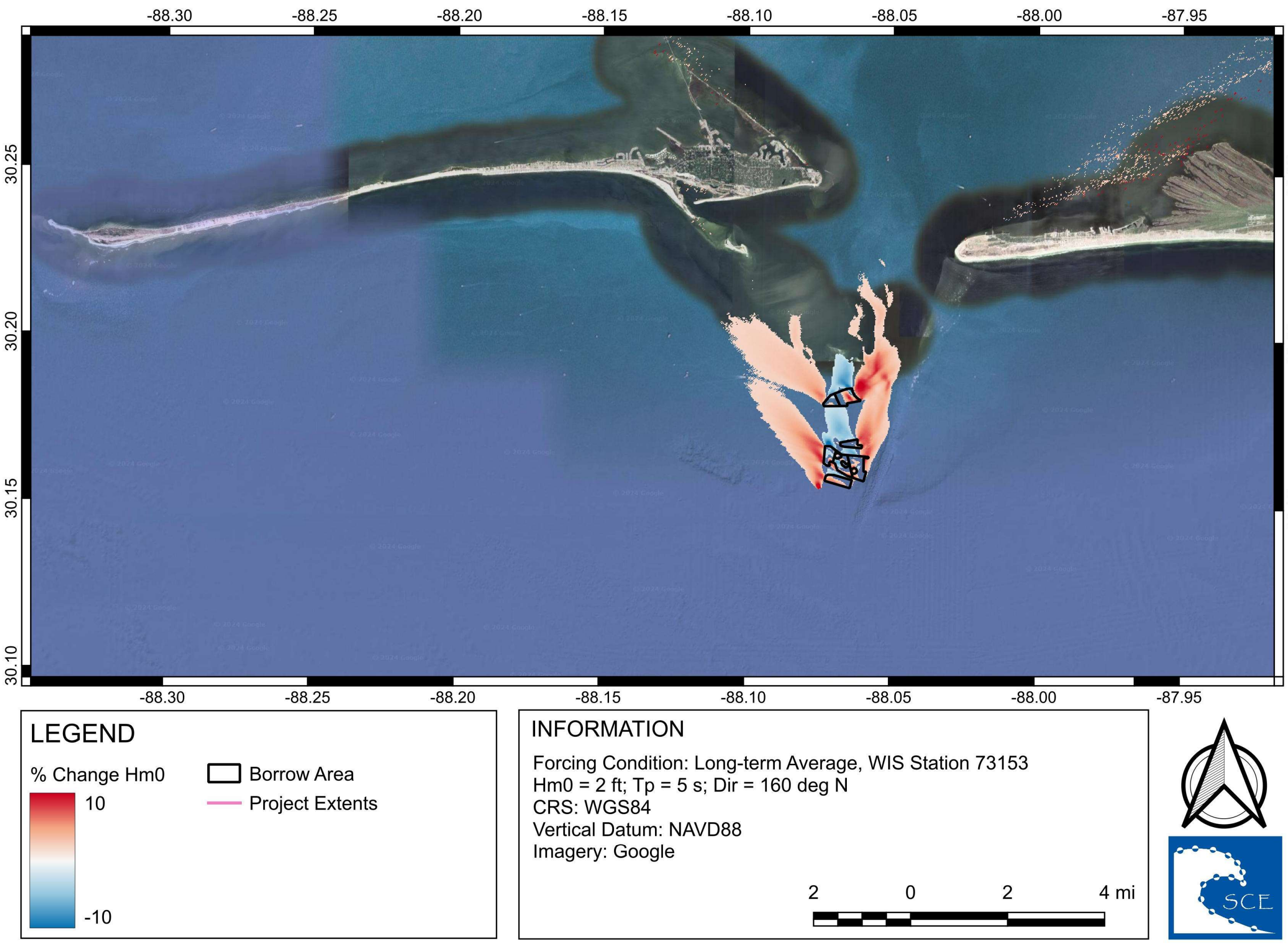


**Figure 7. Percent change in the long-term average spectrally significant wave height. Values between -2 and +2 percent are set transparent.**

