Appendix A – Engineering

Mary Rhodes Pump Station, TX

Section 14

Draft Integrated Detailed Project Report and Environmental Assessment

August 2022

US Army Corps of Engineers
Galveston District

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1 GENERAL

1.1 Purpose

This Engineering Appendix documents the engineering analysis and evaluations for the Mary Rhodes Pump Station Feasibility Study. It also provides the baseline cost estimate for construction. The study will detail the engineering information that was collected, design references and guidance used, computer programs used, the design criteria assumed, design parameters, assumptions made, and methods of analyses. Narratives of the engineering analyses was broken out by discipline covering hydrology and hydraulics, surveying and mapping, geotechnical engineering, structural engineering, and civil design.

1.2 Scope of Study

The City of Corpus Christi has dealt with significant streambank erosion along the portion of the Colorado River at the Mary Rhodes Pump Station (MRPS). The erosion has caused the bank to recede approximately 16-27 feet since 2014 and is as close as approximately 40 feet from the facility in various locations along the project area (Figure 1-2 and Appendix drawing EXHIBIT 5-1 & 5-2). Due to the severe bank erosion, nearby power transmission poles are in imminent danger of failure, with the erosion exposing the foundation of the power transmission poles (Figure 1-4 and Figure 1-5).

1.3 Project Location

Mary Rhodes Pump Station is located on the west bank of the Colorado River near Bay City, Matagorda County, Texas. Bay City, the County Seat of Matagorda County, is 142 miles northeast from Corpus Christi. The Mary Rhodes Pump Station is approximately 7000 feet north of the Lower Colorado River Authority Dam.

The project is located along the portion of the streambank upstream of the Texas State Highway 35 Bridge, which crosses over the Colorado River west of Bay City in Matagorda County (Figure 1-1). The pump station facility covers 75 acres, including two water treatment ponds, pumping stations, water treatment purifiers and chlorinators, water lines, electrical lines, and access roads, along the Colorado River.

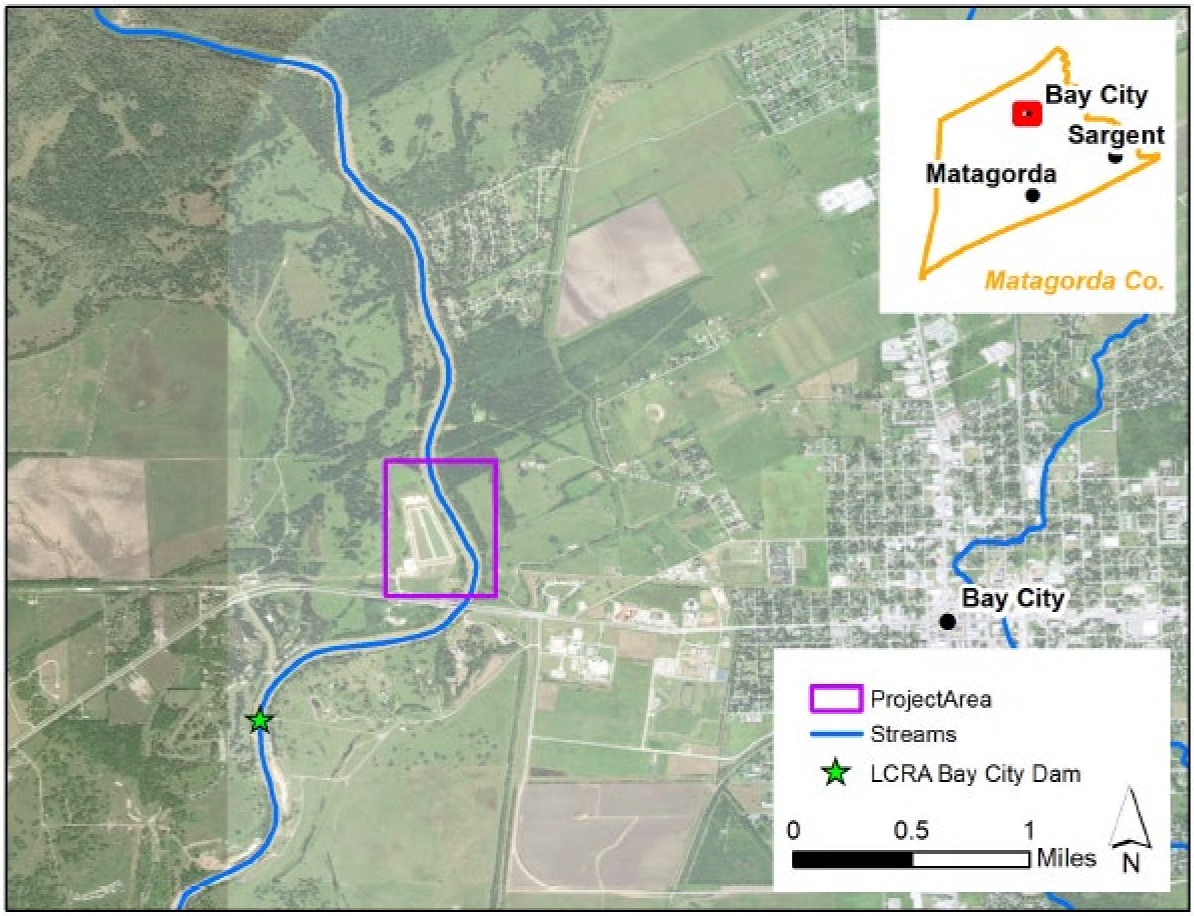


Figure 1-1: Project Location

Figure 1-2: Distance from edge of bank to fence line

1.4 Existing Site Description and Major Features

The portion of Colorado River at the Mary Rhodes Pump Station appears to be experiencing high levels of shear stress and erosion which is typical of alluvial channels such as the Colorado River. During the site visit, it was observed that the evolution of the erosional process on the river involves slumping of large masses of bank onto the toe of the riverbank, which is then washed away in subsequent high flows unless anchored by shrubs and trees. (Figure 1-2 through Figure 1-9).

The Colorado River is a large lowland sand-bed river that flows through the state of Texas. As with similar rivers, temporal evolution is marked by meander migration; the bank near the Mary Rhodes Pump Station has moved approximately 80 feet since the 1940s. As stated in Section 1.2, the bank has moved approximately 16-27 feet since the construction of the facility in 2014. The project site is at the downstream end of a cutbank of a meander. There is a small unnamed tributary upstream of the MRPS, just downstream of a pipeline crossing (Figure 1-3).

Field observations suggest rotational failure as a bank loss mechanism at the site. The banks had variable levels of vegetation, although the area near the intake was an area with relatively minimal vegetative cover. Other areas had some slump material that had revegetated with time to offer a degree of stability locally, though this material could be removed in subsequent flow events causing renewed erosive attack on the toe material. There were locations with relatively mature vegetation, though apparently robust vegetation can be undermined by an erodible toe material. See Figure 1-4 – Figure 1-9 for examples of vegetation along the Colorado River at the MRPS.

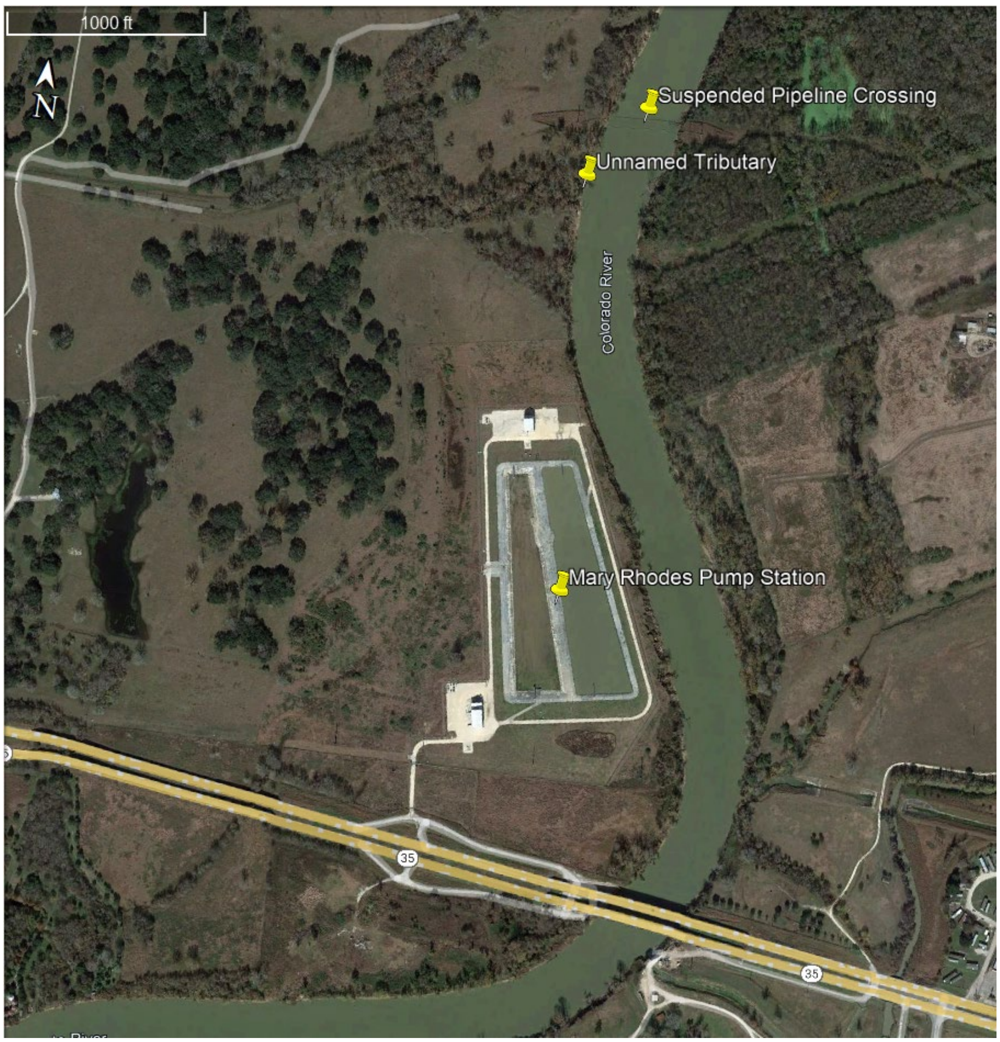


Figure 1-3: MRPS with Unnamed Tributary and Suspended Pipeline Crossing

Figure 1-4: Exposed Power Transmission Poles near Mary Rhodes Pump Station

Figure 1-5: Exposed Power Transmission Poles near Mary Rhodes Pump Station (Up-close)

Figure 1-6: Erosion along the Colorado riverbank at Mary Rhodes Pump Station

Figure 1-7: Riverbank Erosion just north of the intake pipe for MRPS.

Figure 1-8: Looking south towards the MRPS - The building visible in the photo is on the facility land

Figure 1-9: Unnamed tributary (far right) with the riverbank coming from the MRPS (approximately 650 north of the MRPS)

2 ALTERNATIVES CONSIDERED

In accordance with the guidelines outlined in ER 1105-2-100, the development and evaluation of
alternatives reflected the magnitude and scope of a Section 14 study. A non-structural solution, vegetation and/or slope grading, was considered but discounted based on engineering experience and judgment. The lack of available land to cut back the slope, and the inability to establish vegetation, eliminated any type of "soft" erosion protection project from further consideration. The alternatives for addressing the imminent threat to the Mary Rhodes Pump Station facility considered typical structural solutions using the following steps:

- Identify the slope instability problem
- Identify the cause(s) of the slope instability problem
- Develop alternatives based on engineering judgment and experience that address the slope instability problem threatening the pump station facility.
- Based on engineering judgment and experience, decide on the alternative that would address the slope instability problem in the least costly manner

2.1 Alternative 1 – Relocation (No Action)

If no action is taken, erosion of the stream bank would continue. If the erosion continues, the Mary Rhodes Pump Station function will be interrupted. If the facility were to be undermined, the City of Corpus Christi could no longer use this facility for residents and businesses. Furthermore, this area could become a public safety hazard because of the highly eroded stream bank. Eventually, this "no action" alternative would lead to the City of Corpus Christi undertaking more frequent, temporary repairs until there is an interruption in service.

2.2 Alternative 5 – Rebuild the Bank Out + Bank Sloping + Toe Riprap

Alternative 5 consists of rebuilding the bank out, bank sloping and toe rip rap (longitudinal fill stone toe protection). A feature of this alternative consists of riprap tiebacks, refer to Section 3.5, embedded under the top of the bank at approximately a spacing of 500 feet along the project length. The riprap tiebacks will be embedded 50 feet into the top of bank. Tieback thickness will consist of 3 feet of riprap. The steepest reconstructed slope for this alternative will be approximately 1.5H:1V along the riprap tiebacks. The majority of the upper bank will remain near existing conditions and change primarily to accommodate the riprap tiebacks. The existing natural slope gradient follows a 1.5H:1V slope based on recent survey data due to the nature of soil type after subject erosion. The tiebacks will provide the upper bank protection. Given the existing failure mode the toe protection is the most significant project feature. The toe protection will consist of longitudinal fill stone toe protection along the entire project length (approximately 2,630 feet*). The launching stone, poorly sorted **stone** that will fall (self-**launch**) into scour holes, quantity will be approximately 14.7 tons per linear foot. The height from the bottom of the toe protection to the top of the tiebacks is approximately 44 feet.

Figure 2-1 is a typical cross-section of a tieback and Figure 2-2 is a real-world application of this alternative.

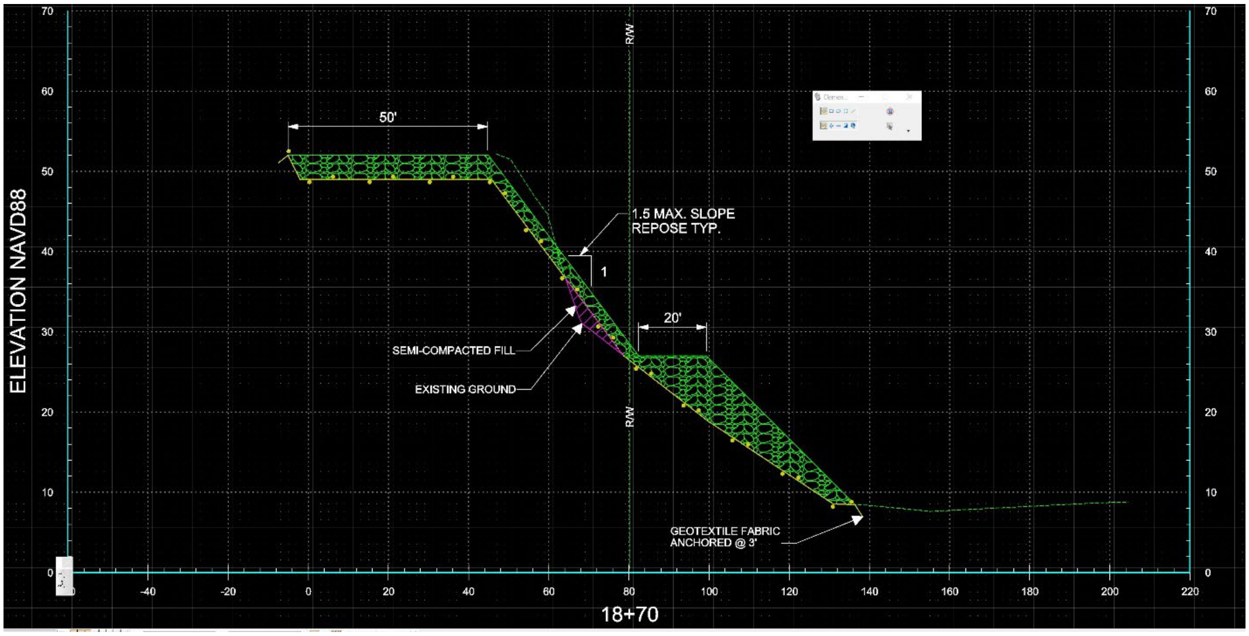


Figure 2-1: Alternative 5 Typical Cross-Section (Tieback)

Figure 2-2: Example of Alternative 5 as constructed on the Brazos River near Richmond, TX

2.3 Alternative 6 – Rebuild the Bank Out + Bank Sloping + Slope Riprap + Toe Riprap

Alternative 6 consists of rebuilding the bank out, bank sloping, slope riprap, and toe riprap (longitudinal fill stone toe protection). The slope of this alternative will be set at a 3:1 H:V. This alternative has more slope reconstruction than Alt 5; therefore, it includes riprap up the slope to an elevation of approximately 46 feet, along the entire length of the project. This is estimated to be approximately 2,630 feet. The slope riprap will have a thickness of 2 feet with 1 foot of bedding stone. The toe protection will consist of longitudinal fill stone toe protection along the entire project length. The launching stone quantity will be approximately 14.7 tons per linear foot.

