TIRZ 21 Drainage Study

Prepared for:

NEAR NORTHSIDE
REDEVELOPMENT AUTHORITY

Tax Increment Reinvestment Zone 21

Prepared By:

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ENGINEERING

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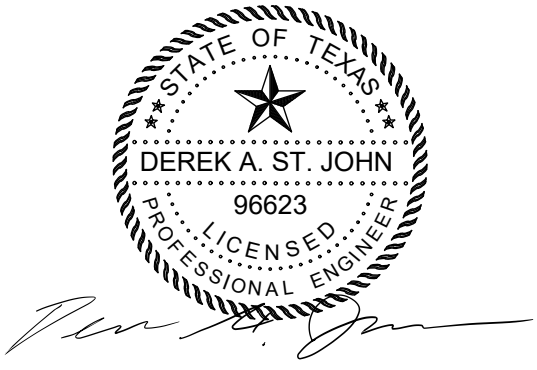

12/20/2021

December 2021

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1.0 INTRODUCTION

The Tax Increment Reinvestment Zone (TIRZ) 21 in Houston, Texas, has contracted with Gauge Engineering to develop a Capital Improvement Plan (CIP) that prioritizes future infrastructure improvements in the TIRZ. As part of this effort, a drainage analysis was performed to evaluate future potential drainage projects and priorities that can be incorporated into the TIRZ 21 Capital Improvements Plan. In addition to defining drainage focused capital projects, the drainge analysis also sets the foundation for drainage in the area by establishing where and why we have drainage issues, and it provides a roadmap for the drainage component of all future capital projects within the TIRZ.

TIRZ 21 is located just north of Downtown Houston, and the study area includes commercial, industrial, and residential properties. **Exhibit 1** shows the Study Area Map, and **Figure 1** shows the TIRZ 21 boundary. The study area is located north of Buffalo Bayou and east of Little White Oak Bayou upstream of where these two bayous join. While the area topography, in general, slopes from north to south, local runoff is often impeded by nearby highways and rail lines that act as overland flow barriers and drainage area boundaries. This drainage study is focused on understanding these issues and developing effective solutions to reduce their associated flood risk.

Local historical flooding in the TIRZ 21 area is the result of both local sheet flow and riverine flooding from Little White Oak Bayou. Riverine flooding from Little White Oak Bayou has been extensively evaluated through recent HCFCD and TxDOT studies. Projects are underway to reduce riverine flood risk including an HCFCD bond project for Little White Oak Bayou and the joint TxDOT/HCFCD/City North Canal project. Additionally, Segment II of the TxDOT NHHIP project will replace the existing IH-45 box culvert crossings or Little White Oak Bayou with more hydraulically efficient bridge structures. In conjunction with the North Canal project, the NHHIP improvements will greatly reduce riverine flood risk for the study area. The combination of the North Canal project and the NHHIP project will also improve the efficiency of the drainage infrastructure within our study area that outfall to Little White Oak Bayou by reducing the bayou water surface elevation (WSEL) that our drainage systems push against when discharging.

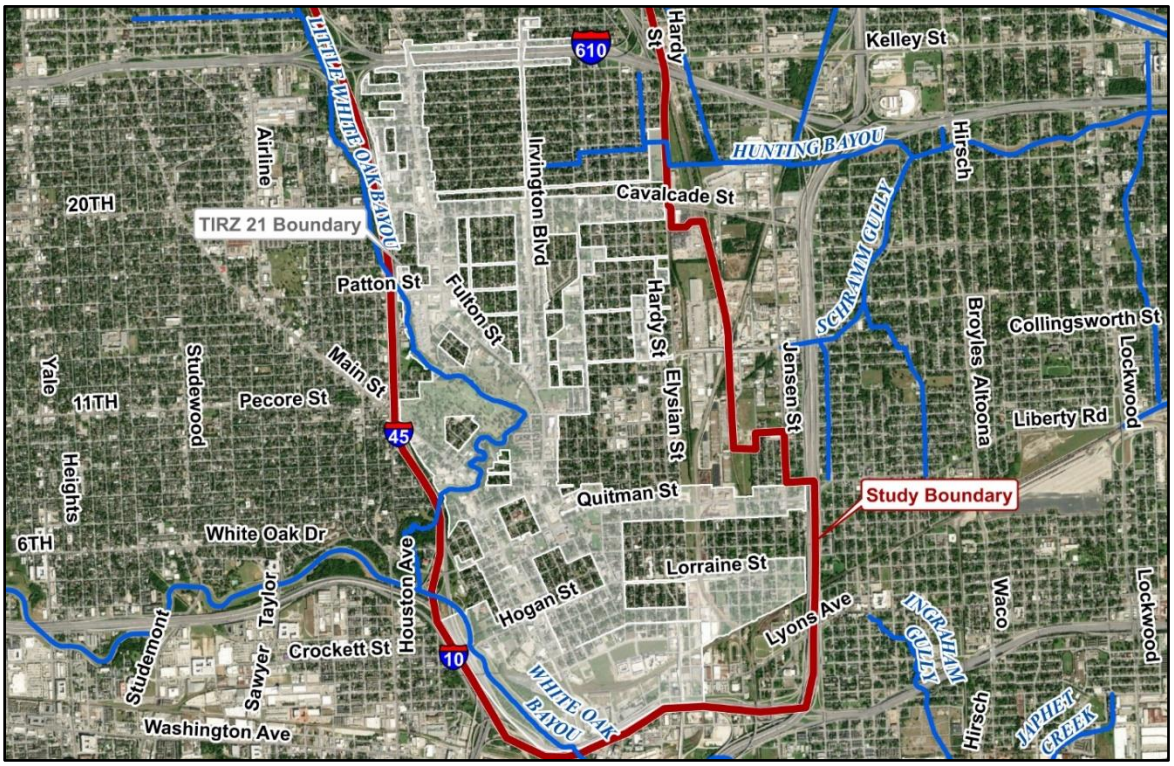


Figure 1 - TIRZ 21 Boundary

2.0 METHODOLOGY

This study focuses on the local drainage issues including ditch and storm sewer capacity and overland sheet flow. The TIRZ 21 area was evaluated using a two-dimensional (2D) rain-on-grid model for the TIRZ 21 boundary and the watershed draining to it. The existing conditions 2D model utilized Innovyze's Infoworks ICM software and including the following features:

- The latest Atlas 14 rainfall data for the 100-year storm event.
- A ground model representing the best available 2018 LiDAR elevations.
- Landuse polygons representing the streets, developments, parks, and rivers. See **Table 1** for the Manning's value used for each landuse type. These are typical values recommended by HCFCD for rain-on-grid analyses.
- Buildings in the area were modeled using a high n value to represent storage but not conveyance in the structure.
- Major existing storm drain trunklines and laterals in addition to key laterals and inlets determined to be important for the modeling effort.
    - Storm drain data was originally sourced from the City of Houston (COH) GIMS website, and elevations were revised based on an appropriate datum adjustment for the area. Since the COH GIMS data had many pipe segments missing elevations, appropriate assumptions were made, and the elevations were interpolated or estimated based on flow direction and surrounding pipe elevations.
    - Survey verification of the drainage network was not performed for this study.
- A dynamic tailwater was applied using available unsteady-state models for Little White Oak Bayou that were obtained from the TxDOT NHHIP I-45 Segment 2 Analysis. A 500-year tailwater condition was used as an approximation for the 100-year, Atlas 14 storm event.

Table 1. Manning's N-Values for 2D Model Landuse

Landuse Class	Manning's N-Value
Building	10
Developed, High Intensity	0.03
Developed, Medium Intensity	0.18
Pasture/Grassland	0.22
Streets	0.02

3.0 EXISTING CONDITIONS EVALUATION

The following section documents the existing conditions drainage infrastructure in TIRZ 21, and the drainage problem areas that were identified. See **Exhibit 2** and **Figures 2a and 2b** for the existing storm sewer and the area topography.

The existing conditions storm sewer in the project area consists of the following:

- A large trunkline that serves the northern sections of the TIRZ, extending from NE to SW from Cavalcade St. to Fulton St., and ranging in size from a 78" RCP on the upstream end to a 114" RCP on the downstream end. This existing trunkline is also located along a low area of topography and helps capture and convey ponding that collects in the streets.
- The middle portion of the TIRZ is drained by a large trunkline that starts on Hardy St. and then turns to run east-west along a low area on Bigelow St. South of Collingsworth St., this trunkline is an 84" RCP. It becomes a 96" RCP when it makes the turn from Hardy St. to Bigelow St.

- Several other minor trunklines ranging in size from 42” to 60” drain the southern portion of the project area. South of Hogan and Lorraine St., there is a low area that is surrounded by high terrain features such as roadways and railroads. This low area is drained by a 48” RCP that runs north-south and becomes a 60” RCP before entering the TxDOT ROW along I-10.

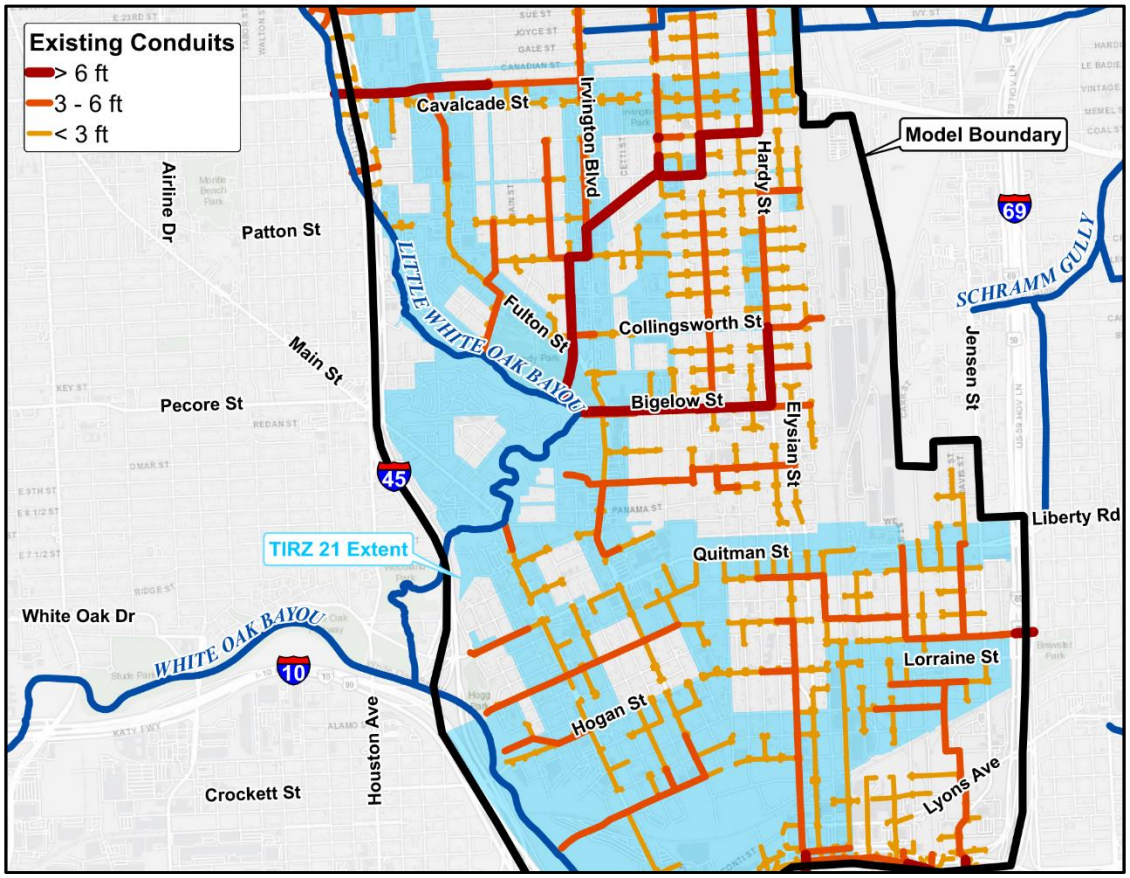


Figure 2a – Existing Storm Sewer Systems.

The existing conditions topography shown in Figure 2b clearly identifies isolated low points within the study area that are graphically illustrated by the turquoise shaded areas. Railroad corridors and elevated roadways that block overland flow are also clearly visible.

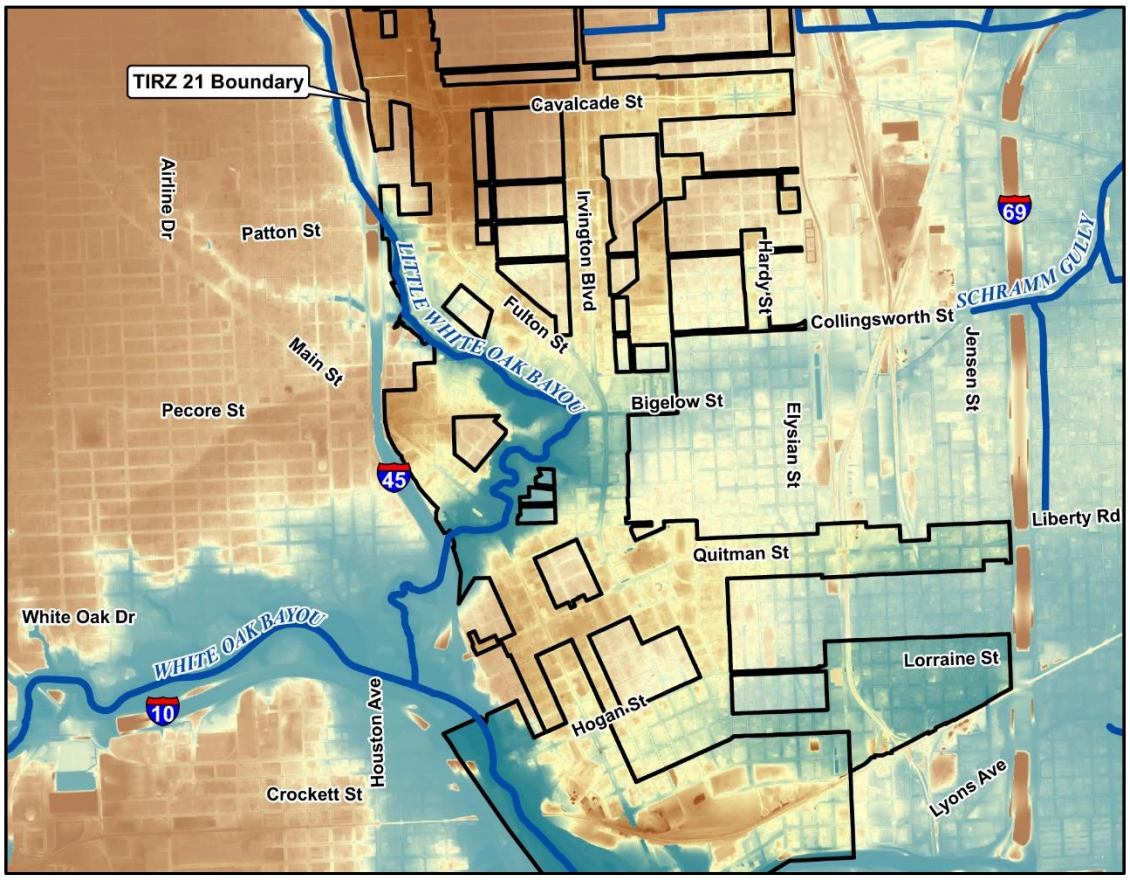


Figure 3b – Existing Topography. High ground (Brown); Low Ground (Blue).

