Surge Sensitivity Analysis for Sabine Neches Water Way Navigation Project

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Surge Modeling for Sabine Project

Introduction

The work described in this report was performed for the Galveston District (SWG) by Coastal and Hydraulics Laboratory (CHL) staff. The purpose was to conduct a sensitivity analysis to determine what effect the Sabine Neches Water Way (SNWW) navigation project may have on surge levels in Port Arthur, Texas and the surrounding area. The navigation project consisted of channel deepening and the creation of several dredged material placement areas. The ADCIRC model was run to estimate water levels for two hypothetical storms with and without features of the proposed SNWW project in place. The base condition mesh is an extension of a mesh developed for the Louisiana coast and is consistent with a mesh under development that is being validated with Hurricane Ike. Validation is ongoing under a separate effort. Validation is outside the scope of this study. However, because the mesh has a high level of detail in the project area and the project features are well represented, the results provide a reasonable estimate of how peak water levels will be altered by the presence of the project. The mesh is considered satisfactory for sensitivity analysis purposes. Two storms selected from the existing storm suite developed for the Louisiana FEMA study were simulated and used for the sensitivity analysis. No statistical analysis was performed.

Storm Selection

Storms in the existing storm suite developed for the Louisiana FEMA study are appropriate for application in this study. Based on results of simulations run for the Louisiana FEMA study, approximate 100-yr and 500-yr still water levels were estimated for the Sabine project area on the Texas coast and are provided in Figure 1. It should be noted that the resolution of the Louisiana FEMA mesh in this area was coarse compared to that which was applied for this study. Therefore, the estimated 100-yr and 500-yr water levels provided in Figure 1 are only intended for the informational purpose of putting the sensitivity storms into a statistical water surface context and should not be taken as design levels or for any other purpose.

Two storms that produced water levels near or higher than the estimated 500-yr level were selected for simulation. It is expected that these storms will result in greater increases in surge levels than lower surge potential storms as they push a greater amount of water into the project area. Storm 208 is a hypothetical storm that tracked to the west of Port Arthur with a very low minimum central pressure of 900 mb, an offshore pressure radius of 14.9 nm, and a forward speed of 11 knots. This intense storm produced peak surges of approximately 13 to 16 ft in the Port Arthur, Texas area. Storm 269 is a hypothetical storm that tracked to the west of Port Arthur with a very low minimum central pressure of 900 mb, an offshore pressure radius of 18.4 nm, and a forward speed of 11 knots. This storm produced peak surges of approximately 15 to 17 ft in the Port Arthur, Texas area.

Figure 1. Approximate 100-yr and 500-yr still water levels in Sabine Lake based on simulations run for FEMA in Louisiana.

Mesh Modifications

ADCIRC storm surge simulations are made to determine the potential effects of planned placement areas on surge levels in the Port Arthur, Texas area. The base condition mesh is an extension of a mesh developed for the Louisiana coast. Westerink et al. (2008) and Bunya et al. (2009) document the development and validation of a high-resolution coupled riverine flow, tide, wind, wave, and storm surge model for South Louisiana that employs this base mesh. The peak water level predictions were validated with high water mark data from Hurricanes Katrina and Rita in Bunya et al. (2009). Bunya et al. (2009) documents that the estimated average absolute errors range for comparisons to data for Hurricane Katrina is between 0.26-0.27 m, and the estimated standard deviation of the errors is 0.37-0.43 m. For Hurricane Rita, the model average absolute errors range from 0.15-0.20 m with a standard deviation ranging from 0.28-0.35 m.

The mesh applied for this study is an extension of the Louisiana mesh with increased resolution in the Sabine Lake area. It is consistent with a mesh being validated under a separate effort, but validation in the project area has not yet been completed. Due to time and cost constraints, validation was outside the scope of this study. Only the surge

model is being run – not coupled surge and wave models. The eventual validated mesh is not expected to undergo significant revisions in the Sabine project area.

The mesh applied for this study has a high level of detail in the Sabine project area. Figure 2 shows the base condition bathymetry in the ADCIRC mesh with the placement areas outlined with black lines. The brown line in Figure 2 is a levee that surrounds Port Arthur on 3 sides, tying in with upland areas on the remaining (open) side. The levee elevation ranges from (14.2-24.2 ft (4.3 to 7.5 m), with the majority of the levee ranging from 15.4-17.7 ft (4.7-5.4 m). Figure 3 shows the with project ADCIRC mesh with the modified elevations for the placement areas. The post-construction elevations for these placement areas are listed in Table 1. Figures 4-6 show the placement areas overlaid onto Google Earth images to demonstrate the placement locations with aerial photography.

