EXHIBIT E

HUITT-ZOLLARS

WHITE OAK BAYOU
PRELIMINARY DRAINAGE ANALYSIS
(I-45 CONCEPTUAL PLAN)

Prepared for:

HOUSTON PARKS BOARD

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Table of Content

1 Purpose and Scope

As requested by Houston Parks Board (HPB), Huitt-Zollars, Inc. has looked into potential drainage impacts on White Oak Bayou due to the future I-45 widening project by TxDOT as described in the I-45 Conceptual Layout Segment 3 near Downtown Houston.

The limit of this work is from I-45 Bridge over White Oak Bayou near Quitman Street to the I-10 Bridge over White Oak Bayou near Main Street.

The intent of this limited study is to investigate and note potential encroachments into the White Oak Bayou floodplain Boundary by the I-45 widening.

2 Project Description

The IH-45 conceptual layout prepared by HNTB for TxDOT dated 5/7/2018 was used to identify potential encroachments into the White Oak Bayou floodplain boundary. The study assumptions are listed below:

- I-45 Bridge over White Oak Bayou
  - It was assumed that the hydraulic footprint of proposed I-45 Bridges over White Oak Bayou near Quitman Street is similar to the existing I-45 Bridges. Relocating existing bridges but not increasing the size.
  - No changes were made to HEC-RAS model in this report at I-45 Bridge over White Oak Bayou near Quitman Street.
- Upstream of Hogan Street
  - I-45 has been widened by about 60 feet since 2015 (Bridge with piers in Floodplain)
  - Proposed I-45 will be widened by another 30 feet (Bridge with piers in Floodplain).
  - Three columns were added to HEC-RAS model in this report to represent I-45 ramp to Milam Street.
- Hogan Street Bridge
  - I-45 has been widened by about 50 feet since 2015 (Bridge with piers in Floodplain)
  - Widening I-45 further as shown in the IH-45 conceptual layout would need to utilize the next span under Hogan Street Bridge which will place I-45 piers at the centerline of White Oak Bayou within permanent waters of us and require USACE permits. Adding piers in middle of the channel near the centerline will have significant impacts on the conveyance capacity and create maintenance problems.
  - This report assumed the 50 feet widening that was done since 2015 will remain and the mid span of Hogan Bridge will remain open.

- Downstream of Hogan Street
  - I-45 has been widened by about 30 feet since 2015 (fill in channel side slope and new retaining wall)
  - The proposed I-45 will be widened by another 30 feet (retaining wall or Bridge).
  - The side slope fill and retaining walls were added to the HEC-RAS model to develop the post project model (including the wall built since 2015).
- Union Pacific Railroad Bridge
  - No changes were made to HEC-RAS model at Union Pacific Railroad Bridge
- Downstream of Union Pacific Railroad Bridge
  - Proposed I-45 will be widened by about 144 feet for ramp to Milam Street and Louisiana Street (Bridge with piers in Floodplain).
  - Three columns were added to HEC-RAS model to represent the ramps to Milam Street and Louisiana Street
- Proposed I-10 Bridge over White Oak Bayou
  - The proposed crossing consists of six bridge structures crossing the Bayou at varying angle with column in the bayou.
  - The proposed bridge structures were added to the HEC-RAS model as a single structure as wide as the combined width of the six bridge structures.
- Existing I-10 Bridge over White Oak Bayou
  - The existing bridge is constructed above the Main Street bridge and Union Pacific Bridge. The effective FEMA HEC-RAS model consist of the Main Street Bridge , UPRR Bridge and the I-10 abutment on the south side as an ineffective area.
  - The ineffective area and bridge abutment was removed from the HEC-RAS model.
- Fill in the floodplain Volume
  - Majority of the proposed improvements consist of Bridges with low chord elevation above the BFE elevation which will not result in significant amount of fill volume in the floodplain boundary. We did not have detailed information on the proposed bridge abutments at this time. It is assumed that the proposed fill in the floodplain will be mitigated by new cut in the floodplain boundary.

The proposed improvements require some fill within White Oak Bayou floodplain and floodway boundary which need to be mitigated. The proposed fill at the piers are relatively small and can be mitigated by excavation at the existing upper shelf under the I-45 bridges. This report does not include any changes in White Oak Bayou HEC-HMS model due to fill in the floodplain and assumes it will be mitigated at the site.

3 Methodology

This report analyzes the Pre-Project and Post-Project condition HEC-RAS models for 100-year storm event. The FEMA HEC-RAS model of White Oak Bayou was utilized for the hydraulic analysis.

Sections 3085 & 2915 were added to the FEMA HEC-RAS model to develop the Pre-Project model and include the proposed IH-10 bridge in the post project model. The proposed I-45 improvements were then added to the Pre-Project model to develop Post-Project model. The 100-yr WSE from the Pre-Project and Post-Project models were compared for any impact.
The FEMA effective model and Pre-Project models do not include work that was done in the side slope since 2015 downstream of Hogan Street while the Post-Project model includes the 2015 work and the newly proposed work in that area.

4 Post Project Condition

The proposed IH-45 improvements listed in Section 1.2 were added to the Pre-Project model to develop the Post Project Model no new cross sections were added. There were no changes made in the Post-Project channel “n” value.

Table 1 in Appendix presents the 100-yr WSE comparison between the Pre-Project model and the Post-Project model. There is up to 0.12 feet of increase in 100-yr WSE. It was observed that removing the existing I-10 bridge did not reduce the WSE significantly due to Existing UPRR Bridge and Main Street Bridge under the I-10 Bridge that will remain. The proposed I-10 bridge had the largest impact on 100-yr WSE (about 0.08 feet of increase) while the proposed piers and retaining wall along the Bayou also had a significant impact.

