

Sabine Neches Navigation Improvement Project Integrated Section 203 Feasibility Report and Environmental Assessment

Appendix A Attachment 4 Storm Surge Modeling Report



February 2026

Executive Summary

Hydrodynamic modeling of the Sabine-Neches Waterway (SNWW) was performed to support a Section 203 Integrated Feasibility Report for a proposed channel improvement project (Project). A channel deepening project (SNWW Channel Improvement Project) is currently in construction. The modeling performed in this effort is focused on channel widening that is not included in the channel deepening project. The overall modeling effort for the Section 203 Integrated Feasibility Report includes two-dimensional modeling of hydrodynamics associated with daily tides, storm surge events, hydrodynamic modeling of passing vessels in the SNWW, and three-dimensional modeling of hydrodynamics to assess water quality changes. This report discusses the hydrodynamic modeling of storm surge events.

Modeling was performed using the MIKE21 Flow Model HD FM on a flexible mesh designed to resolve the navigation channel, surrounding area, and important hydraulic features. The model mesh extends approximately 50 km (31 mi) landward from the SNND jetties, approximately 23 km (14 mi) to the east and 34 km (21 mi) to the west of the main shipping channel. The model was forced at an offshore boundary located 20 km from the SNND jetties using ADCIRC water level time series and parametric wind data from the U.S. Army Engineer Research and Development Center (USACE, 2015). Calibration was performed with ADCIRC water level time series internal of the model domain. Additional model runs were performed to qualitatively assess changes due to relative sea level change (RSLC).

Six channel configurations were considered for the modeling: (1) Existing Conditions (EC), (2) Future without Project (FWOP) representing the channel deepening without the proposed widening, (3) Future with Project Full Build (FWPFB) which included the largest considered widening width and extent, and three smaller widening variations referred to as (4) Alternative 1, (5) Alternative 2, and (6) Alternative 3. The three alternatives have not been modeled at this point and will be included in a later version of this report. The Existing Conditions (EC) model was used for model calibration and the primary model comparisons were made between the FWOP and FWP alternatives to capture changes that could occur as a result of the proposed channel improvements.

Two synthetic storm surge events were modeled to assess water level changes within the SNWW and near the existing and planned flood defenses bordering eastern Jefferson and southern Orange counties. Water level differences between the FWOP and FWPFB models were de minimis and are summarized as follows:

- Model calibration resulted in a mean error of 10 cm.
- Comparisons of peak water level along the channel alignment and at the Orange flood defense structure showed a maximum increase of 7 cm between the FWOP and FWPFB conditions, and a maximum increase of 3 cm between the FWOP and Alternative 1 (TSP) conditions.
- Evaluation of model time series showed no change in inundation duration.
- The inclusion of relative sea level change resulted in smaller differences between FWOP and the channel widening alternatives.

Based on the results of the modeling, the changes to peak surge elevations due to the channel widening are de minimis and the Project is not expected to have an impact on the surge elevations or durations around the SNWW.

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1 Introduction

1.1 Modeling Scope

The Sabine-Neches Waterway (SNWW) provides a valuable avenue for waterborne commerce to transit between the Gulf of Mexico and the inland ports. The SNWW navigation channels are significantly deeper than the natural channels and tend to concentrate tidal current flows. These deeper navigation channels provide a conduit for saltwater to penetrate further into the inland system during elevated water levels on the coast. Therefore, it is important to study the effects of any changes to the SNWW channel configurations on system hydrodynamics and circulation.

The Sabine-Neches Navigation District (SNND) is conducting a study of potential channel improvements to the SNWW to be used for preparing a Section 203 Integrated Feasibility Report and appropriate environmental analyses. These improvements are in addition to the U.S. Army Corps of Engineers (USACE) channel improvement project (SNWW CIP) that is currently under construction to reconfigure and deepen the existing channel. The purpose of the new evaluation is to examine measures to widen portions of the navigation channel to increase vessel traffic efficiency and navigation safety along the SNWW in conjunction with the expanded vessel sizes allowed by the current deepening improvements.

This technical report documents the numerical modeling performed for analysis of storm surge hydrodynamics and is developed to serve as a standalone document. Information from this report will be used in the effects analysis and will also help generate portions of the Engineering Appendix for the Section 203 Integrated Feasibility Report.

The general project area and channel reaches considered for widening are shown in Figure 1-1. The proposed widening reaches shown in the figure represent all the potential widening locations considered, although alternatives are also considered for widening at only select locations.

1.2 Units and Datums

All models applied in this study were developed using International units, however, following common practice all channel depths and widths are presented in English units. Therefore, there is a mix of feet (ft) and meters (m) presented in this report. For datums, all models are referenced to NAD83 Texas State Plane South Central horizontal coordinate system and the North Atlantic Vertical Datum of 1988 (NAVD88). Channel depths were defined relative to mean lower low water (MLLW) and were converted to NAVD88 using VDatum software during model scatter development.

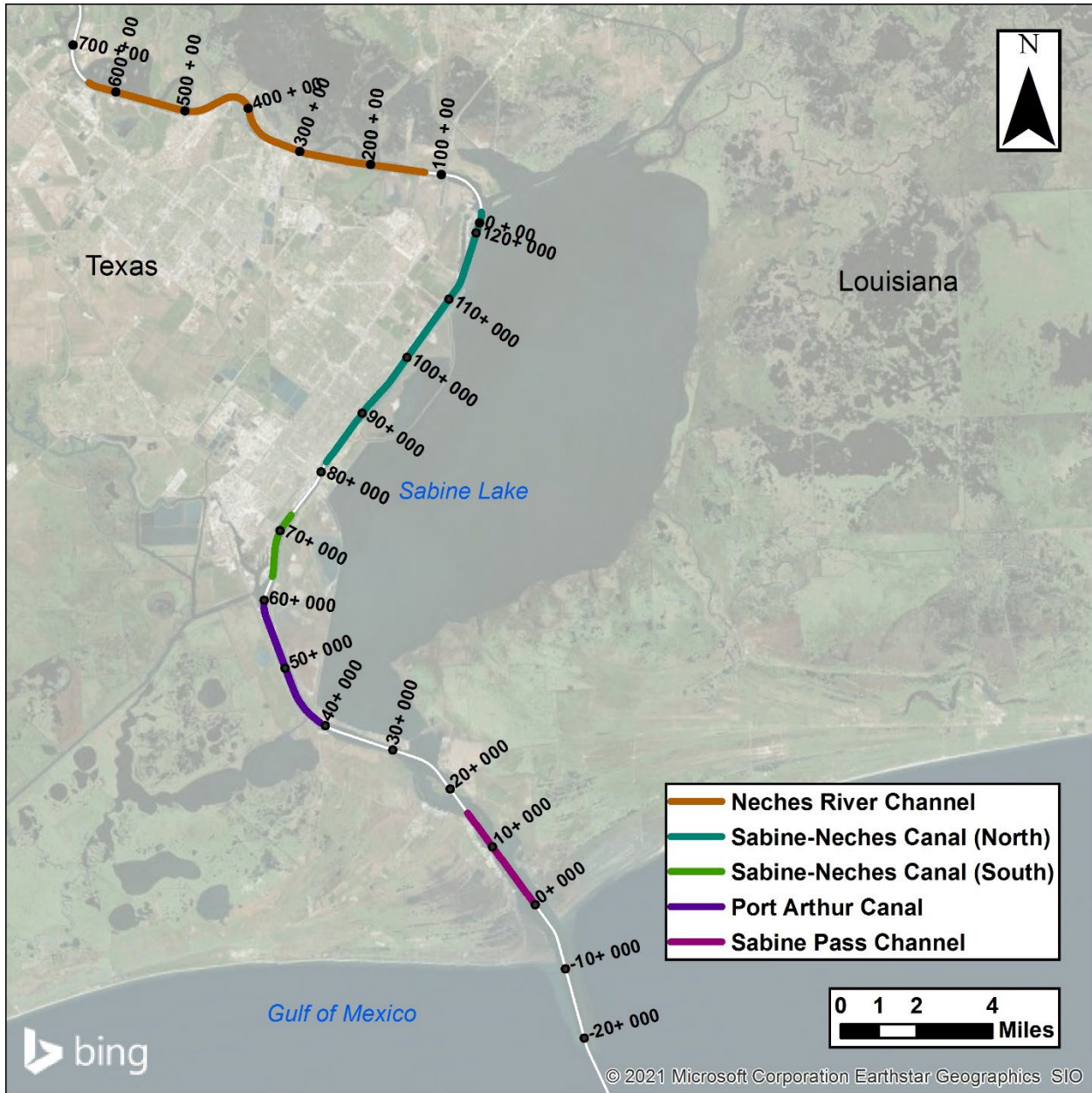


Figure 1-1
SNWW Locations Considered for Widening¹.

HDR performed an analysis to examine the influence of widening portions of the SNWW channel on storm surge hydrodynamics, specifically peak water levels. This analysis uses the MIKE 21 Flow Model HD FM (hydrodynamic modeling using flexible mesh) to simulate the hurricane-generated storm surge inundation within the existing channel, surrounding inundation plain, and future project alternatives. Model results for each of these alternatives were compared along the length of the channel based on peak water levels also known as peak storm surge. Model

¹ The color coding does not capture the full extent of each reach; rather, it refers to the name of the reach where each of the widening areas are considered.

calibration/validation was based on comparisons of similar storm surge modeling developed by USACE as part of the Sabine to Galveston (S2G) modeling study (USACE, 2015). Several additional simulations were also compared for future project alternatives including predicted relative sea level change (RSLC). This document describes methodology and results of the surge analysis.

2 Previous Studies

2.1.1 Sabine-Neches Waterway Channel Improvement Project (2003-2011)

USACE published a Final Engineering Appendix in 2008 for the Sabine-Neches Waterway Channel Improvement Feasibility Study (2011)² to assess impacts to the SNWW from proposed deepening and widening alternatives. Engineering studies included ship simulations, storm surge, erosion, and salinity investigations by the USACE's Engineer Research and Development Center (ERDC).

Storm surge inundation that would result from implementing a 48-foot channel deepening project was specifically investigated as part of the feasibility study as documented in the Engineering Appendix. A boundary tidal signal was generated from the tidal signal recorded at Sabine Pass during Tropical Storm Frances, which hit the Texas Coast on September 11, 1998. The rivers were assigned constant inflows, which represent moderate inflow conditions. Maximum storm surge differences observed in the model runs varied between 0.0 and 0.1 m increases in water surface elevation. The model did not allow for the significant overbank flooding that would occur in an actual storm. The authors point out that the estimate of water surface elevation increase should be considered conservative.

2.1.2 Sabine Pass to Galveston Bay Wave and Water Level Modeling (2015)

The USACE Galveston District (SWG) published the Sabine Pass to Galveston Bay (S2G) Feasibility Study (USACE, 2015). The goal of the study was to determine Coastal Storm Damage Risk Management (CSDRM) project implementation for the Brazoria and Sabine regions of the Texas coast. The report summarizes computation of storm inundation depths and correlated waves and associated uncertainty for the without-project and with-project alternatives.