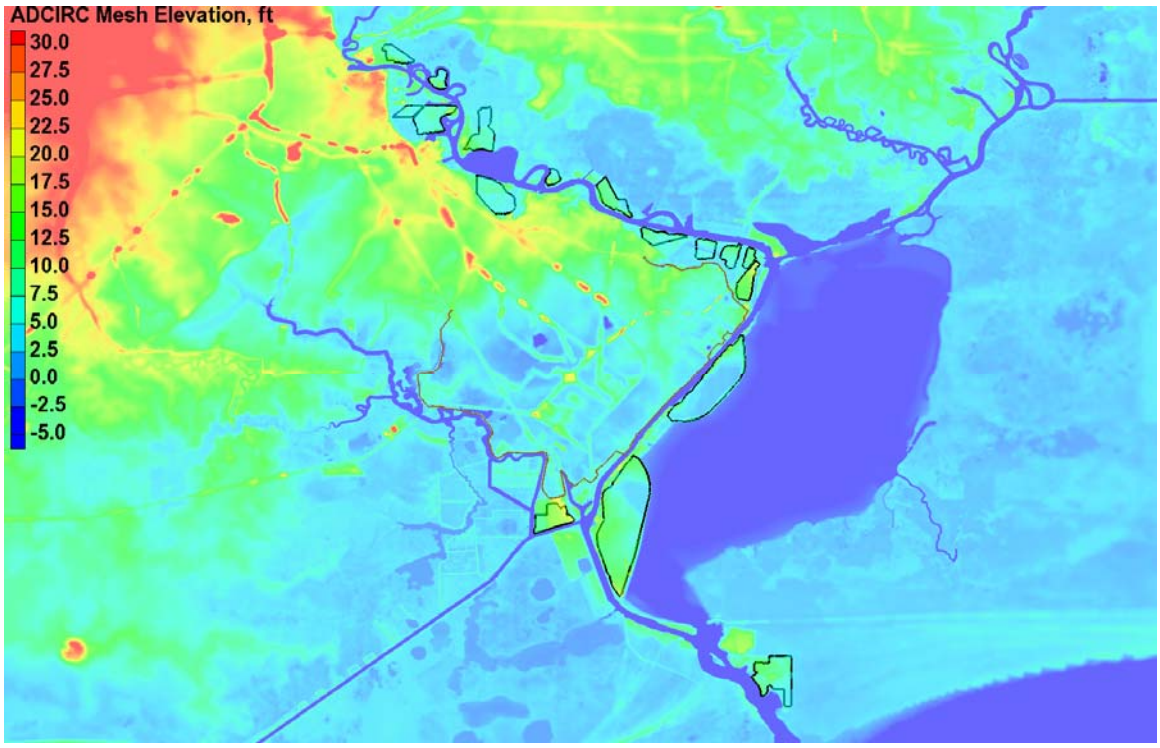

Figure 2. Existing conditions ADCIRC mesh with placement locations outlined in black.

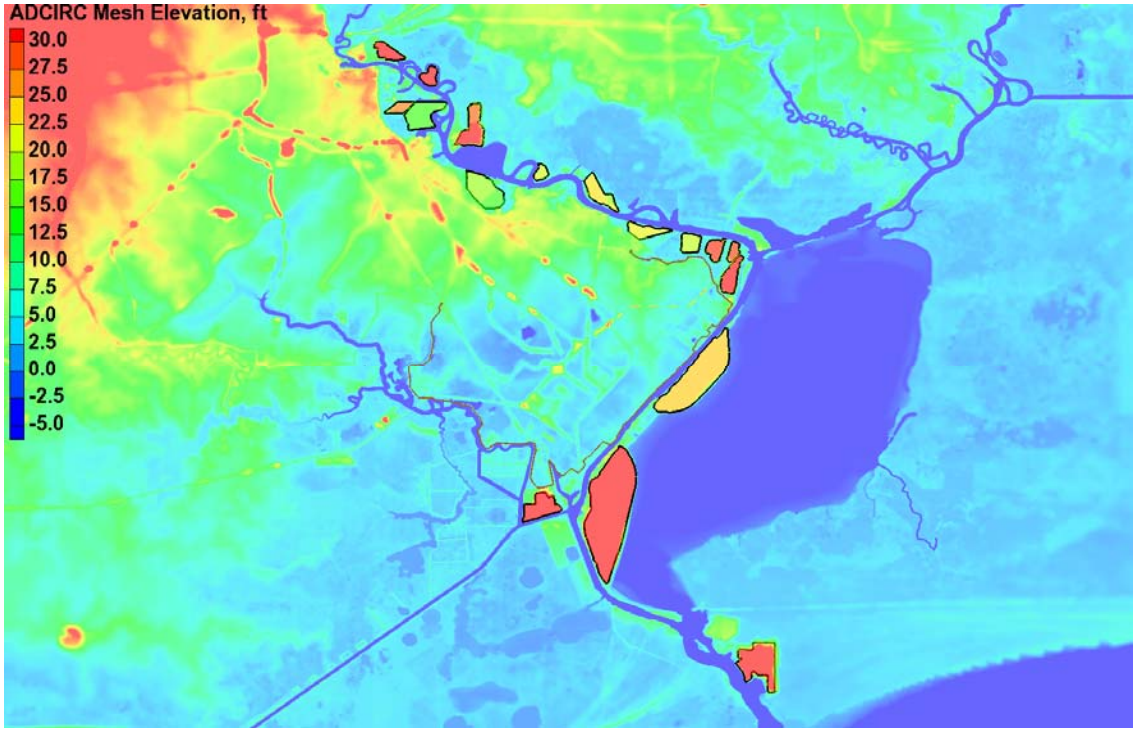

Figure 3. ADCIRC mesh with the planned placements.