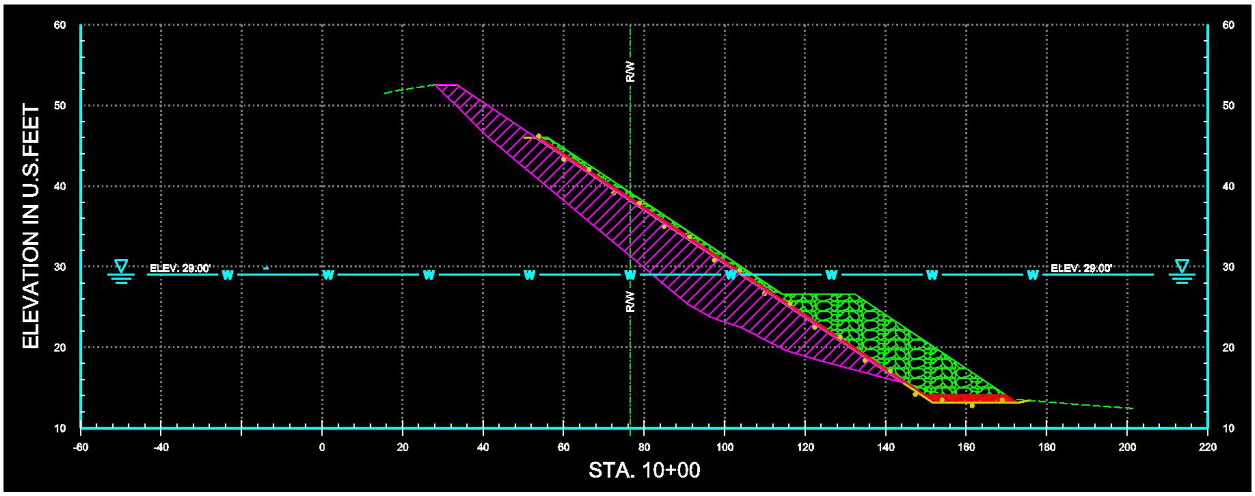


Figure 2-3: Alternative 6 Typical Cross-Section

2.4 Other Alternatives Considered

2.4.1 Sheet Piles

The use of steel sheet piles in combination with other measures, like longitudinal fill stone toe protection, were investigated and determined to not be cost effective in providing similar or better protection against riverine erosion.

2.4.2 Streambank Soil Bioengineering

The use of living and nonliving plant materials in combination with natural and synthetic support materials for slope stabilization and erosion reduction were investigated and were determined to be unsupportive of the river velocities. The use of living vegetation along with the need to harvest locally in the area poses a challenge along with the additionally maintenance for a 50-year project life. Bioengineering could be considered as a refinement of the alternatives, but not a defining feature.

3 H&H

3.1 Hydrology

Error! Reference source not found. shows the USGS gage locations on the lower Colorado River from Wharton to Matagorda Bay. Figure 3-2 shows the flow frequency analysis done with HEC-SSP software using USGS Bulletin 17C methods (England et al., 2019). Table 3-1 lists the frequencies and associated velocities for four statistical events. The Mary Rhodes Pump Station is approximately 7,000 ft. upstream of the Lower Colorado Authority (LRCA) Bay City Dam.

LCRA impounds water upstream of the dam for pumping operations related to their water supply operation. The target water-surface elevation upstream of the dam is 26.5-feet NAVD 88 (according to representatives from LCRA – Riley, personal communication). The dam is fully opened when the upstream flow rate exceeds approximately 3,000 cfs and is returned to a closed position on the receding limb of the flood wave. The dam is practically open for large flow events and is not a hydrologic control on design conditions for this project.

Figure 3-1: USGS gages on the Lower Colorado River

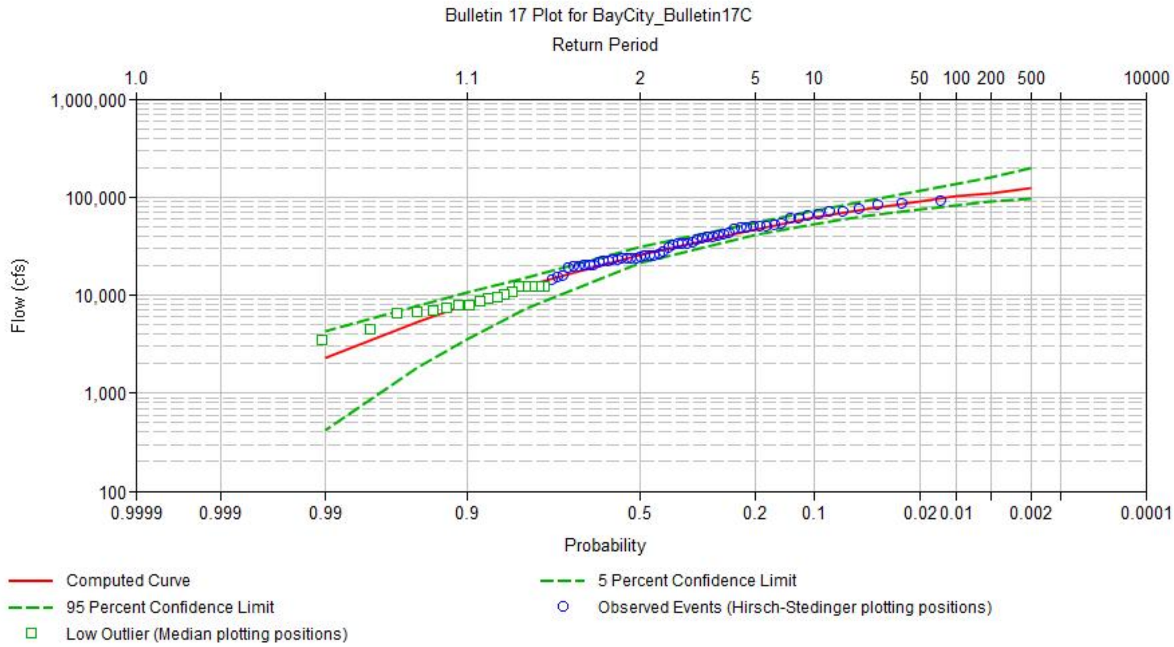


Figure 3-2: Flow Frequency relationship for Bay City gage (USGS #08162500)

3.2 Hydraulics

Hydraulic conditions at the project site were evaluated using a HEC-RAS model obtained from Schiebe Consulting (2022). Their firm completed a floodplain study of the Colorado River through the three counties nearest the terminus at Matagorda Bay. The provided model was run in HEC-RAS version 6.1 for this effort.

The unsteady model was run in steady mode, i.e., with constant upstream boundary conditions, for the four frequency events shown in Table 3 1. The primary purpose of the modeling was identify velocities near the project site to inform design on the alternatives, primarily related to riprap size. The model provided included several 2D flow areas which precludes a steady flow simulation. To that end, a flow hydrograph boundary condition that was time invariant was used in the hydraulic model based on the frequency analysis in Figure 3-2. Lateral inflow in the provided model was minimal compared to flow at the upstream end and peaked well before the peak of the Colorado River at the project site. A sensitivity run of the provided model with and without the lateral inflows showed minimal difference in simulated peak conditions at the project site. Additionally, there was minimal attenuation between the upstream boundary and the project site for the sensitivity runs (Figure 3-3).

The model results for water-surface elevation and velocity for the four frequency events (2-, 10-, 50-, and 100-yr) are shown in Table 3 1. No with-project conditions were hydraulically simulated for this project. The selected plan riprap placement represents a minimal change to the channel cross-section and would constitute a corresponding minimal impact to local hydraulics, particularly for such a large river. The selected plan is a direct bank stabilization measure which have minimal impact on opposite and adjacent banks. Indirect stabilization measures can cause river changes elsewhere; this direct stabilization measure has minimal redirection of energy by comparison. The recommended plan provides the launch stone required to accommodate scour, and generally the bank returns to apparent natural, though stabilized, conditions over a period of years.

Table 3-1 Flow frequency, simulated channel velocity, local velocity, and water-surface elevations

ACE [%]	Avg. Return Period [yr]	Flow [cfs]	WSEL [ft]	Avg. Chan. Velocity [ft/sec]	Local Velocity (U/S Bend) [ft/sec]	Local Velocity (at facility) [ft/sec]
50	2	26,175	35.02	3.62	4.06	4.35
10	10	61,500	45.88	5.47	6.01	6.44
2	50	89,930	52.48	6.03	6.53	6.93
1	100	100,670	54.05	6.16	6.69	7.02

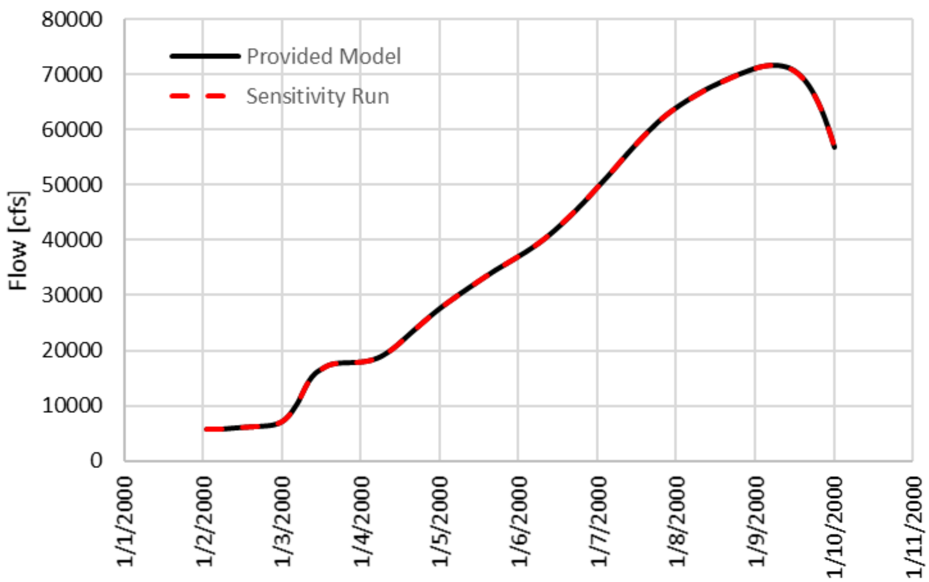


Figure 3-3: Result from sensitivity run of the provided model. Flow results from the two simulations plot very similarly

3.3 Climate Change

There are two considerations for climate change at the project site: (1) climate-impacted hydrology and (2) sea-level change.

3.3.1 Climate-Impacted Hydrology

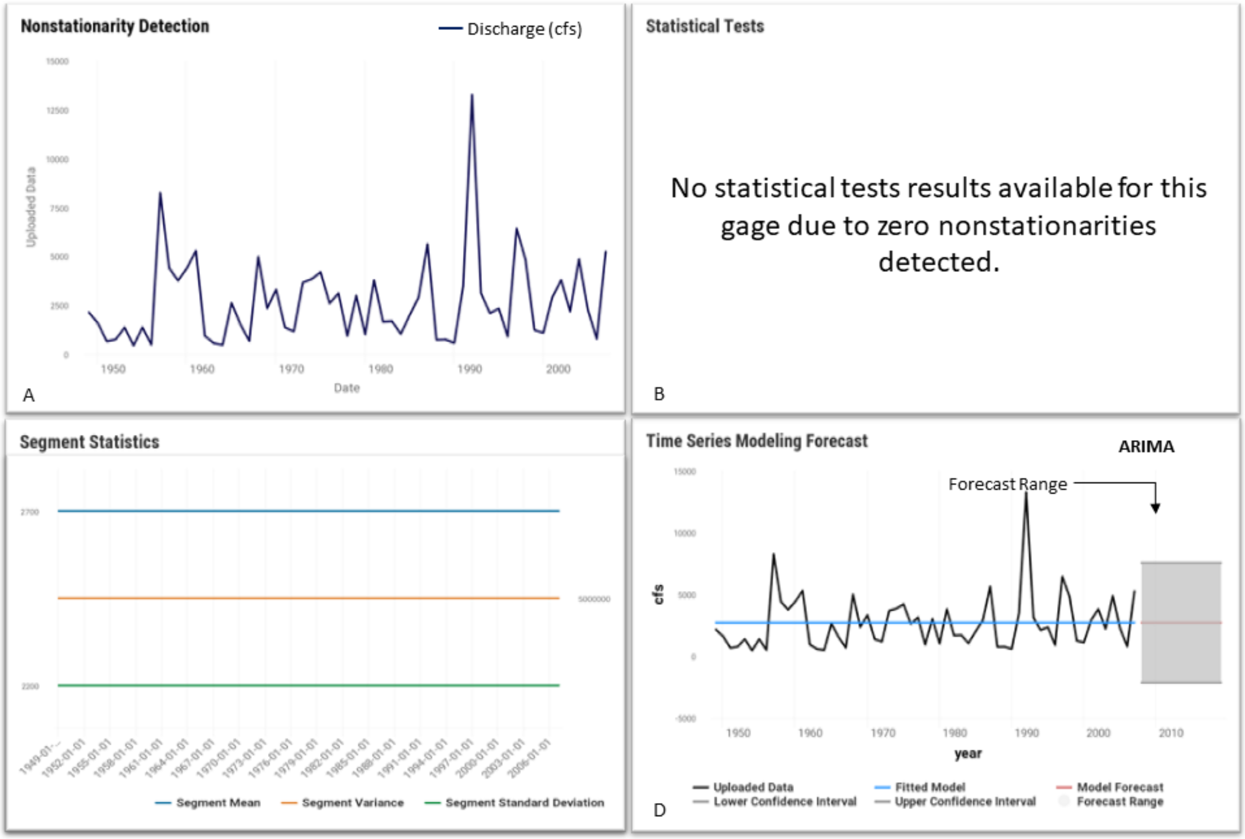
ECB 2018-14 (USACE, 2018) provides guidance for incorporating climate change impacts to inland hydrology related to proposed USACE projects and measures. This section describes the qualitative assessment of hydrologic conditions.

Multiple authors have evaluated historical precipitation, with most concluding increasing precipitation over time. The Texas-Gulf Region has experienced a linearly increasing trend in annual precipitation from 1895-2009 (USACE, 2015). Climate projections in the summary matrix of USACE (2015) indicate increases in precipitation extremes with decreases in overall streamflow.

An analysis of the furthest downstream gage with suitable data along Colorado River was completed to look at how the discharge has changed from 1949 to 2021. The USGS gage used for this analysis was 08162500 Colorado River near Bay City, TX. The Timeseries Toolbox (USACE, 2019) did not detect any nonstationarities at this location. ARIMA model analysis predicts little change in the future discharge. Analysis of historic observations are not statistically significant for the gage height at this location. Table 3.2 shows a summary of breakpoint and statistically significant tests.

Table 3.2: Summary of breakpoint analysis and statistical significance tests - USGS Gage 08162500

			Statistical Test p-value			
USGS Gage Number	**Gage Location**	**Breakpoint**	**t-test**	**Mann-Kendall**	**Spearman R-O**	**Statistical Significance**
08162500	Colorado River near Bay City, TX	No Breakpoint	0.21239	0.15024	0.12124	Not Significant



Graph A: Nonstationarity Detection over the analyzed time frame. Graph B: Statistical tests that detected nonstationarity over the analyzed time frame. Graph C: Mean, Variance, Standard Deviation changes over time after nonstationarity detections. Graph D: ARIMA forecast of potential trend in time.

Figure 3-4: Output from Nonstationary Detection Toolbox: (A) Nonstationary Detection plot, (B) Statistical Method Nonstationary Test Results plot, (C) Statistical Changes plot, and (D) ARIMA forecast of potential trend changes plot.

The Climate Hydrology Assessment Tool (CHAT) (USACE, 2015) was used to investigate potential future stream flow trends for HUC 1209. Figure shows the mean and range of projected annual maximum monthly stream flows computed from 93 different climate change hydrologic model runs for the period of 1950-2099. Global circulation models (GCM) combined with various greenhouse gas emission scenarios create climate changed hydrology outputs to project precipitation and temperature data. The meteorological outputs are spatially downscaled using the Bias Corrected Spatial Downscaling (BCSD) statistical method and then input in the U.S. Bureau of Reclamation's Variable Infiltration Capacity (VIC) precipitation-runoff model to generate streamflow response.

The CHAT also provides **trends in mean annual maximum of average monthly streamflow from 64 climate-changed hydrology models on the HUC 8-digit basis. This is shown for HUC 12090203 in** Figure 3-.

