Corpus Christi Ship Channel Deepening Project: Approach to Assessing Project Impact

Prepared for

Port of Corpus Christi Authority (PCCA)

PORT CORPUS CHRISTI®

222 Power Street
Corpus Christi, Texas 78403

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AECOM
5444 Westheimer Road, Suite 400
Houston, Texas 77056
T 713.780.4100 | F 713.780.0838

CONTENTS

LIST OF FIGURES

LIST OF TABLES

PROJECT OVERVIEW

The Port of Corpus Christi Authority (PCCA) is requesting permit authorization from the U.S. Army Corps of Engineers (USACE) – Galveston District for the PCCA to conduct dredge and fill activities related to the deepening of a portion of the Corpus Christi Ship Channel (CCSC). The project would deepen the portion of the CCSC from Harbor Island into the Gulf of Mexico, an overall distance of approximately 13.8 miles (Station 110+00 to Station -620+00) as shown in Figure 1 below.

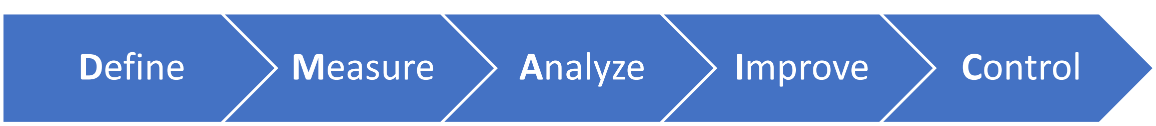
The proposed project is needed to accommodate transit of fully laden very large crude carriers (VLCCs) that draft approximately 70 feet. The deepening activities would be completed within the footprint of the authorized CCSC channel width. The proposed project does not include widening the channel; however, some minor incidental widening of the channel slopes is expected to meet side slope requirements and to maintain the stability of the channel. The project would generate approximately 46.3 million cubic yards (MCY) of new material.

On behalf of PCCA, AECOM has conducted a number of modeling studies to assess potential project impacts and to optimize the project design where needed. This analysis provides an in-depth review of the various models completed to date and the results achieved.

APPROACH

AECOM seeks to thoroughly examine its projects and plans through the lens of the community, engineering practices, environmental resiliency, and economic well-being. The Six Sigma standard endeavors through key performance metrics to lead to products that meet the high-quality standards that communities whom AECOM interacts with deserve. The utilization of this approach ultimately culminates in an environment where quality is the core tenet of every project, whether it's a building, treatment plant, or port development.

This review will utilize the Six Sigma approach known as DMAIC to summarize the modeling that AECOM has implemented in considering the Corpus Christi Ship Channel Deepening Project. DMAIC is an acronym for a list of steps that one should take to develop informed, refined solutions.



In reference to the modeling for the Corpus Christi Ship Channel Deepening DMAIC can be broken down into the following steps:

1. **Define:** PCCA has proposed the deepening of the CCSC from the Gulf of Mexico to Harbor Island up to a depth of -75 feet Mean Lower Low Water (MLLW). PCCA understands that this project may potentially directly or indirectly impact the community, environment, and economy. To address these concerns, PCCA has undertaken several outreach activities for the sake of transparency and environmental studies including several modeling efforts. For the sake of this analysis, we will focus on summarizing the modeling which addresses the environmental variables.

2. **Measure:** To determine what impacts this course of action could potentially have, specific variables or metrics must be identified as the measurement system with which the project outcomes will be evaluated. Validating a set of metrics and means of measuring changes is an important step in this process. The metrics modeled include tide, water velocity, shoaling, and salinity. These will be measured through well-established, proven models and methods.

3. **Analyze:** The results of the measurements are benchmarked against historical real-world data and thoroughly examined to determine the magnitude and effect of changes on the surrounding environment.

