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North Houston Highway Improvement Project Segment 3B from Alabama Street to Canal Street Drainage Study

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North Houston Highway Improvement Project Segment 3B from Alabama Street to Canal Street Drainage Study

Harris County, Texas

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(Preliminary design sheets include Drainage Area Maps, Plan and Profile Sheets, and Hydraulic Data Sheets)

- I-69/SH-288/I-45 Depressed Section
- Hamilton Street Collector
- St. Emanuel Street Collector
- Chartres Street
- I-45 South
- SH-288 South
- Proposed Pump Stations (I-45 Pump Station & Buffalo Bayou Pump Station)
- Pond A Layout Sheet
- Pond A Inflow Structure Details

List of Appendices

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- Supporting Technical Memoranda
- Record Drawings

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- Utility Conflict Table
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- I-69/SH-288/I-45 Depressed Section
- I-45 South
- Chartres Street – North of Elgin
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- Hamilton Street
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Appendix D Hydrologic and Hydraulic Models **(Included on USB only)**

- HEC-HMS
    - Overland Flow Analysis
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- SWMM Models
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List of Acronyms

AEP	Annual Exceedance Probability
CFS	Cubic Feet Per Second
COH	City of Houston
CSJ	Control-Section-Job
DEIS	Draft Environmental Impact Statement
GIMS	Geographical Information Management System
GPM	Gallon Per Minute
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FT	Feet
HCFCD	Harris County Flood Control District
HDM	Hydraulic Design Manual
IN/HR	Inches Per Hour
LiDAR	Light Detection and Ranging
MCC	Motor Control Center
NAVD	North American Vertical Datum
NHHIP	North Houston Highway Improvement Project
NOAA	National Oceanic and Atmospheric Administration
$NPSH_a$	Available Net Positive Suction Head
NRCS	Natural Resources Conservation Service
NUSA	Non-Uniform Subsidence Adjustment
RCB	Reinforced Concrete Box
RCP	Reinforced Concrete Pipe
ROW	Right-Of-Way
SCADA	Supervisory Control and Data Acquisition
SWMM	Storm Water Management Model
TDH	Total Dynamic Head
TxDOT	Texas Department of Transportation
WSEs	Water Surface Elevations

Executive Summary

General

This document represents the drainage study and preliminary drainage design for Segment 3B of the North Houston Highway Improvement Project (NHHIP). The NHHIP is a proposed Texas Department of Transportation (TxDOT) project to address the existing Interstate Highway 45 (I-45) traffic capacity limitations, obsolete functionality of certain aspects of the corridor, and existing major design deficiencies. The report documents the preliminary results of the drainage analysis and design and will be used to assist TxDOT and a future design-build contractor in the design/construction phase of the project. The preliminary design recommendations presented in this study are for review purposes only and should not be used for construction purposes.

The NHHIP project consists of 3 main segments, Segments 1 through 3. Segment 3 has been further subdivided into five segments; A through E. Segment 3B extends along I-69 for 2.3 miles from Canal Street to Alabama Street and includes small sections of I-45 South and SH-288 South.

The drainage study considered the recent flooding due to Hurricane Harvey in the analysis and proposed drainage recommendations. Hurricane Harvey made landfall on August 25, 2017 and continued to produce rainfall through August 29, 2017, causing a catastrophic flood event over the Greater Houston Area. The area in the vicinity of Segment 3 received approximately 33 inches of rainfall over a 4 day period; this is equivalent to a storm event in excess of a 500-year event.

Project Overview

The project, Segment 3B, is limited to the realignment of I-69, the proposed depressed section from Commerce Street to Alabama Street, a section of I-45 South and a section of SH-288 South. The major drainage components of the project include:

- Overland flow collector systems protecting the depressed section from overland flow west and east of the I-69 corridor,
- Storm drain systems,
- Pump station facilities, and
- Mitigation facilities.

These design features can be seen on the **Segment 3B Drainage Plan Summary Exhibit,** which follows directly after the executive summary.

The drainage criteria for this study were established in coordination with the five separate Segment 3 drainage teams and TxDOT. The I-45/I-69 corridor will continue to serve as an evacuation route, thereby, requiring a 100-year level of protection for the main lanes, at a minimum. In addition, the project specific design criteria developed by TxDOT and the Segment 3 drainage teams includes designing the depressed section pump stations for a 100-year plus 25-percent storm event. It was agreed with TxDOT that the 250-year storm event could be used as the design event for the pump station design, as it is comparable to the 100-year plus 25-percent storm event.

In November 2017, the National Oceanic and Atmospheric Administration (NOAA) released preliminary Atlas 14 rainfall data for Texas. This report, based on new statistical analysis of historic rainfall, determines new recommended design event rainfall depths for different return frequencies. The preliminary rainfall data from Atlas 14 shows an average increase of 3 to 4 inches in the 100-year, 24 hour rainfall depths across Harris County. As the Atlas 14 data was not finalized at the time of this study,

TxDOT's direction was to reference the current rainfall data for the drainage system design. However, in regards to the pump station design, TxDOT required that the pump station account for the anticipated increase in rainfall depths by designed for the 100-year plus 25-percent/current 250-year storm event rainfall. The current 250-year storm event is similar to the anticipated Atlas 14 100-year rainfall depth.

Overland Flow Analysis

As the I-69 corridor is proposed to be depressed from Spur 527 to Canal Street (Segments 3A and 3B), it was necessary to quantify the overland flow draining to the proposed depressed section and design a collector system to prevent the overland flow from entering the depressed section. The overland flow analysis was completed using SWMM for the 100-year, 250-year, 500-year and Hurricane Harvey storm events.

The overland flow analysis identified overland flow paths across the existing I-69 corridor and overland flow access points into the existing depressed section, located between Bell Street and SH-288. The overland flow access points include all exit and entrance ramp locations along the existing depressed section. For the existing condition 100-year storm event, the analysis results indicate the low area along Hamilton Street near Holman Street is where the majority of the overland flow (estimated at 362 cfs) enters the existing depressed section. Note, the calculated peak WSEs under the Harvey storm event were lower than the 100-year WSE. The lower ponding depths for Hurricane Harvey can be attributed to the fact that for downtown Houston, the peak intensity of Hurricane Harvey was less than the peak intensity of the hypothetical 100-year 24-hour design storm event, which has the majority of the rainfall falling over a 6 hour period. For the urban storm sewer systems, the peak intensity controls the ponding depths, while the larger riverine systems are largely controlled by storm totals and longer durations. Under proposed conditions, to prevent overland flow from entering the proposed depressed section, overland flow collector systems are recommended along Hamilton Street and St. Emanuel Street to capture the overland flow before it reaches the I-69 corridor, as shown in the **Segment 3B Drainage Plan Summary Exhibit**. The collector systems will convey the overland flow along the east and west sides of the depressed section, therefore preventing overland flow from entering the depressed section. The collector systems were sized to minimize the change in WSEs for the 100-year storm event in the general vicinity of the project and to not adversely impact existing structures in the area. The collector systems carry flows north and outfall into Pond A adjacent to Buffalo Bayou. Impermeable concrete traffic barriers, typically 3-feet high, or other similar structures should be placed along the east and west edge of the depressed section to prevent overland flow from entering the depressed section. In these areas, the model results indicate shallow flood depths, less than 0.75 feet, in a 100-year storm event. There is no collector system recommended for the section of Chartres Street between Alabama Street and I-45 as the overland flow in this area drains away from the depressed section. A storm sewer system will be provided here to drain local flow.

In addition, the proposed roadway profiles were evaluated to identify potential flow access points into the proposed depressed section based on the proposed 100-year WSEs and 500-year WSEs. In general, these flow access points are located at exit and entrance ramp locations to the depressed section. It is recommended these locations be set above the estimated 100-year WSEs, if feasible. These potential access points are shown on the **Segment 3B Drainage Plan Summary Exhibit**.

Storm Drain Design

The preliminary sizing of the proposed drainage systems was completed for the following roadways within Segment 3B:

- The proposed depressed section of I-69/I-45/SH-288, from Alabama Street to Canal Street. A storm sewer system was provided for each main lane system. Design Event – 100-year (Outfall – Buffalo Bayou).
- The collector systems along Hamilton Street and St. Emanuel Street (Outfall Buffalo Bayou), sized to have no adverse impact under a 100-year event.
    - Hamilton Street Collector (varies in size from 48 inch RCP to 10 ft. by 10 ft. RCB)
    - St. Emanuel Street Collector (varies in size from 48 inch RCP to 8 ft. by 8 ft. RCB)
    - In select downstream sections of the systems, it was necessary to reduce the pipe sizes to limit flow being redirected from the City of Houston storm sewer systems to the collector systems. This was done such that there is minimal change in water surface elevations in the surrounding areas between existing and proposed conditions.
- Chartres Street (I-69 northbound frontage road), outfalls to City of Houston storm sewer system along Elgin Street. Design Event – 2-year.
- SH-288 South, from the I-69 and SH-288 interchange to Blodgett Street, outfalls to the existing SH-288 South storm sewer system. Design Event – 2-year.
- I-45 South from the I-69 and I-45 interchange to Tierwester Street, outfalls to the existing I-45 South drainage system. Design Event – 2-year.

Under proposed conditions, the existing storm drains that cross the I-69 corridor were redirected to either the Hamilton Street or St. Emanuel Street Collector systems.

Pump Station Design

The Segment 3B proposed depressed section is serviced by two pump station facilities. The pump station facilities are located south of the I-69 and I-45 interchange (I-45 Pump Station) and north of Runnels Street (Buffalo Bayou Pump Station). The I-45 pump station discharges to gravity systems along St. Emanuel Street and ultimately outfalls to Buffalo Bayou via Pond A. The Buffalo Bayou pump station outfalls to Pond A. The pump stations were sized such that there is no roadway flooding for a 250-year, 24-hour storm event. The following summarizes the pump configuration at each pump station, all pumps are considered to be submersible column pumps.

- I-45 Pump Station (Total Capacity ~ 229,400 GPM)
    - 2 ~ 6,700 GPM pumps
    - 16 ~ 13,500 GPM pumps (inc. one spare)
- Buffalo Bayou Pump Station (Total Capacity ~ 74,000 GPM)
    - 1 ~ 6,500 GPM pumps
    - 5 ~ 13,500 GPM pumps (inc. one spare)

Standby power, diesel driven generators, along with fuel storage tanks will be provided at each pump station facility. The fuel storage tanks are sized to provide for a 3 day continuous run time. In addition, the pump stations will be hydraulically connected by three (3) 6 ft. by 4 ft. RCBs. The operation of flow through this storm sewer system will be controlled by a sluice gate, such that the interaction of flow between the two pump stations will only occur in the event of major pump failure at one pump station facility. It is recommended to provide a SCADA system to connect the control of the gate operation with

the I-45 and Buffalo Bayou pump station operations. The approximate location of the proposed sluice gate valve is at I-69 and Clay Street, as shown on the **Segment 3B Drainage Plan Summary Exhibit.**

Mitigation Analysis

A mitigation analysis was performed to determine detention needs due to the increase in runoff associated with the proposed roadway and drainage improvements (system hydraulics). The analysis also evaluated the mitigation needs associated with the loss of floodplain storage from Buffalo Bayou as a result of the project.

Pond A between Runnels Street and Buffalo Bayou, located in Segment 3C, will provide the required mitigation volume for Segment 3B. The required mitigation volume of 150 ac-ft includes:

- 72 ac-ft for system hydraulics
- 78 ac-ft for loss of floodplain storage

The 78 ac-ft of lost floodplain storage was determined based on tailwater conditions developed from the Segment 3D drainage consultant, LAN. LAN determined that the FEMA effective Buffalo Bayou WSEs were underestimated by approximately 3 feet in the vicinity of the I-69 corridor outfall to Buffalo Bayou. For the purpose of the depressed section mitigation analysis, the LAN corrected effective model results were used for Buffalo Bayou.

Based on the stage storage information for Phase 1 of Pond A, provided by the Segment 3C drainage engineer, CivilTech Engineering, Inc., the lower 9-10 feet of Phase 1 of Pond A will provide 72 ac-ft of storage, which would be allocated to provide the 72 ac-ft needed for system hydraulics. The total storage volume of Phase 1 of Pond A is approximately 237 ac-ft, leaving 165 ac-ft available for floodplain mitigation needs. When Segment 3C and the full footprint of Pond A are constructed, there will be a total storage volume of 450 ac-ft. Approximately 51 ac-ft of detention volume is needed for the system hydraulics of Segment 3C. Therefore, a total of 123 ac-ft of Pond A will be used for system hydraulic storage in the lower 8 feet of the pond, and the remaining 327 ac-ft of the pond will be available for floodplain mitigation needs.

No detention is required for the I-45 South and SH-288 South roadway improvements as the proposed drainage plan results in a reduction in the drainage area, 131 acres to I-45 South and 4 acres to SH-288 South, and peak flows to each roadway system. The I-45 South and SH-288 South drainage systems continue to outfall to the existing TxDOT drainage systems under proposed conditions.

ROW Considerations

All drainage features are to be constructed within the currently defined proposed ROW, with the following two exceptions. At Hamilton Street, north of the George R. Brown Convention Center there is approximately 15 feet between the roadway and proposed ROW. The proposed storm sewer in this area is a 7 ft. by 7 ft. RCB. For construction purposes, it’s recommended that additional ROW be purchased by TxDOT. The adjacent area consists of parking lots that most likely service Minute Maid Park. During this drainage design phase, it was assumed that St. Emanuel Street, north of I-45, would be acquired by TxDOT as part of this project. This should be confirmed in the next phase of the project.

Summary

The proposed drainage system was designed to maintain all main lanes passable under a 100-year storm event. The depressed section drainage system was designed such that no ponding occurs within the depressed section under a 100-year storm event. In addition, the depressed section drainage system

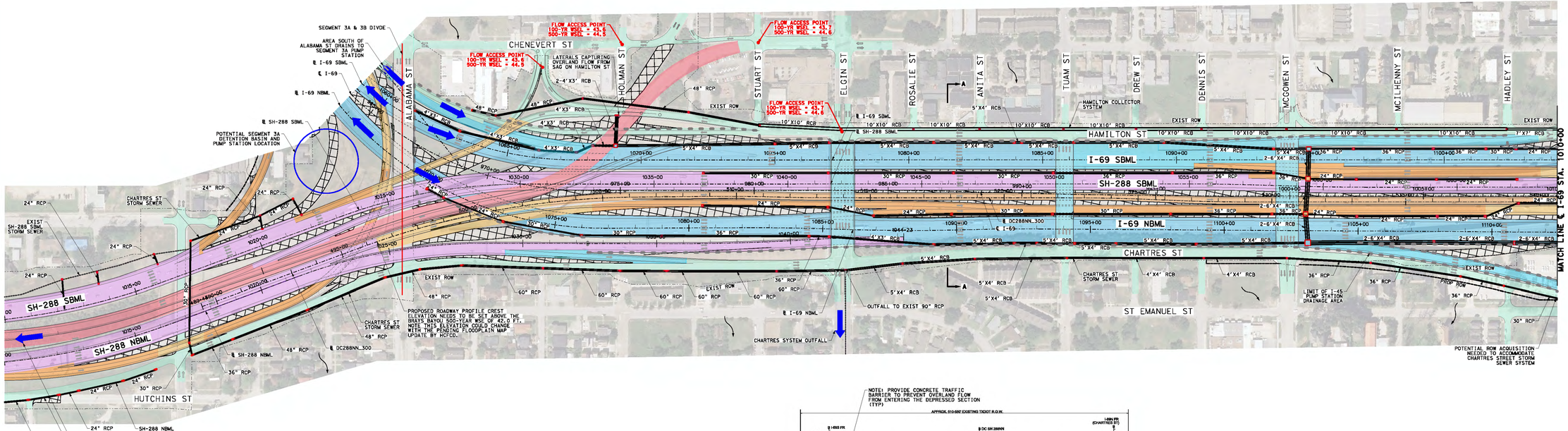
(storm drains and pump stations) was evaluated under various stress scenarios, including the 500-year storm event. The stress scenario results indicate that some of the depressed section lanes should remain passable under each of the stress scenarios. Note, that this analysis did not consider inlet capacity. It is expected that some roadway flooding could potentially occur due to the inlet capacity under the 500-year storm event.

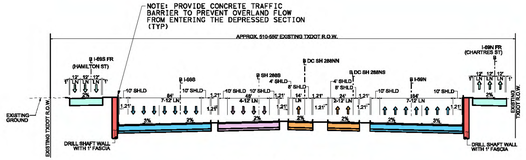
In addition, the drainage system design includes the overland flow collector systems on either side of the depressed section to prevent flow from entering the depressed section under a 100-year storm event and potentially under a 500-year storm event, depending on the final design profile of the exit and entrance ramps into the depressed section.

150 ac-ft of mitigation storage will be provided in Pond A adjacent to the south bank of Buffalo Bayou to mitigate the increase in flows associated with the project and loss of floodplain storage.

A preliminary cost estimate was developed for the proposed drainage features. The cost estimate included the following elements: storm drain components and pump station facilities. The total cost estimate including contingency is $143 million.

In summary, the proposed roadway improvements will not adversely impact the existing conditions at each outfall within the project limits for a 100-year storm event.

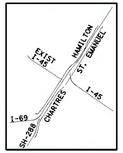




PROP TYPICAL SECTION A-A

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- EXIST STORM SEWER
- ROW CONCERN
- PUMP STATION SERVICE AREA



VICINITY MAP

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.
3. THERE IS NO PONDING ON ALL MAINLANE TRAVEL LANES WITHIN THE DEPRESED SECTION UNDER THE 100-YR STORM EVENT.

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING OR PERMIT PURPOSES.
MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	REVISIONS	BY

AECOM

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HOUSTON, TEXAS 77084
713-677-3400
TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B DRAINAGE PLAN SUMMARY

BEGIN CONST TO STA 1010+00

(℄ I-69) SHEET 1 OF 3

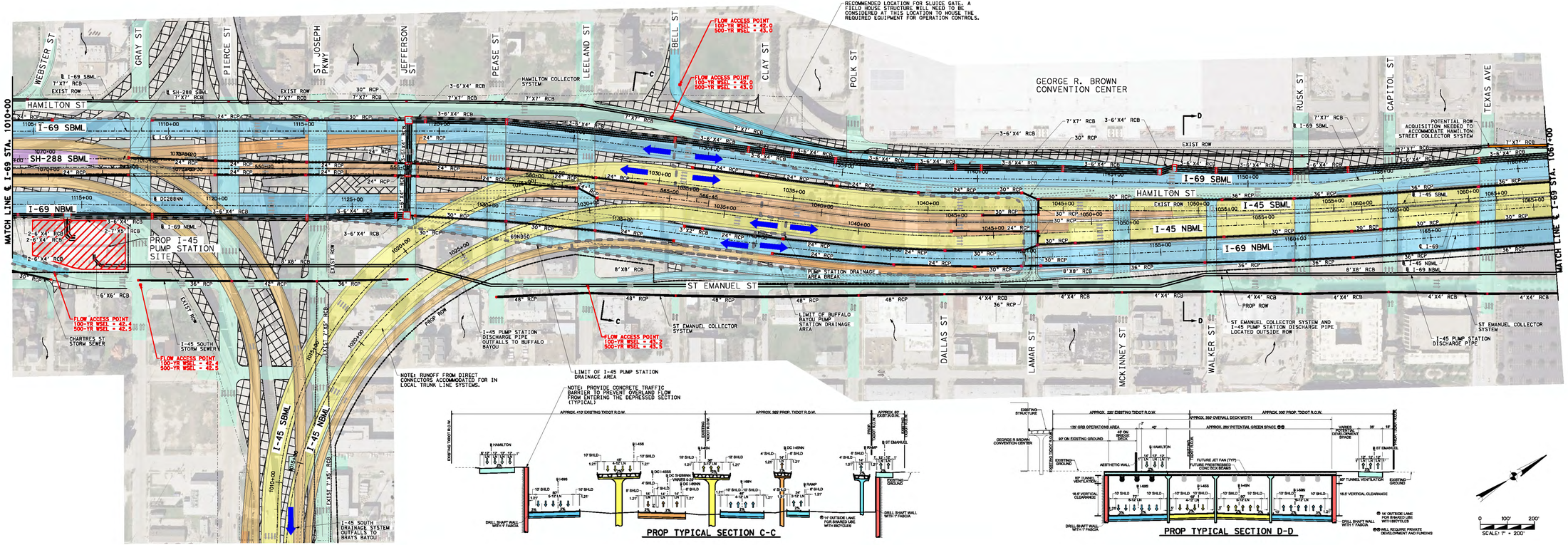
FED. RD. DIST. NO.	PROJECT NO.	SHEET NO.
6	36-71DP5055 WA 2	

STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

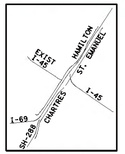
0 100' 200'
SCALE: 1" = 200'

I45_Plan_Overview_Bridge



LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- EXIST STORM SEWER
- ROW CONCERN
- PUMP STATION SERVICE AREA



VICINITY MAP

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.
3. THERE IS NO PONDING ON ALL MAINLANE TRAVEL LANES WITHIN THE DEPRESSED SECTION UNDER THE 100-YR STORM EVENT.

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	REVISION(S)	BY

AECOM

AECOM TECHNICAL SERVICES, INC.
10210 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77024
713-735-2000
TBPE REG. NO. F-3580

Texas Department of Transportation
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NHHIP SEGMENT 3B DRAINAGE PLAN SUMMARY

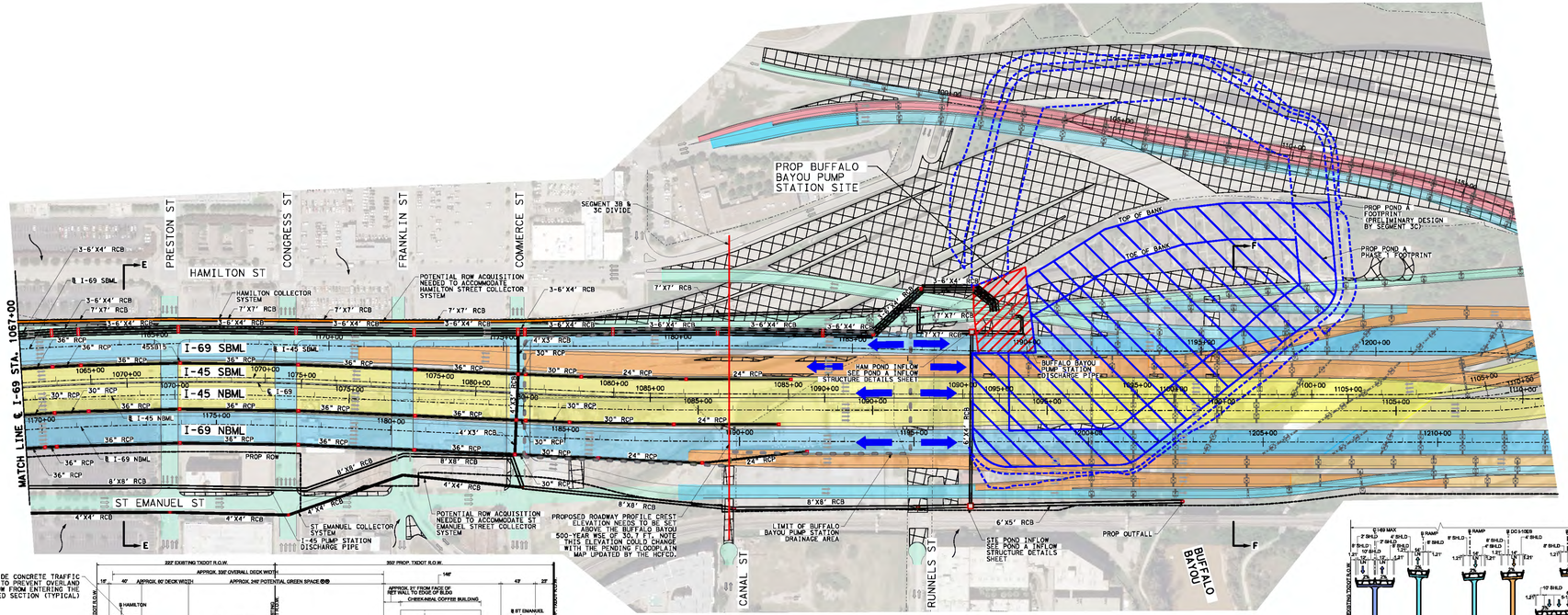
STA 1010+00 TO STA 1067+00
(℄ I-69) SHEET 2 OF 3

FED. RD. DIV. NO.	PROJECT NO.	CONTROL NO.
6	36-710P5055 WA 2	SHTND

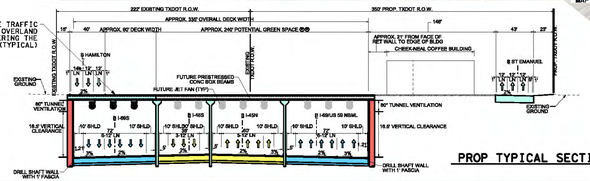
STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

I45_Plan_Overview_02.dgn



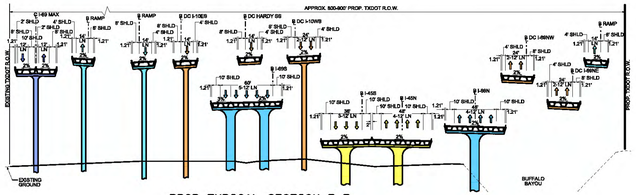
NOTE: PROVIDE CONCRETE TRAFFIC BARRIER TO PREVENT OVERLAND FLOW FROM ENTERING THE DEPRESSED SECTION (TYPICAL)



PROP TYPICAL SECTION E-E

NOTE: IN COORDINATION WITH TXDOT AND HNTB IT WAS AGREED THAT THE RETAINING WALL AT THE SOUTH END OF THE BRIDGE STRUCTURE COULD BE SHIFTED SOUTH, APPROXIMATELY 150 FT FROM RUNNELS STREET. THE PRELIMINARY DESIGN OF THE DETENTION BASIN LAYOUT AND PUMP STATION LAYOUT WERE BASED ON THE SHIFTED RETAINING WALL LOCATIONS. THE UPDATED ROADWAY DATA SHOWING THE SHIFT IN RETAINING WALL LOCATION WAS NOT AVAILABLE AT THE TIME OF THIS STUDY.

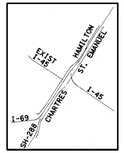
Detention Summary Table	
System Hydraulic Impacts	72 AC-FT
Floodplain Impacts	78 AC-FT
Total Detention Needed	150 AC-FT
Total Storage Volume Provided	450 AC-FT
Surplus Volume Available for Segment 3C Mitigation Needs	300 AC-FT



PROP TYPICAL SECTION F-F

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- EXIST STORM SEWER
- ROW CONCERN
- PUMP STATION SERVICE AREA



VICINITY MAP

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.
3. THERE IS NO PONDING ON ALL MAINLANE TRAVEL LANES WITHIN THE DEPRESSED SECTION UNDER THE 100-YR STORM EVENT.

0 100' 200'
SCALE: 1" = 200'

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	REVISIONS	BY

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AECOM TECHNICAL SERVICES, INC.
10210 KATY FREEWAY, SUITE 100
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713-677-3400
TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B
DRAINAGE
PLAN SUMMARY
STA 1067+00 TO END CONST
(℄ I-69) SHEET 3 OF 3

FED. RD. DIV. NO.	PROJECT NO.	SHEET NO.
6	36-71DP5055 WA 2	

STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

I45_Plan_Overview_03.dgn

1.0 INTRODUCTION

1.1 Overall Study Introduction

The North Houston Highway Improvement Project (NHHIP) is a proposed Texas Department of Transportation (TxDOT) project to address the existing Interstate Highway 45 (I-45) traffic capacity limitations, obsolete functionality of certain aspects of the corridor, and existing major design deficiencies. I-45 is a major north-south transportation route through the Houston metropolitan area. The purpose of the NHHIP is to enhance safety, create additional roadway capacity to manage congestion, and to improve mobility and operational efficiency by better accommodating increasing traffic volumes. The ultimate goal is to provide a facility with additional capacity for project demand by incorporating transit opportunities, travel demand and management strategies, and to provide improved mobility and enhanced safety.

The NHHIP limits begin at the interchange of Interstate Highway 69/US Highway 59 (I-69) and State Highway 288 (SH-288) south of downtown Houston and follow northward along I-45 to the interchange of I-45 and Beltway 8 North, as shown in **Exhibit 1**. The NHHIP project consists of 3 main segments, Segments 1-3, as shown in **Exhibit 1.** Segment 3 is further subdivided into five segments, A-E. Approximate limits of each segment are detailed below and are also shown on **Exhibit 1**. The following summarizes the five segments within Segment 3.

- Segment 3A – Limits from Mount Vernon Street to Alabama Street, and is located within the Brays Bayou watershed.
- Segment 3B – Limits from Alabama Street to Canal Street, including portions of SH-288 from the interchange of I-69 and SH-288 to Blodgett Street and I-45 from the interchange of I-69 and I-45 to Tierwester Street, and is located within the Buffalo Bayou and Brays Bayou watersheds.
- Segment 3C – Limits along I-69 from Canal Street to Union Pacific Railroad, along I-45 from Canal Street to McKee Street, and along I-10 from McKee Street to Waco Street, and is located within the Buffalo Bayou and Little White Oak Bayou watersheds.
- Segment 3D – Limits along I-10 and I-45 from McKee Street to the I-10 and I-45 intersection, and is located within the Buffalo Bayou and White Oak Bayou watersheds.
- Segment 3E – The I-45 direct connector from I-10 into downtown, and is located within the Buffalo Bayou and White Oak Bayou watersheds.

The purpose of this study is to analyze the drainage features specific to Segment 3B and identify any mitigation needs associated with the proposed roadway improvements within Segment 3B. Additionally, this study includes the preliminary trunk level design of the roadways within Segment 3B.

The Segment 3B project limits cross two major watersheds: Buffalo Bayou watershed, and Brays Bayou watershed. Sections of the project are impacted by the Buffalo Bayou effective floodplain. The proximity of the project corridor to the Buffalo Bayou and Brays Bayou presents potential design challenges related to floodplain impacts, and was a key factor in establishing roadway profiles.

1.2 Study Purpose

AECOM Technical Services, Inc. (AECOM) was contracted to provide professional engineering services for the preparation of drainage study for the NHHIP Segment 3B (the project), CSJ No. 0500-03-601. This drainage study provides a preliminary assessment of the drainage features, impacts, and required mitigation of NHHIP Segment 3B. The report documents the preliminary results of the drainage design

and analysis and will be used to assist TxDOT and a future design-build contractor in the design/construction phase of the project. The preliminary design recommendations presented in this study are for review purposes only and should not be used for construction purposes.

1.3 Project Location

The project limits of Segment 3B cover approximately 2.3 miles of I-69/SH-288/I-45 between Alabama Street and Canal Street, 0.49 miles of SH-288 from the I-69 interchange to Blodgett Street, and 0.77 miles of I-45 from the I-69 interchange to Tierwester Street. The project is located within the Buffalo Bayou and Brays Watersheds in Harris County, as shown in **Exhibit 2**.

1.4 Project Scope

A detailed scope of work was authorized by TxDOT, and the major tasks include the following:

- Complete an overland flow analysis from Spur 527 to Canal Street to quantify the amount of runoff draining to, around, and under the existing and proposed roadway, with a focus on flow entering the proposed depressed sections.
- Preliminarily size the proposed roadway drainage systems for the proposed depressed section (I-69, SH-288, I-45), I-45 South from the I-69 Interchange to Tierwester Street, and SH-288 South from the I-69 Interchange to Blodgett Street and associated frontage road system and direct connector systems, including Hamilton Street, Chartres Street, and St. Emanuel Street.
- Preliminarily size required drainage systems for the following proposed direct connectors:
    - I-45 northbound to I-69 southbound/ SH-288 southbound
    - SH-288 northbound /I-69 northbound to I-45 southbound
    - I-45 northbound to I-69 northbound
    - I-69 northbound to SH-288 southbound
    - SH-288 northbound to I-69 southbound
- Identify existing storm sewers crossing the proposed depressed section and evaluate options for accommodating these systems under proposed conditions.
- Preliminarily design for two pump station facilities.
- Complete roadway impact mitigation analysis and determine preliminary detention needs for Segment 3B.
- Coordinate with adjacent Segments, 3A and 3C, regarding the proposed drainage plan.

1.5 Hurricane Harvey

The drainage study considered the recent flooding due to Hurricane Harvey in the analysis, preliminary drainage system design, and proposed drainage recommendations. Hurricane Harvey made landfall on August 25, 2017 and continued to produce rainfall through August 29, 2017, causing a catastrophic flood event over the Greater Houston Area. Based on Harris County Flood Control District's (HCFCD) report Immediate Flood Report Final – Hurricane Harvey, the Segment 3B project received the following maximum rainfall totals within the project area:

Table 1-1: Rainfall Totals and Average Recurrence Intervals

Storm Duration	Rainfall Depth, In.	Average Recurrence Interval (ARI), year.
12 Hour	13.5	>250
24 Hour	16.5	>250
48 Hour	26.2	>500
96 Hour	32.9	> 500

These rainfall depths and average recurrence intervals were taken from the Buffalo Bayou gage at Shepherd Dr. (Gage 2240).

AECOM used data collected during Hurricane Harvey to aid in the drainage analysis for this study. Specifically, time stamped photographs taken during the storm event were used to verify the accuracy of the water surface elevations (WSE) in the Storm Water Management Model (SWMM) model under existing conditions. For further information regarding the modeling of Hurricane Harvey, please refer to **Section 4.5.**

2.0 DATA COLLECTION

2.1 Data Sources

All mapping, GIS data, and survey data in this study are referenced to NAD 83, Texas State Plane South Central, US Survey Feet, with a grid-to-surface scaling factor of 1.000130. Vertical elevations are referenced to NAVD 1988 (unadjusted). The data collected and used for this study includes the following:

- The 2008 Non-Uniform Subsidence Adjustment (NUSA) digital elevation model (DEM) for Harris County, flown in 2008 and vertically adjusted by the Harris County Flood Control District (HCFCD) to the 2001 vertical datum adjustment. This LiDAR dataset was originally produced for Houston-Galveston Area Council (H-GAC). The vertical adjustment from NAVD 1988 (unadjusted), the project datum, to the NAVD 1988, 2001 vertical datum adjustment is approximately -0.06 feet in the project area. For the purpose of this study it was assumed that no datum adjustment was needed between the project datum (NAVD 1988) and the NAVD 1988, 2001 adjustment.
- Survey data from RODS Surveying, Inc., including existing storm sewer flowline elevations in the project vicinity and information on existing roadway features.
- Aerial imagery from a variety of sources, including ESRI Online (2015), Google Maps, etc.
- Record drawings provided by TxDOT and the City of Houston regarding existing roadway and storm sewer information. See **Section 2.3** below for further information.
- Preliminary schematic plans for the NHHIP based on the updated version of the Proposed Recommended Alternatives presented in the Draft Environmental Impact Statement (DEIS), dated April 2017, provided by TxDOT in December 2017.
- Information obtained from field site visits.
- Various drainage reports relevant to the project, as described in **Section 2.2**.

2.2 Previous Studies

Four reports relevant to the study area were obtained. The drainage reports were reviewed as part of the data collection process. The following is a description of the studies reviewed:

- *State Highway 288 – Toll Lanes Preliminary Drainage Design Report*, dated July 2017, and prepared by Tukay Associates, Inc. on behalf of Almeda-Genoa Constructors and TxDOT. The study analyzed the potential impacts associated with the proposed roadway improvements associated with the SH 288 Toll Lanes Project located south of the Harris/Brazoria County line to US 59 (10.3 miles). This project is currently under construction and scheduled to be completed in 2019.
- *North Houston Highway Improvement Project – Preliminary Drainage Study (CSJ: 0912-00-146)*, dated November 2016, and prepared by AECOM. The purpose of the study was to develop a preliminary planning level drainage study of three reasonable alternatives that were identified in a November 2013 NHHIP public meeting. In doing so, a recommended schematic alternative was identified. The current project expands upon this previous study, further analyzing and preliminarily designing the drainage features associated with the recommended schematic alternative.
- *Conceptual Drainage Report & Impact Analysis – West Belt Improvements*, dated April 2015, and prepared by TranSystems. TranSystems completed a drainage analysis for five proposed grade

separation projects along the Houston Belt and Terminal (HB&T) Railroad's West Belt Subdivision. This project is located just east of downtown Houston and at the time of this study final design of this project was still to be completed.

- *Drainage Report IH 45 NB Connectors – From Spur 5 to US 59*, dated August 2011, and prepared by AMEC E&I, Inc. The purpose of the study was to complete a drainage analysis of roadway improvements along I-45, from the US 59 interchange to Cullen Boulevard. The roadway improvements include an urban freeway facility consisting of bridge direct connectors, entrance and exit ramps. This project is currently under construction.

2.3 Record Drawings

Record drawings for previous projects within the limits of the project were obtained from TxDOT and the City of Houston (COH). The record drawings were reviewed and relevant drainage sheets were extracted and used as reference for the drainage study. A summary list of the record drawings used is included in **Appendix A**.

2.4 Field Reconnaissance

Field reconnaissance trips were completed to obtain a better understanding of existing drainage facilities within the study area. Field reconnaissance was conducted at select areas throughout the study area to:

- Confirm existing roadway profiles;
- Confirm existing drainage structures;
- Confirm existing City of Houston storm sewer from the City of Houston's Geographical Information Management System (GIMS);
- Confirm the inverted siphons located on Elgin Street and Calhoun Street (St. Joseph Parkway) underneath the existing depressed section;
- Confirm the dual storm sewers along I-45 northbound from St. Charles Street to St. Emanuel Street;
- Obtain a better understanding of the drainage features in the SH-288/I-69 Interchange; and
- Confirm existing outfall locations.

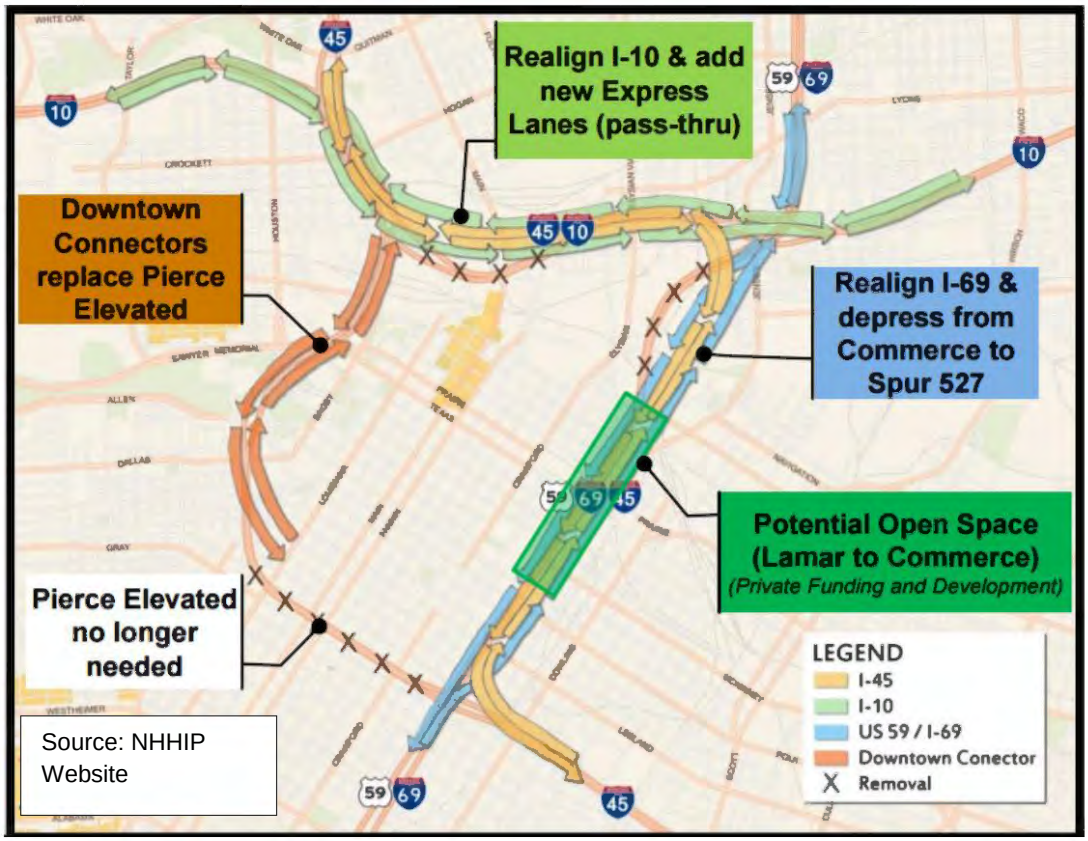
Field measurements were taken, to the extent possible, as part of the survey task to confirm the items listed above.

3.0 PROJECT OVERVIEW

The NHHIP Segment 3 proposed recommended design includes the reconfiguration of the highway system around downtown Houston. The major roadway improvements within Segment 3 include the following; refer to **Figure 3-1** for approximate locations:

- Realignment of I-10 and the addition of new express lanes along I-10;
- Realignment of I-69 and depress I-69 from Commerce Street to Spur 527; and
- I-45 downtown connectors replace the Pierce Elevated structure.

Figure 3-1: Segment 3 Overview



The project, Segment 3B, is limited to the realignment of I-69 and the proposed depressed section from Commerce Street to Alabama Street, a section of I-45 South and a section of SH-288 South, as shown in **Exhibit 2**. The major drainage components of the project include:

- Stormwater collector systems protecting the depressed section from overland flow west and east of I-69,
- Storm drain systems,
- Pump station facilities, and
- Mitigation facilities.

A detailed discussion on each of the major drainage components is provided in **Sections 4.0** through **Section 7.0**.

3.1 Existing Conditions

For the purpose of discussing the existing conditions, the project was divided into three sub-segments, the I-69/SH-288 corridor and associated frontage roads, SH-288 South, and I-45 South. The existing roadway layout of Segment 3B can be seen on **Exhibit 2.** A brief overview of the existing roadway and drainage conditions for each sub-segment follows.

3.1.1 I-69/SH-288 & I-69 Frontage Roads

This sub-segment includes the I-69/SH-288 corridor and associated frontage road systems from Alabama Street to Canal Street. The existing roadway configuration includes:

- Between Alabama Street and the I-69/I-45 Interchange:
  - North and south bound travel lanes, total 16 travel lanes
- Between I-69/I-45 Interchange and Canal Street:
  - North and south bound travel lanes, total 8 travel lanes
- Frontage roads from Alabama Street to Canal Street:
  - Hamilton Street – southbound travel lanes, total 4 travel lanes
  - Chartres Street – northbound travel lanes, total 4 travel lanes

The existing drainage system for this section includes curb and gutter and storm sewers. The roadway from Alabama Street to approximately Bell Street is currently depressed, with the main lanes located approximately 17 feet below natural ground. The drainage system for the depressed section included a 102-inch RCP storm sewer line that begins at Alabama Street and gravity drains north to its outfall at Buffalo Bayou as shown in **Figure 3-2** and **Exhibit 3 (Sheets 4-6)**.

Additionally there are two inverted siphons, one located at Elgin Street and one located at St. Joseph Parkway, that run west-east underneath the depressed section. The siphons allow high flows in the COH storm systems from large storms to cross the depressed section in a west to east direction and ultimately drain to Brays Bayou. In addition, each siphon is connected to the 102-inch RCP that drains the depressed section by a 2 ft. by 1 ft. orifice. The orifices allow part of the COH flow to drain into the 102-inch RCP, which drains to Buffalo Bayou and prevent the siphons from remaining wet between storms.

The drainage outfalls and their associated drainage systems for this sub-segment include the following; refer to **Exhibit 3** for approximate locations:

- Outfall System (Buffalo Bayou) (**Exhibit 3 – Sheets 4-6)**:
  - I-69 from Bell Street to Canal Street via COH storm sewer systems
  - I-69/SH-288 depressed section via 102-inch storm sewer
  - Hamilton Street from Bell Street to Canal Street via COH storm sewer systems
- Outfall System (Brays Bayou) – St. Joseph Parkway Storm Sewer (60-inch RCP) (**Exhibit 3 – Sheets 5-6)**:
  - Hamilton Street from McIlhenny Street to Bell Street via COH storm sewer systems

- Chartres Street from Hadley Street to Franklin Street

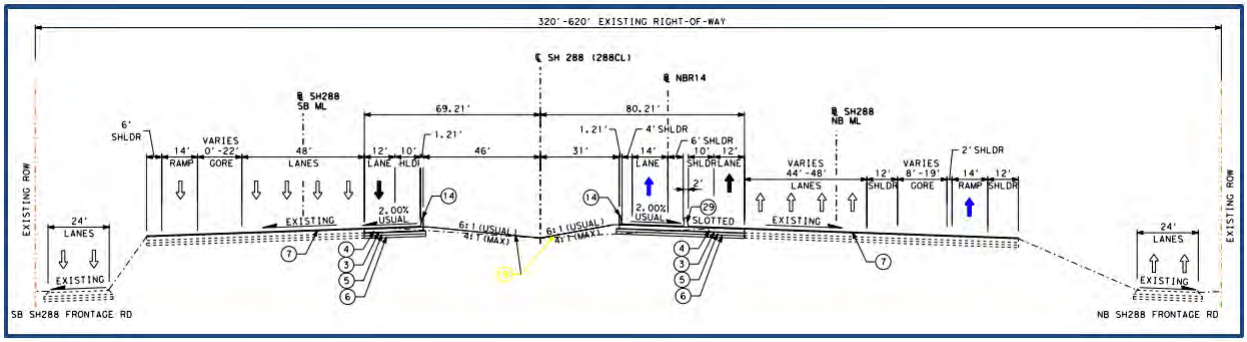
- Outfall System (Brays Bayou) – Elgin Street Storm Sewer (90-inch RCP) (**Exhibit 3 – Sheets 4-5)**:
  - Hamilton Street from Winbern Street to McIlhenny
  - Chartres Street from Alabama Street to McIlhenny Street

Figure 3-2: Existing Storm Sewer System along I-69

3.1.2 SH-288 South

For this project the limits of SH-288 South extend from the SH-288/I-69 interchange to Blodgett Street. This section of SH-288 is a divided highway with 4 lanes in each direction which are on raised embankment, as shown in **Figure 3-3**.

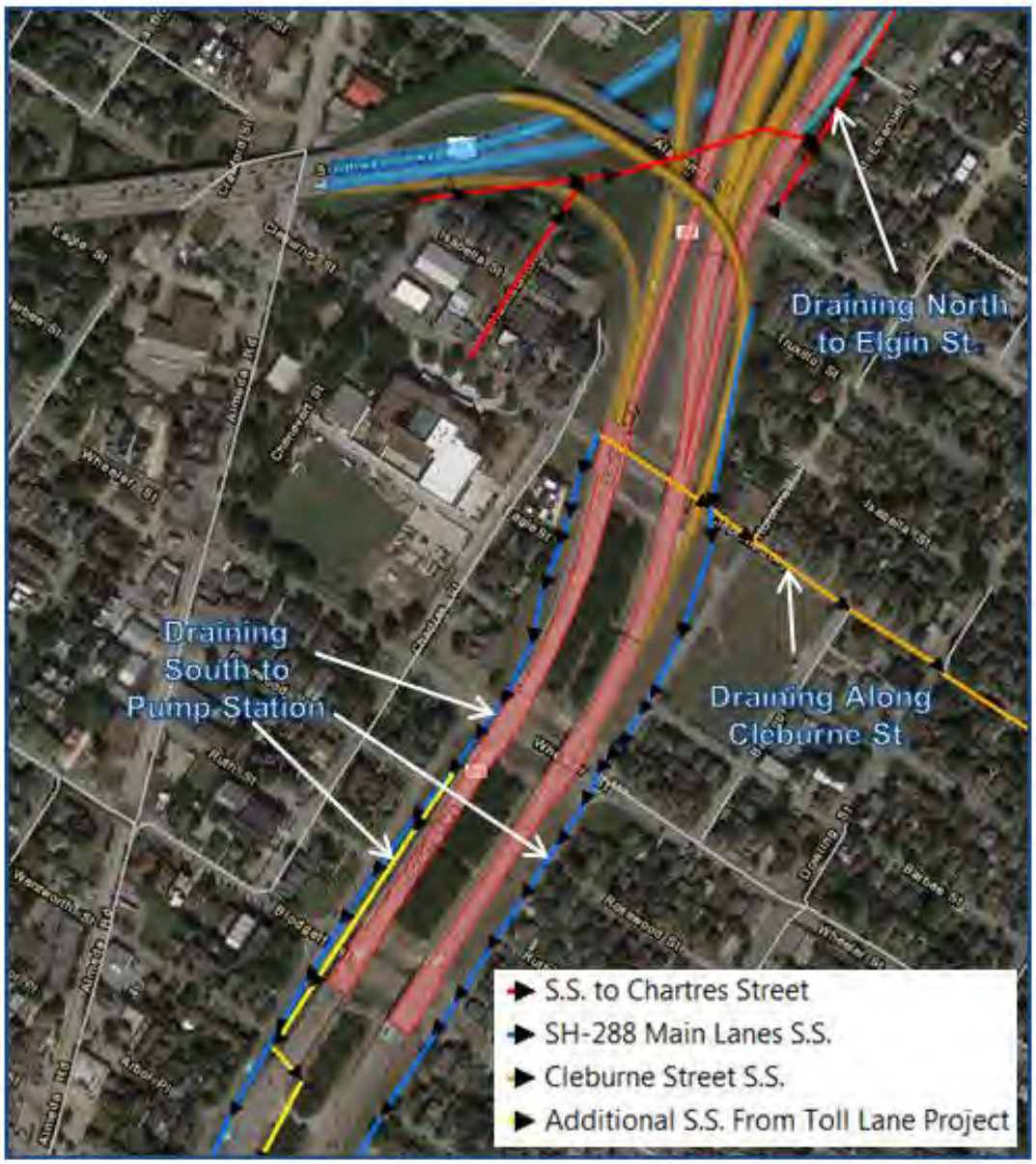
Figure 3-3: SH-288 Existing Typical Section from Southmore to I-69



At the time of this study SH-288 is being improved with the addition of toll lanes to the inside of the main lanes in the project vicinity as part of a design build project. See **Section 2.2** for further information on the SH-288 toll lane project and the associated drainage report. As the toll lane construction is anticipated to be completed in 2019, the final drainage design under the toll lanes project was considered to be existing conditions for this drainage study. During the next phase of the project the as-built conditions should be compared to the assumed existing conditions once the construction of the SH-288 toll lane project is complete.

The existing SH-288 drainage system between I-69 and Blodgett Street includes a storm sewer system along the northbound and southbound frontage roads, as shown in **Figure 3-4**. The storm sewer system ultimately outfalls to Brays Bayou.

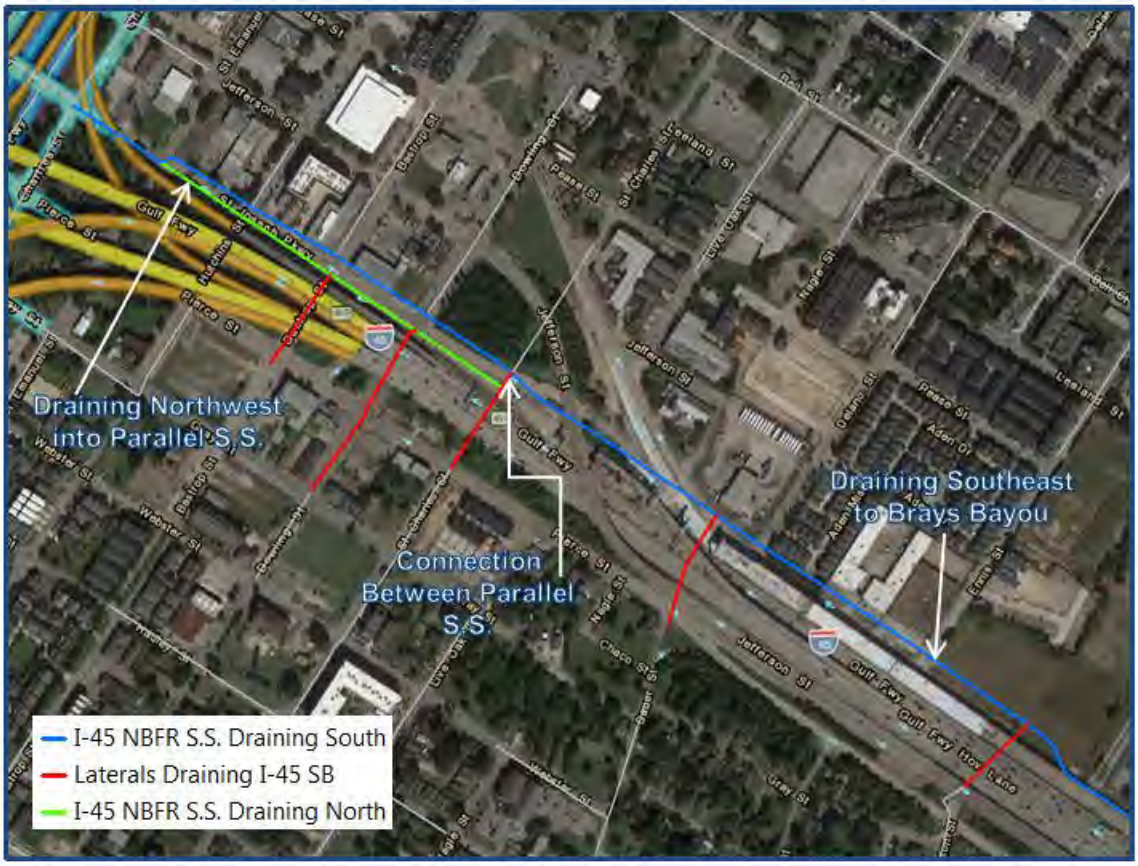
Figure 3-4: Existing Storm Sewer System along SH-288 South



3.1.3 I-45 South

I-45 South, southeast of the interchange of I-69 and I-45, is elevated until approximately Live Oak Street. The main lanes are separated from one another through the interchange with I-69, coming together at Emancipation Avenue, and consist of four lanes in each direction. From St. Emanuel Street to St. Charles Street there are two parallel storm sewers along the I-45 northbound frontage road, which is also St. Joseph Parkway. These two systems are connected both at St. Emanuel Street and at St. Charles Street. This storm sewer system ultimately drains southeast along I-45 and discharges into Brays Bayou. The southbound main lanes are drained by laterals that cross underneath I-45 and discharge into the storm sewers under St. Joseph Parkway. The drainage system along I-45 South can be seen below in **Figure 3-5**.

Figure 3-5: Existing Storm Sewer System along I-45 South



3.2 Proposed Conditions

The main components of the Segment 3B proposed roadway system, I-69/SH-288/I-45, from Alabama Street to Canal Street will be a depressed roadway section. An overall drainage area map and system overview can be seen on **Exhibit 6** (**Sheet 1**). From Lamar Street to Commerce Street, the proposed depressed section will be covered. Ultimately it is intended for this covered area to be converted into a green space, connecting west and east downtown. For this study, it was assumed that the covered area drains to the proposed drainage systems along Hamilton Street and St. Emanuel Street.

From Leeland Street to Canal Street, Chartres Street will be removed to accommodate main lane expansion and St. Emanuel Street will serve as the northbound frontage road. Hamilton Street is proposed to be rerouted from Leeland Street to Canal Street, with a section of the roadway adjacent to the George R. Brown Convention Center being placed on a bridge deck over the depressed section. The proposed roadway in the vicinity of the interchange of I-69 and I-45 is shown below in **Figure 3-6**.

Figure 3-6: Proposed Roadway at the Interchange of I-69 and I-45

3.3 Design Criteria

TxDOT developed a project specific design criteria for the NHHIP Segment 3 Drainage Study. The following table summarizes design criteria for the drainage design of Segment 3B. For more information refer to **Appendix A** for the design criteria document provided by TxDOT.

Table 3-1: Drainage Design Frequencies Criteria

Roadway	Criteria	Additional Design Criteria
Main Lanes (I-69/I-45/SH-288) in Depressed Section	100-year HGL < EOP	Check for main lanes to remain passable in the 500-year storm event
Pump Stations	250-year	Check for depressed section still passable with pump failures
Collector Systems (Hamilton Street and St. Emanuel Street)	Minimum 2-year Capacity	Sized for no adverse impacts to the 100-year WSE Under Proposed Conditions
Chartres Street	2-year Capacity	Check for 10-year
I-45 South Main Lanes (not in Depressed Section)	Main Lane Travel Lanes Passable in a 10-year Storm Event	Check for 10-year
SH-288 South Main Lanes (not in Depressed Section)	Main Lane Travel Lanes Passable in a 2-year Storm Event	N/A

Note, the I-45/I-69 corridor will continue to serve as an evacuation route, thereby, requiring a 100-year level of protection for the main lanes, at minimum.

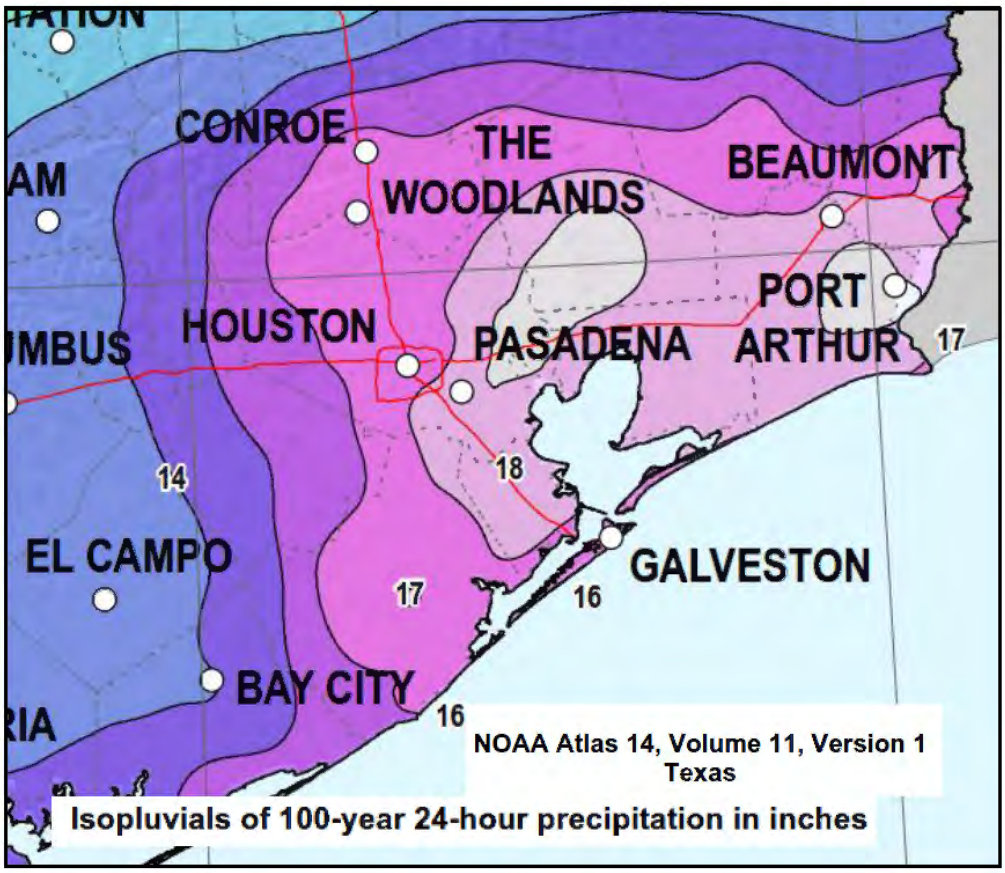
The following rainfall data was used for this drainage design. These values were taken from the Harris County Flood Control District (HCFCD) Hydrology and Hydraulics Guidance Manual, dated 2009, for Region 2. Region 2 includes Buffalo and Brays Bayou watersheds.

Table 3-2: Rainfall Depths for the 24-Hour Storm Event

Roadway	Depth (in.)
100-year	13.2
250-year	16.2
500-year	18.9

In November 2017 the National Oceanic and Atmospheric Administration (NOAA) released a preliminary Atlas 14 rainfall data for Texas. The preliminary rainfall data from Atlas 14 shows an average increase of 3 to 4 inches in the 100-year, 24 hour rainfall depths across Harris County. The Atlas 14 data is anticipated to be finalized and incorporated into the TxDOT Drainage Design Manual in 2019.

Figure 3-7: NOAA Preliminary Atlas 14 100-Year 24-Hour Rainfall Depths (inches)



As the Atlas 14 data was not finalized at the time of this study, TxDOT's direction was to reference the current rainfall data for the drainage system design. However, in regards to the pump station design, TxDOT required that the pump station account for the anticipated increase in rainfall depths by designing for the 100-year plus 25-percent/current 250-year storm event rainfall. The current 250-year storm event is similar to the anticipated Atlas 14 100-year rainfall depth.

4.0 OVERLAND FLOW ANALYSIS

4.1 Purpose of Analysis

The section of I-69 between Canal Street and Spur 527, Segments 3A and 3B, receives runoff from areas east and west of the I-69 corridor, as shown in **Exhibit 3** (**Sheet 1**). The majority of Midtown from approximately Bagby Street to the I-69 corridor has overland flow paths that lead towards I-69, while the storm sewer network generally runs from the south to the north, where it outfalls into Buffalo Bayou. Similarly, east of the I-69 corridor, from the I-69 and I-45 interchange to Runnels Street, there are overland flow paths draining towards I-69.

As the I-69 corridor is proposed to be depressed from Spur 527 to Canal Street, it was necessary to quantify the overland flow draining to the proposed depressed section and design a collector system to prevent the overland flow from entering the depressed section. Additionally, in order to accommodate the proposed depressed section, any storm sewers currently crossing the proposed depressed section will be removed and rerouted. In general, these storm sewers were accommodated by adding collector systems along the frontage roads, Hamilton Street, and St. Emanuel Street. The following discusses the overland flow analysis methods and results. The overland flow analysis includes both Segments 3A and 3B.

4.2 Methodology

The overland flow analysis was completed for the 100-year, 250-year, 500-year and Hurricane Harvey storm events. The Hurricane Harvey event was used as part of the model validation process. The hydrologic analysis was completed using HEC-HMS, as described below. The hydraulic analysis was completed for existing and proposed conditions using EPA SWMM 5.1.012 computational engine, facilitated by the PCSWMM 2017 (version 7.1.2480) user interface. SWMM will be used within this report to reference the storm water modeling system using the PCSWMM interface and the EPA SWMM computational engine. ArcGIS was used to compare the water surface elevation results of the SWMM models to the LiDAR ground surface to create a map of the maximum depths in each grid cell and allow comparisons of existing and proposed water surface elevations (WSEs) throughout the overland flow area.

A detailed summary of the approach used in the development of the hydrology, hydraulic system, tailwater, and Hurricane Harvey rainfall data, is provided in the technical memorandums included in **Appendix A**.

4.3 Design Criteria

The overland flow collector systems were designed to have a minimum capacity to convey the 2-year storm event, and checked for the 100-year storm event to confirm no adverse impacts to the surrounding areas. For the purpose of the overland flow analysis, no adverse impact is considered to be no increase in WSEs greater than 0.1 feet between existing and proposed conditions.

4.4 Existing Conditions

Major components of the existing conditions model include the following; refer to **Exhibit 3** for location reference:

- Depressed Sections:
  - I-69 from Shepherd Drive to Spur 527 (**Sheets 2-3**);

  - I-69 from Alabama Street to Canal Street (**Sheets 4-6**); and
  - SH-288 from Rosedale Street to Brays Bayou (**Sheet 1**).
- Pump stations for the I-69 depressed section near Spur 527 (**Sheet 3**) and the depressed section of SH-288 South just north of Brays Bayou (**Sheets 1**).
- 102-inch RCP storm sewer servicing the I-69 depressed section from Alabama Street to Bell Street (**Sheets 4-6**). As-built drawings for the 102-inch RCP are included in **Appendix A.**
- Inverted siphons crossing I-69, located at Elgin Street (**Sheet 4**) and St. Joseph Parkway (**Sheet 5**), and connected to the 102-inch RCP gravity system via small orifices. As-built drawings for the inverted siphons are included in **Appendix A.**
- Major overland flow paths into the existing depressed sections and crossing the proposed depressed sections (**Sheets 1, 3, 5, 6**).
- Major storm sewer networks.

4.4.1 Existing Conditions 100-Year Storm Event Results

The existing conditions model results were evaluated to determine the general extents of flooding along the study area, identify overland flow paths across the I-69 corridor, and approximate the magnitude of flow entering the existing depressed sections.

In general, the existing SWMM model results show the majority of ponding was limited to the street ROW during the 100-year storm event, as shown in **Exhibit 3**. There were three locations within the project vicinity where significant ponding outside the street ROW was noted. These areas included:

- West Alabama Street and I-69, from Greenbriar Drive to Mandell Street (**Sheet 2**);
- Milam Street to I-69, from Alabama Street to McGowen Street (**Sheet 4-5**); and
- Sauer Street to Velasco Street, from Elgin Street to I-45 (**Sheet 4-5**).

The model results were evaluated to determine the overland flow paths across the I-69 project corridor. After identification of the overland flow paths, the model results were processed to approximate the magnitude of runoff crossing the I-69 corridor. **Table 4-1** provides a summary of the major overland flow paths across the I-69 corridor. These locations are also shown on **Exhibit 3** (**Sheets 1, 3, 5, 6**).

Table 4-1: Major 100-Year Overland Flow Paths Across the I-69 Corridor

Location at I-69	Direction of Flow	Peak Flow (cfs)	Exhibit 3 Sheet Number
Main Street	NE to SW	157	3
In Between Main St. and Fannin St.	NE to SW	97	3
Wheeler St.	NW to SE	46	3
Cleburne St.	NW to SE	68	3
Almeda Rd.	NE to SW	115	3

Table 4-1: Major 100-Year Overland Flow Paths Across the I-69 Corridor

Location at I-69	Direction of Flow	Peak Flow (cfs)	Exhibit 3 Sheet Number
Polk St.	NW to SE	49	5
Texas St.	NW to SE	55	6

As shown in **Table 4-1** the overland flow across the I-69 corridor ranges from 46 cfs to 157 cfs. These overland flow paths are all outside the limits of the current depressed section of I-69. The overland flow paths from Main Street to Almeda Road are in Segment 3A. Note, on the east side of the existing depressed section, along Chartres Street, the model results indicate that overland flow drains away from the depressed section, as shown on **Exhibit 3** (**Sheets 4-5**).

A separate evaluation of the model results was performed to identify the overland flow access points to the current I-69 depressed sections, between SH-288 and Bell Street and between Greenbriar Drive and Spur 527. Between Bell Street and SH-288, the ponding results show that a large section of Midtown drains overland to the current I-69 corridor, as shown on **Exhibit 3** (**Sheets 4-5**)**.** The Midtown area is located south of I-45 and north of I-69. It's western boundary is approximately Spur 527 and Bagby Street and its eastern boundary is the I-69 corridor. The calculated 100-year ponding depths along Hamilton Street range between 1.0 and 2.5 feet and do not overtop the existing concrete barrier (approximately 3-feet high) along the east side of Hamilton Street, adjacent to the I-69 depressed section. In addition, minimal flow enters the depressed section via the overpass bridges as the ponding depths do not exceed the top of curb elevation along most bridge sections. These paths for flow to enter the depressed section are explicitly included in the model.

There are isolated locations along the existing depressed section where overland flow enters the depressed section. These locations are primarily at access ramps to the I-69 corridor. **Table 4-2** includes a summary of the depressed section entry elevations at the main access points to the depressed section and corresponding 100-year and 500-year WSEs.

Table 4-2: Overland Flow Access Points to Existing Depressed Section

Location	Approximate Depressed Section Entry Elevation (ft.)	Existing 100-Year WSE (ft.)	Existing 500-Year WSE (ft.)
Leeland Street Northbound Entrance Ramp	43.1	43.3	43.5
Leeland Street Southbound Exit Ramp	44.0	43.6	43.7
Bell Street Southbound Exit Ramp	43.1	43.6	43.7
Gray Street at Ramp Entrance	42.7	42.5	42.6
Holman Street near Hamilton Street Sag	42.4	43.6	44.1
Stuart Street and Hamilton Street	41.5	43.7	44.3
Elgin Street and Hamilton Street	43.1	43.7	44.3
Hamilton Street and Chenevert Street	42.4	43.6	44.1

Table 4-3 provides a summary of the main overland flow access points and the corresponding 100-year flow at these locations. Refer to **Exhibit 3** (**Sheets 2, 4, and 5**) for the flow access point locations to the depressed section.

Table 4-3: Major 100-Year Overland Flow Paths into Depressed Sections

Location at I-69	Peak Flow (cfs)
Dunlavy St.	102
Hamilton St. @ Holman St.	362
Hamilton St. @ Winbern St.	52
Berry St.	26
McGowen St. Overpass Bridge	43

Note, that some of the identified flow access points in **Table 4-2** are located within the same overland flow path presented in **Table 4-3**. For example Holman Street, Stuart Street, Elgin Street, and Hamilton and Chenevert Street are located within the Hamilton St. @ Holman St. overland flow path.

For the existing I-69 depressed section between Greenbriar Drive and Spur 527, the ponding results show that a large section of Montrose drains overland to the I-69 corridor, as shown on **Exhibit 3** (**Sheet 2**). In general, overland flow ponds at the edge of the depressed section, and a small amount enters the depressed section via the existing weir boxes along the west side of the depressed section.

4.5 Hurricane Harvey Model

The Hurricane Harvey model was developed by updating the existing conditions model to reference the Hurricane Harvey rainfall data. See the technical memo titled Overland Flow Analysis – Rainfall Development for Hurricane Harvey in **Appendix A** for details on the rainfall data used. The Hurricane Harvey model was used as part of the validation process of the model results. The validation process included the comparison of model results to estimated water surface elevations at select locations and times during the storm event. HCFCD and the COH had no available high water mark data for Hurricane Harvey within the project area. The following paragraph describes the process followed to estimate WSE for the purpose of validating the model results.

The estimated WSEs were based on time stamped photographs and videos taken during the storm event that were collected as part of the data collection effort. ArcGIS was used to geo-locate the photographs and videos. Flood depths were estimated based on a process of using Google Street View to reference flood levels against a known marker, such as the top of the wheel of a car or a fire hydrant. After estimating the flood depths, WSEs were approximated by adding the flood depth to the natural ground elevation taken from LiDAR at the reference marker. In addition, the time stamps of the photographs were recorded. The time information and estimated WSEs were used in the comparison to the model results.

The estimated WSEs were compared to the modeled WSEs at the time the photo was taken to determine the accuracy of the model. Minor adjustments were made to select overland flow path connections and inlets in order for model results to closely match the estimated high water marks. The comparison of the model WSEs to the observed WSEs at select locations along the project corridor is shown in **Exhibit 4**.

The comparisons show that in general the Harvey SWMM model results are within 0.5 to one foot of the estimated water surface elevations at the reported time stamp for the photo. In most cases, the photos were taken after an intense rainfall period, when the water surface elevation was falling, with the water elevations in the model generally falling by half a foot or more during the two hour window surrounding

the time the photo was taken. The one exception to this was in the current depressed section of I-69, just east of Stanford Street (Point 16 on **Exhibit 4**), where the modeled WSE was below the estimated WSE. For this location, the difference between the model results and observed flooding may be due to pump station malfunctions, clogged inlets that are not represented in the model, and/or additional overland flow entering the depressed section that was not captured in the model. AECOM recommends that this section of the SWMM model be further refined during the Segment 3A design phase of the project.

Aside from the depressed section point, the model matches the observed results quite well. Of the other 10 points, five are within 0.2 ft, eight are within 0.6 ft, and nine are within 0.8 ft. Only one is off by more than 1 ft.

Given the uncertainties associated with the determination of WSE from a photo, the timing of the comparison modeled WSE, and the local rainfall intensity, the model results are reasonably close to the estimated WSEs. For the purpose of the overland flow analysis the comparison of results were deemed reasonable and the SWMM model network was considered acceptable for analyzing the proposed drainage system and aiding the preliminary drainage design effort.

4.5.1 Comparison of the Existing 100-Year Storm Event and Hurricane Harvey

The results of the 100-year storm event and the Harvey storm event were compared for the existing conditions model. The maximum ponding depths were mapped using ArcGIS and results showed that in general the 100-year storm event resulted in larger inundation areas than the Harvey storm event. Comparison points chosen throughout the overland flow model show that the Harvey maximum ponding depths range between 0.1 to 0.8 feet lower than the maximum ponding depths in the 100-year storm event. The ponding in both storm events and comparison points can be seen in **Exhibit 5**.

The lower ponding depths for Hurricane Harvey can be attributed to the fact that the peak intensity of Hurricane Harvey was less than the peak intensity of the hypothetical 100-year 24-hour design storm event, which has the majority of the rainfall falling over a 6 hour period. However, the cumulative maximum rainfall resulting from Harvey, approximately 32-inches over 4 days, was far in excess of the 100-year 24-hour rainfall depth of 13.2 inches. This difference in rainfall volume is evident in the comparison of the 100-year and Harvey ponding elevations within the existing I-69 depressed section. The maximum ponding elevation within the I-69 depressed section between Bell Street and SH-288 was 0.6 feet higher in Harvey than in the 100-year storm event.

4.6 Preliminary Collector System Design

The three collector systems along the I-69 corridor were preliminarily sized based on the existing conditions results for the 100-year storm event. The three collector systems are:

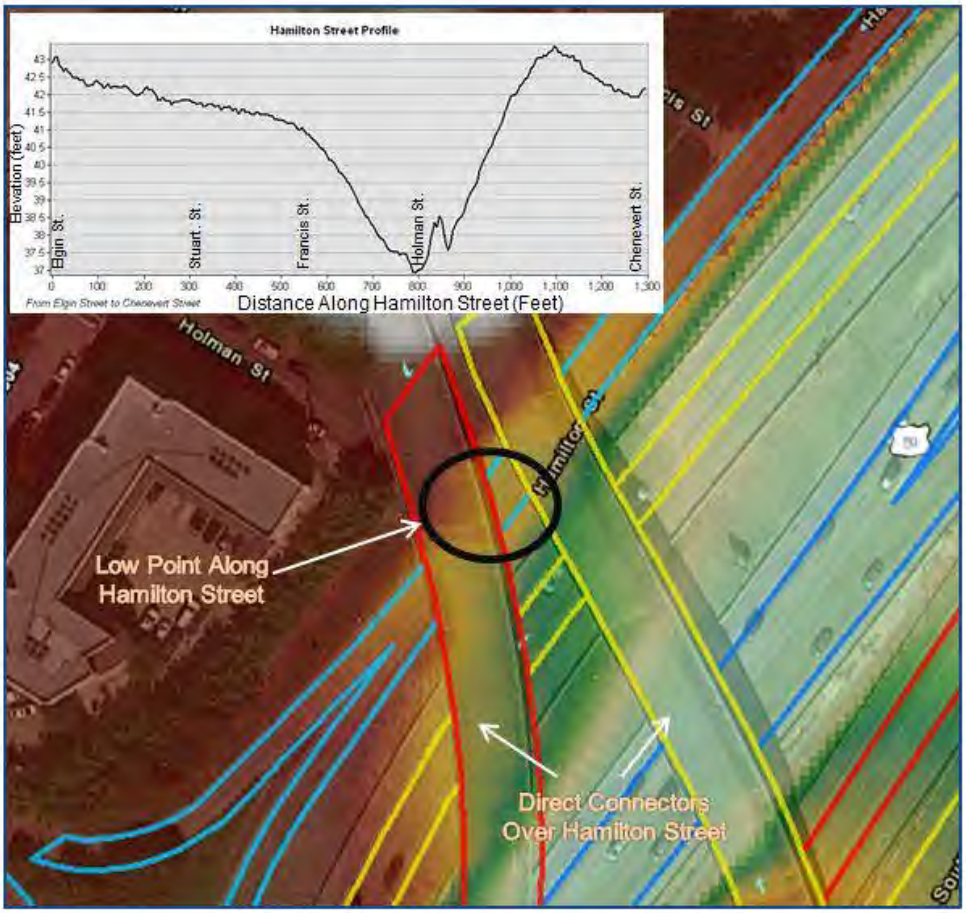
- Spur 527 to Alabama Street (Segment 3A);
- Hamilton Street Collector Line from Winbern Street to Runnels Street; and
- St. Emanuel Street Collector Line from Pease Street to Buffalo Bayou.

The Segment 3A engineer is responsible for sizing the collector system from Spur 527 to Alabama Street; therefore, this study does not include a detailed overview of the Segment 3A preliminary collector system design. However, the overland flow SWMM model does include a preliminary collector line and pump station system for Segment 3A. The Hamilton Street Collector and the St. Emanuel Street Collector system designs are discussed in detail in **Section 5.2.** Note, there is no collector system recommended for the section of Chartres Street between Alabama Street and I-45 as the overland flow in this area drains away from the depressed section.

4.7 Overland Flow Access Points

The major locations where overland flow currently enters the depressed sections is presented in **Table 4-3**. The largest area of concern is along Hamilton Street, near Holman Street. At this location, there is a large sag in Hamilton Street to accommodate two SH-288 direct connectors that cross over Hamilton Street and tie into the local streets, Chenevert Street and Jackson Street. As can be seen in **Figure 4-1**, the profile of Hamilton Street drops from an elevation of approximately 43 feet down to an elevation of approximately 37 feet.

Figure 4-1: Overland Flow Access Point at Hamilton Street



This section of Hamilton Street is lower than the existing Hamilton Street storm sewer system. Therefore, overland flow reaching Hamilton Street between Elgin Street to just east of Chenevert Street initially ponds in this low area before draining to the existing depressed section via an existing storm sewer system. The existing condition 100-year storm event model result indicate approximately 360 cfs enters the depressed section at this location. Refer to **Exhibit 3** (**Sheet 4**) for additional reference regarding this location.

4.8 Overland Flow Impact Analysis

The intent of the overland flow analysis was to quantify the overland and storm sewer flows draining towards the proposed depressed section. This information was then used to adequately size the collector systems to prevent overland flow from entering the depressed section under proposed conditions without adversely impacting the existing Condition in the 100-year storm event. The impact analysis and results are discussed in **Section 8.0**.

5.0 STORM DRAIN DESIGN

5.1 General

This drainage study included the preliminary sizing of the proposed drainage systems for the following roadways within Segment 3B; refer to **Exhibit 6** for approximate locations:

- The collector systems along Hamilton Street (I-69 southbound frontage road) and St. Emanuel Street (Outfall – Buffalo Bayou) (**Sheets 3-8**);
- The main lanes of the proposed depressed section from Alabama Street to Canal Street, including I-69 northbound and southbound, I-45 northbound and southbound, SH-288 southbound, I-45 northbound and south bound direct connectors (Outfall – Buffalo Bayou) (**Sheets 3-8**);
- I-45 South from the I-69 and I-45 interchange to Tierwester Street, outfalls to the existing I-45 drainage system, and ultimately to Brays Bayou (**Sheets 9-10**);
- SH-288 South from the I-69 and SH-288 interchange to Blodgett Street, outfalls to the existing SH-288 drainage system, and ultimately to Brays Bayou (**Sheet 2**); and
- Chartres Street (I-69 northbound frontage road), outfalls to the City of Houston storm sewer system along Elgin Street, and ultimately to Brays Bayou (**Sheets 2-4**);

The following sections outline the methodology, design criteria and proposed systems associated with each drainage system. The impact analysis for the proposed storm drainage design is discussed in **Section 8.0**.

5.1.1 Methodology

The preliminary design of the drainage systems was completed using a combination of Bentley's Power GEOPAK Drainage V8*i*, SELECTseries4 and the overland flow SWMM model. The storm sewer systems were analyzed for the 100-year, 250-year, 500-year and Harvey storm events using the overland SWMM model to confirm the proposed systems had no adverse impact to existing conditions. Discussion on the overland flow analysis and associated methodology for the SWMM model can be found in **Section 4.0** and **Section 4.2**, respectively.

5.2 Collector Systems

Two collector systems were preliminarily designed as part of the Segment 3B drainage study, the Hamilton Street Collector and the St. Emanuel Street Collector. The third collector is located in the Segment 3A section and will not be addressed as part of this study. Note, there is no collector system recommended for the section of Chartres Street between Alabama Street and I-45 as the overland flow in this area drains away from the depressed section.

The Hamilton and St. Emanuel Street Collectors were designed for a 2-year storm event under pipe flowing full conditions with the tailwater set to the top of pipe at the outfall. The collector systems were then checked against the 100-year storm event to confirm the design had no adverse impact on existing conditions under a 100-year storm event. Where necessary, the collector system capacities were increased to eliminate adverse impacts that would have been present with a 2-year design for the storm sewer system. The proposed collector system sizes are:

- Hamilton Street Collector (varies in size from 48-inch RCP to 10 ft. by 10 ft RCB); and

- St. Emanuel Street Collector (varies in size from 48-inch RCP to 8 ft. by 8 ft. RCB).

The sizes listed here are the minimum and maximum sizes of the collector systems. In select downstream sections of the systems, it was necessary to have a reduction in pipe size to limit flow being redirected from the City of Houston storm sewer systems to the collector systems. This was done such that there is minimal change in water surface elevations in the surrounding areas between existing and proposed conditions.

5.2.1 Hydrology

Local drainage areas were developed for the Hamilton Street Collector using a combination of LiDAR, aerial imagery, and the existing storm sewer systems. In general, drainage area boundaries to the north and south were based on the storm sewer systems draining to Hamilton Street. The drainage area boundaries to the west and east were generally midway between Hamilton Street and Chenevert Street and extended to the boundary of the depressed section. All drainage areas remained under 200 acres, and therefore peak flows were developed based on the Rational Method. Rainfall intensities and runoff coefficients were referenced from Chapter 4, Section 12 of the TxDOT Hydraulic Design Manual, dated July 2016.

To account for the combined overland flow and storm sewer flow entering the Hamilton Street Collector from the west, the SWMM model results were used to quantify the peak flow crossing the western boundary of each local drainage area. This “offsite” peak flow was added to the Hamilton Street drainage system network at select inflow points along the system.

5.2.2 Proposed Conditions

The proposed Hamilton Street Collector ranges from a 48-inch RCP to a 10 ft. by 10 ft. RCB and runs from Winbern Street to Runnels Street, as shown on **Exhibit 6** (**Sheets 3-7**). Between Hadley Street and Runnels Street the collector system is reduced from a 10 ft. by 10 ft. RCB to a 7 ft. by 7 ft. RCB. The reduction in storm sewer size is needed in order to minimize the change in ponding elevations under a 100-year storm event.

The proposed St. Emanuel Street Collector ranges from a 48-inch RCP to an 8 ft. by 8 ft. RCBs and runs from Pease Street to an outfall at Buffalo Bayou. Between Runnels Street and the Buffalo Bayou Outfall the collector system is reduced from an 8 ft. by 8 ft. RCB to a 6 ft. by 5 ft. RCB. The reduction in storm sewer size is needed in order to minimize the flow discharging into Buffalo Bayou and help maintain proposed condition peak flows to less than existing condition peak flows to Buffalo Bayou, as discussed in **Section 8.1.2**.

The depressed section from Lamar Street to Commerce Street is proposed to be covered, as presented in **Section 3.2**. It is assumed that any runoff from this area will drain either to the Hamilton or St. Emanuel Collectors. The covered section was assumed to be 85% impervious with the high point of the covered section being in the middle of the depressed section. If a low impact design is implemented for the covered section, the runoff from this area into the collectors should be reevaluated.

Refer to **the Hamilton Street Collector** and **St. Emanuel Street Collector Preliminary Design Sheets** for the plan and profile sheets, drainage area maps, and hydraulic data sheets relevant to the Hamilton Street Collector and St. Emanuel Street Collector, respectively.

5.3 Depressed Section Storm Sewers

A trunkline level preliminary design for the proposed depressed section, from Alabama Street to Canal Street, was completed as part of this drainage study. This included the preliminary sizing and layout of storm sewers for each roadway system within the proposed depressed section, including I-69 northbound and southbound, I-45 northbound and southbound, SH-288 northbound and southbound, and I-45 northbound and southbound direct connectors.

5.3.1 Design Criteria

The depressed section storm sewer systems were designed for a 100-year storm event with the 100-year HGL below the gutter line. The storm sewer systems were checked against the 250-year and 500-year storm events using the overland SWMM model to confirm the depressed section roadway system remains passable under a 500-year storm event. Note, that this analysis did not consider inlet capacity. It is expected that some roadway flooding could potentially occur due to the inlet capacity under the 500-year storm event.

5.3.2 Hydrology

Drainage areas for the depressed section were delineated based on the preliminary roadway profile data provided by HNTB at the start of the study, December 2017. Drainage areas were delineated for each roadway system and subarea breaks were generally set every 300 feet. All drainage areas remained under 200 acres, and therefore, the Rational Method was used to develop peak flows in GEOPAK and as input into the SWMM model.

5.3.2.1 Hydrograph Development

In order to transform the Rational Method peak flows into hydrographs to use as input into the SWMM model, HEC-HMS v. 3.5 was utilized. The Clark Unit Hydrograph (Clark) method was utilized to create hydrographs for each drainage area. For each drainage area, a subbasin was created and assigned the appropriate area, time of concentration (t_c), percent impervious cover, and Green & Ampt loss parameters. All drainage areas within the depressed section were assumed to be 100% impervious. The Clark storage coefficient (R) was then adjusted in an iterative process until the peak flow from each HEC-HMS subbasin was approximately equal to the peak flow developed using the Rational Method. The HEC-HMS models for proposed conditions are included in **Appendix D**.

The Green and Ampt Loss Method parameters, including initial loss, moisture deficit, suction, and conductivity, remained unchanged from the HCFCD M3 effective HEC-HMS models for Buffalo Bayou, as recommended in the *Harris County Flood Control District Hydrology & Hydraulics Guidance Manual*, Section II.2.4. These parameters are summarized in **Table 5-1**.

Table 5-1: Green & Ampt Loss Parameters for All Drainage Areas

Parameter	Initial Loss (in)	Moisture deficit	Suction (in)	Conductivity (in/hr)
Value Used	0.93	0.46	10.03	0.37

5.3.3 Proposed Conditions

The storm sewer system for the proposed depressed section is separated into two drainage systems based on the roadway profile and the location of the proposed pump stations. The I-45 pump station is located just south of the I-69 & I-45 interchange and the Buffalo Bayou pump station is located just north of Runnels Street, as shown on **Exhibit 6** (**Sheets 4, 7, and 8**). For more information on the proposed pump stations see **Section 7.0**.

For the I-45 pump station the proposed storm sewer network extends from Alabama Street to Clay Street. and the network is made up of four main storm sewers, servicing the following main lanes; refer to **Exhibit 6** (**Sheets 3-5**) for locations:

- I-69 Northbound
- I-69 Southbound
- I-45 Northbound to I-69 Northbound Connector
- SH-288 Southbound/I-45 Southbound Connector

The storm sewer system ranges from 24-inch RCP at each trunk's upstream end to two (2) 7 ft. by 5 ft. RCBs at the intake structure to the pump station. The storm sewer systems are connected via laterals, just north of McGowen Street and at Jefferson Street. Additionally, based on the overland flow SWMM model results two (2) 4 ft. by 3 ft. RCBs are proposed at the sag location along Hamilton Street near Holman Street to allow the sag section to drain into the depressed section storm sewer system. The drainage at the sag section along Hamilton Street was previously discussed in **Section 4.7**.

For the Buffalo Bayou pump station the proposed storm sewer network extends from Clay Street to Runnels Street, and is made up of six main storm sewers south of Lamar Street, and four main storm sewers north of Lamar Street. The storm sewers service the following main lanes, refer to **Exhibit 6** (**Sheets 5-7**) for locations:

- I-69 Northbound & Southbound
- I-45 Northbound & Southbound
- I-69 Northbound Connector to I-45 Northbound (South of Lamar Only)
- I-45 Northbound Connector to I-69 Northbound (South of Lamar Only)

The storm sewers begin with 24-inch RCPs at the upstream end of each trunk and increase in size, eventually to three (3) 6 ft. by 4 ft. RCBs at the intake structure into the pump station. The three (3) 6 ft. by 4 ft. storm sewer line runs between the Buffalo Bayou and I-45 pump stations and serves as a redundancy measure in the event of complete failure of one of the pump stations. This is also discussed in **Section 7.5**.

The I-45 northbound and southbound connector lines begin at Clay Street and drain north until they discharge into the I-45 northbound and I-45 southbound storm sewers, respectively, at Lamar Street. There is one lateral, located at Commerce Street, to drain the storm sewers to the I-69 southbound storm sewer and into the Buffalo Bayou pump station. The depressed section from Lamar Street to Commerce Street is proposed to be covered, as shown in **Exhibit 6** (**Sheets 6-7**). For the purpose of this study, it was assumed that runoff from the covered section would drain to either the Hamilton Street or St. Emanuel Street Collectors.

The plan and profile sheets, drainage area maps, and hydraulic data sheets for the proposed storm sewers in the depressed section can be found in the **Depressed Section Preliminary Design Sheets**. The storm sewers have been grouped based on the roadway they service.

5.4 I-45 South Storm Sewer

The studied section of the I-45 South system includes the main lanes and frontage roads. The main lanes are elevated on bridge structures or retaining walls for most of the studied section. In general, runoff from the main lanes drains to the existing storm sewer system along the frontage roads.

A storm sewer level preliminary drainage design was completed for I-45 South, from the interchange of I-69 and I-45 to Tierwester Street. This also includes the preliminary drainage design for the following direct connectors: I-69 northbound to I-45 southbound, I-45 northbound to I-69 southbound/SH-288 southbound, and I-45 northbound to I-69 northbound.

5.4.1 Hydrology

Drainage areas for the I-45 South storm sewer were delineated using the crest and sag information from the preliminary roadway design plans provided by TxDOT. All drainage areas remained under 200 acres, and therefore, the Rational Method was used to develop peak flows in GEOPAK.

5.4.2 Design Criteria

The I-45 South drainage system was preliminarily designed to convey at a minimum the 2-year storm event and checked to ensure the 10-year HGL was maintained below the roadway pavement.

5.4.3 Proposed Conditions

Under proposed conditions, the drainage system utilizes the existing storm sewer system to the extent possible. The proposed modifications to the existing storm sewer system include the following; refer to **Exhibit 6** for locations:

- I-45 Southbound Frontage Road – addition of a storm sewer line from St. Charles Street to just southeast of Nettleton Street. Currently there is no storm sewer line along the southbound frontage road (**Sheets 9-10**);
- Sauer Street & I-45 – proposed lateral structure connecting the proposed I-45 southbound frontage road storm sewer system to the existing northbound frontage road storm sewer system (**Sheet 9**); and
- Removal of existing lateral structures crossing I-45 at St. Charles Street and Nettleton Street (see **Exhibit 7** (**Sheet 1**) for storm sewer removal locations)

The I-45 northbound frontage road storm sewer system remains unchanged from existing conditions due to redirection of the system's upstream drainage area to the proposed St. Emanuel Street Collector under proposed conditions. There is an approximate 131 acre reduction in the I-45 South drainage system area from existing to proposed conditions. The plan and profile sheets, drainage area maps, and hydraulic data sheets for the proposed I-45 South storm sewer system can be found in the **I-45 South Preliminary Design Sheets**.

5.5 SH-288 South Storm Sewer

A storm sewer level preliminary drainage design was completed for SH-288 South, from the interchange of I-69 and SH-288 to Blodgett Street. This also included the preliminary drainage design for the following direct connectors: I-69 northbound to SH-288 southbound and SH-288 northbound to I-69 southbound.

5.5.1 Design Criteria

The SH-288 South drainage system was preliminarily designed to convey, at a minimum, the 2-year storm event.

5.5.2 Hydrology

Drainage areas for the SH-288 South storm sewers were delineated using the crest and sag information from the preliminary roadway design plans provided by TxDOT. All drainage areas remained under 200 acres, and therefore, the Rational Method was used to develop peak flows in GEOPAK.

5.5.3 Proposed Conditions

Under proposed conditions, the drainage system utilizes the existing storm sewer system to the extent possible. The proposed modifications to the existing storm sewer system include the following; refer to **Exhibit 6** (**Sheet 2**) for locations:

- I-69 and SH-288 Interchange, West of Chartres Street – a section of this area will be accounted for in Segment 3A's drainage study and will drain to the proposed Segment 3A detention facility. Refer to the Segment 3A drainage study for further details.
- East of Chartres Street and North of Cleburne Street – area will be rerouted to the proposed Chartres Street drainage system, as described in **Section 5.6** below.
- SH-288 Southbound – proposed laterals draining the proposed toll lanes west to the existing south bound storm sewer system.
- SH-288 Northbound – proposed storm sewer that will replace the existing system from Cleburne Street to Wheeler Street.

The SH-288 southbound storm sewer and SH-288 northbound storm sewer, south of Wheeler Street, remained unchanged from existing conditions due to redirection of the system's upstream drainage area to Segment 3A and the proposed Chartres Street drainage system under proposed conditions. There is an approximate 4 acre reduction in the SH-288 South drainage system area from existing to proposed conditions. The plan and profile sheets, drainage area maps, and hydraulic data sheets for the proposed SH-288 South storm sewer system can be found in the **SH-288 South Preliminary Design Sheets**.

Drainage along Cleburne Street at the north end of the SH 288 system will not be captured by the proposed Chartres Street or SH 288 storm sewer systems. These small drainage areas are included with the SH 288 South system descriptions and exhibits to avoid having additional exhibits for a small area with no proposed storm sewer. On the west side of SH 288, the flow at the Chartres Street/Cleburne Street intersection will drain to an existing City of Houston storm sewer system that runs south along Chartres Street, as it does under existing conditions. On the east side, drainage at the Cleburne Street/Hutchins Street intersection will drain into an existing City of Houston storm sewer that runs east along Cleburne Street, as it does under existing conditions. There is no increase in drainage areas or runoff to these systems under proposed conditions. Refer to the **SH-288 South Preliminary Design Sheets** for locations of these systems.

5.6 Chartres Street Storm Sewer

A storm sewer level preliminary drainage design was completed for the I-69 northbound frontage road, Chartres Street, from Webster Street to Cleburne Street.

5.6.1 Existing Conditions

Under existing conditions, Chartres Street is drained by the following drainage systems:

- Alabama Street to McIlhenny Street – storm sewers draining to the Elgin Street storm sewer system, outfalling to Brays Bayou
- Hadley Street to Texas Avenue - storm sewers draining to the St. Joseph Parkway storm sewer system, outfalling to Brays Bayou
- Texas Avenue to Franklin Street – storm sewer draining to the Preston Street storm sewer system, outfalling to Buffalo Bayou

5.6.2 Design Criteria

The Chartres Street drainage system was preliminarily designed to convey, at a minimum, the 2-year storm event.

5.6.3 Hydrology

Drainage areas for the Chartres Street storm sewer were delineated using the crest and sag information from the preliminary roadway design plans provided by TxDOT. All drainage areas remained under 200 acres, and therefore, the Rational Method was used to develop peak flows in GEOPAK.

5.6.4 Proposed Conditions

Under proposed conditions the Chartres Street storm sewer is proposed to drain everything north of Cleburne Street and South of Webster Street. The proposed storm sewer includes the following; refer to **Exhibit 6** for locations:

- SH-288 Southbound Main Lanes from Isabella Street to Cleburne Street – Proposed storm sewer drains south to Cleburne Street (**Sheet 2**)
- Cleburne Street – proposed storm sewer drains west to east, crossing SH-288 (**Sheet 2**)
- Cleburne Street to Elgin Street – proposed storm sewer drains north to Elgin Street and outfalls to the Elgin Street storm sewer system (**Sheets 2-3**)
- Webster Street to Elgin Street – proposed storm sewer drains south to Elgin Street and outfalls to the Elgin Street storm sewer system (**Sheets 3-4**)

North of the I-69 and I-45 interchange, the depressed section is expanded to the east, eliminating Chartres Street. The inverted siphon at Elgin Street and the 42-inch RCP draining the I-69 and SH-288 interchange, west of Chartres Street, will be removed under proposed conditions. This removes a significant amount of flow from the system under proposed conditions, allowing for the redirection of flow from the SH-288 system, north of Cleburne Street. See the description of proposed conditions along the SH 288 South storm sewer (**Section 5.5.3**) for a characterization of the flow conditions along Cleburne Street.

The plan and profile sheets, drainage area maps, and hydraulic data sheets for the proposed Chartres Street storm sewer system can be found in the **Chartres Street Preliminary Design Sheets**.

6.0 CROSS STORM DRAIN DESIGN

This section identifies the potential changes to the existing storm sewer systems in the vicinity of the proposed depressed section in order to accommodate the proposed roadway modifications. This information can be seen in **Exhibit 7.**

The following storm sewer systems cross the I-69 corridor under existing conditions. To accommodate the proposed depressed sections, these systems will be redirected to one of the collector lines or directly to a pump station under proposed conditions. **Table 6-1** provides a summary of the existing storm sewers along the I-69 depressed corridor that are impacted by the proposed project.

Table 6-1: Existing Storm Sewer Redirected Due to Proposed Depressed Section

Location	Size	Redirected To
SH-288 Interchange to I-69 northbound Main Lanes*	42-inch	Segment 3A Pump Station
Elgin Inverted Siphon	6 ft. by 3.5 ft.	Hamilton St. Collector
St. Joseph Parkway Inverted Siphon	6 ft. by 3.5 ft.	Hamilton St. Collector
Bell St. to Chartres St.	36-inch	Hamilton St. Collector
Dallas St. to George R. Brown	36-inch	St. Emanuel St. Collector
Preston St. to Minute Maid Park	36-inch	St. Emanuel St. Collector
Franklin St.	24-inch	Hamilton St. Collector
Commerce St.	24-inch	Hamilton St. Collector
Ruiz St.	20-inch	Hamilton St. Collector

*Local runoff in the area of the 42-inch storm sewer to be removed under proposed conditions will be considered in Segment 3A pump station/ detention basin design.

Table 6-2 identifies the existing storm sewers that need to be removed to accommodate the proposed depressed section and ROW expansion.

Table 6-2: Existing Storm Sewer Removed Under Proposed Conditions

Location	Size
Chartres St. from Hadley St. to St. Joseph Parkway	18-inch to 36-inch
Gray St. from Chartres St. to St. Emanuel St.	18-inch
St. Joseph Parkway from Chartres St. to St. Emanuel St.	18-inch
Chartres Street from Texas St. to St. Joseph Parkway	24-inch to 54-inch
Jefferson St. from Chartres St. to St. Emanuel St.	18-inch

Table 6-2: Existing Storm Sewer Removed Under Proposed Conditions

Location	Size
Existing 102" RCP from Alabama St. to Buffalo Bayou	102-inch
Leeland St. from Chartres St. to St. Emanuel St.	18-inch
Bell St. from Chartres St. to St Emanuel St.	18-inch
Polk St. from Chartres St. to St. Emanuel St.	24-inch
Lamar St. from Chartres St. to St. Emanuel St.	18-inch
Walker St. from Chartres St. to St. Emanuel St.	24-inch
Capitol St. from Chartres St. to St. Emanuel St.	30-inch
Texas Ave from Chartres St. to St. Emanuel St.	18-inch
Chartres St. from Texas Ave to Preston St.	24-inch
Chartres St. from Preston St. to Franklin St.	18-inch
Commerce St. from Chartres St. to St. Emanuel St.	24-inch

Table 6-3 identifies the existing storm sewer that will be replaced under proposed conditions by the proposed Chartres Street storm sewer, Hamilton Street Collector or the St. Emanuel Street Collector.

Table 6-3: Existing Storm Sewers Replaced Under Proposed Conditions

Location	Size	Replaced By
Northbound Frontage Road from Alabama St. to Elgin St.	36-inch to 72-inch	Chartres St. System
Hamilton St. from Winbern to Elgin	48-inch	Hamilton St. Collector
Chartres St. from McIlhenny St. to Elgin St.	18-inch to 48-inch	Chartres St. System
Hamilton St. from McGowen St to Elgin St.	44-Inch	Hamilton St. Collector
Hamilton St. from south of Hadley to St. Joseph Parkway	18-inch to 30-inch	Hamilton St. Collector
St. Emanuel St. from Hadley to Gray St.	24-inch	Chartres St. System
Hamilton Street from just north of Jefferson to St. Joseph Parkway	18-inch	Hamilton St. Collector
Hamilton St. from just south of Leeland St. to Bell St.	24-inch	Hamilton St.
George R. Brown Convention Center from south of Lamar St. to Walker St.	30-inch	Hamilton St. Collector
St. Emanuel St. from Rusk St. to Capitol St.	30-inch	St. Emanuel St. Collector

Table 6-3: Existing Storm Sewers Replaced Under Proposed Conditions

Location	Size	Replaced By
St. Emanuel St. from Preston St. to Franklin St.	24-inch	St. Emanuel St. Collector

These changes to the existing storm sewer were incorporated into the proposed condition overland flow SWMM model. The SWMM model results show the proposed changes result in no adverse impacts to existing conditions for a 100-year storm event.

7.0 PUMP STATIONS

The Segment 3B proposed depressed section is serviced by two pump station facilities. The pump station facilities are located south of the I-69 and I-45 interchange (I-45 Pump Station) and north of Runnels Street (Buffalo Bayou Pump Station) as shown on **Exhibit 6** (**Sheets 4, 7, 8**). The pump stations discharge to gravity systems that ultimately outfall to Buffalo Bayou. The pump stations were analyzed using SWMM. The SWMM model includes the depressed section storm drain system and the two pump station facilities.

7.1 Summary of Capacity Requirements

The I-45 pump station provides flood control for the proposed depressed section from Alabama Street to Clay Street and the Buffalo Bayou pump station provides flood control for the proposed depressed section from Clay Street to Runnels Street. This section of the report provides detailed design and analysis of the proposed pump stations. The pump stations were designed to handle the 250 year storm event, which is similar to the preliminary NOAA Atlas 14 100-year rainfall for a 24-hour storm duration. The peak flow to the I-45 pump station is 508 cfs and the peak flow to the Buffalo Bayou pump station is 144 cfs. The peak flows are based on the assumption that the pump stations operate independently from each other. The peak flows were obtained from the proposed 250-year SWMM pump model.

7.2 Design Criteria

TxDOT has provided the following design constraints to the storm water pump stations to assure design and equipment selection is consistent with other TxDOT pump stations.

- Even number of installed units;
- Redundancy, one spare installed;
- Submersible column pumps;
- Individual pump capacity not to exceed 15,000 gallons per minute;
- 480V AC/3 phase primary;
- Diesel engine driven generator, as backup power supply, sized full station capacity; and
- Onsite fuel storage with a minimum of 72 hours of run time on backup.

7.3 Pump Station Configuration

The pump stations are configured with an inlet chamber, passively screened to collect debris released during high flow scenarios. The flow transition from the passive screens is directed to the pump suction bays. Once there is sufficient rising wetwell level, the pumps initiate in stages, lifting the collected storm water. The individual pump discharges below the top slab into a gravity head box, collecting all the flow for gravity discharge to the I-45 pump station discharge box or the Buffalo Bayou pump station discharge box, both draining to Buffalo Bayou.

For the I-45 pump station, there are 18 constant speed, individual pump units – 17 operating for the required peak flow and one unit standby, in case of a pump failure. Two of the pumps have a selected design point for the individual pump unit of 6,700 gallons per minute (gpm) at 43 feet total dynamic head. The selected design point for the other 16 pumps for the individual pump unit is 13,500 gpm at 50.5 feet total dynamic head (TDH). The static head ranges from 47.5 feet to 35 feet. Available Net Positive Suction Head ($NPSH_a$) at minimum water level is 38.9 feet. **Table 7-1** shows the assumed pump start and

stop elevations for the I-45 pump station. The pump station design sheets are included in the **Preliminary Design Sheets** section.

Table 7-1: I-45 Pump Station Start and Stop Elevations

Pump No.	Cumulative Pump Rate (GPM)	Start Elevation (MSL)	Stop Elevation (MSL)
1	6,706	-11.84	-12.5
2	13,411	-11.19	-11.84
3	26,822	-10.53	-11.19
4-5	53,644	-9.88	-10.53
6-8	93,877	-9.22	-9.88
9-11	134,110	-8.56	-9.22
12-14	174,344	-7.91	-8.56
15-17	214,577	-7.25	-7.91
18*	227,988	-6.59	-7.25

*Pump No. 18 is a redundant pump that will not be activated in storm events up to and including the 250-year storm event.

The two (2) 7 ft. by 5 ft. RCBs discharging into the I-45 pump station have a flowline at elevation minus 12.53. Using elevation minus 12.5 as minimum water level, the submergence and clearance requirements for the proper operation of the pump, as stated in the American National Standard for Rotodynamic Pumps for Intake Design (ANSI 9.8-2012) – Appendix E, places the wetwell floor at elevation minus 20.5.

For the Buffalo Bayou pump station, there are 6 constant speed, individual pump units – 5 operating for the required peak flow and one unit standby, in case of a pump failure. One pump has a selected design point for the individual pump unit of 6,500 gpm at 51 feet total dynamic head. The selected design point for the other five pumps for the individual pump unit is 13,000 gpm at 50 feet total dynamic head (TDH). The static head ranges from 47.0 feet to 35 feet. **Table 7-2** shows the assumed pump start and stop elevations for the Buffalo Bayou pump station.

Table 7-2: Buffalo Bayou Pump Station Start and Stop Elevations

Pump No.	Cumulative Pump Rate (GPM)	Start Elevation (MSL)	Stop Elevation (MSL)
1	6,463	-12.93	-14
2	19,389	-11.86	-12.93
3	32,316	-10.79	-11.86
4-5	59,138	-9.72	-10.79
6	72,064	-8.65	-9.72

The three (3) 6 ft. by 4 ft. RCBs discharging into the Buffalo Bayou pump station have a flowline at elevation minus 13.77. Using elevation minus 14.0 as minimum water level, the submergence and clearance requirements for the proper operation of the pump, established by Hydraulic Institute standards, places the wetwell floor at elevation minus 21.5.

Using the criteria of Hydraulic Institute Standard 9.8 – 2012, Rotodynamic Pumps for Pump Intake Design, the following criteria have been applied to establish the minimum structure dimensions:

- Pump bay length =17 foot 3 inch
- Pump bay width = 6 foot
- Pump bay velocity = 0.67 feet per second for the I-45 pump station and 0.65 feet per second for the Buffalo Bayou pump station
- Cross flow velocity = less than 50% of pump bay velocity

As a result, the wetwell footprint allowance is 88 feet by 150 feet for the I-45 pump station and 80 feet by 54 feet for the Buffalo Bayou pump station, inclusive of the discharge box. Each pump column is 36 inch, with the same size discharge outlet, protected from backflow by a duckbill type check valve. The discharge boxes collect the output from each operating pump unit and convey the flow through the respective pump station discharge box. The I-45 pump station discharge box structure is a 6 ft. by 6 ft. RCB with an estimated HGL of elevation 33.5 feet at the pump station. The floor of the discharge box is at elevation 27.52, with the surrounding containment walls at elevation 45.00, above the surrounding natural grade at elevation 43.5. The Buffalo Bayou pump station discharge box structure is a 6 ft. by 6 ft. RCB with an estimated HGL of elevation 33.16 at the pump station. The floor of the discharge box is at elevation 30, with the surrounding containment walls at elevation 45.50, above the surrounding natural grade at elevation 44.6.

7.4 Pump Station Appurtenances

Pump station maintenance access is provided in four ways:

- Inside the pump stations is an intermediate floor for maintenance access and inspection at elevation 31.00, which is accessible from the top deck through a lockable entryway and down steel frame stairs.
- Access for maintenance in the wetwell is provided through four extraction hatches, each 3 ft. by 4 ft. Two of these hatches are aligned vertically, allowing vertical access to the wetwell (elevation minus 20.5 for the I-45 pump station and elevation minus 21.5 for the Buffalo Bayou pump station), or to the discharge piping deck at elevation 31. This is shown on two locations in the plan view.
- Through the top deck, access is provided into the inlet screens by removal of the grating at elevation 45.0 for the I-45 pump station and elevation 45.5 for the Buffalo Bayou pump station, allowing trash and debris removal after a significant rain event.
- Maintenance for the pump discharge piping and check valves is provided through grating removal over the check valves.

Other appurtenances include a single sump pump, designed to fully drain the storm water pump station wetwell. Once the rain event is concluded and all main storm water pumps have ceased operation, the sump pump will operate, pumping the residual wetwell water to the discharge box. This single pump unit is a submersible, macerator pump, with a capacity of 100 GPM at 40 feet TDH with a 4 inch discharge. This pump discharges to the discharge head box. The sump pump is identical for either pump station.

Although there is sufficient venting of the wetwell through the inlet screens, a wetwell vent has been included on the top slab. In the unlikely, but possible, event of a high water level in the wetwell (above the inlet screen area), the top vent prevents pressurization/vacuum from being applied to the structure.

7.4.1 Standby Power

In the event of primary utility power outage, on-site diesel driven generators have been provided in the design. For the I-45 pump station, to allow for 16 running and the start of the seventeenth pump, two generator sets, each 1750 kW capacity have been included. To house the generators, the structure has an approximate footprint of 50 ft. by 50 ft. and includes a ducted air plenum for cooling air supply and external, silenced engine exhaust and fuel day tanks. The building will also require fire suppression. Fuel storage is placed separately in dual wall diesel tanks and within a containment area. At a total of 18,000 gallons stored, the fuel storage is sufficient for a 3 day continuous run time. A 40 ft. by 40 ft. containment area is sufficient to hold two 10,000 gallon, double wall horizontal tanks.

25 ft. by 50 ft. is the approximate size for an electrical building to house power feed isolation and monitoring, generator paralleling gear, automatic transfer switch and motor control center (MCC). This structure is envisioned to be a temperature controlled enclosure to enhance longevity of the equipment.

For the Buffalo Bayou pump station, to allow for 4 running and the start of the fifth pump, one generator set, sized at 1500 kW capacity have been included. To house the generators, the structure has an approximate footprint of 25 ft. by 50 ft. and includes a ducted air plenum for cooling air supply and external, silenced engine exhaust and fuel day tanks. The building will also require fire suppression. Fuel storage is placed separately in a dual wall diesel tanks and within a containment area. At a total of 8,000 gallons stored, the fuel storage is sufficient for a 3 day continuous run time. A 20 ft. by 40 ft. containment area is sufficient to hold one 10,000 gallon, double wall horizontal tank.

20 ft. by 30 ft. is the approximate size for an electrical building to house power feed isolation and monitoring, generator paralleling gear, automatic transfer switch and MCC. This structure is envisioned to be a temperature controlled enclosure to enhance longevity of the equipment.

7.4.2 Location and Site General Arrangement

The proposed I-45 pump station is positioned at the south east side of the proposed I-45 proposed alignment, adjacent to St. Emanuel Street and Gray Street. Access into the site is off Gray Street, through a secure and gated fence. Onsite general arrangement is for the storm water gravity influent to enter the site from the north west, with the discharge box, leaving the site to the south east. Electrical utility supply will be from the east, along Gray Street, positioning the electric building, generators and fuel storage adjacent to the point of entry of the primary power.

The proposed Buffalo Bayou pump station is positioned at the northwest side of the proposed I-45 proposed alignment, adjacent to Runnels Street and West Street. Access into the site is off Runnels Street, through a secure and gated fence. Onsite general arrangement is for the storm water gravity influent to enter the site from the South, with the pressurized box culvert, leaving the site to the south. Electrical utility supply will be from the west, along Runnels Street, positioning the electric building, generators and fuel storage adjacent to the point of entry of the primary power.

The remainder of both pump station sites is asphalt paved, with sufficient design strength to support fuel delivery and maintenance vehicles. Due to site constraints, the site arrangements do not allow for a circle route for fuel trucks. However, a space for a three point turn has been accommodated on the site.

7.4.3 Pump Station/Depressed Section Stress Scenarios

There are a potentially unlimited number of stress scenarios and combination of stress scenarios that could be analyzed. The scenarios presented below were determined in coordination with TxDOT and represent potential extreme stress scenarios. The stress scenarios included the 500-year 24-hour storm event, as well as the following scenarios, which were run for a 100-year 24-hour storm event:

- Buffalo Pump Station fails prior to the storm, sluice gate open for entire storm;
- I-45 Pump Station fails prior to the storm, sluice gate open for entire storm;
- Buffalo Pump Station fails immediately before peak of the storm (Hour 15), sluice gate opened two hours later (Hour 17); and
- I-45 Pump Station fails immediately before peak of the storm (Hour 15), sluice gate opened two hours later (Hour 17).

Table 7-3 summarizes the results of the stress scenarios at the sag locations along the four major roadways within the depressed section**.** The table presents the stress scenario resulting in the highest HGL for each location.

Table 7-3: Pump Station Stress Scenarios

Roadway	Station	PGL	HGL	PGL – HGL	Stress Scenario
I-69 southbound to I-45 Pump	1101+55	12.88	10.90	1.98	500-year
SH-288 southbound to I-45 Pump	1047+40.65	14.44	14.00	0.44	500-year
I-45 northbound CONN to I-45 Pump	520.78	15.22	13.21	2.01	500-year
I-69 northbound to I-45 Pump	1070+06.54	13.04	11.74	1.30	500-year
I-69 southbound to Buffalo Pump	1164+32.32	1.23	-1.89	3.12	I-45 Pump Fail Before Peak
I-45 southbound to Buffalo Pump	1064+89.24	3.86	-2.28	6.14	I-45 Pump Fail Before Peak
I-45 northbound to Buffalo Pump	1048+01.24	11.36	6.38	4.98	500-year
I-69 northbound to Buffalo Pump	1170+16.96	2.45	-2.29	4.74	I-45 Pump Fail Before Peak

Table 7-3 shows the 500-year storm event and the I-45 pump station failing at hour 15 results in the highest HGLs at the given sag locations. The closest the roadway comes to ponding occurs along SH-288, where the HGL is within 0.5 feet of the PGL in the 500-year storm event. However, all results show that the roadways remain passable in all stress scenarios. Note, that this analysis did not consider inlet capacity. It is expected that some roadway flooding could potentially occur due to the inlet capacity under the 500-year storm event and the other stress scenarios.

It is recommended that a detailed evaluation of the capacity of the inlet structures in the depressed be completed in the design phase of the project to determine the anticipated level of ponding under these stress scenarios.

7.5 Pump Station Redundancy Measures

The following redundancy measure were included as part of the pump station design.

- Power Redundancy at Each Site:
  - Two on-site diesel generators provided; and
  - Fuel stored onsite sufficient for a 3 day continuous run.
- Pump Redundancy:
  - One backup pump provided at each site; and
  - Pump station facilities connected via three (3) 6 ft. by 4 ft. RCB storm sewer system to allow for interaction of flow between the two system in the event of total failure of one pump station facility.

8.0 MITIGATION ANALYSIS

A mitigation analysis was performed for Segment 3B to determine detention needs due to the increase in runoff associated with the proposed roadway and drainage improvements (system hydraulics) for the following roadways:

- The depressed section of the I-69/SH-288/I-45 corridor from Alabama Street to Canal Street, including the Hamilton Street and St. Emanuel Street Collector Systems (Outfall - Buffalo Bayou);
- I-45 South from the interchange of I-69 and I-45 to Tierwester Street (Outfall – Existing I-45 South storm sewer system);
- SH-288 South from the interchange of I-69 and SH-288 to Blodgett Street (Outfall – Existing SH-288 South storm sewer system); and
- Chartres Street between Alabama Street and I-45 South (Outfall – COH storm sewer system along Elgin Street).

The analysis also evaluated the mitigation needs associated with loss of floodplain storage from Buffalo Bayou as a result of the project. The overland flow SWMM model was used to evaluate the detention and floodplain mitigation needs for the project. Detention requirements were based on the design requirement of no increase in flow at outfalls associated with the project drainage system under proposed conditions. The following sections detail the mitigation analyses, including methodology, existing and proposed conditions, and results associated with each roadway system.

8.1 Depressed Section Mitigation

The depressed section outfall to Buffalo Bayou includes all the drainage from the depressed section as served by the two pump stations, plus the Hamilton Street collector system and the St. Emanuel Street collector system. The depressed section mitigation needs were separated into floodplain storage mitigation and detention storage mitigation associated with the increase in impervious and improved drainage systems under proposed conditions.

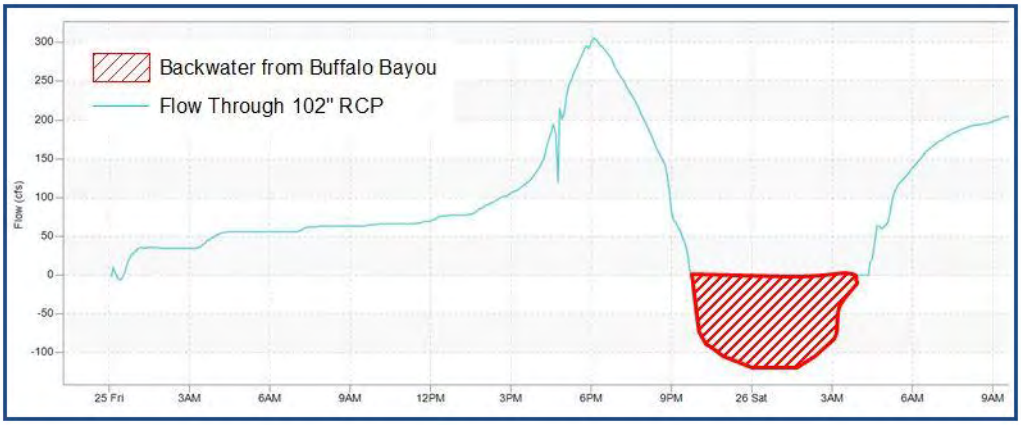
8.1.1 Floodplain Storage Mitigation

The existing I-69 corridor between Alabama Street and Canal Street drains to Buffalo Bayou. The Buffalo Bayou FEMA effective 100-year WSE in the vicinity of the corridor outfall to the Bayou is approximately 28.0 feet. Based on observed high water marks during recent major storm events, Hurricane Harvey (2017), and Tax Day flood event (2016) there were concerns regarding the validity of the Buffalo Bayou effective 100-year WSE. As part of the Segment 3 drainage study effort TxDOT requested the Segment 3D drainage consultant, LAN, to analyze Buffalo Bayou. Under this work effort LAN determined that the FEMA effective Buffalo Bayou WSEs were underestimated by approximately 3 feet in the vicinity of the I-69 corridor outfall to Buffalo Bayou. For the purpose of the depressed section mitigation analysis, the LAN corrected effective model results were used for Buffalo Bayou.

The natural ground elevations at Canal Street, the northern limits of the depressed section, are approximately 45.0 feet, over 15 feet higher than the Buffalo Bayou 100-year WSE. The current I-69 depressed section between Bell Street and SH-288 gravity drains to Buffalo Bayou via a 102-inch storm sewer. The 102-inch storm sewer has no flap gate or backflow preventer at its outfall to Buffalo Bayou, as shown on as-built drawings included in **Appendix A**. The approximate flow line elevation at the Buffalo Bayou outfall of the 102-inch storm sewer is 0.51 feet. This flow line elevation was calculated using the flowline information from the as-built drawings and approximating a vertical datum conversion to NAVD

1988 (unadjusted) (As-Built elevation minus 10.93 feet = NAVD 1988 (unadjusted). The elevation of the lowest portion of the roadway in the depressed section is approximately 23.6 feet, which is approximately 6.5 ft. lower than the Buffalo Bayou 100-year WSE. Therefore, flow from Buffalo Bayou can drain into the existing depressed sections under certain high flow events. The overland flow SWMM model was used to estimate the volume of flow from Buffalo Bayou that drains into the existing depressed section under a 100-year storm event. **Figure 8-1** shows the flow hydrograph taken from the SWMM model at the outfall to Buffalo Bayou. Negative flow on the graph represents flow draining away from the Bayou into the existing depressed section. The 100-year floodplain storage within the existing depressed section was estimated to be 78 ac-ft.

Figure 8-1: Existing 100-Year Flow Through the 102-inch RCP



Under proposed conditions, the 102-inch RCP will be removed and the depressed section will drain to Buffalo Bayou via a combination of a pump station and gravity outfall system. This proposed drainage system will isolate the proposed depressed section from Buffalo Bayou. Therefore, the previous storage volume within the depressed section will not be available for use by Buffalo Bayou. The 78 ac-ft of storage volume that is lost to Buffalo Bayou will be accounted for in proposed Pond A (Segment 3C). The location of proposed Pond A is shown in **Exhibit 8** (**Sheet 8**).

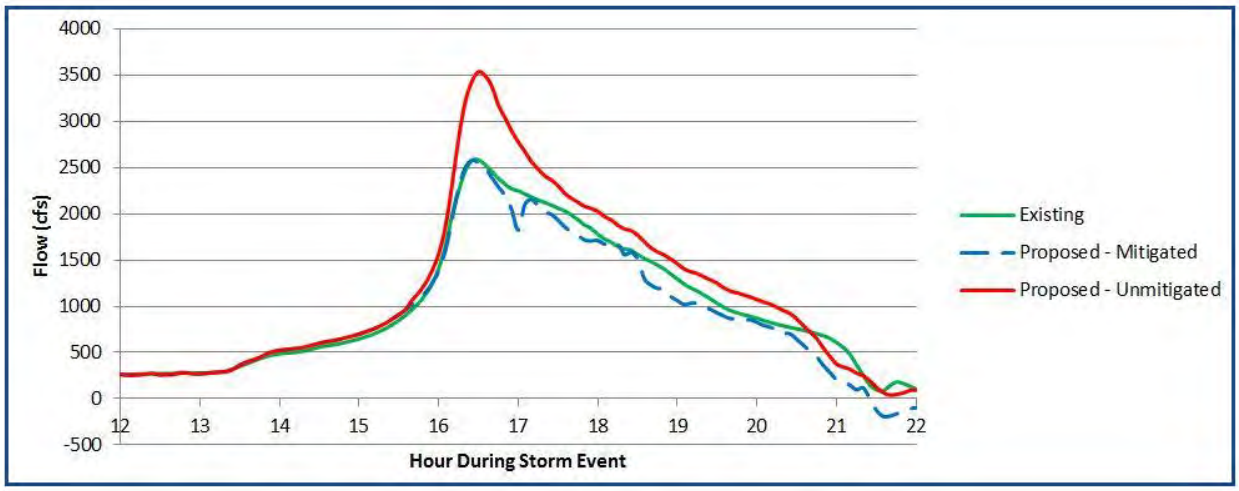
8.1.2 System Hydraulics Mitigation

Due to the improved conveyance provided by the proposed depressed section storm sewer system and collector systems along Hamilton Street and St. Emanuel Street, as presented in **Section 5.0**, and the approximate 16 acre increase in impervious cover due to the proposed roadway features within the depressed section, mitigation storage is required to ensure the proposed peak flows into Buffalo Bayou are less than existing. Approximately 28 ac-ft of storage is needed to mitigate the proposed depressed section and 44 ac-ft is needed to mitigate the improved conveyance as a result of the overland flow collector systems. The mitigation volume needed for the overland flow conveyance improvements was estimated by calculating the overland storage volume reduction between existing and proposed conditions for the 100-year storm. The project impervious cover and internal conveyance improvements make up the reminder of the impact volume.

The proposed peak flows from the pump stations and collector systems are proposed to be mitigated through Pond A, located adjacent to the Buffalo Bayou pump station. Approximately 72 ac-ft of storage is required in the basin during the time of the local peak to ensure the proposed peak flows into Buffalo Bayou are less than existing peak flows. **Figure 8-2** shows a comparison of the existing and proposed conditions 100-year flows discharging to Buffalo Bayou. The existing condition flow is the combined flow from the Austin Street storm sewers and the 102” RCP draining the existing depressed section. The

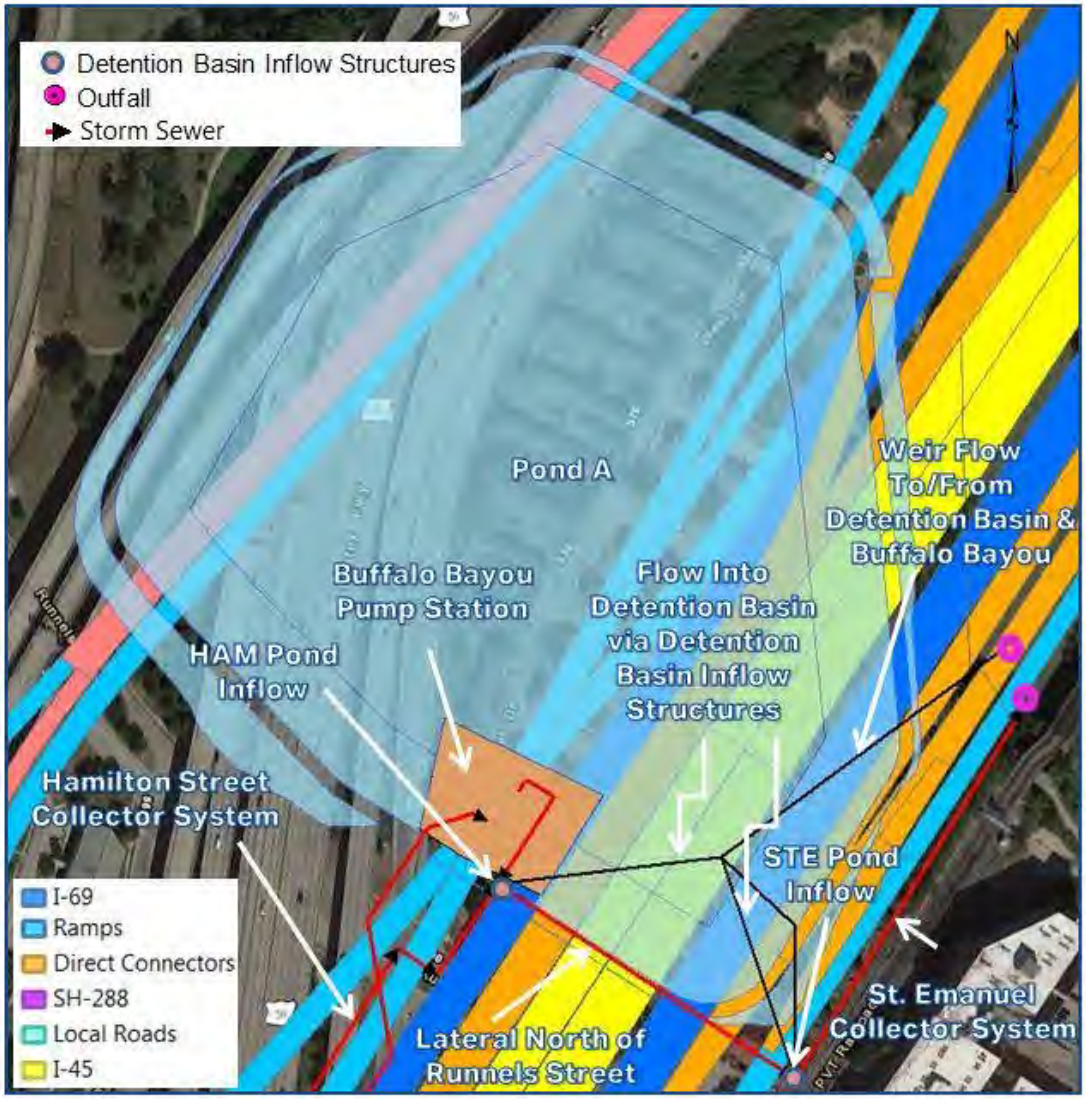
proposed (unmitigated) flow represents the combined flow from the Austin Street and St. Emanuel Street storm sewer systems and the flow into Pond A. The proposed (mitigated) flow is the combined flow from the Austin Street and St. Emanuel storm sewers and the flow out of Pond A. For the purposes of the Segment 3B mitigation analysis, the elevation-area curve of Phase 1 of Pond A was used.

Figure 8-2: 100-Year Flow Comparison at Buffalo Bayou Outfall



The storm sewer flow from the Hamilton Street Collector and the Buffalo Bayou pump discharge are directed to Pond A via the Hamilton Street Pond Inflow (HAM Pond Inflow) structure located on the west side of I-69, as shown in **Figure 8-3.** Flows from the St. Emanuel Street Collector access Pond A via the St. Emanuel Street Pond Inflow (STE Pond Inflow) structure located on the east side of I-69, as shown in **Figure 8-3**. The pond inflow structures are designed to direct high flows from the project into the pond and low flows directly to Buffalo Bayou. Additionally, a weir is proposed connecting Pond A directly to Buffalo Bayou, therefore allowing flow from Buffalo Bayou access to the pond storage volume under Buffalo Bayou high flow conditions.

Figure 8-3: Proposed Drainage System Near Buffalo Bayou



8.1.3 Depressed Section Mitigation Summary

The depressed section mitigation analysis was prepared for two scenarios: one scenario is for Segment 3B in isolation, and one to over-detain Segment 3B, which would compensate for un-detained outflows from Segment 3C.

8.1.3.1 Mitigation Analysis For Segment 3B

Table 8-1 summarizes the mitigation needs for the depressed section for Segment 3B.

Table 8-1: Summary of Mitigation Needs

Required Detention Volume – System Hydraulics	
Mitigation Volume Needed for Depressed Section (ac-ft)	28
Mitigation Volume Needed for Overland Flow Collector System (ac-ft)	44
Subtotal	*72*
Required Detention Volume – Floodplain Storage	
Mitigation Volume Needed for Depressed Section (ac-ft)	78
Subtotal	*78*
Total Mitigation Needs (ac-ft)	**150**

The 72 ac-ft of storage needed to mitigate the roadway and drainage improvements will be provided for in Pond A. Based on the stage storage information for Phase 1 of Pond A provided by the Segment 3C drainage engineer, CivilTech Engineering, Inc., the lower 9-10 feet of Phase 1 of Pond A will provide 72 ac-ft of storage. The total storage volume of Phase 1 of Pond A is approximately 237 ac-ft, leaving 165 ac-ft available for floodplain mitigation needs.

Based on the above results it was determined that the proposed overland flow collector systems and the proposed depressed section storm drain system do not adversely impact existing conditions for the 100-year storm event.

8.1.3.2 Mitigation Analysis for Combined Segment 3B and Segment 3C

The drainage system for the Segment 3C depressed section outfalls to Buffalo Bayou along the north bank of the Bayou. There is no space within the TxDOT ROW in this area to provide detention to mitigate flows from the depressed section. Therefore, the runoff from the Segment 3C depressed section will drain un-detained to Buffalo Bayou with mitigation provided in Pond A.

