MOTT MACDONALD

Passing Vessel Hydrodynamic Study - Additional Analyses

in the vicinity of Ingleside Cove and Ingleside-on-the-Bay, Texas

October 10, 2019

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Contents

Executive summary

This document was prepared for use by the Port of Corpus Christi Authority (PCCA) and summarizes the work performed by Mott MacDonald under Amendment 1 to Service Order No. 2 of PCCA Master Services Agreement No. 18-03. The purpose of this study was to investigate the hydrodynamic effects of the proposed modifications to the BU Site C-Q and La Quinta ship channels, including the deepening of the La Quinta ship channel, construction of a Beneficial Use/Dredged Material Placement Area (BU/DMPA) near the intersection (junction) of the La Quinta and Corpus Christi Ship Channels (BU Site C-Q).

The study was conducted using the two-dimensional (2D) Vessel Hydrodynamics Long-Unsteady wave (VH-LU) numerical model. VH-LU is a proprietary Mott MacDonald model, which simulates the pressure field wave in the form of variations in the water surface elevation and velocities in the modeling domain during passage of a vessel through a channel. An expansive set of model runs was developed to evaluate the impacts from a range of large vessels underling varying channel conditions (existing and proposed). This includes optimization of the BU Site C-Q location for reduction of passing vessel impacts to Ingleside on the Bay, testing a deepened La Quinta channel as a means to reduce passing vessel impacts, and evaluating proposed breakwaters along the Bayshore Drive properties. For the purpose of this study, all ships were modeled during fully laden conditions for conservatism. The worst-case scenario was identified from the list of simulations in MM (2019) and was used as a representative case to further several mitigation concepts.

The VH-LU proposed alternatives analysis showed that the alignment of BUS C-Q provided by PCCA is optimal for reducing passing vessel impacts. C-Q provides measurable benefits to the Ingleside shoreline. Additionally, the deepening of the La Quinta ship channel to a -75 ft MLT does not significantly reduce overtopping conditions along the Bayshore Drive properties thus is not recommended for this purpose.

Preliminary alternatives have been identified for the mitigation measures, developed to reduce passing vessel effects, and are included in the Cost Benefit Analysis within this document. A Cost Benefit Analysis of the shoreline protection alternatives was developed to identify the most cost-effective design. The costs associated with each alternative was compiled from previous Mott MacDonald experience and observations of other existing structures in the area. These alternatives were evaluated and ranked in the Alternatives Analysis based on cost, feasibility and additional criteria developed within this report to determine the preferred alternative for this project.

A preliminary alternatives analysis was conducted to qualitatively compare the performance of each alternative. To perform this exercise, an evaluation matrix was developed. The evaluation matrix was used to assess each alternatives performance in the following categories: Circulation Impacts, Seagrass Impacts, Reduction in Overtopping, Project Cost, Constructability, General Public Perception, Shoreline Access, and Aesthetics. The relative importance of each category was quantified by prescribing a weighted value to each analysis category. Then, each alternative was given a score in each category to develop a weighted total score. The alternatives were then assigned a ranked value to assess their performance from worst to best. This evaluation matrix was intended to provide qualitative comparisons between different categories of alternatives. Therefore, when selecting a single alternative for further analysis, a holistic assessment of the pros and cons of each alternative should be conducted, rather than solely relying on the raw scores from the evaluation matrix. Results from this evaluation indicated that the breakwater options were the costliest and least desirable options while the preferred options would be to raise the bulkhead elevations or install retaining walls along the Ingleside on the bay shoreline. When choosing between these options, consideration should be given to cost, uncertainty in the cost estimate, and general public perception. Currently, building the retaining wall at select sites is assumed to be the most cost-effective alternative because of the low amount of necessary construction materials. However, there is significant uncertainty regarding the condition of the existing bulkhead and its ability to support either an increased bulkhead elevation or retaining wall. Evaluation of the conditions of the existing bulkheads at the properties should be performed before selecting and constructing these structural measures.

1 Introduction

1.1 Background

This document is an extension of MM's previous Hydrodynamic Modeling study for Ingleside on the Bay (MM, 2019) and summarizes the results for additional numerical modeling efforts of vessel hydrodynamics conducted by Mott MacDonald at the request of the Port of Corpus Christi Authority (PCCA) under Service Order NO. 2 of PCCA Master Services Agreement NO. 18-03. The purpose of this study was to investigate the hydrodynamic effects of multiple proposed locations of a beneficial use (BU) Dredged Material Placement Area (DMPA) near the intersection of the La Quinta and Corpus Christi Ship Channels (BU Site C-Q), as well as the deepening of the La Quinta Ship Channel.

An alternatives analysis was also performed for different proposed methods for mitigating impacts from passing vessels to the properties along the La Quinta Ship Channel. The goal of these alternatives is to stabilize the shoreline and prevent overtopping from passing vessels. Further, a comprehensive cost benefit analysis is presented herein.

The goals of this project were as follows:

1. Quantify changes in passing vessel impacts by analyzing water level fluctuations along the shoreline between existing and proposed conditions.
2. Identify and test potential structural and non-structural mitigation measures for reducing impacts to the shoreline due to hydrodynamic conditions created by passing vessels.
3. Perform a feasibility study on proposed alternatives for mitigating overtopping along the Bayshore Drive properties.

1.2 Project Site of Interest

The project is located along the La Quinta Ship Channel near Ingleside, Texas, at the northern end of the Corpus Christi Bay. See Figure 1 for an aerial of the project area and locations of the LQC and CCSC. While the purpose of this analysis is to investigate the potential impacts within the whole project area, focus is placed on the section of shoreline along Bayshore Drive, specifically for the properties where overtopping of the existing bulkheads was observed during the previous study, because this location is known to be most vulnerable to impacts from passing vessel activities during present day conditions due to the close proximity of private homes and bulkheads to the channel.

Figure 1. Project location overview.

2 VHLU Additional Analyses

2.1 Description

This study was conducted using the proprietary two-dimensional (2D) Vessel Hydrodynamics Long-Unsteady wave (VH-LU) numerical model. As per the previous study (MM, 2019), vessel simulations through the LQC and through the CCSC were modeled separately to perform the vessel hydrodynamic analysis in an efficient manner. In other words, different modeling grids were developed and used for the LQC and CCSC simulations. Each LQC grid is a 2.5 m (8.2 ft) resolution grid with 617 cells in the x-direction and 2133 cells in the y-direction. Each CCSC grid has a 3.0 m (9.8 ft) resolution with 1865 cells in the x-direction and 890 cells in the y-direction. The size, extents, and resolution of these grids were selected to best optimize data size and processing, required model run time, and quality of results.

Separate modeling grids were developed to evaluate the changes in vessel induced hydrodynamics between existing and proposed conditions. In summary, grids were developed for the LQC and CCSC that include existing conditions, multiple proposed alignments of BU Site C-Q, and deepening of the LQC.

Region 2 was the primary focus for this additional analysis as it was the area where the most vessel impacts along the shoreline where observed during the previous analysis (MM, 2019). The approximate outline of Region 2 is shown in Figure 2. Additionally, the VHLU simulations in this report were set up using the worst-case scenarios from the previous modeling at Mean Sea Level. This includes using the Suezmax tanker where the draft, speed, and route vary depending on if the LQC or CCSC grid is used. The ship parameters for the two grids are summarized in Table 1.

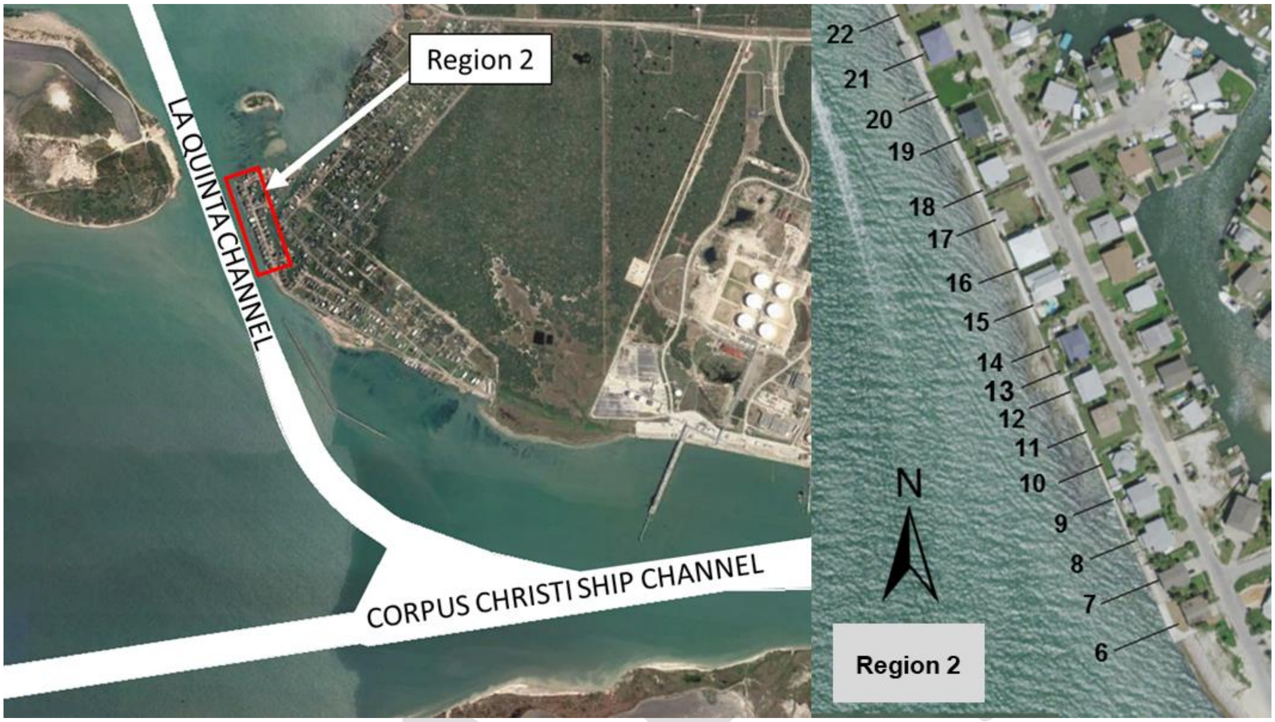

Figure 2. (Left) Overall location of Region 2 and (Right) detail of Region 2 showing transects 6 – 22 as generated in MM (2019).

Table 1. Vessel parameters for VH-LU model runs.

Channel	Ship Hull Type	Route	LOA [ft]	Beam [ft]	Modeled Draft [ft]	Speed [kts]
LQC	Suezmax Tanker	Inbound	900	157	45	6
CCSC	Suezmax Tanker – 52’ Draft	Outbound	900	157	52	11.5

2.2 BU Site C-Q

The construction of a beneficial use (BU) Dredged Material Placement Area (DMPA) is proposed near the intersection of the La Quinta and Corpus Christi Ship Channels (BU Site C-Q). The constructed BUS C-Q consists of a U-shaped outer protection berm and an interior backfill area. For the purpose of this study, the analysis was performed using an emergent protection berm crest, and an interior backfill area that is uniformly set to an elevation below sea level. The crest elevation was set to eliminate any potential overtopping of the structure for this analysis. Figure 3 shows the existing project bathymetry including the new proposed location of BUS C-Q provided by PCCA. This was compared to the previously modeled location, which was closer to Ingleside, to determine if shifting C-Q towards the west would reduce the increases in water surface elevations from passing vessels that were observed during the previous study. In addition to testing this proposed template East/West location, the BUS template was shifted to two locations north and rerun in order to determine the optimal North/South placement of C-Q. Comparisons of water surface elevation between the simulations are presented in this section.

