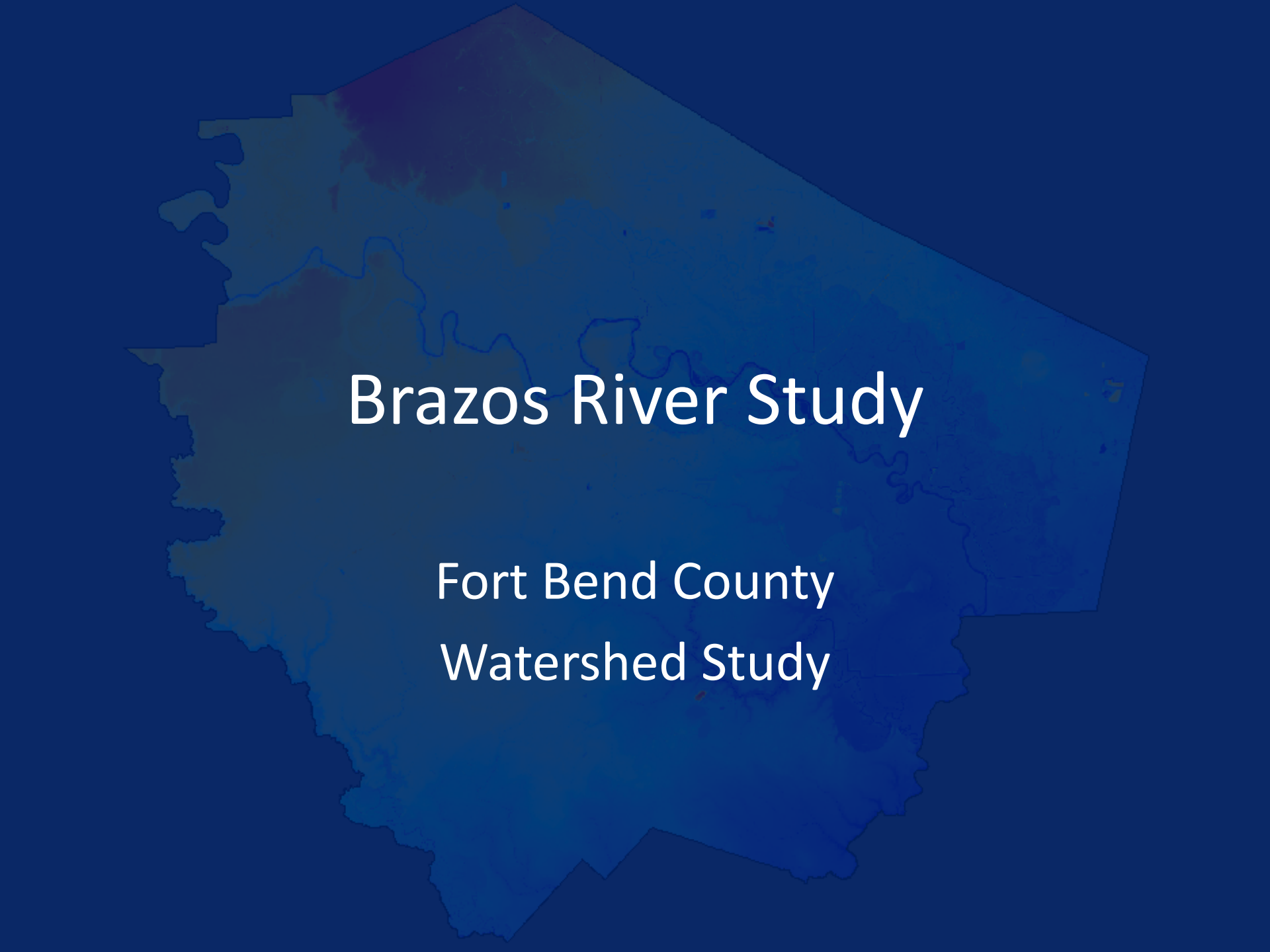


Brazos River Study

Fort Bend County

Watershed Study

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

HALFF

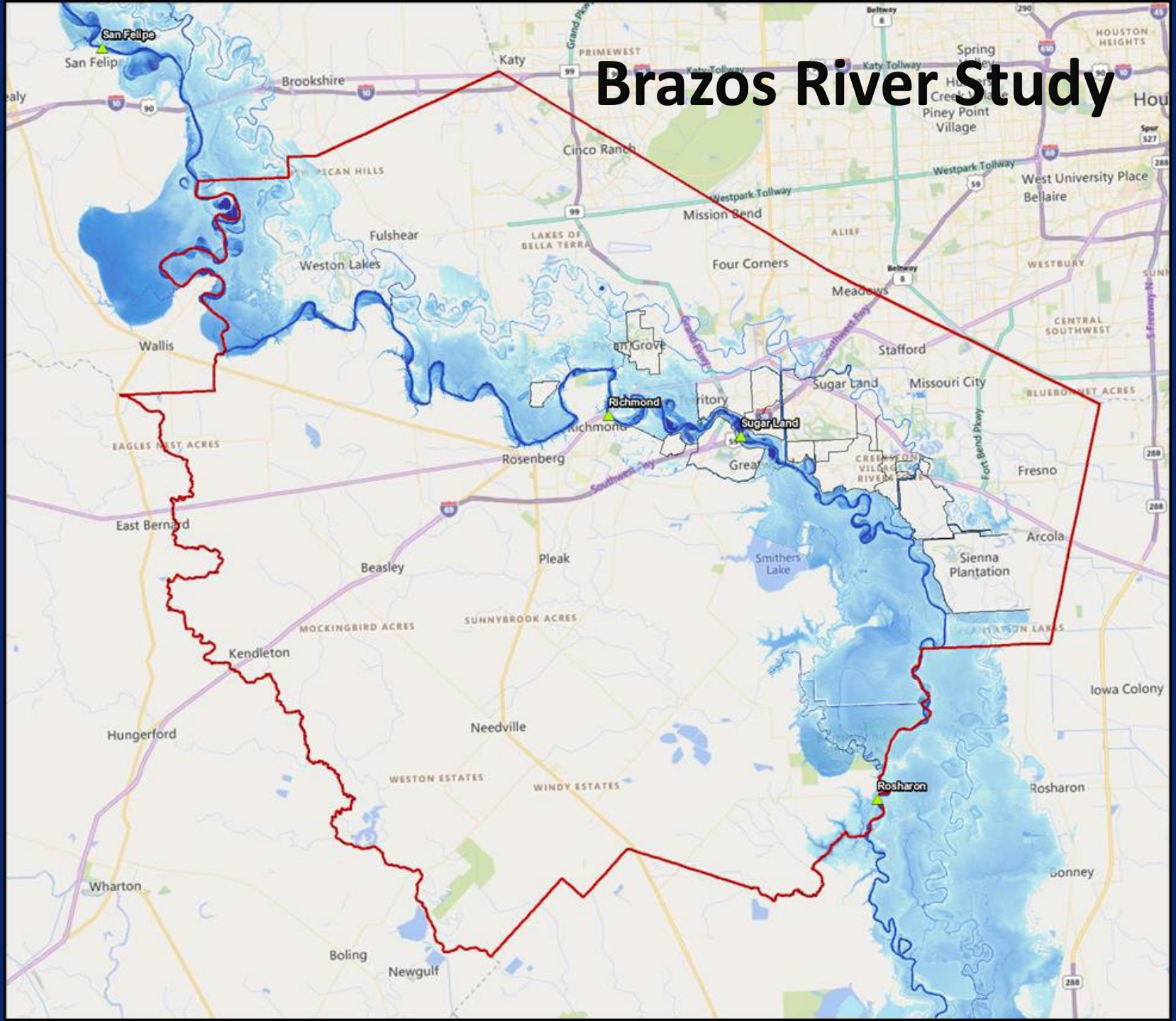


HYDROLOGIC AND HYDRAULIC ANALYSIS OF THE BRAZOS RIVER

Prepared for:

Fort Bend County Drainage District

9/30/2021


Brazos River Study
San Felipe
Brookshire
Katy
Cinco Ranch
Fulshear
Weston Lakes
Mission Bend
Four Corners
Meadows
Stafford
Sugar Land
Missouri City
Richmond
Rosenberg
Fresno
Arcola
Sienna Plantation
East Bernard
Beasley
Pleak
Smithers Lake
Kendleton
Hungerford
Needville
Iowa Colony
Rosharon
Wharton
Boling
Newgulf
Bonney
Piney Point Village
West University Place
Bellaire
Spring
Westpark Tollway
Beltway
Grand Parkway
Southwest Fwy
Fort Bend Pkwy
WESTON ESTATES
WINDY ESTATES
MOCKINGBIRD ACRES
SUNNYBROOK ACRES

Brazos River Study

1. Hydrology (how much water) -- By HALFF
   - HEC-HMS model-- 2019 Lower Brazos Flood Protection Planning Study was updated based on additional information obtained for this study,
   - Re-calibrated to work in conjunction with the hydraulic model that was developed for this study

2. Hydraulic (how deep is the water) – BY Freese & Nichols
   - HEC-RAS 5.0.7, and (1D/2D) model
   - Extends: from HW-290 (Hempstead) to approximately 18 miles south of FM 1462, in Brazoria County, Total 162 river miles.
   - Geometry:
     - Best-available aerial LiDAR (ground contour elevations)
     - River Bathymetry (Shape and depth of the river between the banks)-- collected by the U.S. Army Engineer Research and Development Center (ERDC) in March of 2019.
   - The model results in a detailed representation of the Brazos River and its floodplain.

Brazos River Study Results

Table ES-2: Comparison to Previous Studies at Richmond Gage on the Brazos River

Storm Event	Peak Discharge (cfs)			Water Surface Elevation (feet NAVD 88)		
	Effective FIS	2019 BRA Study	HEC-RAS 1D/2D Model	Effective FIS	2019 BRA Study	HEC-RAS 1D/2D Model
10% ACE	103,000	86,030	90,813	76.65	77.04	77.11
2% ACE	147,000	123,045	120,451	81.34	82.76	81.51
1% ACE	164,000	139,286	132,031	82.81	84.43	82.85
0.02% ACE	206,000	187,213	156,948	85.20	87.66	84.92

Previous Studies

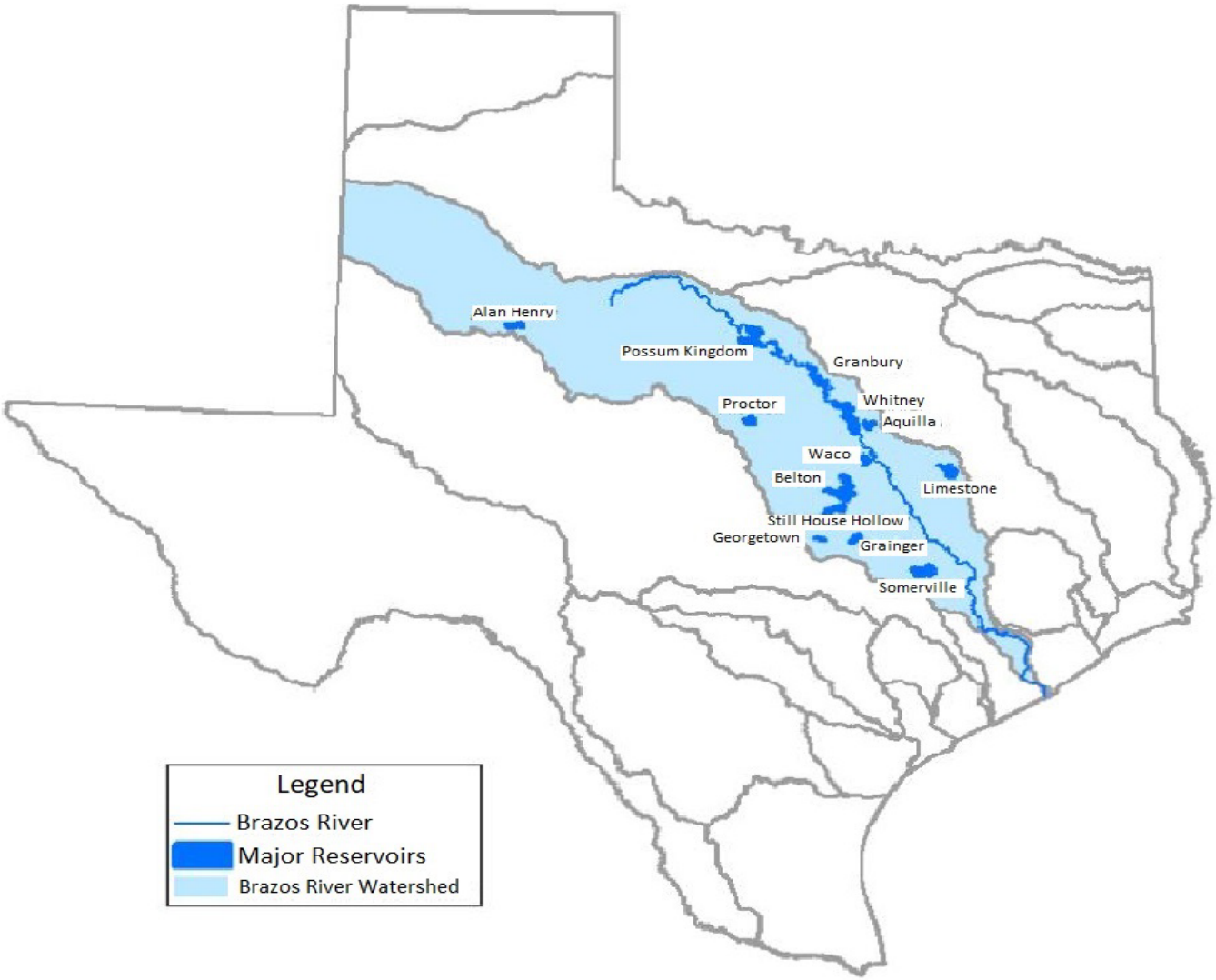
- FEMA Effective Study (2014)
- Lower Brazos Flood Protection Planning Study (BRA)
- USACE-FRM (2020)
- Risk Analysis, Mapping, and Planning Partners 2015

Brazos River Hydrology

1. Update the 2019 Study hydrologic parameters within the vicinity of Fort Bend County to match methodologies recommended for the updated Fort Bend County Drainage Criteria Manual and provide an updated HEC-HMS model.

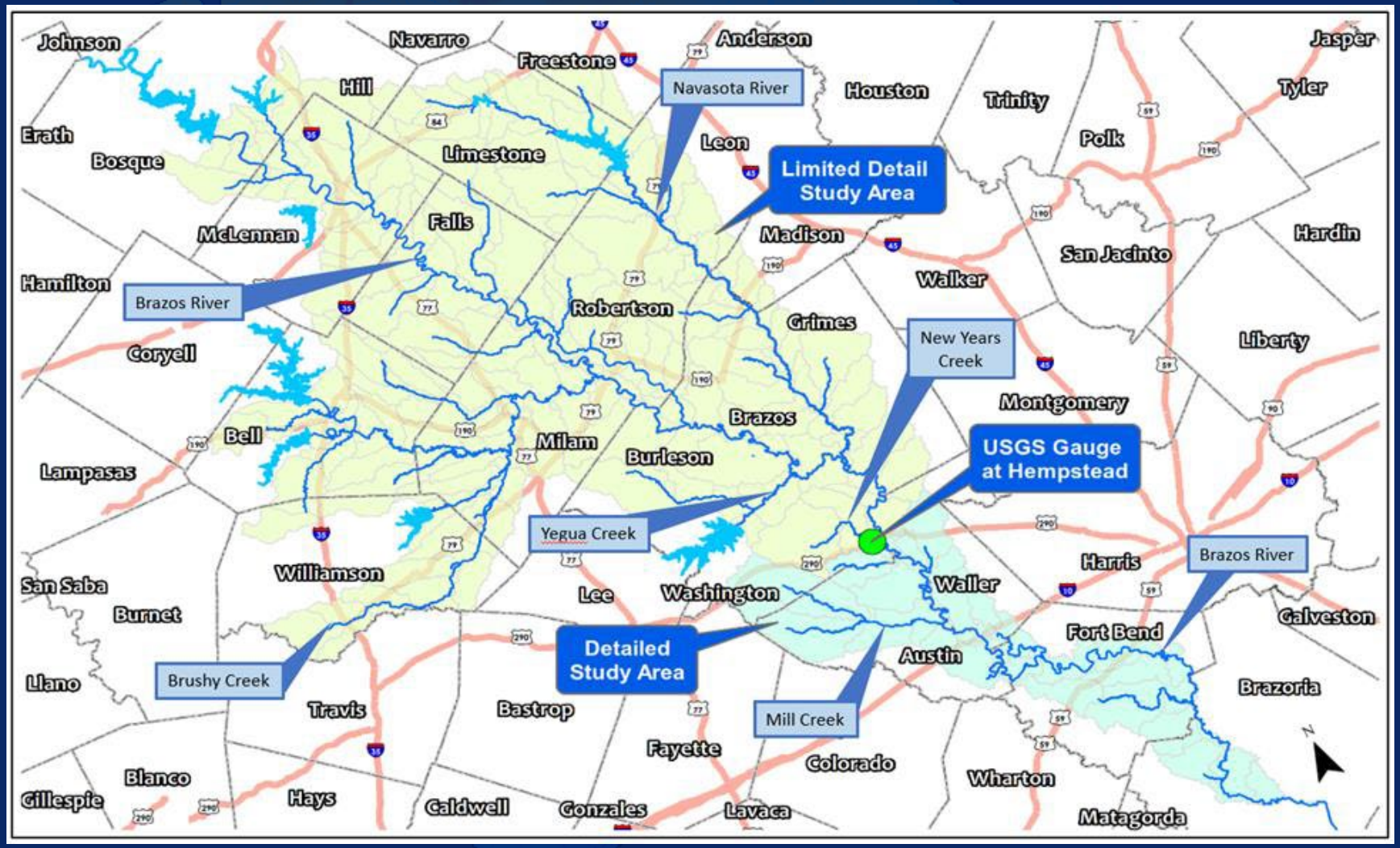
2. Update the design rainfall to reflect rainfall depths from Atlas 14 as well as depth/area reduction factors for the design storm to be consistent with recommendations from Atlas 14.

3. Create and simulate the 2-, 5-, 10-, 25-, 50-, 100-, and 500- year design storms and compare results to the effective flows and BRA Study model



Throughout its history, the Brazos River has experienced major flooding events. The first recorded major flooding occurs in 1833 as the water leaves the Brazos River's banks from Washington to Ringold's Prairie (near present-day Navasota). The latest severe flooding happened in 1913 as the Brazos River and the Colorado River joined to flood more than 3,000 square miles of land and caused the death of at least 177 people and massive property damage (Reference 2). The Brazos River Authority was established in 1929. It has statutory responsibility for developing and conserving the surface water resources of the Brazos River basin in Texas. The Authority in the early 1930s developed its first master plan for control, conservation, and development of the surface-water resources of the Brazos basin. The first major reservoir, Possum Kingdom Lake, was completed in 1941 on the main stem of the Brazos River northwest of Fort Worth. Eleven additional major reservoirs were completed since then, with the latest one, Aquilla Lake, completed in 1983 (Reference 1).