The Pond A inflow and outflow structures are sized such that the basin system will over-detain the runoff from the Segment 3B depressed section to compensate for the un-detained runoff from Segment 3C. A restrictor will be required on the St. Emanuel Collector downstream of the STE Pond A inflow structure to restrict the release rates to Buffalo Bayou to below the allowable release rates. The sizing of the restrictor, inflow and outflow structures of the pond and the determination of the detention needs for Segment 3C were performed in SWMM. The stage storage information for the full capacity of Pond A was used for the combined Segment 3B and Segment 3C mitigation analysis. The model results indicate that 51 ac-ft of storage volume is needed for Segment 3C. Based on the stage storage information, the lower 8 feet of the full capacity pond will provide the total storage volume, 123 ac-ft, needed. The total storage volume of Pond A is 450 ac-ft. Therefore, the remaining 327 ac-ft of the pond will be available for floodplain mitigation needs.

Note that for both Segment 3B and the combined Segment 3B and 3C mitigation analyses, the elevation of the weir structure for Pond A to Buffalo Bayou was set such that no flow from Buffalo Bayou entered the pond prior to the peak of the local storm. Volumes and WSEs in the pond were taken at time 17:10 of the 100-year 24-hour design storm. The restrictor and inflow and outflow structures are discussed in **Section 11.5**.

8.2 I-45 South Mitigation

8.2.1 Introduction

The study limits for the mitigation analysis along I-45 South are from the I-45 interchange with I-69 to Velasco Street, as shown in **Exhibit 10**. The existing storm sewer along St. Joseph Parkway was analyzed from St. Emanuel Street to Velasco Street. The proposed storm sewer along Pierce Street was analyzed from St. Charles Street to the Columbia Tap Rail Trail. See **Section 5.4.3** for a detailed discussion on the proposed storm sewer system. The I-45 South section is located in the Brays Bayou watershed.

8.2.2 Existing Conditions

Existing drainage areas and land use are shown in **Exhibit 10**. The land use in the drainage area is highly developed with the existing interstate highway and city streets along with industrial and multi-family residential areas. The existing drainage area is 258.1 acres and is collected in an existing storm sewer trunk system along St. Joseph Parkway. The trunk system on St. Joseph Parkway from St. Emanuel to Velasco Street ranges from a 7 ft. by 5 ft. RCB to an 8 ft. by 7 ft. RCB and ultimately drains to Brays Bayou. The upstream end of the St. Joseph trunkline (west of the siphon) is interconnected with the Austin Street system via a 60” RCP. The interconnect with the Austin Street system relieves some of the upstream pressure from the I-45 system, resulting in lower peak flows for this system than would be expected for the drainage area that nominally drains to it.

8.2.3 Proposed Conditions

The proposed drainage areas, storm sewer, and land use are shown in **Exhibit 11**. Under proposed conditions, the siphon under I-69 will be removed and the area west of I-69 will be redirected to the Hamilton Street collector system, some of the area east of I-45 will be redirected to the Elgin Street system, and some of the area along I-69 west of I-45 will be redirected to the St. Emanuel Street system, resulting in a reduction of the total area to 126.9 acres. The reduction in drainage area contributing to the St. Joseph Parkway drainage system is shown in **Exhibit 11**.

8.2.4 Results

The proposed roadway and proposed storm sewer systems through downtown along I-69 and I-45 result in a reduction in drainage area and peak flows draining to I-45 South along St. Joseph Parkway. **Table 8-2** summarizes the 100-year peak flow calculations at the I-45 system outfall for existing and proposed conditions.

Table 8-2: I-45 South Mitigation Analysis Results

	Drainage Area (acres)	C-Value	100-Year Storm		Required Storage (ac-ft)
			Q (cfs)	Impacts (cfs)	
Existing	258.1	0.74	425	-4	0
Proposed	126.9	0.75	421		

As shown in **Table 8-2**, the increase in impervious and improved conveyance associated with the roadway and drainage improvements does not result in an increase in peak flow. The nominal reduction in drainage area does not result in a large reduction in peak flow because some of the upstream drainage area's flows are diverted to the Austin Street system through the 60" RCP interconnect under existing conditions. Because there is no increase in peak flow, no mitigation is proposed for the I-45 South section. The limits of the I-45 South section are outside the limits of the Brays Bayou floodplain, therefore, there are no floodplain mitigation needs for this section.

8.3 SH-288 South Street Mitigation

8.3.1 Introduction

The study limits for the mitigation analysis along SH-288 South are from the interchange with I-69 to Blodgett Street, as shown in **Exhibit 12**. North of Cleburne Street, runoff will be redirected north along Chartres Street under proposed conditions.

8.3.2 Existing Conditions

The State Highway 288 – Toll Lanes Design-Build Project Preliminary Drainage Design Report was used as the existing conditions for this drainage study, as the project is currently under construction and will be completed by 2019. Existing drainage areas and land use are shown in **Exhibit 12**. The land use in the drainage areas are highly developed with the existing interstate highway and city streets along with multi-family residential areas. The existing drainage area for the northbound system is 15.5 acres. The existing drainage area for the southbound system is 12.4 acres. The northbound and southbound storm sewers continue to drain south along SH-288, eventually discharging into a pump station that outfalls into Brays Bayou.

At the north end of this drainage area, there are two intersections along Cleburne Street, one east and one west of the project, that are impacted by the proposed construction. These intersections currently drain to City of Houston storm sewers that run southbound along Chartres Street and eastbound along Cleburne Street.

8.3.3 Proposed Conditions

The proposed drainage areas, storm sewer, and land use for the SH-288 systems are shown in **Exhibit 13**. Under proposed conditions, the area north of Cleburne Street will be rerouted north to the Chartres Street storm sewer system. See **Section 5.5.3** for a detailed discussion on the proposed drainage system. Because the drainage area north of Cleburne Street is being removed from the SH-288 South system, the storm sewer system did not need to be improved to accommodate the proposed roadway changes.

For the Cleburne Street intersections, there are no proposed drainage improvements. The only changes are to the drainage area, which is reduced due to proposed bridges that intercept flow that would have fallen on the intersection.

8.3.4 Results

The proposed roadway and proposed storm sewer systems through the SH-288 South corridor result in a small reduction in drainage area to the northbound system and a reduction in peak flows to both the northbound and southbound storm sewers. **Table 8-3** summarizes the 100-year at the SH-288 system outfall for existing and proposed conditions.

Table 8-3: SH-288 South Mitigation Analysis Results

	Drainage Area (acres)	C-Value	100-Year Storm		Required Storage (ac-ft)
			Q (cfs)	Impacts (cfs)	
Existing	27.9	0.62	184	–31	0
Proposed	24.1	0.65	153		

As shown in **Table 8-3**, the 3.8 acre reduction in area to the SH-288 South system compensates for the increase in impervious and improved conveyance associated with the roadway and drainage improvements. Therefore, no mitigation is proposed for the SH-288 South section. The limits of the SH-288 South section are outside the limits of the Brays Bayou floodplain, therefore, there are no floodplain mitigation needs for this section.

8.4 Chartres Street Mitigation

8.4.1 Introduction

The study limits for the mitigation analysis along Chartres Street are from the Cleburne Street to Webster Street, as shown in **Exhibit 14** and **Exhibit 15**. West of I-69, runoff will be redirected north along Hamilton Street under proposed conditions.

8.4.2 Existing Conditions

Existing drainage areas and land use are shown in **Exhibit 14**. The land use in the drainage areas are highly developed with the existing interstate highway and city streets along with industrial and multi-family residential areas. The existing drainage area is 101.4 acres. The existing storm sewers west of I-69 combine into a storm sewer that crosses under the I-69 depressed section via a siphon at Elgin Street, and enter a 90-inch RCP that eventually outfalls into Brays Bayou.

8.4.3 Proposed Conditions

The proposed drainage areas, storm sewer, and land use for the Chartres Street system are shown in **Exhibit 15**. Under proposed conditions, the area west of I-69 will be rerouted north to the Hamilton Street collector system, reducing the drainage area, and portions of the I-45 South and SH 288 South drainage areas are diverted into the Chartres Street system. See **Section 5.6.4** for a detailed discussion on the proposed drainage system. Because the drainage area west of I-69 being removed from the Chartres Street system is larger than the areas being redirected into the Chartres Street system, the storm sewer system did not need to be improved to accommodate the proposed roadway changes.

8.4.4 Results

The proposed roadway and proposed storm sewer systems along Chartres Street results in a large reduction in drainage area and a reduction in peak flow at the outfall at Elgin Street. **Table 8-4** summarizes the 100-year at the Chartres Street system outfall for existing and proposed conditions.

Table 8-4: Chartres Street Mitigation Analysis Results

	Drainage Area (acres)	C-Value	100-Year Storm		Required Storage (ac-ft)
			Q (cfs)	Impacts (cfs)	
Existing	101.4	0.54	169	–55	0
Proposed	64.3	0.62	114		

As shown in **Table 8-4**, the 37.1 acre reduction in area to the Chartres Street system compensates for the increase in impervious cover and improved conveyance associated with the roadway and drainage improvements, and the redirection of drainage areas from the adjacent SH 288 South and I-45 South systems. Therefore, no mitigation is proposed for the Chartres Street section. The limits of the Chartres Street section are outside the limits of the Brays Bayou floodplain, therefore, there are no floodplain mitigation needs for this section.

8.5 Segment 3B Drainage Systems Mitigation Summary

Due to the interconnectedness of the overland flow and the storm sewer systems, it was necessary to evaluate mitigation needs both on a project wide level, as well as by individual systems. The overland flow SWMM model, as presented in **Section 4.0** was used as the overall mitigation model to demonstrate no impacts throughout Segment 3B for the 100-year storm event. Peak flows at the outfall of each system were compared to one another under existing and proposed conditions. This includes:

- Depressed section (Buffalo Bayou outfall) – depressed section drainage system and the Hamilton Street and St. Emanuel Street collector systems;
- I-45 South (Outfall – Existing I-45 South drainage system);
- SH-288 South (northbound & southbound) (Outfall – Existing SH-288 drainage system); and
- Chartres Street (Outfall – Existing COH storm sewer system, Elgin Street).

Results from the 100-year existing and proposed SWMM models are shown below in **Table 8-5**.

Table 8-5: NHHIP Segment 3B Mitigation Analysis Results

Storm Sewer System	Outfall System	Watershed	SWMM Link Name	Existing 100-Year Peak Flow (cfs)	Proposed 100-Year Peak Flow (cfs)	Difference
Depressed Section	Pond A	Buffalo Bayou	See 1, 2	2,586[1]	2,579[2]	-7
I-45 South	St. Joseph Parkway	Brays Bayou	I45_Out	425	421	-4
SH-288 South	SH-288 North of Wentworth St.	Brays Bayou	21L-MHC85, 21L-MHD72, pN2L-47	184	153	-31

Table 8-5: NHHIP Segment 3B Mitigation Analysis Results

Storm Sewer System	Outfall System	Watershed	SWMM Link Name	Existing 100-Year Peak Flow (cfs)	Proposed 100-Year Peak Flow (cfs)	Difference
Chartres Street	Elgin Street	Brays Bayou	C11042	169	114	-55

1. Peak flow computed by combining flow entering Buffalo Bayou via the 102-inch RCP (Outfall = O_Depressed) and Austin Street dual storm sewers (Outfalls = O_2891 and O_2911)
2. Peak flow computed by combining flow discharging into Buffalo Bayou via the Pond A weir (Outfall = OF_BuffaloDSof69), the St. Emanuel Street Collector (Outfall = O_Depressed) and Austin Street dual storm sewers (Outfalls = O_2891 and O_2911)

Results show that there are no adverse impacts to peak flows for the 100-year storm event under proposed conditions. The decreases in peak flows in all systems, with the exception of the depressed section, can be attributed to either a decrease in drainage area or minimal change in land use under proposed conditions.

8.6 Overland Flow Impact Analysis

The intent of the overland flow impact analysis was to evaluate the impact, if any, the proposed project would have on existing overland flow conditions in the 100-year storm event, and to determine revisions to the project that mitigate those impacts. Refer to **Exhibit 8** for the proposed drainage system sizes and locations. A comparison of the existing and proposed maximum ponding depths was made to determine the impact of the proposed drainage systems. The results can be seen in **Exhibit 9**.

The results show that within the project vicinity there is in general a decrease in the maximum ponding depths under proposed conditions for the 100-year storm event. These decreases are generally less than 0.1 feet. The following areas are shown to have the largest benefits:

- Main Street, south of the I-69 corridor, due to a large reduction of both overland flow and storm sewer flow being redirected through the Segment 3A Collector.
- Cleburne Street, from I-69 to Ennis Street, due to the SH-288 interchange and SH-288 main lanes being redirected.
- Alabama Street to I-45, east of the I-69 corridor to Velasco Street, due to the reduced flow in the Elgin Street system, as well as the proposed storm sewer added along I-45 southbound.
- Dennis Street to I-45 and Bell Street to Texas Ave, west of the I-69 corridor, due to the proposed Hamilton Street Collector.

There are two locations where the maximum ponding depth in proposed conditions is greater than the existing conditions. At St. Joseph Parkway and St. Emanuel Street the increase in ponding is 0.07 feet and is located within the proposed TxDOT ROW. The second location is at the intersection of Bastrop Street and Dennis Street and the ponding increase is 0.06 feet in the vicinity of an undeveloped lot. These increased are considered to be negligible.

Note that **Exhibit 9** also includes a comparison of ponding depths for the Segment 3A project. There are increases (less than 0.2 feet) in ponding in the 100-Yr storm event near Main Street and I-69. These impacts will be addressed through the finalization of the Segment 3A project.

9.0 UTILITY CONFLICTS

Utility conflicts were evaluated as part of the drainage study. City of Houston GIMS information was used to locate conflicts related to sanitary and water distribution lines. Electric power transmission lines were also evaluated based on information obtained from the U.S. Energy Information Administration. These conflicts can be seen in **Exhibit 16** and are presented in tabular form in **Appendix B**. **Table 9-1** presents a summary of the utility conflicts with the project area related to the proposed drainage system design. Note this conflict list is based on the subsurface utlity data (SUE) availabe at the time of the study, which did not included a detailed SUE survey.

Table 9-1: Summary of Potential Utility Conflicts with Drainage System

UTILITY TYPE	NUMBER OF CONFLICT LOCATIONS
Sanitary Sewer	100
Water Line	83
Electrical	4
Total	**187**

It is recommended that a detailed SUE survey be completed as part of the design phase of the project to identify all potential utility conflicts along the project corridor.

10.0 PRELIMINARY DRAINAGE COST ESTIMATE & CONSTRUCTION PHASING

A preliminary cost estimate for the primary drainage features of Segment 3B was completed for the project. This included, storm drains, overland flow collector systems, and pump stations. The quantities for each component were based on the preliminary drainage design sheets presented in the **Preliminary Design Sheets** for each drainage system. Unit cost values were referenced from TxDOT's Three-Month Statewide Moving Averages from 2018. **Table 10-1** provides a summary of the cost estimate.

Table 10-1: Drainage Cost Estimate Summary

DRAINAGE COMPONENT	ESTIMATED COST
Storm Drain	$46,350,000
Overland Flow Storm Sewer	$29,888,000
Pump Stations (2)	$33,299,000
Total	**$143,027,000**

The above cost estimate includes a 20% contingency and a 10% mobilization. A detailed breakdown of the cost estimate is provided in **Appendix B**.

The following constraints should be taken into consideration when developing the construction phasing and schedules:

- Generally the program consists of large design/build contracts starting from the south (I-69/SH-288 Interchange) and proceeding to the north (I-69/I-10 Interchange), then proceeding from east (I-69/I-10 Interchange) to west (I-10/I-45 Interchange).
- I-45 cannot be relocated to its new alignment until all of the contracts are generally complete. This constrains the removal of the Pierce Elevated to the end of the program. This will delay construction of some ramps in Segment 3B.
- Segment 3B is included in the first contracts to be let as design/build, but completion is reliant on the completion of all the other contracts in order to remove the existing I-45/I-69 (Pierce Elevated) and complete all works.
- Excavation for storm drains will be deep and wide at many locations. Contractor or TxDOT should perform borings to accurately determine geotechnical risks.
- Trench protection for all pipes must accommodate geotechnical conditions and will require careful study.
- Storm drains under depressed roadways and along St. Emanuel Street cannot be installed until Right of Way is acquired and general roadway excavation is completed. This will delay the stormwater works.
- The Hamilton Street collector system will pass very close to the George R. Brown Convention Center and adjacent roadway structures. Careful attention to excavation and installation must be given to these works.
- The storm drain system cannot be used until pump stations and outfalls are complete. Contractor cannot use the system during construction. The Buffalo Bayou pump station may be one of the last items ready.

- Storm drain lines must be routed around existing columns and footings which cannot be removed prior to installation of pipes. This is especially true of the I-69/I-45 interchange (Pierce Elevated), which cannot be removed until the new I-45 roadway is complete, close to the end of the programs. Careful attention must be given to scheduling the removal of existing structures.

11.0 RECOMMENDATIONS & DESIGN CONSIDERATIONS

11.1 Overland Flow Collector Systems

The overland flow collector systems include the Hamilton Street and St. Emanuel Street collector systems. Each system has independent design constraints and challenges. The following summarizes the main recommendations and design considerations for each system.

11.1.1 Overland Flow Hamilton Street Collector System

The section of the Hamilton Street Collector between Alabama Street and Elgin Street is an area where there is minimal change in the 100-year WSE from the south end to the north end under existing conditions, as water is obstructed by the existing depressed section. Therefore, under proposed conditions, the collector line was sized as a 10 ft. by 10 ft. RCB to minimize head loss between Alabama Street and Elgin Street.

However, extending the 10 ft. by 10 ft. RCB for the length of the collector system to Runnels Street would have resulted in a decrease in WSE in the Midtown area from approximately Elgin Street to I-45, east of Bagby Street and west of the I-69 corridor, and would have required additional mitigation to be provided at the outfall to Buffalo Bayou. Therefore, the Hamilton Street Collector is reduced to a 7 ft. by 7 ft. RCB between Hadley Street and Runnels Street in order to limit the reduction in 100-year WSE between existing and proposed conditions, with a goal of 0.05 feet or less in most areas. Refer to **Exhibit 6** (**Sheets 3-7**) for the location and sizes of the Hamilton Street Collector.

In addition, the proposed roadway profile for the section of Hamilton Street that acts as an underpass to the SH-288 direct connector to downtown is lower than the proposed Hamilton Collector system. Therefore, similar to existing conditions, this section is proposed to drain to the I-69 depressed section as shown in **Exhibit 6** (**Sheet 3**). The preliminary design indicates two (2) 4 ft. by 3 ft. RCBs are adequate to drain the sag section along Hamilton Street.

An alternative design consideration to the single collector system along Hamilton Street would be a dual storm sewer system that would service different sections along Hamilton Street. One storm sewer line would service the area along Hamilton Street from Runnels Street to McGowen Street. A second, separate line, between Runnels Street and Alabama Street would service the section of Hamilton Street between McGowen Street and Alabama Street. This would result in less change in the 100-year WSE between existing and proposed conditions in the area between McGowen Street and Alabama Street. Preliminary results also indicate this design alternative would reduce the overland flow to the proposed sag location along Hamilton Street near the SH-288 direct connector to downtown. This alternative was not selected as the preferred alternative due to the potential ROW issues associated with having two major separate storm sewer lines along Hamilton Street.

11.1.2 Overland Flow St. Emanuel Street Collector System

The St. Emanuel Street Collector services the area east of the depressed section and north of I-45. This collector system will begin at Pease Street and drain north towards Buffalo Bayou. The I-45 pump station will be pumped into an outfall pipe that will run parallel to the St. Emanuel Street Collector system and will connect to the St. Emanuel Street Collector system at Commerce Street. The St. Emanuel Street Collector will continue north and outfall into Buffalo Bayou. Refer to **Exhibit 6** (**Sheets 4-8**) for the location and sizes of the St. Emanuel Street Collector system and the I-45 pump station outfall pipe.

An alternative design was considered that included combining the I-45 pump station outfall line and the St. Emanuel collector system into one storm sewer system. The storm sewer size required to convey the discharge from the I-45 pump station resulted in a decrease in excess of 0.1 feet at select locations in the 100-year WSEs along St. Emanuel Street. Therefore, due to the potential mitigation volume needed to compensate for the decrease in the 100-year WSE this design alternative was not recommended.

11.2 Potential Overland Flow Access Points to Depressed Section

To prevent overland flow from entering the proposed depressed section, it is recommended that the proposed roadway profile at the following locations be raised above the 100-year WSE. This information is presented in **Exhibit 8** (**Sheets 3-5**).

Table 11-1: Potential Sheet Flow Access Points

Location	Approximate Proposed PGL (ft.)	100-Year WSE	500-Year WSE
Leeland Street Northbound Entrance Ramp	42.2	43.2	43.5
Leeland Street Southbound Exit Ramp	42.2	42.0	43.0
Bell Street Southbound Exit Ramp	42.9	42.0	43.0
Gray Street at Ramp Entrance	41.4	42.4	42.5
Holman Street near Hamilton Street Sag	42.4*	43.6	44.5
Stuart Street and Hamilton Street	41.5*	43.7	44.6
Elgin Street and Hamilton Street	43.0	43.7	44.6
Hamilton Street and Chenevert Street	43.3	43.6	44.5

*Based on approximate existing ground elevations

Raising the PGLs of the collector streets and ramp to limit flow into the depressed section would likely result in a smaller collector system along Hamilton Street, as well as eliminate the need for the connection to the depressed section storm sewer in this location. See **Figure 11-1** for the roadway locations that are recommended to be raised near the Hamilton Street sag location. However, these design and drainage changes would need to be reevaluated at a later phase in the project.

Figure 11-1: Recommended Roadway Elevations Near Hamilton Street

If the proposed roadway design cannot be adjusted to be above the estimated 100-year WSE at the identified entrance and exit ramps, the following are potential design alternatives:

- Provide inlets prior to the access point to the depressed section that are sized to accept the peak 100-year flow and increase the size of the collector system, as needed.
- Design the local street bridge crossings of the proposed depressed section to convey the overland flow across the depressed section. This design alternative would potentially cause an adverse impact to existing conditions east of the depressed section between SH-288 and Bell Street, as under existing conditions the overland flow does not cross the depressed section in this area. As a result this alternative was not considered a viable design.
- Outside of the Hamilton Street sag, allow some of the overland flow to access the depressed section. This is not recommended as it has the potential to overtax the depressed section drainage system and the pump stations.

Additionally, in the design phase all inlets along Hamilton Street and St. Emanuel Street should be evaluated to ensure minimal ponding and to minimize the potential for overland flow to access the depressed section.

11.3 Depressed Section

The lowest sections of the depressed section storm sewers occur at the discharge pipes into the I-45 and Buffalo Bayou pump stations, and are proposed to be at an elevation near -13 feet. Due to the close

proximity of the project to Buffalo Bayou, ground water could potentially be an issue during construction, and appropriate measures should be taken to minimize potential groundwater issues throughout the life of the storm sewer systems.

11.4 Pump Station

Resilience of the pump stations to pump station failure conditions was considered in the design of the I-45 and Buffalo Bayou pump station systems. The depressed section storm sewer was designed such that the I-45 and Buffalo Bayou storm sewer systems are connected in the event of pump failure. The proposed storm sewers are connected to one another along the I-69 southbound lanes at Clay Street. An automated sluice gate will be installed at the connection of the two systems, near Clay Street, isolating the systems from one another under normal operating conditions. In an event of complete failure or partial failure of one pump station the sluice gate will open allowing for the interaction of flow between the two systems. The storm sewer system connecting the two pump stations consists of three (3) 6 ft. by 4 ft. RCBs. Details on the proposed storm sewer can be found in the **Depressed Section Preliminary Design Sheets**. It is recommended to provide a SCADA system to connect the control of the gate operation with the I-45 and Buffalo Bayou pump station operations.

The Buffalo Bayou pump station footprint is proposed to be located partially underneath the proposed I-10 WB and I-69 southbound ramps (schematic profiles RP010WB306 and RP069SB303). At the time of this study the ramps profiles were not provided and it was assumed the profile provided adequate clearance for access to the pump systems. This assumption will need to be confirmed prior to the design phase of the project, and the placement of bridge bents may need to be adjusted to avoid conflicts with the pump station.

Additionally, the Buffalo Bayou pump station is located adjacent to Pond A and Buffalo Bayou. The pump station is considered a critical facility, as such, the berms of the detention basin adjacent to the pump station should be raised above the 500-year WSE to ensure the pump station facility is not inundated in a 500-year storm event. It's recommended the berm elevations are no lower than 38.2 feet. Also access to the pump station facility should be reviewed to confirm that the final access route chosen is also above the Buffalo Bayou 500-year WSEs.

11.5 Detention Basin and Outfall Pipes to Buffalo Bayou

In order to mitigate the increase in impervious cover due to the proposed roadways and increased conveyance capacity of the proposed storm sewer system, Pond A near Buffalo Bayou will be utilized for storage purposes to reduce the proposed peak flows into the Bayou below existing conditions peak flows. In order to do this, two pond inflow structures have been analyzed to allow high flows to enter Pond A via three (3) 10 ft. by 5 ft. RCBs. The inlet elevations of the three (3) 10 ft. by 5 ft. RCBs at the pond inflow structures were set high enough to allow low flows to outfall directly to Buffalo Bayou early in the storm, when the Bayou has capacity, and reserve the volume in Pond A for larger storm events. See the detention basin and pond inflow structure details provided as part of the **Preliminary Design Sheets**.

Table 11-2: Detention Basin Inflow Box Characteristics

Location	Size	Inlet Elevation
Hamilton Street Pond Inflow Structure	3-10'x5' RCBs	13.3
St. Emanuel Street Pond Inflow Structure	3-10'x5' RCBs	13.3

A weir is proposed connecting Pond A directly to Buffalo Bayou. The weir configuration was preliminarily designed to accommodate the phasing of Pond A, that is, to mitigate flows from the depressed section for Phase 1 of Pond A (Segment 3B) and for the full expansion of Pond A (Segments 3B and 3C). The weir was sized to provide the minimum storage needed to reduce peak flows within Buffalo Bayou below existing conditions for Segments 3B and 3C. These results and recommendations are presented below in **Table 11-3**. It is recommended that the weir elevation and configuration be optimized during a later phase of the project, which will likely result in a higher usable volume of Pond A for reducing peak flows within Buffalo Bayou.

Table 11-3: Pond A to Buffalo Bayou Weir Characteristics

Type	Height (ft.)	Length (ft.)	Side Slopes (ft/ft)	Weir Elevation Phase 1 of Pond A	Weir Elevation Full Expansion of Pond A
Trapezoidal	25	100	4H:1V	12.5	14.0

A flap gate or backflow preventer structure will be required at the outfall of the St. Emanuel Street Collector, a 6 ft. by 5 ft. RCP, to Buffalo Bayou to prevent backwater from the Bayou entering the storm sewer network, as well as Pond A. Similarly, a 48-inch RCP is proposed to be installed to drain Pond A after storm events. This pipe will also need to include a flap gate at its outfall to the Bayou. A restrictor is proposed on the 6 ft. by 5 ft. portion of the St. Emanuel Collector, just downstream of the St. Emanuel detention basin inflow structure, to be placed when Pond A is expanded and Segment 3C is constructed. The restrictor is proposed to have an opening that is 3.5 feet tall and 2 feet wide and is necessary to over-detain the Segment 3B flow to compensate for the un-detained Segment 3C runoff. The inflow and outflow structures referenced in this section were sized in the overland flow SWMM model which includes the entire depressed section drainage system, storm sewer systems, pump stations, and Pond A.

11.6 ROW Considerations

North of George R. Brown, along Hamilton Street there is approximately 15 feet between the roadway and proposed ROW. The proposed storm sewer in this area is a 7 ft. by 7 ft. RCB. For construction purposes, it's recommended that additional ROW be purchased by TxDOT. The adjacent area consists of parking lots that most likely service Minute Maid Park.

During this drainage design it was assumed that St. Emanuel Street, north of I-45, would be acquired by TxDOT as part of this project. This should be confirmed in the next phase of the study.

12.0 CONCLUSION

The drainage analysis and preliminary drainage design completed as part of the Segment 3B drainage study includes analysis and preliminary design of the following major drainage components:

- Stormwater collector systems protecting the depressed section from overland flow west and east of I-69,
- Storm drain systems,
- Pump station facilities, and
- Mitigation facilities.

12.1 Overland Flow/Stormwater Collector System

An overland flow analysis was completed for Segments 3A and 3B, along the I-69 corridor from Drexel Drive to Canal Street for the purpose of determining a recommended solution for isolating the depressed section from overland flow. Segment 3A includes the proposed depressed section from Spur 527 to Alabama Street and Segment 3B includes the proposed depressed section from Alabama Street to Canal Street. The recommended solution includes collector systems along the west and east sides of the depressed section that will capture the overland flow and prevent it from entering the depressed section. The proposed collector systems for Segment 3B include:

- Hamilton Street Collector (varies in size from 48-inch RCP to 10 ft. by 10 ft. RCB)
- St. Emanuel Street Collector (varies in size from 48-inch RCP to 8 ft. by 8 ft. RCB)

The detailed design of the Segment 3A collector was completed separately from this study as part of the Segment 3A drainage design project. At the time of this study, the preliminary collector line system for Segment 3A included a system along the west side of the I-69 corridor between Alabama Street and Main Street.

In addition, the overland flow analysis results were used to identify potential flow access points to the depressed section under proposed conditions. The identified access points and the corresponding proposed 100-year and 500-year WSEs at these locations are provided in **Table 12-1**.

Table 12-1: Potential Sheet Flow Access Points

Location	Approximate Proposed PGL (ft.)	100-Year WSE	500-Year WSE
Leeland Street Northbound Entrance Ramp	42.2	43.2	43.5
Leeland Street Southbound Exit Ramp	42.2	42.0	43.0
Bell Street Southbound Exit Ramp	42.9	42.0	43.0
Gray Street at Ramp Entrance	41.4	42.4	42.5
Holman Street near Hamilton Street Sag	42.4*	43.6	44.5
Stuart Street and Hamilton Street	41.5*	43.7	44.6
Elgin Street and Hamilton Street	43.0	43.7	44.6
Hamilton Street and Chenevert Street	43.3	43.6	44.5

*Based on approximate existing ground elevations

It is recommended that in the next phase of the study the roadway designers consider the above referenced WSEs when finalizing the roadway profile at these access points. If it is not feasible to adjust roadway profiles above the 100-year WSEs then provisions should be made in the drainage design to provide adequate inlet capacity to capture the 100-year flow before reaching the identified access points and increase the collector system capacity as needed.

12.2 Proposed Storm Drain System

The proposed Segment 3B storm drain system includes the following sections:

- Depressed section between Canal Street and Alabama Street;
- The collector systems along Hamilton Street (I-69 southbound frontage road) and St. Emanuel Street;
- Chartres Street (I-69 northbound frontage road);
- SH-288 South from the I-69 and SH-288 interchange to Blodgett Street; and
- I-45 South from the I-69 and I-45 interchange to Tierwester Street.

The proposed depressed section storm sewer network includes a separate storm sewer system for each roadway system, for example, I-69 northbound and I-69 southbound have separate storm sewer systems. The depressed section storm sewer system was designed for a 100-year storm event. The proposed storm sewer systems for Chartres Street, SH-288 South, and I-45 South were all designed for the 2-year storm event.

12.3 Proposed Pump Station Facilities

The Segment 3B proposed depressed section is serviced by two pump station facilities. The pump station facilities are located south of the I-69 and I-45 interchange and north of Runnels Street. The pump station discharge to gravity systems that ultimately outfall to Buffalo Bayou. The pump stations were sized such that there is no roadway flooding for a 250-year, 24-hour storm event. **Table 12-2** provides a summary of the pump configuration at each pump station facility.

Table 12-2: Pump Station Configurations

Pump Station	No. of Active Pumps	Pump Rate (GPM)	No. of Active Pumps	Pump Rate (GPM)	No. of Redundant Pumps	Pump Rate (GPM)
I-45 Pump Station	2	6,700	15	13,500	1	13,500
Buffalo Bayou Pump Station	1	6,500	4	13,000	1	13,000

12.4 Mitigation Facilities

A mitigation analysis was performed for Segment 3B to determine detention needs due to the increase in runoff associated with the proposed roadway and drainage improvements (system hydraulics) for the following roadways:

- The depressed section of the I-69/SH-288/I-45 corridor from Alabama Street to Canal Street
- I-45 South from the interchange of I-69 and I-45 to Tierwester Street
- SH-288 South from the interchange of I-69 and SH-288 to Blodgett Street

The analysis also evaluated the mitigation needs associated with loss of floodplain storage from Buffalo Bayou as a result of the project.

The depressed section mitigation needs were separated into detention storage mitigation associated with the increase in impervious cover and improved drainage systems under proposed conditions (system hydraulics), and floodplain storage mitigation. **Table 12-3** summarizes the mitigation needs for the depressed section.

Table 12-3: Summary of Mitigation Needs

Required Detention Volume – System Hydraulics	
Mitigation Volume Needed for Depressed Section (ac-ft)	28
Mitigation Volume Needed for Overland Flow Collector System (ac-ft)	44
Subtotal	*72*
Required Detention Volume – Floodplain Storage	
Mitigation Volume Needed for Depressed Section (ac-ft)	78
Subtotal	*78*
Total Mitigation Needs (ac-ft)	**150**

The 72 ac-ft of storage needed to mitigate the roadway and drainage improvements will be provided for in Pond A. Phase 1 of Pond A has the capacity to provide 237 ac-ft of storage volume. The remainder of the total storage volume available, 165 ac-ft, will be utilized for the 78 ac-ft of floodplain storage needed for Segment 3B and any additional floodplain mitigation needs. After completion of Segment 3C and the full expansion of Pond A, there will be a total storage volume of 450 ac-ft. Approximately 51 ac-ft of detention volume is needed for the system hydraulics of Segment 3C. Therefore, a total of 123 ac-ft of Pond A will be used for system hydraulic storage in the lower 8 feet of the pond, and the remaining 327 ac-ft of the pond will be available for floodplain mitigation needs.

For the I-45 South and SH-288 South sections, mitigation is not needed as the proposed drainage improvements result in a reduction in the drainage area to each system. In addition, the limits of both sections are outside the limits of the Brays Bayou floodplain, therefore, there are no floodplain mitigation needs for each section.

12.5 Summary

The proposed drainage system was designed to maintain all main lanes passable under a 100-year storm event. The depressed section drainage system was designed such that no ponding occurs within the depressed section under a 100-year storm event. In addition, the depressed section drainage system (storm drains and pump stations) was evaluated under various stress scenarios, including the 500-year

storm event. The stress scenario results indicate that some of the depressed section lanes should remain passable under each of the stress scenarios. Note, that this analysis did not consider inlet capacity. It is expected that some roadway flooding could potentially occur due to the inlet capacity under the 500-year storm event. It is recommended that a detailed evaluation of the capacity of the inlet structures in the depressed section be completed in the design phase of the project to determine the anticipated level of ponding under events equal to or greater than a 100-year event.

In addition, the preliminary drainage system design includes overland flow collector systems on either side of the depressed section to prevent flow from entering the depressed section under a 100-year storm event. A mitigation storage volume of 150 ac-ft will be provided in Pond A, adjacent to the south bank of Buffalo Bayou in order to mitigate the increase in flows associated with the project.

A preliminary cost estimate was developed for the proposed drainage features. The cost estimate included the following elements: storm sewers, laterals, and pump station facilities. The total cost estimate including a contingency is $143 million.

In summary, the proposed roadway improvements will not adversely impact the existing conditions at each outfall within the project limits for a 100-year storm event. The preliminary design recommendations presented in this study are for review purposes only and should not be used for construction purposes.

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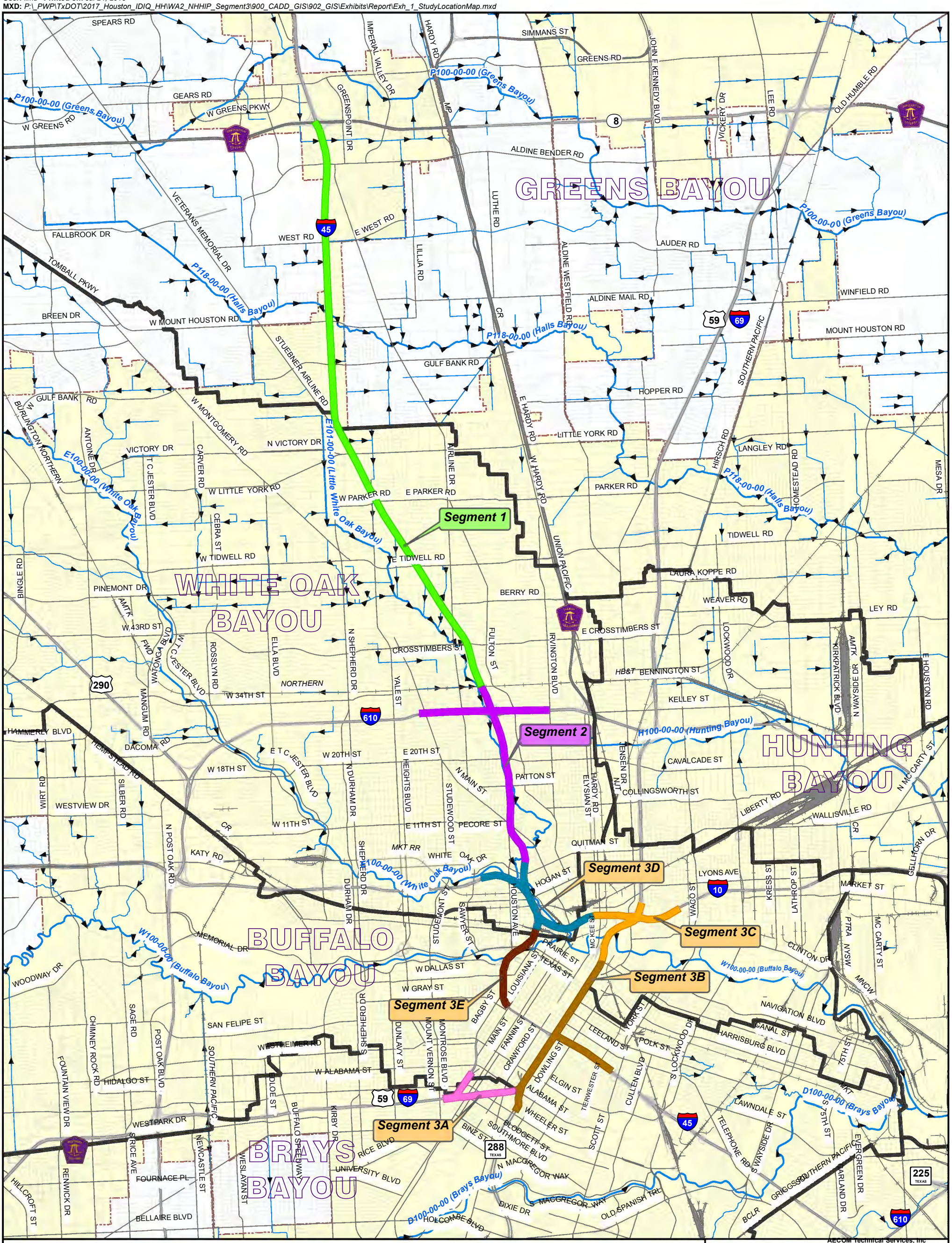

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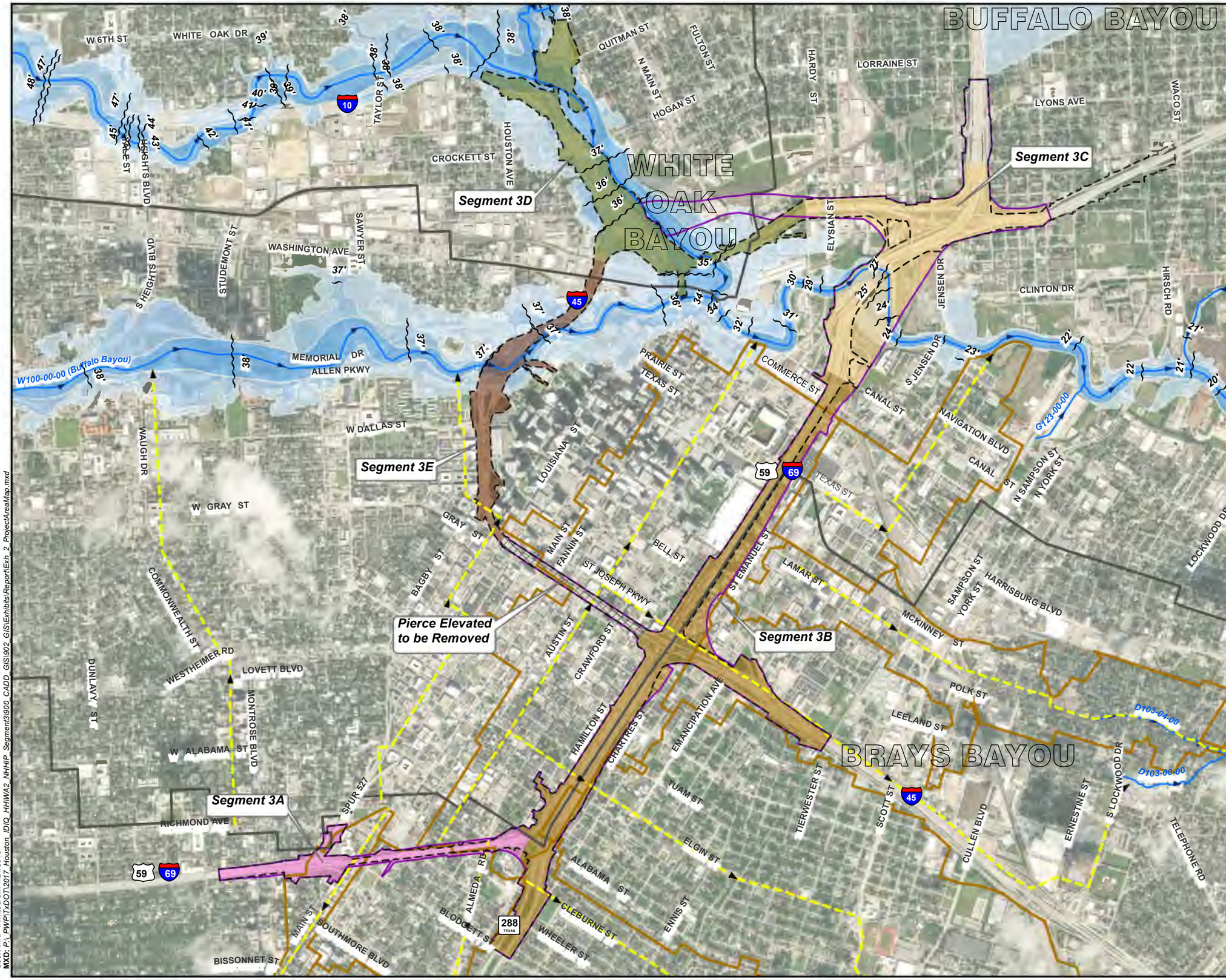
North Houston Highway Improvement Project
Segment 3B Drainage Study

Study Location Map

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	1



Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- HCFCD Open Channels
- HCFCD Watersheds
- COH Primary Outfall
- COH Primary Outfall Drainage Area

Segment

- 3A
- 3B
- 3C
- 3D
- 3E
- Pierce Elevated to be Removed

FEMA Flood Hazard Zones

- Regulatory Floodway
- 1% Annual Chance Flood Hazard
- 0.2% Annual Chance Flood Hazard
- FEMA Base Flood Elevation

N

0 1,000 2,000 Feet

Date of Aerial: 2017
Datum: NAVD 1988, 2001 Adj.

Note:
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North Houston Highway Improvement Project
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Project Area Map

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	2

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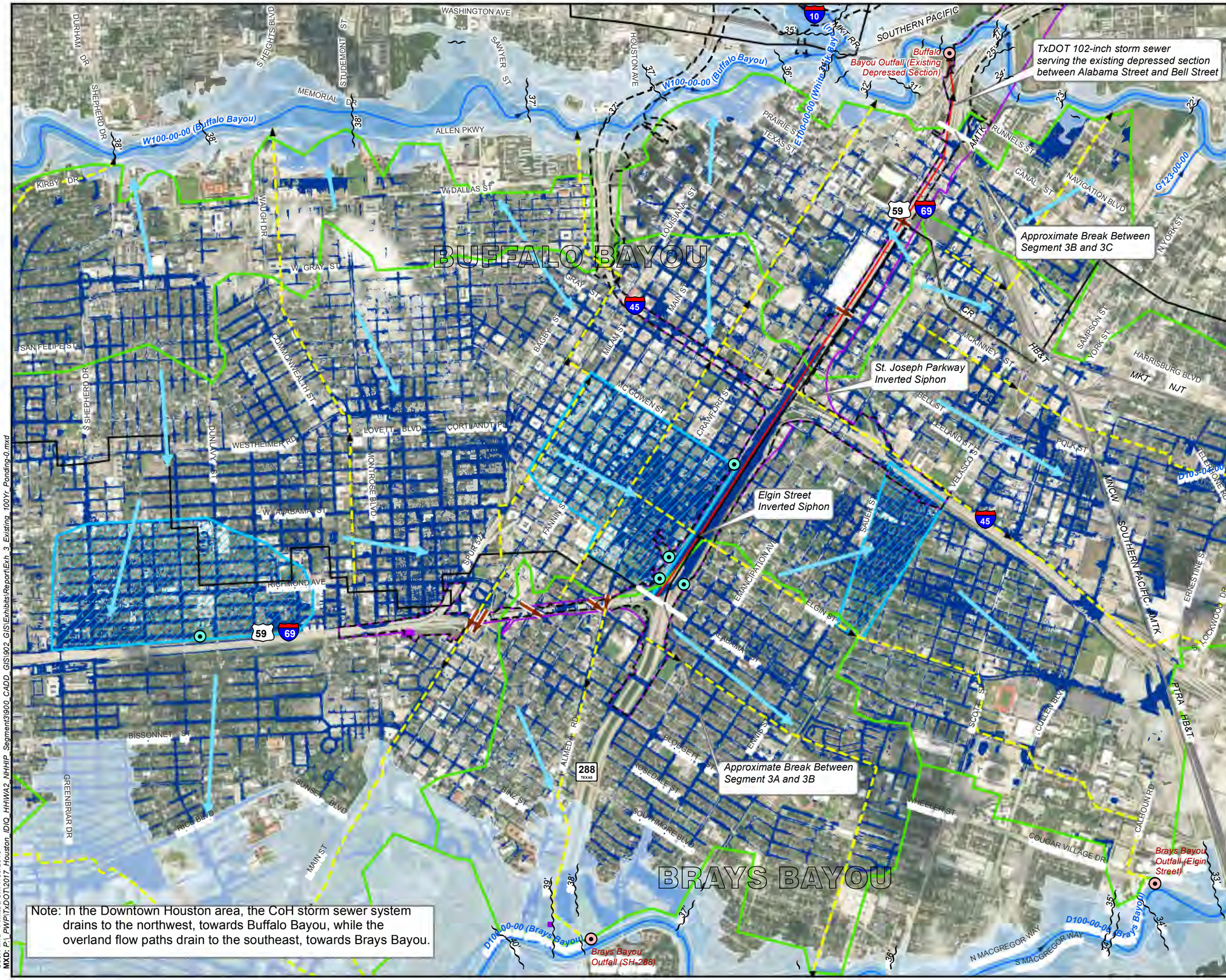

Note: In the Downtown Houston area, the CoH storm sewer system drains to the northwest, towards Buffalo Bayou, while the overland flow paths drain to the southeast, towards Brays Bayou.

Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- Railroads
- HCFCD Streams
- HCFCD Watersheds
- Existing Pump Stations
- TxDOT Storm Sewer
- COH Primary Outfall
- Existing Outfalls
- Existing Flow Access Points
- Major Overland Flowpaths
- General Overland Flow Direction
- Potential Sheetflow Limits
- Existing 100-Yr Ponding
- Major Ponding Areas

FEMA Flood Hazard Zones

- Regulatory Floodway
- 1% Annual Chance Flood Hazard
- 0.2% Annual Chance Flood Hazard
- Base Flood Elevation

N

0 1,000 2,000

Date of Aerial: 2017
Datum: NAVD 1988, 2001 Adj.

Note:
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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Existing 100-Year Storm Event Ponding

SHEET 1 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	3

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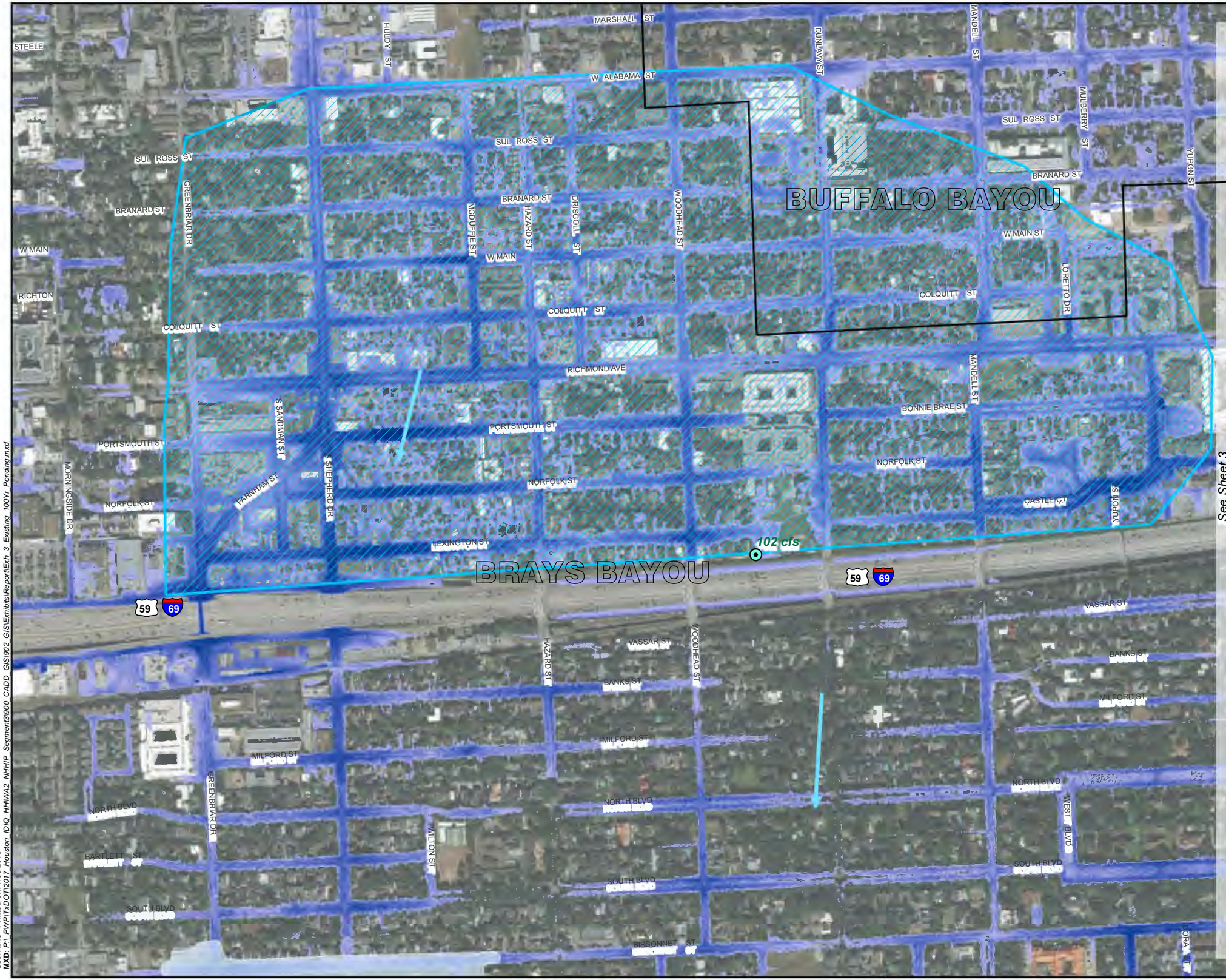

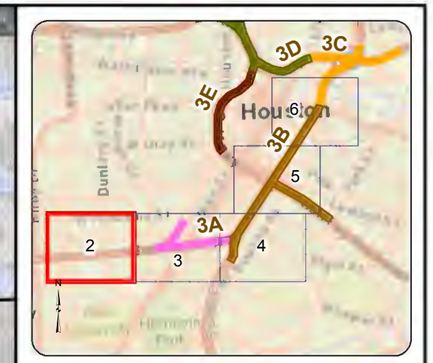

Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- HCFCD Streams
- HCFCD Watersheds
- COH Primary Outfall
- Existing Outfalls
- Existing Flow Access Points
- General Overland Flow Direction
- Potential Sheetflow Limits
- Major Ponding Areas

Existing 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

FEMA Flood Hazard Zones

- 0.2% Annual Chance Flood Hazard

N

0 250 500

Feet

Date of Aerial: 2017
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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Existing 100-Year Storm Event Ponding

SHEET 2 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	3

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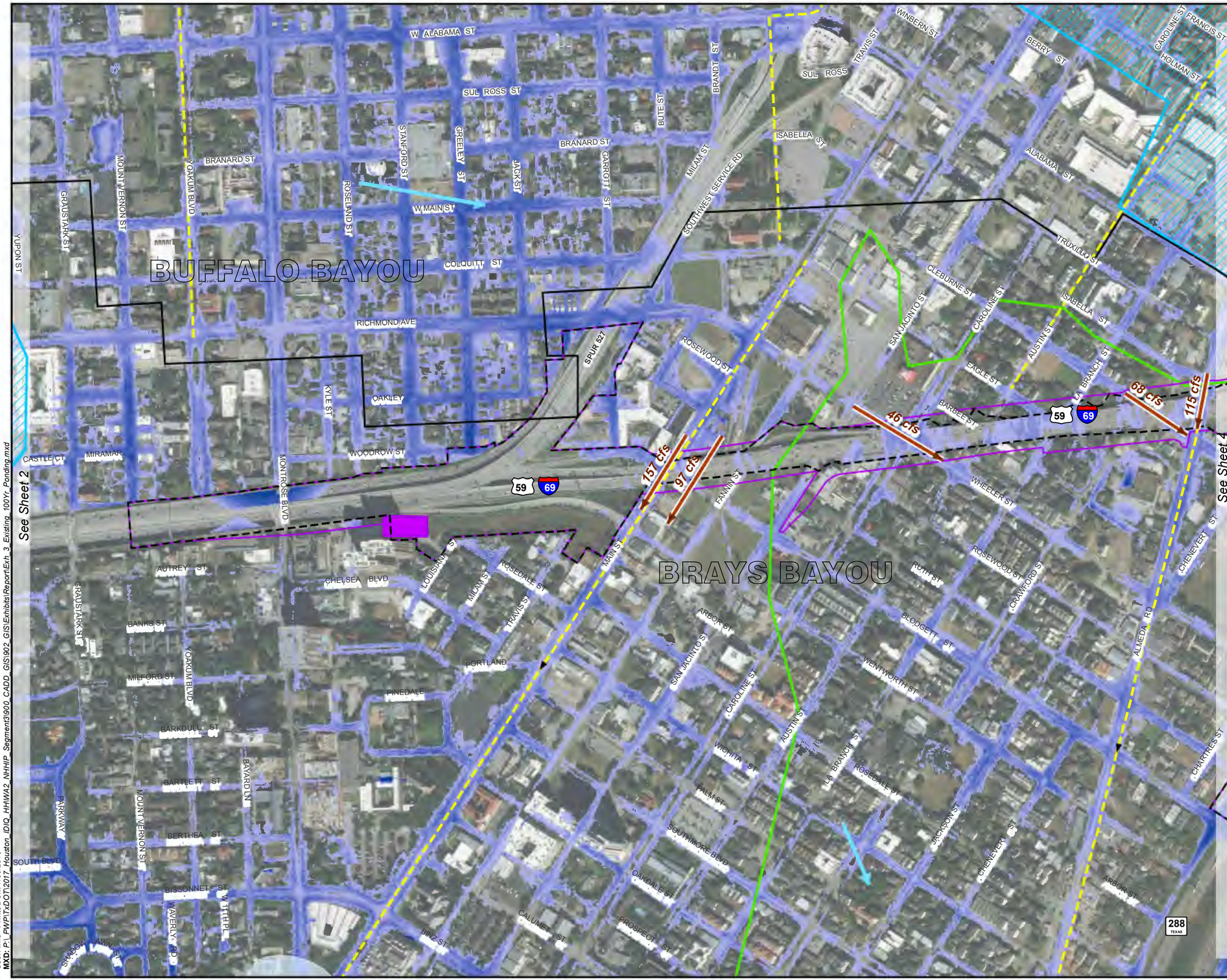
BUFFALO BAYOU
BRAYS BAYOU
See Sheet 2
See Sheet 4
157 cfs
97 cfs
46 cfs
68 cfs
115 cfs
59
69
288
W ALABAMA ST
SUL ROSS ST
BRANARD ST
W MAIN ST
COLQUITT ST
RICHMOND AVE
OAKLEY
WOODROW ST
SPUR 527
SOUTHWEST SERVICE RD
ROSEWOOD ST
ISABELLA ST
TRUXILLO ST
CLEBURNE ST
EAGLE ST
BARBEE ST
LA BRANCH ST
FANNIN ST
WHEELER ST
ROSEWOOD ST
CRAWFORD ST
CHENEVERT ST
ALMEDA RD
CHARTRES ST
ARBOR ST
BLODGETT ST
WENTWORTH ST
ROSEDALE ST
JACKSON ST
WICHITA ST
PALM ST
SOUTHMORE BLVD
OAKDALE ST
PROSPECT ST
CALUMET ST
BINZ ST
MAIN ST
LOUISIANA ST
MILAM ST
TRAVIS ST
PORTLAND
PINEDALE
CHELSEA BLVD
AUTREY ST
BANKS ST
MILFORD ST
BARKDULL ST
BARTLETT ST
BERTHEA ST
BISSONNET ST
W 11TH PL
SOUTH BLVD
SHADOW LAWN
WAVERLY RD
BAYARD LN
PARKWAY
MOUNT VERNON ST
YORKUM BLVD
GRAUSTARK ST
YUPON ST
CASTLE CT
MIRAMAR
MONTROSE BLVD
KYLE ST
ROSELAND ST
STANFORD ST
GREELEY ST
JACK ST
GARROTT ST
BUTE ST
BRANDT ST
TRAVIS ST
WINBERN ST
BERRY ST
CAROLINE ST
FRANCIS ST
HOLMAN ST
ALABAMA ST
SAN JACINTO ST
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AUSTIN ST
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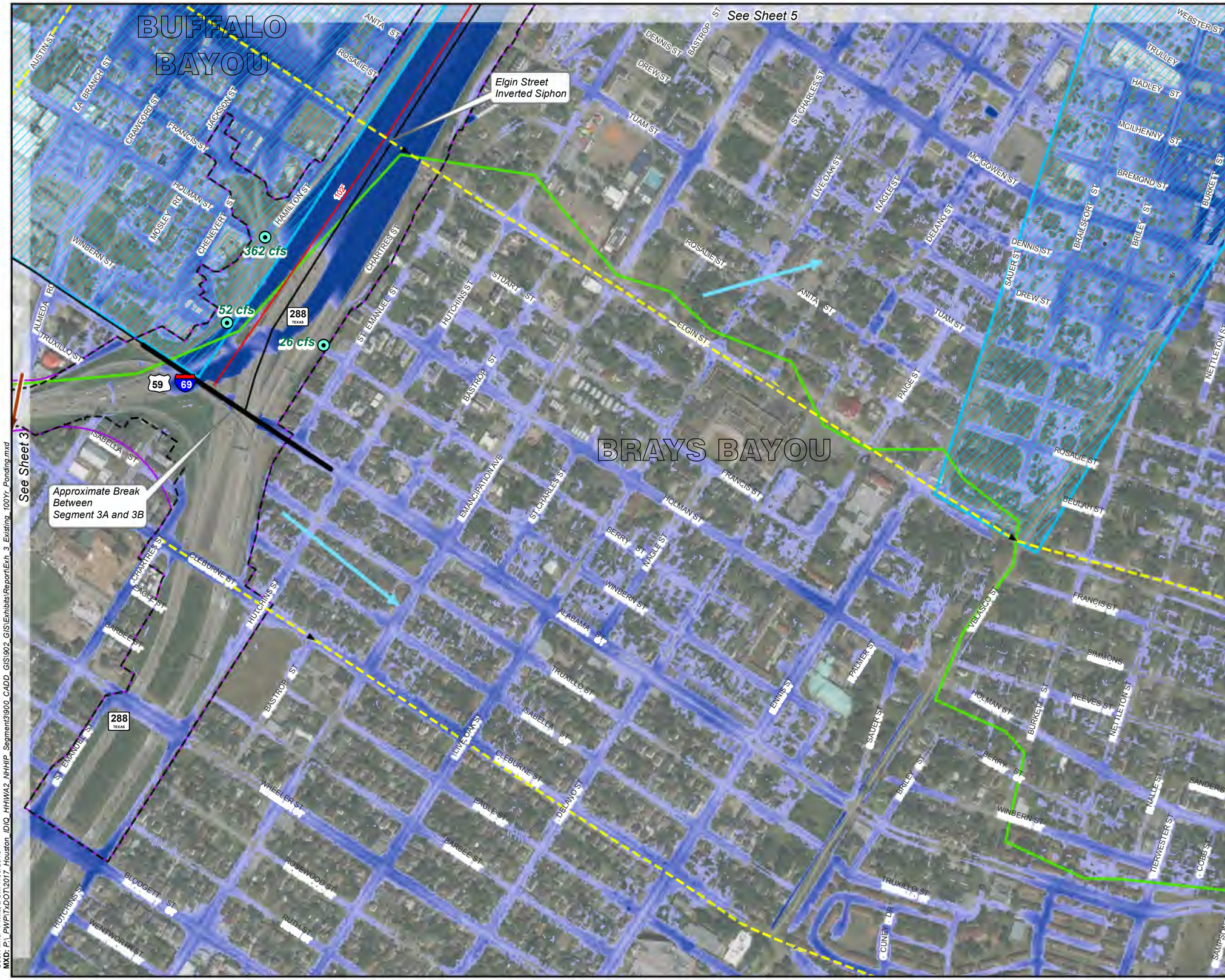
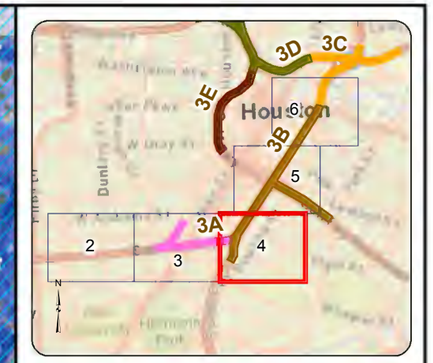
PINEDALE





Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- HCFCD Streams
- HCFCD Watersheds
- TxDOT Storm Sewer
- COH Primary Outfall
- Existing Outfalls
- Existing Flow Access Points
- Major Overland Flowpaths
- General Overland Flow Direction
- Potential Sheetflow Limits
- Major Ponding Areas

Existing 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 250 500

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Existing 100-Year Storm Event Ponding

SHEET 4 OF 6

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HOU	HARRIS	0500	03	601	3

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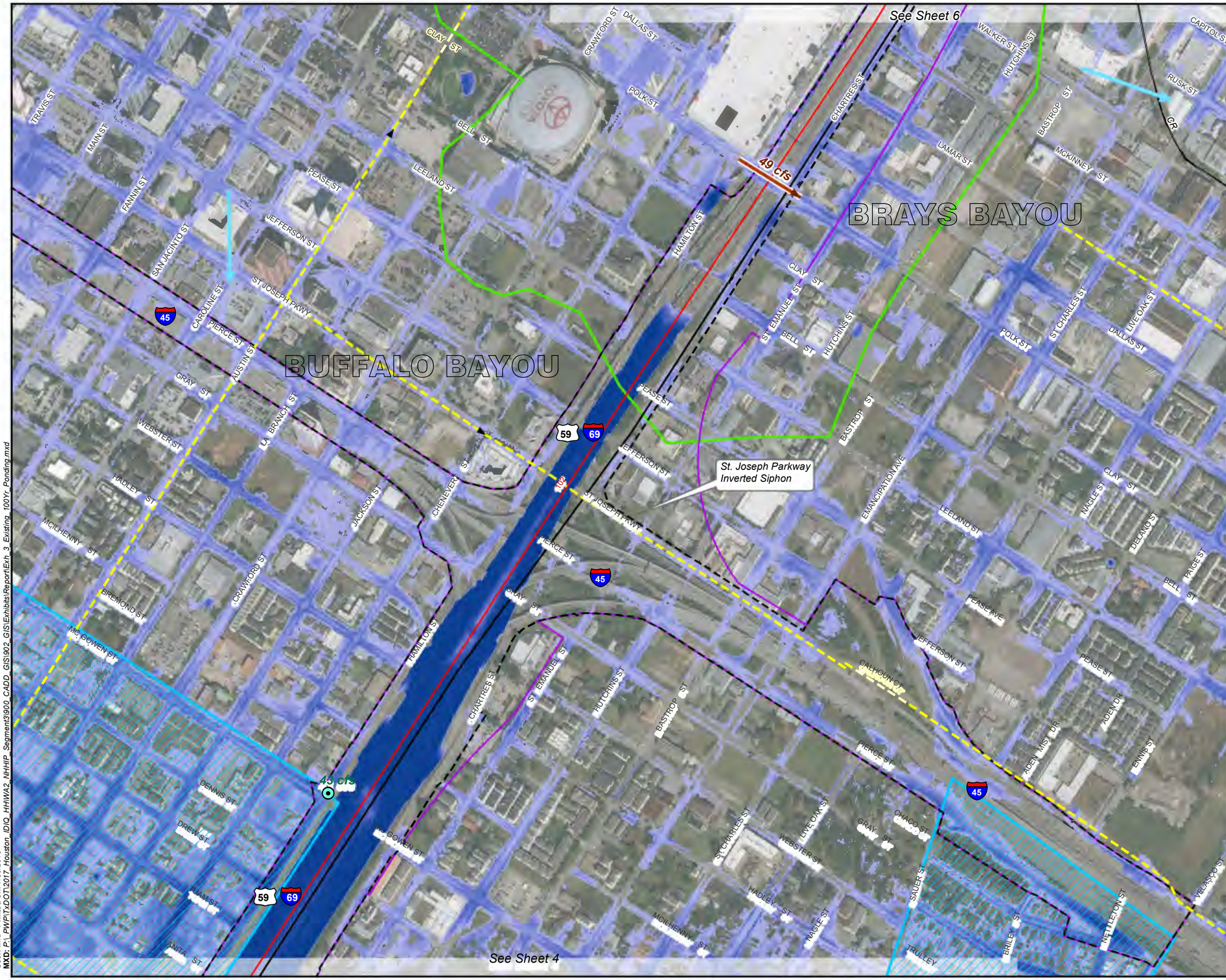

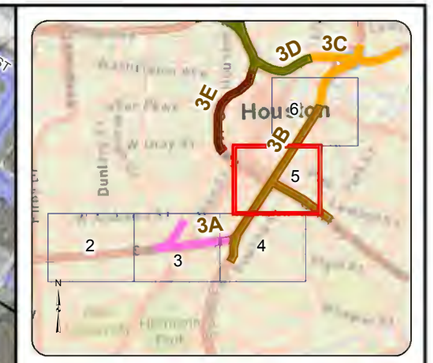

Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- HCFCD Streams
- HCFCD Watersheds
- TxDOT Storm Sewer
- COH Primary Outfall
- Existing Outfalls
- Existing Flow Access Points
- Major Overland Flowpaths
- General Overland Flow Direction
- Potential Sheetflow Limits
- Major Ponding Areas

Existing 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 250 500

Date of Aerial: 2017
Datum: NAVD 1988, 2001 Adj.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Existing 100-Year Storm Event Ponding

SHEET 5 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	3

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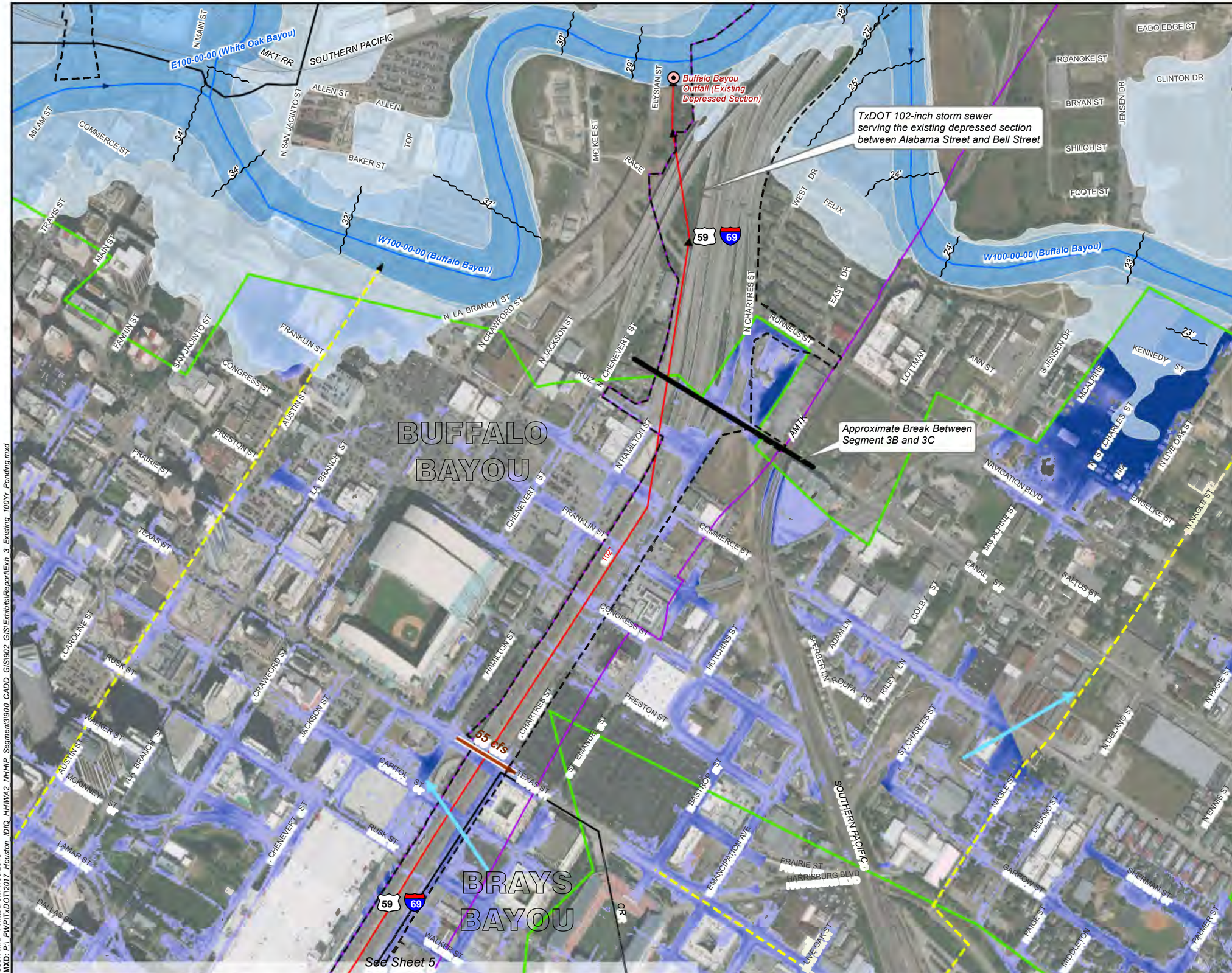

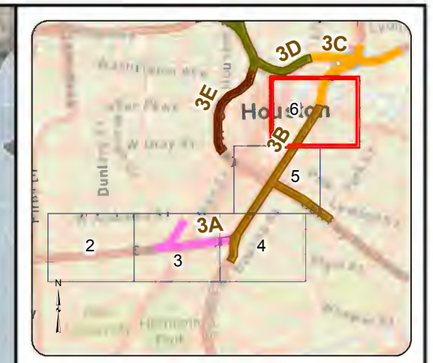

Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- HCFCD Streams
- HCFCD Watersheds
- TxDOT Storm Sewer
- COH Primary Outfall
- Existing Outfalls
- Major Overland Flowpaths
- General Overland Flow Direction
- Potential Sheetflow Limits

Existing 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

FEMA Flood Hazard Zones

- Regulatory Floodway
- 1% Annual Chance Flood Hazard
- 0.2% Annual Chance Flood Hazard
- Base Flood Elevation

0 250 500

Date of Aerial: 2017
Datum: NAVD 1988, 2001 Adj.

N

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Existing 100-Year Storm Event Ponding

SHEET 6 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	3

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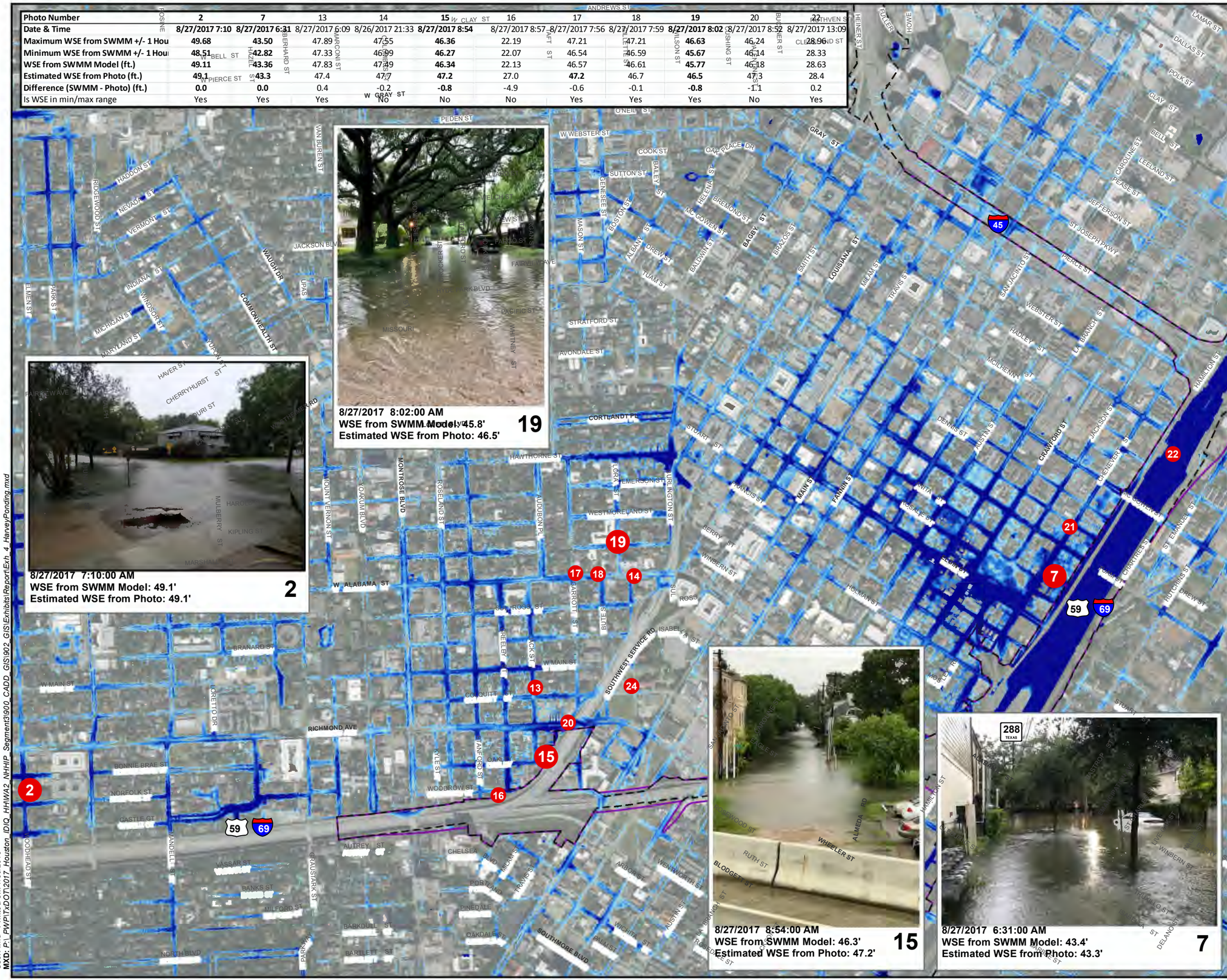
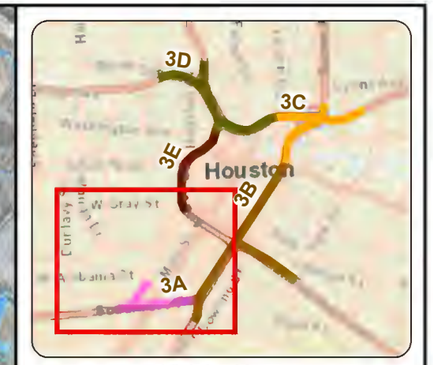
Maximum WSE from SWMM +/- 1 Hou	49.68	43.50	47.89	47.55	46.36	22.19	47.21	47.21	46.63	46.24	28.96
Minimum WSE from SWMM +/- 1 Hou	48.51	42.82	47.33	46.99	46.27	22.07	46.54	46.59	45.67	46.14	28.33
WSE from SWMM Model (ft.)	49.11	43.36	47.83	47.49	46.34	22.13	46.57	46.61	45.77	46.18	28.63
Estimated WSE from Photo (ft.)	49.1	43.3	47.4	47.7	47.2	27.0	47.2	46.7	46.5	47.3	28.4
Difference (SWMM - Photo) (ft.)	0.0	0.0	0.4	-0.2	-0.8	-4.9	-0.6	-0.1	-0.8	-1.1	0.2
Is WSE in min/max range	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes





Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- Harvey Photo Locations
- Existing Harvey Maximum Ponding

N

0 500 1,000 Feet

Date of Aerial: 2017
Datum: NAVD 1988, 2001 Adj.

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Harvey Event Ponding

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	4

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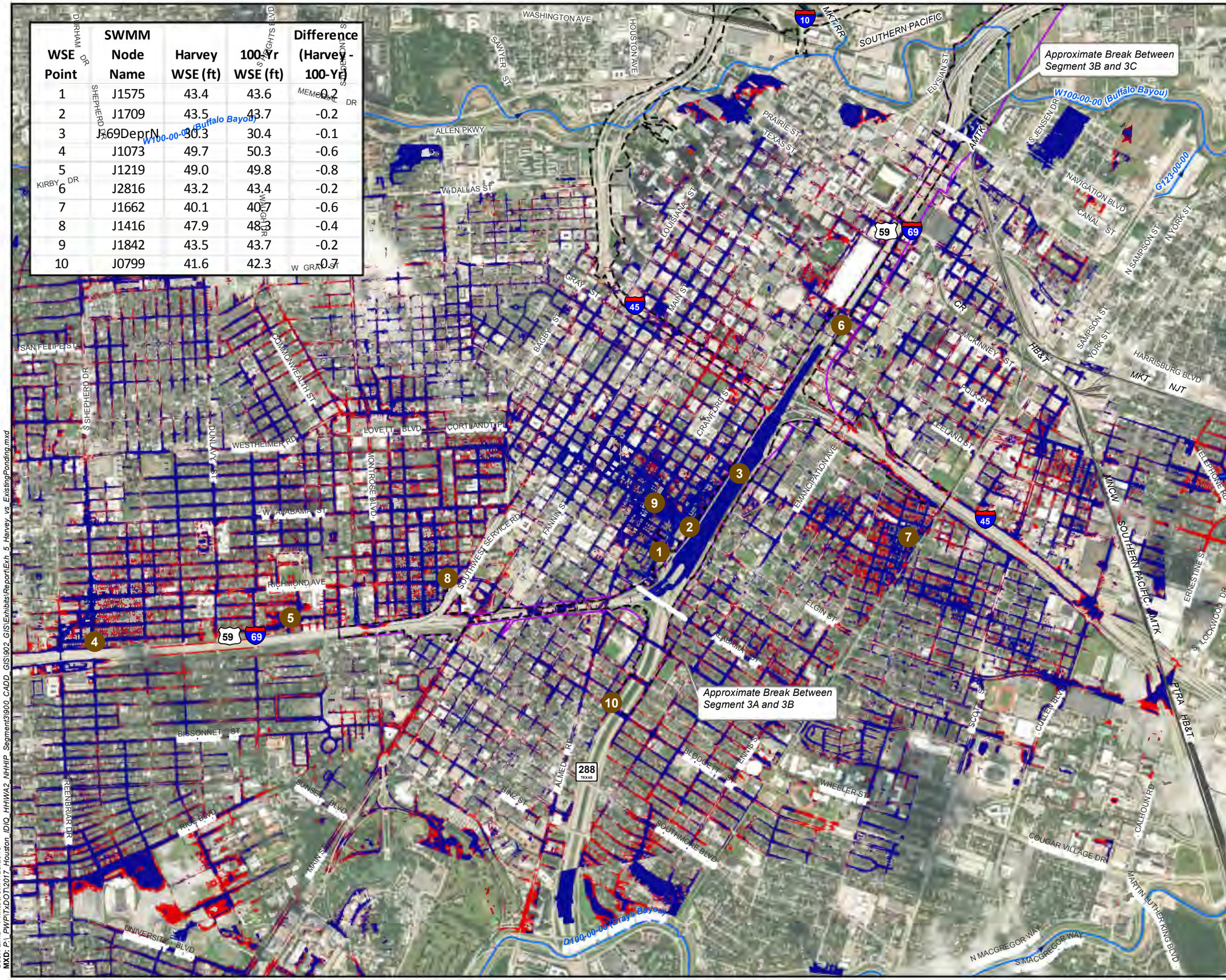
WSE Point	SWMM Node Name	Harvey WSE (ft)	100-Yr WSE (ft)	Difference (Harvey - 100-Yr)
1	J1575	43.4	43.6	-0.2
2	J1709	43.5	43.7	-0.2
3	J269DeprN	30.3	30.4	-0.1
4	J1073	49.7	50.3	-0.6
5	J1219	49.0	49.8	-0.8
6	J2816	43.2	43.4	-0.2
7	J1662	40.1	40.7	-0.6
8	J1416	47.9	48.3	-0.4
9	J1842	43.5	43.7	-0.2
10	J0799	41.6	42.3	-0.7



Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- Railroads
- HCFCD Streams
- WSE Comparison Points
- Existing 100-Yr Ponding
- Harvey Ponding

N

0 1,000 2,000

Date of Aerial: 2017
Datum: NAVD 1988, 2001 Adj.

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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North Houston Highway Improvement Project
Segment 3B Drainage Study
Overland Flow Analysis
Harvey Event vs.
Existing 100-Year Storm Event Ponding

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	5

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Pond A

Pond A – Phase 1

Depressed Section + Hamilton Street + St Emanuel Street

The Buffalo Bayou Pump Station Services the Depressed Section from Clay Street to Canal Street.

Existing System Outfalls to Buffalo Bayou

Approximate Break Between Segment 3B and 3C

Note:
There will be an automated sluice gate to allow the systems to connect in case of pump station failure.

Existing System Outfalls to Brays Bayou

I-45 South

I-45 Pump Station Services the Depressed Section from Alabama Street to Clay Street

Chartres Street

Existing System Outfalls to Brays Bayou

Potential Segment 3A Detention and Pump Station Location

Approximate Break Between Segment 3A and 3B

SH-288 SB

SH-288 NB

Existing System Outfalls to Brays Bayou

Notes:
1. Flows for the Hamilton Street and St. Emanuel Collector Systems are based on a combination of the rational method and overland flows determined from the overland flow analysis as discussed in Section 4 of the Drainage Report.
2. Refer to the Design Sheets for the Proposed I-45 Pump Station Layout Sheets.
3. Refer to the Detention Basin Design Sheet and Buffalo Bayou Pump Station Design Sheets for further details on these layouts.

Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- Proposed Covered Section
- Water Feature
- Proposed System Outfalls
- Emergency Storm Connection
- Pond A
- Pond A – Phase 1
- Proposed Pump Station Site
- Potential Segment 3A Detention and Pump Station Location

Proposed Drainage Area System

- Chartres
- Cleburne
- Depressed Section
- Hamilton Street
- I-45 South
- SH-288 North
- SH-288 South
- St. Emanuel

FEMA Flood Hazard Zones

- Regulatory Floodway
- 1% Annual Chance Flood Hazard
- 0.2% Annual Chance Flood Hazard

N

0 1,000 2,000 Feet

Imagery from ESRI, DigitalGlobe, 2017;
Existing storm sewer from the City of Houston, Public Works and Engineering on 3/19/2014.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 1 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6

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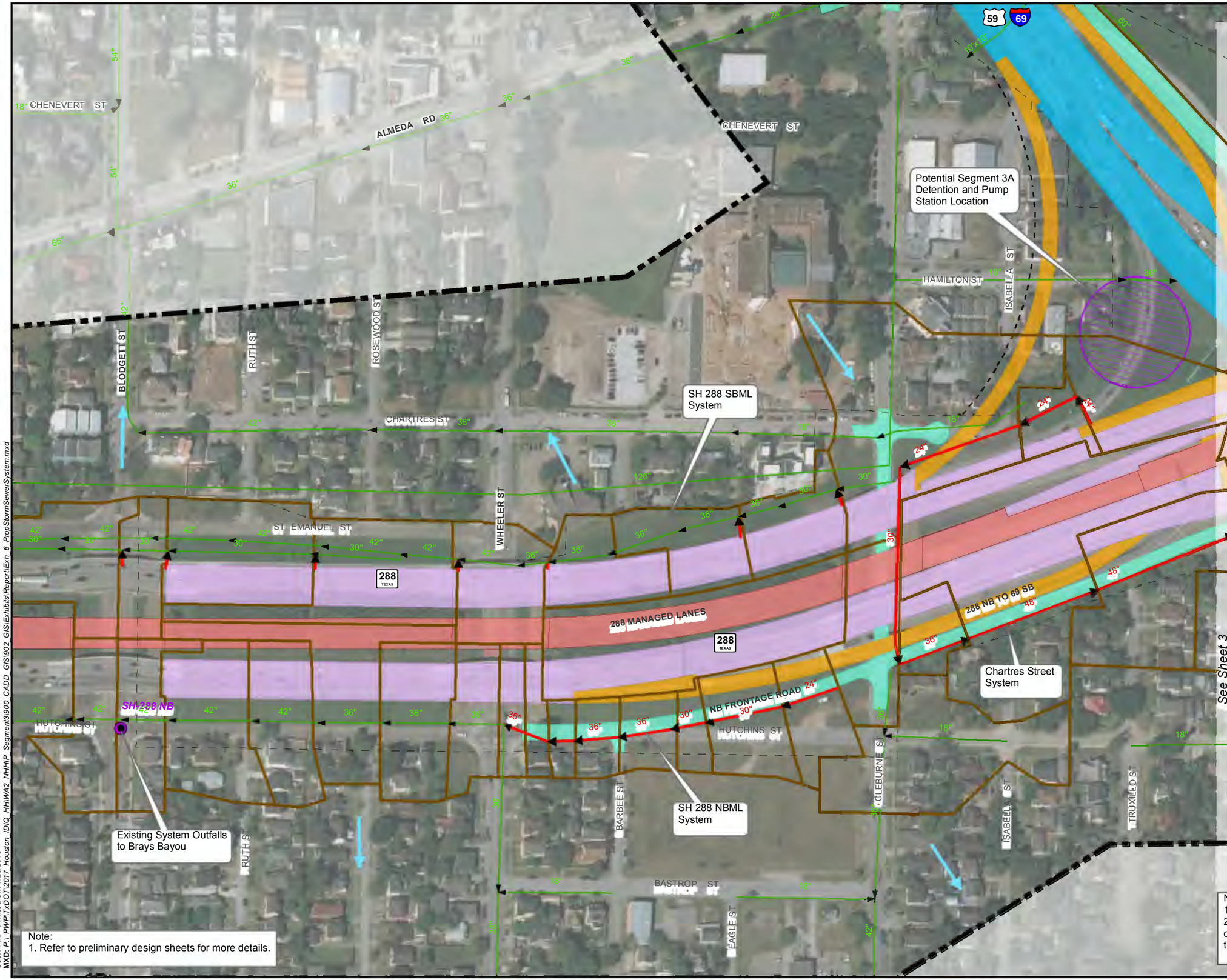

Note:
1. Refer to preliminary design sheets for more details.

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Sheetflow Direction
- Proposed System Outfalls
- Existing Storm Sewer
- Proposed Trunklines
- Proposed Drainage Areas
- Potential Segment 3A Detention and Pump Station Location

Proposed Roadways

- I-69/US 59 Mainlanes
- Max Lanes
- Direct Connectors
- SH 288 Mainlanes
- Frontage/Local Roads

N

0 100 200 Feet

Imagery from ESRI, DigitalGlobe, 2017;
Existing storm sewer from the City of Houston, Public Works and Engineering on 3/19/2014.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 2 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6

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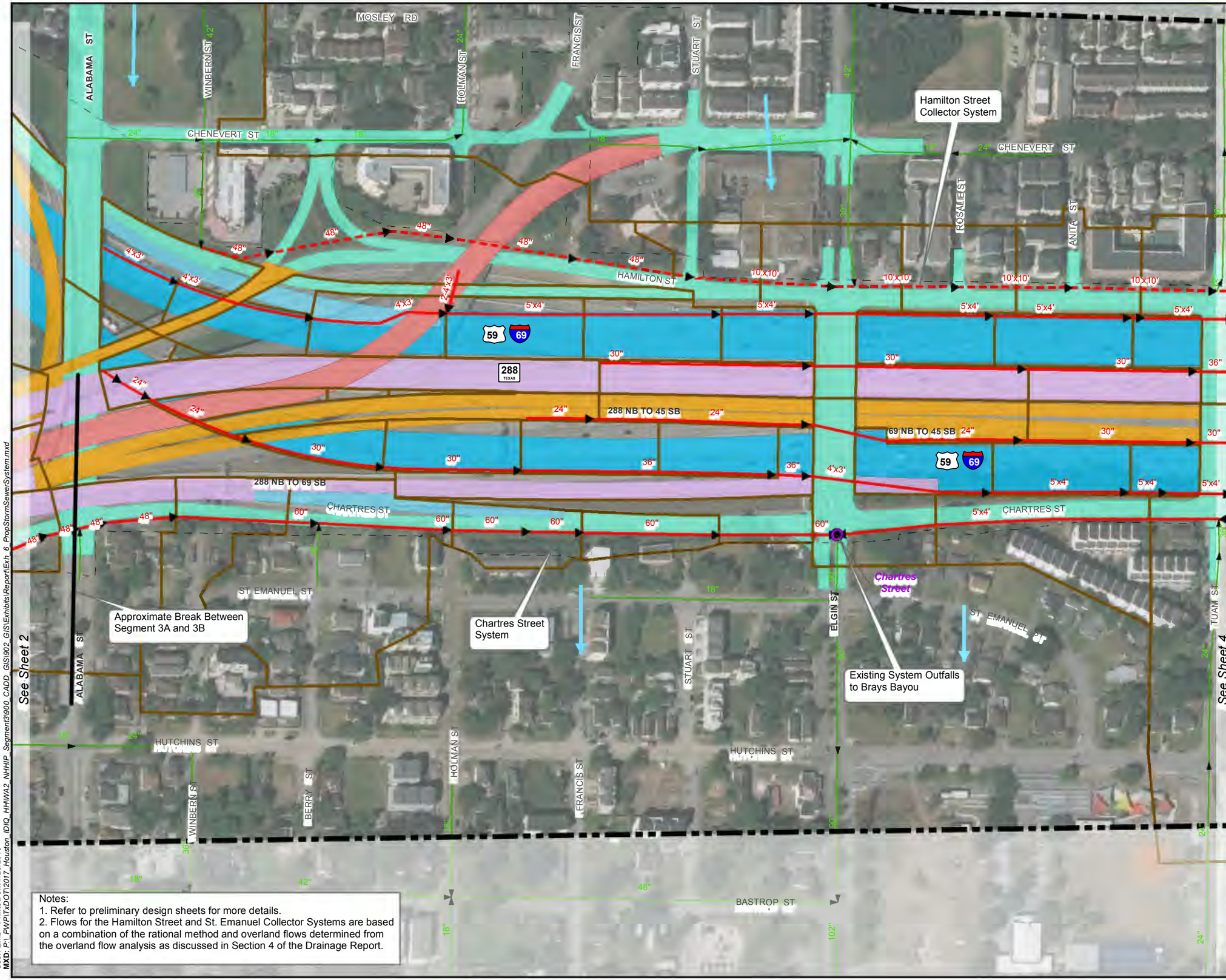

Notes:
1. Refer to preliminary design sheets for more details.
2. Flows for the Hamilton Street and St. Emanuel Collector Systems are based on a combination of the rational method and overland flows determined from the overland flow analysis as discussed in Section 4 of the Drainage Report.

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Sheetflow Direction
- Proposed System Outfalls
- Existing Storm Sewer
- Proposed Trunklines
- Proposed Collector Systems
- Proposed Drainage Areas

Proposed Roadways

- I-69/US 59 Mainlanes
- Max Lanes
- Ramps
- Direct Connectors
- SH 288 Mainlanes
- Frontage/Local Roads

0 100 200 Feet

Imagery from ESRI, DigitalGlobe, 2017; Existing storm sewer from the City of Houston, Public Works and Engineering on 3/19/2014.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 3 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6

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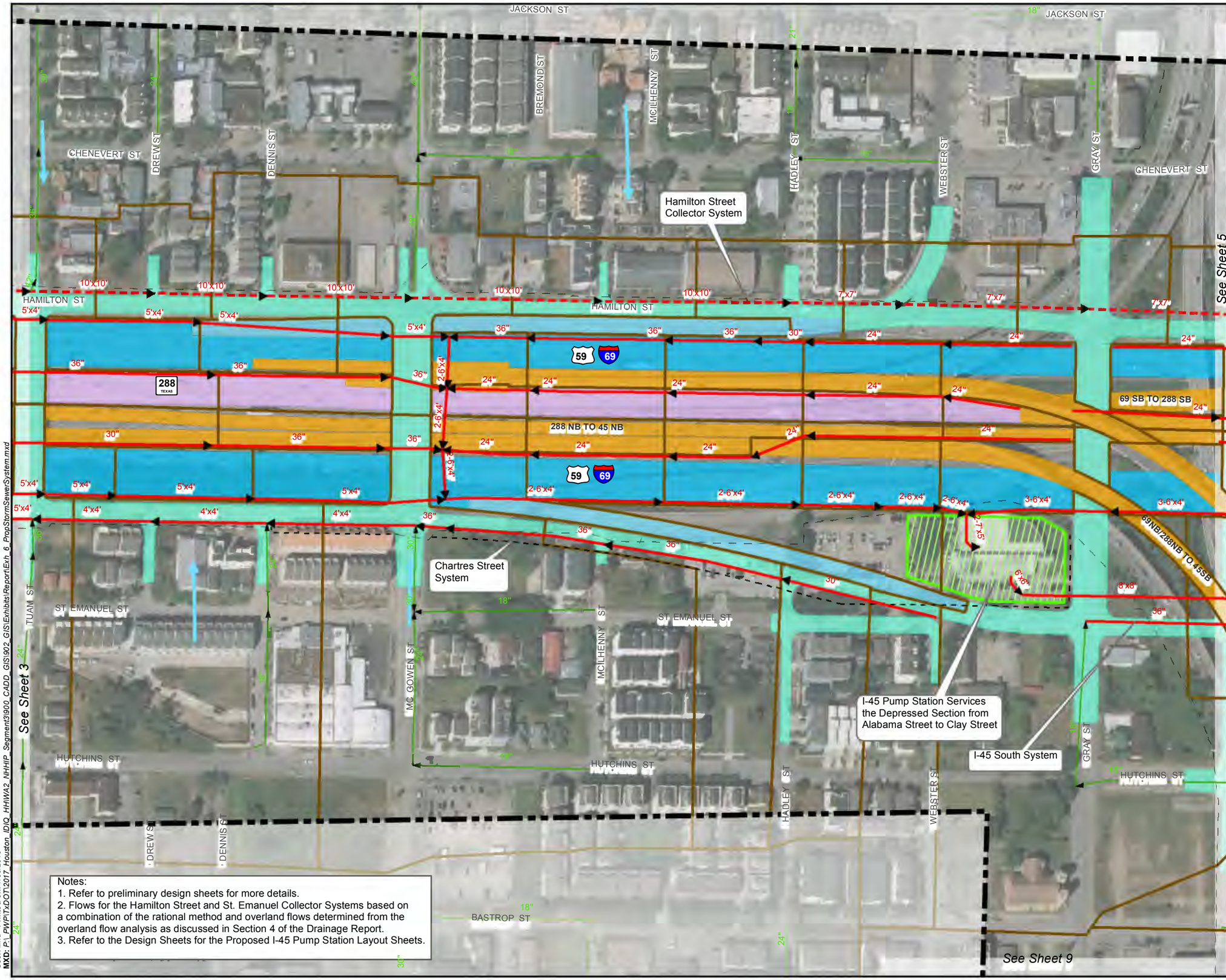

Notes:
1. Refer to preliminary design sheets for more details.
2. Flows for the Hamilton Street and St. Emanuel Collector Systems based on a combination of the rational method and overland flows determined from the overland flow analysis as discussed in Section 4 of the Drainage Report.
3. Refer to the Design Sheets for the Proposed I-45 Pump Station Layout Sheets.

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Sheetflow Direction
- Existing Storm Sewer
- Proposed Trunklines
- Proposed Collector Systems
- Proposed Drainage Areas
- Proposed Pump Station Site

Proposed Roadways

- I-69/US 59 Mainlanes
- Ramps
- Direct Connectors
- SH 288 Mainlanes
- Frontage/Local Roads

0 100 200 Feet

Imagery from ESRI, DigitalGlobe, 2017; Existing storm sewer from the City of Houston, Public Works and Engineering on 3/19/2014.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 4 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6

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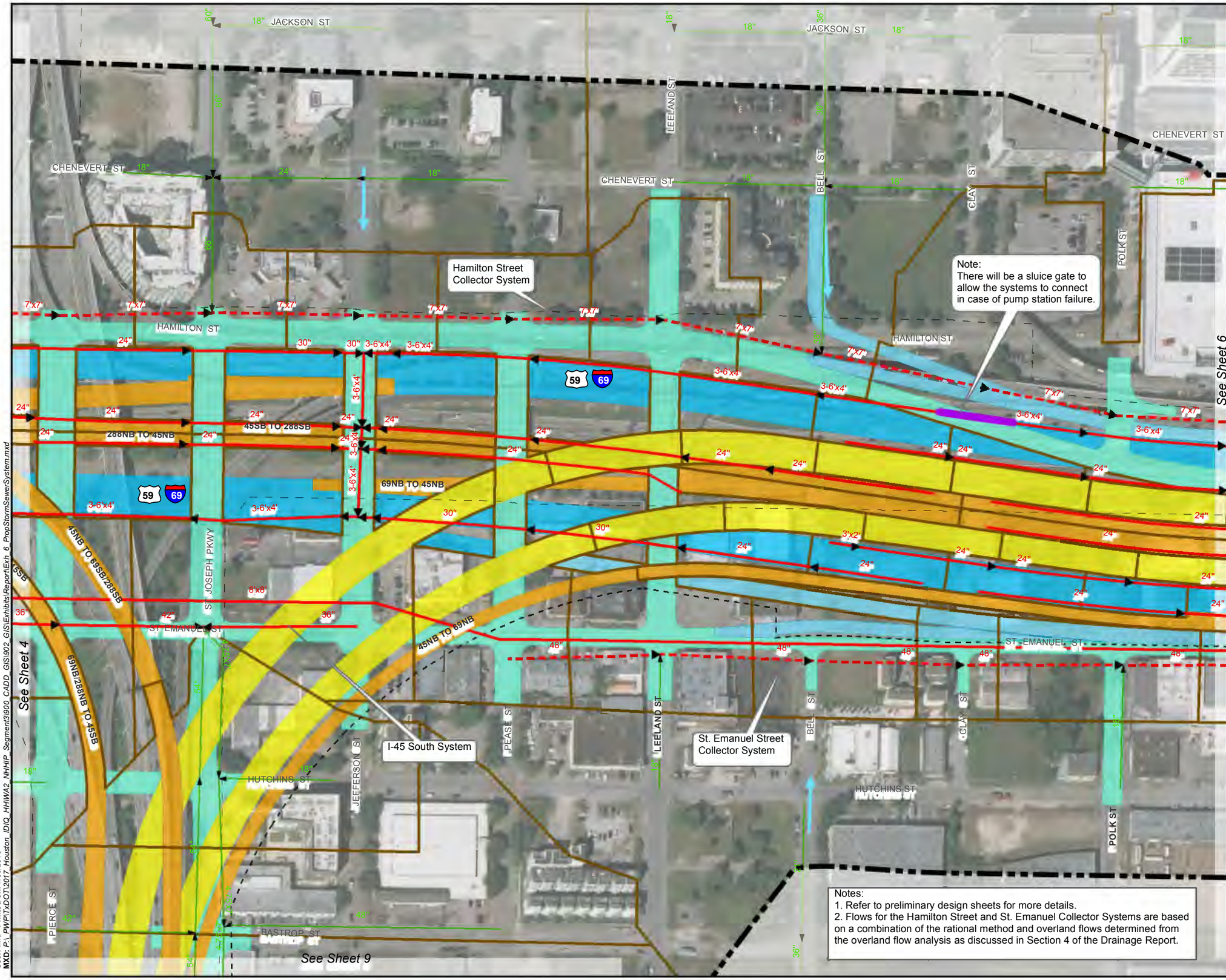

Notes:
1. Refer to preliminary design sheets for more details.
2. Flows for the Hamilton Street and St. Emanuel Collector Systems are based on a combination of the rational method and overland flows determined from the overland flow analysis as discussed in Section 4 of the Drainage Report.

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Sheetflow Direction
- Existing Storm Sewer
- Proposed Trunklines
- Proposed Collector Systems
- Emergency Storm Connection
- Proposed Drainage Areas

Proposed Roadways

- I-69/US 59 Mainlanes
- Ramps
- Direct Connectors
- Frontage/Local Roads
- I-45 Mainlanes

N

0 100 200 Feet

Imagery from ESRI, DigitalGlobe, 2017;
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North Houston Highway Improvement Project
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 5 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6

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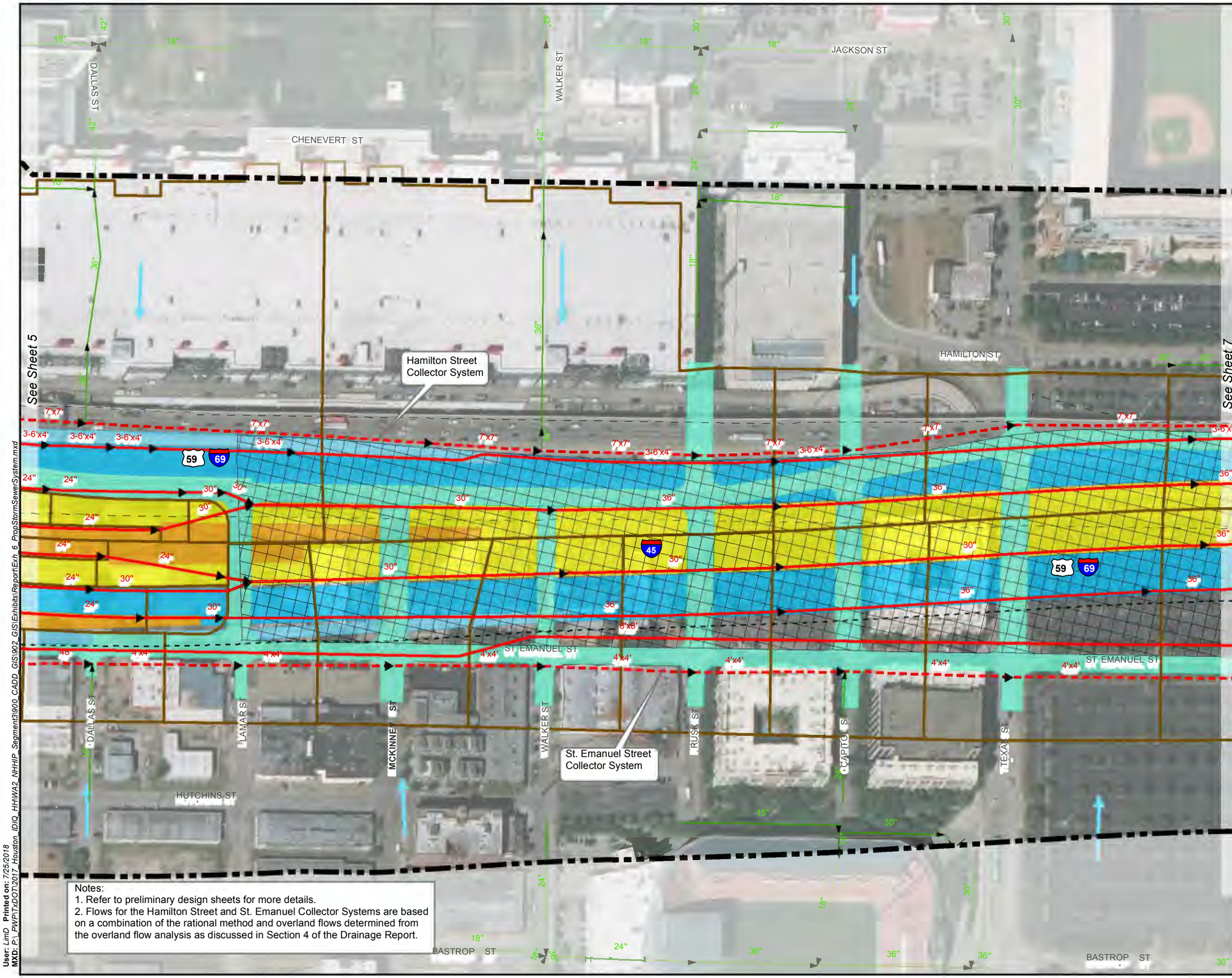

Notes:
1. Refer to preliminary design sheets for more details.
2. Flows for the Hamilton Street and St. Emanuel Collector Systems are based on a combination of the rational method and overland flows determined from the overland flow analysis as discussed in Section 4 of the Drainage Report.

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Proposed Covered Section
- Water Feature
- Sheetflow Direction
- Existing Storm Sewer
- Proposed Trunklines
- Proposed Collector Systems
- Proposed Drainage Areas

Proposed Roadways

- I-69/US 59 Mainlanes
- Ramps
- Direct Connectors
- Frontage/Local Roads
- I-45 Mainlanes

N

0 100 200 Feet

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 6 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6

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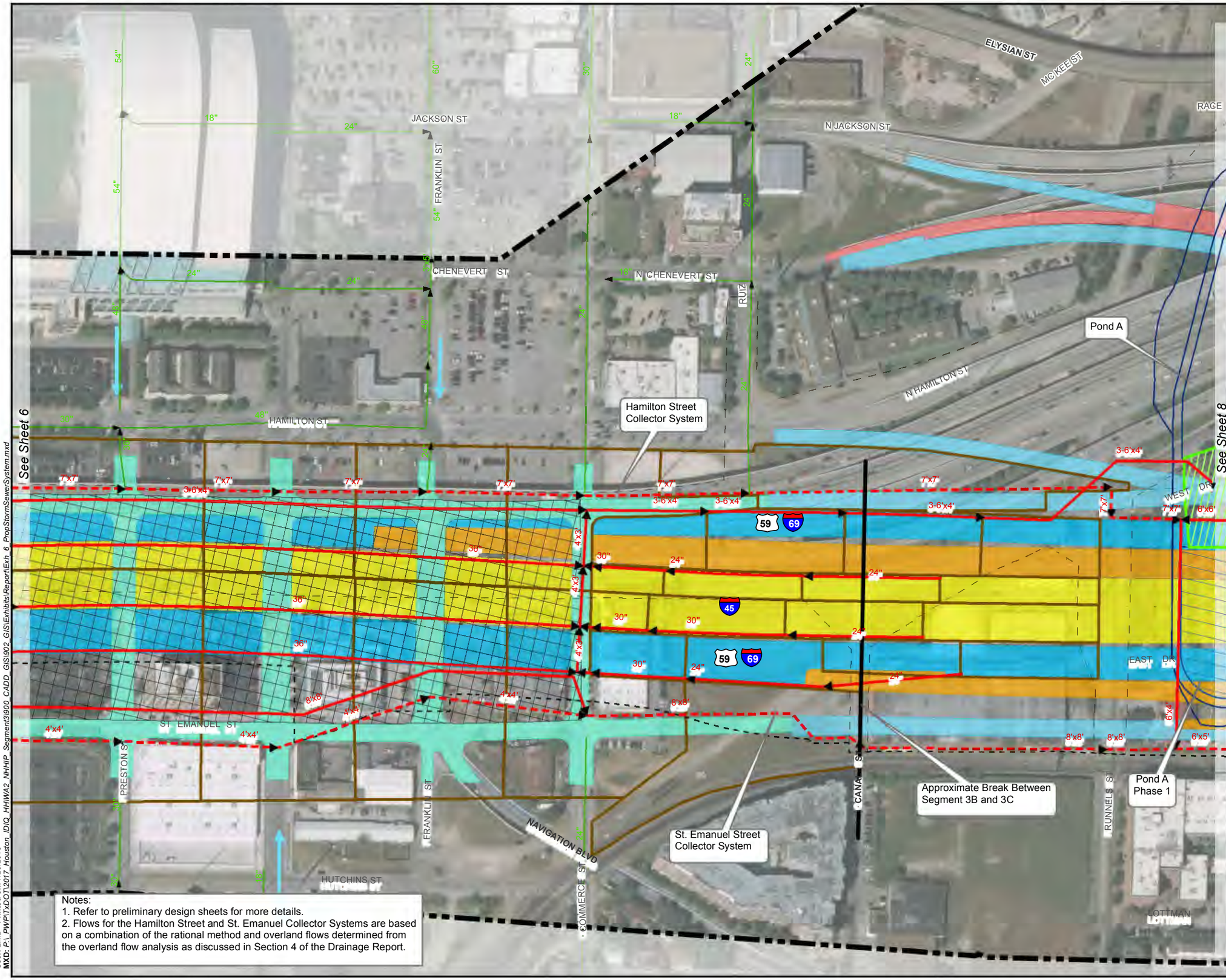

Notes:
1. Refer to preliminary design sheets for more details.
2. Flows for the Hamilton Street and St. Emanuel Collector Systems are based on a combination of the rational method and overland flows determined from the overland flow analysis as discussed in Section 4 of the Drainage Report.

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Proposed Covered Section
- Water Feature
- Sheetflow Direction
- Existing Storm Sewer
- Proposed Trunklines
- Proposed Collector Systems
- Proposed Drainage Areas
- Pond A
- Pond A – Phase 1
- Proposed Pump Station Site

Proposed Roadways

- I-69/US 59 Mainlanes
- Max Lanes
- Ramps
- Direct Connectors
- Frontage/Local Roads
- I-45 Mainlanes

FEMA Flood Hazard Zones

- 0.2% Annual Chance Flood Hazard

N

0 100 200 Feet

Imagery from ESRI, DigitalGlobe, 2017; Existing storm sewer from the City of Houston, Public Works and Engineering on 3/19/2014.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 7 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6

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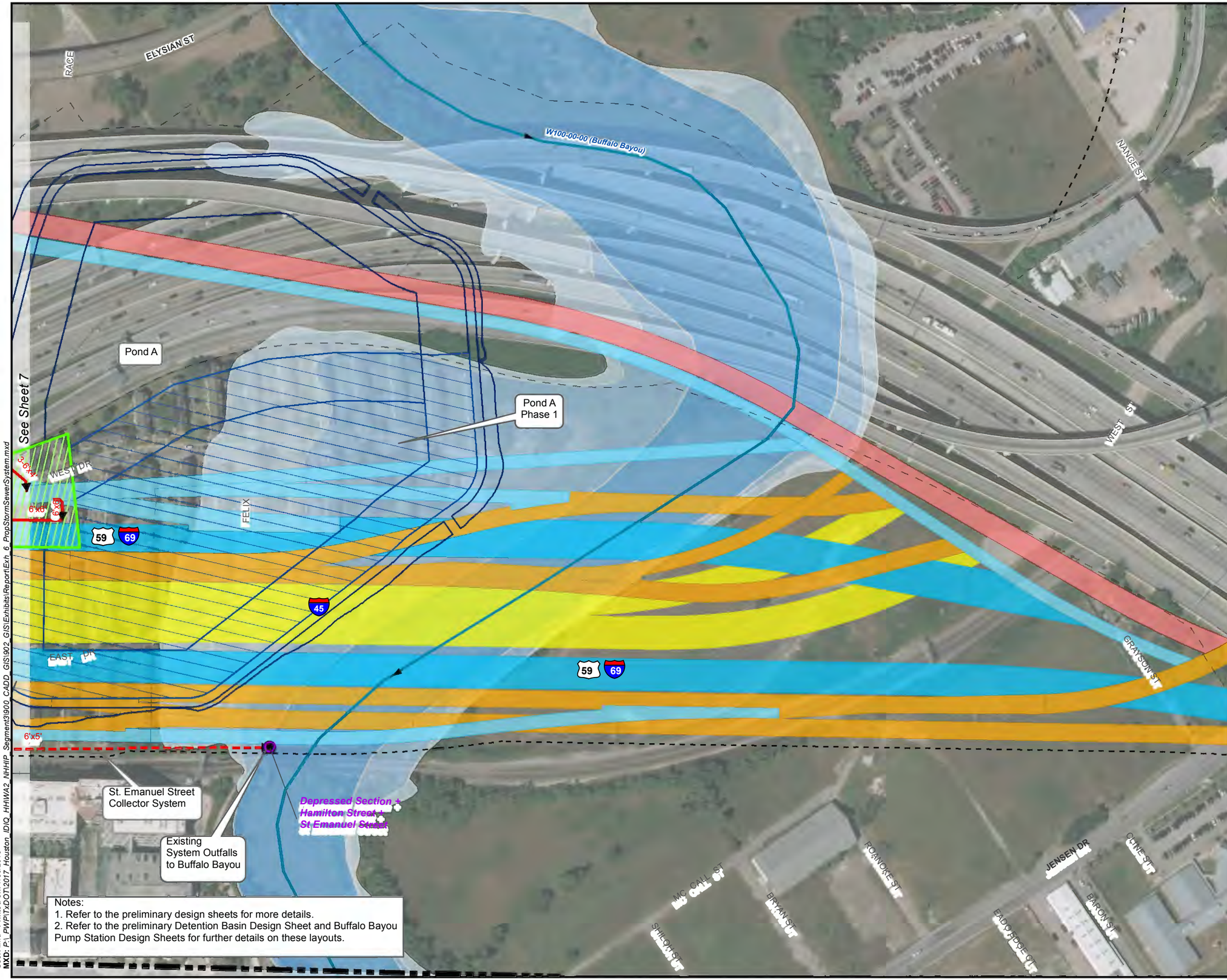

Notes:
1. Refer to the preliminary design sheets for more details.
2. Refer to the preliminary Detention Basin Design Sheet and Buffalo Bayou Pump Station Design Sheets for further details on these layouts.

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Proposed System Outfalls
- Proposed Trunklines
- Proposed Collector Systems
- Pond A
- Pond A – Phase 1
- Proposed Pump Station Site

Proposed Roadways

- I-69/US 59 Mainlanes
- Max Lanes
- Ramps
- Direct Connectors
- I-45 Mainlanes

FEMA Flood Hazard Zones

- Regulatory Floodway
- 1% Annual Chance Flood Hazard
- 0.2% Annual Chance Flood Hazard

N

0 100 200 Feet

Imagery from ESRI, DigitalGlobe, 2017;
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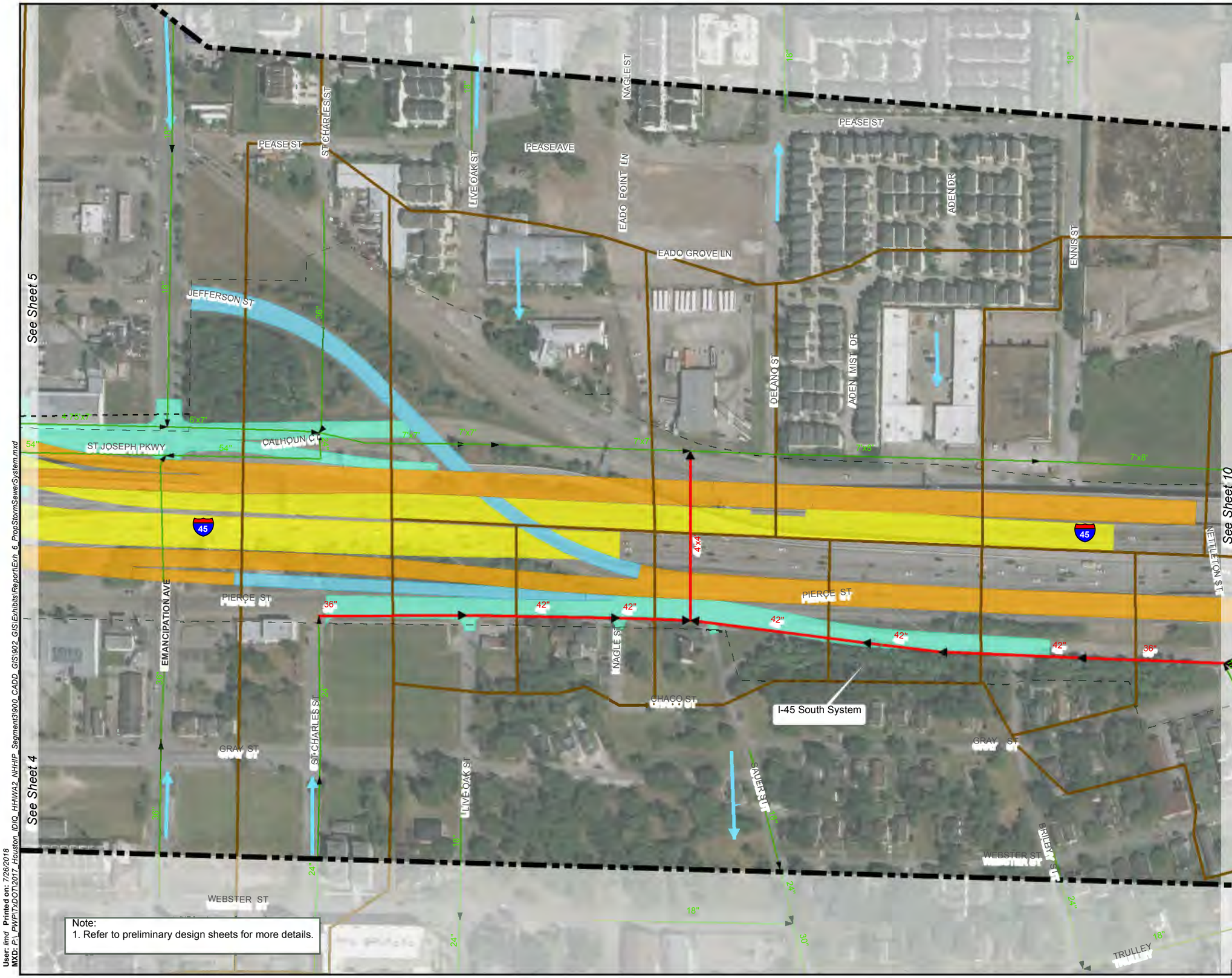
North Houston Highway Improvement Project
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 8 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6

User: limd Printed on: 7/30/2018
MXD: P:_PWP\TxDOT\2017_Houston_IDIQ_HHWA2_NHHIP_Segment3\900_CADD_GIS\902_GIS\Exhibits\Report\Exh_6_PropStormSewerSystem.mxd



Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Sheetflow Direction
- Existing Storm Sewer
- Proposed Trunklines
- Proposed Drainage Areas

Proposed Roadways

- Ramps
- Direct Connectors
- Frontage/Local Roads
- I-45 Mainlanes

N

0 100 200 Feet

Imagery from ESRI, DigitalGlobe, 2017;
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North Houston Highway Improvement Project
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 9 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6

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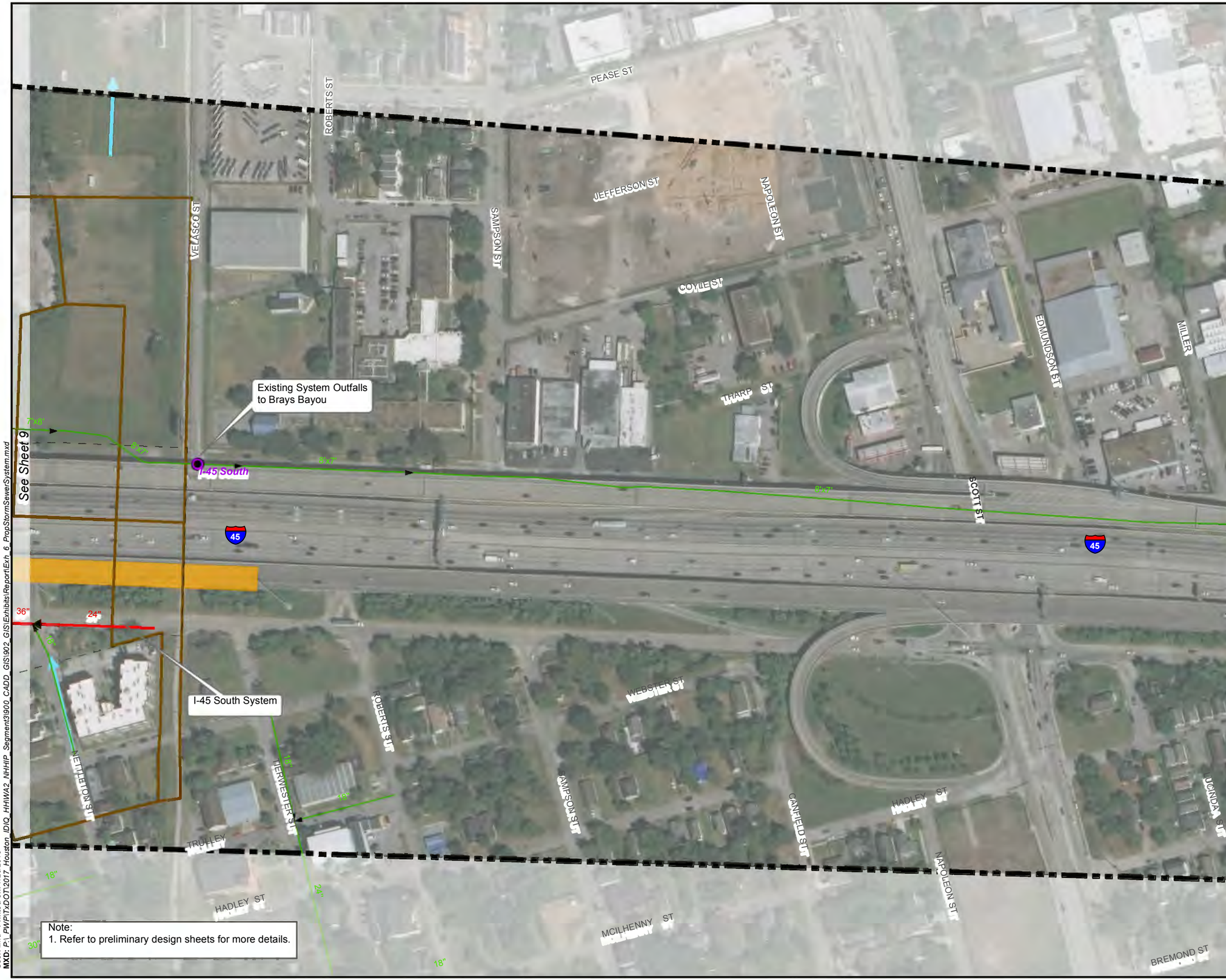

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Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Sheetflow Direction
- Proposed System Outfalls
- Existing Storm Sewer
- Proposed Trunklines
- Proposed Drainage Areas

Proposed Roadways

- Direct Connectors

N

0 100 200 Feet

Imagery from ESRI, DigitalGlobe, 2017;
Existing storm sewer from the City of Houston,
Public Works and Engineering on 3/19/2014.

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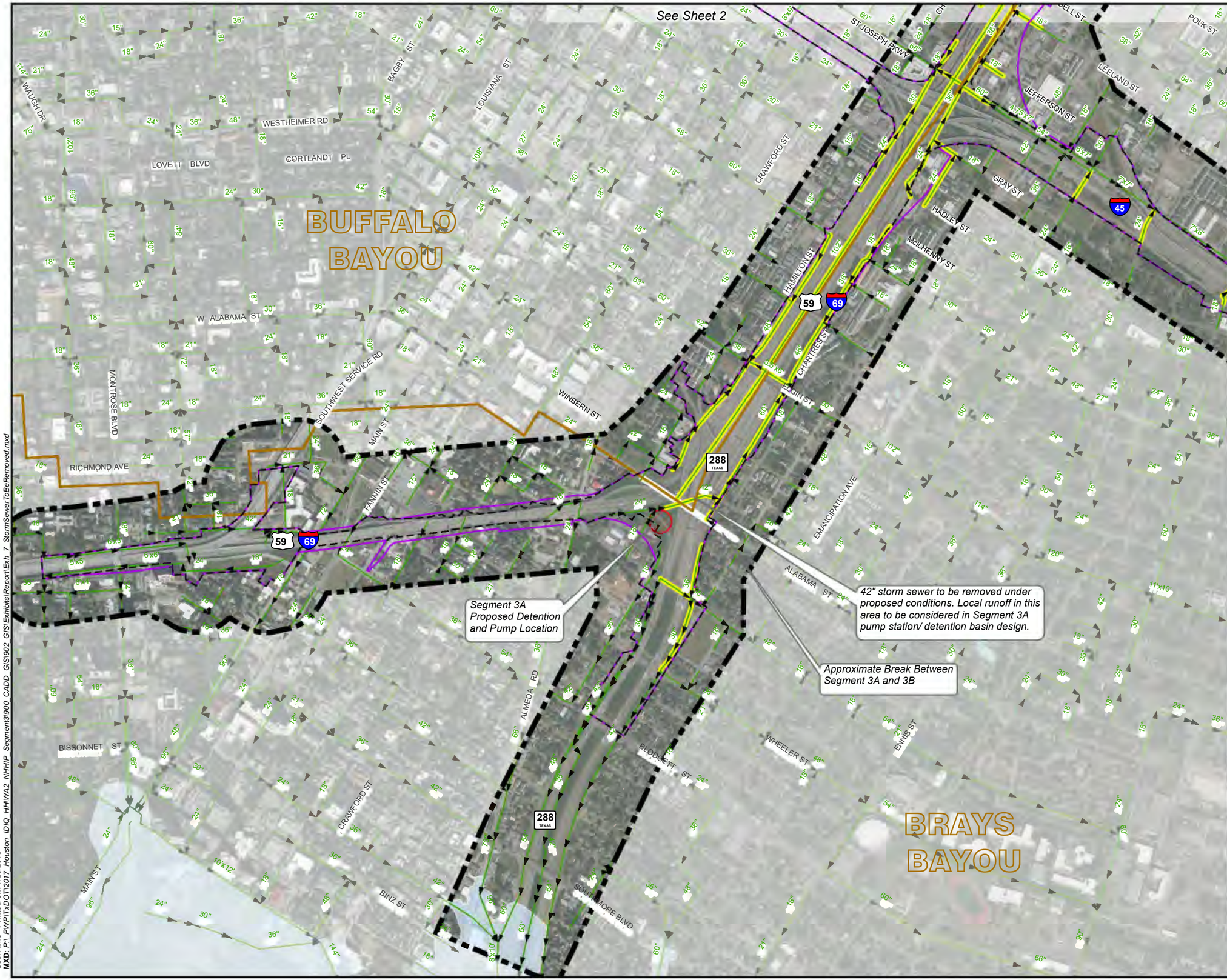
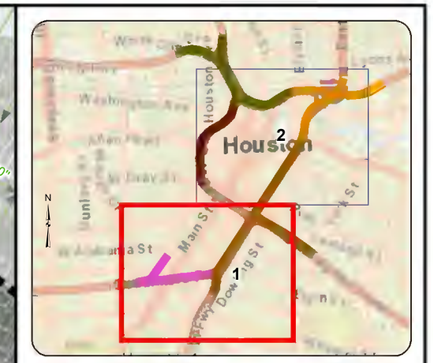
Segment 3B Drainage Study

Storm Drain Design
Proposed Storm Sewer System

SHEET 10 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	6





Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- HCFCD Streams
- HCFCD Watersheds
- Existing Storm Sewer
- Storm Sewer to be Removed
- Proposed Pump Station Site

FEMA Flood Hazard Zones

- 0.2% Annual Chance Flood Hazard

N

0 500 1,000

Date of Aerial: 2017
Datum: NAVD 1988, 2001 Adj.

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Potential Storm Sewer Removal

SHEET 1 OF 2

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	7

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WHITE OAK BAYOU

BUFFALO BAYOU

BRAYS BAYOU

E100-00-00 (White Oak Bayou)

W100-00-00 (Buffalo Bayou)

G123-00-00

TxDOT 102-inch storm sewer serving the existing depressed section between I-45 and SH-288

Approximate Break Between Segment 3B and 3C

See Sheet 1

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Railroads
- HCFCD Streams
- HCFCD Watersheds
- Existing Storm Sewer
- Storm Sewer to be Removed

FEMA Flood Hazard Zones

- Regulatory Floodway
- 1% Annual Chance Flood Hazard
- 0.2% Annual Chance Flood Hazard
- Base Flood Elevation

N

0 500 1,000

Feet

Date of Aerial: 2017
Datum: NAVD 1988, 2001 Adj.

