



# Memorandum

**To:** Danny Cameron, P.E.  
Carol Harrison, P.E., ENV SP

**Date:** 2/9/2024

**From:** Johnny Kim, P.E., CFM

**AVO:** 54460.001

**Email:** jkim@halff.com

**Subject:** City of West University Place West Side Drainage Modeling

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## Introduction

Halff has been contracted by the City of West University Place to evaluate drainage improvements that would provide flood relief to the west side of the City. This area has been studied previously by HT&J (2021) and CobbFendley (2023). The current study consists of the following tasks:

- Enhancing hydraulic models from the previous analyses
- Determining the drainage improvements needed to provide flood relief
- Assessing mitigation requirements
- Simulating scenarios with varying levels of restriction
- Estimating opinion of probable cost of construction

The existing and proposed conditions were analyzed with the 2-, 10-, 25-, 50-, and 100-year storm events using NOAA Atlas 14 rainfall. The modeled study area is shown below in **Figure 1** and in **Exhibit 1**.

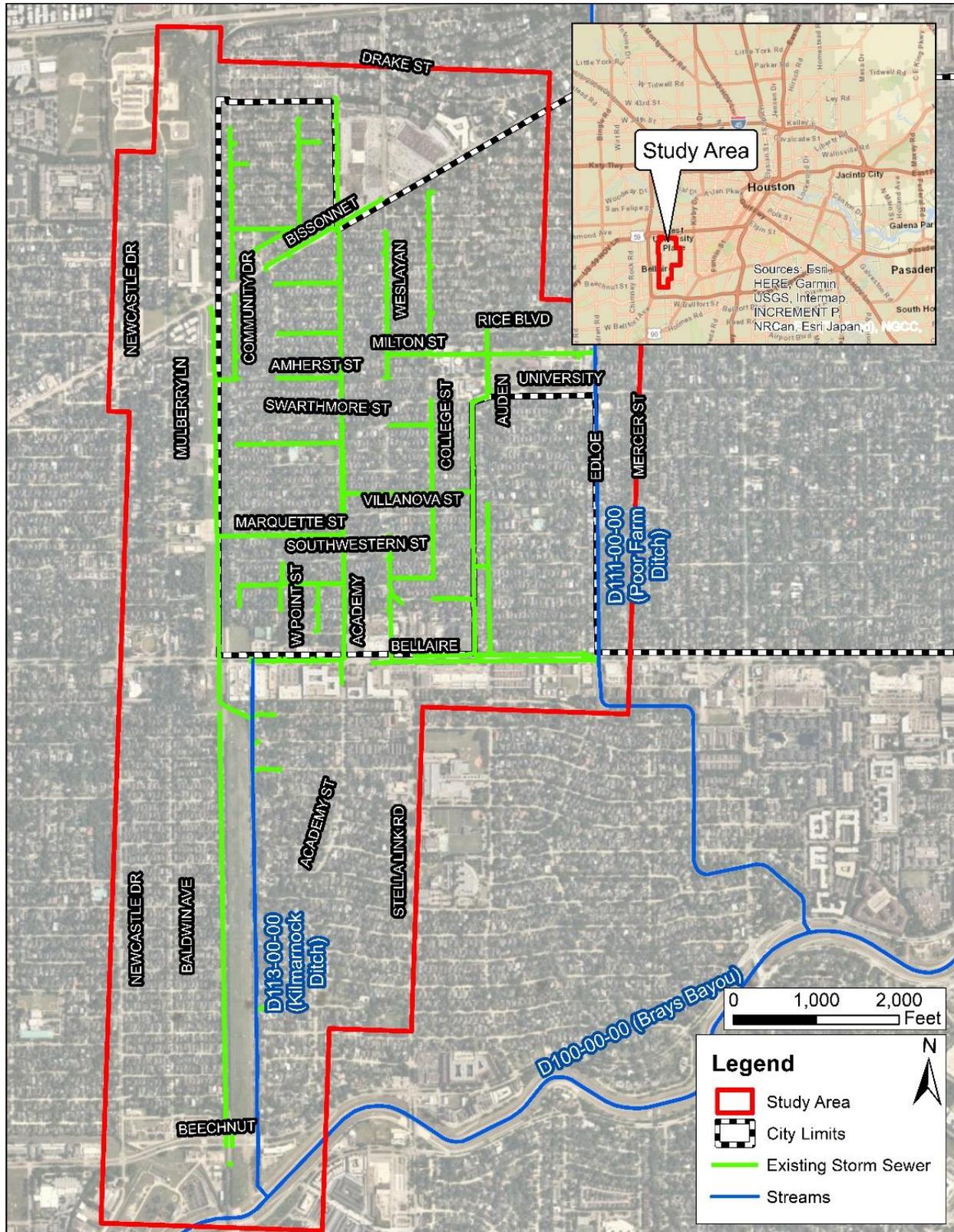


Figure 1: Study Area

## Previous Studies & Data Collection

The City of West University Place has had previous studies conducted to identify drainage issues and recommend solutions. These studies are summarized below:

- HT&J West University Place City-Wide Drainage Study (2021) – completed in 2021 to identify existing drainage issues. Provided high-level concepts for improving system draining to Kilmarnock Ditch.
- CobbFendley PW20-07 Street and Drainage West Preliminary Engineering Report (May 2023 PER) – 1D modeling analysis to improve storm drainage throughout west side. A number of drainage alternatives were reviewed, but no ultimate recommendation was made.

Several datasets were collected to assist in the study. The datasets included:

- Hydraulic models from previous HT&J and Cobb Fendley studies
- Survey and Preliminary Engineering Report from Cobb Fendley
- West University GIS storm sewer data

A site visit was conducted on July 27, 2023, to observe local drainage conditions and take photographs of the inlets and culverts along the Union Pacific railroad, Poor Farm Ditch, Kilmarnock Ditch, and to measure dimensions of select culvert structures. The field observation report from the site visit is provided in **Appendix A**.

## Existing Conditions Model Updates

The existing conditions model developed by CobbFendley was a 1D XPSWMM model (version 2019.1.2). Storm sewer was modeled as 1D underground conduits, and overland flow was modeled as 1D channel sections connected by weirs. Updates were made to both the hydrologic and hydraulic models for the current study, including expanding the drainage area to incorporate offsite flow and enhancing the hydraulic model to simulate overland flow in 2D. Details are provided below.

### HYDROLOGY

The Rational Method hydrology was performed by CobbFendley in the previous analysis and adopted for the current analysis. Halff reviewed the drainage area delineations and made one revision to add offsite drainage area to the northwest side of the model, which was not previously included. The additional offsite drainage area is shown in **Figure 2**. 2018 lidar for the study area is shown in **Exhibit 2**.

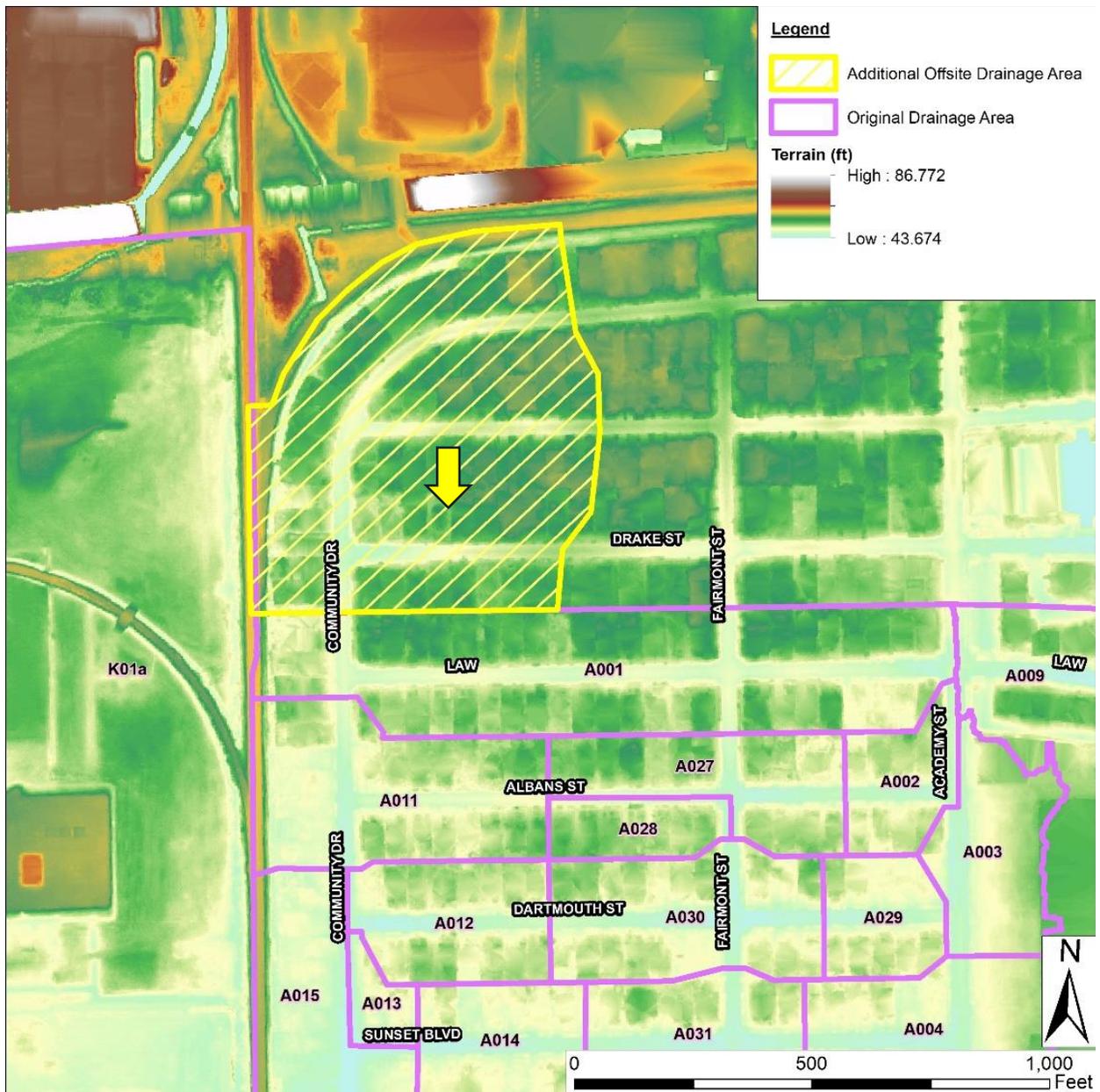


Figure 2: Additional Drainage Area

### HYDRAULIC MODEL UPDATES

The hydraulic model developed by CobbFendley was converted from a 1D model to a 1D/2D model. The hydraulic model conversion consisted of:

- Removing 1D storage from nodes and weirs representing overland flow
- Adding terrain, 2D grid, land use, and buildings
- Moving nodes to low spots in terrain and connecting nodes to the 2D grid
- Adding exit loss coefficients at outfall locations
- Applying dynamic tailwater conditions at outfall locations

The changes allowed for a more realistic accounting of surface flows and ponding throughout the study area by allowing overflows from the underground system to flow and pond on the surface as defined by the terrain. The existing storm sewer layout is provided on **Exhibit 3**.

The hydraulic model has three outfall locations in existing conditions: the Kilmarnock Ditch outfall to Brays Bayou, a storm sewer outfall to Poor Farm Ditch at Amherst Street, and a storm sewer outfall to Poor Farm Ditch at Bellaire Boulevard. **Table 1** shows the modeling assumptions that were made for tailwater conditions of the receiving channels. The tailwater elevations are taken from hydraulic models of Brays Bayou and Poor Farm Ditch that use Atlas 14 rainfall.

*Table 1: Tailwater Conditions*

| Storm Event | Tailwater Condition of Receiving Channel |
|-------------|--|
| 2-year      | Free outfall                             |
| 10-year     | Dynamic 2-year water surface elevation   |
| 25-year     | Dynamic 2-year water surface elevation   |
| 50-year     | Dynamic 5-year water surface elevation   |
| 100-year    | Dynamic 10-year water surface elevation  |

## Proposed Drainage Improvements

The goal of the proposed drainage improvements is to provide localized 100-year flood relief within the west side of the City of West University Place. The major improvements include the following, with additional detail below:

- Construct a new storm sewer trunkline within the ELPH Enterprises pipeline corridor on the west side of the City.
- Reroute existing storm sewer network for efficiency and direct toward the new trunkline.
- Upsize storm sewers throughout.

The proposed trunkline within the ELPH corridor consists of double-barrel 10'x10' reinforced concrete boxes (RCBs) that extend from Bissonnet Street to Brays Bayou. This provides a new route for the City to discharge flows directly into Brays Bayou. Additional storm sewer connections are needed to tie the existing network into the proposed trunkline. Connections to the trunkline are proposed at Bissonnet Street, Amherst Street, Byron Street, Marquette Street, and just south of Ruskin Street.

Portions of the existing storm sewer network contain circuitous routes that are inefficient for drainage. The proposed improvements include rerouting portions of the network for efficiency and to direct stormwater flow west toward the new trunkline. This includes adding new storm sewer lines under select roads. Many pipes throughout the project area are upsized in order to fully contain the expected 2-year flows underground and to keep ponding within the City's right of way in the 100-year event. The proposed improvements are shown on **Exhibit 4**, and major changes are noted below:

- Bissonnet Street upsized to a 96-inch line and redirected west toward the proposed trunkline
- A new line (up to 60-inch) on West Point Street between Coledridge and Amherst Streets
- Case Street between Academy and Community upsized from a 30-inch line to a 66-inch line
- New and upsized pipes (up to 96-inch) on Wesleyan Street between Marlowe and Marquette Streets
- Marquette Street between Wesleyan Street and the proposed trunkline upsized to up to a 108-inch line



On the western border of the study area, there is an existing trunkline (60-inch to 84-inch diameter) that runs parallel to and west of the Union Pacific railroad. Small portions of the City's existing storm sewer network tie into this trunkline in three locations – Amherst Street (24-inch outfall), Byron Street (18-inch outfall), and Marquette Street (30-inch outfall). In proposed conditions, these City systems will be improved and will tie into the proposed double-barrel 10'x10' RCBs instead, thereby reducing the flow contribution from the City into the 84-inch trunkline. The hydraulic model does not show noticeable increases in ponding west of the railroad due to the disconnecting of the City systems from the 84-inch trunkline, but relief connections can be modeled in the design phase if the final analysis shows any impact to this system.

## Mitigation Assessment

The proposed improvements to the storm sewer network divert approximately 70 acres of drainage area from the Poor Farm Ditch watershed to the Kilmarnock Ditch watershed (see **Figure 3**). At the same time, the proposed improvements to the storm sewer network improve drainage efficiency. Both of these factors result in an increase in runoff in the Kilmarnock Ditch watershed.