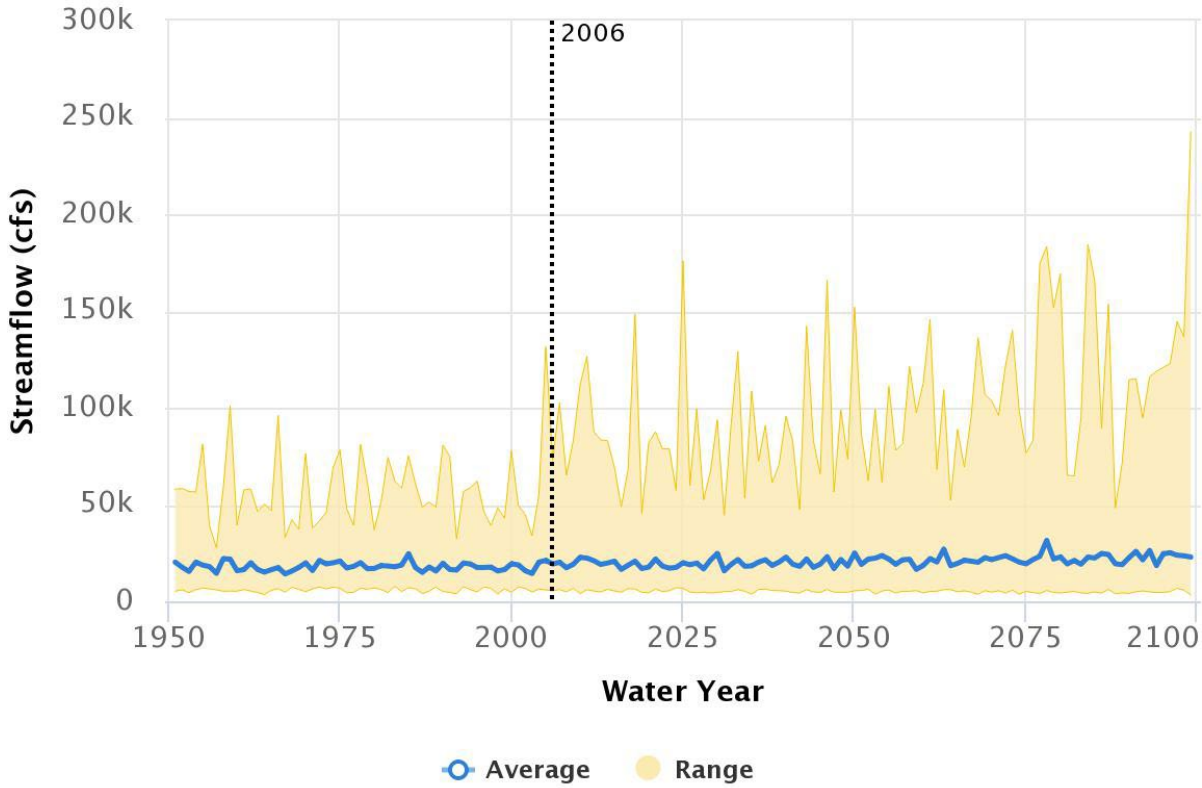


Figure 3-5: Range of 93 Climate-Changed Hydrology Models of HUC 1209

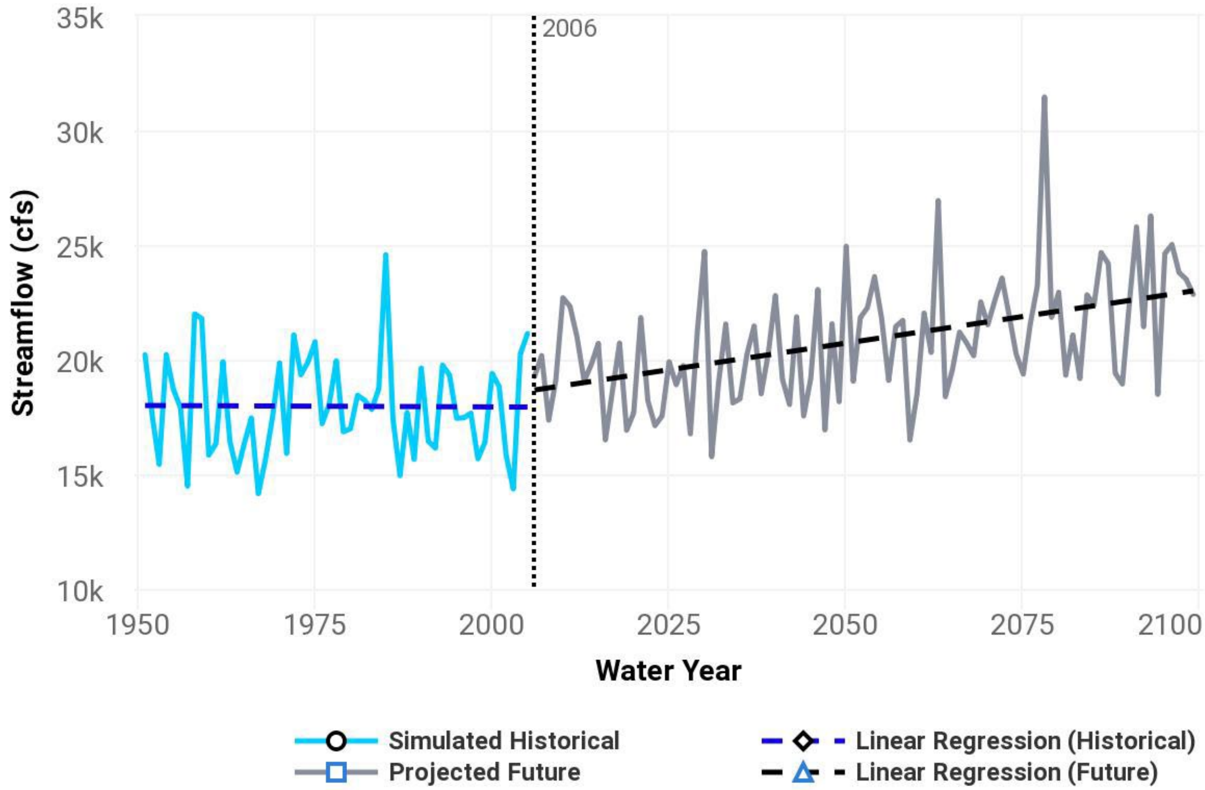


Figure 3-6: Trends in Mean of 93 Climate-Changed Hydrology Models of HUC 12090302

Figure shows the wide range of projected annual maximum monthly streamflow on the 4-digit HUC basin in the Lower Colorado basin. Thought the range is large the mean is relatively consistent. The further downscaled information in Figure 3- shows an increasing trend in in maximum annual monthly mean streamflow. A significant caveat to the projections both on the HUC 1209 and HUC 12090203 basis is that the streamflow projections are for an unregulated condition. The Lower Colorado River has 7 dams in the USACE National Inventory of Dams (NID) (USACE, 2022). Not all significantly regulate flows, though some are on the main stem of the river. LCRA also has a series of dams along the Colorado River basin which regulate flow. One additional caveat to the streamflow projections is that they are based on average monthly data. The projections don’t necessarily inform average maximum values or associated flow frequency. While the projection in Figure 3- would indicate a somewhat wetter future (at least for a particular month during the year), it does not indicate a particular increase in flow associated with a particular frequency event.

The Vulnerability Assessment (VA) Tool (USACE, 2016) was used to qualitatively characterize flood risk management climate vulnerability in the four-digit HUC 1209 watershed. This tool uses runoff estimated from Global Climate Models (GCM) projections. The GCM projections are divided into two groups. The group with the lower cumulative runoff projections is used to compute values for the dry scenario and the group with the higher runoff projections is used to compute values for the wet scenario.

Weighted order weighted average (WOWA) scores are created for all the indicators, higher values indicate higher vulnerability, and aggregated by base year, two future scenarios (Wet and Dry), over two epochs (2050 and 2085). The VA tool did not indicate vulnerability in the Flood Risk Reduction business line for any of the four future climate scenarios.

3.3.2 Sea-Level Change

In addition to a qualitative assessment of climate-impacted hydrology, ECB 2018-14 (USACE, 2018) requires a determination related to sea-level change for projects below 50-feet NAVD88. The project site sits at approximately 45-feet NAVD88 with the thalweg lower.

The nearest USACE-compliant NOAA water-level gage to the project area is station 8772440 at Freeport. The high RSLC project for the Freeport gage is +6' above Local Mean Sea Level through 2100. The most significant consideration related to RSLC at the project location is the Bay City Dam situated 1.3 miles downstream. Even under the high RSLC scenario the downstream dam would restrain future upstream propagation of the daily tidal influence. As such, the performance of the project is expected to be the same across potential future RSLC conditions and not a significant concern for the project.

3.3.3 Qualitative Vulnerability of TSP

Table 3.3 shows the vulnerability assessment of the bank stabilization features, considering potential triggers, hazards, harms, and likelihood. **Error! Reference source not found.**

Table 3.3: Vulnerability assessment of TSP feature

Feature or Measure	Trigger	Hazard	Harm	Qualitative Likelihood
Bank Stabilization	Increases in frequency or intensity of low frequency flow events	Increased flow during low frequency events	Increased velocity at the project site. A factor ameliorating the harm is that velocities do not increase substantially after bank full conditions have been met.	Possible
	RSLC	Increased water-surface elevations	Minimal considering the Bay City Dam just downstream of the project site restraining increased water-surface elevations from RSLC.	Likely

3.4 Geomorphology

The watershed-level geomorphology is important to evaluate for bank stabilization projects. Site-specific projects can be undermined if the instability is more systemic. The specific gage analysis for the Bay City gage is shown in Figure 3-6. The downward trend indicates either degradation or widening at the gage location between 1960 and 2000. This is likely associated with the construction of the Bay City dam which was completed sometime between 1957 and 1965 based on historic aerials. The degradational trend appears to have been replaced by dynamic equilibrium since 2000.

The specific gage analysis is supported by observations during a series of site visits along the lower Colorado River conducted during August 2019. Throughout the multiple sites visited there was no evidence of watershed-level degradation or instability. Areas of problematic bank erosion appear to be isolated issues and not part of a larger problem.

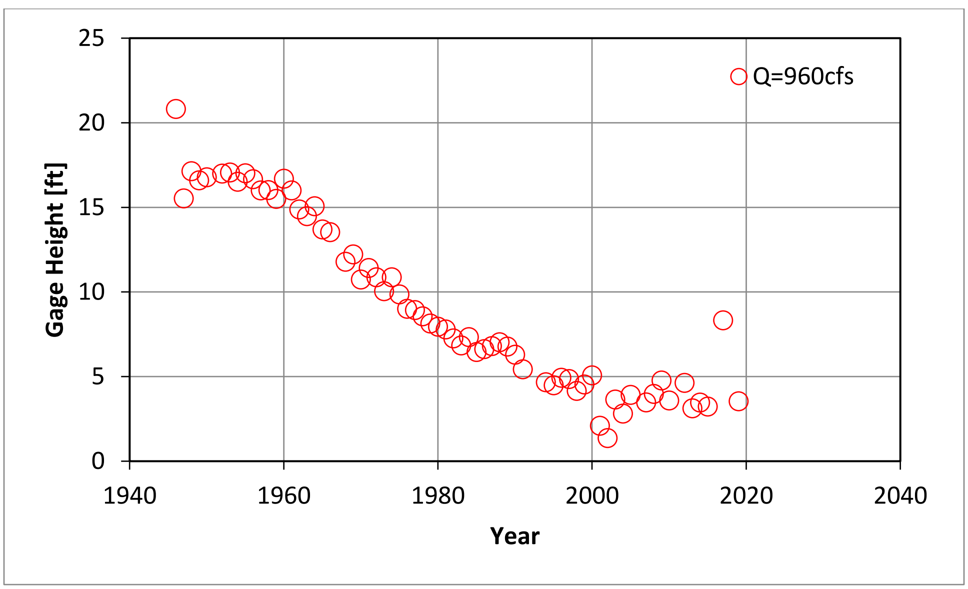


Figure 3-7: Specific gage plot for USGS gage 08162500 (Bay City)

3.5 Design Considerations

3.5.1 Riprap Size

EM 1110-2-1601 (USACE, 1994) includes guidance regarding riprap size which is calculated according to:

$$d_{30} = S_f C_S C_f C_V C_T y \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{1/2} \frac{U}{\sqrt{K_1 g y}} \right]^{2.5}$$

where d_{30} is the riprap size which has thirty percent finer, S_f is the factor of safety, C_V is the vertical velocity distribution coefficient, C_S is the stability coefficient, C_T is a layer-thickness coefficient, γ_w is the unit weight of water, γ_s is the unit weight of the rock, U is the local depth-averaged velocity, K_1 is a side-slope correction factor, and y is the local water depth.

For the flow and water properties, the average channel velocity is output from the HEC-RAS model (Table 3-1). The flow depth for side slopes is taken as the water depth above a point twenty percent up the slope from the toe; this is approximated as 35 feet. Calculated stone size is minimally sensitive to water depth and the water weight; the most sensitive parameter is channel velocity.

For the riprap properties, the stone is assumed angular with a unit weight equal to 155 lb/ft3. The 3:1 (H: V) side-slope is the backfilled slope. A factor of safety of 1.20 is applied to the design. Channel properties were estimated from aerial imagery and the HEC-RAS model geometry. A circle superimposed over the meander at the project site has an approximate radius of 1850 ft (Figure 3-). The bankfull width, estimated at the prior upstream crossing, is 350 ft. This gives an Rc/W equal to 5.3.

The stability coefficient is taken as 0.30 for angular riprap. The vertical velocity distribution coefficient is calculated as:

$$C_v = 1.283 - 0.2\log(R_c/W)$$

which is appropriate for the outside of bends with Rc/W<26. The layer thickness coefficient is based on the calculated riprap size and associated required layer thickness.

For riprap on side slopes the average channel velocity is adjusted to account for the difference in average channel velocity and the local depth-averaged velocity on the subject slope, particularly at the outside of a meander. The ratio between the design side-slope velocity and average channel velocity is a function of Rc/W:

$$\frac{U_{des}}{U_{avg}} = 1.74 - 0.52\ \log(R_c/W)$$

The K1 side-slope correction factor is selected based on Maynord (1988) as a function of the side slope angle, θ, and the riprap angle of repose, ϕ (assume to be 40 degrees) (plate 39 in EM 1110-2-1601).

Based on historical minimum sizing of riprap used in TxDot projects and H&H investigation into various software and tools, a D100 of 15 inches was selected for the stone size for use in the MRPS. See Table 3- for the graduation requirements.

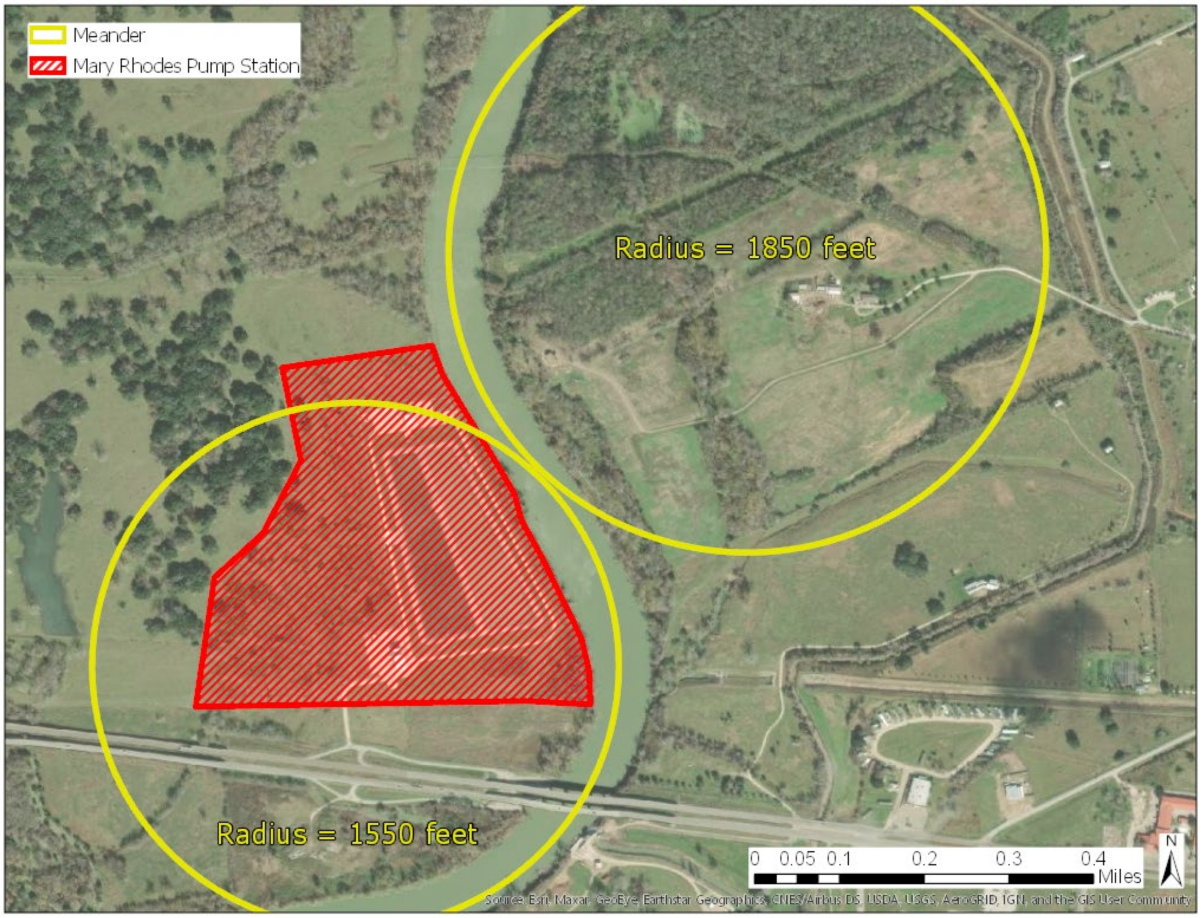


Figure 3-8: Colorado River Meanders at Mary Rhodes Pump Station

Table 3-4: TxDoT Protection Riprap Gradation Requirements and Stone Size

Size	Maximum Size (lb.)	90% Size (lb.)	50% Size (lb.)	8% Size Minimum (lb.)	Dmax (in.)	D90 (in.)	D50 (in.)	D8 (in.)
15 in.	320	170-300	60-165	20	16.10	13.04-15.75	9.21-12.91	6.39

3.5.2 Scour Potential and Toe Protection

The scour potential for a given meander is the expected depth below the thalweg in the upstream crossing because of natural processes associated with the river curvature. There are several methods by which the scour potential for a site can be calculated. The methods are typically empirical and subject to the circumstances associated with their determination. Four scour potential equations were applied to the project site: Maynord (1996), Zeller (Simons Li and Associates, 1985), Thorne et al. (1995), and USACE (1994). Table 3- shows the relevant channel properties and calculated scour depth for the methods. For the purposes of this study and the feasibility design the scour potential will be taken as 24 feet.

The selected toe protection will need to handle vertical bed displacement up to the scour potential. Fixed structures not protecting to this depth are at risk of undermining during scour. Adaptable features, such as longitudinal fill stone toe, need enough riprap to launch during scour.

The quantities for the stone toe alternative include two components, the peaked stone toe section, and the launch stone to account for scour. The crest of the peaked stone toe is taken as one-third the bank height (Biedenharn et al., 1997). EM 1110-2-1601 guidance for launch stone quantities based on a calculated scour depth greater than 15 feet with wet placement is given by:

$$V_{LS} = 1.75\sqrt{5}D_S T$$

where D_S is the scour depth and T is the riprap layer thickness. The calculated launch stone quantity required in addition to the riprap revetment or peaked stone toe section is 14.7 tons/ft

Table 3-5). The longitudinal fill stone toe total quantity is 17.5 tons/ft.

