VOLUME 2

2023 REGIONAL FLOOD PLAN
REGION 6
SAN JACINTO

July 2023

PREPARED FOR THE **SAN JACINTO REGIONAL FLOOD PLANNING GROUP**

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LOWER CLEAR CREEK AND DICKINSON BAYOU FLOOD MITIGATION PLAN

Lower Clear Creek Alternatives Evaluation and Recommendation

FINAL REPORT

Prepared for:

City of League City

June 2021

Prepared by:

FREESE AND NICHOLS, INC.
11200 Broadway St. Suite 2320
Pearland, Texas 77584

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1 EXECUTIVE SUMMARY

The purpose of this study was to develop a comprehensive flood mitigation plan for the Lower Clear Creek Watershed with a focus on the riverine impacts along the main channel beginning near Farm to Market Road 1959 through the outlet of Clear Creek/Clear Lake into Galveston Bay. In conjunction with Harris County Flood Control District's MAAPnext effort, Freese and Nichols, Inc. (FNI) developed state-of-the-art hydrologic and hydraulic models leveraging current NOAA Atlas 14 rainfall, 2018 LiDAR data, and a 1D/2D unsteady-state modeling approach. FNI evaluated both existing and future conditions flood risks based on the 24-hour duration 2-, 5-, 10-, 50-, 100-, and 500-year Atlas 14 storm events, as well as Hurricane Harvey rainfall. FNI identified vulnerabilities in the Lower Clear Creek Watershed, including instances of flooding at structures and the resulting damage estimates, as well as impacts to critical infrastructure and transportation systems.

FNI investigated and modeled a total of 16 flood mitigation projects along Clear Creek. These projects consist of detention basins, linear conveyance improvements, channel and tunnel diversions, and crossing improvements. FNI evaluated each project based on four quantitative metrics including instances of flooding, flood damages reduced, constructions costs, and transportation system impacts. FNI also assessed five qualitative (non-cost) metrics in its project evaluation, including operations and maintenance requirements, and impacts to aesthetics and the community. Each concept was modeled individually, and based on the analysis of each discrete project's impacts, FNI developed three combination alternatives that incorporate multiple projects to optimize benefits while preventing adverse impacts. A summary of these flood mitigation alternatives is presented in **Table 1** provided on the next page. Maps presenting these alternatives are provided in **Section 3** of this report as **Figure 8**, **Figure 12**, and **Figure 16**.

Based on discussions with stakeholders, all of the combination alternatives and any of the individual projects greater than $50 million in capital cost are unlikely to be funded by an individual entity. Mitigation will require partnerships and cost sharing agreements between the entities. These agreements could be developed piecemeal on a project by project basis, or by development of a watershed-wide entity focused on flood damage reduction along the main channel of Clear Creek. In addition to local funding opportunities through ad valorem, additional grant and matching programs exist at the Federal and State level that should be further evaluated as this study progresses into future phases.

Table 1: Summary of Flood Mitigation Alternatives

Alternative	Discrete Projects	Cost	Non-Cost Score	Reductions Over the 50-year Design Period		Reductions During Harvey	
				Damages	Flooding Instances	Damages	Flooding Instances
1: Detention + Conveyance	Friendswood Detention Basin Timber Creek Golf Course Detention Basin Clearing and De-snagging - FM 1959 to Bay Area Blvd. SH 3 and UPRR Capacity Improvements FM 270 Auxiliary Opening Clear Lake Outlet Expansion	$275 M	4.4	$60 M	1,960	$100 M	930
2: Detention + Conveyance + FM 2351 Tunnel	Friendswood Detention Basin Timber Creek Golf Course Detention Basin Clearing and De-snagging - FM 1959 to Bay Area Blvd. 40-Foot Diam Tunnel Diversion from FM 2351 to Clear Lake SH 3 and UPRR Capacity Improvements FM 270 Auxiliary Opening Clear Lake Outlet Expansion	$1,250 M	3.6	$95 M	3,110	$155 M	1,490
3: Detention + Conveyance + I-45 Tunnel	Friendswood Detention Basin Timber Creek Golf Course Detention Basin Channel Benching Above OHWM - FM 1959 to Bay Area Blvd. 40-Foot Diam Tunnel Diversion from I-45 to Galveston Bay SH 3 and UPRR Capacity Improvements FM 270 Auxiliary Opening	$1,150 M	3.4	$70 M	2,300	$125 M	1,150

FNI proposes the following conclusions resulting from this study:

1. The alternatives proposed in this study are targeted toward mitigating the riverine flood risk during large, infrequent storms. For structures at risk of flooding under smaller, more frequent storms such as the 2-year and the 5-year events, elevating the structure or acquiring the property and removing it from the floodplain is likely the most cost-effective approach. FNI calculated that 54 structures flood during the 5-year event under future conditions.
2. Improvements should be implemented wholistically – from FM 1959 down to Galveston Bay to prevent adverse impacts.
    a. Large scale vegetative clearing or channel improvements through Friendswood cannot be constructed as stand-alone projects, and upstream or inline detention may not provide sufficient mitigation to prevent increases in discharges and water surface elevations in the downstream sections of the Creek.
    b. Increasing the conveyance upstream of Clear Lake necessitates increasing the conveyance out of the Lake into Galveston Bay. Increasing the capacity of the outlets to Galveston Bay could expose this area to greater storm surge risk and environmental impacts, and should be analyzed further as this study progresses into future phases. A solution should be developed in conjunction with the improvements proposed as part of the Coastal Texas Study at the Clear Lake outlets.
3. Tunnel solutions are less cost efficient than other alternatives, and do not score well based on the 50-year project window used by USACE and FEMA given they are designed to operate during storm events equal to or exceeding the 10-year storm. However, they provide the greatest level of protection during events of catastrophic magnitude such as the 500-yr storm event and Hurricane Harvey, and can be designed to provide additional benefits to local drainage systems.
4. The project benefits captured in this study do not fully account for the benefits the proposed alternatives could provide to the local drainage systems, which could be significant, particularly for the tunnel projects. The output from the alternatives developed in this study's hydraulic models should be integrated into local storm sewer network models to capture additional benefits achieved outside of the riverine floodplain of Clear Creek and its major tributaries.

5. The proposed alternatives mitigate but do not eliminate the flood risk in the study area. Significant residual risk persists due to certain low-lying structures and the compound effect of rainfall and storm surge that will likely become more severe in the future due to rising sea levels.

Based on these conclusions, FNI recommends a feasibility study be conducted to:

- Refine the combination alternatives proposed as part this study,
- Identify supplemental benefits the alternatives could provide to areas located outside of the riverine floodplains, particularly as it relates to the tunnel projects,
- Reduce the uncertainty associated with the compound flooding results by conducting further analyses to improve the understanding of its impacts on the alternatives' benefits,
- Identify efficiencies in the alternatives to reduce cost,
- Develop a project delivery plan, and
- Recommend a distinct alternative for implementation.

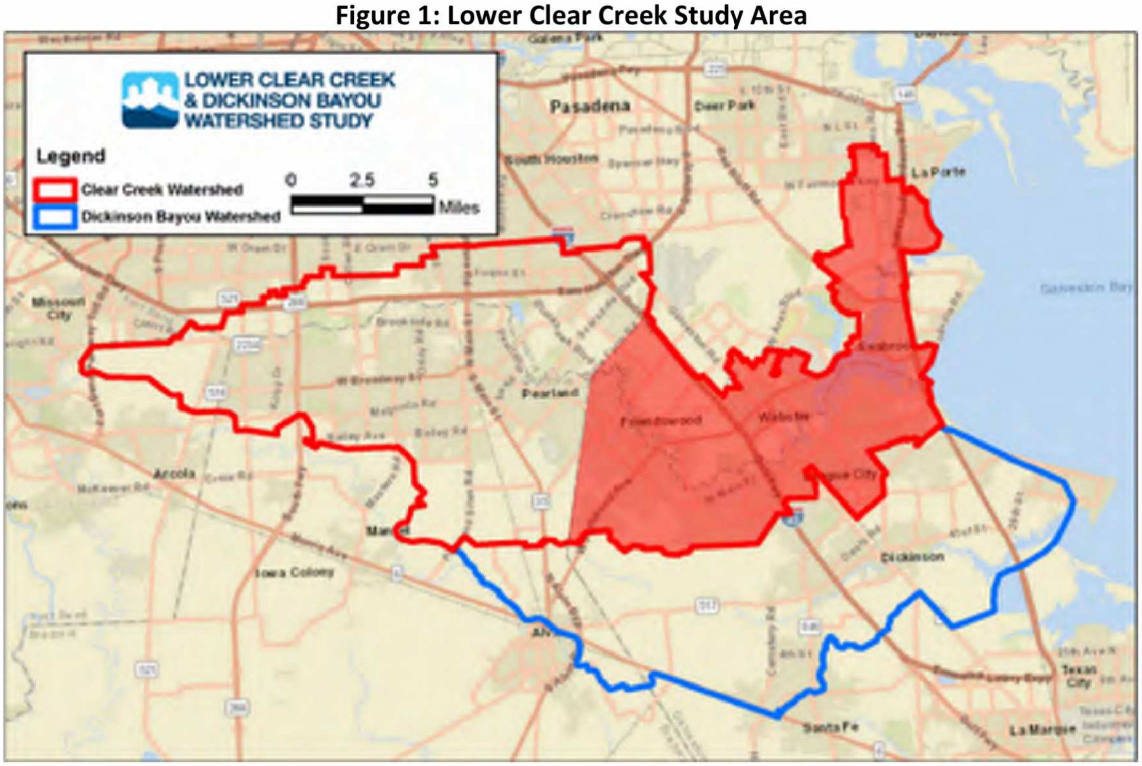
2 BACKGROUND

In August 2017, Hurricane Harvey struck the Texas coast, bringing a historic amount of rainfall to the Houston region. The storm produced never-before-seen precipitation depths in Galveston, Harris, and Brazoria Counties, as well as surrounding counties. As was the case with most of the watersheds in the region, Clear Creek and Dickinson Bayou experienced widespread flooding, which resulted in significant flood damages in the region.

The goal of this study was to develop a comprehensive flood mitigation plan for the Lower Clear Creek and Dickinson Bayou Watersheds with a focus on the riverine impacts along the main channel of each waterway. The flood mitigation plan is focused on mitigating the risk of extreme events similar to Hurricane Harvey, Tropical Storm Allison, and other large tropical storms, as well as flood damages from smaller more frequent storms. The targeted reduction in flood depths was set as multiple feet of reduction at Interstate 45 (I-45) during a 100-year storm.

This evaluation and recommendation report is focused on the Clear Creek Watershed, and more specifically the area defined as Lower Clear Creek (shown in red in **Figure 1** below) which includes the Clear Creek Watershed within Galveston and Harris Counties beginning near Farm to Market Road 1959 (FM 1959) through the outlet of Clear Creek/Clear Lake into Galveston Bay.

Figure 1: Lower Clear Creek Study Area



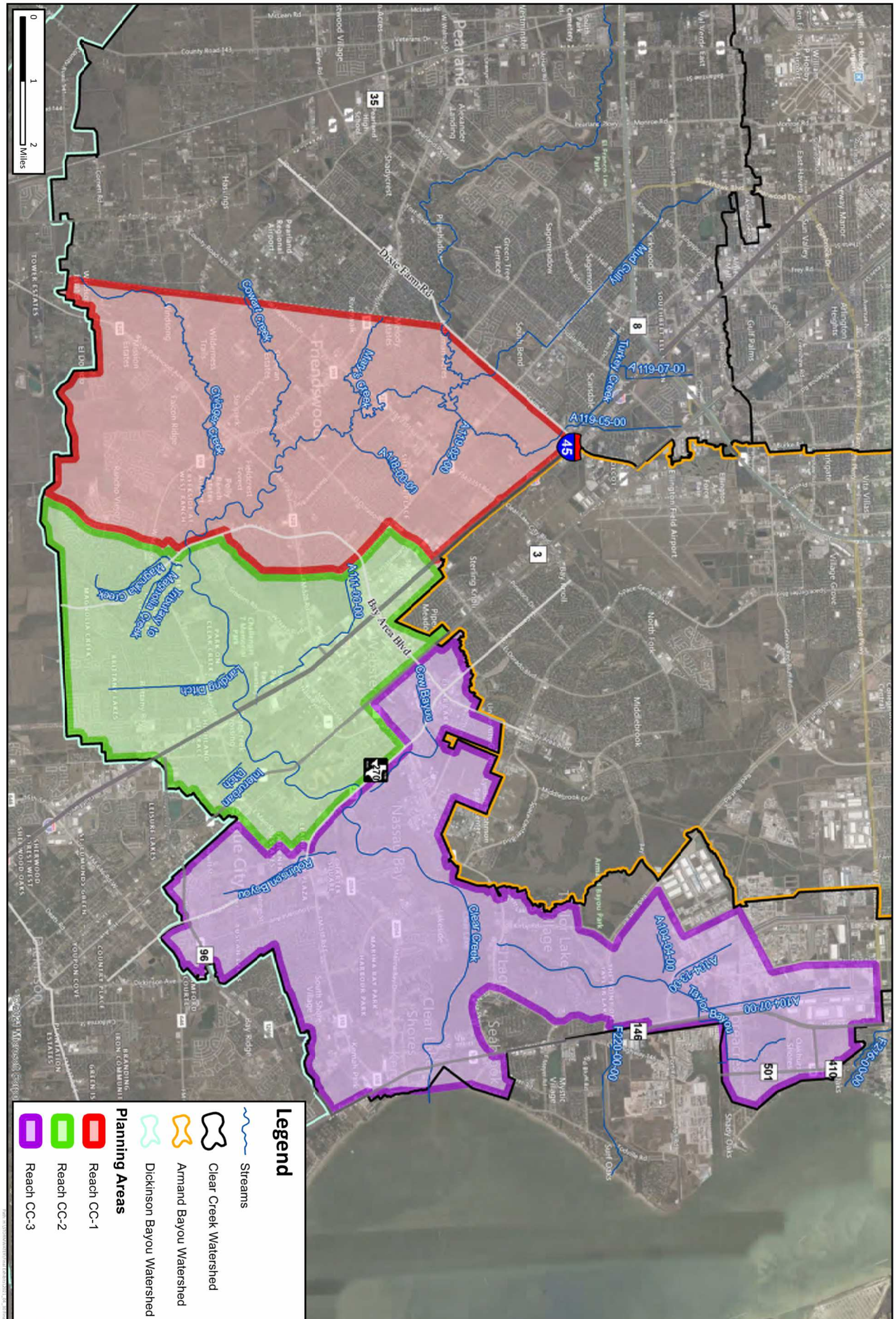
The flood mitigation projects that FNI developed as part of this study reflect a concept-level analysis. Although this level of detail is adequate to evaluate the general efficacy of the projects in providing flood risk mitigation, the preliminary siting and sizing that was performed will need to be refined in a future phase as part of a feasibility study.

In order to distinguish project improvements along the Creek and to acknowledge the different characteristics of the Creek between FM 1959 and Galveston Bay, the project area was divided into three Planning Areas as shown in **Figure 2** provided on the following page.

1. Reach 1 (CC-1) from FM 1959 to Bay Area Boulevard passes through Friendswood and is characterized by a constrained main creek channel that is joined by multiple major tributaries including Turkey Creek, Mary's Creek, Cowart Creek, and Chigger Creek. Nearly all development is built slab on grade even in close proximity to the channel.

2. Reach 2 (CC-2) from Bay Area Boulevard to Farm to Market Road 270 (FM 270) is a transitory section of the creek between the higher elevation in Friendswood and the tidally influenced section of the Creek. Reach CC-2 crosses major transportation corridors including I-45, Texas State Highway 3 (SH 3), FM 270, and the Union Pacific Railroad (UPRR) tracks. This is the least developed section of the Creek, although additional development is planned for the future. Nearly all development is constructed slab on grade in this reach.

3. Reach 3 (CC-3) from FM 270 to the outlet at Galveston Bay is entirely tidally influenced and includes Clear Lake and its surrounding communities. Reach CC-3 is subject to significant inflows from Armand Bayou and Taylor Lake. Many of the structures in this reach are elevated due to storm surge risks and previous damage from Hurricane Ike and other coastal storm events.



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Lower Clear Creek

Planning Areas

FN JOB NO	LEA19668
FILE	Fig2.LCC_PlanningAreas
DATE	4/19/2021
SCALE	1:8
DRAFTED	90206

FIGURE 2

2.1 PROJECT PHASING

To maximize the effectiveness of the study, the effort was divided into Phases. This Alternatives Evaluation and Recommendation report represents the culmination of Phase 3: Project(s) Identification. The previous phases completed were:

- Phase 1: Discovery & Baselining
- Phase 2: Watershed Study

The deliverables for the prior two phases are included as **Appendix B**, **Appendix C**, and **Appendix D** to this report for reference. This report includes the alternatives analysis and recommendations that conclude Phases 1 through 3 of the project. Future phases may be authorized and developed by the City of League City and other stakeholders based on the results of this study.

2.2 PLANNING PARTNERS

League City led the engagement of numerous stakeholders along Lower Clear Creek to fund Phases 1 through 3 of this study. League City also entered into an agreement to receive Planning Assistance to States (PAS) funding from the United States Army Corps of Engineers (USACE) under the authority provided by Section 22 of the Water Resources Development Act of 1974 (PL 93-251), as amended. USACE Galveston District provided in-kind services and was engaged in all aspects of the project including technical reviews and a downstream boundary condition analysis accounting for storm surge and future sea level rise.

Key planning partners and contributors included:

- The United States Army Corps of Engineers (USACE)
- Harris County Flood Control District (HCFCD) including MAAPnext consultant Pape-Dawson Engineers, Inc. (Pape-Dawson)
- Galveston County including consultant RPS Group, Inc. (RPS)
- City of Friendswood

Additional planning partners and study contributors included:

- Galveston County Consolidated Drainage District
- LJA Engineering, Inc. (LJA) through their work on the League City Municipal Drainage Plan
- Other members of the Clear Creek Watershed Steering Committee

2.3 HYDROLOGY AND HYDRAULICS

As part of Phase 2 of this project, FNI performed a hydrologic and hydraulic study of the Clear Creek Watershed (refer to **Appendix B** and **Appendix C** for more details). The model development for the main stem of Clear Creek was conducted by Pape-Dawson per the partnership agreement with HCFCD as part of the MAAPnext effort. FNI focused its modeling effort on the main tributaries within Galveston County beginning downstream of FM 1959, and that effort was integrated into the overall Clear Creek Watershed hydrologic and hydraulic models.

2.3.1 Data Sources

The main data sources used in this study included:

- 2018 LiDAR: FNI developed the study's topographic information using Light Detection and Ranging (LiDAR) data obtained from the Texas Natural Resources Information System (TNRIS) and the Houston-Galveston Area Council of Governments (HGAC). This LiDAR data was collected January through March 2018, and uses the vertical datum GEOID12B.
- Atlas 14 Rainfall: Precipitation data was obtained from NOAA's Atlas 14, Volume 11 Version 2.0 (Atlas 14). Atlas 14 is the most up to date precipitation data.
- Effective Models: The effective hydrologic and hydraulic models for the main stem of Clear Creek were downloaded from HCFCD's Model and Map Management (M3) System. A data request was submitted to the Federal Emergency Management Agency (FEMA) in February 2020 to gather all available effective models within the study area.

2.3.2 Hydrology

FNI generated updated hydrologic parameters based on the Basin Development Factor (BDF) methodology. The hydrologic model was developed using the USACE Hydrologic Engineering Center's Hydrology Modeling System (HEC-HMS) version 4.3. FNI executed 24-hour duration storm events in the model including the Annual Exceedance Probabilities (AEP) of 50% (2-year), 20% (5-year), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), and 0.2% (500-year), as well as historical storm events such as Hurricane Harvey. FNI analyzed both existing conditions based on current land use, and future conditions based on predicted future development occurring without detention. The study's results for the 100-year storm event are summarized in **Table 2** provided on the next page.

Table 2: 100-Year Peak Discharges (cfs) at Key Locations

Location	Contributing Drainage Area (Sq M)	FEMA Effective	FNI		
			Existing	Future	% Increase
Watershed Outfall (SH 146)*	256	47,042	86,764	86,890	0.1%
Downstream of Armand Bayou Confluence*	247	47,042	86,715	86,847	0.15%
FM 270 (Upstream of Armand Bayou Confluence)	162	24,535	36,788	37,145	0.97%
I-45	152	23,660	34,983	35,401	1.2%
Chigger Creek Confluence	141	22,891	32,486	32,972	1.5%
Turkey Creek Confluence	78	12,497	18,338	18,738	2.2%
FM 1959	55	5,376	9,614	10,011	4.1%

These 100-year results show significant increases between the effective discharges and the discharges computed as part of this study. These increases can be attributed to multiple factors, including:

- Increases in rainfall depths associated with the latest and improved Atlas 14 precipitation data: For the 24-hour duration 100-year storm event, depths increased from 13.5 inches to 18 inches.
- Differences in the hydrologic modeling methodology including hydrologic routing.
- Increases in resolution of the hydrologic and hydraulic models that were developed.

(*) It is important to note that revised hydrologic and hydraulic modeling is currently under development for the Armand Bayou Watershed as part of the MAAPnext effort. Consequently, the discharges presented in **Table 2** downstream of the Armand Bayou confluence with Clear Creek are not finalized and subject to change.

2.3.3 Hydraulics

The hydraulic model was developed using the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 5.0.7. The hydraulic modeling approach consisted in developing detailed combined 1D/2D unsteady-state models for the main stem of Clear Creek and all its major tributaries. The models were then combined into a single hydraulic model that covers the entire Lower Clear Creek Watershed. The model was calibrated using historical storms including Hurricane Harvey. To properly model tidal and storm surge impacts, stages were applied on the downstream end of Clear Creek based on guidance provided by USACE Galveston District.

To capture future conditions, the existing conditions model was adjusted to include:

- Fully-developed discharges,
- Expected future sea level rise (+1.52 feet) over the 50-year project horizon based on the Medium Sea Level Change Scenario analyzed by the USACE,
- Major projects under construction since 2018, which included the Imperial Estates floodplain benching in Friendswood and the I-45 TxDOT bridge improvements.

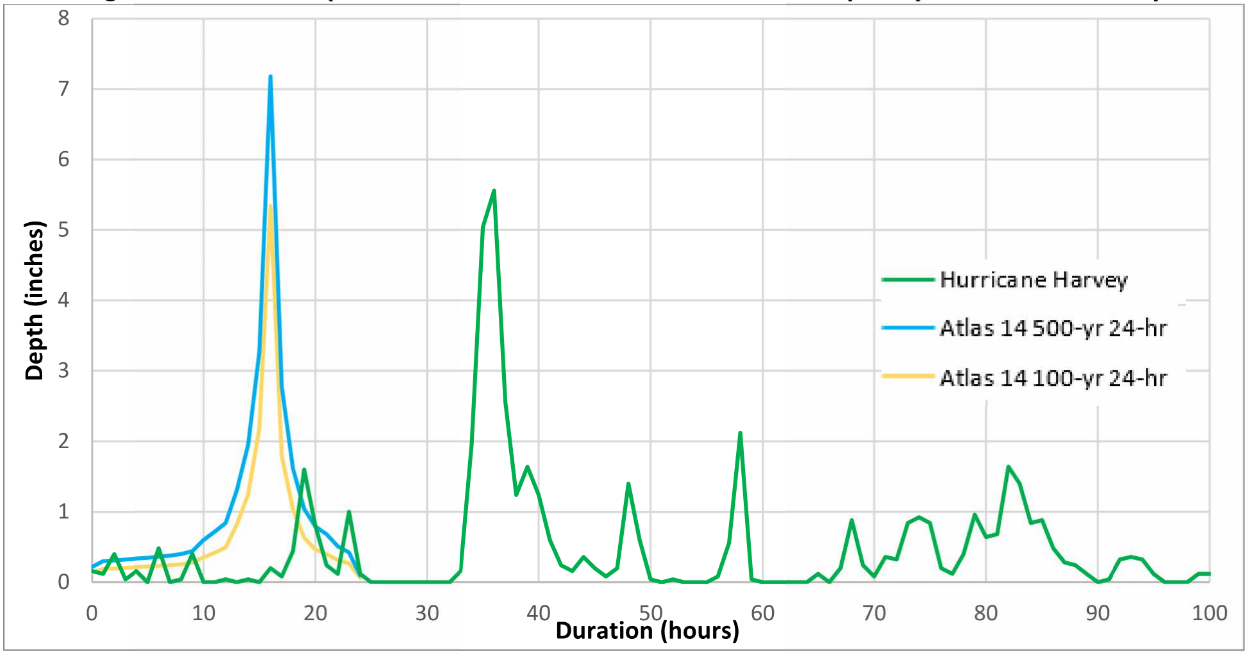
2.3.4 Hurricane Harvey

Because this flood mitigation plan is focused on mitigating the risk of extreme events, it was important to evaluate Hurricane Harvey as it is the most recent catastrophic flood event whose impacts are still felt by stakeholders and the public today. This evaluation included a comparison of rainfall depths and intensity to the new NOAA Atlas 14 events. Rainfall induced flooding is the result of both rainfall intensity and duration. High intensity storms cause flooding when the precipitation rate exceeds the infiltration capacity of soils and the conveyance capacity of the natural channels and stormwater systems. However, total runoff volume is also an important contributor to flooding, particularly in flat, low-lying areas such as Harris and Galveston Counties: Long duration storms of lesser intensity can also result in flooding by filling detention ponds designed to reduce the stress on the conveyance system, as once the design volume is exceeded the detention no longer mitigates the impacts to the conveyance system.

Hurricane Harvey was both a high intensity storm and a long duration storm, and therefore resulted in significant inundation in Clear Creek and other watersheds in the Houston metropolitan area. The data presented in green in **Figure 3** provided on the next page corresponds to rainfall depths measured at the I-45 gage on Clear Creek starting August 25 at 12:00 pm. Rainfall from Harvey lasted over 96 hours (4 days) and exceeded a peak intensity of 5 inches in an hour at approximately hour 37 (August 27 01:00 am). **Figure 3** also shows the Atlas 14 500-year and 100-year 24-hour storm intensities in blue and yellow, respectively, for comparison.

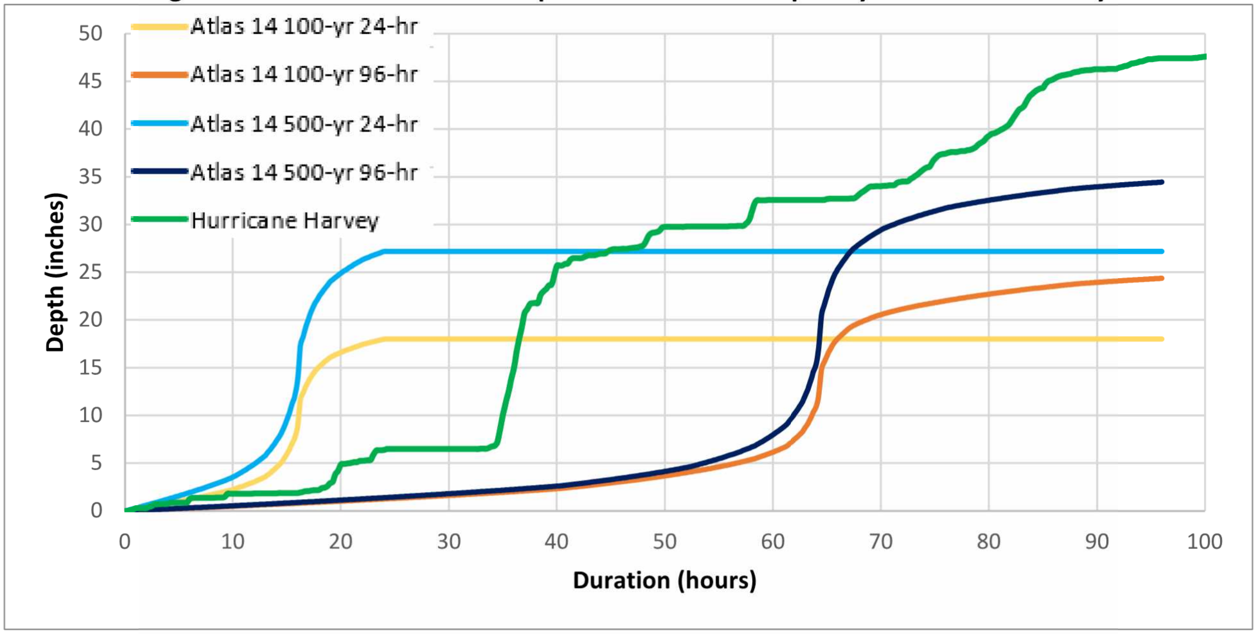
Harvey's maximum intensity was greater than the Atlas 14 100-year 24-hour event but less than the 500-year 24-hour event; however Harvey held that intensity for a long duration and was accompanied by other rainfall exceeding a rate of 1 inch an hour nearly 7 times over the 96 hour period. Prior to the peak intensity beginning at approximately hour 32, over 6 inches of rain had already fallen, saturating the soil and reducing available detention storage. When the maximum intensity occurred, the local storm drainage systems and detention ponds were already stressed, resulting in even greater stress to the conveyance system.

Figure 3: Rainfall Depths at 1-Hour Increments for Atlas 14 Frequency Storms and Harvey



As can be seen in **Figure 4**, rainfall depths from Hurricane Harvey cummulated over the entire storm duration exceeded the Atlas 14 500-year 96-hour duration depths.

Figure 4: Cumulative Rainfall Depths for Atlas 14 Frequency Storms and Harvey



To evaluate project benefits during high-intensity rainfall events, all the combination alternatives were analyzed using the Atlas 14 24-hour storm events to confirm that they were able to convey the maximum storm intensity. To confirm efficacy during long-duration storm events such as tropical storms and hurricanes that produce high volumes of runoff, Hurricane Harvey rainfall was also modeled through the combination alternatives.

2.4 FLOOD RISK

As part of Phase 2 of this study, FNI performed an inundation damages assessment to identify vulnerabilities in the Lower Clear Creek Watershed, including instances of flooding at structures and the resulting damage estimates (refer to **Appendix D** for more details). These two quantitative metrics are detailed in **Section 2.5.1**. A structural inventory was developed in GIS to identify the structures that are located within the floodplains developed as part of the hydraulic modeling effort. Property value information and property type classification were acquired from the Harris County Appraisal District (HCAD) and Galveston Central Appraisal District (GCAD), and associated with the building footprints. Most structures were assigned an assumed finished floor elevation of 0.5 feet above the lowest ground elevation at the structure. As feasible, certain structures were identified as elevated (not built on at-grade slab) and assigned a separate depth-damage curve to compute the flood risk. The elevated structures that were identified are primarily located in Reach CC-3.

FNI evaluated both existing and future conditions flood risks based on the 2-, 5-, 10-, 50-, 100-, and 500-year storm events, as well as a statistical prediction of what those risks could amount to over the 50-year project design period. A discount rate of 7% was used to calculate the net present value of the damages. This report focuses on future conditions instances of flooding and structural damages, as those factors served as the relevant baseline against which the flood mitigation projects proposed as part of Phase 3 were evaluated. FNI also evaluated the impacts that Hurricane Harvey produced in the riverine model (see **Section 2.5.3** for the limitations of the riverine model). These results are shown in **Table 3** and **Table 4**.

Table 3: Structural Damages ($M) for Future Conditions and Hurricane Harvey

Planning Area	Frequency Storms – Future Conditions							Harvey
	500-Yr	100-Yr	50-Yr	10-Yr	5-Yr	2-Yr	50-Yr Period	
CC-1	519.2	124.9	59.5	9.3	3.3	0.8	106.3	163.4
CC-2	153.5	44.7	19.0	6.5	1.8	0.8	43.2	66.0
CC-3	247.6	133.1	99.0	57.5	7.2	5.9	215.6	127.0
Totals	**920.4**	**302.7**	**177.4**	**73.2**	**12.3**	**7.5**	**365.1**	**356.5**

Table 4: Instances of Flooding for Future Conditions and Hurricane Harvey

Planning Area	Frequency Storms – Future Conditions							Harvey
	500-Yr	100-Yr	50-Yr	10-Yr	5-Yr	2-Yr	50-Yr Period	
CC-1	4,840	1,128	584	90	26	7	3,595	1,442
CC-2	1,353	364	154	37	6	3	1,067	635
CC-3	2,322	1,153	832	452	22	12	5,349	1,117
Totals	**8,515**	**2,645**	**1,570**	**579**	**54**	**22**	**10,011**	**3,194**

2.5 EVALUATION FACTORS

2.5.1 Quantitative Metrics

Four quantitative metrics were used in this study to identify the concepts that provide the greatest flood risk mitigation:

1. Instances of Flooding: Number of structures flooded in a given storm event (e.g. 100-year), as well as the number of times a given structure is predicted to flood over a 50-year period. This was analyzed for each of the 2-, 5-, 10-, 50-, 100-, and 500-year storm events, as well as a statistical prediction of what the instances could amount to over the 50-year project design period. An instance of flooding reports whether a given structure is inundated or not. See **Appendix D** for more information.

2. Structural Damages: Monetary value resulting from the damages caused by floodwaters at a given structure. This was analyzed for each of the 2-, 5-, 10-, 50-, 100-, and 500-year storm events, as well as a statistical prediction of what the damages could amount to over the 50-year project design period. Structural damages are a function of floodwater depths at a given structure, and are computed based on depth-damage relationships developed by USACE. See **Appendix D** for more information.

3. Transportation System Impacts: Frequency and risk of pedestrian, roadway, and railroad crossings being overtopped by floodwaters. These impacts are representative of public safety hazards, mobility constraints, and impacts to emergency responders. The level of service and hazard was calculated for all main channel and tributary crossings located in the study area. See **Appendix D** for more information.

4. Capital Cost: Cost to construct the improvement in 2021 dollars. Operations and maintenance (O&M) costs were not calculated at this time, but O&M requirements were taken into account as one of the non-cost factors. Capital cost was developed on a rough order of magnitude (ROM) basis for comparative purposes between projects. FNI performed cost estimation in a matter that is consistent with an AACE Level 5 estimate based on a project maturity level of 0 to 2% using parametric methods and unit price quantity take-offs. An estimate of this class carries an accuracy that ranges between -20% to -30% on the low end to +30% to +50% on the high end.

2.5.2 Qualitative Metrics

Quantitative metrics alone do not fully describe the benefits or challenges of the projects analyzed. In order to better capture the full impact of the projects, non-cost factors were also developed in coordination with the key stakeholder group. The group determined that the following non-cost factors, in conjunction with the quantitative factors, would best capture the project impacts:

1. Land Acquisition: Ease of property acquisition. Property already owned by public entities will receive highest scoring. Projects requiring acquisition of numerous parcels, particularly residential and commercial acquisition, will receive the lowest scoring. Subterranean easements required for tunnel projects are seen as less difficult to acquire even through residential and commercial areas.

2. Community Impact/Aesthetics: How easily will the project gain public support by minimizing disruption during construction and providing a long-term amenity with aesthetic and recreational benefits during operation? What is the scale of the disturbance during construction, is the disturbance isolated to a single area or does it cover a large area? What are its transportation impacts to bridges and roads?

3. O&M/Resiliency: How simple is the system to operate, how much energy and manpower is required to operate it, and how resilient is it to natural disaster (loss of power)? Projects that include only routine operation and maintenance already performed by the sponsors will score the highest. Projects that operate passively without the need to operate control structures and pumps will also score the highest. Projects that have ongoing operational cost (pump stations) will score the lowest.

4. Other Agency Coordination: How much coordination is required outside of the project sponsor group with entities including but not limited to TXDOT, railroad and environmental groups?

5. Speed of Implementation: How quickly can the project be planned, designed and constructed including all necessary land acquisition and permitting? Projects that are the fastest at delivering benefits will score the highest.

A pair-wise analysis was conducted to develop a weighting of these non-cost factors in a May 2020 meeting with the key stakeholders. The results and weighting of this effort is shown below in **Table 5**. A score of 1 means the row category is less important than the column category, 2 means it is equally important, and 3 means it is more important.

Table 5: Non-Cost Factors Pair-Wise Matrix

Factor	Land Acquisition	Community Impact/Aesthetics	O&M/Resiliency	Other Agency Coordination	Speed of Implementation	Total	Weight
Land Acquisition	-	3	2	3	1	**9**	**22.5%**
Community Impact/Aesthetics	1	-	2	3	2	**8**	**20.0%**
O&M/Resiliency	2	2	-	3	3	**10**	**25.0%**
Other Agency Coordination	1	1	1	-	1	**4**	**10.0%**
Speed of Implementation	3	2	1	3	-	**9**	**22.5%**

2.5.3 Limitations

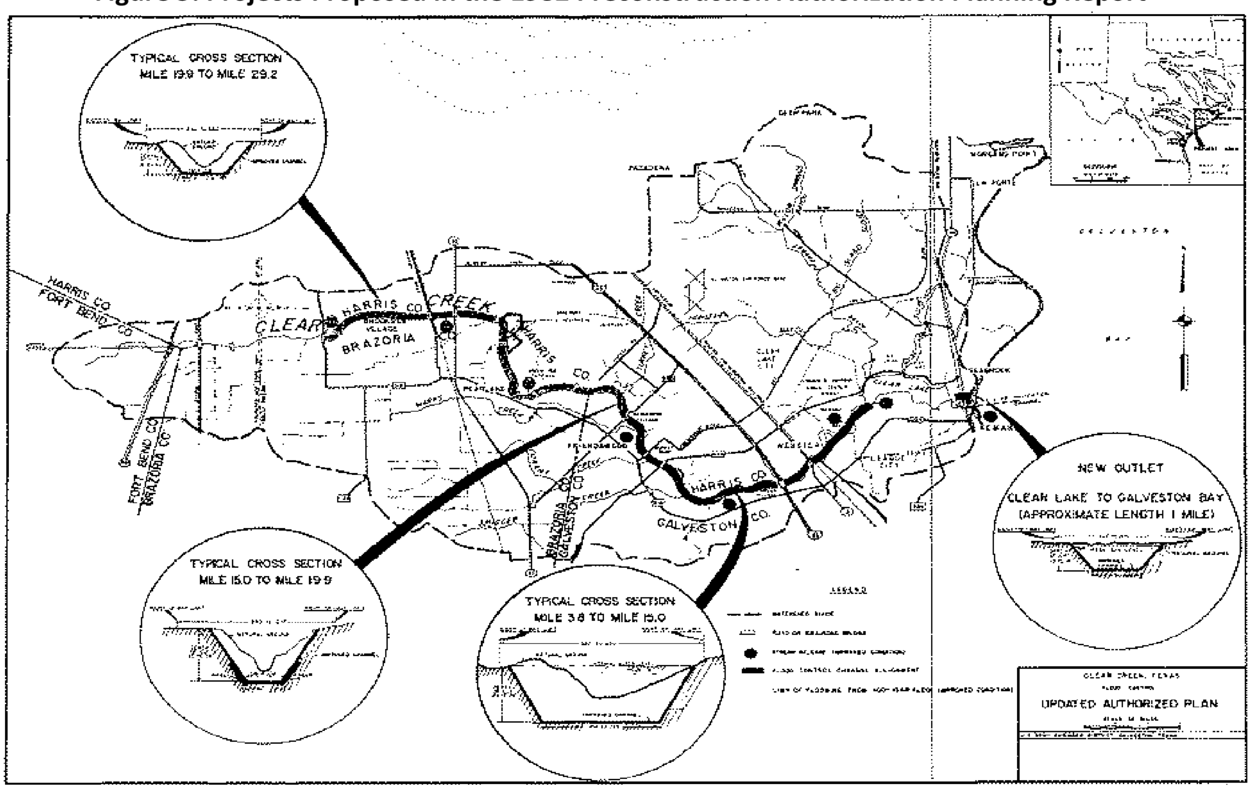
This study is focused on mitigating riverine flooding along Clear Creek. The model that was developed was calibrated to historical storms and water level measurements along the Creek, as discussed in **Appendix C**. The model incorporates the main stem of Clear Creek and all its major tributaries, and was developed to accurately capture the flooding risks associated with the swelling of the creeks. The model is not meant to accurately depict the propagation of floodwaters within neighborhoods and on roadways located outside of the riverine floodplains. It was beyond the scope of this study to fully capture the instances of flooding and structural damages that are caused by ponding water that cannot be conveyed effectively to the streams through the local storm sewer/culvert network. This is evidenced by flood damages and rescues that occurred during Hurricane Harvey in Friendswood and League City outside of the riverine floodplains. To fully capture the instances of flooding and structural damages occurring away from the main stem of Clear Creek and its major tributaries, the output from this study's hydraulic models should be integrated into local storm sewer network models. The results presented herein do not account for local drainage system benefits and therefore likely underpredict the actual reductions in instances of flooding and structural damages provided by the solutions.

The flood mitigation projects that FNI developed as part of this study reflect a concept-level analysis. Although this level of detail is adequate to evaluate the general efficacy of the projects in providing flood risk mitigation, the preliminary siting and sizing that was performed will need to be refined in a future phase as part of a feasibility study.

2.6 PREVIOUS STUDIES AND PROJECT CONSTRAINTS

Flood risk management efforts on Clear Creek have been discussed for decades, dating back at least to the 1960s. A major Federal civil works project has been planned for Clear Creek for nearly as long, dating back to the USACE 1982 Preconstruction Authorization Planning Report. The improvements proposed in the 1982 report included improvements to the outlet of Clear Lake into Galveston Bay, and channel widening of Clear Creek from the Lake all the way upstream to Mykawa Road in Pearland, Texas. The Clear Lake outlet structure improvements were constructed in 1997 including a new outlet channel and gated structure, but the remaining proposed improvements were met with environmental and community roadblocks that delayed and eventually prevented their construction.

Figure 5: Projects Proposed in the 1982 Preconstruction Authorization Planning Report



Hurricane Harvey and the never-before-seen flood damages in the watershed prompted a review of previous efforts, and galvanized additional project funding for the completion of studies and the construction of mitigation improvements. The largest of these projects is the Clear Creek Federal Project being advanced by USACE and HCFCD. Currently, a design-build package is underway for construction of conveyance improvements and detention along the main channel of Clear Creek and its tributaries from State Highway 288 to FM 1959. The funds for this project were appropriated by Congress in 2018.

The section of Clear Creek from FM 1959 to the outlet at Clear Lake was not included as part of the Federal project in part due to the environmental and community concerns raised in this section of the creek in the early 1980s. Previous project recommendations for major channel modifications such as widening did not receive local stakeholder support at that time. These community and environmental concerns led to the development of the following conceptual design constraints which informed our approach in this study:

1. No channel widening on Clear Creek downstream of Bay Area Blvd: Environmental concerns exist in this tidally-influenced section due to the prevalence of wetlands, which increase both cost and permitting schedule.

2. No new open cut crossings of Interstate 45: I-45 is a major transportation corridor, thus an open cut crossing would result in major traffic disruptions that would impact not only the local stakeholders but also regional and national stakeholders.

3. No additional conveyance to Clear Lake without additional conveyance out of the lake: The current outlet capacity from Clear Lake to Galveston Bay is finite. Conveyance improvements made upstream of Clear Lake will affect the timing and rate of floodwaters discharging into the Lake. Providing additional conveyance out of the Lake is necessary to prevent an increase in flooding instances and damages in the Lake communities.

4. No clearing/de-snagging downstream of Bay Area Blvd. on Clear Creek: Similarly to constraint 1, significant vegetative clearing along the banks of Clear Creek downstream of Bay Area Blvd. is likely to impact wetland habitats and would be difficult and time consuming to permit. Furthermore, this section of the creek is not as densely vegetated as other parts upstream, and therefore the opportunity to increase conveyance through vegetative clearing is more limited.

Considering these constraints, FNI evaluated numerous flood risk mitigation concepts. These concepts included one or a combination of the following:

- Detention basins,
- Channel modifications including benching, widening and deepening,
- Vegetative clearing and de-snagging of channel banks,
- Diversions including bypass channels and tunnels,
- Capacity improvements at key structures such as roadway and railroad crossings,
- Structural elevations and voluntary property buyouts

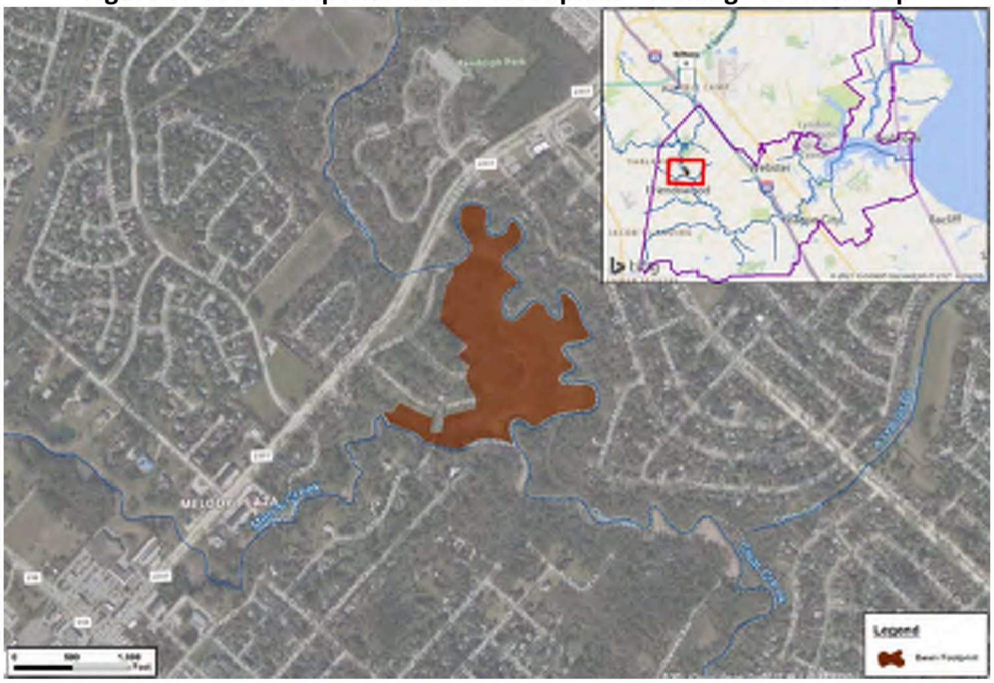
The performance of these concepts has been evaluated based on the quantitative and qualitative factors presented above. The results are presented collectively as combination alternatives in **Section 3**, and individually in **Appendix A**.

2.7 IMPROVEMENTS MADE SINCE HURRICANE HARVEY

In addition to the multiple study efforts that began following Hurricane Harvey, there have been improvements completed along Clear Creek by the Galveston County Consolidated Drainage District (GCCDD) and HCFCD, particularly in Reach CC-1. Minor improvements have been made including localized vegetative clearing, but the following improvements represent major modifications to the behavior of Clear Creek:

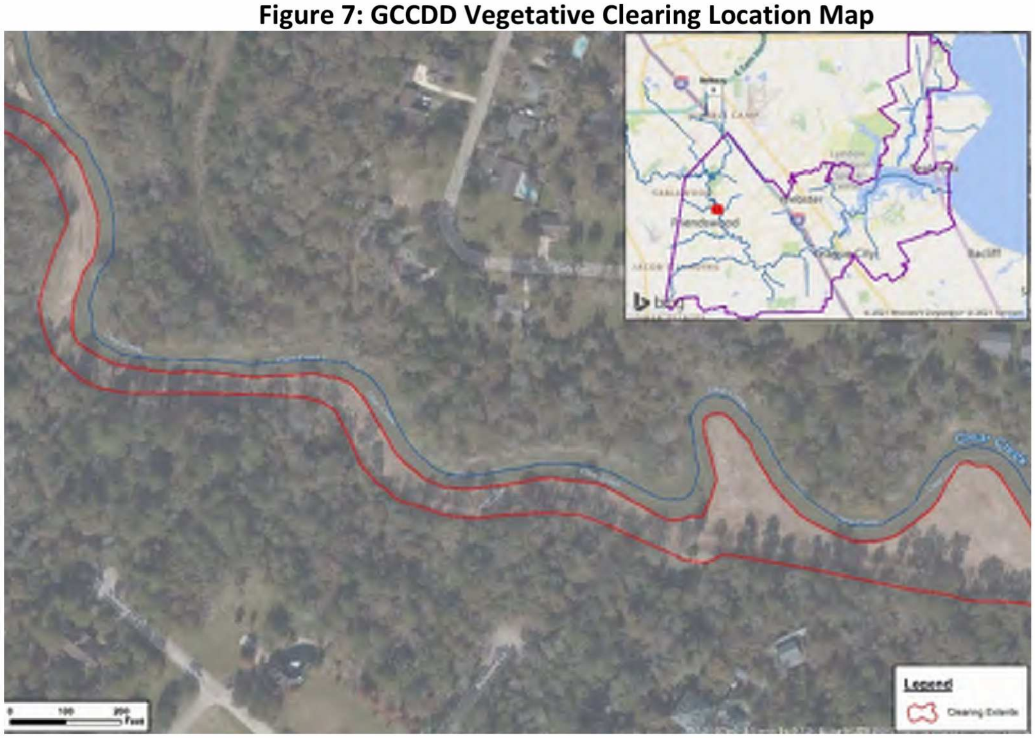
- Imperial Estates Floodplain Benching: The GCCDD has completed a floodplain benching project along the west side of Clear Creek in the Imperial Estates neighborhood just downstream of FM 2351. The grading starts at the ordinary high water mark elevation, slopes upward at a 1% slope, and then transitions to existing grade at the interior limits with a 4:1 slope. 880 acre-feet of material has been removed from the site. A location map for this project is shown in **Figure 6** provided on the next page.

Figure 6: GCCDD Imperial Estates Floodplain Benching Location Map



- <u>Clearing of West Bank of Clear Creek from FM 2351 to FM 528:</u> As part of a bond project completed in May 2019, GCCDD has performed vegetative clearing on the west bank of Clear Creek between FM2351 and FM 528. The clearing extends about 60 feet up the bank, and corresponds to a complete clearing of all vegetation, as can be seen in **Figure 7**.

Figure 7: GCCDD Vegetative Clearing Location Map



2.8 COASTAL TEXAS STUDY – CLEAR LAKE GATE SYSTEM

The Coastal Texas Protection and Restoration Feasibility Study Draft Report published in October 2020 presents a *Multiple Lines of Defense* strategy used to design cost-effective, environmentally friendly solutions that will reduce risks of storms impacting the coastal communities and restore important wildlife habitat at the same time. For Clear Creek, the draft plan proposes the following:

- In the southernmost of the two Clear Lake outlets, a 75-foot floating sector gate would be constructed to accommodate boat traffic into and out of the Lake. The sector gate would have a sill elevation of -10 feet (NAVD88) to match the authorized depth of the existing channel. To the right and left of the sector gate, circulation gates would be added to address potential water quality concerns and assure tidal flow between the outlet and Clear Lake.
- In the northernmost outlet, a pumping station would be needed so that, when the gates are closed, water coming down from the watershed (due to rainfall) would be pumped out to the Bay. The pumping station would have a designed capacity of 20,000 cubic feet per second.
- To tie the gates and the pumping station together, and to connect to the land on both sides, a floodwall system at an elevation of 17 feet would be constructed. The floodwall and closure structure would start on the west side of State Highway 146, near NASA Road 1, and end on the south side of the outlet, near Marina Bay Drive west of State Highway 146.

The primary objective of the FNI study presented in this report is to analyze and mitigate the risks associated with riverine flooding. Although this objective differs from the Coastal Texas Study's objective, the two studies' objective interconnect in the downstream reach of Clear Creek near its outlet to Galveston Bay. As these two studies are refined in the years to come, solutions should be jointly designed to mitigate risks associated with both riverine and coastal flooding along this downstream section of Clear Creek.

3 COMBINATION ALTERNATIVES

FNI investigated and modeled a total of 16 flood mitigation projects along Clear Creek. These projects consist of detention basins, linear conveyance improvements, channel and tunnel diversions, and crossing improvements, and are presented individually in detail in **Appendix A**. Based on the analysis of each discrete project's impacts, FNI developed three combination alternatives that incorporate multiple projects to optimize benefits while preventing adverse impacts. These alternatives were analyzed based on the 2-, 5-, 10-, 50-, 100-, and 500-year storm events, and their benefits were calculated over the 50-year design period. To confirm efficacy during long-duration storm events, Hurricane Harvey rainfall was also modeled through the combination alternatives.

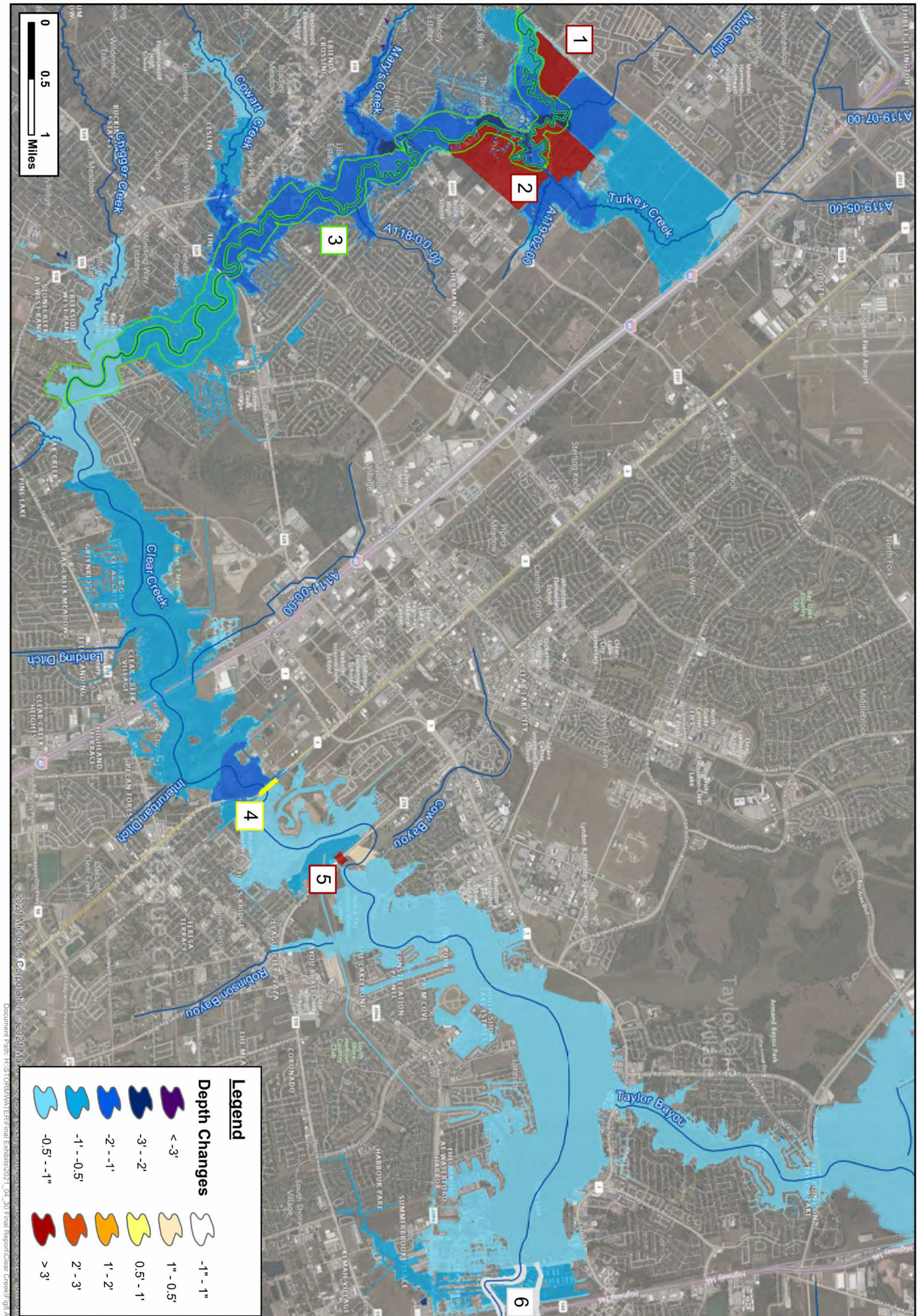
3.1 ALTERNATIVE 1: DETENTION + CONVEYANCE IMPROVEMENTS

Alternative 1 corresponds to the combination of the following projects, as shown in **Figure 8**:

1. Friendswood Detention Basin
2. Timber Creek Golf Course Detention Basin
3. Clearing and De-snagging – FM 1959 to Bay Area Blvd.
4. SH 3 and UPRR Capacity Improvements
5. FM 270 Auxiliary Opening
6. Clear Lake Outlet Expansion

The estimated capital cost for Alternative 1 is $275 million. The 100-year Inundation Depth Changes Map is shown in **Figure 8**. **Figure 9** shows the 100-year future conditions and Alternative 1 water surface profiles plotted with the estimated finished floor elevations of structures along the Clear Creek.

Alternative 1 provides the greatest benefits in Reach CC-1 through the City of Friendswood, with water surface elevation reductions of about 1.5 feet in the 100-year storm event. Reach CC-2 sees notable benefits in the vicinity of I-45, with maximum reductions in 100-year water surface elevations of about 0.9 feet. Reach CC-3 through Clear Lake benefits from the expansion of the Lake's outlet, with reductions in 100-year water surface elevations of about 0.5 feet.



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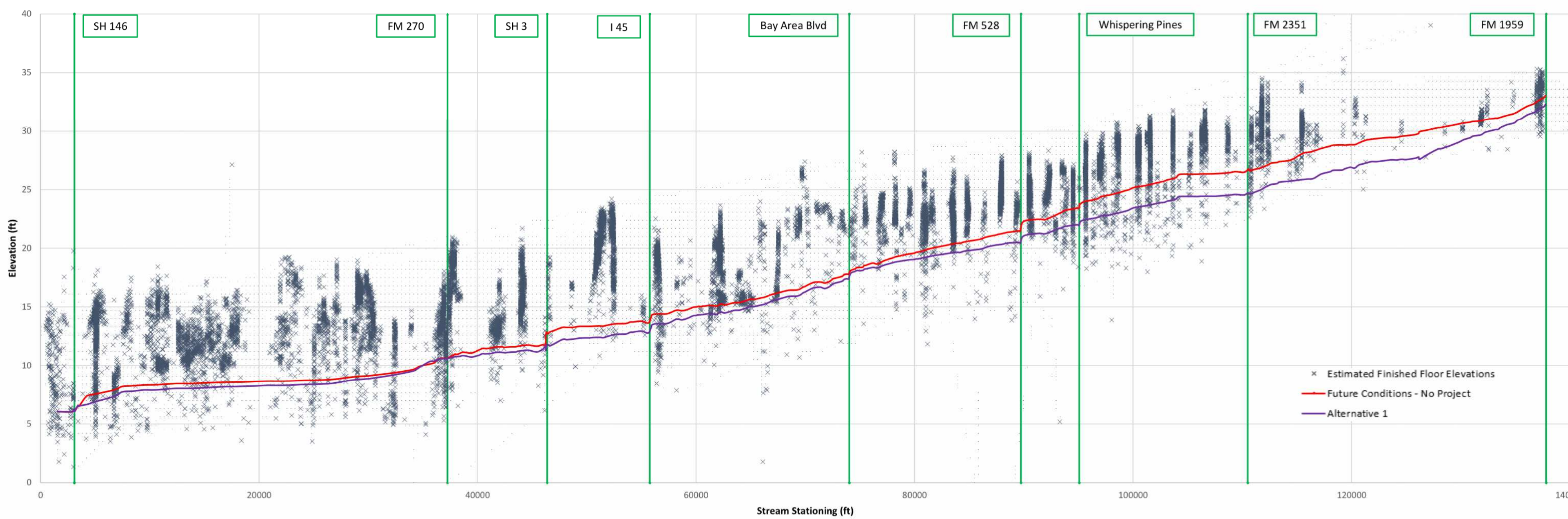
Alternative 1

Location Map - 100-yr Inundation Depth Changes

FN JOB NO	LEA19688
FILE	Fig8.Alternative1_LocationMap
DATE	4/27/2021
SCALE	1:50,000
DRAFTED	90206

FIGURE **8**

Figure 9: Alternative 1 100-Year Water Surface Profile



The increased conveyance through Reach CC-1 associated with the clearing and de-snagging occurs without causing adverse impacts downstream of Bay Area Blvd. thanks to:

- The decrease in peak discharges upstream associated with the detention at the Friendswood and Timber Creek Golf Course basins.
- The increase in conveyance capacity associated with the improvements of the SH 3, UPRR, and FM 270 crossings, as well as the expansion of the Clear Lake outlet.

The implementation sequencing for Alternative 1 is as follows:

No mitigation required, can be completed at any time	Mitigation required, must be completed in the following order
Friendswood Detention Basin	1. Clear Lake Outlet Expansion
Timber Creek Golf Course Detention Basin	2. FM 270 Auxiliary Opening
Clear Lake Outlet Expansion	3. SH 3 and UPRR Capacity Improvements
Structural Elevations and Voluntary Buyouts	4. Clearing and De-snagging – FM 1959 to Bay Area Blvd.

The non-cost factors associated with this combination alternative are presented in **Table 6**.

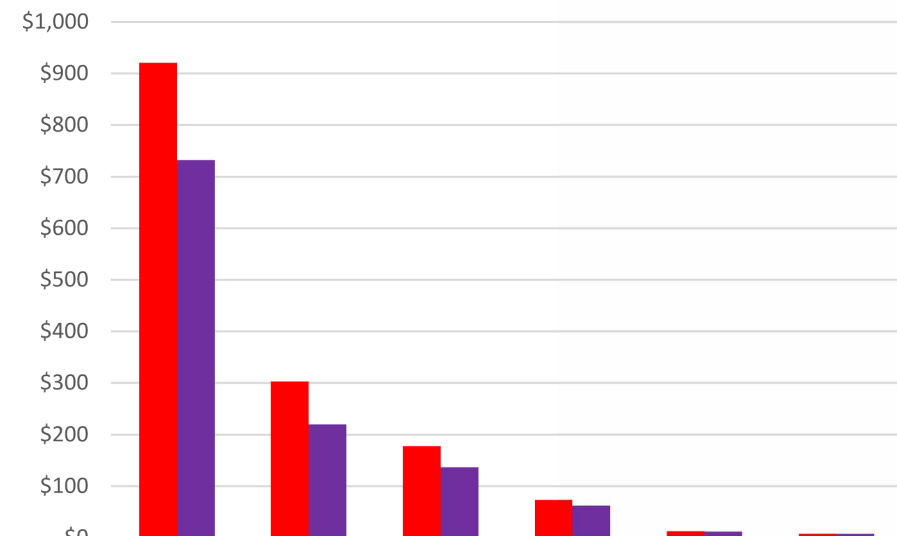
Table 6: Alternative 1 Non-Cost Factors

Factor	Score
Land Acquisition	4
Community Impact/Aesthetics	5
O&M/Resiliency	5
Other Agency Coordination	3
Speed of Implementation	4
Non-Cost Factor Weighted Score	**4.4**

The structural damages and flooding instances for future conditions (no project) and Alternative 1 are presented in **Figure 10** and **Figure 11**, respectively. Over the 50-year design period, Alternative 1 leads to a decrease in flood damages of $60 million, and 1,960 reductions in flooding instances. This translates to 7.1 instances of flooding reduced for every $ million spent in construction costs, and a benfit/cost ratio of 0.23. Additionally, Alternative 1 leads to 45 reductions in roadway overtopping over the 50-year design period.

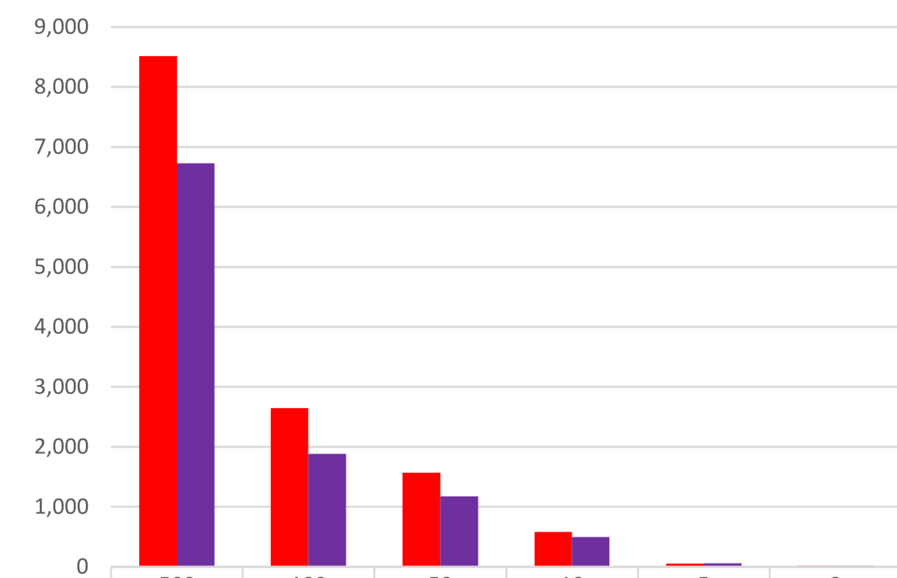
FNI also ran a Hurricane Harvey simulation to assess Alternative 1's performance during tropical storms and hurricanes that can produce large amounts of rainfall over multiple days. Alternative 1 would have reduced structural damages by $100 million and flooding instances by 930, without creating adverse impacts.

Figure 10: Structural Damages ($M) by Event – Alternative 1



	500	100	50	10	5	2
Future Conditions	920.3	302.7	177.4	73.2	12.3	7.5
Alternative 1	731.7	219.5	136.5	62.3	11.9	7.2

Figure 11: Flood Instances by Event – Alternative 1



	500	100	50	10	5	2
Future Conditions	8,515	2,645	1,570	579	54	22
Alternative 1	6,728	1,883	1,172	497	57	21

Key Take-Aways:

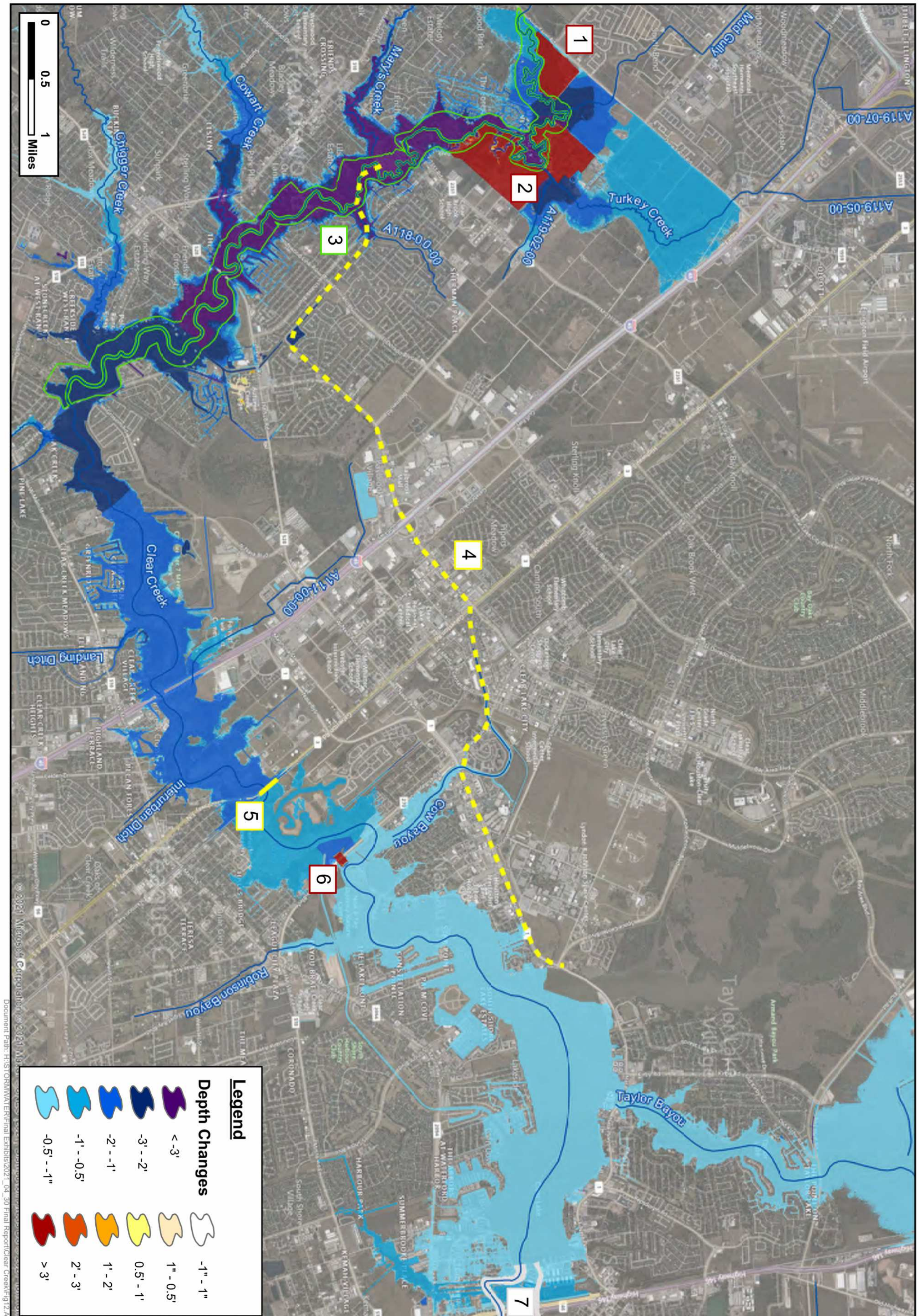
1. Clearing and de-snagging significantly increase conveyance through Reach CC-1 (Friendswood).
2. The downstream impacts associated with the clearing and de-snagging from FM 1959 to Bay Area Blvd. are partially offset by the Friendswood and Timber Creek Golf Course Detention Basins.
3. Improving the capacity of the SH 3 and UPRR bridge crossings provides greater benefit than improving the capacity of the bridge opening at I-45.
4. Increasing the conveyance out of Clear Lake is necessary to increase conveyance through the SH 3, UPRR, and FM 270 crossings.
5. Storm surge and the predicted future sea level rise limit the efficacy of projects to mitigate the flood risk in the Clear Lake communities.
6. Dredging of Clear Lake is not anticipated to improve conveyance during large storm events due to elevated water levels in Galveston Bay and Clear Lake.
7. Significant residual risk remains with the construction of Alternative 1.

3.2 ALTERNATIVE 2: DETENTION + CONVEYANCE + FM 2351 TUNNEL

Alternative 2 corresponds to the combination of the following projects, as shown in **Figure 12:**

1. Friendswood Detention Basin
2. Timber Creek Golf Course Detention Basin
3. Clearing and De-snagging – FM 1959 to Bay Area Blvd.
4. 40-Foot Diameter Tunnel Diversion from FM 2351 to Clear Lake
5. SH 3 and UPRR Capacity Improvements
6. FM 270 Auxiliary Opening
7. Clear Lake Outlet Expansion

The estimated capital cost for Alternative 2 is $1,250 million. The 100-year Inundation Depth Changes Map is shown in **Figure 12**. **Figure 13** shows the 100-year future conditions and Alternative 2 water surface profiles plotted with the estimated finished floor elevations of structures along the Clear Creek.



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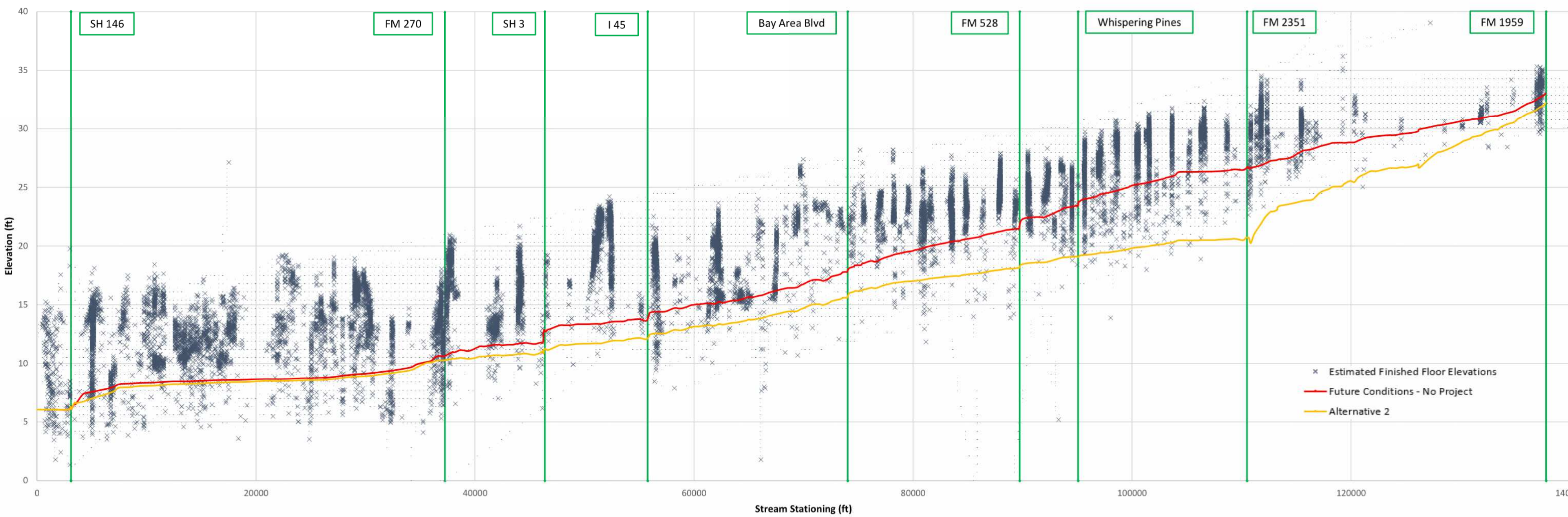
Alternative 2

Location Map - 100-yr Inundation Depth Changes

FN JOB NO	LEA19688
FILE	Fig12.Alternative2_LocationMap
DATE	5/12/2021
SCALE	1:50,000
DRAFTED	90206

FIGURE
12

Figure 13: Alternative 2 100-Year Water Surface Profile



As described in detail in **Appendix A**, the 40-foot FM 2351 to Clear Lake tunnel was retained based on an efficiency analysis of various tunnel configurations. This alternative provides the greatest benefits in Reach CC-1 through the City of Friendswood, with water surface elevation reductions of over 6 feet in the 100-year storm event at FM 2351. Water surface elevation reductions and benefits lessen moving downstream away from the tunnel intake. In Reach CC-2, I-45 sees a reduction in 100-year water surface elevations of 1.8 feet. Reach CC-3 through Clear Lake benefits from the expansion of the Lake's outlet, with reductions in 100-year water surface elevations of about 0.5 feet.

The tunnel diverts flow from FM 2351 down to Clear Lake thus bypassing most of Reach CC-1, and all of Reach CC-2. This not only provides significant water surface elevation reductions in these reaches, but also allows for the clearing and de-snagging to occur without causing adverse impacts. However, the tunnel diversion provides a more efficient pathway for water get to Clear Lake than the winding densely vegetated creek, and therefore increasing the conveyance out of the Lake is necessary to offset the increase in peak discharges that occurs at the tunnel outlet. The implementation sequencing for Alternative 2 is as follows:

No mitigation required, can be completed at any time	Mitigation required, must be completed in the following order
Friendswood Detention Basin	1. Clear Lake Outlet Expansion
Timber Creek Golf Course Detention Basin	2. FM 270 Auxiliary Opening
Clear Lake Outlet Expansion	3. SH 3 and UPRR Capacity Improvements
Structural Elevations and Voluntary Buyouts	4. 40-Foot Diameter Tunnel Diversion from FM 2351 to Clear Lake
	5. Clearing and De-snagging – FM 1959 to Bay Area Blvd.

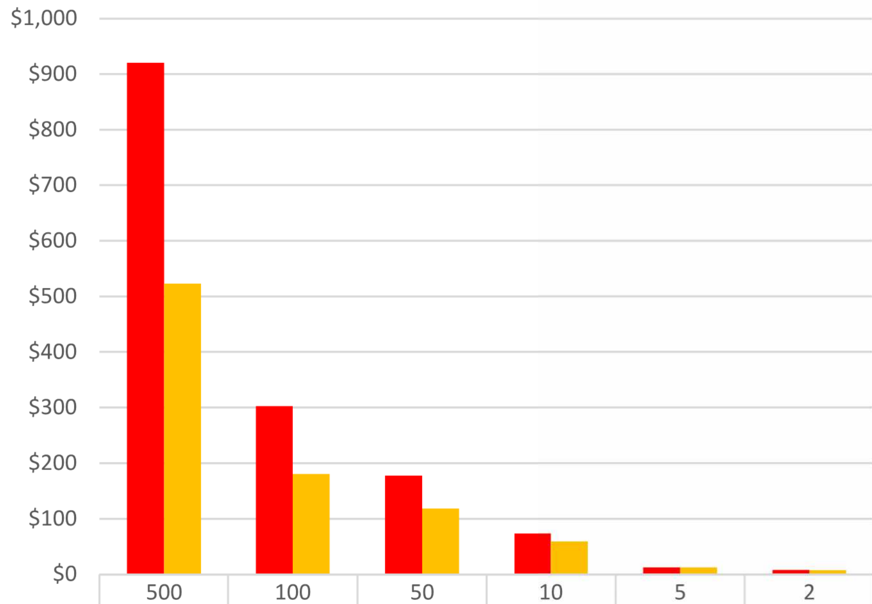
The non-cost factors associated with this project are presented in **Table 7**.

Table 7: Alternative 2 Non-Cost Factors

Factor	Score
Land Acquisition	4
Community Impact/Aesthetics	4
O&M/Resiliency	3
Other Agency Coordination	2
Speed of Implementation	4
Non-Cost Factor Weighted Score	**3.6**

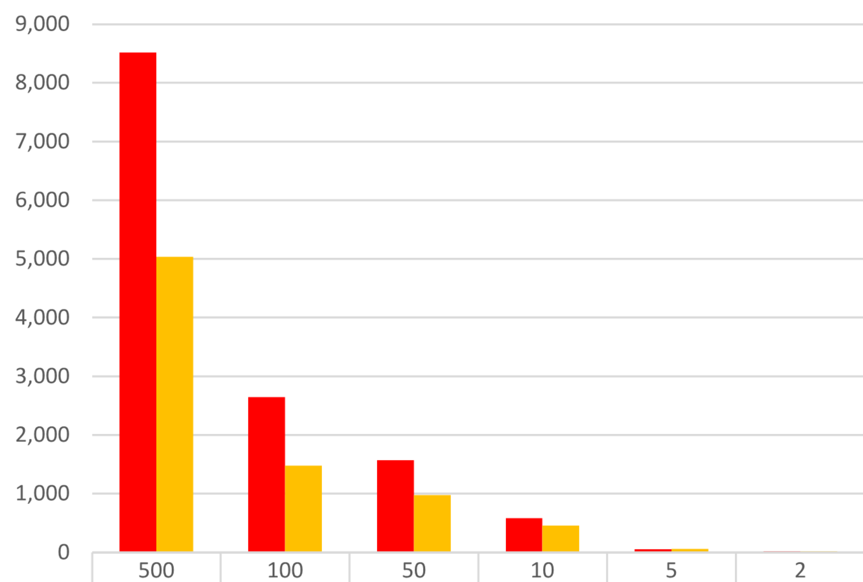
The structural damages and flooding instances for future conditions (no project) and Alternative 2 are presented **Figure 14** and **Figure 15**, respectively.

Figure 14: Structural Damages ($M) by Event – Alternative 2



	500	100	50	10	5	2
Future Conditions	920.3	302.7	177.4	73.2	12.3	7.5
Alternative 2	523.1	180.4	118.0	59.0	11.9	7.2

Figure 15: Flood Instances by Event – Alternative 2



	500	100	50	10	5	2
Future Conditions	8,515	2,645	1,570	579	54	22
Alternative 2	5,031	1,477	975	455	57	21

Over the 50-year design period, Alternative 2 leads to a decrease in flood damages of $95 million, and 3,110 reductions in flooding instances. This translates to 2.5 instances of flooding reduced for every $M spent in construction costs, and a benfit/cost ratio of 0.08. Additionally, Alternative 2 leads to 50 reductions in roadway overtopping over the 50-year design period.

Alternative 2 is shown to provide significant flood mitigation benefits in events of catastrophic magnitude such as the 500-year storm event: Alterative 2 reduces structural damages by $400 million, and flooding instances by 3,480.

FNI also ran a Hurricane Harvey simulation to assess Alternative 2's performance during tropical storms and hurricanes that can produce large amounts of rainfall over multiple days. Alternative 2 would have reduced structural damages by $155 million and flooding instances by 1,490, and not create adverse impacts.

Key Take-Aways:

1. The FM 2351 tunnel diversion, in combination with the clearing and de-snagging, significantly reduces water surface elevations through Reach CC-1 (Friendswood).
2. Having the tunnel discharge into Clear Lake requires an expansion of the Lake's outlet capacity.
3. The tunnel could be supplemented with a pump station that would increase its maximum conveyance capacity by pulling more water through the syphon. This could provide either increased benefits or a decrease in construction costs by reducing the tunnel diameter.
4. The tunnel presents opportunity for local drainage connections along its alignment in Friendswood, Webster, and Houston that could provide additional flood risk mitigation not captured in this study.
5. Because the tunnel is designed to only operate during storm events equal to or exceeding the 10-year storm, Alternative 2 provides limited benefits in frequent storm events such as the 2-year and 5-year events, and therefore does not score well on a 50-year basis. However, Alternative 2 provides significant flood risk mitigation during storm events of catastrophic magnitude such as the 500-year storm.
6. Improving the capacity of the SH 3 and UPRR bridge crossings provides greater benefit than improving I-45.

7. Storm surge and the predicted future sea level rise limit the efficacy of projects to mitigate the flood risk in the Clear Lake communities.
8. Dredging of Clear Lake is not anticipated to improve conveyance during large storm events due to elevated water levels in Galveston Bay and Clear Lake.
9. Significant residual risk remains with the construction of Alternative 2.

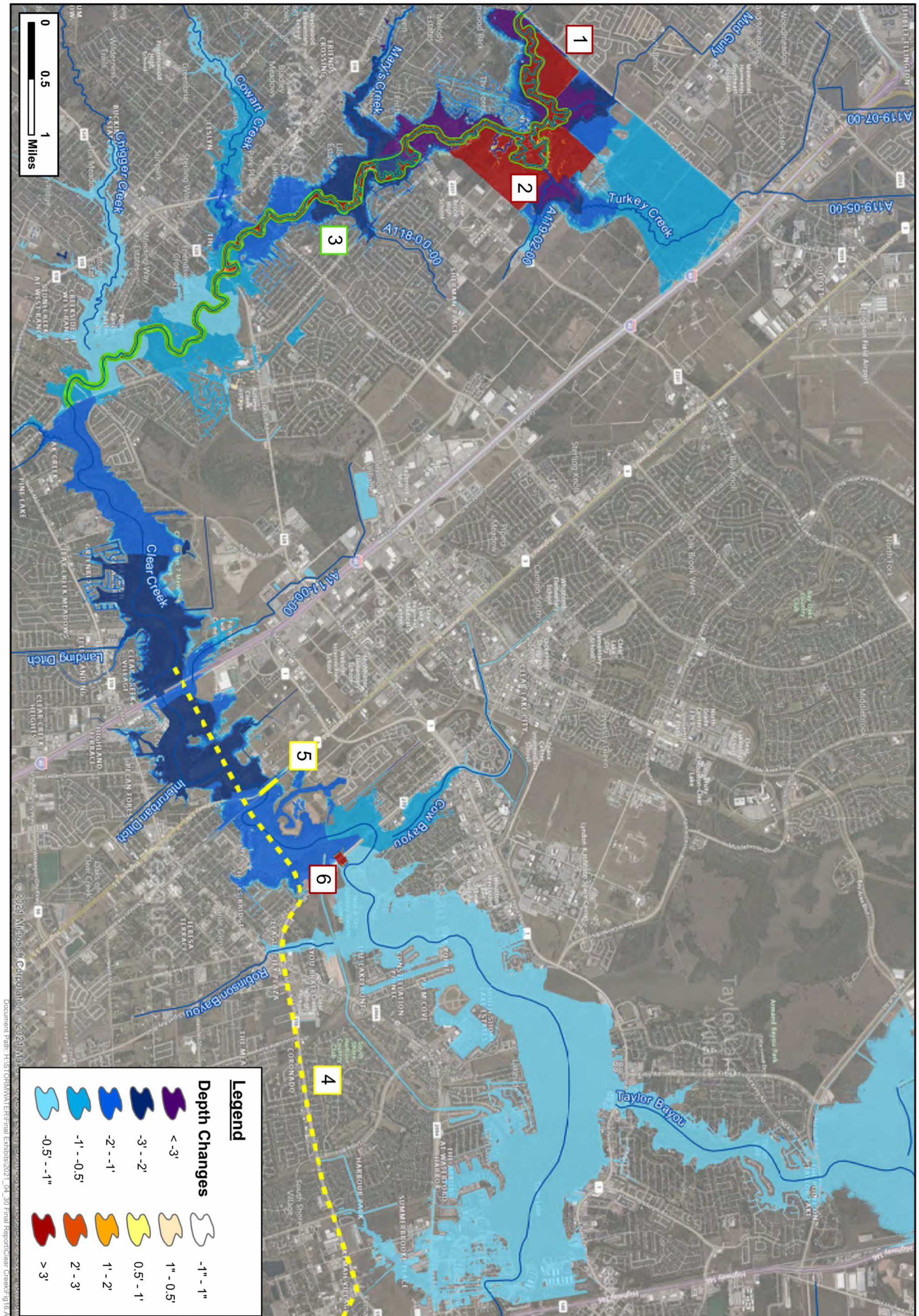
3.3 ALTERNATIVE 3: DETENTION + CONVEYANCE + I-45 TUNNEL

Alternative 3 corresponds to the combination of the following projects, as shown **Figure 16**:

1. Friendswood Detention Basin
2. Timber Creek Golf Course Detention Basin
3. Channel Benching Above OHWM – FM 1959 to Bay Area Blvd.
4. 40-Foot Diameter Tunnel Diversion from I-45 to Galveston Bay
5. SH 3 and UPRR Capacity Improvements
6. FM 270 Auxiliary Opening

The estimated capital cost for Alternative 3 is $ 1,150 million. The 100-year Inundation Depth Changes Map is shown in **Figure 16**. **Figure 17** shows the 100-year future conditions and Alternative 3 water surface profiles plotted with the estimated finished floor elevations of structures along the Clear Creek.

As described in detail in **Appendix A**, the 40-foot I-45 to Galveston Bay tunnel was retained based on an efficiency analysis of various tunnel configurations. This alternative provides significant benefits in Reach CC-1 through the City of Friendswood, with water surface elevation reductions of over 7 feet in the 100-year storm event immediately downstream of FM 1959. Alternative 3 also provides notable water surface elevation reductions in Reach CC-2 in the vicinity of I-45, with reductions exceeding 2 feet in the 100-year storm event. Reach CC-3 through Clear Lake benefits from water being diverted by the tunnel out of Clear Creek and bypassing the Lake down to Galveston Bay. Unlike for Alternatives 1 and 2 that necessitate an improvement of the Lake's outlet capacity, the information presented in **Figure 16** and **Figure 17** reflect the Lake's primary and second outlets being left in their existing state.



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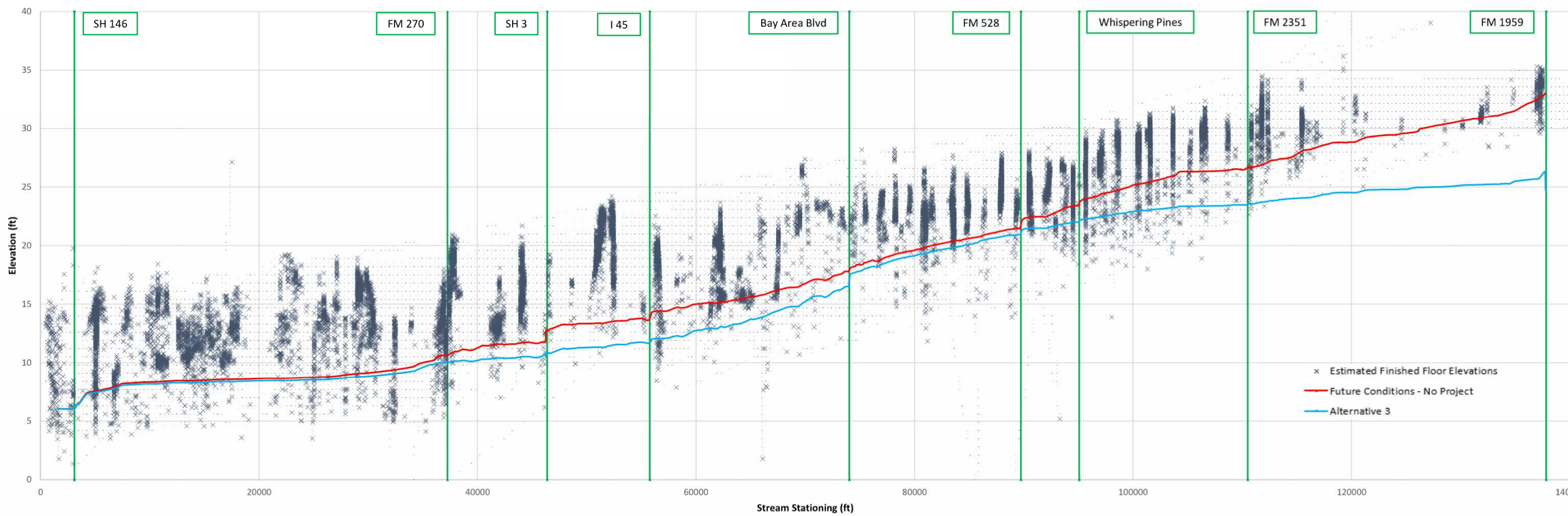
Alternative 3

Location Map - 100-yr Inundation Depth Changes

FN JOB NO	LEA19688
FILE	Fig16.Alternative3_LocationMap
DATE	5/12/2021
SCALE	1:50,000
DRAFTED	90206

FIGURE 16

Figure 17: Alternative 3 100-Year Water Surface Profile



Placing the tunnel intake on the upstream side of I-45 downstream of the proposed channel benching allows this alternative to include major channel improvements in Friendswood (OHWM benching) to achieve a significant increase in conveyance without causing adverse impacts downstream. Additionally, placing the intake at I-45 maximizes the water surface elevation reductions in that section of the reach, notably at the Clear Creek Village neighborhood that is shown to include multiple structures at risk of flooding during the 100-year storm event. This alignment also follows FM 518 through League City, presenting an opportunity to benefit the local drainage system with various connections along the alignment. Finally, this tunnel alignment bypasses Clear Lake and outfalls to Galveston Bay directly, which removes the need to expand the Lake's outlet capacity.

The implementation sequencing for Alternative 3 is as follows:

No mitigation required, can be completed at any time	Mitigation required, must be completed in the following order
Friendswood Detention Basin	1. 40-Foot Diameter Tunnel Diversion from I 45 to Galveston Bay
Timber Creek Golf Course Detention Basin	2. FM 270 Auxiliary Opening
40-Foot Diameter Tunnel Diversion from I 45 to Galveston Bay	3. SH 3 and UPRR Capacity Improvements
Structural Elevations and Voluntary Buyouts	4. Channel Benching Above OHWM

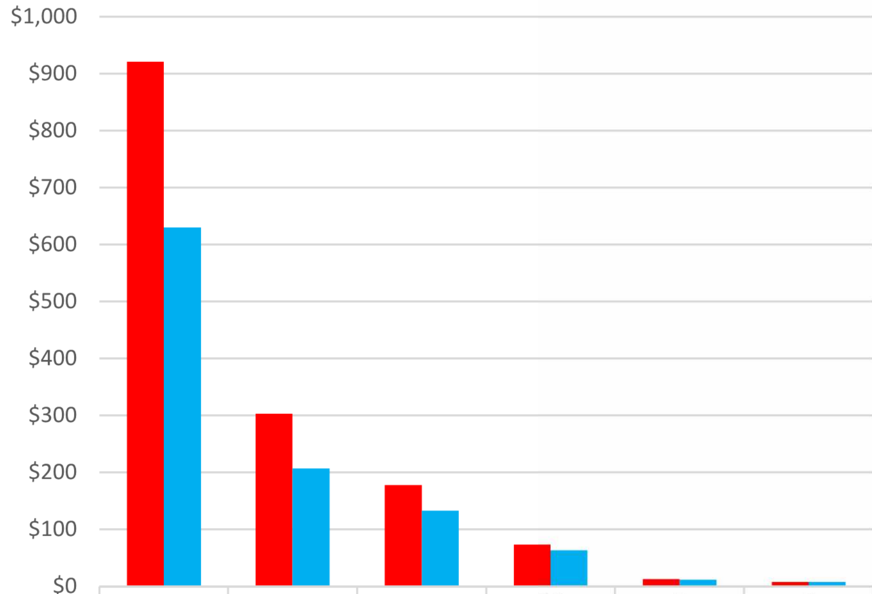
The non-cost factors associated with this project are presented in **Table 8**.

Table 8: Alternative 3 Non-Cost Factors

Factor	Score
Land Acquisition	3
Community Impact/Aesthetics	4
O&M/Resiliency	3
Other Agency Coordination	3
Speed of Implementation	4
Non-Cost Factor Weighted Score	**3.4**

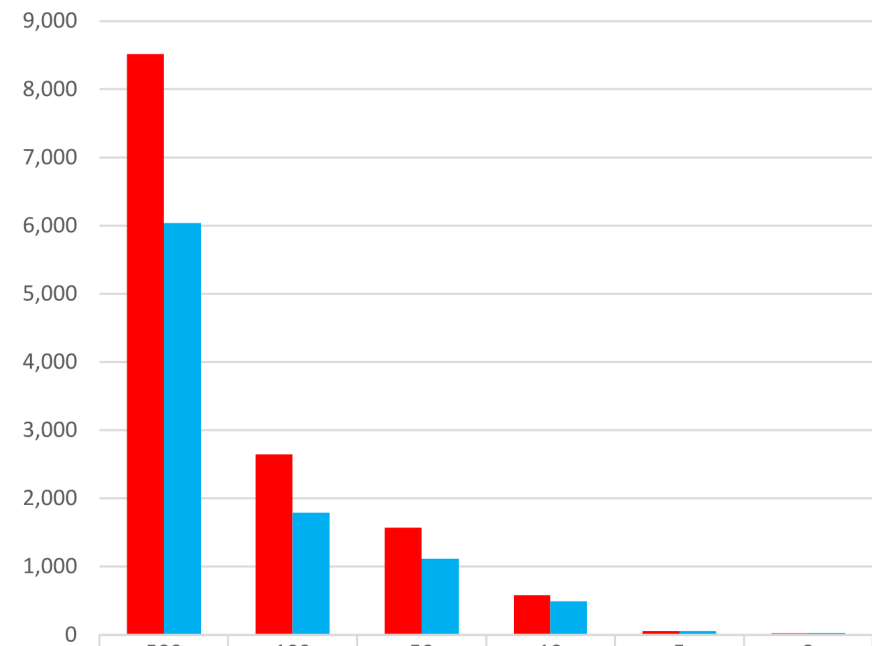
The structural damages and flooding instances for future conditions (no project) and Alternative 3 are presented in **Figure 18** and **Figure 19,** respectively.

Figure 18: Structural Damages ($M) by Event – Alternative 3



	500	100	50	10	5	2
Future Conditions	920.3	302.7	177.4	73.2	12.3	7.5
Alternative 3	629.4	206.8	132.9	63.0	11.4	7.5

Figure 19: Flood Instances by Event – Alternative 3



	500	100	50	10	5	2
Future Conditions	8,515	2,645	1,570	579	54	22
Alternative 3	6,035	1,792	1,113	488	52	24

Over the 50-year design period, Alternative 3 leads to a decrease in flood damages of $70 million, and 2,300 reductions in flooding instances. This translates to 2 instances of flooding reduced for every $M spent in construction costs, and a benfit/cost ratio of 0.06. Additionally, Alternative 3 leads to 82 reductions in roadway overtopping over the 50-year design period.

Alternative 3 is shown to provide significant flood mitigation benefits in events of catastrophic magnitude such as the 500-year storm event: Alterative 3 reduces structural damages by $290 million, and flooding instances by 2,480.

FNI also ran a Hurricane Harvey simulation to assess Alternative 3's performance during tropical storms and hurricanes that can produce large amounts of rainfall over multiple days. Alternative 3 would have reduced damages by $125 million and flooding instances by 1,150, and not create adverse impacts.

<u>Key takeaways:</u>

1. This alternative does not require expanding Clear Lake's outlet capacity.
2. The tunnel could be supplemented with a pump station that would increase its maximum conveyance capacity by pulling more water through the syphon. This could provide either increased benefits or a decrease in construction costs by reducing the tunnel diameter.
3. The tunnel presents a major opportunity for local drainage connections along its alignment in League City that could provide additional flood risk mitigation not captured in this study.
4. Because the tunnel is designed to only operate during storm events equal to or exceeding the 10-year storm, Alternative 3 provides limited benefits in frequent storm events such as the 2-year and 5-year events, and therefore does not score well on a 50-year basis. However, Alternative 3 provides significant flood risk mitigation during storm events of catastrophic magnitude such as the 500-year storm.
5. Improving the capacity of the SH 3 and UPRR bridge crossings provides greater benefit than improving I-45.
6. Storm surge and the predicted future sea level rise limit the efficacy of projects to mitigate the flood risk in the Clear Lake communities.
7. Dredging of Clear Lake is not anticipated to improve conveyance during large storm events due to elevated water levels in Galveston Bay and Clear Lake.
8. Significant residual risk remains with the construction of Alternative 3.

4 CONCLUSIONS

Table 9 shows the 100-year peak water surface elevation reductions at FM 2351 and I-45 between Alternatives 1, 2, and 3, and future conditions (no project). A comparison of the complete 100-year water surface profiles is presented in **Figure 20** provided on the next page.

Table 9: 100-Year Peak Water Surface Elevation Reductions at FM 2351 and I-45

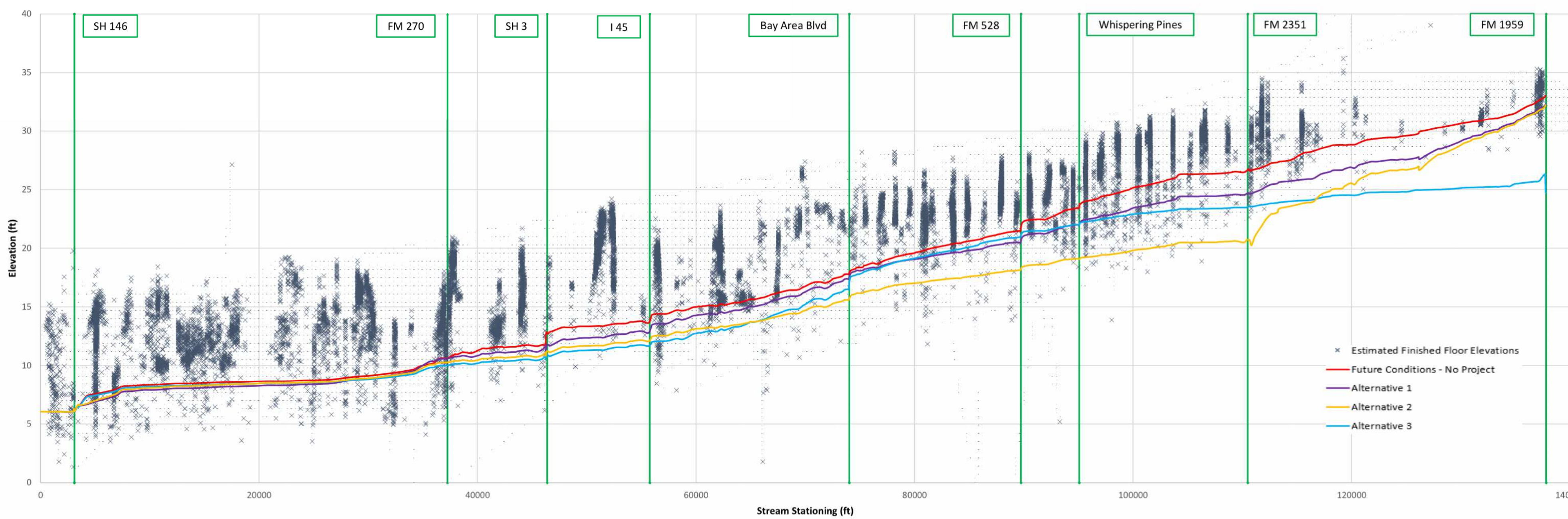
Alternative	FM 2351	I-45
1: Detention + Conveyance Improvements	2.04 feet	0.88 feet
2: Detention + Conveyance + FM 2351 Tunnel	6.06 feet	1.82 feet
3: Detention + Conveyance + I-45 Tunnel	2.83 feet	2.28 feet

As presented in **Section 3**, Alternative 1 Detention + Conveyance Improvements is the lowest capital cost alternative and provides significant flood risk mitigation compared to pre-project conditions. Alternative 1 provides the highest 50-year design period benefit/cost ratio, but does not provide the greatest reductions in water surface elevations.

Alternatives 2 and 3 provide greater flood risk mitigation than Alternative 1, but this increase in benefits is not linearly correlated with their increase in construction costs. To better evaluate the benefits of all three alternatives, and particularly Alternatives 2 and 3, the riverine analysis prepared for this study needs to be integrated with local storm drainage networks to capture both riverine and localized storm drain benefits to better define the true benefit/cost ratios.

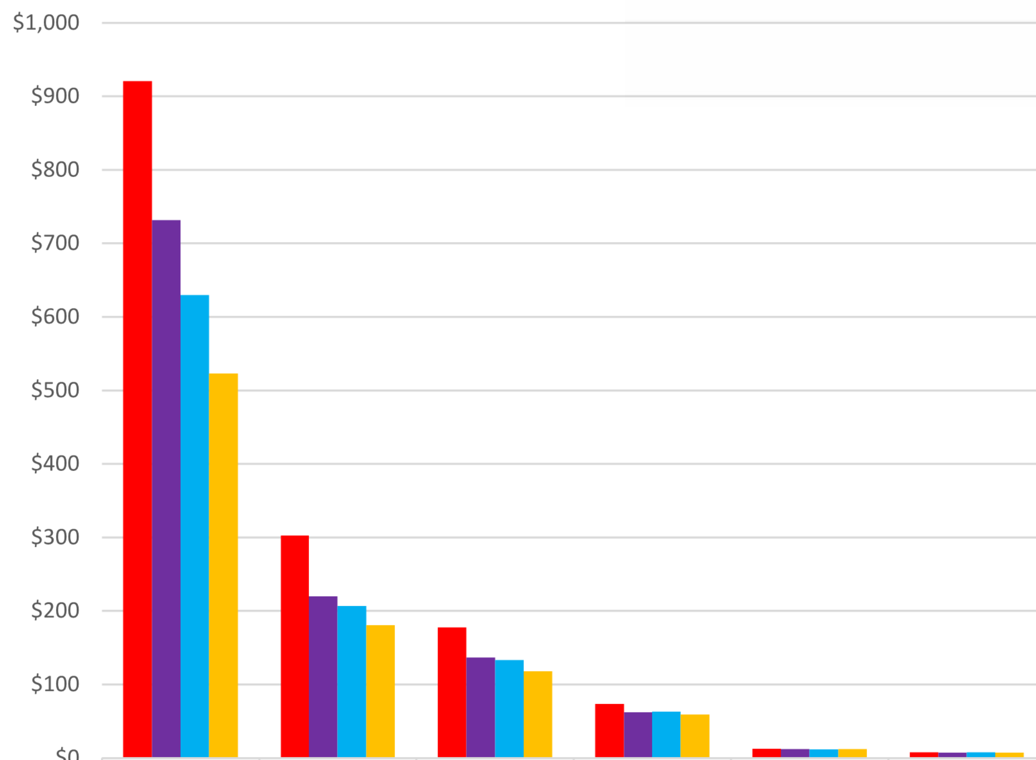
In addition to integrating localized benefits, Alternatives 2 and 3 can also be further refined: The analysis presented was based on a 40-foot diameter gravity flow tunnel. Opportunities exist for the tunnels to supplement gravity conveyance with stormwater pump stations, potentially reducing construction costs and increasing benefits.

Figure 20: 100-Year Water Surface Profiles



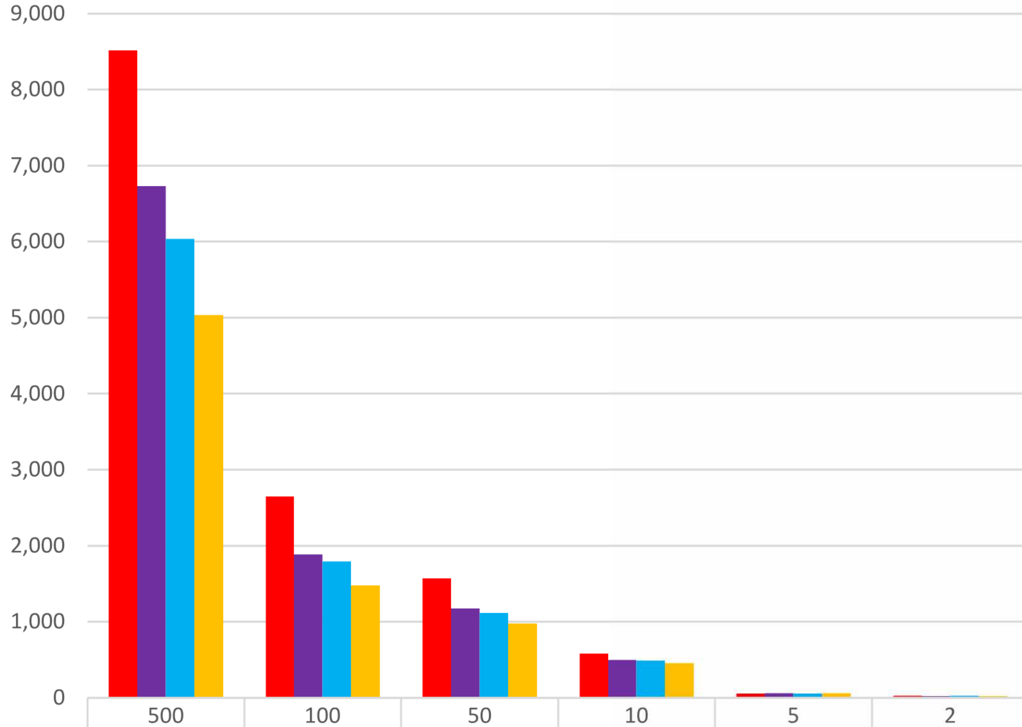
Flood risk mitigation in Reach CC-3 is very difficult. Implementing projects that reduce water levels downstream of FM 270 during large storm events is very challenging due to the high flows discharged by Armand Bayou, elevated Bay and Lake elevations generated by tropical storms and hurricanes such as Harvey, and future predicted sea level rise. It may be possible to increase the outlet capacity of Clear Lake into Galveston Bay, but increasing the size of the opening to Galveston Bay could also expose this area to greater storm surge risk and environmental impacts. Furthermore, the outlet at Clear Lake is being considered for a surge gate as part of the Texas Coastal study. Recommendations for any increase or change to the outlet from Clear Lake into Galveston Bay will require coordination with a number of entities including USACE, HCFCD, GLO, and environmental and community interests. Alternative 3 discharges directly into Galveston Bay thus mitigating this conflict, and could provide even greater benefits if coordinated with the improvements proposed at the existing outlet by the Texas Coastal Study. **Figure 21** and **Figure 22** summarize the structural damages and instances of flooding associated with each Alternative compared to future conditions (no project).

Figure 21: Summary of Structural Damages ($M) by Event for All Alternatives



	500	100	50	10	5	2
Future Conditions	920.3	302.7	177.4	73.2	12.3	7.5
Alternative 1	731.7	219.5	136.5	62.3	11.9	7.2
Alternative 3	629.4	206.8	132.9	63.0	11.4	7.5
Alternative 2	523.1	180.4	118.0	59.0	11.9	7.2

Figure 22: Summary of Flood Instances by Event for All Alternatives



	500	100	50	10	5	2
Future Conditions	8,515	2,645	1,570	579	54	22
Alternative 1	6,728	1,883	1,172	497	57	21
Alternative 3	6,035	1,792	1,113	488	52	24
Alternative 2	5,031	1,477	975	455	57	21

FNI proposes the following conclusions:

1. The alternatives proposed in this study are targeted toward mitigating the riverine flood risk during large, infrequent storms. For structures at risk of flooding under smaller, more frequent storms such as the 2-year and the 5-year events, elevating the structure or acquiring the property and removing it from the floodplain is likely the most cost-effective approach. FNI calculated that 54 structures flood during the 5-year event under future conditions.

2. Improvements should be implemented wholistically – from FM 1959 down to Galveston Bay to prevent adverse impacts.

    a. Large scale vegetative clearing or channel improvements through Friendswood cannot be constructed as stand-alone projects, and upstream or inline detention may not provide sufficient mitigation to prevent increases in discharges and water surface elevations in the downstream sections of the Creek.

   b. Increasing the conveyance upstream of Clear Lake necessitates increasing the conveyance out of the Lake into Galveston Bay. Increasing the capacity of the outlets to Galveston Bay could expose this area to greater storm surge risk and environmental impacts, and should be analyzed further as this study progresses into future phases. A solution should be developed in conjunction with the improvements proposed as part of the Coastal Texas Study at the Clear Lake outlets.

3. Tunnel solutions are less cost efficient than other alternatives, and do not score well based on the 50-year project window used by USACE and FEMA given they are designed to operate during storm events equal to or exceeding the 10-year storm. However, they provide the greatest level of protection during events of catastrophic magnitude such as the 500-yr storm event and Hurricane Harvey, and can be designed to provide additional benefits to local drainage systems.
4. The project benefits captured in this study do not fully account for the benefits the proposed alternatives could provide to the local drainage systems, which could be significant, particularly for the tunnel projects. The output from the alternatives developed in this study's hydraulic models should be integrated into local storm sewer network models to capture additional benefits achieved outside of the riverine floodplain of Clear Creek and its major tributaries.
5. The proposed alternatives mitigate but do not eliminate the flood risk in the study area. Significant residual risk persists due to certain low-lying structures and the compound effect of rainfall and storm surge that will likely become more severe in the future due to rising sea levels.

5 RECOMMENDATIONS

Since the combination alternatives analyzed do not have a benefit/cost ratio greater than 1.0, project recommendations are closely tied to project funding potential with a focus on local funding for a significant share of the project.

5.1 PROJECT FUNDING

5.1.1 Local Funding

All of the combination alternatives and any of the individual projects greater than $50 million in capital cost are unlikely to be funded by an individual entity such as the City of League City or the City of Friendswood. These improvements will require partnerships and cost sharing agreements between the entities. These agreements could be developed piecemeal on a project by project basis, but would be better accomplished through the development of a watershed-wide entity focused on flood risk mitigation along the main channel of Clear Creek such as the Clear Creek Flood Control District originally proposed in 1995 and offered for consideration again at the State level in 2019.

Such an entity would have a clear mission of flood protection for Clear Creek and provide a single clear partner for larger entities such as USACE, the Texas General Land Office, and the Texas Water Development Board. This entity would not conflict or restrict Harris County Flood Control District, Brazoria County Drainage District 4, Galveston County Consolidated Drainage District, and other entities along the Creek from their responsibilities. Instead, the newly formed Clear Creek Flood Control District would allow other entities to focus their efforts on tributary drainage to Clear Creek thus maximizing the benefit of their existing ad valorem taxes. The Clear Creek Flood Control District would need to be created by the Texas State Legislature and then voted upon by the Watershed's residents to grant it taxing authority. The tax rate for the District would be a function of the projects recommended following the next phase of this study. Discussions with state and local officials as well as the Clear Creek Watershed Steering Committee to gain traction for this concept should proceed immediately.

5.1.2 External Funding

In addition to local funding opportunities through ad valorem, additional grant and matching programs exist at the Federal and State level that should be evaluated once clear cost benefit metrics are prepared including local benefits. These funding entities and their programs are discussed in greater detail in **Appendix E** and include:

- United States Army Corps of Engineers
- Texas General Land Office
- Federal Emergency Management Agency
- Texas Water Development Board
- United States Department of Housing and Urban Development
- United States Department of Agriculture

There are many different financial partnership opportunities, but external sources come with their own objectives. Even if a project may qualify and be selected for a program, most programs require a local match that is a significant percentage, and many programs have strings attached. Each partner will have distinct eligibility and accountability criteria by which they are legally obligated to, often including benefit/cost ratios.

Many of these requirements include:

- Additional Protections for Cultural Resources and the Environment
- Restrictions on what actions are reimbursable
- Additional reporting requirements on how money is spent
- Transparency and fairness in how contracts are advertised and awarded
- Special contract provisions regarding how work will be recorded and conducted

As these programs are pursued, it is important to understand the implications that each program's requirements may impose on the project. Because of the makeup of the communities along Clear Creek, these projects will not perform well for programs that put a heavy emphasis on low to moderate income and socially vulnerable populations.

For structures at risk of flooding under frequent storms, elevating the structure or acquiring the property and removing it from the floodplain is likely the most cost-effective approach. This can be specifically undertaken with the help of the following programs:

- NRCS-EWP Pilot Program
- FEMA-HMGP
- FEMA-BRIC
- TWDB-FIF

5.2 NEXT STEPS

The first recommendation and next step is to integrate the outputs from the alternatives developed as part of this study into local storm sewer network models for Friendswood, League City, Webster, Houston, and other municipalities to capture additional benefits achieved outside of the riverine floodplain of Clear Creek and its major tributaries. This should be completed for all three alternatives, but especially for Alternatives 2 and 3 which provide opportunities to route the tunnels in a way that allows the tunnel to improve local drainage system performance with additional shafts.

The only individual project with a capital cost less than $50 million that can be pursued independently is the Friendswood Detention Basin which, if not being included as part of the Clear Creek Federal Project to mitigate upstream impacts, should be prioritized for design and construction as the land is already owned by Harris County Flood Control District and a conceptual design of the basin exists.

The other project elements are all contingent on either one of the large tunnels and/or improvements to the Clear Lake outlet into Galveston Bay. Further analysis of the Clear Lake outlet into Galveston Bay in coordination with the potential surge gate from the Texas Coastal Study should proceed immediately. Improvements to the outlet would allow other smaller capital cost improvements including the FM 270 Bypass and SH 3/UPRR bridge replacement to be initiated, as well as larger improvements such as the FM 2351 Tunnel or clearing and de-snagging of the Creek from FM 1959 to Bay Area Boulevard.

Appendix A

Evaluation of Discrete Projects

Appendix B

Hydrologic Technical Memorandum

Appendix C

Hydraulic Technical Memorandum

Appendix D

Inundation Damages Assessment

Technical Memorandum

Appendix E

Preliminary Funding Memorandum

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LOWER CLEAR CREEK AND DICKINSON BAYOU FLOOD MITIGATION PLAN

Dickinson Bayou Alternatives Evaluation and Recommendation

FINAL REPORT

Prepared for:

City of League City

June 2021

Prepared by:

FREESE AND NICHOLS, INC.
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Pearland, Texas 77584

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1 EXECUTIVE SUMMARY

The purpose of this study was to develop a comprehensive flood mitigation plan for Dickinson Bayou with a focus on the riverine impacts along the main channel beginning near Farm to Market Road 528 through the outlet into Dickinson Bay. In conjunction with RPS Group, Inc. (RPS), Freese and Nichols, Inc. (FNI) developed state-of-the-art hydrologic and hydraulic models leveraging current NOAA Atlas 14 rainfall, 2018 LiDAR data, and a 1D/2D unsteady-state modeling approach. FNI evaluated both existing and future conditions flood risks based on the 24-hour duration 2-, 5-, 10-, 50-, 100-, and 500-year Atlas 14 storm events, as well as Hurricane Harvey rainfall. FNI identified vulnerabilities in the Dickinson Bayou Watershed, including instances of flooding at structures and the resulting damage estimates, as well as impacts to critical infrastructure and transportation systems.

FNI investigated and modeled a total of 10 flood mitigation projects along Dickinson Bayou. These projects consist of detention basins and channel diversions. FNI evaluated each project based on four quantitative metrics including instances of flooding, flood damages reduced, constructions costs, and transportation system impacts. FNI also assessed five qualitative (non-cost) metrics in its project evaluation, including operations and maintenance requirements, and impacts to aesthetics and the community. Each concept was modeled individually, and based on the analysis of each discrete project's impacts, FNI developed two combination alternatives that incorporate multiple projects to optimize benefits while preventing adverse impacts. A summary of these flood mitigation alternatives is presented in **Table 1** provided on the next page. Maps presenting these alternatives are provided in **Section 3** of this report as **Figure 7** and **Figure 11**.

Based on discussions with stakeholders, the combination alternatives and any of the individual projects greater than $50 million in capital cost are unlikely to be funded by an individual entity. Mitigation will require partnerships and cost sharing agreements between the entities. These agreements could be developed piecemeal on a project-by-project basis, or by development of a watershed-wide entity focused on flood damage reduction along the main channel of Dickinson Bayou. In addition to local funding opportunities through ad valorem, additional grant and matching programs exist at the Federal and State level that should be further evaluated as this study progresses into future phases. For improvements in and around the City of Dickinson, population metrics may qualify for grants through the Texas General Land Office (Community Development Block Grants (CDBG)).

Table 1: Summary of Flood Mitigation Alternatives

Alternative	Discrete Projects	Cost	Non-Cost Score	Reductions Over the 50-year Design Period		Reductions During Harvey	
				Damages	Flooding Instances	Damages	Flooding Instances
1: Detention	Mc Farland Rd. Detention Basin W Cemetery Rd. Detention Basin Hilton Ln. Detention Basin Magnolia Bayou and Borden Gully Detention Basins	$220 M	3.7	$40 M	2,490	$35 M	420
2: Detention + Bypass Channel	Mc Farland Rd. Detention Basin W Cemetery Rd. Detention Basin Hilton Ln. Detention Basin Magnolia Bayou and Borden Gully Detention Basins Desel Dr. 11,000 cfs Channel Diversion	$500 M	2.9	$245 M	15,100	$180 M	1,940

FNI proposes the following conclusions resulting from this study:

1. The alternatives proposed in this study are targeted toward mitigating the riverine flood risk during large, infrequent storms. For structures at risk of flooding under smaller, more frequent storms such as the 2-year and the 5-year events, elevating the structure or acquiring the property and removing it from the floodplain is likely the most cost-effective approach. FNI calculated that over 1,300 structures flood during the 5-year event under future conditions. A significant number of these structures are located in the Dickinson “Bowl” in the vicinity of I-45.
2. Placing detention in the upstream portion of the watershed where undeveloped land is currently available will prove critical as the area develops in the future, but offers limited benefits in the Dickinson “Bowl” where most of the structures at risk of flooding are located.
3. Constructing a diversion channel from downstream of I-45 to the Bayou’s outlet provides significant flood risk mitigation in the population centers located around I-45 that are at the highest risk of riverine flooding.
4. The project benefits captured in this study do not fully account for the benefits the proposed alternatives could provide to the local drainage systems, which could be significant. The output from the alternatives developed in this study’s hydraulic models should be integrated into local storm sewer network models to capture additional benefits achieved outside of the riverine floodplain of Dickinson Bayou and its major tributaries.
5. The proposed alternatives mitigate but do not eliminate the flood risk in the study area. Significant residual risk persists east of I-45 due to an abundance of low-lying structures in the Dickinson “Bowl”. Flooding risks will likely increase in the future as the upstream portion of the watershed develops, and the compound effect of rainfall and storm surge becomes more severe due to rising sea levels.

Based on these conclusions, FNI recommends a feasibility study be conducted to:

- Refine the combination alternatives proposed as part this study,
- Identify supplemental benefits the alternatives could provide to areas located outside of the riverine floodplains,
- Reduce the uncertainty associated with the compound flooding results by conducting further analyses to improve the understanding of its impacts on the alternatives' benefits,
- Identify efficiencies in the alternatives to reduce cost,
- Develop a project delivery plan, and
- Recommend a distinct alternative for implementation.

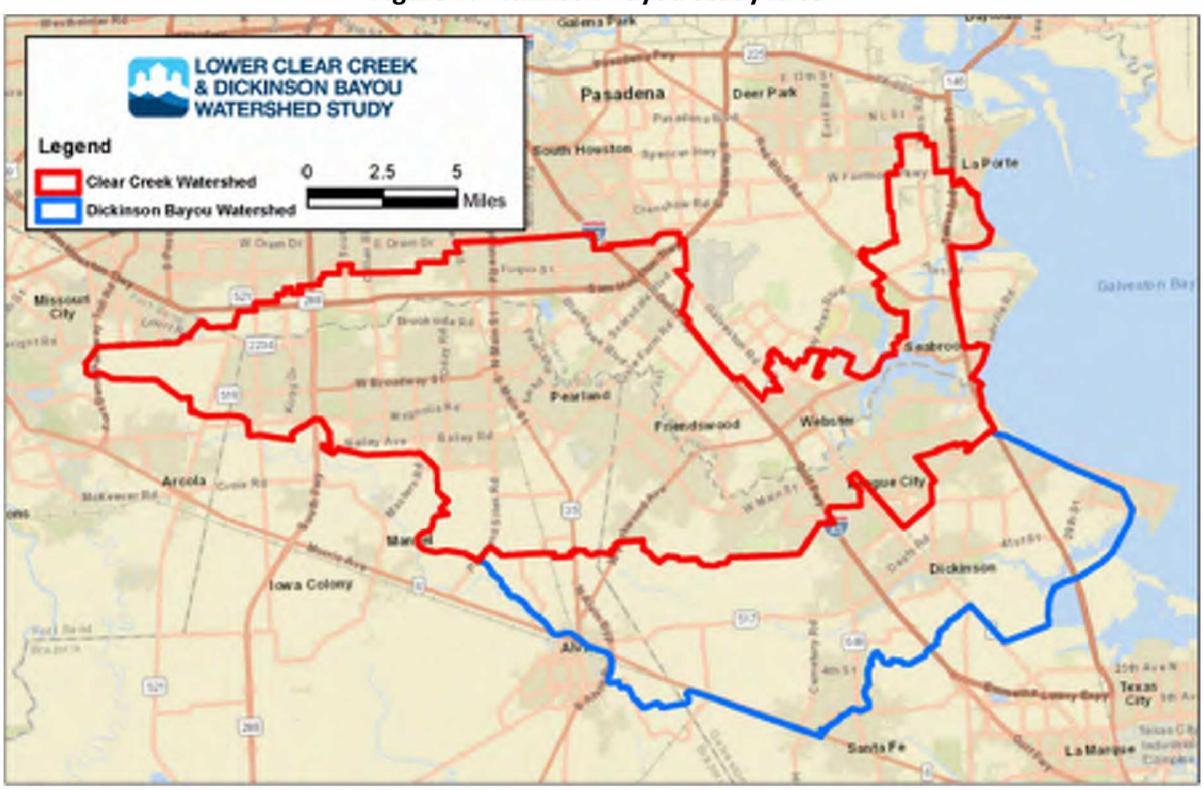
2 BACKGROUND

In August 2017, Hurricane Harvey struck the Texas coast, bringing a historic amount of rainfall to the Houston region. The storm produced never-before-seen precipitation depths in Galveston, Harris, and Brazoria Counties, as well as surrounding counties. As was the case with most of the watersheds in the region, Clear Creek and Dickinson Bayou experienced widespread flooding, which resulted in significant flood damages in the region.

The goal of this study was to develop a comprehensive flood mitigation plan for the Lower Clear Creek and Dickinson Bayou Watersheds with a focus on the riverine impacts along the main channel of each waterway. The flood mitigation plan is focused on mitigating the risk of extreme events similar to Hurricane Harvey, Tropical Storm Allison, and other large tropical storms, as well as flood damages from smaller more frequent storms. The targeted reduction in flood depths was set as multiple feet of reduction at Interstate 45 (I-45) during a 100-year storm.

This report is focused on the Dickinson Bayou Watershed shown in blue in **Figure 1** below. The detailed planning area extends from the American Canal downstream of FM 528 down to the outlet on the upstream side of State Highway 146.

Figure 1: Dickinson Bayou Study Area



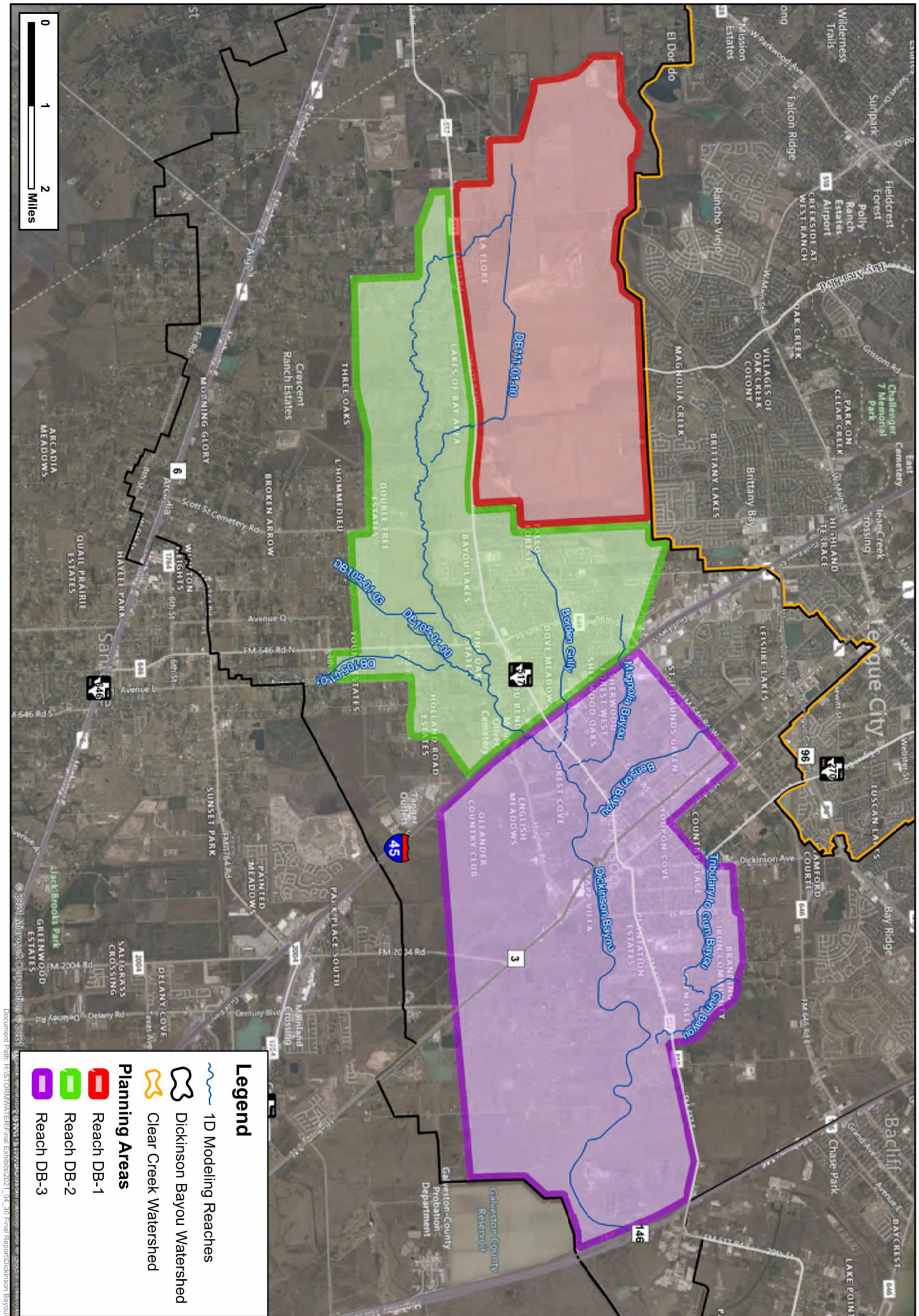
The flood mitigation projects that FNI developed as part of this study reflect a concept-level analysis. Although this level of detail is adequate to evaluate the general efficacy of the projects in providing flood risk mitigation, the preliminary siting and sizing that was performed will need to be refined in a future phase as part of a feasibility study.

In order to distinguish project improvements along the Bayou and to acknowledge the different characteristics of the Bayou between FM 528 and SH 146, the project area was divided into three Planning Areas as shown in **Figure 2** provided on the following page.

1. Reach 1 (DB-1) from the American Canal downstream of FM 528 to FM 517 passes through mostly undeveloped land in the western part of League City. Nearly all existing development is built slab on grade, even in close proximity to the main channel and an existing channel bypass in this reach, but there are very few structures. This area is slated for large residential developments which are already being constructed.

2. Reach 2 (DB-2) from FM 517 to I-45 is a more populated section of the watershed. Beginning at Cemetery Road, low density residential properties begin to line the Bayou on both banks. The Bayou is easily navigable up to Cemetery Road for recreational watercraft. Approaching I-45, higher density suburban residential developments abut the bayou. Nearly all development is constructed slab on grade in this reach.

3. Reach 3 (DB-3) from I-45 to SH 146 is the most densely populated section of the watershed, particularly the section between I-45 and SH 3 referred to as the Dickinson “Bowl” due to its low-lying elevation. Within the “Bowl”, there are many structures at low elevation at risk of riverine and storm surge flooding. Most of the structures located in the “Bowl” are slab on grade, while further east towards SH 146 structures begin to be mostly elevated. Water levels are controlled by Galveston Bay throughout this reach.



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Dickinson Bayou

Planning Areas

FN JOB NO	LEA19668
FILE	Fig3_DB_PlanningAreas
DATE	4/13/2021
SCALE	1:67,645
DRAFTED	90206

FIGURE 2

2.1 PROJECT PHASING

To maximize the effectiveness of the study, the effort was divided into Phases. This Alternatives Evaluation and Recommendation report represents the culmination of Phase 3: Project(s) Identification. The previous phases completed were:

- Phase 1: Discovery & Baselining
- Phase 2: Watershed Study

The deliverables for the prior two phases are included as **Appendix B**, **Appendix C**, and **Appendix D** to this report for reference. This report includes the alternatives analysis and recommendations that conclude Phases 1 through 3 of the project. Future phases may be authorized and developed by the City of League City and other stakeholders based on the results of this study.

2.2 PLANNING PARTNERS

League City led the engagement of numerous stakeholders along Dickinson Bayou to fund Phases 1 through 3 of this study. League City also entered into an agreement to receive Planning Assistance to States (PAS) funding from the United States Army Corps of Engineers (USACE) under the authority provided by Section 22 of the Water Resources Development Act of 1974 (PL 93-251), as amended. USACE Galveston District provided in-kind services and was engaged in all aspects of the project including technical reviews and a downstream boundary condition analysis accounting for storm surge and future sea level rise.