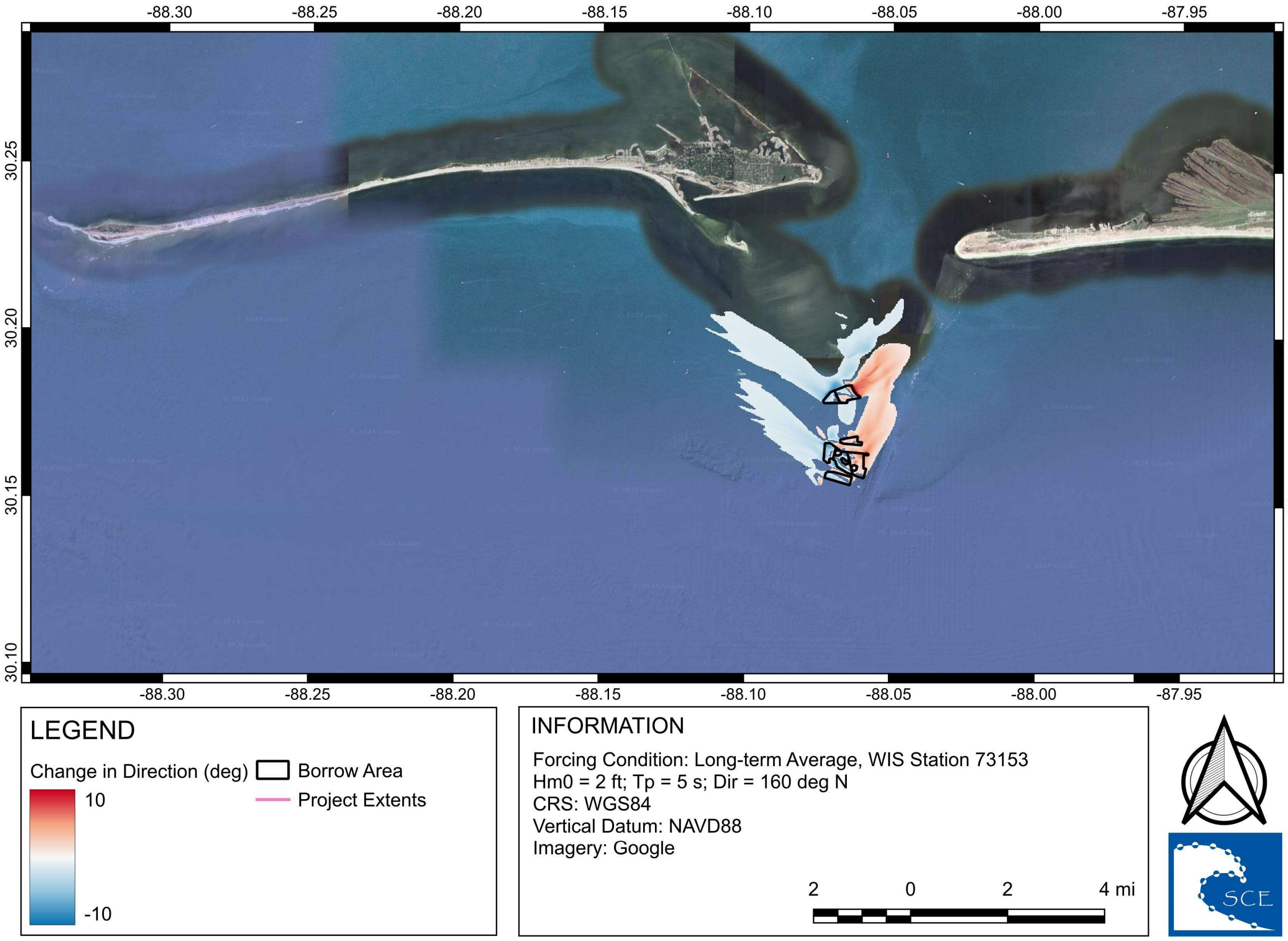


**Figure 8. Change in the long-term average wave direction (proposed - existing) in degrees. Directional changes between -1 and +1 degree are set transparent.**

