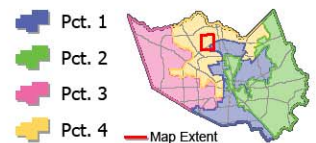


Project ID: K500-23-00-E002

Watershed: Cypress Creek

Precinct: 4



HCFCF PROJECT ID# K500-23-00-E002

HCFCF Unit K500-23-00
Precinct: 4 Key Map: 331 JKN



9900 Northwest Freeway
Houston, TX 77092
713-684-4000

Engineer	Ruben J. De La Fuente, Jr., P.E Pacheco Koch
<hr/>	
Location	The project is located in the northern portion of Harris County, Texas within the Cypress Creek Watershed. The TC Jester Stormwater Detention Basin is part of the Cypress Creek Watershed Major Tributaries Regional Drainage Plan Update. There are 118 acres of the project area located at the northern overbank of Cypress Creek. An additional 20 acres of the project site lies south of Cypress Creek. The project limits include an existing detention basin, Unit Number K500-15-00, located immediately east of TC Jester Boulevard. This basin is owned by Harris County and maintained by HCFCF.
<hr/>	
Background	Cypress Creek Watershed Major Tributaries Regional Drainage Plan by Michael Baker International, dated February 2020 recommended 26,546 acre-feet of detention volume throughout Cypress Creek Watershed.
<hr/>	
Purpose	The purpose of this project is to dig as much as volume as possible in support of flood damage reduction with respect to the environmental and utilities constraints and maintaining vegetative/riparian buffers in consideration of community values.
<hr/>	

Evaluation

This study is intended to evaluate proposed site improvements based on the local permitting requirements related to stormwater drainage and detention as defined by HCFCD criteria manuals and design standards. The study objectives are outlined below:

- Evaluate existing site conditions.
 - Perform boundary, topographic and tree survey
 - Provide geotechnical analysis
 - Prepare environmental assessment
 - Collect and review utility information
 - Update existing conditions hydraulic analysis (10-, 100- and 500-year)
 - Develop three proposed alternatives: and
 - Prepare basin layout configurations
 - Develop hydraulic model for each alternative
 - Prepare benefit cost analysis
 - Provide recommended alternative for final design and implementation
-

Recommended Plan

Based on the evaluation of performance metrics, and the assumptions, constraints, and information available, Alternative 2 is recommended. Please see below the basin layout and cross section in the Exhibits.

The following bullet points outline the key features of the recommended alternative:

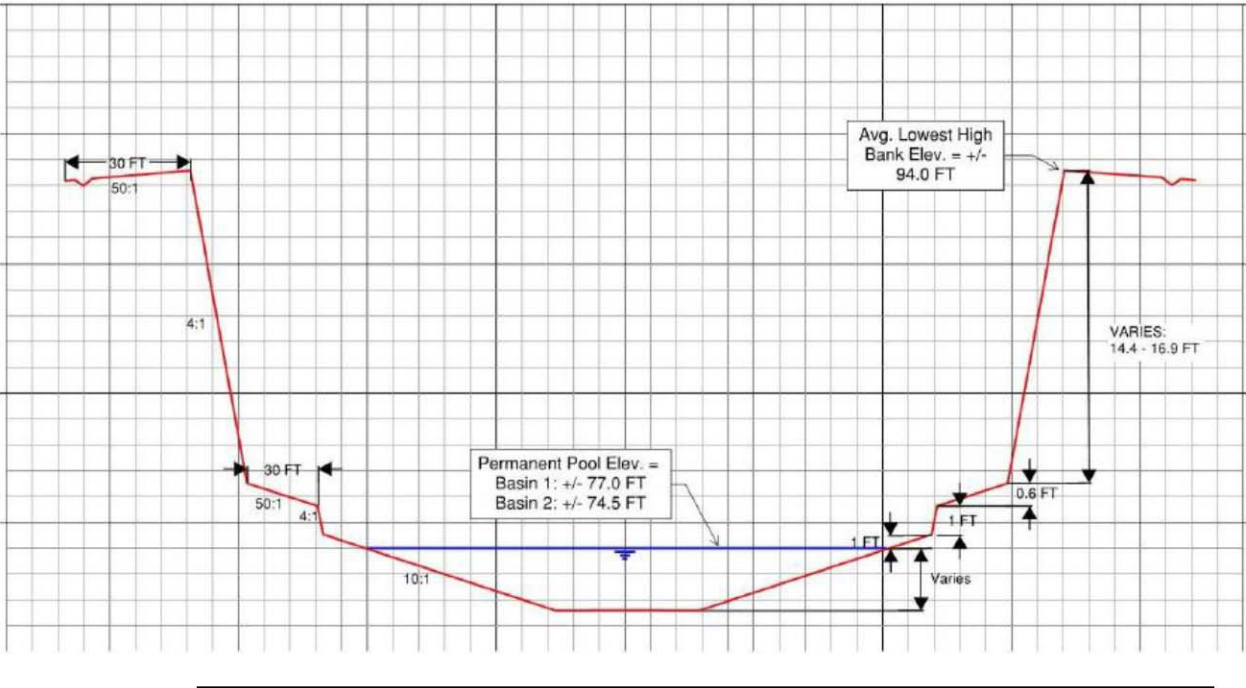
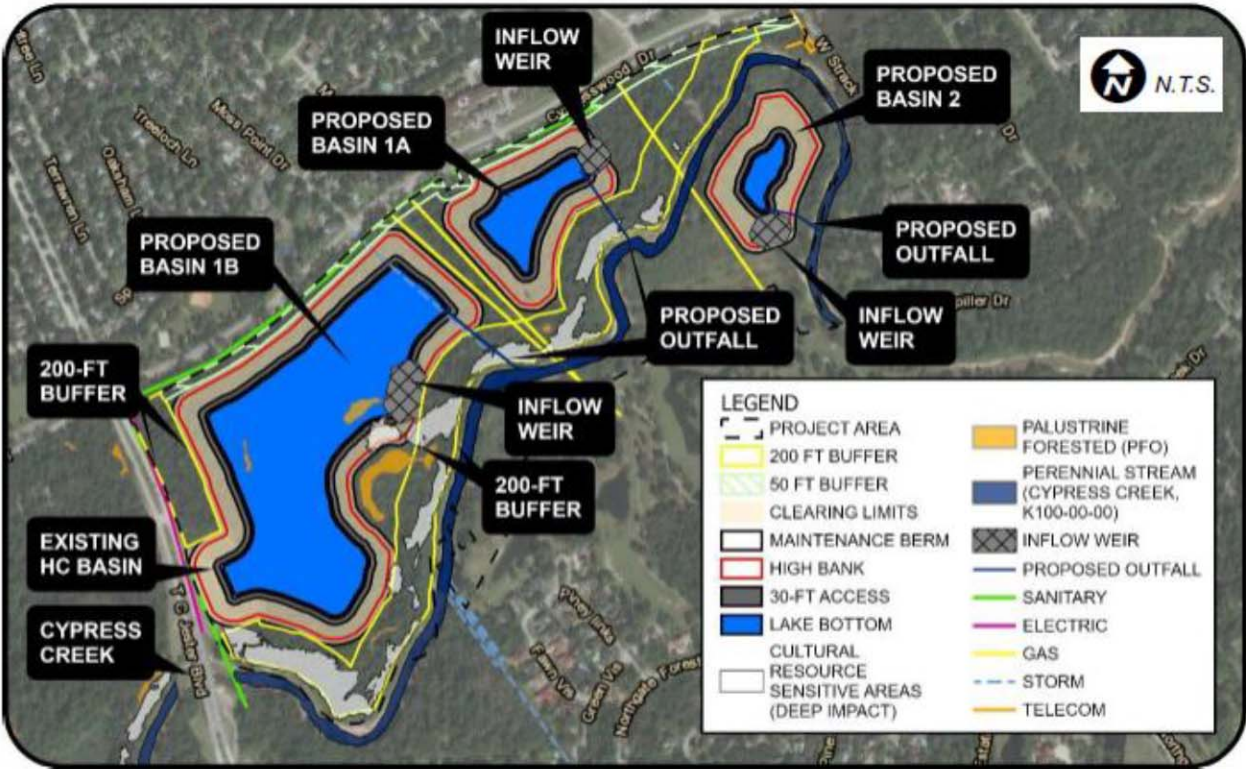
- Three (3) wet ponds with minimal impacts to environmental features and avoidance of onsite pipelines.
 - A 200-foot vegetative buffer is provided along Cypress Creek south of the proposed basins as shown in below layout.
 - A 200-foot vegetative buffer is provided along TC Jester Boulevard, west of proposed basin as shown in below layout.
 - A 50- foot vegetative is provided along Cypresswood Dr., north of proposed basin as shown in below layout.
 - A minimum 30-foot maintenance berm was provided along the perimeter of the proposed detention basins. Side slopes are 4:1
 - A 30-foot access/bottom shelf is located two (2) feet above the permanent pool elevation of the basins.
-

Benefits

The proposed detention basins provide 931 ac-ft of detention volume and will remove the 100-year floodplain from approximately 26 structures valued at \$13,787,800; and will remove the 500-year floodplain from 43 structures valued at \$29,592,600.

The 10-, 100- and 500-year water surface elevations of Cypress Creek have a maximum decrease of 0.44 feet, 0.35 feet, and 0.23 feet, respectively. The Benefit Cost Ratio is 0.46 for the 100-year storm, and 0.98 for the 500-year storm.

Exhibits:



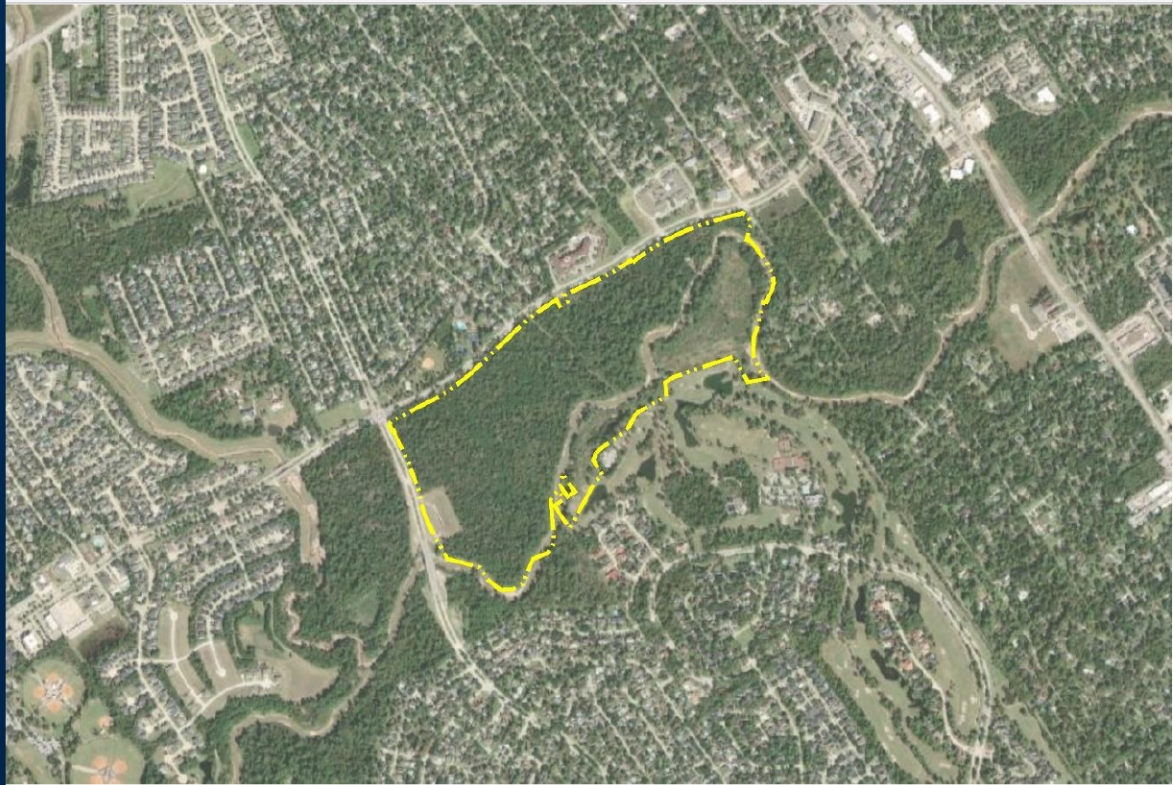
TC JESTER DETENTION BASIN

HCFCFCD PROJECT ID: K500-23-00-E002

PRELIMINARY ENGINEERING REPORT

HARRIS COUNTY, TEXAS

FINAL PER SUBMITTAL
07/28/21



PREPARED BY:



JULY 28, 2021

TX REG. ENGINEERING FIRM F-469
TX REG. SURVEYING FIRM LS-100080-00
PK No. 4676-20.315

20329 STATE HWY 249
SUITE 350
HOUSTON, TEXAS 77070

TC JESTER DETENTION BASIN HCFCFCD PROJECT ID: K500-23-00-E002

PRELIMINARY ENGINEERING REPORT

HARRIS COUNTY, TEXAS

PREPARED FOR:



Rub J De La Fuente Jr

07/28/2021

PREPARED BY:



EXECUTIVE SUMMARY

Harris County Flood Control District (HCFCD) has retained the services of Pacheco Koch Consulting Engineers, Inc. to provide a Preliminary Engineering Report (PER) for the TC Jester Stormwater Detention Basin, HCFCD project ID: K500-23-00-E002. The study objectives are outlined below:

- Evaluate existing site conditions;
 - Perform boundary, topographic and tree survey
 - Provide geotechnical analysis
 - Prepare environmental assessment
 - Collect and review utility information
 - Update existing conditions hydraulic analysis (10-, 100- and 500-year)
- Develop three proposed alternatives; and
 - Prepare basin layout configurations
 - Develop hydraulic model for each alternative
 - Prepare benefit cost analysis
- Provide recommended alternative for final design and implementation.