The Existing Conditions 1D/2D analysis clearly identified three problem areas within the TIRZ. These problem areas are shown in **Figure 3** and **Exhibit 3** with the existing conditions 100-year inundation and align closely with the low areas in the terrain shown in **Figure 2b**. All three problem areas are the result of similar issues. The underground conveyance systems are sized to convey a 2-yr storm event. When the capacity of the system is exceeded and overland flow initiated, the surface conveyance is inadequate to convey runoff to the outfall, Little White Oak Bayou. The problem areas are low lying relative to their surroundings or are "trapped" by rail roads and elevated roadways. These conditions force water to pond to undesirable depths before continuing to sheet flow to the bayou.

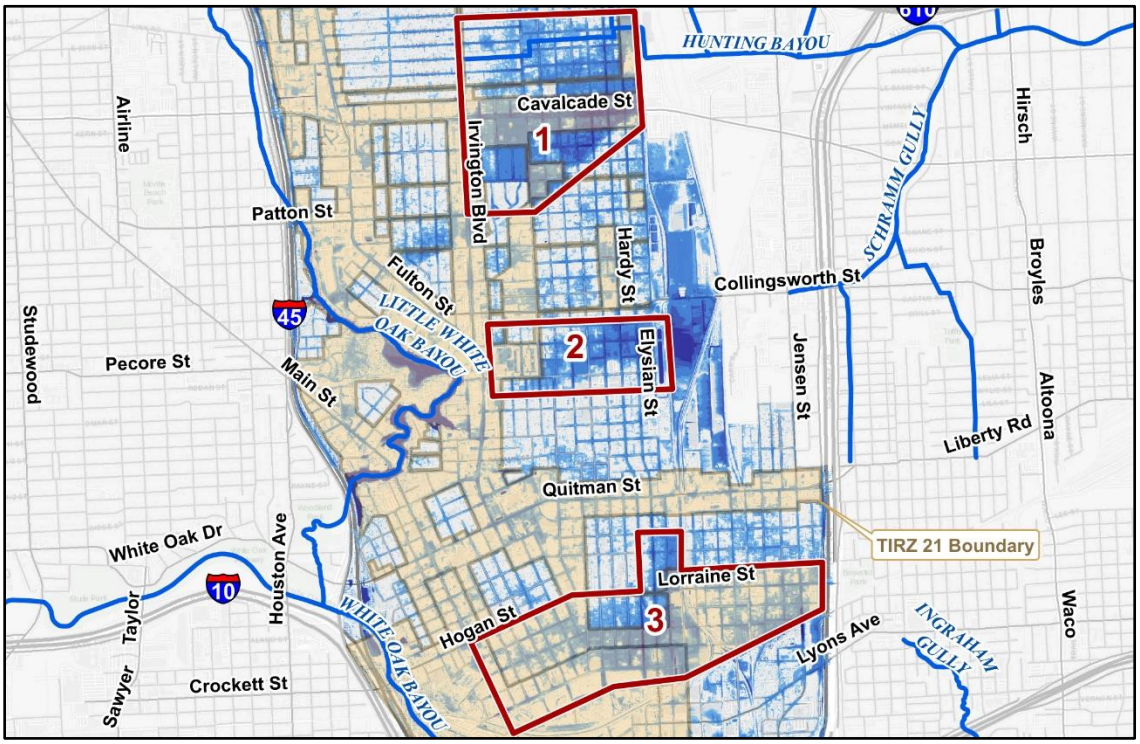


Figure 3 – Problem Areas with Existing 100-Yr Inundation

Problem Area 1

Problem Area 1 is on the north end of TIRZ 21 and is made up mostly of residential structures with some commercial facilities spread throughout. The existing conditions ponding ranges from depths of 0.25 ft – 2.75 ft for most of the problem area with maximum depths of up to 4.7 ft along Cavalcade St. As can be seen in **Exhibit 4** and **Figure 4**, Problem Area 1 has the highest concentration of flooded structures in the TIRZ.

Problem Area 2

Problem Area 2 is directly south of Problem Area 1 on the east side of TIRZ 21 and includes residential, commercial, and industrial developments. The majority of the ponding in this area exists just outside of the TIRZ boundary. In Problem Area 2, existing conditions ponding ranges from depths of 0.25 ft – 2.5 ft, with maximum depths of 3.75 ft occurring in the streets close to Elysian St. It was included in this study largely because it has the second highest density of flooded structures in the project area, as shown by **Figure 4**.

Problem Area 3

Problem Area 3 is near the south end of TIRZ 21 and is comprised of mostly residential structures with. Intersecting railroad tracks provide barriers to sheet flow that causes heavy ponding in the area. In Problem Area 2, existing

conditions ponding ranges from depths of 0.25 ft – 2.5 ft, with maximum depths of 3.54 ft occurring in the streets south of Lorraine. Because the majority of residences are on pier and beam foundations in this area, it has a lower concentration of flooded structures relative to Problem Areas 1 and 2. However, this area still poses a concern for roadway access and for ponding drawdown time during a storm event.

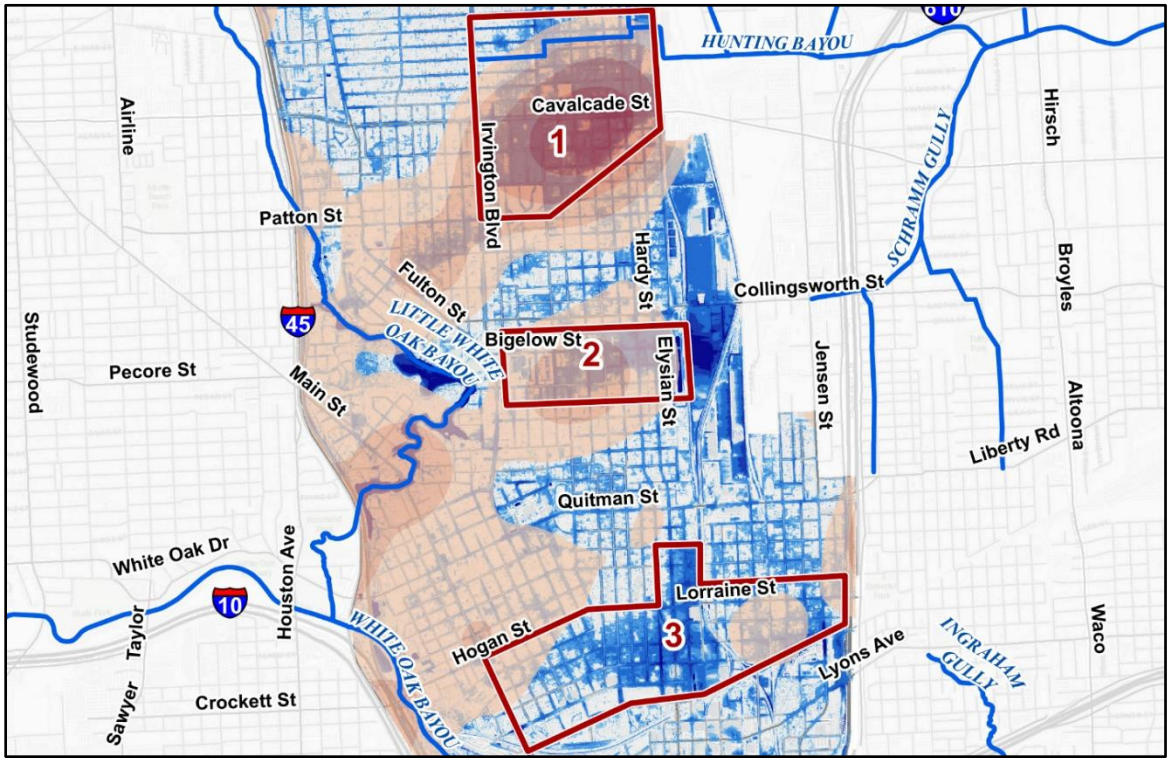


Figure 4 – Flood Structure Density

4.0 PROPOSED CONDITIONS

The proposed conditions analysis for this drainage study focused on providing strategic recommendations for areas where proposed new or improved storm drain might improve ponding conditions in the TIRZ. Improvements were developed for each of the three identified problem areas. However, the improvement corridors chosen for this analysis are not the only approach to address each of the problem areas. Because of the problem areas size and general gridded nature of the road network, alternative alignments to those chosen for this report should be explored if roadway or utility improvements are planned. Shifting an improvement corridor one or two adjacent blocks may still be an effective solution.

Four different improvement options were analyzed for each of the three problem areas.

1. Option 1A – Major Trunklines with Full Conveyance (Unrestricted Outfalls)
2. Option 1B – Major Trunklines with Restricted Outfalls
3. Option 2A – Expanded Improvements with Full Conveyance (Unrestricted Outfalls)
4. Option 2B – Expanded Improvements with Restricted Outfalls

Option 1B is the same as Option 1A, but with restrictors placed at the outfalls to prevent downstream improvements. Similarly, Options 2B is the same as Option 2A, but with restrictors placed at the outfalls. Options 1A and 2A show the benefit that could be achieved if it could be shown that the unrestricted proposed outfalls would not cause downstream impacts to Little White Oak Bayou, White Oak Bayou, and Buffalo Bayou, or if downstream impacts can

be mitigated. These options would provide the maximum benefit in the TIRZ. **Section 5.0** describes the downstream impact analysis that was performed.

Options 1B and 2B shows the benefit that could be achieved if restrictors are placed out the outfalls to prevent downstream impacts. These options provide less benefit than Options 1A and 2A. However, should either Options 1B or 2B be pursued, it may be possible to construct the design with restrictors in the interim, and remove the restrictors when either mitigation or approval can be achieved.

4.1 Option 1A – Major Trunklines with Full Conveyance

The Option 1A storm drain improvements represent an option with full conveyance and major trunklines only. The project layout can be seen in **Exhibit 5** and **Figure 5**.

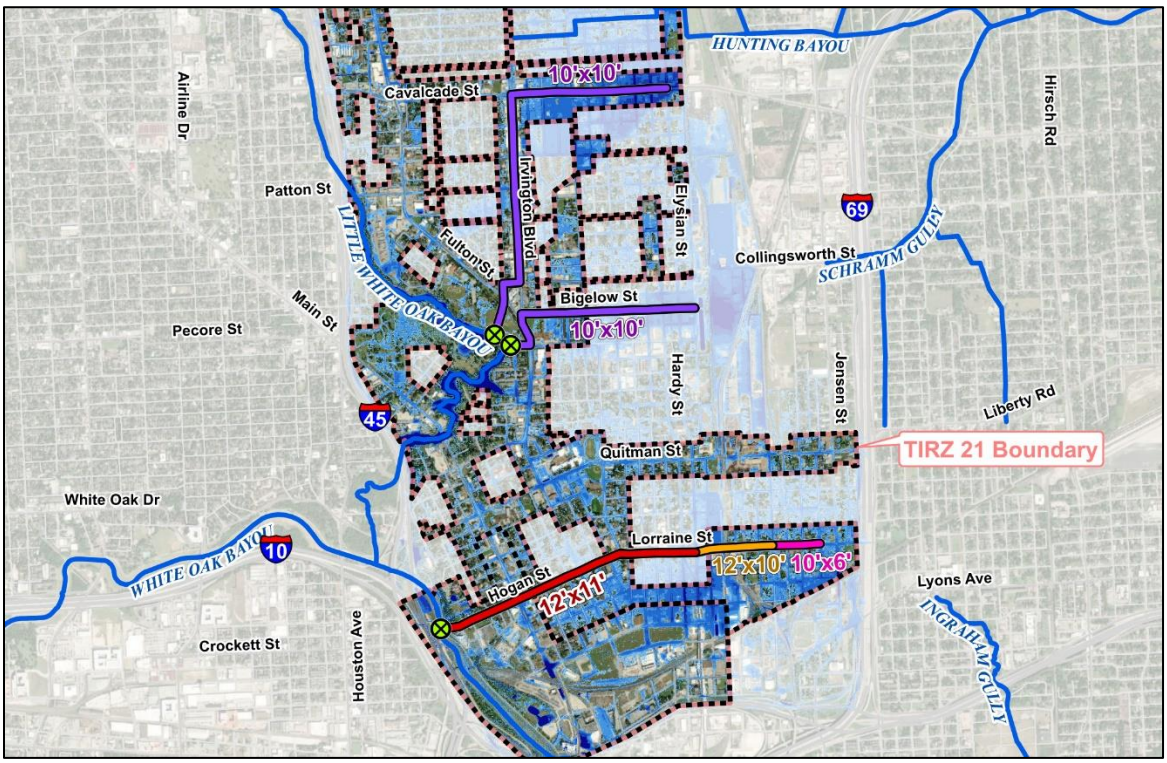


Figure 5 – Option 1A Proposed Improvements

The Options 1A improvements consist of the following.