Key planning partners and contributors included:

- The United States Army Corps of Engineers (USACE)
- Harris County Flood Control District (HCFCD) including MAAPnext consultant Pape-Dawson Engineers, Inc. (Pape-Dawson) for the work on Lower Clear Creek.
- Galveston County including consultant RPS
- City of Friendswood

Additional planning partners and study contributors included:

- Galveston County Consolidated Drainage District
- LJA Engineering, Inc. (LJA) through their work on the League City Municipal Drainage Plan

2.3 HYDROLOGY AND HYDRAULICS

During Phase 2 of this project, FNI performed a hydrologic and hydraulic study of the Dickinson Bayou Watershed (refer to **Appendix B** and **Appendix C** for more details). The model development was conducted by RPS per the partnership agreement with Galveston County as part of the Mainland Galveston County Master Drainage Plan Update.

2.3.1 Data Sources

Some of the main data sources used in this study were:

- 2018 LiDAR: The study's topographic information was developed using Light Detection and Ranging (LiDAR) data obtained from the Texas Natural Resources Information System (TNRIS) and the Houston-Galveston Area Council of Governments (HGAC). This LiDAR data was collected January through March 2018, and uses the vertical datum GEOID12B.
- Atlas 14 Rainfall: Precipitation data was obtained from NOAA's Atlas 14, Volume 11 Version 2.0 (Atlas 14). Atlas 14 is the most up to date precipitation data.
- Effective Models: A data request was submitted to the Federal Emergency Management Agency (FEMA) in February 2020 to gather all available effective models within the study area.
- Previous Studies: Models developed by JKC Engineering in a previous study were obtained and reviewed.

2.3.2 Hydrology

FNI generated updated hydrologic parameters based on the Basin Development Factor (BDF) methodology. The hydrologic model was developed using the USACE Hydrologic Engineering Center's Hydrology Modeling System (HEC-HMS) version 4.3. FNI executed 24-hour duration storm events in the model including the Annual Exceedance Probabilities (AEP) of 50% (2-year), 20% (5-year), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), and 0.2% (500-year), as well as historical storm events such as Hurricane Harvey. FNI analyzed both existing conditions based on current land use, and future conditions based on predicted future development occurring without detention. The study's results for the 100-year storm event are summarized in **Table 2** provided on the next page.

Table 2: 100-Year Peak Discharges (cfs) at Key Locations

Location	Contributing Drainage Area (Sq M)	FEMA Effective	RPS/FNI		
			Existing	Future	% Increase
Watershed Outfall (SH 146)	98.9	22,000	22,495	23,855	6.0%
Gum Bayou Confluence	86.4	17,100	20,965	22,409	6.9%
Benson Bayou Confluence	69.1	12,000	15,948	17,202	7.9%
I-45	52.5	5,920	11,936	12,629	5.8%
FM 517	24.6	N/A	3,893	4,179	7.3%

These 100-year results show increases between the effective discharges and the discharges computed as part of this study, especially in the upstream sections of the reach. These increases can be attributed to multiple factors, including:

- Increases in rainfall depths associated with the latest and improved Atlas 14 precipitation data. For the 24-hour duration 100-year storm event, depths increased from 13.5 inches to 18 inches.
- Differences in the hydrologic modeling methodology including hydrologic routing.
- Increases in resolution of the hydrologic and hydraulic models that were developed.

2.3.3 Hydraulics

The hydraulic model was developed using the U.S. Army Corps of Engineers Hydrologic (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 5.0.7. A detailed 1D/2D unsteady-state model was developed for the main stem of Dickinson Bayou and its major tributaries. To properly model tidal and storm surge impacts, stages were applied on the downstream end of Dickinson Bayou based on guidance provided by USACE Galveston District. To capture future conditions, the existing conditions model was adjusted to include:

- Fully-developed discharges,
- Expected future sea level rise (+1.52 feet) over the 50-year project horizon, based on the Medium Sea Level Change Scenario analyzed by the USACE,
- Major projects under construction along the Bayou since 2018, which included the I-45 TxDOT bridge improvements on Dickinson Bayou, Borden Gully, and Magnolia Bayou.

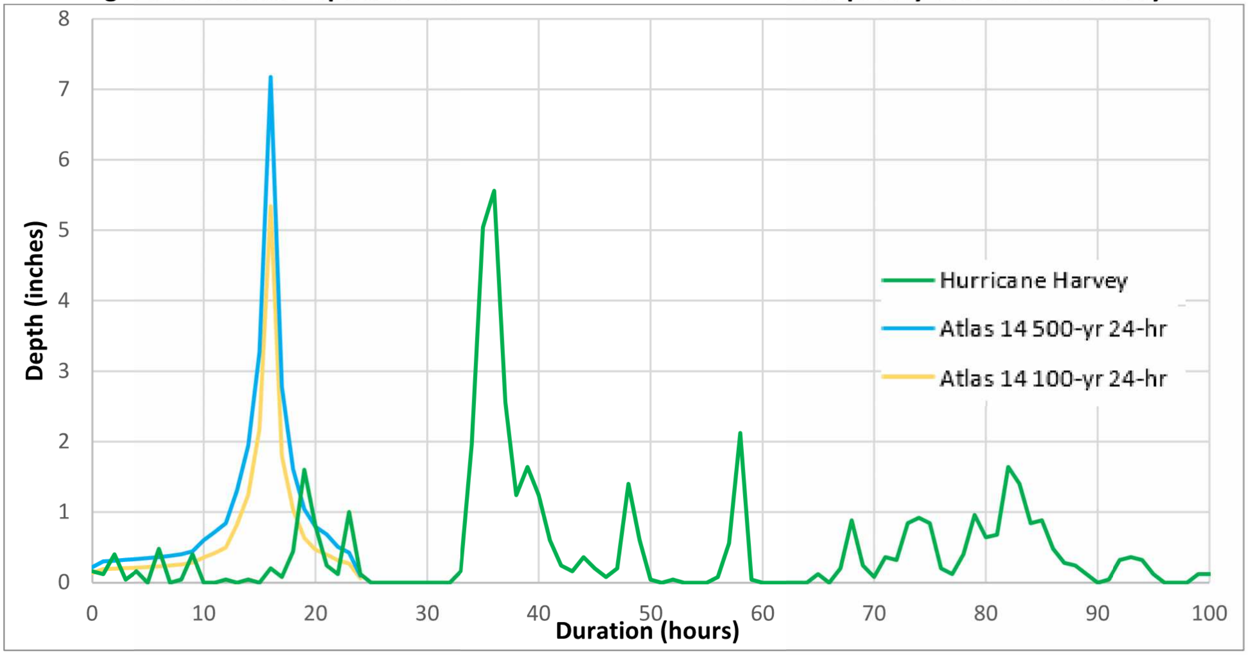
2.3.4 Hurricane Harvey

Because this flood mitigation plan is focused on mitigating the risk of extreme events, it was important to evaluate Hurricane Harvey as it is the most recent catastrophic flood event whose impacts are still felt by stakeholders and the public today. This evaluation included a comparison of rainfall depths and intensity to the new NOAA Atlas 14 events. Rainfall induced flooding is the result of both rainfall intensity and duration. High intensity storms cause flooding when the precipitation rate exceeds the infiltration capacity of soils and the conveyance capacity of the natural channels and stormwater systems. However, total runoff volume is also an important contributor to flooding, particularly in flat, low-lying areas such as Harris and Galveston Counties: Long duration storms of lesser intensity can also result in flooding by filling detention ponds designed to reduce the stress on the conveyance system, as once the design volume is exceeded the detention no longer mitigates the impacts to the conveyance system.

Hurricane Harvey was both a high intensity storm and a long duration storm, and therefore resulted in significant flooding in Dickinson Bayou and other watersheds in the Houston metropolitan area. The data presented in green in **Figure 3** provided on the next page corresponds to rainfall depths measured at the I-45 gage on Clear Creek starting August 25 at 12:00 pm. Rainfall from Harvey lasted over 96 hours (4 days) and exceeded a peak intensity of 5 inches in an hour at approximately hour 37 (August 27 01:00 am). **Figure 3** also shows the Atlas 14 500-year and 100-year 24-hour storm intensities in blue and yellow, respectively, for comparison.

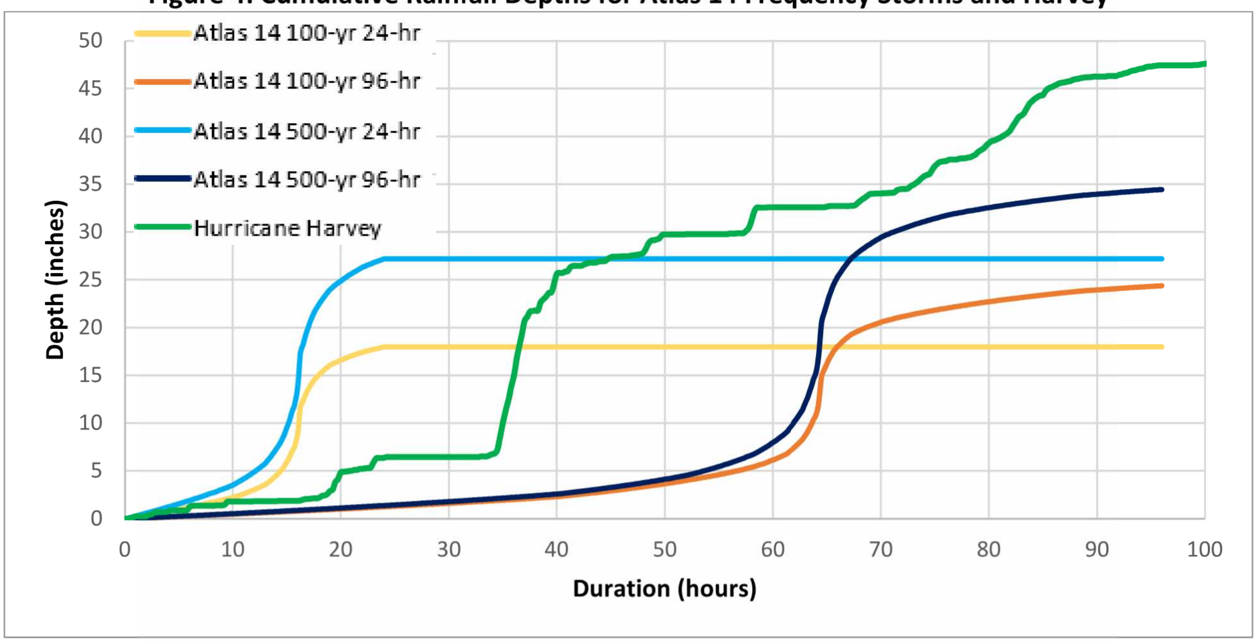
Harvey's maximum intensity was greater than the Atlas 14 100-year 24-hour event but less than the 500-year 24-hour event; however Harvey held that intensity for a long duration and was accompanied by other rainfall exceeding a rate of 1 inch an hour nearly 7 times over the 96 hour period. Prior to the peak intensity beginning at approximately hour 32, over 6 inches of rain had already fallen, saturating the soil and reducing available detention storage. When the maximum intensity occurred, the local storm drainage systems and detention ponds were already stressed, resulting in even greater stress to the conveyance system.

Figure 3: Rainfall Depths at 1-Hour Increments for Atlas 14 Frequency Storms and Harvey



As can be seen in **Figure 4**, rainfall depths from Hurricane Harvey cummulated over the entire storm duration exceeded the Atlas 14 500-year 96-hour duration depths.

Figure 4: Cumulative Rainfall Depths for Atlas 14 Frequency Storms and Harvey



To evaluate project benefits during high-intensity rainfall events, all the combination alternatives were analyzed using the Atlas 14 24-hour storm events to confirm that they were able to convey the maximum storm intensity. To confirm efficacy during long-duration storm events such as tropical storms and hurricanes that produce high volumes of runoff, Hurricane Harvey rainfall was also modeled through the combination alternatives.

2.4 FLOOD RISK

As part of Phase 2 of this study, FNI performed an inundation damages assessment to identify vulnerabilities in the Dickinson Bayou Watershed, including instances of flooding at structures and the resulting damage estimates (refer to **Appendix D** for more details). These two quantitative metrics are detailed in **Section 2.5.1**. A structural inventory was developed in GIS to identify the structures that are located within the floodplains developed as part of the hydraulic modeling effort. Property value information and property type classification were acquired from the Harris County Appraisal District (HCAD) and Galveston Central Appraisal District (GCAD), and associated with the building footprints. Structures were assigned an assumed finished floor elevation of 0.5 feet above the lowest ground elevation at the structure.

FNI evaluated both existing and future conditions flood risks based on the 2-, 5-, 10-, 50-, 100-, and 500-year storm events, as well as a statistical prediction of what those risks could amount to over the 50-year project design period. A discount rate of 7% was used to calculate the net present value of the damages. This report focuses on future conditions instances of flooding and structural damages, as those factors served as the relevant baseline against which the flood mitigation projects proposed as part of Phase 3 were evaluated. FNI also evaluated the impacts that Hurricane Harvey produced in the riverine model (see **Section 2.5.3** for the limitations of the riverine model). These results are shown in **Table 3** and **Table 4**.

Table 3: Structural Damages ($M) for Future Conditions and Hurricane Harvey

Planning Area	Frequency Storms – Future Conditions							Harvey
	500-Yr	100-Yr	50-Yr	10-Yr	5-Yr	2-Yr	50-Yr Period	
DB-1	0.9	0.6	0.5	0.2	0.1	0.0	1.3	0.4
DB-2	398.5	164.2	100.7	28.5	15.5	8.0	227.2	227.2
DB-3	419.1	240.6	182.4	79.0	38.7	20.3	483.5	325.7
Totals	**818.5**	**405.5**	**283.6**	**107.7**	**54.4**	**28.4**	**712.0**	**553.3**

Table 4: Instances of Flooding for Future Conditions and Hurricane Harvey

Planning Area	Frequency Storms – Future Conditions							Harvey
	500-Yr	100-Yr	50-Yr	10-Yr	5-Yr	2-Yr	50-Yr Period	
DB-1	62	54	45	15	3	2	62	34
DB-2	6,421	3,153	1,995	566	304	136	6,421	4,111
DB-3	8,147	5,789	4,784	2,044	1,018	444	8,147	7,030
Totals	**14,630**	**8,996**	**6,824**	**2,625**	**1,325**	**582**	**14,630**	**11,175**

2.5 EVALUATION FACTORS

2.5.1 Quantitative Metrics

Four quantitative metrics were used in this study to identify the concepts that provide the greatest flood risk mitigation:

1. <u>Instances of Flooding:</u> Number of structures flooded in a given storm event (e.g. 100-year), as well as the number of times a given structure is predicted to flood over a 50-year period. This was analyzed for each of the 2-, 5-, 10-, 50-, 100-, and 500-year storm events, as well as a statistical prediction of what the instances could amount to over the 50-year project design period. An instance of flooding reports whether a given structure is inundated or not. See **Appendix D** for more information.

2. <u>Structural Damages:</u> Monetary value resulting from the damages caused by floodwaters at a given structure. This was analyzed for each of the 2-, 5-, 10-, 50-, 100-, and 500-year storm events, as well as a statistical prediction of what the damages could amount to over the 50-year project design period. Structural damages are a function of floodwater depths at a given structure, and are computed based on depth-damage relationships developed by USACE. See **Appendix D** for more information.

3. <u>Transportation System Impacts:</u> Frequency and risk of pedestrian, roadway, and railroad crossings being overtopped by floodwaters. These impacts are representative of public safety hazards, mobility constraints, and impacts to emergency responders. The level of service and hazard was calculated for all main channel and tributary crossings located in the study area. See **Appendix D** for more information.

4. Capital Cost: Cost to construct the improvement in 2021 dollars. Operations and maintenance (O&M) costs were not calculated at this time, but O&M requirements were taken into account as one of the non-cost factors. Capital cost was developed on a rough order of magnitude (ROM) basis for comparative purposes between projects. FNI performed cost estimation in a manner that is consistent with an AACE Level 5 estimate based on a project maturity level of 0 to 2% using parametric methods and unit price quantity take-offs. An estimate of this class carries an accuracy that ranges between -20% to -30% on the low end to +30% to +50% on the high end.

2.5.2 Qualitative Metrics

Quantitative metrics alone do not fully describe the benefits or challenges of the projects analyzed. In order to better capture the full impact of the projects, non-cost factors were also developed in coordination with the key stakeholder group. The group determined that the following non-cost factors, in conjunction with the quantitative factors, would best capture the project impacts:

1. Land Acquisition: Ease of property acquisition. Property already owned by public entities will receive highest scoring. Projects requiring acquisition of numerous parcels, particularly residential and commercial acquisition, will receive the lowest scoring. Subterranean easements required for tunnel projects are seen as less difficult to acquire even through residential and commercial areas.

2. Community Impact/Aesthetics: How easily will the project gain public support by minimizing disruption during construction and providing a long-term amenity with aesthetic and recreational benefits during operation? What is the scale of the disturbance during construction, is the disturbance isolated to a single area or does it cover a large area? What are its transportation impacts to bridges and roads?

3. O&M/Resiliency: How simple is the system to operate, how much energy and manpower is required to operate it, and how resilient is it to natural disaster (loss of power)? Projects that include only routine operation and maintenance already performed by the sponsors will score the highest. Projects that operate passively without the need to operate control structures and pumps will also score the highest. Projects that have ongoing operational cost (pump stations) will score the lowest.

4. Other Agency Coordination: How much coordination is required outside of the project sponsor group with entities including but not limited to TXDOT, railroads and environmental groups?

5. Speed of Implementation: How quickly can the project be planned, designed and constructed including all necessary land acquisition and permitting? Projects that are the fastest at delivering benefits will score the highest.

A pair-wise analysis was conducted to develop a weighting of these non-cost factors in a May 2020 meeting with the key stakeholders. The results and weighting of this effort is shown below in **Table 5**. A score of 1 means the row category is less important than the column category, 2 means it is equally important, and 3 means it is more important.

Table 5: Non-Cost Factors Pair-Wise Matrix

Factor	Land Acquisition	Community Impact/Aesthetics	O&M/Resiliency	Other Agency Coordination	Speed of Implementation	**Total**	**Weight**
Land Acquisition	-	3	2	3	1	**9**	**22.5%**
Community Impact/Aesthetics	1	-	2	3	2	**8**	**20.0%**
O&M/Resiliency	2	2	-	3	3	**10**	**25.0%**
Other Agency Coordination	1	1	1	-	1	**4**	**10.0%**
Speed of Implementation	3	2	1	3	-	**9**	**22.5%**

2.5.3 Study Limitations

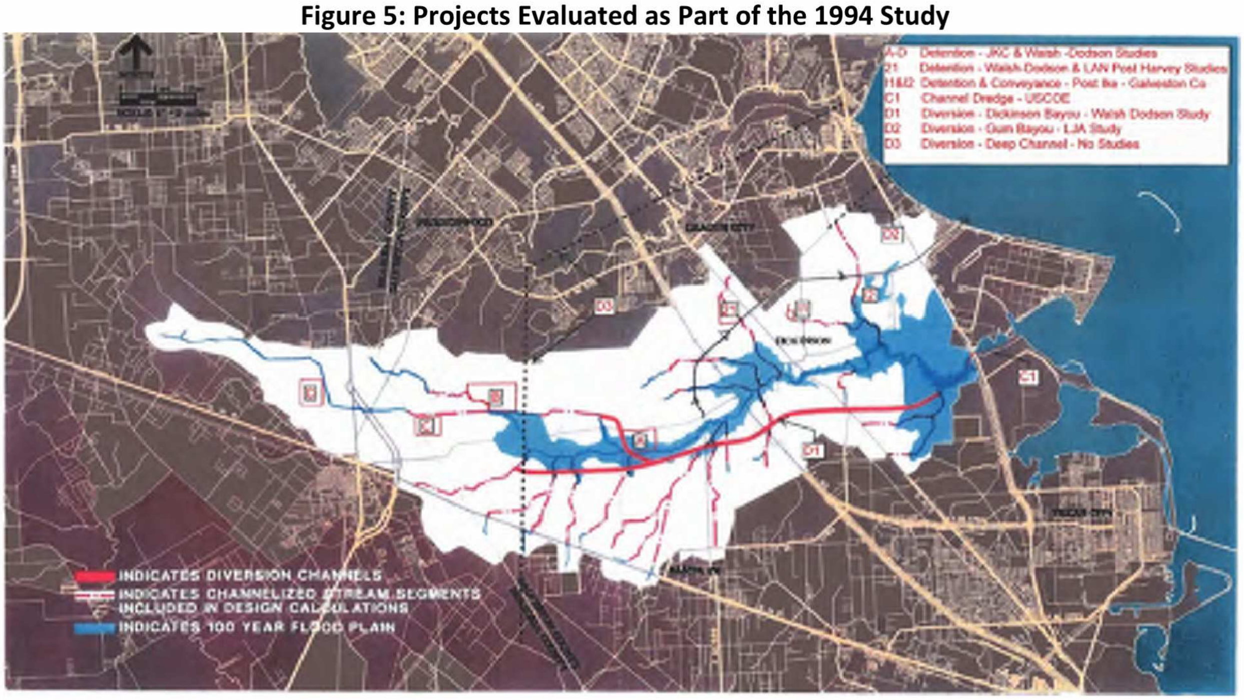
This study is focused on mitigating riverine flooding along Dickinson Bayou. The model incorporates the main stem of Dickinson Bayou and all its major tributaries, and was developed to accurately capture the flooding risks associated with the swelling of the streams. The model is not meant to accurately depict the propagation of floodwaters within neighborhoods and on roadways located outside of the riverine floodplains. It was beyond the scope of this study to fully capture the instances of flooding and structural damages that are caused by ponding water that cannot be conveyed effectively to the streams through the local storm sewer/culvert network. This is evidenced by flood damages and rescues that occurred during Hurricane Harvey in League City and Dickinson outside of the riverine floodplains. To fully capture the instances of flooding and structural damages occurring away from the main stem of Dickinson Bayou and its major tributaries, the output from this study's hydraulic models should be integrated into local storm sewer network models. The results presented herein do not account for local drainage system benefits and therefore likely underpredict the actual reductions in instances of flooding and structural damages provided by the solutions.

The flood mitigation projects that FNI developed as part of this study reflect a concept-level analysis. Although this level of detail is adequate to evaluate the general efficacy of the projects in providing flood risk mitigation, the preliminary siting and sizing that was performed will need to be refined in a future phase as part of a feasibility study.

2.6 PREVIOUS STUDIES AND PROJECT CONSTRAINTS

A watershed wide flood study of Dickinson Bayou had not been completed since the mid 1990s. Walsh Engineering Inc. and Dodson & Associates completed a study in 1994 that recommended construction of a major bypass channel and other flood improvements including detention, channel dredging, and tributary improvements as shown in **Figure 5**.

Figure 5: Projects Evaluated as Part of the 1994 Study



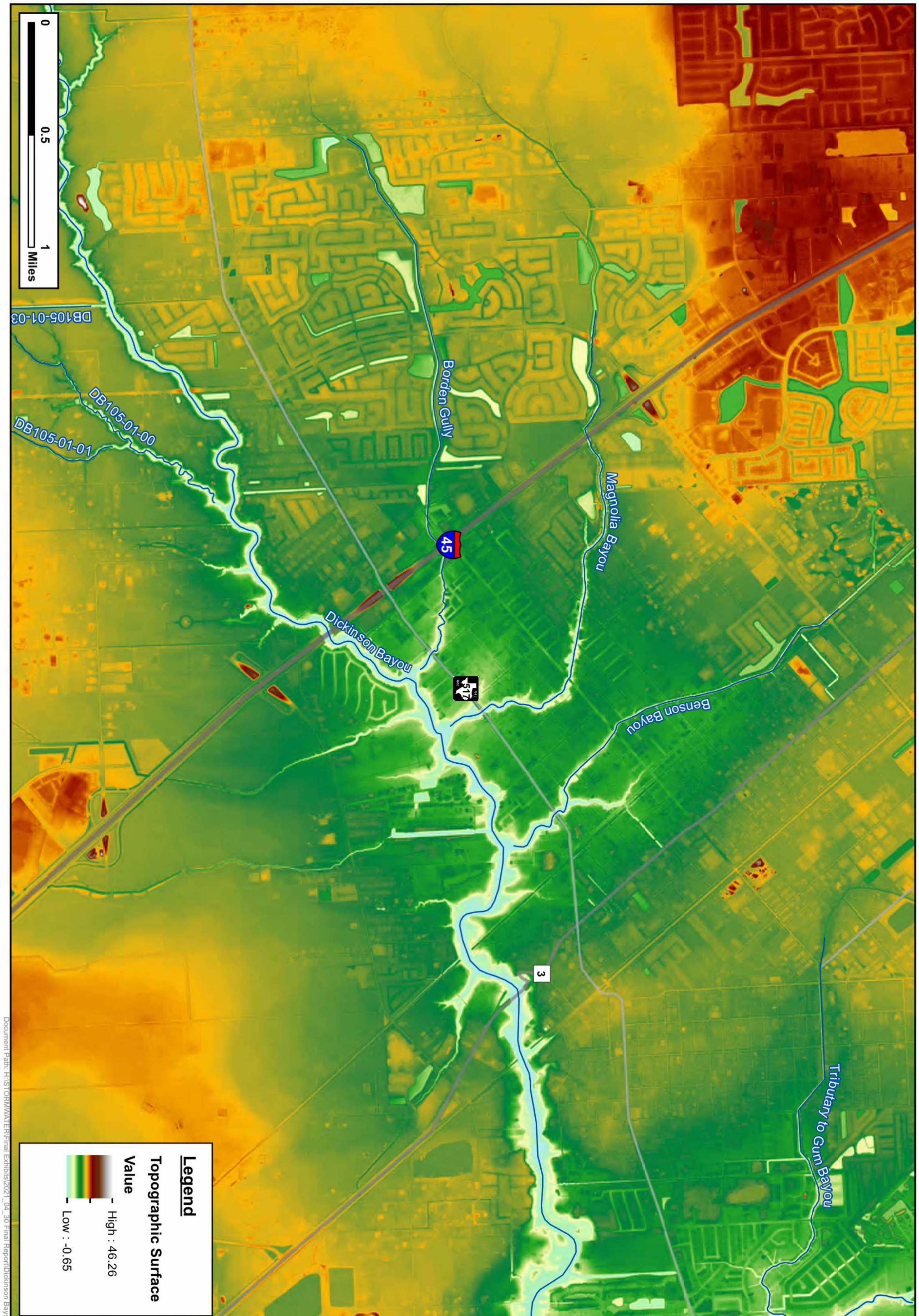
Previous project recommendations for major channel modifications such as widening did not receive local stakeholder support at that time. FNI developed the following conceptual design constraints which guided concept development towards solutions with higher probability of implementation. Those constraints included:

1. No channel widening: Downstream of Cemetery Road, a project that would significantly impact aesthetics and the community in that section of the Bayou is not seen as a favorable alternative. Upstream of Cemetery Road, the low number of structures at risk does not justify a major conveyance improvement.

2. No significant benefits achievable through vegetative clearing and de-snagging: Dickinson Bayou, unlike other natural streams in the region such as Clear Creek, is not densely vegetated in the areas most at risk of riverine flooding. The more densely vegetated sections of the Bayou are located upstream of FM 646, and a clearing project in this low population density area would not produce significant benefits while potentially creating adverse impacts downstream.

3. No new open cut crossings of Interstate 45: I-45 is a major transportation corridor, thus an open cut crossing would result in major traffic disruptions that would impact not only the local stakeholders but also regional and national stakeholders.

4. Infeasible to eliminate flood risk in Dickinson "Bowl": As shown in **Figure 6** provided on the next page, a topographic depression exists between I-45 and SH 3. This topographic "Bowl" coincides with the confluence of Borden Gully, Magnolia Bayou, and Benson Bayou, three major flow contributors in the watershed. This area has a significant number of low-lying structures at risk of flooding during frequent storm events like the 2-year and 5-year events. While significant reductions in the flood risk can be achieved in this area, removal of all structures from the floodplain is not feasible.



FREESE AND NICHOLS 2711 North Haskell Ave. Suite 3300 Dallas, Texas 75204 P: 214-217-2200	N	**Dickinson Topographic "Bowl"** Dickinson Bayou Watershed	FN JOB NO LEA19688 FILE Fig6.TopographicBowl DATE 5/10/2021 SCALE 1:25,000 DRAFTED 90206	FIGURE 6

2.7 COASTAL TEXAS STUDY – DICKINSON BAY GATE SYSTEM

The Coastal Texas Protection and Restoration Feasibility Study Draft Report published in October 2020 presents a *Multiple Lines of Defense* strategy used to design cost-effective, environmentally friendly solutions that will reduce risks of storms impacting the coastal communities and restore important wildlife habitat at the same time. For Dickinson Bayou, the draft plan proposes the following:

- There is only one outlet from Dickinson Bayou into Galveston Bay. At the entrance into Dickinson Bay, the plan calls for a 100-foot-wide floating sector gate with a sill depth of -9 feet (NAVD88) to match the authorized depth of the existing channel. To allow for additional tidal flow through the system, the gate width would be 40 feet wider than the authorized channel (which is 60 feet).
- A pumping station would be constructed, that, when the gates are closed, would pump water coming from the watershed (due to rainfall) out to the bay. The pumping station would have a designed capacity of 19,500 cubic feet per second.
- To the north and south of the sector gate-pumping station complex, a tie into the land with an 18-foot-high floodwall would be required. The entire structure would start on the west side of State Highway 146, near Avenue T, and end on the south side of the bayou, near Waterman's Harbor west of State Highway 146.

The primary objective of the FNI study presented in this report is to analyze and mitigate the risks associated with riverine flooding. Although this objective differs from the Coastal Texas Study's objective, the two studies' objectives interconnect in the downstream reach of Dickinson Bayou near its outlet to Galveston Bay. Additionally, due to the compound flooding risk in Reach 3 east of I-45, implementation of the Dickinson Bayou Gate may allow additional flood mitigation measures to be implemented once the surge barrier is constructed to address riverine impacts. As these two studies are refined in the years to come, solutions should be jointly designed to mitigate risks associated with both riverine and coastal flooding along this downstream reach of Dickinson Bayou.

3 COMBINATION ALTERNATIVES

FNI investigated and modeled a total of 10 flood mitigation projects along Dickinson Bayou. These projects consist of detention basins and channel diversions, and are presented individually in detail in **Appendix A**. Based on the analysis of each discrete project's impacts, FNI developed two combination alternatives that incorporate multiple projects to optimize benefits while preventing adverse impacts. These alternatives were analyzed based on the 2-, 5-, 10-, 50-, 100-, and 500-year storm events, and their benefits were calculated over the 50-year design period. To confirm efficacy during long-duration storm events, Hurricane Harvey rainfall was also modeled through the combination alternatives.

3.1 ALTERNATIVE 1: DETENTION

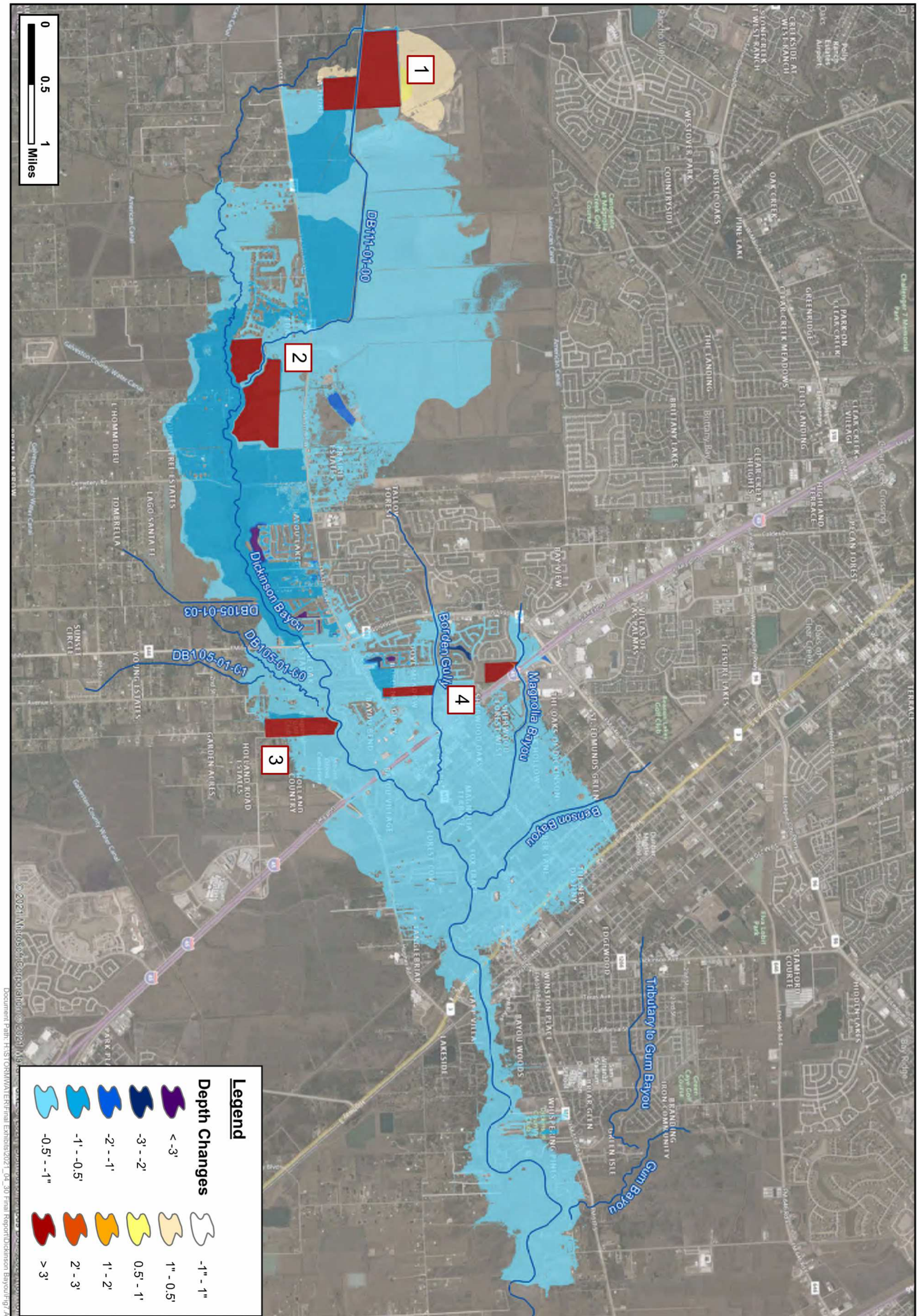
Alternative 1 focuses solely on mitigation by detention and includes the following projects, as shown in **Figure 7**:

1. Mc Farland Rd. Detention Basin
2. W Cemetery Rd. Detention Basin
3. Hilton Ln. Detention Basin
4. Magnolia Bayou and Borden Gully Detention Basins

The estimated capital cost for Alternative 1 is $220 million. The 100-year Inundation Depth Changes Map is shown in **Figure 7**. **Figure 8** shows 100-year future conditions and Alternative 1 water surface profiles plotted with the estimated finished floor elevations of structures along Dickinson Bayou.

Reach DB-1 sees maximum reductions in 100-year water surface elevations of about 0.5 feet. Alternative 1 provides the greatest benefits in Reach DB-2 upstream of FM 646, with water surface elevation reductions of over 0.6 feet in the 100-year storm event. Reach DB-3 downstream of I-45 sees limited benefits from this alternative, with reductions in 100-year water surface elevations of up to about 0.25 feet.

Since Alternative 1 consists of detention basins only, all of its individual projects can be completed independently without adverse impacts. The minor increases in depths in the immediate vicinity of the Mc Farland Rd. basin are caused by ponding overland drainage, and can be mitigated as the project is refined in future phases. The non-cost factors associated with this combination alternative are presented in **Table 6**.



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Alternative 1

Location Map - 100-yr Inundation Depth Changes

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FILE	Fig7_Alternative1_LocationMap
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FIGURE
7

Figure 8: Alternative 1 100-Year Water Surface Profile

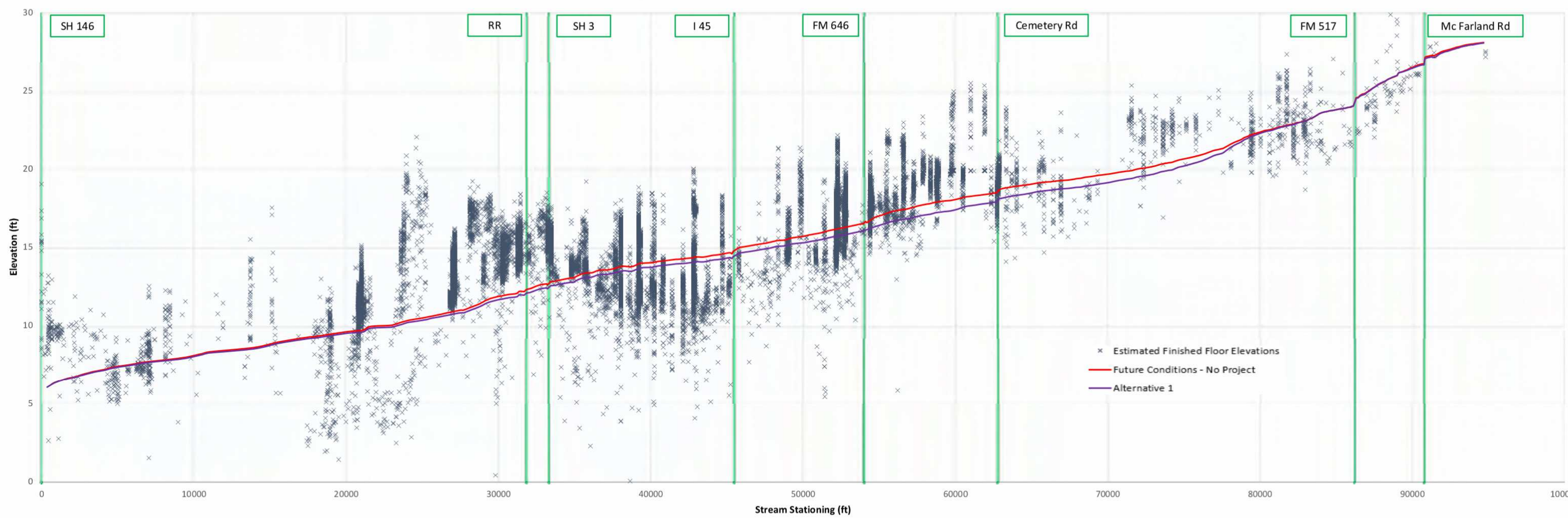


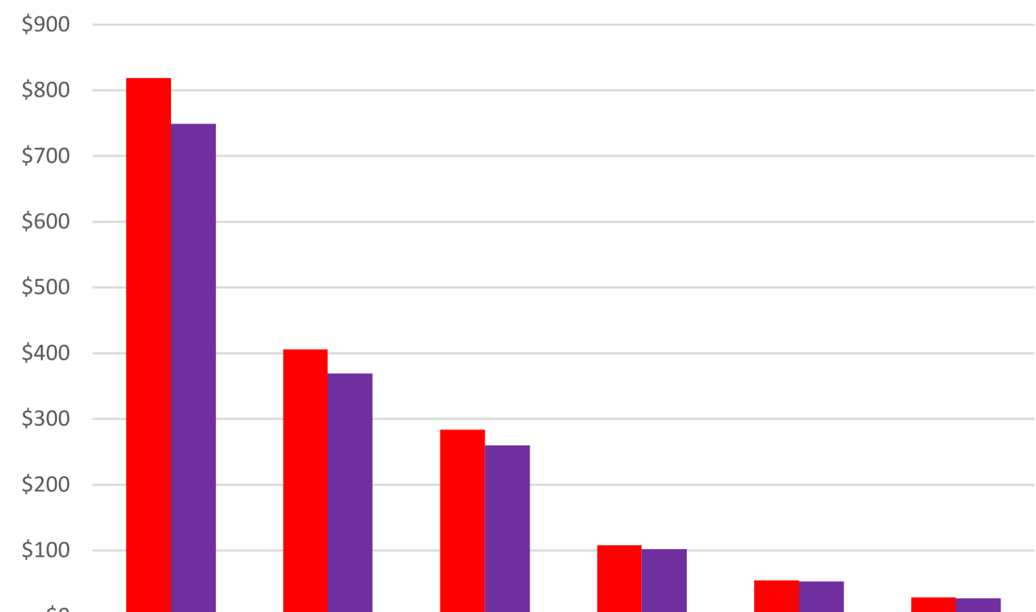
Table 6: Alternative 1 Non-Cost Factors

Factor	Score
Land Acquisition	2
Community Impact/Aesthetics	4
O&M/Resiliency	4
Other Agency Coordination	5
Speed of Implementation	4
Non-Cost Factor Weighted Score	**3.7**

The flood damages and instances for future conditions (no project) and Alternative 1 are presented in **Figure 9** and **Figure 10,** respectively. Over the 50-year design period, Alternative 1 leads to a decrease in flood damages of $40 million, and 2,490 reductions in flooding instances. This translates to 11.3 instances of flooding reduced for every $ million spent in construction costs, and a benefit-cost ratio of 0.19. Additionally, Alternative 1 leads to 40 reductions in roadway overtopping over the 50-year design period.

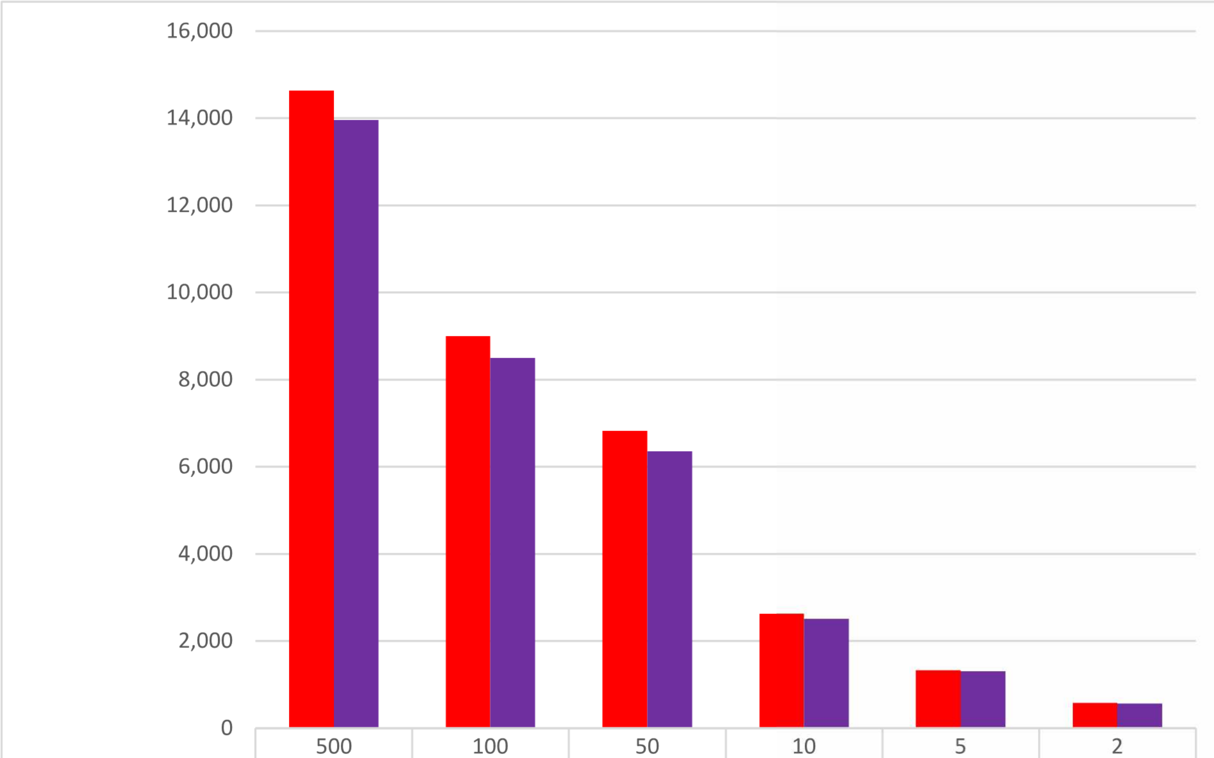
FNI also ran a Hurricane Harvey simulation to assess Alternative 1's performance during tropical storms and hurricanes that can produce large amounts of rainfall over multiple days. Alternative 1 would have reduced structural damages by $35 million, and flooding instances by 420.

Figure 9: Flood Damages ($M) by Event – Alternative 1



	500	100	50	10	5	2
Future Conditions	$818.5	$405.5	$283.6	$107.7	$54.4	$28.4
Alternative 1	$748.8	$369.3	$259.5	$102.1	$52.9	$27.1

Figure 10: Flood Instances by Event – Alternative 1



	500	100	50	10	5	2
Future Conditions	14,630	8,996	6,824	2,625	1,325	582
Alternative 1	13,960	8,499	6,355	2,506	1,305	565

<u>Key Take-Aways:</u>

1. The Dickinson Bayou Watershed upstream of Cemetery Rd. is mostly undeveloped, and therefore the quantifiable benefits associated with the inundation depth reductions provided by Alternative 1 are limited. New development should be built with slab elevations above flood risk levels.
2. A portion of the land in Reach DB-1 and DB-2 that is undeveloped today should be set aside for regional detention to allow for future development to occur without generating adverse impacts downstream.
3. Placing detention in the upstream portion of the watershed where undeveloped land is currently available has limited benefits in the Dickinson "Bowl" where most of the structures at risk of flooding are located.
4. Significant residual risk remains with the construction of Alternative 1.

3.2 ALTERNATIVE 2: DETENTION + BYPASS CHANNEL

Alternative 2 corresponds to the combination of the following projects, as shown in **Figure 11**.

1. Mc Farland Rd. Detention Basin
2. W Cemetery Rd. Detention Basin
3. Hilton Ln. Detention Basin
4. Magnolia Bayou and Borden Gully Detention Basins
5. Desel Dr. 11,000 cfs Channel Diversion

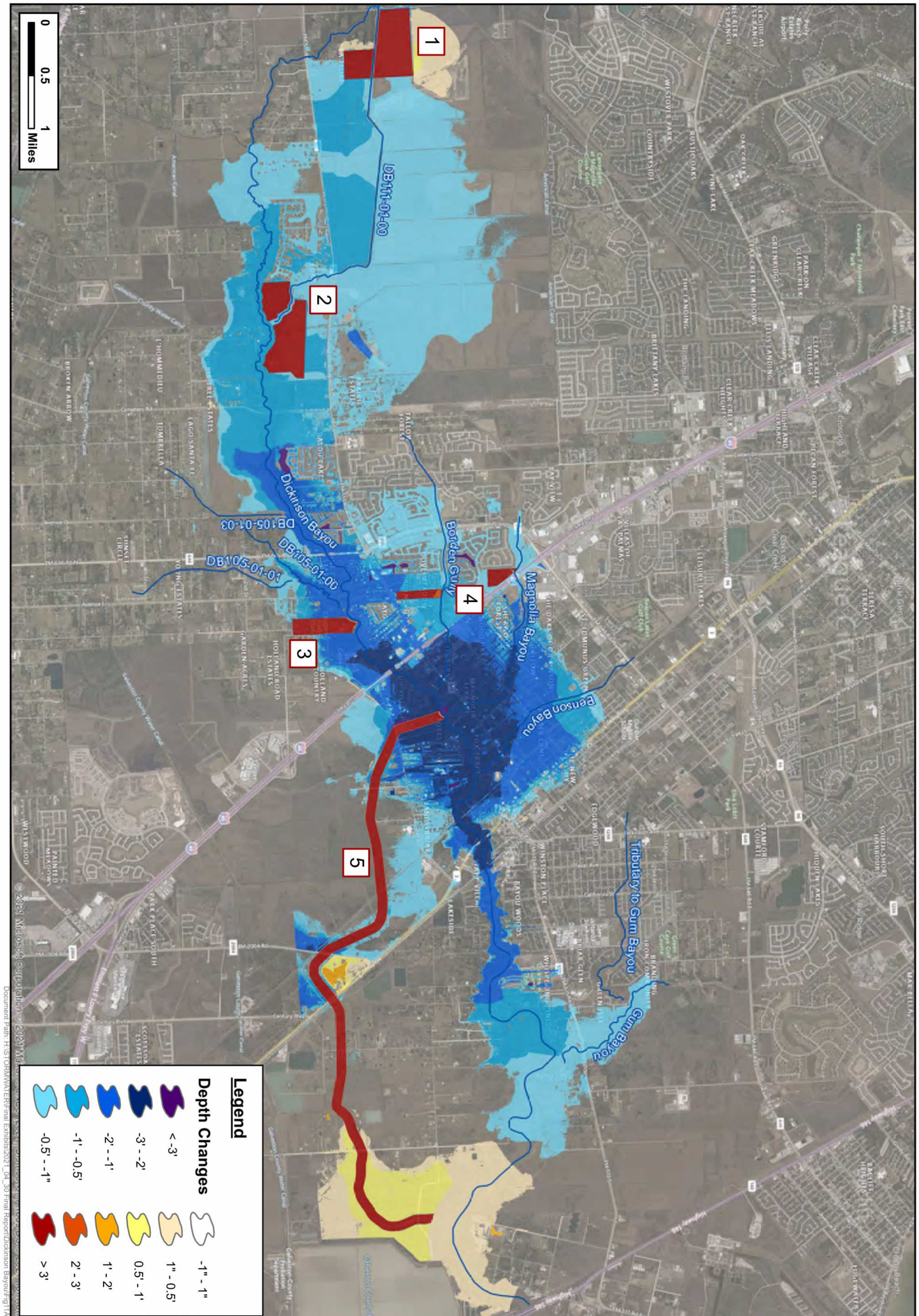
The estimated capital cost for Alternative 2 is $500 million. The 100-year Inundation Depth Changes Map is shown in **Figure 11**. **Figure 12** shows 100-year future conditions and Alternative 2 water surface profiles plotted with the estimated finished floor elevations of structures along Dickinson Bayou.

Reach DB-1 sees maximum reductions in 100-year water surface elevations of about 0.5 feet. The benefits of Alternative 2 become progressively greater moving downstream towards the bypass channel's intake. Reach DB-2 sees water surface elevation reductions of up to 2 feet in the 100-year storm event just upstream of I-45. Alternative 2 provides the greatest water surface elevation reduction in reach DB-3 where the bypass channel's intake is located, with reductions in 100-year water surface elevations of up to 3 feet.

The detention basins proposed as part of Alternative 2 can be completed independently without adverse impacts. The minor increases in depths in the immediate vicinity of the Mc Farland Rd. basin are caused by ponding overland drainage, and can be mitigated as the project is refined in future phases. The bypass channel is shown to cause a rise in water surface elevations at its downstream confluence with Dickinson Bayou. Although this increase occurs in an area of low population density, further property-specific evaluations should be conducted to determine what measures are required to mitigate the flooding impacts at these properties. The non-cost factors associated with this combination alternative are presented in **Table 7**.

Table 7: Alternative 2 Non-Cost Factors

Factor	Score
Land Acquisition	1
Community Impact/Aesthetics	2
O&M/Resiliency	5
Other Agency Coordination	3
Speed of Implementation	3
Non-Cost Factor Weighted Score	**2.9**



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Alternative 2

Location Map - 100-yr Inundation Depth Changes

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FILE	Fig11Alternative2_LocationMap
DATE	5/7/2021
SCALE	1:53,000
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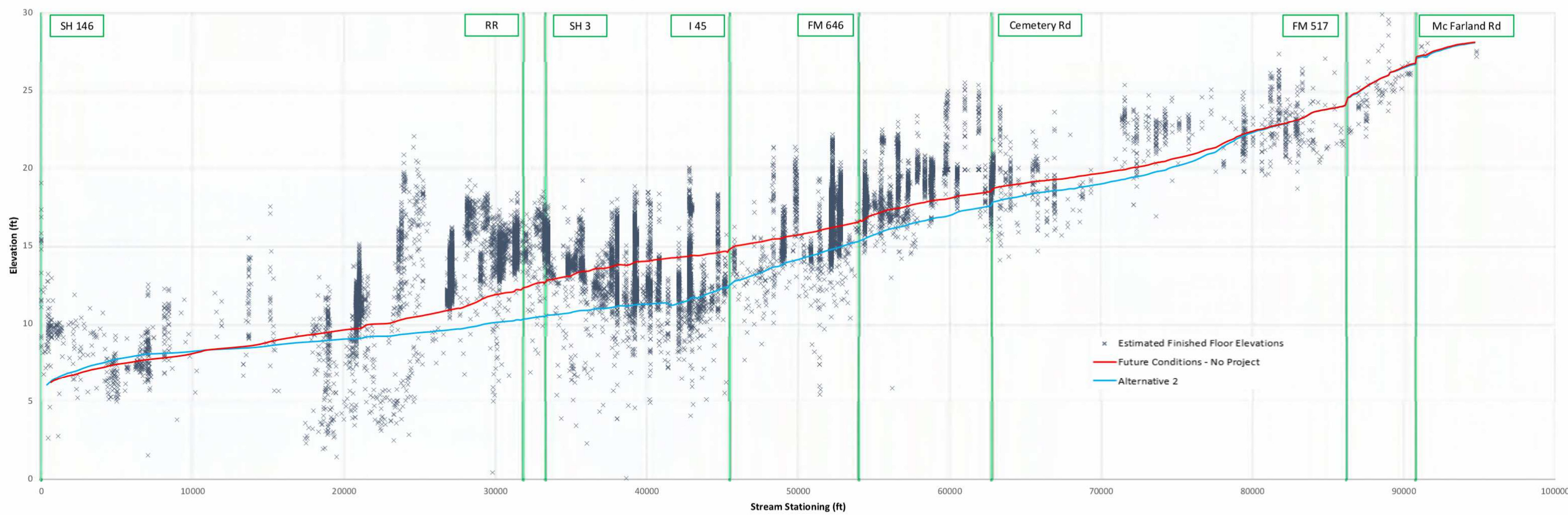
FIGURE 11

Figure 12: Alternative 2 100-Year Water Surface Profile

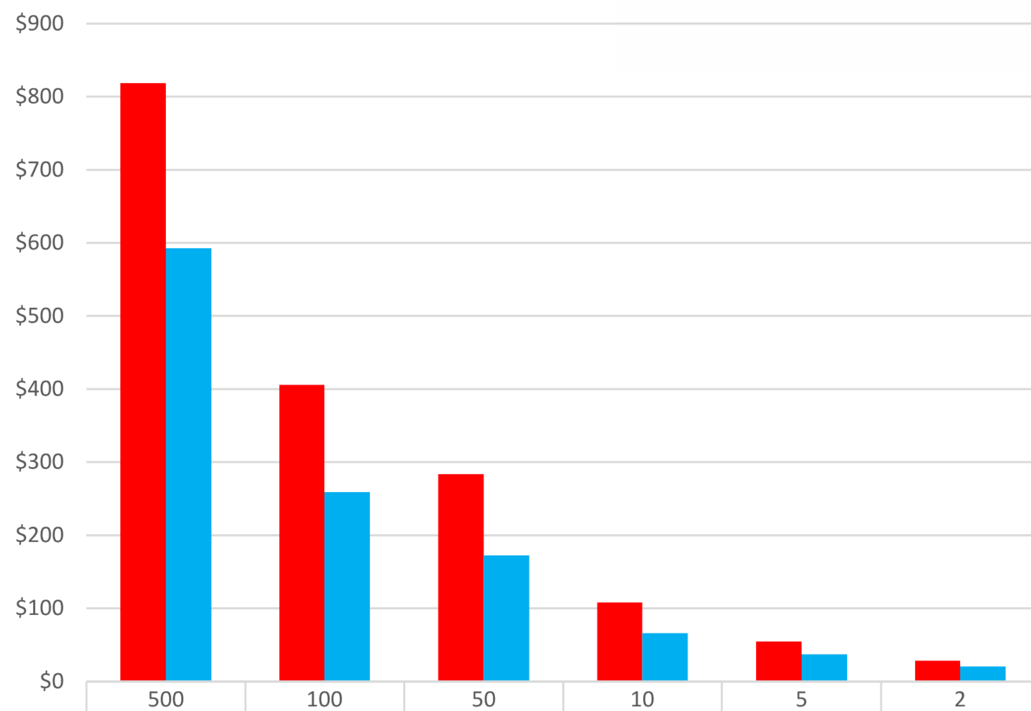


The flood damages and instances for future conditions (no project) and Alternative 2 are presented in **Figure 13** and **Figure 14**, respectively. Over the 50-year design period, Alternative 2 leads to a decrease in flood damages of $245 million, and 15,100 reductions in flooding instances. This translates to 30.2 instances of flooding reduced for every $ million spent in construction costs, and a benefit-cost ratio of 0.49. Additionally, Alternative 2 leads to 111 reductions in roadway overtopping over the 50-year design period.

Alternative 2 is shown to provide significant flood mitigation benefits in events of catastrophic magnitude such as the 500-year storm event: Alternative 2 reduces structural damages by $225 million, and flooding instances by 1,900.

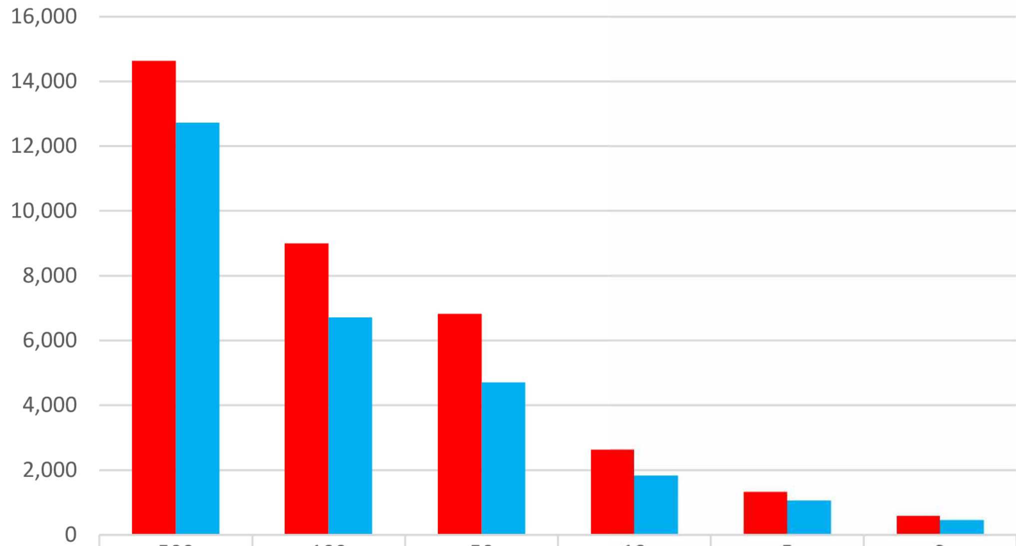
FNI also ran a Hurricane Harvey simulation to assess Alternative 2's performance during tropical storms and hurricanes that can produce large amounts of rainfall over multiple days. Alternative 2 is shown to reduce structural damages by $180 million, and flooding instances by 1,940.

Figure 13: Flood Damages ($M) by Event – Alternative 2



	500	100	50	10	5	2
Future Conditions	$818.5	$405.5	$283.6	$107.7	$54.4	$28.4
Alternative 2	$592.4	$258.8	$172.3	$65.8	$36.9	$20.1

Figure 14: Flood Instances by Event – Alternative 2



	500	100	50	10	5	2
Future Conditions	14,630	8,996	6,824	2,625	1,325	582
Alternative 2	12,727	6,711	4,700	1,830	1,054	452

Key Take-Aways:

1. The Dickinson Bayou Watershed upstream of Cemetery Rd. is mostly undeveloped, and therefore the quantifiable benefits associated with the inundation depth reductions provided by Alternative 2 are limited. New development should be built with slab elevations above flood risk levels.
2. A portion of the land in Reach DB-1 and DB-2 that is undeveloped today should be set aside for regional detention to allow for future development to occur without generating adverse impacts downstream.
3. Constructing a diversion channel from downstream of I-45 to the Bayou's outlet provides significant flood risk mitigation in the population centers located around I-45, particularly in the Dickinson "Bowl" east of I-45. It also eliminates the need to build a channel across I-45. Alternative 2 has a benefit/cost ratio of 0.5 which is the highest of any alternative evaluated as part of the Lower Clear Creek and Dickinson Bayou Flood Mitigation Plan.
4. The Dickinson "Bowl" contains a vast number of low-lying structures at risk of flooding during frequent storm events like the 2-year and 5-year events. Alternative 2 cannot adequately mitigate the flood risk at these structures. Voluntary buyouts and elevation of the finished floors is recommended for these structures.
5. Significant residual risk remains with the construction of Alternative 2.

4 CONCLUSIONS

Table 8 shows the 100-year peak water surface elevation reductions at Cemetery Rd. and I-45 between Alternative 1, Alternative 2, and future conditions (no project). A comparison of the complete 100-year water surface profiles is presented in **Figure 15** provided on the next page.

Table 8: 100-Year Peak Water Surface Elevation Reductions at Cemetery Rd. and I-45

Alternative	Cemetery Rd.	I-45
1: Detention	0.59 feet	0.37 feet
2: Detention + Diversion Channel	0.88 feet	2.29 feet

Alternative 1 is about half the cost of Alternative 2 but provides significantly less flood risk mitigation. Alternative 2 has a benefit/cost ratio of 0.5 which is the highest of any alternative evaluated as part of the Lower Clear Creek and Dickinson Bayou Flood Mitigation Plan. The proposed diversion channel provides significant flood risk mitigation in the population centers located around I-45 that are subject to an elevated risk of riverine flooding. As presented in **Appendix A**, increasing the channel capacity increases constructions costs but also the benefits obtained from the project. As this study progresses into future phases, the design of the diversion channel can optimized based on available funds and flood risk mitigation objectives.

Figure 15: 100-Year Water Surface Profiles

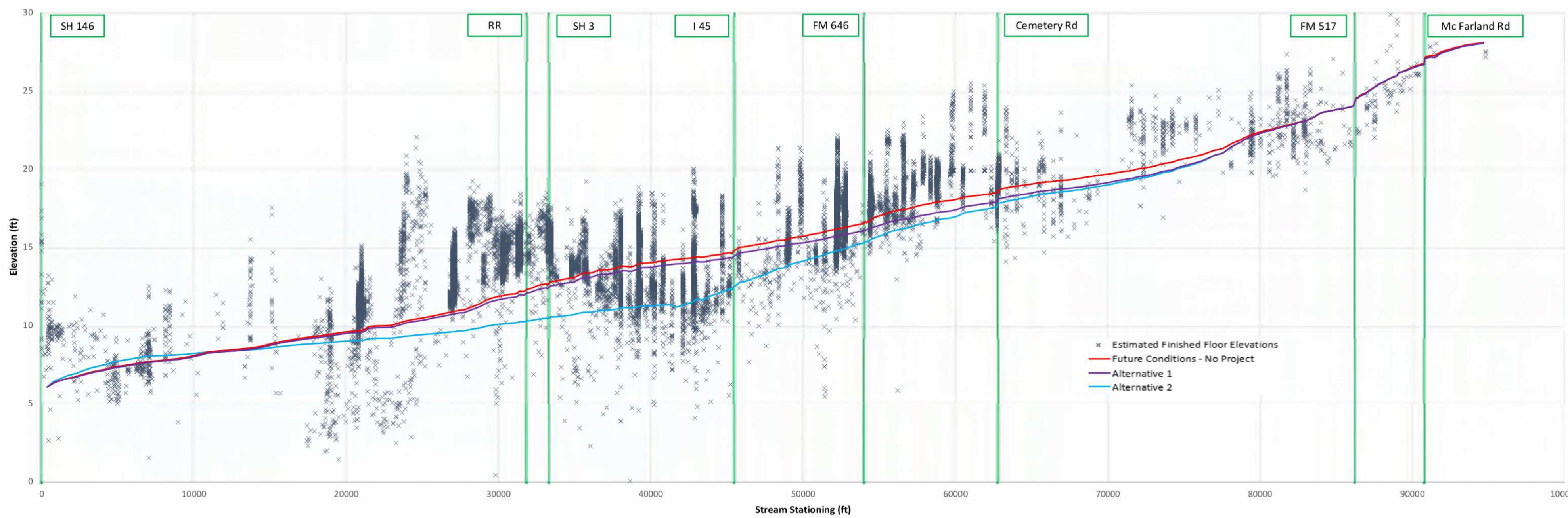
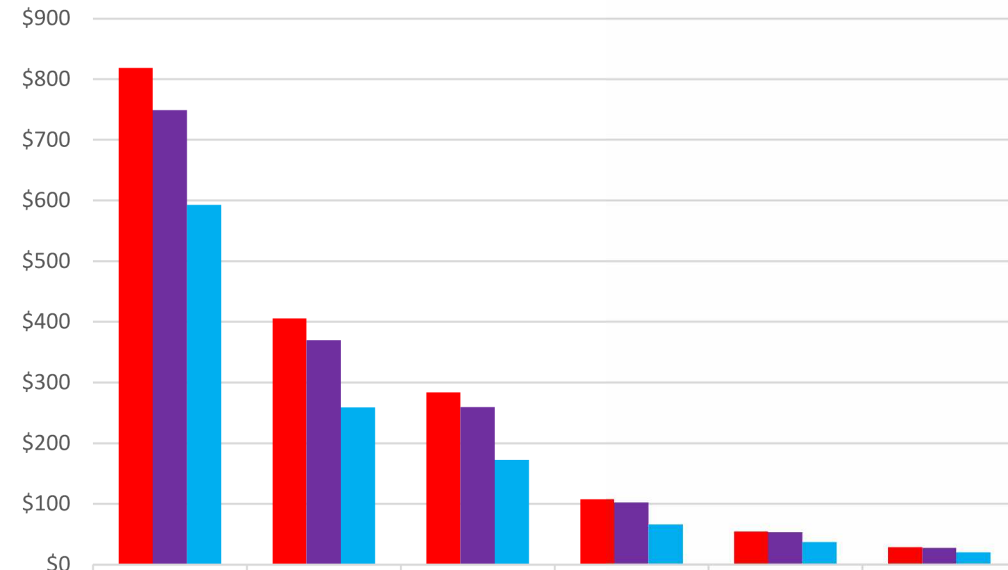


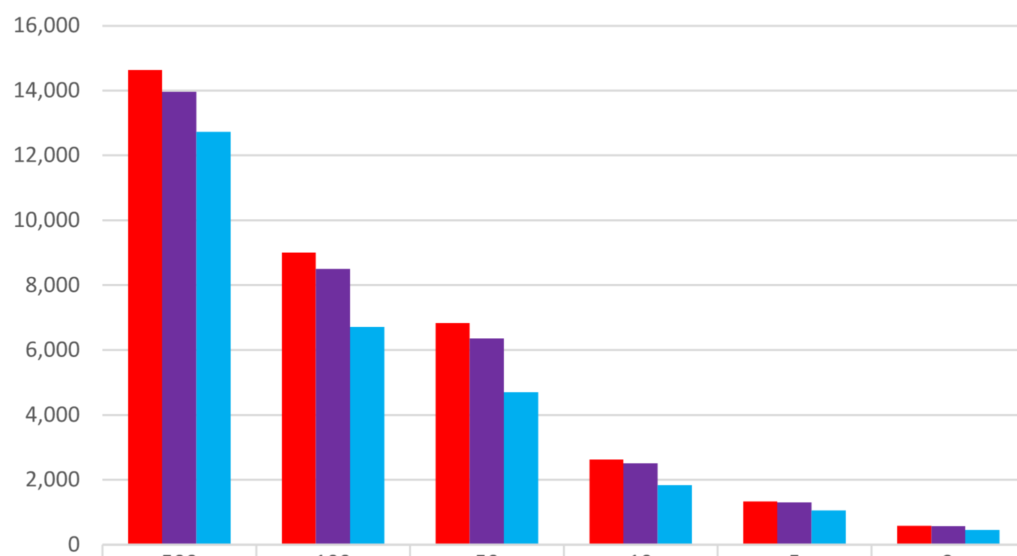
Figure 16 and **Figure 17** summarize the structural damages and instances of flooding associated with each alternative compared to future conditions (no project).

Figure 16: Summary of Structural Damages ($M) by Event for All Alternatives



	500	100	50	10	5	2
Future Conditions	818.5	405.5	283.6	107.7	54.4	28.4
Alternative 1	748.8	369.3	259.5	102.1	52.9	27.1
Alternative 2	592.4	258.8	172.3	65.8	36.9	20.1

Figure 17: Summary of Flood Instances by Event for All Alternatives



	500	100	50	10	5	2
Future Conditions	14,630	8,996	6,824	2,625	1,325	582
Alternative 1	13,960	8,499	6,355	2,506	1,305	565
Alternative 2	12,727	6,711	4,700	1,830	1,054	452

FNI proposes the following conclusions resulting from this study:

1. The alternatives proposed in this study are targeted toward mitigating the riverine flood risk during large, infrequent storms. For structures at risk of flooding under smaller, more frequent storms such as the 2-year and the 5-year events, elevating the structure or acquiring the property and removing it from the floodplain is likely the most cost-effective approach. FNI calculated that over 1,300 structures flood during the 5-year event under future conditions. A significant number of these structures are located in the Dickinson “Bowl” in the vicinity of I-45.
2. Placing detention in the upstream portion of the watershed where undeveloped land is currently available will prove critical as the area develops in the future, but offers limited benefits in the Dickinson “Bowl” where most of the structures at risk of flooding are located.
3. Constructing a diversion channel from downstream of I-45 to the Bayou’s outlet provides significant flood risk mitigation in the population centers located around I-45 that are at the highest risk of riverine flooding.
4. The project benefits captured in this study do not fully account for the benefits the proposed alternatives could provide to the local drainage systems, which could be significant. The output from the alternatives developed in this study’s hydraulic models should be integrated into local storm sewer network models to capture additional benefits achieved outside of the riverine floodplain of Dickinson Bayou and its major tributaries.
5. The proposed alternatives mitigate but do not eliminate the flood risk in the study area. Significant residual risk persists east of I-45 due to an abundance of low-lying structures in the Dickinson “Bowl”. Flooding risks will likely increase in the future as the upstream portion of the watershed develops, and the compound effect of rainfall and storm surge becomes more severe due to rising sea levels.

5 RECOMMENDATIONS

Since the combination alternatives analyzed do not have a benefit-cost ratio greater than 1.0, project recommendations are closely tied to project funding potential with a focus on local funding for a significant share of the project.

5.1 PROJECT FUNDING

5.1.1 Local Funding

All of the combination alternatives and any of the individual projects greater than $50 million in capital cost are unlikely to be funded by an individual entity such as the City of League City or the City of Dickinson. These improvements will require partnerships and cost sharing agreements between the entities. These agreements could be developed piecemeal on a project-by-project basis, but would be better accomplished through development of a watershed-wide entity focused on flood damage reduction along the main channel of Dickinson Bayou such as the Clear Creek Flood Control District originally proposed in 1995 and offered for consideration again at the State level in 2019.

Such an entity would have a clear mission of flood protection for Dickinson Bayou and provide a single clear partner for larger entities such as USACE, Texas General Land Office, and the Texas Water Development Board. This entity would not conflict or restrict Galveston County Consolidated Drainage District and other entities along the Bayou from their responsibilities. Instead, the newly formed Dickinson Bayou Flood Control District would allow other entities to focus their efforts on tributary drainage to Dickinson Bayou thus maximizing the benefit of their existing ad valorem taxes. The Dickinson Bayou Flood Control District would need to be created by the Texas State Legislature and then voted upon by the Watershed's residents to grant it taxing authority. The tax rate for the District would be a function of the projects recommended following the next phase of this study. Discussions with state and local officials to gain traction for this concept should proceed immediately.

5.1.2 External Funding

In addition to local funding opportunities through ad valorem, additional grant and matching programs exist at the Federal and State level that should be evaluated once clear cost/benefit metrics are prepared that include potential local benefits. These funding entities and their programs are discussed in greater detail in **Appendix E** and include:

- United States Army Corps of Engineers
- Texas General Land Office
- Federal Emergency Management Agency
- Texas Water Development Board
- United States Department of Housing and Urban Development
- United States Department of Agriculture

There are many different financial partnership opportunities, but external sources come with their own objectives. Even if a project may qualify and be selected for a program, most programs require a local match that is a significant percentage and many programs have strings attached. Each partner will have distinct eligibility and accountability criteria by which they are legally obligated to, often including benefit cost ratio.

Many of these requirements include:

- Additional Protections for Cultural Resources and the Environment
- Restrictions on what actions are reimbursable
- Additional reporting requirements on how money is spent
- Transparency and fairness in how contracts are advertised and awarded
- Special contract provisions regarding how work will be recorded and conducted

As these programs are pursued it is important to understand the implications that each program's requirements may impose on the project; these projects will not perform well for programs that put a heavy emphasis on low to moderate income and socially vulnerable populations.

For structures at risk of flooding under frequent storms, elevating the structure or acquiring the property and removing it from the floodplain is likely the most cost-effective approach. This can be specifically undertaken with the help of the following programs:

- NRCS-EWP Pilot Program
- FEMA-HMGP
- FEMA-BRIC
- TWDB-FIF

5.2 NEXT STEPS

FNI recommends that this concepts analysis study be followed by a feasibility study to:

- Refine the combination alternatives proposed as part this study,
- Identify supplemental benefits the alternatives could provide to areas located outside of the riverine floodplains. The outputs from the alternatives developed as part of this study should be integrated into local storm sewer network models for League City, Dickinson, and other municipalities,
- Reduce the uncertainty associated with the compound flooding results to improve the understanding of its impacts on the alternatives' benefits,
- Identify efficiencies in the alternatives to reduce cost,
- Develop a project delivery plan, and
- Recommend a distinct alternative for implementation.

Appendix A

Evaluation of Discrete Projects

Appendix B

Hydrologic Technical Memorandum

Appendix C

Hydraulic Technical Memorandum

Appendix D

Inundation Damages Assessment Technical Memorandum

Appendix E

Preliminary Funding Memorandum

Appendix 5-4C:
San Jacinto Master Drainage Plan

APPENDIX 5-4H SJMDP

The San Jacinto Regional Master Drainage Plan report can be accessed at the following location.

Citation:

Halff Associates, Inc. & Freese and Nichols, Inc. "San Jacinto Regional Watershed Master Drainage Plan." 2020. Document.

Website:

https://www.hcfcd.org/Activity/Active-Projects/San-Jacinto-River/C-17-San-Jacinto-River-Watershed-Study

Appendix 5-4D:
Galveston Bay Storm Surge Protection Coastal Storm Risk Management

APPENDIX 5-4D COASTAL TEXAS PROTECTION AND RESTORATION FEASIBILITY STUDY FINAL REPORT

The Coastal Texas Protection and Restoration Feasibility Study Final Report can be accessed at the following location.

Citation:

USACE. "Coastal Texas Protection and Restoration Feasibility Study Final Report." 2021. Document.

Website:

https://coastalstudy.texas.gov/draft-proposal/index.html

Appendix 5-4E:
City of Houston Fifth Ward Area Flood Mitigation

FIFTH WARD MASTER DRAINAGE PLAN
TECHNICAL MEMORANDUM

CITY OF HOUSTON, TEXAS

WBS No. M-000100-0015-3 Work Order No. 21
CobbFendley Project No. 1311-013-21

STATE OF TEXAS
CANDYCE WARD
108949
LICENSED
PROFESSIONAL ENGINEER

10/9/2020

October 2020

Submitted By:

CobbFendley
Texas Registration No. 274

Civil Engineering ◆ Construction Management ◆ GIS/CADD ◆ Land Development ◆ Land Surveying
Municipal ◆ Right-of-Way ◆ Site Development ◆ Subsurface Utility Engineering
Hydraulics/Hydrology ◆ Telecommunications ◆ Transportation ◆ Utility Coordination

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Exhibits

1. Study Area Location and Description

The City of Houston (City) contracted with Cobb Fendley & Associates, Inc to perform an Existing Condition Analysis for the drainage systems associated with the area commonly referred to as the Greater Fifth Ward Super Neighborhood near downtown Houston. The study area is in City Council District B just northeast of downtown and can be found on Key Map grids 494A through 494L, see Exhibit 1 – Project Location Map.

Under the Capital Improvement Projects program, several areas of concern were identified as drainage concerns or as needing street repairs performed. As such, the City determined these were "Need Areas" and assigned individual project numbers to each. Drainage studies were performed for each of these Need Areas (M-2013-B01, N-2013L-B01, and N-2014L-B02), but an overall solution was not possible on an individual project basis. As such, this project combines those areas into what is now referred to as the Greater Fifth Ward Drainage Masterplan. As a drainage masterplan, it is now possible to combine the improvements associated with each individual area into a larger, more comprehensive, solution which serves the area with a regional solution, rather than having to obtain additional right-of-way (ROW) in order to have several small detention ponds scattered throughout the region.

The project location is primarily residential, comprised of single-family homes. The majority of drainage systems in the project location are comprised of concrete curb and gutter streets with underground storm sewer systems, but there are also a few areas with asphalt streets and roadside ditches. Buffalo Bayou (HCFCD Unit# W100-00-00) serves as the primary outfall location at 3 different locations.

2. Scope of Work

The purpose of this study is to review and evaluate existing conditions for the project area in order to facilitate solutions which will address the flooding problems. Specific tasks include

- Define the existing condition drainage area boundaries
- Identify existing drainage systems and outfall locations
- Develop drainage area map
- Determine hydrologic drainage parameters
- Perform existing condition drainage system capacity analysis
- Identify existing drainage problem locations

It should be noted that findings within this report are preliminary and were intended to find possible solutions to address the identified deficiencies. Any proposed improvements will be verified through a more detailed proposed condition analysis.

3. Methodology

3.1. Hydrology

The July 2019 City of Houston Infrastructure Design Manual was followed for the hydrologic analysis. The total study area is comprised of approximately 1,309 acres. Newly obtained LiDAR data for this project location was utilized to study the overland terrain allowing for identification of sheetflow patterns in order to determine drainage area boundaries. To perform hydrologic calculations, the rational method was used to calculate peak flow rates for the 2-, 10-, 100-, and 500-year Atlas-14 rainfall event using City of Houston Time of Concentration calculation. The calculated rational method drainage area peak flows were used to calibrate the flows for each rainfall event which were generated within runoff mode of the XP-SWMM model. The drainage area map is provided in Exhibit 2 and existing condition Hydrologic calculations are provided in Exhibit 3

3.2. Hydraulics

XP-SWMM models were created for the 2-, 10-, and 100-year rainfall events to simulate conveyance through interconnected drainage systems within the Greater Fifth Ward area. These XP-SWMM models are comprehensive models which allow interconnection of all drainage systems (roadside ditches, culverts, storm sewer trunks) with Buffalo Bayou as the primary outfall location. The drainage system network was created by utilizing collected survey data, City of Houston GIMS data, and as-built plan sets. The topographic survey was collected through the use of a new LiDAR data set with detailed high definition points to identify overland terrain as well as cross sectional roadside ditch details. Storm sewer manholes were identified from the LiDAR data and top of rim elevations were determined. Storm sewer sizing and flowline elevation was manually obtained via on-site measurements and observations. The outfall boundary condition for the XP-SWMM model utilized rating curves to establish the backwater effect on the drainage system at each outfall location. The rating curves utilize established water surface elevations for the various rainfall events with respect to expected flows for each event. For instance, the 2-year rainfall event utilizes the top of pipe elevation, the 10- and 100-year models utilize the 10- and 100-year water surface elevations and flows from the Effective FEMA HEC-RAS models.

4. Existing Condition

According to the Effective FEMA 100- and 500-year floodplain data (FEMA Floodplain Map Number 48201C0690N, Effective 1/6/2017), water surface elevations remain within the banks of Buffalo Bayou throughout the extents of the project area; therefore, the project is primarily located outside the 100-, and 500-year floodplains. However, the northern most portion of the project area is located within the Hunting Bayou 500-year floodplain. Although storm sewer systems within this area convey flow south towards Buffalo Bayou, the Hunting Bayou (north of the project location) 500-year water surface elevations reach as far south as the Southern Pacific Railroad as shown in Exhibit 4 – Floodplain map.

The existing storm sewer system ranges in size from 18” reinforced concrete pipes (RCPs) to 12’x 10’ reinforced concrete boxes (RCBs) and there is a small section of open channel where Ingraham Gully (HCFCD Unit# G122-00-00) was previously located, which was primarily enclosed in RCBs years ago.

Analysis of the existing storm sewer systems and roadside ditches (where applicable) indicated the majority of the existing drainage infrastructure within the project area is undersized and does not have adequate capacity to convey the 2-year Atlas 14 rainfall event to the outfall locations, resulting in significant street ponding in areas, see Exhibit 5 – Existing Condition Storm Sewer Layout. Compounded with the undersized drainage system, overland sheetflow is unable to be conveyed directly to the channel in some locations as well. Areas north of the railroad tracks are unable to convey overland sheetflow south towards Buffalo Bayou because the railroad tracks are elevated and act similar to a dam, preventing flow further south. As such, water is stored above ground until it can either enter the storm sewer system/culverts under the tracks or reaches an elevation in which it eventually flows north into Hunting Bayou. As shown in Exhibit 6A, B and C –2-, 10- 100-year Overland Ponding Map respectively, there is significant ponding north of the railroad tracks and along the historical flow path of what used to be Ingraham Gully. Coincidentally, these ponding areas identified on the overland ponding map coincide with the majority of the repetitive loss claims.

5. Proposed Condition

The proposed project was developed to encompass the four project areas included in this assessment, M-2013-B01, N-2013L-B01, M-2017-TDO03, and N-2014L-B02, along with any additional area that would logically drain to the proposed storm sewer. This solution was selected because it addresses the extreme event sheet flow deficiencies and uses a continuous trunk throughout the entire project area. The proposed storm sewer system, which largely runs along Gregg St, will have sufficient capacity to convey the 2-year rainfall event and keep the extreme event contained within the ROW along the proposed storm sewer trunkline, see Exhibit 7A, B, C, D, and E, – Proposed Ponding Maps. This proposed storm sewer trunk will provide relief necessary for the undersized pipes in the north side of the project area. The proposed storm sewer ranges in size from a 54" RCP at the upstream end to 3 – 11' x 10' RCBs at the outfall, see Exhibit 8. The roadways required to be reconstructed to install the proposed storm sewer, will be replaced with equivalent sections to the existing condition.

For constructability, this proposed project has been broken in to 4 sub-projects, see Exhibit 8. The sub-projects are ordered from downstream to upstream. The first sub-project is from the outfall to Buffalo Bayou to just north of IH-10. The second sub-project continues from the end of sub-project 1 and ends just north of the railroad. The third sub-project includes the remaining portion north of the railroad. The fourth sub-project is located just east of sub-project 2.

The proposed project has a combined overall cost of $67,193,376, see Exhibit 9 for a per sub-project cost. The proposed project reduces the length of impassible streets in the 100-year by 9.29 miles, reduced the risk of flooding in the 100-year for 915 structures, see Exhibit 10 for a Benefitted Population Map.

6. Mitigation Analysis

In order to determine if the project had an adverse impact to Buffalo Bayou, the increase in flow from the proposed project was incorporated in to the effective HEC-HMS and HEC-RAS models. Since the proposed project was analyzed using Atlas-14 and the effective HEC-HMS and HEC-RAS models have not yet been updated, the difference between the existing and propose XP-SWMM hydrographs was input in to the effective HEC-HMS model to determine if the project caused the flows in Buffalo Bayou to increase.

The proposed project is located in the most downstream basin in the effective HEC-HMS model, sub-basin W100O, which has a 100-year (TP-40) peak flow of 5,230 cfs and peaks at Day 1 18:30. Just upstream of the tie in with this sub basin, Buffalo Bayou has a peak flow of 59,034 and peaks at Day 2 2:15. Downstream of the tie in, the peak flow is 61,636 and peaks at Day 2 1:45.

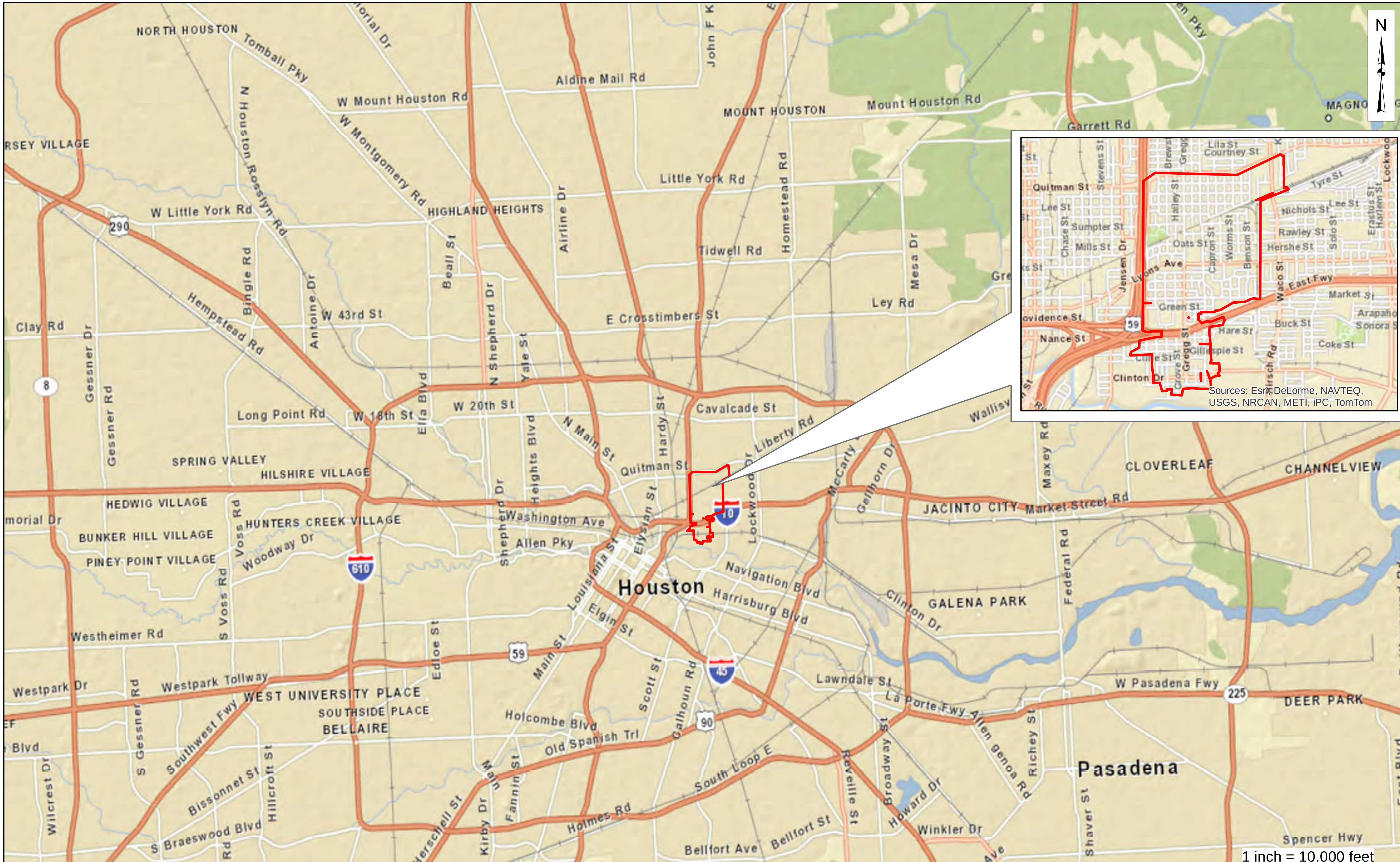
The proposed project allows the area to drain more effectively, which increases peak flow and causes the area to peak earlier. When taking the proposed project in to account, sub basin W100O has a proposed peak flow of 6,064 and peaks at Day 1 18:00, an increase of 834 cfs. When combined with the mainsteam of Buffalo Bayou, which is unchanged from the existing condition, Buffalo Bayou downstream of the tie in with W100O has a peak flow of 61,306 and peaks at Day 2 2:00, a decrease of 330 cfs. This shows that the proposed project does not increase the peak flows along the mainsteam of Buffalo Bayou.

Additionally, any detention that was included in the proposed storm sewer system delayed the peak, which causes it to negatively affect the flows in Buffalo Bayou. If detention is included in this project, it would be more effective along Buffalo Bayou and not included as part of the proposed storm sewer system.

7. Additional Considerations

It is noteworthy to mention that this project location is immediately adjacent to the Texas Department of Transportation's North Houston Highway Improvement Project (NHHIP) which is currently under design. The NHHIP project is intended to relocate Interstate 45 so that it no longer passes directly through downtown Houston but will divert towards the east side of downtown and merge with US-69. It should also be noted that the current IH-10 storm sewer system does not have any connections with the City of Houston storm sewer system in this area. Drainage improvements recommended in the proposed condition analysis should include consideration for this future construction to ensure the recommendations do not negatively impact the progress of the future freeway construction. See Exhibit 11 – TxDOT NHHIP Schematic

Recommended improvements resulting from the proposed condition analysis could potentially result in negative impacts to Buffalo Bayou, either by increased flow to the Bayou or increased water surface elevations. Typically, detention ponds are recommended to mitigate these types of impacts. It should be noted that there is a potential Superfund Site (See Exhibit 12 – Superfund Sites) in the general vicinity and additional research should be performed to determine if there is contamination prior to deciding where to locate the detention facilities if deemed necessary.



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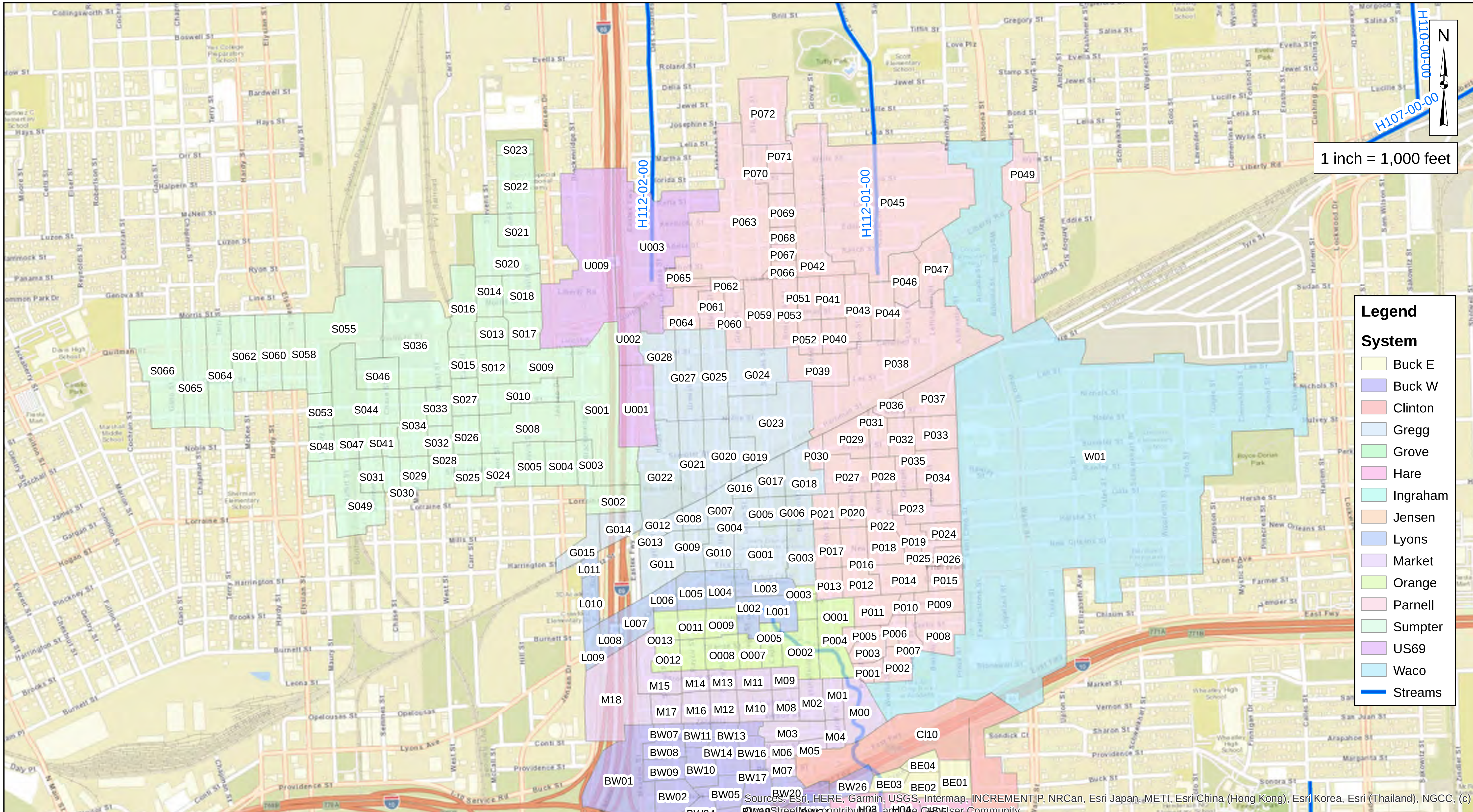
Fifth Ward Master Drainage Plan
Project Location Map

Date: April 2020	EXHIBIT 1



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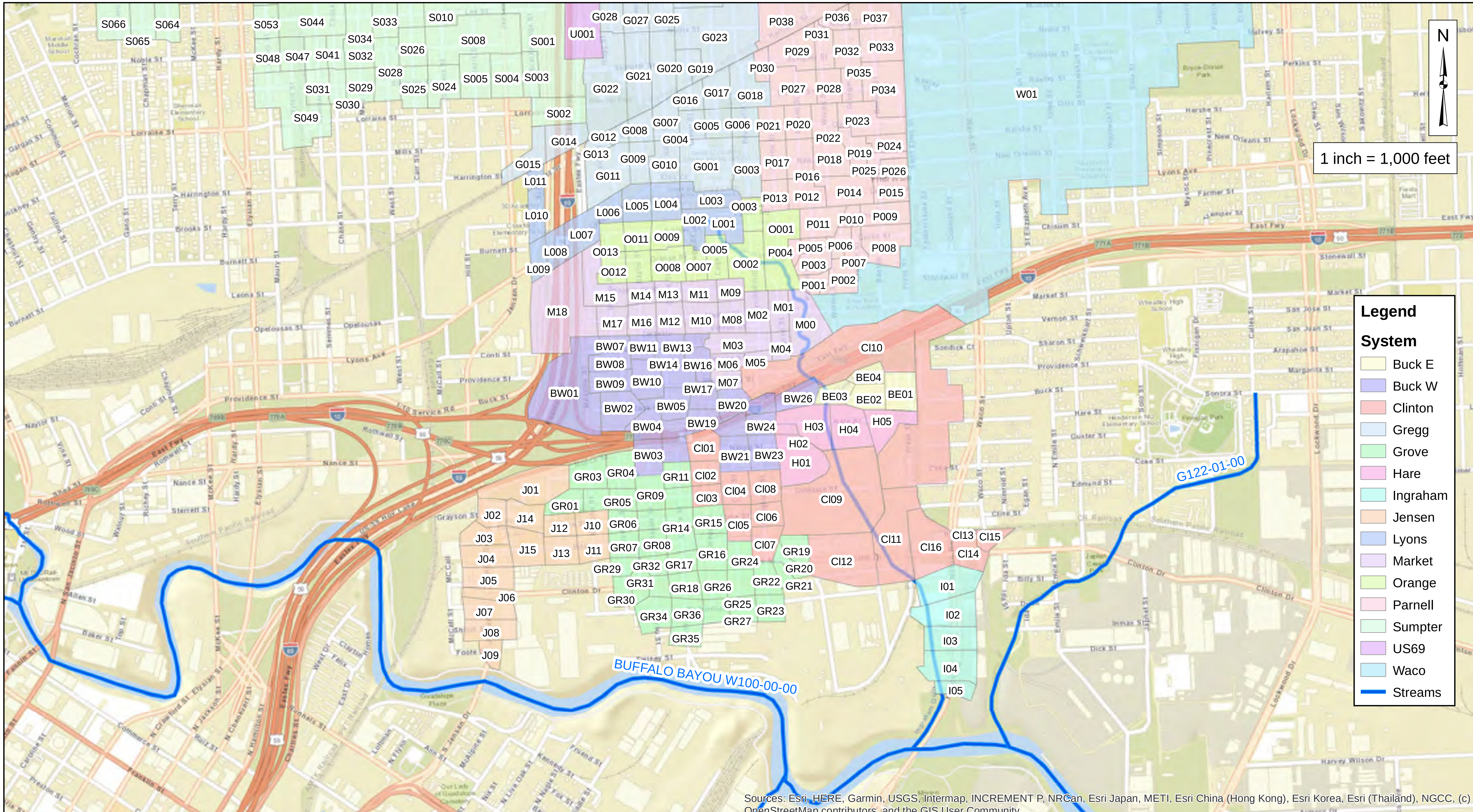
5th Ward Drainage Masterplan
Drainage Area Map North

Date: April 2020	EXHIBIT 2A



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5th Ward Drainage Masterplan
Drainage Area Map South

Date: April 2020	EXHIBIT 2B

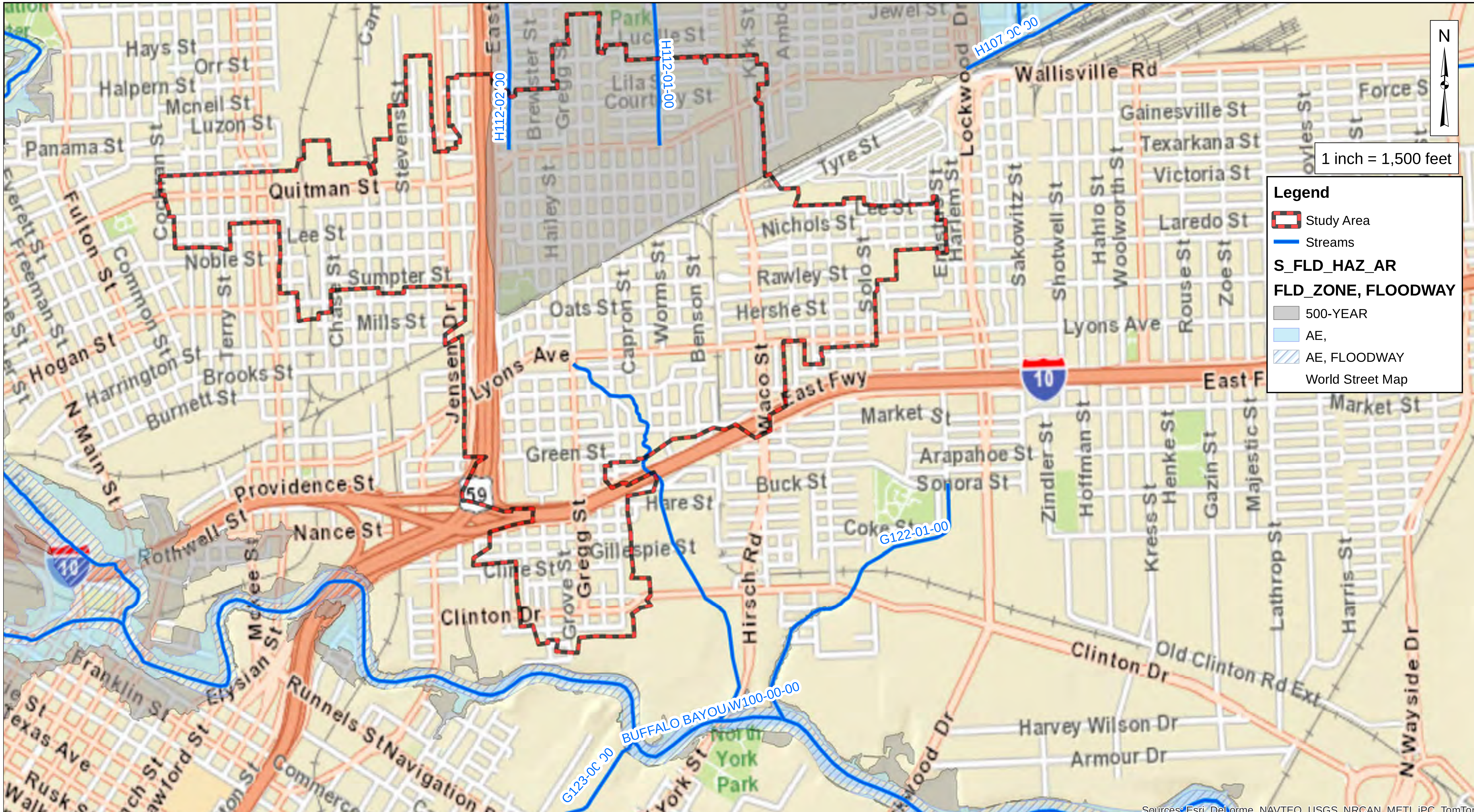
EXHIBIT 3 - Existing Condition Hydrologic Calculations

						2 year		5 year		10 year		25 year		50 year		100 year	
OUTFALL	Drainage Area	Area (acre)	Tc (min)	C	%IMP	Intensity I (in/hr)	Flow Q (cfs)	Intensity I (in/hr)	Flow Q (cfs)	Intensity I (in/hr)	Flow Q (cfs)	Intensity I (in/hr)	Flow Q (cfs)	Intensity I (in/hr)	Flow Q (cfs)	Intensity I (in/hr)	Flow Q (cfs)
Buck E	BE01	3.05	27.17	0.45	41.67	3.59	4.93	4.50	6.17	5.28	7.25	6.39	8.78	7.29	10.01	8.19	11.25
Buck E	BE02	2.27	26.55	0.35	25.00	3.63	2.88	4.55	3.61	5.34	4.24	6.47	5.14	7.37	5.85	8.29	6.58
Buck E	BE03	1.80	26.09	0.35	25.00	3.67	2.31	4.59	2.90	5.39	3.40	6.53	4.11	7.44	4.69	8.36	5.27
Buck E	BE04	1.49	25.72	0.45	41.67	3.70	2.47	4.63	3.09	5.43	3.63	6.57	4.39	7.49	5.01	8.42	5.63
Buck W	BW01	11.97	30.48	0.80	100.00	3.37	32.25	4.22	40.45	4.96	47.53	6.02	57.63	6.87	65.80	7.73	74.05
Buck W	BW02	3.53	27.49	0.65	75.00	3.57	8.19	4.47	10.26	5.25	12.04	6.35	14.59	7.25	16.64	8.15	18.70
Buck W	BW03	2.61	26.84	0.55	58.33	3.61	5.18	4.53	6.49	5.31	7.61	6.43	9.22	7.33	10.51	8.24	11.82
Buck W	BW04	2.19	26.48	0.65	75.00	3.64	5.18	4.56	6.48	5.35	7.61	6.48	9.21	7.38	10.51	8.30	11.81
Buck W	BW05	2.72	26.92	0.65	75.00	3.61	6.37	4.52	7.98	5.30	9.37	6.42	11.34	7.32	12.93	8.23	14.54
Buck W	BW06	1.12	25.20	0.80	100.00	3.74	3.35	4.68	4.20	5.49	4.92	6.64	5.96	7.57	6.79	8.50	7.63
Buck W	BW07	1.16	25.26	0.35	25.00	3.73	1.51	4.67	1.90	5.48	2.22	6.63	2.69	7.56	3.07	8.49	3.45
Buck W	BW08	1.98	26.28	0.65	75.00	3.65	4.70	4.58	5.89	5.37	6.91	6.50	8.37	7.41	9.54	8.33	10.72
Buck W	BW09	2.30	26.58	0.65	75.00	3.63	5.43	4.55	6.81	5.34	7.99	6.46	9.67	7.37	11.03	8.28	12.39
Buck W	BW10	2.94	27.09	0.65	75.00	3.59	6.86	4.50	8.59	5.29	10.09	6.40	12.21	7.30	13.93	8.21	15.66
Buck W	BW11	1.60	25.87	0.65	75.00	3.69	3.84	4.62	4.81	5.42	5.64	6.56	6.83	7.47	7.79	8.40	8.75
Buck W	BW12	0.98	24.97	0.65	75.00	3.76	2.40	4.70	3.00	5.52	3.52	6.68	4.26	7.61	4.85	8.54	5.45
Buck W	BW13	1.33	25.51	0.65	75.00	3.71	3.21	4.65	4.02	5.45	4.71	6.60	5.70	7.52	6.50	8.45	7.30
Buck W	BW14	1.74	26.03	0.65	75.00	3.67	4.16	4.60	5.21	5.40	6.11	6.53	7.40	7.45	8.43	8.37	9.47
Buck W	BW15	0.77	24.54	0.45	41.67	3.79	1.31	4.74	1.63	5.57	1.92	6.73	2.32	7.67	2.64	8.62	2.97
Buck W	BW16	1.82	26.12	0.65	75.00	3.67	4.34	4.59	5.44	5.39	6.38	6.52	7.73	7.44	8.81	8.36	9.90
Buck W	BW17	1.84	26.13	0.65	75.00	3.66	4.38	4.59	5.49	5.39	6.44	6.52	7.80	7.43	8.89	8.35	9.99
Buck W	BW18	1.58	25.83	0.65	75.00	3.69	3.78	4.62	4.73	5.42	5.55	6.56	6.72	7.48	7.66	8.40	8.60
Buck W	BW19	1.74	26.02	0.65	75.00	3.67	4.15	4.60	5.19	5.40	6.09	6.54	7.38	7.45	8.41	8.37	9.45
Buck W	BW20	2.01	26.31	0.55	58.33	3.65	4.03	4.57	5.05	5.37	5.92	6.50	7.17	7.41	8.18	8.33	9.19
Buck W	BW21	2.63	26.86	0.45	41.67	3.61	4.28	4.52	5.36	5.31	6.29	6.43	7.61	7.33	8.68	8.24	9.76
Buck W	BW22	1.48	25.71	0.80	100.00	3.70	4.37	4.63	5.48	5.43	6.43	6.58	7.78	7.49	8.86	8.42	9.96
Buck W	BW23	2.54	26.78	0.35	25.00	3.62	3.22	4.53	4.03	5.32	4.73	6.44	5.73	7.34	6.53	8.25	7.34
Buck W	BW24	1.61	25.87	0.65	75.00	3.68	3.85	4.61	4.82	5.42	5.65	6.56	6.84	7.47	7.80	8.40	8.76
Buck W	BW25	1.24	25.38	0.80	100.00	3.72	3.68	4.66	4.61	5.47	5.41	6.62	6.55	7.54	7.47	8.47	8.39
Buck W	BW26	2.34	26.62	0.65	75.00	3.63	5.53	4.55	6.93	5.33	8.13	6.46	9.84	7.36	11.22	8.28	12.61
Clinton	Cl01	2.41	26.67	0.65	75.00	3.62	5.67	4.54	7.11	5.33	8.34	6.45	10.10	7.36	11.51	8.27	12.94
Clinton	Cl02	1.79	26.08	0.45	41.67	3.67	2.95	4.60	3.70	5.39	4.34	6.53	5.25	7.44	5.99	8.36	6.73
Clinton	Cl03	1.60	25.86	0.45	41.67	3.69	2.65	4.62	3.32	5.42	3.90	6.56	4.72	7.47	5.38	8.40	6.04
Clinton	Cl04	2.38	26.65	0.55	58.33	3.63	4.75	4.54	5.95	5.33	6.98	6.46	8.45	7.36	9.63	8.27	10.83
Clinton	Cl05	2.38	26.65	0.65	75.00	3.63	5.60	4.54	7.02	5.33	8.23	6.46	9.97	7.36	11.37	8.27	12.77
Clinton	Cl06	1.86	26.15	0.45	41.67	3.66	3.06	4.59	3.83	5.38	4.50	6.52	5.44	7.43	6.21	8.35	6.97
Clinton	Cl07	2.37	26.64	0.65	75.00	3.63	5.59	4.54	7.00	5.33	8.21	6.46	9.94	7.36	11.34	8.27	12.74
Clinton	Cl08	2.62	26.85	0.35	25.00	3.61	3.31	4.53	4.14	5.31	4.86	6.43	5.89	7.33	6.72	8.24	7.55
Clinton	Cl09	17.40	31.54	0.18	0.00	3.30	10.35	4.15	12.98	4.87	15.26	5.91	18.51	6.75	21.14	7.60	23.80
Clinton	Cl10	38.56	34.02	0.50	50.00	3.17	61.02	3.97	76.63	4.68	90.13	5.68	109.44	6.49	125.09	7.31	140.97
Clinton	Cl11	8.36	29.53	0.45	41.67	3.43	12.90	4.30	16.17	5.05	19.00	6.12	23.03	6.98	26.28	7.86	29.57
Clinton	Cl12	8.40	29.55	0.80	100.00	3.43	23.03	4.30	28.87	5.05	33.91	6.12	41.11	6.98	46.92	7.86	52.79
Clinton	Cl13	0.29	23.06	0.90	100.00	3.92	1.04	4.90	1.30	5.75	1.52	6.95	1.84	7.91	2.09	8.88	2.35
Clinton	Cl14	2.53	26.77	0.80	100.00	3.62	7.31	4.53	9.16	5.32	10.75	6.44	13.02	7.34	14.84	8.25	16.68
Clinton	Cl15	1.36	25.56	0.80	100.00	3.71	4.05	4.64	5.07	5.45	5.95	6.60	7.20	7.52	8.21	8.44	9.22
Clinton	Cl16	5.78	28.62	0.45	41.67	3.49	9.07	4.37	11.37	5.13	13.35	6.22	16.17	7.10	18.45	7.98	20.75
GREGG	G001	2.86	27.03	0.45	41.67	3.60	4.63	4.51	5.80	5.29	6.80	6.41	8.24	7.31	9.40	8.21	10.56
GREGG	G002	2.85	27.03	0.45	41.67	3.60	4.62	4.51	5.79	5.29	6.80	6.41	8.23	7.31	9.38	8.21	10.55
GREGG	G003	3.02	27.15	0.45	41.67	3.59	4.88	4.50	6.11	5.28	7.17	6.39	8.69	7.29	9.91	8.20	11.14
GREGG	G004	1.89	26.19	0.45	41.67	3.66	3.12	4.58	3.91	5.38	4.58	6.51	5.55	7.43	6.33	8.34	7.11
GREGG	G005	1.99	26.28	0.45	41.67	3.65	3.27	4.58	4.09	5.37	4.80	6.50	5.81	7.41	6.62	8.33	7.44
GREGG	G006	1.99	26.29	0.45	41.67	3.65	3.27	4.58	4.10	5.37	4.81	6.50	5.83	7.41	6.64	8.33	7.47
GREGG	G007	2.65	26.87	0.45	41.67	3.61	4.31	4.52	5.40	5.31	6.33	6.43	7.67	7.33	8.75	8.24	9.83
GREGG	G008	1.72	26.00	0.45	41.67	3.67	2.85	4.60	3.57	5.40	4.18	6.54	5.06	7.45	5.77	8.37	6.49
GREGG	G009	2.29	26.57	0.45	41.67	3.63	3.74	4.55	4.69	5.34	5.50	6.47	6.66	7.37	7.59	8.28	8.54
GREGG	G010	3.05	27.17	0.45	41.67	3.59	4.93	4.50	6.18	5.28	7.25	6.39	8.78	7.29	10.02	8.19	11.26
GREGG	G011	5.44	28.47	0.45	41.67	3.50	8.56	4.38	10.73	5.15	12.60	6.24	15.26	7.12	17.41	8.00	19.58
GREGG	G012	1.03	25.06	0.45	41.67	3.75	1.74	4.69	2.18	5.51	2.56	6.66	3.10	7.59	3.53	8.53	3.97
GREGG	G013	0.98	24.96	0.45	41.67	3.76	1.66	4.70	2.07	5.52	2.43	6.68	2.94	7.61	3.35	8.54	3.77
GREGG	G014	2.96	27.11	0.80	100.00	3.59	8.52	4.50	10.67	5.28	12.53	6.40	15.17	7.30	17.30	8.20	19.45
GREGG	G015	2.75	26.95	0.45	41.67	3.60	4.46	4.52	5.59	5.30	6.56	6.42	7.95	7.32	9.06	8.23	10.18
GREGG	G016	1.64	25.92	0.45	41.67	3.68	2.72	4.61	3.41	5.41	4.00	6.55	4.85	7.46	5.53	8.39	6.21
GREGG	G017	2.56	26.80	0.45	41.67	3.62	4.16	4.53	5.22	5.32	6.12	6.44	7.41	7.34	8.45	8.25	9.50
GREGG	G018	4.06	27.80	0.45	41.67	3.54	6.48	4.44	8.12	5.21	9.53	6.32	11.54	7.20	13.17	8.10	14.81
GREGG	G019	1.97	26.26	0.45	41.67	3.66	3.23	4.58	4.05	5.37	4.75	6.50	5.75	7.41	6.56	8.33	7.37
GREGG	G020	4.47	28.02	0.45	41.67	3.53	7.10	4.42	8.90	5.19	10.45	6.29	12.66	7.18	14.44	8.07	16.24
GREGG	G021	5.22	28.38	0.45	41.67	3.50	8.23	4.39	10.32	5.16	12.12	6.25	14.68	7.13	16.75	8.02	18.84
GREGG	G022	9.15	29.77	0.45	41.67	3.41	14.06	4.28	17.63	5.03	20.71	6.09	25.11	6.96	28.65	7.83	32.24
GREGG	G023	12.84	30.68	0.45	41.67	3.36	19.40	4.21	24.33	4.95	28.59	6.00	34.67	6.85	39.59	7.71	44.56
GREGG	G024	6.78	29.01	0.45	41.67	3.46	10.56	4.34	13.24	5.10	15.55	6.18	18.84	7.05	21.50	7.93	24.19
GREGG	G025	5.82	28.64	0.45	41.67	3.49	9.13	4.37	11.45	5.13	13.45	6.22	16.29	7.10	18.59	7.98	20.91
GREGG	G027	5.81	28.63	0.45	41.67	3.49	9.12	4.37	11.43	5.13	13.43	6.22	16.27	7.10	18.56	7.98	20.88
GREGG	G028	6.17	28.78	0.45	41.67	3.48	9.65	4.36	12.10	5.12	14.21	6.20	17.21	7.08	19.64	7.96	22.09
Grove	GR01	1.97	26.27	0.35	25.00	3.65	2.52	4.58	3.16	5.37	3.71	6.50	4.49	7.41	5.12	8.33	5.75
Grove	GR02	1.44	25.67	0.55	58.33	3.70	2.94	4.63	3.68	5.44	4.32	6.58	5.23	7.50	5.96	8.43	6.69
Grove	GR03	2.77	26.97	0.35	25.00	3.60	3.50	4.51	4.38	5.30	5.14	6.42	6.23	7.32	7.10	8.22	7.98
Grove	GR04	2.63	26.86	0.35	25.00	3.61	3.33	4.52	4.17	5.31	4.89	6.43	5.93	7.33	6.76	8.24	7.60
Grove	GR05	1.55	25.80	0.65	75.00	3.69	3.71	4.62	4.65	5.42	5.45	6.56	6.60	7.48	7.52	8.41	8.46
Grove	GR06	1.60	25.87	0.65	75.00	3.68	3.84	4.61	4.81	5.42	5.65	6.56	6.84	7.47	7.79	8.40	8.76
Grove	GR07	1.93	26.23	0.65	75.00	3.66	4.59	4.58	5.75	5.38	6.75	6.51	8.17	7.42	9.31	8.34	10.46
Grove	GR08	1.90	26.19	0.65	75.00	3.66	4.51	4.58	5.65	5.38	6.63	6.51	8.03	7.42	9.15	8.34	10.29
Grove	GR09	2.56	26.80	0.65	75.00	3.62	6.01	4.53	7.54	5.32	8.84	6.44	10.71	7.34	12.21	8.25	13.72
Grove	GR10	1.37	25.57	0.65	75.00	3.71	3.30	4.64	4.13	5.45	4.84	6.59	5.86	7.52	6.68	8.44	7.50
Grove	GR11	1.79	26.07	0.45	41.67	3.67	2.95	4.60	3.69	5.39	4.33	6.53	5.25	7.44	5.98	8.36	6.72
Grove	GR12	1.47	25.70	0.35	25.00	3.70	1.90	4.63	2.38	5.43	2.80	6.58	3.38	7.50	3.86	8.42	4.33
Grove	GR13	1.34	25.53	0.45	41.67	3.71	2.24	4.65	2.80	5.45	3.28	6.60	3.98	7.52	4.53	8.45	5.09

Grove	GR14	1.75	26.04	0.65	75.00	3.67	4.19	4.60	5.24	5.40	6.15	6.53	7.45	7.45	8.49	8.37	9.54
Grove	GR15	2.26	26.55	0.65	75.00	3.63	5.35	4.55	6.70	5.34	7.86	6.47	9.52	7.37	10.86	8.29	12.20
Grove	GR16	2.87	27.04	0.65	75.00	3.60	6.72	4.51	8.42	5.29	9.88	6.41	11.97	7.31	13.65	8.21	15.34
Grove	GR17	1.58	25.84	0.65	75.00	3.69	3.79	4.62	4.75	5.42	5.58	6.56	6.75	7.48	7.69	8.40	8.64
Grove	GR18	2.00	26.30	0.45	41.67	3.65	3.29	4.57	4.12	5.37	4.84	6.50	5.86	7.41	6.68	8.33	7.51
Grove	GR19	1.81	26.10	0.80	100.00	3.67	5.31	4.59	6.66	5.39	7.81	6.52	9.46	7.44	10.78	8.36	12.11
Grove	GR20	1.18	25.30	0.65	75.00	3.73	2.86	4.67	3.58	5.48	4.20	6.63	5.09	7.56	5.80	8.49	6.51
Grove	GR21	0.77	24.56	0.35	25.00	3.79	1.03	4.74	1.29	5.56	1.51	6.73	1.83	7.67	2.08	8.61	2.34
Grove	GR22	2.02	26.32	0.35	25.00	3.65	2.58	4.57	3.24	5.37	3.80	6.50	4.60	7.41	5.24	8.32	5.89
Grove	GR23	1.98	26.28	0.65	75.00	3.65	4.70	4.58	5.89	5.37	6.91	6.50	8.36	7.41	9.53	8.33	10.72
Grove	GR24	1.85	26.15	0.65	75.00	3.66	4.41	4.59	5.52	5.39	6.48	6.52	7.84	7.43	8.94	8.35	10.05
Grove	GR25	1.83	26.13	0.30	16.67	3.67	2.02	4.59	2.53	5.39	2.96	6.52	3.59	7.43	4.09	8.35	4.60
Grove	GR26	1.99	26.28	0.45	41.67	3.65	3.27	4.58	4.09	5.37	4.80	6.50	5.81	7.41	6.62	8.33	7.44
Grove	GR27	1.79	26.08	0.30	16.67	3.67	1.97	4.60	2.47	5.39	2.90	6.53	3.51	7.44	4.00	8.36	4.49
Grove	GR28	1.58	25.84	0.30	16.67	3.69	1.75	4.62	2.19	5.42	2.57	6.56	3.12	7.48	3.55	8.40	3.99
Grove	GR29	1.15	25.24	0.65	75.00	3.73	2.78	4.67	3.48	5.48	4.09	6.64	4.94	7.56	5.63	8.50	6.33
Grove	GR30	1.39	25.60	0.45	41.67	3.71	2.32	4.64	2.90	5.44	3.41	6.59	4.13	7.51	4.70	8.44	5.28
Grove	GR31	1.60	25.86	0.55	58.33	3.69	3.24	4.62	4.06	5.42	4.76	6.56	5.76	7.47	6.57	8.40	7.38
Grove	GR32	1.17	25.28	0.45	41.67	3.73	1.96	4.67	2.46	5.48	2.88	6.63	3.49	7.56	3.98	8.49	4.47
Grove	GR33	1.07	25.12	0.30	16.67	3.74	1.20	4.69	1.50	5.50	1.76	6.65	2.13	7.58	2.43	8.52	2.73
Grove	GR34	2.84	27.02	0.30	16.67	3.60	3.07	4.51	3.84	5.29	4.51	6.41	5.46	7.31	6.23	8.22	7.00
Grove	GR35	1.67	25.94	0.30	16.67	3.68	1.84	4.61	2.31	5.41	2.71	6.55	3.28	7.46	3.73	8.38	4.20
Grove	GR36	2.17	26.47	0.30	16.67	3.64	2.37	4.56	2.97	5.35	3.49	6.48	4.23	7.39	4.82	8.30	5.41
Hare	H01	5.23	28.38	0.18	0.00	3.50	3.30	4.39	4.13	5.16	4.85	6.25	5.88	7.13	6.71	8.02	7.54
Hare	H02	0.61	24.17	0.18	0.00	3.82	0.42	4.78	0.53	5.61	0.62	6.79	0.75	7.73	0.85	8.68	0.95
Hare	H03	4.11	27.83	0.18	0.00	3.54	2.62	4.44	3.28	5.21	3.86	6.31	4.67	7.20	5.33	8.10	5.99
Hare	H04	4.00	27.77	0.18	0.00	3.55	2.55	4.44	3.20	5.22	3.76	6.32	4.55	7.21	5.19	8.10	5.84
Hare	H05	3.16	27.24	0.45	41.67	3.58	5.09	4.49	6.38	5.27	7.49	6.38	9.07	7.28	10.34	8.18	11.62
Ingraham	I01	4.44	28.00	0.80	100.00	3.53	12.54	4.42	15.72	5.19	18.46	6.29	22.36	7.18	25.50	8.07	28.68
Ingraham	I02	4.19	27.87	0.80	100.00	3.54	11.88	4.43	14.88	5.21	17.47	6.31	21.17	7.19	24.14	8.09	27.15
Ingraham	I03	3.26	27.31	0.80	100.00	3.58	9.32	4.48	11.68	5.26	13.71	6.37	16.60	7.27	18.93	8.17	21.28
Ingraham	I04	4.26	27.91	0.80	100.00	3.54	12.06	4.43	15.11	5.20	17.74	6.30	21.50	7.19	24.52	8.08	27.57
Ingraham	I05	1.44	25.66	0.80	100.00	3.70	4.26	4.63	5.34	5.44	6.26	6.58	7.58	7.50	8.64	8.43	9.71
Jensen	J01	6.28	28.82	0.45	41.67	3.47	9.82	4.36	12.31	5.11	14.46	6.20	17.52	7.07	19.99	7.95	22.49
Jensen	J02	1.94	26.24	0.80	100.00	3.66	5.69	4.58	7.12	5.37	8.36	6.51	10.12	7.42	11.54	8.34	12.97
Jensen	J03	2.35	26.62	0.35	25.00	3.63	2.98	4.55	3.73	5.33	4.38	6.46	5.30	7.36	6.05	8.28	6.80
Jensen	J04	2.83	27.01	0.45	41.67	3.60	4.59	4.51	5.74	5.29	6.74	6.41	8.17	7.31	9.31	8.22	10.47
Jensen	J05	2.75	26.95	0.35	25.00	3.60	3.47	4.52	4.35	5.30	5.10	6.42	6.18	7.32	7.05	8.23	7.92
Jensen	J06	1.45	25.67	0.55	58.33	3.70	2.94	4.63	3.69	5.44	4.33	6.58	5.24	7.50	5.97	8.43	6.71
Jensen	J07	2.66	26.88	0.55	58.33	3.61	5.28	4.52	6.62	5.31	7.77	6.43	9.41	7.33	10.73	8.24	12.06
Jensen	J08	2.75	26.95	0.55	58.33	3.60	5.45	4.52	6.83	5.30	8.01	6.42	9.71	7.32	11.07	8.23	12.44
Jensen	J09	1.33	25.51	0.55	58.33	3.71	2.71	4.65	3.39	5.45	3.98	6.60	4.81	7.52	5.48	8.45	6.16
Jensen	J10	1.94	26.24	0.65	75.00	3.66	4.61	4.58	5.77	5.38	6.78	6.51	8.20	7.42	9.35	8.34	10.51
Jensen	J11	2.08	26.38	0.65	75.00	3.65	4.93	4.57	6.18	5.36	7.25	6.49	8.78	7.40	10.00	8.31	11.24
Jensen	J12	1.81	26.10	0.45	41.67	3.67	2.98	4.59	3.74	5.39	4.39	6.53	5.31	7.44	6.05	8.36	6.80
Jensen	J13	2.43	26.70	0.65	75.00	3.62	5.73	4.54	7.18	5.33	8.43	6.45	10.20	7.35	11.63	8.27	13.07
Jensen	J14	2.52	26.77	0.80	100.00	3.62	7.29	4.53	9.13	5.32	10.71	6.44	12.97	7.34	14.79	8.25	16.62
Jensen	J15	3.18	27.26	0.45	41.67	3.58	5.12	4.49	6.41	5.27	7.53	6.38	9.12	7.28	10.40	8.18	11.69
LYONS	L001	3.94	27.73	0.45	41.67	3.55	6.30	4.45	7.89	5.22	9.26	6.32	11.22	7.21	12.79	8.11	14.39
LYONS	L002	1.36	25.56	0.45	41.67	3.71	2.28	4.64	2.85	5.45	3.34	6.60	4.05	7.52	4.61	8.45	5.18
LYONS	L003	4.01	27.77	0.45	41.67	3.55	6.40	4.44	8.02	5.22	9.42	6.32	11.41	7.21	13.01	8.10	14.63
LYONS	L004	2.86	27.03	0.45	41.67	3.60	4.63	4.51	5.80	5.29	6.81	6.41	8.24	7.31	9.40	8.21	10.57
LYONS	L005	2.75	26.95	0.45	41.67	3.60	4.47	4.52	5.60	5.30	6.57	6.42	7.96	7.32	9.07	8.23	10.20
LYONS	L006	1.60	25.87	0.45	41.67	3.68	2.66	4.62	3.33	5.42	3.91	6.56	4.73	7.47	5.39	8.40	6.06
LYONS	L007	3.29	27.33	0.80	100.00	3.58	9.41	4.48	11.79	5.26	13.84	6.37	16.76	7.27	19.11	8.17	21.49
LYONS	L008	1.82	26.12	0.80	100.00	3.67	5.35	4.59	6.70	5.39	7.86	6.52	9.52	7.44	10.85	8.36	12.19
LYONS	L009	1.62	25.88	0.80	100.00	3.68	4.77	4.61	5.97	5.41	7.00	6.55	8.48	7.47	9.66	8.39	10.86
LYONS	L010	2.21	26.50	0.45	41.67	3.64	3.62	4.56	4.53	5.35	5.32	6.47	6.44	7.38	7.34	8.30	8.25
LYONS	L011	0.81	24.63	0.45	41.67	3.78	1.38	4.74	1.72	5.55	2.02	6.72	2.45	7.66	2.79	8.60	3.13
LYONS	L012	7.44	29.24	0.80	100.00	3.45	20.52	4.32	25.73	5.08	30.21	6.15	36.62	7.02	41.79	7.90	47.01
MARKET	M00	4.94	28.25	0.45	41.67	3.51	7.82	4.40	9.80	5.17	11.50	6.26	13.94	7.15	15.90	8.04	17.88
MARKET	M01	2.09	26.38	0.45	41.67	3.65	3.42	4.57	4.29	5.36	5.03	6.49	6.10	7.40	6.95	8.31	7.81
MARKET	M02	2.58	26.82	0.45	41.67	3.61	4.20	4.53	5.26	5.31	6.18	6.43	7.48	7.34	8.53	8.25	9.59
MARKET	M03	3.16	27.25	0.45	41.67	3.58	5.10	4.49	6.39	5.27	7.50	6.38	9.09	7.28	10.36	8.18	11.65
MARKET	M04	1.36	25.55	0.45	41.67	3.71	2.26	4.65	2.84	5.45	3.33	6.60	4.03	7.52	4.59	8.45	5.16
MARKET	M05	0.79	24.60	0.45	41.67	3.79	1.35	4.74	1.69	5.56	1.98	6.73	2.40	7.66	2.73	8.61	3.07
MARKET	M06	1.43	25.65	0.55	58.33	3.70	2.92	4.64	3.65	5.44	4.29	6.58	5.19	7.50	5.91	8.43	6.65
MARKET	M07	1.40	25.60	0.55	58.33	3.71	2.84	4.64	3.56	5.44	4.18	6.59	5.06	7.51	5.76	8.44	6.48
MARKET	M08	2.20	26.49	0.45	41.67	3.64	3.61	4.56	4.52	5.35	5.30	6.48	6.42	7.38	7.32	8.30	8.23
MARKET	M09	1.54	25.79	0.45	41.67	3.69	2.56	4.62	3.20	5.42	3.76	6.57	4.55	7.48	5.18	8.41	5.82
MARKET	M10	2.75	26.95	0.45	41.67	3.60	4.46	4.52	5.59	5.30	6.56	6.42	7.95	7.32	9.06	8.23	10.18
MARKET	M11	1.95	26.25	0.45	41.67	3.66	3.21	4.58	4.02	5.37	4.72	6.51	5.72	7.42	6.52	8.33	7.33
MARKET	M12	2.29	26.57	0.35	25.00	3.63	2.91	4.55	3.64	5.34	4.27	6.47	5.18	7.37	5.90	8.29	6.63
MARKET	M13	1.44	25.66	0.55	58.33	3.70	2.93	4.63	3.66	5.44	4.30	6.58	5.20	7.50	5.93	8.43	6.66
MARKET	M14	1.51	25.75	0.45	41.67	3.69	2.51	4.63	3.14	5.43	3.69	6.57	4.47	7.49	5.09	8.41	5.72
MARKET	M15	4.24	27.90	0.45	41.67	3.54	6.75	4.43	8.46	5.20	9.93	6.30	12.03	7.19	13.73	8.09	15.43
MARKET	M16	2.30	26.58	0.45	41.67	3.63	3.76	4.55	4.71	5.34	5.52	6.46	6.69	7.37	7.62	8.28	8.57
MARKET	M17	2.33	26.61	0.35	25.00	3.63	2.96	4.55	3.71	5.34	4.35	6.46	5.27	7.37	6.01	8.28	6.75
MARKET	M18	12.01	30.49	0.80	100.00	3.37	32.36	4.22	40.58	4.96	47.68	6.02	57.82	6.87	66.01	7.73	74.29
ORANGE	O001	6.53	28.91	0.45	41.67	3.47	10.19	4.35	12.77	5.11	15.00	6.19	18.18	7.06	20.74	7.94	23.33
ORANGE	O002	4.59	28.08	0.45	41.67	3.52	7.28	4.42	9.13	5.19	10.72	6.28	12.98	7.17	14.81	8.06	16.66
ORANGE	O003	1.30	25.48	0.45	41.67	3.72	2.18	4.65	2.73	5.46	3.20	6.61	3.88	7.53	4.42	8.46	4.96
ORANGE	O004	1.47	25.70	0.45	41.67	3.70	2.44	4.63	3.06	5.43	3.59	6.58	4.34	7.50	4.95	8.42	5.56
ORANGE	O005	1.69	25.97	0.45	41.67	3.68	2.80	4.61	3.51	5.40	4.12	6.54	4.99	7.46	5.69	8.38	6.39
ORANGE	O006	0.65	24.26	0.45	41.67	3.81	1.11	4.77	1.39	5.60	1.63	6.77	1.97	7.72	2.24	8.66	2.52
ORANGE	O007	1.81	26.10	0.45	41.67	3.67	2.98	4.59	3.74	5.39	4.39	6.53	5.31	7.44	6.05	8.36	6.80
ORANGE	O008	2.89	27.06	0.45	41.67	3.60	4.68	4.51	5.87	5.29	6.89	6.41	8.34	7.30	9.51	8.21	10.69
ORANGE	O009	2.25	26.54	0.45	41.67	3.63	3.69	4.55	4.62	5.34	5.42	6.47	6.56	7.38	7.48	8.29	8.41
ORANGE	O010	1.98	26.28	0.45	41.67	3.65	3.25	4.58	4.07	5.37	4.78	6.50	5.78	7.41	6.59	8.33	7.41
ORANGE	O011	1.99	26.29	0.45	41.67	3.65	3.27	4.58	4.09	5.37	4.81	6.50	5.82	7.41	6.63	8.33	7.45