The study took advantage of previous modeling conducted for the Federal Emergency Management Agency (FEMA) Region VI National Flood Insurance Program (NFIP) Risk MAP study reported in FEMA (2011). All storm statistics as well as response statistics were recomputed using a new software system developed at ERDC called StormSim.

3 Modeled Channel Configurations

The hydrodynamic modeling described in this report analyzes six channel configurations which are presented in this section. References to channel depth are based on the authorized depth relative to mean lower low water (MLLW). A summary of the configuration-specific widening locations and dimensions is provided in Table 3-1.

² Referred to as the Sabine Neches Navigation Channel Improvement Project in the Engineering Appendix.

3.1 Channel Configuration 1: Existing Conditions

Referred to as Existing Conditions (EC), this configuration represents the channel conditions in place during the time of the data record used for model calibration (2018-2020 timeframe) prior to the start of the SNWW CIP construction. The authorized channel depth for this configuration is 40 ft below MLLW, although the conditions modeled are based on the available survey data and were not modified (see Section 4.2). This model condition will primarily serve as a model calibration/validation. This condition will also help qualify the cumulative changes predicted from the Future without Project (CIP Completed) and widening alternatives. Note the effects for the Future without Project (CIP Completed) condition were already captured in the 2011 CIP feasibility study (USACE, 2011).

3.2 Channel Configuration 2: Future without Project (CIP Completed)

Referred to as Future without Project or FWOP, this configuration represents the approved channel deepening to an authorized depth of 48 ft below MLLW (USACE, 2011). While this channel configuration is not yet completed, the SNWW CIP's new-start construction was funded in Fiscal Year (FY) 2019 by the Army Civil Works Program FY 2019 Work Plan (USACE, 2018a), and construction was initiated in 2020. The entire CIP is expected to take 7-10 years to complete construction. Updated levee and floodwall Hurricane Flood Risk Reduction (HFRR) measures are also included in this alternative, and in all future-with-project channel alternatives, as approved by the S2G study (USACE, 2017).

3.3 Channel Configuration 3: Future with Project Full Build

Referred to as Future with Project Full Build or FWPFB, this channel configuration represents the largest combination of proposed widening measures. The authorized channel depth is 48 ft below MLLW, same as the FWOP. Figure 1-1 shows the locations of the widening features.

3.4 Channel Configuration 4: Alternative 1

Alternative 1 includes widening to 500 ft (+100) reaches of the Sabine-Neches Canal and the Neches River Channel. Authorized depth remains 48 ft below MLLW.

3.5 Channel Configuration 5: Alternative 2

Alternative 2 includes widening to 600 ft (+200) reaches of the Sabine-Neches Canal and the Neches River Channel. Authorized depth remains 48 ft below MLLW. This alternative focuses on widening in the same locations as Alternative 1, but increases the width by 100 ft.

3.6 Channel Configuration 6: Alternative 3

Alternative 3 includes widening to 500 ft (+100) reaches of the Sabine-Neches Canal and the Neches River Channel and widening to 700 ft (+200) the Sabine Pass Channel and the Port Arthur Canal. This alternative is the same as Alternative 1 in the Sabine-Neches Canal and Neches River Channel but also includes widening of the southern reaches.

Table 3-1
Widening Locations and Dimensions for the Six Channel Configurations

Reach	Station (Start)	Station (End)	Existing Condition (EC)	Future without Project (FWOP)	Future With Project Full Build (FWPFB)	Alternative 1 (ALT1)	Alternative 2 (ALT2)	Alternative 3 (ALT3)
Sabine Pass Channel	0+150	15+990	500 ft	500 ft	700 ft	No change to existing	No change to existing	700 ft (same centerline)
Port Arthur Canal	43+900	59+740	500 ft	500 ft	(same centerline)			
Sabine Neches Canal (South)	63+500	72+700	400 ft	400 ft	600 ft	500 ft	600 ft	500 ft
Sabine Neches Canal (North)	81+510	35+00	400 ft	400 ft	(same western boundary; shift to east)	(same western boundary; shift to east)	(same western boundary; shift to east)	(same western boundary; shift to east)
Neches River Channel¹	122+40	640+00	400 ft	400 ft	600 ft	500 ft	600 ft	500 ft
					(same western boundary; shift to east)	(same western boundary; shift to east)	(same western boundary; shift to east)	(same western boundary; shift to east)

¹ Around Station 623+00 in the Neches River Channel, expansion of Anchorage Basin 4 from 18 acres to 97 acres was initially considered and was included in modeled with-project configurations but was later eliminated from the final alternatives

4 Model Setup

4.1 Model Selection and Description

MIKE 21 Flow Model HD FM (hydrodynamic modeling using flexible mesh) is a state-of-the-art commercial software distributed by Danish Hydraulics Institute (DHI) that simulates hydrodynamics based on oceanic tidal boundary conditions and meteorological forcing (wind and pressure). DHI's MIKE 21 Flow Model HD FM is an integrated modelling system that uses a flexible mesh approach. The hydrodynamic module is based on the numerical solution of the two-dimensional shallow water equations. The model consists of continuity and momentum equations (DHI, 2017). MIKE 21 Flow Model HD FM has been validated for applications within oceanographic, coastal, and estuarine environments. The flexible mesh allows higher resolution at

locations requiring more resolution of the hydrodynamics (e.g., near the project site, confined shipping channel, complex bathymetry).

HDR is proficient in the application of MIKE21 for hydrodynamic modeling of currents and storm surge and therefore applied this model for this analysis. Note for modeling of vessel effects HDR has historically used the USACE model AdH and therefore applied AdH for the vessel effects model discussed in a separate report. While application of MIKE21 for vessel effects modeling is now being marketed by model developers, the application is new HDR's proficiency for vessel modeling is in AdH.

4.2 Bathymetry and Topography Data

Bathymetric and topographic elevation data in the vicinity of the existing navigation channel were retrieved from two sources:

1. National Oceanic and Atmospheric Administration (NOAA) "Online Data Access Viewer" in the form of the Continuously Updated Digital Elevation Model (CUDEM) Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado (CIRES, 2014).
2. FEMA 2011 Texas Flood Study ADCIRC Mesh (FEMA, 2011)

The primary data set for the model elevation data is the NOAA CUDEM. This data set is a merged product of topography and bathymetry and is developed by NOAA to support different NOAA objectives such as inundation modeling. Elevation data in the CUDEM originated from various sources and is provided with 3 m resolution horizontally. This data set was compared to USACE hydrographic surveys of the SNWW Navigation channel to check for consistency with good qualitative agreement. Elevation differences between CUDEM and USACE survey data of several ft at isolated locations were attributed to the CUDEM data, as developed by CIRES, including a low-pass median filter covering approximately 50 m horizontally.

During the comprehensive review of the data, several areas of localized non-federal dredging were noted as not included in the NOAA CUDEM elevation data. In these areas, the elevation data were manually adjusted to capture the new berth dredging depths. Also, the model mesh and project limits extend beyond 30° north latitude, but the NOAA CUDEM data set does not. For the northern portion of the meshes where NOAA CUDEM data were not available, the mesh from the FEMA (2011) modeling was converted to elevation data and merged. The resolution of the elevation data from the FEMA (2011) modeling varied depending on the ADCIRC mesh resolution, but in general the resolution increased around areas of hydraulic significance. A depiction of the spatial extent of the elevation data sets applied geographically for mesh development is shown in Figure 4-1.

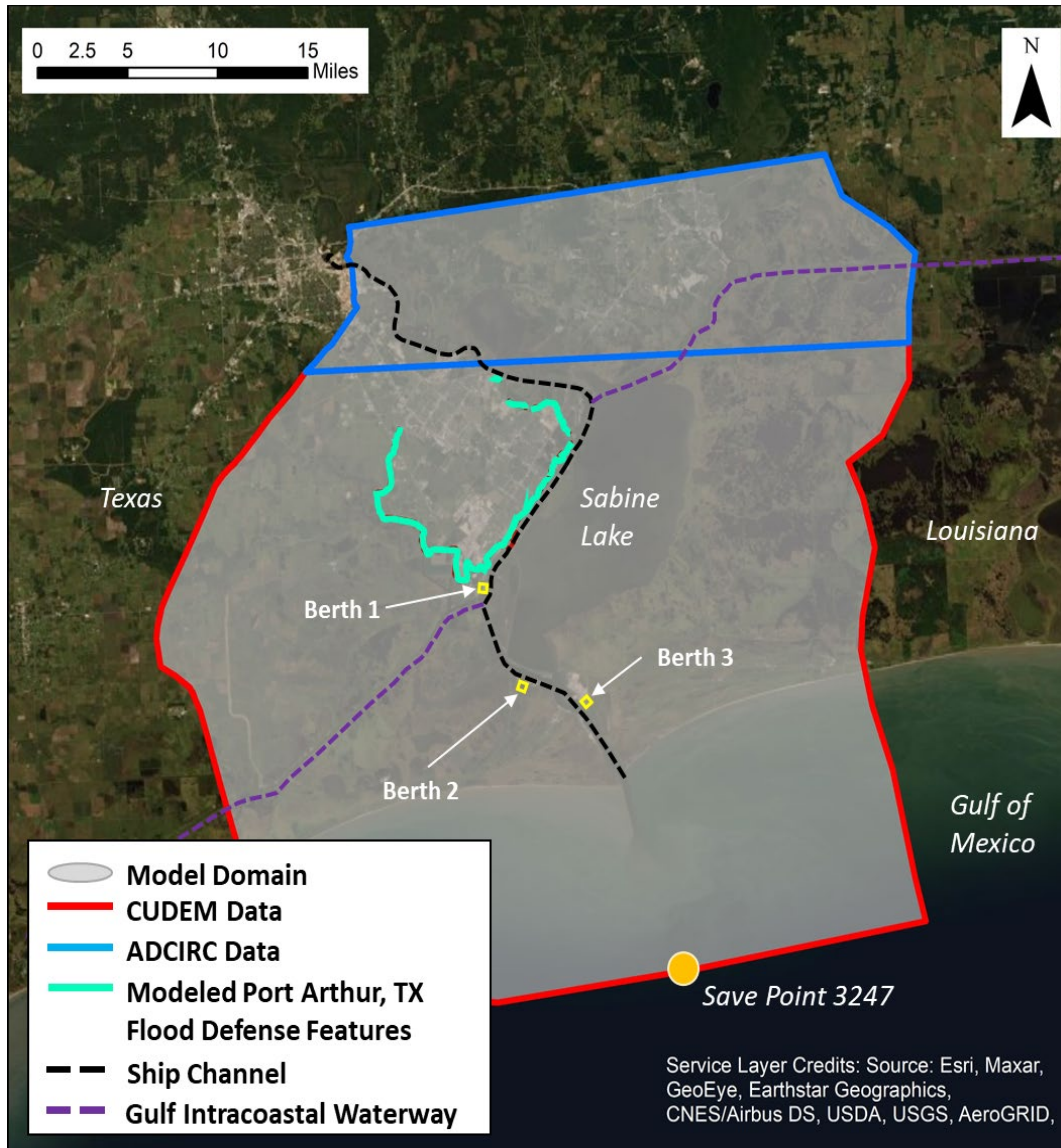


Figure 4-1
Storm Surge Model Domain and Elevation Source Data Summary

The various channel configurations for modeling are discussed in Section 3. For the Existing Conditions (EC) modeling, primarily used as a calibration model, additional manipulation of the elevation data was not performed. For all future channel configurations, the elevation data were adjusted based on the proposed channel template, but elevation data beyond the impact of the proposed conditions were not modified. All modified channel configurations applied channel side slopes of 2H:1V which is the design slope in the preliminary engineering phase. It is likely the channel slope will ultimately begin to become shallower (i.e. less steep) after project construction. The same 2H:1V slope is used for the SNWW CIP as described in USACE (2011).

