COASTAL TEXAS STUDY

Coastal Texas Protection and Restoration Feasibility Study

Final Feasibility Report

Appendix D – Annex 3:

Mott MacDonald (MM) Report #2 - Galveston Ring Barrier Overtopping Memorandum

August 2021

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Galveston Ring Barrier Overtopping Memorandum

Coastal Texas Protection and Restoration Study

February 19, 2020

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Galveston Ring Barrier Overtopping Memorandum

Coastal Texas Protection and Restoration Study

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Executive summary

A hydrologic and hydraulic (H&H) evaluation memorandum was previously submitted to the Texas General Land Office (GLO) on August 31st, 2018 that summarized the pump facilities required to mitigate the impacts of the proposed risk reduction features on the fluvial and overland flows at Clear Creek, Dickinson Bayou, and the City of Galveston. After submittal of that memorandum, the extremal wave and water surface elevation statistics used to compute overtopping of the proposed risk reduction features were updated by the United States Army Corps of Engineers (USACE). As part of Amendment 6 to Work Order No. A987 under GLO Contract No. 18-127-044, Mott MacDonald was tasked with updating the overtopping calculations along the Galveston Ring Barrier using the revised statistics provided by the USACE. As part of this Amendment, the revised overtopping calculations were performed along the Galveston Ring Levee only. No additional overtopping calculations along the proposed seawall improvement were included in this Amendment.

As part of the H&H evaluation memorandum previously submitted on August 31st, 2018, the hydrologic and hydraulic modeling for the City of Galveston was conducted using the Environmental Protection Agency Storm Water Management Model (EPA SWMM). The analysis included the evaluation of five storm return periods: 10, 25, 50, 100, and 500-year precipitation events. Based on discussions and guidance from the USACE, the precipitation depths and distributions were taken from the Harris County Flood Control District (HCFCD) Hydrology and Hydraulic Manual, with the total rainfall depths augmented by 30% to reflect the anticipated revisions to the National Oceanographic and Atmospheric Administration (NOAA) Atlas 14 Volume 9 data. A comparison of the augmented rainfall depths, with the actual NOAA Atlas 14 data showed similar rainfall amounts, with the augmented rainfall depths slightly higher.

Within the City of Galveston watershed, use was made of existing storage capacity within Offatts Bayou by dewatering the interior area in advance of the storm (to -1 ft MLLW) and by allowing the interior water surface to rise to a predetermined maximum elevation (+4’ NAVD88) to attenuate peak flow without causing damages. No changes to the rainfall events used in the original H&H evaluation were made in this updated memorandum per the scope of work included in Amendment 6.

The revised extremal wave and water surface elevations provided by the USACE were used to develop updated overtopping calculations for the 100-year event. To determine the 100-year overtopping event, each storm the JPM-OS suite developed by the USACE was analyzed. A representative storm was chosen at each extraction point, and the peak water surface elevation was scaled to match the 100-year wave and water surface elevations provided by the USACE. The waves were then transformed to the base of the structure, and input into analytical overtopping equations. Note that per discussion with the USACE, overtopping was calculated for the 100-year, 90% Confidence Interval (CI), 0.0’ SLR scenario. It is assumed that floodwall elevations will be increased to combat future SLR to mitigate additional overtopping in the future.

The Galveston Hydrology model, previously developed in earlier phases of this work, was updated to include the latest overtopping calculations. The hydrology and hydraulic models were used to develop the design facilities for the 25-year (+30%) fluvial event in combination with the overtopping rate associated with the 100-year tropical storm. The revised model was used to estimate any required changes in the capacity of the proposed pump stations and

conveyance channels due to the inclusion of the 100-year overtopping rates. A summary of the revised pump station and conveyance channel size estimates can be seen below in ES Table 1.

ES Table 1. Comparison of estimated facilities for the 25-yr+30% rainfall event for Galveston between the previous analysis (without overtopping) and revised analysis (with overtopping).

Pump Station Location	Previous Pumping Rate [cfs]	Revised Pumping Rate [cfs]	Previous Conduit Channel Dimensions	Revised Conduit Channel Dimensions
Offatts Bayou (Pump Site No. 1)	250	4500	30' wide x 13' high 390 sf	32' wide x 13' high 416 sf
Pump Site No. 2	1,500	1500	20' wide X 10' high 200 sf	20' wide X 10' high 200 sf
Pump Site No. 3	4,500	5000	20' wide X 10' high 200 sf	30' wide x 10' high 300 sf
Pump Site No. 4	1,500	5000	20' wide X 10' high 200 sf	25' wide x 10' high 250 sf

Note that this analysis does not include overtopping of the seawall along the Gulf. The pump facilities shown in ES Table 1 do not account for seawall overtopping since it was not included in the scope of work. Once the USACE has finalized the seawall design, it is recommended that comprehensive overtopping analysis be conducted. If significant overtopping of the seawall is found once the design has been finalized, the pump station capacities outlined in this report may need to be revised. The additional overtopping increase in pump station capacity and conveyance conduits sizes shown in ES Table 1 were included in the Rough Order of Magnitude (ROM) costs developed under Task E and summarized in a separate memorandum.

1 Introduction

The Selected Plan for the Coastal Texas Protection and Restoration Study calls for erecting a coastal flood barrier along portions of Galveston Island. Wind and low atmospheric pressures accompanying tropical and extra-tropical storm events also produce extreme rain events. Without proper measures, coastal flood defenses intended to mitigate flooding resulting from storm surge can form a barrier to runoff generated during the rainfall event.

This memorandum serves to update the previous technical memo submitted August 31, 2018 (Mott MacDonald, 2018) with revised overtopping volumes. The USACE has updated the extremal water surface elevation and wave conditions, and as a result the overtopping estimates for the bayside of Galveston Island have also changed. This memorandum serves to update the required pump sizes to mitigate this additional overtopping volume.

Significant coordination has been conducted with the USACE Galveston District to agree upon input conditions, design requirements, as well as overtopping limits for this analysis. A summary of these conditions is as follows:

- Floodwall Elevation: A floodwall elevation of +14.0' NAVD88 is assumed for all ring barrier alignments.
- Design Condition for Overtopping: Overtopping shall be calculated for the 100-year, 90% Confidence Interval (CI), 0.0' SLR event. The 0.0' SLR event was chosen to reduce initial construction costs. It is assumed that the floodwall elevation will be increased in the future to mitigate any impacts to SLR.
- Overtopping Limits: The USACE (USACE, 2019) has provided limits on overtopping rates. These limits are a no damage limit of 0.1 cfs/ft for the 90% Confidence Interval event, and 1.0 cfs/ft as an ultimate limit. Any sections of ring barrier that exceed these limits should have additional armoring measures implemented to prevent damage of infrastructure behind the floodwall.
- Seawall Overtopping Analysis: No analysis of overtopping of the proposed seawall improvement is included in these calculations or pump size estimates. The USACE is separately developing a finalized design for the seawall improvement, as well as quantifying overtopping. If significant overtopping of the seawall is noted, the pump and conduits sizes shown in this memorandum may need to be revised.

Using these design criteria, the existing model was updated with new overtopping rates to resize the pump stations and conveyance conduits. No other updates were made to the existing model developed by Matt MacDonald, 2018. Since development of the original model, the USACE has revised the ring barrier alignment. The revised modeling does take into account increased overtopping volumes due to a revised ring barrier length (See Section 3.4.1), but does not modify the drainage area used in the model. This was done due to time and budget constraints. However, a qualitative discussion of potential pump size changes due to the change in drainage area from the revised alignment is conducted in Section 3.4.3.

2 Galveston Ring Barrier Overtopping

2.1 Alignment Comparison

An overtopping analysis was conducted along the proposed Galveston Ring Barrier using revised extremal statistics provided by the USACE. This analysis was conducted to determine whether overtopping of the ring barrier causes any changes in the required pump capacity. In previous stages of analysis, a high-level hydrologic and hydraulic (H&H) model was developed for the city of Galveston to evaluate pump facilities required to mitigate the impacts of the proposed risk reduction features on the fluvial and overland flows. This model was developed in 2018 with the proposed Tentatively Selected Plan (TSP) Ring Barrier alignment. Since then, the United States Army Corps of Engineers (USACE) has revised the proposed Ring Barrier Alignment (USACE, 2019). The USACE has also proposed new locations for the pump stations. A comparison of the two alignments and pump station locations is shown in Figure 1.

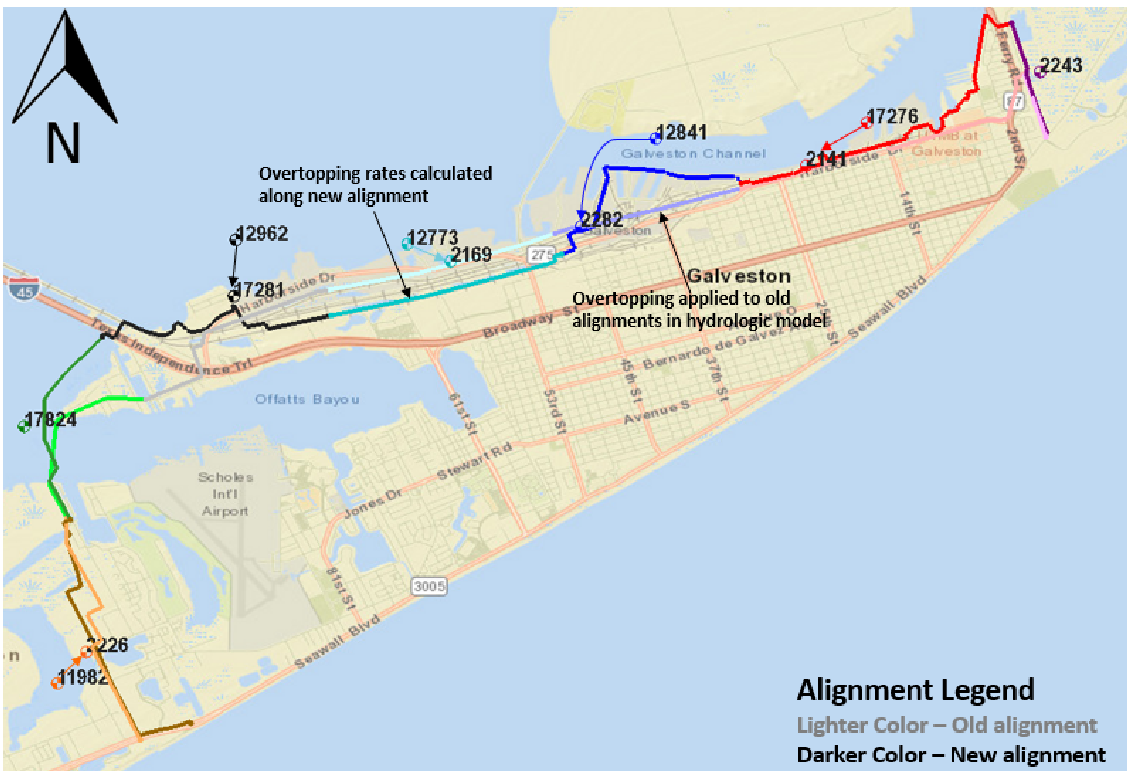

Figure 1. Comparison of original and revised barrier alignments. Color coded arrows represent linear shoaling to transform waves to structure.

As shown in Figure 1, there are differences in the two alignments. The analysis conducted in this memorandum utilized the existing model due to scope and schedule constraints. In order to obtain meaningful results and account for the new length of the revised barrier alignment, while still utilizing the existing model, a scaling procedure was proposed. The procedure involves the following steps, which relates the overtopping rates calculated for the revised barrier alignment to the original model:

1. First, extraction points were identified where extremal wave and water surface elevation timeseries were developed for the 100-year event.

2. The results from each point were then transformed to the toe of the proposed structure along the revised barrier alignment using linear wave shoaling theory.
3. For each extraction point, a corresponding reach of the revised barrier alignment was identified.
4. Overtopping rates were calculated at each point using the transformed wave results. This overtopping rate was then applied to the corresponding reach of ring barrier to get an overtopping volumetric rate per section of the revised barrier alignment.
5. The volumetric rate per section of the revised barrier alignment was then applied to the existing H&H model to determine the required pump capacity and conveyance channel cross section sizes.

Note that no changes were made to the conveyance channel layout, locations, or lengths for this analysis. Similarly, no changes were made to the pump site locations. The extraction points and applicable alignment reaches used for this analysis can be seen in Figure 1.

Also note that while this methodology considers changes in overtopping rates due to the revised alignment, it does not account for the increased acreage inside of the refined alignment which could capture rainfall. Section 3.4.3 of this memorandum attempts to qualitatively discuss the potential changes in pump station capacity due to these changes. However, a quantitative assessment, including revising the model to include the revised alignment and pump facility locations, is recommended in future stages of analysis.

2.2 Assumed Structure Design and Sea Level Rise (SLR) Scenario

Overtopping of coastal structures is highly dependent on both the cross-sectional design of the protection element and the adjacent water body conditions during a storm event. The USACE has indicated that the proposed top elevation of the floodwall is +14.0’ NAVD88. For this analysis, the USACE directed Mott MacDonald to use the 0.0’ Sea Level Rise (SLR) case for all overtopping calculations. It is assumed that the floodwall elevation will be increased over time in accordance with the appropriate SLR rate. While all calculations in this analysis assumed 0.0’ SLR, Section 9 examines the peak overtopping rates for the 2.1’ SLR design scenario.

2.3 Extremal WSE and Wave Conditions

The USACE modeled 170 storms comprising the Joint Probability with Optimal Sampling (JPM-OS) storm suite using a coupled ADCIRC-STWAVE model. The USACE used these storms to develop extremal wave and water surface elevation statistics. These statistics erroneously showed high-water surface elevations along the backside of Galveston Island. To correct for this error, the USACE supplied revised water surface elevations at selected points for use in this analysis. A comparison of the initial results (blue) and revised results (red) is shown in Figure 2.