ORANGE	O012	2.00	26.30	0.45	41.67	3.65	3.28	4.58	4.11	5.37	4.83	6.50	5.84	7.41	6.66	8.33	7.49
ORANGE	O013	1.89	26.18	0.45	41.67	3.66	3.11	4.59	3.89	5.38	4.57	6.51	5.53	7.43	6.31	8.35	7.09
PANNELL	P001	1.27	25.43	0.45	41.67	3.72	2.13	4.66	2.67	5.46	3.13	6.61	3.79	7.54	4.32	8.47	4.85
PANNELL	P002	2.64	26.86	0.45	41.67	3.61	4.29	4.52	5.37	5.31	6.31	6.43	7.64	7.33	8.71	8.24	9.79
PANNELL	P003	1.95	26.25	0.45	41.67	3.66	3.21	4.58	4.02	5.37	4.71	6.51	5.71	7.42	6.50	8.34	7.31
PANNELL	P004	0.68	24.34	0.45	41.67	3.81	1.16	4.77	1.45	5.59	1.70	6.76	2.06	7.70	2.35	8.65	2.63
PANNELL	P005	0.97	24.94	0.45	41.67	3.76	1.63	4.70	2.04	5.52	2.40	6.68	2.90	7.61	3.31	8.55	3.71
PANNELL	P006	1.35	25.55	0.45	41.67	3.71	2.26	4.65	2.83	5.45	3.32	6.60	4.02	7.52	4.58	8.45	5.15
PANNELL	P007	1.22	25.36	0.45	41.67	3.72	2.05	4.66	2.56	5.47	3.01	6.62	3.64	7.55	4.15	8.48	4.66
PANNELL	P008	4.30	27.93	0.45	41.67	3.54	6.84	4.43	8.57	5.20	10.06	6.30	12.19	7.19	13.90	8.08	15.64
PANNELL	P009	2.84	27.02	0.45	41.67	3.60	4.60	4.51	5.77	5.29	6.77	6.41	8.20	7.31	9.35	8.22	10.51
PANNELL	P010	0.99	24.98	0.45	41.67	3.75	1.67	4.70	2.09	5.51	2.45	6.67	2.96	7.60	3.38	8.54	3.79
PANNELL	P011	3.12	27.22	0.45	41.67	3.59	5.04	4.49	6.31	5.27	7.41	6.39	8.97	7.28	10.23	8.19	11.50
PANNELL	P012	2.65	26.87	0.45	41.67	3.61	4.30	4.52	5.38	5.31	6.32	6.43	7.65	7.33	8.73	8.24	9.81
PANNELL	P013	2.09	26.38	0.45	41.67	3.65	3.43	4.57	4.29	5.36	5.04	6.49	6.10	7.40	6.95	8.31	7.81
PANNELL	P014	3.86	27.68	0.45	41.67	3.55	6.17	4.45	7.73	5.23	9.08	6.33	10.99	7.22	12.54	8.12	14.10
PANNELL	P015	2.23	26.52	0.45	41.67	3.64	3.65	4.55	4.57	5.35	5.36	6.47	6.49	7.38	7.40	8.29	8.32
PANNELL	P016	2.66	26.88	0.45	41.67	3.61	4.32	4.52	5.41	5.31	6.35	6.43	7.69	7.33	8.77	8.24	9.86
PANNELL	P017	2.68	26.89	0.45	41.67	3.61	4.35	4.52	5.45	5.31	6.39	6.43	7.74	7.33	8.83	8.23	9.92
PANNELL	P018	3.38	27.39	0.45	41.67	3.57	5.43	4.48	6.80	5.26	7.99	6.36	9.67	7.26	11.03	8.16	12.40
PANNELL	P019	2.43	26.69	0.45	41.67	3.62	3.97	4.54	4.97	5.33	5.83	6.45	7.06	7.35	8.05	8.27	9.05
PANNELL	P020	2.35	26.62	0.45	41.67	3.63	3.83	4.55	4.80	5.33	5.64	6.46	6.83	7.36	7.78	8.28	8.75
PANNELL	P021	2.29	26.57	0.45	41.67	3.63	3.75	4.55	4.69	5.34	5.51	6.47	6.67	7.37	7.61	8.28	8.55
PANNELL	P022	2.28	26.57	0.45	41.67	3.63	3.73	4.55	4.68	5.34	5.49	6.47	6.64	7.37	7.58	8.29	8.51
PANNELL	P023	4.37	27.97	0.45	41.67	3.53	6.95	4.43	8.71	5.20	10.22	6.30	12.38	7.18	14.13	8.08	15.88
PANNELL	P024	1.70	25.98	0.45	41.67	3.68	2.81	4.60	3.52	5.40	4.13	6.54	5.00	7.46	5.70	8.38	6.41
PANNELL	P025	1.13	25.22	0.45	41.67	3.73	1.91	4.68	2.39	5.49	2.80	6.64	3.39	7.57	3.86	8.50	4.34
PANNELL	P026	1.38	25.58	0.45	41.67	3.71	2.30	4.64	2.88	5.45	3.38	6.59	4.09	7.51	4.66	8.44	5.24
PANNELL	P027	4.40	27.98	0.45	41.67	3.53	6.99	4.43	8.76	5.20	10.29	6.29	12.46	7.18	14.22	8.07	15.99
PANNELL	P028	2.13	26.43	0.45	41.67	3.64	3.49	4.56	4.38	5.36	5.14	6.48	6.22	7.39	7.09	8.31	7.97
PANNELL	P029	4.03	27.78	0.45	41.67	3.55	6.42	4.44	8.05	5.22	9.45	6.32	11.45	7.21	13.05	8.10	14.68
PANNELL	P030	1.18	25.29	0.45	41.67	3.73	1.98	4.67	2.48	5.48	2.91	6.63	3.52	7.56	4.01	8.49	4.50
PANNELL	P031	2.08	26.37	0.45	41.67	3.65	3.41	4.57	4.27	5.36	5.01	6.49	6.06	7.40	6.91	8.32	7.77
PANNELL	P032	2.56	26.80	0.45	41.67	3.62	4.17	4.53	5.22	5.32	6.13	6.44	7.42	7.34	8.46	8.25	9.51
PANNELL	P033	3.68	27.58	0.45	41.67	3.56	5.89	4.46	7.38	5.24	8.66	6.34	10.49	7.23	11.97	8.13	13.46
PANNELL	P034	5.49	28.50	0.45	41.67	3.50	8.64	4.38	10.83	5.15	12.72	6.24	15.41	7.11	17.58	8.00	19.77
PANNELL	P035	1.82	26.12	0.45	41.67	3.67	3.01	4.59	3.77	5.39	4.42	6.52	5.36	7.44	6.10	8.36	6.86
PANNELL	P036	1.31	25.49	0.45	41.67	3.71	2.20	4.65	2.75	5.46	3.23	6.60	3.91	7.53	4.45	8.46	5.00
PANNELL	P037	5.05	28.30	0.45	41.67	3.51	7.98	4.40	10.00	5.16	11.74	6.26	14.22	7.14	16.23	8.03	18.25
PANNELL	P038	26.72	32.83	0.45	41.67	3.23	38.84	4.05	48.75	4.77	57.32	5.79	69.57	6.61	79.48	7.45	89.53
PANNELL	P039	4.92	28.24	0.45	41.67	3.51	7.78	4.40	9.75	5.17	11.45	6.26	13.87	7.15	15.82	8.04	17.79
PANNELL	P040	2.35	26.62	0.45	41.67	3.63	3.83	4.55	4.80	5.33	5.63	6.46	6.82	7.36	7.77	8.28	8.74
PANNELL	P041	2.73	26.93	0.45	41.67	3.61	4.43	4.52	5.54	5.30	6.51	6.42	7.88	7.32	8.99	8.23	10.10
PANNELL	P042	12.32	30.56	0.55	58.33	3.36	22.80	4.22	28.59	4.96	33.60	6.01	40.74	6.86	46.51	7.72	52.35
PANNELL	P043	4.24	27.90	0.45	41.67	3.54	6.75	4.43	8.46	5.20	9.93	6.30	12.04	7.19	13.73	8.09	15.44
PANNELL	P044	3.60	27.53	0.45	41.67	3.56	5.77	4.46	7.23	5.24	8.49	6.35	10.29	7.24	11.73	8.14	13.19
PANNELL	P046	3.54	27.50	0.45	41.67	3.57	5.69	4.47	7.13	5.24	8.36	6.35	10.13	7.24	11.55	8.14	12.99
PANNELL	P047	4.87	28.21	0.45	41.67	3.52	7.70	4.41	9.65	5.17	11.33	6.27	13.72	7.15	15.65	8.04	17.60
PANNELL	P048	8.12	29.46	0.45	41.67	3.43	12.54	4.30	15.72	5.06	18.47	6.13	22.38	6.99	25.55	7.87	28.74
PANNELL	P049	11.21	30.30	0.45	41.67	3.38	17.04	4.24	21.37	4.98	25.11	6.04	30.45	6.89	34.76	7.76	39.12
PANNELL	P050	5.19	28.37	0.45	41.67	3.51	8.19	4.39	10.27	5.16	12.06	6.25	14.61	7.13	16.67	8.02	18.74
PANNELL	P051	2.52	26.77	0.45	41.67	3.62	4.10	4.53	5.13	5.32	6.03	6.44	7.30	7.34	8.32	8.25	9.35
PANNELL	P052	2.07	26.37	0.45	41.67	3.65	3.40	4.57	4.26	5.36	5.00	6.49	6.05	7.40	6.90	8.32	7.75
PANNELL	P053	4.30	27.93	0.45	41.67	3.54	6.84	4.43	8.57	5.20	10.06	6.30	12.19	7.19	13.90	8.08	15.63
PANNELL	P059	4.78	28.17	0.45	41.67	3.52	7.57	4.41	9.48	5.18	11.13	6.27	13.49	7.16	15.39	8.05	17.30
PANNELL	P060	3.35	27.37	0.45	41.67	3.57	5.38	4.48	6.75	5.26	7.92	6.37	9.59	7.26	10.94	8.16	12.30
PANNELL	P061	2.50	26.75	0.45	41.67	3.62	4.08	4.53	5.11	5.32	6.00	6.44	7.26	7.35	8.28	8.26	9.31
PANNELL	P062	1.03	25.05	0.45	41.67	3.75	1.74	4.69	2.18	5.51	2.55	6.66	3.09	7.59	3.52	8.53	3.96
PANNELL	P063	21.10	32.11	0.55	58.33	3.27	37.97	4.11	47.65	4.83	56.01	5.86	67.96	6.69	77.63	7.53	87.42
PANNELL	P064	3.52	27.48	0.45	41.67	3.57	5.65	4.47	7.09	5.25	8.32	6.35	10.07	7.25	11.49	8.15	12.92
PANNELL	P065	2.07	26.37	0.45	41.67	3.65	3.40	4.57	4.26	5.36	5.00	6.49	6.05	7.40	6.90	8.32	7.75
PANNELL	P066	1.29	25.46	0.45	41.67	3.72	2.16	4.65	2.71	5.46	3.18	6.61	3.85	7.53	4.39	8.46	4.93
PANNELL	P067	1.08	25.14	0.55	58.33	3.74	2.23	4.68	2.79	5.50	3.28	6.65	3.96	7.58	4.52	8.51	5.07
PANNELL	P068	1.07	25.12	0.55	58.33	3.74	2.20	4.69	2.75	5.50	3.23	6.65	3.91	7.58	4.45	8.52	5.00
PANNELL	P069	2.21	26.49	0.45	41.67	3.64	3.61	4.56	4.52	5.35	5.31	6.48	6.43	7.38	7.33	8.30	8.24
PANNELL	P070	3.37	27.39	0.55	58.33	3.57	6.63	4.48	8.31	5.26	9.75	6.37	11.81	7.26	13.47	8.16	15.15
PANNELL	P071	1.89	26.18	0.45	41.67	3.66	3.11	4.59	3.90	5.38	4.57	6.51	5.53	7.43	6.31	8.35	7.09
PANNELL	P072	7.92	29.40	0.45	41.67	3.44	12.26	4.31	15.37	5.06	18.05	6.13	21.88	7.00	24.97	7.88	28.09
PANNELL	P073	39.47	34.10	0.55	58.33	3.16	68.63	3.97	86.18	4.67	101.37	5.67	123.09	6.48	140.70	7.30	158.56
SUMPTER	S001	18.02	31.64	0.45	41.67	3.30	26.74	4.14	33.56	4.86	39.44	5.90	47.84	6.74	54.64	7.59	61.52
SUMPTER	S002	3.85	27.68	0.45	41.67	3.55	6.15	4.45	7.71	5.23	9.05	6.33	10.96	7.22	12.50	8.12	14.05
SUMPTER	S003	1.85	26.14	0.45	41.67	3.66	3.05	4.59	3.82	5.39	4.48	6.52	5.42	7.43	6.18	8.35	6.95
SUMPTER	S004	3.55	27.50	0.45	41.67	3.57	5.69	4.47	7.13	5.24	8.37	6.35	10.13	7.24	11.56	8.14	12.99
SUMPTER	S005	3.50	27.47	0.45	41.67	3.57	5.62	4.47	7.05	5.25	8.27	6.36	10.02	7.25	11.43	8.15	12.85
SUMPTER	S008	9.50	29.86	0.45	41.67	3.41	14.56	4.27	18.25	5.02	21.44	6.08	26.00	6.94	29.67	7.81	33.39
SUMPTER	S009	5.09	28.32	0.45	41.67	3.51	8.03	4.40	10.07	5.16	11.82	6.26	14.32	7.14	16.34	8.03	18.37
SUMPTER	S010	5.04	28.30	0.45	41.67	3.51	7.97	4.40	9.99	5.17	11.73	6.26	14.21	7.14	16.21	8.03	18.23
SUMPTER	S012	3.22	27.29	0.45	41.67	3.58	5.18	4.49	6.50	5.27	7.63	6.38	9.24	7.27	10.53	8.18	11.84
SUMPTER	S013	2.39	26.66	0.45	41.67	3.63	3.91	4.54	4.89	5.33	5.74	6.45	6.95	7.36	7.93	8.27	8.91
SUMPTER	S014	2.78	26.97	0.45	41.67	3.60	4.50	4.51	5.64	5.30	6.62	6.42	8.02	7.32	9.15	8.22	10.28
SUMPTER	S015	2.17	26.46	0.45	41.67	3.64	3.55	4.56	4.44	5.35	5.22	6.48	6.32	7.39	7.20	8.30	8.09
SUMPTER	S016	5.30	28.41	0.45	41.67	3.50	8.35	4.39	10.46	5.15	12.28	6.24	14.88	7.12	16.98	8.01	19.09
SUMPTER	S017	3.23	27.29	0.45	41.67	3.58	5.20	4.49	6.52	5.26	7.65	6.38	9.27	7.27	10.57	8.17	11.88
SUMPTER	S018	3.63	27.55	0.45	41.67	3.56	5.81	4.46	7.28	5.24	8.55	6.35	10.36	7.24	11.81	8.14	13.28
SUMPTER	S020	6.90	29.05	0.45	41.67	3.46	10.73	4.34	13.46	5.09	15.80	6.17	19.15	7.04	21.86	7.92	24.59
SUMPTER	S021	3.16	27.25	0.45	41.67	3.58	5.10	4.49	6.38	5.27	7.49	6.38	9.08	7.28	10.35	8.18	11.63
SUMPTER	S022	5.54	28.52	0.45	41.67	3.49	8.71	4.38	10.91	5.14	12.82	6.23	15.53	7.11	17.72	8.00	19.93
SUMPTER	S023	1.38	25.58	0.45	41.67	3.71	2.30	4.64	2.88	5.45	3.38	6.59	4.09	7.51	4.67	8.44	5.24
SUMPTER	S024	3.10	27.21	0.45	41.67	3.59	5.01	4.49	6.28	5.27	7.37	6.39	8.92	7.28	10.17	8.19	11.44
SUMPTER	S025	2.89	27.06	0.45	41.67	3.60	4.68	4.51	5.86	5.29	6.88	6.41	8.33	7.30	9.50	8.21	10.68

SUMPTER	S026	2.70	26.91	0.45	41.67	3.61	4.38	4.52	5.49	5.30	6.44	6.42	7.80	7.32	8.90	8.23	10.00
SUMPTER	S027	2.54	26.78	0.45	41.67	3.62	4.13	4.53	5.17	5.32	6.07	6.44	7.35	7.34	8.38	8.25	9.42
SUMPTER	S028	2.20	26.49	0.45	41.67	3.64	3.60	4.56	4.51	5.35	5.30	6.48	6.41	7.38	7.31	8.30	8.22
SUMPTER	S029	2.46	26.72	0.45	41.67	3.62	4.02	4.54	5.03	5.32	5.90	6.45	7.15	7.35	8.15	8.26	9.16
SUMPTER	S030	1.50	25.75	0.45	41.67	3.69	2.50	4.63	3.13	5.43	3.67	6.57	4.45	7.49	5.07	8.42	5.70
SUMPTER	S031	2.07	26.36	0.45	41.67	3.65	3.39	4.57	4.25	5.36	4.99	6.49	6.04	7.40	6.88	8.32	7.74
SUMPTER	S032	1.89	26.19	0.45	41.67	3.66	3.12	4.58	3.91	5.38	4.59	6.51	5.55	7.43	6.33	8.34	7.11
SUMPTER	S033	2.52	26.77	0.45	41.67	3.62	4.10	4.53	5.14	5.32	6.03	6.44	7.31	7.34	8.33	8.25	9.36
SUMPTER	S034	4.85	28.21	0.45	41.67	3.52	7.67	4.41	9.62	5.17	11.29	6.27	13.68	7.15	15.60	8.04	17.55
SUMPTER	S036	13.03	30.72	0.45	41.67	3.35	19.66	4.21	24.66	4.94	28.98	5.99	35.14	6.84	40.12	7.70	45.16
SUMPTER	S040	1.51	25.75	0.45	41.67	3.69	2.51	4.63	3.14	5.43	3.69	6.57	4.47	7.49	5.09	8.41	5.72
SUMPTER	S041	1.88	26.18	0.45	41.67	3.66	3.10	4.59	3.88	5.38	4.55	6.52	5.51	7.43	6.28	8.35	7.06
SUMPTER	S044	8.74	29.65	0.30	16.67	3.42	8.97	4.29	11.25	5.04	13.21	6.11	16.02	6.97	18.28	7.84	20.57
SUMPTER	S046	3.38	27.39	0.45	41.67	3.57	5.44	4.48	6.81	5.25	7.99	6.36	9.68	7.26	11.04	8.16	12.41
SUMPTER	S047	2.14	26.43	0.30	16.67	3.64	2.34	4.56	2.93	5.35	3.43	6.48	4.16	7.39	4.74	8.31	5.33
SUMPTER	S048	2.21	26.50	0.45	41.67	3.64	3.62	4.56	4.53	5.35	5.32	6.47	6.44	7.38	7.34	8.30	8.25
SUMPTER	S049	9.54	29.88	0.45	41.67	3.41	14.62	4.27	18.33	5.02	21.53	6.08	26.10	6.94	29.80	7.81	33.53
SUMPTER	S053	2.08	26.37	0.45	41.67	3.65	3.41	4.57	4.27	5.36	5.01	6.49	6.06	7.40	6.91	8.32	7.77
SUMPTER	S055	15.29	31.17	0.30	16.67	3.33	15.26	4.17	19.15	4.90	22.50	5.95	27.29	6.79	31.16	7.65	35.08
SUMPTER	S058	4.79	28.18	0.45	41.67	3.52	7.58	4.41	9.50	5.18	11.15	6.27	13.51	7.15	15.41	8.05	17.33
SUMPTER	S060	4.79	28.18	0.45	41.67	3.52	7.59	4.41	9.51	5.18	11.16	6.27	13.53	7.15	15.43	8.05	17.35
SUMPTER	S062	4.80	28.18	0.45	41.67	3.52	7.59	4.41	9.52	5.18	11.17	6.27	13.54	7.15	15.44	8.05	17.36
SUMPTER	S064	7.08	29.11	0.45	41.67	3.46	11.00	4.33	13.80	5.09	16.20	6.17	19.64	7.04	22.41	7.91	25.21
SUMPTER	S065	6.90	29.05	0.45	41.67	3.46	10.74	4.34	13.47	5.09	15.82	6.17	19.17	7.04	21.87	7.92	24.60
SUMPTER	S066	11.49	30.37	0.45	41.67	3.38	17.45	4.23	21.88	4.97	25.71	6.03	31.17	6.88	35.59	7.75	40.05
US59	U001	7.36	29.21	0.65	75.00	3.45	16.50	4.32	20.68	5.08	24.29	6.15	29.44	7.02	33.60	7.90	37.79
US59	U002	3.26	27.32	0.65	75.00	3.58	7.59	4.48	9.51	5.26	11.16	6.37	13.52	7.27	15.42	8.17	17.33
US59	U003	23.61	32.45	0.45	41.67	3.25	34.55	4.08	43.36	4.80	50.98	5.82	61.87	6.65	70.68	7.49	79.60
US59	U009	25.03	32.63	0.45	41.67	3.24	36.51	4.07	45.82	4.78	53.87	5.81	65.38	6.63	74.69	7.47	84.13
WACO	W01	216.20	40.77	0.55	58.33	2.85	338.74	3.59	426.36	4.23	502.53	5.15	611.81	5.89	700.79	6.66	791.70



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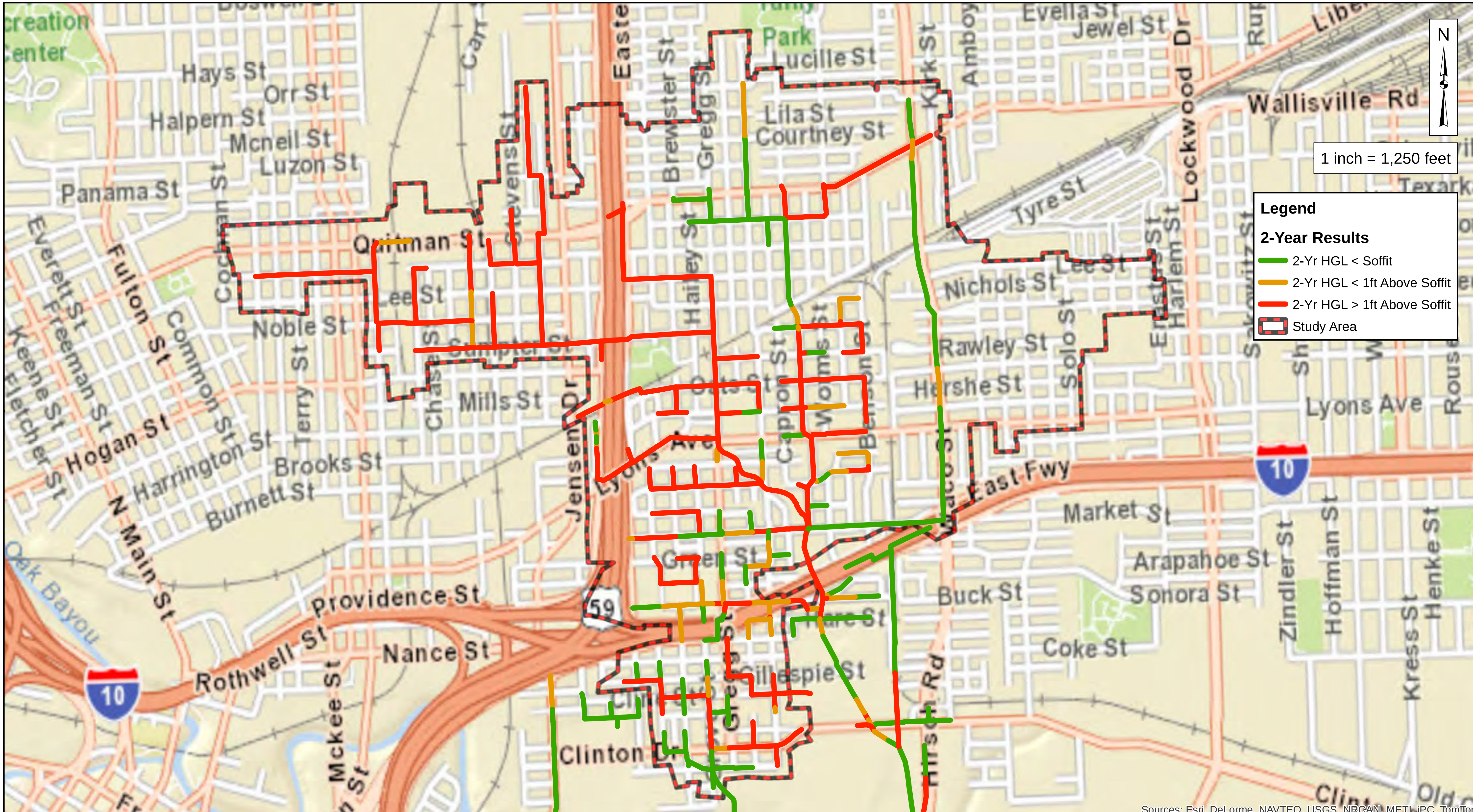
www.cobbfendley.com

5th Ward Drainage Masterplan
Effective FEMA Floodplain Boundaries

Date: April 2020

EXHIBIT 4



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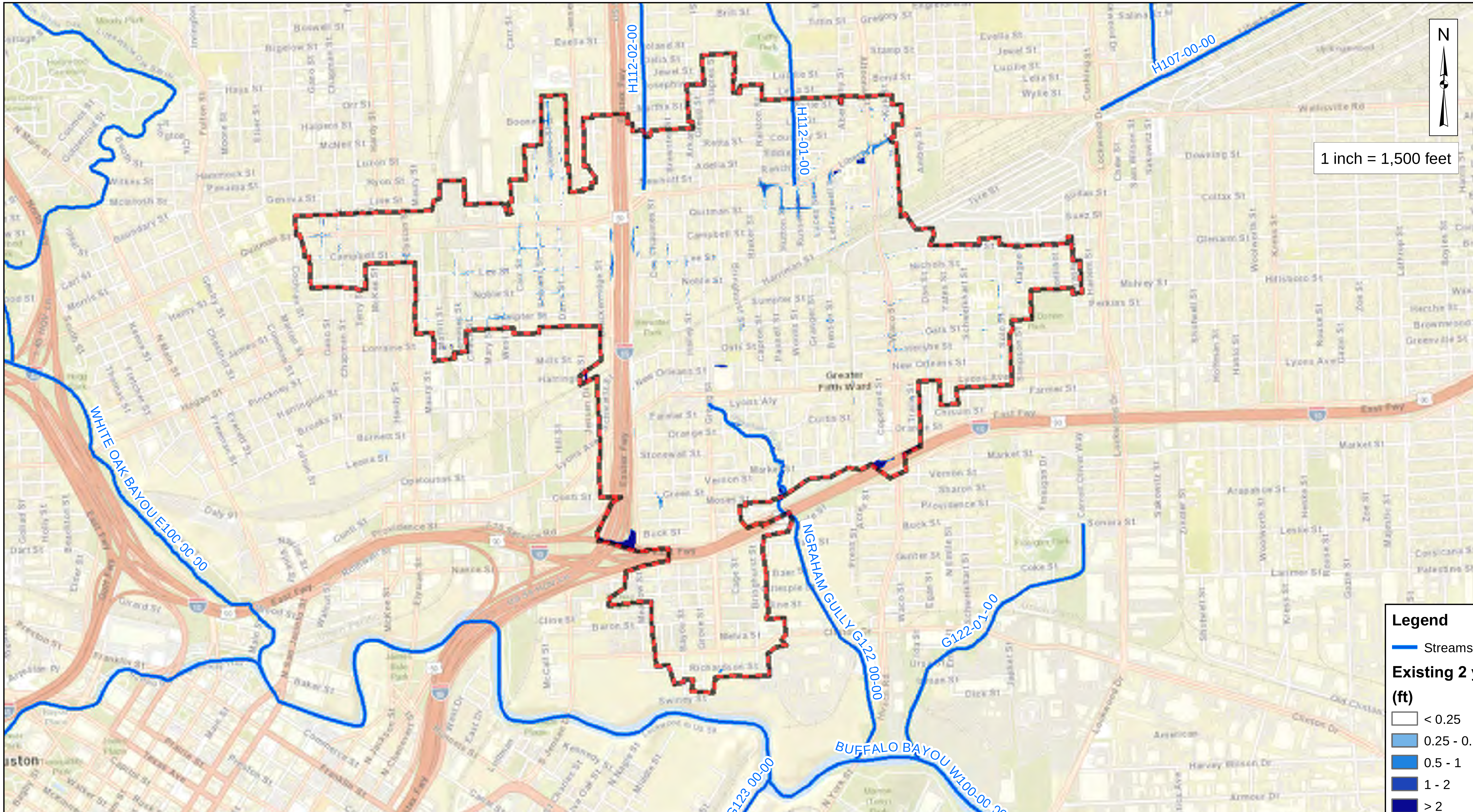
5th Ward Drainage Masterplan
Existing Condition Storm Sewer Layout

Date: May 2020	**EXHIBIT 5**



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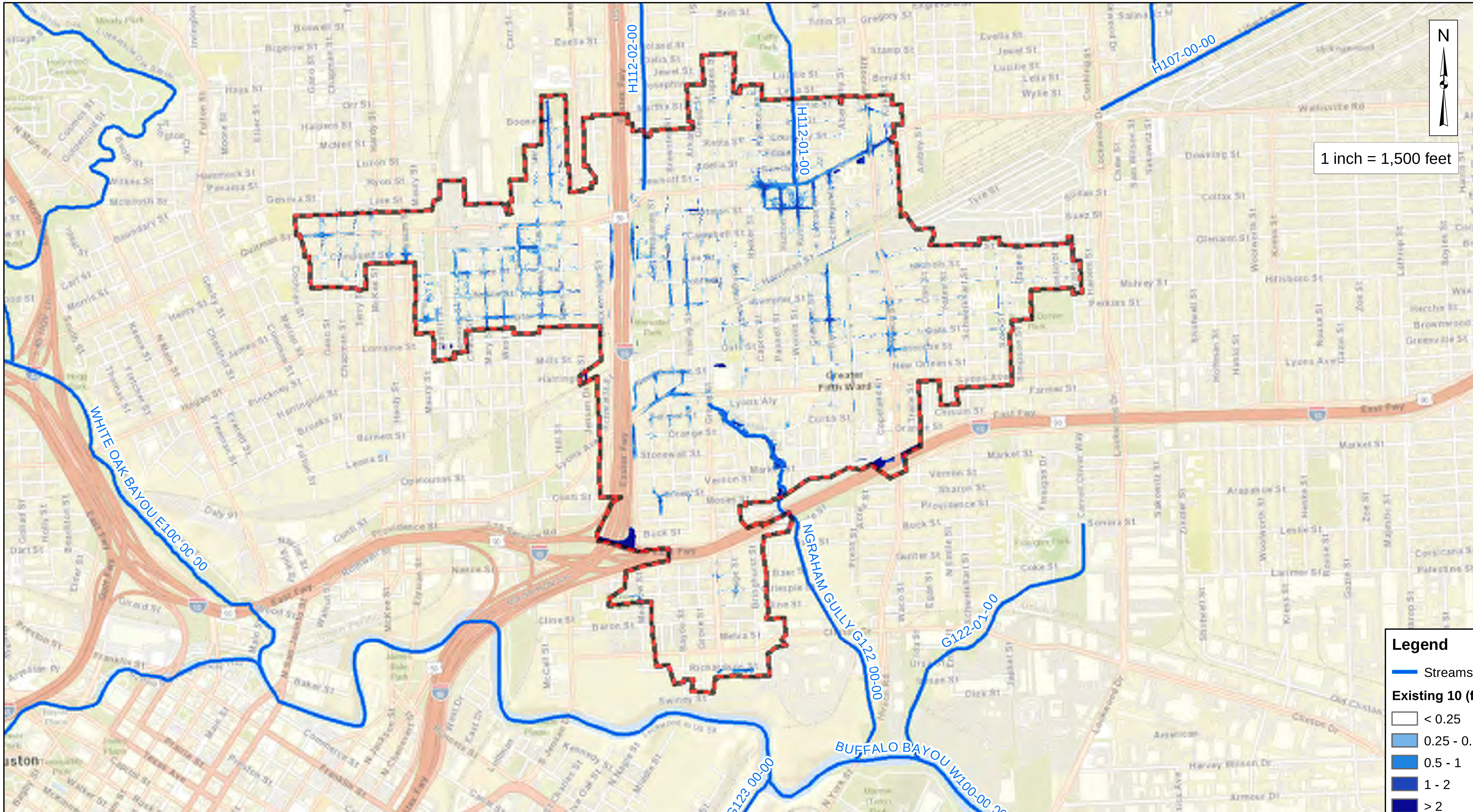
5th Ward Drainage Masterplan
Existing 2 year

Date: Sept ember 2020	EXHIBIT 6A



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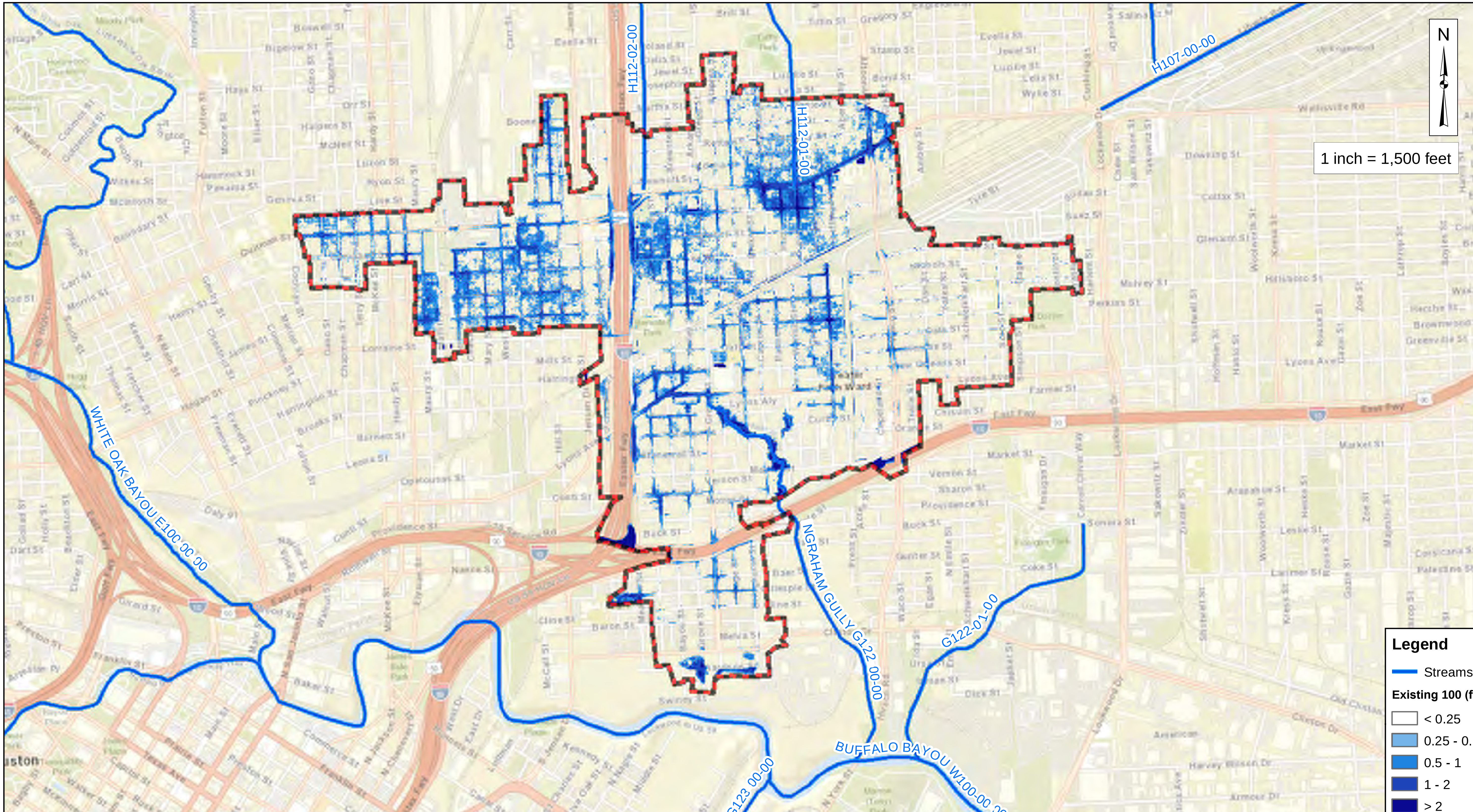
5th Ward Drainage Masterplan
Existing 10 year

Date: September 2020	**EXHIBIT 6B**



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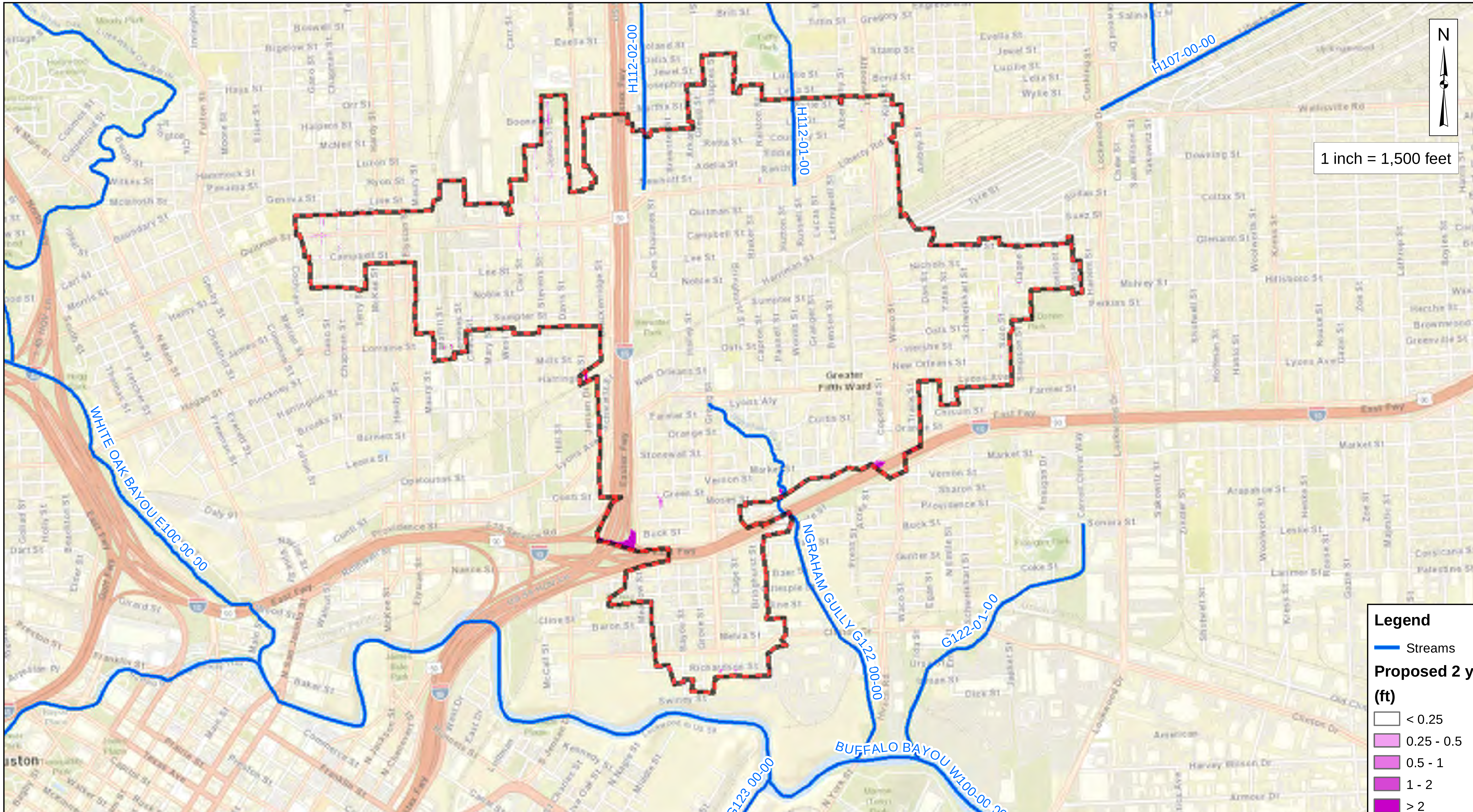
5th Ward Drainage Masterplan
Existing 100 year

Date: September 2020

EXHIBIT 6C



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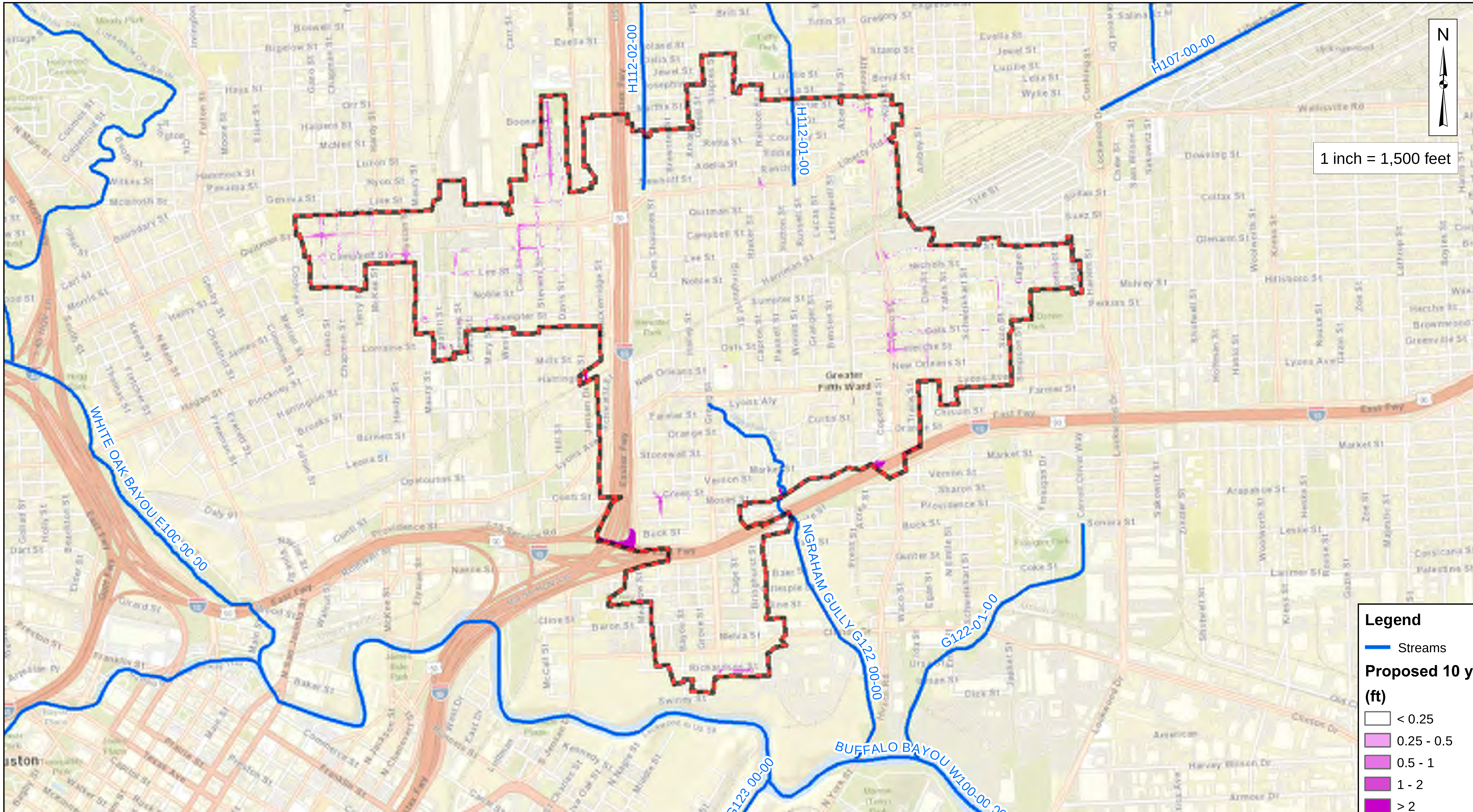
5th Ward Drainage Masterplan
Proposed 2 year

Date: September 2020	EXHIBIT 7A



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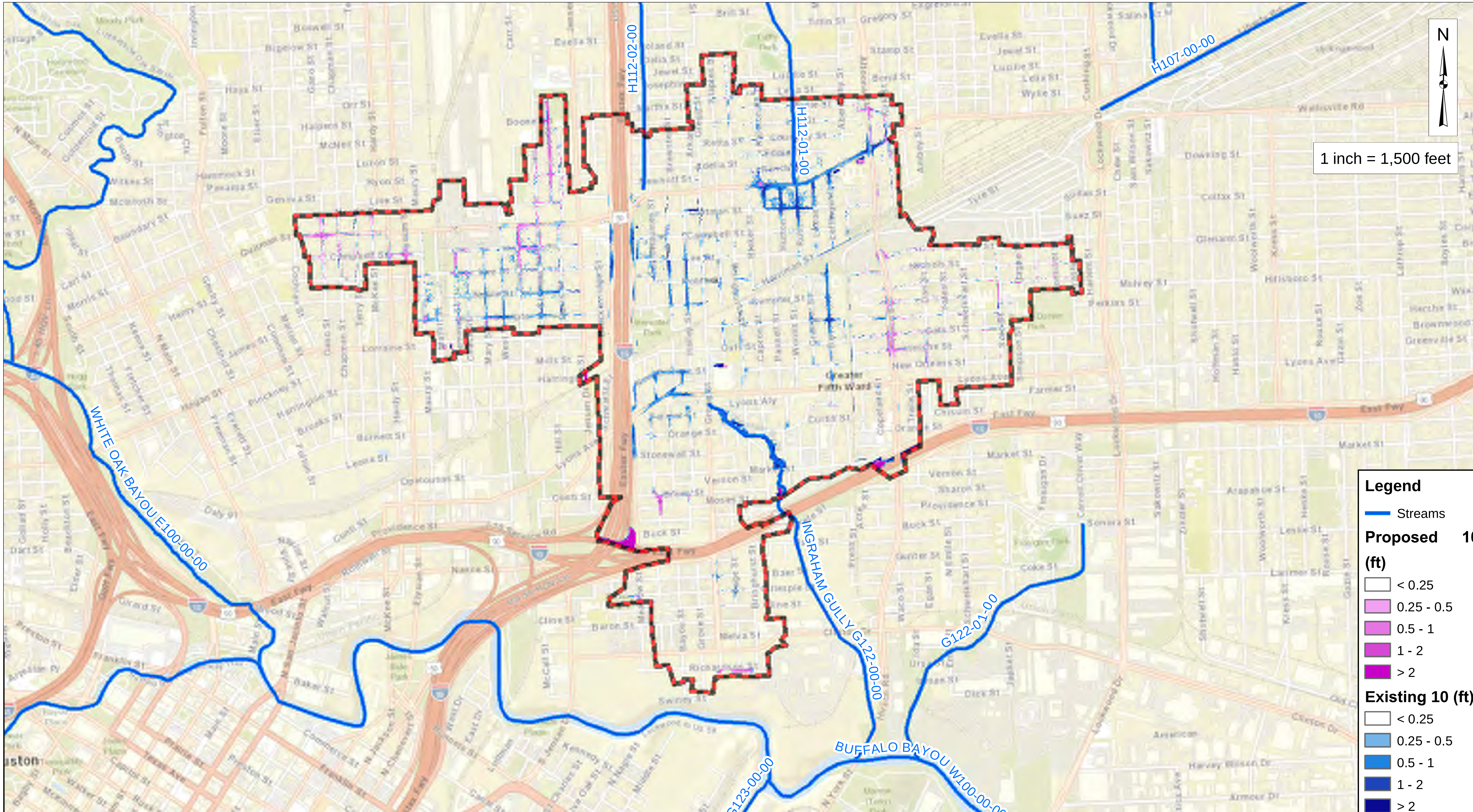
5th Ward Drainage Masterplan
Proposed 10 year

Date: September 2020

EXHIBIT 7B



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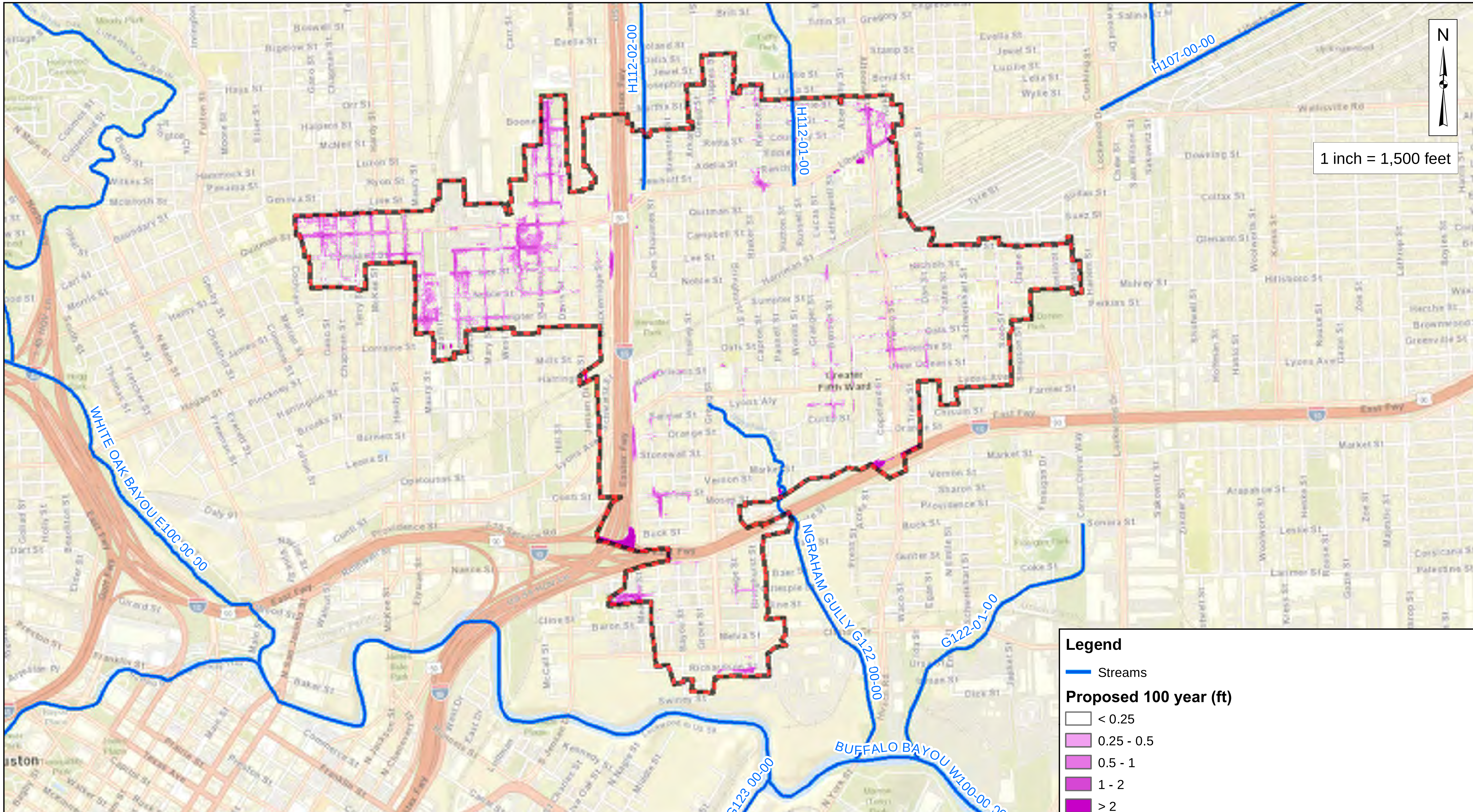
5th Ward Drainage Masterplan
Proposed 10 year with Existing

Date: July 2020

EXHIBIT 7C



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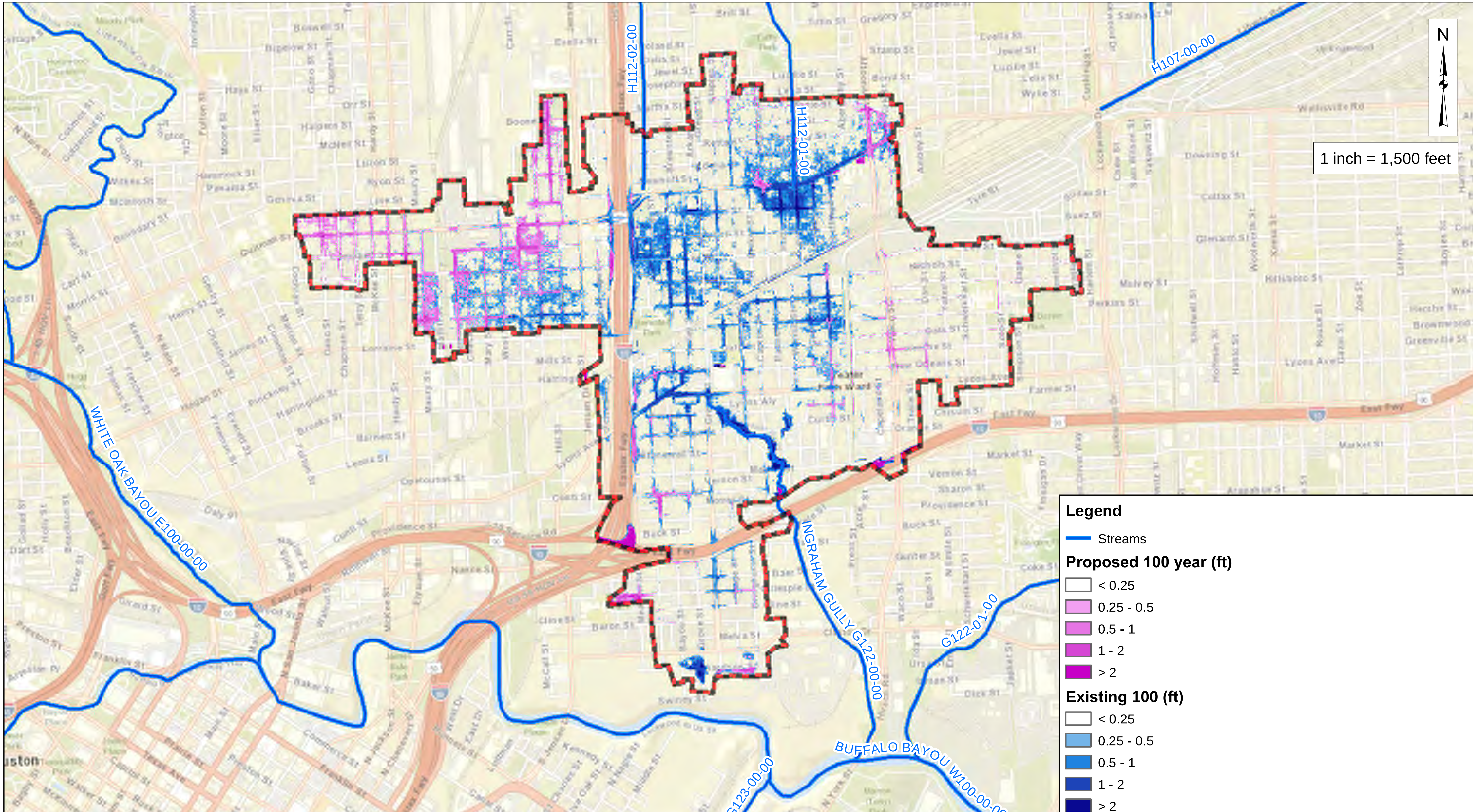
5th Ward Drainage Masterplan
Proposed 100 year

Date: September 2020

EXHIBIT 7D



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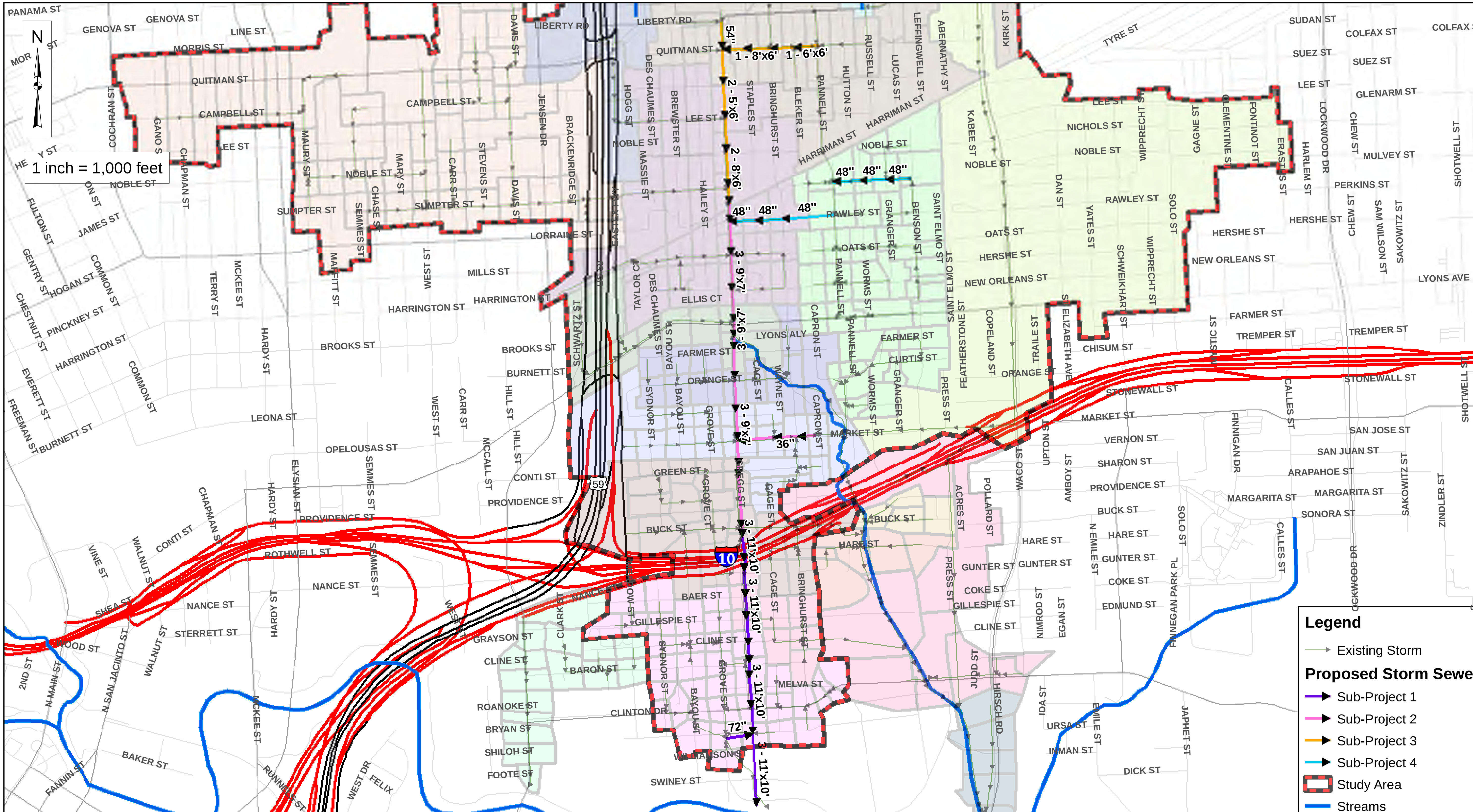
5th Ward Drainage Masterplan
Proposed 100 year with Existing

Date: September 2020

EXHIBIT 7E



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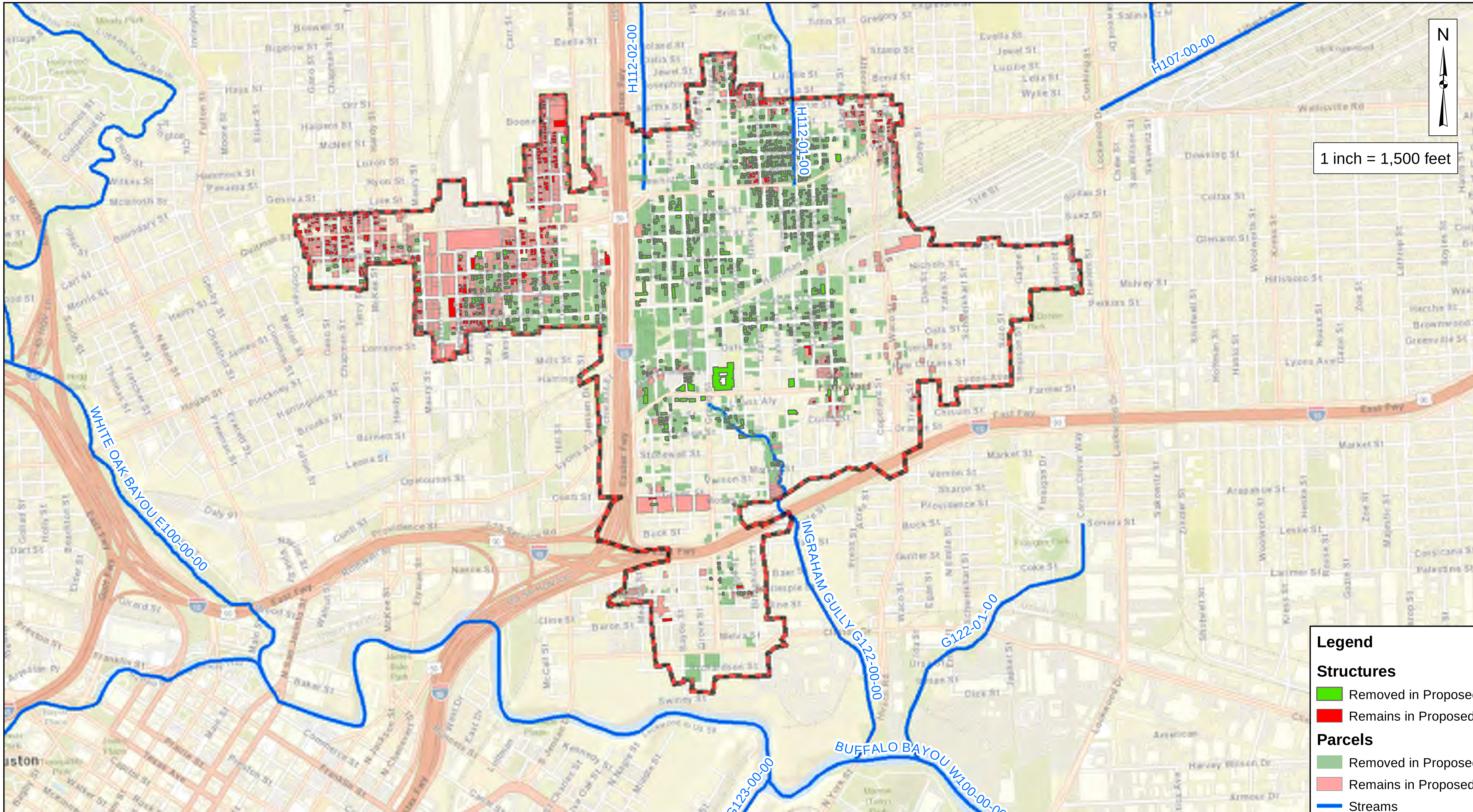
5th Ward Drainage Masterplan
Proposed Storm Sewer Map

Date: August 2020

EXHIBIT 8

Exhibit 9 - Cost/Benefit Matrix

	Cost	Flooded Quantities in Each Condition				Benefit			
	Total Cost	Flooded Streets (miles) > 6" Deep		Flooded Parcels > 3"	Flooded Structures > 3" Deep	Reductions			
		10-Year	100-Year	100-Year	100-Year	10-Year Street Miles	100-Year Street Miles	Parcels	Structures
Existing	**N/A**	3.7	13.0	2370	1240				
Sub-Project 1+2	**$ 56,322,906**	2.1	6.8	1483	768	1.58	6.24	887	472
Sub-Project 3	**$ 7,843,438**	0.9	4.1	841	338	1.22	2.72	642	430
Sub-Project 4 (2.5)	**$ 3,027,032**	0.8	3.8	771	325	0.05	0.33	70	13
TOTAL	**$ 67,193,376**					**2.86**	**9.29**	**1599**	**915**



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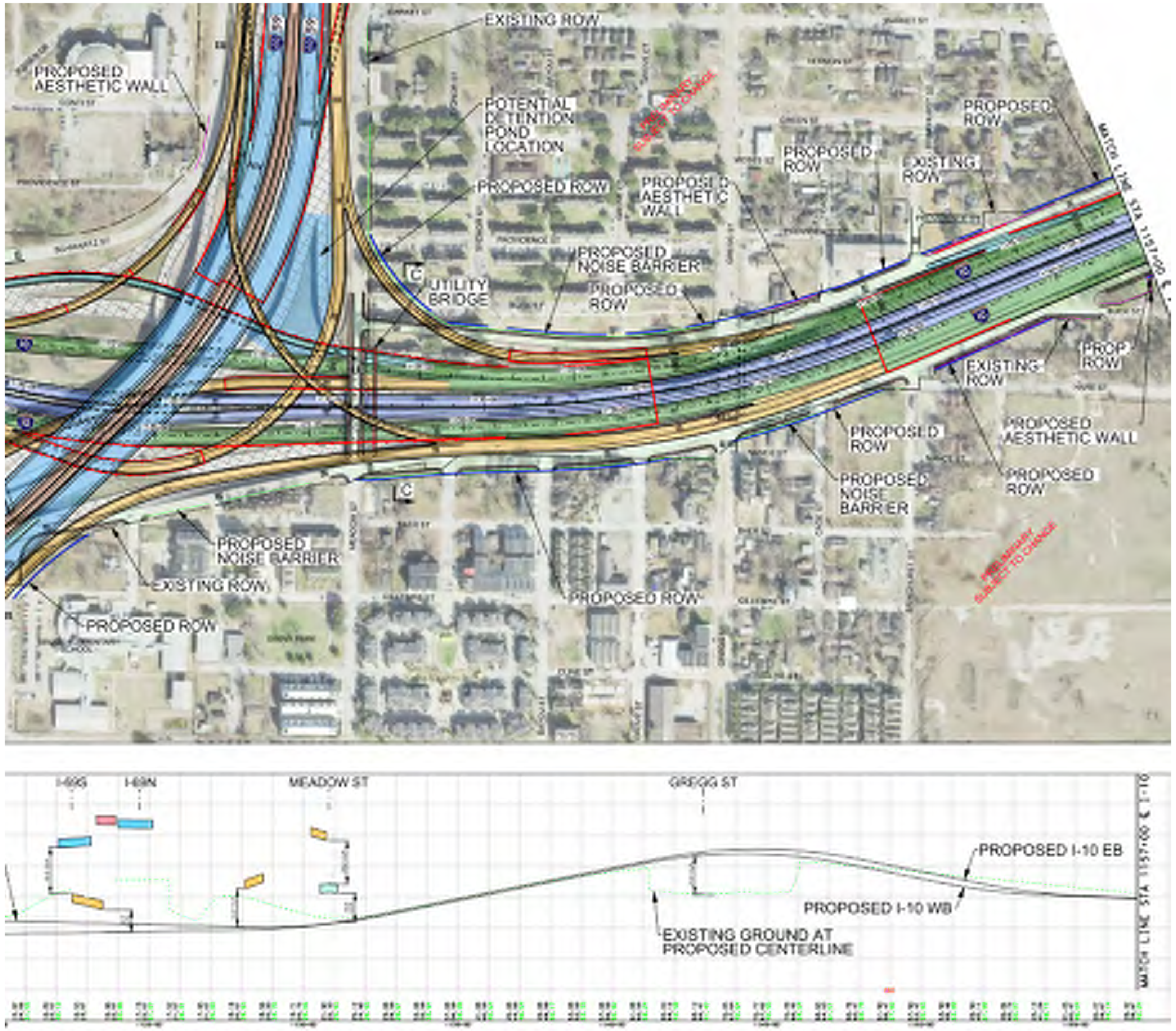
5th Ward Drainage Masterplan
Benefitted Structures

Date: September 2020

EXHIBIT 10



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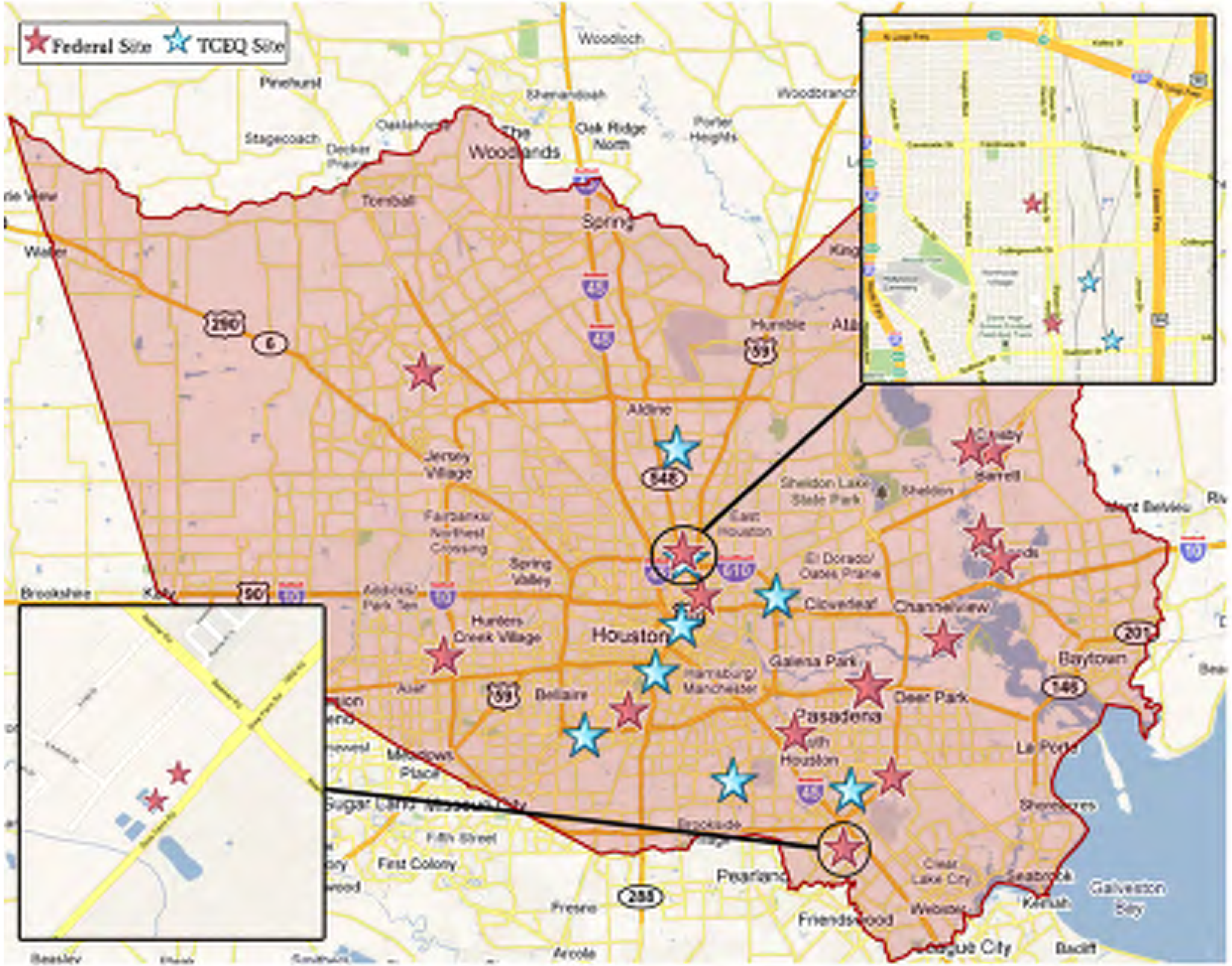
5th Ward Drainage Masterplan
TxDOT NHHIP Schematic

Date: April 2020	EXHIBIT 11



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5th Ward Drainage Masterplan
Superfund Sites

Date: April 2020	**EXHIBIT 12**

HUITT-ZOLLARS

Houston Greater Fifth Ward Area Flood Mitigation Project
Benefit-Cost Analysis Report

Prepared for:

CITY OF HOUSTON
PUBLIC WORKS

HUITT-ZOLLARS, INC.
10350 RICHMOND AVE. SUITE 300
HOUSTON, TEXAS 77042-4248
TBPE Reg. No. F-761
(281) 496-0066
October 13, 2020

Study Purpose and Scope

The goal of the "Houston Greater Fifth Ward Area Flood Mitigation Project" is to reduce the long-term risk of loss of life, injury, damage to and loss of property, and suffering and hardship by more rapidly conveying water from the identified service areas to reduce flooding. Dynamic hydraulic and hydrologic (H&H) modeling was used to identify existing ponding impacts and illustrate the benefits of reduced ponding associated with the proposed project.

The target areas are listed as Fifth Ward and Market Square, and both projects are located within the Greater Fifth Area. The project areas are located just north of Buffalo Bayou and to the east and west side of US-59 in Houston, Harris County, TX. The limits of the studied areas are shown in Exhibit 1. The Greater Fifth Ward Area neighborhood drainage infrastructure was constructed between 1940 and 1970. The existing drainage system is a curb and gutter system and provides less than 2-year level of service (LOS) under Atlas 14 rainfall, with potential structural and street flooding during a 100-year storm event.

The H&H modeling identified flooding issues under existing conditions, including structural inundation and ponding that impacts safe roadway mobility. The impacts are further validated by other data points including FEMA National Flood Insurance Program (NFIP) data, FEMA Individual Assistance (IA) data, and/or calls for service.

The proposed project in Fifth Ward will add a new trunk line draining directly to Buffalo Bayou. The proposed work in Market Square will add new trunk lines through the neighborhood and outfall into Japhet Creek. Japhet Creek has sufficient capacity and drains to Buffalo Bayou. The proposed drainage improvement in both neighborhoods will reduce flood risk to existing properties and improve street ponding. The new trunklines will provide resiliency in the neighborhood and create reliable access for infrastructure and public transportation.

Data Collection

The following documents and data were obtained and used to guide this study:

- 2018 LiDAR dataset
- Building Footprint GIS shapefile
- COH Technical Memorandum "Fifth Ward Master Drainage Plan", prepared by CobbFendley, August 2020.
- COH Technical Memorandum "Market Square Area Paving and Drainage", Prepared by Jacobs, August 2020

Methodology

FEMA "Benefit-Cost Calculator" Version V.6.0 and FEMA guidelines and procedures were used to develop this BCA. The BCA determines the future risk reduction benefits for a specific drainage improvement project and compares those benefits to the construction cost for the drainage improvements. The Benefit-Cost Ratio (BCR) is calculated by dividing the estimated benefit for all structures by the proposed improvements' construction cost.

The 2018 Lidar, building footprint shapefile, limited survey and site visits were used to determine the lowest floor elevation of each building. Buildings that are on piers or are elevated were identified using available data and the lowest floor elevation were adjusted accordingly.

The proposed drainage improvements (see Exhibit 2) were modeled in detail using two-dimensional unsteady modeling using the XPSWMM program. The “Fifth Ward Master Drainage Plan” and “Market Square Area Paving and Drainage” Technical Memorandums provide pre-improvements and post-improvement 2-, 10-, 50 and 100-Year water surface elevations and discharge values which were used in this BCA report. The 100-yr ponding limits of existing and proposed condition are shown in Exhibit 3 and Exhibit 4, respectively.

Exhibit 5 presents the location of structures where 100-yr Water Surface Elevation (WSE) is higher than the lowest floor elevation. These Structures will directly benefit from lowering the WSE after the proposed drainage improvements are implemented (Benefited Structures). These Benefitted Structures were utilized to develop the BCA.

BCA Toolkit

The Benefitted Structures are mainly residential with each structure is identified by the latitude and longitude at its centroid.

The mitigation action and project cost are based on drainage improvements identified in the “Fifth Ward Master Drainage Plan” and “Market Square Area Paving and Drainage” Technical Memorandums.

The values for Hazard Probability Parameters (flood) such as discharge and water surface elevation, for storm events with a recurrence interval of 2-, 10-, 50 and 100-Year were used from “Fifth Ward Master Drainage Plan” and “Market Square Area Paving and Drainage” Technical Memorandums.

The BCA toolkit’s default values and standard processes were used to calculate the standard building benefit. Only values for the first floor of each structure were used (one story), with no basement. Standard benefit for each building is calculated using the first floor square footage multiply by the default building replacement value.

In the BCA, it was assumed that utilities are not elevated. The BCA toolkit’s default values for contents and displacement were used. No volunteer, ecosystem services, or social benefits were used in these calculations.

The total drainage improvement cost were distributed between all benefitted structures uniformly, resulting in similar BCR value for consistency.

The total project cost and benefit are the summation of all the structures' costs and benefits. The total BCR is presented in **Table 1**. The detail of each structure BCR calculation is provided in **Attachment 1**.

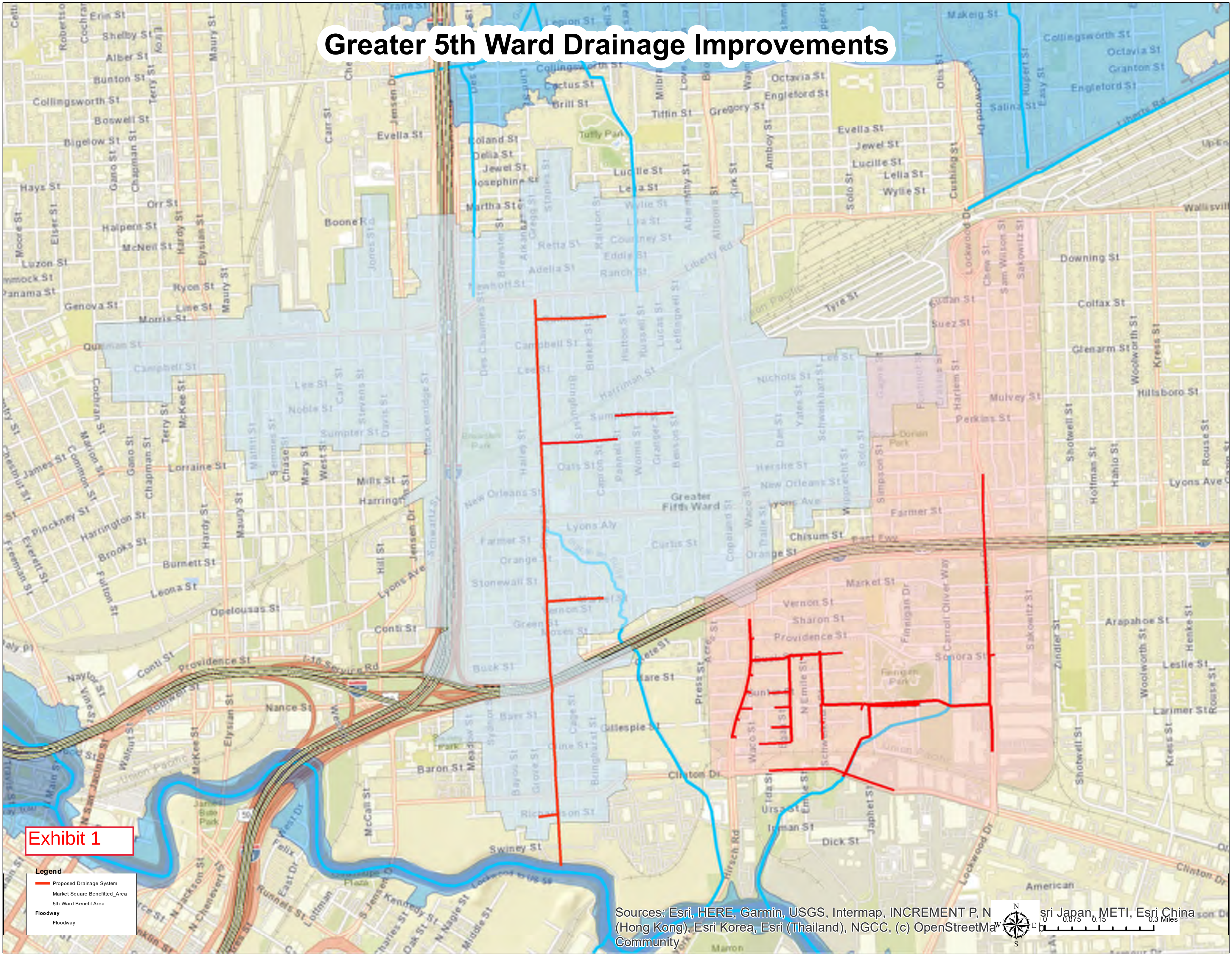
Table 1. Total Benefit-Cost Ratio

Project Name (-)	Total Benefit ($)	Total Cost ($)	Total BCR (-)
Fifth Ward	$ 117,313,214	$ 68,267,901	1.72
Market Square	$ 50,643,729	$ 21,485,586	2.35
TOTAL	$ 167,956,943	$ 89,753,487	1.87

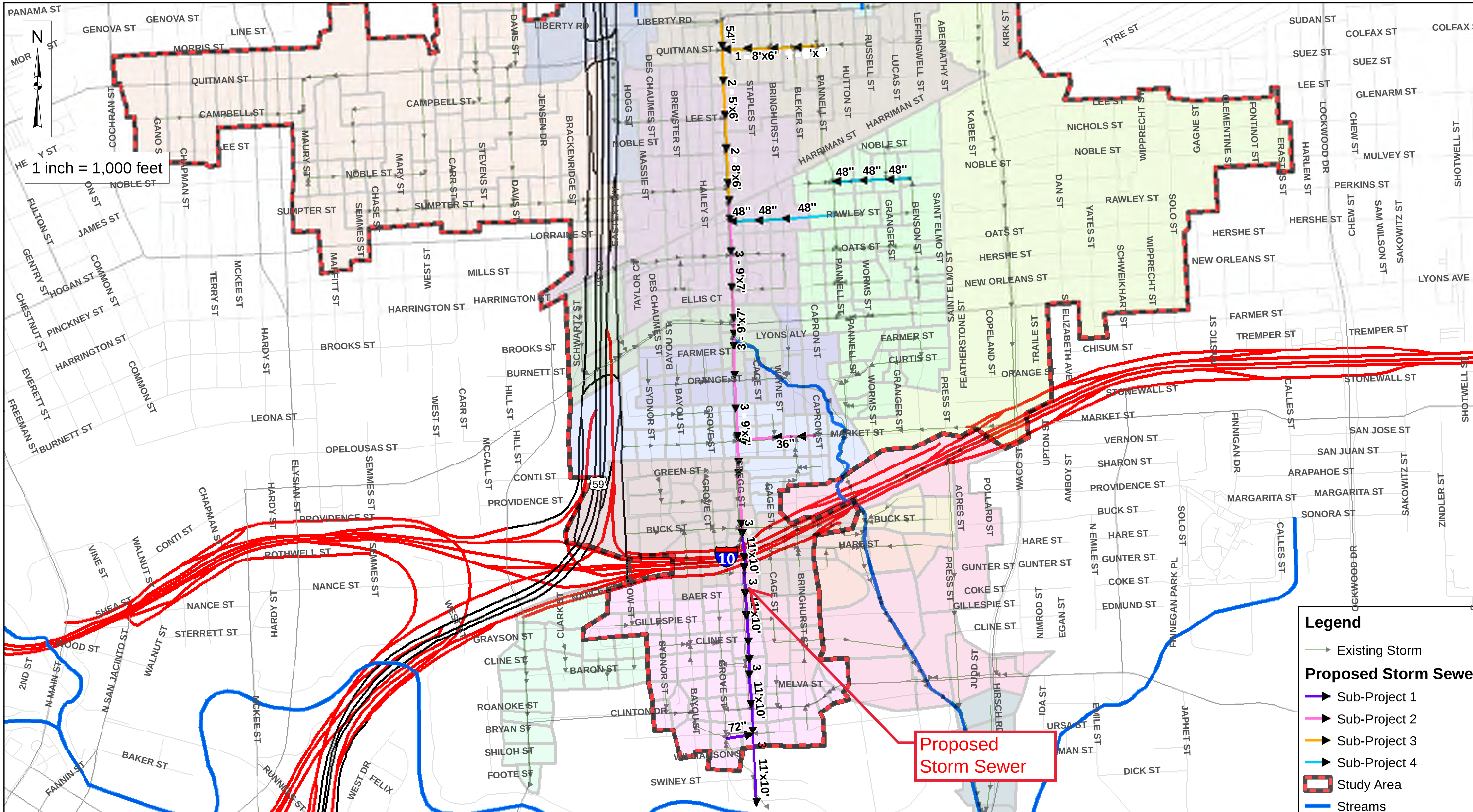
Conclusion

The "Houston Greater Fifth Ward Area Flood Mitigation Project" has a benefit-cost ratio greater than 1.

Greater 5th Ward Drainage Improvements

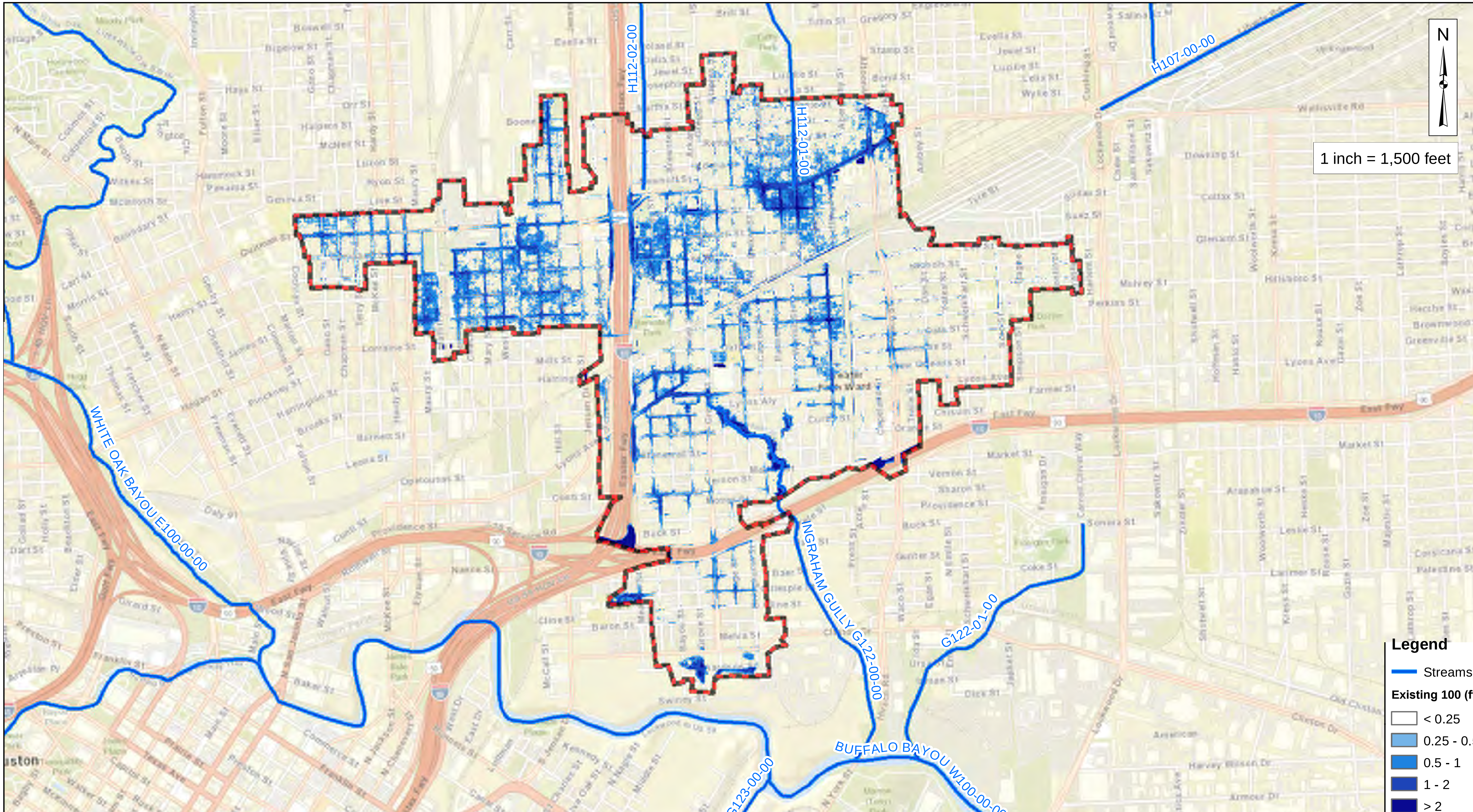


Fifth Ward



CobbFendley Texas Registration No. 274 13430 Northwest Freeway, Suite 1100 Houston, Texas 77040 713.462.3242 | fax 713.462.3262 www.cobbfendley.com	**5th Ward Drainage Masterplan** **Proposed Storm Sewer Map**
	Date: October 2020 | **EXHIBIT 2**

Fifth Ward



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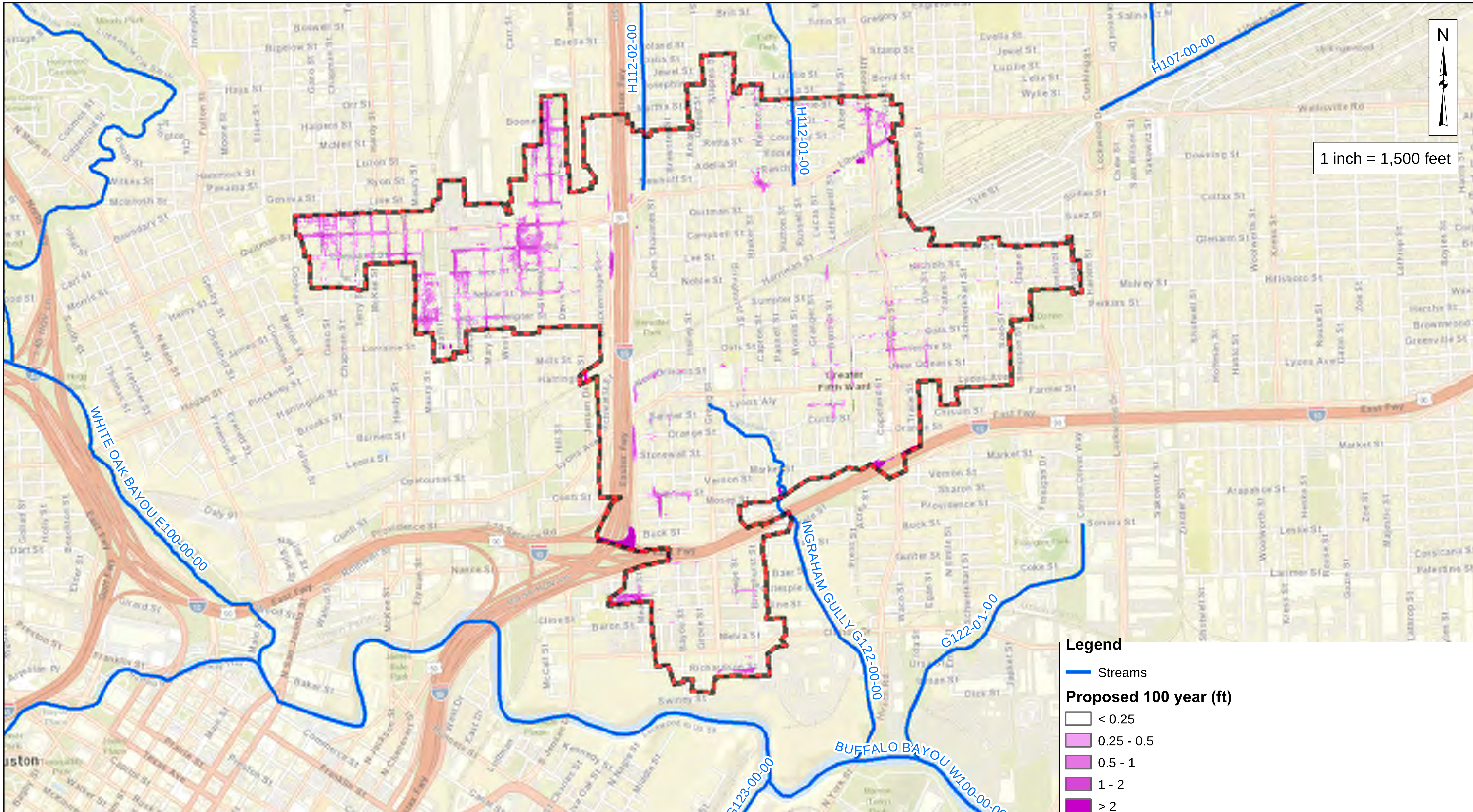
5th Ward Drainage Masterplan
Existing 100 year

Date: October 2020	**EXHIBIT 3**

Fifth Ward



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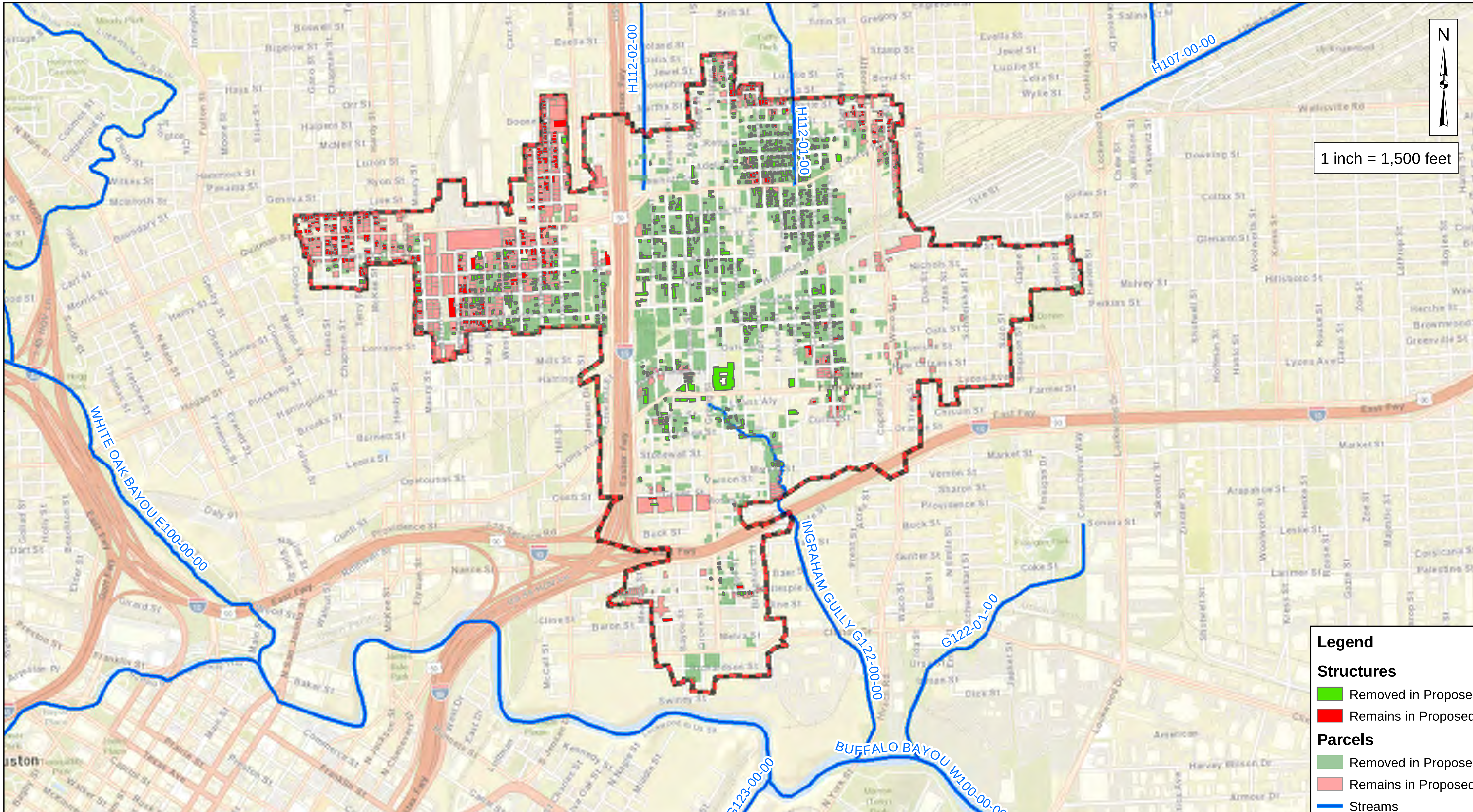
5th Ward Drainage Masterplan
Proposed 100 year

Date: October 2020	EXHIBIT 4

Fifth Ward



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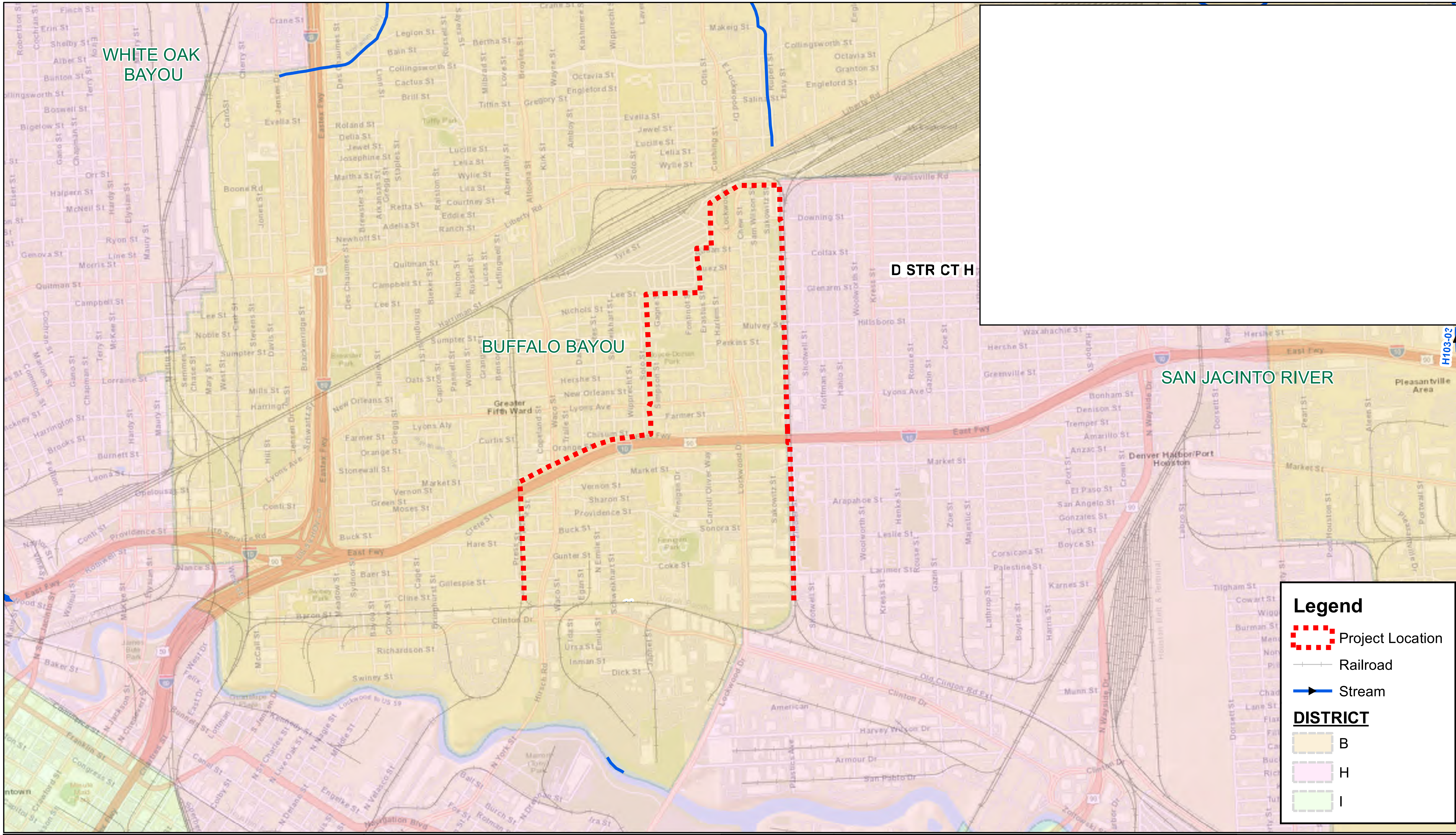
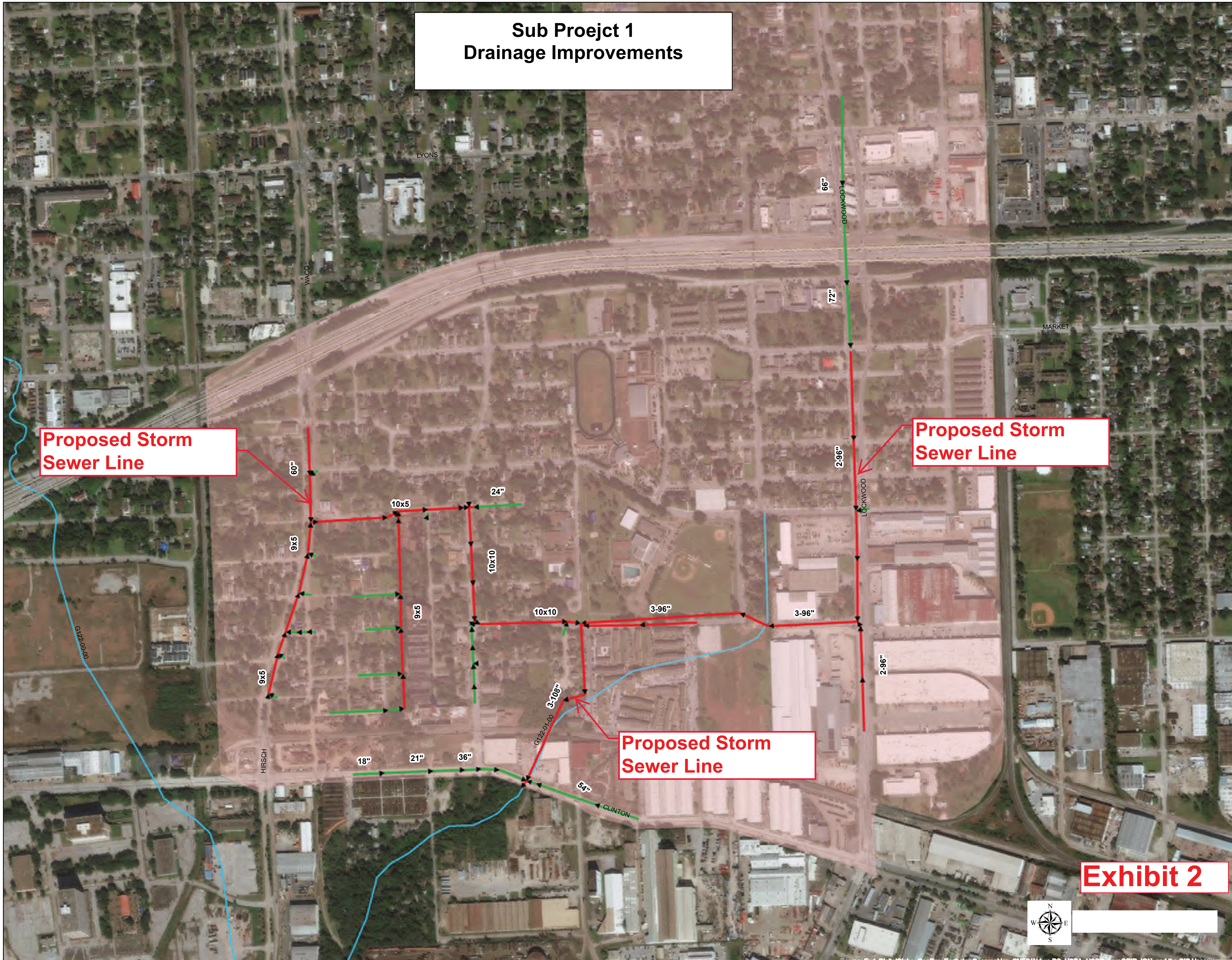
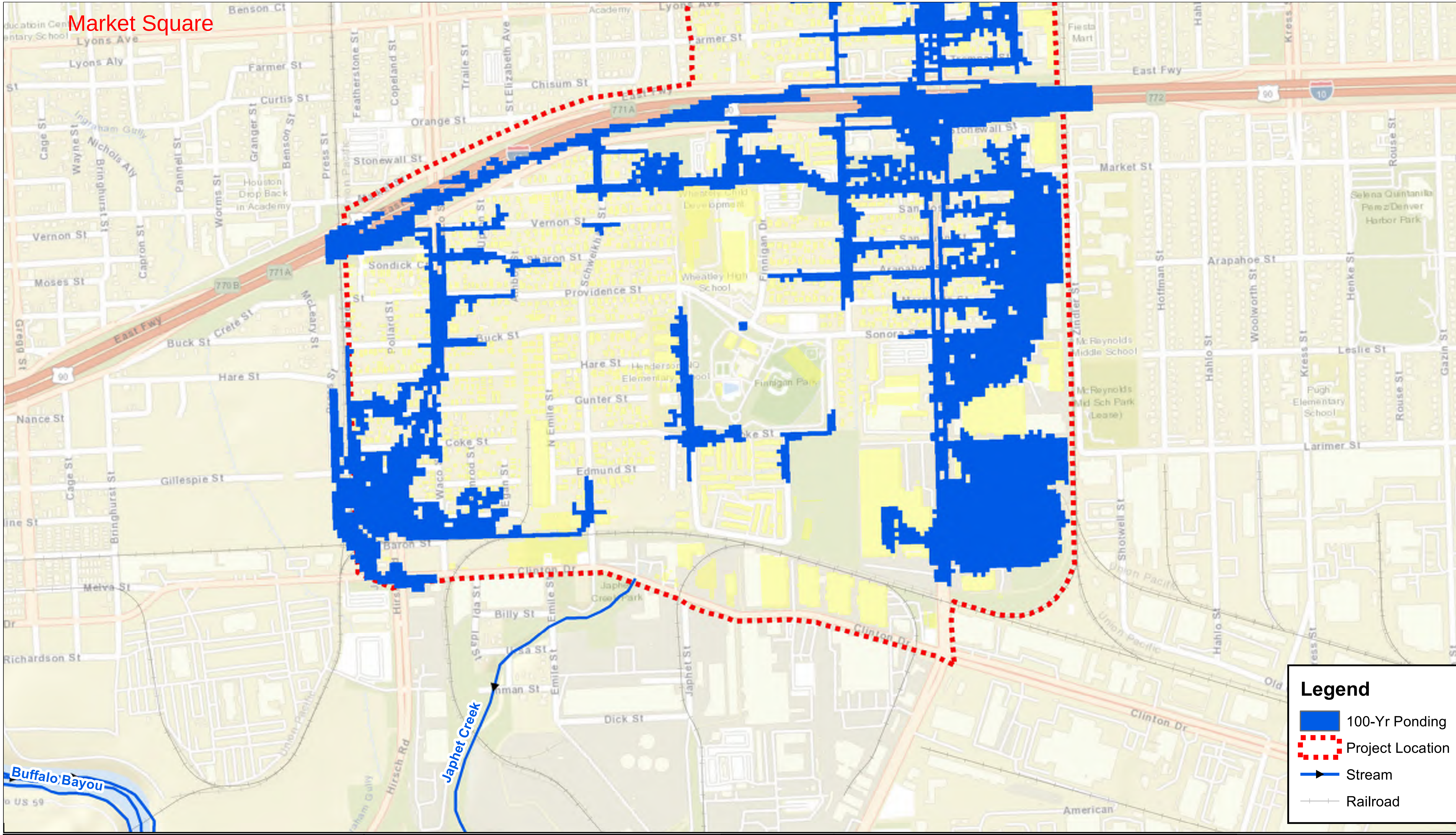
5th Ward Drainage Masterplan
Benefitted Structures

Date: October 2020	EXHIBIT 5

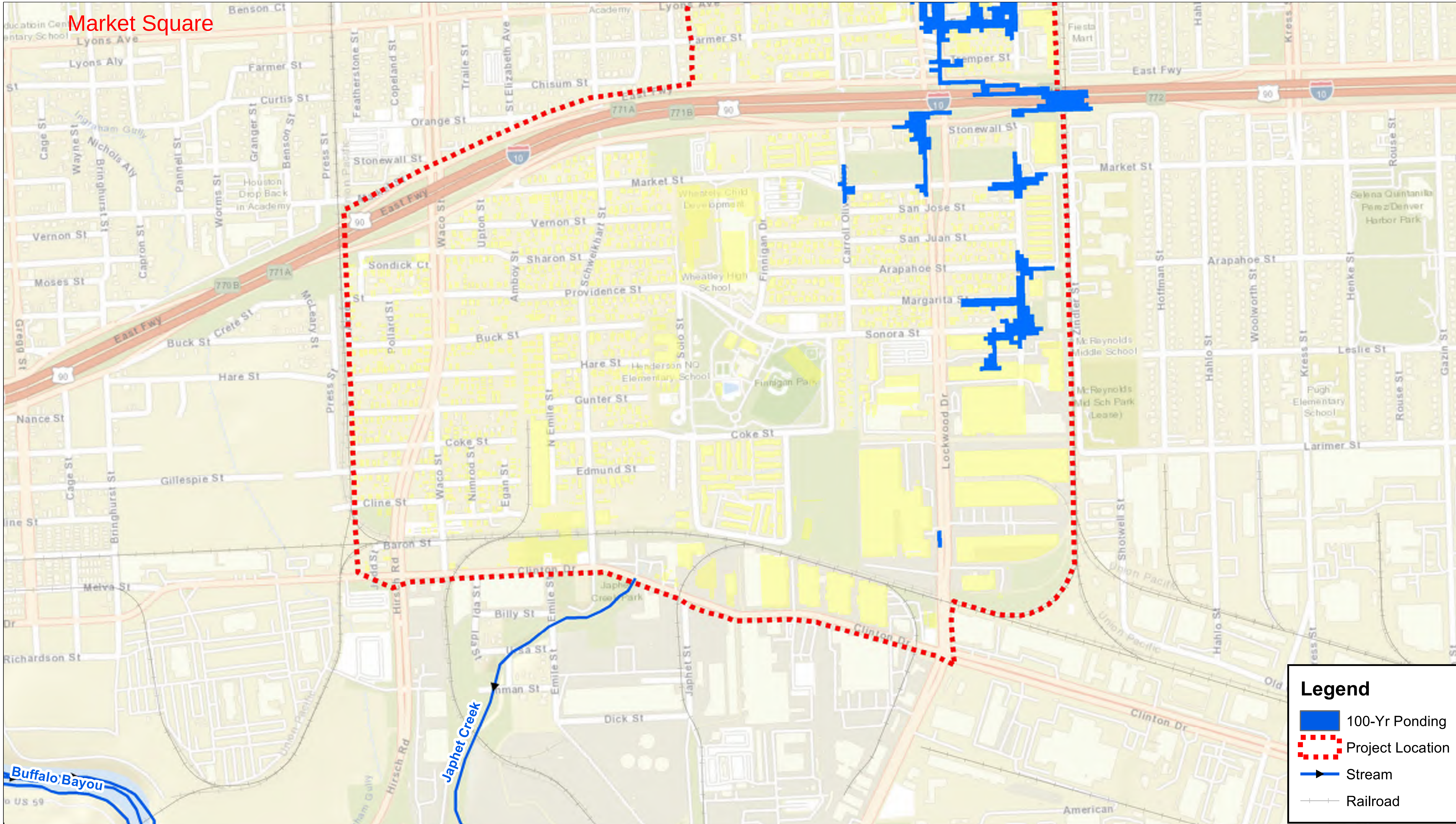


HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. N□210010□0001□3 (MARKET SQUARE)		DATE	SCALE	EXHIBIT 1
			OCTOBER 2020	0 1,000 2,000 Feet	LOCATION MAP


Sub Proejct 1
Drainage Improvements
Proposed Storm
Sewer Line
Proposed Storm
Sewer Line
Proposed Storm
Sewer Line
LYONS
WACO
MARKET
LOCKWOOD
LOCKWOOD
HIRSCH
CLINTON
66"
72"
2-96"
2-96"
3-96"
3-96"
10x10
10x10
10x5
9x5
9x5
9x5
60"
24"
3-108"
18"
21"
36"
54"
G122-00-00
G122-01-00
Exhibit 2



HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. N□210010□0001□3 (MARKET SQUARE)		DATE	SCALE	EXHIBIT 3
			OCTOBER 2020	0 500 1,000 Feet	100-YR PONDING LIMITS EXISTING CONDITION

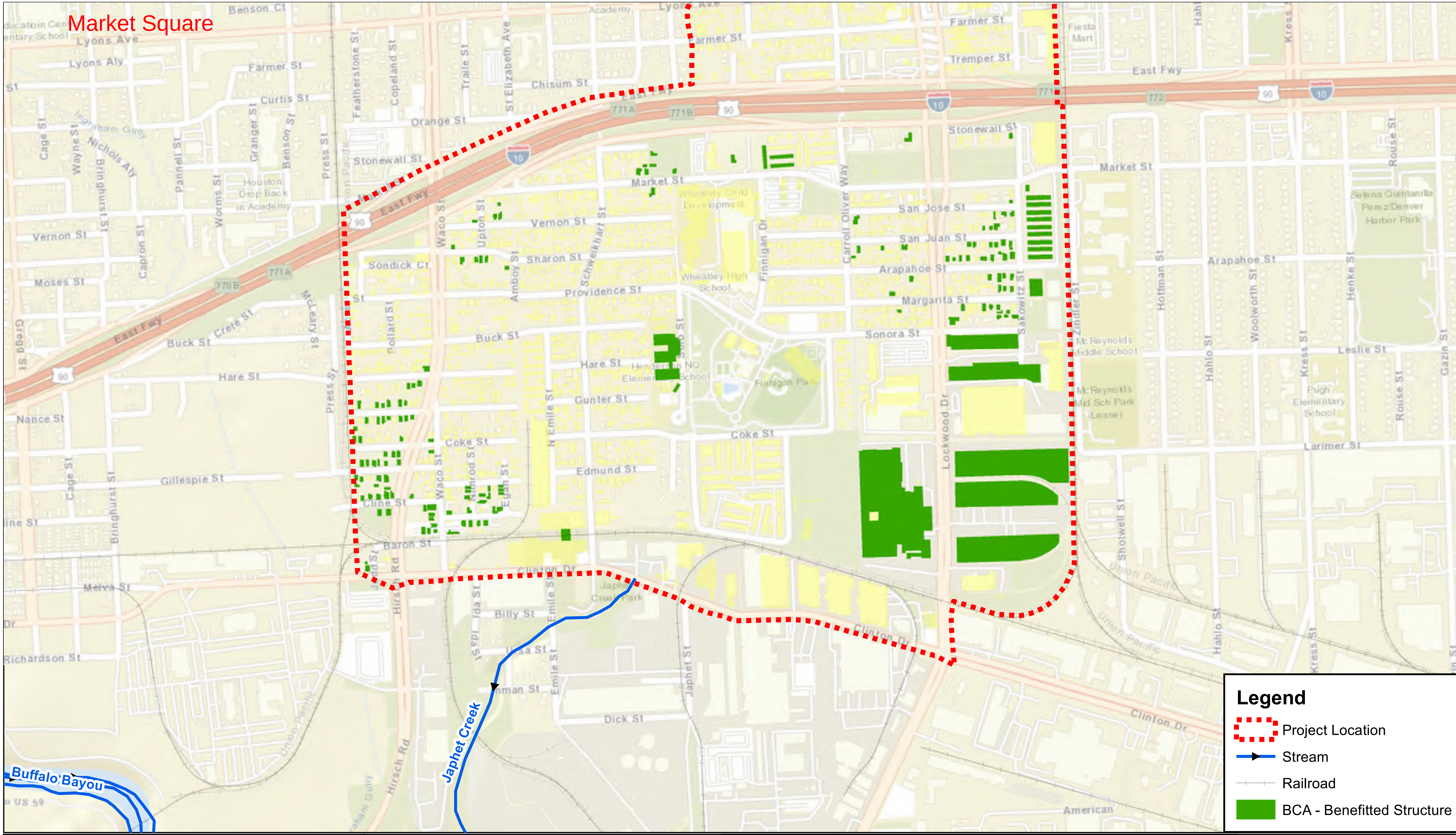


HUITT-ZOLLARS

HUITT-ZOLLARS, INC.
10350 Richmond Avenue, Suite 300 Houston, TX 77042
Phone 281.496.0066
Firm No. F-761
Fax 713.496.0220

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. N□210010□0001□3
(MARKET SQUARE)

DATE	SCALE	EXHIBIT 4
OCTOBER 2020	0 500 1,000 Feet	100-YR PONDING LIMITS PROPOSED CONDITION



HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. N□210010□0001□3 (MARKET SQUARE)		DATE OCTOBER 2020	SCALE 0 500 1,000 Feet	EXHIBIT 5 BENEFIT-COST ANALYSIS BENFITTED STRUCTURES

Attachment 1

Note: Due to the high number of benefitted structures and BCA Toolkit's limit, the BCR calculation is split into 6 excel files as listed below:

Fifth Ward

- Group 1
- Group 2
- Group 3
- Group 4
- Group 5
- Group 6
- Group 7
- Group 8
- Group 9

Market Square

- Group 10
- Group 11

Appendix 5-4F:
City of Houston Port Area Flood Mitigation

Halff Associates, Inc.
100 I-45 North, Suite 260
Conroe, Texas 77301
(936) 756-6832
Fax (936) 756-6833

MEMORANDUM

TO:	Maureen Crocker Assistant Director Transportation and Drainage Operations	**DATE:**	April 6, 2020
FROM:	C. Andrew Moore, P.E., CFM	**AVO:**	31051
EMAIL:	amoore@halff.com		
SUBJECT:	WO121 – Pleasantville Detention Analysis		

INTRODUCTION

The City of Houston (City) has contracted Halff Associates, Inc. (Halff) to perform a stormwater analysis of the Pleasantville area using Atlas 14 rainfall to determine how detention could reduce drainage improvements needed while increasing the level of service for the neighborhood. Goals of the study included:

- Updating the existing drainage models (previously developed by Halff) to incorporate the Atlas 14 rainfall and determining the level of service of the drainage network for both existing conditions and the recommended Alternative 1A-1.
- Identifying locations for potential detention that would provide benefit to the Pleasantville neighborhood. Selecting most feasible detention site(s) for detailed modeling.
- Updating the previously recommended subprojects identified as Alternative 1A-1 to include the detention pond. Determine the actual detention volume needed to improve drainage and storm sewer improvements needed to achieve the highest level of service possible for the neighborhood.
- Providing opinions of probable construction cost for the drainage and paving improvements for the previous recommended Alternative 1A-1 and the new Detention Alternative.

LOCATION AND PREVIOUS STUDIES

The Pleasantville area is located west of 610 East, south of Market Street Rd, east of Pearl St and north of Clinton Dr. The project area is shown on **Exhibit 1**.

The existing storm sewer system was constructed in the 1960s and 1970s. Drainage improvements, known as Subproject 1 and Subproject 1A (described below) were constructed in 2016 and 2017 per the *2013 Study*. These improvements provide relief from flooding for residents within the Pleasantville area. The improvements consisted of large RCBs that convey flow towards the outfall that is near the existing TxDOT system at IH-610 East. The existing storm

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sewer system range in size from 18” RCPs to 10’x10’ RCBs. Storm water is drained via Type-B inlets throughout the drainage area . The existing storm sewer layout is shown in **Exhibit 2**.

The Pleasantville neighborhood has had several previous studies conducted to identify drainage issues and recommend solutions. These studies are summarized below:

- Pleasantville/Glendale Preliminary Engineering Report (2012 PER) – Preliminary Engineering Report completed in 2012 of the Pleasantville/Glendale neighborhood to identify existing drainage issues and propose solutions. The PER recommended neighborhood wide storm sewer upgrades and detention located on the southwest portion of the neighborhood.
- Pleasantville/Glendale Additional Services (2013 Study) – The detention ponds sought in the *2012 PER* were not pursued and therefore additional alternatives were analyzed to determine changes to the proposed storm sewer system. The study recommended Alternative 1A-1 which consisted of large trunklines throughout the neighborhood outfalling into the TxDOT system along I-610 providing a 25-year level of service (pre-Atlas 14).
- Pleasantville/Glendale Storm Sewer Design Subproject 1 (2016) – Completed in 2016, the first subproject of the neighborhood drainage that installed the main trunk line from Industrial Drive near I-610 to the west end of Guinevere Street. Project included 6’x6’ RCB and 10’x10’ RCB.
- Pleasantville/Glendale Storm Sewer Design Subproject 1A (2017) – Completed in 2017, the second subproject of the drainage system that installed the final piece of the storm sewer trunk along Industrial Drive and additional storm sewer along Turning Basin.

ATLAS 14 HYDROLOGY UPDATE

Hydrology calculations prepared from the previous studies were updated to account for the new rainfall documented in the NOAA Atlas 14 Precipitation-Frequency Atlas of the United States Volume 11 (*Atlas 14)* and the *City of Houston Infrastructure Design Manual* (IDM). The updated rainfall includes new e, b, d values used to calculate rainfall intensity. A table of the rainfall parameters based on the previous National Weather Service documents and NOAA Atlas 14 is shown below in **Table 1**.

Table 1. Rainfall Intensity Parameters

Rainfall Event	National Weather Service			NOAA Atlas 14		
	b	d	e	b	d	e
2-yr	75.01	16.2	0.8315	48.35	9.07	0.7244
10-yr	93.53	18.9	0.7742	54.68	6.96	0.6623
25-yr	115.9	21.2	0.7808	57.79	5.89	0.6294
100-yr	125.4	21.8	0.7500	60.66	4.44	0.5797

A graph comparing the previous IDF curves to the Atlas 14 IDF curves is shown below in **Figure 1**.

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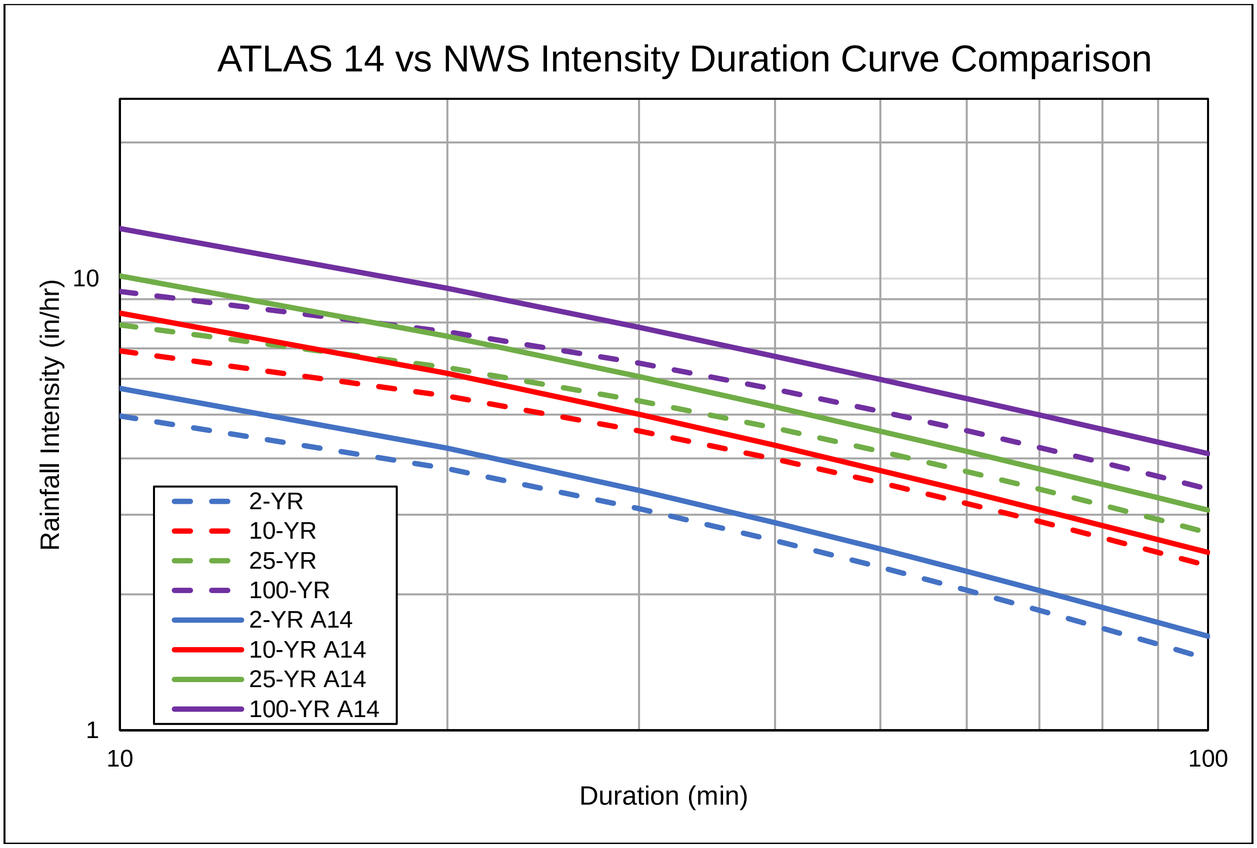

Figure 1. Comparison of Pre-Atlas 14 and Atlas 14 IDF Curves

The drainage basins delineated as part of the *2013 Study* were used to determine new flows from the updated rainfall parameters based on Atlas 14.

As of late 2019, construction began on an approximately 84-acre area east of Pearl St and south of Northton St and consists of an industrial complex with onsite detention. A figure showing the before and after pictures of the area being developed is shown below **Figure 2**.

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Figure 2. Before and After Photos of Development

Prior to development, runoff from this site sheet-flowed north into the Pleasantville neighborhood. After construction, the development appears to now drain west to the storm sewer on McCarty Street. Therefore, these drainage areas were removed from the analysis performed for this study. The existing topography of the Pleasantville area is shown in **Exhibit 3.** The removed subbasins are shown below in **Figure 3**. The drainage basins used for the hydrologic analysis in Pleasantville are shown in **Exhibit 4**.

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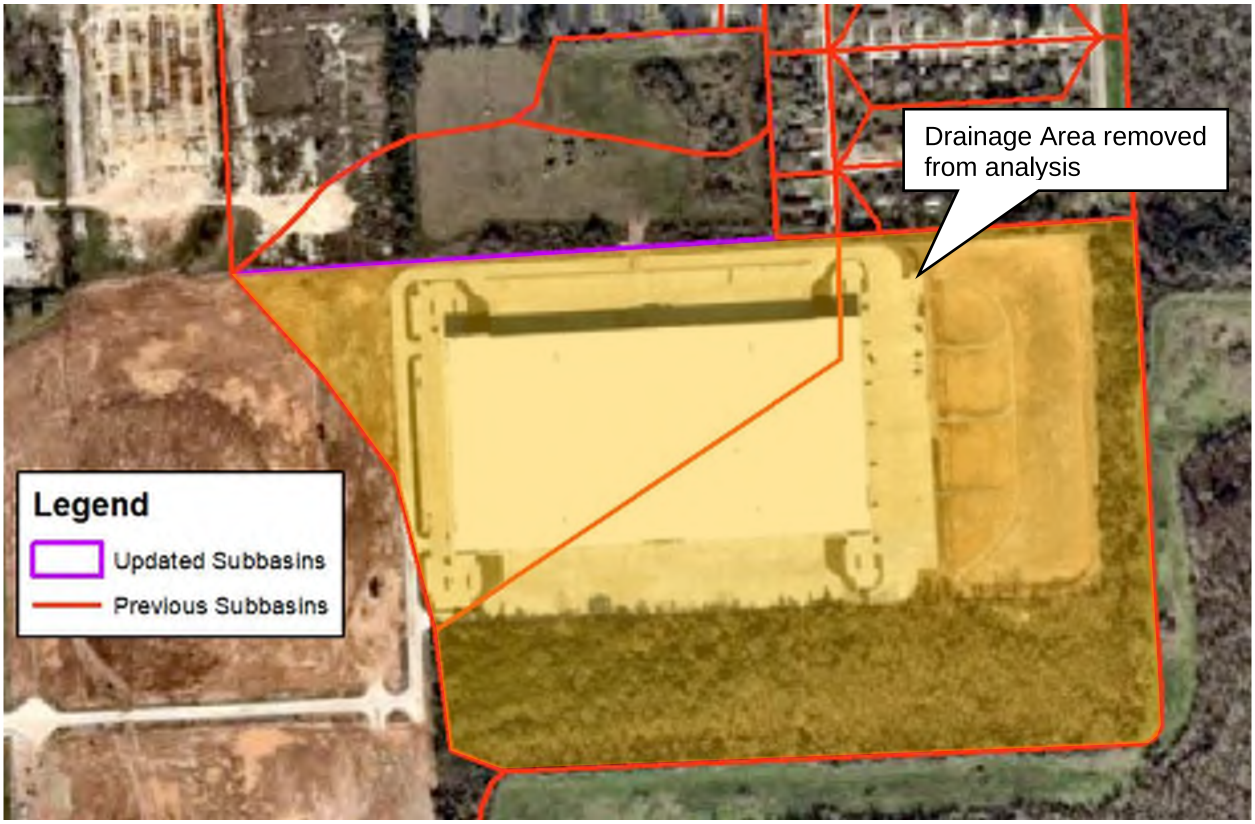

Figure 3. Previous vs Updated Subbasins - Offsite Area

Flows were determined in previous studies using the Rational Method. The methodology was updated with Atlas 14 rainfall intensity parameters. Flow hydrographs for each basin were developed using the HEC-HMS model from the *2013 Study.* In general, flow rates increased by 11% for the 2-year storm event, 11% for the 10-year storm event, 15% for the 50-year storm event, and 23% for the 100-year storm event. The Rational Method peak flow rate calculations are included in **Appendix A**.