Figure 4. Picture showing all of the Placement Locations.

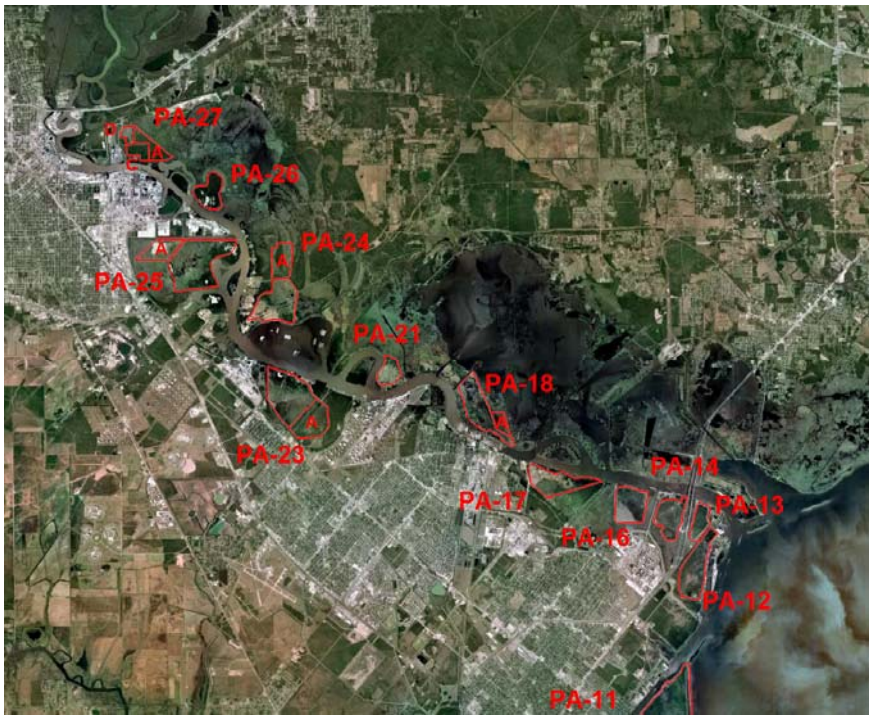

Figure 5. Zoomed in picture of the Placement Areas (north).

Figure 6. Zoomed in picture of the Placement Areas (south).

Table 1. Placement Area Elevations.

Placement Area	Final Elevation (ft)
PA-05	34
PA-08	41
PA-09	42
PA-09A	37
PA-11	23.2
PA-12	33.7
PA-13	28.5
PA-14	29
PA-16	19
PA-17	21
PA-18	22
PA-18A	17
PA-21	19.5
PA-23	17.5
PA-23A	14
PA-24	31
PA-24A	27
PA-25	14
PA-25A	26
PA-26	35
PA-27A	39
PA-27C	32
PA-27D	32

The "with project" ADCIRC mesh also included the proposed channel deepening. This consisted of deepening the current ship channel from 42 ft (12.8 m) to 52 ft (15.8 m). Note that 52 feet is an approximate average deepening. The planned deepening is variable along the channel length but the approximate average deepening was deemed adequate for performing storm surge sensitivity analyses. This deepening extended from the Gulf of Mexico to Beaumont, Texas.

Model Simulations

Storms 208 and 269 from the Louisiana FEMA suite were modeled with ADCIRC. The circulation model ADCIRC (Luettich et al. 1992, Westerink et al. 1994, Luettich and Westerink 2004) is run to compute the pressure- and wind-driven surge levels. ADCIRC is a two-dimensional, depth-integrated coastal ocean model. The model is formulated with the depth-averaged shallow water equations. The standard quadratic parameterization is applied for bottom stress and baroclinic terms and advection effects are neglected for this application. The ADCIRC model solves the defined governing equations with a finite-element algorithm. This algorithm allows for flexible spatial discretizations over the entire computational domain. The unstructured grid allows for larger elements in open ocean regions where less resolution is needed, whereas smaller elements can be applied in the nearshore and estuary areas where finer resolution is required to resolve hydrodynamic details and more accurately simulate storm surge propagation onto a complex coastal landscape.

ADCIRC estimates the water level across the entire grid at each time step. A time history of water levels can be saved at any grid location for the duration of a storm. To provide peak water levels, the entire spatial domain is examined every 15 minutes to determine if water levels exceeded the previous time steps maximum water level at each point in the domain. The result of this analysis is a maximum envelope of water level for a given simulation.

