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

Appendix A Attachment 3

Tidal Circulation 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 under 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 vessels in the SNWW, and three-dimensional modeling of hydrodynamics to assess water quality changes. This report discusses hydrodynamic modeling of daily tides.

Modeling was performed using the MIKE 21 Flow Model HD FM (hydrodynamic modeling using flexible mesh) designed to resolve the navigation channel and important hydraulic features. The model mesh extends approximately 50 km (31 mi) landward from the SNND jetties, approximately 53 km (33 mi) to the east and 43 km (27 mi) to the west of the main shipping channel. The model was forced at the entrance to the Gulf of Mexico using water level, as well as two additional upstream water level boundaries and one upstream discharge boundary based on available National Oceanic and Atmospheric Administration (NOAA) and U.S. Geologic Survey (USGS) gauges. Model runs simulated a two-week period and model calibration was performed using NOAA gauges located within the model domain. Additional model runs were performed to qualitatively assess changes due to relative sea level change (RSLC) and wind. The techniques applied for this work were developed after a review of the previous hydrodynamic modeling of daily tides that was completed for the SNWW Channel Improvement Project, and of similar work for Houston Ship Channel (HSC). This review of previous work is provided to add context to the results presented herein.

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 (ALT1), (5) Alternative 2 (ALT2), and (6) Alternative 3 (ALT3). The 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.

The MIKE 21 Flow Model HD FM modeling of daily currents was performed to assess changes in current speeds or current directions which might induce shoaling changes in the channel. Using the uncalibrated velocity, the greatest current speed differences between the FWOP and FWPFB models were approximately 0.2 m/s. Qualitatively, this difference is relatively small. Trends indicated the current speed would increase in sections of the channel that were not widened but decrease in sections of the channel that were widened. Efforts are also underway to characterize any expected changes to shoaling, for both erosion and deposition, based on these tidal model hydrodynamic results. This approach is also being informed based on a review of previous Texas port feasibility studies. In addition to the shoaling efforts presented in this report, a review of historical dredging records within the channel are being researched and historical shoaling hotspots evaluated. This analysis is presented in the Engineering Appendix of the Section 203 Integrated Feasibility Report.

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1 Introduction

1.1 Overview

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. Potential hydrodynamic changes associated with these channel improvement measures are evaluated using numerical modeling. This analysis will investigate potential effects of proposed alternative configurations on the movement of water in and out of the SNWW such as changes to tidal water surface elevations, current speed, or current directions to infer impacts to navigation or possible sedimentation changes.

This technical report documents the numerical modeling performed for typical (non-storm) tidal hydrodynamics, including effects of relative sea level change and wind, 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. A few instances of shoaling volumes are also presented in cubic yards, also common practice. 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). The depths for the channel configurations detailed in Section 3 are defined relative to mean lower low water (MLLW) but were converted to NAVD88 using VDatum software during model scatter development.

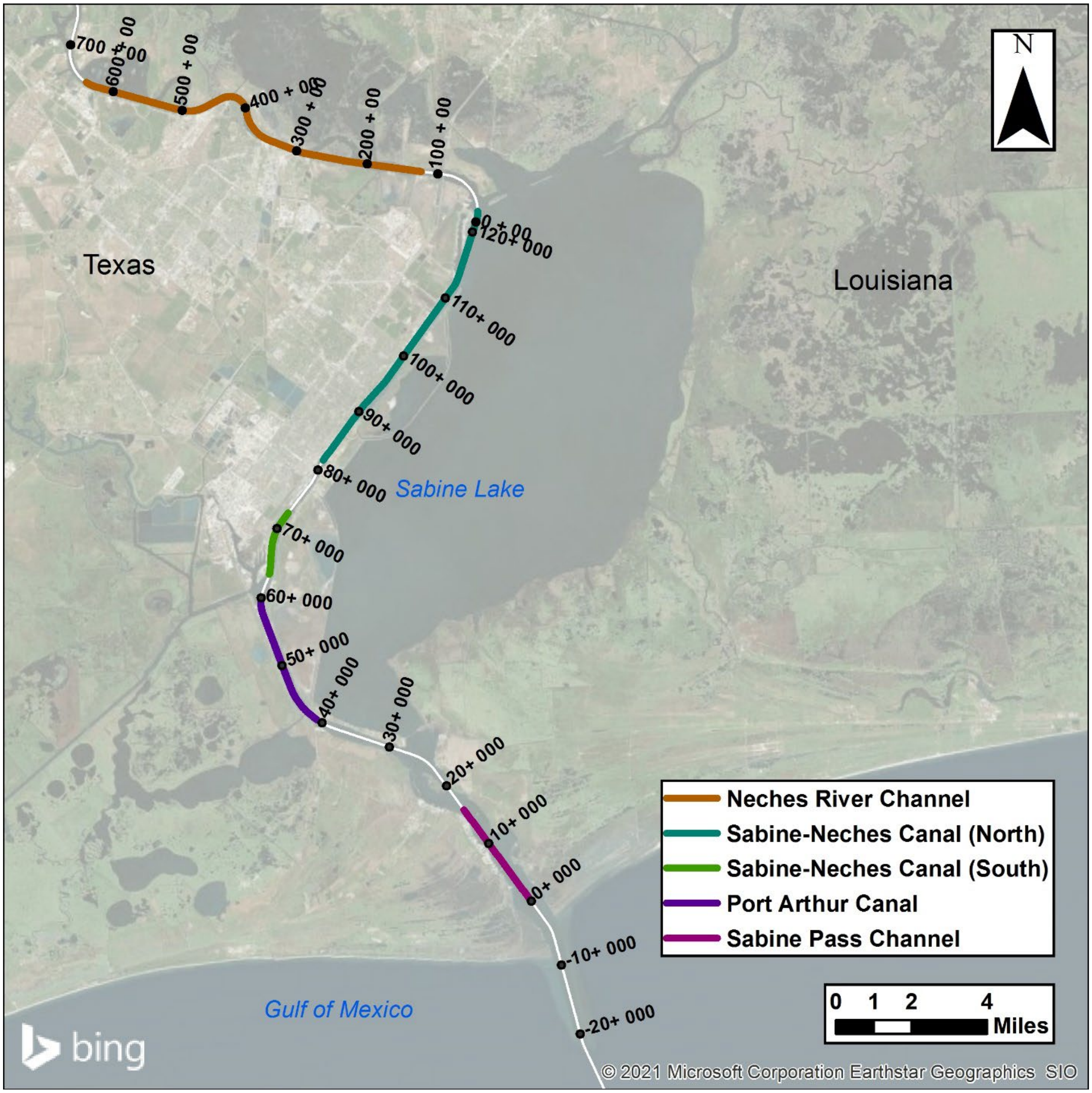

Figure 1-1
SNWW Locations Considered for Widening[1].

HDR performed this analysis to examine the influence of widening portions of the Sabine-Neches Waterway (SNWW) on typical (non-storm) astronomical tidal fluctuations. This analysis used MIKE 21 Flow Model HD FM to simulate potential changes in current speed and direction due to changes in channel configurations. Hydrodynamics are a primary factor in sedimentation and shoaling. The results of the modeling discussed in this report can be used to assess potential changes that could affect maintenance dredging or navigational hazards. The effects of relative sea level change and wind were also included in the investigations for this modeling. In conjunction

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[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.

with this effort, separate models specific to water quality (primarily salinity, residence time, etc.), vessel effects modeling, and storm surge modeling are presented as separate reports.

2 Previous Studies

Two relevant feasibility studies related to channel improvements are the SNWW Channel Improvement Project (USACE, 2011) and the Houston Ship Channel Improvement Project (USACE, 2019). Further, these studies provide examples of hydraulic modeling for feasibility studies. The current and water level modeling for these studies provide a good reference for work that has been done in the past in this general geographic area. These reports go through an Independent Technical Review (ITR) process which often results in addendums, for example the SNWW CIP engineering appendix addendum (USACE, 2010). A review of the modeling approaches and major conclusions from each of these feasibility study components is provided here.

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

2.1.1 Numerical Model of Potential Salinity Impacts Due to Proposed Navigation Improvements to the Sabine-Neches Waterway (USACE, 2007)

As an initial stage of the SNWW CIP feasibility study, a numerical model was developed to investigate changes to circulation and salinity that may result from modifications to the navigation channel. This study applied USACE's hydrodynamic model "TABS-MDS", a hybrid two- (2D) and three-dimensional (3D) model, to develop and validate a tidal circulation model for the SNWW system. The model was used to perform long-term (6 months) simulations of changes resulting from various deepening and widening plans on both salinity and storm surge (widening considerations were removed in the USACE (2010) Engineering Appendix Addendum). The model is considered hybrid because the deeper channel areas and portions of Sabine Lake, where salinity stratification may be present, were modeled in 3D and the remainder of the model domain was modeled in 2D.

The model was forced with river boundary discharge conditions based on three US Geological Survey (USGS) stations for the Neches River and tributaries, and a fourth for the Sabine River. Two tidally averaged discharge boundary conditions were placed on the Gulf Intracoastal Waterway (GIWW) east and west as a functional relationship to the river discharges. Tidal forcing was given at the ocean boundary extending approximately 55 miles into the Gulf of Mexico. The model was calibrated based on water levels from June to August 2001 at 12 observation locations distributed in the channel and the marshes. Model validation used water level data from the same 12 stations for July to December 2001, and velocity data from June to December 2001. Discharge data measured at several transects for a single tide cycle was also compared for a validation. Finally, salinity observations from the 12 observation stations were used for model validation. While these salinity data were not used for calibration, an inability to achieve verification meant an artificial adjustment of horizontal mixing was needed along the navigation channel up the confluence of the Sabine and Neches Rivers.

The model was run for with and without project conditions and evaluated with respect to velocity, water surface elevation, and salinity. The model showed some increases in velocities in the project areas of 0 to 20 percent with the largest observed changes in the Sabine-Neches Canal. It is further stated that these small increases in velocities are not expected to contribute significantly to bank erosion, which are primarily caused by vessel wakes.

2.1.2 Sabine-Neches Navigation Channel Improvement Project Final Engineering Appendix (USACE, 2008)

USACE published a Final Engineering Appendix in 2008 for the Sabine-Neches Waterway Channel Improvement Feasibility Study (USACE, 2011)[2] to evaluate and quantify expected changes to the SNWW from proposed deepening and widening alternatives. Note that widening considerations were dropped in the updated Engineering Appendix released in 2010 (USACE, 2010). Engineering studies included ship simulations, erosion, and salinity investigations by the USACE's Engineer Research and Development Center (ERDC).

The hydrodynamic tidal modeling presented in USACE (2008) contains summarized results from USACE 2007 along with additional analysis. Again, the report's focus is on changes to tidal circulation that would result from implementing a 48 ft channel deepening project. This hydrodynamic modeling tested base conditions (denoted herein as Existing Conditions (EC)) against planned conditions using the numerical model TABS-MDS. The additional analysis on hydrodynamic tide modeling evaluated salinity, velocity, and shoaling at 10 locations along the channel. Spring tides were modeled for both SE and NW wind conditions. Geometry of the EC channel included actual depths rather than authorized depths[3] to capture changes to tides between the existing condition and the proposed 48 ft deep channel. The model calibration is the same as USACE 2007 and the model was deemed to perform reasonably well, with better agreement near the coast and slightly reduced agreement in the upper reaches of the Sabine River. Discharge and current velocity observations matched model output at most, but not all comparison locations. Observed field data of the flow split between Sabine-Neches Canal and Sabine Lake were somewhat different than in the model. Model results for peak tidal velocities for both flood and ebb at the bottom of the channel were compared between base and plan at the 10 locations along the channel. These comparisons showed that peak bottom velocities generally increased for plan conditions along the entire channel but were of small absolute magnitude. The report concluded that the deeper and wider channel would increase dredging quantities due to shoaling from about 8 million cubic yards annually for the existing 40 ft channel to 15.6 million cubic yards annually for the 48 ft channel. Of the 15.6 million cubic yards, about 0.75 million cubic yards are in the extended outer channel (i.e., not an increase due to deepening an existing reach). Further analysis is presented along Pleasure Island where some relative changes in velocities were predicted, but their absolute values are small.

2.1.3 Sabine-Neches Navigation Channel Improvement Project Engineering Appendix Addendum (USACE, 2010)

After the ITR review of the USACE (2008) engineering appendix, some additional updates were made to the hydrodynamic tidal modeling. Particularly, all considerations of widening were removed from the analysis. Updates to the calibration and validation comparison plots as described in USACE (2007) are presented with very minor changes. Also, of note, is an additional analysis

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

[3] Authorized depth of the channel is the depth authorized by Congress to be constructed and maintained by USACE; actual existing bathymetry may extend below the authorized depth from advanced maintenance and allowable overdepth dredging. The existing bathymetry could also be shallower than the authorized depth if heavy shoaling has occurred.

of RSLC on the velocity and shoaling estimates. The value selected for the most likely sea level rise over the project life was 0.34 m based on the NRC Curve II (intermediate level). Future conditions with RSLC are expected to increase the tidal prism and hence slightly increase the tidal velocity shear stresses. RSLC is expected to have little influence on shoaling and dredging requirements. The annual shoaling rate for the 48 ft channel (for the entire SNWW including the offshore extension channel) was reduced from 15.6 to 14.1 million cubic yards per year after removal of the widening component (USACE, 2010). Updates were also made to the storm surge and salinity analysis.

2.1.4 Final Feasibility Report for Sabine-Neches Waterway Channel Improvement Project (USACE, 2011) and Final Environmental Impact Statement for Sabine-Neches Waterway Channel Improvement Project (USACE, 2011a)

The FFR and FEIS reports summarize the model finding from the USACE (2007), USACE (2008) and USACE (2010) reports. These reports concluded that little or no increases to water surface elevations are expected due to a deeper navigation channel. The channel deepening results generally in a small increase in velocity (0.15 m/s along the entire channel. The largest changes observed were in the Sabine-Neches Canal. Finally, the deeper channel is expected to be slightly more favorable to sedimentation and will require more maintenance dredging compared to the existing condition.

2.2 Houston Ship Channel Improvement Project

A feasibility study was recently completed for improvements to the Houston Ship Channel that included both widening and deepening long segments of the federal navigation channel. The feasibility study performed an analysis of potential changes the channel improvements may have on the tidal circulation. The numerical model AdH was used for this analysis, which replaced the previous model TABS-MDS that is no longer supported by USACE. A full description of the numerical modeling is detailed in “Houston Ship Channel Expansion Channel Improvement Project (HSC ECIP) Numerical Modeling Report,” (USACE, 2019b). The objective of the study was to develop a fully calibrated 3D hydrodynamic and sediment transport model covering the project area that establishes base conditions against which the proposed project conditions could be evaluated. Base and plan alternatives were modeled for both present and future conditions, such that the predicted changes from the project could be distinguished from changes to the tidal circulation that were to occur without the project during the future. Modeling sediment transport meant shoaling rates were directly produced by the model instead of through an analysis based on modeled velocities. Because the modeled shoaling rate for the existing condition did not match the historical dredge volume, the modelers used multiple methods to determine a scaling factor to convert the shoaling volume from the model to an actual shoaling volume. This same factor was then applied to comparisons of the without project and with project models to determine the impact to the shoaling rates.

The reporting focuses on presenting annual shoaling volumes for the various reaches of the Houston Ship Channel for the with and without project conditions. The results show large amounts of variability in shoaling depending on which scaling method is applied. Because the analysis used direct model output of shoaling and sedimentation, the reports do not provide comparison for how the hydraulics and hydrodynamic changes from the project features impact the shoaling. The report does provide discussion about how changes to channel depth and/or channel width affect the geometry and can ultimately affect the shoaling volume and dredge frequency even for a constant shoaling rate.