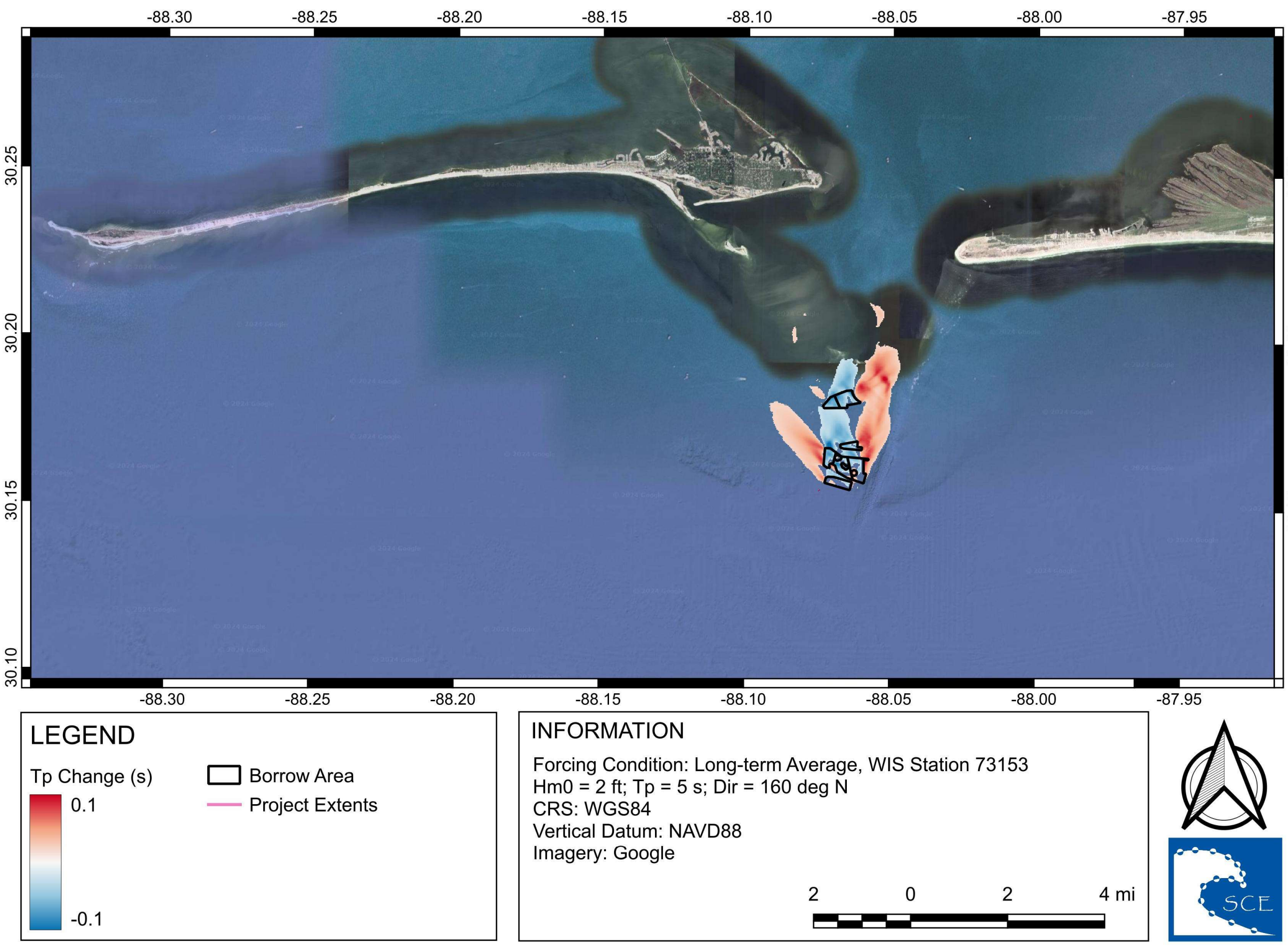


**Figure 9. Change in the long-term average wave period (proposed - existing). Changes between -0.05 and +0.05 seconds are set transparent.**