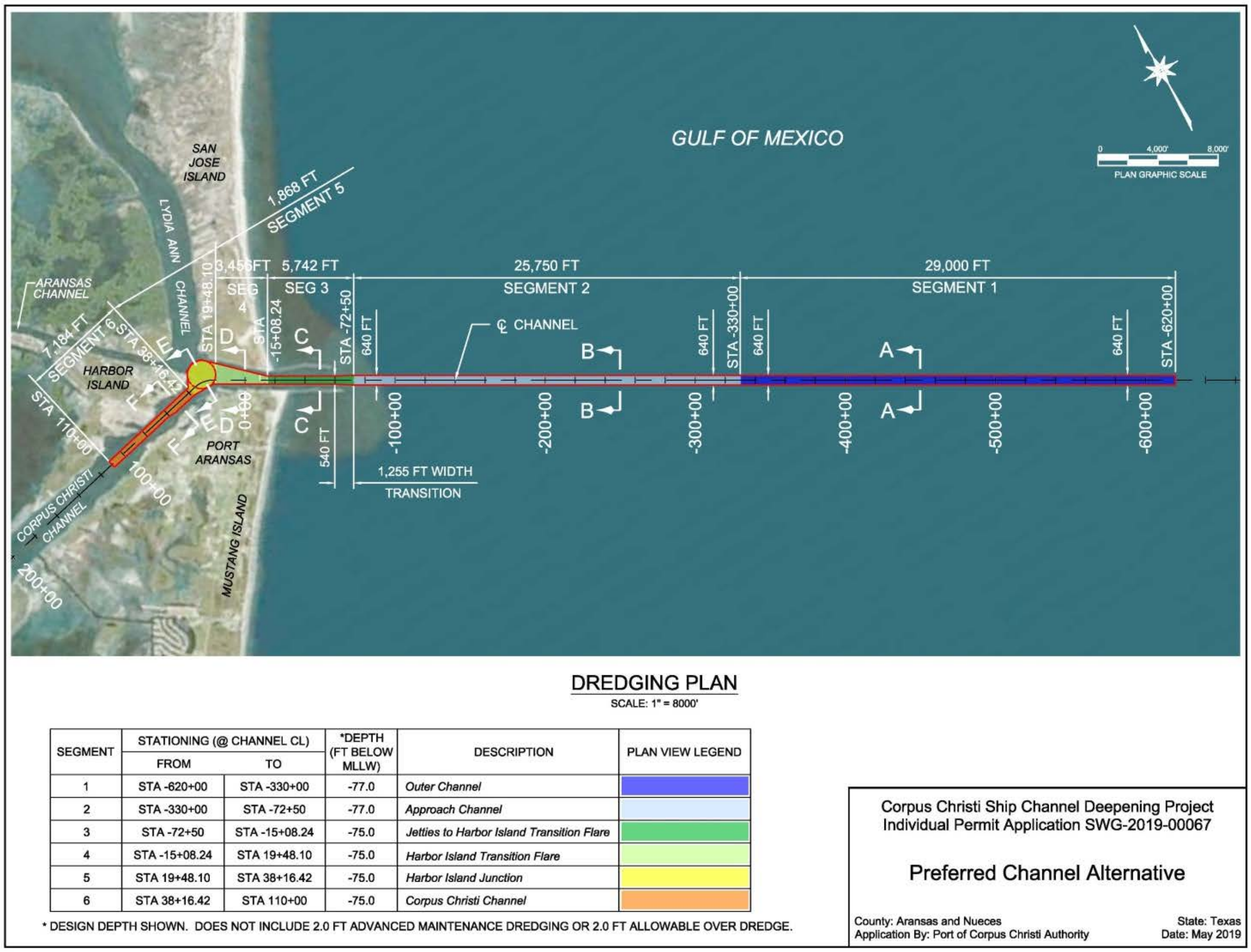
4. **Improve:** If the analysis identifies results or impacts which are deemed adverse then solutions must be created in order to avoid, minimize, or mitigate for those impacts.

5. **Control:** A feedback loop is formed through consistent and continuous monitoring which leads to process and product improvement.

DEFINE

The CCSC is currently authorized by the USACE to project depths of -54 feet and -56 feet Mean Lower Low Water (MLLW) from Station 110+00 to Station -330+00 as part of the Corpus Christi Ship Channel Improvement Project (CCSCIP). The currently authorized width of the CCSC is 600 feet inside the jetties and 700 feet in the entrance channel. The proposed project would deepen the channel from Station 110+00 to Station -72+50 to a maximum depth of -79 feet MLLW (-75 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge), and from Station -72+50 to Station -330+00, the channel would be deepened to a maximum depth of -81 feet MLLW (-77 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge). The project includes a 29,000-foot extension of the CCSC from Station -330+00 to Station -620+00 to a maximum depth of -81 MLLW (-77 feet MLLW plus two feet of advanced maintenance and two feet of allowable overdredge) to reach associated bathymetric contour in the Gulf of Mexico.

