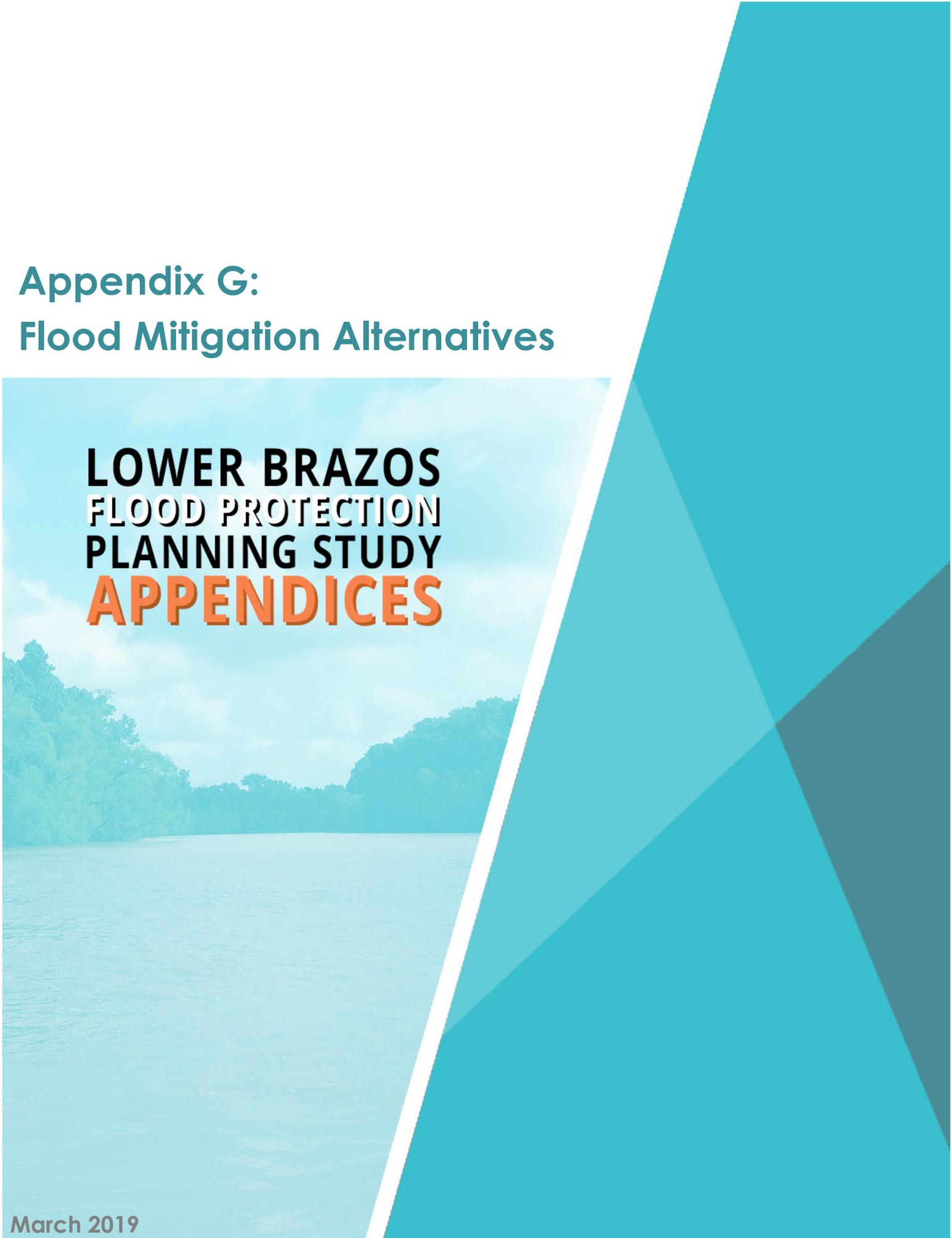


Appendix G: Flood Mitigation Alternatives



LOWER BRAZOS FLOOD PROTECTION PLANNING STUDY APPENDICES

March 2019

Appendix G –Flood Mitigation Alternatives

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Appendix G - Flood Mitigation Alternatives

G.1.0 Introduction

A broad range of conceptual flood mitigation alternatives were evaluated to mitigate flooding to structures located along the Lower Brazos River. The flood mitigation alternatives consist of structural buyouts, construction of levees and raising existing levees, as well as large scale projects including large scale detention, channel excavation and channel diversion to reduce the computed 1% ACE water surface elevation. Alternatives were selected based on the following criteria:

- ability to provide benefits to as many impacted structures as possible
- alternative should not result in measurable increases in the extent and magnitude of flooding in another area
- avoid adverse impacts to buildings and roadways
- benefit to cost analysis (BCA) equal to one or greater where the total average annual benefits should equal or exceed total average annual costs

The conceptual flood mitigations alternatives in this report are presented as projects that local sponsors may consider and evaluate further to help reduce flood risk. As such, the conceptual flood mitigations alternatives presented do not reflect the position of the Brazos River Authority or study partners as to whether these alternatives should be implemented or how they should be prioritized. The alternatives are provided for stakeholder informational use based on various meetings held throughout the lower basin. Any downstream adverse impacts or increases in water surface elevation associated with these alternatives would need to be further evaluated and mitigated per local criteria. Each flood mitigation alternative discussed in this section was independently evaluated utilizing the updated Lower Brazos hydraulic models. Preliminary costs estimates have been included for both local and large-scale alternatives. The preliminary costs are intended for conceptual planning purposes only and are not intended for grant application, bidding, or construction.

G.2.0 Potential Buyout Locations

Buyouts, or acquisition, of frequently flooded structures is a way to reduce flood risk and damages. Structural buyouts are less expensive than other flood mitigation alternatives and have the flexibility of being implemented as funding becomes available. A structural buyout program offers the shortest time of implementation and allows for prioritization of the most at risk homes. In addition to these benefits, this alternative has the least environmental impact to the Lower Brazos River.

Buyouts can be completed under the FEMA Hazard Mitigation Grant Program (HMGP) or Hazard Mitigation Assistance (HMA) programs. FEMA HMGP provides funding for projects using the state's priority based on the potential to reduce future disaster losses. FEMA funds 75% of the project cost with the remaining 25% funded by the state or local communities. Projects that are eligible for funding under the HMGP or HMA must be cost effective and have a BCA of 1.0 or greater. FEMA has pre-calculated the cost effectiveness of structural buyouts. The acquisition of a structure located in the 1% ACE floodplain that costs less than or equal to \$276,000 is predetermined to have a BCA of 1.0 or greater. For projects containing multiple structures, the average cost of all

structures in the projects must meet this criterion. For FEMA grants, there is no need to develop a separate benefit cost analysis for projects that meets this criterion.

Potential structural buyout areas were selected based on areas with large amounts of FEMA repetitive losses (more than one FEMA flood claim for the structure) present in the FEMA flood claims and for structures located within the Lower Brazos River 1% ACE inundation area. Additional consideration was given to areas with severe repetitive loss properties (more than three FEMA flood claims per structure). Property values were determined from Appraisal District for each county. Table G-1 shows the potential buyout locations, county, number of potential structures, repetitive loss structures, severe repetitive loss structures, and estimated property values. Exhibit G-1 shows the locations of the potential buyout areas.

Table G-1: Potential Buyout Locations

Location	County	Number of Structures	Repetitive Loss Structures	Severe Repetitive Loss Structures	Estimated Cost
Jones Creek	Brazoria	110	9	1	\$11,500,000
Lake Jackson Farms	Brazoria	281	18	11	\$65,000,000
Mann Lake	Brazoria	42	5	3	\$4,300,000
Lochridge	Brazoria	21	4	1	\$3,800,000
Harris Reservoir	Brazoria	43	5	2	\$5,400,000
Mill Drive	Brazoria	129	4	2	\$13,000,000
Richmond	Fort Bend	82	3	2	\$10,000,000
Simonton	Fort Bend	60	3	2	\$13,000,000
Simonton	Fort Bend	205	35	13	\$52,000,000
Near Brazos Country	Waller	36	6	1	\$8,500,000
Lazy River	Waller	43	4	1	\$3,500,000
Near San Felipe	Austin	9	2	0	\$3,000,000
Total Buyouts	-	1,061	98	39	\$193,000,000

G.3.0 Flood Mitigation Alternatives

A broad range of conceptual flood mitigation alternatives were evaluated to mitigate flooding to structures located along the Lower Brazos River including levees to protect areas prone to flooding from the 1% ACE storm event. A high-level feasibility analysis was prepared with a cursory look at the following:

- potential alignments
- hydraulic impacts
- environmental permitting impacts
- project costs
- potential benefits

Levees can be effective flood mitigation solutions as they prevent flood waters from reaching flood prone areas reducing the damage to structures and flooding of roadways. FEMA criteria

require levees to have a minimum freeboard (height above the 1% ACE water level) of at least three feet for the entire length of the levee and 3.5 feet of freeboard at the upstream and downstream tie-in locations.

Figure G-1 shows a typical levee cross-section utilized for this analysis. The proposed levees would include a 15-foot wide crest with an all-weather access/maintenance road on top. The height of the levee was assumed to be four feet above the 1% ACE water level to ensure that FEMA freeboard requirements were met. The proposed levee was assumed to have 4:1 side slopes and right-of-way would be acquired for 20-feet beyond each toe. An inspection trench would also be constructed.

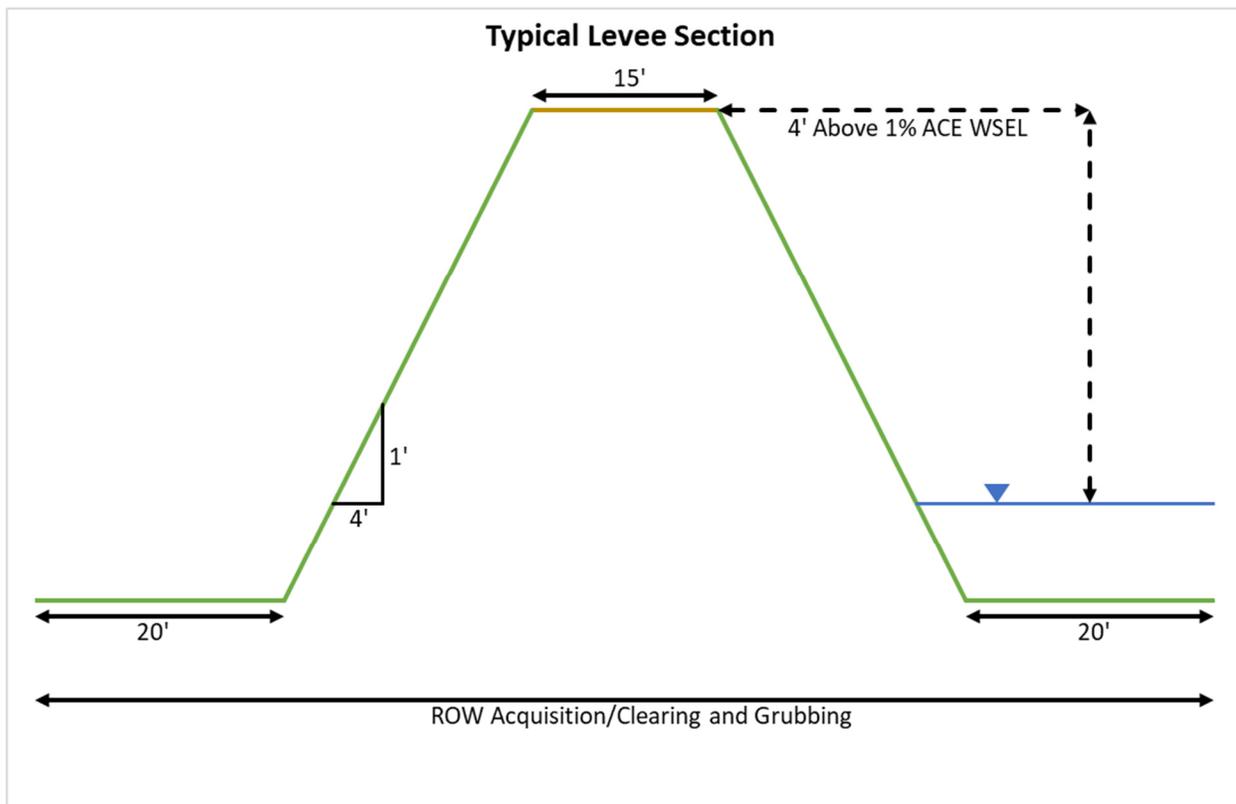


Figure G-1: Typical Levee Section

Even though a high-level feasibility analysis was prepared with a cursory look at potential alignments, hydraulic impacts, environmental permitting impacts, costs, and potential benefits, a more detailed analysis (beyond the scope of this project) would be required to more thoroughly identify constraints, refine the design concept and develop detailed cost estimates.

Several high-level assumptions were made in preparing the cost estimate for new levees including:

- Start-up/Mobilization was assumed to be 5% of construction total
- Utility relocation was assumed to be 3% of construction total
- Levee embankment assumes a 30% compaction factor
- Unit cost of levee embankment set to \$25 per cubic yard given no geotechnical information. Levee may have to be zoned, stabilized, and/or suitable fill material hauled in for construction to meet geotechnical requirements

- Pump station costs based on \$40 per gallon per minute. Pumping capacity assumed equal to one cfs per acre of internal drainage area
- Sump volume assumed equal to 0.4 acre-feet per acre of internal drainage area
- Roadway replacement assumes 6-inch flex base plus 6-inch Hot Mix Asphalt Concrete (HMAC)
- Right-of-way acquisition was assumed to be \$2 per square foot of land
- A 30% construction contingency was used due to the high-level assumptions
- Operation and maintenance costs are not included

Levees typically require substantial amounts of additional conveyance along the stream corridor because they generally reduce the conveyance area of the natural floodplain. Any adverse impacts caused by the reduction in conveyance may require mitigation and a more detailed analysis which is beyond the scope of this study. Levees also require internal drainage systems to accommodate localized rainfall and associated stormwater runoff from within the levees. Standard internal drainage systems include storm drainage network, storage areas, gravity outlets, and pumping stations. Internal drainage systems were not fully evaluated for this high-level feasibility analysis.

G.3.1 Simonton Ring Levee

A levee around portions of Simonton could protect the Brazos Valley Development between Bessies Creek and the Brazos River from the 1% ACE floodplain. The levee would be bounded by Rue Road to the north, Chisholm Road to the East, and FM 1093 to the south. The western portion of the Brazos Valley Development was not included with this proposed flood mitigation alternative due to the location of the area in relation to the Brazos River. The estimated average height of the levee would be seven feet with a maximum height of nine feet and a length of 23,700 feet (4.5 miles). An internal drainage system would be required to mitigate approximately 580 acres of runoff inside the levee. An approximate sizing for pump stations and a sump were determined for the high-level feasibility cost estimate. The proposed alignment can be seen in Exhibit G-2.

Cost Estimation

- The estimated project cost for the proposed Simonton Ring Levee is **\$57,200,000**

Environmental Impacts

- **Land Use** - The levee appears to be located on maintained grassland throughout most of the alignment.
- **Potential Impacts** - The proposed levee would not impact any known cultural or historical sites, oil and gas facilities, park systems, or areas where threatened or endangered species have been observed to occur.
- **Wetlands** - The U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) maps several wetlands along the western extent of the levee. A wetland ranking map, created by Halff (see Appendix F), suggests several areas of medium wetland potential present along the northeastern and southwestern limit of the proposed levee.
- **Waters of the United States** - A National Hydrography Data (NHD) flowline is seen crossing the western portion of the levee. If it is determined any construction activity would place fill within any water of the United States, coordination with the United States Army Corps of Engineers (USACE) Galveston District will be required. The levee also intersects areas

mapped by the Texas Parks and Wildlife Department (TPWD) Ecological Mapping System (EMST) as "Columbia Bottomlands". If requesting a permit for construction within a water of the United States found within "Columbia Bottomlands", the activity may not be authorized by a nationwide permit.

Land & Easement Acquisition Required

- The right-of-way required for the proposed Simonton Ring Levee is approximately **6,150,000 square feet (141 acres)**. This includes area for the pump station and sump as well as the area 20 feet beyond the toe of the levee embankment.

Benefits

- **Moderate timeline for implementation** – The estimated timeline for implementation (not including time to obtain funding) is 7-10 years due to the required property and easement acquisition and estimated timeline to construct the levee.
- **Remove property from the 1% ACE floodplain** – This flood mitigation alternative could be utilized to eliminate structural flooding for all at risk homes from the 1% ACE in the Brazos Valley Development. At risk homes include approximately 200 homes, 35 of which are repetitive loss structures, and 1 severe repetitive loss structure.

Constraints

- **Levee compliance and permitting** – The levee must be designed and constructed in accordance with FEMA's levee criteria to remove the 1% ACE floodplain from the FEMA Flood Insurance Rate Maps (FIRM). Once a levee is constructed significant effort would be required to maintain FEMA levee compliance.
- **Environmental impacts** – Construction would potentially impact water quality, wildlife, and trees.
- **Internal drainage challenges** – Internal drainage for the local rainfall that falls behind the levee must be considered to avoid increasing localized flooding inside within the proposed levee. An internal drainage system would be required to drain approximately 582 acres of neighborhood drainage located inside the levee.

G.3.2 Weston Lakes Levees

The Weston Lakes subdivision is within the 1% ACE inundation areas of both the Brazos River and Bessies Creek. The northern portion of the development discharges into Pecan Lake (an old tributary to Bessies Creek). Runoff is stored within Pecan Lake and eventually discharges north into Bessies Creek through a spillway at FM 1093. During large events the Brazos River spills into Bessies Creek. The spill causes FM 1093 to be overtopped and begins to back up into Pecan Lake as well as the northern portion of the Weston Lakes development. The southern portion of the Weston Lakes development floods due to the Brazos River spilling its banks during large events. A ring levee, that may provide full protection of the development, was determined to be impractical due to the large area (approximately 2,000 acres) that would be contained within the levee. Two separate levees may provide the largest amount of protection to the Weston Lakes subdivision and keep costs and potential impacts to a minimum.

The first levee would begin approximately 600 feet west of the intersection of Woodbine Drive and Wellspring Lake Drive, continue south to the Brazos River, and extend downstream along the Brazos River to a point approximately 1,000 feet northeast of Waterhouse Court. The estimated

average height of the levee is seven feet with a maximum height of 15 feet. The levee would have a length of 11,000 feet (2 miles).