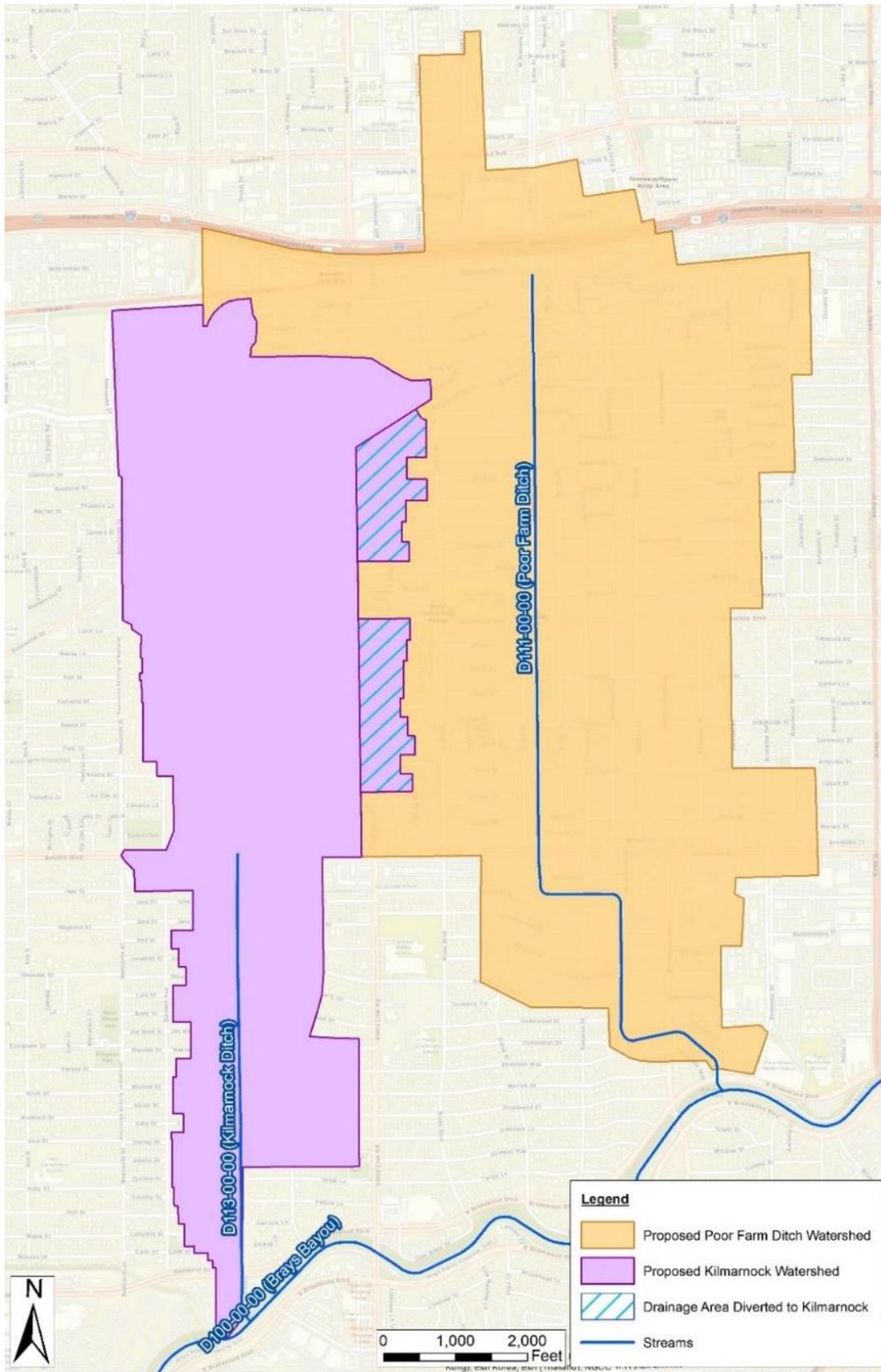


Figure 3: Proposed Conditions Watersheds

Basin Development Factor (BDF) hydrology is well-suited for assessing potential mitigation requirements because BDF quantifies the impact of development and improved drainage in a watershed. BDF calculations were performed on both watersheds in the existing and proposed conditions to determine Clark Unit hydrograph parameters and resulting runoff values. A summary is provided in **Table 2**, and detailed BDF calculations are provided in **Appendix B**.

*Table 2: BDF Runoff Calculations*

| Watershed                           | HMS Basin ID     | Drainage Area (ac) | Composite BDF | 100-year Peak Flow (cfs) | 100-year Maximum Volume Change |
|-------------------------------------|------------------|--------------------|---------------|--------------------------|--------------------------------|
| Kilmarnock Ditch<br><i>Existing</i> | D113_01_RevEX    | 800.3              | 7.37          | 1,435                    | + 208 ac-ft                    |
| Kilmarnock Ditch<br><i>Proposed</i> | D113_01_PROP_001 | 626.1              | 10.74         | 2,008                    |                                |
|                                     | D113_01_PROP_002 | 244.2              | 5.57          |                          |                                |
| Poor Farm Ditch<br><i>Existing</i>  | D111_01_RevEX    | 1,480.1            | 8.36          | 2,562                    | - 92 ac-ft                     |
| Poor Farm Ditch<br><i>Proposed</i>  | D111_01_PROP     | 1,410.1            | 8.36          | 2,471                    |                                |

According to the hydrologic analysis, in a 100-year storm event, the proposed improvements result in a maximum volume increase of 208 acre-feet in runoff in the Kilmarnock Ditch watershed and a maximum decrease of 92 acre-feet in the Poor Farm Ditch watershed. This amounts to a net gain of 116 acre-feet due to the project. Because the proposed improvements outfall to Brays Bayou, coordination with the Harris County Flood Control District (HCFCD) is needed to determine the necessity and volume of mitigation and the appropriate method of providing mitigation (e.g., through offsite detention along Brays Bayou).

## Mitigation Scenarios

Three scenarios were simulated, with each scenario assuming that a certain amount of offsite detention along Brays Bayou has been provided. The underlying assumption is that without any offsite detention, the City would be required to restrict flows from the proposed trunkline into Brays Bayou such that proposed flows from both the double 10x10 RCB outfall plus Kilmarnock Ditch do not exceed existing flows from Kilmarnock Ditch. On the other hand, if the City obtains all of the required mitigation volume in offsite detention, then the City could release flows without restriction, assuming there are no increases in maximum water surface elevations in Brays Bayou. And finally, if the City obtains only a portion of the required mitigation volume in offsite detention, then the outfall could be partially restricted. The three mitigation scenarios are listed below:

- **Scenario 1: Unrestricted outfall.** Assumes 100% of offsite detention is obtained; therefore, no restrictions are placed on the proposed outfall to Brays Bayou.
- **Scenario 2: Fully restricted outfall.** Assumes no offsite detention is obtained; therefore, in-line detention is provided within the City's drainage network, and restrictor plates are placed on both boxes of the proposed outfall to Brays Bayou such that proposed flows do not exceed existing flows. Based on the modeling, one of the restrictor plates must have a circular opening with a diameter of 21 inches.
- **Scenario 3: Partially restricted outfall.** Assumes approximately half of the offsite detention is obtained; therefore, one box outfall has a restrictor plate and the other does not.

The outfall configuration for each mitigation scenario is shown in **Figure 5**.

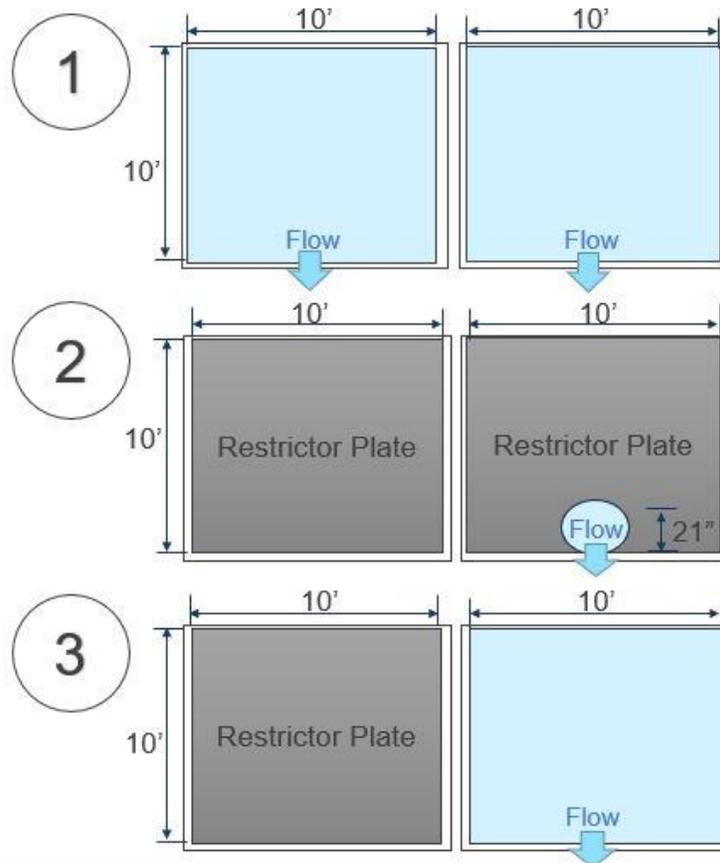


Figure 4: Trunkline Outfall Configurations

## RESULTS

The existing and proposed conditions were simulated for the 2-, 10-, 25-, 50-, and 100-year storm events. Existing ponding depths for the study area are shown on **Exhibits 5-8** for the various storm events. In the 2-year storm event, there are areas of street ponding, most notably on West Point and Academy Streets, but in general the ponding is contained within the City's right of way. In the 100-year storm event, the storm sewer network surcharges, and the overland flow cascades through the streets toward the southeast due to the terrain. The east-west dead-end streets near College Street experience major flooding outside the right of way due to the buildup of overland flow and the relatively high ground of the row of houses along Auden Street.

Proposed ponding depths for the Unrestricted, Fully Restricted, and Partially Restricted scenarios are shown on **Exhibits 9-12**, **Exhibits 13-16**, and **Exhibits 17-20**, respectively. All proposed scenarios eliminate extended-duration street ponding in the 2-year storm event (see **Exhibits 9, 13, and 17**). In all storm events larger than the 2-year, the extent of ponding reduction differs between the proposed scenarios.

Of the three proposed conditions, the Unrestricted scenario provides the greatest benefit to the project area. **Exhibit 12** shows that the 100-year ponding is greatly improved throughout the project area due to the proposed drainage improvements. The ponding is contained within the right of way, resulting in no expected structural flooding for the 100-year storm event and all smaller storm events.

The Fully Restricted scenario provides benefit to the north and west portions of the project area. **Exhibit 16** shows that the 100-year ponding is greatly improved along and near Bissonnet Street and generally contained within the right of way west of Wesleyan Street. However, there is little to no benefit in maximum

100-year ponding depths east of Wesleyan Street and south of University Boulevard due to the restrictors on the dual outfall at Brays Bayou.

The benefits of the Partially Restricted scenario resemble more closely those of the Unrestricted scenario than of the Fully Restricted scenario. **Exhibit 20** shows that the 100-year ponding is greatly improved throughout the project area. The ponding is contained within the right of way mostly everywhere, with a few minor exceptions east of College Street. The difference in ponding between the Partially Restricted and Unrestricted scenarios for the 10- and 25-year storm events are almost imperceptible. The modeling indicates that ponding benefits for the City are sensitive to the amount of restriction on the proposed dual outfall to Brays Bayou.

A comparison of 100-year ponding depths at select intersections throughout the project area (see **Figure 5**) is provided in **Table 3**.

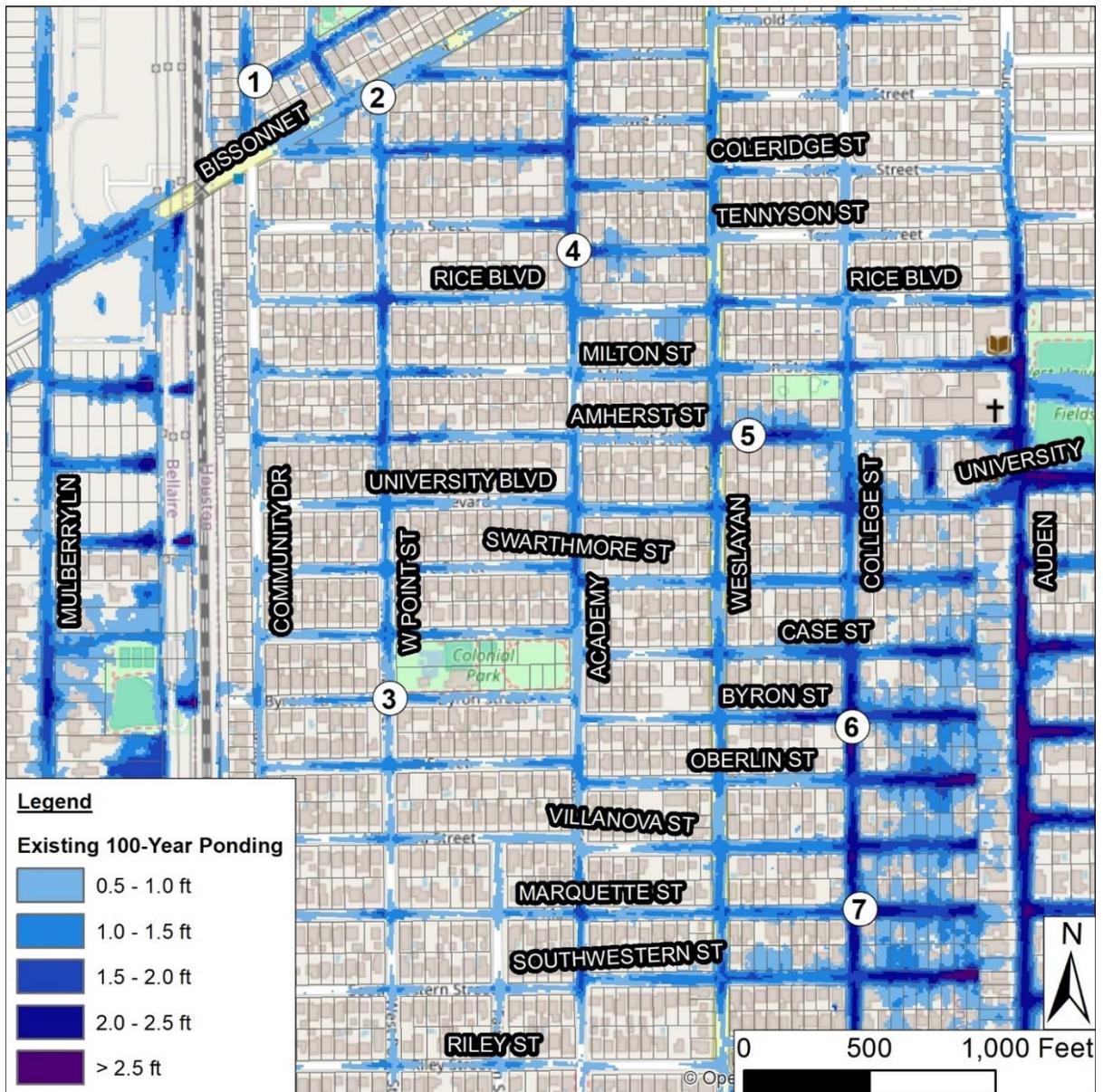


Figure 5: Selected Intersections for Ponding Depth Comparison

Table 3: Street Ponding Depths (100-year)

| Intersection             | Existing Ponding Depth (ft) | Proposed Ponding Depth (ft) |       |                  |       |                      |       |
|--------------------------|-----------------------------|-----------------------------|-------|------------------|-------|----------------------|-------|
|                          |                             | Unrestricted                | Δ     | Fully Restricted | Δ     | Partially Restricted | Δ     |
| 1 Community & S Judson   | 1.95                        | None                        | -1.95 | 1.56             | -0.39 | None                 | -1.95 |
| 2 West Point & Bissonnet | 1.06                        | None                        | -1.06 | 0.54             | -0.52 | None                 | -1.06 |
| 3 West Point & Byron     | 1.36                        | None                        | -1.36 | 1.29             | -0.07 | 0.55                 | -0.81 |
| 4 Academy & Tennyson     | 2.07                        | 0.5                         | -1.57 | 1.75             | -0.32 | 1.08                 | -0.99 |
| 5 Wesleyan & Amherst     | 2.01                        | 1.05                        | -0.96 | 1.94             | -0.07 | 1.18                 | -0.83 |
| 6 College & Byron        | 2.93                        | 1.47                        | -1.46 | 3.01             | 0.08  | 1.80                 | -1.13 |
| 7 College & Marquette    | 2.59                        | 1.12                        | -1.47 | 2.69             | 0.10  | 1.39                 | -1.20 |

Again, the results show that the Unrestricted and Partially Restricted scenarios provide large reductions in 100-year ponding throughout the project area, while the benefits of the Fully Restricted scenario are generally confined to the north side of the project area (locations 1, 2, and 4 on **Figure 5**). The Fully Restricted solution has slight increases of 0.08 and 0.10 feet at locations 6 and 7, respectively.