4.3 Sabine to Galveston Flood Defenses

The MIKE Flow Model HD FM model domain also includes one of two major flood defenses either existing or planned within the Sabine Region (Figure 4-2). The Port Arthur flood defense system helps protect the town of Port Arthur, TX from hurricane surge via an earthen levee that surrounds the town on three sides. The barrier is comprised of five separate features—four earthen dikes along the western shore of SNWW and a wave barrier located on the western shore of Sabine Lake. The Port Arthur features were modeled in MIKE 21 Flow Model HD FM as an “infinitely tall” wall, consistent with the approach used during the S2G study (USACE, 2015).

The S2G study also includes a proposed flood defense feature meant to reduce risk to the town of Orange, TX. This feature is, however, still under design and was consequently not included as a “Project Feature” in this study. References from the USACE have identified two possible future alignments including one identified in the ERDC study (USACE, 2015) (see Figure 4-2) and the other in Holmes et al. (2020) (see Figure 4-3). In Section 6.2, time series are extracted along the windward face of the Orange flood defense from Holmes et al. (2020) to quantify future project impacts.



Figure 4-2
Port Arthur, TX And Proposed Orange, TX Flood Defense Features, USACE (2015)

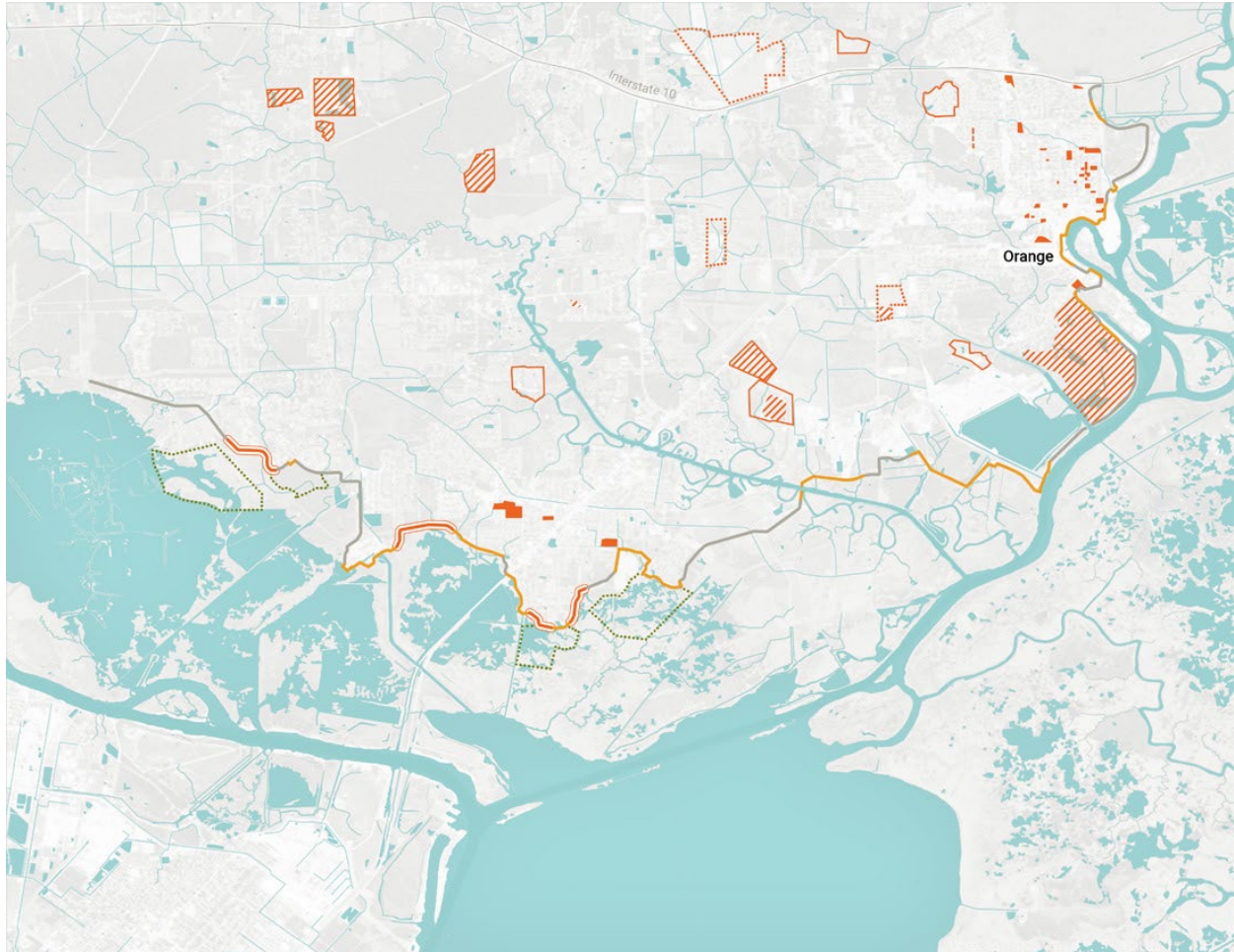


Figure 4-3
Orange, TX Flood Defense Feature, Holmes et al. (2020)

4.4 Model Mesh Development

The model mesh includes an offshore boundary, two lateral boundaries, and one hinterland boundary (see Figure 4-1 and Figure 4-4). The offshore boundary is located 20 km south of the SNWW jetties. The east and west (lateral boundaries) are located 23 km and 34 km from the SNWW entrance, respectively. The location of all boundaries roughly coincides with the S2G Base Condition without Project published on USACE's Coastal Hazards System (CHS) (USACE, 2019). The data are published as save points that coincide with model node locations from the S2G Base Condition without Project. The Port Arthur flood defense was added to the model mesh as an internal slender element with infinite height.

Mesh resolution varied from approximately 50 to 2,000 m throughout the modeling domain. The smallest elements are focused within the SNWW and are intended to resolve the variability between project features. The largest elements are located along the model's offshore boundary (see Figure 4-4) where bathymetric variability is small. Resolution transitions were manually edited within the model mesh to produce smooth solution transitions between areas of variable bathymetry.

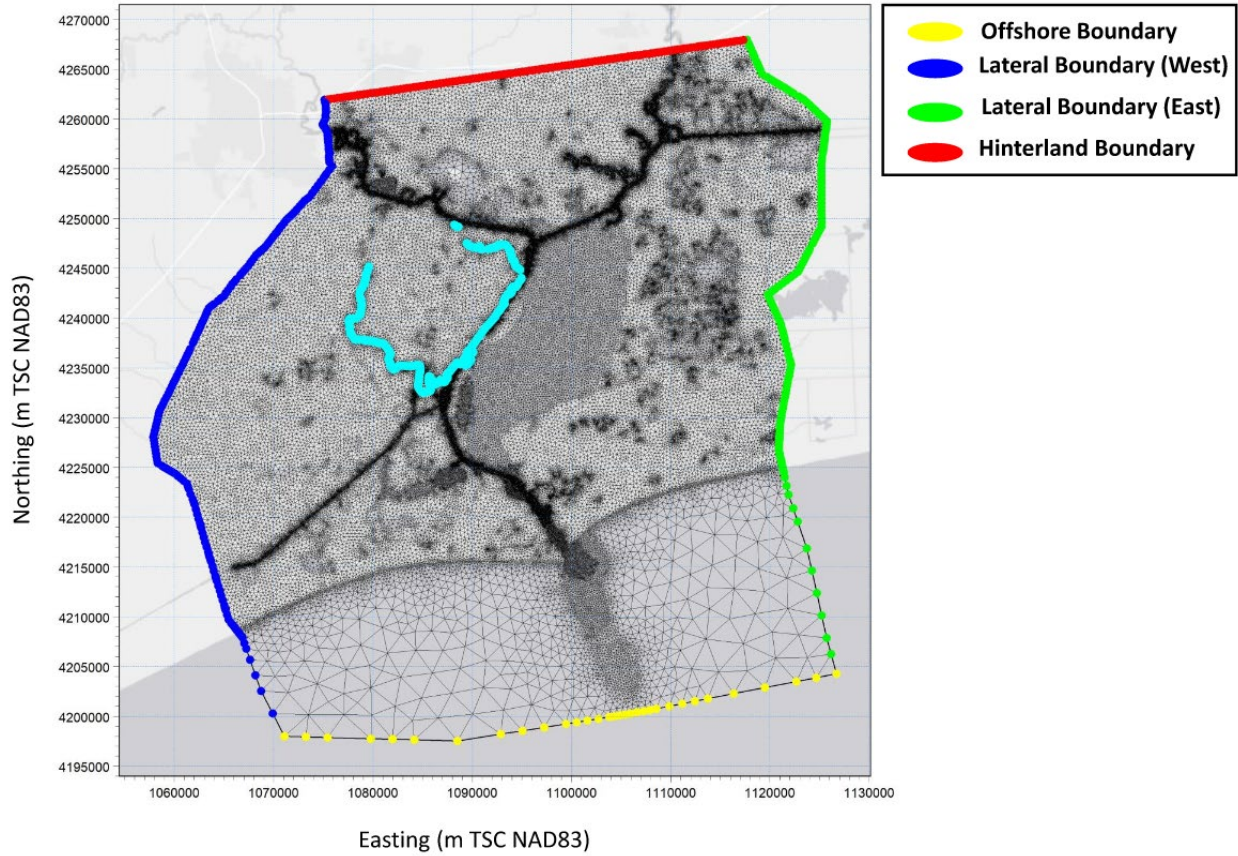


Figure 4-4
Storm Surge Model Domain
 (the Port Arthur flood defense internal boundary is highlighted in cyan)

4.5 Model Forcing and Boundary Conditions

The CHS is a national resource providing probabilistic coastal hazard assessment results and statistics based on high-resolution numerical modeling of coastal storms (USACE, 2015). These data were developed by the CHS team, USACE partners, and other third parties. Synthetic storm track data and modeled water level elevations were downloaded directly from the website for this project. The modeling adopts a subset of storms that were used for FEMA's flood insurance mapping (FEMA, 2011) and more recently in USACE's S2G study (USACE, 2015) and the Coastal Texas Study (CTS) (USACE, 2018).