The project is located in the northern portion of Harris County, Texas within the Cypress Creek Watershed. The TC Jester Stormwater Detention Basin is part of the Cypress Creek Watershed Major Tributaries Regional Drainage Plan Update. There are 118 acres of the project area located at the northern overbank of Cypress Creek. An additional 20 acres of the project site lies south of Cypress Creek. The project limits include an existing detention basin, Unit Number K500-15-00, located immediately east of TC Jester Boulevard. This basin is owned by Harris County and maintained by HCFCD.

The proposed detention basin includes added storage volume north and south of Cypress Creek and auxiliary inflow and outflow structures. This project does not include bridge/culvert modifications, channel conveyance improvements, or storm sewer conveyance improvements. There are three local storm sewer outfalls in the vicinity of the proposed basin footprint. These local outfalls were not evaluated as part of this PER. These outfalls will be incorporated as needed during final design of the recommended alternative. Three (3) basin configuration alternatives were developed to identify a feasible and cost effective design to reduce flood related damages. The objective of each alternative is shown below:

Alternative 1: Maximize detention and provide 200-foot buffer;

Alternative 2: Minimize environmental impacts and provide 200-foot buffer; and

Alternative 3: Minimize environmental impacts and provide 400-foot buffer

TC Jester Stormwater Detention Basin PER

Project ID: K500-23-00-E002

Harris County, Texas

July 28, 2021

Alternative 2 with 931 acre-feet of detention volume is recommended. The 10-, 100- and 500-year water surface elevations of Cypress Creek have a maximum decrease of 0.44 feet, 0.35 feet, and 0.23 feet, respectively. The maximum Cypress Creek water surface elevation decreases occur upstream of the proposed project. Table 1 below shows the maximum difference in the Cypress Creek 10-, 100- and 500-year WSELs for Alternative 2. A negative difference indicates a decrease between the existing and Alternatives hydraulic models.

Alternative 2 Cypress Creek Maximum WSEL Difference (Ft)		
10- Year	100- Year	500- Year
-0.44	-0.35	-0.23

Table 1: Alternative 2 Maximum WSEL Difference

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1.0 INTRODUCTION

1.1 History and Purpose

Harris County Flood Control District (HCFCD) has retained the services of Pacheco Koch Consulting Engineers, Inc. to provide a Preliminary Engineering Report (PER) for the TC Jester Stormwater Detention Basin, HCFCD Project ID: K500-23-00-E002. The project is located in the northern portion of Harris County, Texas within the Cypress Creek Watershed. This report documents the procedures and findings of the drainage analysis. Technical supporting documentation is provided in accompanying appendices.

1.2 Project Limits

The project is located southeast of the intersection of TC Jester Boulevard and Cypresswood Drive along Cypress Creek. The stream flows from west to east bisecting the site. Figure 1 shows the location of the site in relation to Cypress Creek. The project site includes an existing Harris County detention facility located on the west side of the site adjacent to TC Jester Boulevard. A vicinity map is included in Exhibit 1.

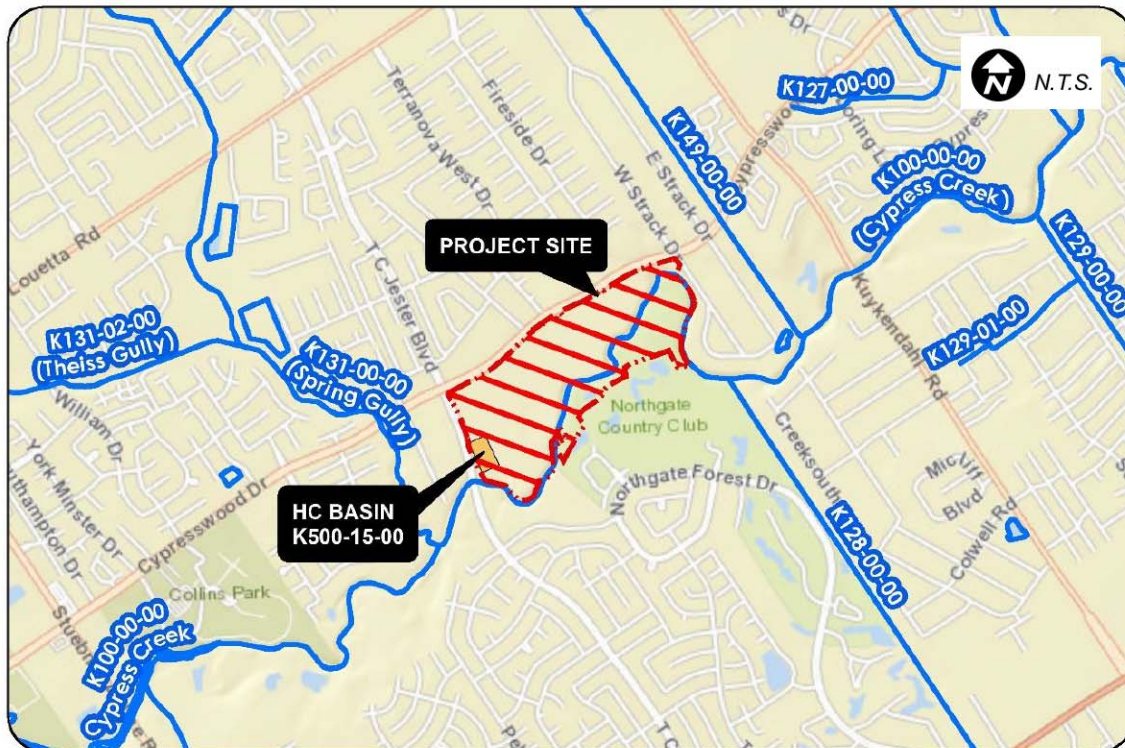


Figure 1: Location Map Key Map 331 JKN

TC Jester Stormwater Detention Basin PER

Project ID: K500-23-00-E002

Harris County, Texas

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1.3 Data Collection

Table 2 provides a summary of relevant data collected throughout this analysis.

Data	Source	Purpose
Cypress Creek Watershed Major Tributaries Regional Drainage Plan Update dated 02/04/2020 – Michael Baker International	HCFCFCD	Reference Material of Previous Study
Post-USACE Verified Wetland and Waterbody Delineation Report; K100-00-00-P005 dated 03/2021 (North of K100)	Spirit Environmental	Wetland Location Constraints
Threatened and Endangered Species Review K100-00-00-P005 dated 12/10/2019 (North of K100)	Spirit Environmental	Identify Endangered Species
Archaeological Deep Testing within Approximately 171-Acre; K500-23-00-E001 & K500-23-00-E002 dated 09/24/2020 (North of K100)	Gray & Pape, Inc	Cultural Resource Constraints
USACE Approved Jurisdictional Determination; SWG-2019-00857 dated 03/08/2021 (North of K100)	USACE	USACE Concurrence with Delineation
USACE Approved Jurisdictional Determination; SWG-2020-00633 dated 04/14/2021 (South of K100)	USACE	USACE Concurrence with Delineation
Post-USACE Verified Wetland and Waterbody Delineation Report; K500-00-00-E002 dated 04/2021 (South of K100)	Spirit Environmental	Wetland Location Constraints
Threatened and Endangered Species Review K500-23-00-E002 dated 07/14/2020 (South of K100)	Spirit Environmental	Presence of Endangered Species
Archaeological Deep Testing within Approximately 29 Acres; K500-23-00-E002 dated 12/31/2020 (South of K100)	Gray & Pape, Inc	Cultural Resource Constraints
Design Guidelines for HCFCFCD Wet Bottom Detention Basins and Water Quality Features dated 04/2014	HCFCFCD	Design Material
Structural Inventory Database dated 05/25/2018	HCFCFCD	Design Material
Greater Houston Off Road Biking Association (GHORBA) Suggested Trail Map dated 05/08/2020 - GHORBA	HCFCFCD	Existing Trail Locations
Migratory Bird Treaty Act Survey dated 08/25/2020	HCFCFCD	Migratory Bird Survey
Phase 1- Environmental Site Assessment for TC Jester Detention Basin Project dated 09/2020	SWCA	Environmental Assessment
Boundary Survey dated 12/15/2020	Pacheco Koch Consulting Engineers	Boundary Limits
Topographic Survey dated 12/15/2020	Pacheco Koch Consulting Engineers	Topographic Survey
Tree Survey dated 12/15/2020	Pacheco Koch Consulting Engineers	Tree Survey
Geotechnical Evaluation Report dated 12/28/2020	Ninyo & Moore	Geotech Constraints
Pipeline Crossing and Relocation Guidelines dated 04/18/2019	HCFCFCD	Pipe Relocation Recommendations

Table 2: Data Collection

1.4 Project Objectives

This study is intended to evaluate proposed site improvements based on the local permitting requirements related to stormwater drainage and detention alternatives as defined by HCFCD criteria manuals and design standards. The study objectives are outlined below:

- Evaluate existing site conditions;
 - Perform boundary, topographic and tree survey
 - Provide geotechnical analysis
 - Prepare environmental assessment
 - Collect and review utility information
 - Update existing conditions hydraulic analysis (10-, 100- and 500-year)
- Develop three proposed alternatives; and
 - Prepare basin layout configurations
 - Develop hydraulic model for each alternative
 - Prepare benefit cost analysis
- Provide recommended alternative for final design and implementation.

1.5 Assumptions and Constraints

The hydrologic methodology remained unrevised from the previously approved Michael Baker study dated February 4, 2020 to remain consistent throughout Cypress Creek. While updated rainfall is available through Atlas-14, it is beyond the scope of this detention basin study to update and revise the entire Cypress Creek hydrologic model. The pre-Atlas-14 500-year storm event is used as a proxy for the updated Atlas-14 100-year storm event.

There is an existing detention facility, K500-15-00, (3.3 acres) currently maintained by HCFCD within the project limits. The existing detention facility will be incorporated in the proposed detention basin. The basin will be located and fully contained within 138.1 acres of HCFCD right-of-way. Additional assumptions and constraints are discussed for each alternative. Existing trees, jurisdictional Waters of the United States, and riparian buffers will serve as constraints to the proposed improvements.

1.6 Design Criteria

Upon HCFCD's approval, the Project will progress to the design phase. The analysis and design will follow HCFCD's design requirements as outlined in:

- Interim Policy Criteria and Procedure Manual (PCPM), dated July 2019
- HCFCD's Design Guidelines for HCFCD Wet Bottom Detention Basins with Water Quality Features, dated April 2014.
- HCFCD's Survey Guidelines, dated May 2019.

1.7 Project Funding

The TC Jester Stormwater Detention Basin is currently funded through the Design stage. Funding for construction is being aggressively pursued, including partnership opportunities.

1.8 Joint Use Agreements

Discussions have been initiated with Harris County Precinct 4 regarding the construction and implementation of the TC Jester Stormwater Detention Basin and the potential for recreational facilities. A written joint use agreement with Harris County Precinct 4 does not exist at this time. An interagency agreement between HCFCD and Harris County was approved in the September 7, 2010 Harris County Commissioners Court meeting. The agreement was for HCFCD's acceptance of the existing K500-15-00 as part of HCFCD's maintenance system. A total of 3.3 acres of right-way were dedicated to HCFCD per Harris County Clerk's File No. 20100180408, recorded on May 4, 2010. No other joint use discussions or agreements are known at this time.

1.9 Public Engagement

A public engagement meeting for the TC Jester Stormwater Detention Basin CDBG-MIT Application occurred on September 22, 2020. Public Comments from the September 22, 2020 public engagement meeting were considered during preliminary engineering. A public engagement meeting for the TC Jester Stormwater Detention Basin PER occurred on June 16, 2021. Comments from the public meeting were considered during preparation of the final TC Jester Stormwater Detention Basin PER.

