HALFF

Lower South Mayde Creek (U101-00-00) Bypass Channel and Channel Improvements Preliminary Engineering Report

Prepared for:

HARRIS COUNTY FLOOD CONTROL DISTRICT

HCFCD Project ID# U101-00-00-P003

Prepared by:

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Executive Summary

The South Mayde Creek watershed has experienced repeated structural and roadway flooding over the past decade. A feasibility study that focused on assessing existing conditions and identifying alternatives to reduce the depth, duration, and frequency of structural and street flooding within the watershed was submitted to Harris County Flood Control District (HCFCD) in January 2017.

Halff was selected to complete a PER for the conveyance capacity improvements, building on the work completed during the feasibility phase through the incorporation of newly collected data and additional detailed H&H modeling. The specific objectives of the PER study included the following:

- Reduce flooding along South Mayde Creek by lowering peak flows and water surface elevations
- Identify potential projects that minimize environmental impacts (self-mitigating if possible) and have low maintenance requirements with appropriate access
- Reduce the potential for sedimentation and erosion along South Mayde Creek by keeping velocities within an acceptable, stable range
- Improve hydraulic conveyance without producing adverse impacts in the form of increases to water surface elevations or peak flow
- Identify a permitting strategy related to Section 404/408 permits required for the proposed improvements

Data collection activities included a geotechnical investigation, survey of channel and structures, geomorphic assessment of South Mayde Creek, and an environmental field delineation. The existing conditions assessment involved converting the feasibility study hydraulic model to 1D/2D unsteady state to provide a more accurate representation of overland flow patterns and inundation extents. No subbasin boundary adjustments or hydrologic parameter calculations were done as part of this PER.

The recommended improvements outlined in the feasibility study were used as a starting point, and modifications were made based on newer collected data or constraint information, such as existing infrastructure or Right-of-Way (ROW) boundaries that could have an impact on the layout and functionality of proposed improvements. This PER study focused on two primary and two secondary flood reduction improvements:

Primary Drainage Improvements

- Conveyance capacity improvements to South Mayde Creek (Fry to Greenhouse Road)
- Construction of a bypass channel north of Cullen Park (Greenhouse to Barker Cypress Road)

Secondary Drainage Improvements

- Regional detention basins (between Morton and Fry Road)
- Replacement of the Greenhouse Road bridge

Eleven scenarios grouped into three alternatives were evaluated through detailed hydraulic modeling and calculation of flood evaluation metrics. The alternatives progressively added different improvements to evaluate the flood risk reduction effectiveness and potential benefits incrementally. While all the evaluated scenarios reduced WSELs to varying degrees, these potential benefits were weighed again potential impacts and other considerations, including estimated costs, environmental or permitting requirements, ROW acquisition, and constructability challenges). Based on the analysis performed, Halff recommended the following:

- Alternative 2, Scenario 1 be moved forward into design in the short-term
    - Channel conveyance improvements between Fry and Greenhouse Road that consist of a benched trapezoidal widening of the channel within the existing ROW
    - Regional detention basins between Morton and Fry Road (2 basins south of Mayde Creek)
- Alternative 2, Scenario 2 be focused on for future design in the long-term
    - Channel improvements and regional detention as described for Alternative 2, Scenario 1
    - Bypass channel between Greenhouse and Barker Cypress Road
    - Sedimentation basins located just upstream of Greenhouse Road

The estimated costs for Alternative 2, Scenario 1 and Scenario 2 are $20.2M and $31.8M. The cost estimates included typical construction and site preparation items, ROW acquisition, engineering design (15% of construction costs)/construction management (8% of construction costs), and a 20% contingency. The ROW costs assumed the channel improvements and bypass channel would be constructed on either existing HCFCD ROW or within USACE property, where in both cases there be no cost to acquire the land needed for construction. ROW acquisition costs have been included for the sedimentation basins, but not for the regional detention basins based on costs provided from the detention basins PER consultant.

A summary of expected benefits for the short-term and long-term recommendation is provided below:

- Alternative 2, Scenario 1
    - Average WSEL reduction between Fry and Greenhouse Road of 0.1-1.8' for the 10% AEP event and 0.1-1.9' for the 1% AEP event
    - 17 structures removed from the 10% AEP event inundation and 841 structures removed from 1% AEP event inundation
- Alternative 2, Scenario 2
    - Average WSEL reduction between Fry and Greenhouse Road of 0.9-2.3' for the 10% AEP event and 0.8-2.3' for the 1% AEP event
    - 32 structures removed from the 10% AEP event and 1,203 structures removed from 1% AEP event inundation

The results from the impact analysis developed in conjunction with the USACE indicated that both recommendations do not result in an adverse change in peak flow rate or rate-of-rise for the Addicks Reservoir. Given the recently complete desilting efforts along South Mayde Creek, another proposed conditions scenario was modeled to evaluate if the excavated sediment would remove the WSEL impacts; the modeling results showed that the WSEL impacts were lessened in some areas but increased in others.

The effect of the Barker Cypress Road bridge should also be further investigated due to its location between the end of the bypass channel and the main storage pool of the Addicks Reservoir. Although the modeling indicated minor WSEL increases at certain locations along South Mayde Creek exist during the 1% and 0.2% AEP events, the alternative analysis demonstrated the potential benefit of a comprehensive flood risk reduction strategy combining multiple drainage improvements. These improvements could be implemented in phases as funding becomes available such that short-term flood risk reduction is achieved while also creating the framework for a long-term solution to flooding on South Mayde Creek.

1.0 Introduction

Halff Associates, Inc. (Halff) was contracted by the Harris County Flood Control District (HCFCD) to develop and evaluate alternatives to reduce existing flood risk along Lower South Mayde Creek (HCFCD Unit U101-00-00). The proposed improvements that are the primary focus of this study are located between Fry Road and Barker Cypress Road along the western side of the Addicks Reservoir in Harris County, Texas. Additional complementary improvements in the form of regional detention basins are located upstream along South Mayde Creek between Morton Road and Fry Road. The project location is shown below as **Figure 1**. The project study area is illustrated in **Exhibit 1.**

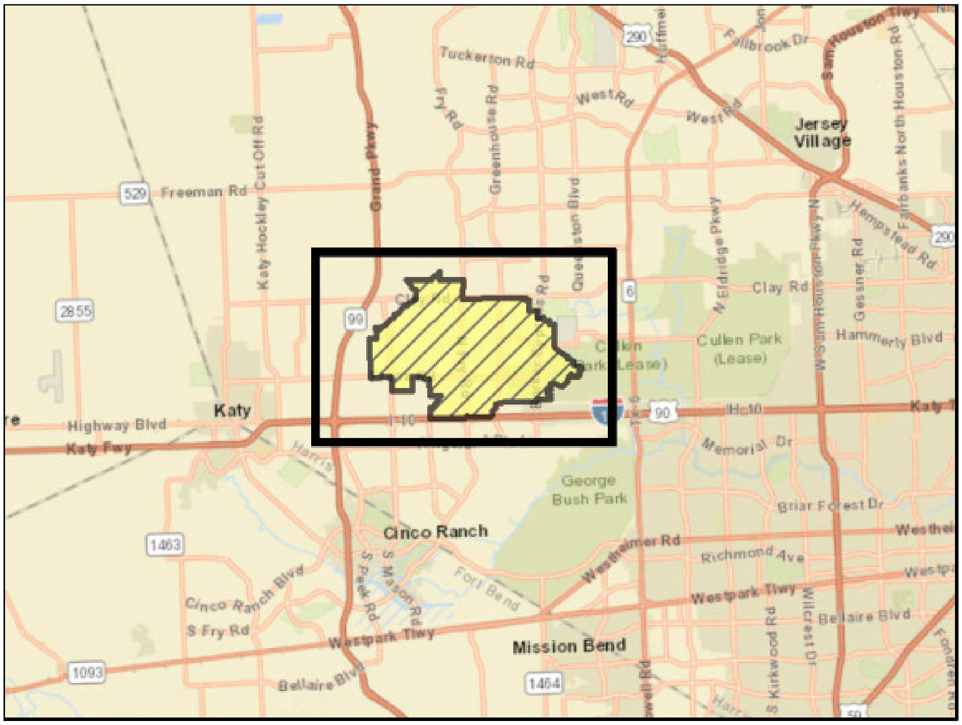


Figure 1: Project Location Map

1.1 Purpose

The purpose of the project is to lower water surface elevations along South Mayde Creek to reduce existing flooding issues. This is accomplished by adding conveyance capacity through channel conveyance improvements and a bypass channel. This study serves as a continuation and refinement of the alternative development and analysis performed as part of the *Lower South Mayde Creek Drainage Feasibility Study* (HDR 2017).

HCFCD has also recently completed an evaluation of regional detention basins with the similar goal of reducing future flood risk along South Mayde Creek by reducing downstream peak flow rates. Brooks and Sparks was engaged by HCFCD to prepare a Preliminary Engineering Report (PER) for the detention basins located further upstream from the improvements being evaluated in the Halff PER. HDR, Inc. (HDR) was engaged by Brooks & Sparks, Inc. (BSI) to perform the H&H analysis for the detention basins. The detention analysis performed by HDR and the H&H alternative analysis performed by Halff have been completed concurrently in a coordinated effort.

1.2 Background

The South Mayde Creek watershed has experienced repeated structural flooding over the past decade. In addition, frequent inundation of roads and shallow ponding is prevalent within the area. HCFCD contracted HDR, Inc. (HDR) to complete a feasibility study for the South Mayde Creek watershed and present planning level alternatives to reduce flood risk long-term. The feasibility study was submitted to HCFCD in January 2017. The report documented existing conditions flooding issues and identified several alternatives to reduce depth, duration, and frequency of structural and street flooding within the watershed.

Halff was selected to complete a PER for the conveyance capacity improvements that built on the work completed during the feasibility phase through the incorporation of newly collected data and additional detailed H&H modeling.

1.3 Project Objectives

The project objectives are listed below:

- Reduce flooding along South Mayde Creek by lowering peak flows and water surface elevations
- Identify potential projects that minimize environmental impacts (self-mitigating if possible) and have low maintenance requirements with appropriate access
- Reduce the potential for sedimentation and erosion along South Mayde Creek by keeping velocities within an acceptable, stable range
- Improve hydraulic conveyance without producing adverse impacts in the form of increases to water surface elevations or peak flow
- Identify a permitting strategy related to Section 404/408 permits required for the proposed improvements

2.0 Existing Conditions Assessment

2.1 Watershed and Channel Description

The proposed drainage improvements being evaluated are located in the South Mayde Creek Watershed, which is located west of the Addicks Reservoir in western Harris County. South Mayde Creek (U101-00-00) serves as the primary drainage channel for this watershed and extends from upstream of SH 99 near Katy Hockley Cut Off Road to the western edge of the Addicks Reservoir. The South Mayde Creek watershed is shown in **Exhibit 2** and **Figure 2** below.

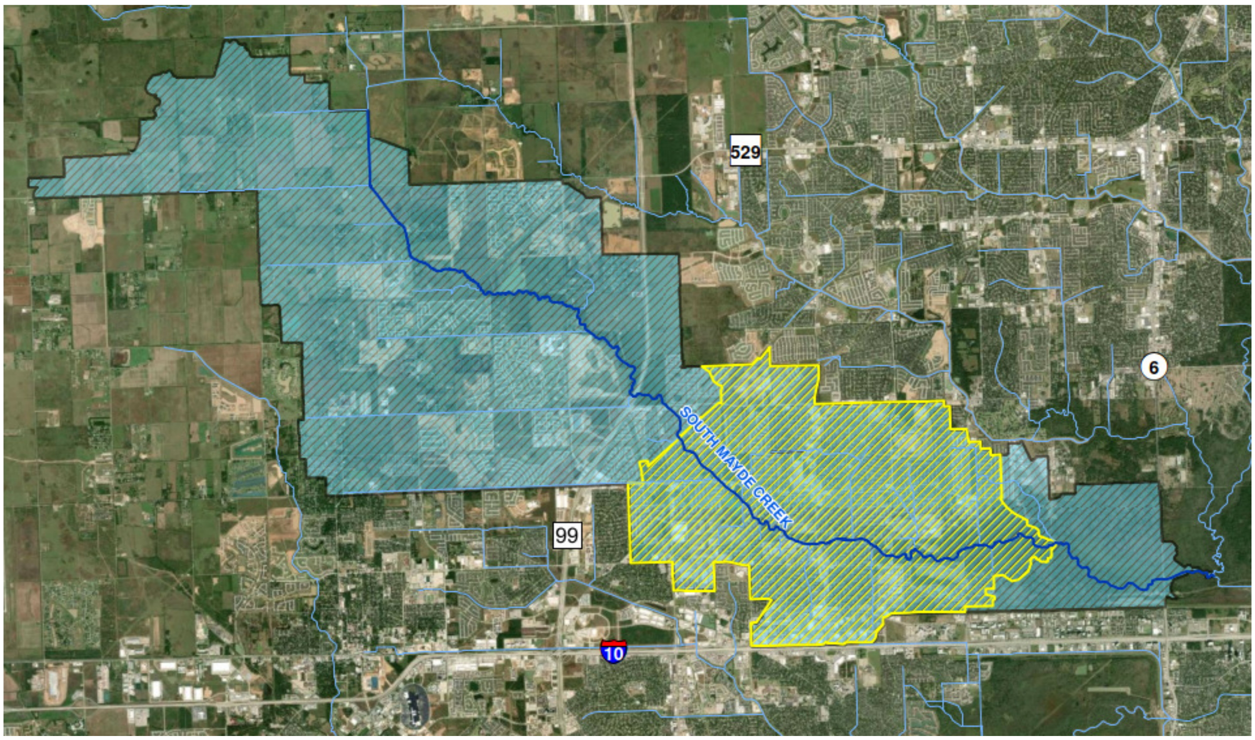


Figure 2: Project Location Map

Watershed characteristics vary throughout the watershed and include:

- **Upstream of Clay Road:** South Mayde Creek remains a sinuous natural channel with heavy vegetation along the banks. The channel upstream of Clay Road has a depth of 10-20 feet and a top width of 50-125 feet. This portion of the watershed has limited impervious cover reflecting lower levels of development, although continued urbanization is expected within this area in the future.
- **Between Clay Road and Greenhouse Road**: South Mayde Creek is a grass-lined, trapezoidal channel. Within this section, the channel depth is approximately 20 feet and the channel top width is approximately 100 to 200 feet. This portion of the watershed is more developed with predominately residential and commercial land uses. Multiple areas of erosion and deposition of sediment were observed within this section of channel.
- **Downstream of Greenhouse Road**: South Mayde Creek transitions back to a natural channel characterized by shallow depths, narrow top widths, and heavy vegetation along the channel

banks and overbanks. Downstream of Greenhouse Road, the channel has a depth of roughly 10 feet and a top width of 40 to 100 feet. This transition from engineered to natural channel creates a restriction to flow and is one of the contributing factors to the flooding in the area. Side slope erosion was also observed in sections of the channel. The channel flows east, meandering south of Cullen Park, before discharging into the Addicks Reservoir.

2.2 Right-of-Way

Harris County Flood Control provided Halff with GIS information for the existing HCFCD Right-of-Way (ROW). The ROW easement varies in width along South Mayde Creek from 80 feet at the upstream end to 300 feet at the downstream end. The east portion of the proposed improvements are located within the Addicks Reservoir on USACE property. Any future construction of drainage projects within the Addicks Reservoir will need to be approved by the USACE and access granted through a temporary construction easement (TCE). The existing HCFCD ROW along South Mayde Creek within the study area as well as the USACE property boundary are shown on **Exhibit 3**.

2.3 Hydrologic/Hydraulic Conditions

Repetitive historical flooding has been documented along South Mayde Creek, including recently:

- Tax Day Flood (2016): Approximately 14” of rainfall in 12 hours across the watershed
- Hurricane Harvey (2017): More than 32” of rainfall over a 5-day period across the watershed

Local neighborhood flooding has been observed even in more frequent events resulting from the high peak stage of South Mayde Creek coupled with the low existing conveyance capacity in some sections of the channel. Inundation of local roadways has also been reported by residents in the neighborhoods surrounding South Mayde Creek, including major thoroughfares through the area such as Greenhouse Road.

2.3.1 Land Use and Hydrology

The South Mayde Creek watershed land use transitions from mostly undeveloped west of SH 99 to primarily residential with pockets of commercial development further east between SH 99 and the Addicks Reservoir. Within the eastern half of the watershed, high levels of existing development and a well-defined drainage network conveying flow into South Mayde Creek contribute to a typical urban drainage scenario including a relatively rapid rise in WSEL. In addition, Cypress Creek overflow often magnifies flooding issues by introducing significant volumes of additional water. Updating existing hydrology was not a focus of this study, and the hydrologic analysis performed from the feasibility study was used without modification.

2.3.2 Hydraulic Restrictions

Previous drainage studies of South Mayde Creek and feedback from HCFCD and Harris County have mentioned several locations where the current channel conditions introduce hydraulic restrictions that hinder the flow of water downstream and result in higher WSELs. One example of these locations is Greenhouse Road where a restriction exists due to a combination of a bridge with relatively low deck elevation and a significant reduction in channel cross-sectional area between the upstream and downstream sides of the structure. There has also been significant sedimentation at points along the channel resulting from severe weather events, including Tax Day 2016 and Hurricane Harvey. This sedimentation further reduces the conveyance capacity of the channel and likely exacerbates flooding along South Mayde Creek.

2.4 Previous Studies, Reports, and Plans

The feasibility study for flood risk reduction improvements was completed by HDR in 2017 and explored various ways to reduce the frequency, depth, and duration of riverine flooding events along South Mayde Creek. The goal of the feasibility study was to achieve a level of protection equal to the 1% AEP storm event. The feasibility study recommended stormwater conveyance improvements for South Mayde Creek downstream of the Grand Parkway to Greenhouse Road and construction of a bypass channel east of Greenhouse Road within the Addicks Reservoir property. The study also considered the potential for future stormwater detention and retention as well as property buyouts. The recommendations contained within the HDR feasibility study were used a starting point for this PER. The HDR feasibility study is provided in **Appendix A**.

2.5 Ongoing and Planned Projects

As recommended in the HDR feasibility study, two regional detention basins were proposed upstream of Fry Road to reduce peak flow rates and water surface elevations downstream. HDR was contracted by HCFCD to perform a PER study for these detention basins. The final PER was submitted in April 2020. Since the regional detention basins being evaluated by HDR were incorporated into the modeling developed for the Halff PER, coordination between HDR and Halff occurred routinely to ensure that the Halff modeling correctly reflected the most current detention basin layouts as well as captured the intended hydraulic design of the proposed basins. The regional detention basins are discussed more in Section 4.4 and are referred to as the HDR detention basins to distinguish them from the detention ponds proposed by Halff to mitigate flow increases associated with the channel conveyance capacity improvements.

HCFCD currently has plans to perform a feasibility study for additional regional detention basins to be located further upstream on South Mayde Creek, just west of SH 99. These regional basins could further reduce peak flows far enough downstream to complement proposed improvements that were evaluated as part of this PER project. The alternative analysis and recommendations developed as part of this report should be reevaluated as part of any planned projects that have the potential to affect the hydrology and hydraulics of South Mayde Creek.

2.6 Utilities in Project Area

Several existing utilities were observed during a review of aerial imagery and the site reconnaissance visit. In an effort to identify utility conflicts that may impact the feasibility/cost of the proposed improvements, Halff performed a subsurface utility engineering (SUE) investigation of Quality Level C & D along South Mayde Creek in accordance with ASCE CI/ASCE 38-02 (Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data). Halff completed utility research using publicly available GIS data, like the Texas Railroad Commission GIS map, and the One Call system to identify potential utility companies in the area. These companies were contacted and records requested to obtain utility location and elevation information. Halff then produced a CAD drawing which showed approximate utility location and compiled utility owner contact information in a spreadsheet for future reference. Utilities identified from the SUE investigation are shown in **Exhibit 4**. Several gas lines, multiple overhead electric lines, and a water lines were located, particularly adjacent to existing bridges, but no major utility conflicts that would have a significant impact on the feasibility of constructing the proposed improvements were identified. Some modification of the existing pipeline crossings may be required to accommodate the drainage improvements; for example, changes could be required to the supports of pipelines crossing Mayde Creek to allow for widening of the channel.

2.7 Geotechnical Investigation

A geotechnical investigation was conducted by Aviles Engineering Corporation (AEC) for the proposed improvements of South Mayde Creek between Fry Road and Barker Cypress Road. The final geotechnical report (AEC Report No. G125-18, dated March 5, 2020) is presented in **Appendix B**.

AEC drilled a total of twenty-two (22) soil borings to depths ranging from 25 to 50 feet below existing grade, as shown in **Exhibit 5**. Clayey and granular (i.e. sand and silt) soils were encountered throughout the borings; however, the amount of granular soils was significant in many locations. No signs of visual staining or odors were encountered during field drilling or during processing of the soil samples in the laboratory.

AEC performed slope stability analyses on selected cross-sections for the channel improvements between Fry Road and Greenhouse Road and the proposed diversion channel between Greenhouse Road and Barker Cypress Road to determine if the proposed slopes will be stable. Based on the slope stability analyses performed for the Mayde Creek channel improvements and diversion channel, a H:V = 4:1 slope generally meets HCFCD minimum safety factor requirements under short term, long term, and rapid drawdown conditions.

Granular soils are anticipated to be present within the channel along most of the project alignment; granular soils were encountered in Borings B-1 through B-7, B-9, B-11, B-12, B-16, and B-20 through B-22. Without erosion protection, such as using riprap, the granular soils in the channel banks and bottom will experience erosion and can result in additional sedimentation downstream. In order to maintain stability where granular soils are present, AEC recommends the use of a 2-foot-thick rip rap layer (wrapped with filter fabric, and then with 8 to 12 inches of topsoil on top) on the upper side slopes of the channel. If budget allows, a 2-foot-thick riprap layer should also be used on the lower side slopes and channel bottoms whenever granular soils are present. Rip rap is not required whenever cohesive soils are present on the slopes.