To address Problem Area 1:

- 1-10'x10' RCB along Cavalcade St., Irvington Blvd., Collingsworth St., and Billingsley St.

To address Problem Area 2:

- 1-10'x10' RCB along Bigelow St., Fulton St. to Hays St., and Hays St.

To address Problem Area 3:

- 1-10'x6' RCB alone Lorraine St. from Davis St. to West St.
- 1-12'x10' RCB along Lorraine St. from West St. to Elysian St.
- 1-12'x11' RCB along Lorraine St. and Hogan St. from Elysian St. to the outfall at White Oak Bayou

It should be noted that the Problem Area 3 improvements were identified as a potential partnership with the City of Houston. The proposed improvements on Lorraine St. and Hogan St. were previously proposed in a Preliminary Engineering Report (PER) for the City of Houston, dated November 2016. The project was put on hold due to funding issues. A partnership may be one way to keep the proposed improvements moving forward.

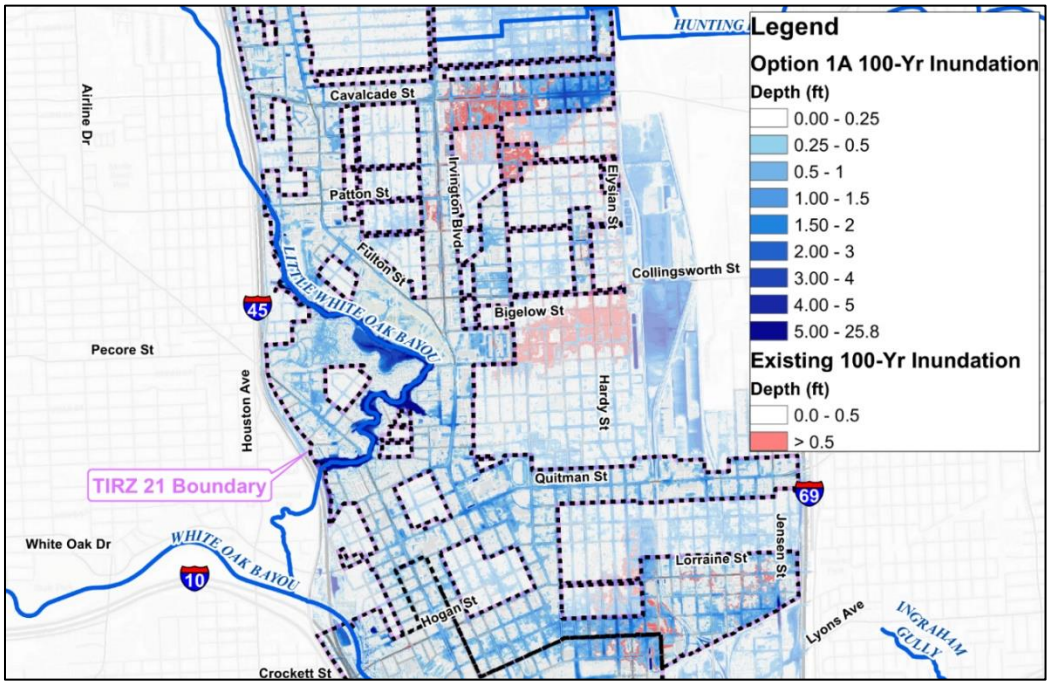


Figure 6 – Option 1A 100-Yr Inundation

The proposed conditions 100-Yr inundation for Option 1A shows a significant reduction in ponding with for all three problem areas, but particularly for Problem Areas 1 and 2 (see **Exhibit 6** and **Figure 6**). The improvements in Problem Area 3 along Lorraine St. and Hogan St. provide some benefit from the proposed trunklines. However, more benefit will be realized with additional improvements to the south to help direct more of the ponding to the proposed trunklines. These could include improvements to the existing roadside ditches, or additional roadway improvements that construct lateral storm drains. Options 2A and 2B explore the potential benefits of adding lateral storm drains to Lorraine St. and Hogan St. trunkline improvements.

4.2 Option 1B – Major Trunklines with Restricted Outfalls

Option 1B is the same as Option 1A but with a restriction placed at the outfall of each of the proposed storm drain trunk lines to maintain flow rates to Little White Oak Bayou. This option prioritizes using the trunk line capacity as storage rather than solely for conveyance, while significantly restricting the peak flows into Little White Oak Bayou and White Oak Bayou. If mitigation for the storm sewer improvements can be provided elsewhere, or if it can be accepted that a full conveyance option does not impact the downstream systems, then the restrictors could potentially be removed and the full benefit of Option 1A could be realized.

The 100-Yr inundation for Option 1B is shown in **Exhibit 7** and **Figure 7**. Option 1B shows a slight reduction in ponding for Problem Area 3 with minimal improvements for Problem Areas 1 and 2.

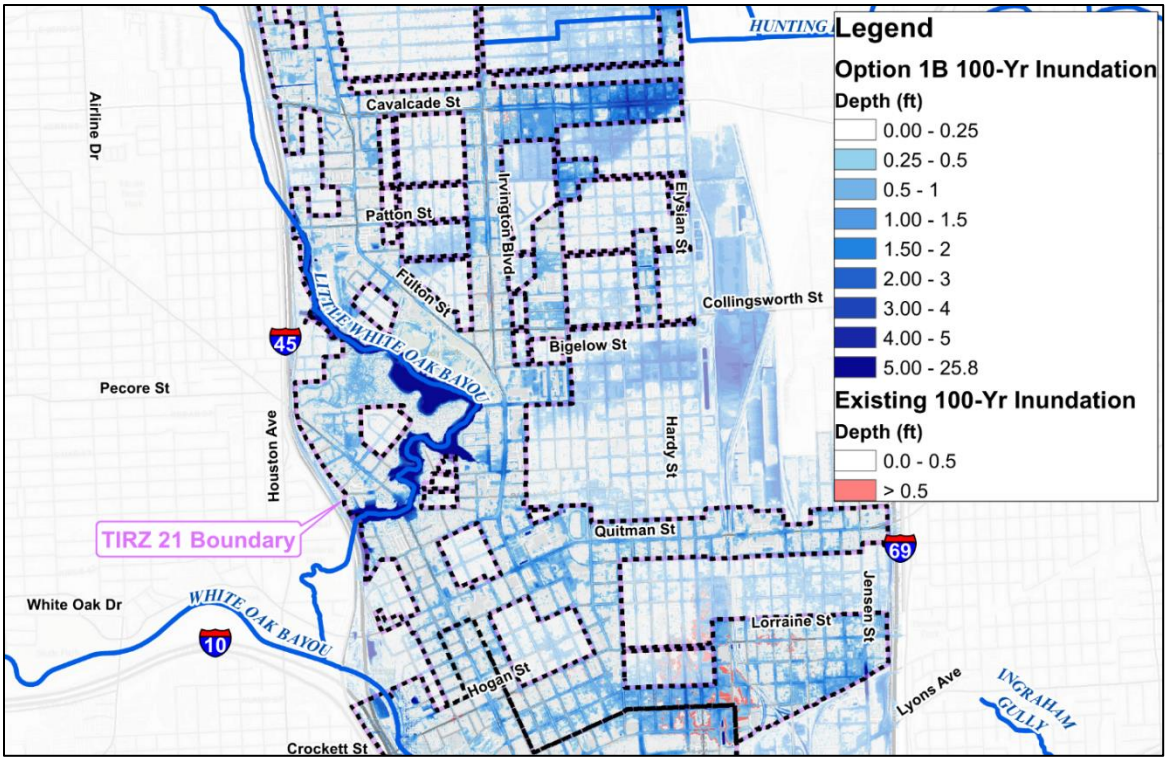


Figure 7 – Option 1B 100-Yr Inundation

4.3 Option 2A – Expanded Improvements with Full Conveyance

Option 2A expands on Option 1A by adding 6'x6' laterals that branch off each of the major trunk lines (See **Exhibit 8** and **Figure 8**). The analysis attempted to place the laterals in the areas of deepest ponding in order to have the greatest benefit. This alternative is conceptual and intended to illustrate that the proposed Option 1A improvements have future potential to be expanded upon for even greater benefit. The alignments of any laterals is flexible and can be opportunistic coinciding with planned construction in the area that is necessary for other reasons.

In Option 2A, the Cavalcade trunkline is proposed to receive flow from laterals at the following locations.

- Along Elysian St. from Gale St. to Cavalcade St.
- Along Terry St. between Gale St. and Frawley St.
- Along Chapman St. from Frawley St. to Cavalcade St.
- Along Frawley St. from Robertson St. to Irvington Blvd.

The Bigelow trunkline is proposed to receive flow from laterals at the following locations.

- Along Elysian St. between Boswell St. and Bardwell St.
- Along Terry St. between Boswell St. and Bardwell St.
- Along Cochran St. from Hays St. to Bigelow St.

The Lorraine trunkline is proposed to receive flow from laterals at following locations:

- Along Elysian St. between Campbell St. and Brooks St.
- Along Maury St. between Nobel St. and Burnett St.
- Along Harrington St. between Chapman St. and Elysian St.
- Along Brooks St. between Chapman St. and Maury St.

- Along McKee St. between Brooks St. and Burnett St.
- Along Sumpter St. between Maury St. and Maffitt St.

The 100-Yr inundation shows that Option 2A would provide the greatest benefit with significant reduction in ponding for all three problem areas (see **Exhibit 9** and **Figure 9**).

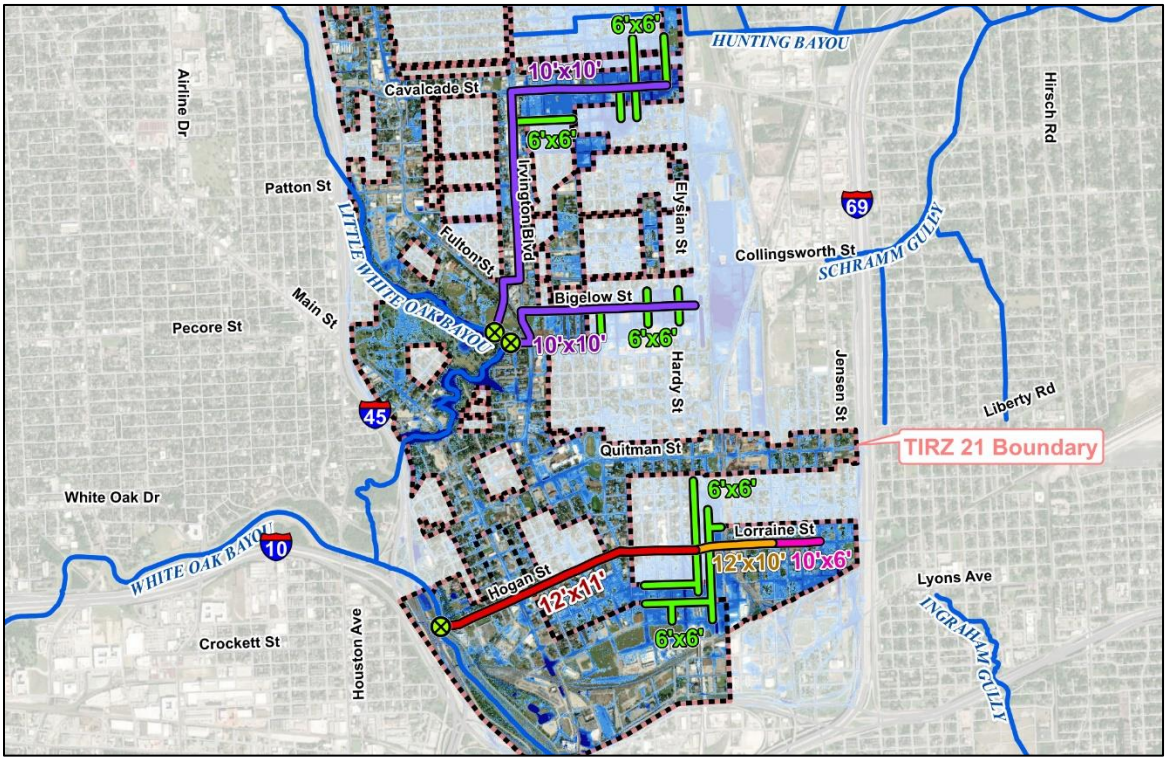


Figure 8 – Option 2A Proposed Improvements

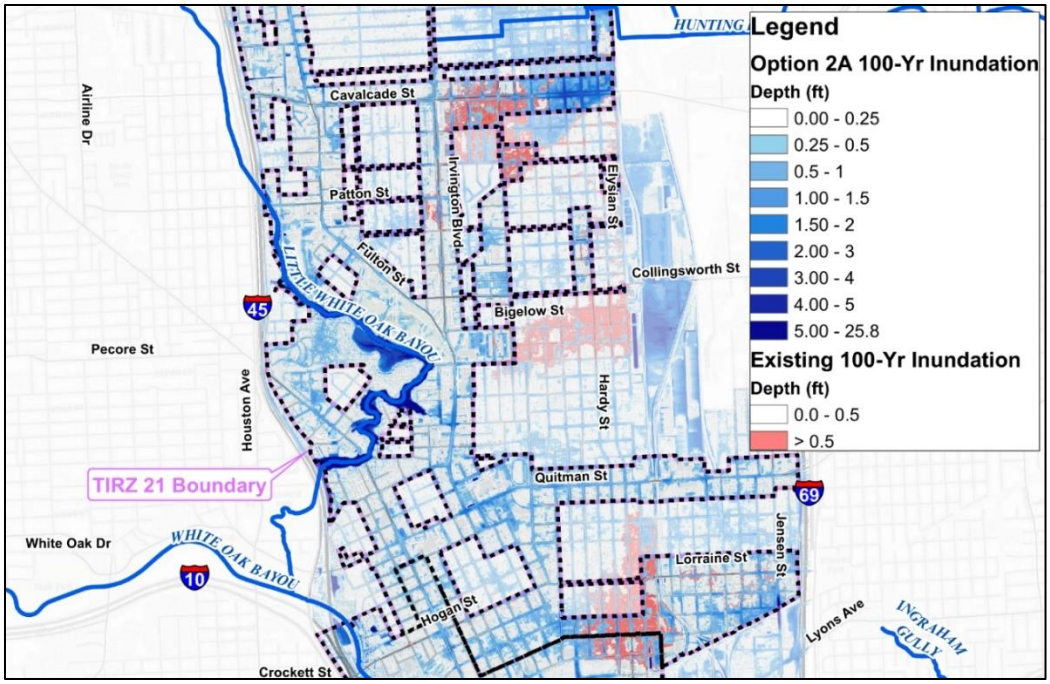


Figure 9 – Option 2A 100-Yr Inundation

4.4 **Option 2B – Expanded Improvements with Restricted Outfalls**

Option 2B is the same as Option 2A, but like Option 1B, would add restrictors at each proposed outfall location. Like Option 1B , the benefit from Option 2B would be minimal unless the restrictors at the outfalls can one day be removed. This could be achieved if mitigation is provided elsewhere, or, if it can be accepted that the proposed improvements would not have downstream impacts. See **Figure 10** and **Exhibit 10** for the proposed Option 2B 100-year inundation.