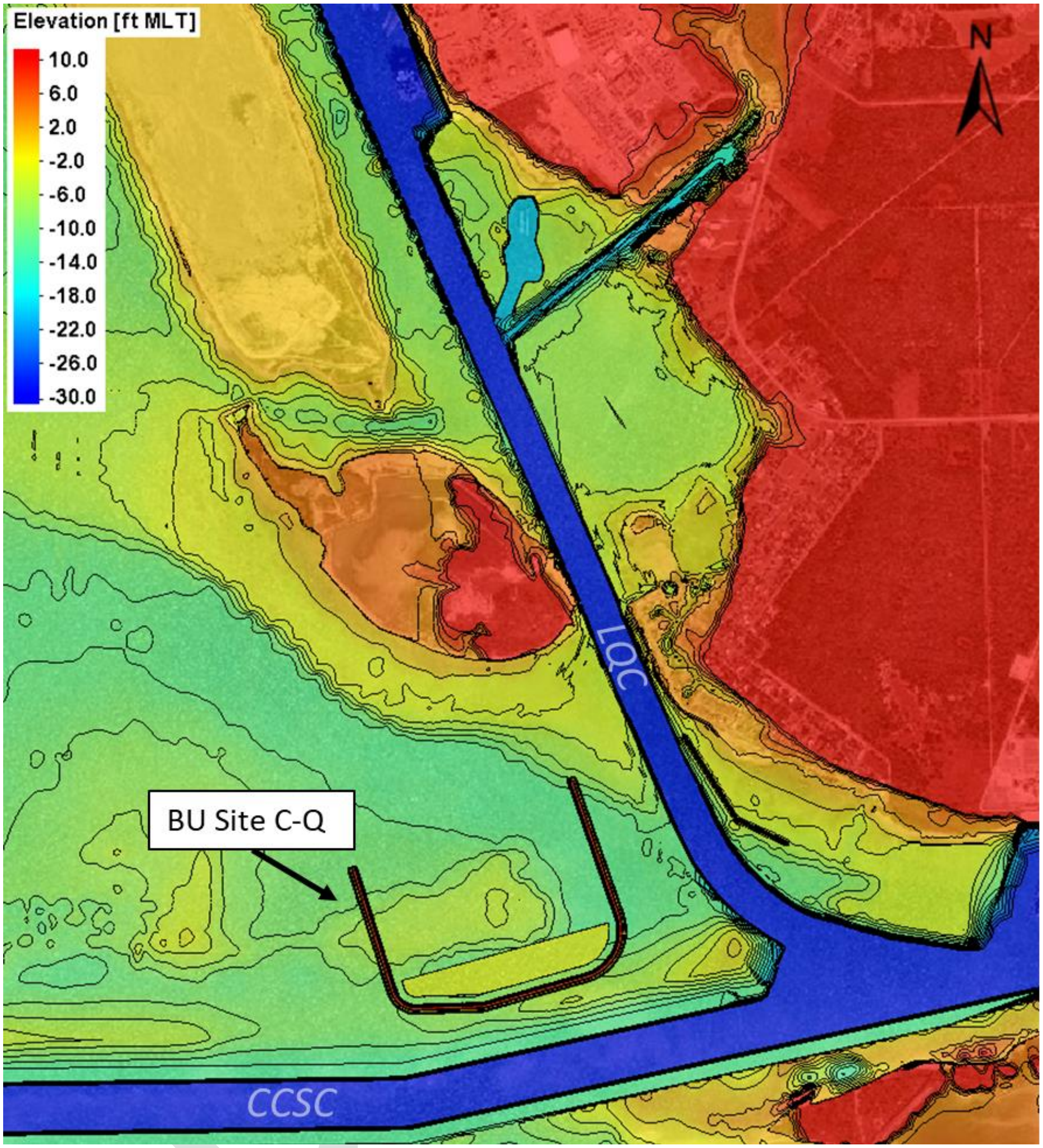

Figure 3. Compiled bathymetry at the project site including proposed BU Site C-Q.

2.2.1 Proposed BU Site C-Q Alignment

The exact location of the proposed BUS C-Q alignment was provided by PCCA for this analysis; however, it varies significantly from what was used in MM (2019). Originally, the eastern border of BUS C-Q was nearly right up against the channel limits of LQC (MM, 2019). Therefore, it is important to test the changes in vessel induced water levels as a result of moving the C-Q template to the west, approximately 750 ft. The modeling grids for LQC and CCSC with the proposed BUS C-Q are shown in Figure 4 and Figure 5.

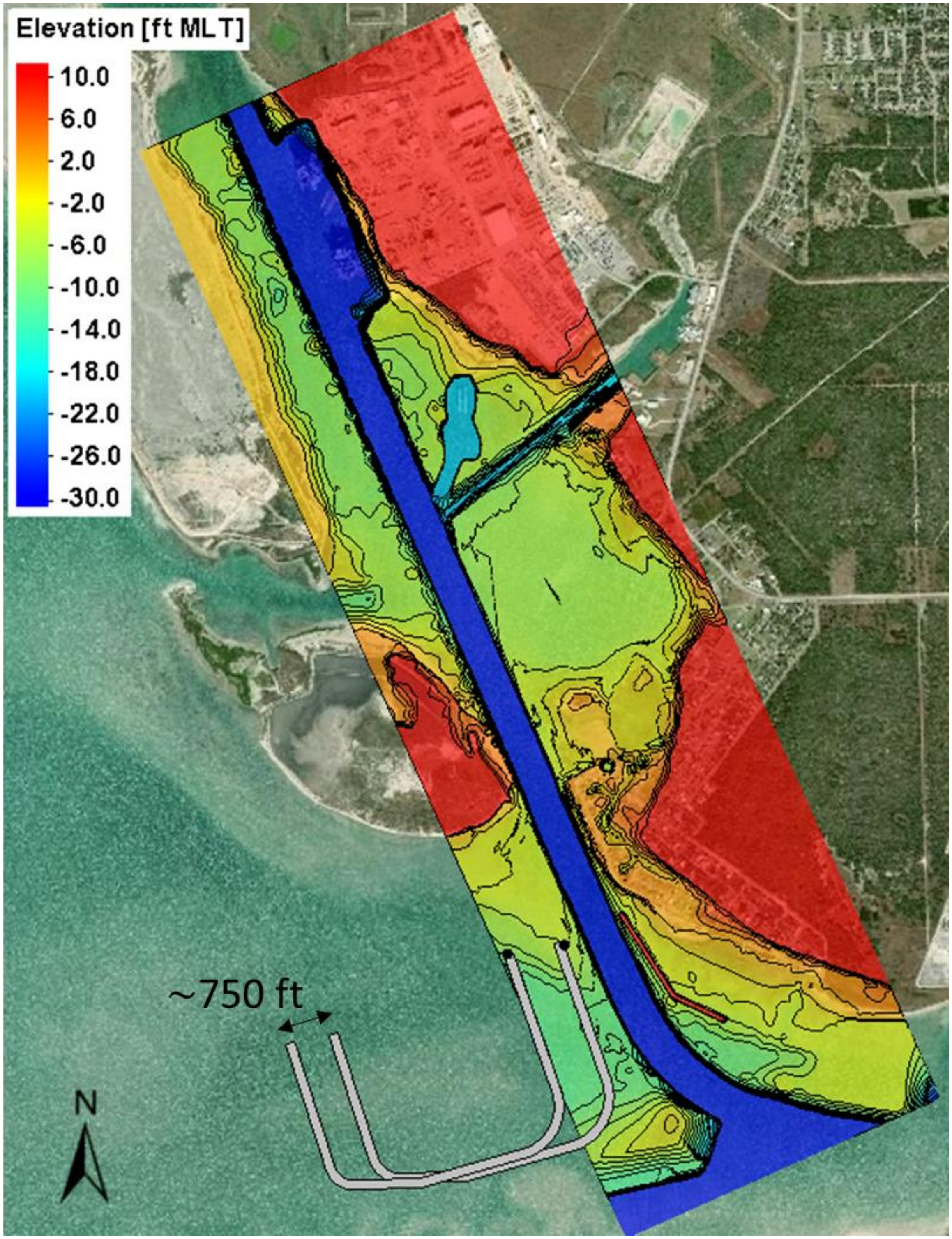

Figure 4. Existing bathymetry including the proposed BU Site C-Q interpolated onto the LQQ model grid.

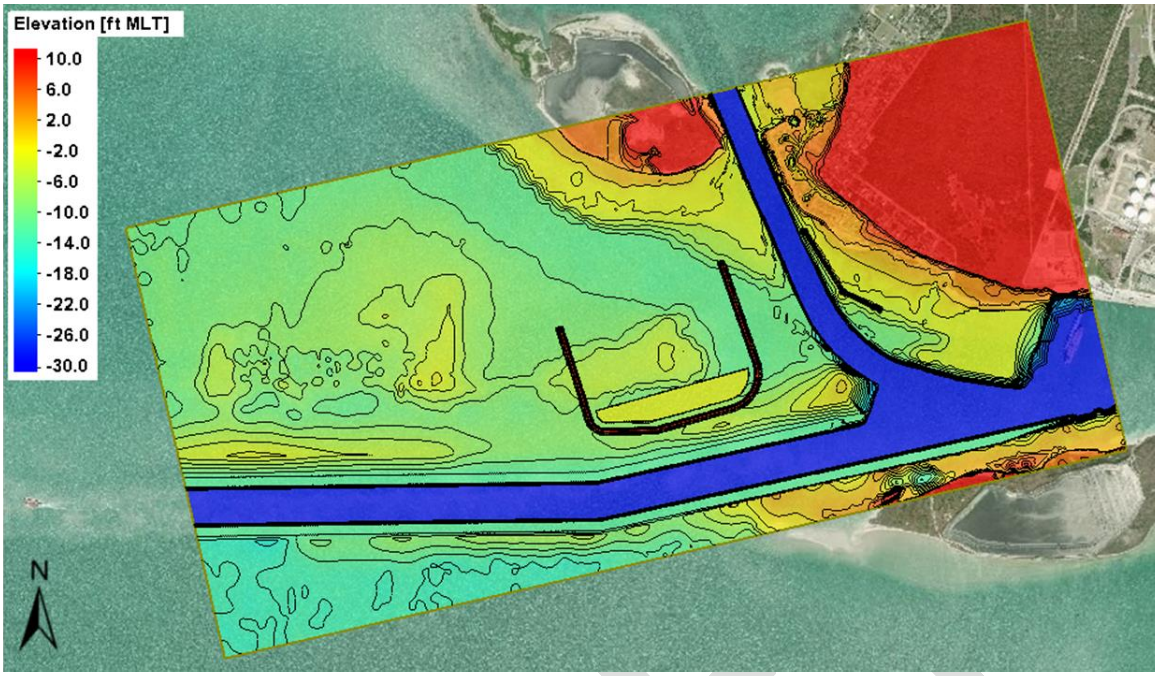

Figure 5. Existing bathymetry including the proposed BU Site C-Q interpolated onto the CCSC model grid.

Results from the proposed BUS C-Q site were compared with both existing conditions and the previous C-Q alignment from MM (2019). Difference plots were generated to show the spatial distribution of changes in water surface elevations (WSEs) between the simulations. Figure 6 shows the difference in WSE between the proposed BUS C-Q site and existing conditions. Note that light blue color is visible near Region 2, indicating that this simulation resulted in a slight improvement in WSE near the Bayshore Drive properties. The strong red color on the west side of the channel is due to the introduction of the C-Q berm into the bathymetry set. This is because the ship wave is confined to propagating along the berm whereas before it propagated out toward Corpus Christi Bay. However, the increase at that location does not result in any increase in overtopping impacts along the project shoreline. Overall, introducing the BUS C-Q does not have any adverse effects on overtopping at the Bayshore Drive properties in Region 2.

A comparison between the proposed BUS C-Q site and the previous alignment from MM (2019) was made for both LQC and CCSC simulations in Figure 7 and Figure 8, respectively. Similar to Figure 6, the same reduction in WSE in Region 2 for the LQC simulation can be observed. For the CCSC simulation, a negligible change in WSE, on the order of < 0.1 ft, can be observed in Region 2 (Figure 8). Again, the red color on the west side of the channel is due to the shifting of the C-Q berm westward in the bathymetry set. In conclusion, results from the model analysis for the proposed C-Q alignment show an overall improvement in WSE for the LQC simulation, and a negligible change for the CCSC simulation, when comparing to the previously modeled C-Q alignment near Region 2. Based on these results it was determined that the proposed C-Q alignment is at the optimal location.