Storm 208

Storm 208 is a hypothetical storm with a very low minimum central pressure of 900 mb, an offshore pressure radius of 14.9 nm, and a forward speed of 11 knots. The storm approaches the coast on a track heading in a northwesterly direction (see Figure 7). The storm produces maximum surges of over 18 ft at the coast near Sabine Pass and surges of 13 to 14 ft in Sabine Lake near Port Arthur, Texas (see Figures 8 and 9). There is some flooding within Port Arthur for this storm, with and without the proposed project in place due to overtopping on the west side levee boundary where the peak surge (approximately 15-16 ft 4.5-5.0 m) exceeds the levee threshold (approximately 15.4 ft 4.7 m). Figure 10 is a difference in maximum surge level plot (with project – base condition). As seen in Figure 10, water levels in the placement areas are reduced compared to the base condition because raising the placement area levees prevents surge from inundating these areas. That is, the with-project levees are higher than the simulated surge level in these areas. There is little change in water levels outside the placement areas and no changes within the city. Increases in surge due to the proposed project are on the order of 8 in (0.2 m) or less. The greatest changes are north of Port Arthur along the Neches River. As seen in Figure 10, all changes are local in that water levels are only increased in the low-lying areas adjacent to the project features. Surge is not increased in Sabine Lake or areas further to the east.

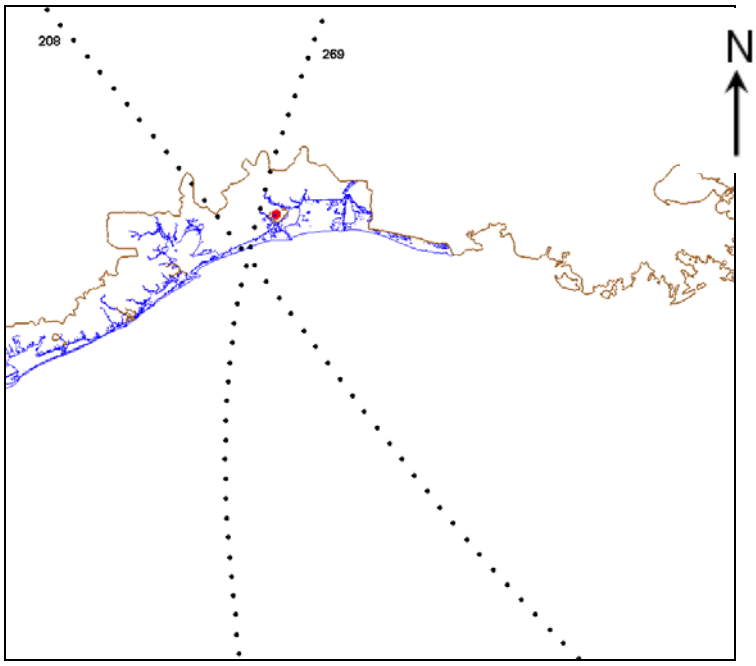

Figure 7. Storm tracks. The red dot indicates the project site.

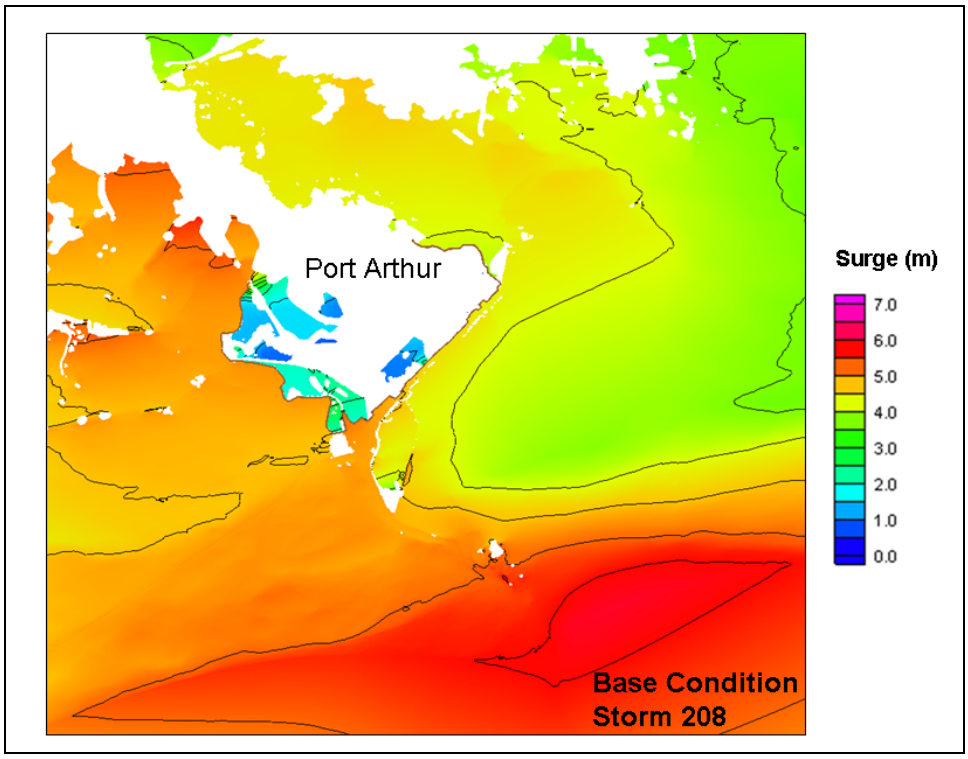

Figure 8. Peak water levels for base condition, Storm 208 (water levels in meters).