The relative sea level rise value recommended for the navigation portion of the project was based on USACE's low sea-level curve. Including sea level rise and subsidence in the project design was assumed to result in less dredging than otherwise anticipated since the channel depth increases because of those factors. Sea level rise was also assumed to increase erosion, ship wakes, and wind waves and cause changes in water chemistry (salinity and dissolved oxygen).

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 MLLW. A summary of the configuration-specific widening locations and dimensions is provided in Table 3-1.

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.

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

Referred to as Alternative 1 or ALT1, this channel configuration includes widening to 500 ft (+100 ft) 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

Referred to as Alternative 2 or ALT2, this channel configuration includes widening to 600 ft (+200 ft) reaches of the Sabine-Neches Canal and the Neches River Channel. Authorized depth remains 48 ft below MLLW. ALT2 focuses on widening in the same locations as ALT1, but increases the width by 100 ft.

3.6 Channel Configuration 6: Alternative 3

Referred to as Alternative 3 or ALT3, this channel configuration includes widening to 500 ft (+100 ft) reaches of the Sabine-Neches Canal and the Neches River Channel and widening to 700 ft (+200 ft) the Sabine Pass Channel and the Port Arthur Canal. Authorized depth remains 48 ft below MLLW. ALT3 is the same as ALT1 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 (same centerline)	No change to existing	No change to existing	700 ft (same centerline)
Port Arthur Canal	43+900	59+740	500 ft	500 ft				
Sabine Neches Canal (South)	63+500	72+700	400 ft	400 ft	600 ft (same western boundary; shift to east)	500 ft (same western boundary; shift to east)	600 ft (same western boundary; shift to east)	500 ft (same western boundary; shift to east)
Sabine Neches Canal (North)	81+510	35+00	400 ft	400 ft				
Neches River Channel[1]	122+40	640+00	400 ft	400 ft	600 ft (same western boundary; shift to east)	500 ft (same western boundary; shift to east)	600 ft (same western boundary; shift to east)	500 ft (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). The flexible mesh module allows for higher resolution model gridding at locations requiring more resolution of the hydrodynamics (e.g., near the project site and key features such as jetties and channel openings). Notably, this model is on the FEMA list of "Hydraulic Numerical Models Meeting the Minimum Requirement of National Flood Insurance Program," and use of MIKE 21 Flow Model HD FM for this type of project is consistent with industry standards. This model is 2D in the sense that it simulates hydrodynamics using vertically depth averaged equations.

HDR is proficient in the application of MIKE21 for hydrodynamic modeling of currents and storm surge and therefore applied this model for these analyses. 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.

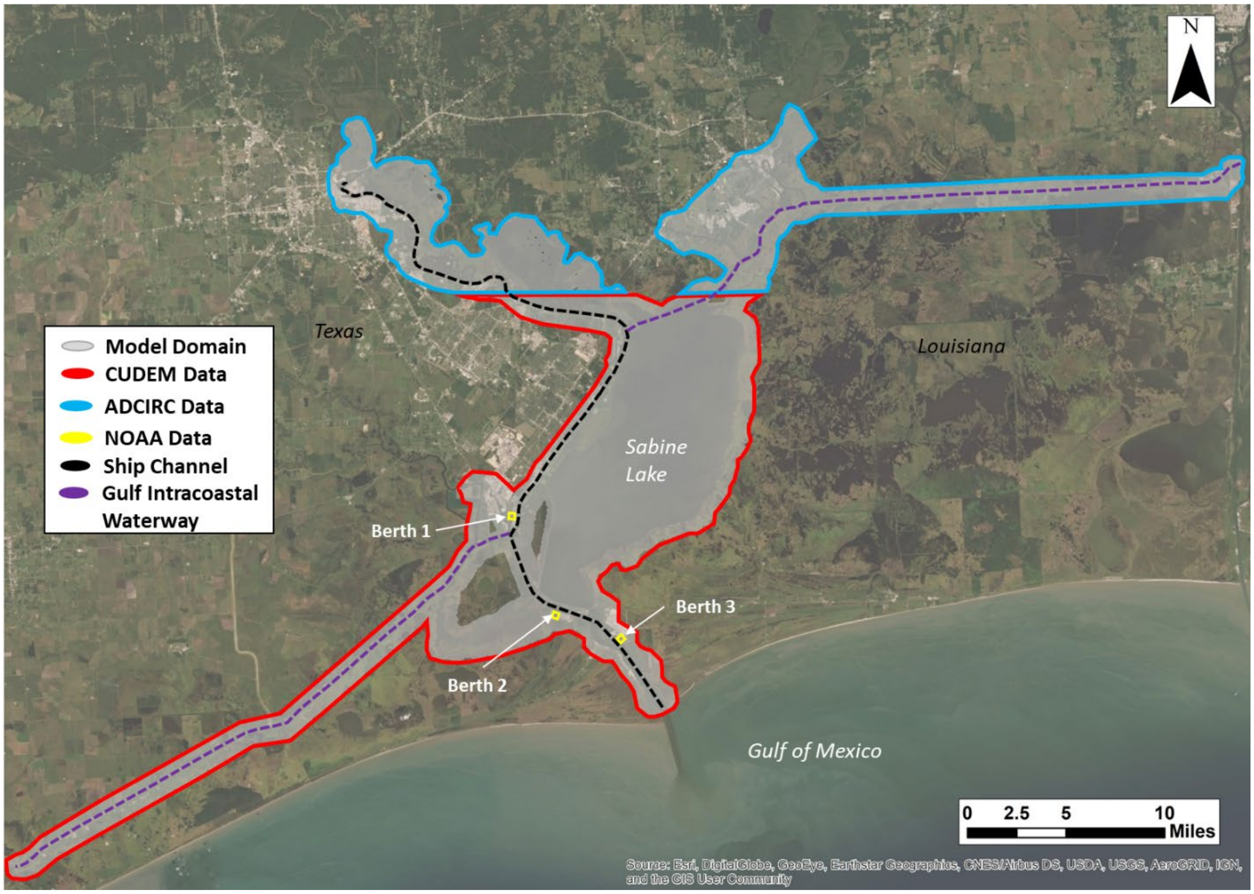
4.2 Bathymetry and Topography Data

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. Within the navigation channel, the primary CUDEM data source is USACE hydrographic surveys. Spot checks between CUDEM and USACE hydrographic surveys compared well, however, elevation differences 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 based on depths listed on NOAA navigation charts. 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.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 4-1
Elevation Source Data Summary

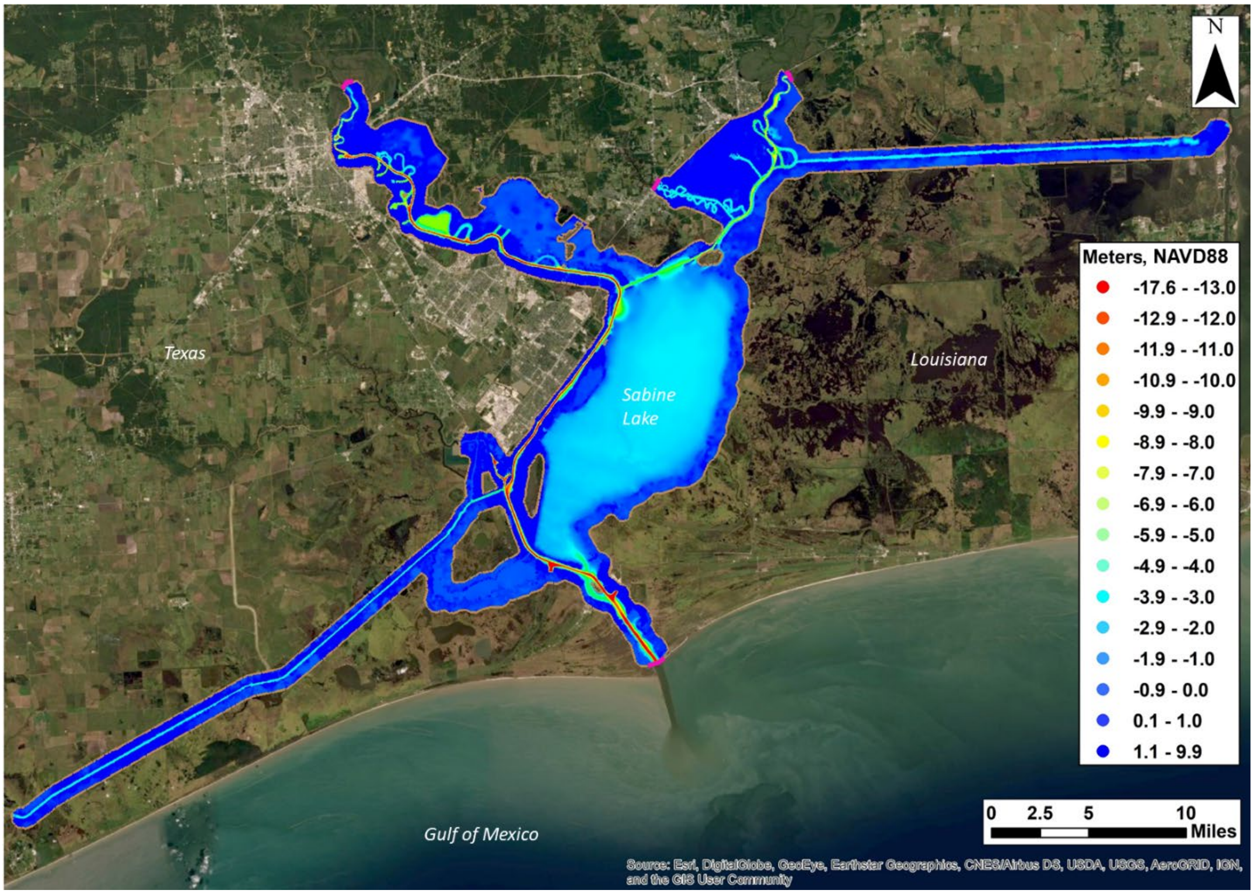
The various channel configurations for modeling are discussed in Section 3. For the EC modeling, primarily used as a calibration model, additional manipulation of the elevation data was not performed. For all future channel configurations, the elevation data were adjusted based on the proposed channel 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. The same 2H:1V slope is used for the SNWW CIP as described in USACE (2011).

The vertical datums for both the CUDEM and FEMA data sets originated as with respect to NADV88 (m) and was not modified. The horizontal coordinates both originated as NAD83 geographic and were converted using SMS software to NAD83 Texas State Place South Central (m). The vertical datum for the channel configurations detailed in Section 3 are defined with respect to MLLW and were then transformed to NADB88 using VDatum software.

4.3 Model Mesh Development

The MIKE 21 Flow Model HD FM domain covers the SNWW and surrounding area. The domain, shown in Figure 4-1 in gray and in Figure 4-2 in blue, extends approximately 50 km (31 mi) landward from the SNND jetties, approximately 53 km (33 mi) to the east and 43 km (27 mi) to the west of the main shipping channel. Model resolution varied from approximately 1,000 m2 within the channel to approximately 40,000 m2 in Sabine Lake. This mesh and model are solely focused on tide circulation which differs from the SNWW CIP (USACE, 2007) that focused on salinity, storm surge, and tides. The model uses a triangular mesh defined by nodes that are connected to form elements as shown in Figure 4-3. The total number of elements ranged from approximately 155,000 elements to approximately 195,000 elements depending on the alternative being modeled. The added elements were the result of increasing the mesh resolution along the channel toe for the wider channel alternatives to better resolve the channel. This mesh is considered high resolution when compared to the hydrodynamic modeling performed for the 2011 CIP feasibility study (USACE, 2011), where the total number of elements was stated to be 45,915.

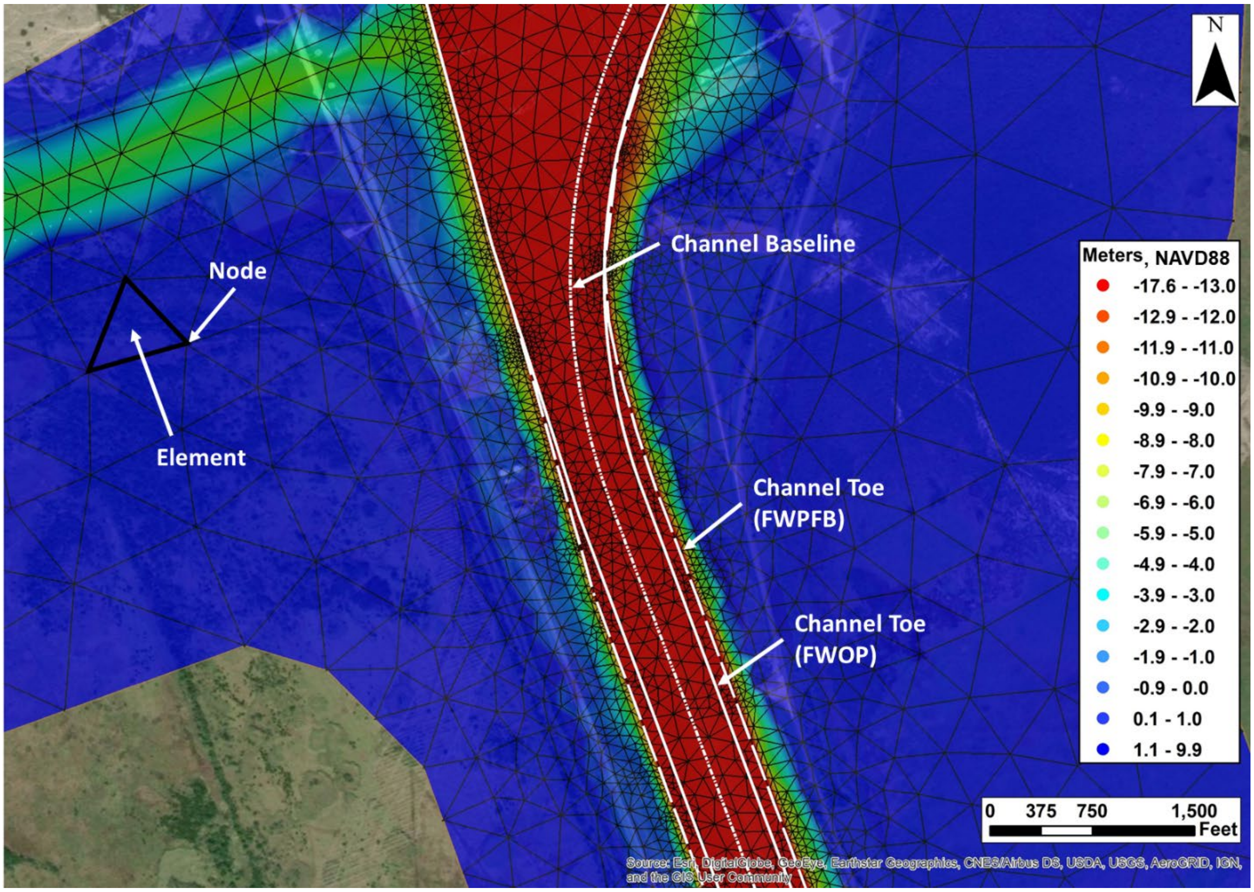
In addition, a mesh convergence test was performed on the EC model. In the test the element size was reduced by approximately 25%, increasing the total number of elements from approximately 155,000 to 230,000 to assess whether mesh resolution was affecting the hydrodynamic results. The mesh convergence test showed water surface elevation normalized variance varied by less than 0.2%, indicating the base mesh resolution was adequately capturing the bathymetry and the physical processes.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 4-2
Merged and Interpolated Elevation Data for Existing Conditions (EC)

The mesh for each of the channel alternatives discussed in Section 3 has the same overall extent and is duplicated except in the immediate area of the channel. Small variations were made to the element spacing and location along the channel to better resolve the channel alternative being modeled. Figure 4-3 presents an example of the model mesh from the Port Arthur Canal, which demonstrates how the mesh resolution increased along the channel toe and side slopes to capture the changes that could be attributable to the different design alternatives.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 4-3
MIKE 21 Flow Model HD FM Mesh – Elevation Data for Widening Conditions

4.4 Model Forcing and Boundary Conditions

4.4.1 Model Simulations

In total, ten combinations of channel configurations, model forcing, and boundary conditions were modeled as summarized in Table 4-1. Note additional model runs were performed to further assess the conclusions drawn in this report but are not presented here to streamline the results. The primary model simulations (runs 1, 2, and 3) applied water level and flow discharge to force typical tidal conditions based on measured data at USGS and NOAA gauges. The boundary conditions focused on a one-and-a-half-week (276 hour) period beginning January 5, 2020. During this period, data were available at all four of the boundary conditions gauges. Locations and names of the boundary conditions are shown in Figure 4-4 and

Table 4-2 and are discussed in detail later in this section. Initially, these boundary conditions were applied to the EC model domain as part of the calibration and validation effort (see Section 5). Wind was not applied as a boundary condition to the model runs during the calibration and validation. Model runs applying the water level and flow discharge boundary conditions were performed for all three channel configurations (runs 1, 2, and 3) and used as the primary comparison for changes associated with the different action alternatives.