The Channel Deepening Project extents are shown below in Figure 1.



SEGMENT	STATIONING (@ CHANNEL CL) FROM	TO	*DEPTH (FT BELOW MLLW)	DESCRIPTION	PLAN VIEW LEGEND
1	STA -620+00	STA -330+00	-77.0	*Outer Channel*	
2	STA -330+00	STA -72+50	-77.0	*Approach Channel*	
3	STA -72+50	STA -15+08.24	-75.0	*Jetties to Harbor Island Transition Flare*	
4	STA -15+08.24	STA 19+48.10	-75.0	*Harbor Island Transition Flare*	
5	STA 19+48.10	STA 38+16.42	-75.0	*Harbor Island Junction*	
6	STA 38+16.42	STA 110+00	-75.0	*Corpus Christi Channel*	

* DESIGN DEPTH SHOWN. DOES NOT INCLUDE 2.0 FT ADVANCED MAINTENANCE DREDGING OR 2.0 FT ALLOWABLE OVER DREDGE.

Figure 1: Preferred Channel Alternative

<u>Model Mesh:</u> The Delft3D Model was utilized in multiple phases of the modeling efforts. AECOM selected a mesh (modeling extent) that encompasses and surpasses the reasonably expected impacted areas. The Delft3D model configuration was adopted from an existing TxBLEND model developed by the Texas Water Development Board (TWDB, 2011). TxBLEND is a version of the BLEND model, developed by Dr. William Gray of Notre Dame University, (Gray, 1987), which was modified by TWDB engineers for use in the shallow bays and estuaries of Texas. In Figure 2 below, the modeling extent is shown in blue.