Water level and hurricane wind speed parameterization data from the S2G study Base Condition without Project were analyzed as part of this modeling study (see Figure 4-5). One average storm (approximate 50-percent exceedance storm) and one higher recurrence interval (approximate 10-percent exceedance storm) were selected to bracket the storm severity. Here, storm severity is defined in terms of peak offshore water levels (discussed in detail in the next section). The associated offshore water level and wind field was used to force the model for each storm.

4.5.1 Water Level

Peak water level data for all storms were downloaded at Save Point 3247 (see Figure 4-1). The CHS provided a total of 61 synthetic storm events. Note the individual identification numbers were non-consecutive and varied from 32 to 360 according to the CHS definitions. Figure 4-5 shows the downloaded storms and corresponding peak water level from each of the storms at Save Point 3247. The horizontal axis in the figure is organized by Storm ID which is an identification number and does not represent storm intensity or any other meteorological or oceanographic ranking. The figure highlights three Storm ID's that are selected for the modeling. The reasoning for the Storm ID selection is discussed in the remainder of this section.

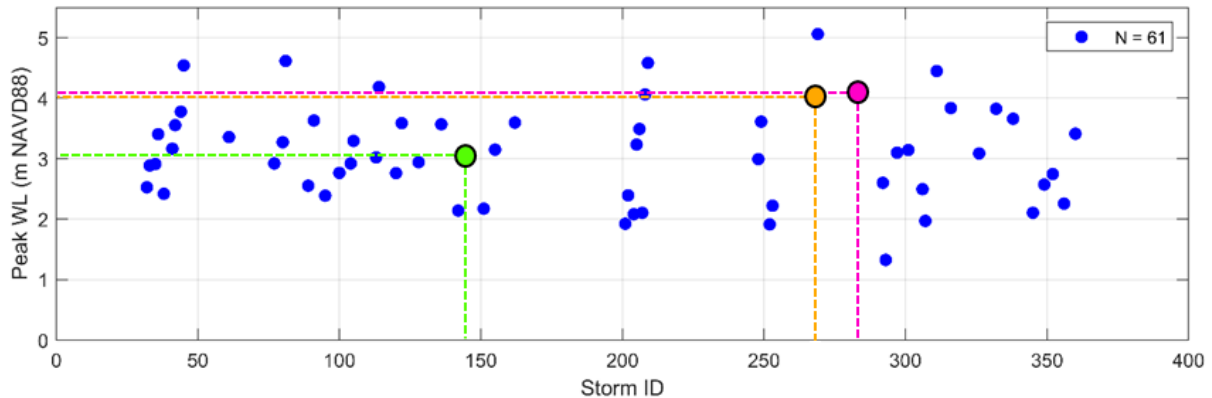


Figure 4-5
Peak Water Level Data from USACE's CHS (at Save Point 3247)
 (highlighted storm IDs were selected for modeling in this analysis)

The CHS data were sorted to define a cumulative density function (CDF) of synthetic storm peak water levels. The peak water level CDF was used to define two storm populations for this modeling effort (see Figure 4-6). Subsets of the CHS data were used to define representative exceedances because the analysis shows some variability in peak water level rank by save point. The first population, the 45% to 55% exceedance (defined here as 50% exceedance), is representative of the average peak water levels modeled at Save Point 3247. The second population, the 5% to 15% exceedance (defined here as 10% exceedance), is representative of the upper bound of storms available on CHS modeled at Save Point 3247. The 50% exceedance and 10% exceedance segments of the total cumulative density function are shown in Figure 4-6. Corresponding Storm IDs are shown to the right of each datapoint.

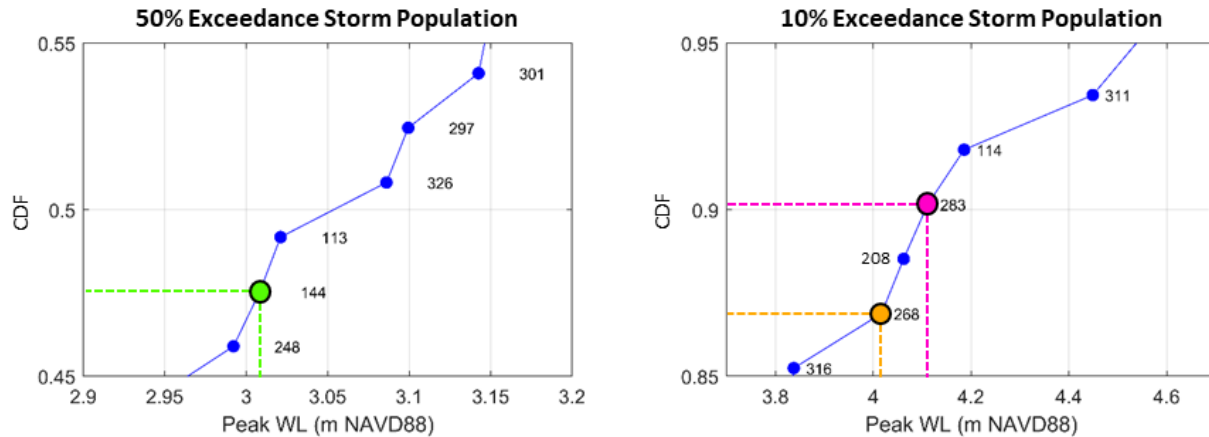


Figure 4-6
Peak Water Level CDF for approximately 50% and 10% Exceedance Ranges
 (highlighted storm IDs were selected for modeling in this analysis.
 Numbers adjacent to data points represent the Storm ID)

Three storms in total were selected from Save Point 3247 to model in this study based upon the previous defined populations. These storms include:

- Storm ID 144 with a peak water level of 3.0 m NAVD88
- Storm ID 268 with a peak water level of 4.0 m NAVD88
- Storm ID 283 with a peak water level of 4.1 m NAVD88

Storm ID 283 was identified as the calibration event. Storm ID 144 and Storm ID 268 were selected as the 50% exceedance and 10% exceedance storm events. The two design events form the basis of the alternatives analysis discussed later in this report.

The corresponding hydrographs from the CHS/S2G studies (see Figure 4-7) were imposed as boundary conditions along the offshore model boundary. The boundary condition varied in time but was uniform along the offshore boundary.

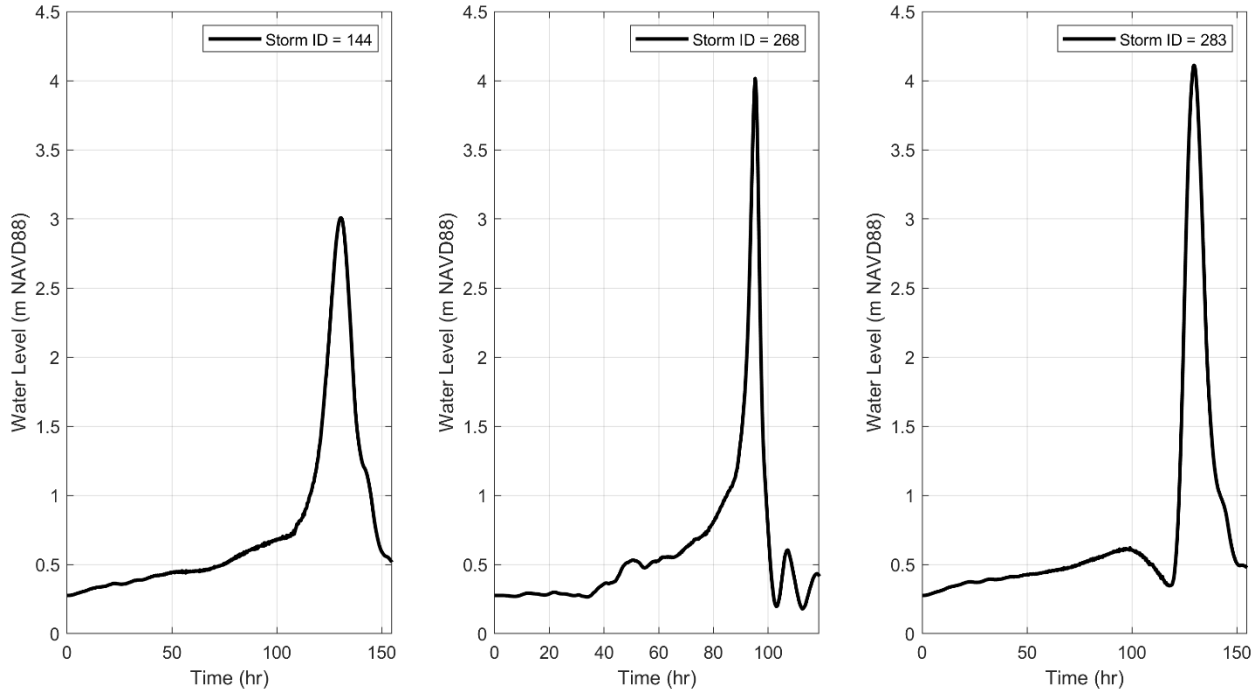


Figure 4-7
Offshore Water Level Time Series from USACE's S2G Study (Save Point 3247)

4.5.2 Wind and Hurricane Track

The CHS also included the wind parameters that correspond with the water level boundary condition. Unlike the save points which provide time series of water level, the wind data on the CHS gives parameterized hurricane information including storm track latitude/longitude, maximum wind speed, and central pressure (among other quantities).

Three storms were selected from Save Point 3247 to model in this study and are consistent with the water level boundary condition. These storms include:

- Storm ID 144 with a maximum wind speed of 45.1 m/s
- Storm ID 268 with a maximum wind speed of 57.0 m/s
- Storm ID 283 with a maximum wind speed of 49.1 m/s

The associated hurricane tracks are shown in Figure 4-8.

The MIKE 21 Cyclone Wind Generation tool allows users to compute the wind and pressure field given the parametric data available on the CHS. Several cyclone parametric models are included in the tool including the Holland – Double Vortex model (Holland, 1980 and Cardone et al., 1994, 1996) that was also used in the S2G modeling. The data provided on the CHS for Storm IDs 144, 268 and 283 limits our application to the Holland single vortex model (Holland, 1980). The wind data was integrated into the hydrodynamic model by interpolating the parametric model onto a regularly spaced grid that covers the entirety of the model domain. Output quantities from the MIKE 21 Cyclone Wind Generation tool include the northerly and easterly component of the cyclonic wind as well as the atmospheric pressure field. All three quantities vary in both space and time.