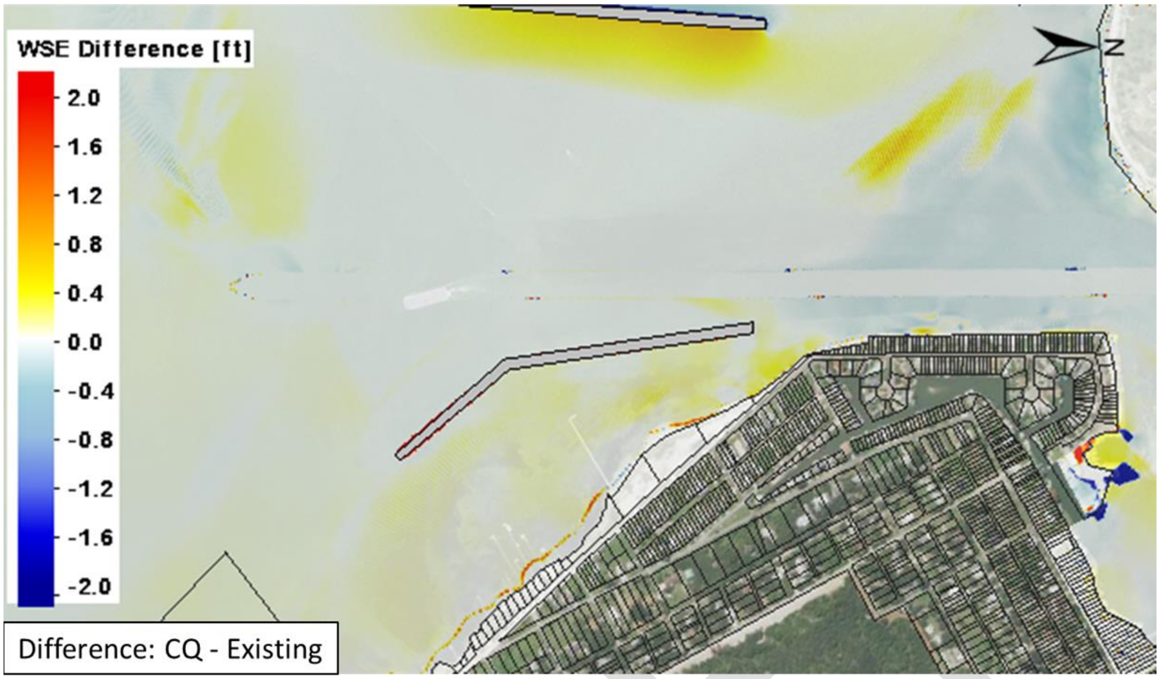

Figure 6. Differences in WSE between the proposed CQ alignment and existing conditions using the LQC simulation. Warm colors (yellow-reds) indicate where areas experience a higher max WSE due to the proposed BUS C-Q site, and cool colors (light-dark blue) show areas where max WSEs are lower due to the proposed site. Note that light blue color is visible in Region 2, indicating that this simulation resulted in a slight improvement in WSE near the Bayshore Drive properties.

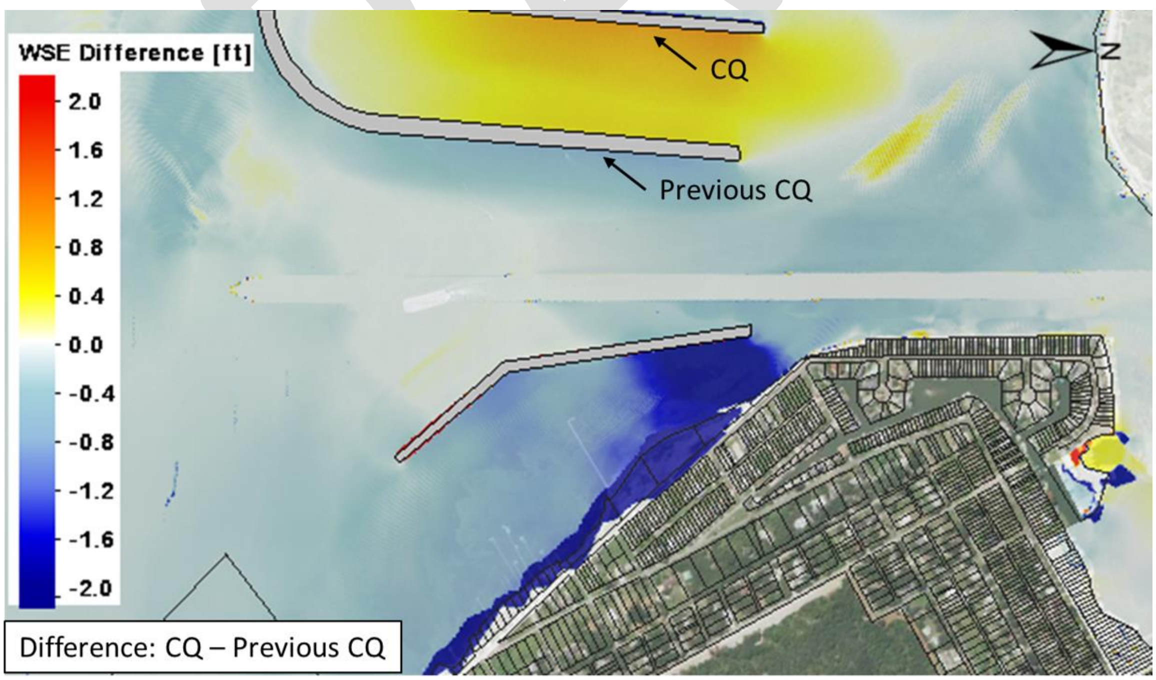

Figure 7. Differences in WSE between the proposed and previous CQ alignments using the LQC simulation.

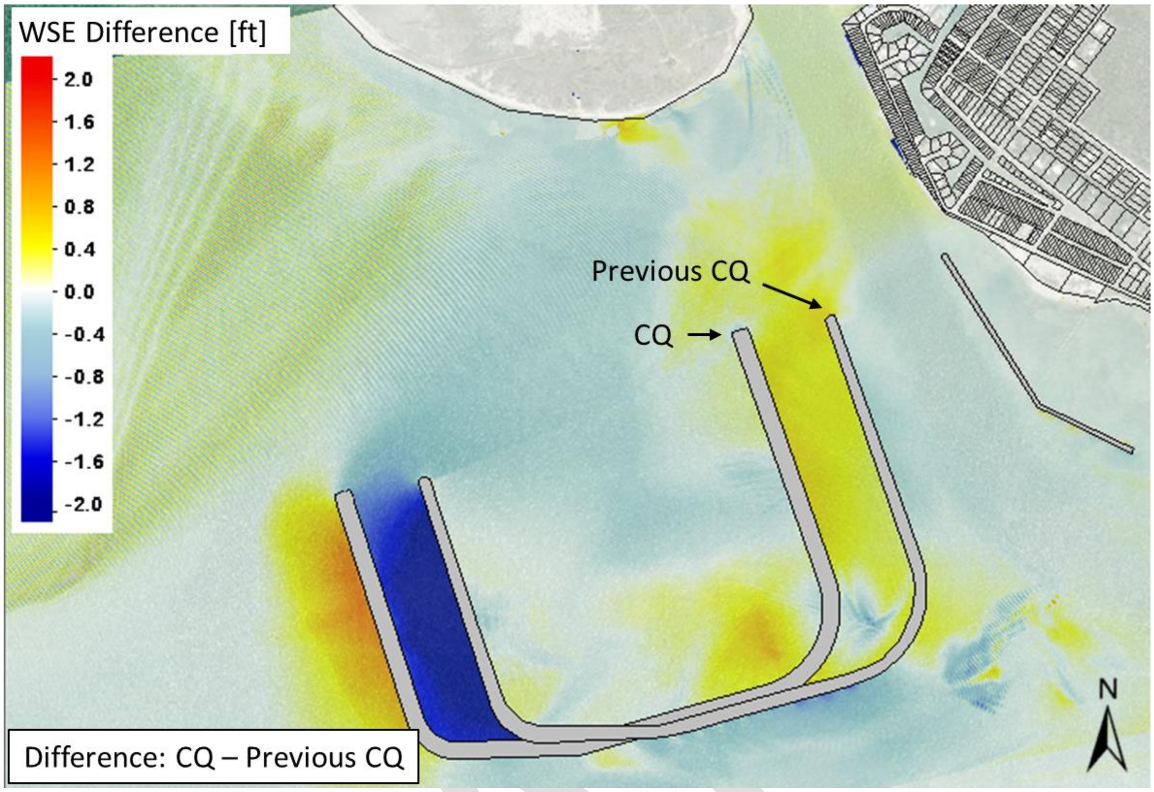

Figure 8. Differences in WSE between the proposed and previous CQ alignments using the CCSC simulation.

Although the spatial distributions provide a good understanding of WSE across the project site, it is important to take a closer look at the bulkheads in Region 2. Following each VH-LU model run, the resulting WSEs along each transect were evaluated over the full timeseries. Note that in Figure 2, the transects extend from the offshore region to a sufficient distance onshore. This ensures that any potential overtopping is fully captured on the transects. The maximum WSEs experienced at the shoreline over the full timeseries were extracted. The average maximum WSE value was then calculated using the total number of transects. These max WSE values for each modeled scenario are used to compare proposed conditions to the previous C-Q conditions and evaluate the potential impacts of the proposed conditions.

The resulting average max WSE values in Region 2 for each simulation is summarized in Table 2. For the LQC simulation, the average max WSE for the proposed C-Q alignment is 5.08 ft MLT, with an average 0.01% increase. For the CCSC simulation, the average max WSE for the proposed C-Q alignment is 2.86 ft MLT, with an average -0.02% decrease. Since the change in WSE elevation between the C-Q alignments is considered to be negligible as it is within the range of error within the model, overtopping at the lower elevations of the bulkhead (< 5 ft MLT) is still to be expected. Therefore, multiple mitigation measures were investigated in Section 3.1.

Table 2. Resulting average max WSE values along Region 2.

Run	Water Level Condition	Region 2 (Bulkheads) [ft MLT]	Region 2 % Diff. from Previous CQ
LQC: Existing	MSL (1.7 ft MLT)	5.01	n/a
LQC: Previous C-Q	MSL (1.7 ft MLT)	5.06	n/a
LQC: C-Q	MSL (1.7 ft MLT)	5.08	0.01
CCSC: Existing	MSL (1.7 ft MLT)	3.88	n/a
CCSC: Previous C-Q	MSL (1.7 ft MLT)	2.86	n/a
CCSC: C-Q	MSL (1.7 ft MLT)	2.86	-0.02

2.2.2 BU Site C-Q Alignment Optimization

Now that the horizontal alignment of BUS C-Q has been optimized and shown to have negligible impacts to passing vessel surges within the LQC, the alignment was shifted to two locations north and rerun to determine the optimal vertical placement of C-Q. Placement of C-Q is bounded vertically by the CCSC to the south and Berry Island to the north. Since the proposed C-Q alignment is already immediately bounded by the CCSC to the south, the alignment was shifted to two locations in the north. The first shift moved it as close to Berry Island as possible, leaving a 500 ft buffer zone. The second shift moved it halfway between its current proposed location and Barry Island. The templates for C-Q can be seen in Figure 9 and were called out by their distance from Berry Island.