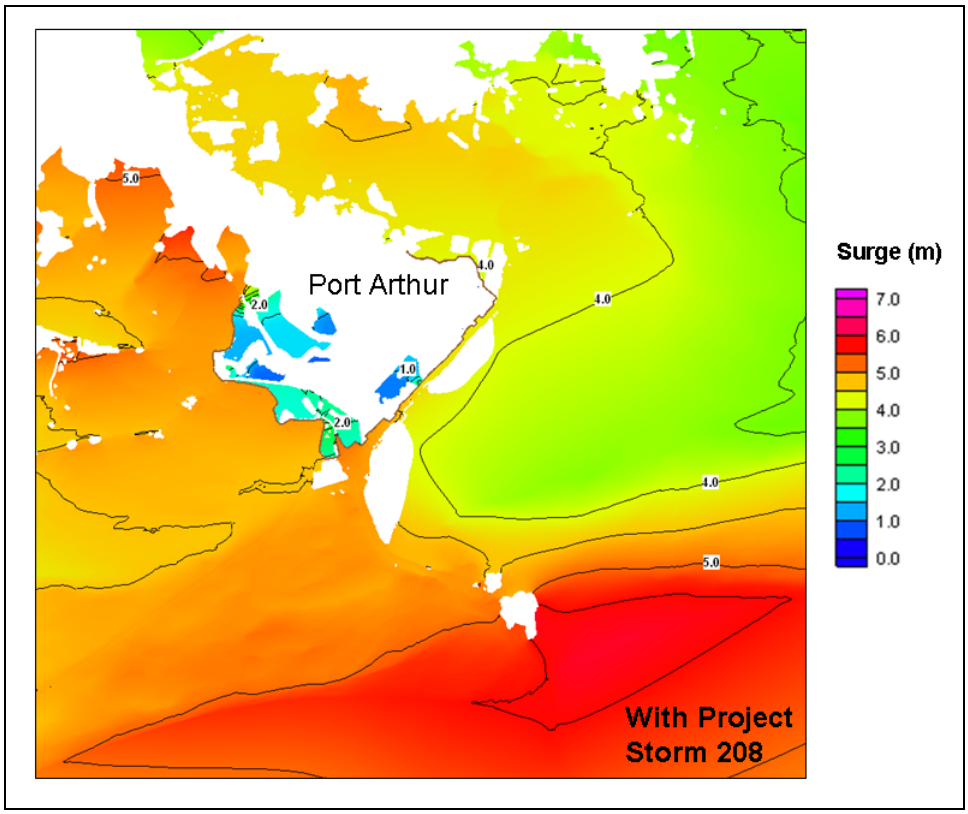

Figure 9. Peak water levels for with project condition, Storm 208 (water levels in meters).

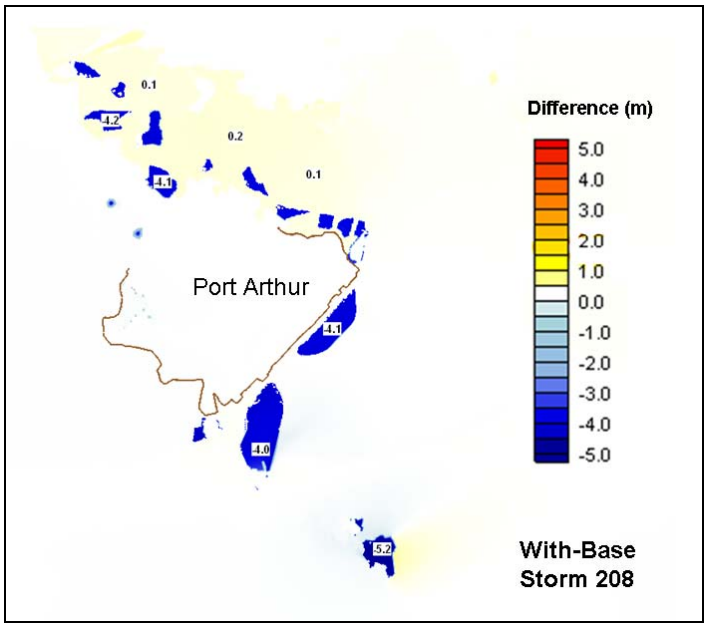

Figure 10. Storm 208 peak water level difference plot (with project – base condition, in meters).