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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Segment 3B Drainage Study

Potential Storm Sewer Removal

SHEET 2 OF 2

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	7

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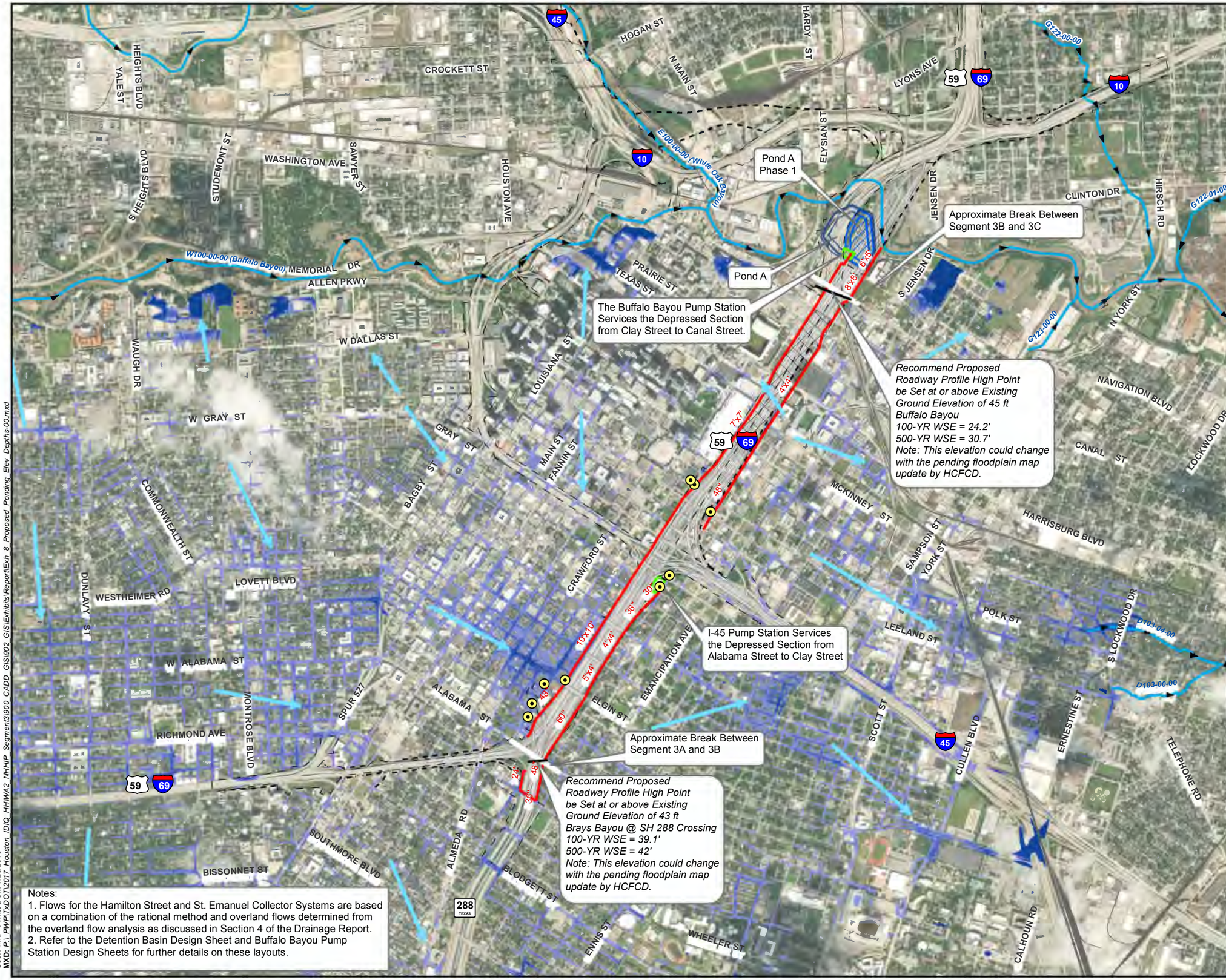

Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- Potential Sheet Flow Access Points
- Proposed Covered Section
- Water Feature
- Sheetflow Direction
- Proposed Trunklines
- Pond A
- Proposed Pump Station Site
- Pond A – Phase 1
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 1,000 2,000 Feet

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 1 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

Notes:
1. Flows for the Hamilton Street and St. Emanuel Collector Systems are based on a combination of the rational method and overland flows determined from the overland flow analysis as discussed in Section 4 of the Drainage Report.
2. Refer to the Detention Basin Design Sheet and Buffalo Bayou Pump Station Design Sheets for further details on these layouts.

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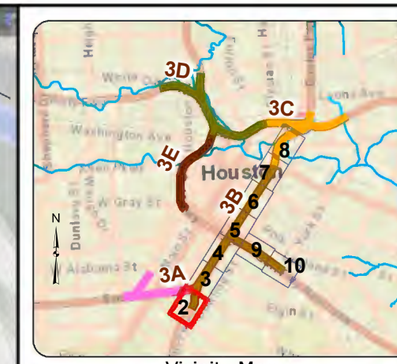

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Sheetflow Direction
- Proposed Trunklines
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 100 200 Feet

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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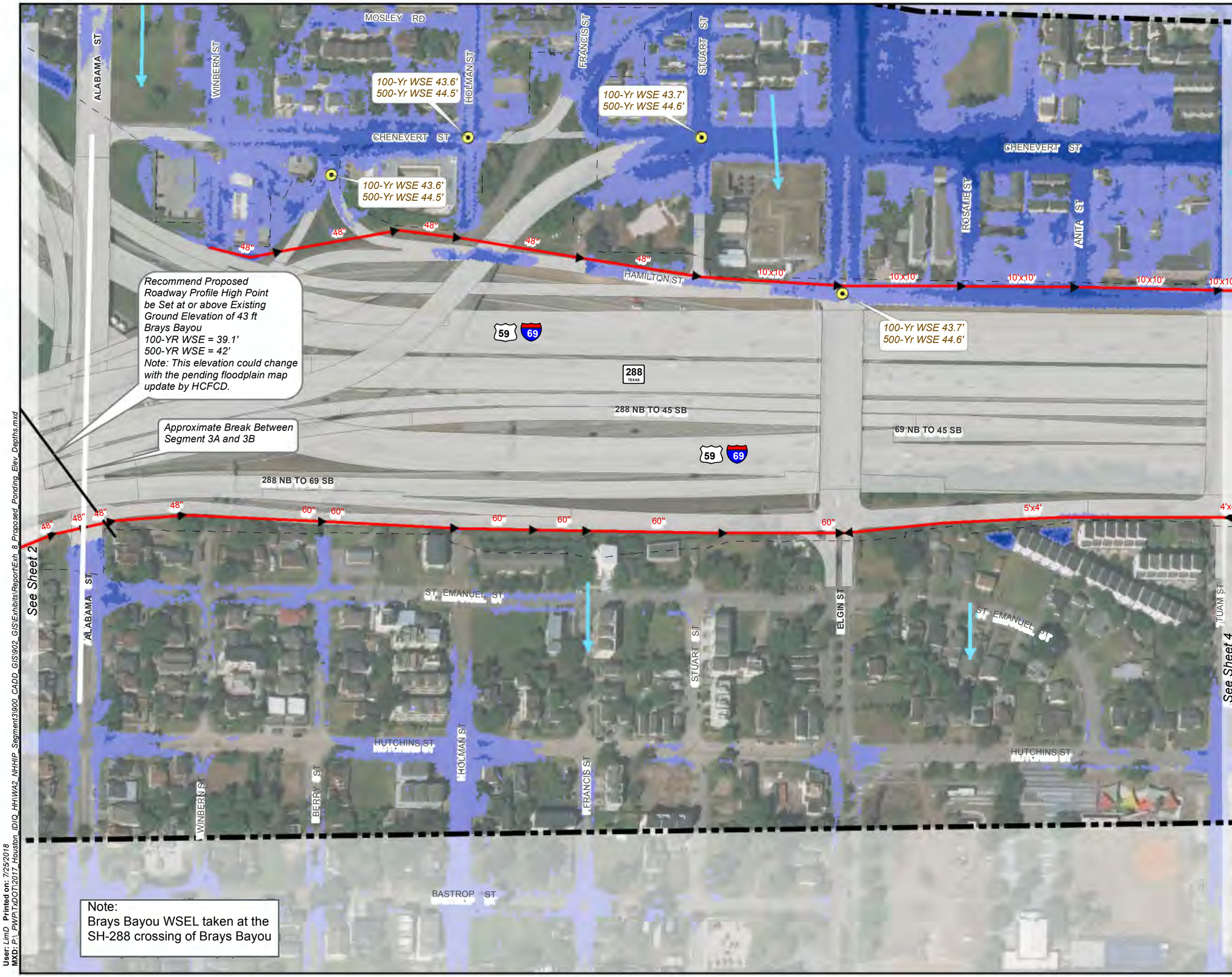
North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 2 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-71DP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

User: LimD Printed on: 7/25/2018
MXD: P:_PW\PTxDOT\2017_Houston_IDIQ_HH\WA2_NHHIP_Segment3\900_CADD_GIS\902_GIS\Exhibits\Report\Exh_8_Proposed_Ponding_Elev_Depths.mxd



Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Potential Sheet Flow Access Points
- Water Feature
- Sheetflow Direction
- Proposed Trunklines
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 100 200 Feet

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 3 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

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Note:
Refer to Appendix A for the Proposed I-45 Pump Station Layout Sheets

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Potential Sheet Flow Access Points
- Water Feature
- Sheetflow Direction
- Proposed Trunklines
- Proposed Pump Station Site
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 100 200 Feet

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 4 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

User: LimD Printed on: 7/25/2018
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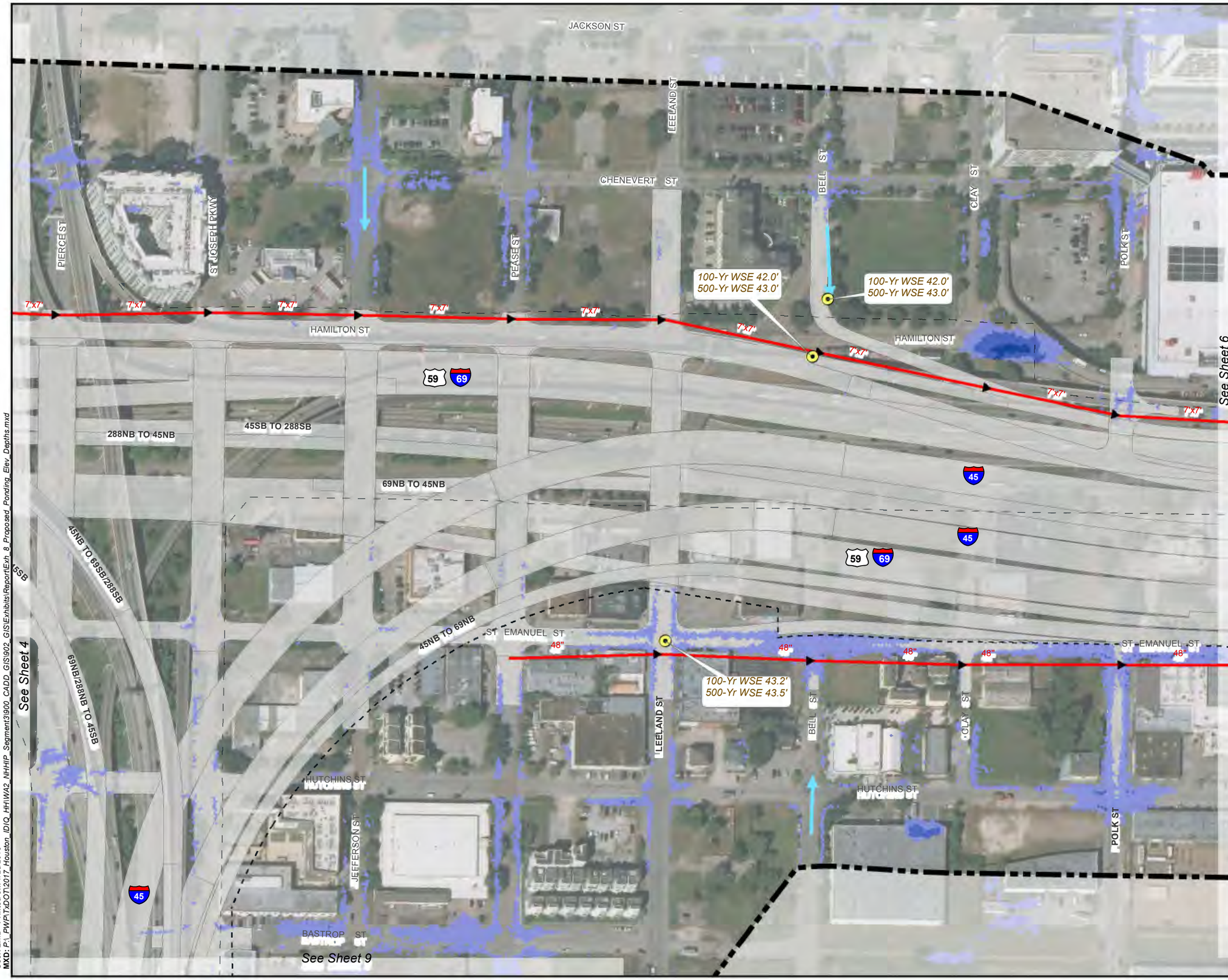

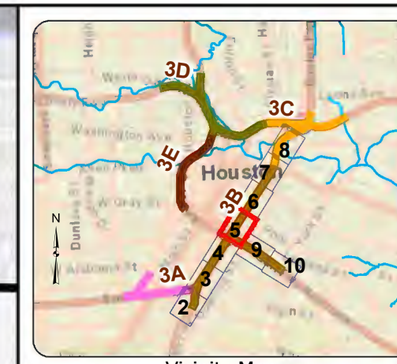

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Potential Sheet Flow Access Points
- Water Feature
- Sheetflow Direction
- Proposed Trunklines
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 100 200 Feet

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 5 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

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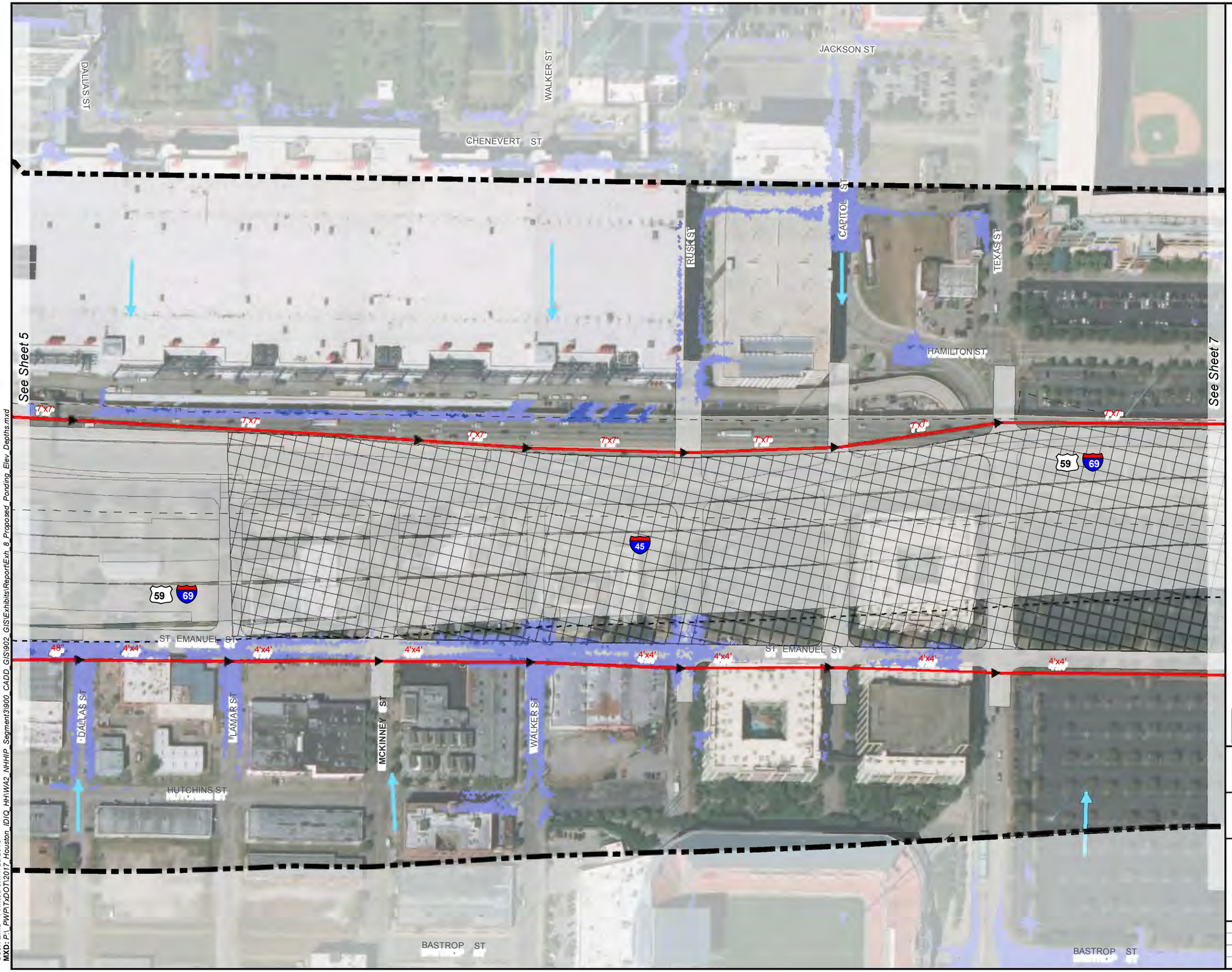

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Proposed Covered Section
- Water Feature
- Sheetflow Direction
- Proposed Trunklines
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 100 200 Feet

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 6 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

User: LimD Printed on: 7/25/2018
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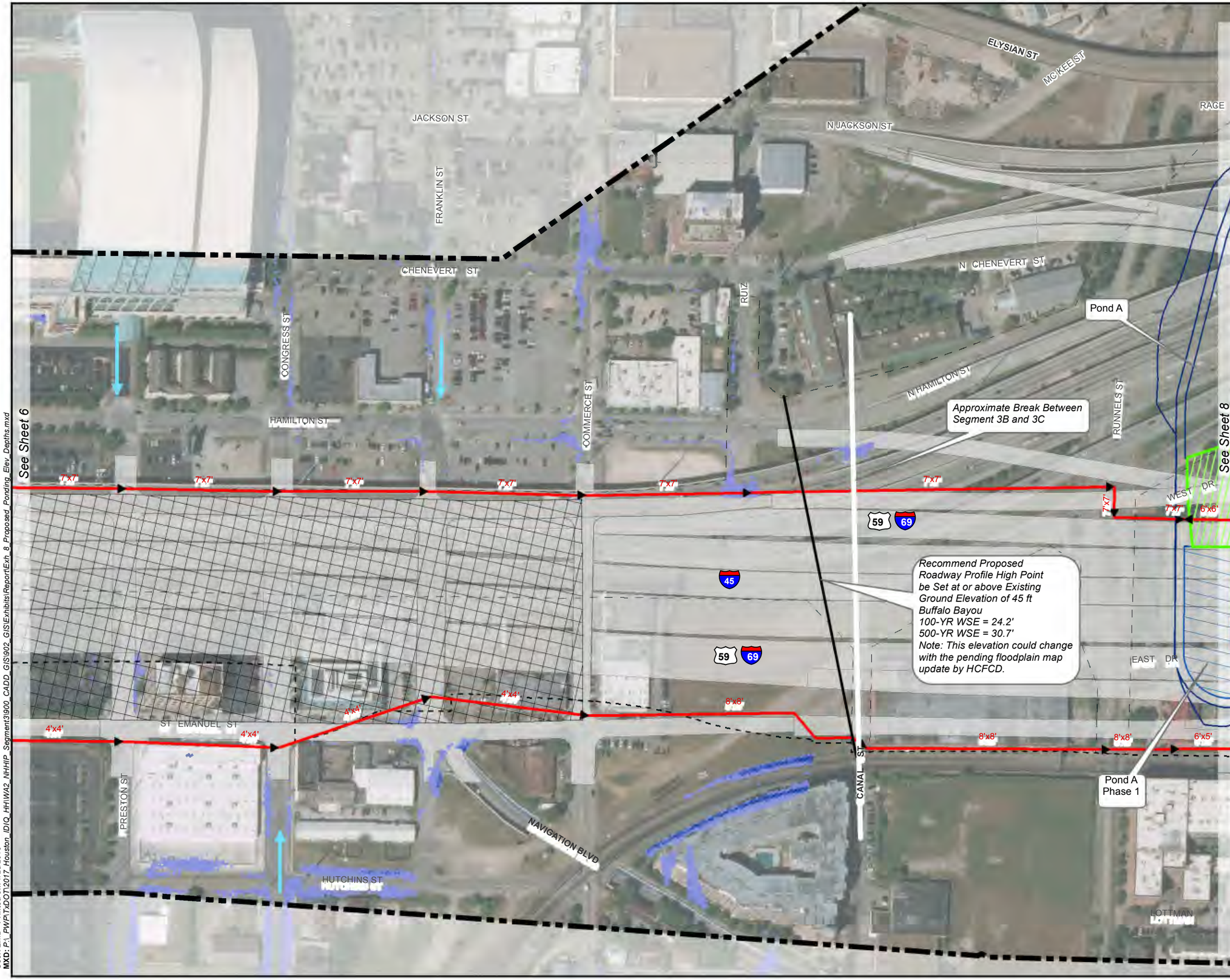

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Proposed Covered Section
- Water Feature
- Sheetflow Direction
- Proposed Trunklines
- Pond A
- Pond A – Phase 1
- Proposed Pump Station Site
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 100 200 Feet

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 7 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-71DP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

User: LimD Printed on: 7/25/2018
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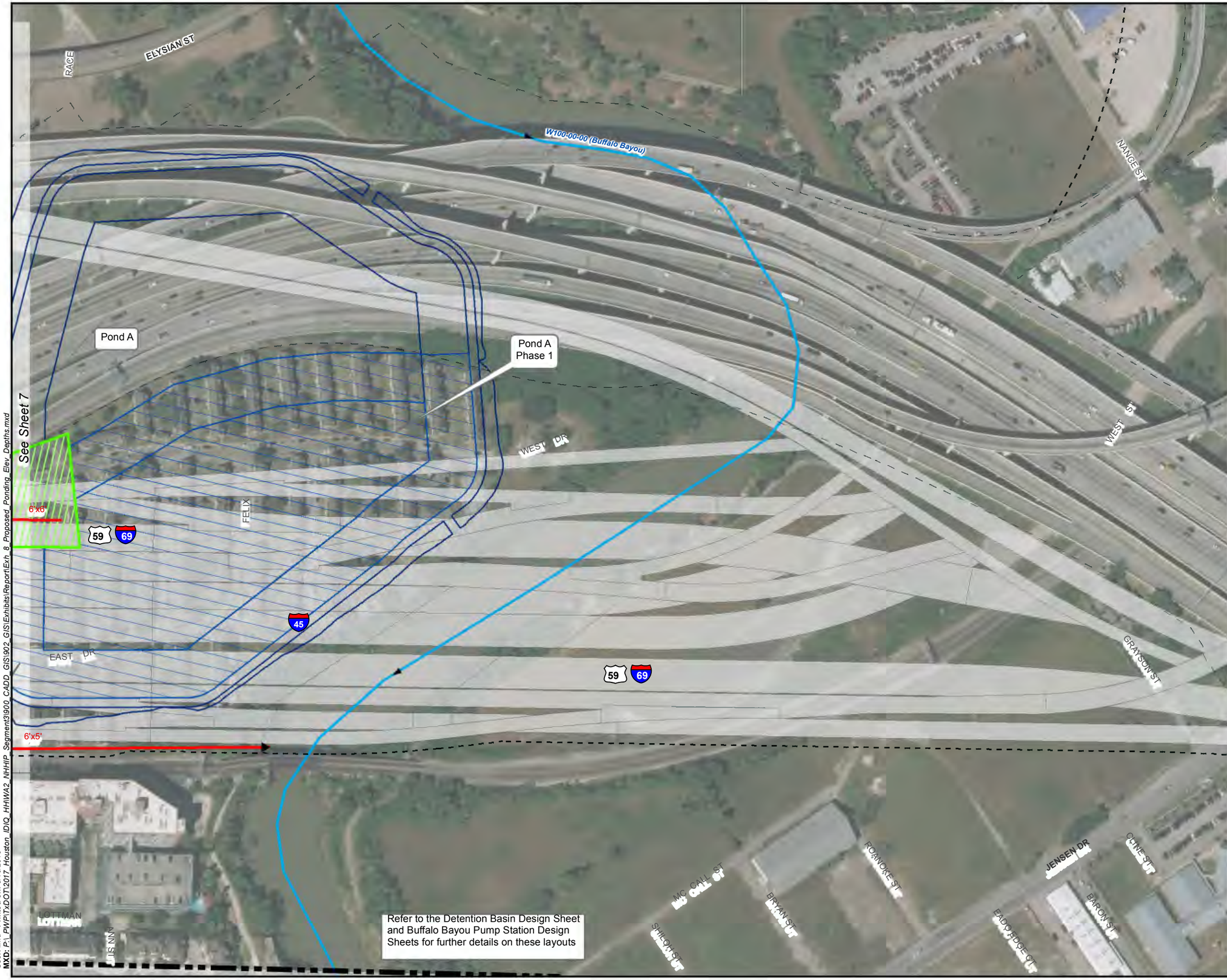

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Proposed Trunklines
- Pond A
- Pond A – Phase 1
- Proposed Pump Station Site
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 100 200 Feet

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 8 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

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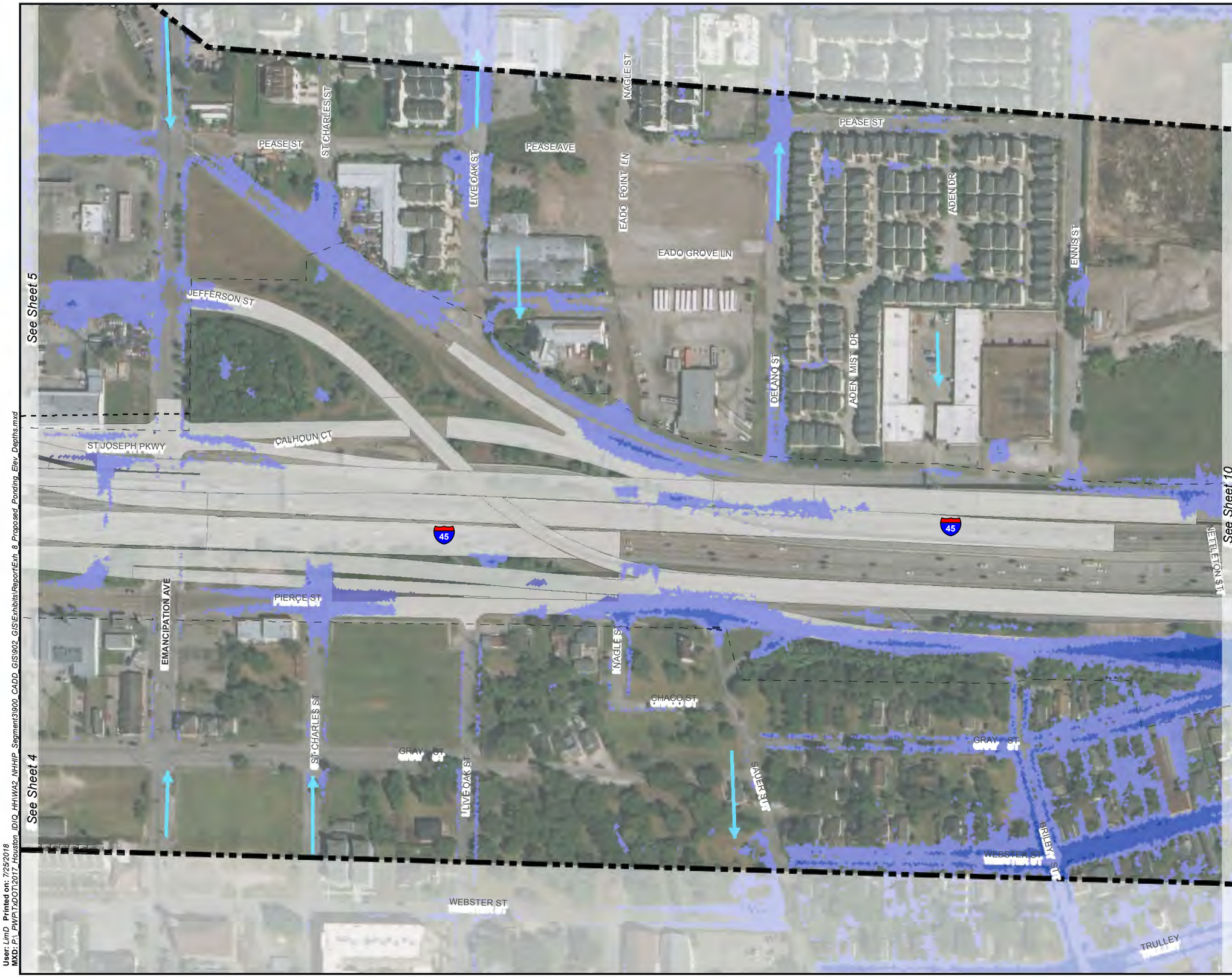

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Sheetflow Direction
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 100 200 Feet

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 9 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-71DP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

User: LimD Printed on: 7/25/2018
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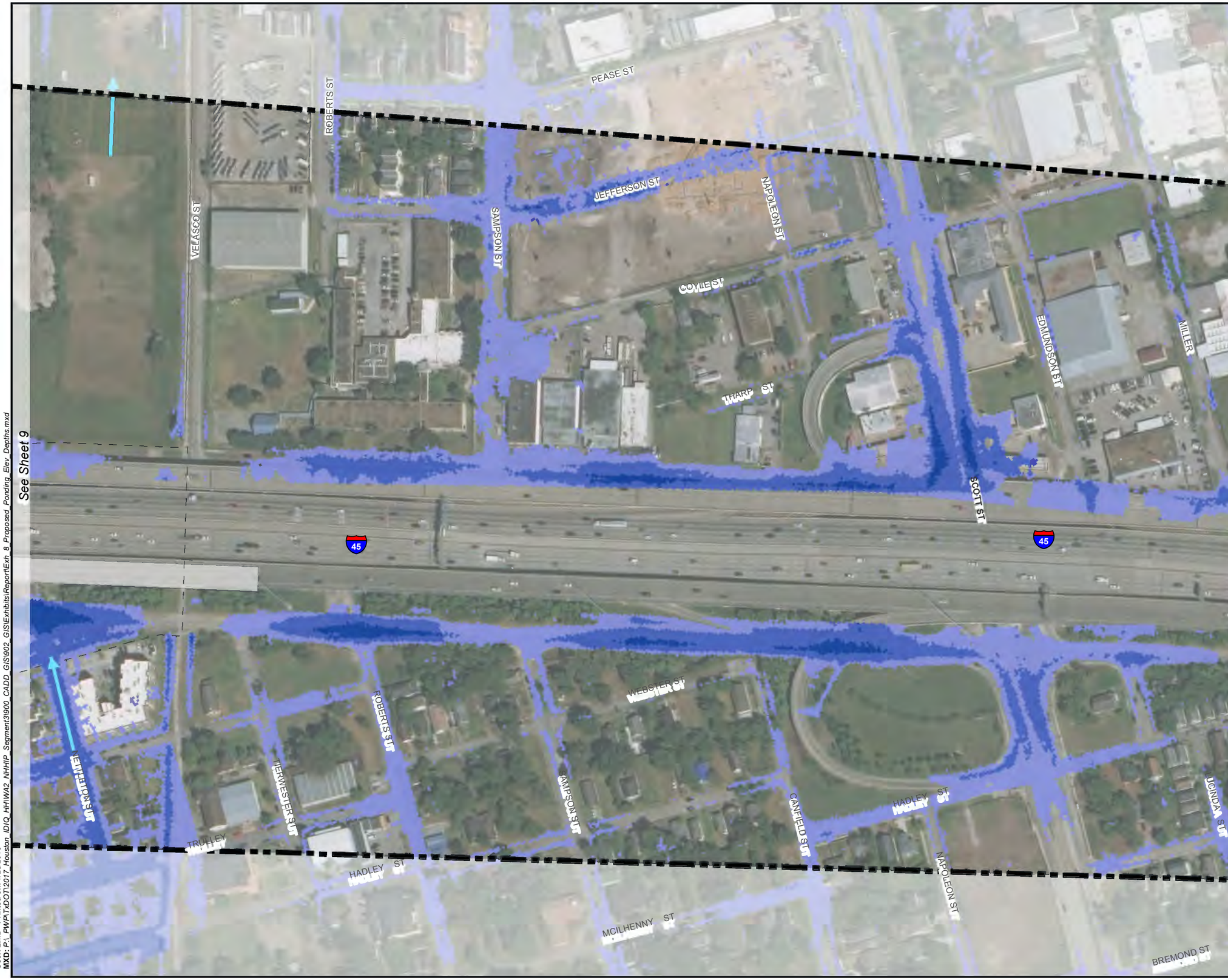

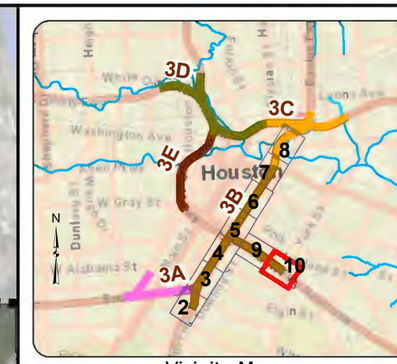

Vicinity Map

LEGEND

- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Water Feature
- Sheetflow Direction
- Proposed Roadways

Proposed 100-Yr Ponding

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

N

0 100 200 Feet

Note:
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Segment 3B Drainage Study

Overland Flow Analysis
Proposed Ponding Elevations and Depths

SHEET 10 OF 10

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-71DP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	8

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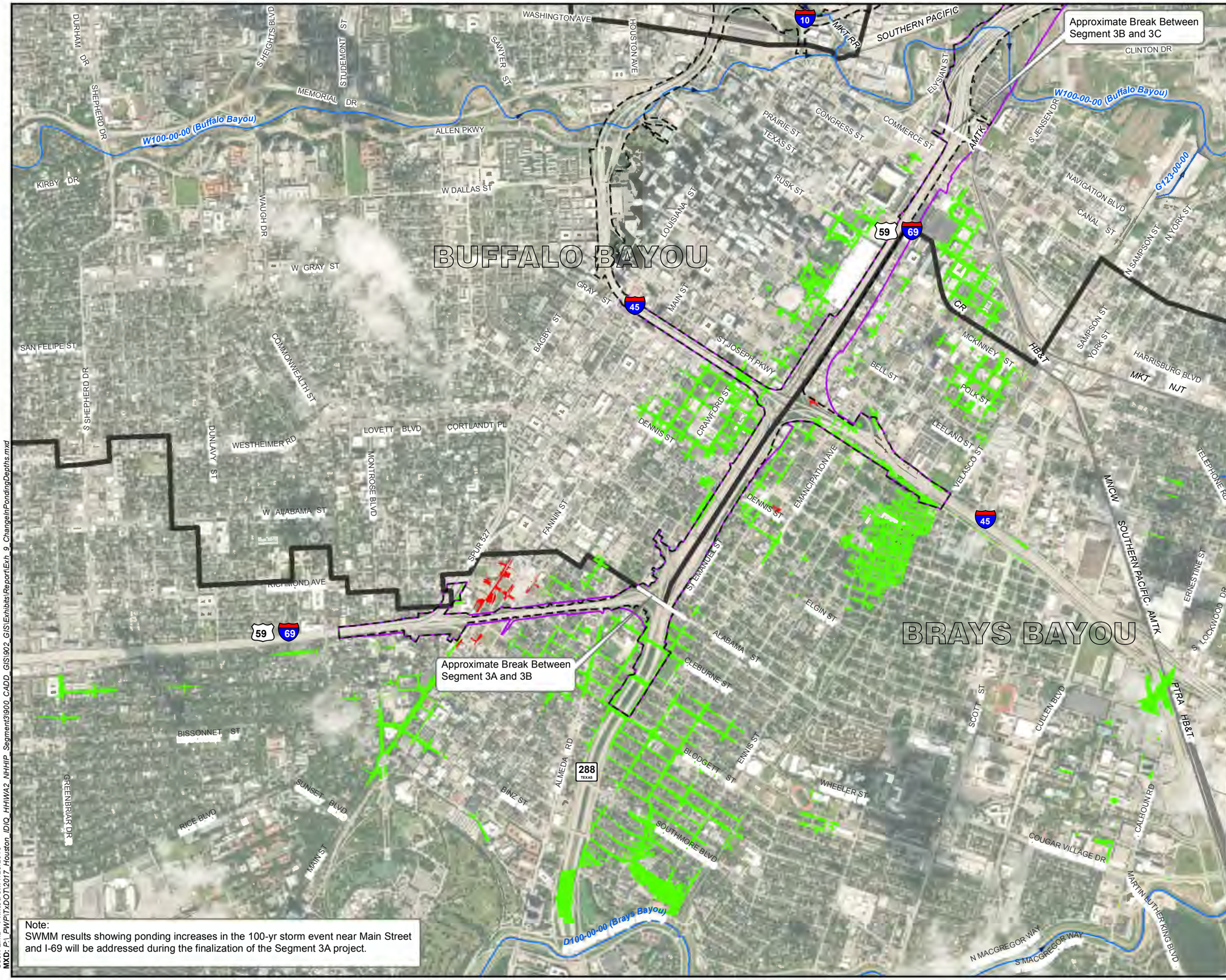

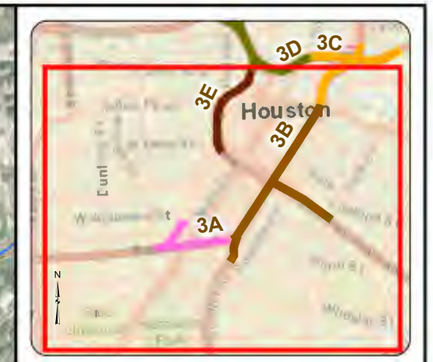

Vicinity Map

LEGEND

- Existing TxDOT ROW
- Proposed TxDOT ROW
- HCFCD Streams
- HCFCD Watersheds

100-Yr Ponding Depth Change

- Decrease in Ponding (< 0.1 ft)
- Increase in Ponding (> 0.1 ft)

N

0 1,000 2,000

Date of Aerial: 2017
Datum: NAVD 1988, 2001 Adj.

Note:
The required vertical datum adjustment from NAVD88 (unadjusted) to NAVD88 (2001 adjusted) is -0.06 ft. in the project vicinity.

Note:
SWMM results showing ponding increases in the 100-yr storm event near Main Street and I-69 will be addressed during the finalization of the Segment 3A project.

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Segment 3B Drainage Study

Overland Flow Analysis
Change in Ponding Depths

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA 2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	9

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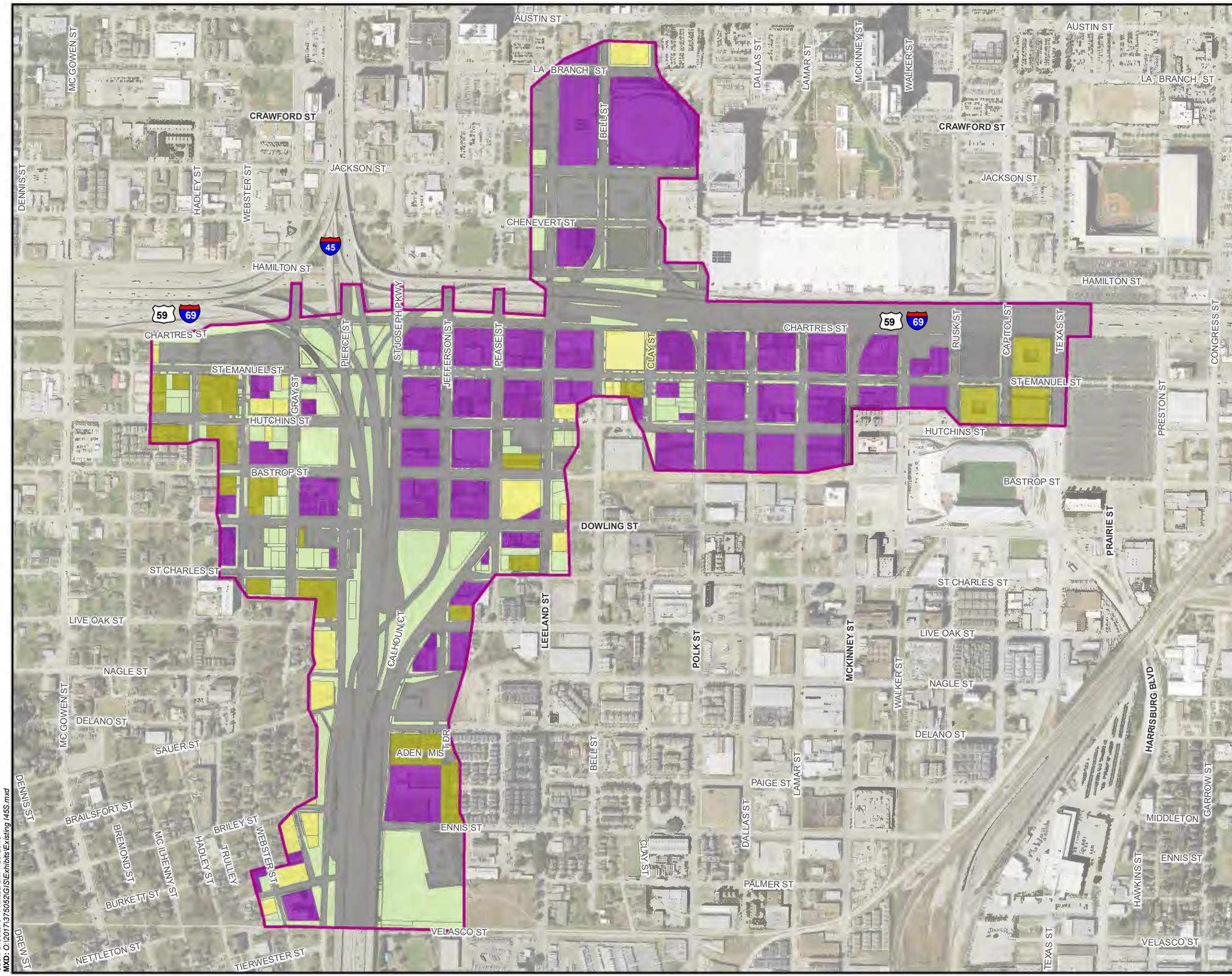

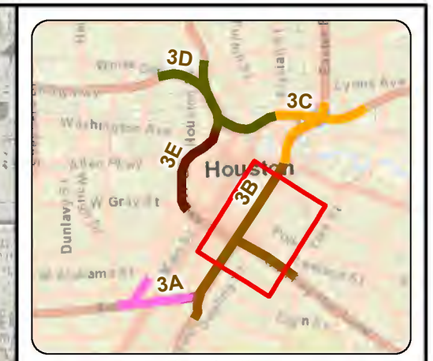

Vicinity Map

LEGEND

- Existing Drainage Area

Existing Land Use

- Undeveloped
- Residential Urban (Small Lot)
- Residential Urban (Large Lot)
- Industrial
- Pavement

N

0 300 600 Feet

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Segment 3B Drainage Study

Existing Drainage Conditions I-45 South

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	PROJECT NO.			HIGHWAY NO.
6	TEXAS	60563838			I-45/I-69/SH-288
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	10

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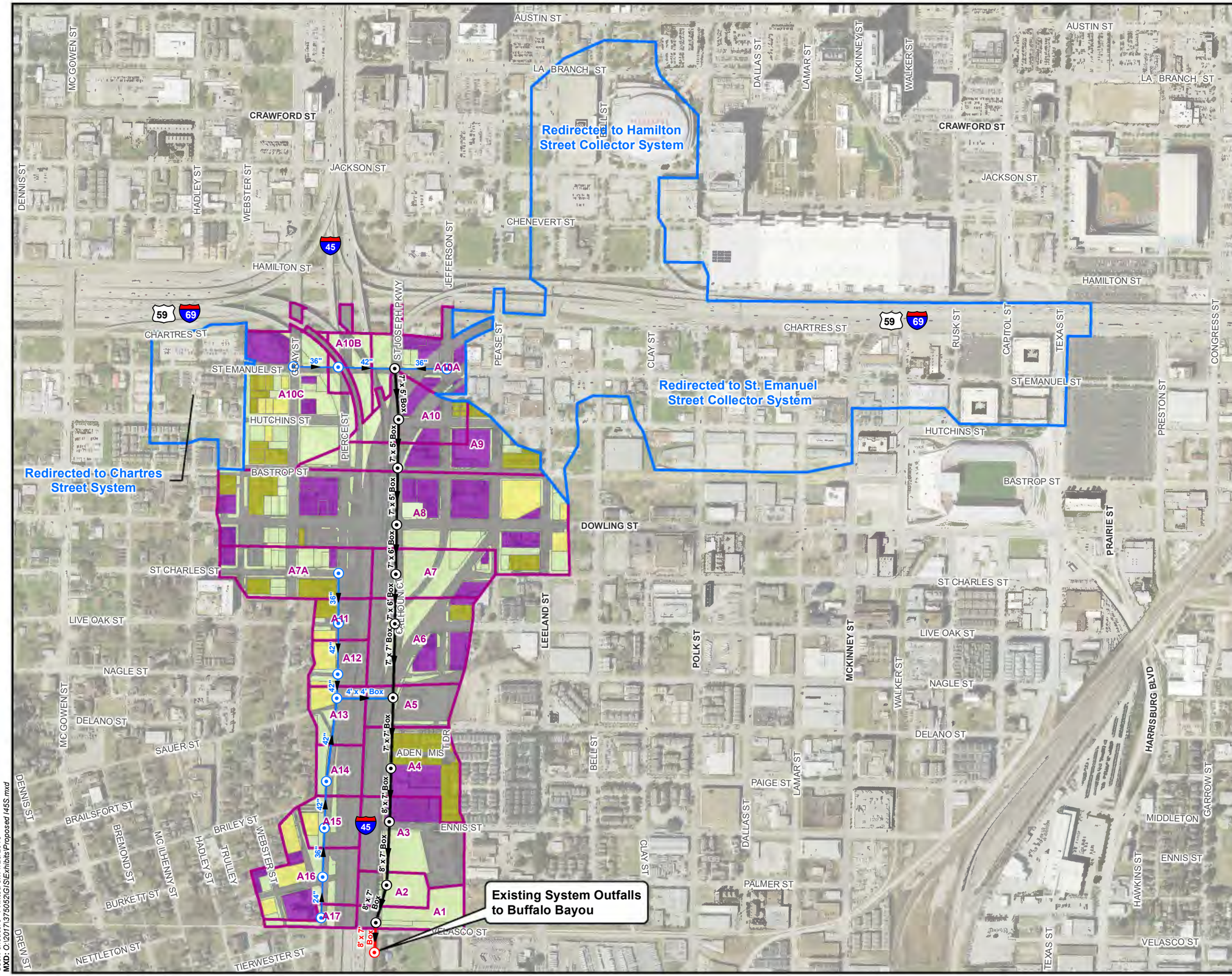

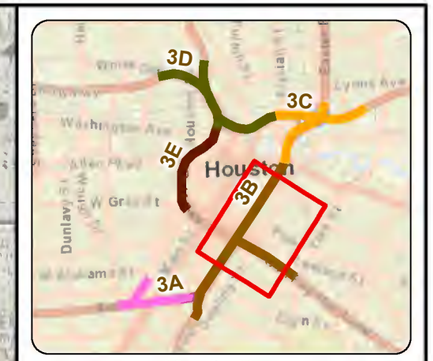

Vicinity Map

LEGEND

- Existing Outfall
- Proposed Node
- Existing Node
- St. Joseph Pkwy Outfall
- Proposed Storm Sewer
- Existing Storm Sewer
- Redirected Areas
- Proposed Drainage Areas

Proposed Land Use

- Undeveloped
- Residential Urban (Small Lot)
- Residential Urban (Large Lot)
- Industrial
- Pavement

N

0 300 600 Feet

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Segment 3B Drainage Study

Proposed Drainage Conditions I-45 South

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	PROJECT NO.			HIGHWAY NO.
6	TEXAS	60563838			I-45/I-69/SH-288
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	11

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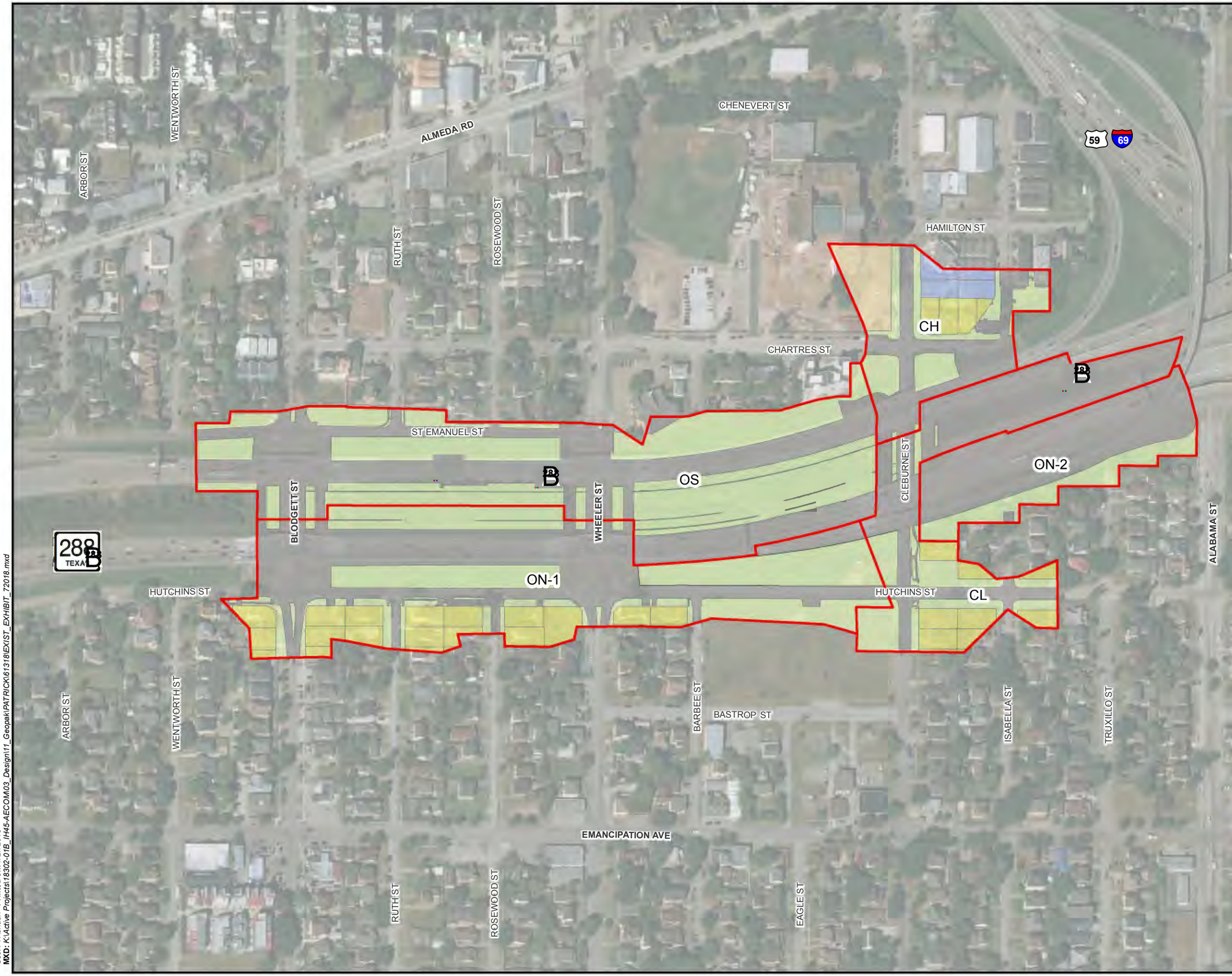

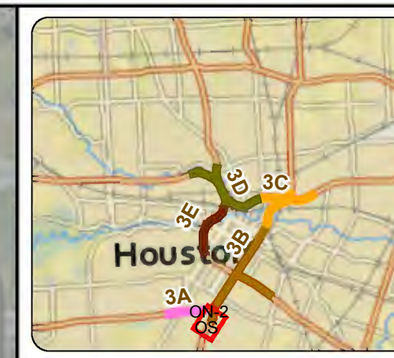

Vicinity Map

LEGEND

- Existing Drainage Areas

Land Use Code

- Comercial
- Undeveloped
- Pavement
- School
- Residential Urban (Small Lot)

Notes:
Drainage Area CL
drains to COH existing storm sewer on Cleburne Street.

Drainage Area CH
drains to COH existing storm sewer on Chartres Street.

N

0 90 180 360
Feet

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Existing Drainage Conditions
SH-288 South

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	PROJECT NO.			HIGHWAY NO.
6	TEXAS	60563838			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	12

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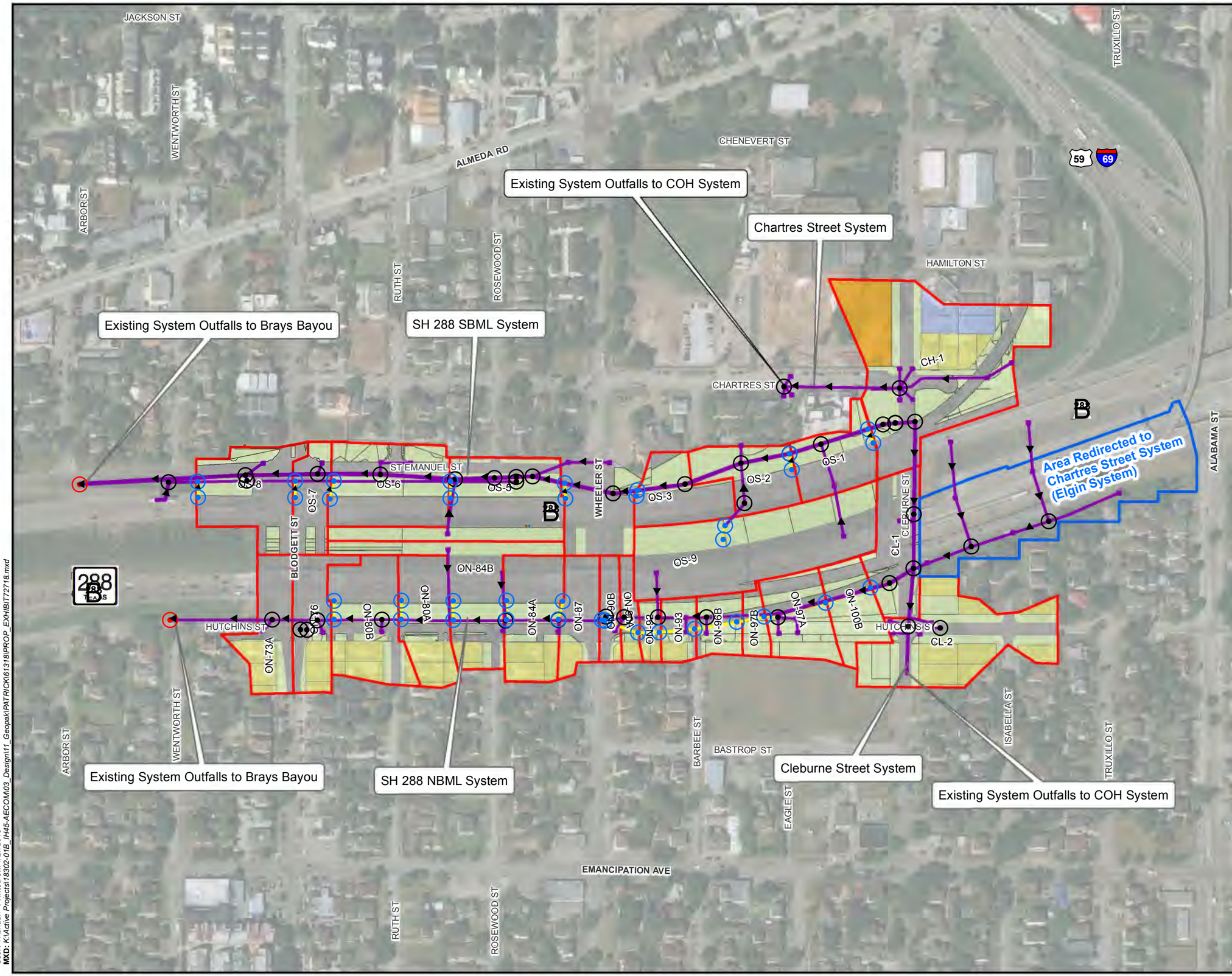

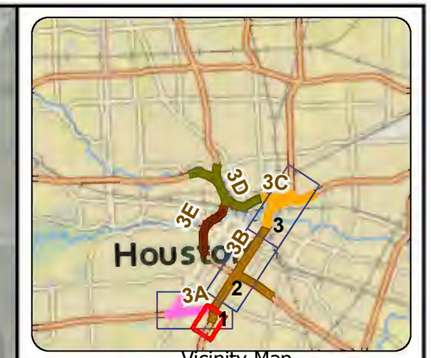

Vicinity Map

LEGEND

- Existing Outfall
- Proposed Nodes
- Existing Nodes
- Existing Storm Sewer
- Proposed Storm Sewer
- Redirected Area
- Proposed Drainage Area

Land Use Code

- Commercial
- Undeveloped
- Pavement
- School
- Residential Urban (Small Lot)

Notes:
Drainage Areas CL-1 and CL-2 drain to COH existing storm sewer on Cleburne Street.

Drainage Area CH-1 drains to COH existing storm sewer on Chartres Street.

N

0 90 180 360 Feet

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Proposed Drainage Conditions
SH-288 South

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	PROJECT NO.			HIGHWAY NO.
6	TEXAS	60563838			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	13

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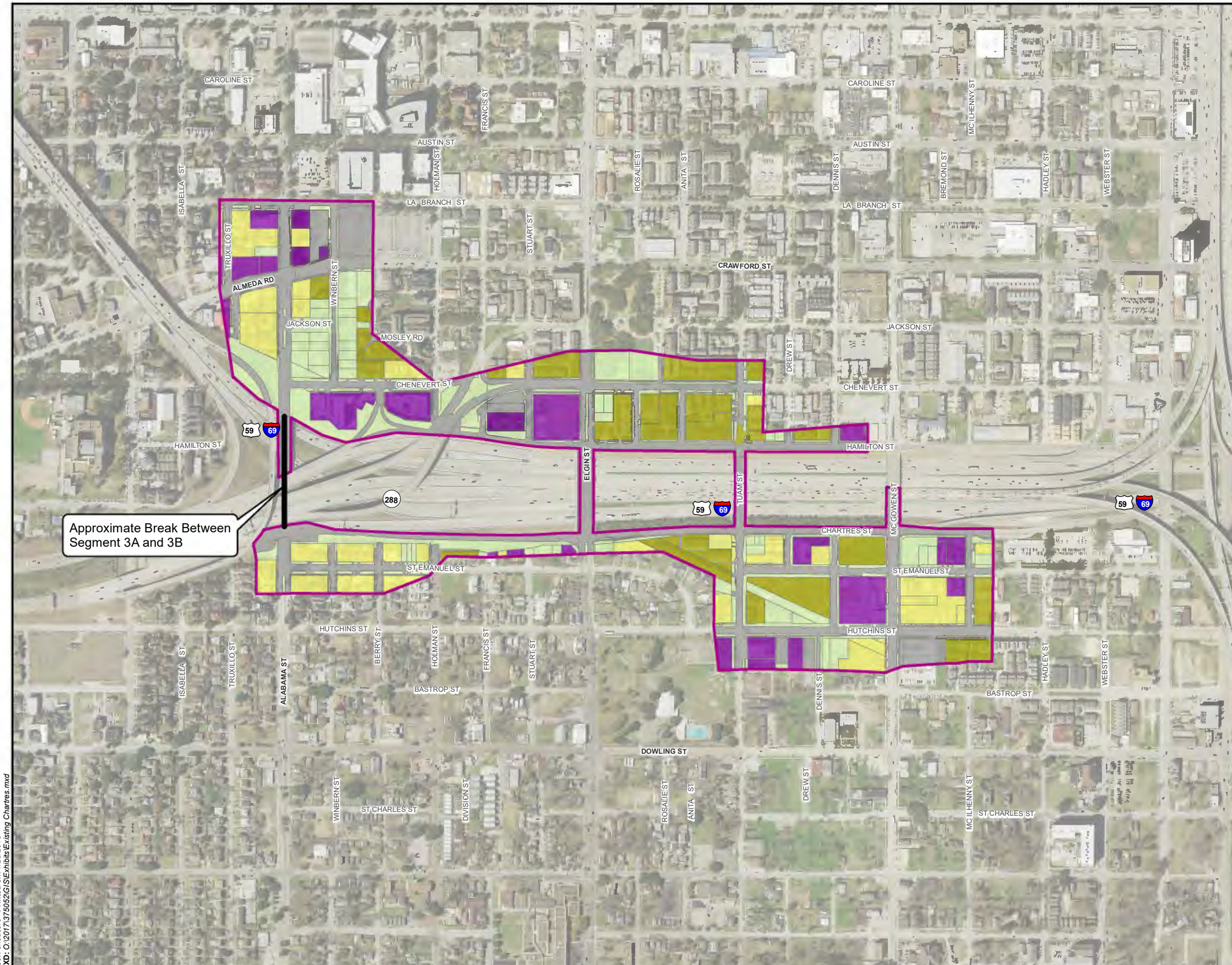

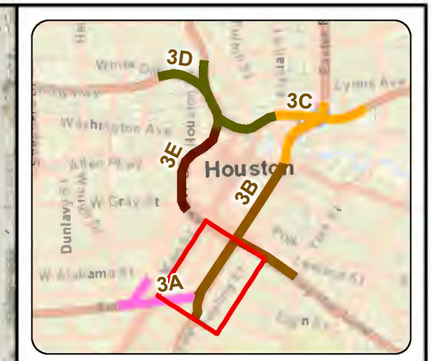

Vicinity Map

LEGEND

- Existing Drainage Area

Existing Land Use

- Pavement
- Undeveloped
- Residential Urban (Small Lot)
- Residential Urban (Large Lot)
- Industrial

N

0 250 500 Feet

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North Houston Highway Improvement Project
Segment 3B Drainage Study

Existing Drainage Conditions
Chartres Street

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	PROJECT NO.			HIGHWAY NO.
6	TEXAS	60563838			I-45/I-69/SH-288
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	14

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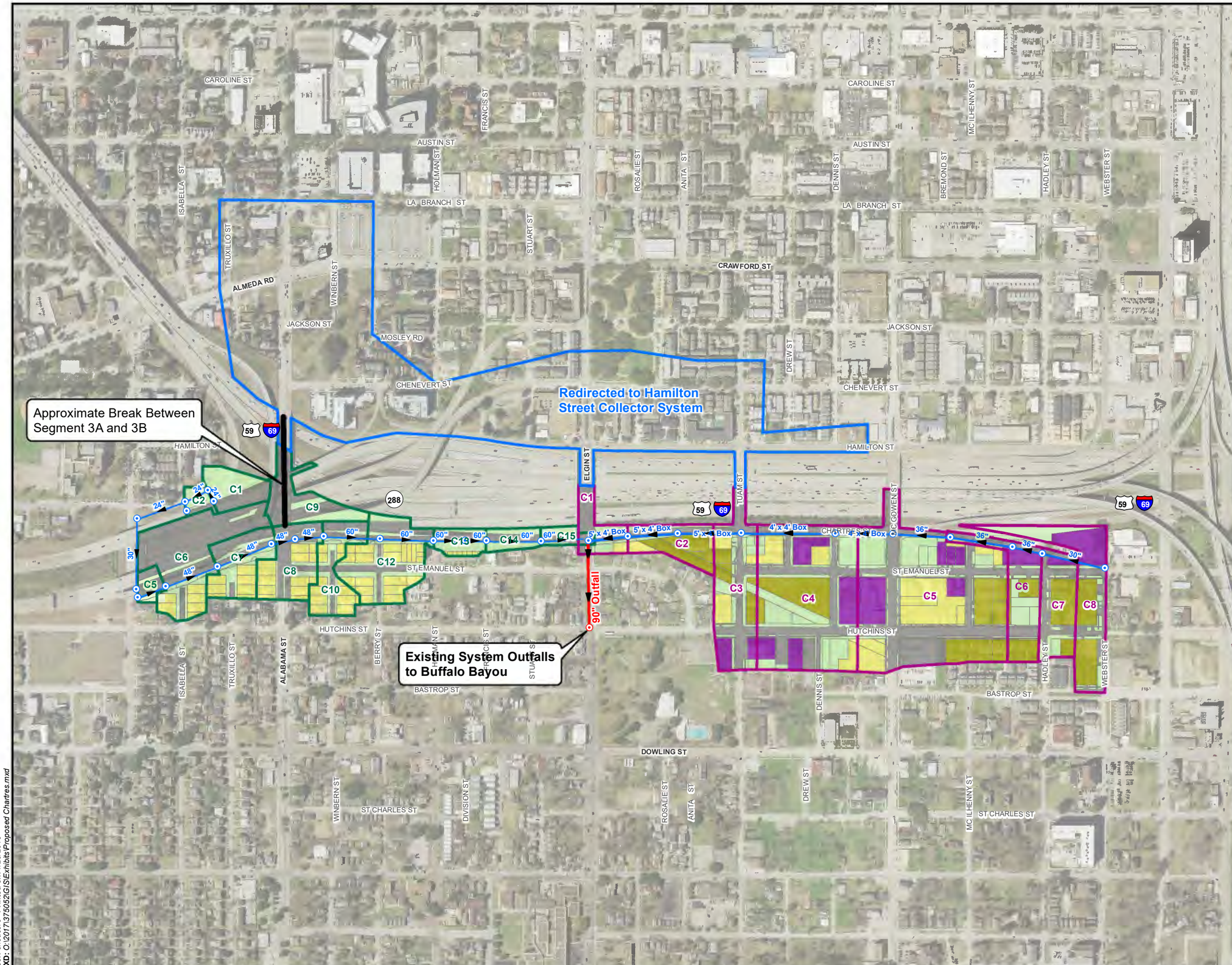

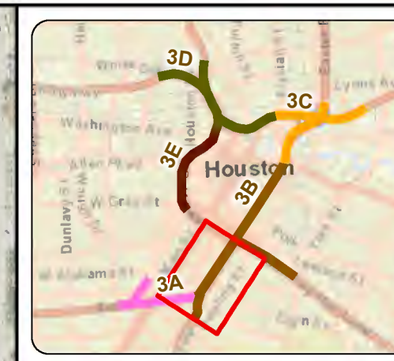

Vicinity Map

LEGEND

- Existing Outfall
- Proposed Nodes
- Elgin Outfall
- Proposed Storm Sewer
- Redirected Areas
- Proposed Drainage Areas (North of Elgin Street)
- Proposed Drainage Areas (South of Elgin Street)

Proposed Land Use

- Undeveloped
- Residential Urban (Small Lot)
- Residential Urban (Large Lot)
- Industrial
- Pavement
- Light Commercial

N

0 250 500 Feet

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Segment 3B Drainage Study

Proposed Drainage Conditions
Chartres Street

SHEET 1 OF 1

FED. RD. DIV. NO.	STATE	PROJECT NO.			HIGHWAY NO.
6	TEXAS	60563838			I-45/I-69/SH-288
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	15

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Remainder of Segment 3A Proposed Roadways Not Shown

Segment 3B Project Limits

NOTE: REFER TO APPENDIX B FOR DESCRIPTIONS OF THE UTILITY CONFLICTS SHOWN

See Sheet 2

CRAWFORD ST
WENTWORTH ST
JACKSON ST
ALMEDA RD
CHENEVERT ST
ARBOR ST
RUTH ST
ROSEWOOD ST
BARBEE ST
EAGLE ST
CLEBURNE ST
ISABELLA ST
TRUXILLO ST
WINBERN ST
HAMILTON ST
CHARTRES ST
BLODGETT ST
WHEELER ST
ST EMANUEL ST
HUTCHINS ST
BASTROP ST
ALABAMA ST
BERRY ST
288 MANAGED LANES
NB FRONTAGE ROAD
288NB TO 69SB
288SB TO 69SB
288NB TO 69NB
955+00
960+00
965+00
970+00
1025+00
1030+00
1020+00
1015+00
1010+00
1005+00
1000+00
995+00
59
69
288
TEXAS
1
2
3, 48
4
5
27
28
30
35
42
43

Vicinity Map

LEGEND

- Proposed Storm Sewer
- Electric Power Transmission Lines
- Existing Sanitary Lines
- Water Distribution Main
- I-69/US 59 Mainlanes
- Max Lanes
- Ramps
- Direct Connectors
- SH 288 Mainlanes
- Frontage/Local Roads
- I-45 Mainlanes
- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Railroads
- Channel Centerline

N

0 150 300 Feet

Notes:
1. Imagery from H-GAC, 2016
2. See Exhibit 9 for Exist Storm

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Segment 3B
Potential Utility Conflicts

SHEET 1 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	16

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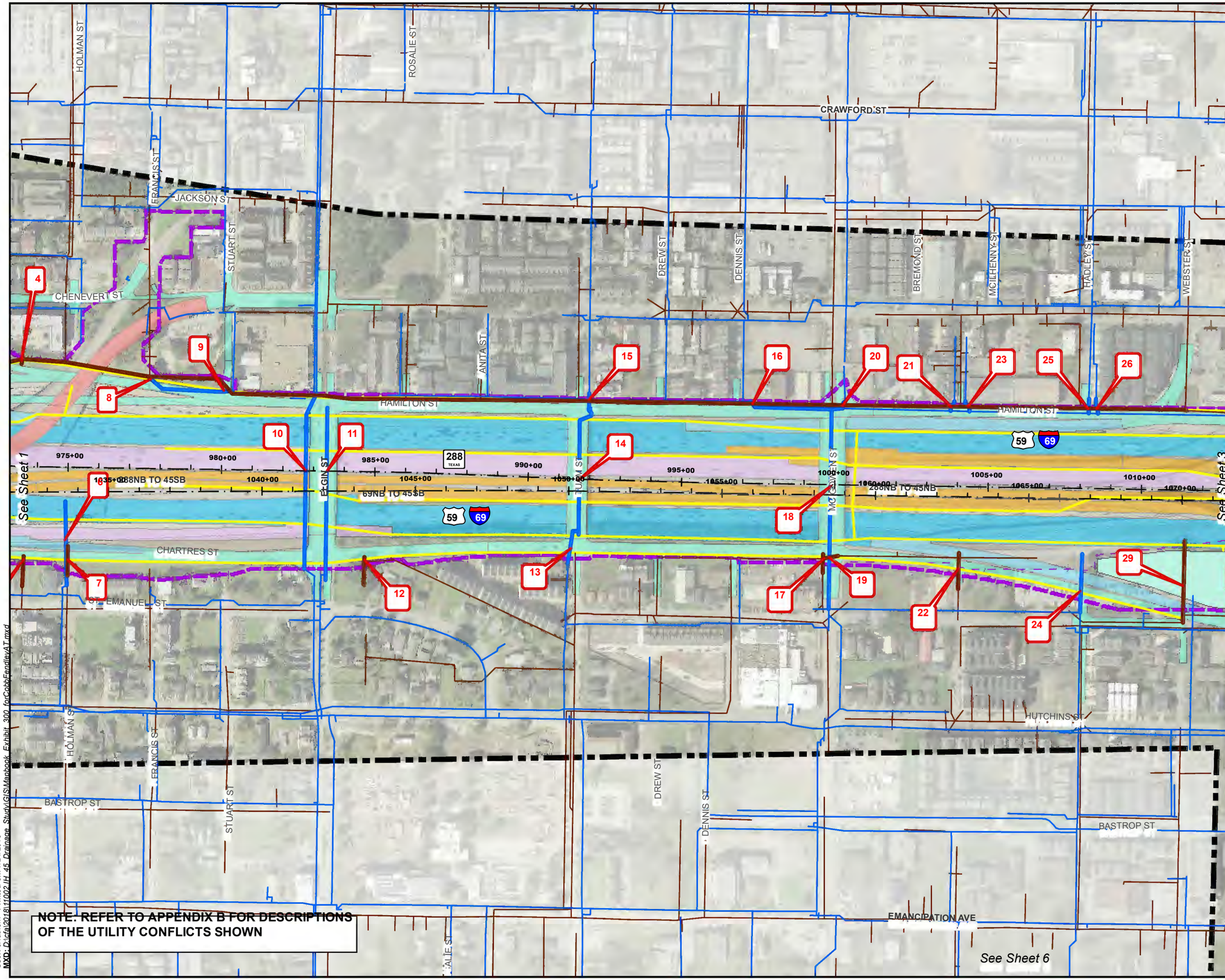

NOTE: REFER TO APPENDIX B FOR DESCRIPTIONS OF THE UTILITY CONFLICTS SHOWN

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Vicinity Map

LEGEND

- Proposed Storm Sewer
- Electric Power Transmission Lines
- Existing Sanitary Lines
- Water Distribution Main
- I-69/US 59 Mainlanes
- Max Lanes
- Ramps
- Direct Connectors
- SH 288 Mainlanes
- Frontage/Local Roads
- I-45 Mainlanes
- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Railroads
- Channel Centerline

N

0 150 300 Feet

Notes:
1. Imagery from H-GAC, 2016
2. See Exhibit 9 for Exist Storm

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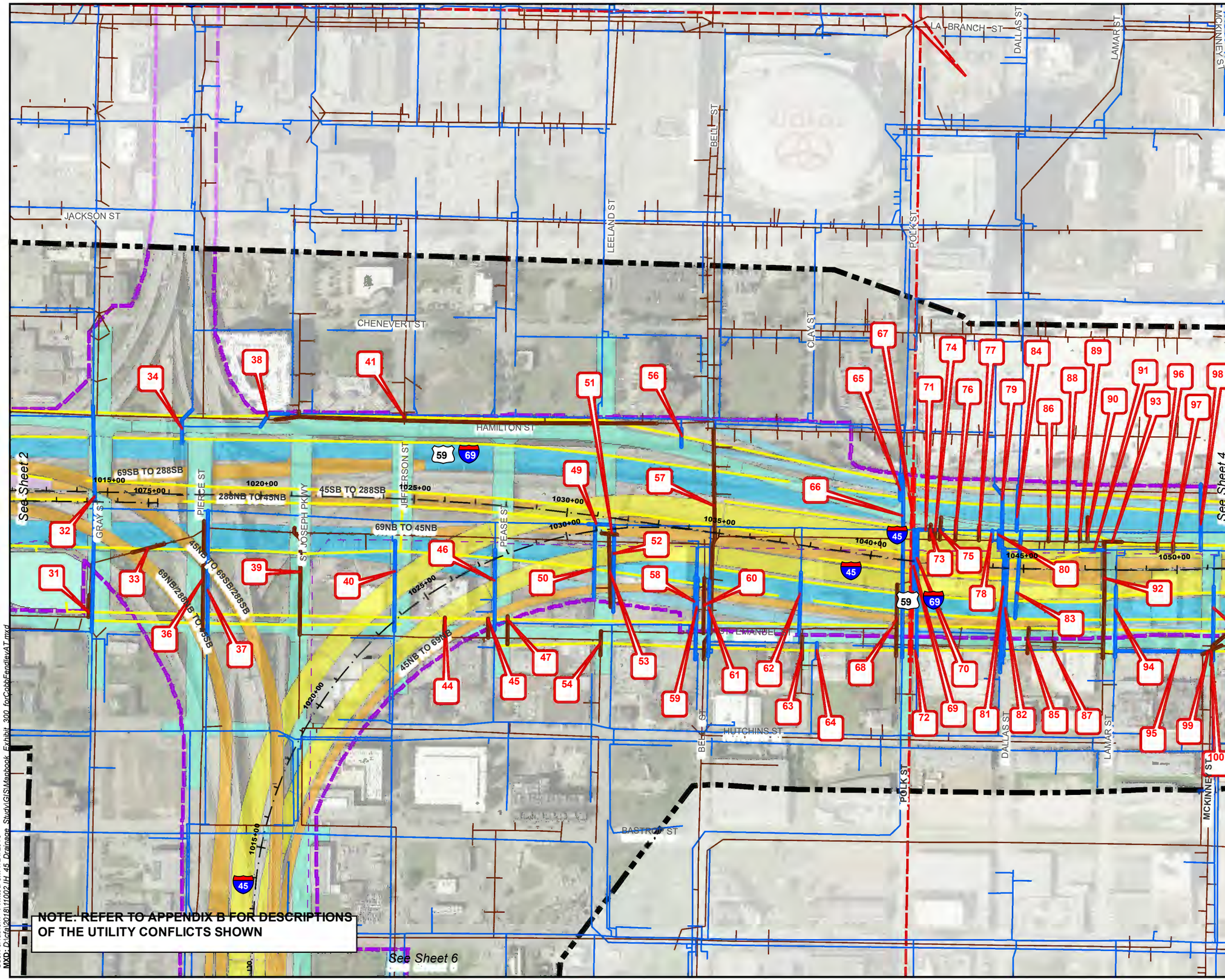
Drainage Study

Segment 3B
Potential Utility Conflicts

SHEET 2 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055.WA2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	16



Vicinity Map

LEGEND

- Proposed Storm Sewer
- Electric Power Transmission Lines
- Existing Sanitary Lines
- Water Distribution Main
- I-69/US 59 Mainlanes
- Max Lanes
- Ramps
- Direct Connectors
- SH 288 Mainlanes
- Frontage/Local Roads
- I-45 Mainlanes
- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Railroads
- Channel Centerline

N

0 150 300 Feet

Notes:
1. Imagery from H-GAC, 2016
2. See Exhibit 9 for Exist Storm

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Drainage Study

Segment 3B
Potential Utility Conflicts

SHEET 3 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	16

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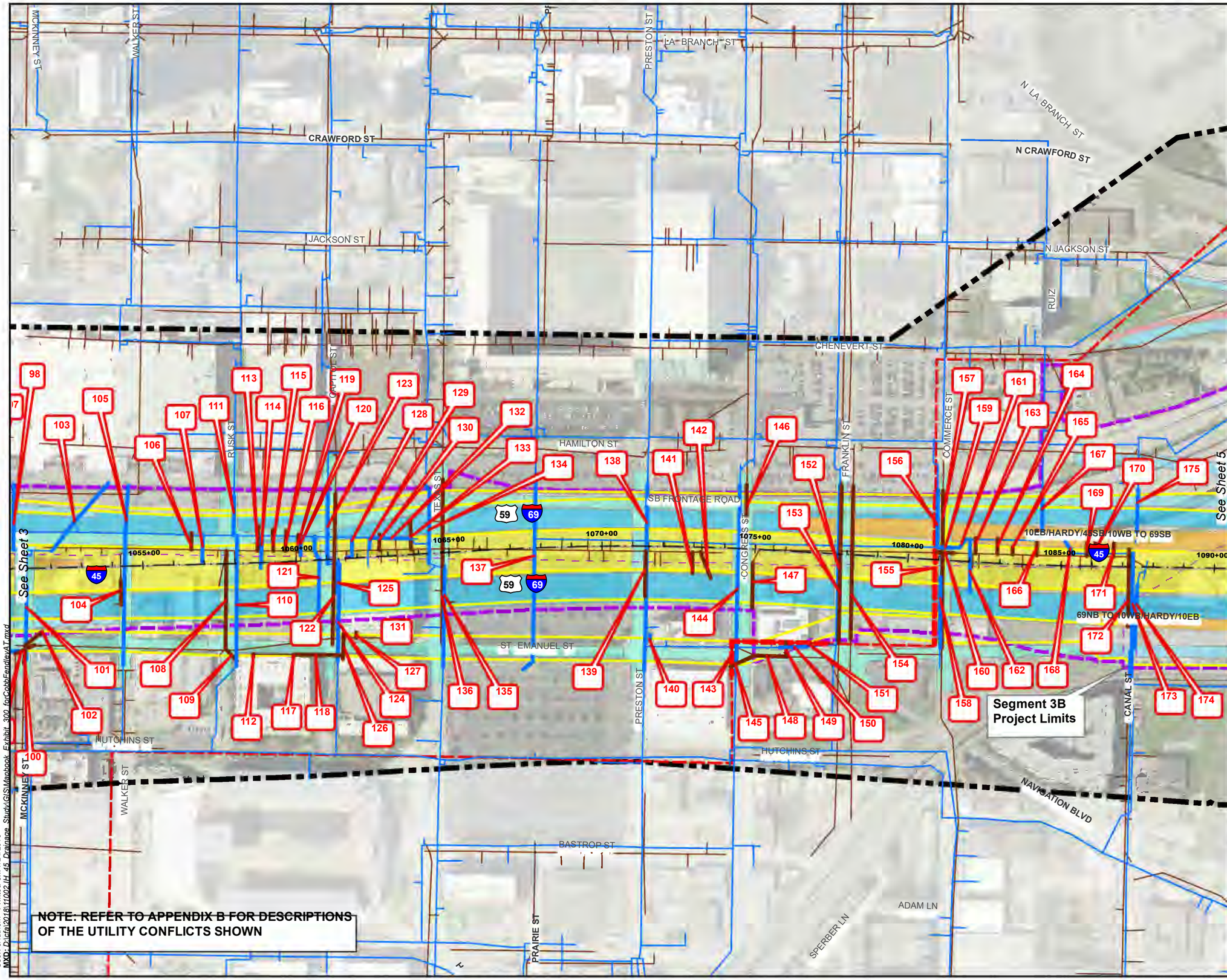

Vicinity Map

LEGEND

- Proposed Storm Sewer
- Electric Power Transmission Lines
- Existing Sanitary Lines
- Water Distribution Main
- I-69/US 59 Mainlanes
- Max Lanes
- Ramps
- Direct Connectors
- SH 288 Mainlanes
- Frontage/Local Roads
- I-45 Mainlanes
- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Railroads
- Channel Centerline

N

0 150 300 Feet

Notes:
1. Imagery from H-GAC, 2016
2. See Exhibit 9 for Exist Storm

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Segment 3B
Potential Utility Conflicts

SHEET 4 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	16

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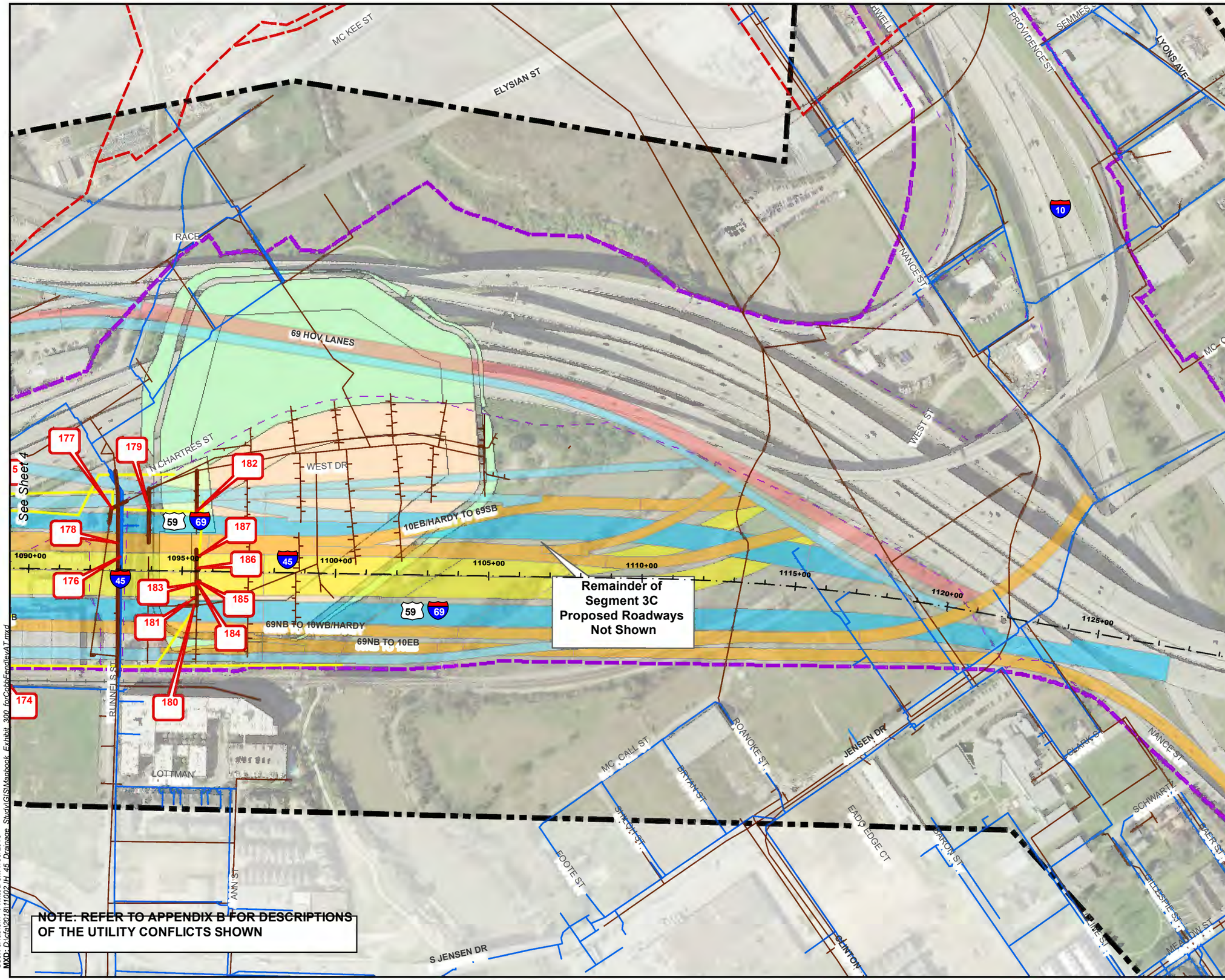

Vicinity Map

LEGEND

- Proposed Storm Sewer
- Electric Power Transmission Lines
- Existing Sanitary Lines
- Water Distribution Main
- I-69/US 59 Mainlanes
- Max Lanes
- Ramps
- Direct Connectors
- SH 288 Mainlanes
- Frontage/Local Roads
- I-45 Mainlanes
- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Railroads
- Channel Centerline

N

0 150 300 Feet

Notes:
1. Imagery from H-GAC, 2016
2. See Exhibit 9 for Exist Storm

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Drainage Study

Segment 3B
Potential Utility Conflicts

SHEET 5 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	16

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See Sheet 2

See Sheet 3

ST CHARLES ST
LIVE OAK ST
NAGLE ST
DELANO ST
SAUER ST
BRAILSFORT ST
BRILEY ST
BURKETT ST
NETTLETON ST
TIERWESTER ST
ROBERTS ST
MC GOWEN ST
MCILHENNY ST
HADLEY ST
WEBSTER ST
BREMOND ST
DENNIS ST
CHACO ST
PIERCE ST
GRAY ST
CALHOUN CT
JEFFERSON ST
PEASE ST
PEASE AVE
EADO GROVE LN
LEELAND ST
ADEN MIST DR
ENNIS ST
VELASCO ST
PAIGE ST
BELL ST
PALMER ST
CLAY ST
45
1010+00
1005+00
1000+00
995+00
990+00
985+00

Segment 3B
Project Limits

NOTE: REFER TO APPENDIX B FOR DESCRIPTIONS OF THE UTILITY CONFLICTS SHOWN

Vicinity Map

LEGEND

- Proposed Storm Sewer
- Electric Power Transmission Lines
- Existing Sanitary Lines
- Water Distribution Main
- I-69/US 59 Mainlanes
- Max Lanes
- Ramps
- Direct Connectors
- SH 288 Mainlanes
- Frontage/Local Roads
- I-45 Mainlanes
- Study Area
- Existing TxDOT ROW
- Proposed TxDOT ROW
- Railroads
- Channel Centerline

N

0 150 300 Feet

Notes:
1. Imagery from H-GAC, 2016
2. See Exhibit 9 for Exist Storm

CobbFendley
Cobb, Fendley & Associates, Inc
13430 Northwest Freeway, Suite 1100
Houston, Texas 77040
TBPE Reg. No. 274

Texas Department of Transportation
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North Houston Highway Improvement Project
Drainage Study

Segment 3B
Potential Utility Conflicts

SHEET 6 OF 6

FED. RD. DIV. NO.	STATE	CONTRACT NO.			HIGHWAY NO.
6	TEXAS	36-7IDP5055 WA2			I-45
STATE DISTRICT	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	EXHIBIT NO.
HOU	HARRIS	0500	03	601	16

User: JHathorn Printed on: 7/24/2018
MXD: D:\cfa\2018\11002\I-45_Drainage_Study\GIS\Mapbook_Exhibit_300_forCobbFendleyAT.mxd

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS
CONVEYANCE CONFIGURATION DATA

I-45 PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
288SB-1	288SB-1	288SB-2	300	Circular	1	2	n/a	0.013	0.20	7.17	6.57
288SB-10	288SB-10	288SB-9	467	Circular	1	2.5	n/a	0.013	0.20	9.01	8.08
288SB-2	288SB-2	288SB-3	299	Circular	1	2	n/a	0.013	0.20	6.57	5.97
288SB-3	288SB-3	288SB-4	181	Circular	1	2	n/a	0.013	0.20	5.97	5.60
288SB-4	288SB-4	45NBC11	132	Box	2	4	6	0.015	0.20	-1.06	-1.33
288SB-5	288SB-5	288SB-4	130	Circular	1	3	n/a	0.013	0.20	4.25	3.99
288SB-6	288SB-6	288SB-5	378	Circular	1	3	n/a	0.013	0.20	5.01	4.25
288SB-7	288SB-7	288SB-6	446	Circular	1	3	n/a	0.013	0.20	5.90	5.01
288SB-8	288SB-8	288SB-7	373	Circular	1	2.5	n/a	0.013	0.20	7.14	6.40
288SB-9	288SB-9	288SB-8	467	Circular	1	2.5	n/a	0.013	0.20	8.08	7.14
45NBC10	45NBC10	45NBC11	192	Circular	1	2	n/a	0.013	0.20	5.68	5.30
45NBC1067+00	45NBC1067+00	45NBC9	179	Circular	1	2	n/a	0.013	0.20	6.63	6.28
45NBC11	45NBC11	69NB-41	108	Box	2	4	6	0.015	0.20	-1.33	-1.54
45NBC12	45NBC12	45NBC11	126	Circular	1	3	n/a	0.013	0.20	5.55	5.30
45NBC13	45NBC13	45NBC12	378	Circular	1	3	n/a	0.013	0.20	6.31	5.55
45NBC14	45NBC14	45NBC13	442	Circular	1	2.5	n/a	0.013	0.20	7.69	6.81
45NBC15	45NBC15	45NBC14	377	Circular	1	2.5	n/a	0.013	0.20	8.44	7.69
45NBC16	45NBC16	45NBC16A	172	Circular	1	2	n/a	0.013	0.20	9.87	9.53
45NBC16A	45NBC16A	45NBC15	293	Circular	1	2	n/a	0.013	0.20	9.53	8.94
45NBC17	45NBC17	45NBC16	469	Circular	1	2	n/a	0.013	0.21	10.87	9.87
45NBC2	45NBC2	45NBC2B	82	Circular	1	2	n/a	0.013	0.20	11.91	11.74
45NBC2B	45NBC2B	45NBC3	591	Circular	1	2	n/a	0.013	0.20	11.74	10.56
45NBC3	45NBC3	LAT-2C	38	Circular	1	2	n/a	0.013	0.19	10.56	10.49
45NBC4	45NBC4	LAT-2C	46	Circular	1	2	n/a	0.013	0.20	10.58	10.49
45NBC5	45NBC5	45NBC4	331	Circular	1	2	n/a	0.013	0.20	11.24	10.58
45NBC6	45NBC6	45NBC5	336	Circular	1	2	n/a	0.013	0.20	11.91	11.24
45NBC7	45NBC7	45NBC8	573	Circular	1	2	n/a	0.013	0.20	8.03	6.90
45NBC8	45NBC8	45NBC1067+00	134	Circular	1	2	n/a	0.013	0.20	6.90	6.63
45NBC9	45NBC9	45NBC10	300	Circular	1	2	n/a	0.013	0.20	6.28	5.68
45SB-1	45SB-1	45SBC3	328	Circular	1	2	n/a	0.013	0.20	9.04	8.39
45SBC2	45SBC2	45SB-1	185	Circular	1	2	n/a	0.013	0.20	9.41	9.04
45SBC3	45SBC3	45SBC4	332	Circular	1	2	n/a	0.013	0.20	8.39	7.72
45SBC4	45SBC4	LAT-2B	36	Circular	1	2	n/a	0.013	0.17	7.72	7.66
45SBC5	45SBC5	LAT-2B	46	Circular	1	2	n/a	0.013	0.20	9.53	9.44
45SBC6	45SBC6	45SBC5	330	Circular	1	2	n/a	0.013	0.20	10.19	9.53
45SBC7	45SBC7	45SBC6	337	Circular	1	2	n/a	0.013	0.20	10.87	10.19
45SBC8	45SBC8	45SBC7	321	Circular	1	2	n/a	0.013	0.20	11.51	10.87
69NB-28	69NB-28	69NB-29	71	Circular	1	2	n/a	0.013	0.20	7.04	6.90
69NB-29	69NB-29	69NB-30	239	Circular	1	2	n/a	0.013	0.20	6.90	6.43
69NB-30	69NB-30	69NB-31	297	Circular	1	2.5	n/a	0.013	0.17	5.93	5.43
69NB-31	69NB-31	69NB-32	300	Circular	1	2.5	n/a	0.013	0.20	5.43	4.84
69NB-32	69NB-32	69NB-33	551	Circular	1	3	n/a	0.013	0.20	4.34	3.24
69NB-33	69NB-33	69NB-34	75	Circular	1	3	n/a	0.013	0.20	3.24	3.09
69NB-34	69NB-34	69NB-35	393	Box	1	3	4	0.015	0.20	3.09	2.30
69NB-35	69NB-35	69NB-36	301	Box	1	4	5	0.015	0.20	1.30	0.70
69NB-36	69NB-36	69NB-37	84	Box	1	4	5	0.015	0.20	0.70	0.53
69NB-37	69NB-37	69NB-38	141	Box	1	4	5	0.015	0.20	0.53	0.25
69NB-38	69NB-38	69NB-39	155	Box	1	4	5	0.015	0.20	0.25	-0.06
69NB-39	69NB-39	69NB-40	300	Box	1	4	5	0.015	0.20	-0.15	-0.75
69NB-40	69NB-40	69NB-41	416	Box	1	4	5	0.015	0.19	-0.76	-1.55
69NB-41	69NB-41	69NB-42	471	Box	2	4	6	0.015	0.18	-1.55	-2.40
69NB-42	69NB-42	69NB-43	300	Box	2	4	6	0.015	0.20	-2.40	-3.00
69NB-43	69NB-43	69NB-44	181	Box	2	4	6	0.015	0.20	-3.00	-3.36
69NB-44	69NB-44	69NB-45	128	Box	2	4	6	0.015	0.20	-3.36	-3.62
69NB-45	69NB-45	I45 OUT-1	55	Box	2	4	6	0.015	0.20	-3.62	-3.73
69NB-46	69NB-46	I45 OUT-1	314	Box	3	4	6	0.015	0.10	-11.03	-11.35
69NB-47	69NB-47	69NB-46	571	Box	3	4	6	0.015	0.10	-10.43	-11.00
69NB-48	69NB-48	69NB-47	329	Box	3	4	6	0.015	0.10	-10.10	-10.43

I-45 PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
69NB-49	69NB-49	LAT-2D	32	Circular	1	2.5	n/a	0.013	0.19	8.05	7.99
69NB-50	69NB-50	69NB-49	336	Circular	1	2.5	n/a	0.013	0.20	8.73	8.05
69NB-51	69NB-51	69NB-50	332	Circular	1	2.5	n/a	0.013	0.20	9.39	8.73
69NB-52	69NB-52	69NB-51	293	Circular	1	2	n/a	0.013	0.20	10.48	9.89
69SB-23	69SB-23	69SB-24	184	Box	1	3	4	0.015	0.20	6.91	6.54
69SB-24	69SB-24	69SB-25	303	Box	1	3	4	0.015	0.20	6.54	5.94
69SB-25	69SB-25	69SB-25A	142	Box	1	3	4	0.015	0.20	5.94	5.66
69SB-25A	69SB-25A	69SB-25B	66	Box	1	3	4	0.015	0.20	5.66	5.52
69SB-25B	69SB-25B	69SB-26	85	Box	1	3	4	0.015	0.20	5.52	5.35
69SB-26	69SB-26	69SB-27	596	Box	1	4	5	0.015	0.20	4.35	3.16
69SB-27	69SB-27	69SB-28	203	Box	1	4	5	0.015	0.20	3.16	2.75
69SB-28	69SB-28	69SB-29	391	Box	1	4	5	0.015	0.20	2.75	1.97
69SB-29	69SB-29	69SB-30	300	Box	1	4	5	0.015	0.20	1.97	1.37
69SB-30	69SB-30	69SB-31	28	Box	1	4	5	0.015	0.20	1.37	1.32
69SB-31	69SB-31	69SB-32	195	Box	1	4	5	0.015	0.20	1.32	0.93
69SB-32	69SB-32	69SB-33	337	Box	1	4	5	0.015	0.20	0.93	0.25
69SB-33	69SB-33	69SB-34	410	Box	1	4	5	0.015	0.20	0.25	-0.57
69SB-34	69SB-34	LAT-1A	131	Box	1	4	5	0.015	0.20	-0.57	-0.83
69SB-35	69SB-35	LAT-1A	167	Circular	1	3	n/a	0.013	0.20	4.09	3.75
69SB-36	69SB-36	69SB-35	299	Circular	1	3	n/a	0.013	0.20	4.69	4.09
69SB-37	69SB-37	69SB-36	196	Circular	1	3	n/a	0.013	0.20	5.07	4.69

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

AECOM
AECOM TECHNICAL SERVICES, INC.
19219 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77094
WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation
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I-45/I-69/SH-288
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS

SHEET 1 OF 3

FED.RD DIV.ND.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

7/25/2018 7:30:37 AM
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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS
CONVEYANCE CONFIGURATION DATA

I-45 PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
69SB-38	69SB-38	69SB-37	113	Circular	1	2.5	n/a	0.013	0.20	5.80	5.57
69SB-39	69SB-39	69SB-38	301	Circular	1	2	n/a	0.013	0.20	6.90	6.30
69SB-40	69SB-40	69SB-41	572	Circular	1	2	n/a	0.013	0.20	10.65	9.51
69SB-41	69SB-41	69SB-42	328	Circular	1	2.5	n/a	0.013	0.20	9.01	8.36
69SB-42	69SB-42	LAT-2A	48	Circular	1	2.5	n/a	0.013	0.21	8.36	8.26
69SB-43	69SB-43	LAT-2A	61	Box	3	4	6	0.015	0.10	-9.65	-9.71
69SB-44	69SB-44	69SB-43	301	Box	3	4	6	0.015	0.10	-9.34	-9.65
69SB-45	69SB-45	69SB-44	626	Box	3	4	6	0.015	0.10	-8.72	-9.34
69SB-46A	69SB-46	69SB-45	274	Box	3	4	6	0.015	0.10	-8.44	-8.72
Hamilton	Hamilton	69SB-26	102	Box	2	3	4	0.015	0.29	8.14	7.85
I45 OUT-1	I45 OUT-1	I45 OUT-0	88	Box	2	5	7	0.015	0.20	-12.35	-12.53
LAT-1A	LAT-1A	288SB-4	111	Box	2	4	6	0.015	0.21	-0.83	-1.06
LAT-2A	LAT-2A	LAT-2B	161	Box	3	4	6	0.015	0.10	-9.71	-9.87
LAT-2B	LAT-2B	LAT-2C	46	Box	3	4	6	0.015	0.10	-9.87	-9.91
LAT-2C	LAT-2C	LAT-2D	147	Box	3	4	6	0.015	0.10	-9.91	-10.06
LAT-2D	LAT-2D	69NB-48	40	Box	3	4	6	0.015	0.10	-10.06	-10.10

BUFFALO BAYOU PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
45NB-1	45NB-1	45NB-2	68	Box	1	2	3	0.015	0.22	10.98	10.83
45NB-10	45NB-10	45NB-11	362	Circular	1	2.5	n/a	0.013	0.20	-1.46	-2.18
45NB-1046+50	45NB-1046+50	45NB-7	140	Circular	1	2.5	n/a	0.013	0.20	2.10	1.82
45NB-1058+20	45NB-1058+20	45NB-10	107	Circular	1	2.5	n/a	0.013	0.20	-1.24	-1.46
45NB-1067+45	45NB-1067+45	45NB-14	261	Circular	1	3	n/a	0.013	0.20	-3.60	-4.12
45NB-11	45NB-11	45NB-12	361	Circular	1	2.5	n/a	0.013	0.20	-2.18	-2.90
45NB-12	45NB-12	45NB-1067+45	97	Circular	1	2.5	n/a	0.013	0.20	-2.90	-3.10
45NB-14	45NB-14	45NB-15	340	Circular	1	3	n/a	0.013	0.20	-4.12	-4.80
45NB-15	45NB-15	45NB-16	335	Circular	1	3	n/a	0.013	0.20	-4.80	-5.47
45NB-16	45NB-16	LAT-4C	290	Circular	1	3	n/a	0.013	0.20	-5.47	-6.05
45NB-17	45NB-17	LAT-4C	27	Circular	1	2.5	n/a	0.013	0.30	4.68	4.60
45NB-18	45NB-18	45NB-17	125	Circular	1	2.5	n/a	0.013	0.20	5.35	5.10
45NB-19	45NB-19	45NB-18	300	Circular	1	2.5	n/a	0.013	0.20	9.80	9.20
45NB-2	45NB-2	45NB-3	300	Circular	1	2	n/a	0.013	0.20	10.83	10.23
45NB-20	45NB-20	45NB-19	300	Circular	1	2	n/a	0.013	0.20	21.60	21.00
45NB-3	45NB-3	45NB-4	300	Circular	1	2	n/a	0.013	0.20	10.23	9.63
45NB-4	45NB-4	45NB-5	301	Circular	1	2	n/a	0.013	0.20	9.63	9.03
45NB-5	45NB-5	45NB-5B	288	Circular	1	2.5	n/a	0.013	0.20	2.79	2.22
45NB-5B	45NB-5B	45NB-1046+50	60	Circular	1	2.5	n/a	0.013	0.20	2.22	2.10
45NB-6	45NB-6	45NB-1046+50	48	Circular	1	2.5	n/a	0.013	0.21	2.20	2.10
45NB-7	45NB-7	45NB-8	550	Circular	1	2.5	n/a	0.013	0.20	1.82	0.72
45NB-8	45NB-8	45NB-1058+20	473	Circular	1	2.5	n/a	0.013	0.20	0.72	-0.22
45NBC1	45NBC1	45NB-6	320	Circular	1	2	n/a	0.013	0.20	3.34	2.70
45SB -1055+60	45SB-1055+60	45SB-12	477	Circular	1	3	n/a	0.013	0.20	-2.33	-3.29
45SB -1064+70	45SB-1064+70	45SB-15	284	Circular	1	3	n/a	0.013	0.20	-4.16	-4.72
45SB-10	45SB-10	45SB-1055+60	206	Circular	1	3	n/a	0.013	0.20	-1.93	-2.33
45SB-1044+00	45SB-1044+00	45SB-9	679	Circular	1	2.5	n/a	0.013	0.20	0.47	-0.91
45SB-12	45SB-12	45SB-13	354	Circular	1	3	n/a	0.013	0.20	-3.29	-3.99
45SB-13	45SB-13	45SB-1064+70	81	Circular	1	3	n/a	0.013	0.20	-3.99	-4.16
45SB-15	45SB-15	45SB-16	338	Circular	1	3	n/a	0.013	0.20	-4.72	-5.39
45SB-16	45SB-16	45SB-17	335	Circular	1	3	n/a	0.013	0.20	-5.39	-6.06
45SB-17	45SB-17	LAT-4B	296	Circular	1	3	n/a	0.013	0.20	-6.06	-6.65
45SB-18	45SB-18	LAT-4B	21	Circular	1	3	n/a	0.013	0.57	4.16	4.04
45SB-19	45SB-19	45SB-18	160	Circular	1	2.5	n/a	0.013	0.20	5.73	5.41
45SB-2	45SB-2	45SB-3	240	Circular	1	2	n/a	0.013	0.20	3.55	3.07
45SB-20	45SB-20	45SB-19	301	Circular	1	2	n/a	0.013	0.20	11.59	10.99

BUFFALO BAYOU PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
45SB-21	45SB-21	45SB-20	300	Circular	1	2	n/a	0.013	0.20	23.65	23.05
45SB-3	45SB-3	45SB-4	298	Circular	1	2	n/a	0.013	0.20	3.07	2.47
45SB-4	45SB-4	45SB-5	302	Circular	1	2	n/a	0.013	0.20	2.47	1.87
45SB-5	45SB-5	45SB-6	297	Circular	1	2	n/a	0.013	0.20	1.87	1.27
45SB-6	45SB-6	45SB-7	85	Circular	1	2.5	n/a	0.013	0.20	0.77	0.60
45SB-7	45SB-7	45SB-1044+00	67	Circular	1	2.5	n/a	0.013	0.20	0.60	0.47
45SB-9	45SB-9	45SB-10	267	Circular	1	3	n/a	0.013	0.20	-1.41	-1.93
45SBC1	45SBC1	45SB-1044+00	217	Circular	1	2.5	n/a	0.013	0.21	0.92	0.47
69NB-1162+00	69NB-1162+00	69NB-61	463	Circular	1	3	n/a	0.013	0.20	-2.94	-3.87
69NB-1170+10	69NB-1170+10	69NB-63	34	Circular	1	3	n/a	0.013	0.20	-4.54	-4.60
69NB-53	69NB-53	69NB-54	451	Circular	1	2	n/a	0.013	0.20	2.44	1.54
69NB-54	69NB-54	69NB-55	300	Circular	1	2	n/a	0.013	0.20	1.54	0.94
69NB-55	69NB-55	69NB-56	173	Circular	1	2.5	n/a	0.013	0.20	0.44	0.10
69NB-56	69NB-56	69NB-57	70	Circular	1	3	n/a	0.013	0.21	-0.41	-0.55
69NB-57	69NB-57	69NB-58	608	Circular	1	3	n/a	0.013	0.21	-0.55	-1.81
69NB-58	69NB-58	69NB-59	327	Circular	1	3	n/a	0.013	0.21	-1.81	-2.49
69NB-59	69NB-59	69NB-1162+00	221	Circular	1	3	n/a	0.013	0.21	-2.49	-2.94
69NB-61	69NB-61	69NB-1170+10	333	Circular	1	3	n/a	0.013	0.20	-3.87	-4.54
69NB-63	69NB-63	69NB-64	353	Circular	1	3	n/a	0.013	0.20	-4.60	-5.31
69NB-64	69NB-64	69NB-65	339	Circular	1	3	n/a	0.013	0.20	-5.31	-5.99
69NB-67	69NB-67	LAT-4D	30	Circular	1	2.5	n/a	0.013	0.20	2.66	2.60
69NB-68	69NB-68	69NB-67	209	Circular	1	2.5	n/a	0.013	0.20	3.41	2.99
69NB-69	69NB-69	69NB-68	298	Circular	1	2	n/a	0.013	0.20	8.47	7.87
69NB-70	69NB-70	69NB-69	303	Circular	1	2	n/a	0.013	0.20	15.70	15.09

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

AECOM
AECOM TECHNICAL SERVICES, INC.
10210 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77094
WWW.AECOM.COM
TBPE REG. NO. F-3580

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I-45/I-69/SH-288
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS

SHEET 2 OF 3

FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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sd.penultimate

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS
CONVEYANCE CONFIGURATION DATA

BUFFALO BAYOU PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
69SB-1133+00	69SB-1133+00	69SB-47	162	Box	3	4	6	0.015	0.10	-8.13	-8.30
69SB-1153+70	69SB-1153+70	69SB-55	485	Box	3	4	6	0.015	0.10	-10.20	-10.68
69SB-1162+80	69SB-1162+80	69SB-58	287	Box	3	4	6	0.015	0.10	-11.11	-11.39
69SB-46B	69SB-46B	69SB-1133+00	162	Box	3	4	6	0.015	0.10	-7.97	-8.13
69SB-47	69SB-47	69SB-48	301	Box	3	4	6	0.015	0.10	-8.30	-8.60
69SB-48	69SB-48	69SB-49	143	Box	3	4	6	0.015	0.10	-8.60	-8.74
69SB-49	69SB-49	69SB-50	96	Box	3	4	6	0.015	0.10	-8.74	-8.84
69SB-50	69SB-50	69SB-51	302	Box	3	4	6	0.015	0.10	-8.84	-9.14
69SB-51	69SB-51	69SB-51A	359	Box	3	4	6	0.015	0.10	-9.14	-9.50
69SB-51A	69SB-51A	69SB-51B	52	Box	3	4	6	0.015	0.10	-9.50	-9.55
69SB-51B	69SB-51B	69SB-52	158	Box	3	4	6	0.015	0.10	-9.55	-9.71
69SB-52	69SB-52	69SB-53	278	Box	3	4	6	0.015	0.10	-9.71	-9.99
69SB-53	69SB-53	69SB-1153+70	210	Box	3	4	6	0.015	0.10	-9.99	-10.20
69SB-55	69SB-55	69SB-56	349	Box	3	4	6	0.015	0.10	-10.68	-11.03
69SB-56	69SB-56	69SB-1162+80	77	Box	3	4	6	0.015	0.10	-11.03	-11.11
69SB-58	69SB-58	69SB-59	337	Box	3	4	6	0.015	0.10	-11.39	-11.73
69SB-59	69SB-59	69SB-60	338	Box	3	4	6	0.015	0.10	-11.73	-12.07
69SB-60	69SB-60	LAT-4A	298	Box	3	4	6	0.015	0.10	-12.07	-12.37
69SB-61	69SB-61	69SB-62	253	Box	3	4	6	0.015	0.10	-12.39	-12.64
69SB-62	69SB-62	69SB-63	300	Box	3	4	6	0.015	0.10	-12.64	-12.94
69SB-63	69SB-63	69SB-64	302	Box	3	4	6	0.015	0.10	-12.94	-13.24
69SB-64	69SB-64	BUF OUT-2	145	Box	3	4	6	0.015	0.10	-13.24	-13.39
69SB-65	69NB-65	69NB-66	333	Circular	1	3	n/a	0.013	0.20	-5.99	-6.65
69SB-66	69NB-66	LAT-4D	288	Circular	1	3	n/a	0.013	0.20	-6.65	-7.23
BUF OUT-1	BUF OUT-1	BUF OUT-0	144	Box	3	4	6	0.015	0.10	-13.58	-13.72
BUF OUT-2	BUF OUT-2	BUF OUT-1	191	Box	3	4	6	0.015	0.10	-13.39	-13.58
LAT-4A	LAT-4A	69SB-61	19	Box	3	4	6	0.015	0.10	-12.37	-12.39
LAT-4B	LAT-4B	LAT-4A	121	Box	1	3	4	0.015	0.20	-7.75	-7.99
LAT-4C	LAT-4C	LAT-4B	131	Box	1	3	4	0.015	0.20	-7.49	-7.75
LAT-4D	LAT-4D	LAT-4C	98	Box	1	3	4	0.015	0.20	-7.29	-7.49

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13210 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77094
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TBPE REG. NO. F-3580

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I-45/I-69/SH-288
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS

SHEET 3 OF 3

FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE HYDRAULIC COMPUTATIONS

I-45 PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM VELOCITY (FT/S)	UNIFORM DEPTH (FT)	ACTUAL VELOCITY (FT/S)	ACTUAL DEPTH (FT)
288SB-1	288SB-1	288SB-2	8.74	8.61	5.29	10.88	3.26	1.03	2	1.57
288SB-10	288SB-10	288SB-9	17.09	15.83	21.25	19.73	4.44	2.5	4.33	2.5
288SB-2	288SB-2	288SB-3	8.61	8	10.21	10.88	3.7	1.64	3.25	2
288SB-3	288SB-3	288SB-4	8	6.99	14.78	10.99	4.83	2	4.71	2
288SB-4	288SB-4	45NBC11	4.41	4.25	189.44	302.94	5.67	2.78	3.95	4
288SB-5	288SB-5	288SB-4	7.42	6.33	51.83	32.09	7.52	3	7.33	3
288SB-6	288SB-6	288SB-5	9.21	7.42	45.92	32.09	6.67	3	6.5	3
288SB-7	288SB-7	288SB-6	10.86	9.21	40.57	32.09	5.89	3	5.74	3
288SB-8	288SB-8	288SB-7	13.52	10.86	34.66	19.73	7.24	2.5	7.06	2.5
288SB-9	288SB-9	288SB-8	15.83	13.52	28.84	19.73	6.03	2.5	5.88	2.5
45NBC10	45NBC10	45NBC11	7.58	6.63	13.63	10.83	4.45	2	4.42	1.9
45NBC1067+00	45NBC1067+00	45NBC9	8.05	7.97	4.99	10.75	3.19	1	2.08	1.42
45NBC11	45NBC11	69NB-41	4.25	4.02	242.68	297.67	6.05	3.34	5.06	4
45NBC12	45NBC12	45NBC11	8.4	7.49	45.05	32.09	6.54	3	6.5	2.84
45NBC13	45NBC13	45NBC12	9.69	8.4	39.34	32.17	5.71	3	5.57	3
45NBC14	45NBC14	45NBC13	12.5	9.69	32.73	19.68	6.84	2.5	6.67	2.5
45NBC15	45NBC15	45NBC14	13.97	12.5	25.66	19.68	5.36	2.5	5.23	2.5
45NBC16	45NBC16	45NBC16A	17.06	15.92	18.44	10.88	6.02	2	5.87	2
45NBC16A	45NBC16A	45NBC15	15.92	13.97	18.44	10.88	6.02	2	5.87	2
45NBC17	45NBC17	45NBC16	18.37	17.06	11.92	11.23	3.89	2	3.79	2
45NBC2	45NBC2	45NBC2B	13.14	12.97	7.06	10.88	3.47	1.23	3.48	1.23
45NBC2B	45NBC2B	45NBC3	12.97	11.78	7.06	10.88	3.47	1.23	3.48	1.23
45NBC3	45NBC3	LAT-2C	11.78	11.52	8.28	10.52	3.5	1.41	4.13	1.22
45NBC4	45NBC4	LAT-2C	11.47	11.24	4.53	10.77	3.13	0.94	3.35	0.89
45NBC5	45NBC5	45NBC4	11.98	11.47	2.96	10.88	2.83	0.73	2.79	0.74
45NBC6	45NBC6	45NBC5	12.39	11.98	1.26	10.88	2.19	0.48	2.19	0.48
45NBC7	45NBC7	45NBC8	8.73	8.14	2.64	10.83	2.67	0.7	2.67	0.7
45NBC8	45NBC8	45NBC1067+00	8.14	8.05	4.99	10.86	3.19	1	2.44	1.24
45NBC9	45NBC9	45NBC10	7.97	7.58	8.94	10.88	3.62	1.47	3.15	1.69
45SB-1	45SB-1	45SBC3	10.62	9.95	9.76	10.86	3.66	1.58	3.68	1.58
45SBC2	45SBC2	45SB-1	10.69	10.62	4.4	10.86	3.1	0.92	2.07	1.28
45SBC3	45SBC3	45SBC4	9.95	9.17	9.9	10.94	3.71	1.58	3.77	1.56
45SBC4	45SBC4	LAT-2B	9.17	8.86	11.26	9.88	3.68	2	4.6	1.46
45SBC5	45SBC5	LAT-2B	10.74	10.45	8.09	10.77	3.59	1.35	4.06	1.21
45SBC6	45SBC6	45SBC5	11.38	10.74	6.67	10.88	3.48	1.17	3.43	1.19
45SBC7	45SBC7	45SBC6	11.88	11.38	5.14	10.91	3.28	1	3.2	1.02
45SBC8	45SBC8	45SBC7	12.3	11.88	3.26	10.88	2.89	0.78	2.84	0.79
69NB-28	69NB-28	69NB-29	9.01	8.99	3.02	10.77	2.74	0.76	0.96	1.97
69NB-29	69NB-29	69NB-30	8.99	8.72	7.68	10.8	3.58	1.29	2.45	2
69NB-30	69NB-30	69NB-31	8.72	8.38	13.87	18.14	3.75	1.76	2.82	2.5
69NB-31	69NB-31	69NB-32	8.38	7.5	22.24	19.58	4.65	2.5	4.53	2.5
69NB-32	69NB-32	69NB-33	7.5	6.4	29.75	32.01	4.79	2.46	4.21	3
69NB-33	69NB-33	69NB-34	6.4	6.2	34.81	32.17	5.05	3	4.93	3
69NB-34	69NB-34	69NB-35	6.2	5.44	47.2	59.42	4.71	2.51	3.93	3
69NB-35	69NB-35	69NB-36	5.44	5.25	53.37	116.6	4.93	2.17	2.67	4
69NB-36	69NB-36	69NB-37	5.25	5.18	59.24	117.18	5.04	2.35	2.96	4
69NB-37	69NB-37	69NB-38	5.18	5.06	62.34	116.6	5.04	2.47	3.12	4
69NB-38	69NB-38	69NB-39	5.06	4.91	65.28	116.6	5.15	2.54	3.26	4
69NB-39	69NB-39	69NB-40	4.91	4.57	71.55	116.31	5.26	2.72	3.58	4
69NB-40	69NB-40	69NB-41	4.57	4.02	77.01	113.65	5.19	2.97	3.85	4
69NB-41	69NB-41	69NB-42	4.02	2.27	327.32	285.26	6.89	4	6.82	4
69NB-42	69NB-42	69NB-43	2.27	1.12	333.56	300.69	7.02	4	6.95	4
69NB-43	69NB-43	69NB-44	1.12	0.51	340.81	299.94	7.17	4	7.1	4
69NB-44	69NB-44	69NB-45	0.51	-0.03	349.6	302.94	7.36	4	7.53	3.87
69NB-45	69NB-45	I45 OUT-1	-0.03	-0.7	359.47	300.69	7.56	4	8.35	3.59
69NB-46	69NB-46	I45 OUT-1	-7.26	-7.31	119.82	320.52	3.36	1.98	1.77	3.77
69NB-47	69NB-47	69NB-46	-7.17	-7.26	118.98	318.93	3.56	1.86	2.03	3.26
69NB-48	69NB-48	69NB-47	-7.1	-7.17	114.97	318.93	3.44	1.86	2.13	3
69NB-49	69NB-49	LAT-2D	10.43	9.98	34.24	19.28	7.16	2.5	7.1	2.38
69NB-50	69NB-50	69NB-49	11.87	10.43	26.9	19.88	5.62	2.5	5.48	2.5
69NB-51	69NB-51	69NB-50	12.64	11.87	19.73	19.68	4.12	2.35	4.02	2.5
69NB-52	69NB-52	69NB-51	12.97	12.64	7.67	10.86	3.58	1.29	2.44	2

I-45 PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM VELOCITY (FT/S)	UNIFORM DEPTH (FT)	ACTUAL VELOCITY (FT/S)	ACTUAL DEPTH (FT)
69SB-23	69SB-23	69SB-24	8.53	8.38	20.72	59.28	3.85	1.35	3.19	1.62
69SB-24	69SB-24	69SB-25	8.38	7.99	28.57	59.28	4.16	1.72	3.89	1.84
69SB-25	69SB-25	69SB-25A	7.99	7.69	37.53	59.28	4.49	2.09	4.57	2.05
69SB-25A	69SB-25A	69SB-25B	7.69	7.54	37.53	59.28	4.49	2.09	4.62	2.03
69SB-25B	69SB-25B	69SB-26	7.54	7.34	37.53	59.28	4.49	2.09	4.66	2.01
69SB-26	69SB-26	69SB-27	7.34	7.07	51.11	116.6	4.86	2.1	3.43	2.98
69SB-27	69SB-27	69SB-28	7.07	6.94	57.6	116.6	5.03	2.29	2.94	3.91
69SB-28	69SB-28	69SB-29	6.94	6.61	62.22	116.6	5.03	2.47	3.11	4
69SB-29	69SB-29	69SB-30	6.61	6.3	67.89	116.6	5.22	2.6	3.39	4
69SB-30	69SB-30	69SB-31	6.3	6.27	73.79	117.76	5.42	2.72	3.69	4
69SB-31	69SB-31	69SB-32	6.27	6.01	77.31	116.6	5.43	2.85	3.87	4
69SB-32	69SB-32	69SB-33	6.01	5.48	84.35	116.6	5.45	3.09	4.22	4
69SB-33	69SB-33	69SB-34	5.48	4.75	89.7	116.6	5.58	3.22	4.49	4
69SB-34	69SB-34	LAT-1A	4.75	4.48	96.39	116.6	5.56	3.46	4.82	4
69SB-35	69SB-35	LAT-1A	6.9	5.87	42.48	32.33	6.17	3	6.17	2.81
69SB-36	69SB-36	69SB-35	7.81	6.9	37.68	32.09	5.47	3	5.33	3
69SB-37	69SB-37	69SB-36	8.2	7.81	29.57	31.76	4.76	2.46	4.18	3
69SB-38	69SB-38	69SB-37	8.49	8.2	20.99	19.88	4.39	2.5	4.28	2.5
69SB-39	69SB-39	69SB-38	9.42	8.49	12.6	10.88	4.11	2	4.01	2
69SB-40	69SB-40	69SB-41	12.24	11.21	9.7	10.86	3.63	1.58	3.61	1.6
69SB-41	69SB-41	69SB-42	11.21	10.55	18.83	19.58	4.11	2.2	4.11	2.2
69SB-42	69SB-42	LAT-2A	10.55	10.06	27.96	20.22	5.84	2.5	6.15	2.18

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
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TBPE REG. NO. F-3580

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I-45/I-69/SH-288
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS

SHEET 1 OF 3

FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE HYDRAULIC COMPUTATIONS

I-45 PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM VELOCITY (FT/S)	UNIFORM DEPTH (FT)	ACTUAL VELOCITY (FT/S)	ACTUAL DEPTH (FT)
69SB-43	69SB-43	LAT-2A	-7.06	-7.06	29.53	318.93	2.21	0.74	0.63	2.59
69SB-44	69SB-44	69SB-43	-7.05	-7.06	21.34	320.52	1.92	0.62	0.52	2.29
69SB-45	69SB-45	69SB-44	-7.04	-7.05	12.87	318.93	1.65	0.43	0.43	1.67
69SB-46A	69SB-46	69SB-45	-7.04	-7.04	4.1	318.93	1.05	0.22	0.16	1.4
Hamilton	Hamilton	69SB-26	8.68	8.07	5	141.52	2.11	0.3	1.15	0.54
I45 OUT-1	I45 OUT-1	I45 OUT-0	-7.31	-7.53	442.15	495.51	7.04	4.49	6.32	5
LAT-1A	LAT-1A	288SB-4	4.48	4.41	130.34	305.91	5.16	2.1	2.72	4
LAT-2A	LAT-2A	LAT-2B	-7.06	-7.07	53.63	318.93	2.68	1.11	1.12	2.65
LAT-2B	LAT-2B	LAT-2C	-7.07	-7.07	69.24	318.93	2.96	1.3	1.37	2.8
LAT-2C	LAT-2C	LAT-2D	-7.07	-7.09	79.64	318.93	2.98	1.48	1.56	2.84
LAT-2D	LAT-2D	69NB-48	-7.09	-7.1	106.59	318.93	3.42	1.73	1.99	2.97

BUFFALO BAYOU PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM VELOCITY (FT/S)	UNIFORM DEPTH (FT)	ACTUAL VELOCITY (FT/S)	ACTUAL DEPTH (FT)
45NB-1	45NB-1	45NB-2	18.82	18.81	4.72	24.89	2.67	0.59	0.79	2
45NB-10	45NB-10	45NB-11	6.08	3.69	33.34	19.73	6.97	2.5	6.79	2.5
45NB-1046+50	45NB-1046+50	45NB-7	14.47	13.54	33.34	19.73	6.97	2.5	6.79	2.5
45NB-1058+20	45NB-1058+20	45NB-10	6.78	6.08	33.34	19.73	6.97	2.5	6.79	2.5
45NB-1067+45	45NB-1067+45	45NB-14	0.66	0.01	33.34	32.09	4.84	3	4.72	3
45NB-11	45NB-11	45NB-12	3.69	1.3	33.34	19.73	6.97	2.5	6.79	2.5
45NB-12	45NB-12	45NB-1067+45	1.3	0.66	33.34	19.73	6.97	2.5	6.79	2.5
45NB-14	45NB-14	45NB-15	0.01	-0.84	33.34	32.09	4.84	3	4.72	3
45NB-15	45NB-15	45NB-16	-0.84	-1.68	33.34	32.09	4.84	3	4.72	3
45NB-16	45NB-16	LAT-4C	-1.68	-2.4	33.34	32.09	4.84	3	4.72	3
45NB-17	45NB-17	LAT-4C	6.48	6.21	22.36	24.17	5.18	2.05	5.92	1.8
45NB-18	45NB-18	45NB-17	7.28	6.62	20.08	19.83	4.2	2.35	4.95	1.93
45NB-19	45NB-19	45NB-18	11.44	10.48	14.43	19.78	4.1	1.69	4.24	1.64
45NB-2	45NB-2	45NB-3	18.81	18.28	9.53	10.88	3.71	1.53	3.03	2
45NB-20	45NB-20	45NB-19	22.97	22.04	8.45	10.83	3.58	1.41	3.67	1.38
45NB-3	45NB-3	45NB-4	18.28	17.19	13.62	10.88	4.45	2	4.34	2
45NB-4	45NB-4	45NB-5	17.19	15.4	17.48	10.86	5.71	2	5.56	2
45NB-5	45NB-5	45NB-5B	15.4	14.63	21.22	19.68	4.44	2.5	4.32	2.5
45NB-5B	45NB-5B	45NB-1046+50	14.63	14.47	21.22	19.68	4.44	2.5	4.32	2.5
45NB-6	45NB-6	45NB-1046+50	14.52	14.47	14.24	20.07	4.25	1.61	2.9	2.5
45NB-7	45NB-7	45NB-8	13.54	9.91	33.34	19.73	6.97	2.5	6.79	2.5
45NB-8	45NB-8	45NB-1058+20	9.91	6.78	33.34	19.68	6.97	2.5	6.79	2.5
45NBC1	45NBC1	45NB-6	14.9	14.52	7.7	10.88	3.59	1.29	2.45	2
45SB -1055+60	45SB-1055+60	45SB-12	1.68	0.58	32.01	32.09	4.65	2.82	4.53	3
45SB -1064+70	45SB-1064+70	45SB-15	-0.42	-1.07	32.01	32.01	4.65	2.82	4.53	3
45SB-10	45SB-10	45SB-1055+60	2.16	1.68	32.01	31.76	4.65	2.82	4.53	3
45SB-1044+00	45SB-1044+00	45SB-9	6.91	2.77	32.01	19.83	6.69	2.5	6.52	2.5
45SB-12	45SB-12	45SB-13	0.58	-0.23	32.01	32.09	4.65	2.82	4.53	3
45SB-13	45SB-13	45SB-1064+70	-0.23	-0.42	32.01	32.09	4.65	2.82	4.53	3
45SB-15	45SB-15	45SB-16	-1.07	-1.85	32.01	32.01	4.65	2.82	4.53	3
45SB-16	45SB-16	45SB-17	-1.85	-2.62	32.01	32.01	4.65	2.82	4.53	3
45SB-17	45SB-17	LAT-4B	-2.62	-3.31	32.01	32.01	4.65	2.82	4.53	3
45SB-18	45SB-18	LAT-4B	5.42	5.21	15.61	54.26	6.3	1.14	5.53	1.26
45SB-19	45SB-19	45SB-18	7.27	6.65	13.6	19.78	4.06	1.61	4.29	1.54
45SB-2	45SB-2	45SB-3	12.23	12.08	5.7	10.88	3.28	1.09	1.82	2
45SB-20	45SB-20	45SB-19	13.09	12.1	9.65	10.86	3.61	1.58	3.8	1.51
45SB-21	45SB-21	45SB-20	24.69	23.87	5.43	10.91	3.23	1.06	3.3	1.04
45SB-3	45SB-3	45SB-4	12.08	11.38	10.94	10.91	3.57	1.88	3.48	2
45SB-4	45SB-4	45SB-5	11.38	9.92	15.73	10.86	5.14	2	5.01	2
45SB-5	45SB-5	45SB-6	9.92	7.49	20.43	10.94	6.67	2	6.5	2
45SB-6	45SB-6	45SB-7	7.49	7.18	24.8	19.78	5.18	2.5	5.05	2.5
45SB-7	45SB-7	45SB-1044+00	7.18	6.91	26.33	19.58	5.5	2.5	5.36	2.5

BUFFALO BAYOU PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM VELOCITY (FT/S)	UNIFORM DEPTH (FT)	ACTUAL VELOCITY (FT/S)	ACTUAL DEPTH (FT)
45SB-9	45SB-9	45SB-10	2.77	2.16	32.01	31.76	4.65	2.82	4.53	3
45SBC1	45SBC1	45SB-1044+00	6.97	6.91	6.71	19.98	3.53	1.03	1.37	2.5
69NB-1162+00	69NB-1162+00	69NB-61	2	1.09	29.64	32.09	4.77	2.46	4.19	3
69NB-1170+10	69NB-1170+10	69NB-63	0.43	0.36	29.64	32.09	4.77	2.46	4.19	3
69NB-53	69NB-53	69NB-54	6.34	5.86	7.34	10.88	3.52	1.26	2.34	2
69NB-54	69NB-54	69NB-55	5.86	5.11	11.31	10.88	3.69	2	3.6	2
69NB-55	69NB-55	69NB-56	5.11	4.43	25.83	19.73	5.4	2.5	5.26	2.5
69NB-56	69NB-56	69NB-57	4.43	4.29	29.64	32.64	4.94	2.38	4.19	3
69NB-57	69NB-57	69NB-58	4.29	3.09	29.64	32.64	4.94	2.38	4.19	3
69NB-58	69NB-58	69NB-59	3.09	2.44	29.64	32.64	4.94	2.38	4.19	3
69NB-59	69NB-59	69NB-1162+00	2.44	2	29.64	32.64	4.94	2.38	4.19	3
69NB-61	69NB-61	69NB-1170+10	1.09	0.43	29.64	32.09	4.77	2.46	4.19	3
69NB-63	69NB-63	69NB-64	0.36	-0.34	29.64	32.09	4.77	2.46	4.19	3
69NB-64	69NB-64	69NB-65	-0.34	-1.01	29.64	32.09	4.77	2.46	4.19	3
69NB-67	69NB-67	LAT-4D	4.61	4.28	24.18	19.68	5.05	2.5	5.89	1.95
69NB-68	69NB-68	69NB-67	5.39	4.61	19.72	19.73	4.12	2.35	4.72	1.99
69NB-69	69NB-69	69NB-68	10.22	9.1	11.72	10.88	3.83	2	4.02	1.75
69NB-70	69NB-70	69NB-69	16.83	15.98	6.28	10.88	3.38	1.14	3.42	1.13
69SB-1133+00	69SB-1133+00	69SB-47	-7.9	-7.97	4.1	318.93	1.05	0.22	0.97	0.24
69SB-1153+70	69SB-1153+70	69SB-55	-9.31	-9.33	11.42	318.93	1.58	0.4	0.72	0.88
69SB-1162+80	69SB-1162+80	69SB-58	-9.34	-9.34	11.42	318.93	1.58	0.4	0.36	1.77
69SB-46B	69SB-46B	69SB-1133+00	-7.43	-7.9	4.1	315.73	1.05	0.22	0.42	0.55
69SB-47	69SB-47	69SB-48	-7.97	-8.24	8.07	318.93	1.38	0.32	1.38	0.33
69SB-48	69SB-48	69SB-49	-8.24	-8.34	8.47	320.52	1.38	0.34	1.33	0.35
69SB-49	69SB-49	69SB-50	-8.34	-8.43	11.42	320.52	1.58	0.4	1.57	0.4