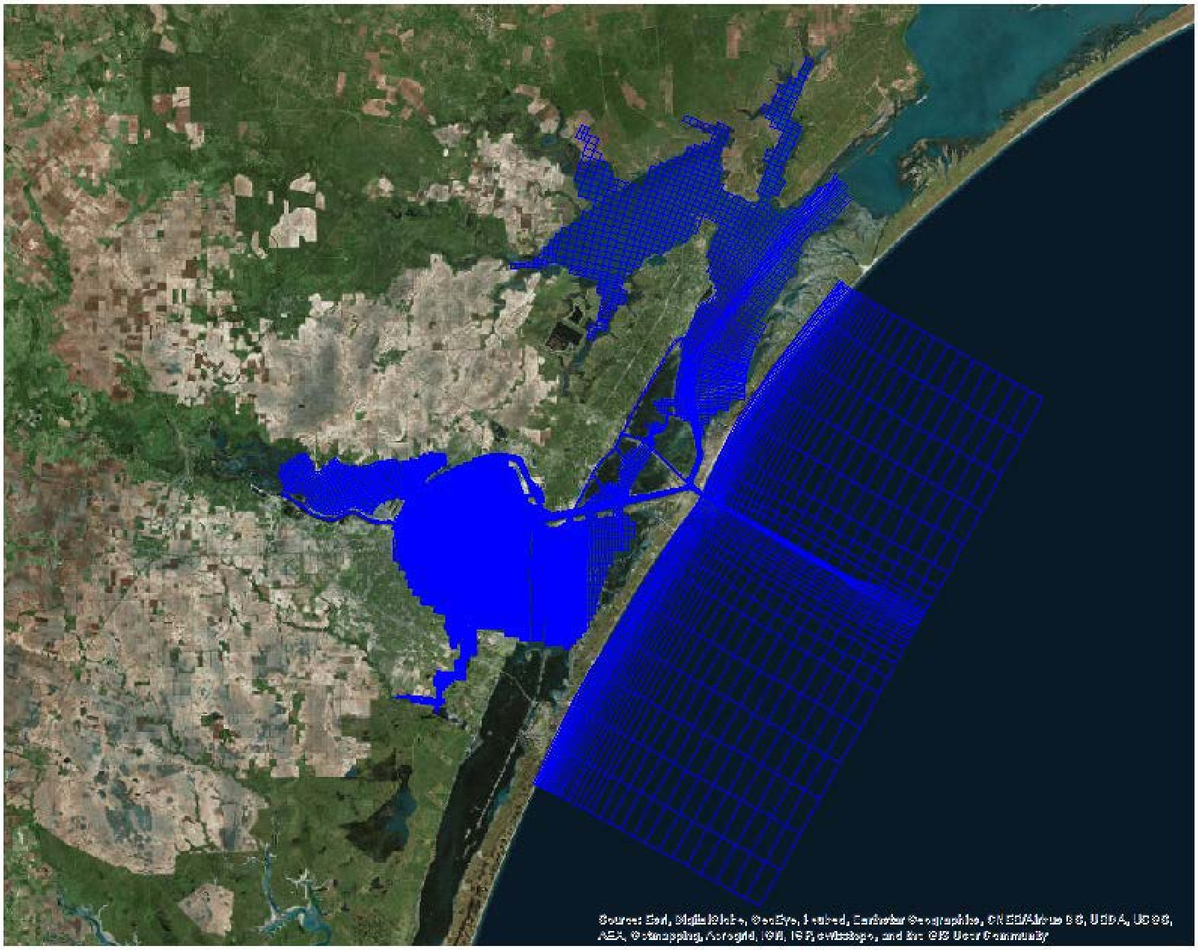


Figure 2: Delft3D Model Mesh

- **<u>Hydrodynamics:</u>** Tide and velocity are measured utilizing historical data as a benchmark and a well-established model known as the Delft3D model configuration. The use of an established model validates that the measurement system being used is well founded with a proven track record and will yield pertinent results.

- **<u>Shoaling:</u>** The amount of material that will infill the new channel profile is based on historical data as a benchmark and a well-established methodology of Rosati and Kraus (2009).

- **<u>Salinity:</u>** Salt levels are measured utilizing historic and collected data as a benchmark and the Delft3D model configuration. The use of this established model validates that the salinity measurement system being used is well founded and will yield pertinent results.

- **<u>Vessel Wake:</u>** Wake is a multifaceted variable which is explored by comparing the suspension of sediment on the shoreline as a result of the waves caused by a vessel moving through a body of water against the suspension of sediment caused by ambient conditions.

MEASURE

- **Hydrodynamics:**
  - The spring-tide range in the bay will increase from 4 percent to 12 percent. These increases equate to less than one inch for Redfish Bay and generally less than one-half inch for Aransas, Copano, Corpus Christi, and Nueces Bays.
  - The spring-tide tidal prism will increase by approximately 8 percent. The deeper channel has a larger cross-sectional area which allows more water to enter through the entrance channel.
  - The velocity magnitudes in the entrance channel will be lower.
    - The average speeds will decrease from 2.0 fps to 1.7 fps
    - The peak speeds during maximum spring tides will decrease from 5.0 fps to 4.4 fps.
  - The most notable change in maximum velocity magnitudes when comparing the difference between the FP (-75 ft/CIP2) and NP (-54 ft/CIP1) is at the inshore end of the project near the basin and along the CCSC.
    - These are likely due to the channel depth transitioning from -75 ft to -54 ft.
    - These are minor and relatively negligible changes to erosion and sediment transport.

- **Shoaling:**
  - Shoaling as a result of the channel deepening (Harbor Island to GOM) would increase by 399,000 CY per year.
  - The frequency of required maintenance dredging cycles to maintain the channel at the new depth would increase from one cycle every 2.5 years to one cycle every 1.9 years on average.
  - The vast majority of this shoaling would occur within the portion of the channel seaward of Harbor Island.

- **Salinity:**
  - The simulated differences in the average salinity range from 0.07 ppt to 0.38 ppt.
  - The differences in the maximum salinity range from 0.08 to 0.53 ppt.
  - The CDP impacts on the salinity relative to the CCSCIP in Corpus Christi Bay were assessed using the Delft3D modeling system (Deltares, 2010).
    - Delt3D can be applied to 2D or 3D modeling. The 2D application was utilized due to the shallow depth of the bay.
  - The Delft3D model configuration was adopted from an existing TxBLEND [2D] model developed by the Texas Water Development Board (TWDB, 2011) for the CCSCIP.
  - Since the bay system is relatively shallow and includes some relatively large freshwater inputs, it was assumed the salinity was fairly well mixed and relatively uniform through the water column.
    - To confirm this assumption, the Conrad Blucher Institute was conducted 3D temperature and salinity measurements in the bay and channels.
    - The results of these vertical profile measurements of salinity and temperature indicated fairly uniform conditions throughout the water column, even in the deeper channels.
    - This 3D data also confirmed that the 2D model was an appropriate approach.