## 3.2 90th Percentile Conditions

Simulations of the 90th percentile wave conditions resulted in some change near and around the borrow areas. The longer wave period associated with the 90th percentile wave height results in a higher degree of interaction with the seabed and, thus, additional wave transformation. Increases and decreases in wave height as a result of the proposed borrow areas are shown in Figure 10. Changes in the significant wave height are limited to ±2 feet and extend approximately 3 miles from the borrow areas. The percent change in wave height from existing to proposed conditions is shown in Figure 11. As shown, changes generally fall within ±10 percent but do reach magnitudes of 20 percent in some areas. Changes in wave direction are shown in Figure 12 and again fall within ±10 degrees. Non-negligible changes in wave direction extend up to 4 miles from the borrow areas. Changes in wave period (Figure 13) are negligible.

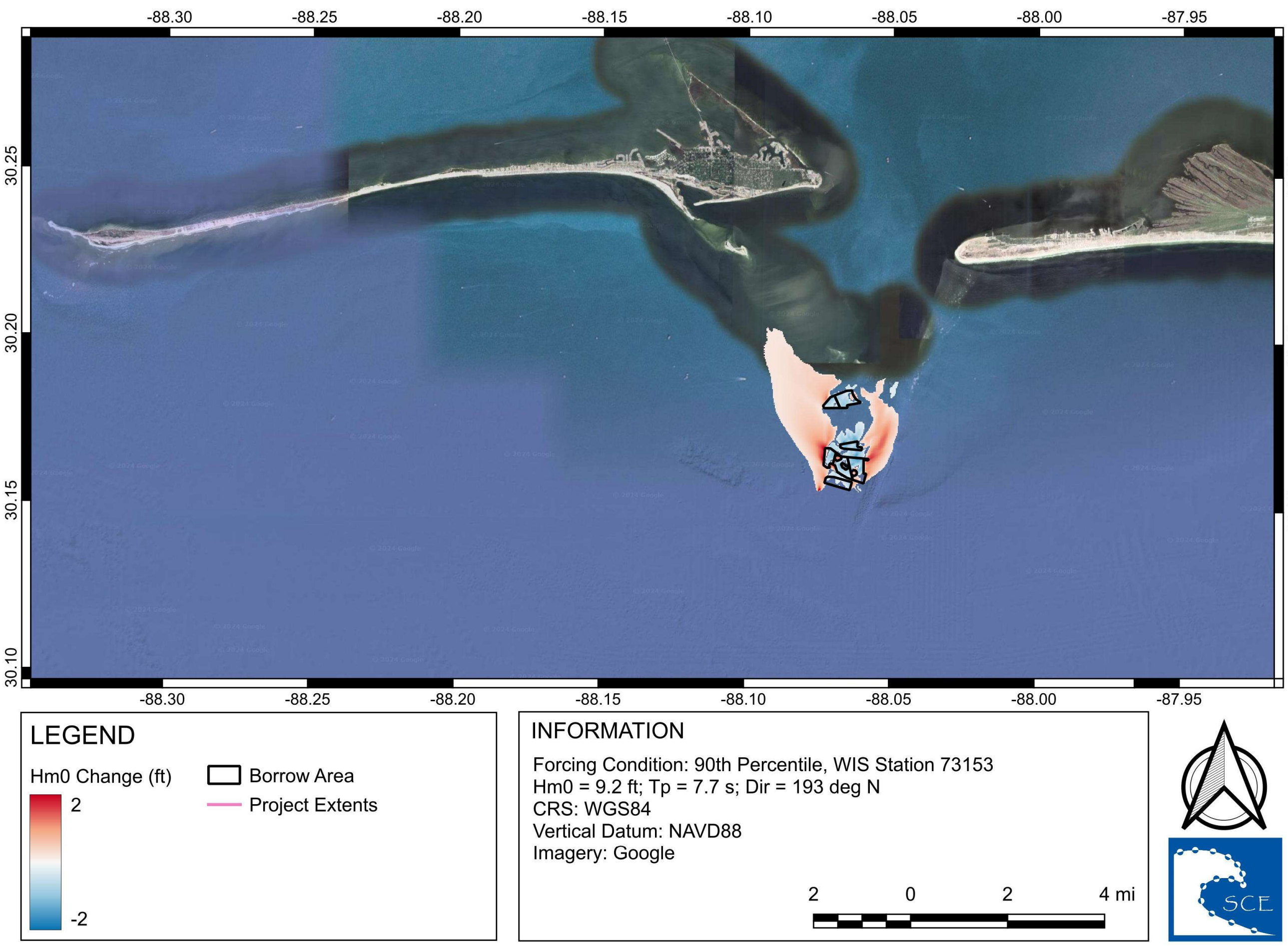


**Figure 10. Change in the 90th percentile spectrally significant wave height (proposed – existing). Values between -0.2 and +0.2 feet are set transparent.**