## Cost Estimate

A planning-level cost estimate was prepared for the construction of the recommended drainage improvements. The cost estimate was divided into two parts: (1) ELPH trunkline, and (2) internal west side improvements. The opinion of probable cost of construction for the ELPH trunkline and the internal west side improvements is approximately **\$71,167,200** and **\$29,731,000**, respectively. The total estimated cost is **\$100,898,200**.

The cost estimate includes removal and disposal of the abandoned pipelines, all proposed drainage infrastructure and associated paving costs, and a 30% contingency. Offsite mitigation, acquisition of the ELPH pipeline corridor, and water and sanitary relocation costs are not included. The detailed cost estimate, including unit prices and quantities, is provided in **Appendix C**.



## Recommendations & Next Steps

Halff recommends that the proposed drainage improvements presented in this study move into preliminary design. Next steps include the following:

- Consult with HCFCD to vet the approach and mitigation strategy
- Verify and eliminate slight increases in ponding depth where noted for the Fully Restricted scenario
- Determine project phasing
- Scope preliminary design

Halff was pleased to have the opportunity to serve the City of West University Place on this important study. If you have any questions or need additional information, please contact me.

### Halff Associates, Inc.

Texas Firm Registration No. 312

Johnny Kim, PE, CFM  
Water Resources Team Leader



2/9/2024

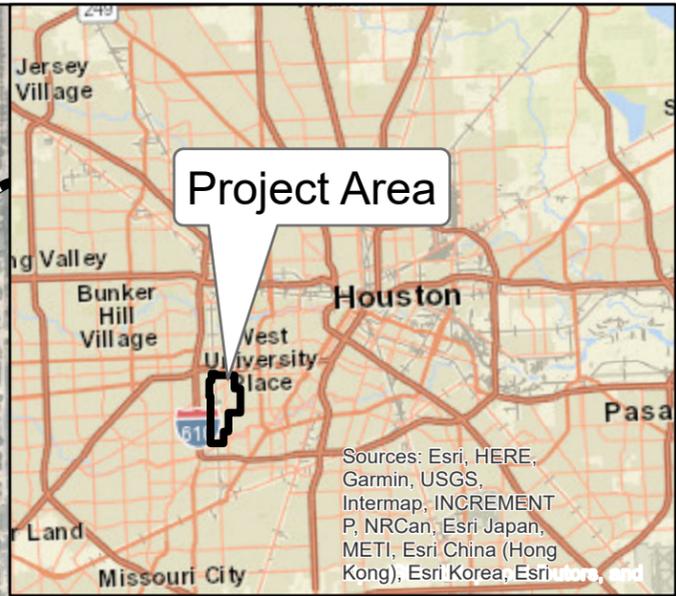
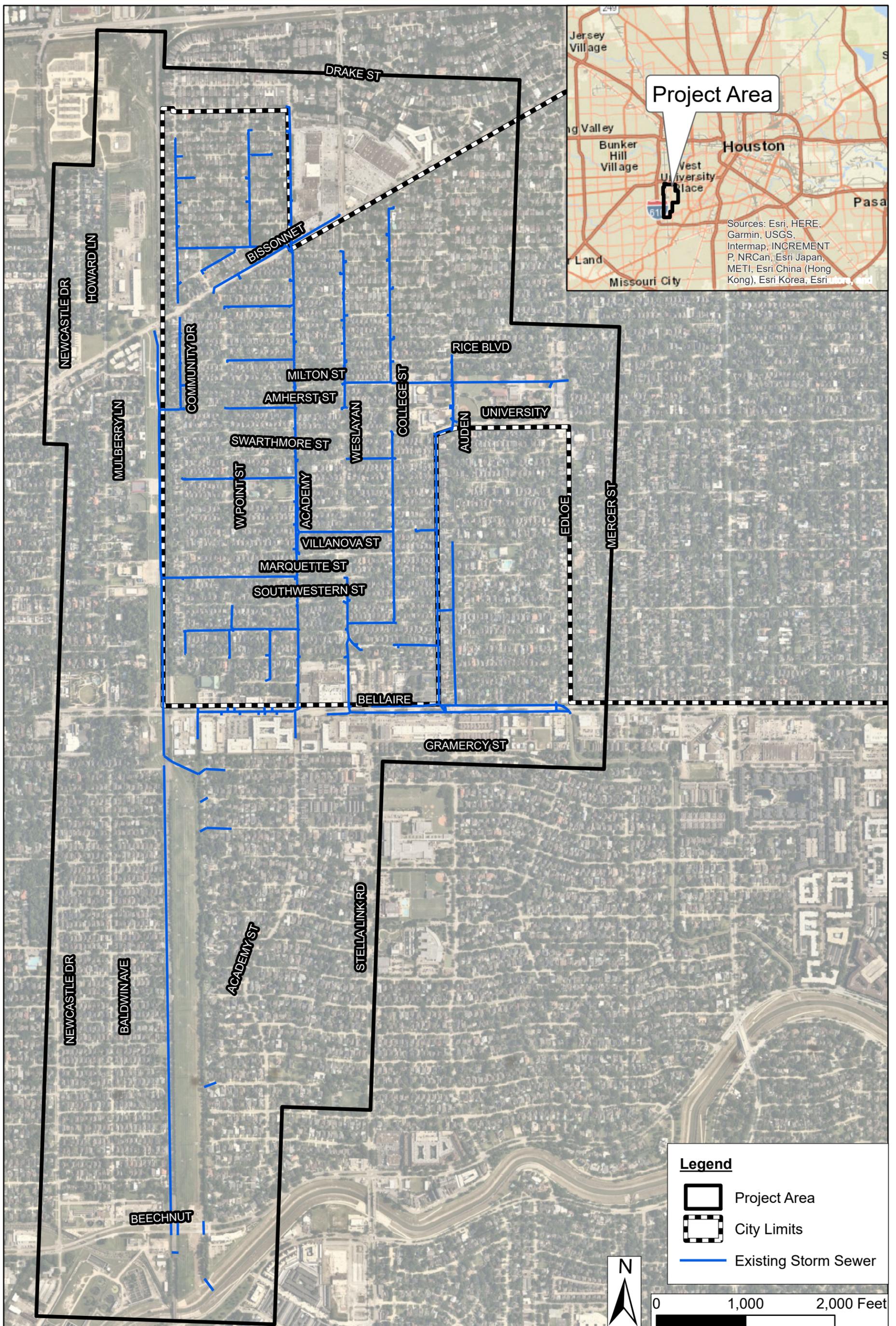
### Enclosures:

### Exhibits

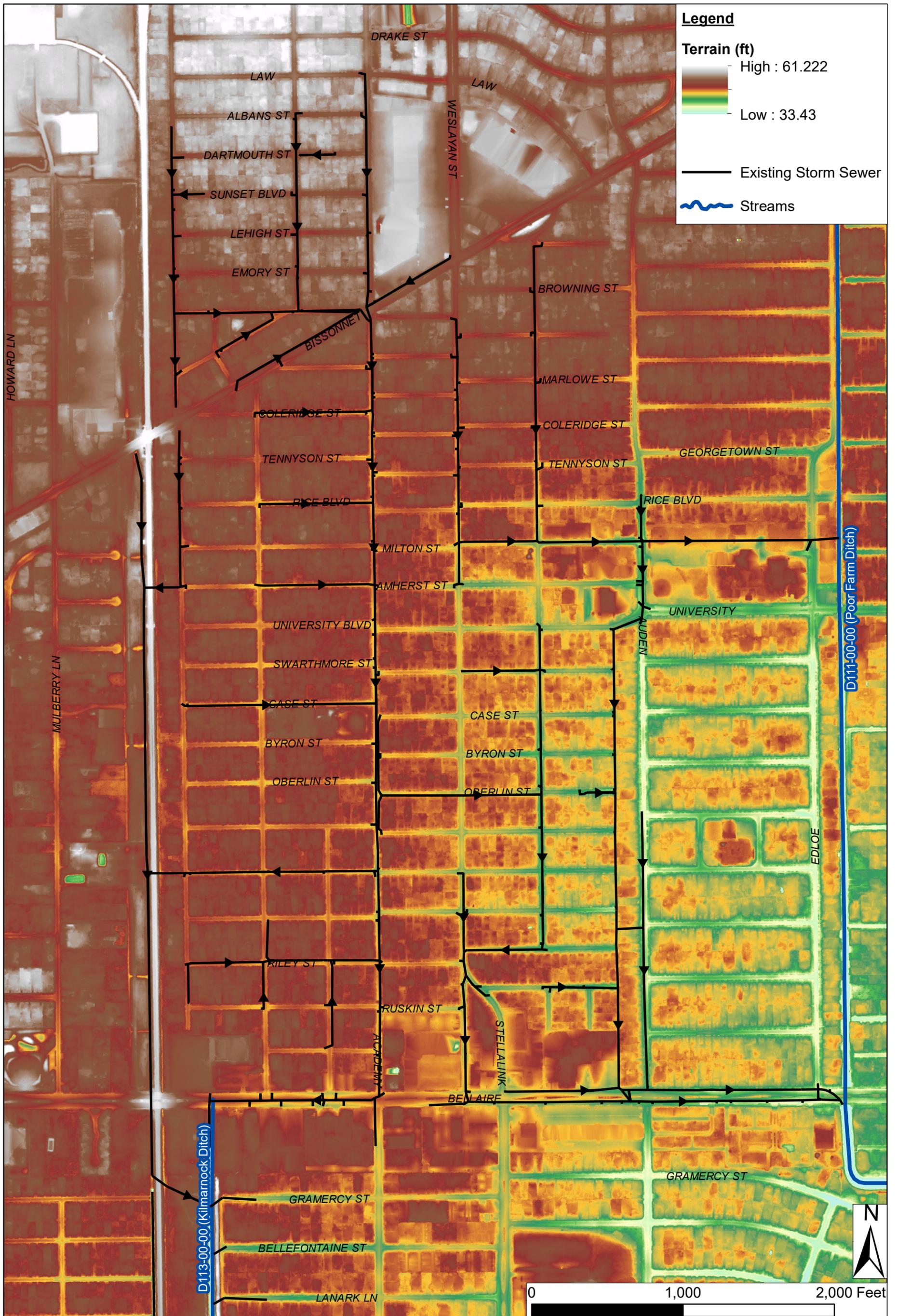
1. Location Map
2. Terrain
3. Existing Storm Sewer
4. Proposed Storm Sewer
5. Existing 2-Year Ponding
6. Existing 10-Year Ponding
7. Existing 25-Year Ponding
8. Existing 100-Year Ponding
9. Proposed Unrestricted (Ultimate) 2-Year Ponding
10. Proposed Unrestricted (Ultimate) 10-Year Ponding
11. Proposed Unrestricted (Ultimate) 25-Year Ponding
12. Proposed Unrestricted (Ultimate) 100-Year Ponding
13. Proposed Fully Restricted 2-Year Ponding
14. Proposed Fully Restricted 10-Year Ponding
15. Proposed Fully Restricted 25-Year Ponding
16. Proposed Fully Restricted 100-Year Ponding
17. Proposed Partially Restricted 2-Year Ponding
18. Proposed Partially Restricted 10-Year Ponding
19. Proposed Partially Restricted 25-Year Ponding
20. Proposed Partially Restricted 100-Year Ponding

### Appendices

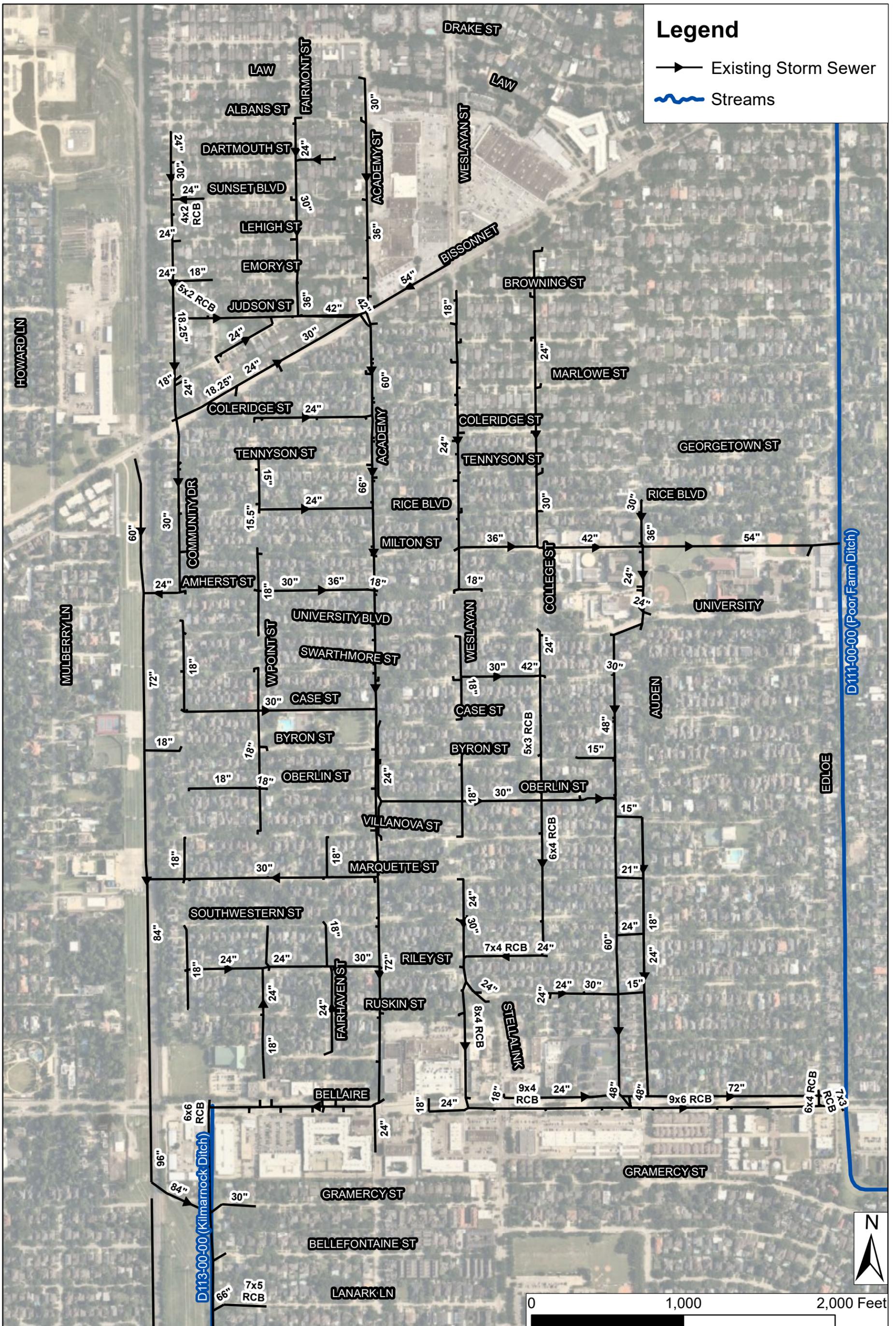
- A. Field Observation Report
- B. Detailed BDF Calculations
- C. Detailed Cost Estimate



|                            |  |  |   |  |             |
|----------------------------|--|--|---|--|-------------|
| <b>Exhibit</b><br><b>1</b> | <br><b>City of West University Place</b> | <br><b>HALFF ASSOCIATES, INC.</b><br>14800 ST. Mary's Lane, Suite 160<br>Houston, Texas 77079-2943<br>www.halff.com<br>TBPELS Firm No. F-312 | <b>Location Map</b>   |  | PROJECT AVO |
|                            |  |  | CoWU Westside Drainage Modeling   |  | 54460       |
|                            |  |  | DATUM & COORDINATE SYSTEM<br>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet |  |             |

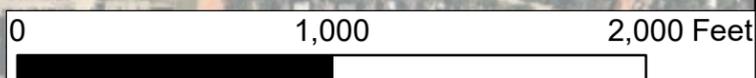


|                            |  |                                 |  |
|----------------------------|--|---------------------------------|--|
| <b>Exhibit</b><br><b>2</b> | <br><b>halff</b><br><small>HALFF ASSOCIATES, INC.<br/>         14800 St. Mary's Lane, Suite 160<br/>         Houston, Texas 77079-2943<br/>         www.halff.com<br/>         TBPELS Firm No. F-312</small> | <b>Terrain</b>                  | PROJECT AVO<br>54460   |
|                            |  | CoWU Westside Drainage Modeling | DATUM & COORDINATE SYSTEM<br><small>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet</small> |