The soils within the location of the channel improvements and bypass channel consist of non-dispersive to highly dispersive clays. Intermediate to highly dispersive clayey soils are highly susceptible to reacting with certain ions that are present in either surface runoff or groundwater and can dissolve and erode over time. Wherever encountered during construction within the channel sides slopes or bottom, AEC recommends that a minimum of 3 foot of exposed dispersive clay soils be over-excavated and then replaced with compacted select fill. An additional measure to counteract the high erosion potential of dispersive soils is to reduce the amount of surface sheet flow that will across the channel top bank. AEC also recommends adding backslope interceptor swales along both sides of the channel in the vicinity of dispersive soils and reducing the spacing of interceptor outfalls to make them closer together.

2.8 Geomorphic Considerations

Stantec evaluated the feasibility of incorporating a geomorphic channel into the bypass channel following the HCFCD draft guidelines for Natural Stable Channel Design (NSCD). The final geomorphic field investigation report is provided in **Appendix C**.

Stantec performed a field reconnaissance of the study area for Lower South Mayde Creek location in Houston, Texas on August 15, 2018. The study area began upstream of Greenhouse Road and extended downstream to Barker Cypress Road. The goal of the field visit was to visually observe and document existing stream conditions and stream geomorphology. Field observations indicated the following:

- Upstream of Greenhouse Road, the flood control channel contains an inset smaller channel. The channel transitions abruptly to a natural channel downstream of the Greenhouse Road bridge. At this location, the left bank is eroding, and the floodplain is constricted causing backwater to occur.
- Between Greenhouse Road and Park Road, the channel is entrenched, and the stream banks are composed of sandy material. Entrenchment refers to the vertical containment of a channel relative to the surrounding terrain. An entrenched channel occurs when the stream is connected to the floodplain such that higher flows result in water spreading out farther from the channel to create a wider flood prone area. Little to no vegetation is present on the stream banks. The channel bed slope is relatively flat and consists of medium to fine sand.
- Between Park Road and Groeschke Road, the channel is less entrenched and can access a vegetated floodplain bench. An unnamed tributary enters the channel and transitions from grass swale to natural stream channel. Stantec did not investigate the unnamed tributary further.
- From Groeschke Road to Barker Cypress Road, the channel again becomes entrenched with conditions similar to Greenhouse Road to Park Road. The overall area around the channel consists of mature forest.

Stantec performed an analysis of the streamflow record at USGS stream gage and reviewed the geomorphic indicators of the bankfull flow (Q_{BKF}) in South Mayde Creek. These observations were coupled with the results of the Halff HEC-RAS hydraulics model for South Mayde Creek and the USGS Stream gage analysis to estimate a Q_{BKF} of South Mayde Creek within the project area of approximately 357 cfs.

Stantec provided Halff with preliminary sizing, conceptual layout feedback, and typical cross-section details to be used in the development of modeling for the proposed bypass channel. More information on the preliminary design, NSCD recommendations, and future design considerations is provided in Section 4.3.5.

2.9 Environmental Assessment and Permitting Considerations

This PER study focused on two primary proposed projects for flood reduction:

- Conveyance capacity improvements to South Mayde Creek (Fry to Greenhouse Road)
- Construction of a bypass channel north of Cullen Park (Greenhouse to Barker Cypress Road)

Since these projects include proposed improvements to an existing stream, there are several environmental considerations that must be identified and managed during the project. These considerations include the presence of jurisdictional Waters of the United States (WOTUS) including wetlands, cultural resources that may be present along the stream, and threatened and endangered species or habitat along the study area, all of which must be evaluated as part of the Section 404 Permitting requirements, regardless of ownership.

Additionally, the proposed bypass channel lies within the Addicks Reservoir, a United States Army Corps of Engineers (USACE) Civil Works project. The USACE may grant permission for another party (in this case HCFCD) to alter a Civil Works project under a Section 408 Permit upon the determination that the alteration proposed will not be injurious (likely to cause damage or harm) to the public interest and will not impair the usefulness of the Civil Works project. Part of this analysis will include a consideration of environmental impacts under the National Environmental Policy Act (NEPA) and environmental clearance, with the USACE acting as the lead federal agency and HCFCD being the local project sponsor. Additionally, pursuing the Section 408 permit authorization would include a multi-phased review period by USACE to evaluate the effects of the proposed alteration including but not limited to technical analysis and design review, hydrology and hydraulics review, Safety Assurance Review (SAR), Environmental/Cultural review, Real Estate Requirements, and development/review of Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) plans.

Halff performed a wetlands delineation, a preliminary jurisdictional determination, and a desktop threatened and endangered species habitat assessment within the study area. In addition, a cultural resources assessment was performed by a subcontractor, Moore Archeological Services (MAC).

2.9.1 Phase I Environmental Site Assessment (Phase I ESA)

No Phase 1 was completed as part of this PER. If additional ROW acquisition is pursued for the implementation of the proposed improvements, a Phase 1 ESA will need to be completed.

2.9.2 Waters of the United States (WOTUS) & Wetlands

Halff performed a Section 404 jurisdictional determination and wetlands identification and delineation of the study area. During the field work, Halff observed three perennial stream reaches, five intermittent streams, one ephemeral stream, two ditches, twelve emergent wetlands, three forested wetlands, and three scrub-shrub wetlands. It is Halff's opinion that the perennial streams, intermittent streams, ephemeral stream, wetlands, and one ditch features would be considered jurisdictional and therefore regulated by the USACE. Halff has submitted a preliminary jurisdictional determination (PJD) form to the USACE for concurrence of jurisdictional waters (WOTUS) within the study area. A verification site visit with the USACE and HCFCD occurred on January 17, 2019. A revised delineation report and PJD form were then provided to HCFCD in February 2019 for submittal to the USACE. Environmental field delineation report and PJD forms are included as **Appendix D**.

It is anticipated that because of the location and extent of the aquatic resources observed within the study area, any proposed project alternative would result in a regulated activity within WOTUS. Regulated activities (i.e. discharge/placement of dredged or fill) in WOTUS require authorization from the USACE under a Section 404 permit. The appropriate permitting mechanism will be dependent on the selected project alternative and final design as well as the project's purpose, need, and the extent of impacts to WOTUS. Projects impacting less than 300 linear feet of stream or 0.5 acre of wetlands are typically permitted under the USACE's Nationwide Permit Program. For projects exceeding these impact thresholds, a Standard Individual Permit would likely be required. Additionally, projects exceeding 1/10th acre of impact would typically require compensatory mitigation to offset the loss of aquatic function. In some cases, mitigation may not be required, even for extensive impacts to aquatic resources, if the permittee can demonstrate no loss, or a net-gain, in the function and extent of WOTUS. An example of this would be incorporating Natural Stable Channel Design (NSCD) features into the proposed design, as was done for the bypass channel and discussed in Section 4.3.5.

2.9.3 Cultural Resources Assessment

As part of the environmental data collection and assessment process, an archeological investigation was performed. In order to facilitate the project goals, the archeological investigation was split into two distinct projects based on permitting requirements.

- Western project area between Fry and Greenhouse Roads (MAC Project #18-33)
- Eastern project area between Greenhouse and Barker Cypress Roads (MAC Project #18-34)

This division was made because the western project area is located within an HCFCD ROW whereas the eastern area is within USACE property. As the HCFCD is a political subdivision of the State, the project was subject to review under the Antiquities Code of Texas (ACT) and field investigations required a Texas Antiquities Committee (TAC) permit. The eastern portion is located on U.S. Army Corps of Engineers (USACE) owned lands (Cullen Park) and required an Archaeological Resources Protection Act (ARPA) permit and USACE coordination prior to conducting field investigations. Both final cultural investigation reports are provided in **Appendix E**.

Western Project Area Cultural Investigation

The western project area is approximately 1.06 miles in length and impacted approximately 37.6 acres along South Mayde Creek. The field investigations, conducted under TAC Permit No. 8580, were carried out on October 3rd and October 4th, 2019.

The area along South Mayde Creek has been altered by stabilization and channelization projects. These improvement efforts were undertaken in the 1970's and included the construction of low-lying earthen berms to restrict flood waters. Additionally, both banks of the creek had been modified (leveled) to support pedestrian traffic along multi-use, asphalt trails. PVC piping for sprinkler systems, concrete culverts for storm water drainage, path lights, and other recreational equipment are located within the proposed project area. A total of thirty-six shovel tests were excavated. No cultural materials were identified; therefore, no additional archeological investigations were recommended for this portion of the project area.

Eastern Project Area Cultural Investigation

The eastern portion of the project area extends approximately 5,600 feet along South Mayde Creek, between Greenhouse and Barker Cypress Roads. After initial consultation with USACE prior to the field investigation, the field methodology was expanded to include investigations of pimple mounds by excavating two shovel tests per mound, a site revisit, and shovel testing along the northern boundary to ensure that a nearby archeological site did not extend into the project area. This more intensive methodology exceeded Council of Texas Archeologists (CTA) and Texas Historical Commission (THC) minimum survey standards. An ARPA permit application was submitted and signatures were received on February 5, 2019. Field investigations were conducted under ARPA permit number DACQ6-4-19-338. MAC archeologists were able to conduct field investigations between February 20 and March 8, 2019.

The intensive archeological survey included both surface and subsurface investigations, shovel tested two possible pimple mounds, and identified modern cultural material likely associated with recent flood events. A total of 171 shovel tests and one test unit were excavated over the course of the survey. Field investigations assessed potential impacts to an existing archeological site (41HR612) and had the potential to impact a second site (41HR436). Archeological site 41HR436 is a prehistoric site that is listed on the National Register of Historic Places. Shovel testing was conducted along the northern boundary of the project area determined that the site will not be impacted by the proposed undertaking. Site 41HR612 was re-visited during the survey, and identified through surface survey, shovel test delineation, and the excavation of a single 1-meter by 1-meter test unit to determine the overall integrity of the site. This site was first identified as a scatter of refuse at the start of a slough that drained into South Mayde Creek. The results of the site re-visit showed that flood events had intermixed modern materials in with the older deposits. This includes glass, aluminum cans, plastics, Styrofoam, and plastic-coated wire. Therefore, MAC did not recommend the site as eligible for listing on the National Register of Historic Places (NRHP).

Field investigations found that the far western portion of the APE, along with Site 41HR612, had been impacted by Hurricane Harvey. In the west, especially in the vicinity of South Mayde Creek, shovel tests indicated that fine sandy loam and sand had been deposited across the area. These included mounded deposits adjacent to berms of mounded materials, which were often found trapped in dense vegetation or around trees. A buried organic layer composed of leaves were identified in shovel tests in close proximity to South Mayde Creek. No pimple mounds were observed in this area. Moving eastward, soils transitioned to clay loam and clay, reflecting this area's history of rice cultivation. Two possible pimple mounds were observed to the east of Groeschke Road; however, these did not produce any cultural materials. Based on the results of field investigations, no additional archeological investigations were recommended within the project area. An assessment of shallowly buried deposits and surface impacts found that the integrity of these deposits had been affected by previous flood events. This includes the deposition of soil along the channel of South Mayde Creek and the redistribution of modern cultural materials across the entirety of the APE.

2.9.4 Threatened and Endangered (T&E) Species

Halff performed a Threatened and Endangered (T&E) evaluation of the study area to determine if preferred habitat or designated critical habitat for any listed species is present and whether any listed species is likely to occur. Species listed as threatened or endangered by the U.S. Fish and Wildlife Service (USFWS) are provided full protection under the Endangered Species Act (ESA) including a prohibition of indirect take such as destruction of known critical habitat (i.e., areas formally designated by USFWS in the Federal Register). The results of the evaluation recommend a no-effect determination for federal-listed threatened or endangered species. However, it should be noted that the determinations and recommendations herein are based on the best available data and are subject to modification based on further field verification and the publication of revised data from the USFWS. Additionally, the perennial and intermittent tributaries observed within the study area may provide suitable habitat for state-listed threatened freshwater mussels including sandbank pocketbook (*Lamsilis satura*) and Louisiana pigtoe (*Pleurobema riddelii*). Prior to conducting work within these channels, coordination with the Texas Parks and Wildlife Department's Kills and Spills Team for a mussel survey and/or Aquatic Resource Relocation Plan may be necessary. Halff's T&E memorandum is included as **Appendix F**.

2.10 Summary of Existing Conditions and Constraints

The South Mayde Creek watershed has a well-documented history of flooding that is caused by several key factors, including sections of channel with inadequate existing conveyance capacity and hydraulic restrictions that hinder the effective moment of water eastward into the Addicks Reservoir. Significant erosion and sedimentation in segments of the channel also have contributed to flooding issues.

Given the presence of environmentally sensitive areas along and adjacent to South Mayde Creek, consideration of environmental mitigation will be an important factor in the selection of any proposed alternative. Environmental permitting will also be key component during the design phase, especially for the bypass channel construction on USACE property. Given the presence of granular, sandy soils in the project area, incorporation of erosion control measures, such as placement of riprap, will be an important consideration to minimize the potential for future erosion and sedimentation within the channel.

Part of the USACE permitting process will require detailed H&H analysis to demonstrate no adverse impact to the Addicks Reservoir; this impact analysis will be additional to the standard identification of any WSEL increases throughout the project extents and within the upstream and downstream vicinity. Given the recommended improvements from the HDR feasibility study, evaluation of potential impacts and identification of alternatives where these impacts are mitigated will be critical. This PER provides the detailed H&H analysis necessary to demonstrate which propose scenarios will result in no adverse impacts.

ROW availability will be a significant constraint of the proposed projects. The channel conveyance improvements upstream of Greenhouse Road are to be located wholly within the existing HCFCD ROW. No additional ROW is expected to be acquired. As such, both the channel augmentation and the walking trail replacement will need to fit in the existing ROW. The proposed bypass channel is planned to be located within the Addicks Reservoir and adjacent to a City of Houston Park, which is leased by the City from USACE. HCFCD will need to enter into an agreement with USACE to utilize the property within the Addicks Reservoir for the bypass channel. In both cases, existing features such as channel confluences and walking trails will require consideration to ensure that existing drainage patterns are appropriately maintained, and community amenities are not negatively impacted.

3.0 Hydrology and Hydraulics

After the data collection phase of the project was completed, the primary effort shifted to performing the alternative analysis. The alternative analysis involved an analysis of both existing and proposed conditions drainage through the development of detailed H&H modeling. The models that were developed as part of this PER study formed the basis for estimation of both potential impacts in the form of peak flow and WSEL increases and potential benefits in the form of WSEL reduction.

3.1 Hydrology

The existing hydrologic model developed by HDR as part of the 2017 feasibility study was used as the basis for the development of existing models for this PER study. No subbasin boundary adjustments or hydrologic parameter calculations were done as part of this PER study; the HEC-HMS model provided by HDR was used without modification.

3.1.1 Subbasins and Peak Flow Calculation

HEC-HMS subbasins U101E and U101F encompass the proposed projects in the study area.

- Subbasin U101E contains all drainage from Morton Road to the confluence of South Mayde Creek and tributary U101-03-00. It contains a few significant tributaries to South Mayde Creek including U101-05-00, U101-06-00, and U101-19-00.
- U101F continues from the confluence of U101-03-00 into the Addicks Reservoir. U101F contains the tributaries U101-02-00 and U101-01-00.

Both subbasins are largely developed by residential areas mixed with some commercial and U101F contains large undeveloped areas within the Addicks Reservoir. Existing subbasins are shown in **Exhibit 6** and below in **Figure 3**.

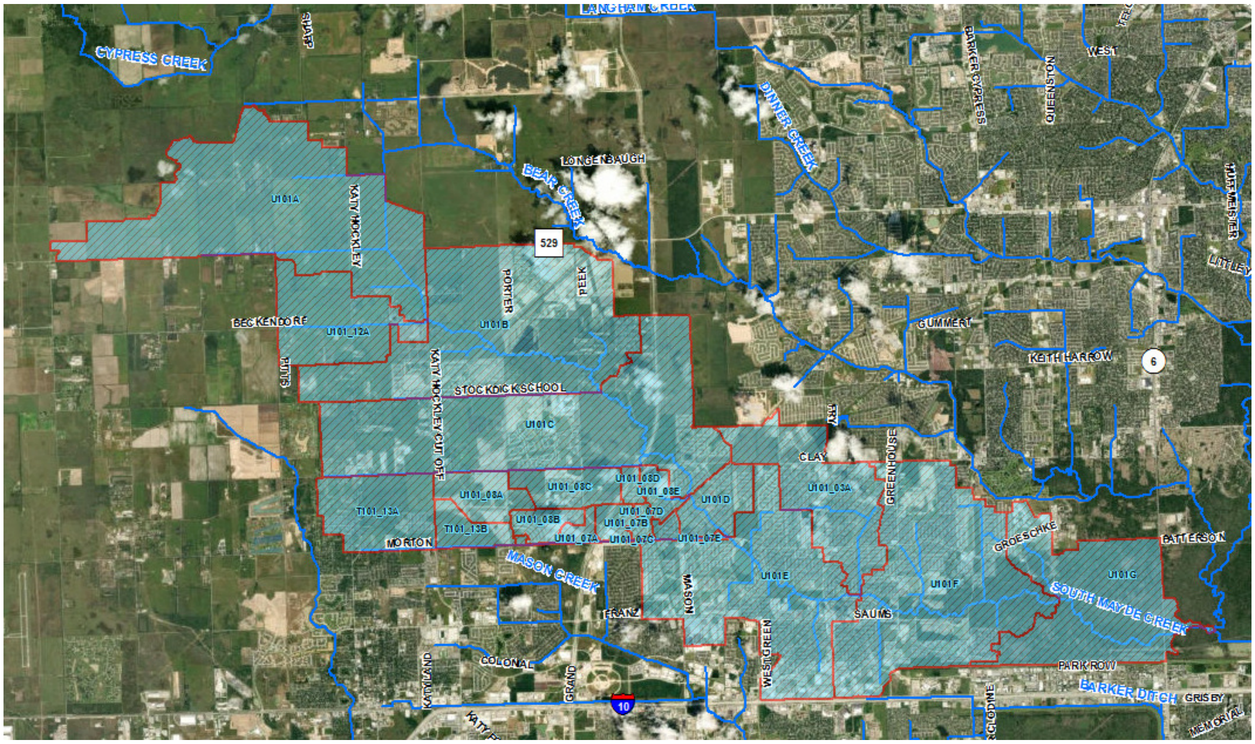


Figure 3. Effective Subbasin Boundaries

The effective subbasin boundaries were checked against 2018 LiDAR and aerial imagery. No significant changes to the subbasins were identified so the effective subbasins were used without modification. In order to more appropriately distribute the flow within the study area and more accurately apply the flow within the unsteady state hydraulic models, the effective subbasins were further subdivided. These subdivided areas were referred to as Flow Application Areas (FAAs). The subbasins were divided such that individual hydrographs could be generated for each location where flow was to be entered in the hydraulic model. These FAA hydrographs were developed by using the area ratio of the FAA to the overall corresponding subbasin. The total area, area ratios, and peak flow rates for these subbasins and FAAs are summarized below in **Table 1** and are shown in **Exhibit 7**.

Table 1: Summary of Flow Application Areas (FAAs) Area and Peak Flow

Effective Subbasin	Flow Application Area	Area (mi²)	Percent Area	Peak Flows (cfs)	Total Area (mi²)
U101F	U101F	0.59	10.88%	2,103	5.45
	U101F_H	0.14	2.66%		
	U101F_G	0.26	4.73%		
	U101F_F	0.33	6.08%		
	U101F_E	0.17	3.14%		
	U101F_D	0.64	11.75%		
	U101F_C	0.81	14.78%		
	U101F_B	1.73	31.67%		
	U101F_A	0.78	14.31%		
U101E	U101E	1.32	28.45%	2,816	4.64
	U101E_C_1	0.11	2.29%		
	U101E_C_2	0.85	18.26%		
	U101E_C_3	0.06	1.20%		
	U101E_C_4	0.07	1.46%		
	U101E_C_5	0.10	2.10%		
	U101E_C_6	0.56	12.16%		
	U101E_B	0.52	11.25%		
	U101E_A	1.06	22.83%		
U101_03A	N/A	2.31	100%	1,369	2.31
U101D	U101D	0.48	68.32%	739	0.70
	U101D_A	0.22	31.68%		
U101_07E	N/A	0.14	100%	246	0 .14
All Upstream	N/A	25.46	100%	6,267	25.46

3.2 Hydraulics

HDR provided Halff with their HEC-RAS model from the feasibility study. This hydraulic model was used as the starting point for the development of revised hydraulic models as part of the PER. The revised existing hydraulic models served as the baseline for comparison to the proposed conditions alternatives.

3.2.1 Existing Conditions Modeling

The existing conditions hydraulics task involved updating the HDR feasibility study hydraulic model by converting it to a 1D/2D unsteady state to provide a more accurate representation of overland flow patterns and inundation extents. The methodology Halff used to develop their existing conditions models is described in more detail in the following sections.

Based on discussions with HCFCD, Halff planned to develop two existing conditions hydraulic models. One model focused on incorporating the new survey data that would reflect the sedimentation observed along South Mayde Creek and represent an "as-is" condition. The other focused on representing the channel assuming that planned desilting maintenance work was performed and the channel was returned to its former cross-sectional shape. The two existing conditions models are described more in **Table 2** below.

Table 2: Existing Conditions Model Descriptions

Model Name	Description	Base Model	Terrain Source
Existing_Converted	Direct conversion of HDR model	HDR steady state model	Channel cross-sections from HDR RAS model; 2008 LiDAR in overbanks
Existing_AsIs	Adding new survey to Existing_Converted model; add 2D areas	Halff Converted unsteady state 1D/2D model	New survey for channel cross-sections; 2018 LiDAR in overbanks

The revised existing hydraulic model extends from approximately 1,000 feet upstream of Lakes of Bridgewater Road to slightly more than 1 mile downstream of Barker Cypress Road into the Addicks Reservoir. The total modeled length of South Mayde Creek was approximately 5.75 miles. The extents of the model were chosen to provide enough distance upstream and downstream of the proposed improvements to determine if adverse impacts occurred. Development of the model geometry was completed using ArcGIS and HEC-GeoRAS. The 2D portion of the model was developed in accordance with the *HCFCD Two-Dimensional Modeling Guidelines*. A summary of the revised existing hydraulic model development process is presented below. Additional details and technical information are discussed in the *Halff H&H Modeling Technical Memo*, which is presented in **Appendix G**.