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

AECOM
AECOM TECHNICAL SERVICES, INC.
10210 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77094
WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation
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I-45/I-69/SH-288
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS

SHEET 2 OF 3

FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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sd.pmurphy

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS
CONVEYANCE HYDRAULIC COMPUTATIONS

BUFFALO BAYOU PUMP STATION SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM VELOCITY (FT/S)	UNIFORM DEPTH (FT)	ACTUAL VELOCITY (FT/S)	ACTUAL DEPTH (FT)
69SB-50	69SB-50	69SB-51	-8.43	-8.73	11.42	318.93	1.58	0.4	1.57	0.4
69SB-51	69SB-51	69SB-51A	-8.73	-9.07	11.42	318.93	1.58	0.4	1.57	0.41
69SB-51A	69SB-51A	69SB-51B	-9.07	-9.11	11.42	318.93	1.58	0.4	1.49	0.43
69SB-51B	69SB-51B	69SB-52	-9.11	-9.21	11.42	318.93	1.58	0.4	1.46	0.44
69SB-52	69SB-52	69SB-53	-9.21	-9.29	11.42	318.93	1.58	0.4	1.28	0.5
69SB-53	69SB-53	69SB-1153+70	-9.29	-9.31	11.42	318.93	1.58	0.4	0.92	0.69
69SB-55	69SB-55	69SB-56	-9.33	-9.34	11.42	318.93	1.58	0.4	0.47	1.35
69SB-56	69SB-56	69SB-1162+80	-9.34	-9.34	11.42	318.93	1.58	0.4	0.38	1.69
69SB-58	69SB-58	69SB-59	-9.34	-9.35	11.42	318.93	1.58	0.4	0.31	2.05
69SB-59	69SB-59	69SB-60	-9.35	-9.35	11.42	318.93	1.58	0.4	0.27	2.39
69SB-60	69SB-60	LAT-4A	-9.35	-9.35	11.42	318.93	1.58	0.4	0.23	2.72
69SB-61	69SB-61	69SB-62	-9.36	-9.44	146.16	318.93	3.65	2.23	2.68	3.03
69SB-62	69SB-62	69SB-63	-9.44	-9.54	153.44	318.93	3.83	2.23	2.67	3.19
69SB-63	69SB-63	69SB-64	-9.54	-9.64	160.79	318.93	3.8	2.35	2.63	3.39
69SB-64	69SB-64	BUF OUT-2	-9.64	-9.68	166.85	318.93	3.75	2.47	2.57	3.6
69SB-65	69NB-65	69NB-66	-1.01	-1.66	29.64	32.09	4.77	2.46	4.19	3
69SB-66	69NB-66	LAT-4D	-1.66	-2.23	29.64	32.09	4.77	2.46	4.19	3
BUF OUT-1	BUF OUT-1	BUF OUT-0	-9.7	-9.72	108.96	318.93	3.49	1.73	1.56	3.87
BUF OUT-2	BUF OUT-2	BUF OUT-1	-9.68	-9.7	108.96	318.93	3.49	1.73	1.64	3.7
LAT-4A	LAT-4A	69SB-61	-9.35	-9.36	141.27	318.93	3.52	2.23	2.6	3.02
LAT-4B	LAT-4B	LAT-4A	-3.31	-4.99	126.55	59.13	10.65	3	10.55	3
LAT-4C	LAT-4C	LAT-4B	-2.4	-3.31	88.98	58.98	7.49	3	7.41	3
LAT-4D	LAT-4D	LAT-4C	-2.23	-2.4	44.73	59.72	4.63	2.41	3.73	3

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

AECOM
AECOM TECHNICAL SERVICES, INC.
10219 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77024
WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation
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I-45/I-69/SH-288
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS

SHEET 3 OF 3

FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS
RUNOFF COMPUTATIONS FOR DESIGN FREQUENCY

I-45 PUMP STATION SYSTEM						
ID	RUNOFF C	DRAINAGE AREA (ACRES)	TIME OF CONC. (MIN)	TIME USED (MIN)	INTENSITY (IN/HR)	DISCHARGE (CFS)
288SB-1	1	0.45	6.78	10	11.69	5.29
288SB-10	1	1.82	6.13	10	11.69	21.25
288SB-2	1	0.46	4.72	10	11.69	5.43
288SB-3	1	0.46	4.23	10	11.69	5.42
288SB-4	1	0.33	3.15	10	11.69	3.8
288SB-5	1	0.71	5.18	10	11.69	8.35
288SB-6	1	0.67	5.19	10	11.69	7.8
288SB-7	1	0.65	4.81	10	11.69	7.56
288SB-8	1	0.65	4.04	10	11.69	7.55
288SB-9	1	0.79	4.25	10	11.69	9.2
45NBC10	1	0.52	4.16	10	11.69	6.03
45NBC11	1	0.36	3.07	10	11.69	4.27
45NBC12	1	0.7	5.18	10	11.69	8.22
45NBC13	1	0.76	5.57	10	11.69	8.84
45NBC14	1	0.77	5.39	10	11.69	8.98
45NBC15	1	0.75	5.08	10	11.69	8.72
45NBC16	1	0.66	4.31	10	11.69	7.7
45NBC17	1	1.02	5.23	10	11.69	11.92
45NBC2	1	0.6	7.45	10	11.69	7.06
45NBC3	1	0.18	5.4	10	11.69	2.07
45NBC4	1	0.17	3.42	10	11.69	1.97
45NBC5	1	0.17	3.24	10	11.69	1.94
45NBC6	1	0.11	1.73	10	11.69	1.26
45NBC7	1	0.23	3.15	10	11.69	2.64
45NBC8	1	0.25	3.84	10	11.69	2.91
45NBC9	1	0.41	4.32	10	11.69	4.84
45SB-1	1	0.49	1.94	10	11.69	5.68
45SBC2	1	0.38	3.85	10	11.69	4.4
45SBC3	1	0.05	3.84	10	11.69	0.62
45SBC4	1	0.17	9.08	10	11.69	1.99
45SBC5	1	0.17	4.13	10	11.69	1.97
45SBC6	1	0.17	3.91	10	11.69	1.99
45SBC7	1	0.19	4.03	10	11.69	2.18
45SBC8	1	0.28	4.03	10	11.69	3.26
69NB-28	1	0.26	2.44	10	11.69	3.02
69NB-29	1	0.41	2.04	10	11.69	4.77
69NB-30	1	0.58	3.8	10	11.69	6.76
69NB-31	1	0.83	4.17	10	11.69	9.71
69NB-32	1	0.79	4.05	10	11.69	9.18
69NB-33	1	0.66	3.67	10	11.69	7.75
69NB-34	1	1.28	9.62	10	11.69	15
69NB-35	1	0.82	4.19	10	11.69	9.59
69NB-36	1	0.77	4.05	10	11.69	9.04
69NB-37	1	0.38	3.2	10	11.69	4.44
69NB-38	1	0.4	3	10	11.69	4.64
69NB-39	1	0.78	4.62	10	11.69	9.12
69NB-40	1	0.79	4.47	10	11.69	9.26
69NB-41	1	1.41	3.52	10	11.69	16.53
69NB-42	1	0.74	4.56	10	11.69	8.6
69NB-43	1	0.85	4.45	10	11.69	10
69NB-44	1	1.04	4.77	10	11.69	12.13
69NB-45	1	1.16	5.59	10	11.69	13.62
69NB-46	1	0.86	3.54	10	11.69	10.08
69NB-47	1	0.92	4	10	11.69	10.78
69NB-48	1	1.02	4.24	10	11.69	11.97
69NB-49	1	0.77	4.6	10	11.69	9.04
69NB-50	1	0.74	4.35	10	11.69	8.61
69NB-51	1	1.11	7.38	10	11.69	12.92
69NB-52	1	0.66	3.98	10	11.69	7.67

I-45 PUMP STATION SYSTEM						
ID	RUNOFF C	DRAINAGE AREA (ACRES)	TIME OF CONC. (MIN)	TIME USED (MIN)	INTENSITY (IN/HR)	DISCHARGE (CFS)
69SB-23	1	1.77	9.82	10	11.69	20.72
69SB-24	1	0.73	6.5	10	11.69	8.57
69SB-25	1	0.91	5.45	10	11.69	10.63
69SB-26	1	0.92	4.28	10	11.69	10.71
69SB-27	1	0.89	3.64	10	11.69	10.45
69SB-28	1	0.56	2.65	10	11.69	6.54
69SB-29	1	0.78	3.72	10	11.69	9.18
69SB-30	1	0.79	3.83	10	11.69	9.18
69SB-31	1	0.39	3.16	10	11.69	4.59
69SB-32	1	0.88	9.84	10	11.69	10.23
69SB-33	1	0.8	6.12	10	11.69	9.4
69SB-34	1	1.03	9.83	10	11.69	12.01
69SB-35	1	0.54	3.35	10	11.69	6.37
69SB-36	1	0.8	4.5	10	11.69	9.34
69SB-37	1	0.8	4.84	10	11.69	9.32
69SB-38	1	0.79	3.78	10	11.69	9.21
69SB-39	1	1.08	3.62	10	11.69	12.6
69SB-40	1	0.83	5.1	10	11.69	9.7
69SB-41	1	0.91	3.75	10	11.69	10.69
69SB-42	1	0.94	3.95	10	11.69	11.05
69SB-43	1	1.01	6.8	10	11.69	11.81
69SB-44	1	1.01	3.4	10	11.69	11.87
69SB-45	1	0.75	3.21	10	11.69	8.78
69SB-46	1	0.64	3.18	10	11.69	7.51

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS
RUNOFF COMPUTATIONS FOR DESIGN FREQUENCY

BUFFALO BAYOU PUMP STATION SYSTEM						
ID	RUNOFF C	DRAINAGE AREA (ACRES)	TIME OF CONC. (MIN)	TIME USED (MIN)	INTENSITY (IN/HR)	DISCHARGE (CFS)
45NB-1	1	0.4	1.84	10	11.69	4.72
45NB-17	1	0.24	1.95	10	11.69	2.81
45NB-18	1	0.57	3.32	10	11.69	6.68
45NB-19	1	0.57	2.74	10	11.69	6.62
45NB-2	1	0.42	1.82	10	11.69	4.94
45NB-20	1	0.72	3	10	11.69	8.45
45NB-3	1	0.4	1.79	10	11.69	4.73
45NB-4	1	0.4	1.82	10	11.69	4.69
45NB-5	1	0.4	1.86	10	11.69	4.66
45NB-6	1	0.62	2.21	10	11.69	7.21
45NBC1	1	0.66	8.01	10	11.69	7.7
45SB-18	1	0.21	3.6	10	11.69	2.51
45SB-19	1	0.41	3.06	10	11.69	4.74
45SB-2	1	0.49	1.9	10	11.69	5.7
45SB-20	1	0.4	2.55	10	11.69	4.69
45SB-21	1	0.46	2.34	10	11.69	5.43
45SB-3	1	0.48	1.92	10	11.69	5.66
45SB-4	1	0.48	1.95	10	11.69	5.67
45SB-5	1	0.49	1.99	10	11.69	5.71
45SB-6	1	0.47	2.27	10	11.69	5.44
45SB-7	1	0.17	2.77	10	11.69	1.95
45SBC1	1	0.57	2.49	10	11.69	6.71
69NB-53	1	0.63	3.96	10	11.69	7.34
69NB-54	1	0.41	3.19	10	11.69	4.74
69NB-55	1	1.42	2.36	10	11.69	16.6
69NB-56	1	0.4	2.05	10	11.69	4.72
69NB-67	1	0.47	3.18	10	11.69	5.49
69NB-68	1	0.79	3.86	10	11.69	9.19
69NB-69	1	0.51	3.05	10	11.69	6
69NB-70	1	0.54	2.83	10	11.69	6.28
69SB-47	1	0.34	3	10	11.69	3.97
69SB-48	1	0.08	3.05	10	11.69	0.9
69SB-49	1	0.31	2.7	10	11.69	3.68
69SB-61	1	0.62	3.44	10	11.69	7.28
69SB-62	1	0.93	3.95	10	11.69	10.86
69SB-63	1	0.94	3.42	10	11.69	10.95
69SB-64	1	0.77	2.71	10	11.69	9.02

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

AECOM
AECOM TECHNICAL SERVICES, INC.
10210 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77024
WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation
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I-45/I-69/SH-288
HYDRAULIC DATA SHEET
RUNOFF COMPUTATIONS

SHEET 1 OF 1

FED.RD DIV.ND.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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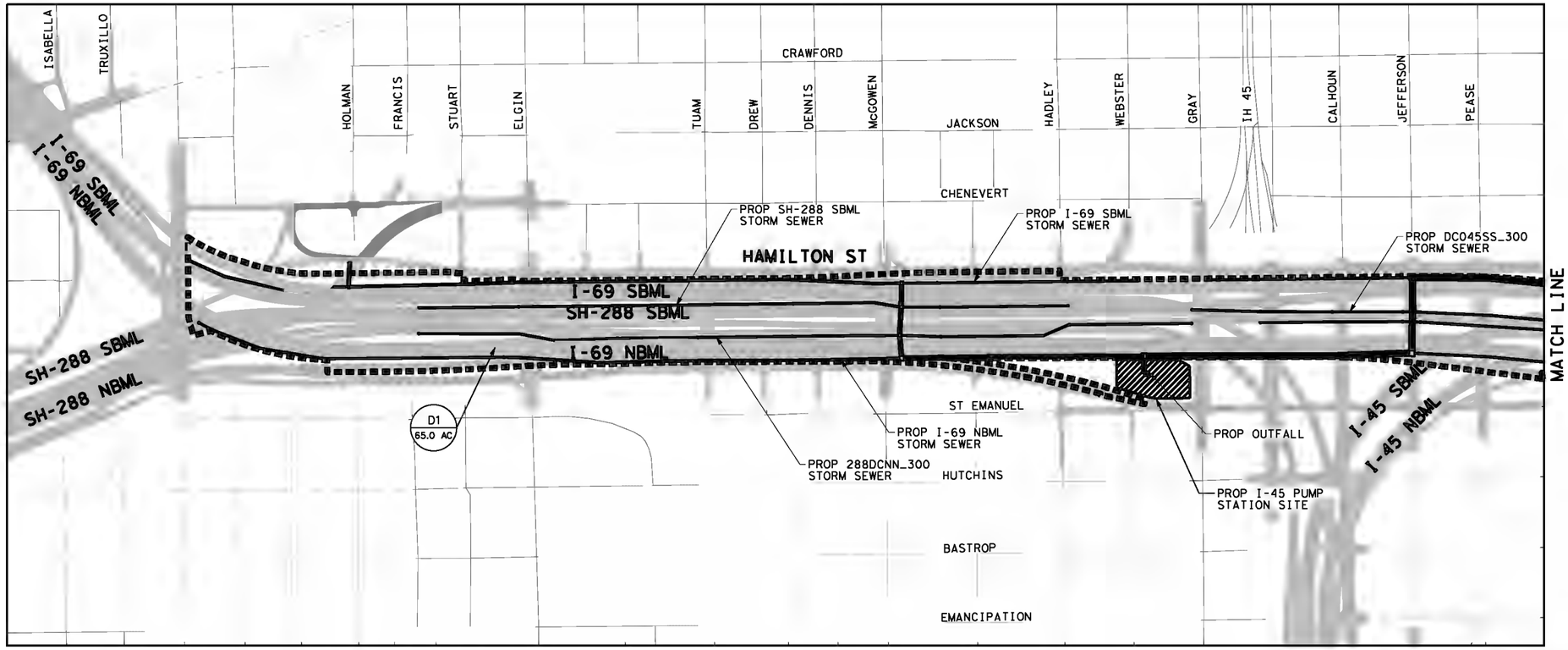
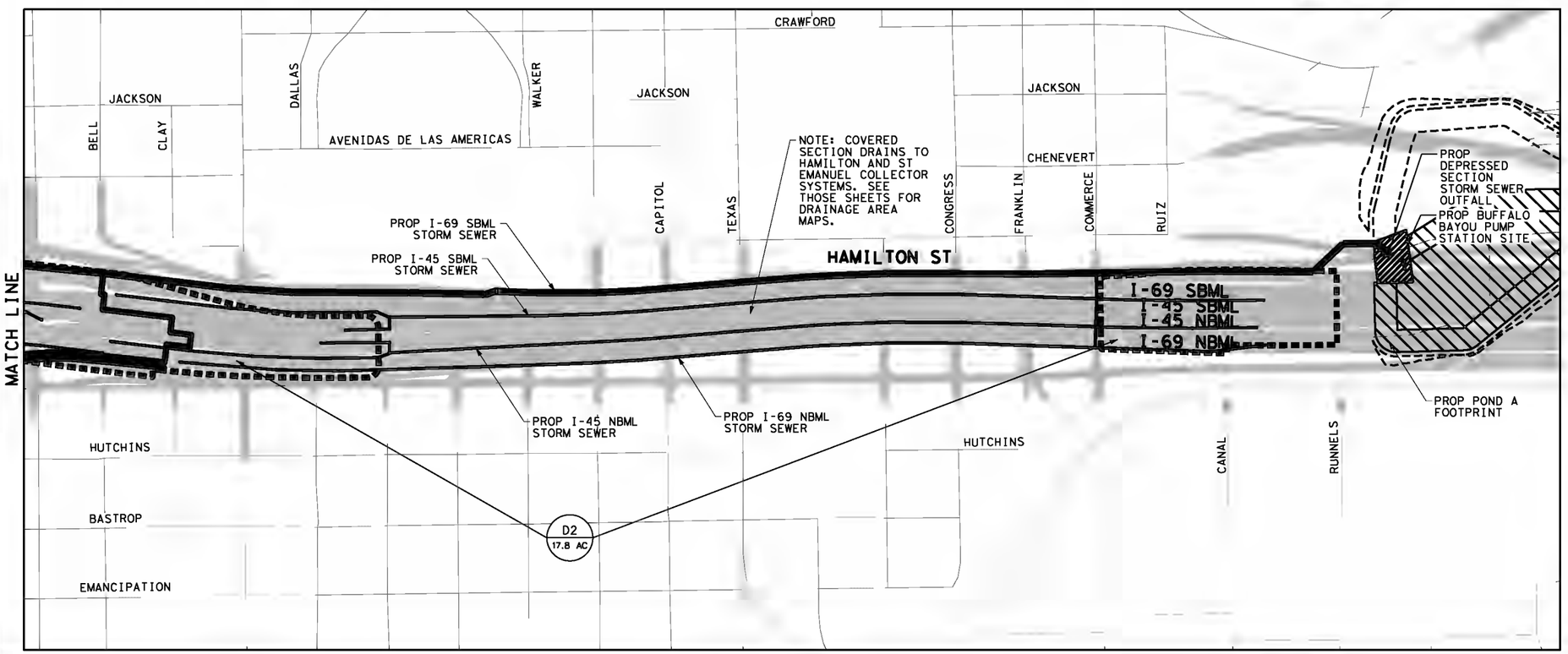
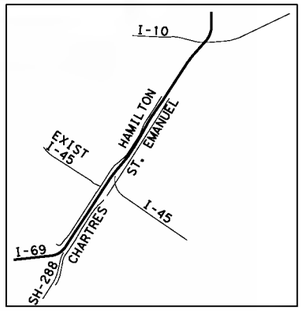




LEGEND

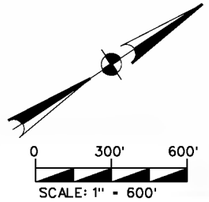
- DIRECTION OF FLOW
- OVERALL DRAINAGE BOUNDARY
- SYSTEM ID — X•• / XX — SUB AREA ID / ACREAGE
- PROPOSED ROADWAY



VICINITY MAP

NOTES:

1. ANY OFFSITE FLOW DRAINING TOWARDS THE DEPRESSED SECTION WILL BE CAPTURED BY PROPOSED COLLECTOR SYSTEMS.



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MICHAEL F. McGOVERN
96792
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19219 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77094
WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B DEPRESSED SECTION OVERALL DRAINAGE AREA MAP

SHEET 1 OF 1

FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	1-45/1-69/SH-288

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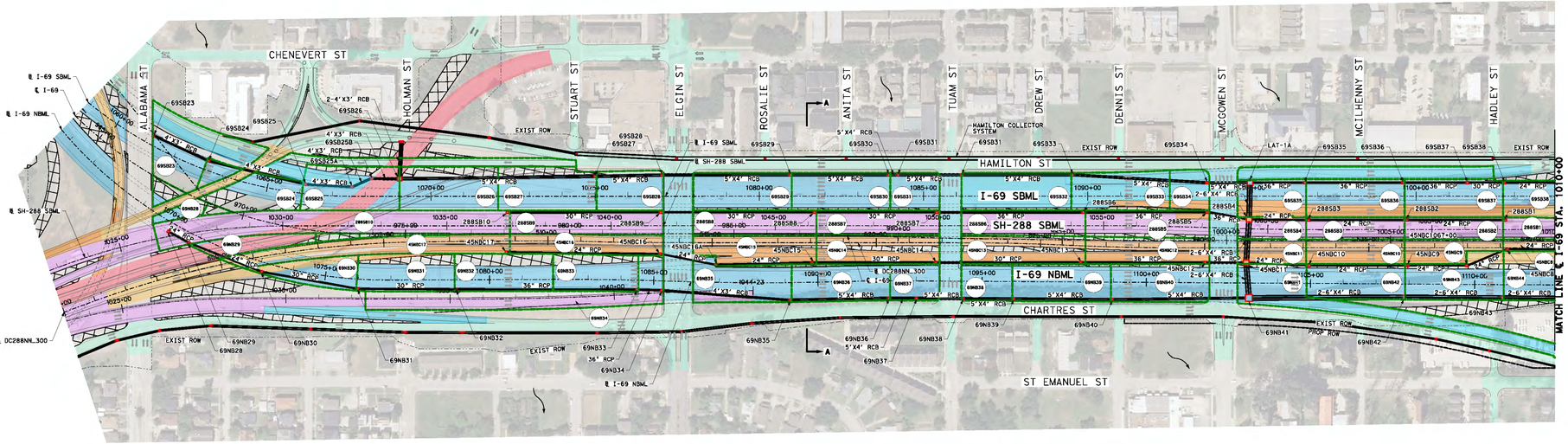

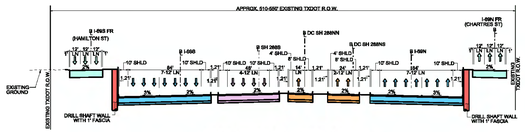

PROP TYPICAL SECTION A-A

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- DRAINAGE AREA NAME

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.
3. THERE IS NO PONDING ON ALL MAINLANE TRAVEL LANES WITHIN THE DEPRESSED SECTION UNDER THE 100-YR STORM EVENT.

0 100' 200'

SCALE: 1" = 200'

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7/31/2018
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HOUSTON, TEXAS 77024
713-690-7100
TBPE REG. NO. F-3580

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NHHIP SEGMENT 3B DEPRESSED SECTION STORM SEWER PLAN

BEGIN CONST TO STA 1010+00

(℄ I-69) SHEET 1 OF 3

FED. RD. DIV. NO.	PROJECT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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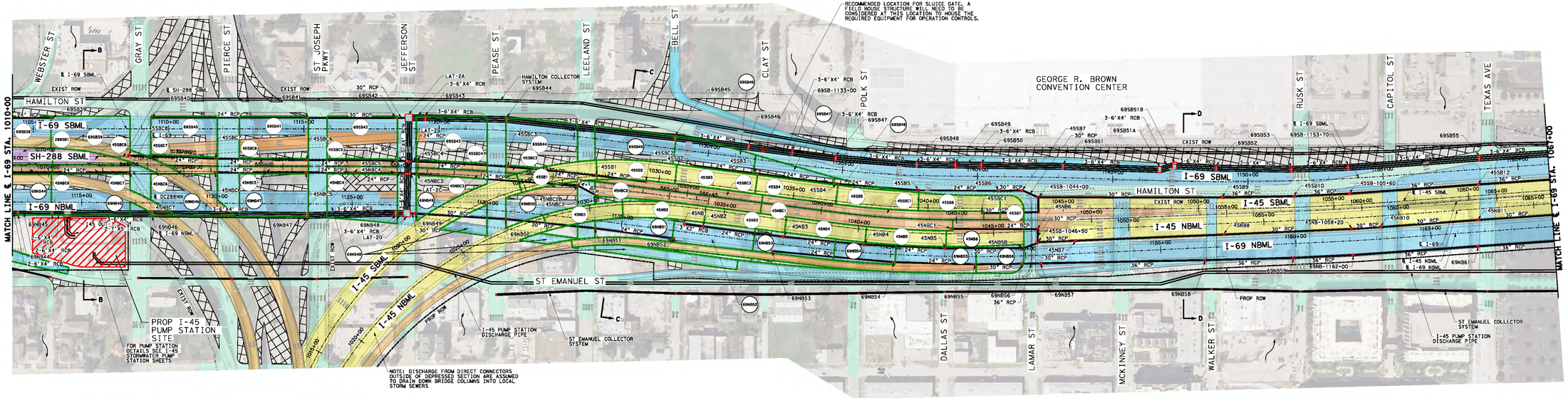
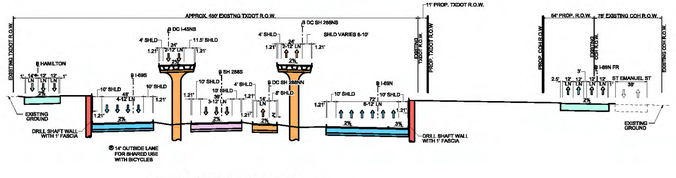
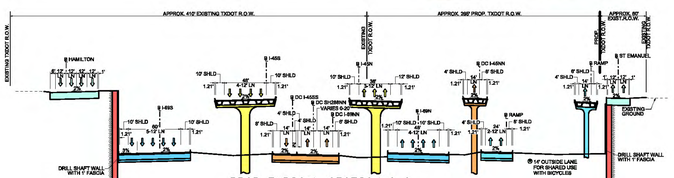
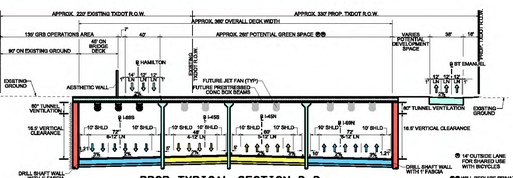




PROP TYPICAL SECTION B-B



PROP TYPICAL SECTION C-C



PROP TYPICAL SECTION D-D

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- DRAINAGE AREA NAME

NOTES:

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0 100' 200'
SCALE: 1" = 200'

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

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10219 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77024
713-690-7100
TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B DEPRESSED SECTION STORM SEWER PLAN

STA 1010+00 TO STA 1067+00
(℄ I-69) SHEET 2 OF 3

FED. RD. DIV. NO.	PROJECT NO.	SHEET NO.
6	36-71DP5055 WA 2	SHTND

STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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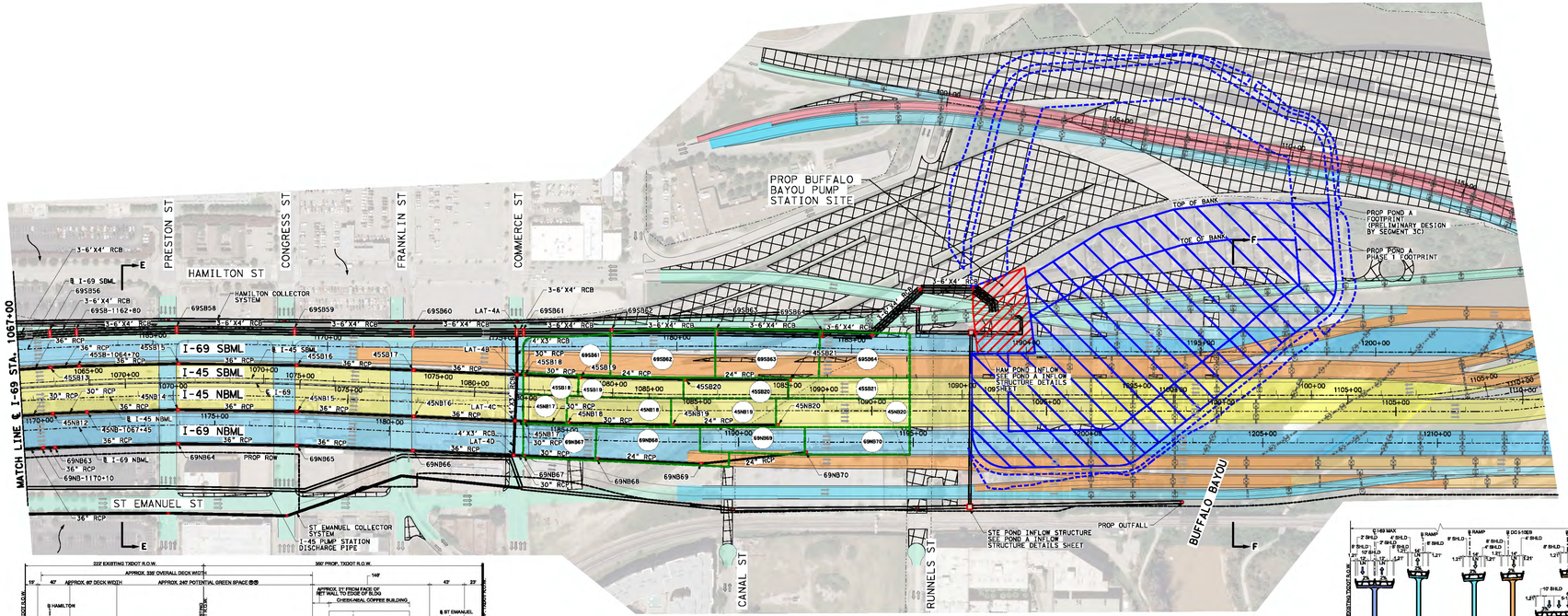
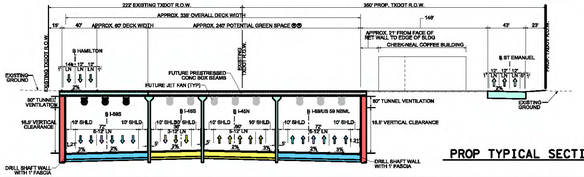
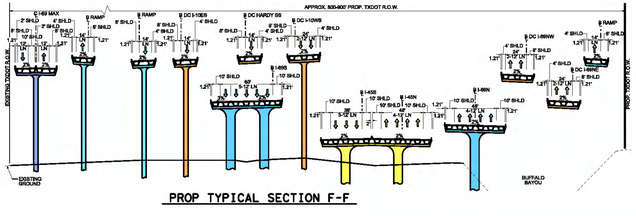


NOTE: IN COORDINATION WITH TXDOT AND HNTB IT WAS AGREED THAT THE RETAINING WALL AT THE SOUTH END OF THE BRIDGE STRUCTURE COULD BE SHIFTED SOUTH, APPROXIMATELY 150 FT FROM RUNNELS STREET. THE PRELIMINARY DESIGN OF THE DETENTION BASIN LAYOUT AND PUMP STATION LAYOUT WERE BASED ON THE SHIFTED RETAINING WALL LOCATIONS. THE UPDATED ROADWAY DATA SHOWING THE SHIFT IN RETAINING WALL LOCATION WAS NOT AVAILABLE AT THE TIME OF THIS STUDY.



PROP TYPICAL SECTION E-E



PROP TYPICAL SECTION F-F

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME

NOTES:

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0 100' 200'
SCALE: 1" = 200'

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

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10210 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77024
713-677-3400
TBPE REG. NO. F-3580

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NHHIP SEGMENT 3B
DEPRESSED SECTION
STORM SEWER
STA 1067+00 TO END CONST
(℄ I-69) SHEET 3 OF 3

FED. RD. DIV. NO.	PROJECT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTND
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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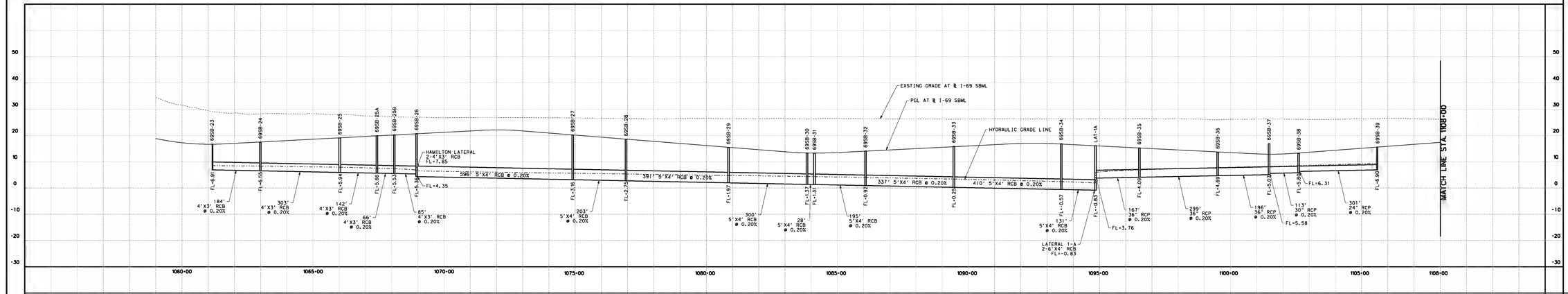

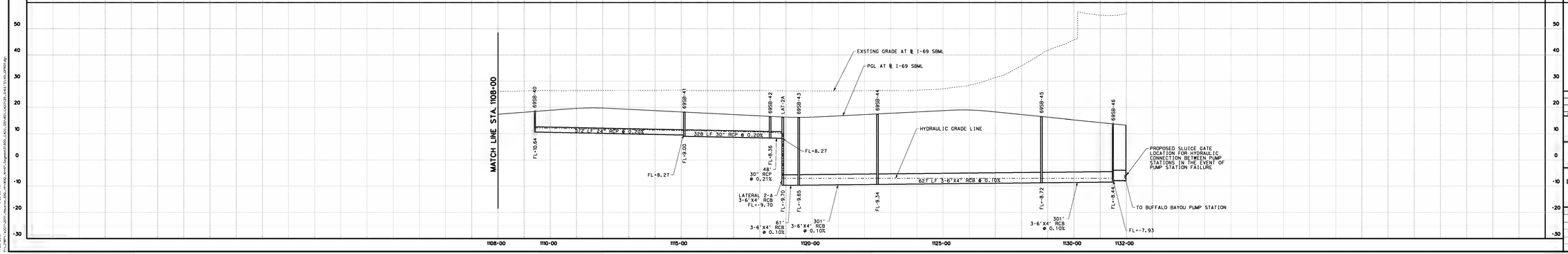

LEGEND

- PROP STORM SEWER
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

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0 100' 200'
SCALE: 1" = 200'H
1" = 20'V

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

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TBPE REG. NO. F-3580

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NHHIP SEGMENT 3B
I-45 PUMP STATION STORM SEWER PROFILE
STA 1060+00 TO STA 1132+00
(℄ I-69 SBML) SHEET 1 OF 3

FED. RD. DIV. NO.	PROJECT NO.	SHEET NO.
6	36-71DPS055 WA 2	SHTNO

STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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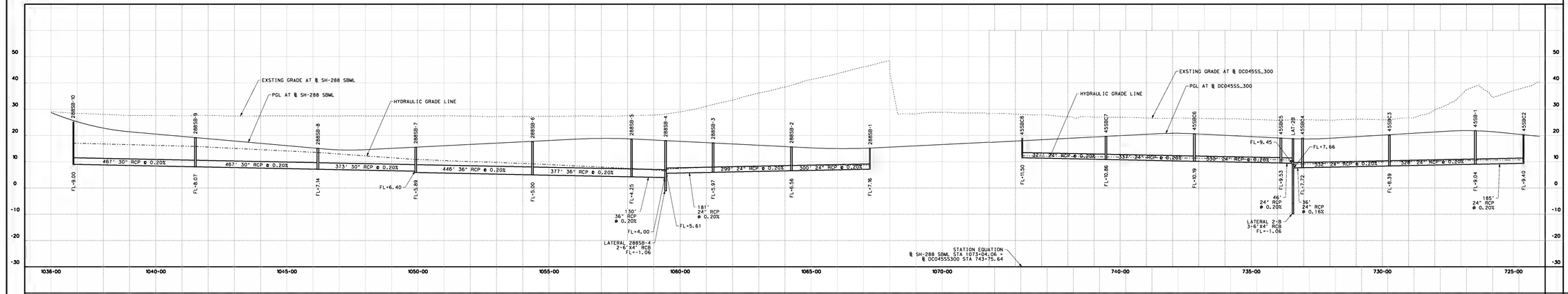

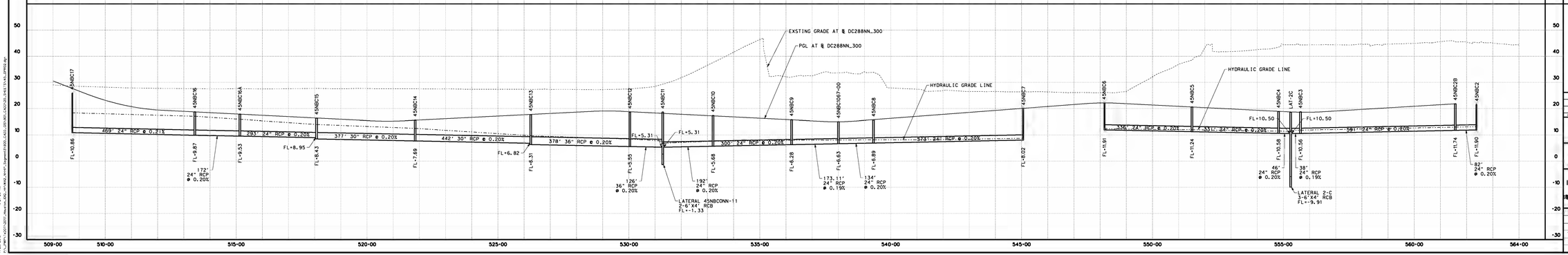

LEGEND

- PROP STORM SEWER
- HYDRAULIC GRADE LINE
- NATURAL GROUND

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NHHIP SEGMENT 3B
I-45 PUMP STATION STORM SEWER PROFILE
℄ SH-288 SBML, ℄ DC0455S_300, ℄ DC288NN_300

SHEET 2 OF 3

CSJ NO. DIV. NO.	PROJECT NO.	SHEET NO.
6	36-710P5055 WA 2	SHTNO

STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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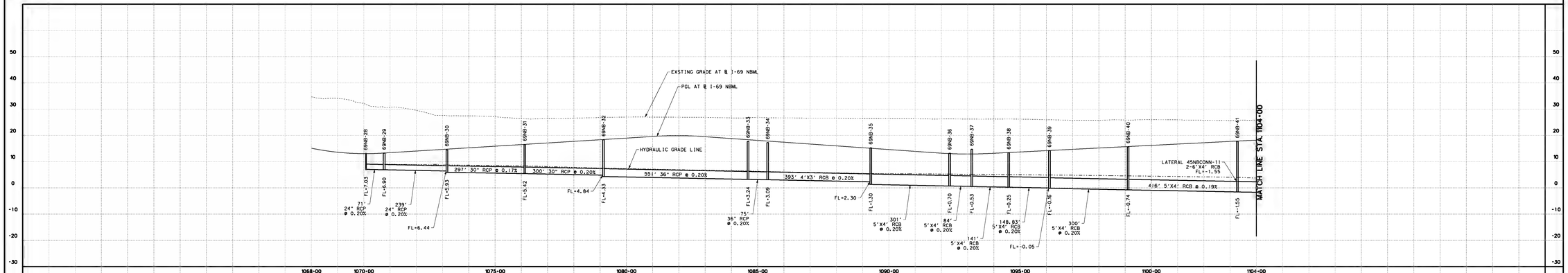

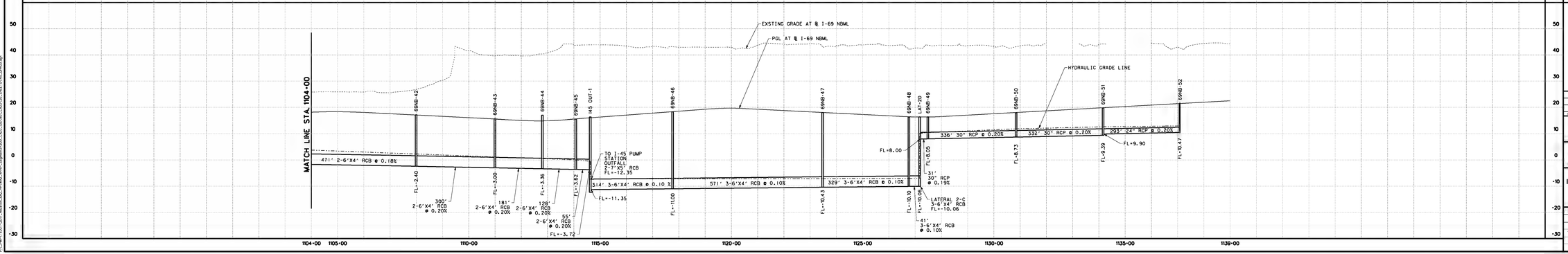

LEGEND

- PROP STORM SEWER
- HYDRAULIC GRADE LINE
- NATURAL GROUND

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HOUSTON, TEXAS 77079
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NHHIP SEGMENT 3B
I-45 PUMP STATION STORM SEWER PROFILE

STA 1068+00 TO STA 1139+00
(℄ I-69 NBML) SHEET 3 OF 3

FED. RD. DIV. NO.	PROJECT NO.	SHEET NO.
6	36-710P5055 WA 2	SHTNO

STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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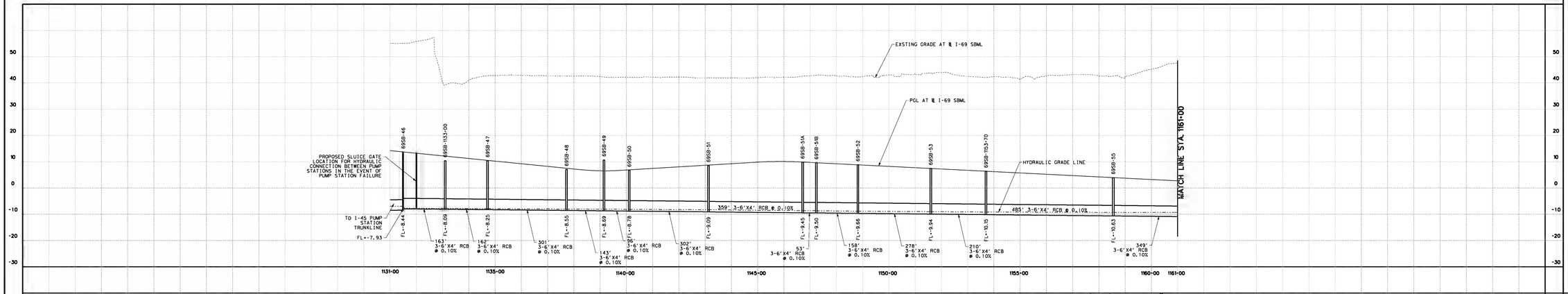

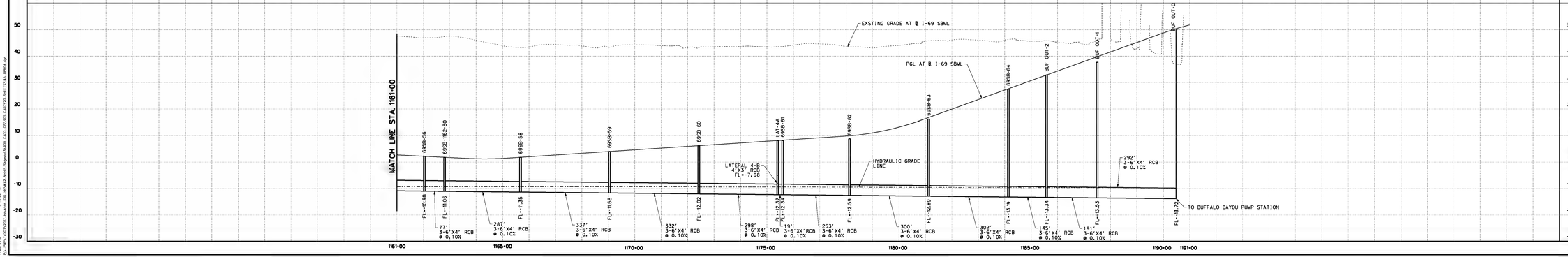

LEGEND

- PROP STORM SEWER
- HYDRAULIC GRADE LINE
- NATURAL GROUND

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NHHIP SEGMENT 3B
BUFFALO BAYOU PUMP STATION
STORM SEWER PROFILE

STA 1131+00 TO STA 1191+00
(℄ I-69 SBML) SHEET 1 OF 3

FED. RD. DIV. NO.	PROJECT NO.	SHEET NO.
6	36-710P5055 WA 2	SHTNO

STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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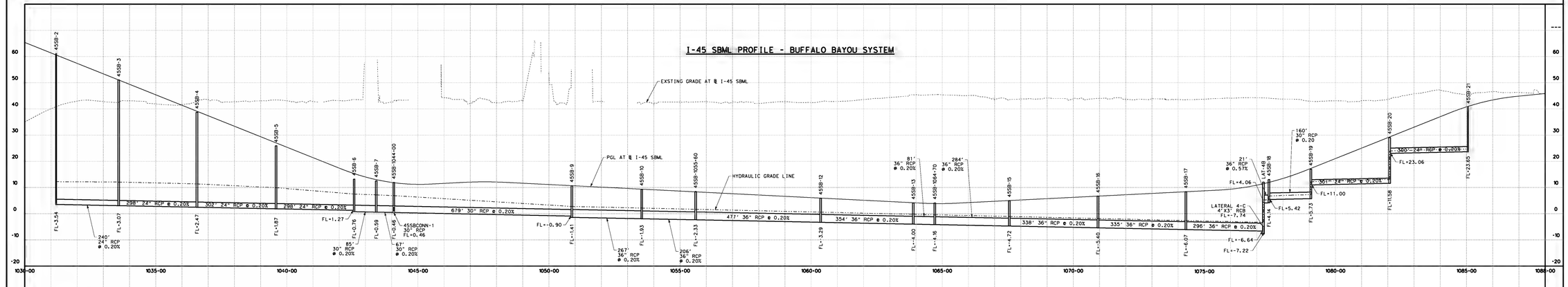

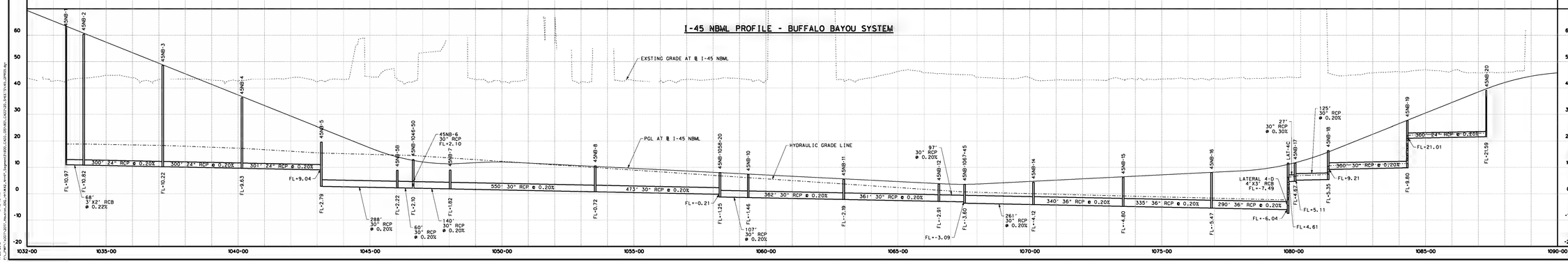

LEGEND

- PROP STORM SEWER
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.
3. THERE IS NO PONDING ON ALL MAINLANE TRAVEL LANES WITHIN THE DEPRESED SECTION UNDER THE 100-YR STORM EVENT.

0 100' 200'
SCALE: 1" = 200'H
1" = 20' V

DOCUMENT IS FOR INTERIM REVIEW AND NOT INTENDED FOR CONSTRUCTION BIDDING, OR PERMIT PURPOSES.
MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

AECOM

AECOM TECHNICAL SERVICES, INC.
10219 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77024
WWW.AECOM.COM
TBPE REG. NO. F-3580

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NHHIP SEGMENT 3B
BUFFALO BAYOU PUMP STATION
STORM SEWER PROFILE
(℄ I-45 SBML, ℄ I-45 NBML)

SHEET 2 OF 3

CSJ DIV. NO.	PROJECT NO.	SHEET NO.
6	36-71DP5055 WA 2	SHTNO

STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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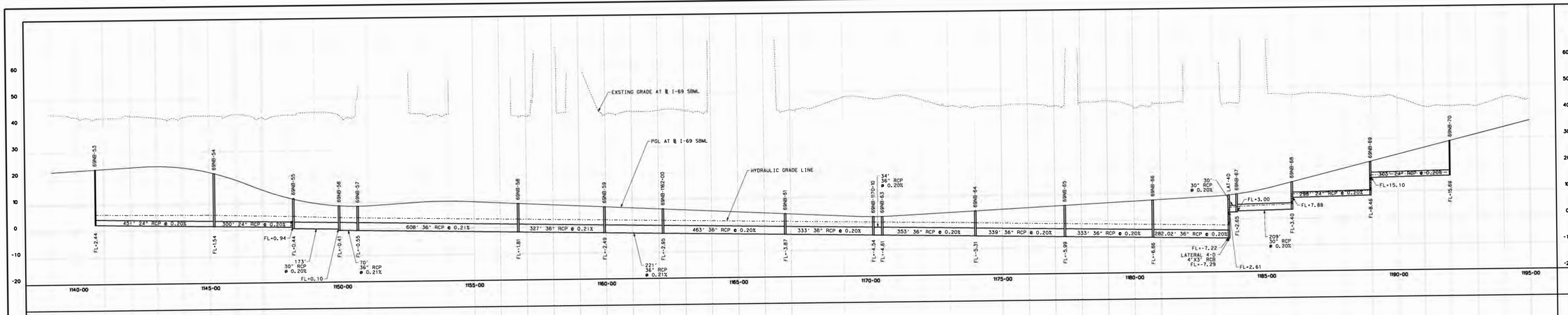

LEGEND

PROP STORM SEWER

HYDRAULIC GRADE LINE

NATURAL GROUND

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.
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19219 KATY FREEWAY, SUITE 100
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WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B
BUFFALO BAYOU PUMP STATION
STORM SEWER PROFILE

STA 1139-00 TO STA 1195-00
(℄ I-69 NBML) SHEET 3 OF 3

FED. RD. DIV. NO.	PROJECT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

14.5_SHPROF.dgn

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

RUNOFF COMPUTATIONS FOR DESIGN FREQUENCY

I-45 HAMILTON STREET SYSTEM						
ID	RUNOFF C	DRAINAGE AREA (ACRES)	TIME OF CONC. (MIN)	TIME USED (MIN)	INTENSITY (IN/HR)	DISCHARGE (CFS)
H28	0.50	2.42	13.94	13.94	4.72	5.7
H27	0.85	1.96	10.00	10.00	5.47	9.1
H26	0.85	2.23	10.00	10.00	5.47	10.4
H25	0.85	2.14	10.00	10.00	5.47	9.9
H24	0.85	3.23	10.00	10.00	5.47	15.0
H23	0.85	3.71	10.00	10.00	5.47	17.2
H22	0.85	2.58	10.00	10.00	5.47	12.0
H21	0.88	15.23	20.91	20.91	3.84	51.5
H20	0.88	18.61	20.17	20.17	3.92	64.1
H19	0.87	34.51	22.38	22.38	3.70	111.3
H18	0.88	2.75	14.37	14.37	4.65	11.3
H17	0.85	2.00	18.75	18.75	4.07	6.9
H16	0.88	1.91	15.96	15.96	4.42	7.5
H15	0.90	2.25	10.00	10.00	5.47	11.1
H14	0.83	2.09	22.60	22.60	3.68	6.4
H13	0.79	1.95	22.38	22.38	3.70	5.7
H12	0.86	1.85	10.00	10.00	5.47	8.7
H11	0.83	1.36	13.55	13.55	4.78	5.4
H10	0.84	1.55	10.00	10.00	5.47	7.1
H9	0.90	2.80	10.00	10.00	5.47	13.8
H8	0.87	1.98	10.00	10.00	5.47	9.4
H7	0.83	1.36	11.95	11.95	5.07	5.7
H6	0.84	1.80	10.00	10.00	5.47	8.3
H5	0.83	1.22	10.00	10.00	5.47	5.6
H4	0.84	1.07	10.00	10.00	5.47	4.9
H3	0.85	1.70	11.43	11.43	5.17	7.4
H2	0.83	0.84	11.07	11.07	5.24	3.7
H1	0.67	23.45	26.78	26.78	3.34	52.4
H30	0.67	23.45	26.78	26.78	3.34	52.4

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JAMES C. HATHORN
98292
TEXAS SERIAL NO.
7/18/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

CobbFendley
TBPE Firm Registration No. 274
TBPLS Firm Registration No. 10046?
13430 Northwest Freeway, Suite 1100
Houston, Texas 77040
713.462.3242 | fax 713.462.3262
www.cobbfendley.com

Texas Department of Transportation
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NHHIP SEGMENT 3B
HAMILTON ST
HYDRAULIC DATA SHEET
RUNOFF COMPUTATIONS

SHEET 1 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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$TIME$
$DATE$
$FILES$

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE CONFIGURATION DATA

I-45 HAMILTON STREET SYSTEM											
ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
H33	H33	STE WEIR	498	Box	1	4	6	0.013	0.10	5.90	5.40
H32	H32	H33	152	Box	1	7	7	0.013	0.13	12.63	12.43
H28	H28	H32	66	Box	1	7	7	0.013	0.11	12.70	12.63
H27	H27	H28	1147	Box	1	7	7	0.013	0.13	14.19	12.70
H26	H26	H27	344	Box	1	7	7	0.013	0.13	14.64	14.19
H25	H25	H26	322	Box	1	7	7	0.013	0.13	15.06	14.64
H24	H24	H25	333	Box	1	7	7	0.013	0.13	15.49	15.06
H23	H23	H24	649	Box	1	7	7	0.013	0.13	16.33	15.49
H22	H22	H23	361	Box	1	7	7	0.013	0.13	16.80	16.33
H21	H21	H22	334	Box	1	7	7	0.013	0.13	17.24	16.80
H20	H20	H21	1668	Box	1	7	7	0.013	0.13	19.40	17.24
H19	H19	H20	660	Box	1	7	7	0.013	0.13	20.26	19.40
H18	H18	H19	348	Box	1	7	7	0.013	0.13	20.72	20.26
H17	H17	H18	321	Box	1	7	7	0.013	0.13	21.13	20.72
H16	H16	H17	328	Box	1	7	7	0.013	0.13	21.56	21.13
H15	H15	H16	326	Box	1	7	7	0.013	0.13	21.98	21.56
H14	H14	H15	332	Box	1	7	7	0.013	0.13	22.41	21.98
H13	H13	H14	340	Box	1	7	7	0.013	0.13	22.86	22.41
H12	H12	H13	403	Box	1	7	7	0.013	0.13	23.38	22.86
H11	H11	H12	244	Box	1	7	7	0.013	0.13	23.70	23.38
H10	H10	H11	413	Box	1	10	10	0.013	0.13	24.23	23.70
H9	H9	H10	411	Box	1	10	10	0.013	0.13	24.77	24.23
H8	H8	H9	317	Box	1	10	10	0.013	0.13	25.18	24.77
H7	H7	H8	245	Box	1	10	10	0.013	0.13	25.50	25.18
H6	H6	H7	271	Box	1	10	10	0.013	0.13	25.85	25.50
H5	H5	H6	313	Box	1	10	10	0.013	0.13	26.26	25.85
H4	H4	H5	247	Box	1	10	10	0.013	0.13	26.58	26.26
H3	H3	H4	269	Box	1	10	10	0.013	0.13	26.93	26.58
H2	H2	H3	309	Box	1	10	10	0.013	0.13	27.33	26.93
H1	H1	H2	266	Circular	1	4	n/a	0.013	0.13	27.68	27.33
H1C	H1C	H1	398	Circular	1	4	n/a	0.013	0.13	28.19	27.68
H1B	H1B	H1C	331	Circular	1	4	n/a	0.013	0.13	28.62	28.19
H1A	H1A	H1B	92	Circular	1	4	n/a	0.013	0.13	28.74	28.62

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JAMES C. HATHORN
98292
TEXAS SERIAL NO.
7/18/2018
DATE

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NHHIP SEGMENT 3B
HAMILTON ST
HYDRAULIC DATA SHEET
STORM SEWER CONFIGURATION

SHEET 2 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE HYDRAULIC COMPUTATIONS

I-45 HAMILTON STREET SYSTEM										
							UNIFORM		ACTUAL	
ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	VELOCITY (FT/S)	DEPTH (FT)	VELOCITY (FT/S)	DEPTH (FT)
H33	H33	H-OUT	13.12	9.40	268.0	123.0	11.3	4.0	11.2	4.0
H32	H32	H33	17.04	16.00	268.0	352.8	6.8	5.6	8.7	4.4
H28	H28	H32	17.27	17.04	268.0	318.0	6.3	6.1	8.4	4.6
H27	H27	H28	19.46	17.27	265.5	350.9	6.7	5.6	7.2	5.3
H26	H26	H27	19.97	19.46	264.8	350.9	6.7	5.6	7.1	5.3
H25	H25	H26	20.43	19.97	263.4	350.9	6.7	5.6	7.0	5.4
H24	H24	H25	20.89	20.43	262.3	350.9	6.7	5.6	6.9	5.4
H23	H23	H24	21.76	20.89	261.7	350.9	6.6	5.6	6.9	5.4
H22	H22	H23	22.23	21.76	257.8	350.9	6.8	5.4	6.8	5.4
H21	H21	H22	22.65	22.23	255.8	350.9	6.8	5.4	6.8	5.4
H20	H20	H21	24.60	22.65	239.6	350.9	6.6	5.2	6.6	5.2
H19	H19	H20	25.20	24.60	206.7	350.9	6.5	4.6	6.0	4.9
H18	H18	H19	25.34	25.20	137.6	350.9	6.1	3.3	4.2	4.6
H17	H17	H18	25.49	25.34	133.5	350.9	5.9	3.3	4.4	4.4
H16	H16	H17	25.66	25.49	131.2	350.9	5.8	3.3	4.6	4.1
H15	H15	H16	25.86	25.66	128.9	350.9	5.7	3.3	4.8	3.9
H14	H14	H15	26.08	25.86	125.7	350.9	5.7	3.1	4.9	3.7
H13	H13	H14	26.34	26.08	123.2	350.9	5.8	3.0	5.1	3.5
H12	H12	H13	26.69	26.34	121.5	350.9	5.7	3.0	5.2	3.3
H11	H11	H12	26.92	26.69	118.7	350.9	5.6	3.0	5.3	3.2
H10	H10	H11	27.07	26.92	118.1	908.4	5.5	2.2	4.2	2.8
H9	H9	H10	27.29	27.07	117.1	908.4	5.4	2.2	4.7	2.5
H8	H8	H9	27.51	27.29	112.1	908.4	5.4	2.1	4.8	2.3
H7	H7	H8	27.71	27.51	108.7	908.4	5.4	2.0	4.9	2.2
H6	H6	H7	27.97	27.71	107.1	908.4	5.3	2.0	5.1	2.1
H5	H5	H6	28.31	27.97	104.6	908.4	5.2	2.0	5.1	2.1
H4	H4	H5	28.59	28.31	103.2	908.4	5.1	2.0	5.1	2.0
H3	H3	H4	28.94	28.59	102.2	908.4	5.1	2.0	5.1	2.0
H2	H2	H3	29.30	28.94	99.8	908.4	5.2	1.9	5.1	2.0
H1	H1	H2	32.04	30.34	98.7	55.7	8.1	4.0	7.9	4.0
H1C	H1C	H1	32.57	32.04	52.4	55.7	4.8	3.3	4.2	4.0
H1B	H1B	H1C	33.01	32.57	52.4	55.7	4.8	3.3	4.2	4.0
H1A	H1A	H1B	33.13	33.01	52.4	55.7	4.8	3.3	4.2	4.0

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98292
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NHHIP SEGMENT 3B
HAMILTON ST
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS

SHEET 3 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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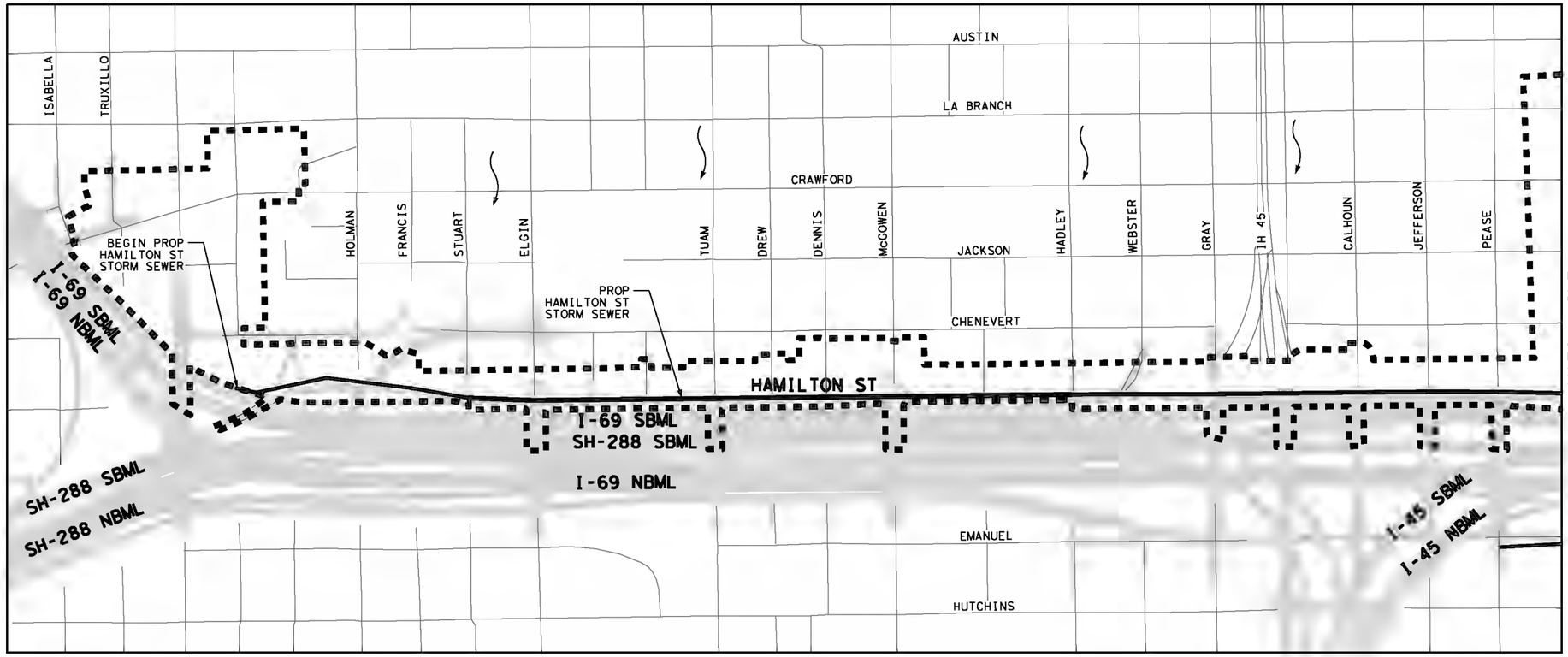
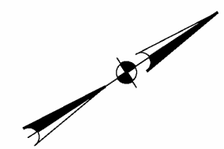


LEGEND

- DIRECTION OF FLOW
- OVERALL DRAINAGE BOUNDARY
- PROPOSED ROADWAY
- SYSTEM ID — H / XX — OVERALL AREA ID / ACREAGE



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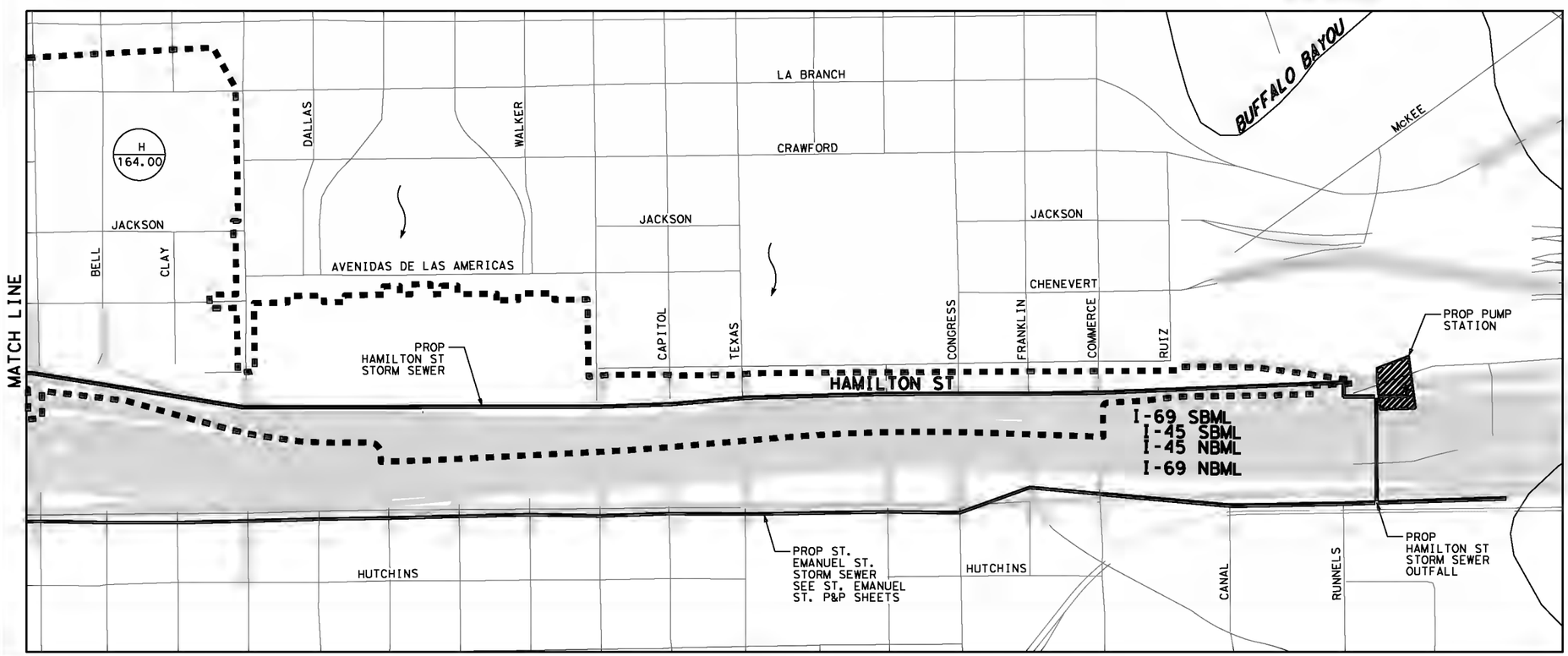
SCALE: 1" = 600′



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Texas Department of Transportation

NHHIP SEGMENT 3B
HAMILTON ST
OVERALL DRAINAGE AREA MAP

SHEET 1 OF 1

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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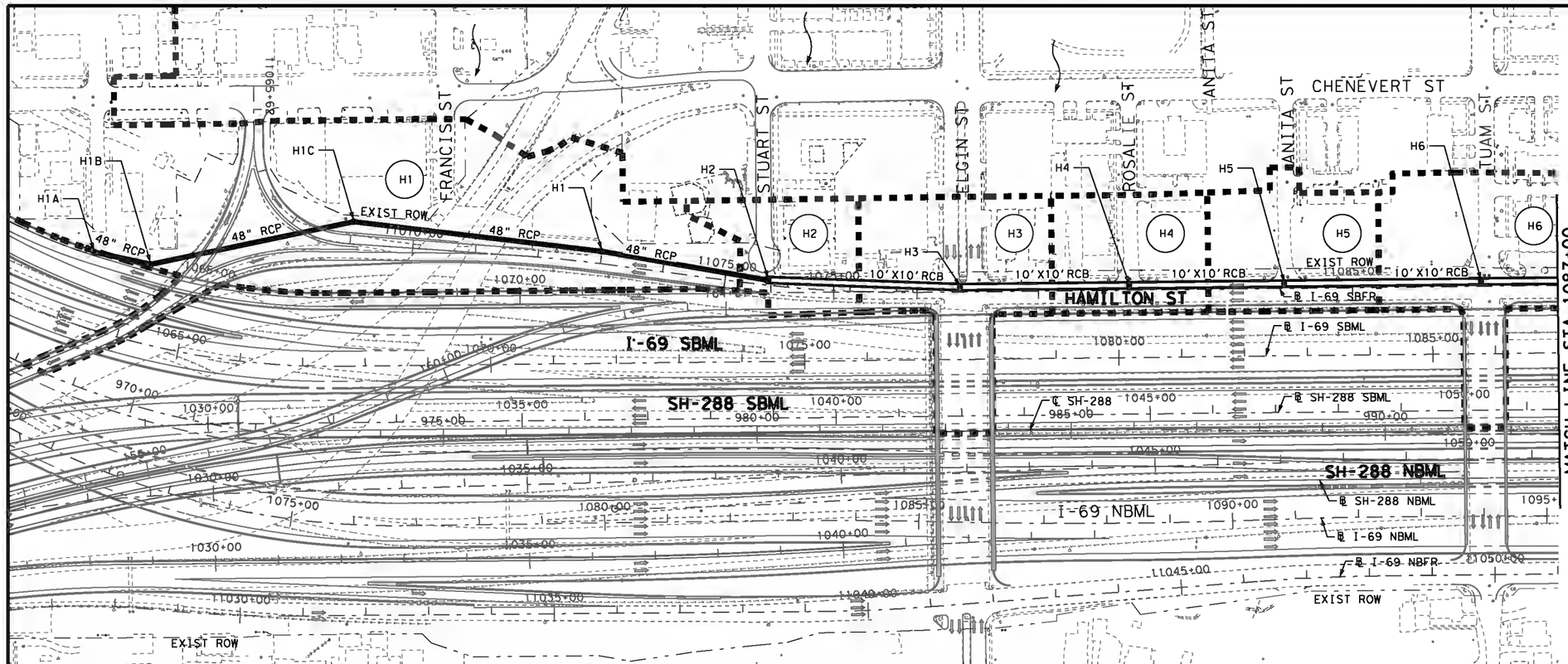


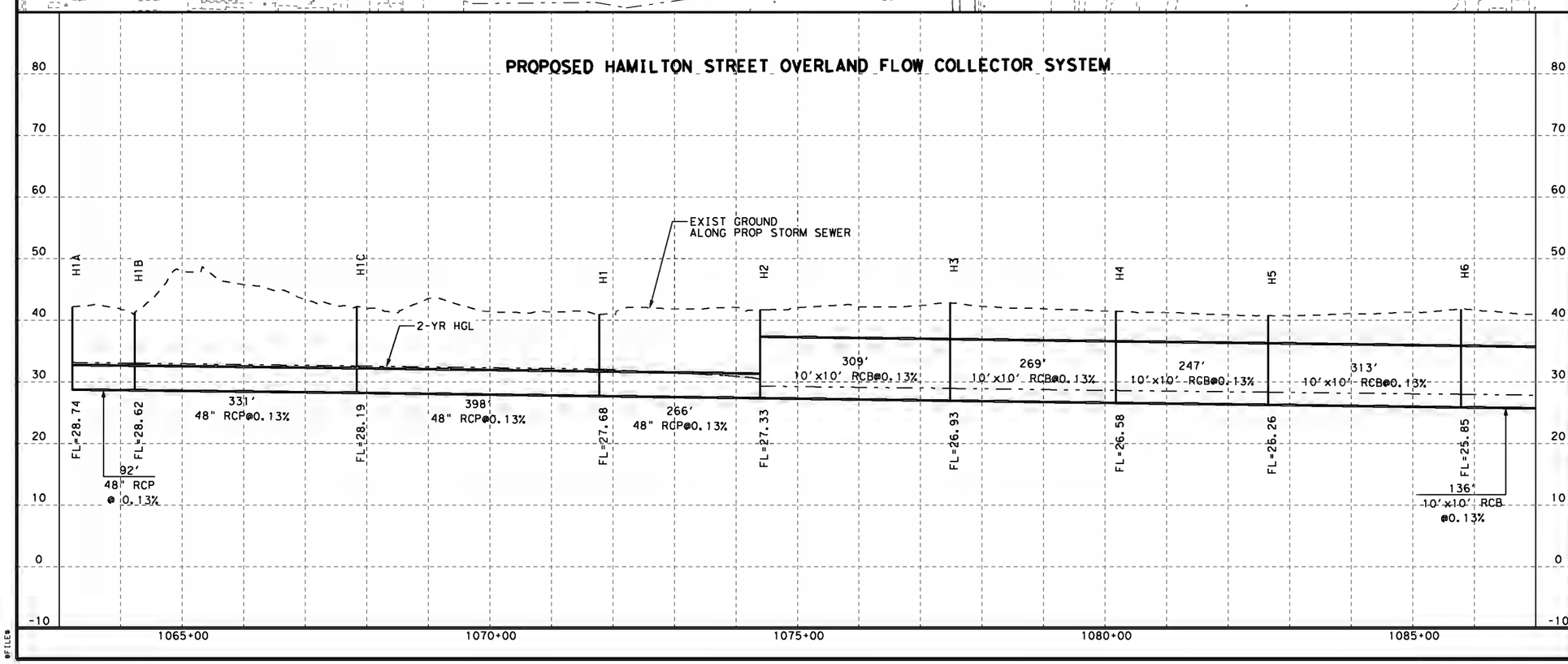
LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WHERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100- YR STORM EVENT.
3. ALL FRONTAGE ROADS REMAIN PASSABLE UNDER A 2- YR STORM EVENT.
4. ALL COLLECTOR SYSTEMS HAVE A MINIMUM CAPACITY TO CONVEY THE 2-YR STORM EVENT AND HAVE BEEN DESIGNED FOR NO ADVERSE IMPACTS TO PONDING IN THE 100-YR STORM EVENT
5. FLOWS FOR THE 100-YR STORM EVENT FOR ALL COLLECTOR SYSTEMS BASED ON A COMBINATION OF THE RATIONAL METHOD AND OVERLAND SHEET FLOWS DETERMINED FROM THE OVERLAND SHEET FLOW ANALYSIS AS DISCUSSED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.

0 100' 200'
SCALE: 1" = 200'H
1" = 20' V



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NHHIP SEGMENT 3B
HAMILTON ST
STORM SEWER PLAN & PROFILE
BEGIN CONST TO STA 1087+00
(℄ I-69 SBML)

SHEET 1 OF 7

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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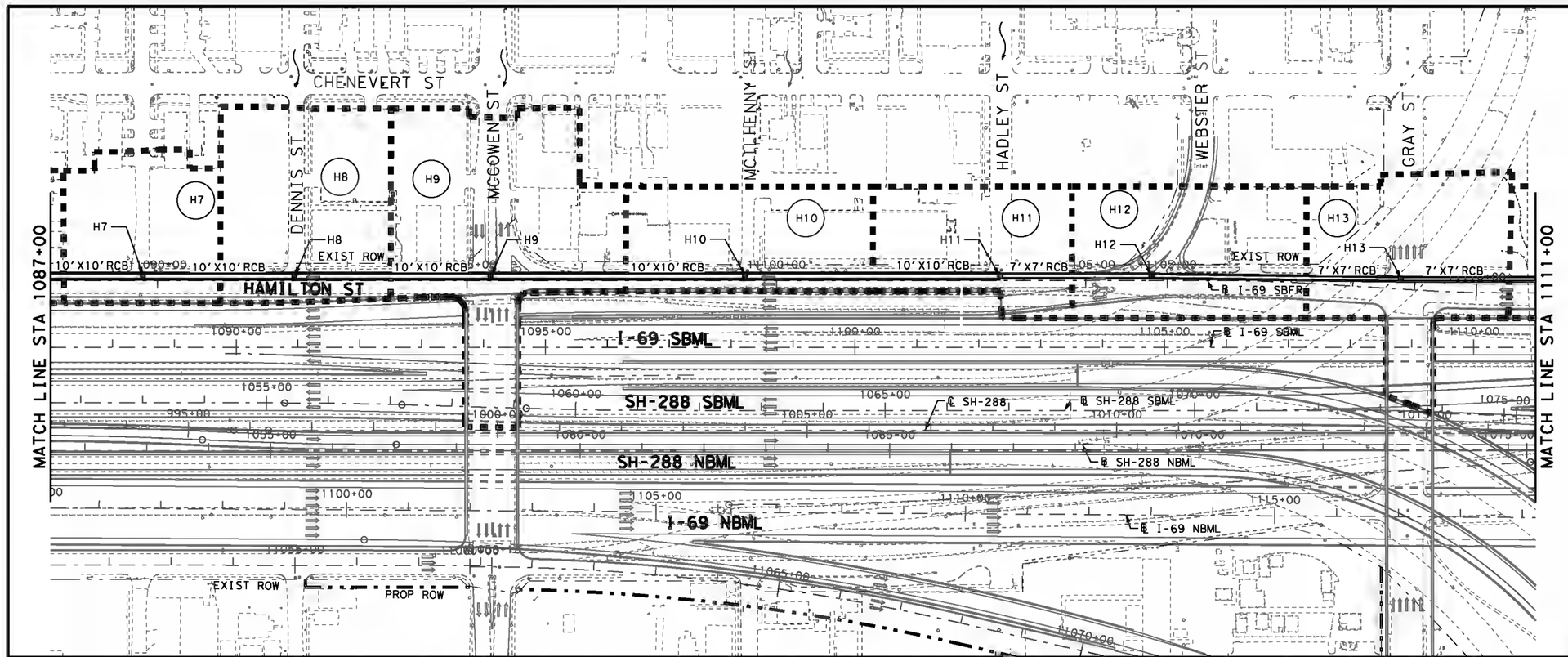

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WHERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100- YR STORM EVENT.
3. ALL FRONTAGE ROADS REMAIN PASSABLE UNDER A 2- YR STORM EVENT.
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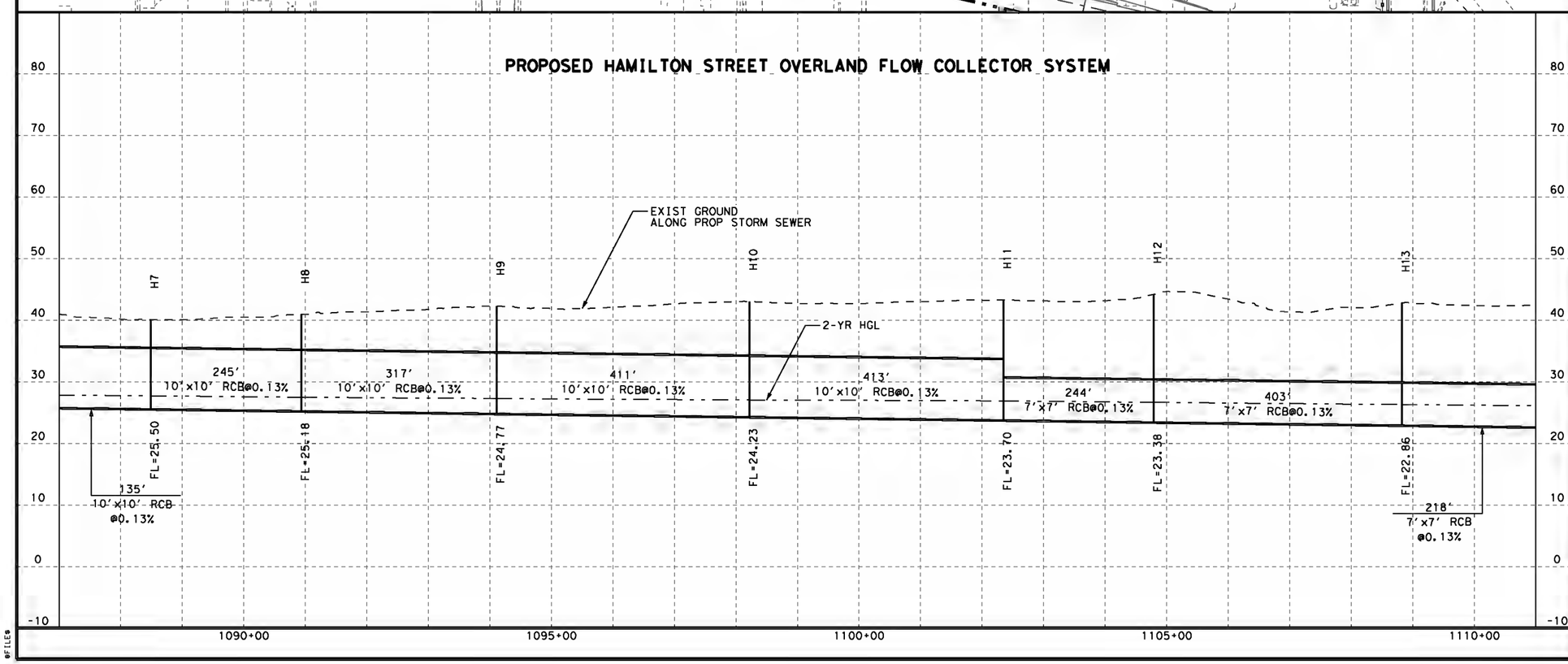
0 100' 200'
SCALE: 1" = 200'H
1" = 20' V

PROPOSED HAMILTON STREET OVERLAND FLOW COLLECTOR SYSTEM



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JAMES C. HATHORN
98292
TEXAS SERIAL NO.
7/23/2018
DATE

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TBPLS Firm Registration No. 10087
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713.462.3242 | fax 713.462.3262
www.cobbfendley.com

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SHEET 2 OF 7

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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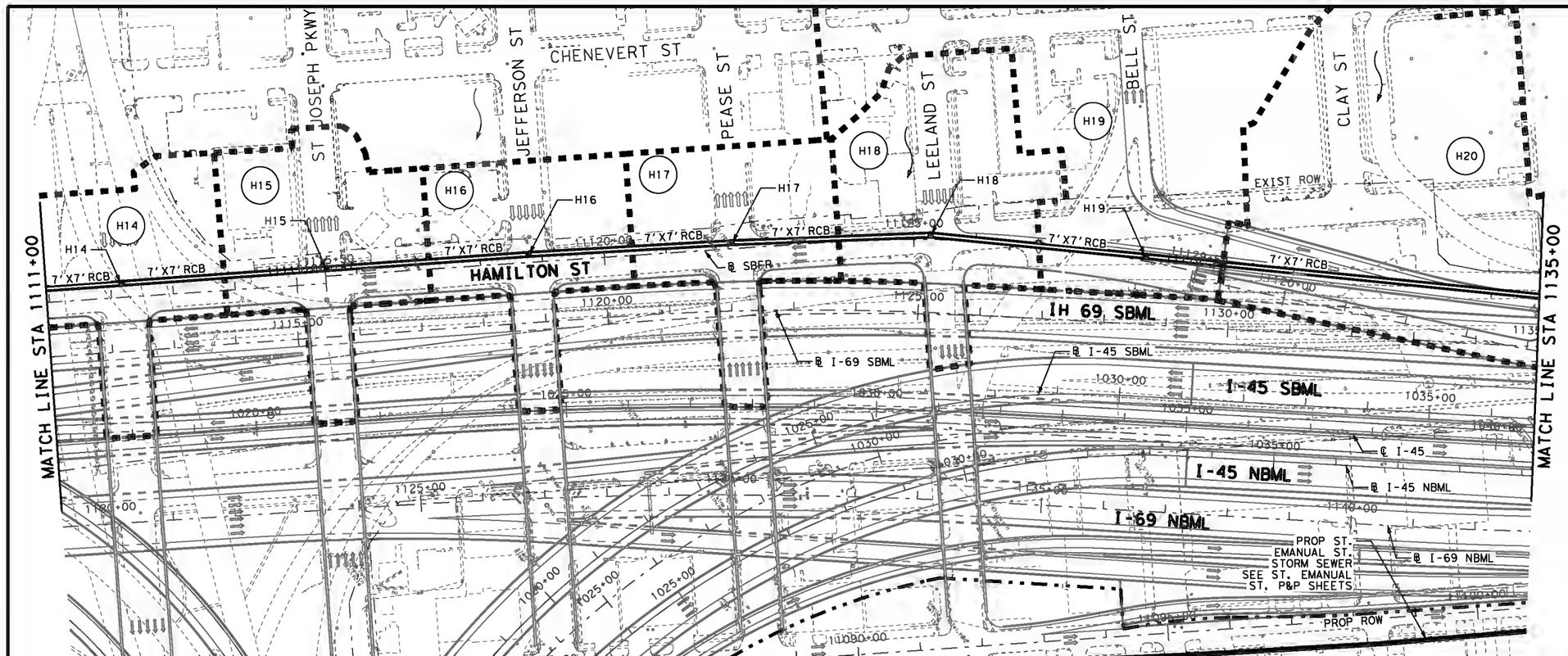

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

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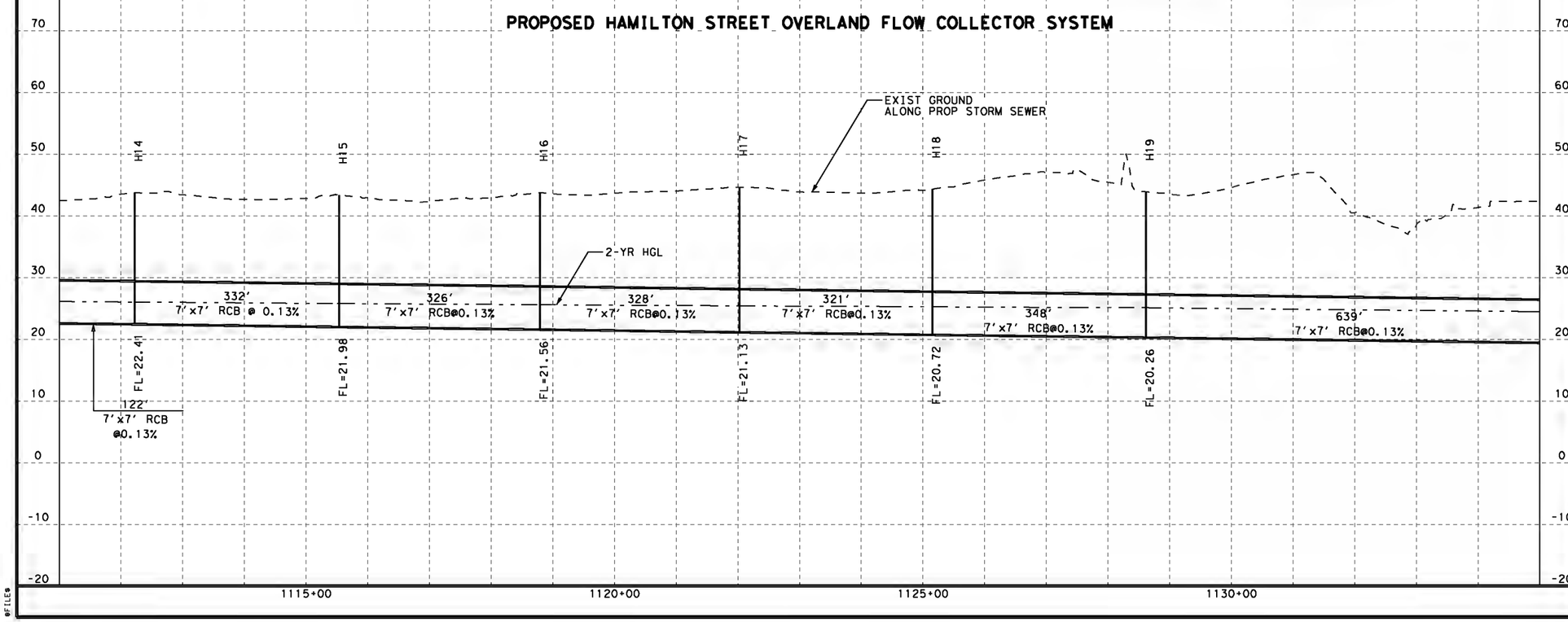
0 100' 200'
SCALE: 1" = 200'H
1" = 20' V

PROPOSED HAMILTON STREET OVERLAND FLOW COLLECTOR SYSTEM



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JAMES C. HATHORN
98292
TEXAS SERIAL NO.
7/23/2018
DATE

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www.cobbfendley.com

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(℄ I-69 SBML)

SHEET 3 OF 7

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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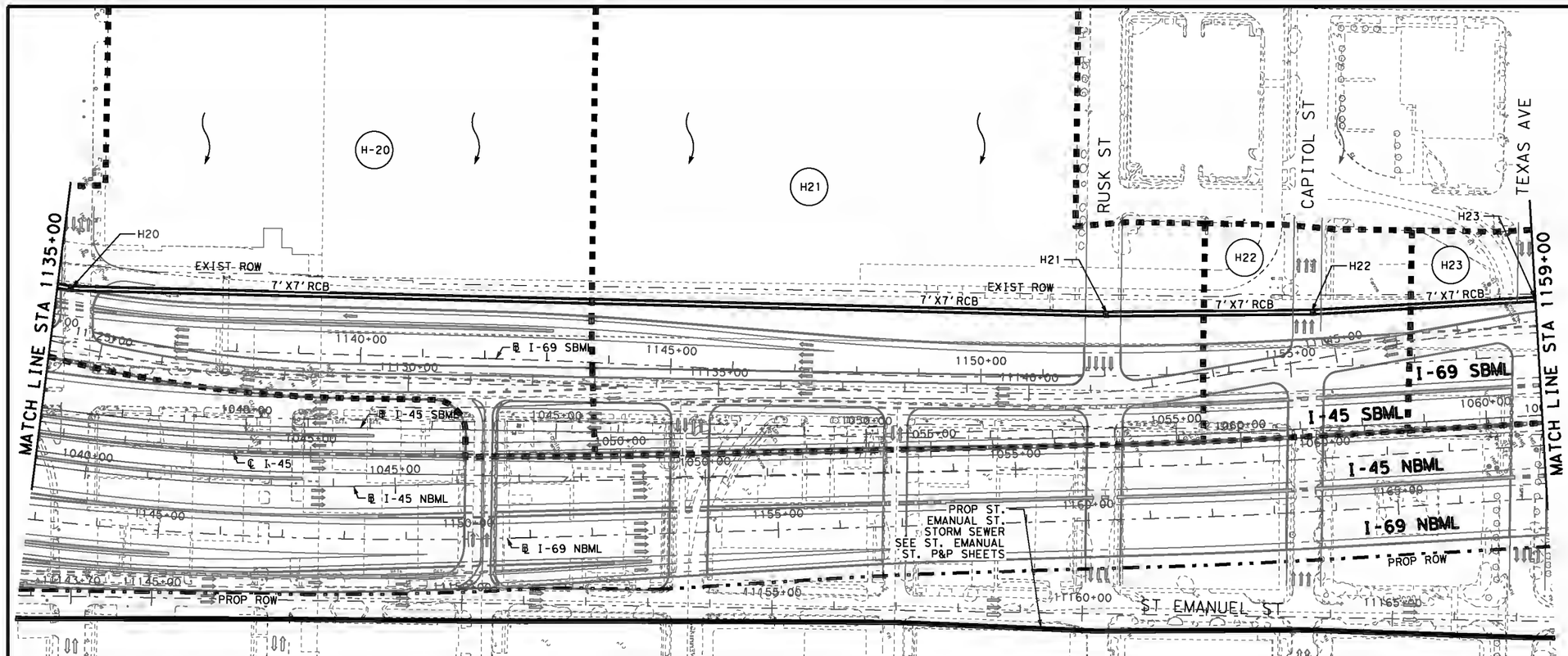

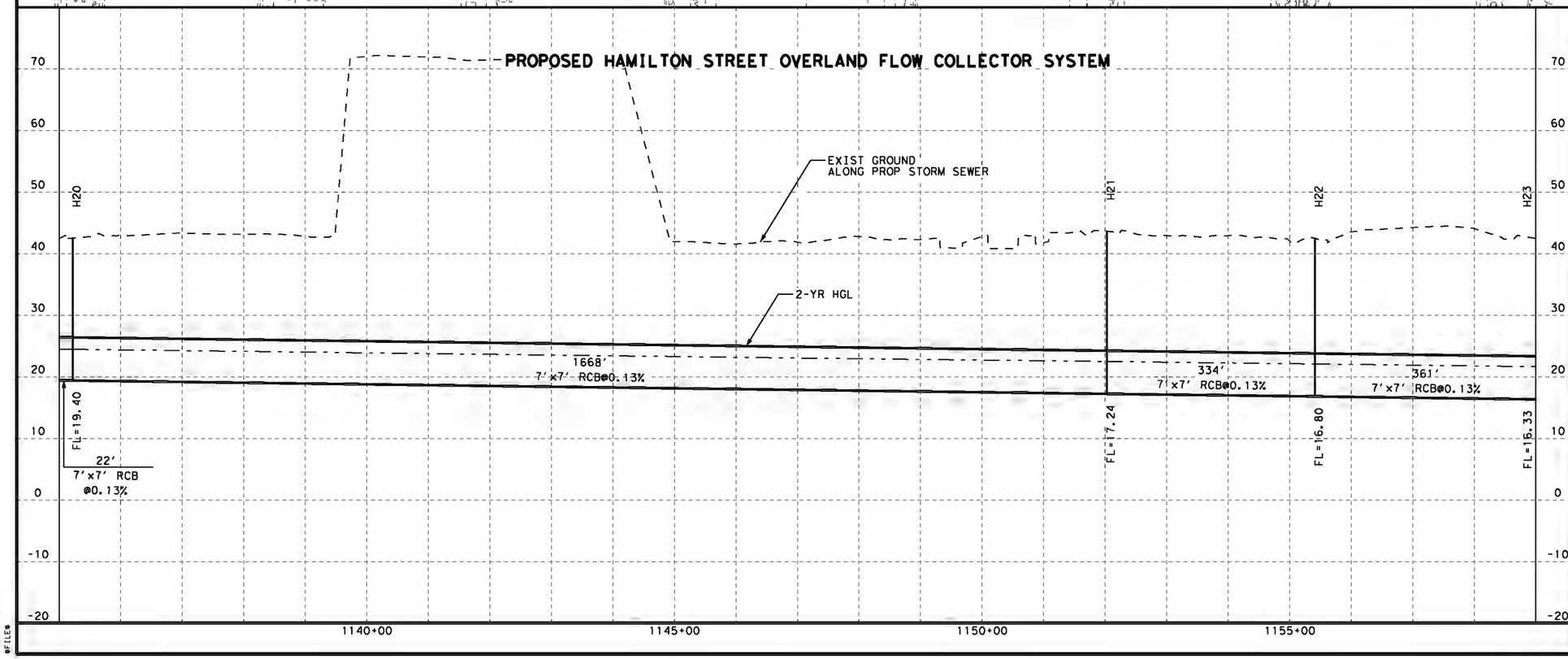

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
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0 100' 200'
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1" = 20' V

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JAMES C. HATHORN
98292
TEXAS SERIAL NO.
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www.cobbfendley.com

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(℄ I-69 SBML)

SHEET 4 OF 7

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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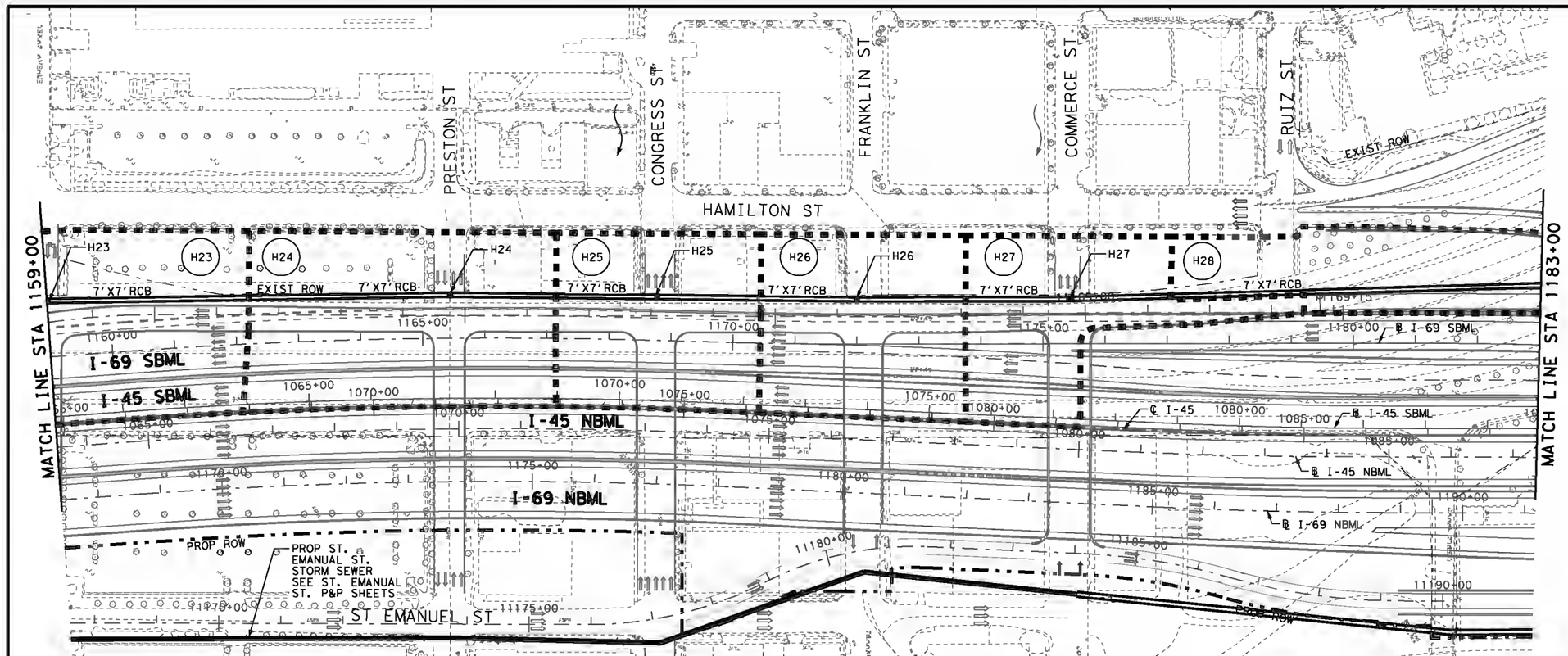

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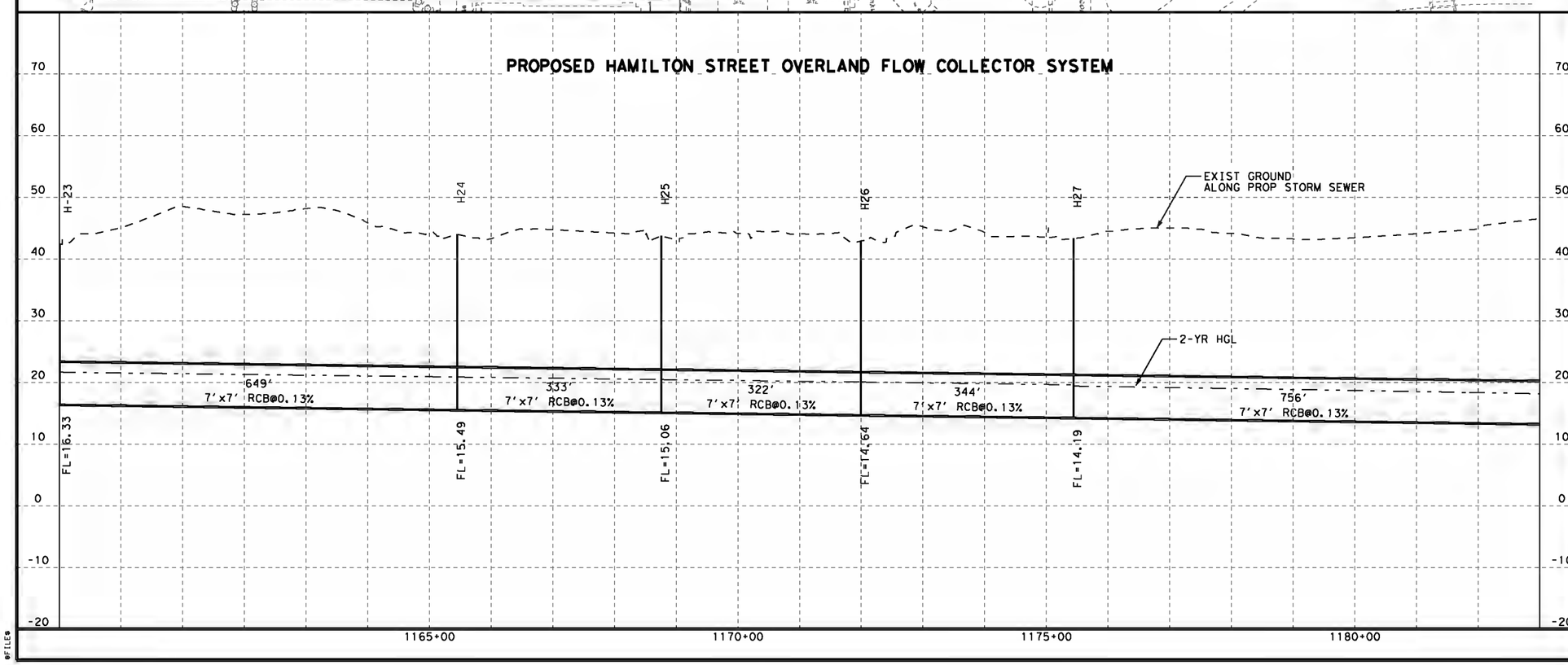
PROPOSED HAMILTON STREET OVERLAND FLOW COLLECTOR SYSTEM



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98292
TEXAS SERIAL NO.
7/23/2018
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STA 1159+00 TO STA 1183+00
(℄ I-69 SBML)

SHEET 5 OF 7

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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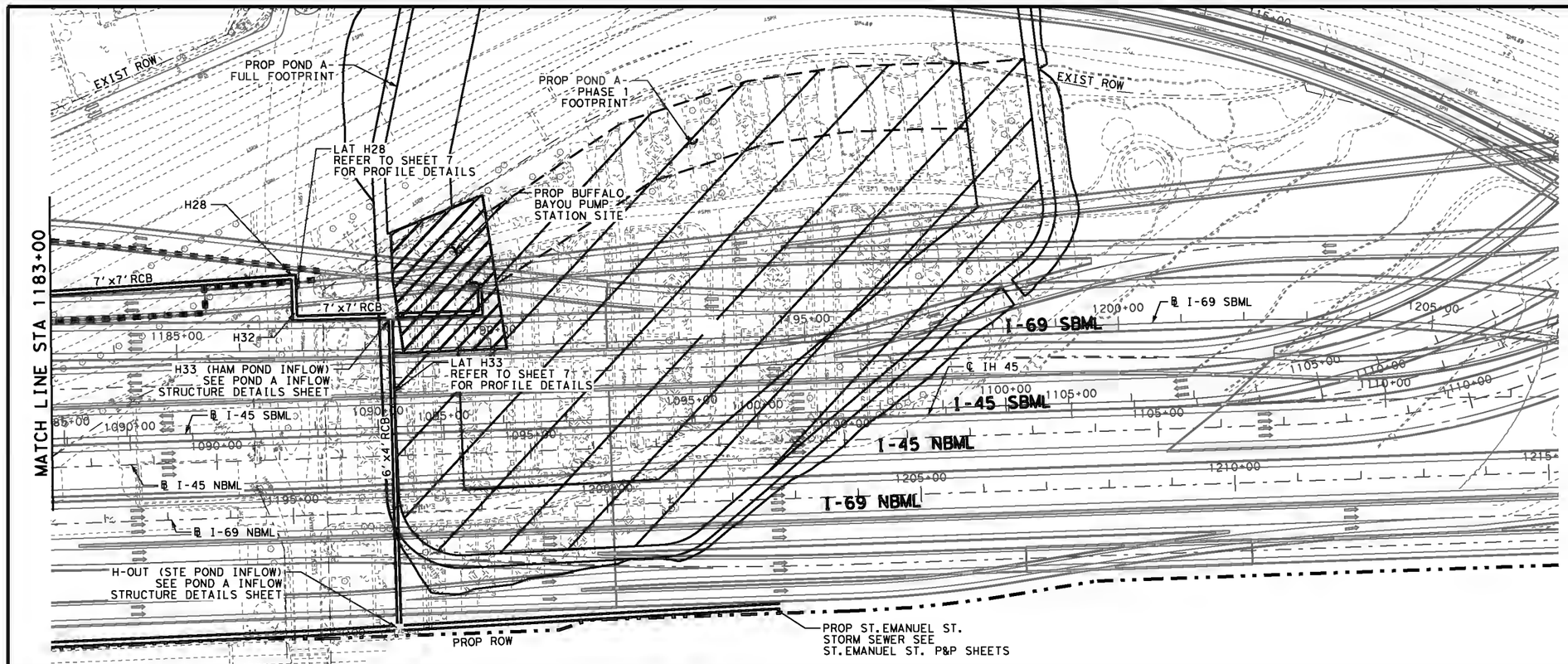

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
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0 100' 200'
SCALE: 1" = 200'H
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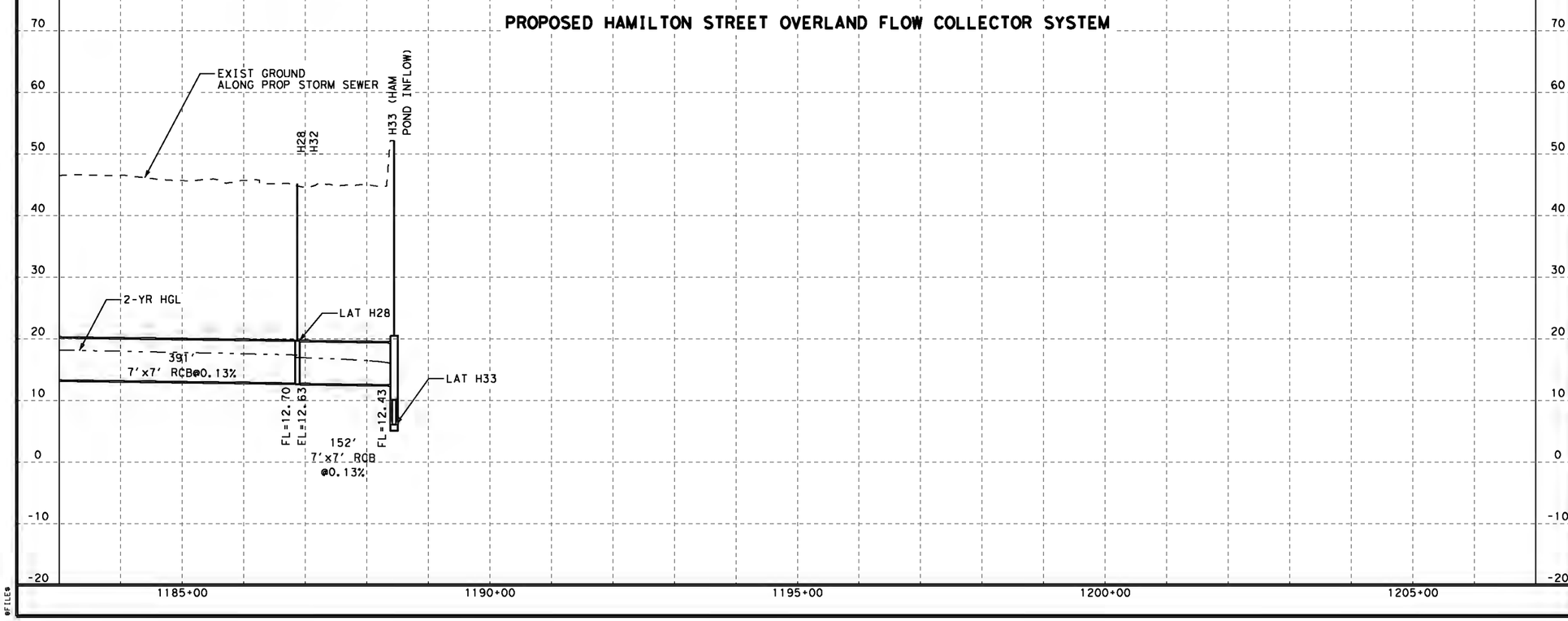
PROPOSED HAMILTON STREET OVERLAND FLOW COLLECTOR SYSTEM



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JAMES C. HATHORN
98292
TEXAS SERIAL NO.
7/23/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

CobbFendley
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TBPLS Firm Registration No. 10087
13430 Northwest Freeway, Suite 1100
Houston, Texas 77040
713.462.3242 | fax 713.462.3262
www.cobbfendley.com

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STA 1183+00 TO END CONST
(℄ I-69 SBML)

SHEET 6 OF 7

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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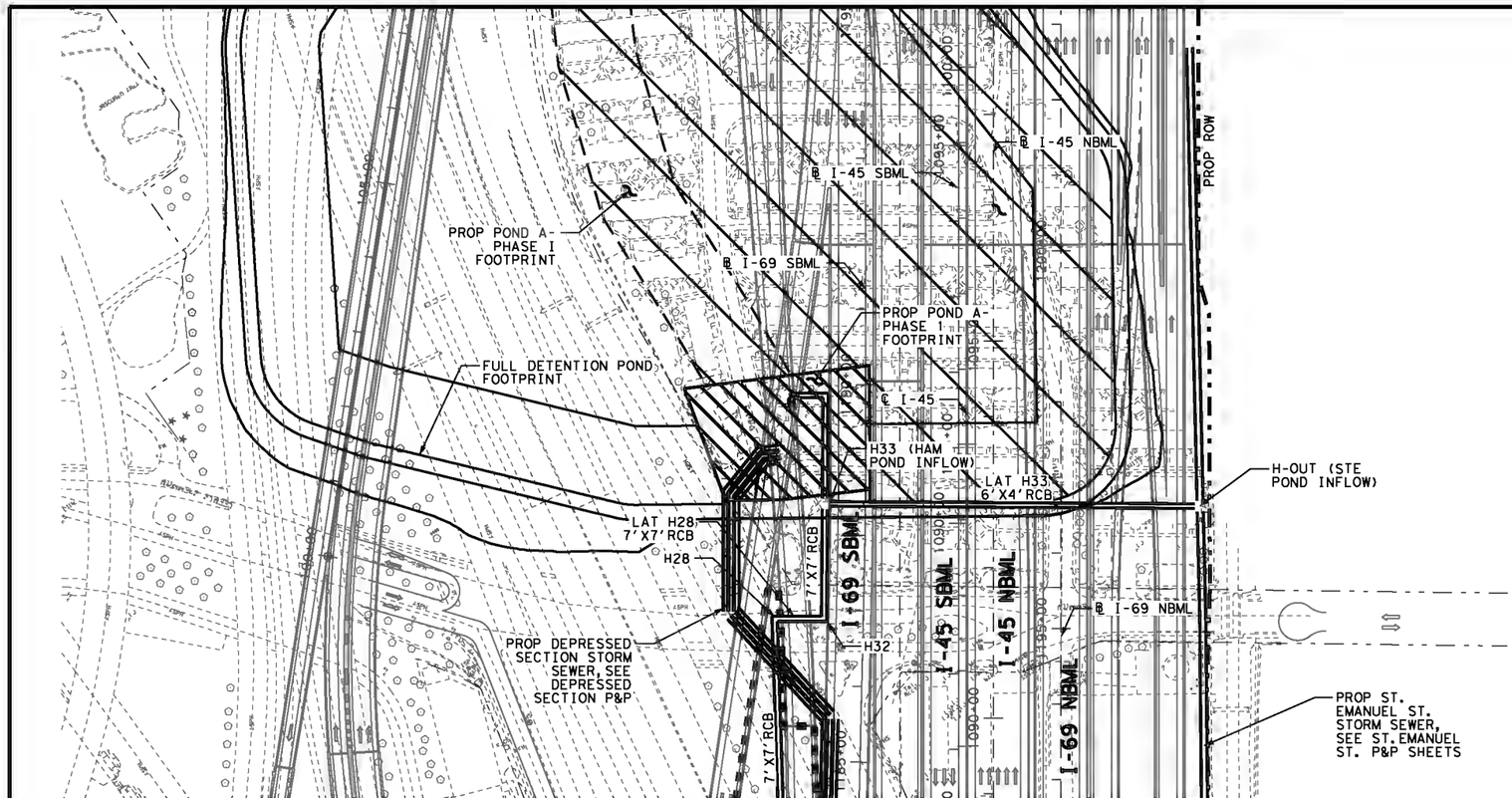

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
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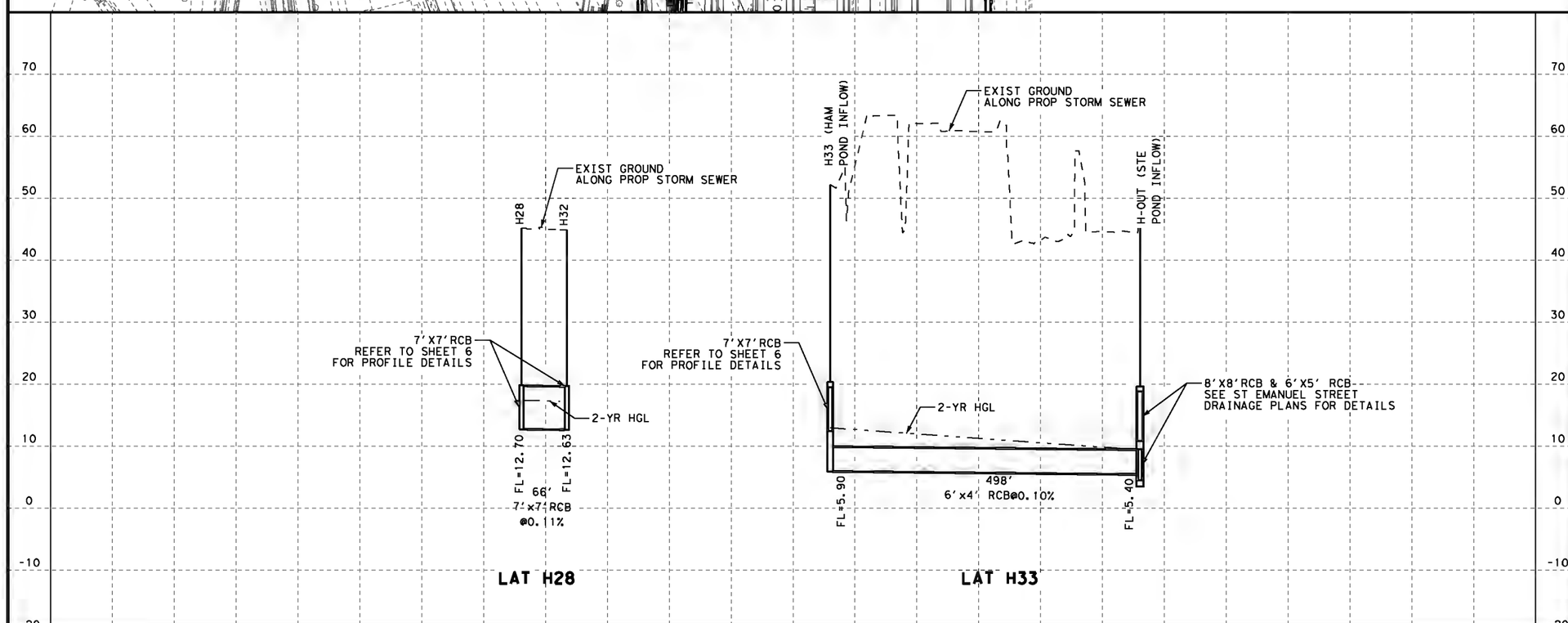

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JAMES C. HATHORN
98292
TEXAS SERIAL NO.
7/23/2018
DATE

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CobbFendley
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TBPLS Firm Registration No. 10087
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Houston, Texas 77040
713.462.3242 | fax 713.462.3262
www.cobbfendley.com

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SYSTEM H LATERALS
(℄ I-69 SBML)

SHEET 7 OF 7

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

$FILES$

PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

RUNOFF COMPUTATIONS FOR DESIGN FREQUENCY

ST. EMANUEL STREET COLLECTOR SYSTEM

ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	VELOCITY (FPS)
SE1	SE1	SE2	332	Circular	1	4	n/a	0.013	0.13	24.38	23.95	43.2	43.05	14.58	2.92
SE2	SE2	SE3	333	Circular	1	4	n/a	0.013	0.13	23.95	23.52	43.05	42.96	28.84	2.3
SE3	SE3	SE4	330	Circular	1	4	n/a	0.013	0.13	23.52	23.10	42.96	43.05	55.94	4.45
SE4	SE4	SE5	345	Circular	1	4	n/a	0.013	0.13	23.10	22.64	43.05	43.21	61.36	4.88
SE5	SE5	SE6	317	Circular	1	4	n/a	0.013	0.13	22.64	22.23	43.21	43.21	71.06	5.65
SE6	SE6	SE7	327	Box	1	4	4	0.013	0.13	22.23	21.80	43.21	43.2	78.82	4.93
SE7	SE7	SE8	330	Box	1	4	4	0.013	0.13	21.18	21.37	43.2	43.2	81.92	5.12
SE8	SE8	SE9	331	Box	1	4	4	0.013	0.13	21.37	20.94	43.2	43.19	88.17	5.51
SE9	SE9	SE10	329	Box	1	4	4	0.013	0.13	20.94	20.50	43.19	43.15	104.52	6.53
SE10	SE10	SE11	325	Box	1	4	4	0.013	0.13	20.50	20.10	43.15	42.97	114.35	7.15
SE11	SE11	SE12	365	Box	1	4	4	0.013	0.13	20.10	19.62	42.97	42.46	129.7	8.11
SE12	SE12	SE13	656	Box	1	4	4	0.013	0.13	19.62	18.76	42.46	40.13	139.36	8.71
SE13	SE13	SE14	339	Box	1	4	4	0.013	0.13	18.76	18.32	40.13	36.67	191.49	11.97
SE14	SE14	SE15	347	Box	1	4	4	0.013	0.13	18.32	17.87	36.67	32.36	202.43	12.65
SE15	SE15	SE16	345	Box	1	4	4	0.013	0.13	17.87	17.44	32.36	28.5	311.33	19.75
SE16	SE16	SE17	636	Box	1	8	8	0.013	0.21	13.44	12.10	28.5	28.53	667.96	10.81
SE17	SE17	SE18	528	Box	1	8	8	0.013	0.21	12.10	11.00	28.53	28.53	668.14	11.8
SE18	SE18	SE19	150	Box	1	8	8	0.013	0.15	11.00	10.77	28.53	28.51	668.16	13.14
SE19	SE19	SE20	607	Box	1	6	5	0.013	0.10	4.40	3.80	28.51	28.48	318.06	10.6

Notes:
The St. Emanuel Collector System was designed using SWMM. The results presented here are taken from the Proposed Overland Flow SWMM Model as described in Section 4.7 and Section 5.2 of the drainage report.
The hydrologic analysis for the St. Emanuel Collector System was completed using the methodology outlined in the Hydrologic Technical Memo found in Appendix A. HEC-HMS v. 3.5 was used to develop the flows to input into the SWMM

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

AECOM
AECOM TECHNICAL SERVICES, INC.
10219 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77064
WWW.AECOM.COM
TBPE REG. NO. F-3580

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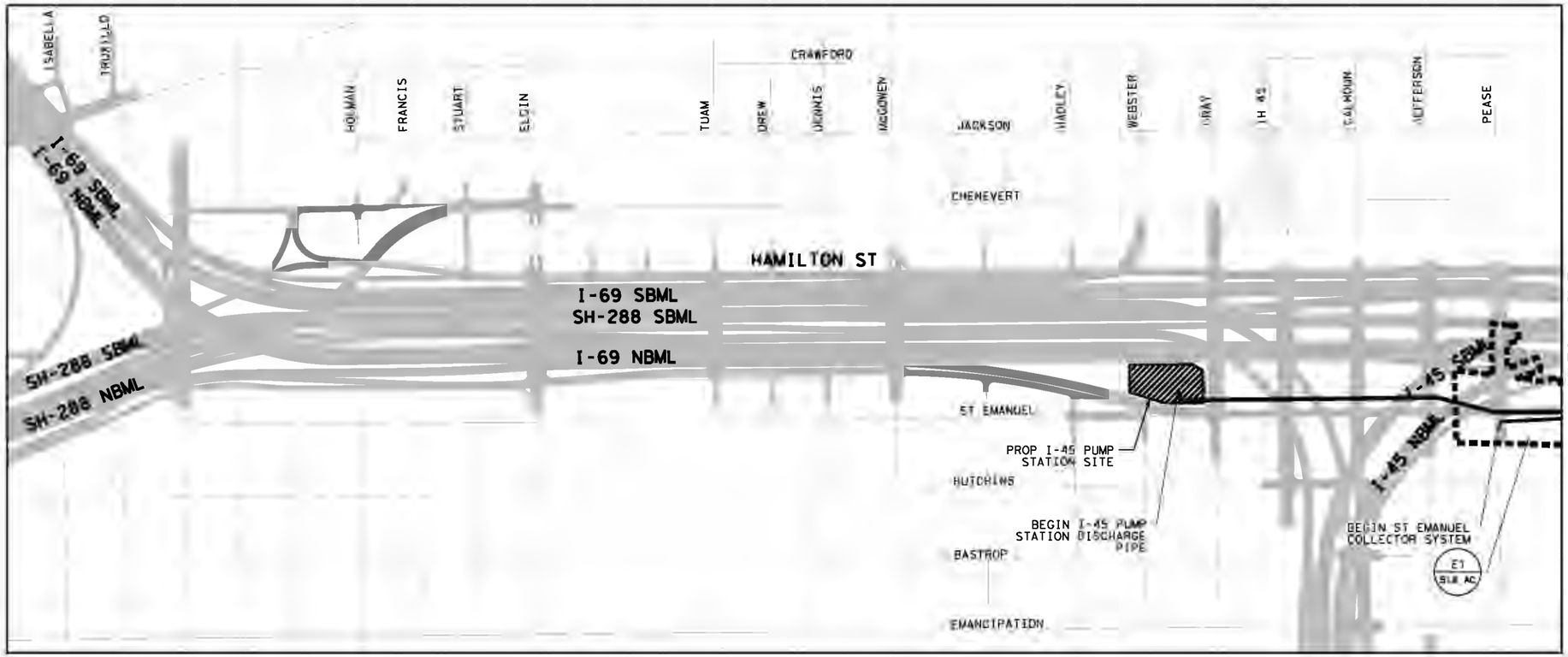
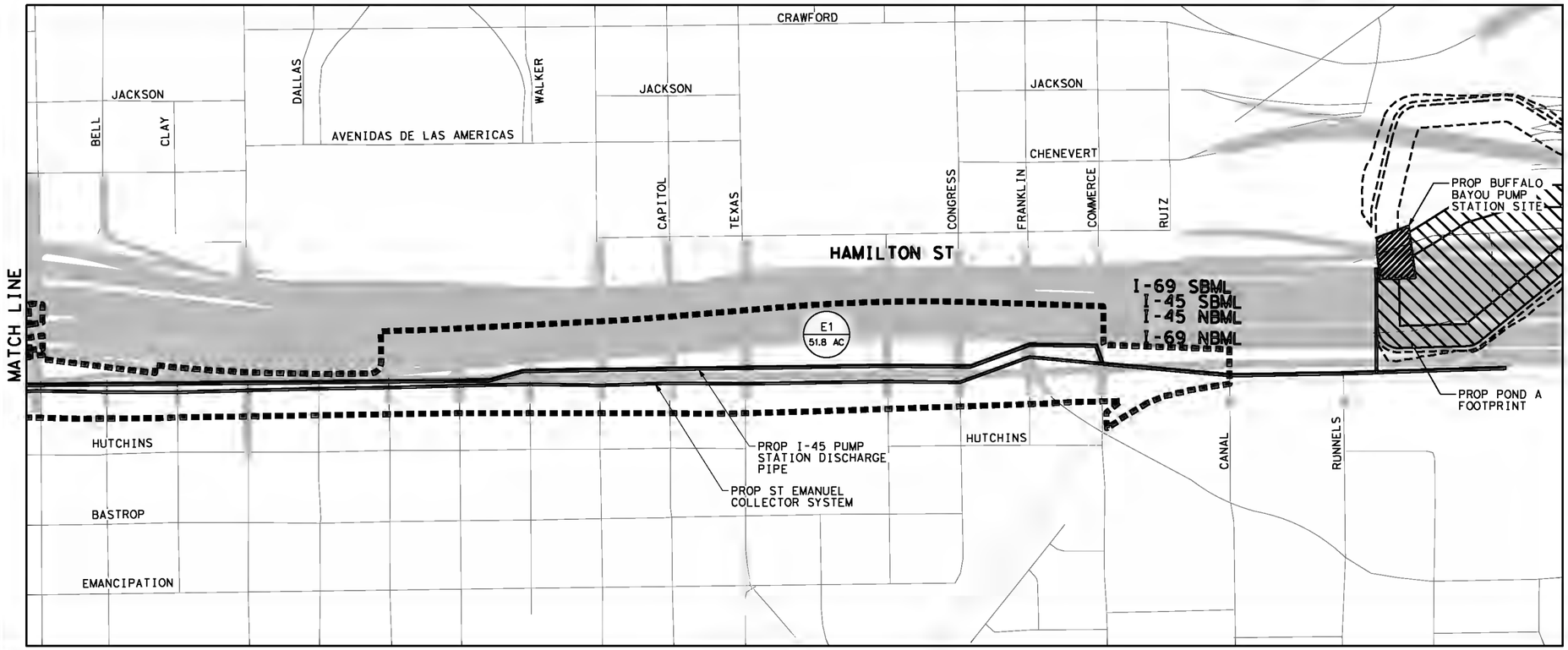
ST. EMANUEL COLLECTOR SYSTEM
HYDRAULIC DATA SHEET

SHEET 1 OF 1

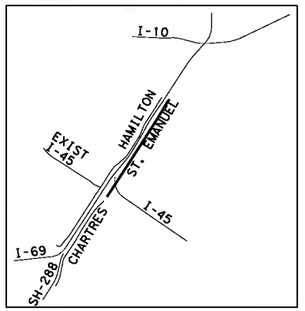
FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	1-45/1-69/SH-288





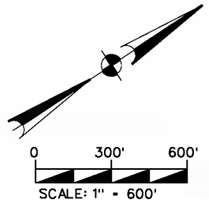
LEGEND

- DIRECTION OF FLOW
- OVERALL DRAINAGE BOUNDARY
- SYSTEM ID — X•• / XX — SUB AREA ID / ACREAGE
- PROPOSED ROADWAY



VICINITY MAP

NOTES:
1. ANY OFFSITE FLOW DRAINING TOWARDS THE DEPRESSED SECTION WILL BE CAPTURED BY PROPOSED COLLECTOR SYSTEMS.



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96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

AECOM
AECOM TECHNICAL SERVICES, INC.
19219 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77094
WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B
ST EMANUEL COLLECTOR SYSTEM
OVERALL DRAINAGE AREA MAP

SHEET 1 OF 1

FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	1-45/1-69/SH-288

7/28/2018 2:07:53 PM
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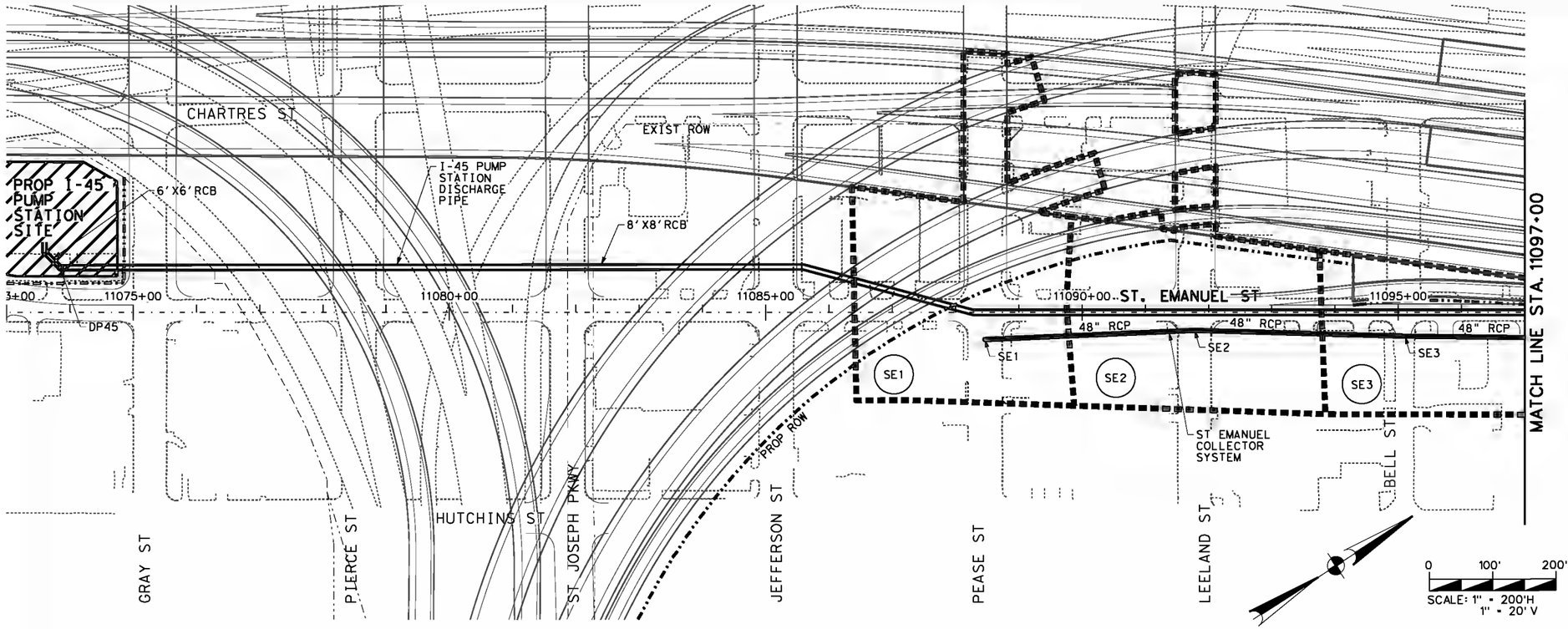


LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- (XXXX) DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.