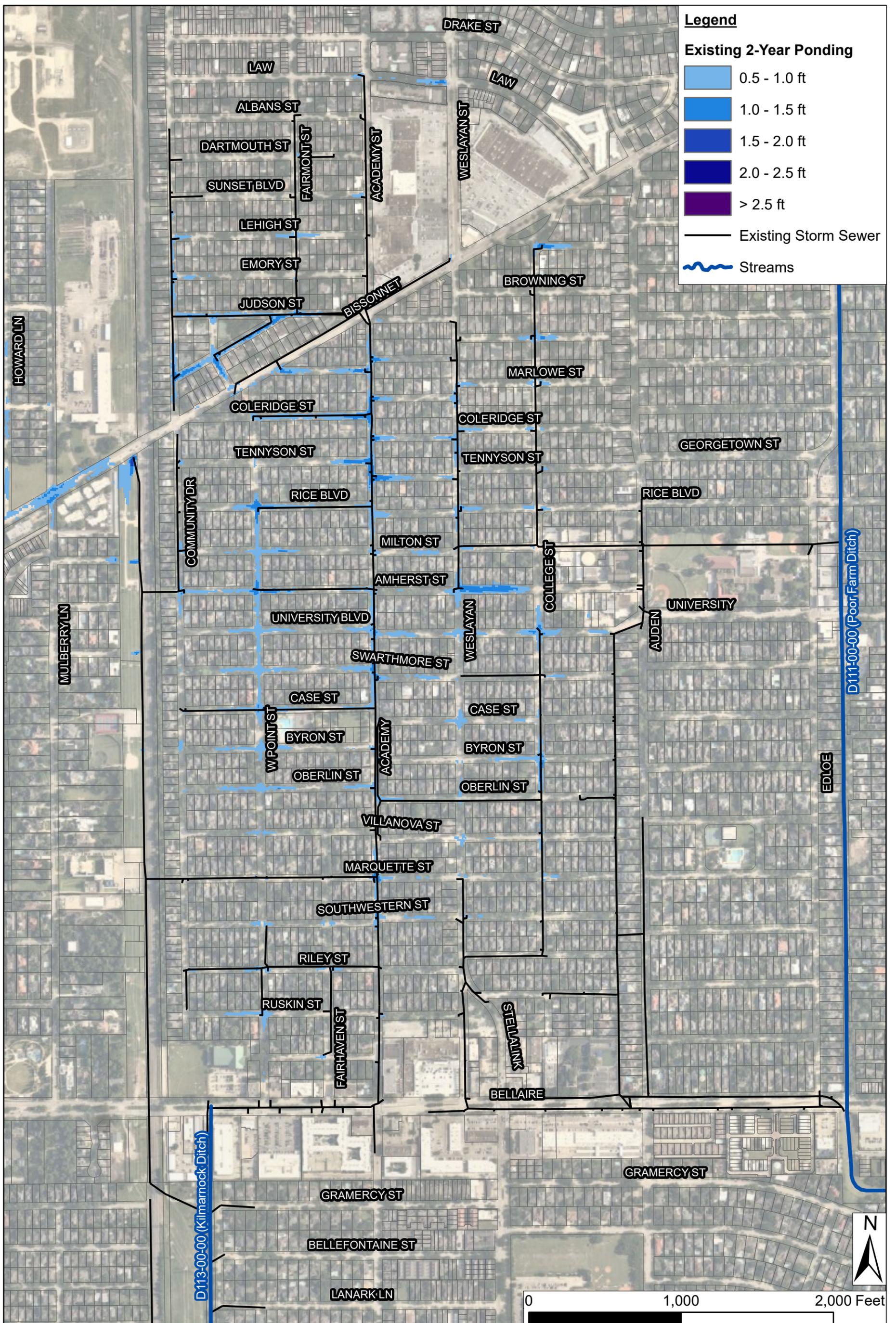
**Legend**

- Existing Storm Sewer
- Streams

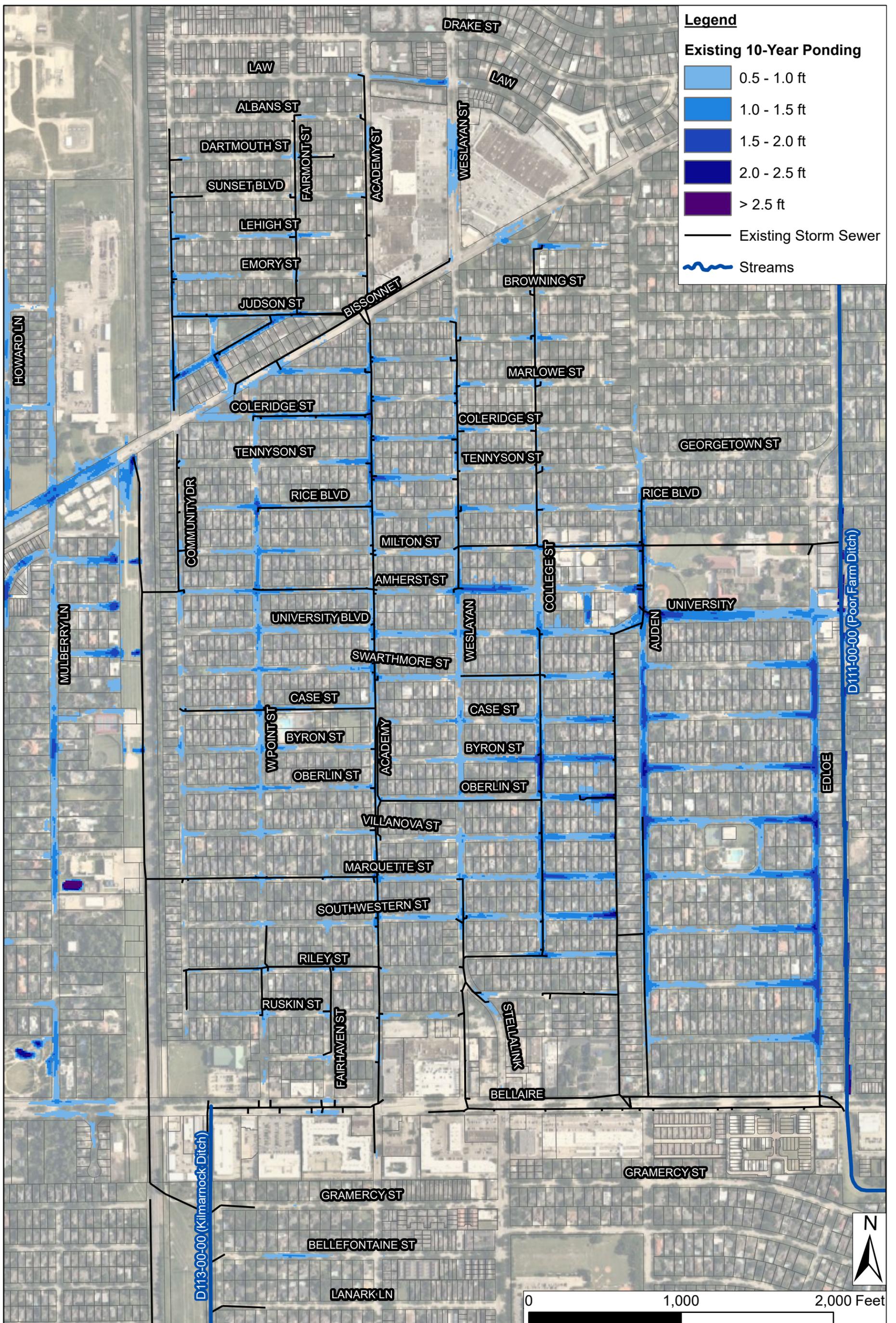


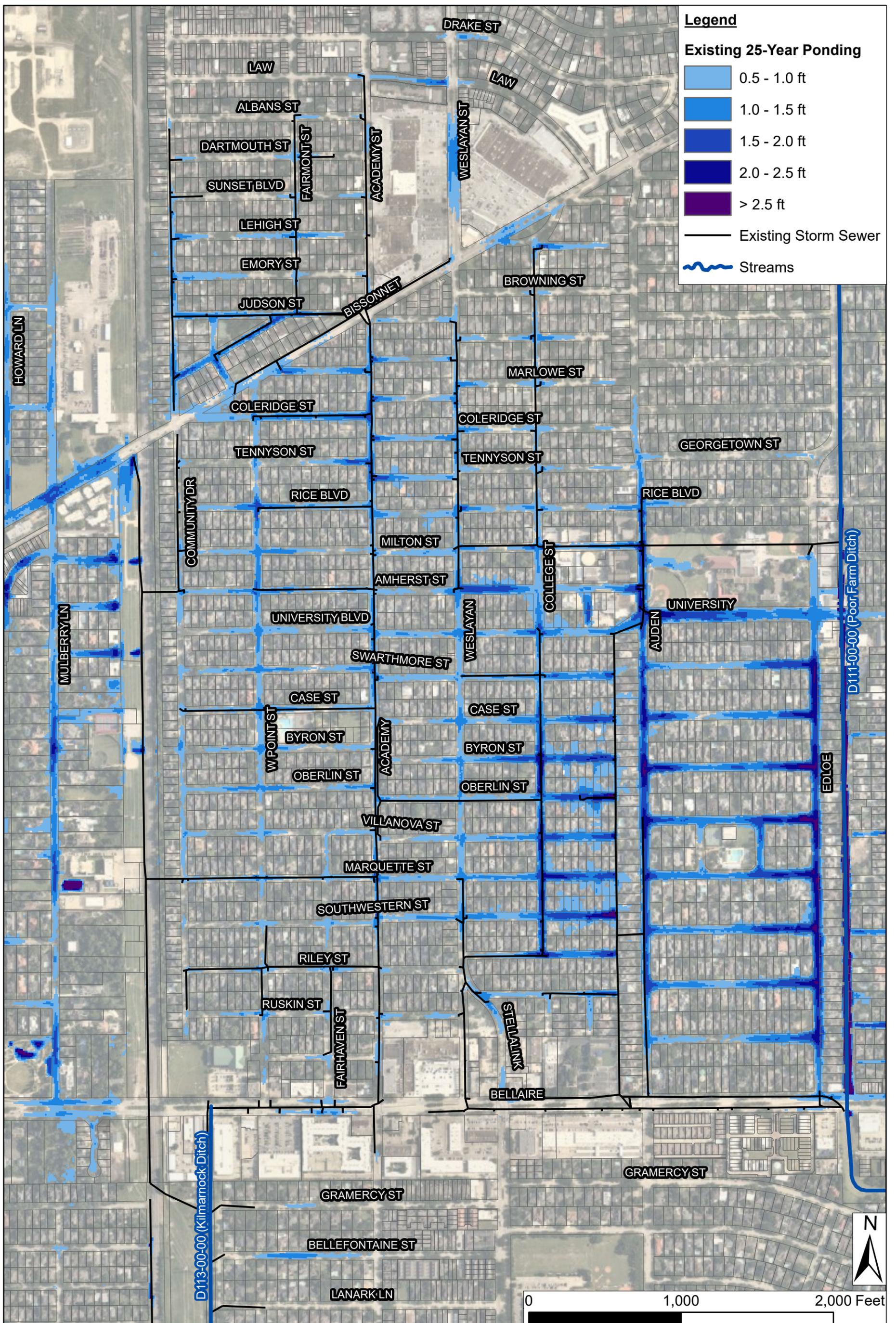
|                     |  |                                    |  |
|---------------------|--|------------------------------------|--|
| <b>Exhibit</b><br>3 | <br><br><small>HALFF ASSOCIATES, INC.<br/>14800 St. Mary's Lane, Suite 160<br/>Houston, Texas 77079-2943<br/>www.halff.com<br/>TBPELS Firm No. F-312</small> | <b>West U Existing Storm Sewer</b> | PROJECT AVO<br>54460   |
|                     |  | CoWU Westside Drainage Modeling    | DATUM & COORDINATE SYSTEM<br><small>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet</small> |



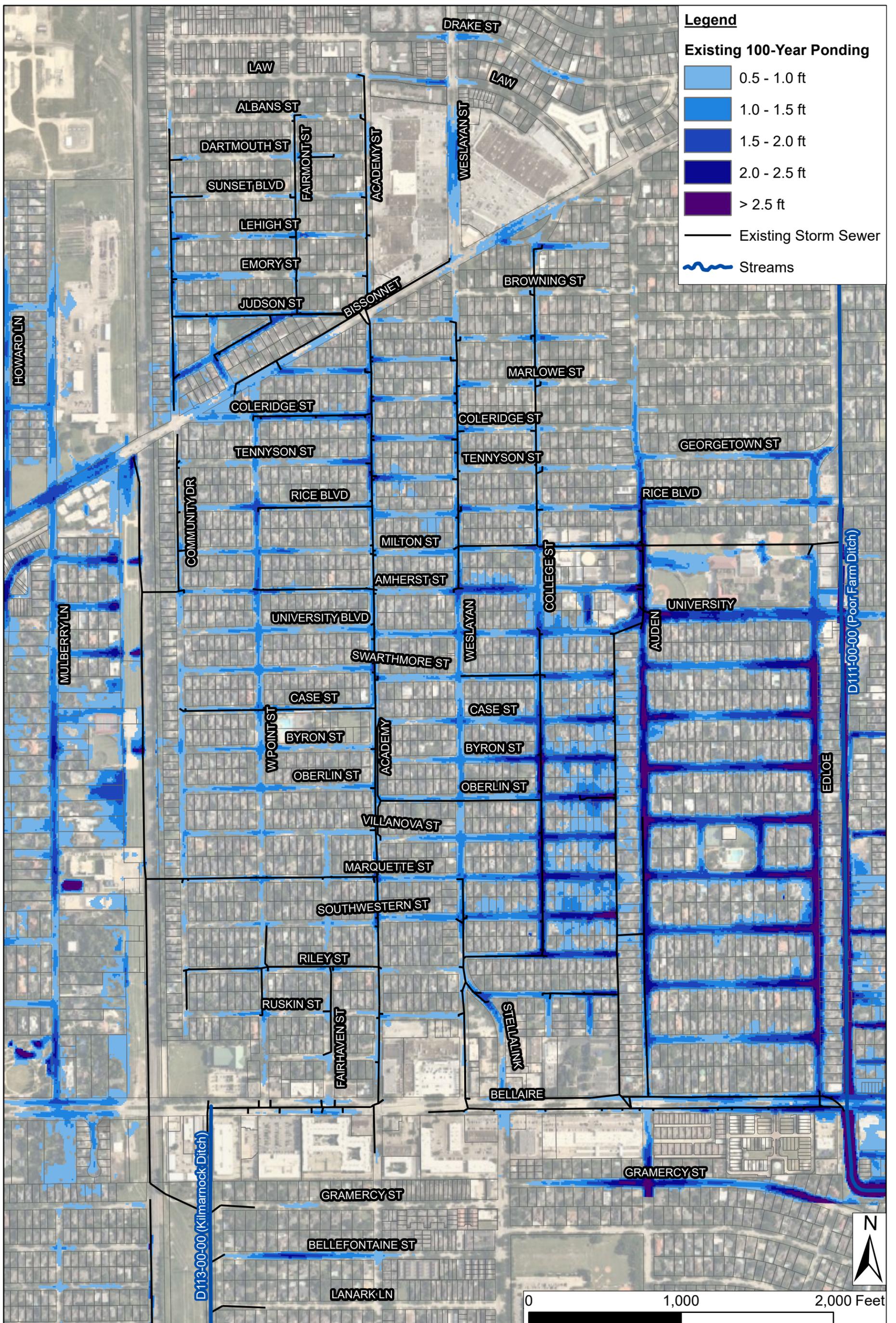


|                     |  |                                 |   |
|---------------------|--|---------------------------------|---|
| <b>Exhibit</b><br>5 | <br>City of<br>West University<br>Place<br><br>HALFF ASSOCIATES, INC.<br>14800 St. Mary's Lane, Suite 160<br>Houston, Texas 77079-2943<br>www.halff.com<br>TBPELS Firm No. F-312 | <b>Existing 2-Year Ponding</b>  | PROJECT AVO<br>54460  |
|                     |  | CoWU Westside Drainage Modeling | DATUM & COORDINATE SYSTEM<br>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet |

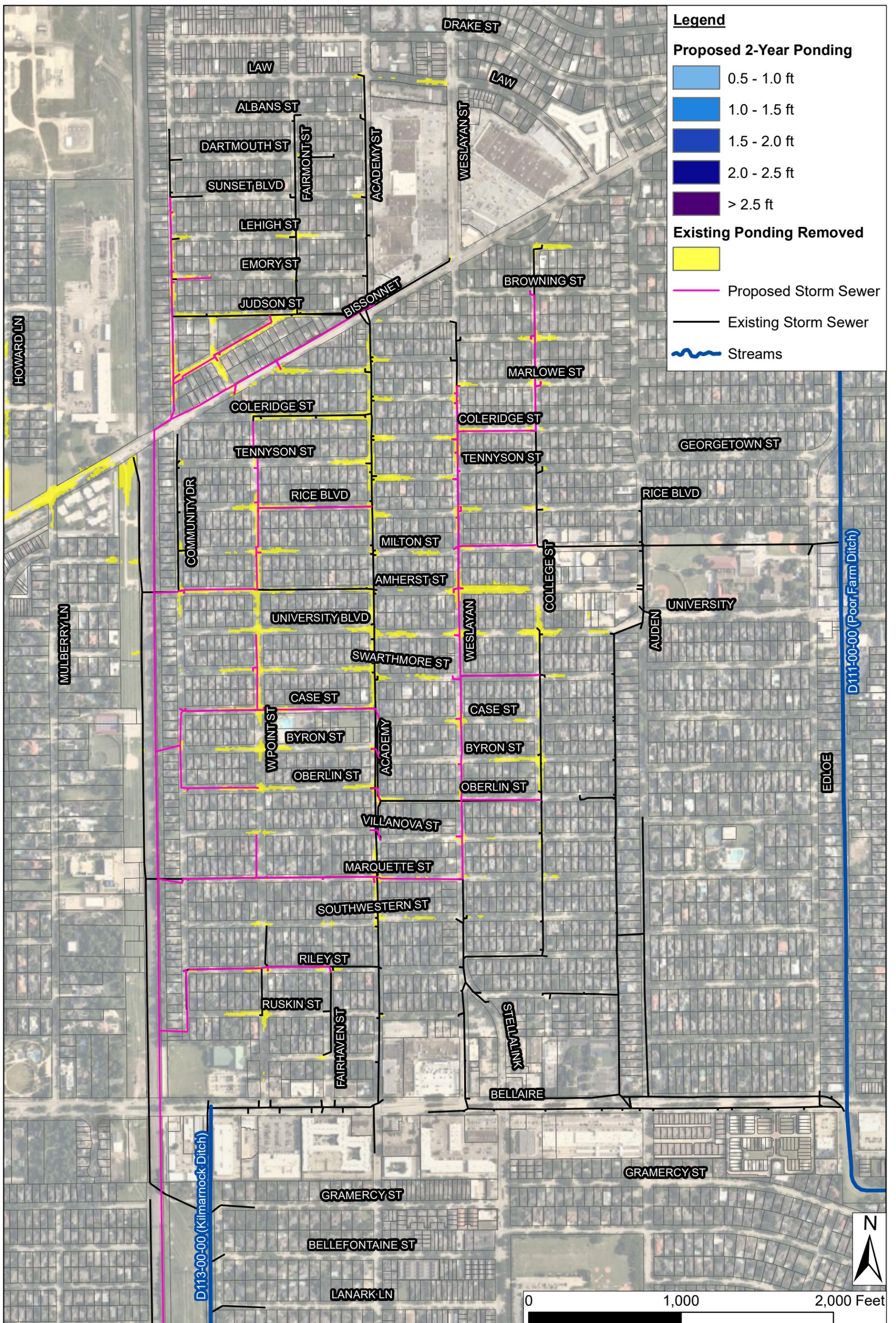


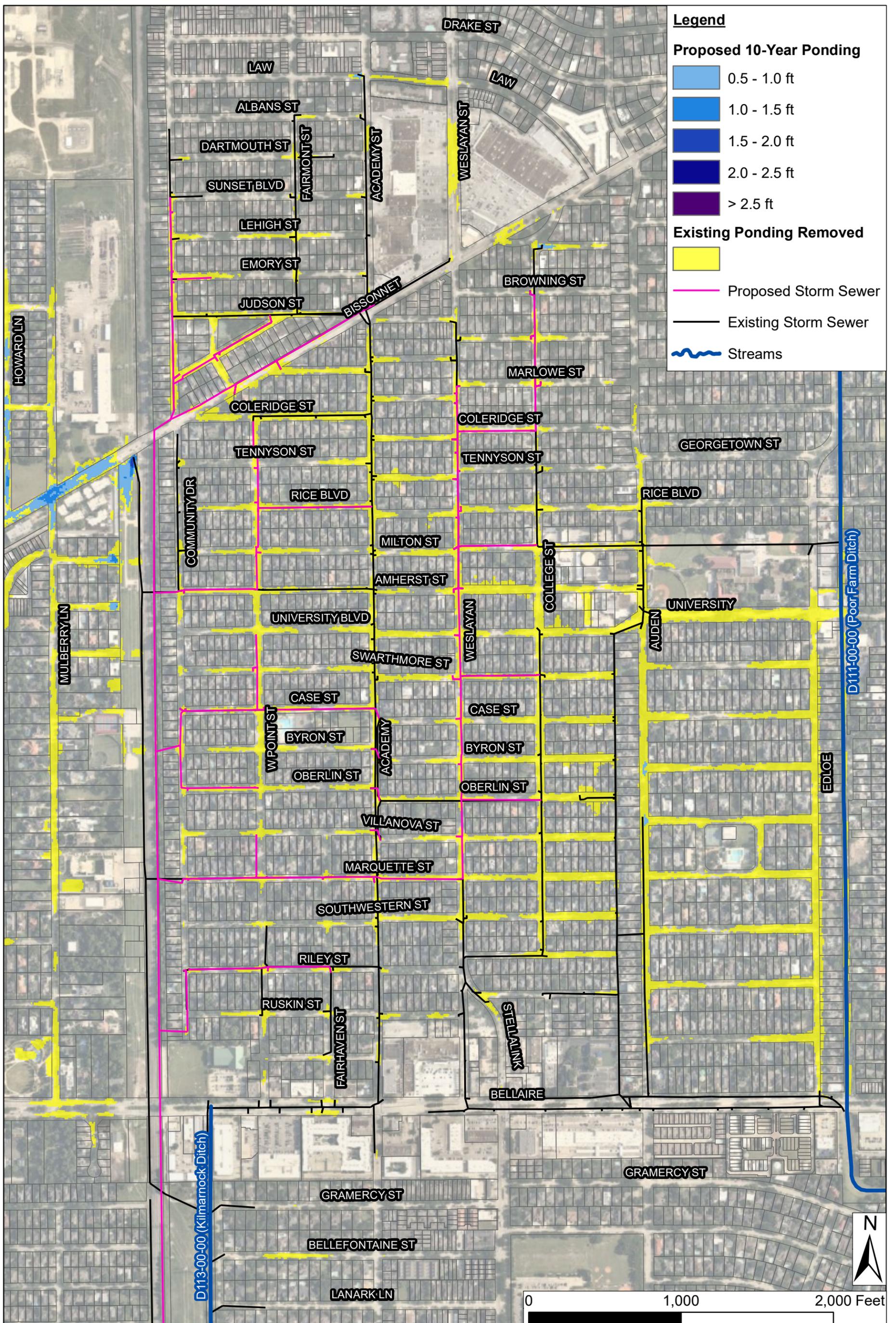


|                             |   |   |  |
|-----------------------------|---|---|--|
| <p><b>Exhibit</b><br/>7</p> |  <p><b>halff</b><br/>HALFF ASSOCIATES, INC.<br/>14800 St. Mary's Lane, Suite 160<br/>Houston, Texas 77079-2943<br/>www.halff.com<br/>TBPELS Firm No. F-312</p> | <p><b>Existing 25-Year Ponding</b></p> <p>CoWU Westside Drainage Modeling</p> | <p>PROJECT AVO<br/>54460</p> <p>DATUM &amp; COORDINATE SYSTEM<br/>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet</p> |
|-----------------------------|---|---|--|



|                     |  |  |  |
|---------------------|--|--|--|
| <b>Exhibit</b><br>8 | <br><b>halff</b><br><small>HALFF ASSOCIATES, INC.<br/>14800 St. Mary's Lane, Suite 160<br/>Houston, Texas 77079-2943<br/>www.halff.com<br/>TBPELS Firm No. F-312</small> | <b>Existing 100-Year Ponding</b>       | <b>PROJECT AVO</b>   |
|                     |  | <b>CoWU Westside Drainage Modeling</b> | 54460<br><br><b>DATUM &amp; COORDINATE SYSTEM</b><br><small>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet</small> |





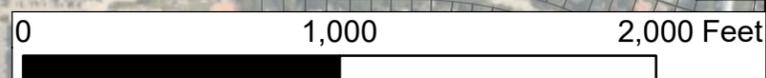
**Legend**

**Proposed 10-Year Ponding**

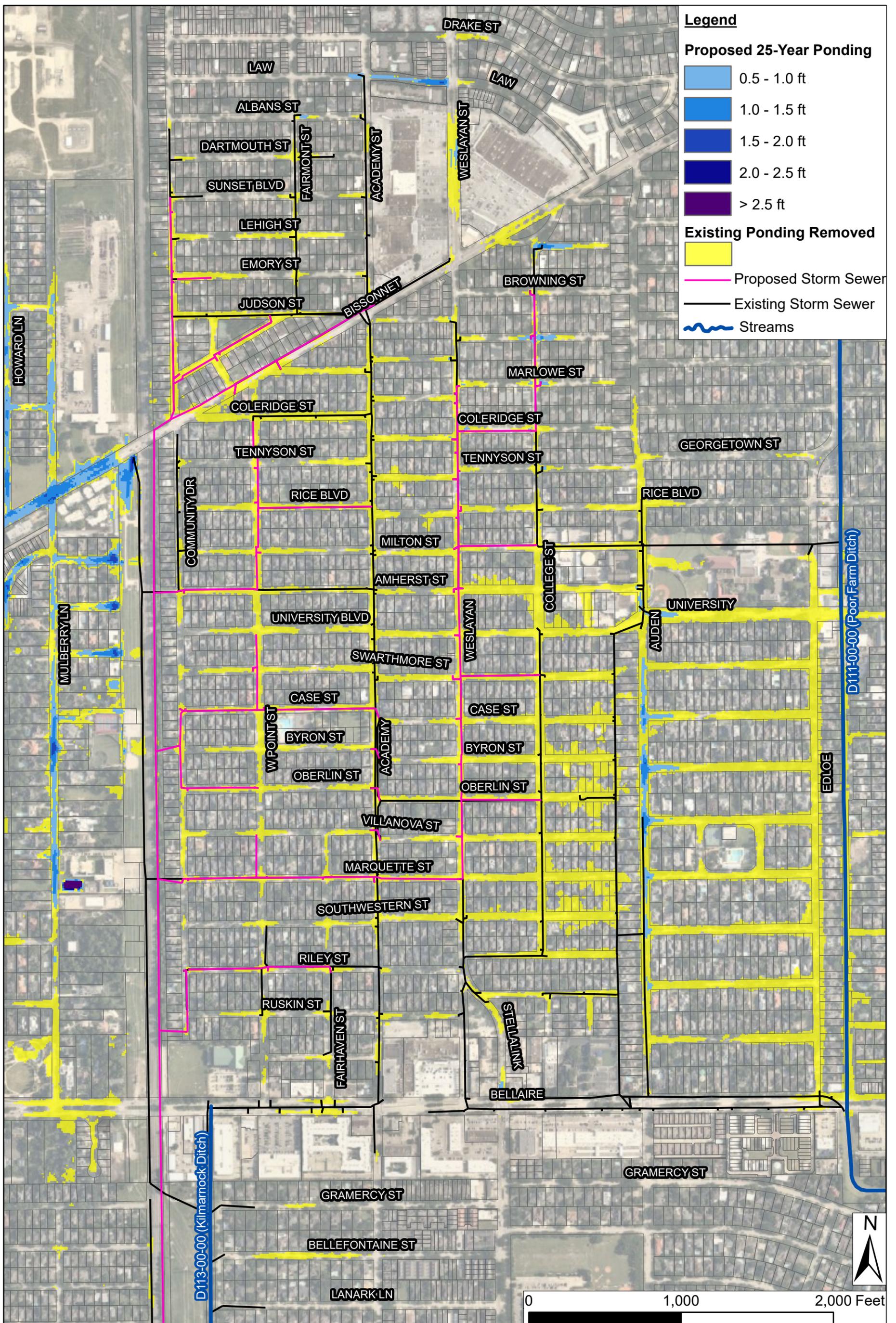
- 0.5 - 1.0 ft
- 1.0 - 1.5 ft
- 1.5 - 2.0 ft
- 2.0 - 2.5 ft
- > 2.5 ft

**Existing Ponding Removed**

- Proposed Storm Sewer
- Existing Storm Sewer
- Streams



|                   |  |   |   |              |
|-------------------|--|---|---|--------------|
| <b>Exhibit 10</b> | <br><b>City of West University Place</b><br><br><small>HALFF ASSOCIATES, INC.<br/>14800 St. Mary's Lane, Suite 160<br/>Houston, Texas 77079-2943<br/>www.halff.com<br/>TBPELS Firm No. F-312</small> | <b>Proposed Unrestricted (Ultimate) 10-Year Ponding</b> | <b>PROJECT AVO</b>  | <b>54460</b> |
|                   |  | <b>CoWU Westside Drainage Modeling</b>                  | <b>DATUM &amp; COORDINATE SYSTEM</b><br><small>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet</small> |              |