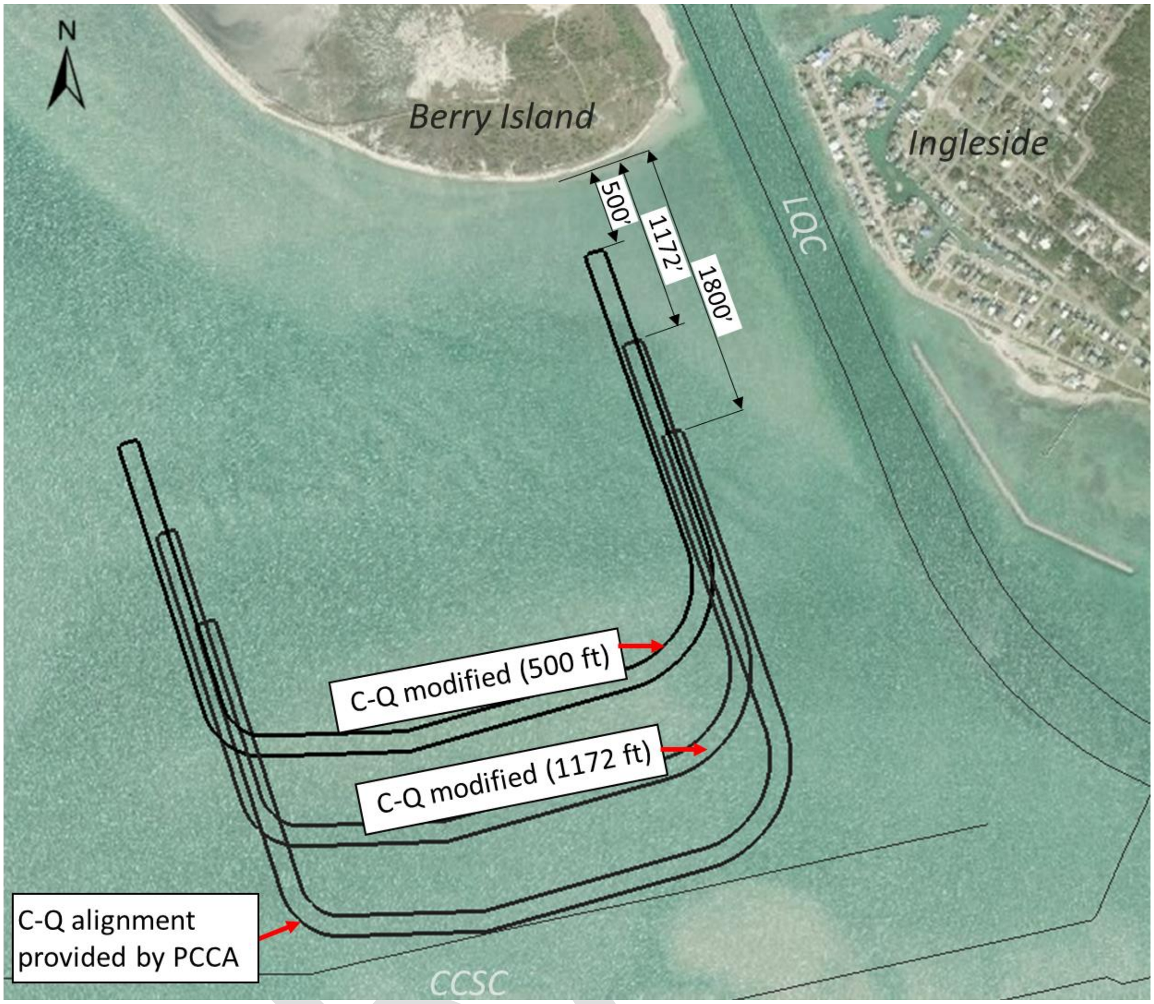

Figure 9. Outline of BU Site C-Q template shifting it to two locations north for testing in the VHLU model. Distances are measured from the edge of Berry Island.

Results from the proposed BUS C-Q site were compared with both modified C-Q alignments. Difference plots were generated to show the spatial distribution of changes in WSE. Figure 10 shows the difference in WSE between the proposed BUS C-Q site and C-Q modified (500 ft). Note the change in WSE is minimal within the bounds of the LQC. However, there is a notable increase in WSE close to Berry Island and near the southern portion of the Bayshore Drive properties in Region 2. This could potentially increase erosion along the southern shoreline of Berry Island, which is private property, and may cause additional overtopping along the Bayshore Drive properties. Figure 11 shows the difference in WSE between the proposed BUS C-Q site and C-Q modified (1172 ft). Similar trends to the C-Q modified (500 ft) are observed for the C-Q modified (1172 ft) although the magnitude of increased WSE is noticeably reduced. Therefore, the currently proposed C-Q alignment, provided by PCCA, should be used moving forward as it has been determined to be in the optimal location to reduce impacts from inbound and outbound vessels within the CCSC while not increasing surge impacts from inbound and outbound vessels within the LQC. The results also show that the inclusion of C-Q provides measurable benefits to the Ingleside shoreline when compared to existing conditions.

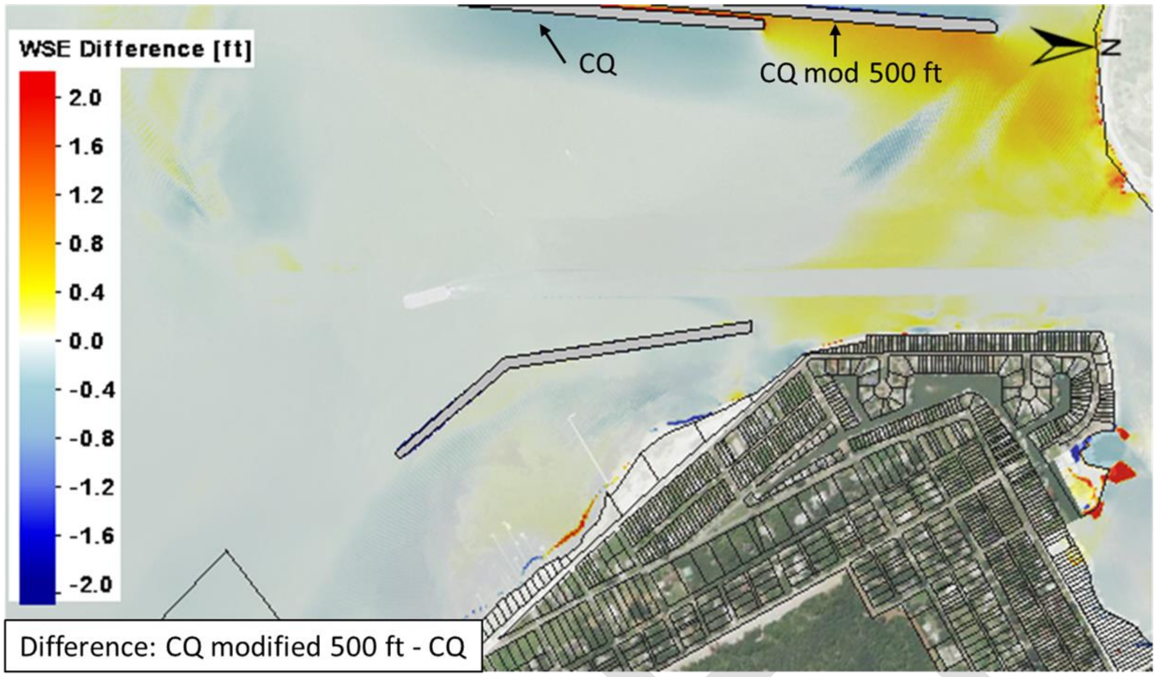

Figure 10. Differences in WSE between the CQ modified (500 ft) and the CQ alignments using the LQC simulation.

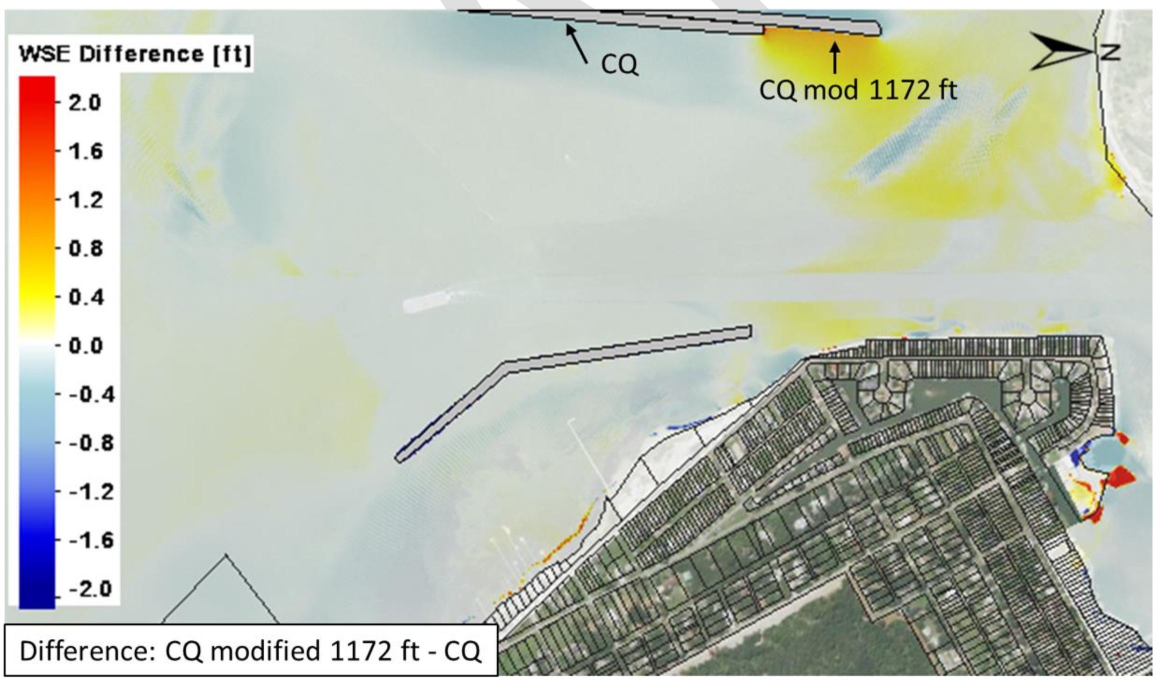

Figure 11. Differences in WSE between the CQ modified (1172 ft) and the CQ alignments using the LQC simulation.

Although the original proposed BUS C-Q alignment yielded the best results in the spatial distributions, it is still important to check the results at the bulkheads in Region 2. Similar to the testing of the proposed horizontal alignment location, maximum WSEs experienced along the transects in Region 2 were extracted from the full timeseries. The average maximum WSE value was then calculated using the total number of transects. The results for the C-Q modified (500 ft) and (1172 ft) are summarized in Table 3. For the C-Q modified (500 ft) simulation, the average max WSE for the proposed C-Q alignment is 5.01 ft MLT, with an average -0.01% decrease. For the CCSC simulation, the average max WSE for the proposed C-Q alignment is 5.00 ft MLT, with an average -0.02% change.

Table 3. Resulting average max WSE values per region for each of the evaluated Future Water Level Conditions.

Run	Water Level Condition	Region 2 (Bulkheads) [ft MLT]	Region 2 % Diff. from CQ.
LQC: Proposed C-Q	MSL (1.7 ft MLT)	5.08	n/a
LQC: C-Q Modified 500 ft	MSL (1.7 ft MLT)	5.01	-0.01
LQC: C-Q Modified 1172 ft	MSL (1.7 ft MLT)	5.00	-0.02

2.3 La Quinta Ship Channel Dredging

Deepening of the LQC from an average depth of -45 ft MLT to -75 ft MLT with a 2 ft overdredge was also tested in the VH-LU model to determine if this would be an effective option for reducing overtopping from passing vessels. The purpose of this analysis was to quantify the reduction in max WSE in Region 2 along the Bayshore Drive properties by deepening the channel as it was observed during the previous analysis that increasing that increasing the depth resulted in a slight reduction of vessel surge effects along the Ingleside shoreline. This was achieved by adjusting the channel bathymetry in the existing conditions setup of the VH-LU model (not including the effects of BUS C-Q) and rerunning the model. Using the same existing channel geometry of LQC, the new depth was set to -77 ft MLT (75’ channel +2’ overdredge). This depth was selected as, based on the channel geometry and proximity of the channel to the Ingleside bulkheads, a deeper channel would encroach on the existing properties. Additionally, an exaggerated increase in water level occurs in the model at the North/South boundary of the dredge template due to the steep transition in bathymetry. Therefore, the North/South extents of the dredge template were extended beyond Region 2 to reduce this effect on the results. However, for the dredge volume estimates presented in Section 3.1.1, the calculation was performed only for the area in front of the Bayshore Drive properties.

