CLEAR CREEK FLOOD RISK MANAGEMENT PROJECT

Preconstruction Engineering Design
P2: 472990

HYDROLOGY & HYDRAULIC (H&H) PRODUCTS

REVIEW PLAN

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Approval Date 10 March 2020

1. Purpose

This Review Plan (RP) for the Hydrology and Hydraulic (H&H) products of the Clear Creek Flood Risk Management (FRM) Project will help ensure a quality-engineering project is developed by the Corps of Engineers in accordance with EC 1165-2-217, "Review Policy for Civil Works." As part of the Project Management Plan, this RP establishes an accountable, comprehensive, life-cycle review strategy for Civil Works products and describes the scope of review for the current phase of work. This document highlights key hydrologic and hydraulic analysis products that will be reviewed for ensuring quality control and quality assurance of the Clear Creek FRM project. This includes but not limited to hydrologic & hydraulic models, critical datasets, risk and uncertainty analysis, erosion analysis, induced flooding risk evaluations. This plan also documents risk, schedule, reviewer conflicts, choice of review mechanism, and types of reviews that will be performed for ensuring quality control of the project.

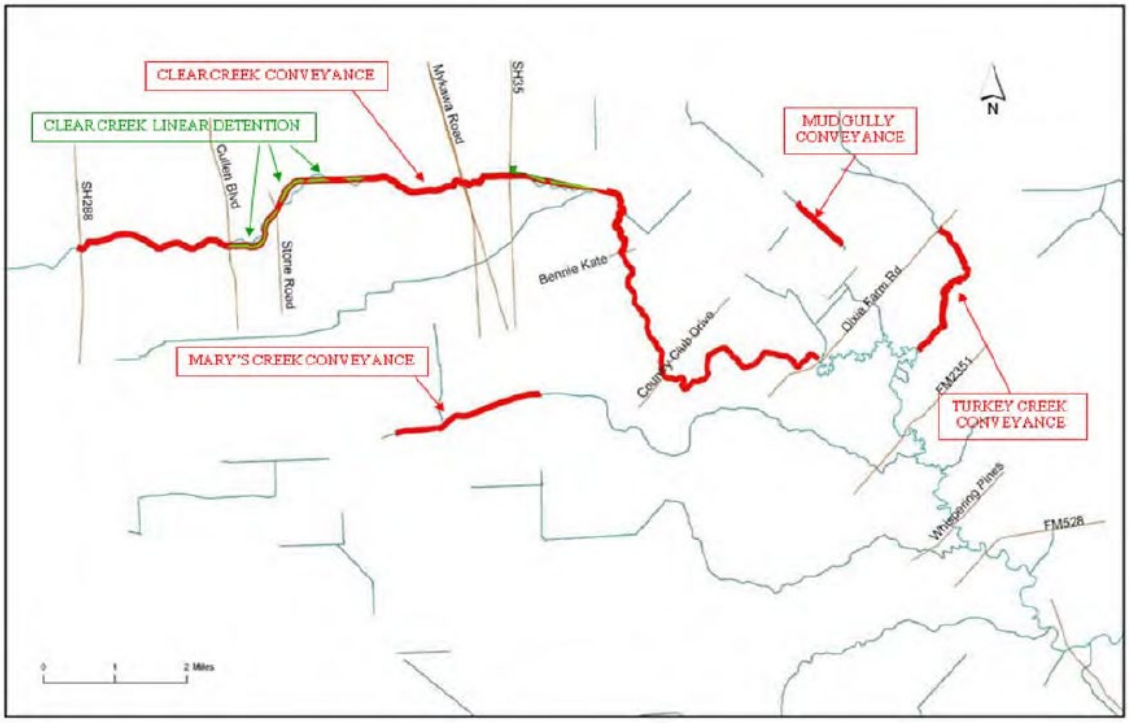

Figure 1: Clear Creek Channel Improvement FRM components

2. Project Description

The Clear Creek Flood Risk Management Project includes channel conveyance improvement along the main stem Clear Creek and its three tributaries (e.g., Mud Gully, Turkey Creek, and Mary's Creek). Red-colored bold lines on Figure 1 denote channel improvement locations along mainstem Clear Creek, Turkey Creek, Mud Gully and Mary's Creek. The main stem Clear Creek channel improvement will include approximately 15.1

miles of natural channel with Floodplain bench cuts designed to improve conveyance. Additional FRM components along main stem Clear Creek include inline detention, reconnection of oxbows, and low flow channel reshaping. The location of the Clear Creek channel improvements and inline detention can be seen in Figure 2. The typical cross sectional view of the main stem Clear Creek channel improvements, inline detention, and low flow channel reshaping can be found in Figures 3 through 7. The locations where the oxbows will be reconnected can be found in Figure 8.

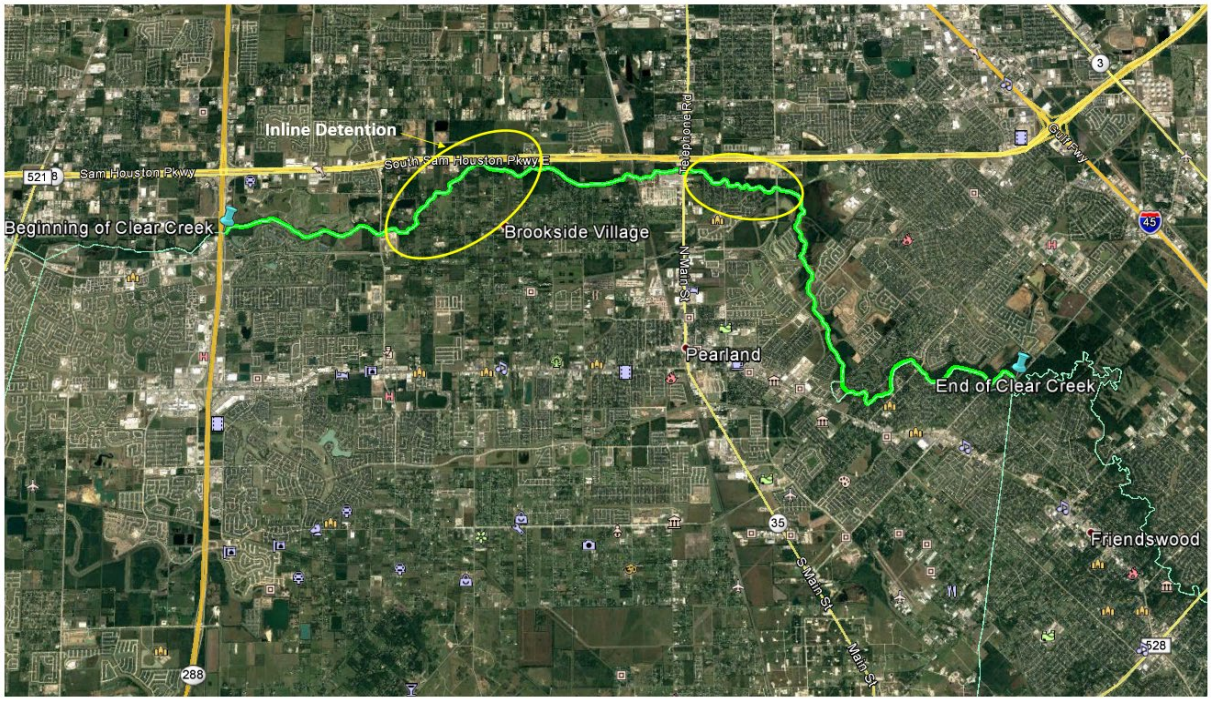

Figure 2: Inline Detention along Clear Creek Channel Improvement

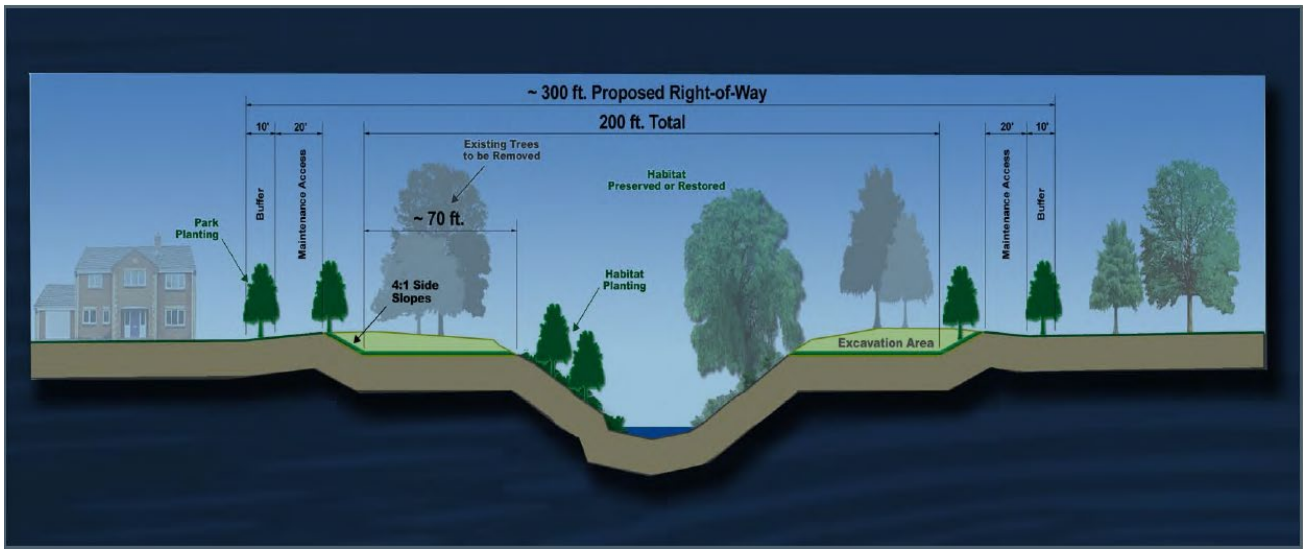

Figure 3: Cross-Section of Clear Creek Channel Conveyance Improvement (From SH 288 to Bennie Kate Road)