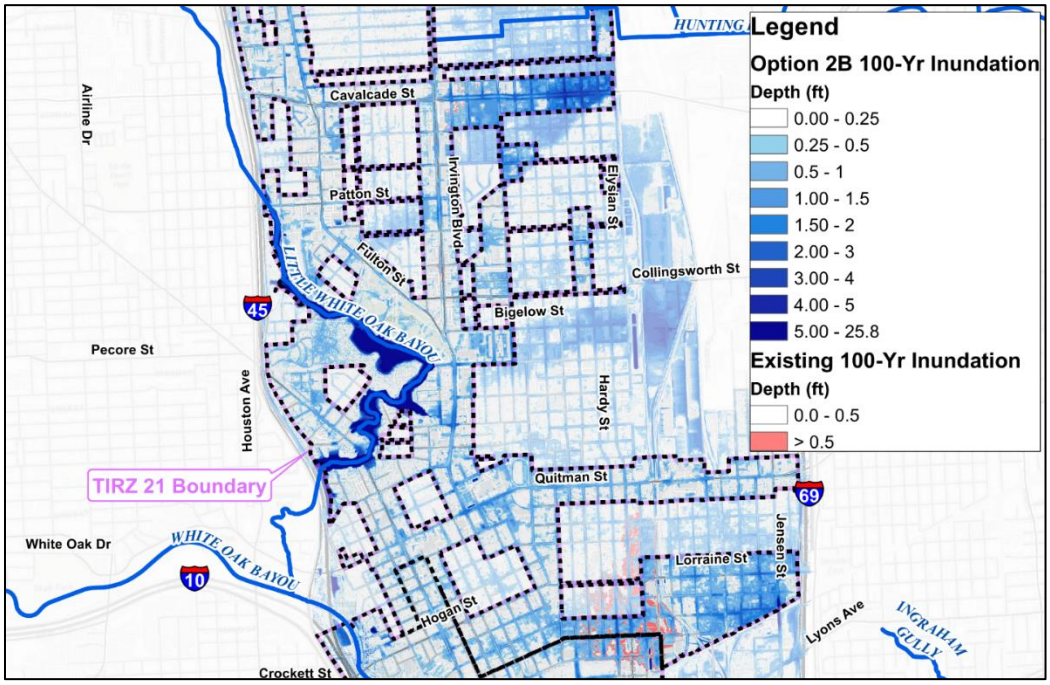


Figure 10 – Option 2B 100-Yr Inundation

4.5 Cost Estimate

Planning level cost estimate was developed for each of the improvement identified in Option 1. The secondary lateral improvements that are part of Option 2 are assumed to be add-ons to other projects overtime. The cost estimates are based on historical bid tabulation data for similar projects within the City of Houston. A unit cost of $1,250,000 per lane mile was applied and accounts for the full roadway and utility construction minus the cost of the storm sewer concrete boxes. Unit cost for each box size were applied individually based on recent bid tabulations. Complete roadway reconstruction was assumed (all lanes of pavement) for the cost estimates. The following costs estimates were identified.

1. Problem Area 1 – Cavalcade Trunkline: $ 15,164,000.00
2. Problem Area 2 – Bigelow Trunkline: $ 9,240,000.00
3. Problem Area 3 – Lorraine Trunkline: $ 15,755,000.00

5.0 DOWNSTREAM IMPACTS

As mentioned in earlier sections, Options 1A and 2A can only be performed if the increased conveyance to Little White Oak Bayou is mitigated so that there are no downstream impacts to Little White Oak Bayou, White Oak Bayou, or Buffalo Bayou. The Texas Department of Transportation (TxDOT) is currently evaluating drainage improvements to Little White Oak Bayou as part of the NHHIP Segment 2 Improvements. Additionally, in a joint effort by the City of Houston, TxDOT and HCFCD, the North Canal project would work together with the NHHIP improvements to reduce the WSEL on Buffalo Bayou, White Oak Bayou, and Little White Oak Bayou, while simultaneously addressing downstream impacts. Gauge evaluated whether the TxDOT NHHIP and North Canal improvements could potentially provide the mitigation that is needed to construct the TIRZ 21 Option 1A improvements. Option 2A impacts and necessary mitigation are very similar to Option 1A. The results from the Option 1A analysis are fully expected to hold true for Option 2A. Therefore, only Option 1A was analyzed for mitigation.

This analysis was performed using the HEC-HMS and HEC-RAS models for the NHHIP Segment 2 improvements. As recommended by the Drainage Study for NHHIP Segment 2 improvements, Alternative B (TxDOT Improvements with the proposed North Canal Improvements) was evaluated as the proposed option to mitigate the proposed improvements for Option 1A.

The process by which downstream impacts were evaluated is detailed below.

1. The Little White Oak Bayou HEC-HMS drainage areas from the TxDOT NHHIP Segment 2 report were subdivided to isolate the TIRZ 21 project area. Subbasins E101G, E101H, and E100P were subdivided into E101Ga and E101Gb, E101Ha and E101Hb, and E100Pa and E100Pb. The hydrologic parameters were reassessed and recalculated for the existing conditions including the Tc&R parameters and the contributing drainage area size. See **Exhibit 11** for a graphical representation of the subbasin subdivision.
2. The combined discharge hydrographs to the receiving bayous were captured from the Infoworks ICM model and combined to form a single discharge hydrograph for the existing and proposed conditions associated with each HEC-HMS subbasin. This procedure accounted for both the enclosed storm sewer and overland flow discharge to the bayous and was performed for both the existing conditions and improvement Option 1A. See **Exhibit 12** for a graphical representation example of the outfall discharge points and overland flows lines.
3. The percent change in timing and peak flow from the combined Infoworks ICM discharge hydrographs were defined and used to develop a proposed (with project) conditions hydrograph in HEC-HMS for the three influenced subbasins. The storage coefficient was modified to adjust the peak flow and the Tc was modified to adjust the time to peak. The resulting proposed conditions HMS hydrograph is representative of the post

project improvements for Option 1A. **Exhibit 13** depicts an example of the InfoWorks ICM hydrographs and the adjusted HEC-HMS hydrographs.

4. The HEC-HMS models were run with both the existing and proposed conditions hydrographs. The proposed conditions hydrographs represent the scenario where the TIRZ 21 improvements are implemented independently.
5. The resulting hydrographs form the HEC-HMS existing and proposed runs were applied to the unsteady HEC-RAS models from the NHHIP Segment 2 project. The HEC-RAS cross sections where the HEC-HMS hydrographs were applied were maintained between the pre- and post-project models. The location of the hydrograph input was relatively close to the location of the proposed improved outfall so there was no need to modify the hydrograph input location. See **Exhibit 14** for the location of the hydrograph input cross sections.

The analysis results confirmed that the proposed TIRZ 21 drainage improvements cannot be constructed as a stand-alone project as they would result in an increase in flow and WSEL on Little White Oak Bayou. If constructed after the completion of the NHHIP Segment 2 project and the North Canal project, the impact analysis confirmed that the TIRZ 21 improvements would have a nominal reduction in the overall benefits provided by the 2 regional projects.

6.0 CAPITAL IMPROVEMENT RECOMMENDATIONS

The identified projects target the heart of the drainage issues, lack of adequate overland conveyance. The nature of the issues requires the construction of sub-surface conveyance to convey the 100-yr event. These improvements tend to be expensive as the rely on large reinforced concrete boxes. Because the TIRZ 21 budget is limited, the recommended drainage improvements are intended to be a roadmap for future project opportunities or to be combined with mobility improvements. As improvements to the local roadways are made, the recommended drainage improvements can be slowly implemented over time. Additionally, grant opportunities can be explored for the identified improvements. The modeling approach facilitates the development of grant specific benefit cost ratios (BCRs). As can be seen in **Exhibits 6, 7, 9, and 10**, Options 1A and 2A provide the greatest ponding benefits and are the primary recommended improvements if pure drainage projects were being considered.

7.0 SUMMARY AND CONCLUSIONS

The objective of the drainage analysis was to establish an overall understanding of drainage issues in the TIRZ, determine the causes of flooding and severity of flooding for identified problem areas, and to provide improvement recommendations to help guide the development of the TIRZ Capital Improvement Plan (CIP).

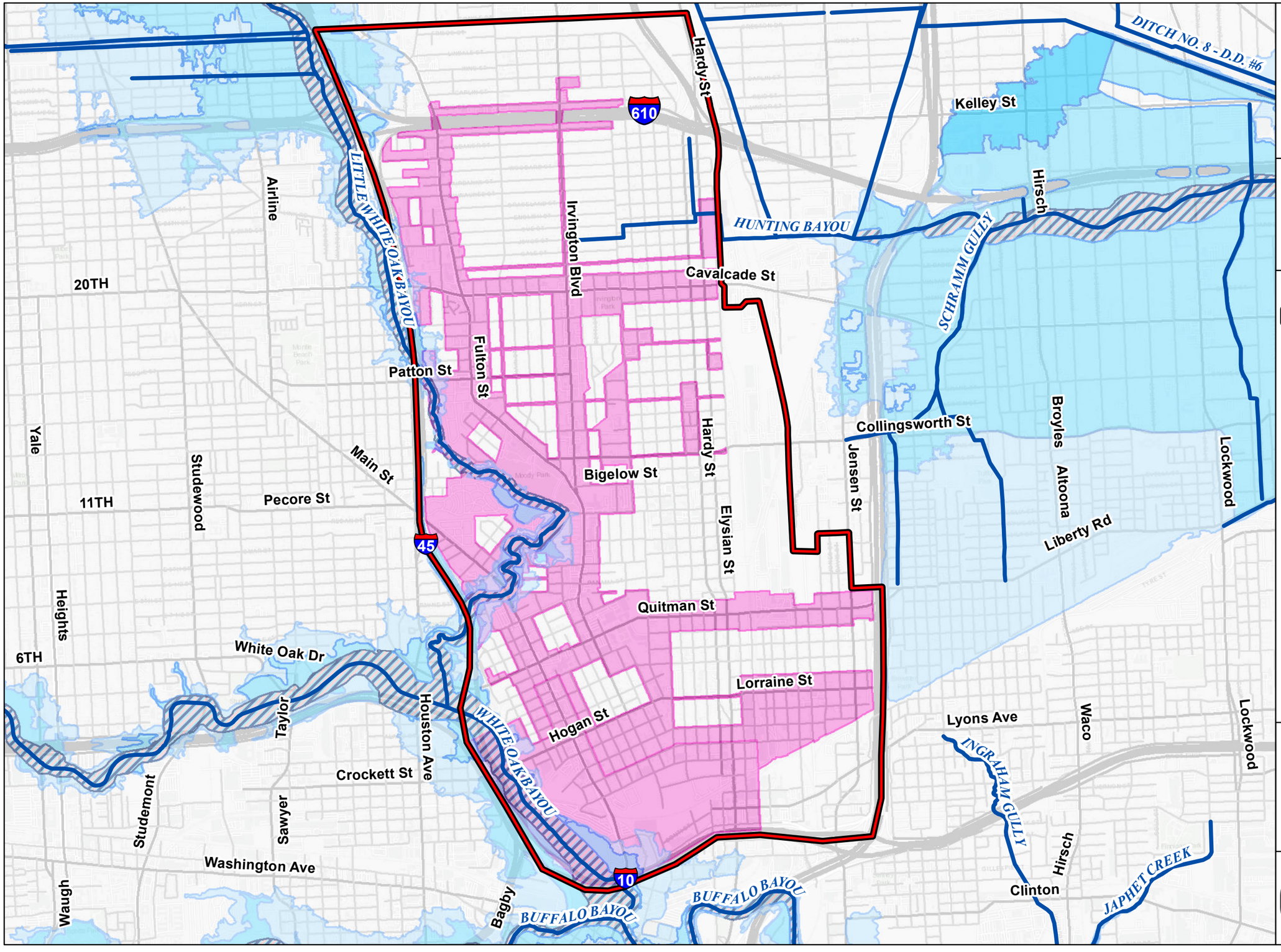
An existing conditions model was developed using InfoWorks ICM. The analysis included the evaluation of both sub-surface and overland flow based on GIMS and LiDAR data. Three problem areas were identified within or around the TIRZ boundary based on existing conditions evaluation results (See **Exhibit 3**). Potential storm sewer improvements were then identified for each problem area that would best improve local drainage, reduce structural flooding and address excessive street ponding.

Key findings from the drainage analysis include the following.