5 Conclusion

There is a significant amount of work proposed within the White oak Bayou floodway boundary and the project need to result in zero rise in the 100-yr water surface elevation in order to meet TxDOT, City of Houston and FEMA requirements.

Based on the results of the Pre-Project and Post-Project HEC-RAS models, the proposed I-45 improvements can potentially increase the 100-yr WSE in White Oak Bayou by 0.12 feet. For a large channel like White Oak Bayou, 0.12 feet of rise in WSE is significant and may require drastic measures to mitigate and meet the zero rise requirements.
The proposed I-10 bridge over White Oak Bayou had the largest impact on 100-yr WSE (about 0.08 feet of increase). The proposed I-45 ramp piers and retaining walls along the Bayou also had a significant impact on 100-yr WSE.

The majority of the proposed improvements near White Oak Bayou consist of bridges with low chord elevation above the BFE elevation which will not result in a significant amount of fill in the floodplain boundary. It is assumed that the proposed fill in the floodplain and floodway boundary can be mitigated by new excavation under the proposed bridges.

The proposed improvements have significant impact on cross sectional conveyance capacity and result in 0.12 feet in 100-yr WSE. Mitigating this impact within the I-45 corridor would be very difficult due to limited space and may require offsite drainage improvements or changes in the conceptual roadway design. A more detailed study is recommended with consideration to offsite drainage improvements as mitigation options within this conceptual design phase.

APPENDIX
EXHIBITS & HEC-RAS MODELS

HOUSTON DISTRICT
PROJECT DEVELOPMENT

NHHIP - SEGMENT 3

PRELIMINARY
SUBJECT TO CHANGE

HNTB

CONCEPTUAL LAYOUT
NHHIP

COUNTY: HARRIS
LIMITS FROM: I610
LIMITS TO: SPUR 527

CSJ:
DATE: 5/7/2018
APPROVED: / /

NOT A BIDDING DOCUMENT

PLAN LEGEND

SYMBOLOGY	ROADWAY	STYLE
CENTERLINE		
I-45 MAINLANES		
I-45/US 59 MAINLANES		
I-10 MAINLANES		
SH 288 MAINLANES		
I-610 MAINLANES		
I-10 EXPRESS LANES		
MAX LANES		
FRONTAGE ROADS		
LOCAL STREETS		
RAMPS		
DIRECT CONNECTOR		
POTENTIAL GREENSPACE		
EXISTING ROW? TO BE REMOVED		
SURPLUS ROW		
EMBANKMENT		
PROPOSED CONTROL OF ACCESS		
PROP DEB ROW		
PROP FEB ROW		
EXISTING ROW		
ACCESS ROAD		
METRO RAIL RED (MAIN STREET LINE)		
METRO RAIL(EAST END LINE)		
METRO RAIL(SOUTHEAST LINE)		
RAILROAD		
LIMITS OF FLOODWAY		
EXISTING LANE DIRECTIONAL INDICATOR:		
MAIN LANES		
FRONTAGE ROADS/TURNAROUNDS		
PROPOSED LANE DIRECTIONAL INDICATOR:		
MAIN LANES		
FRONTAGE ROADS/TURNAROUNDS		
RAMPS		
DIRECT CONNECTOR		
MAX LANES		

SCALE
0 400 800 1200 1600

INTERSECTION GEOMETRY AND THE PROPOSED NUMBER OF LANES IS SUBJECT TO CHANGE BASED ON FURTHER DEVELOPMENT OF THE PROPOSED RECOMMENDED ALTERNATIVE.

SEGMENT 3
LOCATION MAP : N.T.S.

SURVEY DATA: TEXAS SOUTH CENTRAL
ZONE 4204 (HARRIS COUNTY)
ADJUSTED TO SURFACE USING
COMBINED SCALE FACTOR 1.00013

PRELIMINARY SUBJECT TO CHANGE

PROPOSED TXDOT IMPROVEMENTS BY SH 288 PROGRAM

PROPOSED TXDOT IMPROVEMENTS CURRENTLY UNDER DESIGN

LIMITS OF FLOODWAY

FUTURE DIRECT CONNECTORS BY OTHERS

PEDESTRIAN TRAIL/BRIDGE

UPRR RR

RAILROAD BRIDGE

POTENTIAL DETENTION

METRO RAIL RED (MAIN STREET LINE)

METRO RAIL (SOUTHEAST LINE)

METRO RAIL (EAST END LINE)

SURPLUS ROW

GEORGE R. BROWN OPERATIONS AREA

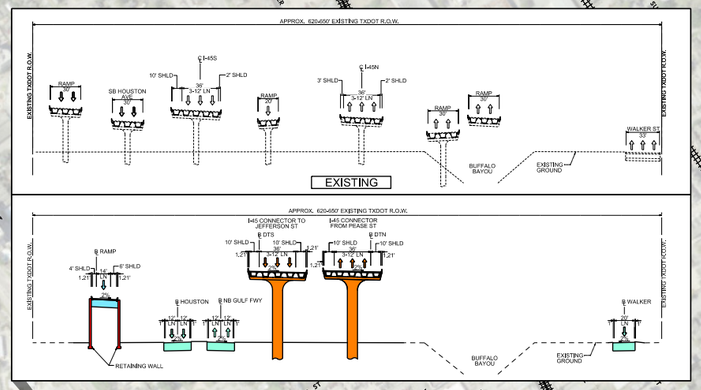
POTENTIAL FUTURE BYPASS CHANNEL BY OTHERS