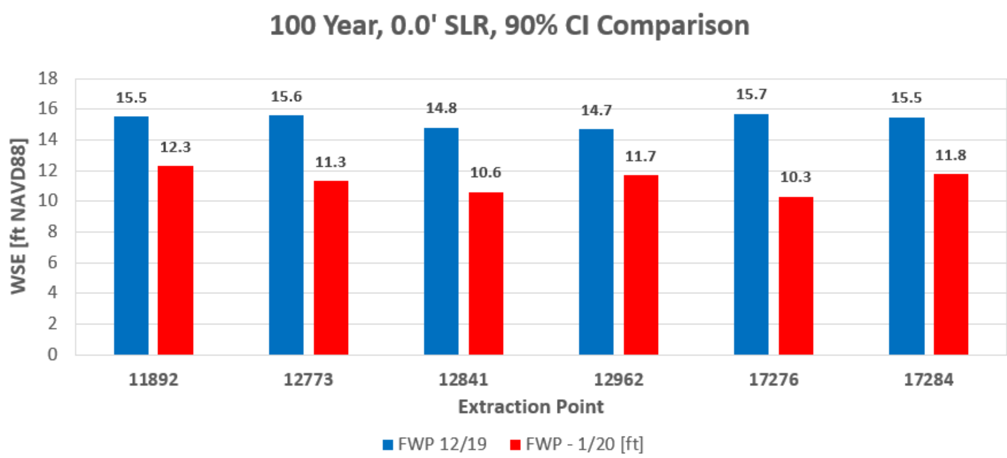

Figure 2. Comparison of initial and revised 100-year, 0.0’ SLR, 90% Confidence Interval results provided by USACE.

The wave conditions provided by the USACE did not require a bias correction. Therefore, the original future with project extremal wave results were used for this analysis. A summary of the final extremal wave and water surface elevations is shown below in Table 1. Note that these are the offshore wave conditions. The shoaled wave conditions are examined further in Section 2.5.

Table 1. Summary of 50% and 90% Confidence Interval (CI) results for the 0.0' SLR, 100-year case.

Point	WSE [ft NAVD88] - 50% CI	WSE [ft NAVD88] - 90% CI	Hs [ft] - 50% CI	Hs [ft] - 90% CI
11892	10.0	12.3	2.1	2.5
12773	9.2	11.3	5.3	6.2
12841	8.6	10.6	2.0	2.4
12962	9.6	11.7	5.8	6.8
17276	8.3	10.3	3.3	3.9
17284	9.6	11.8	4.0	4.6

2.4 Storm Selection

To determine the 100-year overtopping rate, the peak water surface elevation during each storm timeseries was compared to the 100-year, 90%, present day water surface elevation (0.0’ SLR) shown in Table 1. A representative storm was selected using the following methodology, in coordination with the USACE:

1. Extract the peak WSE and wave height for each storm at all seven offshore extraction points shown in Figure 1.
2. Find the difference between the peak WSE and 100 year, 0.0’ SLR, 90% CI WSE for each storm, at each point.
3. Find the difference between the wave height and 100 year, 0.0’ SLR, 90% CI wave height for each storm, at each point.
4. Select the storm that minimized the absolute error in WSE at each point. Also compare the wave height error and ensure that an under conservative storm is not selected.

5. Scale the peak WSE of the selected storm so that it matches the 100-year value at each point.
    a. Note – no scaling was performed on the peak wave heights of the selected storm. This was done to preserve realistic storm dynamics, maintain a peak wave height distribution that is realistic across all extraction points.

An example of the error calculation is shown below in Table 2, for the 5 storms which resulted in a peak WSE that is closest to the 100-year, 0.0’ SLR, 90% CI value.

Table 2. Five storms that cause the closest absolute WSE to the 100-year, 90% CI value. Values shown are averaged across all extraction points

Storm Number	WSE Avg. Absolute Diff from 100yr [m]	Hs Avg. Absolute Diff. from 100yr [m]
0261	0.28	0.44
0074	0.41	0.15
0634	0.43	0.25
0595	0.44	0.28
0260	0.53	0.37

As shown in Table 2, Storm 0261 minimized the average absolute error when compared to the extremal values. In addition, the wave heights were close to the 100-year value, however the absolute error is higher than the other 4 storms shown. However, the wave heights are slightly above the 100-year values. Therefore, to maintain a slightly conservative estimate at this stage of planning, Storm 0261 was selected as the representative storm for the 100-year, 0.0’ SLR, 90% CI scenario. Figure 3 shows a comparison of the peak values for Storm 0261, and the extremal values at each extraction point.

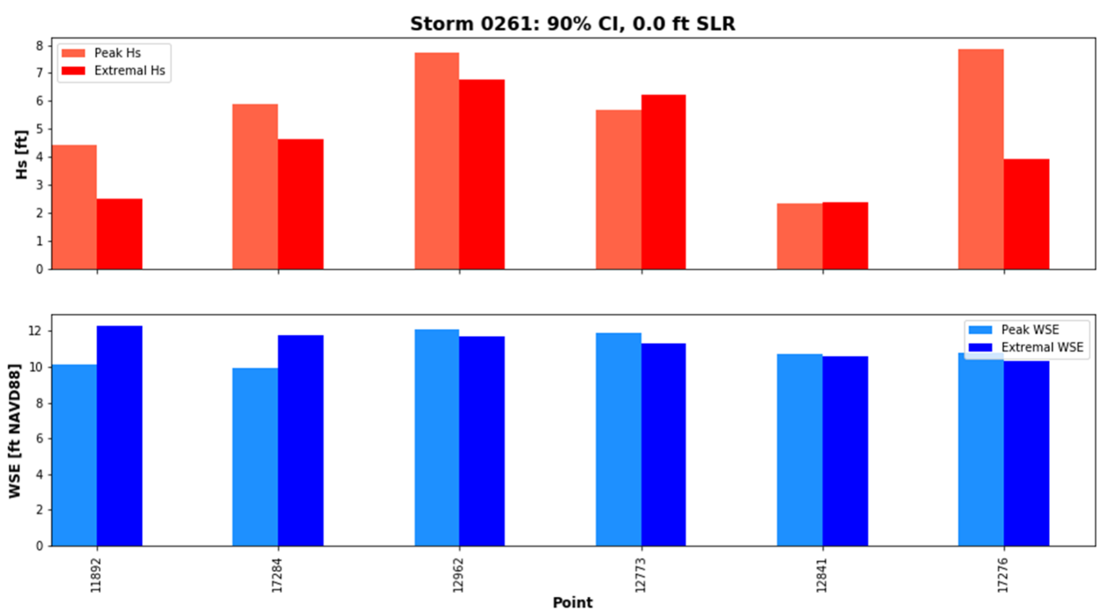

Figure 3. Comparison of peak wave and water surface elevations to 100-year, 0.0' SLR, 90% CI values.

2.5 Scaling and Shoaling of Representative Storm

Once a representative storm was selected, the peak water surface elevation was then scaled to the 100-year, 90% CI value. This process was performed at each extraction point, so the representative storm has a peak value that matches all 100-year, 90% CI values. Finally, the waves were shoaled to a representative extraction point at the toe of the structure. The representative extraction points were selected manually, to approximately represent the average depth along each segment of floodwall. See Appendix A for a full summary of all input conditions used for overtopping at the specified extraction points.

2.6 Overtopping Timeseries Calculation

As described in the previous section, Storm 0261 was selected as the representative storm, and the wave and water surface elevation timeseries were developed for all extraction points. Then the overtopping rates were calculated using the shoaled wave heights, and the scaled water surface elevations. Vertical wall overtopping equations from the Eurotop, 2018 manual were used to calculate an overtopping timeseries along the proposed ring barrier improvements for the selected storm. A timeseries showing the scaled water surface elevation and wave heights at point 17824 is shown below in Figure 4. Note that point 17824 was adjacent to the proposed gate structure, so no shoaling or transformation was conducted.

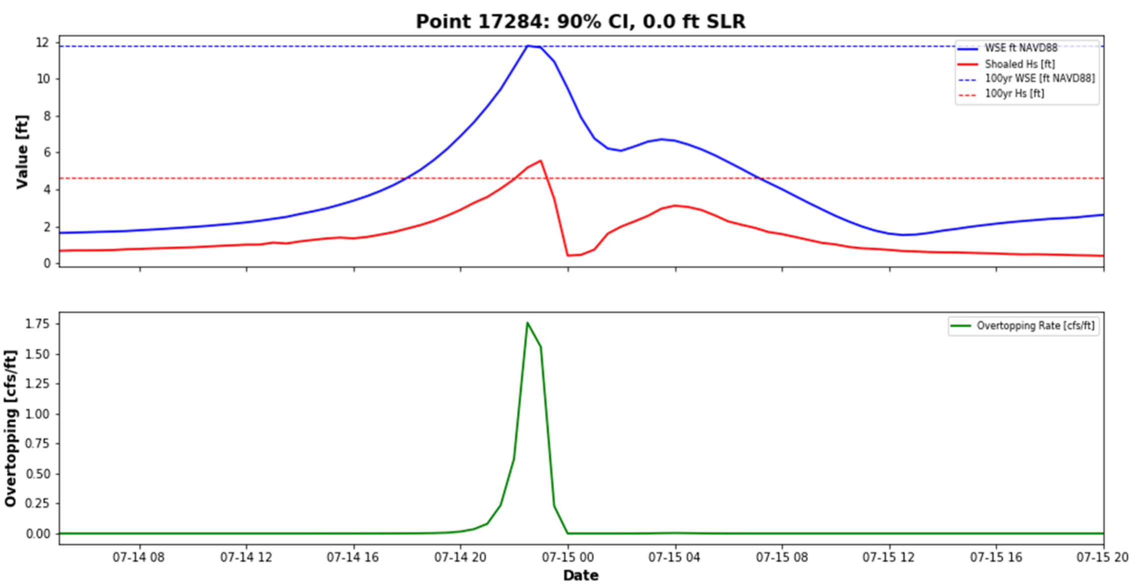

Figure 4. Timeseries of water surface elevation and wave heights (top) compared to overtopping rates (bottom).

Overtopping timeseries similar to Figure 4 were produced at all extraction points, and applied to the hydrologic model as described in Section 3. A summary of the peak overtopping rates for the design condition agreed upon with the USACE (100-year, 90% CI, 0.0’ SLR) are shown below in Table 3.

Table 3. Summary of Peak Overtopping Rates [cfs/ft] for all extraction points.

Point	100-year, 90% CI, 0.0' SLR [cfs/ft]
11892	0.61
17284	1.76
12962	1.06
12773	0.19
12841	0.01
17276	0.39

The overtopping rates shown above are color coded to represent exceedance of different thresholds, given by USACE, 2019. The design guidance thresholds are 1.0 cfs/ft for the ‘ultimate limit’, and 0.1 cfs/ft at the 90% CI for the ‘no damage’ criteria. These overtopping limits are also detailed in USACE, 2012. Red values indicate that the peak over overtopping limit exceeds the ‘ultimate limit’ threshold, and orange values indicate that the ‘no damage’ limit is exceeded.

Based on the results shown in Table 3, large portions of the proposed floodwall are expected to exceed the limit criteria. Therefore, armoring, reinforcement, or selected raising of the floodwall height is recommended to prevent excessive damage behind the floodwall.

2.7 Peak Overtopping Rates for Other Scenarios

In addition to the design scenario of 100-year, 90% CI, 0.0’ SLR, other scenarios were investigated. A summary of the other scenarios investigated is below:

- <u>100-year, 90% CI, 0.0’ SLR:</u> Design scenario agreed upon with USACE.
- <u>100-year, 50% CI, 0.0’ SLR:</u> Lower assurance, with 0.0’ SLR.
- <u>100-year, 90% CI, 2.1’ SLR:</u> With SLR condition scenario. Investigated to see overtopping in future and assess potential floodwall raises needed.
- <u>100-year, 50% CI, 2.1’ SLR:</u> Lower assurance, with SLR.

A summary of the overtopping results for the scenarios listed above is shown below in Table 4.

Table 4. Summary of peak overtopping rates [cfs/ft] for different confidence interval and SLR scenarios.

Point	100-year, 50% CI, 0.0' SLR [cfs/ft]	100-year, 90% CI, 0.0' SLR [cfs/ft]	100-year, 50% CI, 2.1' SLR [cfs/ft]	100-year, 90% CI, 2.1' SLR [cfs/ft]
11892	0.03	0.61	0.11	1.08
17284	0.30	1.76	0.58	2.98
12962	0.07	1.06	0.64	4.17
12773	0.003	0.19	0.18	1.86
12841	0.002	0.01	0.001	0.11
17276	0.05	0.39	0.03	0.90

Table 4 shows that the with SLR condition causes large increases in peak overtopping rates. For the 90%, with SLR scenario, most extraction points show peak rates above the ‘ultimate limit’, with the highest value of 4.17 cfs/ft at extraction point 12962. To mitigate these large overtopping rates in the future, it is recommended that the floodwall elevation be raised in the future to combat SLR and mitigate any future increases in overtopping. Figure 5 shows sensitivity testing for different floodwall heights, comparing the peak overtopping rate for the 100-year, 90%CI, 2.1’ SLR scenario to the ‘ultimate’ and ‘no damage’ limits.