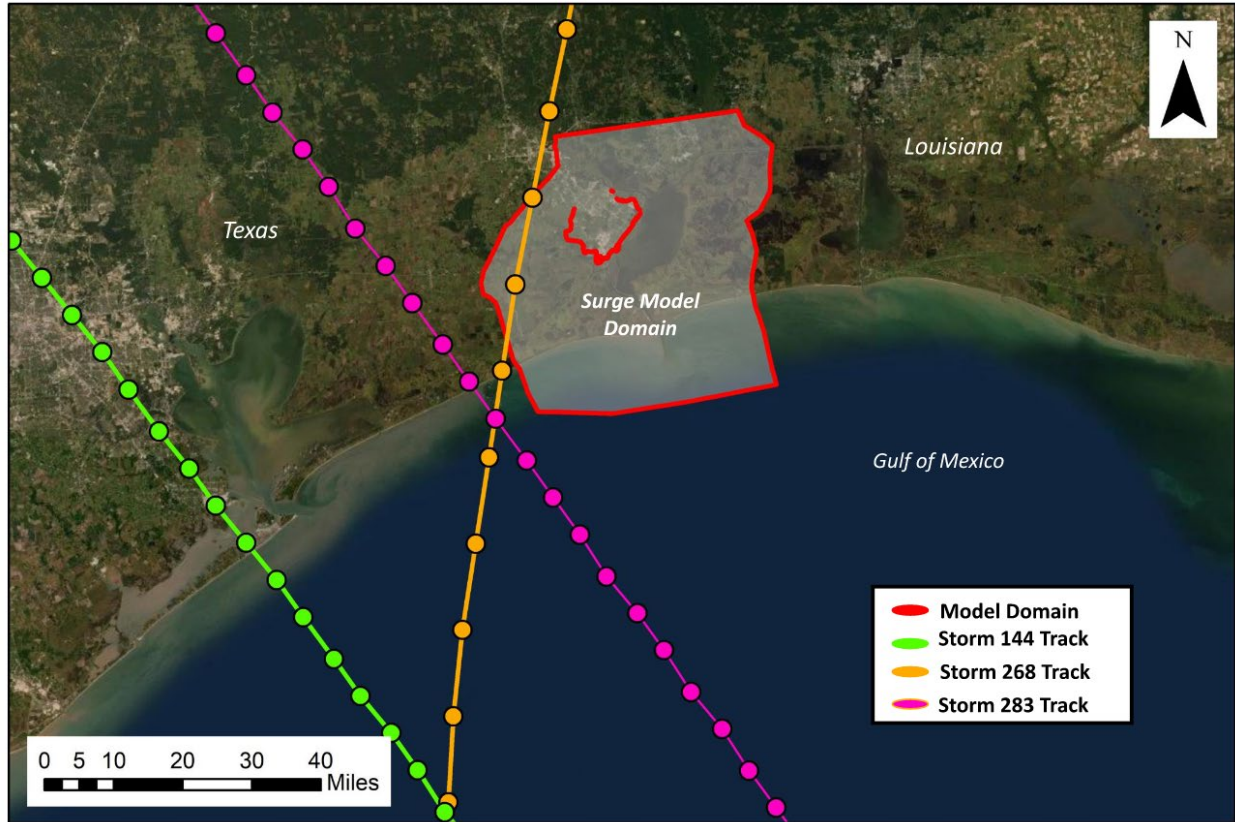


Figure 4-8
Synthetic Storm Tracks from USACE's S2G Study

4.5.3 Relative Sea Level Change

Analysis of relative sea level change (RSLC) was incorporated into the SNWW hydrodynamic modeling in accordance with USACE guidance contained in ER 1100-2-8162 “Incorporating Sea Level Change in Civil Works Programs.” ER 1100-2-8162 provides a method (or methods) for determining the range of possible future rates of global, regional, and local RSLC that planning studies are required to consider. The RSLC rates represent eustatic sea level change and vertical land motion, and are classified as “low,” “intermediate,” or “high” scenarios, as follows:

- The low rate is based on linear trends developed from historical observed data from tide stations.
- The intermediate rate is determined based on the modified NRC Curve I (NRC 1987).
- The high rate is determined based on the modified NRC Curve III (NRC 1987).

The low, intermediate, and high RSLC scenarios for this study are based on NOAA 8770570 Sabine Pass North, TX located near the entrance from the Gulf of Mexico to the SNWW. Scenarios for RSLC rates for 20, 50 and 100 years were generated using USACE’s online sea-level calculator (https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html) based on start of the SNWW CIP construction in 2020 and a 50-year period of analysis for the channel widening starting in 2025.

Values for the RSLC scenarios are given in Table 4-1, and curves for 2020 to 2075 are shown in Figure 4-9.

Table 4-1
RSLC Values Developed from USACE's Online Sea-Level Calculator
 (for NOAA 8770570)

Scenario	2020-2045	2020-2075	2020-2125
Low	0.14 m (0.46 ft)	0.31 m (1.02 ft)	0.59 m (1.95 ft)
Intermediate	0.20 m (0.64 ft)	0.48 m (1.56 ft)	1.05 m (3.45 ft)
High	0.37 m (1.22 ft)	1.00 m (3.29 ft)	2.51 m (8.22 ft)

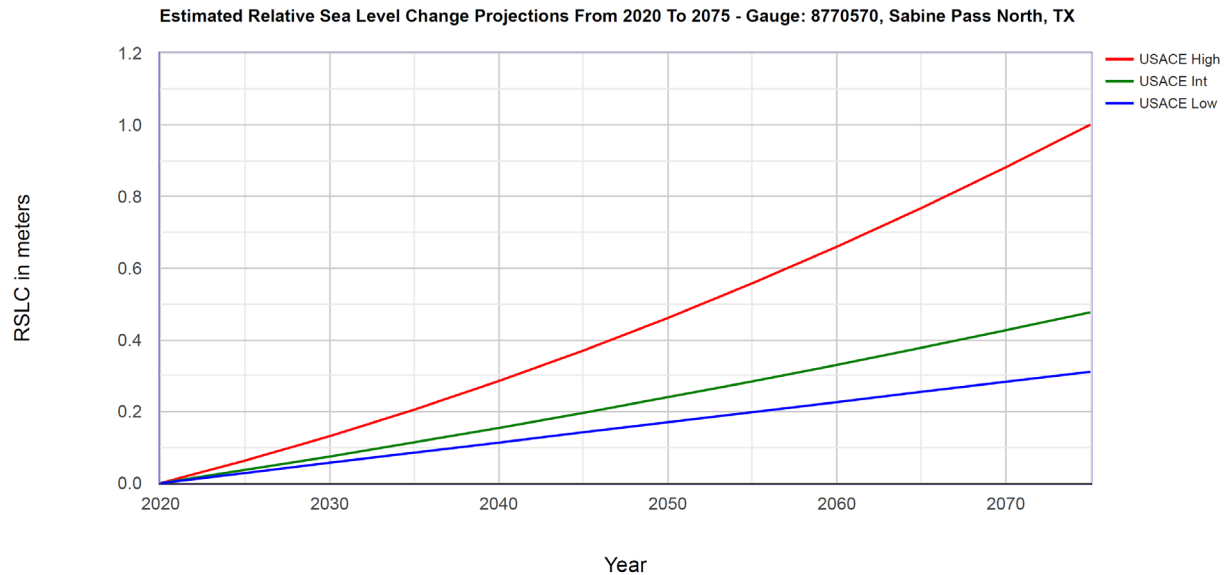


Figure 4-9
RSLC Curves Developed from USACE's Online Sea-Level Calculator

The low RSLC rate, based on the observed data at NOAA 8770570, is approximately 5.66 mm/yr and gives 0.31 m RSLC over the period of analysis of the SNWW plan alternatives. The intermediate and high RSLC scenarios show accelerating RSLC and result in 0.48 m and 1.00 m, respectively, at the end of the analysis period. The ER 1100-2-8162 guidance suggests a single scenario can be used to identify the preferred alternative under that scenario. The preferred alternative's performance can then be evaluated under all RSLC scenarios to determine its overall performance. This approach is appropriate when project performance is not highly sensitive to RSLC. For this analysis, the high scenario for the 50-year RSLC is used within the hydrodynamic modeling. The high scenario was applied to blanket possible RSLC effects that could then be used to infer project performance for other scenarios. Note the high RSLC value is 1.00 m, however a value of 0.95 m was used in the storm surge model runs based on a previous analysis that utilized an earlier start date for the 50-year analysis period. At the time the analysis was updated to capture the expected completion date of 2025 the storm surge modeling had been completed and the analysis discussed in Section 6.3 showed that the RSLC makes the model less sensitive to changes

to the channel. Therefore, additional effort was not made to incorporate the 0.05 m difference in RSLC.

5 Model Calibration

The calibration event, Storm ID 283, is shown in Figure 4-8. With a peak water level of 4.1 m at Save Point 3247, this storm is the largest of the three storms selected and was used to bound this analysis. The water level timeseries suggest that Storm ID 283 comes ashore as a strong positive pulse of water that propagates up the SNWW. Some reduction in surge amplitude is observable but the elevated water levels travel upstream as shown in Figure 5-1.

The MIKE 21 Flow Model HD FM model results were compared to the S2G results at seven locations along the SNWW. Save points extended from ocean entrance to SNWW at Sabine Pass (Save Point 3597) to near Beaumont, TX (Save Point 5711). The calibration was performed by varying the model's bottom roughness from a default Manning's Coefficient value of 32 to a value of 38. Mike 21 Flow Model HD FM uses an inverse definition of the traditional Manning's roughness, known as the Manning's Coefficient, where generally increasing the Manning's Coefficient decreases the bottom friction.

The mean absolute error was used to assess model calibration convergence. The mean absolute error is defined as:

$$\text{Error}_{\text{model}} = \frac{\sum |\eta_{\text{max:MIKE}} - \eta_{\text{max:CHS}}|}{N}$$

where: $\eta_{\text{max:MIKE}}$ = MIKE 21 Flow Model HD FM peak water level, $\eta_{\text{max:CHS}}$ = save point peak water level and, N = number of calibration locations. Model calibration and mean absolute error is shown in Figure 5-1. A value of 36 was selected as the optimal value for the model calibration, providing an $\text{Error}_{\text{model}}=0.1$ m. A value of 38 further decreased the model error; however, the break in the model calibration slope suggests the model may be reaching the bottom friction limit.