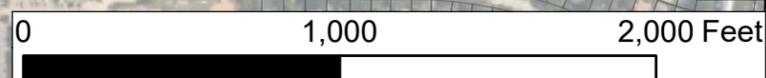
**Legend**

**Proposed 25-Year Ponding**

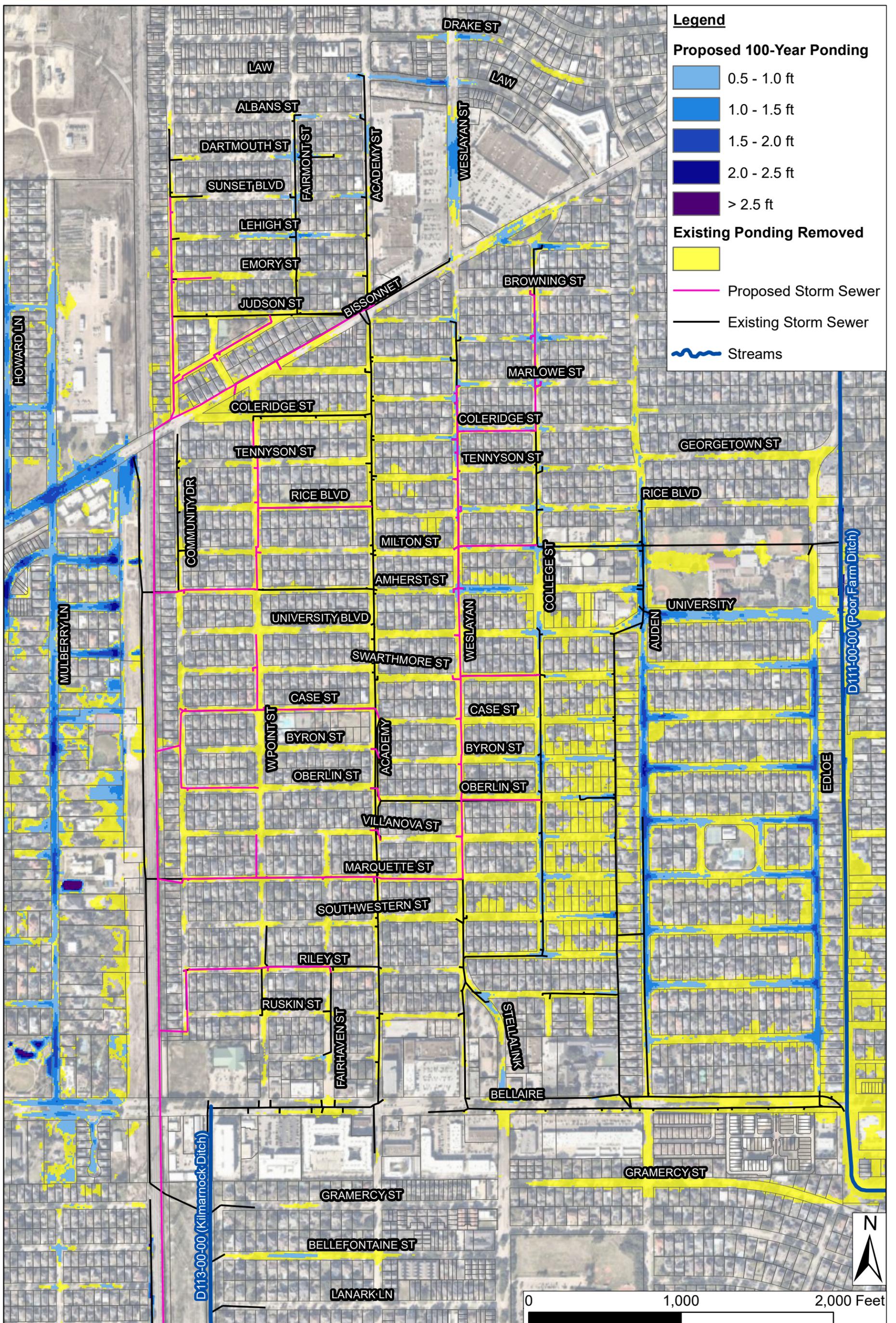
- 0.5 - 1.0 ft
- 1.0 - 1.5 ft
- 1.5 - 2.0 ft
- 2.0 - 2.5 ft
- > 2.5 ft

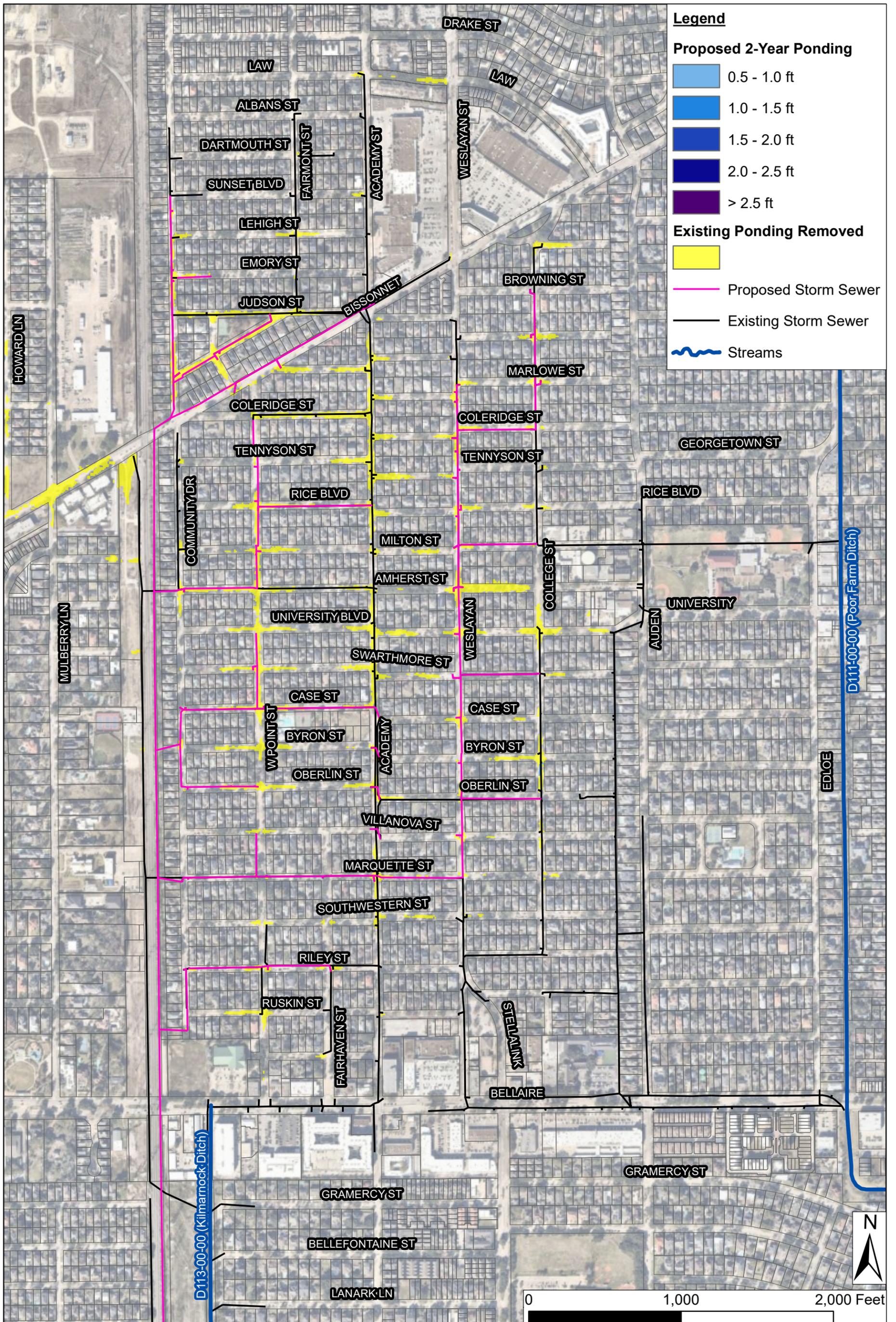
**Existing Ponding Removed**

- Proposed Storm Sewer
- Existing Storm Sewer
- Streams

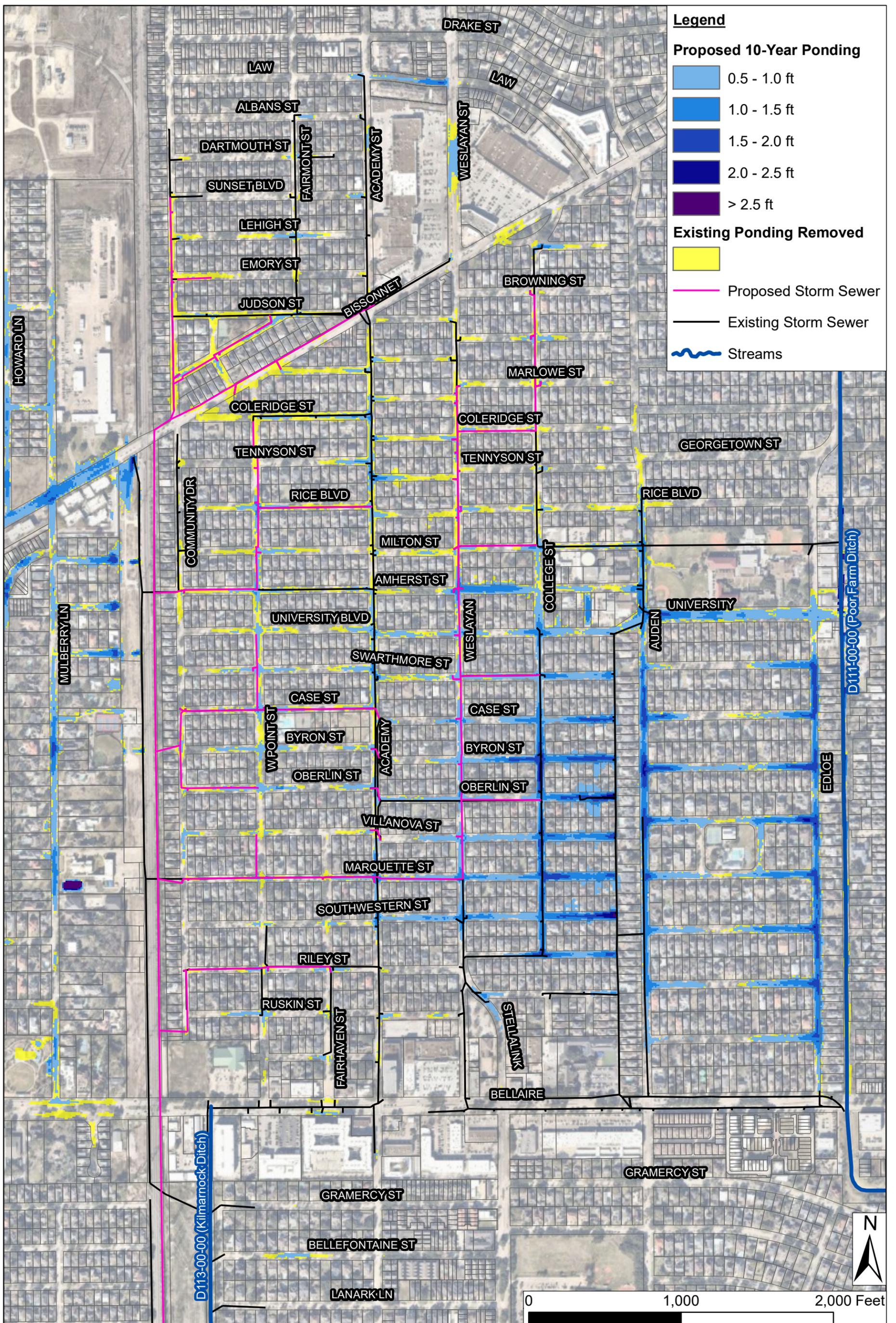


|                   |  |   |                    |
|-------------------|--|---|--------------------|
| <b>Exhibit 11</b> | <br><b>halff</b><br><small>HALFF ASSOCIATES, INC.<br/>14800 St. Mary's Lane, Suite 160<br/>Houston, Texas 77079-2943<br/>www.halff.com<br/>TBPELS Firm No. F-312</small> | <b>Proposed Unrestricted (Ultimate) 25-Year Ponding</b>   | <b>PROJECT AVO</b> |
|                   |  | <b>CoWU Westside Drainage Modeling</b>  | <b>54460</b>       |
|                   |  | <b>DATUM &amp; COORDINATE SYSTEM</b><br><small>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet</small> |                    |





|                              |  |   |  |
|------------------------------|--|---|--|
| <p><b>Exhibit</b><br/>13</p> |   <p>HALFF ASSOCIATES, INC.<br/>14800 St. Mary's Lane, Suite 160<br/>Houston, Texas 77079-2943<br/>www.halff.com<br/>TBPELS Firm No. F-312</p> | <p><b>Proposed Fully Restricted 2-Year Ponding</b></p> <p>CoWU Westside Drainage Modeling</p> | <p><b>PROJECT AVO</b></p> <p>54460</p> <p><b>DATUM &amp; COORDINATE SYSTEM</b></p> <p>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet</p> |
|------------------------------|--|---|--|



**Legend**

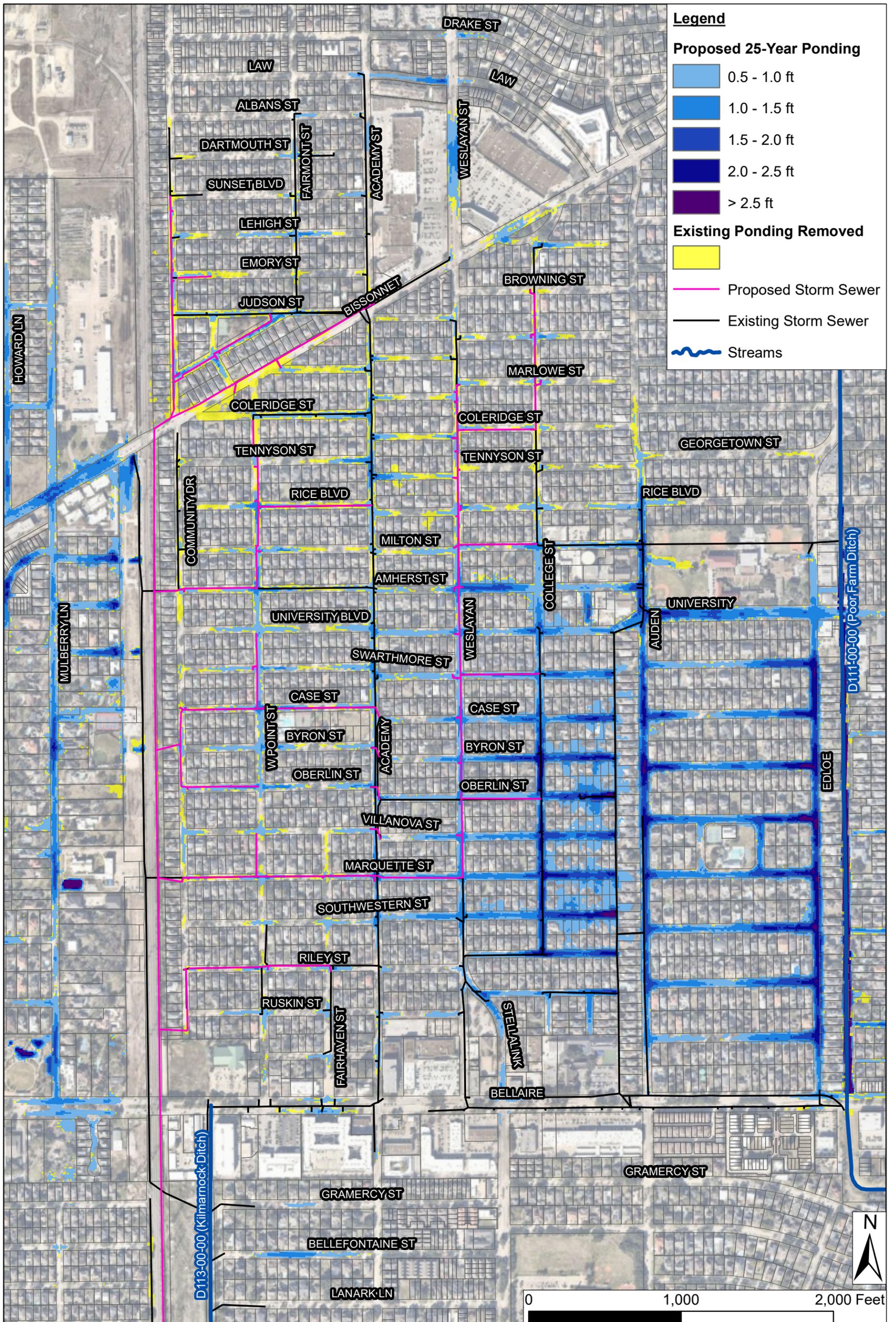
**Proposed 10-Year Ponding**

- 0.5 - 1.0 ft
- 1.0 - 1.5 ft
- 1.5 - 2.0 ft
- 2.0 - 2.5 ft
- > 2.5 ft

**Existing Ponding Removed**

- 
- Proposed Storm Sewer
- Existing Storm Sewer
- Streams

|  |  |   |   |
|--|--|---|---|
| <p><b>Exhibit</b><br/><b>14</b></p>  | <p>City of<br/>West University<br/>Place</p> | <p><b>Proposed Fully Restricted 10-Year Ponding</b></p> | <p>PROJECT AVO<br/><br/>54460</p>   |
| <p>HALFF ASSOCIATES, INC.<br/>14800 St. Mary's Lane, Suite 160<br/>Houston, Texas 77079-2943<br/>www.halff.com<br/>TBPELS Firm No. F-312</p> |  | <p>CoWU Westside Drainage Modeling</p>                  | <p>DATUM &amp; COORDINATE SYSTEM<br/>NAD 1983 (2011) State Plane Texas South Central FIPS 4204 Feet</p> |