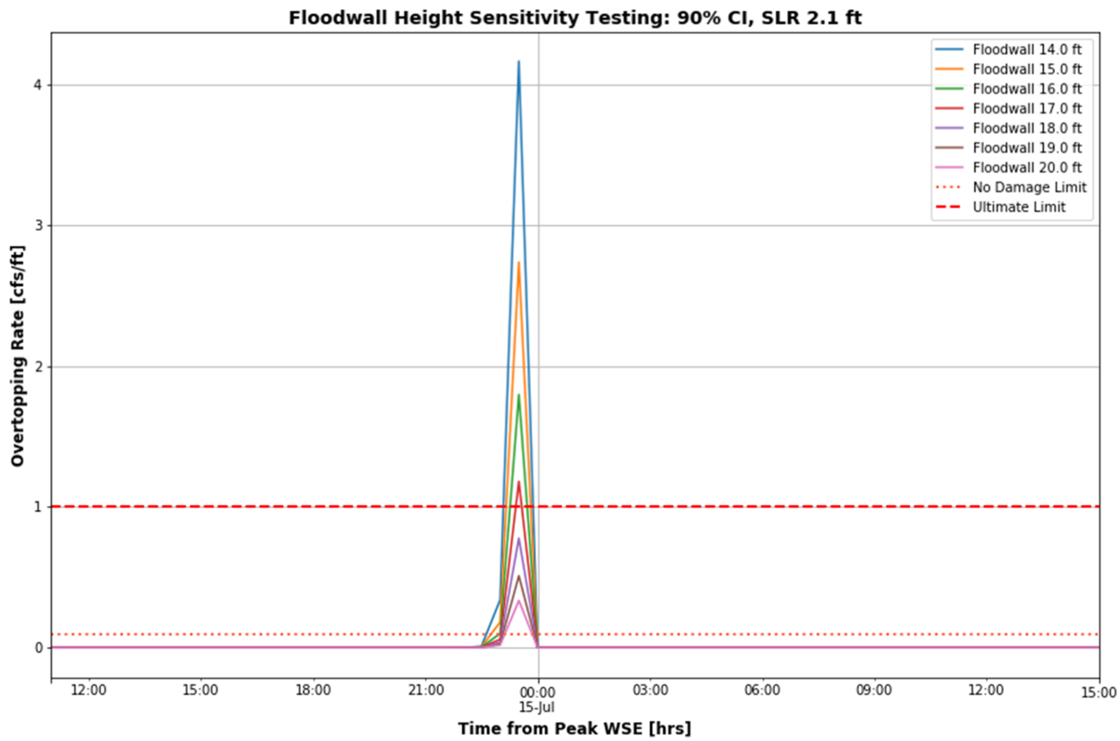

Figure 5. Floodwall height sensitivity testing for 100-year, 90% CI, 2.1' SLR scenario.

As shown in Figure 5, in order to reduce the peak overtopping rate below the ultimate limit for the 100-year, 90% CI, 2.1’ SLR scenario, the floodwall would need to be raised to +18.0’ NAVD88. Note that the with SLR scenario included a linear addition of SLR to the extremal WSE. In addition, the wave shoaling accounted for the increase in WSE due to SLR, however the data at the offshore extraction point was unaltered from the without SLR scenario due to lack of sufficient extremal data for the with SLR condition. Therefore, it is highly recommended that in future phases of the study, overtopping requirements for the with SLR condition be investigated further. The results and recommendations for the with SLR condition shown in this Section are for study planning only, and further analysis is required in future phases of the study.

3 Revised Hydrologic Modeling

3.1 Review of Original Pump Site Layout

At the conclusion of the original analysis and modeling effort, four pump sites with conveyance channels were recommended for the Galveston project area. Pump sites were proposed at the following locations:

- Pump Site 1: Offatts Bayou
- Pump Site 2: Old Port Industrial
- Pump Site 3: Wharf Road lot at 20th Street
- Pump Site 4: Lot by Harborside Drive and 10th Street

During the original analysis, the required pump and stormwater conduit sizes for each site were designed for the 25-yr+30% rainfall event. The results of the original modeling effort are summarized in Table 5 below.

Table 5. Summary of original pump and conduit sizes for the 25-yr+30% rainfall event.

Pump Site	Pump Size	Conduit Channel Cross Section Size	Max Water Surface Elevation in Offatts Bayou
Offatts Bayou (Pump Site 1)	250 cfs	30’ wide x 13’ high 390 sf	2.5 ft NAVD88
Pump Site 2	1500 cfs	20' wide X 10' high 200 sf	-
Pump Site 3	4500 cfs	20' wide X 10' high 200 sf	-
Pump Site 4	1500 cfs	20' wide X 10' high 200 sf	-

An aerial showing the general location of these pump sites is provided in Figure 6. Detailed figures showing the proposed pump site and conduit layout locations from the original analysis are provided in Figure 7 through Figure 10.

Figure 6. Overview of original pump site locations at Galveston.

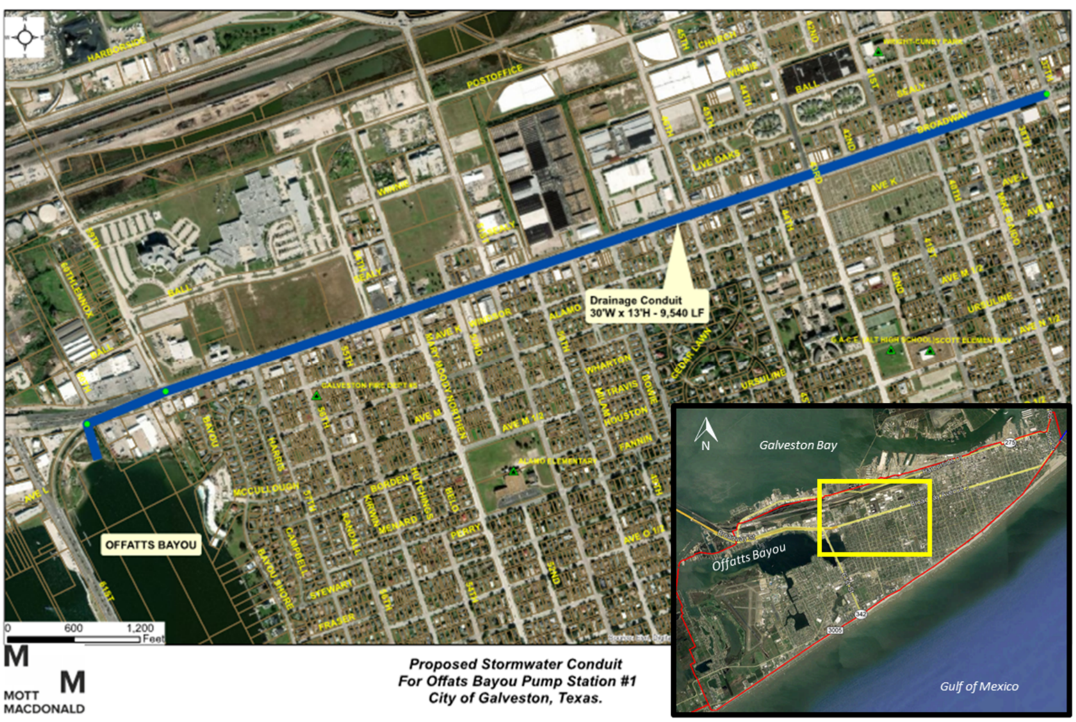

Figure 7. Original proposed stormwater conduit location and size into Offatts Bayou for Pump Site 1.

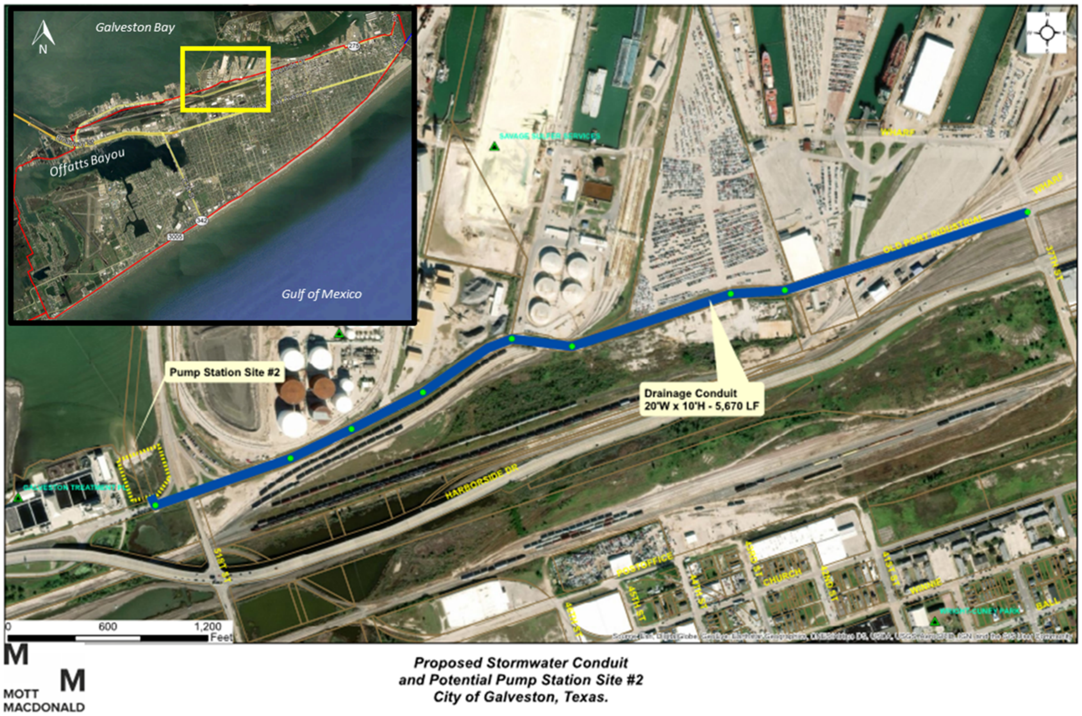

Figure 8. Original proposed stormwater conduit into Pump Site 2.

Figure 9. Original proposed stormwater conduit into Pump Site 3.

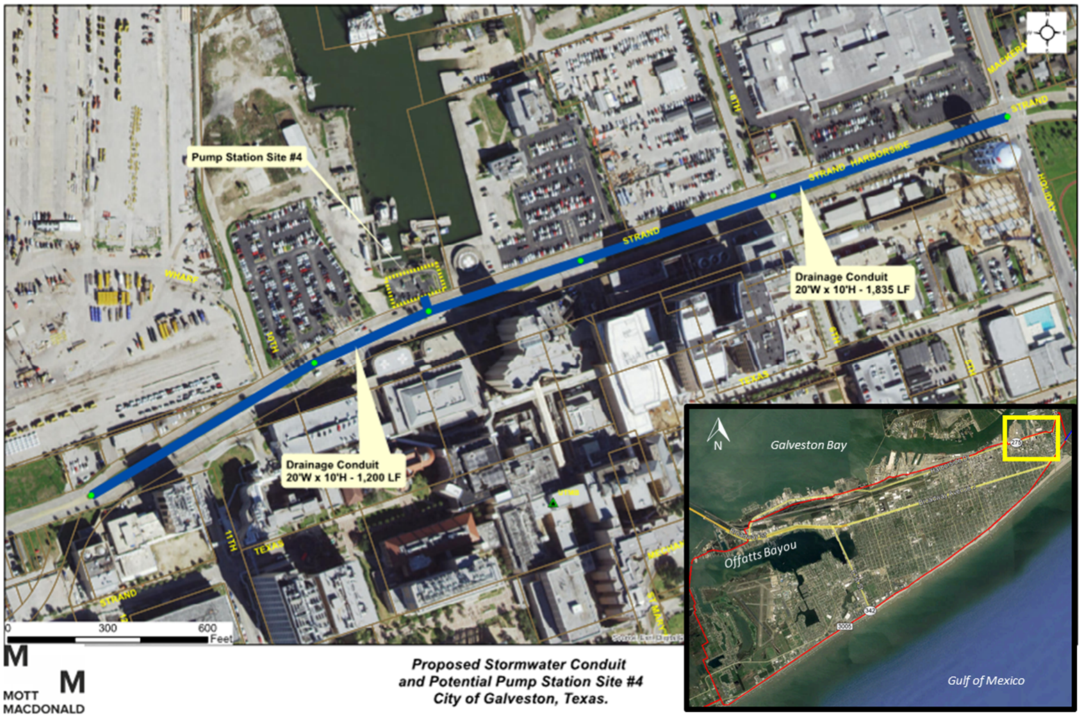

Figure 10. Original proposed stormwater conduit into Pump Site 4.

3.2 Review of Existing SWMM Model

The interior drainage model for the Galveston Watershed was developed during the original analysis using the Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) (USEPA, 2015). The Galveston Watershed SWMM model consists of 16 different sub-basins to represent segmented areas of runoff within the watershed and utilizes the previous flood barrier alignment as the external boundary for the model domain. Each sub-basin was connected to one of the four proposed pump sites either through direct runoff or through conveyance via a conduit channel. The pump sizes and conduit channel sizes were then designed to accommodate the 25-yr+30% 24-hr rainfall using the following performance criteria:

- Initial water level in Offatts Bayou de-watered to 1 ft below Mean Low Water (MLW)
- Offatts Bayou mouth gate in the closed position for the duration of the simulated storm
- Maximum water surface elevation of 4 ft NAVD88 in Offatts Bayou
    - This was determined by examining the topography adjacent to Offatts Bayou to minimize inland flooding.
- No allowable surface flooding within Galveston Ring Barrier.

A schematic of the Galveston Watershed SWMM model that was developed for the 25-yr+30% rainfall scenario is provide in Figure 11. The resulting pump and conduit channel sizes which were incorporated into the model are shown in the previous Table 5. Note that the model only serves as a visual representation of the system and does not show actual physical locations of the proposed pump sites or channels.