Once the VH-LU simulation using the new deepened channel was complete, the same transect analysis that was performed in Section 2.2.1 and 2.2.2 was applied here. The resulting average max WSE values in Region 2 for both simulations is summarized in Table 4. For the LQC depth = 75 ft simulation, the average max WSE is 5.00 ft MLT, with an average -0.20% decrease.

Table 4. Resulting average max WSE values per region for each of the evaluated Future Water Level Conditions.

Run	Water Level Condition	Region 2 (Bulkheads) [ft MLT]	Region 2 % Diff. from E.C.
LQC: E.C. depth = 45 ft	MSL (1.7 ft MLT)	5.01	n/a
LQC: Proposed depth = 75 ft	MSL (1.7 ft MLT)	5.00	-0.2%

A more detailed view of the max WSE at each transect in Region 2 is shown in Figure 12. It can be observed that the max WSE at each transect between the two runs are nearly identical. Additionally, note that overtopping does occur at Transect 13, which is where it is known to occur during present-day/existing conditions (Figure 12). However, no overtopping is observed at any of the other transects. Thus, dredging the LQC to a depth of 75 ft MLT is not expected to significantly improve overtopping rates within Region 2.

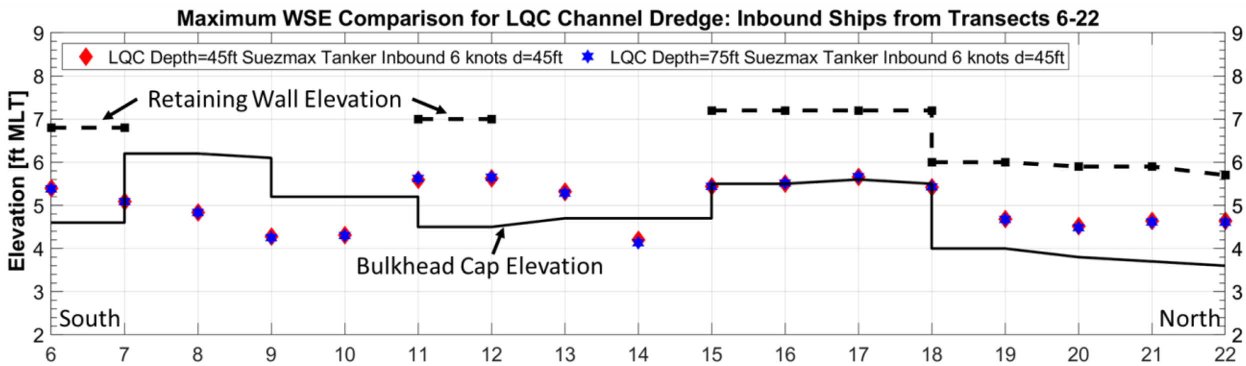

Figure 12. Resulting max WSEs per transect within Region 2 for the Existing LQC Depth = 45 ft and Proposed LQC Depth = 75 ft.

3 Alternatives Analysis and Evaluation

3.1 Mitigation Measures

Since specific areas within the project site are known to be vulnerable to passing vessel activities under normal/present-day conditions, mitigation measures were developed to reduce passing vessel effects. A total of three mitigation measures were developed for investigation. The feasibility of these measures are evaluated in this study. These potential mitigation measures are listed and discussed below which include: 1) dredging the La Quinta Ship Channel, 2) installing a protection structure seaward of Bayshore Drive bulkheads, and 3) increase cap elevations of Bayshore Drive bulkheads/retaining walls.

3.1.1 Dredging the La Quinta Ship Channel

One mitigation measure considered in this analysis was to dredge the LQC from -45 ft MLT to -75 ft MLT with a 2 ft overdredge (Figure 13). In theory, this would allow the ship to displace a larger volume of water laterally along the centerline of the ship channel and less would propagate perpendicular, toward the shoreline. However, as was determined in Section 2.3, the reduction in max WSE by deepening the channel was negligible (-0.2%). Additionally, it would cost roughly $16 million to $30 million to dredge the approximately 2 million cubic yards of material in the LQC along Region 2 assuming a dredging rate of $8/CY to $15/CY.

The results from the VH-LU simulation, in conjunction with the price it would cost to dredge the LQC, makes this option not feasible. Therefore, deepening the LQC should not be considered for mitigating overtopping at the Bayshore Drive properties.

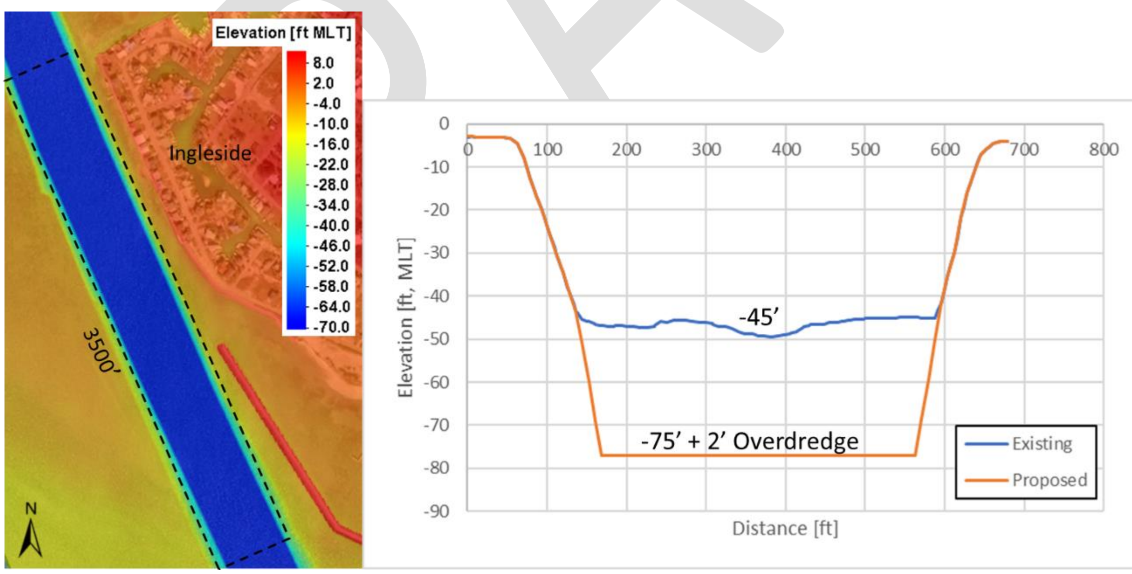

Figure 13. Bathymetry for proposed deepening of LQC (left) and cross section of proposed and existing channel (right). Dashed line (left) denotes approximate boundaries for dredge volume estimate.

3.1.2 Seaward Shore Protection

This mitigation measure involves extending/elongating the existing breakwater structure towards the northwest. The structure would extend up to the northern-most end of Bayshore

Drive. The purpose of the emergent breakwater would be to intercept the passing vessel wakes and reduce the wave and surge energy experienced at the shoreline. The proposed breakwater could be constructed of sheet piling or stone riprap similar to the existing Ingleside breakwater. The crest elevation of the structure would also be determined during the future detailed analysis, but it is expected that the crest would be similar to the existing Ingleside breakwater (+6 ft MLT). It is important to note that this mitigation measure may result in additional impacts to the channel, environment (such as circulation and seagrass), and adjacent residential properties and recreational access to the channel.

It is anticipated that the proposed stone riprap breakwater will follow the existing breakwater template that consists of a 70 ft bottom width footprint, along the 2,100 linear feet of shoreline (Figure 14). The centerline of the stone breakwater option would be 50 feet from the existing shoreline bulkhead, leaving approximately 13 to 15 feet between the public properties along Bayshore Drive and the toe of the stone breakwater. Due to the adjacent channel slope the structure would need to be placed along the narrow bench adjacent to the Ingleside bulkheads. A concern for this alternative would be the large footprint of the structure and the distance that would be left between the structure and adjacent properties.

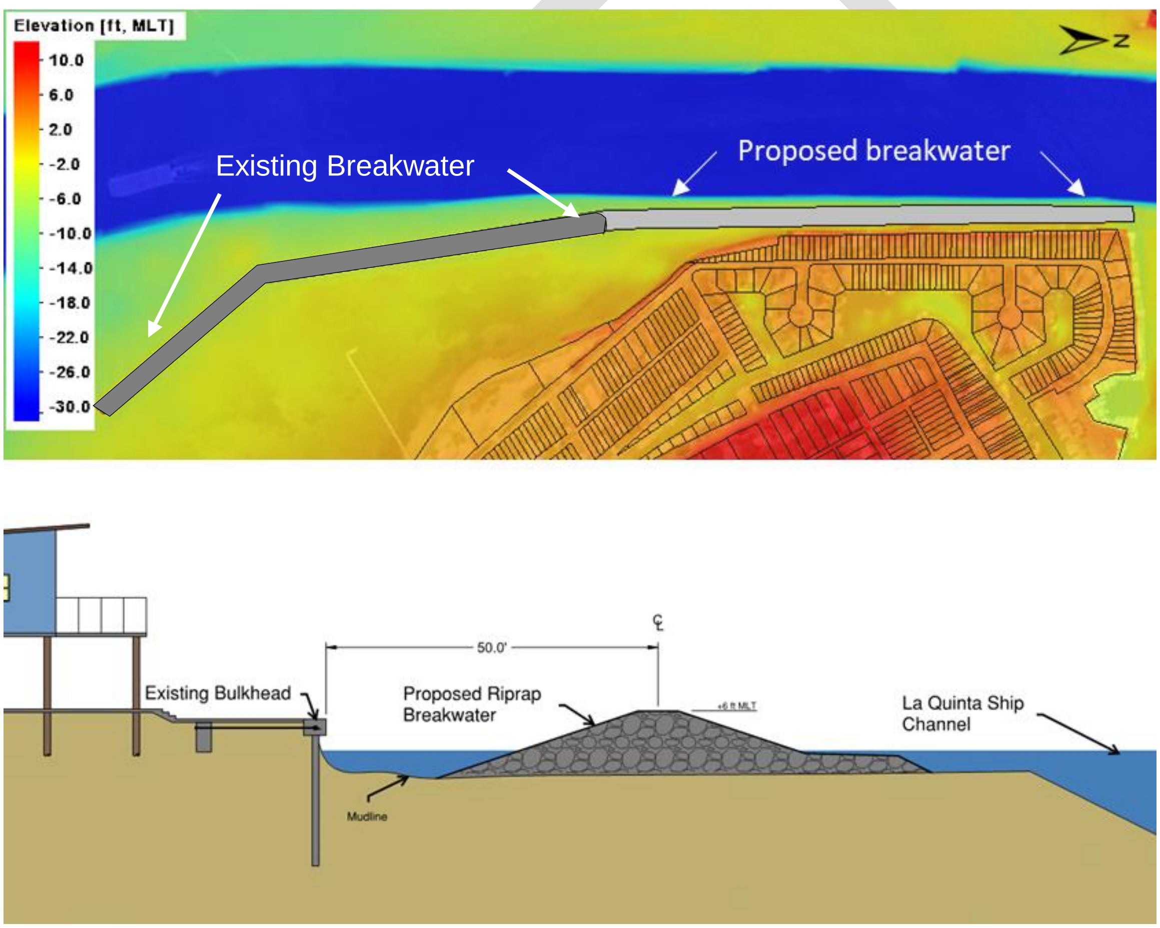

Figure 14. Alternative 2A – Riprap Breakwater. Plan view (top) and profile view (bottom).

The proposed steel sheetpile section for the new breakwater was assumed to be an AZ type section of treated steel with a reinforced concrete cap. Further structural analysis is required to determine the embedment and size of the sheetpile section. The proposed sheetpile breakwater would extend the existing stone breakwater 2,100 linear feet, along Bayshore Drive, with a centerline approximately 70 feet from the seaward edge of the existing bulkhead (Figure 15). This option was considered as the sheetpile has a much smaller footprint than the stone breakwater.