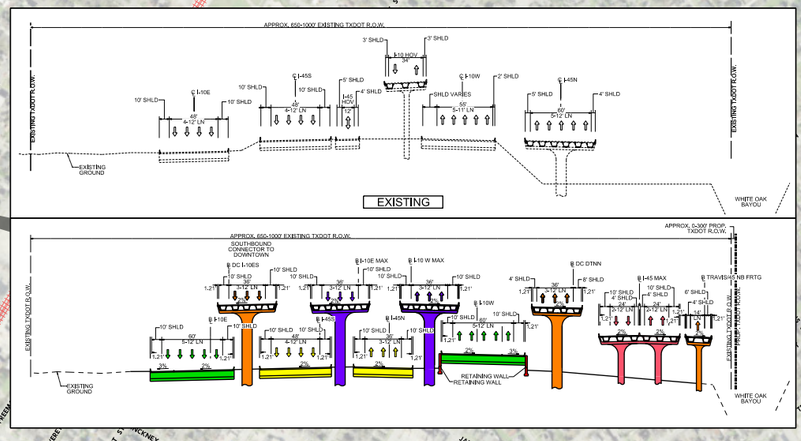
BNSF RR

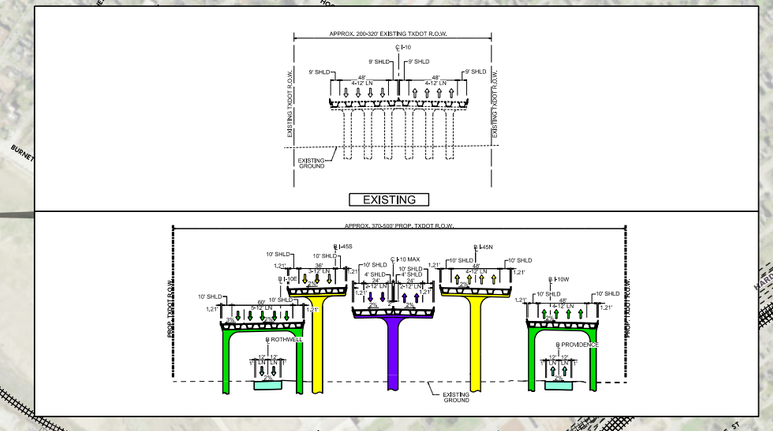
UTILITY BRIDGE

PEDESTRIAN BRIDGE

EXHIBIT 1







I-45 BRIDGE OVER WHITE OAK BAYOU

PEDESTRIAN TRAIL/BRIDGE

UPRR RR

RAILROAD BRIDGE

UPRR RR

FUTURE DIRECT CONNECTORS BY OTHERS

LIMITS OF FLOODWAY

POTENTIAL DETENTION

PROP I-10 BRIDGE OVER WHITE OAK BAYOU

LIMITS OF FLOODWAY

EXISTING I-10 BRIDGE OVER WHITE OAK BAYOU, TO BE REMOVED

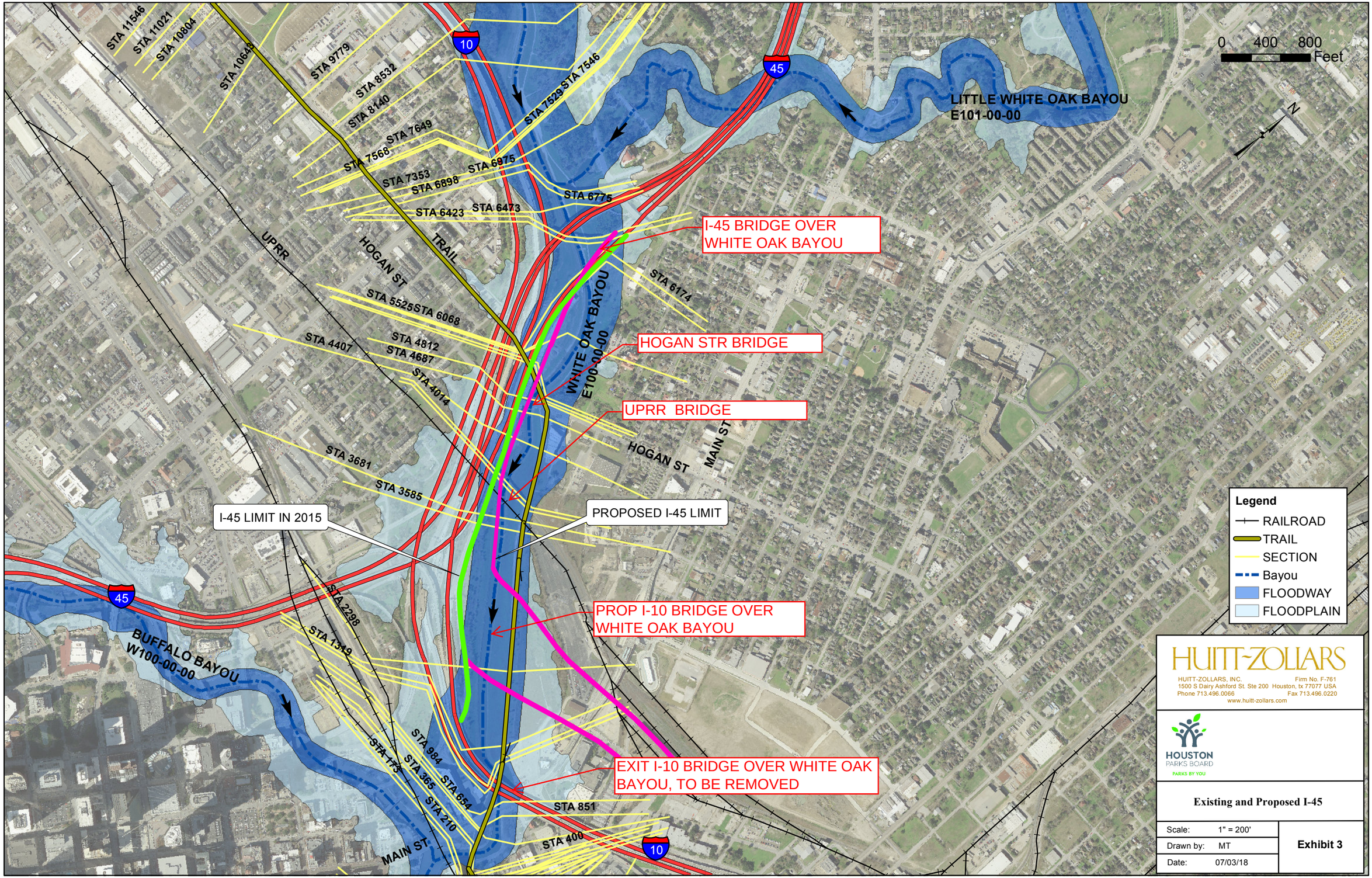
BNSF RR

PRELIMINARY SUBJECT TO CHANGE