1. In the vast majority of the TIRZ area, the highest flooding risk is from local sheet flow, rather than flooding from White Oak Bayou and Little White Oak Bayou.
2. Due to the grid-like nature of the streets in the TIRZ, there are many potential options for drainage improvements that would provide ponding benefit to the region.
    a. This allows the TIRZ increased flexibility when developing a CIP that will provide both mobility and drainage improvements.

b. The flexible nature of potential drainage improvements means that roadway improvements to enhance mobility in the region can also have a drainage component that will likely fit into an overall drainage improvement plan.

3. The main goal of the proposed drainage improvements is to capture the ponding that is in the low-lying problem areas and convey it to the bayou. However, there could by multiple routes by which this conveyance occurs as can be seen in **Exhibits 5 and 8**.
4. The unrestricted conveyance improvements in Options 1A and 2A are effective at reducing flood risk. Ponding benefits can be seen in **Exhibits 6, 7, 9, and 10**.
5. The unrestricted options can work in unison with the planned North Canal and NHHIP improvements to demonstrate no adverse impact. The addition of Option 1A to the North Canal and NHHIP improvements has a negligible effect on the benefits provided by the North Canal and NHHIP project.
6. Improvement Options 1A and 2A can be constructed as standalone projects and restricted (Options 1b and 2b) to prevent downstream impacts. Options 1b and 2b can serve as interim scenarios that can then be transitioned to the aforementioned Options 1A and 2A by removing the restrictions. The restricted 1b and 2b options provide limited benefit relative to the unrestricted version 1A and 2A.
7. The City of Houston Lorraine St. and Hogan St. project identified similar improvements to those recommended in this report. To maximize the benefit of the Lorraine/Hogan project we recommend expanding the improvements to those identified in Option 2b. This can be done over time via multiple contracts or constructed in a single contract. This presents an opportunity for partnership between the City and TIRZ 21.



NEAR NORTHSIDE
REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 1
Study Area Map

Legend

- 2D Model Boundary
- TIRZ 21 Boundary
- Channel

FEMA Flood Zones

- AE Floodway
- Zone A Floodplain (100-Yr)
- Zone AE Floodplain (100-Yr)
- X (500-Yr)

N

0 1,000 2,000 4,000
Feet

Gauge ENGINEERING

NEAR NORTHSIDE
REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 2
Area Topography and Existing Storm Sewer

Legend

- 2D Model Boundary
- TIRZ 21 Boundary
- Channel

Existing Conduit

- > 6 ft
- 3 - 6 ft
- < 3 ft

N

0 1,000 2,000 4,000
Feet

Gauge ENGINEERING

Hardy St
610
Airline
Irvington Blvd
Kelley St
DITCH NO. 8 - D.D. #6
HUNTING BAYOU
Hirsch
SCHRAMM GULLY
Cavalcade St
20TH
Fulton St
Patton St
Yale
Main St
LITTLE WHITE OAK BAYOU
Bigelow St
Hardy St
Collingsworth St
Broyles
Jensen St
Altoona
Lockwood
11TH
Studewood
Pecore St
Elysian St
Liberty Rd
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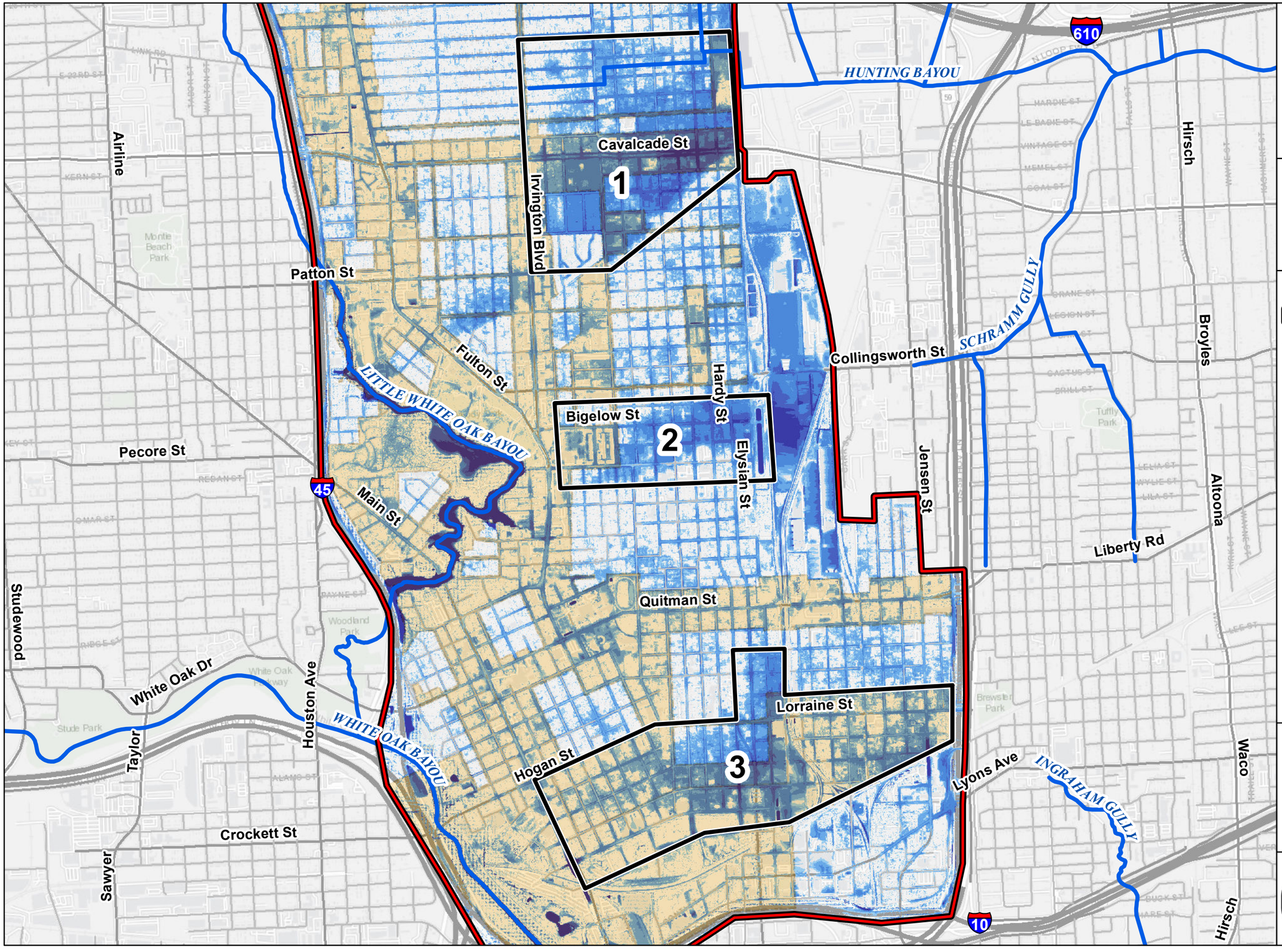
Quitman St
White Oak Dr
6TH
Lorraine St
Hogan St
Houston Ave
Taylor
Lyons Ave
Waco
Lockwood
WHITE OAK BAYOU
Crockett St
Studemont
Sawyer
INGRAHAM GULLY
Washington Ave
Hirsch
Clinton
JAPHET CREEK
Waugh
Bagby
BUFFALO BAYOU
BUFFALO BAYOU
10



NEAR NORTHSIDE REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 3
Problem Areas
Existing 100-Yr Inundation

Legend

- 2D Model Boundary
- Problem Areas
- TIRZ 21 Boundary
- Channel

Existing 100-Yr Inundation

Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.50 - 1
- 1.00 - 2
- 2.00 - 3
- 3.00 - 4

N

0 750 1,500 3,000

Feet

Gauge ENGINEERING

NEAR NORTHSIDE
REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 4
Flood Structure Density Map
Existing 100-Yr Inundation

Legend

- 2D Model Boundary
- TIRZ 21 Boundary
- Channel

Existing 100-Yr Inundation Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.50 - 1
- 1.00 - 2
- 2.00 - 3
- 3.00 - 4

Flooded Structure Heat Map

N

0 750 1,500 3,000
Feet

Gauge ENGINEERING

Airline Dr
Patton St
Pecore St
White Oak Dr
Crockett St
Houston Ave
Main St
Irvington Blvd
Fulton St
Cavalcade St
Elysian St
Bigelow St
Collingsworth St
Hardy St
Quitman St
Hogan St
Lorraine St
Lyons Ave
Jensen St
Hirsch Rd
Liberty Rd
HUNTING BAYOU
SCHRAMM GULLY
INGRAHAM GULLY
LITTLE WHITE OAK BAYOU
WHITE OAK BAYOU
610
69
45
10

NEAR NORTHSIDE
REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 5
Option 1A Proposed Improvements
Existing 100-Yr Inundation

Legend

- 2D Model Boundary
- Proposed Trunk Line
- Existing Conduit
- Channel
- Outfall

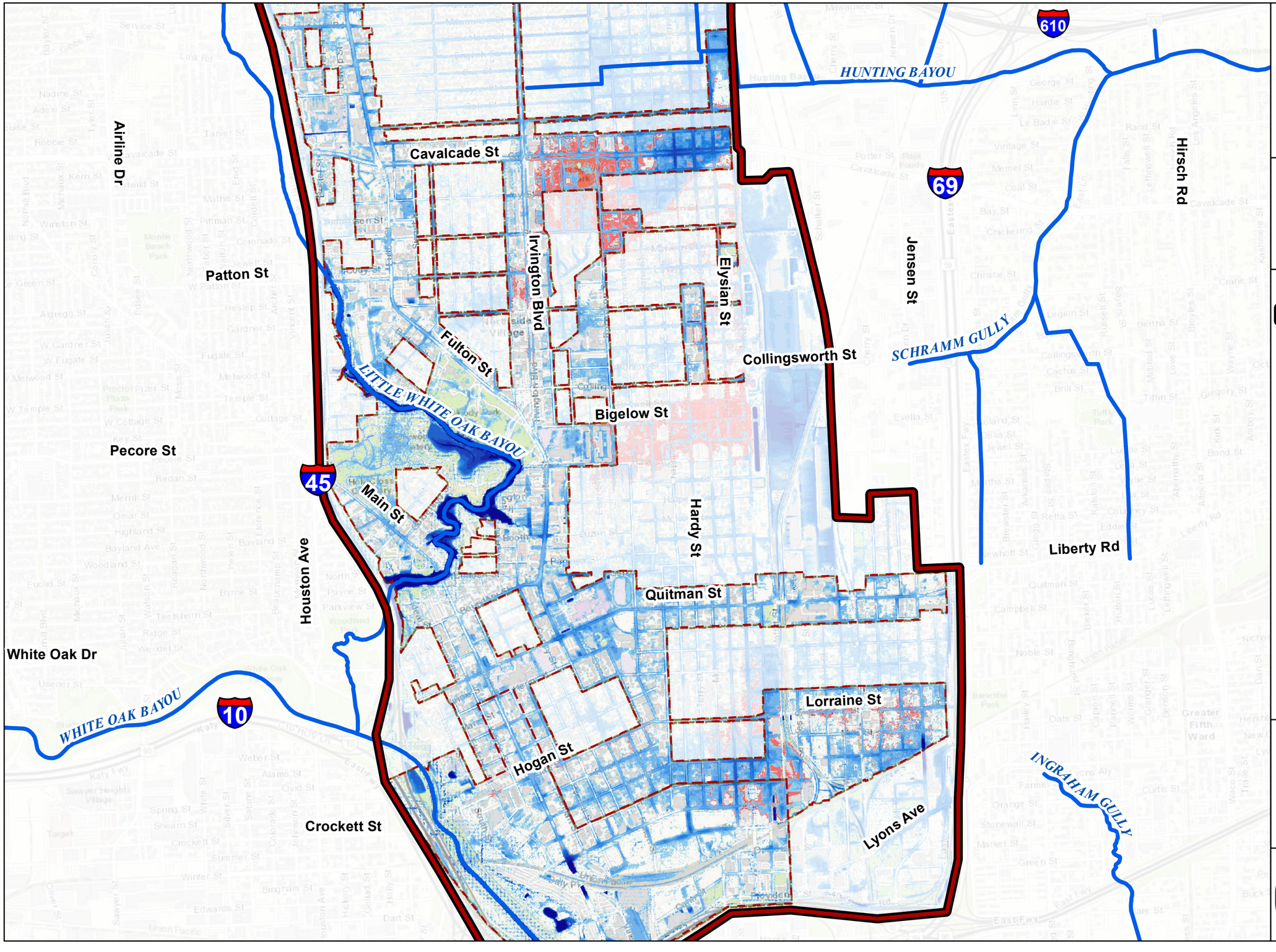
Existing 100-Yr Inundation Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.50 - 1
- 1.00 - 2
- 2.00 - 3
- 3.00 - 4

N

0 750 1,500 3,000
Feet

Gauge ENGINEERING



NEAR NORTHSIDE
REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 6
Option 1A
100-Yr Inundation Difference

Legend

- 2D Model Boundary
- TIRZ 21 Boundary
- Channel

Option 1A 100-Yr Inundation Depth (ft)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1.00 - 1.5
- 1.50 - 2
- 2.00 - 3
- 3.00 - 4
- 4.00 - 5
- 5.00 - 25.8