The second levee along Bessies Creek would begin approximately 450 feet west of Waterford Crest Lane at FM 1093, runs along FM 1093 to Bessies Creek, and follow Bessies Creek for approximately 1,400 feet. The estimated average height of the levee is five feet with a maximum height of 11 feet. The levee would have a length of 5,100 feet (one mile). The proposed levee alignments can be seen in Exhibit G-3.

Cost Estimation

- The estimated project cost for the proposed Weston Lakes Brazos River alignment is **\$9,300,000** and the Weston Lakes Bessies River alignment is **\$5,700,000** with a combined project cost of **\$15,000,000**. Cost estimations do not include internal drainage systems. Both alternatives could potentially use the existing drainage systems with the addition of flap gates or sluice gates assuming the storage areas behind the levees has adequate capacity.

Environmental Impacts

- **Land Use** - The Bessies Creek alignment appears to be located on maintained grassland with minimal hardwood tree species.
- **Potential Impacts** - The levee would not impact any known cultural/historical sites, oil and gas facilities, or park systems.
- **Endangered Species** - According to the TPWD Natural Diversity Database (NDD), a record of occurrence of the bald eagle (*Haliaeetus leucocephalus*) intersects both the Bessies Creek and Brazos River alignments. Federal law prohibits the take of bald eagles and the removal of bald eagle nests.
- **Wetlands** - No potential wetlands appear to be crossed by the proposed levees.
- **Waters of the United States** - Two unnamed NHD flowlines are seen crossing a portion of the Brazos River alignment, while the Bessies Creek alignment crosses and parallels Pecan Lake. If it is determined any construction activity would include the placement of fill to any water of the United States, coordination with the USACE Galveston District will be required. The levee also intersects areas mapped by TPWD Ecological Mapping System as "Columbia Bottomlands". If requesting a permit for construction within a water of the United States found within "Columbia Bottomlands", the activity may not be authorized by a nationwide permit.

Land & Easement Acquisition Required

- The right-of-way required for the Brazos River alignment and the Bessies Creek levees are **1,000,000 square-feet (24 acres)** and **600,000 square-feet (13 acres)**, respectively. This includes area 20 feet beyond the toe of the levee embankment.

Benefits

- **Remove property from the 1% ACE floodplain** – This flood mitigation alternative could be utilized to eliminate structural flooding for approximately 370 homes (315 to the North along Bessies and 55 to the south along the Brazos River) from the 1% ACE inundation area. There are no repetitive loss structures being protected by the proposed levee alignment.

Constraints

- **Multiple projects required** – This alternative requires a combination of projects to provide flood mitigation benefits in the study area.
- **Levee Alignment (Potential Buyouts)** – The proposed levee alignment comes to within 70 feet of some homes. Some homes may require buyouts for right-of-way easements.
- **Additional Analyses** – Internal drainage systems would require additional analyses whose costs are not yet accounted for in these alternatives.
- **Levee compliance and permitting** – The levee must be designed and constructed in accordance with FEMA's levee criteria to remove the 1% ACE floodplain from the FEMA Flood Insurance Rate Maps (FIRM). Once a levee is constructed significant effort would be required to maintain FEMA levee compliance.
- **Environmental impacts** – Construction could potentially impact water quality, wildlife, and trees.
- **Internal drainage challenges** – When a levee is constructed, internal drainage for the local rainfall that falls behind the levee must be considered to avoid localized flooding inside the protected area. The oxbow lakes within the development could potentially be used as storage facilities. Internal drainage systems would require additional analyses whose costs are not yet accounted for in these alternatives.

G.3.3 Columbia Lakes Levee

The Columbia Lakes Development is in Brazoria County just north of the town of West Columbia. During Hurricane Harvey, in 2017, the existing Columbia Lakes Levee was overtopped. This alternative considers raising the existing levee to exceed the freeboard requirements when compared to the updated Brazos River 1% ACE water surface elevation. Two separate sections of the existing levee, approximately 17,000 feet (3.2 miles) or 49% of the existing levee would be raised an average of four feet to meet the FEMA freeboard requirements. The proposed locations are shown in Exhibit G-4.

Cost Estimation

- The estimated project cost for raising the Columbia Lakes Ring Levee is **\$9,800,000**

Land & Easement Acquisition Required

- The right-of-way required for the Columbia Lake levees is approximately **520,000 square-feet (12 acres)**. This includes area 20 feet beyond the toe of the levee embankment.
 - with.

Benefits

- **Remove property from the 1% ACE floodplain** – This flood mitigation alternative could be utilized to eliminate structural flooding for approximately 400 structures including 4 repetitive loss structures, 1 severe repetitive loss structure, and 1 critical facility from the 1% ACE inundation area.

Constraints

- **Levee compliance and permitting** – The levee must be designed and constructed in accordance with FEMA's levee criteria to remove the 1% ACE floodplain from the

- FEMA Flood Insurance Rate Maps (FIRM). Once a levee is constructed significant effort would be required to maintain FEMA levee compliance.
- **Environmental impacts** – Construction could potentially impact water quality, wildlife, and trees.
 - **Location Restrictions** – The proposed levee extensions are located adjacent to Varner Creek and Lagoon Reservoir. Widening of the levees towards the creek or reservoir would require further analysis to determine its feasibility.

G.3.4 Brazoria Reservoir–Oyster Creek Levee

A ring levee for the Lake Jackson Farms development between the Brazoria Reservoir and Oyster Creek may prevent flooding from occurring in the neighborhood and prohibit the transfer of over flow from Oyster Creek to the Brazos River.

The levee would be located along the bank of Oyster Creek and to the east of the Lake Jackson Farms development. The levee would then follow along the northern edge of the neighborhood, join with the Brazoria Reservoir levee and then follow along the southern edge of the neighborhood parallel to Brazoria Road. Buffalo Camp Bayou runs through the Lake Jackson Farms development and would have to be gated to prevent water from backing up into the development from both the Brazos River and Oyster Creek.

The estimated height of the levee is approximately seven feet with a maximum height of 13 feet and a length of 50,000 feet (9 miles). An internal drainage system would be required to mitigate approximately 3,000 acres of runoff within the levee. Exhibit G-5 shows the Oyster Creek Levee alignment at Brazoria Reservoir.

Cost Estimation

- The estimated project cost for the proposed Oyster Creek Levee is **\$160,000,000**.

Environmental Impacts

- **Land Use** - The southern, western and northern extent of the levee appears to be located on maintained grassland.
- **Historical Sites and Endangered Species** - The levee would not impact any known cultural/historical sites, park systems, or areas where threatened or endangered species have been observed to occur.
- **Pipelines** - Pipeline data from the Railroad Commission of Texas shows seven pipelines crossing the levee north to south in the western portion of the system.
- **Wetlands** - According to the NWI, several wetlands are mapped along the western extent of the levee. A wetland ranking map, created by Halff (see Appendix F), suggests several areas of medium wetland potential present along the northern and southern levee in the western portion of the system.
- **Waters of the United States** - Several NHD flowlines are shown crossing the proposed levee alignment including McFadden Bayou, Buffalo Camp Bayou, and several unnamed flowlines. If it is determined any construction activity would include fill within a water of the United States, coordination with the USACE Galveston District will be required. The levee also intersects areas mapped by the TPWD Ecological Mapping System as "Columbia Bottomlands". If requesting a permit for construction within a water of the United States

found within "Columbia Bottomlands", the activity may not be authorized by a nationwide permit.

Land & Easement Acquisition Required

- The right-of-way required for the Oyster Creek Levee is approximately 5,300,000 square feet (122 acres). This includes area 20 feet beyond the toe of the levee embankment. The cost estimate does not include home buyouts.

Benefits

- **Remove property from the 1% ACE inundation area** – This alternative prevents flooding from occurring within the Lake Jackson Farms development for the 1% ACE event. The proposed levee would protect 870 homes and 25 repetitive loss properties.
- **Lowers water surface elevations in the Brazos River** – Water surface elevations are lowered in the Brazos River downstream of FM 521 to the Gulf of Mexico ranging from 0.5 feet to 2.5 feet.
- **Mitigates impacts in Jones Creek** – 1% ACE water surface elevation depths in the Jones Creek area would be reduced because of the levee.
- **Lowers 1% ACE water surface elevations in Oyster Creek** – Water surface elevations are lowered in Oyster Creek just upstream of FM 2004 to Lake Jackson ranging from 0.25 feet to 1.0 feet.

Constraints

- **Adverse impacts in Oyster Creek** - Raises water surface elevations in Oyster Creek upstream of the railroad bridge to FM 2004 ranging from 0.01 feet to 2.5 feet.
- **Structural buyouts** - Potential structural buyouts would be necessary along the proposed levee alignment.
- **Internal drainage challenges** – When a levee is constructed, internal drainage for the local rainfall that falls behind the levee must be considered to avoid localized flooding inside the protected area. Gate structures would be needed for channel located inside neighborhood to prevent flooding during large storm events.
- **Coordination with industrial entities** – The proposed levee has potential to affect and/or disrupt diversion canals used for industrial activities. Planning and construction of the levee would likely have to be communicated/coordinated with industrial entities in the area.

G.3.5 Pecan Grove Levee

A ring levee around the area near Bullhead Bayou and Pecan Grove could prevent flooding within the area. The levee would be placed along the right overbank of the Brazos River near Rio Vista and Rivers Edge to Autumn Ridge to prevent overflow from the Brazos River. A levee would also be placed along Pitts Road to prevent overflow from Bullhead Bayou.

The estimated height of the levee is approximately seven feet with a maximum height of 18 feet and a length of 26,000 feet (5 miles). In addition, an internal drainage system would be required to mitigate approximately 1,000 acres of runoff within the levee. Exhibit G-6 shows the proposed Pecan Grove levee alignment.

Cost Estimation

- The estimated project cost for the proposed Pecan Grove Levee is **\$76,000,000**.

Environmental Impacts

- **Land use** - The levee appears to be located on primarily maintained grassland and riparian and fence line forests throughout most of the alignment.
- **Potential Impacts** - The proposed levee would not impact any known cultural or historical sites, oil and gas facilities, park systems, or areas where threatened or endangered species have been observed to occur.
- **Wetlands** - The USWFS National Wetland Inventory maps several wetlands along the western extent of the levee. A wetland ranking map, created by Halff (see Appendix F), suggests several areas of medium wetland potential present along the western and southeastern limit of the levee. An area of high wetland potential is also found near the western limit of the study area.
- **Waters of the United States** - Several NHD flowlines are seen crossing the eastern and southern limit of the levee. If it is determined any construction activity would result in the placement of fill within any water of the United States, coordination with the USACE Galveston District will be required. The levee also intersects areas mapped by the TPWD Ecological Mapping System as "Columbia Bottomlands". If requesting a permit for construction within a water of the United States found within "Columbia Bottomlands", the activity may not be authorized by a nationwide permit.

Land & Easement Acquisition Required

- The right-of-way required for the levee is approximately **3,000,000 square feet (68 acres)**. This includes area 20 feet beyond the toe of the levee embankment. This estimate does not include structural buyouts.

Benefits

- **Remove property from the 1% ACE Floodplain** – The proposed levee would potentially protect 1,150 homes and one repetitive loss property.
- **Minimized home buyouts** – Right-of-way acquisition within the area is sufficient to avoid most of the developed areas.
- **Pecan Grove levee** – The proposed levee would tie into the existing Pecan Grove levee.

Constraints

- **Adverse impacts in Oyster Creek** – The proposed levee could potentially raise water surface elevations in Oyster Creek from FM 1093 to Creek Bend Drive ranging from 0.01 feet to 0.5 feet.
- **Adverse impacts in the Brazos River** - Raises water surface elevations in the Brazos River upstream of Simonton to the Riverpark West area from 0.01 feet to 0.5 feet.
- **Pitts Road** –Construction of the proposed levee would require Pitts Road between Pecan Grove and US 90A to be closed off and replace.

G.3.6 Levee Freeboard Check

The updated 1% ACE water surface elevations from the Lower Brazos Floodplain Protection Planning Study were compared to existing levee elevations (from study LiDAR) to confirm that FEMA's minimum freeboard requirements are met. The minimum FEMA freeboard required for a certified levee is three feet above the 1% ACE water surface elevation, an additional one foot within 100 feet of structures, and an additional 0.5 foot at the upstream end of a levee. Table G-2 shows the freeboard range for levees within the Fort Bend area. The analyses showed that levees with less than three feet of freeboard may require further investigation to confirm that the minimum freeboard requirement is met based on the 1% ACE water surface elevation determined with this study.

Table G-2: Levee Freeboard Check

Levee District	Freeboard Range (feet)
LID #2	4.4 – 5.4
LID #6	2.6 – 4.0
LID #7	3.8 – 4.9
LID #10	2.9 – 3.6
LID #11	2.4 – 4.5
LID #14	2.9 – 4.1
LID #15	3.0 – 5.3
LID #17	3.1 – 3.2
LID#19	4.8 – 5.3
LID #20	2.0 – 4.2
MUD 121	3.5 – 3.8
Pecan Grove	2.2 – 4.0
First Colony	3.5 – 4.7
Sienna Plantation	2.2 – 4.0

G.4.0 Bank Station Changes

Large amounts of bank erosion have been observed in recent years after major flooding has occurred on the Brazos River. When channel banks erode the material is deposited downstream changing both the alignment and hydraulic properties (water surface elevations) of the Brazos River. The goal of this analysis is to show how the Brazos River has changed with time due to meanders, scour, and deposition. To accomplish this goal, the Brazos River banks were delineated based on aerial imagery from Google Earth for 2006, 2008, 2015, and 2017. The results were then compared against each other to show the rate at which the banks have changed. Exhibit G-7 shows an example of the bank comparison from 2006 to 2017 near Simonton. A complete workmap is provided after this appendix. The exhibits show how dynamic the Lower Brazos River system has been just over the last decade. The bank station comparison found that old abandoned oxbows exist where the Brazos River flowed at some historic time but have become

cut off from the main channel. Design of proposed flood mitigation alternatives as well as future development should consider the geomorphology of the Lower Brazos River.

G.5.0 Large Scale Detention

A large-scale detention alternative was evaluated to determine the volume of water that would need to be diverted and detained from the Brazos River to minimize flooding impacts along developed areas for the 1% ACE event. Detention was evaluated in both Waller and Brazoria county to mitigate flooding in repetitive loss areas. The engineering design of the detention areas was not considered in this analysis. Only the volume required to reduce the 1% ACE flood impacts on the Brazos River calculated. In Waller County, the diversion point was set just upstream of San Felipe while the diversion point for Brazoria County was set downstream of Sienna Plantation development.

Cost Estimation

- The estimated conceptual project cost for the large-scale detention is \$92,234,300,000 and \$151,201,500,000 for Waller County and Brazoria County respectively.

Benefits

Waller County

- **Lower water surface elevations in the Brazos River** – Water surface elevations are lowered in the Brazos River from FM 529 in Waller County to the Gulf of Mexico ranging from **0.01 feet to 9 feet**.
- **Mitigates repetitive loss areas** - Many of the repetitive loss areas in are no longer inundated during the 1% ACE event.

Brazoria County

- **Lower water surface elevations in the Brazos River** - Water surface elevations are lowered in the Brazos River from the Pecan Grove area in Fort Bend County to the Gulf of Mexico ranging from **0.01 feet to 7 feet**.
Mitigates repetitive loss areas - Many of the repetitive loss areas in Brazoria County are no longer inundated during the 1% ACE event.

Constraints

Waller County

- **Required Volume** - Requires approximately **1 million acre-feet** of detention to reduce water surface elevations in the Brazos River.
- **Non-Uniform Mitigation Impacts** – Mitigation impacts along the Brazos River are not uniform. For some areas the flood mitigation is excessive while flooding in other areas is not mitigated enough.
- **Land acquisition** – Requires almost **65,000 acres** of land.
- **Pumping** – Would require massive pumping to divert flood flows from the Brazos River to the off-channel detention area.
- **Environmental Impacts** – The proposed detention pond could potentially impact water quality, wildlife, and trees.

Brazoria County

- **Required Volume** - Requires approximately **2 million acre-feet** of detention to reduce water surface elevations in the Brazos River.
 - **Non-Uniform Mitigation Impacts** – Mitigation impacts along the Brazos River are not uniform. For some areas the flood mitigation is excessive while flooding in other areas is not mitigated enough.
 - **Land acquisition** – Requires almost **100,000 acres** of land.
 - **Pumping** – Would require massive pumping to divert flood flows from the Brazos River to the off-channel detention area.
- Environmental Impacts** – The proposed detention pond could potentially impact water quality, wildlife, and trees.

To visualize the magnitude of the large-scale detention options, Exhibit G-8 shows comparisons of the detention area footprint with Somerville Lake, located in Burleson County west of the detailed study area. Somerville Lake currently covers 24,000 acres (38 square miles) and has an approximate volume of 507,000 acre-feet. The proposed detention areas were assumed at a depth of 20 feet in determining the surface area.

G.6.0 Channelization

Channelizing the Brazos River consisted of locating reaches along the river that would mitigate flooding impacts at locations where a high density of FEMA flood claims is located, and areas of high development have been located within the 1% ACE floodplain. Two channelization alternatives were analyzed which included locations within Fort Bend County and Brazoria County. The channel geometry consisted of a trapezoidal section with a bottom width of 600 feet at 4:1 (horizontal: vertical) side slopes. The bed slope was determined by utilizing the existing downstream and upstream channel inverts and grading between those points to create the channel profile. Figure G-2 shows a typical channel section for the proposed channelization.

In Fort Bend County, the proposed channel begins just downstream of the Fort Bend/Waller County Line and ends just upstream of the USGS Richmond Gauge near Rivers Edge. Channel sections were adjusted to ensure the alternative would fit without encroaching into existing properties along the river. The goal of Fort Bend Channelization alternative was to lower water surface elevations in Simonton, Rosenberg and the Richmond area.

In Brazoria County, the proposed channel was separated into two sections. The first section begins downstream of FM 1462 and ends near the unincorporated community of Otey. The second section begins just upstream of the Columbia Lakes subdivision and ultimately ends at the Gulf of Mexico. The goal of this channel was to lower water surface elevations for Columbia Lakes, West Columbia, Brazoria and Jones Creek. Exhibit G-9 and G-10 show the channelization limits in Fort Bend and Brazoria Counties, respectively.