Brazos River Hydrology



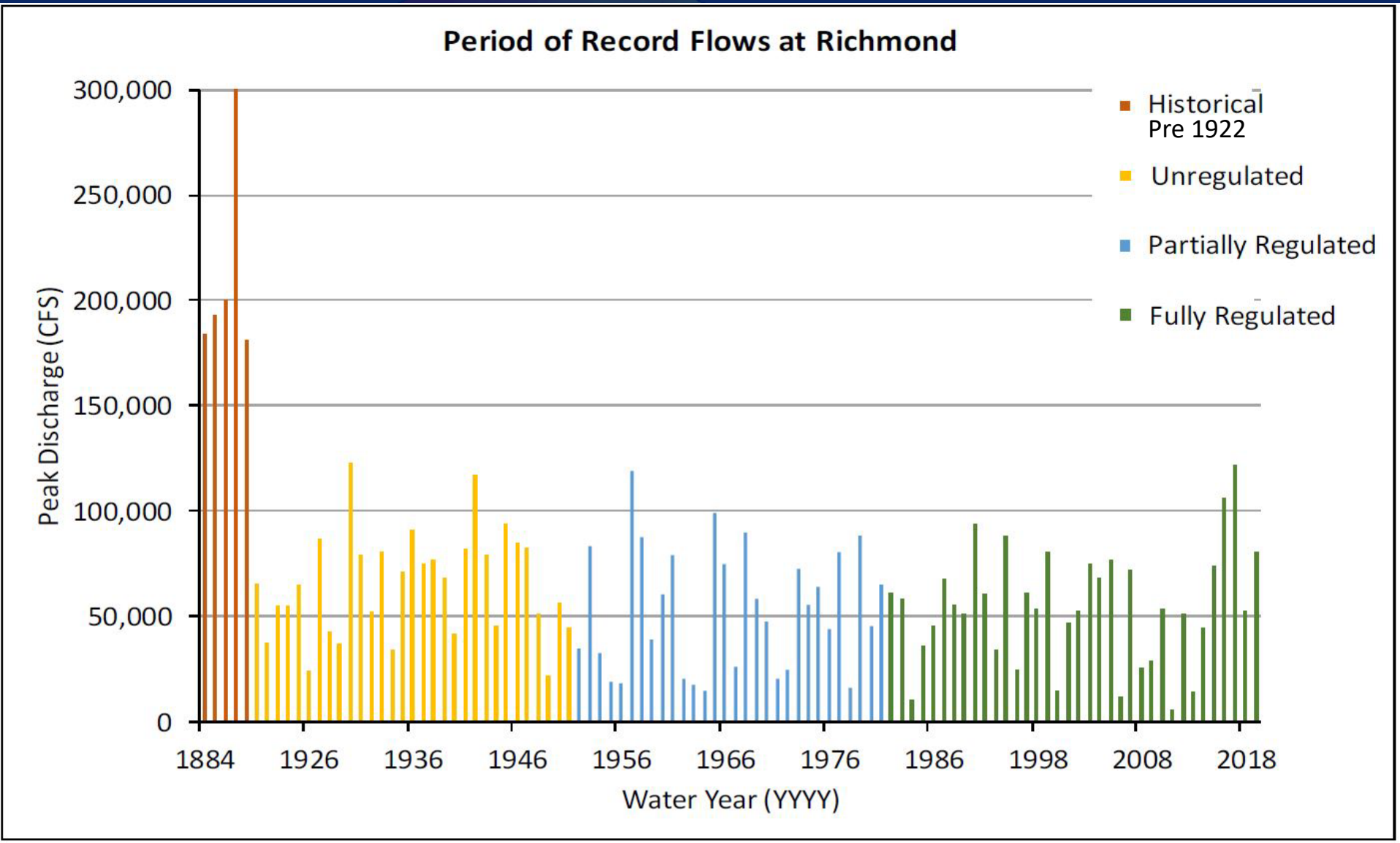
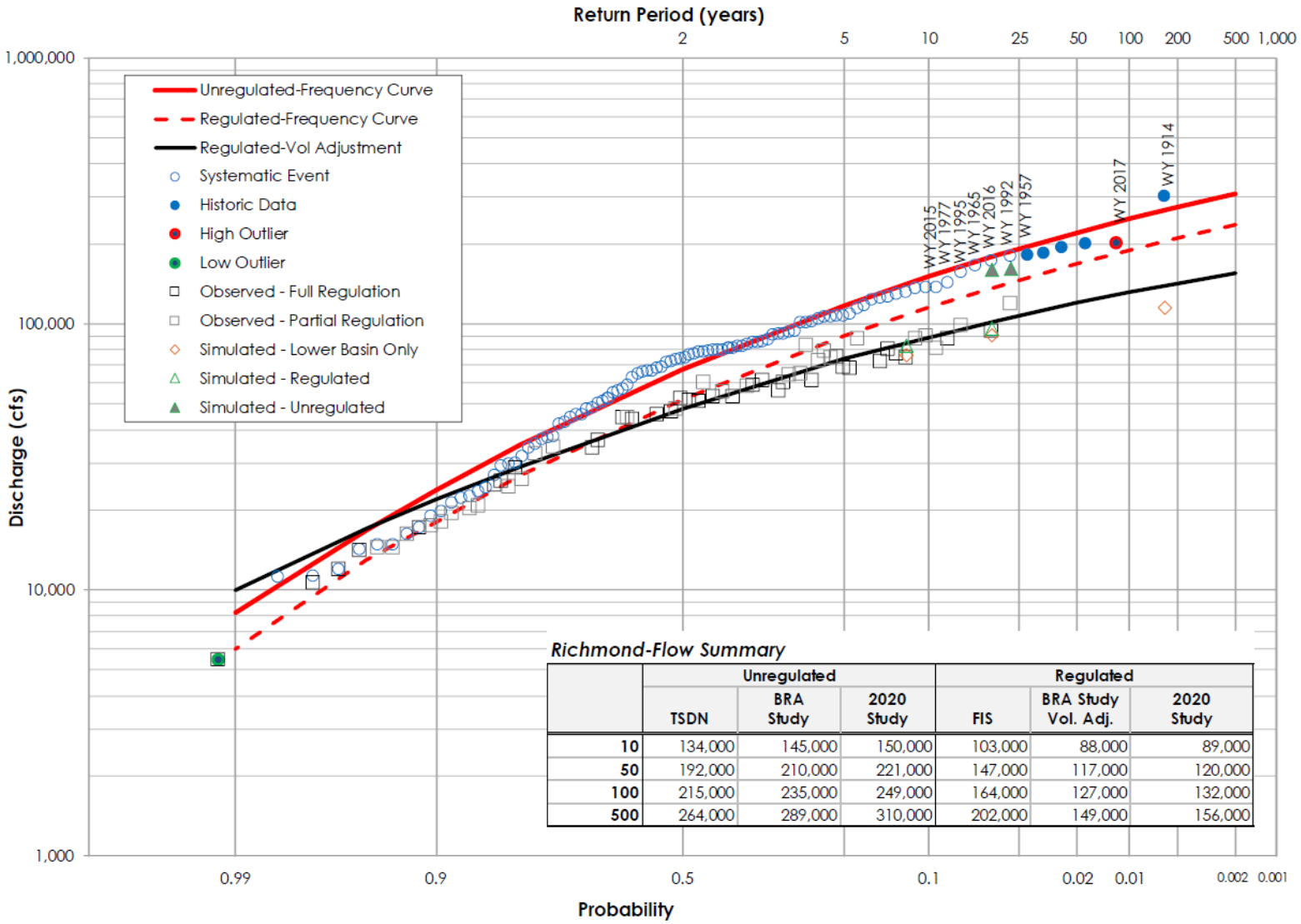


Figure 3-8: USGS Period of Record Flows at Richmond



Richmond-Flow Summary

	Unregulated			Regulated		
	TSDN	BRA Study	2020 Study	FIS	BRA Study Vol. Adj.	2020 Study
10	134,000	145,000	150,000	103,000	88,000	89,000
50	192,000	210,000	221,000	147,000	117,000	120,000
100	215,000	235,000	249,000	164,000	127,000	132,000
500	264,000	289,000	310,000	202,000	149,000	156,000

Figure 3-12: Flood Frequency Analysis Curve for USGS Gage at Richmond

Brazos River Hydrology

Table ES-1: Flood Frequency Analysis for Full Period of Record for Richmond Gage

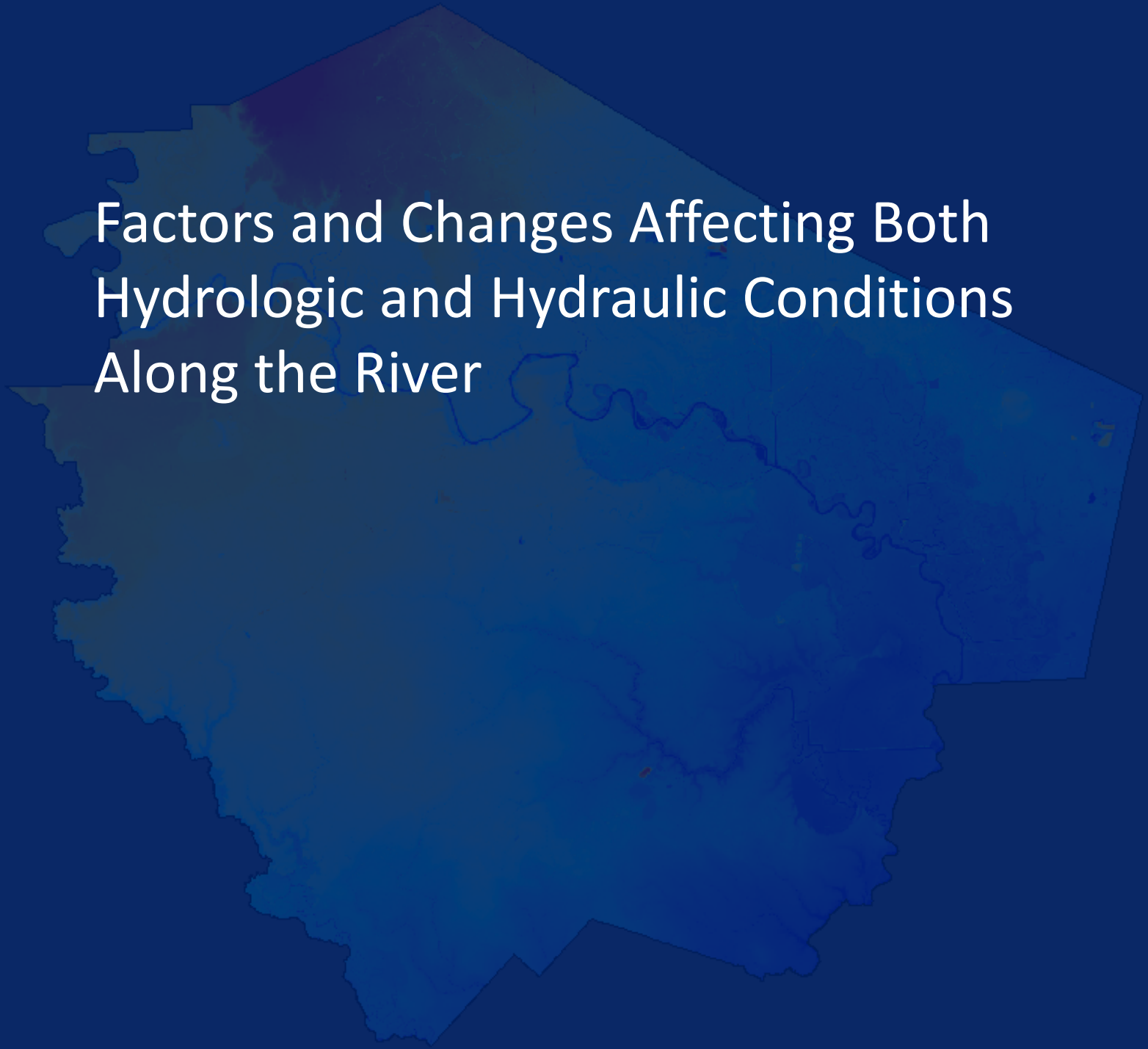
AEP	Unregulated Flows At Richmond (CFS)	Regulated Flows at Richmond (CFS)
500-Year	310,000	156,000
100-Year	249,000	132,000
50-Year	221,000	120,000
25-Year	190,000	107,000
10-Year	150,000	89,000
5-Year	117,000	74,000
2-Year	67,000	48,000

Brazos River Hydrology

Table 3-8: Comparison of Variations in Flood Frequency Analysis at Hempstead and Richmond

Flow Source	Hempstead 100-year Flow	Richmond 100-year Flow
Effective Flows	207,000	164,000
BRA Study Flood Frequency Analysis	157,000	127,000
Current Study Flood Frequency Analysis	155,000	132,000
Scenario 1 – Fully Regulated Period of Record Only	159,000	127,000
Scenario 2 – Non-Historic Events Only	128,000	116,000
Scenario 3 – Adjusted Flows Based on Model Calibration	155,000	132,000
Scenario 4 – Flood Frequency Analysis without Conversion	166,000	136,000
Scenario 5 – Fully-Regulated with Adjusted Flows	159,000	135,000
Scenario 6 – FFA without Conversion, with Adjusted Flows	166,000	137,000
Average of Scenario 1 and Scenario 5	159,000	131,000
Average of Current Study and All Scenarios	155,400	130,700

Factors and Changes Affecting Both Hydrologic and Hydraulic Conditions Along the River



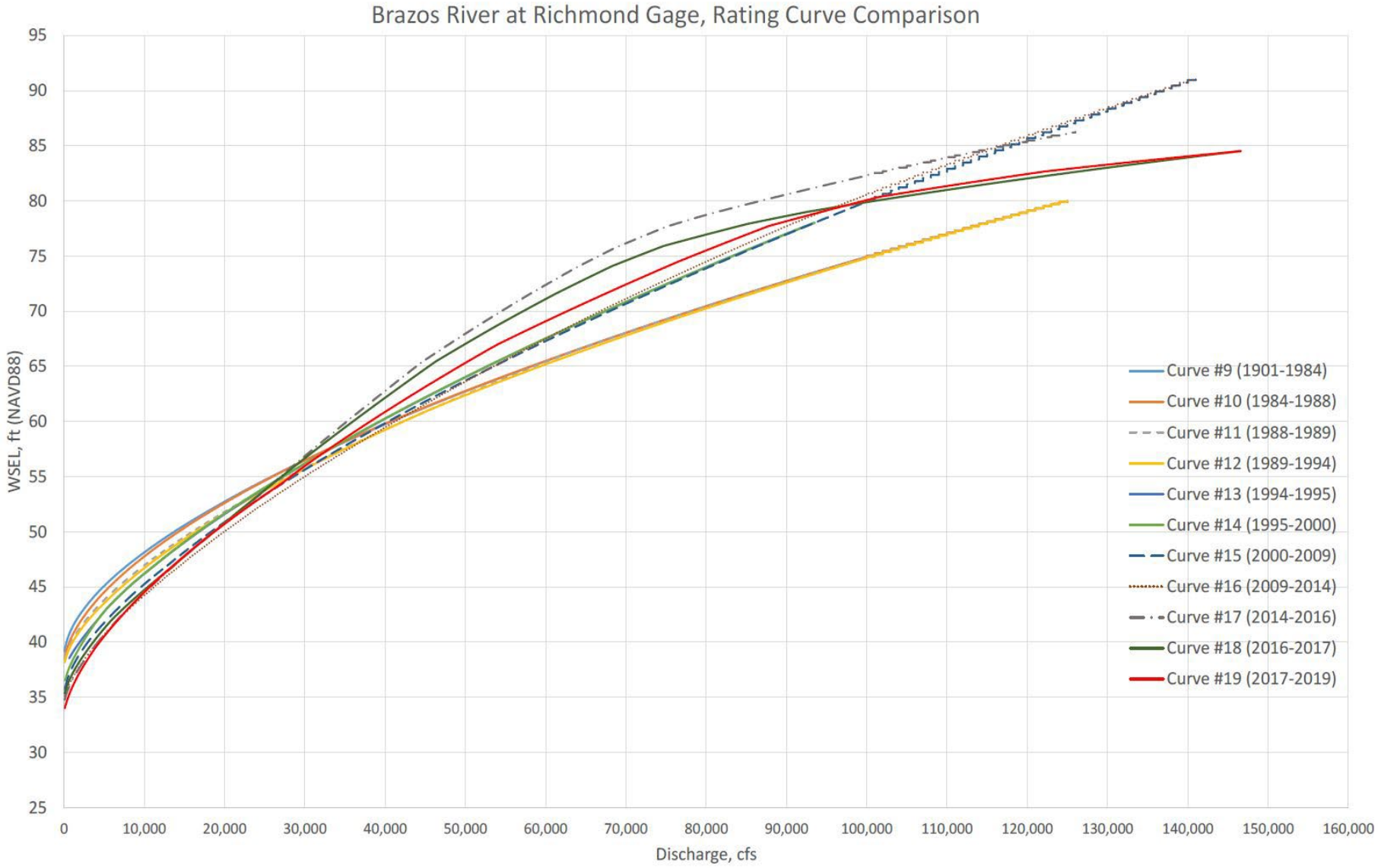


Figure 7. Brazos River at Richmond Gage, Rating Curve Comparison (WSEL vs discharge)

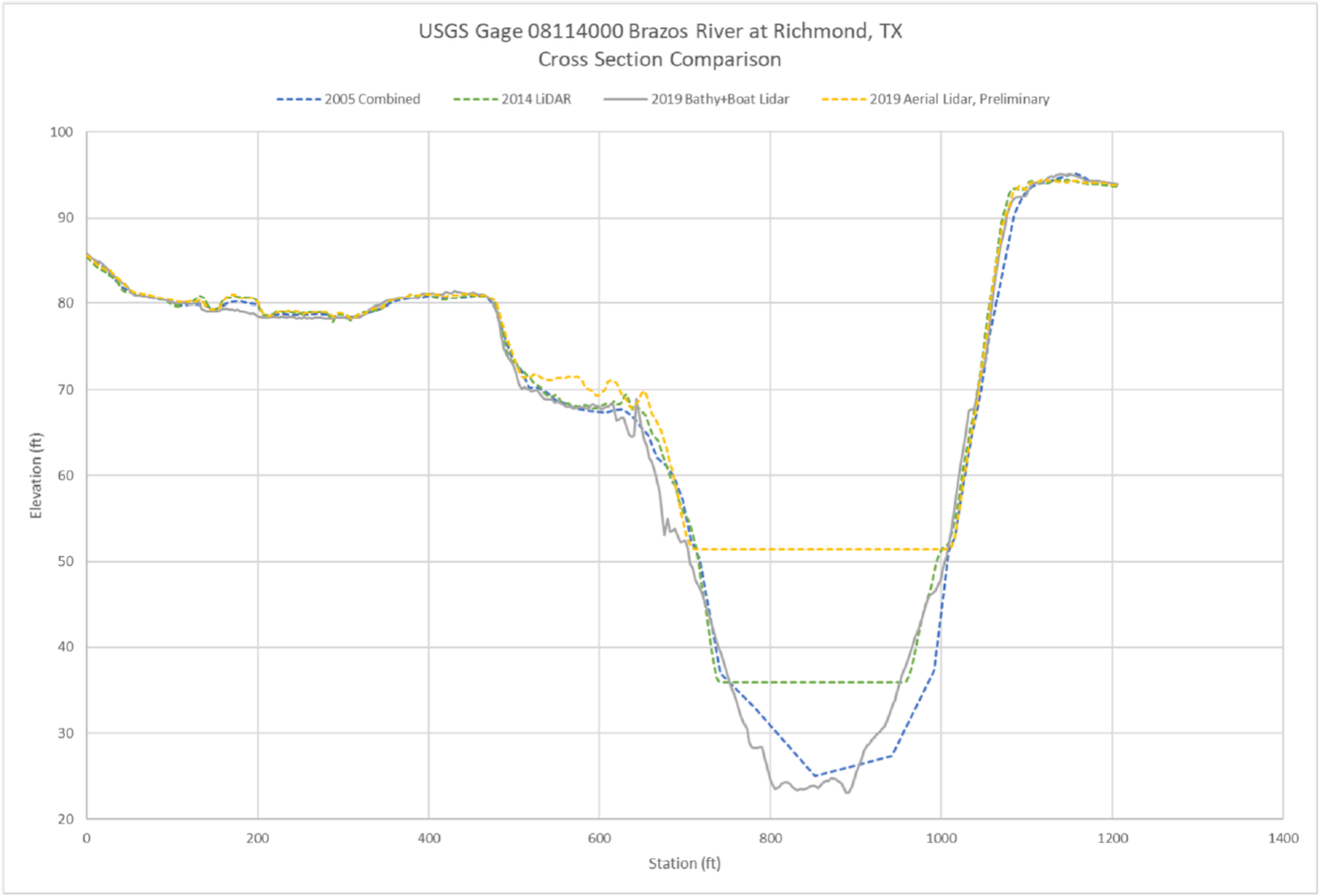


Figure 3: Terrain cross section comparison using the 2005, 2014, and 2019 available terrain models for the Brazos River at USGS Gage 08114000. The 2019 terrain incorporated river bathymetry and provided the most detail data to represent the channel bed.