1.10 Stakeholders and Coordination with Local Governments

Stakeholders for the TC Jester Stormwater Detention Basin, K500-23-00-E002 include:

- Harris County Flood Control
- Harris County Precinct 4
- Local residents
- Northgate Country Club
- Harris County MUD 20 and 211
- Klein and Spring Independent School Districts
- Spring Fire Station 77
- GHORBA
- Northgate Country Club
- Sunoco Gas (pipeline)
- Kinder Morgan Gas (pipeline)
- Louetta Road Utility District
- Explorer Pipeline
- CenterPoint Electric
- Comcast
- AT&T
- T-Mobile

2.0 EXISTING CONDITIONS

2.1 Watershed Description

The majority of the Cypress Creek watershed is located within Harris County. The upstream end of the Cypress Creek watershed is located in Waller County. Cypress Creek Watershed is developed with various land uses, single family residential, multifamily residential, commercial, recreational and parks. The Cypress Creek Watershed in Waller County and western Harris County is primarily undeveloped based on the aerial imagery dated December 2020. There are approximately 210 square miles of watershed upstream of the project site. A drainage area map is included in Exhibit 2.

2.2 Prior Studies

The following drainage studies have previously been completed for the Cypress Creek watershed:

- Cypress Creek Watershed Major Tributaries; Regional Drainage Plan Update by Michael Baker International, dated February 2020. This study recommended 26,546 acre-feet of detention volume throughout Cypress Creek Watershed. The K500-23-00-E002 project site corresponds with Detention Basin IDs 8 and 9. Basins 8 and 9 have a combined detention volume of 4,754 ac-ft.
- TC Jester and Westador Detention Basins Hydraulic Analysis by Freese & Nichols, dated August 2020. This study had 1,898 acre-feet of detention volume for the TC Jester Ultimate Detention Basins.
- Flood Insurance Study (FIS¹) for Harris County and the effective Flood Insurance Rate Map (FIRM) Number 48201C0265M, dated, October 16, 2013.
- FEMA Letter of Map Revision (LOMR) 18-06-3326P dated November 18, 2019.

2.3 Flood Hazard Area Historical Flooding

The floodplain along Cypress Creek is defined by the FIS for Harris County and the effective FIRM Number 48201C0265M, dated, October 16, 2013. The FIRM indicates the entire K500-23-00-E002 site is designated as a Zone AE floodplain. The effective floodway extends into the project site. A copy of the effective FIRM is provided in Appendix 1.

Historical flooding has occurred for decades, but the two most recent events are the 2016 Tax Day flood and the 2017 Hurricane Harvey flood. The historical rainfall depths exhibits from the Michael Baker study are included in Exhibit 4.

2.4 Study Area

The study area and inundation limits extend from Fry Road to Hardy Toll Road. There are a total of 4,615 structures, and 24 roadway crossings within the inundation limits. The structures include single-family residential, multi-family residential, commercial buildings, and other public structures as defined by the Structural Inventory database.

¹ FIS: <https://msc.fema.gov/portal/home>

There are 118 acres of the project area located at the northern overbank of Cypress Creek. An additional 20 acres of the project site lies south of Cypress Creek, adjacent to the Northgate Country Club. There are 11 verified wetlands within the property limits north of Cypress Creek, respectively. The existing project site is heavily wooded, consisting of hardwood and conifer trees. The GHORBA has established multiple bike trails throughout the project site. There is an existing Harris County Precinct 4 canoe launch at Cypress Creek near the TC Jester Boulevard bridge. There is an existing Harris County detention facility located on the west side of the site adjacent to TC Jester Boulevard. Two site visits were conducted on June 5th and July 15th, 2020. Site photos can be found in Appendix 2. The existing site conditions are shown on the boundary, topographic and tree surveys found in Appendix 9. The existing site conditions are shown in Figure 2 below. Trees with a diameter at breast height (DBH) greater than 30 inches are shown by species. An existing conditions exhibit is included in Exhibit 4.



2.6 HCFCF Facilities and Right-of-Way

The project site contains the following HCFCF facilities and Right-of-Way:

- Cypress Creek, Unit No. K100-00-00, and Harris County Basin, Unit No. K500-15-00; and
- Drainage easements north and south of the stream centerline.

The HCFCF properties are shown in Figure 3 below. No additional property acquisition is anticipated for the proposed improvements.

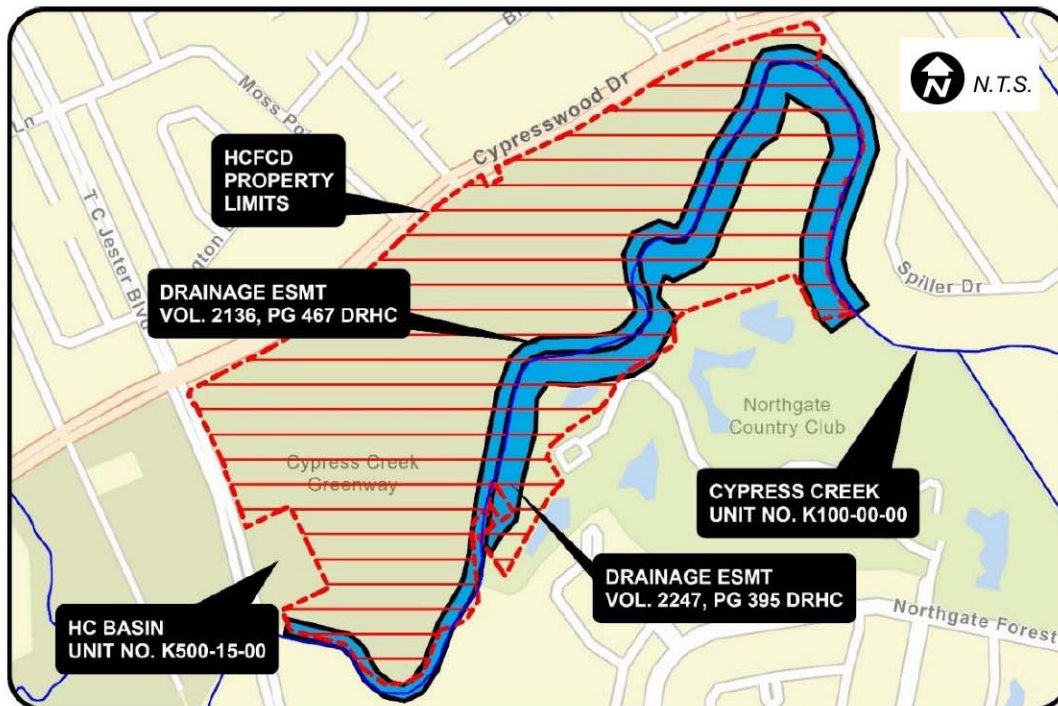


Figure 3: HCFCF Property Map

2.7 Surveys

Topographic and boundary surveys were conducted by Pacheco Koch in October 2020. The topographic survey data in conjunction with 2018 LiDAR point-cloud data was used to develop terrain data for the site. The topographic survey was vertically tied to the following HCFCD benchmarks described in Table 3.

BM ID	Published Elevation	Description
RM #110065	109.01'	BRASS DISC – 1.4 MILES SOUTH ALONG KUYKENDAHL FROM INTERSECTION OF LOUETTA AND KUYKENDAHL
RM #110470	106.36'	BRASS DISC – 1.4 MILES SOUTHWEST ALONG CYPRESSWOOD FROM INTERSECTION OF CYPRESSWOOD AND KUYKENDAHL

Table 3: Survey Benchmarks

A tree survey was conducted by Pacheco Koch in October 2020. The tree survey was used to determine tree buffers along TC Jester Boulevard, Cypresswood Drive and Cypress Creek. The tree survey also identified potential trees to preserve or move within the project site. Copies of the topographic, boundary and tree surveys are provided in Appendix 9.

2.8 Geotechnical Conditions

Technical Memorandum assessing geotechnical conditions was performed by Ninyo & Moore dated, December 9, 2020. Phase 1 Geotechnical Investigation by Ninyo & Moore with eight borings to a depth of 35 feet found:

- Alluvial soils from the Lissie Formation consisting of alternating strata of cohesive soils (clays) and cohesionless soils (silts and sands);
- Slope stability analysis indicates preliminary design side slopes of 4:1 or flatter will meet HCFCD guidelines;
- Some of the lean clay strata were found to have dispersive soils which are subject to erosion and not suitable for select fill;
- Where slopes contain dispersive and cohesionless soils erosion control measures are recommended such as backslope interceptor swales;
- Existing slopes of Cypress Creek may be unstable due to potential seepage and erosion between the basin and the channel and could lead to failure of detention basin slopes. Additional analysis recommended during design phase;
- Observed 24-hour groundwater depth of 8.5 to 20 feet, subject to seasonal variation. Dewatering may be needed during construction; and
- Ground water levels be kept 5 feet or more below the bottom of excavation.
- An independent back-up system whenever workers are nearby excavations needing dewatering.

TC Jester Stormwater Detention Basin PER

Project ID: K500-23-00-E002

Harris County, Texas

July 28, 2021

- Cohesionless soils along the bottom and side slopes of the proposed detention ponds may allow seepage from Cypress Creek with the potential to cause slope failure. To address these issues, additional measures may be necessary such as over-excavating and replacing cohesionless soils with select fill (clay or sodium bentonite) or installing a sheet pile system.
- A detailed seepage analysis should be performed by the geotechnical engineer as part of the design phase evaluation.

A copy of the Geotechnical Report is provided in Appendix 4. The eight geotechnical borehole locations are shown in Figure 4 below.

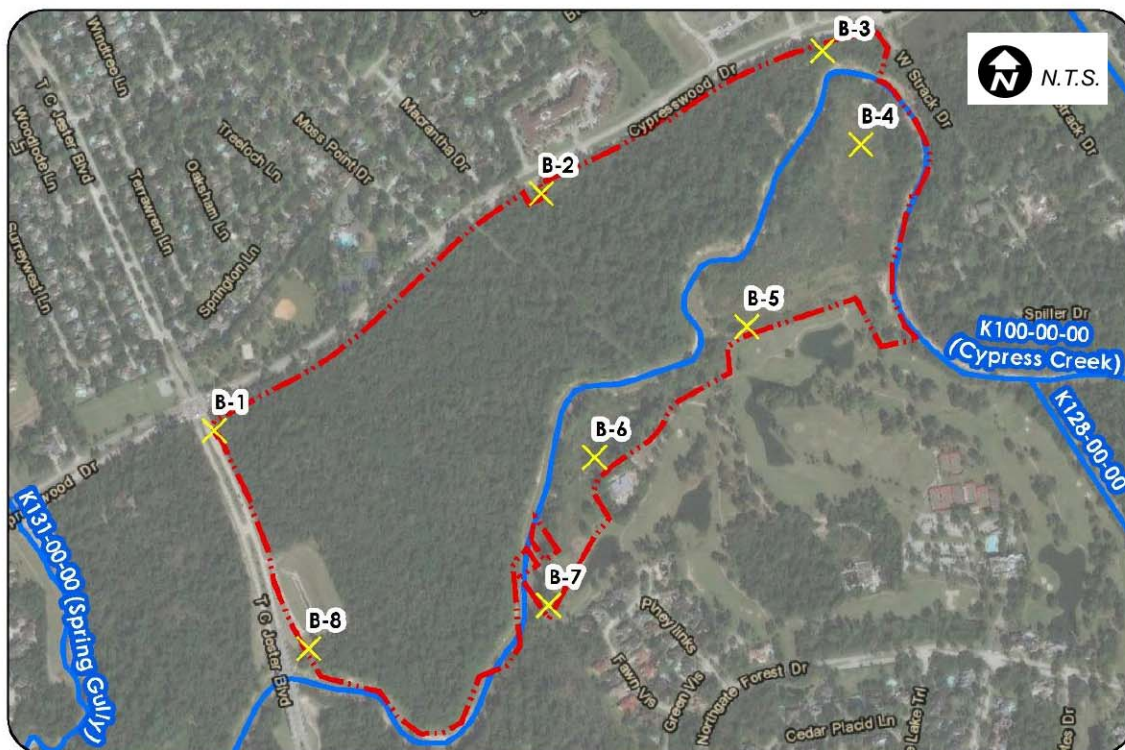


Figure 4: Geotechnical Borehole Map

2.9 Existing Utilities

A Subsurface Utility Engineering (S.U.E) Level B and D Investigation was conducted by Cobb-Fendley. A Louetta Road Utility District sanitary forcemain and Centerpoint Energy electric line run parallel to TC Jester Boulevard east of the roadway. A Sunoco gas line and Explorer gas line run northwest to southeast through the project site. A Kinder Morgan gas line bisects the site approximately 1,300 feet east of the previously mentioned gas lines. Three storm sewer pipelines are located within the project limits. Three storm sewer pipelines are located outside of the project limits on the south side of Cypress Creek. Comcast and AT&T telecom lines, and T-Mobile cell tower are located on the northeast corner of the site. The pipeline locations are shown in Figure 5 below.