Hydrographs for each drainage area were developed using HEC-HMS v 3.5. Drainage area size, impervious percentage and time of concentration were input to the HEC-HMS model based on the basin characteristics. The transform parameter storage coefficient “R” value was adjusted so that the resultant peak flow from the HEC-HMS model matched with the Rational Method peak flows. The “R” values were adjusted separately for each of the 2-, 10-, 25-, 50-, and 100-year storm events. The runoff hydrographs were imported into the InfoWorks ICM model which was used to calculate storm sewer capacity and flooding extents.

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ATLAS 14 HYDRAULIC UPDATE

Existing Conditions

The existing conditions ICM model was updated to include the Atlas 14 runoff hydrographs and the newly constructed storm sewer improvements from Subproject 1. The storm sewer characteristics were input into the model from the design drawings. The revised hydraulic model was then simulated for the 2-year, 10-year, 25-year, 50-year and 100-year storm events to determine the revised existing level of service based on the Atlas 14 rainfall.

Existing Results

In the *2013 Study*, the existing storm sewer system had a 25-year LOS with pre-Atlas 14 rainfall. Based on the new existing conditions results, the storm sewer system generally has less than a 2-year level of service (LOS) since there is 2-year ponding with Atlas 14 rainfall. A table of ponding depths for various intersections for the 2-year and 100-year events is shown below in **Table 2**.

Table 2. Existing Ponding Depths (Atlas 14)

Intersection	Ponding Depths (ft)	
	2YR	100YR
Bucroft - Pleasantville	0.85	2.82
Fillmore - Gellhorn	0.20	2.24
Bucroft - Gellhorn	0.32	3.18
Northton - Gellhorn	0.84	3.28
Josie - Gellhorn	1.84	2.78
Ledwicke - Guinevere	0.00	2.65
Flossie Mae - Quaker	0.00	2.35
Laurentide - Pattibob	0.00	2.39
Cowart - Ledwicke	0.00	1.58
Laurentide - Tilgham	0.00	1.80
Berndale - Candy	0.29	1.62
Laurentide - Candy	0.00	1.78
Tilgham - Teanaway	0.00	1.01
Norvic - Teanaway	0.40	1.77
Wiggins - Silverdale	0.31	2.13
Berndale - Silverdale	0.51	2.63

Several intersections have ponding depths above 0.5 feet during the 2-year. During the 100-year event, there is potential structural flooding that occurs within the Pleasantville area. The homes with flooding potential are concentrated in the east and the south ends of the neighborhood. The ponding depths also indicate that for many intersections, ponding occurs past the ROW line based

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on the assumed ROW depth (6 inches of curb + 15 inches from curb to ROW). Ponding maps for the 2-year and 100-year existing conditions are shown in **Exhibit 5** and **Exhibit 6**, respectively.

Ponding in the existing conditions is caused by undersized storm sewer throughout the neighborhood, lack of overland sheet flow patterns, and limited outfall capacity of the TxDOT system. While the main trunk line was upsized during the construction of Subproject 1, the rest of the storm sewer is still undersized for both the frequent and extreme events. The neighborhood also is located a low area and that has no positive overland flow outfall. The neighborhood is blocked by I-610 to the east and the dredge sites to the south. Runoff that is not conveyed in the storm sewer does not flow out of the neighborhood but remains above ground until the storm system has the capacity to convey the flow.

Alternative 1A-1 (*2013 Study)*

Alternative 1A-1 was previously analyzed in the *2013 Study* and included improvements on the existing storm sewer systems in Pleasantville. The alternative was analyzed in this study to determine the level of service based on Atlas 14 rainfall. The proposed improvements consisted of upsizing trunklines along Gellhorn Dr, Ledwicke Dr and east of Pleasantville Dr along with the receiving lateral systems upsized. The proposed storm sewer improvement sizes range from a 24” RCP to a 120” RCP. The Alternative 1A-1 storm sewer layout is shown in **Exhibit 7**.

The cost estimate for the alternative was updated to reflect increases in unit prices. The opinion of probable construction cost of the paving and storm sewer improvements is approximately **$27.1 million**. The estimate includes:

- $4.8 million for roadway reconstruction assuming full pavement where storm sewer is placed.
- $15.3 million for storm sewer improvements
- $6.2 million for mobilization and contingencies

The opinion of probable cost is shown in **Appendix B.1**.

Alternative 1A-1 Results

The alternative was simulated in the updated ICM model with the Atlas 14 hydrology to determine the revised level of service based on the 2-year, 10-year, 25-year, 50-year and 100-year storm events.

The improvements recommended in Alternative 1A-1 show a reduction in ponding throughout the project. There is no significant ponding for the 2-year event while the 100-year event shows ponding depths are reduced by up to 1.1 feet. In addition to reduction of ponding depths as a result of Alternative 1A-1, there are no flow increases into the TxDOT system. A table of ponding depths for various intersections for the 2-year and 100-year events compared to the existing conditions is shown below in **Table 3**.

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Table 3. Existing vs Alternative 1A-1 Ponding Depths

Intersection	EX Depths (ft)		Alt1A 1 Depths (ft)	
	2YR	100YR	2YR	100YR
Bucroft - Pleasantville	0.85	2.82	0.14	2.10
Fillmore - Gellhorn	0.20	2.24	0.00	0.96
Bucroft - Gellhorn	0.32	3.18	0.00	2.41
Northton - Gellhorn	0.84	3.28	0.00	2.45
Josie - Gellhorn	1.84	2.78	0.00	2.92
Ledwicke - Guinevere	0.00	2.65	0.00	2.70
Flossie Mae - Quaker	0.00	2.35	0.00	2.34
Laurentide - Pattibob	0.00	2.39	0.00	2.34
Cowart - Ledwicke	0.00	1.58	0.00	1.57
Laurentide - Tilgham	0.00	1.80	0.00	1.73
Berndale - Candy	0.29	1.62	0.00	1.65
Laurentide - Candy	0.00	1.78	0.00	1.70
Tilgham - Teanaway	0.00	1.01	0.00	0.76
Norvic - Teanaway	0.40	1.77	0.00	1.55
Wiggins - Silverdale	0.31	2.13	0.00	2.27
Berndale - Silverdale	0.51	2.63	0.00	2.71

Based on the results from **Table 3**, Alternative 1A-1 provides a benefit for the 2-year event when compared to the existing conditions. The benefit is diminished slightly during the 100-year storm event in which a number of intersections are reduced by less than 0.5 feet. Ponding maps for the 2-year and 100-year are shown in **Exhibit 8** and **Exhibit 9** respectively.

While Alternative 1A-1 improves the drainage system, the capacity of the main trunk line is still limited due to the limited capacity of the TxDOT system. Without improving the system downstream or creating additional storage within the neighborhood, the alternative is limited to a 10-year level of service.

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PRELIMINARY DETENTION LOCATIONS

Six sites were initially investigated as potential locations for detention ponds to assist in reducing ponding elevations throughout the neighborhood. The initial sites were identified based on availability of open land and are shown in **Figure 4**. A preliminary grading plan was developed for each site with consideration to potential invert elevations of the existing storm sewer and typical HCFCD design criteria including side slopes and maintenance berms. The preliminary grading plans provided a maximum available detention volume. The preliminary grading plans of the initial locations are shown in **Figure 4** and Appendix B.

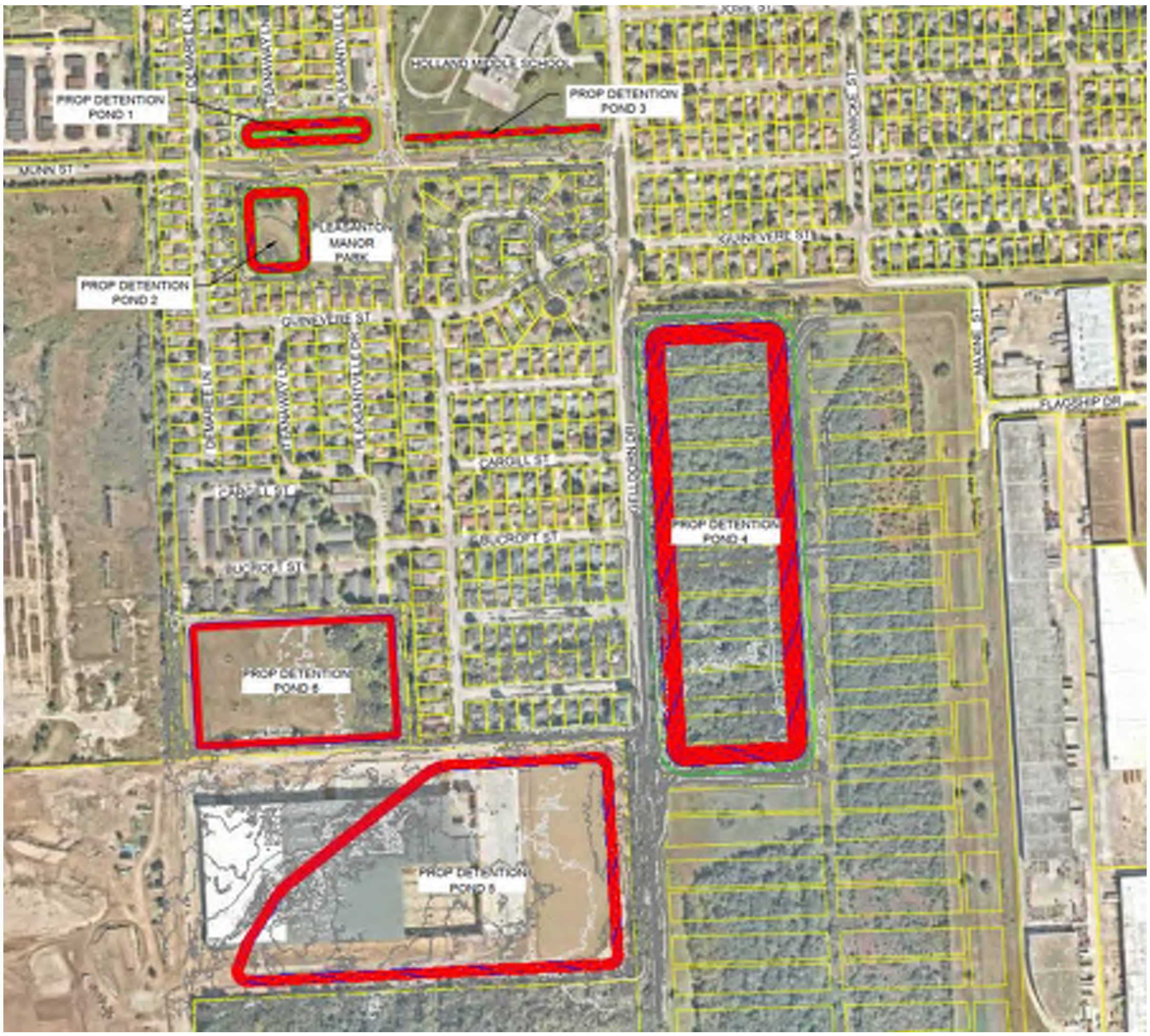

Figure 4: Potential Detention Pond Locations

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The sites were then further screened based on landowner, potential detention benefit of the pond alone, and conflicting utilities to determine which sites were most feasible for further study. The screening is summarized below and in **Table 4**.

- Pond #1 – Located on the northwest side of the neighborhood at the end of Pleasantville Drive and Teanaway Lane. The pond provides approximately 8.4 acre-feet of detention across 1.1 acres owned by the City of Houston and private owners. The pond has the potential to outfall into the recently constructed 6'x6' RCB constructed in Subproject #1. By constructing the pond without any other improvements in the neighborhood, regional benefits are negligible due to the size and location on the upstream end of the neighborhood.
- Pond #2 – Located on the existing Pleasanton Manor Park on the west side of the neighborhood, the pond provides approximately 17 acre-feet of detention on 1.7 acres. The pond has the potential to outfall into the recently constructed 6'x6' RCB constructed in Subproject #1. By constructing the pond without any other improvements in the neighborhood, regional benefits are negligible due to the size and location on the upstream end of the neighborhood.
- Pond #3 – Located on a small piece of land owned by the Houston Independent School District, the pond provides approximately 0.75 acre-feet of detention on 1.1 acres. The pond has the potential to outfall into the recently constructed 10'x8' RCB constructed as part of Subproject #1. However, the pond location near the school and lack of available volume shows no benefit for this site.
- Pond #4 – Located on the existing Port of Houston Authority site near the downstream trunkline, the pond provides up to 350 acre-feet of detention on 19 acres. The pond can outfall into the existing 10'x10' RCB along Ledwicke Street. By constructing the pond, the existing 100-year ponding is reduced up to 1.2 feet and reduces downstream flows. The pond has the potential of improving the level of service in the neighborhood and reducing the local infrastructure costs. The City indicated that the Port of Houston was receptive to using the area for detention. The site has a USACE easement that is used for placing dredge material which could affect acquisition for the detention pond. The site is also raised 3 to 6 feet higher than the adjacent roadways of the neighborhood. Therefore, additional excavation may be required.
- Pond #5 – This pond location was identified in the *2012 PER* as a potential location of detention. As previously discussed, a large industrial facility has been constructed on this site.
- Pond #6 – This pond was identified in the *2012 PER* as a potential location of detention for offsite flow. The pond is located on the southwestern portion of the neighborhood and could provide up to 51 acre-feet of detention and would outfall into the storm sewer along Pleasantville Drive. The existing 100-year water surface elevation is reduced up to 3-inches. However, the location of the pond only provides local benefits in the southwestern portion of the neighborhood.

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Table 4: Preliminary Detention Location Summary

Site Number	Max. Volume	Land Owner Type	Reduction in Ponding	Public Utility Conflicts
Pond #1	8.4 acre-feet	COH & Private	0.16 ft	Yes
Pond #2	17.0 acre-feet	COH	0.16 ft	No
Pond #3	0.75 acre-feet	Houston ISD	0.16 ft	No
Pond #4	350 acre-feet	Port of Houston	1.2 ft	No
Pond #5	------	Private	------	Yes
Pond #6	50.6 acre-feet	Private	0.25 ft	Yes

Of the initial sites, Pond #4 was the only detention pond that provided benefit to the whole neighborhood and was therefore recommended for further investigation and more detailed modeling.

DETENTION ALTERNATIVE

The proposed detention pond, Pond #4, can provide up to 350 ac-feet of detention improving the level of service and reducing ponding in the neighborhood. The Detention Alternative consists of a combination of detention and storm sewer improvements within Pleasantville. Proposed pipe sizes range from a 24" RCP to a 10'x10' RCB and also include upsizing inlets from B Inlets to 5-foot BB Inlets. The improvements consisted of upsizing the Ledwicke St trunkline system and the lateral systems from the adjacent streets, the lateral system along Norvic St, and the systems along Pleasantville Dr, Bucroft St and Gellhorn Dr. The proposed storm sewer layout is shown in **Exhibit 10**.

The opinion of probable construction cost including the paving, detention, and storm sewer improvements is approximately **$24.3 million**. The estimate includes:

- $3.8 million for roadway reconstruction assuming full pavement where storm sewer is placed.
- $10.5 million for storm sewer improvements
- $3.7 million for detention construction
- $6.3 million for mobilization and contingencies

The opinion of probable cost is shown in **Appendix B.2**.

Detention Alternative Results

The Detention Alternative resultant ponding depths in both the 2-year and 100-year storm events are reduced from existing conditions. Most of the ponding during the 2-year event is below top of gutter and within the street during the 100-year event. Ponding depths are reduced during the 100-year event by up 2.5 feet. In addition to reducing ponding depths there is no increase of flow into the TxDOT system. A table of ponding depths for various intersections for the 2-year and 100-year events compared to the existing conditions is shown below in **Table 5**.

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Table 5. Existing vs Detention Alternative Ponding Depths

Intersection	EX Depths (ft)		Det. Alt Depths (ft)	
	2YR	100YR	2YR	100YR
Bucroft - Pleasantville	0.85	2.82	0.49	1.10
Fillmore - Gellhorn	0.20	2.24	0.00	0.00
Bucroft - Gellhorn	0.32	3.18	0.00	0.76
Northton - Gellhorn	0.84	3.28	0.00	0.91
Josie - Gellhorn	1.84	2.78	0.48	2.45
Ledwicke - Guinevere	0.00	2.65	0.00	1.38
Flossie Mae - Quaker	0.00	2.35	0.00	1.65
Laurentide - Pattibob	0.00	2.39	0.00	1.56
Cowart - Ledwicke	0.00	1.58	0.00	1.14
Laurentide - Tilgham	0.00	1.80	0.00	1.13
Berndale - Candy	0.29	1.62	0.00	1.37
Laurentide - Candy	0.00	1.78	0.00	1.12
Tilgham - Teanaway	0.00	1.01	0.00	1.00
Norvic - Teanaway	0.40	1.77	0.00	1.38
Wiggins - Silverdale	0.31	2.13	0.32	1.72
Berndale - Silverdale	0.51	2.63	0.37	2.42

The Detention Alternative provided more benefit during the 100-year event compared to Alternative 1A-1, with the entire neighborhood achieving a 100-year level of service. Ponding depths during the 2-year event are slightly less beneficial when compared to Alternative 1A but overall provide a substantial reduction in ponding. Ponding maps for the 2-year and 100-year existing conditions are shown in **Exhibit 11** and **Exhibit 12** respectively.

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CONCLUSION

The Pleasantville Neighborhood has a history of drainage concerns. Previous studies have indicated that significant improvements are needed throughout the neighborhood and have included both detention and storm sewer.

Altas 14 rainfall has increased rainfall rates and reduced the level of service of the existing drainage system. The existing conditions drainage network level of service was reduced from a 10-year (pre-Atlas 14) to less than a 2-year level of service as a result of Atlas 14 rainfall.

The Alternative 1A-1 from the *2013 Study* has a 10-year level of service based on Atlas 14 rainfall. The updated opinion of probable construction cost for Alternative 1A-1 is $27.1 million.

A preliminary screening of six potential detention sites within the area resulted in one potential location which provides substantial benefit. The Port of Houston property between Gellhorn and Lanewell provides a possible location for detention and can provide up to 350 acre-feet of detention. The City should continue discussion with the Port Authority and with the USACE to determine the feasibility of obtaining a portion of this land for detention. The City should also conduct an environmental assessment as the land could have hazardous material and may be costly to excavate.

If a 350 acre-foot detention pond is constructed on the Port property in conjunction with storm sewer improvements within Pleasantville, the neighborhood can be made to achieve a 100-year level of service and a potential reduction in overall construction cost. The opinion of probable construct cost for the Detention Alternative is $24.3 million.

The City should continue to explore funding opportunities and partnerships for constructing the detention facility. Potential funding partners may include the HCFCD, the Port of Houston, and the General Land Office. If the facility is constructed, the future subprojects or the neighborhood can be revised as shown in the Detention Alternative.

If you have any questions or need additional information, please do not hesitate to contact me.

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Texas Firm Registration No. 312

C. Andrew Moore, P.E., CFM
TX PE No. 124910
Water Resources Team Leader

STATE OF TEXAS
C. ANDREW MOORE
124910
LICENSED
PROFESSIONAL ENGINEER

LEGEND

Project Area

Notes:

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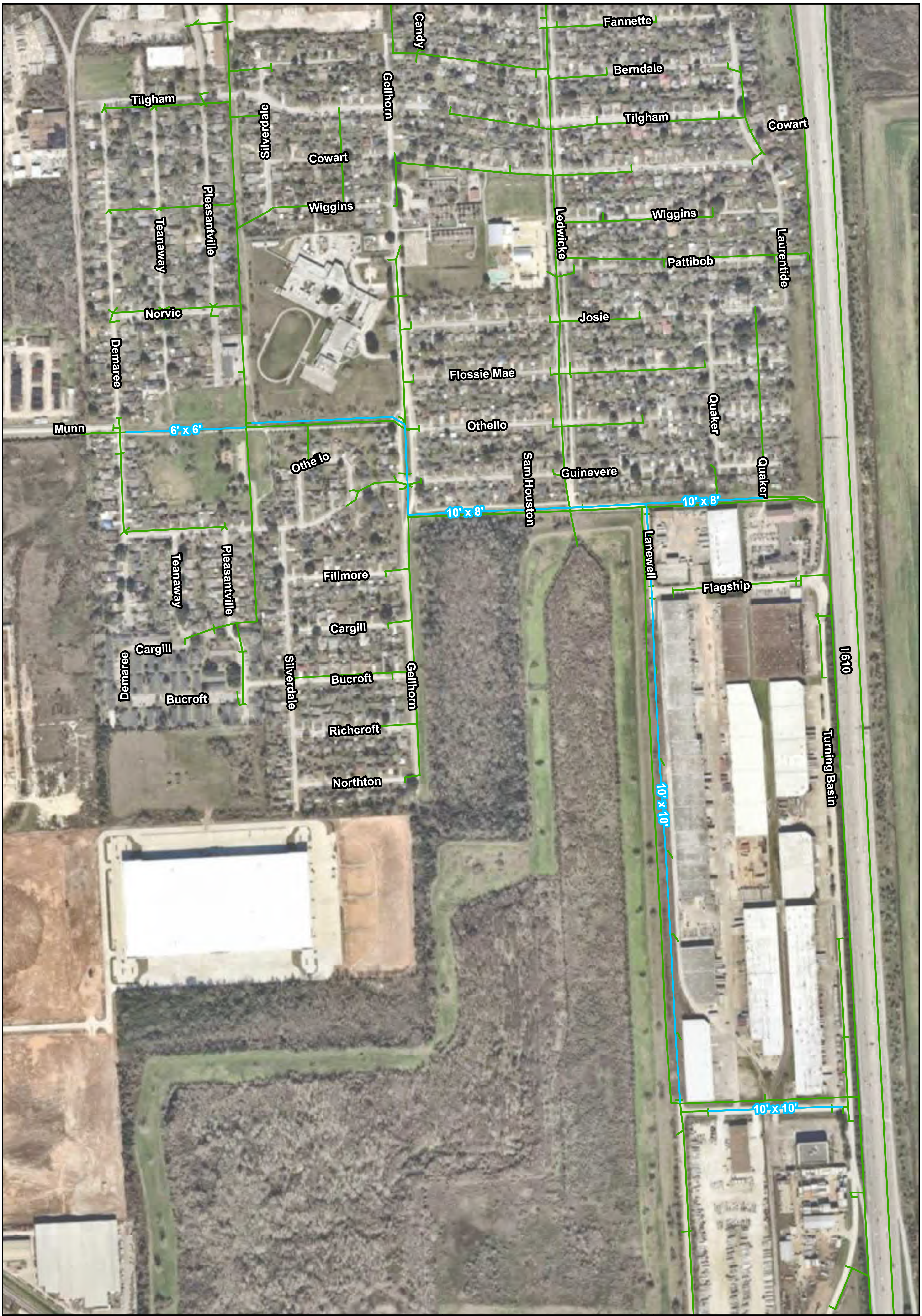
0 500 1,000 2,000 Feet

WORK ORDER 121
PLEASANTVILLE DETENTION ANALYSIS

Project Area

Exhibit 1



LEGEND

- Subproject 1 - Existing Storm Sewer
- Existing Storm Sewer

Notes:

1. Subproject 1 storm sewer was constructed in 2016 and 2017.

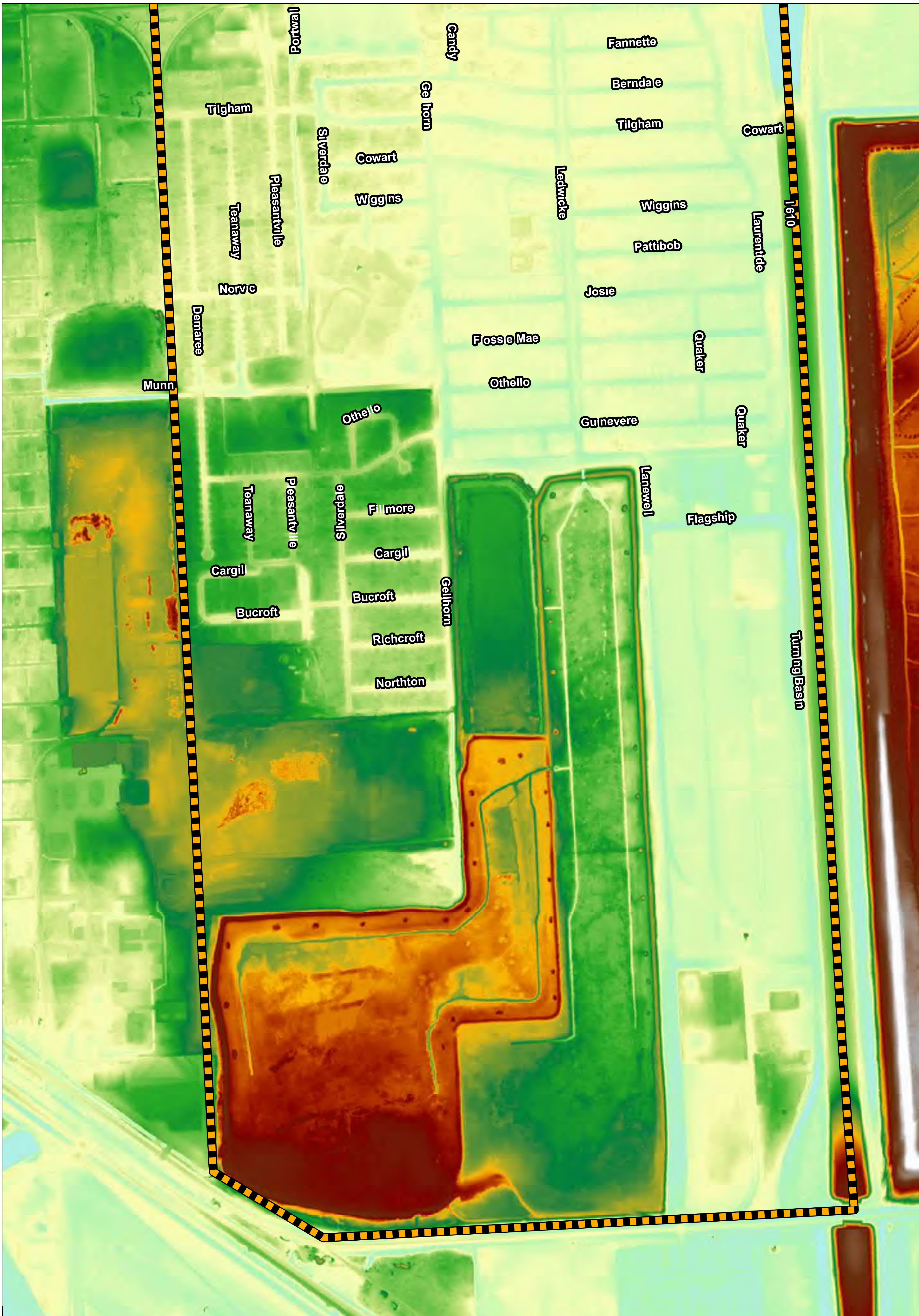
HALFF

0 250 500 1,000 Feet

WORK ORDER 121
PLEASANTVILLE DETENTION ANALYSIS

Existing Storm Sewer Layout

Exhibit 2



LEGEND

Project Area

Terrain

Feet

High : 22.77

Low : 5.18

Notes:

HALFF

0 300 600 1,200 Feet

WORK ORDER 121

PLEASANTVILLE DETENTION ANALYSIS

Terrain

Exhibit 3

LEGEND

Basins

Notes:

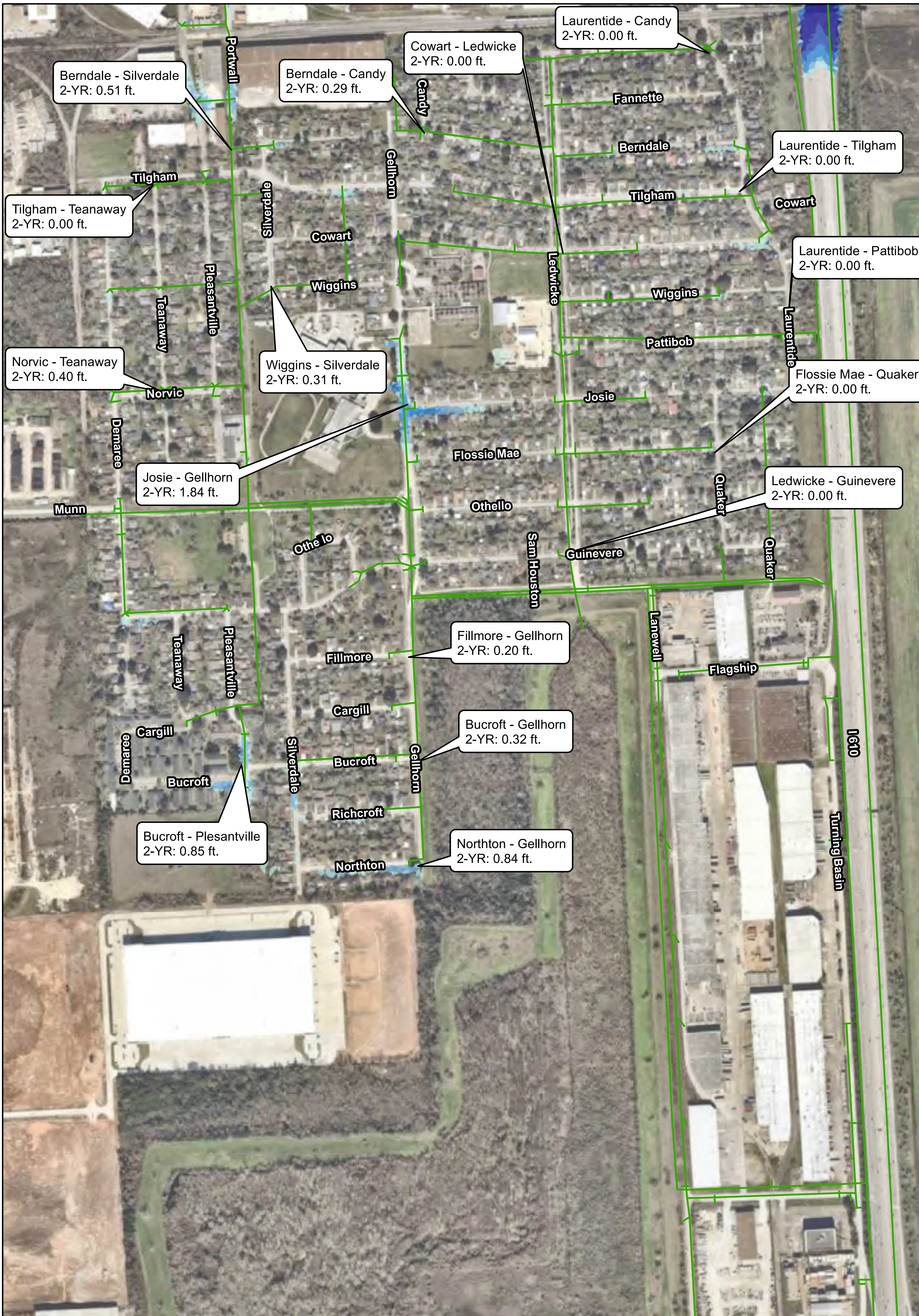
HALFF

0 400 800 1,600 Feet

WORK ORDER 121
PLEASANTVILLE DETENTION ANALYSIS

Drainage Areas

Exhibit 4



LEGEND

Existing Storm Sewer

DEPTH (FT)

- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3.00

Notes:

HALFF

0 250 500 1,000 Feet

N

WORK ORDER 121
PLEASANTVILLE DETENTION ANALYSIS

Existing 2-YR Ponding with Depths

Exhibit 5

Legend

Existing Storm Sewer

DEPTH (FT)

- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3.00

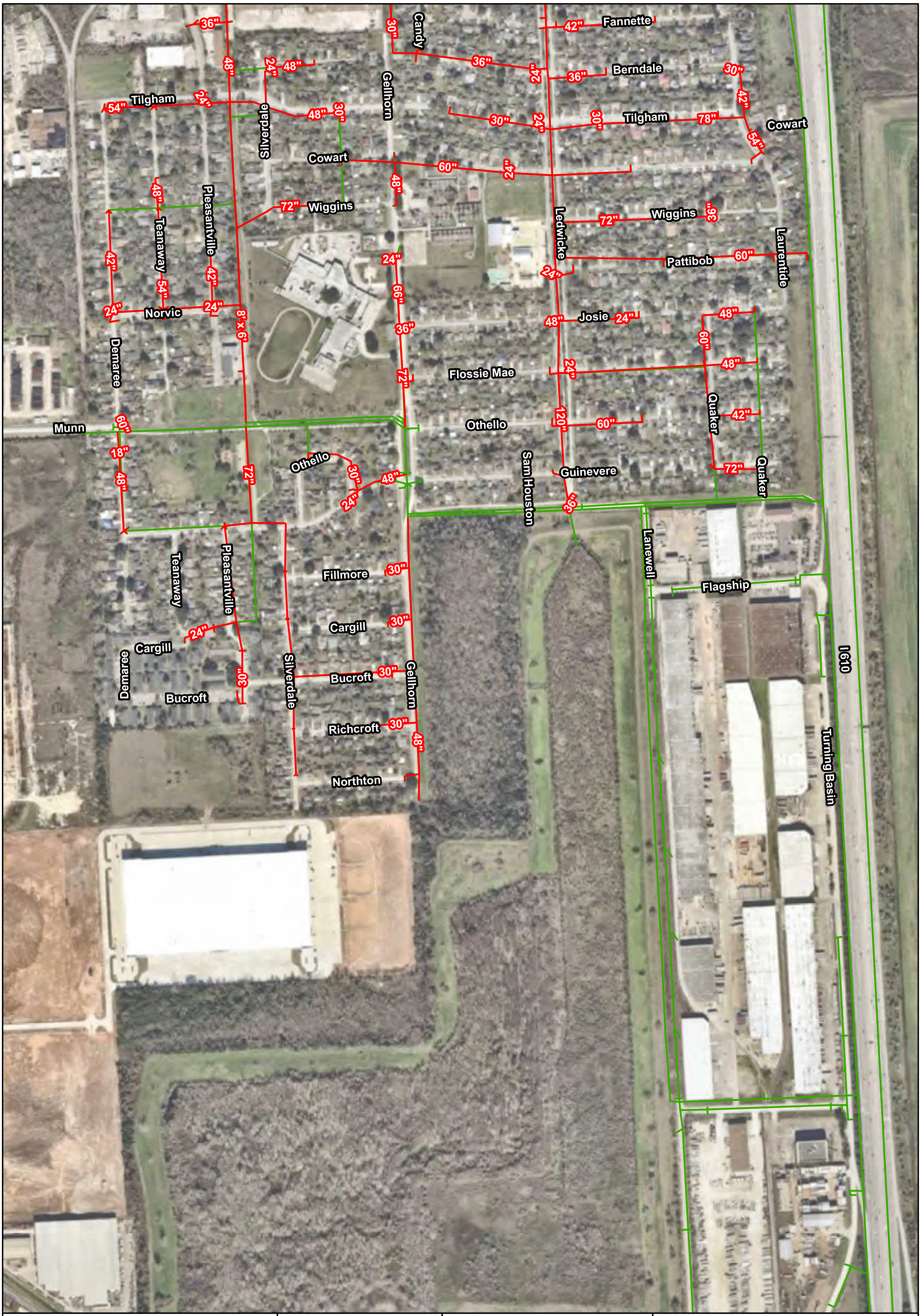
Notes:

HALFF

WORK ORDER 121
PLEASANTVILLE DETENTION ANALYSIS

Existing 100-YR Ponding with Depths

Exhibit 6



LEGEND

- Alternative 1A-1 Storm Sewer
- Existing Storm Sewer

Notes:

1. Alternative 1A-1 Improvements were derived from "2013 Study"

HALFF

0 250 500 1,000 Feet

WORK ORDER 121
PLEASANTVILLE DETENTION ANALYSIS

Alternative 1A-1 Improvements

Exhibit 7

LEGEND

Alternative 1A-1 Storm Sewer

Existing Storm Sewer

DEPTH (FT)

0.25 - 0.50

0.50 - 1.00

1.00 - 2.00

2.00 - 3.00

> 3.00

Notes:

HALFF

0 250 500 1,000 Feet

WORK ORDER 121

PLEASANTVILLE DETENTION ANALYSIS

Alternative 2-YR Ponding with Depths

Exhibit 8

LEGEND

Alternative 1A-1 Storm Sewer

Existing Storm Sewer

DEPTH (FT)

- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3.00

Notes:

HALFF

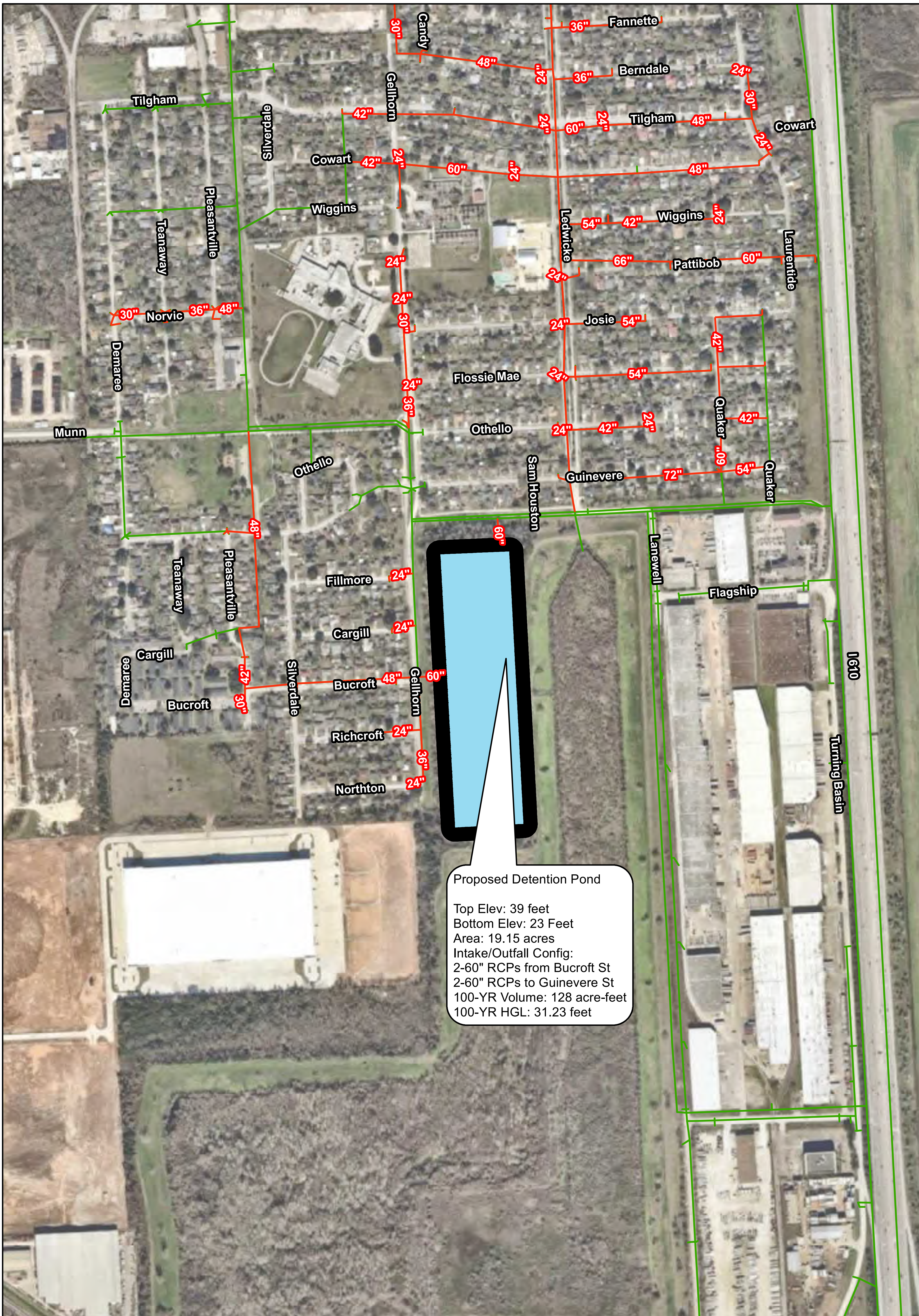
0 250 500 1,000 Feet

WORK ORDER 121

PLEASANTVILLE DETENTION ANALYSIS

Alternative 1A-1 100-YR Ponding with Depths

Exhibit 9



LEGEND

- Proposed Pond
- Proposed Storm Sewer
- Existing Storm Sewer

Notes:

HALFF

0 250 500 1,000 Feet

WORK ORDER 121
PLEASANTVILLE DETENTION ANALYSIS

Detention Alternative

Exhibit 10

LEGEND

- Proposed Pond
- Proposed Storm Sewer
- Existing Storm Sewer

DEPTH (FT)

- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3.00

Notes:

HALFF

0 250 500 1,000 Feet

WORK ORDER 121
PLEASANTVILLE DETENTION ANALYSIS

Proposed 2-YR Ponding with Depths

Exhibit 11

LEGEND

- Proposed Pond
- Proposed Storm Sewer
- Existing Storm Sewer

DEPTH (FT)

- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 3.00
- > 3.00

Notes:

HALFF

0 250 500 1,000 Feet

WORK ORDER 121
PLEASANTVILLE DETENTION ANALYSIS

Proposed 100-YR Ponding with Depths

Exhibit
12

APPENDIX A

Atlas 14 Rational Method Calculations																	
Basin Name	Area (sqmi)	Area (AC)	C	% Impr	TC (min)	TC (hr)	I2 (in/hr)	Q2 (cfs)	I10 (in/hr)	Q10 (cfs)	I25 (in/hr)	Q25 (cfs)	I50 (in/hr)	Q50 (cfs)	I100 (in/hr)	Q100 (cfs)
001P	0.0013	0.85	0.75	92	24.72	0.41	3.77	2.4	5.54	3.5	6.71	4.3	7.64	4.9	8.59	5.5
003P	0.0015	0.95	0.20	0	24.91	0.42	3.76	0.7	5.52	1.0	6.68	1.3	7.61	1.4	8.55	1.6
002P	0.0027	1.74	0.65	75	26.03	0.43	3.67	4.2	5.40	6.1	6.53	7.4	7.45	8.4	8.37	9.5
007P	0.0013	0.86	0.65	75	24.74	0.41	3.77	2.1	5.54	3.1	6.71	3.7	7.64	4.3	8.58	4.8
009P	0.0015	0.97	0.65	75	24.95	0.42	3.76	2.4	5.52	3.5	6.68	4.2	7.61	4.8	8.55	5.4
011P	0.0015	0.97	0.65	75	24.95	0.42	3.76	2.4	5.52	3.5	6.68	4.2	7.61	4.8	8.55	5.4
006P	0.0015	0.97	0.65	75	24.94	0.42	3.76	2.4	5.52	3.5	6.68	4.2	7.61	4.8	8.55	5.4
014P	0.0057	3.62	0.25	8	27.54	0.46	3.56	3.2	5.24	4.7	6.35	5.7	7.24	6.6	8.14	7.4
012P	0.0040	2.56	0.65	75	26.80	0.45	3.62	6.0	5.32	8.9	6.44	10.7	7.34	12.2	8.25	13.7
004P	0.0013	0.81	0.30	17	24.63	0.41	3.78	0.9	5.56	1.3	6.72	1.6	7.66	1.8	8.60	2.1
015P	0.0141	9.00	0.60	67	29.72	0.50	3.42	18.5	5.03	27.3	6.10	33.0	6.96	37.7	7.83	42.4
016P	0.0040	2.57	0.74	90	26.81	0.45	3.61	6.9	5.31	10.1	6.44	12.2	7.34	14.0	8.25	15.7
017P	0.0018	1.14	0.34	24	25.23	0.42	3.73	1.5	5.49	2.1	6.64	2.6	7.57	3.0	8.50	3.3
018P	0.0101	6.47	0.73	89	28.89	0.48	3.47	16.5	5.11	24.2	6.19	29.4	7.06	33.5	7.95	37.7
019L	0.0029	1.88	0.78	96	26.18	0.44	3.66	5.3	5.38	7.9	6.52	9.5	7.43	10.8	8.35	12.2
021L	0.0034	2.19	0.55	58	26.48	0.44	3.64	4.4	5.35	6.4	6.48	7.8	7.38	8.9	8.30	10.0
020L	0.0027	1.73	0.55	58	26.01	0.43	3.67	3.5	5.40	5.1	6.54	6.2	7.45	7.1	8.37	8.0
038P	0.0048	3.06	0.55	58	27.18	0.45	3.59	6.0	5.28	8.9	6.39	10.8	7.29	12.3	8.19	13.8
043P	0.0014	0.89	0.68	80	24.80	0.41	3.77	2.3	5.54	3.4	6.70	4.1	7.63	4.6	8.57	5.2
044P	0.0009	0.59	0.55	58	24.10	0.40	3.83	1.2	5.62	1.8	6.80	2.2	7.74	2.5	8.69	2.8
045P	0.0007	0.46	0.55	58	23.72	0.40	3.86	1.0	5.66	1.4	6.85	1.7	7.80	2.0	8.76	2.2
046P	0.0038	2.43	0.55	58	26.69	0.44	3.62	4.8	5.33	7.1	6.45	8.6	7.35	9.8	8.27	11.0
047L	0.0017	1.11	0.55	58	25.18	0.42	3.74	2.3	5.49	3.3	6.65	4.0	7.57	4.6	8.51	5.2
026L	0.0020	1.30	0.55	58	25.47	0.42	3.72	2.7	5.46	3.9	6.61	4.7	7.53	5.4	8.46	6.0
025L	0.0020	1.28	0.55	58	25.44	0.42	3.72	2.6	5.46	3.8	6.61	4.7	7.53	5.3	8.46	6.0
027L	0.0012	0.79	0.55	58	24.59	0.41	3.79	1.6	5.56	2.4	6.73	2.9	7.66	3.3	8.61	3.7
022L	0.0040	2.55	0.55	58	26.79	0.45	3.62	5.1	5.32	7.5	6.44	9.0	7.34	10.3	8.25	11.6
028L	0.0023	1.48	0.55	58	25.72	0.43	3.70	3.0	5.43	4.4	6.57	5.4	7.49	6.1	8.42	6.9
034L	0.0021	1.32	0.55	58	25.51	0.43	3.71	2.7	5.46	4.0	6.60	4.8	7.52	5.5	8.45	6.2
039L	0.0022	1.41	0.55	58	25.62	0.43	3.70	2.9	5.44	4.2	6.59	5.1	7.51	5.8	8.44	6.5
048L	0.0025	1.58	0.55	58	25.83	0.43	3.69	3.2	5.42	4.7	6.56	5.7	7.48	6.5	8.40	7.3
060P	0.0025	1.58	0.55	58	25.84	0.43	3.69	3.2	5.42	4.7	6.56	5.7	7.48	6.5	8.40	7.3
061L	0.0028	1.81	0.55	58	26.11	0.44	3.67	3.7	5.39	5.4	6.52	6.5	7.44	7.4	8.36	8.3
029L	0.0021	1.36	0.55	58	25.56	0.43	3.71	2.8	5.45	4.1	6.60	4.9	7.52	5.6	8.45	6.3
032L	0.0020	1.29	0.55	58	25.45	0.42	3.72	2.6	5.46	3.9	6.61	4.7	7.53	5.3	8.46	6.0
035L	0.0013	0.85	0.55	58	24.71	0.41	3.78	1.8	5.55	2.6	6.71	3.1	7.64	3.6	8.59	4.0
040L	0.0032	2.08	0.55	58	26.38	0.44	3.65	4.2	5.36	6.1	6.49	7.4	7.40	8.5	8.32	9.5
049L	0.0032	2.08	0.55	58	26.37	0.44	3.65	4.2	5.36	6.1	6.49	7.4	7.40	8.4	8.32	9.5
062L	0.0014	0.92	0.55	58	24.85	0.41	3.76	1.9	5.53	2.8	6.69	3.4	7.62	3.8	8.56	4.3

Atlas 14 Rational Method Calculations																
Basin Name	Area (sqmi)	Area (AC)	C	% Impr	TC (min)	TC (hr)	I2 (in/hr)	Q2 (cfs)	I10 (in/hr)	Q10 (cfs)	I25 (in/hr)	Q25 (cfs)	I50 (in/hr)	Q50 (cfs)	I100 (in/hr)	Q100 (cfs)
023L	0.0019	1.25	0.55	58	25.40	0.42	3.72	2.6	5.47	3.8	6.62	4.5	7.54	5.2	8.47	5.8
024L	0.0024	1.54	0.42	37	25.79	0.43	3.69	2.4	5.42	3.5	6.57	4.3	7.48	4.8	8.41	5.4
030L	0.0018	1.16	0.55	58	25.27	0.42	3.73	2.4	5.48	3.5	6.63	4.2	7.56	4.8	8.49	5.4
031L	0.0032	2.02	0.46	43	26.32	0.44	3.65	3.4	5.37	5.0	6.50	6.0	7.41	6.8	8.32	7.7
033L	0.0030	1.94	0.55	58	26.24	0.44	3.66	3.9	5.37	5.7	6.51	7.0	7.42	7.9	8.34	8.9
036L	0.0029	1.85	0.55	58	26.15	0.44	3.66	3.7	5.38	5.5	6.52	6.6	7.43	7.6	8.35	8.5
041L	0.0023	1.50	0.55	58	25.73	0.43	3.70	3.0	5.43	4.5	6.57	5.4	7.49	6.2	8.42	6.9
037L	0.0051	3.27	0.37	28	27.32	0.46	3.58	4.3	5.26	6.3	6.37	7.6	7.27	8.7	8.17	9.8
050L	0.0020	1.27	0.55	58	25.42	0.42	3.72	2.6	5.46	3.8	6.61	4.6	7.54	5.2	8.47	5.9
063L	0.0028	1.78	0.55	58	26.07	0.43	3.67	3.6	5.39	5.3	6.53	6.4	7.44	7.3	8.36	8.2
064L	0.0017	1.12	0.55	58	25.20	0.42	3.74	2.3	5.49	3.4	6.64	4.1	7.57	4.7	8.50	5.2
076L	0.0016	1.02	0.55	58	25.03	0.42	3.75	2.1	5.51	3.1	6.67	3.7	7.60	4.2	8.53	4.8
065L	0.0023	1.46	0.55	58	25.69	0.43	3.70	3.0	5.43	4.4	6.58	5.3	7.50	6.0	8.42	6.8
075L	0.0028	1.78	0.55	58	26.07	0.43	3.67	3.6	5.39	5.3	6.53	6.4	7.44	7.3	8.36	8.2
082L	0.0022	1.41	0.55	58	25.62	0.43	3.70	2.9	5.44	4.2	6.59	5.1	7.51	5.8	8.44	6.5
081L	0.0024	1.52	0.55	58	25.77	0.43	3.69	3.1	5.43	4.5	6.57	5.5	7.49	6.3	8.41	7.0
089L	0.0030	1.90	0.55	58	26.20	0.44	3.66	3.8	5.38	5.6	6.51	6.8	7.42	7.8	8.34	8.7
095L	0.0032	2.04	0.55	58	26.33	0.44	3.65	4.1	5.36	6.0	6.50	7.3	7.40	8.3	8.32	9.3
108L	0.0032	2.06	0.55	58	26.36	0.44	3.65	4.1	5.36	6.1	6.49	7.4	7.40	8.4	8.32	9.4
094L	0.0019	1.20	0.55	58	25.33	0.42	3.73	2.5	5.47	3.6	6.63	4.4	7.55	5.0	8.48	5.6
088L	0.0034	2.20	0.55	58	26.49	0.44	3.64	4.4	5.35	6.5	6.48	7.8	7.38	8.9	8.30	10.0
080L	0.0034	2.20	0.55	58	26.49	0.44	3.64	4.4	5.35	6.5	6.48	7.8	7.38	8.9	8.30	10.0
107L	0.0026	1.64	0.55	58	25.91	0.43	3.68	3.3	5.41	4.9	6.55	5.9	7.47	6.7	8.39	7.5
074L	0.0012	0.77	0.55	58	24.55	0.41	3.79	1.6	5.56	2.4	6.73	2.9	7.67	3.3	8.61	3.7
109L	0.0014	0.91	0.55	58	24.83	0.41	3.77	1.9	5.53	2.8	6.69	3.3	7.63	3.8	8.57	4.3
112L	0.0021	1.34	0.55	58	25.52	0.43	3.71	2.7	5.45	4.0	6.60	4.8	7.52	5.5	8.45	6.2
111L	0.0026	1.66	0.55	58	25.93	0.43	3.68	3.4	5.41	4.9	6.55	6.0	7.46	6.8	8.39	7.6
110L	0.0012	0.80	0.55	58	24.61	0.41	3.78	1.7	5.56	2.4	6.72	2.9	7.66	3.4	8.60	3.8
113L	0.0020	1.26	0.55	58	25.42	0.42	3.72	2.6	5.46	3.8	6.61	4.6	7.54	5.2	8.47	5.9
114L	0.0026	1.67	0.55	58	25.94	0.43	3.68	3.4	5.41	5.0	6.55	6.0	7.46	6.8	8.38	7.7
115L	0.0017	1.11	0.55	58	25.18	0.42	3.74	2.3	5.49	3.3	6.65	4.0	7.57	4.6	8.51	5.2
116L	0.0007	0.44	0.55	58	23.64	0.39	3.86	0.9	5.67	1.4	6.86	1.6	7.81	1.9	8.77	2.1
128H	0.0021	1.36	0.55	58	25.56	0.43	3.71	2.8	5.45	4.1	6.60	4.9	7.52	5.6	8.45	6.3
136H	0.0025	1.62	0.48	47	25.88	0.43	3.68	2.9	5.41	4.2	6.55	5.1	7.47	5.8	8.39	6.5
141H	0.0027	1.74	0.51	51	26.02	0.43	3.67	3.2	5.40	4.7	6.54	5.7	7.45	6.5	8.37	7.3
140L	0.0027	1.74	0.55	58	26.03	0.43	3.67	3.5	5.40	5.2	6.53	6.3	7.45	7.1	8.37	8.0
135L	0.0035	2.22	0.55	58	26.51	0.44	3.64	4.4	5.35	6.5	6.47	7.9	7.38	9.0	8.29	10.1
127L	0.0037	2.39	0.55	58	26.66	0.44	3.63	4.8	5.33	7.0	6.45	8.5	7.36	9.7	8.27	10.9
139L	0.0020	1.27	0.55	58	25.43	0.42	3.72	2.6	5.46	3.8	6.61	4.6	7.54	5.3	8.47	5.9

Atlas 14 Rational Method Calculations																
Basin Name	Area (sqmi)	Area (AC)	C	% Impr	TC (min)	TC (hr)	I2 (in/hr)	Q2 (cfs)	I10 (in/hr)	Q10 (cfs)	I25 (in/hr)	Q25 (cfs)	I50 (in/hr)	Q50 (cfs)	I100 (in/hr)	Q100 (cfs)
106L	0.0045	2.85	0.49	48	27.02	0.45	3.60	5.0	5.29	7.4	6.41	8.9	7.31	10.2	8.22	11.4
087L	0.0074	4.71	0.34	23	28.14	0.47	3.52	5.6	5.18	8.2	6.28	10.0	7.16	11.4	8.05	12.8
105G	0.0079	5.04	0.42	37	28.29	0.47	3.51	7.5	5.17	11.0	6.26	13.3	7.14	15.2	8.03	17.1
079L	0.0038	2.41	0.55	58	26.67	0.44	3.62	4.8	5.33	7.1	6.45	8.5	7.36	9.7	8.27	10.9
126L	0.0024	1.54	0.55	58	25.79	0.43	3.69	3.1	5.42	4.6	6.57	5.6	7.48	6.3	8.41	7.1
134L	0.0023	1.46	0.55	58	25.69	0.43	3.70	3.0	5.43	4.4	6.58	5.3	7.50	6.0	8.42	6.8
125G	0.0023	1.45	0.55	58	25.67	0.43	3.70	2.9	5.44	4.3	6.58	5.2	7.50	6.0	8.43	6.7
133G	0.0021	1.37	0.55	58	25.57	0.43	3.71	2.8	5.45	4.1	6.59	5.0	7.52	5.7	8.44	6.3
104G	0.0010	0.62	0.67	78	24.18	0.40	3.82	1.6	5.61	2.3	6.78	2.8	7.73	3.2	8.68	3.6
092L	0.0016	1.00	0.42	37	24.99	0.42	3.75	1.6	5.51	2.3	6.67	2.8	7.60	3.2	8.54	3.6
086L	0.0004	0.24	0.42	36	22.75	0.38	3.94	0.4	5.79	0.6	7.00	0.7	7.96	0.8	8.94	0.9
073L	0.0026	1.67	0.55	58	25.95	0.43	3.68	3.4	5.41	5.0	6.54	6.0	7.46	6.9	8.38	7.7
078L	0.0007	0.48	0.55	58	23.78	0.40	3.85	1.0	5.66	1.5	6.84	1.8	7.79	2.0	8.75	2.3
072P	0.0024	1.54	0.55	58	25.79	0.43	3.69	3.1	5.42	4.6	6.56	5.6	7.48	6.3	8.41	7.1
077P	0.0030	1.89	0.55	58	26.19	0.44	3.66	3.8	5.38	5.6	6.51	6.8	7.43	7.7	8.34	8.7
059P	0.0014	0.87	0.55	58	24.77	0.41	3.77	1.8	5.54	2.7	6.70	3.2	7.64	3.7	8.58	4.1
058P	0.0017	1.09	0.55	58	25.16	0.42	3.74	2.2	5.49	3.3	6.65	4.0	7.58	4.5	8.51	5.1
085P	0.0029	1.84	0.55	58	26.14	0.44	3.66	3.7	5.39	5.5	6.52	6.6	7.43	7.5	8.35	8.5
091P	0.0021	1.37	0.55	58	25.57	0.43	3.71	2.8	5.45	4.1	6.59	5.0	7.52	5.7	8.44	6.4
090P	0.0015	0.95	0.55	58	24.91	0.42	3.76	2.0	5.52	2.9	6.68	3.5	7.61	4.0	8.55	4.5
084P	0.0033	2.09	0.55	58	26.38	0.44	3.65	4.2	5.36	6.2	6.49	7.5	7.40	8.5	8.31	9.5
093P	0.0021	1.38	0.55	58	25.58	0.43	3.71	2.8	5.45	4.1	6.59	5.0	7.51	5.7	8.44	6.4
057P	0.0017	1.11	0.46	44	25.19	0.42	3.74	1.9	5.49	2.8	6.64	3.4	7.57	3.9	8.51	4.4
083P	0.0034	2.15	0.45	42	26.44	0.44	3.64	3.5	5.35	5.2	6.48	6.3	7.39	7.2	8.30	8.1
056P	0.0003	0.18	0.55	58	22.37	0.37	3.98	0.4	5.83	0.6	7.05	0.7	8.03	0.8	9.01	0.9
051P	0.0012	0.78	0.55	58	24.56	0.41	3.79	1.6	5.56	2.4	6.73	2.9	7.67	3.3	8.61	3.7
052P	0.0009	0.56	0.55	58	24.03	0.40	3.83	1.2	5.63	1.7	6.81	2.1	7.75	2.4	8.70	2.7
053P	0.0011	0.70	0.55	58	24.40	0.41	3.80	1.5	5.58	2.2	6.75	2.6	7.69	3.0	8.64	3.3
054P	0.0009	0.55	0.55	58	24.00	0.40	3.83	1.2	5.63	1.7	6.81	2.1	7.76	2.3	8.71	2.6
070P	0.0038	2.43	0.55	58	26.69	0.44	3.62	4.8	5.33	7.1	6.45	8.6	7.35	9.8	8.27	11.0
069P	0.0025	1.63	0.55	58	25.90	0.43	3.68	3.3	5.41	4.8	6.55	5.9	7.47	6.7	8.39	7.5
068P	0.0026	1.70	0.55	58	25.97	0.43	3.68	3.4	5.40	5.0	6.54	6.1	7.46	7.0	8.38	7.8
067P	0.0027	1.71	0.55	58	25.99	0.43	3.68	3.4	5.40	5.1	6.54	6.1	7.45	7.0	8.38	7.9
066P	0.0033	2.14	0.51	52	26.43	0.44	3.64	4.0	5.35	5.8	6.48	7.1	7.39	8.1	8.31	9.1
096P	0.0026	1.64	0.55	58	25.91	0.43	3.68	3.3	5.41	4.9	6.55	5.9	7.47	6.7	8.39	7.6
097P	0.0020	1.27	0.55	58	25.44	0.42	3.72	2.6	5.46	3.8	6.61	4.6	7.53	5.3	8.47	5.9
098P	0.0023	1.50	0.55	58	25.74	0.43	3.70	3.0	5.43	4.5	6.57	5.4	7.49	6.2	8.42	6.9
099P	0.0023	1.48	0.55	58	25.72	0.43	3.70	3.0	5.43	4.4	6.57	5.4	7.49	6.1	8.42	6.9
100P	0.0014	0.89	0.55	58	24.80	0.41	3.77	1.8	5.54	2.7	6.70	3.3	7.63	3.7	8.57	4.2

Atlas 14 Rational Method Calculations																
Basin Name	Area (sqmi)	Area (AC)	C	% Impr	TC (min)	TC (hr)	I2 (in/hr)	Q2 (cfs)	I10 (in/hr)	Q10 (cfs)	I25 (in/hr)	Q25 (cfs)	I50 (in/hr)	Q50 (cfs)	I100 (in/hr)	Q100 (cfs)
101P	0.0007	0.47	0.55	58	23.75	0.40	3.86	1.0	5.66	1.5	6.85	1.8	7.80	2.0	8.76	2.3
102P	0.0022	1.38	0.26	10	25.59	0.43	3.71	1.3	5.45	2.0	6.59	2.4	7.51	2.7	8.44	3.0
123P	0.0102	6.52	0.35	25	28.91	0.48	3.47	7.9	5.11	11.7	6.19	14.1	7.06	16.1	7.94	18.1
122P	0.0010	0.61	0.49	48	24.17	0.40	3.82	1.1	5.61	1.7	6.79	2.0	7.73	2.3	8.68	2.6
121P	0.0024	1.56	0.55	58	25.82	0.43	3.69	3.2	5.42	4.7	6.56	5.6	7.48	6.4	8.40	7.2
120P	0.0009	0.55	0.55	58	24.00	0.40	3.83	1.2	5.63	1.7	6.81	2.1	7.76	2.3	8.71	2.6
119P	0.0008	0.53	0.55	58	23.96	0.40	3.84	1.1	5.63	1.7	6.82	2.0	7.76	2.3	8.72	2.6
118P	0.0005	0.32	0.55	58	23.19	0.39	3.90	0.7	5.73	1.0	6.93	1.2	7.89	1.4	8.86	1.6
117P	0.0008	0.52	0.51	52	23.91	0.40	3.84	1.0	5.64	1.5	6.82	1.8	7.77	2.1	8.73	2.3
A-4	0.0026	1.65	0.55	58	25.92	0.43	3.68	3.3	5.41	4.9	6.55	5.9	7.46	6.8	8.39	7.6
A-5	0.0022	1.38	0.55	58	25.59	0.43	3.71	2.8	5.45	4.1	6.59	5.0	7.51	5.7	8.44	6.4
A-8	0.0080	5.10	0.31	18	28.32	0.47	3.51	5.5	5.16	8.2	6.26	9.9	7.14	11.3	8.03	12.7
A-10	0.0045	2.91	0.55	58	27.07	0.45	3.60	5.7	5.29	8.4	6.40	10.2	7.30	11.7	8.21	13.1
154H	0.0015	0.96	0.55	58	24.93	0.42	3.76	2.0	5.52	2.9	6.68	3.5	7.61	4.0	8.55	4.5
153H	0.0034	2.20	0.35	25	26.49	0.44	3.64	2.8	5.35	4.1	6.48	4.9	7.38	5.6	8.30	6.3
170H	0.0154	9.86	0.27	12	29.96	0.50	3.40	9.1	5.01	13.5	6.07	16.3	6.93	18.6	7.80	21.0
171H	0.0024	1.54	0.47	45	25.79	0.43	3.69	2.7	5.42	3.9	6.57	4.7	7.48	5.4	8.41	6.1
172H	0.0040	2.58	0.41	35	26.82	0.45	3.61	3.8	5.31	5.6	6.43	6.8	7.34	7.8	8.25	8.7
156H	0.0058	3.70	0.55	58	27.59	0.46	3.56	7.2	5.23	10.6	6.34	12.9	7.23	14.7	8.13	16.5
162H	0.0017	1.09	0.55	58	25.15	0.42	3.74	2.2	5.49	3.3	6.65	4.0	7.58	4.5	8.51	5.1
163H	0.0012	0.76	0.55	58	24.53	0.41	3.79	1.6	5.57	2.3	6.74	2.8	7.67	3.2	8.62	3.6
202P	0.0058	3.69	0.33	22	27.59	0.46	3.56	4.4	5.24	6.5	6.34	7.8	7.23	8.9	8.13	10.0
179H	0.0053	3.38	0.55	58	27.40	0.46	3.57	6.7	5.25	9.8	6.36	11.8	7.26	13.5	8.16	15.2
180H	0.0053	3.36	0.55	58	27.38	0.46	3.57	6.6	5.26	9.7	6.37	11.8	7.26	13.4	8.16	15.1
181H	0.0029	1.87	0.55	58	26.17	0.44	3.66	3.8	5.38	5.5	6.52	6.7	7.43	7.6	8.35	8.6
203P	0.0003	0.21	0.65	75	22.59	0.38	3.96	0.5	5.81	0.8	7.02	1.0	7.99	1.1	8.97	1.2
205P	0.0003	0.21	0.65	75	22.59	0.38	3.96	0.5	5.81	0.8	7.02	1.0	7.99	1.1	8.97	1.2
211P	0.0023	1.45	0.65	75	25.68	0.43	3.70	3.5	5.44	5.1	6.58	6.2	7.50	7.1	8.43	8.0
212P	0.0017	1.10	0.65	75	25.16	0.42	3.74	2.7	5.49	3.9	6.65	4.7	7.58	5.4	8.51	6.1
215P	0.0032	2.03	0.65	75	26.33	0.44	3.65	4.8	5.37	7.1	6.50	8.6	7.41	9.8	8.32	11.0
214P	0.0179	11.44	0.32	21	30.36	0.51	3.38	12.5	4.97	18.5	6.03	22.4	6.89	25.6	7.75	28.8
219Pb	0.0167	10.71	0.20	0	30.18	0.50	3.39	7.3	4.99	10.7	6.05	13.0	6.91	14.8	7.77	16.7
204P	0.0012	0.79	0.65	75	24.60	0.41	3.79	1.9	5.56	2.9	6.73	3.5	7.66	3.9	8.61	4.4
220Gb	0.0389	24.89	0.20	0	32.61	0.54	3.24	16.1	4.78	23.8	5.81	28.9	6.63	33.0	7.47	37.2
225Gb	0.0573	36.70	0.20	0	33.86	0.56	3.17	23.3	4.69	34.4	5.69	41.8	6.51	47.7	7.33	53.8
224G	0.0040	2.53	0.55	58	26.77	0.45	3.62	5.0	5.32	7.4	6.44	9.0	7.34	10.2	8.25	11.5
221G	0.0034	2.15	0.55	58	26.44	0.44	3.64	4.3	5.35	6.3	6.48	7.7	7.39	8.7	8.30	9.8
218G	0.0028	1.80	0.55	58	26.09	0.43	3.67	3.6	5.39	5.3	6.53	6.4	7.44	7.3	8.36	8.3
216G	0.0005	0.34	0.55	58	23.27	0.39	3.90	0.7	5.72	1.1	6.92	1.3	7.88	1.5	8.84	1.6

Atlas 14 Rational Method Calculations																
Basin Name	Area (sqmi)	Area (AC)	C	% Impr	TC (min)	TC (hr)	I2 (in/hr)	Q2 (cfs)	I10 (in/hr)	Q10 (cfs)	I25 (in/hr)	Q25 (cfs)	I50 (in/hr)	Q50 (cfs)	I100 (in/hr)	Q100 (cfs)
213G	0.0040	2.55	0.55	58	26.79	0.45	3.62	5.1	5.32	7.4	6.44	9.0	7.34	10.3	8.25	11.6
206G	0.0005	0.35	0.55	58	23.30	0.39	3.89	0.7	5.71	1.1	6.91	1.3	7.87	1.5	8.84	1.7
207G	0.0028	1.78	0.55	58	26.07	0.43	3.67	3.6	5.39	5.3	6.53	6.4	7.44	7.3	8.36	8.2
182G	0.0048	3.10	0.55	58	27.20	0.45	3.59	6.1	5.27	9.0	6.39	10.9	7.28	12.4	8.19	13.9
199G	0.0046	2.92	0.55	58	27.08	0.45	3.60	5.8	5.29	8.5	6.40	10.3	7.30	11.7	8.21	13.2
197G	0.0028	1.77	0.55	58	26.06	0.43	3.67	3.6	5.39	5.3	6.53	6.4	7.44	7.3	8.36	8.2
194G	0.0034	2.16	0.55	58	26.45	0.44	3.64	4.3	5.35	6.4	6.48	7.7	7.39	8.8	8.30	9.9
183H	0.0027	1.72	0.55	58	26.01	0.43	3.67	3.5	5.40	5.1	6.54	6.2	7.45	7.1	8.37	7.9
184H	0.0031	1.96	0.55	58	26.26	0.44	3.66	3.9	5.37	5.8	6.51	7.0	7.42	8.0	8.33	9.0
217G	0.0040	2.55	0.55	58	26.79	0.45	3.62	5.1	5.32	7.5	6.44	9.0	7.34	10.3	8.25	11.6
195H	0.3220	206.07	0.20	0	40.56	0.68	2.86	117.8	4.24	174.7	5.16	212.7	5.91	243.6	6.68	275.2
185H	0.0042	2.66	0.20	0	26.88	0.45	3.61	1.9	5.31	2.8	6.43	3.4	7.33	3.9	8.24	4.4
186H	0.0029	1.88	0.25	8	26.18	0.44	3.66	1.7	5.38	2.5	6.52	3.1	7.43	3.5	8.35	3.9
187L	0.0007	0.45	0.50	50	23.69	0.39	3.86	0.9	5.67	1.3	6.86	1.5	7.81	1.8	8.77	2.0
173H	0.0022	1.39	0.55	58	25.59	0.43	3.71	2.8	5.45	4.2	6.59	5.0	7.51	5.7	8.44	6.4
174L	0.0020	1.29	0.55	58	25.46	0.42	3.72	2.6	5.46	3.9	6.61	4.7	7.53	5.3	8.46	6.0
B-12	0.0021	1.32	0.55	58	25.50	0.43	3.71	2.7	5.46	4.0	6.60	4.8	7.52	5.5	8.45	6.1
166L	0.0022	1.41	0.55	58	25.62	0.43	3.70	2.9	5.44	4.2	6.59	5.1	7.51	5.8	8.43	6.5
159L	0.0022	1.42	0.55	58	25.63	0.43	3.70	2.9	5.44	4.2	6.59	5.1	7.51	5.8	8.43	6.6
B-4	0.0020	1.30	0.55	58	25.48	0.42	3.71	2.7	5.46	3.9	6.61	4.7	7.53	5.4	8.46	6.1
175L	0.0016	1.02	0.55	58	25.04	0.42	3.75	2.1	5.51	3.1	6.66	3.8	7.59	4.3	8.53	4.8
167L	0.0022	1.40	0.55	58	25.60	0.43	3.71	2.8	5.44	4.2	6.59	5.1	7.51	5.8	8.44	6.5
124G	0.0106	6.78	0.50	50	29.01	0.48	3.46	11.7	5.10	17.3	6.18	21.0	7.05	23.9	7.93	26.9
137G	0.0021	1.34	0.55	58	25.53	0.43	3.71	2.7	5.45	4.0	6.60	4.9	7.52	5.5	8.45	6.2
143G	0.0017	1.11	0.55	58	25.18	0.42	3.74	2.3	5.49	3.3	6.65	4.0	7.57	4.6	8.51	5.2
B-3	0.0023	1.50	0.55	58	25.74	0.43	3.69	3.1	5.43	4.5	6.57	5.4	7.49	6.2	8.42	7.0
B-1	0.0002	0.15	0.80	100	22.13	0.37	4.00	0.5	5.87	0.7	7.09	0.8	8.07	0.9	9.06	1.1
A-14	0.0017	1.08	0.55	58	25.13	0.42	3.74	2.2	5.50	3.3	6.65	3.9	7.58	4.5	8.52	5.0
150L	0.0026	1.65	0.55	58	25.92	0.43	3.68	3.3	5.41	4.9	6.55	5.9	7.46	6.8	8.39	7.6
144L	0.0019	1.22	0.55	58	25.36	0.42	3.72	2.5	5.47	3.7	6.62	4.5	7.55	5.1	8.48	5.7
138L	0.0023	1.47	0.55	58	25.70	0.43	3.70	3.0	5.43	4.4	6.58	5.3	7.50	6.1	8.42	6.8
145L	0.0020	1.28	0.55	58	25.45	0.42	3.72	2.6	5.46	3.8	6.61	4.7	7.53	5.3	8.46	6.0
151L	0.0035	2.23	0.55	58	26.52	0.44	3.64	4.5	5.35	6.6	6.47	8.0	7.38	9.1	8.29	10.2
160L	0.0035	2.22	0.55	58	26.51	0.44	3.64	4.4	5.35	6.5	6.47	7.9	7.38	9.0	8.29	10.1
146L	0.0027	1.76	0.55	58	26.04	0.43	3.67	3.5	5.40	5.2	6.53	6.3	7.45	7.2	8.37	8.1
147H	0.0027	1.75	0.51	51	26.04	0.43	3.67	3.3	5.40	4.8	6.53	5.8	7.45	6.6	8.37	7.4
152H	0.0022	1.42	0.49	49	25.64	0.43	3.70	2.6	5.44	3.8	6.59	4.6	7.51	5.3	8.43	5.9
161H	0.0022	1.41	0.49	49	25.63	0.43	3.70	2.6	5.44	3.8	6.59	4.6	7.51	5.3	8.43	5.9
169H	0.0027	1.73	0.51	51	26.01	0.43	3.67	3.2	5.40	4.7	6.54	5.7	7.45	6.5	8.37	7.3

Atlas 14 Rational Method Calculations																
Basin Name	Area (sqmi)	Area (AC)	C	% Impr	TC (min)	TC (hr)	I2 (in/hr)	Q2 (cfs)	I10 (in/hr)	Q10 (cfs)	I25 (in/hr)	Q25 (cfs)	I50 (in/hr)	Q50 (cfs)	I100 (in/hr)	Q100 (cfs)
168H	0.0025	1.61	0.55	58	25.87	0.43	3.68	3.3	5.42	4.8	6.55	5.8	7.47	6.6	8.40	7.4
176H	0.0025	1.60	0.55	58	25.86	0.43	3.69	3.2	5.42	4.8	6.56	5.8	7.47	6.6	8.40	7.4
177H	0.0012	0.75	0.55	58	24.52	0.41	3.79	1.6	5.57	2.3	6.74	2.8	7.68	3.2	8.62	3.6
178H	0.0012	0.79	0.44	41	24.58	0.41	3.79	1.3	5.56	1.9	6.73	2.3	7.66	2.7	8.61	3.0
189H	0.0009	0.60	0.25	8	24.15	0.40	3.82	0.6	5.61	0.8	6.79	1.0	7.73	1.2	8.69	1.3
188H	0.0014	0.92	0.23	5	24.85	0.41	3.76	0.8	5.53	1.2	6.69	1.4	7.62	1.6	8.56	1.8
190M	0.0009	0.56	0.31	19	24.04	0.40	3.83	0.7	5.62	1.0	6.80	1.2	7.75	1.4	8.70	1.5
191M	0.0007	0.42	0.50	50	23.58	0.39	3.87	0.8	5.68	1.2	6.87	1.4	7.82	1.6	8.79	1.8
A1	0.0003	0.20	0.80	100	22.53	0.38	3.96	0.6	5.81	0.9	7.03	1.1	8.00	1.3	8.98	1.4
208M	0.0026	1.69	0.39	32	25.96	0.43	3.68	2.4	5.40	3.6	6.54	4.3	7.46	4.9	8.38	5.5
222M	0.0026	1.66	0.39	32	25.94	0.43	3.68	2.4	5.41	3.6	6.55	4.3	7.46	4.9	8.38	5.5
226M	0.0025	1.62	0.38	30	25.89	0.43	3.68	2.3	5.41	3.3	6.55	4.0	7.47	4.6	8.39	5.1
227M	0.0023	1.48	0.37	29	25.72	0.43	3.70	2.1	5.43	3.0	6.57	3.7	7.49	4.2	8.42	4.7
229M	0.0032	2.03	0.36	27	26.33	0.44	3.65	2.7	5.37	3.9	6.50	4.8	7.40	5.4	8.32	6.1
103G	0.0060	3.81	0.71	85	27.66	0.46	3.55	9.6	5.23	14.1	6.33	17.1	7.22	19.5	8.12	22.0
071P	0.0018	1.16	0.55	58	25.27	0.42	3.73	2.4	5.48	3.5	6.63	4.2	7.56	4.8	8.49	5.4
055P	0.0007	0.44	0.55	58	23.66	0.39	3.86	0.9	5.67	1.4	6.86	1.7	7.81	1.9	8.77	2.1
164H	0.0009	0.55	0.55	58	24.01	0.40	3.83	1.2	5.63	1.7	6.81	2.1	7.76	2.4	8.71	2.6
132P	0.0026	1.69	0.69	81	25.97	0.43	3.68	4.3	5.40	6.3	6.54	7.6	7.46	8.7	8.38	9.7
H102A	0.0587	37.55	0.39	32	33.94	0.57	3.17	46.7	4.68	68.9	5.68	83.7	6.50	95.6	7.32	107.8
225G	0.0043	2.73	0.55	58	26.94	0.45	3.61	5.4	5.30	8.0	6.42	9.7	7.32	11.0	8.23	12.4
219P	0.0008	0.52	0.20	1	23.92	0.40	3.84	0.4	5.64	0.6	6.82	0.7	7.77	0.8	8.72	0.9
220G	0.0040	2.54	0.55	58	26.79	0.45	3.62	5.1	5.32	7.4	6.44	9.0	7.34	10.3	8.25	11.5
005P	0.0038	2.42	0.80	100	26.69	0.44	3.62	7.0	5.33	10.3	6.45	12.5	7.36	14.2	8.27	16.0
008P	0.0018	1.15	0.80	100	25.24	0.42	3.73	3.4	5.48	5.0	6.64	6.1	7.56	6.9	8.50	7.8
010P	0.0027	1.74	0.80	100	26.03	0.43	3.67	5.1	5.40	7.5	6.53	9.1	7.45	10.4	8.37	11.7
013P	0.0063	4.03	0.80	100	27.78	0.46	3.55	11.4	5.22	16.8	6.32	20.4	7.21	23.2	8.10	26.1
042P	0.0012	0.77	0.80	100	24.55	0.41	3.79	2.3	5.56	3.4	6.73	4.1	7.67	4.7	8.61	5.3
A9	0.0005	0.35	0.80	100	23.30	0.39	3.89	1.1	5.72	1.6	6.91	1.9	7.87	2.2	8.84	2.5
A7	0.0002	0.15	0.80	100	22.16	0.37	4.00	0.5	5.86	0.7	7.09	0.8	8.07	1.0	9.06	1.1
D-19	0.0002	0.15	0.55	58	22.19	0.37	3.99	0.3	5.86	0.5	7.08	0.6	8.06	0.7	9.05	0.8
D-20	0.0002	0.11	0.80	100	21.82	0.36	4.03	0.4	5.91	0.5	7.14	0.7	8.13	0.7	9.12	0.8
D-21	0.0004	0.27	0.55	58	22.94	0.38	3.93	0.6	5.76	0.9	6.97	1.0	7.93	1.2	8.90	1.3
D-22	0.0002	0.14	0.80	100	22.09	0.37	4.00	0.5	5.87	0.7	7.10	0.8	8.08	0.9	9.07	1.0
A-3	0.0003	0.17	0.55	58	22.30	0.37	3.98	0.4	5.84	0.5	7.07	0.7	8.04	0.7	9.03	0.8
A-2	0.0004	0.22	0.55	58	22.69	0.38	3.95	0.5	5.79	0.7	7.01	0.9	7.98	1.0	8.95	1.1
A-6	0.0005	0.33	0.55	58	23.23	0.39	3.90	0.7	5.72	1.0	6.92	1.3	7.88	1.4	8.85	1.6
A-12	0.0020	1.27	0.55	58	25.43	0.42	3.72	2.6	5.46	3.8	6.61	4.6	7.54	5.3	8.47	5.9
B-8	0.0012	0.79	0.55	58	24.60	0.41	3.79	1.6	5.56	2.4	6.73	2.9	7.66	3.3	8.61	3.8

Atlas 14 Rational Method Calculations																	
Basin Name	Area (sqmi)	Area (AC)	C	% Impr	TC (min)	TC (hr)	I2 (in/hr)	Q2 (cfs)	I10 (in/hr)	Q10 (cfs)	I25 (in/hr)	Q25 (cfs)	I50 (in/hr)	Q50 (cfs)	I100 (in/hr)	Q100 (cfs)
B-14	0.0002	0.15	0.80	100	22.15	0.37	4.00	0.5	5.86	0.7	7.09	0.8	8.07	1.0	9.06	1.1
B-16	0.0002	0.10	0.80	100	21.70	0.36	4.04	0.3	5.93	0.5	7.16	0.6	8.15	0.7	9.15	0.8
B-10	0.0002	0.10	0.80	100	21.64	0.36	4.05	0.3	5.93	0.5	7.17	0.6	8.16	0.6	9.16	0.7
B-11	0.0001	0.06	0.80	100	21.06	0.35	4.10	0.2	6.01	0.3	7.27	0.3	8.27	0.4	9.28	0.4
B-7	0.0005	0.30	0.80	100	23.08	0.38	3.91	0.9	5.74	1.4	6.95	1.7	7.91	1.9	8.88	2.1
B-5	0.0001	0.05	0.80	100	20.93	0.35	4.11	0.2	6.03	0.2	7.29	0.3	8.29	0.3	9.31	0.4
B-6	0.0001	0.09	0.80	100	21.55	0.36	4.05	0.3	5.95	0.4	7.19	0.5	8.18	0.6	9.18	0.7
C3	0.0004	0.28	0.55	58	23.01	0.38	3.92	0.6	5.75	0.9	6.96	1.1	7.92	1.2	8.89	1.4
B-15	0.0017	1.08	0.55	58	25.14	0.42	3.74	2.2	5.50	3.3	6.65	4.0	7.58	4.5	8.51	5.1
F1	0.0001	0.09	0.20	0	21.53	0.36	4.06	0.1	5.95	0.1	7.19	0.1	8.18	0.1	9.18	0.2
B32	0.0208	13.31	0.79	98	30.78	0.51	3.35	35.1	4.94	51.8	5.99	62.8	6.84	71.7	7.70	80.7
B37	0.0026	1.66	0.79	98	25.94	0.43	3.68	4.8	5.41	7.1	6.55	8.6	7.46	9.8	8.38	11.0
B26	0.0009	0.58	0.57	61	24.07	0.40	3.83	1.2	5.62	1.8	6.80	2.2	7.74	2.5	8.70	2.8
B27	0.0018	1.15	0.34	23	25.25	0.42	3.73	1.5	5.48	2.1	6.64	2.6	7.56	2.9	8.50	3.3
B30	0.0077	4.93	0.78	97	28.24	0.47	3.51	13.5	5.17	19.9	6.26	24.1	7.15	27.5	8.04	31.0
B31	0.0112	7.17	0.79	98	29.15	0.49	3.45	19.5	5.08	28.7	6.16	34.8	7.03	39.7	7.91	44.7
B36	0.0024	1.54	0.79	98	25.79	0.43	3.69	4.5	5.42	6.6	6.57	7.9	7.48	9.1	8.41	10.2
B23	0.0006	0.38	0.49	49	23.45	0.39	3.88	0.7	5.70	1.1	6.89	1.3	7.85	1.5	8.81	1.7
B24	0.0014	0.90	0.37	28	24.81	0.41	3.77	1.2	5.53	1.8	6.70	2.2	7.63	2.5	8.57	2.8
B25	0.0013	0.83	0.45	41	24.68	0.41	3.78	1.4	5.55	2.1	6.71	2.5	7.65	2.8	8.59	3.2
B33	0.0008	0.51	0.34	23	23.89	0.40	3.84	0.7	5.64	1.0	6.83	1.2	7.77	1.3	8.73	1.5
B34	0.0004	0.26	0.56	60	22.87	0.38	3.93	0.6	5.77	0.8	6.98	1.0	7.94	1.1	8.92	1.3
B28	0.0036	2.30	0.79	98	26.58	0.44	3.63	6.6	5.34	9.7	6.46	11.7	7.37	13.4	8.28	15.0
B35	0.0023	1.47	0.79	98	25.70	0.43	3.70	4.3	5.43	6.3	6.58	7.6	7.50	8.7	8.42	9.8
B21	0.0008	0.51	0.46	44	23.89	0.40	3.84	0.9	5.64	1.3	6.83	1.6	7.77	1.8	8.73	2.1
B22	0.0017	1.09	0.36	26	25.15	0.42	3.74	1.4	5.50	2.1	6.65	2.6	7.58	2.9	8.51	3.3
B9	0.0011	0.70	0.61	69	24.40	0.41	3.80	1.6	5.58	2.4	6.75	2.9	7.69	3.3	8.64	3.7
MH-6	0.0038	2.43	0.75	92	26.69	0.44	3.62	6.6	5.33	9.7	6.45	11.8	7.35	13.4	8.27	15.1
B19	0.0041	2.62	0.73	88	26.85	0.45	3.61	6.9	5.31	10.1	6.43	12.3	7.33	14.0	8.24	15.7
IN-B8	0.0009	0.58	0.20	0	24.07	0.40	3.83	0.4	5.62	0.6	6.80	0.8	7.74	0.9	8.70	1.0
IN-B5	0.0020	1.28	0.20	0	25.44	0.42	3.72	1.0	5.46	1.4	6.61	1.7	7.53	1.9	8.46	2.2
B2	0.0024	1.54	0.20	0	25.79	0.43	3.69	1.1	5.42	1.7	6.57	2.0	7.48	2.3	8.41	2.6
IN-B6	0.0010	0.64	0.44	40	24.24	0.40	3.81	1.1	5.60	1.6	6.78	1.9	7.72	2.2	8.67	2.4
IN-B7	0.0010	0.64	0.65	75	24.24	0.40	3.81	1.6	5.60	2.3	6.78	2.8	7.72	3.2	8.67	3.6
IN-B3	0.0004	0.26	0.63	72	22.87	0.38	3.93	0.6	5.77	0.9	6.98	1.1	7.94	1.3	8.92	1.4
IN-B4	0.0004	0.26	0.55	58	22.87	0.38	3.93	0.6	5.77	0.8	6.98	1.0	7.94	1.1	8.92	1.3
IN-B1	0.0112	7.17	0.78	97	29.15	0.49	3.45	19.4	5.08	28.5	6.16	34.5	7.03	39.4	7.91	44.3
B17	0.0023	1.47	0.71	85	25.70	0.43	3.70	3.9	5.43	5.7	6.58	6.9	7.50	7.8	8.42	8.8
B20	0.0009	0.58	0.36	26	24.07	0.40	3.83	0.8	5.62	1.2	6.80	1.4	7.74	1.6	8.70	1.8

Table A.1
Atlas 14 Rational Method Flows

Atlas 14 Rational Method Calculations																
Basin Name	Area (sqmi)	Area (AC)	C	% Impr	TC (min)	TC (hr)	I2 (in/hr)	Q2 (cfs)	I10 (in/hr)	Q10 (cfs)	I25 (in/hr)	Q25 (cfs)	I50 (in/hr)	Q50 (cfs)	I100 (in/hr)	Q100 (cfs)
B18	0.0003	0.19	0.57	62	22.48	0.37	3.97	0.4	5.82	0.6	7.04	0.8	8.01	0.9	8.99	1.0
IN-B15	0.0058	3.71	0.66	77	27.60	0.46	3.56	8.7	5.23	12.9	6.34	15.6	7.23	17.8	8.13	20.0
IN-B16	0.0011	0.70	0.39	32	24.40	0.41	3.80	1.0	5.58	1.5	6.75	1.9	7.69	2.1	8.64	2.4
B13	0.0025	1.60	0.31	19	25.86	0.43	3.69	1.9	5.42	2.7	6.56	3.3	7.47	3.8	8.40	4.2
IN-B14	0.0017	1.09	0.29	15	25.15	0.42	3.74	1.2	5.50	1.7	6.65	2.1	7.58	2.4	8.51	2.7
IN-B10	0.0009	0.58	0.76	93	24.07	0.40	3.83	1.7	5.62	2.5	6.80	3.0	7.74	3.4	8.70	3.8
IN-B11	0.0011	0.70	0.45	41	24.40	0.41	3.80	1.2	5.58	1.8	6.75	2.1	7.69	2.4	8.64	2.7
IN-B12	0.0008	0.51	0.45	42	23.89	0.40	3.84	0.9	5.64	1.3	6.83	1.6	7.77	1.8	8.73	2.0
B29	0.0101	6.46	0.77	95	28.89	0.48	3.47	17.3	5.11	25.4	6.19	30.8	7.06	35.2	7.95	39.5
230M	0.0002	0.11	0.80	100	21.79	0.36	4.03	0.4	5.91	0.5	7.15	0.6	8.13	0.7	9.13	0.8
IN-A2	0.0003	0.20	0.80	100	22.53	0.38	3.96	0.6	5.81	0.9	7.03	1.1	8.00	1.3	8.98	1.4
IN-A6	0.0002	0.15	0.80	100	22.12	0.37	4.00	0.5	5.87	0.7	7.09	0.8	8.08	0.9	9.06	1.1
IN-A10	0.0005	0.29	0.80	100	23.06	0.38	3.92	0.9	5.75	1.3	6.95	1.6	7.91	1.9	8.88	2.1

APPENDIX B

HALFF ASSOCIATES, Inc.
100 I-45 North, Suite 260, Conroe, Texas 77301
Halff Associates, Inc

CLIENT:	City of Houston	**DATE:**	03/27/20
PROJECT:	Pleasantville Detention Analysis	**AVO:**	31051 - WO121
PREPARED BY:	Halff	**FILE NAME:**	31051_WO121_Costs

PLEASANTVILLE ALTERNATIVE 1A-1 IMPROVEMENTS
PRELIMINARY OPINION OF PROBABLE COSTS

Item No.	QUAN.	UNIT	DESCRIPTION	COST PER UNIT	TOTAL COST
Paving Items					
1	84548	SY	Remove and dispose concrete pavements (all thickness, w/ or w/o asphalt, including base and subgrade, w/ or w/o curb, all depths)	$ 7.00	$ 591,836.00
2	4157	SY	Remove and dispose of existing asphaltic pavements (all thickness, including base and subgrade, w/ or w/o curb, all depths)	$ 10.00	$ 41,570.00
3	84548	SY	Hot-Mix asphaltic pavement (all thickness, including surfacing, base, and subgrade)	$ 45.00	$ 3,804,660.00
4	4157	SY	Concrete pavement (all thickness, including reinforcement, asphaltic surfacing, base, and subgrade)	$ 75.00	$ 311,775.00
Subtotal Paving Items				**$**	**4,749,841.00**
Storm Sewer Items					
1	29	EA	Manholes (For 42" diameter pipe and smaller; all types)	$ 3,500.00	$ 101,500.00
2	60	EA	Manholes (For 48" to 72" diameter pipe and smaller; all types)	$ 6,500.00	$ 390,000.00
3	29	EA	Manholes (For 72" diameter pipe and larger; all types)	$ 16,500.00	$ 478,500.00
4	47	LF	Remove and dispose 12-inch diameter storm sewer, all types	$ 6.00	$ 282.00
5	16152	LF	Remove and dispose 18-inch diameter storm sewer, all types	$ 8.00	$ 129,212.00
6	2333	LF	Remove and dispose 21-inch diameter storm sewer, all types	$ 12.00	$ 27,992.40
7	5439	LF	Remove and dispose 24-inch diameter storm sewer, all types	$ 15.00	$ 81,583.50
8	1850	LF	Remove and dispose 30-inch diameter storm sewer, all types	$ 30.00	$ 55,488.00
9	921	LF	Remove and dispose 36-inch diameter storm sewer, all types	$ 32.00	$ 29,472.00
10	522	LF	Remove and dispose 42-inch diameter storm sewer, all types	$ 35.00	$ 18,252.50
11	530	LF	Remove and dispose 48-inch diameter storm sewer, all types	$ 37.00	$ 19,595.20
12	978	LF	Remove and dispose 54-inch diameter storm sewer, all types	$ 40.00	$ 39,116.00
13	1365	LF	Remove and dispose 60-inch diameter storm sewer, all types	$ 42.00	$ 57,338.40
14	1524	LF	Remove and dispose 66-inch diameter storm sewer, all types	$ 44.00	$ 67,038.40
15	671	LF	Remove and dispose 72-inch diameter storm sewer, all types	$ 48.00	$ 32,208.00
16	116	EA	Remove Storm Manhole (All depths, all types)	$ 560.00	$ 64,960.00
17	4321	LF	24-inch RCP	$ 115.00	$ 496,915.00
18	5290	LF	30-inch RCP	$ 150.00	$ 793,500.00
19	1759	LF	36-inch RCP	$ 180.00	$ 316,620.00
20	3046	LF	42-inch RCP	$ 215.00	$ 654,890.00
21	6891	LF	48-inch RCP	$ 250.00	$ 1,722,750.00
22	1625	LF	54-inch RCP	$ 315.00	$ 511,812.00
23	5055	LF	60-inch RCP	$ 375.00	$ 1,895,625.00
24	384	LF	66-inch RCP	$ 425.00	$ 163,327.50
25	3043	LF	72-inch RCP	$ 485.00	$ 1,475,806.50
26	1063	LF	78-inch RCP	$ 550.00	$ 584,650.00
27	2718	LF	120-inch RCP	$ 1,050.00	$ 2,853,501.00
28	231	LF	4-foot by 4-foot RCB	$ 280.00	$ 64,736.00
29	203	LF	6-foot by 4-foot RCB	$ 445.00	$ 90,112.50
30	703	LF	8-foot by 4-foot RCB	$ 580.00	$ 407,856.00
31	1788	LF	8-foot by 6-foot RCB	$ 770.00	$ 1,377,068.00
32	173	LF	10-foot by 8-foot RCB	$ 960.00	$ 165,888.00
33	29	EA	Storm Junction Box, Cast in place or Precast	$ 20,000.00	$ 580,000.00
34	37337	LF	Trench Safety System	$ 2.00	$ 74,673.60
Subtotal Storm Sewer Items				**$**	**15,822,269.50**

Total Project Construction Cost Summary

Subtotal Paving Items	**$ 4,749,841.00**
Subtotal Storm Sewer Items	**$ 15,822,269.50**
Subtotal Construction Costs	**$ 20,572,110.50**
Mobilization (4% of Construction Subtotal)	**$ 822,885.00**
Contingencies (30% of Construction and Mobilization Total)	**$ 6,418,500.00**
GRAND TOTAL	**$ 27,813,495.50**

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.

HALFF ASSOCIATES, Inc.
100 I-45 North, Suite 260, Conroe, Texas 77301
Halff Associates, Inc

CLIENT:	City of Houston	**DATE:**	03/27/20
PROJECT:	Pleasantville Detention Analysis	**AVO:**	31051 - WO121
PREPARED BY:	Halff	**FILE NAME:**	31051_WO121_Costs

PLEASANTVILLE PROPOSED IMPROVEMENTS
PRELIMINARY OPINION OF PROBABLE COSTS

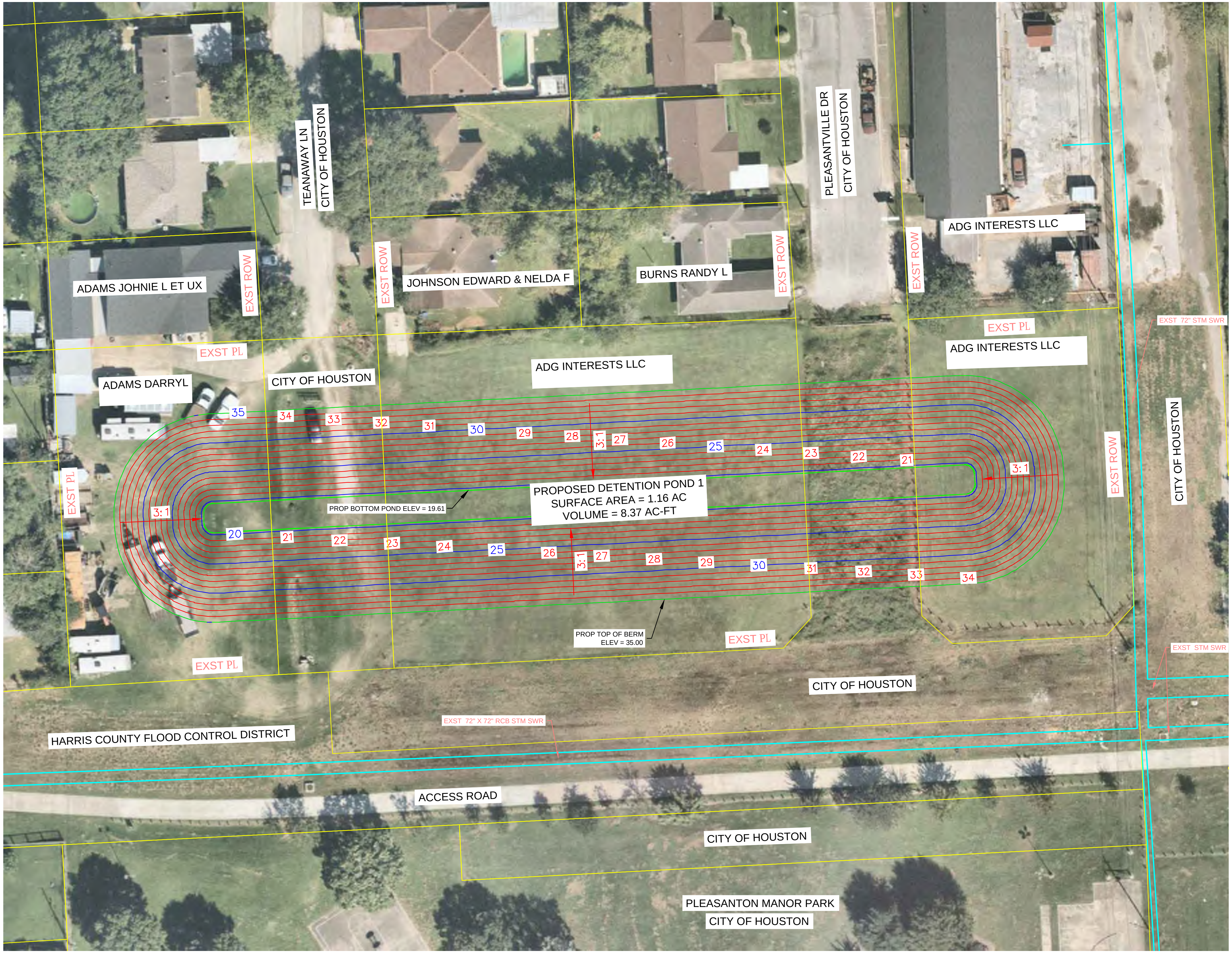
Item No.	QUAN.	UNIT	DESCRIPTION	COST PER UNIT	TOTAL COST
Paving Items					
1	60,806	SY	Remove and dispose of existing asphaltic pavements (all thickness, including base and subgrade, w/ or w/o curb, all depths)	$ 7.00	$ 425,642.00
2	7,189	SY	Removing and disposing of concrete pavements (including all thickness, w/ or w/o asphalt, including base & subgrade, w/ or w/o curb, all depths)	$ 10.00	$ 71,890.00
3	60,806	SY	Hot-Mix asphaltic pavement (all thickness, including surfacing, base, and subgrade)	$ 45.00	$ 2,736,270.00
4	7,189	SY	Concrete pavement (all thickness, including curb and gutter, base, and subgrade)	$ 75.00	$ 539,175.00
Subtotal Paving Items				**$**	**3,772,977.00**
Storm Sewer Items					
1	31	EA	Manholes (For 42" diameter pipe and smaller; all types)	$ 3,500.00	$ 108,500.00
2	25	EA	Manholes (For 48" to 72" diameter pipe and smaller; all types)	$ 6,500.00	$ 162,500.00
3	19	EA	Manholes (For 72" diameter pipe and larger; all types)	$ 16,500.00	$ 313,500.00
4	11,891	LF	Remove and dispose 18-inch diameter storm sewer, all types	$ 8.00	$ 95,128.00
5	1,467	LF	Remove and dispose 21-inch diameter storm sewer, all types	$ 12.00	$ 17,604.00
6	4,034	LF	Remove and dispose 24-inch diameter storm sewer, all types	$ 15.00	$ 60,510.00
7	1,940	LF	Remove and dispose 30-inch diameter storm sewer, all types	$ 30.00	$ 58,200.00
8	1,180	LF	Remove and dispose 36-inch diameter storm sewer, all types	$ 32.00	$ 37,760.00
9	549	LF	Remove and dispose 42-inch diameter storm sewer, all types	$ 35.00	$ 19,215.00
10	562	LF	Remove and dispose 54-inch diameter storm sewer, all types	$ 40.00	$ 22,480.00
11	824	LF	Remove and dispose 60-inch diameter storm sewer, all types	$ 42.00	$ 34,608.00
12	1,001	LF	Remove and dispose 66-inch diameter storm sewer, all types	$ 44.00	$ 44,044.00
13	66	EA	Remove Storm Manhole (All depths, all types)	$ 560.00	$ 36,960.00
14	3,584	LF	24-inch RCP	$ 115.00	$ 412,160.00
15	1,156	LF	30-inch RCP	$ 150.00	$ 173,400.00
16	2,037	LF	36-inch RCP	$ 180.00	$ 366,660.00
17	4,856	LF	42-inch RCP	$ 215.00	$ 1,044,040.00
18	4,428	LF	48-inch RCP	$ 250.00	$ 1,107,000.00
19	1,731	LF	54-inch RCP	$ 315.00	$ 545,265.00
20	3,258	LF	60-inch RCP	$ 375.00	$ 1,221,750.00
21	581	LF	66-inch RCP	$ 425.00	$ 246,925.00
22	822	LF	72-inch RCP	$ 485.00	$ 398,670.00
23	250	LF	8-foot by 5-foot RCB	$ 660.00	$ 165,000.00
24	271	LF	10-foot by 5-foot RCB	$ 850.00	$ 230,350.00
25	285	LF	10-foot by 6-foot RCB	$ 880.00	$ 250,800.00
26	513	LF	10-foot by 7-foot RCB	$ 920.00	$ 471,960.00
27	286	LF	10-foot by 8-foot RCB	$ 960.00	$ 274,560.00
28	1,286	LF	10-foot by 10-foot RCB	$ 1,300.00	$ 1,671,800.00
29	115	EA	Remove Inlet	$ 750.00	$ 86,250.00
30	115	EA	Replace Inlet (Type BB)	$ 3,500.00	$ 402,500.00
31	17	EA	Storm Junction Box, Cast in place or Precast	$ 20,000.00	$ 340,000.00
32	26,661	LF	Trench Safety System	$ 2.00	$ 53,322.00
33	457,127	CY	Excavation	$ 8.00	$ 3,657,016.00
34	922	SY	Concrete Pilot Channel (5" Thick Concrete)	$ 70.00	$ 64,540.00
35	2	EA	Headwall/Wingwall	$ 12,000.00	$ 24,000.00
Subtotal Storm Sewer Items				**$**	**14,218,977.00**

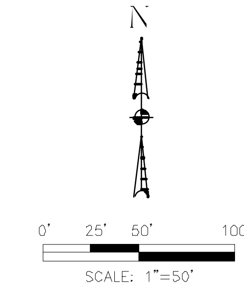
Total Project Construction Cost Summary

Subtotal Paving Items	**$ 3,772,977.00**
Subtotal Storm Sewer Items	**$ 14,218,977.00**
Subtotal Construction Costs	**$ 17,991,954.00**
Mobilization (4% of Construction Subtotal)	**$ 719,680.00**
Contingencies (30% of Construction and Mobilization Total)	**$ 5,613,490.00**
GRAND TOTAL	**$ 24,325,124.00**

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.

APPENDIX C





LEGEND

- 50 — MAJOR CONTOUR
- 52 — MINOR CONTOUR
- PROPERTY LINE/ RIGHT OF WAY

NOTES:

1. 8.37 ACRE-FOOT DETENTION POND.
2. DETENTION POND DESIGNED AS A DRY BOTTOM POND.

HALFF
100 I-45 N SUITE 260
CONROE, TEXAS 77301
TEL (936) 756-6832
FAX (936) 756-6833
TBPE FIRM NUMBER F-312

PRELIMINARY
FOR INTERIM REVIEW ONLY
THESE DOCUMENTS ARE FOR INTERIM REVIEW AND NOT INTENDED FOR REGULATORY APPROVAL, PERMIT, BIDDING OR CONSTRUCTION PURPOSES. THEY WERE PREPARED BY OR UNDER THE SUPERVISION OF:

LONG NGUYEN — NAME; 114452 — P.E. NO.
DATE 1/16/20

SURVEYED BY:
FB NO. 000000

CITY OF HOUSTON
HOUSTON PUBLIC WORKS

PLEASANTVILLE DR
TEANAWAY LN
POND 1

WBS NUMBER	FOR CITY OF HOUSTON USE ONLY
X-000X00-0000-X	
DRAWING SCALE	
-S NOTED	
CITY OF HOUSTON PM	
JOHN DOE, P.E.	
SHEET NO. 1 OF 2	

PLOTTED: 1/16/2020 5:21 PM
PLOT STYLE:
FILE P-TH: I:\31000s\31051\TechSprtSvcs\W0121\Pleasantville\Detention Ponds\C-DD\Sheets\Exhibit-Pond1.dwg

N

0' 25' 50' 100'

SCALE: 1"=50'

LEGEND

- 50 — MAJOR CONTOUR
- 52 — MINOR CONTOUR
- PROPERTY LINE/ RIGHT OF WAY

NOTES:

1. 17.03 ACRE-FOOT DETENTION POND.
2. DETENTION POND DESIGNED AS A DRY BOTTOM POND.

HALFF
100 I-45 N SUITE 260
CONROE, TEXAS 77301
TEL (936) 756-6832
FAX (936) 756-6833
TBPE FIRM NUMBER F-312

PRELIMINARY

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LONG NGUYEN — NAME; 114452 — P.E. NO.

DATE 1/16/20

SURVEYED BY:

FB NO. 000000

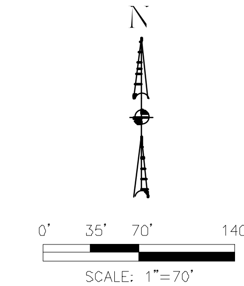
CITY OF HOUSTON

HOUSTON PUBLIC WORKS

PLEASANTON MANOR PARK POND 2

WBS NUMBER	FOR CITY OF HOUSTON USE ONLY
X-000X00-0000-X	
DRAWING SCALE	
-S NOTED	
CITY OF HOUSTON PM	
JOHN DOE, P.E.	
SHEET NO. 1 OF 2	

FILE P-TH: I:\31000s\31051\TechSprtSvcs\W0121\Pleaseantville\Detention Ponds\C-DD\Sheets\Exhibit-Pond1.dwg PLOT STYLE: PLOTTED: 1/16/2020 5:16 PM



LEGEND

50	MAJOR CONTOUR
52	MINOR CONTOUR
	PROPERTY LINE/ RIGHT OF WAY

NOTES:

1. 0.74 ACRE-FOOT DETENTION POND.
2. DETENTION POND DESIGNED AS A DRY BOTTOM POND.

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CITY OF HOUSTON
HOUSTON PUBLIC WORKS

HOLLAND MIDDLE SCHOOL POND 3

WBS NUMBER	FOR CITY OF HOUSTON USE ONLY
X–000X00–0000–X	
DRAWING SCALE	
-S NOTED	
CITY OF HOUSTON PM	
JOHN DOE, P.E.	
SHEET NO. 1 OF 2	

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0' 75' 150' 300'
SCALE: 1"=150'

LEGEND

- 50 — MAJOR CONTOUR
- 52 — MINOR CONTOUR
- PROPERTY LINE/ RIGHT OF WAY

NOTES:

1. 349.65 ACRE-FOOT DETENTION POND.
2. DETENTION POND DESIGNED AS A DRY BOTTOM POND.

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100 I-45 N SUITE 260
CONROE, TEXAS 77301
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LONG NGUYEN	114452
NAME	P.E. NO.
DATE	1/16/20

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CITY OF HOUSTON
HOUSTON PUBLIC WORKS

PORT OF HOUSTON AUTHORITY
POND 4

WBS NUMBER	FOR CITY OF HOUSTON USE ONLY
X-000X00-0000-X	
DRAWING SCALE	
-S NOTED	
CITY OF HOUSTON PM	
JOHN DOE, P.E.	
SHEET NO. 1 OF 2	

FILE P-TH: I:\31000s\31051\TechSprtSvcs\W0121\Pleasantville\Detention Ponds\C-DD\Sheets\Exhibit-Pond4.dwg
PLOT STYLE:
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N

0' 25' 50' 100'
SCALE: 1"=50'

LEGEND

- 50 — MAJOR CONTOUR
- 52 — MINOR CONTOUR
- PROPERTY LINE/ RIGHT OF WAY

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CONROE, TEXAS 77301
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NAME — P.E. NO.
DATE — 1/16/20

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CITY OF HOUSTON
HOUSTON PUBLIC WORKS

POND 5

WBS NUMBER
X-000X00-0000-X
DRAWING SCALE
AS NOTED
CITY OF HOUSTON PM
JOHN DOE, P.E.
SHEET NO. 1 OF 2

FOR CITY OF HOUSTON USE ONLY

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N

0' 40' 80' 160'

SCALE: 1"=80'

LEGEND

50 MAJOR CONTOUR

52 MINOR CONTOUR

PROPERTY LINE/
RIGHT OF WAY

NOTES:

1. 50.60 ACRE-FOOT DETENTION POND.
2. DETENTION POND DESIGNED AS A DRY BOTTOM POND.

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NAME P.E. NO.
DATE 1/16/20

SURVEYED BY:
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CITY OF HOUSTON

HOUSTON PUBLIC WORKS

POND 6

WBS NUMBER	FOR CITY OF HOUSTON USE ONLY
X-000X00-0000-X	
DRAWING SCALE	
-S NOTED	
CITY OF HOUSTON PM	
JOHN DOE, P.E.	
SHEET NO. 1 OF 2	

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Halff Associates, Inc.
14800 St Marys Ln #160
Houston, TX 77079
TBPE Firm No. F-312

MEMORANDUM

TO:	Adam Eaton, PE, ENV SP	**DATE:**	October 28, 2020
FROM:	C. Andrew Moore, PE, CFM	**AVO:**	31051 WO163
EMAIL:	amoore@halff.com		
SUBJECT:	Pleasantville Benefit-Cost Analysis (Work Order 163)		

Introduction

This memorandum presents the findings of the Pleasantville Benefit-Cost Analysis (BCA). The purpose of this task was to perform a FEMA-compliant benefit-cost analysis for the proposed drainage improvements recommended in the "Pleasantville Detention Analysis" (Work Order 121). In addition to the drainage improvements, the proposed project includes the construction of a Community and Disaster Recovery Center.

BCA Methodology

The FEMA BCA Toolkit Version 6.0 was used to estimate the pre-project and post-project damage costs, which are necessary to calculate a benefit-cost ratio (BCR) for the recommended drainage improvements. The following building structure data were obtained from the Harris County Appraisal District's (HCAD) website: latitude/longitude, property type, land value, improvement value, building footprint, and year built. There is a total of 1,199 structures in the project area.

In the BCA Toolkit, the damage and frequency relationship was based on modeled damages, not historical damages since comprehensive historical data were not available for this site. The project's useful life was assumed to be 50 years, which is FEMA's standard value for drainage infrastructure projects. Where appropriate, the BCA Toolkit's default values were used in the calculation of the BCR. The United States Army Corps of Engineers (USACE) Generic Depth Damage Curve was used to estimate economic damages for each residential structure (one-story without basement) based on the risk of inundation. The default non-refrigerated warehouse damage curve was used to estimate economic damages for the non-residential structures in the area.

Water surface elevation (WSEL) grids were developed from the hydraulic models and used to estimate the maximum flood depth at structures within the project area. The 10-, 25-, 50-, and 100-year storm events were used for this BCA. Additional benefits that could increase the BCR of the mitigation project (i.e., volunteer, social, and ecosystem services) were not included in the BCA given a lack of supporting documentation. A structure's building replacement value per square foot was estimated in two different ways: (1) FEMA's default value ($100/sqft), and (2) the structure's improvement value from HCAD. This resulted in two different BCRs, as explained in the Results section below.

Structures that fronted along the same streets and had similar finished floor elevations and modeled water surface elevations were aggregated into groups for use in the BCA Toolkit. There were 41 groups in total.

For each group, the following were calculated: average finished floor elevation, average water surface elevation, total building square footage, average building value per square foot, and total number of residents (assumed four residents per residential structure). If one or more structures in a group experienced inundation for any storm event in existing conditions, the group was input into the BCA Toolkit. A total of 22 groups were inputted.

BCA Results

The cost estimate for the recommended project was provided by the City of Houston and totals $99,021,350.13. The cost breakdown is provided in **Table 1**.

Table 1: Cost Estimate for the City of Houston Port Area Drainage Improvements

Material/Service	Cost
Drainage Improvements	
Construction Subtotal	$24,542,146.56
Engineering Design	$3,681,321.98
Environmental Investigation and Permitting	$1,472,528.79
Disposal of Excavated Material	$18,285,080.00
Grant Administration	$1,472,528.79
TOTAL	$49,453,606.13
Community & Disaster Recovery Center	
Construction Subtotal	$39,029,720.00
Engineering Design	$5,854,458.00
Environmental Investigation and Permitting	$2,341,783.20
Grant Administration	$2,341,783.20
TOTAL	$49,567,744.40
GRAND TOTAL	**$99,021,350.53**

The total calculated benefits are $29,674,935 when using FEMA's default value for building replacement. The benefit-cost ratio for the recommended project is calculated to be 0.30.

The total calculated benefits are reduced to $13,958,141 when using the structure's improvement value from HCAD for building replacement. The BCR for the recommended project is 0.14. The FEMA BCA Toolkit spreadsheets are included electronically with this submittal.

This FEMA benefit-cost analysis is based on benefits to individual structures and the reduction in potential structural inundation achieved through the proposed improvements. It must be noted that the proposed improvements provide additional benefits that are not reflected in the benefit-cost ratio. They are as follows:

- The proposed flood control and drainage improvements in the Pleasantville neighborhood reduce ponding on major streets, increasing the number of lane miles that are passable during major events, which allows residents to leave the neighborhood and for emergency services to enter in such an event.
- The detention basin proposed as part of these improvements will be constructed on a dredge disposal site. The construction will require removal and disposal of the existing dredged material. The basin can be developed as park space that will provide health and quality of life benefits to residents of the neighborhood.

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- The proposed Community and Disaster Recovery Center will serve as a "lily pad," allowing a point of refuge for residents to reduce suffering and hardship during and following events, as well as a command center to coordinate emergency services during an extreme event.

If you have any questions or need additional information, please do not hesitate to contact me.

HALFF ASSOCIATES, Inc.
Texas Firm Registration No. 312

C. Andrew Moore

C. Andrew Moore, P.E., CFM
Water Resources Team Leader

STATE OF TEXAS
C. ANDREW MOORE
124910
LICENSED
PROFESSIONAL ENGINEER

C. Andrew Moore
TBPE 124910
F-312
10/28/2020

Appendix 5-4G:
City of Houston Kashmere Gardens Area Flood Mitigation

List of Exhibits

1 Introduction

Study Purpose and Scope

Huitt-Zollars (HZ) was tasked with providing professional engineering services to investigate the limitation and deficiencies of the existing drainage system for Kashmere Gardens neighborhood in the City of Houston (COH). The project is referenced as M-430100-0020-3. HZ used Need Area M-2017-002 study as a starting point, recommended adjustments to the drainage boundaries, and designated the offsite areas that affect the study area.

This letter report summarizes the finding of the existing drainage system investigation. The scope of this work includes:

- Define the existing condition drainage area boundary
- Identify the existing drainage systems and their outfalls
- Identify the FEMA floodplain boundary
- Identify the existing overland flow paths
- Survey the main trunklines to obtain storm sewer flowline elevation and pipe size.
- Develop a dynamic hydraulic model to identify the drainage issues

Project Location and Background

The project is located within the historic Kashmere Gardens which is located just south of 610 Loop in Houston, TX. The limits of detailed study were defined by HZ through early stages of the work and finalized through coordination with COH and is shown in Exhibit 1. The studied area is located between an industrial area to the east, Union Pacific rail corridor to the south, Schrum Gully (H112-00-00) to the west and Hunting Bayou (H100-00-00) to the north. The existing land use is mainly single-family residential lots and commercial developments. The Parcel Land Use map is shown in Exhibit 2.

The existing drainage system consists of storm sewer and roadside ditches in the project location and is shown in Exhibit 3. The study area is located within the Hunting Bayou watershed. Hunting Bayou and its tributaries serves as an outfall for the local drainage systems. A tributary of Hunting Bayou (H110-00-00) divides the study area into two parts. On the east side of H110-00-00, most drainage systems run from east to west direction and outfall into H110-00-00. On the west side, the major drainage systems run from south to north direction and outfall into Hunting Bayou.

During an intense rainfall event, Hunting Bayou does not provide adequate flood protection, nor does the channel serve as an adequate outfall source for the local drainage system. Beside, flat topography and channel conveyance obstructions are the other contributing factors to the frequent flooding in the Kashmere Garden area.

Data Collection

The following documents and data were obtained and relied upon in this study:

- City of Houston Infrastructure Drainage Manual (IDM), 2019
- Technical Modeling Guidelines for 2D Dynamic Stormwater Analysis, COH, Technical Paper (TP) – 102, 2019
- COH GIMS
- Record Construction Drawings from COH's Public Records Department
- Topographic survey performed by Landtech, Inc

Methodology

The hydrologic and hydraulic analysis was performed in accordance with COH IDM. Peak discharges were computed using Rational Method. Peak discharges were computed for the 2, 10, 100 and 500 year storm events. Runoff hydrographs for drainage areas were generated based on the Clark Unit Hydrograph using USACE HEC-HMS (Version 3.3) and calibrated to the Rational Method peak flows. Storm sewer and ditch analysis was performed using Innovyze XPSWMM (Version 2018.2).

Drainage system components including drainage areas, land use, storm sewer and ditches connectivity, cross-sections and flowlines obtained from COH GIMS data. The drainage systems were verified utilizing combination of provided as-built information, field reconnaissance, Lidar, aerial photography and survey data. Drainage area is shown in Exhibit 4.

FEMA Special Flood Hazard Areas

The study area is located within Hunting Bayou 100 year floodplain boundary and shaded Zone X (500-yr) boundary. The BFE elevation for the site is about 45 feet. Hunting Bayou and Channel H100-00-00 are FEMA studied streams with regulatory floodplains as shown on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) 48201C0715M dated January 06, 2017. The floodplain boundaries are shown in Exhibit 5.

Hunting Bayou Improvement Project

Harris County Flood Control District (HCFCD) is in the final stages of completing Hunting Bayou channel improvement. HCFCD project consists of approximately 3.8 miles of grass-lined channel modifications to a maximum 60-foot bottom width from downstream of the Englewood Railroad Yard to US 59 and 1000 acre-feet of detention in a 75–acre detention basin.

Based on "Hunting *Bayou Flood Risk Management Report"* dated 2014, the improvements in Hunting Bayou will reduce the 100 year Water Surface Elevation (WSE) near Lockwood Bridge by about four feet. This study assumes the HCFCD improvements are complete and as a result the WSE in Hunting Bayou has been lowered.

Site Visit

A site visit was performed on December 23, 2019 to obtain photographs and to document the existing drainage patterns and land uses at the study area.

2 Existing Drainage System

The existing drainage system consists of storm sewer and roadside ditches in the project location and is shown in Exhibit 3. The drainage systems were modeled to check if they meet the COH criteria and discussed in detail below.

Drainage Area

The total study area is approximately 873 acres and drainage areas are shown in Exhibit 4. There is about 570 acres offsite drainage with storm sewer lines draining away from the study area while their surcharges on the streets ultimately entering into the study area.

The existing ground elevations range from 41-ft at the bank of Hunting Bayou to 45-ft at the Railroad site south of Liberty Rd. The existing topography throughout this area is relatively flat with average slope of 0.07%. The Lidar Map is shown is Exhibit 6.

Exhibit 7 shows the sheet flow patterns through the project area. The general overland flow direction is from west to east and south to north on the west side of H110-00-00. On the east side, water flows from east to west direction and outfalls into H110-00-00.

Drainage Outfall Channels

Hunting Bayou is an earthen channel with the recently improved banks at the study limits. The channel serves as a major outfall for local drainage systems.

Channel H110-00-00 is a trapezoidal concrete lined channel with a rectangular pilot channel. Based on the FEMA Effective model, the channel has adequate capacity to convey the 100 year storm event without flooding outside the banks. However, the backwater from the Hunting Bayou inundates the H110-00-00 during extreme storm events.

Channel H112-00-00 is an earthen trapezoidal channel with a concrete lined rectangular pilot channel. Based on the FEMA Effective model, the channel has adequate capacity to convey the 100 year storm event without flooding outside the banks. However, the backwater from the Hunting Bayou inundates the Schrum Gully during extreme storm events.

Historic Flooding

The study area has a long flooding history according to the flood damages records. The flood damage complaints from Hurricane Harvey (2017) and previous major storms is shown in Exhibit 8. This map indicates the area is frequently prone to the flooding.

Hydraulic & Hydrologic Analysis

Exhibit 4 present the drainage areas and storm sewer systems that were modeled in XPSWMM. Drainage Systems A, to G are located on the west side of H110-00-00. Drainage Systems EH1 to EH10 are located on the east side of H110-00-00. Along Channel H100-00-00 there are several small drainage systems that have sufficient capacity and therefore were not included in the XPSWMM model (see Exhibit 4).

System EH1, EH2 and EH3 are modeled as a ditch with averaged 2-ft depth and 2-ft bottom with 3H:1V side slopes. All the other systems consist of underground storm sewer lines with curb and gutter road. System F1, G1 and EH10 outfall into COH storm sewer. Other drainage systems drain into HCFCD channels within the project location. Storm sewers and ditches were analyzed using XPSWMM model.

Runoff hydrographs were developed separately and entered in the XPSWMM model. The XPSWMM model include 2D surface for modeling the sheet flow in the street. The XPSWMM model nodes and links are shown in Exhibit 7. Model parameters including tailwater elevations, Manning's roughness and mesh size were established in accordance with COH IDM and TP-102. An electronic copy of XPSWMM model files is provided on a USB flash drive.

3 Drainage Findings

The drainage system capacity was evaluated for 2 , and 100 year storm events and the result are provided in Exhibits 9 to 13.

West Side of H110-00-00

2 Year Storm

- Exhibits 10 and Exhibit 11 present the ponding limits and ponding depth for 2 year storm, respectively. The existing 90" storm sewer along Lavender Street in system A and the existing 96" storm sewer along Wayne Street in System D (offsite) do not have sufficient capacity to carry the 2 year storm event. This results in more than one foot of ponding depth along Collingsworth between Wayne Street and Lavender Street. Based on XPSWMM model result, there is about 100 cfs sheet flows from system D (offsite) onto System A during the 2 year Storm event along Collingsworth Street.

- The storm sewer along Wayne Street south of Crane Street consist of a 78" RCP and a 60" RCP which has more capacity than the 90" storm sewer line downstream of this section. This could potentially result in excessive sheet flow along Collingsworth.

- The 2 year HGL in System A near Jewel Street exceed the gutter elevation which is mainly due to limited capacity in existing storm sewer line.

- System C drains a small area north of Union Pacific railroad site. However, the 24" RCP storm sewers south of Lucille Street and along Liberty Road does not have sufficient capacity for a 2 year storm.

100 Year Storm

- Exhibits 11 and Exhibit 12 present the ponding limits and ponding depth for 100 year storm, respectively. There is significant ponding during 100 year storm event outside the roadway ROW which can potentially result in structural flooding. This condition can be attributed to limited storm sewer and sheet flow conveyance capacity.

- The hydraulic analysis result indicated that there is about 400 cfs offsite sheet flow along Collingsworth St enters the study area. This additional flow is causing the ponding depth to exceed the 1.5 feet above the top of curb along Collingsworth Street.

East Side of H110-00-00

2 Year Storm

- The hydraulic analysis of drainage system along Rand Street indicated that the existing roadside ditches do not have enough capacity to carry the 2 year flows.

- The 54" RCP along Cavalcade Street (System EH5) does not have adequate capacity for a 2 year Storm.

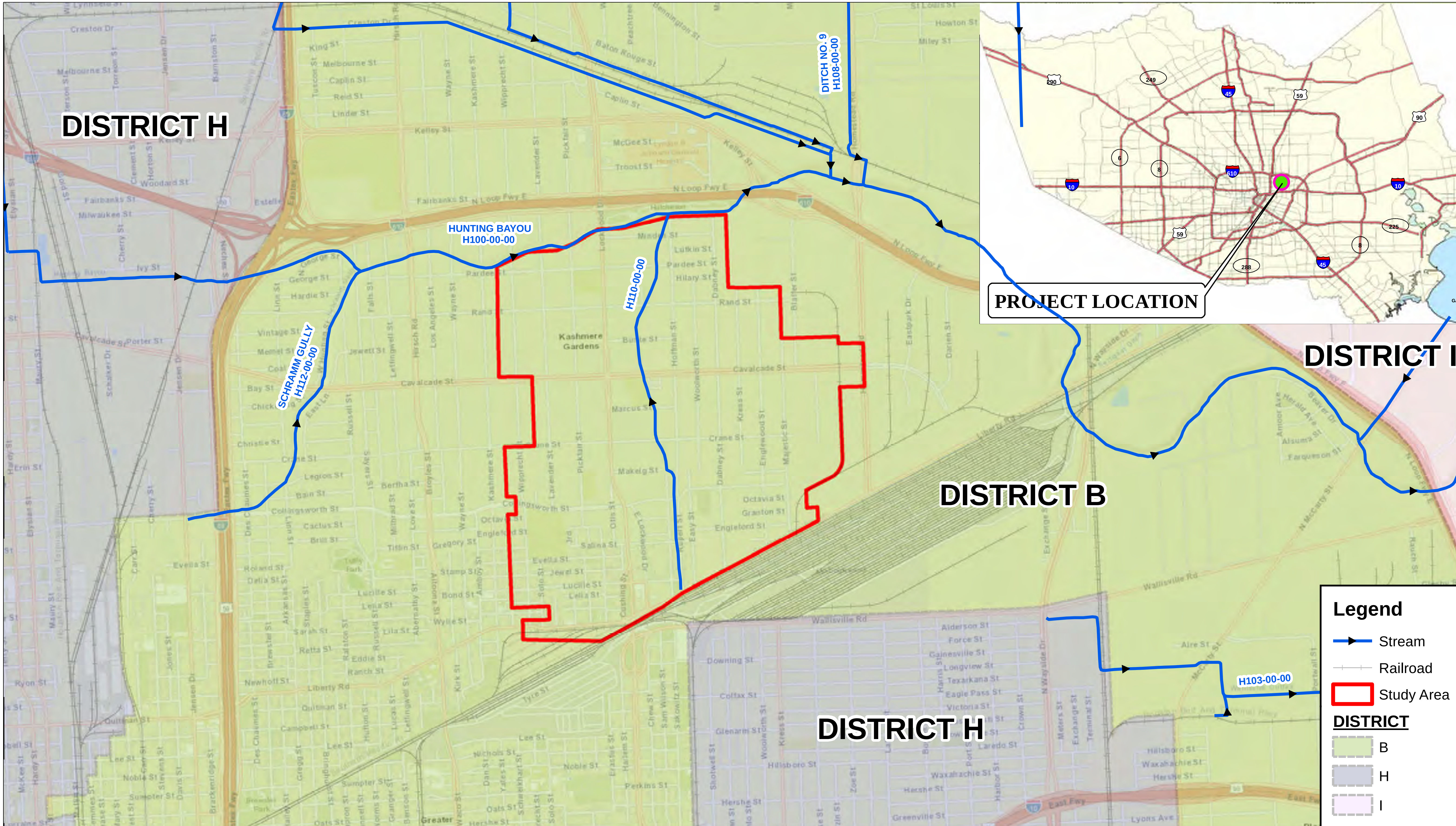
- The 36" RCP along Crane Street (System EH7) does not have adequate capacity for a 2 year Storm.

100 Year Storm

- As shown in Exhibit 13, there is considerable ponding during 100 year storm event outside the road ROW which can potentially result in structural flooding. This condition can be attributed to limited storm sewer and sheet flow conveyance capacity.

- The existing roadside ditches in System EH1 to EH3 do not have sufficient capacity for 100 year Storm. The existing roads are higher than the private property in this area, which result in excessive ponding outside the ROW during a 100 year Storm.