Table 3-5: Scour potential calculations

SCOUR POTENTIAL			
Parameter	**Symbol**	**Value**	**Units**
HYDRAULIC PROPERTIES			
Average Water Depth, Upstream Crossing	D_{mnc}	34.29	ft
Max Water Depth, Upstream Crossing		37.85	ft
Max Water Depth, Bend		37.85	ft
Average Velocity, Upstream Crossing		6.16	ft/sec
Energy Slope, Upstream Crossing		0.000214	-
CHANNEL PROPERTIES			
Radius of Curvature	R_c	1850	ft
Channel Width	W	350	ft
Radius of Curvature to Width	R_c/W	5.3	
COMPUTED SCOUR AND STONE VOLUME			
Scour Below Thalweg (Maynord, 1996)		23.9	ft
Scour Below Thalweg (Zeller)		4.8	ft
Scour Below Thalweg (Thorne et al., 1995)		33.3	ft
Scour Below Thalweg, sand bed (USACE, 1994)		40.3	ft

Table 3-6: Launching Stone Quantity

LAUNCHING STONE QUANTITY			
Parameter	**Symbol**	**Value**	**Units**
PEAKED STONE TOE VOLUME			
Bank Height		39	ft
Crest Height as Fraction of Bank Height		0.10	
Crest Height		3.90	ft
Peaked Toe Volume		2.8	tons/ft
CHANNEL PROPERTIES			
Scour Potential		24.2	ft
RIPRAP PLACEMENT			
Dry or Wet Placement		W	
Riprap Layer Thickness	T	2.00	ft
Bulk Unit Weight of Rock (including voids)	g_s	155.0	lb/ft^3
COMPUTED STONE VOLUME			
Launching Stone Quantity		14.7	tons/ft

3.5.3 Other Design Considerations

Tiebacks:

Tiebacks were considered as a feature to help hold the bank in place and provide additional support to the eroding bank, as well as the LFSTP. Tiebacks are provided approximately perpendicular to the toe protection. Tiebacks connect to the toe protection and are embedded into the bank to provide the upper bank protection.

End protection:

Special protection was considered on the terminal ends of the project length to provide a risk in flanking to the protection in place. The additional end protection will help to maintain adequate site protection along the Colorado River.

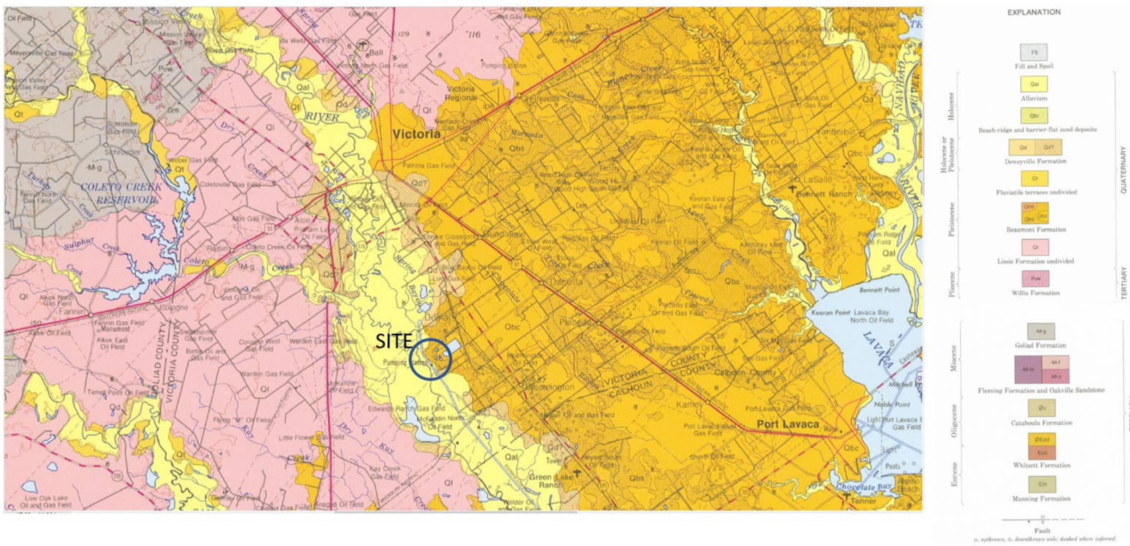
Site runoff:

Special consideration will be made to ensure that the new protection does not create a scenario where runoff can be directed down the restored bank and ensure the new protection will not be compromised.

4 GEOTECHICAL

4.1 Regional and Site Geology

The regional geology across the Pump Station of this project is primarily deposits of the Alluvium (Qal). Alluvium is loose gravel, sand, silt, or clay deposited by current or past streams. The geology for the Mary Rhodes Pump Station is shown on Figure 4-1. Regional Geology map.



Reference: Geologic Atlas of Texas, Beeville-Bay City Sheet, Alexander Deussen Memorial Edition, Rev. 1987, https://www.twdb.texas.gov/groundwater/aquifer/GAT/index.asp

Figure 4-1: Regional Geology

4.2 Explorations

No soil investigations were conducted for the development of the Engineering Appendix. It is recommended that soil investigation and surveys be conducted during the preconstruction engineering and design (PED) phase to provide data for design of the project.

4.3 Anticipated Construction Techniques

Potential earthwork activities associated with the Mary Rhodes Pump Station Streambank erosion repair alternatives as follows:

- Alternative 5- Placement of Riprap along the streambank as toe protection and placement of Riprap as tiebacks perpendicular to the toe protection.
- Alternative 5- Placement of a woven geotextile under the blanket bedding stone as part of an erosion protection system.
- Alternative 5- Placement of semi-compacted earth fills with a slope of 1.5 Horizontal to 1 Vertical (1.5H:1V) MAX using clayey soils. Semi-compacted fill placement will involve degrading the loose onsite soils and placing and compacting the semi-compacted fills as horizontal lifts.
- Alternative 6- Remove the unsuitable soils/debris from the slope surface as part of slope ground preparation for repair.

- Alternative 6- Placement of semi-compacted earth fills with a slope of 3 Horizontal to 1 Vertical (3H:1V) using imported clayey soils.
- Alternative 6- Placement of blanket bedding stone (min.1-foot thick) /Riprap (min. 2-foot thick) as part of an erosion protection system.
- Alternative 6- Placement of a woven geotextile under the blanket bedding stone as part of an erosion protection system.

4.4 Borrow and Disposal Sites

4.4.1 Borrow Sources

Satisfactory borrow material would be obtained from within the construction area. Satisfactory borrow material for semi-compacted fill shall consist of clayey soils including clays, sandy clays and silty clays classified as CH, CL, CL-ML, free from oversized soil materials, roots, trash, debris, and other organic materials in accordance with ASTM D2487. However, if satisfactory borrow material are not available on site the construction Contractor would obtain the material from commercial sources.

4.4.2 Disposal Sites

Materials obtained from clearing, grubbing, and removal of debris from the construction site. Debris consisting of inert and essentially insoluble industrial solid wastes including, but not limited to rock, brick, dirt, concrete, shingles, and glass materials that are not readily decomposable, and that are categorized as Class III wastes, would be removed from the construction area and disposed of in accordance with local, state, and federal regulations. Debris consisting of trees, shrubs, and logs would be disposed of in a Type IV landfill in accordance with State of Texas regulations.

4.5 Design Considerations

4.5.1 Stone Protection.

Riprap design will be in accordance with EM 1110-2-1601. Quantity estimates assumed a 24-inch layer of riprap to be placed on a 12-inch layer of bedding stone for Alternative 6. Future soil investigations will determine if the proposed stone protection system performance will be sufficient to prevent subject riverbank erosion.

Alternative 5 Conceptual design is suggested by the H&H engineer based on its performance identified in similar riverbank erosion protection projects. This conceptual design considers an erosion protection design with minimal cost (minimal earthwork, limited amount of riprap) for project construction. Alternative 5 consists of the placement of riprap along the toe and the tie-back locations to control the riverbank erosion rather than stabilize the slope surface against other failure modes, including rotational or wedge slope failures. The existing natural slope gradient follows a 1.5H:1V slope based on recent survey data due to the nature of soil type after subject erosion. And the 1.5H:1V slope surface is adopted as a stable slope bottom to carry the tie-back riprap at the study level design. This slope gradient is shallower than the typical riprap's angle of repose in the absence of geotechnical test data and detailed geotechnical design. Therefore, the design of the slope gradient shall be revisited during the PED phase based on future geotechnical investigation and detailed stability analyses. In other words, the slope may be excavated at the tie-back locations with a slope gradient shallower than 1.5H:1V to prepare the slope bottom to receive the riprap tie-back fills during the PED phase.

4.5.2 Geotextile.

Woven geotextile will be required to protect the foundation material beneath the riprap/bedding stone layer from hydrostatic pressures that could produce potential piping for Alternative -5 and -6. It is recommended that soil investigation be conducted during the preconstruction engineering and design (PED) phase to provide detail geotextile design.

Table 4-1: Minimum Geotextile Properties

PROPERTY	TEST METHOD	UNITS	MINIMUM VALUE
Apparent Opening Size	ASTM D 4751	U.S.Sieve	#40
Permittivity	ASTM D 4491	sec^{-1}	4.20
Puncture	ASTM D 4833	lbs	150
Tensile Strength	ASTM D 4632	lbs	115
Breaking Elongation	ASTM D 4632	percent	15
Burst Strength	ASTM D 4884	psi	480
Trapezoidal Tear	ASTM D 4533	lbs	40
Percent Open Area	ASTM D 3884	percent	20
Ultraviolet Degradation (percent strength retained at 500 hours)	ASTM D 4355	percent	50
Abrasion Resistance	---	lbs	*

5 CIVIL DESIGN

5.1 Survey, Mapping and Other Geospatial Requirements

The existing topographic contours were created from a LIDAR survey of Mary Rhodes Pump Station. The primary study area consists of Mary Rhodes Pump Station. The horizontal and vertical datum used in the engineering analyses and models conform to the current Federal standard. Horizontal coordinates are referenced to the North American Datum of 1983 (NAD 83). Elevations for proposed project features are reference to the North American Vertical Datum of 1988 (NAVD 88), unless otherwise stated. Other surveying, mapping, and geospatial information/tools came from the following resources:

- National Geospatial Data Clearinghouse
- Satellite imagery and data published by Google Earth Pro

5.2 Design Considerations

5.2.1 Alignment.

The alignment of the slope repair will follow the natural curvature of the river.

5.2.2 Quantity Calculations

Mary Rhodes Pump Station alternative quantities were calculated using MicroStation. Volumes were computed by applying average end method to the alternative quantities.

5.2.3 Real Estate

No additional real estate acquisitions are required to conduct the repair. The effort to repair and access the site will be within the existing rights-of-way of Mary Rhodes Pump Station.

5.2.4 Relocations

There are no known relocation components to the alternatives.

6 ADDITIONAL ANALYSIS REQUIRED

This feasibility study was completed using available data and constraints set upon the team. The feasibility phase of CAP projects are completed using existing data and minimal analysis. Additional investigations and analysis will be completed as needed during the design phase.

7 OPERATION, MAINTENANCE, REPAIR, REPLACEMENT AND REHABILITATION (OMRRR) AND CONTINUING CONSTRUCTION

During plan comparison there were future construction actions that were considered OMRR&R and some that were consider continuing construction. Future work associated with Rip Rap Replacement, Debris Removal and Revegetation Establishment, and Inspection, was considered OMRR&R and continuing construction. The assumptions and quantities for OMRR&R and continuing construction were identified for each measure in the feature design section and shown in Table 7-1.

Table 7-1: Operation, maintenance, Repair, Replacement and Rehabilitation (OMRR&R) and Continuing Construction

		Quantity	Unit	Notes
Alternative 5 - Riprap Along Slope & Toe w/ Riprap Tiebacks				
1	***Annual*** Inspection	4	Hr	Annual visual inspection/documentation
2	***5-Year*** Revegetation Establishment	0.04	AC	Reestablish turf areas due to drought periods, assume 50% of initial
	Debris Removal	16	CY	Remove collected flood debris, 16 CY every 5 years
3	***10-Year*** Riprap Replacement	4926.44	Ton	Assume 10% of orginial total placement
Alternative 6 - Riprap slope w/ Toe Protection				
1	**Annual** Inspection	4	Hr	Annual visual inspection/documentation
2	**5-Year** Revegetation Establishment	0.80	AC	Reestablish turf areas due to drought periods, assume 50% of initial
	Debris Removal	16	CY	Remove collected flood debris, 16 CY every 5 years
3	**10-Year** Riprap Replacement	5379.79	Ton	Assume 10% of orginial total placement

8 COST ESTIMATE OF TENATIVELY SELECTED PLAN (TSP)

This study focuses on bank stabilization at Mary Rhodes Pump Station.

Nine alternatives for streambank protection were proposed by the team. Three of nine proposals were estimated for cost comparison purposes; the other six proposals were eliminated. Class 4 cost estimates and an Abbreviated Risk Analysis (ARA) were developed for the three alternatives, which included a “No Action” alternative. The ARA was conducted 15 Mar 2022, and the ARA can be found in Attachment 4. Cost estimate assumes construction will start February 2024, with construction completion estimated for February 2025. The estimated construction duration of 12 months includes mobilization and demobilization, all necessary construction activities, and final acceptance documentation.

The least cost plan, “Alternative 5,” was selected as the TSP shown in Table 1. A Class 3 cost estimate and an updated ARA were developed for the TSP.

Table 8-1: TSP

WBSNu	Description of Item	Estimated Cost*
01	Lands and Damages	$62,900
06	Fish and Wildlife Facilities	$81,800
16	Bank Stabilization	$9,095,500
18	Cultural Resource Preservation	$102,200
30	Engineering and Design	$909,600
31	Construction Management	$545,700
	Total Estimated Cost	**$10,797,700**

* Cost plus contingency. Does not include escalation (First Cost) or inflation (Fully Funded Cost).

The PDT developed, quality controlled, and verified quantities. The estimate was organized in accordance with the work breakdown structure using the following codes of account.

ACCOUNT CODE 01 – LANDS AND DAMAGES: The Galveston District Real Estate Division developed costs and contingency for Lands and Damages.

ACCOUNT CODE 06 – FISH AND WILDLIFE FACILITIES: The Galveston District Environmental Point of Contact developed costs and contingency for Environmental Mitigation.

ACCOUNT CODE 16 – BANK STABILIZATION: The Galveston District Engineering and Construction Division provided quantities associated with this account based on preliminary designs with limited geotechnical and project site survey information.

ACCOUNT CODE 18 – CULTURAL RESOURCE PRESERVATION: The Galveston District Culture Resources Point of Contact developed costs and contingency for this account.

ACCOUNT CODE 30 – PLANNING, ENGINEERING, AND DESIGN: The cost for this account code was developed using a percentage of the construction work and in coordination with the PM/PDT.

ACCOUNT CODE 31 – CONSTRUCTION MANAGEMENT: The cost for this account code was developed using a percentage of the construction work and in coordination with the PM/PDT.

9 REFERENCES

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ATTACHMENT 1

Alternatives 5 & 6 Feasibility Study Quantities

Attachment 1: Alternative 5 & 6 Feasibility Study Quantities

SEMI-COMPACTED FILL			
STA	UNEXAGGERATED	LENGTH	C.Y
3+70		0	0
5+00	196.22	130	472.37
10+00	387.09	500	5400.93
15+00	580.46	500	8958.75
20+00	1271.33	500	17146.16
24+93	688.50	493	17892.48
		TOTAL	***49870.68***

WOVEN GEOTEXTILE FABRIC			
STA	LENGTH	INTERVAL	S.Y.
3+70	0	0	0
5+00	76.59	130	553.15
10+00	78.27	500	4301.67
15+00	85.10	500	4538.06
20+00	92.16	500	4923.89
24+93	74.95	493	4576.96
		TOTAL	***18893.72***

EXCAVATION AREA			
STA	UNEXAGGERATED	LENGTH	C.Y
3+70	0.00	0	0
5+00	187.47	130	451.32
10+00	33.63	500	2047.22
15+00	77.58	500	1029.72
20+00	77.80	500	1438.70
24+93	91.02	493	1541.26
		TOTAL	***6508.23***

TURFING			
STA	LENGTH	INTERVAL	S.Y.
3+70	0	0	0
5+00	45.82	130	330.92
10+00	68.85	500	3185.28
15+00	45.83	500	3185.56
20+00	48.17	500	2611.11
24+93	29.76	493	2134.42
		TOTAL	***11447.28***

RIP RAP			
STA	UNEXAGGERATED	LENGTH	TON
3+70	0.00	0	0
5+00	255.00	130	982.22
10+00	255.00	500	7555.56
15+00	255.00	500	7555.56
20+00	255.00	500	7555.56
24+93	255.00	493	7449.78
		TOTAL	***31098.67***

TURFING TIE-BACKS			
STA	AREA		S.Y.
3+70	0.00	0	0
3+78	57.34	10	63.71
6+13	57.34	10	63.71
8+48	57.34	10	63.71
10+83	57.34	10	63.71
13+18	57.34	10	63.71
15+53	47.00	10	52.22
17+88	47.00	10	52.22
20+23	38.97	10	43.30
22+58	38.97	10	43.30
24+93	38.97	10	43.30
			552.90

RIP RAP TIE-BACKS			
STA	UNEXAGGERATED	THICKNESS	TON
3+70	0.00		0
3+78	1781.60	2	211.15
6+13	1373.70	2	162.81
8+48	1373.70	2	162.81
10+83	1373.70	2	162.81
13+18	1373.70	2	162.81
15+53	1373.70	2	162.81
17+88	1373.70	2	162.81
20+23	1373.70	2	162.81
22+58	1373.70	2	162.81
24+93	1781.60	2	211.15
		TOTAL	***1724.78***

CLEARING & GRUBBING			
STA	LENGTH	INTERVAL	S.Y.
3+70	0	0	0
5+00	36.41	130	0.05
10+00	29.07	500	0.38
15+00	47.48	500	0.44
20+00	13.67	500	0.35
24+93	28.12	493	0.24
		TOTAL	***1.46***

BEDDING STONE			
STA	**UNEXAGGERATED**	**LENGTH**	**TON**
3+70	0	0	0
5+00	33.5	130	129.04
10+00	33.5	500	992.59
15+00	33.5	500	992.59
20+00	33.5	500	992.59
24+93	33.5	493	978.70
		TOTAL	***4085.51***