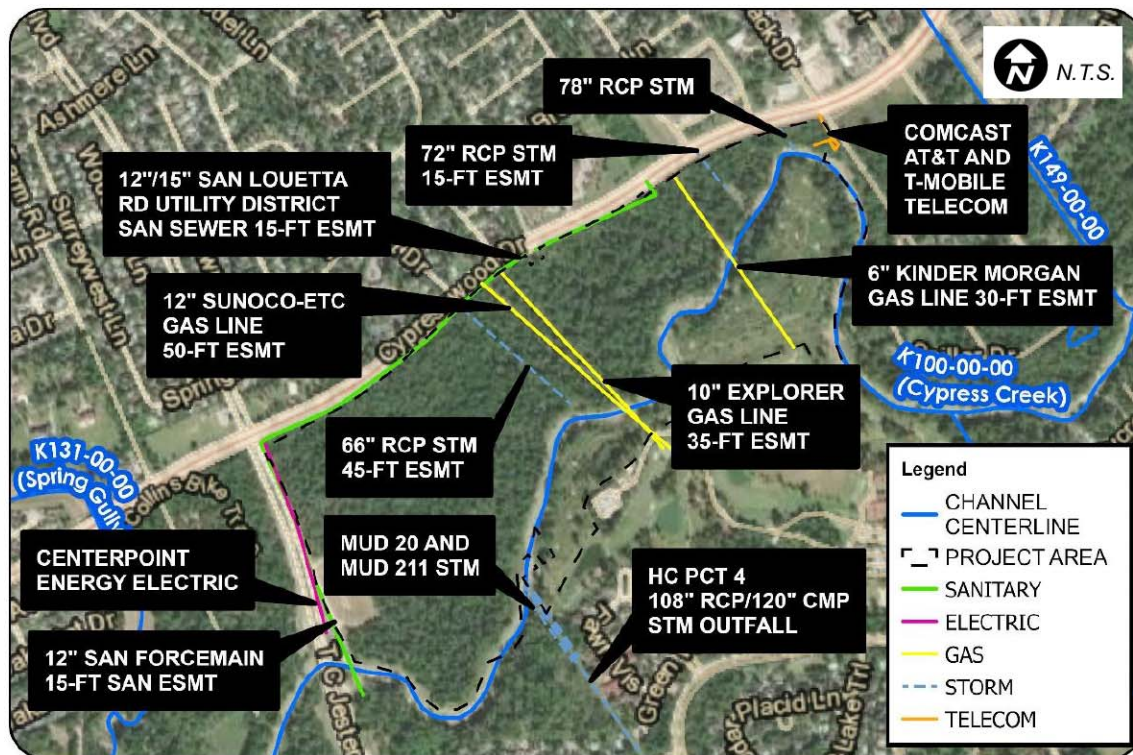


Figure 5: Existing Utilities Map

2.10 Environmental Conditions

A wetland and waterbody delineation was performed by Spirit Environmental and documented in report titled, "Wetland and Waterbody Delineation Report; HCFCD Project ID K100-00-00-P005," dated October 2020 and verified by USACE in Approved Jurisdictional Determinations dated March 8, 2021 and April 14, 2021. A Phase I Environmental Site Assessment (ESA) for the TC Jester Stormwater Detention Basin Project was performed by SWCA Environmental Consultants and documented in report titled, "Phase I Environmental Site Assessment for the TC Jester Stormwater Detention Basin Project in Harris County, Texas," dated September 2020. Technical Memorandum assessing cultural resources constraints was performed by Gray & Pape dated, May 22, 2020.

TC Jester Stormwater Detention Basin PER

Project ID: K500-23-00-E002

Harris County, Texas

July 28, 2021

The waterbody delineation by Spirit Environmental, cultural resources study by Gray & Pape and Phase 1 Environmental Site Assessment by SWCA Environmental found:

- Approximately 2.0 acres of wetlands and 5,594 linear feet of jurisdictional waters were identified onsite;
- The potential for historical cultural resources were identified within the proposed improvement limits;
- No recognized environmental conditions were identified on the subject property;
- Available information does not suggest any environmental impairment significant enough to adversely affect the planned site development;
- Proper disposal methods in handling dumped materials are recommended for activities occurring within the subject property;
- The jurisdictional area impacted by the proposed improvements is quantified in discussion of each proposed alternative;
- SWCA recommends all best management practices (BMPs) be followed according to the TCEQ Best Management Practices Manual while construction is conducted.
- SWCA also agrees with the recommendations provided by Geotech.

A copy of the environmental assessments and water body delineation are provided in Appendix 5 and the cultural resources reports are provided in Appendix 6. Figure 6 below shows the delineated jurisdictional waterbodies and cultural resource sensitive areas.

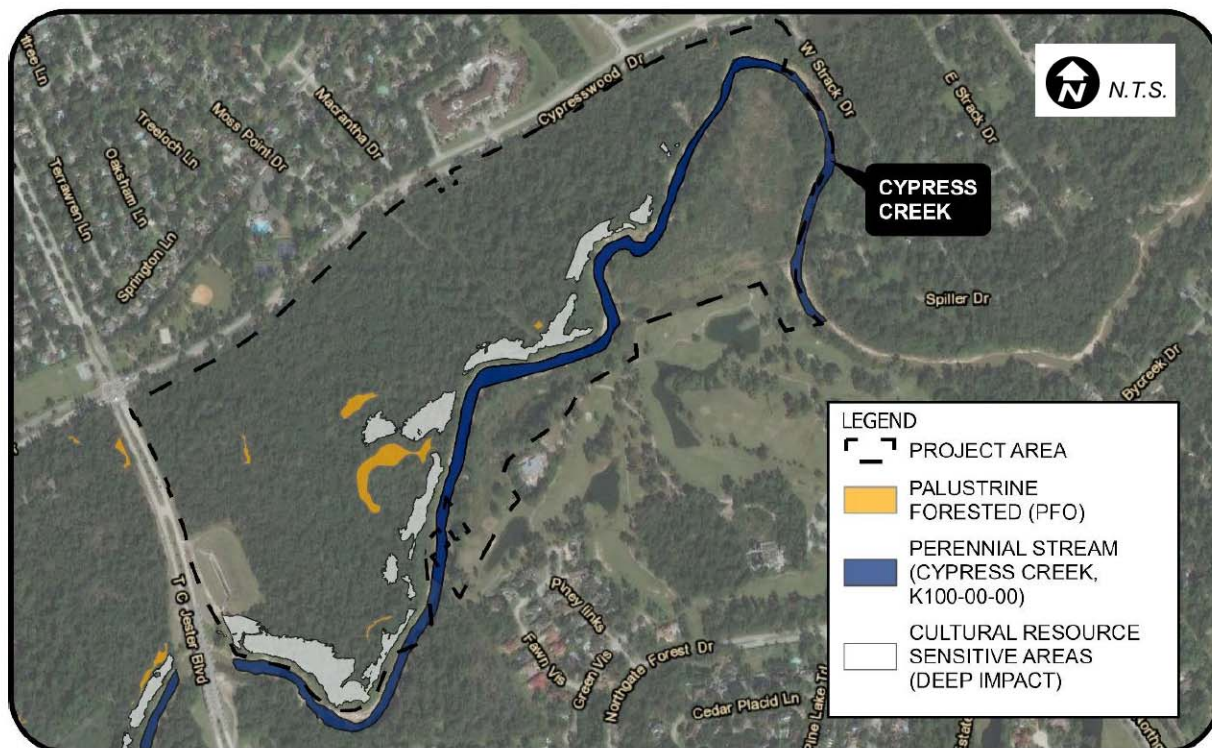


Figure 6: Jurisdictional Waterbodies and Cultural Areas

2.11 Pre-Project Conditions Analysis Objective

The objective of the pre-project condition analysis is to develop a baseline condition for development of proposed detention alternatives. This study is based on pre-Atlas-14 rainfall data to remain consistent with the previously approved Michael Baker study.

2.12 Pre-Project Hydrologic Methodology

Cypress Creek Watershed was analyzed by Michael Baker using the computer program HEC-HMS², Hydrologic Modeling System, developed by the Hydrologic Engineering Center of the US Army Corps of Engineers (USACE) (Version 3.4, August 2009). The hydrologic methodology remained unrevised from the previously approved Michael Baker study to remain consistent throughout Cypress Creek. While updated rainfall is available through Atlas-14, it is beyond the scope of this detention basin study to update and revise the entire Cypress Creek hydrologic model. The pre-Atlas-14 500-year storm event is used as a proxy for the updated Atlas-14 100-year storm event.

2.13 Pre-Project Hydraulic Methodology

Cypress Creek was analyzed using the computer program HEC-RAS 2D, developed by the Hydrologic Engineering Center of the USACE (Version 5.0.6, November 2018). The Michael Baker Baseline Hydraulic Models required minor revisions including updated geometry to reflect the pre-project conditions in the vicinity of the project site.

2.14 Duplicate Base Conditions Model (DBM)

The Duplicate Base Conditions Model was obtained from the Michael Baker study. The flow data reflects the fully developed condition of the watershed with detention provided. This results in the hydrology accounting for the developed runoff volume but restricted to a predevelopment peak flow rate. The geometry file is based on 2008 LiDAR and the FEMA effective Cypress Creek HEC-RAS steady state model downloaded from the HCFCD M3 system. Michael Baker performed model calibration using 2017 Hurricane Harvey rainfall event and validated using the 2016 Tax Day rainfall event.

2.15 Revised Base Conditions Models (RBM)

The following revisions were made to the Duplicate Base Model to create the Revised Base Conditions Model. The cross-section geometry was updated within the project limits between sections 82375 and 75290. The TC Jester Blvd bridge was added based the geometric file provided by MBI. The TC Jester Blvd bridge is assumed to be correct. The 2D flow areas and lateral structures were revised to reflect revisions to the cross sections. Terrain data was revised to reflect 2018 LiDAR within the project limits. Figure 7 shows the cross-section and 2D flow locations relative to the project site.

² USACE: <http://www.hec.usace.army.mil/software/hech-hms/>

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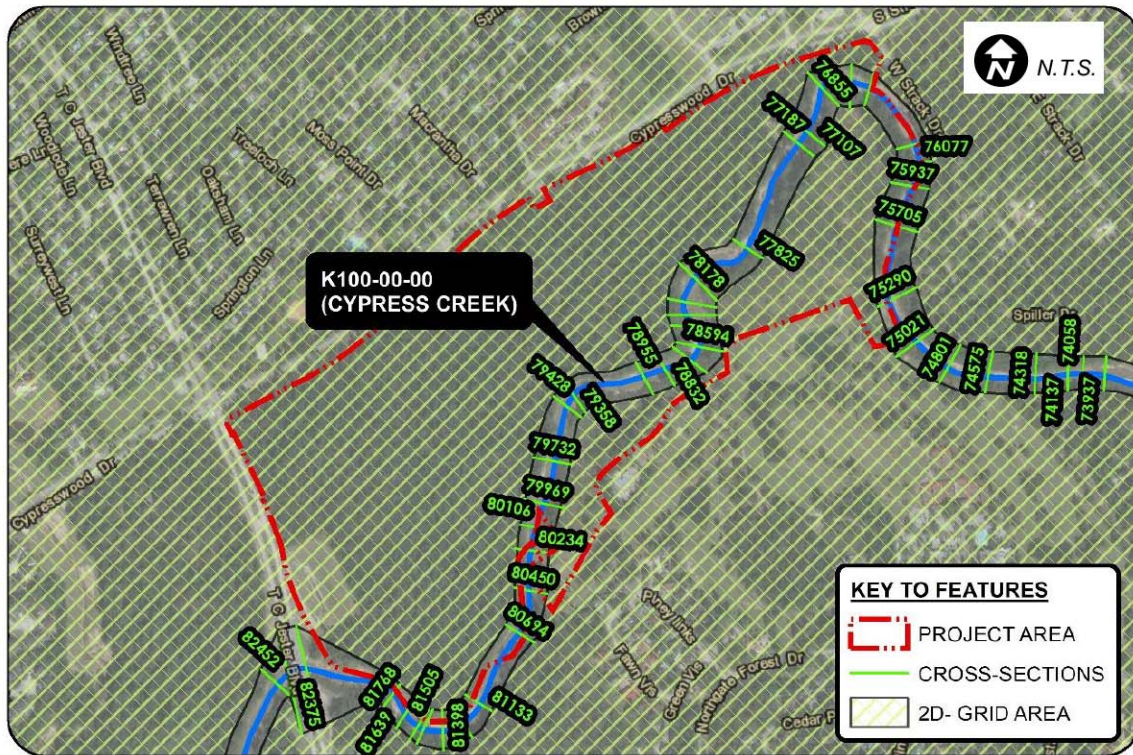


Figure 7: Hydraulic Model Cross Section Map

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Table 4 describes the changes made in the Duplicate Base Conditions Model to create the Revised Base Conditions Models. Output for the RBM is provided in Exhibit 10.

