CORPUS CHRISTI SHIP CHANNEL DEEPENING PROJECT: OVERVIEW & MODELING APPROACH TO ASSESS ENVIRONMENTAL IMPACTS

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The Corpus Christi Ship Channel in Texas connects the Port of Corpus Christi to the Gulf of Mexico. In 2020 the channel carried the third largest amount of tonnage in the United States and recorded a 35% increase in tonnage from 2019 (IWR 2021). The Port of Corpus Christi is the leading U.S. port for the export of crude oil, which has only been permitted since 2015, and the 13.5% total increase in crude oil exports for the U.S. has been a major driver for the Port's growth. The Port is seeking to deepen the Corpus Christi Ship Channel to 22.9m (75ft) nominal depth in order to allow fully loaded very large crude carriers (VLCC's) to access proposed terminals within the port complex.

As a part of the environmental coordination requirements of the National Environmental Policy Act (NEPA) the Port Authority prepared a number of studies to assess the potential environmental impacts of the proposed channel deepening. These included assessing changes in hydrodynamics, salinity, storm surge, and sedimentation patterns including sediment movement generated by vessel generated currents. The channel design was also verified through vessel maneuvering studies which were conducted using modeled currents, dynamic underkeel clearance assessment, and propeller scour potential determination. The fate of proposed beneficial use of dredged materials to construct a submerged beach berm and perform beach nourishment was also assessed.

A variety of models were used to assess these impacts and perform design verifications. The Danish Hydraulic Institute's (DHI's) MIKE3 model was used as the primary hydrodynamic and salinity transport model and the DHI MT and ST models were used for sediment transport. The impacts of the channel deepening on water levels, both tidal datums (Figure 1) and storm surge, was found to be greater than expected in the localized areas in vicinity of the jetties.

Figure 1 - Change in Mean Tide Range

Salinity changes were of particular importance. Portions of the Corpus Christi Bay complex are unique in that they often become hypersaline during summer months. The three-dimensional hydrodynamic and salinity transport modeling showed that, while there are short term impacts, the long-term changes are anticipated to be relatively minor (Figure 2). The model was also able to replicate the complex three-dimensional current patterns at the entrance channel jetties (Figure 3) which are critical for navigation of large vessels into and out of the port.

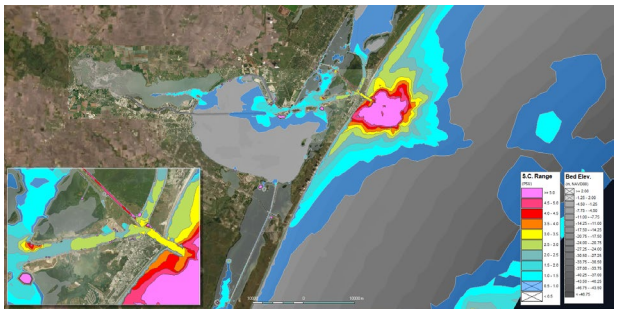

Figure 2 - Change in Salinity Range (Maximum minus Minimum Values)

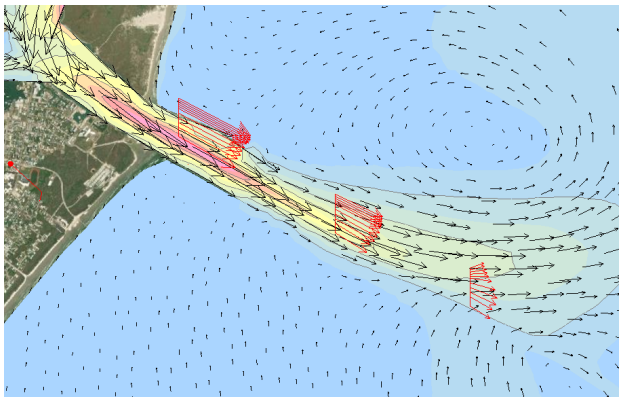

Figure 3 - 3D Currents in the Entrance Channel

The sediment transport models, which were calibrated with existing dredging records, were able to provide insight on expected future maintenance dredging requirements and showed that much of the increased expected dredging is due to the longer channel length offshore to reach deep water. The Corps Shoaling Analysis Tool (CSAT), developed by USACE, calculates channel shoaling volumes using historical channel surveys. The sedimentation model was calibrated and validated against the CSAT data which was divided into two periods for model calibration and model validation.

Figure 4 – Sediment Plume from Nueces Bay

Most sedimentation in Corpus Christi Bay occurs between the months of April and July. The predominant wind direction in the area is from 135 degrees (or southeast). Southeasterly winds and associated waves generated within Corpus Christi Bay are the key contributing factor to sediment resuspension in the northeastern part of Corpus Christi Bay and in Nueces Bay (Figure 4). This allowed us to establish a relationship between wind energy and sedimentation rate which was then used to predict long-term sedimentation rates and corresponding maintenance dredging needs.

Sedimentation in the outer channel is dominated by sand transport processes. Individual hurricane events (such as Hurricane Allen and Harvey) could result in sedimentation volumes in the outer channel that are several times higher than the average annual sedimentation. In contrast, the impact of hurricane on the inner channel sedimentation was found to be small. The impact of beach nourishment and dredge disposal mound on channel sedimentation were also investigated.

While the sediment in the inner bays is mostly muddy (i.e., silt and clay), the shorelines of Mustang and San José islands in the Gulf of Mexico, are predominantly sandy out to approximately the 15 m depth contour in the Gulf. In order to assess the fate of a proposed beneficial use of dredged material to create a submerged berm and nourish adjacent beaches. Several cross-shore evolution models were used to assess the stability of the beach nourishment and submerged berm. Additionally, a sediment budget tool, presented in a separate abstract, was created based on cross-shore and longshore sediment transport properties to estimate long-term evolution.