Storm 269

Storm 269 is a hypothetical storm with a very low minimum central pressure of 900 mb, an offshore pressure radius of 18.4 nm, and a forward speed of 11 knots. The storm approaches the coast on a track heading in a north - northeasterly direction (see Figure 7). The storm produces greater surges than storm 208 with maximum surges of over 20 ft at the coast near Sabine Pass and surges over 15 ft in Sabine Lake near Port Arthur, Texas (see Figures 11 and 12). There is extensive flooding within Port Arthur both with and without the project in place due to overtopping of mainly the west and south surrounding levees where the peak surge (approximately 15-17 ft 4.5-5.2 m) exceeds the levee threshold (approximately 15.4 ft 4.7 m). Figure 13 is a difference in maximum surge level plot (with project – base condition). As seen in Figure 13, raising the placement area levees reduces water levels inside the placement areas because raising the placement area levees prevents surge from inundating these areas. There are also areas of increased flooding within Port Arthur, likely due to a slight increase in the surge elevation or duration overtopping the south/west levees. The deepening of the channel and raising of the placement area levees increases flood propagation along the periphery of Port Arthur by only about 4 in (0.1 m), but this induces flooding in areas that that do not flood in the base condition, resulting in an increase of over 6.5 ft (2 m) or more at isolated locations. While these results are and indication of possible implications due to increased surges within the region, the ADCIRC model is not an urban flooding model and should not be applied for "street-level" flooding. The increase in peak water levels outside the placement areas is relatively small in most places. The greatest increases north of Port Arthur along the Neches River are on the order of 8 in (0.2 m) or less. As seen in Figure 13, all changes are once again local to the project area in that water levels are only increased in the low-lying areas (including the city) adjacent to the project features and are not far-reaching into Louisiana.

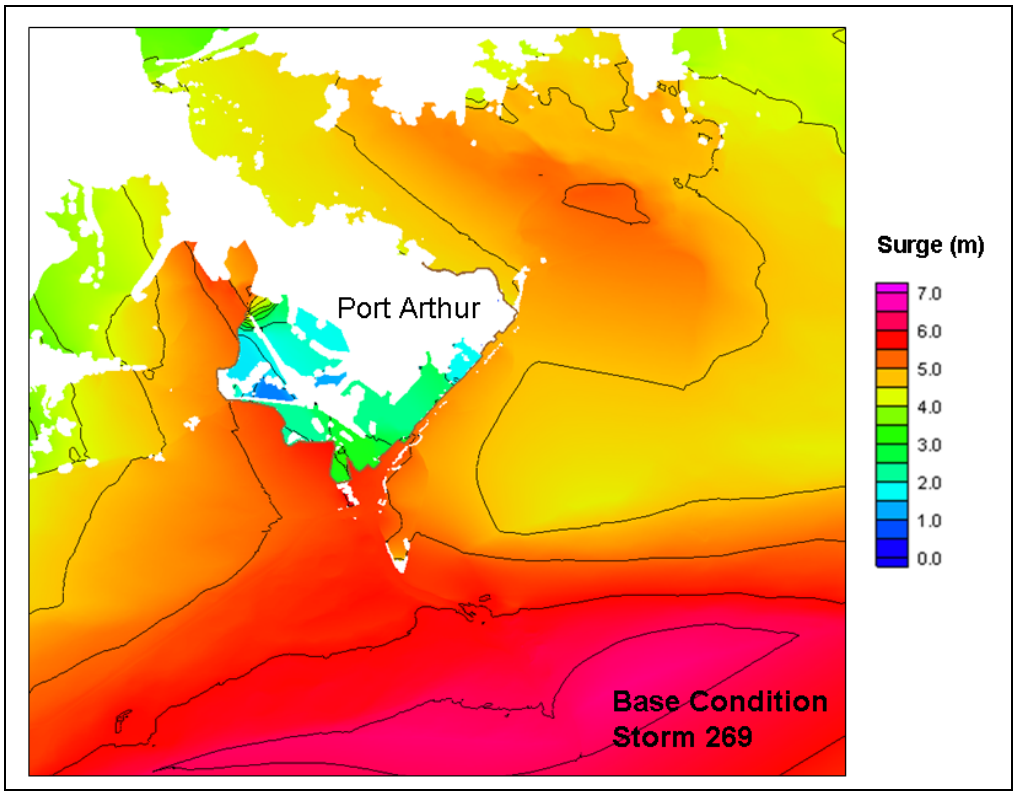

Figure 11. Peak water levels for base condition, Storm 269 (water levels in meters).