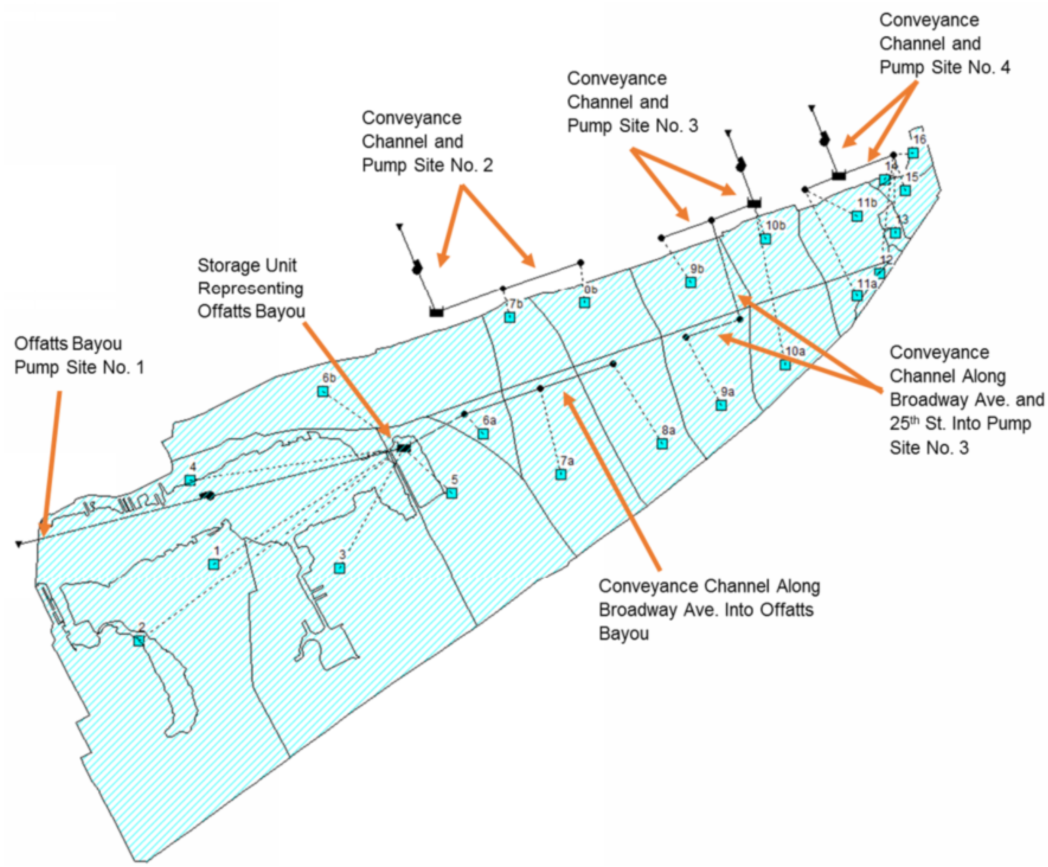

Figure 11. Schematic of the Galveston Watershed SWMM model. Sub-basins are identified by the numerical values 1 – 16.

3.3 NOAA Atlas 14 and 25+30% Rainfall Comparison

At the time the original analysis was being conducted in 2018, NOAA Atlas 14 point precipitation frequency estimates for Texas were undergoing updates and were not publicly available. The USACE was a member of the NOAA Atlas 14 update review team, and as such, the USACE advised Mott MacDonald to apply a 30% increase to the extremal rainfall values from the available data sources in order to best approximate the anticipated updated NOAA Atlas 14 rainfall results. Thus, as instructed, at 30% increase was applied to the rainfall values derived from the Harris County Flood Control District Hydrology & Hydraulics Guidance Manual (HCFCD, 2009) for use in the original analysis. Since then, the NOAA Atlas 14, Volume 11, Version 2 point precipitation frequency estimates have been published (NOAA, 2018), and are available at https://hdsc.nws.noaa.gov/hdsc/pfds/. A comparison was performed to evaluate the updated values against the modified values with the 30% increase for the 25-yr, 24-hr rainfall, which is shown in Table 6. The comparison shows that the values are relatively close; the updated NOAA Atlas 14 values are slightly lower than the 25-yr+30% values which were used in the original analysis. It should be noted that updates to rainfall values for modeling efforts were not included in this scope. Therefore, this analysis continues to use the 25-yr+30% rainfall values in order to keep consistency with the original analysis as well as the analysis performed for the Clear Creek and Dickinson Bayou watersheds.

Table 6. Comparison of the 25-year, 24-hr rainfall values between the updated NOAA Atlas 14 (NOAA, 2018) and the original analysis which used the HCFCD (2009) values + 30%.

Dataset	24-hr Rainfall [in]	24-hr Rainfall Intensity [in/hr]
Original Analysis HCFCD (2009): 25-year + 30%	12.7	0.524
Updated NOAA Atlas 14, Volume 11, Version 2: 25-year	11.5	0.479

3.4 Revisions due to New Alignment and New Overtopping

As discussed at the beginning of this report, the USACE has provided updated design conditions since the completion of the original model development and facility sizing analysis. These updated design conditions result in a modified flood barrier alignment as well as new wave overtopping values along the bay side of the Galveston Watershed. It was expected that these new design conditions would impact the previously designed facility sizes, and as such, an investigation into the impacts to the facility designs was determined to be necessary. However, revising the Galveston Watershed SWMM model domain and facility layout for the new design conditions was not included in this scope. Therefore, in order to investigate the impacts due to the new design conditions, the analysis was performed using the existing SWMM model domain (i.e., boundary, sub-basins), pump site locations, and conduit layout (length, slope, depth, clearance, and invert elevation), and only the pump size capacities and conduit channel cross section widths were modified to accommodate the new design conditions. The following sections detail the process that was used to perform this updated analysis and discuss the results.

3.4.1 Model Updates

The overtopping rates discussed in Section 1 were incorporated into the SWMM model using the following methodology:

1. Overtopping rates were applied to the pump site and conduit systems using the overtopping rate (cfs/ft) multiplied by the section length (ft) of the new alignment that is located adjacent to each existing sub-basin. This results in a new inflow timeseries of volumetric overtopping (cfs) per pump site system. A list the sub-basins and the associated pump systems which they flow into is provided below, and a sketch showing the sub-basins and the associated sections of floodwall is provided in Figure 12.
   - Overtopping within sub-basins 1, 2, 4 and 6b flows into Offatts Bayou (Pump Site 1 and conduit system)
   - Overtopping within sub-basins 7b and 8b flows into Pump Site 2 and conduit system
   - Overtopping within sub-basins 9b and 10b flows into Pump Site 3 and conduit system
   - Overtopping within sub-basins 11b, 14, 15, and 16 flows into Pump Site 4 and conduit system
2. The timesteps of the volumetric overtopping inflow per pump site system were then modified so that the peak overtopping inflow occurs at the same timestep as the peak rainfall runoff inflow. It is noted that this is a conservative approach; however, this scope does not include the work necessary to perform a full analysis of joint probability between peak overtopping and peak rainfall runoff.
3. The modified volumetric overtopping timeseries were then incorporated into the SWMM model at the appropriate nodes as direct inflow into each pump site system. Similarly, this is

acknowledged to be a conservative approach because this method does not account for any potential volume loss due to infiltration; however, this scope does not include the work necessary to properly simulate overtopping surface runoff, which would require modifications to the SWMM model domain and sub-basins.

4. Run the SWMM model with the 25-yr+30% 24-hr rainfall and overtopping input timeseries. Modify the facility sizes accordingly to accommodate the new inflows while meeting the design criteria discussed in Section 3.2.

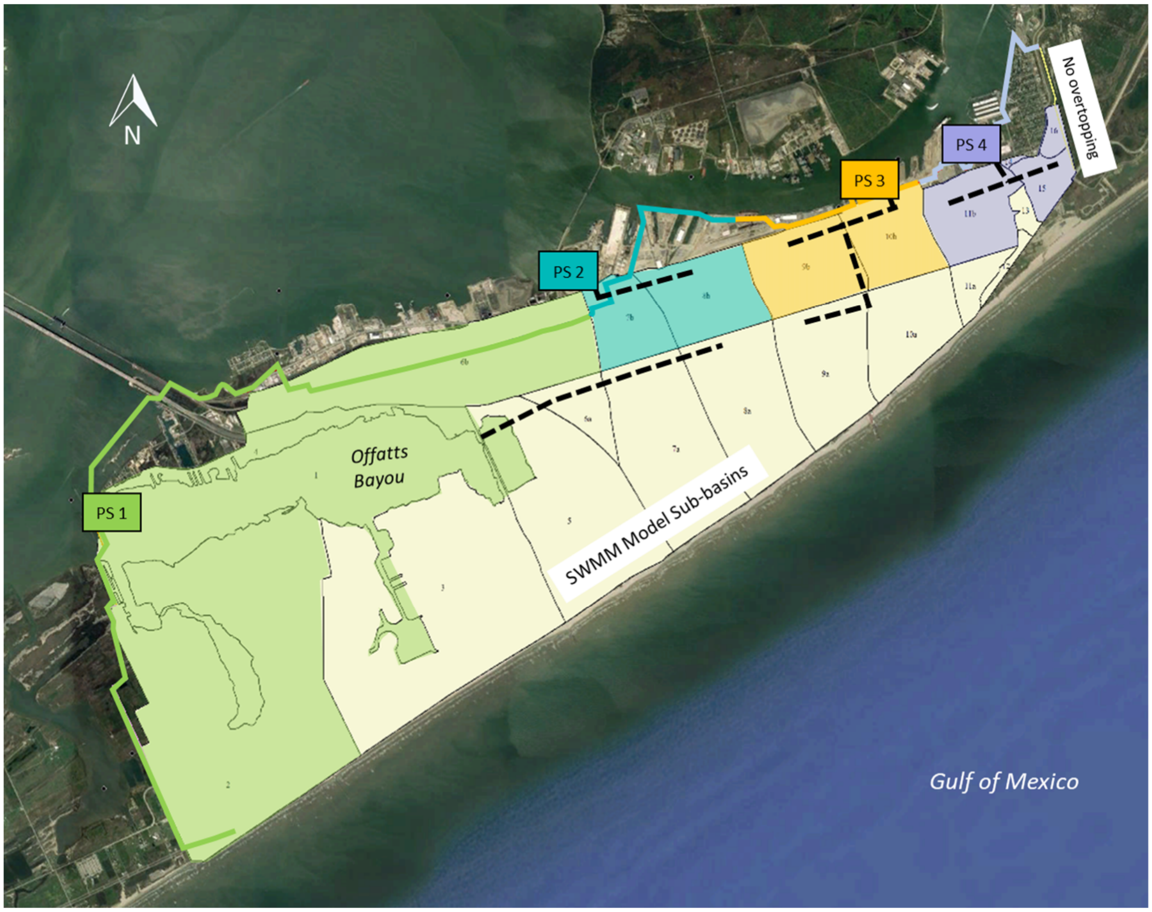

Figure 12. Schematic of the SWMM model sub-basins with the revised alignment. The sections of alignment, sub-basins, and Pump Sites (PS) are color coordinated to show where overtopping contributes to each pump site. No overtopping was observed along the northeastern section of alignment. Note that pump sites and conduit channels (dashed lines) are for visual representations only and do not accurately portray the proposed physical locations of the facilities.

The timeseries of inflow from rainfall runoff compared to overtopping per pump site is displayed in Figure 13. In this plot, the rainfall runoff inflows are represented by the dotted lines, and the overtopping inflows are represented by the solid lines. The x-axis, which represents model timestep was trimmed for ease of visibility; the full input timeseries extends a 24-hr period. The following observations are made from this plot:

- For Pump Site 1, inflow quantities from overtopping is significantly greater than inflow quantities from rainfall runoff over multiple timesteps. The large overtopping volume is due to the large wave conditions present at these sections of floodwall.

- This indicates that the facility sizes for Pump Site 1 (Offatts Bayou) will likely need to be greatly increased if the storage capacity of Offatts Bayou itself cannot accommodate the additional volume of inflow.
- For Pump Site 2, the inflow from overtopping is relatively minor compared to the inflow from rainfall runoff. This indicates that the original facility sizes for Pump Site 2 may be able to accommodate the additional volume of inflow.
- For Pump Site 3, the overtopping inflow quantities do not appear to substantially surpass the rainfall runoff inflows. However, it will still cause an increase in total inflow volume, and thus it is expected that facilities at this pump site will likely need to be increased.
- For Pump Site 4, the overtopping inflows are approximately twice that of rainfall runoff inflow over multiple timesteps. This indicates that the facility sizes for Pump Site 4 will likely need to be increased in order to accommodate the additional volume.

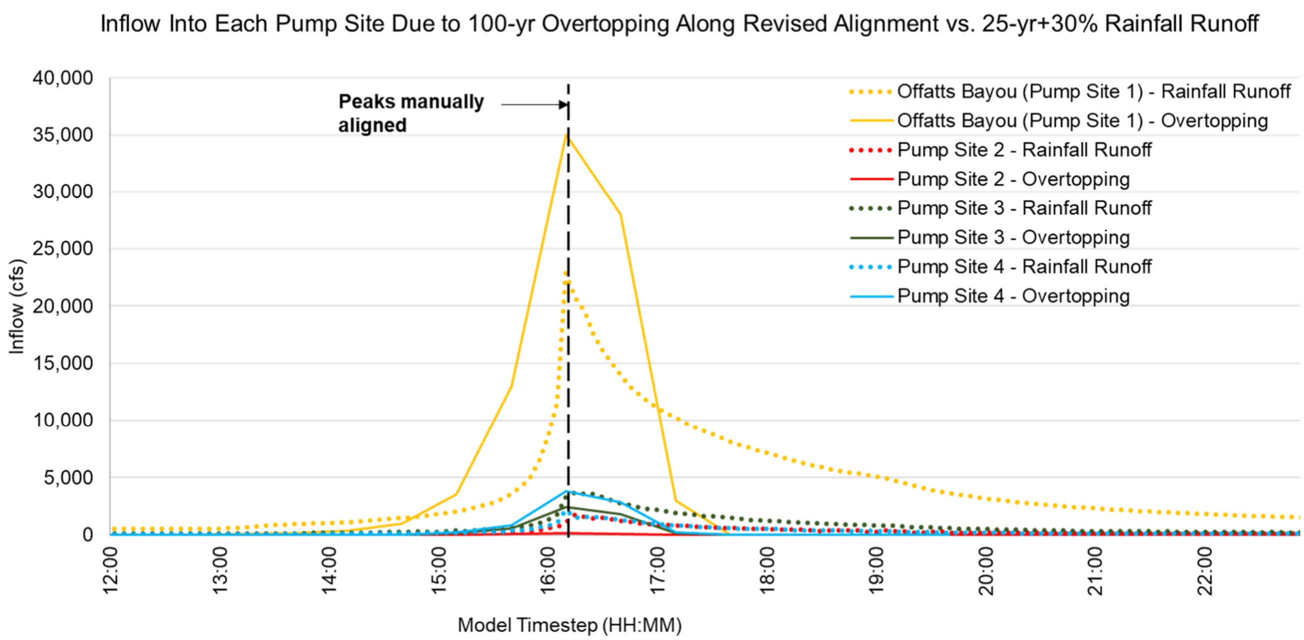

Figure 13. Comparison of input timeseries for the overtopping and rainfall runoff inflows per pump site.