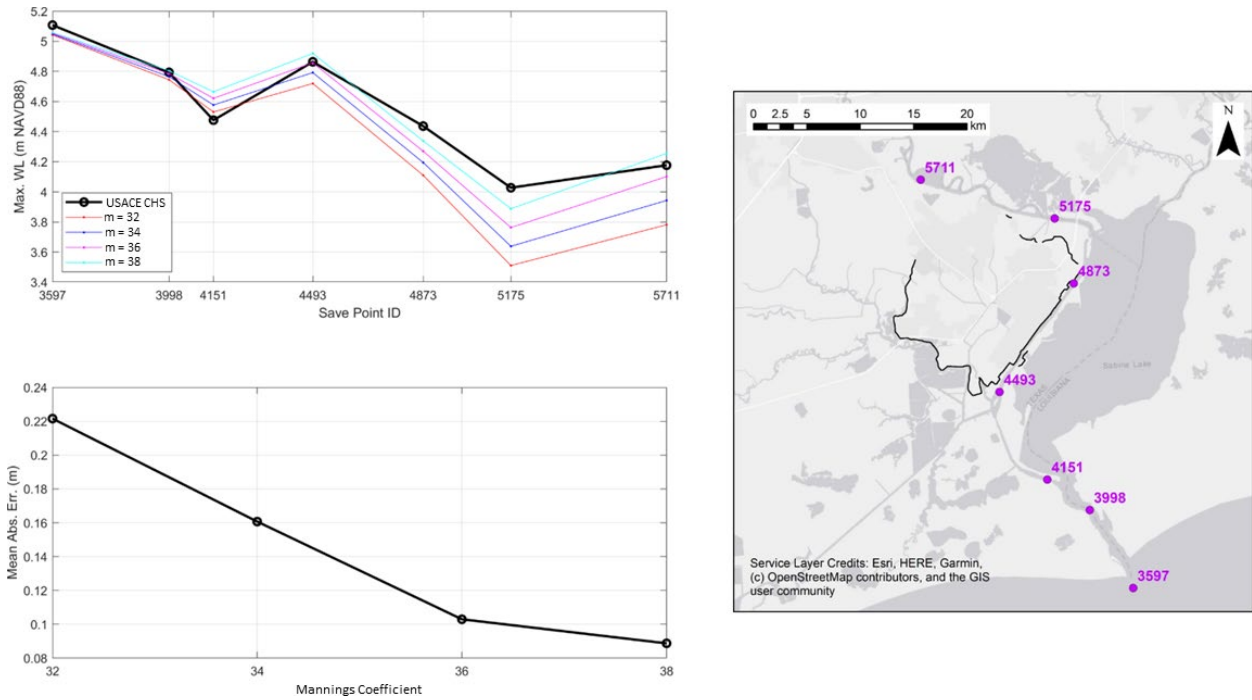


Figure 5-1
Model Calibration Results for Storm ID 283

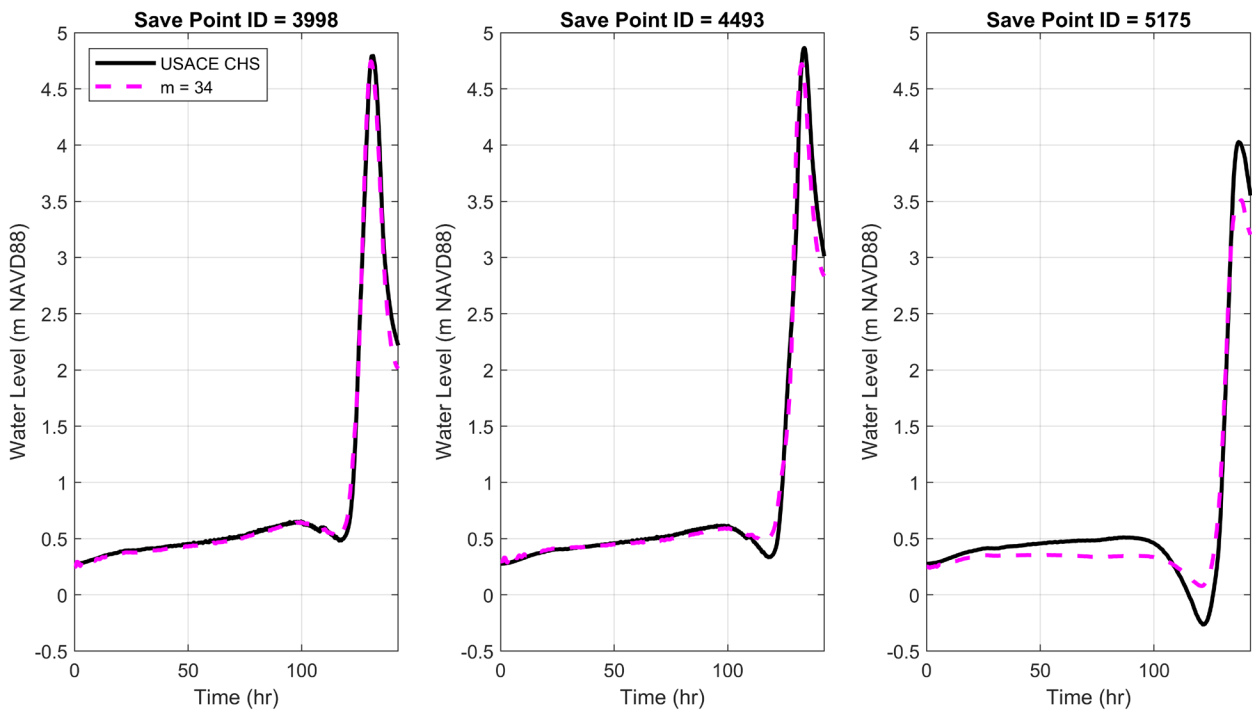


Figure 5-2
USACE CHS and Calibrated Water Level Time Series
(from Save Points 3998, 4493 and 5175)

The calibration tests' model error indicates that model predictions of surge elevations have uncertainty bounds of approximately ± 0.1 m at the prediction points. Since comparing one model result to another model result eliminates some of the error in modeling, the uncertainty bounds for comparing plans (e.g., FWOP and FPWFB) is smaller, sometimes assumed to be approximately half the calibration/validation uncertainty.

6 Results and Discussion

Details of the various project alternatives are discussed below for Storm ID 144 and 268. Primary results include one set of results corresponding to the calibration sites and another set of results extracted along the proposed Orange flood defense. The effects of including 0.95 m of RSLC are also included in the discussion.

Modeling and comparison of channel alternatives was performed for two different synthetic storms that produced an average exceedance and high exceedance storm surge offshore of SNWW (see Section 4.5). Results between the two storms and comparison of alternatives followed the same qualitative trends. However, storm surge is driven by several storm parameters including storm track, storm size, storm intensity, and more. While the results in this report are believed to capture the representative geophysical features of hurricane propagation through SNWW, the full suite of synthetic storm tracks from CHS would need to be simulated to constrain the statistical space.

Sea level rise was also modeled as part of this study (see Section 4.5). We did not consider increases to storm intensity, changes to storm track or storm size or other large scale oceanographic patterns that could result from climate change. Additionally, we did not consider the associated changes to sedimentation that could be produced within SNWW from the prolonged water level changes associated with sea level rise.

6.1 Calibration Site Comparisons

The MIKE 21 Flow Model HD FM model results were compared at seven locations along the SNWW (correspond to the calibration sites from Section 5). These extraction points extended from the ocean entrance to SNWW at Sabine Pass (Save Point 3597) upstream to Beaumont, TX (Save Point 5711).

Peak water levels for Storm ID 144 are shown in Figure 6-1 and Table 6-1. For the Existing Conditions (EC), peak water levels varied from a maximum of 3.6 m NAVD88 near the entrance to SNWW (Save Point 3597) to a minimum of 3.1 m NAVD88 at Save Point 3873. Worthy of note is that the peak water level increased further inland from Save Point 4873 to Save Point 5711 for all alternatives and existing condition. The specific reason for the increase was not further investigated but could be a result of storm path and wind direction. Model results indicate peak water level variability between the various alternatives was small. Variability between the FWOP and FWPFB, including any of the channel widening alternatives, was largest at Save Point 5711 and was only 1 cm max. The slight increase in peak water level along the northern reaches of the SNWW can be attributed to the FWOP and FWPFB. The model results indicate the deepening project leads to a slight increase in water level. The increases in depth and width reduce channel resistance and allow the surge to propagate more easily up the SNWW. However, the increases are small and very close to the ability of the model to resolve differences.

Peak water levels for Storm ID 268 are also shown in Figure 6-1 and Table 6-1. Under the Existing Condition, the peak water levels varied from a maximum of nearly 5.0 m NAVD88 near the entrance to SNWW (Save Point 3597) to a minimum of 2.2 m NAVD88 at Save Point 5711. Even with an increase in offshore water levels, model results suggest variability between the various alternatives was comparably small. Variability between the Existing Conditions (EC) and FWOP, FWPFB, and Alternatives 1-3 at Save Point 5711 was largest at Save Point 5711 and limited to 11 cm difference (compare FWPFB to Existing Condition in Table 6-1). However, comparing FWOP to any of the channel widening alternatives, or the FWPFB, had a max difference of 7 cm. Like Storm 144, the slight increase in peak water levels along the northern reaches of the SNWW can be attributed to the FWOP and FWP increases in water depth. This variability is within the model calibration error.

Table 6-1
Peak water levels (m NAVD88) at the Calibration Sites Along SNWW
 (for Storm ID 144 & 268*)

Save Point ID	3597	3998	4151	4493	4873	5175	5711
Storm ID 144:							
Existing Condition	3.58	3.37	3.25	3.42	3.10	3.13	3.46
Future without Project	3.58	3.38	3.26	3.41	3.11	3.15	3.48
Future with Project Full Build	3.58	3.38	3.25	3.40	3.12	3.18	3.49
Alternative 1	3.58	3.38	3.25	3.41	3.11	3.17	3.48
Alternative 2	3.58	3.38	3.25	3.40	3.12	3.18	3.49
Alternative 3	3.58	3.38	3.25	3.41	3.11	3.17	3.49
Mean	3.58	3.38	3.25	3.41	3.11	3.16	3.48
Std. Dev.	0.00	0.00	0.00	0.01	0.01	0.02	0.01
Storm ID 268:							
Existing Condition	4.93	4.75	4.39	4.50	3.03	2.57	2.17
Future without Project	4.93	4.76	4.39	4.48	3.03	2.60	2.21
Future with Project Full Build	4.93	4.76	4.38	4.43	3.07	2.61	2.28
Alternative 1	4.93	4.76	4.39	4.45	3.06	2.61	2.24
Alternative 2	4.93	4.76	4.39	4.42	3.07	2.61	2.27
Alternative 3	4.93	4.76	4.38	4.45	3.06	2.61	2.24
Mean	4.93	4.76	4.39	4.46	3.05	2.60	2.24
Std. Dev.	0.00	0.00	0.00	0.03	0.02	0.02	0.04

* Note: Variance smaller than the Mean Absolute Model Error of 0.1 m are not precise. Extra digits are shown for clarity.