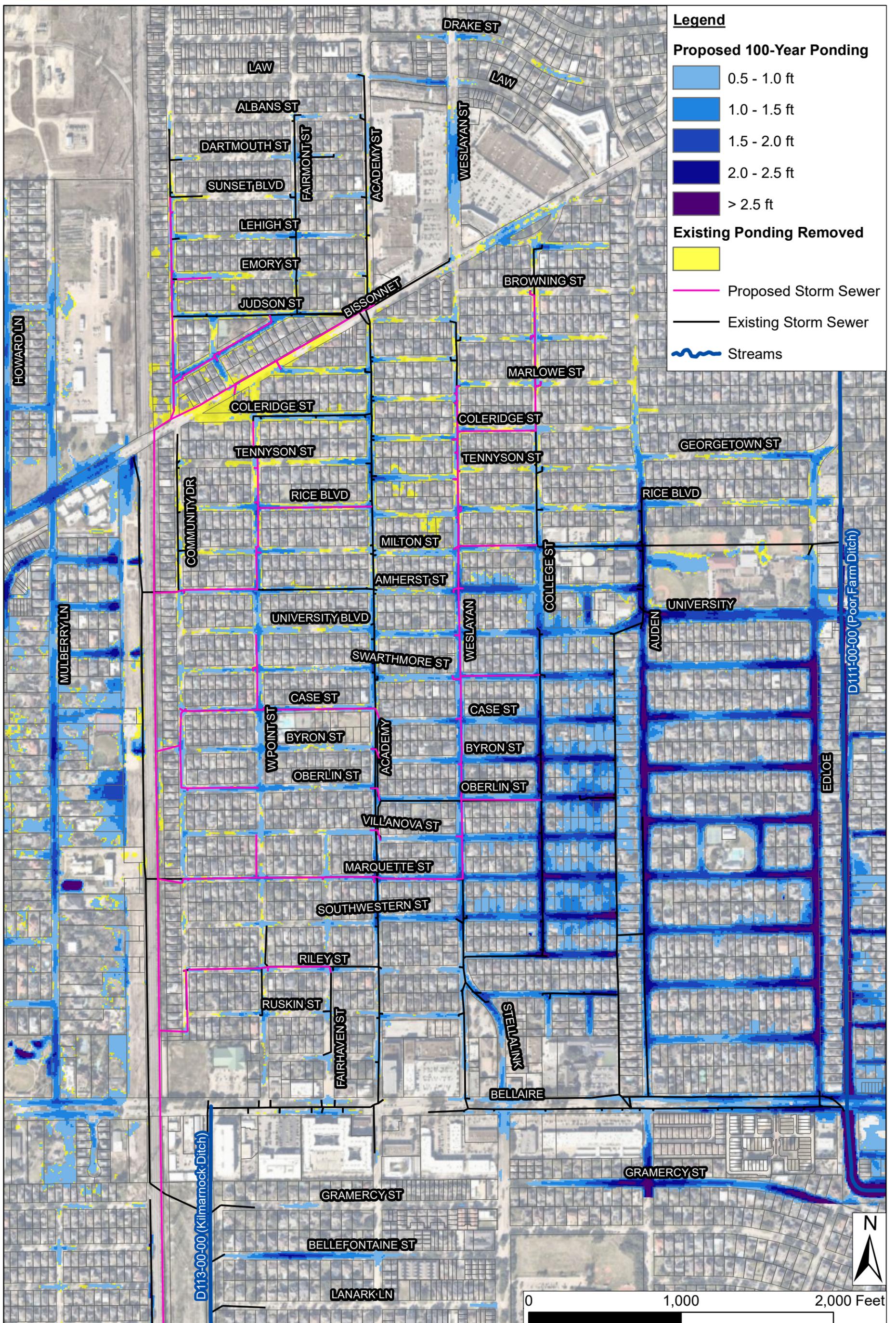
**Legend**

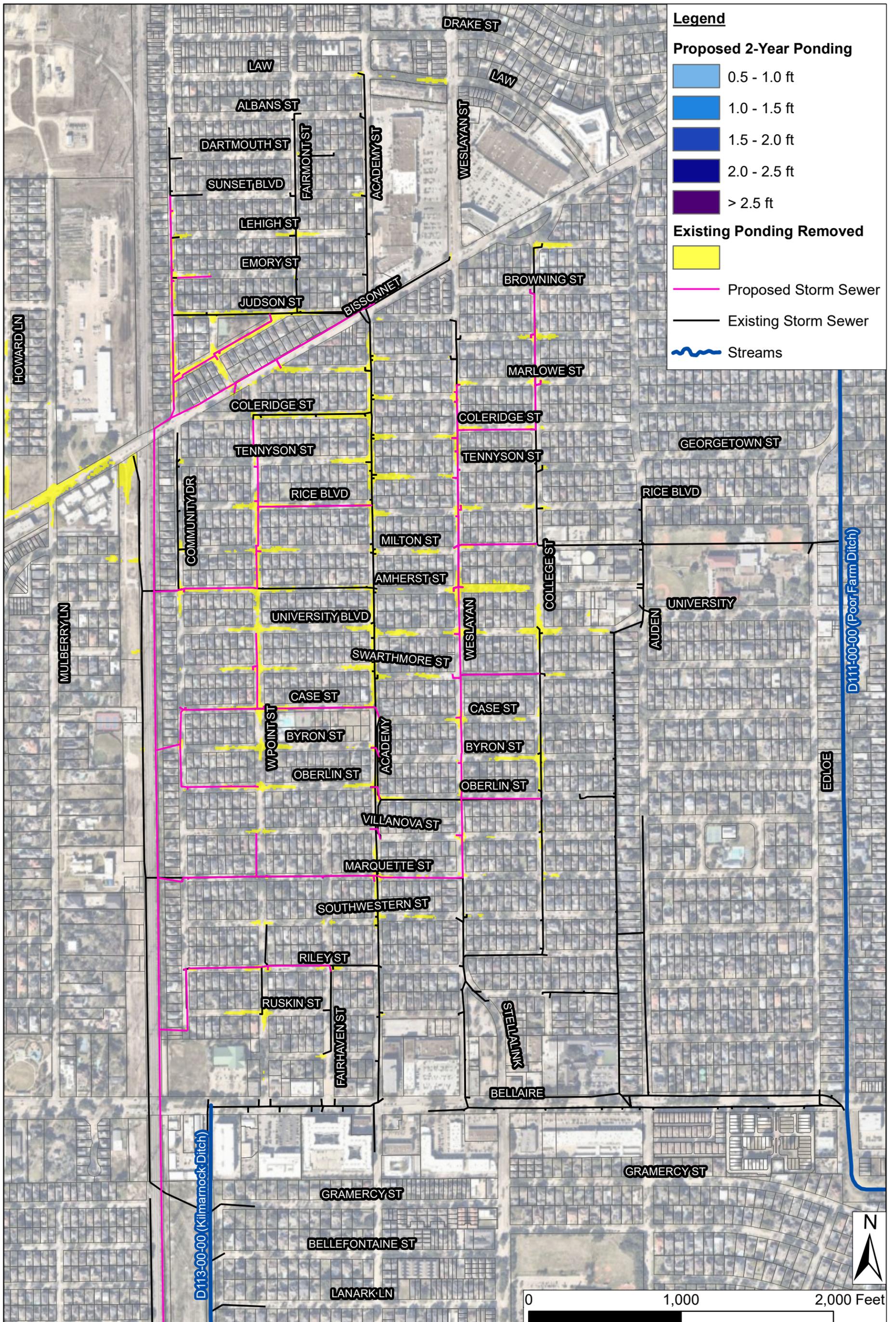
**Proposed 25-Year Ponding**

- 0.5 - 1.0 ft
- 1.0 - 1.5 ft
- 1.5 - 2.0 ft
- 2.0 - 2.5 ft
- > 2.5 ft

**Existing Ponding Removed**

- 
- Proposed Storm Sewer
- Existing Storm Sewer
- Streams





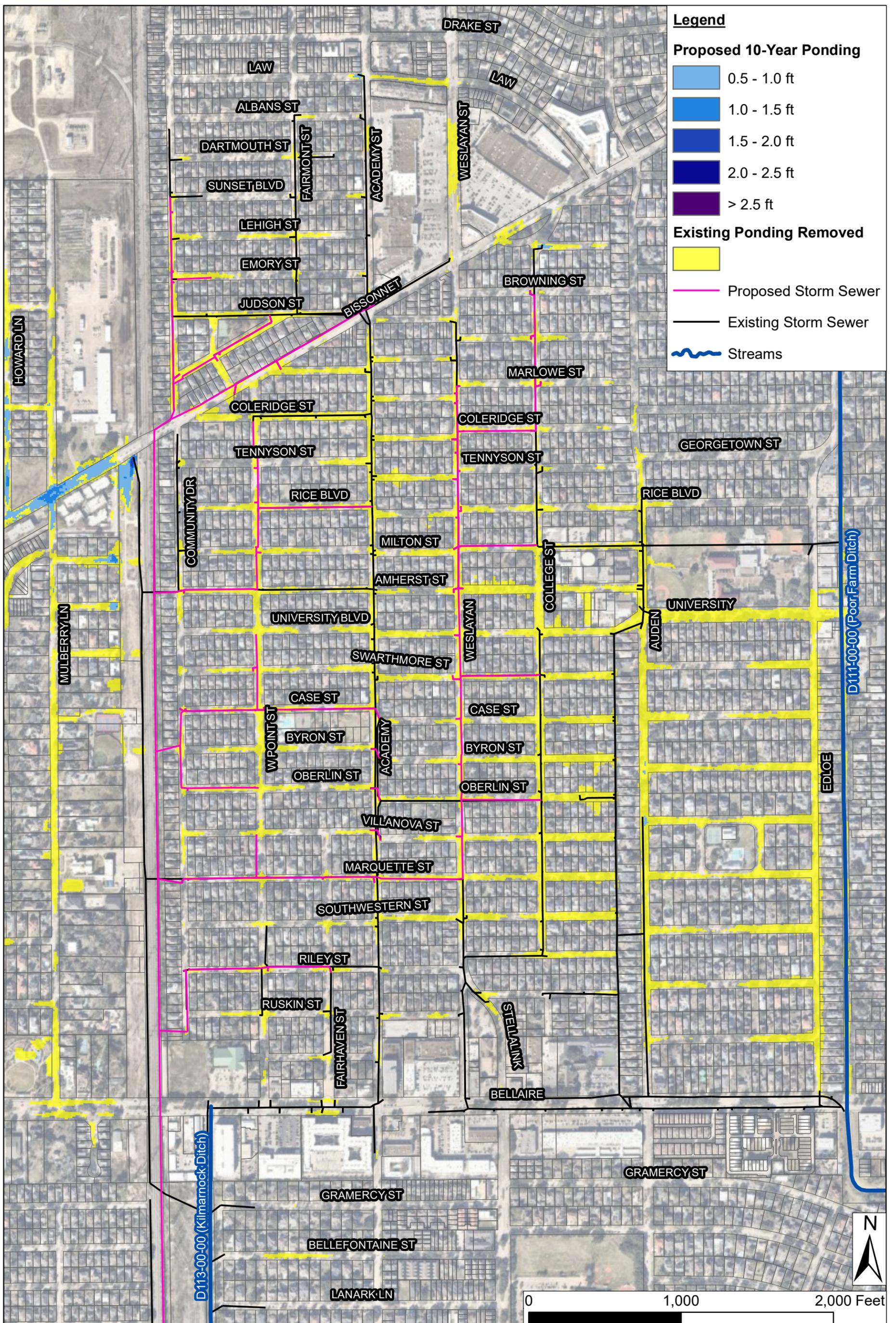
**Legend**

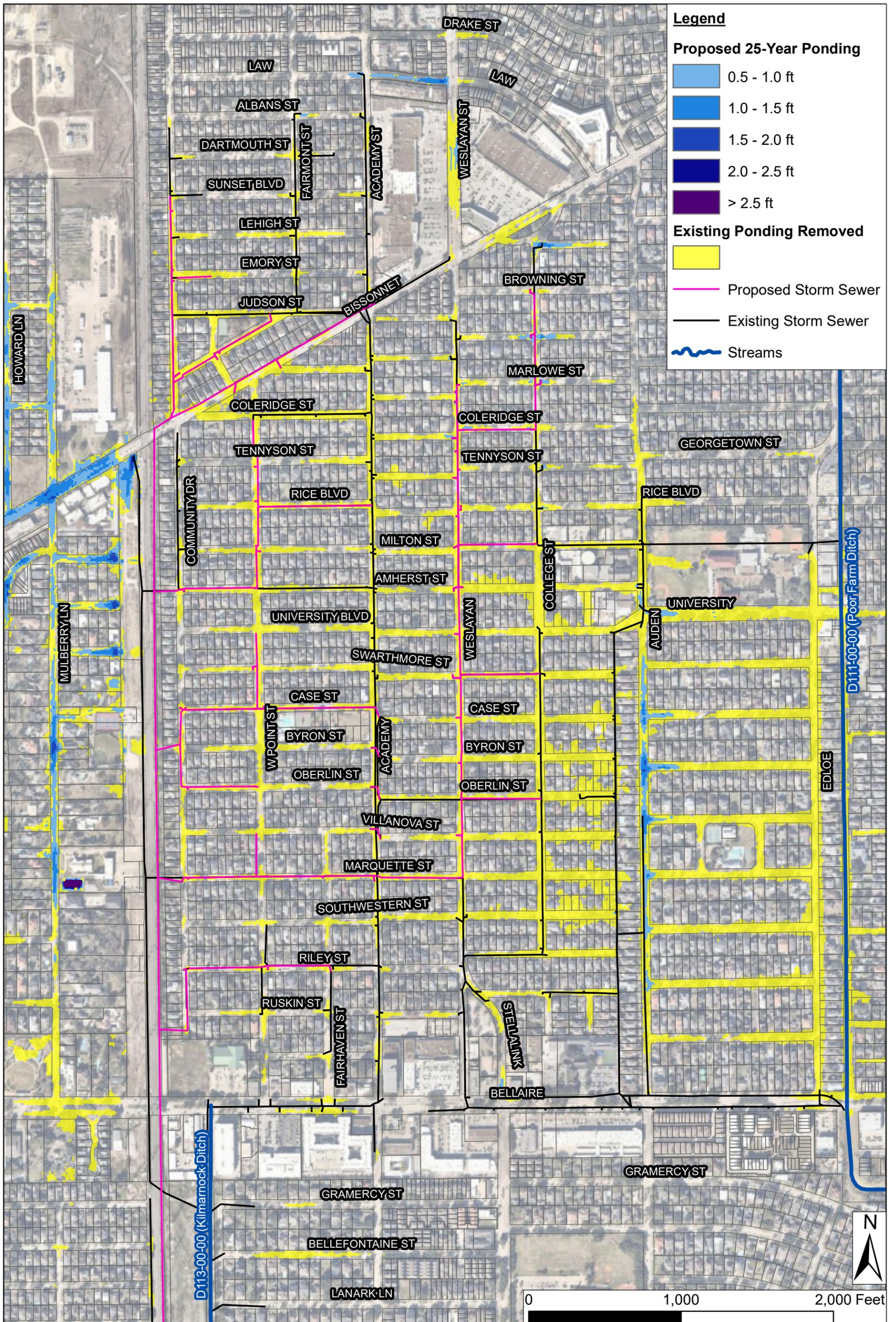
**Proposed 2-Year Ponding**

- 0.5 - 1.0 ft
- 1.0 - 1.5 ft
- 1.5 - 2.0 ft
- 2.0 - 2.5 ft
- > 2.5 ft

**Existing Ponding Removed**

- 
- Proposed Storm Sewer
- Existing Storm Sewer
- Streams





**Legend**

**Proposed 25-Year Ponding**

- 0.5 - 1.0 ft
- 1.0 - 1.5 ft
- 1.5 - 2.0 ft
- 2.0 - 2.5 ft
- > 2.5 ft

**Existing Ponding Removed**

- 

**Proposed Storm Sewer**

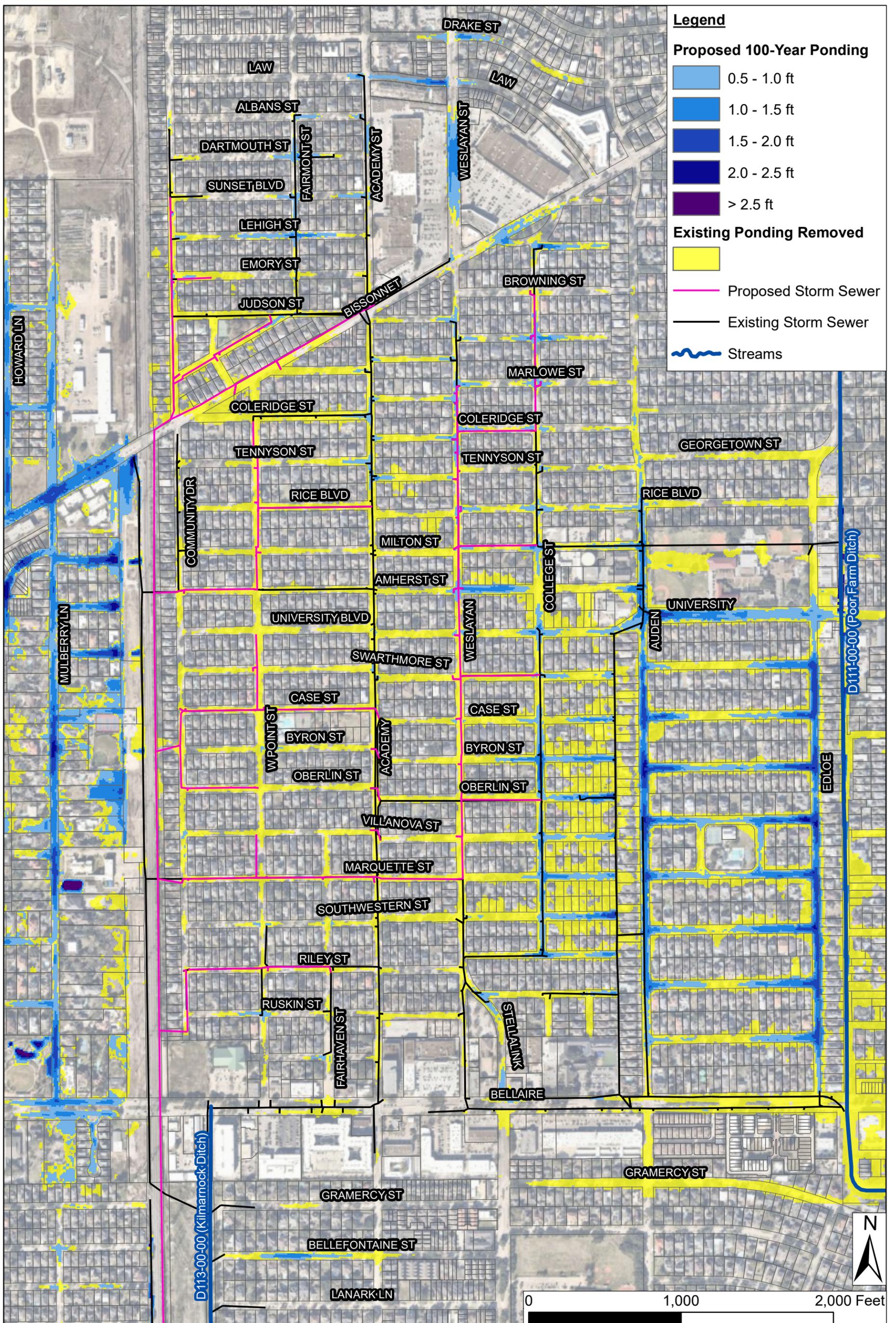
- 

**Existing Storm Sewer**

- 

**Streams**

-



**Legend**

**Proposed 100-Year Ponding**

- 0.5 - 1.0 ft
- 1.0 - 1.5 ft
- 1.5 - 2.0 ft
- 2.0 - 2.5 ft
- > 2.5 ft

**Existing Ponding Removed**

- 
- Proposed Storm Sewer
- Existing Storm Sewer
- Streams



## Field Observation Report

**Project:** West University Place      **Report Number:** 1  
**Client:** City of West University Place      **Date and Time:** 7/27/2023 10:00 AM  
**Subject:** West University Place Site Visit      **AVO:** 54460.001

### WEATHER

Clear       Snow       Warm  
 Overcast       Foggy       Hot  
 Rain       Cold       Very Hot

### SITE CONDITIONS

Clear       Dusty  
 Muddy        
 Temperature

### DAY

Monday       Thursday  
 Tuesday       Friday  
 Wednesday     

### OBSERVATIONS

As part of the drainage analysis, a site visit effort was conducted in the City of West University Place which is located within the Houston-Sugarland metropolitan area. The primary objective of the site visit was to observe the existing drainage network, confirm GeoLink information/record drawings, and identify locations that could not be completely evaluated through aerial imagery and lidar. No survey was conducted at these locations, so photographs and draw-down measurements were gathered on-site. Photographs obtained from the field visit are presented in this report. As shown from the photos, the inlets have vegetational overgrowth and debris.

### PHOTOGRAPHS

| Photo 1   | View of Poor Farm Ditch | Photo 2  | View of outfall farthest upstream into Poor Farm Ditch |
|---|-------------------------|--|--|
|  |                         |  |  |



|   |  |  |   |
|---|--|--|---|
| <p>Photo 3</p>  | <p>View of Poor Farm Ditch</p>                                     | <p>Photo 4</p>   | <p>View of inlet by the intersection of University Blvd and College St.</p> |
|   |  |   |   |
| <p>Photo 5</p>  | <p>View of inlet by the intersection of Amherst and Academy St</p> | <p>Photo 6</p>   | <p>View of inlet west of the railroad and south of Bellaire Blvd.</p>       |
|  |  |  |   |



|                |   |                 |   |
|----------------|---|-----------------|---|
| <p>Photo 7</p> | <p>View of channel east of the railroad and south of Bellaire Blvd.</p> | <p>Photo 8</p>  | <p>View of inlet east of the railroad and south of Bellaire Blvd.</p> |
|                |   |                 |   |
| <p>Photo 9</p> | <p>View of channel by the railroad south of Bellaire Blvd.</p>          | <p>Photo 10</p> | <p>View of channel by the railroad south of Bellaire Blvd.</p>        |
|                |   |                 |   |



|   |   |  |  |
|---|---|--|--|
| <p>Photo 11</p>   | <p>Manhole west of railroad,<br/>south of Bellaire Blvd.</p>  | <p>Photo 12</p>  | <p>Culverts north of Beechnut St<br/>and west of railroad.</p> |
|   |   |   |  |
| <p>Photo 13</p>   | <p>Culvert north of Beechnut St<br/>and east of railroad.</p> | <p>Photo 14</p>  | <p>View of Kilmarnock Ditch</p>                                |
|  |   |  |  |



Appendix C - Detailed Cost Estimate

| City of West University Place   |                               |  |              |          |                |                        |
|---------------------------------|-------------------------------|--|--------------|----------|----------------|------------------------|
| ELPH Trunkline                  |                               |  |              |          |                |                        |
| Item No.                        | City of Houston Specification | Item Description   | Unit Measure | Unit Qty | Unit Price     | Total in Figures       |
| 1                               | 01502<br>01502S               | Mobilization / Remobilization  | LS           | 1        | \$1,595,000.00 | \$1,595,000.00         |
| 2                               | 01555<br>01555S               | Traffic Control and Regulation   | LS           | 1        | \$54,000.00    | \$54,000.00            |
| 3                               | 01555<br>01555S               | Flagmen  | LS           | 1        | \$50,000.00    | \$50,000.00            |
| 4                               | 01570                         | Storm Water Pollution Prevention Control   | MO           | 10       | \$4,000.00     | \$40,000.00            |
| 5                               | 01740                         | Site Restoration for Pipeline Corridor   | LF           | 22100    | \$20.00        | \$442,000.00           |
| 6                               | 02631<br>02631S               | 10-foot by 10-foot box storm sewer by open cut   | LF           | 22042    | \$2,200.00     | \$48,492,400.00        |
| 7                               | 02632<br>TXDOT 466-6190       | Outfall Structure-Wingwall (PW-2) (HW = 15FT)  | EA           | 1        | \$150,000.00   | \$150,000.00           |
| 8                               | 02260                         | Trench safety system for trench excavations  | LF           | 22100    | \$3.00         | \$66,300.00            |
| 9                               | DWG                           | Remove and dispose - abandoned 8" crude oil transmission pipeline  | LF           | 11012    | \$80.00        | \$880,960.00           |
| 10                              | DWG                           | Remove and dispose - abandoned 12" crude oil transmission pipeline   | LF           | 11012    | \$110.00       | \$1,211,320.00         |
| 11                              | DWG                           | Remove and dispose - abandoned 18" crude oil transmission pipeline   | LF           | 11012    | \$160.00       | \$1,761,920.00         |
| <b>SUB-TOTAL</b>                |                               |  |              |          |                | <b>\$54,744,000.00</b> |
| <b>CONTINGENCY (30%)</b>        |                               |  |              |          |                | <b>\$16,423,200.00</b> |
| <b>TOTAL ESTIMATED COST:</b>    |                               |  |              |          |                | <b>\$71,167,200.00</b> |
| Internal West Side Improvements |                               |  |              |          |                |                        |
| Item No.                        | City of Houston Specification | Item Description   | Unit Measure | Unit Qty | Unit Price     | Total in Figures       |
| 1                               | 01502<br>01502S               | Mobilization / Remobilization  | LS           | 1        | \$779,000.00   | \$779,000.00           |