3.4.2 Results

The process of resizing the facilities to accommodate the new inflows was performed iteratively in order to find an optimized balance between conduit cross section size as pump size capacity. For the conduit sizes, only the width parameter was modified; all other channel parameters such as length, location, slope, depth, invert elevation, etc., were not changed. The resulting required facility sizes are provided in Table 7

Table 7. Resulting required facility sizes.

Pump Site	Pump Size	Conduit Channel Cross Section Size	Max Water Surface Elevation in Offatts Bayou
Offatts Bayou (Pump Site 1)	4500 cfs	32’ wide x 13’ high 416 sf	3.25 ft NAVD88
Pump Site 2	1500 cfs	20' wide X 10' high 200 sf	-
Pump Site 3	5000 cfs	30' wide X 10' high 300 sf	-
Pump Site 4	5000 cfs	25' wide X 10' high 250 sf	-

A comparison of these revised facility sizes to those of the original analysis are provided in the following figures, where Figure 14 compares pump size capacity, Figure 15 compares cross section area of the conduit channels, and Figure 16 compares the resulting maximum water surface elevation in Offatts Bayou experienced over the duration of the simulated storm.

Figure 14 shows that Pump Sites 1 and 4 require the greatest increase to pump capacities, Pump Site 3 requires a relatively minor increase to pump capacity, and Pump Site 2 requires no change to pump capacity. For conduit channel cross section sizes (Figure 15), the channels for Pump Sites 1, 3 and 4 increased; the channel size for Pump Site 2 did not change. See Appendix B for detailed plan-view layouts of the revised conduit channels.

Lastly, the resulting maximum water surface elevation in Offatts Bayou (Figure 16) that was experienced over the duration of the simulated storm increased from 2.5 ft NAVD88 (per the original Pump Site 1 system design) to 3.25 ft NAVD88 (per the revised Pump Site 1 system design). Considering the maximum allowable water surface elevation of 4.0 ft NAVD88 as stated in the performance criteria, this indicates that the resulting freeboard (the vertical clearance between the water surface and the maximum allowable elevation) decreased from 1.5 ft (per the original Pump Site 1 system design) to 0.75 ft (per the revised Pump Site 1 system design).

These results align with what was expected due to the increase in inflow volume from overtopping, as discussed in Section 3.4.1.

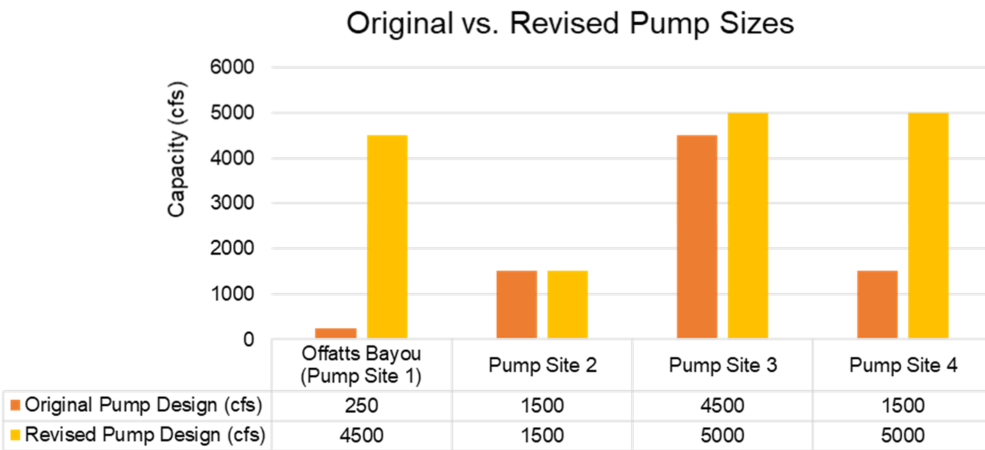

Figure 14. Comparison of original (orange) and revised (yellow) designed pump size capacities.

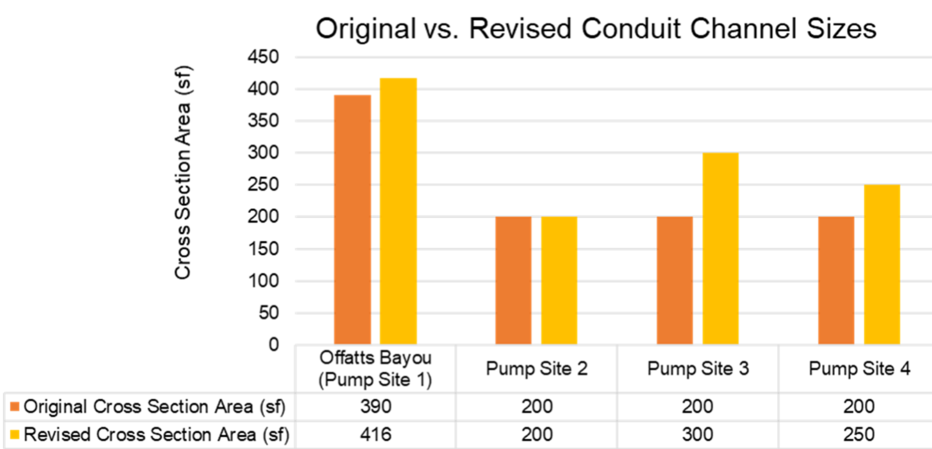

Figure 15. Comparison of original (orange) and revised (yellow) designed conduit channel cross section areas.

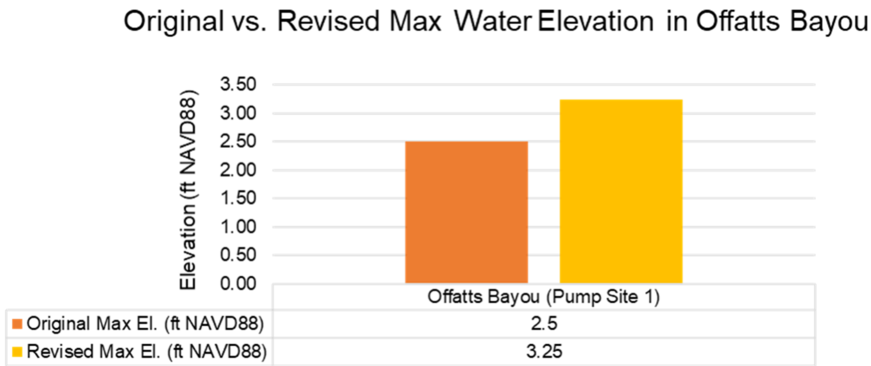

Figure 16. Comparison of original (orange) and revised (yellow) maximum water surface elevations in Offatts Bayou over the simulated storm duration.

3.4.3 Discussion of discrepancy between model domain and revised alignment

As discussed throughout this memorandum, the analysis preformed in this scope utilizes overtopping volumes calculated with the revised alignment, but applied to the Galveston SWMM model that was developed during the original analysis. Updating the model domain and sub-basins to account for the revised alignment was not included in this scope. Thus, because of this discrepancy, the following points are noted:

- The revised alignment causes an increase in surface area within several areas the watershed. This can be seen in Figure 12, where the revised alignment extends outside the model domain footprint. This analysis does not account for the additional rainfall runoff over the new areas created by the new alignment. Thus, it is possible that the additional rainfall runoff would require another increase in pump site facilities and conduit sizes. Furthermore, the location of the conduit channels may need to be modified or extended in order to properly collect surface runoff from the additional areas within the floodwall alignment.
- Through observation of footprint alone, it appears that Pump Sites 2 and 4 may be most impacted by the additional rainfall runoff; this is due to the large expansion in the floodwall alignment around the sub-basins that flow into these two pump sites.
- The revised alignment causes an increase in surface area within the watershed around Pump Site 3. The increase appears to be relatively small, but this area also appears to be predominantly industrial with mostly non-pervious ground surfaces. Thus, increases to the proposed Pump Site 3 facility sizes also may be necessary.
- Lastly, the revised alignment causes multiple changes to the areas and extents of the sub-basins that flow into Pump Site 1 (Offatts Bayou). The revised alignment appears to reduce footprint within sub-basin 6b but increase footprint adjacent to sub-basin 4 and include areas within Galveston Bay. Due to the complexity of these modified areas, an expected impact to the proposed Pump Site 1 facilities cannot be predicted without performing updated modeling efforts.

It is important to note that the points discussed above are derived solely from observation of the new alignment against the existing Galveston model domain. The increase in surface area caused by the revised alignment is not the only contributing factor that will have an impact on required pump site facilities. Other contributing factors for the additional areas created by the revised alignment include parameters such as land coverage type, percent impervious, slope, equivalent width, etc. Thus, it is strongly recommended that additional modeling efforts be performed to update the Galveston model domain, sub-basins and attributes in order to account for the changes caused by the revised alignment and evaluate the impacts to the proposed pump site facilities.

4 Suggested Future Analysis

The drainage analysis conducted in this study is highly dependent on historical rainfall and surge data. The analysis for the Galveston watershed assumes that the peak rainfall and overtopping events coincide, and that the gate structure must remain closed the full duration of the storm event. To further refine and potentially reduce pump sizes, a Joint Probability Analysis (JPA) should be conducted correlating rainfall and surge events. It is anticipated that this process would be similar to the standard JPM-OS analysis that is currently conducted to determine extremal storm surges. Conducting this analysis could refine the design pump and conduit sizes and potentially reduce project costs.

In order to improve the interior drainage analysis for Galveston, new data collection is recommended. The following recommendations are suggested to help improve the future analysis:

- Install flow meters in the existing storm sewer system to collect real data and calibrate the SWMM model;
- Map existing storm drainage system within the Galveston watershed to include in the SWMM model;
- Obtain a higher resolved and more recent DEM of the Galveston watershed; and
- Once the seawall expansion/flood barrier designs are finalized, re-evaluate the impact of overtopping on the required pump and channel sizes. It is recommended that physical modeling be conducted to determine the final overtopping design volumes.
- Acquire additional utility information in the vicinity of the pumping station and consolidation conduits.
- Conduct revised modeling to include additional drainage area from new alignment.
- Include overtopping from seawall once design is finalized and assess any impacts to pump size.
- Conduct a Joint Probability Analysis (JPA) should be conducted correlating rainfall and surge events

It is recommended that future analysis consider the items listed above, in addition to any other data gaps identified in future phases of the study.

5 References

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A. Input Conditions for Overtopping Analysis

Site	Galveston Ring Barrier
USACE Extraction Point	11892
JPM-OS Storm Number	261

Timestep [hrs]	**WSE [ft NAVD 88]**	**Hs [ft]**	**Tp [s]**	**Assumed Elevation at Structure [ft NAVD88]**	**Rc [ft]**	**T.O. Wall [ft NAVD88]**	**q [cfs/ft]**
0.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
1	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
1.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
2	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
2.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
3	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
3.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
4	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
4.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
5.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
6	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
6.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
7	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
7.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
8	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
8.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
9	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
9.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
10	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
10.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
11	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
11.5	N/A	N/A	N/A	3.67	N/A	14.00	0.00E+00
12	3.70	0.02	2.67	3.67	10.30	14.00	4.86E-12
12.5	4.04	0.22	2.67	3.67	9.96	14.00	1.26E-07
13	4.40	0.44	2.67	3.67	9.60	14.00	2.05E-06
13.5	4.72	0.62	2.67	3.67	9.28	14.00	8.90E-06
14	5.14	0.86	2.94	3.67	8.86	14.00	4.07E-05
14.5	5.65	1.13	2.94	3.67	8.35	14.00	1.46E-04
15	6.17	1.42	3.24	3.67	7.83	14.00	4.79E-04
15.5	6.73	1.70	3.24	3.67	7.27	14.00	1.23E-03
16	7.34	2.00	3.56	3.67	6.66	14.00	3.32E-03
16.5	8.27	2.48	3.56	3.67	5.73	14.00	1.22E-02
17	9.39	3.04	3.91	3.67	4.61	14.00	5.78E-02
17.5	10.62	3.44	3.56	3.67	3.38	14.00	1.74E-01