HOUSTON DISTRICT
PROJECT DEVELOPMENT

NHHIP - SEGMENT 3

EXHIBIT 2



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HOUSTON PARKS BOARD
PARKS BY YOU

Existing and Proposed I-45

Scale:	1" = 200'
Drawn by:	MT
Date:	07/03/18

Exhibit 3

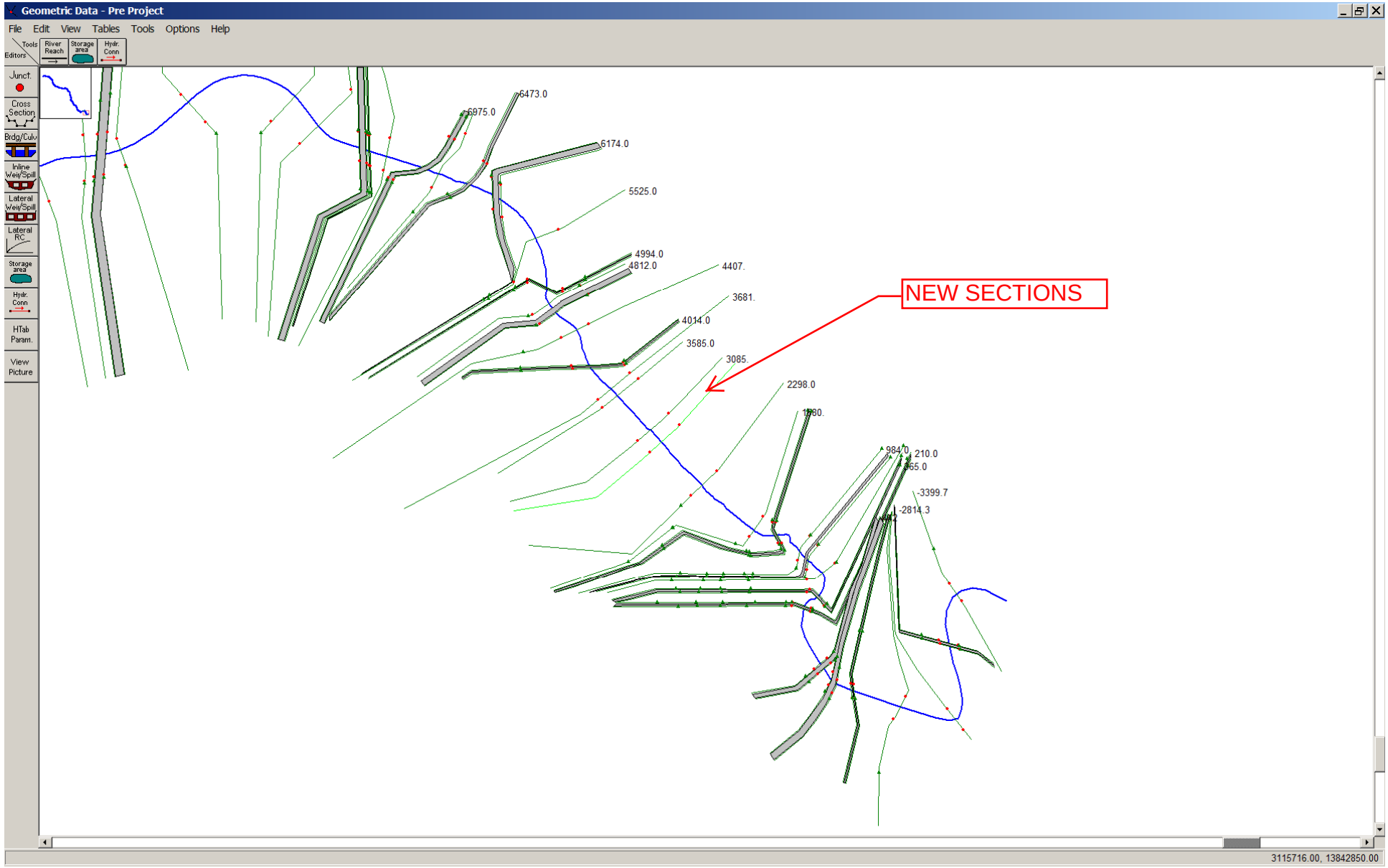

Untitled Map
Write a description for your map.
Legend
Hogan St @ South St
XREF_HBT_AALN
1-45
HOGAN ST BRIDGE
CENTERAL SPAN OF THE BAYOU WIDENING I-45 INTO THIS SPAN IS DIFFICULT
Google earth
© 2018 Google
6.47 ft
N
EXHIBIT 4