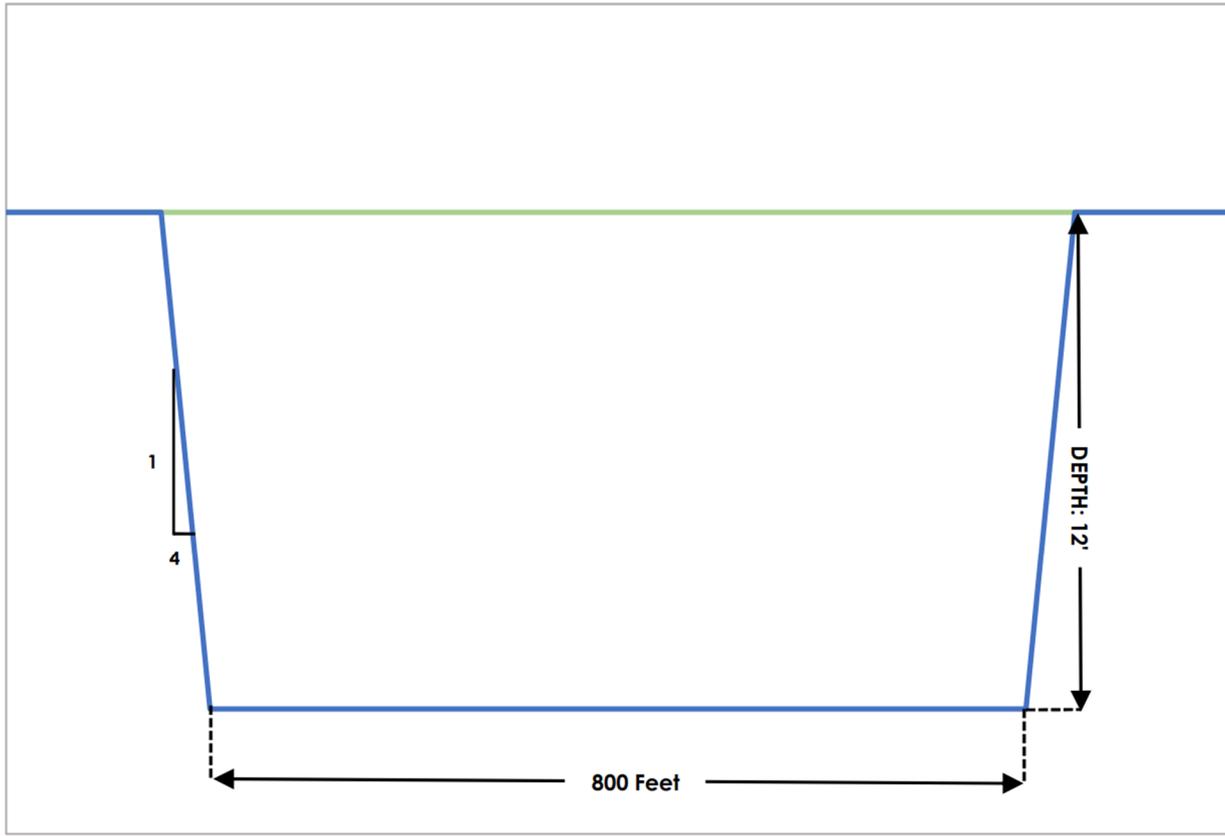


Figure G-2: Typical Channelized Section

Cost Estimation

- The estimated conceptual project cost for channelization is \$241,173,100,000 and \$232,074,600,000 for Fort Bend County and Brazoria County respectively.

Benefits

Fort Bend County

- **Lower 1% ACE water surface elevations** – Water surface elevations are lowered in the Brazos River from the San Felipe USGS gauge to US 90A in Richmond ranging from **0.01 feet to 11 feet**.
- **Mitigates impacts** – Reduces flooding along the Brazos River resulting a smaller 1% ACE flood inundation area.

Brazoria County

- **Lower 1% ACE water surface elevations** – Water surface elevations are lowered in the Brazos River near Sienna Plantation to the Gulf of Mexico ranging from **0.01 feet to seven feet**.
- **Mitigates flood impacts** – Reduces flooding along the Brazos River resulting a smaller 1% ACE flood inundation area.

Constraints

Fort Bend County

- **Adverse impacts in the Brazos River** - Raises water surface elevations in the Brazos River from Richmond to the Gulf of Mexico ranging from 0.01 feet to 0.2 feet.
- **Conflicts with development** – Properties along the banks of the Brazos River can potentially be affected by this alternative.
- **Excavation** - Approximately 2 billion cubic yards of excavation is needed to build out the channel.
- **Structure conflicts** - Impacts to bridges and existing infrastructure along Brazos River.
- **Environmental impacts** - The proposed detention pond could potentially impact water quality, wildlife, and trees.

Brazoria County

- **Adverse impacts in the Brazos River** - Raises water surface elevations in the Brazos River in areas just downstream of Rosharon and near Lake Jackson ranging from 0.01 feet to 1.5 feet.
- **Conflicts with development** – Properties along the banks of the Brazos River can potentially be affected by this alternative.
- **Excavation** - Approximately 2 billion cubic yards of excavation is needed to build channel.
- **Structure conflicts** - Impacts to bridges and existing infrastructure along Brazos River.
- **Environmental impacts** - The proposed detention pond could potentially impact water quality, wildlife, and trees.

G.7.0 Bypass Channel

The Bypass Channel alternative consists of diverting water from the Brazos River through a proposed channel from Fort Bend County downstream towards the Gulf of Mexico. The Bypass Channel could lower the 1% ACE water surface elevations in both Fort Bend and Brazoria County and reduce flood inundation in areas with a high density of FEMA flood claims. The bypass would be located west of Rosenberg with the alignment staying clear of existing water bodies. Exhibit G-11 shows the location of the proposed bypass channel.

The proposed bypass channel was sized as a trapezoidal section with a bottom width of 800 feet and a side slope of 4:1 (horizontal to vertical) at a channel depth of 12 feet. Figure G-3 shows a typical channel section of the proposed bypass channel. The proposed by channel is outside of the Lower Brazos River Basin and current terrain was unavailable. The proposed by-pass channel was cut down at a uniform slope from the invert elevation of the proposed bypass channel to the Gulf of Mexico. The upstream invert elevation was determined through iterations in the hydraulic modeling to ensure the channel reached maximum capacity.

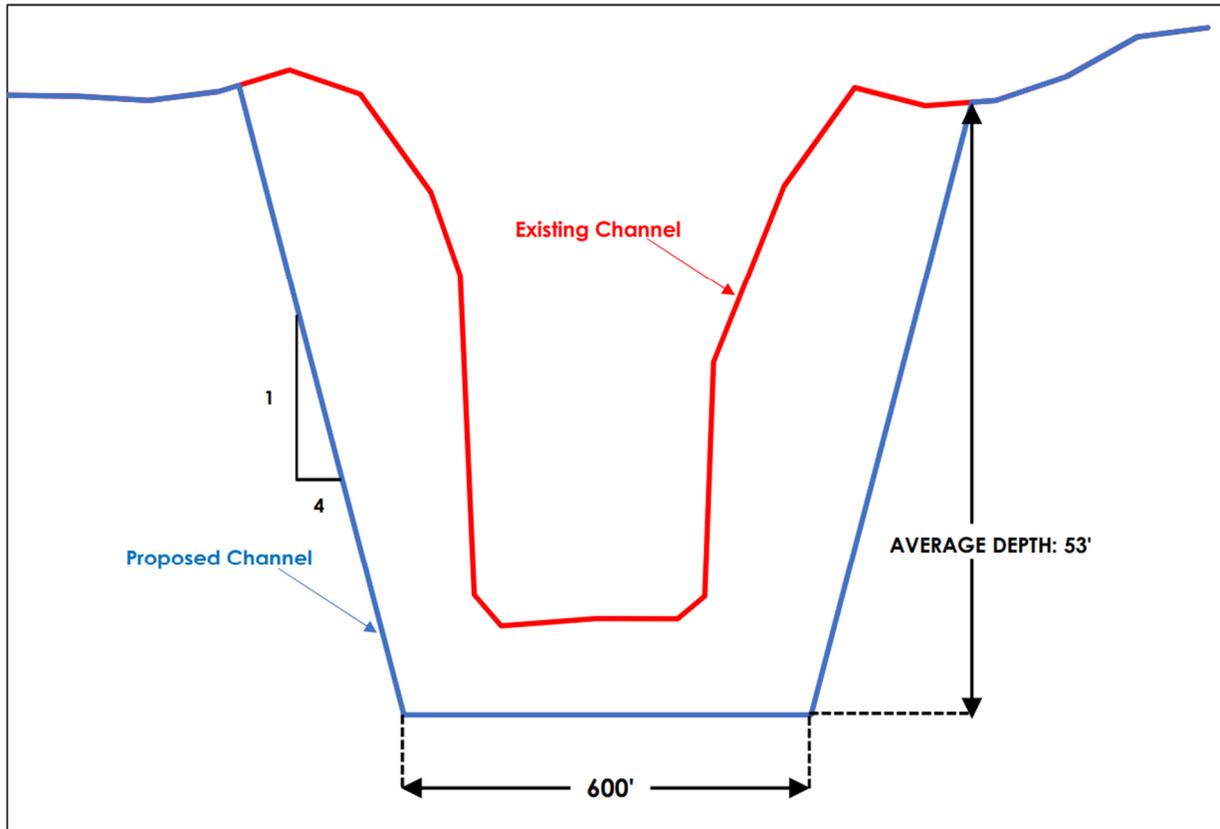


Figure G-3: Typical Bypass Channel Cross Section

Cost Estimation

- The estimated conceptual project cost for the diversion channel is \$171,673,000,000

Benefits

- **Lower 1% ACE water surface elevations** – Water surface elevations are lowered in the Brazos River through the entire reach (Waller County Line to Gulf of Mexico) ranging from 0.3 feet to 10 feet.
- **Mitigates flood impacts** – Reduces flooding along the Brazos River resulting a smaller 1% ACE flood inundation area.

Constraints

- **Excavation** – The bypass channel will require a large amount of excavation.
- **Structure/Drainage conflicts** - Several structure and drainage crossings would need to be modified because of the bypass channel.
- **Floodplain Encroachment** - Bypass channel could coincide with existing floodplains. Berms may need to be implemented to prevent flooding overflow into other rivers.
- **Land acquisition** – Alignment of the bypass channel has yet to be determined. Land along the alignment of the Bypass channel will have to be purchased from existing land owners.
- **Environmental impacts** -The proposed detention pond could potentially impact water quality, wildlife, and trees.

G.8.0 Potential Alternative Environmental Impacts

Levee height improvements may entail lateral expansion of the levee footprint, introducing potential impacts to waters of the United States regulated under Section 404 of the Clean Water Act (Section 404). USACE utilizes nationwide permits for categories of activities that cause only minimal individual and cumulative adverse impacts. Nationwide Permit 3 – *Maintenance* (NWP 3) is often used to authorize levee rehabilitation, replacement, or improvement projects where the proposed action involves fill in waters of the United States. In determining the applicability of nationwide permits, the project must also assess the project effects on threatened and endangered species and cultural resources, each of which can often be mitigated if present. According to the nationwide permit regional conditions for the USACE Galveston District, the District will not issue a nationwide permit authorization for activities that occur in the Columbia Bottomland land cover type. NWP 3 is an exception to this condition; however, the applicant must notify the USACE prior to commencing the project.

In contrast, the scope of large-scale detention would require a large land acquisition in the lower Brazos River 0.1% ACE inundation areas in Waller and Brazoria counties. The scope of Brazos River channelization would entail several miles of channel in Fort Bend and Brazoria counties. Either of these proposed alternatives would result in impacts to waters of the United States, the scale of which would likely exceed those allowed under a nationwide or standard individual permit. All regulatory actions under Section 404 must comply with the National Environmental Policy Act (NEPA). The NEPA requires an environmental impact statement (EIS) when a project is federally controlled (or federally permitted) and the project is likely to have a significant impact on the quality of the human environment, even after mitigation factors are considered. Although requirements differ between situations, an EIS must address the total impact on the environment and consider numerous factors, including but not limited to:

- the environmental impact of the proposed action (e.g. waters of the United States; threatened and endangered species; downstream flows; cultural resources; land use/communities)
- any adverse environmental effects which cannot be avoided should the proposal be implemented
- alternatives to the proposed action
- mitigation actions

The completion of an EIS is the responsibility of the federal agency controlling the project (USACE) who is also responsible for any legal consequences of the EIS. The USACE may prepare its own EIS or may require the permit applicant to hire a contractor to work with the USACE to prepare an EIS as part of the permit decision process. If the document is prepared under a contract, the USACE must participate in the preparation and will independently evaluate the statement prior to its approval. The EIS is used as a comprehensive document when making the decision to approve or deny the proposed Section 404 action.

G.9.0 Fort Bend County Effective Flow Boundary

Fort Bend County has established an effective flow boundary along the Brazos River that potentially impacts the available conveyance of the river. The effective flow boundary was

established from the effective model of Fort Bend County to determine how far development can encroach into the Brazos River while maintaining conveyance through the river. This encroachment line was downloaded from the Fort Bend County Drainage District website and used to determine where to place encroachments in the unsteady hydraulic model.

Blocked obstructions were used to block off flows from the areas beyond the effective flow boundary. Overflow of the Brazos River to Bessies Creek and the Pecan Grove area was prohibited for this analysis while the overflow into Lower Oyster Creek was maintained. Blocked obstructions were placed in Oyster Creek based on the encroachment line and between the banks of Oyster Creek to maintain conveyance and ensure model stability. Exhibit G-12 shows the extents of the Fort Bend Development Line.

Encroachments up to the development line result in increases in the 1% ACE water surface elevation of 0.01 to 4 feet in several areas within Fort Bend County. The areas where water surface elevations increase are located from Simonton to Richmond and Ditch H down to Brazoria County. Slight decreases in water surface elevation were also observed from Richmond to Ditch H and within Brazoria County down to the Gulf of Mexico.

An effective flow boundary along the Brazos River provides information regarding the relationship between conveyance and storage volume in the river. Unsteady state hydraulic modeling determined that maintaining storage volume in the floodplain is important to reducing hydraulic impacts. Therefore, the effective flow boundary concept should be revisited to determine if this policy should be continued.

G.10.0 Economic Analysis

An economic analysis was developed to identify and quantify the extent of flood problems and, on a comparable basis, evaluate solutions to reduce flood losses. The USACE Hydrologic Engineering Center Flood Damage Reduction Analysis (HEC-FDA, Version 1.2.5, March 2010) software was utilized to develop the economic analysis of the flood reduction alternatives. For each alternative, a base flood damage assessment was developed to represent the expected (average) annual damages if no alternatives were implemented based on the water surface elevations computed with the hydraulic model developed for this study (see Appendix E). A "with project" flood damage assessment was developed to represent the expected annual damages if the alternative was fully constructed.

Parcel data was collected for Brazoria, Fort Bend, Waller, Washington, and Austin Counties and compiled into a single shapefile. The estimated finished floor elevation was developed by intersecting the parcel layer with the study LiDAR data. Survey elevations of structures were not taken for this high-level feasibility economic analysis. The parcel data included the building use which consisted of either commercial, single family houses or mobile homes. Structure value and land value were included for each parcel.

Damage curves were assigned to each building type based on the occupancy type. The damage curves define the relations of damage to a structure for each foot of flood height at the building. The damage is determined as a percentage of the total structure value. Damage curves were also used to determine the amount of damage to contents of each building in relation to

the flood depths. Damage reaches for each alternative were defined by grouping fully or partially inundated buildings within the 0.2% ACE inundation limits based on the locations in the Brazos River.

Water surface profile elevations for flood events based on the results of the Lower Brazos Floodplain Protection Planning Study were used for the base flood damage assessment and additional hydraulic models were developed for each local alternative to determine reduction in the water surface elevations.

G.11.0 Benefit Cost Analysis

A Benefit-Cost Analysis (BCA) was performed for the flood mitigation alternatives. The BCA was established as the standard to provide technical and financial assistance for implementation of flood or hazard mitigation undertakings. The minimum criteria for state and federal funding is a BCA of 1.0 or greater meaning that the benefit of the proposed project would match the annual cost of the project. Benefit is increased if flooding occurs at structures during more frequent events. From the BCA analysis it was determined that the three of the final alternatives meet the minimum criteria for state and federal funding. High-level cost estimates for each project are included after this appendix. Table G-3 shows the estimated total project costs, average annual project cost, damage prevented, and BCA ratios for each of the flood mitigation alternatives stated earlier.

Table G-3: Cost Benefit Analysis

Alternative	Estimated Total Project Cost	Average Annual Project Cost	Damages Prevented	BCA
Simonton Ring Levee	\$57,200,000	\$2,700,000	\$448,000	0.2
Weston Lakes Levee	\$15,000,000	\$700,000	\$650,000	0.9
Columbia Lakes Levee	\$75,900,000	\$3,500,000	\$6,000,000	1.7
Brazoria Reservoir -Oyster Creek Levee	\$160,000,000	\$7,500,000	\$8,500,000	1.1
Pecan Grove Levee	\$76,000,000	\$3,500,000	\$4,800,000	1.4

Notes: Discount Rate assumed to be 4%, analysis period is 50 years, and monetary values reflect 2018 dollars and costs estimates

G.12.0 Conclusions and Recommendations

The Lower Brazos Floodplain Protection Planning Study evaluated several high-level feasibility alternatives to reduce the flood risk along the Lower Brazos River. The flood mitigation objectives were to minimize flooding risk to structures within the 1% ACE floodplain and to focus on areas with large numbers of FEMA flood insurance claims and repetitive losses.

Buyouts are less expensive than regional large-scale alternatives or local levee alternatives. A buyout program has the flexibility of being implemented as funding becomes available. A buyout program offers the shortest time of implementation and allows for prioritization of the most at risk structures. In addition to these benefits, this alternative has the least environmental impact to the Brazos River.

Local levee alternatives could be used to offer flood protection to some areas along the Brazos River. The local alternatives have a high project cost, long time of implementation, complex permitting, and potential environmental impacts.

Large scale alternatives were found to provide flood protection to some areas and little to no protection to other areas. The large alternatives have an extremely high cost, long time of implementation, complex permitting, property acquisition, and large environmental impact.

The flood mitigation alternatives developed for the Lower Brazos Floodplain Protection Planning Study are at a high-level feasibility study level. All alternatives, damages, and costs were analyzed at a preliminary level. Any results from this study, including post-project flood risk and estimated project costs, would need to be refined should any of the projects contemplated in this analysis be recommended for further evaluation.