- **Vessel Wake:**
  - Vessel wake can be broken down into two aspects for analysis
    - Bow Waves: the waves emanate from the front of the vessel as it cuts through the water.
    - Vessel Drawdown: the water that the vessel displaces flows under and around the stern producing a valley that moves with it and as the displaced water returns into the trough it generates a longer period wave. The wave created by drawdown will temporarily lower the water level along a shoreline and can expose additional areas of the shoreline to erosional forces. The drawdown can also induce significant flow speeds as it propagates from the channel across shallower banks.
  - These two components account for the waves that generally impact adjacent shorelines and are of primary interest, they will be considered at 10 observations points which span the entire ship channel and fall as close as 811 feet and as far as 4,700 feet away
  - The height of the waves created are an obvious metric but will not provide a full impact of characteristics as the shoreline may have armoring or bulkheads protecting sediment from direct impact.
  - For this reason, the impact of vessel wake will be measured by;
    - accounting for the number of vessel-originating waves that will occur (derived from vessel traffic analysis)
    - calculating the resulting net sediment transport which will be defined as annual sediment mobilized (cubic yards per yard), and
    - considering the number and impact of ambient waves for context.
  - Analysis of both the vessel-originating and ambient waves will be accomplished by using a comprehensive model extent that will encompass areas of potential impact.
  - The bow wave impacts are calculated using semi-empirical formulas developed by Sireli (2002). Sireli's equations are based on a summary of previous predictive formulas. The semi-empirical formulas were evaluated using full-scale vessel wake measurements (Nece, 1985) and laboratory-scale data (Sireli, 2002).
  - 10 years' worth of data was used to model the ambient waves and were sourced from the US Army Corps of Engineers Wave Information Study, Station ID 73040 (offshore waves) and National Oceanic and Atmospheric Administration, Station No. 8775792 (wind data for wind-driven shallow water waves).
  - These data sets were plugged into the well-established Coastal Modeling System (CMS) Wave model.

ANALYZE

- **Hydrodynamics:** A tidal increase of less than one inch for Redfish Bay and generally less than a one-half inch for Aransas, Copano, Corpus Christi, and Nueces Bays is not considered significant. This change is regarded as negligible as it represents a 4% to 12% increase in the tidal prism. As is evident on the tidal chart below, this increase has minimal impact on the observed tidal range for the area.

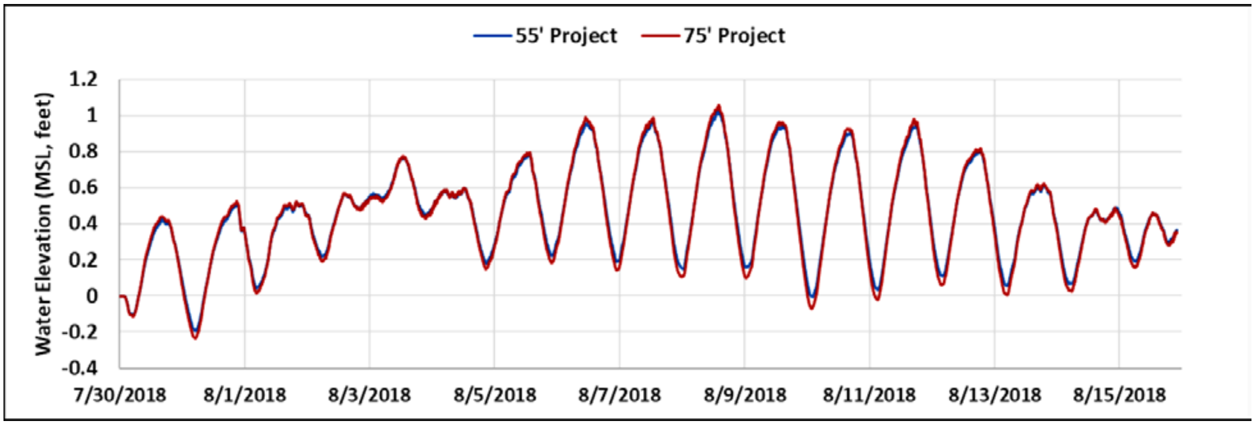


Figure 3: Comparison of Tidal Amplitude

Regarding the velocity, the average speeds will decrease from 2.0 to 1.7 feet per second and the peak speeds during maximum spring tides will decrease from 5.0 fps to 4.4 fps. This change is considered negligible as it represents a 12% and 14% decrease respectively. According to the chart below, this decrease in velocity is only most evident in the peak and trough ranges for the water velocity.