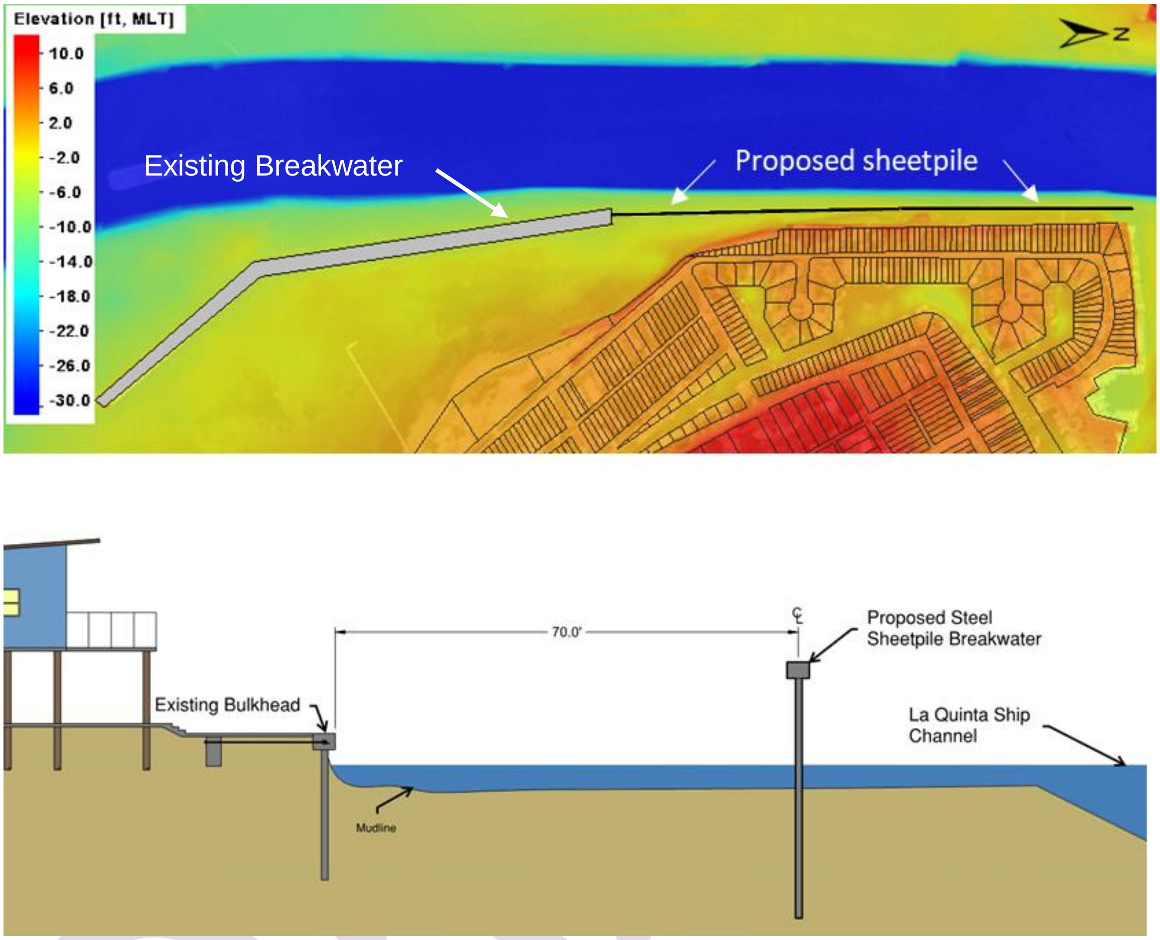

Figure 15. Alternative 2B – Steel Sheetpile Breakwater. Plan view (top) and profile view (bottom).

Both the stone and sheetpile options for this alternative would reduce access to the ship channel and bay from the bulkheads. This could potentially affect the constructability of the structures, but more importantly would limit the access to vessels attempting to access the properties along this region, especially the riprap breakwater option.

The structures may also result in reduced water quality due to the decrease in water circulation behind the structures. This could result in issues with water quality and could affect seagrasses along the project site. This may be mitigated through the addition of gaps along the structure, but these gaps would also decrease the effectiveness of the structures.

Furthermore, based on preliminary observations from the site and review of project aerials, there appear to be seagrasses within the structure footprints that would be impacted by the installation of the structures, especially from the riprap breakwater which would have a much larger footprint than the sheetpile.

3.1.3 Increase Bulkhead and Retaining Wall Elevations

Neither an overall assessment of the existing bulkhead structure integrity nor inspection and assessment of individual structural components was performed as part of this study. The existing condition of the structures should be examined to further refine applicability of structural solutions described herein.

The purpose of this mitigation measure would be to prevent overtopping at the bulkheads/retaining walls along the waterfront properties along Bayshore Drive caused by passing vessel scenarios evaluated during this study. The proposed new cap elevation for the bulkheads/retaining wall shall exceed the highest water surface elevation that results within this area (referred to as Region 2) from the passing vessel simulations with proposed conditions. The proposed bulkhead could be constructed of vinyl sheetpile with a concrete cap and anchoring system, and the retaining wall with pre-cast or cast in place concrete.

For this alternative, additional retaining wall or increasing the existing bulkhead elevation were considered for select properties with bulkhead elevations less than +5.8 ft MLT and without existing retaining walls (Figure 16). Based on the maximum water surface elevations modeled for all scenarios of inbound and outbound ships, the residential properties at transects 10, 13 & 14 experience notable overtopping due to low bulkhead elevations and no retaining wall. The proposed retaining wall or bulkhead would be installed to an elevation of +6 ft MLT for these select transects, an approximate length of 186 linear feet. For the retaining wall option, it is assumed that the wall could be installed without affecting the existing bulkheads. Raising of the bulkheads would require additional construction as it is unknown whether the existing structures could withstand the additional load from a larger concrete cap. Also, in general it was observed that the bulkheads in the area, especially those at lower elevations, tend to be older and rapidly deteriorating. Due to this it was assumed that raising the bulkheads would require a complete replacement of the structure with a new bulkhead at a higher elevation.

Another option considered was the reconstruction of the existing bulkhead to an elevation of +6 ft MLT along the full length of Region 2, an approximate length of 1,300 linear feet. This option was considered and evaluated in this analysis as it would be better received by the property owners as all would be addressed equally rather than repairing only a few properties.

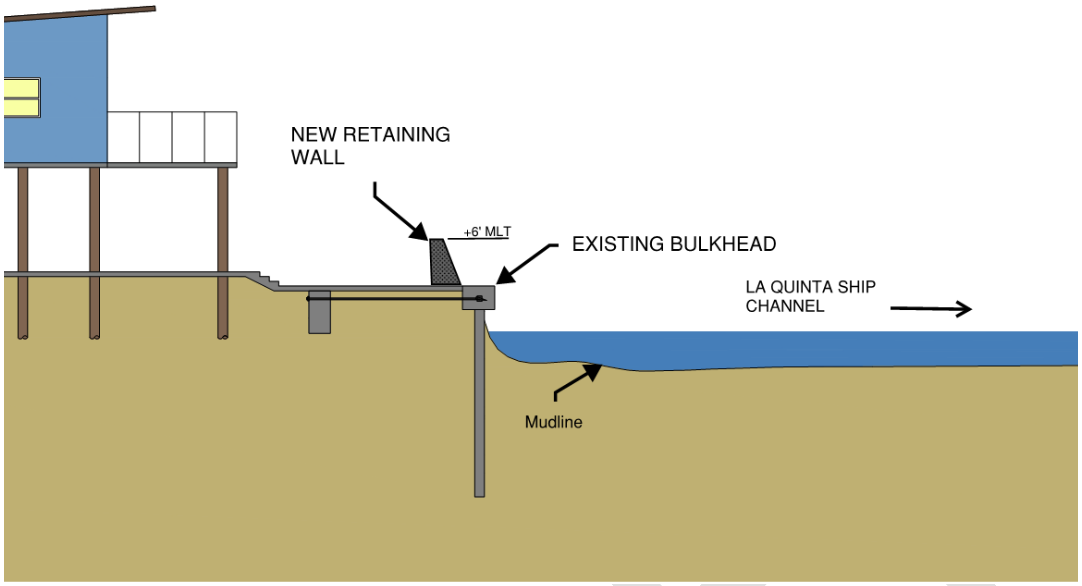

Figure 16. Alternative 3C – Build Retaining Wall at select sites

The options described previously (raising the bulkhead at select transects, adding retaining wall at select transects or raising the bulkhead along the full length of the transects at Region 2) are not expected to impact water circulation in the area as they would all be constructed on land. These options are anticipated to be the least complicated to construct, since this alternative only involves land-based construction. However, it should be noted that the quality of the existing bulkhead and retaining wall is unknown.

3.2 Cost Benefit Analysis

For each alternative, conceptual level costs were analyzed in order to estimate a range of price for the construction of this project. The alternatives and the associated price ranges for construction were based on discussions with contractors and/or estimated based on similar projects conducted by Mott MacDonald in the area. The following assumptions shall apply to the preliminary cost ranges presented in this section:

- Costs do not include final engineering, bidding phase support, construction oversight, or construction administration.
- Costs do not account for any changes in the final design of the preferred alternative and are intentionally incomplete as they are only for preliminary comparison purposes only.
- Unit costs based on discussions with contractors and/or estimated based on similar projects in the area

3.2.1 Alternative 1 - Dredging of the La Quinta Ship Channel

Alternative 1 consists of dredging the La Quinta Ship Channel (LQC) from -45 ft MLT to -75 ft MLT with a 2 ft overdredge. Mott MacDonald estimates that it would cost roughly $16 million to $30 million to dredge 2 million CY amount of material, in the LQC along Region 2, assuming a dredging cost ranging from $8/CY to $15/CY.

3.2.2 Alternative 2A - Riprap Breakwater

Alternative 2A consists of the construction of approximately 2,100 linear feet of riprap stone breakwater to extend the existing breakwater (Figure 14). The proposed breakwater centerline would be 50 feet seaward of existing bulkheads with a cross section that follows the existing stone breakwater template. The breakwater is anticipated to have a bottom width of 70-75 feet and a crest elevation of 6 ft MLT. With a large footprint, this alternative could lead to constructability issues and would limit access to the bay/channel area. Mott MacDonald estimates that this alternative would cost approximately $2,500 to $3,500 per linear foot of riprap stone breakwater construction or a total cost approximately between $5.0 to $7.5 million.

3.2.3 Alternative 2B - Sheetpile Breakwater

Alternative 2B consists of the construction of approximately 2,100 linear feet of steel sheetpile, reinforced concrete cap, and batter or soldier piles (Figure 15). This option would have a smaller footprint than the previous alternative, leaving more space between the centerline and the existing bulkhead, approximately 70 feet. The steel sheet pile section for the breakwater extension is anticipated to be an AZ type section of steel sheetpile. Further structural analysis is required to determine the embedment and size of the sheetpile section. Mott MacDonald estimates that this alternative would cost $2,000 to $3,000 per linear foot of steel sheetpile breakwater construction or a total cost approximately between $4 to $6.5 million.

3.2.4 Alternative 3A - Increase Bulkhead Elevation – select sites

Alternative 3A consists of raising the existing bulkhead elevation to 6 ft MLT at select sites with bulkhead elevations less than 5.8 ft MLT and without existing retaining walls (Figure 17). This could include removing all or a portion of the existing concrete cap and panels, installing sheetpile (Vinyl or Fiber Reinforced Plastic), a new concrete cap at least 2' thick and 3' wide, and installing anchor tiebacks for an approximate length of 186 linear feet. Mott MacDonald estimates that this alternative would cost $2,000 to $2,500 per linear foot of bulkhead installed for a total approximate cost between $350,000 to $500,000.