Section ID		Comments	PROJECT SITE
DBM	RBM		
North_2DArea	North_2DArea	Update terrain with 2018 LiDAR and boundary revised to match cross sections.	
South_2DArea	South_2DArea	Update terrain with 2018 LiDAR and boundary revised to match cross sections.	
Lat. Struct. 83386	Lat. Struct. 83386	Revised lateral structure. Downstream portion of DBM Lat. Struct. 83386	
Lat. Struct. 83384	Lat. Struct. 83384	Revised lateral structure. Downstream portion of DBM Lat. Struct. 83384	
82452	82452	Revised reach lengths	
-	82375	Added cross section	
82323	-	Removed cross section	
-	82290	Added TC Jester Blvd bridge	
-	82266	Added cross section	
-	Lat. Struct. 81974	Added lateral structure. Downstream portion of DBM Lat. Struct. 83386	
-	Lat. Struct. 81972	Added lateral structure. Downstream portion of DBM Lat. Struct. 83384	
77187	77187	Cut section line, revise right bank station and extend South_2DArea	
76855	76855	Cut section line, revise right bank station and extend South_2DArea	
76681	76681	Cut section line, revise right bank station and extend South_2DArea	
76574	76574	Cut section line, revise right bank station and extend South_2DArea	

Table 4: Alterations from DBM to RBM

A tabular comparison between the duplicate effective and revised baseline model was made to evaluate and verify the changes made to the revised baseline model did not result in major changes to the duplicate effective. The comparisons include review of the 500-year WSELs and notes the percent difference between the two models.

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The results of the comparison show the two models have negligible differences with less than 0.1% difference and are shown in Table 5 below.

Section Id	500-Yr Wsel (Ft)			Project Site
	DBM	RBM	% Diff	
82452 – TC Jester Blvd Bridge	107.24	107.26	0.02	
81836	107.02	106.96	-0.06	
78955	106.33	106.33	0.00	
78178	106.27	106.28	0.01	
76574	105.90	105.89	-0.01	
75290	105.74	105.75	0.01	
71520 – Kuykendahl Rd. Bridge	103.98	103.98	0.00	
51161 – IH45 Bridge	96.64	96.64	0.00	
50807	94.82	94.81	-0.01	
50514	94.39	94.39	0.00	
49972	94.17	94.16	-0.01	
42017 – Hardy Toll Road (Downstream Limit of Study)	90.75	90.75	0.00	

Table 5: DBM vs RBM 500-Year WSE Verification

Table 6 describes the performance metrics based on results of the 100- and 500-year floodplains. The performance metrics are based on the HCFCD Structure Inventory Database within the corresponding floodplain between the Fry Road and Hardy Toll Road crossings.

Performance Metric	100-Year Floodplain	500-Year Floodplain
Structures in Floodplain	1,668	4,615

Table 6: Existing Flooded Structures

2.16 Conclusions

The Cypress Creek Level-of-Service is less than the 10-year storm event within the study limits from Fry Road to the Hardy Tollroad. The Cypress Creek 500-year floodplain has:

- 4,615 structures within the floodplain.

3.0 PROPOSED CONDITIONS

3.1 Flood Control Components

An alternatives analysis was prepared based on three (3) proposed detention basin alternatives. The detention improvements include added storage volume north and south of Cypress Creek and auxiliary Inflow and outflow structures. This project does not include bridge/culvert modifications, channel conveyance improvements, or storm sewer conveyance improvements. There are two local storm sewer outfalls in the vicinity of the proposed basin footprint. These outfalls may be modified during final design of the recommended alternative.

3.2 Proposed Conditions Alternatives Analysis Objective

The objective of the alternative analysis is to identify a feasible and cost effective detention alternative to alleviate flooding and reduce flood related damages. Performance metrics are determined for each alternative describing limits of inundation, and number of impacted structures versus the cost of construction. The primary objective of each alternative is shown below:

Alternative 1: Maximize detention and provide 200-foot buffer;

Alternative 2: Minimize environmental impacts and provide 200-foot buffer; and

Alternative 3: Minimize environmental impacts and provide 400-foot buffer

3.3 Proposed Conditions Alternatives Hydrologic Methodology

The hydrologic methodology remained unrevised from the previously approved Michael Baker study to remain consistent throughout Cypress Creek. The pre-Atlas-14 500-year storm event serves as a proxy for the updated Atlas-14 100-year storm event.

3.4 Proposed Conditions Alternatives Hydraulic Methodology

The proposed conditions alternatives models were developed by updating the Revised Baseline Hydraulic Model with the proposed improvements for each alternative. The proposed improvements include offline storage areas with lateral inflow weirs and outflow pipes. The configuration of storage and structures were modified to meet each alternative objective.

3.5 Alternative Identifications/Description

Identifications and descriptions were determined for the three (3) detention basin configuration alternatives. All alternatives will include a 50-foot vegetation buffer adjacent to Cypresswood Drive. The alternatives were developed using the following criteria:

Alternative 1 - Maximum Volume and provide 200-foot buffer

This alternative produces the maximum detention volume, resulting in higher impacts to environmental features and onsite utilities. The 6-inch Kinder Morgan gas line is avoided. A 200-foot vegetation buffer is provided north of Cypress Creek and East of TC Jester Boulevard.

Alternative 2 - Minimal Impacts and provide 200-foot buffer

This alternative minimizes impacts to environmental features and avoids relocating the 12-inch Sunoco-ETC gas line, 10-inch Explorer gas line and 6-inch Kinder Morgan gas line. Alternative 2 results in a reduction of detention volume as a result of avoiding impacts. The same 200-foot vegetation buffer is provided with this alternative both north of Cypress Creek and East of TC Jester Boulevard.

Alternative 3 – Minimal Impact and 400-foot buffer

This alternative has the least impacts to environmental features and gas lines. Alternative 3 avoids relocating the 12-inch Sunoco-ETC gas line, 10-inch Explorer gas line and 6-inch Kinder Morgan gas line. A 400-foot vegetation buffer is provided north of Cypress Creek, resulting in the least amount of detention volume of the three alternatives. The same 200-foot vegetation buffer is located east of TC Jester Boulevard.

3.5.1 Channel and/or Detention Layout

The three detention basin configuration alternatives are described below. An existing 66-inch RCP storm sewer pipe from Cypresswood Drive needs to be incorporated into each alternative layout during final design of the recommended alternative. Each basin in Alternatives 1, 2 and 3 have an inflow weir to allow flows from Cypress Creek to spill into the basin. The weirs are located at the existing low points along the creek high banks where the creek would naturally spill into the proposed basins. The 2D flow areas within the hydraulic analysis indicate these elevations are typically between elevations 95 feet and 96 feet. Due to the erosive nature of the sandy soils along Cypress Creek, any kind of hard armor erosion protection such as concrete or articulated concrete blocks is not recommended within the creek. Earthen weirs are recommended with 6:1 side slopes. Establishing vegetation to hold the soil in place is key to maintaining stable slopes. Articulated blocks that allow vegetation are recommended within the weir and basin side slopes. The design of the weir and extents of the armoring will be finalized during the design phase. There are no proposed modifications to Cypress Creek. The existing recreational features and navigability in Cypress Creek will not be impacted for any of the alternatives.

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The detention volume provided was determined for each alternative. The previous MBI study assumed 4,754 acre-feet of ultimate volume which is significantly more than what was available based on existing site constraints. The large difference was because the MBI study did not include vegetation buffers north of Cypress Creek, east of TC Jester Blvd or south of Cypresswood Drive, jurisdictional wetlands were not avoided, the assumed side slopes are nearly vertical, and an assumed excavation area south of Cypress Creek of 108 acres compared to 20 acres. Table 7 below shows the total volume provided in each alternative.

Alternative	Volume (Ac-Ft)
Alt 1	1070
Alt 2	931
Alt 3	636

Table 7: Volume Provided

Alternative 1 - Maximum Volume and provide 200-foot buffer

Alternative 1 consists of two (2) wet bottom detention basins located north and south of Cypress Creek. The proposed inflow weirs have 4:1 side slopes and bottom widths of 200 feet and 100 feet for Basin 1 and Basin 2, respectively. The proposed outflow structures are a 60 inch and 48-inch Reinforced Concrete Pipe (RCP) for Basin 1 and Basin 2, respectively. A 30-foot maintenance berm was provided along the perimeter of the proposed detention basins. This maintenance berm transitions to the existing 30-foot maintenance berm near the existing Harris County detention basin adjacent to TC Jester Boulevard. A 30-foot access/bottom shelf was provided two (2) feet above the permanent pool elevation. Side slopes vary with a maximum slope of 4:1 and flatter as required for stormwater quality features. Backslope swales and interceptor structures are recommended to prevent erosion of side slopes. Figure 8 below shows the Alternative 1 basin layout. The detailed Alternative 1 layout and typical sections are provided in Exhibit 7.

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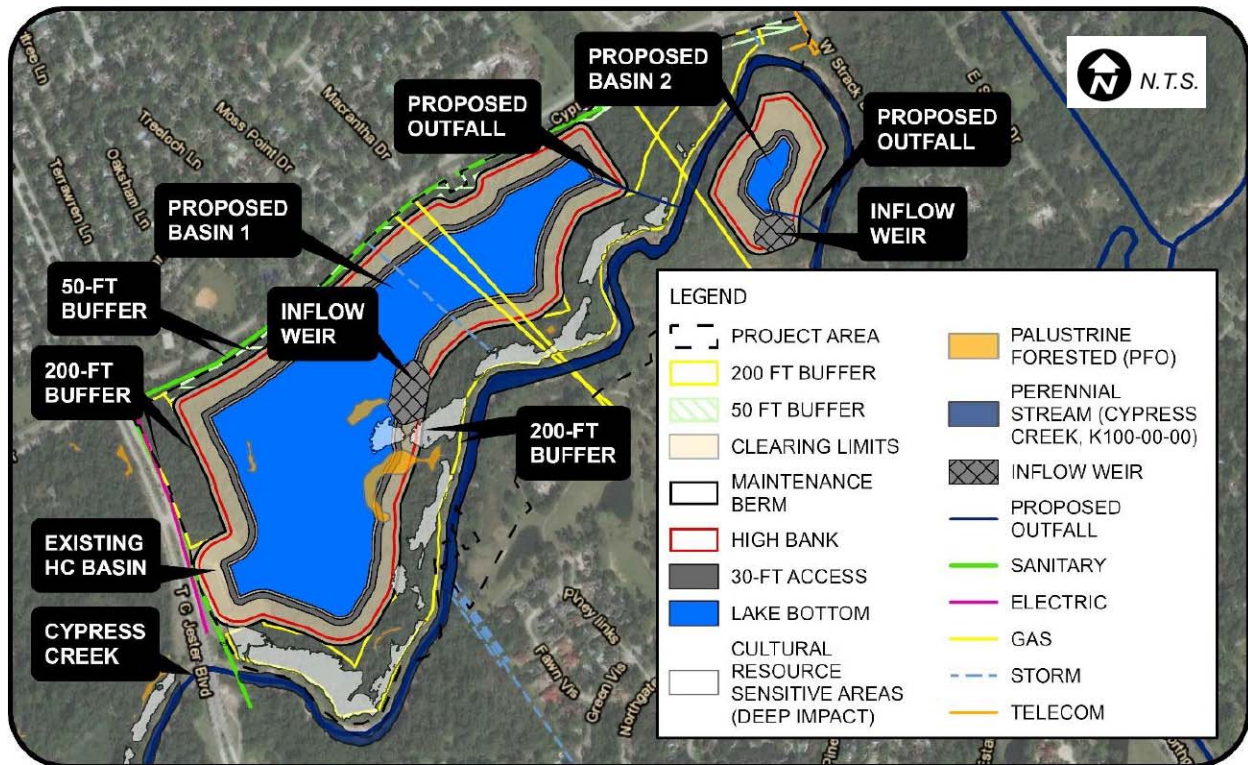


Figure 8: Alternative 1 Basin Layout

Basin 1 has a depth of 17 feet and contains 983-acre feet while basin 2 has a depth of 19.5 feet and contains 87-acre feet. The detention basin depths and volumes provided are shown in Table 8 below.

Basin Name	Depth (Ft)	Volume (Ac-Ft)
1	17.0	983
2	19.5	87
Total	-	1070

Table 8: Basin Layout Alternative 1 – Volume Provided

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Alternative 2 - Minimal Impacts and provide 200-foot buffer

The detention basin configurations were modified to minimize impacts to environmental features and avoid on-site utility conflicts. The area between the 10-inch Explorer Pipeline and 6-inch Kinder Morgan gas line utilities was avoided with this alternative. There are two basins north of Cypress Creek split by the pipelines. Basin 1a has a proposed inflow weir with a 100-foot bottom width weir and 48-inch RCP outfall. Basin 1b has the same inflow and outflow structures as alternative 1 basin 1. Figure 9 below shows the Alternative 2 basin layout. The detailed Alternative 2 layout and typical sections are provided in Exhibit 8.