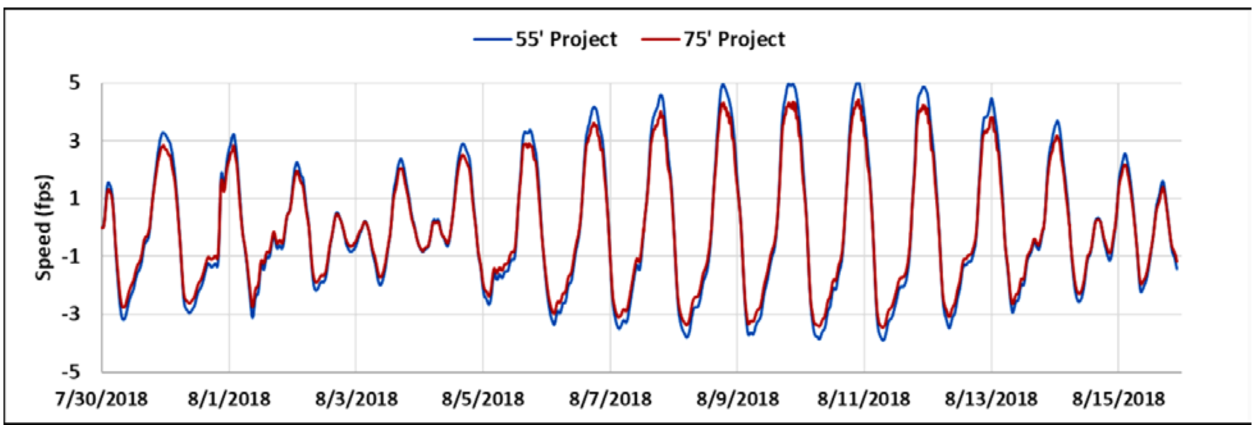


Figure 4: Comparison of Tidal Velocities

- **Shoaling:** The shoaling rate increase relative to historical shoaling rates is a factor of 2.7 for the ongoing 54-ft channel project and 2.7 for the proposed 75-ft channel deepening. This means that the shoaling rate will increase by 399,000 CY per year necessitating an increase in dredging maintenance cycle frequency to one cycle every 1.9 years on average. The increase in shoaling will be most readily observed in the area seaward of Harbor Island. This could lead to increased opportunity for Beneficial Use of Dredged Material Projects locally. This increased frequency in dredging is not viewed as a drastic increase, in comparison, the Brazos Island Harbor Channel between South Padre Island and Boca Chica has maintained a dredge frequency of every 12 months for the last 25 years. This consistent dredging has resulted in over 9.6 million cubic yards much of which has been used to nourish their beaches.

- **Salinity:** The salinity model results indicate that the average salinity levels will increase on the order of 0.07 to 0.38 ppt, and the maximum expected salinity levels increase is on the order of 0.08 to 0.53 ppt. The chart below shows the current average salinity range for the bays in the Corpus Christi area in blue and the maximum impact that the channel expansion project could have on this range in orange. The optimum salinity ranges of some of the most prolific aquatic flora and fauna have been overlaid. It does not appear that even if the maximum salinity impact were to occur that it would negatively impact these species.