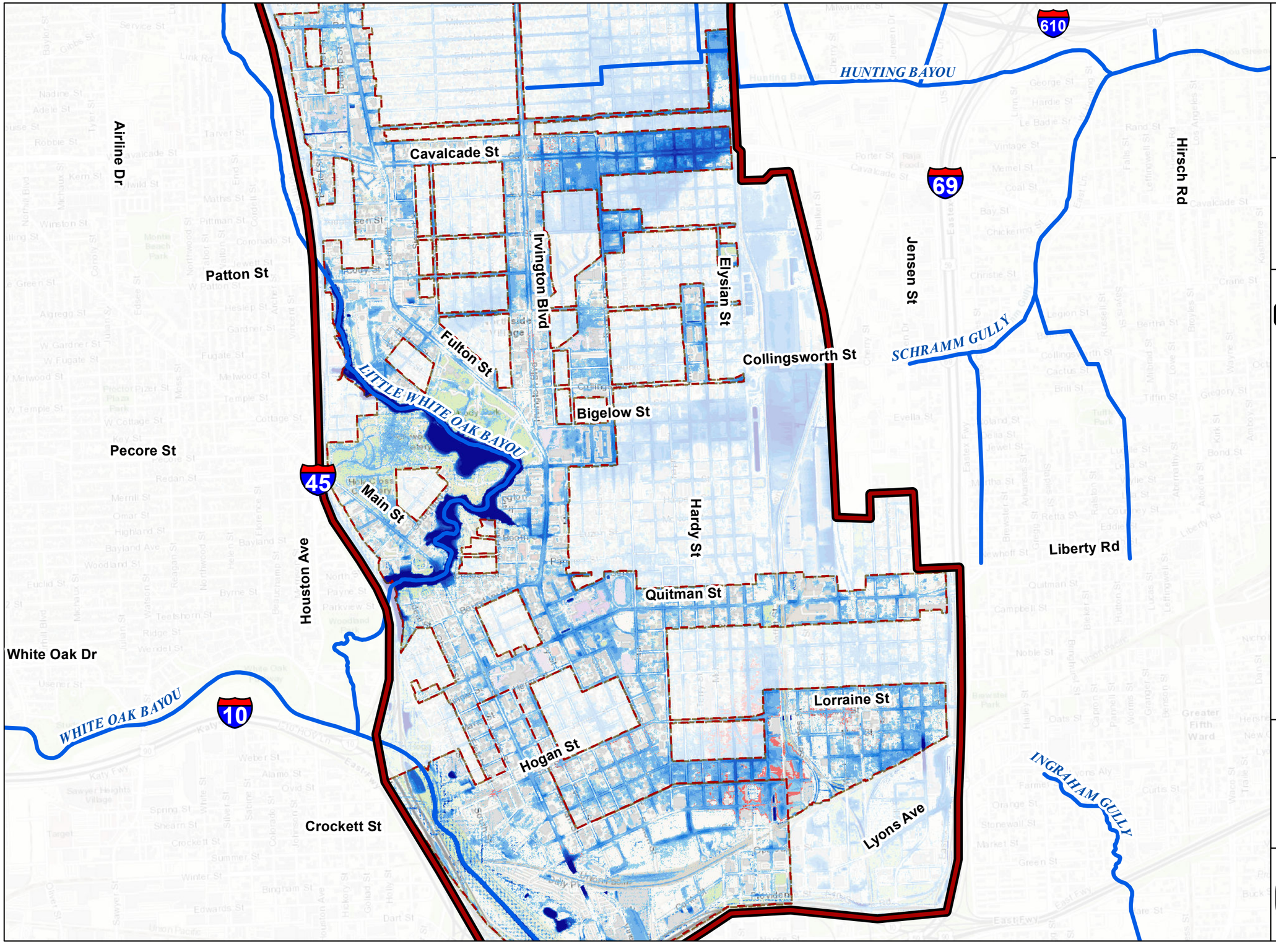
Existing 100-Yr Inundation Depth (ft)

- 0.0 - 0.5
- > 0.5

N

0 750 1,500 3,000
Feet

Gauge ENGINEERING



NEAR NORTHSIDE
REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 7
Option 1B
100-Yr Inundation Difference

Legend

- 2D Model Boundary
- TIRZ 21 Boundary
- Channel

Option 1B 100-Yr Inundation Depth (ft)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1.00 - 1.5
- 1.50 - 2
- 2.00 - 3
- 3.00 - 4
- 4.00 - 5
- 5.00 - 25.8

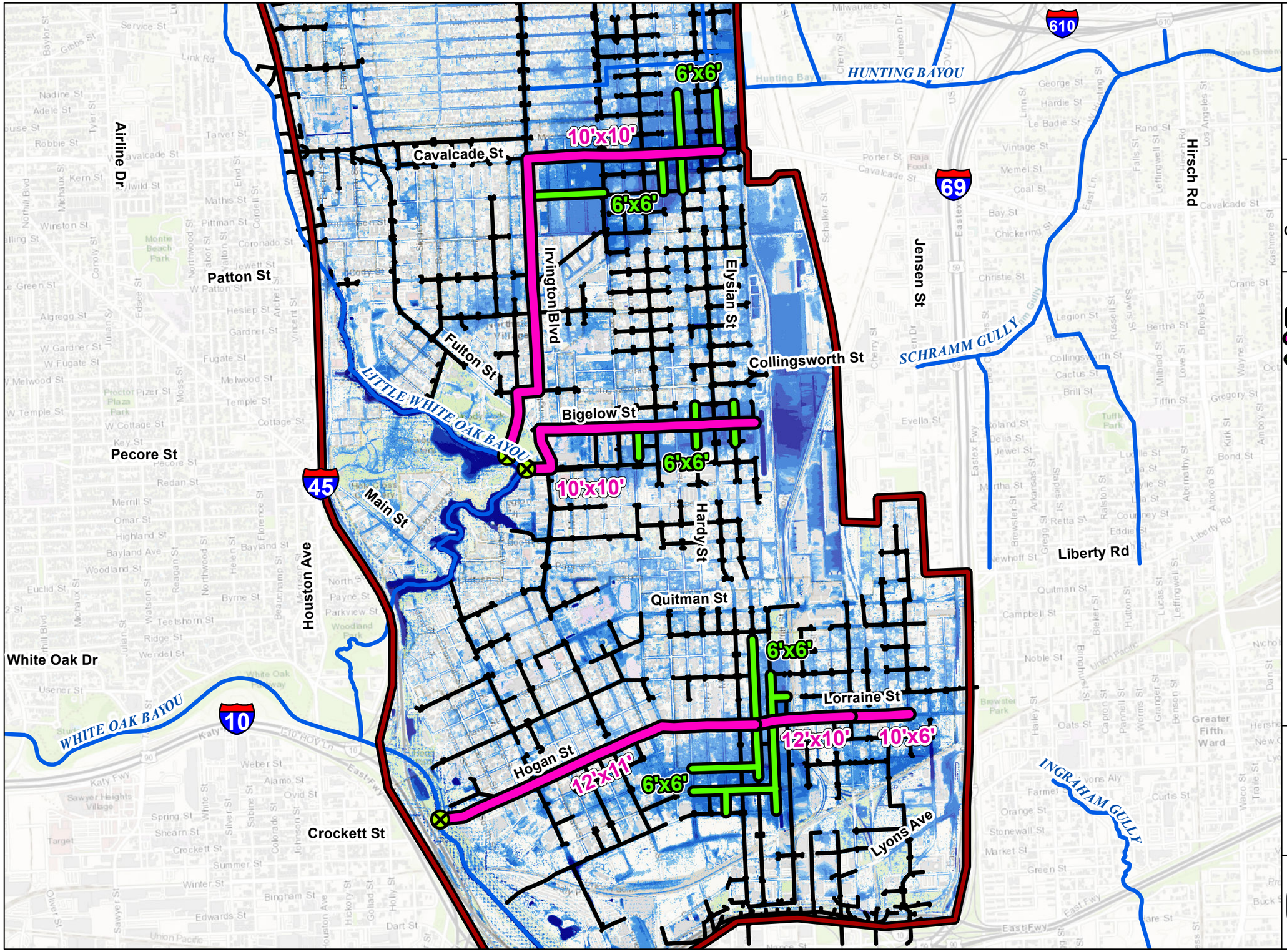
Existing 100-Yr Inundation Depth (ft)

- 0.0 - 0.5
- > 0.5

N

0 750 1,500 3,000
Feet

Gauge ENGINEERING



NEAR NORTHSIDE REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 8
Option 2A Proposed Improvements
Existing 100-Yr Inundation

Legend

- 2D Model Boundary
- Proposed Trunkline
- Proposed Lateral
- Existing Conduit
- Channel
- Outfall

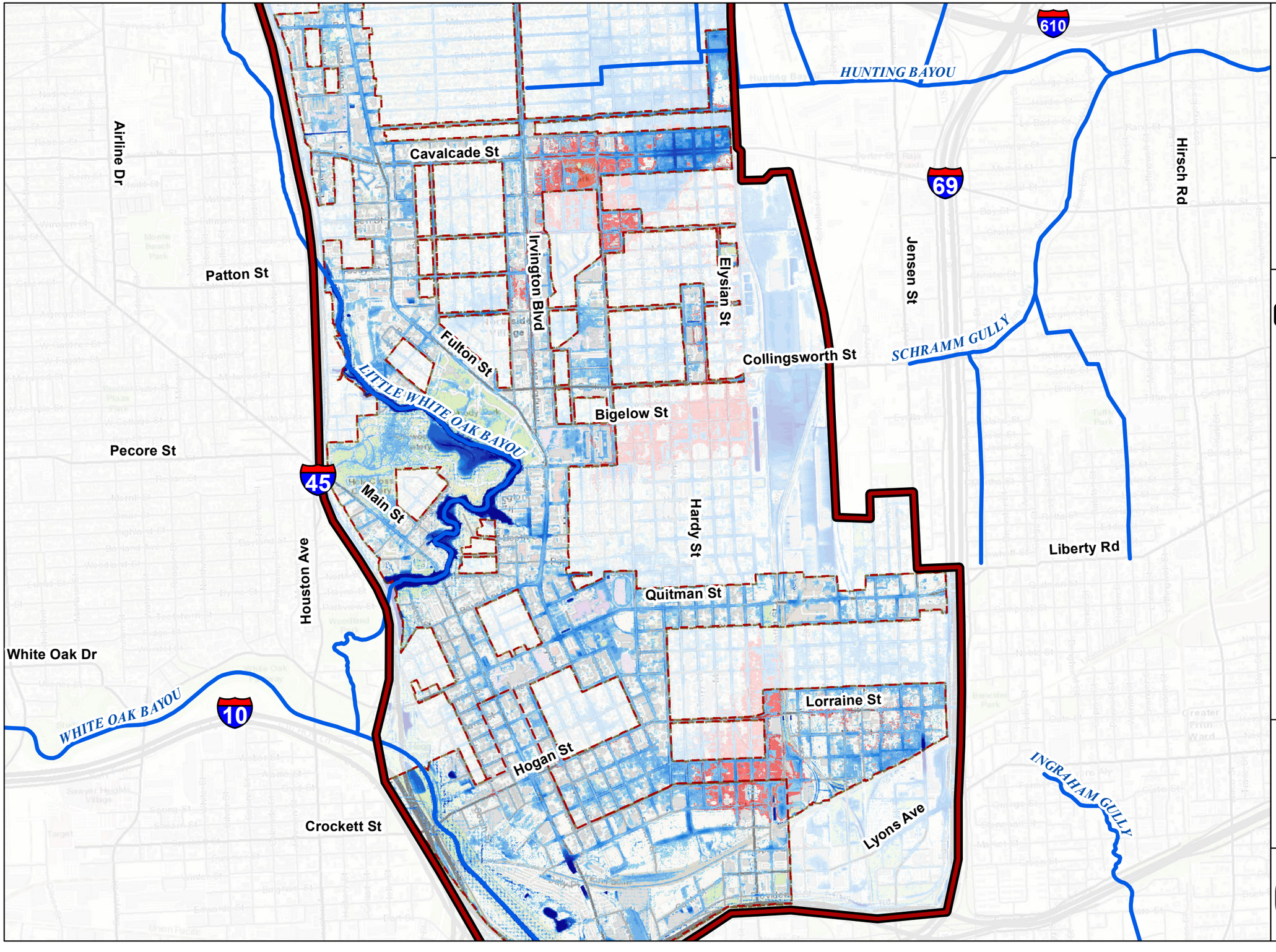
Existing 100-Yr Inundation Depth (ft)

- 0 - 0.25
- 0.25 - 0.5
- 0.50 - 1
- 1.00 - 2
- 2.00 - 3
- 3.00 - 4

N

0 750 1,500 3,000
Feet

Gauge ENGINEERING



NEAR NORTHSIDE REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 9
Option 2A
100-Yr Inundation Difference

Legend

- 2D Model Boundary
- TIRZ 21 Boundary
- Channel

Option 2A 100-Yr Inundation Depth (ft)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1.00 - 1.5
- 1.50 - 2
- 2.00 - 3
- 3.00 - 4
- 4.00 - 5
- 5.00 - 25.8