Appendix G: Flood Mitigation Alternatives

Exhibits



Brazos River Authority

Lower Brazos River Floodplain Protection Planning Study

Exhibit G-1

FEMA Flood Claims Map

-  Potential Buyouts
-  1% ACE Inundation Mapping
-  Basin Limits
-  County Line

Study Streams

-  Limited Detail
-  Incorporated Study
-  Detailed Unsteady

Flood Claim Heat Map

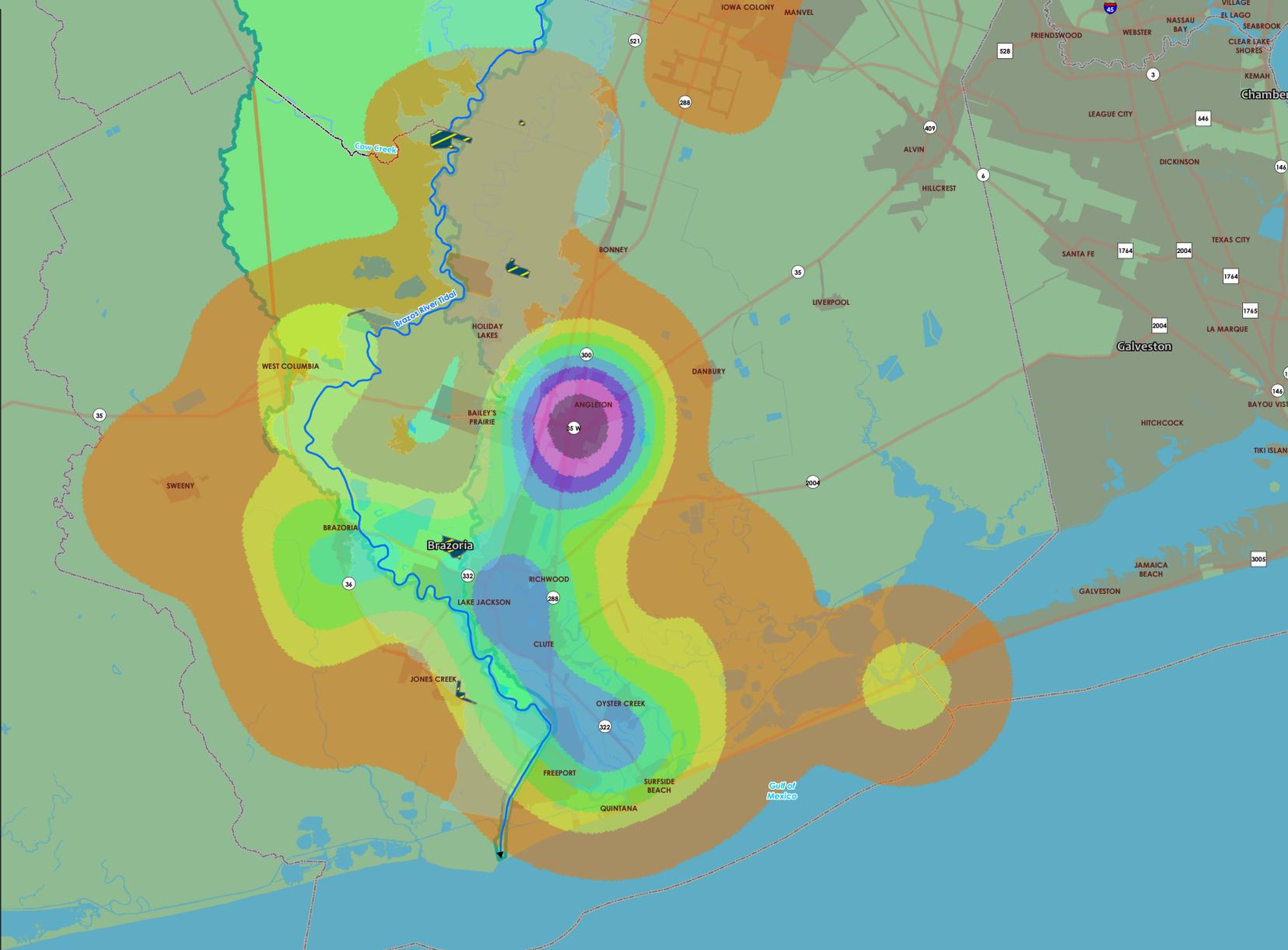
-  Low Density Flood Claims
-  
- 
- 
- 
- 
-  High Density Flood Claims

0 7,500 15,000 30,000 Feet

1 inch = 16,000 feet




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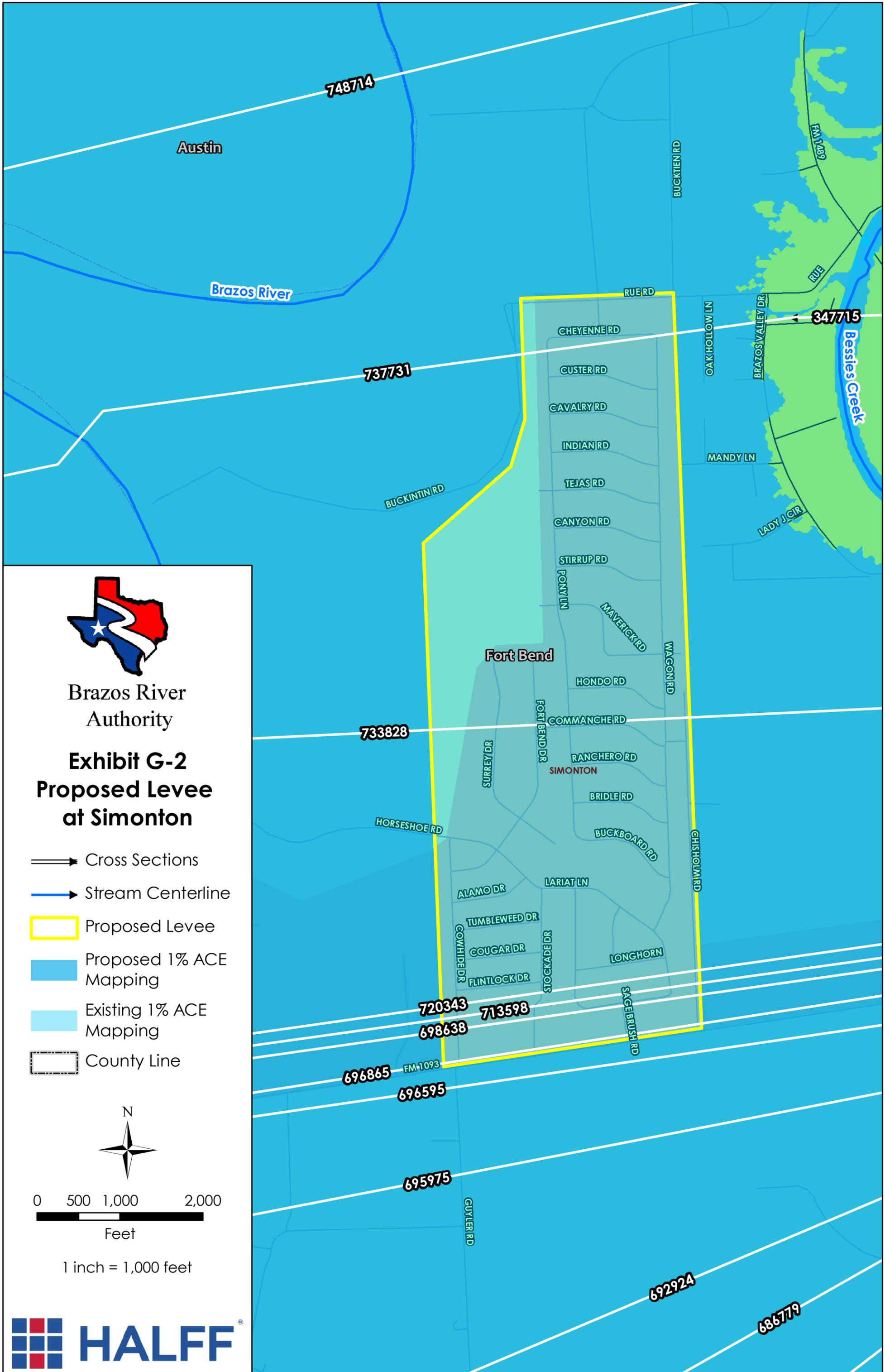
Exhibit G-2 Proposed Levee at Simonton

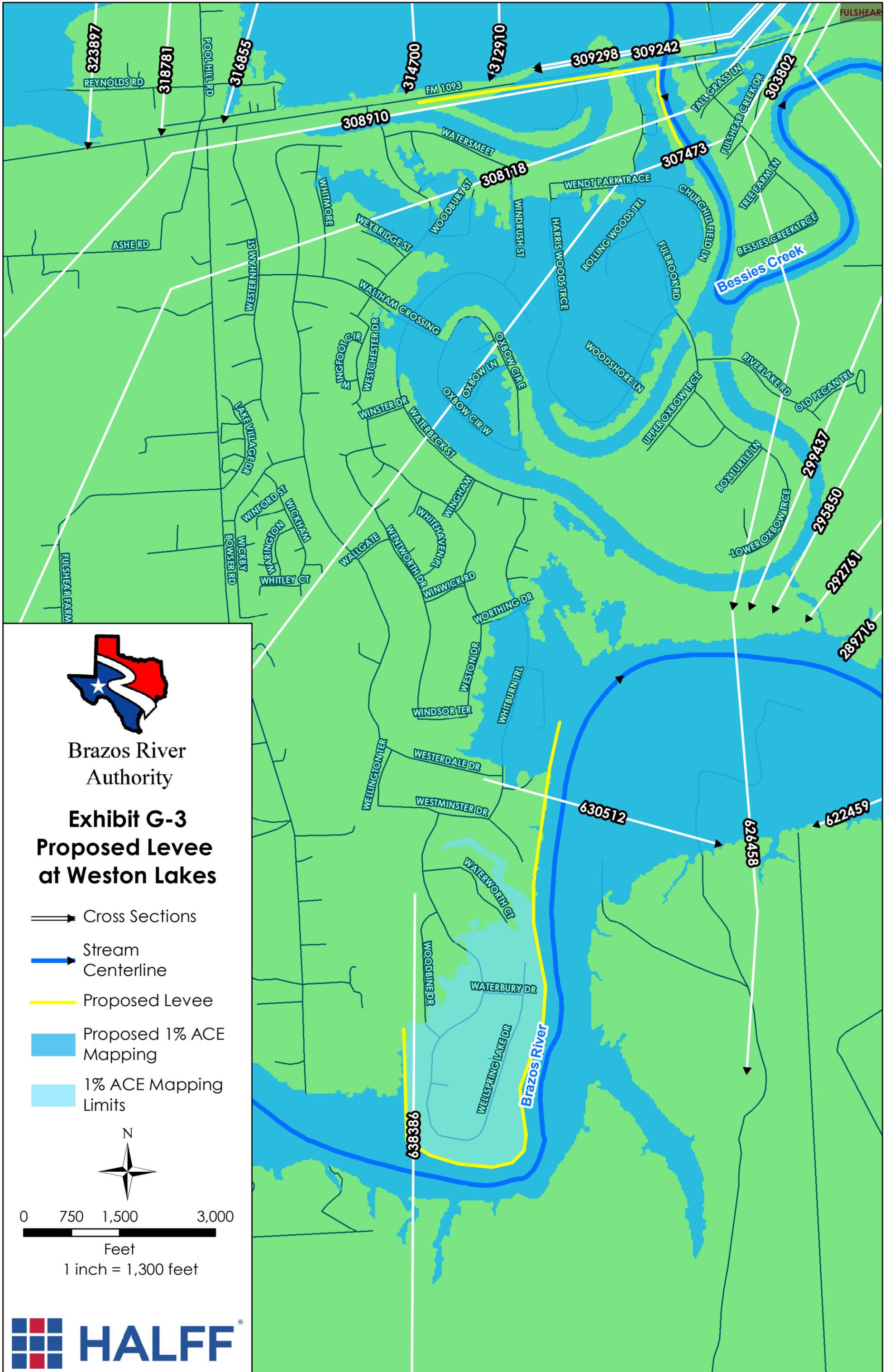
- Cross Sections
- Stream Centerline
- Proposed Levee
- Proposed 1% ACE Mapping
- Existing 1% ACE Mapping
- County Line



0 500 1,000 2,000
Feet

1 inch = 1,000 feet





Brazos River Authority

Exhibit G-3 Proposed Levee at Weston Lakes

- Cross Sections
- Stream Centerline
- Proposed Levee
- Proposed 1% ACE Mapping
- 1% ACE Mapping Limits



0 750 1,500 3,000



Feet

1 inch = 1,300 feet





Brazos River
Authority

Exhibit G-4 Proposed Levee at Columbia Lakes

- Cross Sections
- ▬ Levee to be Raised
- ▬ Brazoria Levees
- Stream Centerline
- Proposed 1% ACE Mapping



0 500 1,000 2,000
Feet
1 inch = 1,000 feet





Brazos River
Authority

Exhibit G-6 Proposed Levee Near Pecan Grove

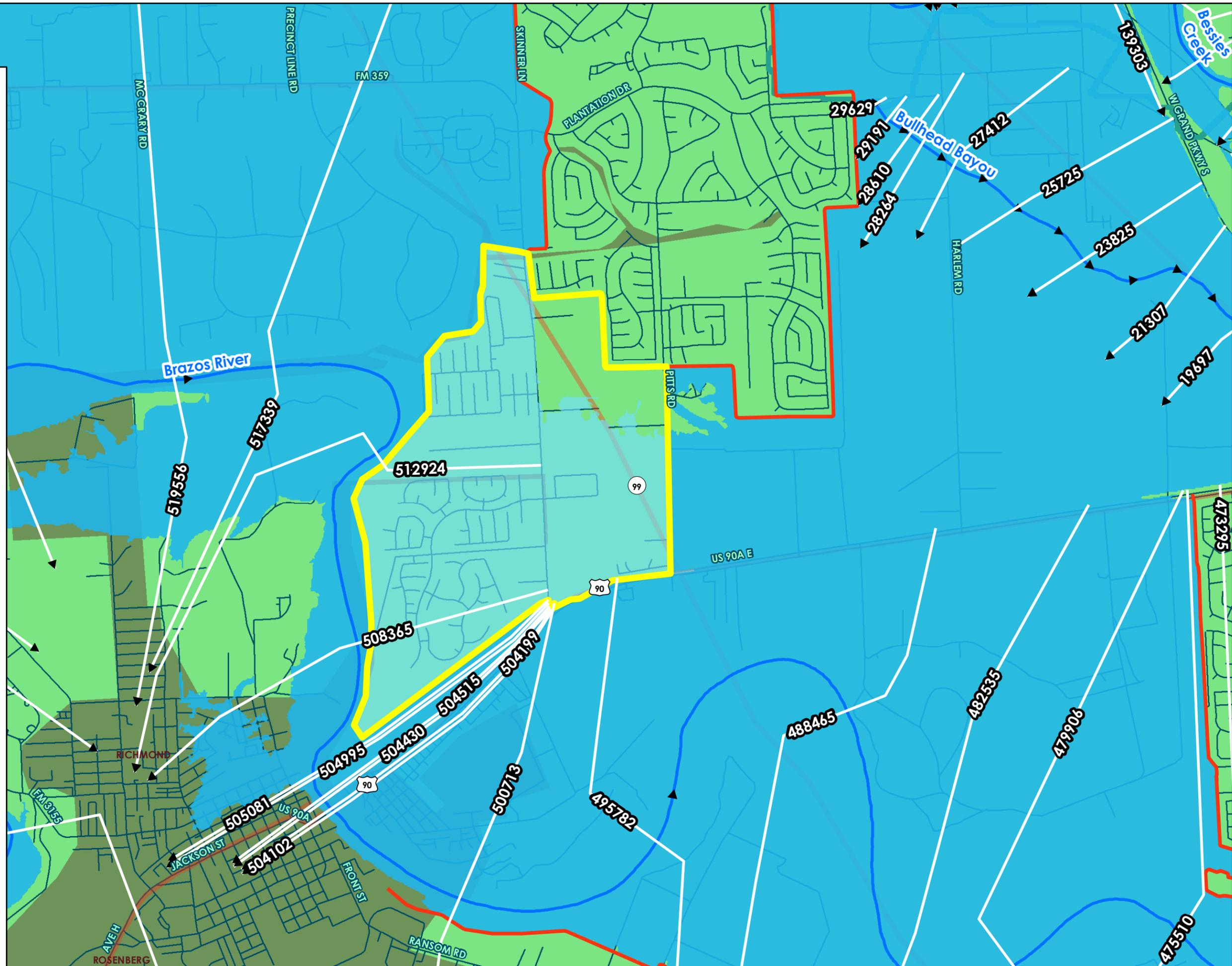
- Cross Sections
- Stream Centerline
- Fort Bend Levee
- ▭ Proposed Bullhead Levee
- 1% ACE Proposed Mapping
- 1% ACE Mapping Limits
- ▭ Basin Limits



0 1,000 2,000 4,000

Feet

1 inch = 2,000 feet





Brazos River Authority

Lower Brazos River Floodplain Protection Planning Study

Exhibit G-7 Bank Station Changes Between 2006 and 2017

Index

-  USGS Gauge
 -  Lateral Weir
 -  Levee
 -  Brazos River
 -  Basin Limits
 -  County Line
- Bank Changes
-  Eroded Area
 -  Deposit Area
 -  No Change