The boundary condition on the GIWW on the east and west end of the mesh was set as closed due to lack of data availability and need to further extend the mesh. To avoid the closed boundaries impacting the model results, the model location of the closed boundary conditions on the GIWW were extended far from the project area (further east and west). Two tests were performed to check the sensitivity of the model with a closed boundary condition on the GIWW: (1) the Existing Condition model was run with a water level boundary condition at each end of the GIWW using the nearest available gauge data, and (2) the closed boundary condition location on the GIWW was moved in toward the SNWW by 1 km to compare effects on model results. Both sensitivity checks resulted in a change to the model water surface elevation error (normalized variance) of less than 0.1% and velocity RMSE[4] of less than 0.03 m/s, therefore, the model was not considered sensitive to the boundary condition and production runs were performed with the closed boundary conditions on the GIWW as shown in Figure 4-4.

Table 4-1
Summary of Model Runs

Run	Model Scenario	Model Forcing			
		Water Level	**Flow Discharge**	**Wind**	**RSLC**
1	EC	X	X	--	--
2	FWOP	X	X	--	--
3	FWPFB	X	X	--	--
4	FWOP (Wind)	X	X	X	--
5	FWPFB (Wind)	X	X	X	--
6	FWOP (RSLC)	X	X	--	X
7	FWPFB (RSLC)	X	X	--	X
8	Alternative 1	X	X	--	--
9	Alternative 2	X	X	--	--
10	Alternative 3	X	X	--	--

Since wind is a primary forcing mechanism for hydrodynamics along the Texas coast, additional investigations were performed to check if the inclusion of wind in the model would change the qualitative comparison of the results between channel alternatives. Runs 4 and 5 were performed on the FWOP and FWPFB model meshes using the same water level and discharge boundary conditions as runs 1, 2, and 3, but also applying a seasonal wind condition (see Wind discussion later in this section).

For consistency with USACE policy, relative sea level change (RSLC) was also considered (see RSLC discussion later in this section). Runs 6 and 7 added 1.0 m of water level to the boundary

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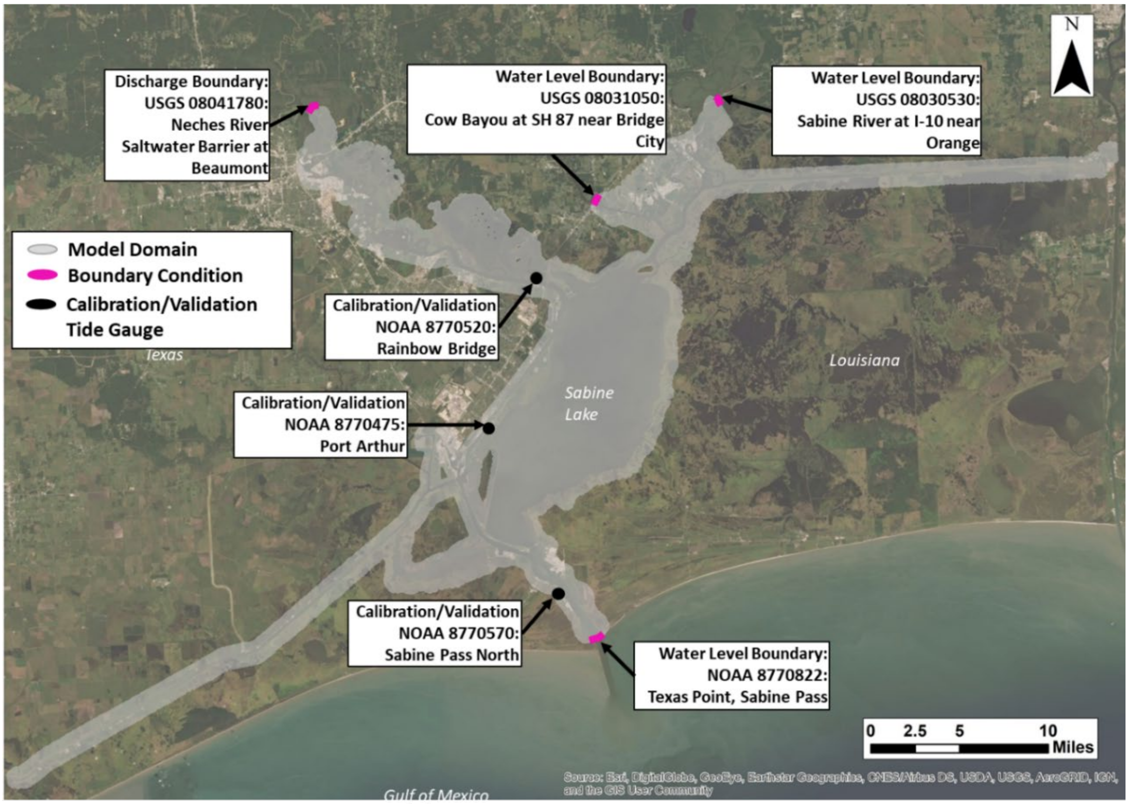
[4] Velocity was not calibrated to measured data. See additional discussion in the Calibration and Validation section. All references to RMSE for velocity are calculated by considering the initial model run as the baseline and comparing the sensitivity model runs.

conditions used for runs 1, 2, and 3. The development of the individual boundary conditions applied for runs 1 through 7 used in this modeling effort are discussed in this section.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 4-4
Model Boundary Conditions and Calibration Locations

Table 4-2
Summary of Model Boundary Conditions and Calibration/Validation Stations

Station Number	Type	Location Description
USGS 08041780	Boundary Condition (Discharge)	Neches River Saltwater Barrier at Beaumont, TX
USGS 08031050	Boundary Condition (Water Level)	Cow Bayou at SH 87 near Bridge City, TX
USGS 08030530	Boundary Condition (Water Level)	Sabine River at I-10 near Orange, TX
NOAA 8770822	Boundary Condition (Water Level)	Texas Point, Sabine Pass, TX
NOAA 8770520	Calibration/Validation (Water Level)	Rainbow Bridge, TX
NOAA 8770475	Calibration/Validation (Water Level)	Port Arthur, TX
NOAA 8770570	Calibration/Validation (Water Level), Wind, Relative Sea Level Change	Sabine Pass North, TX

4.4.2 Water Level

Three model forcing boundaries were implemented using water surface elevation as the inputs. The locations of these boundaries are shown in Figure 4-4 and are summarized in

Table 4-2. These locations were selected based on available data from NOAA and USGS. The offshore model boundary used NOAA Station 8770822 as its input, and the two northeastern water surface elevation (WSE) boundaries were forced using USGS data from Station 08031050 and Station 08030530. Refer to Figure 4-5 for a time series comparison of the water levels used at the three water level boundary conditions.

A discharge boundary condition would be preferred over the water level condition applied for the Sabine River; however, discharge data were not available at USGS Station 08030530. Discharge data were available at USGS Station 08030500 approximately 20 km further upstream than USGS 08030530. Utilizing Station 08030500 would introduce several uncertainties to the model, including:

- The elevation data set north of 30° latitude was relatively coarse and visual review showed the data did not resolve the Sabine River.
- The Sabine River north of NOAA Station 8770822 becomes a relatively wide flood plain with numerous marsh and tributary areas that could introduce additional model error.
- Utilizing the discharge boundary condition further upstream would require additional area and complexity be added to the mesh, reducing run times or reducing resolution in other areas considered more important.

For these reasons, the model was forced with the available water level data at USGS 08030530. Sensitivity testing was performed to check model results were not compromised. The primary sensitivity check was to develop a separate hydrologic model in SRH-2D to translate the discharge boundary condition from Station 08030500 to the production run model boundary at USGS 08030530. A separate Existing Condition model was run using the SRH-2D model results as a discharge input at USGS 08030530. The sensitivity checks resulted in a change to the model water surface elevation error of less than 0.6% and RMSE of velocities of less than 0.1 m/s. Based on these sensitivity checks the model was not considered sensitive to using the water level boundary condition. Further details of the model calibration and validations are discussed in Section 5.

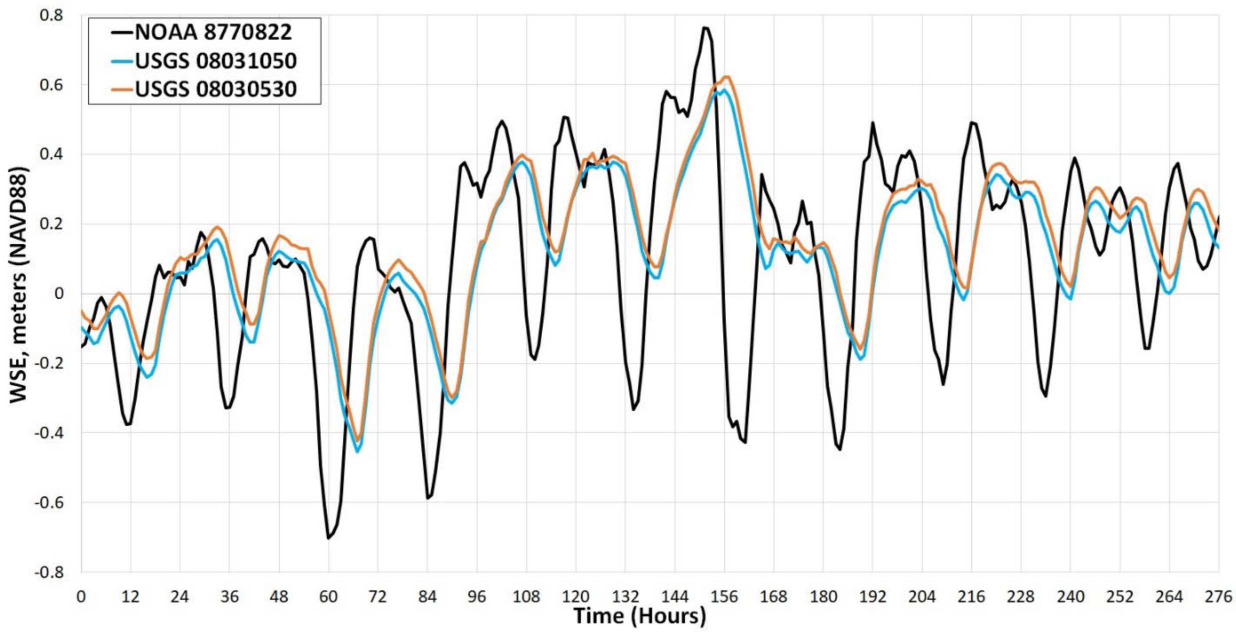


Figure 4-5
Model Forcing Boundary Conditions – WSE

4.4.3 Discharge

One model forcing boundary was implemented using flow discharge as the input (see discussion in the Water Level section). The northwest model boundary on the Neches River used the USGS station 08041780 as its input. Refer to Figure 4-6 for the time series of flow discharge (m3/sec) used to force the MIKE 21 Flow Model HD FM models.

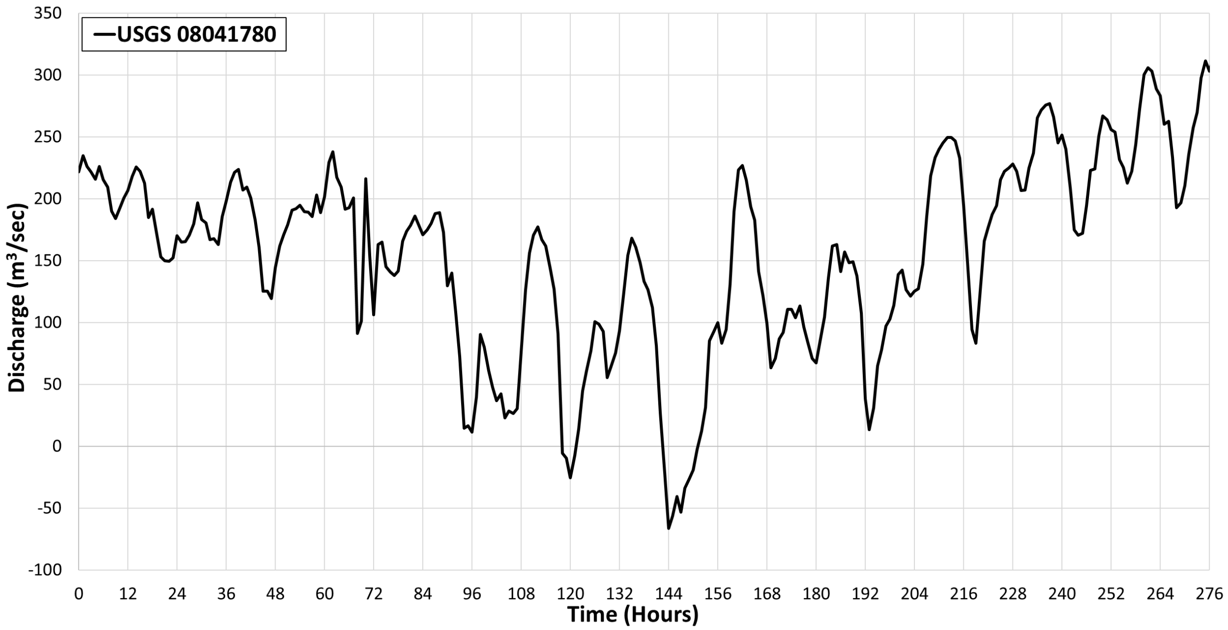


Figure 4-6
Model Forcing Boundary Conditions - Flow Discharge

4.4.4 Wind

Wind forcing was not included in all the model runs but was used in two simulations which were performed to investigate potential changes to the qualitative model results between alternatives. The primary driver of hydrodynamics in the model are the WSE and discharge inputs, but wind was included separately to determine if anything changed qualitatively to the model results.

Wind speed and direction data were collected from the NOAA Water Level Observation Network webpage for Station 8770570 – Sabine Pass North, TX. The collected data reflected time points at 6-minute intervals from January 1, 2010 to December 31, 2019. The full data are depicted as a wind rose shown in Figure 4-7. Based on local experience and the wind rose, the predominant wind for the region is from the SSE. Therefore, data points with direction between 135° and 180° were isolated, and a frequency of exceedance was created from that data (Figure 4-8) to identify a seasonal wind speed to apply in the model. Based on this analysis a wind speed of 5.1 m/s (10 knots) from 157.5° was determined for application in the model runs investigating wind, representing a typical wind from the SE. In these runs the wind was applied constantly in time and uniformly in space. Additional models were tested with faster wind speeds using the same water level and discharge boundary conditions, but the faster winds created model instabilities. Periods of faster winds will be accompanied by different water levels at the boundary conditions than those applied in the model. Because they are measured water levels, the water levels in the model already include wind setup. The model runs performed are expected to capture the qualitative differences between the channel configurations and therefore additional investigation of faster winds was not performed.