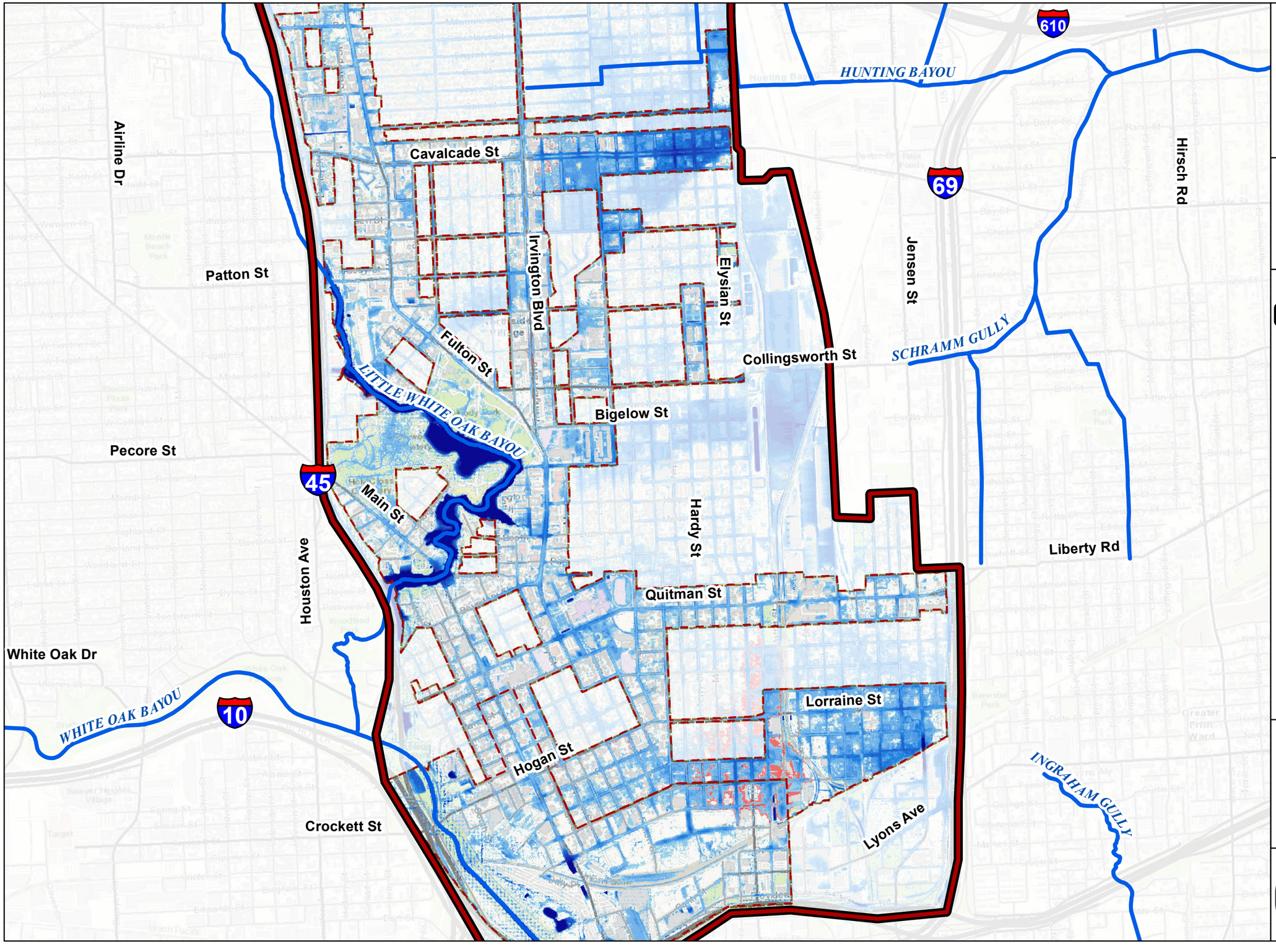
Existing 100-Yr Inundation Depth (ft)

- 0.0 - 0.5
- > 0.5

N

0 750 1,500 3,000
Feet

Gauge ENGINEERING



NEAR NORTHSIDE REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 10
Option 2B
100-Yr Inundation Difference

Legend

- 2D Model Boundary
- TIRZ 21 Boundary
- Channel

Option 2B 100-Yr Inundation Depth (ft)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1.00 - 1.5
- 1.50 - 2
- 2.00 - 3
- 3.00 - 4
- 4.00 - 5
- 5.00 - 25.8

Existing 100-Yr Inundation Depth (ft)

- 0.0 - 0.5
- > 0.5

N

0 750 1,500 3,000

Feet

Gauge ENGINEERING

NEAR NORTHSIDE
REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 11
HEC-HMS Divided Subbasins

Legend

- Subbasin Boundary
- Channel

SUBBASIN

- E101F
- E101G
- E101H
- E100P
- W100O

E101Fa
E101Fb
E101Ga
E101Gb
E101Hb
E101Ha
E100Pb
E100Pa
W100O
W100O

Subbasin Dividing Line
TIRZ 21 Extent

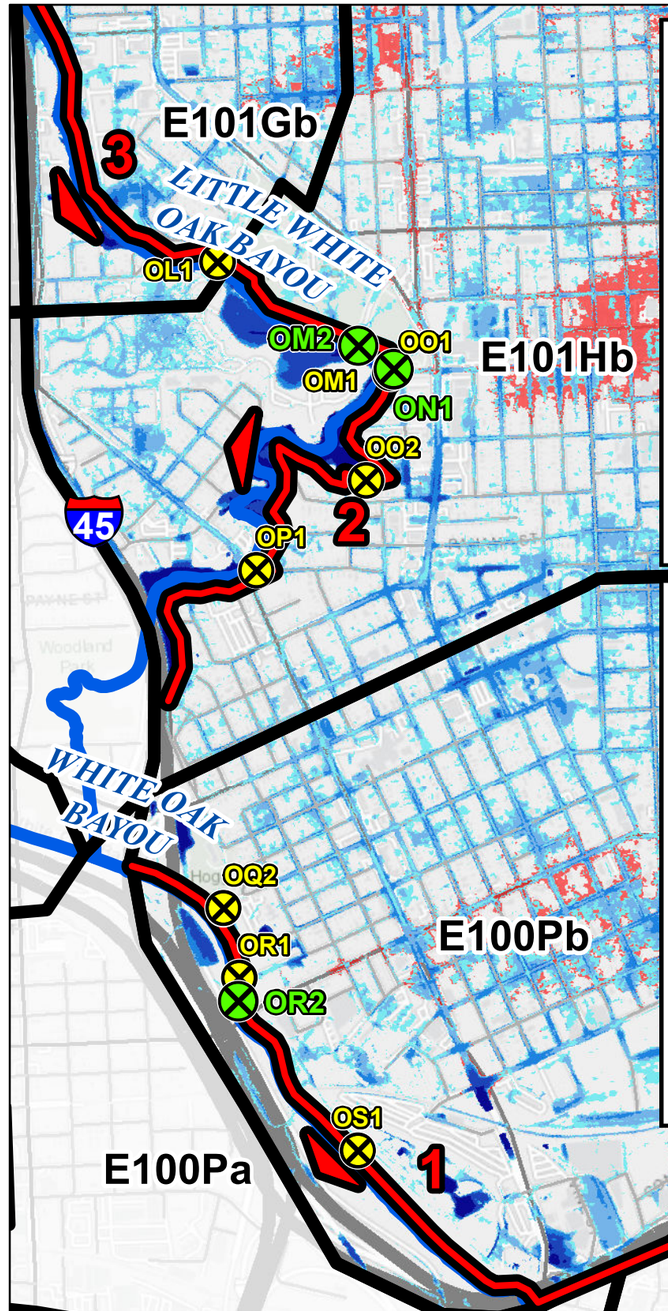
45
610
69
10

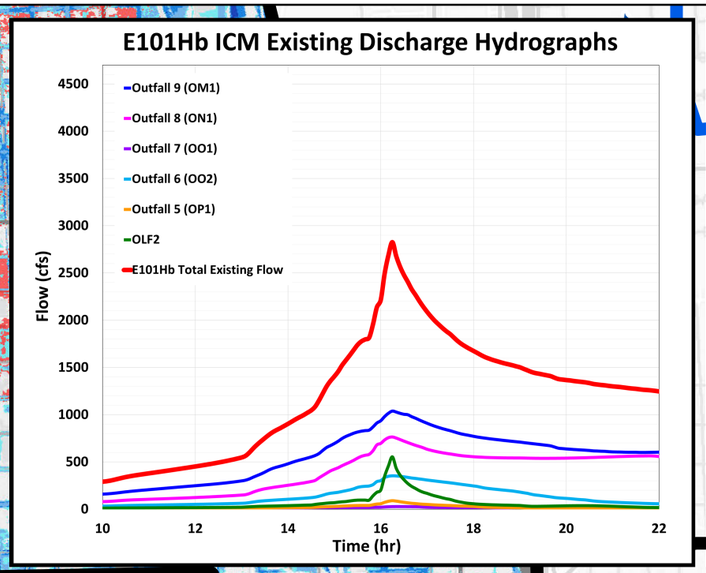
HUNTING BAYOU
LITTLE WHITE OAK BAYOU
SCHRAMM GULLY
TURKEY GULLY
WHITE OAK BAYOU
BUFFALO BAYOU

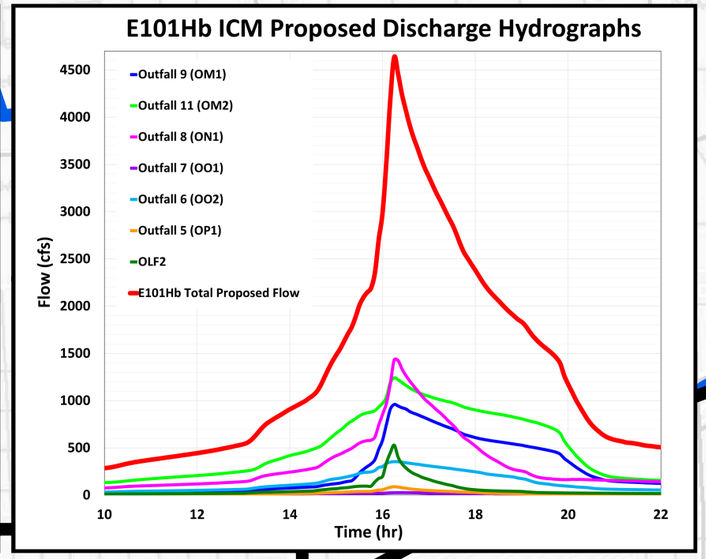
N

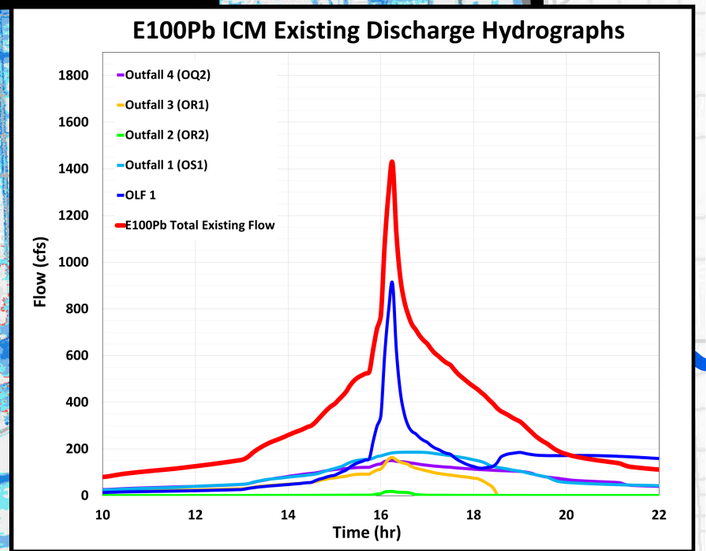
0 1,000 2,000 4,000
Feet

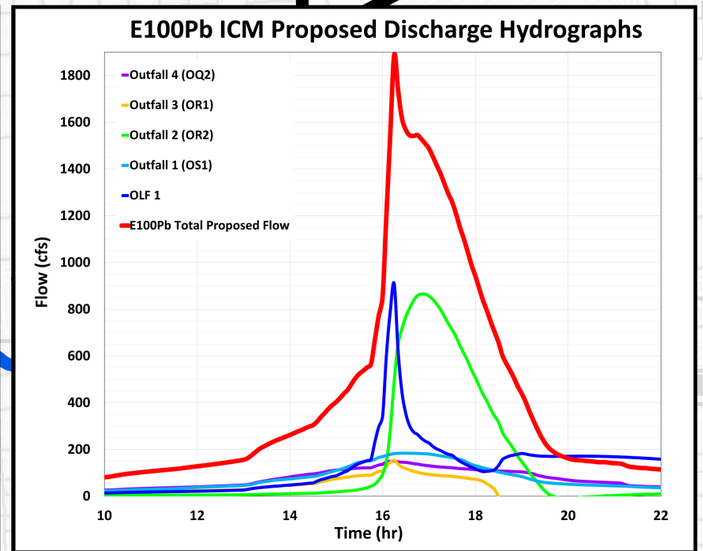
Gauge
ENGINEERING











Outfall	Peak Flow 100yr Inundation (cfs)			
	Existing	Proposed	Delta	% Delta
E101Gb	686	686	0	0.03%
E101Hb	2826	4636	1810	64.04%
E100Pb	1425	1889	463	32.50%
Total	4938	7211	2273	46.04%

NEAR NORTHSIDE REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 12
Outfall Discharge and Overland Flowlines

Legend

- Subbasin Boundary
- Overland Flow Lines
- Channel
- Proposed Outfall
- Existing Outfall