The conversion of the HDR 1D steady model to a 1D/2D unsteady model was an iterative process that involved the following main tasks:

- *1D Cross-Section Adjustment*: the cross-sections were truncated to allow for the addition of 2D areas on either side of South Mayde Creek. **Figure 4** below shows the difference between the original cross-sections (green lines) and the truncated cross-sections (red lines). The cross-section layout for the revised existing model is shown in **Exhibits 8A-8G**. Additional cross-sections were added in some areas to increase model instability. Hydraulic parameters were adjusted as necessary to stabilize the model and conform to Section 4.2.1 of the *HCFCD Unsteady Modeling Guidelines*.

Figure 4: Comparison of Original and Truncated Existing Cross-Sections

- *Unsteady Flow Application*: the hydrograph for each FAA was then entered into the hydraulic model in a location that reflected the expected location of where flow entered South Mayde Creek. Flow boundary conditions shown in **Exhibit 9**. The 1D placement of hydrographs was completed as described in Section 2 of the *HCFCD Unsteady Modeling Guidelines*.

- *Addition of 2D Areas*: a 2D mesh was added on both sides of the channel throughout the entire modeled section of South Mayde Creek to reduce the chance of model instability and ensure modeling results of sufficient accuracy for use in the alternative analysis. **Exhibit 10** shows the location of the 1D and 2D modeling areas within the study area.

- *Addition of 2D Model Components*: land use data, terrain data, and a 2D mesh with associated break lines were added to the model geometry. Land use information was based on the 2015 Harris Galveston Area Council (HGAC) land use raster. The terrain data for the Existing_AsIs model used 2018 LiDAR and was supplemented with new survey data where available.

- *Incorporation of 1D/2D Interface*: the internal 1D/2D boundaries were placed along the assumed elevation divide between the channel and overbank areas determined based on LiDAR and survey. The weir coefficients of the lateral structures were set based on what type of flow situation was being represented (i.e. overbank flow or major channel confluence).

- *Downstream Boundary Condition Adjustment*: initially, a rating curve was used as the tailwater conditions to be consistent with the effective model, but model instability prevented this from successfully being implemented. The use of a normal depth boundary condition was explored next using a lower friction slope (when compared to existing terrain) of 0.001% to simulate the backwater effect of Addicks Reservoir pool. After discussion with HCFCD, it was decided that trying to account for the full backwater effect could be too conservative and result in unrealistically higher WSELs in South Mayde Creek given the typical timing and hydraulic behavior of the reservoir. As a result, the three boundary conditions were switched to friction slopes determined from the existing terrain slope (based on 2018 LiDAR) at the downstream end of the model. The energy slopes used in the hydraulic model for are listed below:
    - North 2D area – 0.34%
    - 1D channel – 0.23%
    - South 2D area – 0.22%

Once the existing hydraulic models were developed and the correct flows applied, the models were run for all modeled storm events so the results could be reviewed and tabulated. Any adjustments needed were made to the model and QA/QC comments addressed before the models were finalized.

3.2.2 Existing Modeling Results

Table 3 - Table 5 below include the results of the existing conditions modeling for the 10% AEP, 1% AEP, and 0.2% AEP storm events and provides a comparison to the previous HDR feasibility study existing model results. Comparison locations were chosen at major roadway crossings or confluences. **Exhibits 11-14** show the inundation for the 50% AEP, 10% AEP, 1% AEP, and 0.2% AEP storm events. **Appendix H** includes detailed existing conditions model results for all storm events.

Table 3: Comparison of HDR Feasibility Study and Halff Existing WSELs - 10% AEP Event

Comparison Location	Feasibility	Existing_AsIs	Feasibility vs Existing_AsIs
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	122.59	121.26	-1.33
Fry Road	114.40	113.72	-0.68
Confluence of U101-03 and U101-00	111.60	111.66	0.06
Greenhouse Road	109.57	110.22	0.65
Groeschke Road	107.28	106.21	-1.07
Barker Cypress Road	106.30	104.87	-1.43
Reservoir	99.52	97.93	-1.59

Table 4: Comparison of HDR Feasibility Study and Halff Existing WSELs - 1% AEP Event

Comparison Location	Feasibility	Existing_AsIs	Feasibility vs Existing_AsIs
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	126.37	124.40	-1.97
Fry Road	117.30	116.54	-0.76
Confluence of U101-03 and U101-00	113.95	113.41	-0.54
Greenhouse Road	111.04	111.24	0.20
Groeschke Road	109.27	107.62	-1.65
Barker Cypress Road	108.74	106.33	-2.41
Reservoir	100.80	99.16	-1.64

Table 5: Comparison of HDR Feasibility Study and Halff Existing WSELs - 0.2% AEP Event

Comparison Location	Feasibility	Existing_AsIs	Feasibility vs Existing_AsIs
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	128.06	126.83	-1.23
Fry Road	119.04	117.76	-1.28
Confluence of U101-03 and U101-00	115.53	114.44	-1.09
Greenhouse Road	111.90	112.04	0.14
Groeschke Road	110.25	108.73	-1.52
Barker Cypress Road	109.68	107.32	-2.36
Reservoir	102.40	99.89	-2.51

There are significant WSEL differences between the two existing conditions models, which become more pronounced at the downstream end of the model where South Mayde Creek is most impacted by the backwater from the Addicks Reservoir. There are similar WSEL differences in the range of 1-6 feet on average between the effective model and the Halff existing model. These relatively large differences in WSEL are expected given the change in modeling approach (from steady state 1D to unsteady 1D/2D) as well as changes to the downstream boundary condition (rating curve to normal depth based on terrain).

After coordinating with HCFCD, it was decided that the 'Existing_AsIs' model would be used as the base model for comparison to the proposed modeling developed during the alternative analysis phase of the project. HDR would also use this Halff existing model as the basis for their regional detention basin analysis being performed concurrently with this PER. This decision was made given the uncertainty of the timing for the desilting maintenance activities. As such, the survey collected for the study was incorporated into the model such that the channel would more accurately capture the current existing conditions.

4.0 Alternative Analysis

The primary focus of this drainage study was to refine and reevaluate potential improvements to reduce flood risk along South Mayde Creek. The recommended improvements outlined in the HDR feasibility study were further refined served as a framework for developing a list of proposed alternatives for detailed H&H analysis.

4.1 Assumptions & Constraints

Several assumptions and constraints are listed below:

1. Standard HCFCD guidelines for channel and detention pond design, including acceptable bank, maintenance berm widths, and slopes and backslope swales/structures, were used unless site conditions required otherwise.
2. The HDR feasibility study recommendations served as a framework for developing a list of proposed alternatives for detailed H&H analysis.
3. The bypass channel would be located on USACE property and therefore subject to applicable USACE permitting requirements. The bypass channel would also incorporate NSCD features.
4. Channel improvements between Fry Road and Greenhouse Road will be entirely located within the existing HCFCD ROW and account for the existing walking trails/pedestrian bridge.
5. Demonstration of no adverse impact is prerequisite for a project to be recommended.

4.2 Alternative Analysis

4.2.1 Alternative Refinement

Before hydraulic modeling of the alternatives was completed, details of the proposed improvements, including the location, alignment, dimensions, and type, were further developed. This information was needed to be refined in order to import into HEC-RAS and create the hydraulic model geometry for the different modeled alternatives. The goal of the alternative refinement phase was to modify the preliminary improvement configurations in order to 1) be more appropriately based on specific existing site conditions, 2) increase their flood risk reductive effectiveness, and 3) present cost-effective and constructible solutions to implement.

As previously mentioned, the recommended improvements outlined in the HDR feasibility study were used as a starting point, and modifications were made based on newer collected data or constraint information. Different configurations were developed to provide flexibility in how the proposed improvements could be implemented and evaluate the potential WSEL reduction and impacts of the improvements across a wide range of scenarios.

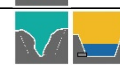
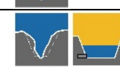
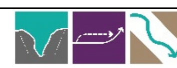
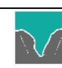
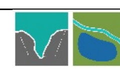
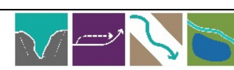
Current existing terrain data (2018 LiDAR and survey data) was reviewed to identify actual channel depths and widths and understand how the proposed improvements could be realistically designed and constructed. Environmental data, specifically OHWM elevations and field delineated wetlands, was used to set the benching elevation for the channel improvements and adjust the bypass channel alignment to minimize environmental impacts.

Information from the site reconnaissance visit was also used to help confirm reported issues such as severe erosion of the channel side banks and the hydraulic restriction near Greenhouse Road. Site visit notes and photographs were helpful during the proposed model development in terms of assessing the feasibility of certain alternatives and understanding how each could be realistically constructed.

Another key part of the alternative refinement process was the identification and consideration of existing site constraints, such as existing infrastructure or ROW boundaries that could have an impact on the layout and functionality of proposed improvements. Examples of this include developing two options for the channel conveyance improvements with different proposed top widths based on avoiding or relocating the existing walking trails along South Mayde Creek and investigating potential layouts for the confluence of U101-01-00 and U101-00-00 if the bypass channel was built.

The modeling matrix lists out the specific scenarios that were evaluated through detailed modeling and provides a summary of the key components of each specific scenario. The proposed modeling matrix is provided below as **Table 6**.

Table 6: Proposed Modeling Matrix

Alternative #	Alternative Name	Alternative Components	Icons
1	Scenario 1A	Channel improvements (full benching)	
	Scenario 1B	Channel improvements (full benching) + detention ponds near GH Road	
	Scenario 1C	Channel improvements (reduced benching)	
	Scenario 1D	Channel improvements (reduced benching) + detention ponds near GH Road	
	Scenario 2	Channel improvements (full benching) + bypass channel	
	Scenario 3	Channel improvements (full benching + Greenhouse bridge	
	Scenario 4	Channel improvements (full benching) + bypass channel + sedimentation basins	
	Scenario 5	Channel improvements (full benching) + completed desilting work	
2	Scenario 1	Full Channel improvements (full benching) + HDR detention basins	
	Scenario 2	Full Channel improvements (full benching) + bypass channel + HDR detention basins + sedimentation basins	
3	Scenario 1	Full Channel improvements (full benching) + bypass channel + sedimentation basins + Greenhouse bridge + HDR detention basins	

Each of the scenarios have been compared to the "Existing_AsIs" condition that was modeled for existing conditions to identify expected WSEL reductions and benefits. In addition to this, comparison tables between scenarios were prepared and can be found in **Appendix I**.

4.2.2 Cost Estimate Development

Cost estimates were developed for each proposed scenario and a total cost for each scenario is provided in the following sections. A more detailed breakdown of total cost can be found in **Appendix J**. The cost estimates included several main categories which are listed below:

1. Construction and site preparation costs
2. Environmental mitigation costs
3. ROW acquisition
4. Professional services costs (as a percentage of total construction cost)
    a. Engineering design (15%)
    b. Construction management (8%)
5. Contingency (20% of total construction cost)

Costs for typical major construction items were determined by calculating quantities and multiplying by a unit price. For proposed scenarios that involved the relocation of the existing walking trails, a high-level planning cost to reconstruct the trails was developed (which equaled approximately $970,000 for just construction), but this cost was not assumed to be funded by HCFCD and therefore not included in the cost estimates. A special item that was factored into the cost estimates was for channel slope stabilization as recommended by the geotechnical consultant which called for a layer of riprap covered in filter fabric with topsoil on top to be installed from the toe to the top of bank of the channel. The installation of this riprap was assumed to be performed along both side of the channel for the entire length of improvements between Fry and Greenhouse Road. Environmental mitigation costs were estimated using a unit price of $30,000 per acres of impact wetlands. Professional services fees were included by utilizing a percentage of the total construction cost.

ROW acquisition costs were based on the most currently available Harris County Appraisal District (HCAD) data with an additional 30% added to account for closing costs and other fees. A “condemned” cost was utilized for the cost estimates, which was equal to two times the voluntary cost from market value plus the additional costs. ROW costs were assumed to be none for the channel improvements and bypass channel as these improvements were proposed either within existing HCFCD ROW or within the USACE property where an inter-agency agreement would need to be created. The cost estimates provided to Halff from the regional detention basin PER consultant did not include ROW acquisition and no separate cost estimation was performed for the regional detention basins specifically.

4.3 Alternative 1 Model Development and Results

Alternative 1 involves the primary improvements recommended from the feasibility study: channel conveyance capacity improvements and a bypass channel. Two different channel benching configurations were evaluated based on whether the existing walking trails along South Mayde Creek would be relocated farther away from the channel to allow for additional widening. The focus of Alternative 1 was on evaluating individual pieces of the overall long-term flood risk reduction solution.

4.3.1 Alternative 1 Scenario 1A: Full Benching Channel Improvements

This alternative involves benching of South Mayde Creek from Fry Road to Greenhouse Road which maximizes the benched width by assuming that the existing walking trails will be relocated.

4.3.1.1 Alternative 1 Scenario 1A: Description of Scenario

This scenario includes only channel improvements from Fry Road to Greenhouse Road with the widened top width transitioning back to the existing width approximately 650 feet upstream of Greenhouse Road. These channel improvements consist of a trapezoidal channel section benched above the OHWM on both sides of South Mayde Creek to minimize environmental impacts.

For Scenario 1A, the proposed channel top width with benching was maximized under the assumption the trails will be relocated farther away from the channel within the HCFCD ROW to allow for additional benching. It was assumed that the relocation of the walking trails would not be completed or funded by HCFCD. The benching width ranges from 10 to 60 feet with 4:1 side slopes back up to existing ground. The depths of the channel range from 7.5 to 12.5 feet which is unchanged from existing conditions. The top width of the channel with the channel improvements ranges from 190 to 215 feet or 250 to 265 feet when a 30-foot maintenance access corridor is included on each side of the channel. A typical section of the proposed channel is shown below as **Figure 5**.

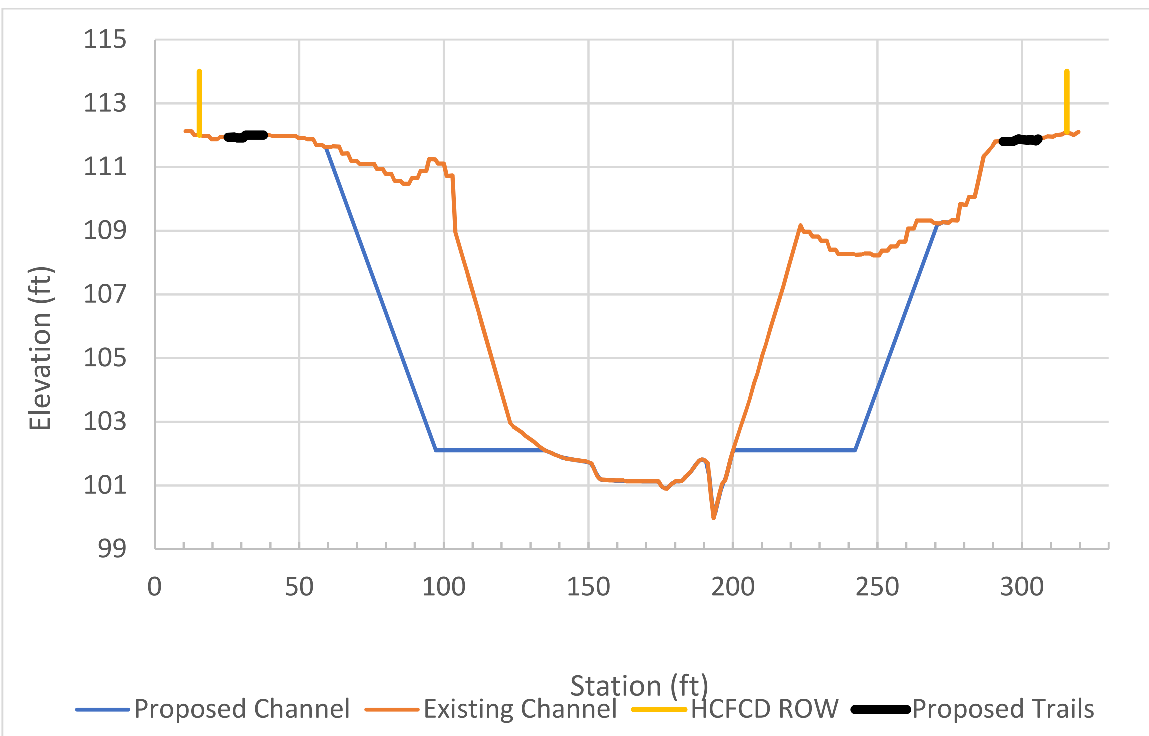


Figure 5: Typical Channel Improvement Section for Alternative 1, Scenario 1A

Based on feedback from the HCFCD and the Harris County Precinct 3, the Heathergold pedestrian bridge was identified as an existing structure not to change unless there was significant hydraulic reason to do so. Existing model results indicated the head loss across this bridge was roughly 0.10 feet which changed to approximately 0.15 feet in Alternative 1, Scenario 1A. Based on this relatively small head loss and preference not to modify the bridge, it was decided to not make any change to the pedestrian bridge and have the proposed channel improvements transition to the existing channel dimensions upstream and downstream of the bridge. The layout of this alternative is included on **Exhibit 15**.

4.3.1.2 Alternative 1 Scenario 1A: Scenario Objective

The goal of this scenario is to increase conveyance capacity within the existing channel to lower the WSEL and reduce the extents of flooding. Implementing benched channel widening has been widely done throughout Harris County and provides flood risk reduction with minimal to no environmental impacts while utilizing only existing HCFCD ROW.

4.3.1.3 Alternative 1 Scenario 1A: Hydraulic Analysis & Results

To develop the proposed channel cross-sections that incorporated benched widening, the Channel Design/Modifications Tool in HEC-RAS was used. **Table 7 - Table 9** provides a summary of the hydraulic model results for the 50%, 10%, and 1% AEP storm events at key comparison locations. **Exhibits 16-18** show the inundation boundaries for the 50%, 10%, and 1% AEP storm events. Detailed results for all modeled storm events are included in **Appendix K**.

Table 7: Alternative 1, Scenario 1A Model Results - 50% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario1a	Existing_AsIs vs Alt1_Scenario1a
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.55	-0.48
Fry Road	111.94	111.04	-0.90
Confluence of U101-03 and U101-00	109.53	109.16	-0.37
Greenhouse Road	108.76	108.68	-0.08
Groeschke Road	104.59	104.53	-0.06
Barker Cypress Road	102.83	102.76	-0.07
Reservoir	95.32	95.25	-0.07

Table 8: Alternative 1, Scenario 1A Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario1a	Existing_AsIs vs Alt1_Scenario1a
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	120.94	-0.32
Fry Road	113.72	112.34	-1.38
Confluence of U101-03 and U101-00	111.66	111.27	-0.39
Greenhouse Road	110.22	110.29	0.07
Groeschke Road	106.21	106.24	0.03
Barker Cypress Road	104.87	104.90	0.03
Reservoir	97.93	97.95	0.02

Table 9: Alternative 1, Scenario 1A Model Results - 1% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario1a	Existing_AsIs vs Alt1_Scenario1a
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.39	-0.01
Fry Road	116.54	115.15	-1.39
Confluence of U101-03 and U101-00	113.41	112.90	-0.51
Greenhouse Road	111.24	111.30	0.06
Groeschke Road	107.62	107.66	0.04
Barker Cypress Road	106.33	106.37	0.04
Reservoir	99.16	99.19	0.03

The model results indicate the channel improvements result in WSEL reductions consistently across the modeled storm events, especially upstream of the confluence of U101-00-00 and U101-03-00. As expected, the highest WSEL reductions occur at or just downstream of Fry Road which corresponds to the beginning of the channel improvements. During the 50% AEP and 10% AEP storms, no increases in WSEL are observed. In storm events equal to or exceeding the 10% AEP, there are minor WSEL increases (< 0.07 feet) beginning at Greenhouse Road and continuing downstream into Addicks Reservoir. This is likely due to the proposed channel transitioning back to existing channel dimensions just upstream of Greenhouse Road.

4.3.1.4 Alternative 1 Scenario 1A: Environmental Considerations

Under this scenario, impacts to WOTUS would be avoided and/or minimized by benching the trapezoidal channel section above the OHWM of South Mayde Creek. To construct this option, temporary discharges or placement of fill into South Mayde Creek might be necessary; however, the benched trapezoidal channel would be designed to result in no net loss in surface area of WOTUS or reduction in function/condition. It is anticipated that minimal/temporary impacts to WOTUS would be authorized under a Nationwide Permit (NWP), likely NWP – 43 (Stormwater Management Facilities). An environmental constraints map is provided for Alternative 1, Scenario 1A as **Exhibit 19**.

4.3.1.5 Alternative 1 Scenario 1A: Right-of-Way Requirements

Construction of this alternative does not require additional purchase of ROW by HCFCD. The proposed channel improvements are located completely within existing HCFCD ROW.

4.3.1.6 Alternative 1 Scenario 1A: Estimated Project Cost

The estimated cost for this scenario is approximately $8.2M and includes the following items:

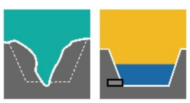
- Construction of channel improvement: $6.9M
  (including 20% contingency and excluding relocation of existing trails)
- ROW acquisition: $0.0M
- Environmental Mitigation: $0.0M
- Professional Services Fees: $1.3M

4.3.1.7 Alternative 1 Scenario 1A: Maintenance & Other Considerations

The standard HCFCD 30-foot wide maintenance access on each side of the channel has been incorporated into the typical section of the proposed channel improvements. The maintenance access corridor would drain via standard HCFCD backslope swales and interceptor pipes.