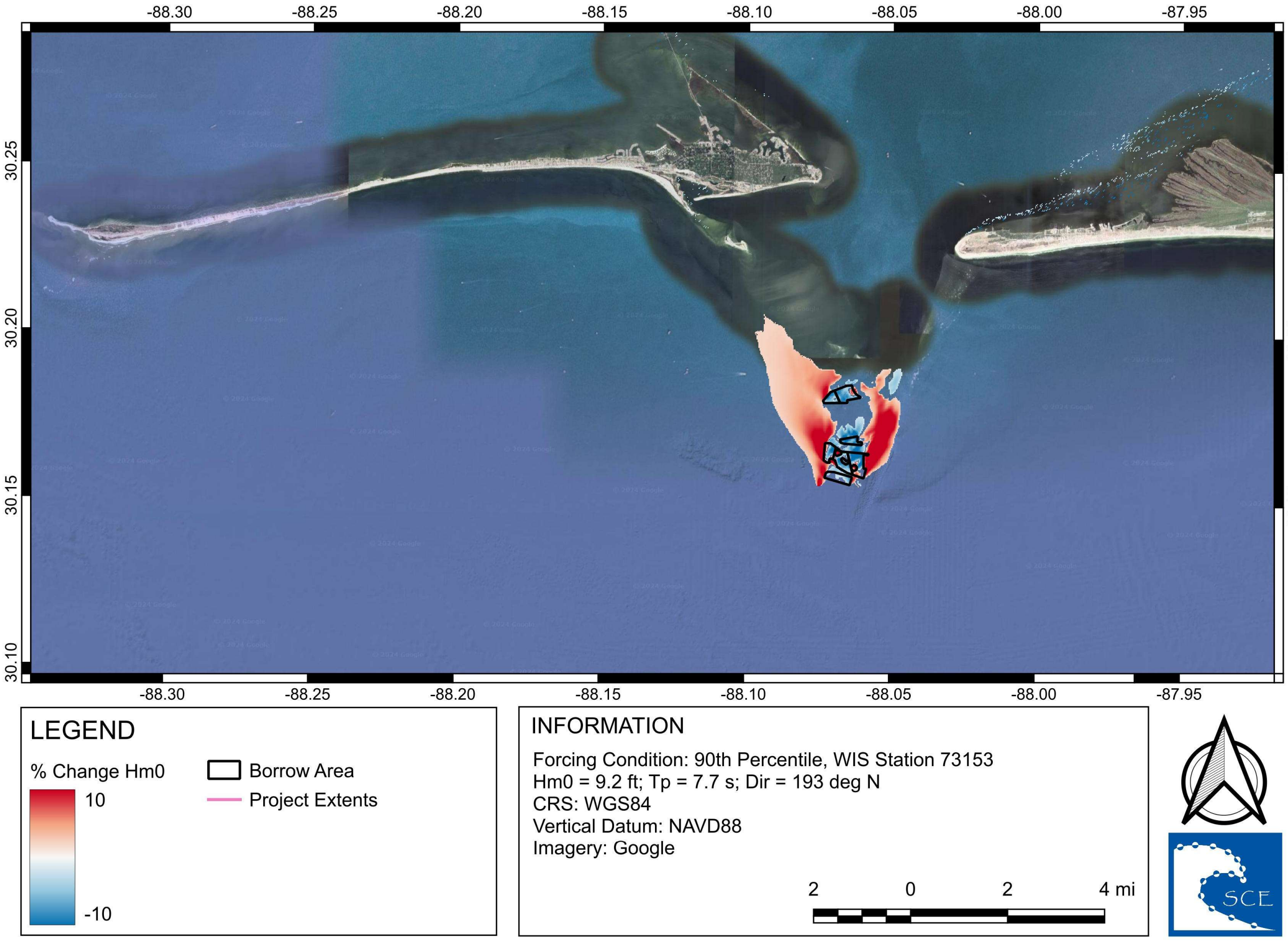


**Figure 11. Percent change in the 90th percentile spectrally significant wave height. Values between -2 and +2 percent are set transparent.**