Table 2. Brazos River at Richmond Gage, USGS Rating Curves, Effective Dates and Notes

Curve #	Years Effective*	USGS Notes
9	1901-1984	
10	1984-1988	The same as curve #9 above 46.52 ft and is based on measurements from 1957 to 1984
11	1988-1989	The same as curve #10 above 56.52 feet
12	1989-1994	
13	1994-1995	
14	1995-2000	The same as curve #13 above 42.22 feet. Shifts expected
15	2000-2009	Rating curve developed to remove head water shifts. Extended to 200-year flows for supplemental
16	2009-2014	Developed to alleviate low and medium flow scour shifts associated with rating number 15
17	2014-2016	Developed to alleviate low and medium flow scour shifts associated with rating number 15
18	2016-2017	Rating change to upper end prior to Harvey, when high flow measurements made, and rating adjusted
19	2017-2019	Adjust upper end of rating based on measurements during Harvey along with other recent high-flow measurements

* Dates shown as obtained from USGS.

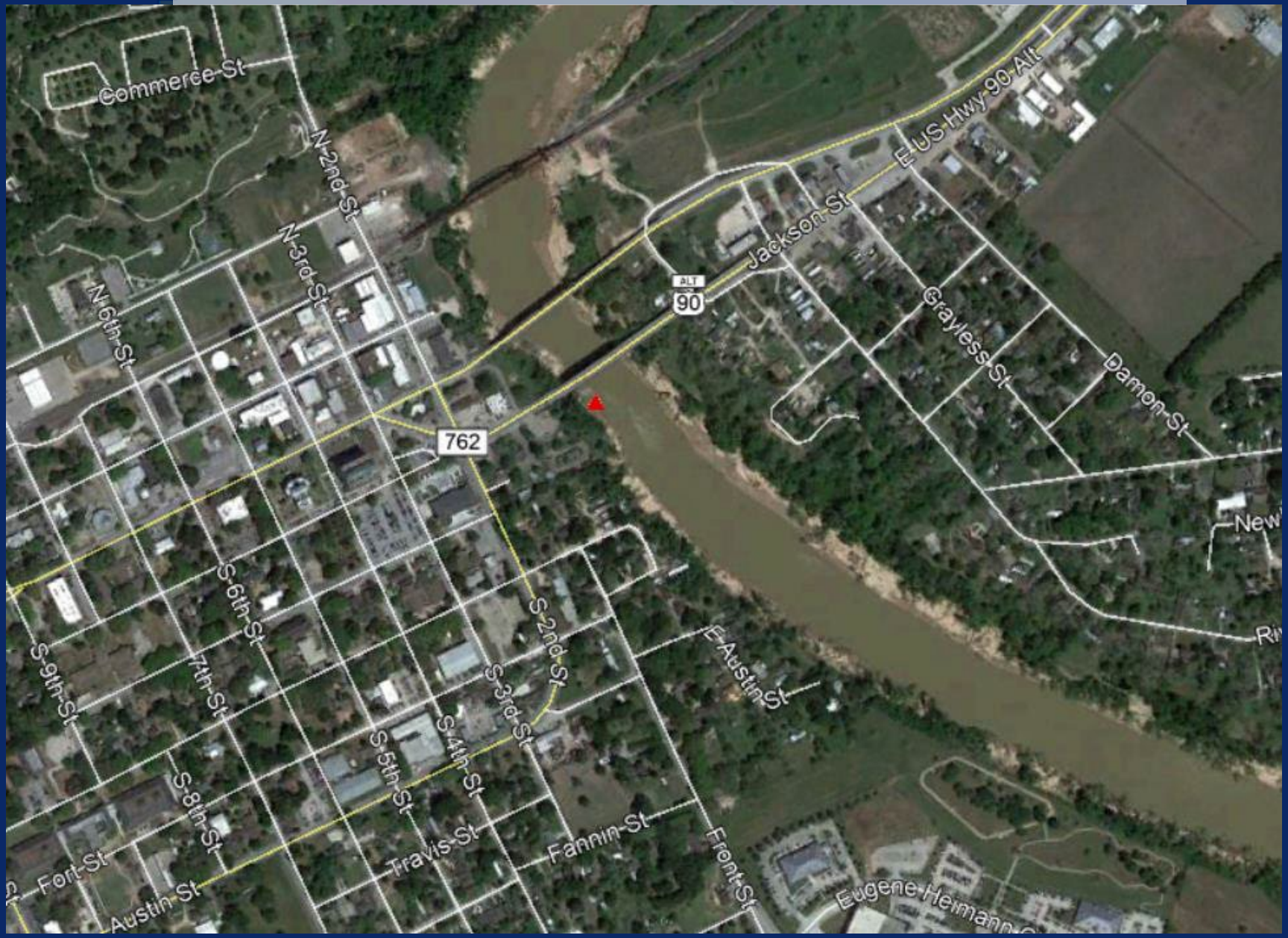
Table 3. USGS Rating Curves Adjusted for WSEL

Discharge (cfs)	Rating Curve #										
	9	10	11	12	13	14	15	16	17	18	19
5,000	45.09	44.53	43.82	43.52	42.76	42.76	41.75	40.68	40.68	41.23	40.52
10,000	48.13	47.77	46.96	46.71	46.20	46.21	45.26	44.23	44.48	44.73	44.52
20,000	52.72	52.59	51.79	51.63	51.59	51.64	50.86	50.02	50.75	50.81	50.71
30,000	56.47	56.47	55.76	55.68	56.16	56.17	55.61	54.99	56.84	56.67	55.97
40,000	59.74	59.78	59.26	59.23	60.24	60.26	59.83	59.45	62.75	62.16	60.87
50,000	62.72	62.75	62.44	62.38	64.00	64.02	63.69	63.60	67.94	67.04	65.31
60,000	65.47	65.48	65.38	65.18	67.52	67.52	67.28	67.48	72.37	71.10	69.09
70,000	68.03	68.03	68.03	67.79	70.83	70.84	70.67	71.12	76.15	74.59	72.42
80,000	70.44	70.45	70.45	70.25	73.98	73.99	73.88	74.48	78.73	76.95	75.51
90,000	72.73	72.74	72.74	72.58	77.01	77.01	76.96	77.69	80.58	78.63	78.16
100,000	74.92	74.92	74.92	74.81	N/A	N/A	79.92	80.55	82.29	79.89	80.07
110,000	76.92	76.92	76.92	76.86	N/A	N/A	82.65	83.14	83.83	81.00	81.35
120,000	78.94	78.94	78.94	78.92	N/A	N/A	85.41	85.75	85.34	82.04	82.44
130,000	N/A	N/A	N/A	N/A	N/A	N/A	88.10	88.28	N/A	83.01	83.29

WSEL in NAVD88 associated to each discharge


A-322
A-121
B-188
Flow Measurements at this location through rating curve 12

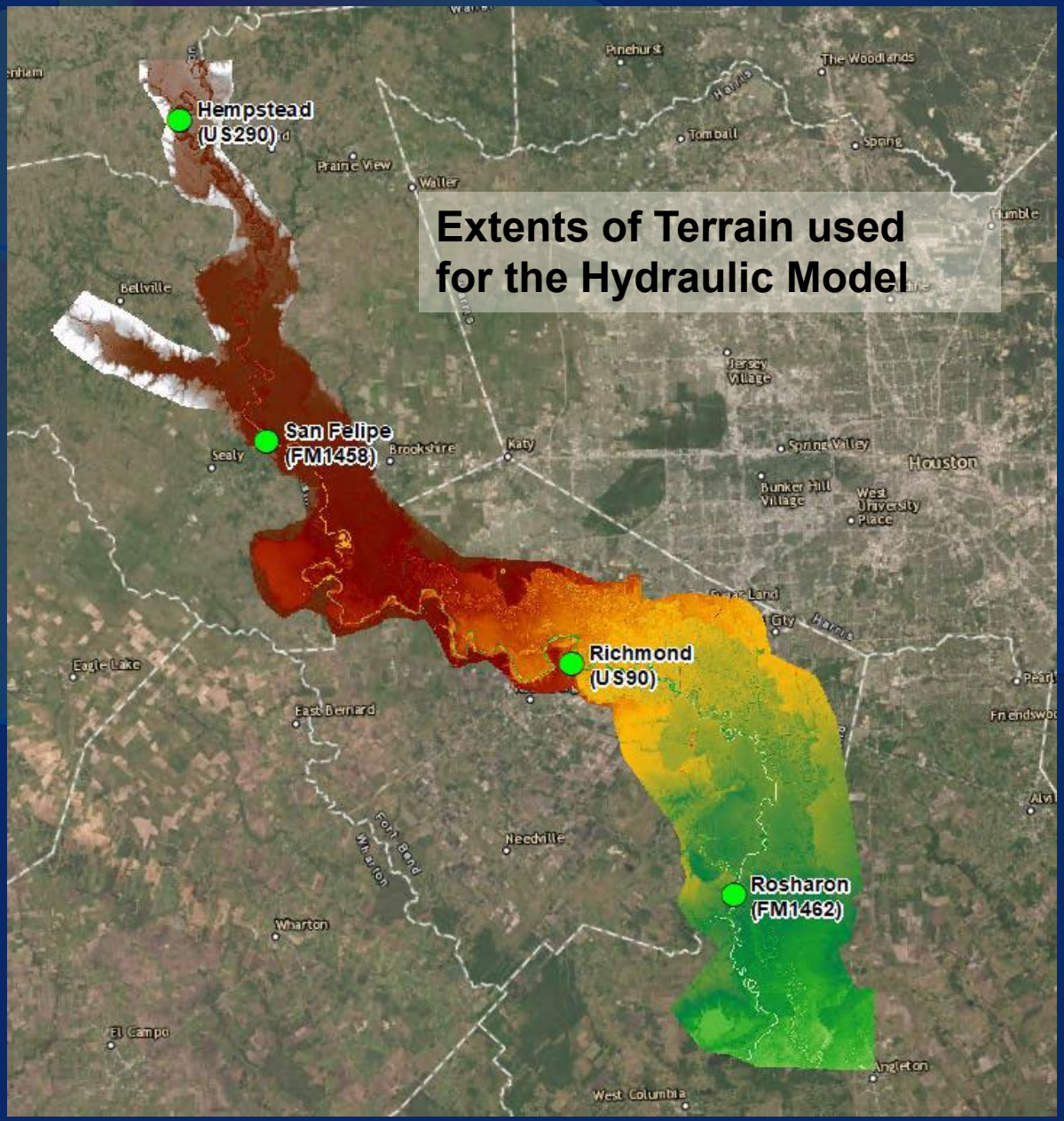
Brazos River @ Richmond Gage



Brazos River Hydraulic

1. Extends from Highway 290 (Hempstead) to approximately 18 miles south of FM 1462, in Brazoria County, for a total of 162 river miles
2. Best available aerial LiDAR (ground contours)
3. River Bathymetry (shape and depth of river between the high banks) collected by the U.S. Army Engineer Research and Development Center (ERDC) in March 2019

Brazos River Hydraulic



Brazos River Hydraulic

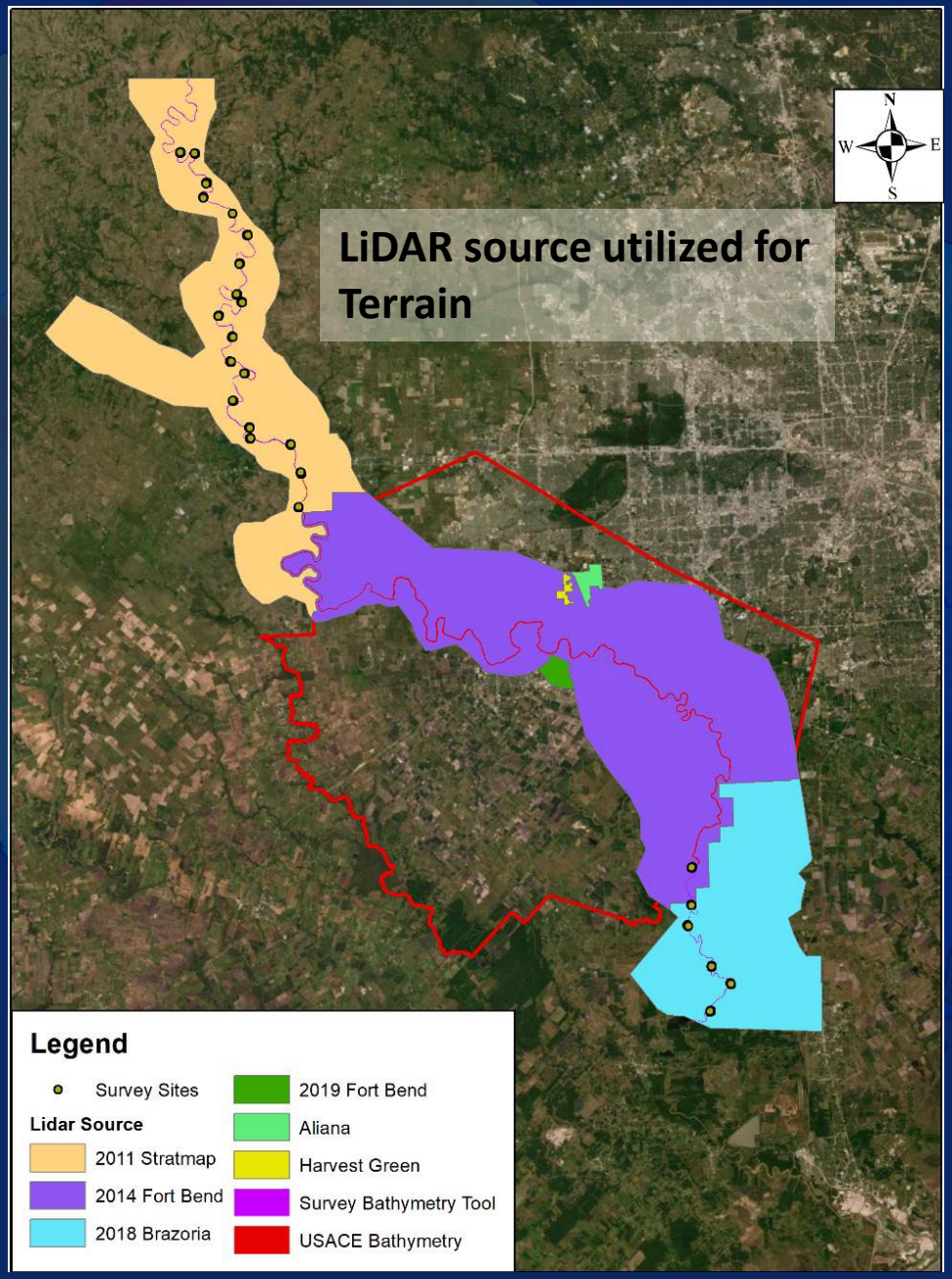
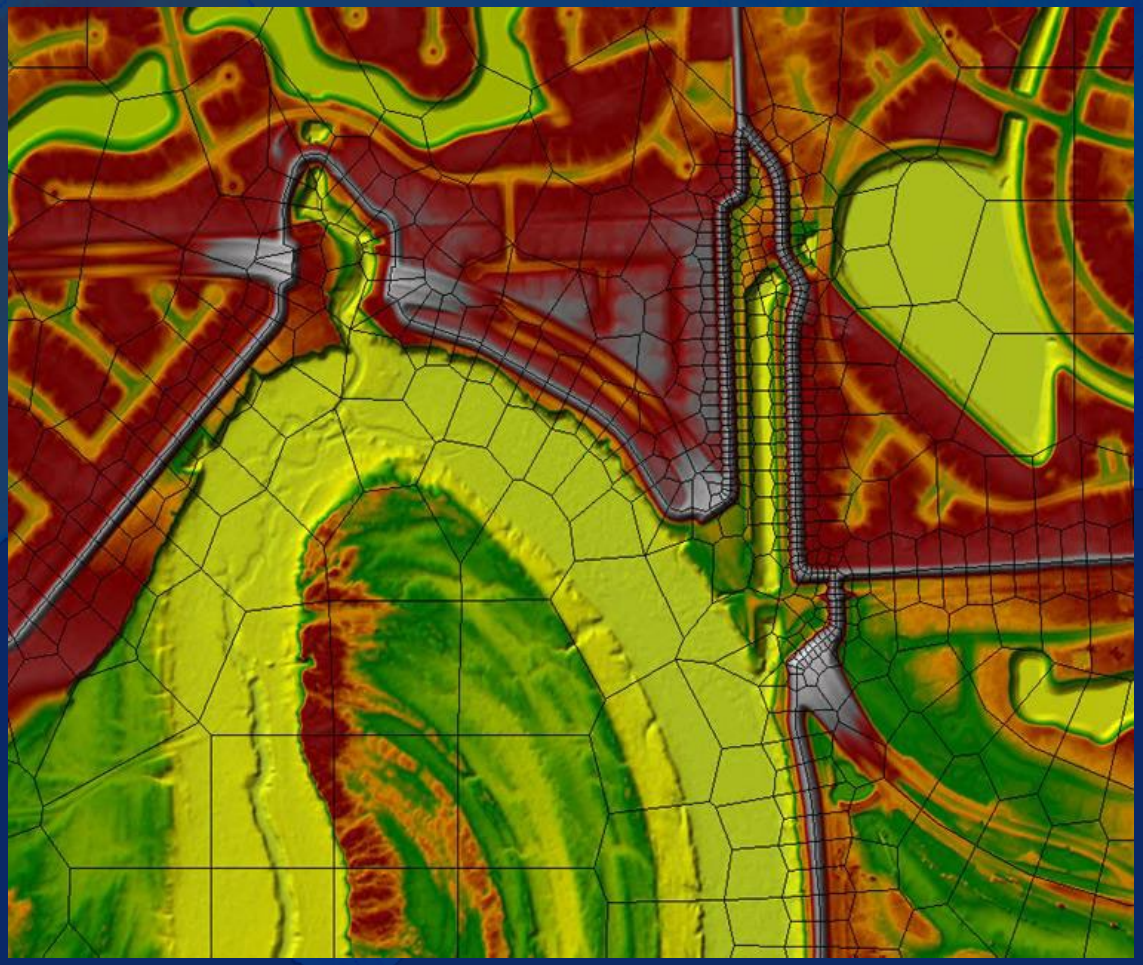


Table 4-2: Default Manning's Roughness Values

LULC	Base n value	Percentage of Modeled Area
Open Water	0.04	1.88%
Developed High Intensity	0.03	1.19%
Developed Medium Intensity	0.12	6.49%
Developed Low Intensity	0.18	10.69%
Developed Open Space	0.05	4.19%
Barren Lands	0.04	0.20%
Forest/Shrubs	0.30	7.80%
Pasture/Grassland	0.12	42.54%
Cultivated Crops	0.14	6.08%
Wetlands	0.30	15.15%