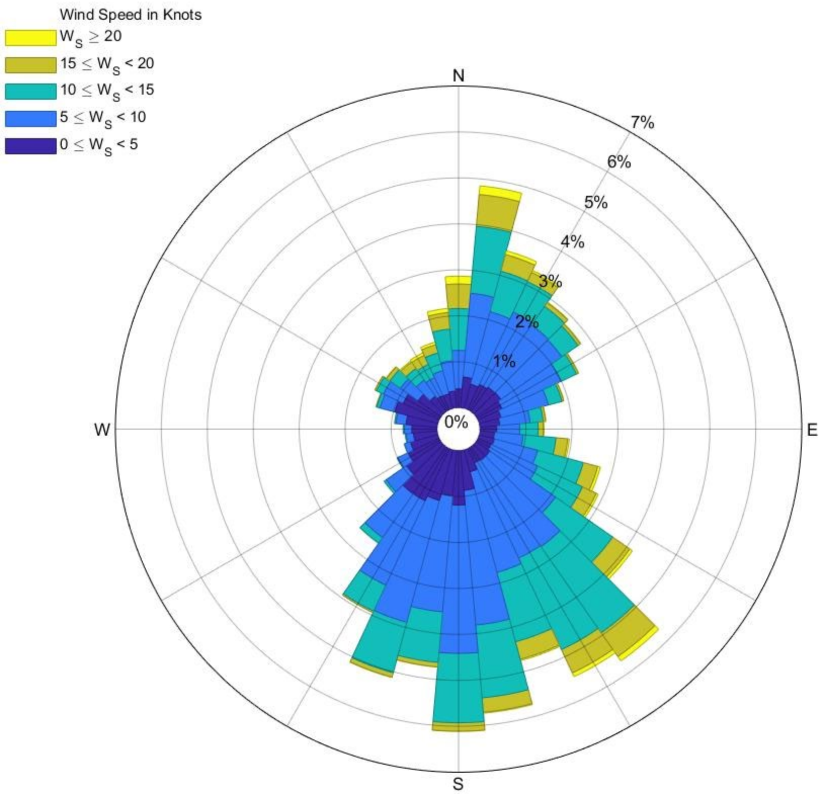


Figure 4-7
Wind Rose for 2010-2019

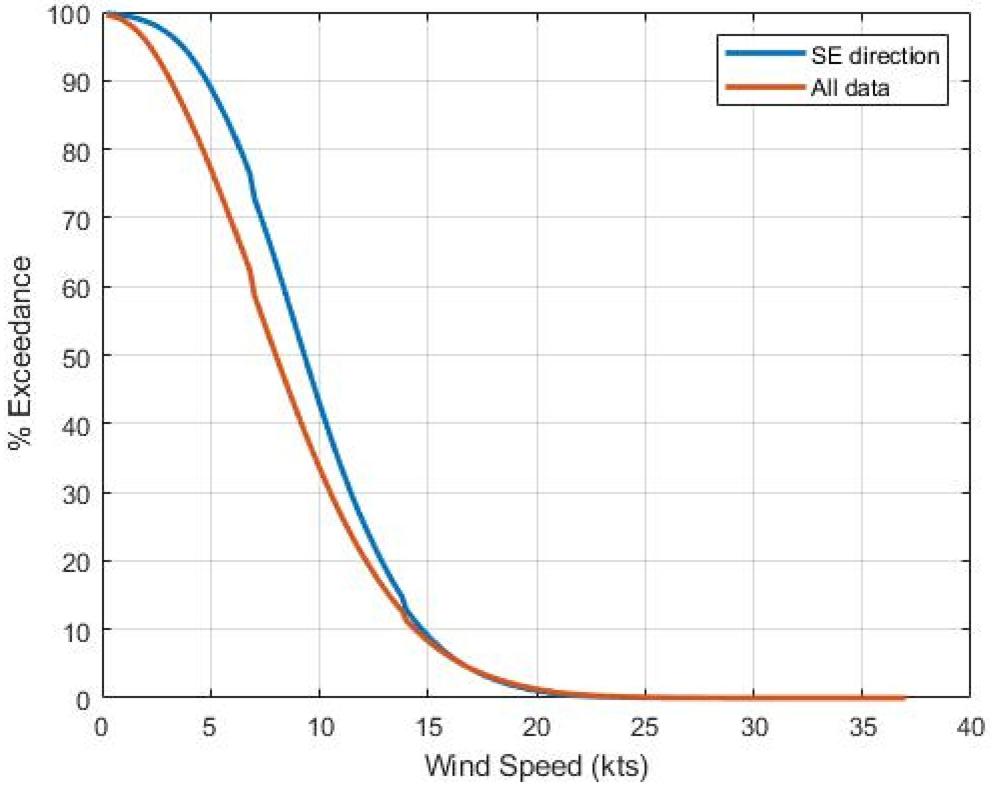


Figure 4-8
Frequency of Exceedance: SE Wind Speed

4.4.5 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 of 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 4-3, and curves for 2020 to 2075 are shown in Figure 4-9.

Table 4-3
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)

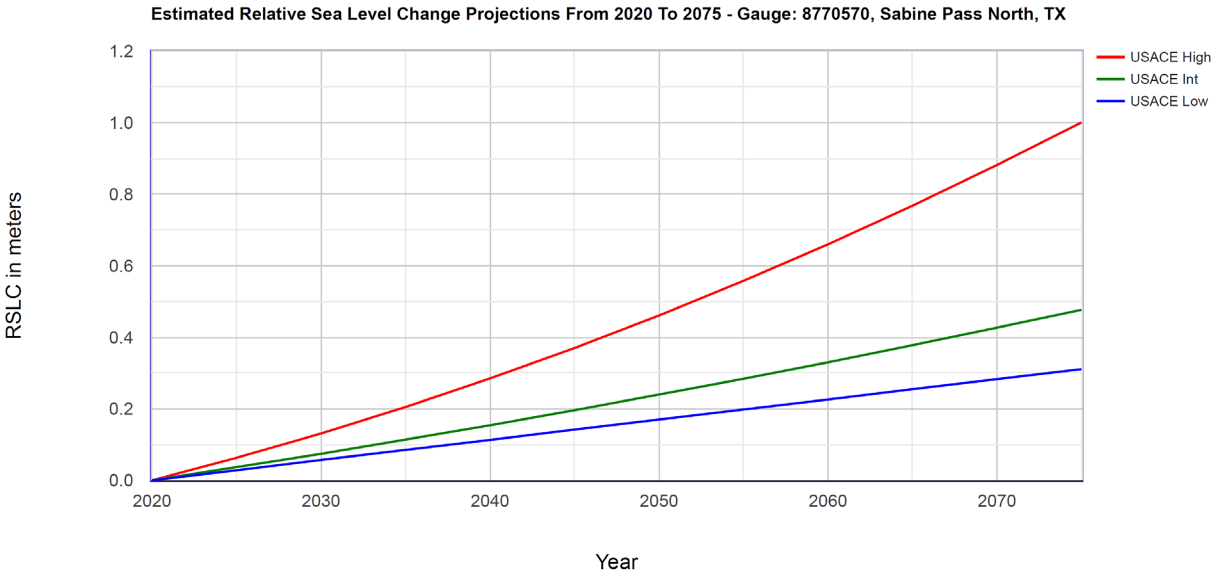


Figure 4-9
RSLC Curves Based on USACE’s Online Sea-Level Calculator for NOAA 8770570 from 2020 to 2075

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.

5 Model Calibration and Validation

5.1 Model Calibration

The model was calibrated for the EC run with no wind (Run 1 in Table 4-1).To calibrate the typical tides model, various bottom roughness values were tested by adjusting the Manning Number value.[5] Five Manning Number values were tested in increments of two (30, 32, 34, 36, and 38), starting with the default value of 32 m1/3/s. Water surface elevation results from each of the calibration runs were analyzed at NOAA Station 8770475 at Port Arthur (Figure 4-2). The normalized variance (Equation 1), correlation coefficient (Equation 2), and root mean square error (RMSE) (Equation 3) were calculated at this location by comparing the recorded WSE to the model output. Refer to Table 5-1 for the results of the model calibration. A time series plots of the WSE is included below (see Figure 5-1). Based on an assessment of results sensitivity and visual inspection of the results the first 24 hours from the 11.5-day total, of model output was removed from the analysis to allow the model to equilibrate from the implementation of five separate boundary conditions. Based on the calibration results presented in Table 5-1 the model was not considered sensitive to the Manning's Number and a value of 34 m1/3/s was chosen for production runs.

$$\sigma^2_{norm} = 100\left(\frac{\sigma^2_{(mod-meas)}}{\sigma^2_{meas}}\right) \tag{1}$$

$$r = \frac{cov(mod, meas)}{\sqrt{\sigma^2_{mod}\sigma^2_{meas}}} \tag{2}$$

$$RMSE = \sqrt{\overline{(mod - meas)^2}} \tag{3}$$

Table 5-1
Model Calibration for Bottom Roughness Parameter (Water Level Comparison)

Bottom Roughness (Manning Number)	NOAA 8770475 Port Arthur		
	Norm. Variance (%)	Correlation Coefficient (r)	RMSE (m)
30	4.90	0.98	0.05
32	4.51	0.98	0.05
34	4.19	0.98	0.05
36	3.74	0.98	0.04
38	3.38	0.98	0.04

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[5] MIKE21 applies the Manning's number which is the reciprocal of the Manning's n value. Note, the bottom roughness model parameter was implemented as spatially constant for all model runs.

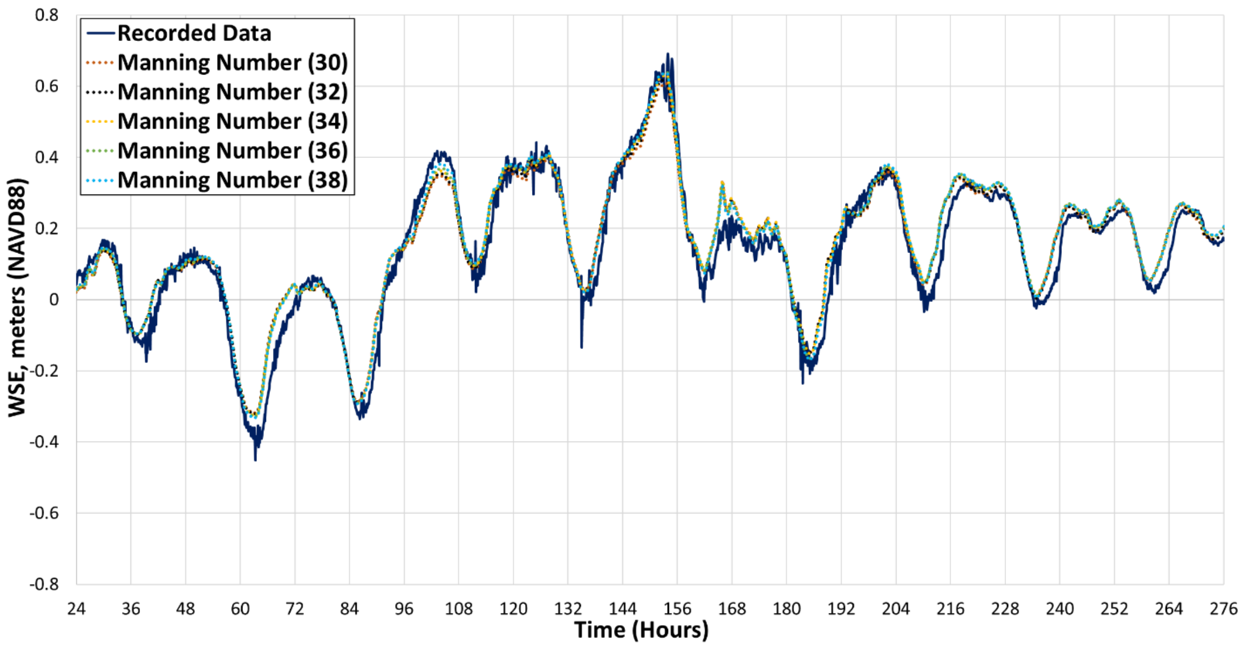

Figure 5-1
Model Calibration - WSE - NOAA Station 8770475 (Port Arthur Canal)

5.2 Model Validation

As part of the model validation, the WSE at NOAA 8770520 and NOAA 8770570 were extracted from the model and compared to the NOAA gauge data. The comparisons were made for the model run using the production manning's Number of 34 m1/3/s as well as the other Manning's Numbers modeled in the calibration effort. Error metrics calculated at the Port Arthur NOAA station for the calibration effort were also calculated here for comparison and to build confidence in the model capability. Error metrics at the two NOAA stations used for model validation are presented in Table 5-2 and time series comparisons are shown in Figure 5-2 and Figure 5-3.

Table 5-2
Model Validation for Bottom Roughness Parameter (Water Level Comparison)

Bottom Roughness (Manning Number)	NOAA 8770520 Rainbow Bridge			NOAA 8770570 Sabine Pass North		
	Norm. Variance (%)	Correlation Coefficient (r)	RMSE (m)	Norm. Variance (%)	Correlation Coefficient (r)	RMSE (m)
30	14.2	0.94	0.08	1.56	0.99	0.08
32	13.2	0.94	0.08	1.52	0.99	0.06
34	12.4	0.94	0.08	1.49	0.99	0.06
36	11.0	0.95	0.08	1.45	0.99	0.06
38	9.80	0.95	0.08	1.41	0.99	0.06

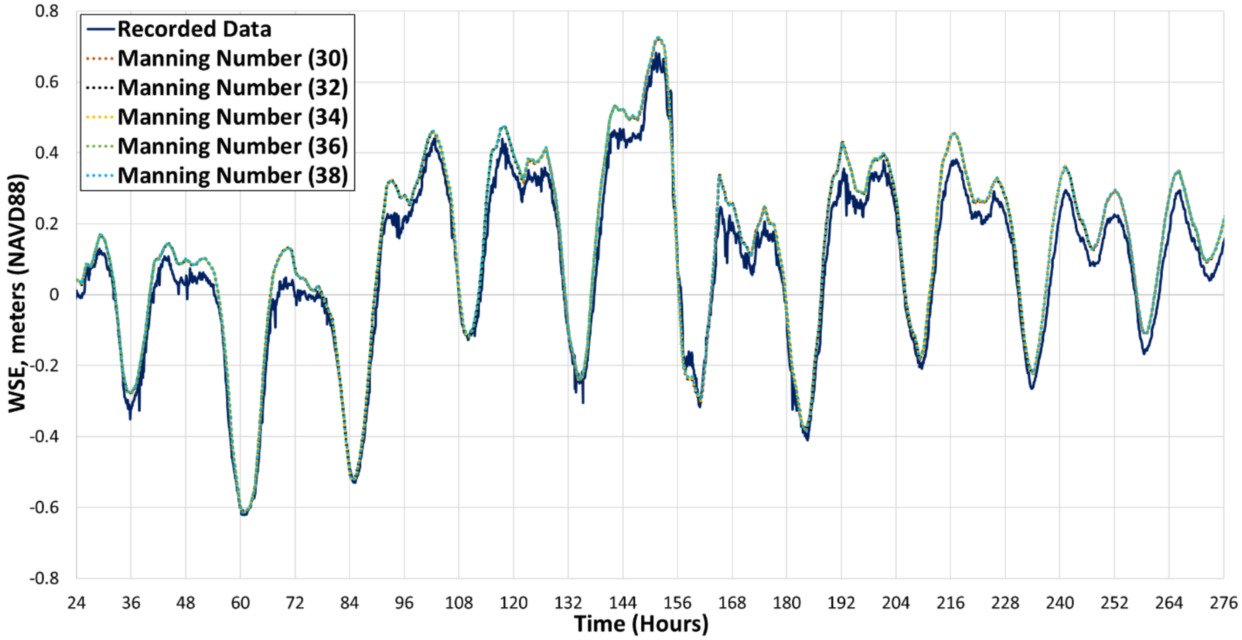

Figure 5-2
Model Validation - WSE - NOAA Station 8770570 (Sabine Pass North)