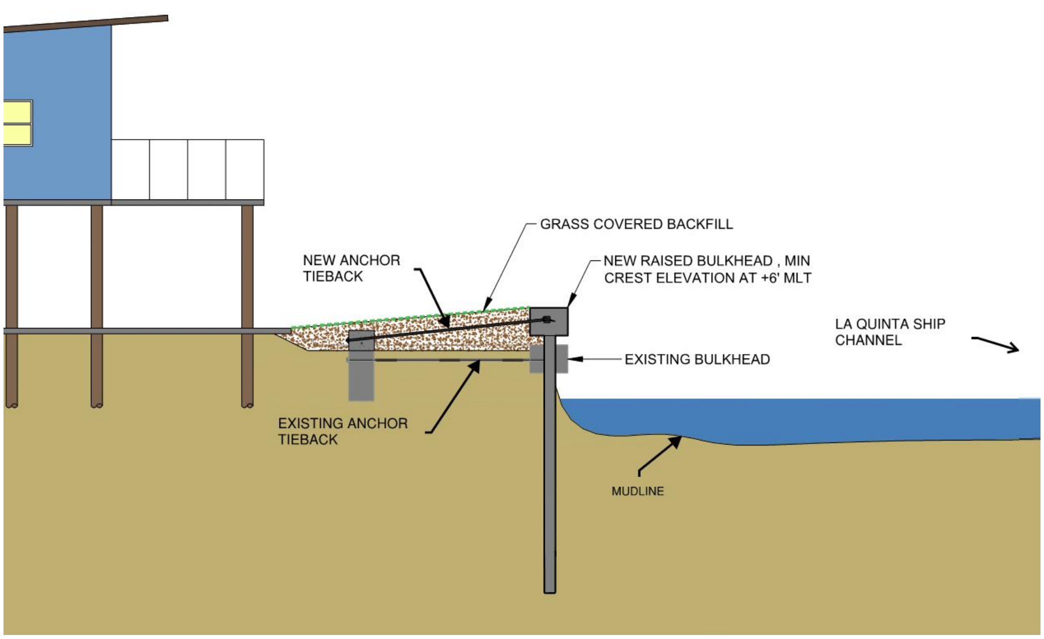

Figure 17. Alternative 3A – Increase Bulkhead Elevation at select sites

3.2.5 Alternative 3B - Increase Bulkhead Elevation – all sites

Alternative 3B consists of raising the existing bulkhead elevation to 6 ft MLT at all sites along Bayshore Drive, an approximate length of 1,300 linear feet (Figure 18). This could include removing all or a portion of the existing concrete cap and panels, installing sheetpiles (Vinyl or Fiber Reinforced Plastic), a new concrete cap at least 2' thick and 3' wide at 6 ft MLT, and installing anchor tiebacks. Mott MacDonald estimates that this alternative would cost $2,000 to $2,500 per linear foot of bulkhead installed for a total approximate cost between $2.5 to $3.5 million.

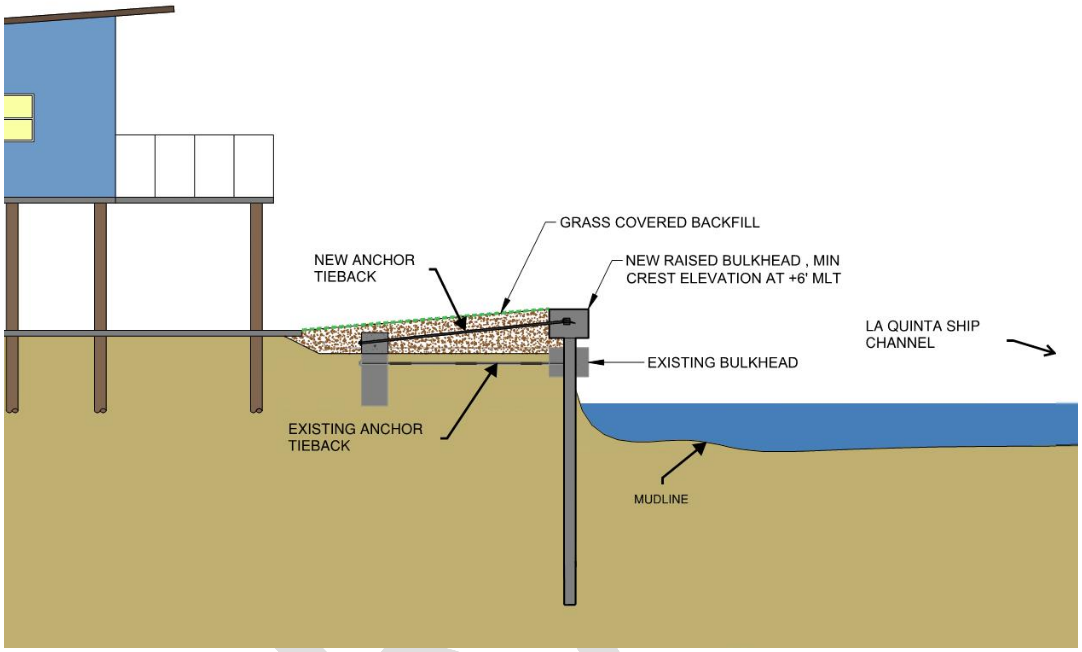

Figure 18. Alternative 3B - Increase Bulkhead Elevation at all sites

3.2.6 Alternative 3C - Build Retaining Wall – select sites

Alternative 3C consists if the installation of additional retaining wall, at an elevation of 6 ft MLT, for select sites with bulkhead elevations less than 5.8 ft MLT and without existing retaining walls (Figure 19). The proposed retaining wall would be placed on the existing bulkheads for these select areas, an approximate length of 186 linear feet. The proposed retaining wall could be constructed using cast-in-place or pre-cast concrete and is estimated that this alternative would cost approximately $150 to $250 per linear foot of retaining wall installed for a total approximate cost between $25,000 to $50,000.

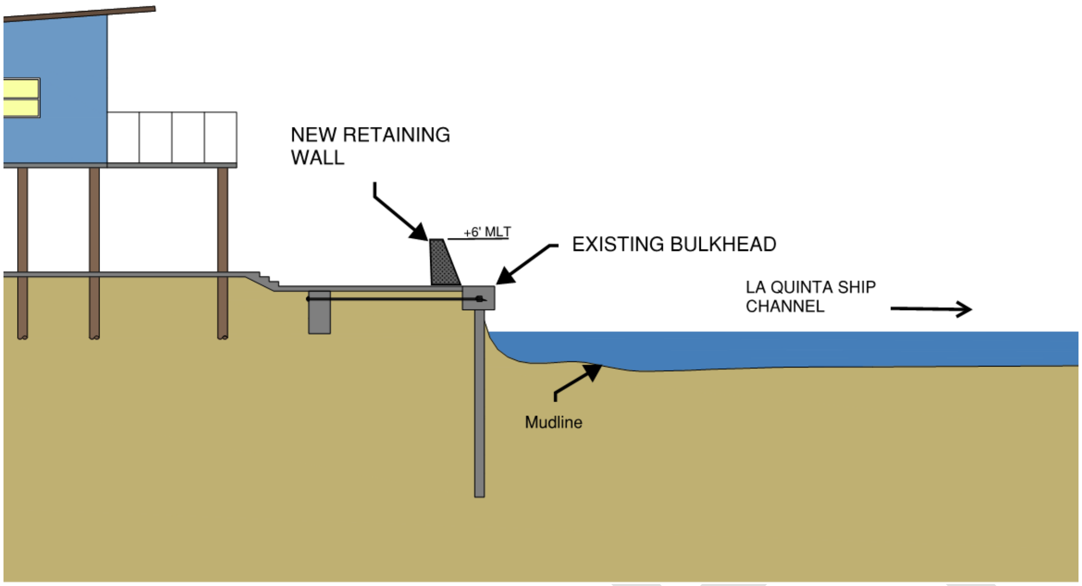

Figure 19. Alternative 3C – Build Retaining Wall at select sites

3.2.7 Total Cost Range for Each Alternative

Table 5, below shows the estimated cost ranges for the alternatives described previously.

Table 5. Preliminary mitigation alternative estimated cost ranges

	Alternative	Total Cost Range:		
1	Dredging of the LQC	$16 million	to	$30 million
2A	Riprap Breakwater	$5.5 million	to	$7.5 million
2B	Steel Sheetpile Breakwater	$4 million	to	$6.5 million
3A	Raise Bulkhead Elev. (select sites)	$350,000	to	$500,000
3B	Raise Bulkhead Elev. (all sites)	$2.5 million	to	$3.5 million
3C	Retaining Wall (select sites)	$25,000	to	$50,000

3.3 Evaluation Matrix

An alternatives analysis and evaluation was conducted to determine which alternative will be selected for future planning, permitting, and detailed design. A summary of the alternatives considered is provided below:

- Alternative 1 – Dredging of the La Quinta Ship Channel
- Alternative 2 – Seaward Shoreline Protection
  - Alternative 2a: Riprap breakwaters placed seaward of existing bulkheads
  - Alternative 2b: Sheetpile breakwaters placed seaward of existing bulkheads
- Alternative 3 – Improvements to existing bulkheads or retaining walls.
  - Alternative 3a: Increase bulkhead elevation – select sites
  - Alternative 3b: Increase bulkhead elevation – all sites
  - Alternative 3c: Build retaining wall – select sites

A list of criteria was established in order to evaluate the alternatives. The criteria developed are listed below:

- Performance
  - Reduction in overtopping
  - Circulation impacts
  - Seagrass impacts
- Construction
  - Total project cost
  - Constructability
- Public Perception
  - General Public Perception
  - Aesthetics
  - Shoreline Access

Considerations for assessing each alternatives ability to meet these criteria along with the scoring system methodology are discussed in the following sections. The scores for each criterion were varied between 1 (worst case) and 5 (best case). A weighting factor was assigned according to the relative importance of each criteria. The weighting factor was then multiplied by the score to develop a weighted score. The weighted scores for each criterion were then summed to develop an overall score for each alternative and rank the proposed alternatives. The resulting scores and rankings of the alternatives are summarized in Section 3.3.4.

3.3.1 Performance

The performance of the alternatives is the most critical criteria to evaluate. A criterion was developed to assess the alternatives ability to meet the project goal of reducing overtopping during passing vessel scenarios. The scoring for this criterion was based on the overtopping analysis described earlier in Section 2. In addition, a qualitative analysis of potential impacts to circulation in the project area was assessed. These criteria are further described in the following Sections.

3.3.1.1 Reduction in Overtopping

Reductions in overtopping were quantified for all alternatives as described earlier in Section 2. The results of this analysis were used to determine which alternatives provided adequate overtopping protection. The analysis showed that under normal, present day conditions, all alternatives except Alternative 1 are expected to meet the project goal of eliminating overtopping. The scoring table and criterion weighting factor are shown in Table 6.

Table 6. Scoring table and weighting factor for overtopping reduction.

Rating	Score	Weighting Factor
No Reduction	1	0.40
Full Reduction	5	

3.3.1.2 Circulation Impacts

This criterion was developed to qualitatively assess the impacts on circulation patterns near the project site. Land based alternatives (Alternatives 3A-3C) are not expected to alter circulation patterns near the project site. However additional dredging of the La Quinta Channel and construction of breakwaters could alter circulation. It is unclear whether these circulation pattern changes would have any negative impacts without additional modeling. Therefore, additional circulation modeling is recommended for alternatives with lower scores here if selected. The scoring table and criterion weighting factor are shown in Table 7.

Table 7: Scoring table and weighting factor for qualitative assessment of circulation impacts.

Rating	Score	Weighting Factor
Worst	1	
Poor	3	0.02
Neutral	5	

3.3.1.3 Seagrass Impacts

This criterion was developed to qualitatively assess the impacts on any seagrass habitats near the project site. This criterion is closely related to the circulation impacts but focuses on any negative impacts to seagrasses in the project area. Similar to the circulation criterion, land-based alternatives (Alternatives 3A-3C) are not expected to alter circulation patterns near the project site, and therefore have minimal impacts to any seagrass habitats. However additional dredging of the La Quinta Channel and construction of breakwaters could alter circulation, and in turn have negative impacts to seagrass. In addition, the in-water template of the breakwater alternative could intersect existing seagrass habitats. The scoring table and criterion weighting factor are shown in Table 8.