The existing walking trails are assumed to be demolished and relocated closer to the HCFCD ROW boundary (farther away from the channel) and within the 30-foot maintenance corridor while maintaining a typical 20- to 25-foot buffer from the TOB of the channel. The relocated channel would be located such that there would be space available between the trails and the channel for backslope interceptor swales. The intention would be no trails are within 5 feet of the proposed channel top of bank. The demolition of the existing trails and the construction of new trails has been included in the cost estimate. The existing pedestrian bridge crossing U101-03-00 on the north side of South Mayde Creek was assumed to remain in place with the future trail alignment being adjusted to not conflict with the bridge and thereby minimize construction cost.

4.3.2 Alternative 1 Scenario 1B: Full Benching Channel Improvements with Detention Ponds



This alternative has the same channel improvements in Scenario 1A but incorporates detention basins located just upstream of Greenhouse Road (downstream of the proposed channel improvements).

4.3.2.1 Alternative 1 Scenario 1B: Description of Scenario

Scenario 1B builds on Scenario 1A by adding two detention basins, one on either side of South Mayde Creek in currently undeveloped tracts of land. These detention ponds were assumed to have a trapezoidal inflow weir and outflow culvert (assumed to be a 10’ x 5’ RCB at approximately 0.5% slope). Simplified volume calculations were performed assuming a flat pond bottom and 4:1 side slopes. The north and south detention ponds have approximately storage volumes of 18.2 ac-ft and 91.2 ac-ft, respectively. The layout of this alternative is included on **Exhibit 20**.

Two different pond configurations were evaluated related to the top of bank elevation: 1) raised top bank elevation to divert water at the peak of larger storm events and 2) top bank elevation near existing ground to maintain existing overland flow patterns and mitigate for the channel improvements in lower events. Raising the detention pond top bank above existing ground caused additional impacts to be introduced as existing overland flow patterns were interrupted and the natural storage above the detention ponds footprints was greatly reduced. Ultimately, setting the pond top bank elevation near the existing ground surface was chosen to minimize WSEL increases and avoid any floodplain fill.

4.3.2.2 Alternative 1 Scenario 1B: Scenario Objective

The goal of this scenario is to reduce or eliminate potential impacts caused by the increased conveyance capacity provided by the channel improvements with full benching.

4.3.2.3 Alternative 1 Scenario 1B: Hydraulic Analysis & Results

A preliminary layout of the detention ponds was prepared first to determine the amount of storage volume provided and generate a stage-storage relationship for input into the model. The ponds were added to the HEC-RAS model as 1D Storage Areas. The lateral structures (both along South Mayde Creek and the premiere of the proposed detention ponds) in the model were modified accordingly to reflect the new pond grading as well as the inflow and outfall pond structures.

Table 10 - Table 12 include the results of the hydraulic analysis for the 50%, 10%, and 1% AEP storm events. **Exhibits 21 - 23** show the inundation boundaries for the 50%, 10%, and 1% AEP storm events. Detailed results for all modeled storm events are included in **Appendix L.**

Table 10: Alternative 1, Scenario 1B Model Results - 50% AEP

Comparison Location	Existing_Asls	Alt1_Scenario1b	Existing_Asls vs Alt1_Scenario1b
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.45	-0.58
Fry Road	111.94	110.79	-1.15
Confluence of U101-03 and U101-00	109.53	108.93	-0.60
Greenhouse Road	108.76	108.58	-0.18
Groeschke Road	104.59	104.48	-0.11
Barker Cypress Road	102.83	102.69	-0.14
Reservoir	95.32	95.16	-0.16

Table 11: Alternative 1, Scenario 1B Model Results - 10% AEP

Comparison Location	Existing_Asls	Alt1_Scenario1b	Existing_Asls vs Alt1_Scenario1b
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	121.11	-0.15
Fry Road	113.72	112.23	-1.49
Confluence of U101-03 and U101-00	111.66	111.10	-0.56
Greenhouse Road	110.22	110.26	0.04
Groeschke Road	106.21	106.24	0.03
Barker Cypress Road	104.87	104.89	0.02
Reservoir	97.93	97.95	0.02

Table 12: Alternative 1, Scenario 1B Model Results - 1% AEP

Comparison Location	Existing_Asls	Alt1_Scenario1b	Existing_Asls vs Alt1_Scenario1b
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.65	0.25
Fry Road	116.54	115.00	-1.54
Confluence of U101-03 and U101-00	113.41	112.72	-0.69
Greenhouse Road	111.24	111.25	0.01
Groeschke Road	107.62	107.64	0.02
Barker Cypress Road	106.33	106.35	0.02
Reservoir	99.16	99.17	0.01

The model results for this scenario exhibit a similar pattern to the results from Scenario 1A. In lower storm events, the WSELs decrease for all comparison locations, while in higher storm events there are WSEL increases downstream of Greenhouse Road. While these WSEL increases are minor (< 0.05 feet), the addition of the two detention ponds does not completely mitigate for any adverse impacts from the channel improvements.

4.3.2.4 Alternative 1 Scenario 1B: Environmental Considerations

In addition to the potential minimal/temporary impacts to South Mayde Creek associated with the channel benching under this scenario, construction of the detention basins would likely result in impacts to wetland areas adjacent to South Mayde Creek that would likely be considered WOTUS. To date, a formal wetland delineation has not been conducted within these areas, however preliminary site reconnaissance and LIDAR/aerial review indicate an extensive (±8 acres) emergent/forested wetland complex in the proposed detention area south of the creek. Impacts to WOTUS in this area would likely exceed 0.5 acres, thereby requiring a Standard Individual Permit (IP) authorization from the USACE and substantial compensatory mitigation. An environmental constraints map is provided for Alternative 1, Scenario 1B as **Exhibit 24**.

4.3.2.5 Alternative 1 Scenario 1B: Right-of-Way Requirements

The construction of the channel improvements will occur within the existing HCFCD ROW. The construction of the two proposed detention ponds would require additional ROW acquisition, specifically two undeveloped tracts of land adjacent to South Mayde Creek.

4.3.2.6 Alternative 1 Scenario 1B: Estimated Project Cost

The estimated cost for this scenario is approximately $13.7M and includes the following items:

- Construction of channel improvement: $6.9M
  (including 20% contingency and excluding relocation of existing trails)
- Construction of detention ponds: $3.2M
  (including 20% contingency)
- ROW acquisition: $1.5M
- Environmental Mitigation: $0.3M

- Professional Services Fees: $1.9M

4.3.2.7 Alternative 1 Scenario 1B: Maintenance & Other Considerations

The general maintenance and other considerations are the same as described for Alternative 1, Scenario 1A. In addition, the proposed detention pond layouts have accounted for a 30-foot maintenance berm around the entire perimeter. The grass-lined detention pond would have similar maintenance requirements as other HCFCD detention facilities.

Another important consideration related to the detention basins is the proper installation of stormwater quality (SWQ) best management practices (BMPs) necessary to meet permitting requirements. These BMPs promote the improvement of water quality by removing debris, sediment, and other pollutants from leaving the detention ponds and entering receiving waters. Example of typical BMPs include floatables collection screens and storage of the initial first flush SWQ volume. The specific BMPs included as part of the final pond layout would need to be further evaluated during the design phase.

4.3.3 Scenario 1C: Reduced Benching Channel Improvements

Similar to the previous Alternative 1 scenarios, Scenario 1C provides additional conveyance capacity from channel improvements between Fry Road and Greenhouse Road. The proposed benching width is less than Scenario 1A because the existing walking trails are assumed to be remain in place.

4.3.3.1 Alternative 1 Scenario 1C: Description of Scenario

This scenario includes only channel improvements from Fry Road to Greenhouse Road, but with a reduced proposed top width. These channel improvements consist of a trapezoidal channel section benched above the OHWM on both sides of South Mayde Creek but preserve the existing walking paths on either side of Mayde Creek.

The benched sections range from 0 to 50 feet of lateral benching and 4:1 side slopes. Some sections of the channel were unable to be benched due to the presence of the existing walking trail. The depth of the channel ranges from 7.5 to 12.5 feet. The top width of the proposed channel ranges from 135 to 205 feet (including maintenance berms would be 195 to 265 feet). A typical section of the proposed channel is shown below as **Figure 6**.

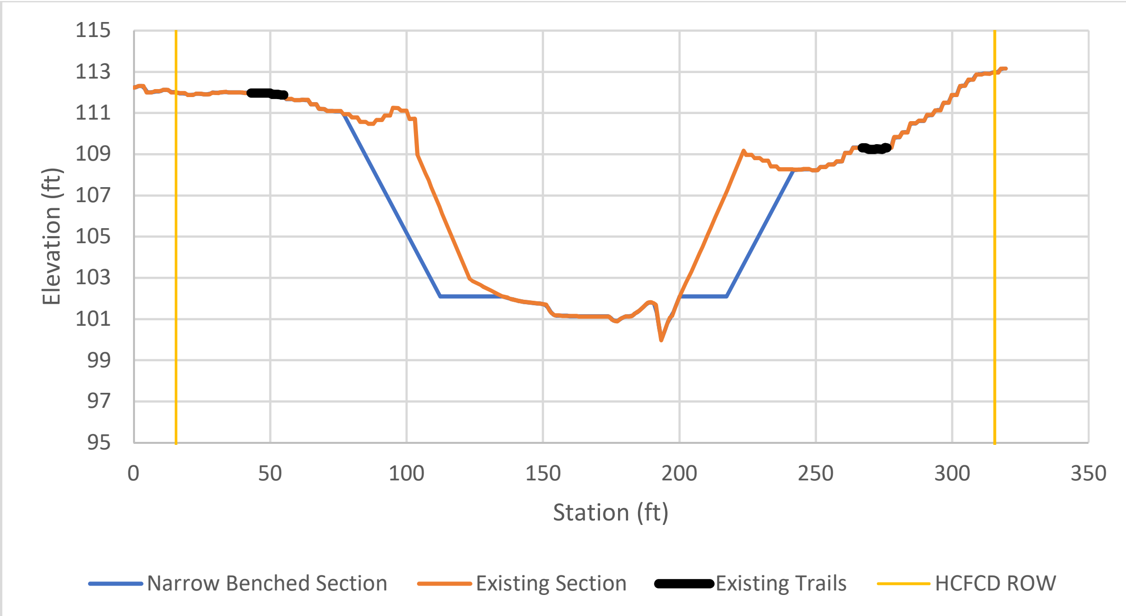


Figure 6: Typical Channel Improvement Section for Alternative 1, Scenario 1C

Again, the Heathergold pedestrian bridge was assumed to not be changed and the proposed channel improvements transitioned back to the existing channel top width upstream and downstream of the bridge. The layout of this alternative is included on **Exhibit 25**.

4.3.3.2 Alternative 1 Scenario 1C: Scenario Objective

The goal of this scenario is to evaluate if reducing the size of the proposed benching would decrease or eliminate potential impacts from the increased conveyance capacity while still providing WSEL reduction benefits. For this scenario, the existing walking trails are assumed to remain in place, avoiding the cost of relocating them while preserving an existing community amenity for continuous use.

4.3.3.3 Alternative 1 Scenario 1C: Hydraulic Analysis & Results

A similar process as was completed for Scenario 1A was performed to create the HEC-RAS geometry that incorporated the partial benching along South Mayde Creek. **Table 13 - Table 15** include the results of the hydraulic analysis for the 50%, 10%, and 1% storm events. **Exhibits 26-28** show the inundation boundaries for the 50%, 10%, and 1% storm events. Full results of the model for all storms included in the analysis are included in **Appendix M**.

Table 13: Alternative 1, Scenario 1C Model Results - 50% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario1c	Existing_AsIs vs Alt1_Scenario1c
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.70	-0.33
Fry Road	111.94	111.31	-0.63
Confluence of U101-03 and U101-00	109.53	109.24	-0.29
Greenhouse Road	108.76	108.69	-0.07
Groeschke Road	104.59	104.54	-0.05
Barker Cypress Road	102.83	102.76	-0.07
Reservoir	95.32	95.27	-0.05

Table 14: Alternative 1, Scenario 1C Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario1c	Existing_AsIs vs Alt1_Scenario1c
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	121.01	-0.25
Fry Road	113.72	112.72	-1.00
Confluence of U101-03 and U101-00	111.66	111.35	-0.31
Greenhouse Road	110.22	110.27	0.05
Groeschke Road	106.21	106.23	0.02
Barker Cypress Road	104.87	104.89	0.02
Reservoir	97.93	97.95	0.02

Table 15: Alternative 1, Scenario 1C Model Results - 1% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario1c	Existing_AsIs vs Alt1_Scenario1c
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.39	-0.01
Fry Road	116.54	115.65	-0.89
Confluence of U101-03 and U101-00	113.41	113.03	-0.38
Greenhouse Road	111.24	111.29	0.05
Groeschke Road	107.62	107.64	0.02
Barker Cypress Road	106.33	106.36	0.03
Reservoir	99.16	99.18	0.02

WSEL reductions occur for this scenario in the upstream portion of the study area for all modeled storm events, with the largest reductions located between Fry Road and the confluence of U101-00-00 and U101-03-00. Starting in the 10% AEP event, minor (<0.05 feet) WSEL increases are present from Greenhouse Road and farther. Similar to Alternative 1, Scenario 1A, the increases in WSEL are not surprising given the transition of the widened channel back to existing conditions upstream of Greenhouse Road. When compared with Alternative 1, Scenario 1A (full benched channel improvements), the WSEL reductions for this scenario are generally 0.1-0.3 feet lower in the more frequent storm events and roughly 0.5 feet lower in the less frequent storm events. The model results indicate that the additional benching of South Mayde Creek does provide some incremental WSEL reduction benefit, although this would have to be weighed against the cost of relocating the existing walking trails.

4.3.3.4 Alternative 1 Scenario 1C: Environmental Considerations
This scenario is similar to Scenario 1A but involves a reduced benching area to preserve an existing walking trail. Impacts to WOTUS would be similar to Scenario 1A (i.e. avoided, minimal, and/or temporary) and would likely be authorized under a Nationwide Permit (NWP), likely NWP – 43 (Stormwater Management Facilities). An environmental constraints map is provided for Alternative 1, Scenario 1C as **Exhibit 29**.

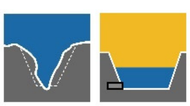
4.3.3.5 Alternative 1 Scenario 1C: Right-of-Way Requirements
Construction of this scenario does not require additional purchase of ROW by HCFCD.

4.3.3.6 Alternative 1 Scenario 1C: Estimated Project Cost
The estimated cost for this scenario is approximately $6.7M and includes the following items:

- Construction of channel improvement: $5.6M
  (including 20% contingency)
- ROW acquisition: $0.0M
- Environmental Mitigation: $0.0M
- Professional Services Fees: $1.1M

4.3.3.7 Alternative 1 Scenario 1C: Maintenance & Other Considerations
Maintenance and other considerations would be similar to what is listed for Alternative 1, Scenario 1A.

4.3.4 Scenario 1D: Reduced Benching Channel Improvements with Detention Ponds



This alternative has the same channel improvements in Scenario 1C but incorporates detention basins located just upstream of Greenhouse Road (downstream of the proposed channel improvements).

4.3.4.1 Alternative 1 Scenario 1D: Description of Scenario
Scenario 1D builds on Scenario 1C by adding the same two detention basins as described for Alternative 1, Scenario 1B. The two detention ponds are located on either side of South Mayde Creek, just upstream of Greenhouse Road. The layout of this alternative is included on **Exhibit 30**.

4.3.4.2 Alternative 1 Scenario 1D: Scenario Objective
The goal of this scenario is to reduce or eliminate potential impacts caused by the increased conveyance capacity provided by the channel improvements with reduced benching.

4.3.4.3 Alternative 1 Scenario 1D: Hydraulic Analysis & Results

The modeling methodology for this alternative is similar to Alternative 1 Scenario 1B as described in Section 4.3.2.3. **Table 16 - Table 18** includes the results of the hydraulic analysis for the 50%, 10%, and 1% storm events. **Exhibits 31-33** show the inundation boundaries for the 50%, 10%, and 1% storm events. Full results of the model for all storms included in the analysis are included in **Appendix N**.

Table 16: Alternative 1, Scenario 1D Model Results - 50% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario1d	Existing_AsIs vs Alt1_Scenario1d
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.59	-0.44
Fry Road	111.94	111.06	-0.88
Confluence of U101-03 and U101-00	109.53	109.00	-0.53
Greenhouse Road	108.76	108.59	-0.17
Groeschke Road	104.59	104.48	-0.11
Barker Cypress Road	102.83	102.70	-0.13
Reservoir	95.32	95.19	-0.13

Table 17: Alternative 1, Scenario 1D Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario1d	Existing_AsIs vs Alt1_Scenario1d
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	121.17	-0.09
Fry Road	113.72	112.61	-1.11
Confluence of U101-03 and U101-00	111.66	111.18	-0.48
Greenhouse Road	110.22	110.24	0.02
Groeschke Road	106.21	106.23	0.02
Barker Cypress Road	104.87	104.89	0.02
Reservoir	97.93	97.94	0.01

Table 18: Alternative 1, Scenario 1D Model Results - 1% AEP

Comparison Location	Existing_Asls	Alt1_Scenario1d	Existing_Asls vs Alt1_Scenario1d
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.65	0.25
Fry Road	116.54	115.57	-0.97
Confluence of U101-03 and U101-00	113.41	112.89	-0.52
Greenhouse Road	111.24	111.24	0.00
Groeschke Road	107.62	107.63	0.01
Barker Cypress Road	106.33	106.35	0.02
Reservoir	99.16	99.17	0.01

The model results for this scenario exhibit a similar pattern to the results from Scenario 1C. In lower storm events, the WSELs decrease for all comparison locations, while in higher storm events there are WSEL increases downstream of Greenhouse Road. While these WSEL increases are minor (< 0.05 feet), the addition of the two detention ponds does not completely mitigate for any adverse impacts from the channel improvements.

4.3.4.4 Alternative 1 Scenario 1D: Environmental Considerations

This scenario is similar to Scenario 1B but involves reduced benching to preserve an existing walking trail. Impacts to the channel would be similar (i.e. avoided, minimal, and/or temporary) and impacts to the wetland complex would be the same as Scenario 1B. It is likely that this scenario would require an IP authorization from the USACE and substantial compensatory mitigation bank credit purchase. An environmental constraints map is provided for Alternative 1, Scenario 1D as **Exhibit 34**.

4.3.4.5 Alternative 1 Scenario 1D: Right-of-Way Requirements

The construction of the channel improvements would occur within the existing HCFCD ROW. The construction of the two proposed detention ponds would require additional ROW acquisition of two undeveloped tracts of land adjacent to South Mayde Creek.

4.3.4.6 Alternative 1 Scenario 1D: Estimated Project Cost

The estimated cost for this scenario is approximately $12.2M and includes the following items:

- Construction of channel improvement: $5.6M
  (including 20% contingency)
- Construction of detention ponds: $3.2M
  (including 20% contingency)
- ROW acquisition: $1.5M
- Environmental Mitigation: $0.3M
- Professional Services Fees: $1.7M

4.3.4.7 Alternative 1 Scenario 1D: Maintenance & Other Considerations

The general maintenance and other considerations are the same as described for Alternative 1, Scenario 1C. In addition, the proposed detention pond layouts have accounted for a 30-foot maintenance berm around the entire perimeter. The grass-lined detention pond would have similar maintenance requirements as other HCFCD detention facilities. The installation of required SWQ BMPs would also be an important consideration.

4.3.5 Scenario 2: Full Channel Improvements and Bypass Channel

Scenario 2 provides additional conveyance through the construction of a bypass channel to more effectively convey water east into the Addicks Reservoir. Scenario 2 also includes the channel improvements that were the focus of Scenario 1.

The bypass channel would be located between Greenhouse Road and Barker Cypress Road, north of South Mayde Creek. This section of the channel has limited capacity due to heavy vegetation and narrow channel widths. This limited capacity serves as a bottleneck and contributes to flooding in the surrounding areas; the bypass channel was first conceptualized as part of the HDR feasibility study as a way to help minimize the hydraulic restriction that occurs in this part of South Mayde Creek.

4.3.5.1 Alternative 1 Scenario 2: Description of Alternative

The full benched channel improvements are the same as described for Alternative 1, Scenario 1A (see Section 4.3.1.1).

The bypass channel is proposed north of South Mayde Creek beginning just downstream of Greenhouse Road, continuing along the north side of Cullen Park, and ending just upstream of Barker Cypress Road. The bypass channel is trapezoidal in shape with an approximate depth of 10 feet. The bypass channel would intersect with U101-01-00 just upstream of the confluence between U101-01-00 and U101-00-00. Flow from U101-01-00 would be enter the bypass channel directly with a new protected confluence constructed.

Construction of the bypass channel would require a new crossing with Groeschke Road. The channel crossing at Groeschke Road was assumed to be a bridge but modeled as a culvert using a 2D connection within the 2D area of the bypass channel to at least partially represent energy losses from the proposed structure. The bridge design was not finalized as the 2D modeling approach provided limited detailed bridge modeling options. The new bypass channel would also require modification to the confluence of U101-00-00 and U101-00-00 since the channel ROW intersects with existing walking trails and a pedestrian bridge. The existing trails would be demolished to provide the needed ROW and the pedestrian bridge would be relocated roughly 180 feet to the northeast to maintain the trail connectivity. This confluence area under existing and proposed conditions is shown below in **Figure 7**.