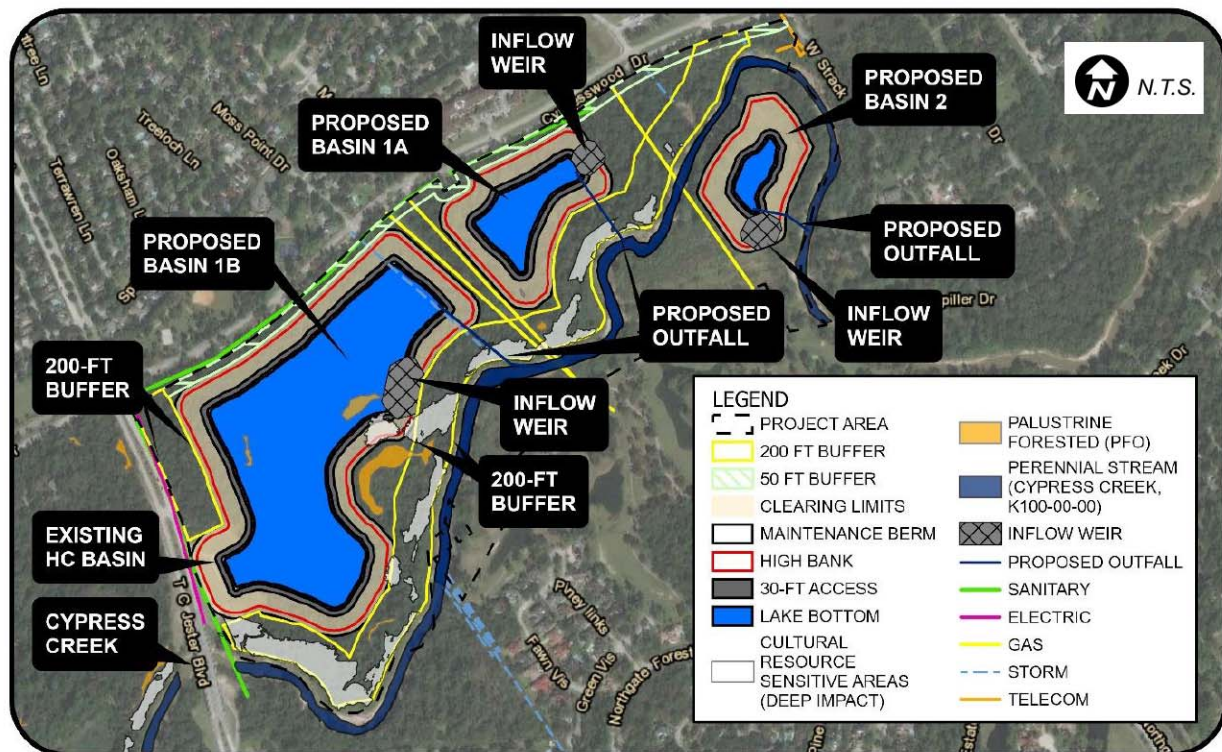


Figure 9: Alternative 2 Basin Layout

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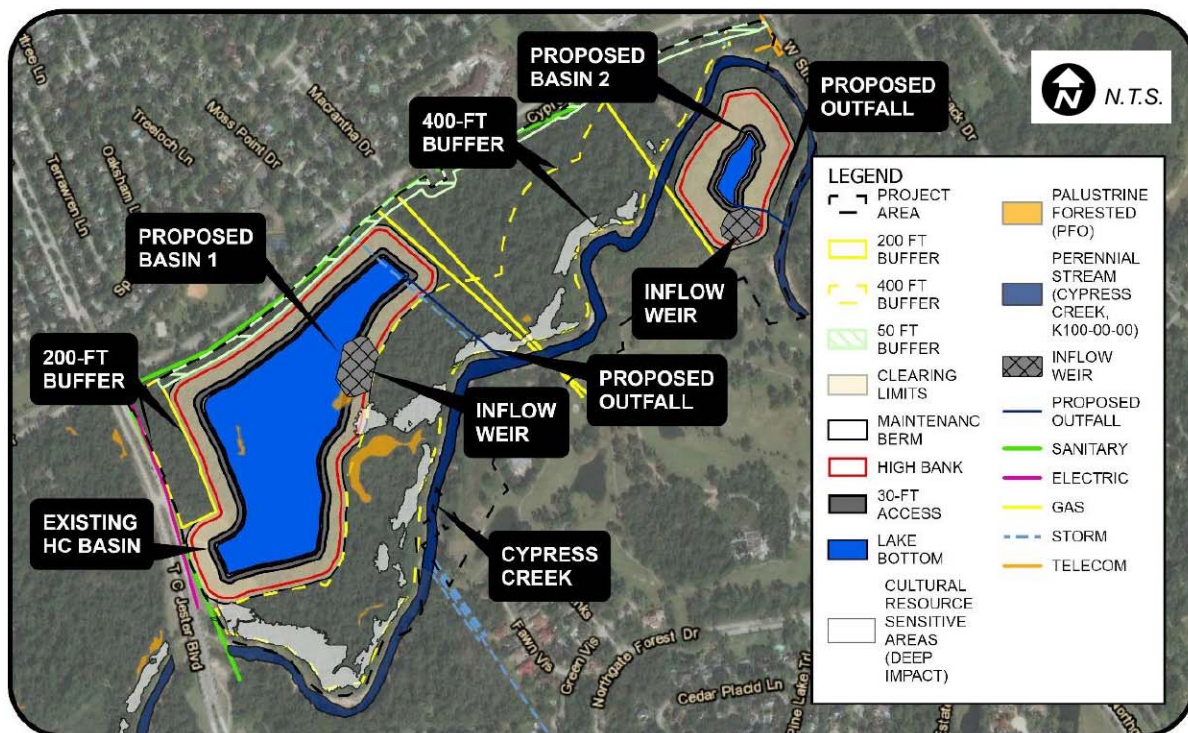
The proposed detention volume is reduced as shown below in Table 9. Basin 1a has a depth of 17 feet and contains 725-acre feet, basin 1b has a depth of 17 feet and contains 119-acre feet and basin 2 has a depth of 19.5 feet and contains 87-acre feet. The detention basin depths and volumes provided are shown in Table 9 below.

Basin Name	Depth (Ft)	Volume (Ac-Ft)
1a	17.0	725
1b	17.0	119
2	19.5	87
Total	-	931

Table 9: Basin Layout Alternative 2 – Volume Provided

Alternative 3 – Minimal Impact and 400-foot buffer

The detention basin configuration was modified to increase the vegetation buffer from 200-feet to 400-feet north of Cypress Creek. The 400-foot vegetation buffer results in no detention basin in the area between the 10-inch Explorer Pipeline and 6-inch Kinder Morgan gas line utilities. All other drainage features remain unchanged from Alternative 2. Figure 10 below shows the Alternative 3 basin layout. The detailed Alternative 3 layout and typical sections are provided in Exhibit 9.



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The proposed detention volume is reduced as shown below in Table 10. Basin 1 has a depth of 16 feet and contains 549-acre feet while basin 2 has a depth of 19.5 feet and contains 87-acre feet. The detention basin depths and volumes provided are shown in Table 10 below.

Basin Name	Depth (Ft)	Volume (Ac-Ft)
1	16.0	549
2	19.5	87
Total	-	636

Table 10: Basin Layout Alternative 3 – Volume Provided

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3.5.2 Results and No Adverse Impact Evaluations

A tabular comparison for revised baseline model and Alternatives 1, 2 and 3 models were made to evaluate no adverse impacts for Alternatives 1, 2 and 3. The comparisons include review of the 10-, 100- and 500-year pre-Atlas 14 WSELs and notes the difference between the revised baseline model and proposed Alternatives 1, 2 and 3 conditions. The minor increases shown in red are believed to be the result of changes between the 2D grid cells from the revised baseline model to Alternative 1 and 2 models. Both alternatives do not add fill and do not modify the geometry of the channel. Only excavation activities are proposed. There should be no increases in water surface elevation.

Alternative 1 - Maximum Volume and provide 200-foot buffer

The proposed 10-, 100- and 500-year water surface elevations were compared with the Revised Baseline Model along Cypress Creek. The model results indicate the proposed detention basin configuration will cause a decrease in water surface elevation throughout the model. The 10-, 100- and 500-year water surface elevations have a maximum decrease near the TC Jester Blvd bridge of 0.40 feet, 0.40 feet, and 0.29 feet, respectively. This maximum decrease occurs upstream of the proposed detention basins. There are slight increases of 0.02 feet in the 10-year storm event at the downstream end of the project area. Tables 11, 12 and 13 below compare the 10-, 100- and 500-year WSELs, respectively, for the two conditions. A negative difference indicates a decrease from the RBM to Alt 1 Model. A full comparison of results is provided in Exhibit 11.

Section Id	10-Yr Wsel (Ft)			
	RBM	Alt 1	Diff	
82452 – TC Jester Blvd Bridge	102.15	101.81	-0.34	Project Site
81836	101.66	101.26	-0.40	
78955	100.58	100.49	-0.09	
78178	100.45	100.23	-0.22	
76574	99.95	99.97	0.02	
75290	99.42	99.44	0.02	
71520 – Kuykendahl Rd. Bridge	97.73	97.73	0.00	
51161 – IH45 Bridge	89.61	89.28	-0.33	
50807	87.34	86.99	-0.35	
50514	86.97	86.60	-0.37	
49972	86.56	86.19	-0.37	
42017 – Hardy Toll Road (Downstream Limit of Study)	82.44	81.94	-0.50	

Table 11: Alternative 1 10-Year Impact Analysis

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Section Id	100-Yr Wsel (Ft)			
	RBM	Alt 1	Diff	
82452 – TC Jester Blvd Bridge	105.09	104.79	-0.30	Project Site
81836	104.63	104.23	-0.40	
78955	103.85	103.76	-0.09	
78178	103.77	103.72	-0.05	
76574	103.30	103.25	-0.05	
75290	103.05	103.00	-0.05	
71520 – Kuykendahl Rd. Bridge	101.50	101.43	-0.07	
51161 – IH45 Bridge	94.04	93.91	-0.13	
50807	91.64	91.52	-0.12	
50514	91.35	91.23	-0.12	
49972	90.95	90.81	-0.14	
42017 – Hardy Toll Road (Downstream Limit of Study)	87.30	87.15	-0.15	

Table 12: Alternative 1 100-Year Impact Analysis

Section Id	500-Yr Wsel (Ft)			
	RBM	Alt 1	Diff	
82452 – TC Jester Blvd Bridge	107.26	107.01	-0.25	Project Site
81836	106.96	106.67	-0.29	
78955	106.33	106.29	-0.04	
78178	106.28	106.26	-0.02	
76574	105.89	105.87	-0.02	
75290	105.75	105.71	-0.04	
71520 – Kuykendahl Rd. Bridge	103.98	103.95	-0.03	
51161 – IH45 Bridge	96.64	96.64	0.00	
50807	94.81	94.72	-0.06	
50514	94.39	94.29	-0.10	
49972	94.16	94.07	-0.09	
42017 – Hardy Toll Road (Downstream Limit of Study)	90.75	90.64	-0.11	

Table 13: Alternative 1 500-Year Impact Analysis

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Alternative 2 - Minimal Impacts and provide 200-foot buffer

The proposed 10-, 100- and 500-year water surface elevations were compared with the Revised Baseline Model along Cypress Creek. The model results indicate the proposed detention basin configuration will cause a decrease in water surface elevation throughout the model. The 10-, 100- and 500-year water surface elevations have a maximum decrease near the TC Jester Blvd bridge of 0.44 feet, 0.35 feet, and 0.23 feet, respectively. This maximum decrease occurs upstream of the proposed detention basins. Tables 14, 15, and 16 below compare the 10-, 100- and 500-year WSELs, respectively, for the two conditions. A negative difference indicates a decrease from the RBM to Alt 2 Model. A full comparison of results is provided in Exhibit 12.