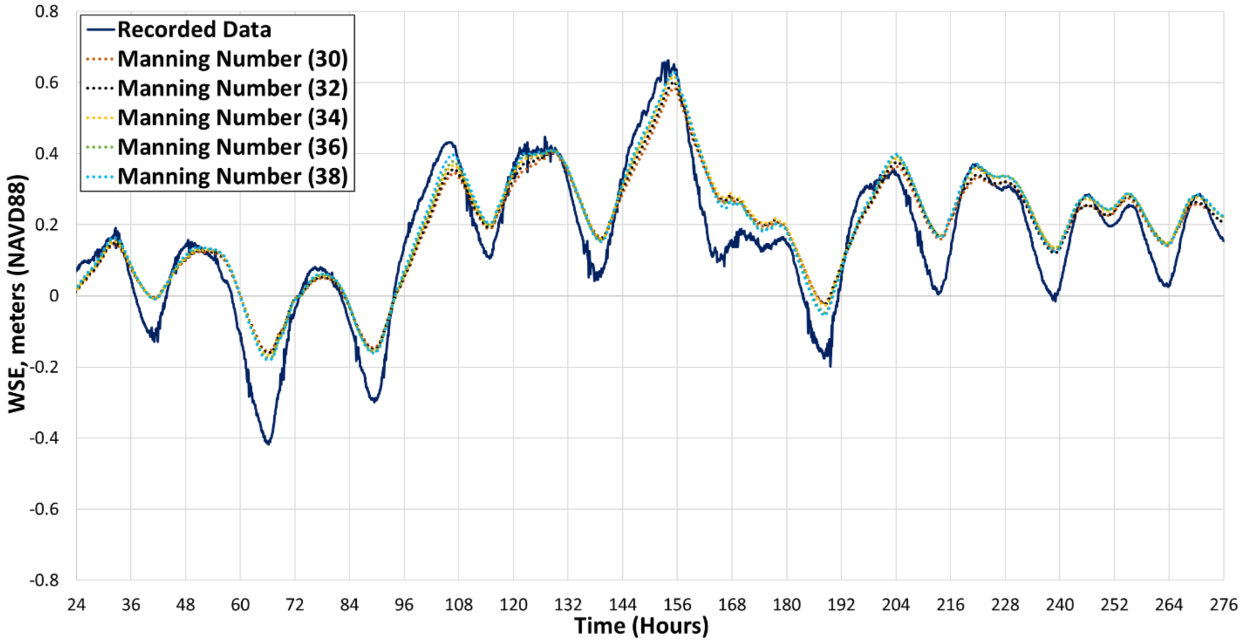

Figure 5-3
Model Validation - WSE - NOAA Station 8770520 (Rainbow Bridge)

The calibration and validation statistics presented in Table 5-1 and Table 5-2, respectively, exhibit good skill with all correlation coefficients above 0.94 and RMSE under 0.08 m. This calibration compares favorably with the hydrodynamic modeling completed for the HSC ECIP (USACE, 2019b), where correlation coefficients ranged from 0.85 to 0.97 and RMSE from 0.012 to 0.05 m.

The model results in Figure 5-2 and Figure 5-1 show good agreement with the tide gauge measurements generally matching the tidal amplitude and phasing. The comparison at the Rainbow Bridge Station (Figure 5-3) shows the least agreement of the validation gauges with the model results approximating the high tide peaks well, but under predicting the low water marks for the low tides.

5.3 Model Sensitivity Checks

Several model adjustments were investigated for general sensitivity testing and to improve model agreement with water surface elevations at Rainbow Bridge and evaluate model velocity sensitivity. These tests are summarized below.

- Increased Mesh Resolution – Model element size was decreased by approximately 25% and 50% to gauge whether a more resolved mesh would better capture the geometry and/or physical processes
- GIWW Boundary Forcing – Boundary conditions were applied at both ends of the GIWW to force water level changes
- Discharge Boundary Forcing on the Sabine River – Analyses were performed to transfer the discharge data from upstream on the Sabine River and then the discharge data was applied to the model boundary condition

Numerous model attempts were made to allow additional water to escape the model including better resolution of marsh channels and ponds, results of which were part of earlier model setup runs and are not shown here. Sensitivity checks resulted in model water surface elevation error changes (normalized variance) less than 0.5% and RMSE values for velocities changes less than 0.1 m/s (see Table 5-3 Velocity RMSE for sensitivity tests.). The extraction locations are shown in Figure 5-4. The model results were not sensitive to these tests. Ultimately, reasons for model error values could be due to uncertainties in bathymetric data where additional ground-truthed data are not available, model dissipation, or other uncertainties.

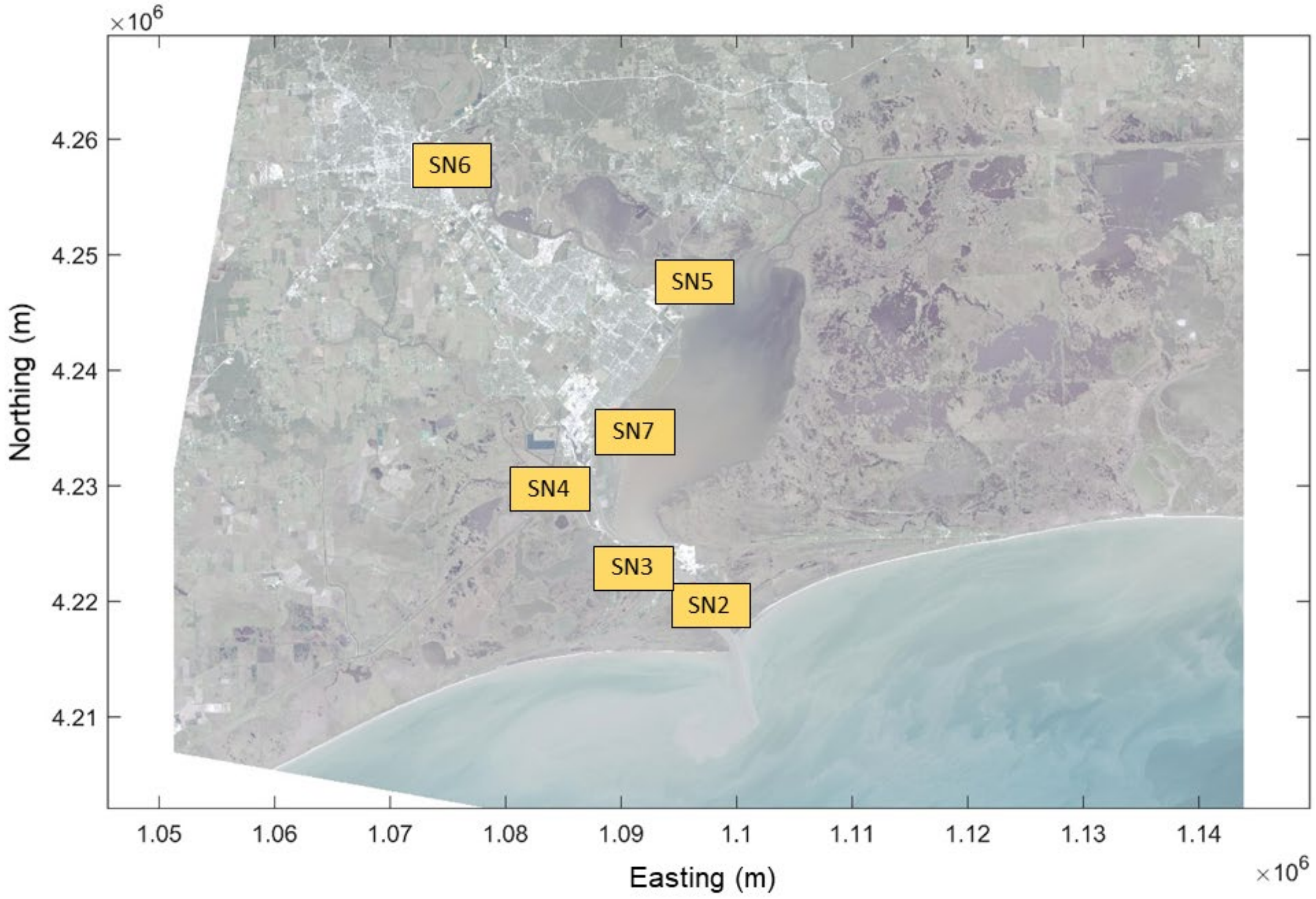

Figure 5-4
Velocity Comparison Location for Sensitivity Tests

Table 5-3
Velocity RMSE for sensitivity tests.

	SN2	SN3	SN4	SN5	SN6	SN7
Base-Base	0.00	0.00	0.00	0.00	0.00	0.00
Discharge-Base	0.01	0.01	0.00	0.00	0.00	0.01
GIWW Res-Base	0.00	0.01	0.03	0.00	0.01	0.00
GIWW Trim-Base	0.00	0.02	0.00	0.00	0.00	0.01
Inc Res 50-Base	0.01	0.01	0.02	0.00	0.00	0.01

Note previous tide modeling efforts associated with the CIP feasibility study (USACE, 2011) also underpredicted minimum low tide water levels when compared to observations, mainly at the Sabine River comparison site, and to a lesser extent at Rainbow Bridge site. Model data differences in the CIP feasibility study persisted despite numerous calibration efforts, which was attributed to the model being overly dissipative in that portion of the model.

6 Results and Discussion

Analysis of the model results and comparison between the channel alternatives focused on the channel area, primarily with respect to current speed. Current velocity is expected to be a driver of changes to sedimentation and shoaling which this modeling effort targets to investigate. The analysis focused on two key parameters: (1) peak current speed along the entire length of the channel and (2) time series of velocity along the channel to compare any trends and isolate flood and ebb velocities for comparison. Both analyses are presented in this section.

6.1 Peak Current Velocity Along Channel Profile

Model results were extracted along the channel centerline at 100 ft intervals. The first 24 hours of model results were removed from the 11.5-day time series so that irregularities during the model equilibration period did not influence the results. The maximum current speed in the remaining time series was then extracted and plotted along the length of the channel for each of the channel configurations modeled.

The peak velocities along the channel centerline for the EC, FWOP, and FWPFB are shown in Figure 6-1. As discussed in Section 4.1, the model is depth averaged and therefore does not resolve the variation of the velocity with depth. The upper subplot shows the maximum current velocity along the channel centerline for the EC, FWOP, and FWPFB conditions. The horizontal axis represents the channel stationing progressing from offshore to inshore (left to right) including the Sabine Pass Channel (Station 0+000) to the Neches River Channel (Station 800+00). The regions within Figure 6-1 that are highlighted “grey” represent the sections of channel that were widened. The lower subplot in Figure 6-1 represents the difference in maximum current velocities between modeled channel configurations along the channel centerline. Comparisons include FWOP-EC and FWPFB-FWOP, where positive values indicate the peak velocity is expected to increase for deepening or widening channel improvements (i.e. the first and second comparisons). Alternatively, negative values in the lower subplot indicate a decrease in peak velocity for the deepening or widening improvements. This peak velocity analysis does not differentiate between flood and ebb. Based on the time series analysis presented in Section 6.2, it appears peak velocities are mostly associated with ebb tide.

The maximum current velocities along the channel centerline follow the same general trend for channel configurations modeled in runs 1, 2, and 3. Overall, the fastest currents (depth averaged) in the channel were approximately 1 m/s and these currents followed a decreasing trend moving inland away from the Gulf. However, there are isolated locations of faster and slower currents. In general, the fastest currents are in areas where the channel is more constricted, such as the Port Arthur Canal, and the slower currents occur where the waterway opens up beyond the channel limits, such as where the Sabine-Neches Canal extends past Pleasure Island and opens into Sabine Lake. North of Sabine Lake the currents are significantly slower, likely associated with the smaller tidal prism.

Reviewing the lower subplot in Figure 6-1, the results show small differences between the channel configurations. The largest difference is approximately 0.2 m/s, but in general the differences are typically 0.1 m/s and less. Qualitatively, this difference is relatively small. Comparing the FWOP and FWPFB, the current speeds increase for the FWPFB where the channel was not widened, and decrease where the channel is widened (e.g., blue line in lower subplot is less than zero where widening occurred (grey areas on plots), and greater than zero where no widening occurred). This result is expected as the widened channel will slightly increase the overall volume entering and exiting the channel. Where the channel is widened the channel has a larger area to transfer the increased volume of water, thus the velocity is still less than without the widening. In the areas where widening is not proposed the channel cross-section remains the same, but the volume transfer increases, thus increasing the velocity. A small increase in velocity is also observed from EC to FWOP, but these changes have been evaluated in the 2011 FIS (USACE, 2011). Beyond the Sabine-Neches Canal the differences in velocity between the channel configurations are not discernable.

This same comparison was made for the Alternative 1, 2, and 3 and the results are shown in Figure 6-2. Results for the alternatives are similar to the results seen for the FWPFB. In general, changes to the uncalibrated current velocity do not increase more than 10 cm/s for the widened alternatives compared to FWOP. In locations where widening is proposed the uncalibrated velocity reduces by up to 20 cm/s due to the wider waterway. Note these results follow expected trends based on foundational hydrodynamics. Using these plots and an understanding of the system the proposed widening is not expected to have a noticeable impact on peak velocities in the channel.