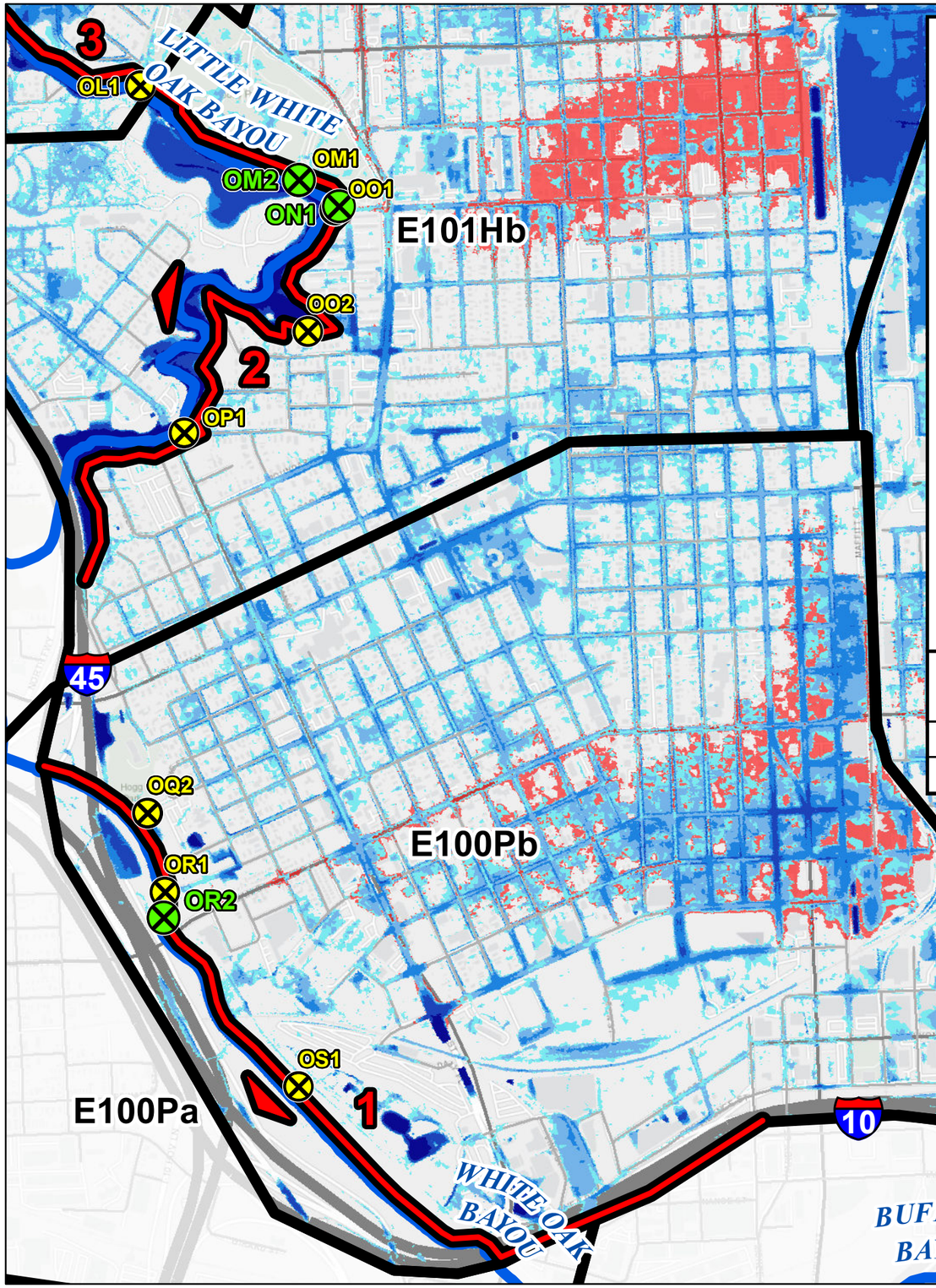
Option 1A 100-Yr Inundation

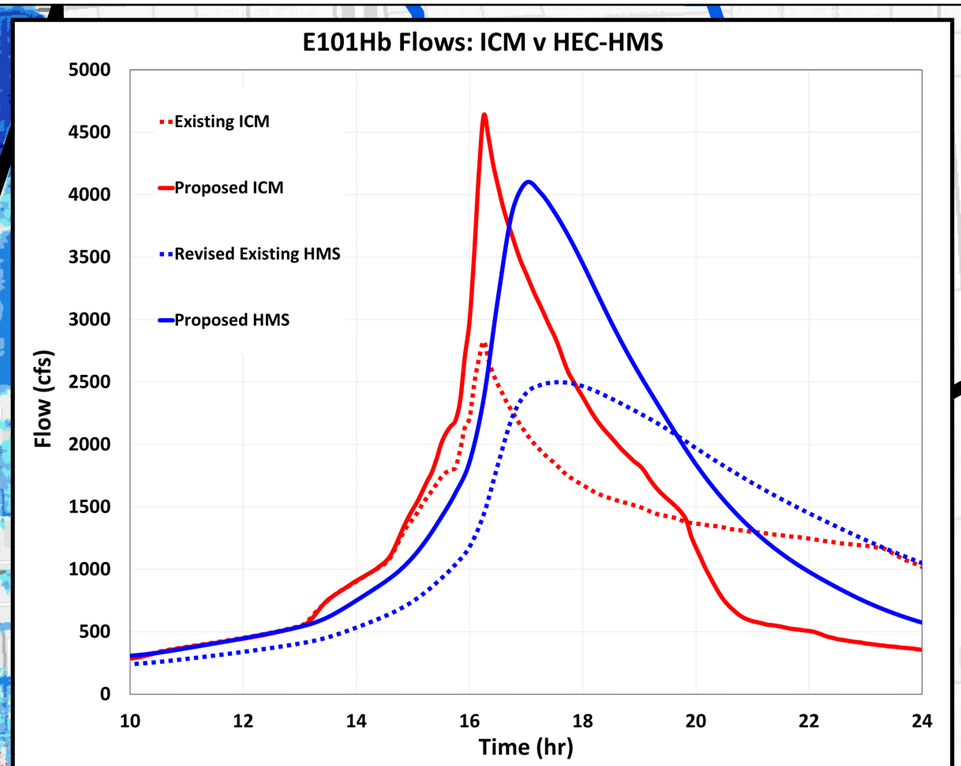
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 5.00
- > 5.00
- 100-Yr Existing Inundation Extent

N

0 500 1,000 2,000
Feet

Gauge ENGINEERING





E101Hb	Peak 100yr Flows (cfs)			
	Existing	Proposed	Delta	% Delta
ICM	2826	4636	1810	64.04%
HEC-HMS	2498	4098	1600	64.04%

NEAR NORTHSIDE REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 13
ICM v HEC-HMS Discharge Hydrographs

Legend

- Subbasin Boundary
- Overland Flow Lines
- Channel
- Proposed Outfall
- Existing Outfall

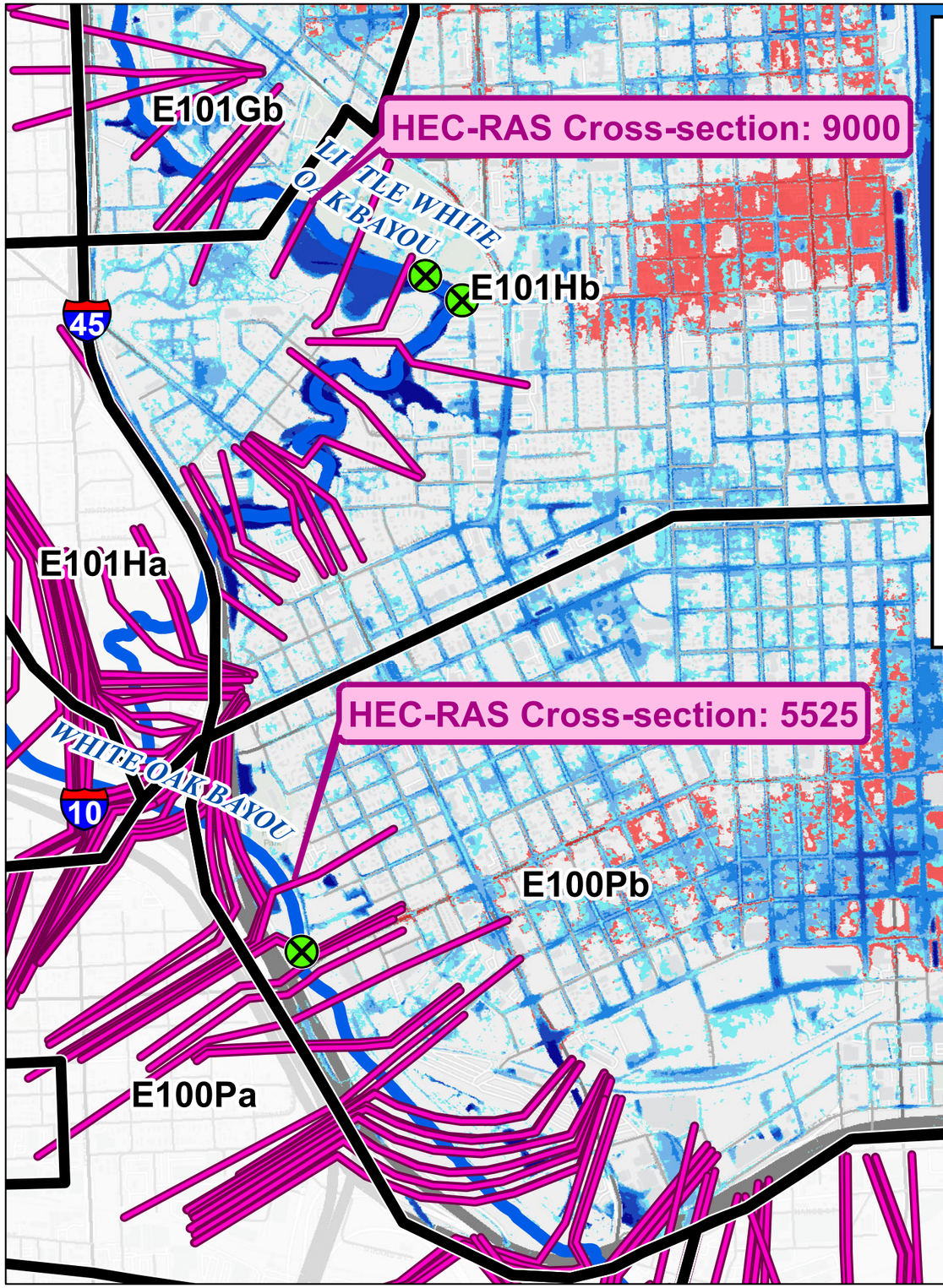
Option 1A 100-Yr Inundation

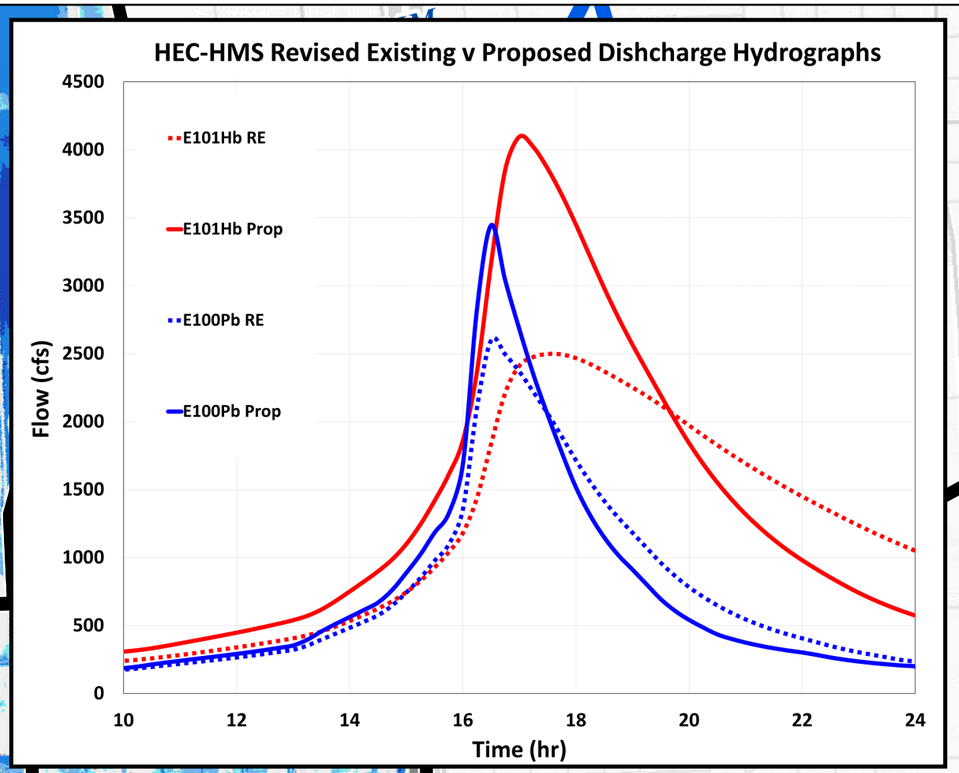
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 5.00
- > 5.00
- 100-Yr Existing Inundation Extent

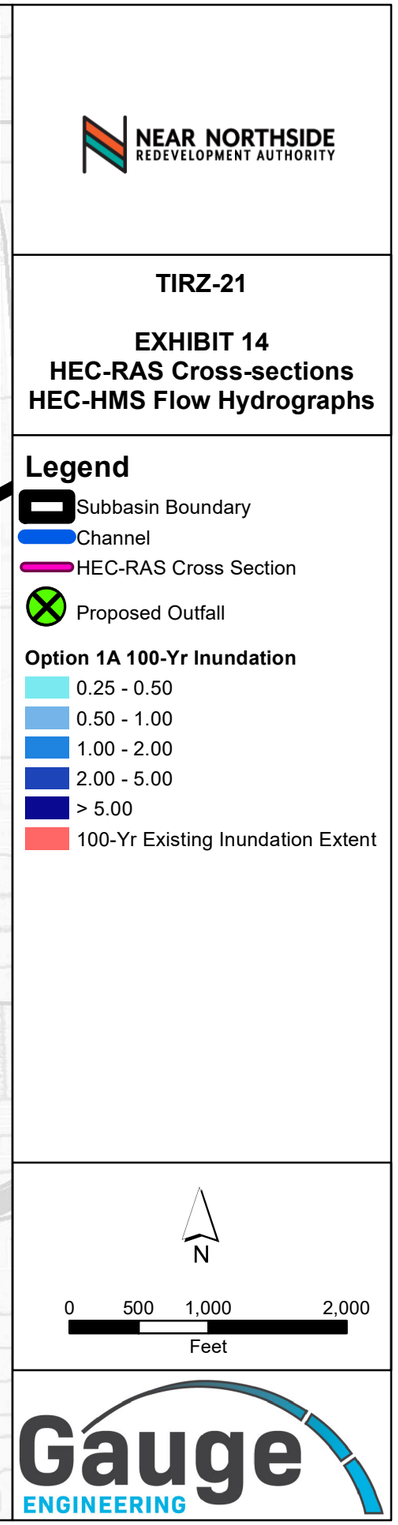
N

0 500 1,000 2,000
Feet

Gauge ENGINEERING







NEAR NORTHSIDE REDEVELOPMENT AUTHORITY

TIRZ-21

EXHIBIT 14
HEC-RAS Cross-sections
HEC-HMS Flow Hydrographs

Legend

- Subbasin Boundary
- Channel
- HEC-RAS Cross Section
- Proposed Outfall

Option 1A 100-Yr Inundation

- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 5.00
- > 5.00
- 100-Yr Existing Inundation Extent

N

0 500 1,000 2,000

Feet

Gauge ENGINEERING