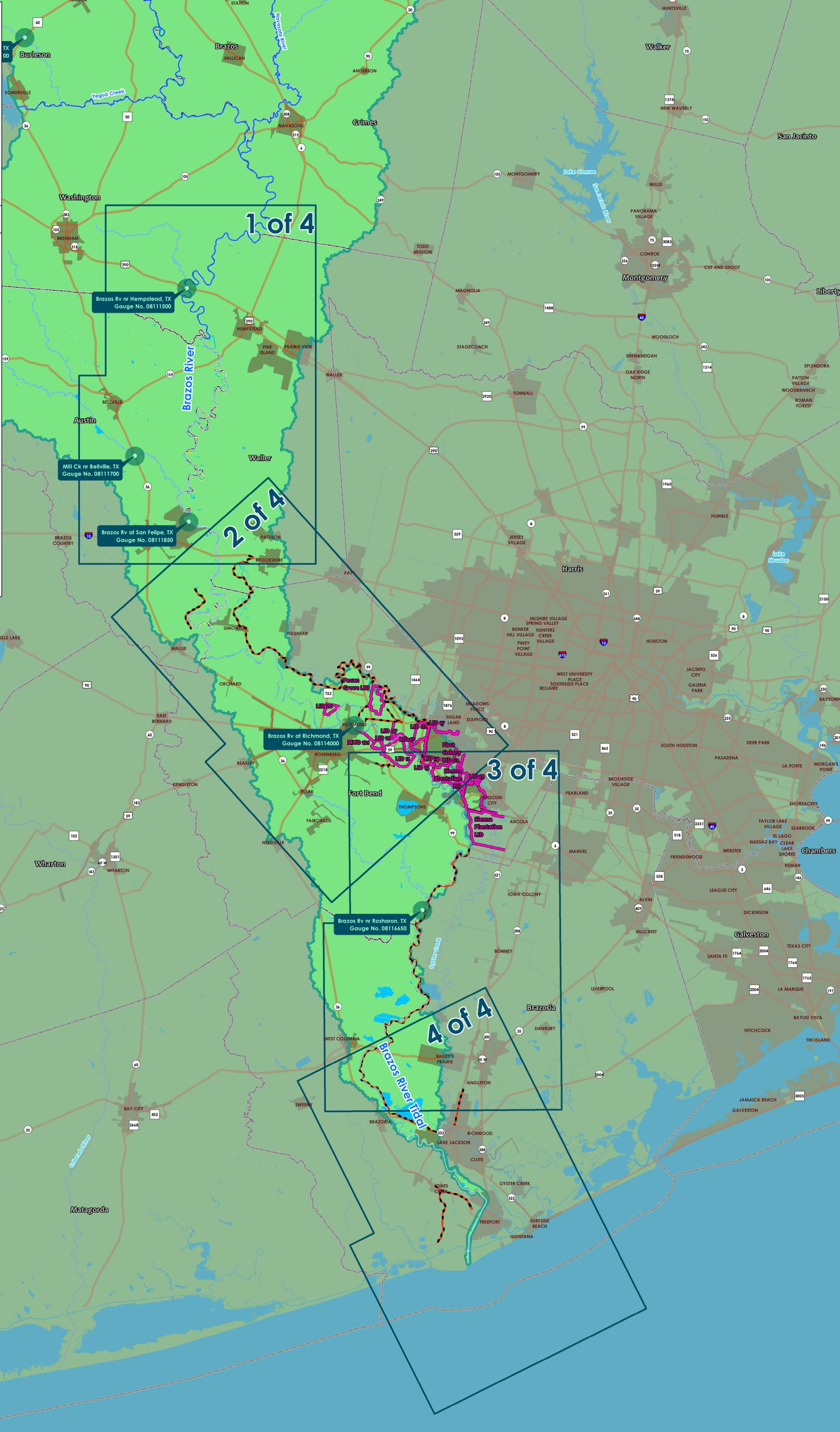


0 4 8
Miles

1 inch = 4 miles



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1 of 4

2 of 4

3 of 4

4 of 4

Brazos Rv nr Hempstead, TX
Gauge No. 08111500

Mill Ck nr Bellville, TX
Gauge No. 08111700

Brazos Rv at San Felipe, TX
Gauge No. 08111850

Brazos Rv at Richmond, TX
Gauge No. 08114000

Brazos Rv nr Rosharon, TX
Gauge No. 08116650

Pecan Grove LID

First Colony LID

Sienna Plantation LID



Brazos River Authority

Lower Brazos River Floodplain Protection Planning Study

Exhibit G-7 Bank Station Changes Between 2006 and 2017

1 of 4

- USGS Gauge
 - Cross Section
 - Lateral Weir
 - Brazos River
 - Basin Limits
 - County Line
- Bank Changes
- Eroded Area
 - Deposit Area
 - No Change

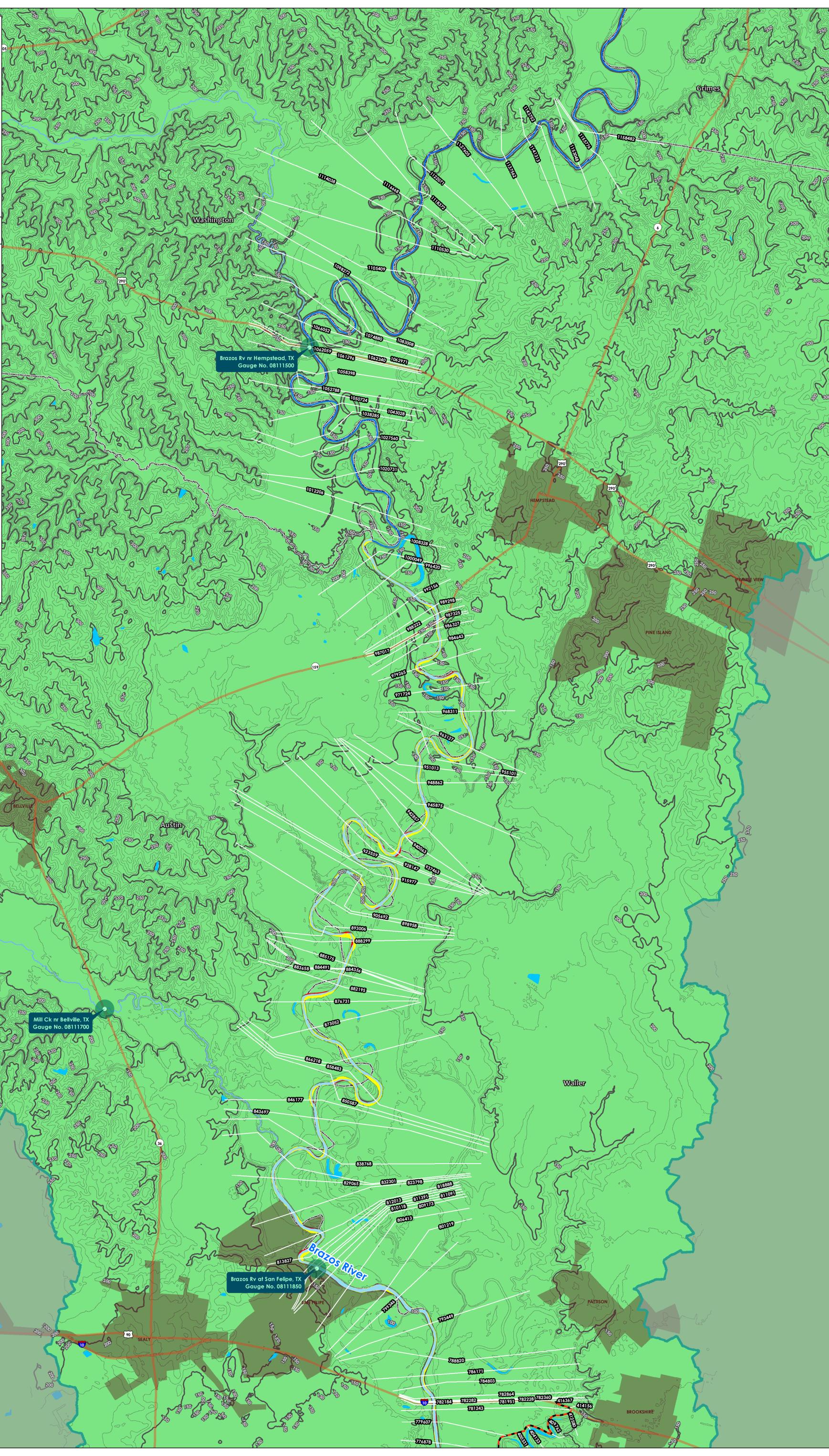


0 1 2 Miles

1 inch = 1 miles



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Brazos River Authority

Lower Brazos River Floodplain Protection Planning Study

Exhibit G-7 Bank Station Changes Between 2006 and 2017

3 of 4

- USGS Gauge
 - Cross Section
 - Lateral Weir
 - Levee
 - Brazos River
 - Basin Limits
 - County Line
- Bank Changes
- Eroded Area
 - Deposit Area
 - No Change

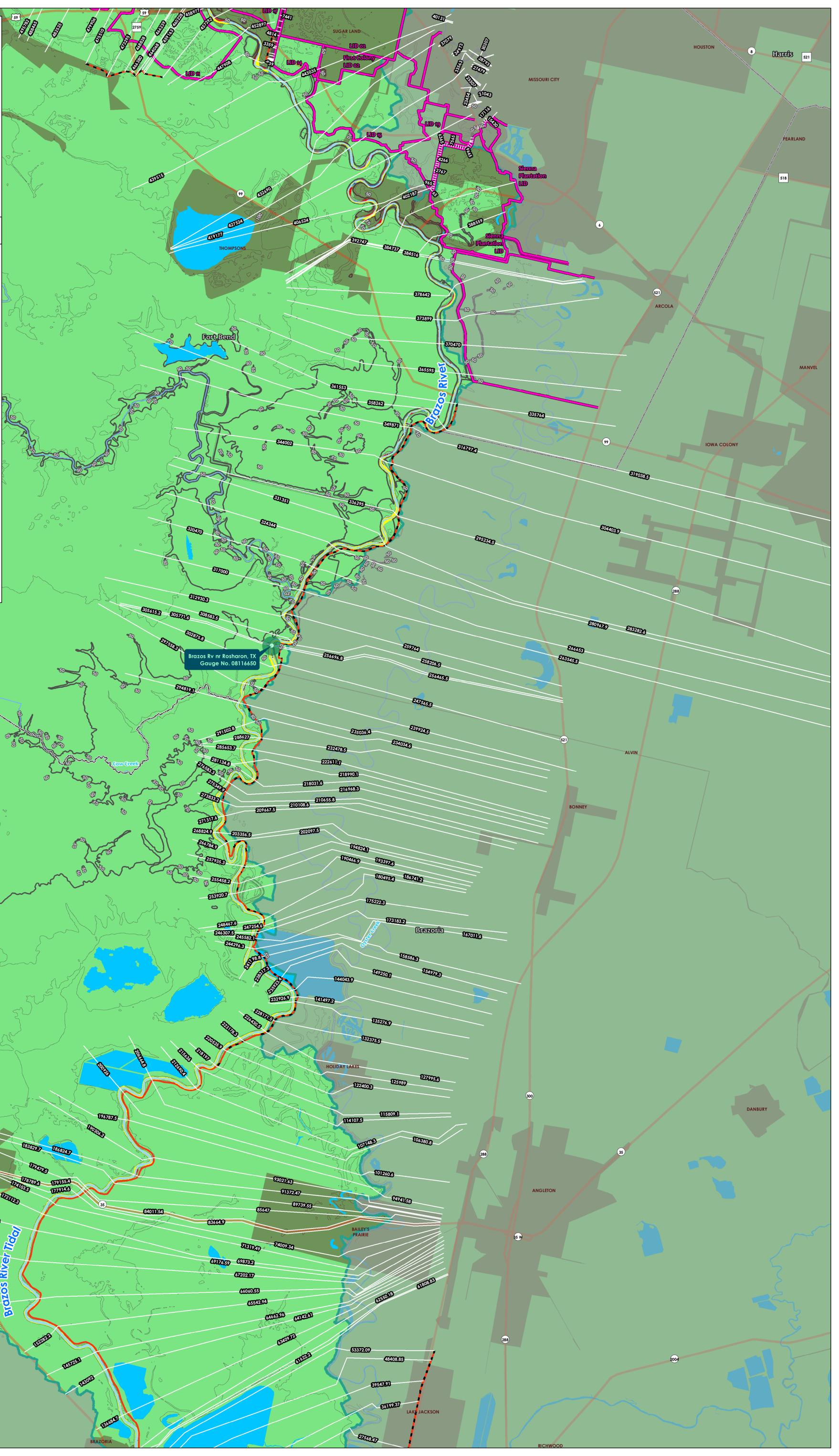


0 1 2 Miles

1 inch = 1 miles



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Brazos River Authority

Lower Brazos River Floodplain Protection Planning Study

Exhibit G-7 Bank Station Changes Between 2006 and 2017

4 of 4

- Cross Section
 - Lateral Weir
 - Brazos River
 - Basin Limits
 - County Line
- Bank Changes
- Eroded Area
 - Deposit Area
 - No Change

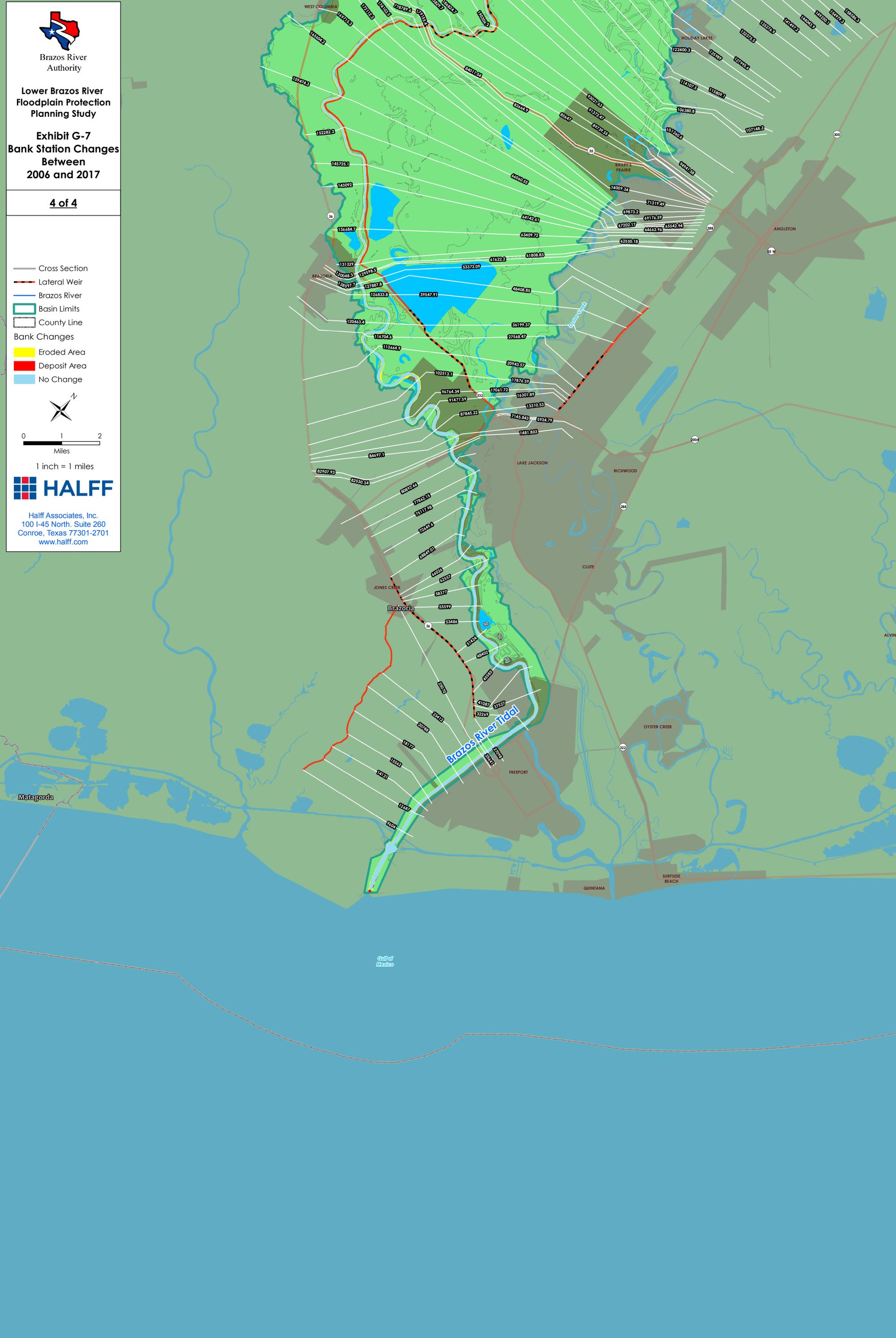


0 1 2 Miles

1 inch = 1 miles



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Brazos River
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Exhibit G-8 Large Scale Detention Comparisons

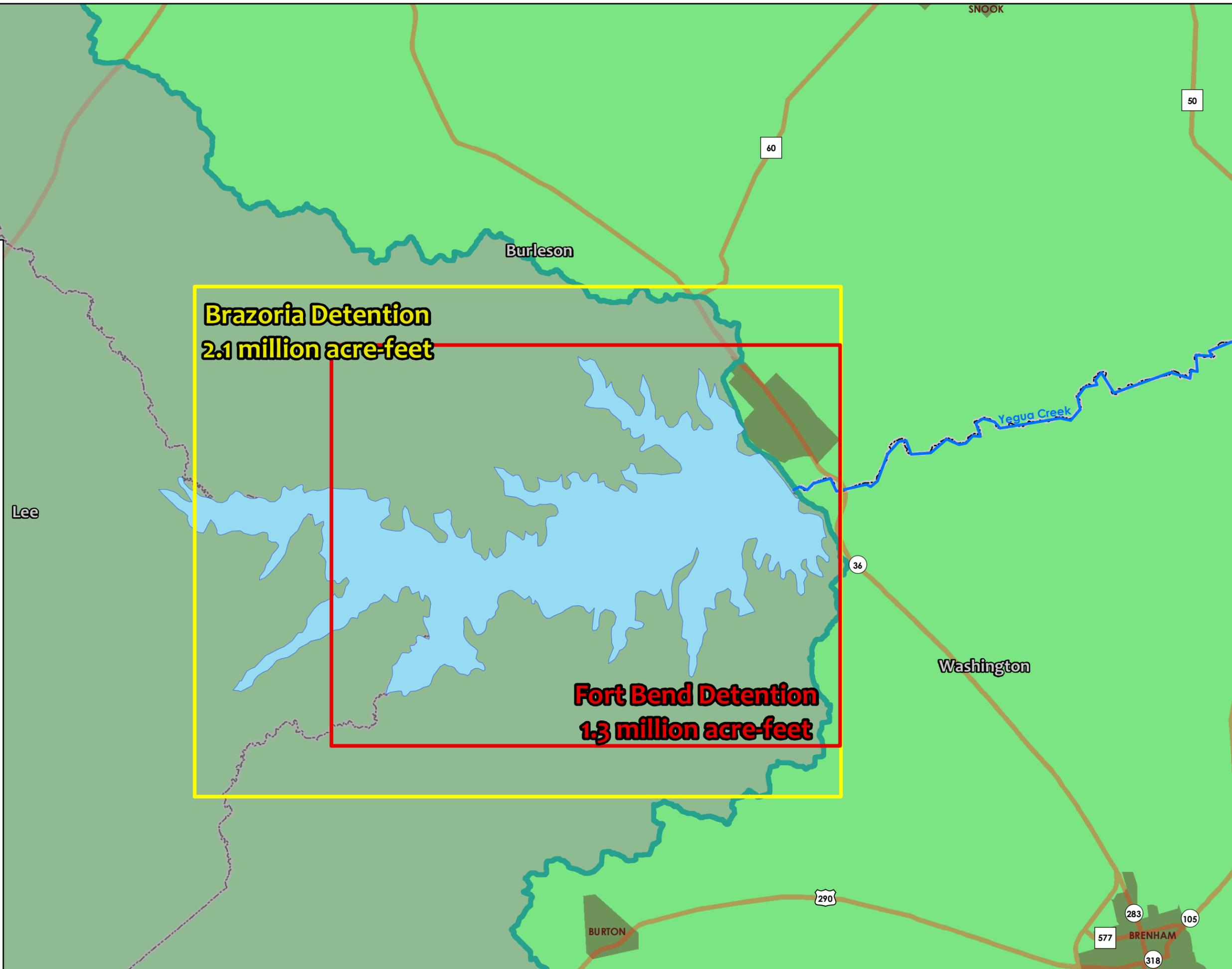
-  Channel
-  Lake Somerville
-  Basin Limits
-  County Limits