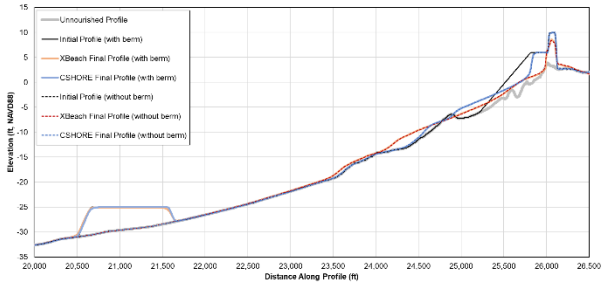

Figure 5 Modeled profile response to 2017 wave conditions including Hurricane Harvey

The propeller scour was assessed using the FLOW-3D model (Figure 6) for hydrodynamics and the scour potential was quantified using an analytical approach. Tug and VLCC generated propeller scour were evaluated to ensure potential erosion hotspots were identified and mitigated if necessary. The propeller operating parameters at critical locations were estimated based on a combination of vessel maneuvering simulation results and input from local pilots.

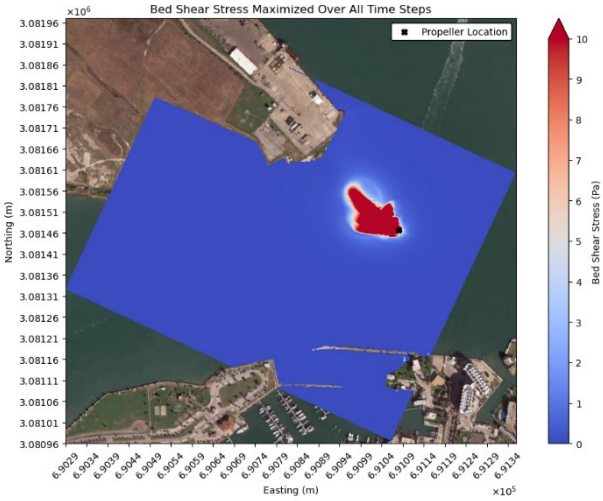

Figure 6 Maximum Bed Shear Stress for Tug Operations

Vessel generated currents and sediment transport impacts were modeled using a combination of FUNWAVE (Figure 7) and XBEACH, respectively, and is presented in a separate abstract. Sediment transport resulting from vessel generated hydrodynamics in the confined channel were also of concern and were modeled to verify the channel dimensions are adequate to minimize erosion impacts.

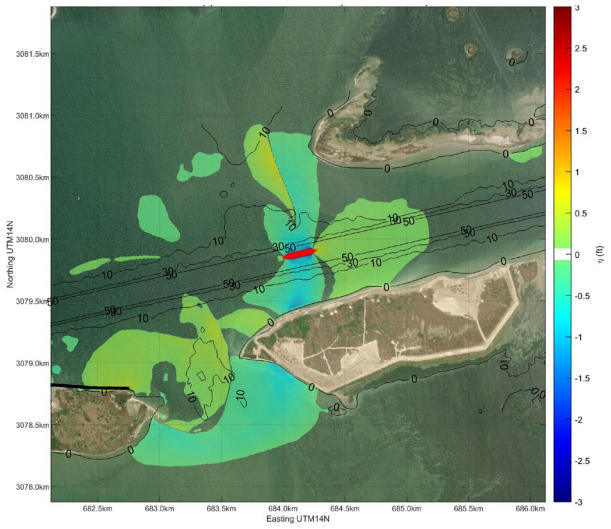

Figure 7 Example Primary Wave Field for an Outbound Suezmax Vessel

The Wavescat model was used to model dynamic underkeel clearance. The depth of the channel was verified including the effects of currents and wave-current interact in the jetty channel. The maximum expected squat and vessel response amplitude were used to verify the maximum draft vessels which can safely transit the channel as designed under varying tidal water level, current, and wave conditions.

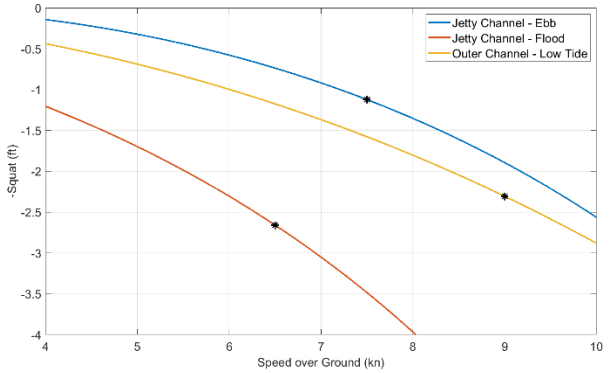

Figure 7 Modeled squat in the Jetty and Outer Channels; values used in the UKC assessment indicated with asterisks (*)

The models were also used to verify the design elements as well as environmental impacts. The integration of a variety of modeling tools, along with qualitative evaluations, was a critical part of the assessment of environmental impacts to the health and ecology of the unique Corpus Christi Bay complex.

REFERENCES

Institute of Water Resources (IWR) (2021): The U.S. Coastal and Inland Navigation System 2020 Transportation Facts & Information, https://www.iwr.usace.army.mil/About/Technical-Centers/WCSC-Waterborne-Commerce-Statistics-Center/.