Section Id	10-Yr Wsel (Ft)			
	RBM	Alt 2	Diff	
82452 – TC Jester Blvd Bridge	102.15	101.76	-0.39	Project Site
81836	101.66	101.22	-0.44	
78955	100.58	100.38	-0.20	
78178	100.45	100.38	-0.14	
76574	99.95	100.31	-0.13	
75290	99.42	99.82	-0.13	
71520 – Kuykendahl Rd. Bridge	97.73	99.29	-0.17	
51161 – IH45 Bridge	89.61	97.56	-0.36	
50807	87.34	89.25	-0.37	
50514	86.97	86.97	-0.38	
49972	86.56	86.59	-0.37	
42017 – Hardy Toll Road (Downstream Limit of Study)	82.44	86.19	-0.47	

Table 14: Alternative 2 10-Year Impact Analysis

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Section Id	100-Yr Wsel (Ft)			
	RBM	Alt 2	Diff	
82452 – TC Jester Blvd Bridge	105.09	104.83	-0.26	Project Site
81836	104.63	104.28	-0.35	
78955	103.85	103.75	-0.10	
78178	103.77	103.70	-0.07	
76574	103.30	103.24	-0.06	
75290	103.05	102.98	-0.07	
71520 – Kuykendahl Rd. Bridge	101.50	101.42	-0.08	
51161 – IH45 Bridge	94.04	93.93	-0.11	
50807	91.64	91.54	-0.10	
50514	91.35	91.25	-0.10	
49972	90.95	90.83	-0.12	
42017 – Hardy Toll Road (Downstream Limit of Study)	87.30	87.18	-0.12	

Table 15: Alternative 2 100-Year Impact Analysis

Section Id	500-Yr Wsel (Ft)			
	RBM	Alt 2	Diff	
82452 – TC Jester Blvd Bridge	107.26	107.06	-0.20	Project Site
81836	106.96	106.73	-0.23	
78955	106.33	106.30	-0.03	
78178	106.28	106.27	-0.01	
76574	105.89	105.88	-0.01	
75290	105.75	105.73	-0.02	
71520 – Kuykendahl Rd. Bridge	103.98	103.96	-0.02	
51161 – IH45 Bridge	96.64	96.64	0.00	
50807	94.81	94.74	-0.07	
50514	94.39	94.31	-0.08	
49972	94.16	94.08	-0.08	
42017 – Hardy Toll Road (Downstream Limit of Study)	90.75	90.66	-0.09	

Table 16: Alternative 2 500-Year Impact Analysis

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Alternative 3 – Minimal Impact and 400-foot buffer

The proposed 10-, 100- and 500-year water surface elevations were compared with the Revised Baseline Model along Cypress Creek. The model results indicate the proposed detention basin configuration will cause a decrease in water surface elevation throughout the model. The 10-, 100- and 500-year water surface elevations have a maximum decrease near the TC Jester Blvd bridge of 0.22 feet, 0.24 feet, and 0.12 feet, respectively. This maximum decrease occurs upstream of the proposed detention basins. The 500-year water surface elevation has a maximum increase of 0.03 feet at the Kuykendahl bridge. There are slight increases of 0.02 feet in the 10-year storm event at the downstream end of the project area. Tables 17, 18 and 19 below compare the 10-, 100- and 500-year WSELs, respectively, for the two conditions. A negative difference indicates a decrease from the RBM to Alt 3 Model. A full comparison of results is provided in Exhibit 13.

Section Id	10-Yr Wsel (Ft)			
	RBM	Alt 3	Diff	
82452 – TC Jester Blvd Bridge	102.15	101.98	-0.17	Project Site
81836	101.66	101.44	-0.22	
78955	100.58	100.56	-0.02	
78178	100.45	100.46	0.01	
76574	99.95	99.96	0.01	
75290	99.42	99.44	0.02	
71520 – Kuykendahl Rd. Bridge	97.73	97.56	-0.17	
51161 – IH45 Bridge	89.61	89.25	-0.36	
50807	87.34	86.97	-0.37	
50514	86.97	86.59	-0.38	
49972	86.56	86.19	-0.37	
42017 – Hardy Toll Road (Downstream Limit of Study)	82.44	81.97	-0.47	

Table 17: Alternative 3 10-Year Impact Analysis

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Section Id	100-Yr Wsel (Ft)			
	RBM	Alt 3	Diff	
82452 – TC Jester Blvd Bridge	105.09	104.91	-0.18	Project Site
81836	104.63	104.39	-0.24	
78955	103.85	103.80	-0.05	
78178	103.77	103.73	-0.04	
76574	103.30	103.26	-0.04	
75290	103.05	103.00	-0.05	
71520 – Kuykendahl Rd. Bridge	101.50	101.45	-0.05	
51161 – IH45 Bridge	94.04	93.98	-0.06	
50807	91.64	91.58	-0.06	
50514	91.35	91.29	-0.06	
49972	90.95	90.88	-0.07	
42017 – Hardy Toll Road (Downstream Limit of Study)	87.30	87.23	-0.07	

Table 18: Alternative 3 100-Year Impact Analysis

Section Id	500-Yr Wsel (Ft)			
	RBM	Alt 3	Diff	
82452 – TC Jester Blvd Bridge	107.26	107.15	-0.11	Project Site
81836	106.96	106.84	-0.12	
78955	106.33	106.36	0.03	
78178	106.28	106.31	0.03	
76574	105.89	105.86	-0.03	
75290	105.75	105.77	0.02	
71520 – Kuykendahl Rd. Bridge	103.984	104.01	0.03	
51161 – IH45 Bridge	96.64	96.64	0.00	
50807	94.81	94.80	-0.01	
50514	94.39	94.37	-0.02	
49972	94.16	94.15	-0.01	
42017 – Hardy Toll Road (Downstream Limit of Study)	90.75	90.73	-0.02	

Table 19: Alternative 3 500-Year Impact Analysis

3.5.3 Drain Time

The K500-23-00-E002 detention basins drain as Cypress Creek recedes to baseflow conditions. The drain times are within 48 hours after Cypress Creek has receded. Table 20 below shows each basin's 500-year storm drain time for Alternatives 1, 2 and 3.

Alternative	500-Year Storm Drain Time (Hr)		
	Basin 1(a)	Basin 1b	Basin 2
Alt 1	36	N/A	<12
Alt 2	32	32	<12
Alt 3	26	N/A	<12

Table 20: Drain Time Summary**3.5.4 Detention Basin Freeboard**

Generally, HCFCD requires a 1-ft freeboard for a new detention basin. However, due to variation of topography on the project site and design flood levels that inundate the creek it is not feasible to provide freeboard in the detention basin for any of the alternatives. Ground elevations vary from approximately 92 to 107, and flood levels range from 100.65 to 105.87 for the 10-year and 500-year design storms respectively as modeled for Alternative 1 which has the largest reductions. Therefore, for even the 10-year storm the creek is out of its banks and containment is not feasible without modifying the banks of the creek, which is outside the scope. The proposed basins extend lengthwise along K100-00-00 (Cypress Creek) approximately 7,000 feet (1.3 mile). The banks of the detention basins will have to match the existing elevations along the creek to prevent substantial blockage of flow into and out of the basin. It is impossible to maintain a constant elevation to provide the 1-foot of freeboard requirement. A profile plot of the channel thalweg and ground elevations along the basins nearest the channel is provided for each alternative in Exhibits 7, 8 and 9.

3.5.5 Structure Inventory

The Cypress Creek Watershed structure inventory tool was provided by HCFCD. The tool is a shapefile showing structures within the Cypress Creek Watershed and the estimated finish floor elevations and improvement value of those structures. This shapefile was used to evaluate the results from the baseline model and the three detention basin configuration alternative models. The complete improvement value amount of the structure was used for this study. The structure inventory matrix was created by comparing number of structures in the 100- and 500-year floodplains. The structure inventory summary for each alternative is shown in Table 21.

Alternative	Structures in Floodplain		Value of Structures in Floodplain	
	100-Yr	500-Yr	100-Yr	500-Yr
Baseline	1,668	4,615	\$884,543,500	\$3,176,038,300
Alt 1	1,636	4,569	\$867,573,800	\$3,144,381,100
Alt 2	1,642	4,572	\$870,755,700	\$3,146,445,700
Alt 3	1,660	4,601	\$880,301,100	\$3,166,035,100

Table 21: Structural Inventory Summary

3.5.6 Maintenance Access Plan Requirements

The maintenance access requirements are met for each alternative by providing a minimum 30-foot maintenance berm along the perimeter of the high banks and a minimum 10-foot access/safety shelf two feet above the permanent pool elevation. The project site north of Cypress Creek has access from TC Jester Boulevard and Cypresswood Drive. The project site south of Cypress Creek has no direct access from a public street. Maintenance access to the project area south of Cypress Creek is available through the 60-ft storm sewer easement by NWHC MUD20 and HC MUD211. Coordination between HCFCD and the MUDs has taken place. The storm sewer easement may need to be reinforced for approximately 1,200 feet to safely accommodate heavy equipment. A maintenance access road approximately 2,500 feet long will need to be constructed from the storm sewer easement to the basin south of Cypress Creek. Long-term erosion potential for the southern maintenance access road will need to be considered during design since the access road is within 100 feet of Cypress Creek's southern high bank. Maintenance roads crossing pipelines will have to be coordinated with the pipeline companies and may need to be reinforced to meet the pipeline company's requirements for heavy equipment. A detailed maintenance access plan into and within the project on both sides of Cypress Creek will be prepared during the design phase in coordination with HCFCD, Northgate Forest Golf Club, Kinder Morgan, Sunoco, Explorer, NWHC MUD 20, and HC MUD 211.

3.5.7 Right-of-Way Requirements

HCFCFCD owns the tracts of land where the proposed improvements are located. No additional property is anticipated for the proposed improvements.

3.5.8 Potential Pipeline and Utility Conflicts

Alternative 1 avoids relocation of the 6-inch Kinder Morgan gas pipeline. Alternative 1 would require the following two gas pipelines to be relocated:

- A 12-inch Sunoco gas pipeline; and
- A 10-inch Explorer gas pipeline.

Alternatives 2 and 3 avoid conflicts with the three existing gas pipelines.

There are multiple local storm sewer outfalls in the vicinity of the proposed basin footprints. The existing 66-inch RCP storm from the Terranova West subdivision needs to be incorporated into each alternative. The gas pipeline relocation guidelines are included in Appendix 3.

3.5.9 Geotechnical Requirements

A slope stability recommendation has been provided by Ninyo & Moore. Ninyo & Moore recommends side slopes of 4:1 or flatter for long term slope stability. Side slopes of 4:1 or flatter are proposed for each alternative.

3.5.10 Environmental and Cultural Resources Issues

As of June 22, 2020, the Navigable Waters Protection Rule (NWPR) is the law of the land. Under the NWPR, ephemeral streams within the property are non-jurisdictional and, therefore, are not subject to permitting. It is possible the federal court will put an injunction on the NWPR, but as of the date of this report no such injunction has occurred. Two approved jurisdictional determinations have been provided by USACE dated March 8, 2021 (SWG-2019-00857) and April 14, 2021 (SWG-2020-00633). Anticipated impacts to the environmental and cultural resources for the resources as delineated are described for each alternative below. Nationwide permit 7 (NWP 7) is applicable for the construction of the outfall structures. Nationwide permit 43 (NWP 43) is applicable if impacts to jurisdictional wetlands and streams are 0.5 acres or less. An individual permit (IP) is required if impacts to jurisdictional wetlands and streams are greater than 0.5 acres. If necessary, each detention basin can be permitted as a standalone project since they have independent inflow and outflow structures to keep impacts below the 0.5-acre threshold. Mitigation is required for stream bed losses exceeding 3 per 100-acre per General Condition 23.d of 2021 NWP's.

Two cultural resources studies were performed by Gray & Pape, Inc for the project areas north and south of Cypress Creek. Concurrence from the Texas Historical Commission (THC) was granted September 24, 2020 (north) and December 15, 2020 (south). The conclusion of the cultural resource study for the area north of Cypress Creek identified multiple sensitive areas for cultural resource.

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The cultural resource sensitive areas are generally located 200-feet north of Cypress Creek from TC Jester Blvd to immediately east of the 6-inch Kinder Morgan gas line. It is recommended to avoid these areas due to the potential of impacting cultural resources buried between 10 to 15 feet below the surface. Excavation monitoring is warranted if excavation occurs between 10 and 15 feet within these areas. The conclusion of the cultural resource study for the area south of Cypress Creek did not identify any such sensitive areas. Per THC, excavation monitoring is not required south of Cypress Creek. The cultural resource studies and THC concurrence are provided in Appendix 6.

Two threatened and endangered species reviews were performed by Spirit Environmental for the project area. The conclusion of the study for the area north of Cypress Creek states that construction within Cypress Creek and clearing nearby forested vegetation may impact four state listed threatened species, specifically western creek chubsucker (*Erimyzon claviformis*), Louisiana pigtoe mussel (*Pleurobema riddellii*), alligator snapping turtle (*Macrochelys temminckii*) and timber rattlesnake (*Crotalus horridus*). Based on Spirit's findings, project activities within the 171.5-acre tract north of Cypress Creek (includes West TC Jester basin project) will not affect federally protected species. The conclusion of the threatened and endangered species study for the area south of Cypress Creek states construction within Cypress Creek may impact a single state listed threatened species, Louisiana pigtoe mussel. Spirit recommends survey and relocation for listed freshwater mussels should direct impacts to the stream bed be required for this project. Based on Spirit's findings, the K500-23-00-E002 project south of Cypress Creek will not affect federally protected species. To avoid incidental take, Spirit recommends a site visit be conducted prior to construction to document the presence of any active nests should clearing activities occur during the migratory bird breeding and nesting season for all areas within the proposed project areas. The threatened and endangered species studies are provided in Appendix 7.

Alternative 1 - Maximum Volume and provide 200-foot buffer

Alternative 1 provides minimal avoidance of environmental and cultural resource areas. This alternative will result in impacts to 0.06 acres of perennial streams, 1.42 acres of palustrine forested wetlands (as currently delineated) and 0.62 acres cultural resource sensitive areas. A USACE IP would be required as part of the permitting process with a substantial timeline (more than 12 months). Alternative 1 would also require purchasing mitigation credits for the impacted wetlands/streams. Stream credits for the TC Jester Stormwater Detention Basin project are available at Katy Prairie Stream Mitigation Bank. Palustrine forested wetland credits would be bought from the Greens Bayou Wetlands Mitigation Bank since no credits are available at Katy Hockley Mitigation Bank.