0 1 2 4

Miles

1 in = 2 miles





Brazos River
Authority

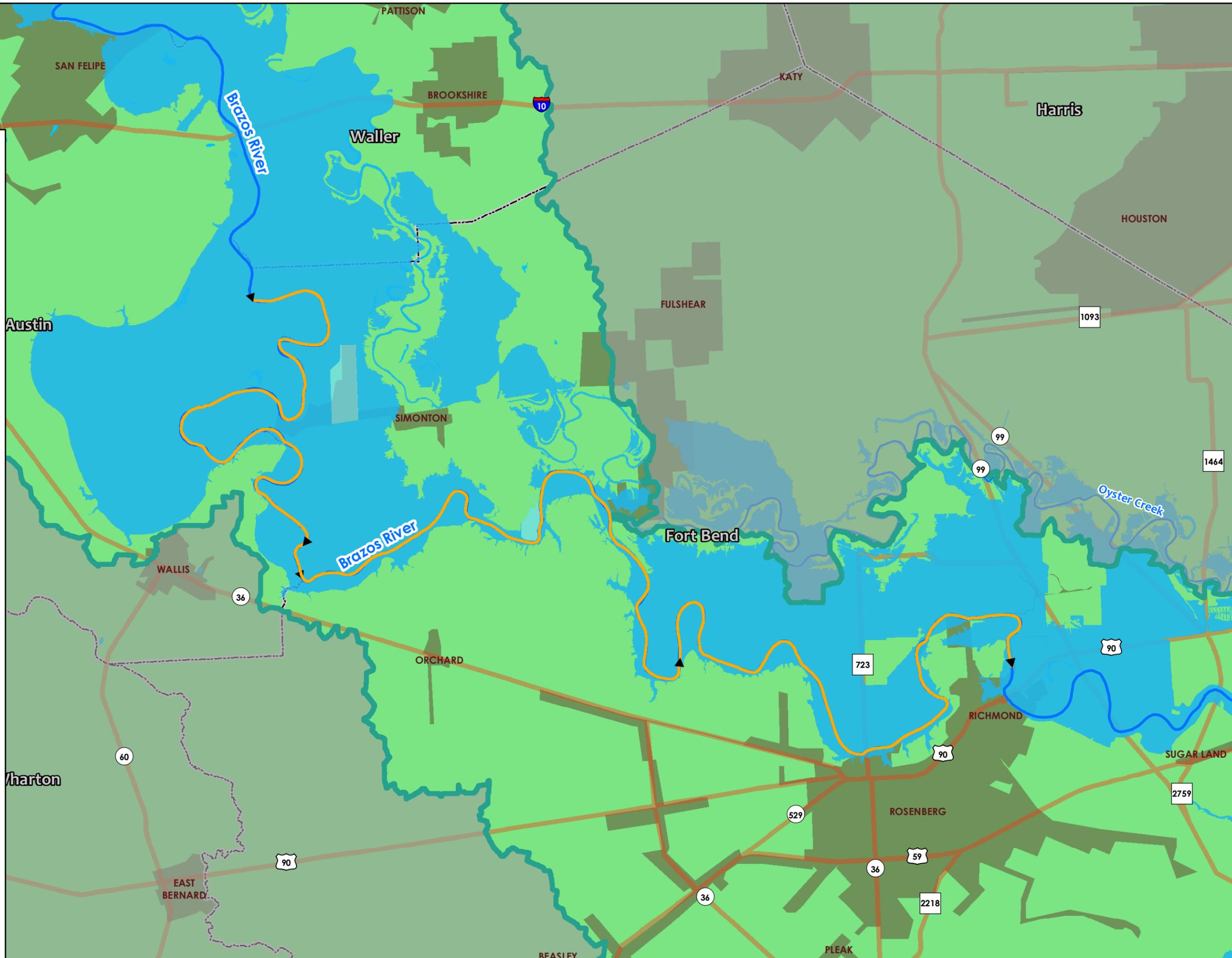
Exhibit G-9 Channelization in Fort Bend County

-  Channelization
-  Stream Centerline
-  Proposed 1% ACE Mapping
-  1% ACE Mapping Limits
-  Basin Limits
-  County Line



Miles

1 in = 2 miles





Brazos River
Authority

Exhibit G-10 Channelization in Brazoria County

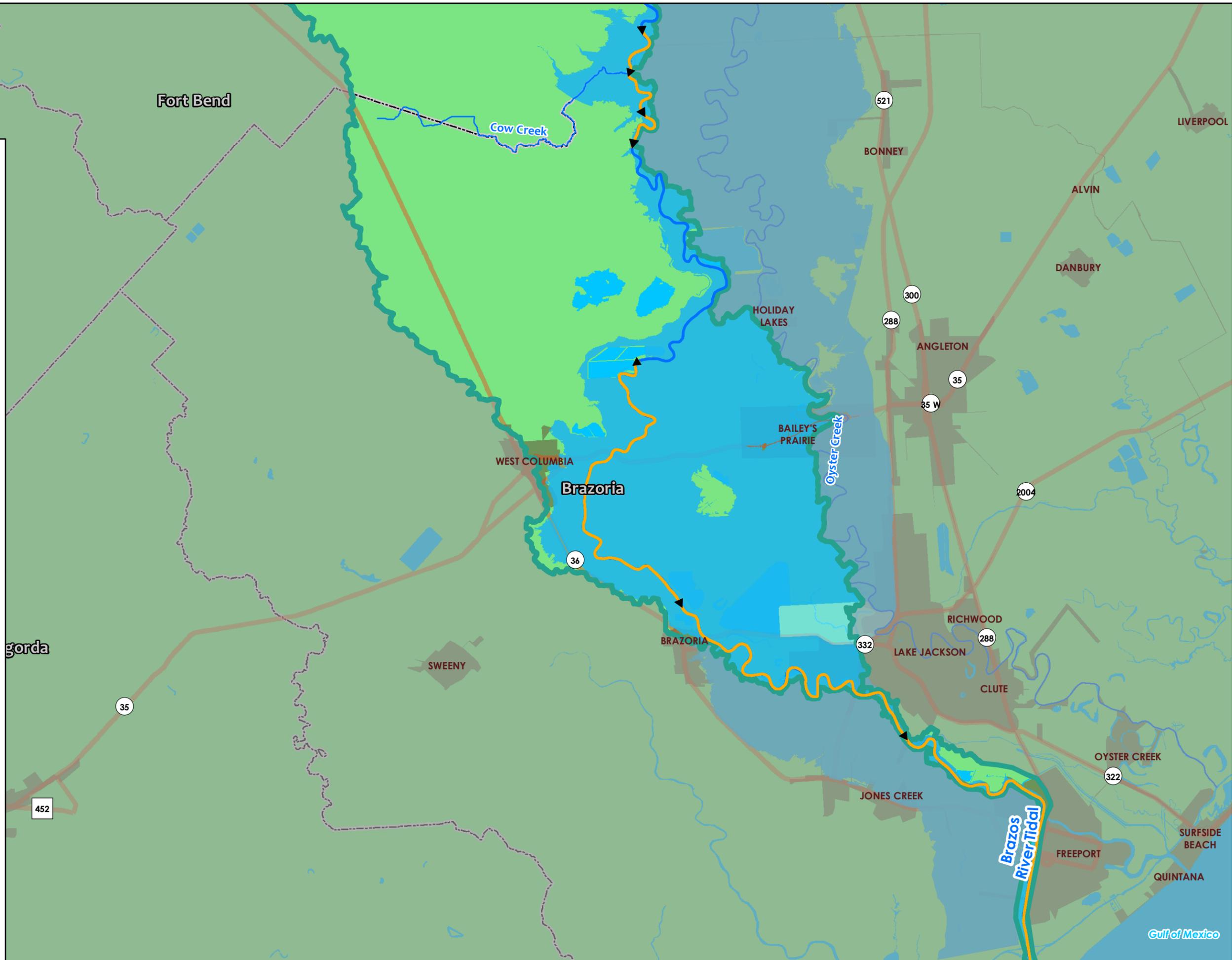
-  Channelization
-  Stream
Centerline
-  Proposed 1% ACE
Mapping
-  1% ACE Mapping
Limits
-  Basin Limits
-  County Line



0 1.5 3 6

Miles

1 in = 3 miles



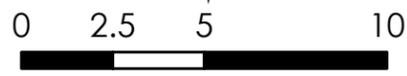
Gulf of Mexico



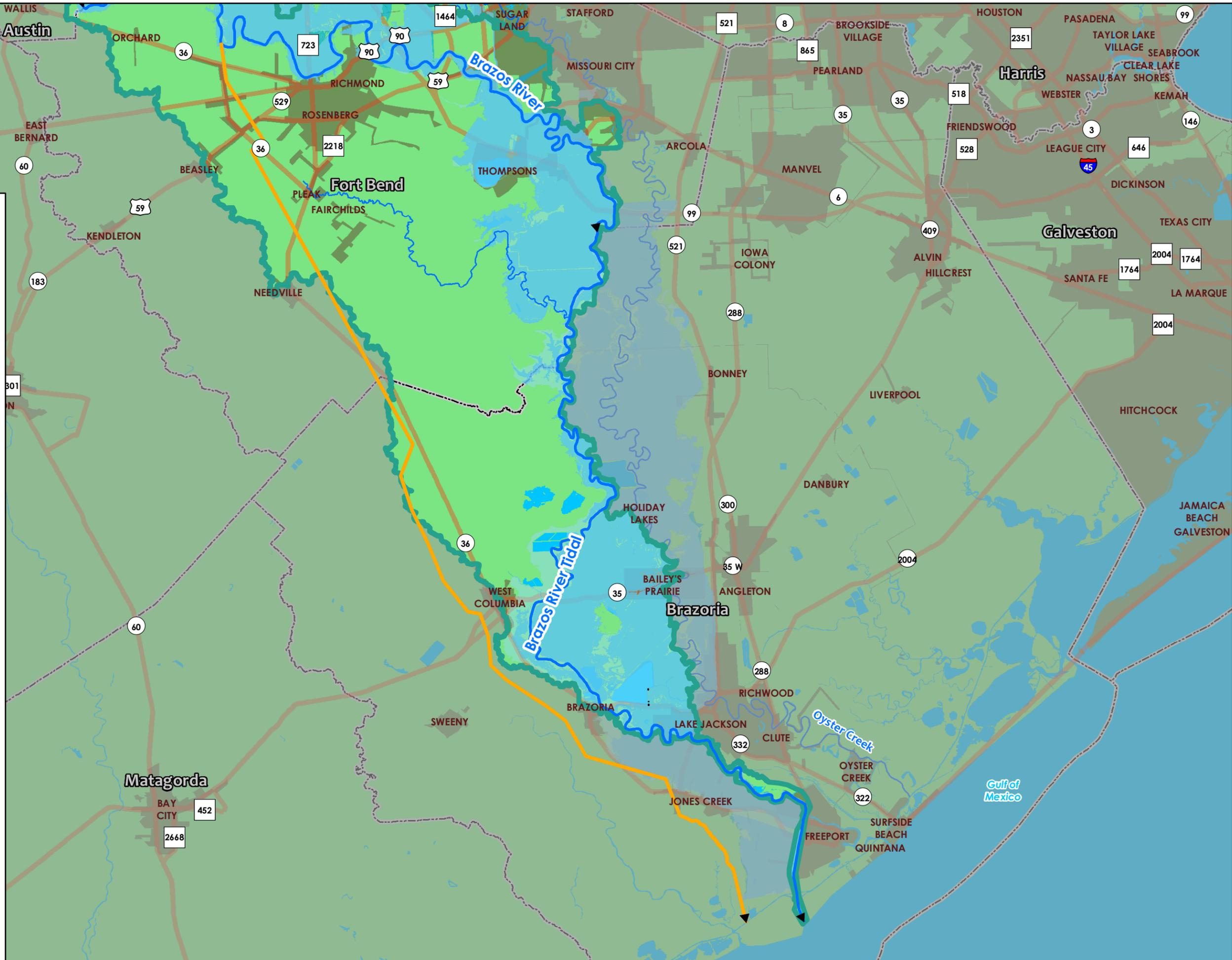
Brazos River
Authority

Exhibit G-11 Proposed Bypass Channel

-  Bypass
-  Stream Centerline
-  Basin Limits
-  1% ACE Mapping Limits
-  Proposed 1% ACE Inundation
-  County Line



Miles
1 inch = 5 miles





Brazos River
Authority

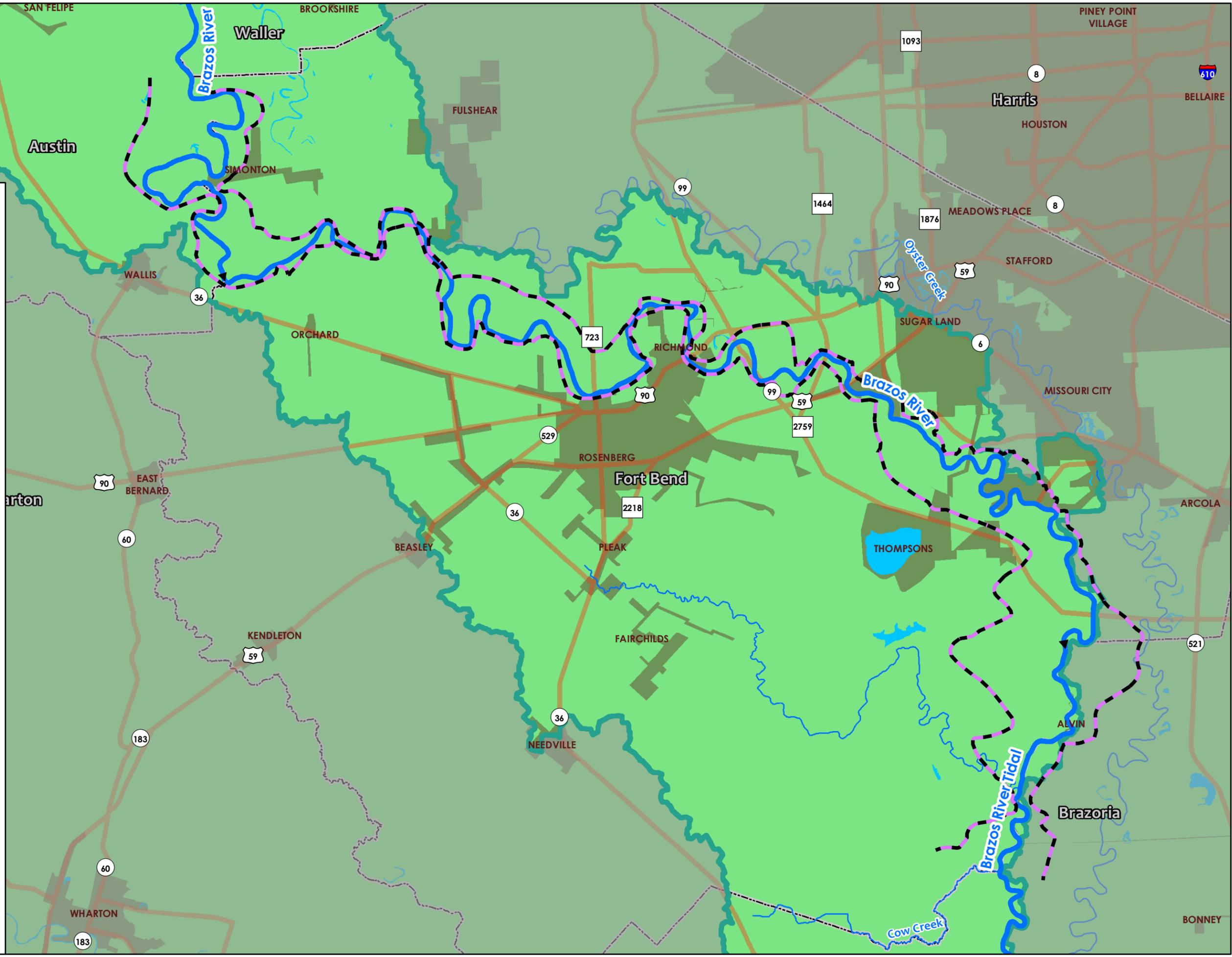
Exhibit G-12 Fort Bend County Development Line

- Fort Bend Effective Flow Boundary
- Brazos River Centerline
- Basin Limits
- County Line



0 1.5 3 6 Miles

1 in = 3 miles



Appendix G: Flood Mitigation Alternatives

Flood Mitigation Alternative Cost Estimates

ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - SIMONTON LEVEE

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Start-Up/Mobilization (Bonds, Insurance, Move-In, Sanitary Facilities)	LS	1	\$1,331,944	\$1,331,944
2	Utility Relocation	LS	1	\$799,167	\$799,167
3	Construction Staking	LF	23,700	\$3.75	\$88,875
4	General Site Preparation/Clearing and Grubbing	AC	61	\$20,000.00	\$1,220,000
5	Remove & Replace Fences	LF	11,500	\$15.00	\$172,500
6	Joint Storm Water Pollution Prevention Plan	LS	1	\$20,000.00	\$20,000
7	Erosion Control	LF	23,700	\$4.00	\$94,800
8	Hydromulch Seeding	AC	61	\$2,000.00	\$122,000
9	Levee Embankment & Inspection Trench	CY	350,000	\$25.00	\$8,750,000
10	Gravity Outlet Works	LF	150	\$550.00	\$82,500
11	Sluice Gate/Flap Gate Structure/Headwalls	LS	1	\$250,000.00	\$250,000
12	Pump Station (Based on internal drainage area)	AC	582	\$17,952.00	\$10,448,064
13	Sump Excavation - (Based on internal drainage area)	AC	582	\$6,453.00	\$3,755,646
14	Remove and Replace roadways over levee	SY	450	\$60.00	\$27,000
15	Levee/Maintenance Road	SY	40,000	\$40.00	\$1,600,000
16	Rock Riprap	CY	30	\$250.00	\$7,500
	Subtotal				\$28,769,996
	30% Construction Contingency				\$8,630,999
	20% Surveying, Engineering, Environmental Permitting				\$5,753,999
	4% Inspection Fees				\$1,150,800
	2% Testing				\$575,400
	Subtotal - Design and Construction				\$44,881,193
	Right-of-way Acquisition (Fee Simple)	SF	6,142,000	\$2.00	\$12,284,000
	Subtotal - Design, Construction, and ROW Acquisition				\$57,165,193
	Rounded Total				\$57,200,000

This statement was prepared utilizing standard cost estimate practices based on preliminary feasibility level concepts. It is understood and agreed that this is an estimate only, and that Engineer shall not be liable to Owner or to a third party for any failure to accurately estimate the cost of the project, or any part thereof. More detailed planning and design (beyond the scope of the current project) would be required to refine the cost estimate.

ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - WESTON LAKES LEVEE (BRAZOS RIVER)

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Start-Up/Mobilization (Bonds, Insurance, Move-In, Sanitary Facilities)	LS	1	\$214,158	\$214,158
2	Utility Relocation	LS	1	\$128,495	\$128,495
3	Construction Staking	LF	10,600	\$3.75	\$39,750
4	General Site Preparation/Clearing and Grubbing	AC	24	\$20,000.00	\$480,000
5	Remove & Replace Fences	LF	6,000	\$15.00	\$90,000
6	Joint Storm Water Pollution Prevention Plan	LS	1	\$20,000.00	\$20,000
7	Erosion Control	LF	10,600	\$4.00	\$42,400
8	Hydromulch Seeding	AC	24	\$2,000.00	\$48,000
9	Levee Embankment & Inspection Trench	CY	100,900	\$25.00	\$2,522,500
10	Gravity Outlet Works	LF	150	\$550.00	\$82,500
11	Sluice Gate/Flap Gate Structure/Headwalls	LS	1	\$250,000.00	\$250,000
12	Pump Station (Based on internal drainage area)	AC	0	\$17,952.00	\$0
13	Sump Excavation - (Based on internal drainage area)	AC	0	\$6,453.00	\$0
14	Remove and Replace roadways over levee	SY	0	\$60.00	\$0
15	Levee/Maintenance Road	SY	17,700	\$40.00	\$708,000
16	Rock Riprap	CY	0	\$250.00	\$0
	Subtotal				\$4,625,802
	30% Construction Contingency				\$1,387,741
	20% Surveying, Engineering, Environmental Permitting				\$925,160
	4% Inspection Fees				\$185,032
	2% Testing				\$92,516
	Subtotal - Design and Construction				\$7,216,251
	Right-of-way Acquisition (Fee Simple)	SF	1,041,000	\$2.00	\$2,082,000
	Subtotal - Design, Construction, and ROW Acquisition				\$9,298,251
	Rounded Total				\$9,300,000

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ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - WESTON LAKES LEVEE (BESSIES CREEK)

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Start-Up/Mobilization (Bonds, Insurance, Move-In, Sanitary Facilities)	LS	1	\$133,751	\$133,751
2	Utility Relocation	LS	1	\$80,251	\$80,251
3	Construction Staking	LF	5,100	\$3.75	\$19,125
4	General Site Preparation/Clearing and Grubbing	AC	13	\$20,000.00	\$260,000
5	Remove & Replace Fences	LF	0	\$15.00	\$0
6	Joint Storm Water Pollution Prevention Plan	LS	1	\$20,000.00	\$20,000
7	Erosion Control	LF	5,100	\$4.00	\$20,400
8	Hydromulch Seeding	AC	13	\$2,000.00	\$26,000
9	Levee Embankment & Inspection Trench	CY	74,300	\$25.00	\$1,857,500
10	Gravity Outlet Works	LF	0	\$550.00	\$0
11	Sluice Gate/Flap Gate Structure/Headwalls	LS	0	\$250,000.00	\$0
12	Pump Station (Based on internal drainage area)	AC	0	\$17,952.00	\$0
13	Sump Excavation - (Based on internal drainage area)	AC	0	\$6,453.00	\$0
14	Remove and Replace roadways over levee	SY	2,200	\$60.00	\$132,000
15	Levee/Maintenance Road	SY	8,500	\$40.00	\$340,000
16	Rock Riprap	CY	0	\$250.00	\$0
	Subtotal				\$2,889,027
	30% Construction Contingency				\$866,708
	20% Surveying, Engineering, Environmental Permitting				\$577,805
	4% Inspection Fees				\$115,561
	2% Testing				\$57,781
	Subtotal - Design and Construction				\$4,506,882
	Right-of-way Acquisition (Fee Simple)	SF	570,000	\$2.00	\$1,140,000
	Subtotal - Design, Construction, and ROW Acquisition				\$5,646,882
	Rounded Total				\$5,700,000

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ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - COLUMBIA LAKES LEVEE

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Start-Up/Mobilization (Bonds, Insurance, Move-In, Sanitary Facilities)	LS	1	\$258,237	\$258,237
2	Utility Relocation	LS	1	\$154,942	\$154,942
3	Construction Staking	LF	16,740	\$3.75	\$62,775
4	General Site Preparation/Clearing and Grubbing	AC	20	\$20,000.00	\$400,000
5	Remove & Replace Fences	LF	0	\$15.00	\$0
6	Joint Storm Water Pollution Prevention Plan	LS	1	\$20,000.00	\$20,000
7	Erosion Control	LF	16,740	\$4.00	\$66,960
8	Hydromulch Seeding	AC	20	\$2,000.00	\$40,000
9	Levee Embankment & Inspection Trench	CY	136,400	\$25.00	\$3,410,000
10	Gravity Outlet Works	LF	0	\$550.00	\$0
11	Sluice Gate/Flap Gate Structure/Headwalls	LS	0	\$250,000.00	\$0
12	Pump Station (Based on internal drainage area)	AC	0	\$17,952.00	\$0
13	Sump Excavation - (Based on internal drainage area)	AC	0	\$6,453.00	\$0
14	Remove and Replace roadways over levee	SY	750	\$60.00	\$45,000
15	Levee/Maintenance Road	SY	28,000	\$40.00	\$1,120,000
16	Rock Riprap	CY	0	\$250.00	\$0
	Subtotal				\$5,577,914
	30% Construction Contingency				\$1,673,374
	20% Surveying, Engineering, Environmental Permitting				\$1,115,583
	4% Inspection Fees				\$223,117
	2% Testing				\$111,558
	Subtotal - Design and Construction				\$8,701,546
	Right-of-way Acquisition (Fee Simple)	SF	535,680	\$2.00	\$1,071,360
	Subtotal - Design, Construction, and ROW Acquisition				\$9,772,906
	Rounded Total				\$9,800,000

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ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - OYSTER CREEK LEVEE

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Start-Up/Mobilization (Bonds, Insurance, Move-In, Sanitary Facilities)	LS	1	\$4,425,766	\$4,425,766
2	Utility Relocation	LS	1	\$2,655,460	\$2,655,460
3	Construction Staking	LF	48,667	\$3.75	\$182,501
4	General Site Preparation/Clearing and Grubbing	AC	122	\$20,000.00	\$2,440,000
5	Remove & Replace Fences	LF	2,000	\$15.00	\$30,000
6	Joint Storm Water Pollution Prevention Plan	LS	1	\$20,000.00	\$20,000
7	Erosion Control	LF	48,667	\$4.00	\$194,668
8	Hydromulch Seeding	AC	122	\$2,000.00	\$244,000
9	Levee Embankment & Inspection Trench	CY	890,178	\$25.00	\$22,254,450
10	Gravity Outlet Works	LF	150	\$550.00	\$82,500
11	Sluice Gate/Flap Gate Structure/Headwalls	LS	2	\$250,000.00	\$500,000
12	Pump Station (Based on internal drainage area)	AC	2,424	\$17,952.00	\$43,515,648
13	Sump Excavation - (Based on internal drainage area)	AC	2,424	\$6,453.00	\$15,642,072
14	Remove and Replace roadways over levee	SY	2,625	\$60.00	\$157,500
15	Levee/Maintenance Road	SY	81,112	\$40.00	\$3,244,480
16	Rock Riprap	CY	30	\$250.00	\$7,500
	Subtotal				\$95,596,545
	30% Construction Contingency				\$28,678,963
	20% Surveying, Engineering, Environmental Permitting				\$19,119,309
	4% Inspection Fees				\$3,823,862
	2% Testing				\$1,911,931
	Subtotal - Design and Construction				\$149,130,610
	Right-of-way Acquisition (Fee Simple)	SF	5,314,320	\$2.00	\$10,628,640
	Subtotal - Design, Construction, and ROW Acquisition				\$159,759,250
	Rounded Total				\$159,800,000

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ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - BULLHEAD BAYOU LEVEE

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Start-Up/Mobilization (Bonds, Insurance, Move-In, Sanitary Facilities)	LS	1	\$2,075,868	\$2,075,868
2	Utility Relocation	LS	1	\$1,245,521	\$1,245,521
3	Construction Staking	LF	26,174	\$3.75	\$98,153
4	General Site Preparation/Clearing and Grubbing	AC	68	\$20,000.00	\$1,360,000
5	Remove & Replace Fences	LF	531	\$15.00	\$7,965
6	Joint Storm Water Pollution Prevention Plan	LS	1	\$20,000.00	\$20,000
7	Erosion Control	LF	26,174	\$4.00	\$104,696
8	Hydromulch Seeding	AC	68	\$2,000.00	\$136,000
9	Levee Embankment & Inspection Trench	CY	517,539	\$25.00	\$12,938,475
10	Gravity Outlet Works	LF	150	\$550.00	\$82,500
11	Sluice Gate/Flap Gate Structure/Headwalls	LS	0	\$250,000.00	\$0
12	Pump Station (Based on internal drainage area)	AC	966	\$17,952.00	\$17,341,632
13	Sump Excavation - (Based on internal drainage area)	AC	966	\$6,453.00	\$6,233,598
14	Remove and Replace roadways over levee	SY	24,032	\$60.00	\$1,441,920
15	Levee/Maintenance Road	SY	43,623	\$40.00	\$1,744,920
16	Rock Riprap	CY	30	\$250.00	\$7,500
	Subtotal				\$44,838,747
	30% Construction Contingency				\$13,451,624
	20% Surveying, Engineering, Environmental Permitting				\$8,967,749
	4% Inspection Fees				\$1,793,550
	2% Testing				\$896,775
	Subtotal - Design and Construction				\$69,948,446
	Right-of-way Acquisition (Fee Simple)	SF	2,979,443	\$2.00	\$5,958,886
	Subtotal - Design, Construction, and ROW Acquisition				\$75,907,332
	Rounded Total				\$75,900,000

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ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - FORT BEND LARGE SCALE DETENTION

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Detention Excavation	CY	2,083,045,653	\$15.00	\$31,245,684,795
2	General Site Preparation/Clearing and Grubbing	AC	65,000	\$20,000.00	\$1,300,000,000
3	Channel Connection at Outfall	EA	1	\$300,000.00	\$300,000
4	Construction Staking	LF	216,480	\$3.75	\$811,800
5	Erosion Control	LF	216,480	\$4.00	\$865,920
6	Dam and Outlet Structures - Based on Lake Somerville	LS	1	#####	\$998,000,000
7	Care of Water	LS	1	\$50,000.00	\$50,000
8	Mobilization (10%)	LS	1		\$0
	Subtotal				\$33,545,712,515
	40% Construction Contingency				\$46,963,997,521
	20% Surveying, Engineering, Environmental Permitting				\$6,709,142,503
	4% Inspection Fees				\$1,341,828,501
	2% Testing				\$670,914,250
	Subtotal - Design and Construction				\$89,231,595,290
	Right-of-way Acquisition (Fee Simple)	SF	2,831,400,000	\$2.00	\$5,662,800,000
	Subtotal - Design, Construction, and ROW Acquisition				\$94,894,395,290
	Rounded Total				\$94,900,000,000

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ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - BRAZORIA LARGE SCALE DETENTION

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Detention Excavation	CY	3,420,231,173	\$15.00	\$51,303,467,595
2	General Site Preparation/Clearing and Grubbing	AC	105,005	\$20,000.00	\$2,100,100,000
3	Channel Connection at Outfall	EA	1	\$300,000.00	\$300,000
4	Construction Staking	LF	274,560	\$3.75	\$1,029,600
5	Erosion Control	LF	274,560	\$4.00	\$1,098,240
6	Dam and Outlet Structures - Based on Lake Somerville	LS	1	#####	\$998,000,000
7	Care of Water	LS	1	\$50,000.00	\$50,000
8	Mobilization (10%)	LS	1		\$0
	Subtotal				\$54,404,045,435
	40% Construction Contingency				\$76,165,663,609
	20% Surveying, Engineering, Environmental Permitting				\$10,880,809,087
	4% Inspection Fees				\$2,176,161,817
	2% Testing				\$1,088,080,909
	Subtotal - Design and Construction				\$144,714,760,857
	Right-of-way Acquisition (Fee Simple)	SF	4,574,011,222	\$2.00	\$9,148,022,444
	Subtotal - Design, Construction, and ROW Acquisition				\$153,862,783,301
	Rounded Total				\$153,900,000,000

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ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - FORT BEND CHANNELIZATION

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Channel Excavation	CY	1,700,000,000	\$15.00	\$25,500,000,000
2	General Site Preparation/Clearing and Grubbing	AC	2,465	\$20,000.00	\$49,300,000
3	Construction Staking	LF	506,402	\$3.75	\$1,899,008
4	Erosion Control	LF	506,402	\$4.00	\$2,025,608
5	Hydromulch Seeding	SY	32,353,461	\$2,000.00	\$64,706,922,000
6	Soil Retention Blankets	SY	32,353,461	\$6.00	\$194,120,766
7	Care of Water	LS	1	\$50,000.00	\$50,000
8	Bridge Modifications at Structure Crossings	EA	3		\$0
9	Mobilization (10%)	LS	1		\$0
	Subtotal				\$90,454,317,382
	40% Construction Contingency				\$126,636,044,334
	20% Surveying, Engineering, Environmental Permitting				\$18,090,863,476
	4% Inspection Fees				\$3,618,172,695
	2% Testing				\$1,809,086,348
	Subtotal - Design and Construction				\$240,608,484,235
	Right-of-way Acquisition (Fee Simple)	SF	282,319,115	\$2.00	\$564,638,230
	Subtotal - Design, Construction, and ROW Acquisition				\$241,173,122,465
	Rounded Total				\$241,200,000,000

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ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - BRAZORIA CHANNELIZATION

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Channel Excavation	CY	1,760,000,000	\$15.00	\$26,400,000,000
2	General Site Preparation/Clearing and Grubbing	AC	2,301	\$20,000.00	\$46,020,000
3	Construction Staking	LF	472,828	\$3.75	\$1,773,105
4	Erosion Control	LF	472,828	\$4.00	\$1,891,312
5	Hydromulch Seeding	SY	30,208,455	\$2,000.00	\$60,416,910,000
6	Soil Retention Blankets	SY	30,208,455	\$6.00	\$181,250,730
7	Care of Water	LS	1	\$50,000.00	\$50,000
8	Bridge Modifications at Structure Crossings	EA	4		\$0
9	Mobilization (10%)	LS	1		\$0
	Subtotal				\$87,047,895,147
	40% Construction Contingency				\$121,867,053,206
	20% Surveying, Engineering, Environmental Permitting				\$17,409,579,029
	4% Inspection Fees				\$3,481,915,806
	2% Testing				\$1,740,957,903
	Subtotal - Design and Construction				\$231,547,401,091
	Right-of-way Acquisition (Fee Simple)	SF	263,601,610	\$2.00	\$527,203,220
	Subtotal - Design, Construction, and ROW Acquisition				\$232,074,604,311
	Rounded Total				\$232,100,000,000