BEDDING STONE TIE-BACKS			
STA	**UNEXAGGERATED**	**THICKNESS**	**TON**
3+70	0.00		0
3+78	685.65	1	40.63
6+13	481.70	1	34.59
8+48	481.70	1	28.55
10+83	481.70	1	28.55
13+18	481.70	1	28.55
15+53	481.70	1	28.55
17+88	481.70	1	28.55
20+23	481.70	1	28.55
22+58	481.70	1	28.55
24+93	685.65	1	34.59
		TOTAL	***309.62***

SEMI-COMPACTED FILL			
STA	UNEXAGGERATED	LENGTH	C.Y
3+70	0.00	0	0
5+00	260.24	130	626.50
10+00	582.47	500	7802.87
15+00	326.53	500	8416.67
20+00	1392.79	500	15919.63
24+93	887.13	493	20814.83
		TOTAL	***53580.50***

WOVEN GEOTEXTILE FABRIC			
STA	LENGTH	INTERVAL	S.Y.
3+70	0	0	
5+00	76.59	130	553.15
10+00	78.27	500	4301.67
15+00	85.10	500	4538.06
20+00	92.16	500	4923.89
24+93	74.95	493	4576.96
		TOTAL	***18893.72***

EXCAVATION AREA			
STA	UNEXAGGERATED	LENGTH	C.Y
3+70	0.00	0	0
5+00	201.98	130	486.25
10+00	15.79	500	2016.39
15+00	140.33	500	1445.56
20+00	11.62	500	1406.94
24+93	49.03	493	553.71
		TOTAL	***5908.85***

TURFING			
STA	LENGTH	INTERVAL	S.Y.
3+70	0	0	
5+00	32.94	130	237.90
10+00	26.68	500	1656.11
15+00	24.46	500	1420.56
20+00	27.53	500	1444.17
24+93	14.91	493	1162.38
		TOTAL	***5921.12***

RIP RAP			
STA	UNEXAGGERATED	LENGTH	TON
3+70	0.00	0	0
5+00	288.53	130	1111.37
10+00	288.76	500	8552.44
15+00	293.35	500	8623.85
20+00	297.82	500	8758.07
24+93	295.84	493	8671.83
		TOTAL	***35717.58***

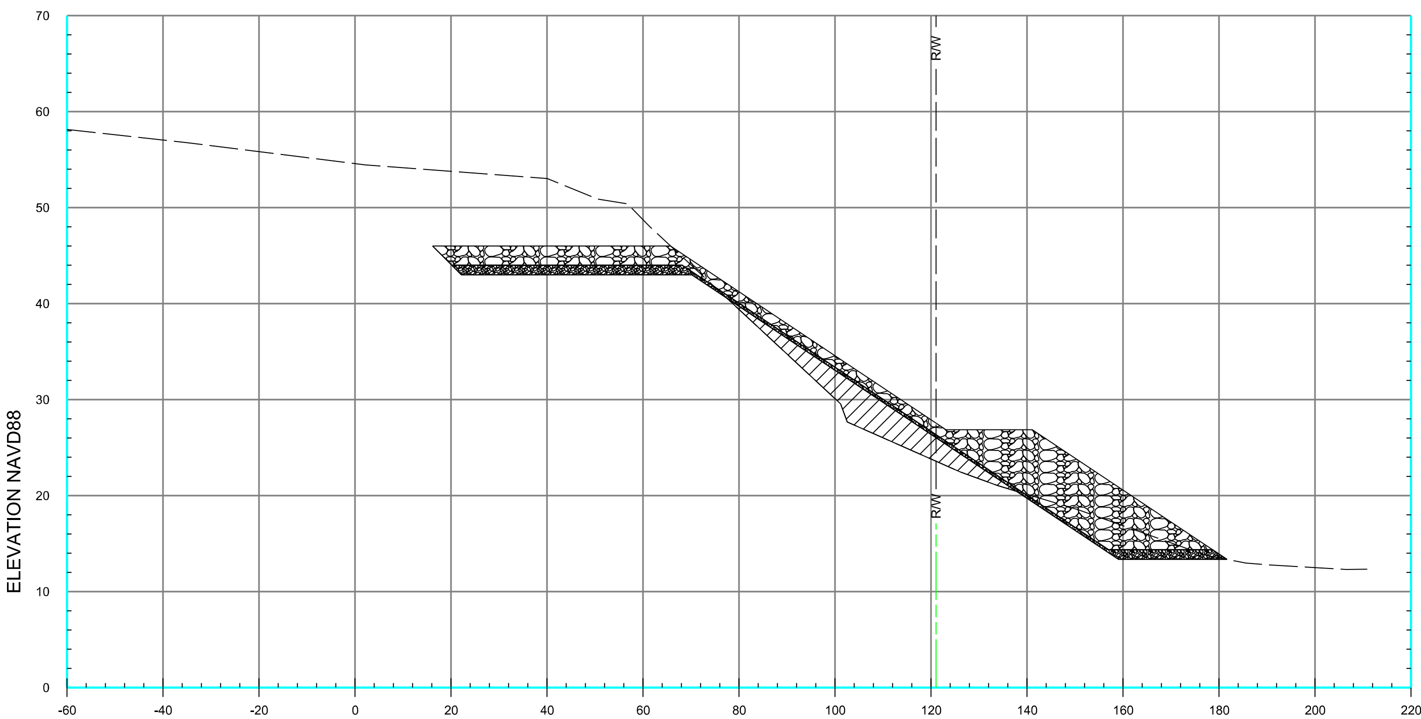
CLEARING & GRUBBING			
STA	LENGTH	INTERVAL	S.Y.
3+70	0	0	
5+00	32.94	130	0.05
10+00	26.68	500	0.34
15+00	24.46	500	0.29
20+00	27.53	500	0.30
24+93	14.91	493	0.24
		TOTAL	***1.22***

BEDDING STONE			
STA	UNEXAGGERATED	LENGTH	TON
3+70	0.00	0	0
5+00	52.68	130	202.92
10+00	52.69	500	1561.04
15+00	55.22	500	1598.67
20+00	57.40	500	1668.44
24+93	56.37	493	1661.88
		TOTAL	***6692.95***

ATTACHMENT 2

Alternative 5 Feasibility Engineering Drawings & Cross Section

Attachment 2: Alternative 5 Feasibility Cross Section



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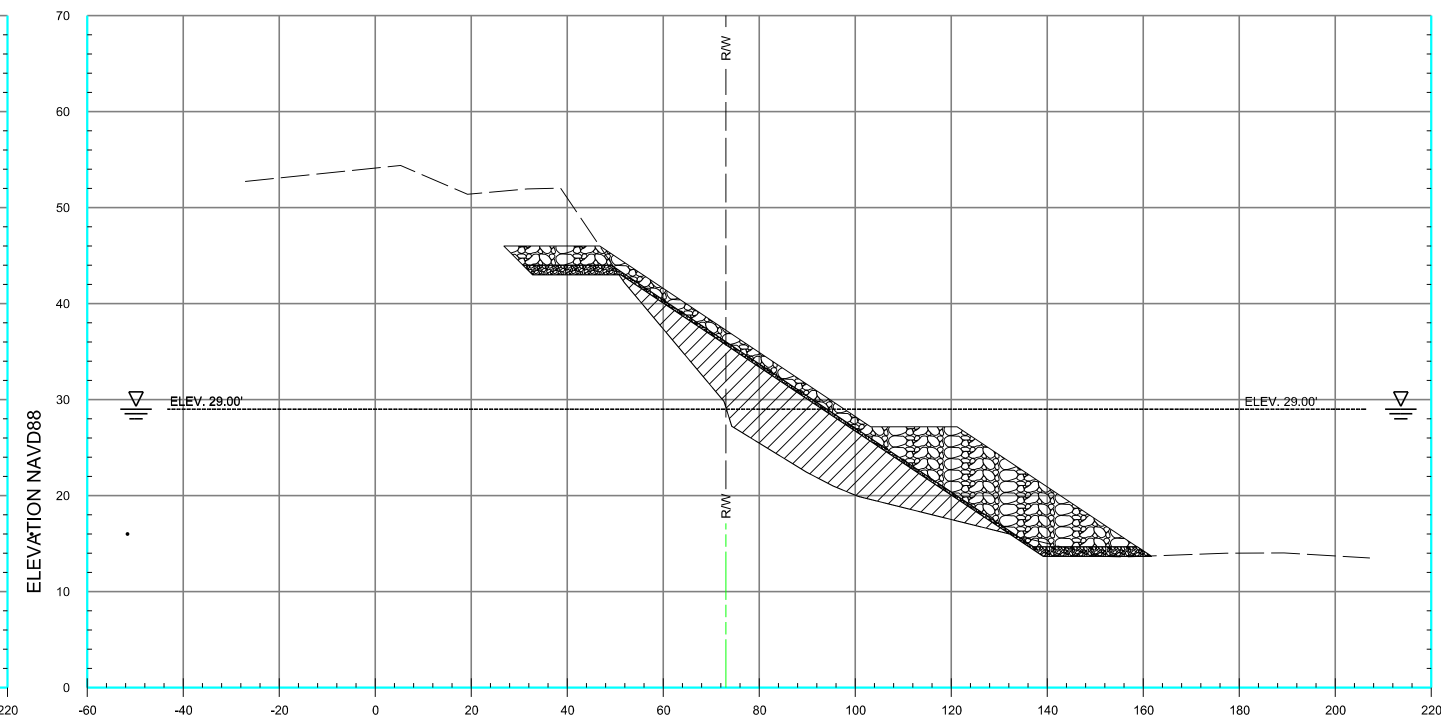

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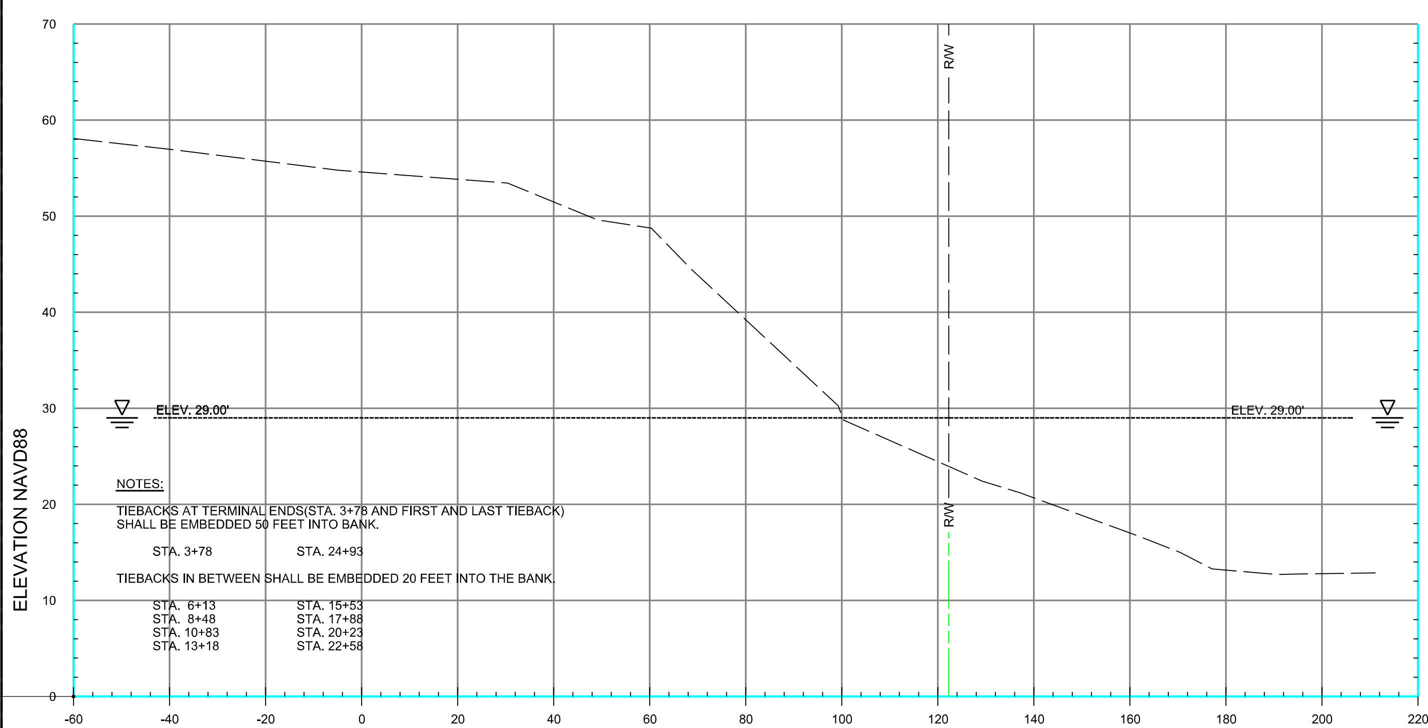

NOTES:

TIEBACKS AT TERMINAL ENDS(STA. 3+78 AND FIRST AND LAST TIEBACK) SHALL BE EMBEDDED 50 FEET INTO BANK.

STA. 3+78 STA. 24+93

TIEBACKS IN BETWEEN SHALL BE EMBEDDED 20 FEET INTO THE BANK.

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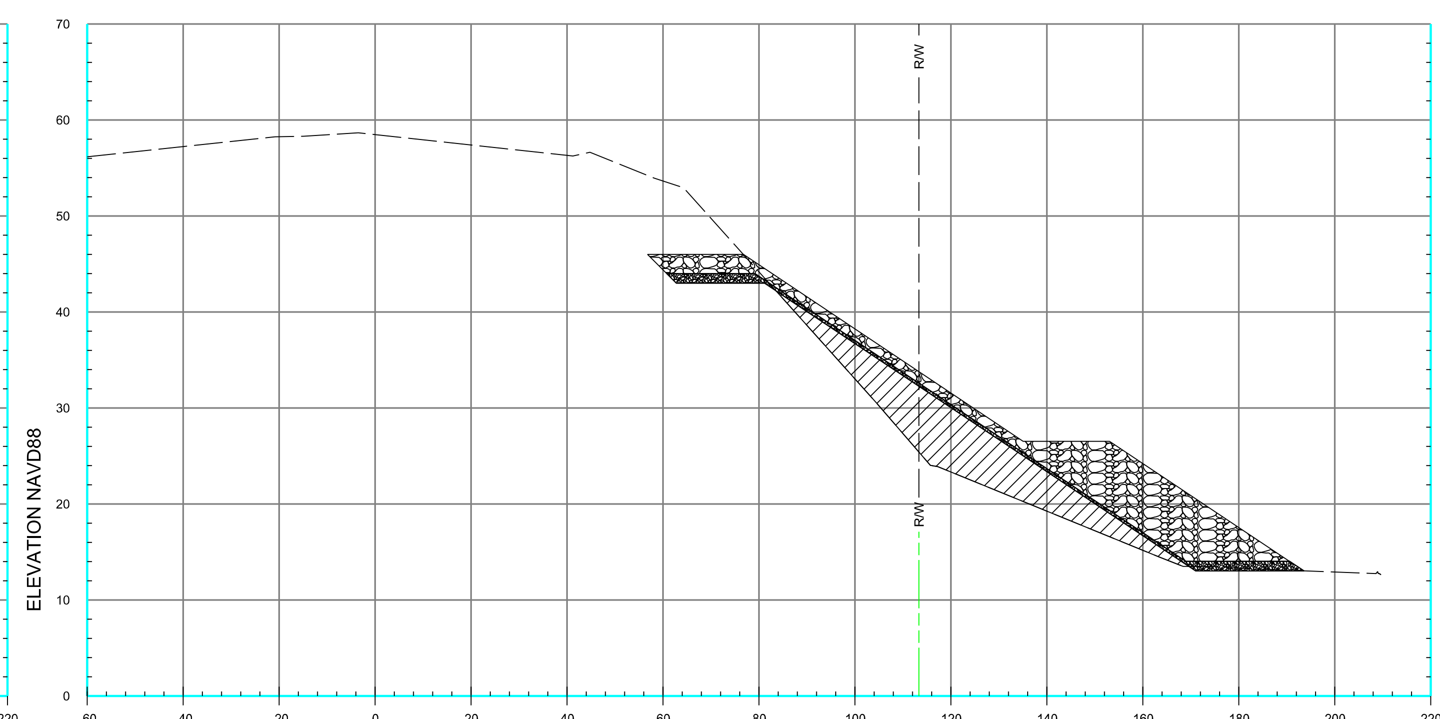
STA. 8+48	STA. 17+88
STA. 10+83	STA. 20+23
STA. 13+18	STA. 22+58

3+70



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U.S. Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