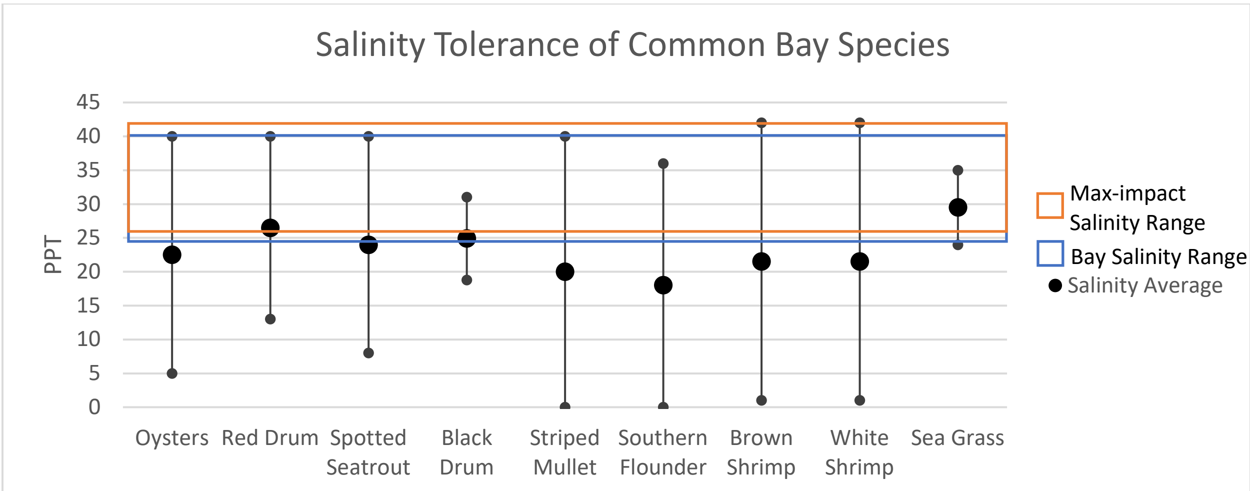


Figure 5: Salinity Tolerance of Common Bay Species

Vertical salinity stratification of bay waters is slight by estuarine standards, generally averaging less than 0.6 ppt/m. There is no apparent correlation between mean salinities and ship channels, suggesting that density currents as a mechanism of salinity intrusion are rarely significant in Corpus Christi Bay (Ward and Armstrong, 1997a).

o **<u>Vessel Wake</u>**: Concerning the bow waves the models and calculations show that the annual mobilized sediment due to the wind-driven (bayside, locations 6 - 10) ambient waves is approximately three orders of magnitude greater than that due to the vessel-originating waves. Another factor that contributes to the reduction in sediment mobilized is the reduction in vessel transits per year from 792 to 528 when comparing the -54-ft project to the -75-ft project respectively. The annual mobilized sediment due to the offshore-driven (GOM, location 1) ambient waves is significantly greater than that produced by the vessel bow waves, at 1,730 cy/y. The conclusion is that magnitudes of the annual mobilized sediment for the 54-foot channel and 75-foot channel scenarios are relatively small and will not likely yield significant shoreline change. The results of the vessel wake simulation have been depicted in both Table 1 and Figure 6. Table 1 compares the annual sediment volumes mobilized via vessel wake associated with both 54 and 75-foot depths. The ten locations listed in Table 1 are depicted in Figure 6 wherein a color ramp has been employed in order to depict the various water depths throughout the project area.

Table 1: Vessel Wake - Comparison of Annual Sediment Mobilized (CY/year)

Location	1	2	3	4	5	6	7	8	9	10
54-ft Project Vessels	0.015	0.026	0.007	0.017	0.009	0.006	0.008	0.005	0.006	0.008
75-ft Project Vessels	0.07	0.011	0.006	0.010	0.007	0.006	0.007	0.005	0.006	0.007
Ambient	1,730	-	-	-	-	1.17	1.47	1.52	1.76	0.93