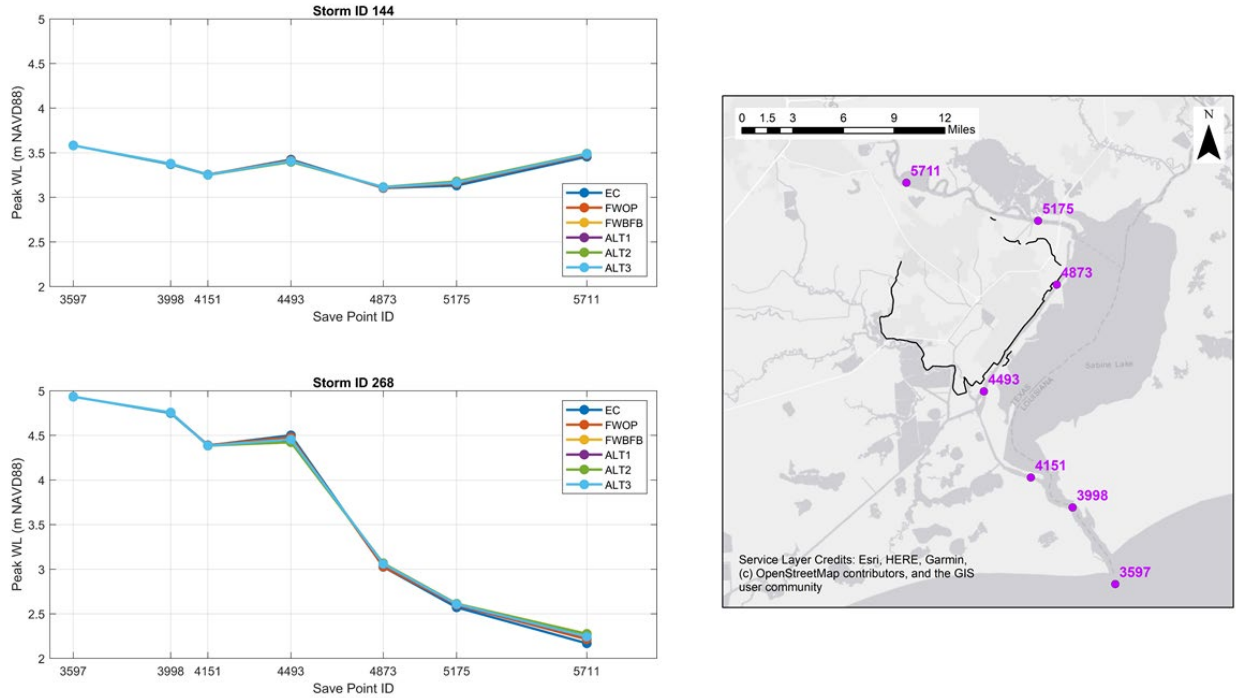


Figure 6-1
Peak Water Levels at Calibration Sites Along SNWW for Storm ID 144 & 268

The time series from Save Point 4493 for Storm ID 144 are shown in Figure 6-2. Very little variability (less than 5 cm) is present in each time series. The water level time series for the Existing Conditions (EC), FWOP and FWBFB are nearly identical in phase. This result suggests that expected variability in surge events from the various alternatives may lead to slight increase and/or increase in peak water level amplitude, but the time-dependent nature (e.g., phase) of the surge event should remain unchanged as a result of the project alternatives. Therefore, surge duration is not expected to change following project implementation.

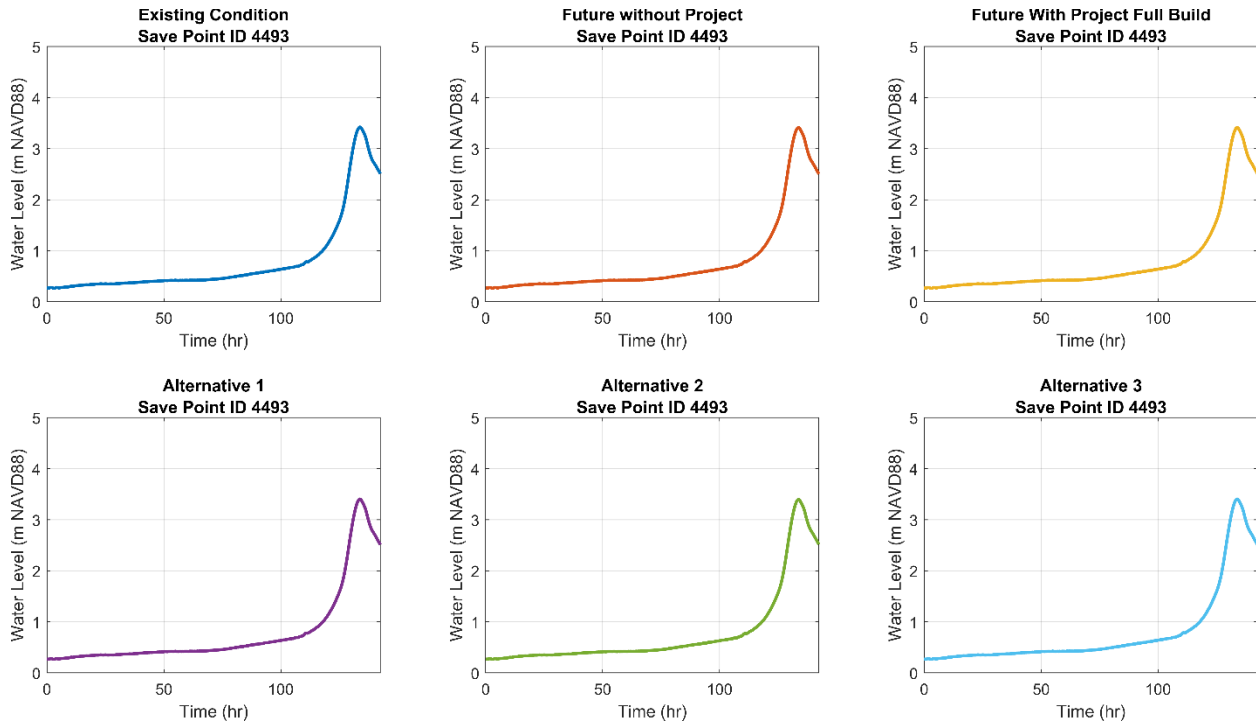


Figure 6-2: Water Level Time Series at Save Point 4493 for Storm ID 144.

6.2 Orange Flood Defense

The MIKE 21 Flow Model HD FM results were also compared at seven locations along the seaward side of the proposed Orange flood defense (shown in Figure 6-3). These points are located approximately 500 m from the proposed dike alignment but were taken at arbitrary distances along the flood defense.

Peak water levels for Storm ID 144 and Storm ID 268 are shown in Figure 6-3 and Table 6-2. Model results suggest the variability between the various alternatives is small. A slight increase (less than 5 cm) in water level results between the Existing Conditions (EC) and FWOP, FWPFB, and Alternative 1-3 can be observed in the results for Storm ID 144. For Storm ID 268, the differences between the alternatives are indiscernible. The blue dotted line that represents the FWOP results disappears behind the FWPFB results (shown in green).

Table 6-2
Peak water levels (m NAVD88) near the Orange Flood Defense
 (for Storm ID 144 & 268*)

Save Point ID	O-1	O-2	O-3	O-4	O-5	O-6	O-7
Storm ID 144:							
Existing Condition	3.47	3.26	3.11	3.02	2.76	2.83	3.46
Future without Project	3.49	3.28	3.12	3.04	2.77	2.83	3.48
Future with Project Full Build	3.51	3.30	3.14	3.04	2.78	2.85	3.49
Alternative 1	3.50	3.29	3.13	3.04	2.77	2.84	3.48
Alternative 2	3.51	3.30	3.14	3.05	2.78	2.85	3.49
Alternative 3	3.50	3.29	3.13	3.04	2.77	2.84	3.49
Mean	3.49	3.28	3.13	3.04	2.77	2.84	2.91
Std. Dev.	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Storm ID 268:							
Existing Condition	2.76	2.83	3.22	2.89	2.30	2.37	2.17
Future without Project	2.84	2.88	3.24	2.91	2.31	2.38	2.21
Future with Project Full Build	2.84	2.88	3.24	2.91	2.31	2.38	2.28
Alternative 1	2.82	2.87	3.23	2.91	2.31	2.38	2.24
Alternative 2	2.84	2.88	3.23	2.92	2.31	2.38	2.27
Alternative 3	2.82	2.87	3.23	2.92	2.31	2.38	2.24
Mean	2.82	2.87	3.23	2.91	2.31	2.38	2.42
Std. Dev.	0.03	0.02	0.01	0.01	0.00	0.00	0.00

* Note: Variance smaller than the Mean Absolute Model Error of 0.1 m are not precise. Extra digits are shown for clarity.

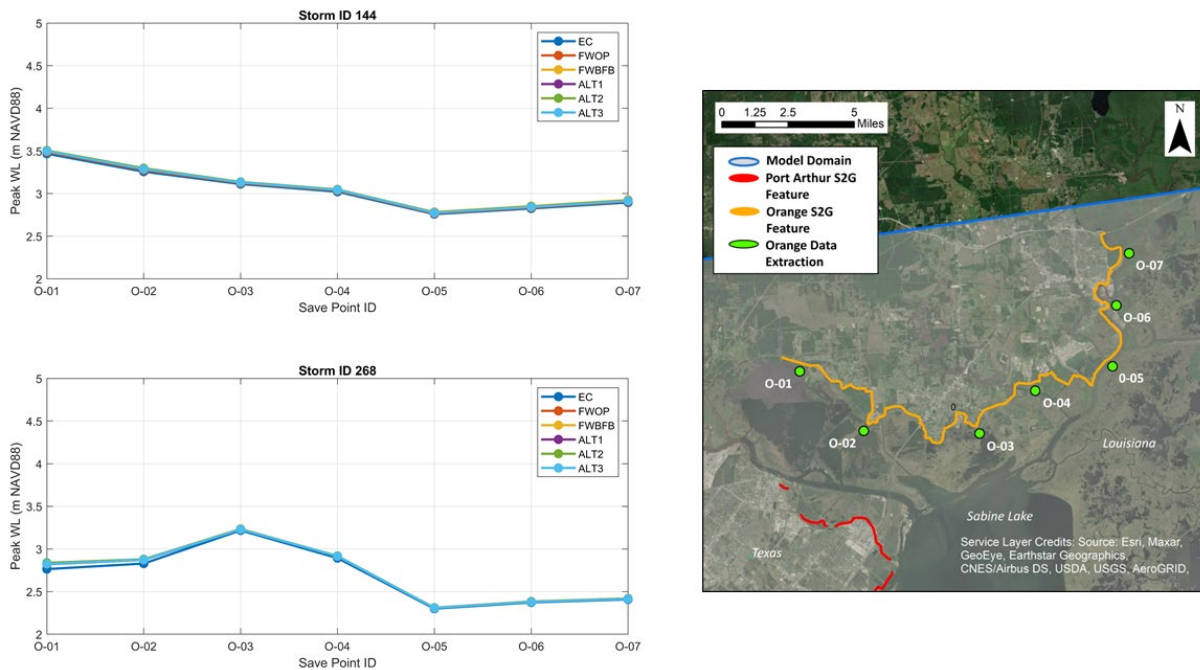


Figure 6-3
Peak Water Levels Along Proposed Flood Defense in Orange, TX
 (Holmes et al., 2020) for Storm ID 144 & 268

The time series from Save Point O-03 for Storm ID 144 are shown in Figure 6-4. Like the calibration results, little variability is present in each time series. The water level time series for the Existing Conditions (EC), FWOP, and FWPFB are nearly identical in shape, with only a small shift in amplitude. The most noticeable feature of these time series is the wet to dry transition. Initially, the land in front of the Orange flood defense is dry. However, as the storm surge propagates up the Sabine River, water levels increase quickly inundating the ground in front of the proposed flood defense before finally decreasing towards the end of the simulation.