U.S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
TIMOTHY R. VAIL,
COLONEL, EN, U.S. ARMY, COMMANDING

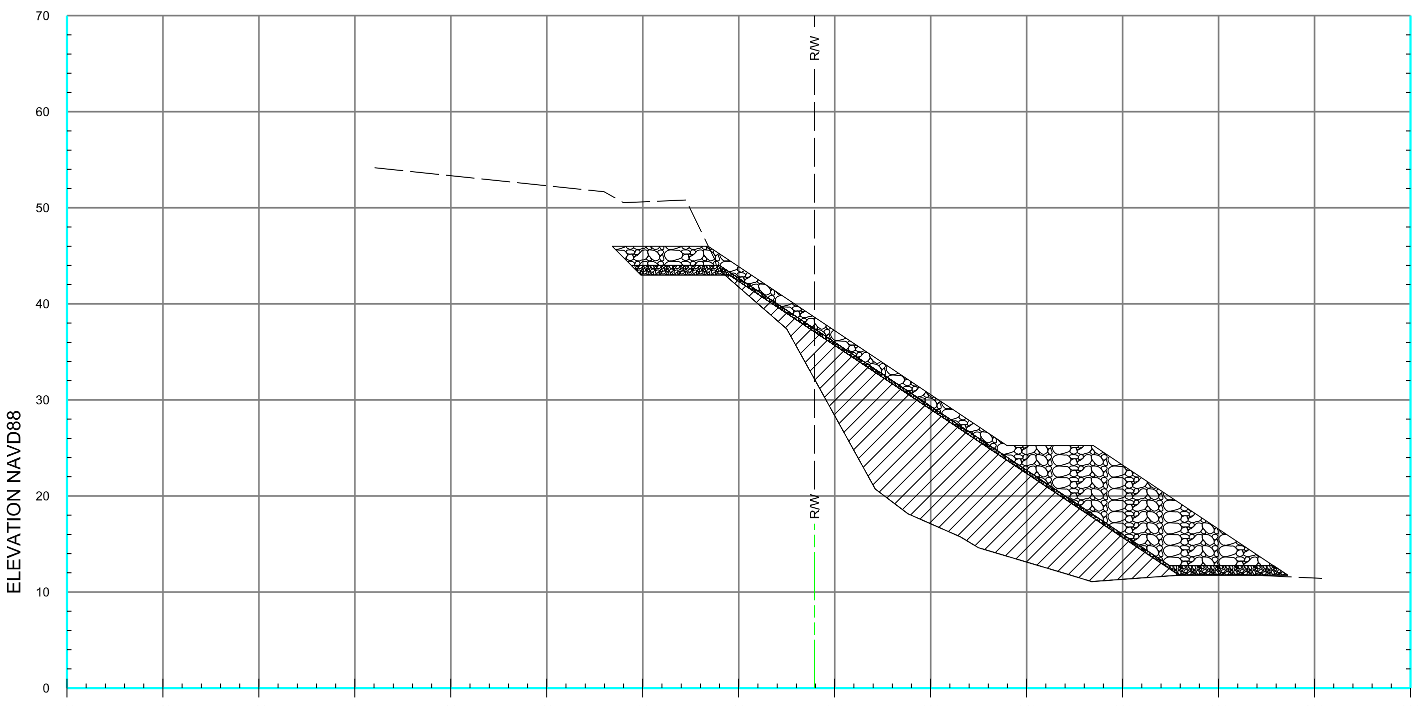
Drawn by: QKJ
Designed by: QKJ
Checked by: RLM
Submitted by: CESAR RAMOS, P.E.
Date: NOV. 2021
Rev.
Scale: AS SHOWN
Approval Recommended: WILLIE JOE HONZA, P.E., Chief, Engineering Branch
Approved by: ROBERT C. THOMAS, P.E., Chief, Engineering and Construction Division

MARY RHODES PUMP STATION CAP 14
EMERGENCY STREAMBANK PROTECTION
BAY CITY, MATAGORDA COUNTY, TEXAS

ALTERNATIVE 5
CROSS SECTIONS
STA. 3+70 TO STA. 8+48

Drawing No.:
ALT 5.0

SWG FILE NO. HSC 401-581



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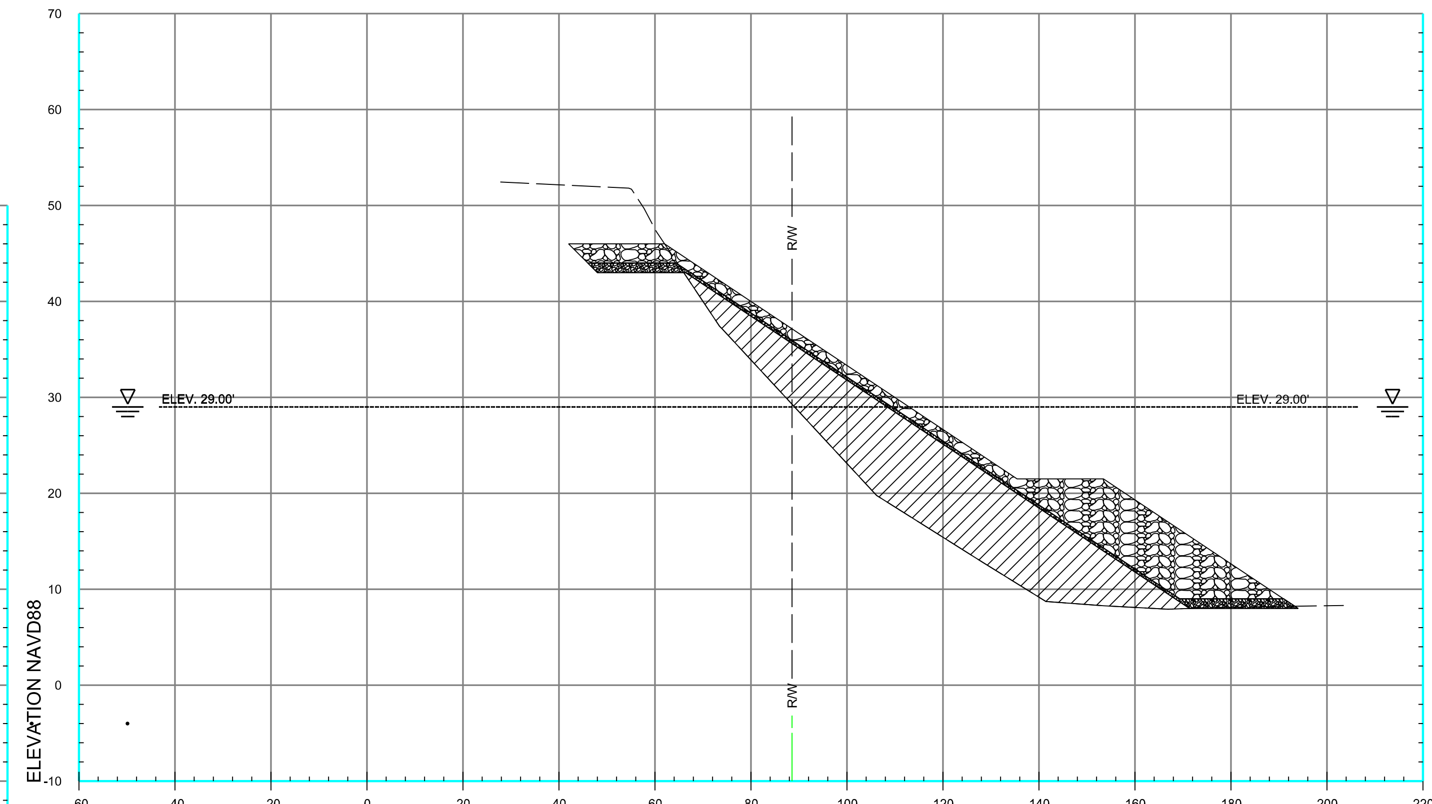

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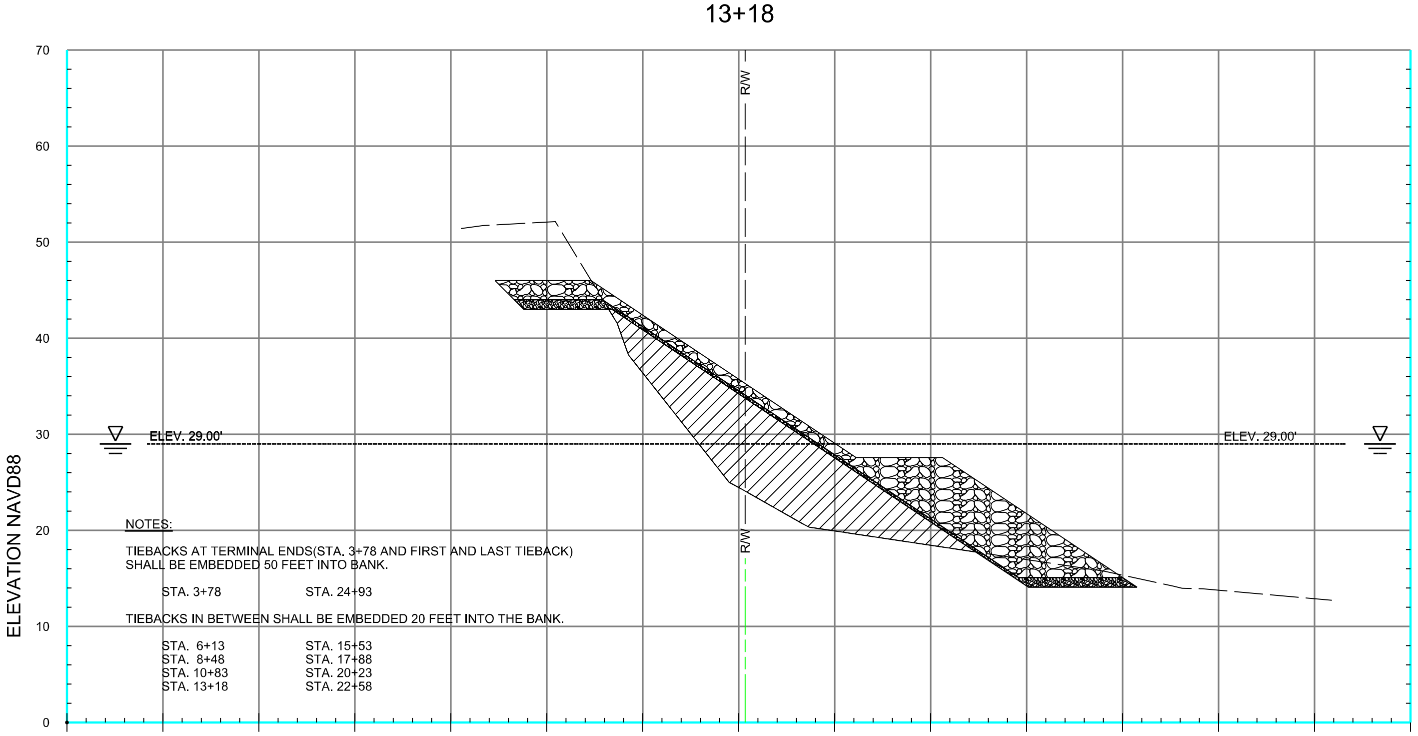

NOTES:

TIEBACKS AT TERMINAL ENDS(STA. 3+78 AND FIRST AND LAST TIEBACK) SHALL BE EMBEDDED 50 FEET INTO BANK.

STA. 3+78 STA. 24+93

TIEBACKS IN BETWEEN SHALL BE EMBEDDED 20 FEET INTO THE BANK.

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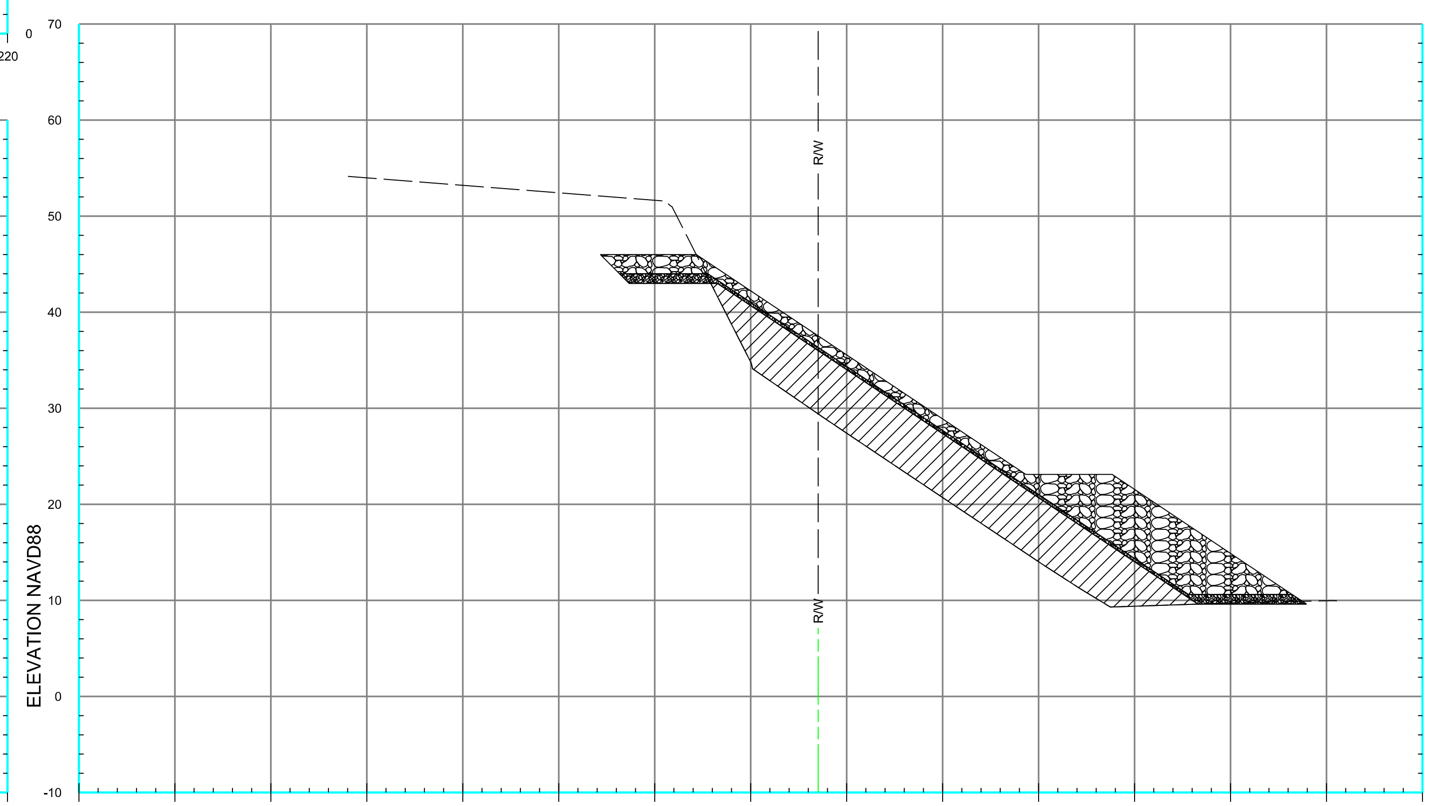
STA. 8+48 STA. 17+88
STA. 10+83 STA. 20+23
STA. 13+18 STA. 22+58

10+83



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SOLICITATION NO.: W912HY20B0032

U.S. Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

Drawn by: QKJ	Date:	Rev.
Designed by: QKJ	NOV. 2021	
Checked by: RLM	Scale: AS SHOWN	
Submitted by: CESAR RAMOS, P.E.	Approval Recommended: WILLIE JOE HONZA, P.E. Chief, Engineering Branch	
Approved by: ROBERT C. THOMAS, P.E. Chief, Engineering and Construction Division		

U.S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

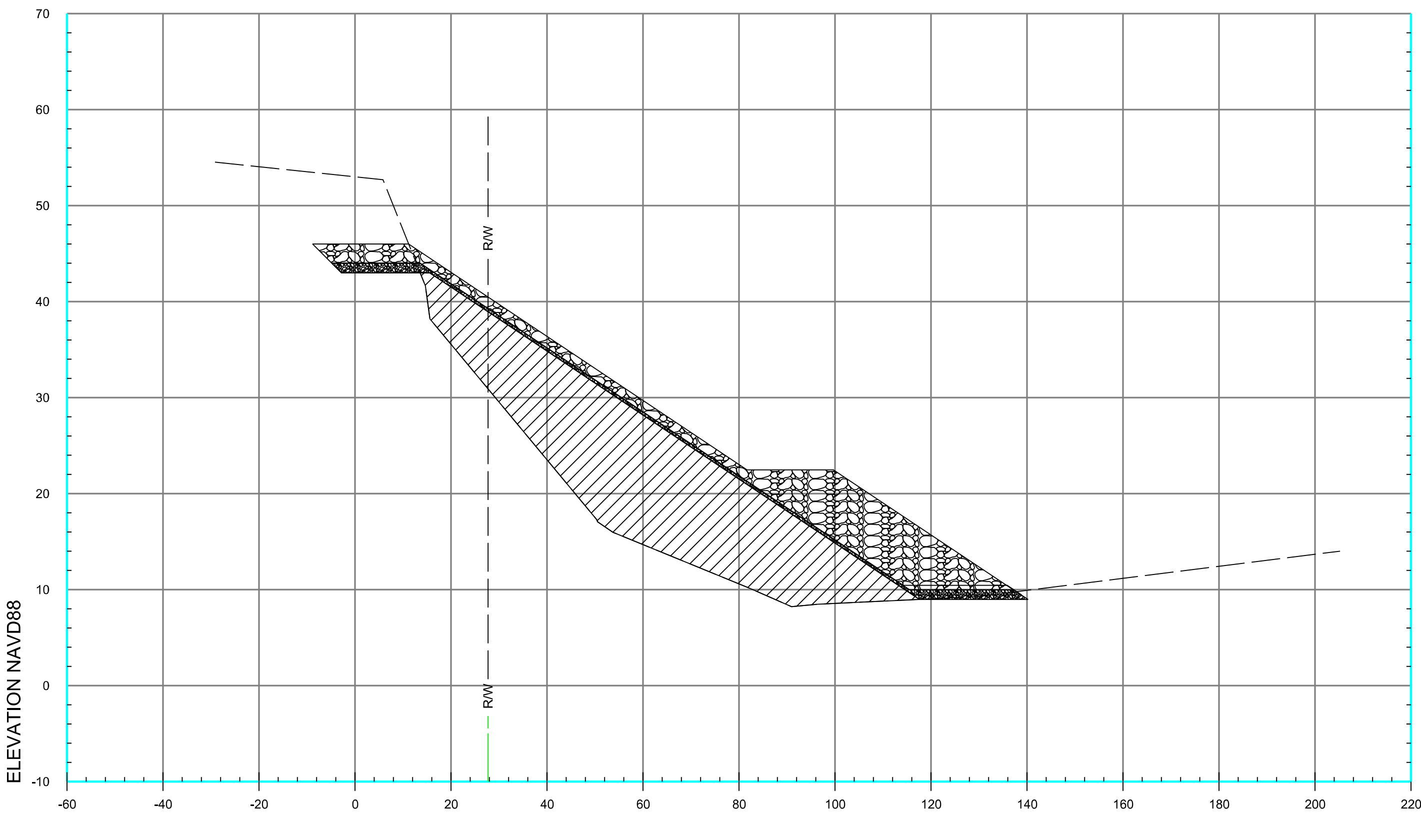
PREPARED UNDER THE DIRECTION OF
TIMOTHY R. VAIL,
COLONEL, EN, U.S. ARMY, COMMANDING