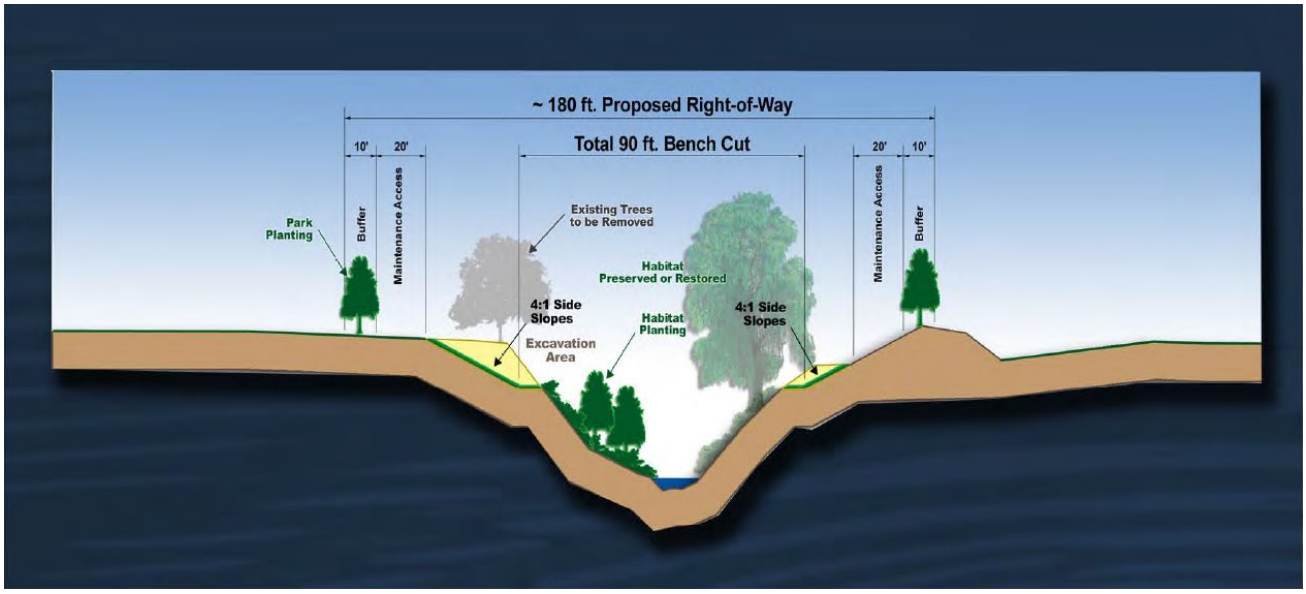

Figure 4: Cross-Section of Clear Creek Channel Improvement (From Bennie Kate Road to Dixie Farm Road)

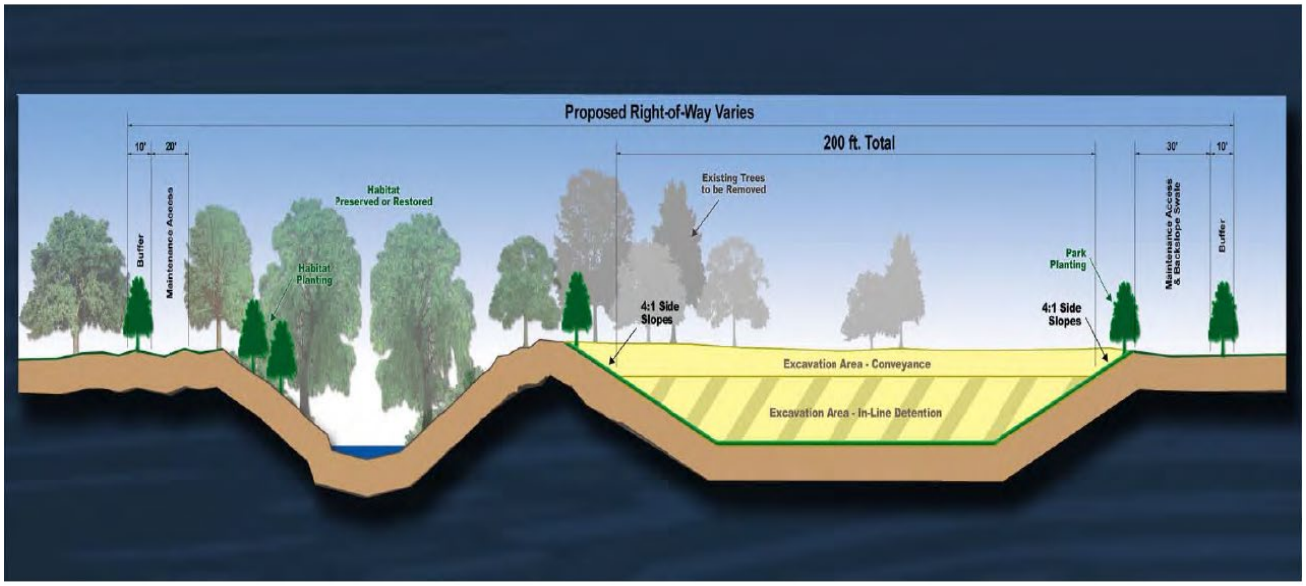

Figure 5: Cross-Section of High-Flow Bench When Not Within Same Footprint as Low-Flow Channel (Hatched X-Section Is Detention Capacity)