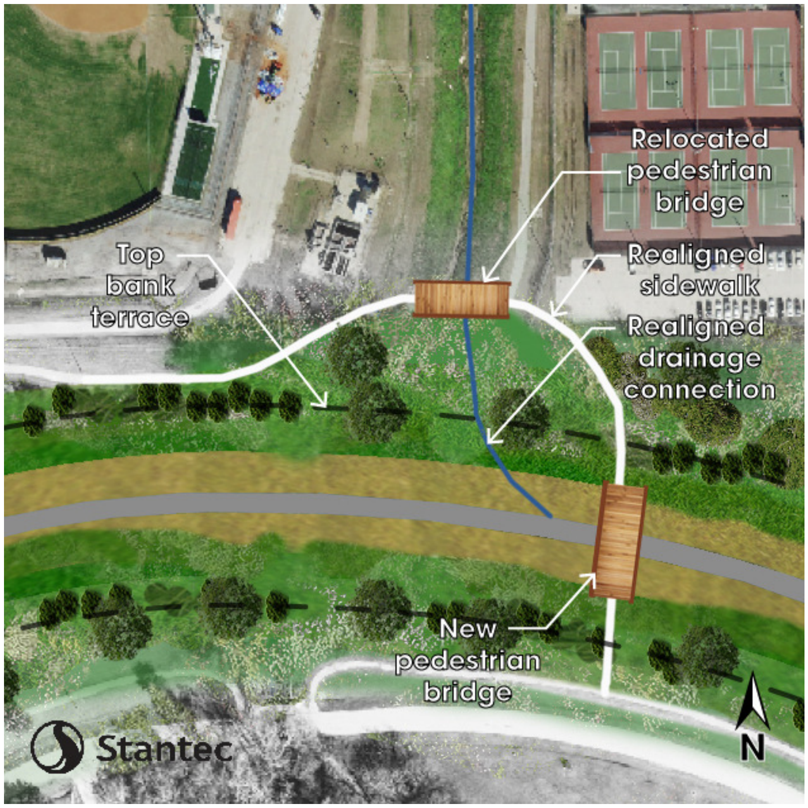


Figure 7: Conceptual Layout of U101-00-00 and U101-01-00 Confluence

The bypass channel incorporates NSCD concepts to provide additional benefits beyond just conveyance capacity such as aesthetics value, reduced long-term erosion and sedimentation, and self-mitigation of environmental impacts. An example of a channel incorporating NSCD features is shown below as Figure 8. Stantec was engaged as a subconsultant to Halff to assist with the NSCD channel preliminary design. The analysis and design process are described below and documented further in the August 2020 Geomorphic Evaluation Memorandum, which is provided in **Appendix O**.

Figure 8: Example of Channel with NSCD Features

The design of the geomorphic channel for the bypass channel cannot perfectly follow the guidelines in the draft *Natural Stable Channel Design Guidance Manual for Harris County, TX* (August 2017). The NSCD manual assumes that the geomorphic channel will convey the Q_{BKF}, thereby behaving like a natural stream. For this project, however, a portion of the South Mayde Creek bankfull flow will remain in the main channel of South Mayde Creek, while a portion of it is diverted into the bypass channel.

Using the regional curve in the draft NSCD manual, a drainage area of 15 square miles (half the drainage area of South Mayde Creek at the project site to approximate half the Q_{BKF}) was used to estimate a bankfull cross sectional area (A_{BKF}) of 104 square feet assuming a Rosgen C-type stream. A width/depth ratio of 10 was then applied to calculate a top width of 30 - 32 feet and a mean depth of 3.2 - 4 feet. Side slopes of 2:1 and a channel slope of 0.0002 – 0.0003 ft/ft were also used in this computation.

The width-depth ratio of the proposed geomorphic channel is near the minimum that we would consider stable for a stream in this setting. A larger ratio, however, would decrease the capacity of the geomorphic channel in the bypass channel. Alternatively, the top width of the geomorphic channel could be increased, but width constraints of the proposed alignment between Cullen Park and the northern property boundary would make this difficult. The target top width of the bypass channel is approximately 160 feet. The NSCD manual recommends that the floor of the bypass channel should be three to five times the top width of the geomorphic channel. The floor of the bypass channel should be as wide as possible, while maintaining geotechnically stable side slopes, to allow the geomorphic channel room to meander and undergo natural stream processes.

Additionally, a tributary (U101-01-00) that enters South Mayde Creek from the north appears to intersect the bypass channel. The bypass channel design would need to be revisited and possibly adjusted to account for this increase in drainage area.

The bypass channel design includes 4:1 side slopes that slope down from natural ground to down to an overbank section sloped at 50:1 on either side of the channel. The bank full channel incorporates 2:1 side slopes and a low flow channel that meanders along the channel bottom. The channel flowline was designed with an average longitudinal slope of 0.11%. The typical NSCD section of the bypass channel is illustrated below in **Figure 9**. The layout of this alternative is included on **Exhibit 35.**

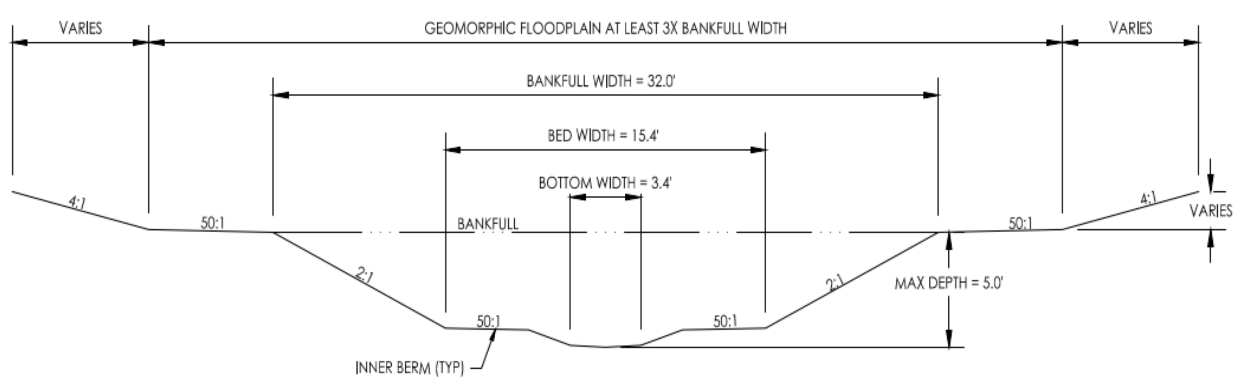


Figure 9: Bypass Channel NSCD Dimensions

4.3.5.2 Alternative 1 Scenario 2: Scenario Objective

The goal of this scenario is to provide additional conveyance capacity in South Mayde Creek and an alternate path for water to drain into Addicks Reservoir besides the existing South Mayde Creek channel south of Cullen Park. Implementation of bypass channels has been done previously in Harris county on other HCFCD channels within the Addicks watershed.

4.3.5.3 Alternative 1 Scenario 2: Hydraulic Analysis & Results

To model this scenario, the bypass channel was incorporated into the geometry from Alternative 1, Scenario 1A that had the full benched channel improvements. The terrain of the model was modified to incorporate the bypass channel since the entirety of the bypass channel was located within the 2D model extents. A proposed grading surface representing the bypass channel was created in Civil3D using the typical cross-section data from Stantec. The bypass channel grading was tied back into existing terrain within an assumed 30-foot maintenance access corridor on each side of the proposed channel. The surface was then exported and overlaid on top of the existing terrain. The lateral structure connections were then recut against the terrain in order to capture the inlet and outlet of the bypass channel.

The bypass channel also required a new bridge be built at the crossing with Groeschke Road. Since the location of this crossing is within the 2D extents, a standard 1D bridge could not be accurately modeled. To approximate a structure at that location and account for some energy loss, a 2D connection was added to the model with culverts aimed at reflecting the open space of a future bridge.

Table 19 - Table 21 include the results of the hydraulic analysis for the 50%, 10%, and 1% AEP storm events. **Exhibits 36-38** show the inundation boundaries for the 50%, 10%, and 1% AEP storm events. Full results of the model for all storms included in the analysis are included in **Appendix P**.

Table 19: Alternative 1, Scenario 2 Model Results - 50% AEP

Comparison Location	**Existing_**AsIs	**Alt1_**Scenario2	**Existing_**AsIs vs Alt1_Scenario2
	W.S. Elev	**W.S. Elev**	**W.S. Elev**
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.31	-0.72
Fry Road	111.94	110.21	-1.73
Confluence of U101-03 and U101-00	109.53	108.02	-1.51
Greenhouse Road	108.76	106.84	-1.92
Groeschke Road	104.59	104.18	-0.41
Barker Cypress Road	102.83	102.93	0.10
Reservoir	95.32	95.49	0.17

Table 20: Alternative 1, Scenario 2 Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario2	Existing_AsIs vs Alt1_Scenario2
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	120.91	-0.35
Fry Road	113.72	112.16	-1.56
Confluence of U101-03 and U101-00	111.66	110.97	-0.69
Greenhouse Road	110.22	109.50	-0.72
Groeschke Road	106.21	105.92	-0.29
Barker Cypress Road	104.87	105.18	0.31
Reservoir	97.93	97.98	0.05

Table 21: Alternative 1, Scenario 2 Model Results - 1% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario2	Existing_AsIs vs Alt1_Scenario2
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.40	0.00
Fry Road	116.54	115.07	-1.47
Confluence of U101-03 and U101-00	113.41	112.77	-0.64
Greenhouse Road	111.24	110.69	-0.55
Groeschke Road	107.62	107.32	-0.30
Barker Cypress Road	106.33	106.52	0.19
Reservoir	99.16	99.20	0.04

Significant WSEL reductions were seen for this scenario, specifically between Fry Road and Greenhouse Road. The maximum reduction in the lower storm events ranged from 1.5-2 feet, although the average WSEL decrease in the same section of South Mayde Creek decreases to between 0.5-1 foot in higher storm events. Decreases in WSEL get progressively smaller the farther downstream from Fry Road, especially in higher storm events.

The higher WSEL reductions compared with just full benched channel improvements (Alternative 1, Scenario 1A) demonstrates the benefit of combining individual improvements together. The model results indicated WSEL increases of 0 to 0.3 feet in all modeled storm events downstream of Groeschke Road, which corresponds to the downstream end of the bypass channel which discharges back into the existing South Mayde Creek just upstream of Barker Cypress Road.

4.3.5.4 Alternative 1 Scenario 2: Environmental Considerations

This scenario includes full benching of South Mayde Creek from Fry Road to Greenhouse Road (i.e Scenario 1A) with the addition of a natural stable bypass channel design constructed downstream of Greenhouse Road. Construction of the bypass channel would result in the loss of approximately 0.57 acre of forested wetland and approximately 0.48 acre/800 linear feet of stream. The channel would be designed to improve aquatic function and offset the associated loss of stream features; however, the 0.57 acre of wetland loss would like require purchase of compensatory mitigation credits from a bank.

Construction of the proposed bypass channel would likely require authorization under a Standard IP from the USACE; however, it may be possible to pursue authorization under NWP 27 (Aquatic Habitat Enhancement). NWP 27 does not have the 0.5 acre/300 linear foot impact thresholds of other NWPs, but it is up to the discretion of the USACE when it is appropriate to utilize this permitting mechanism in lieu of a Standard IP. Additionally, the bypass channel is located within the Federal Civil Works Project footprint of Addicks Reservoir and would require authorization under a Section 408 permit, necessitating additional environmental review under NEPA. An environmental constraints map is provided for Alternative 1, Scenario 2 as **Exhibit 39**.

4.3.5.5 Alternative 1 Scenario 2: Right-of-Way Requirements

No additional ROW would be required for the channel conveyance capacity improvements as all construction would be completed within existing HCDCD ROW. For the bypass channel, construction would occur on the USACE property within the Addicks Reservoir boundary. Currently, the USACE leases the land in the general location of the bypass channel to the City of Houston, which operates Cullen Park just north of South Mayde Creek between Greenhouse Road and Groeschke Road. HCFCD would have to coordinate with the USACE and complete an interlocal agreement to obtain approval to construct the bypass channel. It was assumed no ROW acquisition cost would be required, but this would have to be verified with the USACE.

4.3.5.6 Alternative 1 Scenario 2: Estimated Project Cost

The estimated cost for this scenario is approximately $13.6M and includes the following items:

- Construction of channel improvement: $6.9M
  (including 20% contingency and excluding relocation of existing trails)
- Construction of bypass channel: $4.5M
  (including 20% contingency)
- ROW acquisition: $0.0M
- Environmental Mitigation: $0.0M
- Professional Services Fees: $2.2M

4.3.5.7 Alternative 1 Scenario 2: Maintenance & Other Considerations

Maintenance considerations for the channel improvements are same as described for Alternative 1, Scenario 1A. The proposed bypass channel has included the standard 30-foot maintenance access corridor along both sides. The bypass channel also presents some additional considerations, which are outlined below:

- Requirement to relocate the existing walking trails and pedestrian bridge across U101-00-00 to provide the needed ROW for the bypass channel and to maintain trail connectivity
- Need to maintain existing flow patterns as appropriate around the confluence of U101-00-00 and U101-01-00 to not adversely affect environmentally sensitive areas
- Proper protection of the upstream and downstream confluence of the bypass channel and South Mayde Creek should be incorporated into the final design, including the placement of

concrete slope paving or riprap to minimize erosion potential and the adjustment of the channel alignment to optimize the flow transitions into and out of the bypass channel

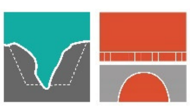
Additional geomorphic future design considerations are discussed below:

To better evaluate the amount of water entering the bypass and the frequency of the geomorphic channel bankfull flow, we recommend first obtaining survey data for multiple cross sections at the proposed location where the bypass channel splits from South Mayde Creek. In addition, a water level logging pressure transducer could be installed to record actual flow hydrographs and corresponding water surface elevations at the divergence location.

Finally, we recommend evaluating opportunities to widen the top width of the bypass channel to gain a larger flood width as well as lowering the bypass channel invert. Widening the bypass would not only increase its flow capacity but would also provide more options for configuring the geomorphic channel and allow for more sinuosity and reduction of shear stress and velocities. Lowering the channel invert to lower than the OHWM would allow for more frequent flows in the bypass, which would help maintain sediment transport through the bypass.

With the elevation of the geomorphic channel invert higher than the invert of the main channel of South Mayde Creek, it is uncertain if the bypass channel will be dry for extended periods of time throughout the year. Vegetation could become established, potentially across the entire bed of the bypass channel, further increasing roughness beyond what would be expected in a typical flood control channel. This increased roughness will have an effect on flow hydraulics as well as the sediment transport capacity of the bypass channel. It should be expected that sediment loads will enter the bypass channel. Hydraulic analysis should estimate the ability of the flow in the bypass channel to convey this sediment under a variety of flow and roughness scenarios as well as considering the amount of water in the Addicks Reservoir during larger flow events and its impact on stream slope.

4.3.6 Scenario 3: Full Channel Improvements and Greenhouse Road Bridge Replacement



This scenario combines channel conveyance capacity improvements along South Mayde Creek between Fry Road and Greenhouse Road with the replacement of the Greenhouse Road bridge. The Greenhouse Road crossing of South Mayde Creek has historically flooded frequently and early on during periods of heavy rainfall.

The Halff revised existing conditions modeling showed the bridge starts to overtop between the 10% AEP and 4% AEP storm events. The existing bridge is also a known hydraulic restriction, increasing WSELs upstream and contributing to the flooding issues of the surrounding areas. Replacing the Greenhouse Road bridge has been discussed and HCFCD would like to understand if improving the structure is worth further investigating.

4.3.6.1 Alternative 1 Scenario 3: Description of Scenario

This scenario includes the same channel improvements as described in Alternative 1, Scenario 1A (see Section 4.3.1.1).

The Greenhouse Road bridge replacement involved raising the bridge deck and widening the bridge opening. Proposed changes to the existing bridge structure were developed based on site assumptions and constraints with input from the Halff transportation and structural engineers. These assumptions and constraints are listed below:

- Relocation of existing driveways serving current developments would be avoided if possible. Secondary driveways, such as those leading to undeveloped land, would be reconstructed based on the new bridge approaches.
- Existing storm inlets within the estimated construction limits would be relocated to the revised low points in the roadway profile and any associated storm sewer pipes adjusted accordingly.
- The vertical curve geometry for the proposed bridge and approach roadway sections would be designed based on the posted speed limit for Greenhouse Road of 40 mph.
- There are several utility conflicts that would need to be addressed during design, including but not limited to the replacement of utilities attached or adjacent to the bridge deck, potential relocation of power poles, and potential adjustment of public utilities (storm sewer and water).
- The existing ROW appears to be 100 feet based on HCAD parcel data. The proposed ground elevations at the ROW boundary should be further investigated to determine if and what changes are needed to properly transition from existing ground to the new roadway.

The primary task in developing the preliminary proposed bridge design was identifying the maximum distance the bridge deck could be raised given existing utilities and roadway intersections along Greenhouse Road north and south of South Mayde Creek. The layout of the proposed bridge was then developed based on a cost-effective and standard design that would provide the required structural data needed for incorporating the new bridge into the hydraulic model. This structural data included the number, spacing, and size of bridge piers as well as the top and bottom bridge deck elevations. The existing and proposed bridge data from HEC-RAS is shown below in **Figure 10**.

Halff estimated that the centerline roadway elevation of Greenhouse Road could be raised approximately

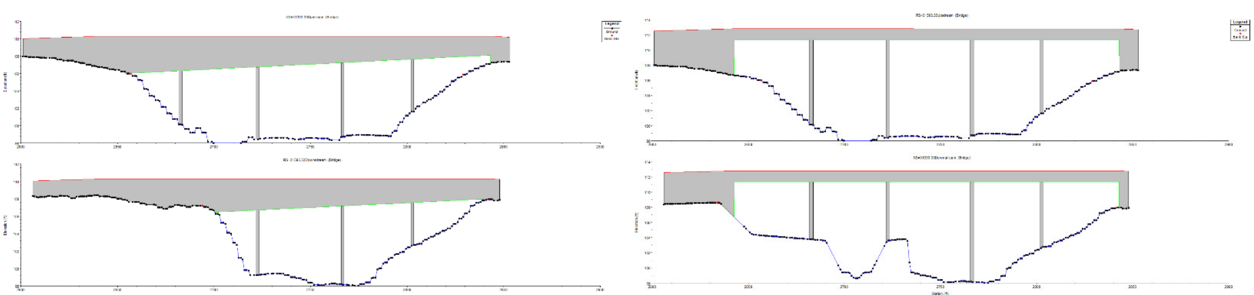


Figure 10: Greenhouse Bridge Improvement

2.5 feet at the center of the bridge. This puts the top of the deck at an elevation of 112.8 feet and low chord elevation of 111.3 feet based on an assumed deck height of 1.5 feet. The bridge consists of five 40-foot spans with 2-foot wide piers. The layout of this alternative is included on **Exhibit 40**. A comparison of the existing and proposed bridge profiles is provided in **Appendix Q**.

4.3.6.2 Alternative 1 Scenario 3: Scenario Objective

The goal of this scenario is to understand the potential incremental WSEL reduction obtained by replacing the Greenhouse Road bridge. If significant WSEL reductions or other mobility benefits could be achieved by replacing the existing bridge, it may be worthwhile to recommend the project as part of an overall long-term solution.

4.3.6.3 Alternative 1 Scenario 3: Hydraulic Analysis & Results

Modifications to the Greenhouse Road bridge were made to the 1D structure to reflect the proposed bridge structure. The change to the approach roadways due to raising the bridge was not incorporated into the model. **Table 22 - Table 24** include the results of the hydraulic analysis for the 50%, 10%, and 1% storm events. **Exhibits 41-43** show the inundation boundaries for the 50%, 10%, and 1% storm events. Full results of the model for all storms included in the analysis are included in **Appendix R**.

Table 22: Alternative 1, Scenario 3 Model Results - 50% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario3	Existing_AsIs vs Alt1_Scenario3
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.55	-0.48
Fry Road	111.94	111.02	-0.92
Confluence of U101-03 and U101-00	109.53	109.13	-0.40
Greenhouse Road	108.76	108.63	-0.13
Groeschke Road	104.59	104.54	-0.05
Barker Cypress Road	102.83	102.77	-0.06
Reservoir	95.32	95.31	-0.01

Table 23: Alternative 1, Scenario 3 Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario3	Existing_AsIs vs Alt1_Scenario3
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	120.94	-0.32
Fry Road	113.72	112.31	-1.41
Confluence of U101-03 and U101-00	111.66	111.23	-0.43
Greenhouse Road	110.22	110.20	-0.02
Groeschke Road	106.21	106.24	0.03
Barker Cypress Road	104.87	104.89	0.02
Reservoir	97.93	97.95	0.02

Table 24: Alternative 1, Scenario 3 Model Results - 1% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario3	Existing_AsIs vs Alt1_Scenario3
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.39	-0.01
Fry Road	116.54	115.11	-1.43
Confluence of U101-03 and U101-00	113.41	112.86	-0.55
Greenhouse Road	111.24	111.14	-0.10
Groeschke Road	107.62	107.66	0.04
Barker Cypress Road	106.33	106.37	0.04
Reservoir	99.16	99.19	0.03

The model results for this scenario showed similar patterns to Alternative 1, Scenario 1A – WSEL reductions generally within the 0.5-1.5 feet range between Fry Road and Greenhouse Road. Starting in the 10% AEP storm event, WSEL increases were observed near Groeschke Road and farther downstream.

Replacing the Greenhouse Road bridge provided minimal benefits, typically less than 0.1 feet incremental WSEL reductions compared to just the channel improvements. Removing the hydraulic restriction at Greenhouse Road does lower the WSELs upstream of the bridge but does introduce impacts downstream as more water is now allowed to continue to flow downstream. One important thing to note is that the model results show instead of overtopping between the 10% AEP and 4% AEP storm event, the proposed bridge would not overtop in the 0.2% AEP, which would allow continued access to the roadway for emergency services and residents in the surrounding area.

It is important to note that the terrain for the approach sections of Greenhouse Road have not been adjusted to reflect the higher road elevation leading to the proposed bridge. This adjustment in the model would likely reduce WSEL reductions further as water would be blocked from flowing east to a higher degree. On the other hand, this would likely reduce impacts downstream. Additionally, the bridge is no longer shown to be overtopped for all modeled storm events; however, flow still flows east around the bridge over the approach sections of Greenhouse Road.

4.3.6.4 Alternative 1 Scenario 3: Environmental Considerations

Under this scenario, impacts to WOTUS would be similar to Scenario 1A with the potential for slightly more extensive temporary impacts associated with the construction of the proposed Greenhouse Road bridge improvements. It is anticipated that minimal/temporary impacts to WOTUS would be authorized under a Nationwide Permit (NWP), likely NWP – 43 (Stormwater Management Facilities). An environmental constraints map is provided for Alternative 1, Scenario 3 as **Exhibit 44**.