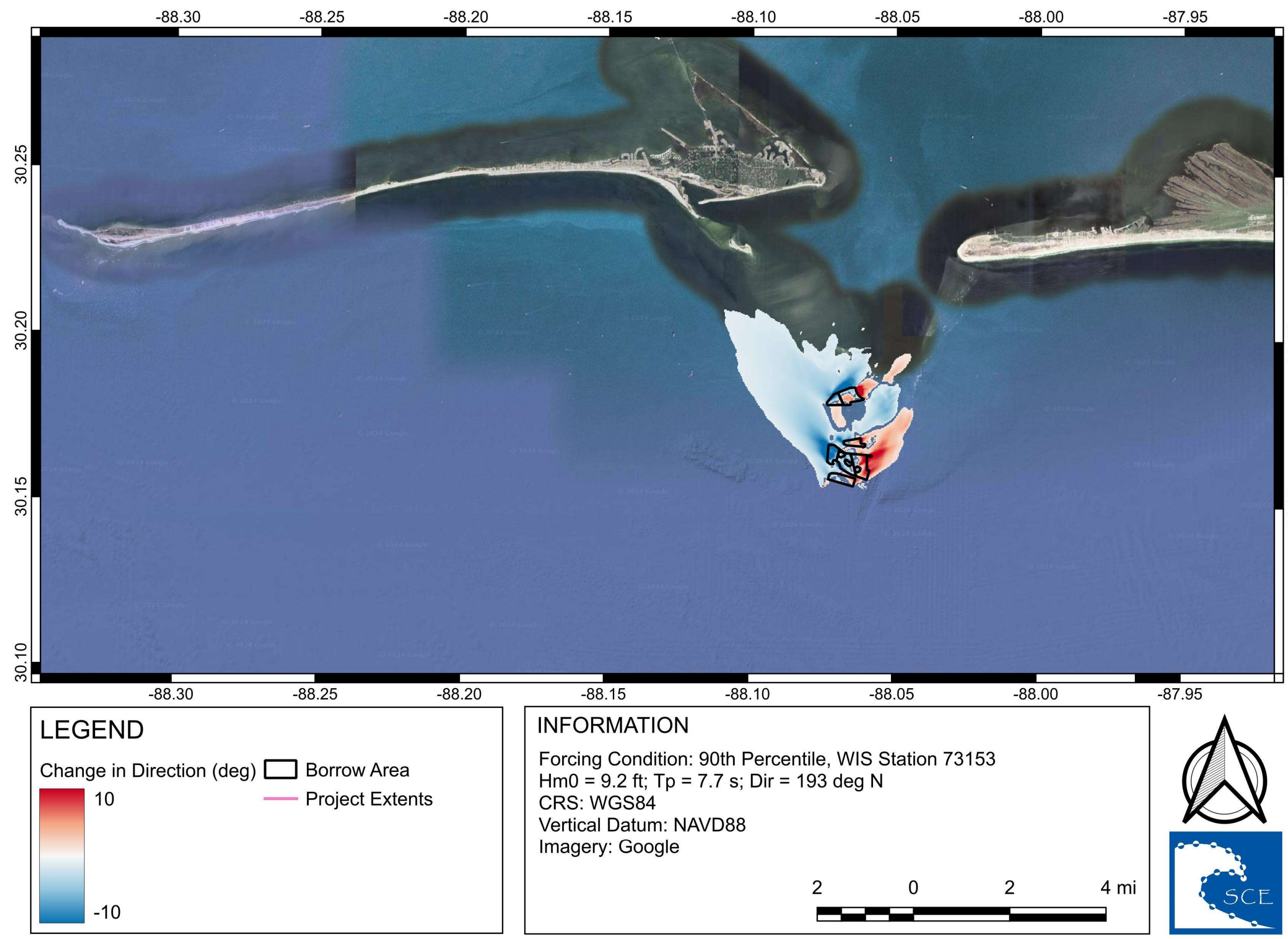


**Figure 12. Change in the 90th percentile wave direction (proposed - existing) in degrees. Directional changes between -1 and +1 degree are set transparent.**


**Figure 13. Change in the 90th percentile wave period (proposed - existing). Changes between -0.05 and +0.05 seconds are set transparent.**

## 3.3 Maximum Conditions

Simulations of the maximum (i.e., 99.99th percentile) wave conditions resulted in some notable changes near and around the borrow areas. Unlike results from the previous scenarios, however, the changes associated with the maximum wave conditions tend to be isolated to a smaller areas around the borrow areas. Increases and decreases in wave height as a result of the proposed borrow areas are shown in Figure 14. These changes are typically limited to a radius of about 2 miles from the borrow area. Changes in the significant wave height mostly fall within the range ±4 feet with few values exceeding +4.5 feet. The percent change in wave height from existing to proposed conditions is shown in Figure 15. As shown, changes generally fall within ±20 percent but do reach magnitudes of 30 percent in some isolated areas. Changes in wave direction are shown in Figure 16 and again fall within ±10 degrees. A few locations near the southern borrow areas have values approaching +20 degrees. Non-negligible changes in wave direction extend up to 5 miles from the borrow areas. Changes in wave period (Figure 17Figure 13) are non-negligible near the southern borrow area, but fall within ±1 second.