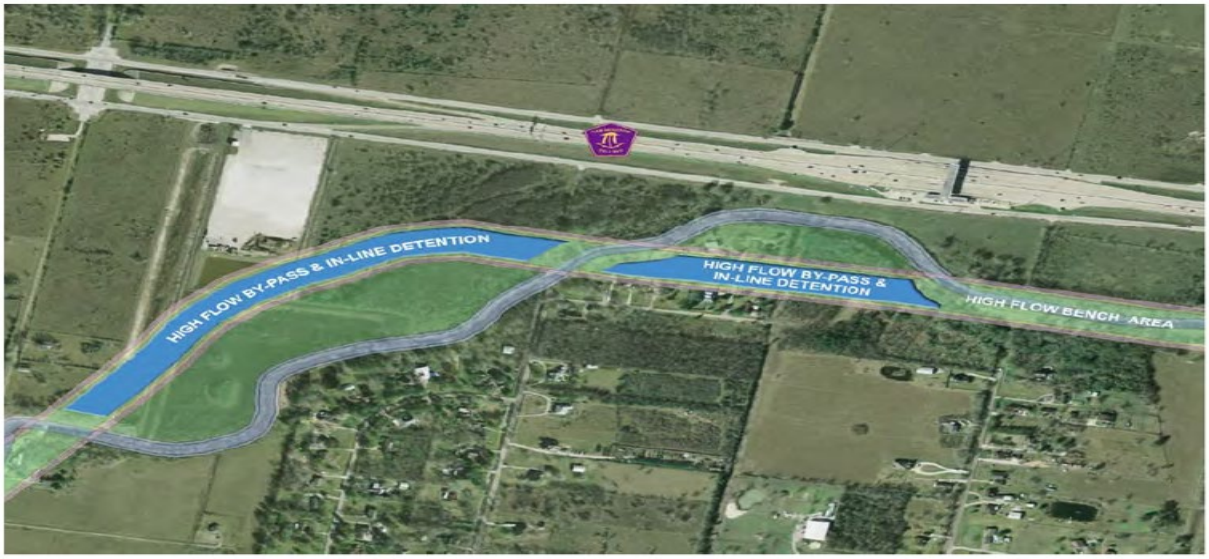

Figure 6: Plan View Example of Clear Creek In-Line Detention

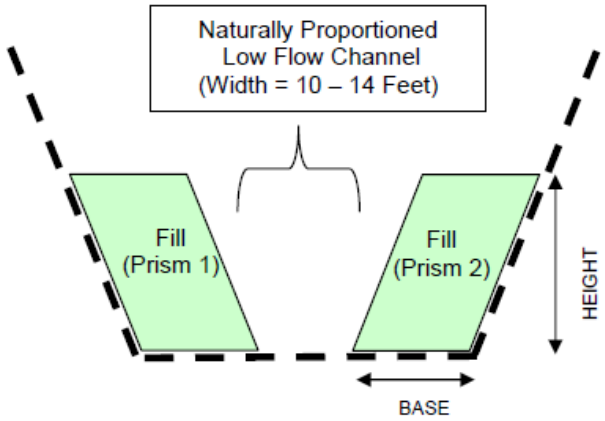

Figure 7: Cross-Section of Clear Creek Low Flow Channel Reshaping

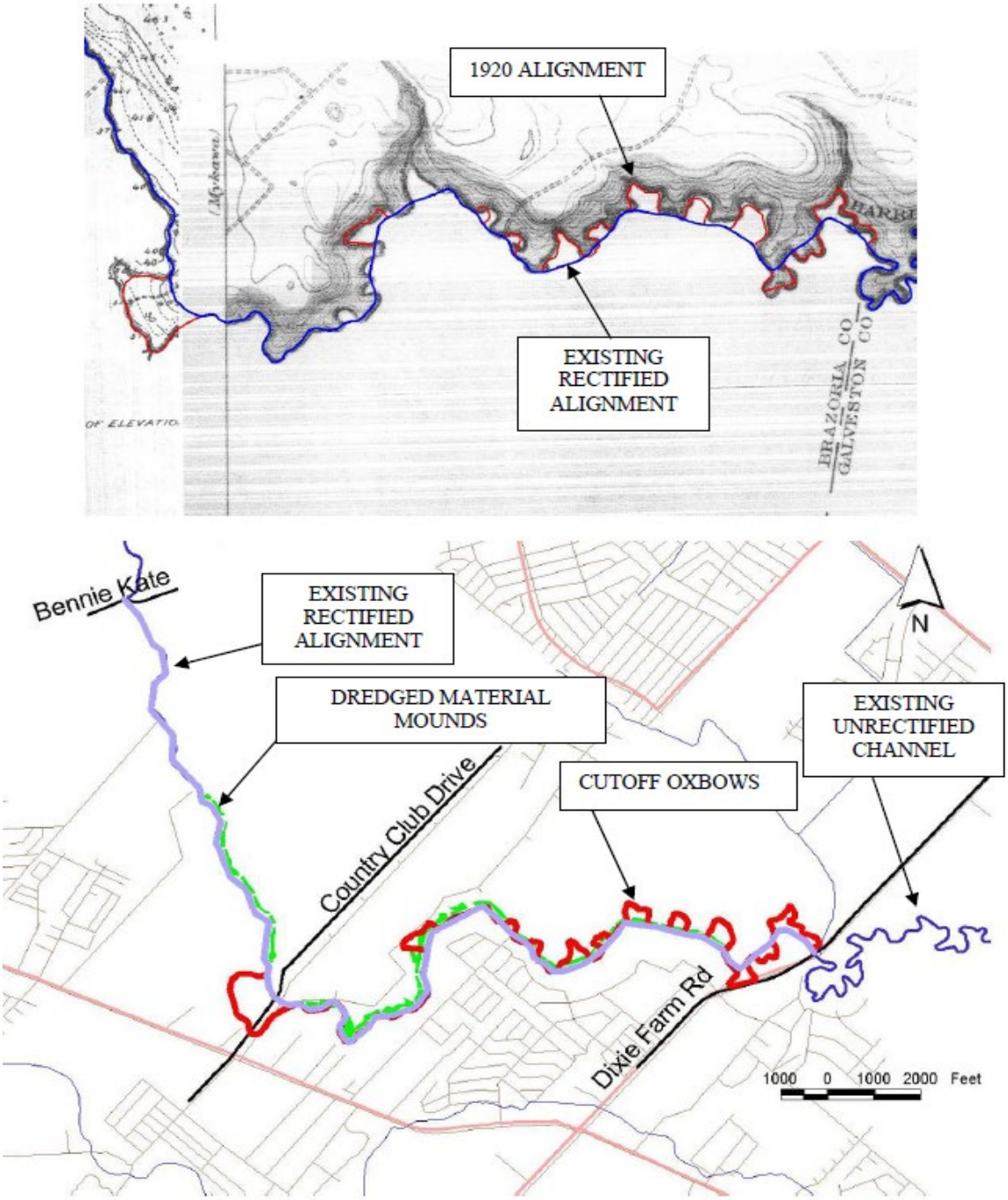

Figure 8: Clear Creek Oxbow Reconnections

The Mary's Creek channel improvement will include approximately 2.1 miles of trapezoidal earthen channel. The location can be seen in Figure 9. The typical cross sectional view of the channel improvement can be found in Figure 10.