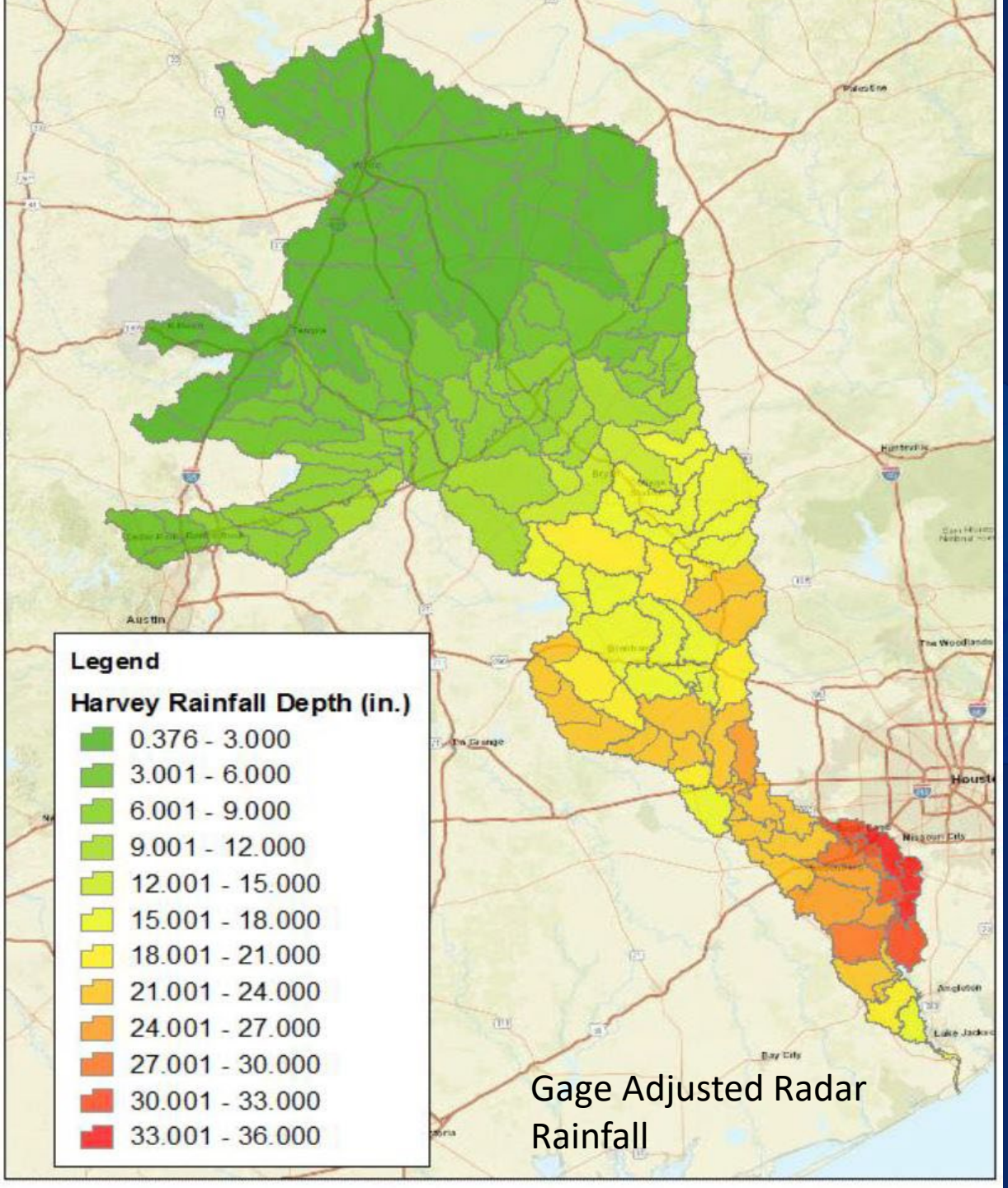
Levee Breaklines in HEC-RAS 2D model Geometry Example



Model Calibration

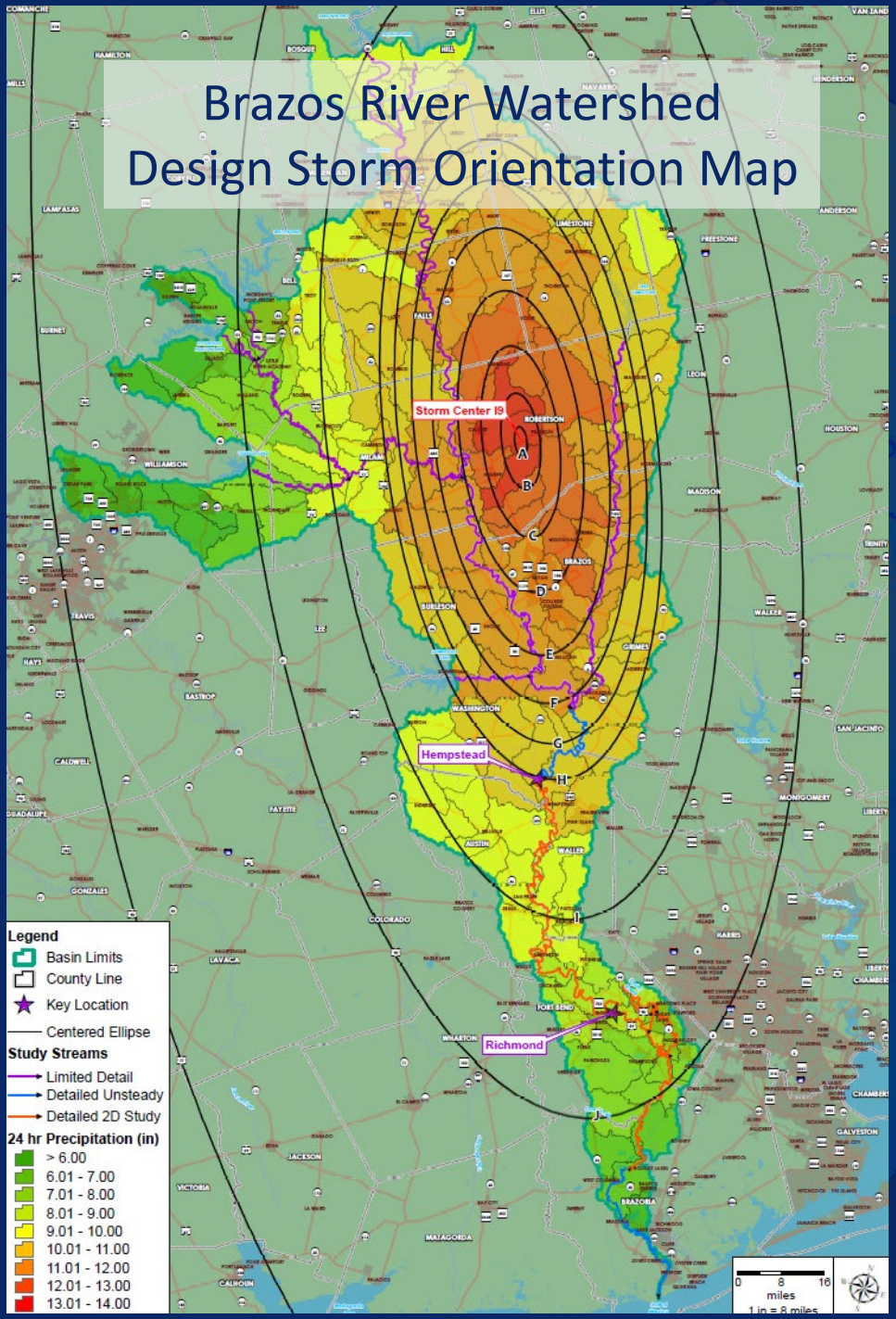
Table 4-3: Summary Table of 2D Model Calibration Comparison to Observed Stages

Max WSE at Comparison Point	Memorial Day 2016		Hurricane Harvey 2017		Winter 2018/19		Tax Day 2016 (Validation)	
	Observed	Modeled	Observed	Modeled	Observed	Modeled	Observed	Modeled
Hempstead (USGS)	162.74'	162.81'	159.11	158.58'	155.21'	155.06'	151.84'	149.99'
San Felipe (USGS)	128.85'	128.56'	128.97'	128.83'	119.72'	119.72'	123.31'	123.42'
FM 1093 (FBCDD)	111.00'	111.05'	111.71'	111.77'	-	-	-	-
FM 1489 (FBCDD)	106.80'	106.78'	108.00'	108.04'	-	-	-	-
FM 723 (FBCDD)	91.45'	91.49'	91.95'	92.03'	-	-	-	-
Richmond (USGS)	81.76'	81.78'	82.20'	82.22'	73.59'	73.14'	76.64'	76.75'
US 59 (FBCDD)	75.20'	74.46'	74.86'	74.84'	-	-	-	-
Rosharon (USGS)	51.14'	51.04'	51.21'	51.19'	47.36'	46.91'	49.62'	49.53'

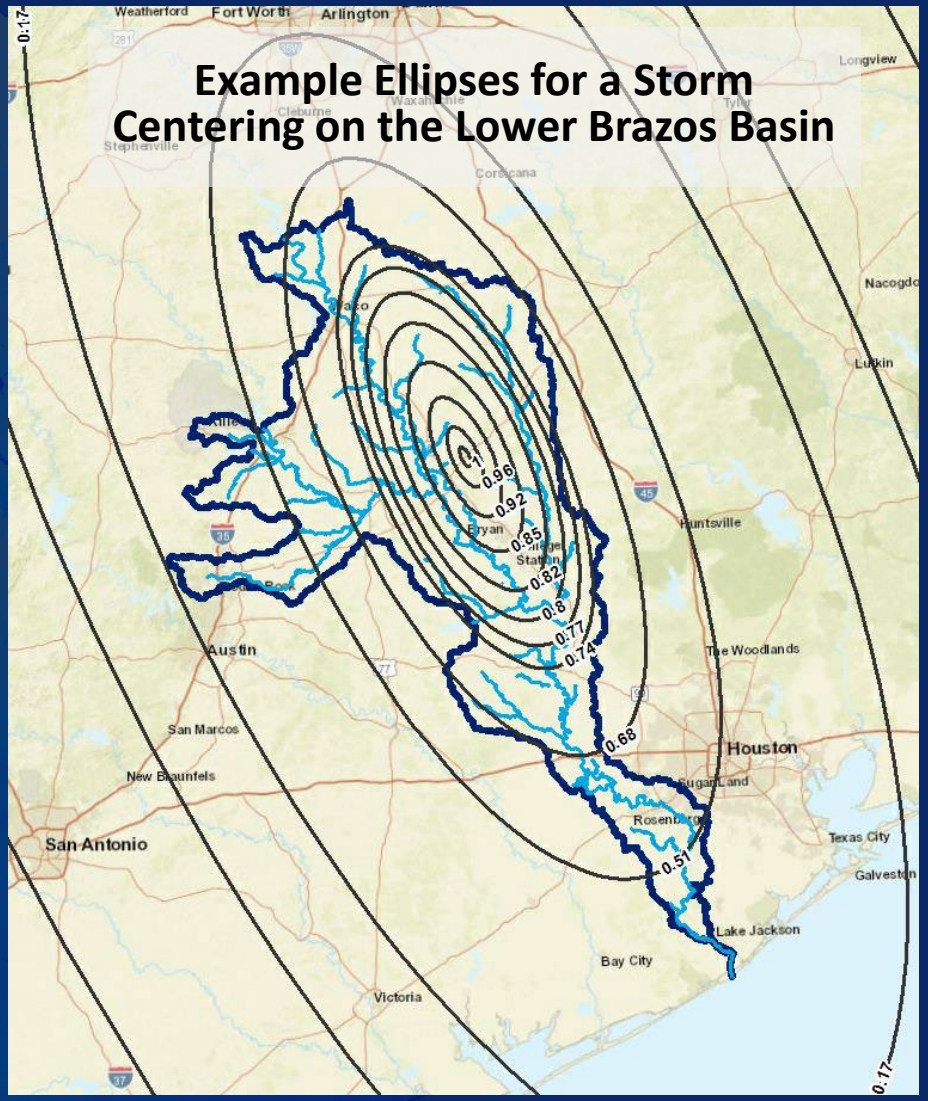


Gage Adjusted Radar Rainfall

Brazos River Watershed
Design Storm Orientation Map



Example Ellipses for a Storm Centering on the Lower Brazos Basin

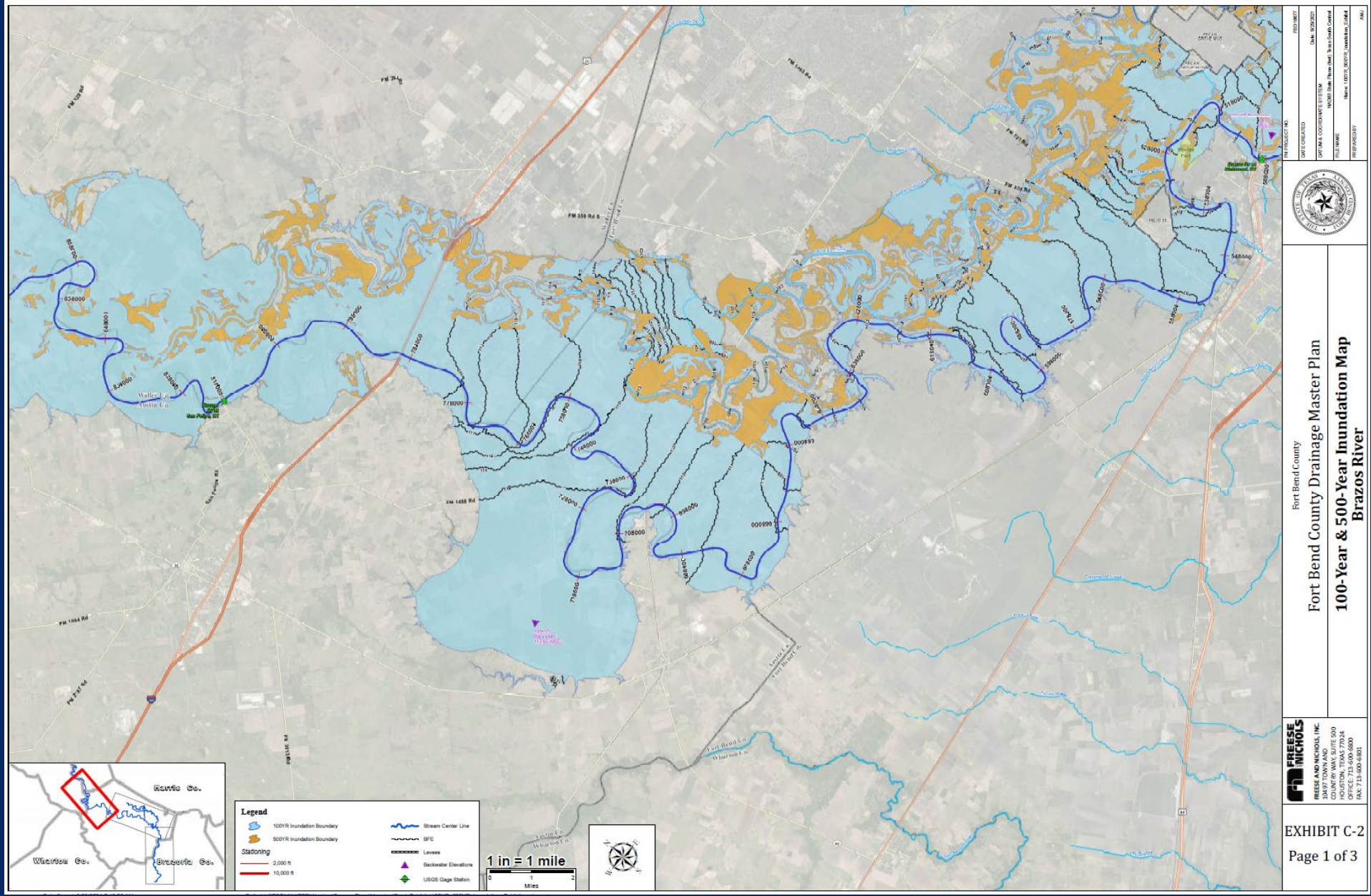


Design Storm Modeling Results

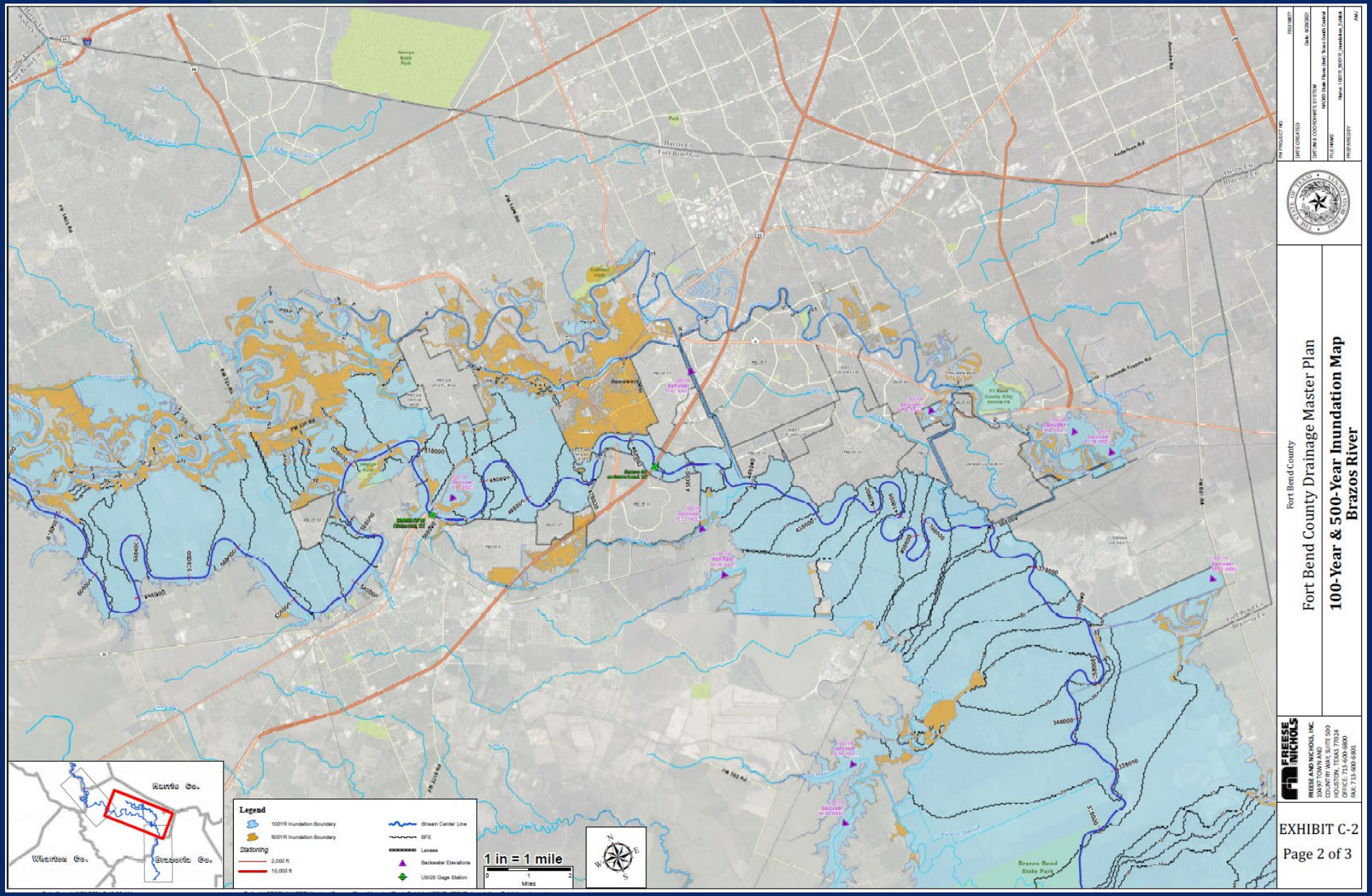
Table 3-12: Storm Centering Peak Flow Results from 1D/2D Models

AEP	Richmond		
	Flow (cfs)	Volume (ac-ft)	Stage (ft)
2-Year	50,932	1,291,485	65.27
5-Year	75,831	1,778,978	73.93
10-Year	90,828	2,277,282	77.11
25-Year	110,000	2,687,407	80.12
50-Year	120,460	2,912,230	81.51
100-Year	132,039	3,125,138	82.85
500-Year	156,947	3,648,567	84.92