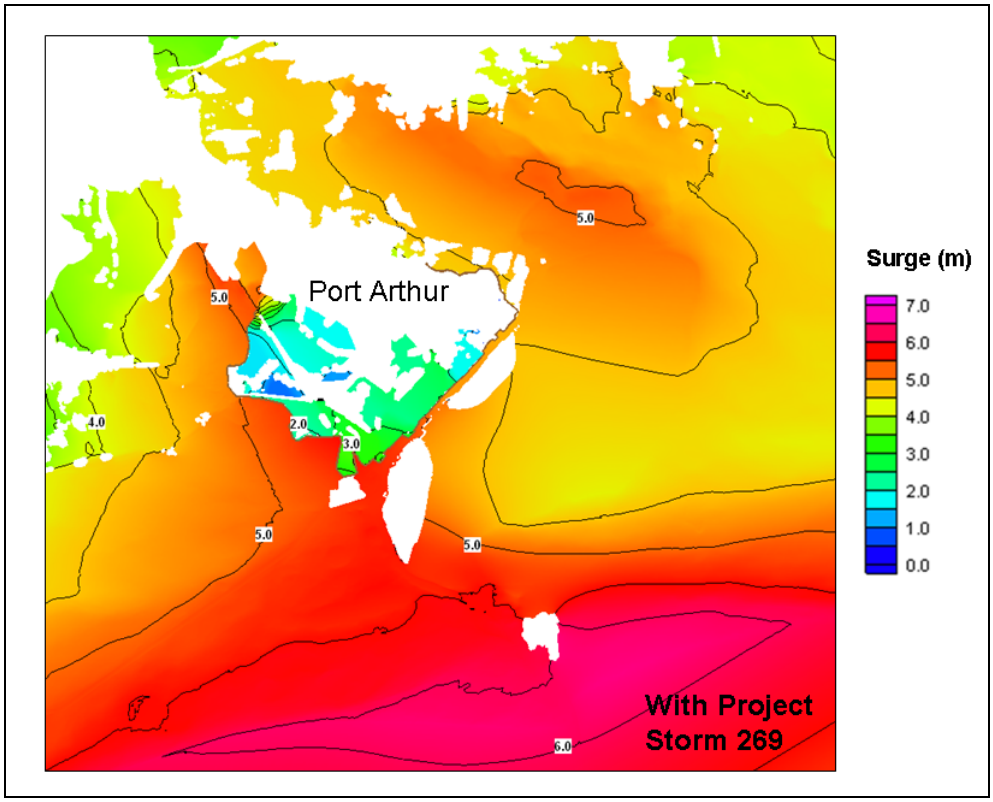

Figure 12. Peak water levels for with project condition, Storm 269 (water levels in meters).

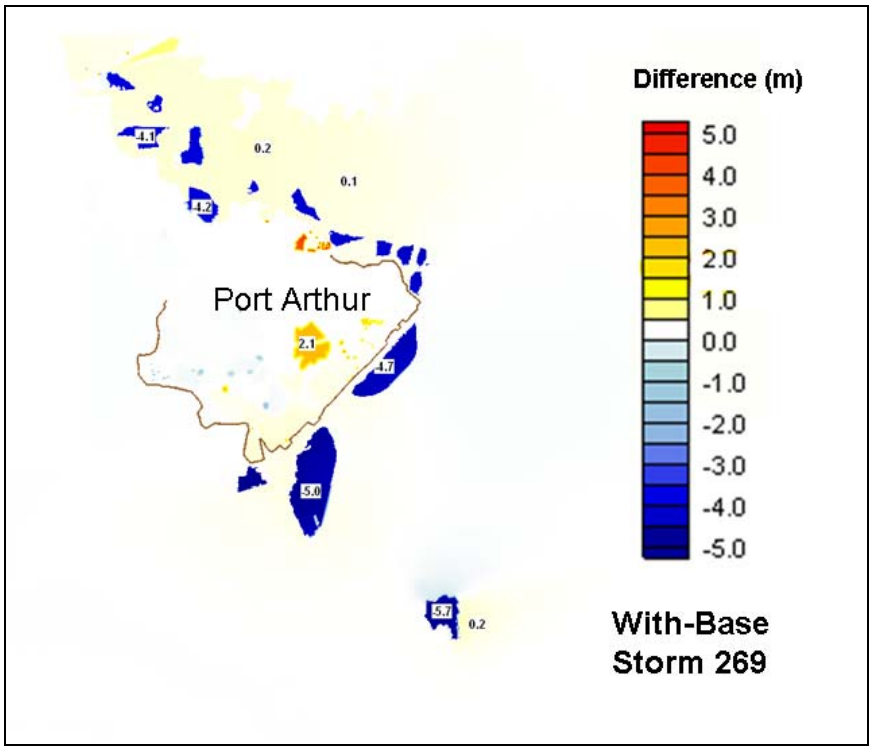

Figure 13. Storm 269 peak water level difference plot (with project – base condition, in meters).