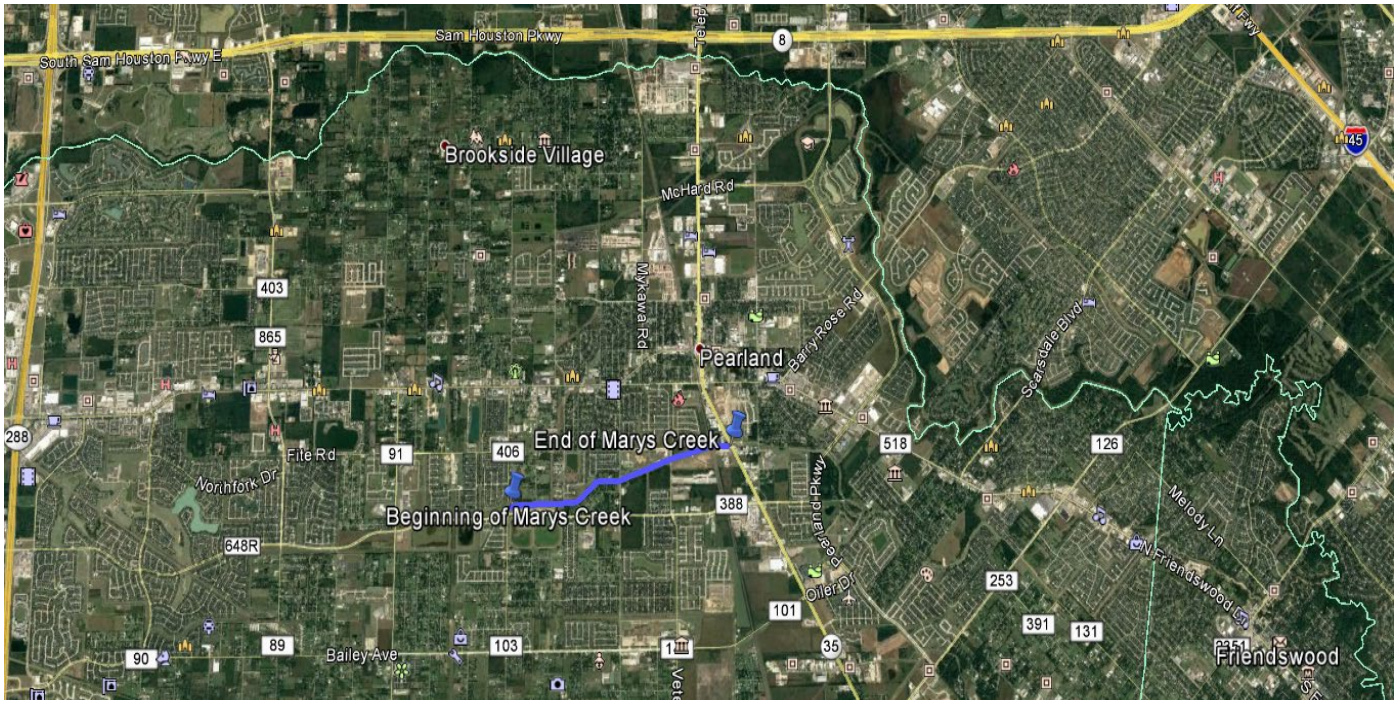

Figure 9: Plan View of Mary's Creek Channel Improvement

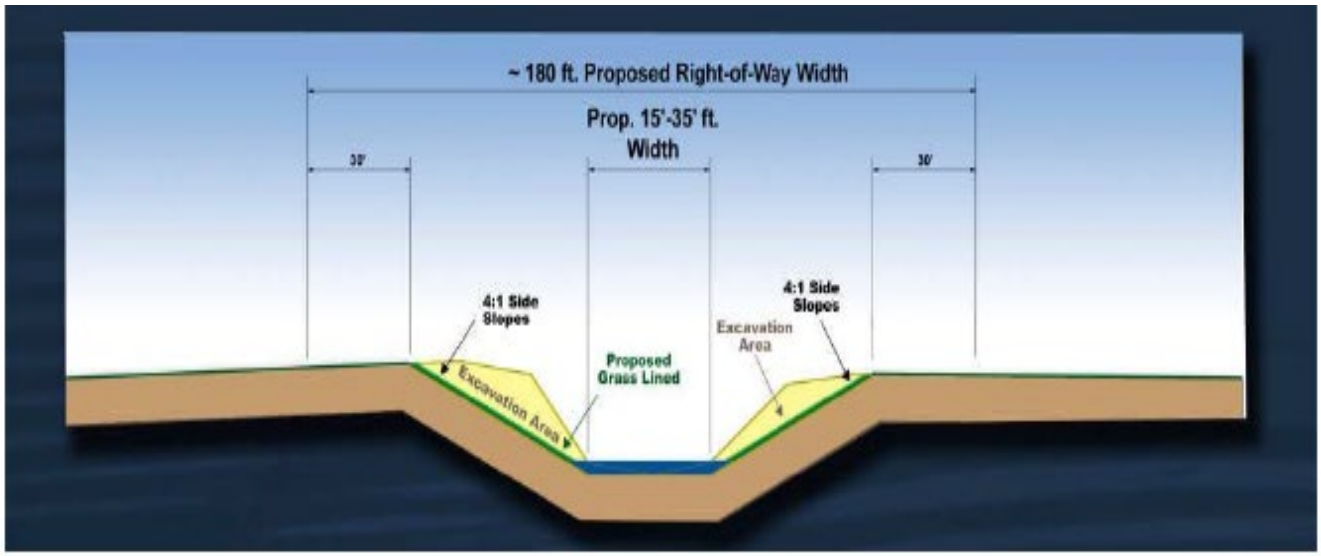

Figure 10: Cross-Section of Mary's Creek Channel Conveyance Improvement (Harkey Road to SH35)

The Turkey Creek channel improvement will include approximately 2.4 miles of trapezoidal earthen channel. The location can be seen in Figure 11. The typical cross sectional view of the channel improvement can be found in Figure 12.

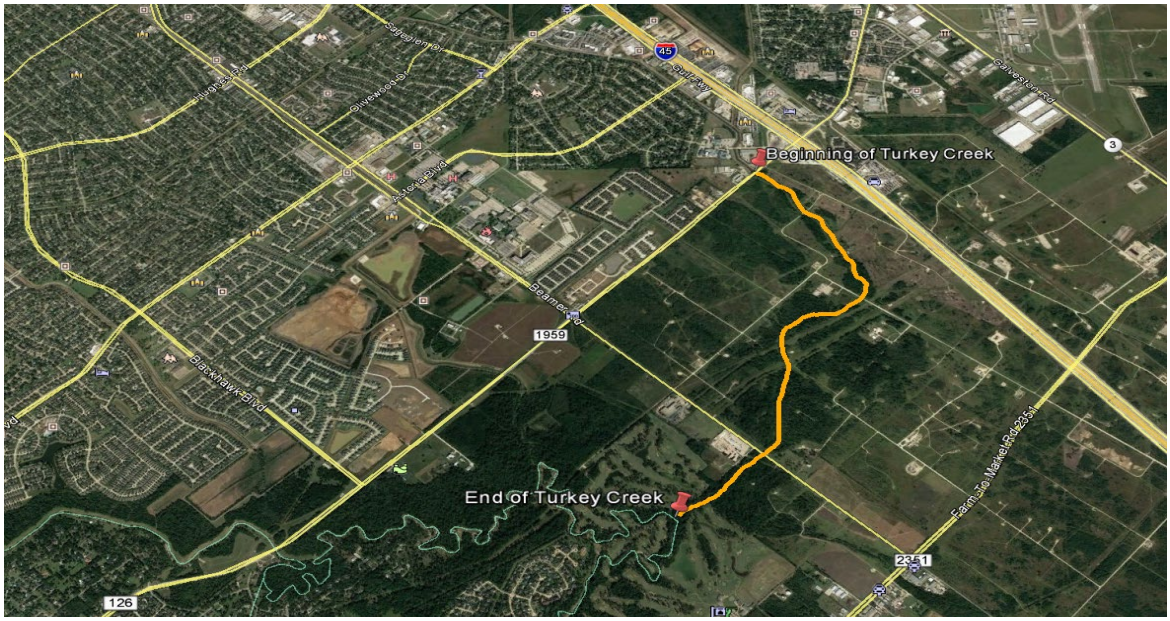

Figure 11: Plan View of Turkey Creek Channel Conveyance Improvement

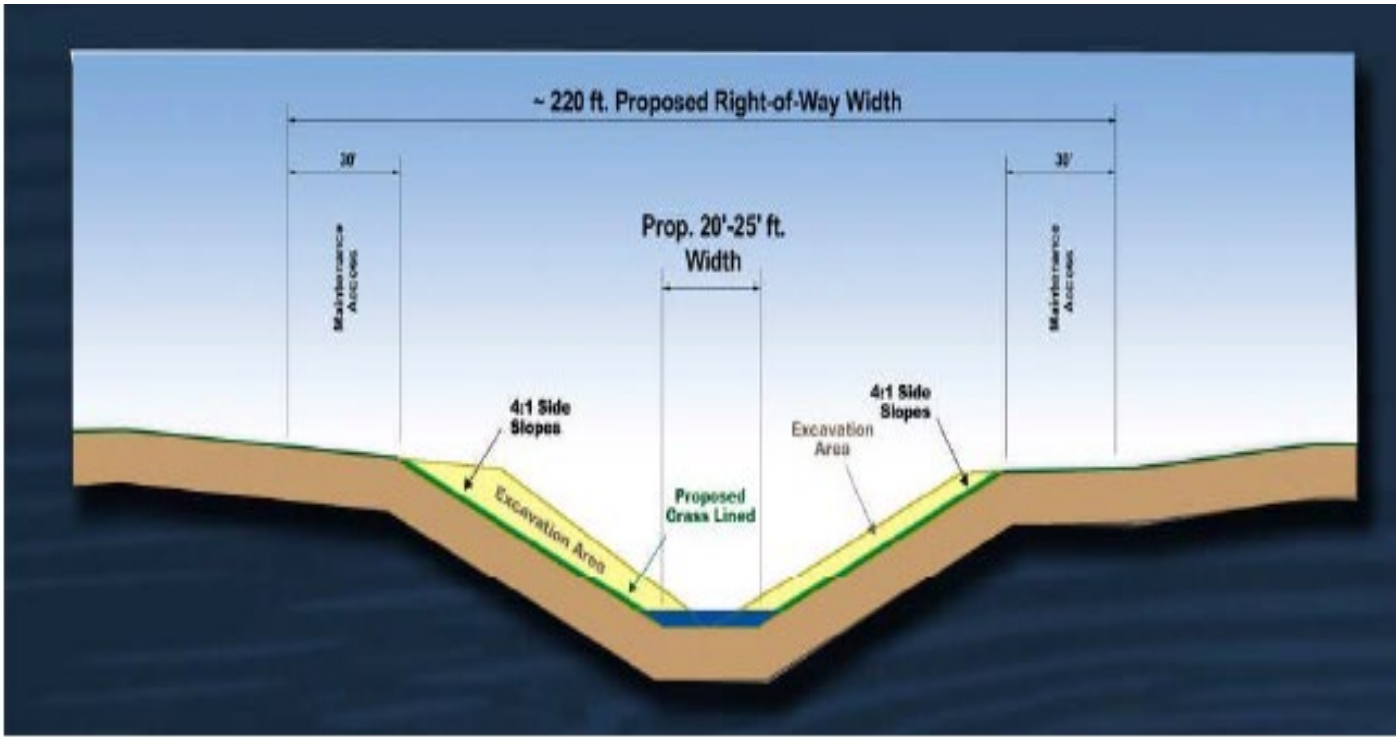

Figure 12: Cross-Section of Turkey Creek Channel Conveyance Improvement (Dixie Farm Road to Mouth)

The Mud Gulley channel improvement will include approximately 0.8 miles of concrete lined channel. The location can be seen in Figure 13. The typical cross sectional view of the channel improvement can be found in Figure 14. Detail description of Clear Creek FRM project contains in the General Reevaluation Report (2012).