PRE-PROJECT
HEC-RAS MODEL

Table 1 Pre-Project and Post-Project 100-yr WSE

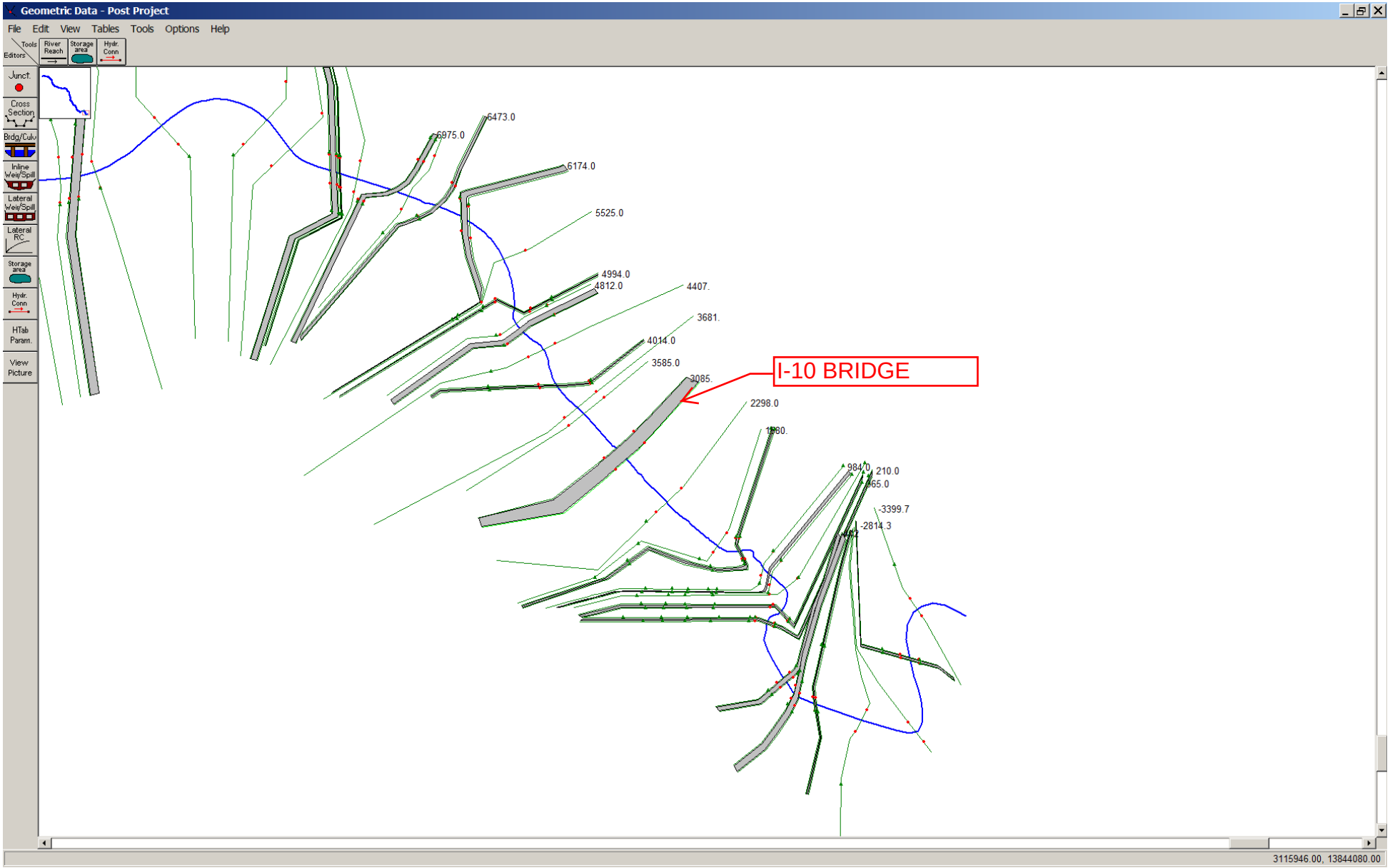
		Pre-Project		Post-Project & Bridge		Increase in
River Sta	Q Total	W.S. Elev	Vel Chnl	W.S. Elev	Vel Chnl	W.S. Elev
	(cfs)	(ft)	(ft/s)	(ft)	(ft/s)	(ft)
7353	32623	37.79	3.5	37.9	3.48	0.11
6975	32623	37.82	2.2	37.93	2.19	0.11
6935	Bridge					0
6898	32623	37.8	2.12	37.91	2.11	0.11
6775	44376	37.72	2.97	37.83	2.95	0.11
6473	44376	37.63	3.41	37.74	3.39	0.11
6448	Bridge					0
6423	44376	37.61	3.45	37.72	3.42	0.11
6174	44376	37.58	3.78	37.69	3.76	0.11
6128	Bridge					0
6068	44376	37.52	3.83	37.64	3.8	0.12
5525	44376	37.5	2.68	37.61	2.66	0.11
4994	44376	37.29	3.95	37.4	3.93	0.11
4980	Bridge					0
4961	44376	37.2	3.98	37.32	3.96	0.12
4812	44376	37.05	4.51	37.17	4.48	0.12
4774.5	Bridge					0
4687	44376	36.94	4.26	37.06	4.23	0.12
4407	44376	36.73	5.13	36.81	5.29	0.08
4014	44376	36.71	3.78	36.79	3.76	0.08
3997	Bridge					0
3976	44376	36.42	3.79	36.51	3.77	0.09
3681	44376	36.23	4.62	36.32	4.6	0.09
3585	44376	36.16	4.83	36.24	4.83	0.08
3085	44376	35.99	4.9	36.06	4.92	0.07
3000	Bridge	I-10				
2915	44376	35.93	4.9	35.95	4.92	0.02
2298	44376	35.8	4.64	35.8	4.66	0
1580	44376	35.67	4.83	35.65	4.83	-0.02
1353	44376	35.42	5.84	35.49	5.53	0.07
1335	Bridge					0
1319	44376	35.24	5.87	35.28	5.67	0.04
984	44376	35.12	5.53	35.12	5.53	0