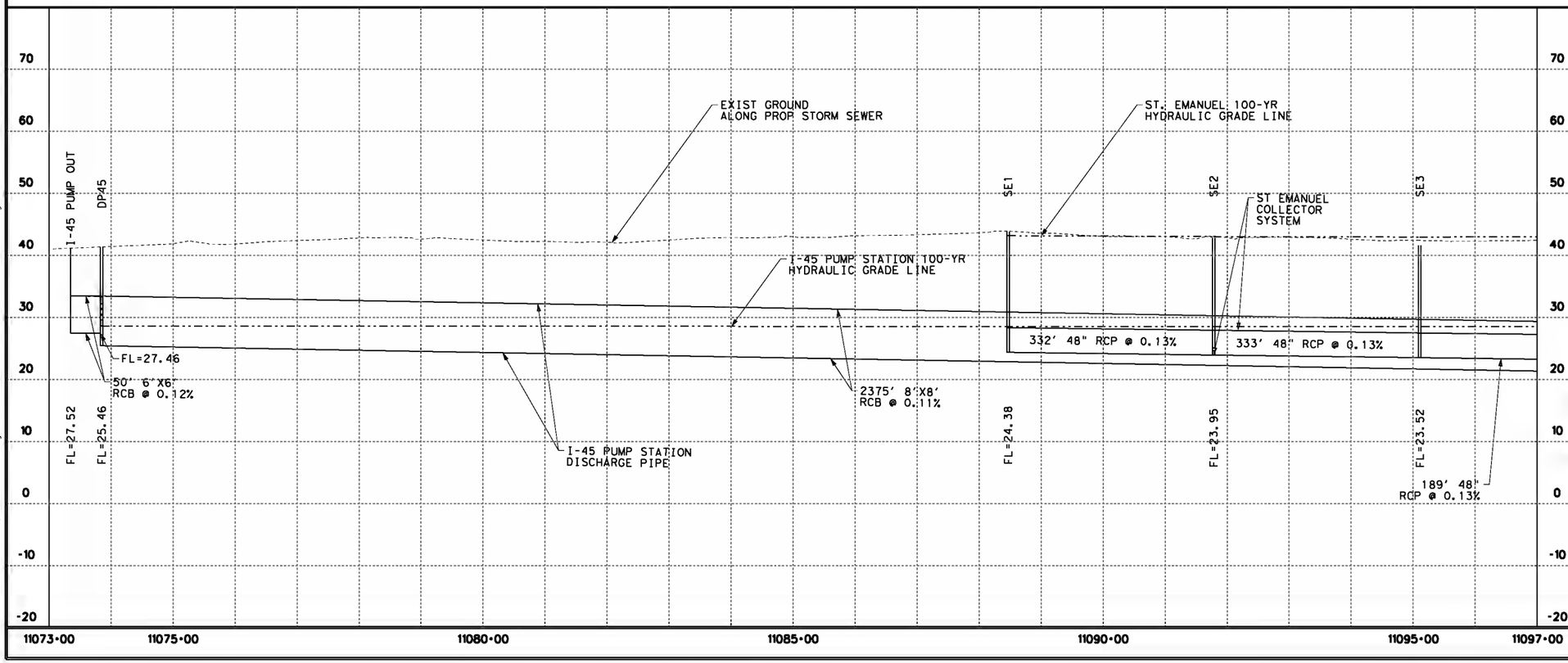
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.

3. ALL FRONTAGE ROADS REMAIN PASSABLE UNDER A 2-YR STORM EVENT.

4. ALL COLLECTOR SYSTEMS HAVE A MINIMUM CAPACITY TO CONVEY THE 2-YR STORM EVENT AND HAVE BEEN DESIGNED FOR NO ADVERSE IMPACTS TO OVERLAND WATER SURFACE ELEVATION IN THE 100-YR STORM EVENT.

5. FLOWS FOR THE 100-YR STORM EVENT FOR ALL COLLECTOR SYSTEMS BASED ON A COMBINATION OF THE RATIONAL METHOD FOR THE SEWERSHED PLUS OVERLAND FLOWS DETERMINED FROM THE OVERLAND FLOW ANALYSIS AS DISCUSSED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.

6. RUNOFF FROM DIRECT CONNECTORS ACCOMMODATED FOR IN MAIN TRUNK LINE SYSTEMS.



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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

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AECOM
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19219 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77094
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TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B
ST. EMANUEL COLLECTOR SYSTEM
STORM SEWER PLAN & PROFILE

STA 11073+00 TO STA 11097+00
(@ ST.EMANUEL) SHEET 1 OF 4

FED.RD DIV.ND.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	1-45/1-69/SH-288

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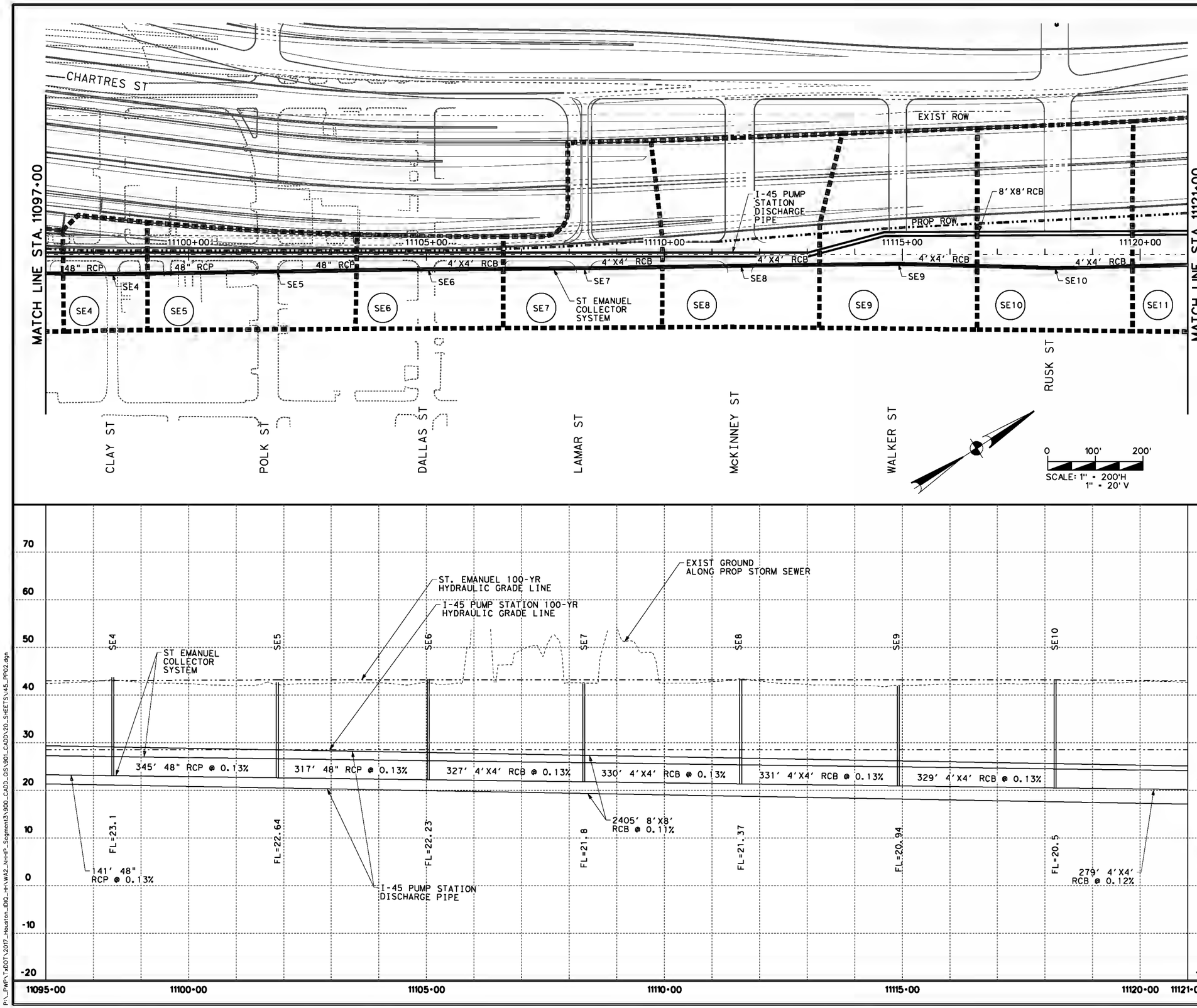

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- XXXX DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.

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3. ALL FRONTAGE ROADS REMAIN PASSABLE UNDER A 2-YR STORM EVENT.

4. ALL COLLECTOR SYSTEMS HAVE A MINIMUM CAPACITY TO CONVEY THE 2-YR STORM EVENT AND HAVE BEEN DESIGNED FOR NO ADVERSE IMPACTS TO OVERLAND WATER SURFACE ELEVATION IN THE 100-YR STORM EVENT.

5. FLOWS FOR THE 100-YR STORM EVENT FOR ALL COLLECTOR SYSTEMS BASED ON A COMBINATION OF THE RATIONAL METHOD FOR THE SEWERSHED PLUS OVERLAND FLOWS DETERMINED FROM THE OVERLAND FLOW ANALYSIS AS DISCUSSED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.

6. RUNOFF FROM DIRECT CONNECTORS ACCOMMODATED FOR IN MAIN TRUNK LINE SYSTEMS.

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
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19219 KATY FREEWAY, SUITE 100
HOUSTON, TEXAS 77094
WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B
ST. EMANUEL COLLECTOR SYSTEM
STORM SEWER PLAN & PROFILE

STA 11097+00 TO STA 11121+00
(@ ST.EMANUEL) SHEET 2 OF 4

FED.RD DIV.ND.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	1-45/1-69/SH-288

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7/23/2018 5:38:11 PM
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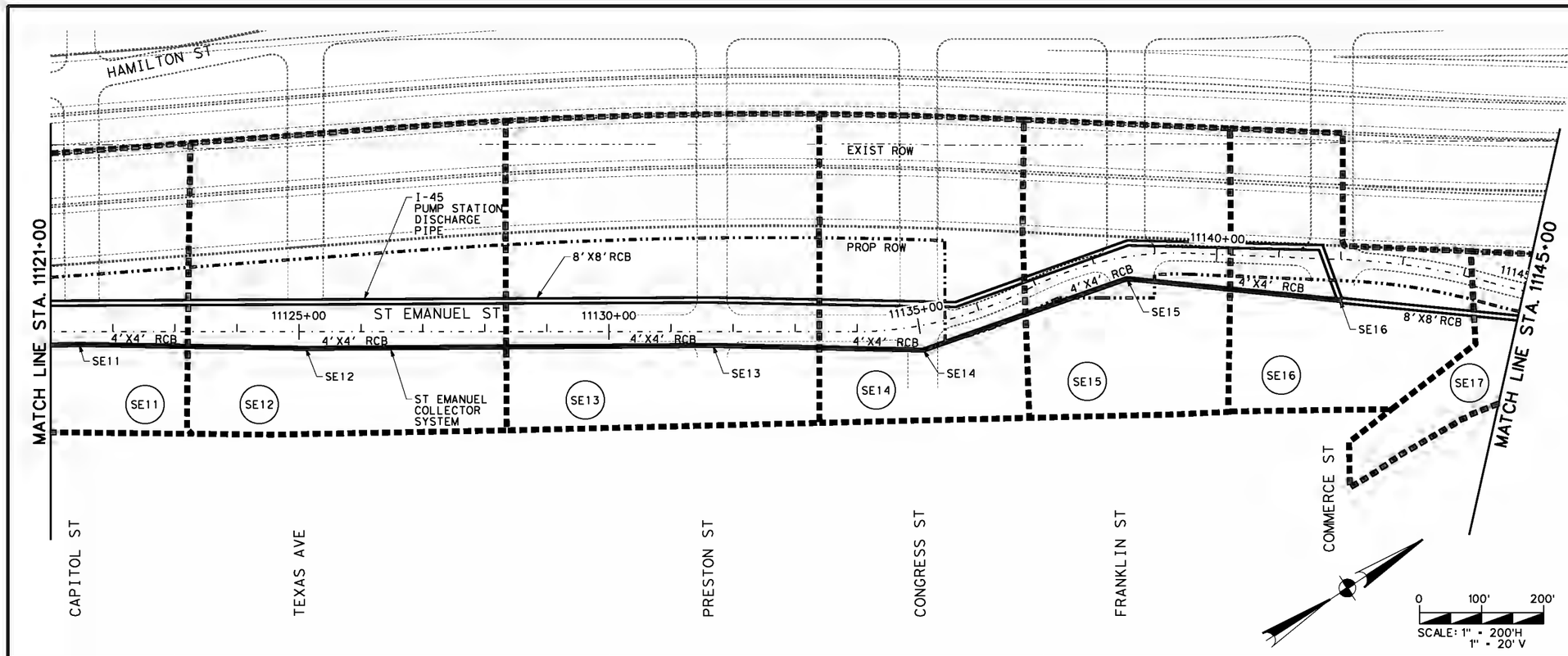

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- XXXX DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
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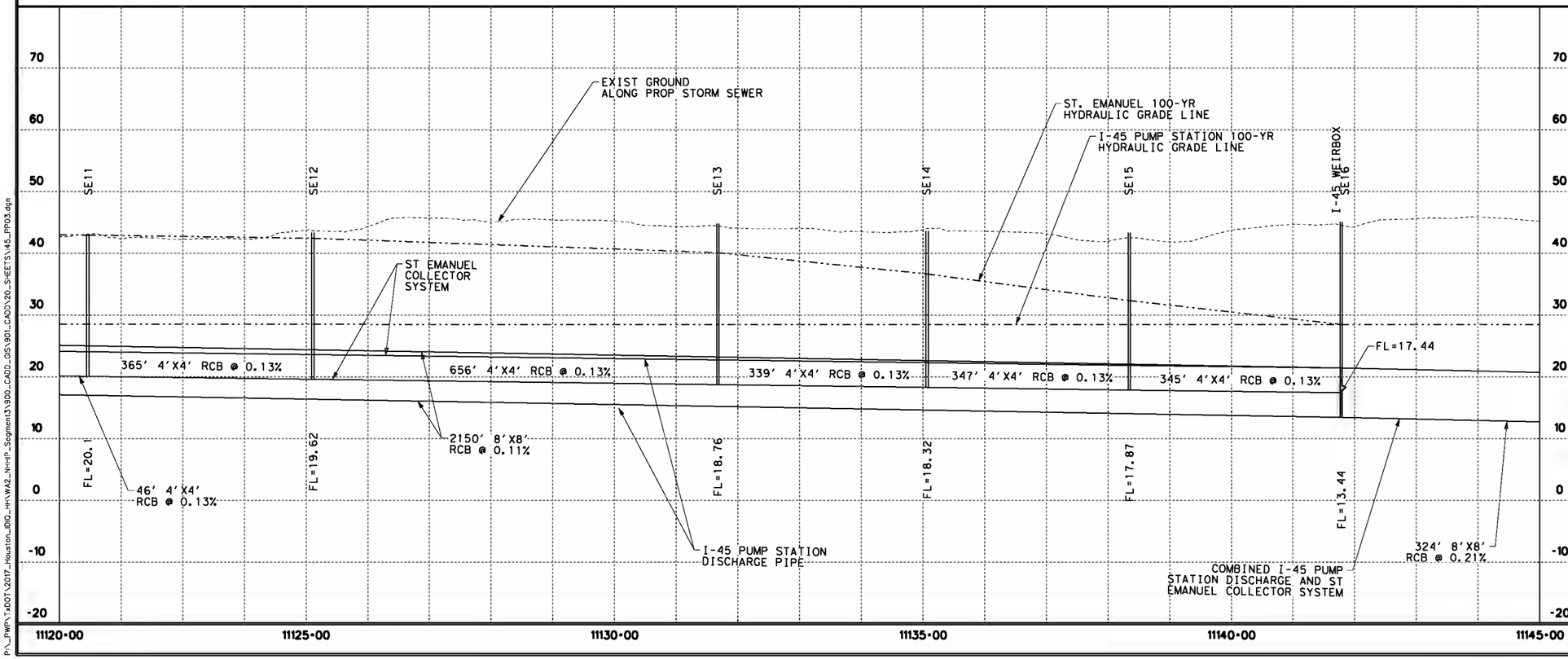

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
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AECOM
AECOM TECHNICAL SERVICES, INC.
19219 KATY FREEWAY, SUITE 100
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WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B
ST. EMANUEL COLLECTOR SYSTEM
STORM SEWER PLAN & PROFILE

STA 11121+00 TO STA 11145+00
(@ ST.EMANUEL) SHEET 3 OF 4

FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	1-45/1-69/SH-288

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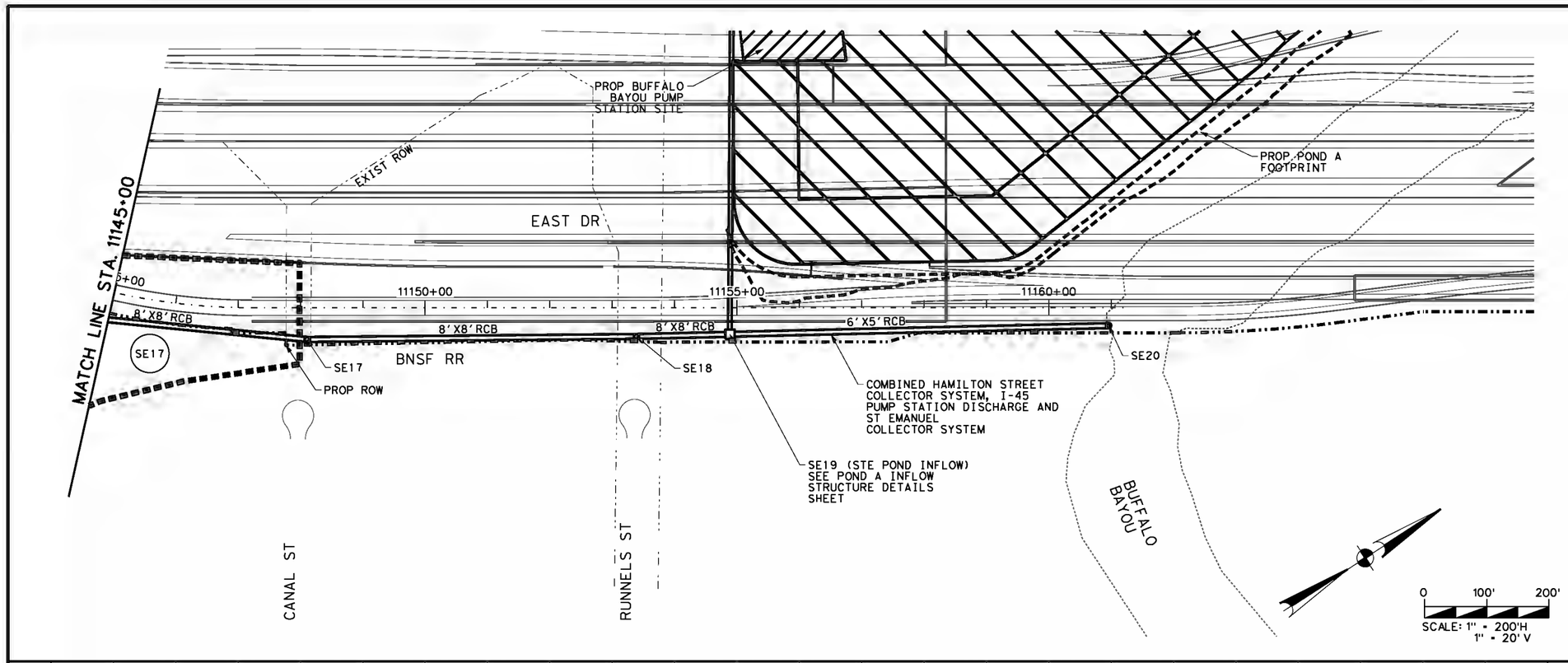

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- XXXX DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

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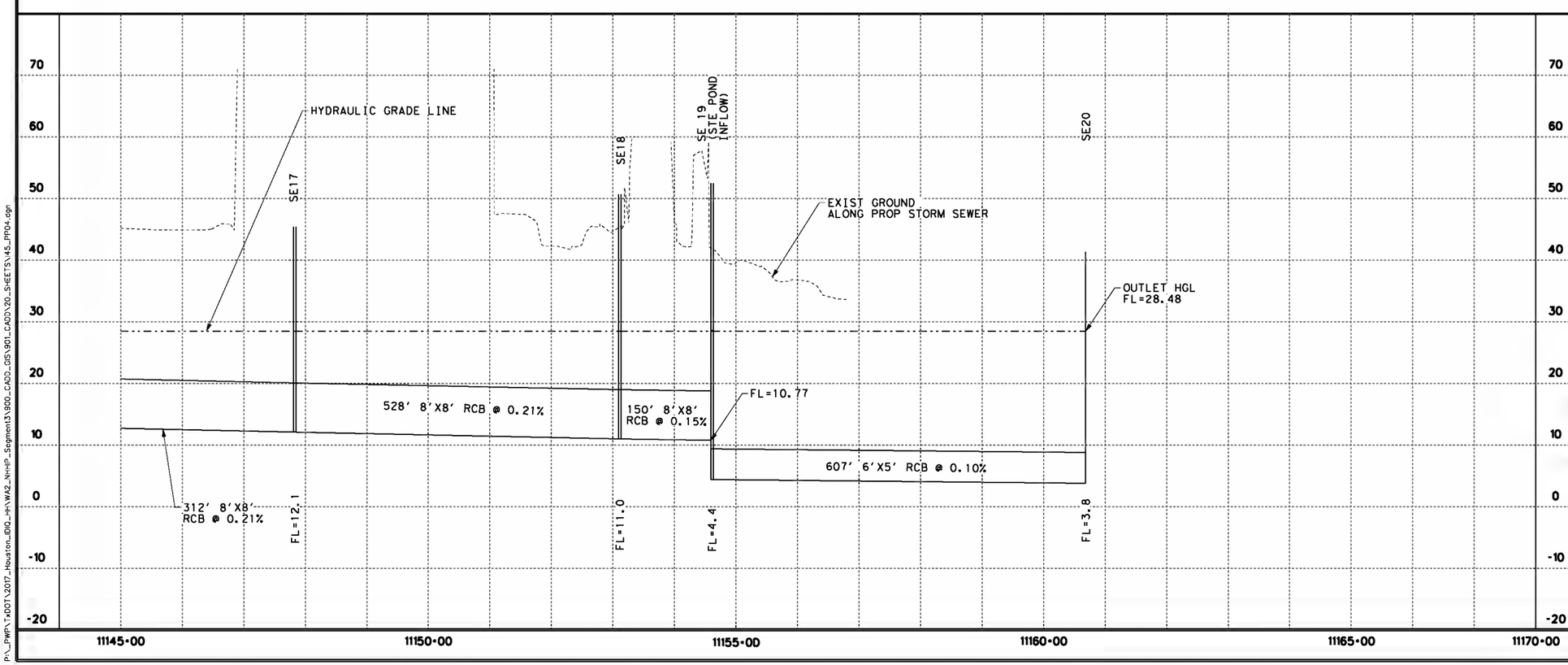

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

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19219 KATY FREEWAY, SUITE 100
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WWW.AECOM.COM
TBPE REG. NO. F-3580

Texas Department of Transportation

NHHIP SEGMENT 3B
ST. EMANUEL COLLECTOR SYSTEM
STORM SEWER PLAN & PROFILE

STA 11145+00 TO END OF PROJECT (@ ST.EMANUEL) SHEET 4 OF 4

FED.RD DIV.NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	1-45/1-69/SH-288

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I45_PP04.dgn

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 2 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

RUNOFF COMPUTATIONS FOR DESIGN FREQUENCY

CHARTRES SYSTEM (NORTH OF ELGIN ST.)						
ID	RUNOFF C	DRAINAGE AREA (ACRES)	TIME OF CONC. (MIN)	TIME USED (MIN)	INTENSITY (IN/HR)	DISCHARGE (CFS)
C16	0.72	1.38	8.71	10.00	5.47	5.4
C17	0.69	2.01	11.10	11.10	5.23	7.3
C18	0.68	4.49	13.51	13.51	4.79	14.7
C19	0.65	9.83	15.12	15.12	4.54	29.0
C20	0.69	13.69	16.33	16.33	4.37	41.5
C22	0.66	3.00	10.72	10.72	5.31	10.5
C23	0.70	2.58	13.22	13.22	4.84	8.7
C24	0.67	4.20	12.23	12.23	5.01	14.2

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CURTIS W. WHITE
113382
TEXAS SERIAL NO.
6/1/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

CivilTech Engineering Inc.
11821 Telge Road
Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

Texas Department of Transportation
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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
RUNOFF COMPUTATIONS
CHARTRES ST (I-69 NBFR)
NORTH OF ELGIN ST

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE CONFIGURATION DATA

CHARTRES SYSTEM (NORTH OF ELGIN ST.)											
ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
C16	C16	C-OUT	214	Box	1	4	5	0.012	0.20	30.38	29.95
C17	C17	C16	266	Box	1	4	5	0.012	0.20	30.92	30.38
C18	C18	C17	342	Box	1	4	5	0.012	0.20	31.61	30.92
C19	C19	C18	507	Box	1	4	4	0.012	0.20	32.63	31.61
C20	C20	C19	307	Box	1	4	4	0.012	0.20	33.25	32.63
C21	C21	C20	310	Circular	1	3	n/a	0.012	0.20	34.88	34.25
C22	C22	C21	336	Circular	1	3	n/a	0.012	0.20	35.56	34.88
C23	C23	C22	162	Circular	1	3	n/a	0.012	0.20	35.89	35.56
C24	C24	C23	347	Circular	1	2.5	n/a	0.012	0.20	37.09	36.39

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TEXAS SERIAL NO.
6/1/2018
DATE

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CivilTech Engineering Inc.
11821 Telge Road
Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
CHARTRES ST (I-69 NBFR)
NORTH OF ELGIN ST
SHEET 2 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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145_CHRT_HDS02.dgn

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN
PROJECT NAME: 1-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 2 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE HYDRAULIC COMPUTATIONS

CHARTRES SYSTEM (NORTH OF ELGIN ST.)										
ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM		ACTUAL	
							VELOCITY (FT/S)	DEPTH (FT)	VELOCITY (FT/S)	DEPTH (FT)
C16	C16	C-OUT	34.15	33.95	109.9	145.7	6.8	3.2	5.5	4.0
C17	C17	C16	34.44	34.15	107.9	145.8	7.0	3.1	5.7	3.8
C18	C18	C17	34.89	34.44	104.8	145.7	6.8	3.1	6.0	3.5
C19	C19	C18	36.19	34.89	95.9	106.0	6.5	3.7	7.3	3.3
C20	C20	C19	36.52	36.19	70.4	105.9	6.2	2.8	5.0	3.6
C21	C21	C20	37.20	36.52	31.1	34.9	5.2	2.4	5.4	2.3
C22	C22	C21	37.91	37.20	31.1	34.8	5.2	2.4	5.3	2.3
C23	C23	C22	38.06	37.91	22.2	34.7	4.9	1.8	3.7	2.3
C24	C24	C23	38.97	38.06	14.2	21.4	4.5	1.5	4.1	1.7

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113382
TEXAS SERIAL NO.
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DATE

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Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

Texas Department of Transportation
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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
CHARTRES ST (I-69 NBFR)
NORTH OF ELGIN ST SHEET 3 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

6/1/2018 6:26:30 AM
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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 2 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

RUNOFF COMPUTATIONS FOR DESIGN FREQUENCY

CHARTRES SYSTEM (SOUTH OF ELGIN ST.)						
ID	RUNOFF C	DRAINAGE AREA (ACRES)	TIME OF CONC. (MIN)	TIME USED (MIN)	INTENSITY (IN/HR)	DISCHARGE (CFS)
C15	0.65	0.59	4.00	10.00	5.47	2.1
C14	0.54	0.79	12.00	12.00	5.06	2.2
C13	0.56	0.90	10.00	10.00	5.47	2.7
C12	0.52	4.00	12.00	12.00	5.06	10.5
C10	0.53	2.29	13.00	13.00	4.88	5.9
C9	0.74	2.23	6.00	10.00	5.47	9.0
C8	0.57	2.66	12.00	12.00	5.06	7.7
C7	0.55	2.29	11.00	11.00	5.25	6.6
C6	0.75	2.83	4.00	10.00	5.47	11.6
C5	0.68	0.52	4.00	10.00	5.47	1.9
C-101B	0.50	0.47	3.00	10.00	5.47	1.3
C-101A	0.58	1.47	7.00	10.00	5.47	4.63

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PATRICK W. PHILLIPS
92917
TEXAS SERIAL NO.
6/18/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

OMEGA ENGINEERS, INC.
16360 PARK TEN PLACE, Ste. #325
HOUSTON TEXAS, 77084
OMEGAENGINEERS.COM
TX PE Firm Reg. No. F-2147
P:281 647 9182 F:281 847 9184

Texas Department of Transportation
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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
CHARTRES (SOUTH OF ELGIN ST)

SHEET 1 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE CONFIGURATION DATA

CHARTRES SYSTEM (SOUTH OF ELGIN ST.)											
ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
C15	C15	OUT-C	253	Circular	1	5	n/a	0.013	0.09	29.23	29.00
C14	C14	C15	292	Circular	1	5	n/a	0.013	0.10	29.52	29.22
C13	C13	C14	110	Circular	1	5	n/a	0.013	0.10	29.63	29.52
C12	C12	C13	167	Circular	1	5	n/a	0.013	0.09	29.78	29.63
C11	C11	C12	284	Circular	1	5	n/a	0.013	0.10	30.07	29.78
C10	C10	C11	301	Circular	1	5	n/a	0.013	0.10	30.37	30.07
C9	C9	C10	150	Circular	1	4	n/a	0.013	0.09	30.51	30.37
C8	C8	C9	127	Circular	1	4	n/a	0.013	0.11	30.65	30.51
C7	C7	C8	312	Circular	1	4	n/a	0.013	0.10	30.97	30.65
C6	C6	C7	295	Circular	1	4	n/a	0.013	0.09	31.26	30.99
C5	C5	C6	157	Circular	1	3	n/a	0.013	0.15	31.49	31.26
C4	C4	C5	43	Circular	1	2.5	n/a	0.013	0.21	31.58	31.49
C3	C3	C4	375	Circular	1	2.5	n/a	0.013	0.20	32.33	31.58
C2	C2	C3	270	Circular	1	2	n/a	0.013	0.23	32.95	32.33
C1	C1	C2	133	Circular	1	2	n/a	0.013	0.20	33.22	32.95
C-101B	C-101B	C2	46	Circular	1	2	n/a	0.013	0.73	34.37	34.03
C-101A	C-101A	C1	64	Circular	1	2	n/a	0.013	0.20	33.35	33.22

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PATRICK W. PHILLIPS
92917
TEXAS SERIAL NO.
6/18/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

OMEGA ENGINEERS, INC.
16360 PARK TEN PLACE, Ste. #325
HOUSTON TEXAS, 77084
OMEGAENGINEERS.COM
TX PE Firm Reg. No. F-2147
P:281 647 9182 F:281 847 9184

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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
CHARTRES (SOUTH OF ELGIN ST)

SHEET 2 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 100 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE HYDRAULIC COMPUTATIONS

CHARTRES SYSTEM (SOUTH OF ELGIN ST.)										
ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM		ACTUAL	
							VELOCITY (FT/S)	DEPTH (FT)	VELOCITY (FT/S)	DEPTH (FT)
C15	C15	OUT-C	32.06	34.30	33.9	91.5	4.1	2.2	1.7	5.0
C14	C14	C15	32.36	32.06	33.8	97.3	4.2	2.1	2.9	2.8
C13	C13	C14	32.47	32.36	32.5	95.4	4.3	2.1	2.8	2.8
C12	C12	C13	32.62	32.47	31.1	91.0	4.1	2.1	2.7	2.8
C11	C11	C12	32.18	32.62	33.1	96.9	4.4	2.1	2.9	2.8
C10	C10	C11	32.47	32.18	32.7	95.8	4.3	2.1	4.1	2.1
C9	C9	C10	32.80	32.47	29.7	51.2	3.9	2.4	4.4	2.1
C8	C8	C9	32.77	32.80	27.9	55.7	4.1	2.1	3.8	2.3
C7	C7	C8	33.09	32.77	24.7	53.6	3.9	2.0	3.7	2.1
C6	C6	C7	33.37	33.09	21.9	51.0	3.8	1.9	3.3	2.1
C5	C5	C6	33.59	33.37	4.8	29.8	3.0	0.8	0.9	2.1
C4	C4	C5	32.39	33.59	4.5	21.8	3.3	0.8	1.0	2.1
C3	C3	C4	33.15	32.39	4.5	21.4	3.3	0.8	3.2	0.8
C2	C2	C3	33.81	33.15	4.5	12.6	3.5	0.9	3.7	0.8
C1	C1	C2	34.00	33.81	3.3	11.9	3.0	0.8	2.6	0.9
C-101B	C-101B	C2	34.99	34.46	2.0	22.5	4.2	0.4	4.2	0.4
C-101A	C-101A	C1	34.21	34.00	3.3	11.9	3.0	0.8	3.0	0.8

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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
CHARTRES (SOUTH OF ELGIN ST)

SHEET 3 OF 3

FED. RD. DIV. NO.	CONTRACT NO.	SHEET NO.
6	36-71DP5055 WA 2	

STATE	DIST	COUNTY
TEXAS	HOU	HARRIS

CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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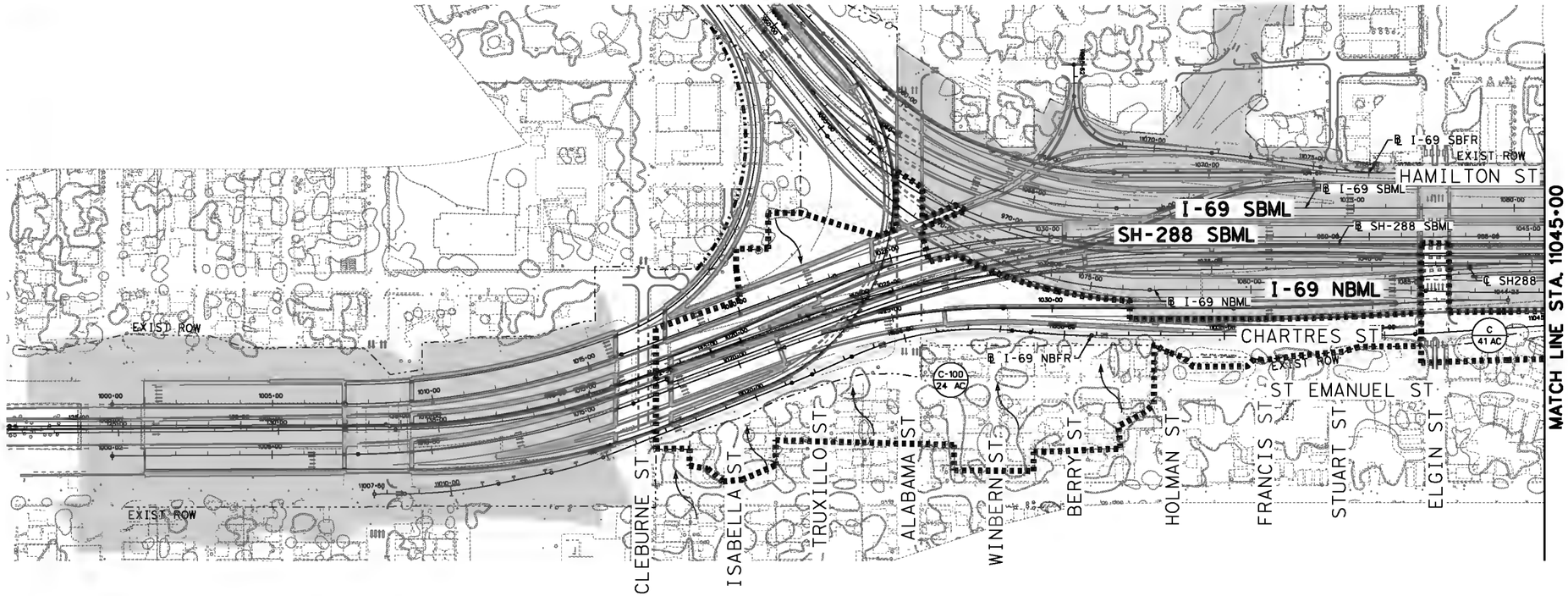
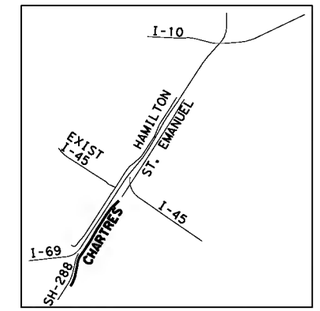
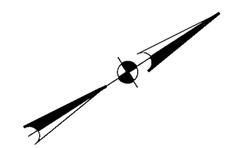


LEGEND

- DIRECTION OF FLOW
- OVERALL DRAINAGE BOUNDARY
- SYSTEM ID — X•• (SUB AREA ID) / XX (ACREAGE)



VICINITY MAP



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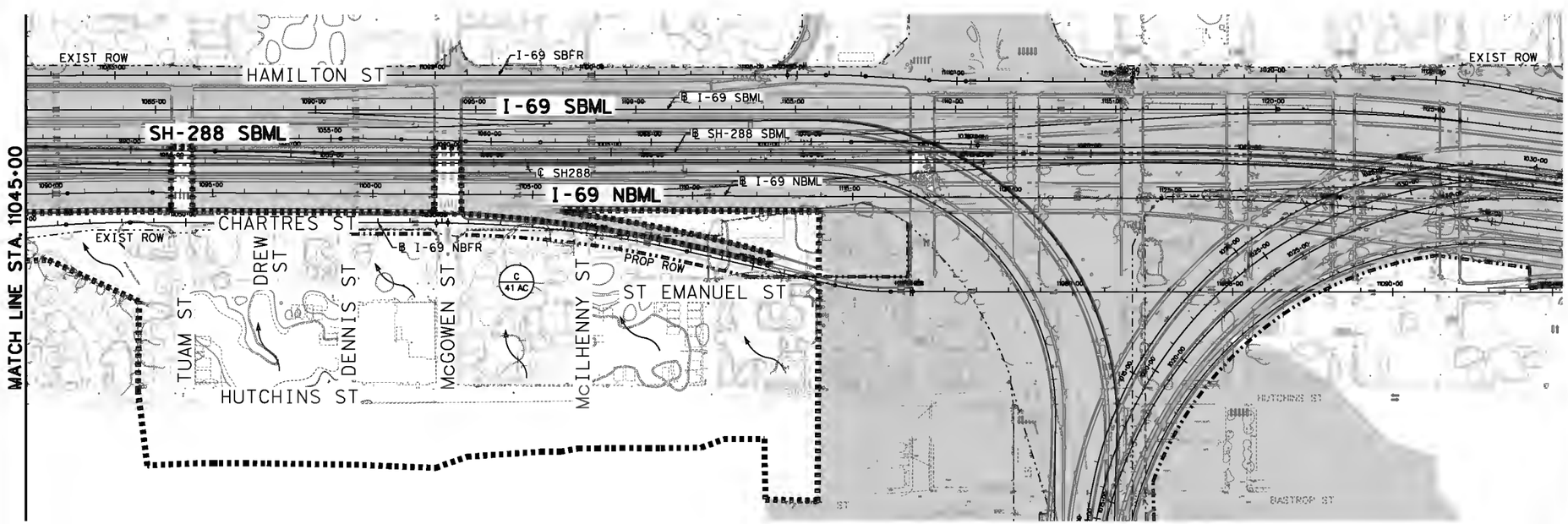

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CURTIS W. WHITE
113382
TEXAS SERIAL NO.
6/15/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

CivilTech Engineering Inc.
11821 Telge Road
Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

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NHHIP SEGMENT 3B
CHARTRES ST (I-69 NBFR) OVERALL DRAINAGE AREA MAP

SHEET 1 OF 1

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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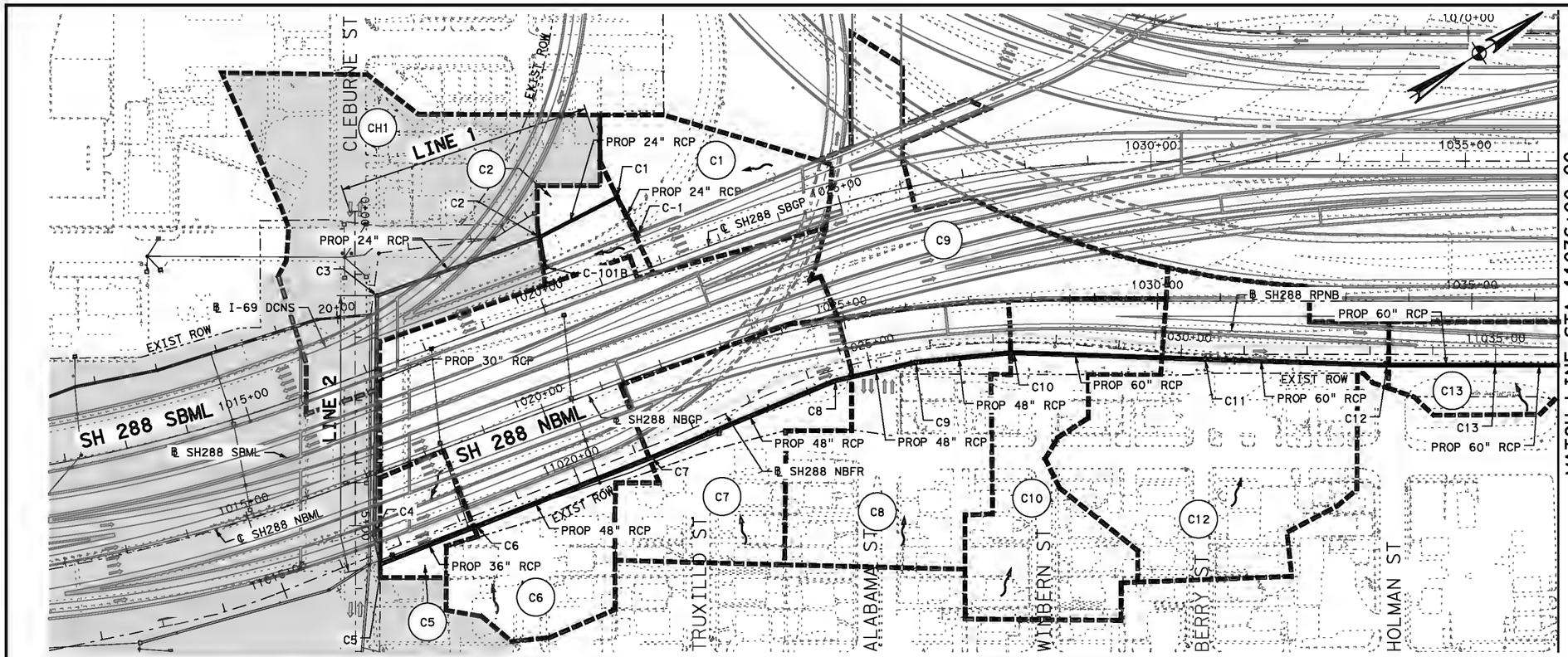


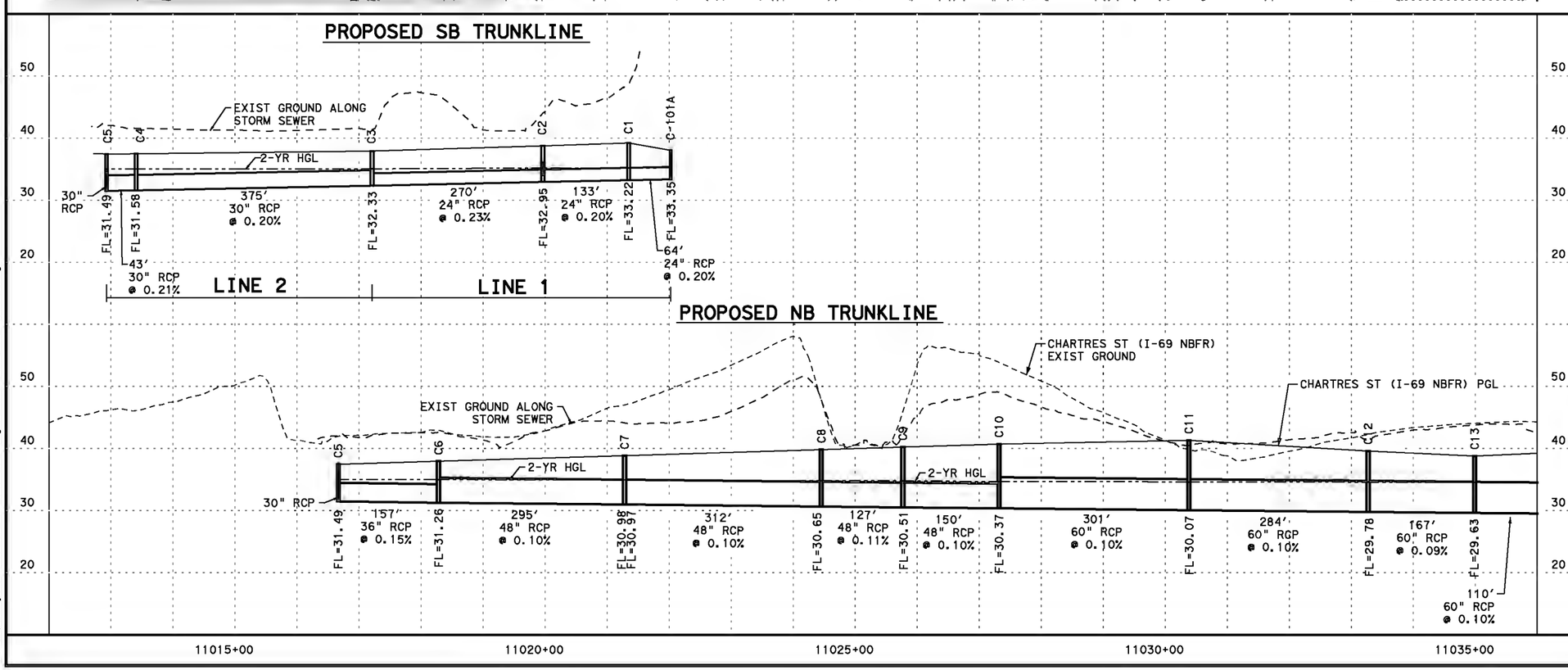
LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACT AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.
3. ALL FRONTAGE ROADS REMAIN PASSABLE UNDER A 2-YR STORM EVENT.

0 100' 200'
SCALE: 1" = 200'H
1" = 20' V



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92917
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HOUSTON TEXAS, 77084
OMEGAENGINEERS.COM
TX PE Firm Reg. No. F-2147
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NHHIP SEGMENT 3B
CHARTRES ST (I-69 NBFR)
STORM SEWER PLAN AND PROFILE

STA 11016+00 TO STA 11036+00
℄ SH288 NBGP SHEET 1 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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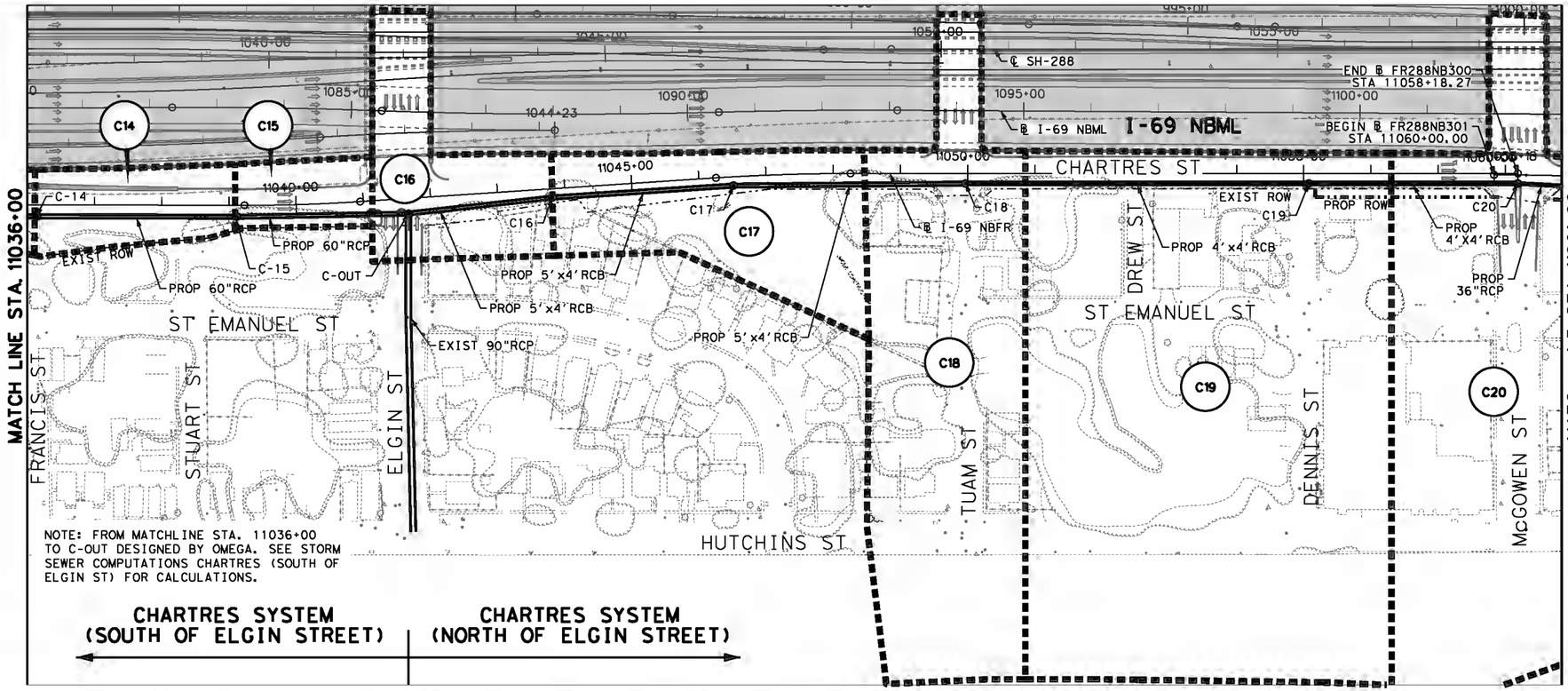

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

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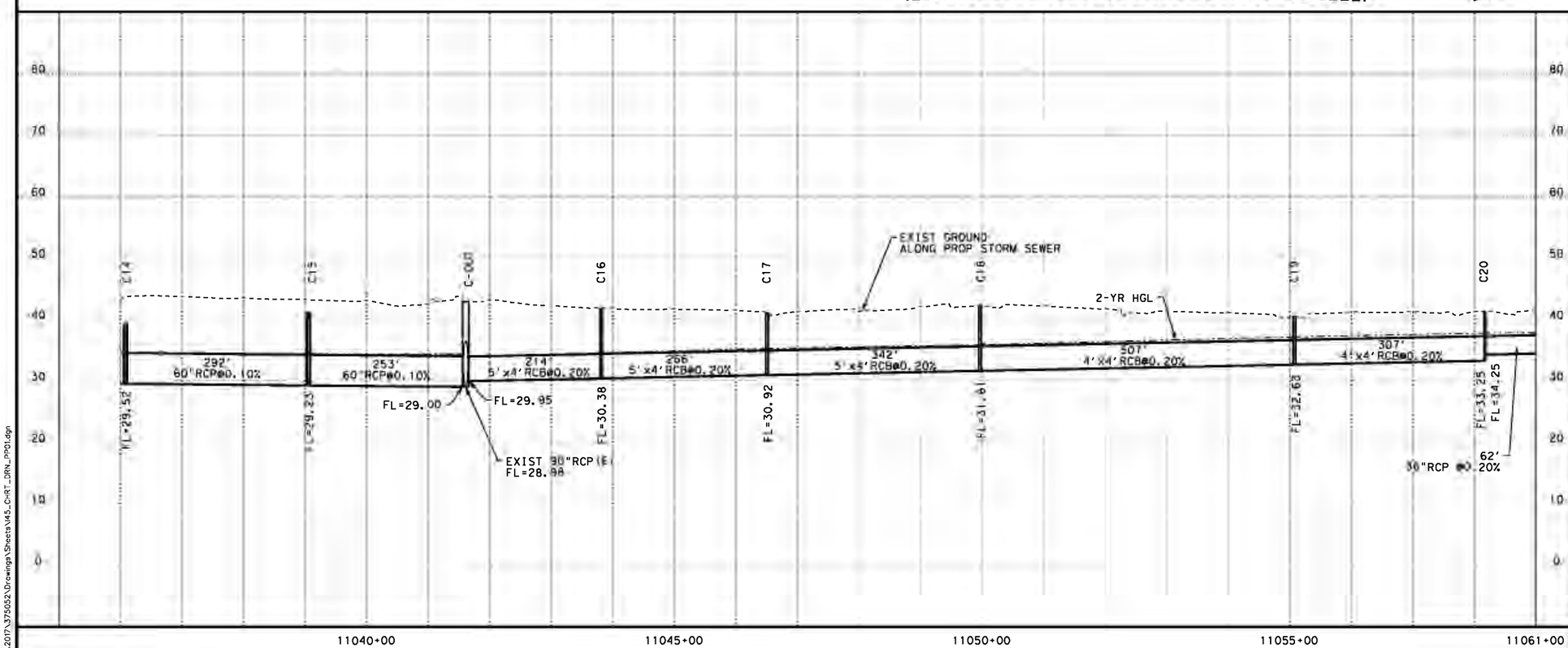
3. ALL FRONTAGE ROADS REMAIN PASSABLE UNDER A 2-YR STORM EVENT.
4. RUNOFF FROM DIRECT CONNECTORS ACCOMMODATED FOR IN MAIN TRUNK LINE SYSTEMS.



SCALE: 1" = 200'H
1" = 20' V

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CURTIS W. WHITE
113382
TEXAS SERIAL NO.
6/15/2018
DATE

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CivilTech Engineering Inc.
11821 Telge Road
Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

Texas Department of Transportation

NHHIP SEGMENT 3B
CHARTRES ST (I-69 NBFR)
STORM SEWER PLAN AND PROFILE
STA 11036+00 TO STA 11061+00
℄ FR288NB300 & ℄FR288NB301
SHEET 2 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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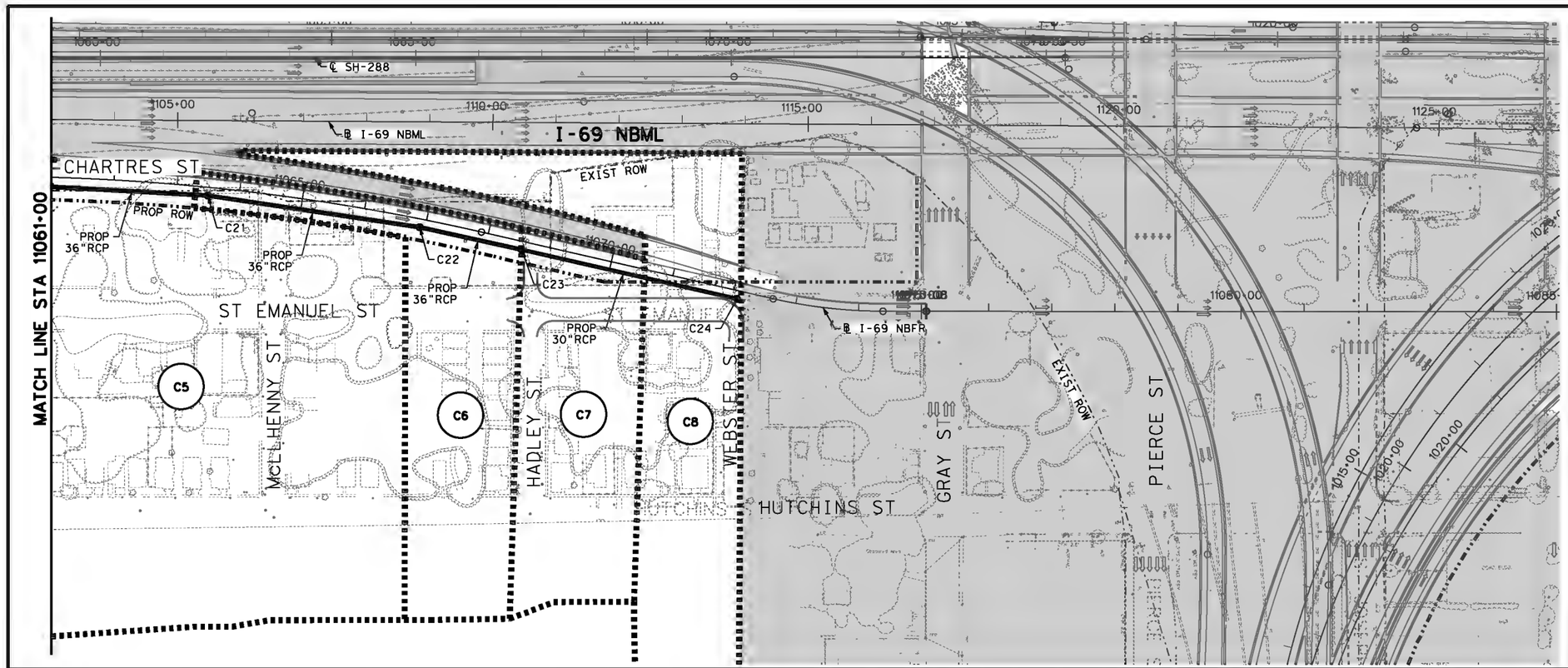

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

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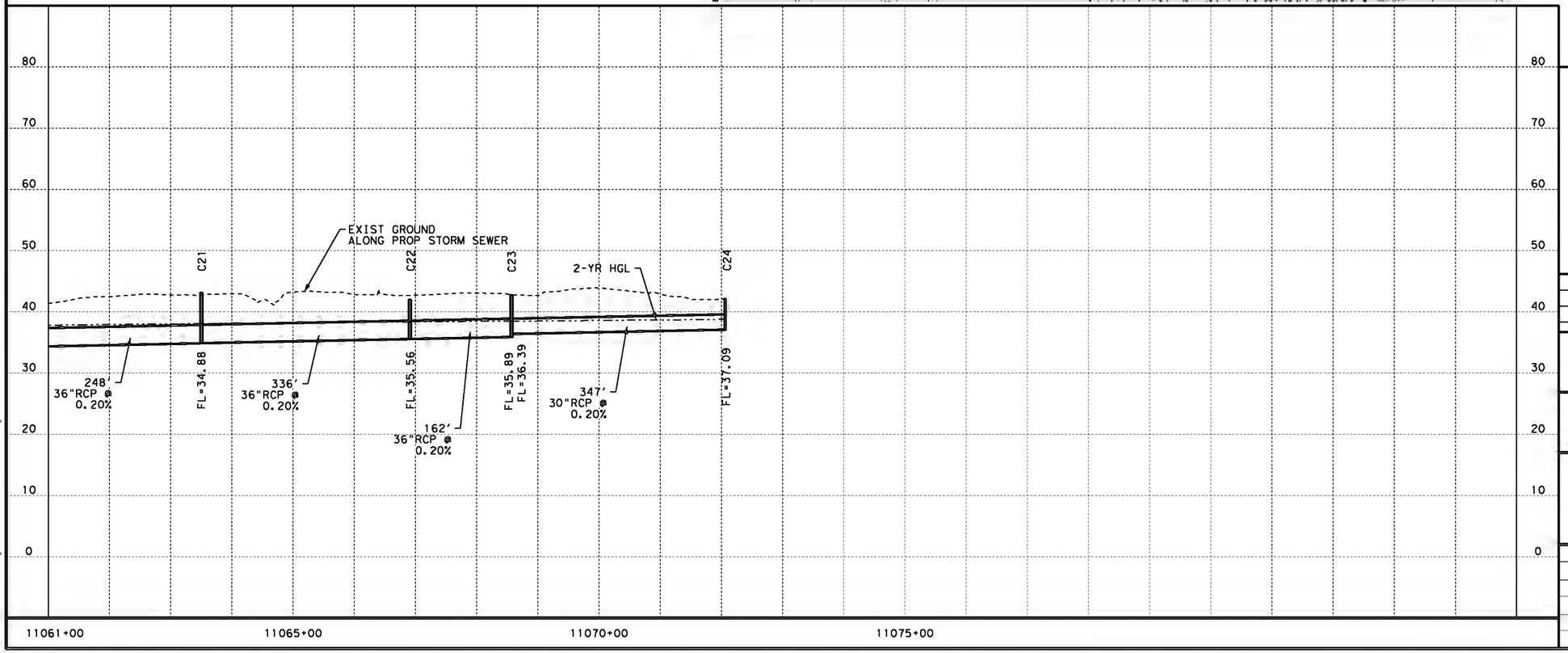
0 100' 200'
SCALE: 1" = 200'H
1" = 20' V



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TEXAS SERIAL NO.
6/15/2018
DATE

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Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

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NHHIP SEGMENT 3B
CHARTRES ST (I-69 NBFR)
STORM SEWER PLAN AND PROFILE
STA 11061+00 TO END
℄ FR288NB301

SHEET 3 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN
PROJECT NAME: 1-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 2 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

RUNOFF COMPUTATIONS FOR DESIGN FREQUENCY

I-45 SOUTH SYSTEM						
ID	RUNOFF C	DRAINAGE AREA (ACRES)	TIME OF CONC. (MIN)	TIME USED (MIN)	INTENSITY (IN/HR)	DISCHARGE (CFS)
A1	0.45	3.04	18.40	18.40	4.11	5.6
A2	0.52	2.34	14.79	14.79	4.59	5.6
A3	0.73	7.58	9.63	10.00	5.47	30.3
A4	0.79	6.83	5.73	10.00	5.47	29.3
A5	0.85	3.59	5.70	10.00	5.47	16.8
A6	0.76	8.50	17.35	17.35	4.24	27.5
A7	0.64	5.66	16.58	16.58	4.34	15.7
A7A	0.69	7.16	5.96	10.00	5.47	27.0
A8	0.73	27.33	21.61	21.61	3.77	75.1
A9	0.75	7.25	16.13	16.13	4.40	23.9
A10	0.80	5.99	20.01	20.01	3.93	18.8
A10A	0.73	5.79	12.44	12.44	4.98	21.1
A10B	0.55	2.80	11.35	11.35	5.18	8.0
A10C	0.60	12.28	16.62	16.62	4.33	32.1
A11	0.79	2.24	14.19	14.19	4.68	8.4
A12	0.74	2.52	15.00	15.00	4.56	8.5
A13	0.74	2.99	16.26	16.26	4.38	9.7
A14	0.73	2.30	14.52	14.52	4.63	7.8
A15	0.71	2.81	14.91	14.91	4.57	9.2
A16	0.70	6.66	15.50	15.50	4.49	20.8
A17	0.66	1.22	15.71	15.71	4.46	3.6

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113382
TEXAS SERIAL NO.
6/1/2018
DATE

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Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
RUNOFF COMPUTATIONS
I-45 SOUTH

SHEET 1 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN
PROJECT NAME: 1-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE CONFIGURATION DATA

I-45 SOUTH SYSTEM											
ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
A1	A1	A-OUT	33	Box	1	7	8	0.012	0.04	25.25	25.24
A2	A2	A1	250	Box	1	7	8	0.012	0.04	25.36	25.25
A3	A3	A2	410	Box	1	7	8	0.012	0.04	25.52	25.36
A4	A4	A3	345	Box	1	7	8	0.012	0.04	25.66	25.52
A5	A5	A4	454	Box	1	7	7	0.012	0.04	25.85	25.66
A6	A6	A5	479	Box	1	7	7	0.012	0.06	26.14	25.85
A7	A7	A6	318	Box	1	6	7	0.012	0.49	27.76	26.19
A7A	A7A	A11	320	Circular	1	3	n/a	0.012	0.15	31.75	31.26
A8	A8	A7	318	Box	1	6	7	0.012	0.40	29.03	27.76
A9	A9	A8	364	Box	1	5	7	0.012	0.17	29.65	29.03
MH-A10	MH-A10	A10	327	Box	1	5	7	0.012	0.16	30.70	30.18
A10A	A10A	MH-A10	335	Circular	1	3	n/a	0.012	0.10	33.04	32.70
A10	A10	A9	314	Box	1	5	7	0.012	0.17	30.18	29.65
A10B	A10B	MH-A10	364	Circular	1	3.5	n/a	0.012	0.22	33.00	32.20
A10C	A10C	A10B	288	Circular	1	3	n/a	0.012	0.32	34.42	33.50
A11	A11	A12	330	Circular	1	3.5	n/a	0.012	0.16	30.76	30.22
A12	A12	A13	152	Circular	1	3.5	n/a	0.012	0.21	30.22	29.89
A13	A13	A5	362	Box	1	4	4	0.012	0.15	29.39	28.85
A14	A14	A13	542	Circular	1	3.5	n/a	0.012	0.15	30.70	29.89
A15	A15	A14	300	Circular	1	3.5	n/a	0.012	0.15	31.15	30.70
A16	A16	A15	314	Circular	1	3	n/a	0.012	0.15	32.12	31.65
A17	A17	A16	263	Circular	1	2	n/a	0.012	0.15	33.51	33.12

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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
I-45 SOUTH

SHEET 2 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN
PROJECT NAME: 1-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 2 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE HYDRAULIC COMPUTATIONS

I-45 SOUTH SYSTEM										
ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM		ACTUAL	
							VELOCITY (FT/S)	DEPTH (FT)	VELOCITY (FT/S)	DEPTH (FT)
A1	A1	A-OUT	32.27	32.24	298.7	255.4	5.4	7.0	5.3	7.0
A2	A2	A1	32.47	32.27	294.2	266.0	5.3	6.9	5.3	7.0
A3	A3	A2	32.78	32.47	290.1	251.3	5.2	7.0	5.2	7.0
A4	A4	A3	33.03	32.78	278.7	256.0	5.0	6.9	5.0	7.0
A5	A5	A4	33.45	33.03	268.8	214.8	5.5	7.0	5.5	7.0
A6	A6	A5	33.69	33.45	194.7	258.4	5.4	5.2	4.0	7.0
A7	A7	A6	33.88	33.69	173.2	608.7	10.8	2.3	4.1	6.0
A7A	A7A	A11	34.92	34.46	27.0	30.3	4.5	2.4	3.8	3.0
A8	A8	A7	33.90	33.88	162.1	548.2	9.8	2.4	3.9	6.0
A9	A9	A8	33.95	33.90	89.9	284.3	6.2	2.1	2.6	4.9
MH-A10	MH-A10	A10	34.01	33.98	54.2	274.8	5.0	1.6	2.0	3.8
A10A	A10A	MH-A10	35.22	34.18	21.1	24.6	3.7	2.3	6.1	1.5
A10	A10	A9	33.98	33.95	70.7	283.1	5.7	1.8	2.4	4.3
A10B	A10B	MH-A10	35.24	34.11	37.9	54.7	5.8	2.3	7.1	1.9
A10C	A10C	A10B	37.24	35.34	32.1	43.7	6.3	2.0	7.1	1.8
A11	A11	A12	34.46	34.18	31.5	47.2	5.1	2.2	3.3	3.5
A12	A12	A13	34.18	33.99	38.9	54.1	5.8	2.3	4.0	3.5
A13	A13	A5	33.99	33.45	75.7	91.1	5.5	3.5	4.7	4.0
A14	A14	A13	34.59	33.99	36.4	45.2	5.0	2.5	3.8	3.5
A15	A15	A14	34.83	34.59	30.6	45.1	4.7	2.3	3.2	3.5
A16	A16	A15	35.16	34.83	23.2	29.9	4.4	2.1	3.3	3.0
A17	A17	A16	35.21	35.16	3.6	10.1	2.8	0.9	1.2	2.0

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CURTIS W. WHITE
113382
TEXAS SERIAL NO.
6/1/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

CivilTech Engineering Inc.
11821 Telge Road
Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

Texas Department of Transportation
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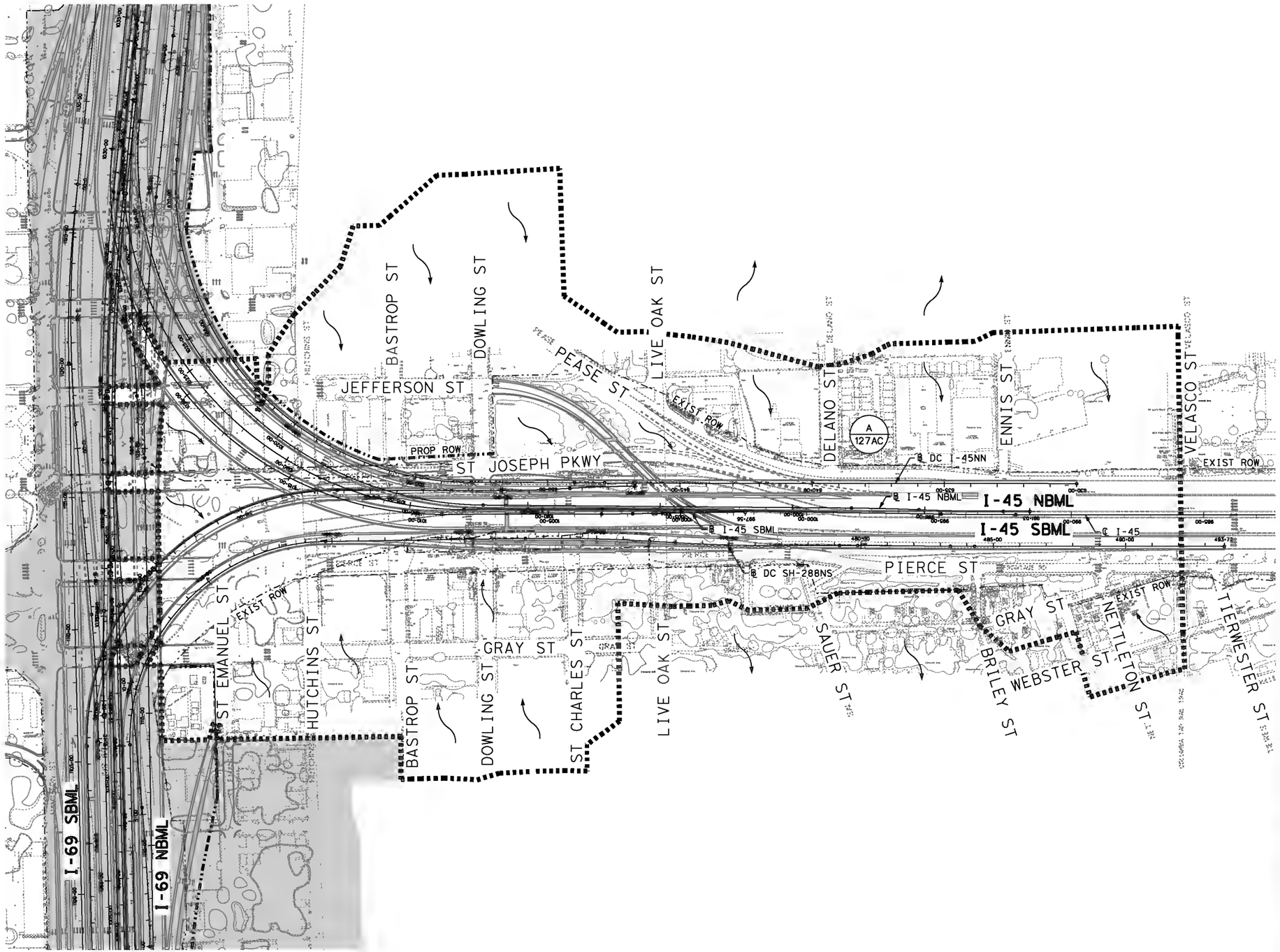
NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
I-45 SOUTH

SHEET 3 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

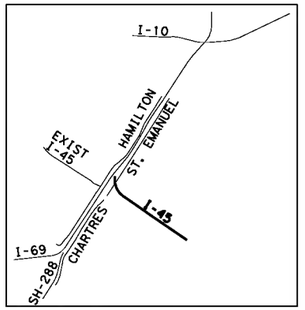


LEGEND

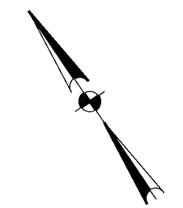
DIRECTION OF FLOW

OVERALL DRAINAGE BOUNDARY

SYSTEM ID — X•• (SUB AREA ID) / XX (ACREAGE)



VICINITY MAP



0 200' 400'

SCALE: 1" = 400'

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CURTIS W. WHITE

113382

TEXAS SERIAL NO.

6/15/2018

DATE

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CivilTech Engineering Inc.
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Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

Texas Department of Transportation

NHHIP SEGMENT 3B
I-45 SOUTH OVERALL DRAINAGE AREA MAP

SHEET 1 OF 1

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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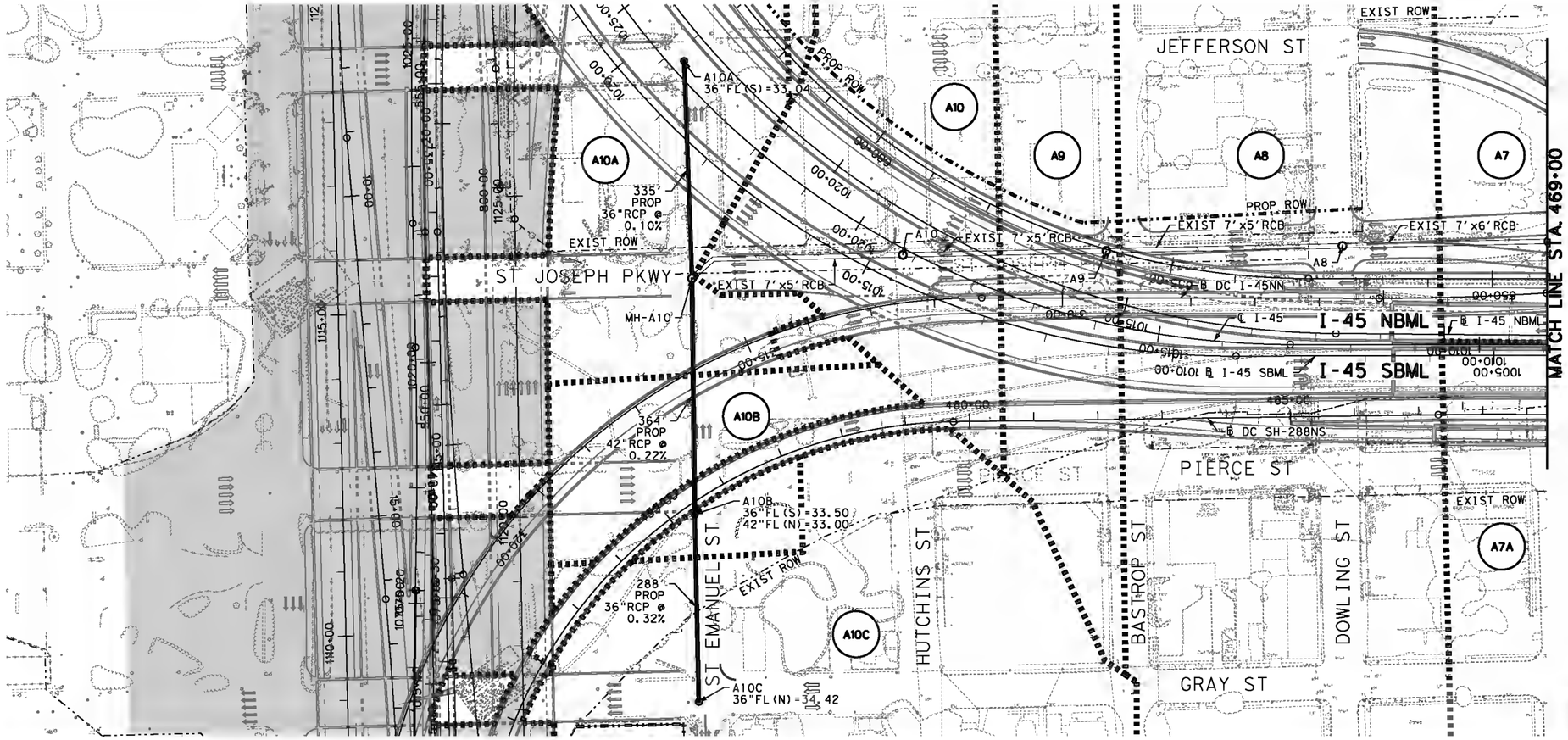


LEGEND

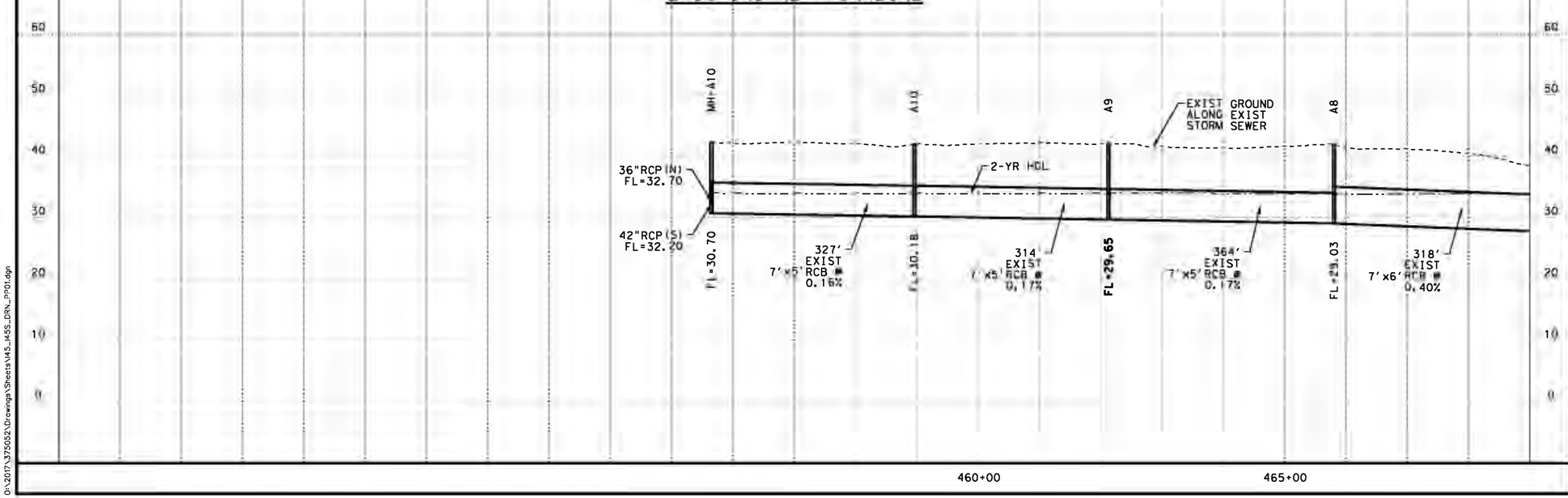
- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACTS AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.
3. RUNOFF FROM DIRECT CONNECTORS ACCOMMODATED FOR IN MAIN TRUNK LINE SYSTEMS.

0 100' 200'
SCALE: 1" = 200'H
1" = 20' V

EXISTING NB TRUNKLINE



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(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

Texas Department of Transportation

NHHIP SEGMENT 3B
I-45 SOUTH STORM SEWER PLAN AND PROFILE

BEGIN TO STA 469+00
℄ DC288NS301 SHEET 1 OF 2

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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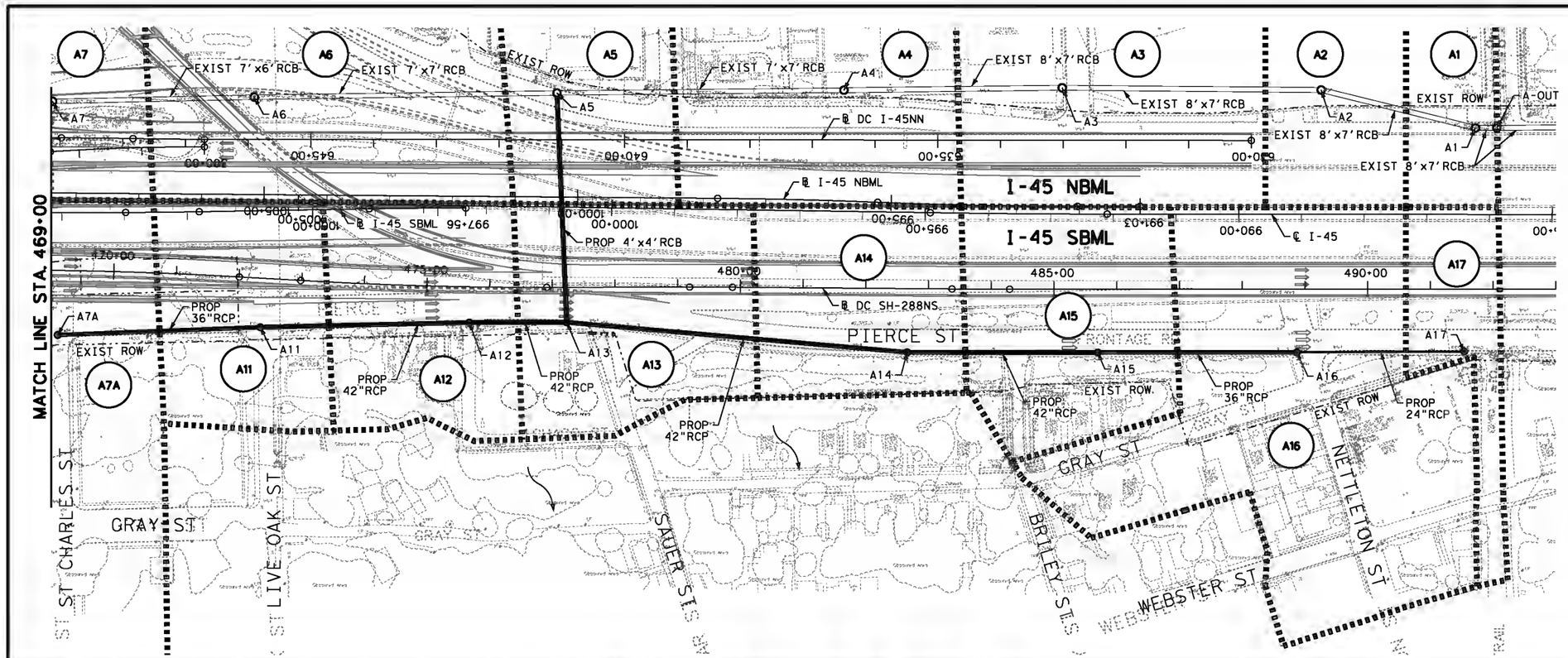

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

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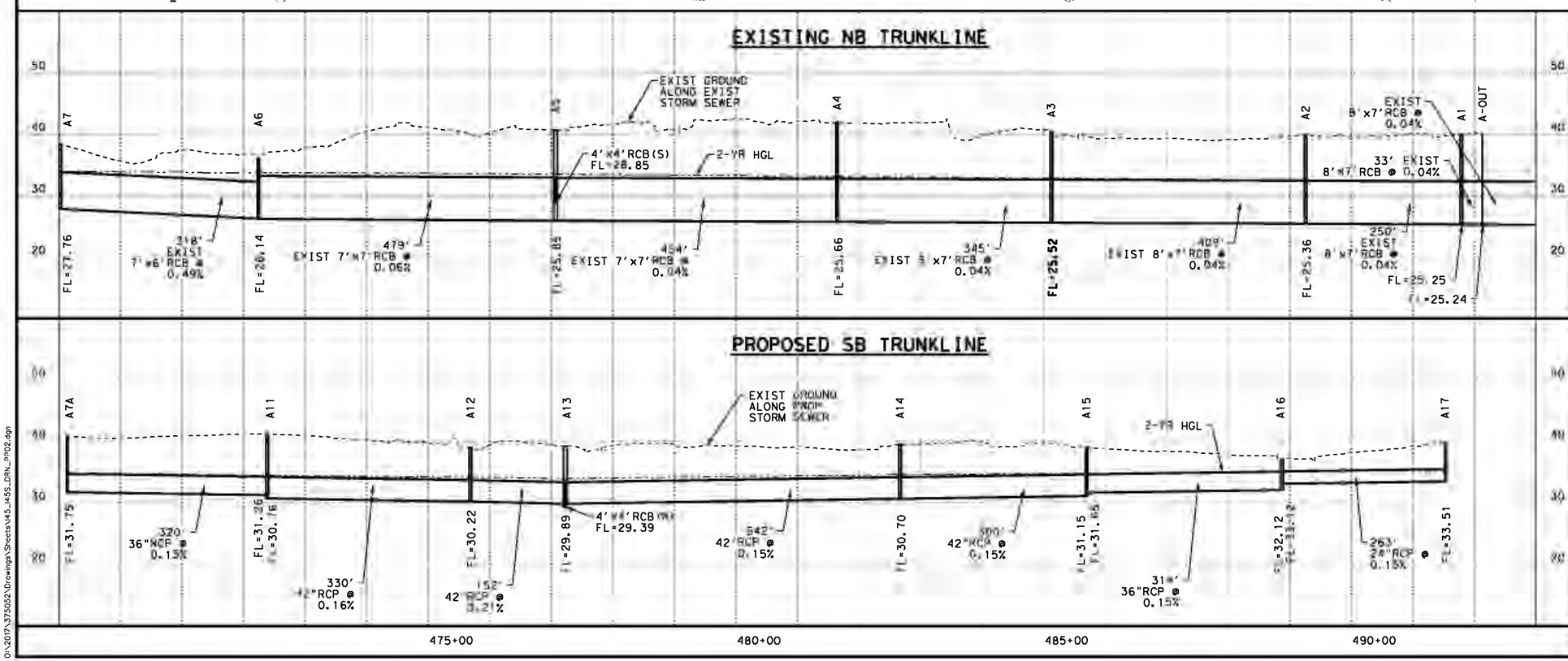
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.
3. RUNOFF FROM DIRECT CONNECTORS ACCOMMODATED FOR IN MAIN TRUNK LINE SYSTEMS.



0 100' 200'
SCALE: 1" = 200'H
1" = 20'V

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6/15/2018
DATE

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Cypress, Texas 77429
(281)304-0200 Fax:(281)304-0210
Firm Registration No. F-382

Texas Department of Transportation

NHHIP SEGMENT 3B
I-45 SOUTH STORM SEWER PLAN AND PROFILE
STA 469+00 TO STA 493+00
℄ DC288NS301 SHEET 2 OF 2

FEDERAL AID PROJ. NO.	CONTRACT NO.		
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 2 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

RUNNOFF COMPUTATIONS FOR DESIGN FREQUENCY

SH-288 SBML SYSTEM						
ID	RUNOFF C	DRAINAGE AREA (ACRES)	TIME OF CONC. (MIN)	TIME USED (MIN)	INTENSITY (IN/HR)	DISCHARGE (CFS)
OS-8	0.74	1.44	5.00	10.00	5.47	5.8
OS-7	0.79	0.66	3.00	10.00	5.47	2.8
OS-6	0.63	1.66	6.00	10.00	5.47	5.7
OS-5	0.58	1.89	6.00	10.00	5.47	6.0
OS-4	0.8	1.14	4.00	10.00	5.47	5.0
OS-3	0.74	0.9	5.00	10.00	5.47	3.7
OS-2	0.58	0.93	4.00	10.00	5.47	3.0
OS-9	0.68	2.95	9.00	10.00	5.47	10.9
OS-1	0.67	0.88	5.00	10.00	5.47	3.2

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PATRICK W. PHILLIPS
92917
TEXAS SERIAL NO.
6/18/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

OMEGA ENGINEERS, INC.
16360 PARK TEN PLACE, Ste. #325
HOUSTON TEXAS, 77084
OMEGAENGINEERS.COM
TX PE Firm Reg. No. F-2147
P:281 647 9182 F:281 847 9184

Texas Department of Transportation
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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
SH-288 SBML

SHEET 1 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE CONFIGURATION DATA

SH-288 SBML SYSTEM											
ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
OS78	OS78	C-OUT	42	Box	1	3.5	4.15	0.013	0.23	30.95	30.86
OS-8	OS-8	OS78	50	Circular	1	2	n/a	0.013	0.51	31.20	30.95
OS206	OS206	OS78	125	Box	1	3.5	4.15	0.013	0.17	31.18	30.96
OS342	OS342	OS206	131	Box	1	3.5	4.15	0.013	0.24	31.50	31.19
OS-7	OS-7	OS342	58	Circular	1	2	n/a	0.013	0.51	31.82	31.52
OS402	OS402	OS342	56	Box	1	3.5	4.15	0.013	0.23	31.65	31.52
OS446	OS446	OS402	41	Box	1	3.5	4.15	0.013	0.09	31.70	31.67
OS-6	OS-6	OS446	61	Circular	1	2	n/a	0.013	0.5	32.01	31.71
OS572	OS572	OS446	122	Box	1	3.5	4.15	0.013	0.07	31.80	31.71
OS776	OS776	OS572	200	Box	1	3.5	4.15	0.013	0.06	31.87	31.76
OS-5	OS-5	OS776	50	Circular	1	2	n/a	0.013	0.5	32.14	31.89
OS882	OS882	OS776	102	Box	1	3.5	4.15	0.013	0.22	32.06	31.84
OS986	OS986	OS882	100	Circular	1	3.5	n/a	0.013	0.19	32.27	32.08
OS1075	OS1075	OS986	85	Box	1	3.5	4.15	0.013	0.2	32.46	32.29
OS-4	OS-4	OS1075	39	Circular	1	2	n/a	0.013	0.5	32.65	32.46
OS1207	OS1207	OS1075	130	Circular	1	3.5	n/a	0.013	0.21	32.73	32.46
OS1275	OS1275	OS1207	62	Circular	1	3	n/a	0.013	0.18	33.15	33.04
OS-3	OS-3	OS1275	13	Circular	1	3	n/a	0.013	0.5	33.25	33.19
OS1407	OS1407	OS1275	127	Circular	1	3	n/a	0.013	0.18	33.38	33.15
OS1568	OS1568	OS1407	157	Circular	1	3	n/a	0.013	0.17	33.66	33.40
OS1538	OS1538	OS1568	105	Circular	1	2	n/a	0.013	0.5	34.23	33.70
OS1701	OS1701	OS1568	130	Circular	1	3	n/a	0.013	0.09	33.78	33.66
OS-2	OS-2	OS1701	43	Circular	1	2	n/a	0.013	0.5	34.08	33.87
OS1791	OS1791	OS1701	85	Circular	1	3	n/a	0.013	0.73	34.44	33.82
OS-9	OS-9	OS1791	251	Circular	1	2	n/a	0.013	0.5	35.88	34.63
OS1924	OS1924	OS1791	130	Circular	1	2.5	n/a	0.013	0.71	35.40	34.48
OS-1	OS-1	OS1924	36	Circular	1	2	n/a	0.013	0.68	35.69	35.44

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PATRICK W. PHILLIPS
92917
TEXAS SERIAL NO.
6/18/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

OMEGA ENGINEERS, INC.
16360 PARK TEN PLACE, Ste. #325
HOUSTON TEXAS, 77084
OMEGAENGINEERS.COM
TX PE Firm Reg. No. F-2147
P:281 647 9182 F:281 847 9184

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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
SH-288 SBML

SHEET 2 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 2 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE HYDRAULIC COMPUTATIONS

SH-288 SBML SYSTEM										
							UNIFORM		ACTUAL	
ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	VELOCITY (FT/S)	DEPTH (FT)	VELOCITY (FT/S)	DEPTH (FT)
OS78	OS78	C-OUT	37.60	37.59	24.6	101.4	5.0	1.2	1.7	3.5
OS-8	OS-8	OS78	37.62	37.6	4.8	18.8	4.8	0.7	1.5	2.0
OS206	OS206	OS78	37.62	37.6	22.1	88.4	4.3	1.3	1.5	3.5
OS342	OS342	OS206	37.64	37.62	22.1	104.1	4.9	1.1	1.5	3.5
OS-7	OS-7	OS342	37.66	37.64	4.2	18.8	4.6	0.7	1.3	2.0
OS402	OS402	OS342	37.65	37.64	18.9	102.5	4.6	1.0	1.3	3.5
OS446	OS446	OS402	37.66	37.65	18.9	63.0	3.2	1.4	1.3	3.5
OS-6	OS-6	OS446	37.68	37.66	5.1	18.6	4.8	0.8	1.6	2.0
OS572	OS572	OS446	37.67	37.66	16.7	57.5	2.9	1.4	1.2	3.5
OS776	OS776	OS572	37.69	37.67	16.7	49.8	2.7	1.5	1.2	3.5
OS-5	OS-5	OS776	37.71	37.69	4.7	18.6	4.7	0.7	1.5	2.0
OS882	OS882	OS776	37.69	37.69	13.9	98.8	4.1	0.8	1.0	3.5
OS986	OS986	OS882	37.71	37.69	13.9	51.6	4.4	1.3	1.5	3.5
OS1075	OS1075	OS986	37.72	37.71	13.9	94.2	3.9	0.9	1.0	3.5
OS-4	OS-4	OS1075	37.73	37.72	3.6	18.6	4.4	0.6	1.2	2.0
OS1207	OS1207	OS1075	37.73	37.72	11.5	54.2	4.3	1.1	1.2	3.5
OS1275	OS1275	OS1207	37.75	37.73	11.5	32.8	4.0	1.3	1.6	3.0
OS-3	OS-3	OS1275	37.75	37.75	2.5	55.1	3.8	0.5	0.4	3.0
OS1407	OS1407	OS1275	37.78	37.75	10.1	32.9	3.9	1.2	1.4	3.0
OS1568	OS1568	OS1407	37.81	37.78	10.1	31.8	3.8	1.2	1.4	3.0
OS1538	OS1538	OS1568	37.81	37.81	1.0	18.6	3.0	0.3	0.3	2.0
OS1701	OS1701	OS1568	37.83	37.81	9.6	23.3	2.9	1.4	1.4	3.0
OS-2	OS-2	OS1701	37.84	37.83	2.1	18.6	3.7	0.5	0.7	2.0
OS1791	OS1791	OS1701	37.84	37.83	7.8	66.5	5.9	0.7	1.1	3.0
OS-9	OS-9	OS1791	37.97	37.84	5.6	18.6	4.9	0.8	1.8	2.0
OS1924	OS1924	OS1791	37.85	37.84	2.7	40.3	4.4	0.5	0.6	2.5
OS-1	OS-1	OS1924	37.85	37.85	2.7	21.8	4.5	0.5	0.9	2.0

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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
SH-288 SBML

SHEET 3 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 2 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

RUNOFF COMPUTATIONS FOR DESIGN FREQUENCY

SH-288 NBML SYSTEM						
ID	RUNOFF C	DRAINAGE AREA (ACRES)	TIME OF CONC. (MIN)	TIME USED (MIN)	INTENSITY (IN/HR)	DISCHARGE (CFS)
ON-73A	0.68	0.97	10.00	10.00	5.47	3.6
ON-76	0.74	0.93	4.00	10.00	5.47	3.7
ON-80B	0.64	1.49	10.00	10.00	5.47	5.2
ON-80A	0.63	1.07	4.00	10.00	5.47	3.7
ON-84B	0.57	1.59	3.00	10.00	5.47	4.9
ON-84A	0.64	1.21	4.00	10.00	5.47	4.2
ON-87	0.78	0.73	3.00	10.00	5.47	3.1
ON-90B	0.82	0.38	9.00	10.00	5.47	1.7
ON-90A	0.74	0.30	9.00	10.00	5.47	1.2
ON-92	0.54	0.22	3.00	10.00	5.47	0.7
ON-93	0.54	0.38	3.00	10.00	5.47	1.1
ON-96B	0.53	0.47	9.00	10.00	5.47	1.4
ON-97B	0.47	0.27	9.00	10.00	5.47	0.7
ON-97A	0.49	0.93	10.00	10.00	5.47	2.5
ON-100B	0.47	0.76	9.00	10.00	5.47	2.0

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PATRICK W. PHILLIPS
92917
TEXAS SERIAL NO.
6/18/2018
DATE

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OMEGA ENGINEERS, INC.
16360 PARK TEN PLACE, Ste. #325
HOUSTON TEXAS, 77084
OMEGAENGINEERS.COM
TX PE Firm Reg. No. F-2147
P:281 647 9182 F:281 847 9184

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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
SH-288 NBML

SHEET 1 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE CONFIGURATION DATA

SH-288 NBML SYSTEM											
ID	UPSTREAM ID	DOWNSTREAM ID	LENGTH (FT)	SHAPE	#	RISE (FT)	SPAN (FT)	N	SLOPE %	UPSTREAM INVERT (FT)	DOWNSTREAM INVERT (FT)
CL-73A	ON-73A	OUT-2	21	Circular	1	3.5	n/a	0.013	0.17	32.15	32.11
E-5	E-5	ON-73A	27	Circular	1	3.5	n/a	0.013	0.16	32.19	32.15
CL-76	ON-76	E-5	59	Circular	1	3.5	n/a	0.013	0.14	32.27	32.19
E-4	E-4	ON-76	54	Circular	1	3.5	n/a	0.013	0.13	32.34	32.27
CL-80B	ON-80B	E-4	39	Circular	1	3.5	n/a	0.013	0.13	32.39	32.34
E-3	E-3	ON-80B	125	Circular	1	3.5	n/a	0.013	0.13	32.55	32.39
CL-80A	ON-80A	E-3	47	Circular	1	3.5	n/a	0.013	0.17	32.63	32.55
E-2	E-2	ON-80A	125	Circular	1	3.5	n/a	0.013	0.18	32.87	32.64
CL-84B	ON-84B	E-2	6	Circular	1	3.5	n/a	0.013	0.17	32.86	32.85
CL-84A	ON-84A	ON-84B	139	Circular	1	3.0	n/a	0.013	0.27	33.23	32.86
CL-87	ON-87	ON-84A	149	Circular	1	3.0	n/a	0.013	0.28	33.64	33.23
CL-90B	ON-90B	ON-87	103	Circular	1	3.0	n/a	0.013	0.27	33.92	33.64
E-1	E-1	ON-90B	1	Circular	1	3.0	n/a	0.013	2.01	34.05	34.02
CL-90A	ON-90A	E-1	91	Circular	1	3.0	n/a	0.013	0.10	34.19	34.10
CL-92	ON-92	ON-90A	53	Circular	1	3.0	n/a	0.013	0.10	34.09	34.04
CL-93	ON-93	ON-92	91	Circular	1	3.0	n/a	0.013	0.10	34.18	34.09
CL-96B	ON-96B	ON-93	111	Circular	1	3.0	n/a	0.013	0.15	34.33	34.16
CL-97B	ON-97B	ON-96B	71	Circular	1	2.5	n/a	0.013	0.20	34.48	34.34
CL-97A	ON-97A	ON-97B	170	Circular	1	2.5	n/a	0.013	0.19	31.46	31.13
CL-100B	ON-100B	ON-97A	125	Circular	1	2.5	n/a	0.013	0.20	35.04	34.79

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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
SH-288 NBML

SHEET 2 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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GEOPAK 2013 DRAINAGE (STORM DRAIN DESIGN)
PROJECT NAME: I-45/I-69/SH-288
JOB NUMBER: 0500-03-601
PROJECT DESCRIPTION: STORM SEWER
DESIGN FREQUENCY: 2 YEARS
MEASUREMENT UNIT: ENGLISH
COUNTY: HARRIS

CONVEYANCE HYDRAULIC COMPUTATIONS

SH-288 NBML SYSTEM										
ID	UPSTREAM ID	DOWNSTREAM ID	UPSTREAM HGL (FT)	DOWNSTREAM HGL (FT)	DISCHARGE (CFS)	CAPACITY (CFS)	UNIFORM		ACTUAL	
							VELOCITY (FT/S)	DEPTH (FT)	VELOCITY (FT/S)	DEPTH (FT)
CL-73A	ON-73A	OUT-2	37.76	37.74	31.3	49.0	5.0	2.2	3.3	3.5
E-5	E-5	ON-73A	37.78	37.76	28.8	47.2	4.9	2.1	3.0	3.5
CL-76	ON-76	E-5	37.83	37.78	28.8	43.5	4.6	2.2	3.0	3.5
E-4	E-4	ON-76	37.86	37.83	26.1	41.7	4.5	2.1	2.7	3.5
CL-80B	ON-80B	E-4	37.89	37.86	26.1	42.7	4.5	2.1	2.7	3.5
E-3	E-3	ON-80B	37.94	37.89	22.4	41.6	4.1	2.0	2.3	3.5
CL-80A	ON-80A	E-3	37.97	37.94	22.4	48.2	4.7	1.8	2.3	3.5
E-2	E-2	ON-80A	38.01	37.97	19.7	50.4	4.6	1.6	2.1	3.5
CL-84B	ON-84B	E-2	38.01	38.01	19.7	47.7	4.4	1.6	2.1	3.5
CL-84A	ON-84A	ON-84B	38.08	38.01	15.8	40.2	5.1	1.4	2.2	3.0
CL-87	ON-87	ON-84A	38.13	38.08	12.4	40.8	4.8	1.2	1.8	3.0
CL-90B	ON-90B	ON-87	38.15	38.13	9.9	40.6	4.5	1.1	1.4	3.0
E-1	E-1	ON-90B	38.15	38.15	8.5	110.1	8.8	0.6	1.2	3.0
CL-90A	ON-90A	E-1	38.16	38.15	8.5	25.1	3.1	1.2	1.2	3.0
CL-92	ON-92	ON-90A	38.17	38.16	7.5	24.2	2.9	1.2	1.1	3.0
CL-93	ON-93	ON-92	38.18	38.17	7.1	24.6	2.9	1.1	1.0	3.0
CL-96B	ON-96B	ON-93	38.19	38.18	6.2	30.1	3.1	1.0	0.9	3.0
CL-97B	ON-97B	ON-96B	38.20	38.19	5.0	21.4	3.4	0.8	1.0	2.5
CL-97A	ON-97A	ON-97B	38.22	38.20	4.4	21.1	3.2	0.8	0.9	2.5
CL-100B	ON-100B	ON-97A	38.22	38.22	2.1	21.4	2.6	0.6	0.4	2.5

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92917
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NHHIP SEGMENT 3B
HYDRAULIC DATA SHEET
STORM SEWER COMPUTATIONS
SH-288 NBML

SHEET 3 OF 3

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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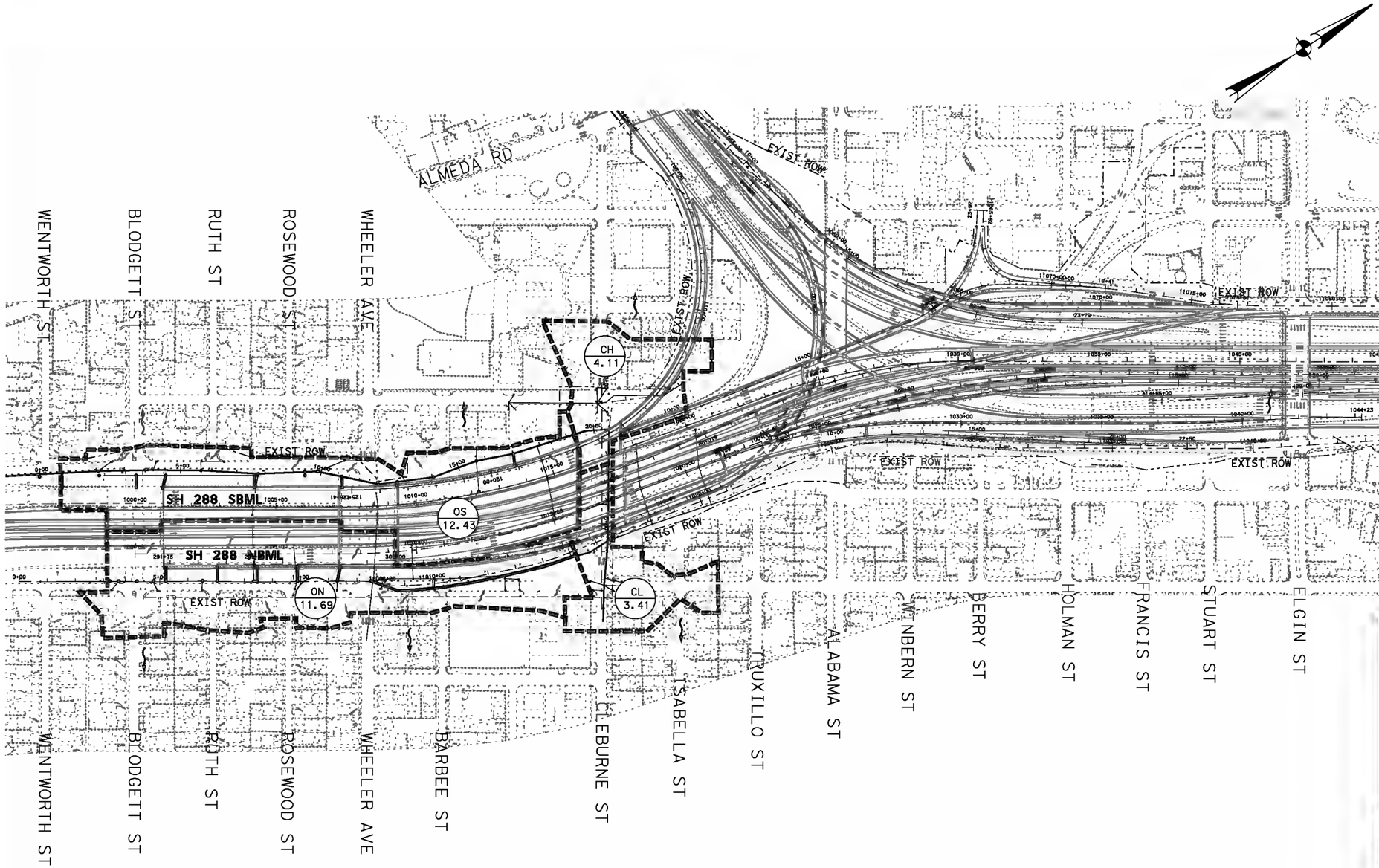
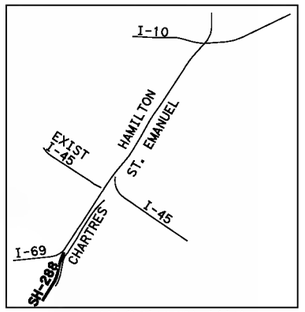


LEGEND

DIRECTION OF FLOW

OVERALL DRAINAGE BOUNDARY

SYSTEM ID — X## (SUB AREA ID) / XX (ACREAGE)



VICINITY MAP

NOTES:

AREA CL DRAINS TO COH STORM SEWER SYSTEM ON CLEBURNE ST.

AREA CH DRAINS TO COH STORM SEWER SYSTEM ON CHARTRES ST.

0 200′ 400′

SCALE: 1" = 400′

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NHHIP SEGMENT 3B
SH-288 SOUTH
OVERALL DRAINAGE
AREA MAP

SHEET 1 OF 1

CONTRACT NO.			
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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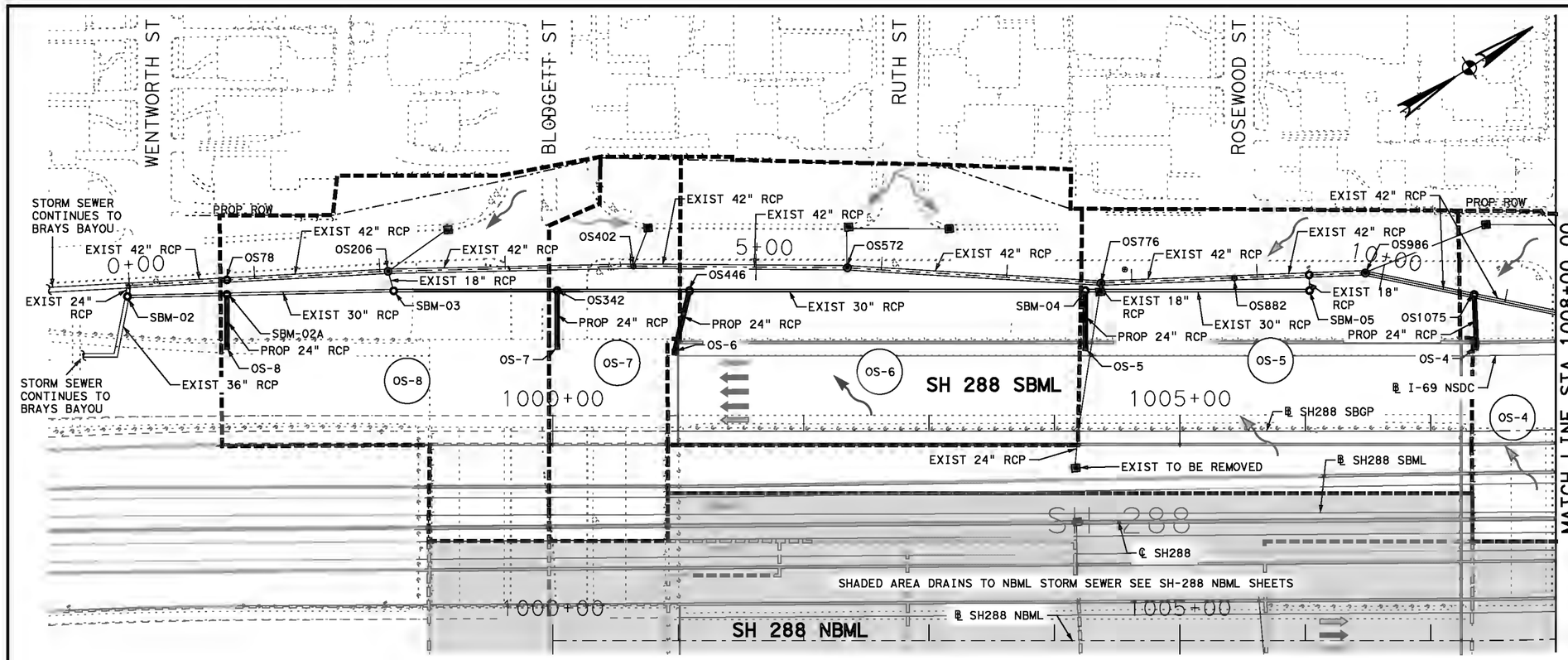
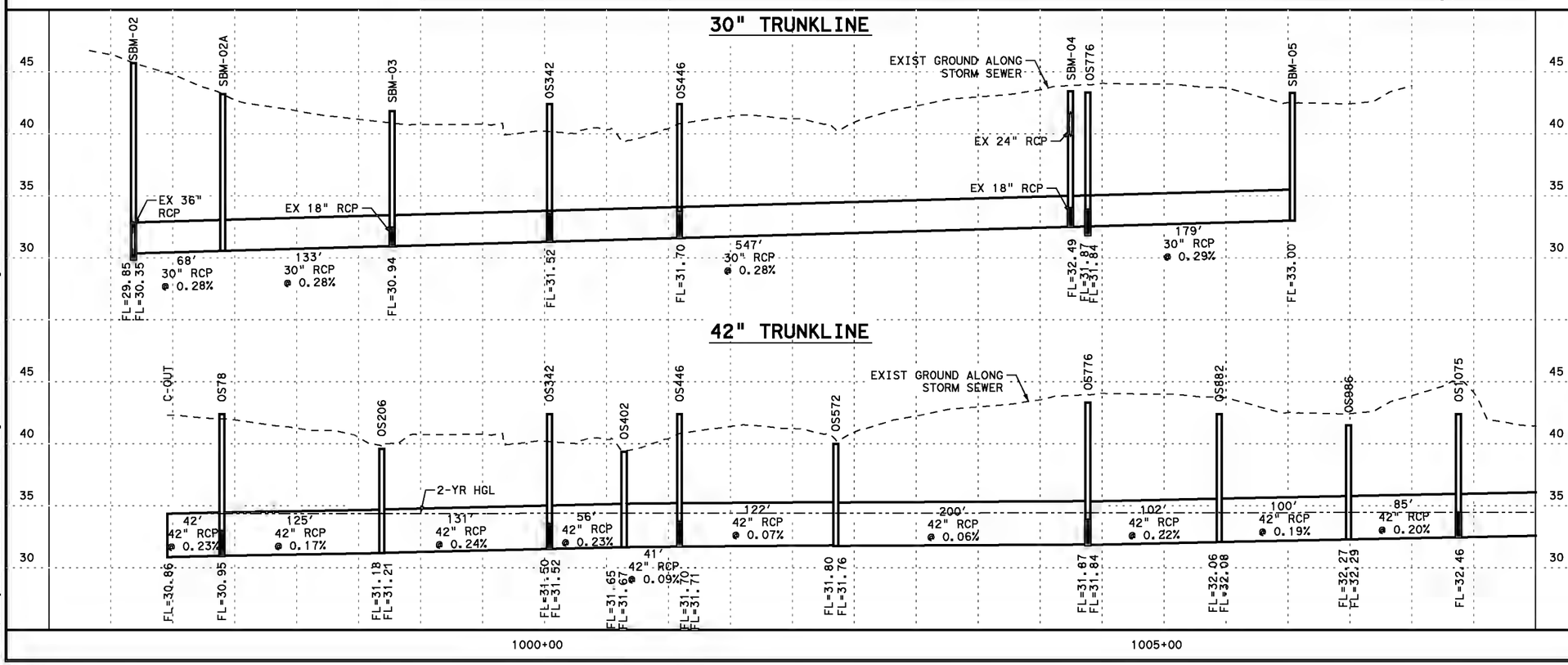


LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

NOTES:

1. THE PROJECT DRAINAGE RUNOFF IMPACT AND MITIGATION MEASURES WERE ANALYZED AND PRESENTED IN PROJECT DRAINAGE REPORT CSJ 0500-03-601.
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.



0 50' 100'
SCALE: 1" = 100'H
1" = 10' V

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NHHIP SEGMENT 3B
SH-288 SBML STORM SEWER PLAN AND PROFILE

STA 1000+00 TO STA 1008+00.00
℄ SH288 SBGP

SHEET 1 OF 2

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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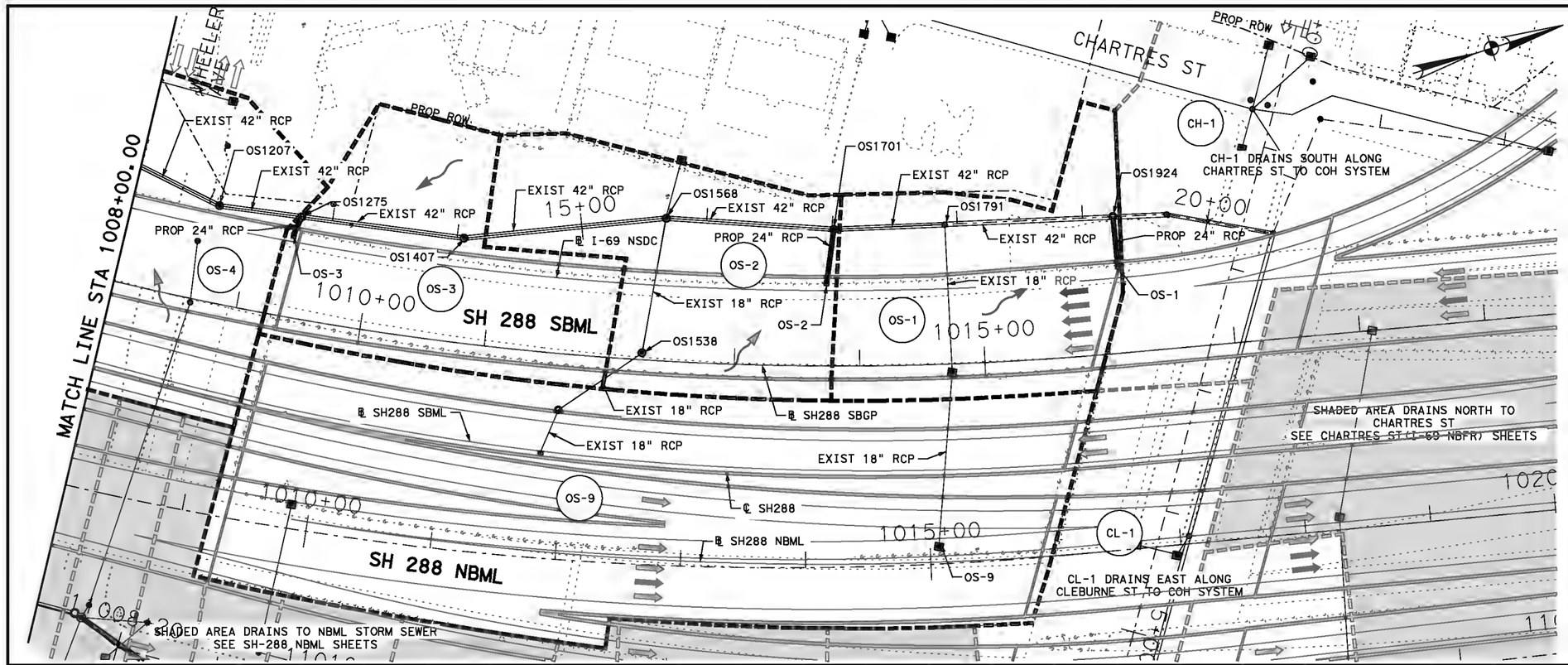

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
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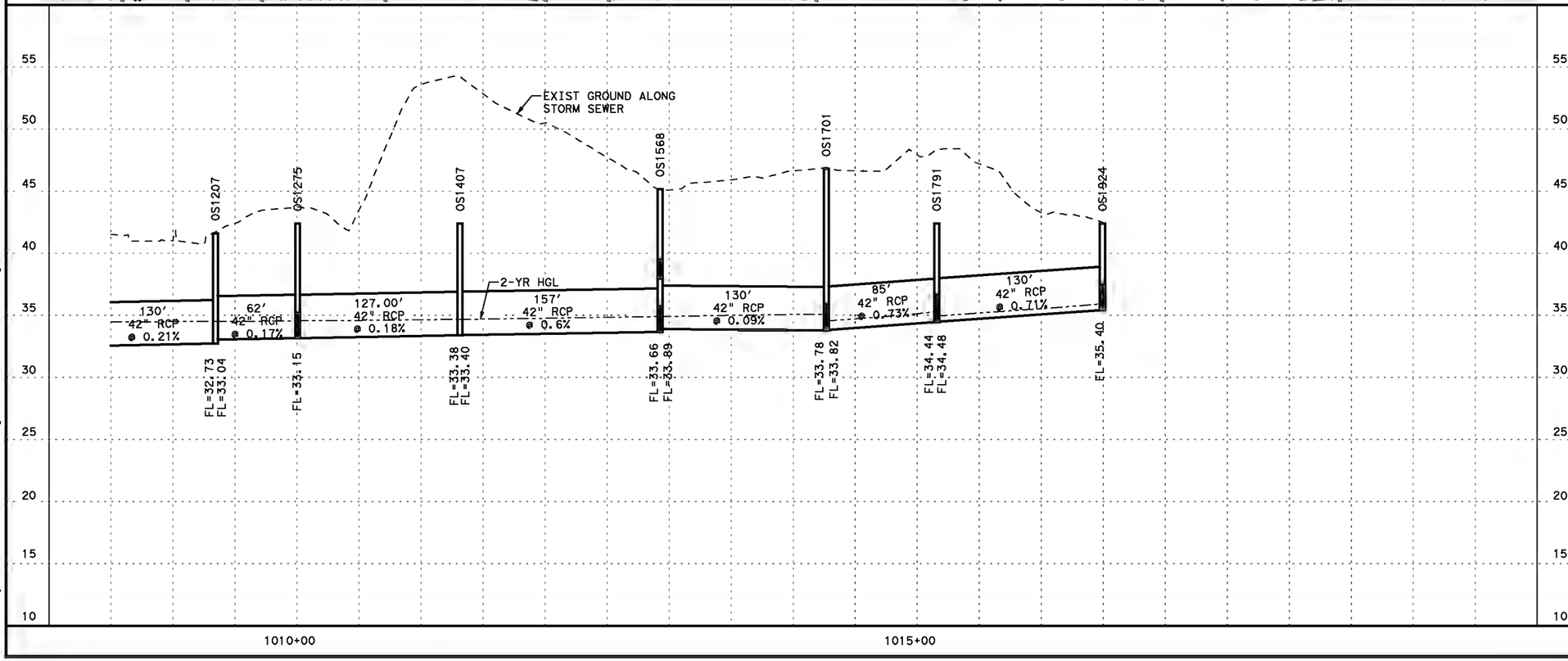
0 50' 100'
SCALE: 1" = 100' H
1" = 10' V



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NHHIP SEGMENT 3B
SH-288 SBML STORM SEWER PLAN AND PROFILE

STA 1008+00 TO STA 1016+50.00
℄ SH288 SBGP SHEET 2 OF 2

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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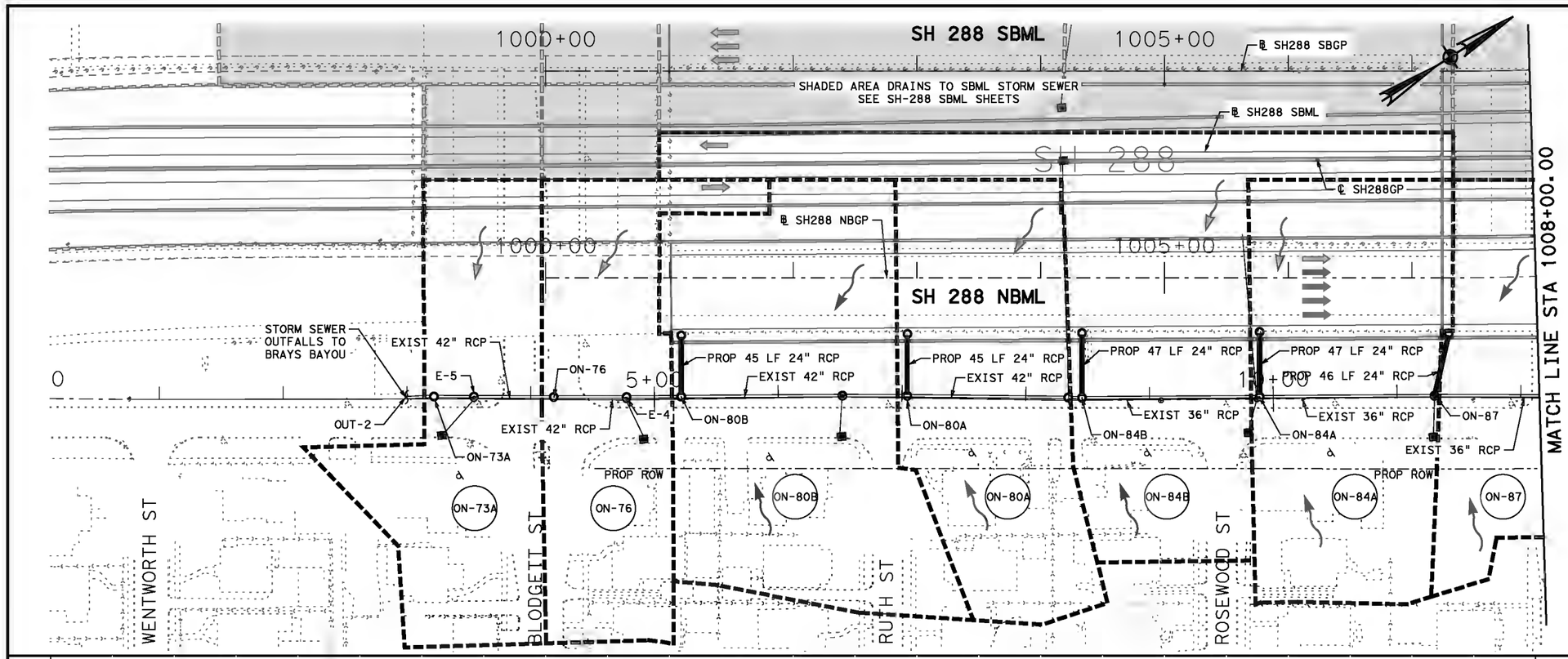

LEGEND

- DIRECTION OF FLOW
- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
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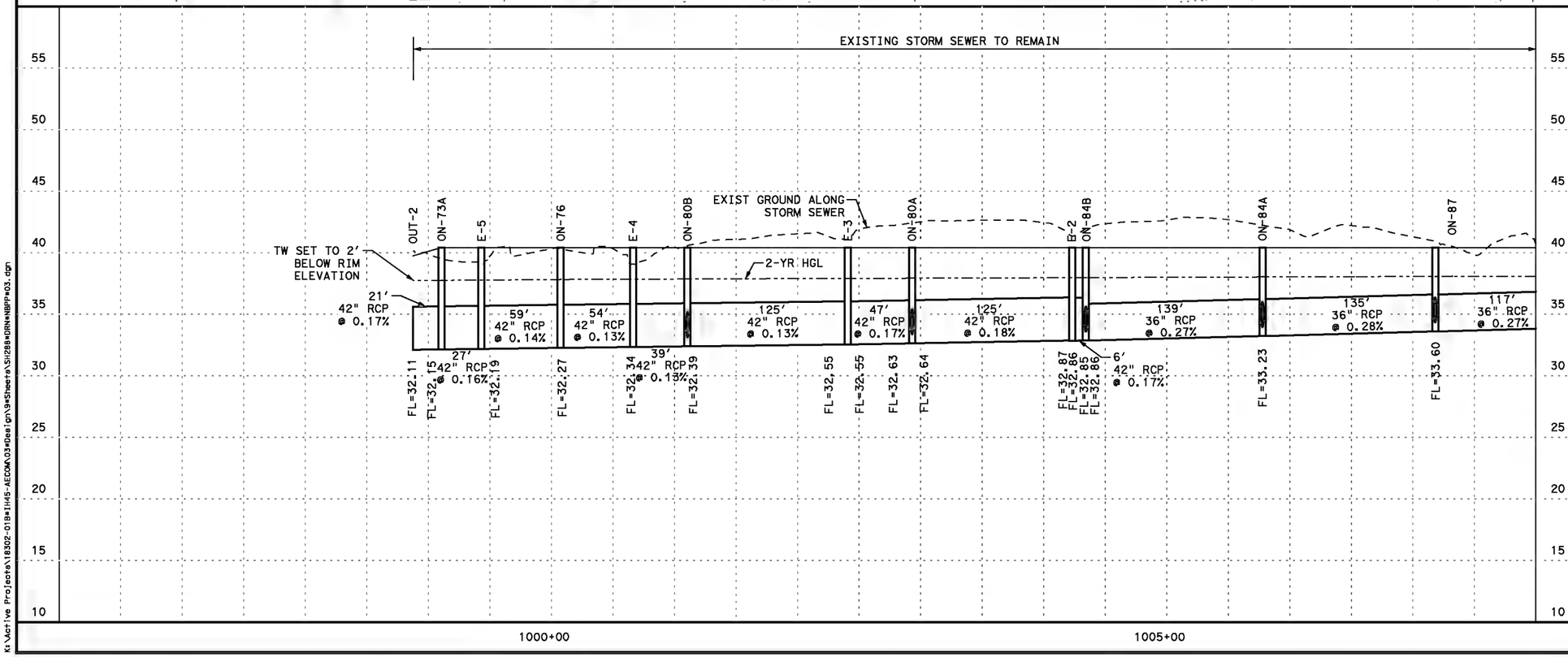

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SH-288 NBML STORM SEWER PLAN AND PROFILE

STA 1000+00 TO STA 1008+00.00
℄ SH288 NBML SHEET 1 OF 2

FED. RD. DIV. NO.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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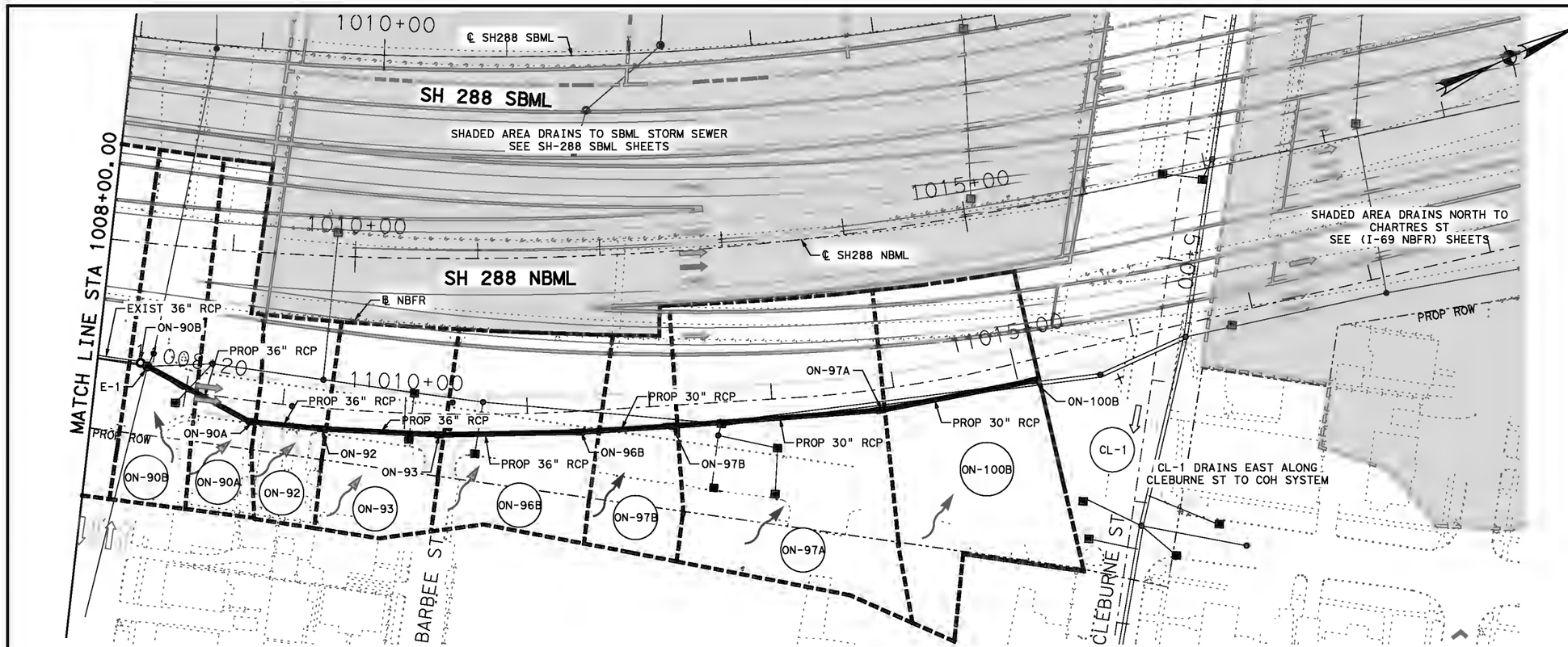

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- OR PROP MANHOLE
- PROP STORM SEWER
- DRAINAGE AREA BOUNDARY
- X## DRAINAGE AREA NAME
- HYDRAULIC GRADE LINE
- NATURAL GROUND

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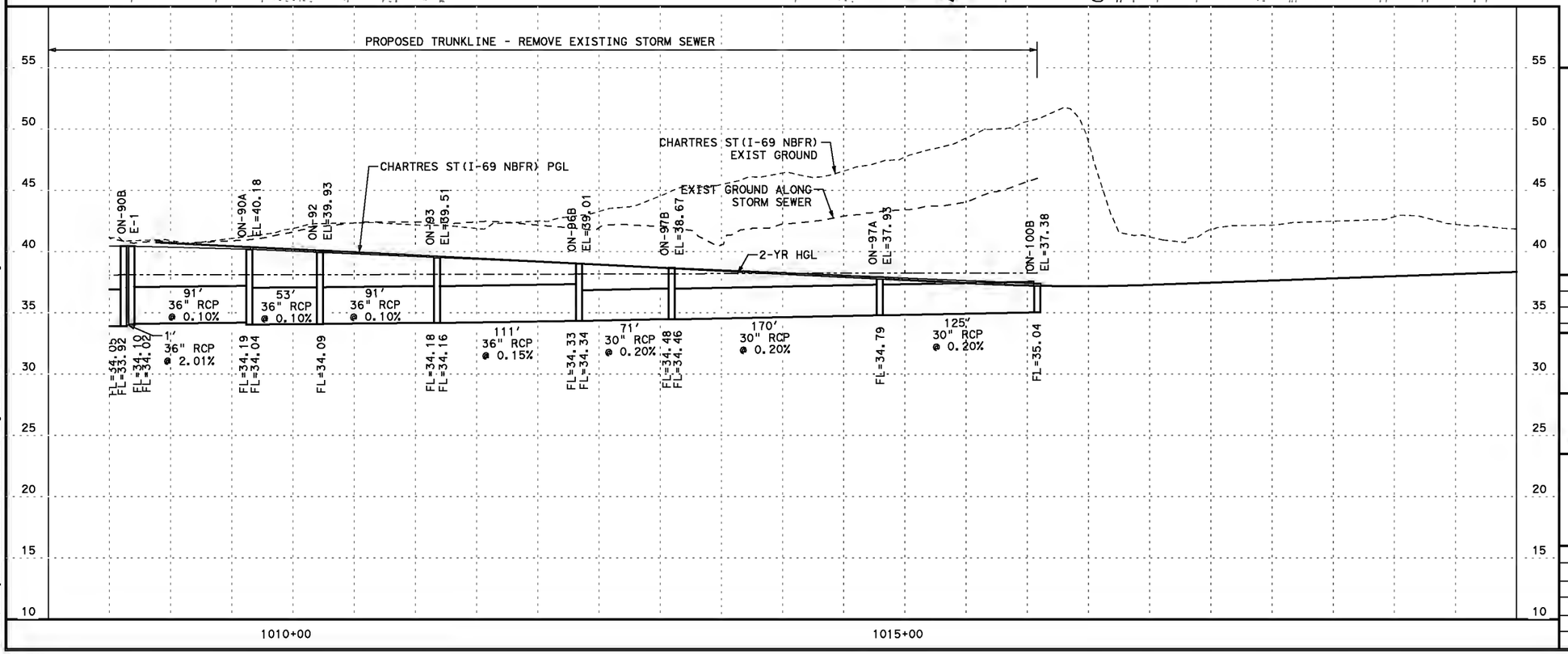
2. THE PROJECT RESULTS IN NO ADVERSE IMPACTS TO EXISTING CONDITIONS FOR STORM EVENTS UP TO AND INCLUDING THE 100-YR STORM EVENT.