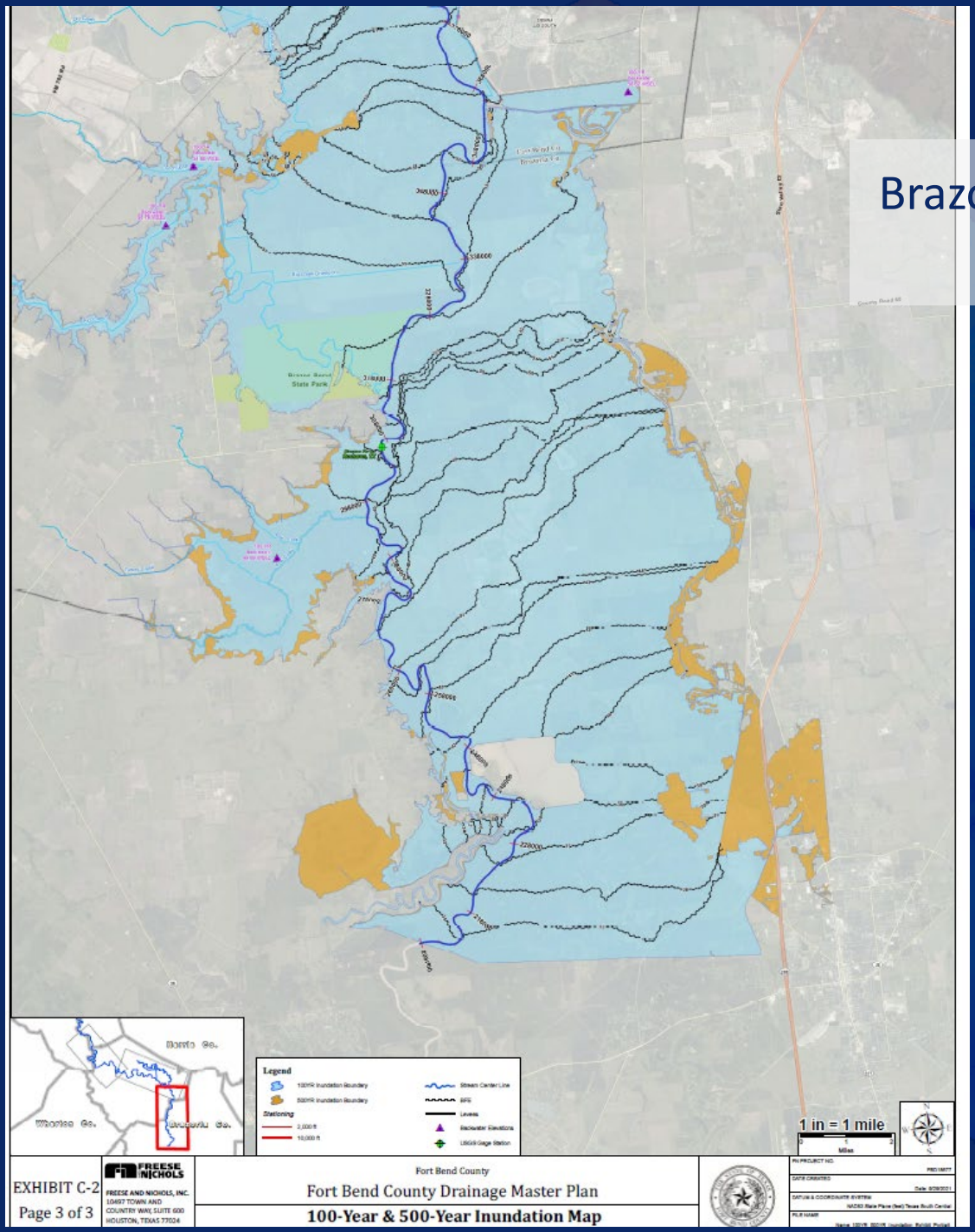
Brazos River 100 year & 500 year Inundation Map



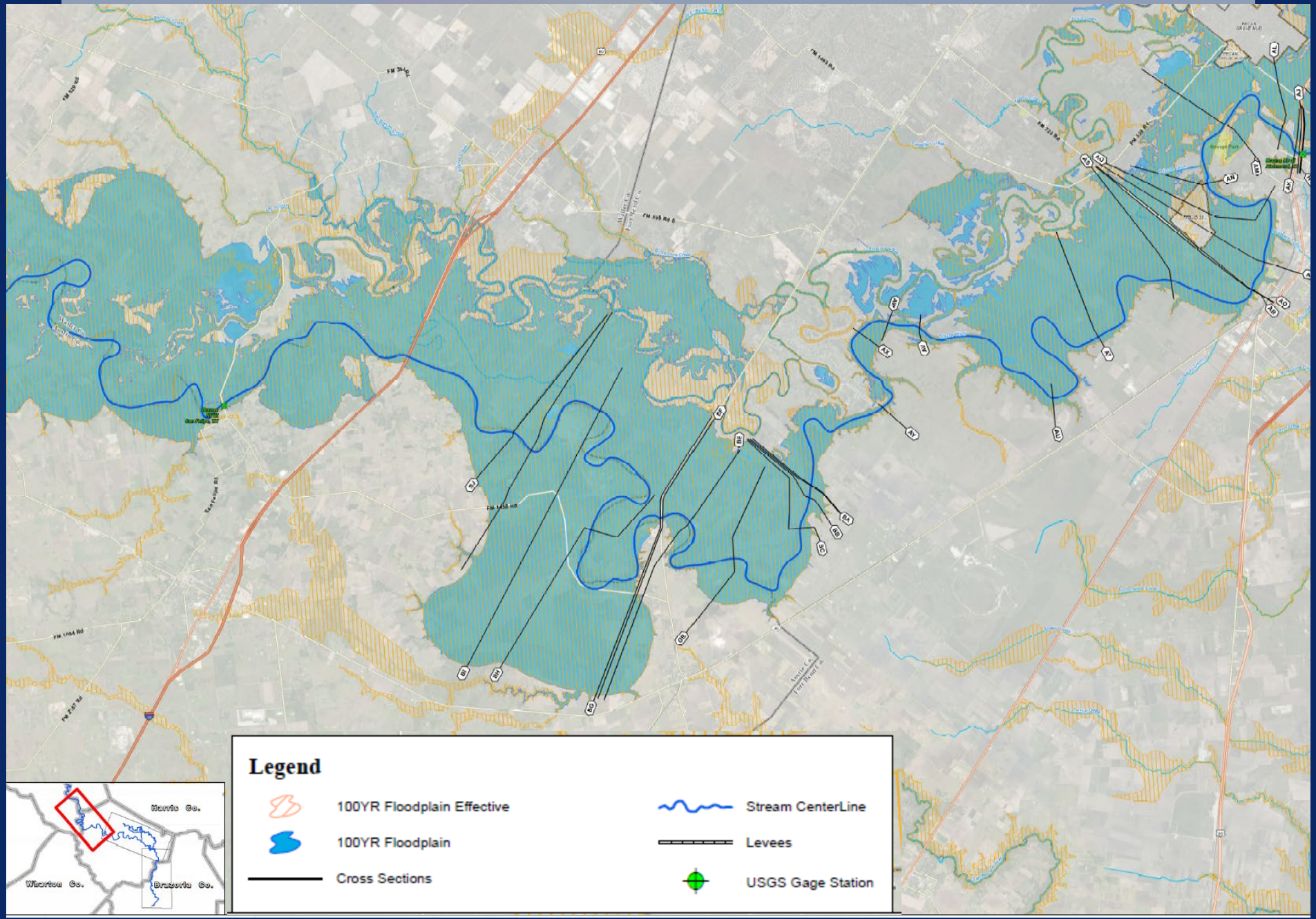
Brazos River 100 year & 500 year Inundation Map



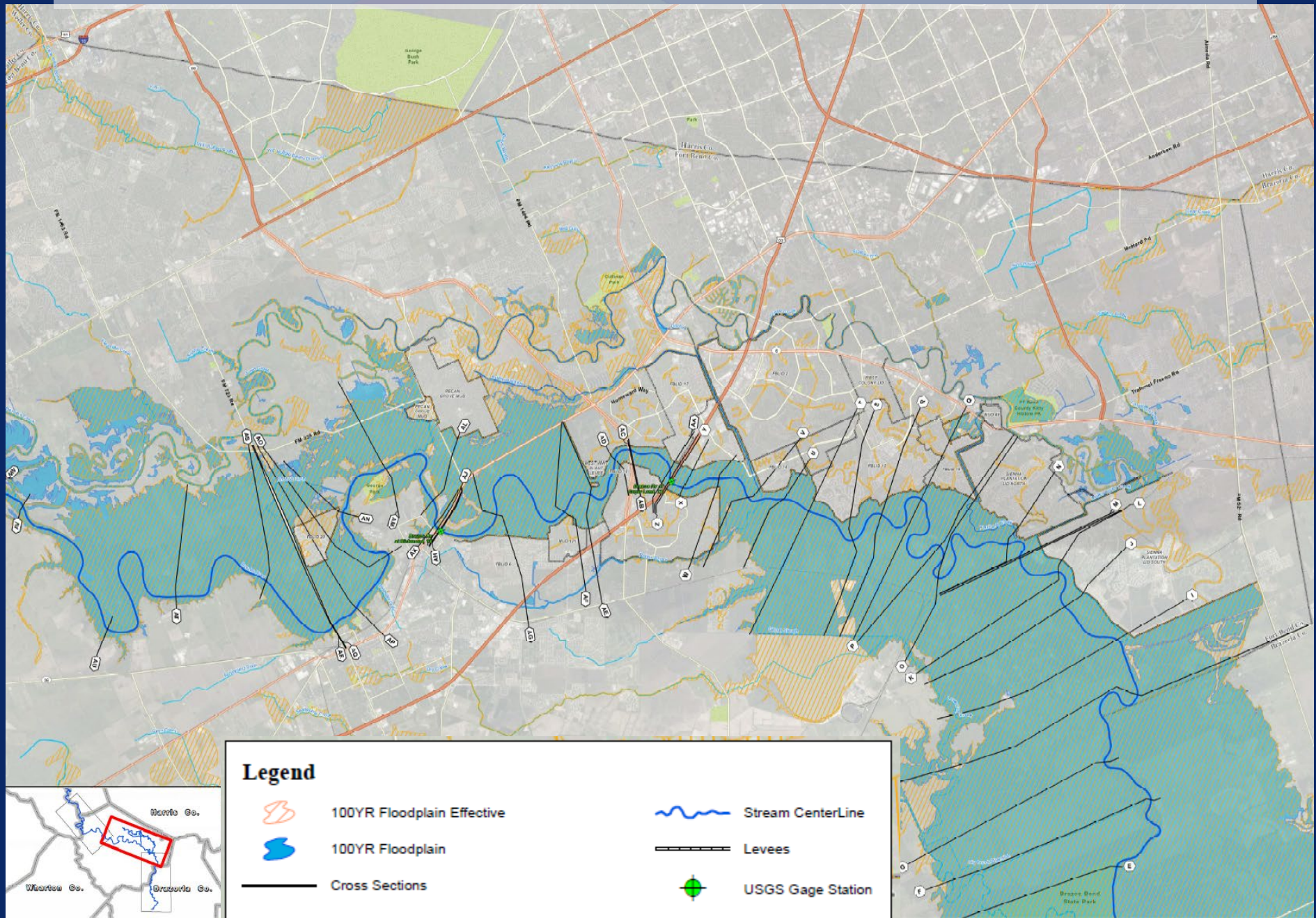
Brazos River 100 year & 500 year Inundation Map



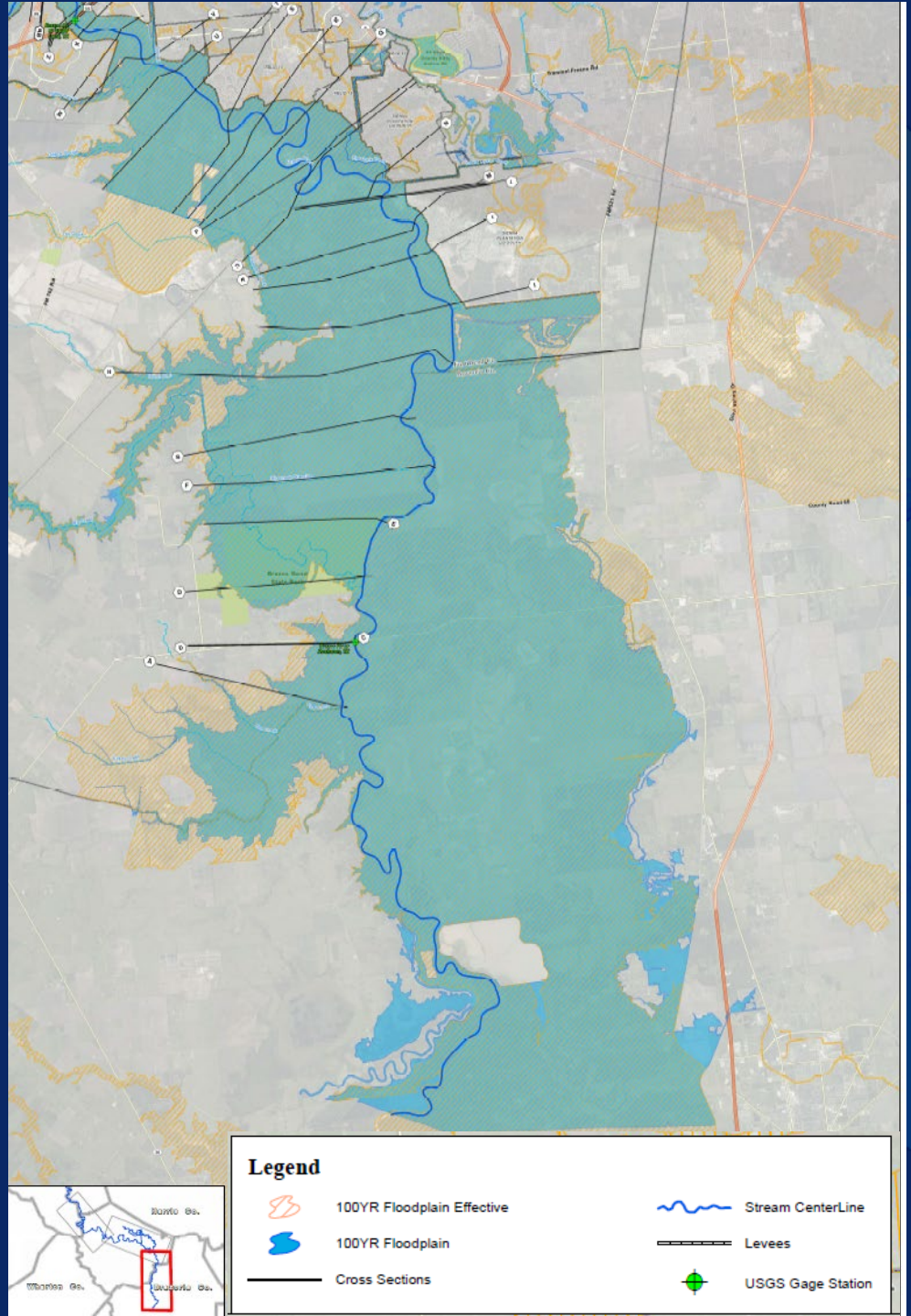
Brazos River 100 year Map change (compared to Effective Map)



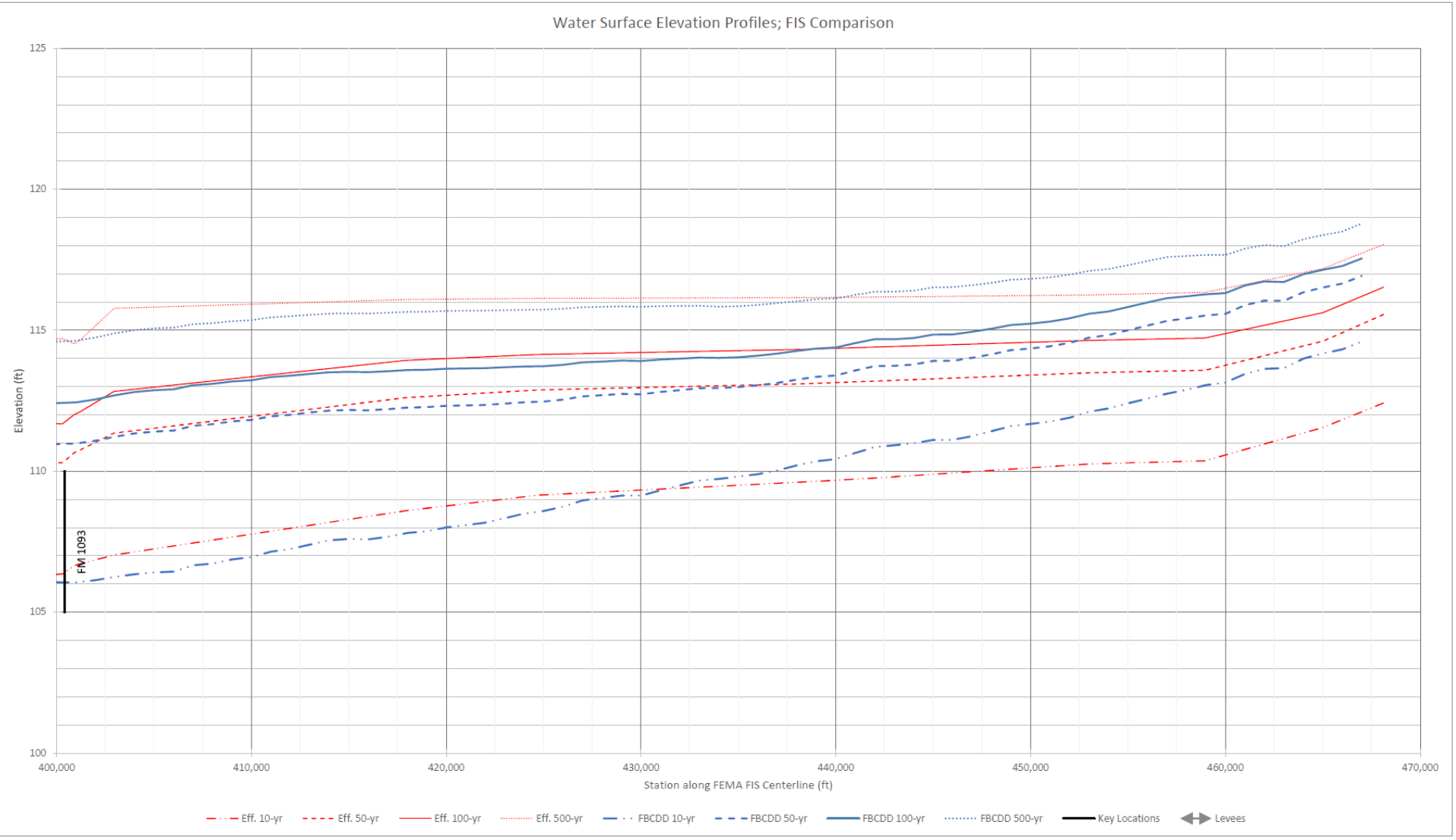
Brazos River 100 year Map change (compared to Effective Map)



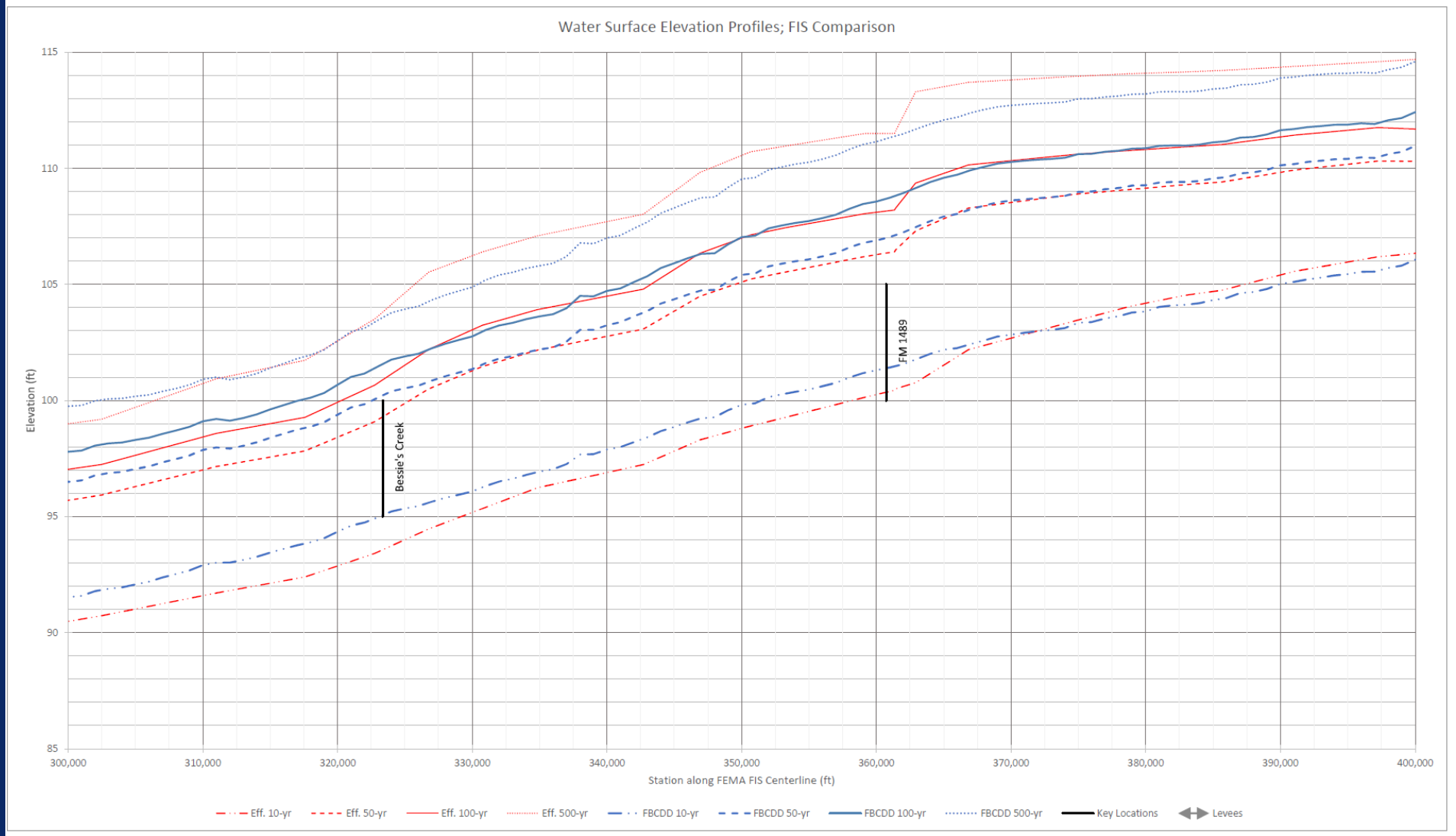
Brazos River 100 year Map change (compared to Effective Map)