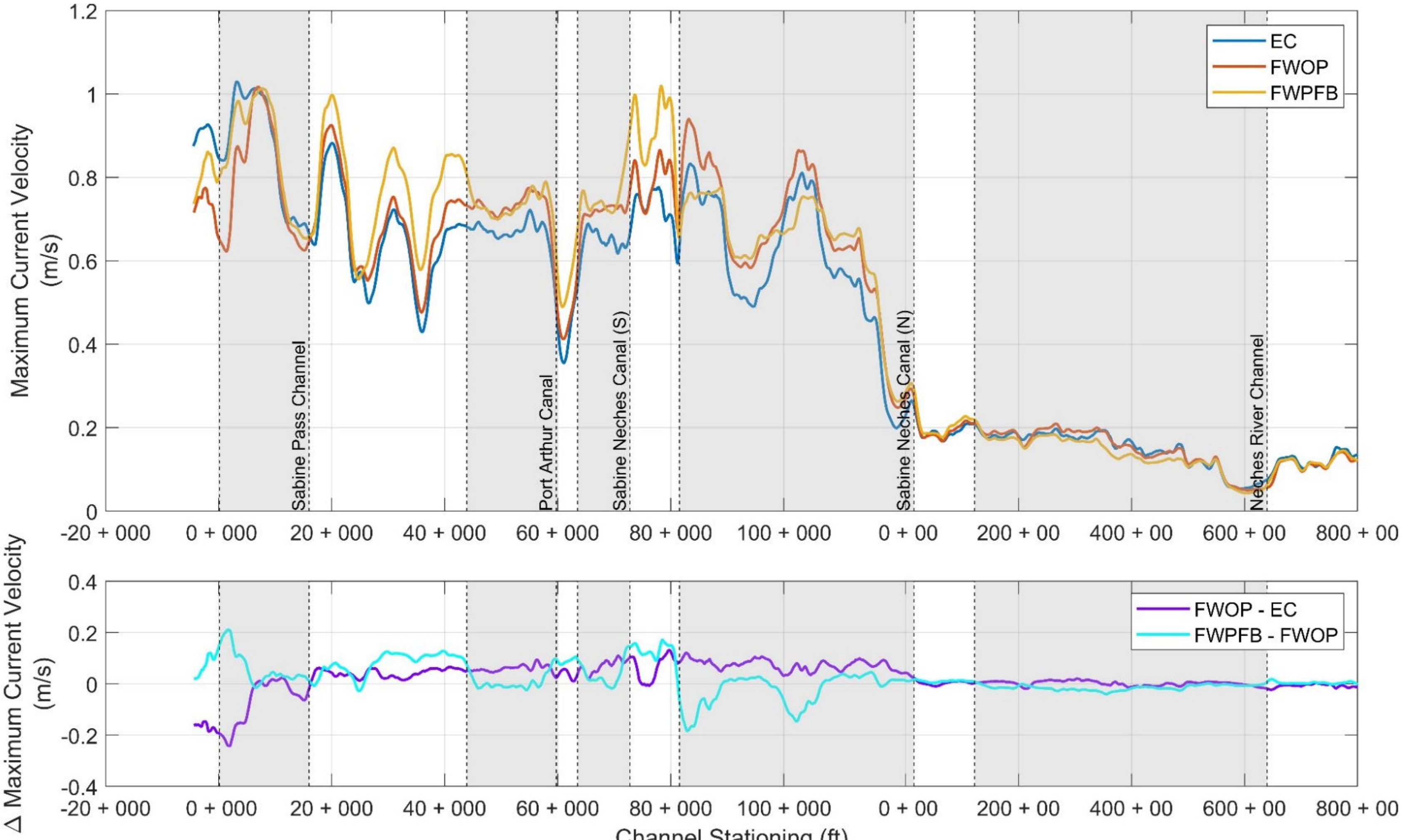

Figure 6-1

Modeled Maximum Current Velocity Comparison Along Channel Centerline for EC, FWOP, and FWPFB. Grey portions of the plot show areas of proposed widening in FWPFB

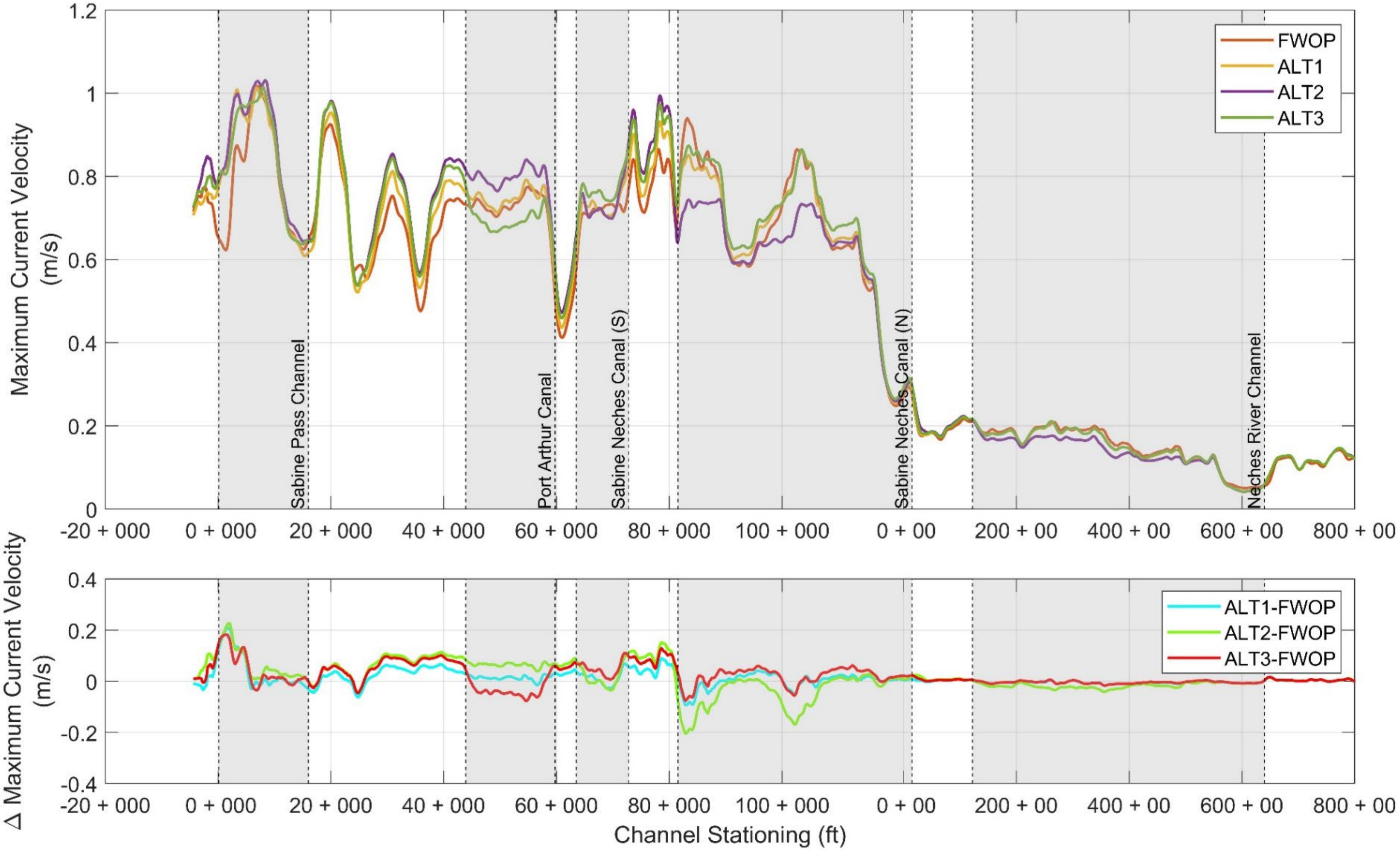

Figure 6-2
Modeled Maximum Current Velocity Comparison Along Channel Centerline for FWOP and Alt 1 to Alt 3. Grey portions of the plot show areas of proposed widening in FWPFB

6.2 Velocity Time Series Analysis

To further analyze potential velocity effects of the alternative designs, time series were extracted at 10 locations along the channel centerline as shown in Figure 6-3. The save point locations were selected to cover each of the channel widening sections, along with one control point outside of the channel widening (Station 32+500). Based on the direction of the current, the peak current velocity for both flood and ebb tide was determined at the 10 save point locations. The peak current velocities recorded at these save points are shown in

Table 6-1 and Table 6-2 for the flood tide and Table 6-3 and Table 6-4 for ebb tide, respectively. Difference calculations are tabulated for FWPFB-FWOP for all forcing boundary conditions (no wind, wind, and RSLC) and for FWOP-EC for the no wind runs.

The no wind results averaged across all 10 save point locations shows a 2 cm/s increase in peak current velocity from the EC to the FWOP design, and a 1 cm/s increase in peak current velocity from the FWOP to the FWPFB (see

Table 6-1 and Table 6-3). The same differences are present when looking at Alternatives 1 through 3 compared to FWOP in Table 6-2 and Table 6-4. Differences in current velocities between the widening alternatives and FWOP are higher at individual locations, although the difference is still considered minimal (with the greatest difference not exceeding 0.16 m/s). For the FWOP-EC comparison, Station 5+000 with closest proximity to the open Gulf of Mexico decreased, while the stations further inland increased. The opposite is generally true for the FWPFB-FWOP comparisons, where the three stations closest to the open Gulf increased, while the stations further inland decreased. The reduction in peak velocities for a wider channel is a similar phenomenon as observed in Figure 6-1, where the peak velocity decreased in the less constricted portions of the SNWW.

Also provided in

Table 6-1 (flood tide) and Table 6-3 (ebb tide) are the peak save point velocities for the model runs that included wind and RSLC. The main reason for comparing the wind and RSLC runs is the relative differences between the FWOP and FWPFB conditions which do not change. The results show almost no change at individual save points and on average for the modeled peak current magnitudes when including the 5 m/s SSE wind for both FWOP and FWPFB. For the RSLC runs, there is a small increase in peak velocities for both FWOP and FWPFB compared to the without RSLC runs, however, the relative comparisons (FWPFB-FWOP) are very similar to the case without RSLC. In other words, RSLC will impact the region with higher water levels, but the impacts of RSLC do not seem to be affected by the channel widening.

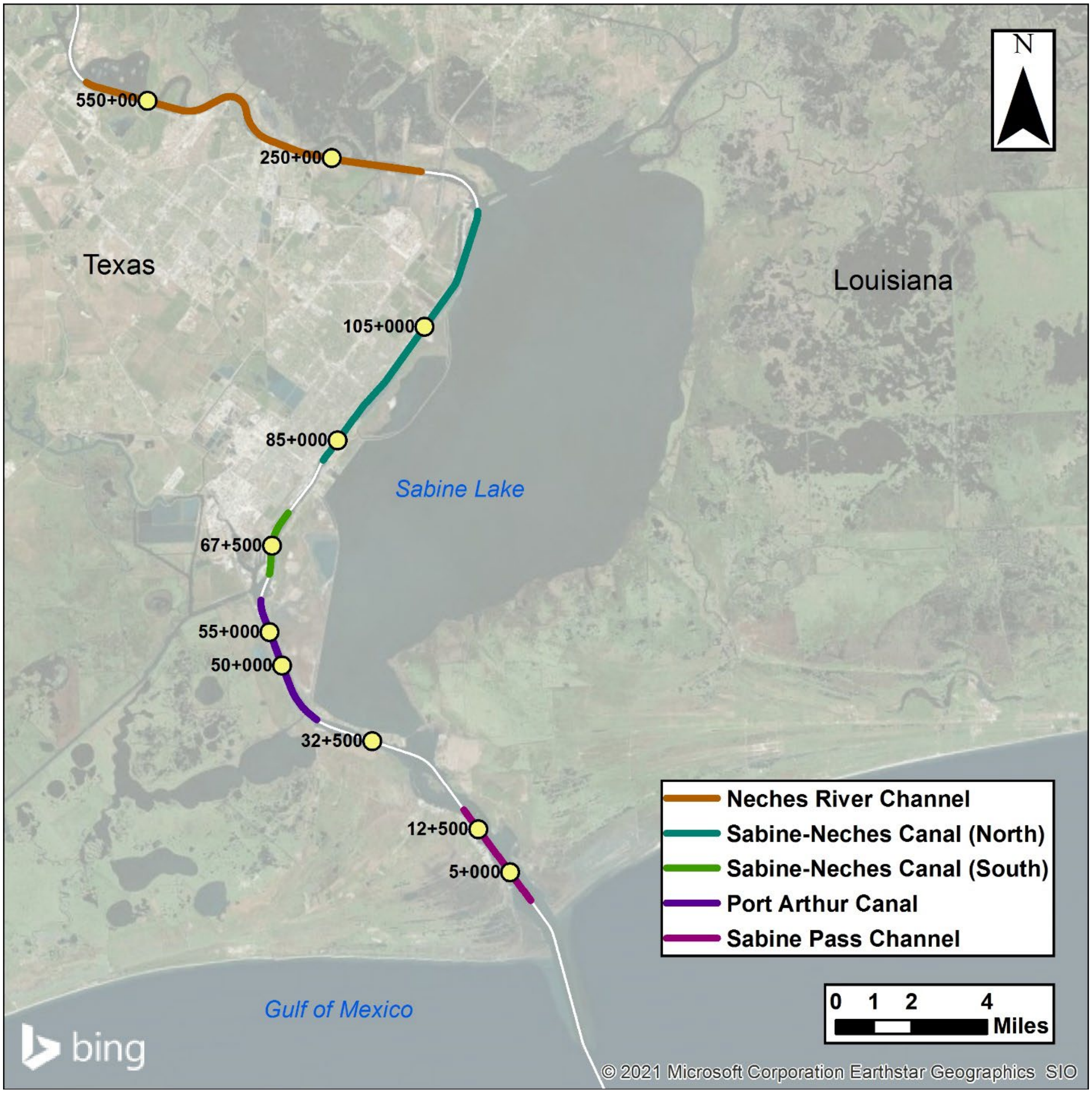

Figure 6-3
Model Save Point Locations Along SNWW Channel Centerline and Locations Considered for Widening

Note: 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.

Table 6-1
Modeled Peak Flood Current Speed for FWPFB

Reach	Station	Peak Flood (m/s)[1]										
		EC	FWOP	FWPFB	FWOP EC	FWPFB FWO	FWOP	FWPFB	FWPFB FWO	FWOP	FWPFB	FWPFB FWO
		No Wind					Wind			RSLC		
Sabine Pass Channel	**5+000**	0.63	0.52	0.64	-0.11	0.12	0.53	0.65	0.12	0.62	0.76	0.14
	12+500	0.51	0.52	0.55	0.01	0.03	0.52	0.54	0.02	0.62	0.70	0.08
Port Arthur Canal	**32+500**	0.50	0.53	0.63	0.03	0.10	0.52	0.62	0.10	0.67	0.67	0.00
	50+000	0.48	0.53	0.53	0.05	0.01	0.52	0.53	0.01	0.58	0.55	-0.02
	55+000	0.54	0.57	0.57	0.03	0.00	0.56	0.56	0.00	0.55	0.59	0.04
Neches Canal	**67+500**	0.51	0.53	0.55	0.03	0.01	0.53	0.54	0.01	0.59	0.54	-0.05
	85+000	0.58	0.65	0.57	0.08	-0.08	0.65	0.57	-0.08	0.52	0.57	0.05
	105+000	0.63	0.69	0.57	0.07	-0.12	0.68	0.57	-0.12	0.64	0.55	-0.08
Neches River Channel	**250+00**	0.10	0.11	0.10	0.01	0.00	0.10	0.10	0.00	0.25	0.25	0.00
	550+00	0.06	0.06	0.06	0.00	-0.01	0.06	0.05	0.00	0.18	0.15	-0.04
Average		**0.45**	**0.47**	**0.48**	**0.02**	**0.01**	**0.47**	**0.47**	**0.00**	**0.52**	**0.54**	**0.01**

[1] Results to the hundredth decimal place are to illustrate small differences and do not necessarily represent significant digits as velocity is uncalibrated.

Table 6-2
Modeled Peak Flood Current Speed for Alternatives.

Reach	Station	Peak Flood (m/s)[1]								
		FWOP	FWPFB	ALT1	ALT2	ALT3	FWPBFB - FWOP	ALT1 - FWOP	ALT2 - FWOP	ALT3 - FWOP
Sabine Pass Channel	**5+000**	0.52	0.64	0.68	0.67	0.66	0.12	0.16	0.15	0.14
	12+500	0.52	0.55	0.53	0.54	0.54	0.03	0.01	0.02	0.02
Port Arthur Canal	**32+500**	0.53	0.63	0.57	0.62	0.61	0.10	0.04	0.09	0.08
	50+000	0.53	0.53	0.54	0.59	0.50	0.01	0.01	0.06	-0.03
	55+000	0.57	0.57	0.59	0.64	0.52	0.00	0.02	0.07	-0.05
Neches Canal	**67+500**	0.53	0.55	0.53	0.53	0.56	0.01	0.00	0.00	0.03
	85+000	0.65	0.57	0.62	0.55	0.64	-0.08	-0.03	-0.10	-0.02
	105+000	0.69	0.57	0.67	0.56	0.66	-0.12	-0.03	-0.13	-0.03
Neches River Channel	**250+00**	0.11	0.10	0.11	0.10	0.11	0.00	0.00	-0.01	0.00
	550+00	0.06	0.06	0.06	0.06	0.06	-0.01	0.00	0.00	0.00
Average		**0.47**	**0.48**	**0.49**	**0.49**	**0.49**	**0.01**	**0.02**	**0.01**	**0.01**

[1] Results to the hundredth decimal place are to illustrate small differences and do not necessarily represent significant digits as velocity is uncalibrated.