0 50' 100'
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1" = 10' V

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NHHIP SEGMENT 3B
SH-288 NBML STORM SEWER
PLAN AND PROFILE

STA 1008+00 TO STA 1016+50.00
℄ SH288 NBML SHEET 2 OF 2

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STATE	DIST	COUNTY	
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CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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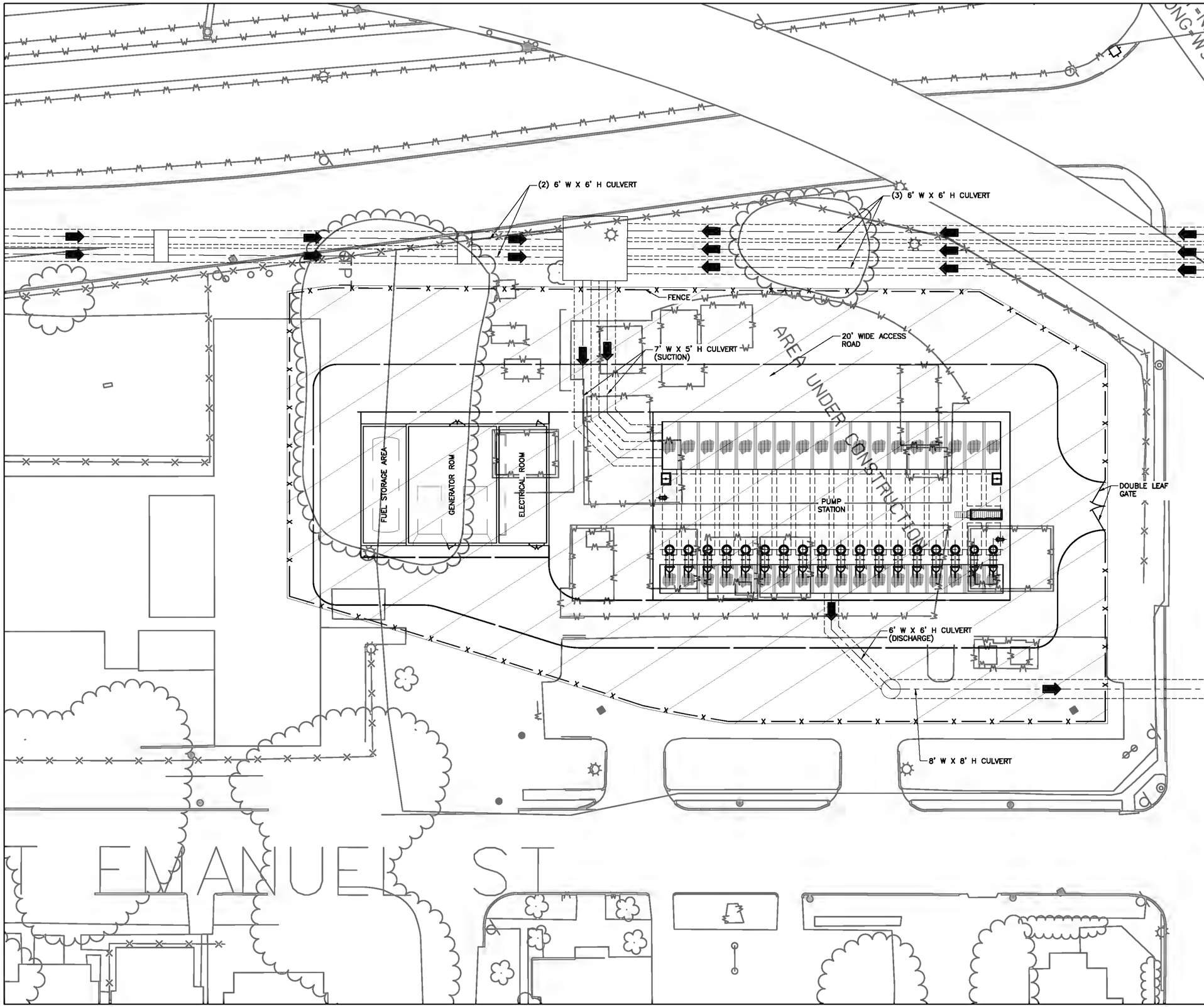

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51815
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JULY 2019
DATE

REV. NO.	DATE	DESCRIPTION	BY

AECOM
AECOM USA GROUP, INC.
9420 BUNKER FREEWAY, SUITE 100
HOUSTON, TEXAS 77054
WWW.AECOM.COM
TBPE REG. NO. F-3580

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I-45 STORMWATER PUMP STATION SITE PLAN

SHEET 1 OF 6

FED.RD. DIV.NO.	PROJECT NO	SHEET NO.
6		

STATE	DIST.	COUNTY	
TEXAS	HOU	HARRIS	
CONT.	SECT.	JOB	HIGHWAY
0900	00	601	I-45/I-69/SH-288

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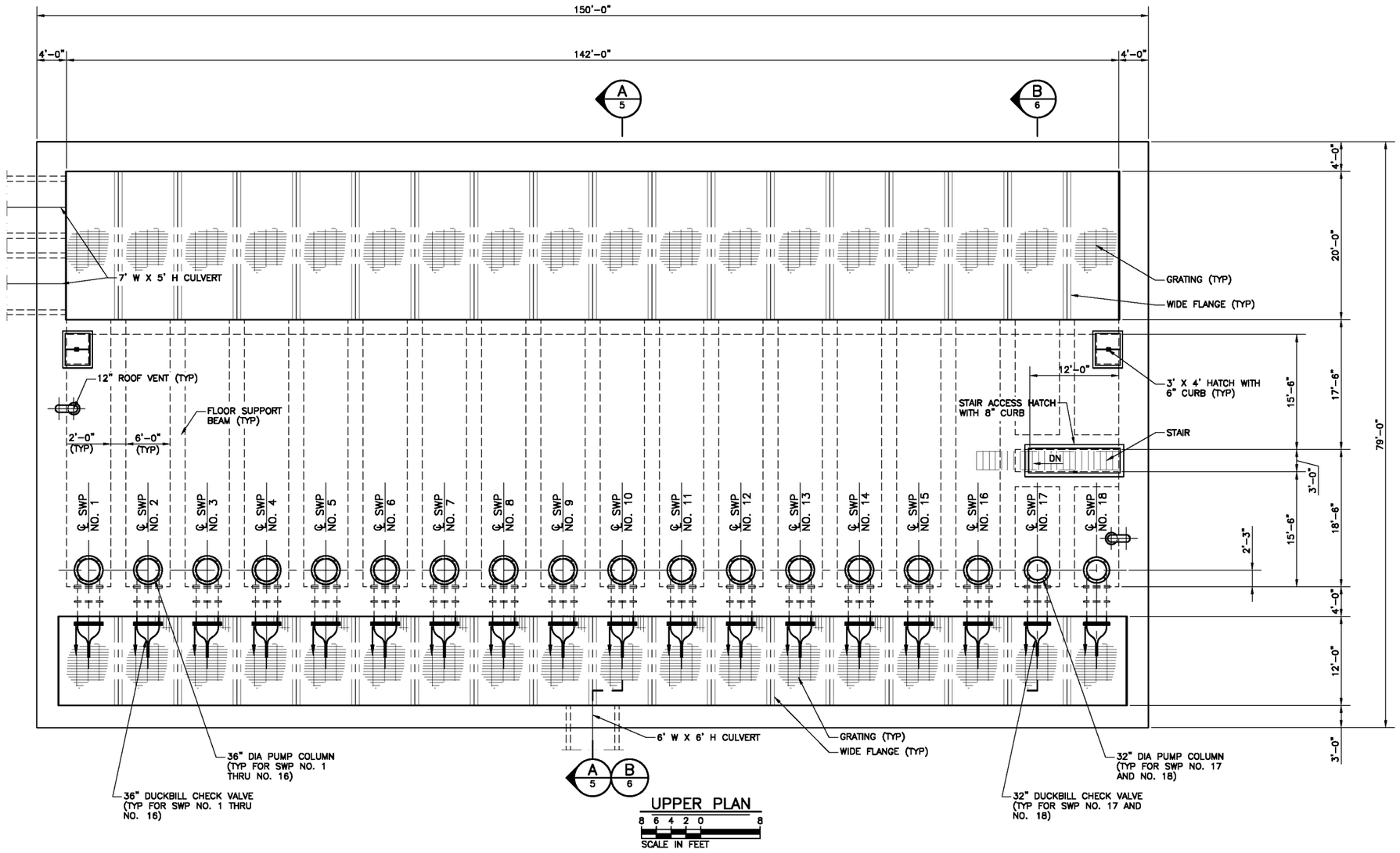

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RONALD M. CASS
51815
TEXAS SERIAL NO.
JULY 2018
DATE

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AECOM

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19219 KATY FREEWAY, SUITE 100
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I-45 STORMWATER PUMP STATION PLAN – 1 OF 3

SHEET 2 OF 6

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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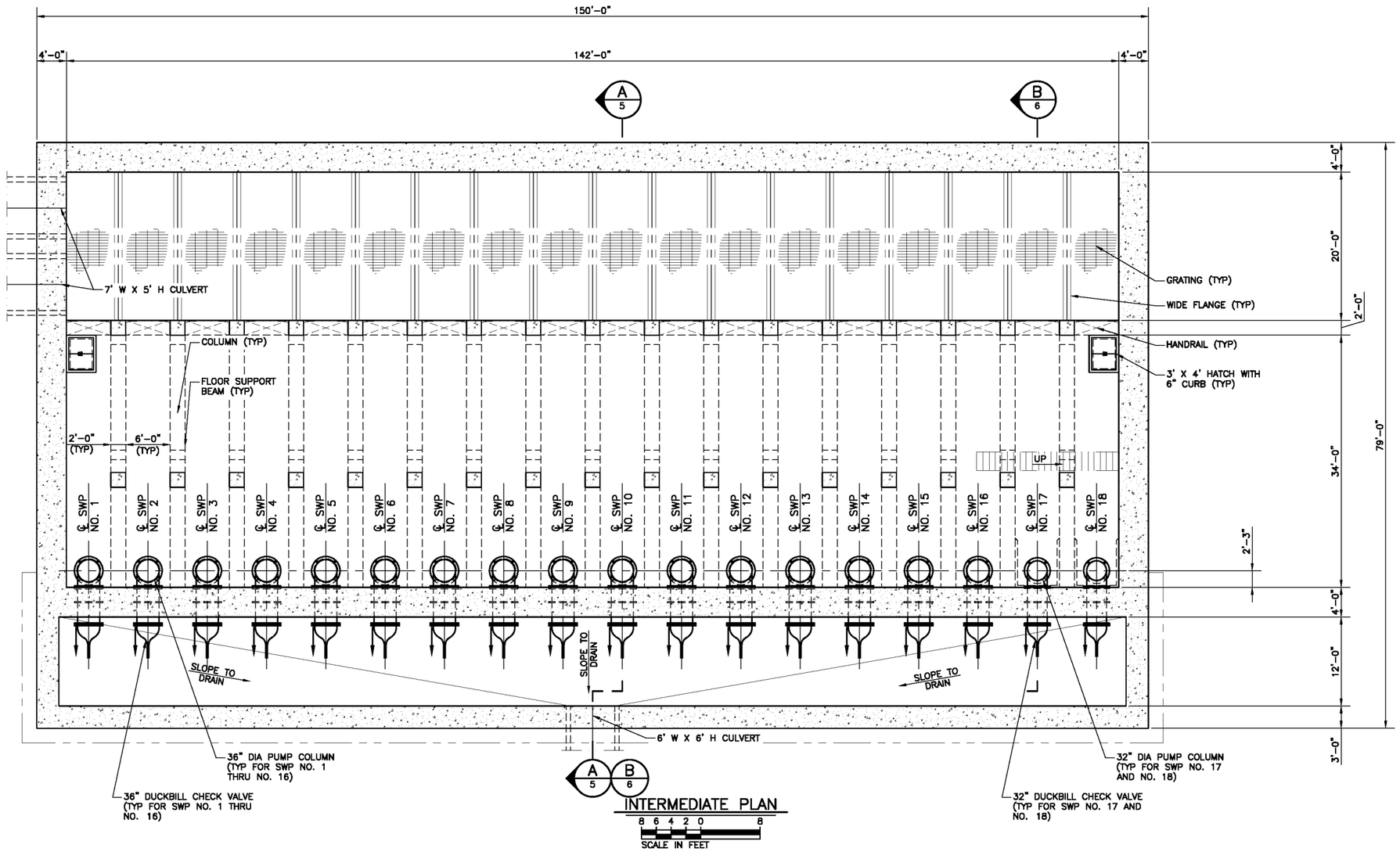

A 5 B 6

INTERMEDIATE PLAN

8 6 4 2 0 8

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I-45 STORMWATER PUMP STATION PLAN – 2 OF 3

SHEET 3 OF 6

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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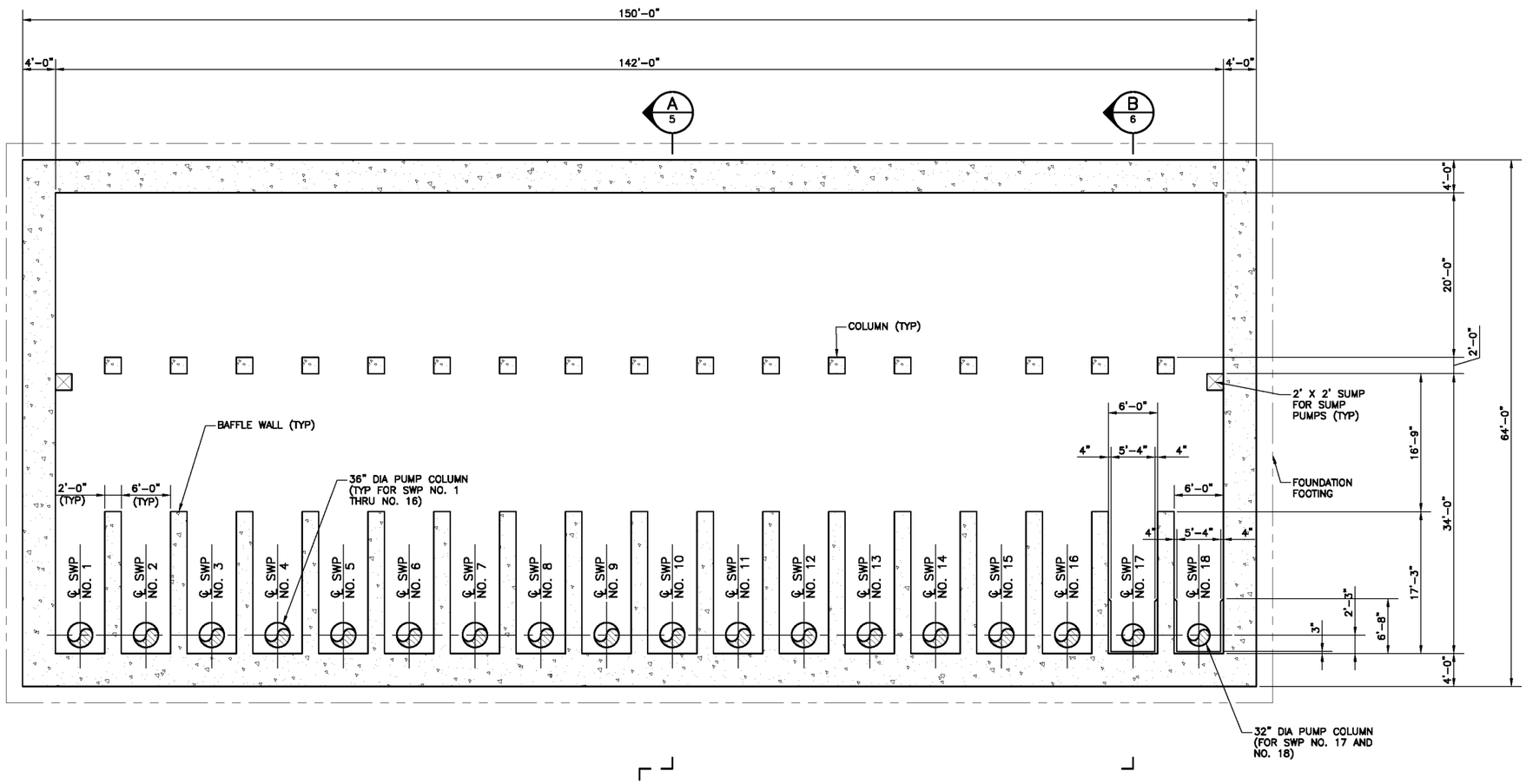

A 5 B 6

LOWER PLAN

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I-45 STORMWATER PUMP STATION PLAN – 3 OF 3

SHEET 4 OF 6

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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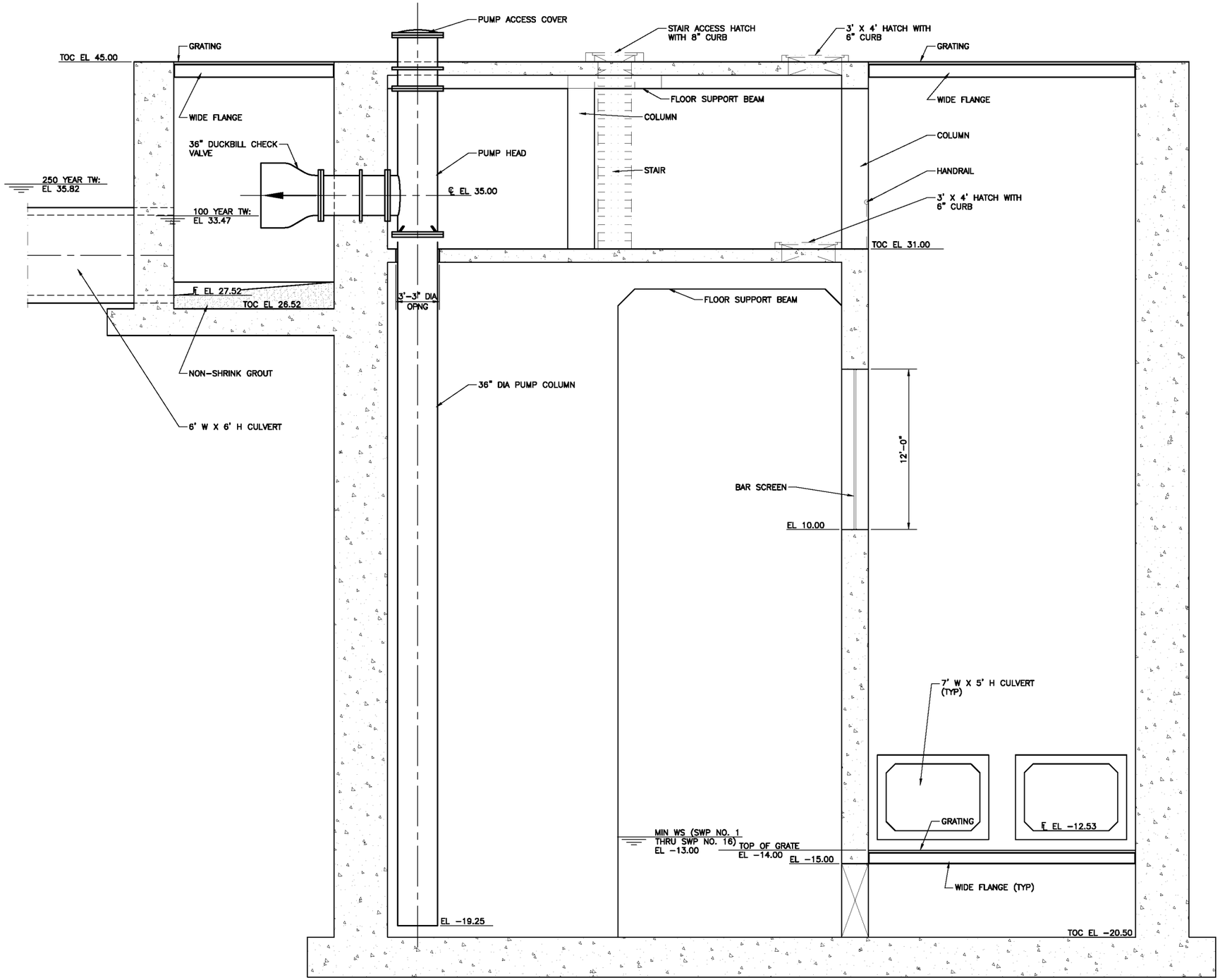

TYPICAL FOR SWP NO. 1 THRU NO. 16

SECTION A

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JULY 2018

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I-45 STORMWATER PUMP STATION SECTION - 1 OF 2

SHEET 5 OF 6

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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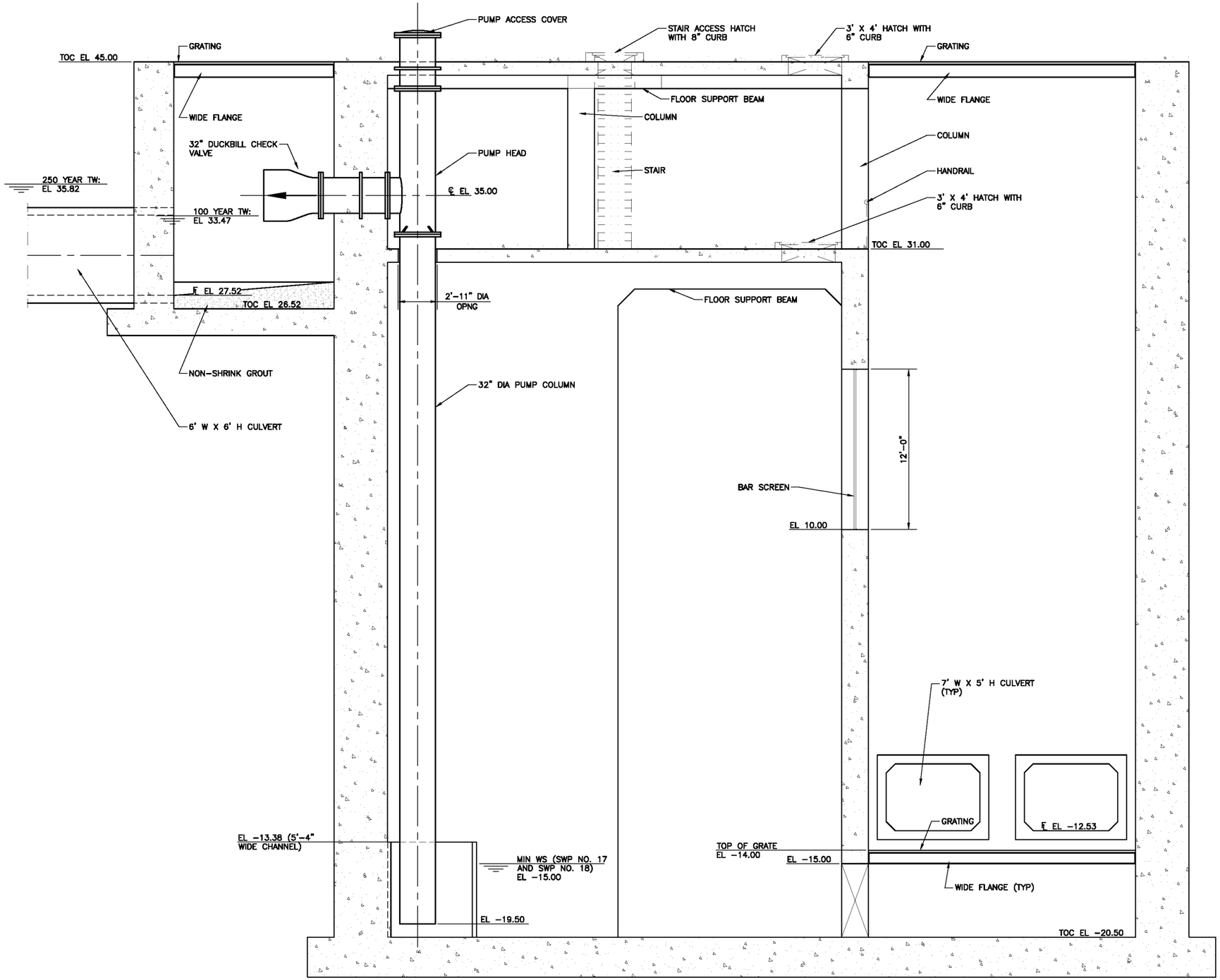

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I-45 STORMWATER PUMP STATION
SECTION – 2 OF 2

SHEET 6 OF 6

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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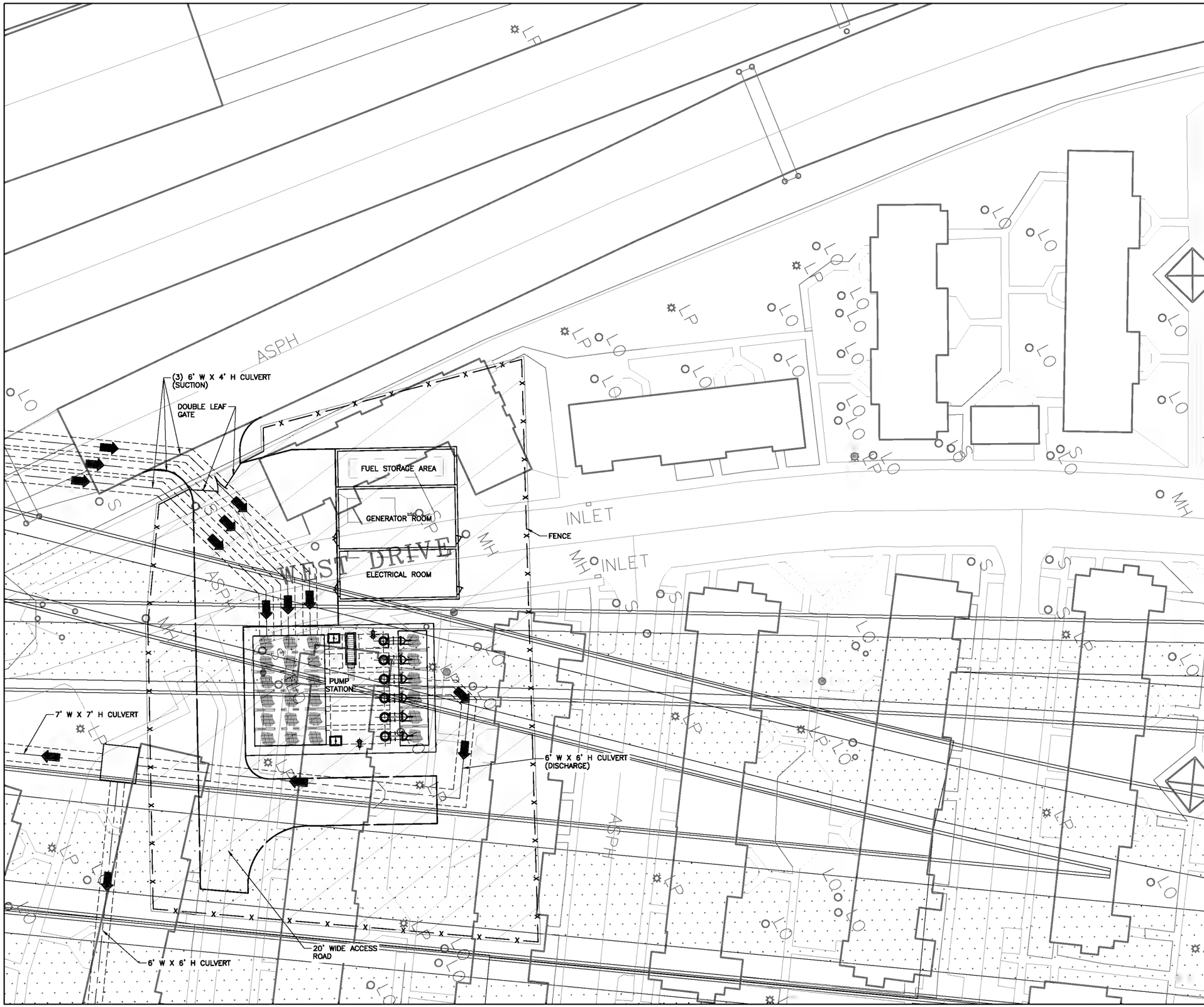

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BUFFALO BAYOU STORMWATER PUMP STATION SITE PLAN

SHEET 1 OF 5

FED.RD. DIV.NO.	PROJECT NO	SHEET NO.
6		

STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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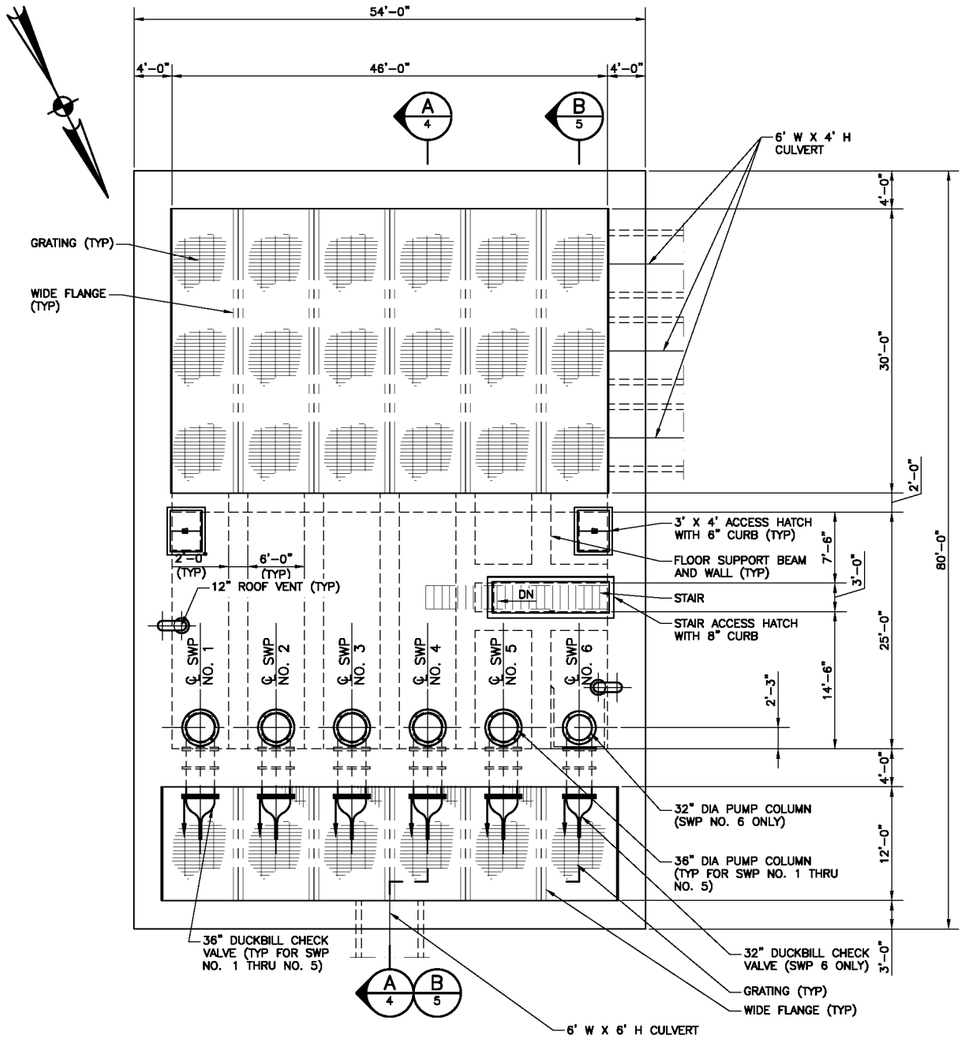

UPPER PLAN

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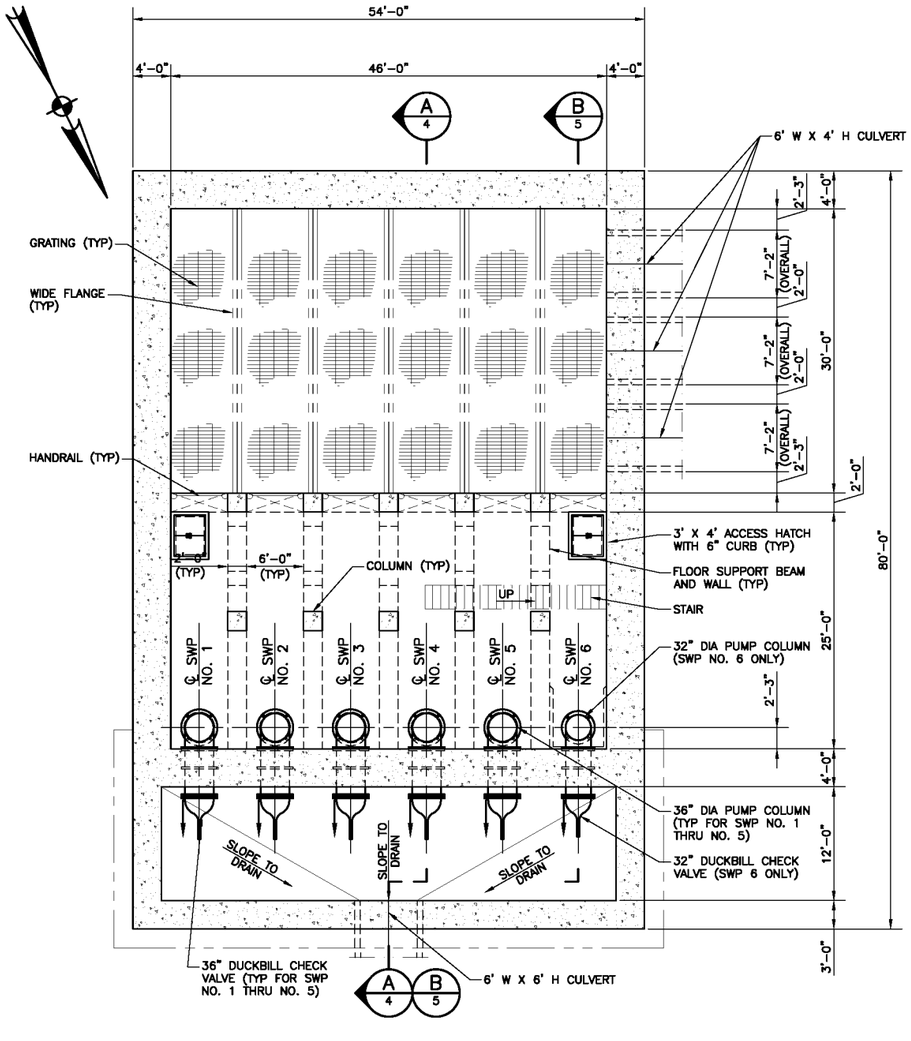

INTERMEDIATE PLAN

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BUFFALO BAYOU STORMWATER PUMP STATION PLANS – 1 OF 2

SHEET 2 OF 5

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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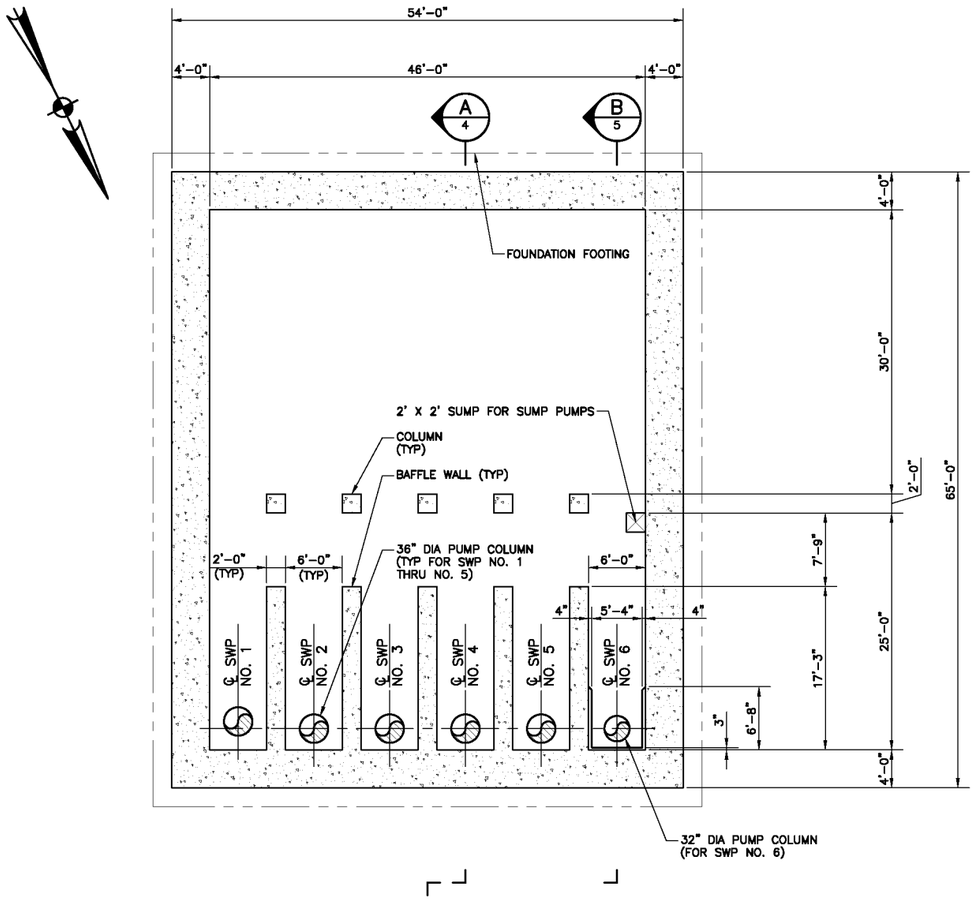

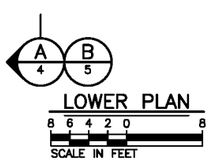

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RONALD M. CASS
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TEXAS SERIAL NO.
JULY 2018
DATE

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BUFFALO BAYOU STORMWATER PUMP STATION PLANS – 2 OF 2

SHEET 3 OF 5

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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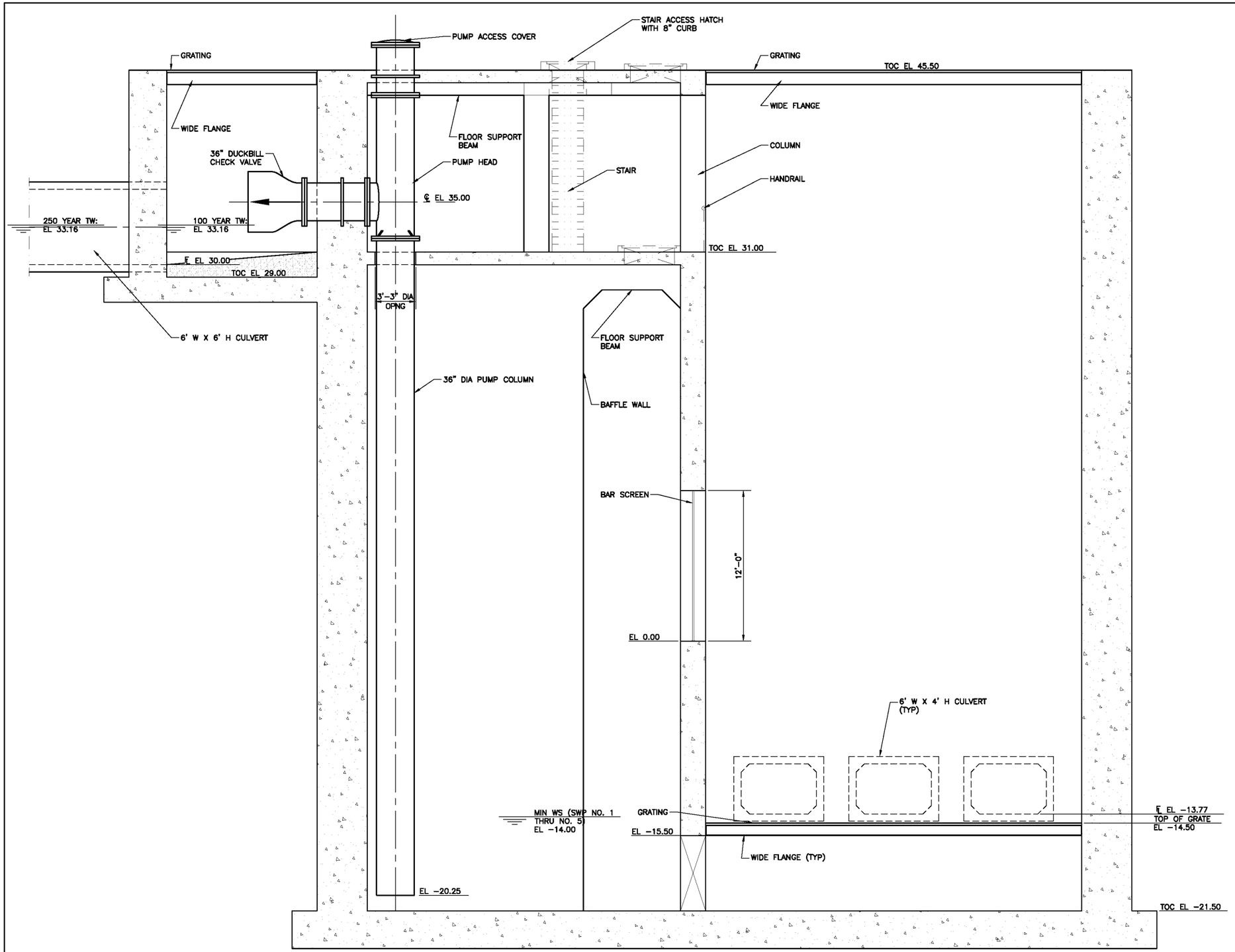

TYPICAL FOR SWP NO. 1 THRU NO. 5

SECTION A –

4 3 2 1 0 4

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BUFFALO BAYOU STORMWATER PUMP STATION SECTION – 1 OF 2

SHEET 4 OF 5

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
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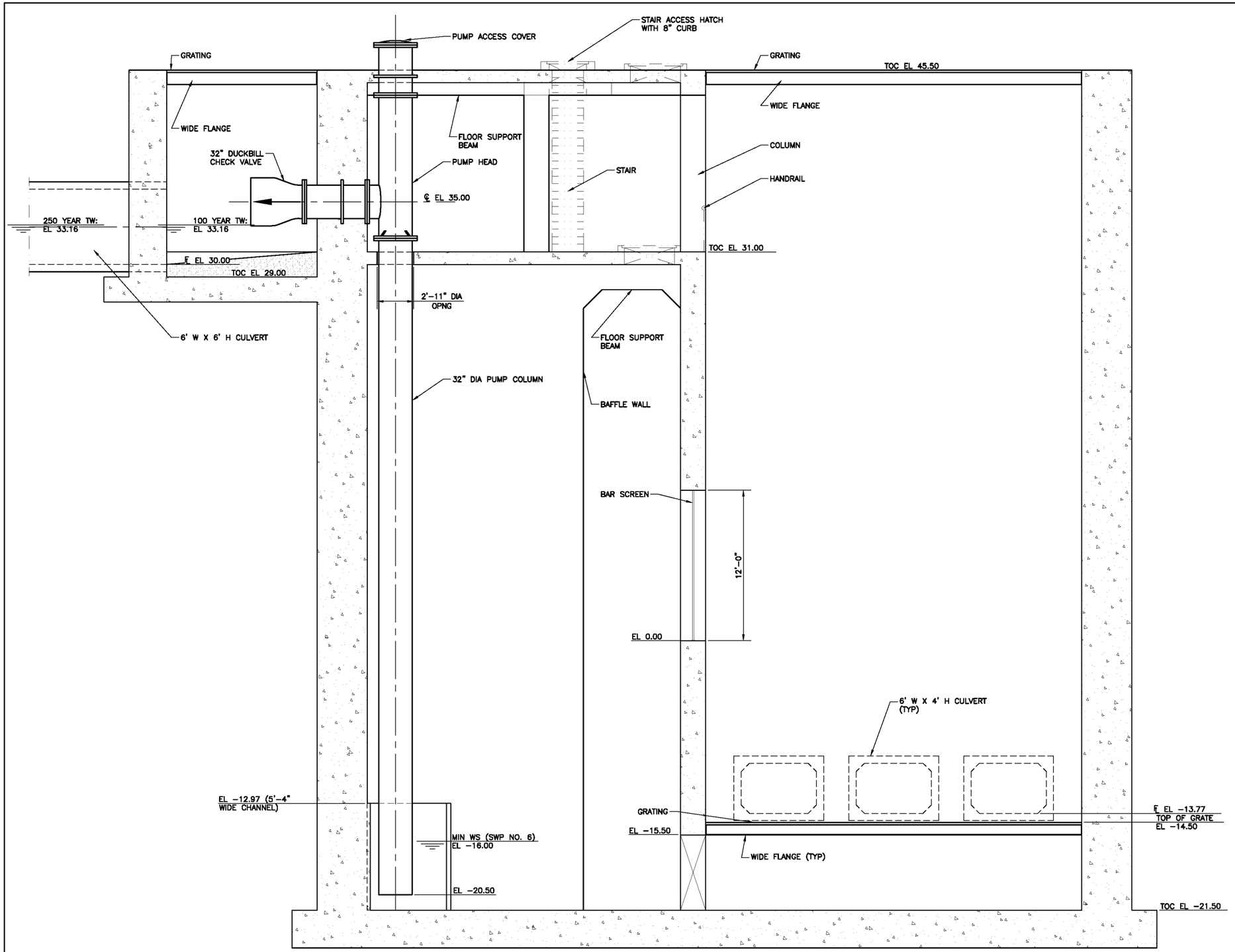

SWP NO. 6 ONLY

SECTION B

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BUFFALO BAYOU STORMWATER PUMP STATION SECTION – 2 OF 2

SHEET 5 OF 5

FED.RD. DIV.NO.	PROJECT NO.		SHEET NO.
6			
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	I-45/I-69/SH-288

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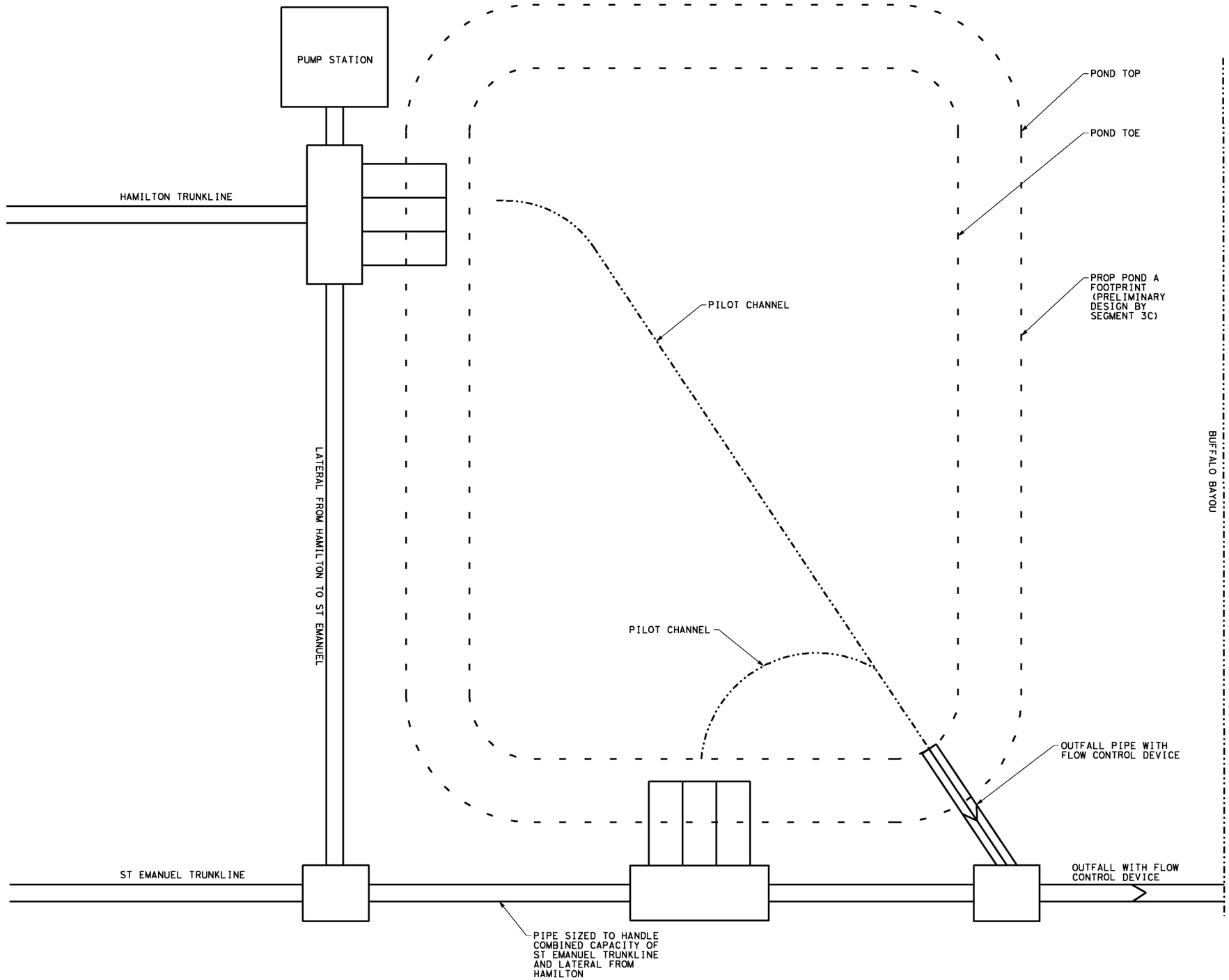

REGIONAL DETENTION BASIN

PLAN VIEW
NOT TO SCALE

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

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NHHIP SEGMENT 3B
PROPOSED POND A

SHEET 1 OF 1

FED.RD DIV.ND.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	1-45/1-69/SH-288

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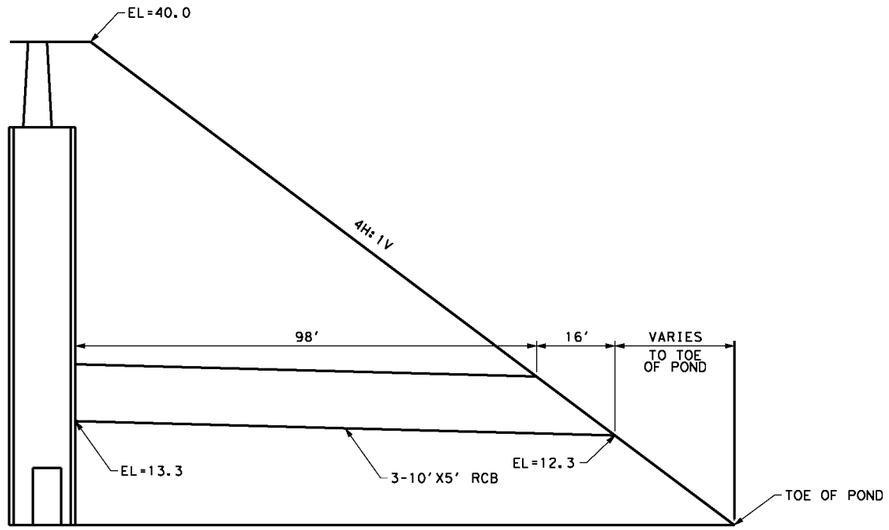

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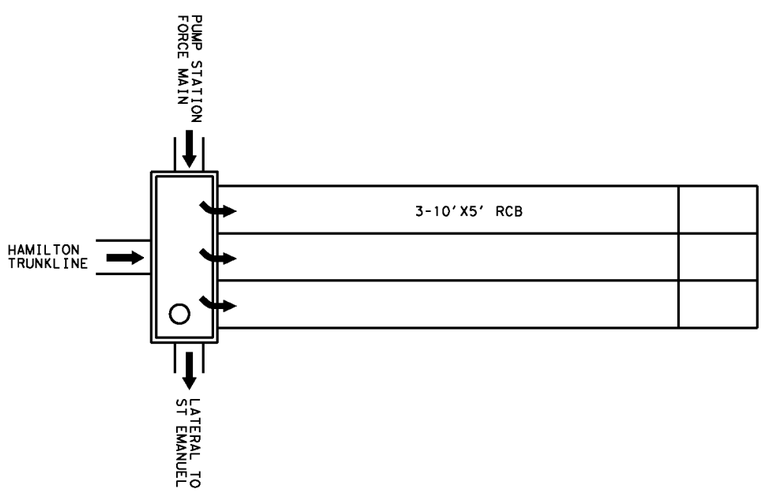
NOT TO SCALE



HAMILTON DETENTION BASIN INFLOW STRUCTURE

PLAN VIEW
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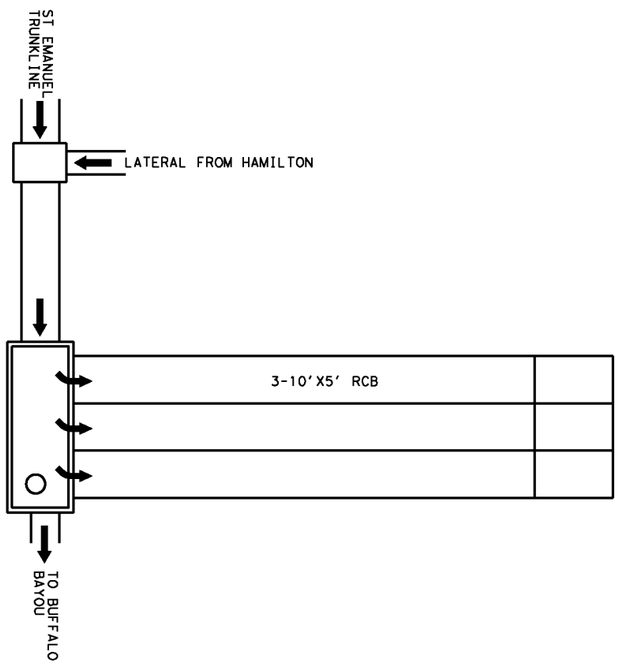

ST EMANUEL DETENTION BASIN INFLOW STRUCTURE

PLAN VIEW
NOT TO SCALE

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MICHAEL F. McGOVERN
96792
TEXAS SERIAL NO.
7/31/2018
DATE

REV. NO.	DATE	DESCRIPTION	BY

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HOUSTON, TEXAS 77094
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NHHIP SEGMENT 3B
POND A
INFLOW STRUCTURE
DETAILS

SHEET 1 OF 1

FED.RD DIV.ND.	CONTRACT NO.		SHEET NO.
6	36-71DP5055 WA 2		SHTNO
STATE	DIST	COUNTY	
TEXAS	HOU	HARRIS	
CONT	SECT	JOB	HIGHWAY
0500	03	601	1-45/1-69/SH-288

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Appendix A – Correspondence

- Design Criteria
- Meeting Minutes
- Supporting Technical Memoranda
- Record Drawings

TEXAS DEPARTMENT OF TRANSPORTATION

TECHNICAL PROVISIONS

NHHIP I-45 SEGMENT 3

DRAINAGE

DRAFT

FEBRUARY 14, 2018

AHW	Allowable High Water	HOU	District Design Practice
HCFCD	Policy Criteria & Procedure Manual (HCFCD)	RCB	Reinforced Concrete Box
HDM	Hydraulic Design Manual (TxDOT)	RCP	Reinforced Concrete Pipe
HGL	Hydraulic Grade Line	WSEL	Water Surface Elevation
EOP	Edge of Pavement	FB	Freedboard

Table 12-1: Drainage Design Frequencies

(Any deviation requires TxDOT approval)

Design Element	Mainlanes	Ramp	Direct Connect.	Frontage Road	Arterial / Cross Street	Application Notes
Minimum Roadway Elevation	100-yr	25-yr	100-yr	10-yr	10-yr*	Crossing or adjacent waterway WSEL, **plus 1' FB at low EOP**. Does not apply to storm drain or roadside ditch HGL. *No FB required.
Bridge Waterway Crossing	100-yr plus 2.5' FB	100-yr plus 1.5' FB	100-yr plus 2.5' FB	100-yr plus 1.5' FB	Match Exist.	Applies to WSEL at new location bridges. **For existing FR bridges**, use min 10-yr w/ Low chord > WSEL
Cross Drain Culverts	100-yr	25-yr	100-yr	10-yr	Match Exist.	Set maximum AHW at 1' below low EOP. Check for 100-year.
Storm Drain Inlets and Pavement Drainage	10-yr	10-yr	10-yr	2-yr	Match Exist. or better	Applies to ponded widths in gutter and inlet capacity.
Storm Drain Conduits	10-yr	10-yr	10-yr	2-yr	Match Exist. or better	Size conduit for non-pressure full flow; i.e. Design Q<= Full Flow Capacity Q. See HGL requirements below.
Storm Drain HGL	100-yr < EOP	25-yr < EOP	100-yr < EOP	10-yr: max 1-lane ponding	10-yr: max 1-lane ponding	Starting HGL at outfall: 25-yr if it works. Otherwise, base the starting HGL on hydrograph timing or top of pipe. Determine and report maximum frequency flood contained in ROW.
Depressed Roadway Storm Drain, Inlets and Pavement Drainage	100-yr	100-yr	100-yr	100-yr	100-yr	Depressed roadway occurs if water has nowhere to drain overland when curb height is exceeded. Size conduit for non-pressure full flow. Check for 100-yr HGL < EOP.
Storm Water Pumping Stations	100-yr	100-yr	100-yr	100-yr	100-yr	Design pump capacity >/= 100-yr Q + 25%. Check for 100-year < EOP.
Detention Ponds	100-year + 3' FB. Provide Detention Summary with Area Serviced, Detention Storage Volume Required, Detention Storage Volume Provided, Maximum Design WSEL, Maximum Outflow Rate Allowed, Maximum Outflow Rate Provided, and Restrictor Size.					Sample plans available from TxDOT upon request.

DRAFT

Design Element	Mainlanes	Ramp	Direct Connect.	Frontage Road	Arterial / Cross Street	Application Notes
Outfall Ditches	Design for No Impact to 100-yr WSEL. Use HCFCD Standard Details for Outfalls and other construction within HCFCD channels and ponds.					
Separation Ditches	10-yr	10-yr	10-yr	N/A	N/A	Separation Ditches are those in medians between adjacent roadways. AHW = 1' below EOP.
Roadside Ditches***	N/A	N/A	N/A	2-yr*	2-yr**	*If required outside curb line. **Or match existing capacity. *** Roadside ditches are those between the roadway and ROW

DRAFT

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Meeting Minutes

Subject	NHHIP – Segment 3A & 3B – SH 288 South Meeting
Project reference	CSJ 0500-03-601
Place	TxDOT Office
Meeting date	03/15/2018
Attendees	TxDOT – Elie Alkhoury, Christen Specht, H&H Resources – Eric Friedrich, Cynthia Carle, BGE – Chris Doherty, Yousef Husain, AECOM – Michael McGovern, Sam Talje, Jessica Rogers
Date prepared	03/15/2018
Prepared by	Jessica Rogers
Distribution	All meeting attendees

MINUTES:

- SH 288 Discussion –
  - The managed lanes roadway alignment from the NHHIP schematic drawing does not match the managed lanes roadway alignment from the Tukay drainage study.
    - Resolution – H&H Resources will work with HNTB to provide the latest proposed roadway alignment and send to AECOM and BGE. This will be used for the NHHIP Segment 3B mitigation analysis and trunk line design for the SH 288 south corridor, from the SH 288 and I-69 interchange to Blodgett Street.
  - The storm sewer system from the SH 288 managed lanes project should be maintained, as much as possible, under proposed conditions.
  - AECOM is planning to outfall to the SH 288 drainage system, opposed to the Segment 3A pump station outfall line.
  - If AECOM has mitigation issues for the SH 288 south system, it is possible to take the flow north of Cleburne Street to the SH 288 detention basin. This will need to be coordinated with BGE.
- AECOM is to assume the covered portion of the depressed section will not overflow into the depressed section. AECOM needs to account for this flow elsewhere (most likely the collector systems).
- ROW/drainage easement is needed along Hamilton Street, north of the George R. Brown Convention Center. There is approximately 8 feet in between the ROW limits and the retaining wall of the proposed depressed section. This area currently serves as parking lots for Minute Maid Park.
- The proposed I-45 South storm sewer system will minimize the lateral crossings of the main lanes to the extent possible.
  - H&H Resources to send design plans to AECOM for the I-45 direct connector project that is currently being constructed by TxDOT.

- Chartres Street, and similar frontage roads, can be designed in SWMM, rather than GeoPak Drainage. A note will be added to the drainage report regarding needed coordination between TxDOT doing the analysis in GeoPak in the future.
- Chartres Street is outfalling into a City of Houston storm sewer system and therefore will be designed based on COH criteria. The trunk line will be designed to a 2-year level of service and flows will be checked at the outfall pipe(s) to ensure no impacts.
- AECOM is proposing to show sub drainage areas on the plan sheets and provide an overall drainage area map, so there will be no detailed drainage area sheets. AECOM is to send TxDOT and H&H Resources an example of one plan and profile sheet to get approval.
- Action Items –
    - H&H Resources to provide update schematic roadway alignment either Friday, 3/16, or Monday, 3/19, and send to BGE and AECOM.
    - H&H Resources to send design plan set to AECOM for the I-45 Direct Connectors.
    - AECOM to send TxDOT and H&H Resources an example plan & profile sheet with drainage areas on it for approval.

Texas Department of Transportation

MEETING SIGN-IN SHEET

Date: March 15, 2018 **Time:** 9:00 am **Location:** TxDOT HOU HQ - RM 531

Hwy/CSJ: I-45 NHHIP Segment 3A & 3B
CSJ 0500-03-601

Meeting Coordinator: Elie Alkhoury

ATTENDANCE (initial)	NAME	COMPANY / DEPARTMENT	TELEPHONE NUMBER	E - MAIL ADDRESS
EA	Elie Alkhoury	TxDOT	713-802-5508	Elie.Alkhoury@txdot.gov
CS	Christen Specht	TxDOT	713-802-5774	Christen.Specht@txdot.gov
EF	Eric Friedrich	H & H Resources	832-220-1205	friedricher@hhresources.com
n	Sam Talje	AECOM	713-855-7401	Sam.Talje@aecom.com
MM	Michael McGovern	AECOM	281-675-1919	Michael.McGovern2@aecom.com
CD	Chris Doherty	BGE	713-488-8142	CDoherty@bgeinc.com
YH	Yousef Husain	BGE	713-488-8337	YHusain@bgeinc.com
JR	Jessica Rogers	AECOM	281-675-7612	jessica.rogers@aecom.com
CC	Cyndi Carle	H+H Resources	281-207-2281x1	carlecr@hhresources.com
SH	Steve Hrncir	HNTB	713-896-7058	shrncir@hntb.com

SLS/ha

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Meeting Minutes

Subject	NHHIP – Segment 3B Drainage Plan Review
Project reference	CSJ 0500-03-601
Place	TxDOT Office
Meeting date	03/23/2018
Attendees	TxDOT – Elie Alkhoury, Christen Specht, H&H Resources – Eric Friedrich, AECOM – Michael McGovern
Date prepared	03/26/2018
Prepared by	Mike McGovern
Distribution	All meeting attendees plus Sam Talje & Jessica Rogers

MINUTES:

- AECOM presented the updated Segment 3B drainage plan, updates included:
    - Relocation of the proposed pump station at the I-45 interchange from the west side to the east side of the interchange. The pump station location was updated due to construction phasing conflicts.
    - The I-45 pump station outfall includes a gravity outfall line that will run along St. Emanuel Street and outfall to Buffalo Bayou.
    - Relocation of the proposed pump station at the outfall to Buffalo Bayou. The pump station was relocated from the west side within the preliminary detention basin footprint to the east side, north of Commerce Street and west of the railway line.
    - This updated location will require additional ROW.
- AECOM to confirm approximate pump station footprint before recommending additional ROW needs.
- TxDOT and H&H Resources both liked the updated pump station locations.
- AECOM gave an update on the mitigation approach for the I-45 south section. The proposed depressed section will reduce the drainage area to the I-45 south system; therefore, no mitigation is anticipated to be needed to compensate for the minor increase in impervious cover associated with the roadway improvements.
    - TxDOT concurred with this mitigation approach.
- SH-288 South Section
    - H&H Resources noted that the HNTB are working on the reconfiguration of the managed lanes. Since the total pavement area will not change as a result of the roadway realignment, AECOM should move ahead with the drainage design based on current alignment.
    - AECOM noted Tukay's hydrology approach that was applied in the SH-288 Managed Lanes drainage study.
    - TxDOT are ok with AECOM using a modified hydrology approach as long as the runoff volumes and peak flows are similar between both approaches.

- H&H Resources noted potential mitigation alternative – redirect Chartres Street drainage system to Elgin Street

- Action Items –
  - H&H Resources to check with HNTB on;
    - Alignment of St. Emanuel Street between Congress and Commerce Street.
    - Proposed east ROW line discrepancy between Pease St. and Congress St. plan view does not agree with Cross-Sections E-E, F-F, G-G, H&H
  - H&H Resources to provide TxDOT I-10/Patterson Street pump station plans
  - AECOM to estimate approximate pump station site footprint and follow up with TxDOT regarding additional ROW needs.
  - AECOM to update conceptual drainage plan technical memorandum and send to TxDOT and H&H Resources for review and comment.

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To: Elie Alkhoury, Christen Specht,

CC: Eric Freidrich,

Project name:
NHHIP Segment 3B

Project ref:
60563838

From:
Michael McGovern & Anthony Holder

Date:
July 27, 2018

NHHIP Segment 3B Drainage Study

Subject: Overland Flow Analysis – Hydrology Methodology

General

The North Houston Highway Improvement Project (NHHIP) is a proposed Texas Department of Transportation (TxDOT) project to address the existing Interstate Highway 45 (I-45) traffic capacity limitations, obsolete functionality of certain aspects of the corridor, and existing major design deficiencies. The project study limits were separated into three Segments. Segment 3 consists of the Downtown Loop including I-45, I-10, and US 59/I-69 (connecting to SH 288 and Spur 527). Segment 3B extends from Canal Street south along US 59/I-69 to the US-59/SH 288 interchange and lies within the Buffalo Bayou and Brays Bayou watersheds.

Segment 3B includes depressed main lane from just south of the US 59/I-69 crossing of Buffalo Bayou at Canal Street to the US-59/SH 288 interchange. Currently, the I-69 corridor from SH 288 to Canal Street drains to Buffalo Bayou via a gravity storm sewer system. The proposed depressed section drainage system will outfall to Buffalo Bayou in the vicinity of the I-69 bridge-crossing of the Bayou, similar to the location of the existing outfall system. The existing topography on the west side of I-69 slopes towards the I-69 corridor. Therefore, under proposed conditions, the potential exists for overland flow to drain to the future depressed section. As part of this drainage study, a detailed overland flow analysis will be completed using SWMM to determine a recommendation to prevent the overland flow from entering the future depressed section. The purpose of this technical memorandum is to outline the approach used to develop the hydrology for the SWMM model.

Objective

Develop an approach to calculate the peak flow and runoff hydrographs (100-year, 250-year, 500-year, and 2017 Hurricane Harvey Flood Event (Harvey)) for the drainage sub areas representing the overland flow model extents. The runoff hydrographs will be used as flow inputs for the overland flow SWMM model.

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Hydrology Methodology

Drainage Areas

The approximate model limits were initially determined from a review of the major City of Houston (COH) trunkline systems and a review of the overland flow paths and 100-year ponding depth grids developed from LiDAR using ArcGIS tools. The drainage limits are shown in **Figure 1**.

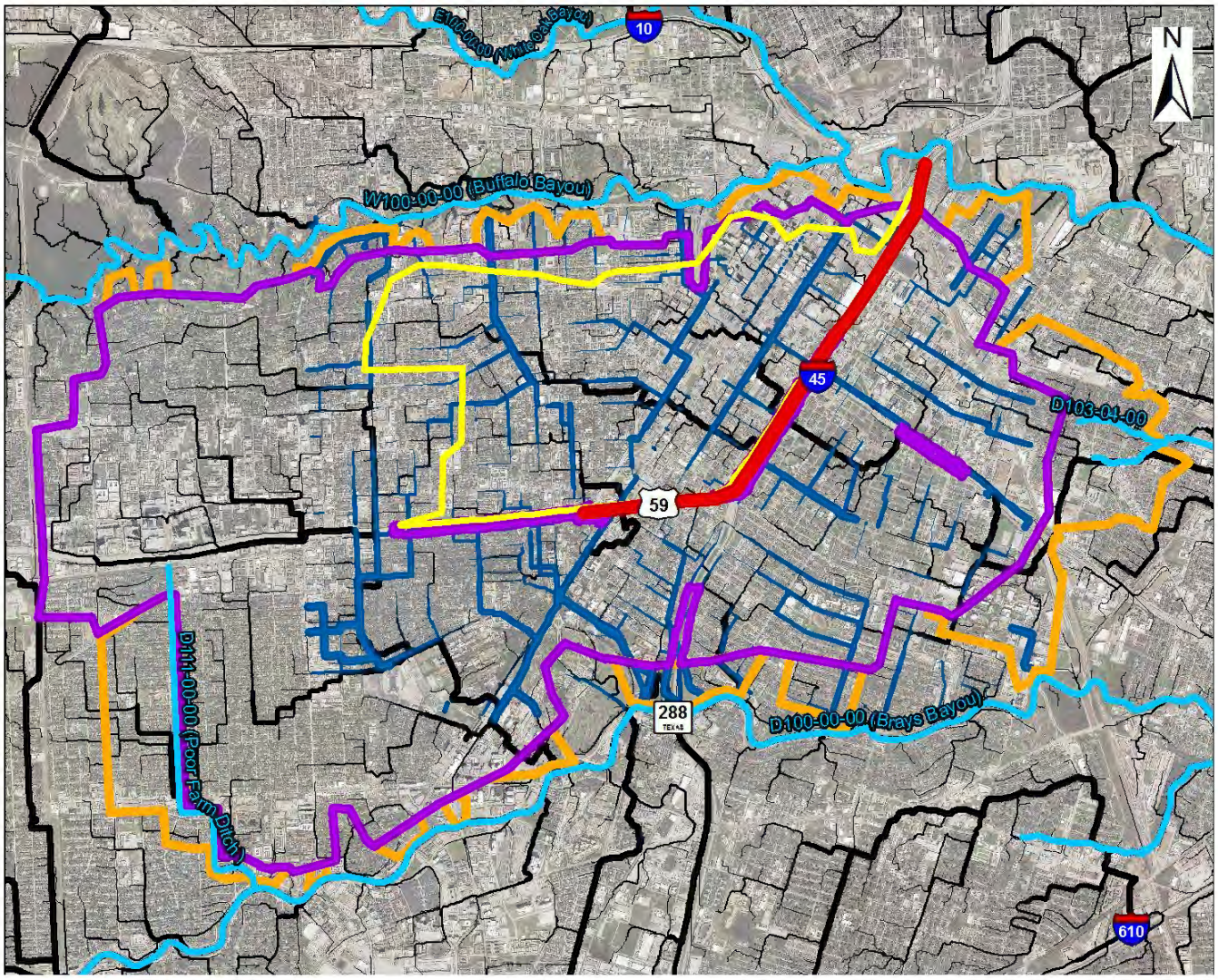

Figure 1 – Drainage Area Limits

Figure Key

- Black Lines – overland flow paths (thicker lines means larger overland flow area)
- Blue lines – storm sewer 36-inch and larger (thicker lines means larger pipe size)
- Yellow boundary – area that drains to I-69 corridor via overland topography
- Purple boundary – Detailed modeled areas
- Orange boundary – Less detailed modeled areas
- Aqua lines – HCFCD channel centerlines

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The areas shown in Figure 1 represent the limits of the SWMM model. The purple area represents the area with detailed hydraulic analysis briefly described below. The area between the purple and orange lines has a lower resolution hydraulic analysis, described in the hydraulics technical memo, Further details of the hydraulic analysis are presented in the hydraulics technical memo. The area that drains overland to the I-69 corridor (yellow subarea) is shown for information only. It did not affect the hydraulics or hydrology calculations.

The detailed drainage area (purple) was subdivided into subareas using the Thiessen polygon methodology with the objective of assigning a drainage area to each node representing a low point in the overland flow system. These points were generally assigned at street intersections, where inlets are found. The Thiessen polygon method creates areas surrounding a point cloud by drawing perpendicular bisectors of the line between the points, and trimming those where they intersect the other perpendicular bisectors that surround that point. **Figure 2** shows the Thiessen polygons in a subset of the model area, with the perpendicular bisectors. Once the Thiessen polygons were created, the boundaries were reviewed and modified as necessary so that they generally represent the high points between the overland flow nodes. Also, the line connecting the two nodes was modified to pass through the center of the perpendicular bisector. The outside area (between purple and orange) was divided primarily based on storm sewer topology, following ridges between the storm sewers. Areas outside the orange line outfall directly to the channels, with no storm sewer connection to the detailed model area. The development of the overland flow system is more fully described in the separate overland flow hydraulics memo.

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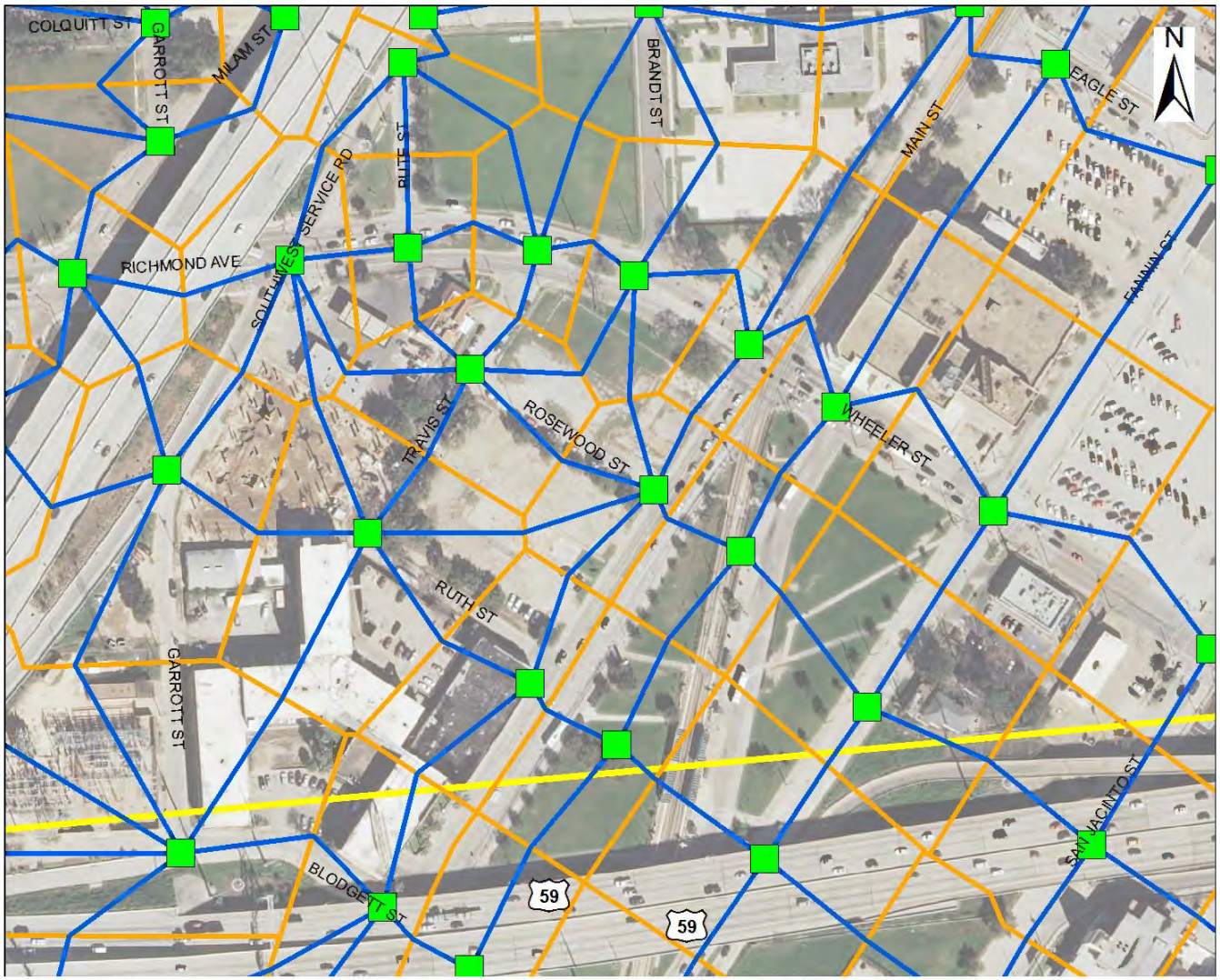

Figure 2 – Thiessen Polygons

Figure Key

- Green squares – Overland sags (typically street intersections)
- Blue lines – Overland flow paths (node to node, modified to pass through the center of the boundary)
- Orange lines – Perpendicular bisectors (modified as appropriate) that are storage area/drainage area boundaries

Percent Impervious Cover and Time of Concentration Estimates

Land use data for each subarea was developed based on the Harris County Flood Control District (HCFCD) land use data categories. The HCFCD land use data is shown in **Table 1**. A composite impervious cover values was determined for each sub area.

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Table 1 – HCFCD Land Use Data

Land Use Categories	Land Use Descriptions	% Impervious	% Development
Undeveloped	Unimproved, natural, or agricultural	0	0
Residential – Rural Lot	≥ 5 acre ranch or farm	5	0
Residential – Large Lot (Newer)	> ½ acre new residential neighborhoods , storm sewers or roadside ditches with adequate capacity	20	100
Residential – Large Lot (Older)	> ¼ acre, older neighborhoods with limited capacity roadside ditches	20	50
Residential – Small Lot	≤ ¼ acre	40	100
Schools	Schools with non-paved areas	40	50
Developed Green Areas	Parks or golf courses	15	50
Light Industrial/ Commercial	Office parks, nurseries, airports, warehouses, or manufacturing with non-paved areas	60	100
High Density	Commercial, business, industrial, or apartments	85	100
Isolated Transportation	Highway or major thoroughfare corridors	90	100
Water	Detention basins, lakes, and channels	100	100

(Source: HCFCD PCPM Manual Section 3.5. dated 2010)

The calculated composite impervious cover values were grouped into five (5) bins;

- 40% impervious cover (0% to 47.5%)
- 55% impervious cover (47.5% to 60%)
- 65% impervious cover (60% to 70%)
- 75% impervious cover (70% to 80%)
- 85% impervious cover (80% to 100%)

For each impervious cover bin, a rational method runoff coefficient (C) was assigned, using the equation C = 0.6 * Impervious Cover + 0.2.

The time of concentration (Tc) was calculated for a select range of drainage areas that covers the general drainage area sizes within the defined overland flow area. The time of concentration was calculated following the NRCS methodology. The selected time of concentration values were compared to the drainage area size, dividing the drainage areas into three subsets, detailed area greater than/less than 80 percent impervious, and outside

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areas. For each of these three subsets, a line was fit to the area/Tc data, and an equation was developed for the line using Excel's trendline function. This equation was used to assign a Tc value to each of the drainage areas.

Similar to the percent impervious cover, the time of concentration values were grouped into six (6) bins;

- 10 minute Tc (10 min to 12.5 min)
- 15 minute Tc (12.5 min to 17.5 min)
- 20 minute Tc (17.5 min to 22.5 min)
- 25 minute Tc (22.5 min to 27.5 min)
- 30 minute Tc (27.5 min to 42.5 min)
- 55 minute Tc (> 42.5 min)

Each model drainage area was then assigned to one of the bins.

Hydrograph Development

A HEC-HMS basin file was developed that contains one subbasin for each combination of the selected Tc and percent impervious cover with an area of 1 acre. 29 subbasins were developed to capture the combinations of the selected Tc and percent impervious cover values (no drainage areas were present in what would have been the thirtieth bin). Loss rate parameters were based on the loss rates used in the FEMA effective HEC-HMS model of Buffalo Bayou.

- Initial Loss: 0.93
- Moisture Deficit: 0.43
- Wetting Front Suction: 10.03
- Hydraulic Conductivity: 0.37

The 100-year peak flow for each of the 29 HEC-HMS subbasins representing a Tc and percent impervious cover bin was calculated using the rational method and the current TxDOT BDE coefficients, the time of concentration, and C value for each bin. Hydrographs were developed for each HEC-HMS subbasin following the Clark Unit Hydrograph method and using the 100-year rainfall data for Harris County Region 2 taken from the HCFCD Hydrology Manual, dated 2009. The Clark UH "R" values for each drainage area were adjusted until the HEC-HMS peak flow values match the calculated rational method peak flow values for each subbasin. The final "R" values were applied for all 4 storm events (100, 250, 500, and Harvey) to develop cfs/acre typical hydrographs for each storm/Tc/impervious cover combination. For Hurricane Harvey, rainfall patterns were extracted from NEXRAD radar and compared to rainfall gages to select a rainfall time series suitable for this project, as described in the memo titled "Overland Flow Analysis – Rainfall Development for Hurricane Harvey".

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Supporting information for the determination of the Tc and percent impervious cover values is included in **Attachment 1**.

Hydrograph Inflows to PC-SWMM

The calculated cfs/acre runoff hydrographs for each of the twenty nine (29) bins were assigned to drainage subareas (and thus were assigned as inflow time series to the overland flow nodes in SWMM) based on the subarea drainage area size and land use (and the storm being modeled). A scaling factor of the drainage area in acres was applied to each inflow hydrograph to convert from cfs/acre to an actual flow rate.

Depressed Section Peak Flow and Hydrograph Development

For the depressed section, the same basic methodology as described above was used to develop peak flows and hydrographs, with a few minor changes. Actual drainage areas were drawn and used. The minimum 10-minute Tc value was used for all drainage areas, as the Tc is representing flow to the inlet and through the very upstream portion of the storm sewer system. A runoff coefficient (C) of 1.0 was used, to represent fully paved areas.

When developing the hydrographs, the Tc was reduced to 5 minutes, as the very high peak flows associated with 100% impervious cover, high C values, and short times of concentration are higher than the Clark UH will produce with a 10 minute time of concentration. These values were used to calibrate an “R” value for each drainage area.

Hydrology Approach QC

The following checks were completed to verify that the selected hydrology approach was generating reasonable results.

- Loss rates – the runoff volume for each of the 1-acre drainage areas were checked to confirm the runoff volume generated by the HMS model was reasonable
- Peak flows - the rational method was used to generate all peak flows. Drainage areas were checked to confirm that the drainage area size was less than or equal 200 acres. In general, the majority of drainage areas are less than 200 acres.

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HYDROLOGY METHODOLOGY

BY: James Hathorn, P.E.

RE: NHHIP_Seg3B_Overland Sheet Flow Analysis

PROJECT NO.: 1811-002

DATE: February 6, 2018

Introduction

As part of preliminary design of the IH-45 project segment 3B, CobbFendley was tasked with calculating hydrologic parameters for overland sheet flow drainage areas, and creating a set of unit hydrographs for the areas. This memo details the methodology used.

Percent Impervious

To calculate the percent imperviousness for each drainage area, CobbFendley started with a land use shapefile from TSARP. Because the file was dated 2002, land uses in the project area were manually checked with current aerial imagery and updated. Each TSARP land use was then matched to a corresponding land use from the HCFCD Hydrology and Hydraulics Guidance Manual, which have an assigned percent impervious value. The “Union” tool in ArcMap GIS was then used to cut the land use to each drainage area, providing composite land use areas for each drainage area. With this data, CobbFendley was able to calculate a composite percent impervious value for each drainage area.

The same process was used to calculate a composite runoff coefficient, C, for each drainage area. Runoff coefficients from chapter 9 of the City of Houston Infrastructure Design Manual were used because they are local to the project and fall within the runoff coefficients ranges listed in the TxDOT Hydraulic Design Manual. The updated TSARP land uses were matched to a corresponding City of Houston land use to obtain runoff coefficients, and a composite runoff coefficient, C, was calculated for each drainage area.

Time of Concentration

It was not practical to hand calculate time of concentration, Tc, for each of the 3,634 drainage areas. Instead, Tc was calculated for a representative sample of areas and plotted against their area size until trends became clear. A total of 84 Tc values were calculated following the NRCS method from the TxDOT Hydraulic Design Manual.

Larger areas correlated to a higher Tc, but slope and impervious cover also had important influence on the Tc.

The outside areas (drainage areas on the fringe of the project area, from SheetFlow_OutsideAreas.shp) generally had higher slopes and were larger in size than the detailed areas (SheetFlow_DetailedAreas.shp). When plotted on a graph showing Tc and area size, the outside areas were on a noticeably different trajectory than the detailed areas. A line of best fit was plotted for the outside areas, and the uncalculated Tc's were interpolated along the line and assigned a value based on their area size, see Chart 1 – Outside Area Tc.

The detailed areas themselves also appeared to be following two different paths on the plot. It was discovered that the areas with high impervious cover had a noticeably lower Tc. Therefore areas with impervious cover of 80% or higher were fitted to their own line of best fit, and the uncalculated Tc values were interpolated along the line and assigned a value based on their area size. Two data point outliers were excluded for developing the line of best fit, see Chart 2 – Detailed Area Tc.

The remaining drainage areas were detailed areas and had less than 80% impervious cover. A line of best fit was applied to these data points (excluding another two outliers), and the Tc values for these areas were interpolated based on area size, see Chart 2 – Detailed Area Tc.

Bin Selection

CobbFendley sorted all the percent impervious and Tc values into bins for simplification. CobbFendley analyzed the distribution of percent impervious values and decided that 5 bins would be appropriate; PctImp40, PctImp55, PctImp65, PctImp75, and PctImp85. Every percent impervious value was delivered to its nearest bin. The bins were chosen so that the mean and median of all values contained within each bin are very close to the bin name. For example, in the PctImp40 bin the mean of its contained values is 39%, and the median is 40%.

CobbFendley analyzed the distribution of Tc values and decided that 6 bins would be appropriate; Tc10, Tc15, Tc20, Tc25, Tc30, Tc55. Every Tc value was delivered to its nearest bin. The bins were again chosen so that the mean and median of all values contained within each bin are very close to the bin name. The Tc bins worked well with this rule except the Tc55 bin, which had a median of 55 minutes and a mean of 68 minutes. The higher mean was the result of a few very large Tc values that skewed the mean upwards, so the median value was chosen as the representative Tc and bin name.

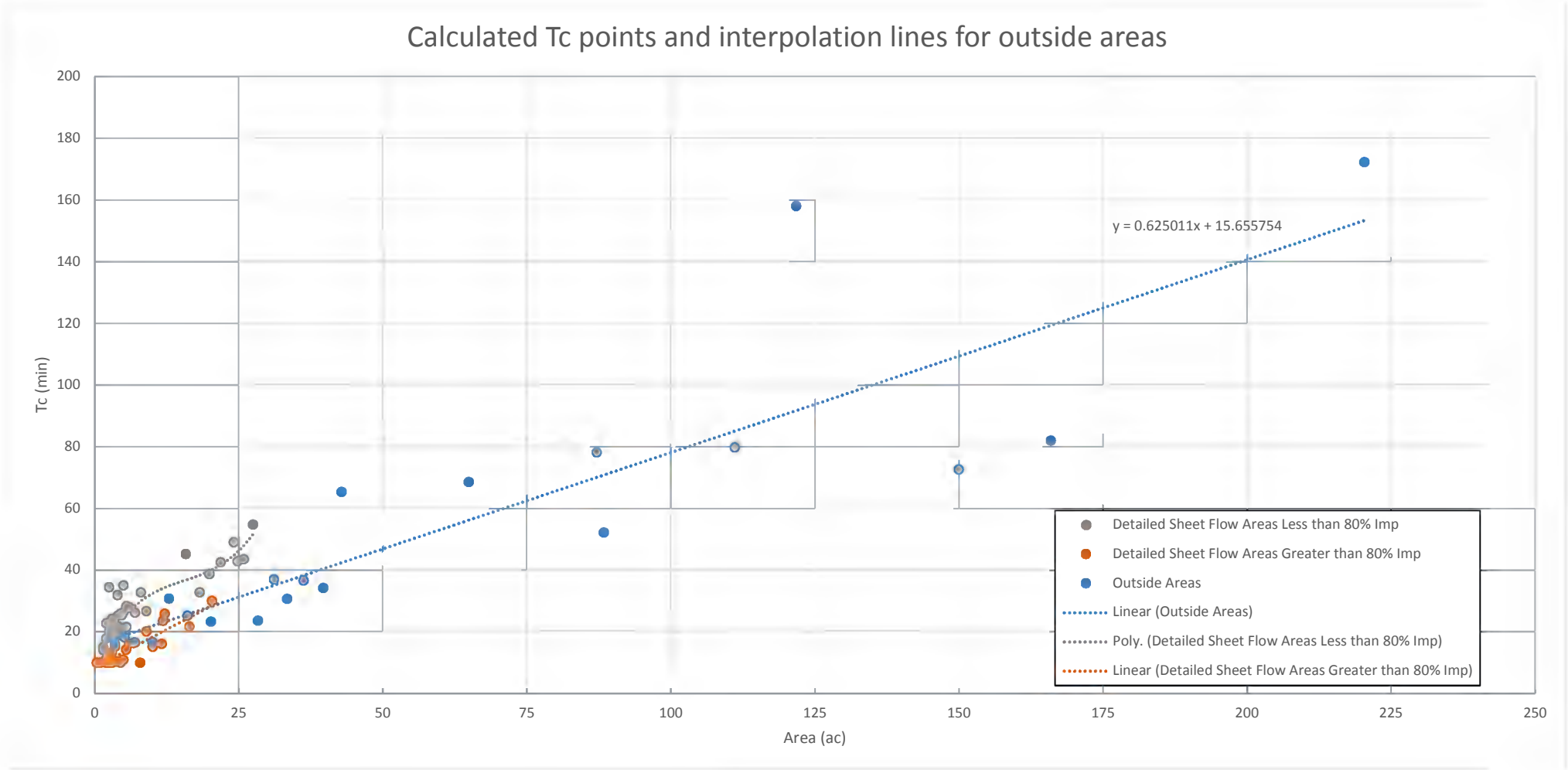
The percent impervious bins and Tc bins were then combined in every combination to form 30 overall bins (5 percent impervious bins multiplied by 6 Tc bins). The Tc10PctImp40 bin had no areas in it so it was deleted, leaving 29 bins, see Chart 3 – Drainage Area Bins, and Table 1 – Bin Quantities.

Hydrographs

To create unit hydrographs for the bins, CobbFendley created a HEC-HMS model with one subbasin for each of the 29 bins. To choose loss rates for the subbasins, CobbFendley looked at the FEMA effective models for Buffalo and Brays Bayous. The loss rates near the project area were all very similar, so the loss rates from a large central subbasin (W100N) were chosen and used. Rainfall data was obtained from the HCFCD Hydrology & Hydraulics Guidance Manual for the Region 2 100-year, 250-year, and 500-year storms. Actual Harvey rainfall data near the project site was used for the Harvey run.

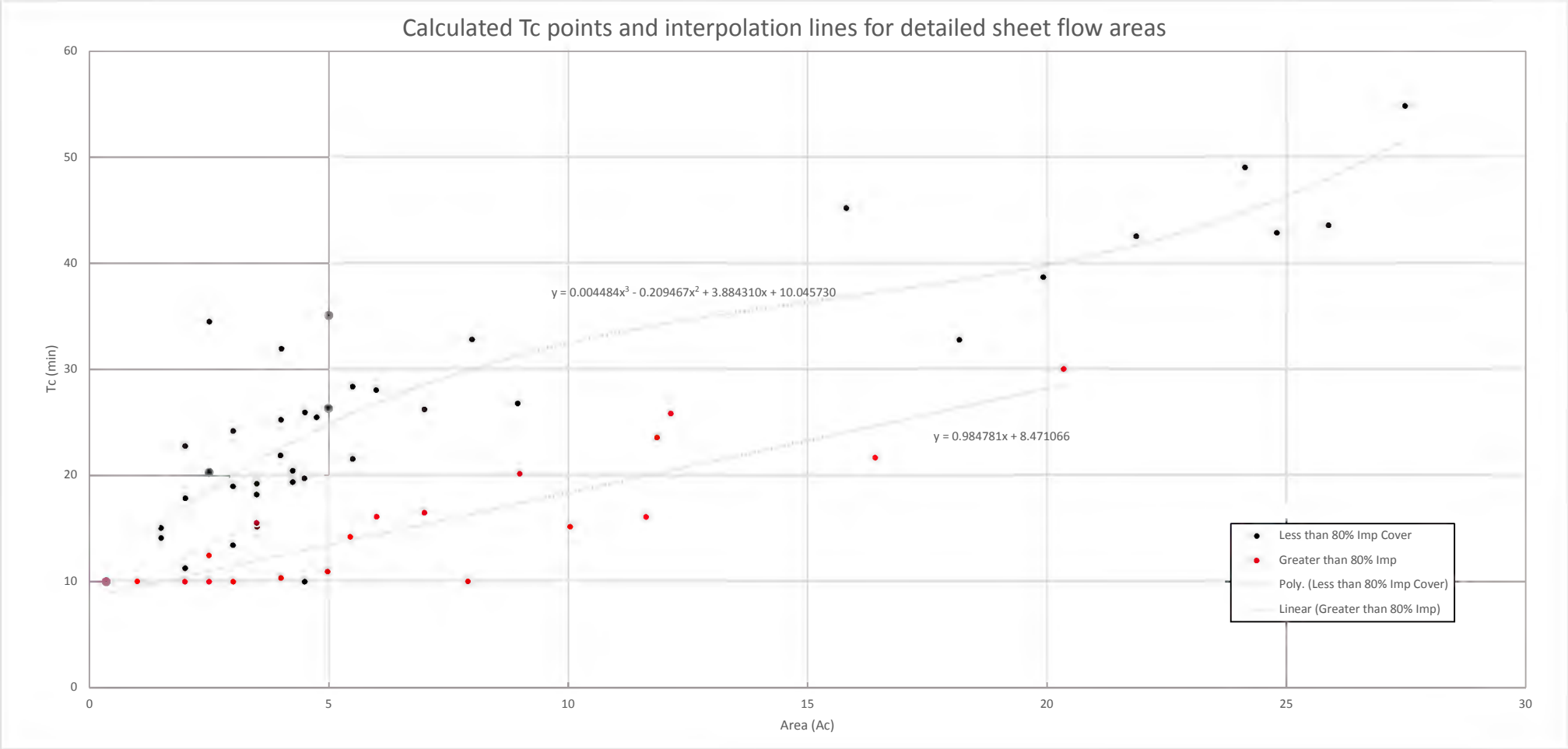
100-year peak flows for each bin were calculated for an area of 1 acre using the rational method and TxDOT BDE coefficients for Harris County. The R values in HEC-HMS were adjusted until the peak flows matched those calculated by the rational method. The model was run for the 100-year, 250-year, 500-year, and Hurricane Harvey storm events. The R values were not recalibrated for the storm events beyond 100-year, which may result in a slight overestimation of peak flows for the larger storm events. The HEC-HMS results were reviewed and the total losses in each storm event appeared reasonable.

Chart 1 - Outside Area Tc



Attachment 1

Chart 2 - Detailed Area Tc



Attachment 1

3073	SJ1422	J1422	0.355	90%	10.00
3069	SJ1235	J1235	0.488	90%	10.00
3067	SJ1135	J1135	0.536	57%	12.07
3480	SJ3484	J3484	0.551	80%	10.00
3092	SJ1779	J1779	0.564	71%	12.17
2896	SJ2988	J2988	0.574	66%	12.21
463	SJ3107	J3107	0.574	63%	12.21
795	SJ0513	J0513	0.579	71%	12.23
832	SJ0567	J0567	0.586	55%	12.25
3184	SJ3088	J3088	0.594	78%	12.28
2886	SJ2978	J2978	0.612	77%	12.35
227	SJ0966	J0966	0.620	86%	10.00
3032	SJ0383	J0383	0.632	82%	10.00
2573	SJ2575	J2575	0.653	76%	12.49
1378	SJ1222	J1222	0.674	75%	12.57
2163	SJ2154	J2154	0.680	68%	12.59
3066	SJ1126	J1126	0.687	51%	12.62
3478	SJ3482	J3482	0.697	78%	12.65
3159	SJ3041	J3041	0.712	80%	10.00
2782	SJ2847	J2847	0.726	79%	12.76
3076	SJ1450	J1450	0.734	72%	12.78
3031	SJ0371	J0371	0.735	58%	12.79
930	SJ0730	J0730	0.739	69%	12.80
950	SJ0786	J0786	0.748	73%	12.84
2867	SJ2958	J2958	0.759	75%	12.87
1574	SJ1438	J1438	0.762	76%	12.89
2941	SJ3089	J3089	0.763	69%	12.89
2942	SJ3096	J3096	0.765	85%	10.00
285	SJ1499	J1499	0.767	61%	12.90
1875	SJ1811	J1811	0.767	85%	10.00
1719	SJ1622	J1622	0.773	80%	12.92
1189	SJ0999	J0999	0.773	88%	10.00
2183	SJ2177	J2177	0.774	79%	12.93
2826	SJ2912	J2912	0.774	77%	12.93
2035	SJ1981	J1981	0.778	44%	12.94
2852	SJ2940	J2940	0.783	72%	12.96
1788	SJ1697	J1697	0.787	62%	12.98
1395	SJ1249	J1249	0.792	77%	12.99
3098	SJ1878	J1878	0.805	77%	13.04
2805	SJ2881	J2881	0.806	81%	10.00

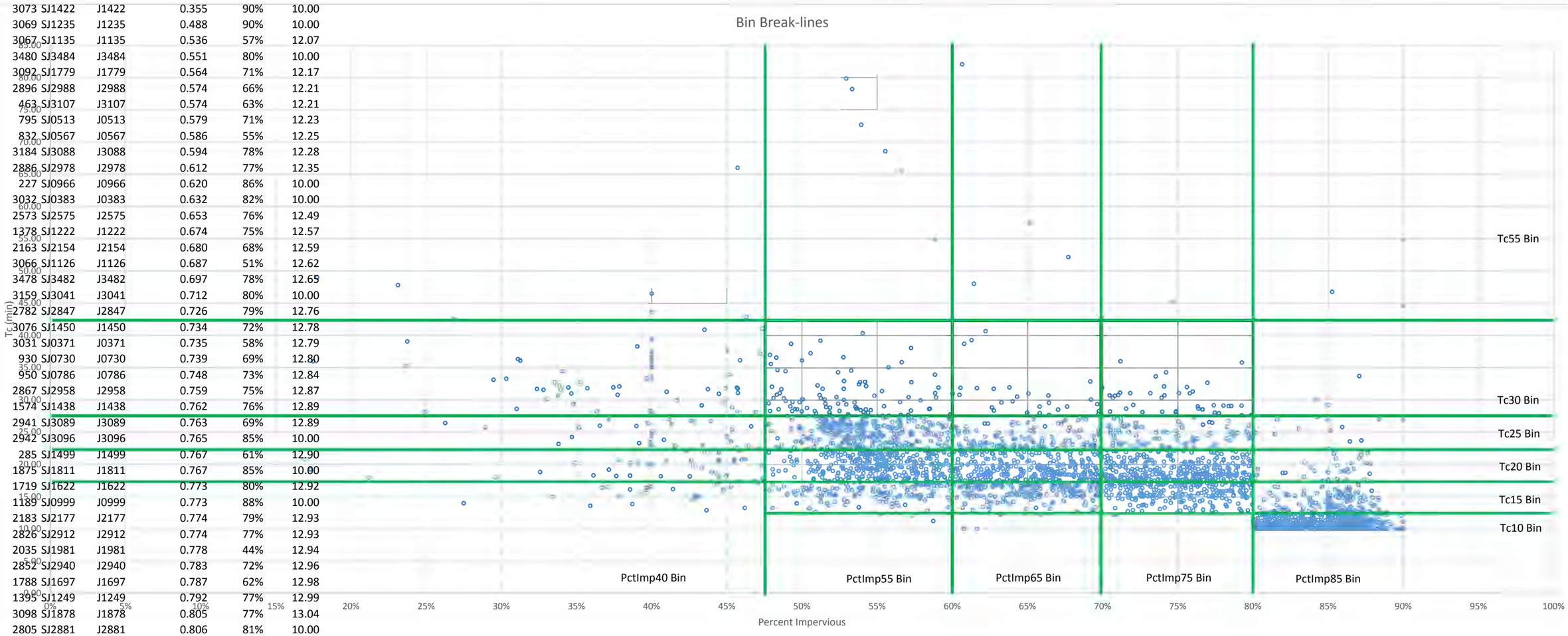


Chart 3 - Drainage Area Bins

Attachment 1

Bin Quantities

Tc Bin \ PctImp Bin	40	55	65	75	85
55	7	8	5	1	3
30	56	92	29	38	3
25	28	256	115	84	12
20	38	349	288	305	30
15	26	146	230	264	134
10		3	4	5	1075

Attachment 1

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To: Elie Alkhoury, Christen Specht

CC: Eric Freidrich

Project name:
NHHIP Segment 3B

Project ref:
60563838

From:
Michael McGovern & Anthony Holder

Date:
June 20, 2018

NHHIP Segment 3B Drainage Study

Subject: Overland Flow Analysis – Hydraulics Methodology

General

The North Houston Highway Improvement Project (NHHIP) is a proposed Texas Department of Transportation (TxDOT) project to address the existing Interstate Highway 45 (I-45) traffic capacity limitations, obsolete functionality of certain aspects of the corridor, and existing major design deficiencies. The project study limits were separated into three Segments. Segment 3 consists of the Downtown Loop including I-45, I-10, and US 59/I-69 (connecting to SH 288 and Spur 527). Segment 3B extends from Canal Street south along US 59/I-69 to the US-59/SH 288 interchange and lies within the Buffalo Bayou and Brays Bayou watersheds.

Segment 3B includes depressed main lane from just south of the US 59/I-69 crossing of Buffalo Bayou at Canal Street to the I-69/SH 288 interchange. Currently, the I-69 corridor from SH 288 to Canal Street drains to Buffalo Bayou via a gravity storm sewer system. The proposed depressed section drainage system will outfall to Buffalo Bayou in the vicinity of the I-69 bridge-crossing of the Bayou, similar to the location of the existing outfall system. The existing topography on the west side of I-69 slopes towards the I-69 corridor. Therefore, under proposed conditions, the potential exists for overland flow to drain to the future depressed section. As part of this drainage study, a detailed overland flow analysis will be completed using SWMM to determine a recommendation to prevent the overland flow from entering the future depressed section. The purpose of this technical memorandum is to outline the approach used to develop the hydraulics for the SWMM model.

Objective

Develop a model that can estimate the amount of overland flow approaching the existing and proposed depressed sections from the north and west, as well as the subsurface flow that currently passes through the right-of-way via storm sewer, siphon, and/or pump station. This model will include overland flow paths and storage capacity, as well as trunk level storm sewer information.

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Hydraulic Methodology

Vertical Datum

The project vertical datum is NAVD88, with no vertical adjustment. The LiDAR on which this analysis was developed is based on NAVD88, 2001 Adjustment. The vertical difference between those datums in the project area is 0.06 ft (NAVD88, 2001 Adj + 0.06 = NAVD88). Because of the nature of the analysis, and the fact that it is relying on LiDAR for storage and other information, this difference of 0.06 ft (about ½ inch) is not deemed sufficient to warrant a vertical adjustment for this overland flow analysis.

Model Extent

The model extent was determined by reviewing the City of Houston GIMS storm sewer network and overland flow paths determined from the 2008 LiDAR dataset. Overland flow toward the project alignment is complicated by the conflicting grades of the overland flow system (generally northwest to southeast) and the storm sewers (generally south to north) in the Downtown Houston area. Because of this conflict, the amount of flow that is captured by the storm sewer system and flows north to Buffalo Bayou and the amount that surcharges the storm sewer system and flows south across the project alignment toward Brays Bayou cannot be determined by a simple drainage area calculation. This complexity affected the selected model extent significantly.

To the north and south, the boundaries of the model were generally at the last ridges that result in gravity drainage toward Buffalo Bayou and Brays Bayou, respectively. Those ridges are shown as the purple line on **Figure 1**. To the east, the model extends to where the major storm sewer systems have an open channel outfall at the upstream end of HCFCD Unit D103-00-00. To the west, the model extends to near HCFCD Unit W129-00-00 north of I-69, and includes HCFCD Unit D111-00-00 (Poor Farm Ditch) south of I-69. These extents are sufficiently far from the project area that minor issues with boundary conditions will have a relatively small impact on the project results.

The model extent is the orange boundary shown in **Figure 1**.

Adjacent open channel system D111-00-00

An open channel with HCFCD Unit Number D111-00-00 (Poor Farm Ditch) runs along the southeast portion of the detailed model area (lower left portion of **Figure 1**). This channel's geometry was imported from the HEC-RAS model downloaded from the HCFCD Model and Map Management (M3) system, and merged with the rest of the SWMM model, with storm sewer and overland connections as appropriate. The model transects along D111 were trimmed to remove the left overbank, because that area is included in the detailed SWMM model. The drainage area west of the channel was included up to the TSARP drainage area boundary with a relatively low resolution, divided into about 5 sub-areas, using the methodology described in the hydrology memo. This area is shown on **Figure 1** between the channel and the orange drainage area boundary line.

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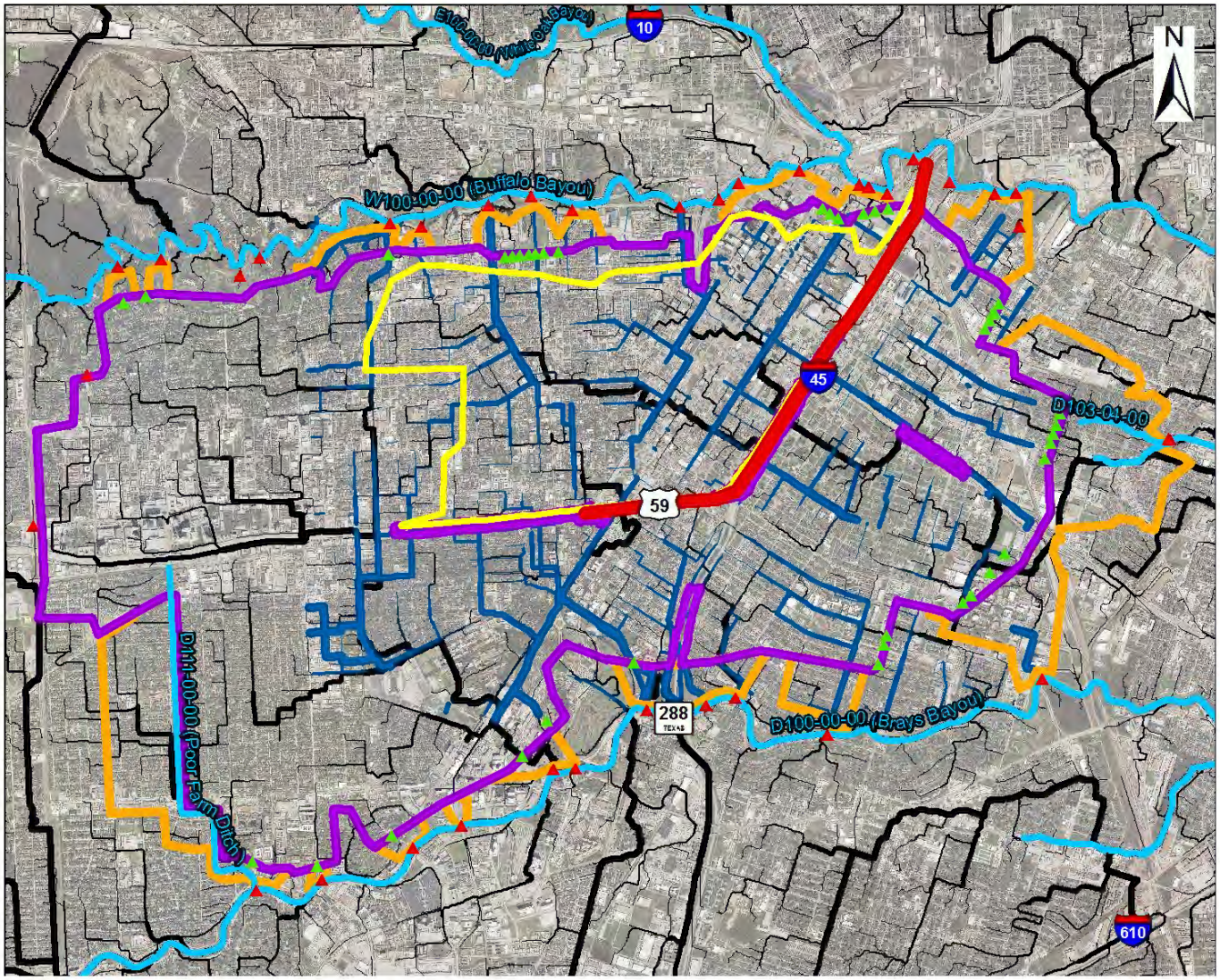

Figure 1 – Drainage Area Limits

Figure Key

- Black Lines – overland flow paths (thicker lines means larger overland flow area)
- Blue lines – storm sewer 36-inch and larger (thicker lines means larger pipe size)
- Yellow boundary – area that drains to I-69 corridor via overland topography
- Purple boundary – Detailed modeled areas
- Orange boundary – Less detailed modeled areas
- Aqua lines – HCFCD channel centerlines

Dual Drainage

A dual-drainage methodology was selected for this analysis. Flow and storage in the overland system and the subsurface system were modeled separately and the two systems were connected for the dual-drainage model.

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Overland Drainage System Modeling

The overland system model is similar to a 2D model, but uses SWMM's 1D features (storage nodes and short channel sections) to model the overland storage and flow, rather than a densely connected grid or mesh. By using this method, the full storage volume in the overland system was modeled, which is important for this project, without the computational burdens of a very fine overland grid. Storage volumes were calculated from the Non-Uniform Subsidence Adjustment (NUSA) LiDAR, on the NAVD 88, 2001 Adjustment vertical datum. The NUSA LiDAR was modified to remove small pits that affect the storage elevation curves, but do not provide significant storage, or represent features such as construction pits for building foundations that have since been filled. When extracting elevation-area data, the minimum elevation in each storage area was compared to its neighbors, and some areas with anomalous pits (sometimes a single cell in the LiDAR) were cleaned up by setting a minimum elevation to start the depth-area curve. In addition, the City of Houston building shapefile was used to increase the LiDAR elevations within building footprints. Overland connectivity was developed by creating 20 ft long natural channel sections between most neighboring overland storage areas. The GIS areas for the storage volume calculations were trimmed by 10 ft on each side from the full drainage area to avoid double-counting storage within the connecting conduits.

In general, the overland storage areas are centered at roadway intersections, with the boundaries being mid-way between them. Thiessen polygons were used as the initial method for determining drainage/storage area boundaries, with some manual clean-up so that most of the drainage paths are down roadways, and that flow cannot 'skip' from block to block across a high back lot line. The intent of the analysis is to have the boundaries generally at the high point between neighboring inlets, however it is understood that for a model of this size, not all boundaries will have been placed at a high point. A description of the Thiessen polygon process is included in the hydrology memo. **Figure 2** shows how the storage areas are connected generally along roadways.

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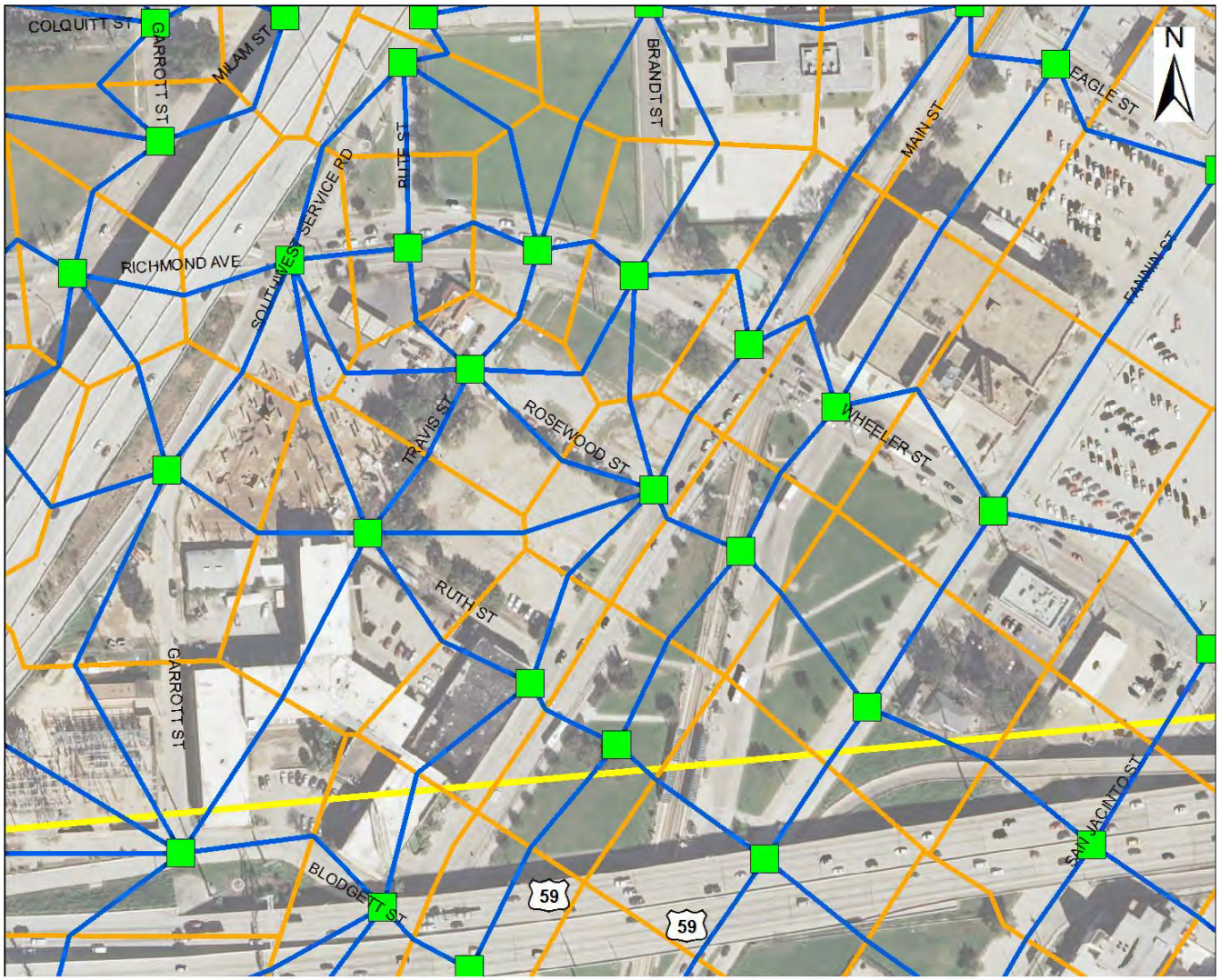

Figure 2 – Storage areas and overland connections

Figure Key

- Green squares – Overland sags (typically street intersections) that are storage nodes in the model
- Blue lines – Overland flow paths
- Orange lines – Storage area/drainage area boundaries

Transects along the boundaries between street low points were created using ArcHydro tools, and connecting conduits were created in PCSWMM between the street low points. No transect shorter than 30 ft long connecting overland nodes was used in the analysis. PCSWMM tools were used to extract station-elevation curves for each transect. Channel banks were set at the edge of pavement using the City of Houston pavement edge shapefile. A custom scripting tool was used to reduce the point density of the transect station-elevation curves created by PCSWMM, while maintaining the overall shape of the curves.

The head loss in the overland system is primarily associated with the flow down the street cross-sections. These flow paths are represented in the model with the 20 ft long channel sections, rather than the full length of the street. With the shorter length, the head loss

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between intersections would be much less than the actual head loss down the full length of roadway between intersections. To achieve an equivalent head loss, the roughness of the cross-section was increased, so that the total head loss between adjacent overland nodes is reasonable and corresponds to the anticipated head loss along the full street length.

A pair of testing models was developed to test this concept and determine an appropriate roughness value to use in the final model to achieve the correct head loss between intersections. These two models consist of the same 15 block linear flow path through the downtown area along Crawford Street, between Pease Street and Elgin Street. Roughness values of 0.015 and 0.055 were selected for the full length model (Long) for the channel (roadway) and overbanks, respectively, to represent unrestricted flow through the street cross-section, and somewhat obstructed flow outside the gutters, including the effects of bushes, trees, trash cans, etc. This model represents the actual head loss expected along this section of roadway. The Long model includes sags and high points, and the full roadway length, with ~150 ft long half-block channel segments, while the Short model includes storage areas and 20 ft long channels at the high points, as are used in the NHHIP SWMM models. **Figure 3** shows the Long model's configuration, with the roadway high and low points and the distance between intersections. **Figure 4** shows the Short model's configuration, showing the intersections separated by the 20 ft long overland channels. The darker line of each color in **Figure 4** shows the "Short" model. The Short model's water surface elevations will not show on the Long model's profile, because there are no nodes at the high points. **Figure 4** shows that the head losses are similar between the two models. Four constant flow values were tested (10 cfs, 50 cfs, 100 cfs, and 250 cfs), representing conditions where most of the flow occurs within the roadway, where the flow slightly exceeds the curb, and two conditions where flow extends outside the public right-of-way. The most downstream block in each model uses the long configuration, so that the downstream boundary conditions are the same for comparison. That block is not shown in the figures.

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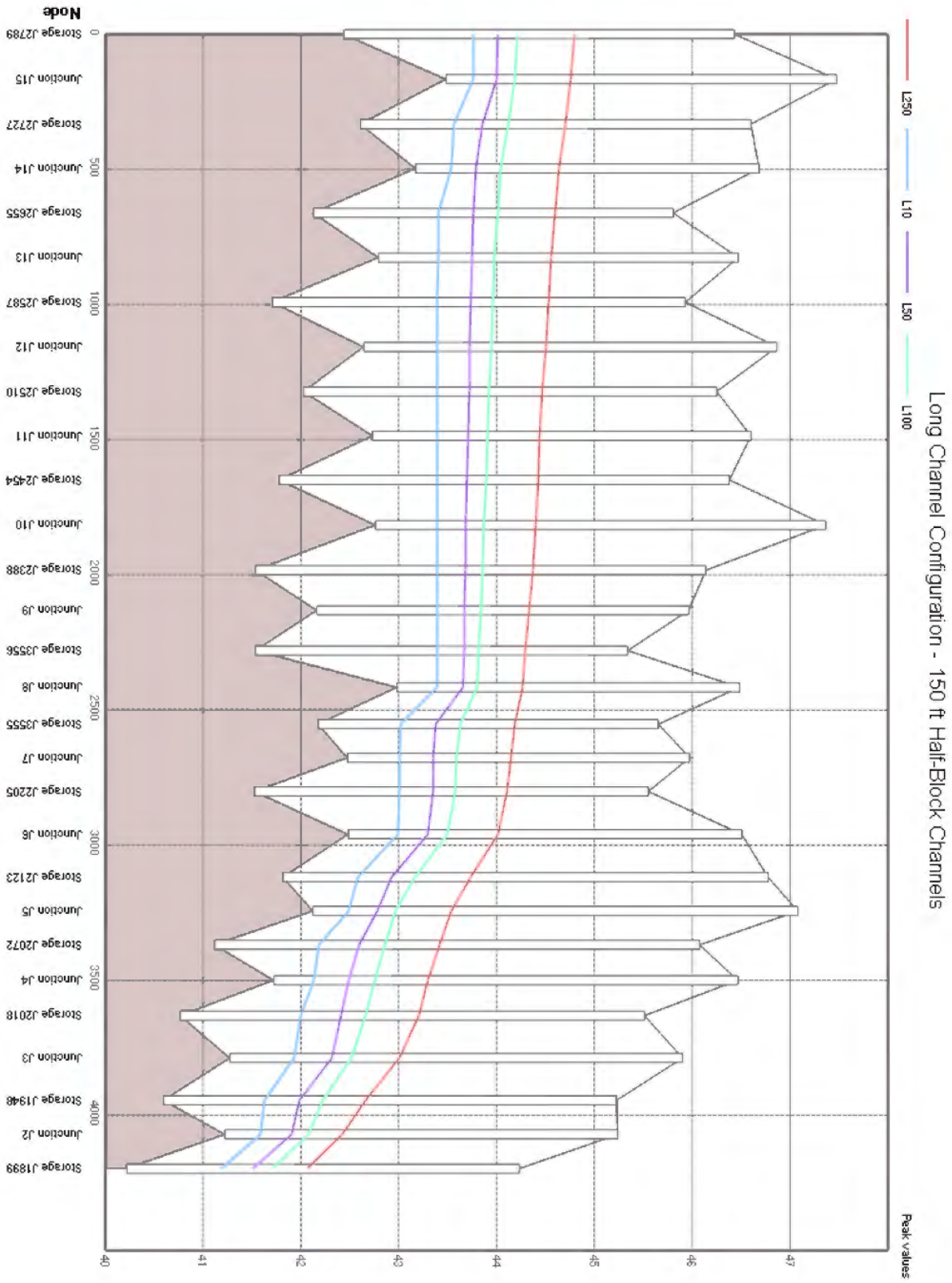

Figure 3 – Overland Flow Path Calibration - Long Configuration

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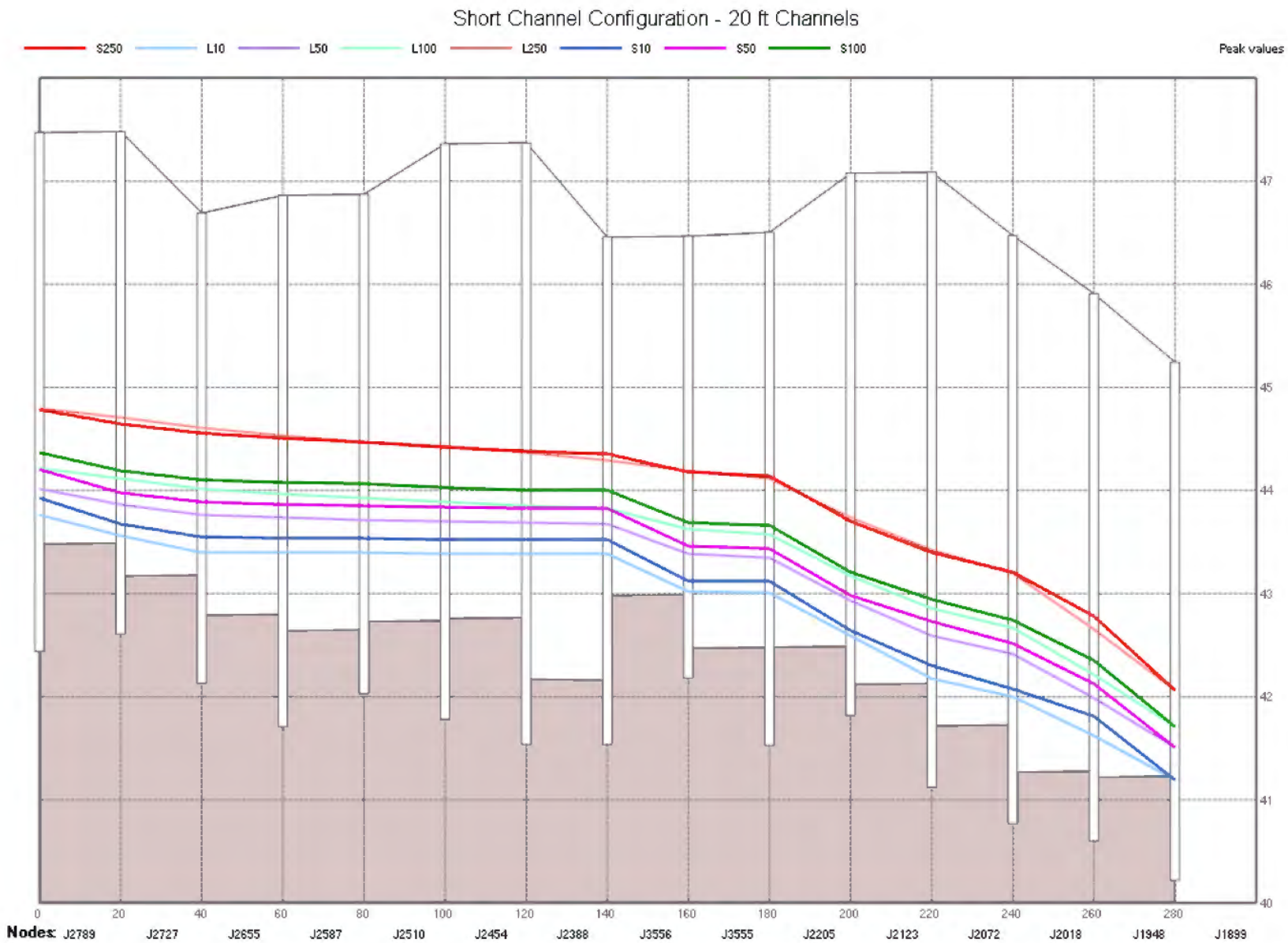

Figure 4 – Overland Flow Path Calibration - Short Configuration, With All WSE Values

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After several comparison runs, roughness values of 0.025 for the channel portion and 0.25 for the overbank portion were selected and used in all the NHHIP overland flow models. Using those roughness values,the WSE values are within about 1 to 2 inches of each other for all four different models, with the water surface elevations in the Short model (i.e., the method used in the NHHIP overland flow SWMM models) being slightly high for lower flows and very close for higher flows.

Subsurface Drainage

The subsurface drainage model was developed using the City of Houston GIMS storm sewer information as a starting point to represent the conveyance capacity of the storm sewer network. A separate subsurface system model was developed, and run with hypothetical inflows for debugging, prior to merging with the surface system model. Major trunklines and laterals from the GIMS system were kept in the model, with the final leads to inlets removed. The GIMS database's connectivity and pipe size data are generally reliable; however the flowline information varies depending on the date of construction. Some pipes do not have flowlines, and others do not have pipe size information.