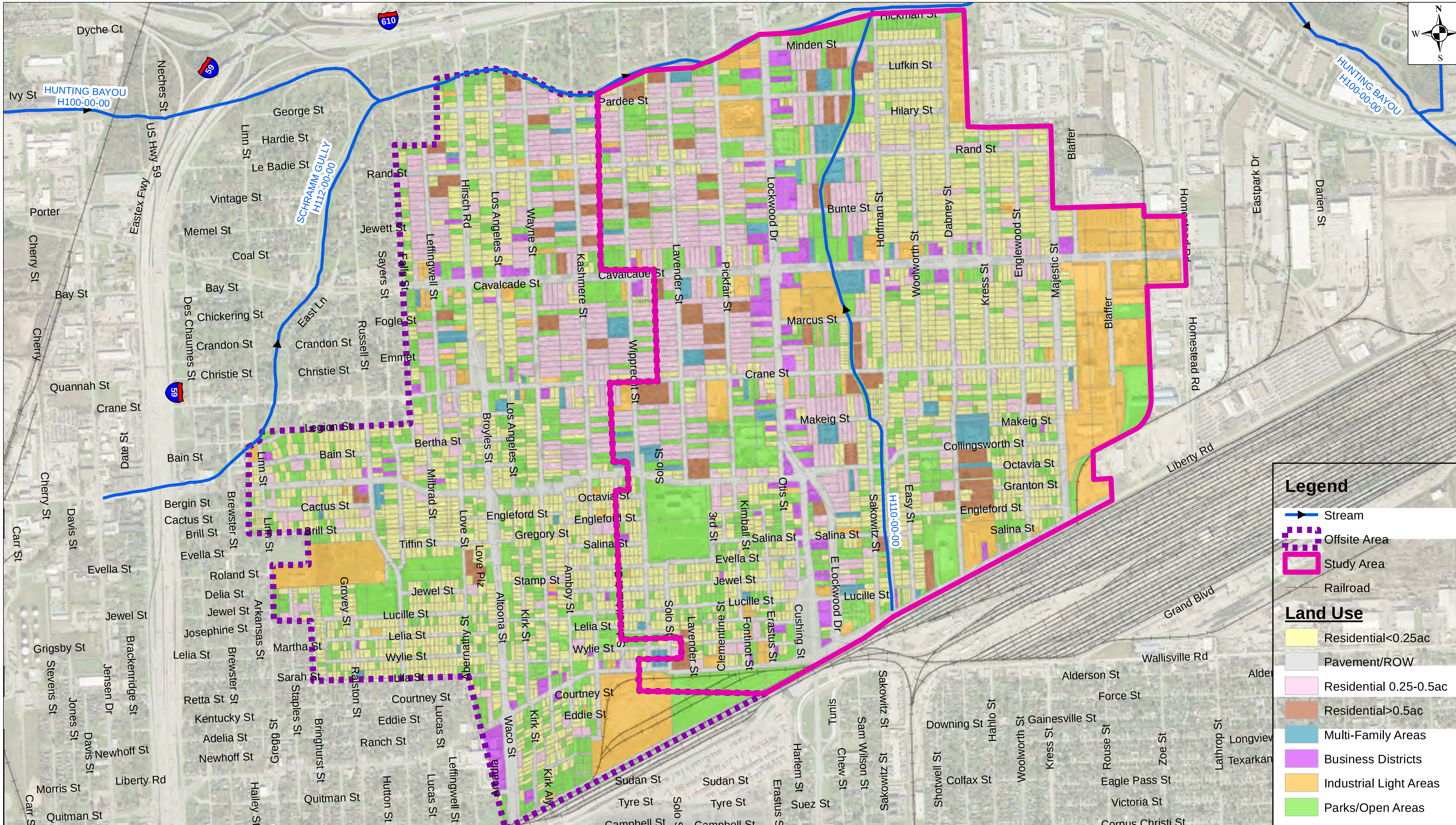
- The hydraulic analysis of drainage system along Cavalcade Street indicates about 2 feet of ponding depth along the roadway corridor between Kress Street and outfall location during a 100 year Storm. The ponding in the street is exacerbated by the higher grades at the bridge crossing over Channel H100-00-00.



HUITT-ZOLLARS

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 1
FEBRUARY, 2020	0 1,000 2,000 Feet	LOCATION MAP



HUITT-ZOLLARS

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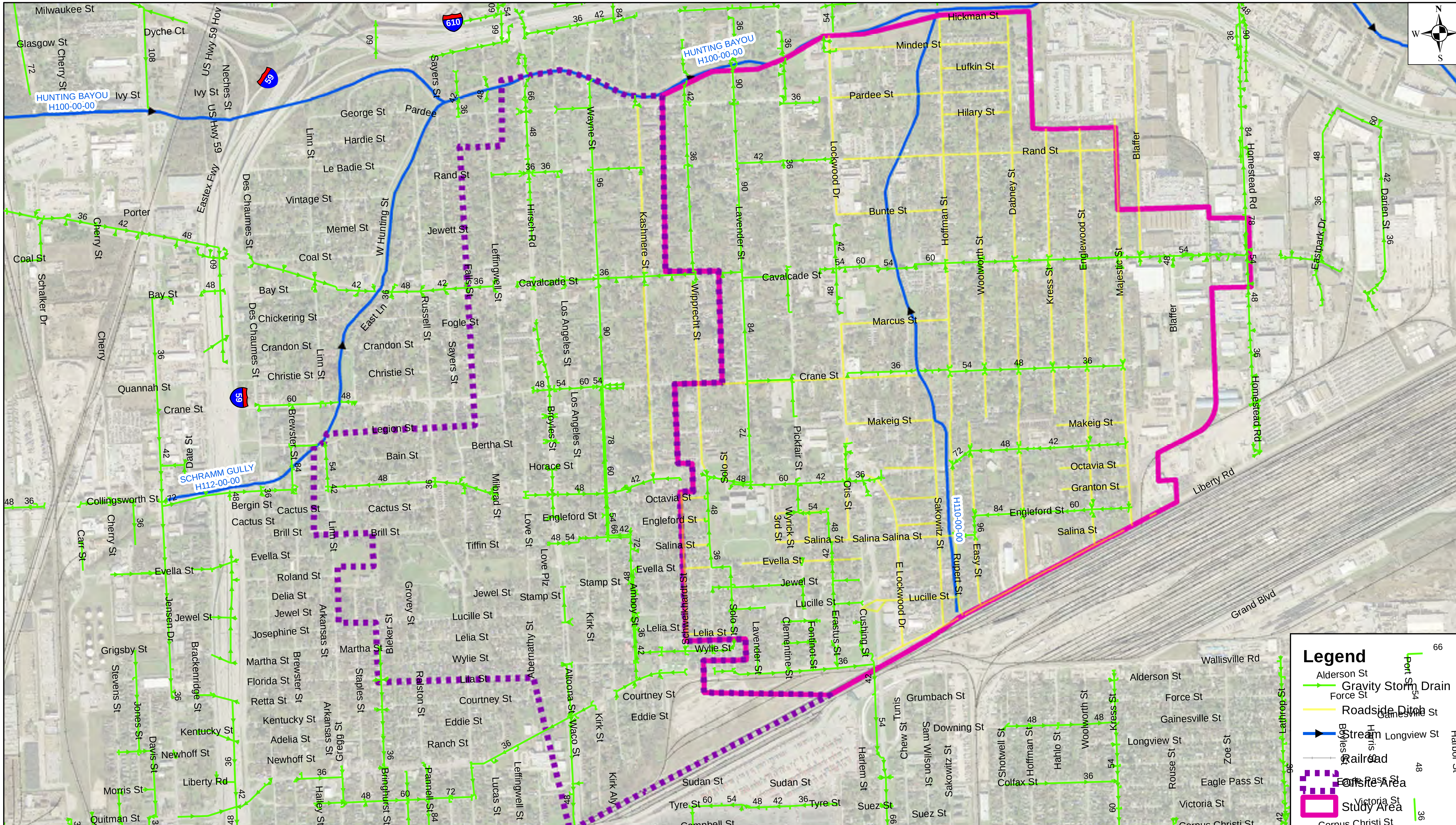
PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

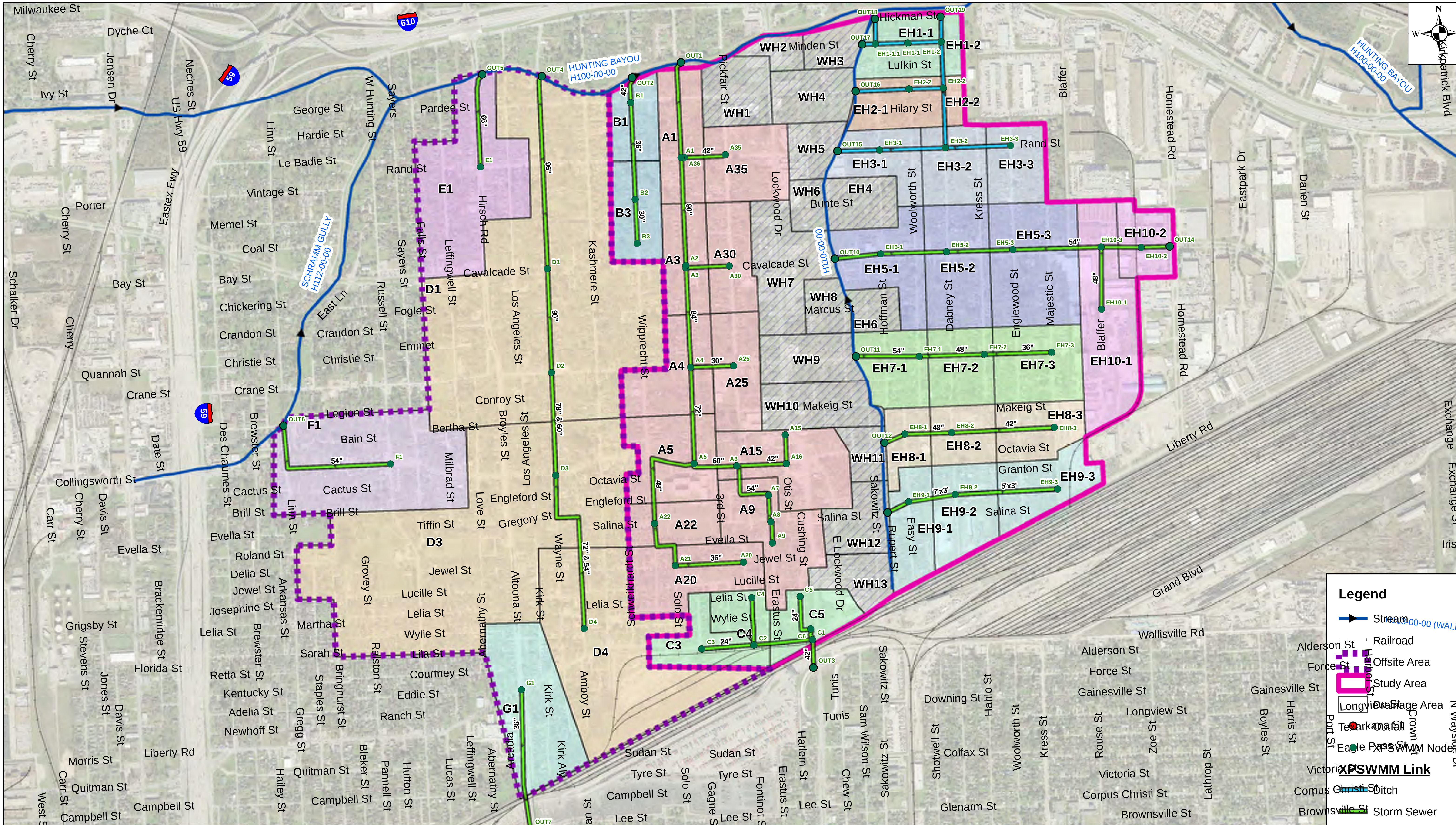
CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 2
FEBURARY, 2020	0 500 1,000 2,000 Feet	PARCEL LAND USE



PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 3
FEBRUARY, 2020	0 500 1,000 2,000 Feet	EXISTING DRAINAGE SYSTEM



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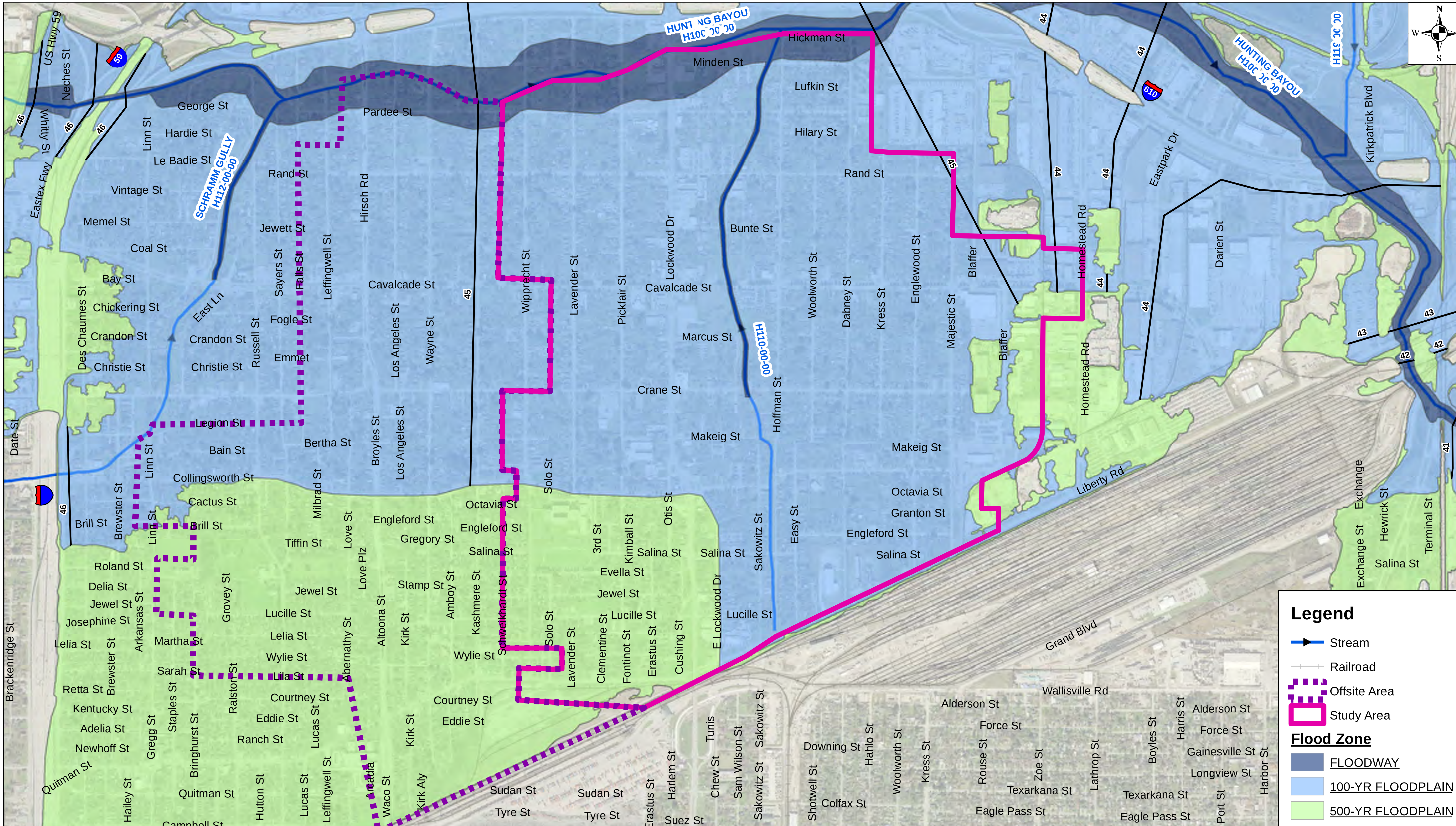
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 4
FEBRUARY, 2020	0 500 1,000 2,000 Feet	DRAINAGE AREA MAP



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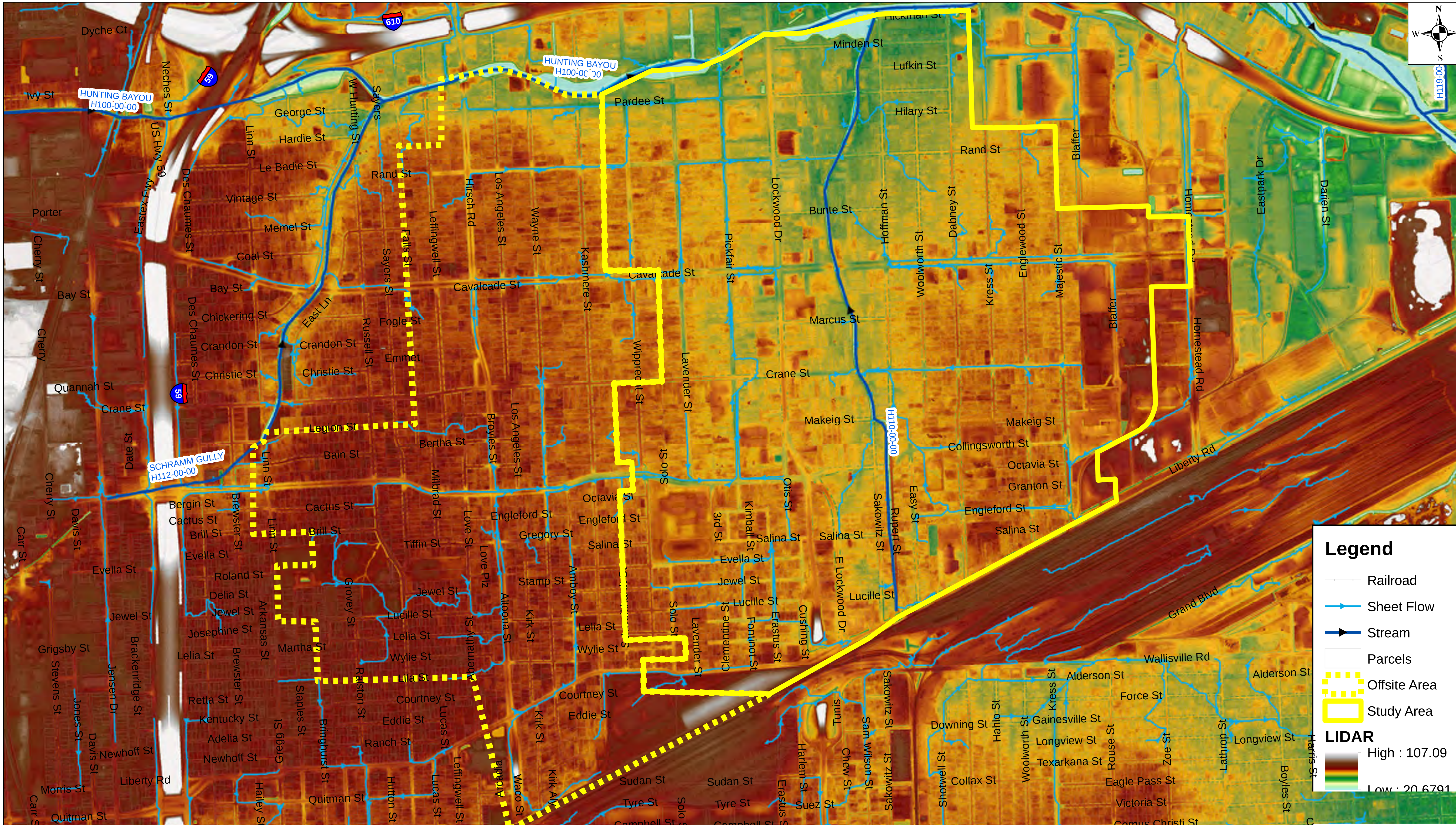
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 5
FEBRUARY, 2020	0 500 1,000 2,000 Feet	FIRM/FLOODPLAIN MAP



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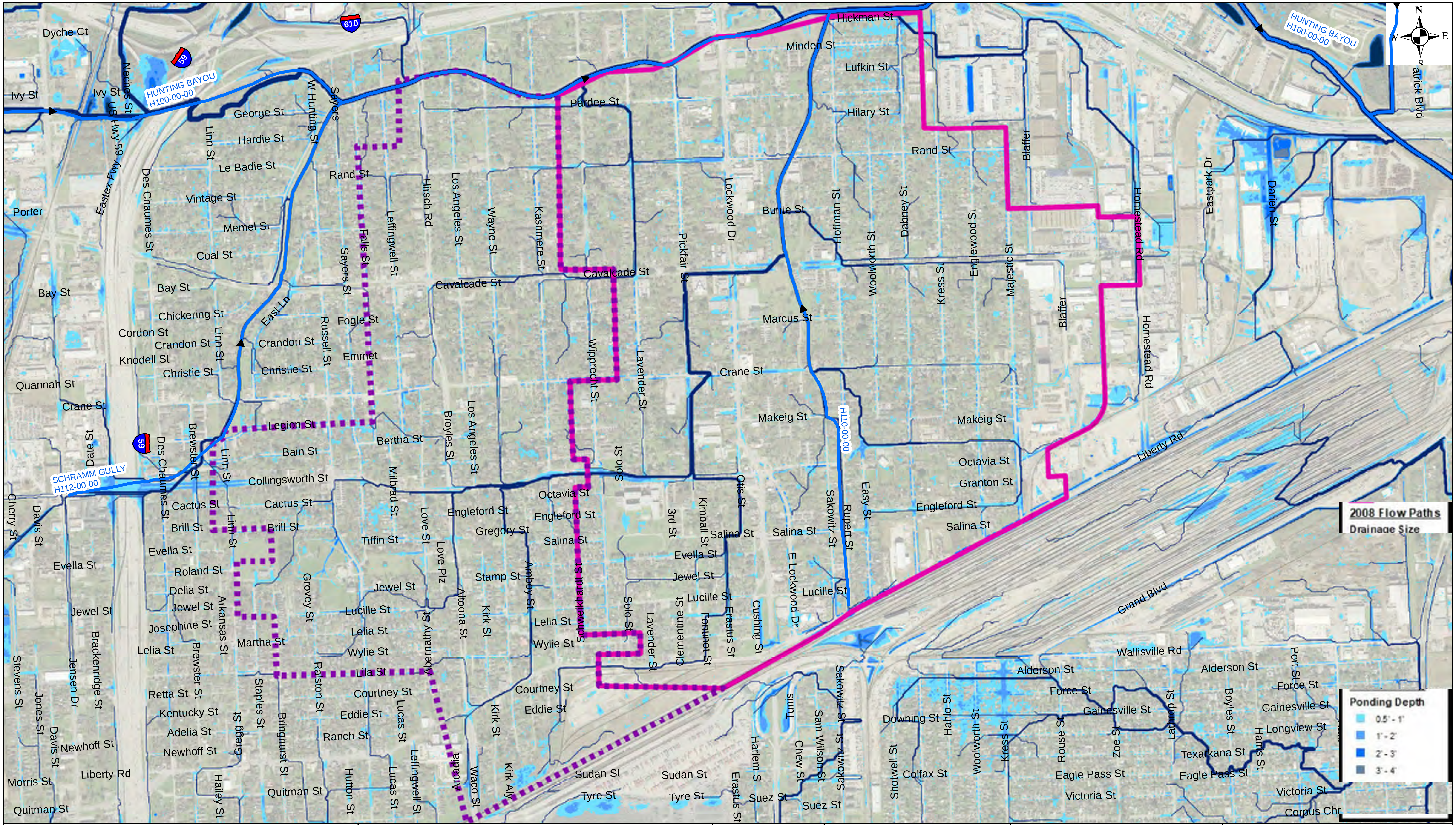
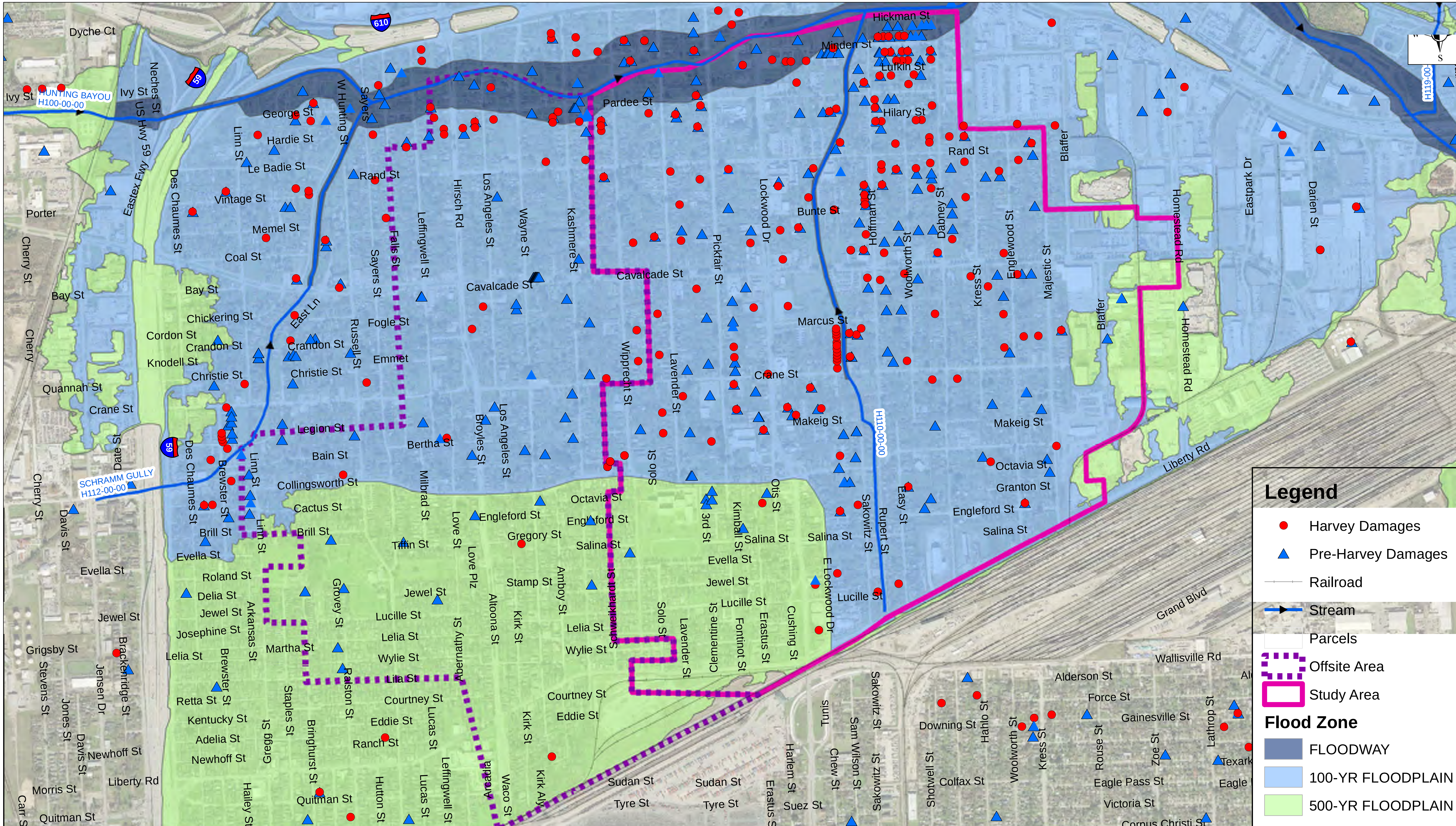
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 6
FEBRUARY, 2020	0 500 1,000 2,000 Feet	LIDAR MAP



HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	EXHIBIT 7
			FEBRUARY, 2020	0 500 1,000 2,000 Feet	SHEET FLOW PATH



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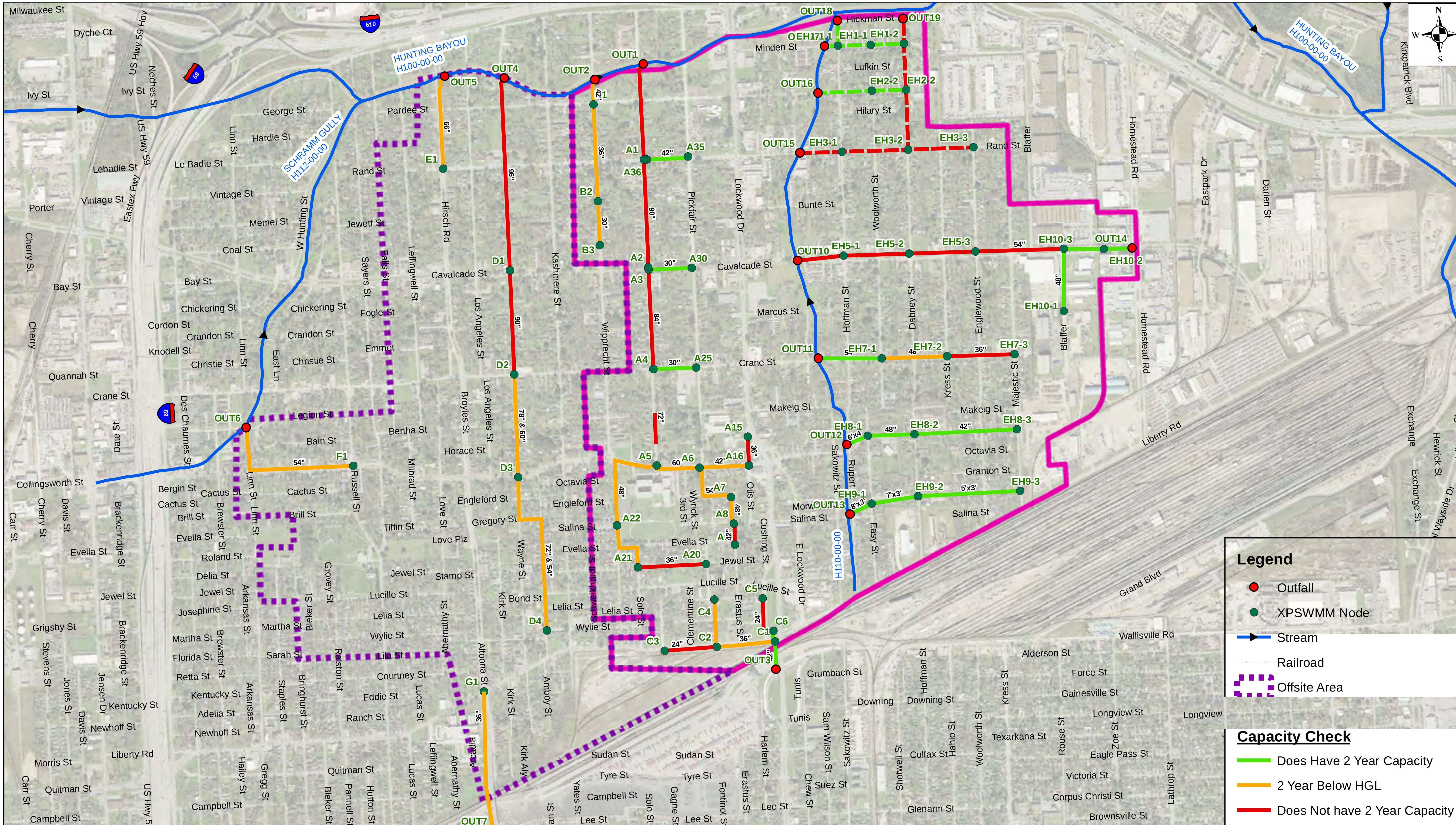
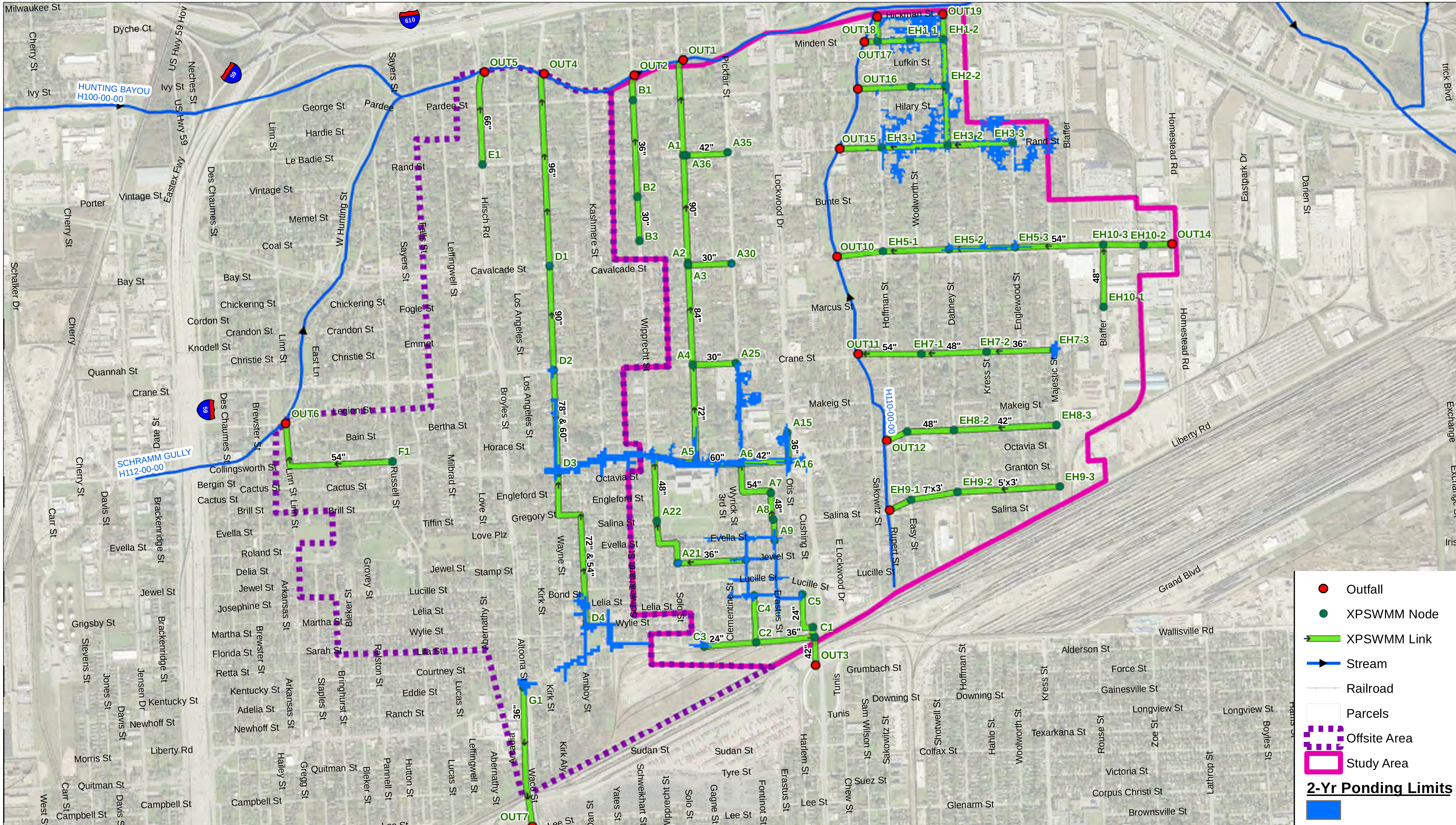
PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 8
FEBRUARY, 2020	0 500 1,000 2,000 Feet	FEMA FLOOD COMPLAINTS



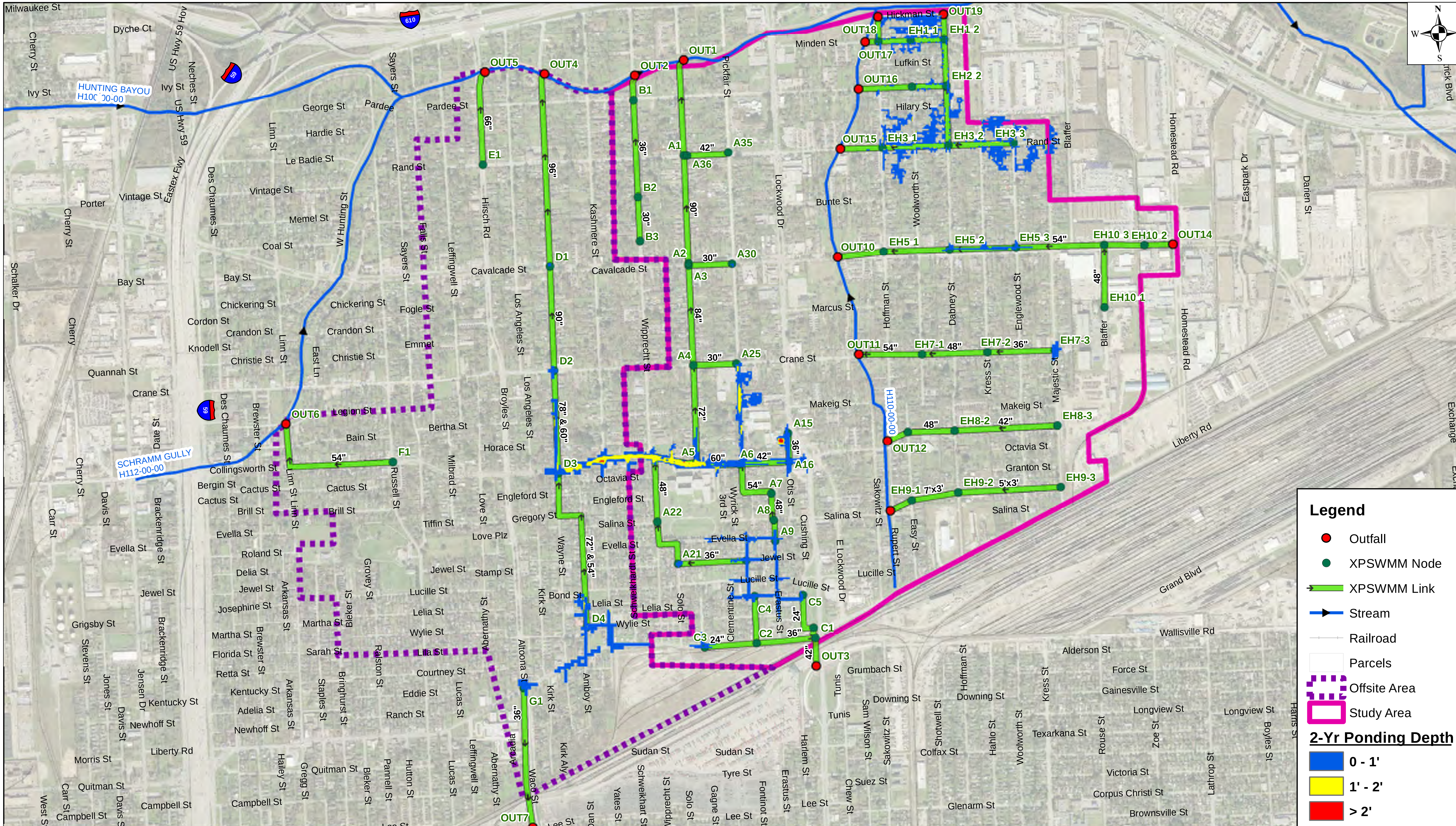
HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	EXHIBIT 9
			FEBRUARY, 2020	0 500 1,000 2,000 Feet	EXISTING STORM CAPACITY



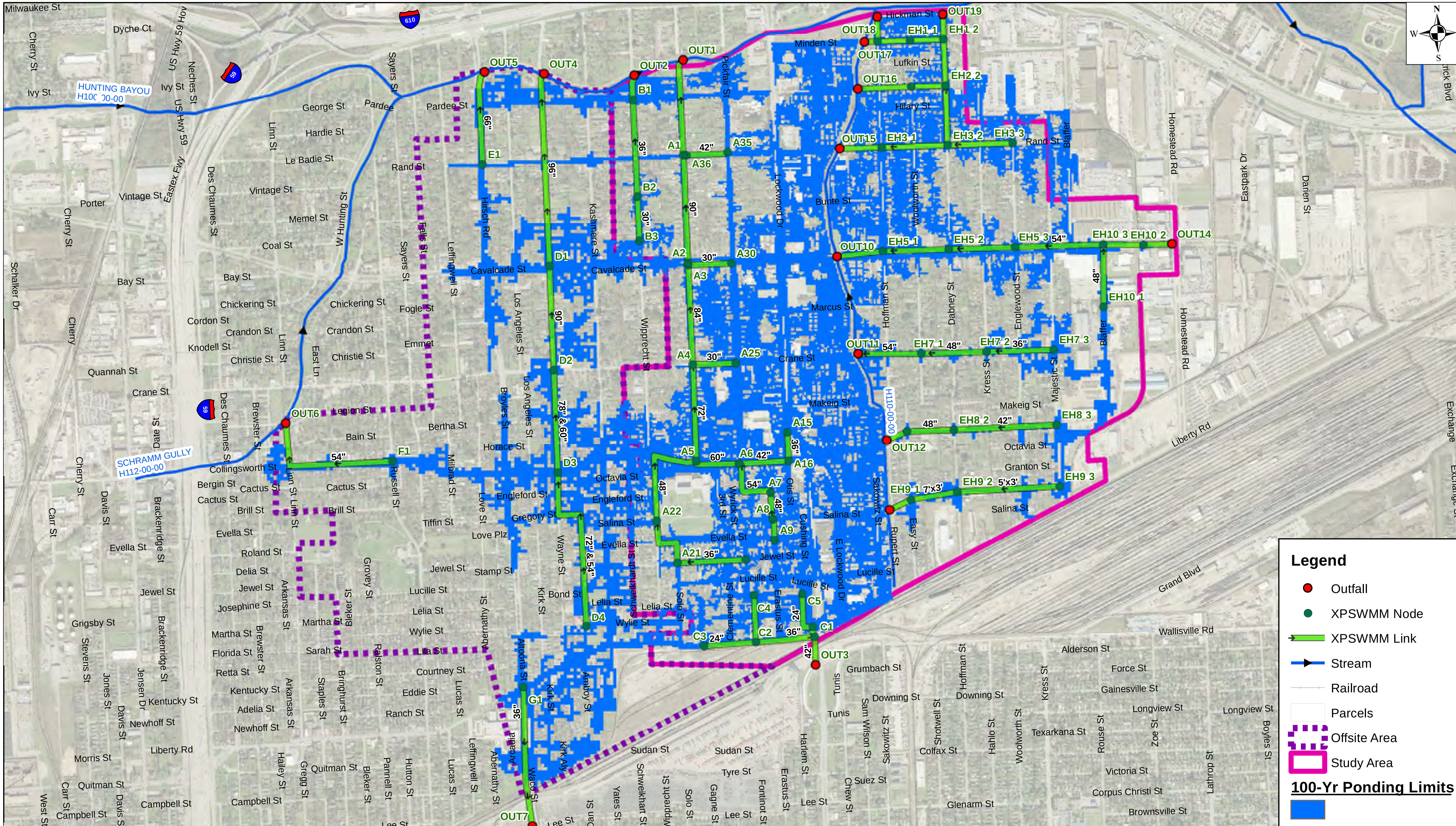
HUITT-ZOLLARS

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 10
FEBRUARY, 2020	0 500 1,000 2,000 Feet	2-YR PONDING LIMITS



	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	DATE	SCALE	EXHIBIT 11
HUITT-ZOLLARS		FEBRUARY, 2020	0 500 1,000 2,000 Feet	2-YR PONDING DEPTH

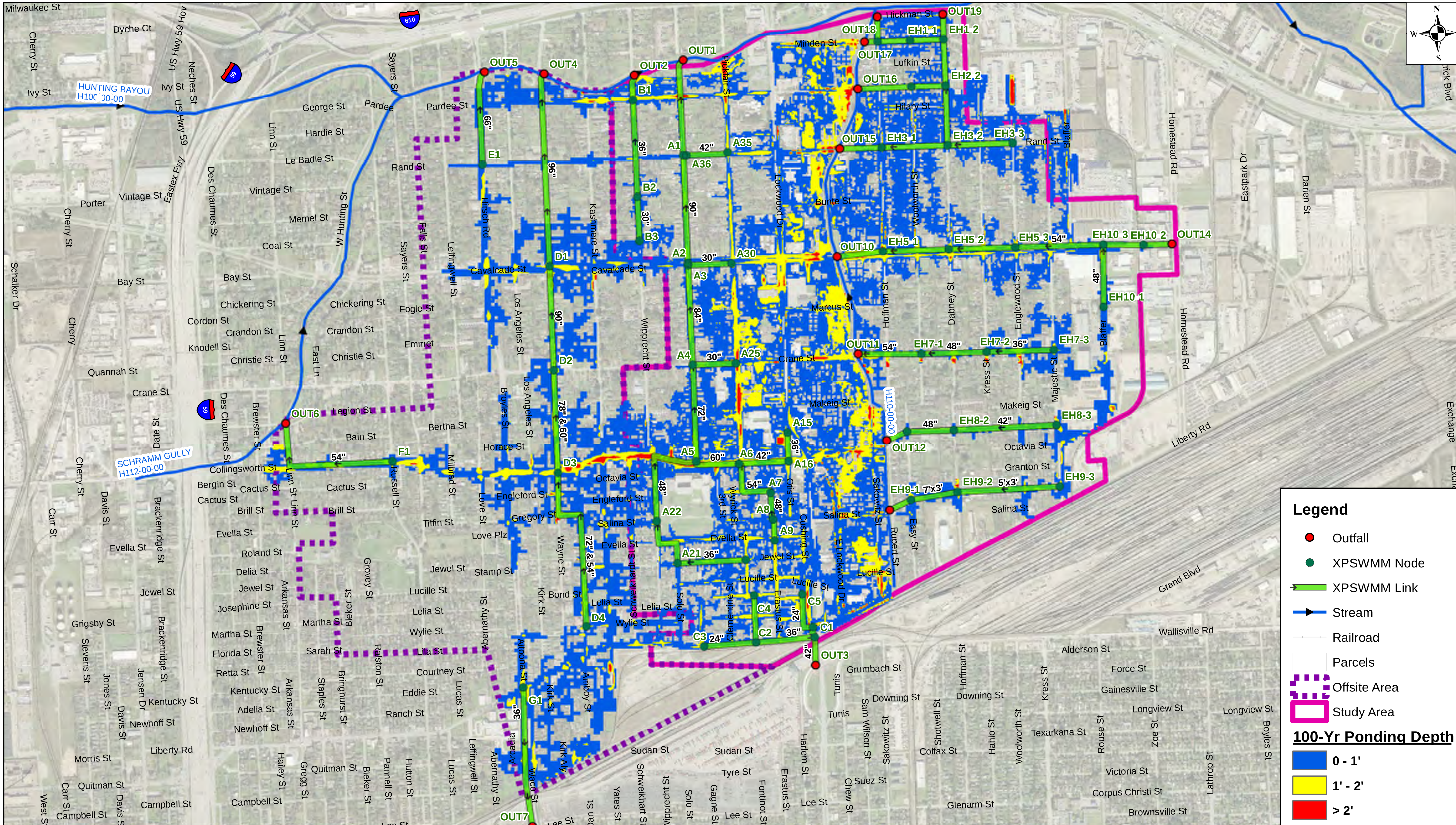


HUITT-ZOLLARS

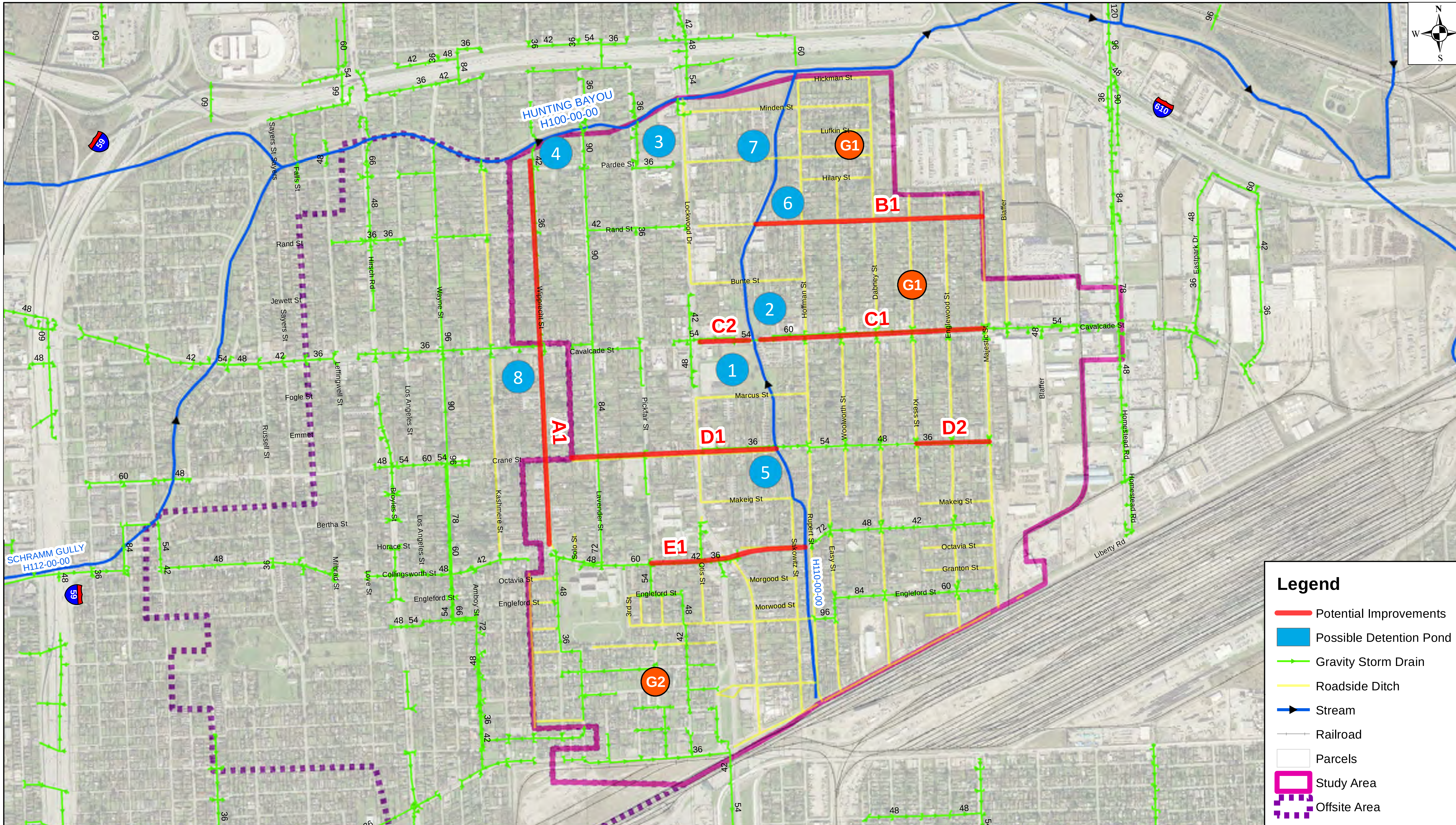
PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 12
FEBRUARY, 2020	0 500 1,000 2,000 Feet	100-YR PONDING LIMITS



HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	EXHIBIT 13
			FEBRUARY, 2020	0 500 1,000 2,000 Feet	100-YR PONDING DEPTH



HUITT-ZOLLARS

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

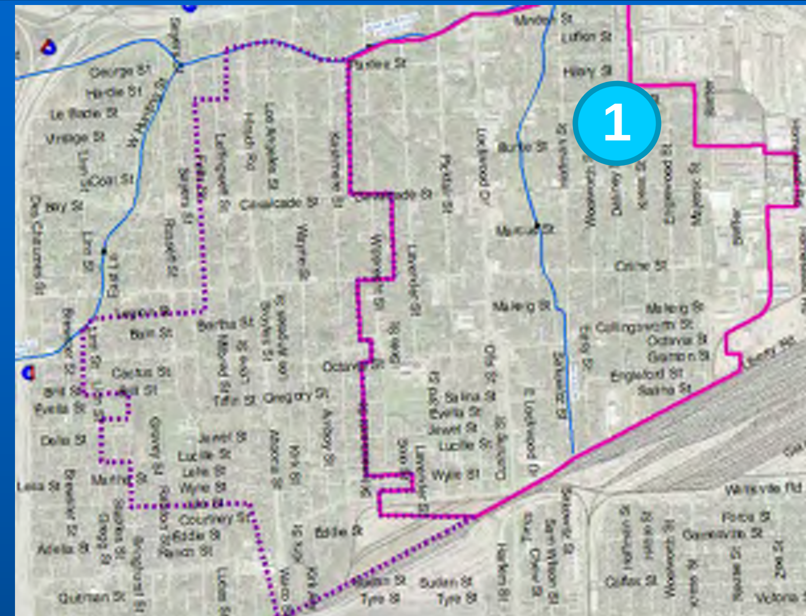
CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 14
FEBRUARY, 2020	0 500 1,000 2,000 Feet	POTENTIAL IMPROVEMENT PROJECT

M-2018-E01 - KASHMERE GARDENS

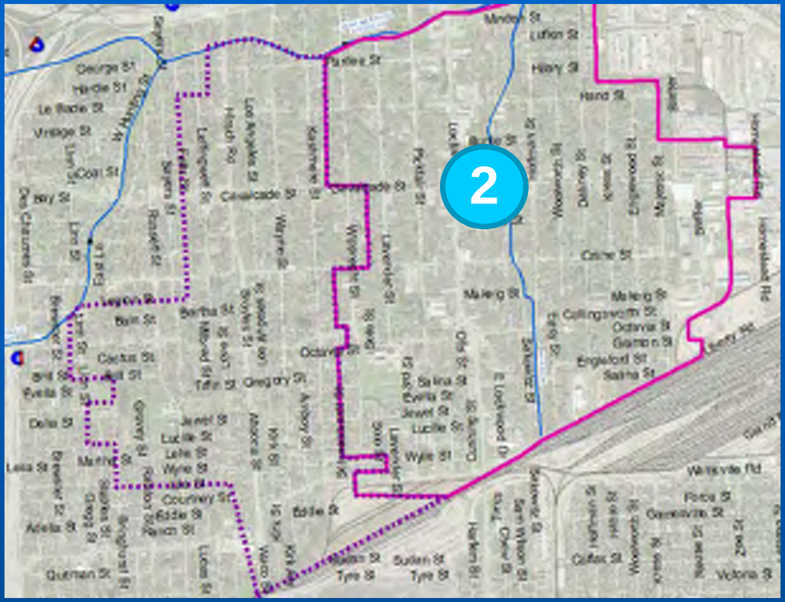
Storm Drainage System

HUITT-ZOLLARS



M-2018-E01 - KASHMERE GARDENS

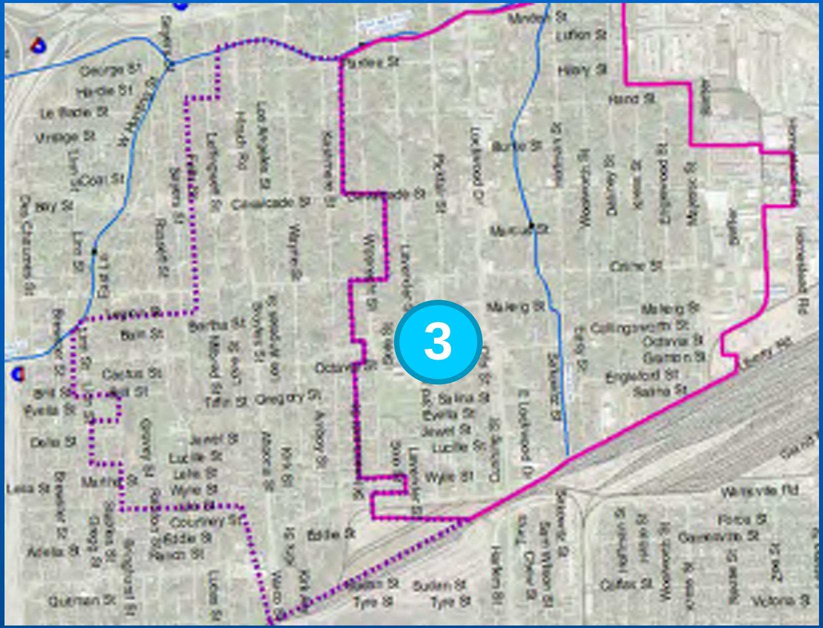
Storm Drainage System



M-2018-E01 - KASHMERE GARDENS

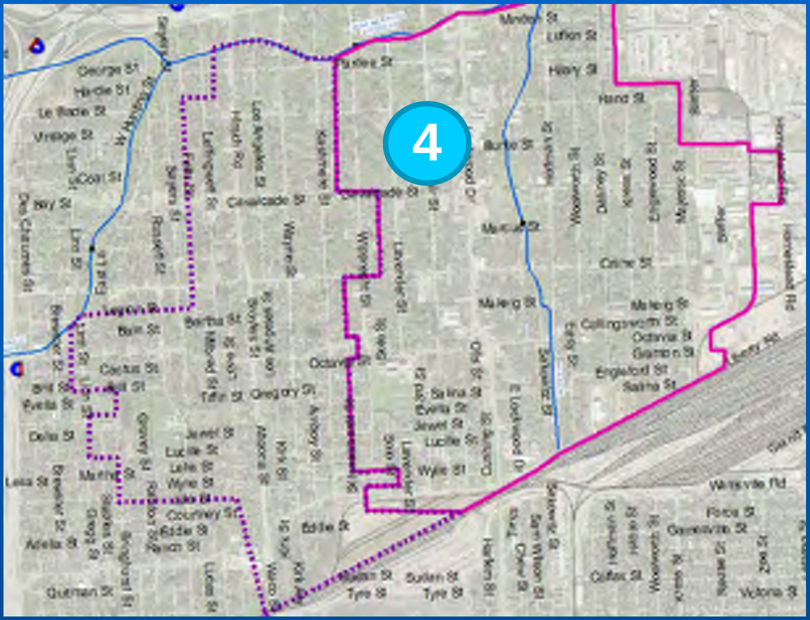
Storm Drainage System

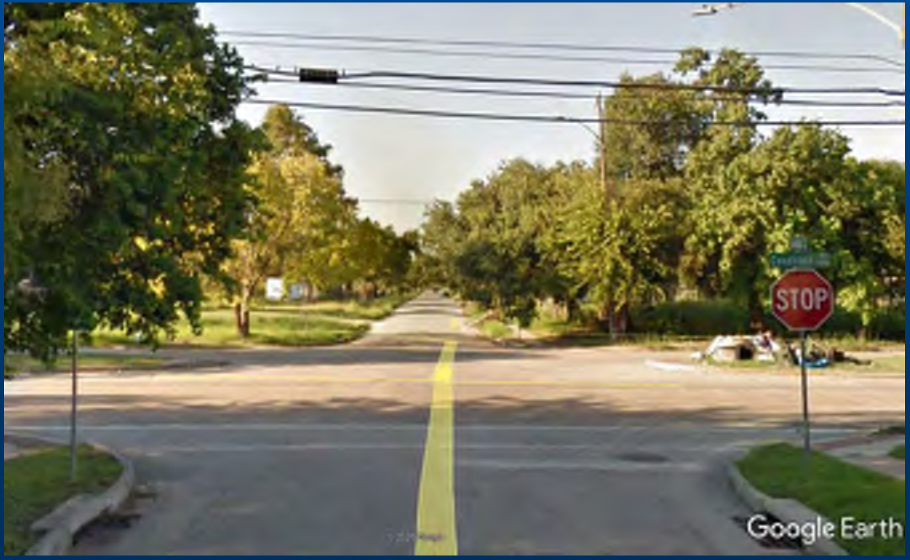
HUITT-ZOLLARS



M-2018-E01 - KASHMERE GARDENS

Storm Drainage System

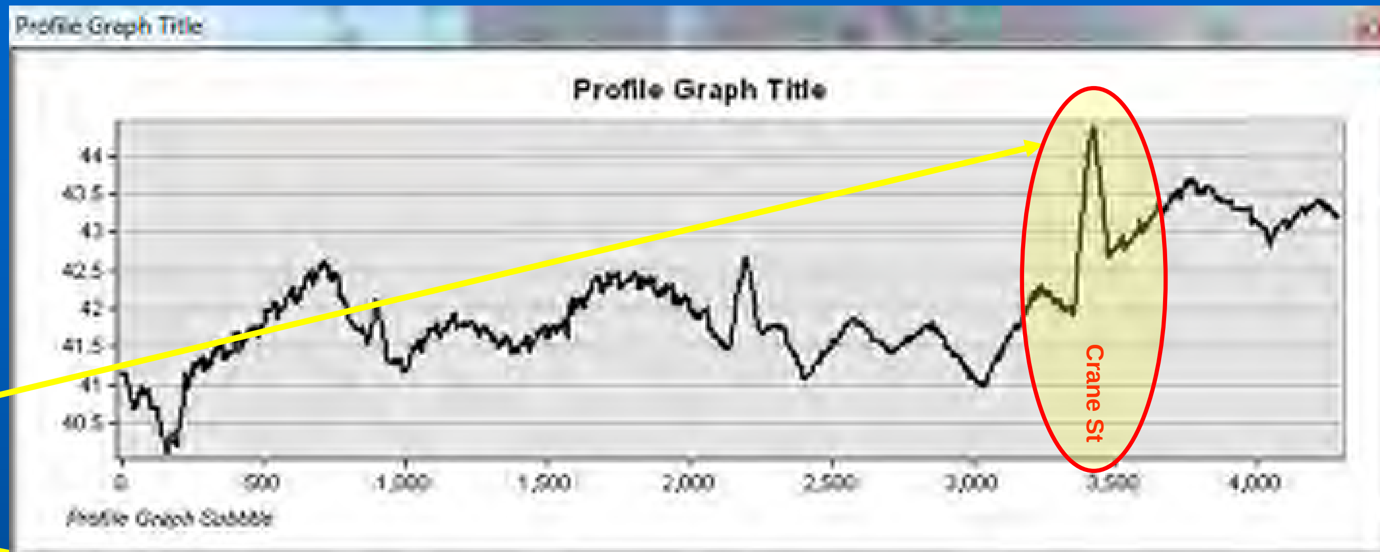




M-2018-E01 - KASHMERE GARDENS

Potential Improvements

HUITT-ZOLLARS

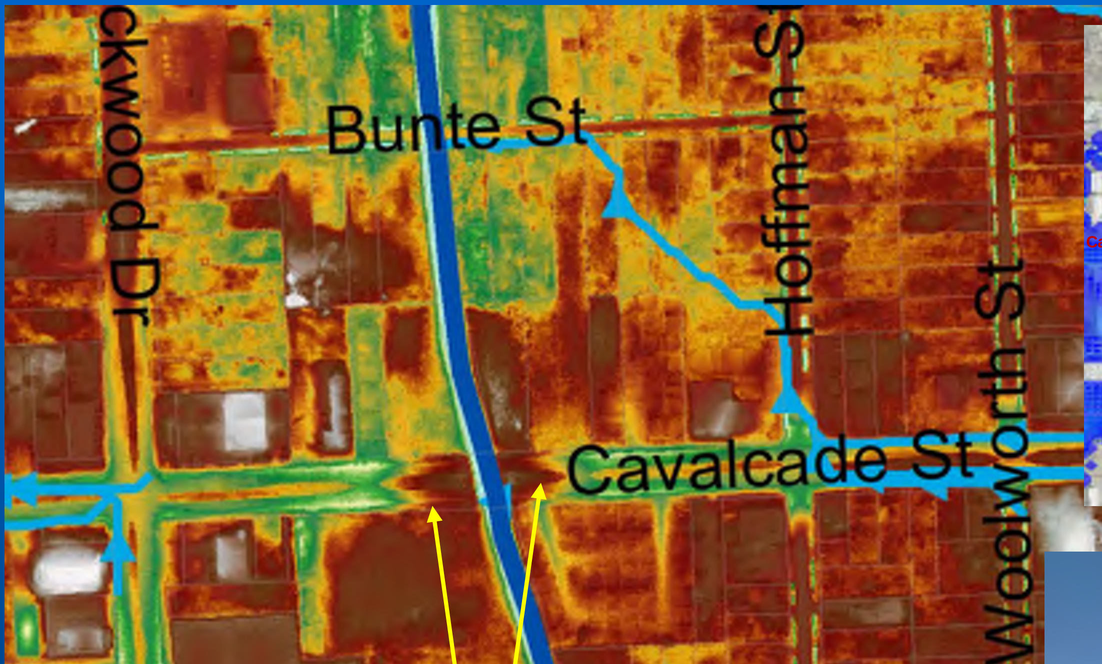


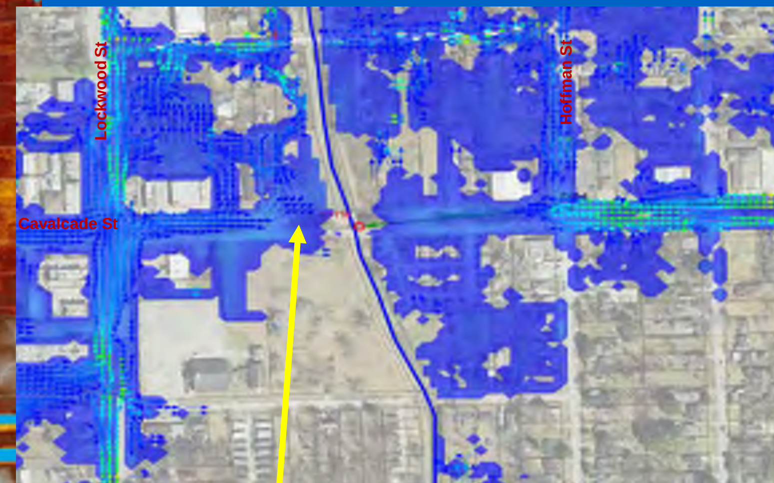
Sheet Flow moving in north direct along Lavender St. The flow is blocked by higher Pavement Grade Elevation (PGL) at Crane Street and re-directed to east along Crane St.

M-2018-E01 - KASHMERE GARDENS

Potential Improvements

HUITT-ZOLLARS





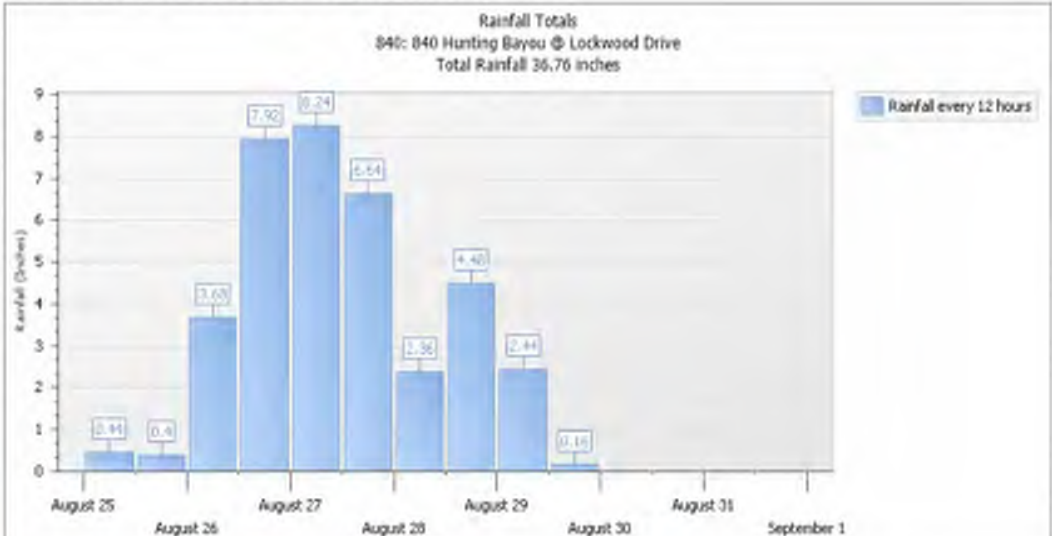
Sheet Flow is blocked from entering into H110-00-00 by higher roadway elevation at the bridge

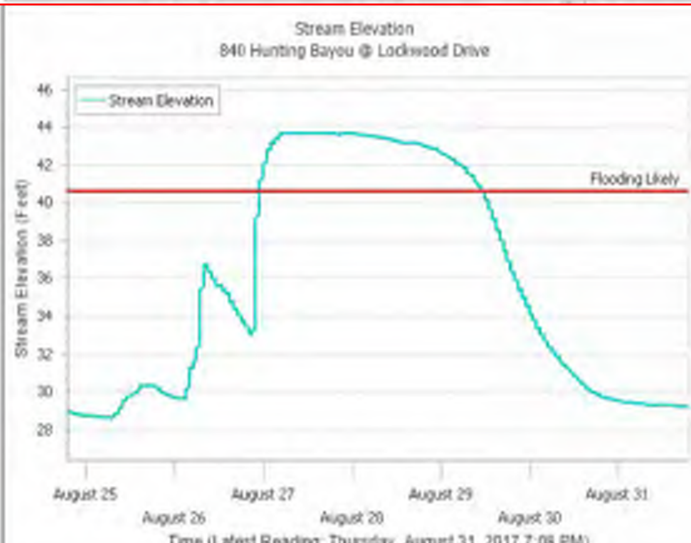
M-2018-E01 - KASHMERE GARDENS

Flooding History

HUITT-ZOLLARS

Showing rainfall totals from 8/25/2017 12:00 AM to 9/1/2017 12:00 AM CDT





Cross Section

Stream Elevation for sensor 839 is **29.22'**
Reading on 8/31/2017 7:08 PM

Stream Elevation Sensor **839**
840 Hunting Bayou @ Lockwood Drive

Key Map 454U	
Sensor ID	**839**
Sensor Type	USGS Radar
Installed	6/28/1995
Flooding Likely	40.60'
Flooding Possible	37.60'
Bottom of Stream	27.49'
Tip of Orifice	43.59'
Measuring Plate	41.93'
External Link	USGS
Benchmark	41.44'

RM 080105 stamped RM 080105 EST 2002 located on the downstream sidewalk at south end bridge, 1988 NAVD, 2001 adjustment. 78 to 01 Adjustment -1.05'
As of July 1, 2007, the elevation datum was changed from 1929 NGVD, 1978 adjustment to the 1988 NAVD, 2001 adjustment.

Flood Frequency	Elevation
10% (10-year)	41.90'
2% (50-year)	44.10'
1% (100-year)	45.00'
.2% (500-year)	46.80'

Historical Storm

Date	Event	Elevation
3/20/1972		40.70'
3/4/1992		41.50'
9/11/1998	Frances	41.40'
6/5/2001	Allison #2	42.20'
6/19/2006		41.00'
10/16/2006		41.30'
8/16/2007	Erin	42.00'
9/13/2008	Ike	42.10'
5/26/2015		40.70'
10/25/2015		38.00'
10/31/2015		41.40'
1/18/2017		40.60'
8/27/2017	Harvey	44.40'
9/19/2019	Imelda	41.40'

High water mark elevations are approximate.

HUNTING BAYOU FLOOD RISK MANAGEMENT, HARRIS COUNTY, TEXAS

GENERAL REEVALUATION REPORT AND INTEGRATED ENVIRONMENTAL ASSESSMENT

APPENDIX 2
HYDROLOGY & HYDRAULICS

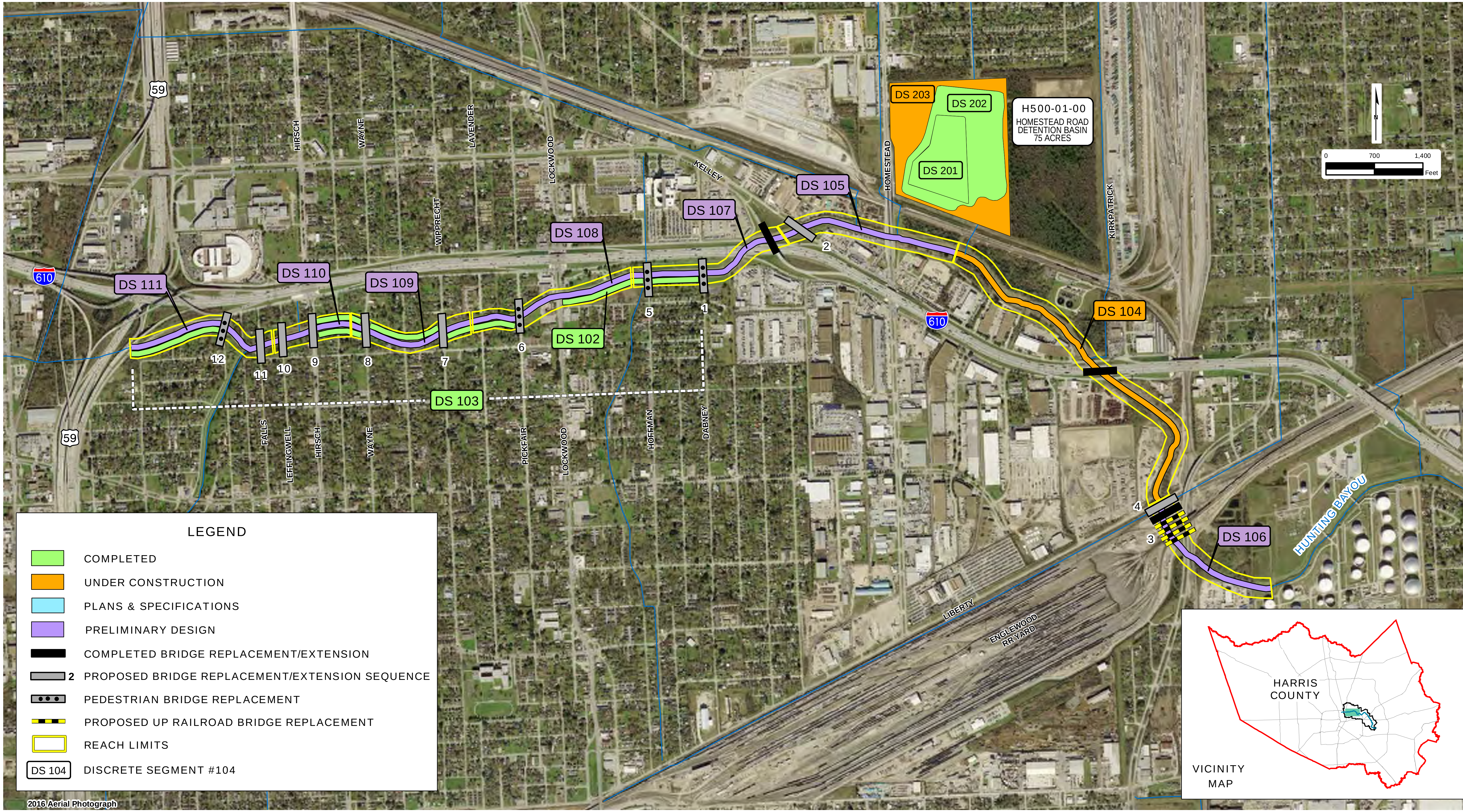
November 2014

HARRIS COUNTY FLOOD CONTROL DISTRICT

Prepared By:

AECOM TECHNICAL SERVICES, INC.

Hunting Bayou



S:\Shared\Ops\EngDiv\Graphics\Projects\H-Hunting_Bayou\H100-00-00\CL-HuntingBayouProject\CL-Hunting Bayou\CL-Hunting Bayou_11x17.mxd

HARRIS COUNTY FLOOD CONTROL DISTRICT

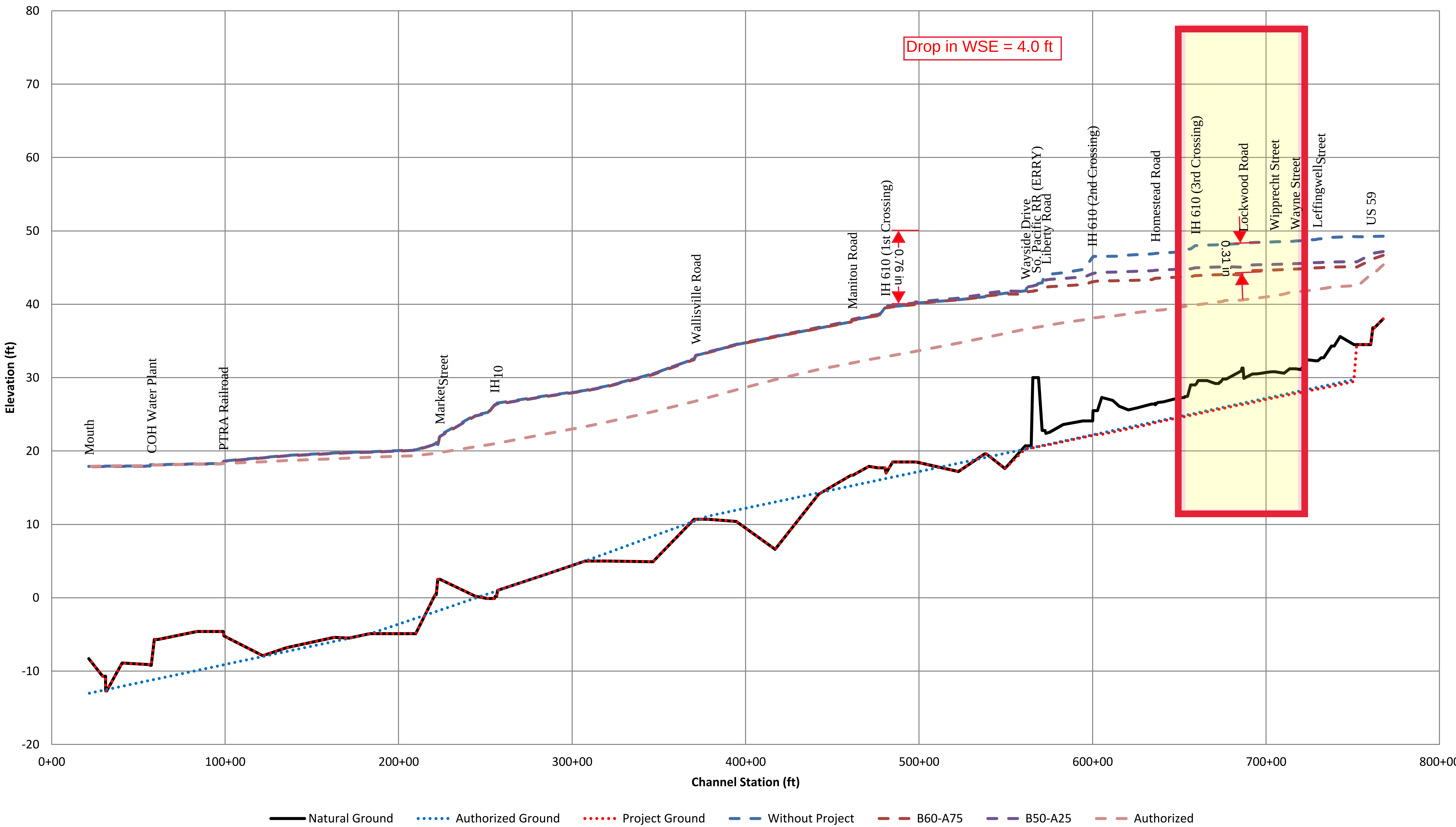
US Army Corps of Engineers
Galveston District

November 8, 2017

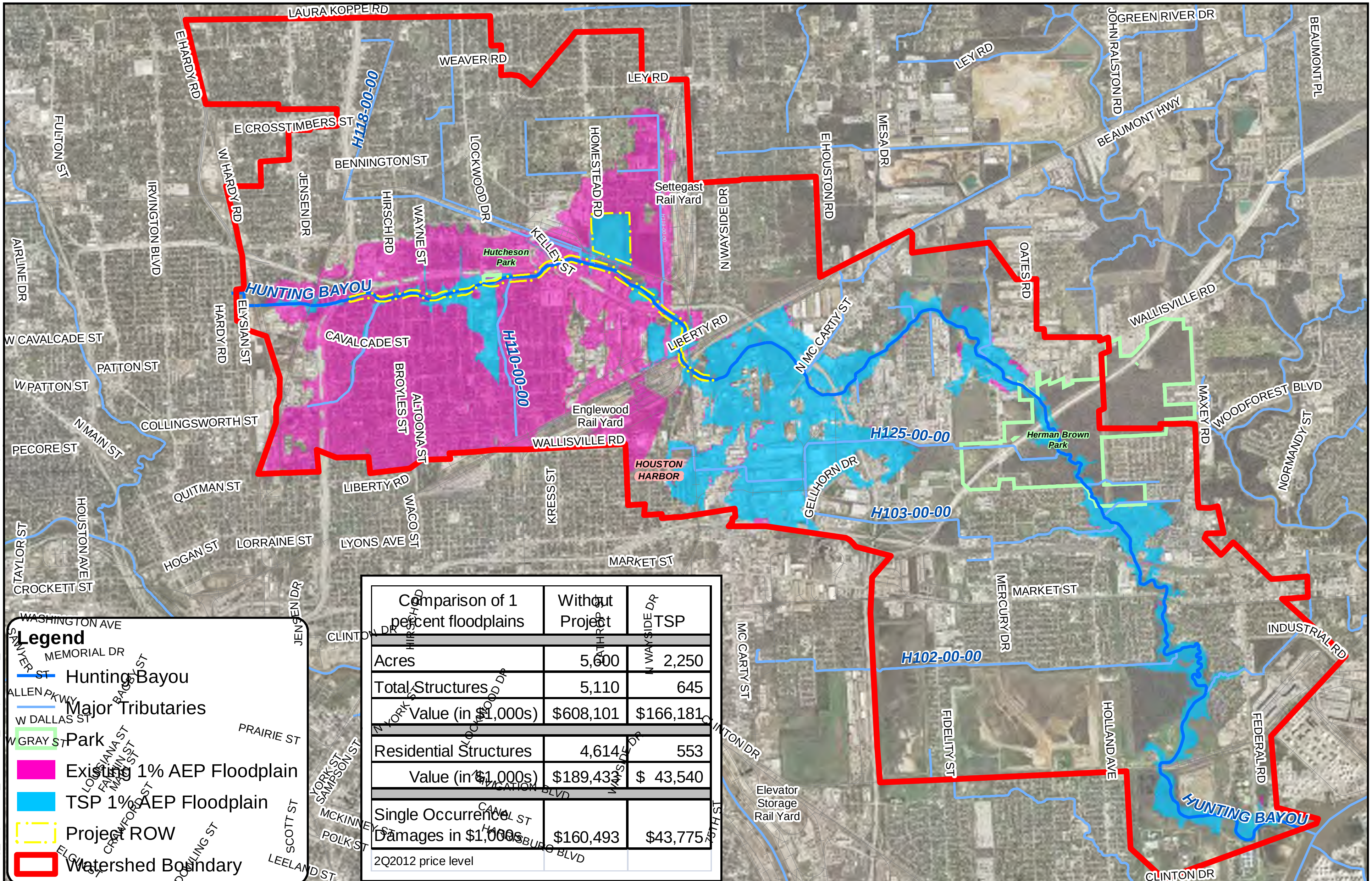
EXHIBIT A2-45

1% AEP Water Surface Profile Comparison

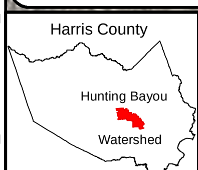
for Existing Without Project Conditions and B50-A25, B60-A75, and Authorized Plans



Path: P:_PWP\60184837_Hunting_Bayou\400_Technical_Discipline\444_GIS\H&H\Exhibit A2-45 1% AEP Floodplain Comparison for the TSP and WOP Conditions.mxd



Comparison of 1 percent floodplains	Without Project	TSP
Acres	5,600	2,250
Total Structures	5,110	645
Value (in $1,000s)	$608,101	$166,181
Residential Structures	4,614	553
Value (in $1,000s)	$189,433	$ 43,540
Single Occurrence Damages in $1,000s	$160,493	$43,775
2Q2012 price level		



Vicinity Map

HARRIS COUNTY FLOOD CONTROL DISTRICT

Exhibit A2-49: 1% AEP Floodplain Comparison for the TSP and WOP Conditions

Hunting Bayou Flood Risk Management Project

Sources:
Hunting Bayou - HCFCD
Park - H-GAC
AEP Floodplains - AECOM
TSP Floodplain - AECOM

US Army Corps of Engineers
Galveston District

N W E S

0 3,000 6,000 Feet

HUITT-ZOLLARS

Houston Kashmere Gardens Area Flood Mitigation Project
Technical Memorandum
WBS No. M-430100-0020-3
Kashmere Gardens

Prepared for:

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

HUITT-ZOLLARS, INC.
10350 RICHMOND AVE. SUITE 300
HOUSTON, TEXAS 77042-4248
TBPE Reg. No. F-761
(281) 496-0066

October 28, 2020

STATE OF TEXAS
AFSHIN GAZERZADEH
135980
LICENSED
PROFESSIONAL ENGINEER

Afshin Gazerzadeh

List of Exhibits

1 Introduction

Study Purpose and Scope

Huitt-Zollars (HZ) was tasked with providing professional engineering services to investigate the deficiencies of the existing drainage system and recommend drainage improvements for the Kashmere Gardens neighborhood in City of Houston (COH). HZ used Need Area M-2017-002 study dated 2015 as a starting point.

This report summarizes findings from the existing condition investigation to identify problem areas and recommend appropriate drainage improvements for those areas. The scope of this work includes:

- Define the study area and identify the drainage systems
- Define the drainage area boundaries and overland flow paths
- Survey the main trunklines to obtain storm sewer flowline elevation and pipe size
- Develop a dynamic hydraulic model to identify the drainage issues
- Develop and evaluate the improvement project

Project Location and Background

The project is located within the historic Kashmere Gardens, which is located just south of North 610 Loop and east of US-59 in Houston, TX. The limits of the detailed study defined by HZ through the early stages of the work and finalized through coordination with COH, are shown in Exhibit 1. The study area is located between an industrial area to the east, Union Pacific rail corridor to the south, Schrum Gully (H112-00-00) to the west and Hunting Bayou (H100-00-00) to the north. The existing land use is mainly single-family residential lots and commercial developments. The existing land use is shown in Exhibit 2.

The existing drainage system within the study area consists of storm sewer lines, roadside ditches, and channels as shown in Exhibit 3. The study area is located within the Hunting Bayou watershed. Hunting Bayou and its tributaries H110-00-00 serve as outfalls for the local drainage systems. Channel H110-00-00, divides the study area into two parts. On the east side of H110-00-00, most drainage systems run from east to west and outfall into H110-00-00. On the west side, the major drainage systems run from south to north and outfall into Hunting Bayou.

During an intense rainfall event, Hunting Bayou has historically come out of the banks and flooded existing structures along the bayou within this study limits. The existing storm sewer lines also have limited capacity, which potentially contributed to the widespread flooding in the neighborhood in the past. The Harris County Flood Control District (HCFCD) is in the final stages of completing improvements to Hunting Bayou, which reduce the water surface elevation in the bayou.

Data Collection

The following documents and data were obtained and used to guide this study:

- City of Houston Infrastructure Drainage Manual (IDM), 2019
- Technical Modeling Guidelines for 2D Dynamic Stormwater Analysis, COH, Technical Paper (TP) – 102, 2019
- COH GIMS
- Record Construction Drawings from COH's Public Records Department
- Topographic survey performed by Landtech, Inc

Methodology

The hydrologic and hydraulic analysis was performed in accordance with the COH IDM using the Rational Method. Peak discharges were computed for the 2, 10, 100 and 500 year storm events. Runoff hydrographs for individual drainage areas within the study area were generated based on the Clark Unit Hydrograph using USACE HEC-HMS (Version 3.3) and calibrated to the Rational Method peak flows. Storm sewer and ditch analysis was performed using Innovyze XPSWMM (Version 2018.2).

Drainage system components including drainage areas, land use, storm sewer and ditch connectivity, cross-sections and flowlines were obtained from COH GIMS data. The drainage systems were verified utilizing a combination of as-built information, field reconnaissance, Lidar, aerial photography and survey data. The drainage area map is shown in Exhibit 4.

FEMA Special Flood Hazard Areas

The study area is located within the Hunting Bayou 100-year floodplain boundary and shaded Zone X (500-year) boundary. The Base Flood Elevation (BFE) for the site is about 45 feet above NAVD 88. Hunting Bayou and Channel H100-00-00 are FEMA studied streams with regulatory floodplains as shown on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) 48201C0715M dated January 06, 2017. The floodplain boundaries are shown in Exhibit 5.

Hunting Bayou Improvement Project

HCFCD is in the final stages of completing improvements to Hunting Bayou. The HCFCD project consists of approximately 3.8 miles of grass-lined channel widening from downstream of the Englewood Railroad Yard to US-59 and 1000 acre-feet of detention in a 75–acre detention basin.

Based on the "*Hunting Bayou Flood Risk Management Report"* dated 2014, the improvements in Hunting Bayou will reduce the 100-year Water Surface Elevation (WSE) near Lockwood Bridge by about four feet. This study assumes the HCFCD improvements are complete and use the lowered WSE in Hunting Bayou in the analyses.

Site Visit

A site visit was performed on December 23, 2019 to obtain photographs and to document the existing drainage patterns and land uses of the study area.

2 Existing Drainage System

The existing drainage system consists of storm sewer and roadside ditches throughout the study area and shown in Exhibit 3. The drainage systems were modeled to determine if they meet the COH criteria and are discussed in detail below.

Drainage Area

The total study area is approximately 873 acres. Additionally, there is about 570 acres offsite drainage with storm sewer lines draining away from the study area, while the surcharges on the streets of this area ultimately enter into the study area.

The existing ground elevations range from 41 feet at the bank of Hunting Bayou to 45 feet at the railroad site south of Liberty Road. The existing topography throughout this area is relatively flat with an average slope of 0.07%. The Lidar Map is shown in Exhibit 6.

Exhibit 7 shows the sheet flow patterns through the study area. The general overland flow direction is from west to east and south to north on the west side of H110-00-00 and outfall to Hunting Bayou. On the east side, water flows from east to west and outfalls into H110-00-00.

Drainage Outfall Channels

Hunting Bayou is an earthen channel with recently improved banks at the study limits. The channel serves as a major outfall for local drainage systems.

Channel H110-00-00 is a trapezoidal concrete-lined channel with a rectangular pilot channel. Based on the FEMA Effective model, the channel has adequate capacity to convey the 100-year storm event without flooding outside the banks. However, the backwater from Hunting Bayou inundates the H110-00-00 during extreme storm events.

Schrum Gully, Channel H112-00-00, is an earthen trapezoidal channel with a concrete lined rectangular pilot channel. Based on the FEMA Effective model, the channel has adequate capacity to convey the 100-year storm event without flooding outside the banks. However, the backwater from Hunting Bayou inundates Schrum Gully during extreme storm events.

Historic Flooding

The study area has a long flooding history according to flood damages records. The flood damage complaints from Hurricane Harvey (2017) and previous major storms are shown in Exhibit 8. This map indicates the area is prone to frequent flooding.

Hydraulic & Hydrologic Analysis

Exhibit 4 present the drainage areas and storm sewer systems that were modeled in XPSWMM. Drainage Systems A to J and WH1 to WH are located on the west side of H110-00-00, and Drainage Systems EH1 to EH10 are located on the east side of H110-00-00. Along H100-00-00, there are several small drainage systems that have sufficient capacity and therefore were not included in the XPSWMM model (see Exhibit 3).

System EH1, EH2 and EH3 were modeled as ditches with average 2 feet depth, 2 feet bottom width and 3H:1V side slopes. All the other systems consist of underground storm sewer lines with curb and gutter road. System F1, G1 and EH10 outfall into COH storm sewer. Other drainage systems drain into HCFCD channels.

Runoff hydrographs were developed separately and entered in the XPSWMM model. The XPSWMM model include 2D surface for modeling the sheet flow in the street. The XPSWMM model nodes and links are shown in Exhibit 4. Model parameters including tailwater elevations, Manning's roughness coefficient and mesh size were established in accordance with the COH IDM and TP-102.

The study area is located in the upper end of Hunting Bayou watershed. During a 100-yr storm, flows in Hunting Bayou peak about 1.2 hours after the flows in the study area have peaked. The fixed tailwater was set to top of pipe for 2-yr storm event. For 100-year storm event, the fixed tailwater was set to 2 feet below top of bank or 10-year WSE in the bayou whichever was lower.

Existing Condition Findings

The capacity of the drainage systems, on west and east side of H110-00-00, were evaluated for 2-year, 10-year and 100-year storm events. Exhibits 10 to 12 present the ponding depth for existing drainage system were. Table 1 & Table 2 compare the 2-year and 100-year water surface elevation with gutter elevation, natural ground at the Right-of-Way (ROW) and estimated Finished Floor Elevation (FFE). The FFE was estimated using 2018 LIDAR data.

West Side of H110-00-00

2-year Storm Event

- The existing 90" storm sewer along Lavender Street in System A and the existing 96" storm sewer along Wayne Street in System D do not have sufficient capacity to carry the 2-year storm event (see Exhibit 9). This results in more than one foot of ponding depth along Collingsworth Street between Wayne Street and Lavender Street. Based on the XPSWMM model result, there is about 50 cubic feet per second sheet flow from System D into System A during the 2-year storm event along Collingsworth Street.

- The storm sewer along Wayne Street south of Crane Street consists of a 78" Reinforced Concrete Pipe (RCP) and a 60" RCP, which has more capacity than the 90" storm sewer line downstream of this section. This is resulted in excessive sheet flow along Collingsworth Street.

- The 2-year Hydraulic Grade Line (HGL) in System A exceeds the gutter elevation along Love Street south of Collingsworth Street. This is mainly due to limited capacity in the existing storm sewer line and roadside ditches.

100-Year Storm Event

- Exhibits 12 present the ponding depth for the 100-year storm event. There is significant ponding during 100-year storm event outside the road ROW which can potentially result in structural flooding. This condition can be attributed to limited storm sewer and sheet flow conveyance capacity.

- The hydraulic analysis results indicated that there is about 250 cfs sheet flow along Collingsworth Street that enters the study area. This additional flow is causing the ponding depth to exceed 1.5 feet above the top of curb along Collingsworth Street.

East Side of H110-00-00

2-year Storm Event

- The hydraulic analysis of the drainage system along Rand Street indicated that the existing roadside ditches do not have enough capacity to carry the 2-year flows. The 2-year capacity map is shown in Exhibit 9,

- The 54" RCP along Cavalcade Street (System EH5) does not have adequate capacity for a 2-year storm event.

- The 36" RCP along Crane Street (System EH7) does not have adequate capacity for a 2-year storm event.

<u>100-Year Storm Event</u>

- As shown in Exhibit 12, there is considerable ponding during the 100-year storm event outside the road ROW, which can potentially result in structural flooding. This condition can be attributed to limited storm sewer and sheet flow conveyance capacity.

- The existing roadside ditches in System EH1 to EH3 do not have sufficient capacity for the100-year storm event. The existing roads are higher than the private property in this area, which results in excessive ponding outside the ROW during a 100-year Storm.

- The hydraulic analysis of the drainage system along Cavalcade Street indicates about 2 feet of ponding depth along the roadway corridor between Kress Street and the outfall location during a 100-year storm event. The ponding in the street is exacerbated by the higher grades at the bridge crossing over Channel H100-00-00.

Table 1 – West of H110-00-00, 2-yr and 100-yr XPSWMM Result

XPSWMM Node ID	Ground Elevation/ Spill Crest (ft)	Gutter/Ditch TOB Elevation (ft)	2-yr WSE (ft)	2-yr to Gutter/TOB Difference (ft)	ROW Elevation (ft)	100-yr WSL (ft)	100-yr to ROW Difference (ft)
A1	41.89	41.00	34.91	-6.09	43.25	42.83	-0.42
A3	42.13	42.00	35.95	-6.05	43.50	43.19	-0.31
A4	43.88	42.60	36.84	-5.76	43.60	43.47	-0.13
A5	41.32	41.50	37.76	-3.74	43.70	43.84	0.14
A6	42.44	42.00	37.98	-4.02	43.50	43.77	0.27
A7	43.12	43.00	38.05	-4.95	43.60	43.78	0.18
A8	43.25	42.50	38.11	-4.39	43.70	43.79	0.09
A9	42.59	42.60	38.21	-4.39	43.80	43.80	0.00
A15	42.72	42.40	38.76	-3.64	43.35	43.57	0.22
A16	42.61	42.20	38.83	-3.37	43.50	43.66	0.16
A20	42.92	42.60	39.39	-3.21	43.80	43.82	0.02
A21	43.38	42.80	38.66	-4.14	44.10	43.82	-0.28
A22	44.48	42.70	38.35	-4.35	44.20	43.96	-0.24
A25	41.75	42.80	41.71	-1.09	43.60	43.42	-0.19
A30	43.20	42.10	37.13	-4.97	43.50	43.20	-0.31
A35	41.96	41.20	35.82	-5.39	43.50	42.12	-1.38
A36	40.33	41.00	33.48	-7.52	43.25	40.62	-2.63
B1	41.14	40.40	32.36	-8.04	41.40	40.09	-1.31
B2	42.70	42.20	33.78	-8.42	43.20	42.62	-0.58
B3	43.83	42.40	35.57	-6.83	43.40	44.00	0.60
C1	44.52	43.00	37.72	-5.28	45.00	40.41	-4.59
C2	43.46	43.10	39.98	-3.12	44.20	43.88	-0.32
C3	43.38	43.10	41.93	-1.17	44.45	44.39	-0.06
C4	42.95	42.60	42.90	0.30	43.90	43.81	-0.09
C5	43.54	43.00	39.84	-3.16	44.00	43.79	-0.21
C6	42.89	42.70	38.00	-4.70	43.70	42.15	-1.55
D1	41.97	42.50	37.20	-5.31	43.50	42.34	-1.16
D2	43.62	42.90	40.20	-2.70	43.90	44.03	0.13
D3	43.60	42.50	43.74	1.24	44.20	44.50	0.30
D4	43.89	43.50	43.89	0.39	44.40	44.01	-0.39
E1	43.78	43.00	37.32	-5.68	44.00	43.78	-0.22
F1	42.59	43.70	39.57	-4.14	44.50	43.98	-0.52
G1	43.99	43.40	37.17	-6.23	44.40	44.85	0.45
I4	40.71	44.40	35.48	-8.92	42.00	41.34	-0.66

Table 2 – East of H110-00-00, 2-yr and 100-yr XPSWMM Result

XPSWMM Node ID	Ground Elevation/ Spill Crest (ft)	Gutter/Ditch TOB Elevation (ft)	2-yr WSE (ft)	2-yr to Gutter/TOB Difference (ft)	ROW Elevation (ft)	100-yr WSL (ft)	100-yr to ROW Difference (ft)
EH5-1	41.23	41.20	39.56	-1.64	42.80	42.81	0.01
EH5-2	41.96	41.60	42.06	0.46	43.40	43.46	0.06
EH5-3	42.31	41.90	42.84	0.94	43.60	43.72	0.12
EH7-1	42.20	41.70	39.94	-1.76	43.10	43.26	0.16
EH7-2	42.80	42.40	40.93	-1.47	43.80	43.90	0.10
EH7-3	43.15	42.70	41.97	-0.73	44.10	44.06	-0.04
EH8-1	41.97	41.50	39.46	-2.04	43.30	41.32	-1.98
EH8-2	42.92	42.40	40.17	-2.23	43.50	42.95	-0.55
EH8-3	43.01	42.60	41.41	-1.19	44.10	43.91	-0.19
EH9-1	41.57	41.40	39.64	-1.76	43.20	42.71	-0.49
EH9-2	42.67	42.00	39.90	-2.10	43.60	43.24	-0.36
EH9-3	42.67	42.40	40.35	-2.05	43.90	43.59	-0.31
EH1-1	41.74	41.74	41.22	-0.52	41.50	41.76	0.26
EH1-1.1	41.24	41.24	40.81	-0.43	41.60	41.54	-0.06
EH1-2	41.24	41.24	41.25	0.01	41.60	41.82	0.21
EH2-1	42.40	42.40	41.75	-0.65	42.10	42.15	0.05
EH2-1.1	41.74	41.74	41.67	-0.07	42.10	42.11	0.01
EH2-2	41.74	41.74	41.73	-0.01	41.80	42.04	0.24
EH3-1	41.74	41.74	42.05	0.31	42.30	42.36	0.06
EH3-1.1	41.24	41.24	42.01	0.77	42.20	42.26	0.06
EH3-2	42.74	42.74	42.39	-0.35	42.40	42.79	0.39
EH3-2.1	42.24	42.24	42.28	0.04	42.40	42.57	0.17
EH3-2.2	42.24	42.24	42.28	0.04	42.30	42.65	0.35
EH3-3	43.74	43.74	43.37	-0.37	43.60	43.64	0.04
EH3-3.1	43.24	43.24	43.06	-0.18	43.10	43.35	0.24

Pavement Condition Rating

Based on the record drawings, existing streets within the project area were constructed in 1980's. Some of the streets show minor cracking and signs of deterioration at specific locations while remaining streets seem to be in good condition.

The condition of a street is assessed by COH based on the physical condition of the roadway – travel surface cracking, potholes, spalling, base failure and other pavement deficiencies. Pavement Condition Index (PCI) is a numerical indicator that rates surface condition of the pavement. Exhibit 13 shows that the existing concrete pavement within the project area are in poor to fair condition.

Sanitary Sewer Lines

The existing water lines shown on Exhibit 14 were all built primarily in the 1980's. The water lines within the study area are primarily 6" to 8" diameter. There is a main 84" water which runs from north to south along Kashmere Street, Collingsworth Street and Lockwood Dr.

Water Lines

The existing sanitary sewer lines shown on Exhibit 15 were built in the 80's. The sanitary sewer lines within the study area are primarily 8"diameter. There is a main 60" sanitary sewer system which runs from north to south along Pickfair Street.

3 Proposed Condition Analysis

This technical memorandum include proposed drainage improvements within the study area. The existing condition XP-SWMM models were updated to incorporate the proposed improvements.

3.1 Proposed Improvement Projects

The drainage improvements include proposing new storm sewer trunkline, detention pond, regrading roadside ditches, driveway culvert replacement, inlet replacement and green stormwater infrastructure. The location of recommended improvements are shown in Exhibit 16 and discussed below. Exhibit 17 present the proposed storm sewer systems map that were modeled in XPSWMM.

The proposed improvements will increase the size of the existing storm sewer lines, which will reduce the risk of excessive street ponding and structural flooding. The proposed storm sewer lines will increase the discharge at the outfall to the bayou. The proposed offsite and inline detention will provide the required mitigation to have no negative impact on the receiving streams.
The proposed drainage improvements are broken down into six groups and labeled as Drainage Improvements P1 to P6, which are discussed in detail below:

<u>Drainage Improvement P1:</u>

- As shown Exhibit 18, the proposed drainage improvements in Systems A and B include a new 12' x 8' RCB trunkline along Wipprecht Street between Collingsworth Street and Hunting Bayou. The existing 36" RCP between Cavalcade Street and Hunting Bayou will be replaced with the proposed 12' x 8' RCB due to limited space and constructability issues.

- The existing 48" RCP pipe along Collingsworth Street will drain to the proposed 12' x 8' RCB trunckline along Wipprecht Street through 2-48" RCP. Based on record drawings, there is sufficient room to build the 2-48" RCP and avoid an existing 84" water line along Collingsworth Street (see Exhibit 18).

- The proposed 12'x8' RCB will provide additional conveyance and in-line detention, which reduce the risk of structural flooding along Lavender Street and Collingsworth Street. The new trunkline will also address the excessive street flooding along Collingsworth St during flashflood events.

<u>Proposed Improvement P2:</u>

- As shown in Exhibit 19, the proposed drainage improvements in Systems A include a storm sewer trunk line along Pickfair Street, Crane Street, Lockwood Dr and Marcus Street. The proposed trunk line drains to Channel H110-00-00 through the proposed Detention Pond A. There is a 60" sanitary sewer line along Pickfair Street. Based on available record drawings, the proposed 6'x3' RCB along Pickfair Street can go over the existing 60" sanitary sewer line.

- Detention Pond A is 21.72 acre-feet, 8 feet deep and located on Cavalcade Street, west of Channel H110-00-00. Pond A is shown in Exhibit 19.

- Crane Street west of Lockwood Drive is about two feet higher than adjacent streets and higher than finish floor of some of the existing homes. Crane Street blocks the sheetflow in the street from southeast to reach Channel H11-00-00 and increase the risk of structural flooding and excessive ponding in the area (see Exhibit 19). The proposed improvement include a new trunkline under the existing pavement along Crane Street, The existing pavement on Crane Street between Lockwood Drive and Pickfair Street need to be replaced and also lowered by up to two feet to facilitate sheetflow.

Proposed Improvement P3:

- As shown Exhibit 20, the proposed drainage improvements include replacing the existing 54" storm sewer with a 10'x5' RCB along Cavalcade Street, between Blaffer Street and Dabney Street. The proposed 10'x5' RCB will be connected to a new storm sewer along Dabney Street.

- Pond F and proposed 10'x5' RCB along Dabney Street will provide the required mitigation in form of offsite and in-line detention. Pond F is 4.38 acre-feet, 8 feet deep and located on Cavalcade Street, east side of Channel H110-00-00. Pond F will be connected to existing 60" RCP on Cavalcade Street. Pond F will reduce the runoff discharge from drainage system EH5 to Channel H110-00-00. Pond F is shown in Exhibit 20.

- The proposed drainage improvement will improve the street ponding on Cavalcade Street during 100-Yr storm event. In addition, the new trunk line along Dabney Street will convey a portion of EH5 storm water runoff to the north and outfall to Hunting Bayou in lieu of discharging to Channel H110-00. This will relieve the drainage system of EH5 surcharge issue and result in less overland flow during flashflood events.

Proposed Improvement P4:

- The proposed drainage improvements include a new 54" RCB pipe along Hoffman Street that connects the existing 54" storm sewer along Crane Street to proposed Detention Pond C (see Exhibit 20).

- Detention Pond C is 4.05 acre-feet, 7 feet deep and located south of Crane Street on the east side of H110-00-00. The pond will serve as the detention mitigation pond and will reduce the runoff discharge to the Channel H110-00-00 from system EH7. Detail of pond layout is shown Exhibit 20.

Proposed Improvement P5:

- The proposed drainage improvements include a new 10'x8' RCB trunkline along Dabney Street between Crane Street and Hunting Bayou. The new pipe will be connected to the existing 48" along Crane Street, the proposed 10'x5' RCB along Cavalcade Street and the proposed 36" along Rand Street. The new storm sewer trunkline will outfall into Pond R and Hunting Bayou. The recommended improvement are shown in Exhibit 20.

- There is no existing storm sewer along Dabney Street between Crane Street and Hunting Bayou. The existing drainage system consist of roadside ditches. The existing roadside ditches along Rand Street and the street north of Rand Street do not have sufficient capacity for a 2-yr storm. There is not enough ROW to increase the size of existing roadside ditches to meet the COH criteria. The proposed 10'x8' RCB Trunkline provides sufficient conveyance capacity to drain this area for a 2-yr Storm and provide some inline detention for 100-yr storm.

- The proposed trunkline takes flows away from channel H110-00-00 and drains them directly into Hunting Bayou in downstream section. The proposed trunkline will lower HGL in existing storm sewer lines along Calvacade Street and Crane Street.

- As shown in The proposed Detention Pond R and 10'x8' RCB trunkline serve as offsite and in-line detention. Detention Pond R provides 4.7 acre-feet of storage and is located just south of Hunting Bayou between Dabney Street and Hoffman Street. COH is acquiring a property north of Hunting Bayou which is labeled in Exhibit 21 as Detention Pond Q. Detention Pond Q will provide about 10.35 acre-feet of detention which can be utilized instead of Detention Pond R if necessary.

Proposed Improvement P6:

- The proposed drainage improvements include a 36" RCP trunkline long Rand Street, between Majestic Street and Dabney Street (see Exhibit 20). The proposed 36" RCP connects to the proposed 10'x8' RCB along Dabney Street.

- The existing roadside ditch drains a large area and does not have capacity to maintain the runoff within the ditch during a 2-Yr storm event. The proposed improvement will provide the required conveyance capacity for a 2-yr storm.

Detention Pond N:

- Proposed Detention Pond N is 7 feet deep, provides 4.99 acre-feet of storage and is located at Cavalcade Street on the west side of H110-00-00. Pond N is shown in Exhibit 22. The existing 54" RCP along Cavalcade Street will drain to Detention Pond N.

- The proposed Detention Pond will provide an extreme event overflow swale connection between the street and Channel H110-00-00. The existing bridge over Channel H11-00-00 is higher than Calvacade Street and prevents the sheetflow in the street from drainage to the channel. The improvements will reduce the runoff discharge to Channel H110-00-00 and provide proper extreme event sheet flow connection between the street and to the channel.

Detention Pond M:

- Pond M will serve as detention mitigation pond for the improvement projects. Pond M is shown in Exhibit 23.

- Detention Pond M provides 3.78 acre-feet of storage, is 5 feet deep and is located on Collingsworth Street at the east side of H110-00-00 (see Exhibit 23). Pond M will be connected to existing 48" RCP along Collingsworth by 2-24" RCP. Pond M will reduce the runoff discharge to existing storm sewer and Channel H110-00-00.

Detention Pond K:

- Pond K will serve as detention mitigation pond for the overall improvement projects. Pond K is shown in Exhibit 24.

- Proposed Detention Pond K provides 2.37 acre-feet of storage, is 10 feet deep and is located on Pickfair Street south of Hunting Bayou. Pond K will be connected to existing 60" RCP along Pickfair Street. Pond K will reduce the runoff discharge to Hunting Bayou. COH is acquiring a property north of Hunting Bayou which is labeled in Exhibit 21 as Detention Pond Q. Detention pond Q will provide about 10.35 acre-feet of detention which can be utilized instead of Detention Pond K if necessary.

Detention Pond Q:

- Pond Q is shown in Exhibit 21. Detention Pond Q is 10.35 acre-feet, 11 feet deep and located on Lavender Street north of Hunting Bayou. Pond Q will reduce the runoff discharge to Hunting Bayou.

Other Proposed Improvements:

- The roadside ditch improvement includes desilting and regarding the existing ditch, replacing driveway culverts and roadway crossing culverts. The location of roadside ditch improvement is shown in Exhibit 16

- Replace existing Type "B" inlets with Type "BB" inlets. The location of inlet replacement is shown in Exhibit 16

- Install green stormwater infrastructure such as structured rain gardens, landscape improvements, sidewalk replacement and roadside ditch improvement. The location of green stormwater infrastructure is shown in Exhibit 16

Impact Analysis – WSE
Table 3 and Table 4 compares the 100-Yr WSE between existing and proposed condition. The ponding limits and depth are shown in Exhibit 25 to Exhibit 27. The proposed improvement will drop the 100-Yr WSE by up to 1.5-2 feet in the study area. This results in flooding limits be to street ROW for most of the study area.

Table 3. West of H110-00-00, Compare 100-Yr XPSWMM Result

XPSWMM Node ID	Exist 100-yr WSE (ft)	Prop 100-yr WSE (ft)	100-yr WSE Diff = (Prop-Exist) (ft)	ROW Elevation (ft)	Prop 100-yr to ROW Difference (ft)
A1	42.83	42.74	-0.09	43.25	-0.51
A3	43.19	43.16	-0.03	43.50	-0.34
A4	43.47	43.28	-0.19	43.60	-0.33
A5	43.84	43.55	-0.30	43.70	-0.16
A6	43.77	43.42	-0.36	43.50	-0.09
A7	43.78	43.56	-0.22	43.60	-0.04
A8	43.79	43.65	-0.14	43.70	-0.05
A9	43.80	43.72	-0.09	43.80	-0.08
A15	43.57	43.30	-0.27	43.35	-0.05
A16	43.66	43.37	-0.30	43.50	-0.13
A20	43.82	43.73	-0.08	43.80	-0.07
A21	43.82	43.73	-0.09	44.10	-0.37
A22	43.96	43.73	-0.23	44.20	-0.47
A23	43.94	43.65	-0.28	43.70	-0.05
A25	43.42	42.79	-0.63	43.60	-0.81
A30	43.20	43.20	0.00	43.50	-0.31
A35	42.12	42.11	-0.01	43.50	-1.39
A36	40.62	39.21	-1.41	43.25	-4.04
C1	40.41	40.04	-0.37	45.00	-4.96
C2	43.88	43.09	-0.79	44.20	-1.11
C3	44.39	44.38	-0.01	44.45	-0.07
C4	43.81	43.73	-0.08	43.90	-0.17
C5	43.79	43.72	-0.07	44.00	-0.28
C6	42.15	41.32	-0.83	43.70	-2.38
D1	42.34	42.34	0.00	43.50	-1.17
D2	44.03	44.02	-0.01	43.90	0.12
D3	44.50	44.50	0.00	44.20	0.30
D4	44.01	44.01	0.00	44.40	-0.39
E1	43.78	43.78	0.00	44.00	-0.22
F1	43.98	43.63	-0.35	44.50	-0.87
G1	44.85	44.85	0.00	44.40	0.45
I4	41.34	41.12	-0.22	42.00	-0.88

Table 4. East of H110-00-00, Compare 100-Yr XPSWMM Result

XPSWMM Node ID	Exist 100-yr WSE (ft)	Prop 100-yr WSE (ft)	100-yr WSE Diff = (Prop-Exist) (ft)	ROW Elevation (ft)	Prop 100-yr to ROW Difference (ft)
EH5-1	42.81	42.75	-0.06	42.80	-0.05
EH5-2	43.46	43.39	-0.07	43.40	-0.02
EH5-3	43.72	43.43	-0.29	43.60	-0.18
EH7-1	43.26	43.01	-0.26	43.10	-0.09
EH7-2	43.90	43.77	-0.13	43.80	-0.03
EH7-3	44.06	44.03	-0.03	44.10	-0.07
EH8-1	41.32	41.19	-0.13	43.30	-2.11
EH8-2	42.95	42.92	-0.03	43.50	-0.58
EH8-3	43.91	43.90	-0.01	44.10	-0.20
EH9-1	42.71	42.71	0.00	43.20	-0.49
EH9-2	43.24	43.24	0.00	43.60	-0.36
EH9-3	43.59	43.58	-0.01	43.90	-0.32
EH1-1	41.76	41.50	-0.26	41.50	0.00
EH1-1.1	41.54	41.50	-0.04	41.60	-0.10
EH1-2	41.82	41.50	-0.32	41.60	-0.10
EH2-1	42.15	42.09	-0.06	42.10	-0.02
EH2-1.1	42.11	42.09	-0.02	42.10	-0.01
EH2-2	42.04	41.65	-0.39	41.80	-0.15
EH3-1	42.36	42.23	-0.13	42.30	-0.07
EH3-1.1	42.26	42.18	-0.08	42.20	-0.02
EH3-2	42.79	42.31	-0.47	42.40	-0.09
EH3-2.1	42.57	42.36	-0.21	42.40	-0.04
EH3-2.2	42.65	42.21	-0.44	42.30	-0.09
EH3-3	43.64	43.14	-0.50	43.60	-0.46
EH3-3.1	43.35	42.68	-0.66	43.10	-0.42

Impact Analysis – Peak Discharge

Table 5 compares the XP-SWMM model existing and proposed condition for 10-Yr and 100-Yr peak discharge to the outfall channels. The project detention ponds provide an overall of 55 acre-feet of storage. The overall peak discharge to Hunting Bayou and Channel H110-00 is calculated by adding all outfall discharge hydrographs and not by adding the peak flow values. The total discharge in proposed condition model decreased by 7.8 and 7.5 for 10-Yr and 100-Yr at the outfall channels, respectively.

The Kashmere Gardens' proposed improvements will not adversely impact the peak discharge into outfall channels.

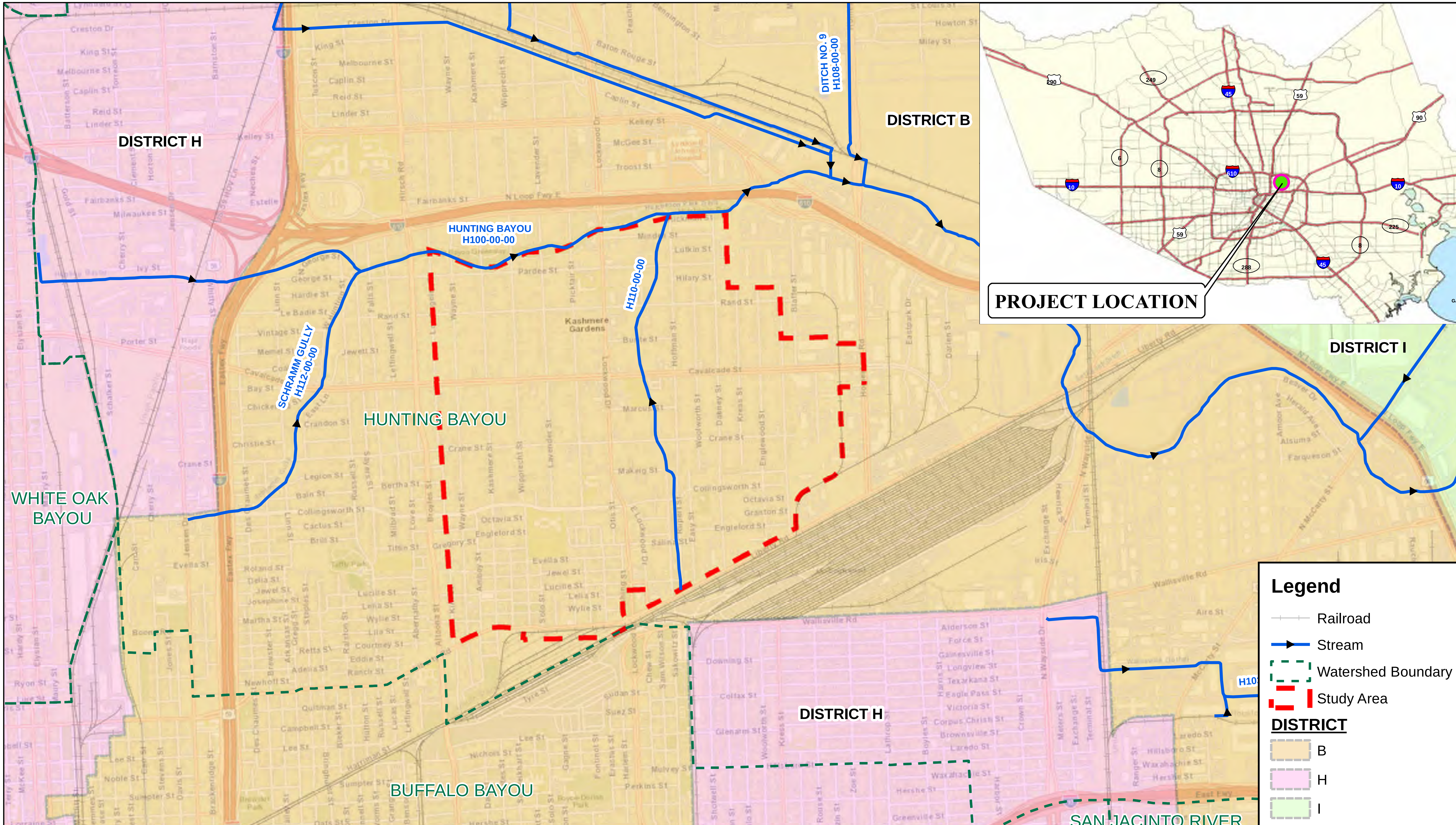
Table 5. Impact Analysis - Peak Discharge Difference

Kashmere Gardens Area Project	10-Yr Peak Discharge TOTAL			100-Yr Peak Discharge TOTAL		
	Exist (cfs)	**Prop (cfs)**	**= (Exist - Prop) (cfs)**	**Exist (cfs)**	**Prop (cfs)**	**= (Exist - Prop) (cfs)**
	1700.0	1692.1	-7.8	2269.7	2262.2	-7.5

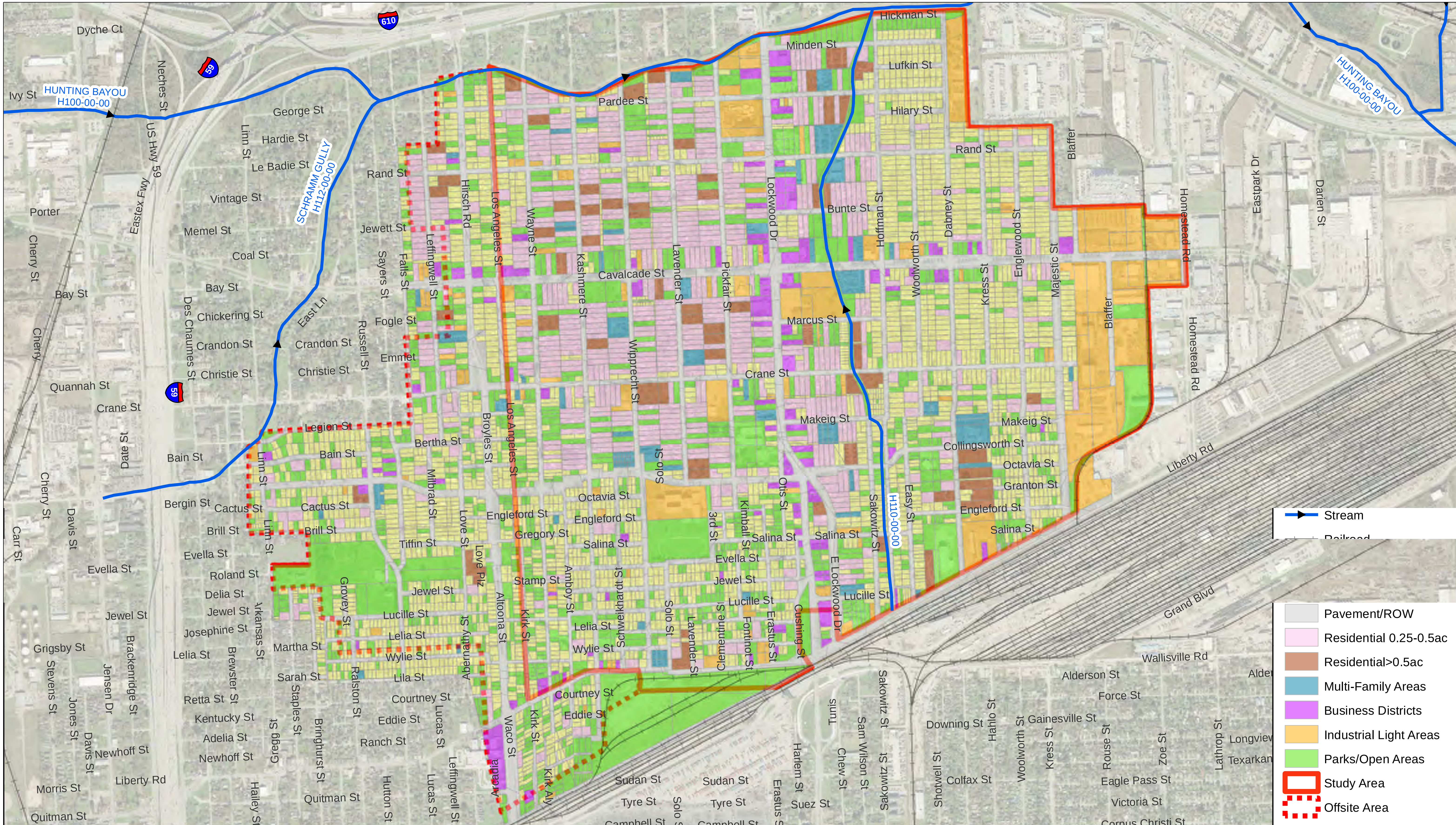
* The overall peak discharge to outfall channels is calculated by adding all outfall discharge hydrographs

Construction Cost Estimate:

The estimated construction cost for proposed improvements is up to $95 million. This cost does not include any right-of-way or easement acquisition. See Appendix for the cost estimate summary.