Table 6-3
Modeled Peak Ebb Current Speed for FWPFB

Reach	Station	Peak Ebb (m/s)[1]										
		EC	FWOP	FWPF B	FWOP -EC	FWPF B- FWOP	FWOP	FWPF B	FWPF B- FWOP	FWOP	FWPF B	FWPF B- FWOP
		No Wind					Wind			RSLC		
Sabine Pass Channel	**5+000**	0.99	0.85	0.95	-0.14	0.11	0.84	0.95	0.11	1.03	1.15	0.13
	12+500	0.69	0.68	0.69	-0.01	0.01	0.67	0.69	0.01	1.03	0.84	-0.19
Port Arthur Canal	**32+500**	0.69	0.70	0.80	0.01	0.10	0.71	0.81	0.10	0.82	0.85	0.03
	50+000	0.66	0.71	0.70	0.05	-0.01	0.72	0.71	-0.01	0.75	0.68	-0.07
	55+000	0.72	0.78	0.77	0.05	-0.01	0.78	0.77	-0.01	0.70	0.73	0.03
Neches Canal	**67+500**	0.68	0.71	0.75	0.04	0.03	0.72	0.75	0.03	0.78	0.64	-0.14
	85+000	0.76	0.84	0.76	0.08	-0.08	0.85	0.77	-0.08	0.63	0.69	0.06
	105+000	0.80	0.84	0.75	0.04	-0.08	0.84	0.76	-0.08	0.73	0.65	-0.08
Neches River Channel	**250+00**	0.19	0.20	0.18	0.01	-0.02	0.20	0.19	-0.02	0.35	0.33	-0.01
	550+00	0.13	0.14	0.13	0.01	-0.01	0.14	0.13	-0.01	0.23	0.22	-0.01
Average		0.63	0.65	0.65	0.02	0.00	0.65	0.65	0.01	0.70	0.68	-0.02

[1] Results to the hundredth decimal place are to illustrate small differences and do not necessarily represent significant digits as velocity is uncalibrated.

Table 6-4
Modeled Peak Ebb Current Speed for Alternatives.

Reach	Station	Peak Ebb (m/s)[1]								
		FWOP	FWPFB	Alt 1	Alt 2	Alt 3	FWPBFB-FWOP	Alt 1-FWOP	Alt 2-FWOP	Alt 3-FWOP
Sabine Pass Channel	**5+000**	0.85	0.95	0.95	0.96	0.97	0.11	0.11	0.11	0.12
	12+500	0.68	0.69	0.66	0.69	0.66	0.01	-0.02	0.01	-0.02
Port Arthur Canal	**32+500**	0.70	0.80	0.74	0.79	0.78	0.10	0.04	0.09	0.08
	50+000	0.71	0.70	0.72	0.77	0.67	-0.01	0.00	0.05	-0.04
	55+000	0.78	0.77	0.78	0.83	0.70	-0.01	0.00	0.05	-0.08
Neches Canal	**67+500**	0.71	0.75	0.72	0.73	0.77	0.03	0.01	0.01	0.06
	85+000	0.84	0.76	0.82	0.73	0.86	-0.08	-0.02	-0.11	0.02
	105+000	0.84	0.75	0.83	0.73	0.83	-0.08	0.00	-0.10	-0.01
Neches River Channel	**250+00**	0.20	0.18	0.19	0.17	0.19	-0.02	-0.01	-0.03	0.00
	550+00	0.14	0.13	0.13	0.13	0.13	-0.01	-0.01	-0.01	-0.01
Average		0.65	0.65	0.66	0.65	0.66	0.00	0.01	0.01	0.01

[1] Results to the hundredth decimal place are to illustrate small differences and do not necessarily represent significant digits as velocity is uncalibrated.

A time series comparison of current speed (m/s) and current direction (degrees, clockwise from North) at Station 85+000 (Sabine-Neches Canal) for the model conditions without wind or RSLC is shown in Figure 6-4. The recorded data at Station 85+000 depicts the overall trends seen between the channel configurations well; with current velocities increasing from EC to FWOP, and then slightly decreasing from the FWOP to FWPFB conditions. The overall current velocities vary minimally (less than 0.1 m/s at the locations of greatest change).

The current direction is shown relative to the vertical axis on the right side of the figure. The intent of the figure is to illustrate changes between the FWOP and the FWPFB. In the figure, all of the dashed lines representing current direction overlay each other indicating there are no major changes to current direction between EC, FWOP, and FWPFB. There is one location at approximately hour 168 where current direction in the FWOP and FWPB vary from each other and the existing condition model run. This occurs at a slack tide when the current speeds are less than 10 cm/s and the tide is switching. This change in direction is therefore not significant as the velocity at the time is minimal and will not impact sediment transport or vessel navigation. Overall, there are no discernable changes to current direction.

Alternatives 1 through 3 are not shown in Figure 6-4 to improve figure clarity, but the results match that of the FWPFB with the current direction not changing for the widening alternatives.

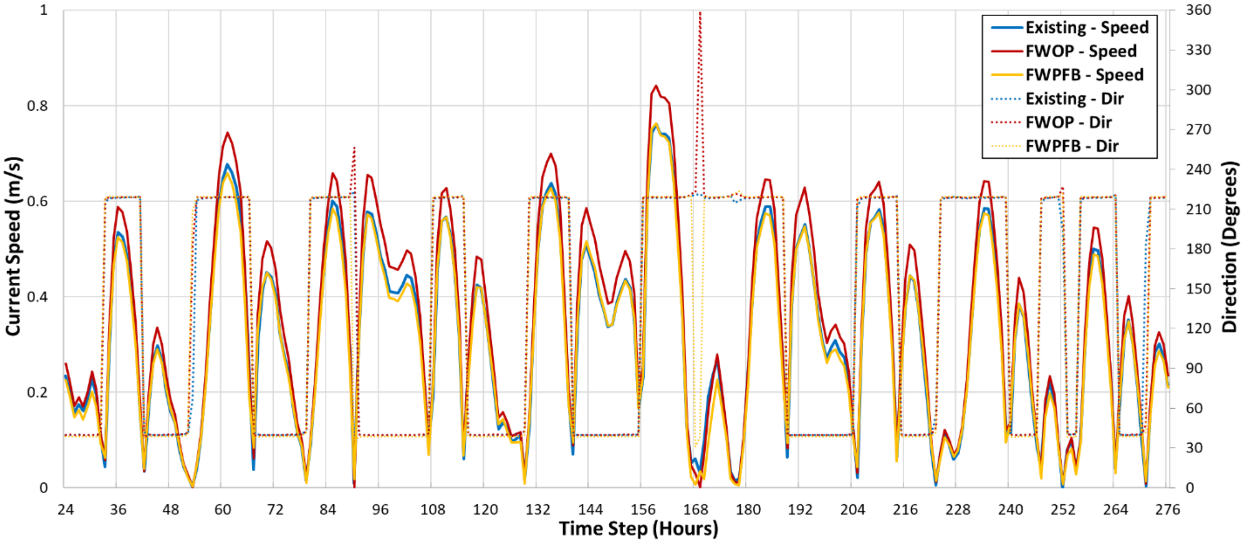

Figure 6-4
Modeled Current Speed and Direction (Station 85+000) – Base Conditions

A time series comparison of current speed and direction when wind was included is shown in Figure 6-5. The wind model was only performed for FWOP and FWPFB conditions, both of which are shown in the figure. The model results in Figure 6-5 (with wind) are consistent with the model results that did not include wind, with the current decreasing up to approximately 0.1 m/s from the FWOP to the FWPFB. It is also valuable to note the overall current is relatively constant in the models with and without a 5 m/s wind from the south-southeast. As seen in Figure 6-4, the dashed lines showing the current direction completely over lay each other, showing no significant difference in current direction between the modeled alternatives except for at approximately hour 168 where current direction in the FWOP and FWPB vary from each other and the existing condition model run. Same as the without wind conditions, this occurs at a slack tide when the current speeds are less than 10 cm/s and the tide is switching. This change in direction is therefore not significant as the velocity at the time is minimal and wont impact sediment transport or vessel navigation.

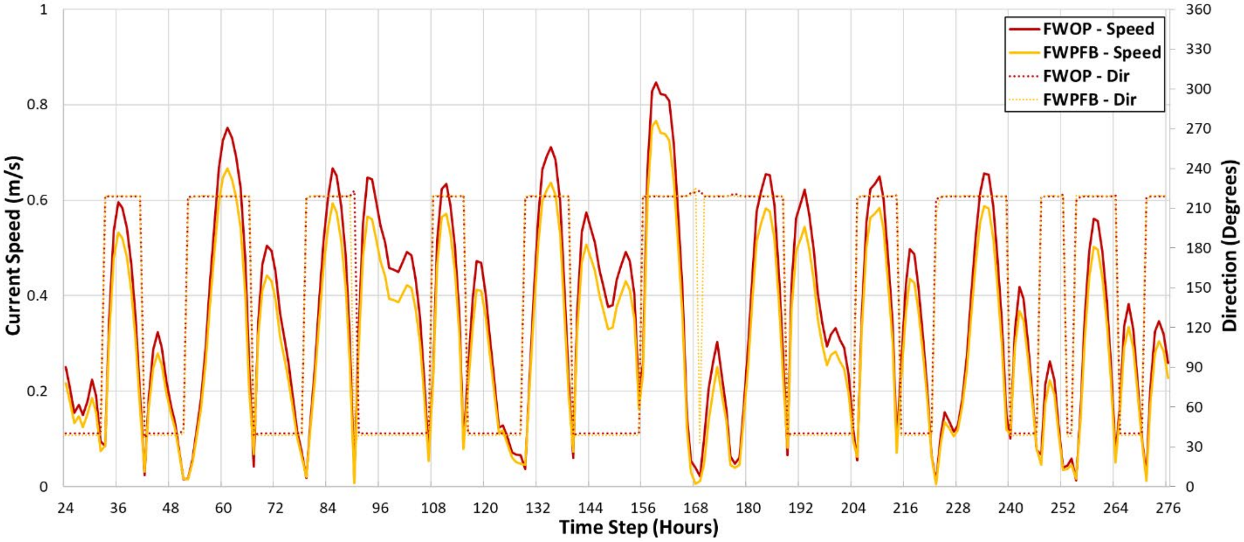

Figure 6-5
Modeled Current Speed and Direction (Station 85+000) – Wind Conditions

Similar to Figure 6-5, a time series comparison of current speed and direction when RSLC was included is shown in Figure 6-6. The RSLC model was only performed for FWOP and FWPFB conditions, both of which are shown in the figure. The model results in Figure 6-6 (with RSLC) are consistent with the model results that did not include RSLC, with the current speed decreasing up to approximately 0.1 m/s from the FWOP to the FWPFB.

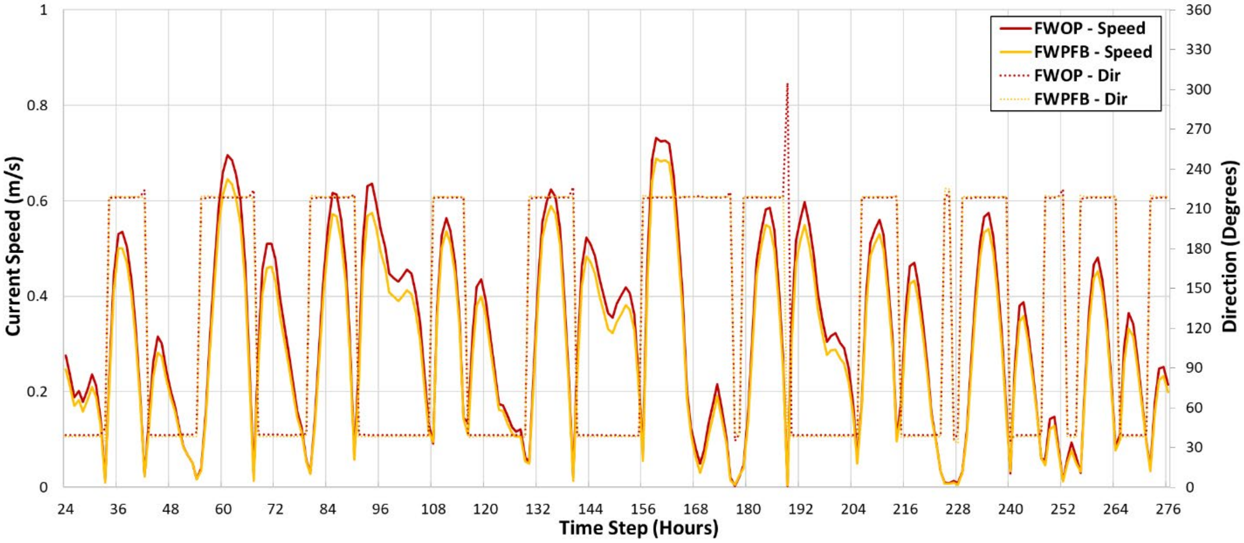

Figure 6-6
Modeled Current Speed and Direction (Station 85+000) – RSLC Conditions

6.3 Water Level Time Series Comparisons

WSEs were compared at the three NOAA stations within the model (Figure 4-2) to help identify any unexpected results. Refer to Figure 6-7 through Figure 6-9 for plots of the WSE recorded at NOAA stations for production runs (EC, FWOP, FWPFB, FWOP (Wind), FWPFB (Wind), FWOP (RSLC), FWPFB (RSLC)). Overall, the differences between WSE for FWOP, EC, and FWPFB without wind or RSLC is less than approximately 5 cm which is also less than the model RMSE. One interesting detail of Figure 6-8 and Figure 6-9 is that the runs with wind included better recreate the low water levels. Note there is minimal difference between FWOP with wind and FWPFB with wind. This could be an indication that the SE wind better drives the hydrodynamics inside the model, but the channel widening still does not change the results qualitatively.