WSE Profiles, FIS Comparison



WSE Profiles, FIS Comparison



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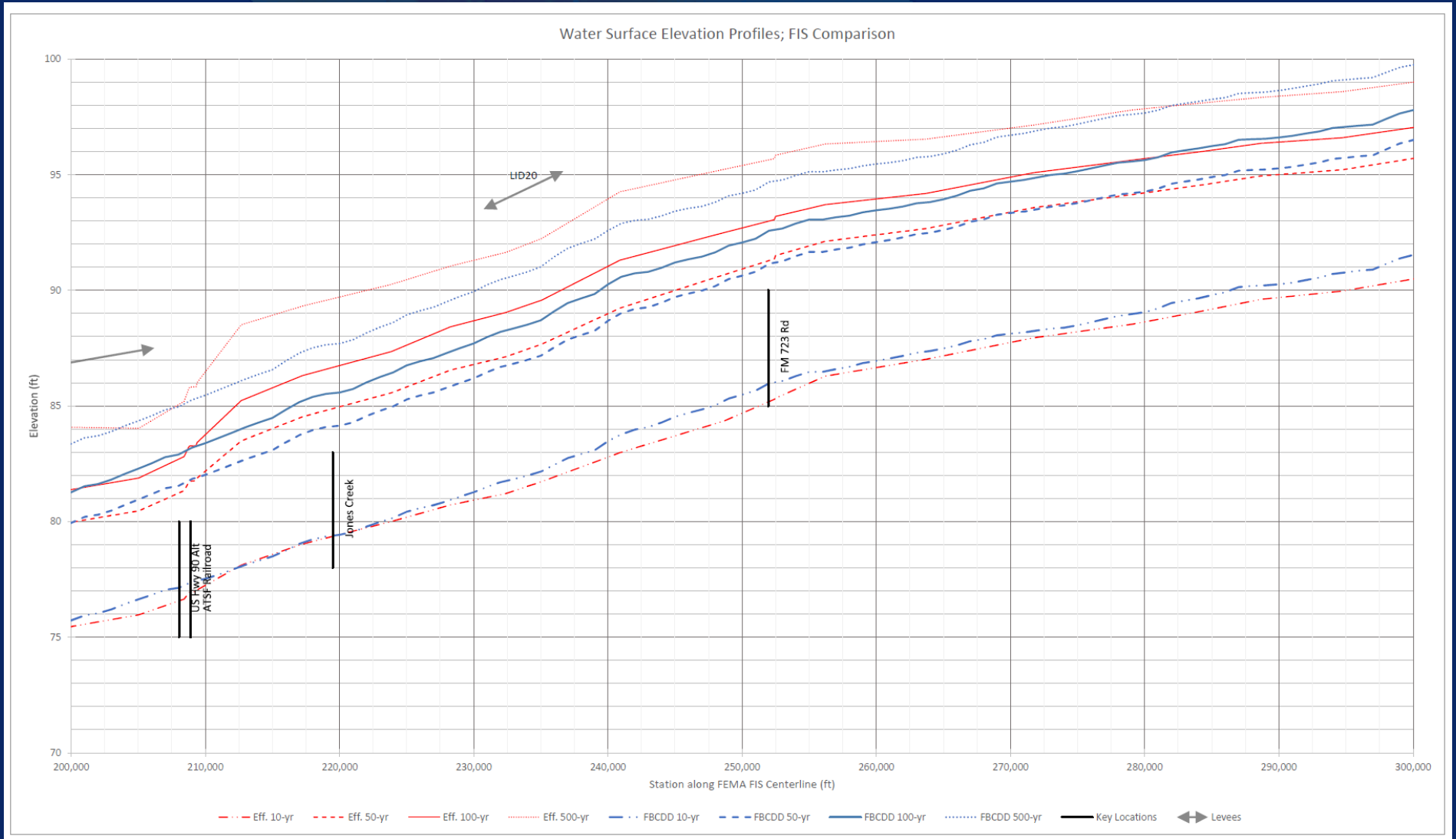
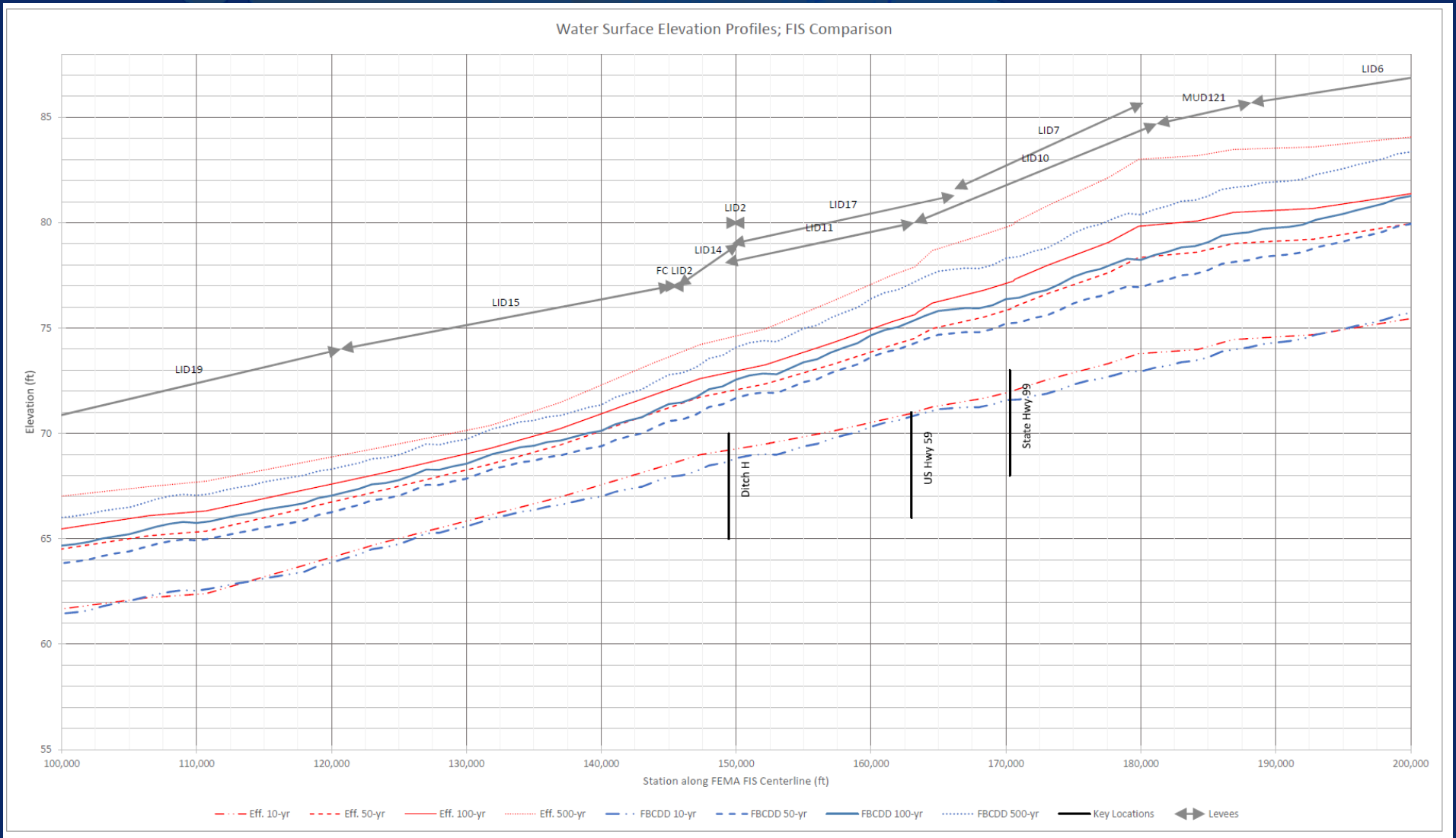


WSE Profiles, FIS Comparison



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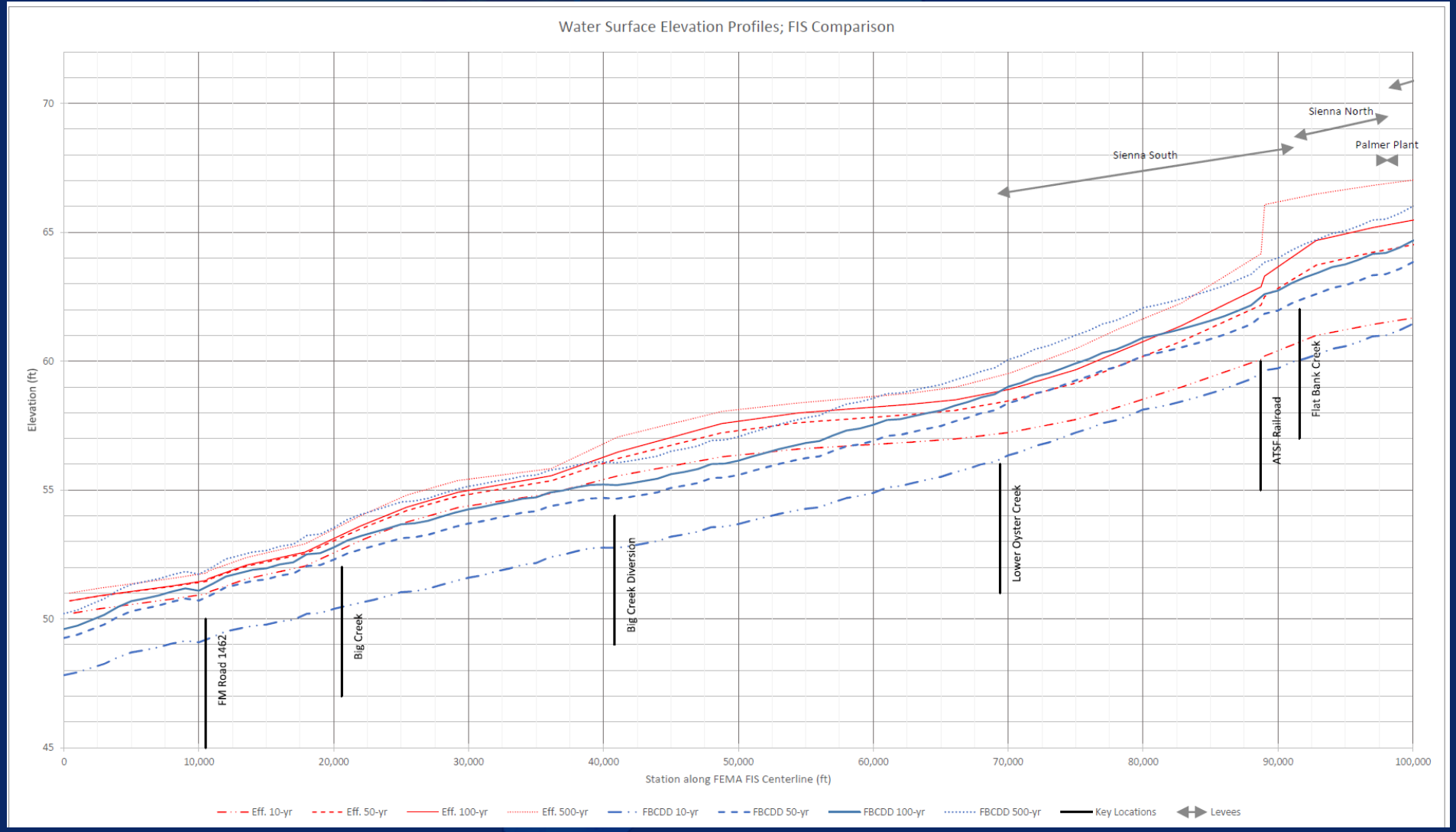


Table 4. Brazos River at Richmond Gage, Discharge Rating Curve from 1D/2D Model

USGS @ Richmond		Brazos River Discharge	Oyster Creek Discharge	Bullhead Bayou Discharge	Combined Peak Discharge
WSEL (ft) NAVD88	Stage (ft)[1]	Discharge (CFS)	Discharge (CFS)	Discharge (CFS)	Discharge (CFS)[2]
53.02	26.00	26,700	0	0	26,700
54.02	27.00	29,100	0	0	29,100
55.02	28.00	31,200	0	0	31,200
56.02	29.00	33,000	0	0	33,000
57.02	30.00	34,800	0	0	34,800
58.02	31.00	36,600	0	0	36,700
59.02	32.00	38,600	0	0	38,600
60.02	33.00	40,600	0	0	40,600
61.02	34.00	42,500	0	0	42,500
62.02	35.00	44,400	0	0	44,500
63.02	36.00	46,500	0	0	46,500
64.02	37.00	48,500	0	0	48,500
65.02	38.00	50,300	0	0	50,300
66.02	39.00	52,300	0	0	52,300
67.02	40.00	54,700	0	0	54,800
68.02	41.00	57,400	0	0	57,400
69.02	42.00	60,100	0	0	60,200
70.02	43.00	62,900	0	0	62,900
71.02	44.00	65,600	0	0	65,600
72.02	45.00	69,100	0	0	69,100
73.02	46.00	72,400	0	0	72,400
74.02	47.00	76,300	0	0	76,300
75.02	48.00	80,300	0	0	80,300
76.02	49.00	84,700	0	0	84,700
77.02	50.00	90,200	0	0	90,200
78.02	51.00	96,000	0	0	96,000
79.02	52.00	102,300	0	0	102,300
80.02	53.00	109,100	0	0	109,200
81.02	54.00	116,400	0	0	116,400
82.02	55.00	124,400	0	0	124,400
83.02	56.00	133,000	200	700	133,400
84.02	57.00	142,100	800	1,900	144,200
85.02	58.00	152,200	2,300	3,900	157,900
86.02	59.00	162,900	3,800	8,900	174,000
87.02	60.00	173,400	4,900	15,900	193,400
87.52	60.50	180,300	6,700	20,500	207,200
88.02	61.00	190,300	9,000	24,900	224,000
88.52	61.50	203,500	12,600	29,500	245,000
88.70	61.68	210,300	14,300	31,300	255,700
88.88	61.86	217,500	16,100	33,100	266,300

[1] Stage at USGS Richmond gage reported in gage datum

[2] Peak total discharge may not occur at the same time as peak discharges at Oyster Creek and Bullhead Bayou

[3] WSEL and discharges based on routing of upstream flood without influence from local inflows. May differ from actual conditions during a flood.

Brazos River @ Richmond Gage

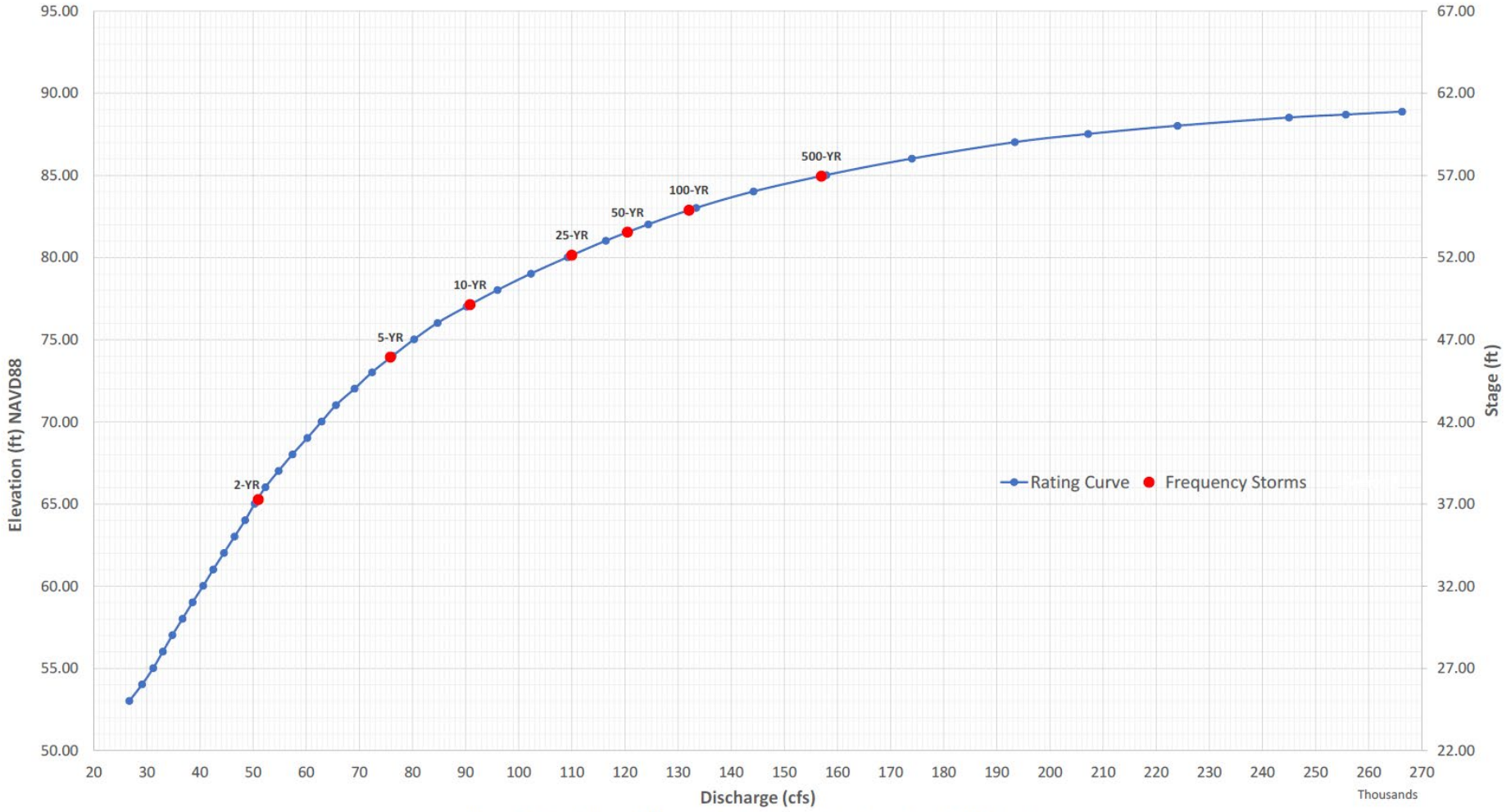


Figure 10. Brazos River at Richmond Gage, Discharge Rating Curve from 1D/2D Model