MARY RHODES PUMP STATION CAP 14
EMERGENCY STREAMBANK PROTECTION
BAY CITY, MATAGORDA COUNTY, TEXAS

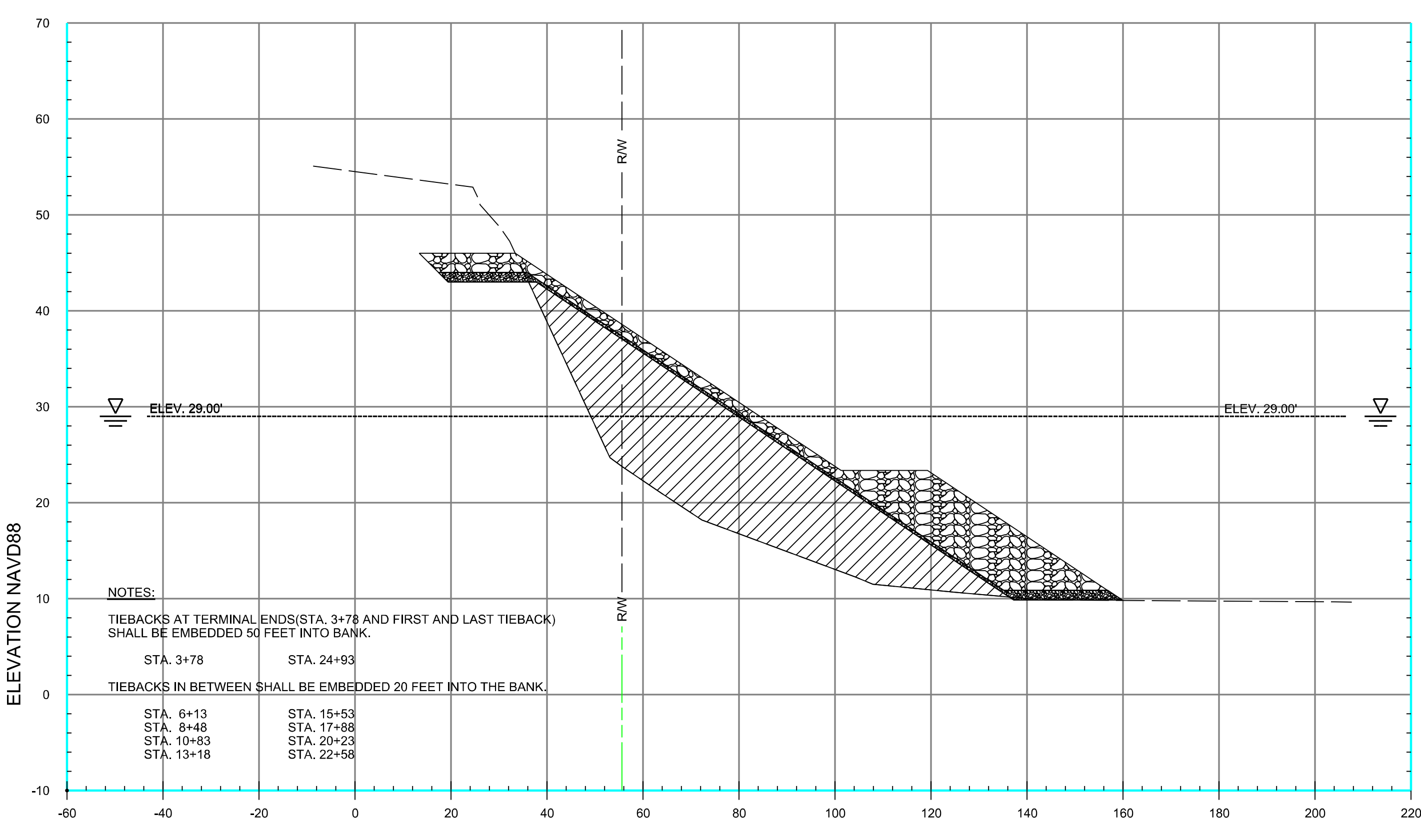
ALTERNATIVE 5
CROSS SECTIONS
STA. 10+83 TO STA. 17+88

Drawing No.:
ALT 5.1

SWG FILE NO. HSC 401-581



22+58



NOTES:

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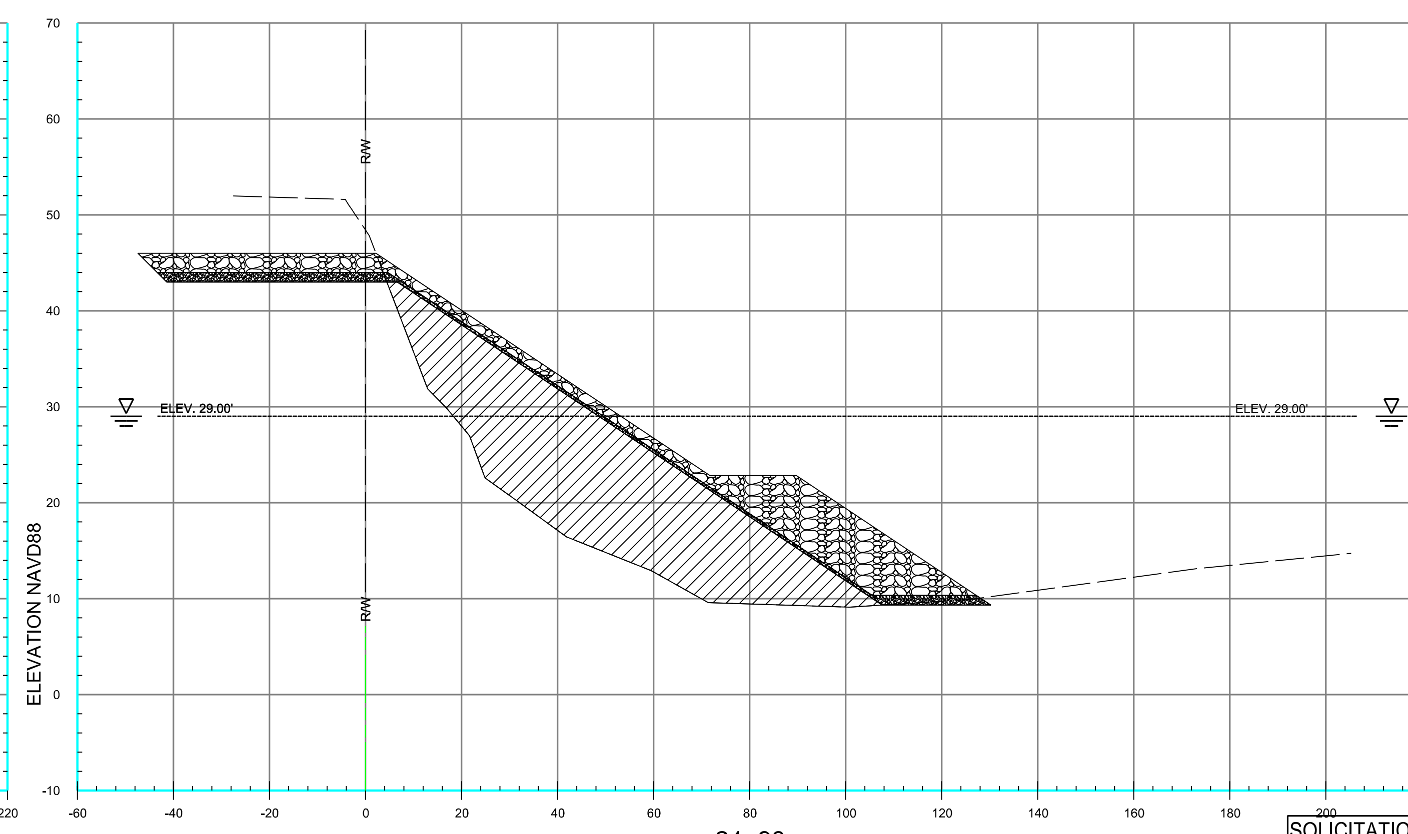
STA. 3+78 STA. 24+93

TIEBACKS IN BETWEEN SHALL BE EMBEDDED 20 FEET INTO THE BANK.

STA. 6+13 STA. 15+53
STA. 8+48 STA. 17+88
STA. 10+83 STA. 20+23
STA. 13+18 STA. 22+58

20+23



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SOLICITATION NO.: W912HY20B0032

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U.S. Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

Drawn by: QKJ
Designed by: QKJ
Checked by: RLM
Submitted by: CESAR RAMOS, P.E.
Approved by: ROBERT C. THOMAS, P.E.
Chief, Engineering and Construction Division

Date: NOV. 2021
Rev.
Scale: AS SHOWN
Approval Recommended: WILLIE JOE HONZA, P.E.
Chief, Engineering Branch

U.S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
TIMOTHY R. VAIL,
COLONEL, EN, U.S. ARMY, COMMANDING

MARY RHODES PUMP STATION CAP 14
EMERGENCY STREAMBANK PROTECTION
BAY CITY, MATAGORDA COUNTY, TEXAS

ALTERNATIVE 5
CROSS SECTIONS
STA. 20+23 TO STA. 24+93

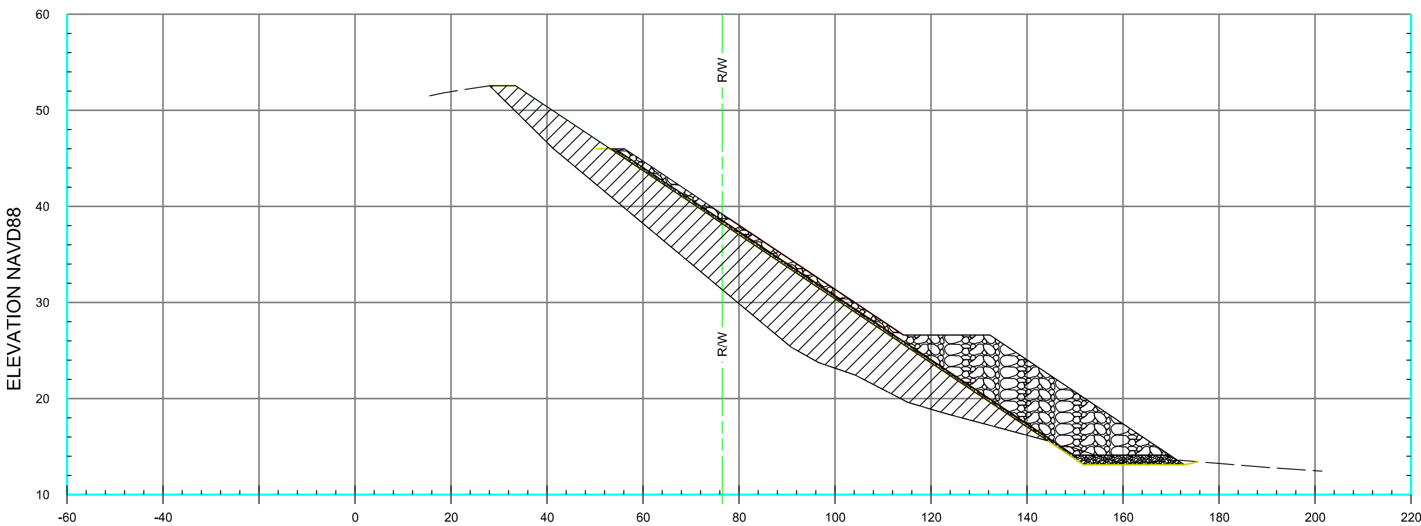
Drawing No.:
ALT 5.2

SWG FILE NO. HSC 401-581

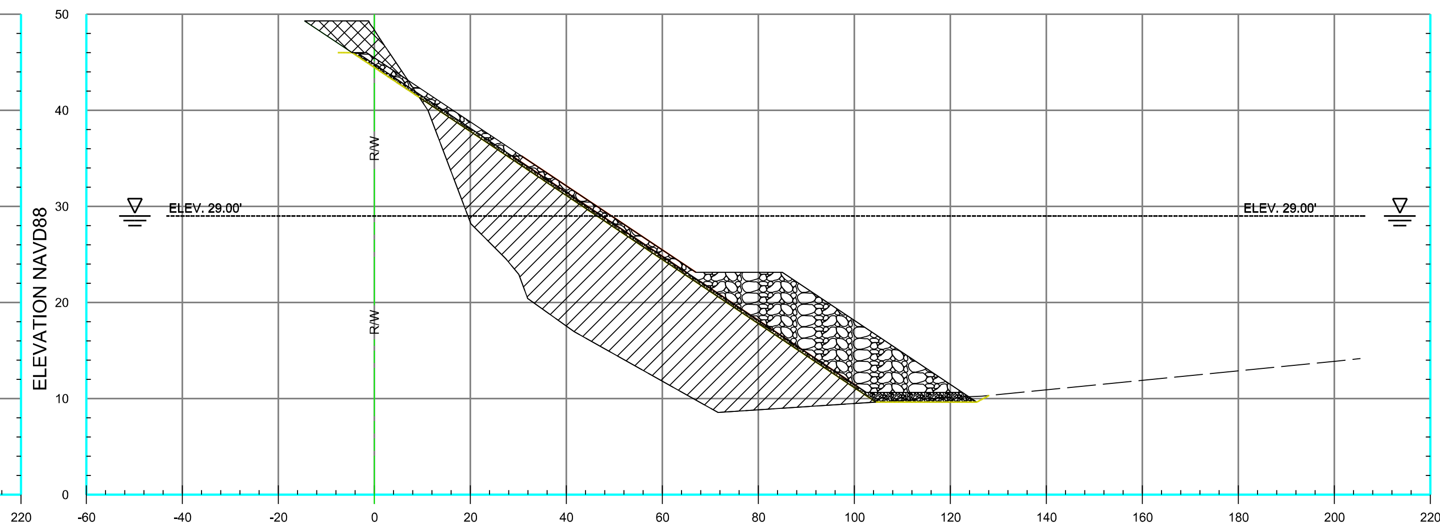
ATTACHMENT 3

Alternative 6 Feasibility Engineering Drawings & Cross Section

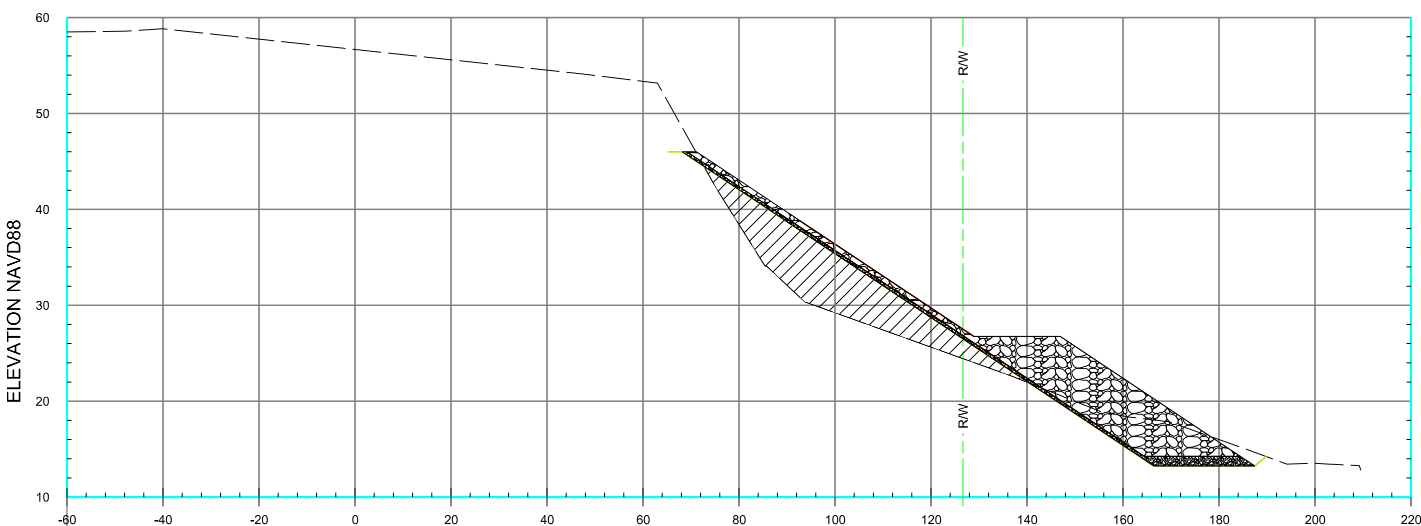
Attachment 3: Alternative 6 Feasibility Cross Section