Marsh Restoration

The SNWW navigation project also includes marsh restoration or beneficial use (BU) of dredged material features (see Figure 14). The influence of marsh restoration on hurricane surge has been documented by Wamsley et al. (2009 a, b). Model results and observed data suggest that wetlands do have the potential to reduce surges but that it is dependent on the landscape (bathymetry, structures, and wetland characteristics/size) and storm characteristics (size, speed, track, and intensity). The effectiveness of wetlands at attenuating surge is primarily dependent on the surrounding coastal landscape and the strength and duration of the relevant forcing. The forcing duration is primarily governed by the forward speed of the storm and the track on which it approaches the coast. The combination of the geometry of the coastal landscape and how a storm approaches that landscape determines the duration over which water is pushed inland. Wetlands do not decrease the mass of water driven into the region by the hurricane winds but they do change the momentum and redistribute the storm surge. Surges tend to slightly increase over and just seaward of the marsh as the surge propagation is slowed, which may result in reductions in peak water levels landward of marsh features. The magnitude of change in peak water levels is correlated with the magnitude of the horizontal extent and elevation changes in the marsh. The impact of marsh restoration features such as those proposed for the SNWW project are relatively small and are expected to only modify peak surge levels locally by a minimal amount. No significant reductions or increases in surge levels should be expected.

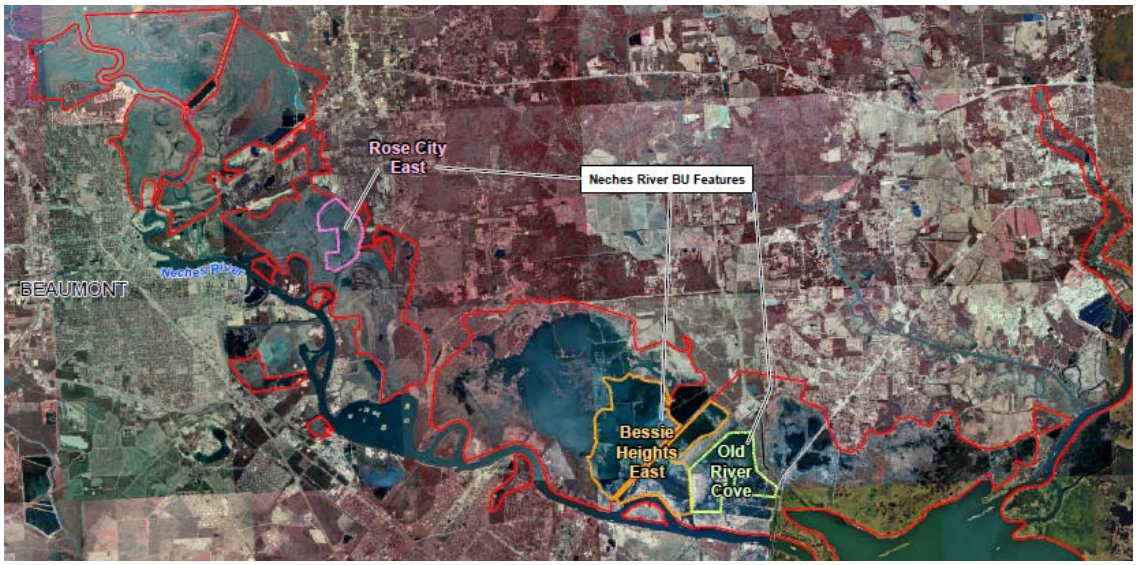

Figure 14. SNWW marsh restoration areas.

Conclusions

A sensitivity analysis using two storms with a very high surge potential was performed to evaluate the impact of the SNWW navigation project on peak surge levels in Port Arthur, Texas and surrounding area. Based on this limited analysis, the primary conclusions are:

1. The impact of the SNWW navigation project is local to the Port Arthur area and does not have a significant impact in Louisiana. Peak surge levels are increased by small amounts adjacent to the project features; areas far removed from the immediate vicinity of the project are not affected. For example, water levels in Louisiana are not increased with the exception of the area in the wetlands adjacent to PA-05.
2. Changes in peak surge north of Port Arthur are caused primarily by deepening of the navigation channel. The maximum increase in peak water levels in this region is less than 1 ft. Due to project time constraints, only a limited analysis was performed. However, the magnitude of change in peak water levels is expected to be greatest for storms with a large surge potential. The greatest change in water level for the two storms analyzed in this study, which produced surge levels at or in excess of the estimated 500-yr level in the project area, was 8 in (0.2 m).
3. Interior flooding can occur and was observed for these two extreme events. Changes in peak surge within the city for these two events, with the project in place, are caused by a slight increase in surge elevation and/or duration causing additional overtopping of the surrounding levee or internal topographic features.
4. Peak surges for 100-yr events are estimated to be approximately 9 ft (2.7 m) in the Port Arthur area. Although simulations of less intense events were not made as part of this study, in light of the 14-24 ft (4.3-7.5 m) levees surrounding Port Arthur, significant interior flooding is not expected for the base condition. Any changes in peak surge on the order of inches should not cause any significant change in interior flooding for the with-project condition.

References

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