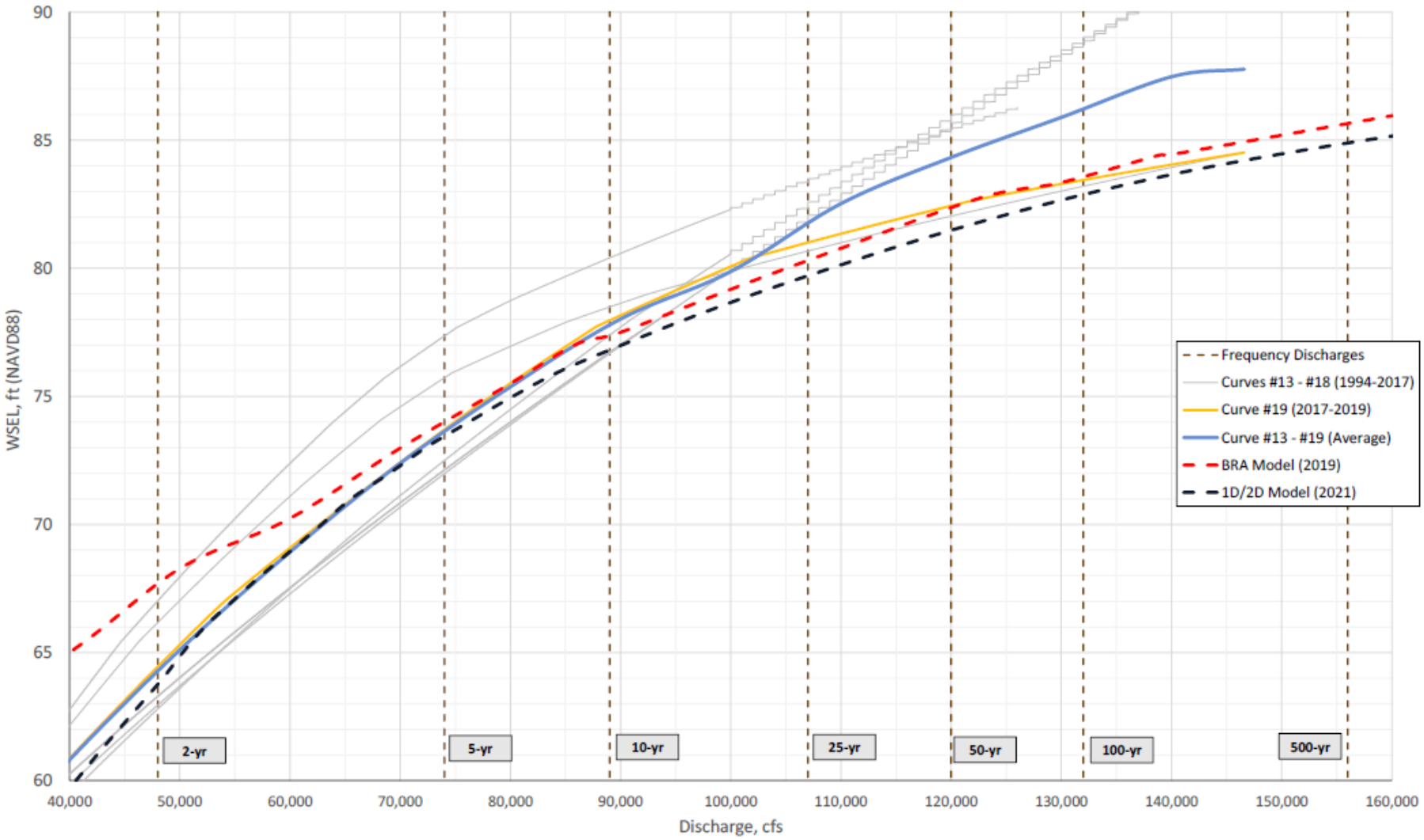


Figure 11. Brazos River at Richmond Gage, Rating Curve Comparison (WSEL vs discharge)

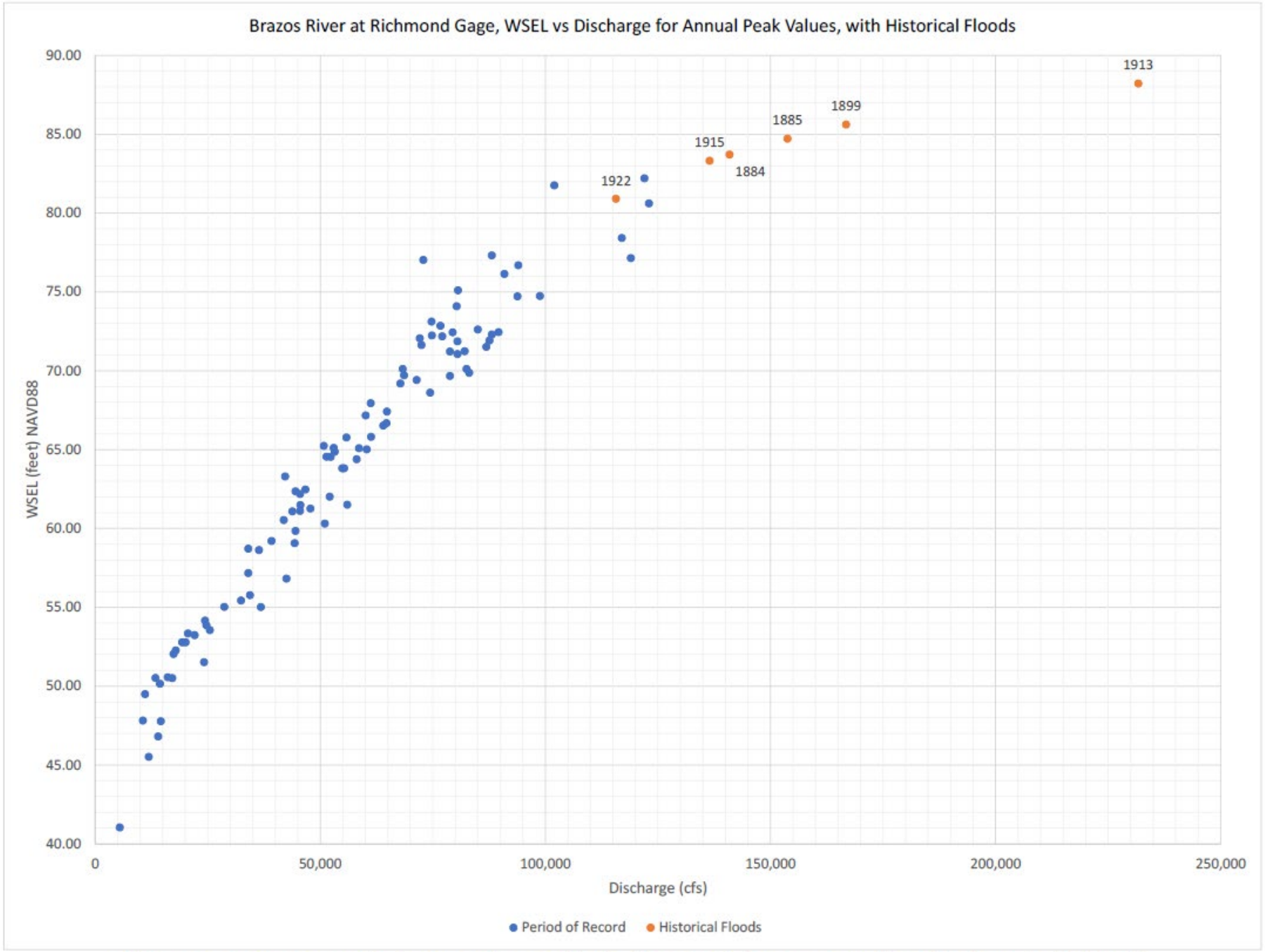


Figure 12. WSEL vs Discharges for Period of Record (1922-2019) and Historical Floods

Brazos River - Water Surface Elevations at Richmond Gage and Key Locations across Fort Bend County

Richmond Gage (NAVD88)	USGS @ Richmond	Approx. Flow @ USGS Richmond	Simonton Outfall	FM 1093	FM 1489	Weston Lakes Outfall	Bessies Creek	FM 723	Overflow North of LID 20 @ Briscoe Ditch	Jones Creek @ FM 359	Jones Creek @ Oyster Creek Overflow	LID 6 Overflow	LID 7 Overflow	SH 99
			Location 1	Location 2	Location 3	Location 4	Location 5	Location 6	Location 7	Location 8	Location 9	Location 10	Location 11	Location 12
WSEL (ft)	Stage (ft)[3]	Flow (CFS)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)
53.02	26.00	26,700	87.74	83.19	79.32	75.24	72.81	62.23	N/A	55.87	N/A	N/A	N/A	47.26
54.02	27.00	29,100	88.83	84.30	80.36	76.22	73.79	63.33	N/A	56.87	N/A	N/A	N/A	48.27
55.02	28.00	31,200	89.91	85.40	81.38	77.16	74.74	64.38	N/A	57.85	N/A	N/A	N/A	49.31
56.02	29.00	33,000	90.98	86.49	82.37	78.06	75.65	65.39	N/A	58.80	N/A	N/A	N/A	50.38
57.02	30.00	34,800	91.86	87.39	83.22	78.88	76.48	66.34	N/A	59.75	N/A	N/A	N/A	51.43
58.02	31.00	36,600	92.69	88.25	84.04	79.68	77.29	67.28	N/A	60.69	N/A	N/A	N/A	52.48
59.02	32.00	38,600	93.47	89.05	84.79	80.42	78.05	68.17	N/A	61.61	N/A	N/A	N/A	53.48
60.02	33.00	40,600	94.23	89.83	85.54	81.16	78.80	69.05	N/A	62.54	N/A	N/A	N/A	54.47
61.02	34.00	42,500	94.96	90.58	86.25	81.89	79.53	69.91	N/A	63.46	N/A	N/A	N/A	55.41
62.02	35.00	44,400	95.69	91.33	86.98	82.60	80.26	70.78	N/A	64.38	N/A	N/A	N/A	56.35
63.02	36.00	46,500	96.43	92.10	87.71	83.31	81.00	71.65	N/A	65.31	N/A	N/A	N/A	57.27
64.02	37.00	48,400	97.12	92.81	88.41	84.00	81.73	72.50	N/A	66.24	N/A	N/A	N/A	58.24
65.02	38.00	50,300	97.70	93.41	89.04	84.68	82.43	73.29	N/A	67.16	N/A	N/A	N/A	59.31
66.02	39.00	52,300	98.27	94.01	89.68	85.36	83.13	74.09	N/A	68.07	N/A	N/A	N/A	60.37
67.02	40.00	54,700	99.10	94.81	90.47	86.15	83.95	74.99	N/A	69.02	N/A	N/A	N/A	61.44
68.02	41.00	57,400	99.97	95.70	91.33	87.00	84.82	75.93	N/A	69.99	N/A	N/A	N/A	62.44
69.02	42.00	60,100	100.85	96.62	92.22	87.88	85.72	76.88	N/A	70.97	N/A	N/A	N/A	63.41
70.02	43.00	62,900	101.79	97.55	93.12	88.78	86.64	77.83	N/A	71.94	N/A	N/A	N/A	64.48
71.02	44.00	65,600	102.77	98.52	94.07	89.72	87.60	78.83	N/A	72.94	N/A	N/A	N/A	65.45
72.02	45.00	69,100	103.91	99.66	95.17	90.81	88.70	79.91	N/A	73.96	N/A	N/A	N/A	66.47
73.02	46.00	72,400	105.15	100.86	96.31	91.94	89.85	81.02	N/A	74.99	N/A	N/A	N/A	67.52
74.02	47.00	76,300	106.39	102.05	97.46	93.08	90.99	82.14	N/A	76.03	N/A	N/A	N/A	68.58
75.02	48.00	80,300	107.60	103.21	98.61	94.22	92.15	83.28	N/A	77.07	N/A	N/A	N/A	69.62
76.02	49.00	84,700	108.88	104.43	99.81	95.44	93.38	84.45	N/A	78.13	N/A	N/A	N/A	70.60
77.02	50.00	90,200	109.91	105.91	101.30	96.86	94.81	85.74	N/A	79.23	N/A	N/A	N/A	71.50
78.02	51.00	96,000	110.82	107.20	102.71	98.16	96.14	86.95	N/A	80.30	N/A	N/A	N/A	72.38
79.02	52.00	102,200	111.49	108.29	103.94	99.37	97.34	88.11	N/A	81.36	N/A	N/A	N/A	73.20
80.02	53.00	109,100	112.12	109.34	105.17	100.51	98.47	89.29	85.75	82.44	N/A	N/A	N/A	74.00
81.02	54.00	116,400	112.80	110.44	106.45	101.68	99.61	90.47	88.88	83.52	N/A	N/A	N/A	74.81
82.02	55.00	124,400	113.52	111.52	107.70	102.77	100.64	91.55	90.25	84.59	N/A	N/A	N/A	75.64
83.02	56.00	133,400	114.31	112.60	108.96	103.83	101.63	92.60	91.37	85.65	N/A	N/A	71.01	76.53
84.02	57.00	144,100	115.15	113.65	110.20	104.88	102.60	93.60	92.36	86.68	N/A	83.68	76.60	77.46
85.02	58.00	157,800	116.03	114.68	111.43	105.94	103.56	94.62	93.34	87.69	88.17	84.68	78.65	78.41
86.02	59.00	173,900	116.81	115.60	112.59	107.04	104.54	95.67	94.41	88.71	88.50	85.69	80.12	79.40
87.02	60.00	193,100	117.74	116.64	113.88	108.32	105.66	96.80	95.54	89.68	89.71	86.71	81.63	80.46
87.52	60.50	206,800	118.21	117.16	114.48	108.91	106.15	97.27	96.00	90.15	90.11	87.23	82.12	80.99
88.02	61.00	223,800	118.79	117.78	115.19	109.59	106.73	97.82	96.53	90.64	90.50	87.75	82.64	81.61
88.52	61.50	245,700	119.57	118.62	116.12	110.50	107.49	98.49	97.18	91.16	90.93	88.25	83.12	82.21
88.70	61.68	256,800	119.95	119.02	116.56	110.93	107.85	98.81	97.47	91.37	91.12	88.43	83.33	82.44
88.88	61.86	267,400	120.37	119.45	117.04	111.40	108.25	99.14	97.78	91.59	91.32	88.61	83.55	82.65

Notes:

(1) N/A denotes area is not affected

(2) WSE results based on routing of upstream flood without local inflows. May differ from actual conditions during a flood.

(3) Stage at USGS Richmond gage reported in gage datum.

Brazos River - Water Surface Elevations at Richmond Gage and Key Locations across Fort Bend County

Richmond Gage (NAVD88)	USGS @ Richmond	Approx. Flow @ USGS Richmond	HWY 59 (Sugar Land)	Rabbs Bayou	Ditch H Backwater @ OysterCreek Overflow	Ditch H @ University Blvd	Flat Bank Creek @ SH 6	Steep Bank Creek @ LID 19 Outfall	Flat Bank Diversion Channel @ L.J. Parkway	Steep Bank Creek @ Sienna Plantation North Outfall	Sienna External Channel @ Sienna Parkway	Sienna External Channel @ South Outfall	FM 1462 (Rosharon)
			Location 13	Location 14	Location 15	Location 16	Location 17	Location 18	Location 19	Location 20	Location 21	Location 22	Location 23
WSEL (ft)	Stage (ft)[3]	Flow (CFS)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)	WSEL (ft)
53.02	26.00	26,700	46.44	N/A	N/A	44.52	39.87	N/A	34.98	34.93	N/A	34.53	23.29
54.02	27.00	29,100	47.46	N/A	N/A	45.54	39.87	N/A	36.07	36.05	N/A	34.56	24.50
55.02	28.00	31,200	48.51	N/A	N/A	46.59	39.88	N/A	37.18	37.17	N/A	35.17	25.77
56.02	29.00	33,000	49.60	N/A	N/A	47.66	39.89	N/A	38.30	38.28	N/A	36.35	27.09
57.02	30.00	34,800	50.66	N/A	N/A	48.72	40.27	N/A	39.47	39.46	N/A	37.59	28.64
58.02	31.00	36,600	51.73	N/A	N/A	49.77	40.72	N/A	40.65	40.64	N/A	38.83	30.23
59.02	32.00	38,600	52.72	N/A	N/A	50.77	41.79	N/A	41.78	41.77	N/A	39.14	31.72
60.02	33.00	40,600	53.71	N/A	N/A	51.75	42.91	N/A	42.90	42.90	N/A	39.44	33.18
61.02	34.00	42,500	54.64	N/A	N/A	52.69	44.02	N/A	44.01	44.01	N/A	40.49	34.38
62.02	35.00	44,400	55.57	55.54	N/A	53.62	45.08	N/A	45.08	45.07	N/A	41.51	35.50
63.02	36.00	46,500	56.48	55.54	N/A	54.55	46.09	N/A	46.09	46.08	N/A	42.51	36.51
64.02	37.00	48,400	57.45	55.84	N/A	55.52	47.18	47.60	47.18	47.17	43.60	43.61	37.64
65.02	38.00	50,300	58.53	56.76	N/A	56.59	48.43	48.55	48.43	48.42	44.91	44.92	39.04
66.02	39.00	52,300	59.60	57.69	N/A	57.66	49.68	49.51	49.68	49.67	46.22	46.22	40.44
67.02	40.00	54,700	60.67	58.76	N/A	58.74	50.82	50.64	50.82	50.82	47.36	47.36	41.48
68.02	41.00	57,400	61.66	59.74	59.73	59.73	51.81	51.65	51.81	51.81	48.31	48.31	42.33
69.02	42.00	60,100	62.63	60.69	60.68	60.68	52.73	52.58	52.73	52.73	49.19	49.19	43.08
70.02	43.00	62,900	63.71	61.92	61.81	61.81	53.83	53.65	53.83	53.83	50.36	50.37	44.02
71.02	44.00	65,600	64.66	62.96	62.78	62.78	54.82	54.64	54.82	54.82	51.47	51.53	44.93
72.02	45.00	69,100	65.68	63.86	63.82	63.82	55.80	55.64	55.80	55.81	52.36	52.39	45.78
73.02	46.00	72,400	66.73	64.86	64.86	64.86	56.77	56.92	56.77	56.78	53.21	53.25	46.53
74.02	47.00	76,300	67.78	65.92	65.91	65.91	57.78	57.95	57.78	57.79	54.13	54.25	47.28
75.02	48.00	80,300	68.80	66.93	66.91	66.91	58.75	58.80	58.75	58.72	55.27	55.04	47.93
76.02	49.00	84,700	69.76	67.84	67.84	67.84	59.63	60.08	59.63	59.55	56.84	55.84	48.50
77.02	50.00	90,200	70.63	68.63	68.63	68.63	60.24	61.02	60.24	60.12	57.81	56.37	48.95
78.02	51.00	96,000	71.46	69.33	69.36	69.36	60.84	61.82	60.84	60.68	58.49	56.82	49.42
79.02	52.00	102,200	72.23	69.92	70.01	70.01	61.45	62.51	61.46	61.25	59.07	57.28	49.83
80.02	53.00	109,100	72.98	70.46	70.63	70.63	62.08	63.15	62.08	61.83	59.61	57.74	50.18
81.02	54.00	116,400	73.73	71.04	71.23	71.23	62.73	63.81	62.74	62.44	60.16	58.20	50.50
82.02	55.00	124,400	74.49	71.65	71.85	71.85	63.42	64.47	63.43	63.08	60.73	58.66	50.80
83.02	56.00	133,400	75.31	72.31	72.56	72.56	64.13	65.16	64.15	63.75	61.34	59.14	51.11
84.02	57.00	144,100	76.16	73.01	72.88	73.31	64.83	65.84	64.85	64.41	61.95	59.63	51.41
85.02	58.00	157,800	77.04	73.87	74.31	74.13	65.56	66.54	65.57	65.09	62.59	60.15	51.73
86.02	59.00	173,900	77.98	74.87	75.85	75.18	66.32	67.30	66.33	65.82	63.26	60.70	52.08
87.02	60.00	193,100	79.00	75.88	77.59	76.25	67.02	67.99	67.02	66.47	63.84	61.19	52.41
87.52	60.50	206,800	79.52	76.36	78.55	76.89	67.54	68.38	67.51	66.91	64.23	61.52	52.66
88.02	61.00	223,800	80.13	76.89	79.43	77.58	68.25	68.89	68.17	67.50	64.76	61.95	52.97
88.52	61.50	245,700	80.81	78.79	80.20	78.44	69.11	69.52	68.98	68.26	65.52	62.56	53.47
88.70	61.68	256,800	81.09	79.37	80.52	78.79	69.44	69.88	69.27	68.52	65.88	62.81	53.69
88.88	61.86	267,400	81.35	79.84	80.80	79.10	69.78	70.22	69.54	68.76	66.27	63.05	53.91