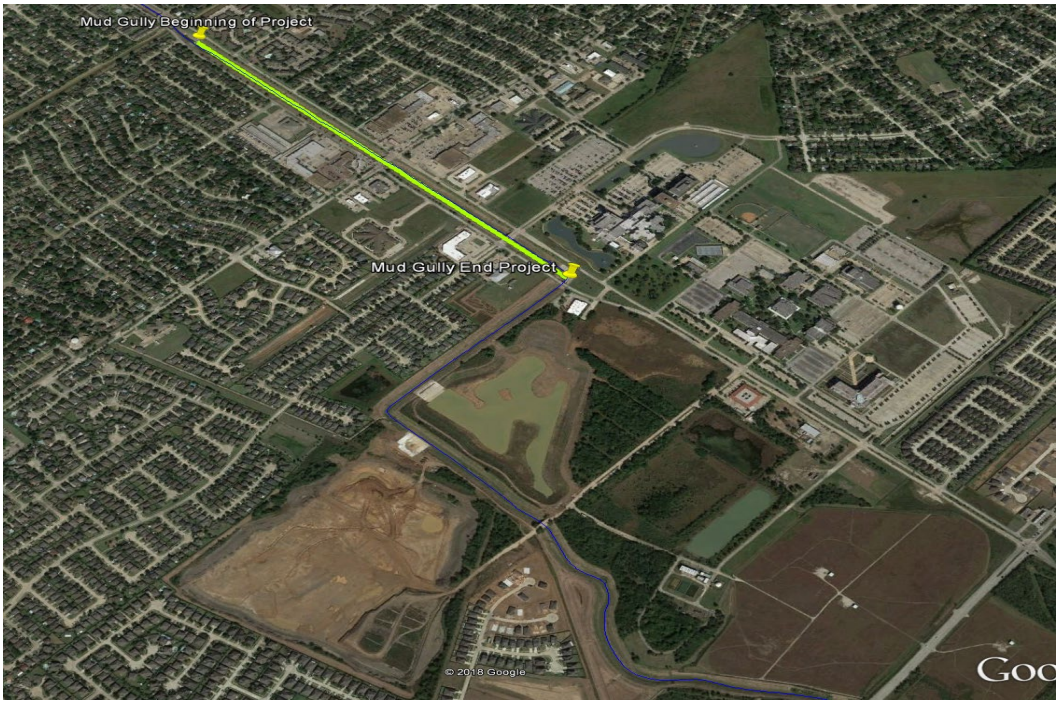

Figure 13: Plan View of Mud Gulley Channel Conveyance Improvement

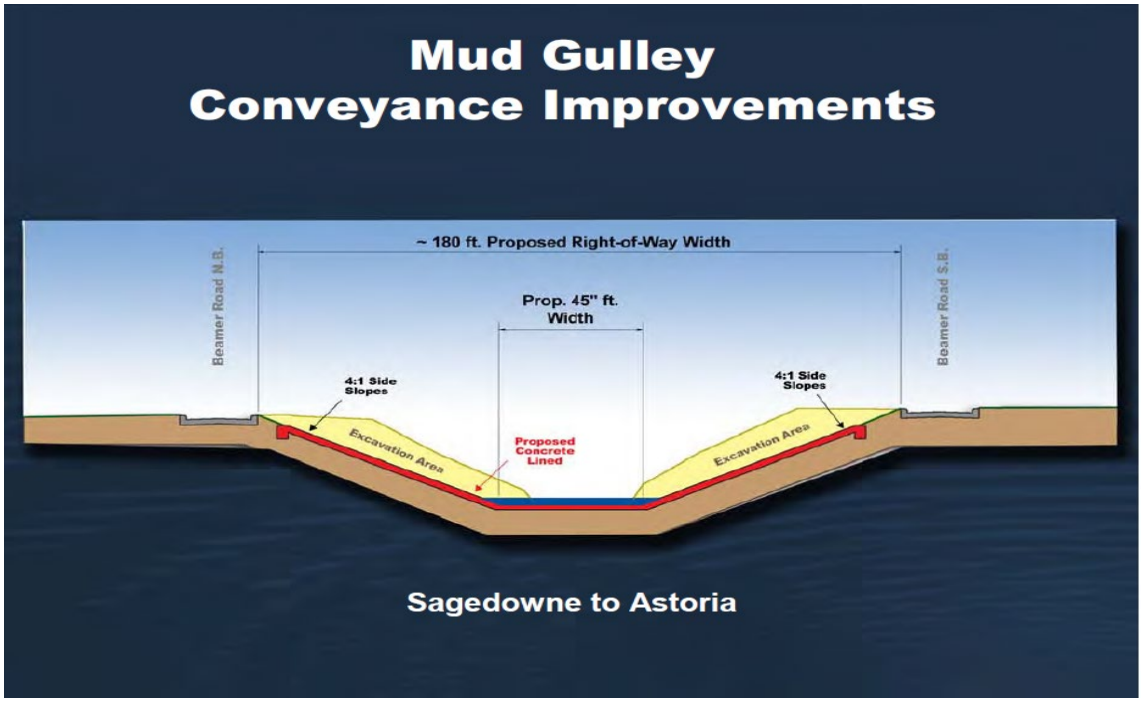

Figure 14: Cross-Section of Mud Gulley Channel Conveyance Improvement

3. Hydrologic & Hydraulic (H&H) Analysis

The hydrologic and hydraulic analysis will primarily involve development of detailed unsteady hydrologic and hydraulic models utilizing updated model datasets to support development of plans and specifications for construction of channel improvements. The FEMA effective hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models, which became effective in June 2007, are the best available source of base models. The current study will utilize the FEMA effective models as base models and make updates necessary for this study. The unsteady model results along with other relevant H&H analysis will provide information to assess induced flooding risks due to the channel improvement projects under changing hydrologic and hydraulic conditions, and support in determination of construction sequences to minimize downstream flooding risks. Differences in output between the 2012 GRR steady-state hydrology & hydraulic model (HEC-1 and HEC-RAS 1D) and the newly-developed unsteady-state hydraulic model with the approved project geometry will be documented. The unsteady models will be used to verify the latest with-project during design is not significantly different from the approved Federal Project in the 2012 GRR. Refer to Section 3.3 for more details.

The unsteady H&H models will be used to evaluate the channel hydraulics, project benefits, and residual risks from with-project conditions in terms of water surface elevation (WSE) and inundation limits. The unsteady H&H models will first be simulated with and without project conditions for the effective 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr, 250-yr, and 500-yr storm frequencies based on the rainfall values from the 1988 USGS Report 98-4044 entitled “Depth-Duration Frequency Precipitation for Texas” (1988 USGS rainfall). These simulation results will be compared against 2012 GRR steady model simulation results to document differences between these two model results. The unsteady H&H models will then be simulated with and without project conditions for the effective 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr, 250-yr, and 500-yr storm frequencies based on NOAA Atlas 14 rainfall values to evaluate project performance and residual flood risk. The modeling tasks to be performed are listed below.

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3.1. Hydrologic (HEC-HMS) Modeling

The FEMA effective HEC-HMS hydrologic model of Clear Creek watershed will be used and necessary updates will be made to represent significant recent developments or land use changes in the watershed. The FEMA effective HEC-HMS model was developed in Version 3.3, therefore, this study will also use the same version for any updates.

The updated model will be first simulated with rainfall datasets using information from 1988 USGS Report 98-4044 entitled “Depth-Duration Frequency Precipitation for Texas” (1988 USGS rainfall). These model simulation results will be compared against 2012 GRR steady model simulation results to document differences between these two model results.

Two diverse scenarios will be run for each storm frequency (i.e., 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr, 250-yr, and 500-yr) based on NOAA Atlas 14 rainfall values to help illustrate flooding risks. The first scenario simulates a hypothetical storm event over the entire Clear Creek watershed and includes the backwater effects from main stem Clear Creek to the individual tributary (e.g., Mud Gully) where channel improvements will be performed. The second scenario simulates an isolated hypothetical storm event falling only on the individual subbasin watershed (e.g., Mud Gully) of interest, with the rest of the Clear Creek watershed receiving no rainfall and thus is not impacted by backwater effects from Clear Creek. These simulations will provide insights on realistic flooding risks which may lie between these two extreme scenarios. The diverse scenarios will be illustrated through water surface profiles as well as inundation maps.

3.2. Hydraulic (HEC-RAS) Modeling

Steady state hydraulic modeling was performed during the GRR study to evaluate flood levels and damages for the main stem Clear Creek and its six major tributaries including Hickory Slough, Mary's Creek, Cowart Creek, Chigger Creek, Mud Gully, and Turkey Creek. However, unsteady hydraulic modeling simulations are critical in order to evaluate the backwater effects on these particularly intertwined flooding sources, since the Project(s) relies so heavily upon storage and timing effects for the minimization of flooding risks. Therefore, detailed unsteady hydraulic model development utilizing the latest version of the HEC-RAS software (Version 5.0.7) is required for supporting development of plans and specifications for construction of channel improvement. The unsteady model can also guide in determination of channel construction sequence by evaluating induced flooding risk under different construction sequences.