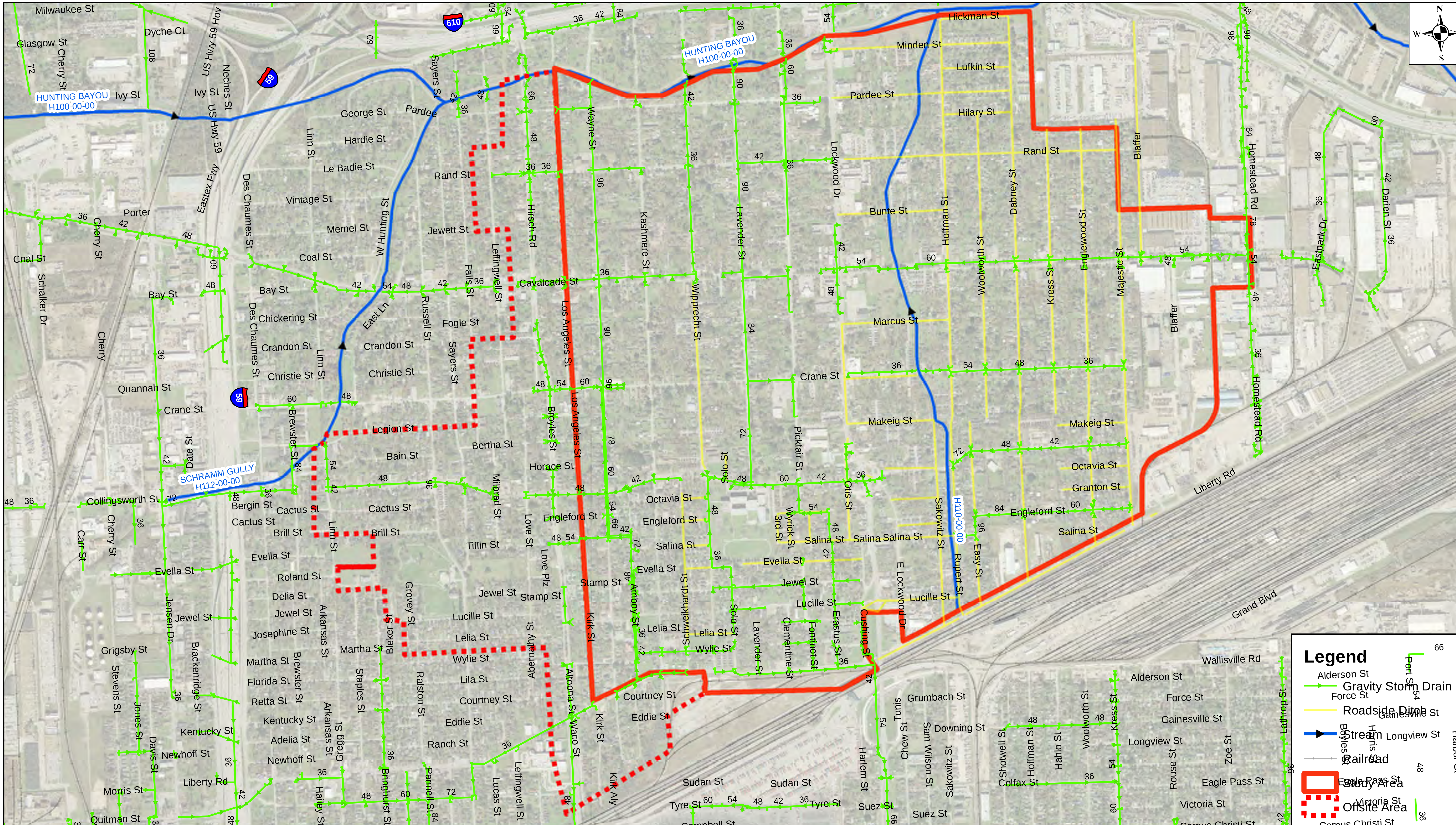
HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)		DATE	SCALE	EXHIBIT 1
			OCTOBER 2020	0 1,000 2,000 Feet	LOCATION MAP



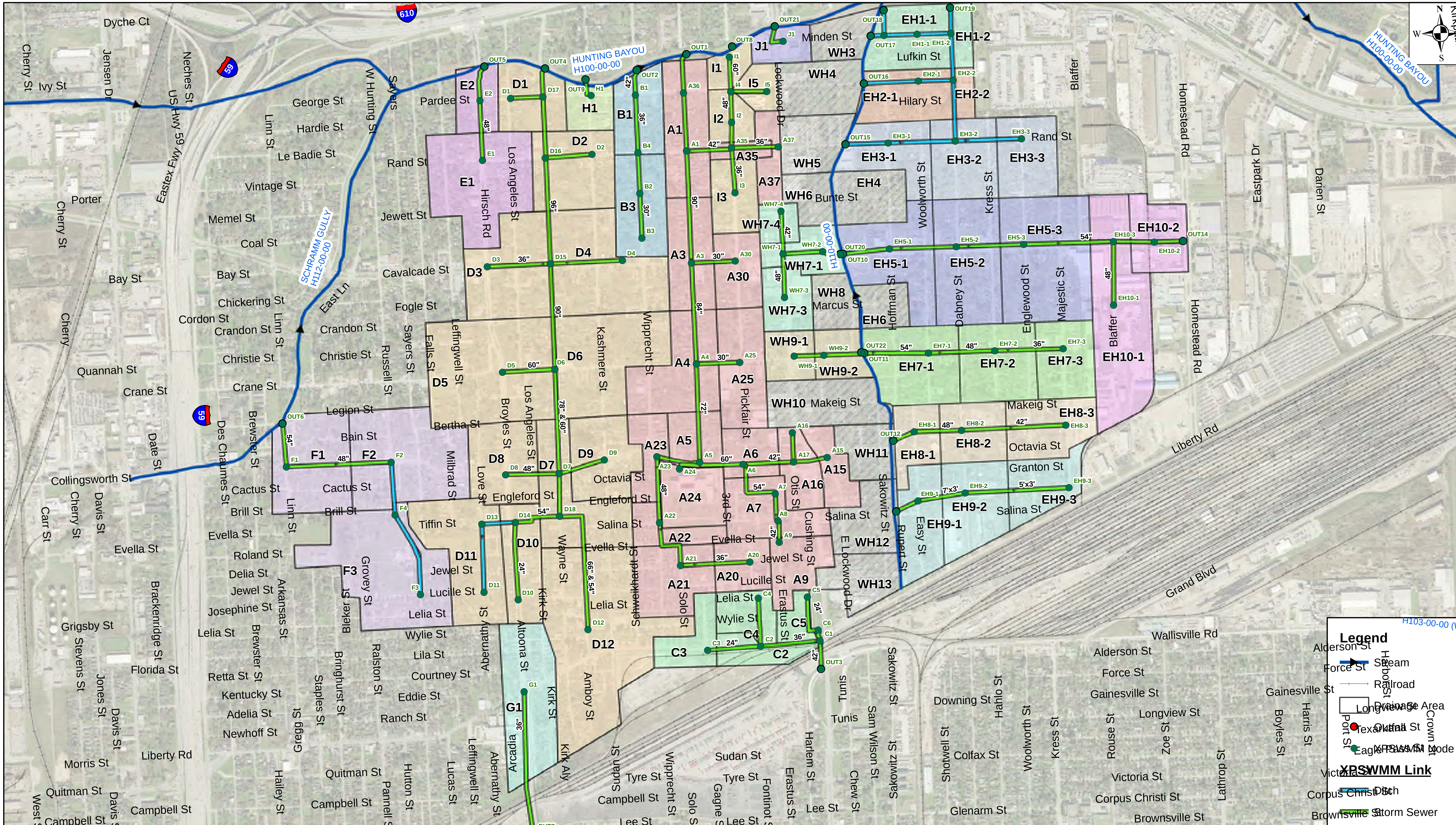
HUITT-ZOLLARS

PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

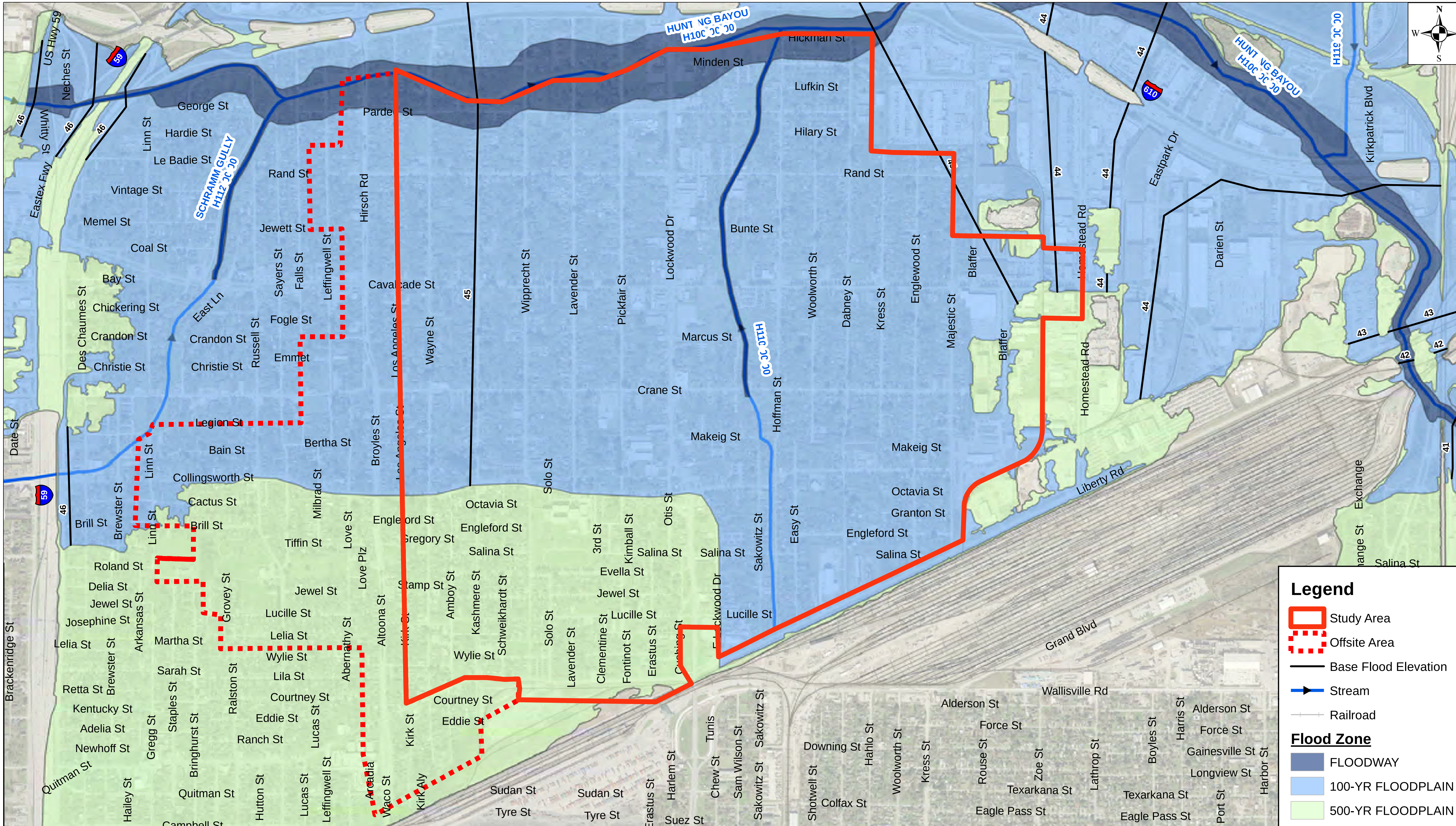
DATE	SCALE	EXHIBIT 2
OCTOBER 2020	0 500 1,000 2,000 Feet	PARCEL LAND USE



HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	EXHIBIT 3
			OCTOBER 2020	0 500 1,000 2,000 Feet	EXISTING DRAINAGE SYSTEM



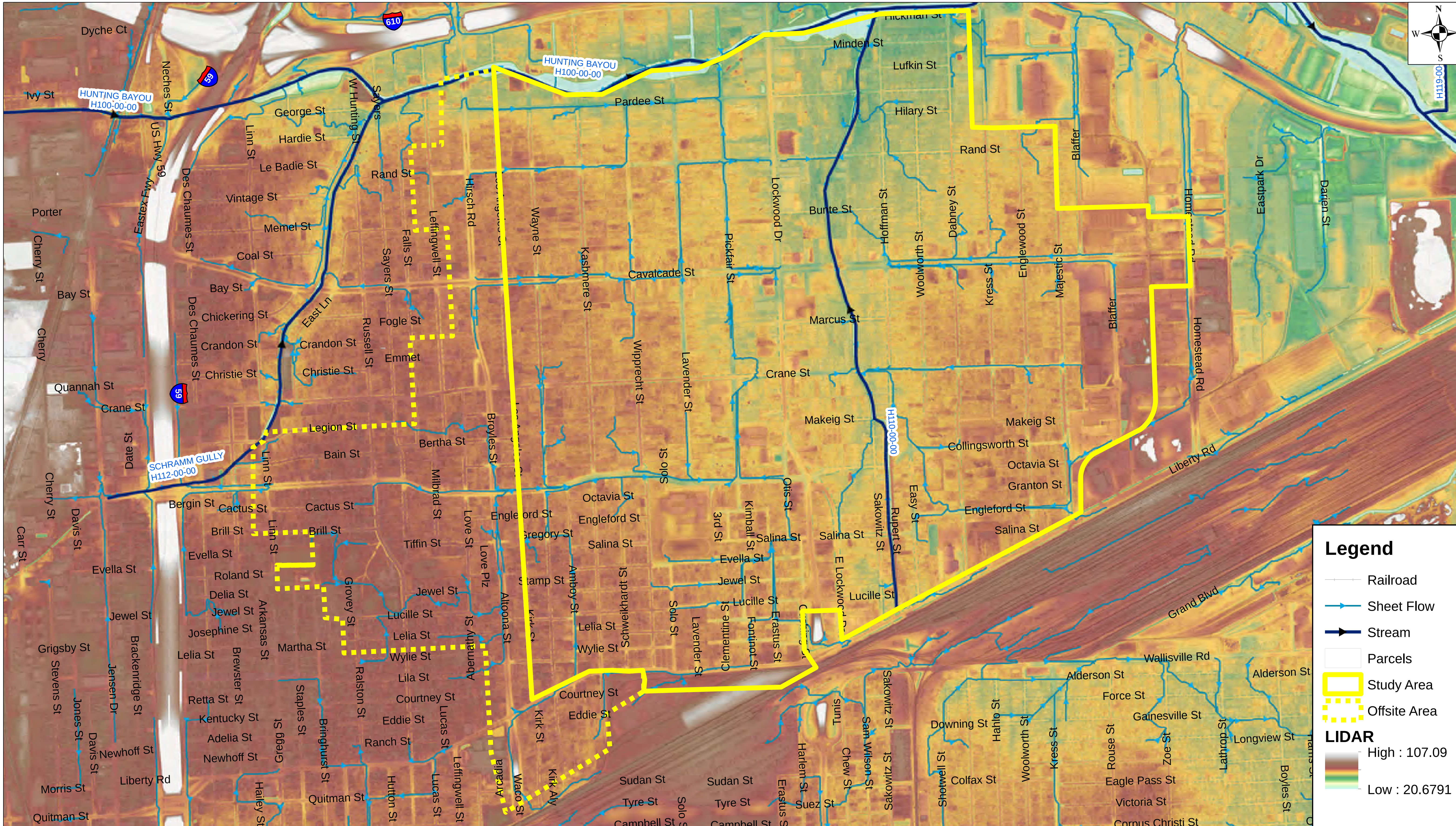
HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	EXHIBIT 4
			OCTOBER 2020	0 500 1,000 2,000 Feet	EXISTING DRAINAGE SYSTEM



HUITT-ZOLLARS

PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 5
FEBRUARY 2020	0 500 1,000 2,000 Feet	FLOODPLAIN MAP

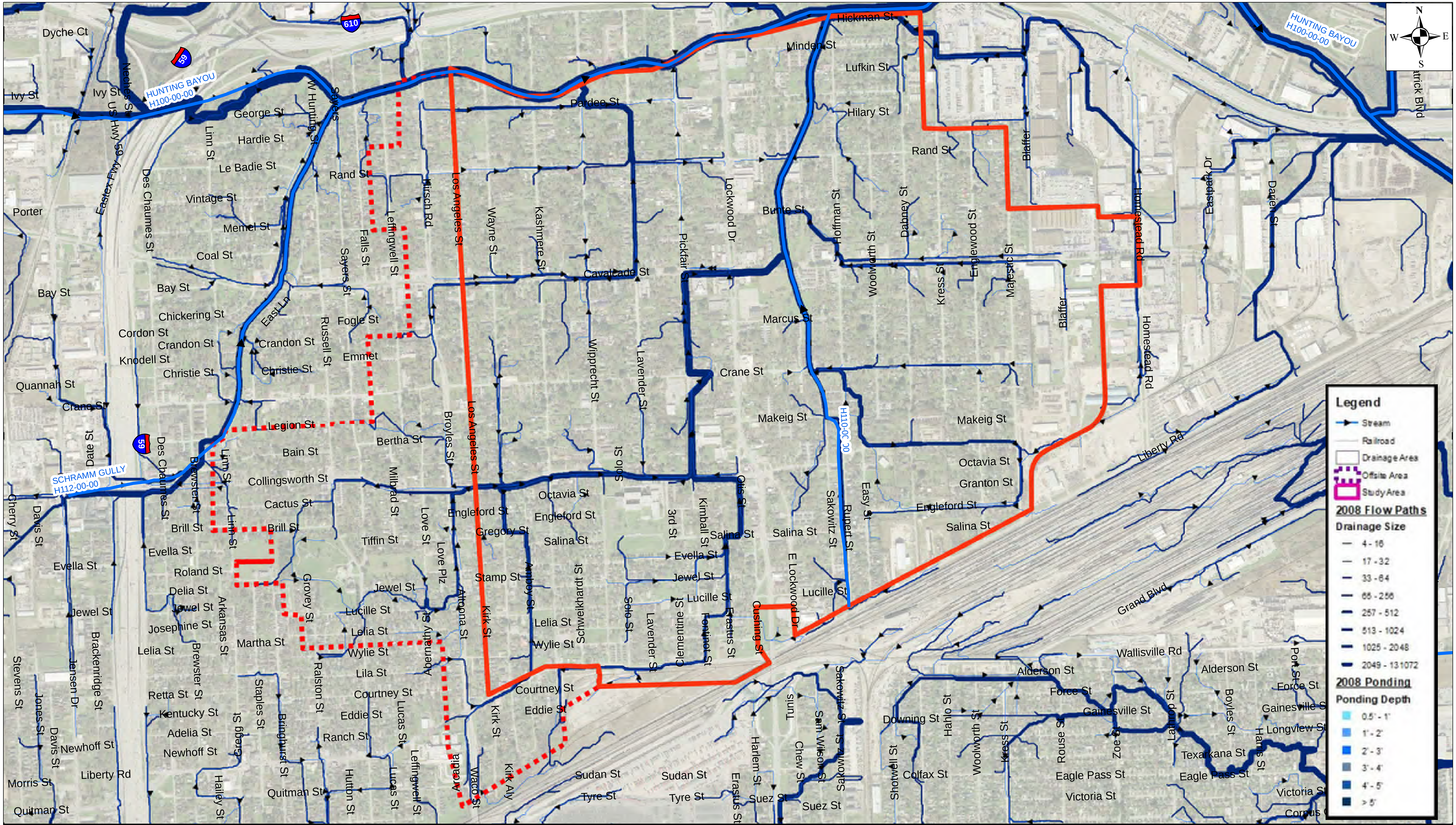


HUITT-ZOLLARS

PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 6
OCTOBER 2020	0 500 1,000 2,000 Feet	LIDAR MAP

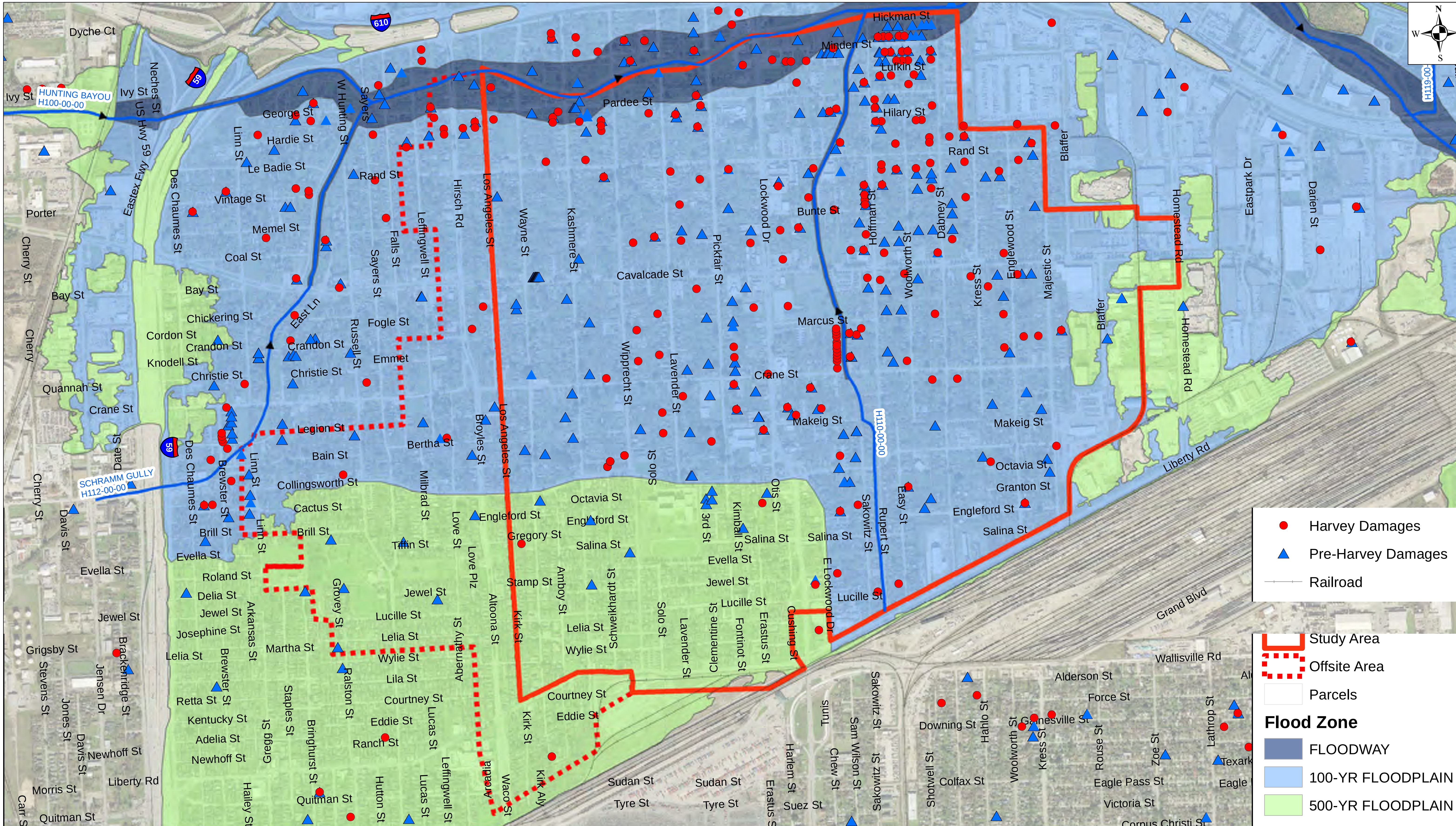


PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

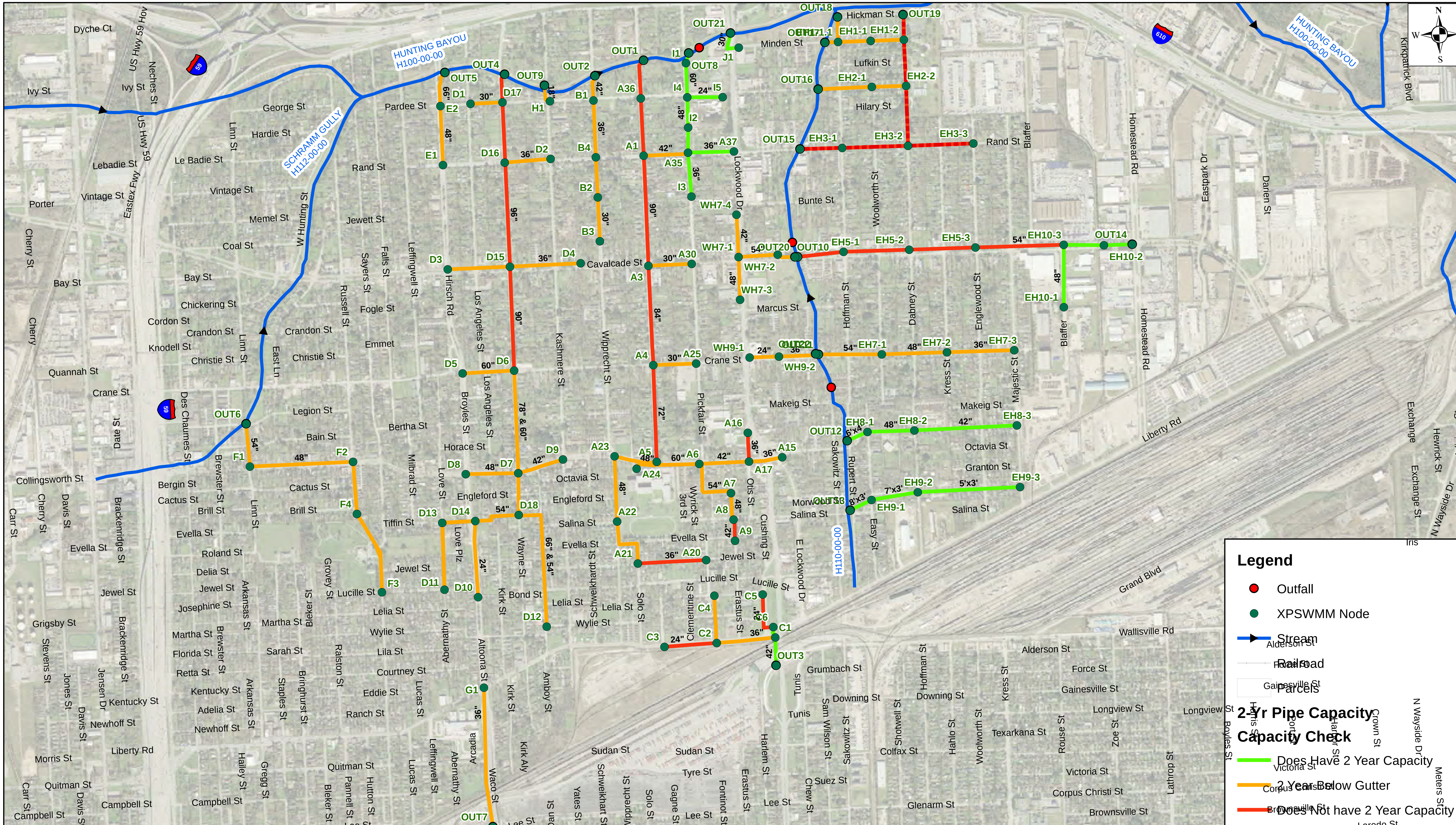
HUITT-ZOLLARS

CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 7
OCTOBER 2020	0 500 1,000 2,000 Feet	SHEET FLOW PATH



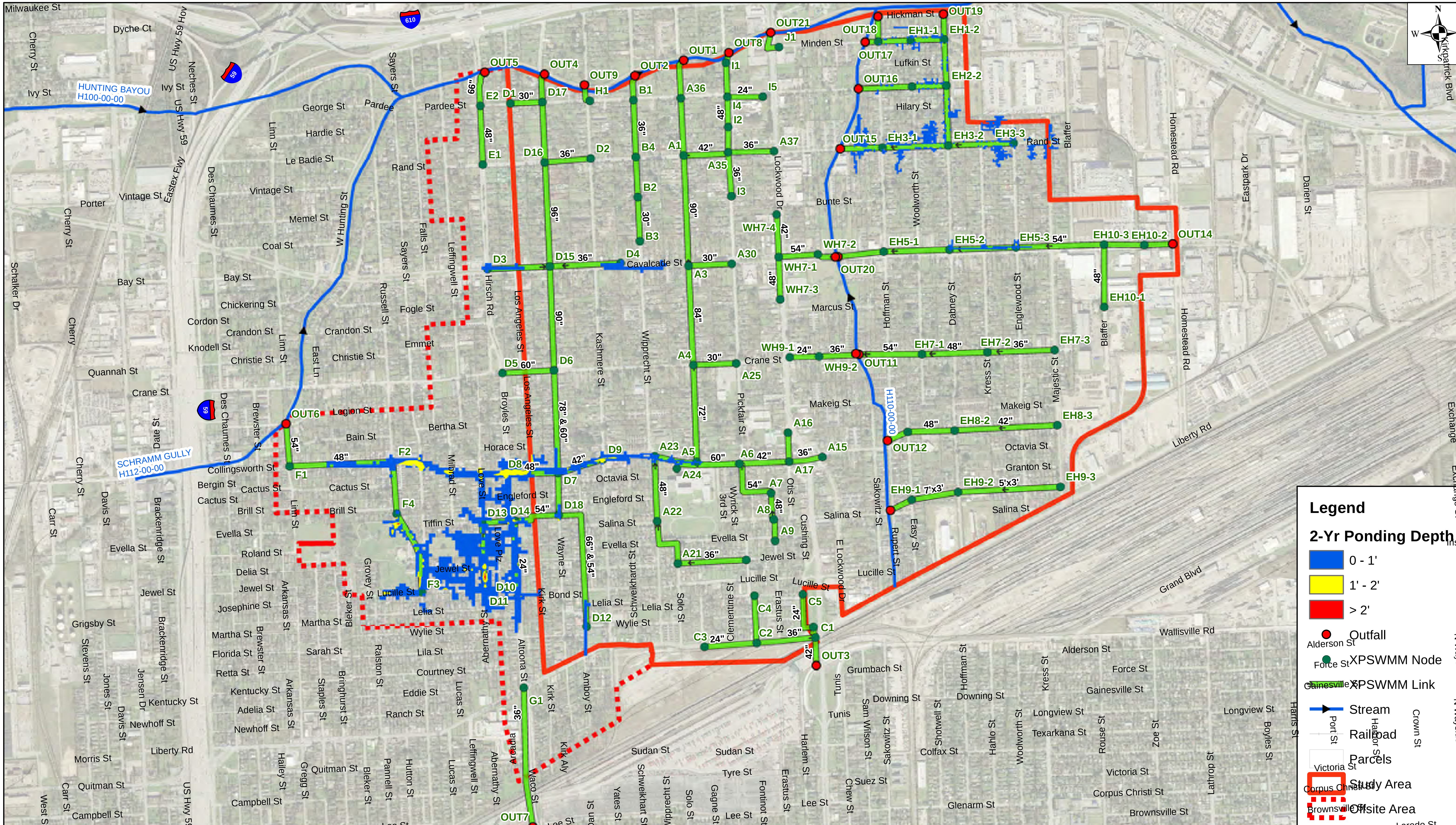
HUITT-ZOLLARS	**PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)**	CITY OF HOUSTON TEXAS	**DATE**	**SCALE**	**EXHIBIT 8**
			OCTOBER 2020	0 500 1,000 2,000 Feet	**FEMA FLOOD COMPLAINTS**



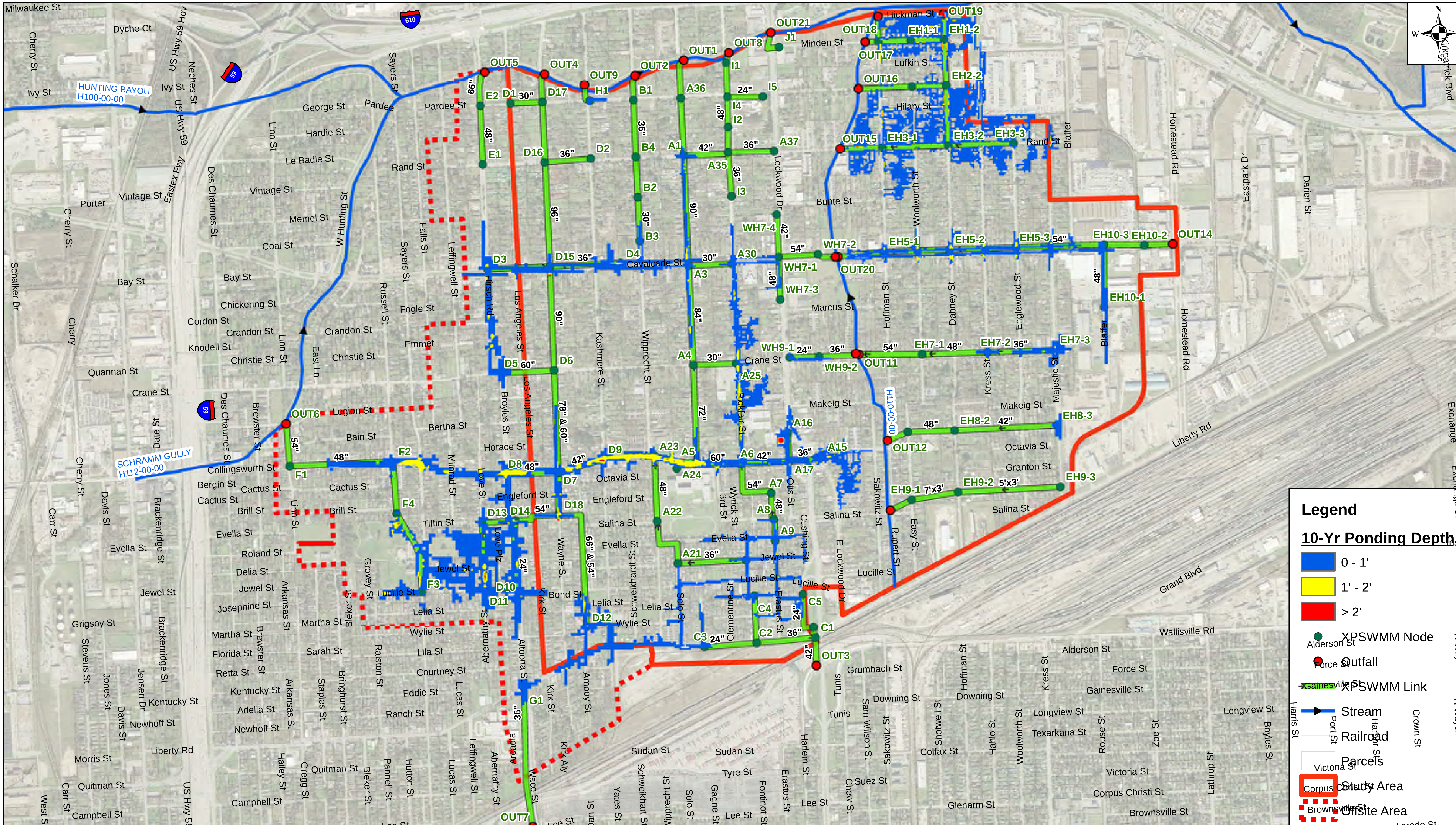
PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 9
OCTOBER 2020	0 500 1,000 2,000 Feet	EXISTING STORM SEWER CAPACITY

HUITT-ZOLLARS



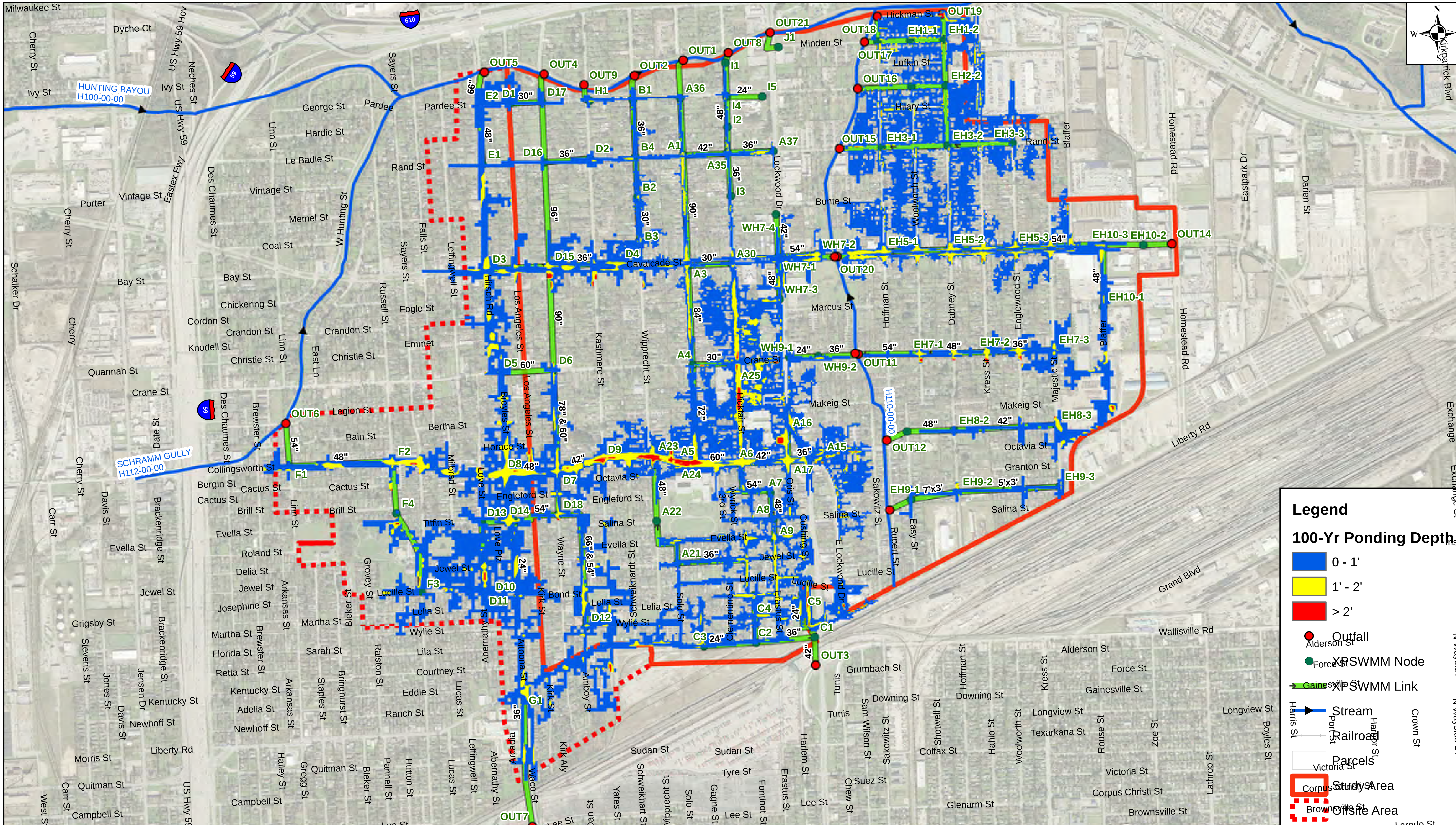
HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE OCTOBER 2020	SCALE 0 500 1,000 2,000 Feet	EXHIBIT 10 2-YR PONDING DEPTH EXISTING CONDITION



PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

HUITT-ZOLLARS

DATE	SCALE	EXHIBIT 11
OCTOBER 2020	0 500 1,000 2,000 Feet	10-YR PONDING DEPTH EXISTING CONDITION

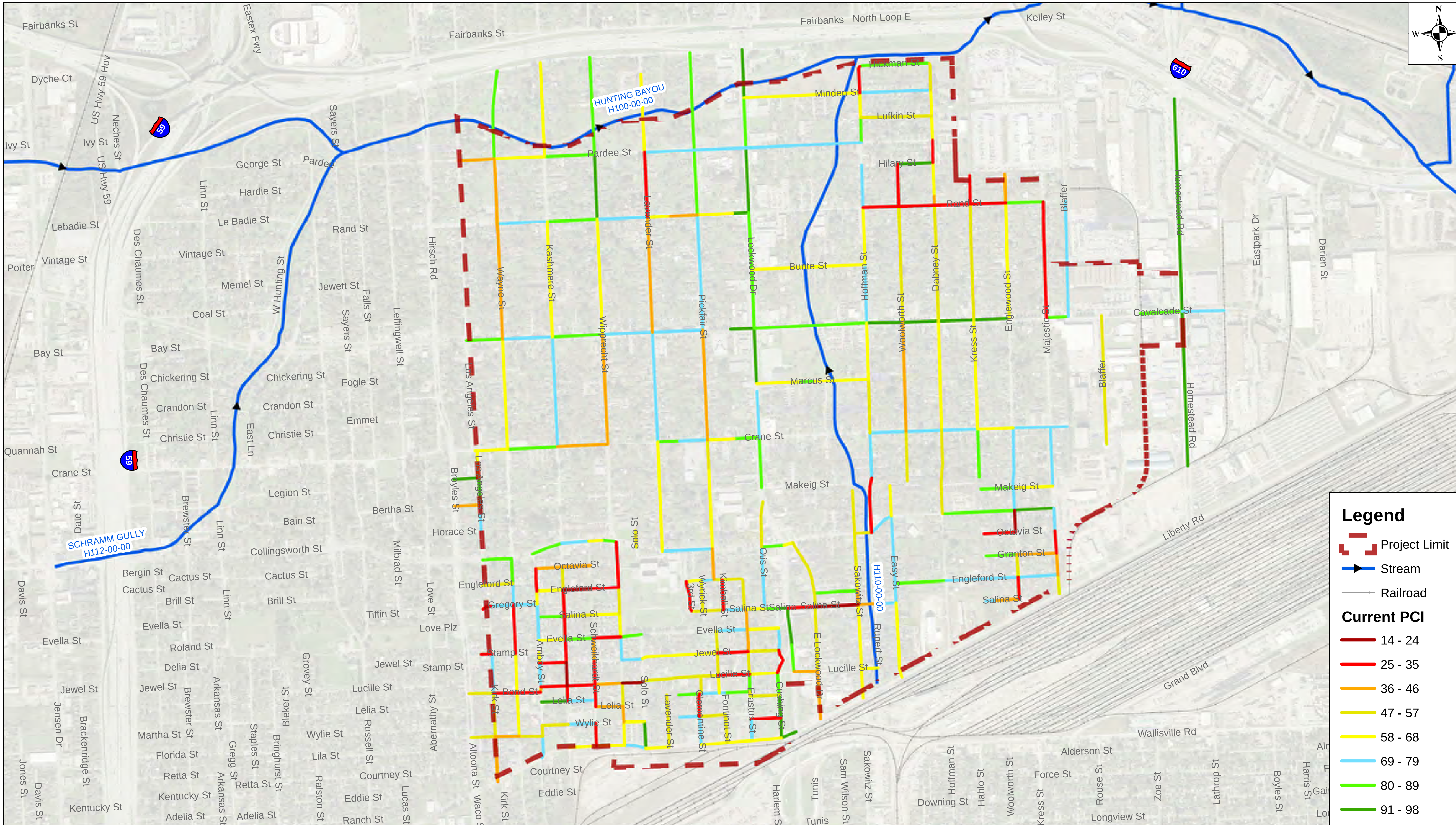


HUITT-ZOLLARS

PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 12
OCTOBER 2020	0 500 1,000 2,000 Feet	100-YR PONDING DEPTH EXISTING CONDITION

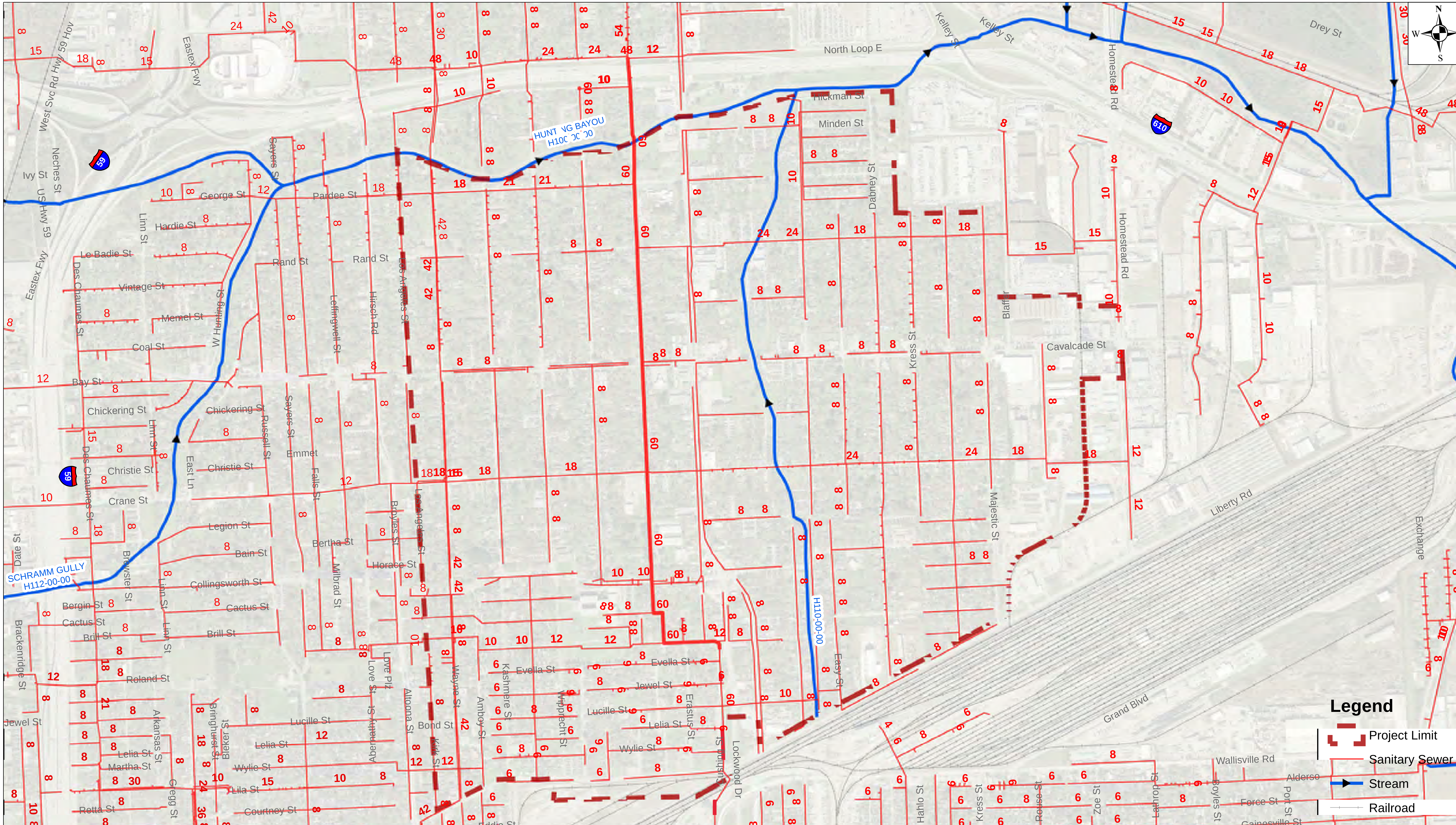


HUITT-ZOLLARS

HUITT-ZOLLARS, INC. Firm No. F-761
10350 Richmond Avenue, Suite 300 Houston, TX 77042
Phone 281.496.0066 Fax 713.496.0220

PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 13
OCTOBER 2020	0 500 1,000 2,000 Feet	STREET CONDITION PAVEMENT CONDITION INDEX (PCI)



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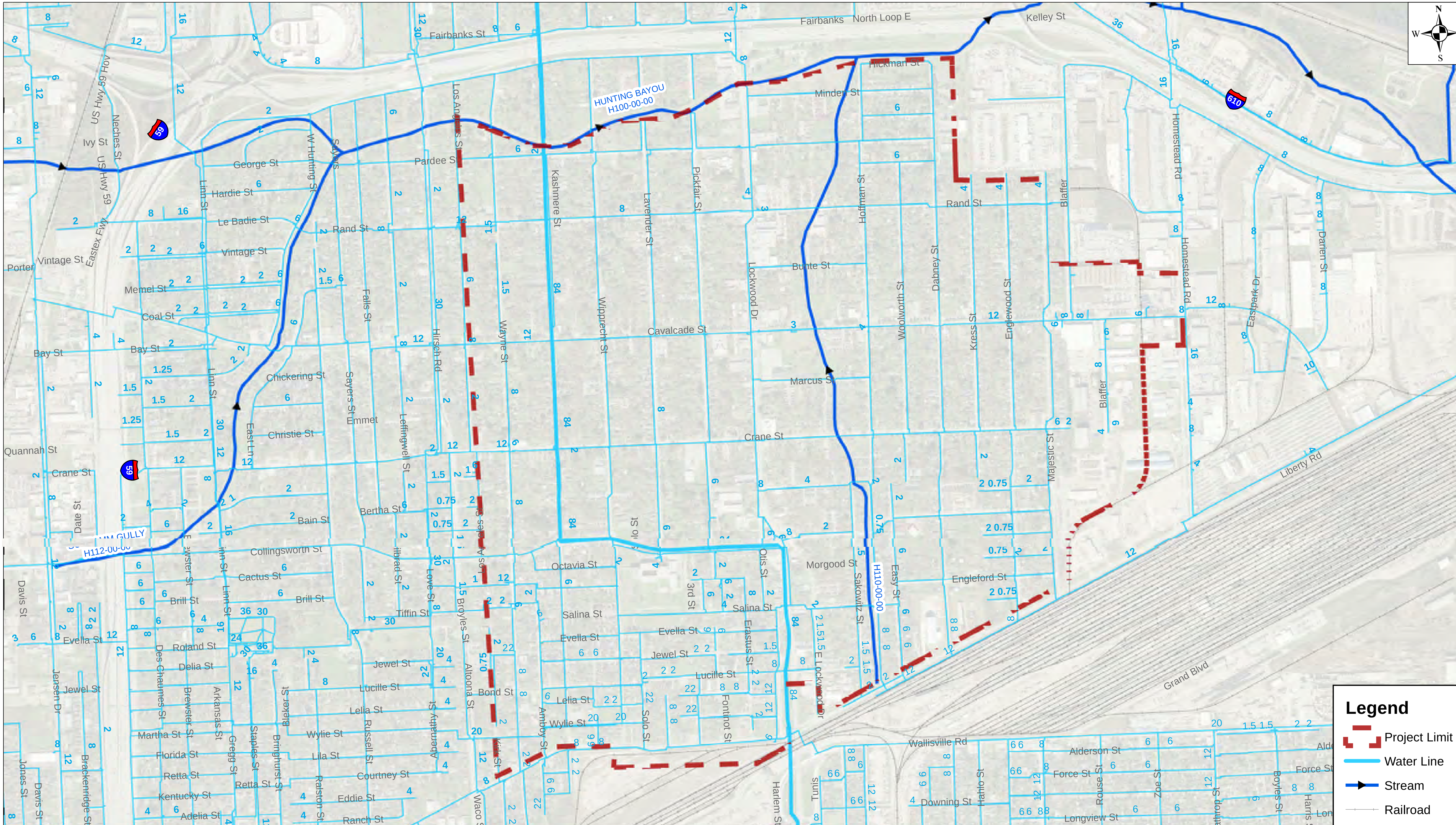
Phone 281.496.0066 Fax 713.496.0220

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

CITY OF HOUSTON TEXAS

DATE	SCALE	EXHIBIT 14
OCTOBER 2020	0 500 1,000 2,000 Feet	SANITARY SEWER



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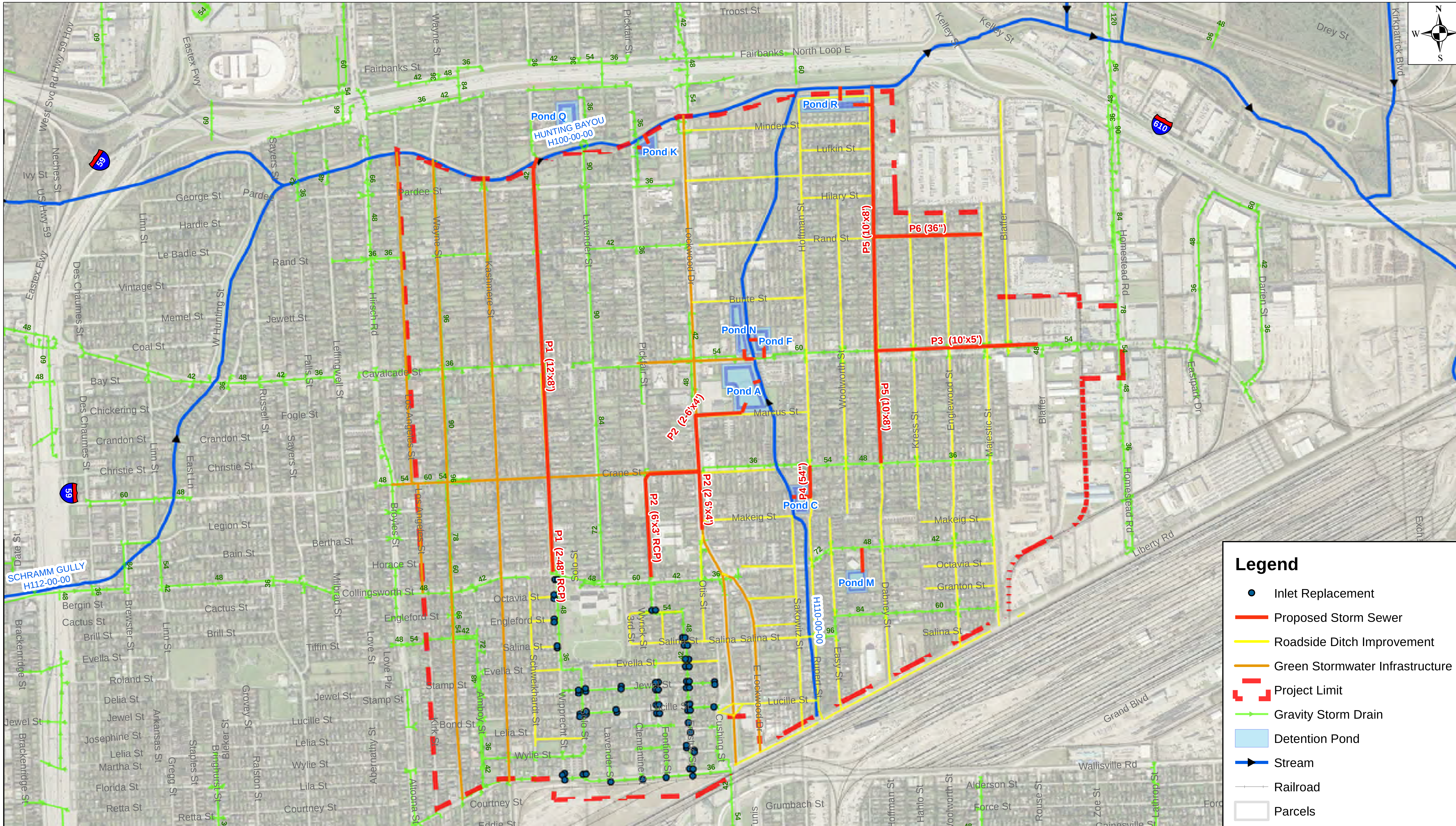
PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

CITY OF HOUSTON TEXAS

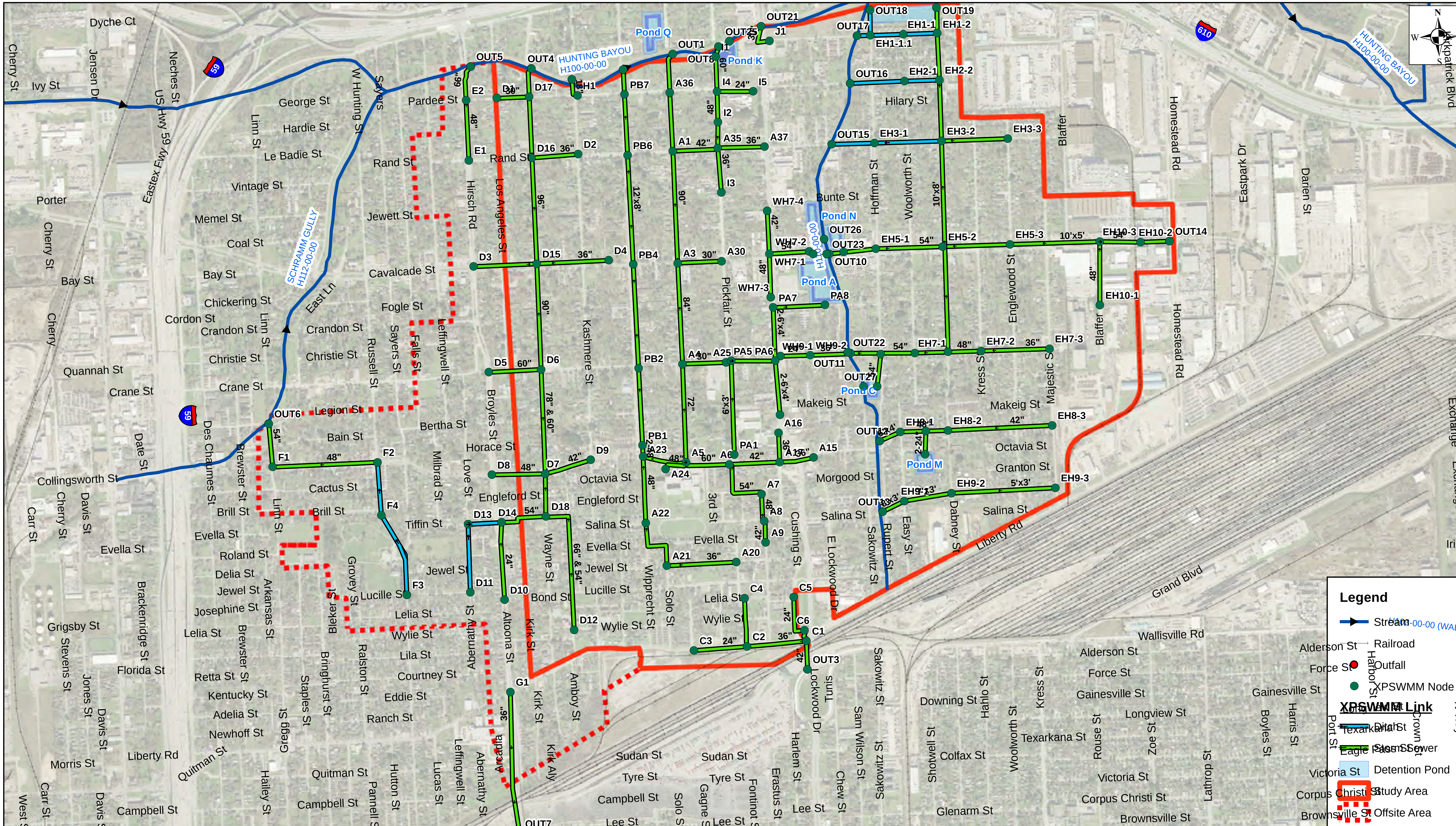
DATE	SCALE	EXHIBIT 15
OCTOBER 2020	0 500 1,000 2,000 Feet	WATER LINE



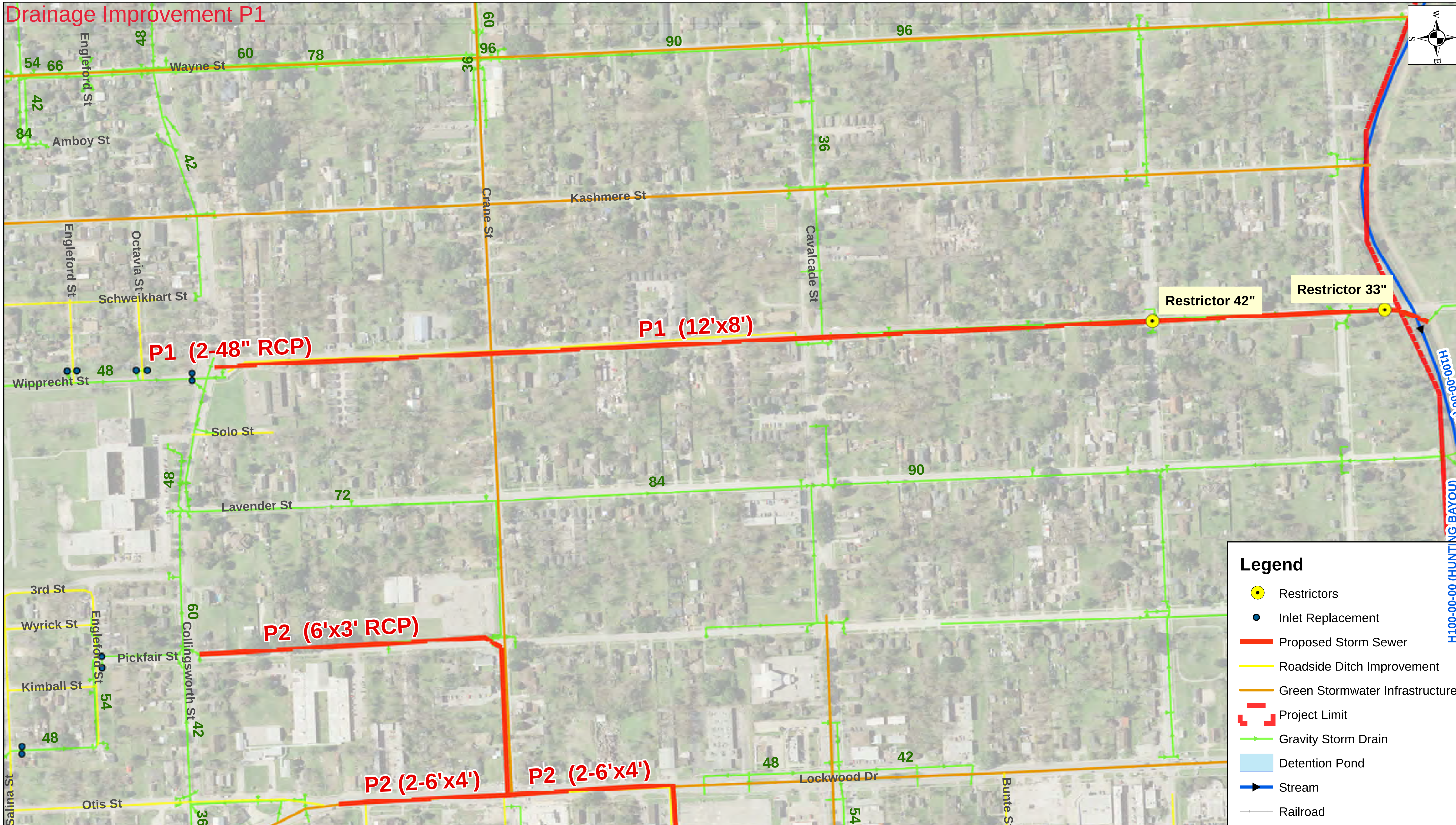
HUITT-ZOLLARS

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 16
OCTOBER 2020	0 500 1,000 2,000 Feet	RECOMMENDED DRAINAGE IMPROVEMENT



HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE OCTOBER 2020	SCALE 0 500 1,000 2,000 Feet	EXHIBIT 17 XPSWMM MODEL PROPOSED CONDITION



HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)		DATE	SCALE	EXHIBIT 18
HUITT-ZOLLARS, INC. Firm No. F-761 10350 Richmond Avenue, Suite 300 Houston, TX 77042 Phone 281.496.0066 Fax 713.496.0220			OCTOBER 2020	0 125 250 500 Feet	DRAINAGE IMPROVEMENT P1

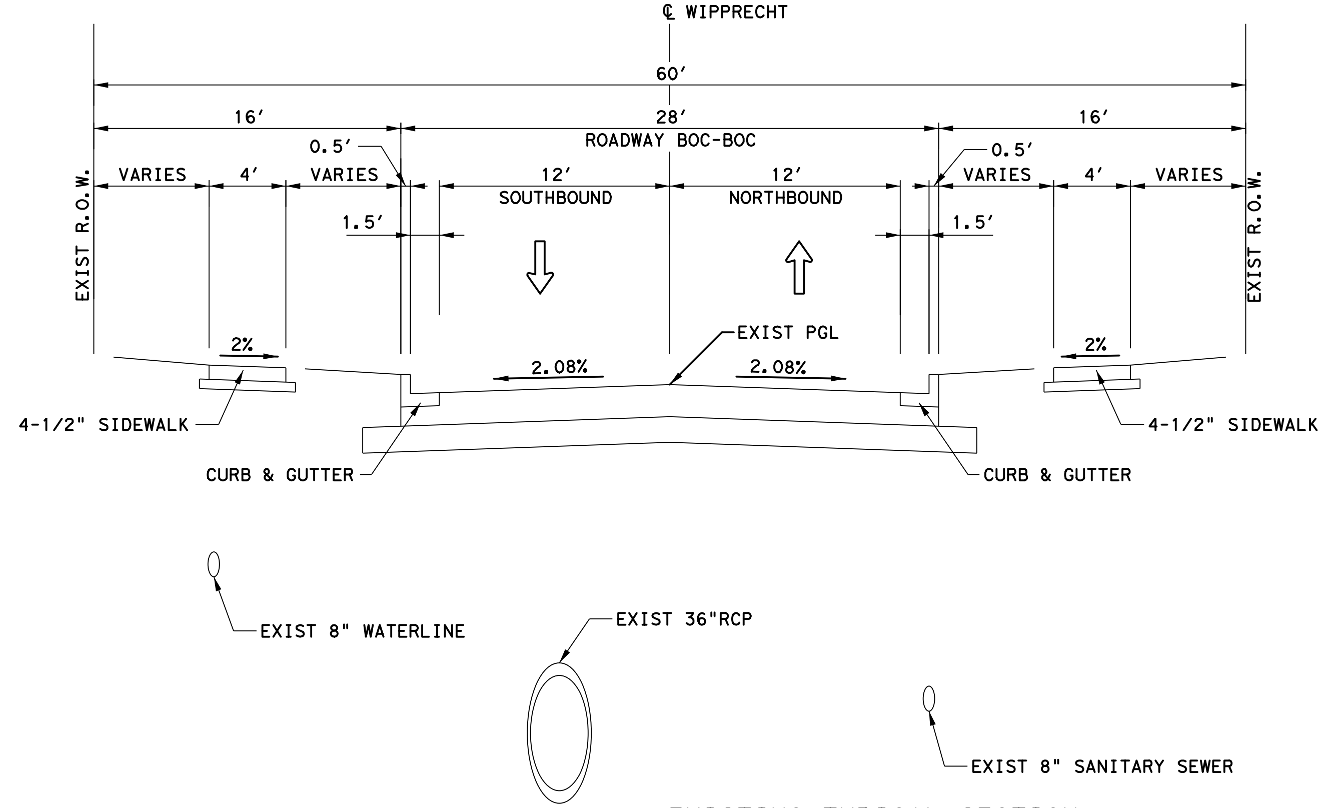
Drainage Improvement P1

Drainage Improvement P1

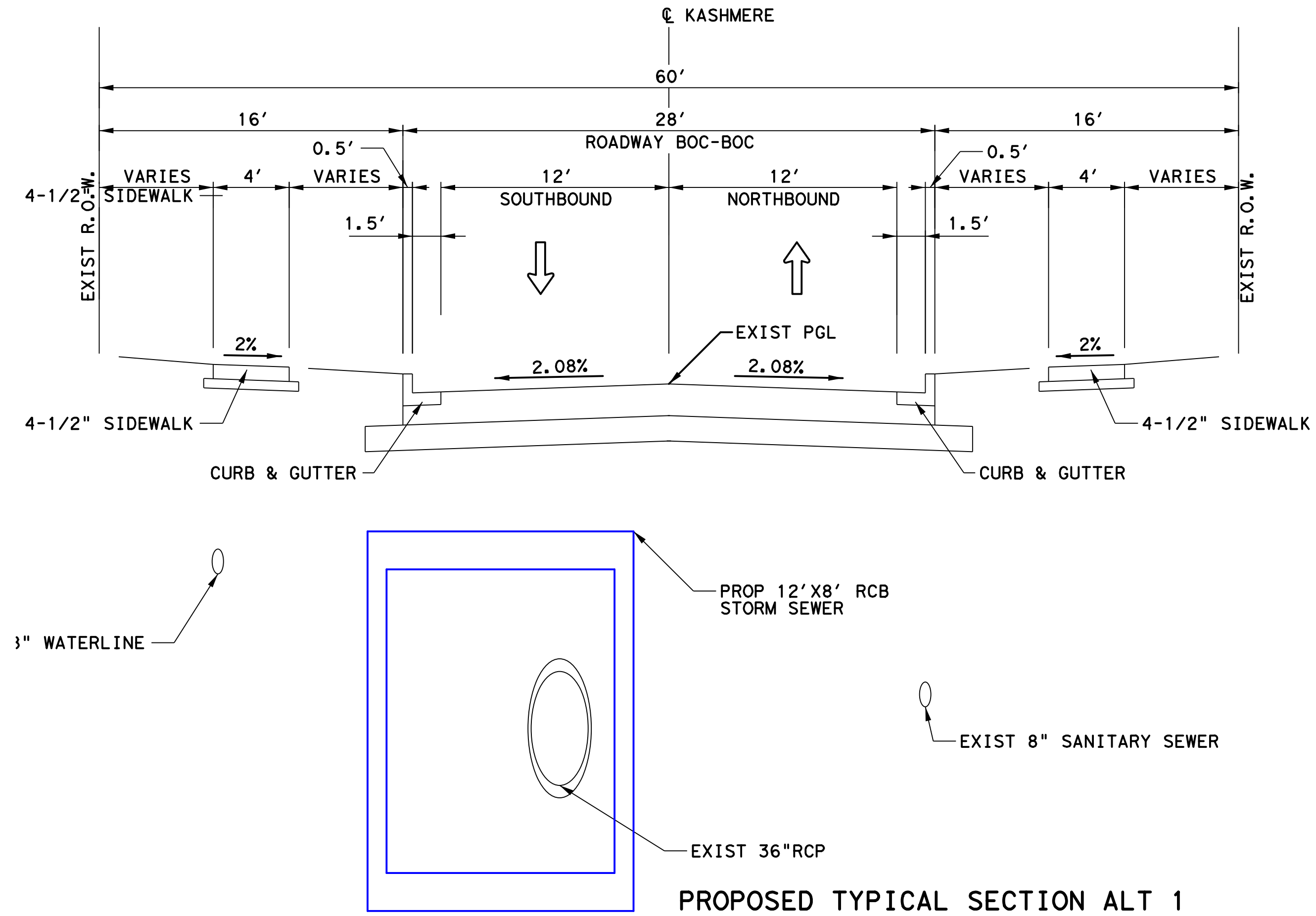
Drainage Improvement P1

WIPPRECHT STREET

(HUNTING BAYOU TO CALVACADE STREET)



EXISTING TYPICAL SECTION



PROPOSED TYPICAL SECTION ALT 1

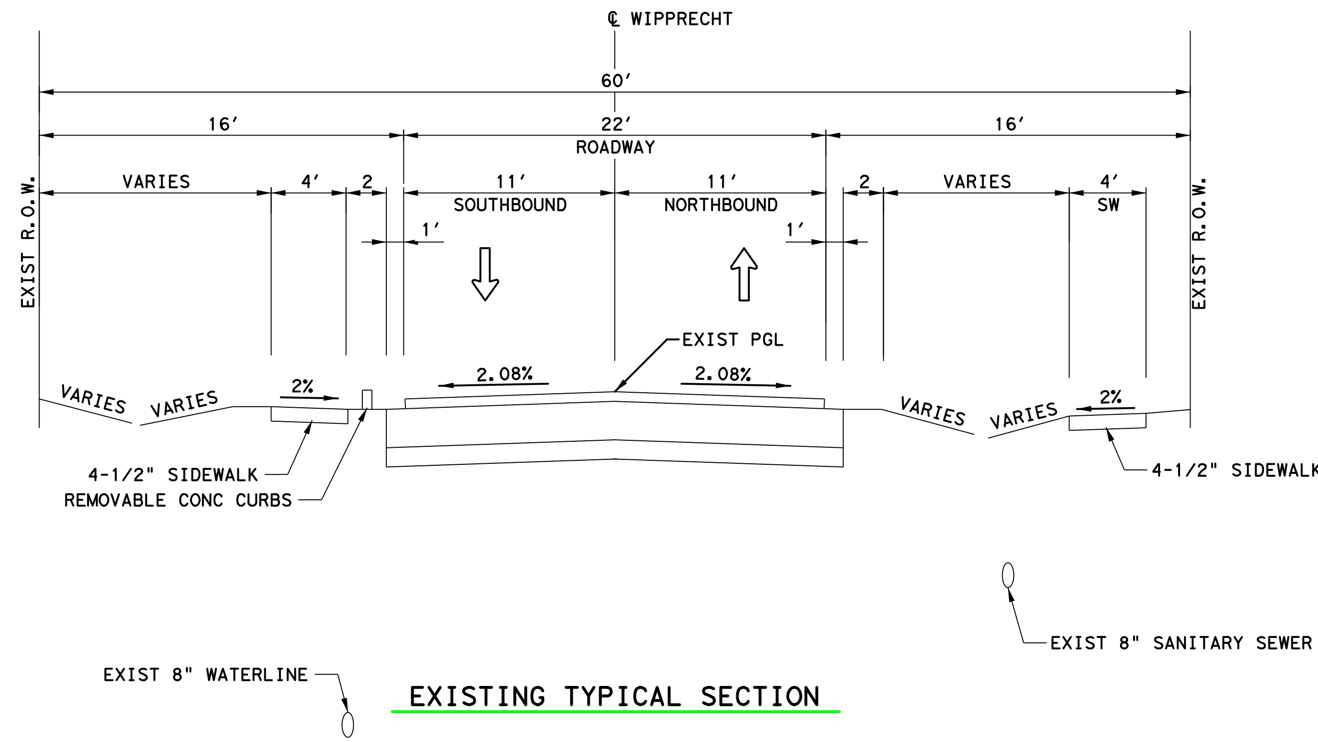
SHEET 1 OF 1

HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	TYPICAL SECTIONS
			6/8/2020	NTS	SECTION 1

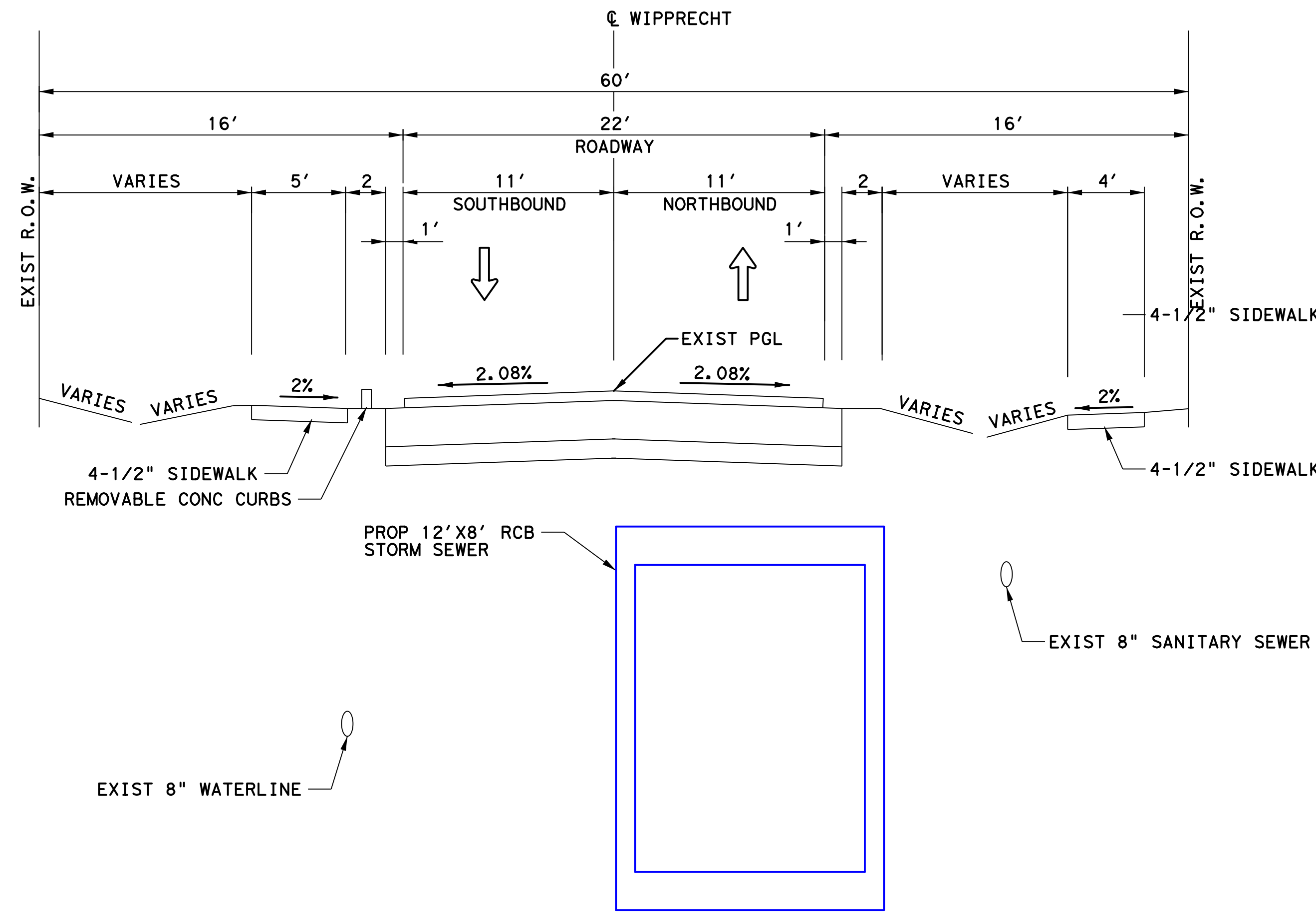
Drainage Improvement P1

WIPPRECHT STREET

(CALVACADE STREET TO COLLINGSWORTH STREET)



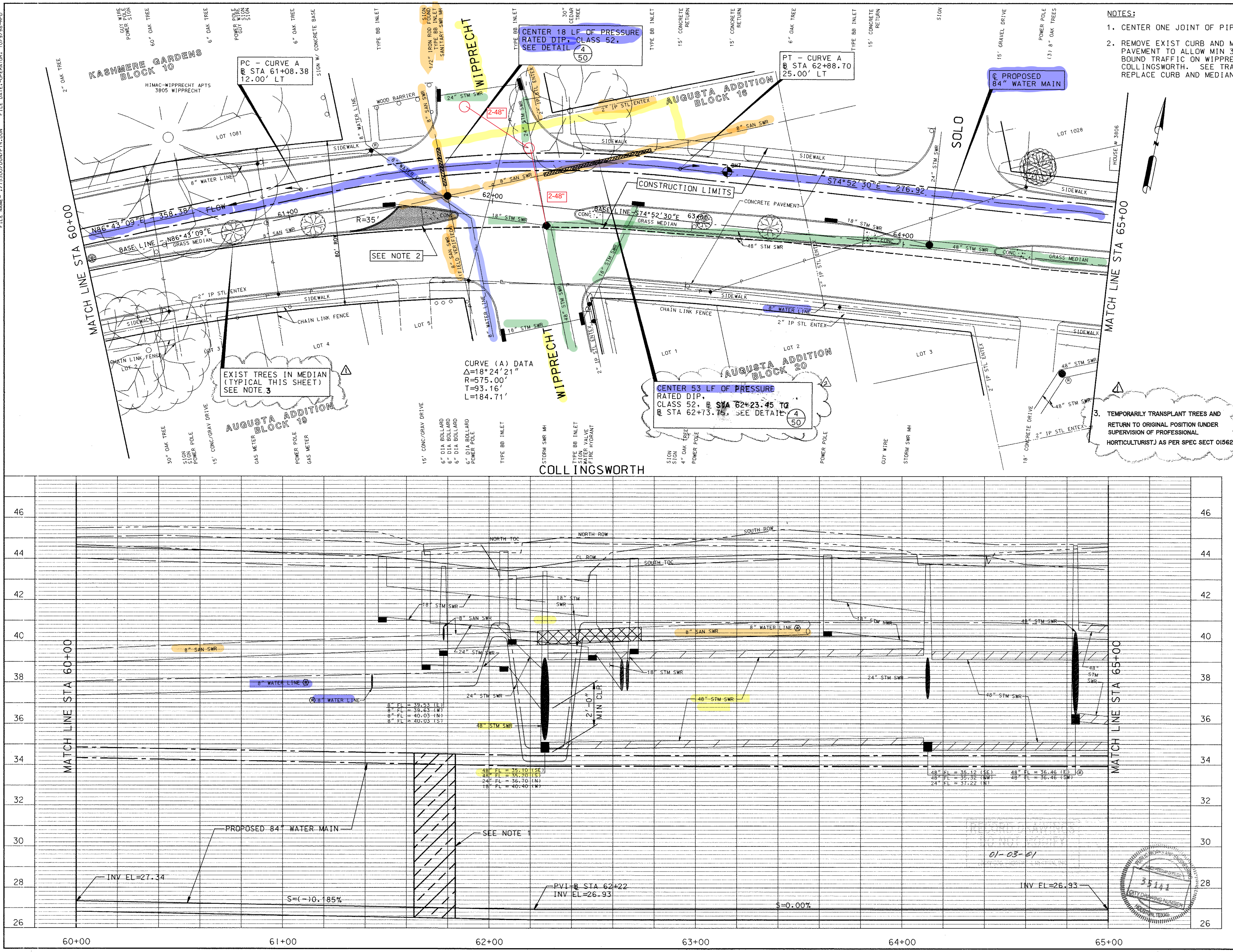
EXISTING TYPICAL SECTION



PROPOSED TYPICAL SECTION ALT 1

SHEET 1 OF 2

		DATE	SCALE	TYPICAL SECTIONS
HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	6/8/2020	NTS	SECTION 2



NOTES:

1. CENTER ONE JOINT OF PIPE UNDER SANITARY CROSSING.
2. REMOVE EXIST CURB AND MEDIAN AND PROVIDE TEMPORARY PAVEMENT TO ALLOW MIN 35' TURNING RADIUS FOR SOUTH BOUND TRAFFIC ON WIPPRECHT TRAVELING WEST ON COLLINGSWORTH. SEE TRAFFIC CONTROL PLANS, SHT 63. REPLACE CURB AND MEDIAN UPON COMPLETION OF THE WORK.

BENCH MARK

TBM 11
"X" CUT IN WEST MEDIAN AT THE INTERSECTION OF COLLINGSWORTH AND SOLO
ELEV = 44.22

TBM 12
"X" CUT IN SIDEWALK AT THE NORTHWEST INTERSECTION OF COLLINGSWORTH AND WIPPRECHT
ELEV = 45.01

No.	Date	Revisions
1	3/8/99	ADDENDUM No. 1
2	3/25/99	ADDENDUM No. 2

PRIVATE UTILITY LINES SHOWN

ENTEX, INC — Diana Hernandez 10/13/98

SOUTHWESTERN BELL TELEPHONE CO — 10-18-98
Valid for One Year Only

HOUSTON LIGHTING & POWER CO — 3-19-98
Approved Only for Crossing Underground Ductlines Unless Noted. Valid At Time of Review Only.

CABLE COMPANY

10-12-98
STATE OF TEXAS — MICHAEL MACHALA — 43408 — REGISTERED PROFESSIONAL ENGINEER
STATE OF TEXAS — EMMANUEL PAU — 82627 — REGISTERED PROFESSIONAL ENGINEER — 3-25-99
For ADDENDUM No. 1&2 ONLY

Binkley & Barfield, Inc.
Consulting Engineers
1710 Seamist Drive Houston, Texas 77008

Approved
Date
QUALITY CONTROL
Date 10-12-98

Lockwood, Andrews & Newnam, Inc.
1500 CityWest Blvd
Houston, Tx 77042
A SUBSIDIARY OF LEO A DALY

Approved
Date 2/3/99
Job No. 0069-20-822-324

SWTP
Surface Water Transmission Program

CONTRACT 2C
COLLINGSWORTH STREET
STA 60+00 TO STA 65+00

FILE NO 9744
GFS NO S-0900-31-3

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING
ENGINEERING, CONSTRUCTION, AND REAL ESTATE GROUP

WATER ENGINEERING 2/8/99
TRAFFIC AND SIGNAL ENGINEERING 2-11-99
WASTEWATER ENGINEERING 2/11/99
STREET AND BRIDGE ENGINEERING 2/10/99
STORM SEWER ENGINEERING 2/8/99
CONSTRUCTION 2/11/99
MANAGER, WATER ENGINEERING 2/16/99

OTHER DEPARTMENTS
PLANNING AND DEVELOPMENT
SPONSOR DEPARTMENT

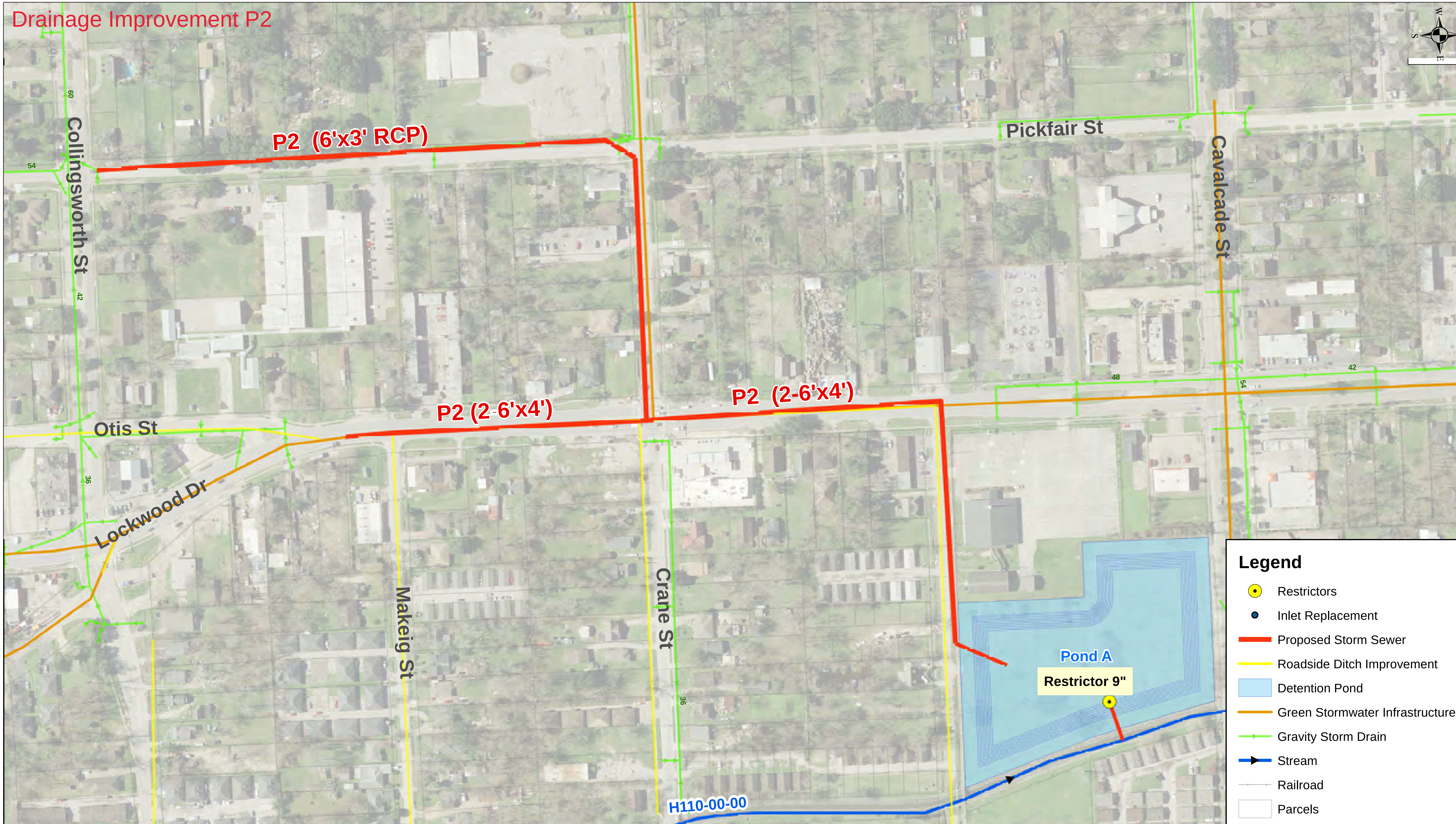
CITY ENGINEER — DATE 2-18-99
DIRECTOR OF PUBLIC WORKS AND ENGINEERING — DATE 2/19/99

SUBMITTED:
SCALE: HORIZ: 1"=20' VERT: 1"=2'
DATE:
SURVEY BY: RBI
FB NO: 215

DESIGNED BY: WDW
DRAWN BY: RPD
SHEET NO 25 OF 68 SHEETS

DWG NO: 35141

FILE NAME: I:/75300/DGN/P14.DGN FILE DATE: OPERATOR: 10/9/98-RPD



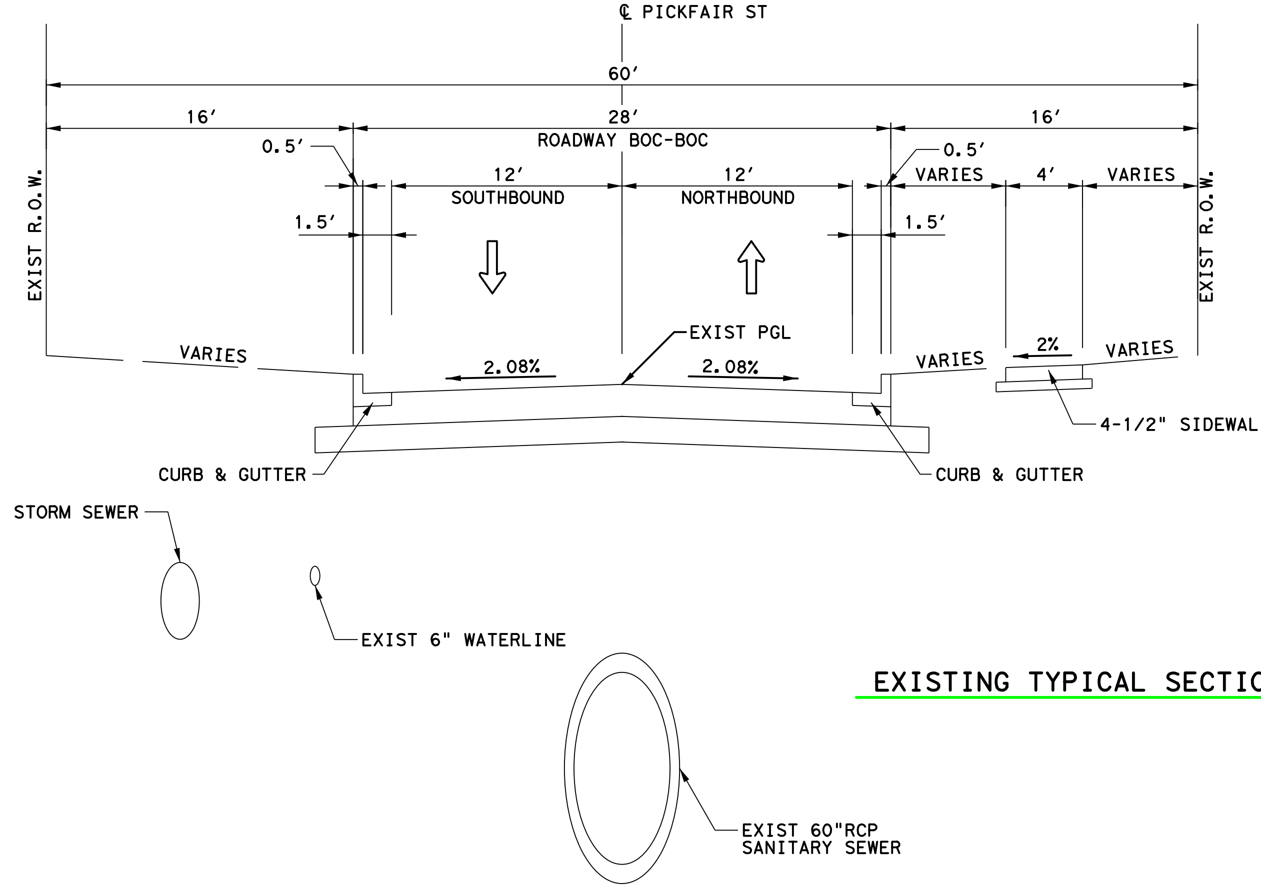
HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)		DATE	SCALE	EXHIBIT 19
HUITT-ZOLLARS, INC. Firm No. F-761 10350 Richmond Avenue, Suite 300 Houston, TX 77042 Phone 281.496.0066 Fax 713.496.0220			OCTOBER 2020	0 100 200 400 Feet	DRAINAGE IMPROVEMENT P2

Drainage Improvement P2

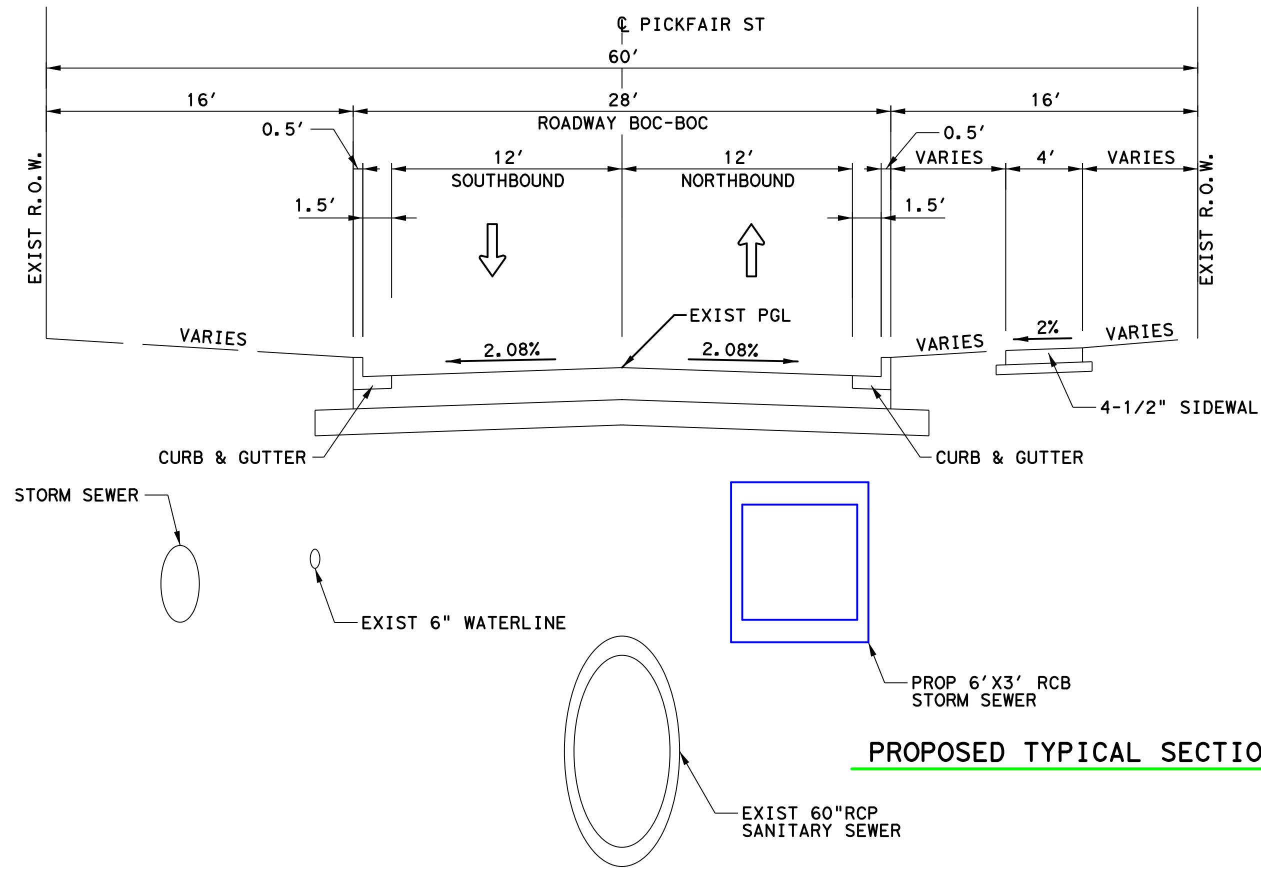
Drainage Improvement P2

PICKFAIR STREET

(CRANE STREET TO COLLINGSWORTH STREET)



EXISTING TYPICAL SECTION



PROPOSED TYPICAL SECTION ALT 1

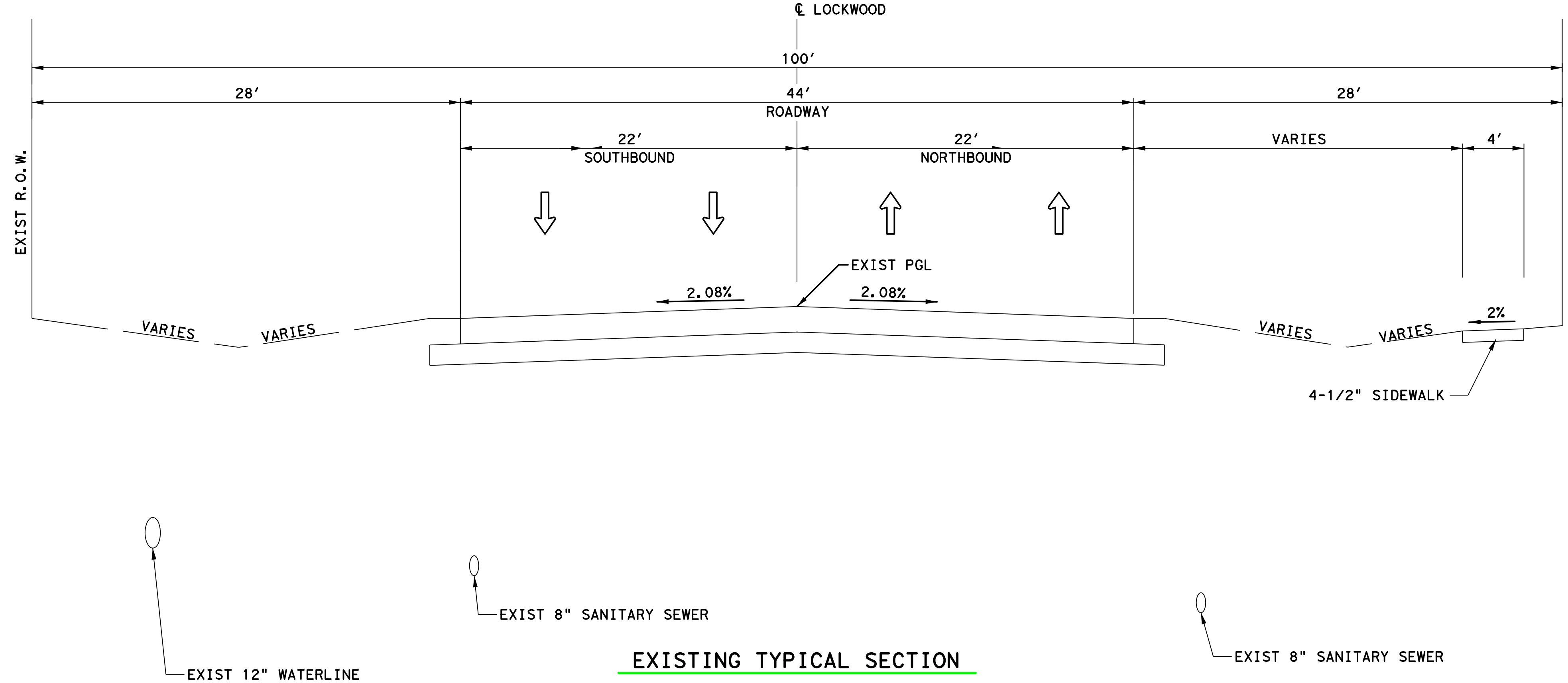
SHEET 1 OF 1

HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	TYPICAL SECTIONS
			6/8/2020	NTS	SECTION 3

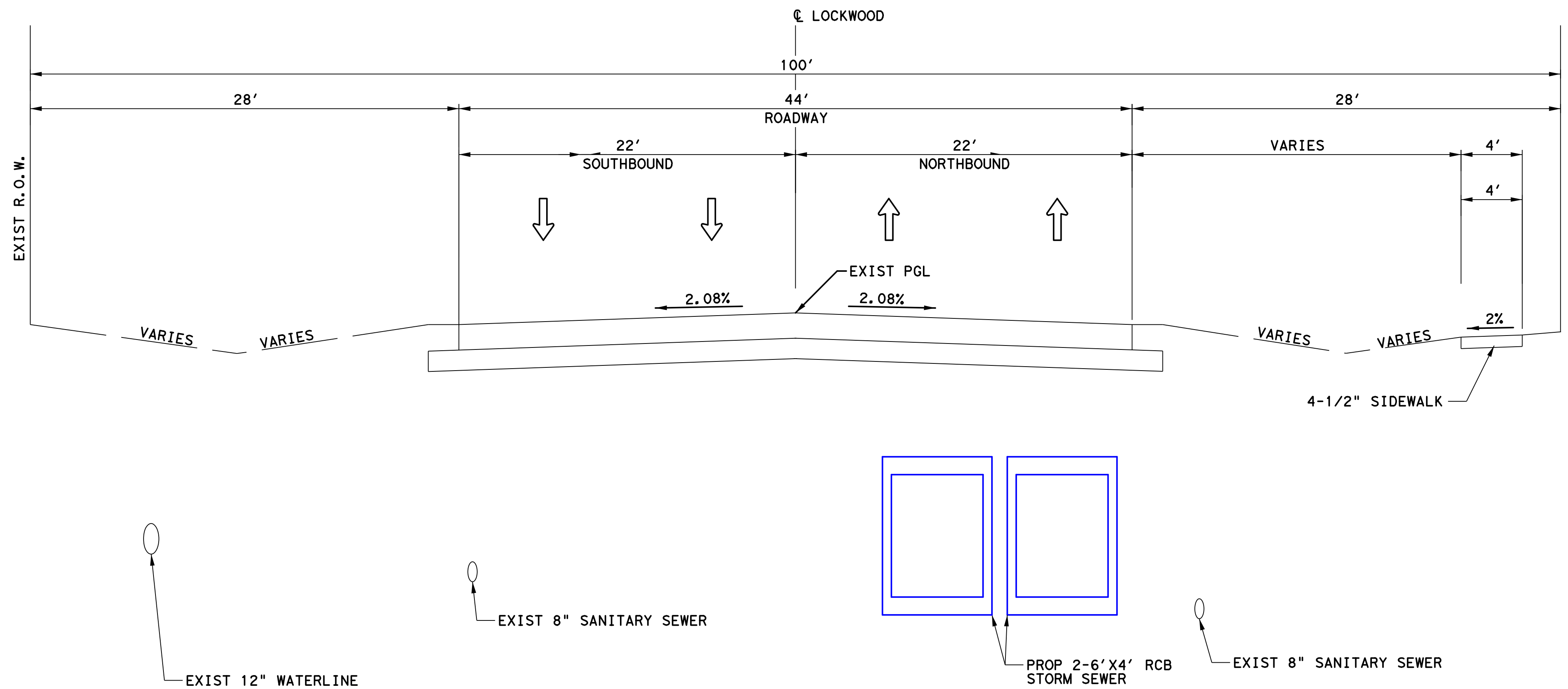
Drainage Improvement P2

LOCKWOOD STREET

(CRANE STREET TO MARCUS STREET)



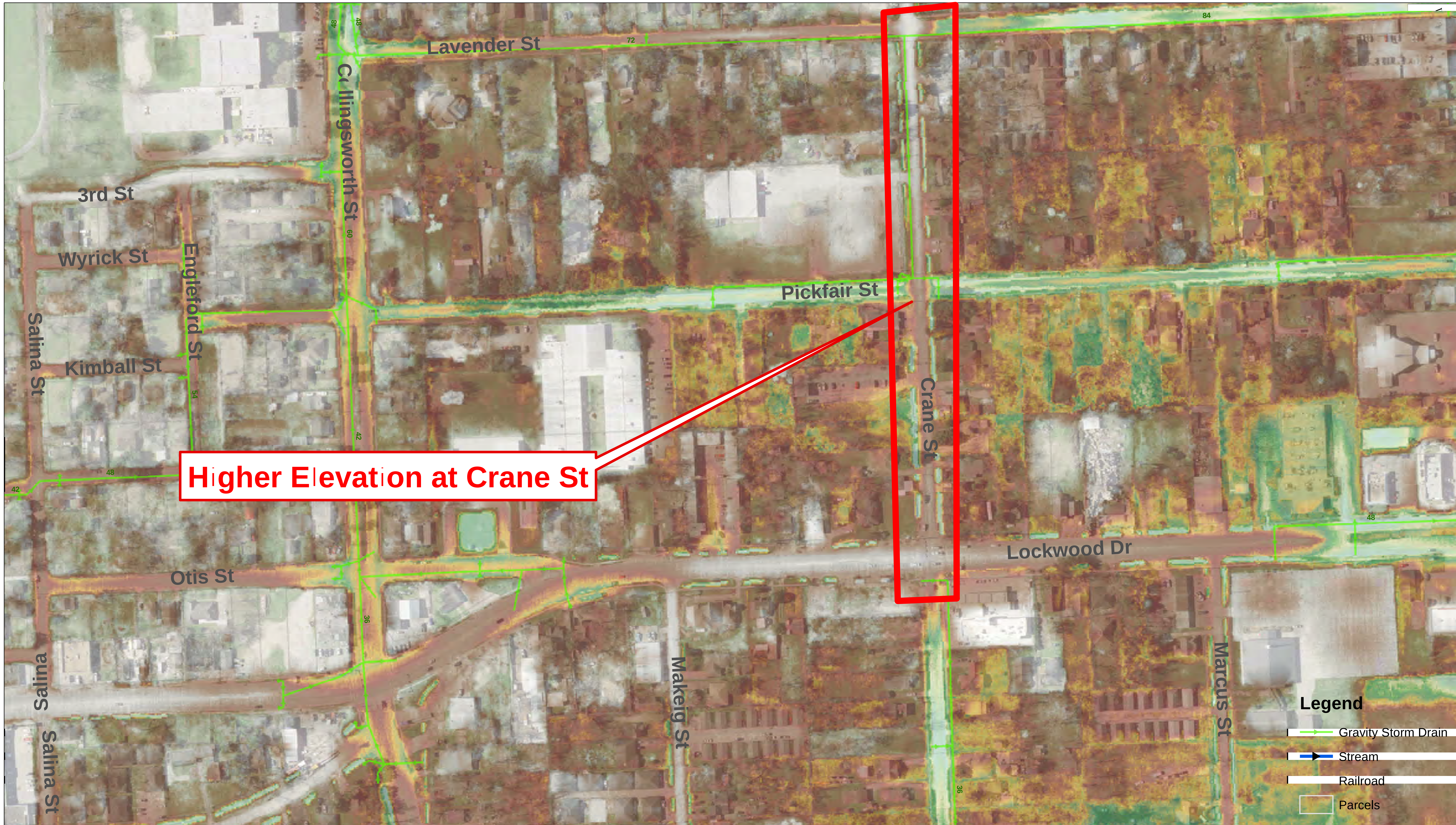
EXISTING TYPICAL SECTION



PROPOSED TYPICAL SECTION ALT 1

HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	TYPICAL SECTIONS
			6/8/2020	NTS	SECTION 4

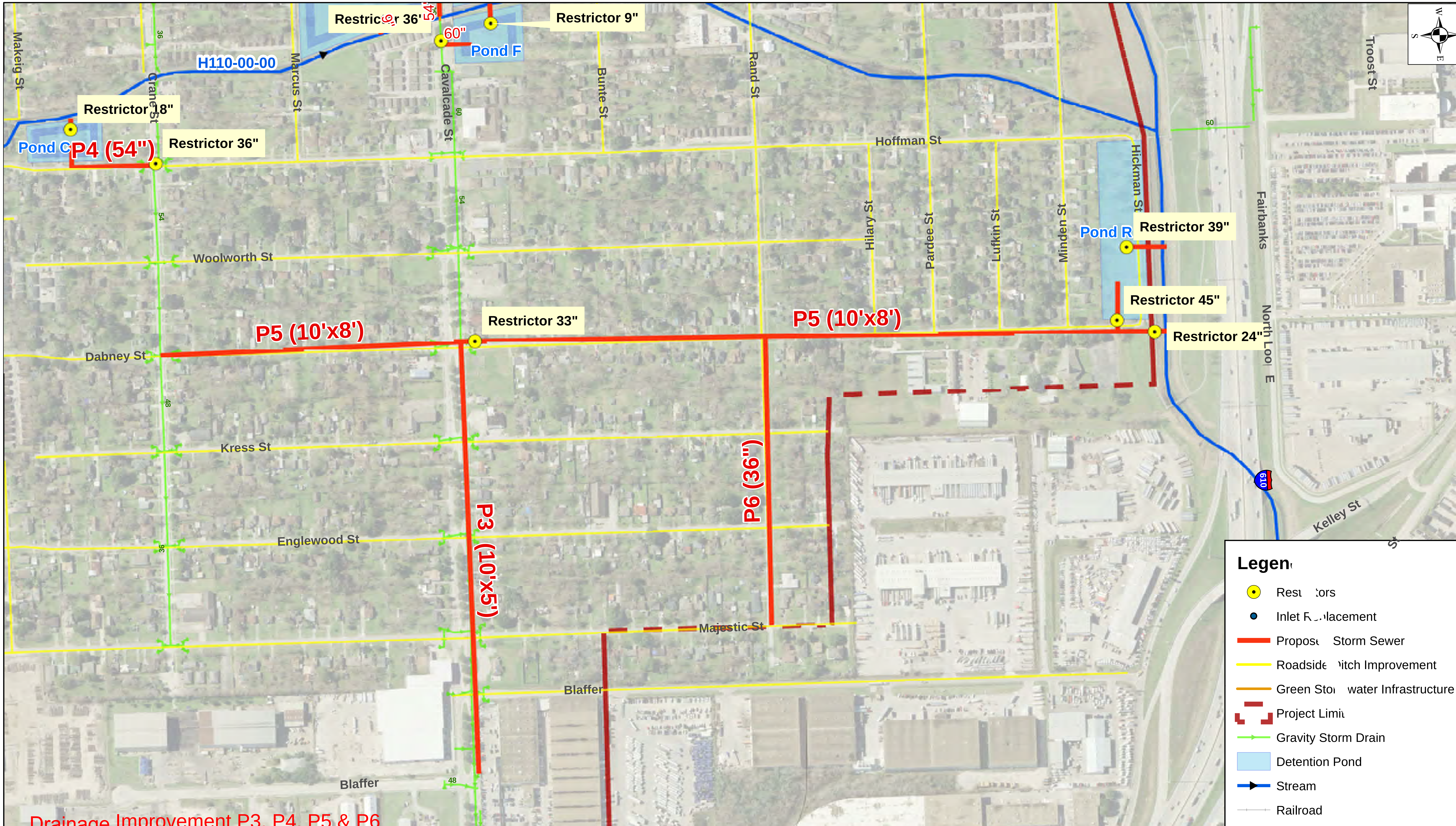
60" Sanitary Sewer
PICKFAIR ST.
PROPOSED 60" MONOLITHIC CONCRETE SANITARY SEWER @ 0.05%
72+69 STD. M.H. TYPE-2
66+56 STD. M.H. TYPE-2
Std. M.H. Type-2 72+69
Std. M.H. Type-2 66+56
2-18" Openings East & West F.L. 41.07
CRANE
FL 37.13
FL 37.57
FL 37.26
FL 36.98
Survey 75+50
Survey 60+50
¢ CAVALCADE BLVD.
Std. M.H. Type-2 84+98
Std. M.H. Type-2 79+03
84+98 STD. M.H. TYPE-2
79+03 STD. M.H. TYPE-2
2-8" Drops East & West FL 48.0
Survey 88+50
Survey 75+50
FL 38.38
FL 38.18
FL 37.88
FL 37.73
50
45
40
35
30
APPROVED FOR:
STORM SEWER SECTION:
SANITARY SEWER SECTION:
PAVING SECTION:
WATER DIVISION:
CHIEF DESIGN ENGINEER:
2-22-52
PROPOSED SANITARY SEWER
TRUNK LINE
VIA CUSHING, SALINA, KIMBALL AND
PICKFAIR, FROM LIBERTY RD. TO
PARDEE.
Horiz. 1"=50' Vert. 1"=5'
12-13-51
MEECE
B-1495
A.G. SAGARNAGA
3 4
9904
W. W. RECORDS
MICROFILM
DATE 5/13/81



HUITT-ZOLLARS

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 19
OCTOBER 2020	0 100 200 400 Feet	Higher Elevation at Crane Street



Drainage Improvement P3, P4, P5 & P6

HUITT-ZOLLARS, INC. Firm No. F-761 10350 Richmond Avenue, Suite 300 Houston, TX 77042 Phone 281.496.0066 Fax 713.496.0220	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)		DATE OCTOBER 2020	SCALE 0 125 250 500 Feet	EXHIBIT 20 DRAINAGE IMPROVEMENT P3, P4, P5 & P6

Drainage Improvement P3
PROPOSED 10'x8' RCB
DABNEY ST
KRESS ST
ENGLEWOOD ST
MAJESTIC ST
BLAFFER ST
CAVALCADE ST
PROPOSED 10'x5' RCB
BLAFFER ST

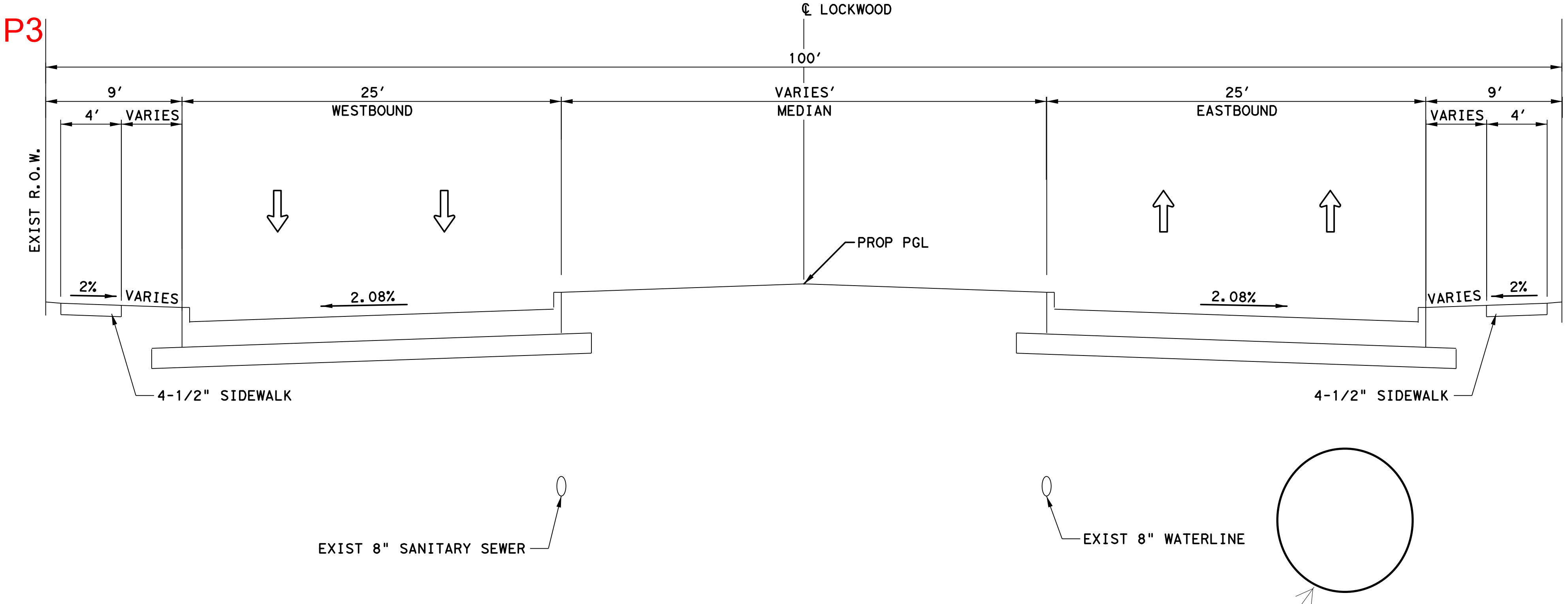
Drainage Improvement P5

Drainage Improvement P5

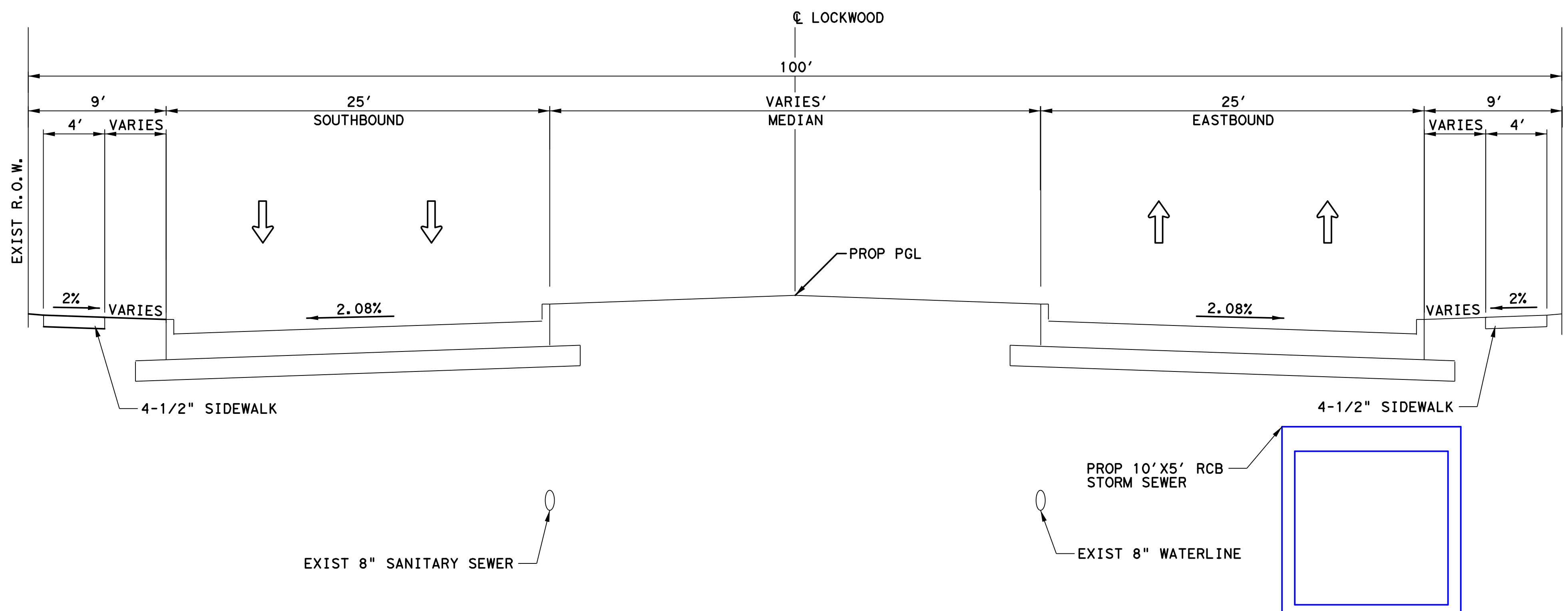
Drainage Improvement P6
HILARY ST
RAND ST
KRESS ST
DABNEY ST
ENGLEWOOD ST
MAJESTIC ST
BLAFFER ST
PROPOSED 36'' RCP
PROPOSED 10'x8' RCB

Drainage Improvement P3

CALVACADE STREET
(DABNEY STREET TO BLAFFER STREET)



EXISTING TYPICAL SECTION



0

PROPOSED TYPICAL SECTION ALT 1

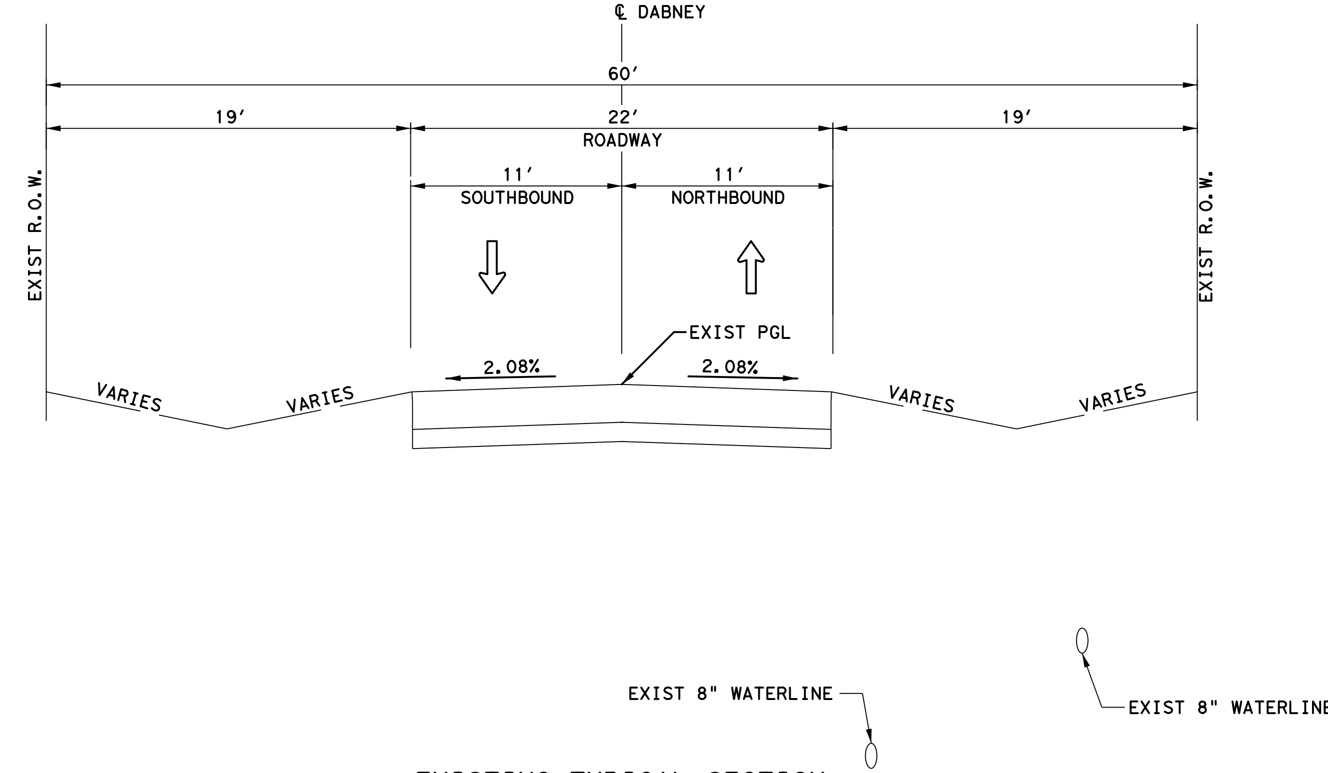
SHEET 1 OF 1

HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	TYPICAL SECTIONS
			6/8/2020	NTS	SECTION 6

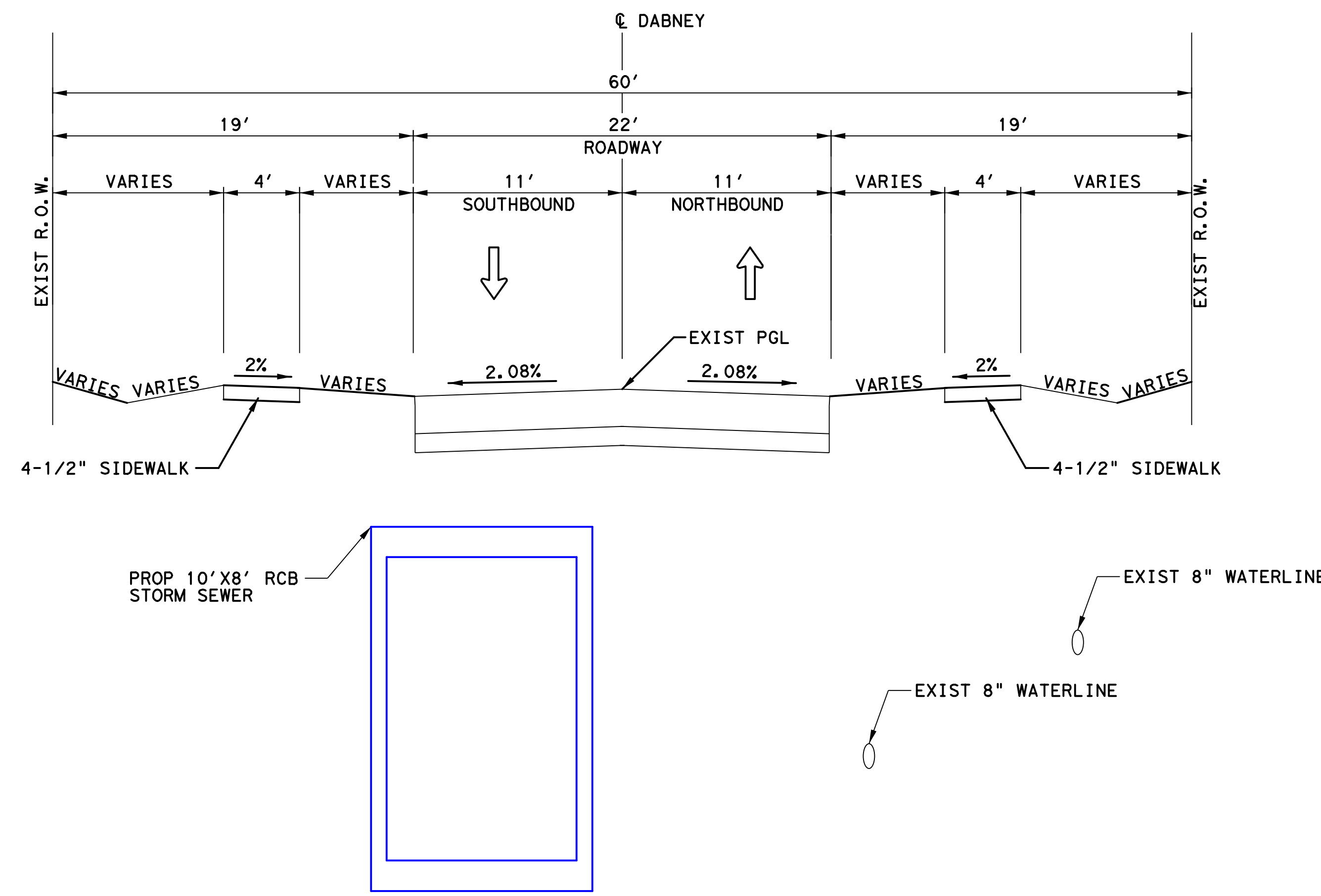
Drainage Improvement P5

DABNEY STREET

(CRANE STREET TO HUNTING BAYOU)



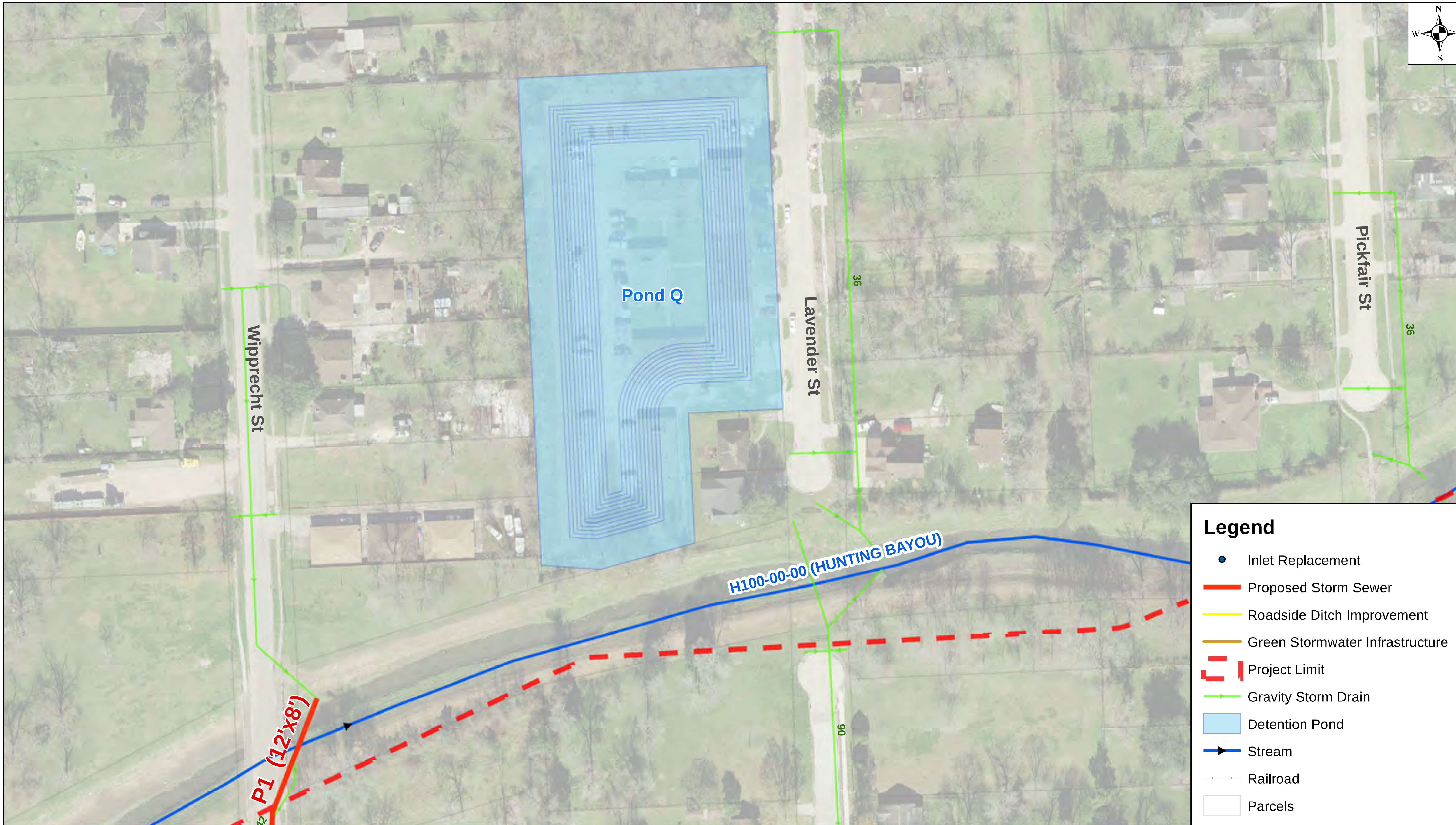
EXISTING TYPICAL SECTION



PROPOSED TYPICAL SECTION ALT 1

SHEET 1 OF 2

PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)		DATE	SCALE	TYPICAL SECTIONS
		6/8/2020	NTS	SECTION 7



HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	DATE OCTOBER 2020	SCALE 0 50 100 200 Feet	EXHIBIT 21 DRAINAGE IMPROVEMENT DETENTION POND Q

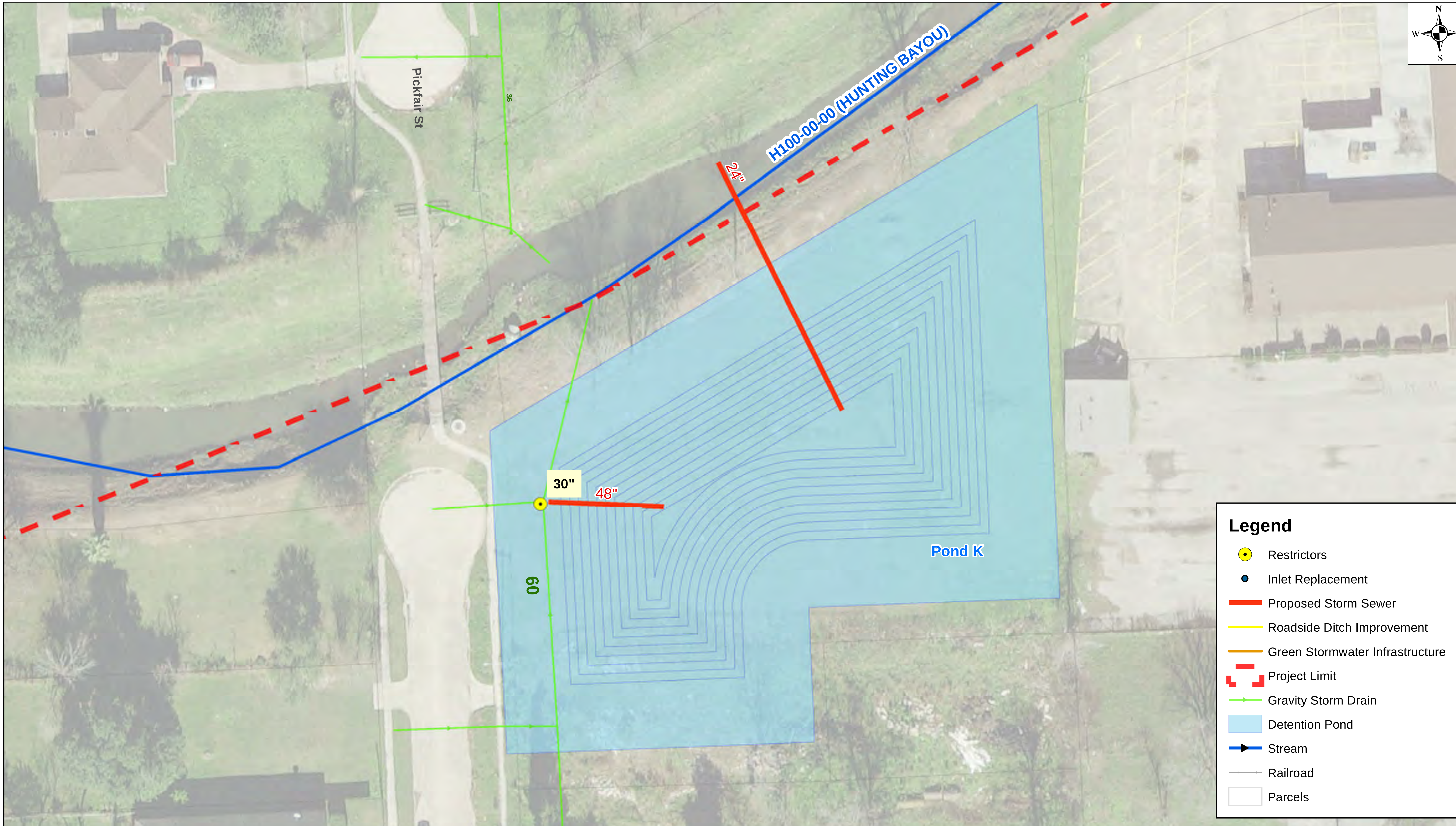
HUITT-ZOLLARS
HUITT-ZOLLARS, INC. Firm No. F-761
10050 Richmond Avenue, Suite 300 Houston, TX 77042
Phone 281.496.0066 Fax 713.496.0220

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 22
OCTOBER 2020	0 25 50 100 Feet	DRAINAGE IMPROVEMENT DETENTION POND N

HUITT-ZOLLARS

HUITT-ZOLLARS	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)		DATE OCTOBER 2020	SCALE 0 25 50 100 Feet	EXHIBIT 23 DRAINAGE IMPROVEMENT DETENTION POND M



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PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

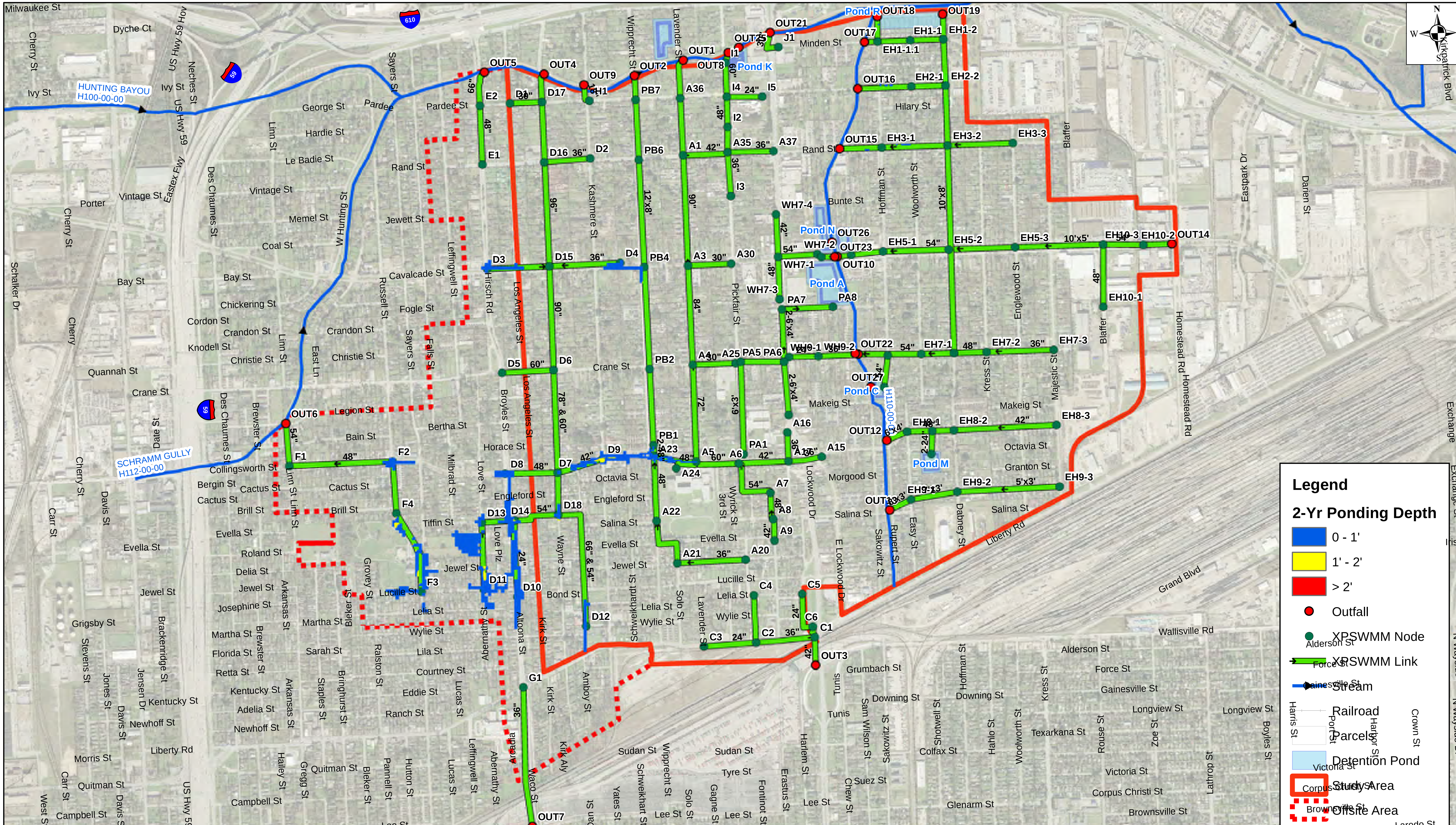
CITY OF HOUSTON TEXAS

DATE
OCTOBER 2020

SCALE
0 12.5 25 50
Feet

EXHIBIT 24

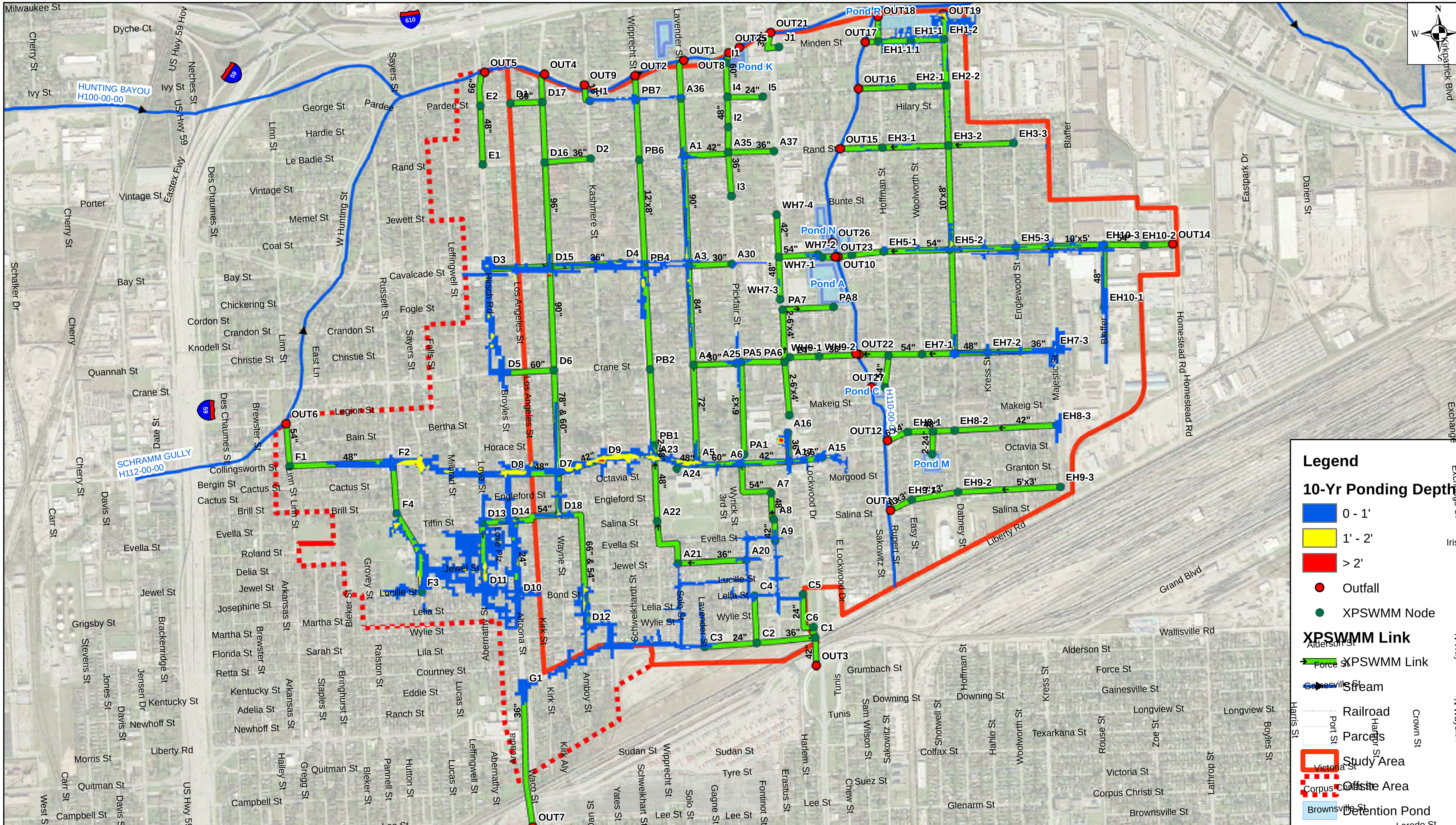
DRAINAGE IMPROVEMENT DETENTION POND K



HUITT-ZOLLARS

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

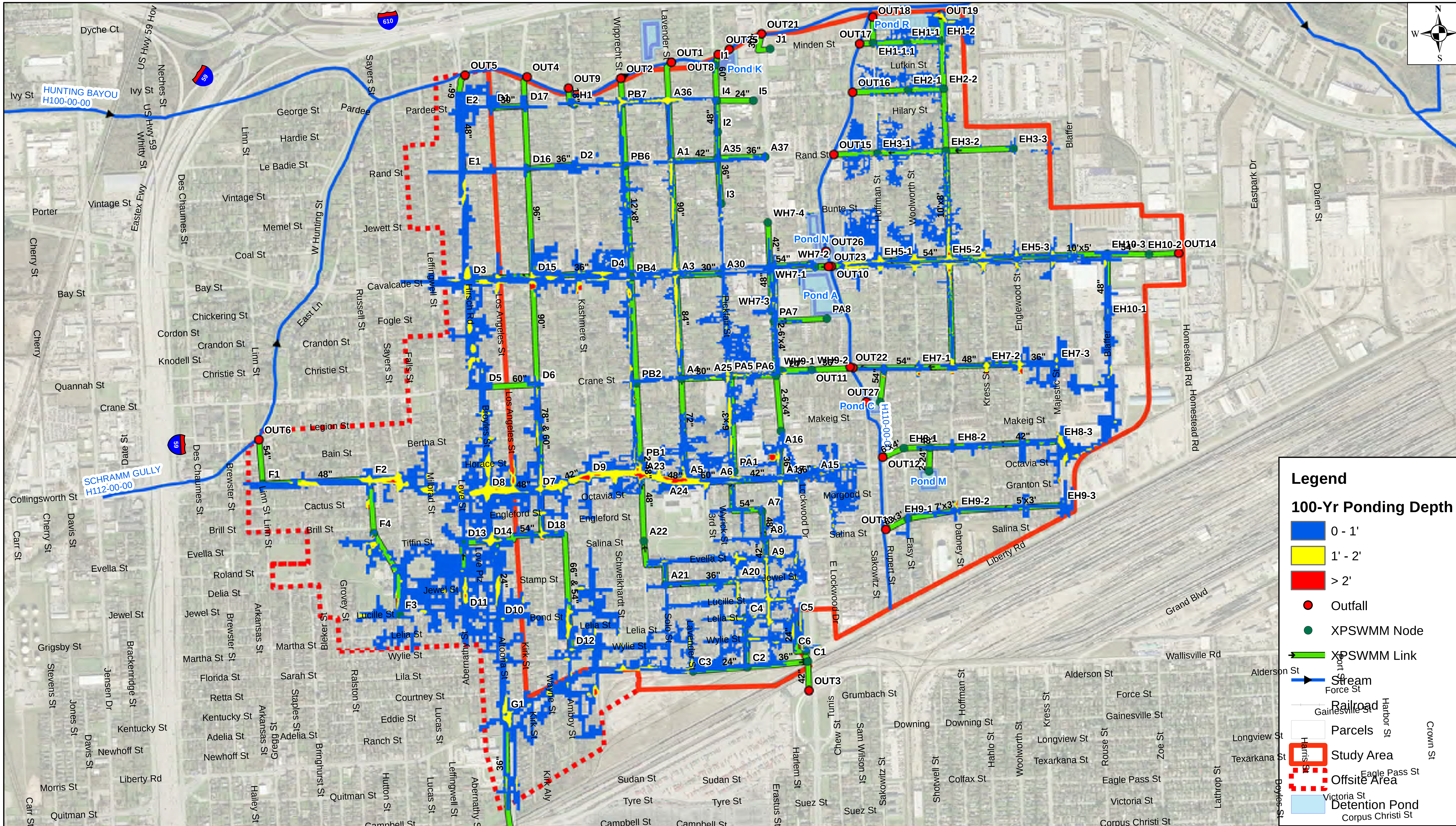
DATE	SCALE	EXHIBIT 25
OCTOBER 2020	0 500 1,000 2,000 Feet	2-YR PONDING DEPTH PROPOSED CONDITION



PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

HUITT-ZOLLARS

DATE	SCALE	EXHIBIT 26
OCTOBER 2020	0 500 1,000 2,000 Feet	10-YR PONDING DEPTH PROPOSED CONDITION



HUITT-ZOLLARS

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 27
OCTOBER 2020	0 500 1,000 2,000 Feet	100-YR PONDING DEPTH PROPOSED CONDITION

Attachment

Probable Construction Cost Estimate

CDBG-MIT: Budget Justification of Retail Costs
(Former Table 2)

Cost Verification Controls must be in place to assure that construction costs are reasonable and consistent with market costs at the time and place of construction.