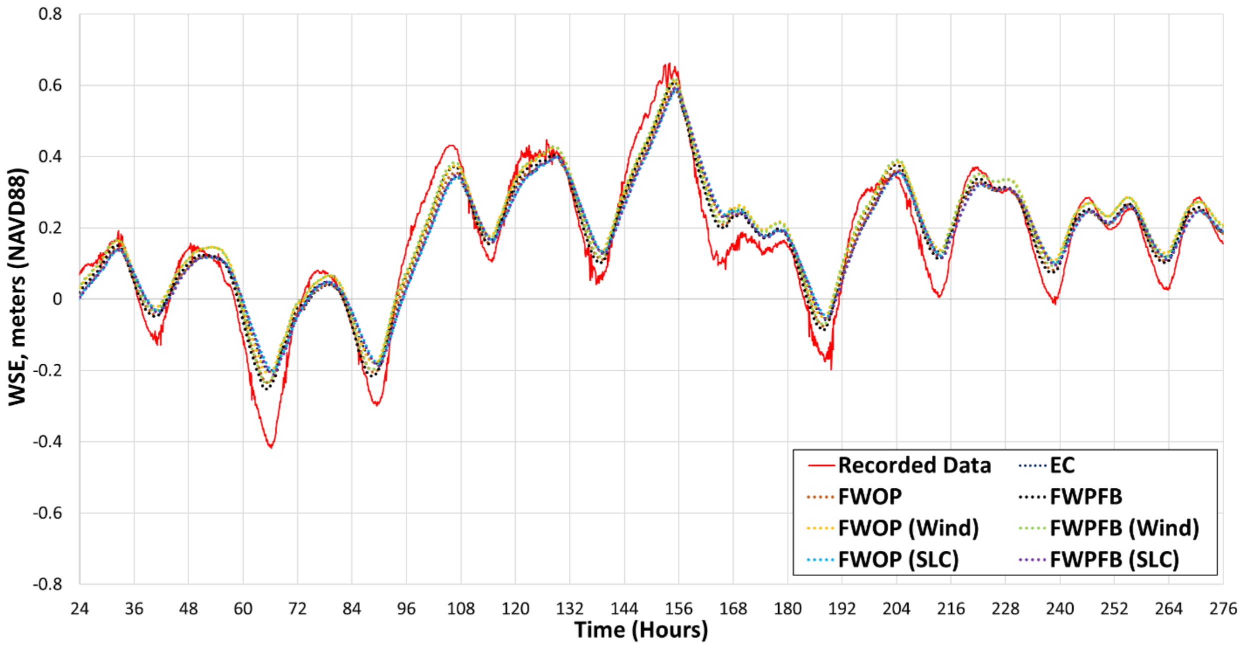

Figure 6-7
Model WSE comparisons for EC, FWOP, and FWPFB - NOAA Station 8770520 (Rainbow Bridge)

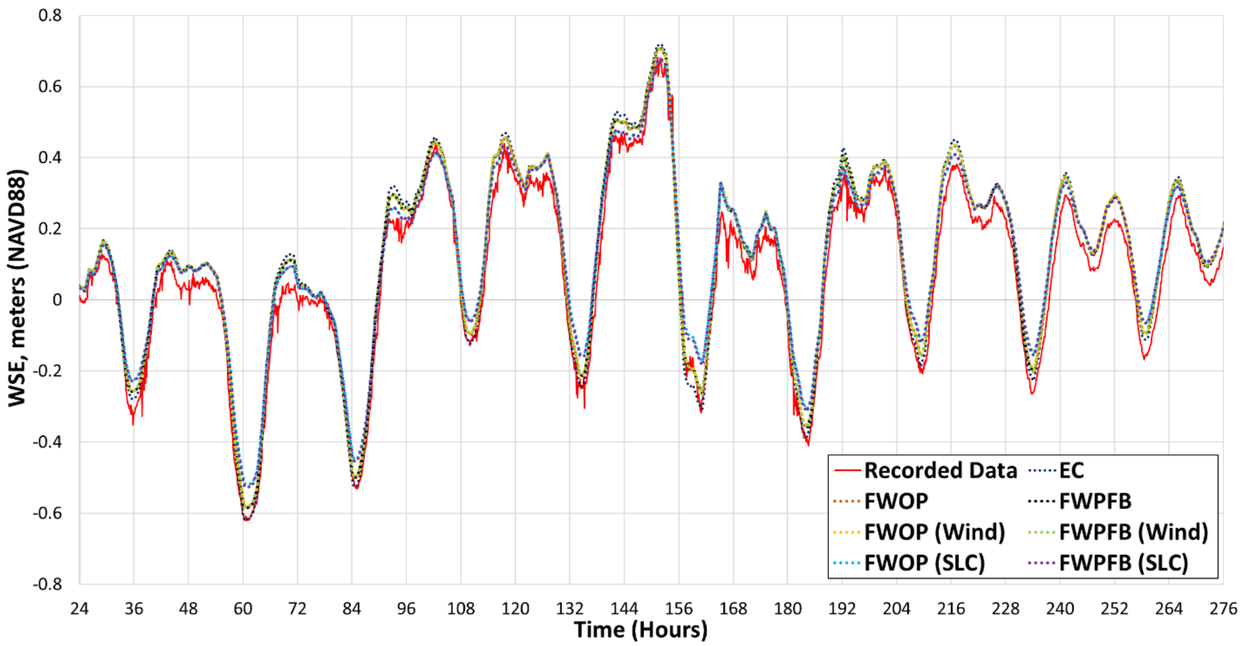

Figure 6-8
Model WSE comparisons for EC, FWOP, and FWPFB - NOAA Station 8770570 (Sabine Pass North)

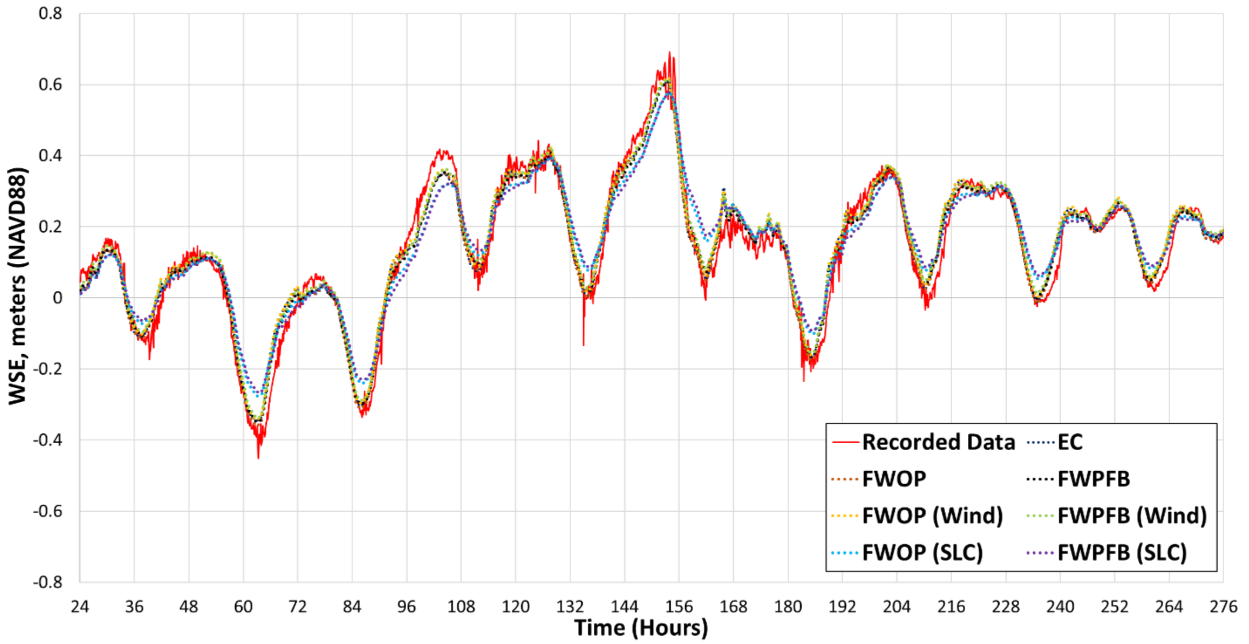

Figure 6-9
Model WSE comparisons for EC, FWOP, and FWPFB - NOAA Station 8770475 (Port Arthur Canal)

The same comparisons were made for Alternatives 1 through 3 and are shown in Figure 6-10 to Figure 6-12. Again, the results show small differences (less than approximately 0.03 m) between FWOP and any of the widening alternatives.

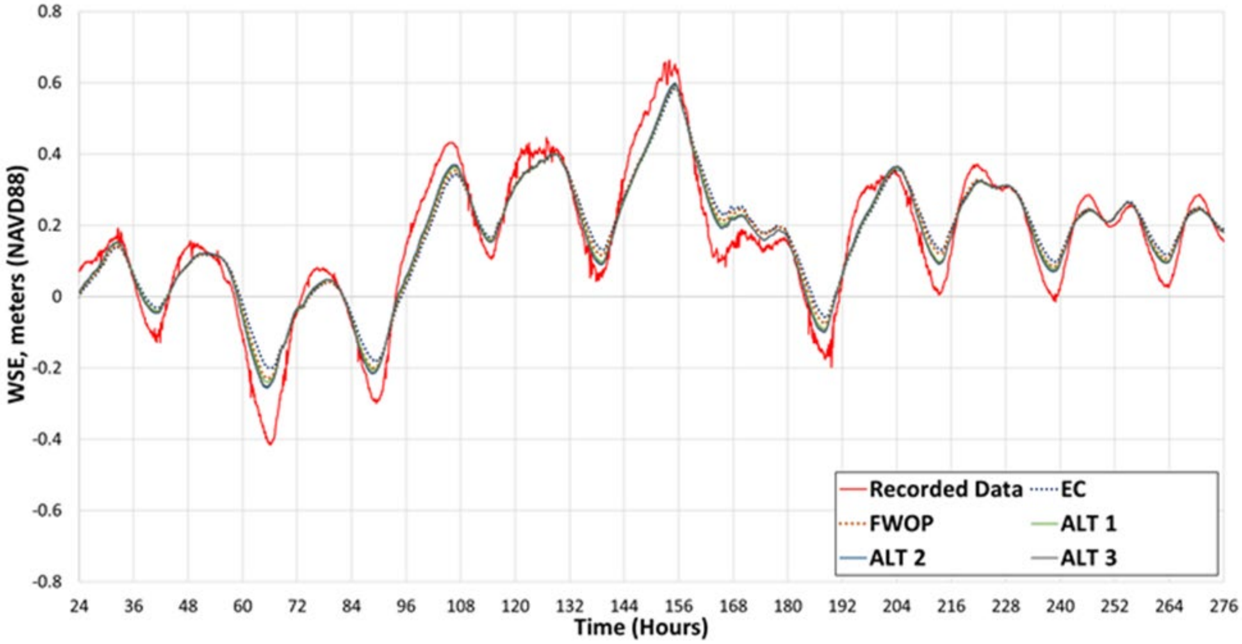

Figure 6-10
Model WSE comparisons for EC, FWOP, and Alternative 1 through 3 - NOAA Station 8770520 (Rainbow Bridge)

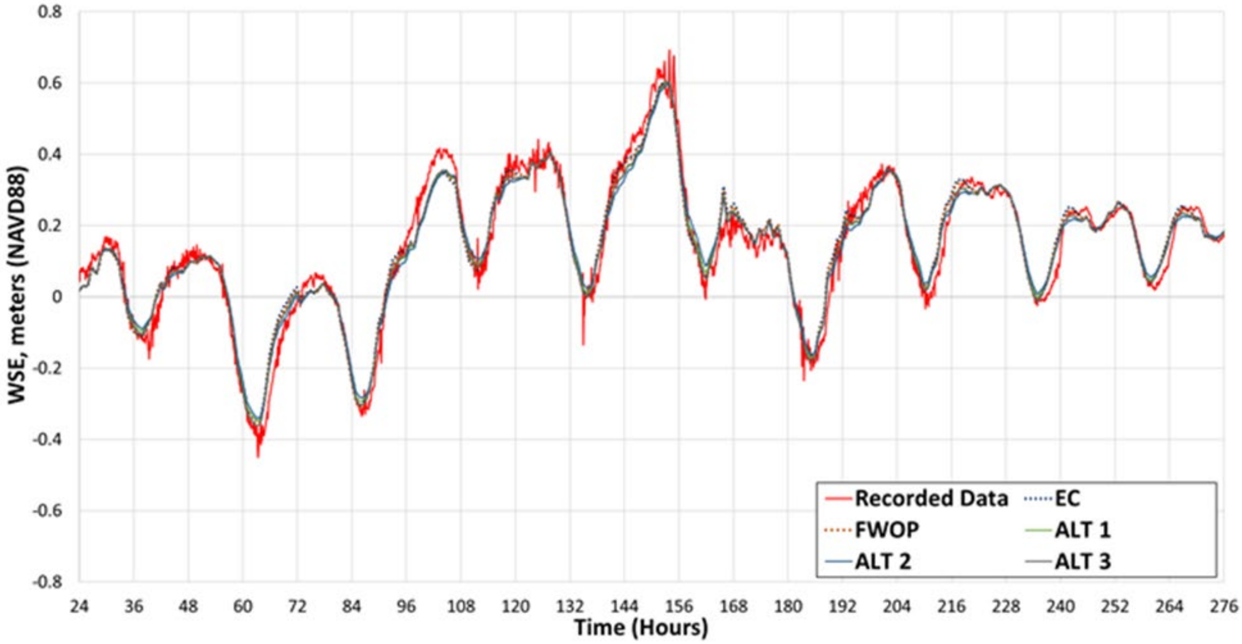

Figure 6-11
Model WSE comparisons for EC, FWOP, and Alternative 1 through 3 - NOAA Station 8770570 (Sabine Pass North)

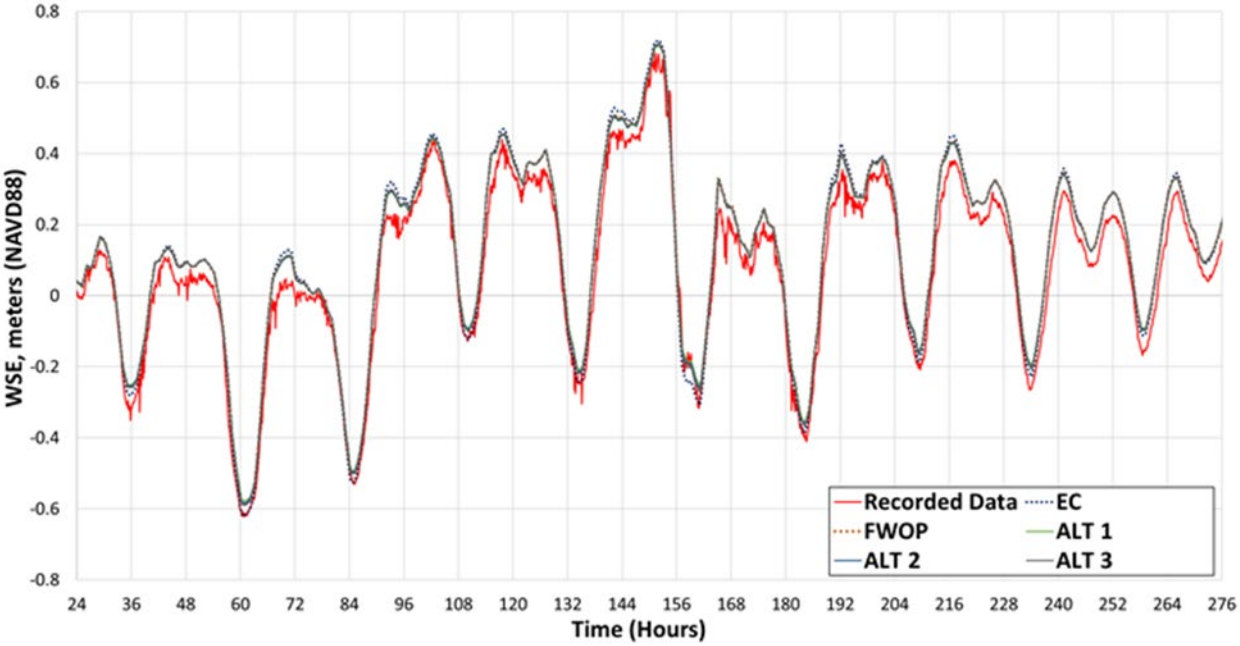

Figure 6-12
Model WSE comparisons for EC, FWOP, and Alternative 1 through 3 - NOAA Station 8770475 (Port Arthur Canal)

7 Conclusions

A series of MIKE 21 Flow Model HD FM model scenarios were developed to investigate the influence of widening portions of the SNWW channel on hydrodynamics associated with typical tidal activity. Model results for the EC, FWOP, and FWPFB conditions are compared based on peak absolute current velocity and peak flood and ebb current velocity and direction. Several additional simulations were also compared for future project alternatives and predicted relative sea level change and the effects of wind. The results from the modeling can be summarized as:

- The FWPFB model generally shows a small decrease in the maximum current speeds within the widened segments of the channel and a small increase in current speeds for areas that are not widened. This result is consistent for both flood and ebb tides.

- The inclusion of RSLC increased peak and average current speeds throughout the domains, but the relationship between the FWOP and FWPFB remained the same.

- Inclusion of a moderate wind in the model domain had little effect on the small differences between the FWOP and FWPFB model comparisons. Model runs with more extreme winds were not performed. Although faster winds may increase current velocities, the comparisons between FWOP and the widened channels is not expected to change.

- Unvalidated model tidal velocity results indicate that base-to-plan changes will be small, less than the model uncertainty bounds of 0.3 m/s.

In summary, small changes in current speeds due to the widening would not affect navigation or shoaling rates associated with the deepened channel. Additional shoaling in the widened areas would increase proportionally to the increase in cross-sectional area that occurs from the channel widening.

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