Since the Clear Creek main stem, Mud Gully, Turkey Creek, and Mary's Creek were included in the final National Economic Development (NED) plan of the approved GRR, only those tributaries will initially be included in the unsteady HEC-RAS model. Tributaries that are not part of the Federal Project (Hickory Slough, Cowarts Creek, and Chiggers Creek) will be evaluated by comparing the HEC-HMS hydrograph peak time from the tributaries with the unsteady HEC-RAS stage-time graph in the main channel. If it is determined that the change in the stage-time relationship in the main channel between with project and without project conditions will have a significant impact on the flows coming into the main channel from the tributaries, HCFCD and USACE will then decide whether those tributaries should be included within the unsteady HEC-RAS model.

The developed hydraulic model domain will include tributaries that affect hydraulic conditions in the channel improvement area. In some areas of the hydraulic model domain, a coupled 1D/2D unsteady flow model configurations may be necessary to accurately simulate the movement of flood water through multiple flow paths in the floodplain. The floodplains for without project and with project conditions will be developed using the

HEC-RAS model. This task will be performed to investigate whether or not the channel improvements increase flooding risk anywhere in the system.

The unsteady HEC-RAS model will use the existing conditions geometry from the FEMA effective HEC-RAS model and make necessary updates to represent the latest existing conditions. The following updates to model input datasets are suggested for evaluating induced flooding risk due to changing hydrologic and hydraulic conditions:

Updated Terrain Data – The latest terrain datasets (2018 LiDAR data) will be used to update the overbank areas of the channel cross sections. The FEMA effective models were developed based on field survey within the channel banks. These channel cross sections within banks will be checked by comparing with latest surveys at select locations. Updated field bathymetric surveys will be conducted, if necessary.

Model Calibration and Validation- The without project models will be calibrated and validated using significant historical storm events with best available datasets.

Compound flooding effects evaluation: Compound flooding may result from combination of two mechanisms (e.g., rainfall-runoff and storm surge) that can occur simultaneously or in close succession. Therefore, it is important to evaluate joint probability of surge and rainfall-runoff flooding. This probability value may then be used for assessment of compound flooding impacts on downstream of the channel improvement by performing sensitivity analysis of the validated hydrodynamic model. The compound effect of rainfall-runoff and storm surge from the Galveston Bay will be evaluated by representing the surge from the bay in the form of a tailwater boundary condition. The joint probability will be determined based on review of previous studies in the region. A detailed joint probability analysis is not anticipated.

3.3 Comparison with the Approved Federal Project

The unsteady HEC-RAS model outputs from the with-project conditions based on the GRR cross sections as-is will be compared with the unsteady H&H model outputs from the with-project conditions based on the latest design. USACE and HCFCD will review the outputs and recommend design changes, as necessary, to ensure there are no significant differences. No Benefit Cost Ratio (BCR) recalculations or economic evaluations are anticipated.

3.4 Geomorphic assessment

The H&H analysis report will identify areas where structural erosion control may be needed based on velocity. General and commonly used measures will be suggested without detailed evaluation and design. Geomorphic assessment and identification of design features where needed will be performed during the design phase. The design

features may include erosion control and outfall structures in the channels, drainage swales in the high flow bypasses, and oxbow reconnections in the environmental mitigation reach. H&H analysis will be conducted during design, where needed. This analysis will also include discussion on sedimentation issues within the project study limits.

3.5 Risk and Uncertainty Analysis

Risks and uncertainties associated with engineering data, modeling results and analysis need to be quantified and documented following the applicable USACE guidance (e.g., EM 1110-2-1619). Risk and uncertainty analysis will include Annual Exceedance Probability (AEP), Conditional Non-exceedance Probability (CNEP), and Long Term Risk (LTR) evaluations.

3.6 Climate Change Effects

Climate change impacts, which may be relevant to the hydrologic analysis, need to be discussed following the USACE guidance (e.g., ECB 2018-14; ER 1105-2-101)
This may include, but not limited to, climate change impact evaluation by representing the impacts in the form of a representative tailwater boundary condition.

3.7 Sea level Rise

The effects of future relative sea level rise on the design and function of the project will be evaluated by representing those effects in the form of a representative tailwater condition.

3.8 Hurricane Harvey Evaluation

Evaluation of Hurricane Harvey storm event will be performed to estimate the project performance, and residual flood risks during the storm event.

3.9 Engineering Model

The following engineering models are anticipated to be used during reviews for understanding sponsor proposed design and in compliance with Section 1043 (b) intent of reviews and oversight:

MODEL / Tools of Analysis
HEC- RAS
HEC-HMS
HEC-LifeSim
HEC-FIA

4. Review Team Site visits

Both DQC and ATR H&H reviewer team will perform site visits for examination of project sites and assessment of existing conditions (including structures and other features).

5. District Quality Control (DQC) Review

All implementation documents (including supporting data, analyses, reports, environmental compliance documents etc.) shall undergo DQC in accordance EC 1165-2-217. A DQC is an internal review process of basic science and engineering work products. It's focused on fulfilling the project quality requirements defined in the PMP. The District shall perform these reviews in accordance with the Galveston District Engineering Division Quality Management System procedures.

H&H analysis products will go through two phases of review. First, H&H models and associated analysis will be gone through DQC review. The results of first phase review will then be provided in the second phase of H&H DQC review of the design phase implementation documents (e.g., plans and specifications). The H&H model products will not require further review unless significant changes are made to them during the design phase that cause previous reviews to be superseded.

5.1 H&H Products to undergo DQC

The deliverable for each review shown below should be the minimum to be included in each deliverable to be reviewed:

DQC submittal for H&H Model Review:

- ***Preliminary (50%) Model Review***
  - Calibrated and validated without-project hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models, with-project hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models. These models will be based on the 1988 USGS rainfall at this stage of review. These models will not include hydraulic detention mitigation at this stage of review.
  - Inundation maps in the form of RAS Mapper output will be provided for with and without project conditions for diverse scenarios including different frequency storms.
  - Detailed Hydrologic & Hydraulic analysis report which will include all relevant information such as data, methods, and results. Water surface profiles and tables, cross sections, and flow and stage hydrographs at key locations will be provided. The content and format will be consistent with Appendix D of EM 1110-2-1150, Engineering and Design for Civil Works Projects.

- ***Draft (75%) Model Review***
  - Hydrologic (HEC-HMS) & Hydraulic (HEC-RAS) models updated based on 50% review comments. Models will include hydraulic detention mitigation elements.

- Inundation maps (e.g., ArcGIS shape files) for with and without project conditions for diverse scenarios including different frequency storms.
- Risk and uncertainty analysis.
- Detailed Hydrologic & Hydraulic analysis report which will include all relevant information such as data, methods, and results. Water surface profiles and tables, cross sections, and flow and stage hydrographs at key locations will be provided. This report will also contain information on geomorphic assessment of the effects of the channel improvement, impact analysis and mitigation based on 1988 USGS rainfall, project performance and residual risk analysis based on Atlas 14, compound flooding effects based on Atlas 14 rainfall. The content and format will be consistent with Appendix D of EM 1110-2-1150, Engineering and Design for Civil Works Projects.

❖ ***Draft (90%) Model Review***

- Hydrologic (HEC-HMS) & Hydraulic (HEC-RAS) models updated based on 75% review comments. Additional modeling scenarios include climate change effects, sea level rise, and Hurricane Harvey.
- Inundation maps (e.g., ArcGIS shape files) for with and without project conditions for diverse scenarios including different frequency storms.
- Risk and uncertainty analysis, geomorphic assessment.
- Detailed Hydrologic & Hydraulic analysis report which will include all relevant information such as data, methods, and results. Water surface profiles and tables, cross sections, and flow and stage hydrographs at key locations will be provided. This report will also contain information on geomorphic assessment of the effects of the channel, impact analysis and mitigation based on 1988 USGS rainfall, project performance and residual risk analysis based on Atlas 14, compound flooding effects based on Atlas 14 rainfall. The content and format will be consistent with Appendix D of EM 1110-2-1150, Engineering and Design for Civil Works Projects.

❖ ***Final (100%) Model Review***

- Hydrologic (HEC-HMS) & Hydraulic (HEC-RAS) models updated based on 90% review comments.
- Inundation maps (e.g., ArcGIS shape files) for with and without project conditions for diverse scenarios including different frequency storms.
- Risk and uncertainty analysis, geomorphic assessment.
- Detailed Hydrologic & Hydraulic analysis report which will include all relevant information such as data, methods, and results. Water surface profiles and cross sections and hydrographs at key locations will be provided. This report will also contain information on geomorphic assessment of the effects of the channel

improvement, impact analysis and mitigation based on 1988 USGS rainfall, project performance and residual risk analysis based on Atlas 14, compound flooding effects based on Atlas 14 rainfall. The content and format will be consistent with Appendix D of EM 1110-2-1150, Engineering and Design for Civil Works Projects.