Applicant/Subrecipient:	City of Houston
Site/Activity Title:	Houston Kashmere Gardens Flood Mitigation
Eligible Activity:	Flood control and drainage improvements

Materials/Facilities/Services	$/Unit	Unit	Quantity	Construction	Acquisition	Total
Wipprecht Street (Collingsworth Street to Hunting Bayou - P1)						
Mobilization	$ 800,000.00	LS	1	$ 800,000.00	$ -	$ 800,000.00
Traffic Control & Regulation	$ 350,000.00	LS	1	$ 350,000.00	$ -	$ 350,000.00
SWPPP	$ 120,000.00	LS	1	$ 120,000.00	$ -	$ 120,000.00
Tree Mitigation	$ 65,000.00	LS	1	$ 65,000.00	$ -	$ 65,000.00
Adjusting Manholes, inlets, and valve boxes to grade	$ 750.00	EA	14	$ 10,500.00	$ -	$ 10,500.00
Service stubs or reconnections with or without stack on sanitary sewer	$ 70.00	LF	1855	$ 129,850.00	$ -	$ 129,850.00
48-Inch Diameter Manhole for RCB	$ 4,200.00	EA	16	$ 67,200.00	$ -	$ 67,200.00
Remove and Dispose Manholes all Sizes/Depth	$ 900.00	EA	11	$ 9,900.00	$ -	$ 9,900.00
Adjust Manhole Frame and Cover to New Grade	$ 750.00	EA	2	$ 1,500.00	$ -	$ 1,500.00
Remove and Dispose Inlets all Sizes/Depth	$ 600.00	EA	16	$ 9,600.00	$ -	$ 9,600.00
Remove and Dispose Culvert 12" to 18"	$ 12.00	LF	555	$ 6,657.60	$ -	$ 6,657.60
Remove and Dispose Storm Pipe 24-Inch Diameter	$ 12.00	LF	851	$ 10,212.00	$ -	$ 10,212.00
Remove and Dispose Storm Pipe 30-Inch Diameter	$ 14.00	LF	406	$ 5,684.00	$ -	$ 5,684.00
Remove and Dispose Storm Pipe 36-Inch Diameter	$ 16.00	LF	1720	$ 27,520.00	$ -	$ 27,520.00
Remove and Dispose Storm Pipe 42-Inch Diameter	$ 18.00	LF	303	$ 5,454.00	$ -	$ 5,454.00
Trench Safety System for Storm Sewer Trench Excavation	$ 5.00	LF	5042	$ 25,210.00	$ -	$ 25,210.00
Junction Box	$ 18,000.00	EA	4	$ 72,000.00	$ -	$ 72,000.00
24-inch Diameter Storm Sewer by open cut	$ 85.00	LF	482	$ 40,970.00	$ -	$ 40,970.00
12' x 8' RCB	$ 1,220.00	LF	4560	$ 5,563,200.00	$ -	$ 5,563,200.00
Type "BB" Inlet	$ 3,800.00	EA	32	$ 121,600.00	$ -	$ 121,600.00
Remove/Dispose Pavement with Base 12 inch Thick	$ 7.00	SY	15763	$ 110,344.11	$ -	$ 110,344.11
Excavation & Haul off	$ 15.00	CY	6800	$ 102,000.00	$ -	$ 102,000.00
Lime Stabilized Subgrade 8-inch Thick	$ 4.00	SY	15763	$ 63,053.78	$ -	$ 63,053.78
Lime for Lime Stabilized Subgrade (Dry Weight)	$ 150.00	TON	284	$ 42,561.30	$ -	$ 42,561.30
Reinforced Concrete Pavement 11-inch Thick	$ 70.00	SY	15763	$ 1,103,441.11	$ -	$ 1,103,441.11
Concrete Driveways Including Excavation 6-inch Thick	$ 10.00	SF	5500	$ 55,000.00	$ -	$ 55,000.00
6-Inch Concrete Curb (Monolithic)	$ 18.00	LF	9795	$ 176,310.00	$ -	$ 176,310.00
Sidewalk 4-1/2-Inch Thick	$ 6.50	SF	39278	$ 255,307.00	$ -	$ 255,307.00
Wheelchair Ramps and Sidewalks, Complete in Place	$ 20.00	SF	120	$ 2,400.00	$ -	$ 2,400.00
8-Inch Diameter Water Line by Open-Cut with Restrained Joints	$ 110.00	LF	61	$ 6,710.00	$ -	$ 6,710.00
6-Inch Diameter Water Line by Open-Cut with Restrained Joints	$ 80.00	LF	67	$ 5,360.00	$ -	$ 5,360.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Short Side	$ 900.00	EA	54	$ 48,600.00	$ -	$ 48,600.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Long Side	$ 1,250.00	EA	50	$ 62,500.00	$ -	$ 62,500.00
Marcus Street (Lockwood Drive to Channel H110-00-00 - P2)						
Mobilization	$ 100,000.00	LS	1	$ 100,000.00	$ -	$ 100,000.00
Traffic Control & Regulation	$ 45,000.00	LS	1	$ 45,000.00	$ -	$ 45,000.00
SWPPP	$ 15,000.00	LS	1	$ 15,000.00	$ -	$ 15,000.00
Tree Mitigation	$ 8,000.00	LS	1	$ 8,000.00	$ -	$ 8,000.00
Adjusting Manholes, inlets, and valve boxes to grade	$ 750.00	EA	1	$ 750.00	$ -	$ 750.00
Service stubs or reconnections with or without stack on sanitary sewer	$ 70.00	LF	180	$ 12,600.00	$ -	$ 12,600.00
Type C Manhole for 48-Inch Diameter Sewers	$ 15,000.00	EA	1	$ 15,000.00	$ -	$ 15,000.00
Junction Box	$ 18,000.00	EA	1	$ 18,000.00	$ -	$ 18,000.00
24-inch Diameter Storm Sewer by open cut	$ 85.00	LF	30	$ 2,550.00	$ -	$ 2,550.00
6' x 4' RCB	$ 580.00	LF	1048	$ 607,840.00	$ -	$ 607,840.00
Type "BB" Inlet	$ 3,800.00	EA	2	$ 7,600.00	$ -	$ 7,600.00
Remove/Dispose Conc Driveway 6-inch Thick/More	$ 3.00	SY	472	$ 1,416.63	$ -	$ 1,416.63
Remove/Dispose Pavement with Base 12 inch Thick	$ 7.00	SY	2044	$ 14,308.17	$ -	$ 14,308.17
Excavation & Haul off	$ 15.00	CY	1150	$ 17,250.00	$ -	$ 17,250.00
Lime Stabilized Subgrade 8-inch Thick	$ 4.00	SY	2044	$ 8,176.10	$ -	$ 8,176.10
Lime for Lime Stabilized Subgrade (Dry Weight)	$ 150.00	TON	37	$ 5,518.87	$ -	$ 5,518.87

Reinforced Concrete Pavement 11-inch Thick	$	70.00	SY	2044	$	143,081.70	$	-	$	143,081.70
Concrete Driveways Including Excavation 6-inch Thick	$	10.00	SF	4250	$	42,498.89	$	-	$	42,498.89
6-Inch Concrete Curb (Monolithic)	$	18.00	LF	1510	$	27,179.42	$	-	$	27,179.42
Sidewalk 4-1/2-Inch Thick	$	6.50	SF	7450	$	48,426.96	$	-	$	48,426.96
Wheelchair Ramps and Sidewalks, Complete in Place	$	20.00	SF	80	$	1,600.00	$	-	$	1,600.00
8-Inch Diameter Water Line by Open-Cut with Restrained Joints	$	110.00	LF	88	$	9,680.00	$	-	$	9,680.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Short Side	$	900.00	EA	7	$	6,300.00	$	-	$	6,300.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Long Side	$	1,250.00	EA	7	$	8,750.00	$	-	$	8,750.00
Fire Hydrant Assembly, All Depths, Including 6-Inch Diameter Gate Valve and Box	$	10,000.00	EA	1	$	10,000.00	$	-	$	10,000.00
Lockwood Drive (Crane Street to Marcus Street - P2)										
Mobilization	$	320,000.00	LS	1	$	320,000.00	$	-	$	320,000.00
Traffic Control & Regulation	$	180,000.00	LS	1	$	180,000.00	$	-	$	180,000.00
SWPPP	$	65,000.00	LS	1	$	65,000.00	$	-	$	65,000.00
Tree Mitigation	$	36,000.00	LS	1	$	36,000.00	$	-	$	36,000.00
Adjusting Manholes, inlets, and valve boxes to grade	$	750.00	EA	12	$	9,000.00	$	-	$	9,000.00
Type C Manhole for 48-Inch Diameter Sewers	$	15,000.00	EA	4	$	60,000.00	$	-	$	60,000.00
Remove and Dispose Manholes all Sizes/Depth	$	900.00	EA	6	$	5,400.00	$	-	$	5,400.00
Adjust Manhole Frame and Cover to New Grade	$	750.00	EA	2	$	1,500.00	$	-	$	1,500.00
Remove and Dispose Inlets all Sizes/Depth	$	600.00	EA	10	$	6,000.00	$	-	$	6,000.00
Remove and Dispose Storm Pipe 24-Inch Diameter	$	12.00	LF	1011	$	12,132.00	$	-	$	12,132.00
Junction Box	$	18,000.00	EA	3	$	54,000.00	$	-	$	54,000.00
24-inch Diameter Storm Sewer by open cut	$	85.00	LF	820	$	69,700.00	$	-	$	69,700.00
6' x 4' RCB	$	580.00	LF	2338	$	1,356,040.00	$	-	$	1,356,040.00
Type "BB" Inlet	$	3,800.00	EA	16	$	60,800.00	$	-	$	60,800.00
Remove/Dispose Conc Driveway 6-inch Thick/More	$	3.00	SY	881	$	2,643.51	$	-	$	2,643.51
Remove/Dispose Pavement with Base 12 inch Thick	$	7.00	SY	13500	$	94,499.84	$	-	$	94,499.84
Excavation & Haul off	$	15.00	CY	1250	$	18,750.00	$	-	$	18,750.00
Lime Stabilized Subgrade 8-inch Thick	$	4.00	SY	13500	$	53,999.91	$	-	$	53,999.91
Lime for Lime Stabilized Subgrade (Dry Weight)	$	150.00	TON	243	$	36,449.94	$	-	$	36,449.94
Reinforced Concrete Pavement 11-inch Thick	$	70.00	SY	13500	$	944,998.40	$	-	$	944,998.40
Concrete Driveways Including Excavation 6-inch Thick	$	10.00	SF	7931	$	79,305.35	$	-	$	79,305.35
6-Inch Concrete Curb (Monolithic)	$	18.00	LF	9167	$	165,001.19	$	-	$	165,001.19
Sidewalk 4-1/2-Inch Thick	$	6.50	SF	17581	$	114,277.52	$	-	$	114,277.52
Wheelchair Ramps and Sidewalks, Complete in Place	$	20.00	SF	160	$	3,200.00	$	-	$	3,200.00
12-Inch Diameter Water Line by Open-Cut	$	140.00	LF	132	$	18,480.00	$	-	$	18,480.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Short Side	$	900.00	EA	18	$	16,200.00	$	-	$	16,200.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Long Side	$	1,250.00	EA	20	$	25,000.00	$	-	$	25,000.00
Fire Hydrant Assembly, All Depths, Including 6-Inch Diameter Gate Valve and Box	$	10,000.00	EA	4	$	40,000.00	$	-	$	40,000.00
Crane Street (Pickfair Street to Lockwood Drive - P2)										
Mobilization	$	65,000.00	LS	1	$	65,000.00	$	-	$	65,000.00
Traffic Control & Regulation	$	34,000.00	LS	1	$	34,000.00	$	-	$	34,000.00
SWPPP	$	11,000.00	LS	1	$	11,000.00	$	-	$	11,000.00
Tree Mitigation	$	6,500.00	LS	1	$	6,500.00	$	-	$	6,500.00
Adjusting Manholes, inlets, and valve boxes to grade	$	750.00	EA	1	$	750.00	$	-	$	750.00
Service stubs or reconnections with or without stack on sanitary sewer	$	70.00	LF	210	$	14,700.00	$	-	$	14,700.00
6' x 3' RCB	$	520.00	LF	380	$	197,600.00	$	-	$	197,600.00
Remove/Dispose Conc Driveway 6-inch Thick/More	$	3.00	SY	537	$	1,612.22	$	-	$	1,612.22
Remove/Dispose Pavement with Base 12 inch Thick	$	7.00	SY	1309	$	9,160.00	$	-	$	9,160.00
Excavation & Haul off	$	15.00	CY	655	$	9,825.00	$	-	$	9,825.00
Lime Stabilized Subgrade 8-inch Thick	$	4.00	SY	1664	$	6,656.00	$	-	$	6,656.00
Lime for Lime Stabilized Subgrade (Dry Weight)	$	150.00	TON	30	$	4,492.80	$	-	$	4,492.80
Reinforced Concrete Pavement 11-inch Thick	$	70.00	SY	1664	$	116,480.00	$	-	$	116,480.00
Concrete Driveways Including Excavation 6-inch Thick	$	10.00	SF	4837	$	48,366.65	$	-	$	48,366.65
6-Inch Concrete Curb (Monolithic)	$	18.00	LF	1220	$	21,960.00	$	-	$	21,960.00
Sidewalk 4-1/2-Inch Thick	$	6.50	SF	6250	$	40,625.00	$	-	$	40,625.00
Wheelchair Ramps and Sidewalks, Complete in Place	$	20.00	SF	80	$	1,600.00	$	-	$	1,600.00
12-Inch Diameter Water Line by Open-Cut	$	140.00	LF	213	$	29,820.00	$	-	$	29,820.00

3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Short Side	$ 900.00	EA	5	$ 4,500.00	$ -	$ 4,500.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Long Side	$ 1,250.00	EA	5	$ 6,250.00	$ -	$ 6,250.00
12-Inch Diameter Wet Connection	$ 1,600.00	EA	1	$ 1,600.00	$ -	$ 1,600.00
8-Inch Diameter Wet Connection	$ 1,200.00	EA	1	$ 1,200.00	$ -	$ 1,200.00
Fire Hydrant Assembly, All Depths, Including 6-Inch Diameter Gate Valve and Box	$ 10,000.00	EA	1	$ 10,000.00	$ -	$ 10,000.00
Pickfair Street (Crane Street to Collingsworth Street - P2)						
Mobilization	$ 150,000.00	LS	1	$ 150,000.00	$ -	$ 150,000.00
Traffic Control & Regulation	$ 60,000.00	LS	1	$ 60,000.00	$ -	$ 60,000.00
SWPPP	$ 25,000.00	LS	1	$ 25,000.00	$ -	$ 25,000.00
Tree Mitigation	$ 23,000.00	LS	1	$ 23,000.00	$ -	$ 23,000.00
Adjusting Manholes, inlets, and valve boxes to grade	$ 750.00	EA	2	$ 1,500.00	$ -	$ 1,500.00
Service stubs or reconnections with or without stack on sanitary sewer	$ 70.00	LF	240	$ 16,800.00	$ -	$ 16,800.00
Type C Manhole for 48-Inch Diameter Sewers	$ 15,000.00	EA	2	$ 30,000.00	$ -	$ 30,000.00
Remove and Dispose Manholes all Sizes/Depth	$ 900.00	EA	4	$ 3,600.00	$ -	$ 3,600.00
Remove and Dispose Inlets all Sizes/Depth	$ 600.00	EA	10	$ 6,000.00	$ -	$ 6,000.00
Remove and Dispose Storm Pipe 24-Inch Diameter	$ 12.00	LF	1800	$ 21,600.00	$ -	$ 21,600.00
Junction Box	$ 18,000.00	EA	5	$ 90,000.00	$ -	$ 90,000.00
24-inch Diameter Storm Sewer by open cut	$ 85.00	LF	283	$ 24,055.00	$ -	$ 24,055.00
6' x 3' RCB	$ 520.00	LF	1218	$ 633,360.00	$ -	$ 633,360.00
Type "BB" Inlet	$ 3,800.00	EA	10	$ 38,000.00	$ -	$ 38,000.00
Remove/Dispose Conc Driveway 6-inch Thick/More	$ 3.00	SY	684	$ 2,052.84	$ -	$ 2,052.84
Remove/Dispose Pavement with Base 12 inch Thick	$ 7.00	SY	4567	$ 31,966.67	$ -	$ 31,966.67
Excavation & Haul off	$ 15.00	CY	2650	$ 39,750.00	$ -	$ 39,750.00
Lime Stabilized Subgrade 8-inch Thick	$ 4.00	SY	4567	$ 18,266.67	$ -	$ 18,266.67
Lime for Lime Stabilized Subgrade (Dry Weight)	$ 150.00	TON	82	$ 12,330.00	$ -	$ 12,330.00
Reinforced Concrete Pavement 11-inch Thick	$ 70.00	SY	4567	$ 319,666.67	$ -	$ 319,666.67
Concrete Driveways Including Excavation 6-inch Thick	$ 10.00	SF	6159	$ 61,585.28	$ -	$ 61,585.28
6-Inch Concrete Curb (Monolithic)	$ 18.00	LF	2974	$ 53,530.63	$ -	$ 53,530.63
Sidewalk 4-1/2-Inch Thick	$ 6.50	SF	13448	$ 87,411.48	$ -	$ 87,411.48
Wheelchair Ramps and Sidewalks, Complete in Place	$ 20.00	SF	80	$ 1,600.00	$ -	$ 1,600.00
8-Inch Diameter Water Line by Open-Cut with Restrained Joints	$ 110.00	LF	60	$ 6,600.00	$ -	$ 6,600.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Short Side	$ 900.00	EA	10	$ 9,000.00	$ -	$ 9,000.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Long Side	$ 1,250.00	EA	10	$ 12,500.00	$ -	$ 12,500.00
8-Inch Diameter Wet Connection	$ 1,200.00	EA	1	$ 1,200.00	$ -	$ 1,200.00
6-Inch Diameter Wet Connection	$ 1,000.00	EA	1	$ 1,000.00	$ -	$ 1,000.00
Fire Hydrant Assembly, All Depths, Including 6-Inch Diameter Gate Valve and Box	$ 10,000.00	EA	2	$ 20,000.00	$ -	$ 20,000.00
Calvacade Street (Dabney Street to Blaffer Street - P3)						
Mobilization	$ 450,000.00	LS	1	$ 450,000.00	$ -	$ 450,000.00
Aluminum Signs (Ground Mounted)-Furnish & Install	$ 150,000.00	LS	1	$ 150,000.00	$ -	$ 150,000.00
SWPPP	$ 85,000.00	LS	1	$ 85,000.00	$ -	$ 85,000.00
Tree Mitigation	$ 25,000.00	LS	1	$ 25,000.00	$ -	$ 25,000.00
Adjusting Manholes, inlets, and valve boxes to grade	$ 750.00	EA	14	$ 10,500.00	$ -	$ 10,500.00
Trench Safety System for Sanitary Sewer Trench Excavation	$ 2.00	LF	3236	$ 6,472.00	$ -	$ 6,472.00
Service stubs or reconnections with or without stack on sanitary sewer	$ 70.00	LF	992	$ 69,440.00	$ -	$ 69,440.00
Type C Manhole On Box Culvert	$ 4,200.00	EA	5	$ 21,000.00	$ -	$ 21,000.00
Remove and Dispose Storm Pipe 24-Inch Diameter	$ 12.00	LF	250	$ 3,000.00	$ -	$ 3,000.00
Junction Box 10 FTx 10 FT	$ 18,000.00	EA	1	$ 18,000.00	$ -	$ 18,000.00
24-inch Diameter Storm Sewer by open cut	$ 85.00	LF	250	$ 21,250.00	$ -	$ 21,250.00
10' x 5' RCB	$ 780.00	LF	1831	$ 1,428,180.00	$ -	$ 1,428,180.00
Type "BB" Inlet	$ 3,800.00	EA	8	$ 30,400.00	$ -	$ 30,400.00
Remove/Dispose Pavement with Base 12 inch Thick	$ 7.00	SY	14123	$ 98,861.00	$ -	$ 98,861.00
Excavation & Haul off	$ 15.00	CY	7355	$ 110,325.00	$ -	$ 110,325.00
Lime Stabilized Subgrade 8-inch Thick	$ 4.00	SY	14123	$ 56,492.00	$ -	$ 56,492.00
Lime for Lime Stabilized Subgrade (Dry Weight)	$ 150.00	TON	254	$ 38,132.10	$ -	$ 38,132.10
Reinforced Concrete Pavement 11-inch Thick	$ 70.00	SY	14123	$ 988,610.00	$ -	$ 988,610.00
Concrete Driveways Including Excavation 6-inch Thick	$ 10.00	SF	5030	$ 50,300.00	$ -	$ 50,300.00
6-Inch Concrete Curb (Monolithic)	$ 18.00	LF	7542	$ 135,756.00	$ -	$ 135,756.00

Sidewalk 4-1/2-Inch Thick	$	6.50	SF	16445	$	106,892.50	$	-	$ 106,892.50
Wheelchair Ramps and Sidewalks, Complete in Place	$	20.00	SF	120	$	2,400.00	$	-	$ 2,400.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Short Side	$	900.00	EA	18	$	16,200.00	$	-	$ 16,200.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Long Side	$	1,250.00	EA	20	$	25,000.00	$	-	$ 25,000.00
Hoffman Street (Crane Street to Pond C - P4)									
Mobilization	$	22,000.00	LS	1	$	22,000.00	$	-	$ 22,000.00
Traffic Control & Regulation	$	10,000.00	LS	1	$	10,000.00	$	-	$ 10,000.00
SWPPP	$	8,500.00	LS	1	$	8,500.00	$	-	$ 8,500.00
Tree Mitigation	$	5,600.00	LS	1	$	5,600.00	$	-	$ 5,600.00
Service stubs or reconnections with or without stack on sanitary sewer	$	70.00	LF	85	$	5,950.00	$	-	$ 5,950.00
48-Inch Diameter Manhole for RCB	$	4,200.00	EA	2	$	8,400.00	$	-	$ 8,400.00
24-inch Diameter Storm Sewer by open cut	$	85.00	LF	42	$	3,570.00	$	-	$ 3,570.00
54-inch Diameter Storm Sewer by open cut	$	320.00	LF	375	$	120,000.00	$	-	$ 120,000.00
Type "BB" Inlet	$	3,800.00	EA	2	$	7,600.00	$	-	$ 7,600.00
Remove/Dispose reinforced concrete with or without base including existing Metro bus pad	$	7.00	SY	750	$	5,250.00	$	-	$ 5,250.00
Lime Stabilized Subgrade 8-inch Thick	$	4.00	SY	750	$	3,000.00	$	-	$ 3,000.00
Lime for Lime Stabilized Subgrade (Dry Weight)	$	150.00	TON	14	$	2,025.00	$	-	$ 2,025.00
Reinforced Concrete Pavement 11-inch Thick	$	70.00	SY	750	$	52,500.00	$	-	$ 52,500.00
Concrete Driveways Including Excavation 6-inch Thick	$	10.00	SF	350	$	3,500.00	$	-	$ 3,500.00
6-Inch Concrete Curb (Monolithic)	$	18.00	LF	283	$	5,094.00	$	-	$ 5,094.00
Sidewalk 4-1/2-Inch Thick	$	6.50	SF	2850	$	18,525.00	$	-	$ 18,525.00
Wheelchair Ramps and Sidewalks, Complete in Place	$	20.00	SF	40	$	800.00	$	-	$ 800.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Short Side	$	900.00	EA	4	$	3,600.00	$	-	$ 3,600.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Long Side	$	1,250.00	EA	4	$	5,000.00	$	-	$ 5,000.00
Dabney Street (Crane Street to Hunting Bayou - P5)									
Mobilization	$	690,000.00	LS	1	$	690,000.00	$	-	$ 690,000.00
Traffic Control & Regulation	$	225,000.00	LS	1	$	225,000.00	$	-	$ 225,000.00
SWPPP	$	98,000.00	LS	1	$	98,000.00	$	-	$ 98,000.00
Tree Mitigation	$	60,000.00	LS	1	$	60,000.00	$	-	$ 60,000.00
Adjusting Manholes, inlets, and valve boxes to grade	$	750.00	EA	10	$	7,500.00	$	-	$ 7,500.00
Service stubs or reconnections with or without stack on sanitary sewer	$	70.00	LF	1596	$	111,720.00	$	-	$ 111,720.00
48-Inch Diameter Manhole for RCB	$	4,200.00	EA	4	$	16,800.00	$	-	$ 16,800.00
Trench Safety System for Storm Sewer Trench Excavation	$	5.00	LF	4168	$	20,840.00	$	-	$ 20,840.00
Junction Box 10 FTx 10 FT	$	18,000.00	EA	6	$	108,000.00	$	-	$ 108,000.00
24-inch Diameter Storm Sewer by open cut	$	85.00	LF	240	$	20,400.00	$	-	$ 20,400.00
10' x 8' RCB	$	1,150.00	LF	4168	$	4,793,200.00	$	-	$ 4,793,200.00
Type "BB" Inlet	$	3,800.00	EA	22	$	83,600.00	$	-	$ 83,600.00
Remove/Dispose Pavement with Base 12 inch Thick	$	7.00	SY	13968	$	97,772.89	$	-	$ 97,772.89
Excavation & Haul off	$	15.00	CY	6580	$	98,700.00	$	-	$ 98,700.00
Lime Stabilized Subgrade 8-inch Thick	$	4.00	SY	13968	$	55,870.22	$	-	$ 55,870.22
Lime for Lime Stabilized Subgrade (Dry Weight)	$	150.00	TON	251	$	37,712.40	$	-	$ 37,712.40
Reinforced Concrete Pavement 11-inch Thick	$	70.00	SY	13968	$	977,728.89	$	-	$ 977,728.89
Concrete Driveways Including Excavation 6-inch Thick	$	10.00	SF	4200	$	42,000.00	$	-	$ 42,000.00
6-Inch Concrete Curb (Monolithic)	$	18.00	LF	8966	$	161,388.00	$	-	$ 161,388.00
Sidewalk 5-1/2-Inch Thick	$	6.50	SF	38404	$	249,626.00	$	-	$ 249,626.00
Wheelchair Ramps and Sidewalks, Complete in Place	$	20.00	SF	120	$	2,400.00	$	-	$ 2,400.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Short Side	$	900.00	EA	40	$	36,000.00	$	-	$ 36,000.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Long Side	$	1,250.00	EA	48	$	60,000.00	$	-	$ 60,000.00
Rand Street (Dabney Street to Majestic Street - P6)									
Mobilization	$	125,000.00	LS	1	$	125,000.00	$	-	$ 125,000.00
Traffic Control & Regulation	$	45,000.00	LS	1	$	45,000.00	$	-	$ 45,000.00
SWPPP	$	35,000.00	LS	1	$	35,000.00	$	-	$ 35,000.00
Tree Mitigation	$	15,000.00	LS	1	$	15,000.00	$	-	$ 15,000.00
Service stubs or reconnections with or without stack on sanitary sewer	$	70.00	LF	126	$	8,820.00	$	-	$ 8,820.00
Type C Manhole for 36-Inch Diameter Sewers	$	4,200.00	EA	10	$	42,000.00	$	-	$ 42,000.00

24-inch Diameter Storm Sewer by open cut	$	85.00	LF	225	$	19,125.00	$ -	$	19,125.00
36-inch Diameter Storm Sewer by open cut	$	160.00	LF	1350	$	216,000.00	$ -	$	216,000.00
Type "BB" Inlet	$	3,800.00	EA	14	$	53,200.00	$ -	$	53,200.00
Remove/Dispose Pavement with Base	$	7.00	SY	4596	$	32,169.67	$ -	$	32,169.67
Excavation & Haul	$	18.00	CY	1532	$	27,574.00	$ -	$	27,574.00
Lime Stabilized Subgrade 8-inch Thick	$	4.00	SY	4596	$	18,382.67	$ -	$	18,382.67
Lime for Lime Stabilized Subgrade (Dry Weight)	$	150.00	TON	83	$	12,408.30	$ -	$	12,408.30
Reinforced Concrete Pavement 11-inch Thick	$	70.00	SY	4596	$	321,696.67	$ -	$	321,696.67
Concrete Driveways Including Excavation 6-inch Thick	$	10.00	SF	560	$	5,600.00	$ -	$	5,600.00
6-Inch Concrete Curb (Monolithic)	$	18.00	LF	2902	$	52,236.00	$ -	$	52,236.00
Sidewalk 4-1/2-Inch Thick	$	6.50	SF	12859	$	83,583.50	$ -	$	83,583.50
Wheelchair Ramps and Sidewalks, Complete in Place	$	20.00	SF	80	$	1,600.00	$ -	$	1,600.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Short Side	$	900.00	EA	6	$	5,400.00	$ -	$	5,400.00
3/4-Inch to 1-Inch Diameter Water Taps and Copper Service Line with Meter Box, Long Side	$	1,250.00	EA	7	$	8,750.00	$ -	$	8,750.00
Roadside Ditch Improvements									
Mobilization	$	450,000.00	LS	1	$	450,000.00	$ -	$	450,000.00
Traffic Control & Temporary Pavement	$	150,000.00	LS	1	$	150,000.00	$ -	$	150,000.00
SWPPP	$	98,000.00	LS	1	$	98,000.00	$ -	$	98,000.00
Desilt Roadside Ditch	$	12.00	LF	45500	$	546,000.00	$ -	$	546,000.00
Replace Driveway Culvert & Pavement	$	6,500.00	EA	546	$	3,549,000.00	$ -	$	3,549,000.00
Inlet Replacement									
Mobilization	$	55,000.00	LS	1	$	55,000.00	$ -	$	55,000.00
Traffic Control & Temporary Pavement	$	35,000.00	LS	1	$	35,000.00	$ -	$	35,000.00
SWPPP	$	40,000.00	LS	1	$	40,000.00	$ -	$	40,000.00
Replace B inlets with BB inlets	$	3,800.00	EA	65	$	247,000.00	$ -	$	247,000.00
Sawcut Pavement/Curb and Replace	$	8,500.00	EA	65	$	552,500.00	$ -	$	552,500.00
DETENTION POND Q									
Mobilization	$	50,000.00	LS	1	$	50,000.00	$ -	$	50,000.00
Traffic Control & Temporary Pavement	$	5,000.00	LS	1	$	5,000.00	$ -	$	5,000.00
SWPPP	$	8,000.00	LS	1	$	8,000.00	$ -	$	8,000.00
Tree Mitigation	$	2,000.00	LS	1	$	2,000.00	$ -	$	2,000.00
Excavation and Haul	$	25.00	CY	16617	$	415,433.33	$ -	$	415,433.33
Backslope Drain & Swale	$	41,543.33	LS	1	$	41,543.33	$ -	$	41,543.33
Outfall & Extreme Event Overflow	$	62,315.00	LS	1	$	62,315.00	$ -	$	62,315.00
Intake Pipe	$	124,630.00	LS	1	$	124,630.00	$ -	$	124,630.00
Hydromulch Seeding	$	5,000.00	AC	3	$	12,500.00	$ -	$	12,500.00
Sodding	$	5.00	SY	1500	$	7,500.00	$ -	$	7,500.00
Concrete Pilot Channel	$	35,000.00	LS	1	$	35,000.00	$ -	$	35,000.00
DETENTION POND K									
Mobilization	$	25,000.00	LS	1	$	25,000.00	$ -	$	25,000.00
Traffic Control & Temporary Pavement	$	5,000.00	LS	1	$	5,000.00	$ -	$	5,000.00
SWPPP	$	8,000.00	LS	1	$	8,000.00	$ -	$	8,000.00
Tree Mitigation	$	2,000.00	LS	1	$	2,000.00	$ -	$	2,000.00
Excavation and Haul	$	25.00	CY	3824	$	95,590.00	$ -	$	95,590.00
Backslope Drain & Swale	$	9,559.00	LS	1	$	9,559.00	$ -	$	9,559.00
Outfall & Extreme Event Overflow	$	14,338.50	LS	1	$	14,338.50	$ -	$	14,338.50
Intake Pipe	$	28,677.00	LS	1	$	28,677.00	$ -	$	28,677.00
Hydromulch Seeding	$	5,000.00	AC	1	$	5,000.00	$ -	$	5,000.00
Sodding	$	5.00	SY	500	$	2,500.00	$ -	$	2,500.00
Concrete Pilot Channel	$	20,000.00	LS	1	$	20,000.00	$ -	$	20,000.00
DETENTION POND R									
Mobilization	$	35,000.00	LS	1	$	35,000.00	$ -	$	35,000.00
Traffic Control & Temporary Pavement	$	5,000.00	LS	1	$	5,000.00	$ -	$	5,000.00
SWPPP	$	8,000.00	LS	1	$	8,000.00	$ -	$	8,000.00
Tree Mitigation	$	2,000.00	LS	1	$	2,000.00	$ -	$	2,000.00
Excavation and Haul	$	25.00	CY	7663	$	191,583.33	$ -	$	191,583.33
Backslope Drain & Swale	$	19,158.33	LS	1	$	19,158.33	$ -	$	19,158.33
Outfall & Extreme Event Overflow	$	28,737.50	LS	1	$	28,737.50	$ -	$	28,737.50
Intake Pipe	$	57,475.00	LS	1	$	57,475.00	$ -	$	57,475.00
Hydromulch Seeding	$	5,000.00	AC	2	$	10,000.00	$ -	$	10,000.00
Sodding	$	5.00	SY	800	$	4,000.00	$ -	$	4,000.00
Concrete Pilot Channel	$	25,000.00	LS	1	$	25,000.00	$ -	$	25,000.00
DETENTION POND N									

Mobilization	$ 38,000.00	LS	1	$ 38,000.00	$ -	$ 38,000.00
Traffic Control & Temporary Pavement	$ 5,000.00	LS	1	$ 5,000.00	$ -	$ 5,000.00
SWPPP	$ 8,000.00	LS	1	$ 8,000.00	$ -	$ 8,000.00
Tree Mitigation	$ 2,000.00	LS	1	$ 2,000.00	$ -	$ 2,000.00
Excavation and Haul	$ 25.00	CY	8051	$ 201,263.33	$ -	$ 201,263.33
Backslope Drain & Swale	$ 20,126.33	LS	1	$ 20,126.33	$ -	$ 20,126.33
Outfall & Extreme Event Overflow	$ 30,189.50	LS	1	$ 30,189.50	$ -	$ 30,189.50
Intake Pipe	$ 60,379.00	LS	1	$ 60,379.00	$ -	$ 60,379.00
Hydromulch Seeding	$ 5,000.00	AC	2	$ 10,000.00	$ -	$ 10,000.00
Sodding	$ 5.00	SY	650	$ 3,250.00	$ -	$ 3,250.00
Concrete Pilot Channel	$ 15,000.00	LS	1	$ 15,000.00	$ -	$ 15,000.00
DETENTION POND F						
Mobilization	$ 32,000.00	LS	1	$ 32,000.00	$ -	$ 32,000.00
Traffic Control & Temporary Pavement	$ 5,000.00	LS	1	$ 5,000.00	$ -	$ 5,000.00
SWPPP	$ 8,000.00	LS	1	$ 8,000.00	$ -	$ 8,000.00
Tree Mitigation	$ 2,000.00	LS	1	$ 2,000.00	$ -	$ 2,000.00
Excavation and Haul	$ 25.00	CY	7066	$ 176,660.00	$ -	$ 176,660.00
Backslope Drain & Swale	$ 17,666.00	LS	1	$ 17,666.00	$ -	$ 17,666.00
Outfall & Extreme Event Overflow	$ 26,499.00	LS	1	$ 26,499.00	$ -	$ 26,499.00
Intake Pipe	$ 52,998.00	LS	1	$ 52,998.00	$ -	$ 52,998.00
Hydromulch Seeding	$ 5,000.00	AC	1	$ 7,000.00	$ -	$ 7,000.00
Sodding	$ 5.00	SY	500	$ 2,500.00	$ -	$ 2,500.00
Concrete Pilot Channel	$ 12,000.00	LS	1	$ 12,000.00	$ -	$ 12,000.00
DETENTION POND A						
Mobilization	$ 150,000.00	LS	1	$ 150,000.00	$ -	$ 150,000.00
Traffic Control & Temporary Pavement	$ 8,000.00	LS	1	$ 8,000.00	$ -	$ 8,000.00
SWPPP	$ 15,000.00	LS	1	$ 15,000.00	$ -	$ 15,000.00
Tree Mitigation	$ 5,000.00	LS	1	$ 5,000.00	$ -	$ 5,000.00
Excavation and Haul	$ 25.00	CY	35042	$ 876,040.00	$ -	$ 876,040.00
Backslope Drain & Swale	$ 87,604.00	LS	1	$ 87,604.00	$ -	$ 87,604.00
Outfall & Extreme Event Overflow	$ 131,406.00	LS	1	$ 131,406.00	$ -	$ 131,406.00
Intake Pipe	$ 262,812.00	LS	1	$ 262,812.00	$ -	$ 262,812.00
Hydromulch Seeding	$ 5,000.00	AC	5	$ 25,000.00	$ -	$ 25,000.00
Sodding	$ 5.00	SY	1800	$ 9,000.00	$ -	$ 9,000.00
Concrete Pilot Channel	$ 35,000.00	LS	1	$ 35,000.00	$ -	$ 35,000.00
DETENTION POND C						
Mobilization	$ 30,000.00	LS	1	$ 30,000.00	$ -	$ 30,000.00
Traffic Control & Temporary Pavement	$ 5,000.00	LS	1	$ 5,000.00	$ -	$ 5,000.00
SWPPP	$ 8,000.00	LS	1	$ 8,000.00	$ -	$ 8,000.00
Tree Mitigation	$ 2,000.00	LS	1	$ 2,000.00	$ -	$ 2,000.00
Excavation and Haul	$ 25.00	CY	6534	$ 163,350.00	$ -	$ 163,350.00
Backslope Drain & Swale	$ 16,335.00	LS	1	$ 16,335.00	$ -	$ 16,335.00
Outfall & Extreme Event Overflow	$ 24,502.50	LS	1	$ 24,502.50	$ -	$ 24,502.50
Intake Pipe	$ 49,005.00	LS	1	$ 49,005.00	$ -	$ 49,005.00
Hydromulch Seeding	$ 5,000.00	AC	1	$ 6,500.00	$ -	$ 6,500.00
Sodding	$ 5.00	SY	450	$ 2,250.00	$ -	$ 2,250.00
Concrete Pilot Channel	$ 12,000.00	LS	1	$ 12,000.00	$ -	$ 12,000.00
DETENTION POND M						
Mobilization	$ 280,000.00	LS	1	$ 280,000.00	$ -	$ 280,000.00
Traffic Control & Temporary Pavement	$ 5,000.00	LS	1	$ 5,000.00	$ -	$ 5,000.00
SWPPP	$ 8,000.00	LS	1	$ 8,000.00	$ -	$ 8,000.00
Tree Mitigation	$ 2,000.00	LS	1	$ 2,000.00	$ -	$ 2,000.00
Excavation and Haul	$ 25.00	CY	6098	$ 152,460.00	$ -	$ 152,460.00
Backslope Drain & Swale	$ 15,246.00	LS	1	$ 15,246.00	$ -	$ 15,246.00
Outfall & Extreme Event Overflow	$ 22,869.00	LS	1	$ 22,869.00	$ -	$ 22,869.00
Intake Pipe	$ 45,738.00	LS	1	$ 45,738.00	$ -	$ 45,738.00
Hydromulch Seeding	$ 5,000.00	AC	1	$ 6,500.00	$ -	$ 6,500.00
Sodding	$ 5.00	SY	450	$ 2,250.00	$ -	$ 2,250.00
Concrete Pilot Channel	$ 12,000.00	LS	1	$ 12,000.00	$ -	$ 12,000.00
Park & Trail						
Mobilization	$ 120,000.00	LS	1	$ 120,000.00	$ -	$ 120,000.00
Traffic Control & Temporary Pavement	$ 5,000.00	LS	1	$ 5,000.00	$ -	$ 5,000.00
SWPPP	$ 15,000.00	LS	1	$ 15,000.00	$ -	$ 15,000.00
Tree Mitigation	$ 65,000.00	LS	1	$ 65,000.00	$ -	$ 65,000.00
Trailhead, Bench, Trash Can, Canopy	$ 185,000.00	EA	5	$ 925,000.00	$ -	$ 925,000.00

Trail	$ 10.50	SF	38400	$ 403,200.00	$ -	$ 403,200.00
SUB TOTAL				$ 42,199,190.00	$ -	$ 42,199,190.00
Risk Assessment Mark-Ups						
Construction Contingency (30%)	$ 12,659,757.00	EA	1	$ 12,659,757.00	$ -	$ 12,659,757.00
SUB TOTAL				$ 12,659,757.00	$ -	$ 12,659,757.00
Soft Costs						
Engineering (Design and Bidding) (15%)	$ 8,228,842.05	EA	1	$ 8,228,842.05	$ -	$ 8,228,842.05
Environmental Investigation and Permitting	$ 3,291,536.82	EA	1	$ 3,291,536.82	$ -	$ 3,291,536.82
Grant Administration (6%)	$ 3,291,536.82	EA	1	$ 3,291,536.82	$ -	$ 3,291,536.82
SUB TOTAL				$ 14,811,915.7	$ -	$ 14,811,915.69
TOTAL				$ 69,670,862.69	$ -	$ 69,670,862.69

1. Identify and explain the annual projected operation and maintenance costs associated with the proposed activities.

Maintenance for the proposed improvements will be supported by the City's Storm Water Func and Dedicated Drainage and Street Renewal Operating Funds. These funds are dedicated to: inspecting, cleaning, and repairing of storm sewers; inspecting, regrading, and desilting of roadside ditches; inspecting, regrading, desilting, mowing, and repairing minor erosion in off-road ditches and detention ponds. Maintenance and Operations funds support minimizing flooding and improving mobility, public safety, and economic vitality.

2. Identify and explain any special engineering activities.

An environmental assessment is required for the project area. Design & construction management services will also be required.

STATE OF TEXAS
MEHRDAD I. TEHRANI
94931
LICENSED
PROFESSIONAL ENGINEER

Seal

Date:	10/6/2020
Phone Number:	2814960066

Signature of Registered Engineer/Architect Responsible For Budget Justification:

TBPE Reg. No. F-761

CDBG-MIT: Budget Justification of Retail Costs
(Former Table 2)

Cost Verification Controls must be in place to assure that construction costs are reasonable and consistent with market costs at the time and place of construction.

Applicant/Subrecipient:	City of Houston					
Site/Activity Title:	Houston Kashmere Gardens Flood Mitigation					
Eligible Activity:	Acquisition					
Materials/Facilities/Services	**$/Unit**	**Unit**	**Quantity**	**Construction**	**Acquisition**	**Total**
DETENTION POND Q						
Pond A	$ -	LS	1	$ -	$ 1,224,000.00	$ 1,224,000.00
Pond C	$ -	LS	1	$ -	$ 818,000.00	$ 818,000.00
Pond F	$ -	LS	1	$ -	$ 773,000.00	$ 773,000.00
Pond K	$ -	LS	1	$ -	$ 130,000.00	$ 130,000.00
Pond N	$ -	LS	1	$ -	$ 680,000.00	$ 680,000.00
SUB TOTAL				$ -	$ 3,625,000.00	$ 3,625,000.00
TOTAL				$ -	$ 3,625,000.00	$ 3,625,000.00

1. Identify and explain the annual projected operation and maintenance costs associated with the proposed activities.

2. Identify and explain any special engineering activities.

STATE OF TEXAS
MEHRDAD I. TEHRANI
94931
LICENSED
PROFESSIONAL ENGINEER

Seal

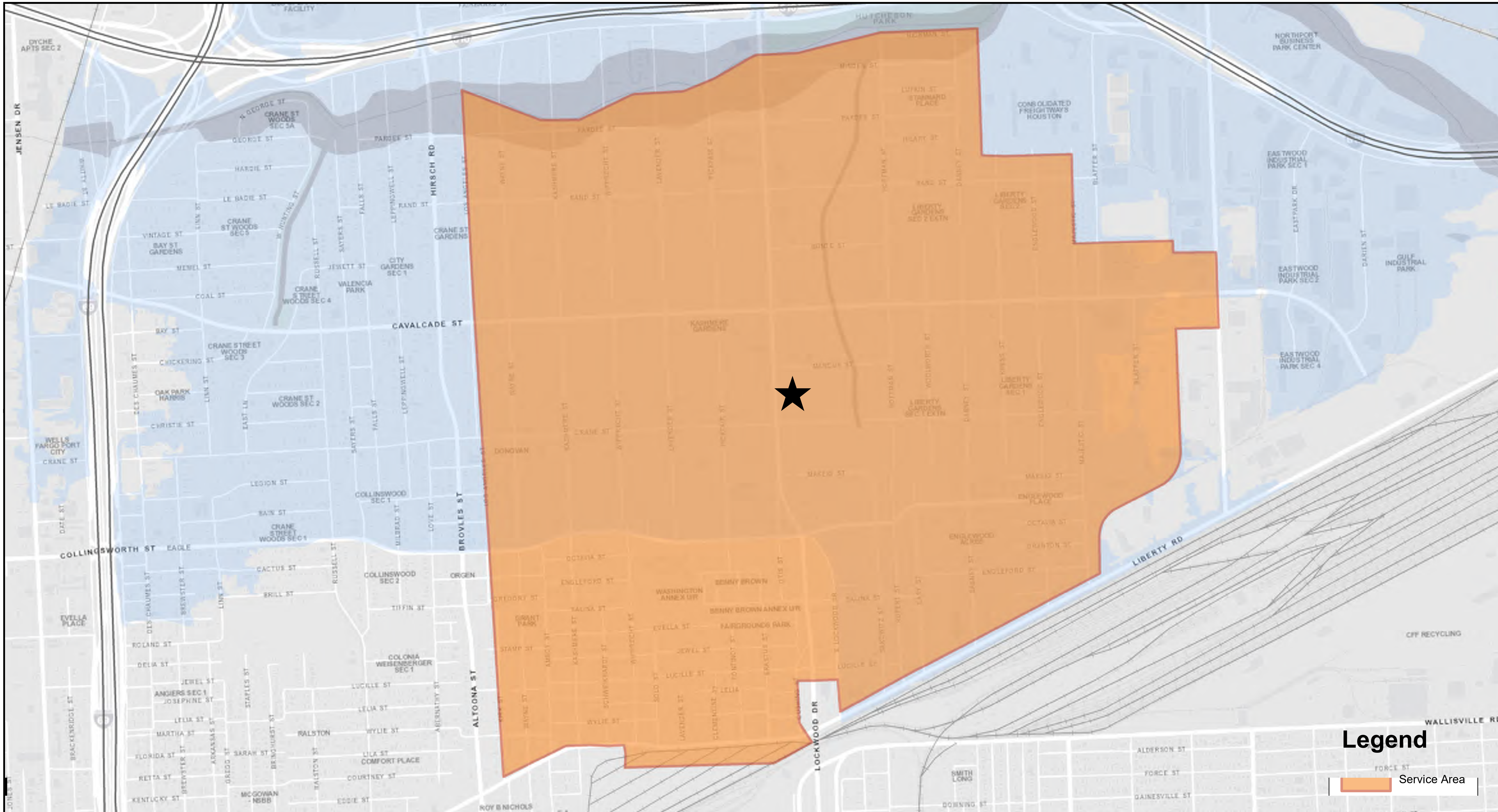
Date:	10/6/2020
Phone Number:	2814960066

Signature of Registered Engineer/Architect Responsible For Budget Justification:

M. Tehrani

TBPE Reg. No. F-761

Houston Kashmere Gardens Area Flood Mitigation - Location Map



★ Latitude: 29.797898
Longitude: -95.316330

Address: 4018 Lockwood Dr
Houston, TX 77026

County: Harris

N

Houston Kashmere Gardens Area Flood Mitigation Project
Benefit-Cost Analysis Report

Prepared for:

CITY OF HOUSTON
PUBLIC WORKS

HUITT-ZOLLARS, INC.
10350 RICHMOND AVE. SUITE 300
HOUSTON, TEXAS 77042-4248
TBPE Reg. No. F-761
(281) 496-0066

October 6, 2020

Study Purpose and Scope

The goal of the “Houston Kashmere Gardens Area Flood Mitigation Project” is to reduce the risks associated with extreme storm events hurricanes/tropical storms in the Kashmere Gardens area. This project will reduce localized and regional flooding by increasing the conveyance capacity in existing drainage systems. Dynamic hydraulic and hydrologic (H&H) modeling was used to identify existing ponding impacts and illustrate the benefits of reduced ponding associated with the proposed drainage improvements.

The target area is located within the historic Kashmere Gardens Area neighborhood which is located just south of North 610 Loop and east of US-59 in Houston, Harris County, TX. The limits of the study area are shown in Exhibit 1. The Kashmere Gardens Area neighborhood drainage infrastructure was constructed beginning in the 1930’s. Harris County Flood Control District (HCFCD) Channel H110-00-00 provides drainage for much of the area, conveying water to Hunting Bayou. The existing drainage system is a mix of curb and gutter and roadside ditch systems and provides less than 2-year level of service (LOS) under Atlas 14 rainfall, with potential structural flooding during a 100-year storm event.

The H&H modeling identified flooding issues under existing conditions, including structural inundation and ponding that impacts safe roadway mobility. The impacts are further validated by other data points including FEMA National Flood Insurance Program (NFIP) data, FEMA Individual Assistance (IA) data, and/or calls for service.

Exhibit 2 presents the proposed drainage improvements in detail. The proposed project will replace and improve existing storm sewers lines, convert some existing roadside ditches to curb and gutter with storm sewers, improve existing roadside ditches and driveway culverts, and replace existing inlets with larger inlets. The proposed improvements will increase the capacity of the existing system, increasing the LOS to 50-year, reduce ponding on street throughout the neighborhood, and reduce flood risk to existing structures. This BCA is based on the proposed drainage improvements benefit on existing structures only.

Data Collection

The following documents and data were obtained and used to guide this study:

- 2018 LiDAR dataset
- Building Footprint GIS shapefile
- COH Technical Memorandum “Kashmere Gardens Area Storm Water Drainage Improvements – Proposed Condition”, prepared by Huitt-Zollars, October 2020.

Methodology

FEMA “Benefit-Cost Calculator” Version V.6.0 and FEMA guidelines and procedures were used to develop this BCA. The BCA determines the future risk reduction benefits for a specific drainage improvement project and compares those benefits to the construction cost for the drainage improvements. The Benefit-Cost Ratio (BCR) is calculated by dividing the estimated benefit for all structures by the proposed improvements’ construction cost.

The 2018 Lidar, building footprint shapefile, limited survey and site visits were used to determine the lowest floor elevation of each building. Buildings that are on piers or are elevated were identified using available data and the lowest floor elevation were adjusted accordingly.

The proposed drainage improvements (see Exhibit 2) were modeled in detail using two-dimensional unsteady modeling using the XPSWMM program. The “Kashmere Gardens Area Storm Water Drainage Improvements – Proposed Condition” Technical Memorandum provide pre-improvements and post-improvement 2-, 10-, 50 and 100-Year water surface elevations and discharge values which were used in this BCA report. The 100-yr ponding limits of existing and proposed condition are shown in Exhibit 3 and Exhibit 4, respectively.

Exhibit 5 presents the location of structures where 100-yr Water Surface Elevation (WSE) is higher than the lowest floor elevation. These Structures will directly benefit from lowering the WSE after the proposed drainage improvements are implemented (Benefited Structures). These Benefitted Structures were utilized to develop the BCA.

BCA Toolkit

The Benefitted Structures are mainly residential with each structure is identified by the latitude and longitude at its centroid.

The mitigation action and project cost are based on drainage improvements identified in the “Kashmere Gardens Area Storm Water Drainage Improvements – Proposed Condition” Technical Memorandum.

The values for Hazard Probability Parameters (flood) such as discharge and water surface elevation, for storm events with a recurrence interval of 2-, 10-, 50 and 100-Year were used from “Kashmere Gardens Area Storm Water Drainage Improvements – Proposed Condition” Technical Memorandum.

The BCA toolkit’s default values and standard processes were used to calculate the standard building benefit. Only values for the first floor of each structure were used (one story), with no basement. Standard benefit for each building is calculated using the first floor square footage multiply by the default building replacement value.

In the BCA, tt was assumed that utilities are not elevated. The BCA toolkit’s default values for contents and displacement were used. No volunteer, ecosystem services, or social benefits were used in these calculations.

The total drainage improvement cost were distributed between all benefitted structures uniformly, resulting in similar BCR value for consistency.

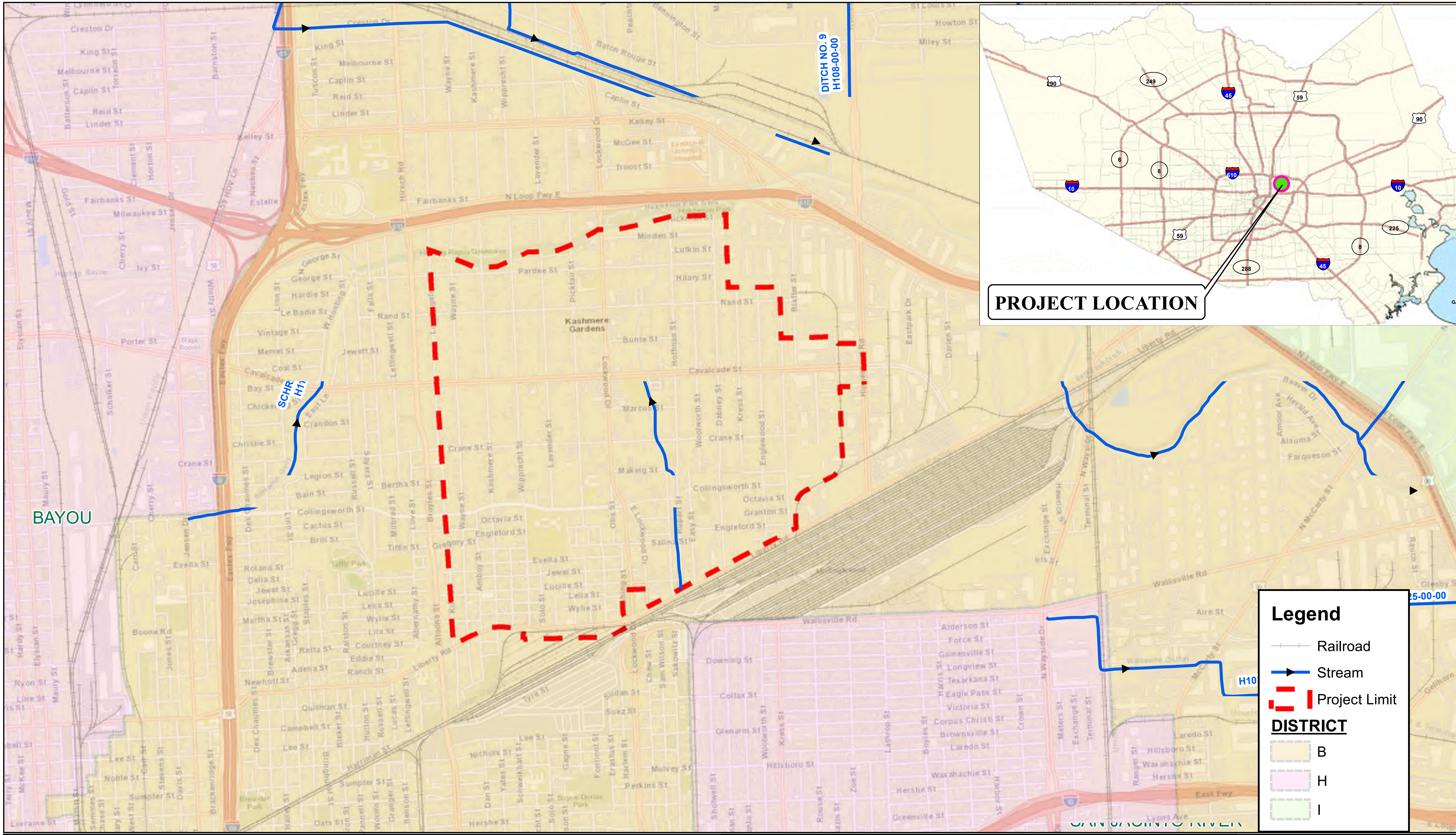
The total project cost and benefit are the summation of all the structures' costs and benefits. The total BCR is presented in **Table 1**. The detail of each structure BCR calculation is provided in **Attachment 1**.

Table 1. Total Benefit-Cost Ratio

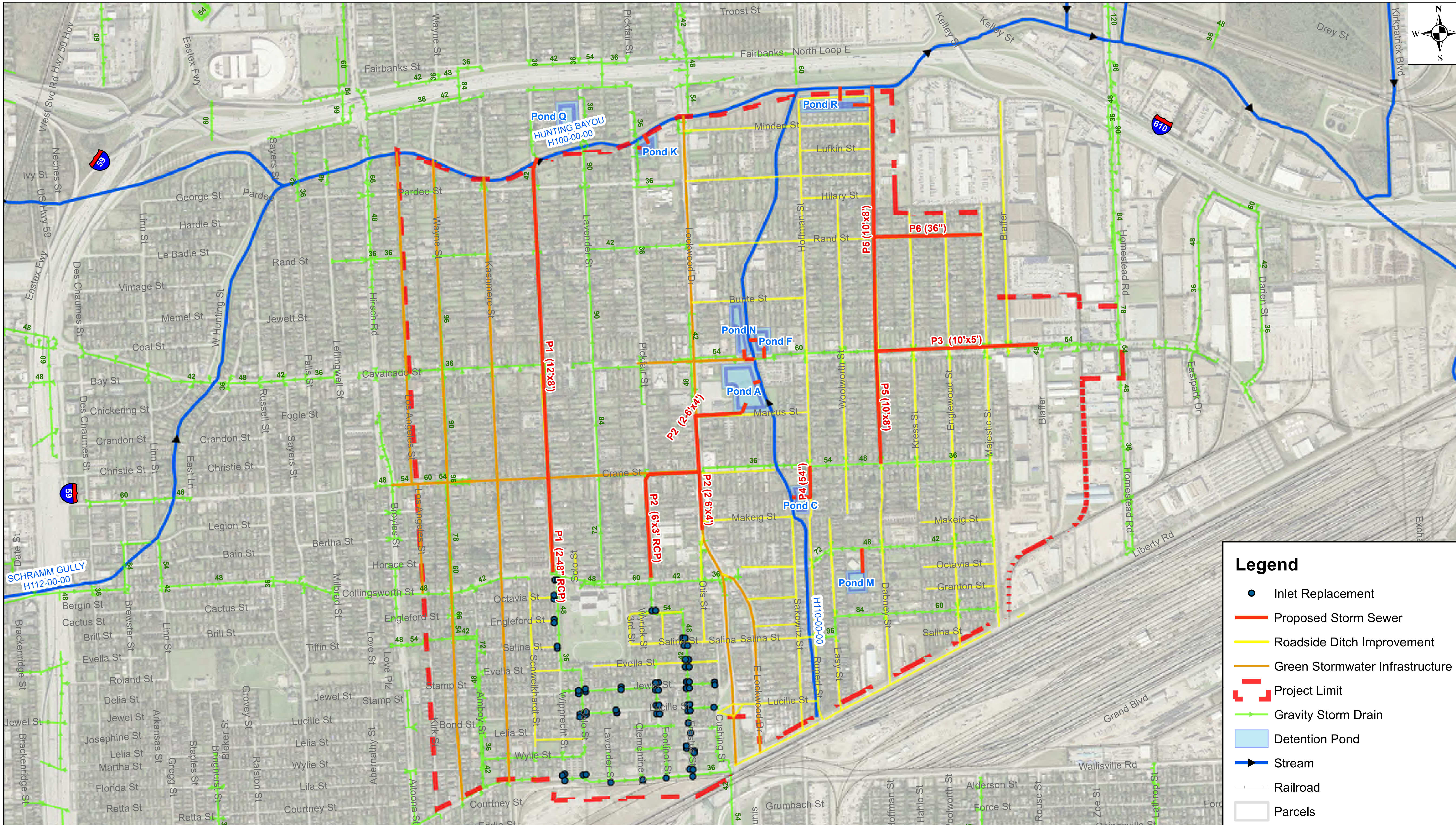
Total Benefit ($)	Total Cost ($)	Total BCR (-)
$103,849,955	$94,879,859	1.09

Conclusion

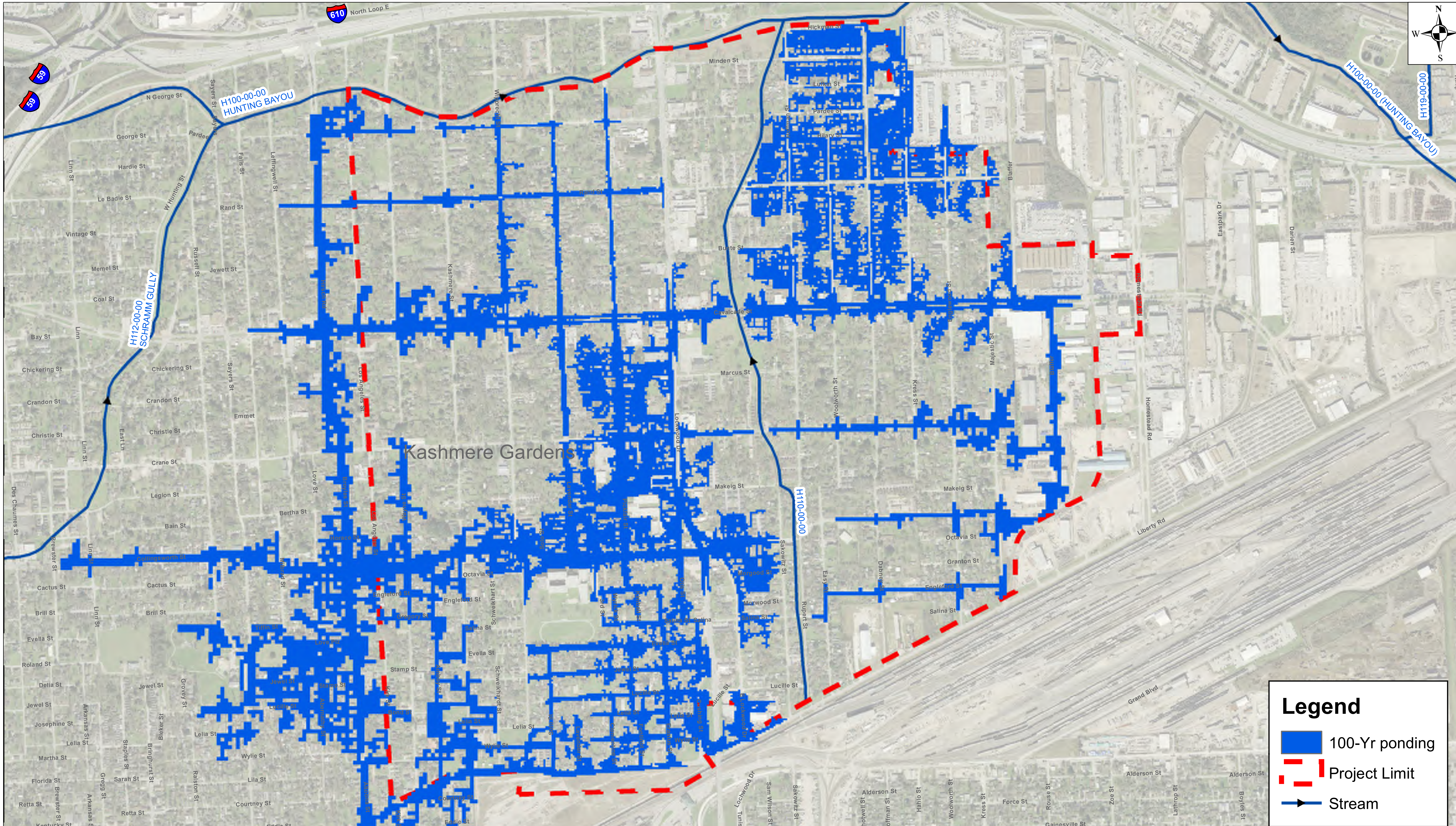
The "Houston Kashmere Gardens Area Flood Mitigation Project" has a benefit-cost ratio greater than 1.



PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	DATE	SCALE	EXHIBIT 1
	OCTOBER 2020	0 1,000 2,000 Feet	LOCATION MAP



HUITT-ZOLLARS HUITT-ZOLLARS, INC. Firm No. F-761 10350 Richmond Avenue, Suite 300 Houston, TX 77042 Phone 281.496.0066 Fax 713.496.0220	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	EXHIBIT 2
			OCTOBER 2020	0 500 1,000 2,000 Feet	RECOMMENDED IMPROVEMENT

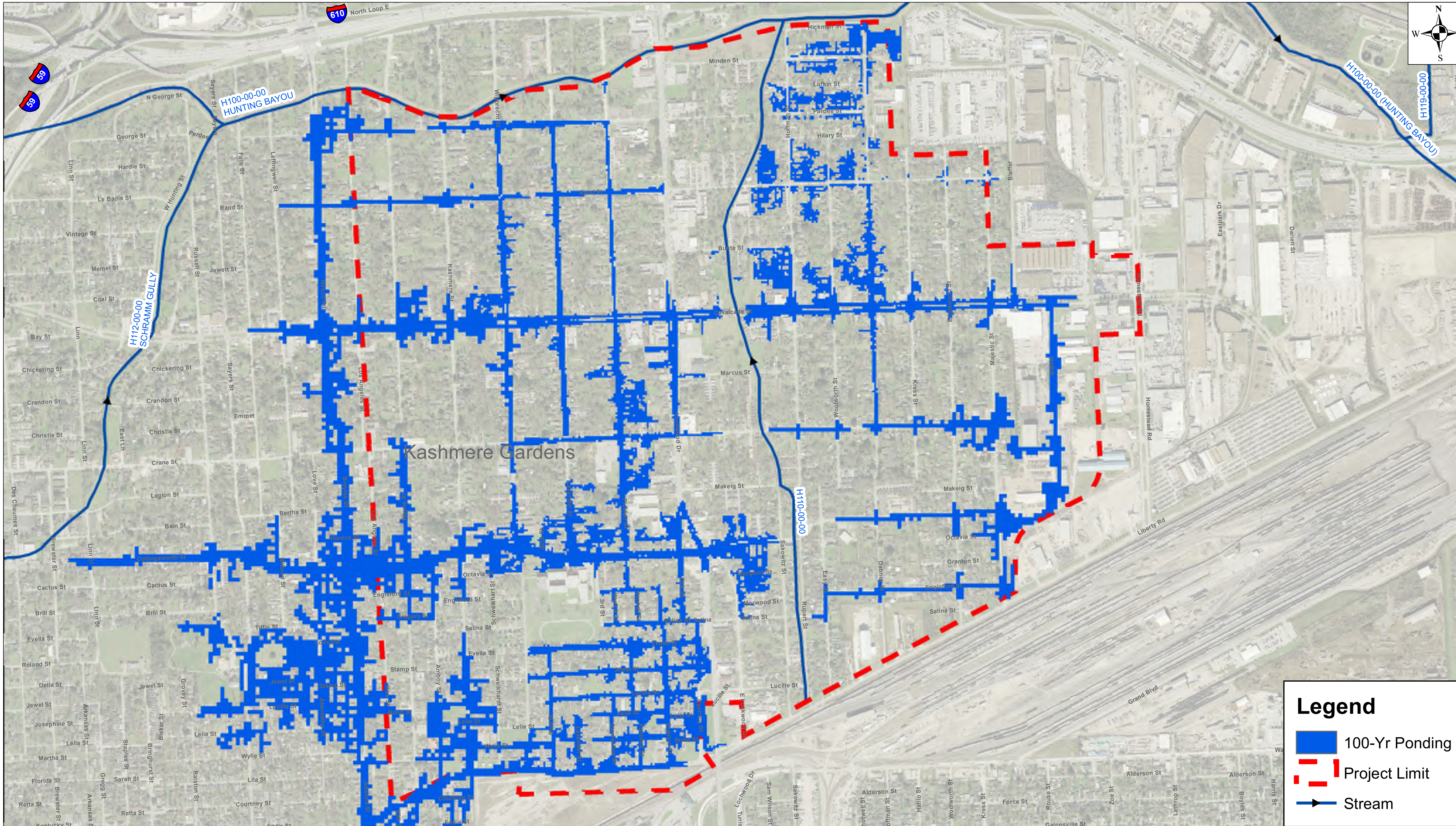


HUITT-ZOLLARS

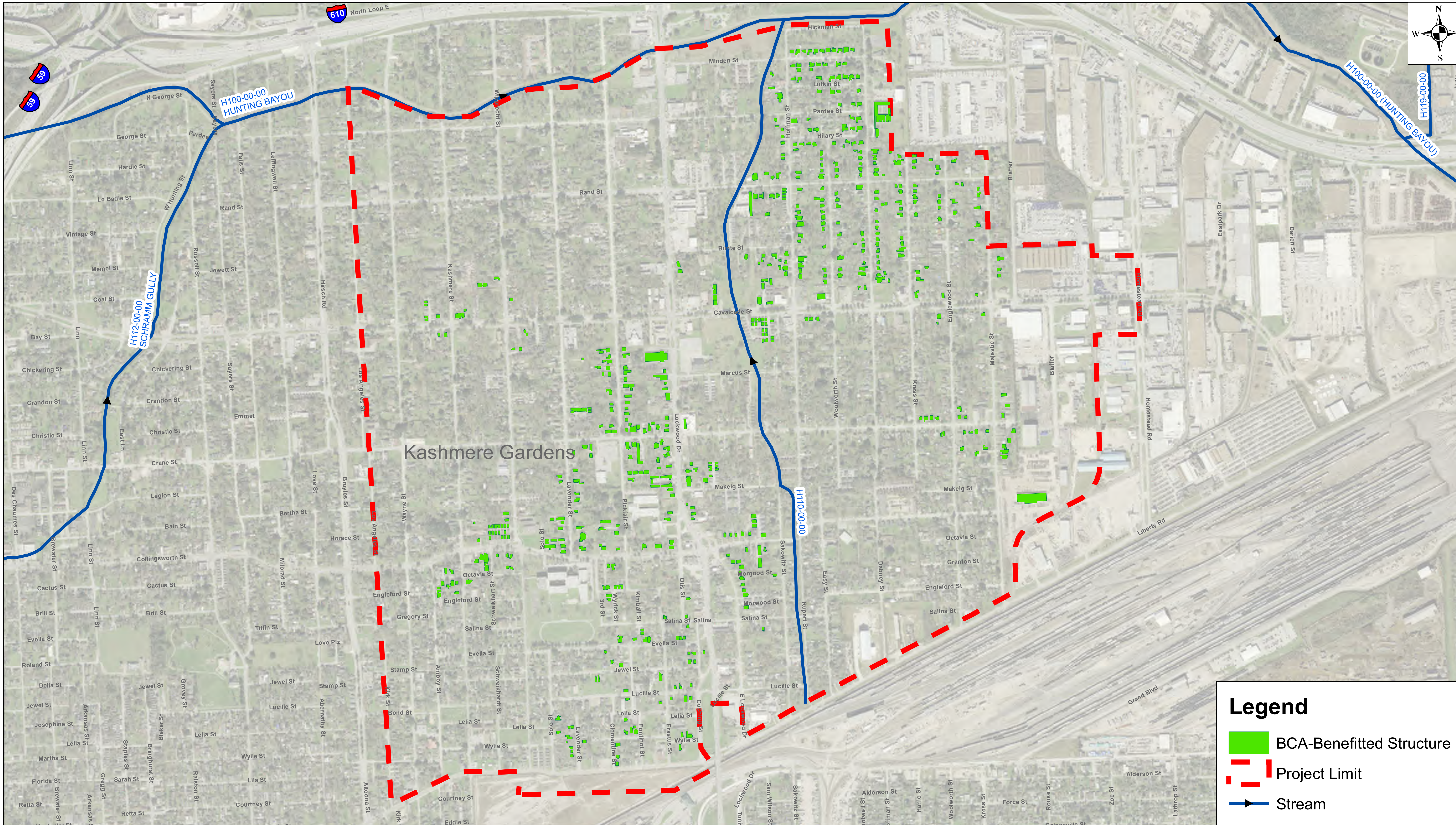
HUITT-ZOLLARS, INC. Firm No. F-761
10350 Richmond Avenue, Suite 300 Houston, TX 77042
Phone 281.496.0066 Fax 713.496.0220

PRE-ENGINEERING SERVICES
OF STORM WATER DRAINAGE IMPROVEMENTS
WBS: NO. M-430100-0020-3
WO NO.3
(KASHMERE GARDENS)

DATE	SCALE	EXHIBIT 3
OCTOBER 2020	0 500 1,000 2,000 Feet	100-YR PONDING LIMITS EXISTING CONDITION



HUITT-ZOLLARS HUITT-ZOLLARS, INC. Firm No. F-761 10350 Richmond Avenue, Suite 300 Houston, TX 77042 Phone 281.496.0066 Fax 713.496.0220	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE	SCALE	EXHIBIT 4
			OCTOBER 2020	0 500 1,000 2,000 Feet	100-YR PONDING LIMITS PROPOSED CONDITION



HUITT-ZOLLARS HUITT-ZOLLARS, INC. Firm No. F-761 10350 Richmond Avenue, Suite 300 Houston, TX 77042 Phone 281.496.0066 Fax 713.496.0220	PRE-ENGINEERING SERVICES OF STORM WATER DRAINAGE IMPROVEMENTS WBS: NO. M-430100-0020-3 WO NO.3 (KASHMERE GARDENS)	CITY OF HOUSTON TEXAS	DATE OCTOBER 2020	SCALE 0 500 1,000 2,000 Feet	EXHIBIT 5 BENEFIT-COST ANALYSIS BENEFITTED STRUCTURES

Attachment 1

Note: Due to the high number of benefitted structures and BCA Toolkit's limit, the BCR calculation is split into 6 excel files as listed below:

- Group 1
- Group 2
- Group 3
- Group 4
- Group 5
- Group 6

Appendix 5-4H:
City of Houston Sunnyside Area Flood Mitigation

Memo

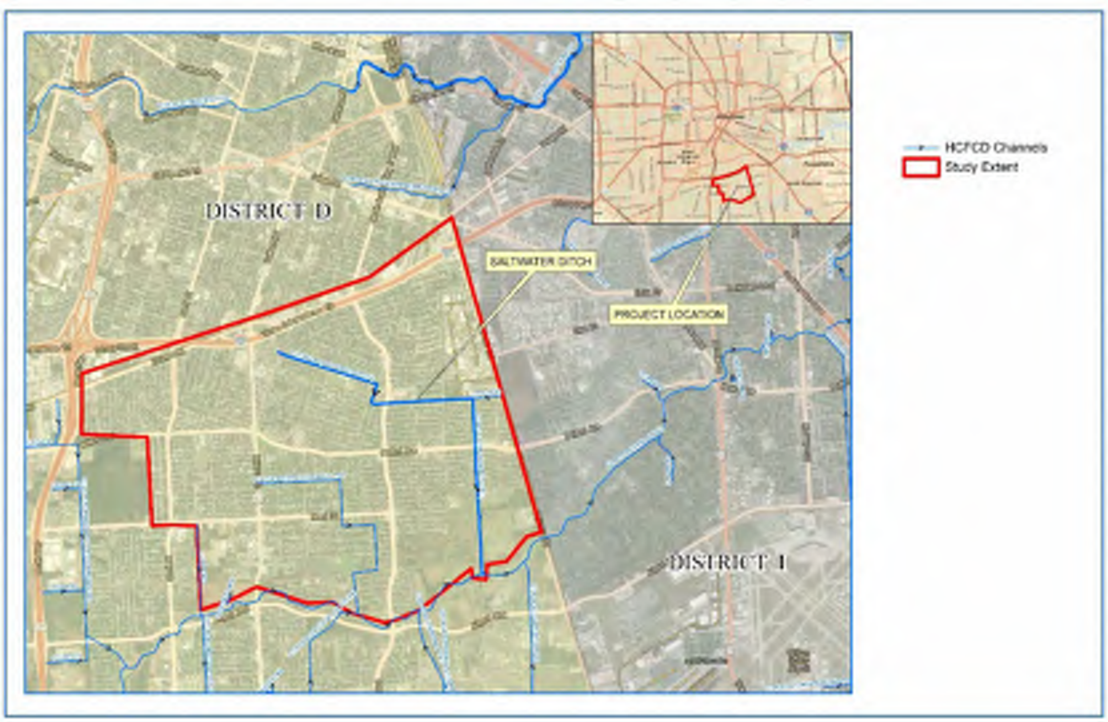
Date:	Monday, April 06, 2020
Project:	City of Houston Drainage Pre-Engineering Services for Storm Water Improvements Work Order # 9 – South Park/Salt Water Ditch Drainage Analysis
To:	Adam Eaton, PE
From:	Jeremy Blevins, PE, CFM
Subject:	Existing Conditions Technical Memorandum

We are writing you to provide the results of the existing conditions analysis of the Salt Water Ditch drainage areas. The following paragraphs provide background information on the project area, describe the methodologies used in the analysis, and summarize the results of the existing conditions analysis.

Data Collection

The South Park neighborhood includes approximately 5,000 acres of development within the southern portion of the City of Houston. The project area is roughly bounded by Loop 610 South on the north, State Highway 288 on the west, Mykawa Road on the east and Sims Bayou on the south. The entire project area is located within City Council District D. Figure 1 below provides a vicinity map of the project area.

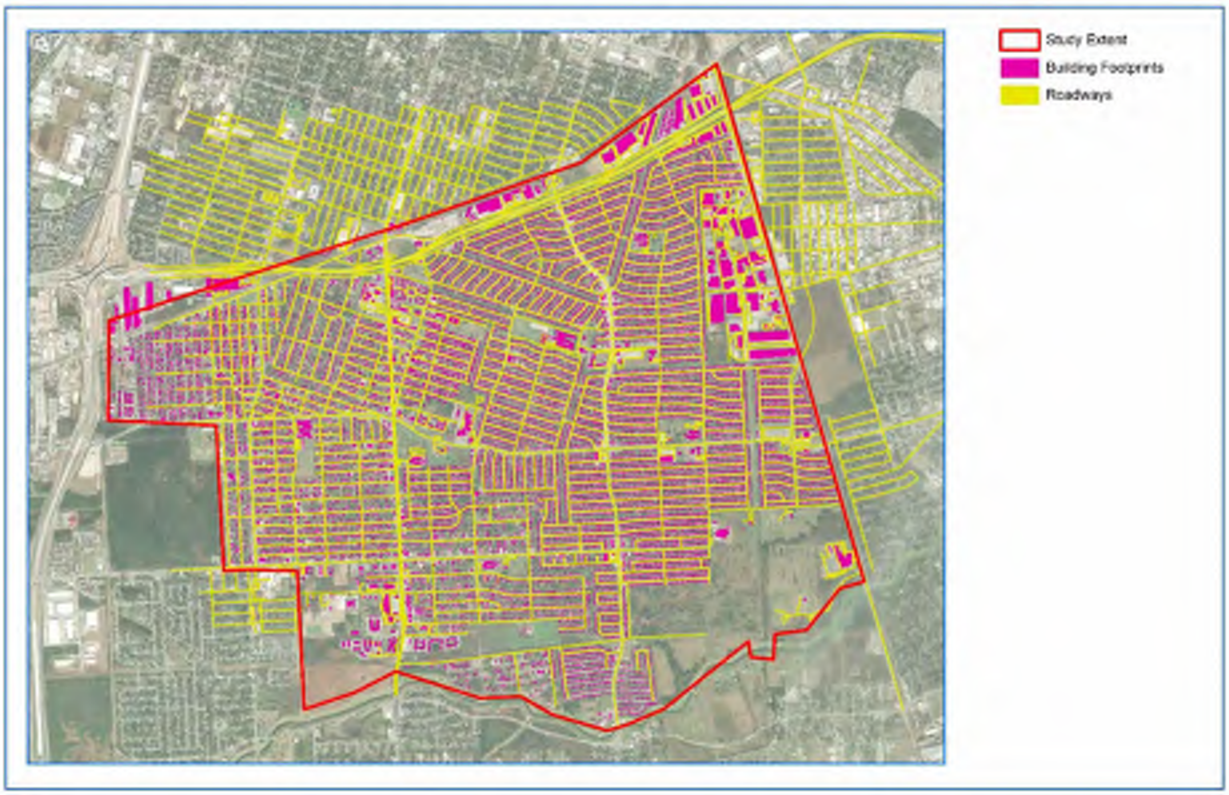
Figure 1: Vicinity Map



A large majority of the project area is located within the Sims Bayou watershed, while a small portion of the area drains to the Loop 610 drainage system and thence to HCFCD Unit D105-00-00 and ultimately Brays Bayou. The portion of the project area within the Sims Bayou watershed is drained via underground storm sewer or roadside ditches to one of three tributaries of Sims Bayou: 1) HCFCD Unit C118-00-00 (Salt Water Ditch); 2) HCFCD Unit C122-00-00; and 3) HCFCD Unit C128-00-00.

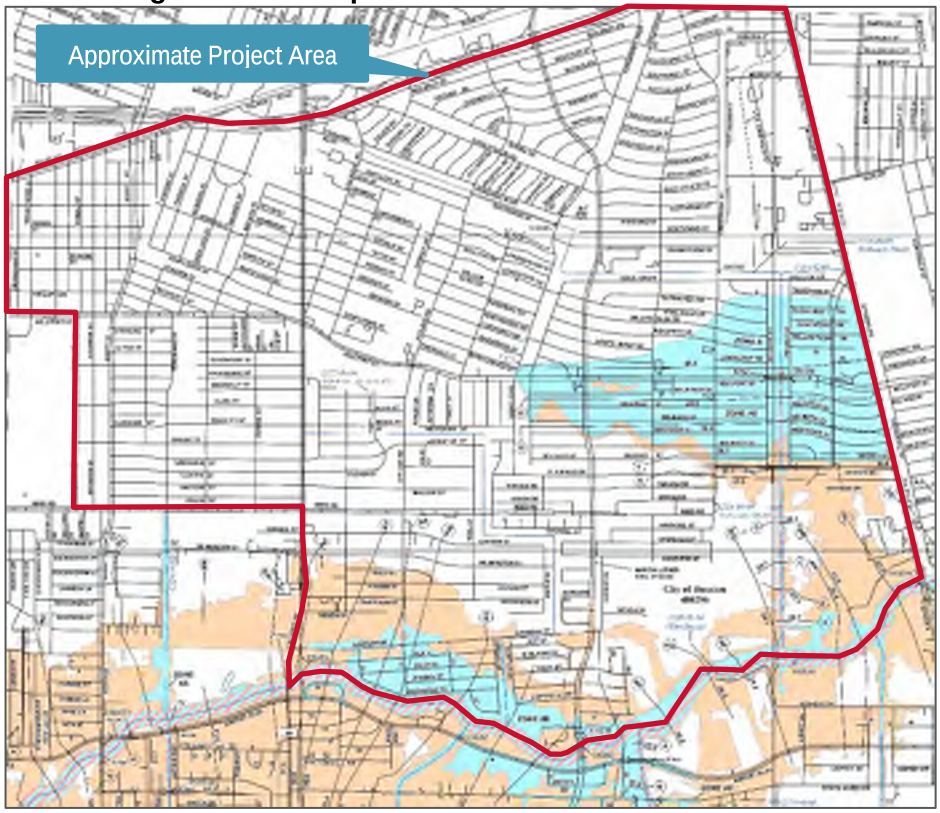
The South Park neighborhood is mainly single-family residential development with some commercial development along major thoroughfares and with local schools located within the project area. Figure 2 below provides a map of land use used in the existing conditions models within the project area.

Figure 2 - Land Use Map for XP-SWMM Model



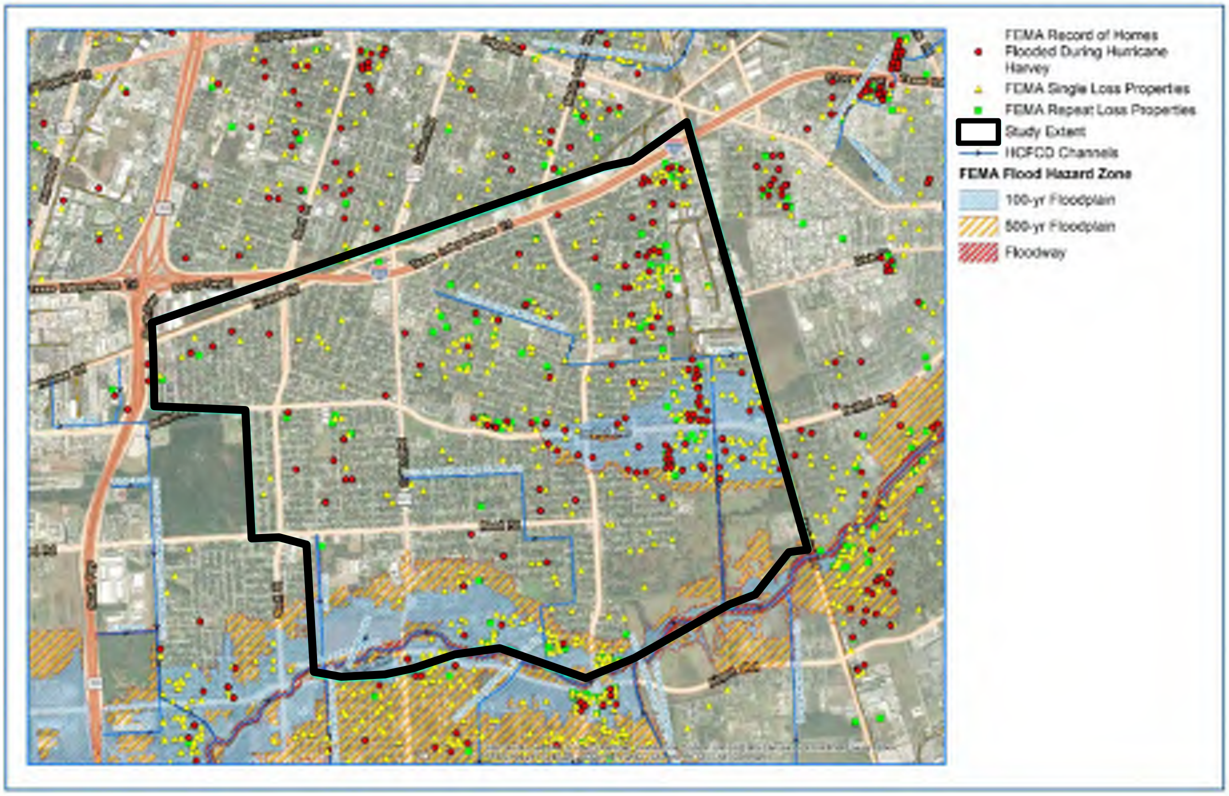
Most of the project area is located outside of the FEMA effective floodplain based on Flood Insurance Rate Map Panel No. 48201C0890M dated May 2, 2019. Figure 3 below provides a snapshot of the referenced FIRM panel. The limit of detailed study of HCFCD Unit C118-00-00 ends just upstream of Bellfort St., and a large area upstream of this limit is designated as Zone A (Approximate Floodplain). HCFCD Units C122-00-00 and C128-00-00 are both unstudied tributaries of Sims Bayou.

Figure 3 – Excerpt from FIRM Panel 48201C0890M



Significant structural flooding has occurred throughout the project area, as documented via FEMA flood insurance claims. The most significant historical structural flooding occurred during Hurricane Harvey. Figure 4 provides a map of FEMA flood insurance claims, including single loss and repetitive loss properties. While there have been significant numbers of flood insurance claims, it is not indicative of the total number of flooded structures, as this neighborhood is relatively low income with many structures likely not having flood insurance policies.

Figure 4 - FEMA Flood Claims



The topography of the project area is relatively flat with land sloping to the south and southeast, which is typical for the Houston area. A large majority of the project area drains to tributary channels including HCFCD Units C118-00-00, C122-00-00, and C128-00-00. Those tributaries drain to Sims Bayou. The northeast portion of the project area drains to an enclosed storm sewer system along Loop 610, which in turn drains to Brays Bayou.

The 2018 LIDAR was obtained from the Houston-Galveston Area Council, which is shown below in Figure 5 as a color-shaded topographic map with red representing higher elevations and green representing lower elevations. Gray shading represents areas that have been significantly elevated via fill, such as highway embankments and landfills. The 2018 LIDAR data was processed using the ArcHydro extension of ArcGIS in order to delineate overland flow patterns and sub-drainage areas within the project area. Those drainage areas and flow paths are shown below on Figure 6.

Figure 5 - Shaded Topographic Data (2018 H-GAC)

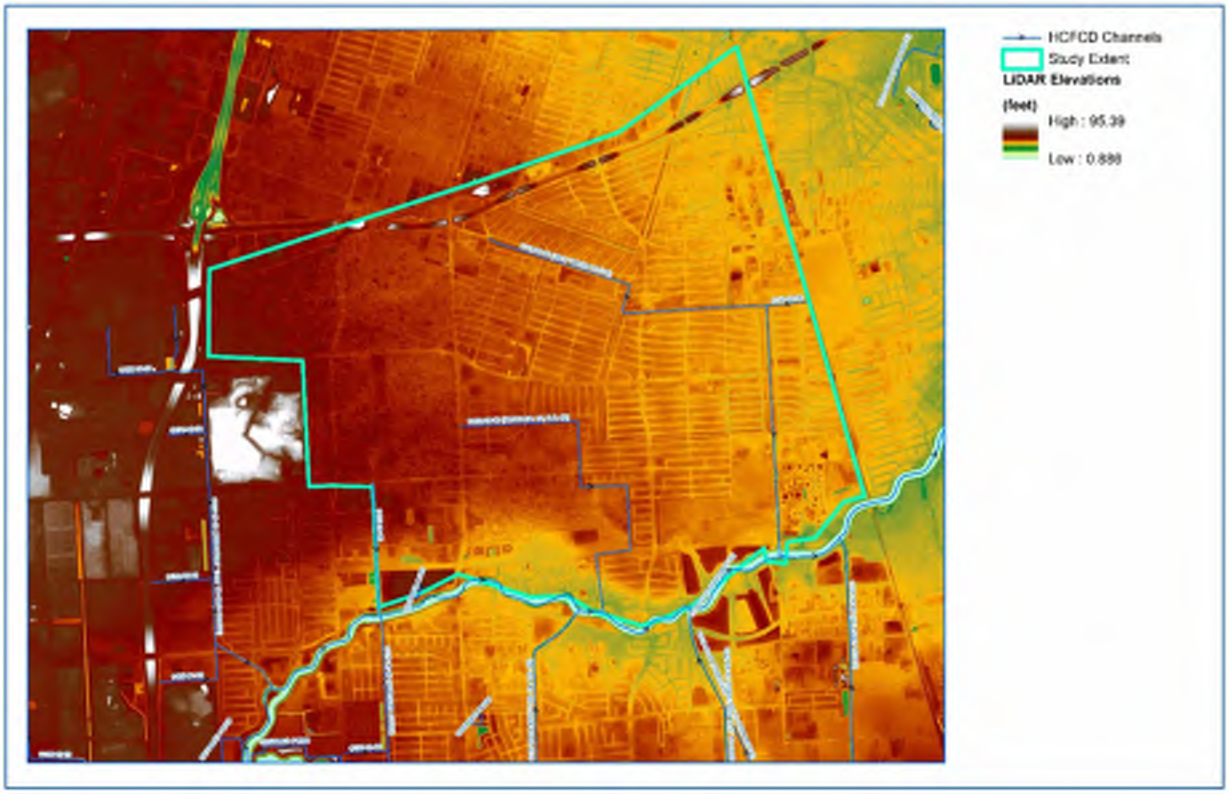
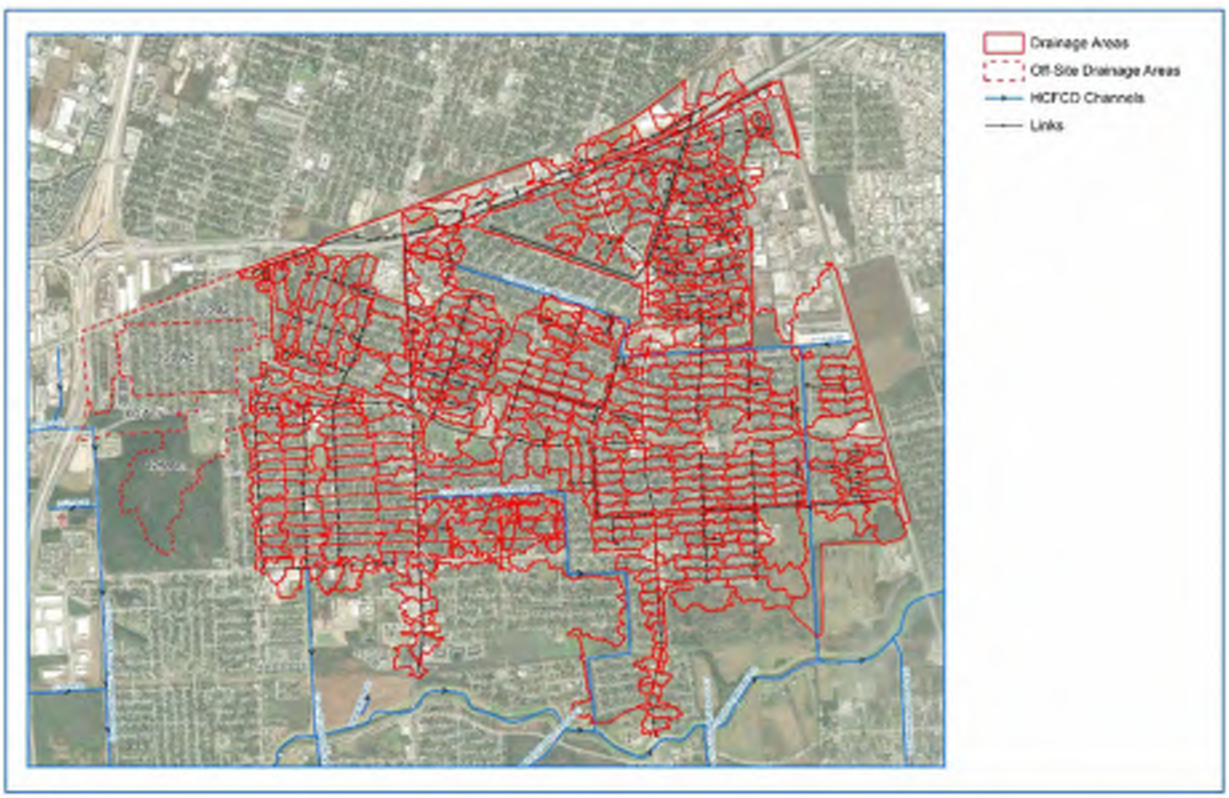
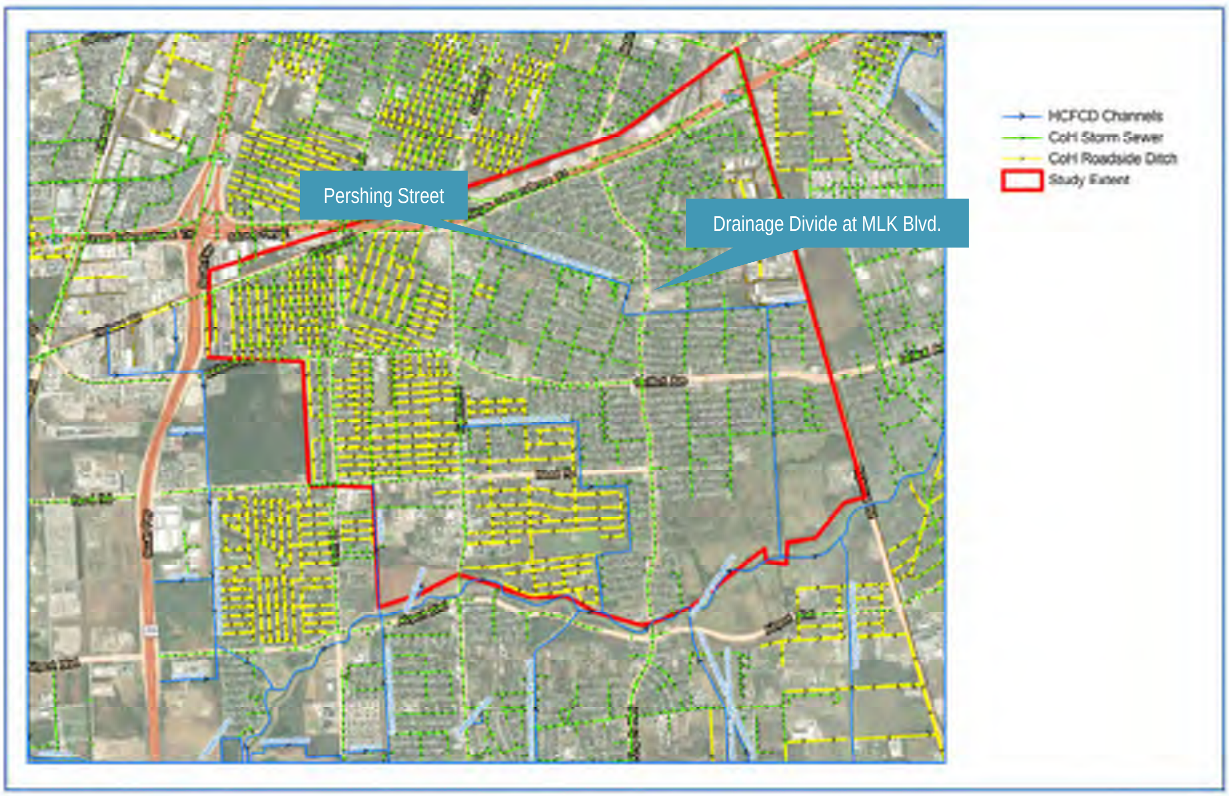


Figure 6 - Drainage Areas & Flow Paths



Existing storm sewer data was obtained from the City of Houston GIMS data, record drawings, and field visits. City of Houston GIMS data was inconclusive in the area near the drainage divide for the system that drains to Brays Bayou, and field visits were completed to verify that the system draining to Loop 610 is not interconnected with the system draining to Salt Water Ditch near the intersection of Martin Luther King Boulevard and Van Fleet Street. Likewise, City of Houston GIMS data indicated that there were multiple outfalls between residential structures draining from Pershing Street into the upstream portion of Salt Water Ditch west of Martin Luther King Boulevard, and field visits were completed to identify if those structures were in place and if they were functioning as designed. According to GIMS data, approximately 12 side-lot outfalls drain from Pershing Street to Salt Water ditch; however, only 3 of those outfalls were located in the field. Drainage boundaries were adjusted as required based on field observations. Figure 7 below provides an overview of the drainage infrastructure within the project area.

Figure 7 - City of Houston GIMS Data



As shown a large portion of the project area is drained via underground storm sewers, and the western portion of the project area is drained via a combination of storm sewer trunk lines and roadside ditches.

Existing Conditions Analysis

In order to assess the risk of structural flooding within the project area, the City of Houston tasked HDR and its subconsultant, HT&J, LLC, with building an existing conditions hydrology and hydraulic model of the project area. Time of Concentration (Tc) was calculated using the

City of Houston method, **TC = 10A$^{0.1761}$ + 15**, where A is the area of the individual drainage sub-basin. The peak flow was calculated using the Rational Method, where the rainfall intensity was calculated using the City of Houston (Harris County) b, d, and e factors developed to reflect Atlas 14 rainfall.

The NOAA Atlas 14 rainfall data was applied with global rainfall in XPSWMM for all the scenarios and the storm events. The Clark unit hydrograph method was used to transform the rainfall into runoff. Since the drainage area for each sub-basin varies and is typically less than 20 acres, the peak flow calculated using the rational method was considered reasonable and appropriate for the individual sub-basins. Thus calculated peak flow was used to develop the hydrology for the XPSWMM model. The Clark unit hydrograph method requires Tc and storage coefficient (R). The TC calculated using the above equation was used and the storage coefficient (R) was adjusted to calibrate the peak flow of each drainage area to match the flow calculated with the Rational Method.

Several iterations were made to minimize any discrepancies in the peak flows calculated using rational method and the peak flow generated in XPSWMM for each sub-basin, and difference was limited within a percentage point.

An XP-SWMM model was built based on as-built drawings and GIMS data. Elevation data for the storm sewer was adapted from 2018 LIDAR data and record drawings. Upon inspection of multiple sets of record drawings and a comparison of corresponding vertical datums, it was determined that there was a wide variance in vertical datum adjustments to the Geoid 12B datum upon which the 2018 LIDAR is based. Because of this, depths to pipe inverts were measured from the record drawings and subtracted from elevations obtained from the 2018 LIDAR throughout the project area in order to establish the elevations of the storm sewers in the existing conditions XP-SWMM model.

Nodes and links were inserted into the model to simulate the existing storm sewer system and manholes. Inlets and inlet leads were not included in the model in order to simplify the model. Runoff hydrographs were inserted into the model at nodes based on the drainage area delineation. The model was run for the 2-year (50% annual chance), 10-year (10% annual chance), 50-year (2% annual chance), and 100-year (1% annual chance) storm events. The model results are shown below on Figures 8 through 14 for the 2-year, 10-year, 50-year, and 100-year storm events.

Figure 8 - 2-Year Storm Event Ponding Map

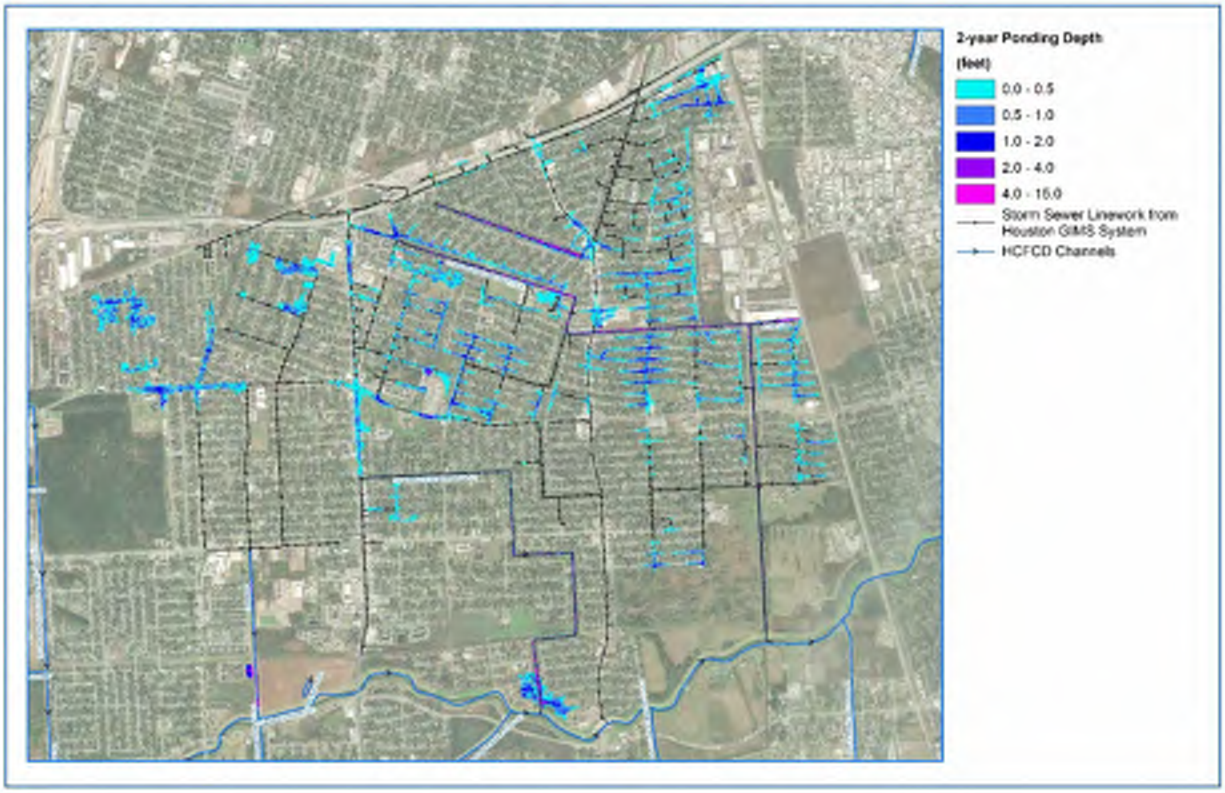


Figure 9 - 10-Year Storm Ponding Results

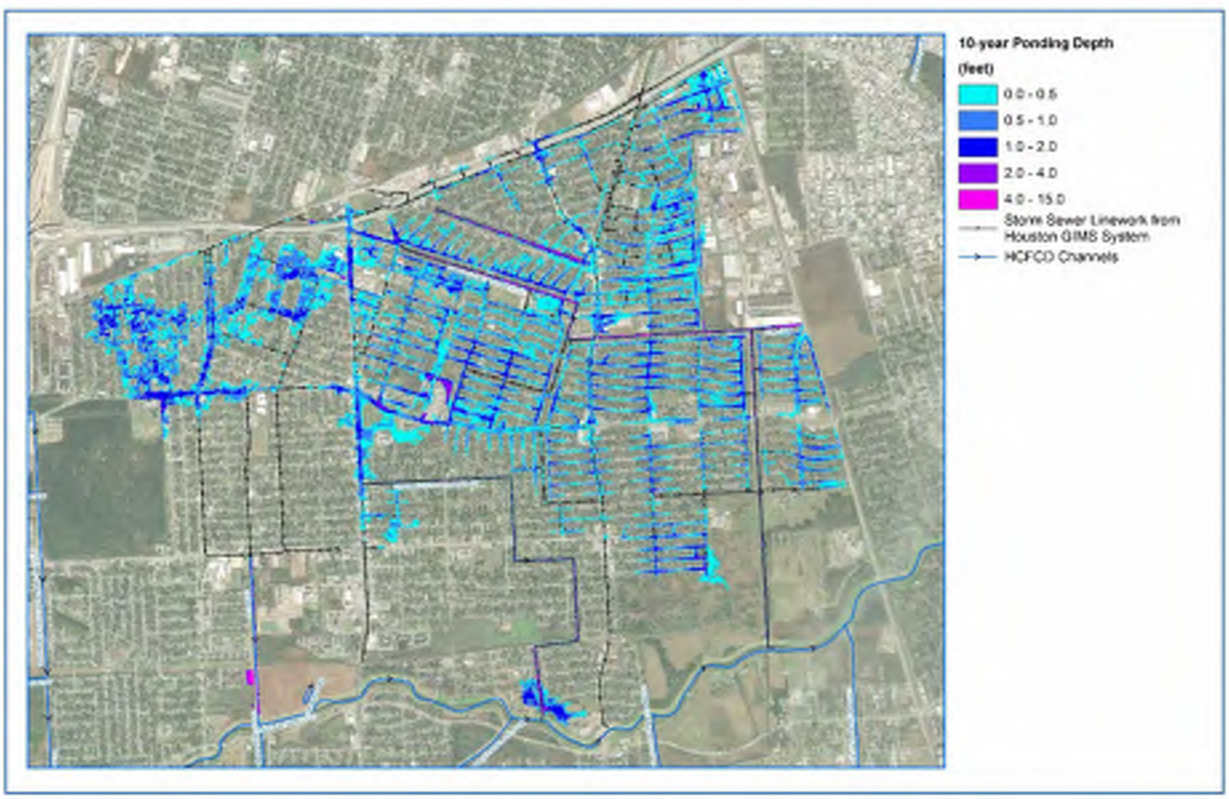


Figure 10 - 50-Year Ponding Results

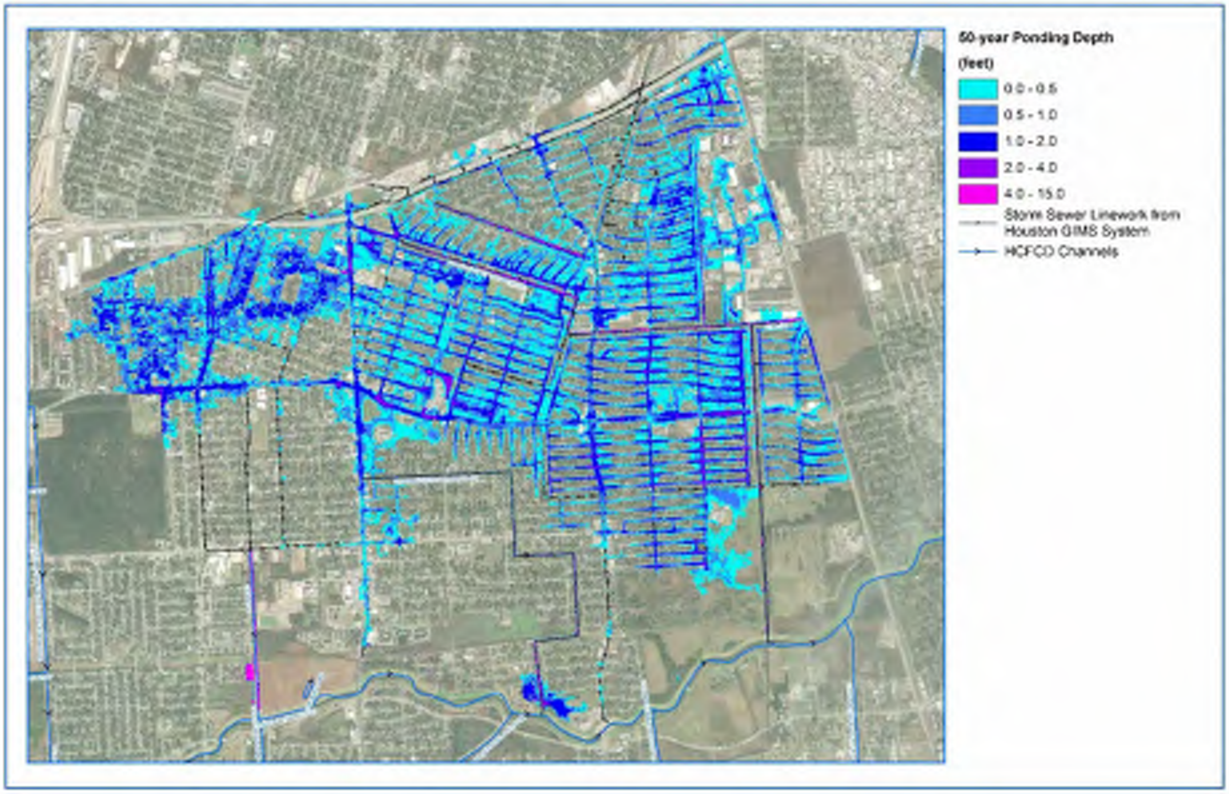


Figure 11 - 100-Year Ponding Results - NW Quadrant

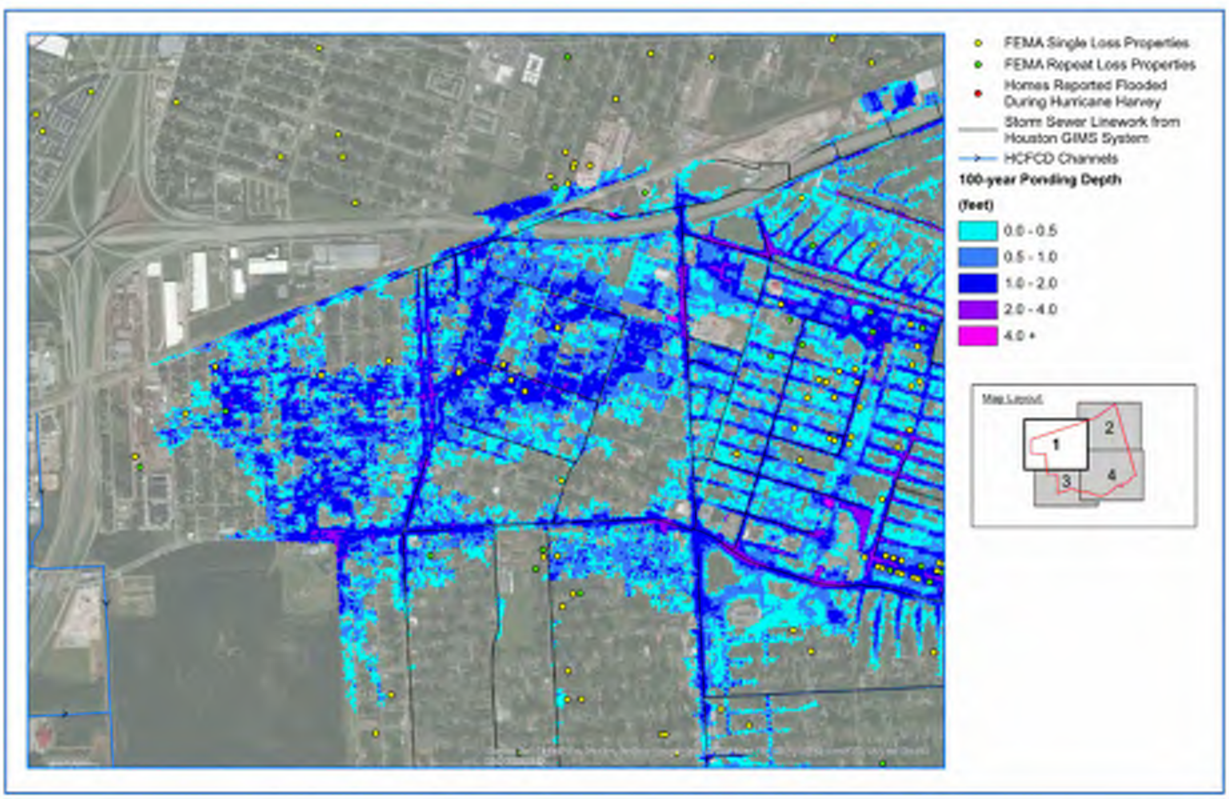


Figure 12 - 100-Year Ponding Results - NE Quadrant

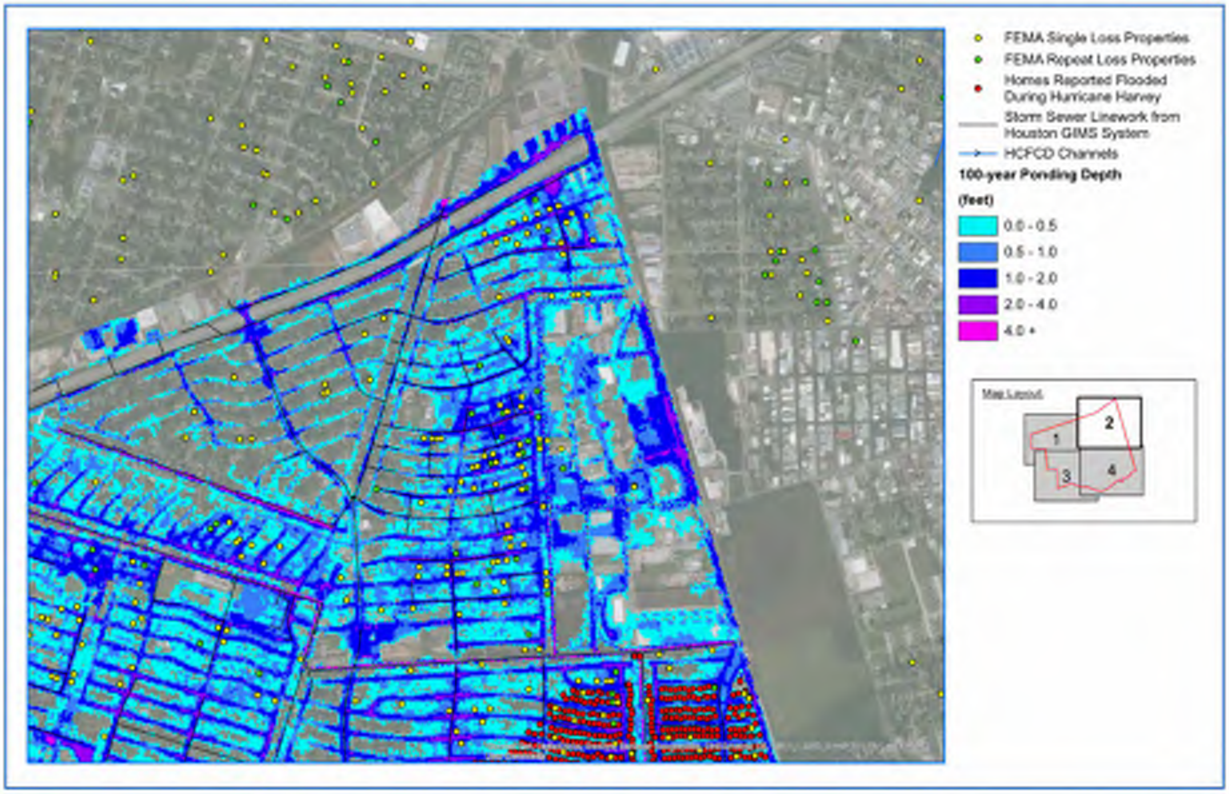


Figure 13 - 100-Year Ponding Results - SW Quadrant

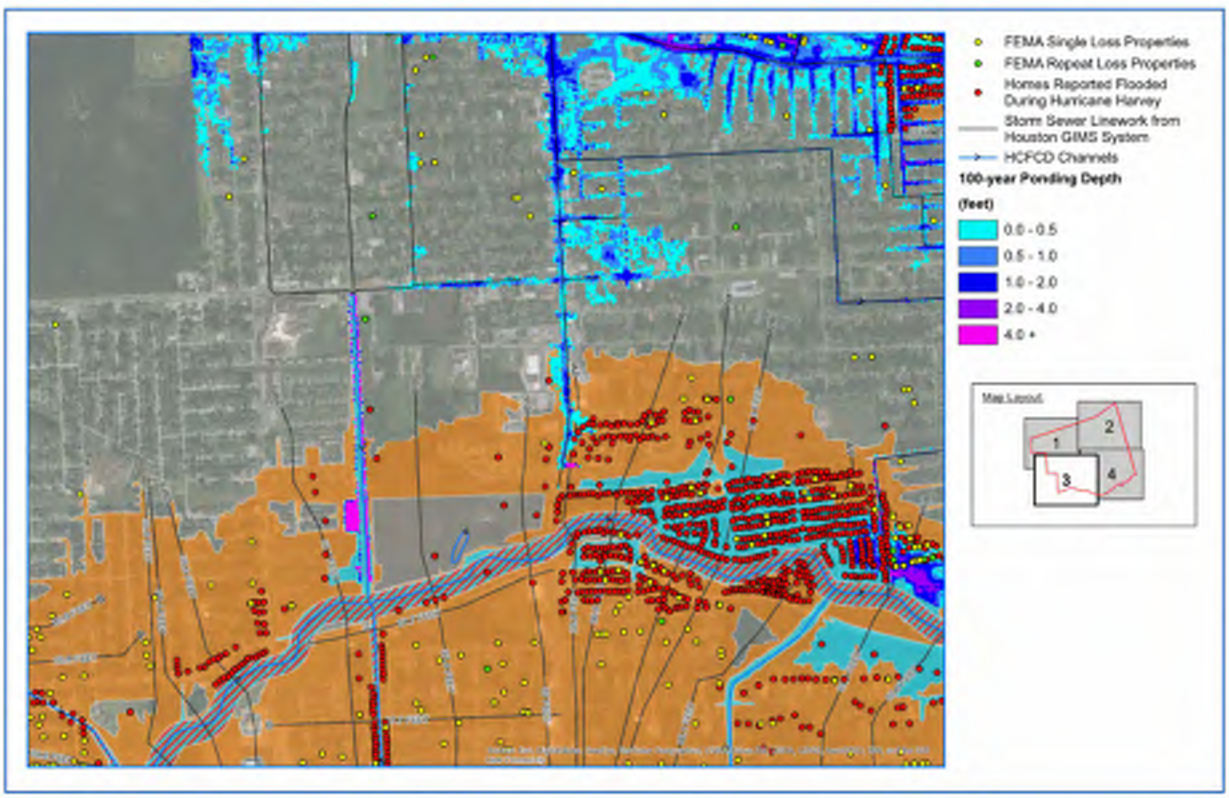
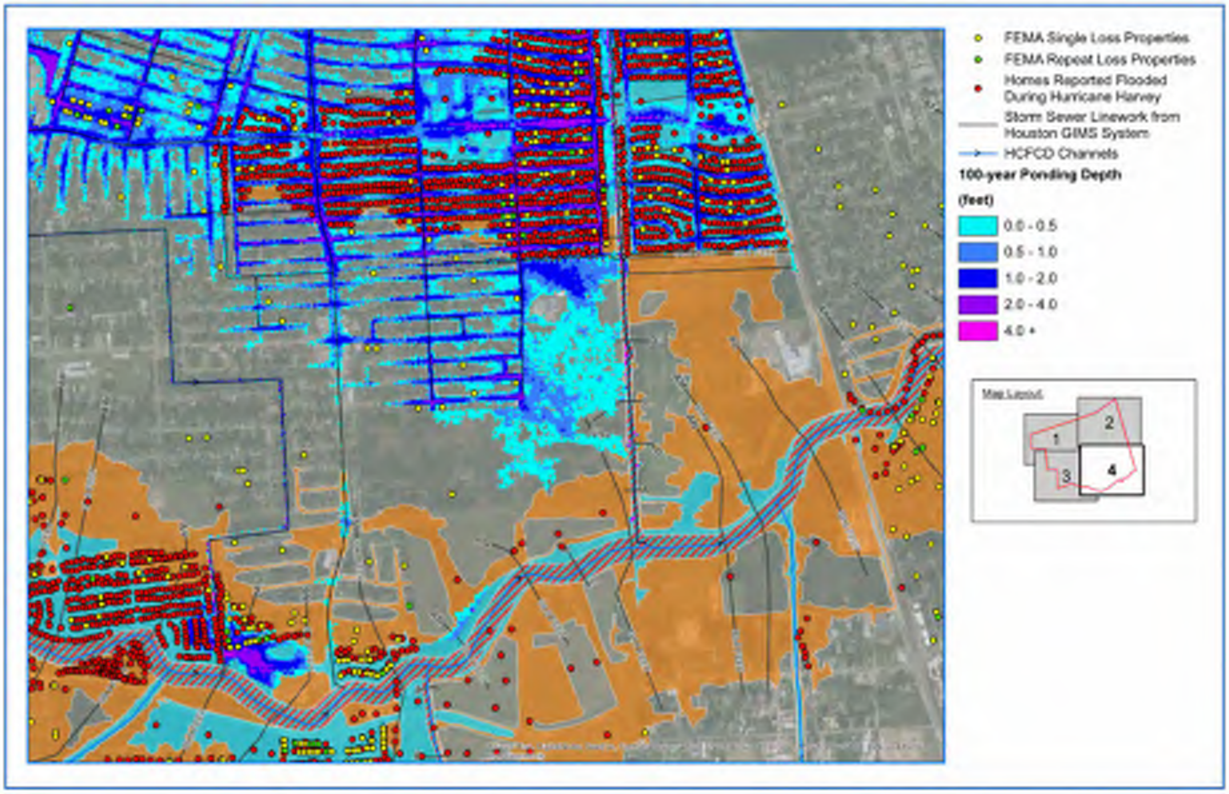


Figure 14 - 100-Year Ponding Results - SE Quadrant



As shown in Figure 8, there is significant street flooding and ponding in multiple areas during a 2-year storm event, which signifies that the existing drainage infrastructure does not satisfy current City of Houston criteria for NOAA Atlas 14. As shown in Figures 9 and 10, structural flooding is anticipated for storm events ranging from the 10-year to 50-year storm event. Figures 11 through 14 show that the City of Houston extreme event drainage criteria are not satisfied, as the 100-year ponding level is not contained within the City rights-of-way, and a significant level of structural flooding is expected. The 100-year storm event was compared with structural flooding from Hurricane Harvey to validate the results of the model, as shown in Figures 10 through 14. Based on the flooding records from Hurricane Harvey and multiple storm event analysis, structural flooding appears to be caused by a combination of riverine flooding along Salt Water Ditch and limited storm sewer capacity within the South Park neighborhood.