Table 8: Scoring table and weighting factor for qualitative assessment of seagrass impacts

Rating	Score	Weighting Factor
Worst	1	
Poor	3	0.03
Neutral	5	

3.3.2 Construction

The construction criteria category includes total project cost and constructability. These criteria are valued moderately high, as they are not valued as high as the performance category due to the project goals.

3.3.2.1 Project Cost

This criterion evaluates each alternative's preliminary total project cost. The scoring table and criterion weighted factor are available in Table 9.

Table 9. Scoring table and weighting factor for project cost.

Rating	Score	Weighting Factor
> $7,000,000	0.63	
$7,000,000 to $6,000,000	1.25	
$6,000,000 to $5,000,000	1.88	0.15
$5,000,000 to $4,000,000	2.50	
$4,000,000 to $3,000,000	3.13	
$3,000,000 to $2,000,000	3.75	

3.3.2.2 Constructability

This criterion assesses the ease of construction for each alternative. The main factors governing the constructability are the access (i.e., shoreline or barge), simplicity of the structure layout, and the interface with the existing bulkheads. The breakwater alternatives will require access from a barge to place the material or drive the sheetpile. In addition, there is limited space adjacent to the proposed breakwater template, which could cause difficult work conditions when working next to the adjacent existing bulkheads. Similarly, the slope of the current La Quinta channel leaves little room for expansion closer to the existing bulkheads. This could complicate construction of the Dredging of the La Quinta ship channel alternative. While the bulkhead/retaining wall improvement alternatives can be constructed by land, the condition of the existing bulkheads is relatively unknown. If the bulkheads are currently in poor condition, the entire bulkhead may need to be replaced before a new cap is added or adjacent retaining wall is constructed. The scoring table and the criterion weighting factor are shown in Table 10.

Table 10: Scoring table and weighting factor for constructability.

Rating	Score	Weighting Factor
Most Difficult	1	
More Difficult	2	
Moderately Difficult	3	0.10
Less Difficult	4	
Least Difficult	5	

3.3.3 Public Perception

Public perception considers how the public will perceive the alternative after construction. This category includes the aesthetics and any possible recreational use of the project site for any given alternative.

3.3.3.1 General Public Perception

The general public perception criterion evaluates the anticipated public reaction to each alternative. The scoring is applied in a qualitative manner but takes into consideration differences in alternative construction and design. For example, Alternative 3A and 3C only propose improvements to selected properties along the project shoreline. These alternatives may result in a negative reaction from adjacent property owners, who have already raised their bulkheads and/or constructed retaining walls. Therefore, Alternative 3B scores higher than 3A or 3C on the general public perception category.

3.3.3.2 Aesthetics

The aesthetics criterion evaluates the anticipated public's reaction to how the alternative will look and merge with the surroundings. The scoring is applied in a subjective manner, but takes into consideration construction material type, natural appearance along the shoreline, and quantity of exposed material above the MLLW line. For example, it is assumed that the public would prefer new sheetpile breakwater over rock breakwater construction material. Similarly, it is assumed that dredging of the existing channel, which makes no changes to the viewshed, would be better received for aesthetics than adding a cap or retaining wall to the existing bulkhead. Finally, it is assumed that a continuous shoreline profile, i.e. increasing the bulkhead elevation at all sites, would be preferable to a varied elevation profile from repairing only selected sites. The scoring table and the criterion weighted factor are shown in Table 11.

Table 11: Scoring table and weighting factor for aesthetics.

Rating	Score	Weighting Factor
Worst	1	0.05
Poor	5	
Neutral	3	
Good	4	
Best	5	

3.3.3.3 Shoreline Access

The shoreline access criteria evaluate the alternatives' ability to allow meet these needs in order to not inhibit public use of the shoreline and nearshore region. Aerial examination of the project site shows multiple docks along the homeowner's land. This criterion evaluates considerations such as access to the shoreline via water and land, and navigation space around existing docks and bulkheads. For example, elongated breakwaters will offer less access to the shoreline from the bay side than the dredging or bulkhead improvement alternatives. The scoring table and the criterion weighted factor are shown in Table 12.

Table 12: Scoring table and weighting factor for aesthetics.

Rating	Score	Weighting Factor
Worst	1	0.10
Poor	5	
Neutral	3	
Good	4	
Best	5	

3.3.4 Final Evaluation Matrix

Each alternative was first evaluated individually against the criteria discussed above. A score was applied to each, and then it's the weighted score was calculated using the weighted factor for each criterion (weighted score = score * weighted factor). After which, each alternative's total score was calculated by summing the weighted score among all the criteria. An evaluation matrix was then developed to compare the resulting total scores among the list of total alternatives. The resulting evaluation matrix is provided in Table 13.

Table 13. Final evaluation matrix for all alternatives

Criteria	Circulation Impacts		Seagrass Impacts		Percent Reduction in Overtopping		Project Cost		Constructability		General Public Perception		Shoreline Access		Aesthetics		
Weighted factor:	0.02		0.03		0.40		0.15		0.10		0.15		0.10		0.05		
Alternatives	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**TOTAL SCORE**
Alt.1 - Dredging La Quinta Ship Channel	3.00	0.06	3.00	0.09	0.00	0.00	0.63	0.09	3.00	0.30	3.00	0.45	5.00	0.50	5.00	0.25	1.74
Alt. 2a- Seaward Shoreline Protection - Riprap	1.00	0.02	1.00	0.03	5.00	2.00	1.25	0.19	1.00	0.10	3.00	0.45	1.00	0.10	5.00	0.25	3.14
Alt. 2b - Seaward Shoreline Protection - Sheetpile	1.00	0.02	1.00	0.03	5.00	2.00	1.88	0.28	2.00	0.20	3.00	0.45	1.00	0.10	1.00	0.05	3.13
Alt. 3a- Increase Bulkhead Elevation - Select Sites	5.00	0.10	5.00	0.15	5.00	2.00	5.00	0.75	3.00	0.30	1.00	0.15	4.00	0.40	4.00	0.20	4.05
Alt. 3b- Increase Bulkhead Elevation - All Sites	5.00	0.10	5.00	0.15	5.00	2.00	3.75	0.56	3.00	0.30	5.00	0.75	4.00	0.40	5.00	0.25	4.51
Alt. 3c - Build retaining wall - Select Sites	5.00	0.10	5.00	0.15	5.00	2.00	5.00	0.75	3.00	0.30	1.00	0.15	4.00	0.40	4.00	0.20	4.05

Based on the results of the total scores provided in the evaluation matrix, and additional input from engineering experience, a final ranking system was applied to the alternatives. First, a color coordinated ranking system was applied to the 3 alternatives general alternative categories. The color rank indicates the overall preference of the type of structural arrangement, where green indicates the preferred type of structural arrangement, yellow indicates not preferred, and red indicates not recommended. Additionally, a numerical ranking system was applied to all the alternatives and each of the different alternative variations, where 1 is the most preferred alternative and material type and 7 is the least preferred alternative and material type. The final ranks per alternative are provided in Table 14.

Table 14: Resulting ranks for alternatives

Alternative	Rank
Alt. 1 - Dredging La Quinta Ship Channel	6
Alt 2a - Seaward Shoreline Protection - Riprap	4
Alt 2b - Seaward Shoreline Protection - Sheetpile	5
Alt 3a - Increase Bulkhead Elevation - Select Sites	2 (Tie)
Alt 3b - Increase Bulkhead Elevation - All Sites	1
Alt 3c - Build retaining wall - Select Sites	2 (Tie)

4 Conclusions

This technical memorandum summarizes the work and results of a numerical modeling study of vessel hydrodynamics conducted by Mott MacDonald at the request of the Port of Corpus Christi Authority (PCCA) under Service Order No. 2 of PCCA Master Services Agreement NO.18-03. The purpose of this study was to investigate the hydrodynamic effects of multiple proposed locations of a beneficial use (BU) Dredged Material Placement Area (DMPA) near the intersection of the La Quinta and Corpus Christi Ship Channels (BU Site C-Q), as well as the deepening of the La Quinta Ship Channel. In addition, a feasibility study was performed on multiple alternatives designed to mitigate overtopping along the Bayshore Drive properties. The project goals are listed below, and following each goal, is a summary of the findings and results from this study.

1. Quantify changes in passing vessel impacts by analyzing water level fluctuations along the shoreline between existing and proposed conditions.
    a. Optimization of the BUS C-Q location was tested in the VH-LU model. First, the East/West alignment was tested in the model. Negligible changes in WSE were found between the two test cases. Therefore, the proposed alignment of C-Q from PCCA was used to test the North/South optimization. Although, there were no significant changes in Region 2 between the simulations, a significant increase in WSE elevation was observed near Berry Island when shifting the alignment northward. This would have adverse effects on the south shore of Berry Island, which is private property. In conclusion, the alignment of BUS C-Q provided by PCCA should be used and does reduce WSE in Region 2 when compared to existing conditions. Therefore, it was concluded that the proposed C-Q alignment is at the optimal location. The results also show that the inclusion of C-Q provides measurable benefits to the Ingleside shoreline when compared to existing conditions.
2. Identify and test potential structural and non-structural mitigation measures for reducing impacts to the shoreline due to hydrodynamic conditions created by passing vessels.
    a. The deepening of the LQC along the Bayshore Drive properties was tested in the VH-LU model. The reduction of WSE was quantified at each transect along the shoreline and was found to be negligible. Additionally, overtopping was still observed at Transect 13. Therefore, this alternative is not feasible.
    b. Based on the cost benefit analysis, the breakwater extension proved to be the second costliest alternative. The steel sheetpile breakwater is less expensive than the riprap breakwater and consists of a smaller footprint, making it the better option. However, this alternative could lead to potential construction issues due to the limiting access to the channel and bay, and water quality issues due to the decrease in water circulation behind the proposed breakwater.
    c. Based on the cost benefit analysis, raising bulkhead/retaining wall elevation was the least costly alternative. Because this alternative only consists of land-based construction, construction costs are anticipated to be much lower than the other alternatives. The bulkhead option proved to be more expensive than the retaining wall per linear foot. Thus, building the retaining wall at select sites is assumed to be the most cost-effective alternative because of the low amount of necessary construction materials.

3. Perform a feasibility study on proposed alternatives for mitigating overtopping along the Bayshore Drive properties.
    a. The deepening of the LQC along the Bayshore Drive properties showed the lowest score among alternatives. This is due to the prohibitively high cost and low reduction in overtopping.
    b. The breakwater alternatives (Alternative 2A and 2B), showed the next lowest score in the evaluation matrix. These relatively low scores are due to the high costs, and potential impacts to circulation patterns and seagrass beds near the project site. If the breakwater alternatives are selected, it is recommended that a full circulation modeling effort be conducted to properly quantify any impacts to the project site.
    c. Finally, the improvements to the existing bulkhead show the highest ratings in the evaluation matrix. Increasing the bulkhead elevation or bulkhead elevation or building a retaining wall have the same score, while increasing the bulkhead elevation across all sites shows the highest score. When choosing between these options, consideration should be given to cost, uncertainty in the cost estimate, and general public perception. Currently, building the retaining wall at select sites is assumed to be the most cost-effective alternative because of the low amount of necessary construction materials. However, there is significant uncertainty regarding the condition of the existing bulkhead and its ability to support either an increased bulkhead elevation or retaining wall. A full site inspection should be performed if either Alternative 3A or 3C are selected to verify the stability of the existing bulkhead. If the bulkhead is deemed deficient, the costs outlined in this memorandum could significantly increase. Finally, public perception of Alternative 3A or 3C is likely to be lower than 3B, due to potential negative reactions from adjacent property owners, who may have already raised their bulkheads and/or constructed retaining walls.

5 References

MM. (2019). *Passing Vessel Hydrodynamic Study in the vicinity of Ingleside Cove and Ingleside-on-the-Bay, Texas.* Corpus Christi: Prepared for Port of Corpus Christi Authority by Mott MacDonald.

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