5.2 Required H&H Expertise for DQC review

Table 1: Required DQC level H&H Team Expertise

DQC Team Members/ Disciplines	Expertise Required
Hydrologic Engineering	The Hydrologic Engineering reviewer will be an expert in the field of hydrology. The individual should have a thorough understanding in hydrologic modeling, flood frequency analysis, and risk-based flood damage reduction analysis, The reviewer should have specialized experience in river engineering and familiarity with rivers with water control structures and dredging projects. The reviewer will be knowledgeable and experienced with the routing of inflow hydrographs through complex hydraulic systems, development of the flood hazard/loading (i.e., stage-frequency and duration relationships). The reviewer should have a demonstrated experience applying and interpreting outputs from models such as HEC-RAS & HEC-HMS.
Hydraulic Engineering	The Hydraulic Engineering reviewer will be an expert in the field of hydrology and the other person will be in the field of channel hydraulics. The individual should have a thorough understanding in hydraulic modeling and hydraulic design of flood control channels including in-line detentions, sedimentation analysis and erosion control design. The reviewer should have specialized experience in river engineering, sediment transport, and familiarity with rivers with water control structures and dredging projects. The reviewer will be knowledgeable and experienced with the routing of inflow hydrographs through complex hydraulic systems. The reviewer should have a demonstrated experience applying and interpreting outputs from models such as HEC-RAS & HEC-HMS.

5.3 DQC Schedule and Estimated Cost

Although DQC is always seamless, the following milestone reviews are scheduled in Table 2 & 3. The cost for two phases of H&H DQC is approximately **$208,900.00** (=$76,500.00+$132,400.00).

Table 2: DQC Schedule for H&H Analysis

DQC Review	Duration	Total labor hours	Cost	Assumptions
Preliminary (50%) Model Review				
H&H DQC product review and feedback	3 weeks			
Address DQC H&H review comments	2 weeks			
Review responses and participate DQC conference	2 week			
Draft (75%) Model Review				
H&H DQC product review and feedback	2 weeks			
Address DQC H&H review comments	2 weeks			
Review responses and participate DQC conference	1 week			
Draft (90%) Model Review				
H&H DQC product review and feedback	2 weeks			
Address DQC H&H review comments	2 weeks			
Review responses and participate DQC conference	1 week			
Final (100%)Model Review				
H&H DQC product review and feedback	2 weeks			
Address DQC H&H review comments	2 weeks			
Review responses and participate DQC conference	1 week			
Total Cost				

Note: * The H&H model for the entire Clear Creek system will be developed before design implementation of any contract. This schedule is for performing DQC review on the H&H model only.
** H&H team for model DQC review will consist of two members: one from each disciplines: hydrologic & hydraulic

6. Agency Technical (ATR) Review

H&H models and associated analysis shall undergo ATR in accordance with EC 1165-2-217. In order to assist with meeting the project schedule, the ATR will be conducted concurrently with the DQC review until the 90% review. The final 100% reviews are

required to be performed sequentially. ATR reviews will occur seamlessly, including early involvement of the ATR team for key decisions. A site visit need to be scheduled for the ATR Team. The ATR will assess whether the analyses are technically correct and comply with guidance, and that documents explain the analyses and results in a clear manner. ATR is performed by a qualified team from outside the home district that is not involved in the day-to-day production of the project/product. ATR is managed within USACE by the designated RMO and the teams will be comprised of certified USACE personnel. The ATR team lead will be from outside the home MSC. If significant life safety issues are involved in a study or project a safety assurance review should be conducted during ATR. ATR teams will be comprised of qualified senior USACE personnel from outside the home district. The ATR team lead will be assigned by the RMC.

The ATR Team is given wide latitude to confirm that the technical data, analysis, and methodology meets current agency and state of the practice standards. In some situations, especially addressing incomplete or unclear information, comments may seek clarification in order to then assess whether further specific concerns may exist. The ATR documentation in DrChecks [SM] will include the text of each ATR concern, the PDT response, a brief summary of the pertinent points in any discussion, including any vertical team coordination (the vertical team includes the district, RMO, MSC, and HQUSACE), and the agreed upon resolution. If an ATR concern cannot be satisfactorily resolved between the ATR team and the PDT, it will be elevated to the vertical team for further resolution in accordance with the policy issue resolution process described in either ER 1110-2-12 or ER 1105-2-100, Appendix H, as appropriate. Unresolved concerns can be closed in DrChecks with a notation that the concern has been elevated to the vertical team for resolution.

6.1 ATR Documentation

Documentation of ATR will be performed using the requirements of EC 1165-2-217. This will generally include the four part comment structure and the use of DrChecks for comment collaboration, response, and back checking.

H&H analysis review comments will be documented in the form of a Word document or DrChecks. After resolution of the comments, the reviewer will sign the ATR completion form. This signature will ensure all comments have been addressed during ATR and signify concurrence.

6.2 Products to Undergo ATR

The ATR will be managed by the RMC and the ATR lead. DrChecks review software will be used to document all ATR comments, responses and associated resolutions accomplished throughout the review process. The deliverable for each review shown below should be the minimum to be included in each deliverable to be reviewed:

ATR submittal for H&H Model Review:

- ***Preliminary (50%) Model Review***
  - Calibrated and validated without-project hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models, with-project hydrologic (HEC-HMS) and hydraulic (HEC-RAS) models. These models will be based on the 1988 USGS rainfall at this stage of review. These models will not include hydraulic detention mitigation at this stage of review.
  - Inundation maps in the form of RAS Mapper output will be provided for with and without project conditions for diverse scenarios including different frequency storms.
  - Detailed Hydrologic & Hydraulic analysis report which will include all relevant information such as data, methods, and results. Water surface profiles and tables, cross sections, and flow and stage hydrographs at key locations will be provided. The content and format will be consistent with Appendix D of EM 1110-2-1150, Engineering and Design for Civil Works Projects.

- ***Draft (75%) Model Review***
  - Hydrologic (HEC-HMS) & Hydraulic (HEC-RAS) models updated based on 50% review comments.
  - Inundation maps (e.g., ArcGIS shape files) for with and without project conditions for diverse scenarios including different frequency storms.
  - Risk and uncertainty analysis.
  - Detailed Hydrologic & Hydraulic analysis report which will include all relevant information such as data, methods, and results. Water surface profiles and tables, cross sections, and flow and stage hydrographs at key locations will be provided. This report will also contain information on geomorphic assessment of the effects of the channel improvement, impact analysis and mitigation based on 1988 USGS rainfall, project performance and residual risk analysis based on Atlas 14, compound flooding effects based on Atlas 14 rainfall. The content and format will be consistent with Appendix D of EM 1110-2-1150, Engineering and Design for Civil Works Projects.

- ***Draft (90%) Model Review***
  - Hydrologic (HEC-HMS) & Hydraulic (HEC-RAS) models updated based on 75% review comments. Additional modeling scenarios include climate change effects, sea level rise, and Hurricane Harvey.
  - Inundation maps (e.g., ArcGIS shape files) for with and without project conditions for diverse scenarios including different frequency storms.
  - Risk and uncertainty analysis, geomorphic assessment.

- Detailed Hydrologic & Hydraulic analysis report which will include all relevant information such as data, methods, and results. Water surface profiles and tables, cross sections, and flow and stage hydrographs at key locations will be provided. This report will also contain information on geomorphic assessment of the effects of the channel improvement, impact analysis and mitigation based on 1988 USGS rainfall, project performance and residual risk analysis based on Atlas 14, compound flooding effects based on Atlas 14 rainfall. The content and format will be consistent with Appendix D of EM 1110-2-1150, Engineering and Design for Civil Works Projects.

❖ ***Final (100%) Model Review***

- Hydrologic (HEC-HMS) & Hydraulic (HEC-RAS) models updated based on 90% review comments.
- Inundation maps (e.g., ArcGIS shape files) for with and without project conditions for diverse scenarios including different frequency storms.
- Risk and uncertainty analysis, geomorphic assessment.
- Detailed Hydrologic & Hydraulic analysis report which will include all relevant information such as data, methods, and results. Water surface profiles and cross sections and hydrographs at key locations will be provided. This report will also contain information on geomorphic assessment of the effects of the channel improvement, impact analysis and mitigation based on 1988 USGS rainfall, project performance and residual risk analysis based on Atlas 14, compound flooding effects based on Atlas 14 rainfall The content and format will be consistent with Appendix D of EM 1110-2-1150, Engineering and Design for Civil Works Projects.