Site	Galveston Ring Barrier
USACE Extraction Point	11892
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
18	11.70	3.82	3.56	3.67	2.30	14.00	5.44E-01
18.5	12.30	3.43	2.94	3.67	1.70	14.00	6.15E-01
19	11.75	1.64	2.67	3.67	2.25	14.00	2.03E-02
19.5	10.11	0.27	2.67	3.67	3.89	14.00	2.18E-18
20	8.73	0.22	2.43	3.67	5.27	14.00	1.68E-29
20.5	7.89	0.59	3.24	3.67	6.11	14.00	3.16E-13
21	7.59	1.19	3.56	3.67	6.41	14.00	3.40E-07
21.5	7.38	1.64	3.56	3.67	6.62	14.00	1.38E-03
22	7.06	1.80	3.56	3.67	6.94	14.00	1.89E-03
22.5	6.80	1.75	3.56	3.67	7.20	14.00	1.58E-03
23	6.63	1.65	3.24	3.67	7.37	14.00	1.05E-03
23.5	6.50	1.59	3.24	3.67	7.50	14.00	8.47E-04
24	6.28	1.48	3.24	3.67	7.72	14.00	5.92E-04
24.5	6.06	1.34	2.94	3.67	7.94	14.00	3.27E-04
25	5.83	1.22	2.94	3.67	8.17	14.00	2.12E-04
25.5	5.62	1.11	2.94	3.67	8.38	14.00	1.35E-04
26	5.35	0.97	2.94	3.67	8.65	14.00	7.23E-05
26.5	5.10	0.84	2.94	3.67	8.90	14.00	3.68E-05
27	4.88	0.70	2.67	3.67	9.12	14.00	1.55E-05
27.5	4.65	0.58	2.67	3.67	9.35	14.00	6.73E-06
28	4.39	0.43	2.67	3.67	9.61	14.00	1.88E-06
28.5	4.23	0.34	2.67	3.67	9.77	14.00	6.59E-07
29	4.08	0.25	2.67	3.67	9.92	14.00	1.85E-07
29.5	3.94	0.16	2.67	3.67	10.06	14.00	3.52E-08
30	3.88	0.13	2.67	3.67	10.12	14.00	1.31E-08
30.5	3.85	0.11	2.67	3.67	10.15	14.00	6.56E-09
31	3.83	0.10	2.67	3.67	10.17	14.00	3.85E-09
31.5	3.82	0.09	2.67	3.67	10.18	14.00	3.22E-09
32	3.81	0.09	2.67	3.67	10.19	14.00	2.68E-09
32.5	3.80	0.08	2.67	3.67	10.20	14.00	1.75E-09
33	3.79	0.07	2.67	3.67	10.21	14.00	1.16E-09
33.5	3.76	0.06	2.67	3.67	10.24	14.00	4.49E-10
34	3.75	0.05	2.67	3.67	10.25	14.00	2.18E-10
34.5	3.73	0.04	2.67	3.67	10.27	14.00	8.74E-11
35	3.72	0.03	2.67	3.67	10.28	14.00	4.33E-11

Site	Galveston Ring Barrier
USACE Extraction Point	11892
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
35.5	3.71	0.02	2.67	3.67	10.29	14.00	7.85E-12
36	3.72	0.03	2.67	3.67	10.28	14.00	2.19E-11
36.5	3.72	0.03	2.67	3.67	10.28	14.00	4.05E-11
37	3.71	0.02	2.67	3.67	10.29	14.00	6.61E-12
37.5	3.69	0.01	2.67	3.67	10.31	14.00	8.22E-13
38	3.70	0.02	2.67	3.67	10.30	14.00	2.82E-12
38.5	3.70	0.02	2.67	3.67	10.30	14.00	4.27E-12
39	3.68	0.00	2.67	3.67	10.32	14.00	9.48E-16
39.5	N./A	N./A	N./A	3.67	N./A	14.00	0.00E+00

Site	Galveston Ring Barrier
USACE Extraction Point	17284
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
0.5	1.64	0.67	2.67	-1.22	12.36	14.00	2.34E-22
1	1.65	0.69	2.67	-1.22	12.35	14.00	1.09E-21
1.5	1.67	0.69	2.67	-1.22	12.33	14.00	1.33E-21
2	1.70	0.70	2.67	-1.22	12.30	14.00	1.92E-21
2.5	1.71	0.71	2.67	-1.22	12.29	14.00	5.48E-21
3	1.74	0.75	2.67	-1.22	12.26	14.00	8.36E-20
3.5	1.78	0.77	2.94	-1.22	12.22	14.00	2.70E-19
4	1.82	0.80	2.94	-1.22	12.18	14.00	1.27E-18
4.5	1.87	0.82	2.67	-1.22	12.13	14.00	4.02E-18
5	1.91	0.84	2.67	-1.22	12.09	14.00	1.41E-17
5.5	1.96	0.86	2.94	-1.22	12.04	14.00	4.13E-17
6	2.01	0.90	2.67	-1.22	11.99	14.00	2.20E-16
6.5	2.08	0.94	2.67	-1.22	11.92	14.00	1.21E-15
7	2.14	0.97	2.67	-1.22	11.86	14.00	4.33E-15
7.5	2.21	1.01	2.67	-1.22	11.79	14.00	1.81E-14
8	2.30	1.01	2.67	-1.22	11.70	14.00	2.38E-14
8.5	2.40	1.12	3.56	-1.22	11.60	14.00	4.58E-05
9	2.51	1.07	3.91	-1.22	11.49	14.00	4.16E-05
9.5	2.66	1.18	3.56	-1.22	11.34	14.00	5.72E-12
10	2.81	1.26	3.91	-1.22	11.19	14.00	9.28E-05
10.5	2.97	1.34	3.91	-1.22	11.03	14.00	1.24E-04
11	3.17	1.39	3.91	-1.22	10.83	14.00	1.49E-04
11.5	3.39	1.34	4.30	-1.22	10.61	14.00	1.49E-04
12	3.63	1.42	4.74	-1.22	10.37	14.00	2.18E-04
12.5	3.91	1.55	4.74	-1.22	10.09	14.00	3.38E-04
13	4.23	1.69	4.74	-1.22	9.77	14.00	5.32E-04
13.5	4.62	1.87	4.74	-1.22	9.38	14.00	9.36E-04
14	5.06	2.06	5.21	-1.22	8.94	14.00	1.76E-03
14.5	5.59	2.29	5.21	-1.22	8.41	14.00	3.27E-03
15	6.19	2.57	5.21	-1.22	7.81	14.00	6.58E-03
15.5	6.89	2.89	5.73	-1.22	7.11	14.00	1.56E-02
16	7.64	3.27	5.73	-1.22	6.36	14.00	3.59E-02
16.5	8.49	3.59	5.73	-1.22	5.51	14.00	8.06E-02
17	9.43	4.04	6.31	-1.22	4.57	14.00	2.36E-01
17.5	10.60	4.55	6.31	-1.22	3.40	14.00	6.23E-01

Site	Galveston Ring Barrier
USACE Extraction Point	17284
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
18	11.78	5.18	7.63	-1.22	2.22	14.00	1.76E+00
18.5	11.69	5.56	3.91	-1.22	2.31	14.00	1.55E+00
19	10.92	3.49	4.30	-1.22	3.08	14.00	2.29E-01
19.5	9.48	0.41	2.67	-1.22	4.52	14.00	3.53E-14
20	7.90	0.45	2.43	-1.22	6.10	14.00	5.04E-17
20.5	6.76	0.74	3.24	-1.22	7.24	14.00	1.76E-12
21	6.21	1.60	5.21	-1.22	7.79	14.00	2.21E-06
21.5	6.09	1.98	4.74	-1.22	7.91	14.00	2.95E-05
22	6.33	2.27	4.30	-1.22	7.67	14.00	1.75E-04
22.5	6.59	2.56	4.30	-1.22	7.41	14.00	7.63E-04
23	6.71	2.95	3.91	-1.22	7.29	14.00	2.84E-03
23.5	6.64	3.11	3.56	-1.22	7.36	14.00	4.06E-03
24	6.43	3.05	3.56	-1.22	7.57	14.00	2.86E-03
24.5	6.17	2.88	3.24	-1.22	7.83	14.00	1.42E-03
25	5.85	2.59	3.24	-1.22	8.15	14.00	3.98E-04
25.5	5.48	2.26	3.24	-1.22	8.52	14.00	6.46E-05
26	5.11	2.08	3.24	-1.22	8.89	14.00	1.50E-05
26.5	4.72	1.91	2.94	-1.22	9.28	14.00	2.92E-06
27	4.36	1.69	2.94	-1.22	9.64	14.00	2.61E-07
27.5	4.01	1.58	2.94	-1.22	9.99	14.00	4.60E-08
28	3.64	1.42	2.94	-1.22	10.36	14.00	3.30E-09
28.5	3.27	1.26	2.94	-1.22	10.73	14.00	1.12E-10
29	2.91	1.10	2.94	-1.22	11.09	14.00	1.58E-12
29.5	2.57	1.02	2.94	-1.22	11.43	14.00	6.67E-14
30	2.26	0.88	2.94	-1.22	11.74	14.00	2.50E-16
30.5	1.98	0.80	2.94	-1.22	12.02	14.00	2.83E-18
31	1.76	0.77	2.67	-1.22	12.24	14.00	2.63E-19
31.5	1.60	0.72	2.67	-1.22	12.40	14.00	7.71E-21
32	1.53	0.66	2.67	-1.22	12.47	14.00	7.91E-23
32.5	1.55	0.64	2.67	-1.22	12.45	14.00	1.22E-23
33	1.64	0.60	2.67	-1.22	12.36	14.00	1.05E-24
33.5	1.76	0.59	2.67	-1.22	12.24	14.00	4.08E-25
34	1.85	0.58	2.67	-1.22	12.15	14.00	3.89E-25
34.5	1.96	0.56	2.67	-1.22	12.04	14.00	7.41E-26
35	2.05	0.54	2.67	-1.22	11.95	14.00	1.74E-26

Site	Galveston Ring Barrier
USACE Extraction Point	17284
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
35.5	2.14	0.53	2.67	-1.22	11.86	14.00	3.52E-27
36	2.22	0.50	2.67	-1.22	11.78	14.00	1.49E-28
36.5	2.28	0.48	2.67	-1.22	11.72	14.00	1.66E-29
37	2.34	0.48	2.67	-1.22	11.66	14.00	5.28E-29
37.5	2.40	0.47	2.67	-1.22	11.60	14.00	9.94E-30
38	2.43	0.45	2.67	-1.22	11.57	14.00	1.31E-30
38.5	2.48	0.43	2.67	-1.22	11.52	14.00	5.29E-32
39	2.55	0.42	2.67	-1.22	11.45	14.00	1.13E-32
39.5	2.61	0.40	2.67	-1.22	11.39	14.00	8.80E-34

Site	Galveston Ring Barrier
USACE Extraction Point	12962
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
0.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
1	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
1.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
2	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
2.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
3	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
3.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
4	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
4.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
5.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
6	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
6.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
7	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
7.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
8	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
8.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
9	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
9.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
10	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
10.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
11	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
11.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
12	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
12.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
13	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
13.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
14	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
14.5	5.14	0.30	4.74	4.66	8.86	14.00	1.04E-06
15	5.78	0.69	4.74	4.66	8.22	14.00	3.64E-05
15.5	6.47	1.11	5.21	4.66	7.53	14.00	3.36E-04
16	7.27	1.58	5.21	4.66	6.73	14.00	1.93E-03
16.5	8.26	2.17	5.73	4.66	5.74	14.00	1.21E-02
17	9.43	2.82	5.73	4.66	4.57	14.00	6.85E-02
17.5	10.69	3.60	6.93	4.66	3.31	14.00	4.62E-01

Site	Galveston Ring Barrier
USACE Extraction Point	12962
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
18	11.71	4.12	6.31	4.66	2.29	14.00	1.06E+00
18.5	11.42	3.83	5.21	4.66	2.58	14.00	6.16E-01
19	10.09	2.84	3.56	4.66	3.91	14.00	6.59E-02
19.5	8.08	0.38	2.67	4.66	5.92	14.00	1.97E-19
20	6.46	0.31	2.67	4.66	7.54	14.00	1.59E-29
20.5	5.31	0.39	2.67	4.66	8.69	14.00	1.80E-06
21	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
21.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
22	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
22.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
23	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
23.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
24	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
24.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
25	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
25.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
26	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
26.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
27	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
27.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
28	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
28.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
29	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
29.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
30	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
30.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
31	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
31.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
32	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
32.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
33	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
33.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
34	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
34.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
35	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00

Site	Galveston Ring Barrier
USACE Extraction Point	12962
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
35.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
36	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
36.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
37	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
37.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
38	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
38.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
39	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00
39.5	N/A	N/A	N/A	4.66	N/A	14.00	0.00E+00

Site	Galveston Ring Barrier
USACE Extraction Point	12773
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
0.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
1	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
1.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
2	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
2.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
3	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
3.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
4	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
4.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
5.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
6	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
6.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
7	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
7.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
8	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
8.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
9	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
9.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
10	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
10.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
11	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
11.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
12	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
12.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
13	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
13.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
14	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
14.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
15	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
15.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
16	7.35	0.26	5.21	6.93	6.65	14.00	1.52E-06
16.5	8.30	0.84	5.73	6.93	5.70	14.00	2.88E-04
17	9.44	1.54	6.31	6.93	4.56	14.00	6.85E-03
17.5	10.64	2.20	5.21	6.93	3.36	14.00	5.80E-02

Site	Galveston Ring Barrier
USACE Extraction Point	12773
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
18	11.32	2.58	5.21	6.93	2.68	14.00	1.90E-01
18.5	10.67	2.16	4.30	6.93	3.33	14.00	4.54E-02
19	9.53	1.47	3.24	6.93	4.47	14.00	3.00E-03
19.5	7.88	0.54	2.43	6.93	6.12	14.00	1.64E-05
20	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
20.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
21	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
21.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
22	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
22.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
23	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
23.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
24	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
24.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
25	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
25.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
26	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
26.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
27	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
27.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
28	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
28.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
29	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
29.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
30	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
30.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
31	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
31.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
32	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
32.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
33	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
33.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
34	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
34.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
35	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00

Site	Galveston Ring Barrier
USACE Extraction Point	12773
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
35.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
36	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
36.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
37	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
37.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
38	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
38.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
39	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00
39.5	N/A	N/A	N/A	6.93	N/A	14.00	0.00E+00