4.3.6.5 Alternative 1 Scenario 3: Right-of-Way Requirements

No additional ROW would be required for the channel conveyance capacity improvements as all construction would be completed within existing HCDCD ROW. It is expected that no additional ROW would be required for the Greenhouse Road bridge replacement assuming that construction is contained within the existing road ROW. Depending on the final vertical profile of the proposed bridge, retaining walls may be needed if traditional sloped embankments could not be used to transition for the higher roadway back down to existing ground at the ROW boundary.

4.3.6.6 Alternative 1 Scenario 3: Estimated Project Cost

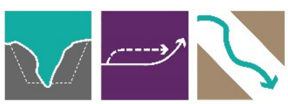
The estimated cost for this scenario is approximately $10.9M and includes the following items:

- Construction of channel improvement: $6.9M
  (including 20% contingency and excluding relocation of existing trails)
- Construction of Greenhouse Road bridge replacement: $2.3M
  (including 20% contingency)
- ROW acquisition: $0.0M
- Environmental Mitigation: $0.0M
- Professional Services Fees: $1.7M

4.3.6.7 Alternative 1 Scenario 3: Maintenance & Other Considerations

Maintenance considerations for the channel improvements are same as described for Alternative 1, Scenario 1A. The new bridge would require inspection and maintenance activities as specified by applicable Harris County and HCFCD guidelines. As mentioned previously, key considerations during the design phase include taking a closer look at the interface point between the modified road and existing ground along the edge of the ROW and confirmation/coordination of utilities relocation. Potential disruptions to local traffic should also be taken into account.

4.3.7 Scenario 4: Channel Improvements and Bypass Channel with Sedimentation Basins



This scenario is similar to Scenario 2 in that it combines channel improvements and the bypass channel. In addition to these improvements, sedimentation basins near Greenhouse Road are also included. The construction of sedimentation basins was further explored based on the initial coordination meeting with the USACE and their request to include a centralized sediment collection location.

4.3.7.1 Alternative 1 Scenario 4: Description of Scenario

This scenario includes the same channel improvements as described in Scenario 1A (see Section 4.3.1.1). These channel improvements consist of a trapezoidal channel section benched above the OHWM on both sides of South Mayde Creek.

A detailed description of the proposed bypass channel is provided in Section 4.3.5.1 for Alternative 1, Scenario 2. The bypass channel incorporates Natural Stable Channel Design elements and would be located north of the existing South Mayde Creek channel between Greenhouse Road and Barker Cypress Road.

Two sedimentation basins are proposed, one on either side of South Mayde Creek just upstream of Greenhouse Road. These undeveloped parcels are the same location for the detention ponds that are part of Scenarios 1B and 1D. By creating a centralized sediment collection location with dedicated access, the removal of accumulated sediment could be more easily completed. Furthermore, the addition of sedimentation basins addresses ongoing sedimentation concerns along South Mayde Creek and the potential adverse impacts of sediment being carried downstream into the Addicks Reservoir. These sedimentation basins were assumed to be a requirement for the construction of the bypass channel.

The sedimentation basins are designed with 4:1 side slopes and have an approximate depth of 7 feet. Flow from South Mayde Creek enters the basins through a new channel constructed through the existing top bank of the channel. The elevation of the northern and southern basin bottom is 101 and 100 feet, respectively. The outfall for the sedimentation basins was designed to be a 10’ x 5’ concrete box culvert with an approximately 0.5% slope. After further evaluation of the sedimentation basins, the configuration was changed to remove the bank between the basin and South Mayde Creek above the OHWM and let the sedimentation basin area serve as an extension of the channel width. The intent of this design was to provide a section of increased cross-sectional area where velocities would decrease, and sediment would settle out before water would flow back freely into the main channel. Ease of access for sediment removal is an important consideration and would need to be factored into the refinement of the sedimentation basins layout during the design phase. The layout of this alternative is included on **Exhibit 45**.

4.3.7.2 Alternative 1 Scenario 4: Scenario Objective

The goal of this scenario is to evaluate the impact of adding sedimentation basins to the combination of channel improvements and a bypass channel. The sedimentation basins were incorporated into the proposed alternatives based on a request from the USACE during the initial coordination meeting to help address the large reported volume of sediment entering the Addicks Reservoir.

4.3.7.3 Alternative 1 Scenario 4: Hydraulic Analysis & Results

This alternative was modeled by modifying the bypass channel terrain. The sedimentation basins were modeled by creating a Civil3D surface with assumed top of bank and bottom elevations and a transition back to exiting ground within a 40-foot maintenance corridor. The channel improvements from Alternative 1, Scenario 1A were then imported into the model. **Table 25 - Table 27** includes the results of the hydraulic analysis for the 50%, 10%, and 1% storm events. **Exhibits 46 - 48** show the inundation boundaries for the 50%, 10%, and 1% storm events. Full results of the model for all storms included in the analysis are included in **Appendix S**.

Table 25: Alternative 1, Scenario 4 Model Results - 50% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario4	Existing_AsIs vs Alt1_Scenario4
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.19	-0.84
Fry Road	111.94	109.93	-2.01
Confluence of U101-03 and U101-00	109.53	107.65	-1.88
Greenhouse Road	108.76	106.80	-1.96
Groeschke Road	104.59	104.15	-0.44
Barker Cypress Road	102.83	102.85	0.02
Reservoir	95.32	95.39	0.07

Table 26: Alternative 1, Scenario 4 Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario4	Existing_AsIs vs Alt1_Scenario4
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	120.92	-0.34
Fry Road	113.72	112.14	-1.58
Confluence of U101-03 and U101-00	111.66	110.63	-1.03
Greenhouse Road	110.22	109.42	-0.80
Groeschke Road	106.21	105.92	-0.29
Barker Cypress Road	104.87	105.18	0.31
Reservoir	97.93	97.98	0.05

Table 27: Alternative 1, Scenario 4 Model Results - 1% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario4	Existing_AsIs vs Alt1_Scenario4
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.40	0.00
Fry Road	116.54	114.89	-1.65
Confluence of U101-03 and U101-00	113.41	112.42	-0.99
Greenhouse Road	111.24	110.49	-0.75
Groeschke Road	107.62	107.27	-0.35
Barker Cypress Road	106.33	106.48	0.15
Reservoir	99.16	99.17	0.01

The model results for this scenario are similar to Alternative 1, Scenario 2. WSEL reductions range from 0.5 to 2 feet between Fry Road and Greenhouse Road. These reductions are slightly higher by 0.1 or 0.2 feet with the sedimentation basins incorporated compared with Alternative 1, Scenario 2. Similar WSEL increases of roughly 0-0.3 feet were observed between Barker Cypress and the downstream end of the model for all storm events. The model results show that there is not an additional adverse impact by adding the sedimentation basins and even some additional storage is provided by the basins. Additional detailed H&H analysis should be performed as the configuration and design of the sedimentation basins is further refined.

4.3.7.4 Alternative 1 Scenario 4: Sedimentation Basin Flow Patterns

The sedimentation basins flow patterns were as expected through the initial part of the hydrograph at that location along South Mayde Creek. The flow within the main channel spreads out through the new benched area representing the sedimentation basins. The flow is then redirected back into the main channel. Given the shape and locations of both sedimentation basins, flow appears to likely move from the northern pond into the southern pond. Average velocities within the sedimentation basins footprints vary from 0.5 to 2 fps (between the 50% and 1% AEP events), which are in a reasonable range to support the deposition of suspended sediment. As the stage in South Mayde Creek rises, water begins to overtop the high bank of the basins and continues draining overland to the east. These flow patterns are shown in Figure 11.

During Initial Part of Hydrograph Once Sedimentation Basins Overtops

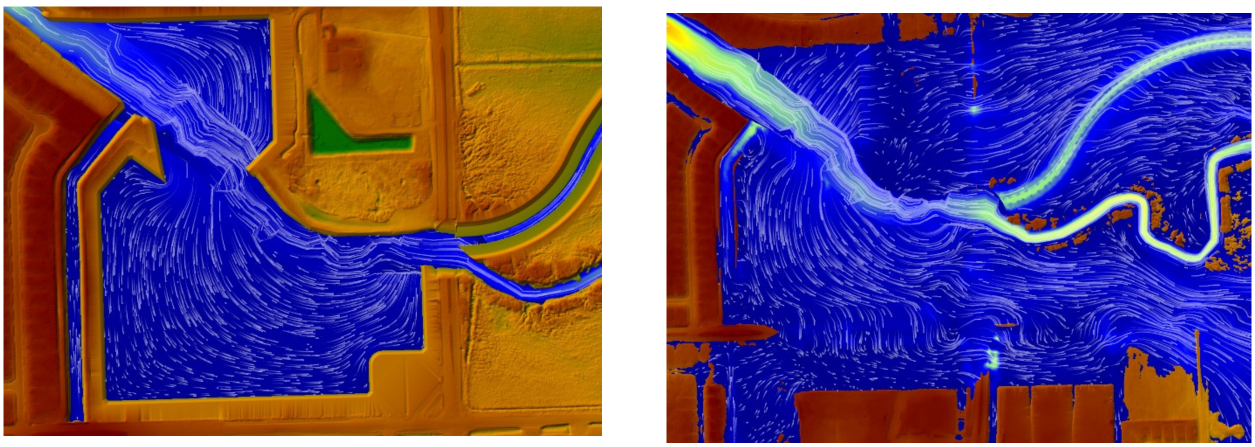


Figure 11: Sedimentation Flow Patterns

It is therefore important to note that the sedimentation basins would exhibit considerably different flow patterns between lower storm events like the 50% AEP compared to higher ones like the 1% AEP. While the model results indicate that an area of reduced velocity could be achieved using the tracts just upstream of Greenhouse Road, additional analysis should be performed to fully understand the existing sediment loading and required basin size and configuration to effectively capture and collect sediment.

4.3.7.5 Alternative 1 Scenario 4: Environmental Considerations

This scenario includes full benching of South Mayde Creek, construction of the natural stable bypass channel, and construction of sedimentation basins upstream of Greenhouse Road. Impacts associated with the channel improvements and the bypass channel would be the same as Scenario 2; however, an additional ±8 acres of wetland impacts are anticipated to facilitate the construction of the sedimentation basins (based on desktop review). This would require authorization of the project under a Standard IP and substantial compensatory mitigation bank credit purchase. Additionally, the bypass channel is located within the Federal Civil Works Project footprint of Addicks Reservoir and would require authorization under a Section 408 permit, necessitating additional environmental review under NEPA. An environmental constraints map is provided for Alternative 1, Scenario 4 as **Exhibit 49**.

4.3.7.6 Alternative 1 Scenario 4: Right-of-Way Requirements

No additional ROW would be required for the channel conveyance capacity improvements as all construction would be completed within existing HCDCD ROW. For the bypass channel, construction would occur on the USACE property within the Addicks Reservoir boundary. Currently, the USACE leases the land in the general location of the bypass channel to the City of Houston, which operates Cullen Park just north of South Mayde Creek between Greenhouse Road and Groeschke Road. HCFCD would have to coordinate with the USACE and complete an interlocal agreement to obtain approval to construct the bypass channel. It was assumed no ROW acquisition cost would be required, but this would have to be verified with the USACE. Construction of the sedimentation basins would require ROW acquisition of two undeveloped parcels just upstream of Greenhouse Road.

4.3.7.7 Alternative 1 Scenario 4: Estimated Project Cost

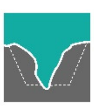
The estimated cost for this scenario is approximately $19.7M and includes the following items:

- Construction of channel improvement: $7.2M
  (including 20% contingency and excluding relocation of existing trails)
- Construction of bypass channel: $4.5M
  (including 20% contingency)
- Construction of sedimentation basins: $3.3M
  (including 20% contingency)
- ROW acquisition: $1.5M
- Environmental Mitigation: $0.4M
- Professional Services Fees: $2.9M

4.3.7.8 Alternative 1 Scenario 4: Maintenance & Other Considerations

The maintenance and other considerations for the channel improvements and bypass channel are described in Section 4.3.5.7 for Alternative 1, Scenario 2. For the sedimentation basins, an inspection and sediment removal plan would need to be developed in conjunction with the USACE. Adequate space should be provided to allow for sediment removal. Engineering details for the sedimentation basins (including basin layout, basin sizing, and interface with Mayde Creek) still require more refinement, including possibly more data collection on sediment loading.

4.3.8 Scenario 5: Channel Improvements with Desilted Conditions



This scenario is similar to Scenario 1A in that it involves the full-width channel improvements but also represents a desilted condition that accounts for the recent HCFCD maintenance project that removed sediment along South Mayde Creek.

4.3.8.1 Alternative 1 Scenario 5: Description of Scenario

The same base model developed for Scenario 1A was used and the lower portion of the cross-section data was adjusted to reflect the removed sediment excavated from the channel as part of the desilting efforts. The desilting project construction plan set can be found in **Appendix T**.

This scenario includes the same channel improvements as described in Scenario 1A (see Section 4.3.1.1). These channel improvements consist of a trapezoidal channel section benched above the OHWM on both sides of South Mayde Creek.

4.3.8.2 Alternative 1 Scenario 5: Scenario Objective

The goal of this scenario was to evaluate whether the desilting work completed along South Mayde Creek would offset all or some of the minor WSEL impacts identified from the model results for Scenario 1A and therefore provide a feasible path forward for the channel improvements to move into design.

4.3.8.3 Alternative 1 Scenario 5: Hydraulic Analysis & Results

This scenario was modeled by using the Channel Design/Modifications Tool in HEC-RAS to modify the proposed cross-sections to match the station and elevation information contained in the plan set provided by HCFCD. **Table 28 - Table 30** includes the results of the hydraulic analysis for the 50%, 10%, and 1% AEP storm events.

Table 28. Alternative 1, Scenario 5 Model Results - 50% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario5	Existing_AsIs vs Alt1_Scenario5
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.04	-0.99
Fry Road	111.94	110.54	-1.40
Confluence of U101-03 and U101-00	109.53	109.02	-0.51
Greenhouse Road	108.76	108.71	-0.05
Groeschke Road	104.59	104.54	-0.05
Barker Cypress Road	102.83	102.77	-0.06
Reservoir	95.32	95.26	-0.06

Table 29. Alternative 1, Scenario 5 Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario5	Existing_AsIs vs Alt1_Scenario5
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	120.62	-0.64
Fry Road	113.72	112.15	-1.57
Confluence of U101-03 and U101-00	111.66	111.02	-0.64
Greenhouse Road	110.22	110.33	0.11
Groeschke Road	106.21	106.24	0.03
Barker Cypress Road	104.87	104.89	0.02
Reservoir	97.93	97.95	0.02

Table 30. Alternative 1, Scenario 5 Model Results - 1% AEP

Comparison Location	Existing_AsIs	Alt1_Scenario5	Existing_AsIs vs Alt1_Scenario5
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.39	-0.01
Fry Road	116.54	114.75	-1.79
Confluence of U101-03 and U101-00	113.41	112.56	-0.85
Greenhouse Road	111.24	111.35	0.11
Groeschke Road	107.62	107.68	0.06
Barker Cypress Road	106.33	106.38	0.05
Reservoir	99.16	99.20	0.04

The model results for this scenario were similar to those for Alternative 1, Scenario 1A. Additional WSEL reductions compared to Scenario 1A ranged from 0.4 to 0.5 feet; however, there are areas where WSEL increases (0.04 feet) were observed too. The analysis showed that accounting for the desilting completed along South Mayde Creek did not completely mitigate all the impacts introduced by the channel improvements.

4.3.8.4 Alternative 1 Scenario 5: Environmental Considerations

The environmental considerations for this scenario are the same as Scenario 1A (see Section 4.1.3.4).

4.3.8.5 Alternative 1 Scenario 5: Right-of-Way Requirements

The Right-of-Way requirements for this scenario are the same as Scenario 1A (see Section 4.1.3.5).

4.3.8.6 Alternative 1 Scenario 5: Estimated Project Cost

The project cost for this scenario is the same as Scenario 1A (see Section 4.1.3.6).

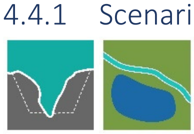
4.3.8.7 Alternative 1 Scenario 5: Maintenance & Other Considerations

Maintenance and others considerations for this scenario are the same as for Scenario 1A (see Section 4.1.3.7).

4.4 Alternative 2 Model Development and Results

This alternative served as a continuation of the improvements evaluated as part of Alternative 1. Alternative 2 focused on adding the proposed detention basins upstream of Fry Road that were studied by HDR. Alternative 2 was divided into two scenarios that combined the HDR detention basins with the main proposed improvements from Alternative 1 (channel improvements and a bypass channel).

4.4.1 Scenario 1: Full Channel Improvements and Regional Detention Basins



Scenario 1 incorporated two detention basins located south of South Mayde Creek near the confluences with U101-05-00 and U101-21-00 with channel improvements between Fry Road and Greenhouse Road.

4.4.1.1 Alternative 2 Scenario 1: Description of Scenario

The channel improvement component of this scenario is the same as described for Alternative 1, Scenario 1A (see Section 4.3.1.1).

The detention basins both have weirs as their inflow structure and RCP culverts for outflow structures. A summary of key pond design details for each pond is provided below.

Sand Pit Basin

- 62.3-acre footprint, 9-foot depth, and roughly 445 ac-ft of storage volume
- Approximately 75-foot weir with a depth of 3 feet and an 8-ft diameter RCP outfall culvert

Sprint and Clay Basin

- 57.6-acre footprint, 13-foot depth, and roughly 579 ac-ft of storage volume
- Approximately 120-foot weir with a depth of 3.5 feet and a 7-ft diameter RCP outfall culvert

Additional information about the proposed detention basins can be found in the HDR drainage report, which is included in **Appendix U**. The layout of this alternative is included on **Exhibit 50**.

4.4.1.2 Alternative 2 Scenario 1: Scenario Objective

The goal of this scenario is to evaluate the ability of the HDR detention basins to mitigate any impacts caused by the channel conveyance capacity improvements. Another objective was to evaluate the flood risk reduction benefit and potential impacts of the combined improvements.

4.4.1.3 Alternative 2 Scenario 1: Hydraulic Analysis & Results

The HDR detention basins were incorporated into the Halff modeling by importing the pond hydraulic data, including the pond storage area and associated outfall structures, directly into the Halff HEC-RAS models. The HDR detention basins were modeled using 1D storage areas, which were imported along with the lateral structures along the perimeter of the basins and along South Mayde Creek. This alternative was modeled by combining the detention basin hydraulic data provided by HDR with the Halff Alternative 1, Scenario 1A model. The terrain was also revised to reflect the detention basins to provide more accurate inundation mapping.

Table 31 - Table 33 include the results of the hydraulic analysis for the 50%, 10%, and 1% storm events. **Exhibits 51-53** show the inundation boundaries for the 50%, 10%, and 1% storm events. Full results of the model for all storms included in the analysis are included in **Appendix V**.

Table 31: Alternative 2, Scenario 1 Model Results - 50% AEP

Comparison Location	Existing_AsIs	Alt2_Scenario1	Existing_AsIs vs Alt2_Scenario1
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.56	-0.47
Fry Road	111.94	111.05	-0.89
Confluence of U101-03 and U101-00	109.53	109.17	-0.36
Greenhouse Road	108.76	108.68	-0.08
Groeschke Road	104.59	104.54	-0.05
Barker Cypress Road	102.83	102.76	-0.07
Reservoir	95.32	95.25	-0.07

Table 32: Alternative 2, Scenario 1 Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt2_Scenario1	Existing_AsIs vs Alt2_Scenario1
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	120.47	-0.79
Fry Road	113.72	112.11	-1.61
Confluence of U101-03 and U101-00	111.66	111.01	-0.65
Greenhouse Road	110.22	110.13	-0.09
Groeschke Road	106.21	106.02	-0.19
Barker Cypress Road	104.87	104.71	-0.16
Reservoir	97.93	97.76	-0.17

Table 33: Alternative 2, Scenario 1 Model Results - 1% AEP

Comparison Location	Existing_AsIs	Alt2_Scenario1	Existing_AsIs vs Alt2_Scenario1
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.36	-0.04
Fry Road	116.54	114.57	-1.97
Confluence of U101-03 and U101-00	113.41	112.55	-0.86
Greenhouse Road	111.24	111.09	-0.15
Groeschke Road	107.62	107.40	-0.22
Barker Cypress Road	106.33	106.11	-0.22
Reservoir	99.16	99.00	-0.16

This scenario resulted in WSEL reductions at all comparison locations for all the modeled storm events, with the exception of increases of approximately 0.1 feet in the 1% AEP (near the HDR detention basins) and 0.2% AEP (downstream of Greenhouse Road). Some key highlights of the model results are provided below:

- The 50% AEP peak WSEL reduction vary from 0.1 to 0.9 feet between Fry Road and Greenhouse Road. WSEL reductions in this area remain in the 0.3-2.3 feet range for higher storm events.
- WSEL reductions decrease towards the downstream end of the model, specifically east of Greenhouse Road as you move farther away from the proposed improvement areas.
- Overall, the model results indicate that the addition of the regional detention ponds mitigates for the full benched channel conveyance improvements.

4.4.1.4 Alternative 2 Scenario 1: Environmental Considerations

This scenario includes full benching of South Mayde Creek, as well as the addition of the sand pit detention basins near upstream of the proposed channel improvements. Impacts to WOTUS associated with the benching would be similar to Alternative 1: Scenario 1A. The benched trapezoidal channel would be designed to result in no net loss in surface area of WOTUS or reduction in function/condition. It is anticipated that minimal/temporary impacts to WOTUS would be authorized under a Nationwide Permit (NWP), likely NWP – 43 (Stormwater Management Facilities). The Sand Pit Detention areas are separate project with independent utility from the South Mayde Creek channel improvements. The detention basins would be designed by Brooks and Sparks and 404 permitting would be evaluated and pursued as a component of that project design. An environmental constraints map is provided for Alternative 2, Scenario 1 as **Exhibit 54**.