Missing pipe size information was inferred from neighboring systems. The majority of missing pipe size information were smaller pipes. For the few larger systems that had missing information, the upstream and downstream pipes of these systems were often either the same size or very close in size, so the missing pipe sizes that were inferred should be close to the correct value. The Harris Gully box culverts that run under Rice University were updated based on prior knowledge of that system's configuration. In addition, the larger systems with estimated sizes were located a sufficient distance away from the project area to not have a significant impact the project results. **Figure 5** shows the locations where the GIMS size data was estimated.

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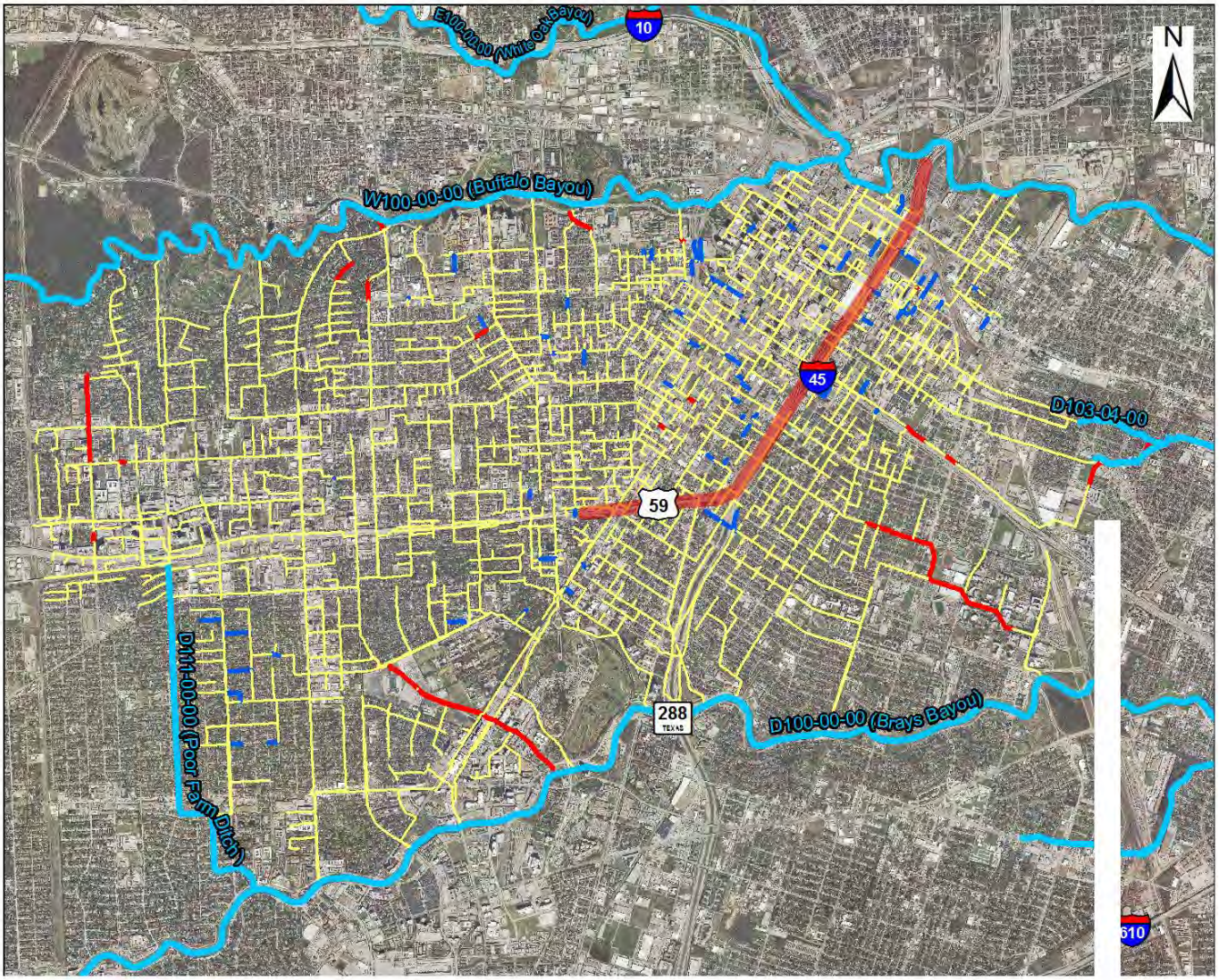

Figure 5 – Locations of GIMS pipes with estimated size.

Figure Key

- Dark Red Lines – GIMS storm sewers with estimated size greater than 3 ft
- Blue Lines – GIMS storm sewers with estimated size less than or equal to 3 ft
- Yellow Lines – GIMS storm sewers with available size information
- Transparent Red Line – Approximate project extent
- Aqua lines – HCFCD channel centerlines

Model connectivity was also inferred from neighboring systems where the model showed inconsistent results and/or model stability issues. In some areas, the GIMS systems were not connected, where trunkline size is growing and there should be a connection. The storm pipes would be connected to two nodes that were almost on top of each other. In these cases, engineering judgment was used to connect the two systems. For systems in the vicinity of the project corridor field survey information was used to verify the connectivity of storm pipes.

Flowline information from GIMS was not utilized in the model, because the GIMS flowline information is based on multiple different vertical datums which are inconsistent with each

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other, and with the ground elevation. Instead, a smoothed out ground surface was developed from the LiDAR data, and the pipe flowlines were assumed to be such that the soffits of the pipes were all 4 ft below ground surface. For much of the modeled area, this assumption provides for a storm system that more or less flows downhill toward either Brays or Buffalo Bayou, depending on which direction the pipe sizes are increasing and where the outfall is located. Throughout the model, but especially for the portions of downtown and other areas where the storm system does not parallel the ground surface, profiles along trunklines with increasing pipe size were selected in PCSWMM and the flowlines along those trunklines were adjusted so that there was a positive slope from upstream to downstream. This simplification is reasonable because the flow in the storm sewer system for the major events being assessed by this model is largely driven by pressure differences, rather than being gravity flow within the pipes. For this reason, the exact elevations and slopes of the pipes are not vital to understanding the capacity of the storm sewer system.

Other, similar issues were addressed as the subsurface drainage model was debugged.

Entrance losses of 0.15 were added to each storm sewer pipe to account for additional head losses associated with manhole access points and other junctions and turns. A test of entrance losses at 0.25 on an early version of the model decreased peak outflow by about 9 to 10%, and increases the overland WSE by about 0.2 ft. A final value of 0.15 was selected, as it represents a typical value for a straight-through access hole.

After the storm sewer information was merged with the surface system, the full model system was further simplified by joining neighboring pipes to eliminate very short pipe segments (<50 ft), where possible. For example, if two laterals enter a trunk at manholes near one another, one of the laterals would be moved, so it entered at the other manhole, and the short segment between the manholes would be joined with its neighbor to have a longer combined pipe. Where a run being joined together consisted of different pipe sizes, PCSWMM estimated an equivalent joined pipe size based on the length-weighted sizes of the pipes being joined. This estimate was reviewed by the engineer, and either accepted or modified after the join, as appropriate.

Outside Areas

Outside the primary area where overland flow is being modeled, volume-elevation curves were developed from the LiDAR, and flows were entered into the storm sewer trunklines without connecting the systems overland. The outside area boundaries were developed primarily based on storm sewer topology, following ridges between the storm sewers. As these areas are well away from the project area, and the overland peak water elevations are typically driven by the tailwater conditions near the outfalls, this level of detail was deemed sufficient. Areas outside the model flow directly to the channels, with no storm sewer connection to the detailed model area.

Overland to Subsurface Connectivity

Most of the overland storage nodes are connected to the subsurface system, with exceptions being based on engineering judgment where an overland connection to the subsurface system did not make sense. These connections were made using circular side-outlet orifices that are 10 ft in diameter. This configuration allows the flow capacity of the connection to

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smoothly begin at zero flow and increase to a substantial capacity without having an abrupt increase from zero to a high capacity that causes model instability. While inlets and leads are not directly simulated in this model, this connection configuration does provide for some head loss between the surface and subsurface systems.

Tailwater

Each of the outfalls (from the storm system and from the overland flow system) was associated with a cross-section from the HEC-RAS model for either Buffalo Bayou or Brays Bayou, as appropriate. For Brays, Bayou, rating curves were developed from the HEC-RAS model results, and flow hydrographs were taken from the HEC-HMS model results. The rating curves were adjusted so that the peak flow in the HEC-HMS hydrograph for the storm being analyzed corresponded with the modeled peak WSE. The rating curves were used to convert the flow hydrograph into a water surface elevation vs time curve for each cross-section associated with an outfall.

For Buffalo Bayou, water surface elevation vs time curves were extracted from the Buffalo Bayou HEC-RAS model developed by LAN, for the Corrected Existing scenario. Using this method, tailwater curves were developed for each outfall location, associated with three of the four storms being analyzed (100-year, 250-year, 500-year) for Brays Bayou and for all four storms, including Hurricane Harvey, for Buffalo Bayou.

For Brays Bayou and Hurricane Harvey, a separate tailwater analysis was performed, using observed high water marks, stream gage data, and the HEC-RAS model results to develop stage-time curves at each location.

Figure 1 shows the outfall locations for the storm sewer and the overland outfalls.

The Hurricane Harvey tailwater development for Brays Bayou is discussed in a separate memo titled “Overland Flow Analysis – Hurricane Harvey Brays Bayou Tailwater Development”.

Existing Depressed Sections

Once the initial model development was complete, using the approximate methods described above, the depressed sections were added to the model, using a combination of LiDAR volume estimates, as-built drawings, surveyed pipe inverts and elevations, and surveyed overland flow connectivity information. In addition to the overland volumes within the depressed section, the subsurface systems surrounding the depressed sections were checked and updated to include the capacity of siphons, pump stations, storm sewer diversions, and other features that may not have been properly represented in the GIMS data.

Calibration

Calibration of the model to Hurricane Harvey is discussed in a separate memo titled “Overland Flow Analysis – Hurricane Harvey Calibration”.

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Project name:
NHHIP Segment 3B

Project ref:
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From:
Michael McGovern & Ted Chu

Date:
June 20, 2018

NHHIP Segment 3B Drainage Study

Subject: Overland Flow Analysis –Rainfall Development for Hurricane Harvey

General

The North Houston Highway Improvement Project (NHHIP) is a proposed Texas Department of Transportation (TxDOT) project to address the existing Interstate Highway 45 (I-45) traffic capacity limitations, obsolete functionality of certain aspects of the corridor, and existing major design deficiencies. The project study limits were separated into three Segments. Segment 3 consists of the Downtown Loop including I-45, I-10, and US 59/I-69 (connecting to SH 288 and Spur 527). Segment 3B extends from Canal Street south along US 59/I-69 to the US-59/SH 288 interchange and lies within the Buffalo Bayou and Brays Bayou watersheds.

Segment 3B includes depressed main lane from just south of the US 59/I-69 crossing of Buffalo Bayou at Canal Street to the IS-59/SH 288 interchange. Currently, the I-69 corridor from SH 288 to Canal Street drains to Buffalo Bayou via a gravity storm sewer system. The proposed depressed section drainage system will outfall to Buffalo Bayou in the vicinity of the I-69 bridge-crossing of the Bayou, similar to the location of the existing outfall system. The existing topography on the west side of I-69 slopes towards the I-69 corridor. Therefore, under proposed conditions, the potential exists for sheet flow to drain to the future depressed section. As part of this drainage study, a detailed overland sheet flow analysis will be completed using SWMM to determine a recommendation to prevent the sheet flow from entering the future depressed section.

In order to examine the hydraulic response of the existing drainage systems, especially the capability of handling extreme storm events, Hurricane Harvey has been selected as the stress testing event. The NEXRAD Level III radar rainfall products were extracted and calibrated to represent the spatial and temporal characteristics of Hurricane Harvey. The processed rainfall time series were compared to a local rainfall gage, and compared spatially against each other to select a rainfall time series. This time series was used to develop inflow hydrographs for the aforementioned SWMM modeling efforts.

The purpose of this technical memorandum is to outline the approach used to develop the rainfall time series for Hurricane Harvey.

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Objective

To obtain NEXRAD radar rainfall for Hurricane Harvey and perform calibration using gage observations. Gage-calibrated rainfall time series for drainage areas within the project area were extracted and compared to gage data to determine a time series for input to the subsequent hydrologic analysis.

Data Sources

- Harris County Flood Control District – Flood Warning System (FWS): rain gage observations
- NOAA's National Centers for Environmental Information: NEXRAD Level III radar products.

Rainfall Data

The two types of rainfall data used in this study are described as follows.

1. Gage Observations

The rainfall measurements from gages that are located within the study area will be downloaded from the Harris County Flood Control District's Flood Warning System (FWS). An initial assessment of the data for Hurricane Harvey has been conducted. It is determined that the majority of the rain of the event was received between the 25th and 31st of August, 2017. Therefore, the rainfall records during this period will be extracted. **Table 1** summarizes the properties of the gage data to be extracted.

Table 1: Properties of gage data

Duration	08/25/2017 00:00 ~ 08/30/2017 24:00
Interval	1 hour
Unit	inch

2. Radar Estimates

Weather radar has the capability of generating different kinds of valuable high-definition meteorological information (e.g., hail, rainfall). In this study, radar rainfall estimates will be used in conjunction with gage measurements. The reflectivity of raindrops received by radar will be converted to rainfall intensity through the *Z-R* relationship. Detailed information regarding the conversion and the use of weather radar can be found on NOAA's websites and in research publications.
The radar estimates were downloaded from NOAA's National Centers for Environmental Information for the time period specified above. Two types of the NEXRAD WSR-88D Level III products DAA (one-hour precipitation) and DPR (Instantaneous Precipitation Rate) from the radar station KHGX (covering Houston and Galveston area, TX) were extracted. For details about the various kinds of radar products, please refer to NOAA's website, http://www.ncdc.noaa.gov/data-access/radar-data/nexrad-products. **Table 2** summarizes the properties of the extracted radar data. The one-hour precipitation data, DAA, can be used to

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produce maps such as hourly rain depth map, hourly cumulative rain depth map, storm frequency map, and maximum rain depth map for various time windows (1, 2, 3, 6, 12, and 24 hours). The instantaneous precipitation rate data, DPR, will be processed to create rainfall time series as inputs to hydrologic models.

Table 2: Properties of radar data

Type	DAA	DPR
Duration	08/25/2017 00:00 ~ 08/30/2017 24:00	08/25/2017 00:00 ~ 08/30/2017 24:00
Interval	1 hour	5 min
Unit	inch	in/hr

Radar Rainfall Calibration

It is known that radar estimates are not readily useable without prior calibration. Although radar estimates preserve the spatial characteristics of a storm event over the target areas, the estimated rainfall amounts are generally lower than the measured values. As an example, the time series comparisons between the radar and gage data at gaging station 2210 are shown in **Figure 1**. The rainfall estimates from radar (red line) follows a similar trend as the gage measurements (black line) but at a lower level.

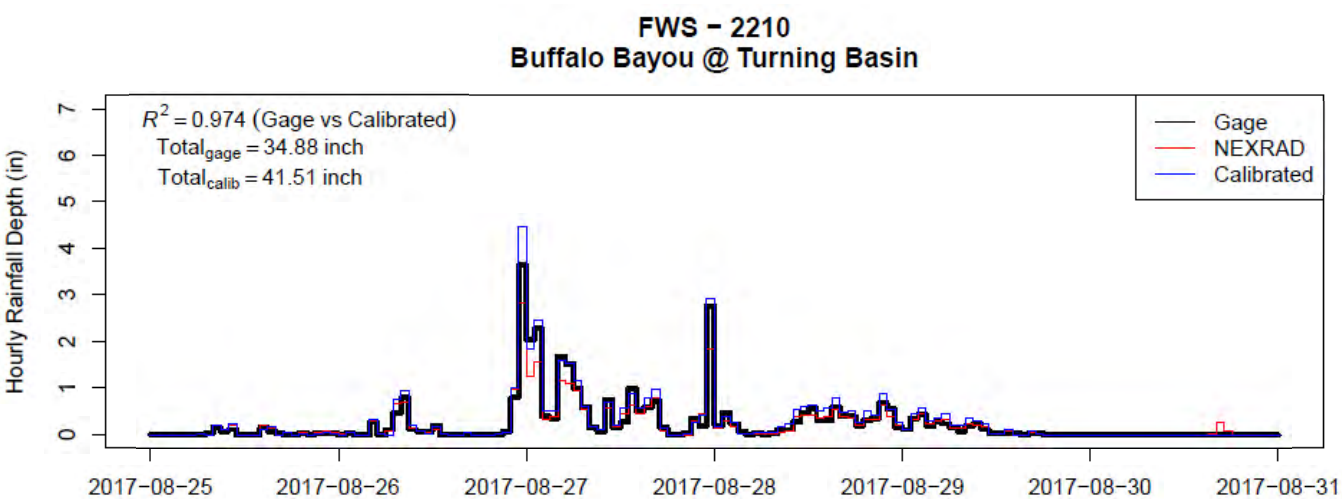

Figure 1: Rainfall time series comparison

In order to calibrate radar values using gage measurements, AECOM will apply the Regression-Kriging (RK) spatial interpolation technique. The process of RK consists of two steps. The first step is a global correction, in which a single factor obtained from the regression analysis will be multiplied uniformly to the radar values over the entire domain. Following the global correction is a regional adjustment. The residuals (difference between the values of gage and radar) at all gage locations will be used to perform the spatial interpolation using the Kriging technique. The gage-calibrated values are expected to follow closely with the gage measurements, as shown in **Figure 1** (blue line).

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Radar-Gage Comparison

Once the radar had been calibrated to the gage data, average rainfall values were extracted over four regions within the overall model area, shown in **Figure 2**. The intent for this division was to determine whether spatial variability would play an important role in the model calibration, or if a single rainfall value could reasonably used for the entire model area.

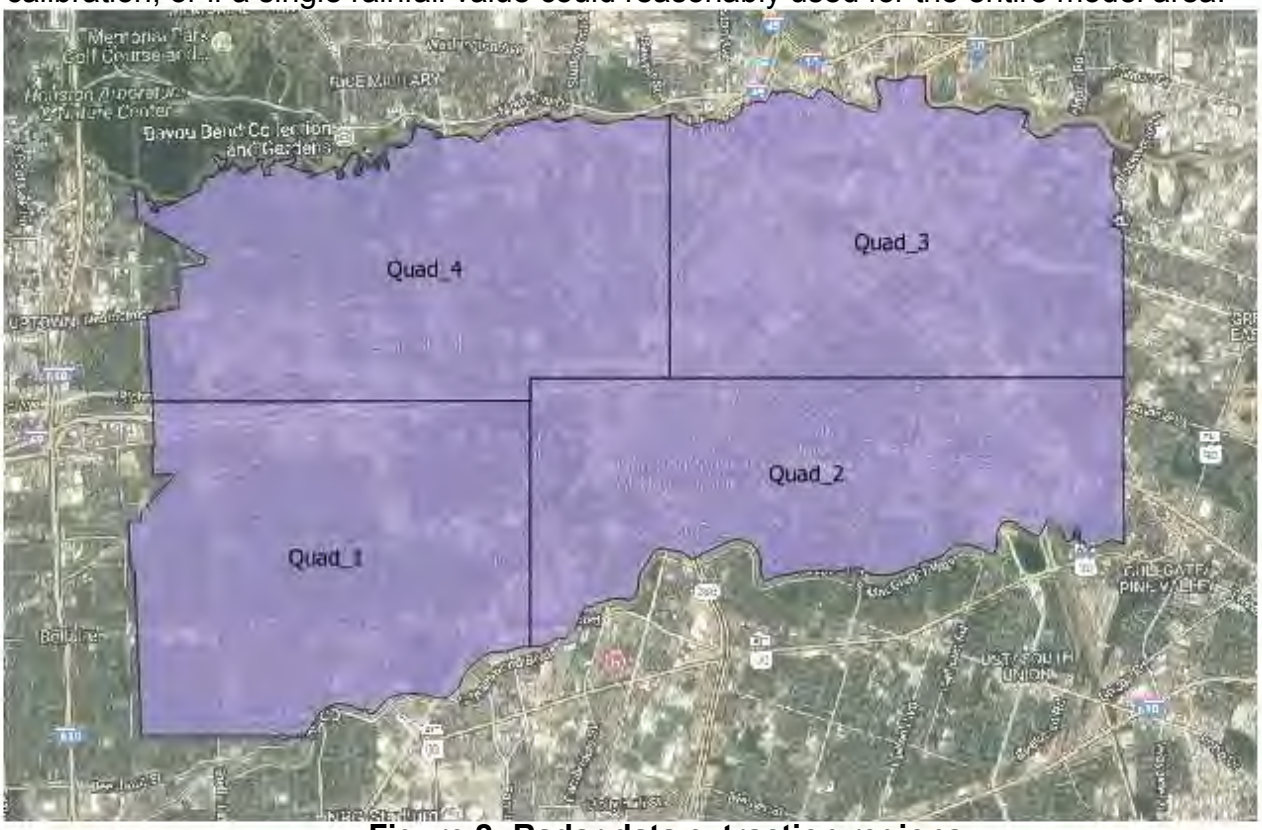

Figure 2: Radar data extraction regions.

The gage-calibrated radar depth extracted for each quadrant was compared to the gage-calibrated total over the entire region, as shown in **Figure 3**. From the figure, the conclusion was that Quad 3 rainfall is very similar to the overall, both in timing and in total rainfall, and that using that as a proxy would be reasonable for the project.

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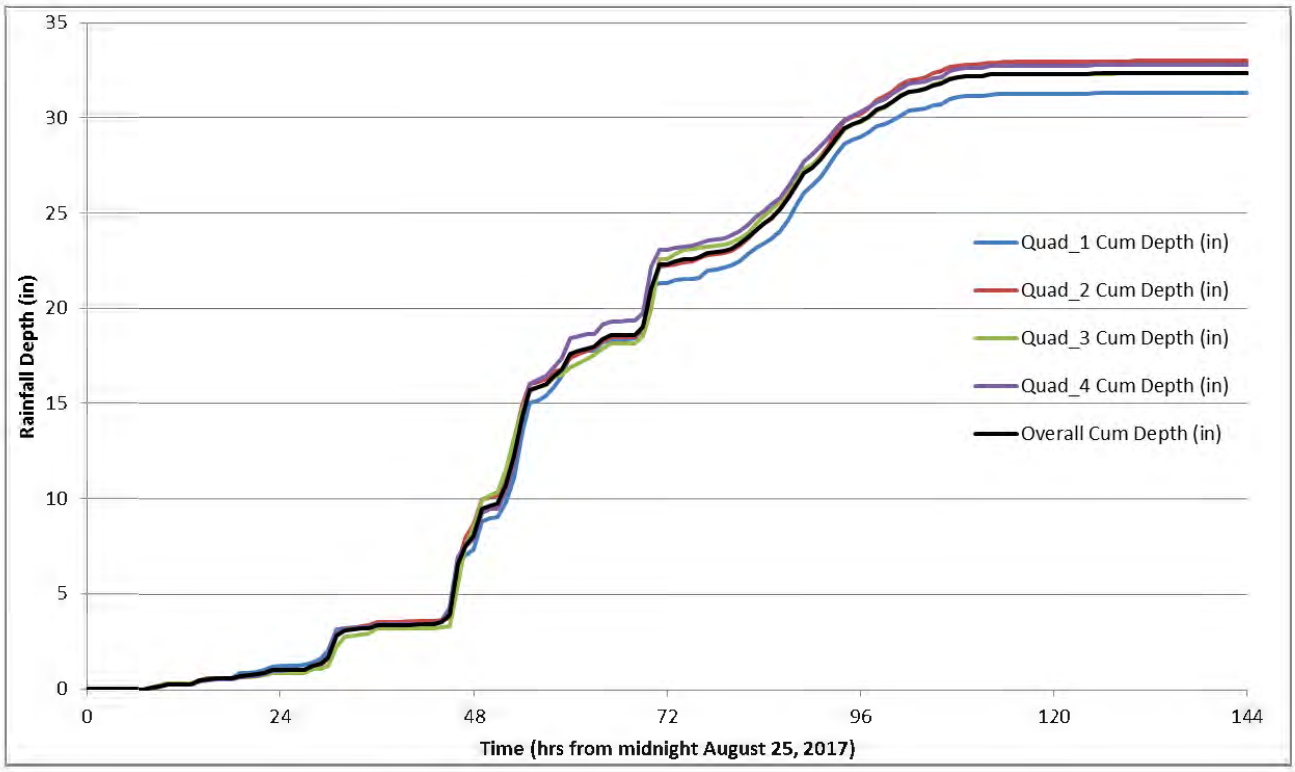

Figure 3: Radar comparison by region.

Next, the Quad 3 total and pattern were compared to three rainfall gages within the project area. These gages were those with ID 3010 (SH 288 @ MacGregor), 3040 (US 59 @ Jefferson), and 3050 (US 59 @ McGowen), with the intent that if a rainfall gage is suitable, it should be used in preference to a radar-derived value. The radar/gage comparison is shown in **Figure 4**.

After a review of the available data, gage 3040, which is located near the I-45/I-69 interchange, was selected as suitable to be used to represent the rainfall patterns for Hurricane Harvey across the entire model domain.

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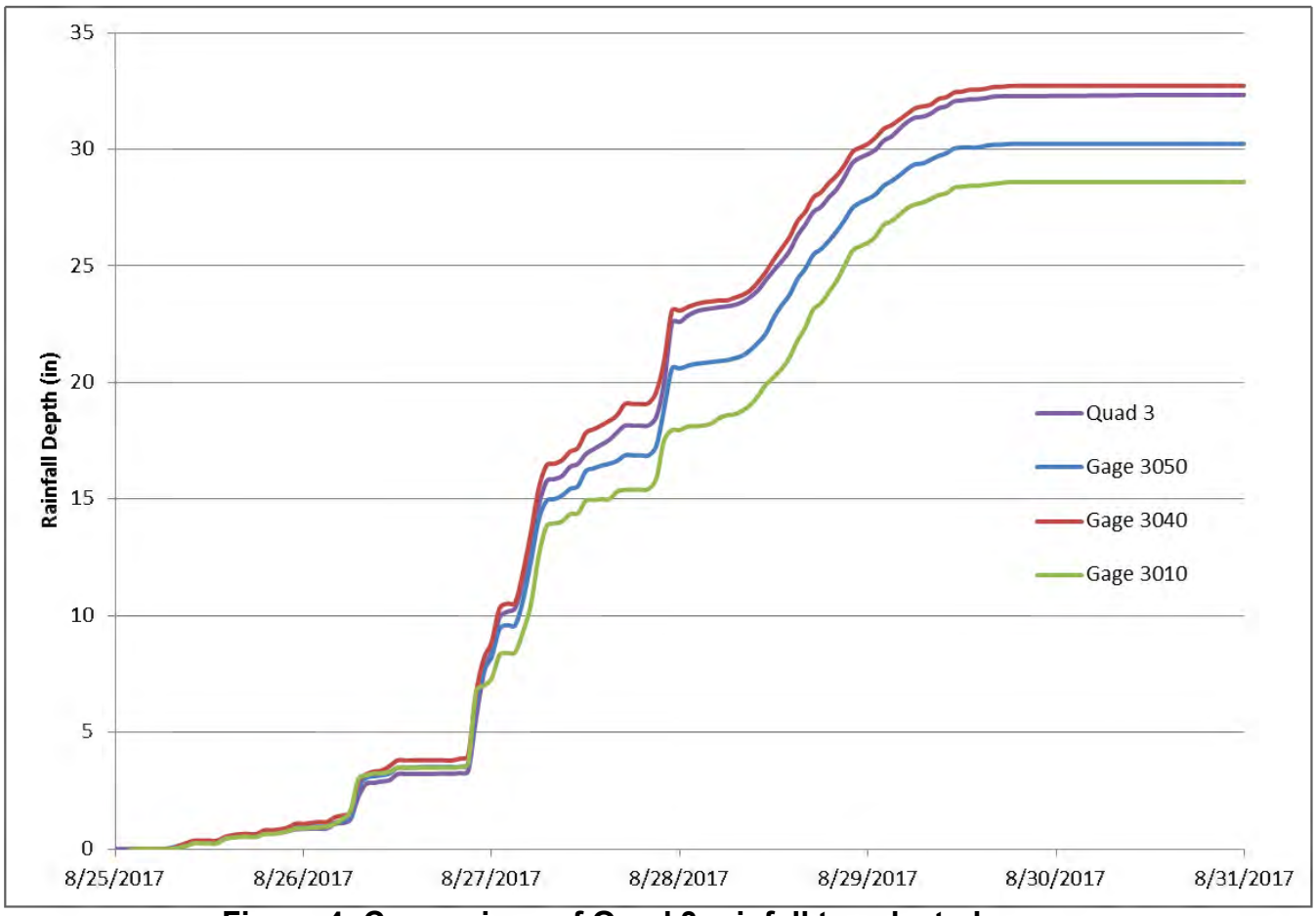

Figure 4: Comparison of Quad 3 rainfall to selected gages.

The final data for Gage 3040 was downloaded with a 5-minute time step for use in the overland flow analysis. This rainfall time series was used in the HEC-HMS model to create Hurricane Harvey rainfall hydrographs for the SWMM model.

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AECOM
19219 Katy Freeway, Suite 100
Houston, TX 77094
aecom.com

To: Elie Alkhoury, Christen Specht

CC: Eric Freidrich

Project name:
NHHIP Segment 3B

Project ref:
60563838

From:
Michael McGovern & Ted Chu

Date:
June 20, 2018

NHHIP Segment 3B Drainage Study

Subject: Overland Flow Analysis – Hurricane Harvey Brays Bayou Tailwater Development

General

The North Houston Highway Improvement Project (NHHIP) is a proposed Texas Department of Transportation (TxDOT) project to address the existing Interstate Highway 45 (I-45) traffic capacity limitations, obsolete functionality of certain aspects of the corridor, and existing major design deficiencies. The project study limits were separated into three Segments. Segment 3 consists of the Downtown Loop including I-45, I-10, and US 59/I-69 (connecting to SH 288 and Spur 527). Segment 3B extends from Canal Street south along US 59/I-69 to the US-59/SH 288 interchange and lies within the Buffalo Bayou and Brays Bayou watersheds.

Segment 3B includes depressed main lane from just south of the US 59/I-69 crossing of Buffalo Bayou at Canal Street to the I-69/SH 288 interchange. Currently, the I-69 corridor from SH 288 to Canal Street drains to Buffalo Bayou via a gravity storm sewer system. The proposed depressed section drainage system will outfall to Buffalo Bayou in the vicinity of the I-69 bridge-crossing of the Bayou, similar to the location of the existing outfall system. The existing topography on the west side of I-69 slopes towards the I-69 corridor. Therefore, under proposed conditions, the potential exists for sheet flow to drain to the future depressed section. As part of this drainage study, a detailed overland sheet flow analysis will be completed using SWMM to determine a recommendation to prevent the sheet flow from entering the future depressed section. In order to obtain reasonable modeling results, proper tailwater conditions at the system outfall nodes are required.

The purpose of this technical memorandum is to outline the approach used to develop the time history of WSE at two outfall locations along Brays Bayou during Hurricane Harvey.

Objective

To interpolate the time series of WSE at two outfall nodes along Bray Bayou during Hurricane Harvey.

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Data Sources

- Harris County Flood Control District – Flood Warning System (FWS): stream gage observations at Stations 400 and 410.

Stream Data

The flow information including flow rate and water surface elevation from gaging stations 400 and 410 located from upstream to downstream along Brays Bayou will be downloaded for the duration of Hurricane Harvey. The locations of the stations as well as the two outfall nodes (Brays_1 and Brays_2) are shown in

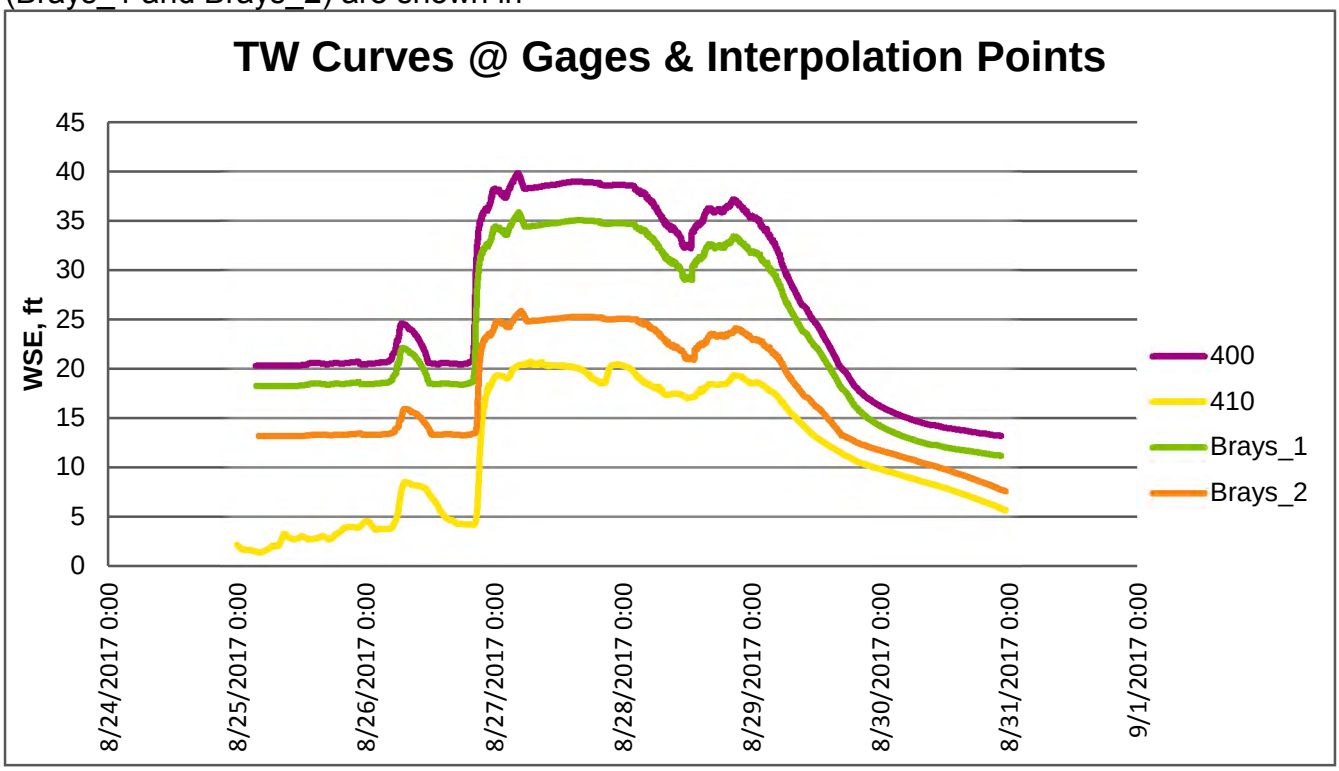

Figure .

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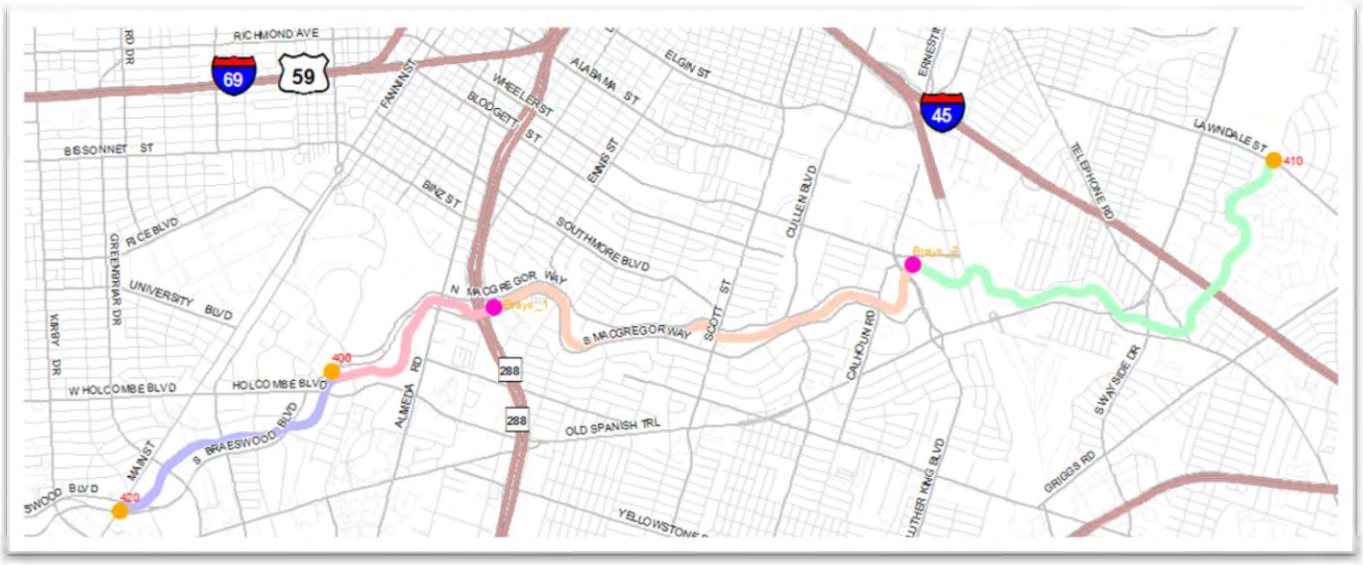

Figure 1: Locations of Gaging Stations and Interpolation Points.

Tailwater WSE Interpolation

The max WSE for outfall nodes Brays_1 and Brays_2 will be linearly interpolated using the maximum WSE at stations 400 and 410. **Table 1** summarizes the maximum WSE recorded at stations 400 and 410. Other information such as the distance and slope between the two stations is also provided.

Table 2: Gaging Station Properties.

Station	WSE_max Harvey	Distance, ft	Slope
400	39.9’	NA	NA
410	20.7’	37280.0	-0.00066

Once the maximum WSE at nodes Brays_1 and Brays_2 are interpolated, adjustment to the time of arrival will need to be made. For this study, the shape of the flood way will be assumed to remain the same as it propagates downstream. The WSE time series at stations 400, Brays_1, Brays_2, and 410 are presented in **Figure 2**. The interpolated maximum WSE and timing adjustment are included in **Table 2**.

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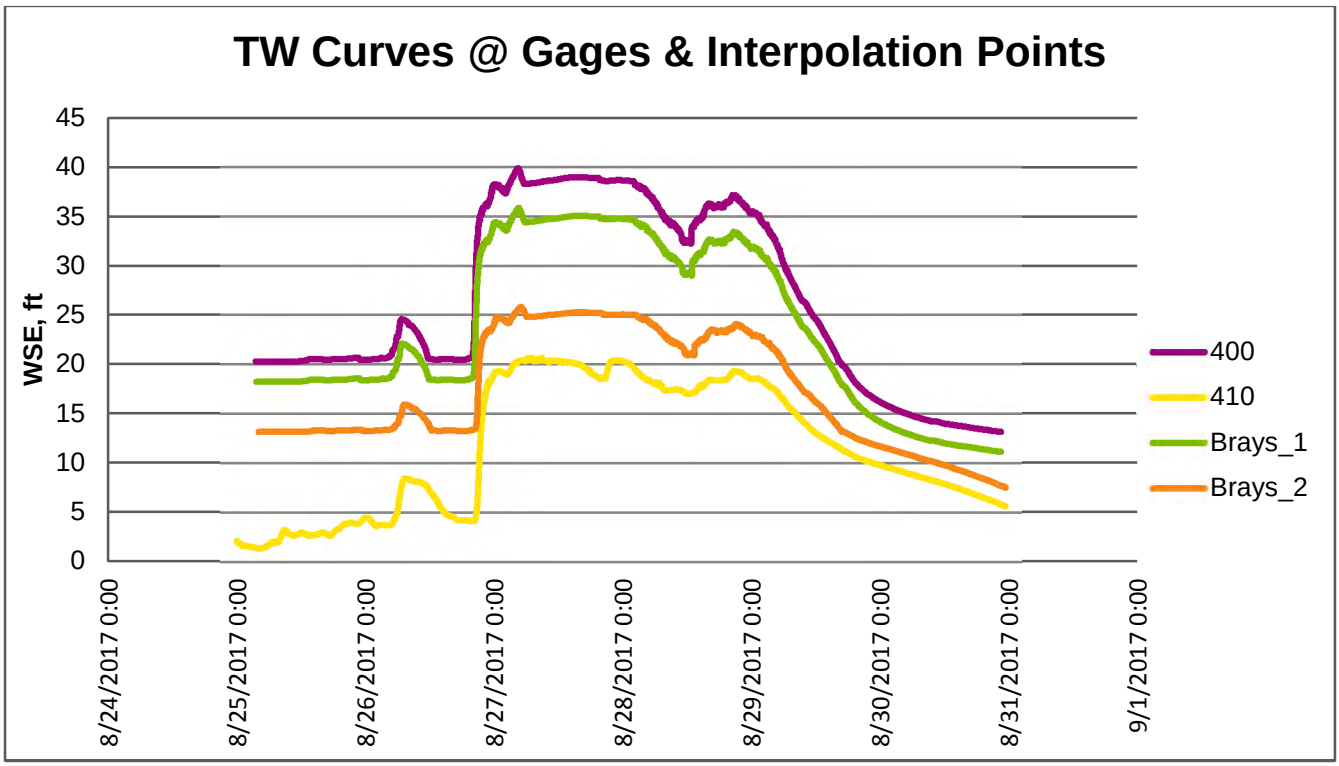

Figure 2: WSE Time Series.

Table 2: Interpolated Information.

	WSE_interp Harvey	Distance from Station 400, ft	Lag, min
Brays_1	35.9’	6102.0	8
Brays_2	25.9’	15211.0	33

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AECOM
19219 Katy Freeway, Suite 100
Houston, TX 77094
aecom.com

To: Elie Alkhoury, Christen Specht, and Eric Friedrich

Project name:
NHHIP Segment 3B Drainage Study

From:
Jessica Rogers & Mike McGovern

Date:
June 18, 2018

I-45 South Mitigation Analysis

General

The North Houston Highway Improvement Project (NHHIP) is a proposed Texas Department of Transportation (TxDOT) project to address the existing Interstate Highway 45 (I-45) traffic capacity limitations, obsolete functionality of certain aspects of the corridor, and existing major design deficiencies. The project study limits were separated into three Segments. Segment 3 consists of the Downtown Loop including I-45, I-10, and US 59/I-69 (connecting to SH 288 and Spur 527). Segment 3B extends from Canal Street south along US 59/I-69 to the US-59/SH 288 interchange and lies within the Buffalo Bayou and Brays Bayou watersheds.

Segment 3B includes the I-45 South corridor from the interchange of I-69 and I-45 to approximately Tierwester Street. This section is drained by a box culvert system along St. Joseph's Street that drains south to Brays Bayou. The purpose of this technical memorandum is to outline the approach to be applied to the mitigation analysis for the I-45 South section of the project.

Objective

Develop a mitigation approach for the I-45 South section from I-69 to Tierwester Street that shows no adverse impact to existing conditions for storm events up to an including the 100-year storm event.

Mitigation Approach

The mitigation approach includes comparing the existing and proposed drainage areas to the I-45 south drainage system and the change in impervious cover associated with the proposed project compared to existing conditions. This comparison of drainage areas and impervious cover values will show that under proposed conditions there is a significantly smaller contributing drainage area to the I-45 south drainage system.

Existing .v. Proposed Drainage Areas

Currently, a section of the I-69 corridor drains to the I-45 South trunk line, as shown by the drainage area in **Figure 1**. This section includes areas west of I-69 between Pease Street and Clay Street. The I-45

South section is serviced by a trunk line along St. Joseph's Street that drains south east, ultimately outfalling into Brays Bayou. This trunkline is assumed to have a 2-year level of service.

Under proposed conditions, the runoff from the area north of St. Emanuel Street will be redirected away from the St. Joseph's Street trunkline via a proposed trunkline system along St. Emanuel Street that will outfall to Buffalo Bayou on the north end of the project. In addition, runoff on the west side of I-69 will be intercepted by the Hamilton Street collector system and will drain north, ultimately outfalling into Buffalo Bayou. The proposed trunk line systems can be seen in **Figure 2**. Redirected flow into the proposed collector systems will be mitigated through the regional detention basin proposed near Buffalo Bayou. The proposed system results in the drainage area to the I-45 South trunkline system being reduced from approximately 234 acres to 116 acres.

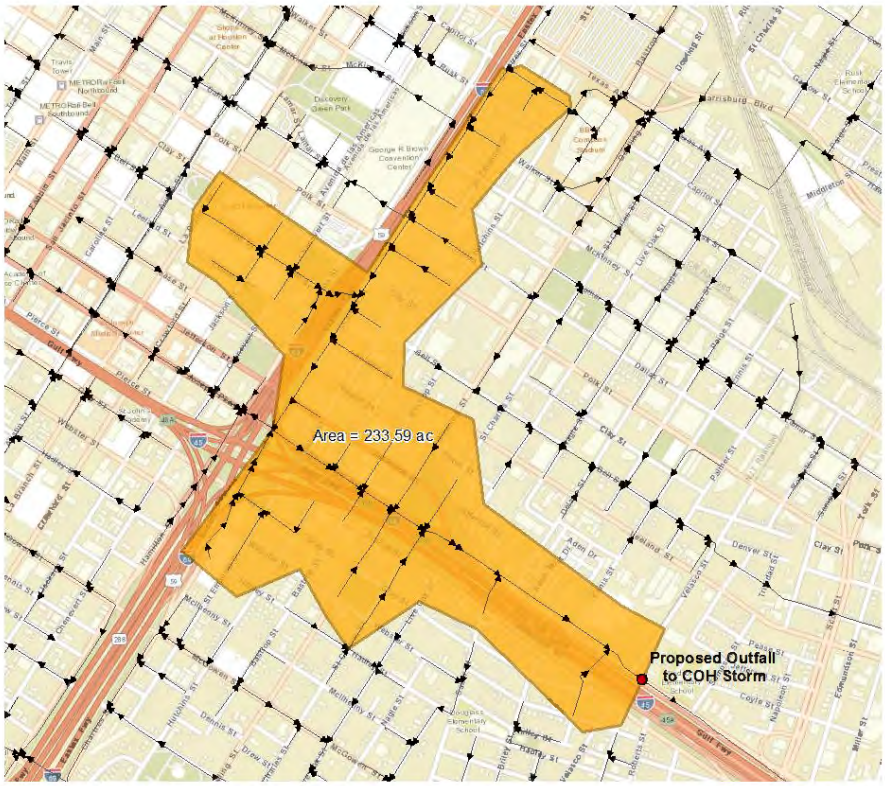


Figure 1 – Existing I-45 South Trunk Line Drainage System

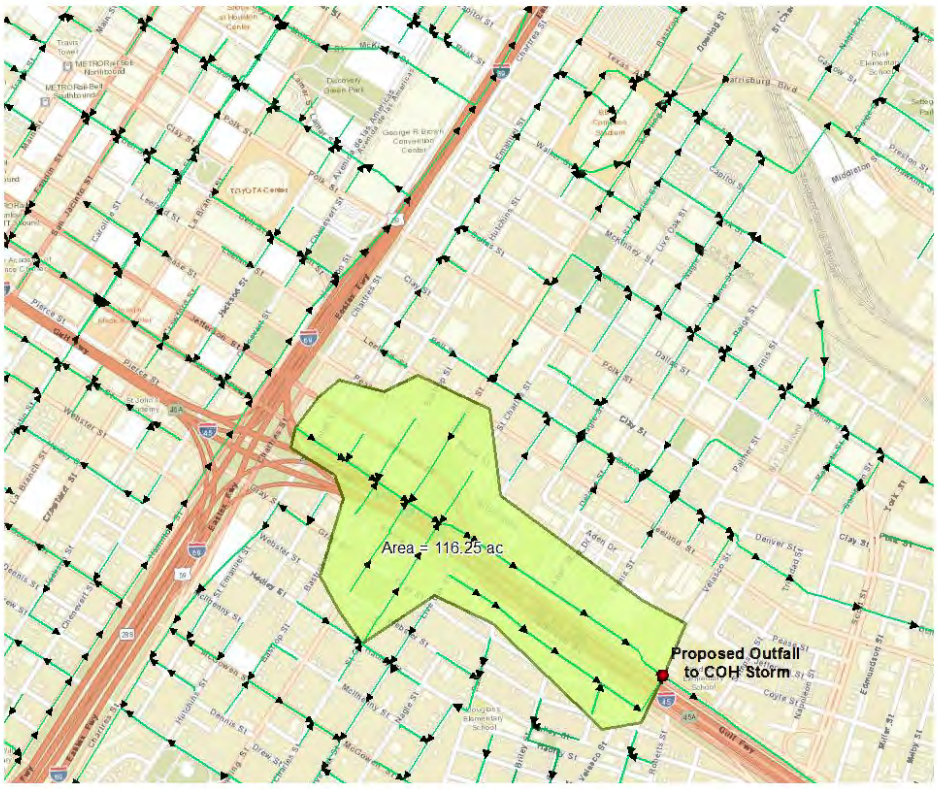


Figure 2 – Proposed I-45 South Trunk Line Drainage System

Existing .v. Proposed Landuse within ROW

It is anticipated the increase in impervious cover associated with the development within the ROW will be insignificant as any increase in additional pavement will potentially be offset by the removal of select roadway sections in the area of the I-45/I-69 interchange.

Recommended Mitigation Approach

- Quantify the change in impervious cover along the I-45 South corridor from existing to proposed conditions, showing there is minimal increase, as the majority of this area is fully developed.
- Design the I-45 South trunk line system in GeoPak Drainage to a 2-year level of service because it's outfalling to a City of Houston storm sewer system.
- Add the proposed trunk line system into the Proposed Condition Overland Sheet Flow Analysis SWMM model and compare flows at the outfall to the City of Houston storm sewer system, showing no increases to peak flows, or increased ponding depths along the I-45 corridor. This will be done for the 100-year, 250-year and 500-year storm events.

CSJ	ROADWAY	TITLE	DATE
0500-03-106 & 0177-11-24	Eastex Freeway	Storm Sewer from Bell St. to Buffalo Bayou	Sep-62
0500-03-70 & 0500-03-75	North Freeway	Freeway (Stage I) and Freeway Bridges Over M.K. & T R.R. and White Oak Bayou	Jan-60
0500-03-58 & 0500-03-68	North Freeway	Interchange with North Loop Freeway	Dec-58
0500-03-83	North Freeway	Interstate Highway No. 45 - Structure and Connecting Pavement	Mar-63
0500-03-97	North Freeway	Freeway (Stage II) from Quitman Street to Interchange with North Loop Freeway	Mar-61
0500-03-125	Interstate Highway I-45	Pierce Street Elevated Approaches	Apr-65
0500-03-335	I-45 North Freeway	Conversion of Freeway Median to Authorized Vehicle Lane	Sep-83
0500-03-412	North Freeway	I-45N ~ Bridge Over White Oak Bayou	Dec-88
0500-03-472	0.02 Mi. South of Dowling St to 0.16 Mi. South of Dallas Street	The Reconsruction of Rehabilition of a Bridge Facility Consisting of New Slabs, Bent Caps, Column Repair and Approaches	Dec-98
0027-13-174 & 0177-11-135	US 59 & Chartres Street	From Pease Intersection to Polk Intersection Along US 59 (Chartres and Main Lanes)	May-02
0500-03-239	I-45 Gulf and Pierce Elevated Freeways	I-45 Gulf and Pierce Elevated Freeways from Scott St. to Fannin St.	May-76
0500-03-316	State Highway 35	Elevated Structure and Approaches from Live Oak to Calhoun	Jun-83
0500-03-340	I.H. 45	I.H. 45 from Quitman St. to U.S. 59	Aug-82
598-01-21	State Highway 288	State Highway 288 from North Macgregor to S.H. 288 - U.S. 59 Interchange	Dec-81
177-11-28	Chartres Street	Chartres Street Elevated	Jun-64
0500-03-151, 27-13-49, 0500-03-129, & 271-17-30	I-45 - U.S. 59	I-45 - U.S. 59 Interchange from Elgin St. to Leeland Ave.	Feb-68
0500-03-320	I-45 AVL	State Department of Highways and Public Transportation Houston Urban Project - I-45 AVL - Downtown Terminus	Mar-85
	IH 45	City of Houston - Proposed 8-Inch Water Main on North Service Rd. Gulf Fwy (IH 45) from Live Oak Street to Ennis, W.D. Project No. 8500	Aug-79
		City of Houston - Storm Sewer Project P.W.A. No. 827 - Washington Terrace System	Aug-34
	Hamilton Street	City of Houston - Paving Profile of Hamilton Street from Franklin to Capitol Ave	Apr-84

CSJ	ROADWAY	TITLE	DATE
		City of Houston - Federal Emergency Adminstration of Public Works. Storm Sewer Project. Washington Terrace System	Aug-34
	Chartres Street	City of Houston - Storm Sewer on Chartres Street from Elgin Street to Francis Street - Dowling Area	Oct-56

Note: Other drainage sheets relevant to the project were obtained from record drawing plan sets from the City of Houston and utilized as part of this drainage study.

H-686-C

STATE OF TEXAS
STATE HIGHWAY DEPARTMENT

PLANS OF PROPOSED STATE HIGHWAY IMPROVEMENT

FEDERAL AID PROJECT

I-45-1(71)046 — STATE CONTROL 500-3-106
U514 (43) — STATE CONTROL 177-11-24

NET LENGTH OF PROJECT

PROJECT	ROADWAY	BRIDGES	TOTAL
I-45-1(71)046	0.00 FT. = 0.000 MI.	0.00 FT. = 0.000 MI.	0.00 FT. = 0.000 MI.
U514 (43)	0.00 FT. = 0.000 MI.	0.00 FT. = 0.000 MI.	0.00 FT. = 0.000 MI.

HOUSTON URBAN EXPRESSWAYS

EASTEX FREEWAY

STORM SEWER FROM BELL ST. TO BUFFALO BAYOU

U.S. 59 HARRIS COUNTY

STORM SEWER & EMBANKMENT

FINAL PLANS

FIELD CHANGES & SUPPLEMENTAL AGREEMENT

FIELD CHANGE NO. 1 Provided for a change of alignment of the 102 inch storm sewer.

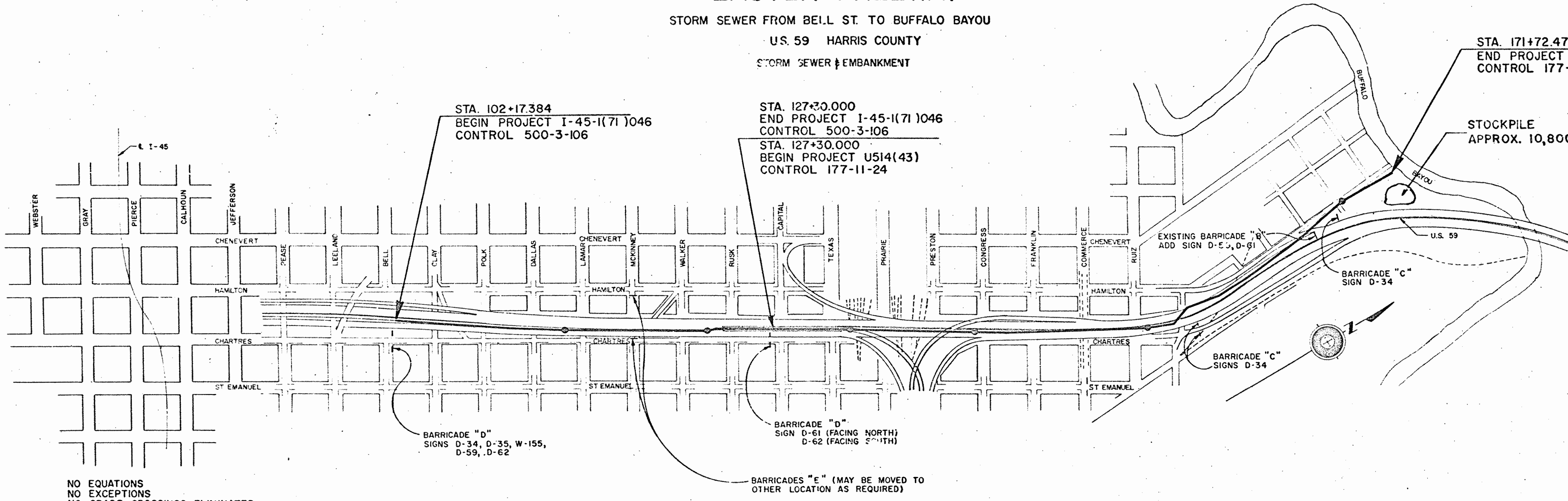
FIELD CHANGE NO. 2 Provided for the use of I beam Ribs with timber lagging under railroads in lieu of corrugated metal liner plates, permitted the splicing of elliptical ring reinforcing bars used in the 102" monolithic pipe sewer, changed the fifth paragraph of Standard Specification Item 476.3 (3), and revised alignment of 102" pipe sewer and minor addition of 18" pipe sewer stub.

LIMITS ON 104 (b) 5 NEEDS ESTIMATE MAP
BEGIN A 12+0.3 MI
END A 12+0.3 MI

DIST.	STATE	FED. AID PROJ. NO.	SHEET NO.
6	TEXAS	I-45-1(71)046 U514 (43)	2
12	HARRIS	500 3 106 / 177 11 24	US 59

INDEX OF SHEETS

SHEET NO.	DESCRIPTION
1	TITLE SHEET
2	TYPICAL CROSS SECTIONS & ROADWAY DETAILS
3	SPECIFICATION DATA SHEET
4-5	ESTIMATE & QUANTITY
6	SUMMARY OF SEWER QUANTITIES
7	PLAN & PROFILE
8	LAYOUT OF DRAINAGE AREA & VICINITY WITH RUNOFF COMPUTATIONS
9-15	STORM SEWER PLAN & PROFILE
16-21	STORM SEWER DETAILS
22-23	OUTFALL STRUCTURE DETAILS
24-25	B.W. 61 (1)(MOD.) & (2)
26	C.I.S. - 61



NO EQUATIONS
NO EXCEPTIONS
NO GRADE CROSSINGS ELIMINATED
NO GRADE CROSSINGS RETAINED

NOTES:
SEE SPECIAL PROVISION REGARDING DESCRIPTION OF PROJECT, SCOPE OF CONTRACT, AND SEQUENCE OF WORK, ETC.
SPECIFICATIONS ADOPTED BY THE STATE HIGHWAY DEPARTMENT OF TEXAS JANUARY 2, 1962, AND SPECIFICATION ITEMS LISTED AND DATED AS FOLLOWS SHALL GOVERN ON THIS PROJECT REQUIRED CONTRACT PROVISIONS FOR FEDERAL AID PROJECTS APPROVED SEPTEMBER 6, 1962.
SEE PROJECT LAYOUT SHEET FOR BARRICADES AND WARNING SIGNS.

LAYOUT SCALE: 1 IN. = 400 FT.

CITY OF HOUSTON

RECOMMENDED FOR APPROVAL 9/10/62
Eugene Maier
DIRECTOR OF PUBLIC WORKS

APPROVED 9-13-62
Louis C. [illegible]
MAYOR

TEXAS HIGHWAY DEPARTMENT

CORRECT 9-6-62
[signature]
ASST. ENGINEER MANAGER

APPROVED 9-6-62
[signature]
ENGINEER MANAGER

APPROVED 10-9-62
Clyde J. [illegible]
BRIDGE ENGINEER

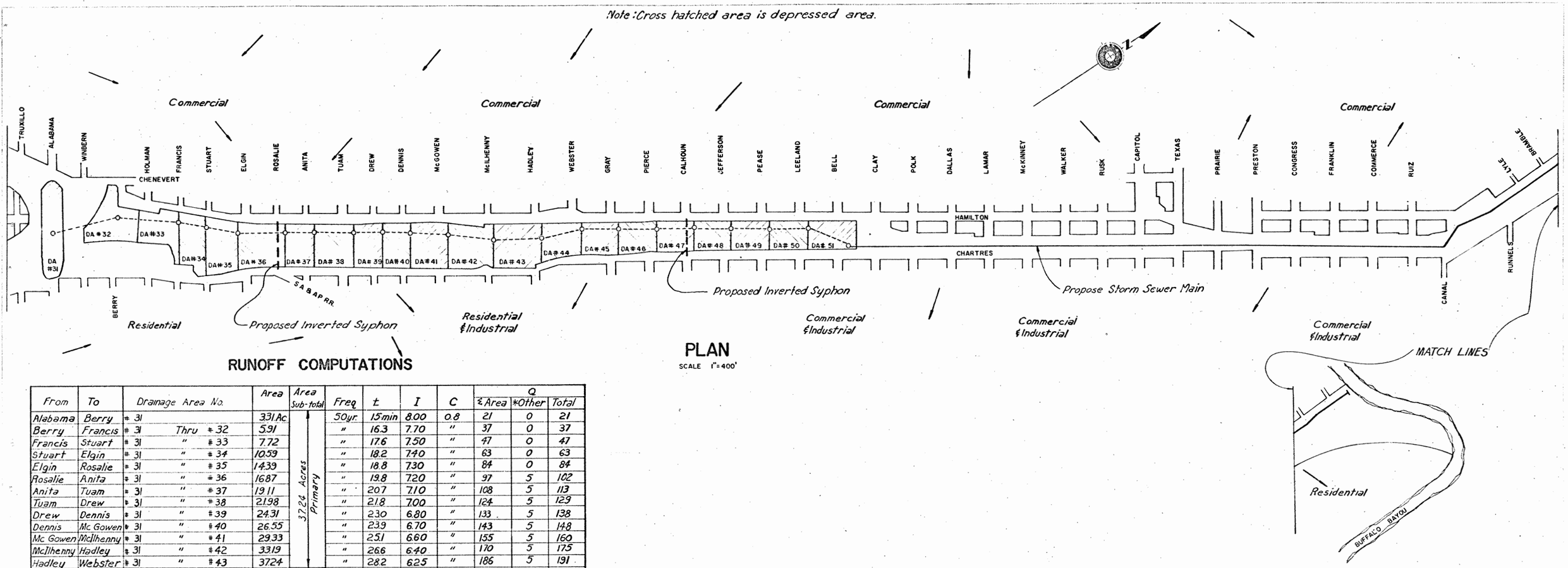
BUREAU OF PUBLIC ROADS
DEPT. OF COMMERCE

APPROVED
DIVISION ENGINEER

COUNTY HARRIS
PROJ. NO. I-45-1(71)046 U514(43)
HWY. NO. U.S. 59 LETTING DATE
DATE ACCEPTED

IPE 6850

2
992
FINAL
TOTAL SHEETS 33
AP. CARDS 3
9
COUNTY Harris
CONTROL 177-11-24
DATE FILMED 9-7-65



PLAN

SCALE 1" = 400'

RUNOFF COMPUTATIONS

From	To	Drainage Area No.	Area	Area Sub-total	Freq	t	I	C	Q % Area	Q *Other	Q Total
Alabama	Berry	# 31	3.31 Ac	37.24 Acres Primary	50yr.	15 min	8.00	0.8	21	0	21
Berry	Francis	# 31 Thru # 32	5.91		"	16.3	7.70	"	37	0	37
Francis	Stuart	# 31 " # 33	7.72		"	17.6	7.50	"	47	0	47
Stuart	Elgin	# 31 " # 34	10.59		"	18.2	7.40	"	63	0	63
Elgin	Rosalie	# 31 " # 35	14.39		"	18.8	7.30	"	84	0	84
Rosalie	Anita	# 31 " # 36	16.87		"	19.8	7.20	"	97	5	102
Anita	Tuam	# 31 " # 37	19.11		"	20.7	7.10	"	108	5	113
Tuam	Drew	# 31 " # 38	21.98		"	21.8	7.00	"	124	5	129
Drew	Dennis	# 31 " # 39	24.31		"	23.0	6.80	"	133	5	138
Dennis	Mc Gowen	# 31 " # 40	26.55		"	23.9	6.70	"	143	5	148
Mc Gowen	McIlhenny	# 31 " # 41	29.33		"	25.1	6.60	"	155	5	160
McIlhenny	Hadley	# 31 " # 42	33.19		"	26.6	6.40	"	170	5	175
Hadley	Webster	# 31 " # 43	37.24		"	28.2	6.25	"	186	5	191
Webster	Gray	# 31 " # 44	39.81	17.20 Acres Interstate	"	29.3	6.20	"	198	5	203
Gray	Pierce	# 31 " # 45	42.08		"	30.9	6.05	"	204	5	209
Pierce	Calhoun	# 31 " # 46	44.13		"	32.6	5.90	"	208	5	213
Calhoun	Jefferson	# 31 " # 47	46.02		"	33.7	5.80	"	214	10	224
Jefferson	Pease	# 31 " # 48	47.91		"	34.8	5.75	"	220	10	230
Pease	Leeland	# 31 " # 49	49.80		"	35.9	5.70	"	228	10	238
Leeland	Bayou	# 31 " # 51	54.44		"	37.1	5.60	"	244	10	254

* Quantity Limited By Pipe or Orifice Size

Basis of Design

In the vicinity of the proposed depressed freeway, the existing city storm sewers are designed on basis of a 2 year frequency.

Those areas from Holman to Hadley along the proposed depressed freeway are subject to ponding in streets and yards. The depression will be isolated from the potential pond by physical barriers.

The existing city storm sewers which now cross the area to be depressed will be replaced by inverted syphons of adequate capacity in the same vicinity. For the purpose of keeping the syphon clean, an orifice with gate mechanism will allow a limited quantity of water from the inverted syphons into the depressed freeway storm sewer only when the hydraulic gradient of the sewer is below grade in the depression.

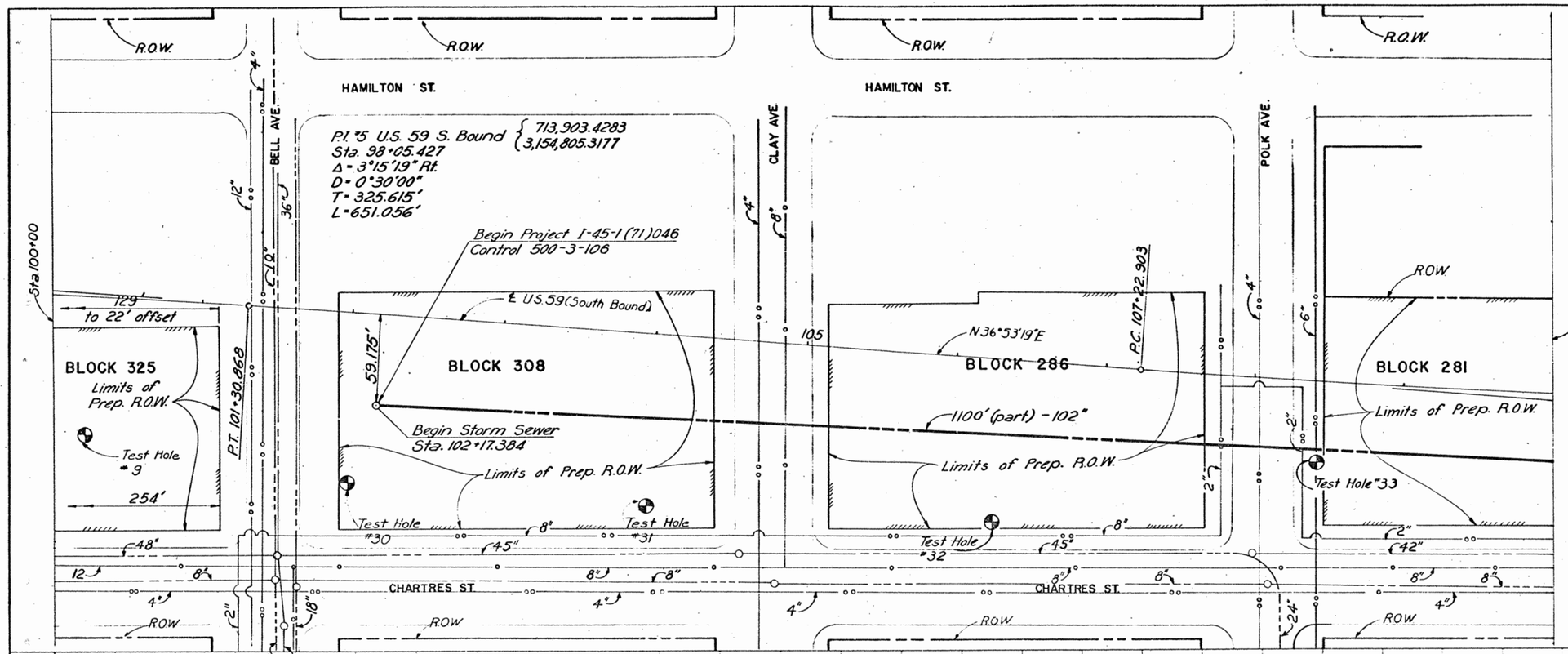
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

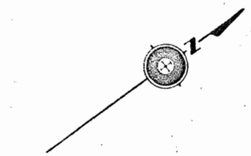
LAYOUT OF DRAINAGE AREAS & VICINITY WITH RUNOFF COMPUTATION

Dr. FWG	Drawing No. ORIGINAL	Date AUG. 1962
Ck. R.C.O.		
Ck. FWG		

I-45-(7)-046 U514 (43) 8

12 HARRIS 500 3 104 177 11 24 US 59

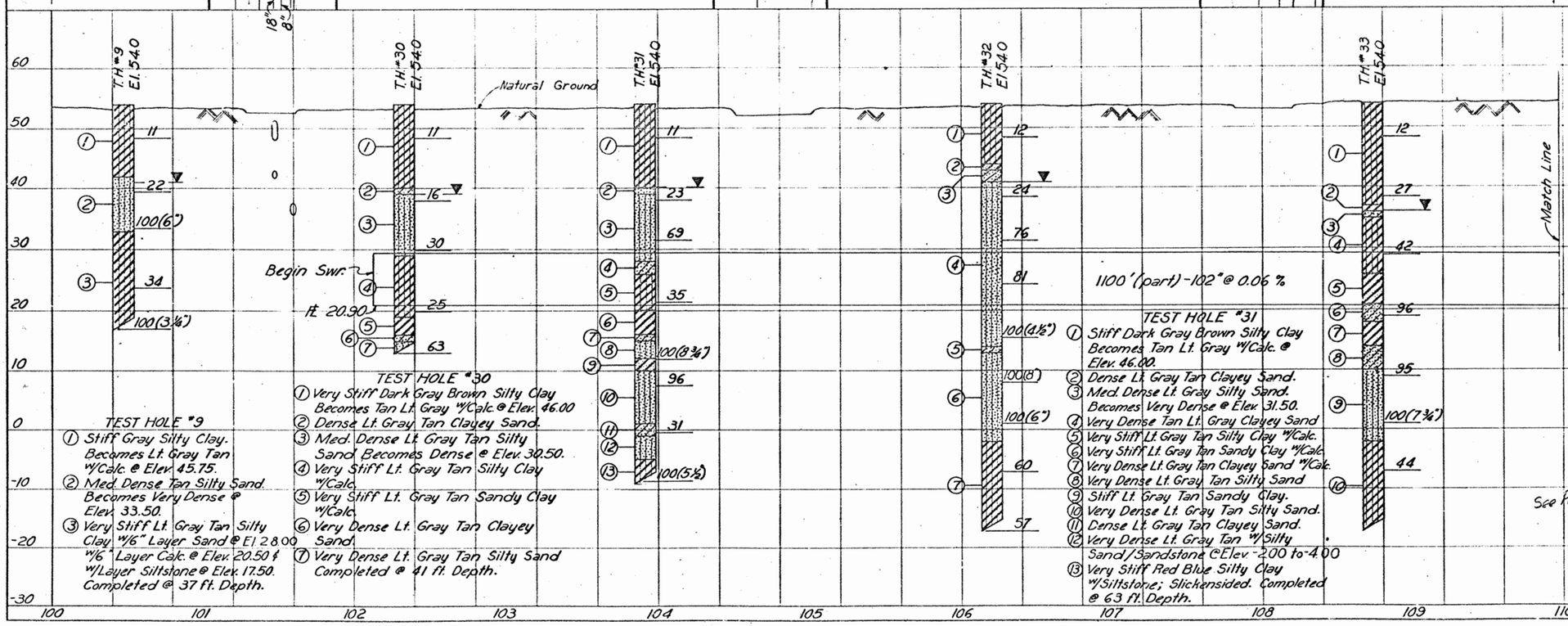




LEGEND

Water Line	—o—o—
Gas Line	—oo—oo—
Sanitary Sewer	— — —
Storm Sewer (Exist.)	— — —
Storm Sewer (New)	— — —
Misc. (As Shown)	— — —

GENERAL NOTES:
The symbol (▼) indicates elevation of water in the test holes.
The location of all utilities are approximate only.
See Sheet No. 7 Plan & Profile Sheet for tabulation of Prep. R.O.W. areas.



TEST HOLE #9
1. Stiff Gray Silty Clay. Becomes Lt. Gray Tan w/Calc. @ Elev. 45.75.
2. Med. Dense Tan Silty Sand. Becomes Very Dense @ Elev. 33.50.
3. Very Stiff Lt. Gray Tan Silty Clay w/6" Layer Sand @ El. 28.00 w/6" Layer Calc. @ Elev. 20.50 & w/Layer Siltstone @ Elev. 17.50. Completed @ 37 ft. Depth.

TEST HOLE #30
1. Very Stiff Dark Gray Brown Silty Clay Becomes Tan Lt. Gray w/Calc. @ Elev. 46.00
2. Dense Lt. Gray Tan Clayey Sand.
3. Med. Dense Lt. Gray Tan Silty Sand Becomes Dense @ Elev. 30.50.
4. Very Stiff Lt. Gray Tan Silty Clay w/Calc.
5. Very Stiff Lt. Gray Tan Sandy Clay w/Calc.
6. Very Dense Lt. Gray Tan Clayey Sand.
7. Very Dense Lt. Gray Tan Silty Sand Completed @ 41 ft. Depth.

TEST HOLE #31
1. Stiff Dark Gray Brown Silty Clay Becomes Tan Lt. Gray w/Calc. @ Elev. 46.00.
2. Dense Lt. Gray Tan Clayey Sand.
3. Med. Dense Lt. Gray Silty Sand. Becomes Very Dense @ Elev. 31.50.
4. Very Dense Tan Lt. Gray Clayey Sand
5. Very Stiff Lt. Gray Tan Silty Clay w/Calc.
6. Very Stiff Lt. Gray Tan Sandy Clay w/Calc.
7. Very Dense Lt. Gray Tan Clayey Sand w/Calc.
8. Very Dense Lt. Gray Tan Silty Sand
9. Stiff Lt. Gray Tan Sandy Clay.
10. Very Dense Lt. Gray Tan Silty Sand.
11. Dense Lt. Gray Tan Clayey Sand.
12. Very Dense Lt. Gray Tan w/Silty Sand/Sandstone @ Elev. -2.00 to -4.00
13. Very Stiff Red Blue Silty Clay w/Siltstone; Slickensided. Completed @ 63 ft. Depth.

TEST HOLE #32
1. Stiff Dark Gray Brown Silty Clay Becomes Lt. Gray Tan w/Calc. @ Elev. 46.00.
2. Stiff Lt. Gray Tan Sandy Clay.
3. Med. Dense Lt. Gray Tan Clayey Sand.
4. Med. Dense Lt. Gray Tan Silty Sand Becomes Very Dense w/Thin Layers Sandstone @ Elev. 31.50.
5. Very Dense Lt. Gray Tan Clayey Sand.
6. Very Dense Lt. Gray Tan Silty Sand w/Thin Layers Sandstone @ Elev. 8.00 Thru Elev. -1.00
7. Very Stiff Red Blue Silty Clay w/Siltstone w/6" Layer Silt @ Elev. -8.00 Slickensided. Complete @ 63 ft. Depth.

TEST HOLE #33
1. Stiff Dark Gray Brown Silty Clay Becomes Lt. Gray Tan w/Calc. @ Elev. 46.00 & Becomes Tan Lt. Gray w/Calc. Slickensided @ Elev. 41.75.
2. Stiff Tan Lt. Gray Sandy Clay.
3. Med. Dense Tan Lt. Gray Clayey Sand.
4. Very Stiff Tan Lt. Gray Silty Clay w/Calc. Becomes Lt. Gray Tan @ 27' Slickensided.
5. Stiff Lt. Gray Tan Sandy Clay.
6. Very Dense Lt. Gray Tan Clayey Sand.
7. Stiff Lt. Gray Tan Sandy Clay.
8. Very Dense Lt. Gray Tan Clayey Sand.
9. Very Dense Lt. Gray Tan Silty Sand.
10. Very Stiff Red Blue Silty Clay w/Siltstone Slickensided Completed @ 71 ft. Depth.

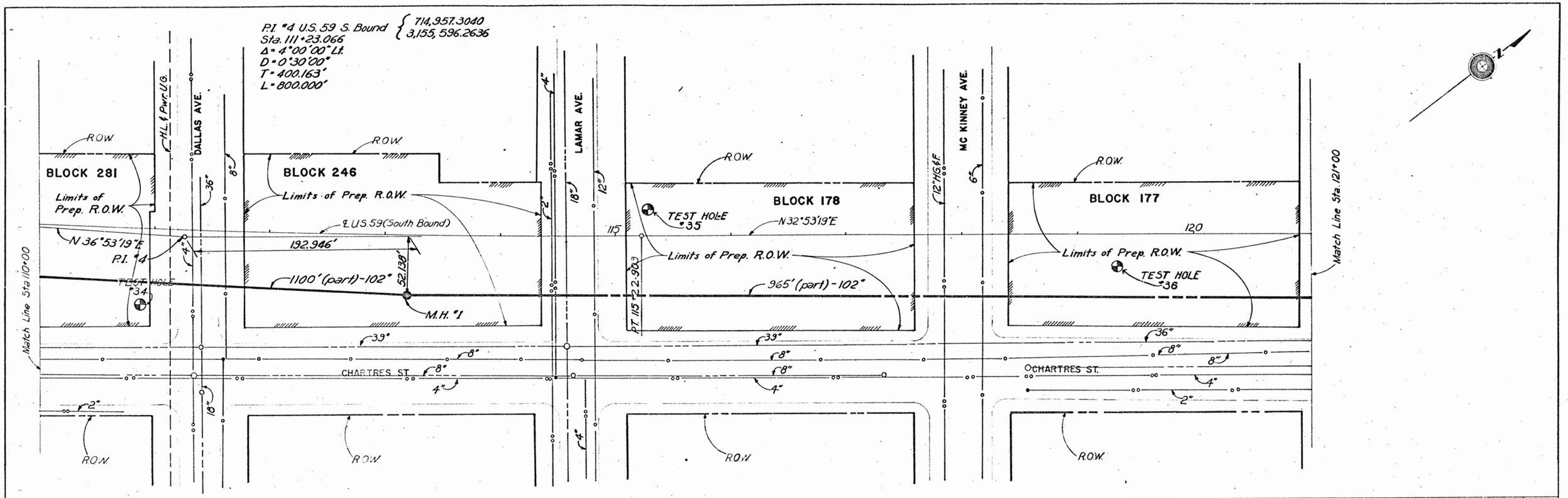
See Revised Sep'a

TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

STORM SEWER PLAN & PROFILE

SHEET 1 OF 7 SHEETS

Dn.	Drawing	Date	FED. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.	HIGHWAY NO.
Ck. Dn.	Original	June 1962	6	TEXAS	I-45-1 (71) 046 / U.S.59-1 (63)	U.S.59
Dn. C.T.M. / Ck. Dn. H.E.B.			STATE DIST. NO.	COUNTY	CONTROL NO. / SECTION NO. / JOB NO.	SHEET NO.
Tr.			12	Harris	500 / 177 / 3 / 11 / 105 / 22	9
Ck. Tr.						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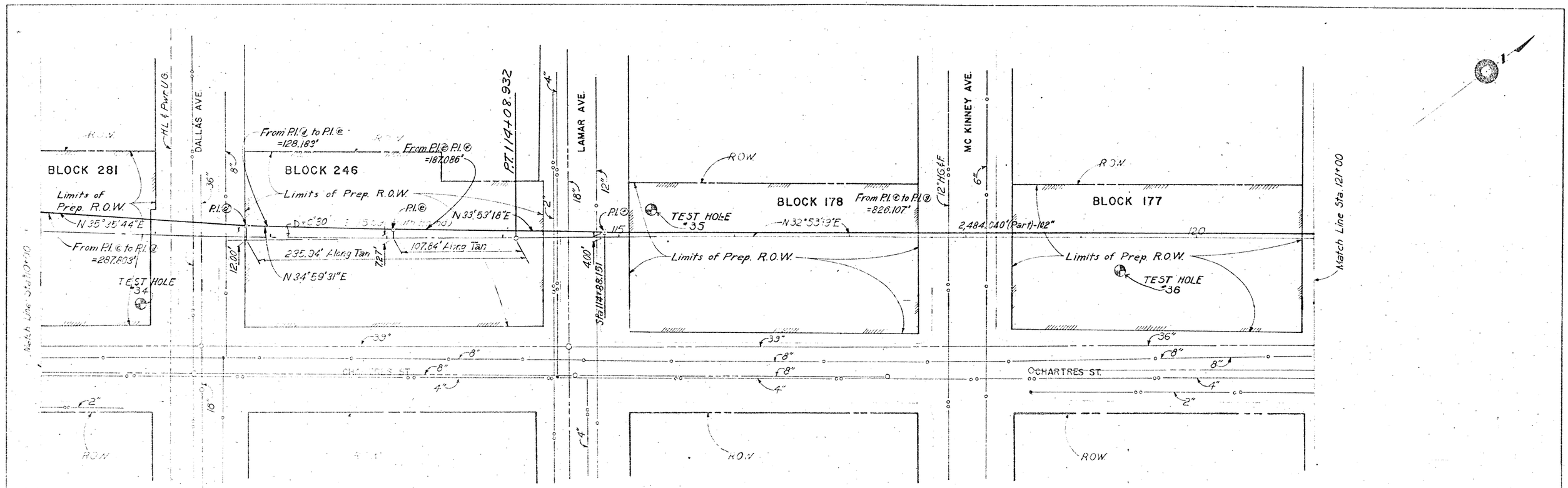
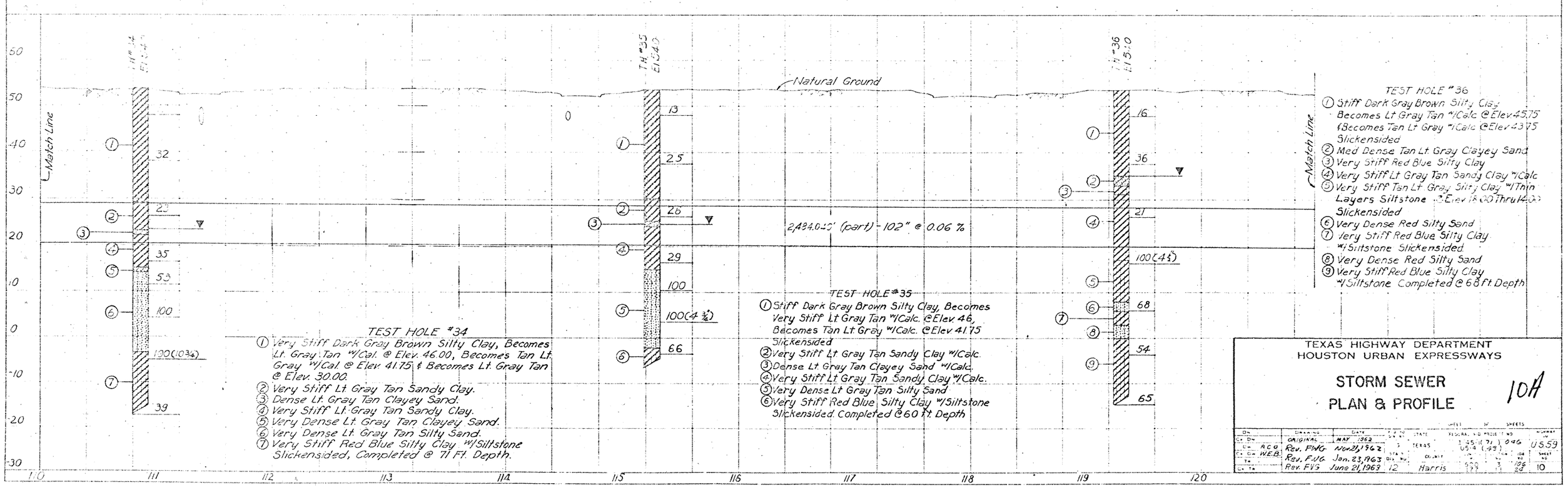
Sta. 111+23.066
Δ = 4°00'00" Lt.
D = 0°30'00"
T = 400.163'
L = 800.000'
H.L. & Pwr. U.G.
DALLAS AVE.
LAMAR AVE.
MC KINNEY AVE.
12" H.G.&F.
BLOCK 281
BLOCK 246
BLOCK 178
BLOCK 177
R.O.W.
Limits of Prep. R.O.W.
℄ U.S. 59 (South Bound)
N 36°53'19" E
P.I. #4
N 32°53'19" E
192.946'
52.138'
1100' (part) - 102"
965' (part) - 102"
PT 115 + 22.903
TEST HOLE #34
TEST HOLE #35
TEST HOLE #36
M.H. #1
CHARTRES ST.
Match Line Sta. 110+00
Match Line Sta. 121+00
Match Line
Natural Ground
T.H. #34 El. 54.0
M.H. #1 Top 54.0
T.H. #35 El. 54.0
T.H. #36 El. 54.0
1100' (part) - 102" @ 0.06%
965' (part) - 102" @ 0.06%
Inv. 20.24
TEST HOLE #34
① Very Stiff Dark Gray Brown Silty Clay, Becomes Lt. Gray Tan w/Cal. @ Elev. 46.00, Becomes Tan Lt. Gray w/Cal. @ Elev. 41.75 & Becomes Lt. Gray Tan @ Elev. 30.00.
② Very Stiff Lt. Gray Tan Sandy Clay.
③ Dense Lt. Gray Tan Clayey Sand.
④ Very Stiff Lt. Gray Tan Sandy Clay.
⑤ Very Dense Lt. Gray Tan Clayey Sand.
⑥ Very Dense Lt. Gray Tan Silty Sand.
⑦ Very Stiff Red Blue Silty Clay w/Siltstone Slickensided, Completed @ 71 Ft. Depth.
TEST HOLE #35
① Stiff Dark Gray Brown Silty Clay, Becomes Very Stiff Lt. Gray Tan w/Calc. @ Elev. 46, Becomes Tan Lt. Gray w/Calc. @ Elev. 41.75 Slickensided
② Very Stiff Lt. Gray Tan Sandy Clay w/Calc.
③ Dense Lt. Gray Tan Clayey Sand w/Calc.
④ Very Stiff Lt. Gray Tan Sandy Clay w/Calc.
⑤ Very Dense Lt. Gray Tan Silty Sand
⑥ Very Stiff Red Blue Silty Clay w/Siltstone Slickensided. Completed @ 60 Ft. Depth
TEST HOLE #36
① Stiff Dark Gray Brown Silty Clay Becomes Lt. Gray Tan w/Calc. @ Elev. 45.75 & Becomes Tan Lt. Gray w/Calc. @ Elev. 43.75 Slickensided
② Med. Dense Tan Lt. Gray Clayey Sand
③ Very Stiff Red Blue Silty Clay
④ Very Stiff Lt. Gray Tan Sandy Clay w/Calc.
⑤ Very Stiff Tan Lt. Gray Silty Clay w/Thin Layers Siltstone @ Elev. 18.00 Thru 14.00 Slickensided
⑥ Very Dense Red Silty Sand
⑦ Very Stiff Red Blue Silty Clay w/Siltstone Slickensided
⑧ Very Dense Red Silty Sand
⑨ Very Stiff Red Blue Silty Clay w/Siltstone Completed @ 68 Ft. Depth
See Revised Sepia
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS
STORM SEWER
PLAN & PROFILE
SHEET 2 OF 7 SHEETS
Dn. -
Ck. Dn. A.C.G.
Ck. Dw. W.E.B.
Tr. -
Ck. Tr. -
Drawing ORIGINAL
Date MAY 1962
F.I.D. NO. DIV. NO. 6
STATE TEXAS
FEDERAL AID PROJECT NO. 45-11 (7) 046 US-4 (27)
HIGHWAY NO. U.S. 59
STATE DIST. NO. 12
COUNTY Harris
CONTROL NO. 500
SECTION NO. 3
JOB NO. 199
SHEET NO. 10





TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

STORM SEWER PLAN & PROFILE

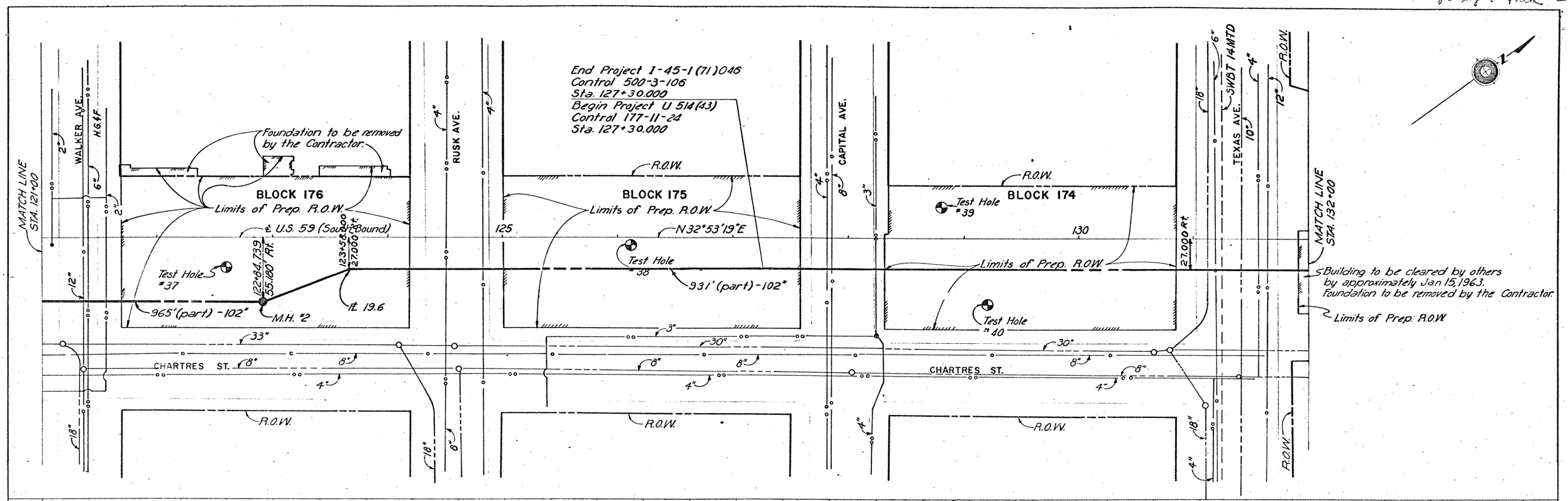
10A

DRAWING NO.	DATE		STATE	FEDERAL AID PROJECT NO.			
ORIGINAL	MAY 1962		TEXAS	1-25(71) 046			US 59
Rev. F.N.G.	Nov. 21, 1962			054 (493)			
Rev. F.J.G.	Jan. 23, 1963	DIST. NO.	COUNTY				
Rev. F.V.G.	June 21, 1963	12	Harris				10

C. O. R. C. O.
C. O. W.E.B.
C. O. T.
C. O. T.

SHEET OF SHEETS

8- 2 yd. Fuel c



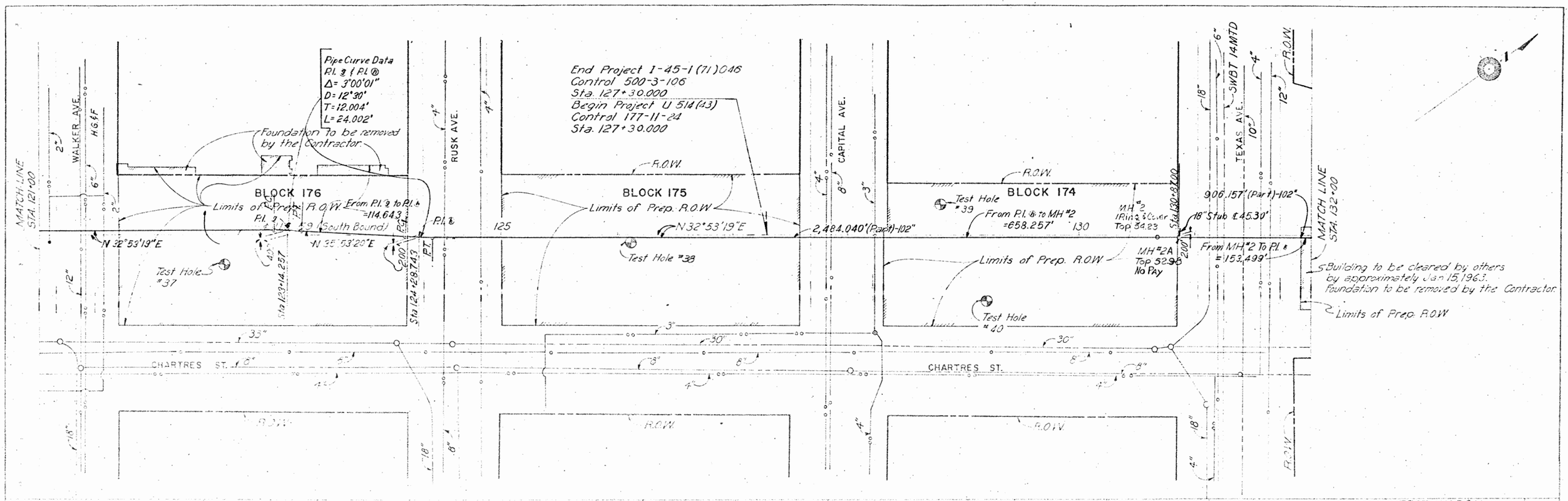
See Revised Sepia

TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

STORM SEWER PLAN & PROFILE

SHEET 3 OF 7 SHEETS

Dn.	Drawing	Date	FED. RD. Div. NO.	STATE	FEDERAL AID PROJECT NO.	HIGHWAY NO.
Ck. Dn.	ORIGINAL	MAY 1962	6	TEXAS	I-45-1(71)046 U514(43)	U.S. 59
Cr. Dn. C.J.M.	Rev. Oct. 15, 1962 SS		STATE DIST. NO.	COUNTY	CONTROL NO. / SECTION NO. / JOB NO.	SHEET NO.
Ck. Dn. W.E.B.			12	Harris	500 / 3 / 187 — 177 / 11 / 24	11
Tr.						
Ck. Tr.						

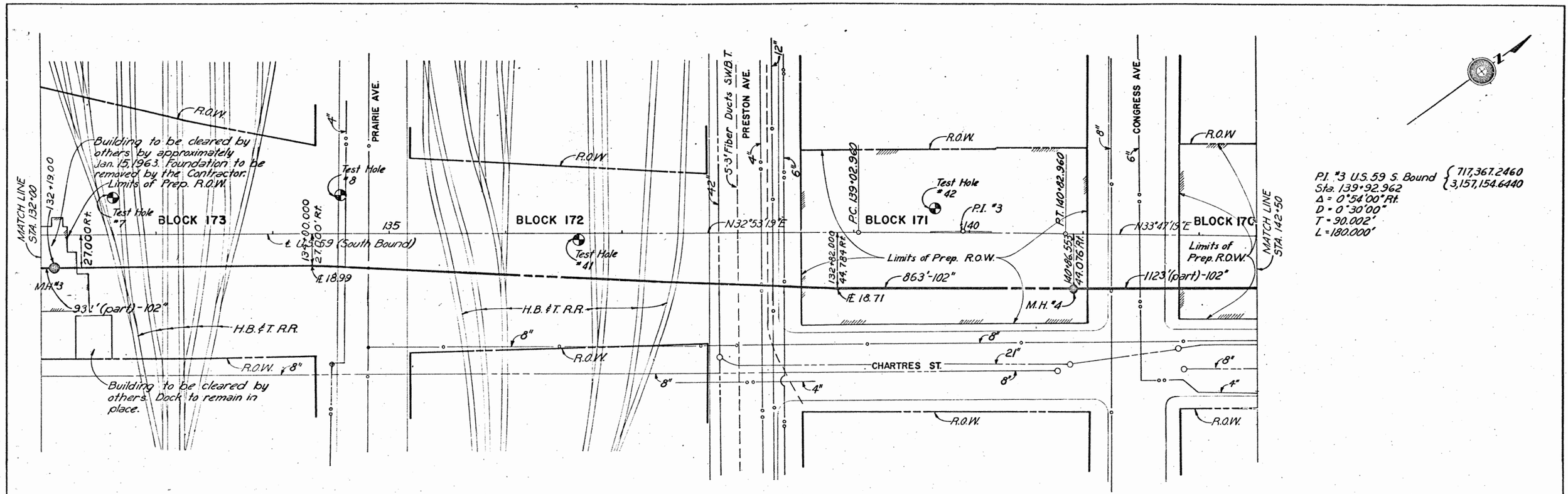


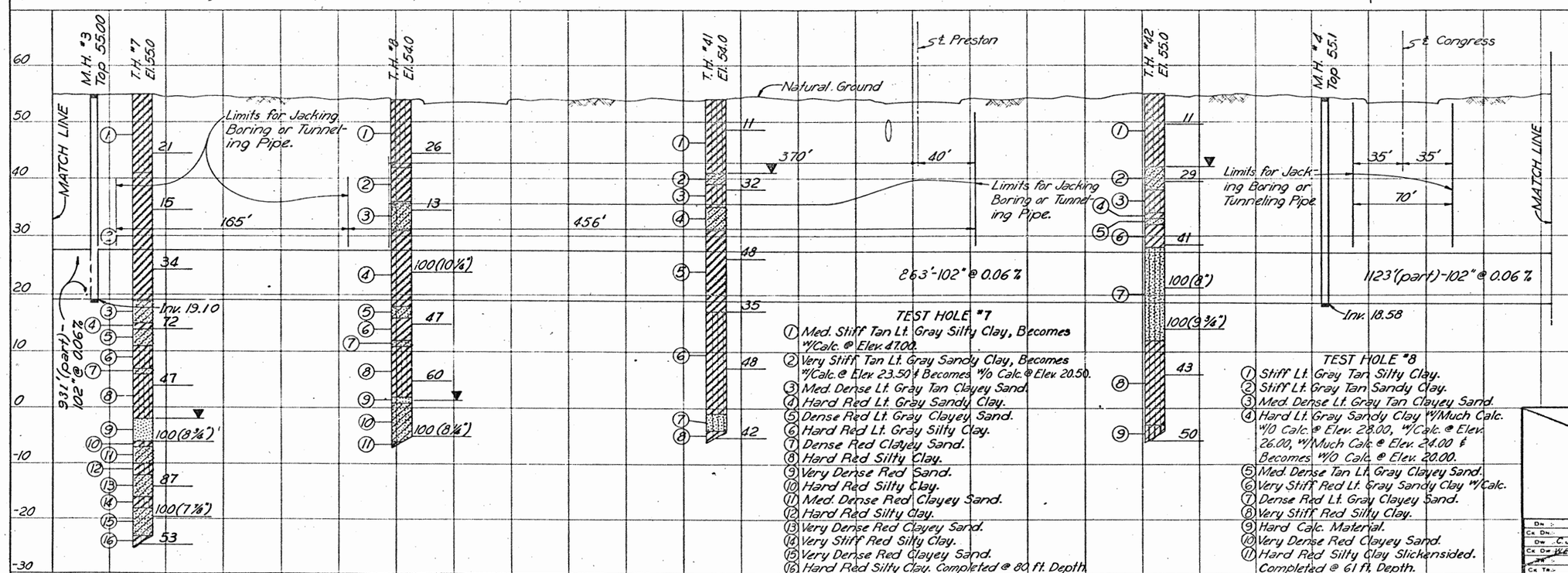
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

STORM SEWER PLAN & PROFILE

11A

	ORIGINAL	MAY 1962			
	C.J.M. Rev. F.J.G. Nov. 21, 1962				
	W.E.B. Rev. F.J.G. Jan. 23, 1963				
	Rev. F.W.S. June 21, 1963		6	TEXAS	US 59
			12	Harris	





TEST HOLE #7

1. Med. Stiff Tan Lt. Gray Silty Clay, Becomes w/Calc. @ Elev. 47.00.
2. Very Stiff Tan Lt. Gray Sandy Clay, Becomes w/Calc. @ Elev. 23.50 & Becomes w/o Calc. @ Elev. 20.50.
3. Med. Dense Lt. Gray Tan Clayey Sand.
4. Hard Red Lt. Gray Sandy Clay.
5. Dense Red Lt. Gray Clayey Sand.
6. Hard Red Lt. Gray Silty Clay.
7. Dense Red Clayey Sand.
8. Hard Red Silty Clay.
9. Very Dense Red Sand.
10. Hard Red Silty Clay.
11. Med. Dense Red Clayey Sand.
12. Hard Red Silty Clay.
13. Very Dense Red Clayey Sand.
14. Very Stiff Red Silty Clay.
15. Very Dense Red Clayey Sand.
16. Hard Red Silty Clay. Completed @ 80 ft. Depth.

TEST HOLE #8

1. Stiff Lt. Gray Tan Silty Clay.
2. Stiff Lt. Gray Tan Sandy Clay.
3. Med. Dense Lt. Gray Tan Clayey Sand.
4. Hard Lt. Gray Sandy Clay w/Much Calc. w/o Calc. @ Elev. 28.00, w/Calc. @ Elev. 26.00, w/Much Calc. @ Elev. 24.00 & Becomes w/o Calc. @ Elev. 20.00.
5. Med. Dense Tan Lt. Gray Clayey Sand.
6. Very Stiff Red Lt. Gray Sandy Clay w/Calc.
7. Dense Red Lt. Gray Clayey Sand.
8. Very Stiff Red Silty Clay.
9. Hard Calc. Material.
10. Very Dense Red Clayey Sand.
11. Hard Red Silty Clay Slickensided. Completed @ 61 ft. Depth.

TEST HOLE #41

1. Stiff Dark Gray Brown Silty Clay. Becomes Lt. Gray Tan w/Calc. @ Elev. 46.00 & Becomes Tan Lt. Gray w/Calc. @ Elev. 43.75.
2. Dense Tan Lt. Gray Clayey Sand.
3. Very Stiff Tan Lt. Gray Silty Clay w/Calc.
4. Very Dense Lt. Gray Tan Clayey Sand w/Calc.
5. Very Stiff Lt. Gray Tan Sandy Clay w/Calc.
6. Very Stiff Brown Lt. Gray Silty Clay w/Calc. Becomes w/6" Layer Sand @ Elev. 11.25, Becomes Red Blue @ Elev. 10.25 & Becomes w/Siltstone @ Elev. 8.50.
7. Very Dense Red Silty Sand w/Thin Layers Sandstone.
8. Very Stiff Red Blue Silty Clay w/Sandstone. Completed @ 60 ft. Depth.

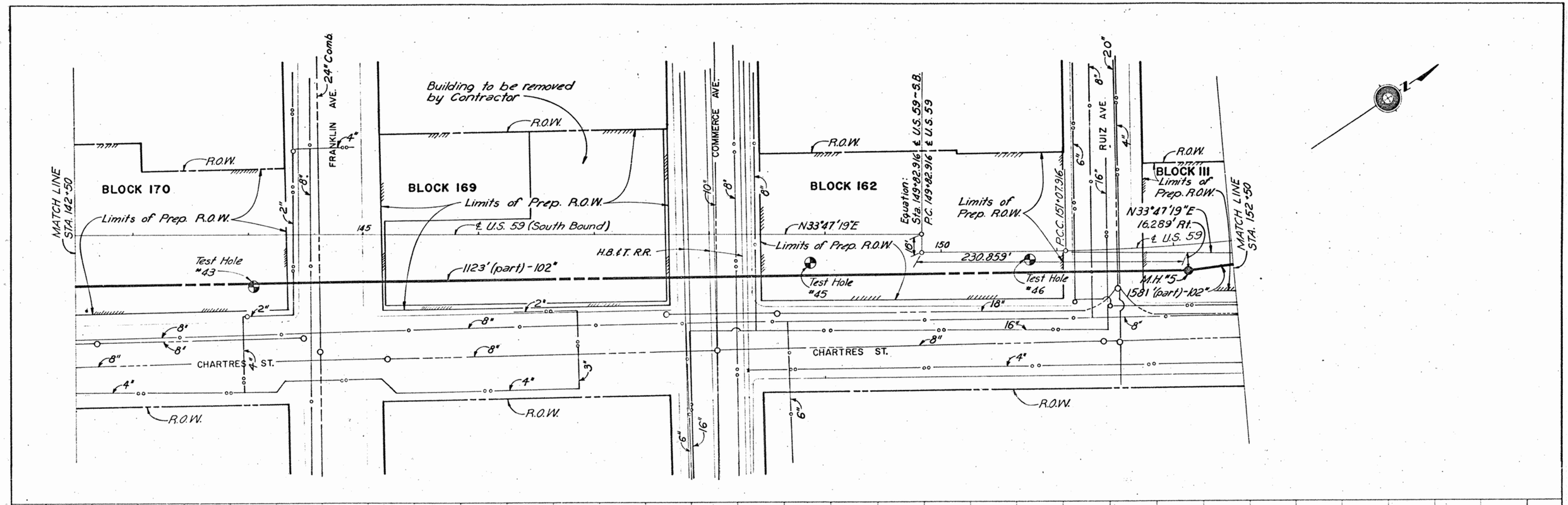
TEST HOLE #42

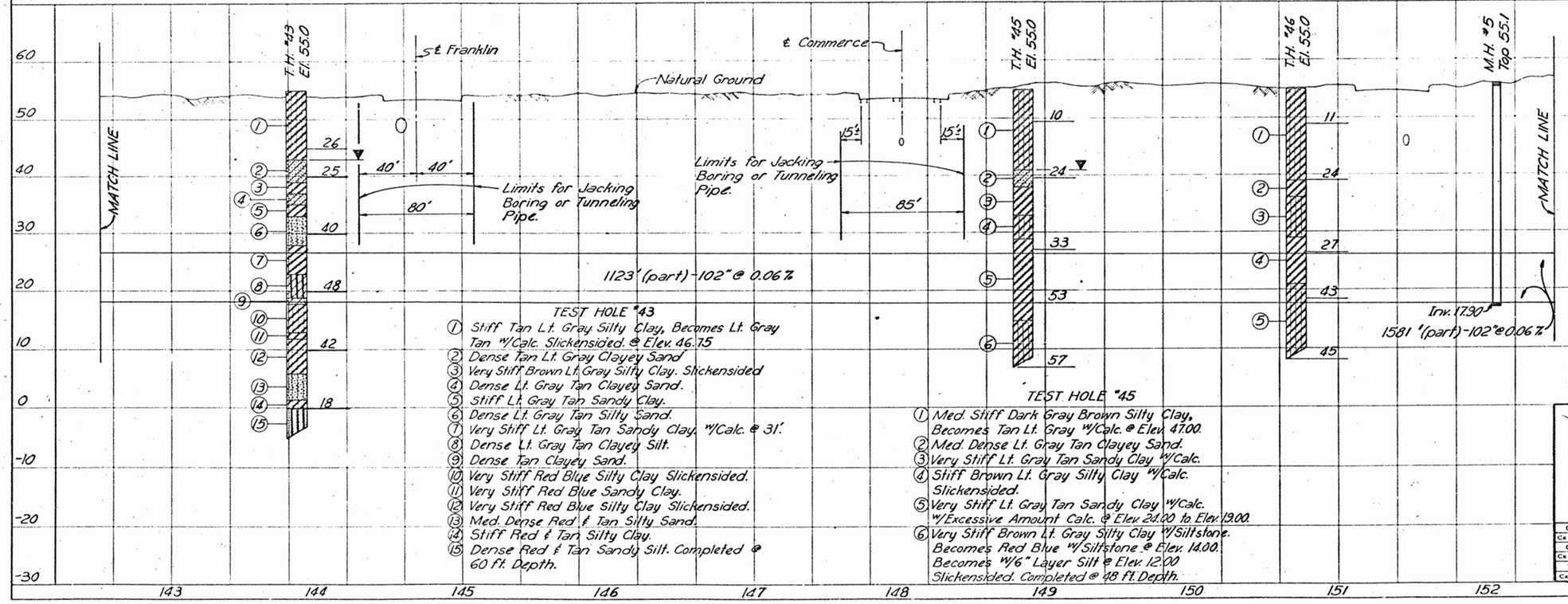
1. Very Stiff Dark Gray Brown Silty Clay. Becomes Tan Lt. Gray w/Calc. @ Elev. 46.75. Slickensided.
2. Med. Dense Tan Lt. Gray Clayey Sand.
3. Very Stiff Brown Lt. Gray Silty Clay w/Sand Lenses.
4. Very Stiff Lt. Gray Tan Sandy Clay.
5. Dense Lt. Gray Tan Clayey Sand.
6. Very Stiff Lt. Gray Tan Sandy Clay w/Calc.
7. Very Dense Lt. Gray Tan Silty Sand.
8. Very Stiff Red Blue Silty Clay w/Sand Lenses. w/o Sand Lenses @ Elev. 9.00 & w/Siltstone. Slickensided. Becomes w/3" Layer Sand @ Elev. -1.00.
9. Very Dense Red Clayey Silt. Completed @ 61 ft. Depth.

TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS
See Revised Sepia
STORM SEWER
PLAN & PROFILE

SHEET 4 OF 7 SHEETS

Dn.	Drawing	Date	F.A.P. No. / S.H. No.	State	Federal Aid Project No.	Highway No.
Ck. Dn.	ORIGINAL	MAY 1962	6	TEXAS	I-45-1 W 1046 / U514 (2)	US 59
Dn. C.J.M.	REV. Oct. 15, 1962 GS					
Ck. Dw. W.E.B.			State Dist. No.	County	Contract No. / Section No. / Job No.	Sheet No.
Ck. Tr.			12	Harris	500 / 3 / 1046 / 11 / 2(2)	12





TEST HOLE #43

1. Stiff Tan Lt. Gray Silty Clay, Becomes Lt. Gray Tan w/Calc. Slickensided. @ Elev. 46.75
2. Dense Tan Lt. Gray Clayey Sand
3. Very Stiff Brown Lt. Gray Silty Clay. Slickensided
4. Dense Lt. Gray Tan Clayey Sand.
5. Stiff Lt. Gray Tan Sandy Clay.
6. Dense Lt. Gray Tan Silty Sand.
7. Very Stiff Lt. Gray Tan Sandy Clay. w/Calc. @ 31'.
8. Dense Lt. Gray Tan Clayey Silt.
9. Dense Tan Clayey Sand.
10. Very Stiff Red Blue Silty Clay Slickensided.
11. Very Stiff Red Blue Sandy Clay.
12. Very Stiff Red Blue Silty Clay Slickensided.
13. Med. Dense Red & Tan Silty Sand.
14. Stiff Red & Tan Silty Clay.
15. Dense Red & Tan Sandy Silt. Completed @ 60 ft. Depth.

TEST HOLE #45

1. Med. Stiff Dark Gray Brown Silty Clay, Becomes Tan Lt. Gray w/Calc. @ Elev. 47.00.
2. Med. Dense Lt. Gray Tan Clayey Sand.
3. Very Stiff Lt. Gray Tan Sandy Clay w/Calc.
4. Stiff Brown Lt. Gray Silty Clay w/Calc. Slickensided.
5. Very Stiff Lt. Gray Tan Sandy Clay w/Calc. w/Excessive Amount Calc. @ Elev. 24.00 to Elev. 19.00.
6. Very Stiff Brown Lt. Gray Silty Clay w/Siltstone. Becomes Red Blue w/Siltstone @ Elev. 14.00. Becomes w/6" Layer Silt @ Elev. 12.00 Slickensided. Completed @ 48 ft. Depth.

TEST HOLE #46

1. Stiff Dark Gray Brown Silty Clay, Becomes Tan Lt. Gray w/Calc. @ Elev. 46.75 Slickensided.
2. Stiff Brown Lt. Gray Sandy Clay.
3. Very Stiff Brown Lt. Gray Silty Clay, w/Calc. @ Elev. 34.00 Slickensided.
4. Very Stiff Lt. Gray Tan Sandy Clay, Becomes w/Calc. @ Elev. 22.50.
5. Very Stiff Brown Lt. Gray Silty Clay Becomes w/Excessive Calc. @ Elev. 19.00. Becomes Red Blue w/Siltstone @ Elev. 16.00 Slickensided. Completed @ 47 ft. Depth.

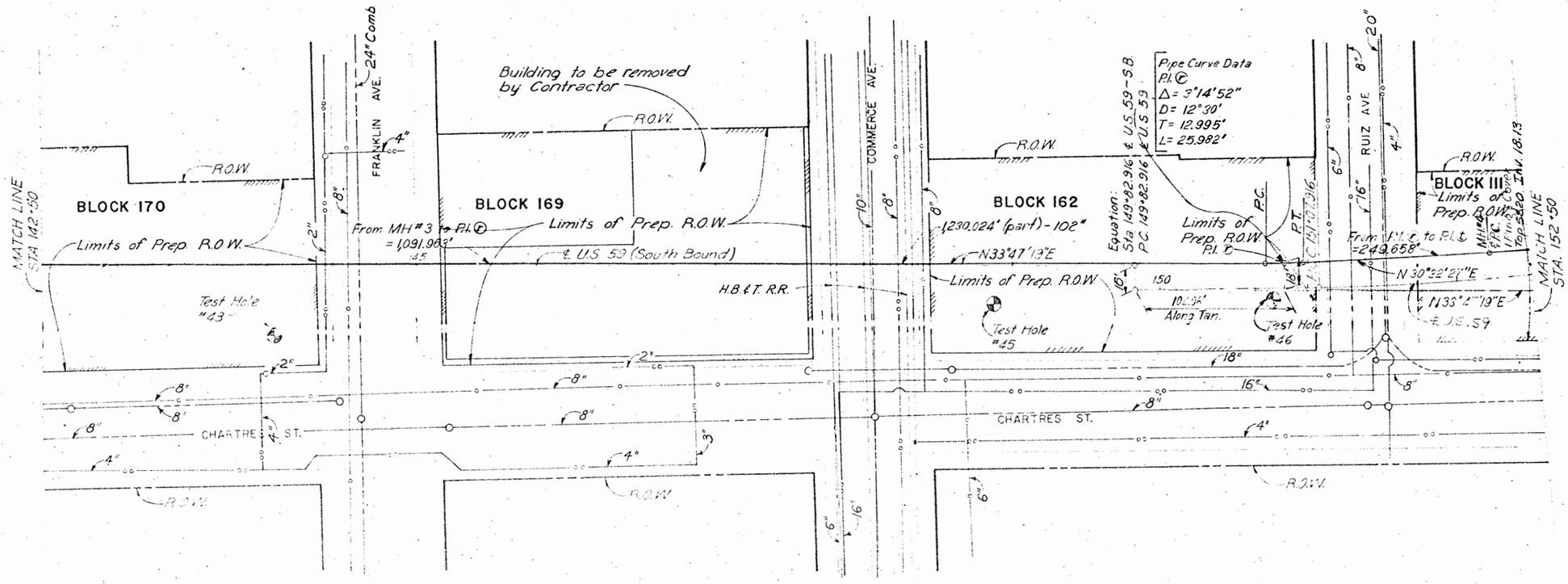
See Revised Sepia

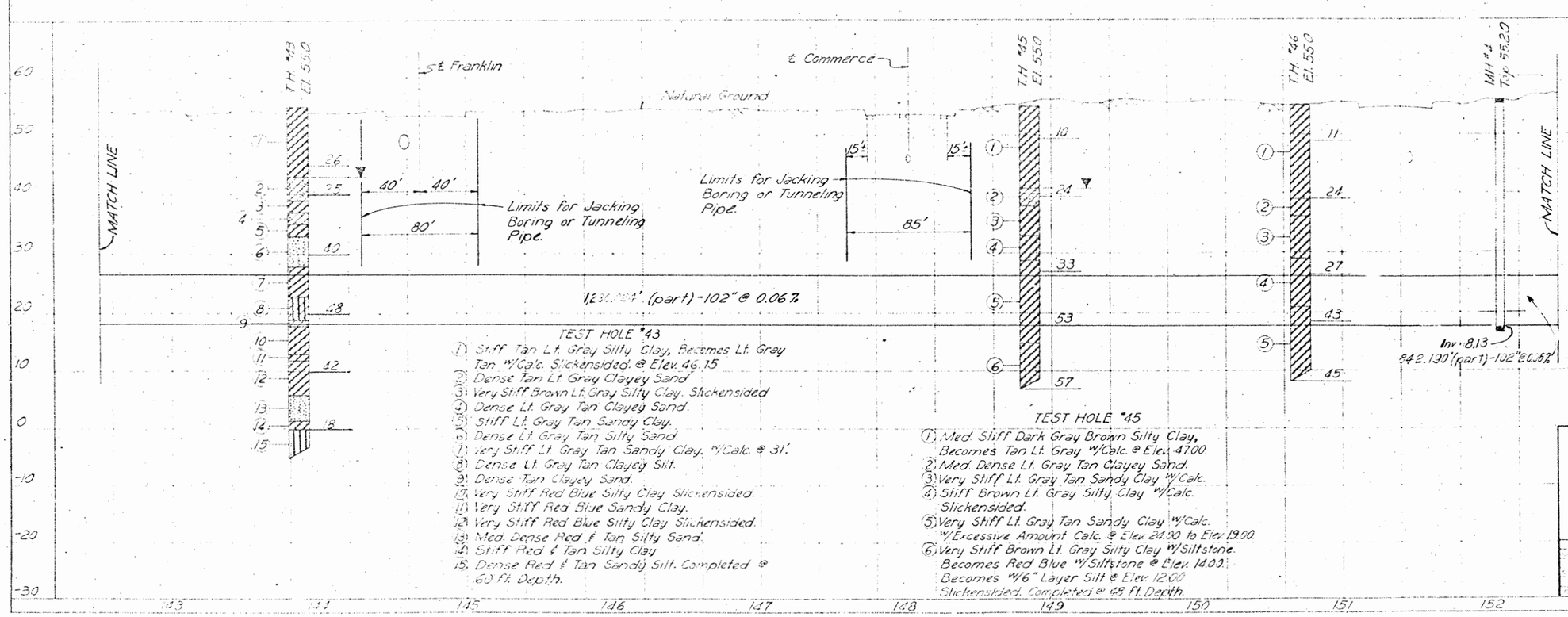
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

STORM SEWER PLAN & PROFILE

SHEET 5 OF 7 SHEETS

DN	DRAWING	DATE	FED. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.	HIGHWAY NO.
CK. DN.	ORIGINAL	MAY 1962	6	TEXAS	I-45, W, 026	U.S. 59
DW. CJM.	Rev. Oct. 15, 1962 SS				U 51-(43)	
CK. DW. W.E.B.			STATE DIST. NO.	COUNTY	CONTROL NO. / STRUCTURE NO. / JOB NO.	SHEET NO.
TR.			12	Harris	500 / 3 / 06	13
CK. TR.					177 / 11 / 27	





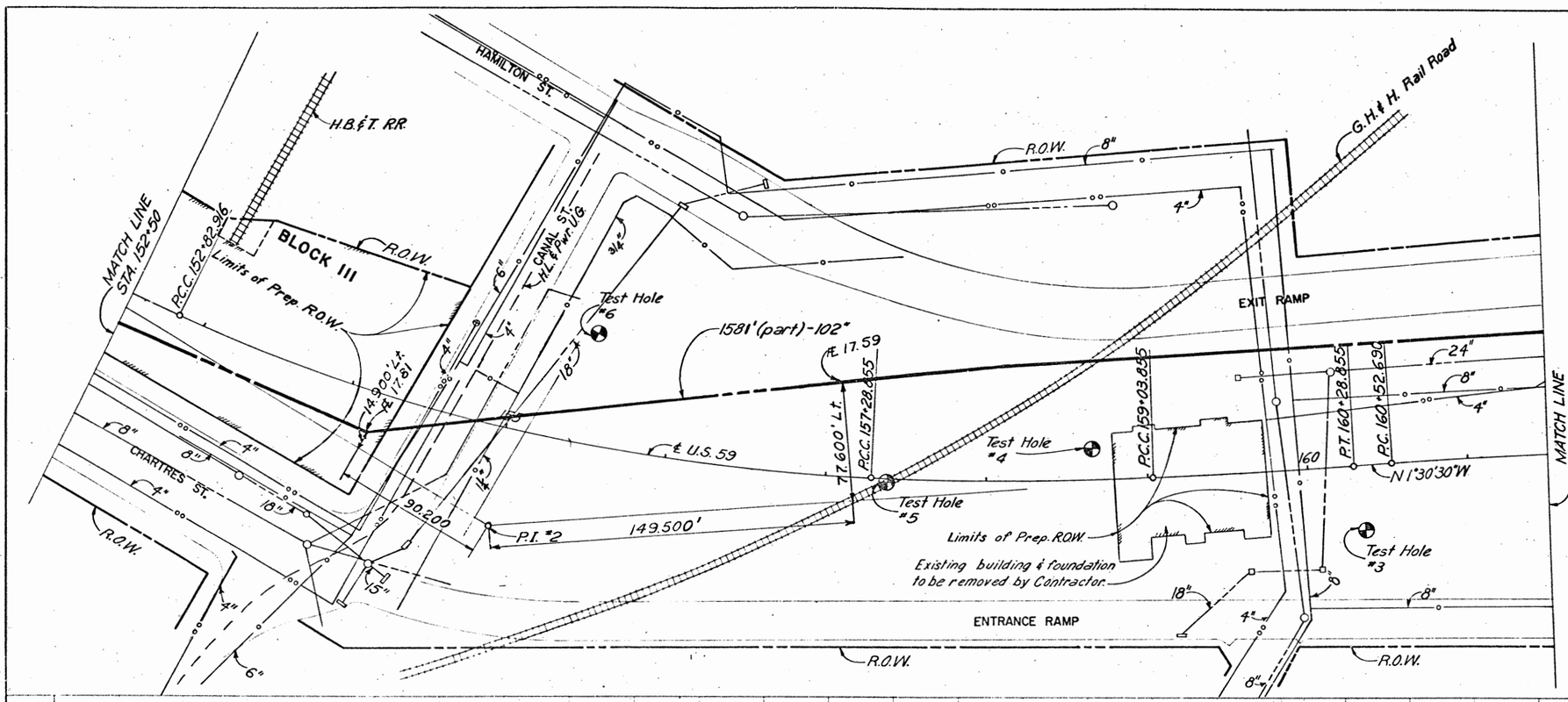
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

STORM SEWER PLAN & PROFILE

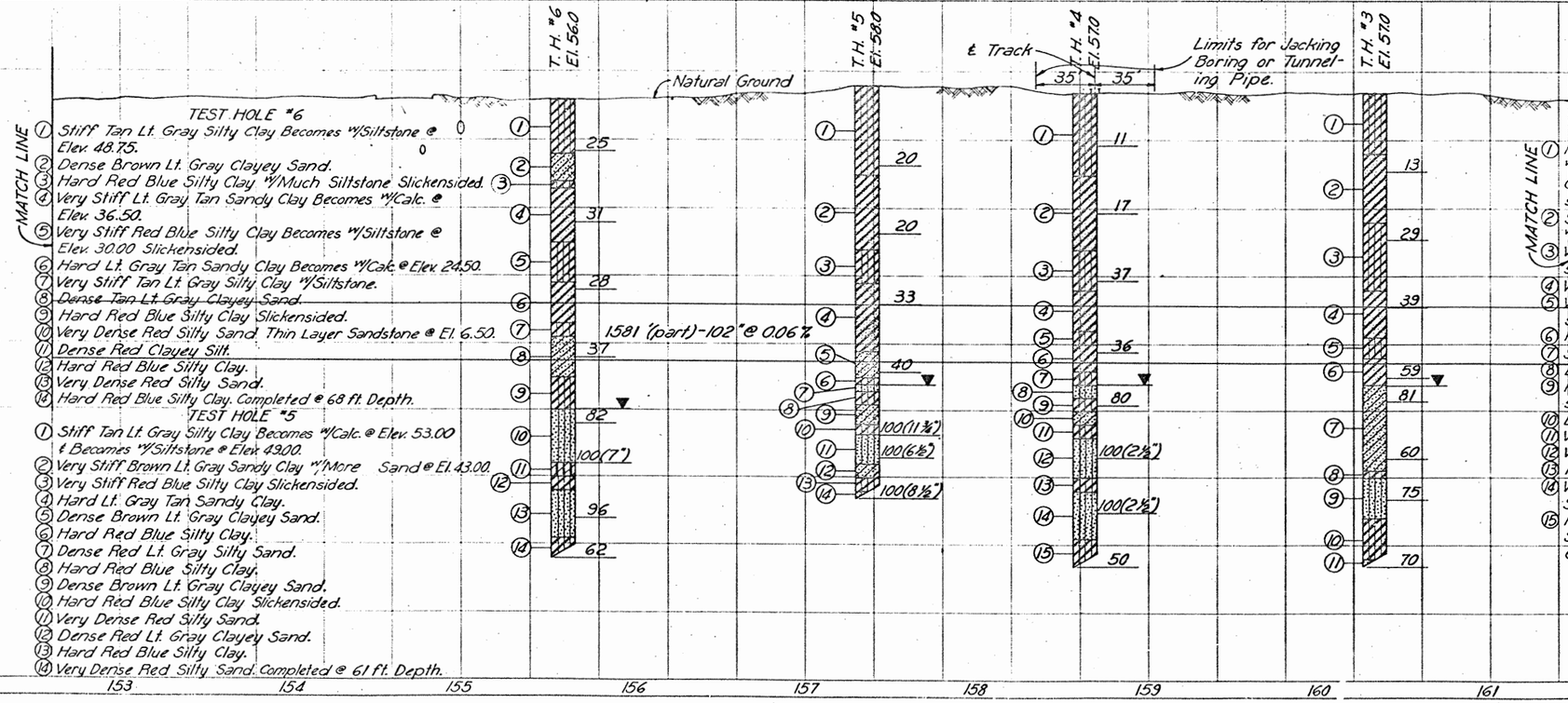
13A

SHEET 5 OF 7 SHEETS

DESIGNED	DRAWING	DATE	FED. RD. DIV. NO.	STATE	FEDERAL AID PROJECT NO.				SHEET NO.
CJM	ORIGINAL	MAY 1962	6	TEXAS	I 45	27	044		US 59
	Rev. E.W.G. Jan. 22, 1963				U S 59	48			
	Rev. F.W.G. June 21, 1963		DISTRICT NO.	COUNTY					
			12	Harris					13



P.I. #2 U.S. 59 Sta. 155+19.148 { 718,626.619 / 3,158,016.608 }
Δ_1 = 1°15'00" Rt. D_1 = 1°00'00"
Δ_2 = 5°15'00" Rt. D_2 = 3°00'00"
Δ_3 = 22°17'49" Rt. D_3 = 5°00'00"
Δ_T = 35°17'49" Rt.
T = 536.232'
L_1 = 125.000'
L_2 = 175.000'
L_3 = 445.939'



TEST HOLE #6

1. Stiff Tan Lt. Gray Silty Clay Becomes w/Siltstone @ Elev. 48.75.
2. Dense Brown Lt. Gray Clayey Sand.
3. Hard Red Blue Silty Clay w/Much Siltstone Slickensided.
4. Very Stiff Lt. Gray Tan Sandy Clay Becomes w/Calc. @ Elev. 36.50.
5. Very Stiff Red Blue Silty Clay Becomes w/Siltstone @ Elev. 30.00 Slickensided.
6. Hard Lt. Gray Tan Sandy Clay Becomes w/Calc. @ Elev. 24.50.
7. Very Stiff Tan Lt. Gray Silty Clay w/Siltstone.
8. ~~Dense Tan Lt. Gray Clayey Sand.~~
9. Hard Red Blue Silty Clay Slickensided.
10. Very Dense Red Silty Sand Thin Layer Sandstone @ El. 6.50.
11. Dense Red Clayey Silt.
12. Hard Red Blue Silty Clay.
13. Very Dense Red Silty Sand.
14. Hard Red Blue Silty Clay. Completed @ 68 ft. Depth.

TEST HOLE #5

1. Stiff Tan Lt. Gray Silty Clay Becomes w/Calc. @ Elev. 53.00 & Becomes w/Siltstone @ Elev. 49.00.
2. Very Stiff Brown Lt. Gray Sandy Clay w/More Sand @ El. 43.00.
3. Very Stiff Red Blue Silty Clay Slickensided.
4. Hard Lt. Gray Tan Sandy Clay.
5. Dense Brown Lt. Gray Clayey Sand.
6. Hard Red Blue Silty Clay.
7. Dense Red Lt. Gray Silty Sand.
8. Hard Red Blue Silty Clay.
9. Dense Brown Lt. Gray Clayey Sand.
10. Hard Red Blue Silty Clay Slickensided.
11. Very Dense Red Silty Sand.
12. Dense Red Lt. Gray Clayey Sand.
13. Hard Red Blue Silty Clay.
14. Very Dense Red Silty Sand. Completed @ 61 ft. Depth.

TEST HOLE #4

1. Med. Stiff Gray Silty Clay Becomes w/Calc. @ Elev. 51.75, Becomes Tan Lt. Gray @ Elev. 49.75 & Becomes w/Siltstone @ Elev. 47.00.
2. Stiff Tan Lt. Gray Sandy Clay Becomes w/Calc. @ Elev. 37.50.
3. Very Stiff Red Blue Silty Clay w/Siltstone Slickensided.
4. Very Stiff Lt. Gray Tan Sandy Clay
5. Very Stiff Tan Lt. Gray Silty Clay w/Siltstone.
6. Hard Brown Lt. Gray Sandy Clay.
7. Stiff Red Blue Silty Clay w/Siltstone.
8. Dense Brown Lt. Gray Silty Sand.
9. Hard Red Blue Silty Clay w/Much Siltstone.
10. Dense Red Lt. Gray Clayey Sand.
11. Very Stiff Red Blue Silty Clay Slickensided.
12. Very Dense Red Silty Sand.
13. Hard Red Silty Clay.
14. Very Dense Red Silty Sand w/Sandstone.
15. Hard Red Silty Clay Slickensided. Completed @ 70 ft. Depth.