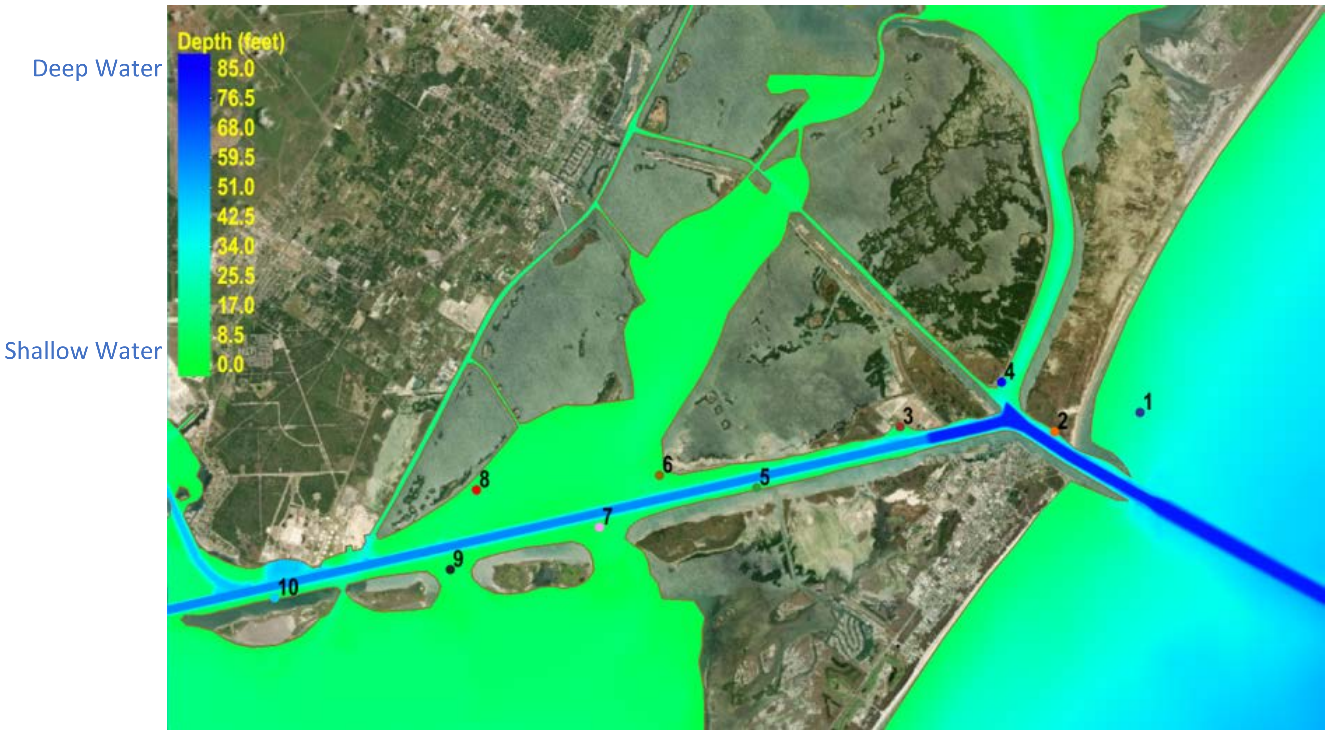


Figure 6: Vessel Wake Modeling Extents

To put the estimated mobilized sediment volumes in perspective, an estimate of the 'net' sediment removed (or added) for a one-foot change in the shoreline position has been calculated. Assuming a 10-degree slope for the shoreface extending 20 feet into the bay, the amount of sediment needed to shift the shoreface profile one foot landward or bayward is approximately 10 CY (per yard of shoreline).

For the vessel drawdown, the analysis of the drawdown impacts indicates that the total area impacted, summed over all transits, will increase slightly for the 75-foot channel when compared to the 54-foot channel. For some transits, the drawdown impacts actually decrease for the 75-foot channel due to the increases in the channel cross-section. The total area impacted, based on the drawdown wave wave-induced bottom stress exceeding the critical stress, is 4,823 acres for the 54-foot channel and 5,632 acres for the 75-foot channel.

IMPROVE

Based on the analyzed results, the recommended improvement for the project is to perform further validations as the project moves forward into the Pre-Construction Engineering and Design (PED) stage, the results described above will be maintained or further minimized.

CONTROL

To meet the goal set forth in the “improve” phase further planning, engineering, and assessment must occur with the utmost care to encompass potential variables and meet or exceed best practices. The control phase allows for the processes undertaken to be continuously enhanced and improved based upon the best available data.

Table 2: Summary of Modeling Results

Models	Changes between -75-ft Project (With Project Conditions) versus -54-ft Project (Without Project Conditions)
Hydrodynamic (Tides and Velocities)	• Average water velocities will decrease by 0.3 feet per second (fps) in the entrance channel. • Peak speeds during maximum spring tides will decrease by 0.6 fps in the entrance channel. • Spring-Tide range increases of less than 1.0 inch in Redfish Bay. • Spring-Tide range increases of less than 0.5 inch in Aransas, Copano, Corpus Christi, and Nueces Bays. • Spring-Tide tidal prism will increase by approximately 8 %.
Shoaling	• Maintenance dredging cycle frequency increases from one cycle per 2.5 years to one cycle per 1.9 years. • Estimated increase of 399,000 CY of maintenance material per year into the channel system.
Salinity	• Average salinity levels will increase on order of 0.07 to 0.38 ppt across the studied bays in the Corpus Christi area. • Maximum expected salinity levels increase on the order of 0.08 to 0.53 ppt across the studied bays in the Corpus Christi area.
Vessel Wake	• Impacted acreage of vessel drawdown wave-induced bottom stress exceeding the critical stress increases by approximately 17%. • Estimated reduction of 264 vessels per year.

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