Site	Galveston Ring Barrier
USACE Extraction Point	17276
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
0.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
1	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
1.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
2	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
2.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
3	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
3.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
4	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
4.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
5.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
6	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
6.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
7	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
7.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
8	1.77	0.01	2.67	1.74	12.23	14.00	4.28E-13
8.5	1.86	0.07	2.67	1.74	12.14	14.00	6.69E-10
9	1.97	0.14	2.67	1.74	12.03	14.00	9.84E-09
9.5	2.09	0.21	2.67	1.74	11.91	14.00	5.86E-08
10	2.25	0.30	2.67	1.74	11.75	14.00	2.55E-07
10.5	2.41	0.40	2.67	1.74	11.59	14.00	7.81E-07
11	2.58	0.50	2.67	1.74	11.42	14.00	2.01E-06
11.5	2.79	0.62	2.67	1.74	11.21	14.00	5.00E-06
12	3.03	0.75	2.67	1.74	10.97	14.00	1.14E-05
12.5	3.34	0.91	2.67	1.74	10.66	14.00	2.68E-05
13	3.67	1.08	2.67	1.74	10.33	14.00	5.76E-05
13.5	4.10	1.32	2.94	1.74	9.90	14.00	1.61E-04
14	4.59	1.56	2.94	1.74	9.41	14.00	3.57E-04
14.5	5.19	1.83	2.94	1.74	8.81	14.00	8.19E-04
15	5.85	2.10	2.94	1.74	8.15	14.00	1.77E-03
15.5	6.60	2.39	2.94	1.74	7.40	14.00	4.06E-04
16	7.39	2.81	3.24	1.74	6.61	14.00	3.57E-03
16.5	8.34	3.31	3.56	1.74	5.66	14.00	2.43E-02
17	9.31	3.66	3.56	1.74	4.69	14.00	8.71E-02
17.5	10.30	4.41	4.30	1.74	3.70	14.00	3.90E-01

Site	Galveston Ring Barrier
USACE Extraction Point	17276
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
18	10.24	4.20	3.91	1.74	3.76	14.00	2.91E-01
18.5	9.35	2.84	3.24	1.74	4.65	14.00	2.32E-02
19	8.39	0.37	2.67	1.74	5.61	14.00	6.33E-19
19.5	7.15	0.61	2.43	1.74	6.85	14.00	2.70E-14
20	5.57	0.69	2.67	1.74	8.43	14.00	3.22E-15
20.5	4.07	1.27	2.67	1.74	9.93	14.00	1.24E-04
21	2.28	0.33	2.67	1.74	11.72	14.00	3.43E-07
21.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
22	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
22.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
23	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
23.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
24	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
24.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
25	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
25.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
26	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
26.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
27	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
27.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
28	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
28.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
29	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
29.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
30	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
30.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
31	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
31.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
32	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
32.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
33	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
33.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
34	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
34.5	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00
35	N/A	N/A	N/A	1.74	N/A	14.00	0.00E+00

Site	Galveston Ring Barrier
USACE Extraction Point	17276
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
35.5	1.79	0.03	2.67	1.74	12.21	14.00	1.26E-11
36	1.91	0.10	2.67	1.74	12.09	14.00	2.56E-09
36.5	1.99	0.15	2.67	1.74	12.01	14.00	1.37E-08
37	2.08	0.20	2.67	1.74	11.92	14.00	5.10E-08
37.5	2.14	0.24	2.67	1.74	11.86	14.00	1.01E-07
38	2.21	0.28	2.67	1.74	11.79	14.00	1.84E-07
38.5	2.23	0.30	2.67	1.74	11.77	14.00	2.33E-07
39	2.30	0.34	2.67	1.74	11.70	14.00	3.84E-07
39.5	2.36	0.37	2.67	1.74	11.64	14.00	5.68E-07

Site	Galveston Ring Barrier
USACE Extraction Point	12841
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
0.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
1	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
1.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
2	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
2.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
3	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
3.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
4	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
4.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
5.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
6	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
6.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
7	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
7.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
8	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
8.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
9	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
9.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
10	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
10.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
11	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
11.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
12	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
12.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
13	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
13.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
14	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
14.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
15	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
15.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
16	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
16.5	8.29	1.76	2.67	4.83	5.71	14.00	2.31E-03
17	9.29	1.83	2.94	4.83	4.71	14.00	1.04E-03
17.5	10.35	1.59	2.94	4.83	3.65	14.00	1.80E-03

Site	Galveston Ring Barrier
USACE Extraction Point	12841
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
18	10.60	1.91	2.94	4.83	3.40	14.00	8.79E-03
18.5	10.06	1.78	2.67	4.83	3.94	14.00	2.55E-03
19	9.34	0.64	2.67	4.83	4.66	14.00	8.51E-10
19.5	7.85	0.25	2.67	4.83	6.15	14.00	7.97E-30
20	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
20.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
21	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
21.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
22	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
22.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
23	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
23.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
24	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
24.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
25	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
25.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
26	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
26.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
27	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
27.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
28	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
28.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
29	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
29.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
30	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
30.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
31	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
31.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
32	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
32.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
33	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
33.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
34	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
34.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
35	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00

Site	Galveston Ring Barrier
USACE Extraction Point	12841
JPM-OS Storm Number	261

Timestep [hrs]	WSE [ft NAVD 88]	Hs [ft]	Tp [s]	Assumed Elevation at Structure [ft NAVD88]	Rc [ft]	T.O. Wall [ft NAVD88]	q [cfs/ft]
35.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
36	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
36.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
37	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
37.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
38	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
38.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
39	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00
39.5	N/A	N/A	N/A	4.83	N/A	14.00	0.00E+00

B. Plan Views of Drainage Conduits

PLAN VIEW

SCALE 1"=100'

Pump Station #1 Collection Conduits

STA 0+00 TO 32+33

PROFILE VIEW

H. SCALE 1"=100'

V. SCALE 1"=10'

MOTT MACDONALD

111 Wood Avenue South
Iselin NJ 08830-4112
United States of America
Certificate No. 24GA28016600

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F +1 (973) 376 1072
www.mottmacamericas.com

Client: USACE

Rev	Date	Drawn	Description	Ch'k'd	App'd

Date ______

Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security STD

Project Number: 393582 | B/O | Total | Drawing Number

Title: TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#1
SHEET 1 OF 3

PLAN VIEW
SCALE 1"=100'

Pump Station #1 Collection Conduits
STA 32+33 TO 64+66

PROFILE VIEW
H. SCALE 1"=100'
V. SCALE 1"=10'

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USACE

Rev	Date	Drawn	Description	Ch'k'd	App'd

Date

Project Number 393582
B/O
Total

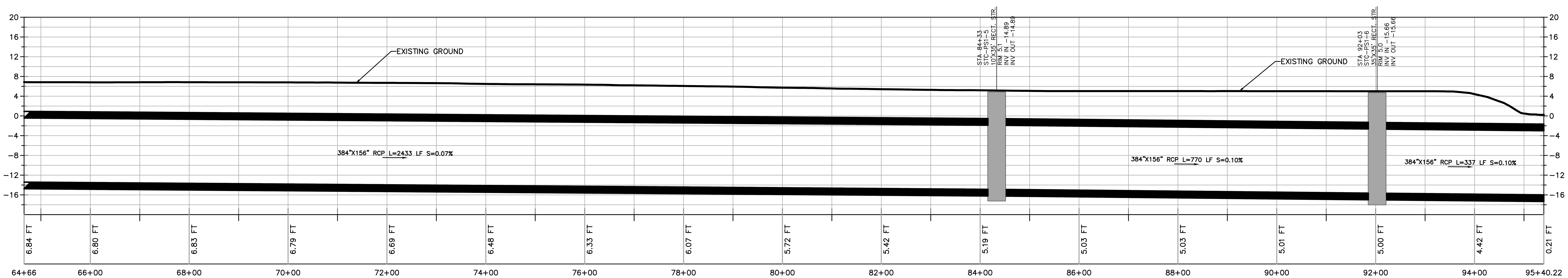
Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security STD

Drawing Number

Title
TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#1
SHEET 2 OF 3

PLAN VIEW

SCALE 1"=100'



Pump Station #1 Collection Conduits
STA 64+66 TO 95+40

PROFILE VIEW

H. SCALE 1"=100'
V. SCALE 1"=10'

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Date ________

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Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security: STD

Project Number: 393582
B/O
Total
Drawing Number

Title:
TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#1
SHEET 3 OF 3

PLAN VIEW

SCALE 1"=100'

Pump Station #2 Collection Conduits
STA 0+00 TO 32+33

PROFILE VIEW

H. SCALE 1"=100'
V. SCALE 1"=10'

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Rev	Date	Drawn	Description	Ch'k'd	App'd

Date ________

Project Number: 393582 | B/O | Total

Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	

Scale at ANSI D | Status | Rev | Security: STD

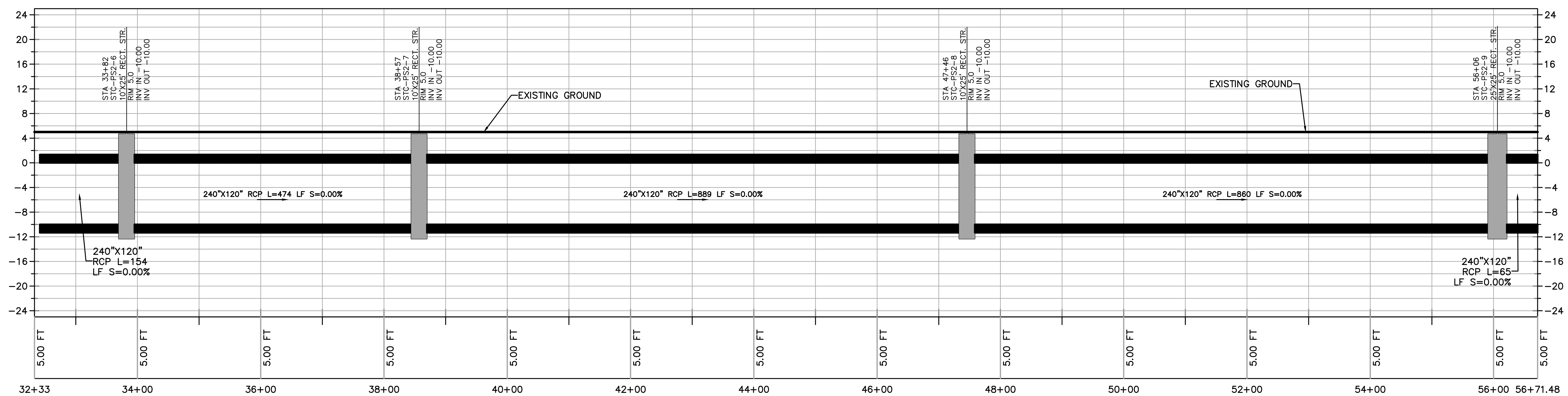
Drawing Number

Title

TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#2
SHEET 1 OF 2

PLAN VIEW

SCALE 1"=100'



Pump Station #2 Collection Conduits
STA 32+33 TO 56+71

PROFILE VIEW

H. SCALE 1"=100'
V. SCALE 1"=10'

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Client: USACE

Rev	Date	Drawn	Description	Ch'k'd	App'd

Date

Project Number: 393582 | B/O | Total

Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security STD

Drawing Number

Title: TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#2
SHEET 2 OF 2

PLAN VIEW
SCALE 1"=100'

Pump Station #3 Collection Conduits East Side
STA 0+00 TO 32+33

PROFILE VIEW
H. SCALE 1"=100'
V. SCALE 1"=10'

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Client: USACE

Rev	Date	Drawn	Description	Ch'k'd	App'd

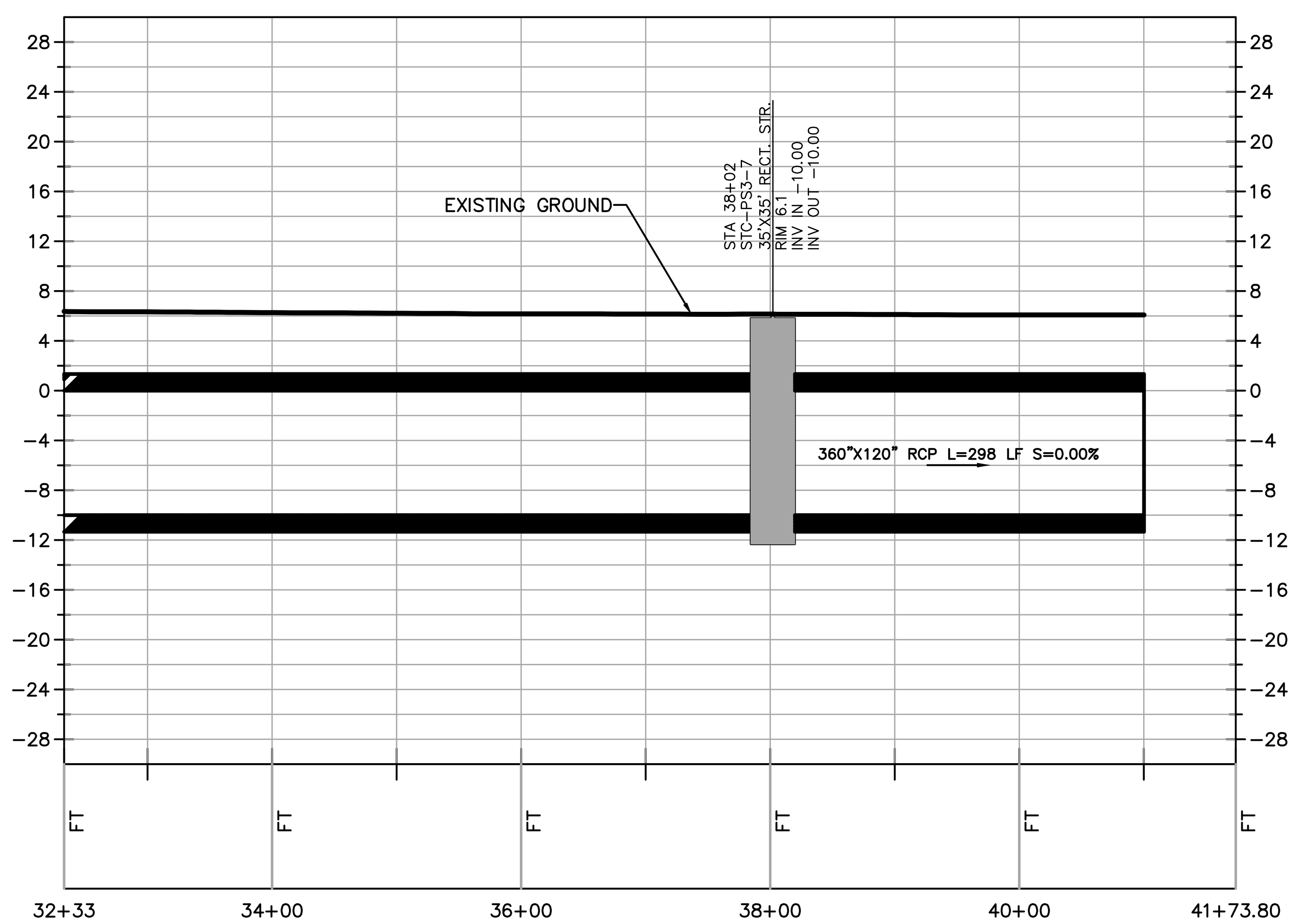
Date

Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security STD

Project Number: 393582 | B/O | Total | Drawing Number

Title:
TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#3
SHEET 1 OF 4

PLAN VIEW
SCALE 1"=100'