6.3 ATR Team member Expertise

Table 4: ATR H&H Team member expertise

ATR Team Members/Disciplines	Expertise Required
Hydrologic Engineering	The Hydrologic Engineering reviewer will be an individual with more than ten years of experience in the field of hydrology. The individual will have a thorough understanding in hydrologic modeling and hydrologic frequency analysis. The reviewer will be knowledgeable and experienced with the routing of inflow hydrographs through complex hydraulic systems, development of the flood hazard/loading (i.e., stage-frequency and duration relationships), and risk-based flood damage reduction analysis. The reviewer should also have a demonstrated experience applying and interpreting outputs from models such as HEC-RAS & HEC-HMS. S/he will also have experience in performing climate change assessments and have an understanding of how this would impact the risk based design for FRM. The reviewer will be familiar with the

	Climate Hydrology Assessment Tool, Non-stationarity Detection Tool, and Vulnerability Assessments. The Reviewer will be certified by the Climate Preparedness and Resilience CoP in CERCAP.
Hydraulic Engineering	The Hydraulic Engineering reviewer will be an individual with more than ten years of experience in the field of hydraulics. The individual will have a thorough understanding in hydraulic design of flood control channels including in-line detentions, sedimentation analysis and erosion control design. The hydraulic engineer will be knowledgeable and experienced with the routing of inflow hydrographs through complex hydraulic systems, and USACE hydraulic modeling. The reviewer should have a demonstrated experience applying and interpreting outputs from models such as HEC-RAS & HEC-HMS. The individual should be a certified professional engineer (PE).

6.4 ATR Schedule and Estimated Cost

The preliminary ATR schedule is listed in Table 5. The cost for H&H ATR review is approximately **$104,500.00**.

Table 5: ATR Schedule for H&H Analysis

ATR Review	Duration	Total labor hours	Cost	Assumptions
Site Visits (3 ATR team members)	**1 week**			
Preliminary (50%) Model Review				
H&H ATR product review and feedback	3 weeks			
Address ATR H&H comments	2 weeks			
Review responses and participate ATR conference	2 week			
Draft (90%) Model Review				
H&H DQC product review and feedback	2 weeks			
Address DQC H&H review comments	2 weeks			
Review responses and participate DQC conference	1 week			
Draft (90%) Model Review				

H&H ATR product review and feedback	2 weeks			
Address ATR H&H comments	2 weeks			
Review responses and participate ATR conference	2 week			
Final (100%) Model Review				
H&H ATR product review and feedback	2 weeks			
Address ATR H&H comments	2 weeks			
Review responses and participate ATR conference	2 week			
Travel budget				
Total Estimated Costs				

Note: * The H&H model for the entire Clear Creek system will be developed before design implementation of any contract.
** H&H team for model ATR review will consist of two members: one from each disciplines: hydrologic & hydraulic

6.5 Statement of Technical Review Report

At the conclusion of Draft and Final milestones, the ATR team will prepare a Statement of Technical Review Report with a completion and certification memo. The report will be prepared in accordance with EC 1165-2-217 and shall:

- Identify the document(s) reviewed and the purpose of the review;
- Disclose the names of the reviewers, their organizational affiliations, and include a short paragraph on both the credentials and relevant experiences of each reviewer;
- Include the charge to the reviewers;
- Describe the nature of their review and their findings and conclusions;
- Identify and summarize each unresolved issue (if any);
- Include a verbatim copy of each reviewer's comments (either with or without specific attributions), or represent the views of the group as a whole, including any disparate and dissenting views.

ATR may be certified when all ATR concerns are either resolved or referred to the vertical team for resolution and the ATR documentation is complete. The ATR Lead will prepare a Statement of Technical Review certifying that the issues raised by the ATR team have been resolved (or elevated to the vertical team).

7. Independent External Peer Review (IEPR)

The IEPR subject is fully expounded in the complementing Review Plan covering P&S development and construction activities. In gist, the District PDT did not find evidence for an IEPR. The factors in determining whether a Type II IEPR review of design and

construction activities of a project is necessary are based on the EC 1165-2-217 Type II IEPR Risk Informed Decision Process. The following EC 1165-2-217 risk decision criteria are followed by a statement that forms the basis for the Type II IEPR determination.

1. The failure of the project would pose a significant threat to human life.

-This project consists of enlarging and / or lining with concrete a below surface drainage channel & detention basins; failure of these features will not pose a significant threat to human life.

2. The project involves the use of innovative materials or techniques.

-This project will utilize methods and procedures used by the Corps of Engineers on other similar works. In addition, standard approved models as identified in section 3.10 will be used for this H&H analysis and vetting of H&H models.

3. The project design lacks redundancy.

-The concept of redundancy does not apply to drainage channel projects.

4. The project has unique construction sequencing or a reduced or overlapping design construction schedule.

-The construction sequence and schedule for this project have been used successfully by the Corps of Engineers, other similar works; in addition, the implementing sponsor has built similar channels in the area. Construction schedules do not have unique sequencing and activities are not reduced or overlapped.

Therefore, the District Chief of Engineering, as the Engineer-In-Responsible-Charge for the H&H analysis, does not recommend a Type II IEPR Safety Assurance Review of the H&H analysis and its' migration into the DDR for this channel work project.

8. Model Certification and Approval

8.1 Engineering Models

The use of certified or approved engineering models is required for all activities to ensure the models are technically and theoretically sound, compliant with USACE policy, computationally accurate, and based on reasonable assumptions. The responsible use of well-known and proven USACE developed and commercial engineering software will continue and the professional practice of documenting the application of the software and modeling results will be followed. The selection and application of the model and the input and output data is still the responsibility of the users and is subject to DQC and ATR. Where such validations have not been completed, appropriate independent checks of

critical calculations will be performed and documented as part of DQC, ATR. The following H&H engineering models, software, and tools are anticipated to be used:

Table 7 Engineering Models and Status

Model Name	Brief Model Description and how it will be used	Validation Date
HEC-HMS	By applying this model, the PDT is able to define the watersheds' physical features, describe the meteorological conditions, estimate pertinent parameters, analyze simulations, and obtain GIS connectivity.	Certified
HEC-RAS	The software performs 1-D steady and unsteady flow river hydraulics calculations and has capability for 2-D (and combined 1-D/2-D) unsteady flow calculations. It will be used for un steady flow analysis to evaluate the future without-project and future with-project conditions.	Certified
HEC-SSP	Hydrologic Engineering Center's (HEC) Statistical Software Package (HEC-SSP) allows users to perform statistical analyses of hydrologic data including flood flow frequency analysis.	Certified

9. Review Management Organization

The USACE Risk Management Center (RMC) is the Review Management Organization (RMO) for this product.

9. References

i. U.S. Army Corps of Engineers, Galveston District, Clear Creek General Reevaluation Report, Hydrologic Analysis for Without Project Conditions, dated October 2012
ii. U.S. Army Corps of Engineers, Galveston District, Clear Creek General Reevaluation Report, Hydrologic Analysis for Without Project Conditions, dated July 2003
iii. ER 1105-2-101, Risk Assessment for Flood Risk Management Studies, 17 July 2017.
iv. ECB 2018-14. Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects. Dated September 10, 2018.
v. EM 1110-2-1150. Engineering and Design for Civil Works Projects, 31 August 1999
vi. EM 1110-2-1416. River Hydraulics.
vii. EM 1110-2-1601. Hydraulics design of flood control channels.
viii. EM 1110-2-1417. Flood-runoff analysis.
ix. EM 1110-2-1415. Hydrologic frequency analysis.
x. EM 1110-2-1619. Risk-based analysis for flood damage reduction studies.
xi. EC 1165-2-217, Review Policy For Civil Works, 20 February 2018
xii. ER 1110-1-12, Quality Management, 31 March 2011
xiii. ER 415-1-11, Biddability, Constructability, Operability, Environmental and Sustainability (BCOES) Reviews,1 January, 2013
xiv. EM 1110-2-1418, Channel Stability Assessment for Flood Control Projects, 31 October 1994
xv. EM 1110-2-2502, Retaining and Flood Walls, 29 September 1989
xvi. EM 1110-2-2504, Design of Sheet Pile Walls, 31 March 1994
xvii. EM 1110-2-2902, Conduits, Culverts, and Pipes, 31 March 1998
xviii. ETL 1110-2-583, Engineering and Design: Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures
xix. U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC), Hydrologic Modeling System HEC-HMS User's Manual, CPD-74A, Hydrologic Engineering Center, Davis, CA.
xx. U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC), HEC-RAS River Analysis System User's Manual, CPD-68, Hydrologic Engineering Center, Davis, CA.