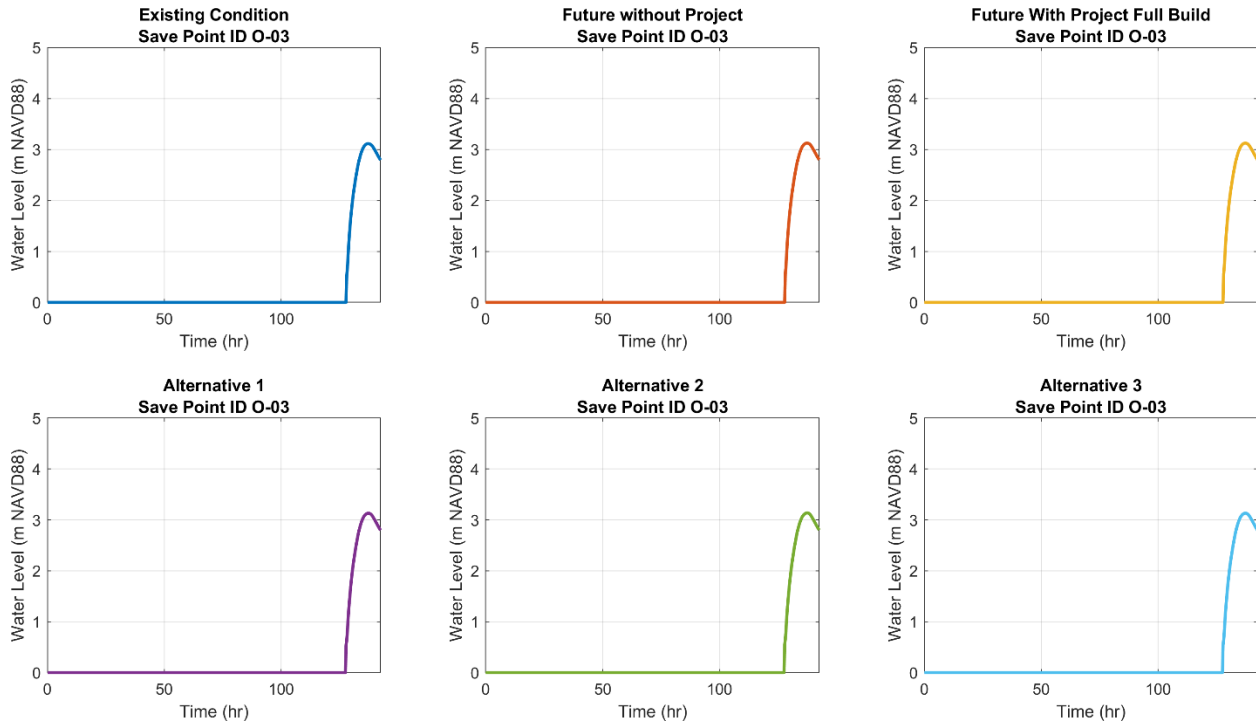


Figure 6-4
Water Level Time Series at Save Point O-03 For Storm ID 144

6.3 Relative Sea Level Change

Storm IDs 258 and 268 were both modeled together for the 50-year high RSLC scenario (Section 4.5) using the Existing Conditions (EC), FWOP, and FWPFB meshes. The with RSLC condition was represented by increasing the water level boundary conditions by 0.95 m. Peak water levels for Storm ID 268 with and without RSLC are shown in Figure 6-5 and Table 6-3.

For Storm ID 258 without RSLC, peak water levels varied from a maximum of nearly 5.0 m NAVD88 near the entrance to SNWW (at Save Point 3597) to a minimum of ~2.2 m NAVD88 (at Save Point 5711). For Storm ID 258 with RSLC, peak water levels varied from a maximum of nearly 5.8 m NAVD88 near the entrance to SNWW (at Save Point 3597) to a minimum of 3.9 m NAVD88 (at Save Point 5711).

This RSLC analysis produces two noticeable change comparisons. The first relates to the relative influence introduced by the various alternatives and the influence of RSLC on the peak water levels within the waterway. Although the difference between the Existing Conditions (EC), FWOP

and FWPFB is small, the model results suggest RSLC decreases the amount of expected variability between the alternatives.

The second difference relates to the storm surge envelope between the with and without RSLC conditions. Cases without RSLC suggest peak water levels from Storm 268 will be reduced by nearly 3 m between the SNWW entrance to Beaumont (mean peak storm surge of 4.93 m at Save Point 3597 versus 2.23 m at Save Point 5711). For the same storm modeled with RSLC this overall peak water level decreases by nearly 2 m (mean peak storm surge of 5.82 m at Save Point 3597 versus 3.88 m at Save Point 5711). RSLC can be thought of as a type of pseudo-deepening, which like the conclusions from Section 6.1 and 6.2, leads to an increase in surge due to decreased bottom friction.

Table 6-3
Peak water levels (m NAVD88) for Storm ID 268
(with and without 0.95 m RSLR at Gulf Boundary*)

Save Point ID	3597	3998	4151	4493	4873	5175	5711
Storm ID 268:							
Existing Condition	4.93	4.75	4.39	4.50	3.02	2.57	2.17
Future without Project	4.93	4.75	4.40	4.49	3.03	2.59	2.21
Future with Project Full Build	4.93	4.75	4.39	4.45	3.06	2.61	2.27
Alternative 1	4.93	4.76	4.39	4.45	3.06	2.61	2.24
Alternative 2	4.93	4.76	4.39	4.42	3.07	2.61	2.27
Alternative 3	4.93	4.76	4.38	4.45	3.06	2.61	2.24
Mean	4.93	4.75	4.39	4.46	3.05	2.60	2.23
Std. Dev.	0.00	0.00	0.00	0.03	0.02	0.02	0.04
Storm ID 268 with 0.95 m Sea Level Rise:							
Existing Condition	5.83	5.68	5.50	5.64	4.68	4.12	3.84
Future without Project	5.82	5.68	5.51	5.64	4.67	4.14	3.87
Future with Project Full Build	5.82	5.68	5.50	5.62	4.70	4.14	3.90
Alternative 1	5.82	5.68	5.50	5.62	4.69	4.14	3.89
Alternative 2	5.82	5.68	5.50	5.61	4.70	4.15	3.91
Alternative 3	5.82	5.69	5.50	5.63	4.69	4.14	3.89
Mean	5.82	5.68	5.50	5.63	4.69	4.14	3.88
Std. Dev.	0.00	0.00	0.00	0.01	0.01	0.01	0.02

* Note: Variance smaller than the Mean Absolute Model Error of 0.1 m are not precise. Extra digits are shown for clarity.

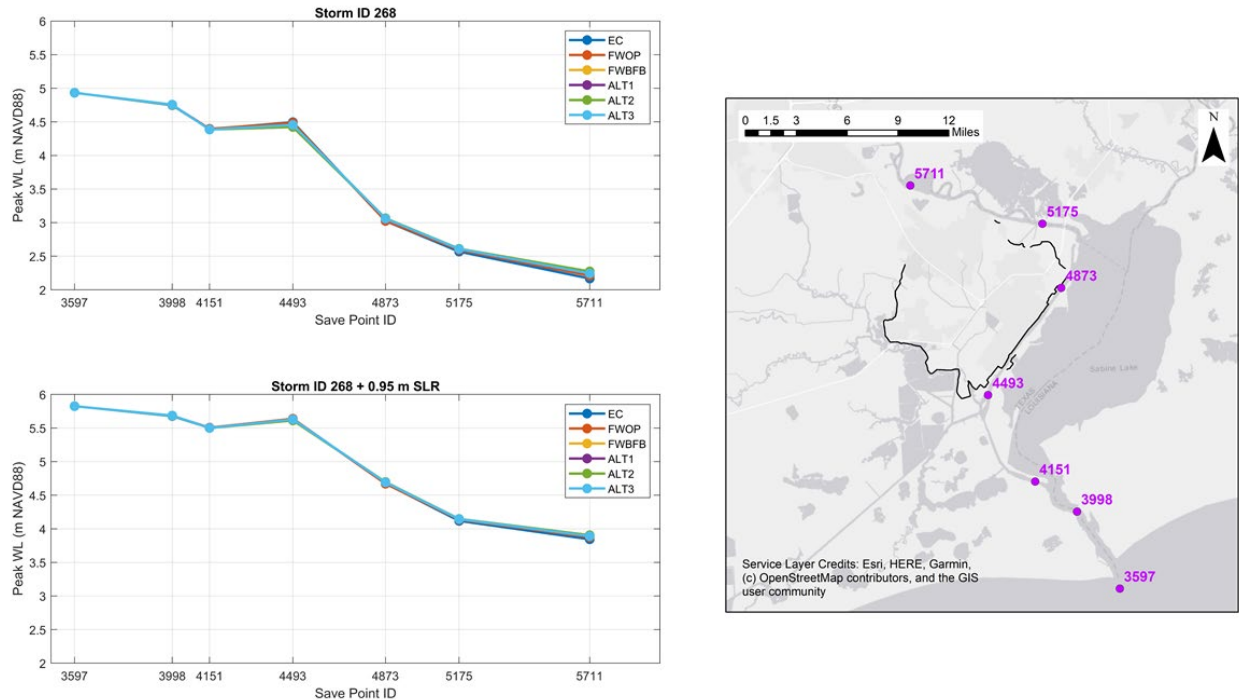


Figure 6-5

Peak Water Levels at Calibration Sites Along SNWW

(for Storm ID 268 and Storm ID 268 with 0.95 m RSLC added as a static water level)

7 Conclusions

Hydrodynamic modeling of storm surge in and around the Sabine-Neches Waterway (SNWW) was performed to support a Section 203 Integrated Feasibility Report for a proposed channel widening project. The modeling was used to assess changes to inundation depths or durations resulting from the channel widening project.

Modeling was performed using the MIKE21 Flow Model HD FM on a flexible mesh designed to resolve the navigation channel, surrounding area, and important hydraulic features. Six channel configurations were considered for the modeling: (1) Existing Conditions (EC), (2) Future without Project (FWOP) representing the channel deepening without the proposed widening, (3) Future with Project Full Build (FWPFB) which included the largest considered widening width and extent, and (4-6) three project alternatives of various combinations of the FWPFB. The modeling performed a calibration and then modeled two synthetic storm surge events to assess changes in water level within the SNWW as well as near the proposed Orange flood defense. The following results were observed from the modeling.

- Model calibration resulted in a mean error of 10 cm.
- Comparisons of peak water level along the channel alignment and at the Orange flood defense structure showed a maximum increase of 7 cm between the FWOP and FWPFB conditions, and a maximum increase of 3 cm between the FWOP and Alternative 1 (TSP) conditions.

- Evaluation of model time series showed no change in inundation duration.
- The inclusion of relative sea level change resulted in smaller differences between FWOP and the channel widening alternatives.

Based on the results of the modeling, the changes to peak surge elevations due to the channel widening are de minimis and the Project is not expected to have an impact on the surge elevations or durations around the SNWW.

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