**Figure 14. Change in the maximum spectrally significant wave height (proposed – existing). Values between -0.2 and +0.2 feet are set transparent.**


**Figure 15. Percent change in the maximum spectrally significant wave height. Values between -2 and +2 percent are set transparent.**


**Figure 16. Change in the maximum wave direction (proposed - existing) in degrees. Directional changes between -1 and +1 degree are set transparent.**


**Figure 17. Change in the maximum wave period (proposed - existing). Changes between -0.2 and +0.2 seconds are set transparent.**

# 4 Conclusions

We performed simulations of the long-term average, 90th percentile, and maximum (i.e., 99.99th percentile) wave conditions, using STWAVE, to investigate potential impacts of the proposed borrow areas on wave characteristics along the Alabama coast. For all conditions modeled, we found that changes in wave height and direction are relatively small and are confined to an area within 3 miles of the borrow areas (almost exclusively to the north). No significant changes in wave height or direction are noted along any part of the Alabama shoreline. Changes in the spectrally significant wave height ($H_{m0}$) are mostly less than ±10 percent, except for under the most extreme conditions when changes can exceed +20 percent near the borrow areas. The largest changes in wave heights are found within 3000 to 5000 feet of a borrow area. Changes in the wave direction associated with the borrow areas fall within the range of ±10 degrees, with most of the changes on the order of ±5 degrees (or smaller). The largest changes in wave direction are found adjacent to the borrow area boundary. Changes in wave period were insignificant.

The results of these model simulations indicate that the proposed borrow area extents and depths will not result in changes in the wave conditions along the Alabama coast.