STA. 10+00

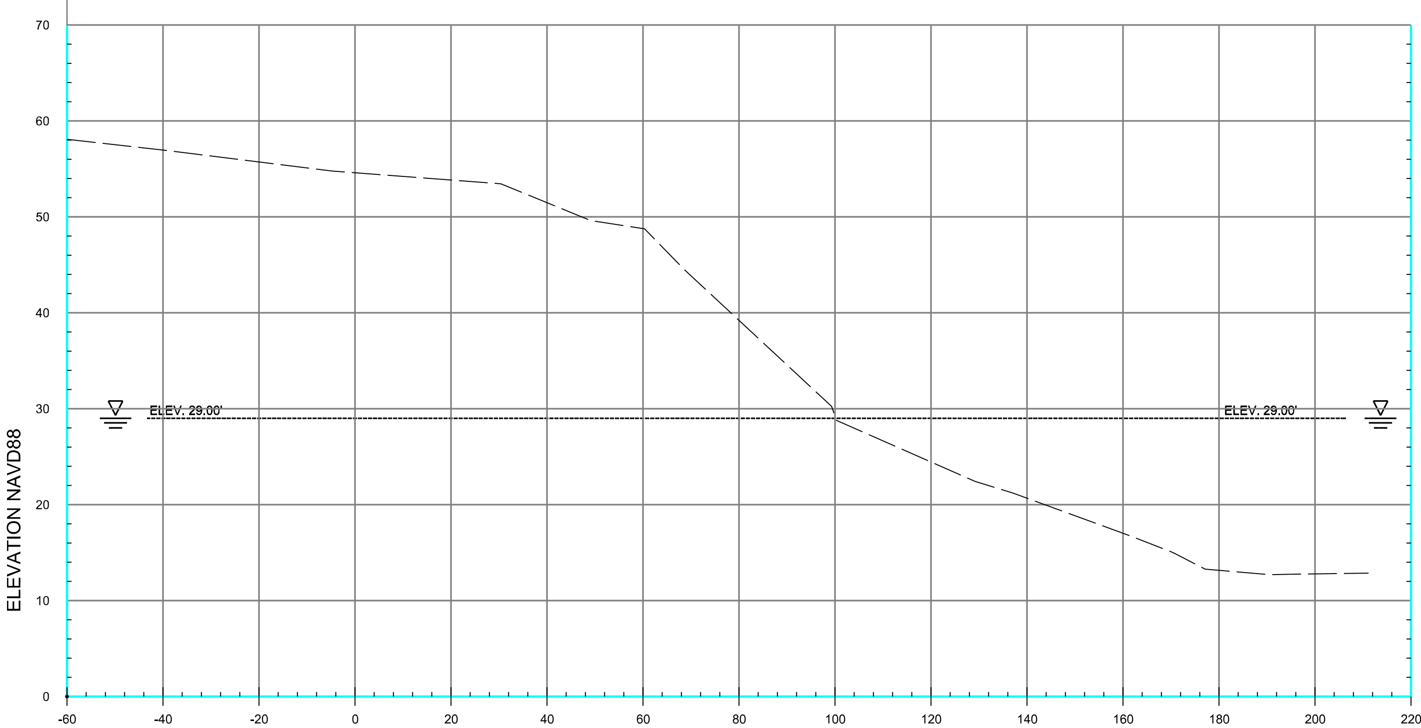


24+93

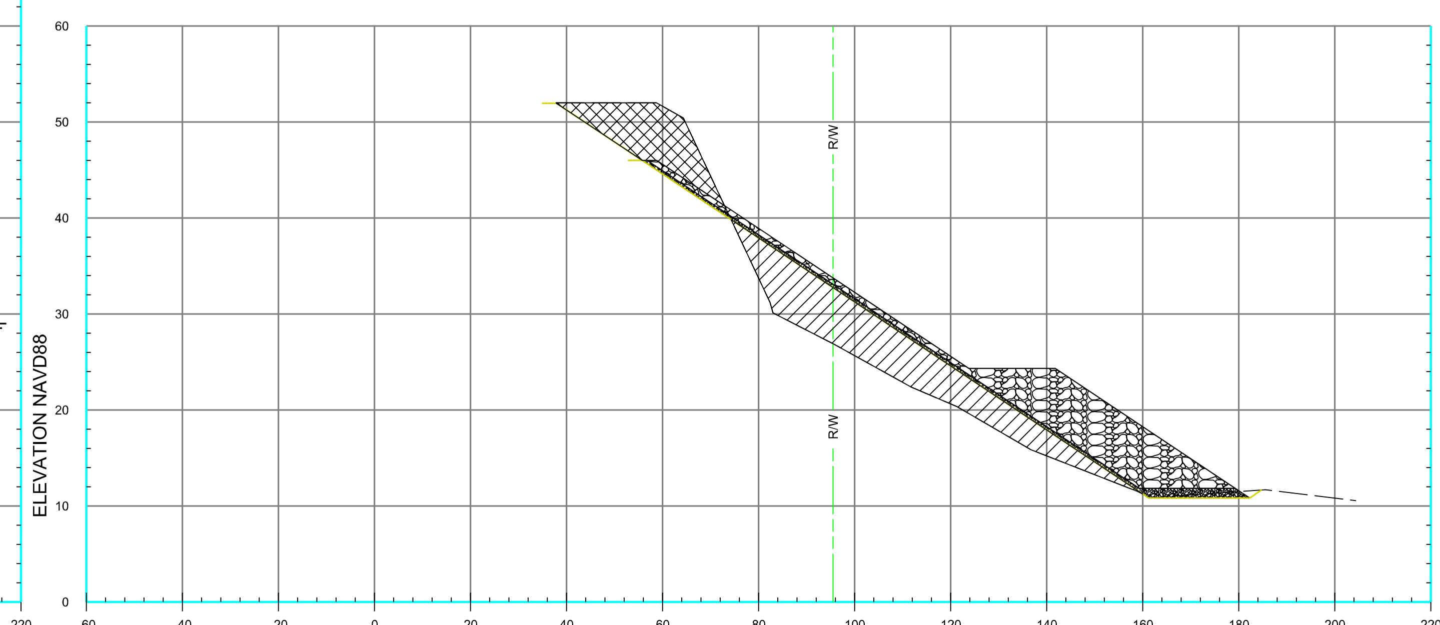


STA. 5+00

STA. 20+00



3+70



STA. 15+00

SOLICITATION NO.:
W912HY20B0032

U.S. Army Corps of Engineers
Galveston District

Rev.	Description	Date	By

Drawn by: QKJ	Date: NOV. 2021	Rev.
Designed by: QKJ		
Checked by: RLM	Scale: AS SHOWN	
Submitted by: CESAR RAMOS, P.E.	Approval Recommended: WILLIE JOE HONZA, P.E. Chief, Engineering Branch	
Approved by: ROBERT C. THOMAS, P.E. Chief, Engineering and Construction Division		

U.S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

PREPARED UNDER THE DIRECTION OF
TIMOTHY R. VAIL,
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MARY RHODES PUMP STATION CAP 14
EMERGENCY STREAMBANK PROTECTION
BAY CITY, MATAGORDA COUNTY, TEXAS

ALTERNATIVE 6
CROSS SECTIONS
STA. 3+70 TO STA. 24+93

Drawing No.:
ALT 6.0

SWG FILE NO. HSC 401-581

File: C:\PLT\Mary Rhodes\Mary Rhodes_CONTRACT-PLANS_TxSc83_qkj.dgn
Model Name: C-304 Date: 11/8/2021 Time: 10:19:53 PM
By: m3eceqkj

ATTACHMENT 4

Cost Engineering Attachments

Abbreviated Risk Analysis

Project (less than $40M): **MRPS (CAP SECTION 14)** — **Alternative: ALT 5**
Project Development Stage/Alternative: **Feasibility (Alternatives)**
Risk Category: **Low Risk: Typical Construction, Simple** — **Meeting Date: 3/15/2022**

Total Estimated Construction Contract Cost = $ 6,808,994

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ 48,400		30.00%	$ 14,520	$ 62,920
2	16 BANK STABILIZATION	ALT 5: Stream Bank Erosion Protection	$ 6,673,994		42.83%	$ 2,858,494	$ 9,532,487
12	All Other	Remaining Construction Items	$ 135,000	2.0%	0.00%	$ -	$ 135,000
13	30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	$ 668,000		0.00%	$ -	$ 668,000
14	31 CONSTRUCTION MANAGEMENT	Construction Management	$ 401,000		0.00%	$ -	$ 401,000
XX	FIXED DOLLAR RISK ADD (EQUALLY DISPERSED TO ALL, MUST INCLUDE JUSTIFICATION SEE BELOW)					$ -	

Totals

	Contract Cost	% Contingency	$ Contingency	Total
Real Estate	$ 48,400	30.00%	$ 14,520	$ 62,920.00
Total Construction Estimate	$ 6,808,994	41.98%	$ 2,858,494	$ 9,667,487
Total Planning, Engineering & Design	$ 668,000	0.00%	$ -	$ 668,000
Total Construction Management	$ 401,000	0.00%	$ -	$ 401,000
Total Excluding Real Estate	**$ 7,877,994**	**36.28%**	**$ 2,858,494**	**$ 10,736,487**

	Base	50%	80%
Confidence Level Range Estimate ($000's)	$7,878k	$9,593k	$10,736k

* 50% based on base is at 5% CL.

Fixed Dollar Risk Add: (Allows for additional risk to be added to the risk analsyis. Must include justification. Does not allocate to Real Estate.

MRPS (CAP SECTION 14) ALT 5 15-Mar-22

Feasibility (Alternatives)

Abbreviated Risk Analysis

Meeting Date: 15-Mar-22

Risk Level

	Negligible	Marginal	Moderate	Significant	Critical
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Impact	Likelihood	Risk Level
Project Management & Scope Growth						Maximum Project Growth	40%
PS-2	ALT 5: Stream Bank Erosion Protection	• Investigations sufficient to support design assumptions?	1. More riprap may be needed than currently planned. 2. Potential for additional cultural resources survey, coordination and compliance during PED. 3. No available borrow site nearby (within 3 miles radius). Hauling distance estimated using 6 miles per cycle. Increasing distances every miles, the costs of hauling will be increased. 4. Schedule and costs concerns.	Background: Team is assuming if borrow materials are needed, it may within reasonable distance of the project area. Use of borrow materials for fill supports the "No potential to affect" determination for the study. No additional compliance efforts required. Impact: There are no known Environmental, Archaeology, nor HTRW concerns related to the project site. If no nearby borrow sites are available, cultural resources (section 106), HTRW, (and Environmental?) compliance of the source may required a study that would translate into additional time and found to complete. Likelihood: It is possible additonal scour or erosion may occur at limits of riprap placement, requiring riprap to be placed more than currently planned (increases project footprint). Overall, it is possible no nearby borrow sites will be available.	Moderate	Possible	2
Acquisition Strategy						Maximum Project Growth	30%
AS-2	ALT 5: Stream Bank Erosion Protection	• Contracting plan firmly established?	Contracting plan is not firmly established. Limited bid competition is anticipated.	Background: The type of contract is unknown. PDT assumes unrestricted best value. Impact: If contract is small business, then the cost increase will be marginal. This agrees with historical bid results. Likelihood: It is likely the acquisition method could become restricted (small business).	Marginal	Likely	2
Construction Elements						Maximum Project Growth	15%
CE-2	ALT 5: Stream Bank Erosion Protection	• Potential for severe adverse weather?	The effects of high water due to catastrophic or near-catastrophic storms was not considered	Background: No care of water and/or diversion plan considered. Stormwater Pollution Prevention problems could be encountered prior to bank stabilization with riprap. Impact: There could be a SIGNIFICANT impact due to high flows resulting in a catastrophic/near catastrophic storm event? There is a minimal impact due to care of water during high flows. Likelihood: It is possible to run into high waters during high flows events.	Significant	Possible	3

T-2	ALT 5: Stream Bank Erosion Protection	• Level of confidence based on design and assumptions?	Insufficient investigations to develop quantities, e.g. topography, bathymetry, survey, subsurface soil investigations etc.	Background: Incomplete topography, bathymetry, or soil surveys, which could impact quantities. Quantities are neatline. Impact: Additional riprap may be required for assumed dimensions and/or subsiding soils. Overall, the impact is marginal. Likelihood: The likelihood is possible.	Moderate	Possible	2
Cost Estimate Assumptions					Maximum Project Growth		25%
EST-2	ALT 5: Stream Bank Erosion Protection	• Reliability and number of key quotes?	No concern with riprap.	Background: Fuel rate at **$4.00/Gallon** due to Ukraine and Russia War at the moment. Riprap around $127/TON historically, however a similar erosion project (City of Columbus) bid midium riprap price (riprap $96/ton, bedding $107/ton in mid 2021). During re-evaluation of TSP, Riprap stone costs are estimated based on a local stone supplier's quote in early 2022. Blanket stone is not proposed by the engineering design team. Impact: If the fuel rate is doubled ($4.00/Gallon), then there will be a negligible to marginal impact. $4.00/Gallon is not an unreasonable fuel rate based on current fuel rates due to oil price spike. No increase for riprap stone as the material cost is conservative. Likelihood: Due to the volatile nature of fuel, it is likely the fuel rate will increase.	Significant	Likely	4
External Project Risks					Maximum Project Growth		20%
EX-2	ALT 5: Stream Bank Erosion Protection	• Accelerated schedule or harsh weather schedule?	Potential for severe, adverse weather.	Background: Severe weather could impact job site. Impact: Elevated riverflow based on abnormal weather conditions could have a moderate impact on work. Equipment may need to be moved during a flood. This could delay the project and have a moderate impact on costs, e.g. mobilization and demobilization of (primarily) general items and personnel to higher ground and/or away from job site. Funding delays could cause a marginal impact. (Do not foresee political issues.) Likelihood: Overall, it is possible for abnormal weather conditions and funding delays.	Significant	Possible	3
EX-3	ALT 5: Stream Bank Erosion Protection	• Potential for scope growth, added features and quantities?	Concern with cost share.	Possible project delayed due to 1. the communication coordination; 2. each organization's business procedures; 3. availability of funds from USACE and the local sponsor. 4. construction sechedule changes due to construction material availablity situations.	Significant	Possible	3

P2-479839 - CAP-14 Project for Mary Rhodes Pump Station Alternative Cost Estimates

October 2021 Price Level

Civil Works Breakdown Structures		Alternative 5 Rebuild bank + Bank sloping + Toe riprap		
WBS Number	Civil works Description	O&M (Total 50YR)	Construction Costs ($)	Construction Costs contingency 36.28% exclude real estates
01[1]	Lands and Damages	$ 48,400.00	$ 48,400.00	$ 62,900.00
02[3]	Relocation			
06[5]	Fish and Wild Life Facilities		$ 60,000.00	$ 81,800.00
16[2&7]	Bank Stabilization	$ 4,010,500.00	$ 6,673,993.64	$ 9,095,500.00
18[6]	Cultural Resource Preservation		$ 75,000.00	$ 102,200.00
30	Planning, Engineering, Desgin and RE	$ 401,100.00	$ 667,400.00	$ 909,600.00
31	Constrcuction Management	$ 240,600.00	$ 400,400.00	$ 545,700.00
	Total Project Estimated	$ 4,700,600.00	$ 7,925,200.00	$ 10,797,700.00

Notes:

1	WBS Code 01 and contingency of 30% is provided by real estate. (Federal Real estate cost $29,000.00 is added to Code 30 in Alt. 5 per DQC comments. *DQC comment)
2	1. Contingency of Alternative #5 is updated to 36.28% after DQC review. 2. Initial contingency was updated after PDT input on Marth 15 2022. 3.Contingency of Alternative #6 is 25% based on initial ARA because there is no design and quantity changes.
3	Relocation assumption is based on escalated construction costs for existing facility provided by sponsor.
4	PED assume 10%; construction management 6% per coordination with PM/PDT.
5	WBS Code 06 Fish and Wildlife Facilities (Environmental Mitigation) was Provided by Environmental.
6	WBS Code 18 was provided by Cultural Resources.
7	Alternative #5 proposal: 1. Requires no works between the tiebacks above the riprap toe, the riverbank will stay at it's existing slope/condition profiles. 2. Assuming ripraps will be delivered at designated staging areas onsite, picked up and hauled to the working locations. 3. With updated fuel rate at $4.92 per gallon in early May 2022. 4. Many of assumptions are made by PDT for planning purposes, however the contractor will be the one to decide how the river bank erosion prevention project to be constructed.

1. Unit prices of City of Columbus were used as reference for the cost comparison for Mary Rhode Pump Station.

2. Mii data base prices are used for the cost estimates, and EM Escalation index are utilized to match the bid prices in Auguset 2021of City of Columbus. the start of escalation index is from 4Q2016 to 4Q2021 as "Escalation" in accordance with EM 1110-2-1304 March 2021. Additional escalation from Aug 2021 to Aug 2022 also applied as "Escalation 2"

3. The purpose of escalation is to estimate the unit price of Mii 2016 to an actual contract of City of Columbus which had bid opening on 5th Aug 2021.

4. The low bidder's price for bedding stone is at $102.07/ton.

5. The low bidder;s price for rip-rap is at 91.30/ton.

6. The lowe bidder's price for Semi-Compaction Fill is $58.81/cy.

7. A couple of the job bid items such as turfing and clearing of Columbus can not be used as reference, becasue the project length along the river is only 65 feet. Mii data base prices are utilized for the job item.

Estimated by Sarah H Xie-DeSoto
Designed by SWG PDT
Prepared by Sarah Xie-DeSoto
Preparation Date 5/5/2022
Effective Date of Pricing 9/30/2021
Estimated Construction Time 365 Days

Description	Quantity	UOM	DirectCost	ContractCost	ProjectCost
Project Cost Summary Report			**5,093,918**	**6,850,545**	**6,871,879**
Alternative 5 updated per DQC comments	**1.00**	**EA**	**5,093,918**	**6,850,545**	**6,871,879**
01 WBS 01- Lands and Damages	**1.00**	**EA**	**48,373**	**48,373**	**62,885**
Non-Federal Costs (O&M)	**1.00**	**EA**	**48,373**	**48,373**	**62,885**
06 WBS 06 - Environmental Mitigation	**1.00**	**EA**	**60,000**	**60,000**	**60,000**
16 WBS 16 - Bank Stabilization	**1.00**	**EA**	**4,910,545**	**6,667,172**	**6,673,994**
0001 Mob, Demob & Prepatory Work	**1.00**	**EA**	**430,429**	**530,426**	**530,426**
0002 Clearing, Grubbing & Removal of Debris	**1.78**	**ACR**	**16,732**	**22,919**	**22,919**
007a Riprap	**49,264.43**	**TON**	**4,008,960**	**5,491,368**	**5,491,368**
0003 Semi-Compacted Fill	**6,731.01**	**CY**	**252,377**	**345,700**	**345,700**
0004 Geotextiles	**37,295.09**	**SY**	**184,461**	**252,670**	**259,492**
0008 Turfing	**3,836.50**	**SY**	**17,587**	**24,090**	**24,090**
WBS 18 - Cultural Resource Preservation	**1.00**	**EA**	**75,000**	**75,000**	**75,000**