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Alternative 2 - Minimal Impacts and provide 200-foot buffer

Alternative 2 minimizes impacts to environmental areas. Alternative 2 impacts 0.08 acres of perennial streams, 0.40 acres of palustrine forested wetlands and 0.62 cultural resource sensitive areas. A USACE NWP would be required as part of the permitting process. Alternative 2 would also require purchasing mitigation credits for the impacted wetlands/streams. Stream credits for the TC Jester Stormwater Detention Basin project are available at Katy Prairie Stream Mitigation Bank.

Alternative 3 – Minimal Impact and 400-foot buffer

Similarly to Alternative 2, Alternative 3 minimizes the amount of environmental and cultural resource areas impacted. Alternative 3 impacts 0.06 acres of perennial streams, 0.39 acres of palustrine forested wetlands and 0.17 cultural resource sensitive areas. A USACE NWP would be required as part of the permitting process. Alternative 3 would also require purchasing mitigation credits for the impacted wetlands/streams. Stream credits for the TC Jester Stormwater Detention Basin project are available at Katy Prairie Stream Mitigation Bank.

The table shows the disturbed areas and linear feet for the different jurisdictional features. Table 22 summarizes the amount of environmental and cultural resource sensitive areas impacted for each alternative.

Impacted Environmental Features	Alt 1	Alt 2	Alt 3
	Area of Impact (ac)		
Perennial Stream (Cypress Creek)	0.06	0.08	0.06
Palustrine Forested Wetlands	1.42	0.40	0.39
NWP vs IP	IP	NWP	NWP
Cultural Resource Sensitive Area (Deep Impact)	0.62	0.62	0.17

Table 22: Impacted Environmental and Cultural Areas

3.5.11 Water Quality

Water quality must be provided to meet Municipal Separate Storm Sewer System (MS4) permit requirements. The K500-23-00-E002 basin project has high water quality opportunity. The basins will have emergent vegetation, submerged vegetation, permanent deep pool, inflow structures located away from the outflow structures to increase circulation time, varying side slopes and floatable materials control devices. The water quality features meet MS4 permitting requirements. The drainage areas included in the hydrology and hydraulic models are on the larger watershed level scale for Cypress Creek and not on an individual neighborhood level. The water quality calculations including wet bottom volume will be addressed during final design. The following wet bottom volumes provided in each alternative are shown below:

- Alternative 1 – 182.4 ac-ft
- Alternative 2 – 139.1 ac-ft
- Alternative 3 – 93.5 ac-ft

3.5.12 Estimated Construction Cost

A high-level estimate of construction cost was prepared for each proposed alternative. The estimate includes typical items for detention basins construction and corresponding auxiliary inflow and outflow structures. A 25% contingency was included within the construction cost to account for some unknowns or future layout changes. A 10% engineering and administration cost was included to account for future design costs. Table 23 below summarizes the estimated construction cost for each alternative. A detailed Opinion of Probable Construction Cost (OPCC) for each alternative is provided in Appendix 8.

Alternative	OPCC		
	Construction	Engineering and Admin	Total
Alt 1	\$34,552,500	\$3,455,250	\$38,007,800
Alt 2	\$27,388,750	\$2,738,875	\$30,127,600
Alt 3	\$19,215,000	\$1,921,500	\$21,136,500

Table 23: OPCC Summary

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3.6 Alternative Performance Metrics

The alternative performance metric was developed comparing volume, OPCC, the 100- and 500-year floodplains removed from number of structures, improvement value of structures removed from the 100- and 500-year floodplains, and benefit cost ratio. Performance metrics for each alternative for the 100- and 500-year analyses are provided in Tables 24 and 25 below.

Performance Metrics	Alt 1	Alt 2	Alt 3
Volume Provided (ac-ft)	1070	931	636
OPCC	\$38,007,800	\$30,127,600	\$21,136,500
Number of Structures with Floodplain Removed	32	26	8
Value of Structures with Floodplain Removed	\$16,969,700	\$13,787,800	\$4,242,400
Benefit Cost Ratio (Value of Structures Removed/OPCC)	0.45	0.46	0.20

Table 24: Alternatives 100-Year Performance Metrics

Performance Metrics	Alt 1	Alt 2	Alt 3
Volume Provided (ac-ft)	1070	931	636
OPCC	\$38,007,800	\$30,127,600	\$21,136,500
Number of Structures with Floodplain Removed	46	43	14
Value of Structures with Floodplain Removed	\$31,657,200	\$29,592,600	\$10,003,200
Benefit Cost Ratio (Value of Structures Removed/OPCC)	0.83	0.98	0.47

Table 25: Alternatives 500-Year Performance Metrics

4.0 RECOMMENDATIONS AND CONCLUSION

4.1 Recommended Alternative

The environmental permitting and benefit cost ratio were the two factors to determine the recommended alternative. Table 26 below summarizes these comparisons for each alternative.

Performance Metrics	Alt 1	Alt 2	Alt 3
Environmental Permitting (NWP vs IP)	IP	NWP	NWP
Benefit Cost Ratio (Value of Structures Removed/OPCC)	0.83	0.98	0.47

Table 26: Alternatives 500-Year Performance Metrics

Based on the evaluation of performance metrics, and the assumptions, constraints and information known at the time of this report, Alternative 2 is recommended.

The following bullet points outline the key features of Alternative 2:

- The OPCC is \$30,127,600;
- The 100-year floodplain is removed from 26 structures valued at \$13,787,800;
- The 500-year floodplain is removed from 43 structures valued at \$29,592,600;
- Benefit cost ratio for 100-year storm is 0.46 and 500-year storm is 0.98;
- Three (3) wet ponds with minimal impacts to environmental features and avoidance of onsite pipelines;
- A 200-foot and 50-foot vegetation buffer is provided east of TC Jester Boulevard, north of Cypress Creek and south of Cypresswood Drive, respectively;
- Impacted palustrine forested wetlands equal 0.40 acres;
- Impacted perennial streams equal 0.08 acres;
- A nationwide permit (NWP 7 and 43) is required;
- Cultural resource monitoring would be required by THC during excavation activities in cultural resource sensitive areas;
- A minimum 30-foot maintenance berm is provided along the perimeter of the proposed detention basins;
- A 30-foot access/bottom shelf is located two (2) feet above the permanent pool elevation of the basins;
- Side slopes are 4:1 or flatter see typical section in Exhibit 8; and
- Basins vary in depth. Depths and volumes are specified in Table 27.

Basin Name	Depth (Ft)	Volume (Ac-Ft)
1	17.0	844
2	19.5	87
Total	-	931

Table 27: Recommended Alternative – Volume Estimation

4.2 Design Considerations

There are certain design aspects of the TC Jester Stormwater Detention Basin project considered but not finalized during the PER. The following design considerations need to be finalized during the design phase:

- The Federal Aviation Administration (FAA) regulations related to Wildlife Hazard are currently pending approval. It is recommended to obtain a copy of the approved regulations and incorporate in the design, since TC Jester Stormwater Detention Basin is located within a 5-mile radius from the D.W. Hooks Memorial Airport.
- Perform water quality calculations and incorporate design requirements as outlined in HCFCD's Design Guidelines for HCFCD Wet Bottom Detention Basins with Water Quality Features dated April 2014.
- A detailed maintenance access plan into and within the project on both sides of Cypress Creek will be prepared in coordination with HCFCD, Northgate Forest Golf Club, Kinder Morgan, Sunoco, Explorer, NWHC MUD 20, and HC MUD 211.

The design considerations are not limited to those listed above. Additional design considerations have been outlined in the PER and specified in various design criteria manuals.

4.3 Conclusion

The proposed TC Jester Stormwater Detention Basin project provides significant hydraulic benefits. We recommend HCFCD continue with the implementation process of the Cypress Creek Regional Drainage Plan. The recommended Alternative 2 meets the project objectives by providing the highest benefit to cost ratio compared to the other two alternatives. Alternative 2 shows no adverse impacts for storm events up to and including the 500-year storm event.

5.0 REFERENCES

Ernest F. Brater, Horace Williams King: *Handbook of Hydraulics*, Sixth Edition, Michigan, 1976.

HCFCFCD. *Design Guidelines for HCFCFCD Wet Bottom Detention Basins with Water Quality Features*. April 2014.

HCFCFCD. *Policy Criteria and Procedure Manual*. 2019.

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United States Army Corps of Engineers. Hydrologic Engineering Center: *HEC-RAS River Analysis System User's Manual, Version 5.0*. Washington, DC: GPO, February 2016.

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United States. Federal Emergency Management Agency. *Flood Insurance Rate Map, No. 48201C0265M, Harris County, Texas and Incorporated Areas*. Washington, DC: GPO, October 16, 2013.

United States. Federal Emergency Management Agency. *Flood Insurance Study, Harris County, Texas and Incorporated Areas*. Washington, DC: GPO, October 16, 2013.

Ven Te Chow, PhD: *Open-Channel Hydraulics*, Illinois, 1959.

6.0 LISTS OF EXHIBITS

1. Vicinity Map
2. Drainage Area Map
3. Existing Conditions Map
4. Historical Rainfall Data
5. LiDAR Based Contour Map
6. Project Layout Map
7. Alternative 1 – Layout Map
8. Alternative 2 – Layout Map
9. Alternative 3 – Layout Map
10. Baseline – WSE Profiles
11. Alternative 1 – WSE Profiles
12. Alternative 2 – WSE Profiles
13. Alternative 3 – WSE Profiles

7.0 LIST OF APPENDICES

1. Effective FIRM
2. Site Photographs
3. Pipeline Relocation Guidelines
4. Geotechnical Report
5. Environmental Site Investigation/Assessment Reports
6. Cultural Resource Reports
7. Threatened and Endangered Species Reports
8. Detailed Engineer's OPCC
9. Topographic, Boundary and Tree Surveys
10. Electronic Files on USB
 - H&H Models
 - Survey CADD Files
 - Final PER PDF

8.0 DEFINITIONS & ACRONYMS

10-Year Flood. The flood event that has a 10-percent chance of being equaled or exceeded each year at a given location, also referred to as the 10-percent annual chance flood.

100-Year Flood. The flood event that has a 1-percent chance of being equaled or exceeded each year at a given location, also referred to as the 1-percent annual chance flood.

500-Year Flood. The flood event that has a 0.2-percent chance of being equaled or exceeded each year at a given location, also referred to as the 0.2-percent annual chance flood.

AC-FT. Acre-Feet

Base Flood Elevation (BFE). Typically refers to the water-surface elevations during the 100-year flood event.

CY. Cubic Yards

Duplicate Baseline Model (DBM). A copy of the baseline model.

FEMA. Federal Emergency Management Agency

FIRM. Flood Insurance Rate Map

FIS. Flood Insurance Study

GHORBA. Greater Houston Off Road Biking Association

HEC-HMS. The Hydrologic Engineering Center – Hydrologic Modeling System is designed to simulate the precipitation-runoff processes of dendritic drainage basins. This includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff. Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation.

HEC-RAS. The Hydrologic Engineering Center – River Analysis System software developed by the US Army Corps of Engineers to perform one-dimensional steady flow and unsteady flow river hydraulic computations. The computer program models the hydraulics of water flow through natural rivers and other channels.

Jurisdictional Waters of the US. All waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide. All interstate waters including interstate wetlands. All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation or destruction of which could affect interstate or foreign commerce including any such waters.

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Letter of Map Revision (LOMR). A Letter of Map Revision is the FEMA's official modification to an effective Flood Insurance Rate Map (FIRM). LOMRs can result in a physical change to the existing regulatory floodway, the effective Base Flood Elevations (BFEs), or the Special Flood Hazard Area (SFHA). LOMR reviews take up to 90 days to process, are subject to an appeal period, and usually become effective within six months after they are issued. Because a LOMR officially revises the effective FIRM, the flood hazard updates shown are used to rate flood insurance policies and enforce flood insurance and development requirements.

NAD83. 1983 North American Datum

Nationwide Permit. Permits issued by the U.S. Army Corps of Engineers authorizing various types of development projects in wetlands and other waters of the United States.

NAVD88. 1988 North American Vertical Datum

OPCC. Opinion of Probable Construction Cost

Overbank. Area outside of the defined channel located within the flood fringe. Right refers to the right side of the channel looking downstream.

Revised Baseline Model (RBM). A hydraulic model that corrects the baseline model with updated existing conditions.

Special Flood Hazard Area (SFHA). A Special Flood Hazard Area (SFHA) is an area identified by FEMA as an area with a special flood or mudflow, and/or flood related erosion hazard, as shown on a flood hazard boundary map or flood insurance rate map. Areas within the SFHA are designated on the flood insurance rate map as Zone A, AO, A1-A30, AE, A99, AH, AR, AR/A, AR/AE, AR/AH, AR/AO, AR/A1-A30, V1-V30 or V.

USACE. United States Army Corps of Engineers

WSEL. Water-Surface Elevation

Zone AE. A 100-year FEMA regulatory floodplain generally determined through detailed analysis and defined by a FIRM.