Pump Station #3 Collection Conduits East Side
STA 32+33 TO 41+74

PROFILE VIEW
H. SCALE 1"=100'
V. SCALE 1"=10'

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Client: USACE

Rev	Date	Drawn	Description	Ch'k'd	App'd

Date ________

Project Number: 393582 | B/O | Total

Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security: STD

Drawing Number

Title
TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#3
SHEET 2 OF 4

PROFILE VIEW
H. SCALE 1"=100'
V. SCALE 1"=10'

Pump Station #3 Collection Conduits South Side
STA 0+00 TO 32+33

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F +1 (973) 376 1072
www.mottmacamericas.com

Client: USACE

Rev	Date	Drawn	Description	Ch'k'd	App'd

Date

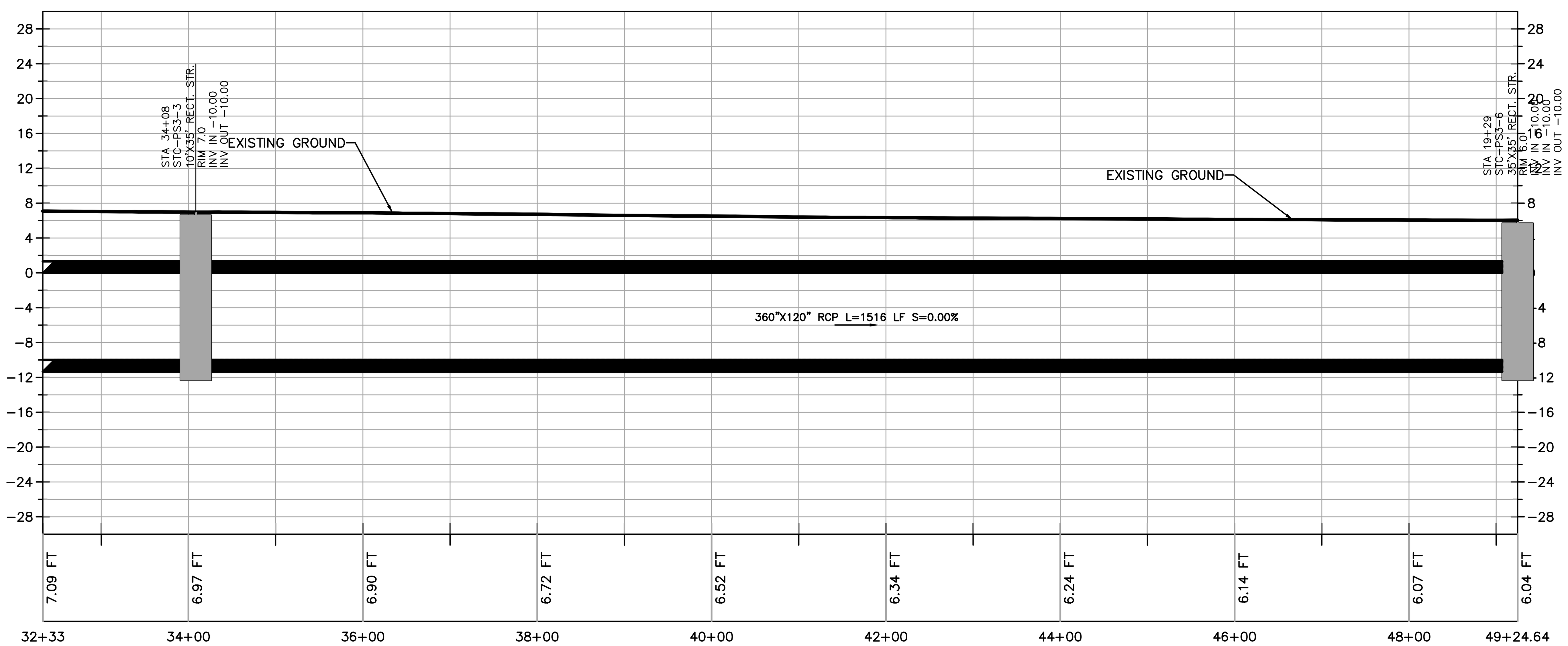
Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security STD

Project Number: 393582
B/O
Total
Drawing Number

Title
TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#3
SHEET 3 OF 4

PLAN VIEW

SCALE 1"=100'



Pump Station #3 Collection Conduits South Side
STA 32+33 TO 49+25

PROFILE VIEW

H. SCALE 1"=100'
V. SCALE 1"=10'

MOTT MACDONALD
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www.mottmacamericas.com

Client: USACE

Rev	Date	Drawn	Description	Ch'k'd	App'd

Date

Project Number: 393582 | B/O | Total

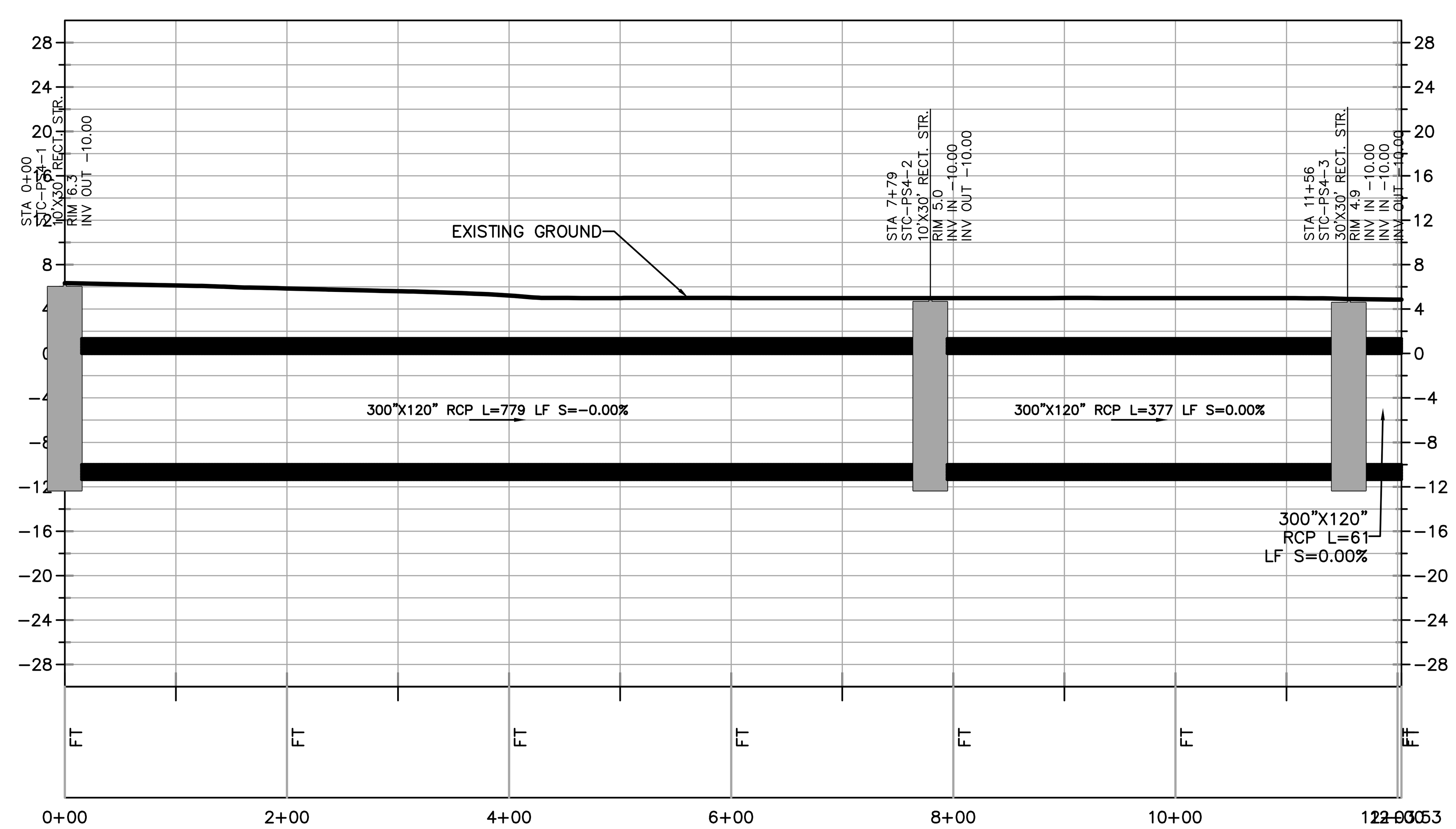
Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security: STD

Drawing Number

Title:
TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#3
SHEET 4 OF 4

PLAN VIEW

SCALE 1"=100'



Pump Station #4 Collection Conduits East Side

STA 0+00 TO 12+04

PROFILE VIEW

H. SCALE 1"=100'

V. SCALE 1"=10'

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Client: USACE

Rev	Date	Drawn	Description	Ch'k'd	App'd

Date ________

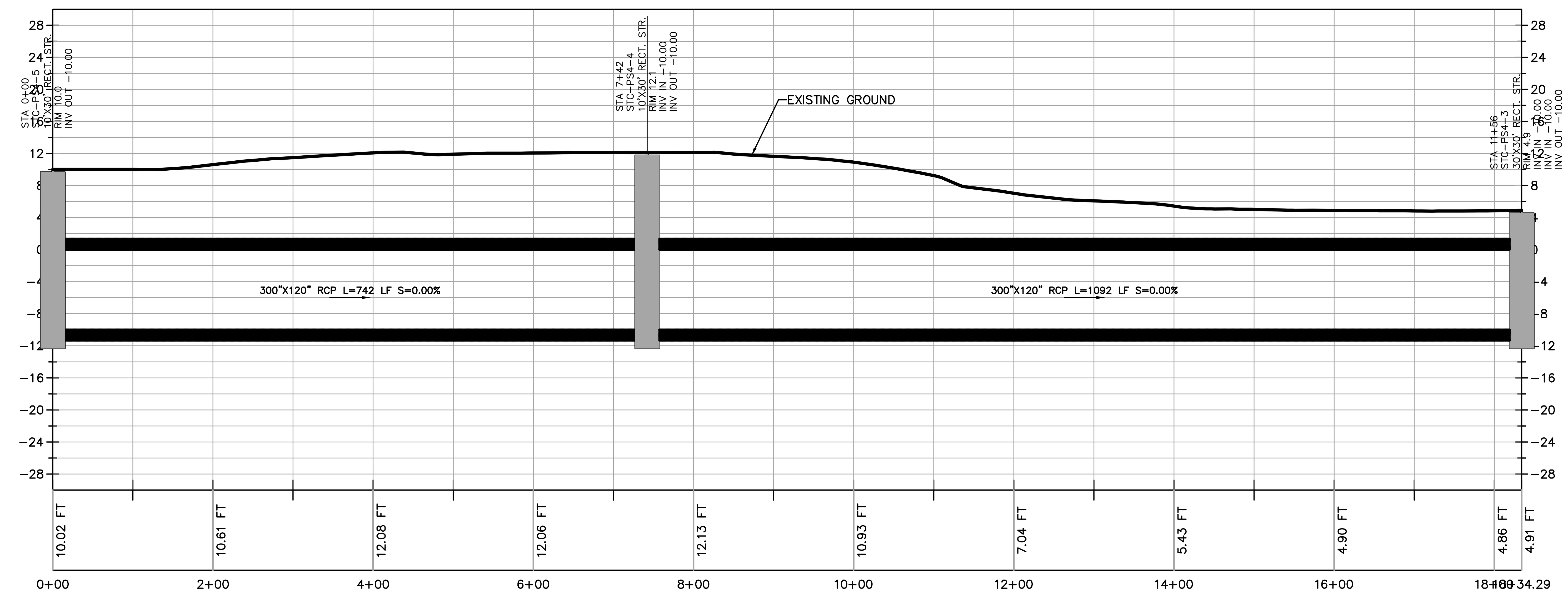
Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security: STD

Project Number: 393582 | B/O | Total | Drawing Number

Title: TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#4
SHEET 1 OF 2

PLAN VIEW

SCALE 1"=100'



Pump Station #4 Collection Conduits West Side
STA 0+00 TO 18+34

PROFILE VIEW

H. SCALE 1"=100'
V. SCALE 1"=10'

M M
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Client: USACE

Rev	Date	Drawn	Description	Ch'k'd	App'd

Date ________

Project Number: 393582 | B/O | Total

Designed	ZMS	Eng check	
Drawn	ZMS	Coordination	
Dwg check		Approved	
Scale at ANSI D	Status	Rev	Security STD

Drawing Number

Title
TEXAS COASTAL PROTECTION AND RESTORATION PROJECT
INTERIOR DRAINAGE AND HYDROLOGY
COLLECTION SYSTEM FOR PUMP STATION#4
SHEET 2 OF 2

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