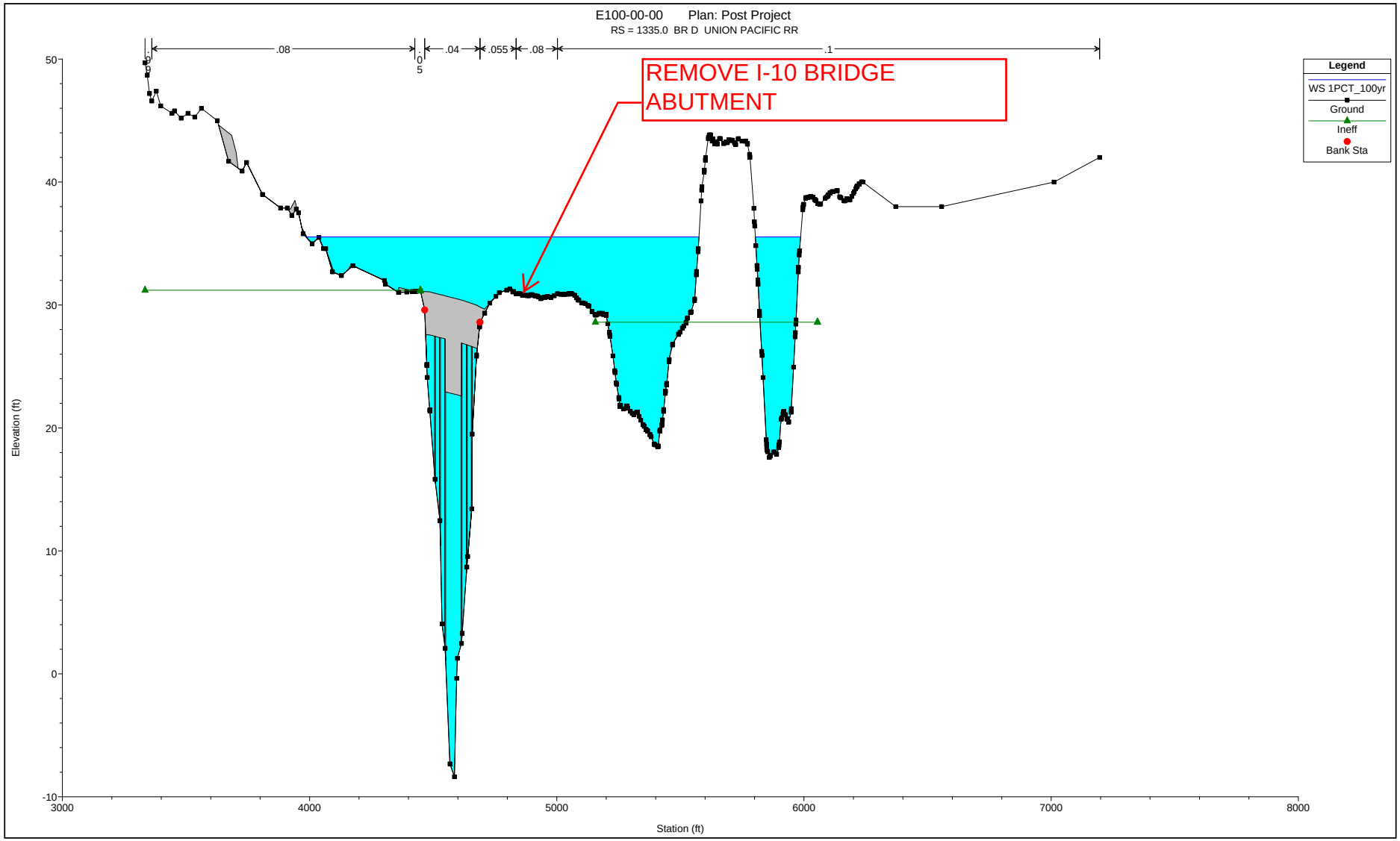
POST PROJECT MODEL

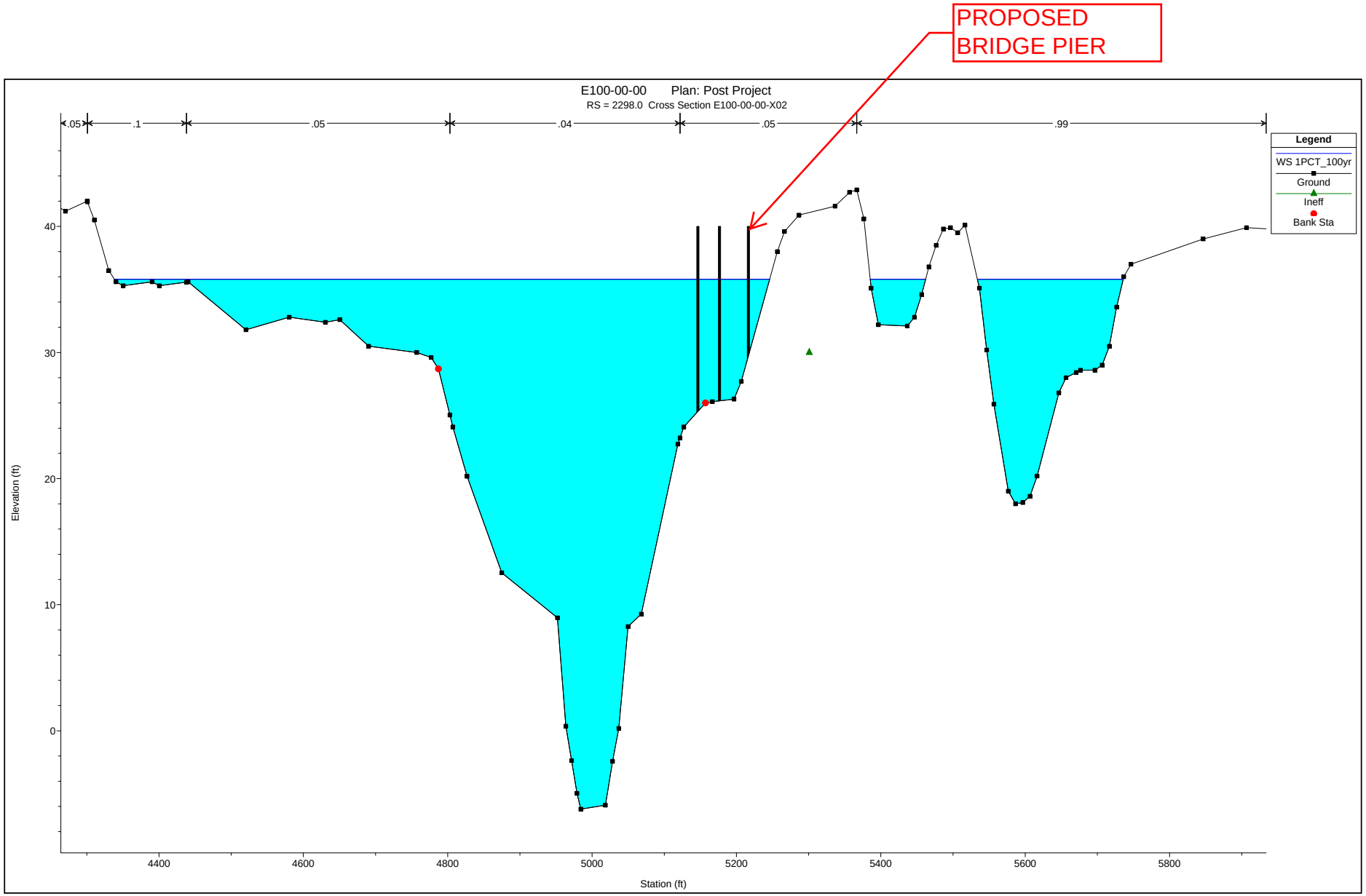


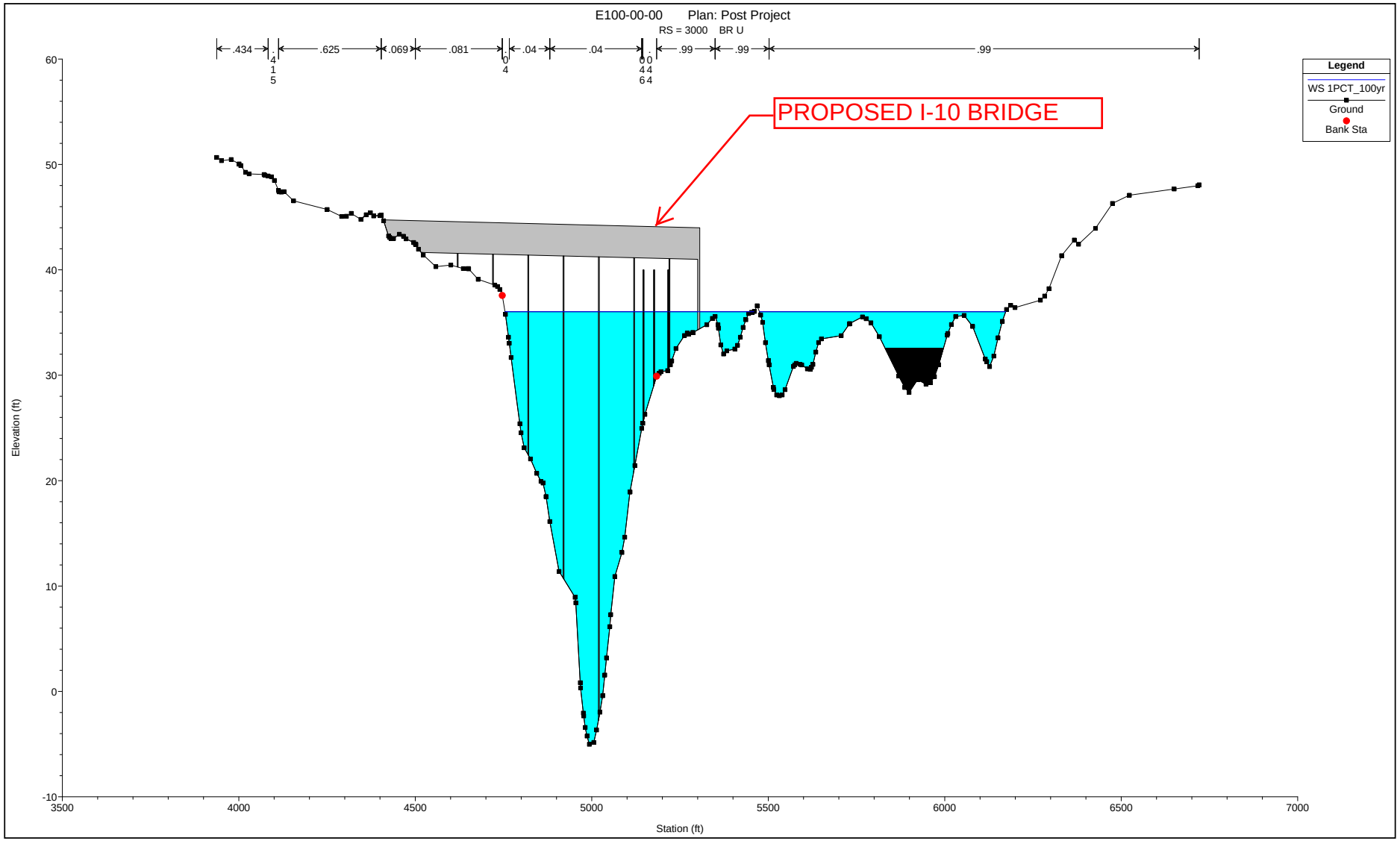
POST-PROJECT
HEC-RAS MODEL

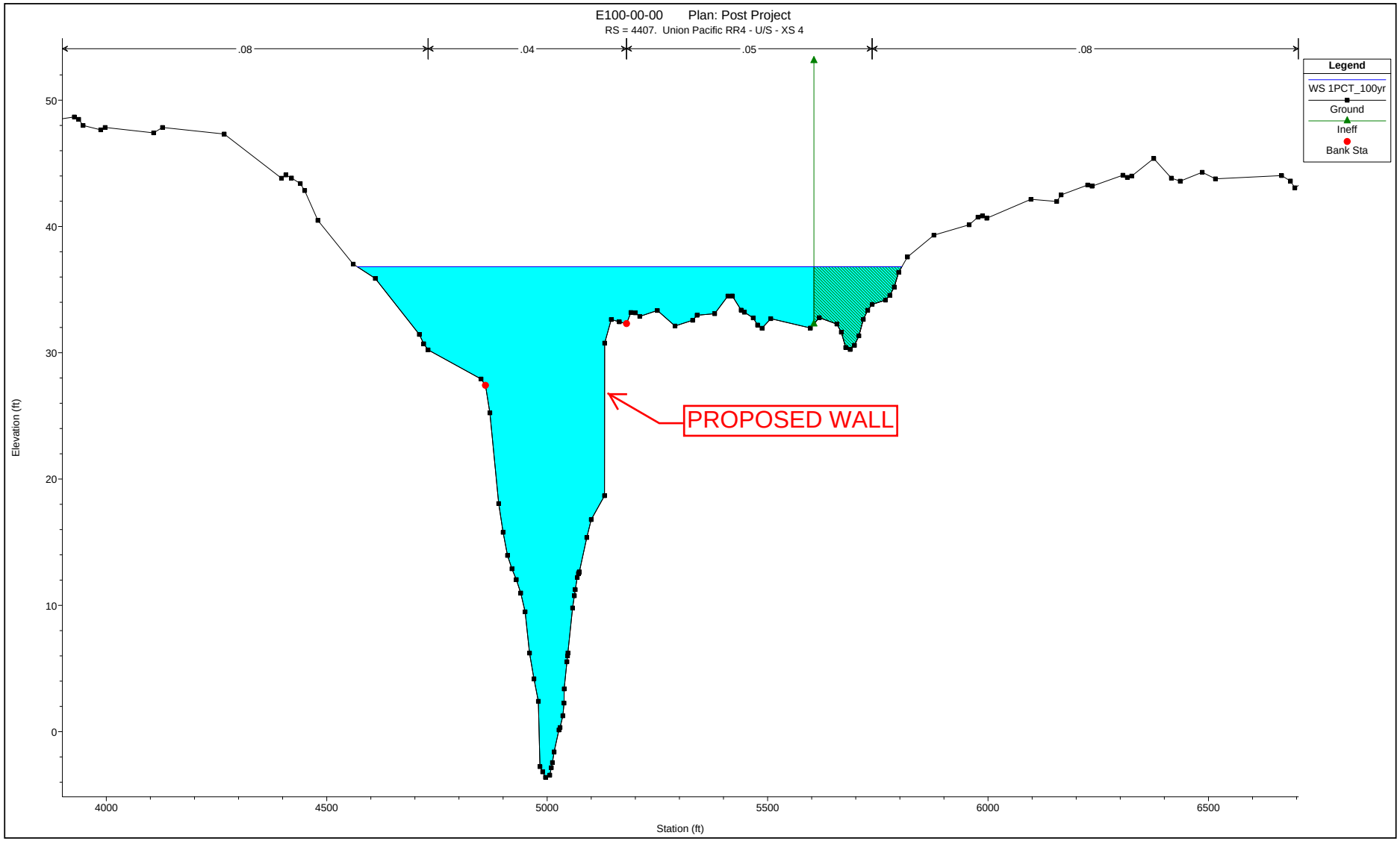
PRE PROJECT MODEL




E100-00-00 Plan: Post Project
RS = 1335.0 BR D UNION PACIFIC RR
.08
.04
.055
.08
.1
REMOVE I-10 BRIDGE ABUTMENT
Legend
WS 1PCT_100yr
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
50
40
30
20
10
0
-10
3000
4000
5000
6000
7000
8000


PROPOSED
BRIDGE PIER
E100-00-00 Plan: Post Project
RS = 2298.0 Cross Section E100-00-00-X02
.05
.1
.05
.04
.05
.99
Legend
WS 1PCT_100yr
Ground
Ineff
Bank Sta
Elevation (ft)
40
30
20
10
0
4400
4600
4800
5000
5200
5400
5600
5800
Station (ft)


E100-00-00 Plan: Post Project
RS = 3000 BR U
.434
.625
.069
.081
.04
.04
.99
.99
.99
PROPOSED I-10 BRIDGE
Legend
WS 1PCT_100yr
Ground
Bank Sta
Elevation (ft)
Station (ft)
60
50
40
30
20
10
0
-10
3500
4000
4500
5000
5500
6000
6500
7000


E100-00-00 Plan: Post Project
RS = 4407. Union Pacific RR4 - U/S - XS 4
.08
.04
.05
.08
Legend
WS 1PCT_100yr
Ground
Ineff
Bank Sta
PROPOSED WALL
Elevation (ft)
Station (ft)
50
40
30
20
10
0
4000
4500
5000
5500
6000
6500