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ENGINEERS ESTIMATE OF PROBABLE CONSTRUCTION COST - BYPASS CHANNEL

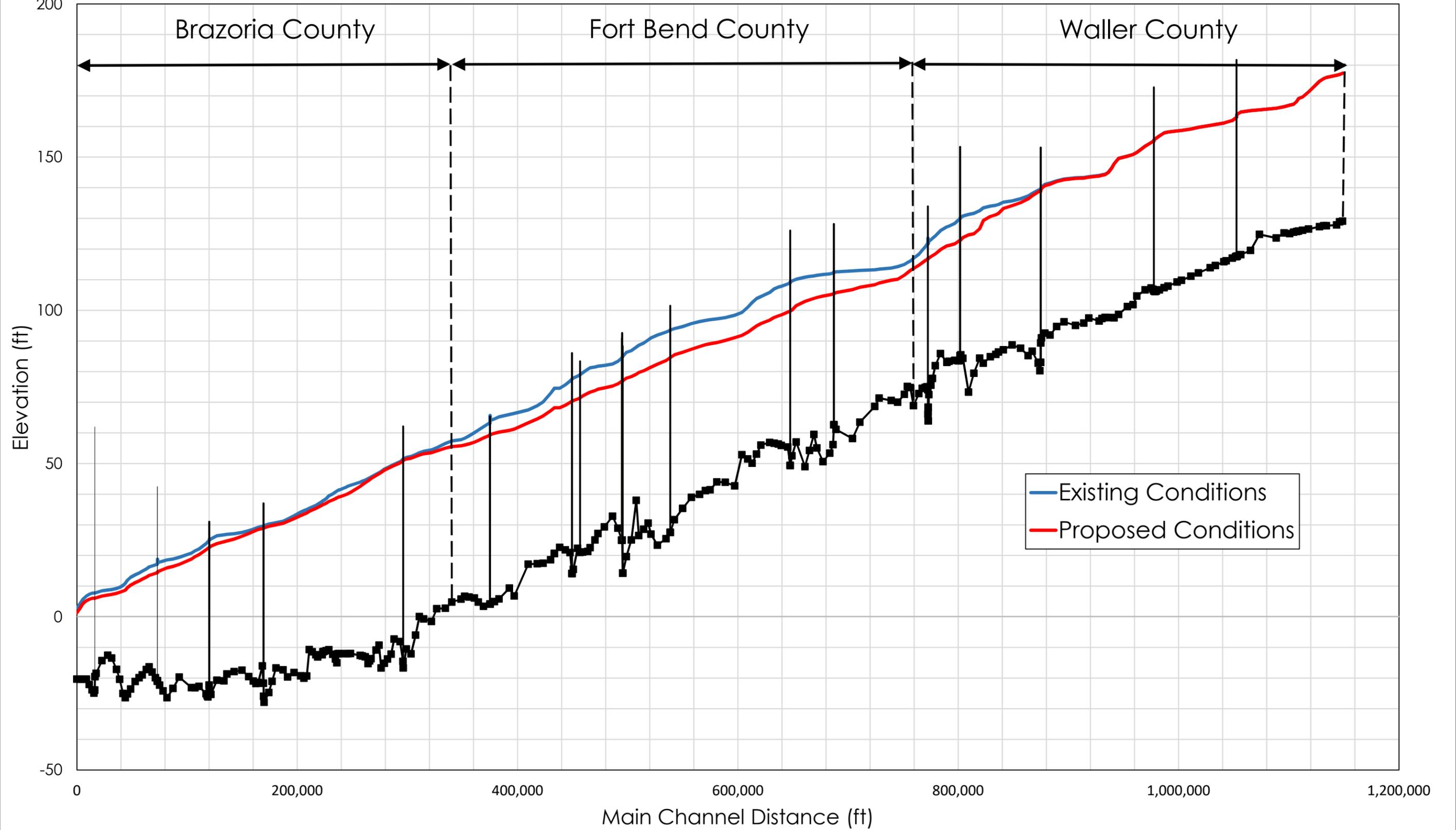
Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Channel Excavation	CY	117,291,689	\$15.00	\$1,759,375,333
2	General Site Preparation/Clearing and Grubbing	AC	6,700	\$20,000.00	\$134,000,000
3	Construction Staking	LF	620,956	\$3.75	\$2,328,585
4	Erosion Control	LF	620,956	\$4.00	\$2,483,824
5	Hydromulch Seeding	SY	31,116,795	\$2,000.00	\$62,233,590,000
6	Soil Retention Blankets	SY	31,116,795	\$6.00	\$186,700,770
7	Care of Water	LS	1	\$50,000.00	\$50,000
8	Mobilization (10%)	LS	1		\$0
	Subtotal				\$64,318,528,512
	40% Construction Contingency				\$90,045,939,917
	20% Surveying, Engineering, Environmental Permitting				\$12,863,705,702
	4% Inspection Fees				\$2,572,741,140
	2% Testing				\$1,286,370,570
	Subtotal - Design and Construction				\$171,087,285,843
	Right-of-way Acquisition (Fee Simple)	SF	291,849,320	\$2.00	\$583,698,640
	Subtotal - Design, Construction, and ROW Acquisition				\$171,670,984,483
	Rounded Total				\$171,700,000,000

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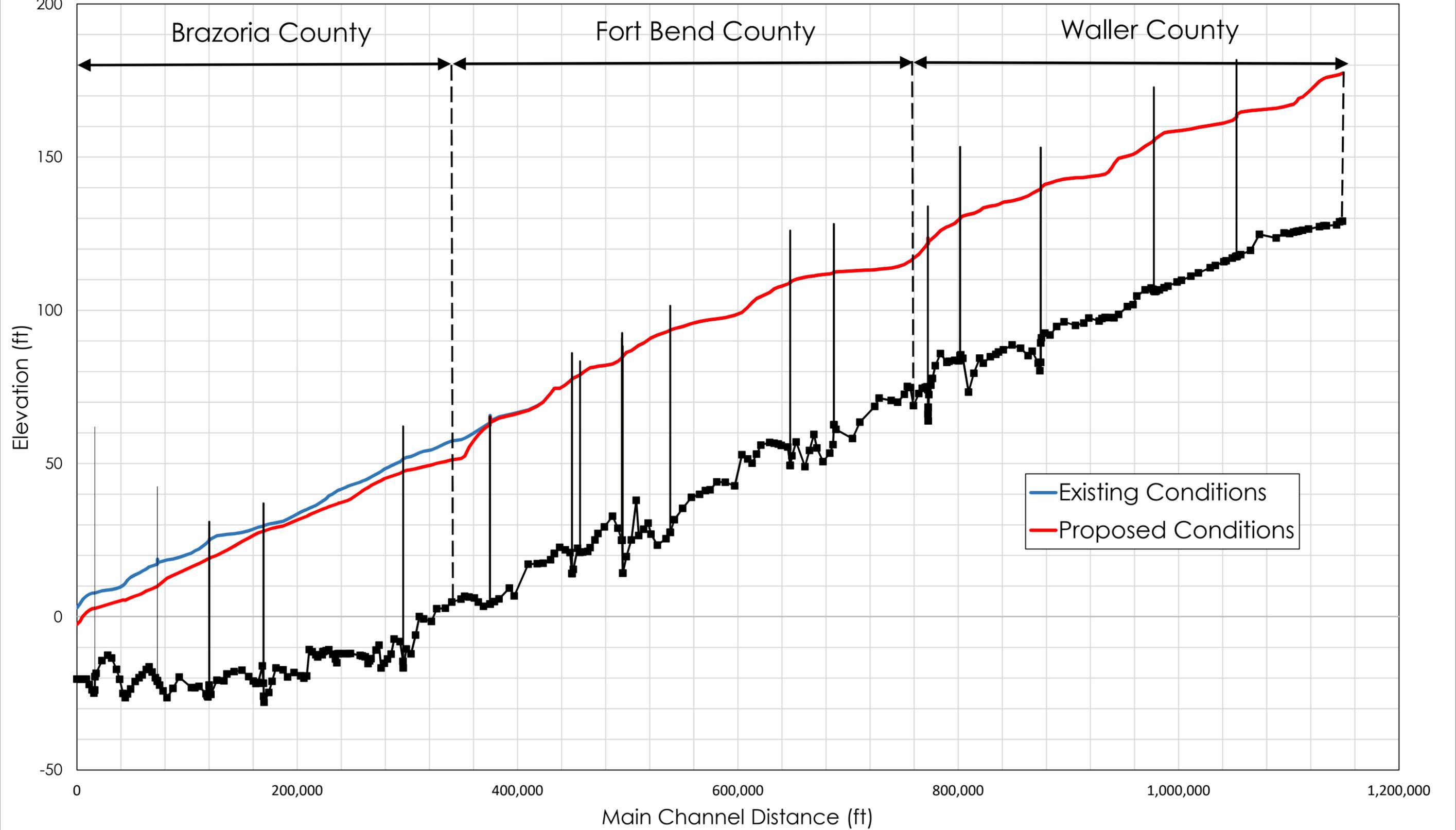
Appendix G: Flood Mitigation Alternatives

Large Scale Detention Hydraulic Profile Comparisons

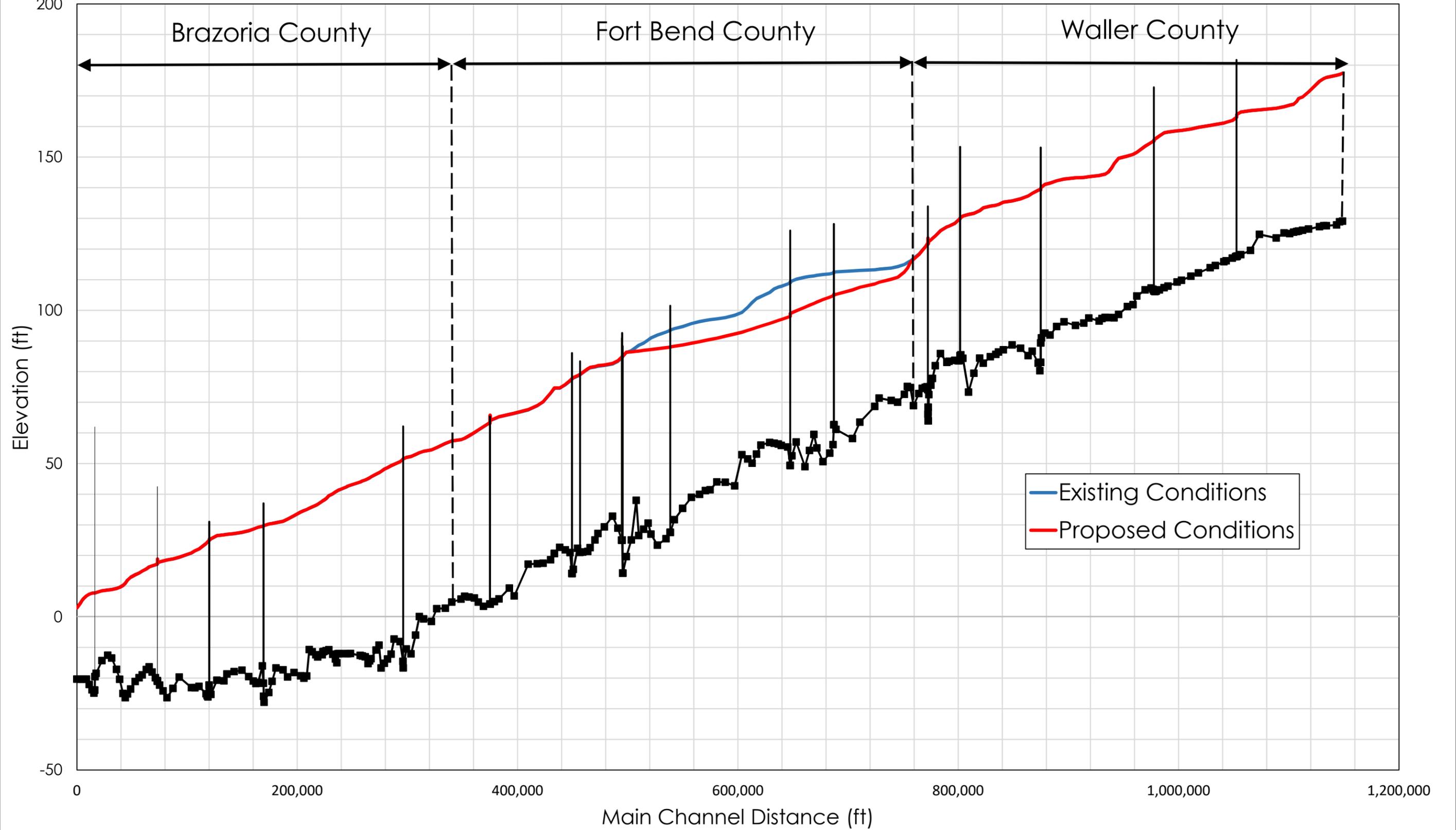
Waller County Large Scale Detention Comparisons (1% ACE)



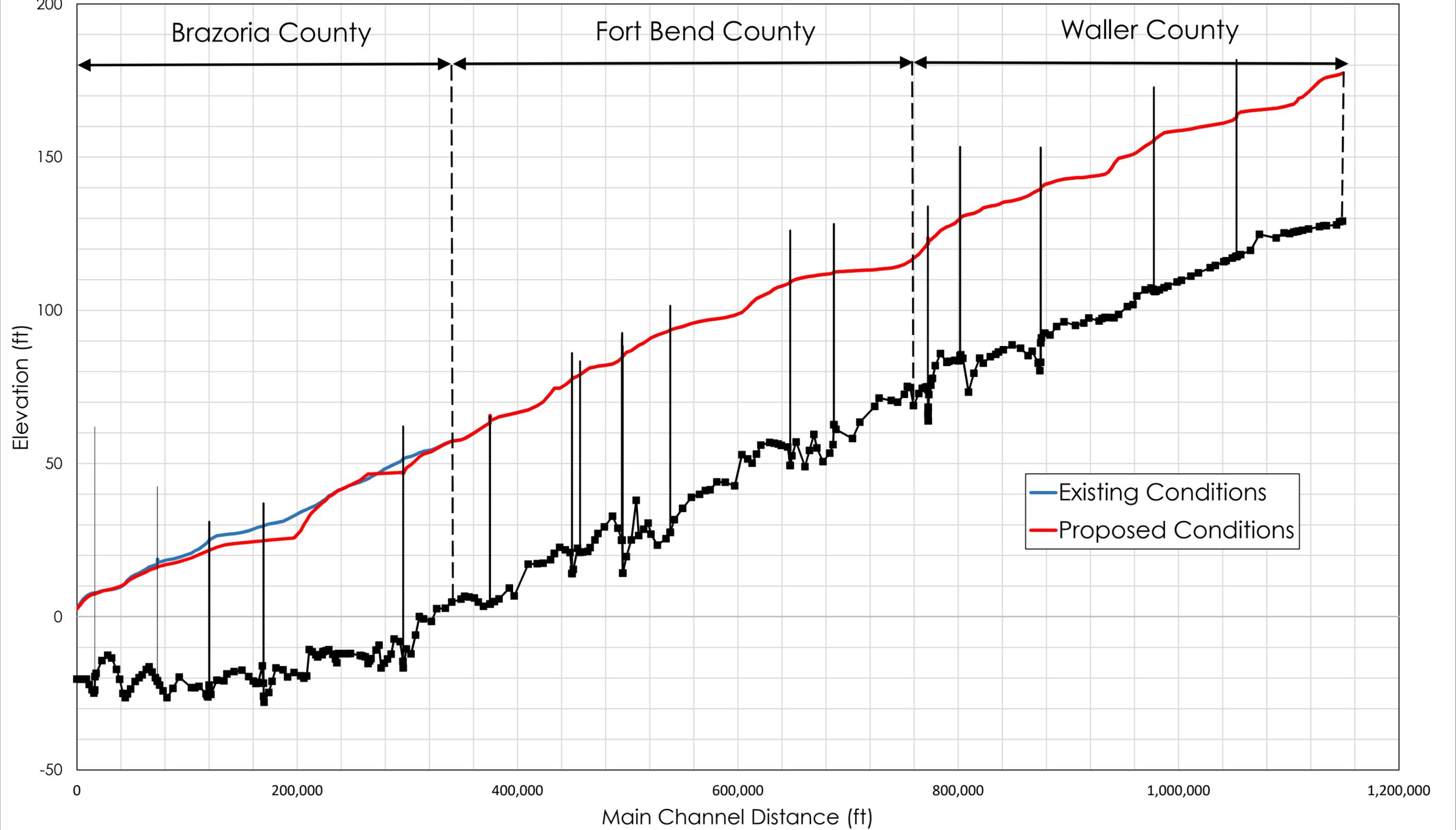
Brazoria County Large Scale Detention Comparisons (1% ACE)



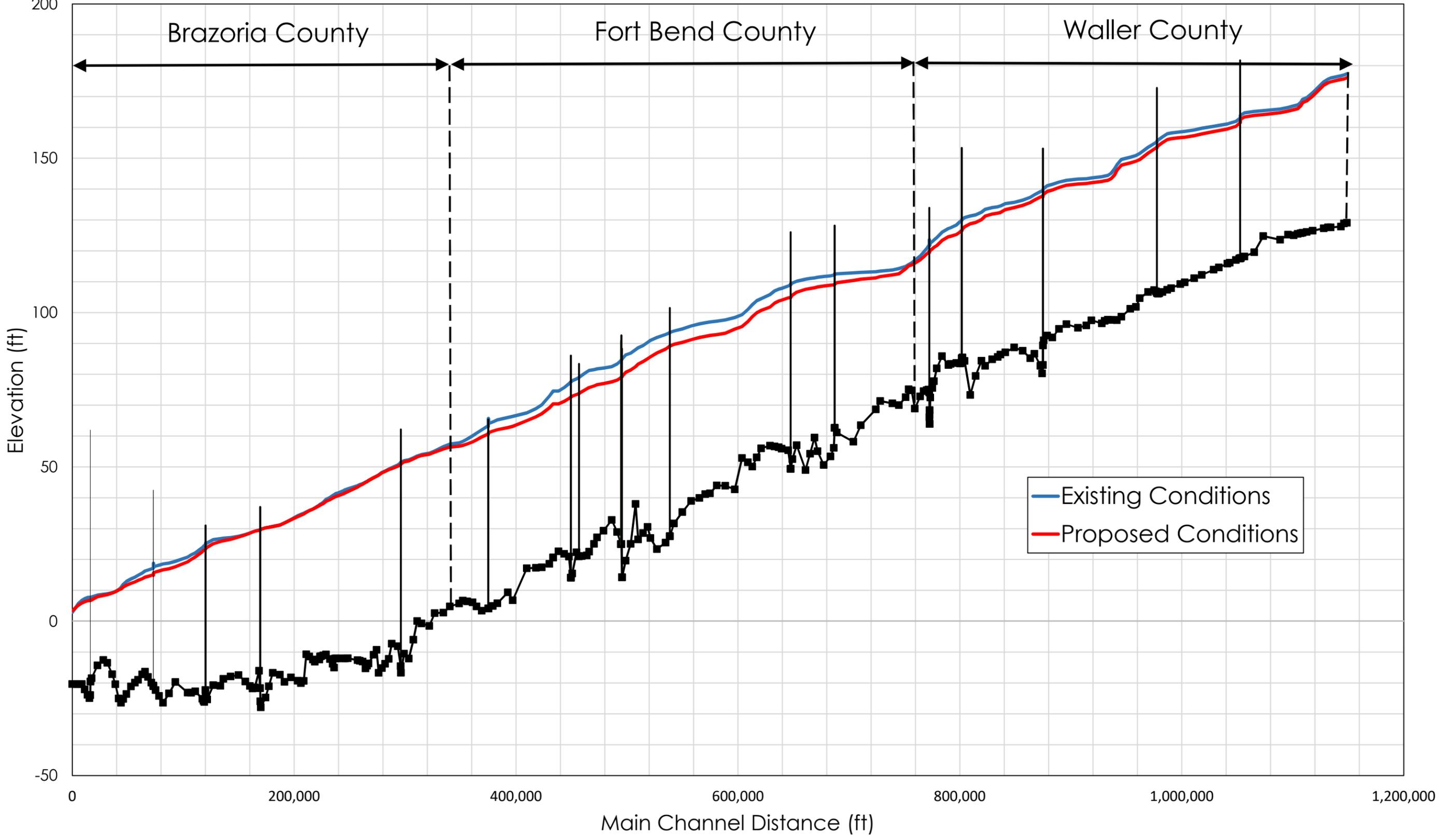
Fort Bend Channelization Comparisons (1% ACE)



Brazoria Channelization Comparisons (1% ACE)



Bypass Channel Comparisons (1% ACE)



Fort Bend Effective Flow Boundary Comparisons (1% ACE)