TEST HOLE #3

1. Stiff Gray Silty Clay Becomes Tan Lt. Gray @ Elev. 50.50 & Becomes w/Siltstone @ Elev. 50.00.
2. Med. Stiff Tan Lt. Gray Sandy Clay Becomes Lt. Gray Tan @ Elev. 44.00 & Becomes w/Calc. @ Elev. 40.00.
3. Stiff Red Blue Silty Clay w/Siltstone Slickensided
4. Very Stiff Lt. Gray Tan Sandy Clay Becomes w/Calc. @ Elev. 23.50.
5. Very Stiff Red Blue Silty Clay.
6. Very Stiff Brown Lt. Gray Sandy Clay.
7. Very Dense Brown Lt. Gray Clayey Sand.
8. Hard Red Silty Clay Slickensided.
9. Very Dense Red Silty Sand.
10. Hard Red Silty Clay Slickensided.
11. Very Dense Red Silty Sand. Completed @ 70 ft. Depth.

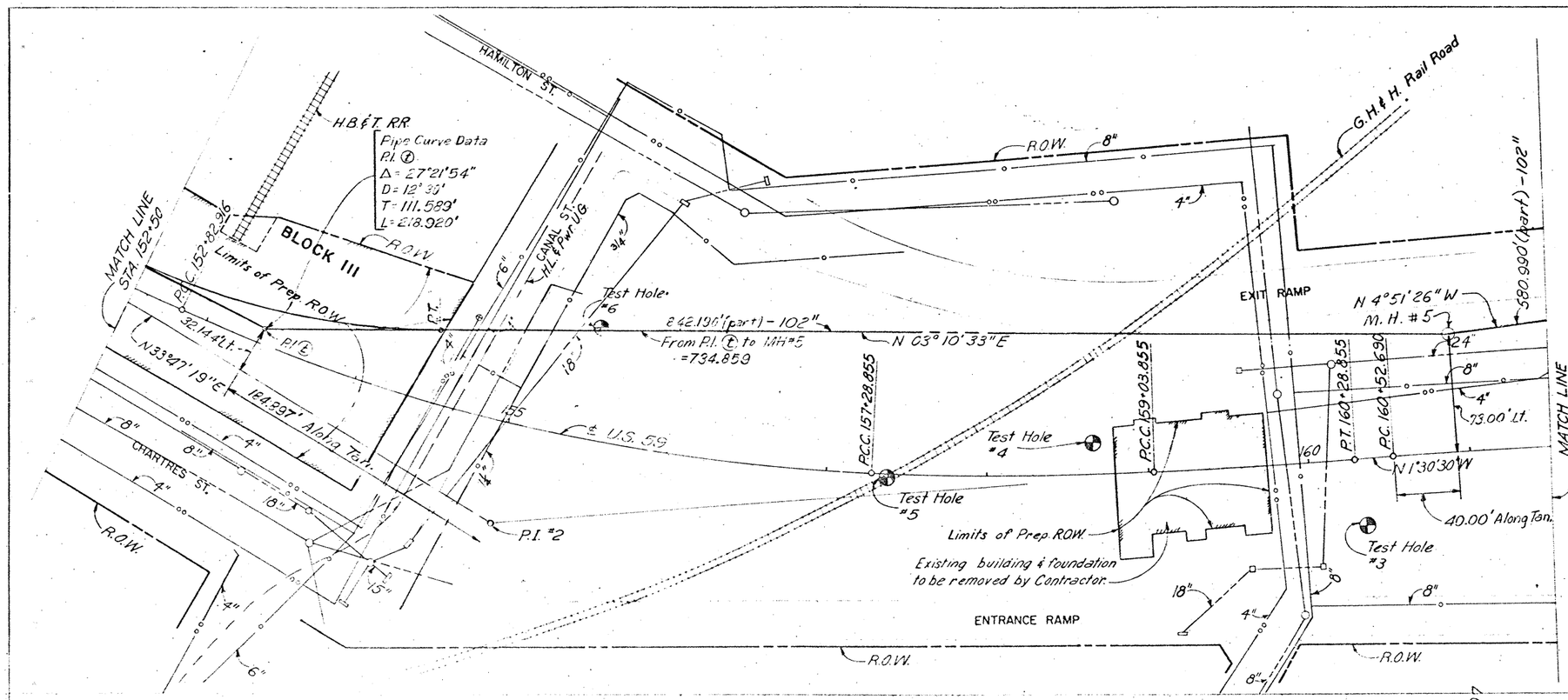
See Revised Sep. 18

TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

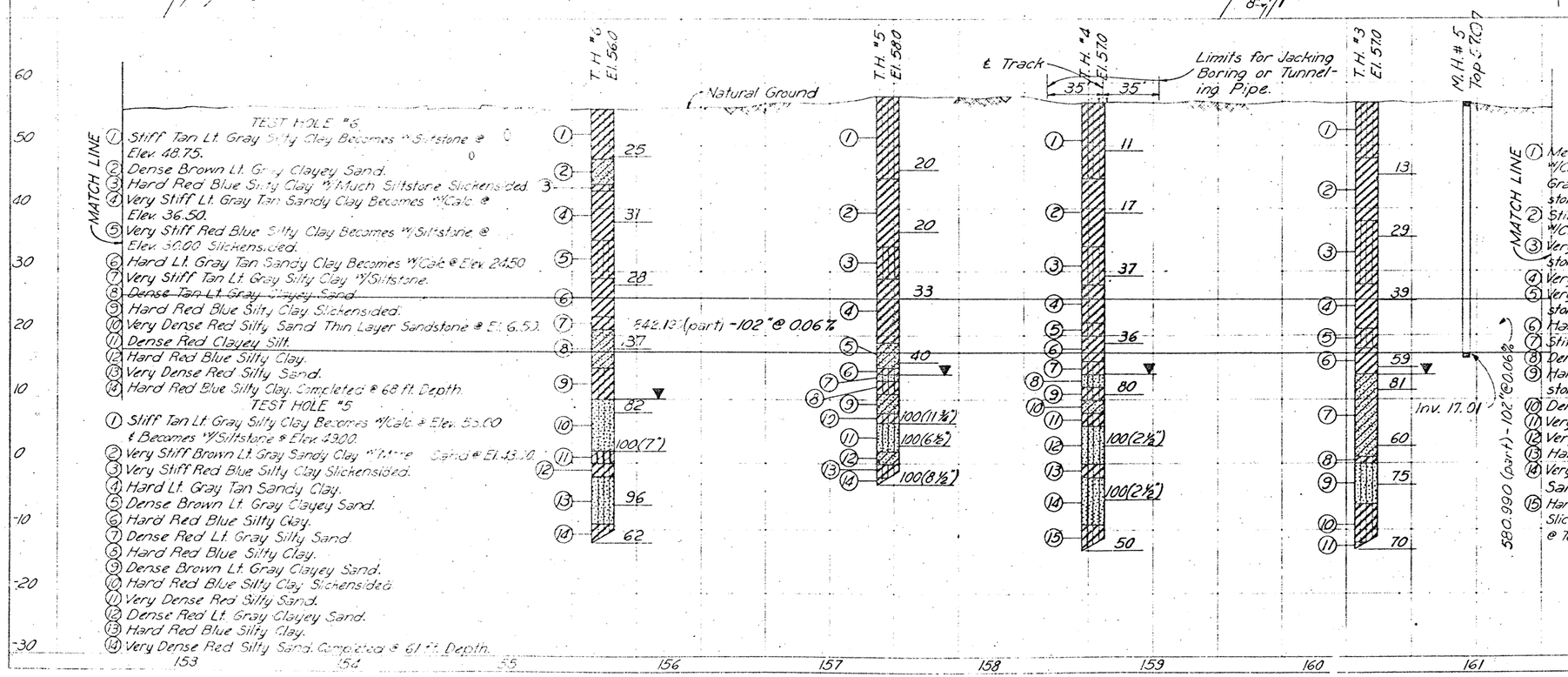
STORM SEWER PLAN & PROFILE

SHEET 6 OF 7 SHEETS

Dn.	Drawing	Date	Fed. Rd. Div. No.	State	Federal Aid Project No.	Highway No.
Ck. Dn.	ORIGINAL	JUNE 1962	6	TEXAS	I 45-U 71 (006) U-514(2-3)	US 59
Dw. C.J.M.	Rev. Oct. 15, 1959 SS					
Ck. Dw. W.L.B.			State Dist. No.	County	Control No. / Section No. / Job No.	Sheet No.
Tr.			12	Harris	500 / 177 / 3 / 11 / 70 / 70	14
Ck. Tr.						



P.I. #2 U.S. 59 { 718,626.619 / 3,158,016.608
Sta. 155+19.148
Δ_1 = 1°15'00" Rt. D_1 = 1°00'00"
Δ_2 = 5°15'00" Rt. D_2 = 3°00'00"
Δ_3 = 22°17'49" Rt. D_3 = 5°00'00"
Δ_T = 35°17'49" Rt.
T = 536.232'
L_1 = 125.000'
L_2 = 175.000'
L_3 = 445.939'



TEST HOLE #6
1. Stiff Tan Lt. Gray Silty Clay Becomes w/Siltstone @ Elev. 48.75.
2. Dense Brown Lt. Gray Clayey Sand.
3. Hard Red Blue Silty Clay w/Much Siltstone Slickensided.
4. Very Stiff Lt. Gray Tan Sandy Clay Becomes w/Calc. @ Elev. 36.50.
5. Very Stiff Red Blue Silty Clay Becomes w/Siltstone @ Elev. 30.00 Slickensided.
6. Hard Lt. Gray Tan Sandy Clay Becomes w/Calc. @ Elev. 24.50
7. Very Stiff Tan Lt. Gray Silty Clay w/Siltstone.
8. ~~Dense Tan Lt. Gray Clayey Sand.~~
9. Hard Red Blue Silty Clay Slickensided.
10. Very Dense Red Silty Sand Thin Layer Sandstone @ El. 6.50.
11. Dense Red Clayey Silt.
12. Hard Red Blue Silty Clay.
13. Very Dense Red Silty Sand.
14. Hard Red Blue Silty Clay. Completed @ 68 ft. Depth.

TEST HOLE #5
1. Stiff Tan Lt. Gray Silty Clay Becomes w/Calc. @ Elev. 55.00 & Becomes w/Siltstone @ Elev. 43.00.
2. Very Stiff Brown Lt. Gray Sandy Clay w/Mine Sand @ El. 43.00.
3. Very Stiff Red Blue Silty Clay Slickensided.
4. Hard Lt. Gray Tan Sandy Clay.
5. Dense Brown Lt. Gray Clayey Sand.
6. Hard Red Blue Silty Clay.
7. Dense Red Lt. Gray Silty Sand.
8. Hard Red Blue Silty Clay.
9. Dense Brown Lt. Gray Clayey Sand.
10. Hard Red Blue Silty Clay Slickensided.
11. Very Dense Red Silty Sand.
12. Dense Red Lt. Gray Clayey Sand.
13. Hard Red Blue Silty Clay.
14. Very Dense Red Silty Sand. Completed @ 61 ft. Depth.

TEST HOLE #4
1. Med. Stiff Gray Silty Clay Becomes w/Calc. @ Elev. 51.75, Becomes Tan Lt. Gray @ Elev. 49.75 & Becomes w/Siltstone @ Elev. 47.00.
2. Stiff Tan Lt. Gray Sandy Clay Becomes w/Calc. @ Elev. 37.50.
3. Very Stiff Red Blue Silty Clay w/Siltstone Slickensided.
4. Very Stiff Lt. Gray Tan Sandy Clay
5. Very Stiff Tan Lt. Gray Silty Clay w/Siltstone.
6. Hard Brown Lt. Gray Sandy Clay.
7. Stiff Red Blue Silty Clay w/Siltstone.
8. Dense Brown Lt. Gray Silty Sand.
9. Hard Red Blue Silty Clay w/Much Siltstone.
10. Dense Red Lt. Gray Clayey Sand.
11. Very Stiff Red Blue Silty Clay Slickensided.
12. Very Dense Red Silty Sand.
13. Hard Red Silty Clay.
14. Very Dense Red Silty Sand w/Sandstone.
15. Hard Red Silty Clay Slickensided. Completed @ 70 ft. Depth.

TEST HOLE #3
1. Stiff Gray Silty Clay Becomes Tan Lt. Gray @ Elev. 50.50 & Becomes w/Siltstone @ Elev. 50.00.
2. Med. Stiff Tan Lt. Gray Sandy Clay Becomes Lt. Gray Tan @ Elev. 44.00 & Becomes w/Calc. @ Elev. 40.00.
3. Stiff Red Blue Silty Clay w/Siltstone Slickensided
4. Very Stiff Lt. Gray Tan Sandy Clay Becomes w/Calc. @ Elev. 23.50.
5. Very Stiff Red Blue Silty Clay.
6. Very Stiff Brown Lt. Gray Sandy Clay.
7. Very Dense Brown Lt. Gray Clayey Sand.
8. Hard Red Silty Clay Slickensided.
9. Very Dense Red Silty Sand.
10. Hard Red Silty Clay Slickensided.
11. Very Dense Red Silty Sand. Completed @ 70 ft. Depth.

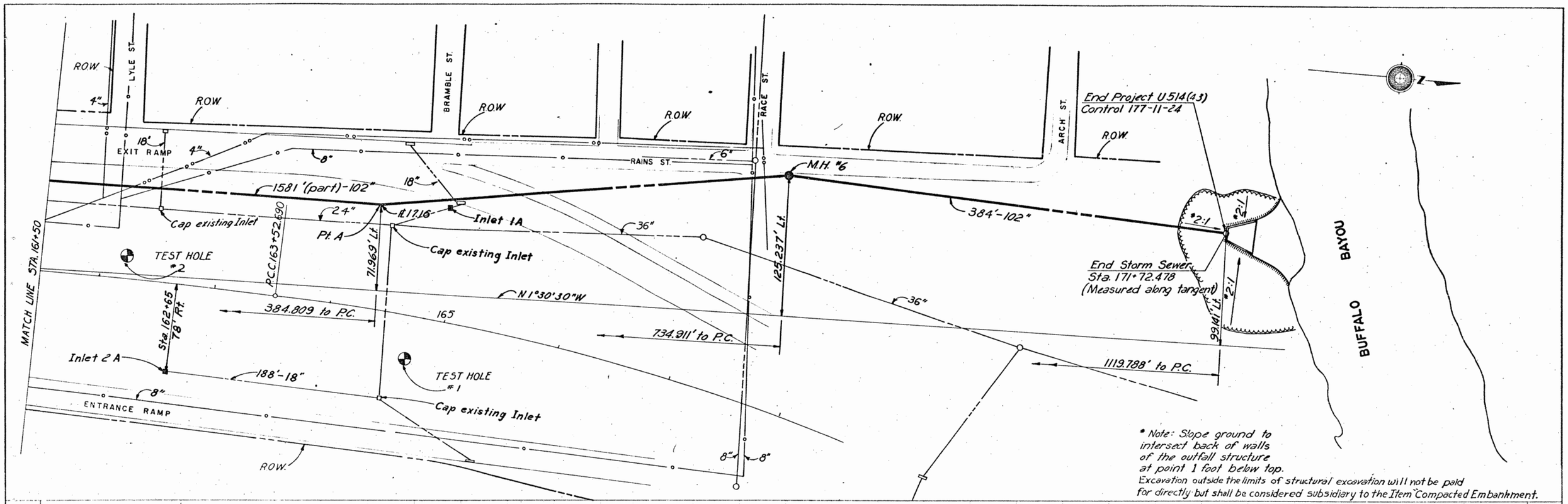
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

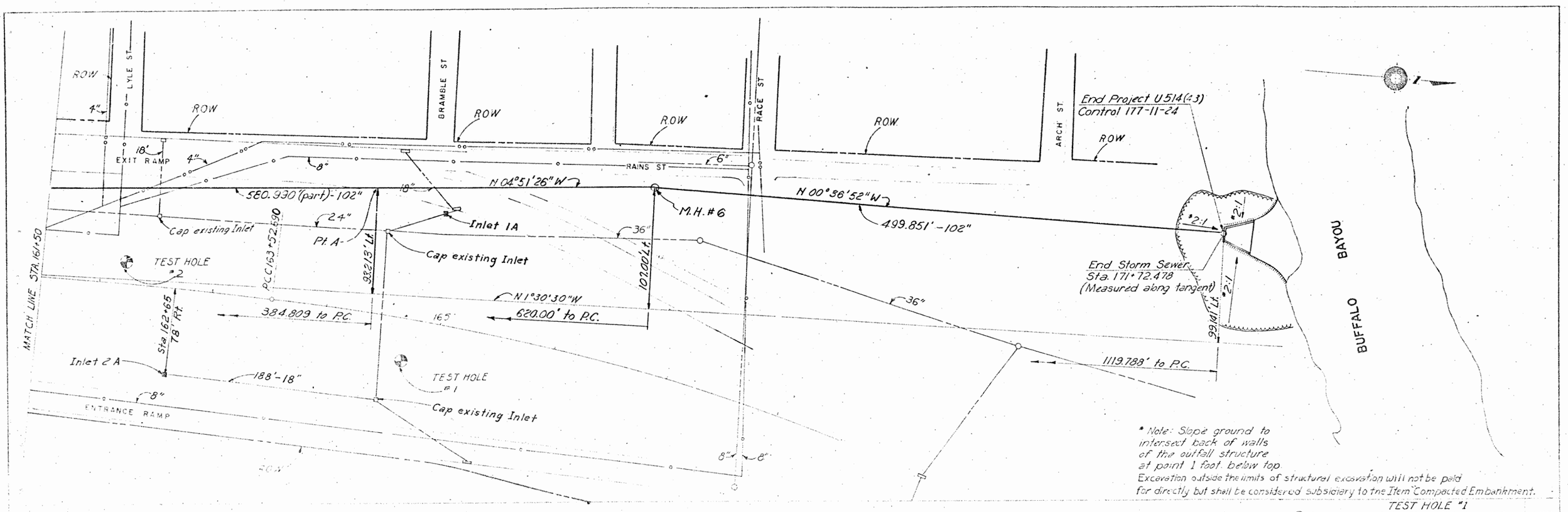
STORM SEWER PLAN & PROFILE

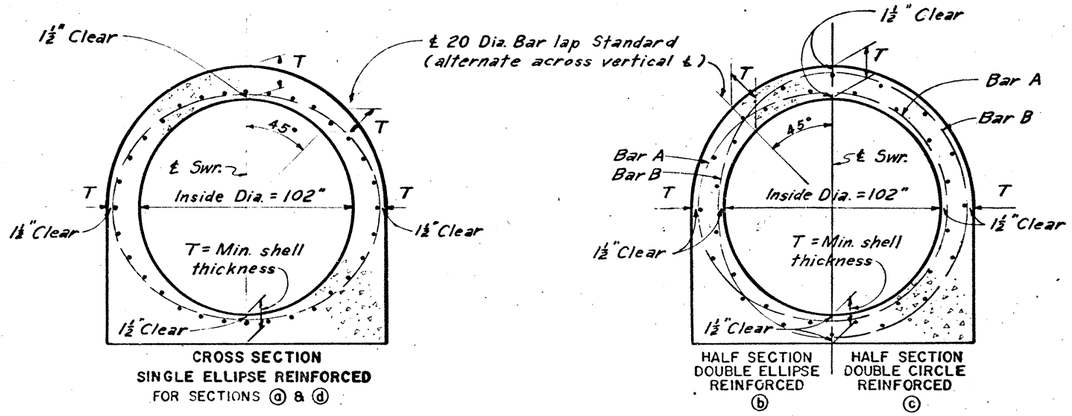
14A

SHEET 6 OF 7 SHEETS

Dn.	Drawing	Date	Fed. Rd. Div. No.	State	Federal Aid Project No.	Number No.
Ck. Dn.	ORIGINAL	JUNE 1962	6	TEXAS	I-45-1(71) 046	US 59
Dn. CJM	Rev. FWG Jan. 23, 1963				U-514(43)	
Ck. Dn. WEB	Rev. FWG June 21, 1963		State Dist. No.	County	Control No. / Section No. / Job No.	Sheet No.
Tr.			12	Harris	500 / 3 / 1066	14
Ck. Tr.					17 / 11 / 84	


ROW
LYLE ST.
BRAMBLE ST.
RACE ST.
ARCH ST.
EXIT RAMP
RAINS ST.
M.H. #6
1581'(part)-102"
384'-102"
Cap existing Inlet
Inlet 1A
Pt. A
TEST HOLE #2
TEST HOLE #1
P.C.C. 163+52.690
71.969' Lt.
125.237' Lt.
N 1°30'30"W
384.809 to P.C.
734.911' to P.C.
1119.788' to P.C.
Sta. 162+65 78' Rt.
Inlet 2A
188'-18"
ENTRANCE RAMP
MATCH LINE STA. 161+50
End Project U514(43)
Control 177-11-24
End Storm Sewer
Sta. 171+72.478
(Measured along tangent)
99.141' Lt.
BUFFALO BAYOU
* Note: Slope ground to intersect back of walls of the outfall structure at point 1 foot below top.
Excavation outside the limits of structural excavation will not be paid for directly but shall be considered subsidiary to the Item "Compacted Embankment."
TH #2 EL 56.0
TH #1 EL 54.0
MATCH LINE
Pt. A
Limits for Jacking Boring or Tunneling Pipe.
165'
1581'(part)-102" @ 0.06%
M.H. #6 Top 41.0
Natural Ground
284'-102" @ 3.81%
Inv. 16.95
2:1 Slope
For details of outfall structure, see sheet Nos. 22 & 23.
100'-102" @ 0.06%
Elev. 6.00
See Revised Sepia
Inlet 2A, 7'x4' Top 53.0
188'-18" @ 0.20%
45.40
45.02
44.52
Existing Inlet (to be capped)
Exist. Inlet (to be capped)
Inlet 1A, 7'x4' Top 46.80
Exist. Inlet
51'±
45.22
45.38
Exist. 18" Swr.
TEST HOLE #2
1. Stiff Gray Silty Clay. Becomes Tan Lt Gray @ Elev 50.75 & Becomes w/Siltstone @ Elev 46.75
2. Very Stiff Lt Gray Tan Sandy Clay
3. Very Stiff Red Blue Silty Clay w/Layers Siltstone Slickensided
4. Hard Lt Gray Tan Sandy Clay
5. Hard Red Blue Silty Clay w/Siltstone
6. Hard Brown Lt Gray Sandy Clay. Slickensided
7. Very Dense Brown Lt Gray Clayey Sand w/Sandstone
8. Very Stiff Red Silty Clay w/Siltstone
9. Very Dense Red Silty Sand
Completed @ 58ft. Depth
TEST HOLE #1
1. Stiff Brown Silty Clay w/Siltstone @ Elev. 48.75.
2. Very Stiff Tan Lt Gray Sandy Clay.
3. Stiff Red Blue Silty Clay w/Layers Siltstone Slickensided.
4. Very Stiff Lt Gray Tan Sandy Clay Becomes w/Calc. @ Elev. 27.00.
5. Very Stiff Red Blue Silty Clay w/Much Siltstone Slickensided.
6. Very Stiff Brown Lt Gray Sandy Clay.
7. Dense Red Silty Sand.
8. Very Stiff Red Blue Silty Clay.
9. Very Dense Red Silty Sand.
10. Very Stiff Red Silty Clay. Slickensided.
11. Dense Red Clayey Sand.
12. Very Dense Red Silty Sand. Completed @ 74 ft. Depth.
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS
STORM SEWER
PLAN & PROFILE
SHEET 7 OF 7 SHEET
ORIGINAL
JUNE 1962
R.C.O.
W.E.B.
TEXAS
Harris
12
U514 (43)
U.S. 59
15


ROW
LYLE ST
BRAMBLE ST
RACE ST
ARCH ST
EXIT RAMP
RAINS ST
N 04°51'26" W
580.990'(part)-102"
Cap existing Inlet
Pt. A
Inlet 1A
M.H. #6
N 00°36'52" W
499.851'-102"
End Project U514(43)
Control 177-11-24
End Storm Sewer
Sta. 171+72.478
(Measured along tangent)
BAYOU
BUFFALO
MATCH LINE STA. 161+50
TEST HOLE #2
PC C163+52.590
32.213' Lt.
101.00' Lt.
N 1°30'30" W
620.00' to P.C.
384.809 to P.C.
Sta. 162+65
78' Rt.
Inlet 2A
188'-18"
TEST HOLE #1
Cap existing Inlet
ENTRANCE RAMP
99.161' Lt.
1119.788' to P.C.
* Note: Slope ground to intersect back of walls of the outfall structure at point 1 foot below top.
Excavation outside the limits of structural excavation will not be paid for directly but shall be considered subsidiary to the Item "Compacted Embankment."
MATCH LINE
580.990(part)-102"@ 0.06%
Pt. A
Limits for Jacking Boring or Tunneling Pipe.
M.H. #6
Natural Ground
113.851'-102"@ 0.06%
286'-102"@ 3.81 %
100'-102"@ 0.06 %
2:1 Slope
For details of outfall structure, see sheet Nos. 22 & 23.
Elev. 6.00
TEST HOLE #2
Inv 17.03
Inlet 2A, Tx A
Existing Inlet (to be capped)
Exist. Inlet (to be capped)
Inlet 1A, Tx A
Exist. Inlet
18"@ 0.20%
Exist. 18" Swr.
TEST HOLE #1
1. Stiff Brown Silty Clay w/Siltstone @ Elev 48.75
2. Very Stiff Tan Lt. Gray Sandy Clay
3. Stiff Red Blue Silty Clay w/Layers Siltstone Slickensided.
4. Very Stiff Lt Gray Tan Sandy Clay Becomes w/Calc. @ Elev 2700.
5. Very Stiff Red Blue Silty Clay w/Much Siltstone Slickensided.
6. Very Stiff Brown Lt. Gray Sandy Clay.
7. Dense Red Silty Sand.
8. Very Stiff Red Blue Silty Clay.
9. Very Dense Red Silty Sand.
10. Very Stiff Red Silty Clay. Slickensided.
11. Dense Red Clayey Sand.
12. Very Dense Red Silty Sand. Completed @ 14 ft. Depth.
TEST HOLE #2
1. Stiff Gray Silty Clay Becomes Tan Lt Gray @Elev 50.75 & Becomes w/Siltstone @Elev 46.75
2. Very Stiff Lt Gray Tan Sandy Clay
3. Very Stiff Red Blue Silty Clay w/Layers Siltstone Slickensided
4. Very Stiff Lt Gray Tan Sandy Clay
5. Very Stiff Red Blue Silty Clay w/Siltstone
6. Very Hard Brown Lt Gray Sandy Clay. Slickensided
7. Very Dense Brown Lt Gray Clayey Sand w/Sandstone
8. Very Stiff Red Silty Clay w/Siltstone
9. Very Dense Red Silty Sand
Completed @ 58ft Depth
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS
STORM SEWER
PLAN & PROFILE
15A
ORIGINAL 7 JUNE 1962
Rev. F.W.G. Jan. 23, 1963
U514 (43)
U.S. 59



CROSS SECTION
SINGLE ELLIPSE REINFORCED
FOR SECTIONS ⓐ & ⓓ

HALF SECTION DOUBLE ELLIPSE REINFORCED ⓑ

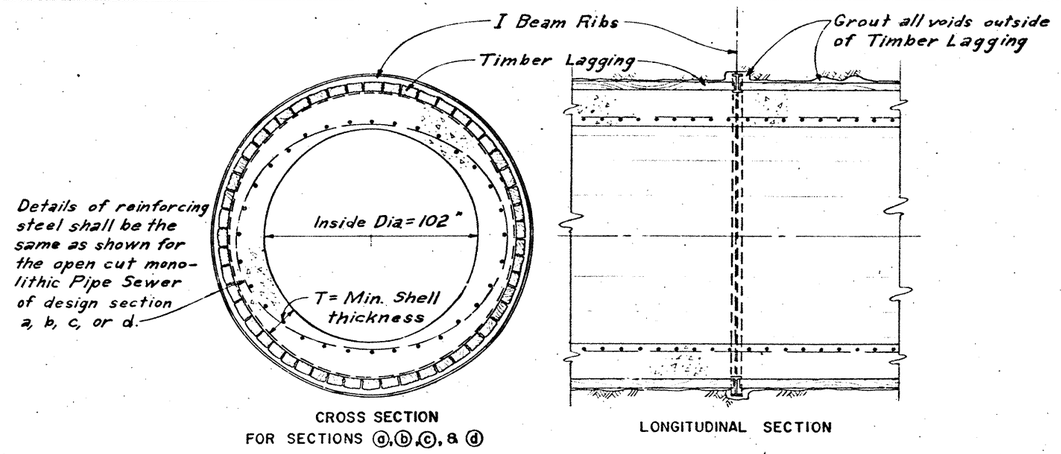
HALF SECTION DOUBLE CIRCLE REINFORCED ⓒ

OPEN CUT MONOLITHIC TYPE PIPE SEWER DETAILS

ELEMENTS OF MONOLITHIC TYPE PIPE SEWER

Design Section	Design Cover ft.	Size	Min. Shell Thickness (T)	Elliptical Reinforcing Bar	Elliptical Reinforcing Size	Elliptical Reinforcing Spa.	Circular Reinforcing Bar	Circular Reinforcing Size	Circular Reinforcing Spa.	Longitudinal Reinf. Size	Longitudinal Reinf. No.	Est. of Quantities (P.L.F.) Reinf. Steel * Lb.	Est. of Quantities (P.L.F.) Class "C" Conc. C.Y. Open Cut	Est. of Quantities (P.L.F.) Class "C" Conc. C.Y. Tunnel
a	30	102"	11"	A	#6	6"	—	—	—	#5	32	126.0	1.427	1.002
b	40	102"	11"	A B	#8 #5	6" 6"	—	—	—	#5	32	264.5	1.427	1.002
c	40	102"	11"	—	—	—	A B	#7 #7	6" 6"	#5	32	286.6	1.427	1.002
d	40	102"	13"	A	#6	5½"	—	—	—	#5	32	136.1	1.660	1.208
e	—	102"	10"	A	#6	6"	—	—	—	#5	32	126.0	—	1.000

*Note: Includes one 20 bar dia. lap per loop.

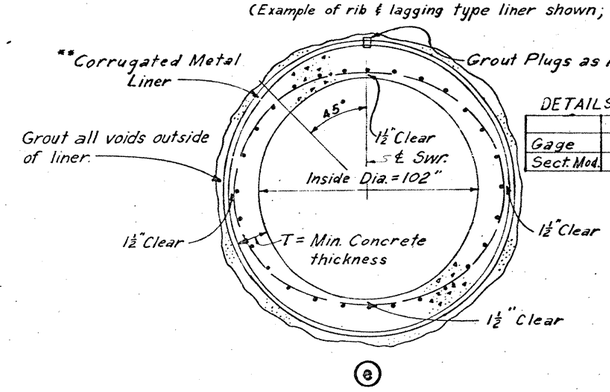


CROSS SECTION
FOR SECTIONS ⓐ, ⓑ, ⓒ, & ⓓ

LONGITUDINAL SECTION

MONOLITHIC TYPE PIPE SEWER TO BE USED IN TUNNELING

(Example of rib & lagging type liner shown; is not acceptable under Railroads.)

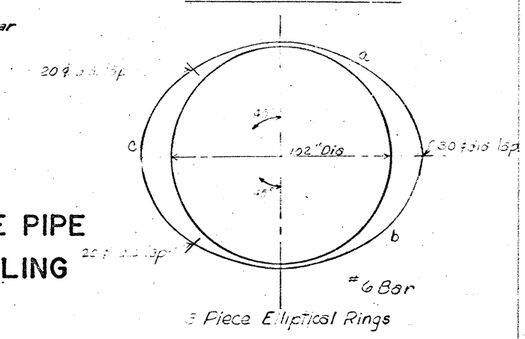


ⓔ

DETAILS OF CORRUGATED METAL LINER PLATE

	Within 15' of a ℄ R.R.	All other places
Gage	#5	#8
Sect. Mod.	0.0918 in.³ per in.	0.0736 in.³ per in.

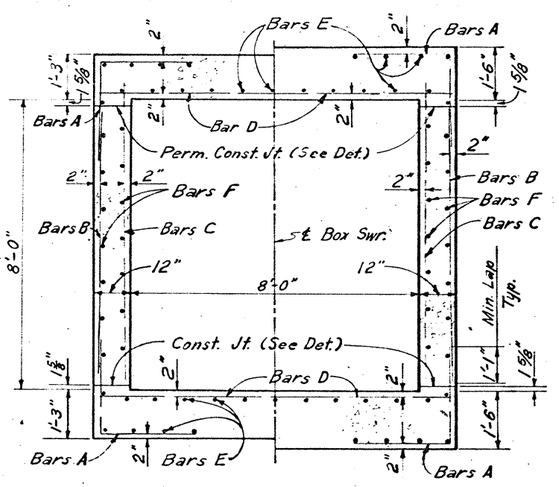
FIELD CHANGE NO. 2*



OPTIONAL MONOLITHIC TYPE PIPE SEWER FOR USE IN TUNNELING

(This section is required under railroads)*

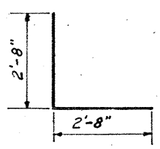
*Field Change #2: Use I beam ribs with timber lagging under railroads in lieu of corrugated metal liner plates as shown on plan sheet. The circular members are to be 4" beams (13lbs/ft) on 3'0" centers, and with the lagging will have a section modulus greater than that specified on the plans. Permit the splicing of elliptical ring reinforcing bars used in the 102" monolitic pipe sewer at the three points shown on the sketch.



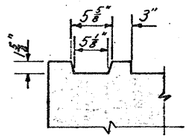
HALF SECTION ⓕ

HALF SECTION ⓖ

OPEN CUT BOX SEWER DETAILS



BAR A
(Box Sewer)



CONST. JT. DETAIL

BOX SEWER TABLE OF REINFORCING

Bar	Section f Size	Section f Spa.	Section f Lenght	Section g Size	Section g Spa.	Section g Length
A	#5	6"	5'-4"	#5	5¾"	5'-4"
B	#5	12"	7'-4"	#5	11½"	7'-6"
C	#5	12"	8'-2"	#5	11½"	8'-5"
D	#5	6"	9'-8"	#5	5¾"	9'-8"
E	#5	10"	Full	#5	10"	Full
F	#5	12"	Full	#5	12"	Full

BOX SEWER EST. OF QUANTITY PER LIN. FT.

Design Section	Design Cover ft.	Reinf. Steel Lbs.	Class "A" Conc. C.Y.
f	30'	191	1.519
g	40'	195	1.704

General Notes:

The Contractor may have two permissible longitudinal construction joints in the monolithic pipe. The elliptical or circular reinforcing shall lap 30 bar diameters when spliced at such joints. The details of such joint shall be submitted to the Engineer for approval.

All quantities shown with these details are for estimating purposes only and are not payment quantities.

Transition round pipe section to square box section in a distance not less than 5 feet nor more than 10 feet. The Contractor shall submit details of his proposed transition to the Engineer for approval.

TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN EXPRESSWAYS

MISCELLANEOUS DETAILS STORM SEWER CONSTRUCTION

SHEET 1 OF 2 SHEETS

Dn. CRW	Drawing	Date	STATE	FEDERAL PROJECT NO.					SHT. NO.
Ck. Dn. FWG	ORIGINAL	AUG. 1962		I-45-11 (7) 096					19
Dw. HMF				US 59 (23)					
Ck. Dw. WEB									
Tr.									
Ck. Tr.			12	HARRIS	500	3	105	US. 59	
					177	11	24		

STATE	FEDERAL AID PROJECT NO.	SHEET NO.
TEXAS	I-45-1(92)046	1

STATE DIST. NO.	COUNTY	CONTROL NO.	SECTION NO.	JOB NO.	HIGHWAY NO.
12	HARRIS	500	3	151	I.H. 45
		27	13	49	U.S. 59

STATE OF TEXAS
STATE HIGHWAY DEPARTMENT

PLANS OF PROPOSED STATE HIGHWAY IMPROVEMENT

FEDERAL AID PROJECT

INTERSTATE I-45-1(92)046
STATE PROJ C 27-13-49
INTERSTATE I-45-1(53)046 R.O.W.
INTERSTATE I-610-7(64)781

STATE CONTROL 500-3-151
STATE CONTROL 27-13-49
STATE CONTROL 500-3-129
STATE CONTROL 271-17-30

NET LENGTH OF PROJECT

PROJECT	ROADWAY	BRIDGES	TOTAL
I-45-1(92)046	3,565.00 FT.=0.675 MI.	0.00 FT.=0.000 MI.	3,565.00 FT.=0.675 MI.*
C 27-13-49	1,704.60 FT.=0.322 MI.	0.00 FT=0.000 MI.	1,704.60 FT.=0.322 MI.
I.610-7(64)781	0.00 FT.=0.000 MI.	0.00 FT=0.000 MI.	0.00 FT.=0.000 MI.

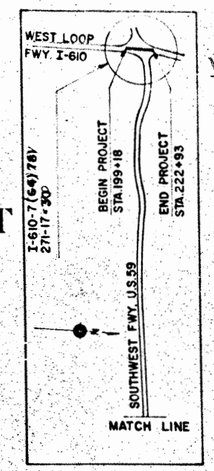
HOUSTON URBAN EXPRESSWAYS
I-45 - U.S.59 INTERCHANGE

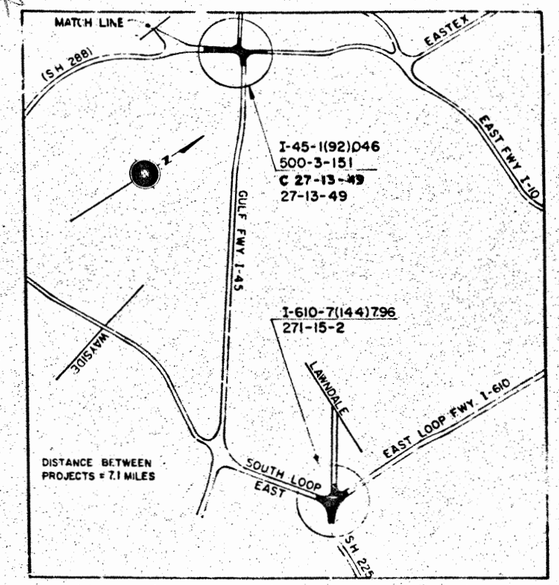
FROM ELGIN ST. TO LEELAND AVE.

U.S. HIGHWAY 59 HARRIS COUNTY

GRADING, STORM SEWER, CEMENT STABILIZED BASE, CONCRETE PAVEMENT, ASPHALTIC CONCRETE PAVEMENT, STRUCTURES, SANITARY SEWERS, WATER LINES, TRAFFIC CONTROL SIGNAL SYSTEMS, ETC.

*U.S. 59 Mileage - No Project Length along I.H. 45





VICINITY MAP

SHOWING RELATIVE LOCATION OF PROJECTS COMBINED IN ONE PROPOSAL

STA.468+40.00
BEGIN PROJECT
C 27-13-49
CONTROL 27-13-49

STA.66+85.00
END PROJECT
C 27-13-49
CONTROL 27-13-49
STA.66+85.00
BEGIN PROJECT
I-45-1(92)046
CONTROL 500-3-151

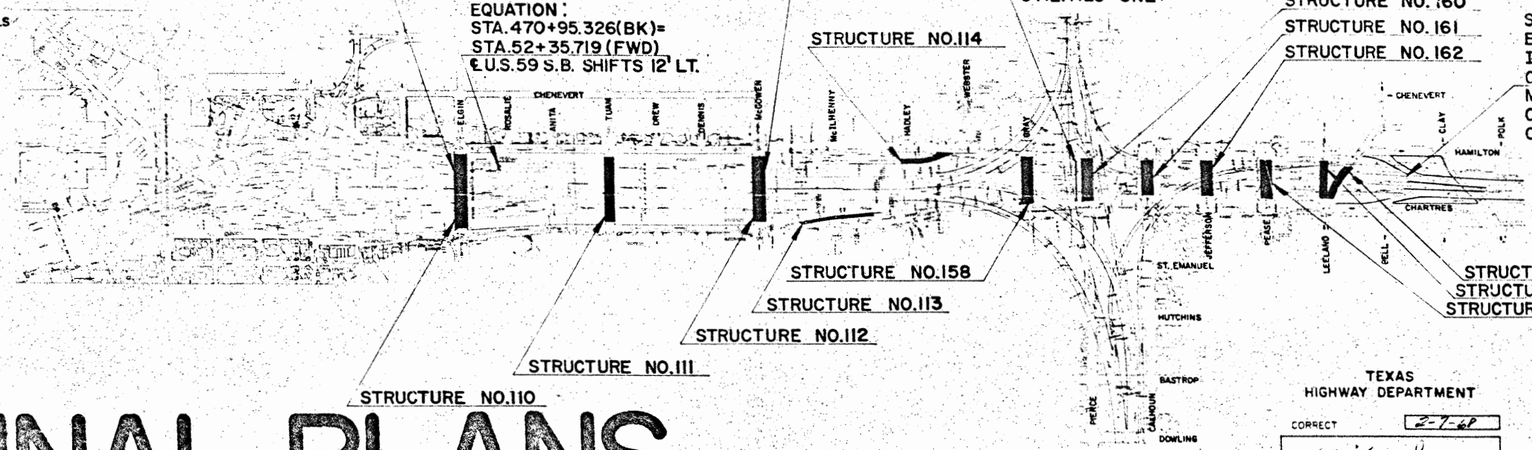
EQUATION:
STA.470+95.326(BK)=
STA.52+35.719(FWD)
℄ U.S.59 S.B. SHIFTS 12' LT.

STRUCTURE NO.159
UTILITIES ONLY

STRUCTURE NO.160
STRUCTURE NO.161
STRUCTURE NO.162

STA.102+50.00
END PROJECT
I-45-1(92)046
CONTROL 500-3-151
MEET F.A.P. U-UG 514(45)
CONTROL 177-11-28
COMPLETED OCT. 7, 1966

STRUCTURE NO.114



STRUCTURE NO.158
STRUCTURE NO.113
STRUCTURE NO.112
STRUCTURE NO.111
STRUCTURE NO.110

STRUCTURE NO.165
STRUCTURE NO.164
STRUCTURE NO.163

FINAL PLANS

ONE EQUATION:
STA.470+95.326(BK) ℄ U.S.59 S.B.=
STA.52+35.719(FWD) ℄ U.S.59 S.B.
NO GRADE CROSSINGS ELIMINATED
NO GRADE CROSSINGS RETAINED
NO EXCEPTIONS
LIMITS ON 104 (b) 5 NEEDS ESTIMATE MAP
BEGIN A 12.0.2 END A 12.0.2

LAYOUT SCALE: 1 IN. = 400 FT.

THE CITY HEREBY CONSENTS TO THE CONSTRUCTION OF THESE HIGHWAY TRAFFIC SIGNALS AS TO LOCATION AND MANNER OF CONSTRUCTION AS INDICATED ON THESE PLANS, SAID INSTALLATION BEING A PART OF "AGGREMENT (TRAFFIC SIGNAL-EXPRESSWAY TYPE E-1A DISTRICT 12)" DATED MAY 7, 1963

APPROVED 7-4-68 DATE

DIRECTOR, TRAFFIC AND TRANSPORTATION
CITY OF HOUSTON

CITY OF HOUSTON

RECOMMENDED FOR APPROVAL 7-4-68
DIRECTOR OF PUBLIC WORKS

APPROVED 7-4-68
MAYOR

TEXAS HIGHWAY DEPARTMENT

CORRECT 2-7-68
URBAN DESIGNING ENGINEER

APPROVED 2-7-68
ENGINEER MANAGER

APPROVED
ENGINEER

DEPT. OF TRANSPORTATION
BUREAU OF PUBLIC ROADS

APPROVED
DIVISION ENGINEER

STATE OF TEXAS — W. HARDY — 10787 — REGISTERED PROFESSIONAL ENGINEER

STATE OF TEXAS — A.C. HYSER — 7516 — REGISTERED PROFESSIONAL ENGINEER

INDEX OF SHEETS

SHEET NO.	DESCRIPTION
1	TITLE SHEET
1A-1B	FIELD CHANGE, SUPPLEMENTAL AGREEMENT, EXTRA WORK ORDER
2-8	TYPICAL CROSS SECTION
9-14	SPEC DATA
15-23	ESTIMATE & QUANTITIES
24-26	PROJECT LAYOUT
27-29	HORIZONTAL CURVE DATA
30-46	R.O.W. LAYOUTS
47-52	ROADWAY PLAN
53-62	ROADWAY PROFILES
63-74	INTERSECTION GRADING & DETAILS
75-104B	ROADWAY DETAILS AND VIA LAYOUT AND DETAILS
105-105G	TYP DTLS JIGGLE BARS & TRAFFIC BUTTONS AND PAVEMENT MARKINGS
106-108A	CONTIN REINF CONC PAV
109-111	MISC ROADWAY DETAILS
112-113	RIPRAP DETAILS
114-115	CHAIN LINK BARRIER FENCE
116	METAL BEAM GUARD FENCE
117	ROADSIDE CLEARANCE DETAILS
118-127	WATER LINES
128	DRAINAGE AREAS & VIC W/RUNOFF COMP
129-134	STM SWR PLANS
135-139	STM SWR PROFILES
140-143	SIPHON LAYOUTS & DETAILS
144-146	JUNCTION BOX DTLS
147-156	SEWER DETAILS
157-161	UTILITY LAYOUTS
162-167	SAN SEWER PLAN & PROFILES
168	SAN SEWER DTLS
169-171	TEST HOLE DATA
172-177	RET WALL A LAYOUT & DETAILS
178-180	RET WALL B LAYOUT & DETAILS
181-183	RET WALL C LAYOUT & DETAILS
184-188	RET WALL D LAYOUT & DETAILS
189-191	RET WALL E LAYOUT & DETAILS
192-195	RET WALL F LAYOUT & DETAILS
196-200	RET WALL G LAYOUT & DETAILS
201-203	RET WALL LH & RH LAYOUT & DETAILS
204	MISC RET WALL DETAILS
205-207	APRON SLAB DETAILS
208-217	CONDT LAYOUTS & DETAILS AND LIGHTING STD FND DETAILS
218-220A	LIGHT BRACKET DETAILS
221-227	TRAFFIC CONT SIG SYSTEM
228	BARRICADES & BEACONS
229-236	ROADWAY RAILING LAYOUT
237-239	RAILING LAYOUT AT BRIDGE COLUMNS
240-240A	MEDIAN RAILING LAYOUT
241	COLUMN GUARD & DRILL SHAFT DTLS
242	ROADWAY MEDIAN RAIL FOOTING DTLS
243-243A	MISC DTLS E-3 CURB & RAILING (TY E-3) AND WINGWALL
244-250	MISC BRIDGE DETAILS
251-262	STRUCT NO 110 LAYOUT & DTLS ELGIN
263-271	STRUCT NO 111 LAYOUT & DTLS TUAM
272-283	STRUCT NO 112 LAYOUT & DTLS McGOWEN
284-301	STRUCT NO 113 LAYOUT & DTLS RAMP K
302-319	STRUCT NO 114 LAYOUT & DTLS RAMP N
320-333	STRUCT NO 158 LAYOUT & DTLS GRAY
334-339	STRUCT NO 159 LAYOUT & DTLS PIERCE UTIL
340-352	STRUCT NO 160 LAYOUT & DTLS PIERCE
353-365	STRUCT NO 161 LAYOUT & DTLS CALHOUN
366-378	STRUCT NO 162 LAYOUT & DTLS JEFFERSON
379-391	STRUCT NO 163 LAYOUT & DTLS PEASE
392-402	STRUCT NO 164 LAYOUT & DTLS LEELAND
403-413	STRUCT NO 165 LAYOUT & DTLS LEELAND-BE
414	R.O.W. PROJECT MARKERS & BENCH MARK DETAILS
415-416	BARRICADES BW-61-(1-MOD) & (2)
417	CIS-67
418	SAFETY PROJECT
419	TOTAL SHEETS

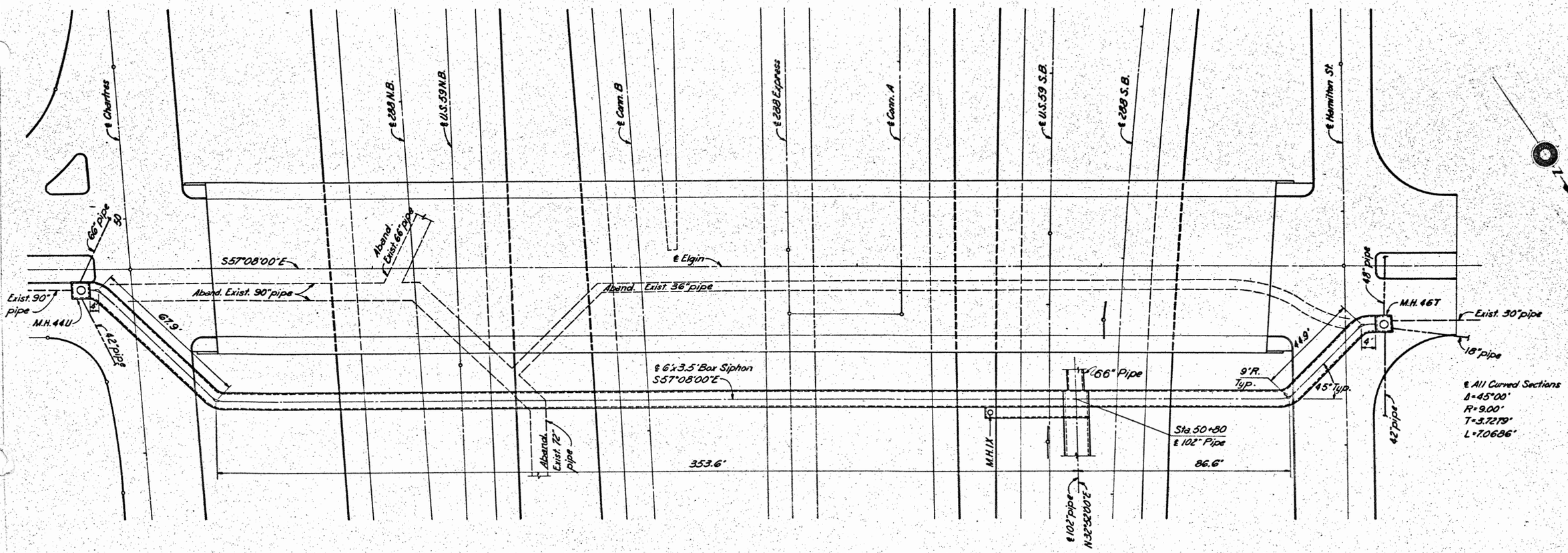
NOTES:

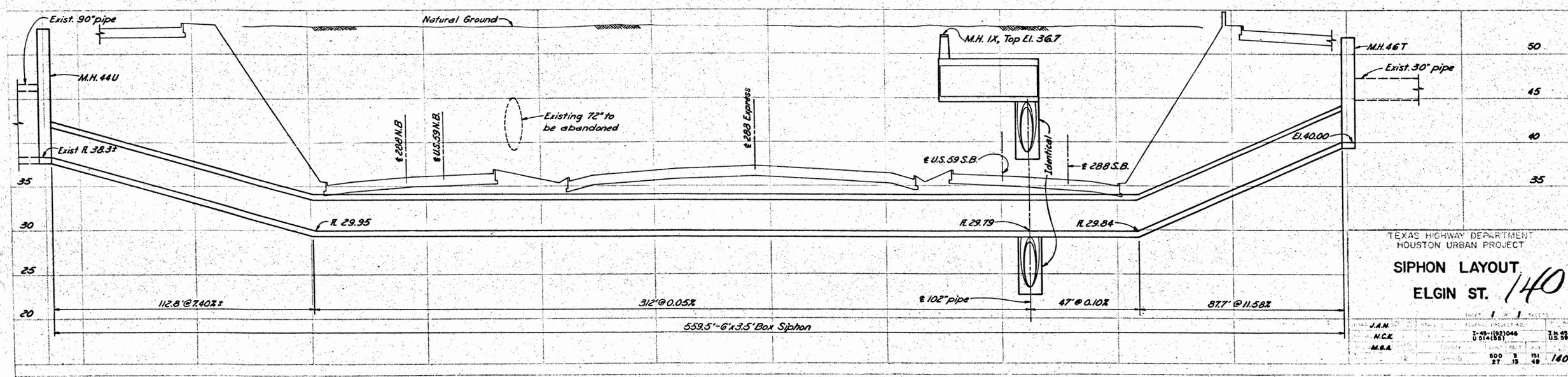
SEE SPECIAL PROVISION REGARDING DESCRIPTION OF PROJECT, SCOPE OF CONTRACT AND SEQUENCE OF WORK, ETC.
SPECIFICATIONS ADOPTED BY THE STATE HIGHWAY DEPARTMENT OF TEXAS JANUARY 2, 1962, AND SPECIFICATION ITEMS LISTED AND DATED AS FOLLOWS SHALL GOVERN ON THIS PROJECT:
REQUIRED CONTRACT PROVISIONS FOR FEDERAL AID CONTRACTS
INTERSTATE HIGHWAYS (FORM PR.-1273, DECEMBER, 1965)

SEE PROJECT LAYOUT SHEETS FOR BARRICADES, WARNING SIGNS, AND OTHER PROJECT LIMITS.

COUNTY HARRIS PROJ. NO. U 514(55) I-45-1(92)046
HWY. NO. I.H. 45 U.S. 59 LETTING DATE I-45-1(53)046 R.O.W.
DATE ACCEPTED

RECORDS MANAGEMENT
RETURN TO
DEPARTMENT OF TRANSPORTATION



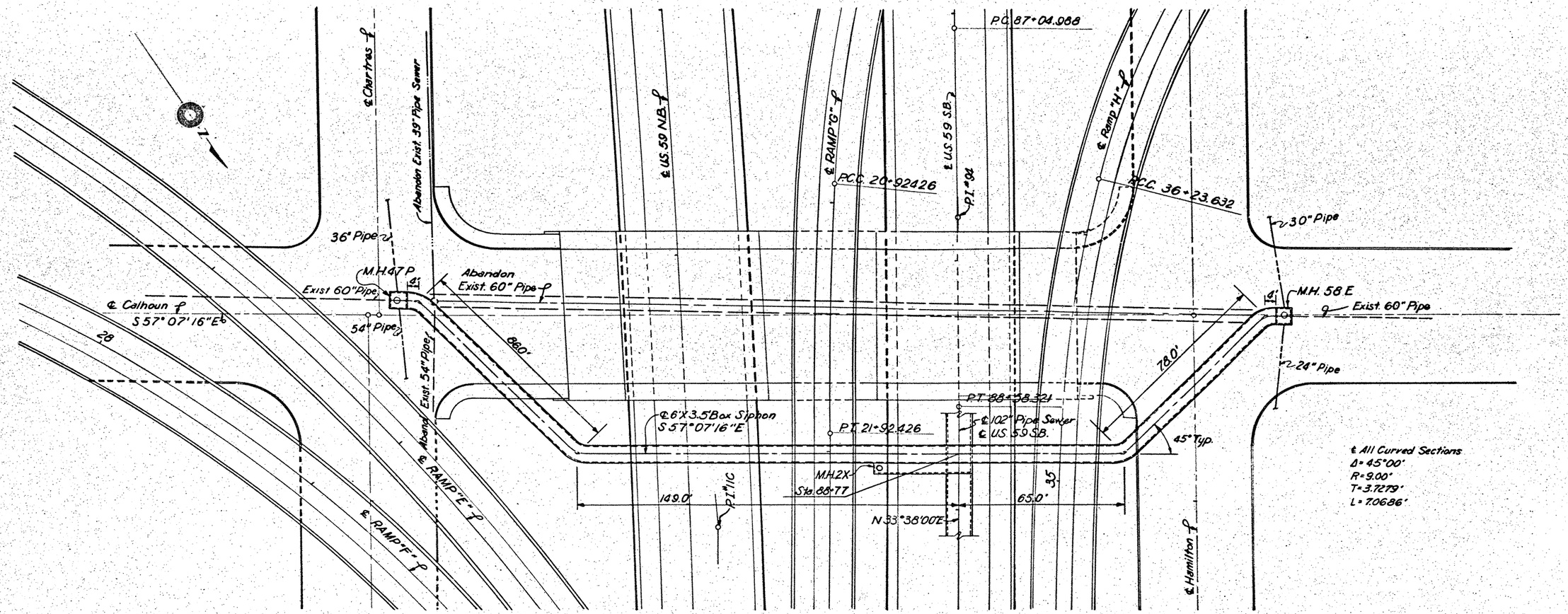


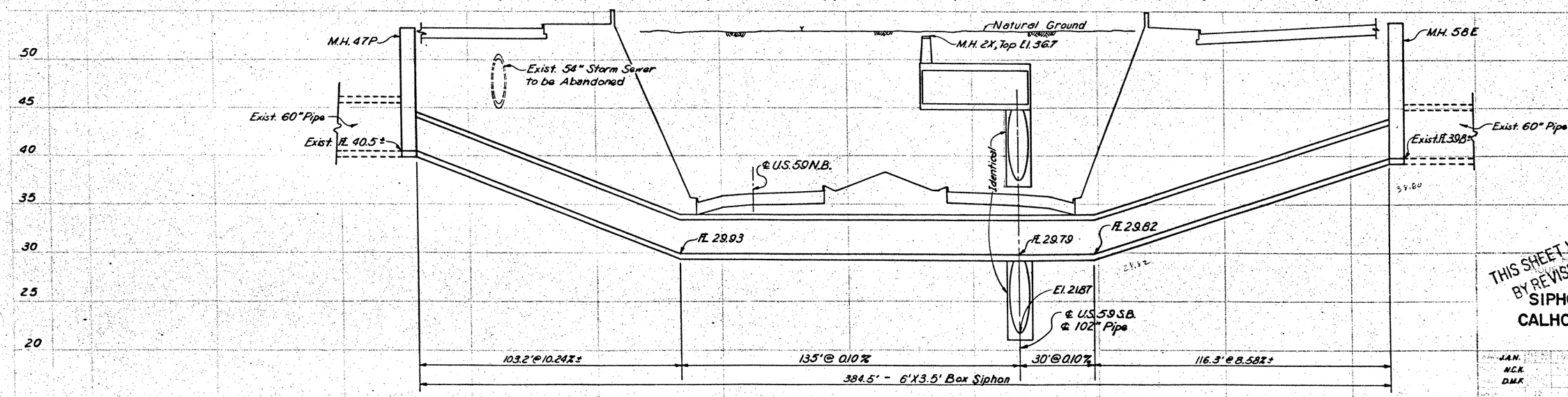
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN PROJECT

SIPHON LAYOUT

ELGIN ST. 140

J.A.M.	FEDERAL PROJECT NO.		
N.C.K.	T-48-1(92)046	T.H. 48	
M.G.A.	U 514(55)	U.S. 59	
	500 3 151	140	
	27 13 48		





THIS SHEET VOID AND REPLACED BY REVISED SHEET NO. 141A

DEPARTMENT
URBAN PROJECT

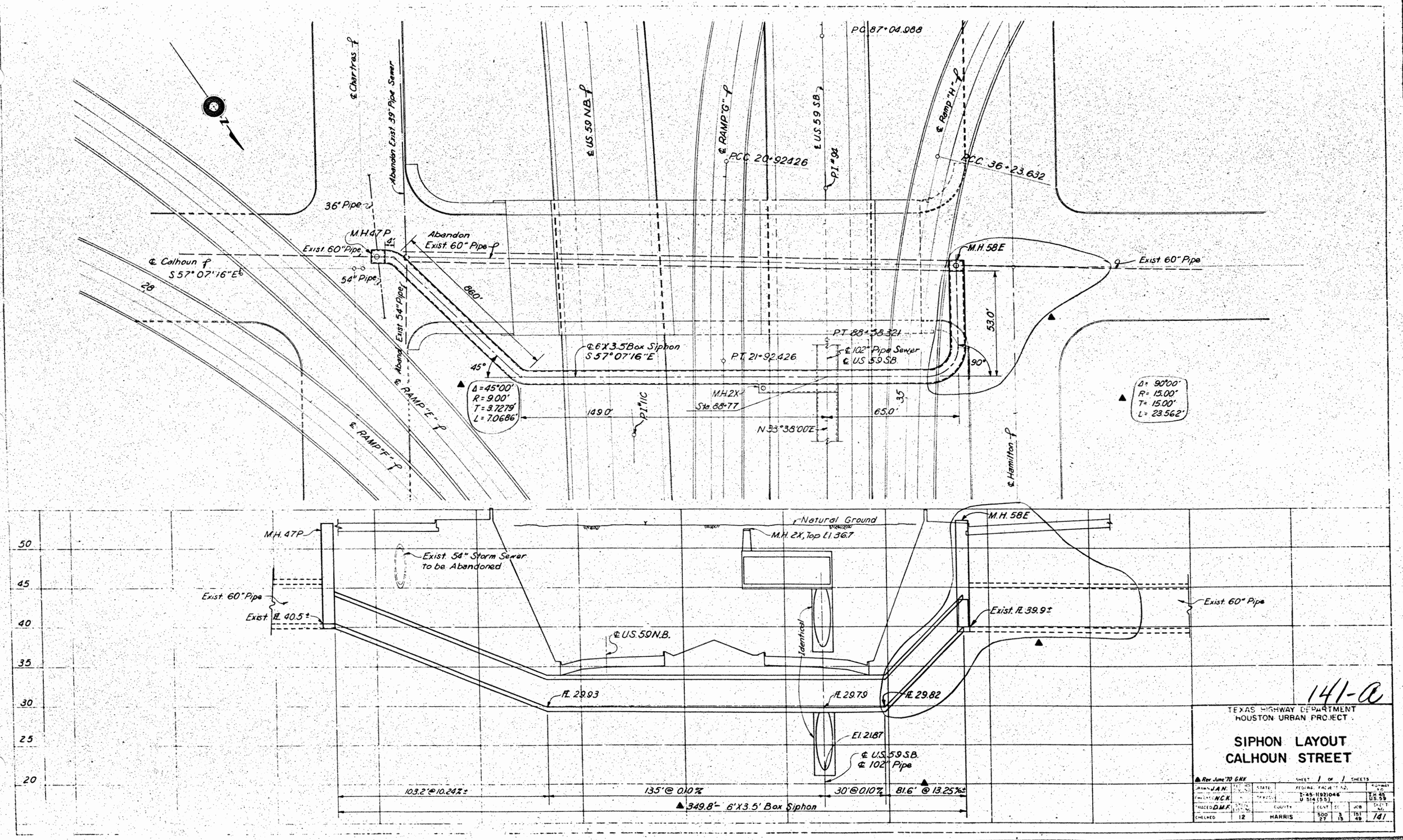
SIPHON LAYOUT
CALHOUN STREET 141

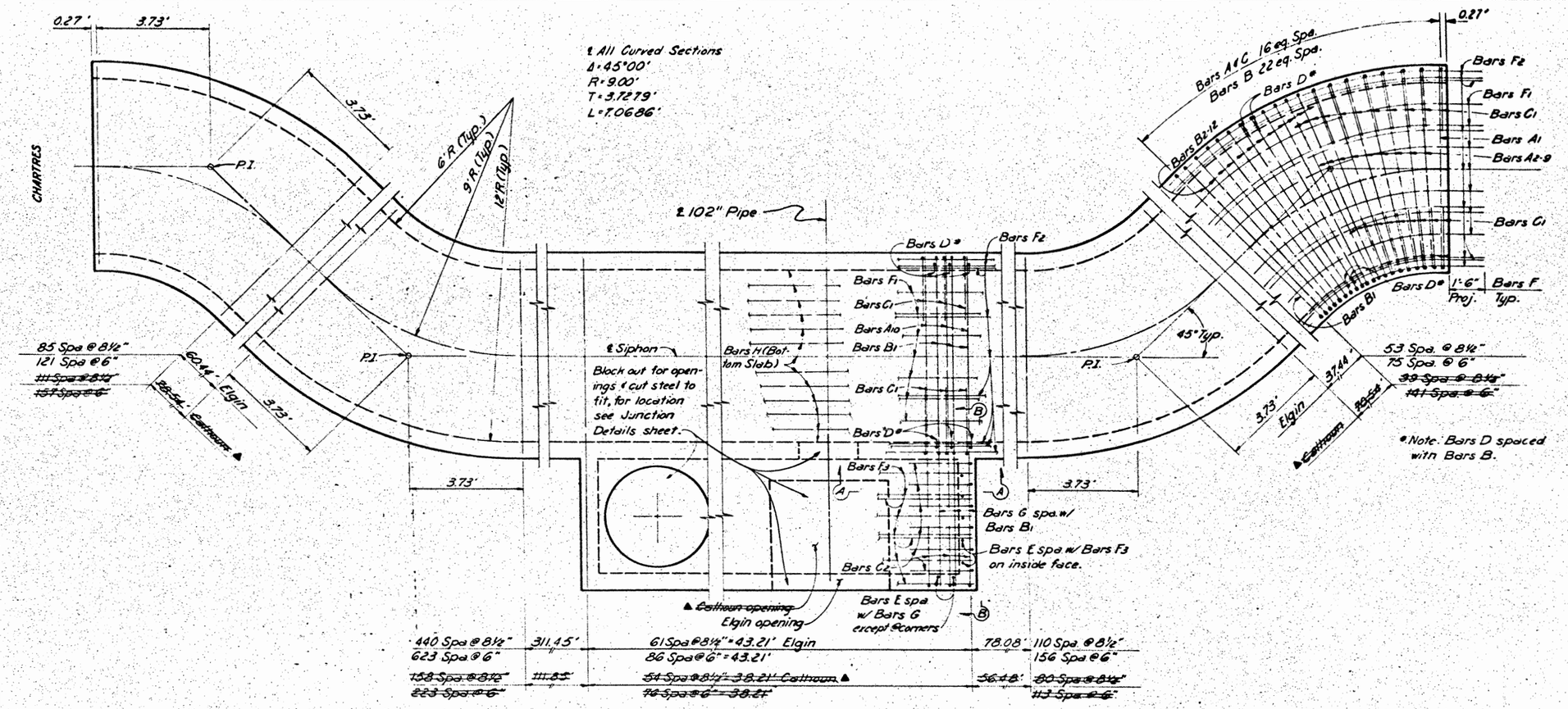
J.A.N.
N.C.K.
D.M.K.

I-45-H(8)1046
U 514(55)

Tex 65
US 59

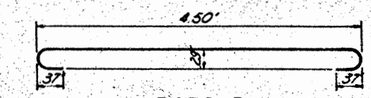
500 27 3 13 151 49 141


PC 87+04.988
℄ Chartres ℘
Abandon Exist. 39" Pipe Sewer
℄ US 59 NB ℘
℄ RAMP "G" ℘
PCC 20+92.426
℄ US 59 SB
PI #94
℄ Ramp "H" ℘
PCC 36+23.632
36" Pipe
M.H. 47P
Exist. 60" Pipe
Abandon Exist. 60" Pipe ℘
℄ Calhoun ℘
S 57° 07' 16" E
54" Pipe
28
860'
Aband. Exist. 54" Pipe
℄ RAMP "E" ℘
℄ RAMP "F" ℘
45°
℄ 6'X3.5' Box Siphon
S 57° 07' 16" E
PT 21+92.426
PT 88+38.321
℄ 102" Pipe Sewer
℄ US 59 SB
M.H. 58E
Exist. 60" Pipe
53.0'
90°
Δ = 45°00'
R = 9.00'
T = 3.7279'
L = 7.0686'
149.0'
PI #11C
M.H. 2X
Sta. 88+77
N 33° 38' 00" E
35
65.0'
℄ Hamilton ℘
Δ = 90°00'
R = 15.00'
T = 15.00'
L = 23.562'
50
45
40
35
30
25
20
M.H. 47P
Exist. 54" Storm Sewer to be Abandoned
Natural Ground
M.H. 2X, Top El. 36.7
M.H. 58E
Exist. 60" Pipe
Exist. Fl. 40.5±
℄ U.S. 59 N.B.
Identical
Exist. Fl. 39.9±
Exist. 60" Pipe
Fl. 29.93
Fl. 29.79
Fl. 29.82
El. 21.87
℄ U.S. 59 S.B.
℄ 102" Pipe
103.2' @ 10.24%±
135' @ 0.10%
30' @ 0.10%
81.6' @ 13.25%±
349.8'± 6'X3.5' Box Siphon
141-a
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN PROJECT
SIPHON LAYOUT
CALHOUN STREET
Rev. June '70 GHV
SHEET 1 OF 1 SHEETS
DRAWN J.A.N.
CHECKED N.C.K.
TRACED D.M.F.
CHECKED
12
STATE
TEXAS
COUNTY
HARRIS
FEDERAL PROJECT NO.
F-45-1(92)046
U 514 (55)
HIGHWAY NO.
IH 45
US 59
CONT.
500
27
SEC.
3
15
JOB
151
49
SHEET NO.
141

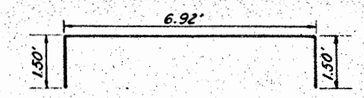


PLAN

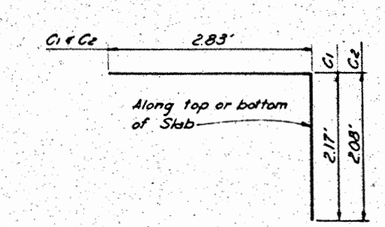
(SHOWING PARTIAL REINFORCING IN TOP & BOTTOM SLAB)



BARS D



BARS B



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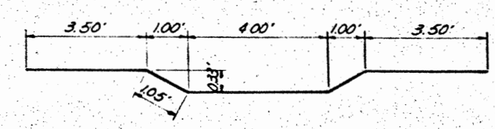

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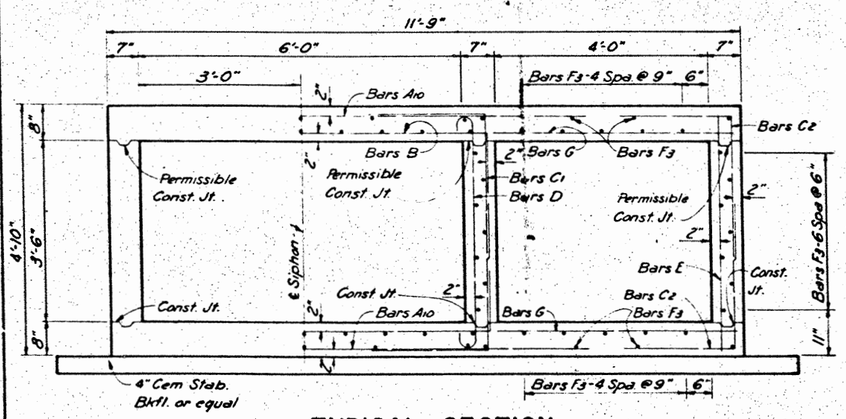
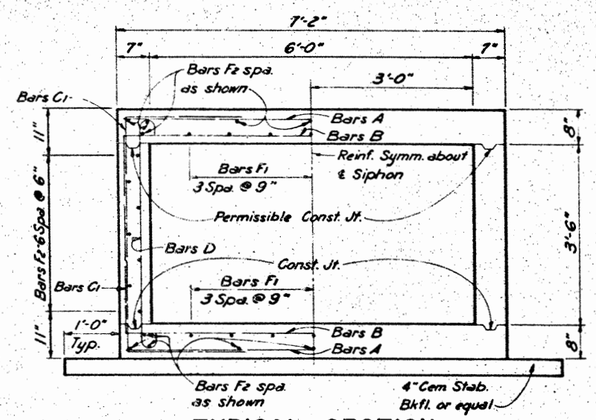
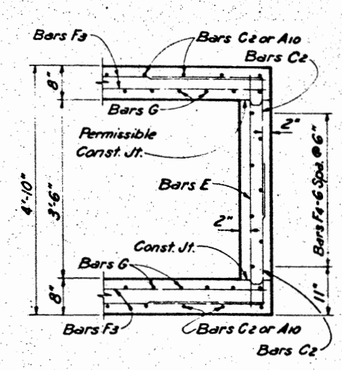


TYPICAL SECTION
SIPHON & MANHOLE EXTENSION



TYPICAL SECTION
SIPHON



SECTION A-A

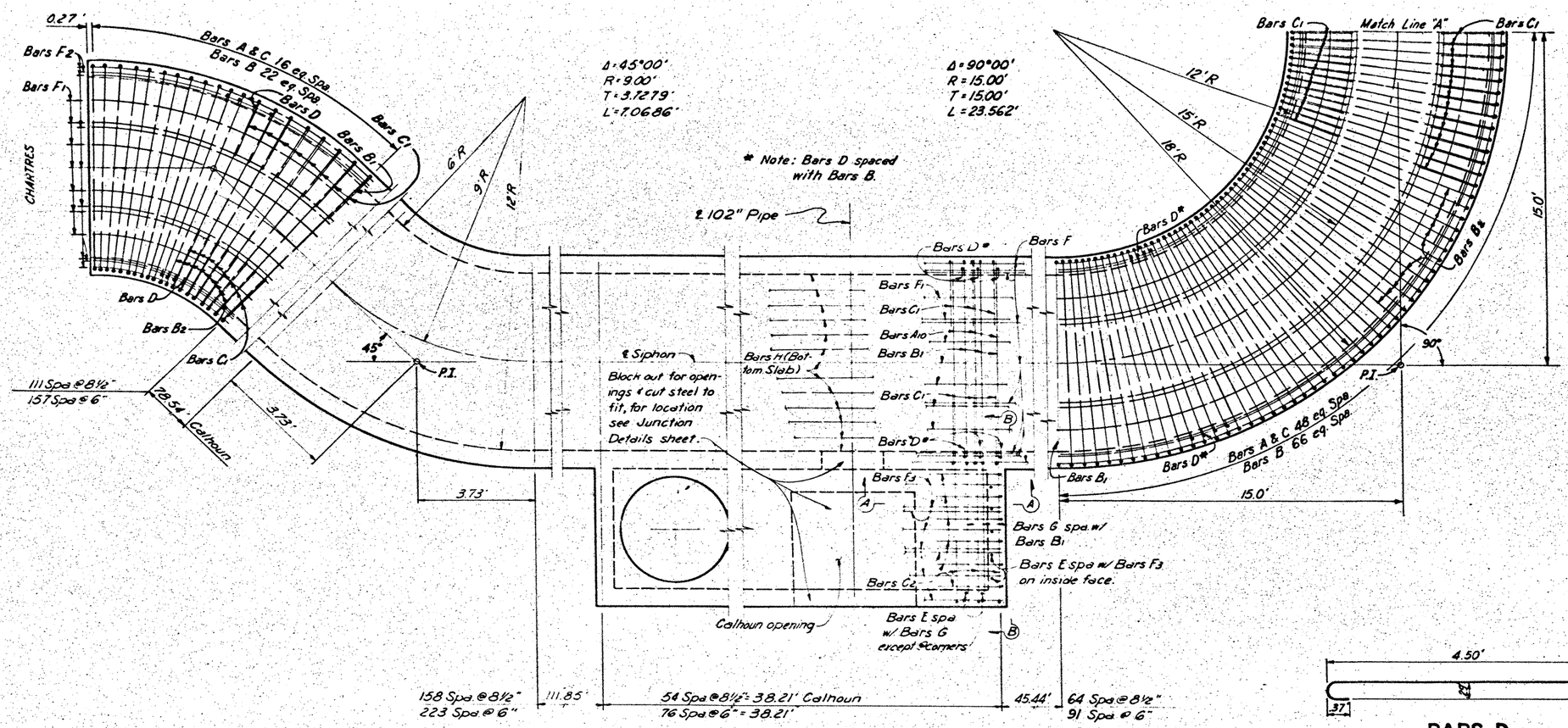
TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN PROJECT

SIPHON DETAILS ▲ELGIN STREET

142

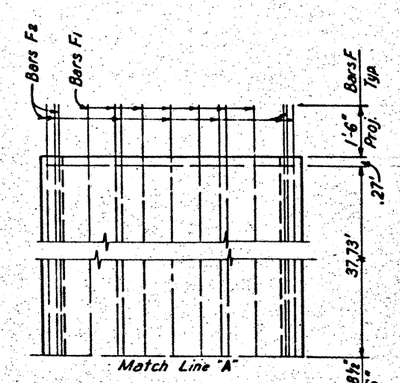
Sheet 1 of 2

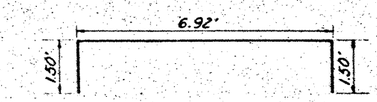
Dr. J.A.N.	Drawn No.	Date	Fed. Road Div. No.	State	Federal Aid Project No.
Ck. Dr. N.C.K.	ORIGINAL	JUNE, 1967	6	TEXAS	I-45-1(927)046
Dr. M.G.A.	Rev. 21 May, 1968				U 516(55)
Ck. Dr. N.C.K.	▲ Rev. June, '70		District No. 12	County Harris	142



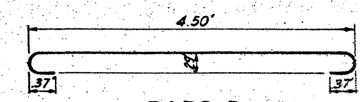
PLAN

(SHOWING PARTIAL REINFORCING IN TOP & BOTTOM SLAB)





BARS B



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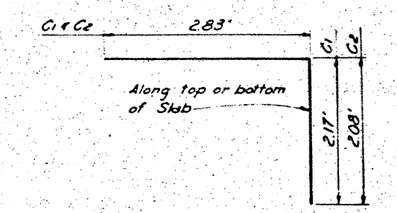
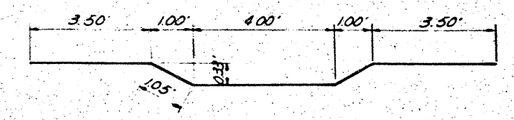
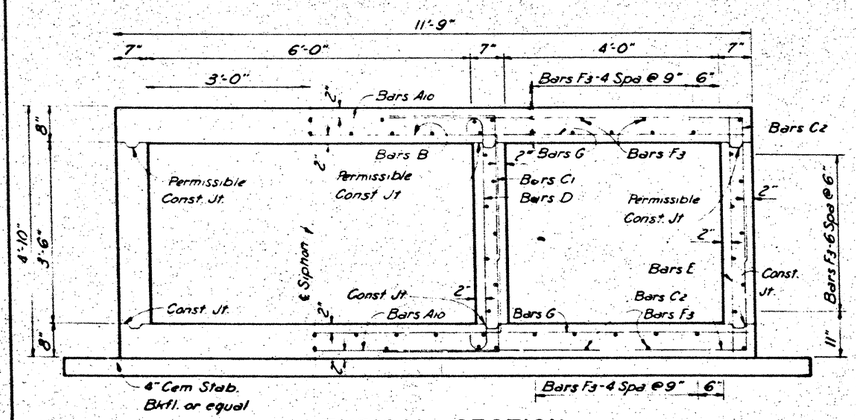


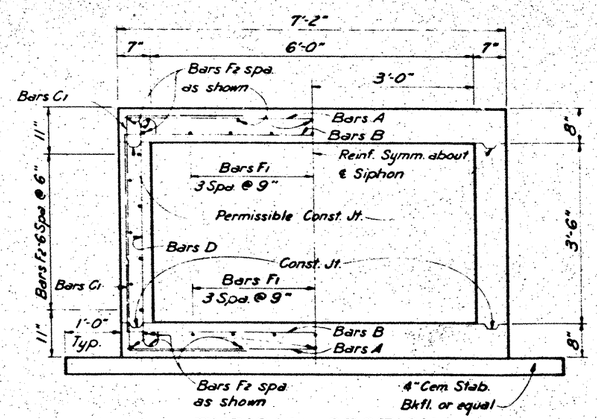
BARS C



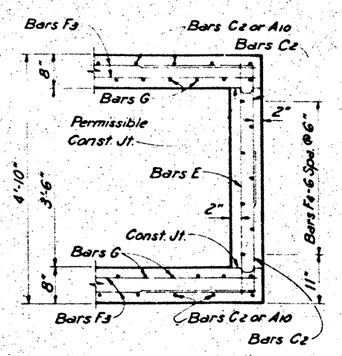
BARS H



TYPICAL SECTION
SIPHON & MANHOLE EXTENSION



TYPICAL SECTION
SIPHON



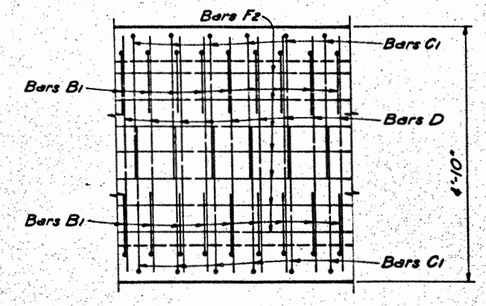
SECTION A-A

TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN PROJECT

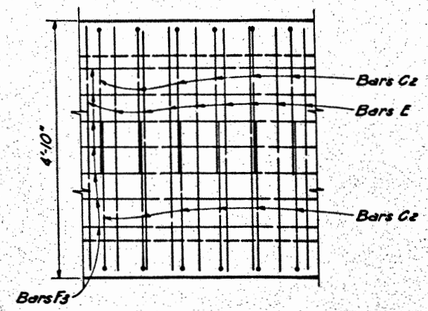
SIPHON DETAILS 142-a
CALHOUN STREET

Sheet 1 of 2

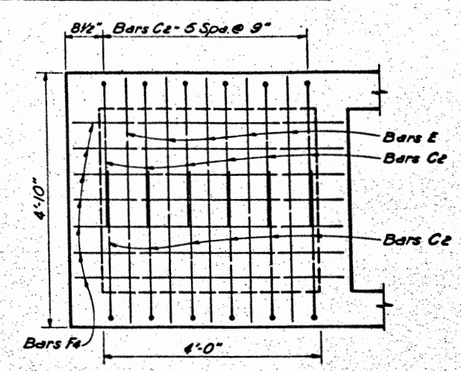
Dr. JAN	Design No.	Date	Fed. Road State	State	Federal Aid Proj. No.
Ck. by NCK	ORIGINAL	JUNE, 1967	6	TEXAS	3-48-(163)046 U 5146(55)
Dr. MGA	Rev 21 May, 1968				142 A
Ck. by NCK					
Dr. No.			District No.	County	Sheet No. / Total Sheets
Ck. No.			12	Harris	505 27 / 13 / 49 / 3 / 49 U 5 59



ELEVATION SECTION
SIPHON



ELEVATION SECTION
MANHOLE EXTENSION

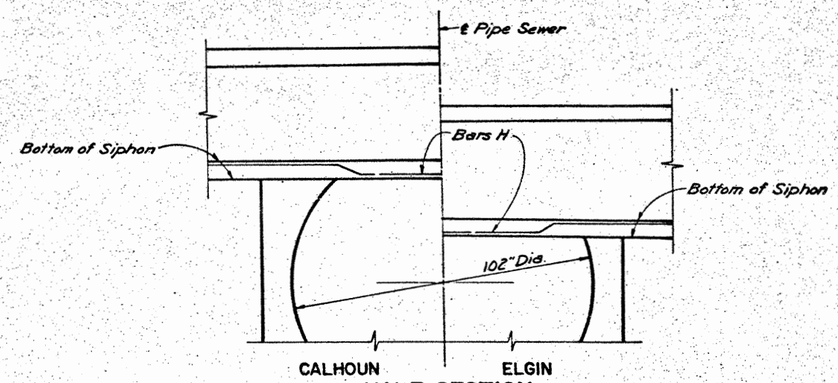


ELEVATION
SECTION B-B

Notes: All concrete shall be class "C".

Transverse Construction Joints shall have rubber waterstops as shown in Waterstop Detail. Cost of waterstops shall be considered incidental.

All dimensions relating to reinforcing steel are to center of bars.



HALF SECTION
(SHOWING PLACING OF
BARS H)

ESTIMATED QUANTITIES

ITEM	UNIT	ELGIN	CALHOUN
Sewer Excav (Box Sewer)	CY	1,907	■ 1458
Cem Stab Bkfl	CY	64.1	■ 41.2
Cl C Conc (Box Sewer)	CY	295.9	■ 189.6
Reinf Stl	LB	74,288	■ 45,639

BILL OF REINFORCING STEEL

ELGIN

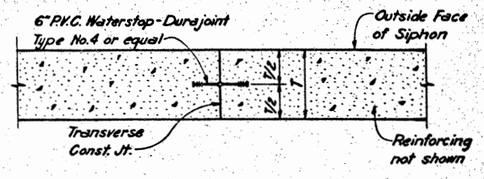
Bar	No.	Size	Spacing	Length	Weight
A1	1384	#4	8½"	6.92'	6,398
A2-9	120	#4	As Shown	6.92'	555
A10	124	#4	8½"	9.00'	745
B1	2132	#5	6"	9.92'	22,059
B2-12	168	#5	As Shown	9.92'	1,738
C1	3256	#4	8½"	5.00'	10,875
C2	148	#4	As Shown	4.92'	486
D	2300	#4	6"	5.58'	8,573
E	95	#4	As Shown	4.58'	291
F1	14	#5	"	579.00'▼	8,455
F2	32	#4	"	579.00'▼	12,377
F3	23	#4	"	43.25'	664
F4	14	#4	"	4.92'	46
G	174	#5	6"	4.67'	848
H	13	#5	6"	13.10'	178
Total				Lbs.	74,288

▼ Includes 10 Laps @ 2 proj. of 1'-6".

CALHOUN

Bar	No.	Size	Spacing	Length	Weight
A1	■782	#4	8½"	6.92'	■3,615
A2-9	■154	#4	As Shown	6.92'	■712
A10	110	#4	8½"	9.00'	■661
B1	■1102	#5	6"	9.92'	■11,402
B2	■214	#5	As Shown	9.92'	■2,214
C1	■2092	#4	8½"	5.00'	■6,987
C2	134	#4	As Shown	4.92'	440
D	■1316	#4	6"	5.58'	■4,905
E	85	#4	As Shown	4.58'	260
F1	14	#5		■358'*	■5,228
F2	32	#4		■358'*	■7,653
F3	23	#4		38.25'	588
F4	14	#4	As Shown	4.92'	46
G	154	#5	6"	4.67'	750
H	13	#5	6"	13.10'	178
Total				Lbs.	■45,639

* Includes ■5 Laps @ 2 proj. of 1'-6".



WATERSTOP DETAIL FOR SIPHON

TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN PROJECT

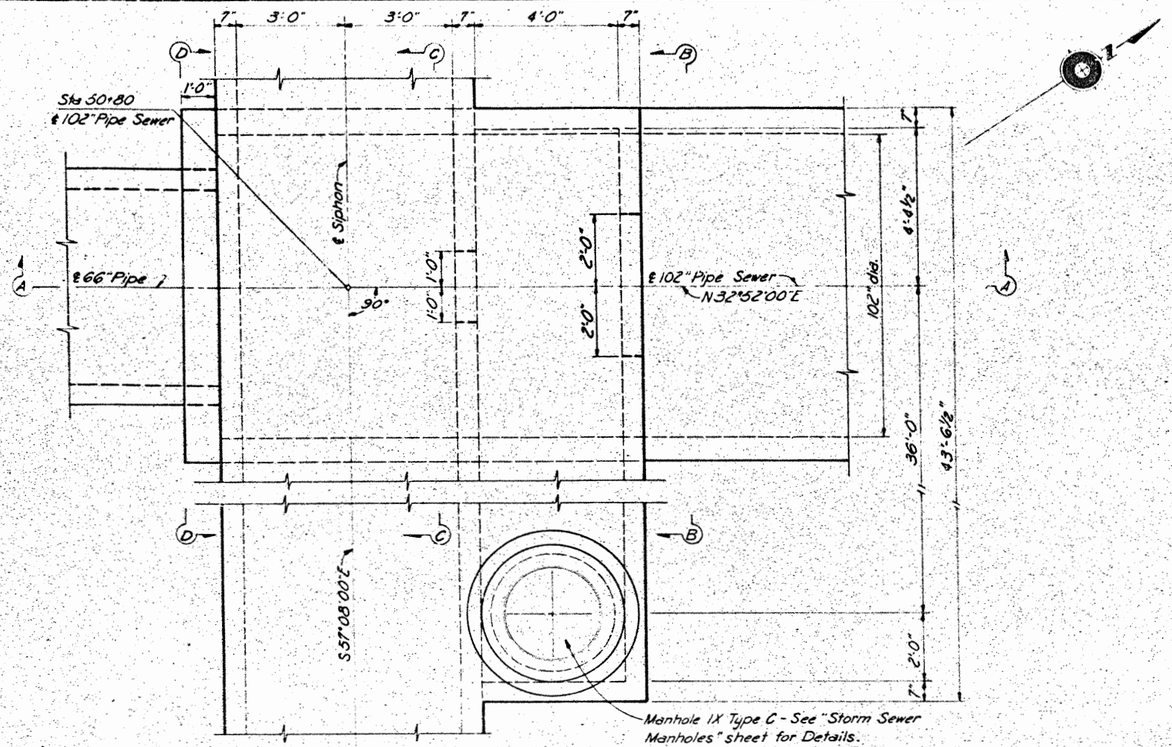
SIPHON DETAILS 143

Sheet 2 of 2

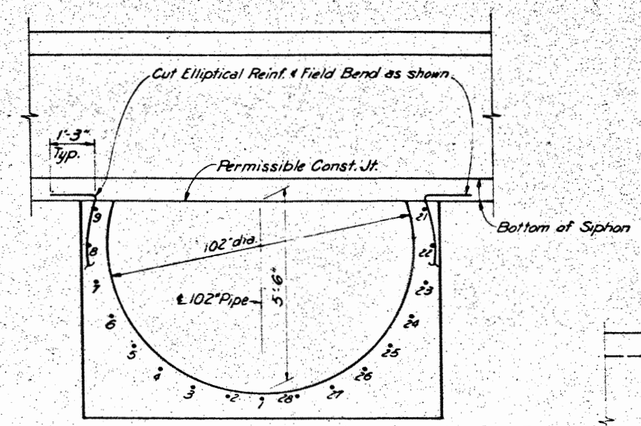
Dn. J.A.N. / Ck. Dn. M.C.K.	Drawing: ORIGINAL / ■ Rev. June '70	Date: JUNE, 1967	Fed. Road Div. No. 6	State: TEXAS	Federal Aid Project No.: I-45-(92)046, U 514 (33)	Sheet No. 143
Dn. M.G.A. / Ck. Dn. M.C.K. / Tr. / Ck. Tr.			State Dist. No.	County	Control / Section / Job / Highway No. 500 / 3 / 151 / I.H. 45; 27 / 13 / 49 / U.S. 59	

Notes: Only portions of Elliptical Reinforcing for 102" dia. pipe sewer have been shown on these details. Longitudinal Reinforcing has been numbered, for clarity, from bottom in a clockwise direction. For details of 102" dia. pipe sewer see "Monolithic Sewer Details".

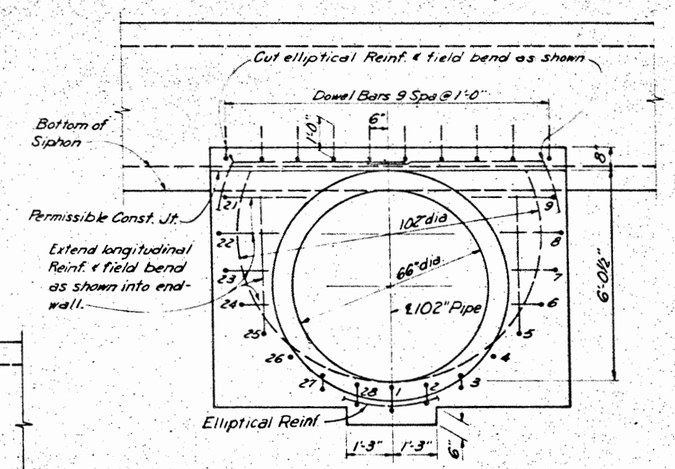
Cost for changes in 102" dia. pipe sewer will be included in unit price bid for 102" dia. pipe sewer.



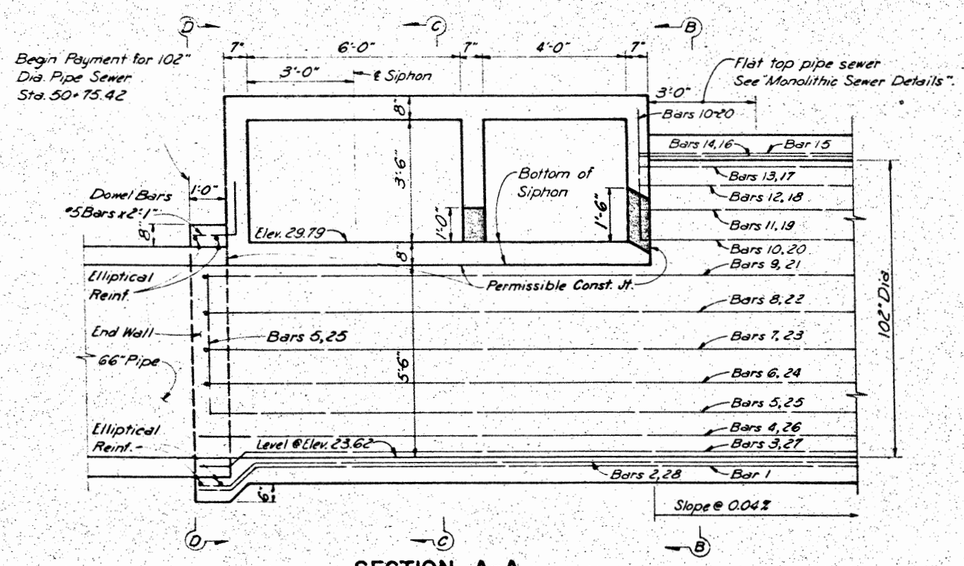
PLAN



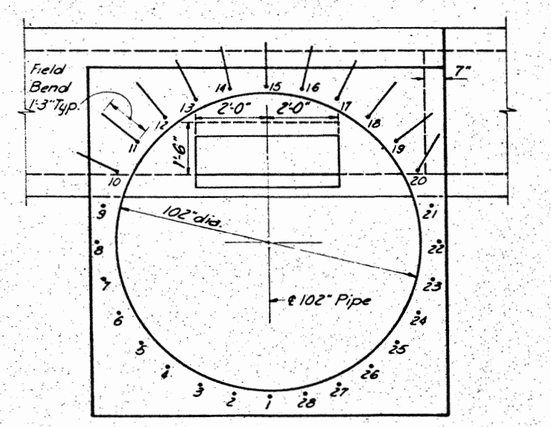
SECTION C-C



SECTION D-D



SECTION A-A
(ELLIPTICAL REINFORCING NOT SHOWN)



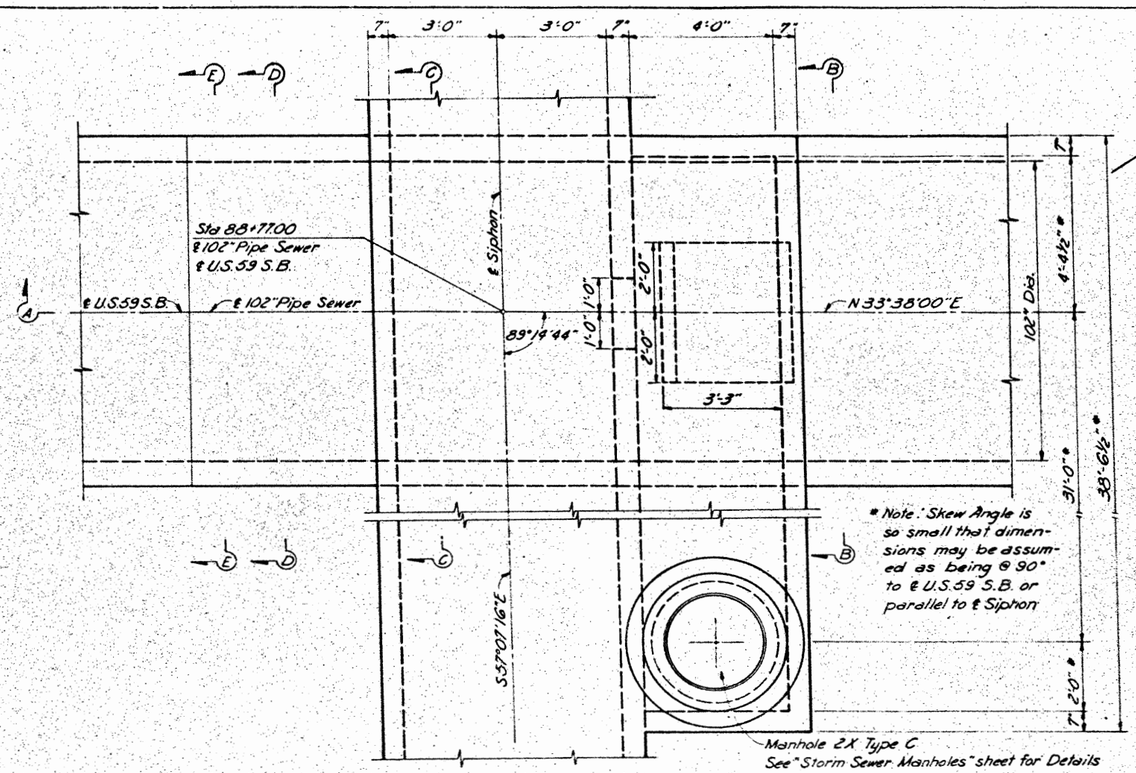
SECTION - B-B
(ELLIPTICAL REINFORCING NOT SHOWN)

TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN PROJECT

JUNCTION DETAILS AT TRUNK AND ELGIN ST. SIPHON

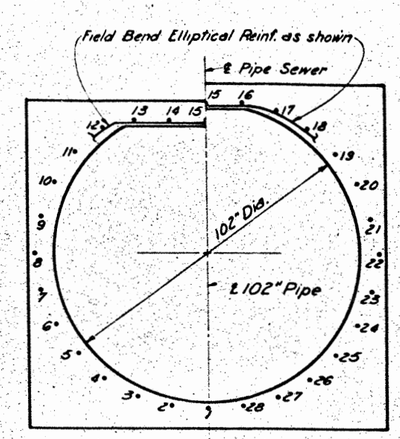
144

Dr. J.A.N.	Drawn	Date	Fed. Road Div. No.	State	Federal Aid Project No.	Sheet No.
Ck. Dr. N.C.K.	ORIGINAL	JUNE, 1967	6	TEXAS	X-48-1(97)046 U 514 (251)	144
Dr. M.G.A.	Rev. 21 May, 1968					
Ck. Dr. N.C.K.			State Dist. No.	County	Section / Block / Sheet / Job	Highway
Yr.			12	Harris	500 / 7 / 151 / 3 to 25	
Ck. Yr.					27 / 13 / 49 / U.S. 59	



* Note: Skew Angle is so small that dimensions may be assumed as being @ 90° to ℄ U.S. 59 S.B. or parallel to ℄ Siphon

PLAN

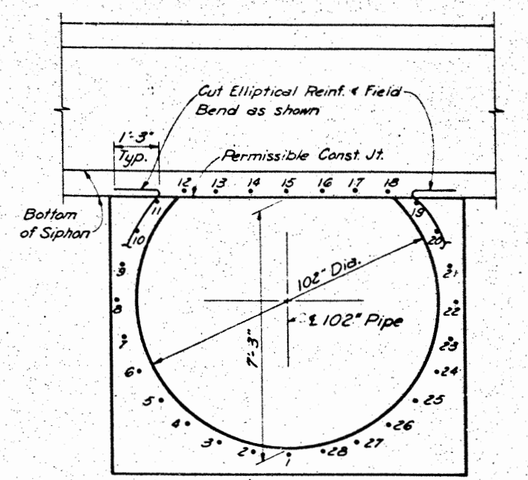


HALF SECTION D-D

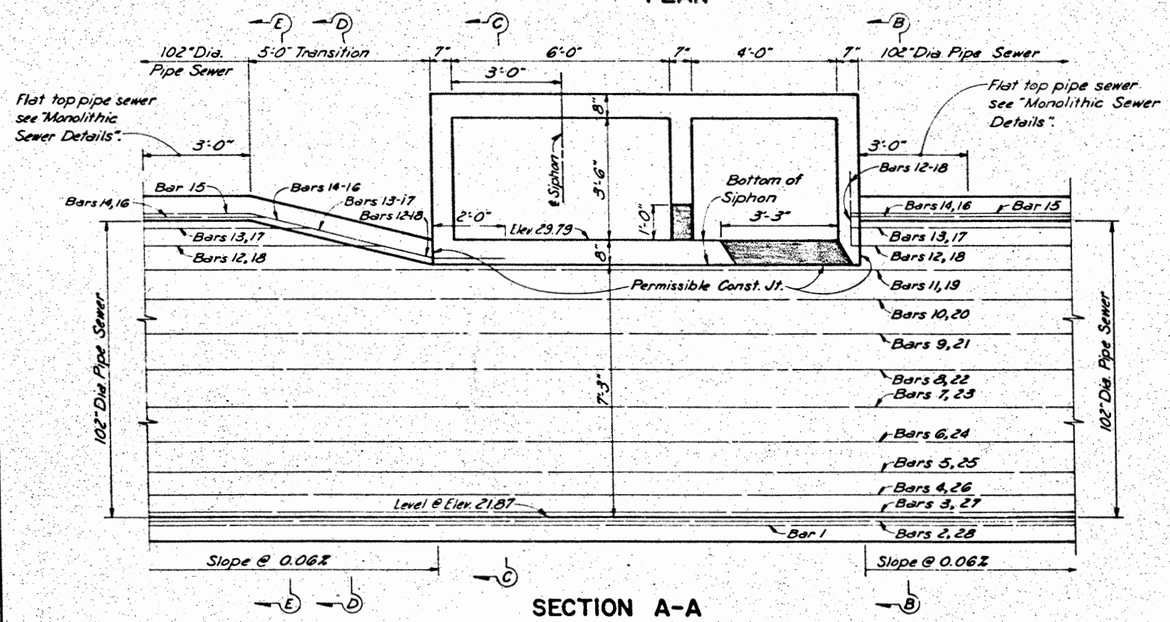
HALF SECTION E-E

Notes: Only portions of Elliptical Reinforcing for 102" Dia. pipe sewer have been shown on these details. Longitudinal Reinforcing has been numbered for clarity from bottom in a clockwise direction. For Details of 102" Dia. pipe sewer, see "Monolithic Sewer Details."

Cost for changes in 102" dia. pipe sewer will be included in unit price bid for 102" dia. pipe sewer.

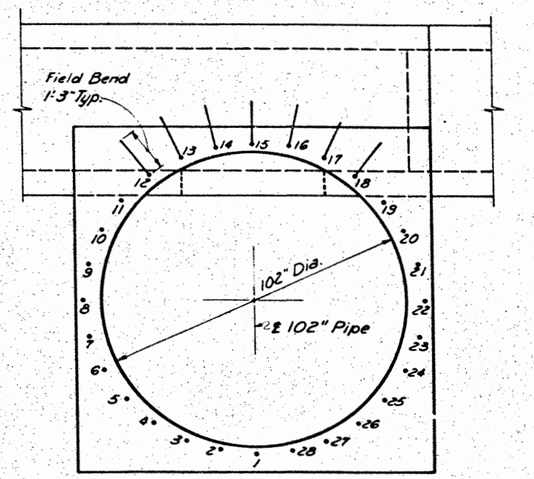


SECTION C-C



SECTION A-A

(ELLIPTICAL REINFORCING NOT SHOWN)



SECTION B-B

(ELLIPTICAL REINFORCING NOT SHOWN)

TEXAS HIGHWAY DEPARTMENT
HOUSTON URBAN PROJECT

JUNCTION DETAILS AT TRUNK AND CALHOUN ST. SIPHON

145

Dn. JAN	Drawing	Date	Fed. Hwy. Adm. No.	State	Federal Aid Project No.	Sheet No.
Ck. Dn. N.C.K.	ORIGINAL	JUNE, 1967	6	TEXAS	2-45-1(92)108 U 1(163)	145
Dn. M.B.A.	Rev. 21 May, 1968					
Ck. Dn. N.C.K.			State Dist. No.	County	Section / Job / Highway No.	
Tr.			12	Harris	800 7 / 3 13 / 131 49	IH 45 US 59
Ck. Tr.						

Appendix B – Utility Conflict and Cost Estimate Information

- Utility Conflict Table
- Cost Estimate Information

CobbFendley
TBPE Firm Registration No. 274 | TBPLS Firm Registration No. 100467

NHHIP Segment 3B - Hamilton Street Storm Sewer
Utility Conflict Matrix
CSJ: 0500-03-601

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
1	Sanitary	12"	unknown	Crossing	I-69 CL	970+13.50	-248.28		
2	Sanitary	12"	unknown	Crossing	I-69 CL	970+47.74	-262.19		
3	Sanitary	unknown	Unknown	Crossing	I-69 CL	971+41.54	313.3		
4	Sanitary	unknown	unknown	Crossing	I-69 CL	973+32.28	-340.51		
5	Sanitary	unknown	Unknown	Crossing	I-69 CL	973+62.56	295.01		
6	Water	8"	CI	Crossing	I-69 CL	974+94.38	169.18	974+98.36	299.81
7	Sanitary	unknown	Unknown	Crossing	I-69 CL	975+02.90	299.9		
8	Water	8"	PVC	Crossing	I-69 CL	977+62.27	-291.55		
9	Water	8"	PVC	Crossing	I-69 CL	979+76.64	-251.9		
10	Water	8"	PVC	Crossing	I-69 CL	982+30.83	-234.1		
11	Water	8"	CI	Crossing	I-69 CL	983+42.14	-179.46	983+43.79	178.65
12	Sanitary	8"	Unknown	Crossing	I-69 CL	984+70.14	282.61		
13	Water	8"	CI	Crossing	I-69 CL	991+44.92	238.83	991+51.13	183.77
14	Water	12"	Unknown	Crossing	I-69 CL	991+64.63	-79.16	991+69.32	73.55
15	Water	8"	PVC	Crossing	I-69 CL	991+89.14	-243.82		
16	Water	8"	CI	Crossing	I-69 CL	997+34.43	-248.98		
17	Sanitary	8"	Unknown	Crossing	I-69 CL	999+64.72	233.27		
18	Water	8"	CI	Crossing	I-69 CL	999+85.15	-175.04	999+85.69	182.25
19	Sanitary	10"	CI	Crossing	I-69 CL	999+96.01	233.3		
20	Water	0.75"	GALV	Crossing	I-69 CL	1000+21.58	-249.02		

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
21	Water	0.75"	GALV	Crossing	I-69 CL	1003+74.07	-249.08		
22	Sanitary	unknown	Unknown	Crossing	I-69 CL	1004+07.82	266.51		
23	Water	0.75"	GALV	Crossing	I-69 CL	1004+35.96	-249.09		
24	Water	8"	CI	Crossing	I-69 CL	1008+07.15	337.71		
25	Water	1.25"	GALV	Crossing	I-69 CL	1008+24.20	-249.14		
26	Water	1.25"	GALV	Crossing	I-69 CL	1008+54.68	-249.15		
27	Sanitary	6"	PEP	Crossing	SH-288 CL	1010+27.95	229.14		
28	Sanitary	6"	PEP	Crossing	SH-288 CL	1010+85.07	227.74		
29	Sanitary	unknown	unknown	Crossing	I-69 CL	1011+43.13	178.17		
30	Sanitary	12"	unknown	Crossing	SH-288 CL	1012+40.00	220.95		
31	Sanitary	15"	CI	Crossing	I-69 CL	1014+44.41	390.03		
32	Water	8"	CI	Crossing	I-69 CL	1014+48.75	-244.37	1014+57.40	180.11
33	Sanitary	15"	CI	Crossing	I-69 CL	1016+35.74	178.8		
34	Water	12"	unknown	Crossing	I-69 CL	1017+43.90	-248.14		
35	Sanitary	12"	unknown	Longitudinal	SH-288 CL	1017+49.37	201.91	1020+32.94	196.07
36	Sanitary	8"	Unknown	Crossing	I-69 CL	1018+15	416.58	1018+15.87	178.41
37	Water	12"	CI	Crossing	I-69 CL	1018+29.40	178.5	1018+30.39	416.61
38	Water	12"	unknown	Crossing	I-69 CL	1020+58.69	-88.32		
39	Sanitary	8"	unknown	Crossing	I-69 CL	1021+31.59	184.45	1021+32.30	416.9
40	Water	8"	CI	Crossing	I-69 CL	1024+44.11	169.81	1024+53.18	406.43

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
41	Sanitary	8"	unknown	Crossing	I-69 CL	1024+55.93	-252.4		
42	Sanitary	12"	unknown	Crossing	SH-288 CL	1024+97.92	172.61		
43	Water	2"	NP	Crossing	SH-288 CL	1025+51.56	172.1		
44	Sanitary	unknown	unknown	Crossing	I-69 CL	1026+25.09	377.79		
45	Sanitary	unknown	unknown	Crossing	I-69 CL	1027+72.73	369.36		
46	Water	8"	CI	Crossing	I-69 CL	1027+78.21	170.99		
47	Sanitary	6"	unknown	Crossing	I-69 CL	1028+39.17	364.72		
48	Sanitary	6"	unknown	Crossing	SH-288 CL	1029+46.34	198.42		
49	Water	12"	CI	Crossing	I-69 CL	1031+01.74	26.58		
50	Water	2"	CI	Crossing	I-69 CL	1031+12.44	171.64		
51	Sanitary	unknown	Unknown	Crossing	I-69 CL	1031+55.28	48.83		
52	Water	1"	GALV	Crossing	I-69 CL	1031+61.94	51.53	1032+02.39	402.57
53	Sanitary	unknown	ESP	Crossing	I-69 CL	1031+63.61	171.8		
54	Sanitary	8"	unknown	Crossing	I-69 CL	1031+64.31	406.42		
55	Sanitary	8"	unknown	Crossing	SH-288 CL	1032+21.53	212.72		
56	Water	6"	unknown	Crossing	I-69 CL	1033+37.02	-270.45		
57	Sanitary	18"	unknown	Crossing	I-69 CL	1034+44.72	-265.89	1035+13.47	290.79
58	Water	6"	unknown	Crossing	I-69 CL	1034+46.86	172.22	1034+61	297.41
59	Water	1"	GALV	Crossing	I-69 CL	1034+52.81	172.23	1034+74.80	375.74
60	Sanitary	10"	unknown	Crossing	I-69 CL	1034+75.49	172.27	1034+91.14	293.6

NHHIP Segment 3B - Hamilton Street Storm Sewer
Utility Conflict Matrix
CSJ: 0500-03-601

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
61	Water	8"	CI	Crossing	I-69 CL	1034+92.81	172.3	1035+18.55	371.18
62	Water	2"	CI	Crossing	I-69 CL	1038+01.93	254.36		
63	Sanitary	8"	ESP	Crossing	I-69 CL	1038+21.20	336.09		
64	Water	0.75"	GALV	Crossing	I-69 CL	1038+68.88	329.59		
65	Water	0.75"	GALV	Crossing	I-69 CL	1040+66.37	-198.88		
66	Water	60"	CONC	Crossing	I-69 CL	1040+72.92	-238.18	1041+34.18	291.53
67	Electric			Crossing	I-69 CL	1041+07.32	-240.8	1041+63.41	287.77
68	Sanitary	8"	ESP	Crossing	I-69 CL	1041+07.77	166.99	1041+20.27	293.42
69	Water	1"	GALV	Crossing	I-69 CL	1041+39.71	-23.96	1041+46.31	32.55
70	Water	8"	AC	Crossing	I-69 CL	1041+50.60	-24.07	1041+81.31	285.62
71	Water	8"	CI	Crossing	I-69 CL	1041+77.17	-106.36		
72	Water	2"	CI	Crossing	I-69 CL	1041+78.96	285.9		
73	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1041+83.26	-106.38		
74	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1042+00.59	-106.39		
75	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1042+17.10	-106.46		
76	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1042+69.05	-106.98		
77	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1043+48.38	-107.57		
78	Water	12"	Steel	Crossing	I-69 CL	1043+92.51	-107.79		
79	Water	12"	DI	Crossing	I-69 CL	1044+01.48	-258.75	1044+25.51	-108.14
80	Water	Unknown	Unknown	Crossing	I-69 CL	1044+14.81	-108.06		

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
81	Water	2"	CI	Crossing	I-69 CL	1044+34.31	266.72	1044+36.06	-25.97
82	Water	1"	GALV	Crossing	I-69 CL	1044+42.12	266.47	1044+46.12	-25.99
83	Water	1"	GALV	Crossing	I-69 CL	1044+75.26	163.06	1044+90.07	-108.23
84	Water	8"	CI	Crossing	I-69 CL	1044+75.78	-203.72	1044+77.11	-258.2
85	Sanitary	6"	Unknown	Crossing	I-69 CL	1045+17.41	265.49	1045+19.90	192.93
86	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1045+80.18	-108.23		
87	Sanitary	6"	Unknown	Crossing	I-69 CL	1046+04.13	264.93		
88	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1046+37.94	-108.38		
89	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1046+82.01	-108.76		
90	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1047+06.74	-109.04		
91	Water	12"	Steel	Crossing	I-69 CL	1047+32.62	-64.31		
92	Sanitary	8"	ESP	Crossing	I-69 CL	1047+62.54	-72.91	1047+62.56	193.16
93	Sanitary	8"	Unknown	Crossing	I-69 CL	1047+89.78	-90.59		
94	Water	12"	CI	Crossing	I-69 CL	1048+00.32	263.74	1048+01.50	81.97
95	Water	2"	CI	Longitudinal	I-69 CL	1048+00.32	263.74	1051+10.10	267.09
96	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1049+37.25	-82.48		
97	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1049+88.04	-81.05		
98	Water	6"	CI	Crossing	I-69 CL	1050+79.56	-77.68	1050+84.28	-246.1
99	Sanitary	36"	Unknown	Crossing	I-69 CL	1050+96.64	266.73		
100	Sanitary	8"	Unknown	Crossing	I-69 CL	1051+07.57	267.01		

NHHIP Segment 3B - Hamilton Street Storm Sewer
Utility Conflict Matrix
CSJ: 0500-03-601

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
101	Water	6"	CI	Crossing	I-69 CL	1051+10.10	267.09	1051+17.71	77.22
102	Sanitary	8"	Unknown	Crossing	I-69 CL	1051+13.17	202.31		
103	Water	12"	Steel	Crossing	I-69 CL	1052+18.36	-72.06	1053+59.47	-232.78
104	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1054+26.09	76.67		
105	Water	12"	CI	Crossing	I-69 CL	1054+29.11	276.31	1054+54.66	-228.17
106	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1056+59.37	-58.8		
107	Water	4"	Unknown	Crossing	I-69 CL	1056+96.10	-58.53		
108	Sanitary	8"	Unknown	Crossing	I-69 CL	1057+64.26	225.7	1057+69.44	75.96
109	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1057+83.83	298.69		
110	Water	8"	AC	Crossing	I-69 CL	1057+97.59	298.93	1058+08.41	-57.68
111	Water	4"	CI	Crossing	I-69 CL	1057+99.98	-154.54	1058+02.30	-211.87
112	Sanitary	12"	PVC	Crossing	I-69 CL	1058+50.80	300.04		
113	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1058+76.13	-56.83		
114	Water	4"	CI	Crossing	I-69 CL	1058+89.13	-56.6		
115	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1059+27.34	-55.81		
116	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1059+67.56	-55.08		
117	Sanitary	12"	PVC	Crossing	I-69 CL	1059+77.15	304.16		
118	Sanitary	12"	PVC	Longitudinal	I-69 CL	1059+77.30	302.16	1061+35.23	312.86
119	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1060+09.96	-55.24		
120	Water	1.5"	GALV	Crossing	I-69 CL	1060+17.63	-55.24		

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
121	Water	1.5"	GALV	Crossing	I-69 CL	1060+63.43	-55.12	1060+70.63	75.69
122	Sanitary	36"	Unknown	Crossing	I-69 CL	1061+04.73	243.94	1061+39.84	-201
123	Water	8"	CI	Crossing	I-69 CL	1061+05.39	-55.02	1061+14.93	-201.61
124	Water	8"	PVC	Crossing	I-69 CL	1061+17.84	312.6	1061+36.00	75.98
125	Water	Unknown	Unknown	Crossing	I-69 CL	1061+31.17	76		
126	Sanitary	12"	PVC	Crossing	I-69 CL	1061+35.12	314.19	1061+41.39	246.5
127	Sanitary	12"	PVC	Crossing	I-69 CL	1061+82.09	249.34		
128	Water	Unknown	Unknown	Crossing	I-69 CL	1061+85.68	-55.02		
129	Water	8"	Steel	Crossing	I-69 CL	1062+43.84	-55.02		
130	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1062+75.05	-55.02		
131	Sanitary	12"	PVC	Crossing	I-69 CL	1063+19.70	258.96		
132	Water	8"	Steel	Crossing	I-69 CL	1063+31.45	-55.02		
133	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1063+77.83	-55.02		
134	Water	12"	Unknown	Crossing	I-69 CL	1064+36.91	-55.02	1064+46.73	-201
135	Water	12"	CI	Crossing	I-69 CL	1064+61.01	343.63	1064+81.61	75.98
136	Sanitary	10"	Unknown	Crossing	I-69 CL	1064+61.90	268.89	1064+91.55	-200.81
137	Water	6"	CI	Crossing	I-69 CL	1067+59.23	362.07	1067+88.91	-185.79
138	Water	12"	CI	Crossing	I-69 CL	1071+39.50	372.11	1071+46.57	-180.6
139	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1071+41.12	76.08		
140	Water	6"	Unknown	Crossing	I-69 CL	1071+58.07	299.3		

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
141	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1072+96.95	76.75		
142	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1073+47.48	76.12		
143	Electric			Crossing	I-69 CL	1074+39.14	375.93		
144	Water	8"	CI	Crossing	I-69 CL	1074+41.90	-180.89	1074+54.61	375.84
145	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1074+49.07	375.88		
146	Sanitary	8"	Unknown	Crossing	I-69 CL	1074+63.77	-181.33	1074+64.73	-152.22
147	Sanitary	6"	ESP	Crossing	I-69 CL	1074+95.12	76.11	1074+98.67	173.55
148	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1075+61.32	343.22		
149	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1076+19.08	320.22		
150	Water	8"	CI	Crossing	I-69 CL	1076+43.99	310.3		
151	Electric			Crossing	I-69 CL	1076+77.25	297.04		
152	Water	8"	CI	Crossing	I-69 CL	1077+66.03	-190.51	1077+82.34	255.16
153	Sanitary	24"	Unknown	Crossing	I-69 CL	1077+70.49	-190.65	1077+87.49	253.11
154	Sanitary	18"	Unknown	Crossing	I-69 CL	1078+08.68	-192.42	1078+26.72	249.01
155	Electric			Crossing	I-69 CL	1080+77.36	-204.89	1081+00.75	265.25
156	Water	8"	PVC	Crossing	I-69 CL	1080+84.48	-205.22	1080+91.74	-55.02
157	Sanitary	10"	Unknown	Crossing	I-69 CL	1081+02.01	-205.69	1081+25.23	266.7
158	Water	6"	CI	Crossing	I-69 CL	1081+10.51	75.98	1081+19.53	266.37
159	Water	8"	CI	Crossing	I-69 CL	1081+19.33	-41.55		
160	Sanitary	8"	Unknown	Crossing	I-69 CL	1081+19.33	-24.34		

NHHIP Segment 3B - Hamilton Street Storm Sewer
Utility Conflict Matrix
CSJ: 0500-03-601

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
161	Water	8"	CI	Crossing	I-69 CL	1081+72.46	-55.02		
162	Water	6"	CI	Crossing	I-69 CL	1081+98.87	-55.02	1082+05.33	75.81
163	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1082+17.47	-55.02		
164	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1082+89.08	-54.77		
165	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1083+39.41	-54.46		
166	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1084+19.17	-53.65		
167	Water	8"	CI	Crossing	I-69 CL	1084+31.69	-226.95	1084+32.82	-187.36
168	Water	8"	CI	Crossing	I-69 CL	1085+28.69	-52.66		
169	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1085+83.11	-52.32		
170	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1086+10.50	-52.16		
171	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1086+70.69	-52.04		
172	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1087+20.57	-52.02	1087+20.69	179.04
173	Water	12"	PVC	Crossing	I-69 CL	1087+30.04	310.54	1087+48.52	75.98
174	Water	6"	CI	Crossing	I-69 CL	1087+35.13	75.98	1087+36.32	177.34
175	Water	6"	CI	Crossing	I-69 CL	1087+45.88	-189.05	1087+46.74	-237.88
176	Water	8"	CI	Crossing	I-69 CL	1092+65.62	-307.22	1092+99.67	312.08
177	Sanitary	12"	Unknown	Crossing	I-69 CL	1092+69.02	-199.65		
178	Sanitary	8"	Unknown	Crossing	I-69 CL	1092+79.20	-307.47	1092+93.13	312.23
179	Sanitary	8"	Unknown	Crossing	I-69 CL	1093+87.94	-196.35		
180	Sanitary	8"	Unknown	Crossing	I-69 CL	1095+41.36	110.44		

Existing Utility Information					Conflict Location				
Number	Type	Size	Material	Orientation	Baseline	Begin STA	Offset	End STA	Offset2
181	Sanitary	6"	Unknown	Crossing	I-69 CL	1095+43.25	86.78		
182	Sanitary	6"	Unknown	Crossing	I-69 CL	1095+44.31	-192.44		
183	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1095+46.82	41.96		
184	Sanitary	6"	Unknown	Crossing	I-69 CL	1095+47.50	33.45		
185	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1095+47.62	31.85		
186	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1095+50.82	-8.31		
187	Sanitary	Unknown	Unknown	Crossing	I-69 CL	1095+54.02	-48.37		

Hamilton Street				
Item	Unit Price	Length	Cost	Rounded Cost
48" RCP	$726.17	1087.00	$789,347	$789,000
10' x 10' Box Culvert	$1,611.05	2795.00	$4,502,885	$4,503,000
7' x 7' Box Culvert	$1,897.24	8685.00	$16,477,529	$16,478,000
6' x 4' Box Culverts	$1,252.77	497.00	$622,627	$623,000
Manholes			$841,947	$842,000
Sub-Total			$23,234,335	$23,235,000

St. Emanuel Street				
Item	Unit Price	Length	Cost	Rounded Cost
48" RCP	$726.17	1658.00	$1,203,990	$1,204,000
4' x 4' Box Culvert	$642.17	3696.00	$2,373,460	$2,373,000
8' x 8' Box Culvert	$1,477.88	1315.00	$1,943,406	$1,943,000
6' x 5' Box Culvert	$1,116.65	607.00	$677,807	$678,000
Manholes			$454,651	$455,000
Sub-Total			$6,653,314	$6,653,000

Chartres Street - North				
Item	Unit Price	Length	Cost	Rounded Cost
24" RCP	$353.92	593.00	$209,875	$210,000
30" RCP	$414.80	499.00	$206,985	$207,000
36" RCP	$406.43	1060.00	$430,816	$431,000
42" RCP	$491.93	842.00	$414,205	$414,000
48" RCP	$578.77	350.00	$202,570	$203,000
4' x 4' Box Culvert	$642.17	814.00	$522,726	$523,000
5' x 4' Box Culvert	$705.82	822.00	$580,184	$580,000
Manholes			$118,628	$119,000
Sub-Total			$2,685,989	$2,687,000

Chartres Street - South				
Item	Unit Price	Length	Cost	Rounded Cost
24" RCP	$341.52	467.13	$159,534	$160,000
30" RCP	$387.78	418.00	$162,092	$162,000
36" RCP	$405.39	157.00	$63,646	$64,000
48" RCP	$497.21	884.00	$439,534	$440,000
60" RCP	$879.54	1380.00	$1,213,765	$1,214,000
Manholes			$84,239	$84,000
Sub-Total			$2,122,810	$2,124,000

SH-288 South SB				
Item	Unit Price	Length	Cost	Rounded Cost
24" RCP	$341.52	337.00	$115,092	$115,000
36" RCP	$405.39	13.00	$5,270	$5,000
Manholes			$64,000	$64,000
Sub-Total			$184,362	$184,000

SH-288 South NB				
Item	Unit Price	Length	Cost	Rounded Cost
24" RCP	$341.52	614.00	$209,693	$210,000
30" RCP	$387.78	111.00	$43,044	$43,000
36" RCP	$405.39	235.00	$95,267	$95,000
Manholes			$72,000	$72,000
Sub-Total			$420,004	$420,000
I-45 South				
Item	Unit Price	Length	Cost	Rounded Cost
24" RCP	$341.52	263.00	$89,820	$90,000
36" RCP	$405.39	1257.00	$509,575	$510,000
42" RCP	$491.93	1706.00	$839,233	$839,000
48" RCP	$497.21	362.00	$179,990	$180,000
Manholes			$52,000	$52,000
Sub-Total			$1,670,618	$1,671,000
Depressed Section - I-45 Pump Station				
Item	Unit Price	Length	Cost	Rounded Cost
24" RCP	$481.34	7727.43	$3,719,521	$3,720,000
30" RCP	$516.57	3,832.65	$1,979,832	$1,980,000
36" RCP	$620.13	2,684.60	$1,664,801	$1,665,000
4x3 Box Culvert	$839.78	1,136.48	$954,393	$954,000
5x4 Box Culvert	$920.43	3,896.84	$3,586,768	$3,587,000
2-6x4 Box Culvert	$1,602.27	1,505.07	$2,411,529	$2,412,000
3-6x4 Box Culvert	$1,951.77	2,737.94	$5,343,829	$5,344,000
2-4x3 Box Culverts	$914.13	99.33	$90,801	$91,000
2-7x5 Box Culverts	$1,966.77	13	$25,568	$26,000
Sub-Total			$19,777,042	$19,779,000
Depressed Section - Buffalo Bayou Pump Station				
Item	Unit Price	Length	Cost	Rounded Cost
24" RCP	$779.46	4,466.95	$3,481,809	$3,482,000
30" RCP	$575.80	4,417.42	$2,543,550	$2,544,000
36" RCP	$564.86	2,896.25	$1,635,976	$1,636,000
4x3 Box Culvert	$1,053.21	332.13	$349,803	$350,000
3-6x4 Box Culvert	$1,830.35	5,649.23	$10,340,068	$10,340,000
3x2 Box Culvert	$741.22	61.86	$45,852	$46,000
Manholes			$1,571,882	$1,572,000
Sub-Total			$19,968,940	$19,970,000
I-45 Pump Station[1]				
Item	Unit Price	Length	Cost	Rounded Cost
Pump Station	$16,118,000.00	-	$16,118,000	$16,118,000
6' x 6' Box Culvert (Discharge Pipe)	$1,320.30	50.00	$66,015	$66,000
8' x 8' Box Culvert (Discharge Pipe)	$1,477.88	6,885.00	$10,175,204	$10,175,000
Sub-Total			$26,359,219	$26,359,000

Buffalo Bayou Pump Station[2]				
Item	Unit Price	Length	Cost	Rounded Cost
Pump Station	$6,668,700.00	-	$6,668,700	$6,669,000
6' x 6' Box Culvert (Discharge Pipe)	$1,320.30	205.00	$270,662	$271,000
Sub-Total			$6,939,362	$6,940,000
10% Mobilization			$11,001,599	$11,002,000
20% Contingency			$22,003,199	$22,003,000
Total Cost			$143,020,790	$143,027,000

[1] See I-45 Pump Station Cost Estimate for More Details

[2] See Buffalo Bayou Pump Station Cost Estimate for More Details

I-45 Stormwater Pump Station				
Name	Unit	Qty	Unit Price	Total
Bond and Insurance (2%)	LS	1		316,000
Site				
Trench Safety	LS	2	20,000	40,000
Dewatering	LS	1	50,000	50,000
Grading	AC	2	4500	9,000
Drainage	LS	1	20,000	20,000
Paving (Concrete Access)	SY	3000	80	240,000
Area Coverage (gravel)	SY	5000	30	150,000
Utilities	LS	1	30,000	30,000
Seed/Sod	SY	2000	0.1	200
Fencing and gates	LF	1000	60	60,000
Inlet conduits (two 7'X5')	LF	300	2500	750,000
Outlet conduits (one 6'X6')	LF	150	1200	180,000
Structures				
Pump Sta base slab	CY	2300	600	1,380,000
Pump Sta walls	CY	3600	700	2,520,000
Pump Sta roof	CY	350	800	280,000
Grating, stairs ladders, hatches	LS	1	50,000	50,000
Electrical SOG	CY	300	600	180,000
Electrical canopy	SF	4000	40	160,000
Equipment				
Large Pumps (215 hp)	ea	16	214,500	3,432,000
Small Pumps (140 hp)	ea	2	170,300	340,600
Dewatering pump (5 hp)	ea	1	3300	3,300
Generator (1750 KW)	ea	2	1,170,000	2,340,000
Fuel storage (20,000 Gal)	ea	1	101,000	101,000
Discharge valves (36")	ea	18	29,500	531,000
Electrical (15%)				1,927,100
Instrument & Control (8%)				1,027,800
			Sum	16,118,000

Buffalo Bayou Stormwater Pump Station				
Name	Unit	Qty	Unit Price	Total
Bond and Insurance (2%)	LS	1		130,800
Site				
Trench Safety	LS	2	20,000	40,000
Dewatering	LS	1	50,000	50,000
Grading	AC	0.75	4500	3,400
Drainage	LS	1	20,000	20,000
Paving (Concrete Access)	SY	1600	80	128,000
Area Coverage (gravel)	SY	2000	30	60,000
Utilities	LS	1	20,000	20,000
Seed/Sod	SY	2000	0.1	200
Fencing and gates	LF	750	60	45,000
Inlet conduits (three 6'X4')	LF	100	2000	200,000
Outlet conduits (one 3' by 3')	LF	100	900	90,000
Structures				
Pump Sta base slab	CY	550	600	330,000
Pump Sta walls	CY	2000	700	1,400,000
Pump Sta roof	CY	120	800	96,000
Grating, stairs ladders, hatches	LS	1	20,000	20,000
Electrical SOG	CY	300	600	180,000
Electrical canopy	SF	4000	40	160,000
Equipment				
Large Pumps (215 hp)	EA	5	214,500	1,072,500
Small Pumps (140 hp)	EA	1	170,300	170,300
Dewatering pump (5 hp)	EA	1	3300	3,300
Generator (1500 KW)	EA	1	1,040,000	1,040,000
Fuel storage (10,000 Gal)	EA	1	50,500	50,500
Discharge valves (36")	EA	6	22,700	136,200
Electrical (15%)				797,300
Instrument & Control (8%)				425,200
			Sum	6,668,700