4.4.1.5 Alternative 2 Scenario 1: Right-of-Way Requirements

Since the channel conveyance capacity improvements are proposed entirely within the existing HCFCD ROW, there is no additional ROW needed. Additional ROW acquisition is required to construct the regional detention ponds. More information on the expected ROW requirements for the two regional detention basins can be found in the PER prepared by Brooks and Sparks.

4.4.1.6 Alternative 2 Scenario 1: Estimated Project Cost

The estimated cost for this scenario is approximately $20.2M and includes the following items:

- Construction of channel improvement: $6.9M
  (including 20% contingency and excluding relocation of existing trails)
- Construction of regional detention basins: $9.8M
  (including 10% contingency and excluding professional services, ROW acquisition, and environmental mitigation)
- ROW acquisition: $0.0M
- Environmental Mitigation: $0.0M
- Professional Services Fees: $3.6M

4.4.1.7 Alternative 2 Scenario 1: Maintenance & Other Considerations

The maintenance required for the channel conveyance capacity improvements and regional detention ponds would involve typical maintenance activities for standard HCFCD channels and detention facilities.

Other considerations regarding the regional detention basins are discussed in the PER prepared by Brooks and Sparks.

4.4.2 Scenario 2: Full Channel Improvements, Bypass Channel, Sedimentation Basins, and Regional Detention Basins

Scenario 2 combined the same two HDR detention basins with both primary Alternative 1 projects (channel improvements and bypass channel). In addition, sedimentation basins located just upstream of Greenhouse Road are included.

4.4.2.1 Alternative 2 Scenario 2: Description of Scenario

The channel improvements component of this scenario is the same as for Alternative 1, Scenario 1A (see Section 4.3.1.1). The proposed bypass channel and sedimentation basins are discussed more in detail in Section 4.3.7.1 as part of Alternative 1, Scenario 4. The layout of this alternative is included on **Exhibit 55**.

4.4.2.2 Alternative 2 Scenario 2: Scenario Objective

The goal of this scenario is to evaluate the ability of the HDR detention basins to mitigate any impacts caused by the channel improvements and bypass channel. Another objective was to evaluate the flood risk reduction benefit and potential impacts of the combined improvements, which includes all of the proposed improvements evaluated in Alternative 1.

4.4.2.3 Alternative 2 Scenario 2: Hydraulic Analysis & Results

This alternative was modeled by combining the detention basin hydraulic data provided by HDR with the Halff Alternative 1, Scenario 4 model. The terrain was also revised to reflect the detention basins to provide more accurate inundation mapping. **Table 34 - Table 36** includes the results of the hydraulic analysis for the 50%, 10%, and 1% AEP storm events. **Exhibits 56-58** show the inundation boundaries for the 50%, 10%, and 1% storm events. Full results of the model for all storms included in the analysis are included in **Appendix W**.

Table 34: Alternative 2, Scenario 2 Model Results - 50% AEP

Comparison Location	Existing_AsIs	Alt2_Scenario2	Existing_AsIs vs Alt2_Scenario2
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.20	-0.83
Fry Road	111.94	109.93	-2.01
Confluence of U101-03 and U101-00	109.53	107.63	-1.90
Greenhouse Road	108.76	106.77	-1.99
Groeschke Road	104.59	104.13	-0.46
Barker Cypress Road	102.83	102.83	0.00
Reservoir	95.32	95.37	0.05

Table 35: Alternative 2, Scenario 2 Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt2_Scenario2	Existing_AsIs vs Alt2_Scenario2
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	120.47	-0.79
Fry Road	113.72	112.11	-1.61
Confluence of U101-03 and U101-00	111.66	110.22	-1.44
Greenhouse Road	110.22	109.11	-1.11
Groeschke Road	106.21	105.59	-0.62
Barker Cypress Road	104.87	104.89	0.02
Reservoir	97.93	97.78	-0.15

Table 36: Alternative 2, Scenario 2 Model Results - 1% AEP

Comparison Location	Existing_AsIs	Alt2_Scenario2	Existing_AsIs vs Alt2_Scenario2
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.35	-0.05
Fry Road	116.54	114.18	-2.36
Confluence of U101-03 and U101-00	113.41	111.98	-1.43
Greenhouse Road	111.24	110.25	-0.99
Groeschke Road	107.62	107.04	-0.58
Barker Cypress Road	106.33	106.27	-0.06
Reservoir	99.16	98.99	-0.17

This scenario, like Alternative 2, Scenario 1, also provides significant WSEL reductions across the modeled storm events. There are several instances where WSEL increases are observed, but these primarily occur at Barker Cypress Road. WSEL increases at this location could be explained by more flow being discharged back in South Mayde Creek from the bypass channel just upstream of Barker Cypress Road. Some key highlights of the model results are provided below:

- The 50% AEP peak WSEL reduction between Fry Road and Greenhouse Road is roughly 2 feet. WSEL reductions in this area remain generally in the 1-2.6 feet range for higher storm events.
- WSEL reductions decrease towards the downstream end of the model, specifically east of Greenhouse Road as you move farther away from the proposed improvement areas.
- There is a 0.05-foot increase in WSEL at the downstream end of the model in the 50% AEP event.
- Overall, the model results indicate that the addition of the regional detention ponds generally mitigates for the other proposed improvements in the majority of storm events.

4.4.2.4 Alternative 2 Scenario 2: Environmental Considerations

This scenario is similar to Alternative 2: Scenario 1 but includes the addition of the natural stable bypass channel and the sedimentation basins previously discussed in Alternative 1. Permanent impacts to WOTUS would include ±8.57 acres of wetland impacts and 0.48 acre/800 linear feet of stream, necessitating a Standard IP submittal to the USACE and substantial compensatory mitigation bank credits. Additionally, the bypass channel is located within the Federal Civil Works Project footprint of Addicks Reservoir and would require authorization under a Section 408 permit, necessitating additional environmental review under NEPA. The Sand Pit Detention areas are separate project with independent utility from the South Mayde Creek channel improvements. The detention basins would be designed by Brooks and Sparks and 404 permitting would be evaluated and pursued as a component of that project design. An environmental constraints map is provided for Alternative 2, Scenario 2 as **Exhibit 59**.

4.4.2.5 Alternative 2 Scenario 2: Right-of-Way Requirements

Since the channel conveyance capacity improvements are proposed entirely within the existing HCFCD ROW, there is no additional ROW needed. The bypass channel would require additional ROW to be acquired through an interagency agreement with the USACE. Additional ROW acquisition is required to construct the regional detention ponds. More information on the expected ROW requirements for the two regional detention basins can be found in the PER prepared by Brooks and Sparks.

4.4.2.6 Alternative 2 Scenario 2: Estimated Project Cost

The estimated cost for this scenario is approximately $31.8M and includes the following items:

- Construction of channel improvement: $7.2M
  (including 20% contingency and excluding relocation of existing trails)
- Construction of regional detention basins: $9.8M
  (including 10% contingency and excluding professional services, ROW acquisition, and environmental mitigation)
- Construction of bypass channel: $4.5M
  (including 20% contingency)
- Construction of sedimentation basins: $3.3M
  (including 20% contingency)
- ROW acquisition: $1.5M
- Environmental Mitigation: $0.4M
- Professional Services Fees: $5.1M

4.4.2.7 Alternative 2 Scenario 2: Maintenance & Other Considerations

The maintenance required for the channel conveyance capacity improvements and regional detention ponds would involve typical maintenance activities for standard HCFCD channels and detention facilities. Other considerations regarding the regional detention basins are discussed in the PER prepared by Brooks and Sparks. The bypass channel and sedimentation basins maintenance and other considerations are the same as described for Alternative 1, Scenario 4 (see Section 4.3.7.5). As mentioned previously, the sedimentation basins were assumed to be required as a complementary drainage improvement in order to construct the bypass channel.

4.5 Alternative 3 Model Development and Results

Alternative 3 represents an ultimate condition that combines all previously evaluated improvements into one comprehensive, long-term solution in order to assess the potential benefits, costs, and impacts if all of the major proposed projects were eventually implemented.

4.5.1 Scenario 1

Scenario 1 combines all of the proposed improvements (channel improvements, bypass channel, sedimentation basins, HDR detention basins, and Greenhouse Road bridge replacement) from previous alternative scenarios into a single, comprehensive alternative.

4.5.1.1 Alternative 3 Scenario 1: Description of Scenario

This scenario includes the same channel improvements from Alternative 1, Scenario 1A (see Section 4.3.1.1), the same bypass channel and sedimentation basins as in Alternative 1, Scenario 4 (see Section 4.3.7.1), and the same HDR detention basins as in Alternative 2, Scenario 1 (see Section 4.4.1.1). Replacement of the Greenhouse Road bridge is discussed in Alternative 1, Scenario 3 (see Section 4.3.6.1). The layout of this alternative is shown on **Exhibit 60**.

4.5.1.2 Alternative 3 Scenario 1: Scenario Objective

The goal of this scenario is to understand the combined benefits and potential impacts of all the major proposed improvements if implemented together. By evaluating a scenario with all the individual improvements that comprise a long-term solution, the potential benefits can be weighed against the cumulative cost and challenges of implementing all the improvements.

4.5.1.3 Alternative 3 Scenario 1: Hydraulic Analysis & Results

This alternative was modeled by importing the proposed Greenhouse Road bridge from Alternative 1 Scenario 3 into the Alternative 2 Scenario 2 model. **Table 37 - Table 39** includes the results of the hydraulic analysis of for the 50%, 10%, and 1% storm events. **Exhibits 61-63** show the inundation boundaries for the 50%, 10%, and 1% storm events. Full results of the model for all storms included in the analysis are included in **Appendix X**.

Table 37: Alternative 3, Scenario 1 Model Results - 50% AEP

Comparison Location	Existing_AsIs	Alt3_Scenario1	Existing_AsIs vs Alt3_Scenario1
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	117.03	116.19	-0.84
Fry Road	111.94	109.92	-2.02
Confluence of U101-03 and U101-00	109.53	107.61	-1.92
Greenhouse Road	108.76	106.74	-2.02
Groeschke Road	104.59	104.12	-0.47
Barker Cypress Road	102.83	102.82	-0.01
Reservoir	95.32	95.35	0.03

Table 38: Alternative 3, Scenario 1 Model Results - 10% AEP

Comparison Location	Existing_AsIs	Alt3_Scenario1	Existing_AsIs vs Alt3_Scenario1
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	121.26	120.47	-0.79
Fry Road	113.72	112.11	-1.61
Confluence of U101-03 and U101-00	111.66	110.12	-1.54
Greenhouse Road	110.22	108.84	-1.38
Groeschke Road	106.21	105.57	-0.64
Barker Cypress Road	104.87	104.87	0.00
Reservoir	97.93	97.77	-0.16

Table 39: Alternative 3, Scenario 1 Model Results - 1% AEP

Comparison Location	Existing_AsIs	Alt3_Scenario1	Existing_AsIs vs Alt3_Scenario1
	W.S. Elev	W.S. Elev	W.S. Elev
	(ft)	(ft)	(ft)
Lakes of Bridgewater Drive	124.40	124.35	-0.05
Fry Road	116.54	114.10	-2.44
Confluence of U101-03 and U101-00	113.41	111.88	-1.53
Greenhouse Road	111.24	109.88	-1.36
Groeschke Road	107.62	107.03	-0.59
Barker Cypress Road	106.33	106.25	-0.08
Reservoir	99.16	98.97	-0.19

The model results show significant WSEL reduction along South Mayde Creek. The WSEL reductions in the upstream part of the model (north of Fry Road) are primarily driven by the regional detention ponds while the channel conveyance capacity improvements and bypass channel further downstream contribute to lower WSELs between Fry Road and Greenhouse Road. Some key highlights of the model results are provided below:

- The 50% AEP peak WSEL reduction of roughly 2 feet occurs between Fry Road and Greenhouse Road. WSEL reductions in this area remain in the 1.5-2 feet range for higher storm events.
- WSEL reductions decrease towards the downstream end of the model, specifically east of Groeschke Road as you move farther away from the proposed improvement areas.
- There is a minor 50% AEP WSEL increase of 0.03 feet at the downstream end of the model as well as a 0.15-foot WSEL increase near Barker Cypress Road in the 4% AEP and 0.2% AEP events.
- Two storm events (4% AEP and 0.2% AEP) have WSEL increases at Barker Cypress Road. This is likely attributed to the additional flow being conveyed through the bypass channel, which discharges back into South Mayde Creek just upstream of Barker Cypress Road.
- The replacement of the Greenhouse Road bridge does provide incremental WSEL reductions or reduction of adverse impacts. The incremental reduction is minimal in the 50% AEP storm event but increases to approximately 0.5 feet in higher storm events. This is likely attributed to the bridge replacement contributing to a continuous section of South Mayde Creek where the conveyance capacity has been increased and existing hydraulic restrictions have been reduced.
- This scenario evaluated a combination of improvements that facilitate increased conveyance from Fry Road downstream into the Addicks Reservoir. Because improvements to the Barker Cypress Road bridge were not part of this study evaluation, it is expected that impacts would be observed in this part of the model which still serves as a hydraulic restriction given the increased peak flow in South Mayde Creek at this bridge.

4.5.1.4 Alternative 3 Scenario 1: Environmental Considerations

This alternative is similar to Alternative 2: Scenario 2 but includes the addition of Greenhouse Road bridge improvements. WOTUS impacts and permitting/mitigation requirements are expected to be similar to Alternative 2: Scenario 2, with only minor/temporary increase in impact to South Mayde Creek associated with bridge reconstruction. An environmental constraints map is provided for Alternative 3, Scenario 1 as **Exhibit 64**.

4.5.1.5 Alternative 3 Scenario 1: Right-of-Way Requirements

The ROW requirements for this scenario are a combination of the ROW requirements needed to construct each of the individual components that comprise this long-term, comprehensive solution. The ROW requirements for each major improvement are summarized below:

- *Channel improvements*: no additional ROW needed (all work contained within existing ROW)
- *Bypass channel*: ROW needed within USACE property (interagency agreement required)
- *Sedimentation basins*: additional ROW needed
- *Regional detention basins*: additional ROW needed

- *Greenhouse Road bridge replacement*: assumed no additional ROW needed

4.5.1.6 Alternative 3 Scenario 1: Estimated Project Cost

The estimated cost for this scenario is approximately $34.5M and includes the following items:

- Construction of channel improvement: $7.2M
  (including 20% contingency and excluding relocation of existing trails)
- Construction of regional detention basins: $9.8M
  (including 10% contingency and excluding professional services, ROW acquisition, and environmental mitigation)
- Construction of bypass channel: $4.5M
  (including 20% contingency)
- Construction of sedimentation basins: $3.3M
  (including 20% contingency)
- Construction of Greenhouse Road bridge replacement: $2.3M
  (including 20% contingency)
- ROW acquisition: $1.5M
- Environmental Mitigation: $0.4M
- Professional Services Fees: $5.6M

4.5.1.7 Alternative 3 Scenario 1: Maintenance & Other Considerations

The majority of the maintenance considerations relate to ensuring the necessary access to the proposed improvement areas such that typical HCFCD maintenance (i.e. moving, debris removal, inspection) can be performed. A summary of the maintenance and other consideration for this scenario is provided below:

- *Channel improvements*: typical HCFCD channel maintenance
- *Bypass channel*: typical NSCD maintenance
- *Sedimentation basins*: inspection and regular removal of accumulated sediment
- *Regional detention basins*: typical HCFCD detention facility maintenance
- *Greenhouse Road bridge replacement*: bridge maintenance would be handled by Harris County

4.6 Evaluation of Flood Metrics

To better quantitively compare the different proposed scenarios, flood metrics were calculated based on the existing and proposed hydraulic model results. By comparing these metrics for each scenario to existing conditions, the relative benefit and flood risk reduction potential could be assessed. The three metrics calculated consisted of the following:

1. Inundation acreage (total acreage of ponding within study area)
2. Inundated roadways (total mileage of roads within inundation extents)
3. Inundated structures (total number of structures within inundation extents)

To calculate the inundated roadway length and structures, the roadway and structures shapefiles were intersected with the inundation extents using ArcGIS. These metrics are provided in *Error! Reference source not found.*.

Table 40: Summary of Metrics

Scenario	Event	Inundated Acreage	Δ Acreage	Road Length Inundated (Mi.)	Δ Road Length	Structures	Δ Structures
Existing As Is	50% AEP	646.9	-	13.7	-	24	-
	10% AEP	1,014.9	-	29.9	-	102	-
	1% AEP	1,690.3	-	50.0	-	1,673	-
	0.2% AEP	2,404.3	-	66.9	-	3,380	-
ALT 1 Scen 1a	50% AEP	632.5	-14.4	13.7	0.0	24	0
	10% AEP	978.0	-36.8	26.7	-3.2	92	-10
	1% AEP	1,554.2	-136.1	48.3	-1.7	1,188	-485
	0.2% AEP	2,297.9	-106.5	63.4	-3.5	3,088	-292
ALT 1 Scen 1b	50% AEP	628.1	-18.8	13.7	0.0	24	0
	10% AEP	972.2	-42.7	26.5	-3.4	89	-13
	1% AEP	1,531.0	-159.4	48.1	-2.0	1,088	-585
	0.2% AEP	2,300.6	-103.7	63.9	-3.0	3,109	-271
ALT 1 Scen 1c	50% AEP	635.5	-11.4	13.7	0.0	24	0
	10% AEP	982.7	-32.1	27.3	-2.7	93	-9
	1% AEP	1,590.3	-100.0	48.9	-1.1	1,350	-323
	0.2% AEP	2,332.0	-72.4	64.5	-2.4	3,171	-209
ALT 1 Scen 1d	50% AEP	631.0	-15.9	13.7	0.0	24	0
	10% AEP	976.2	-38.7	26.6	-3.3	88	-14
	1% AEP	1,575.3	-115.0	48.5	-1.5	1,275	-398
	0.2% AEP	2,335.2	-69.1	65.0	-1.9	3,174	-206
ALT 1 Scen 2	50% AEP	561.6	-85.3	13.2	-0.5	22	-2
	10% AEP	940.3	-74.6	24.6	-5.3	73	-29
	1% AEP	1,480.5	-209.8	47.8	-2.2	1,023	-650
	0.2% AEP	2,229.9	-174.4	62.6	-4.3	2,954	-426
ALT 1 Scen 3	50% AEP	634.1	-12.8	13.4	-0.3	24	0
	10% AEP	975.2	-39.6	26.6	-3.4	72	-30
	1% AEP	1,542.8	-147.5	48.2	-1.8	1,157	-516
	0.2% AEP	2,293.3	-111.0	63.3	-3.6	3,077	-303
ALT 1 Scen 4	50% AEP	577.3	-69.6	13.2	-0.5	22	-2
	10% AEP	936.5	-78.4	23.4	-6.5	72	-30
	1% AEP	1,441.0	-249.4	46.9	-3.1	758	-915
	0.2% AEP	2,192.9	-211.4	61.8	-5.1	2,886	-494
ALT 2 Scen 1	50% AEP	657.5	10.6	13.7	0.0	24	0
	10% AEP	1,013.0	-1.8	25.9	-4.1	85	-17
	1% AEP	1,494.8	-195.5	46.8	-3.2	832	-841

Scenario	Event	Inundated Acreage	Δ Acreage	Road Length Inundated (Mi.)	Δ Road Length	Structures	Δ Structures
	0.2% AEP	2,303.1	-101.2	63.2	-3.7	3,043	-337
ALT 2 Scen 2 	50% AEP	600.2	-46.7	13.1	-0.7	22	-2
	10% AEP	971.2	-43.7	22.9	-7.1	70	-32
	1% AEP	1,395.2	-295.1	44.4	-5.6	470	-1,203
	0.2% AEP	2,201.7	-202.6	61.6	-5.3	2,841	-539
ALT 3 Scen 1 	50% AEP	598.3	-48.6	12.7	-1.0	22	-2
	10% AEP	962.1	-52.8	22.5	-7.5	70	-32
	1% AEP	1,382.1	-308.2	43.9	-6.1	447	-1,226
	0.2% AEP	2,179.5	-224.87	61.32	-5.58	2,807	-573

The flood evaluation metrics results are summarized below:

- Reductions in inundation acreage, inundated roadway miles, and inundated structures are lowest for the 50% AEP storm events and highest in the 1% AEP event. The metrics are lower for the 0.2% AEP because of the more complex 1D/2D flow exchanges that occur with the higher flow rates and WSELs as well as the fact that the drainage improvements would be inundated earlier on in the 0.2% AEP event. This would occur especially in areas along Mayde Creek where existing ponding was estimated to be relatively high, such as just upstream of Greenhouse Road and between Greenhouse and Groeschke Road near Cullen Park.
- Structures removed from inundation in the lower storm events (50% AEP and 10% AEP) generally are less than 50, while in the 1% AEP they range from 300 to over 1,200.
- Alternative 1, Scenarios 1A-1D have 1% AEP inundated structure decreases of 400-600 compared to approximately 900 for Alternative 1, Scenario 4, which includes both channel improvements and the bypass channel. The removal of 900 structures is similar to the average 1% AEP removed structure counts for the Alternative 2 scenarios, which makes sense since the first Alternative 2 scenario only include the channel improvements.
- Inundation area reductions for the 1% AEP event range from approximately 100-250 acres for Alternative 1, 200-300 acres for Alternative 2, and 300 acres for Alternative 3.
- Alternative 3, Scenario 1 had the largest reduction in inundation area and inundated structures removed, but the reductions were similar to Alternative 2, Scenario 2 (295 vs. 308 acres and 1,203 vs. 1,226 structures).
- Reductions in inundated roadways ranged from 0-8 miles across the three storm events analyzed. Although the reductions are typically minor (<0.5 mile) in the 50% AEP storm, even small reductions in the length of inundated roadways could be helpful to increase mobility throughout the area, especially given the documented history of frequent roadway flooding.

5.0 USACE Addicks Reservoir Impact Analysis

In addition to the standard impact assessment aimed at identifying locations where increases in peak flow rate and WSEL may occur, a separate impact analysis was performed as requested by the USACE. The USACE may grant permission through a Section 408 permit for another party (i.e. HCFCD) to alter a Civil Works project upon a determination that the alternation would not be injurious to the public intersect and will not impact the usefulness of the Civil Works project. One of the requirements of the Section 408 permitting process is the completion of a detailed hydrologic and hydraulic analysis.