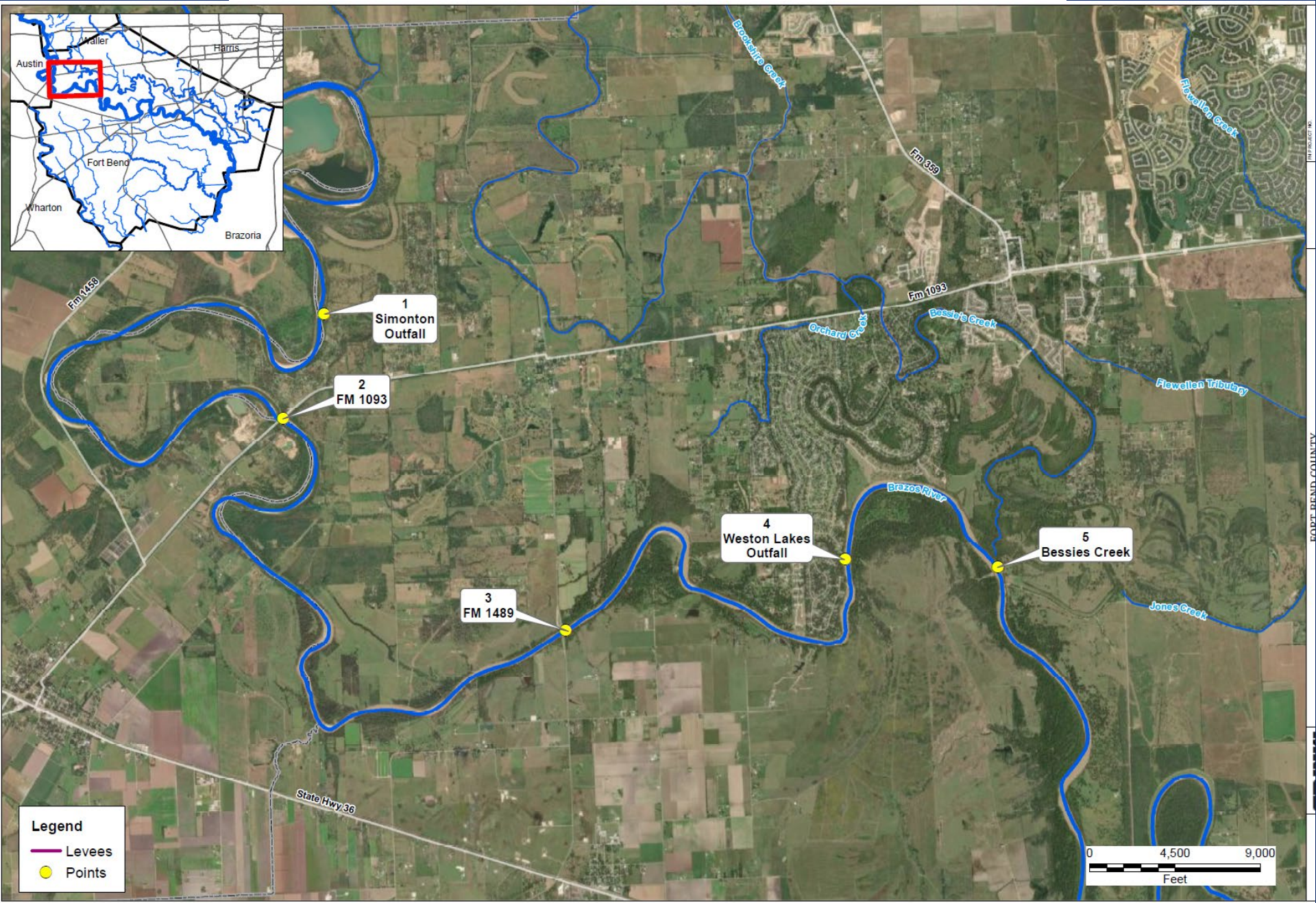
Notes:

(1) N/A denotes area is not affected

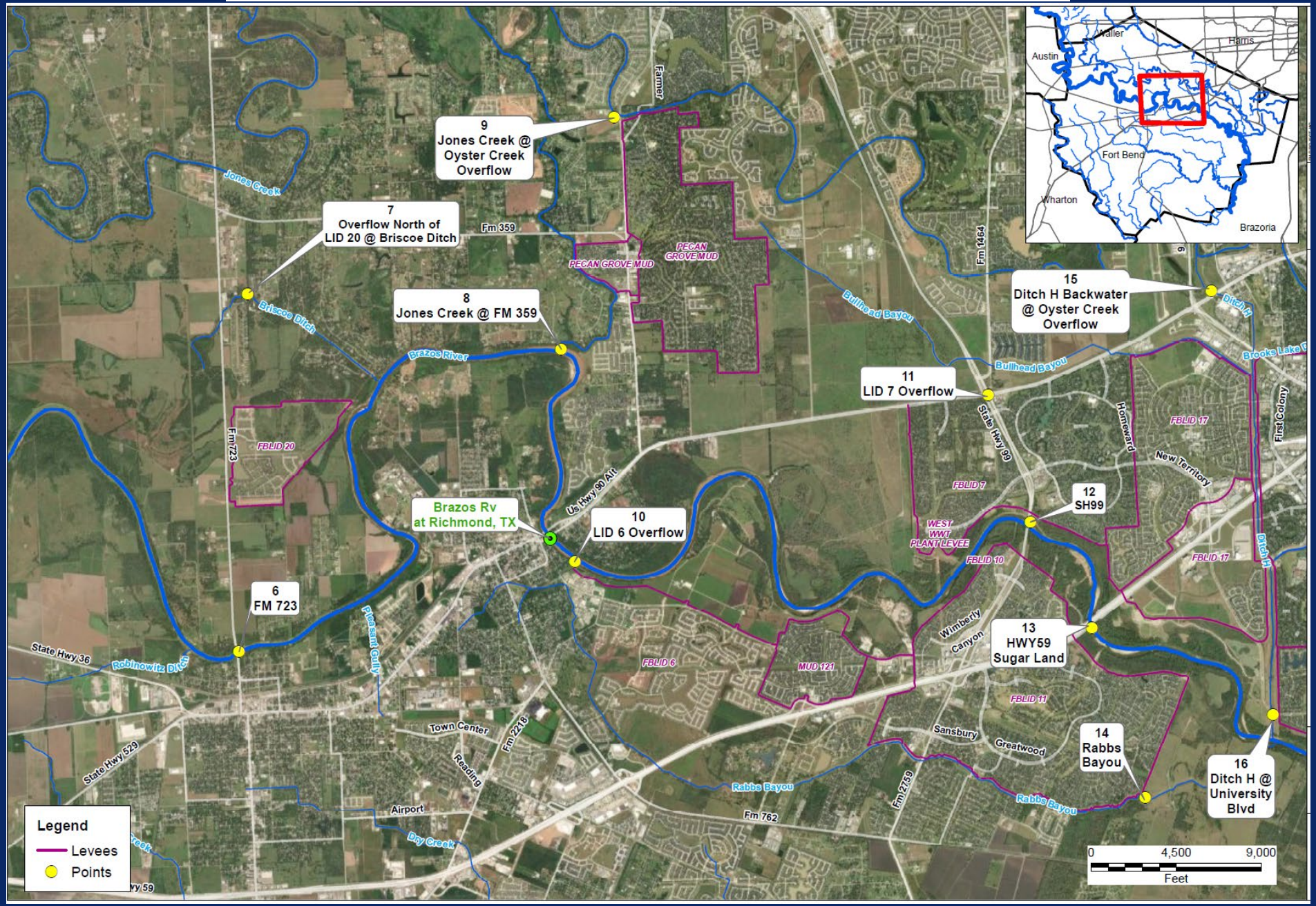
(2) WSE results based on routing of upstream flood without local inflows. May differ from actual conditions during a flood.

(3) Stage at USGS Richmond gage reported in gage datum.

WSEL Key Locations



WSEL Key Locations



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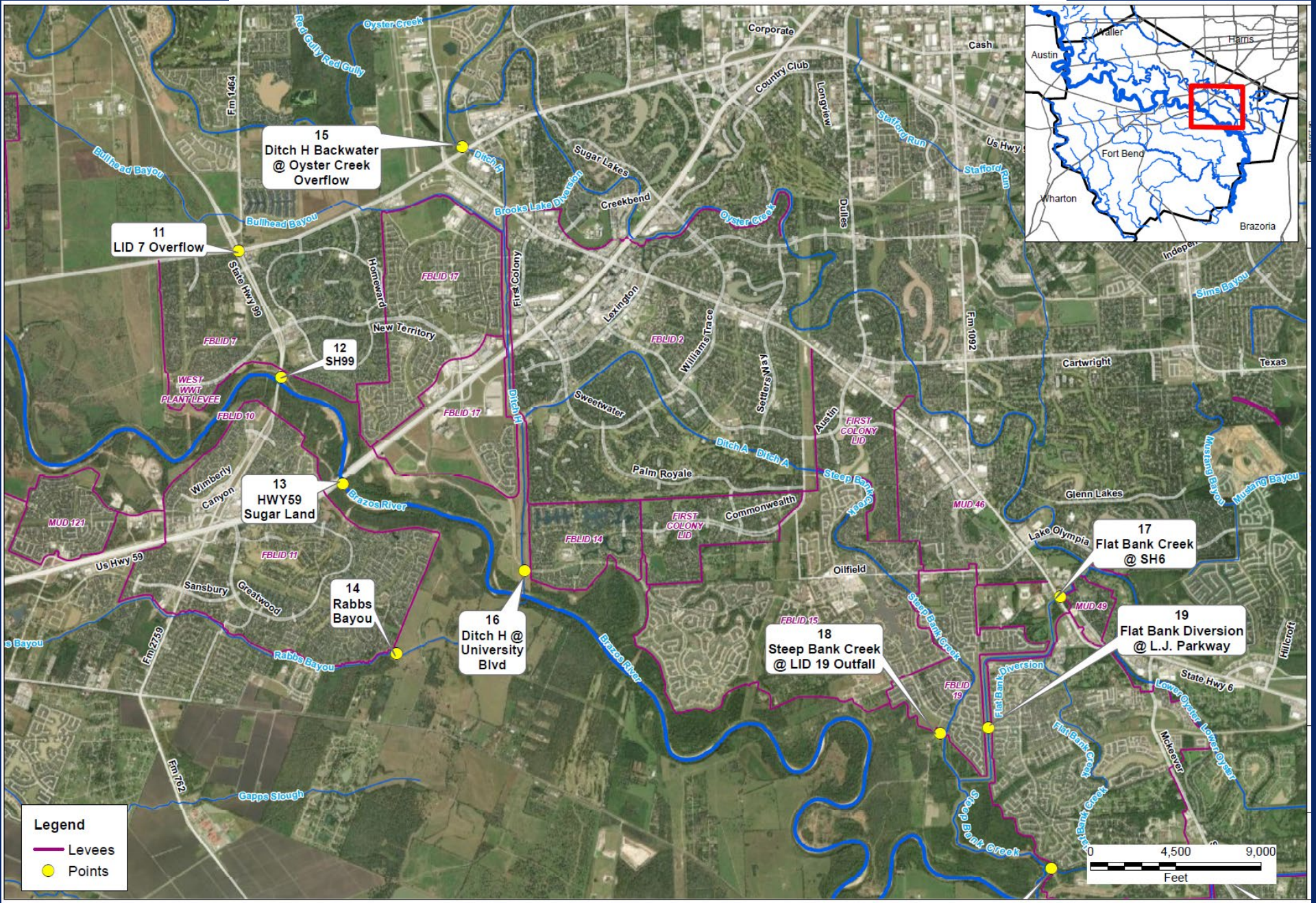
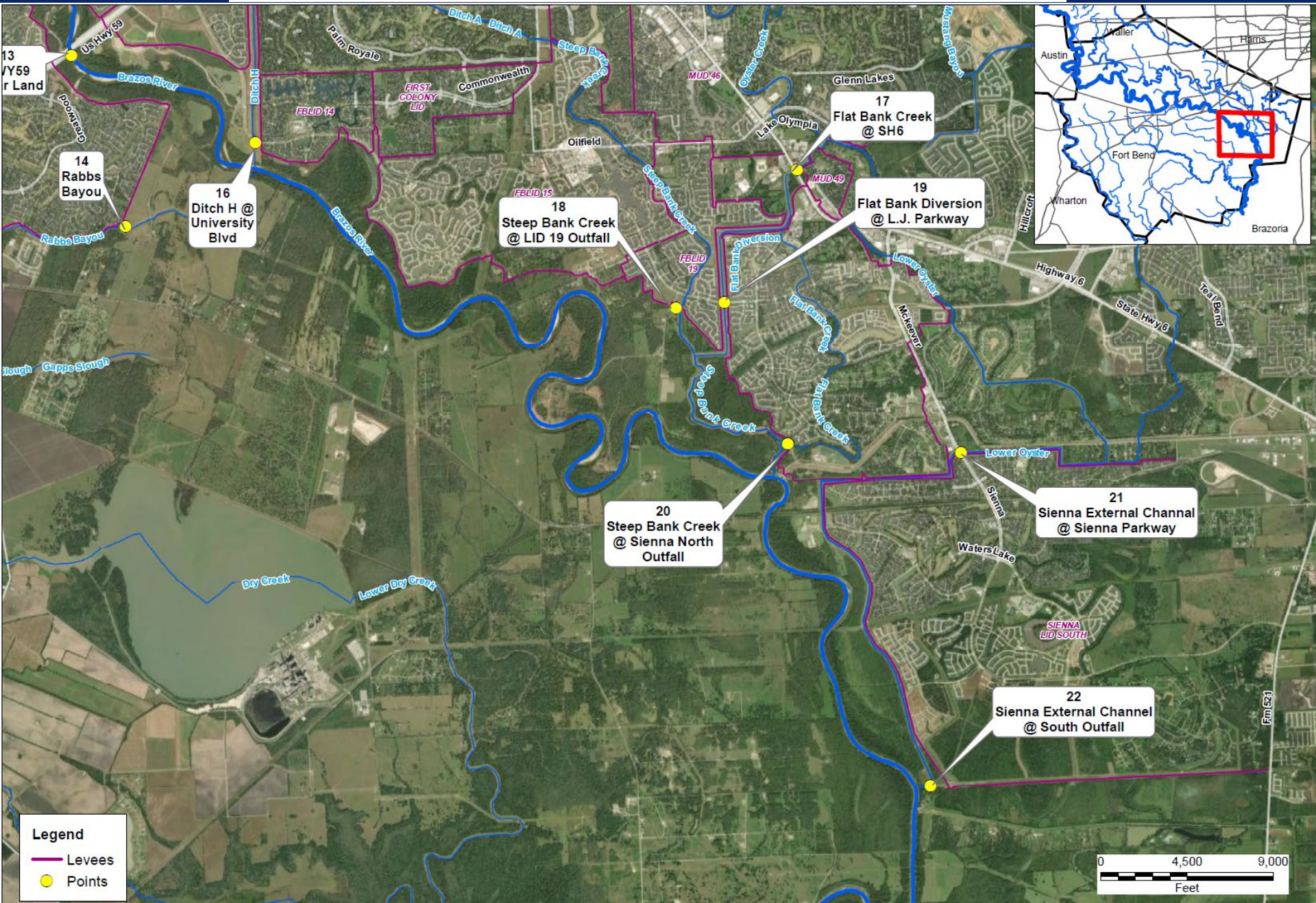
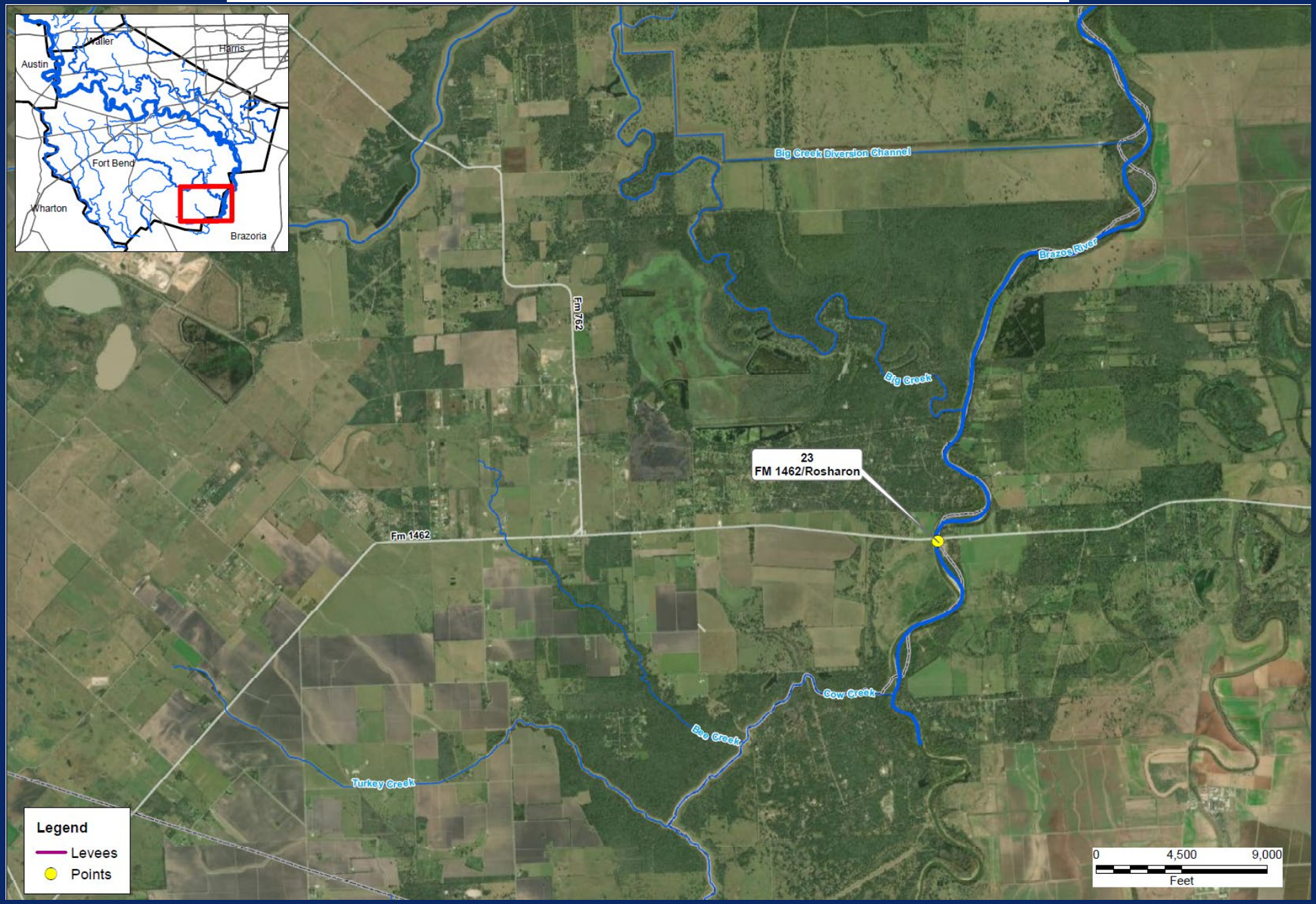


WSEL Key Locations



WSEL Key Locations



Final Look At
Brazos River Study Results

Table ES-2: Comparison to Previous Studies at Richmond Gage on the Brazos River

Storm Event	Peak Discharge (cfs)			Water Surface Elevation (feet NAVD 88)		
	Effective FIS	2019 BRA Study	HEC-RAS 1D/2D Model	Effective FIS	2019 BRA Study	HEC-RAS 1D/2D Model
10% ACE	103,000	86,030	90,813	76.65	77.04	77.11
2% ACE	147,000	123,045	120,451	81.34	82.76	81.51
1% ACE	164,000	139,286	132,031	82.81	84.43	82.85
0.02% ACE	206,000	187,213	156,948	85.20	87.66	84.92

Criteria for Development within the Brazos 100-year Floodplain

No net loss of conveyance capacity (implemented in 2011)

Finish floor elevations at least 2’ above the 100-year floodplain elevation

Floodplain storage mitigation required (implemented Sept. 2021)

No adverse impact resulting from development within the 100-year floodplain