| 2                               | 01555<br>01555S               | Traffic Control and Regulation   | LS           | 1        | \$257,000.00   | \$257,000.00           |
| 3                               | 01562                         | Tree and plant protection (per Work Order)   | LS           | 1        | \$100,000.00   | \$100,000.00           |
| 4                               | 01555<br>01555S               | Flagmen  | LS           | 1        | \$50,000.00    | \$50,000.00            |
| 5                               | 01570                         | Storm Water Pollution Prevention Control   | MO           | 28       | \$4,000.00     | \$112,000.00           |
| 6                               | 02752<br>02752S               | Saw cut concrete or asphalt pavement   | LF           | 4200     | \$3.50         | \$14,700.00            |
| 7                               | 02336                         | Lime Stabilized Subgrade 8-inch thick  | SY           | 58905    | \$8.00         | \$471,240.00           |
| 8                               | 02336                         | Lime for Lime stabilized Subgrade (Dry Weight) (6%)  | TON          | 1111     | \$325.00       | \$361,075.00           |
| 9                               | 02233<br>02233S               | Clearing and Grubbing (within street R.O.W.)   | AC           | 10       | \$10,000.00    | \$100,000.00           |
| 10                              | 02221<br>02221S               | Removing and disposing of concrete pavements (including all thickness, w/ or w/o asphalt, including base & subgrade, w/ or w/o curb, all depths) | SY           | 54100    | \$10.00        | \$541,000.00           |
| 11                              | 02960                         | Remove and dispose of concrete curb or curb and gutter   | LF           | 40000    | \$5.00         | \$200,000.00           |
| 12                              | 02221<br>02221S               | Remove and dispose of concrete sidewalk, wheel chair ramps, and driveways (all thicknesses)  | SY           | 9100     | \$10.00        | \$91,000.00            |
| 13                              | 02260                         | Trench safety system for trench excavations  | LF           | 20000    | \$3.00         | \$60,000.00            |
| 14                              | 02751                         | Reinforced Concrete Pavement 8-inch thick  | SY           | 56100    | \$85.00        | \$4,768,500.00         |
| 15                              | 02754                         | 6-inch concrete driveway, including excavation, subgrade/base material, sawcutting and all joints (construction, expansion and surface)          | SY           | 9,100    | \$75.00        | \$682,500.00           |
| 16                              | 02221                         | Remove and Dispose storm pipe 24-inch to 36-inch diameter concrete storm sewer and leads.  | LF           | 3904     | \$40.00        | \$156,160.00           |
| 17                              | 02771<br>02771S               | Concrete curb up to 6-inches (monolithic)  | LF           | 40000    | \$5.00         | \$200,000.00           |
| 18                              | 02221                         | Remove and Dispose Inlets all Sizes/depth  | EA           | 75       | \$500.00       | \$37,500.00            |
| 19                              | 02082                         | Type "C" manhole for 42-inch diameter and smaller sewers (with or without grate top)   | EA           | 47       | \$6,600.00     | \$310,200.00           |
| 20                              | 02081<br>02082<br>02087       | Type "C" manhole for 48-inch to 72-inch diameter sewers (with or without grate top)  | EA           | 20       | \$7,700.00     | \$154,000.00           |
| 21                              | 02081<br>02082<br>02087       | Type "C" manhole for 78-inch diameter and greater sewers (with or without grate top)   | EA           | 35       | \$9,350.00     | \$327,250.00           |
| 22                              | 02631<br>02631S               | 24-inch diameter storm sewer by open cut (RCP)   | LF           | 464      | \$180.00       | \$83,520.00            |
| 23                              | 02631<br>02631S               | 30-inch diameter storm sewer by open cut (RCP)   | LF           | 476      | \$220.00       | \$104,720.00           |
| 24                              | 02631<br>02631S               | 36-inch diameter storm sewer by open cut (RCP)   | LF           | 1803     | \$300.00       | \$540,900.00           |
| 25                              | 02631<br>02631S               | 42-inch diameter storm sewer by open cut (RCP)   | LF           | 1456     | \$360.00       | \$524,160.00           |
| 26                              | 02631<br>02631S               | 48-inch diameter storm sewer by open cut (RCP)   | LF           | 7424     | \$440.00       | \$3,266,560.00         |
| 27                              | 02631<br>02631S               | 54-inch diameter storm sewer by open cut (RCP)   | LF           | 332      | \$550.00       | \$182,600.00           |
| 28                              | 02631<br>02631S               | 60-inch diameter storm sewer by open cut (RCP)   | LF           | 1249     | \$715.00       | \$893,035.00           |
| 29                              | 02631<br>02631S               | 66-inch diameter storm sewer by open cut (RCP)   | LF           | 998      | \$800.00       | \$798,400.00           |
| 30                              | 02631<br>02631S               | 72-inch diameter storm sewer by open cut (RCP)   | LF           | 1832     | \$880.00       | \$1,612,160.00         |
| 31                              | 02631<br>02631S               | 78-inch diameter storm sewer by open cut (RCP)   | LF           | 163      | \$990.00       | \$161,370.00           |
| 32                              | 02631<br>02631S               | 84-inch diameter storm sewer by open cut (RCP)   | LF           | 688      | \$1,045.00     | \$718,960.00           |
| 33                              | 02631<br>02631S               | 96-inch diameter storm sewer by open cut (RCP)   | LF           | 1452     | \$1,130.00     | \$1,640,760.00         |
| 34                              | 02631<br>02631S               | 108-inch diameter storm sewer by open cut (RCP)  | LF           | 1600     | \$1,320.00     | \$2,112,000.00         |
| 35                              | 02632<br>02633                | Type B-B inlet   | EA           | 75       | \$6,100.00     | \$457,500.00           |
| <b>SUB-TOTAL</b>                |                               |  |              |          |                | <b>\$22,870,000.00</b> |
| <b>CONTINGENCY (30%)</b>        |                               |  |              |          |                | <b>\$6,861,000.00</b>  |
| <b>TOTAL ESTIMATED COST:</b>    |                               |  |              |          |                | <b>\$29,731,000.00</b> |

This statement was prepared utilizing standard cost estimate practices. 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. Land acquisition costs and utility relocation costs are not included in this opinion of probable cost.