The initial submittal to the USACE should indicate if Section 404 permit approval is also being requested so the USACE could conduct the necessary evaluation and permit reviews in a coordinated and concurrent manner, resulting in a single decision document. Early coordination with the USACE is critical since a Section 404 permit can't be issued prior to the Section 408 permit approval.

Impact Analysis Process

The USACE explained the requirement of performing an impact analysis focused on the Addicks Reservoir during the initial coordination meeting between the USACE and HCFCD that took place on April 19, 2018. Halff developed a suggested procedure for this analysis that looked at three primary criteria: peak flow rate, volume, and rate-of-rise in the reservoir. The USACE reviewed the Halff suggested procedure in December 2019 and was in general agreement with it. A brief summary of the procedure is outlined below:

1. Obtain the most current hydrologic model for the Addicks Reservoir watershed, including the major contributing HCFCD channels.
2. Modify the hydrologic model by making the following changes:
    a. Break the two diversions between South Mayde Creek and Bear Creek and send the diverted water to a sink node
    b. Truncate South Mayde Creek downstream of the Halff hydraulic model extents (slightly downstream of Barker Cypress Road) and add a source hydrograph from the Halff unsteady state HEC-RAS model to represent the flow draining from South Mayde Creek into the Addicks Reservoir
    c. Add a storage node to represent the Addicks Reservoir with connectivity that reflects all the flow from the major contributing channels combining before entering the reservoir
3. Use the best available elevation data (2018 LiDAR) to develop a stage-storage curve for the reservoir
4. Coordinate with the USACE to identify an appropriate assumption for the reservoir discharge relationship (i.e. a specific stage-discharge curve or constant outflow)
5. Run the HEC-HMS model for the 4% AEP, 1% AEP, and 0.2% AEP storm events (which approximate the future Atlas 14 10% AEP, 2% AEP, and 1% AEP events) for both existing conditions and different proposed conditions alternatives
6. Tabulate the peak flow and total runoff volume at key hydrologic model junctions as well as compare the stage hydrograph for the Addicks Reservoir storage node

Impact Analysis Results

This analysis was performed for key scenarios that captured the major additional improvements added for each alternative. The scenarios for which the impact analysis was performed are listed below:

- Existing Conditions
- Alternative 1, Scenario 1A
- Alternative 1, Scenario 4
- Alternative 2, Scenarios 1 and 2
- Alternative 3, Scenario 1

A comparison of peak flow rate and runoff volume was performed to identify any increases over existing conditions values. This comparison was done at two locations: 1) the most downstream HMS junction of South Mayde Creek and 2) the HMS junction just upstream of the Addicks Reservoir HMS reservoir node. By comparing peak flow and volume at these locations, both the impacts to South Mayde Creek as well as to the Addicks Reservoir (factoring in all contributing streams) can be assessed. No additional volume was added under proposed conditions since the hydrology (total subbasin area or impervious cover) was not modified. Given the complex flow computations, including continuous exchanges between the 1D and 2D model components, these minor changes in volume were likely due to small, incremental volume fluctuations in the model and not physical changes in volume along South Mayde Creek. A comparison summary is provided below in **Table 41** and detailed comparison tables are provided in **Appendix Y**.

Table 41: Summary of USACE Impact Analysis Results

Alternatives	Event	Impacts In Mayde Creek?		Impacts in Reservoir?	
		Flow	Δ Flow (%)	Flow	Δ Flow (%)
Alternative 1 Scenario 1a	4% AEP	Yes	2.19%	Yes	1.64%
Alternative 1 Scenario 4		Yes	1.71%	Yes	1.77%
Alternative 2 Scenario 1		No	-7.47%	No	-0.81%
Alternative 2 Scenario 2		No	-8.01%	No	-0.11%
Alternative 3 Scenario 1		No	-9.05%	Yes	0.75%
Alternative 1 Scenario 1a	1% AEP	Yes	1.64%	Yes	1.71%
Alternative 1 Scenario 4		Yes	0.65%	Yes	2.02%
Alternative 2 Scenario 1		No	-8.73%	No	-2.00%
Alternative 2 Scenario 2		No	-9.34%	No	-1.99%
Alternative 3 Scenario 1		No	-10.34%	No	-2.16%
Alternative 1 Scenario 1a	0.2% AEP	No	-0.44%	Yes	1.17%
Alternative 1 Scenario 4		No	-1.10%	Yes	1.38%
Alternative 2 Scenario 1		No	-0.11%	No	-1.56%
Alternative 2 Scenario 2		No	-1.59%	No	-1.42%
Alternative 3 Scenario 1		No	-1.97%	No	-1.33%

In general, scenarios that do not include the regional detention basins scenarios had flow increases at both comparison locations. This was expected given the reduction in peak flow the detention basins would provide, which would help mitigate for other improvements further downstream.

The analysis results indicated Alternative 1 scenarios have both peak flow impacts, although the percentage increases are low when compared to existing conditions – peak flow increases average roughly 1.5%. Alternative 2, Scenario 1 has no impacts at both comparison locations. Alternative 2, Scenario 2 and Alternative 3, Scenario 1 have no impacts in the 1% AEP and 0.2% AEP storm events, although minor impacts in the 4% AEP event. The flow increase for Alternative 3, Scenario 1 represents slightly less than a 1% increase from existing condition.

Rate-of-Rise Analysis

The stage hydrographs from the HMS reservoir node were compared to identify if a noticeable change was present and therefore indicate a potential adverse impact to the rate-of-rise of the Addicks Reservoir. No noticeable changes in the stage hydrographs between existing conditions and each proposed scenario were observed, as shown below in **Figure 12-13**. This suggested that any increases in peak flow or volume was not significant enough to affect the overall Addicks Reservoir. Further refinement of the hydraulic model for improvements along South Mayde Creek may result in changes to the results of the impact analysis.

Alternative 1, Scenario 1A

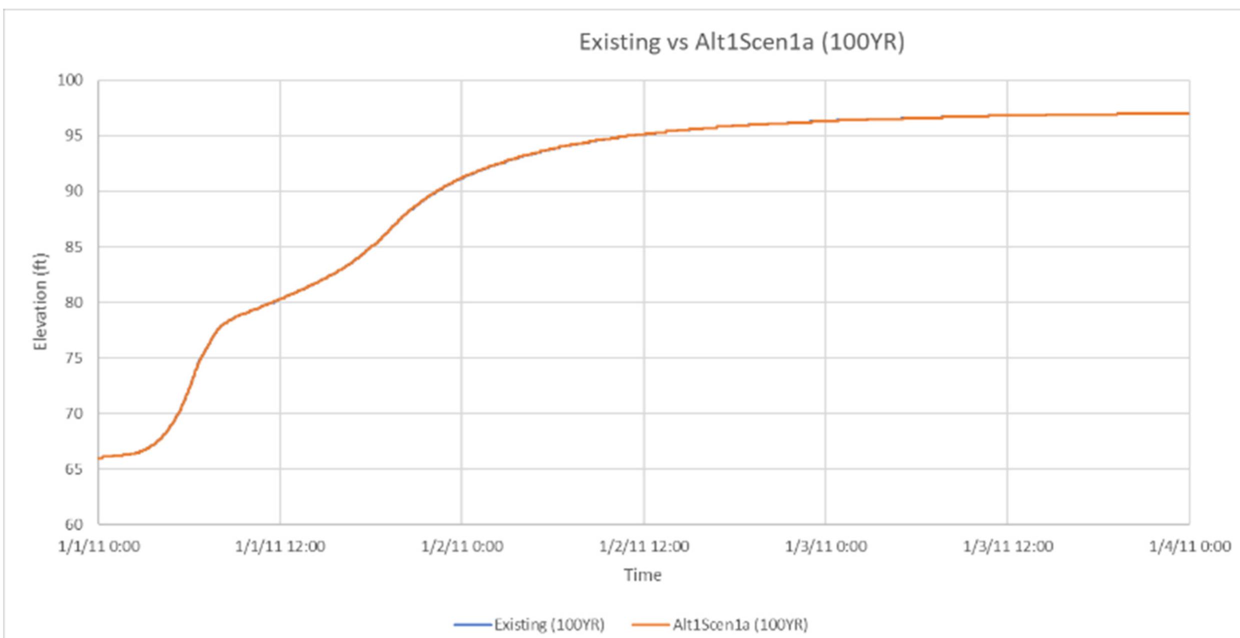


Figure 12: USACE Impact Analysis Stage Hydrograph Comparison for Alternative 1, Scenario 1A

Alternative 2, Scenario 2

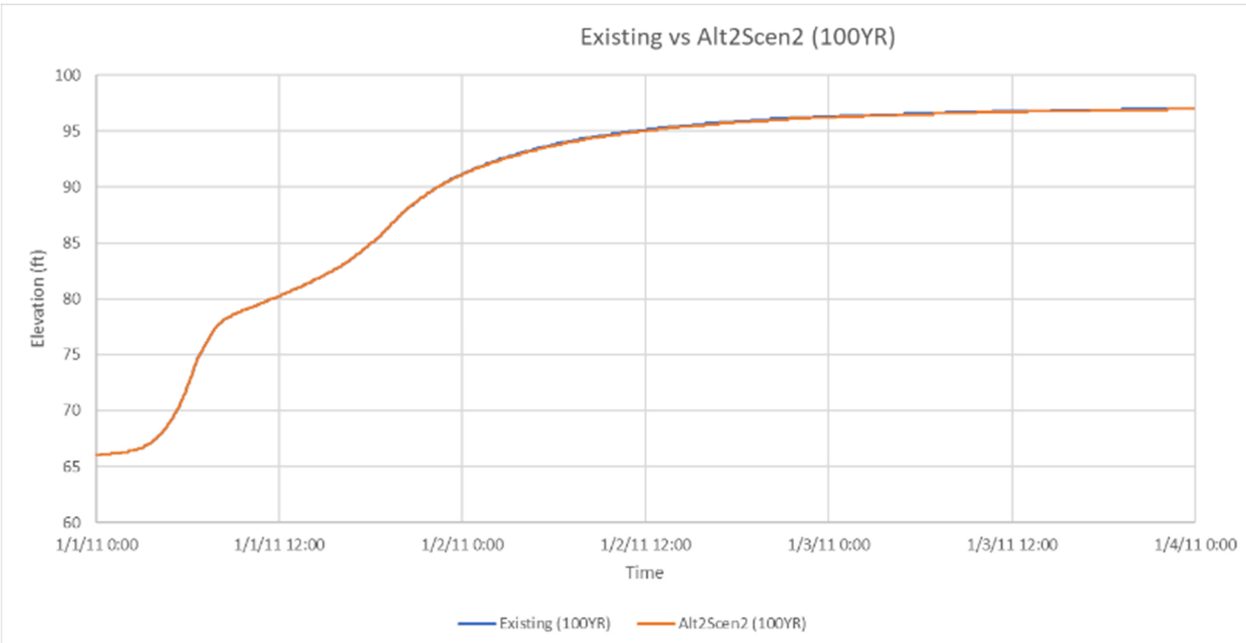


Figure 13: USACE Impact Analysis Stage Hydrograph Comparison for Alternative 2, Scenario 2

6.0 Community Engagement

A central component of the Bond projects is community engagement. The primary purpose of this is twofold – to inform the public about current projects under the HCFCD Bond program and to provide an opportunity for the public to ask questions and give comments. This information is then considered during the alternative development and evaluation process as well as in the identification of the preferred alternatives and creating the associated implementation plan.

The goal of community engagement efforts is to provide transparent and accessible public information about each Bond project and solicit meaningful public input. Information about the status and recommendations of the Bond projects is presented to the public and feedback from the community is collected and tabulated for future consideration.

A joint public meeting for the South Mayde Creek channel conveyance improvements (U101-00-00-P003) and the related stormwater detention (U501-06-00-E001) was held on November 14, 2019 at the Richard & Meg Weekley Community Center. The joint meeting covered both the Halff PER study as well as the HDR detention basin study given the overlap of the two project study areas and that both studies were evaluating proposed improvements that were part of a bigger, comprehensive long-term solution. The public meeting provided an opportunity for HCFCD, Halff, and HDR to present information about the progress of the current studies and receive feedback from the public regarding questions and concerns about the proposed flood control projects.

A total of 36 people attended the public meeting, which featured a presentation by HCFCD personnel and then an open house with HCFCD, partnering agencies such as the USACE, and the project consultant personnel available to provide information to residents and answers any questions. Key community input is summarized below. The community engagement meeting factsheet is provided in **Appendix Z**.

- Request to replace the walking trails, including a bridge over the new bypass channel connecting to Mayde Creek High School
- Request to include 10-foot wide sidewalks on crossing of Groeschke Road and bypass channel
- Request for map showing extents of desnag (vegetation removal) work and information on how much material was removed and duration of debris removal activities
- General concerns about the segment of South Mayde Creek east of Barker Cypress Road
- Concern that too much spending has been allocated to cleaning and widening South Mayde Creek between Fry Road and Greenhouse Road
- Request the bypass channel between Greenhouse Road and Barker Cypress Road be priority

7.0 Alternative Evaluation

After the modeling of the proposed scenarios was completed, the results were tabulated and compared to identify which scenarios should be recommended for further consideration.

7.1 Evaluation Criteria

Multiple factors were considered to developing the recommendations to weigh the potential flood risk reduction against estimated costs as well as consider ROW acquisition needs, permitting requirements, and potential construction challenges. The primary factors are listed below:

- Magnitude and location of WSEL reductions along South Mayde Creek
- Magnitude and location of adverse impacts (WSEL increases) along South Mayde Creek
- Results from the USACE impact analysis, including differences in peak flow rate, volume, and rate-of-rise in Addicks Reservoir
- Estimated cost of construction
- Expected timeline for design and construction
- Importance as part of long-term, comprehensive flood reduction solution

7.2 Recommended Alternative

Based on discussions with HCFCD, there seemed to be a dual goal of the alternative recommendation process: 1) identify a project that could more quickly move into design/construction and 2) outline a more long-term plan to achieve the desired reduction in flood risk. To accomplish both aspects of this goal, Halff had developed both short-term and long-term recommendations.

***Short-term Recommendation*: Alternative 2, Scenario 1 (Full Benched Channel Improvements and Regional Detention Basins)**

- Components:
    1. Full benched channel improvements
    2. Regional detention basins
- Benefits:
    1. Average WSEL reduction between Fry and Greenhouse Road of 0.1-1.8’ for the 10% AEP event and 0.1-1.9’ for the 1% AEP event
    2. 17 structures removed from the 10% AEP inundation and 841 structures removed from 1% AEP inundation
    3. No USACE adverse impacts
- Challenges:
    1. Need to relocate existing walking trails
    2. Regional detention basins are required for mitigation
    3. WSEL impacts remain at certain location during some storm events
        - Maximum 0.13’ in the 0.2 % AEP event upstream of Greenhouse Road
        - Maximum 0.07’ in the 1% AEP event near the regional detention basins

Implementing the channel conveyance capacity improvements could be done in the near future since no additional ROW would be required to be acquired prior to construction. The wider benching option was recommended because it provided WSEL reductions averaging around 0.5 feet more than the narrower benching option. Although the existing walking trails would need to be relocated, Scenario 1A attempts to maximum the use of the existing HCFCD ROW and create the framework for optimizing flood risk reduction benefits of the long-term solution.

The model results indicated that there were some minor WSEL increases, which could be partially attributed to model computational fluctuations. The construction of detention ponds in the undeveloped tracts just upstream of Greenhouse Road did not demonstrate full mitigation of impacts and is therefore not recommended as part-of the short-term solution. In order to mitigate adverse impacts, the proposed regional detention basins should be constructed with the channel improvements.

Long-term Recommendation**: Alternative 2, Scenario 2 (Full Benched Channel Improvements, Bypass Channel + Sedimentation Basins, and Regional Detention Basins)**

- Components:
  1. Full benched channel improvements
  2. Bypass channel
  3. Sedimentation basins
  4. Regional detention basins
- Benefits:
  1. Average WSEL reduction between Fry and Greenhouse Road of 0.9-2.3’ for the 10% AEP event and 0.8-2.3’ for the 1% AEP event
  2. 32 structures removed from the 10% AEP event inundation and 1,203 structures removed from 1% AEP event inundation
  3. No USACE adverse impacts
- Challenges:
  1. Longer timeframe for ROW acquisition
  2. USACE permitting process
  3. WSEL impacts remain at certain location during some storm events
     - Maximum 0.15’ in the 0.2 % AEP event upstream of Barker Cypress Road
     - Maximum 0.07’ in the 1% AEP event near the regional detention basins

Based on feedback from HCFCD, Halff assumed there was high likelihood that the regional detention basins would proceed forward into design and then construction given the estimated reductions in peak flow in South Mayde Creek and potential to be a central part of the overall South Mayde Creek solution to reduce flooding.

The combination of the bypass channel with the channel improvements (Alternative 1, Scenario 4) results in additional average WSEL reductions of between 0 and 1 foot compared to channel improvements by themselves (Alternative 1, Scenario 1A). When comparing the two Alternative 2 scenarios together, the additional WSEL reductions are greater overall (in the 0 to 2 feet range) for the entire length of modeled channel and for all modeled storm events. The bypass channel not only addresses a section of South Mayde Creek that has insufficient conveyance capacity, but also provides additional benefits through use of NSCD features.

7.3 Implementation and Phasing

One of the goals of the alternative analysis approach for this PER was to evaluate incremental improvements that combine to form a long-term, comprehensive solution to reduce flood risk along South Mayde Creek. Implementation of the full combination of drainage improvements will require a coordinated permitting and scheduling effort in addition to a design process that accounts for the progression of flood control improvements over time to ensure that no HCFCD project results in any adverse impacts and the overall benefits are maximized.

HCFCD has expressed interest in moving forward initially with a project focused on the channel conveyance capacity improvements between Fry Road and Greenhouse Road. This project would provide some flood risk reduction benefits while being able to be constructed completed within existing HCFCD ROW thereby reducing the necessary coordination and permitting efforts required.

The regional detention basins could also be phased based on timeline to acquire ROW, available funding, and need to provide mitigation for other downstream improvements. The regional detention basins were found to be able to almost fully mitigate for the channel conveyance capacity improvements and bypass channel so at least one (or a portion of one) of the two detention basins should be included in the initial phasing. The model results incorporating the regional detention basins did show some WSEL increases at certain locations for the 1% and 0.2% AEP events, but in general the adverse impacts were reduced or eliminated throughout the modeled section of South Mayde Creek. The WSEL increases in the 1% AEP storm may not be representative of true adverse impacts, but due to the complex flow exchange near the regional detention basins as well as the fact that some of the larger contributing channels to South Mayde Creek were modeled completely in 2D. Furthermore, the locations of the WSEL increases correspond to the downstream end of the proposed improvements (typically upstream of an existing bridge not planned for improvement) which is where WSEL increases would be expected to potentially occur.

8.0 Conclusion and Path Forward

This PER study involved the refinement and evaluation of drainage improvements along South Mayde Creek between Morton Road and Barker Cypress Road that were proposed as part of the HDR feasibility study. The improvements primarily focused on increasing channel conveyance capacity to more effectively drain water east into the Addicks Reservoir and lower WSELs to reduce future flood risk in the surrounding areas.

An assessment of existing conditions was completed before evaluating the benefits and potential impacts of multiple improvement scenarios through detailed hydraulic modeling that incorporated newly collected data. This PER documents the assumptions, methodologies, and findings of this analysis that was used to develop the Halff recommendations for HCFCD projects that should be considered for future design and construction.

While all the evaluated scenarios reduced WSELs to varying degrees, these potential benefits were weighed against potential impacts and other considerations, including estimated costs, environmental or permitting requirements, ROW acquisition, and constructability challenges). Based on the analysis performed, Halff recommends the following alternatives listed below. A summary of benefits and key issues for both recommended alternatives is provided in Section 7.2.

- *Alternative 2, Scenario 1 be moved forward into design in the short-term ($20.2M)*
  - Channel improvements + regional detention basins
- *Alternative 2, Scenario 2 be focused on in the long-term for future design ($31.8M)*
  - Channel improvements + bypass channel/sedimentation basins + regional detention basins

Given the total estimated costs, individual improvements that are part of the long-term solution could be completed in phases as funding becomes available. Funding for the implementation of the evaluated drainage improvements will be provided through a partnership with the USACE with a 10% local match required. The current Bond budget for the primary improvements (channel improvements and bypass channel) is $10M with $1M being funded by HCFCD. For the regional detention ponds, the total Bond budget is $16M with $1.6M being funded by HCFCD.

Halff presented an overview of the analysis and recommendations to HCFCD management during an Executive Briefing held on July 20, 2020. The methodology and results of the existing conditions assessment and alternatives evaluation, including estimated costs and benefits, were also discussed. Key discussion items are summarized below:

- The regional detention basins are needed to mitigate for adverse impacts caused by the other conveyance improvements
- The timeframe for the construction of the regional detention basins is primarily based on the ability to acquire the needed ROW, which is not expected to proceed forward in the near future
- HCFCD recommends finalizing this PER as an outline for the long-term flood risk reduction plan and focus on how to implement the different improvements in the appropriate order
- Additional analysis of how much storage volume is needed to offset any adverse WSEL impacts could be completed during the initial design phase

It is possible that only one (or a portion of one) of the two detention basins would be needed to mitigate the impacts related to the full benched channel improvements. A separate analysis would be required to determine the amount of storage volume needed to construct the channel improvements between Fry and Greenhouse Road without adverse impacts. USACE permitting and ROW acquisition timeframe are other key factors to be considered moving forward into design.

The effect of the proposed improvements on the Barker Cypress Road bridge should also be further investigated due to its location between the end of the bypass channel and the main storage pool of the Addicks Reservoir. During the design phase, additional refinements to the proposed improvements can be made and the H&H analysis can be revised accordingly. Improvements could be implemented such that short-term flood risk reduction is achieved while also creating the framework for a long-term solution to flooding on South Mayde Creek.