Conclusion

Based on the results of this analysis, we have developed a series of improvements which may reduce the risk of structural flooding within the project area. Those improvements are listed below and are recommended for additional study.

- Incorporate channel improvements and new channel enclosure as recommended by the Harris County Engineering Department study on Salt Water Ditch.
- Improve the storm sewer network and associated outfalls along Pershing Street.

- Improve the storm sewer trunk line along Southbank and the associated laterals north and south of Salt Water Ditch.
- Improve the storm sewer trunk line along Crestmont Street and the associated laterals north and south of Salt Water Ditch.
- Improve the storm sewer systems on Willow Glen Drive and South Wayside Drive.
- Improve the storm sewer systems on Belmark Street and South Wayside Drive.
- Incorporate the improvements included in the City's project along Comal Street and Brandon Street.
- Improve the outfall at Scott Street and Holmes Road.
- Improve the storm sewer trunk line along Scott Street that outfalls to C118-03-00.
- Improve the storm sewer trunk line system along McLean Street north of C118-03-00.
- Improve the storm sewer trunk line system along Cullen Boulevard north of C122-00-00.
- Determine the detention volume needed to mitigate improvements and investigate inline detention opportunities beneath Martin Luther King Boulevard. Evaluate interconnectivity between Martin Luther King Boulevard and Salt Water Ditch.
- Identify and investigate opportunities to implement green infrastructure and low impact development (LID) opportunities associated with the proposed improvements, including above-ground detention sites.
- Identify and investigate options to intercept and accommodate overland sheet flow from offsite areas.
- Identify and investigate other potential improvements to alleviate risk to excessive ponding, address deficiencies in the storm sewer network, and create overland sheet flow connectivity to Salt Water Ditch, C122-00-00, C118-03-00, and Sims Bayou in addition to the improvements listed above, as necessary.

HDR

Memo

Date:	Wednesday, October 21, 2020
Project:	City of Houston Drainage Pre-Engineering Services for Storm Water Improvements Work Order # 9 – South Park/Sunnyside Drainage Analysis
To:	Adam Eaton, PE
From:	Jeremy Blevins, PE, CFM
Subject:	Proposed Conditions Technical Memorandum

This technical memorandum (TM) provides the results of the proposed conditions analysis of the South Park/Sunnyside study area. An existing conditions analysis was completed by HDR in April 2020, and this proposed conditions analysis is a continuation of that study to provide recommendations for flood risk reduction in the study area. Additionally, Harris County Engineering Department (HCED) has undertaken a project to enclose Salt Water Ditch as a closed conduit system. Coordination with HCED is on-going as a part of this study. The following paragraphs provide background information on the study area, describe the methodologies used in the analysis, and summarize the results of the proposed conditions analysis.

Proposed Improvements

Based on the results of the existing conditions analysis, the following improvements were recommended for further refinement and detailed study:

- Improve the storm sewer network and associated outfalls along Pershing Street.
- Improve the storm sewer trunk line along Southbank and the associated laterals north and south of Salt Water Ditch.
- Improve the storm sewer trunk line along Crestmont Street and the associated laterals north and south of Salt Water Ditch.
- Improve the storm sewer systems on Willow Glen Drive and South Wayside Drive.
- Improve the storm sewer systems on Belmark Street and South Wayside Drive.
- Incorporate the improvements included in the City's project along Comal Street and Brandon Street.
- Improve the outfall at Scott Street and Holmes Road.
- Improve the storm sewer trunk line along Scott Street that outfalls to C118-03-00.
- Improve the storm sewer trunk line system along McLean Street north of C118-03-00.
- Improve the storm sewer trunk line system along Cullen Boulevard north of C122-00-00.
- Determine the detention volume needed to mitigate improvements and investigate inline detention opportunities beneath Martin Luther King Boulevard. Evaluate interconnectivity between Martin Luther King Boulevard and Salt Water Ditch.
- Identify and investigate opportunities to implement green infrastructure and low impact development (LID) opportunities associated with the proposed improvements, including above-ground detention sites.

- Identify and investigate options to intercept and accommodate overland sheet flow from offsite areas.
- Identify and investigate other potential improvements to alleviate risk to excessive ponding, address deficiencies in the storm sewer network, and create overland sheet flow connectivity to Salt Water Ditch, C122-00-00, C118-03-00, and Sims Bayou in addition to the improvements listed above, as necessary.

The proposed improvements were also coordinated with the proposed channel improvements to Salt Water ditch, as recommended by HCED.

It was the City's intent to submit proposed improvements for the South Park/Sunnyside area for funding under the Texas General Land Office's CDBG-MIT competition program. The improvements identified during the existing conditions analysis were further refined and analyzed to identify a set of improvements that would provide the most benefit over a large portion of the South Park/Sunnyside area, while fitting to the funding constraints of the CDBG-MIT competition. The proposed improvements are listed below and are shown in Exhibit 1.

PROPOSED INCREASE IN STORM SEWER SIZE:

- Increase all lines on Jutland Road, Herschellwood Drive, and St. Lo Road (that flow into the line between Northridge Drive and Lyndhurst Drive) to 48-inch RCP.
- Increase the line between Northridge Drive and Lyndhurst Drive from Jutland Road to Martin Luther King Boulevard to a 6' x 5' box culvert.
- Increase all lines along Martin Luther King Boulevard from Lyndhurst Drive to the outfall into Sims Bayou to two 10' x 10' box culverts.
- Increase the line on Cullen Boulevard from Briscoe Street to Belfort Avenue to a 10' x 5' box culvert.
- Increase the line on Cullen Boulevard from the start of the line below Belfort Avenue to the outfall into Sims Bayou to two 10' x 8' box culverts.

PROPOSED NEW STORM SEWER LINE:

- Add two 10' x 8' box culverts from the intersection of Belfort Avenue and Cullen Boulevard to the existing storm sewer system on Cullen Boulevard to the south. This connects the Belfort and Cullen systems.
- Starting at the existing line between Lyndhurst Drive and Northridge Drive (near the intersection of Lyndhurst Drive and Sharondale Street) add a 6' x 5' box culvert to connect to the existing line on Lyndhurst Drive. This makes this system flow to Martin Luther King Boulevard instead of directly to Saltwater Ditch.
- Add a 60-inch RCP on Southbank Street from approximately Lyndhurst Drive to Belarbor Street. This connects the redirected line on Southbank Street to the existing line (also to be redirected) further south on Southbank Street.
- Add a 60-inch RCP on Crestmont Street from approximately Lyndhurst Drive to Belarbor Street. This connects the redirected line on Crestmont Street to the existing line (also to be redirected) further south on Crestmont Street.
- Add a 10' x 8' box culvert between Beldart Street and Flamingo Drive, from Southbank Street to Martin Luther King Boulevard. This new line connects the redirected lines from

Southbank Street and Crestmont Street to the larger Martin Luther King Boulevard system.

The proposed improvement to Salt Water Ditch being designed by HCED was not directly included in this analysis, as the proposed improvements for the City CDBG-MIT grant application must be stand alone and have construction cost of $100 million or less.

Proposed Conditions Results

The proposed improvements were input into the existing conditions models to assess the potential benefits within the study area. These improvements were modeled first without the proposed channel enclosure of Salt Water Ditch in order to assess the benefits of this project as a stand-alone project. Ponding maps were developed for the 2-year, 10-year, 25-year, 50-year, and 100-year storm events. Those ponding maps are shown in Exhibits 2 through 6, respectively.

The inundation boundaries for the proposed conditions models were processed in GIS to assess the benefit of the proposed project. Based on the results of the models, it is expected that approximately 1,935 fewer houses will experience structural flooding during a 1% annual chance storm event. Likewise, it is expected that 12.6 fewer miles of roadway will experience ponding during a 1% annual chance storm event. The improvements will increase the level of service from 10-year to 25-year across the area. Table 1 below provides a summary of these results.

Table 1: Summary of Proposed Conditions Results

Item	Existing	Proposed
Level of Service	10-year	25-year
Structures Impacted (100-Year)	6,821	4,886
Parcel Inundation (100-Year)	9,123	7,598
Roadway Inundation (100-Year)	92.3 mi	79.7 mi

A comparison of flow hydrographs at the outfall to Sims Bayou indicates an increase in flow due to the proposed improvements. In order to mitigate those potential adverse impacts, it is necessary to provide storm water detention. Based on a comparison of flow hydrographs, approximately 800 acre-feet of stormwater detention is necessary to mitigate those potential adverse impacts associated with the storm sewer improvements.

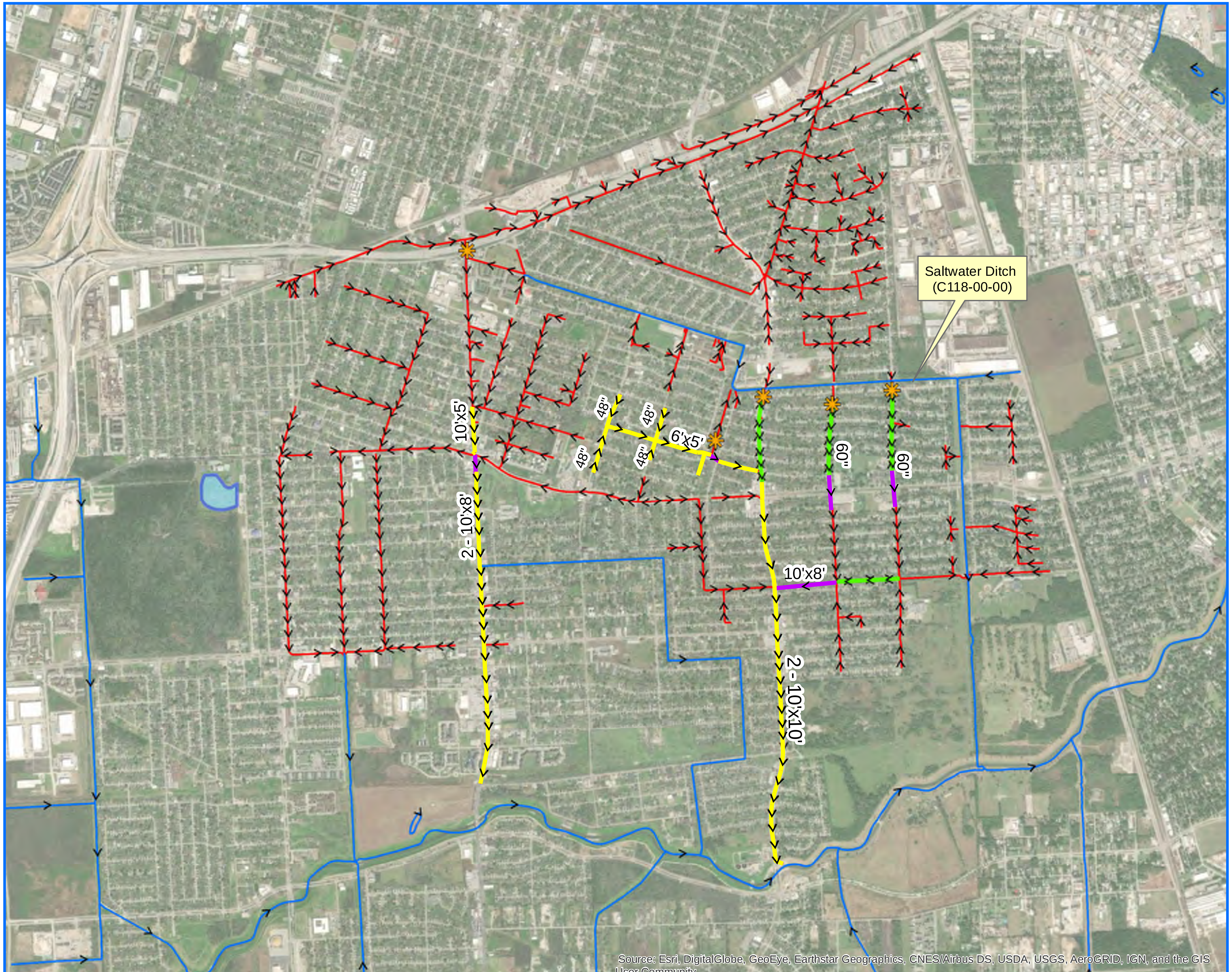
It is important to note that this value does not include any stormwater detention that is necessary to mitigate the potential impacts of the channel enclosure of Salt Water Ditch, which is currently under design by HCED. Additional stormwater detention will be necessary to satisfy requirements for that HCED project. Various detention basin locations have been identified, and coordination with Houston Parks Department and adjacent property owners is on-going.

The proposed improvements were also modeled with the improvements to Salt Water Ditch to determine the overall benefits of the combined improvements. HCED provided the model for their improvements, which were added the existing conditions model with the proposed improvements presented in this TM. The model results indicate that improvements to both the local storm drainage networks and the Salt Water Ditch channel will increase the overall level of service in the area to approximately 50-year. Ponding maps of the combined improvements for the 2-year, 10-year, 25-year, 50-year, and 100-year storm events are presented in Exhibits 7 through 11, respectively.

Opinion of Probable Construction Costs

Based on the proposed improvements presented in this memorandum, it is anticipated that the probable construction cost are approximately $83.9 million. Project administration, design fees, and grant administration costs are expected to be approximately $22.6 million. Land acquisition costs are expected to be $4.7 million. Adding all these values together brings the total project costs to approximately $111.2 million. The detailed opinion of probable construction costs is attached to this memorandum.

A benefit-cost analysis (BCA) was conducted to provide a benefit-cost ration (BCR) that compared the costs of the proposed improvements against the benefits achieved. Benefits were calculated by determining pre- and post-project costs of structural losses, with the difference being the overall benefit. Based on the analysis, the proposed improvements will provide approximately $142.1 million in benefits, against a present value cost of $118.9M (OPCC plus operations and maintenance costs over a 50-year analysis period). This provides a BCR of 1.20 for the improvements.



N

0 2,000 4,000
Feet

Proposed: Detention Pond

Proposed: Disconnect Line

Proposed Storm Sewer Line Reversal

Proposed New Storm Sewer Line

Proposed Storm Sewer Line Size Increase

HCFCD Channels

Existing Storm Sewer

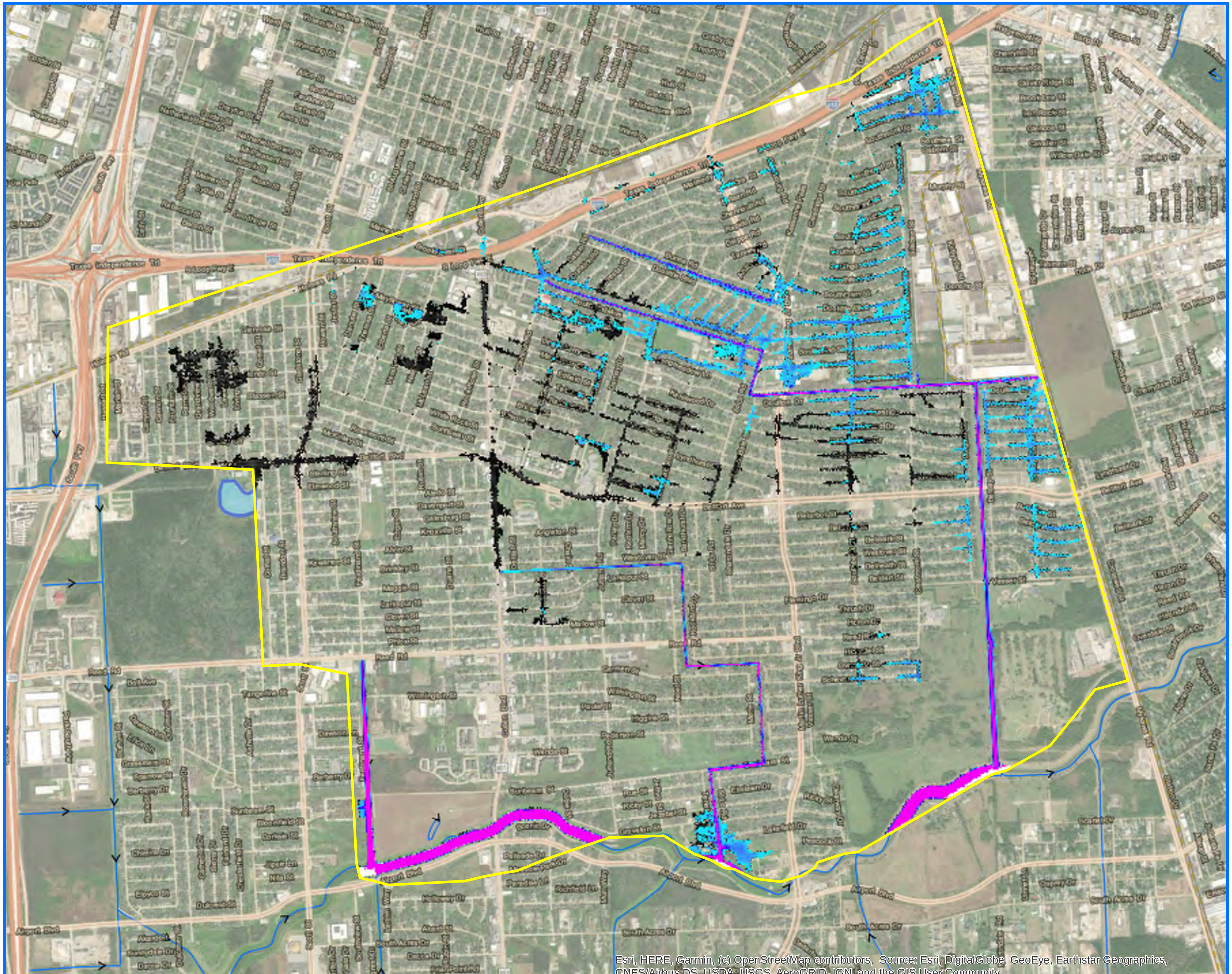
EXHIBIT 1

SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS

HARRIS COUNTY, TX

PROPOSED IMPROVEMENTS

HT&J, LLC
Professional Engineering Services



N

0 2,000 4,000
Feet

2D Analysis Extent

HCFCD Channels

Proposed: Detention Pond

Proposed Condition Ponding Depth (feet)

High : 5

Low : 0

Existing Condition Ponding Depth (feet)

High : 5

Low : 0

EXHIBIT 2

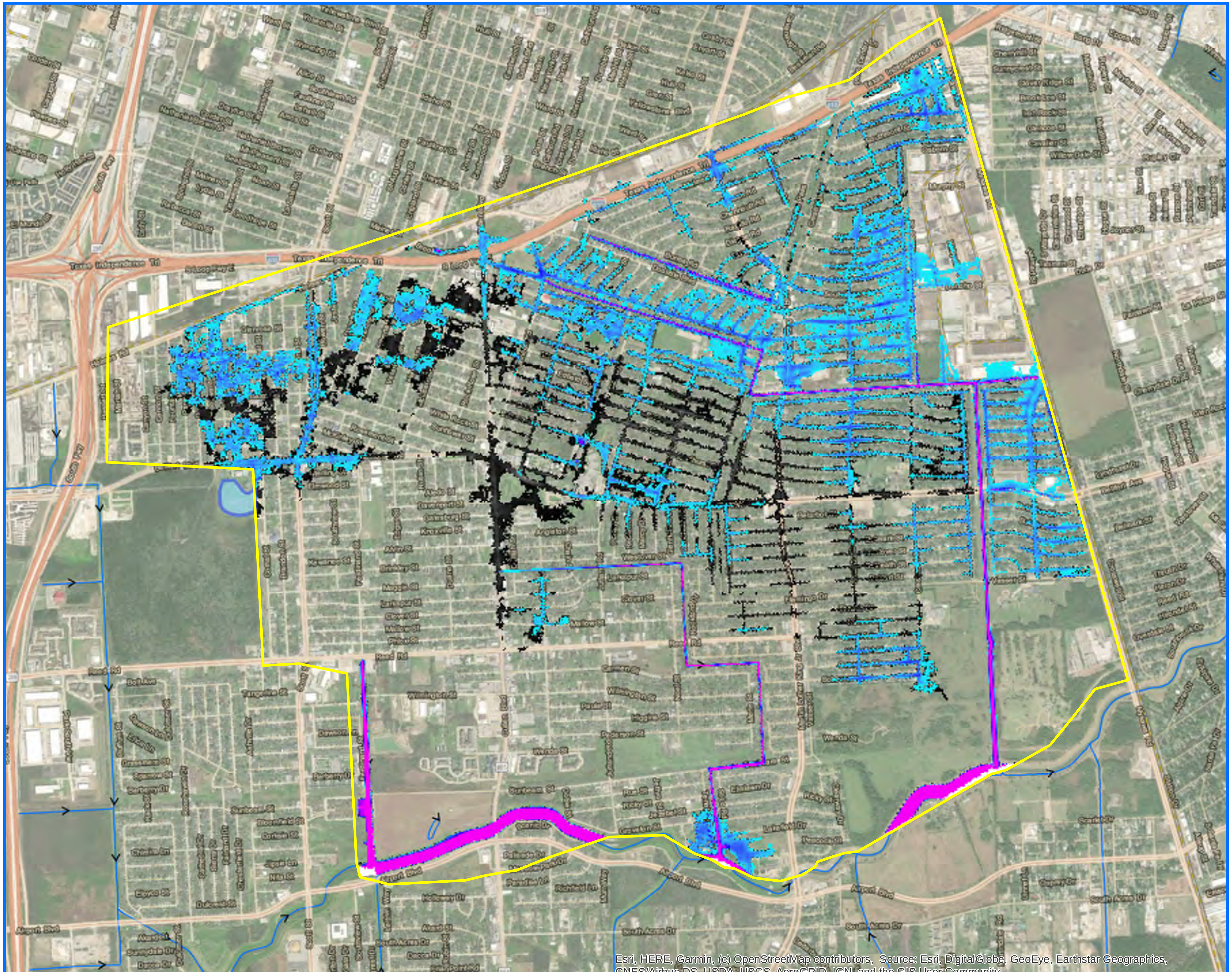
SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS HARRIS COUNTY, TX

07/10/2020 SCENARIO

PONDING RESULTS

2-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services



0 2,000 4,000
Feet

2D Analysis Extent

HCFCD Channels

Proposed: Detention Pond

Proposed Condition Ponding Depth (feet)

High : 5

Low : 0

Existing Condition Ponding Depth (feet)

High : 5

Low : 0

EXHIBIT 3

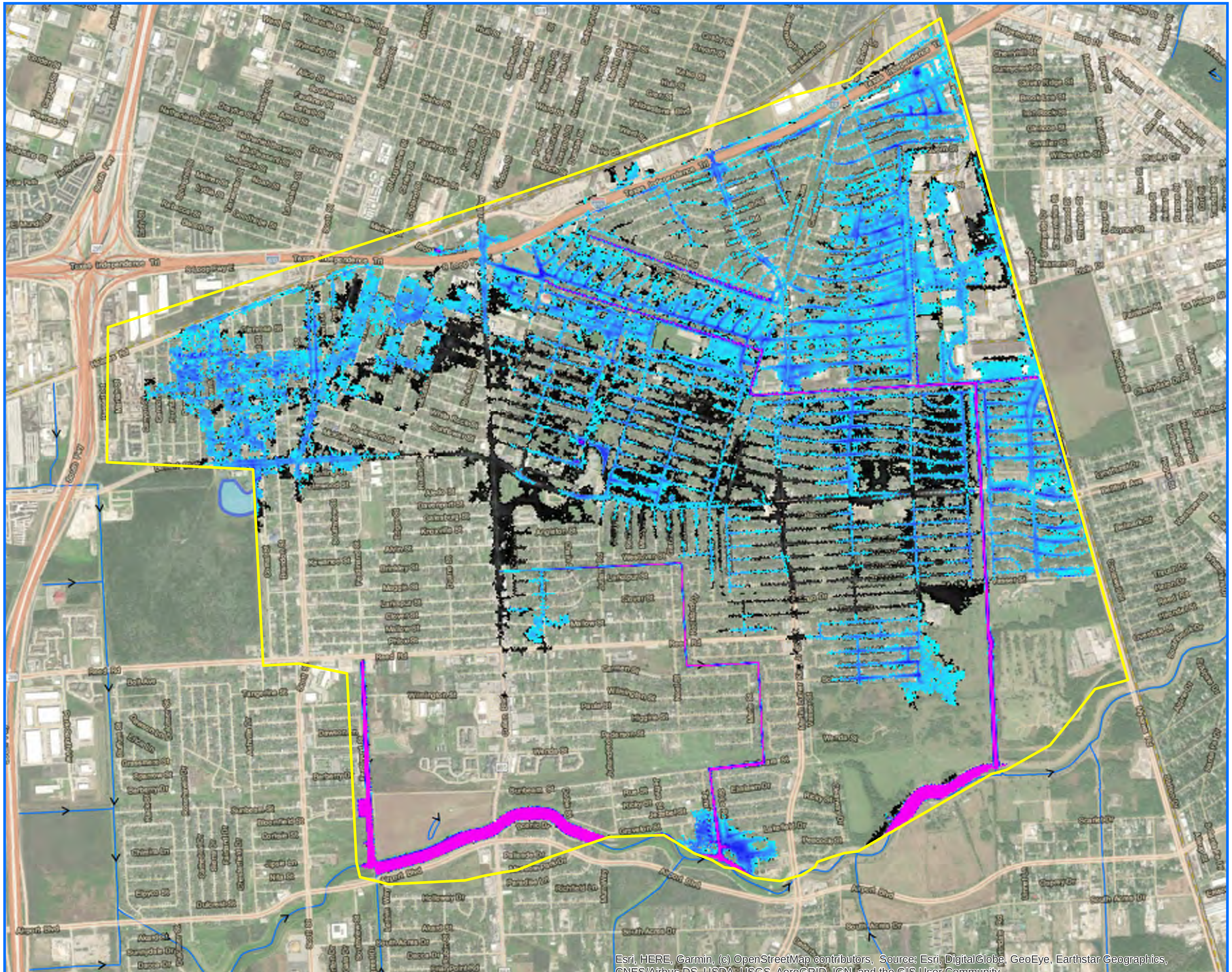
SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS
HARRIS COUNTY, TX

07/10/2020 SCENARIO

PONDING RESULTS

10-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services



N

0 2,000 4,000
Feet

2D Analysis Extent

HCFCD Channels

Proposed: Detention Pond

Proposed Condition Ponding Depth (feet)

High : 5

Low : 0

Existing Condition Ponding Depth (feet)

High : 5

Low : 0

EXHIBIT 4

SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS

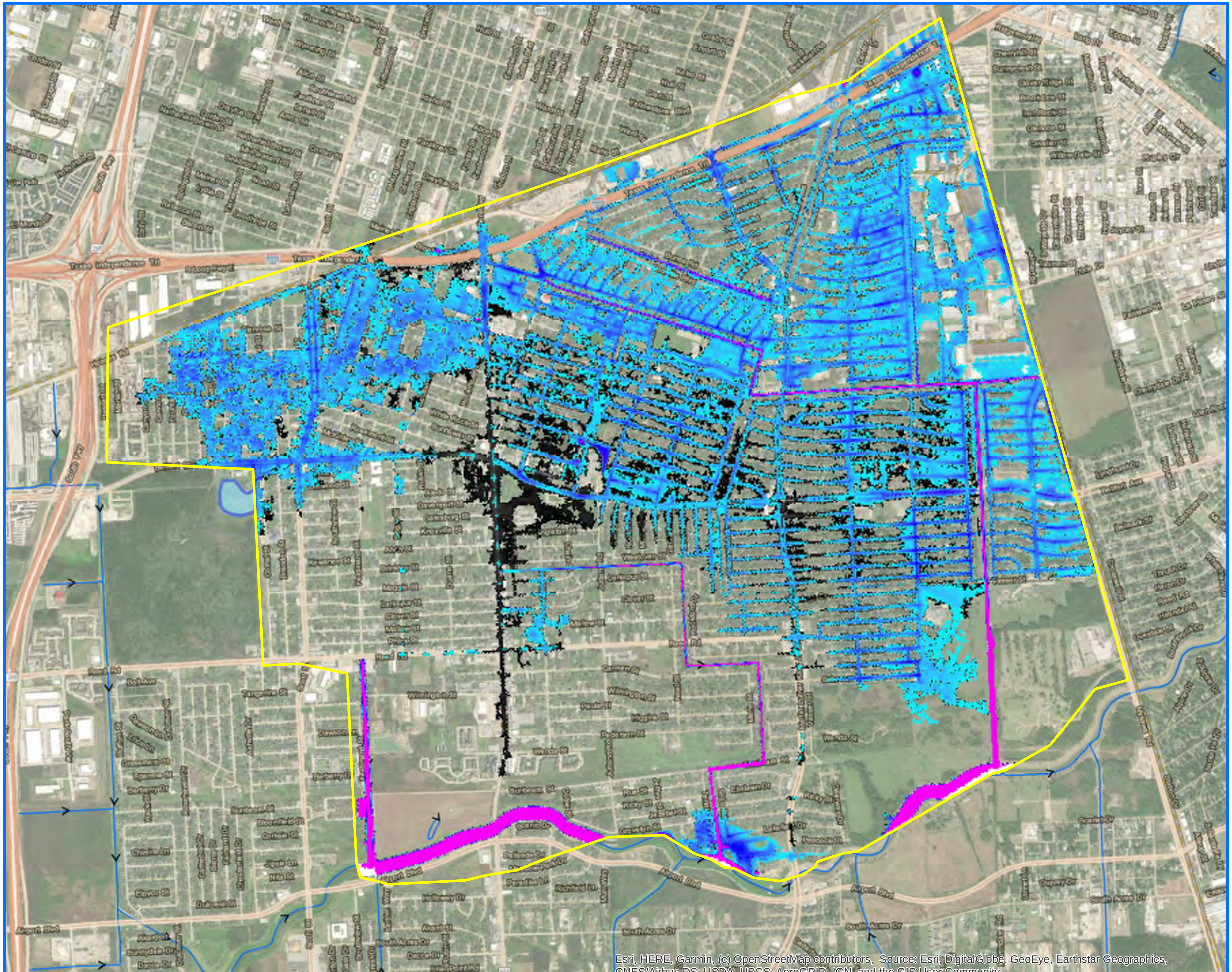
HARRIS COUNTY, TX

07/10/2020 SCENARIO

PONDING RESULTS

25-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services



2D Analysis Extent

Proposed: Detention Pond

Proposed Condition Ponding Depth (feet)

High : 5

Low : 0

Existing Condition Ponding Depth (feet)

High : 5

Low : 0

HCFCD Channels

EXHIBIT 5

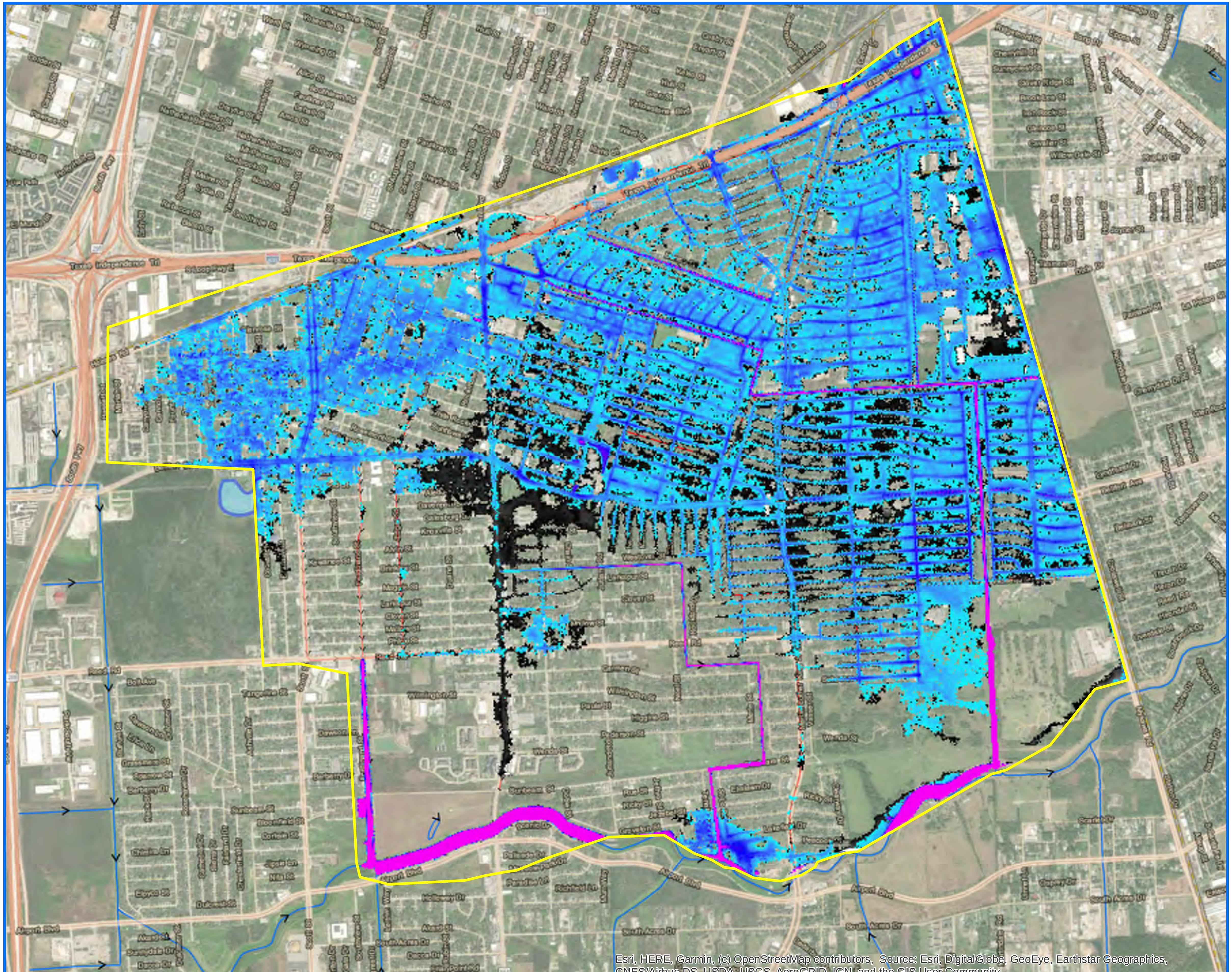
SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS

07/10/2020 SCENARIO

PONDING RESULTS

50-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services



N

0 2,000 4,000
Feet

2D Analysis

Proposed: Detention Pond

Proposed Condition Ponding Depth (feet)

High : 5

Low : 0

Existing Condition Ponding Depth Value

High : 5

Low : 0

HCFCD Channels

Storm Sewer System

EXHIBIT 6

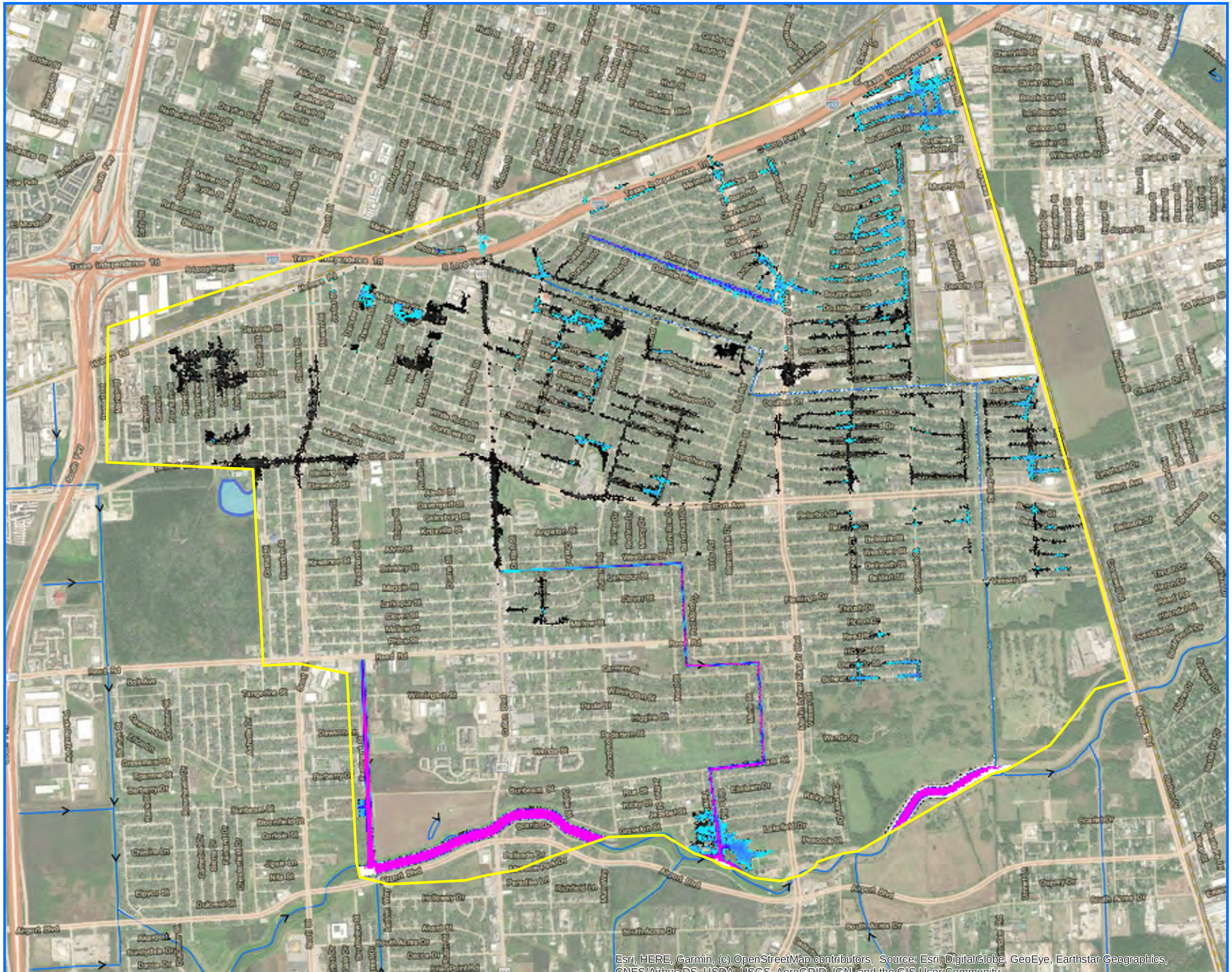
SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS

07/10/2020 SCENARIO

PONDING RESULTS

100-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services



N

0 2,000 4,000
Feet

2D Analysis Extent

HCFCD Channels

Proposed: Detention Pond

Proposed Condition Ponding Depth (feet)

High : 5

Low : 0

Existing Condition Ponding Depth (feet)

High : 5

Low : 0

EXHIBIT 7

SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS

SALT WATER DITCH IMPROVEMENTS & STORM SEWER IMPROVEMENTS

PONDING RESULTS

2-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services

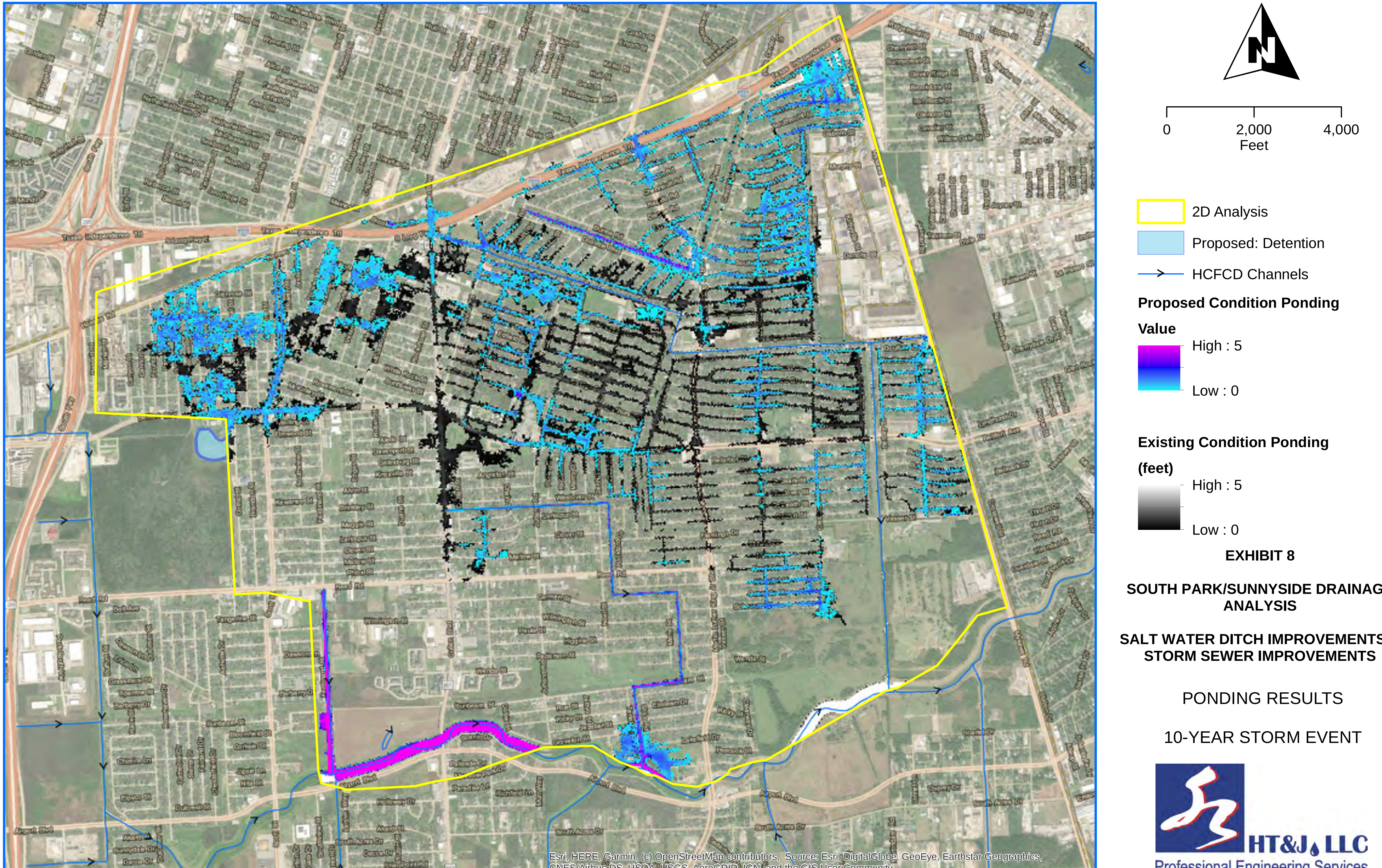


EXHIBIT 8

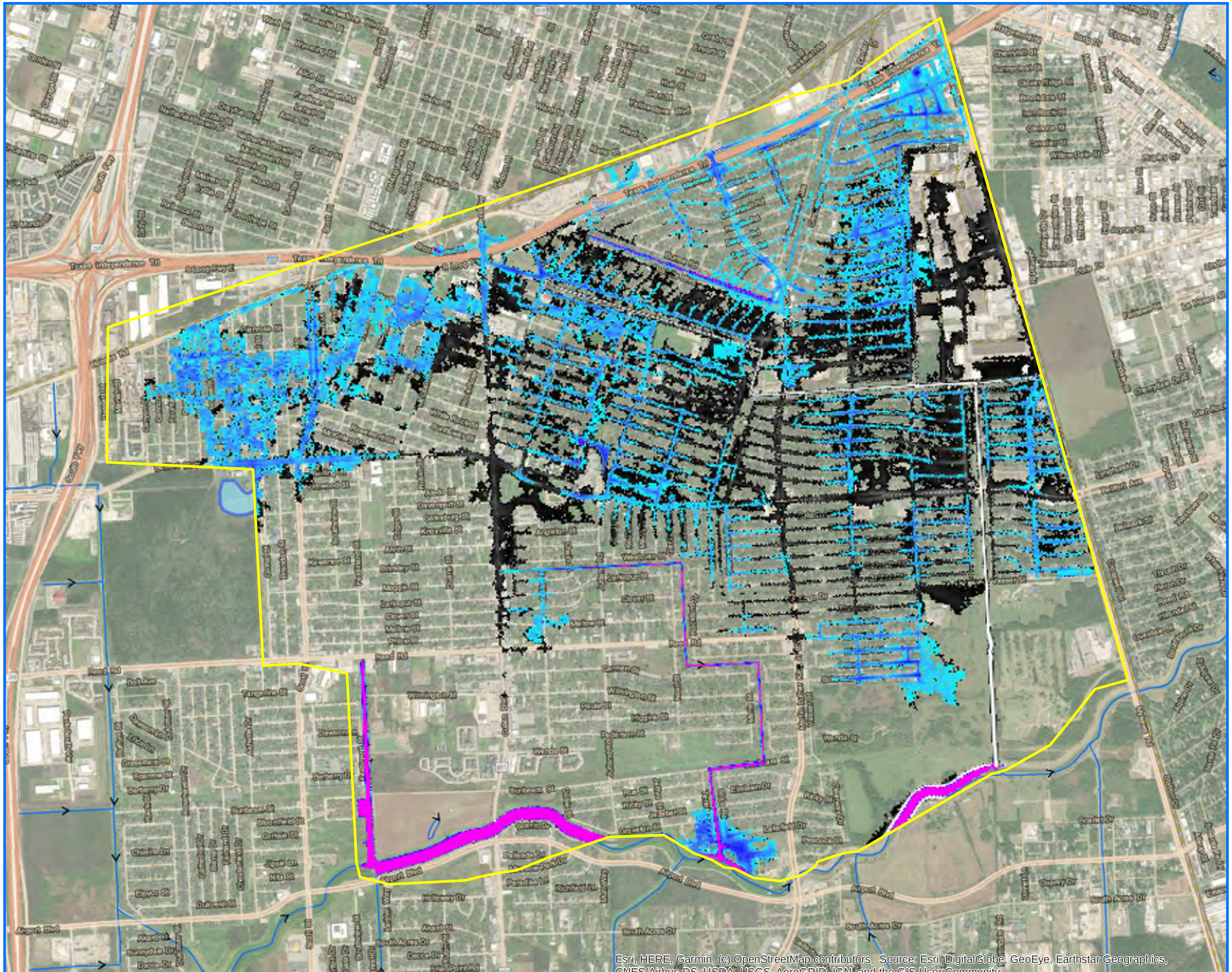
SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS

SALT WATER DITCH IMPROVEMENTS & STORM SEWER IMPROVEMENTS

PONDING RESULTS

10-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services



N

0 2,000 4,000
Feet

2D Analysis Extent

HCFCD Channels

Proposed: Detention Pond

Proposed Condition Ponding Depth (feet)

High : 5

Low : 0

Existing Condition Ponding Depth (feet)

High : 5

Low : 0

EXHIBIT 9

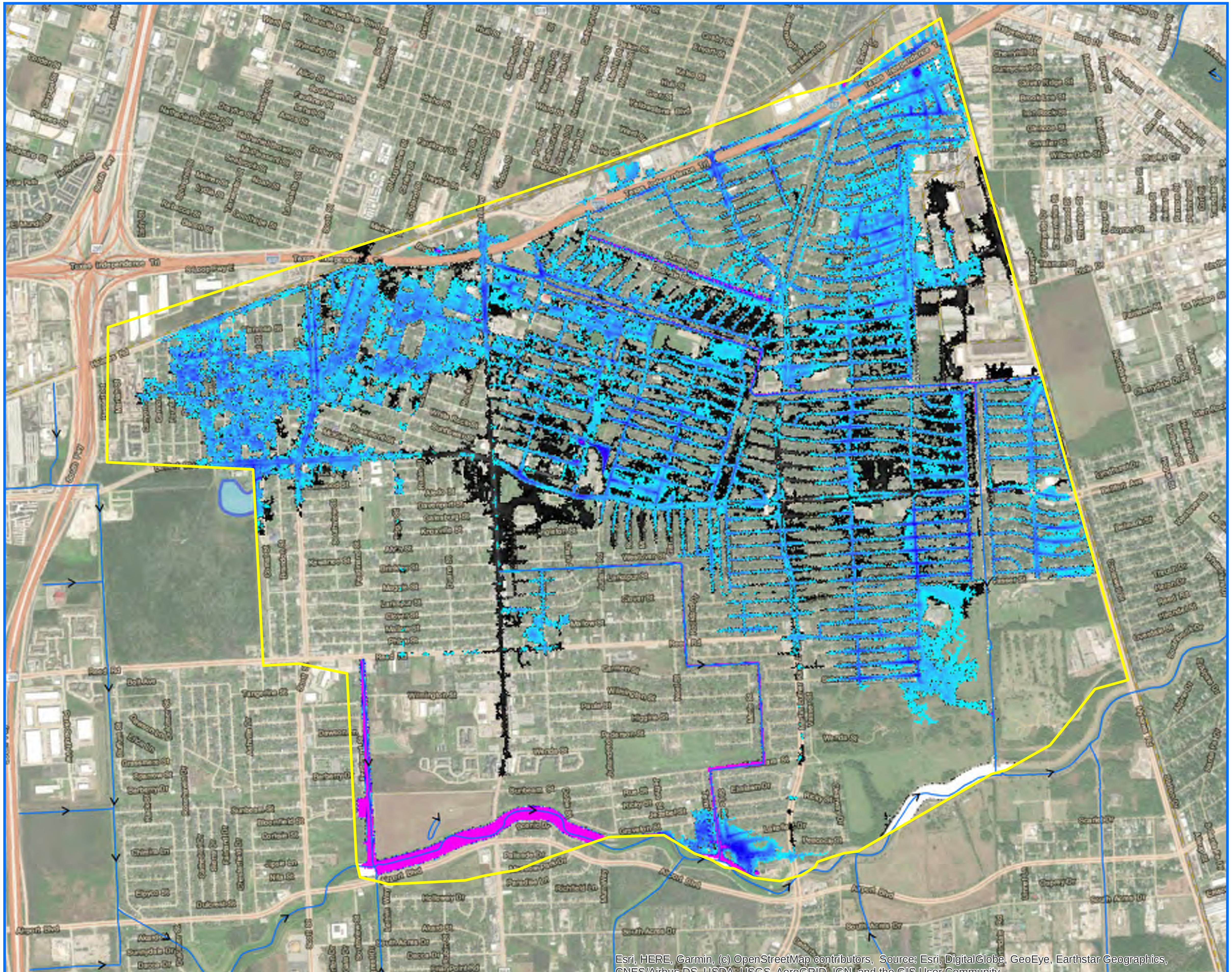
SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS

SALT WATER DITCH IMPROVEMENTS & STORM SEWER IMPROVEMENTS

PONDING RESULTS

25-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services



0 2,000 4,000
Feet

2D Analysis Extent

Proposed: Detention Pond

HCFCD Channels

Proposed Condition Ponding Depth

Value

High : 5

Low : 0

Existing Condition Ponding Depth

(feet)

High : 5

Low : 0

EXHIBIT 10

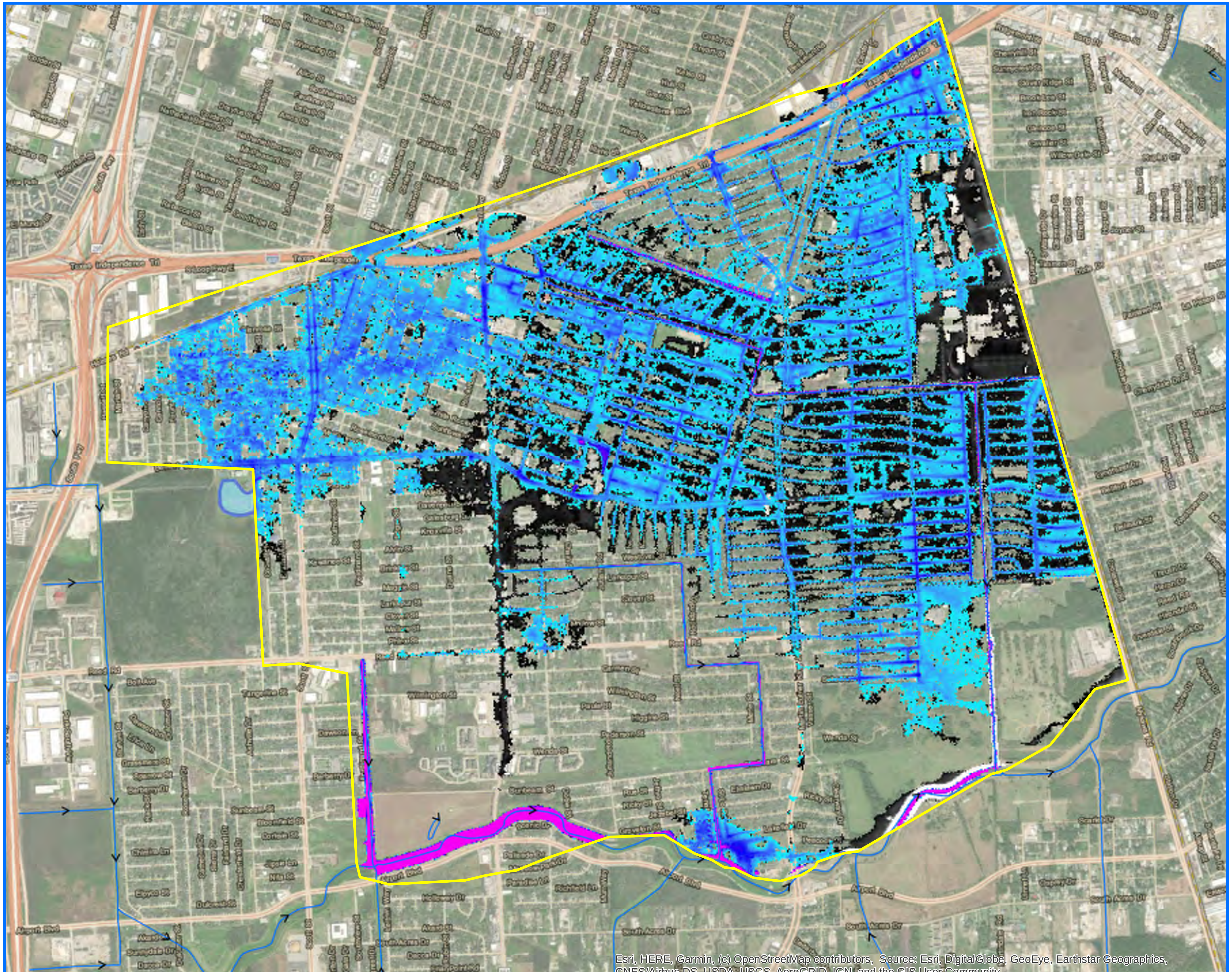
SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS

SALT WATER DITCH IMPROVEMENTS & STORM SEWER IMPROVEMENTS

PONDING RESULTS

50-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services



N

0 2,000 4,000
Feet

2D Analysis Extent

Proposed: Detention Pond

HCFCD Channels

Proposed Condition Ponding Depth

Value

High : 5

Low : 0

Existing Condition Ponding Depth

Value

High : 5

Low : 0

EXHIBIT 11

SOUTH PARK/SUNNYSIDE DRAINAGE ANALYSIS

SALT WATER DITCH IMPROVEMENTS & STORM SEWER IMPROVEMENTS

PONDING RESULTS

100-YEAR STORM EVENT

HT&J, LLC
Professional Engineering Services

CDBG-MIT: Budget Justification of Retail Costs
(Former Table 2)

Cost Verification Controls must be in place to assure that construction costs are reasonable and consistent with market costs at the time and place of construction.

Applicant/Subrecipient:	City of Houston					
Site/Activity Title:	City of Houston Sunnyside/Southpark Drainage Improvements					
Eligible Activity:	Flood control and drainage improvements					
Materials/Facilities/Services	**$/Unit**	**Unit**	**Quantity**	**Construction**	**Acquisition**	**Total**
General items						
Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	$ 1,021,000.00	LS	1	$ 1,021,000.00	$ -	$ 1,021,000.00
Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	$ 590,000.00	LS	1	$ 590,000.00	$ -	$ 590,000.00
Utility Conflicts / Relocation/Adjustment/Landscaping	$ 4,572,500.00	LS	1	$ 4,572,500.00	$ -	$ 4,572,500.00
					Subtotal General Items:	$ 6,183,500.00
Paving items						
Existing Concrete pavement removal, complete in place the sum of:	$ 7.00	SY	21,550	$ 150,850.00	$ -	$ 150,850.00
6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	$ 80.00	SY	21,550	$ 1,724,000.00	$ -	$ 1,724,000.00
11" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	$ 100.00	SY	-	$ -	$ -	$ -
8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	$ 4.00	SY	26,410	$ 105,640.00	$ -	$ 105,640.00
Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	$ 165.00	TON	755	$ 124,575.00	$ -	$ 124,575.00
6" concrete curb, including reinforcement and joints, complete in place the sum of:	$ 5.00	LF	14,920	$ 74,600.00	$ -	$ 74,600.00
5' concrete sidewalk, complete in place the sum of:	$ 65.00	SY	8,150	$ 529,750.00	$ -	$ 529,750.00
Concrete curb ramp per ADA requirements, complete in place the sum of:	$ 2,000.00	EA	70	$ 140,000.00	$ -	$ 140,000.00
Driveway Reconnection	$ 125,900.00	LS	1	$ 125,900.00	$ -	$ 125,900.00
					Subtotal Paving Items:	$ 2,975,315.00
Drainage items						
Remove existing storm sewer, all sizes and all depths, complete in place the sum of:	$ 30.00	LF	41,205	$ 1,236,150.00	$ -	$ 1,236,150.00
Remove existing storm sewer inlet/manhole, complete in place the sum of:	$ 600.00	EA	372	$ 223,200.00	$ -	$ 223,200.00
48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 250.00	LF	3,280	$ 820,000.00	$ -	$ 820,000.00
60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 350.00	LF	6,150	$ 2,152,500.00	$ -	$ 2,152,500.00
96" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 500.00	LF	-	$ -	$ -	$ -
5'x4' RCB, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 325.00	LF	-	$ -	$ -	$ -
6'x5' RCB, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 490.00	LF	3,110	$ 1,523,900.00	$ -	$ 1,523,900.00
9'x6' RCB, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 800.00	LF	-	$ -	$ -	$ -
10'x5' RCB, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 808.00	LF	985	$ 795,880.00	$ -	$ 795,880.00
10'x6' RCB, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 845.00	LF	-	$ -	$ -	$ -
10'x7' RCB, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 865.00	LF	-	$ -	$ -	$ -
10'x8' RCB, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 900.00	LF	15,440	$ 13,896,000.00	$ -	$ 13,896,000.00
10'x9' RCB, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 905.00	LF	-	$ -	$ -	$ -
10'x10' RCB, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	$ 916.00	LF	19,500	$ 17,862,000.00	$ -	$ 17,862,000.00
Manholes (For 48" to 72" Dia. Pipe) (All Typ)	$ 6,340.00	EA	46	$ 291,640.00	$ -	$ 291,640.00
Manholes (For 78" Dia. Pipe and Larger) (All Types)	$ 16,500.00	EA	80	$ 1,320,000.00	$ -	$ 1,320,000.00
Inlets (Type BB with grate)	$ 3,000.00	EA	242	$ 726,000.00	$ -	$ 726,000.00
Detention Excavation, piping, stabilization, complete in place	$ 20.00	CY	-	$ -	$ -	$ -
Detention Excavation, piping, stabilization, complete in place	$ 10.00	CY	-	$ -	$ -	$ -
Detention Excavation, haul off, piping, stabilization, complete in place	$ 12.00	CY	1,209,750	$ 14,517,000.00	$ -	$ 14,517,000.00
					Subtotal Drainage Items:	$ 55,364,270.00
TOTAL				$ 64,523,085.00	$ -	$ 64,523,085.00
					Estimated Probable Cost of Construction:	$ 64,523,085.00
					30% Contingency:	$ 19,356,925.50
					Total Estimated Probable Cost of Construction:	$ 83,880,010.50
Engineering (Design, Bidding, Survey, Geotechnical, Construction Phase Services) (15%)						$ 12,582,001.58
Environmental Investigation and Permitting (6%)						$ 5,032,800.63
Grant Administration (6%)						$ 5,032,800.63
OPCC Including Professional Services						$ 93,945,611.76

1. Identify and explain the annual projected operation and maintenance costs associated with the proposed activities.

2. Identify and explain any special engineering activities.

Date:

Phone Number:

Seal

Signature of Registered Engineer/Architect Responsible For Budget Justification:

CDBG-MIT: Budget Justification of Retail Costs
(Former Table 2)

Cost Verification Controls must be in place to assure that construction costs are reasonable and consistent with market costs at the time and place of construction.

Applicant/Subrecipient:	City of Houston					
Site/Activity Title:	City of Houston Sunnyside/Southpark Drainage Improvements					
Eligible Activity:	Acquisition					
Materials/Facilities/Services	**$/Unit**	**Unit**	**Quantity**	**Construction**	**Acquisition**	**Total**
Pond 1	$ -	LS	1	$ -	$ 4,250,406.00	$ 4,250,406.00
Pond 2	$ -	LS	1	$ -	$ 473,628.00	$ 473,628.00
					Subtotal Acquisition:	$ 4,724,034.00
TOTAL				$ -	$ 4,724,034.00	$ 4,724,034.00

1. Identify and explain the annual projected operation and maintenance costs associated with the proposed activities.

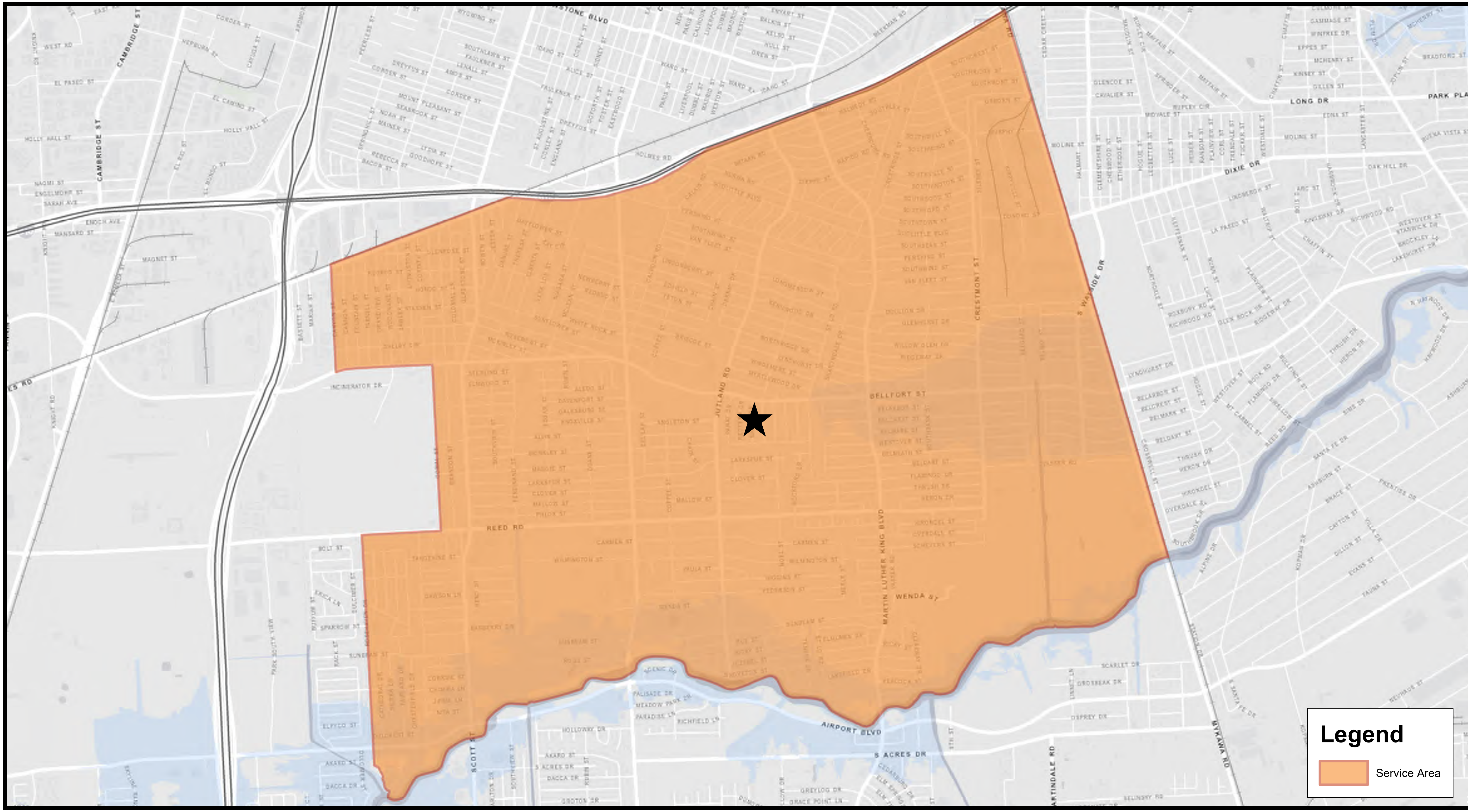
2. Identify and explain any special engineering activities.

Date:	
Phone Number:	

Seal

Signature of Registered Engineer/Architect Responsible For Budget Justification:

Houston Sunnyside Area Flood Mitigation - Location Map



★ Latitude: 29.665045
Longitude: -95.345983

Address: 8127 Marcy Dr
Houston, TX 77033

County: Harris

N

Memo

Date:	Monday, October 12, 2020
Project:	City of Houston Drainage Pre-Engineering Services for Storm Water Drainage Projects Work Order #9 – Sunnyside Drainage Analysis
To:	Adam Eaton, PE, ENV SP
From:	Jeremy Blevins, PE, CFM, Jeremy Cook, & Taylor Hackbart
Subject:	Benefit-Cost Analysis for Sunnyside Area Flood Mitigation CDBG-MIT Application

Introduction

A benefit cost analysis (BCA) has been performed by HDR Engineering to support a potential CDBG-MIT application to obtain federal funds for a project located in Houston, Texas. The mitigation project includes storm sewer and roadway improvements along with the construction of regional detention basins. These improvements will reduce flooding in the South Park and Sunnyside area of Houston.

The BCA utilized an MS Excel based spreadsheet to estimate the present value stream of expected annual benefits and costs of the Sunnyside Drainage Improvement Project over a project life of 50 years. The MS Excel spreadsheet is developed by HDR based on the methodology presented in the FEMA BCA Toolkit version 6.0. All values were updated to current value as needed and adjusted to present value using OMB discount rates (OMB Circular A-94).

The steps HDR used to develop the BCA model are outlined below and are followed by a discussion of the findings.

Methodology

The BCA model was developed in 3 steps. First, hydrology and hydraulic (H&H) models were developed. The H&H models were used to first delineate the flooding extents and then to identify the magnitude of flood impacts. Following completion of the H&H modeling, data for impacted structures was collected. Finally, the H&H and structure data were used to develop the BCA model.

H&H Inputs

STRUCTURE INPUTS

Following completion of the H&H modeling, the pre-project100-yr floodplain was used to inventory all structures impacted by flooding. This inventory captures all residential and non-residential buildings within the 100-yr floodplain. Impacted structures were assigned flood depths for each of the 5 return periods (2-year, 10-year, 25-year, 50-year, and 100-year storm events) under the pre- and post-improvement conditions.

Data for each structure was obtained and linked with the flood depths in order to translate depth of flooding into monetary estimates of flood related damages with each return period. Data needs include surveyed finished floor elevations; building type (residential, non-residential); foundation type; number of stories; non-residential building type; building size (square feet); and assessed value. Damages were only applied to the first story of each impacted structure.

The Harris County Appraisal District provided GIS coverage of parcels including structure information, valuation, and square footage. Foundation heights were determined based on common structure type designs established by FEMA.

BCA MODEL DEVELOPMENT

The complete structure and H&H data was entered into the MS Excel model to estimate pre and post-improvement flood damages. The model computes flood reduction benefits at each structure from the difference in pre and post mitigation damages for each of the five return periods. These individual structure flood hazard mitigation benefits were then aggregated to a comprehensive hazard mitigation benefit. This was then be compared to a present value cost of the project (includes planning, final design, construction, and annual operations and maintenance over 50-years).

Structure damages in the area were evaluated using depth damage estimations developed for the area by FEMA. These estimations relate the level of flooding to the dollar amount of damage to each structure. Key inputs for residential displacement include the number of people per household, lodging costs per day, and meal costs per day.

Findings

MITIGATION PROJECT COSTS

The estimated costs for completing The Project are shown below in Table 1. The total implementation cost of $111.3 million combined with annual O&M of $551,258 over 50 years yields a total present value cost of $118.9 million for the project.

Table 1: Sunnyside Drainage Improvement Total Estimated Project Cost (2020 $s, 7% discount factor, 50 yr period of analysis)

Cost Component	Cost
Total Project Cost	$111,251,647
Annual O&M	$551,258
Total Present Value Cost	$118,859,419

DAMAGE REDUCTION BENEFITS

Table 2 below provides a summary of the total damages under pre and post mitigation conditions. The total annualized damages pre mitigation are $34,938,161 with post mitigation annual damages reduced by $286,567 to $13,637.

Table 2: Sunnyside Drainage Improvement Structure Related Flood Mitigation Damages (2020 $s)

Recurrence Interval	Pre Mitigation Damages		Post Mitigation Damages	
	Total	Annualized	Total	Annualized
2 yr	$33,463,627	$21,632,867	$22,886,853	$14,698,587
10 yr	$87,404,776	$6,437,276	$58,999,065	$4,477,153
25 yr	$131,694,187	$2,965,004	$94,374,843	$2,271,273
50 yr	$166,887,614	$1,850,700	$136,653,993	$1,516,050
100 yr	$205,233,445	$2,052,314	$168,191,767	$1,681,901
Total Annualized		$34,938,161		$24,644,964

BENEFIT-TO-COST ANALYSIS SUMMARY

A summary of the final benefit-to-cost analysis is shown below in **Table** 3. As previously stated the present value cost of the project is $118.9 million when considering a 7% discount factor and 50 year analysis period. As evaluated by the analysis, the project would provide $142 million in flood mitigation benefits resulting in a favorable benefit to cost ratio of 1.20.

Table 3: Sunnyside Drainage Improvement Benefit-to-Cost Summary

Component	Present Value
Total Present Value Cost	$118,859,419
Total Present Value Benefits	$142,053,800
Net Present Value	$36,195,606
Benefit-to-Cost Ratio (BCR)	1.20

Appendix 5-4I:
Galveston 37th Street

Results Report for Galveston 37th St – 063000311

TO: San Jacinto Regional Flood Planning Group

CC: Harris County

Texas Water Development Board

FROM: Ericka Reyes EIT, Brian Edmondson, PE, CFM, Maggie Puckett, PE, CFM

SUBJECT: Galveston 37th Street Benefit-Cost Analysis

DATE: 03/16/2023

PROJECT: San Jacinto Regional Flood Plan

The 37th Street Service Area experiences heavy rainfall, inundation of storm sewers, ponding in streets due to flat topography, and these frequent events impact primary evacuation routes for the Island. The 37th street Drainage Project proposes storm sewer improvements coupled with implementing a stormwater pump station to address 100-year event flooding and improving access to major evacuation routes. The Engineer's Justification Statement for 37th Street Service Area is included as **Appendix A**. This document provides context into common issues the area faces, why the area was focused on, and how the project is intended to provide access to evacuation routes.

Benefit Cost Analysis

TWDB developed the Benefit-Cost Analysis (BCA) Input Tool to facilitate the calculation of flood mitigation benefits due to FMP. This tool receives input of existing and proposed conditions to determine expected benefits related to the construction of the FMP in question. The benefits considered in the analysis include the reduction in damages to residential structures, commercial structures, and flooded street impacts. The BCA Input Tool was modified to handle the nearly 441 structures included in the analysis. The BCA Input Tool was used in conjunction with the Federal Emergency Management Agency (FEMA) BCA Toolkit v6.0.0. Flood street impacts used in the analysis were developed within the TWDB developed BCA.

Flooded Streets

While it would be more accurate to determine the flooded streets impacted per flooded street, the combined benefits would be marginal compared to the benefits shown directly with reduced structural depth. Therefore, the largest roadway inundated was used to determine the flooded street impacts.

I-87 not considered since the flooding in the area did not appear to meet the >6" threshold in the TWDB BCA spreadsheet. The figures below show the existing 100yr depth in the circled area, which is less than approximately 0.5 ft.

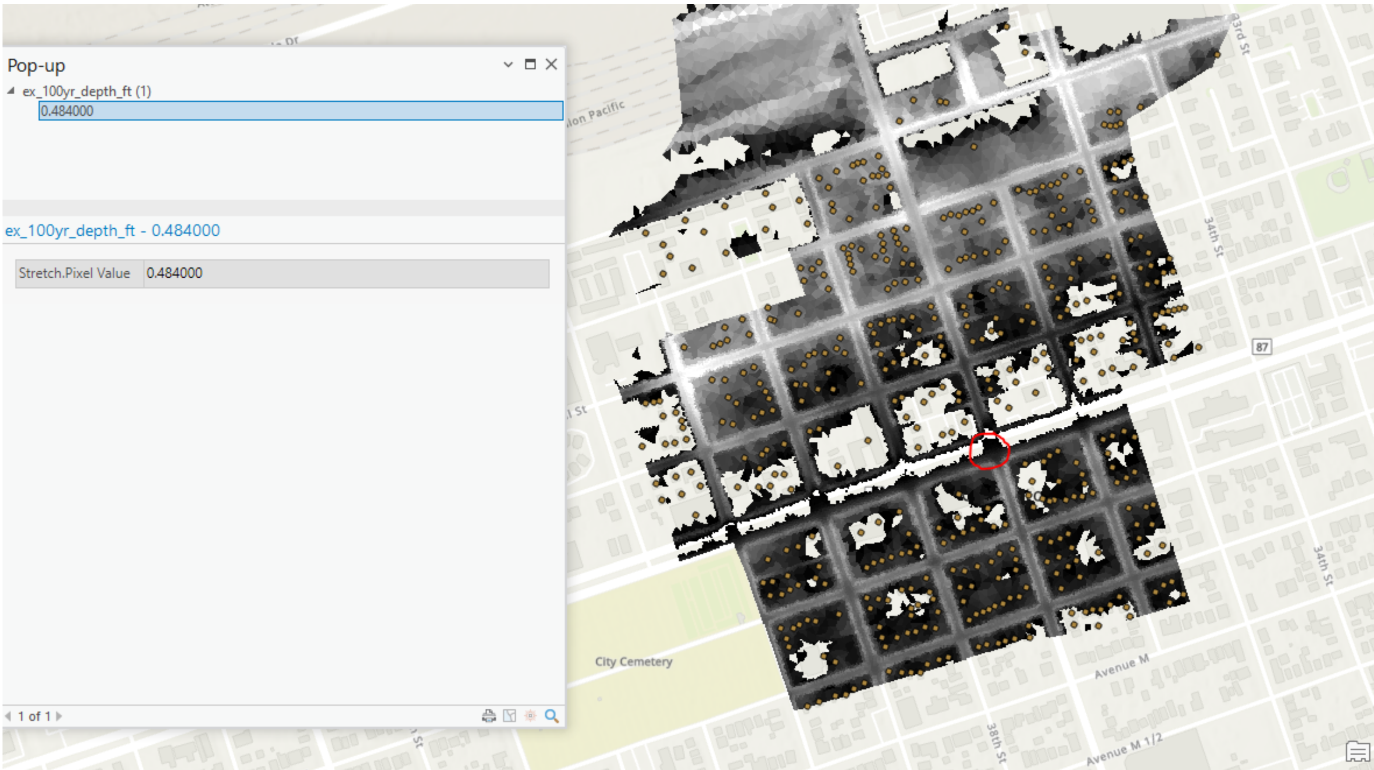


Figure 1: Existing 100yr Depth in Ft at red circled area, along I-87 (0.484 ft).

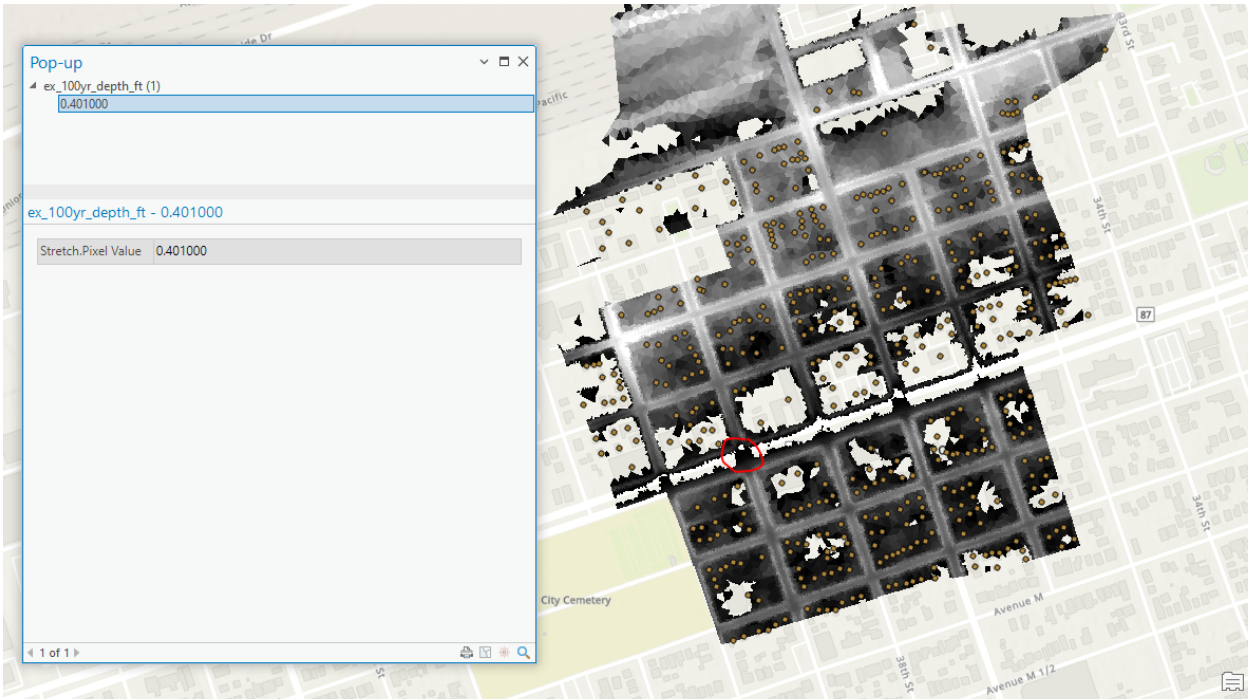


Figure 2: Existing 100yr Depth in Ft at red circled area, along I-87 (0.401 ft).

Miles of roadway flooded

The flood streets benefit calculated are assumed only for 37th, as it appears to have over 1 ft of depth across the roadway. The depth across 37th street appears to vary mostly between 1-3 ft. The miles of roadway inundated was estimated to be about 4,300 ft, as shown in the figure below, which is approximately 0.82 miles of inundated roadway.

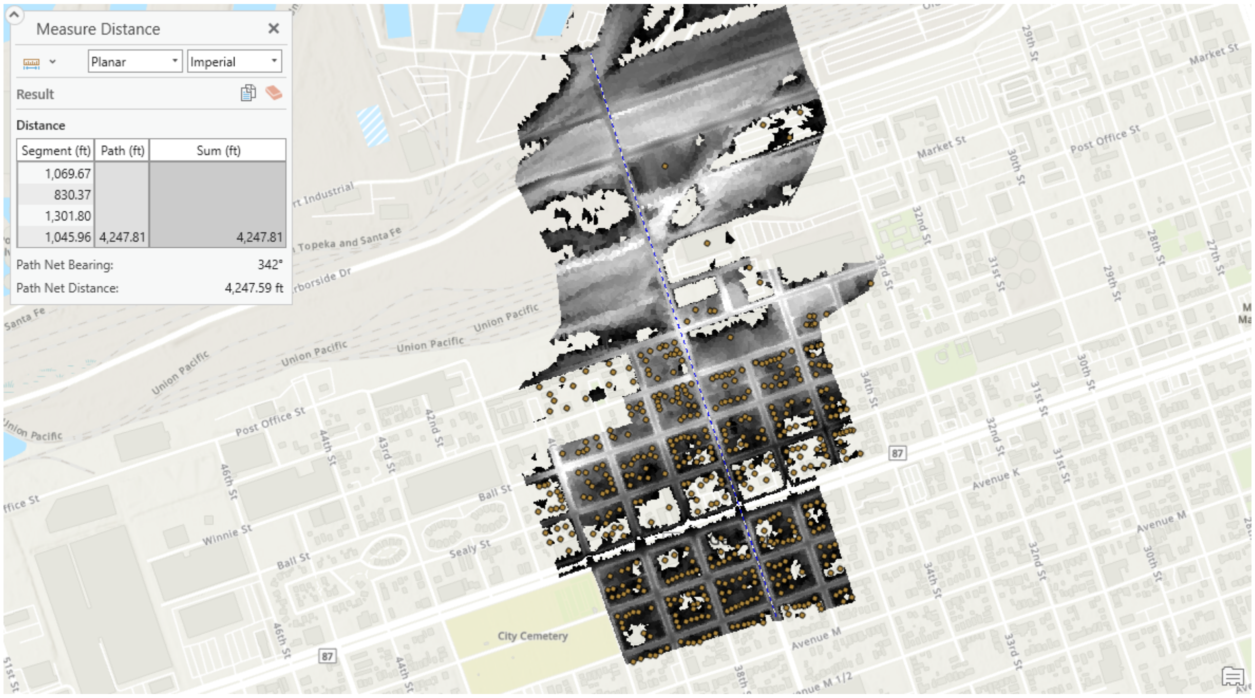


Figure 3:Distance Measured along 37th Street (4247.81 ft)

Duration of impassable roadway

The duration of impassable roadway was determined from the raster data provided. The data provided included the flooding duration in seconds as a raster for each storm event in existing conditions. The durations were estimated as the approximate largest duration in seconds along 37th street. This was estimated by using the explore tool in ArcPro to view the duration in seconds at each point. For the existing 5-yr storm event the largest duration on 37th street was estimated to be 47,800 seconds, which is approximately 13.3 hours. The figure below shows the approximate point at which the largest duration was discovered in the existing 5-yr storm event.

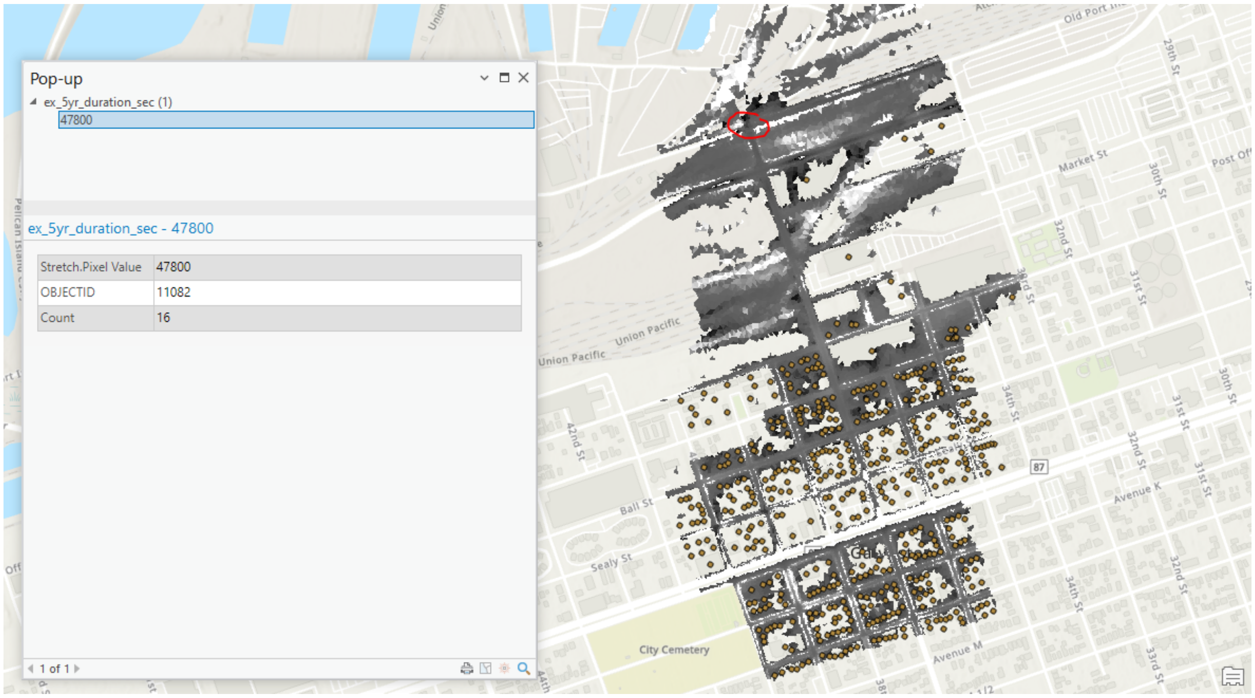


Figure 4: Existing 5yr Duration in Seconds at red circled area (47800 seconds).

For the existing 10-yr storm event the largest duration on 37th street was estimated to be 56,800 seconds, which is approximately 15.7 hours. The figure below shows the approximate point at which the largest duration was discovered in the existing 10-yr storm event.

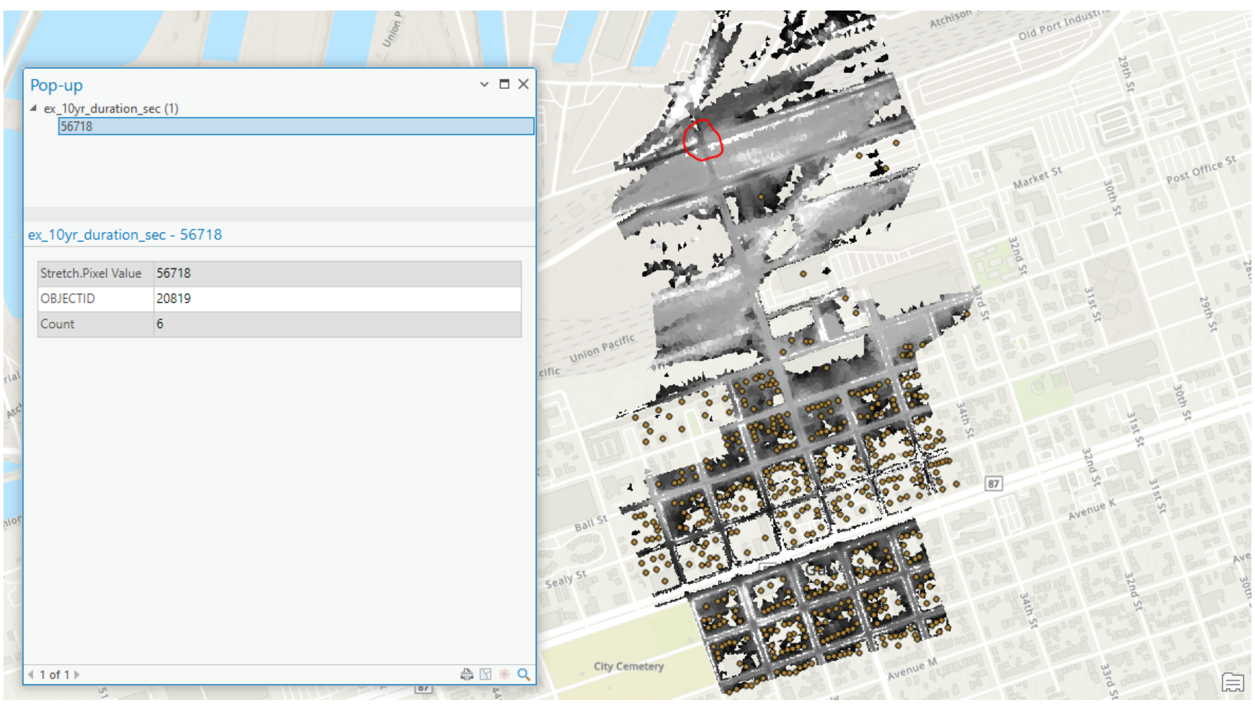


Figure 5: Existing 10yr Duration in Seconds at red circled area (56718 seconds).

For the existing 100-yr storm event the largest duration on 37th street was estimated to be 61,600 seconds, which is approximately 17.2 hours. The figure below shows the approximate point at which the largest duration was discovered in the existing 100-yr storm event.

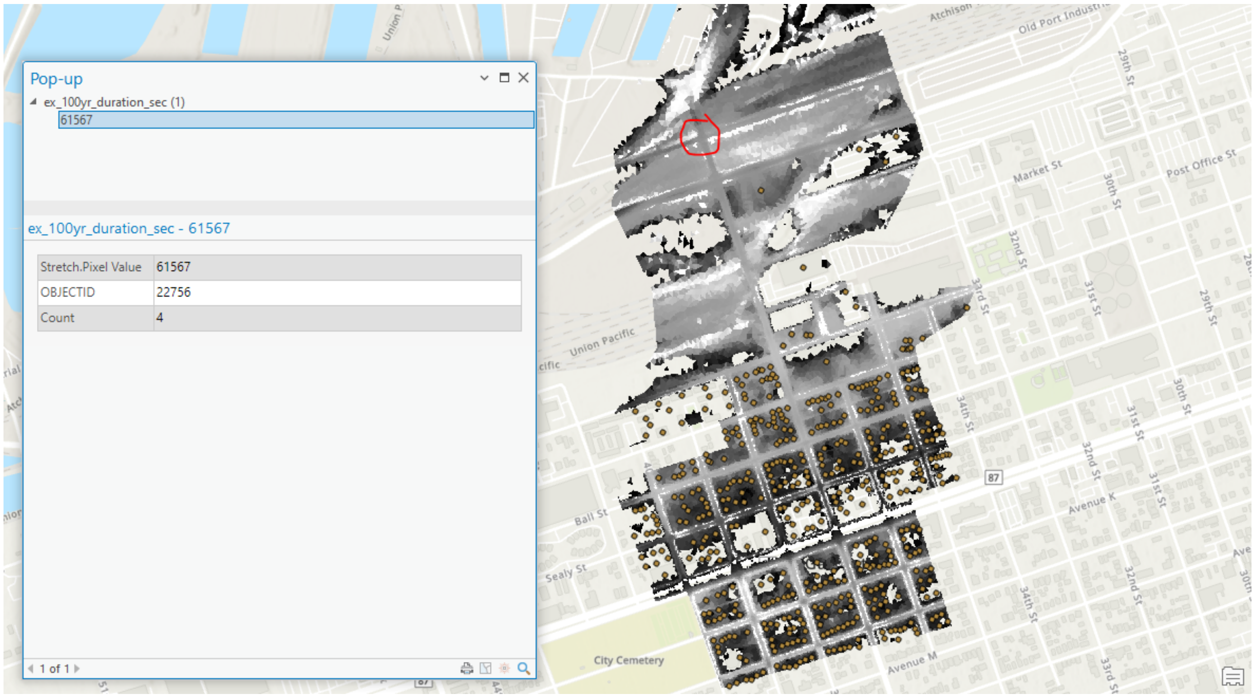


Figure 6: Existing 100yr Duration in Seconds at red circled area (61567 seconds).

Daily Traffic on affected roadways

The average daily traffic on affected roadways was pulled from TxDOT data. The 5-year annual average daily traffic (AADT) from 2021 was 2,224. This was the average daily traffic used for the flooded streets calculation.[1]

Mileage added through detour

The mileage added to detour flooded streets was approximated manually in the area via Google Maps. Google maps directions were used from the furthest point on the improvement area, along 37th street, to the nearest Fire station. This resulted in 4 minutes of travel time with an estimate of 1.3 miles of mileage. The figure below shows the results and path of the initial route.

[1] The AADT was determined from the TPP District Traffic Web Viewer: AADT: https://txdot.maps.arcgis.com/apps/webappviewer/index.html?id=06fea0307dda42c1976194bf5a98b3a1

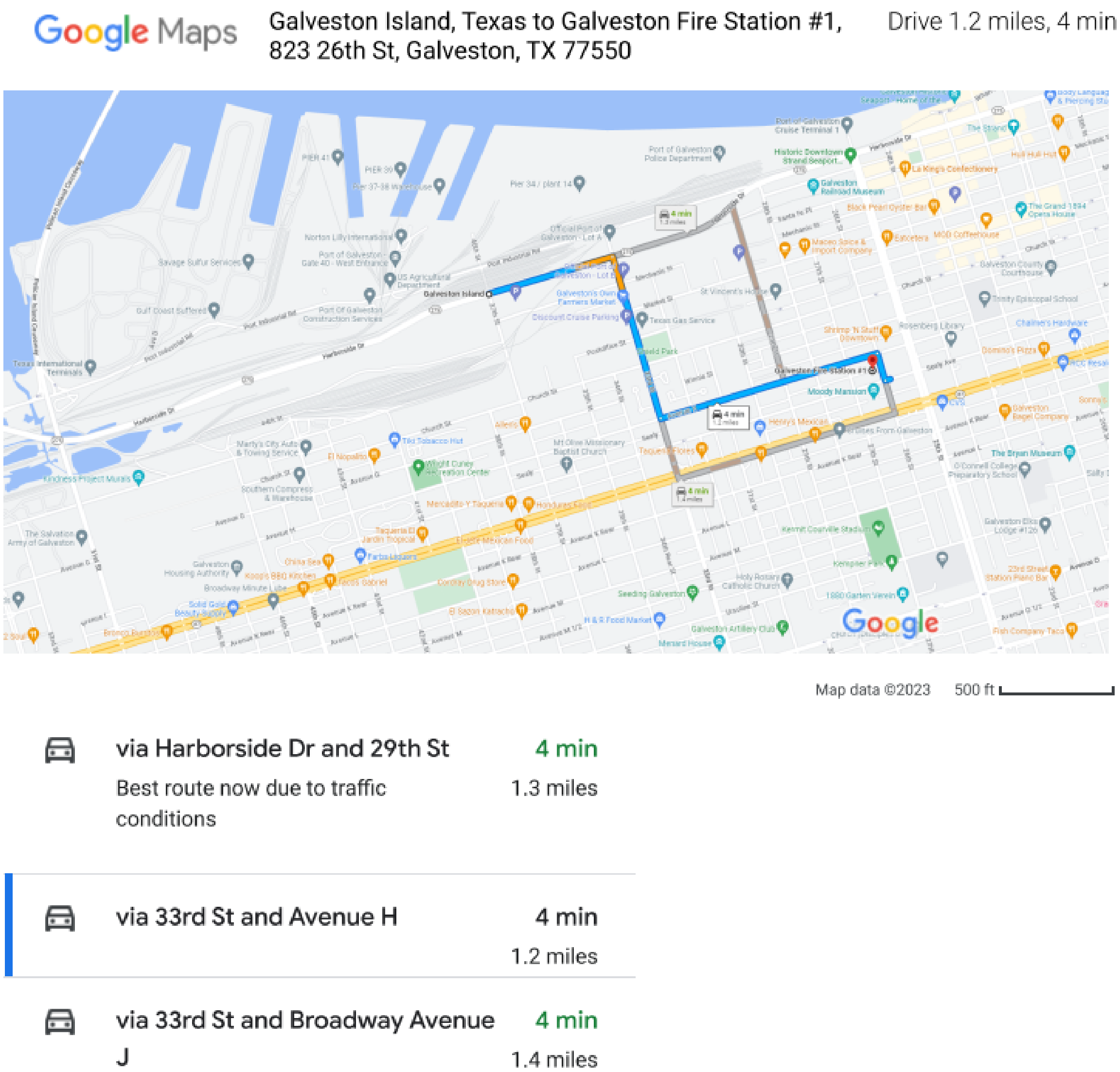
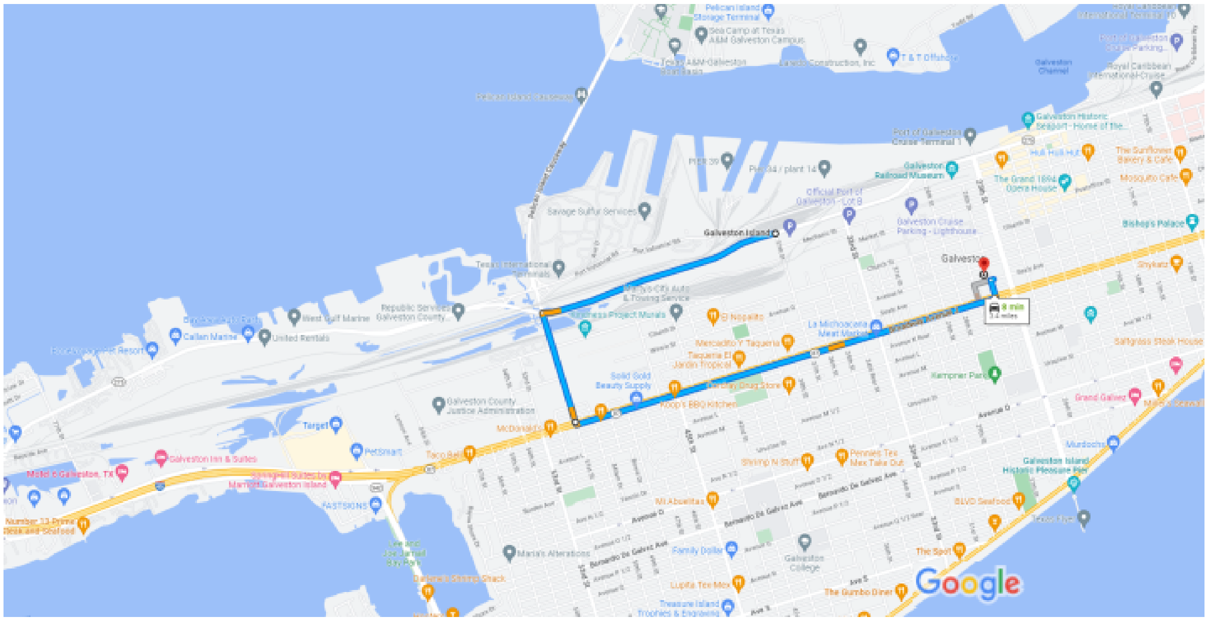


Figure 7: Directions from 37th Street to nearest Fire Station

The mileage added was determined by manually dragging points along major roads to get to the initial starting point along 37th street. This resulted in approximately 9 minutes of travel time with 3.4 miles of mileage estimated. The figure below shows the results from the approximation.

Google Maps Galveston Island, Texas to Galveston Fire Station #1, 823 26th St, Galveston, TX 77550 Drive 3.4 miles, 8 min



Map data ©2023 INEGI 1000 ft

via Harborside Dr and Broadway Avenue J — **8 min** — 3.4 miles
7 min without traffic

via Harborside Dr, 51st St and Broadway Avenue J — **9 min** — 3.4 miles
8 min without traffic

Explore Galveston Fire Station #1

Figure 8: Directions from 37th Street to nearest Fire Station with detour

The mileage added as a result of detouring the flooded roads is estimated to be 2.1 miles (3.4 miles from 1.3 miles.)

EMS Response time

The EMS response time was not immediately available for Galveston, TX or Galveston County, so the EMS response time was determined using the average response time for Harris County (a neighboring county to Galveston County). The average response time for emergencies is about 8.5 minutes.[2] The EMS response time was rounded up to 9 minutes. The EMS response time during storm events was estimated by tripling the normal EMS response time.

Project Costs

According to the CDBG-MIT- budget justification of retail costs the overall cost to construct the 37th street drainage project is $74,794,691 based on 2020 construction costs. The drainage project was assumed to have a useful life of 30 years. The project cost used in the BCA includes the cost of materials, facilities, and services such as the cost of the outfall Pump Station ($28,733,846). The annual operations & maintenance (O&M) for the pumps is estimated to be 1% of the outfall pump station cost, for a total O&M cost of $290,000. This assumption is generally assuming the pump station is electric, runs only in the event of emergencies, has a fulltime operator at 70k/year, with fringe/benefits/administration, and includes lights and lawn-care.

Building Information

The "Texas Buildings with SVI and Estimated Population (November 2021)" dataset provided by TWDB for Regional Flood Planning was used to determine building sizes and building types. The Finished Floor Elevations (FFE) for all structures was assumed to be 0.79 feet above ground level and all structures were assumed to be 1 story. Based on the provided building types, structures were reclassified as either residential, commercial, industrial, or agricultural. Public buildings were reclassified as commercial structures. Buildings marked as "Vacant or Unknown" in the TWDB dataset were reclassified as agricultural buildings.

Finished Floor Elevations

It is recognized that determination of finish floor elevations in coastal communities like the City of Galveston can be difficult since structures in the communities typically display a very wide variety of heights as compared to lowest adjacent grades. Development of high resolution and individualized finish floor elevations for each structure was out of the scope of the BCA and therefore a methodology was developed utilizing previous extensive efforts employed by the City of Galveston in similar analysis described below.

A BCA Data Sheet was provided from the sponsor (or project team) with finished floor elevation (NAVD88) and Lowest Adjacent Grade (NAVD88) grade data for a different project in the same relative area of the 37th Street project. In total, there was 817 buildings with recorded data in the example data. To get an estimate for the finished floor elevations in the 37th Street project area, the median value of the example building data of the lowest adjacent grade was

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2 https://esd11.com/statistics/

subtracted from the finished floor elevation. The median value of the finished floor elevations relative to the lowest adjacent grade was estimated to be 2.90 ft, however this estimate was found to be higher than the maximum existing flood depth (2.59 ft) calculated at building points within the 37th street project. Therefore, upon reviewing the structure data, it was found that using the heights at the 25th percentile (0.79 feet) allowed for a reasonable distribution of damages to be calculated.

Flood Hazard Data

The flood depths for each structure within the study area was determined for the 20%, 10%, and 1% annual chance exceedance. The With project conditions were assumed to have no structural impact. The baseline and with project damages are included in **Table 1**.

Table 1: Flood Hazard Data

	5 – year Storm		10 – Year Storm		100 – Year Storm	
	Baseline	With Project	Baseline	With Project	Baseline	With Project
Residential Flood Damage	$70,284	$0	$877,978	$0	$9,088,928	$0
Commercial Flood Damage	$0	$0	$70,160	$0	$4,555,598	$0
Flood Streets Impact	$5,781	$0	$6,882	$0	$8,159	$0
Total Structural Damage	$76,065	$0	$955,021	$0	$13,652,685	$0

Expected Flood Damages After FMP Implementation

For the structures analyzed, the 37th Street, Galveston FMP results in $15,904,904 in standard mitigation benefits and total net benefits.

Benefit-Cost Summary

The benefit-cost analysis for this project was completed using the FEMA BCA Tool Version 6.0. The final benefit-cost ratio BCR) with standard benefits is 0.08.

Project Useful Life	30 years	
Event Damages	**Baseline**	**Project**
10 - year storm	**$955,021**	**$0**
100 - year storm	**$13,652,685**	**$0**
5 - year storm	**$76,065**	**$0**
Results from BCA Toolkit:		
Total Benefits	$6,061,295	
Other Benefits (Not Recreation)	$0	
Recreation Benefits	$0	
Discounted Total Costs	$78,393,313	
Net Benefits	$6,061,295	
Net Benefits with Recreation	$6,061,295	
Final BCR	**0.08**	

Appendices

Appendix A- Engineer’s Justification Statement for 37th Street Service Area

Date: October 23, 2020

To:

Texas General Land Office (GLO)
C/O: Community Development and Revitalization
P.O. Box 12873
Austin, Texas 78711-2873

From: Dr. Daniel Christodoss, Ph. D., P.E.
City Engineer
City of Galveston
823 Rosenberg
Galveston, Texas 77553

Subject: Engineer's Justification Statement for the 37th Street Drainage Project; CDBG-MIT Hurricane Harvey State Mitigation Competition

To Whom it may concern:

The City of Galveston, located on Galveston Island, is the largest community in the United States established on a barrier island. The Gulf of Mexico forms the southern boundary, and Galveston Bay serves as the northern boundary of the city. This geographic location places the city in the top 10% of Texas jurisdictions with a high level of vulnerability to natural hazards as reflected in the GLO Composite Disaster Index (CDI) which ranks the level of community risk from natural hazards. The high CDI index is reflective of the frequent hurricanes, tropical storms, and tidal flooding originating in the Gulf of Mexico. These frequent events often create intense rainfall accompanied by high tides that cause severe flooding of the lower elevations on the island. After the 1900 Hurricane, the eastern portions of the island were raised behind a seawall which was completed in various phases from 1904 to 1961 while areas west of the seawall continue to retain the natural barrier island characteristics.

The City of Galveston is bounded on the north by SH-275 Harborside Drive (Evacuation Route#1) at Galveston Bay, SH-87 Broadway (Evacuation Route#2) in the central area of the City, and Seawall Blvd which is Evacuation Route#3 (southern boundary) at the Galveston Beach. Ferry Road, running north-south connects Harborside, Broadway and Seawall Blvd. 61st Street (Spur 342) connects Broadway and Seawall in the western area of the City. Between 61st and Ferry Road, all three evacuation routes are connected by Holiday Drive, 11th, and 13th through 16th Streets, 18th and 19th Street, 21st, 23rd, 25th 28th and 29th Street, 33rd Street, 37th and 51st Street.

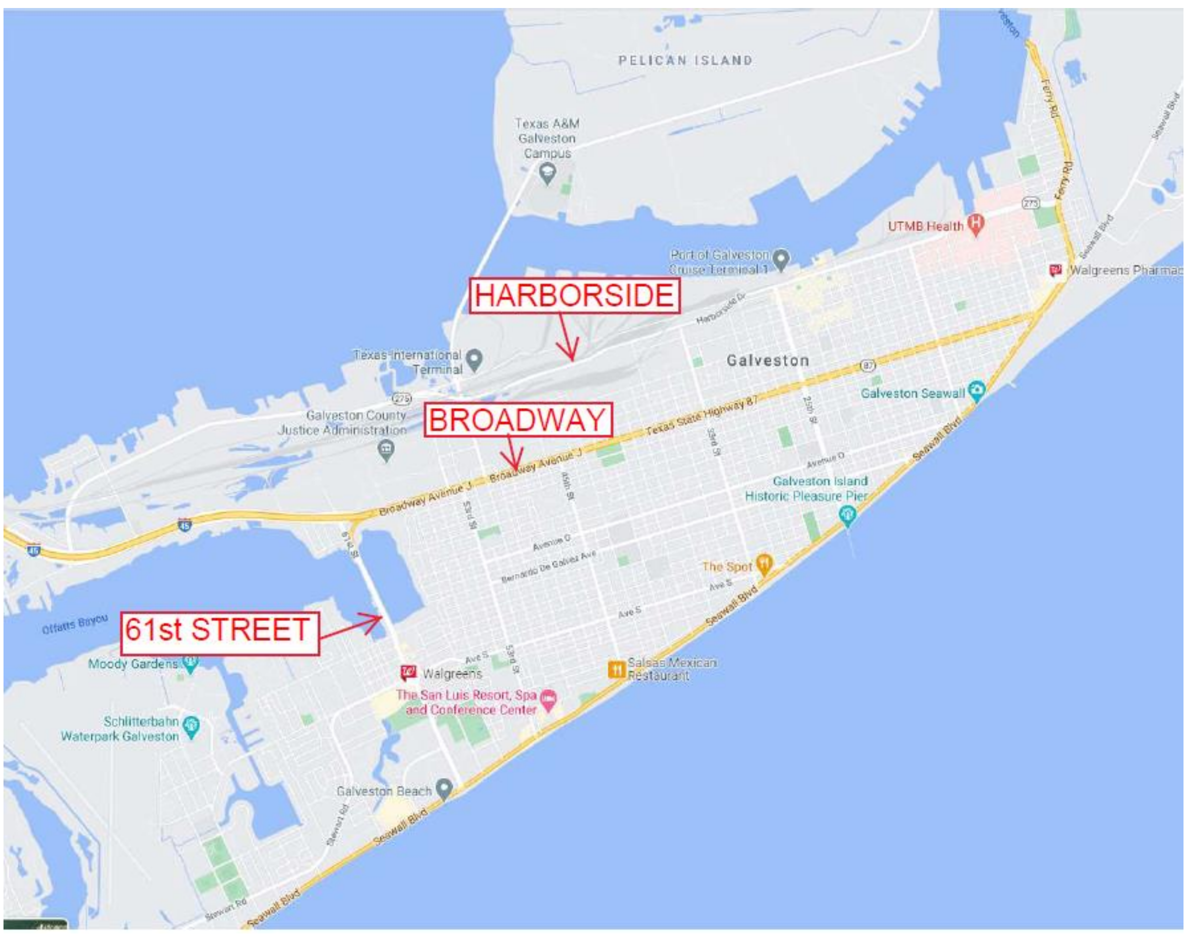

Figure 1 - City of Galveston

The drainage issues in the vicinity of the 37th Street Project improvement area are described below:

1. Numerous locations on Broadway as well as on 37th Street are inaccessible during high tidal and heavy rainfall events.

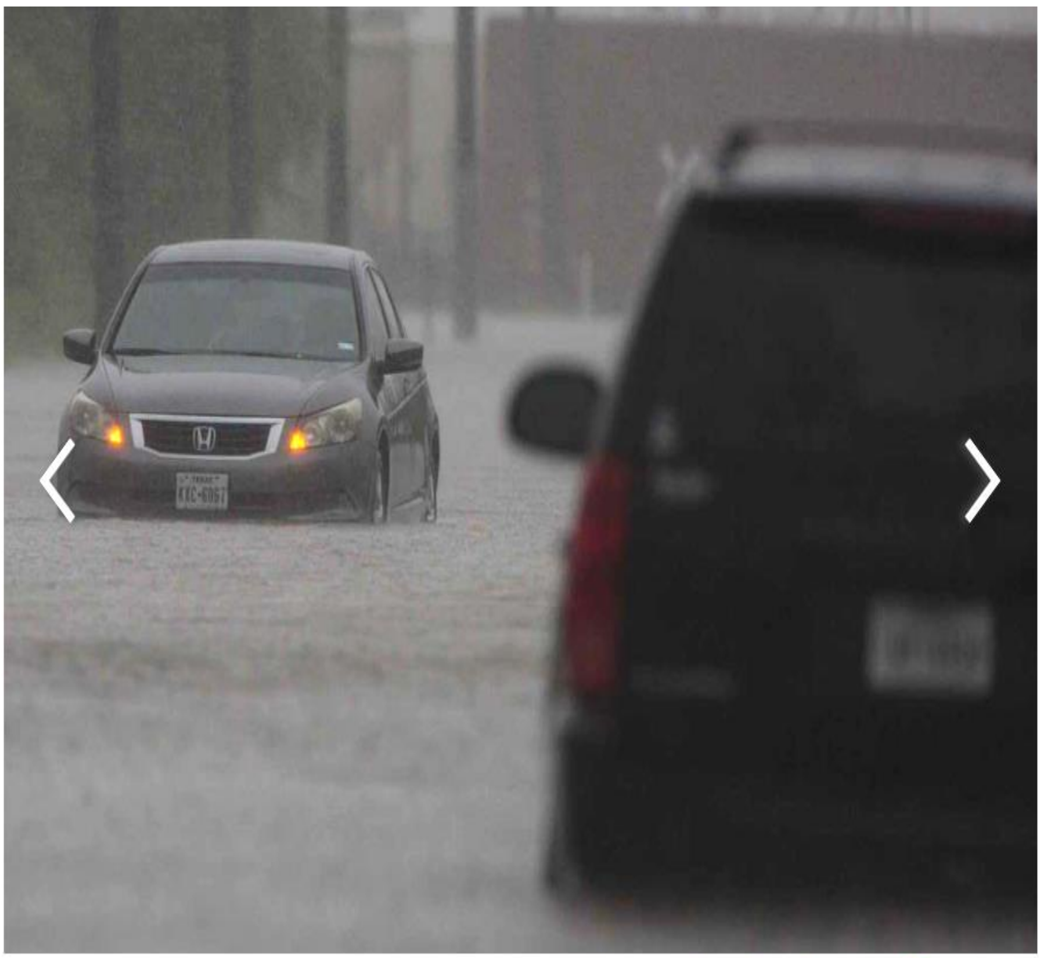

Photo: Yi-Chin Lee, Houston Chronicle

IMAGE 82 OF 107

A car is abandoned in the middle of the flooded 37th Street on Wednesday, Sept. 18, 2019, in Galveston. flooded streets on Wednesday, Sept. 18, 2019, in Galveston.

Figure 2 - 37th Street and Harborside

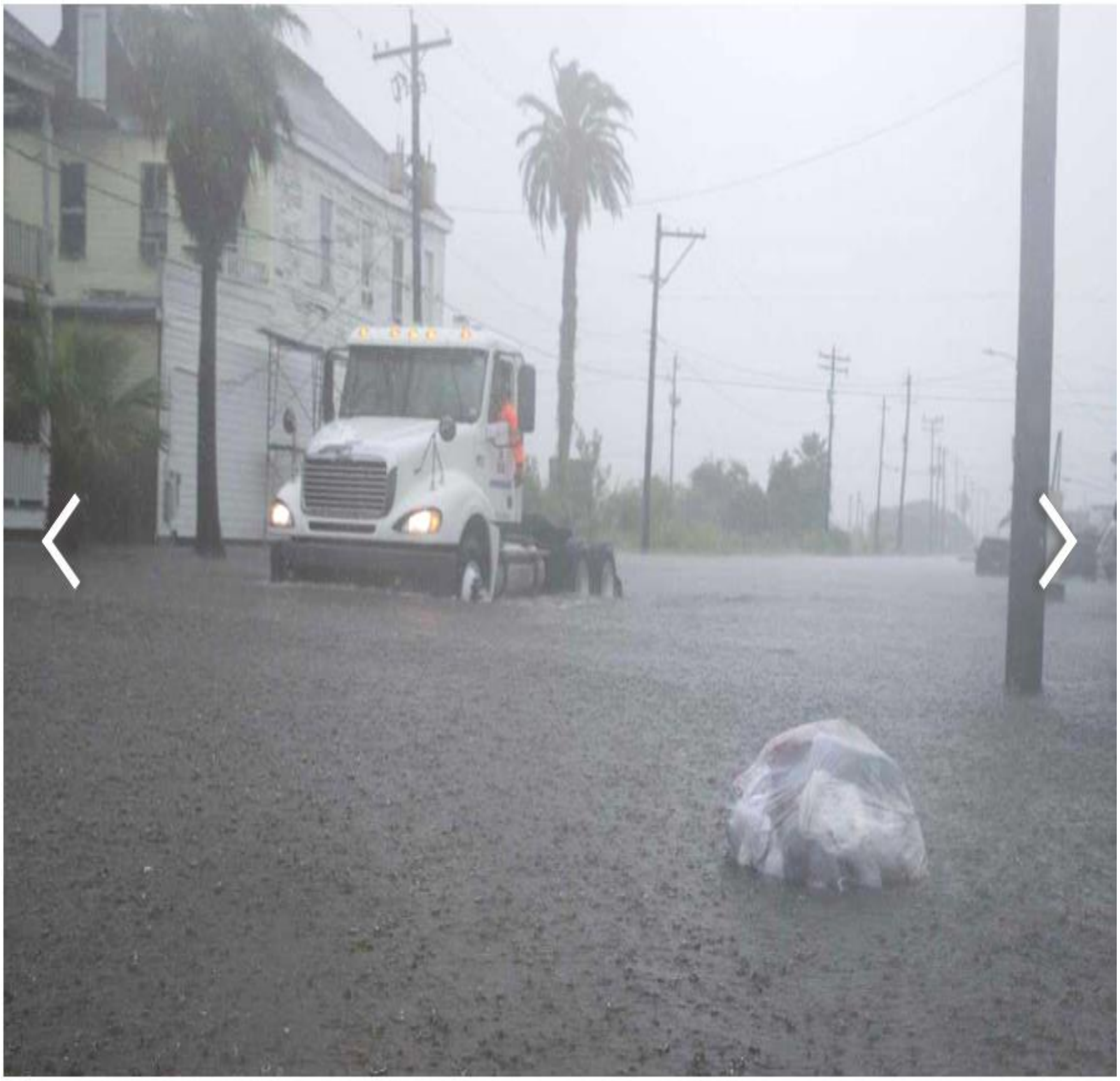

Photo: Yi-Chin Lee, Houston Chronicle

IMAGE 83 OF 107

A bag of personal belongings floats down the flooded 37th Street while a tow truck is searching for stranded vehicles and people on Wednesday, Sept. 18, 2019, in Galveston. flooded streets on Wednesday, Sept. ... more

Figure 3 - 37th Street and Church Street

2. Harborside Road is inundated during high tidal events and/or during heavy rainfall due to the low elevation of the road (SH 287).

Cars are stalled in high water on 37th Street near Harborside Drive in Galveston, Texas, Wednesday, Sept. 18, 2019, as heavy rain from Tropical Storm Imelda caused street flooding on the island.

(Jennifer Reynolds/The Galveston County Daily News via AP)

Figure 4 - 37th Street and Harborside

3. Port of Galveston that serves as the major ingress/egress route for industrial traffic from the Port. Cruise Ship passengers affected by flooding:

Figure 5 - 37th Street and Harborside

The critical need for this pump station is further amplified by photos taken in the 37th Street Project Area that were shown on the previous pages.

During tidal flooding accompanied by heavy rainfall on Harborside and Broadway as is evident from the photo, and flooding on Port Industrial Road, gravity storm sewer systems are ineffective in draining the City. Tidal backflow through the gravity storm pipes in addition to heavy rainfall were responsible for the inundation of the streets depicted in the photo. The photos depict how a gravity storm sewer system without a backflow valve and pump station is ineffective in controlling tidal backflow. If heavy rainfall occurs during high tide, the impacts to City streets, life and property are further exacerbated and result in loss of life and property.

In addition to storm water run-off, sand is another contributor to the drainage system on Galveston Island. Galveston sand is very fine and easily gets airborne due to the prevailing onshore breeze. This sand is deposited over the areas directly adjacent to the beach side of the island and eventually drains into and gets deposited into the storm sewer system. The sand creates an on-going maintenance concern for the existing drainage system which is described by the City's Drainage Master Plan as being undersized due to current evaluation criteria requiring clean and debris free storm sewer infrastructure. As the levels of sand and silt rise during natural events, the capacity of the current system often becomes over-burdened resulting in increased storm water runoff, ponding, and frequent flooding.

Reviews of original construction plans indicate that much of the system was constructed under a two-year storm drainage capacity criterion using monolithic box culverts and clay pipe inlet leads. Many of these inlet leads are smaller than 18- inches in diameter which are easily blocked by debris and silt that limit conveyance capacity. Bridge blocks, or small pipes that connect roadside gutters across intersections also contribute to inefficient storm water runoff in the urbanized areas of Galveston. These structures are sometimes square, or small concrete pipes (<15-inch) and generally serve areas where existing storm sewers do not exist.

Runoff in the city generally flows from south to north towards the Bay. Elevations in this area range from approximately 1 to 18-feet above sea level. As a result, the 37th Street improvement and service areas experience frequent flooding, inundation of storm sewers, and ponding in streets due to the flat topography, inadequate system capacity, and tidal backflow. This frequent flooding also impacts a primary evacuation routes for the island along Harborside as well as access to critical community lifelines such as the University of Texas Medical Branch (the county's only Level 1 Trauma Center), Galveston National Laboratory (GNL), and Island Community Center which serves as a transportation HUB for the evacuation of residents during major disasters. In addition, the current capacity of the existing storm drain system is inadequate to control flooding during minor storm which has resulted in the repetitive flooding of residential neighborhoods and temporary loss of emergency vehicle access to these areas.

The only effective engineering approach to address tidal flooding in conjunction with heavy rainfall is to install a backflow valve at the proposed new outfall pipe/box structure in conjunction with a new pump station. Installation of a backflow valve at the outfall without a pump station will increase head loss in a gravity storm system and increase flooding within the project area. Therefore, it is important to install a gravity drainage system that drains by gravity during low tide and alternatively bypasses the gravity system and drains through the pump station during high tide events through the backflow valve-controlled outfall.

The 37th Street Project Area starts at 35th street, encompasses Broadway, Port Industrial Road and Harborside Drive and traverses west until it encompasses a strategic portion of 41st Street.

The 37th Street Project Area was carefully selected based on the following factors:

1. Presence of a Primary Evacuation Route.
2. Proximity to Water Body to Allow Pump Station Installation.
3. History of prior flooding.
4. Available slope in terrain to facilitate gravity drainage.
5. Flowline of outfall pipe to minimize submergence during high tide.
6. Availability of City Owned property for Pump Station Facility.
7. Presence of existing storm systems that can be integrated into the proposed gravity storm system design. The dark red lines in the map shown below display the storm trunk lines proposed in the 2003 Master

Plan that have not been built. The blue lines illustrate the drainage areas delineated in the 2003 Drainage Master Plan. After Hurricane Harvey in 2017, the City upgraded the 2003 Drainage Criteria from the 2-year storm to the 25-year storm. All developments and capital improvement projects now must be designed for the Atlas 14, 25-year storm intensities per new City Drainage Criteria. See below, a depiction of the trunklines (red) in the 2003 Masterplan that must be upgraded to the current criteria.

8. Cost Feasibility
9. Size of Gravity Storm System vs Right of Way Width Availability
10. Presence of utility conflicts in proposed gravity storm system route
11. Maximizing the inclusion of the project area within the 2003 Masterplan delineated drainage areas
12. Avoiding the need for procuring easements and private property that will impact the administrative feasibility.
13. Vicinity Ports (for Evacuation, National Guard Activation, Flow of Life Saving Equipment and Emergency Personnel)
14. Vicinity to main tourist attractions (Cruise Lines, Downtown Strand District, etc.) that are areas that need to be tidally controlled to prevent loss of life and property during high tidal events that occur in conjunction with or in the absence of heavy rainfall events.
15. Access/route to major pump stations (59th and 30th Water Pump Station) and major wastewater plants (Main Wastewater Treatment Plant)
16. Access to major community life on the Beach and Seawall Entertainment District.
17. Access to Parks and Community Centers

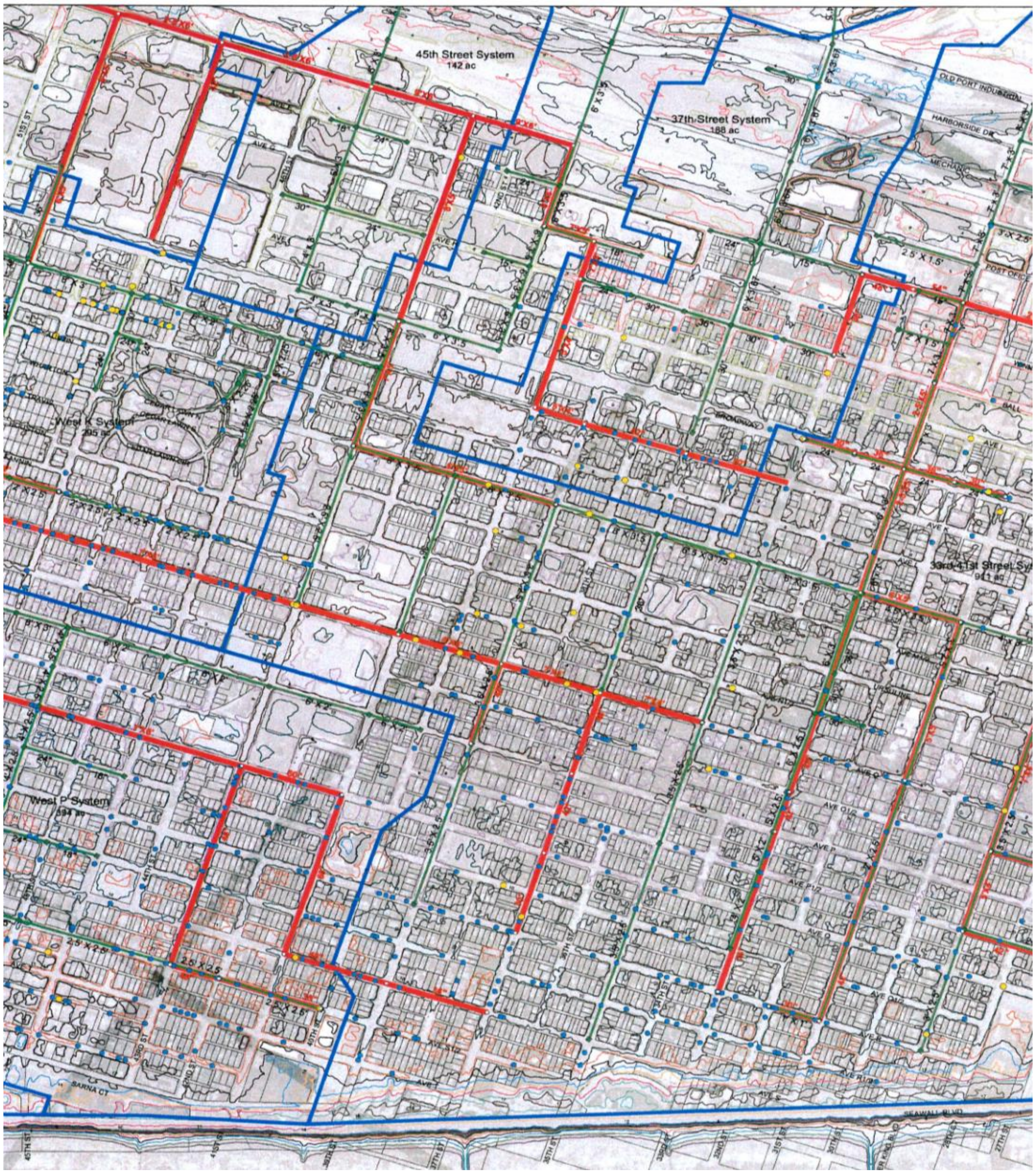

Figure 6 - 2003 Masterplan Stormwater Design Recommendations

The 37th Street System is adjacent to and is the thoroughfare for the East End since it includes Broadway, Harborside, and Port Industrial Road. Upgrading this system is important since flooding in this area will have a significant impact on:

1. Routine and emergency travel (Evacuation, Police, Fire and Medical).
2. Stagnant water East and West of 37th Street which will severely impact public safety, health and hygiene in the 37th Street area.
3. Flooding East and West of 37th Street which has the significant potential to cut off critical communication, water, electricity and gas supply to the 37th Street and entire East end of Galveston Island.
4. Flooding East and West of 37th Street which will greatly impact the ability of emergency responders resulting in potential loss of life.
5. Flooding East and West of 37th Street which will impact critical supply deliveries to the UTMB Emergency, Hospitals and Clinics.

Upon completion of the 37th Street Drainage Project, the rainwater produced by a 100-year event will be contained within the City's right- of-way, and flooding of private property will be eliminated within the boundaries of the project improvement area. In addition, this project will significantly reduce flooding in the project service areas adjacent to the improvement area, reduce flooding on the City's major evacuation route along Harborside Drive, improve routine and emergency travel, provide critical access to community lifelines, and increase the City's resiliency to flooding from future events. Hence, as explained below, the 37th Street Drainage Project benefits the population of the entire City, and the service area for the project is defined by the City's jurisdictional limits.

The 37th Street drainage project in conjunction with the 14th Street (in design) and 18th Street (in construction) will open up Harborside as the main Evacuation Route, and, enable residents to exit the Island off Broadway-I-45. Broadway Avenue typically floods from 51st Street to 43rd Street, beyond the drawdown effects of the 37th Street drainage project. Hence, Broadway Avenue may not be available as an evacuation route for significant storms during a pre-storm flooding event.

During a major evacuation, residents who need transportation off the island will be provided buses at 4700 Broadway, Island Community Center (ICC), and will be shuttled to the ICC from different parts of town. This will not be possible without the cumulative drainage benefits of the 37th Street project area.

The 37th Street project will not have benefits extending to the area at the intersection of 61st street (Spur 342) and I-45 which is a major evacuation route for West Galveston residents through Seawall-61st (Spur 342)-I-45. The buses and the residents in private cars travelling north on 61st can be significantly impacted by flooding that typically occurs at the low spot in the 61st and I-45/Broadway intersection. However, upon completion of the 37th Street drainage project, residents from the West end of the Island will be able to travel East on Seawall Blvd., past the 61st Street intersection, and access Harborside Drive through North Ferry Road that connects South Seawall Blvd., and North Harborside Drive. Residents south and north of Broadway will also be able to access Harborside through multiple routes. Once on Harborside, residents will connect with 51st Street North, and exit Galveston on Broadway through the I-45 overpass.

The 37th Street Drainage Project's flood mitigation improves the accessibility of the Harborside evacuation route during pre-storm flood events. The City was divided into Zones (see below) to help explain the access routes residents of the entire City can use to evacuate safely on Harborside Drive.

Figure 7 - Zone Map

Figure 8 - Zone I

ZONE I (Area North of Broadway and East of 37th Street): This area includes critical community lifelines such as the University of Texas Medical Branch (the county's only Level 1 Trauma unit), Galveston National Laboratory (GNL). Residents in this area have the option of taking a north-south streets - Holiday Drive, 11th, and 13th through 16th Streets, 18th and 19th Street, 21st, 23rd, 25th 28th and 29th Street, or 33rd Street to access the Harborside Drive evacuation route.

Figure 9 - Zone II

ZONE II (Area South of Broadway and East of 37th Street): Similar to the residents in Zone I, these residents have north-south options such as 14th Street, 25th Street and 33rd Street to access the Harborside Drive evacuation route.

Figure 10 - Zone III

ZONE III (Area North of Broadway and West of 37th Street): This area includes the Island Community Center which serves as a transportation HUB for the evacuation of residents during major disasters. Residents in this area have the option of using 37th Street or 51st Street to access the Harborside Drive evacuation route.

Figure 11 - Zone IV

ZONE IV (Area South of Broadway and West of 37th Street): Residents in this area will need to navigate around the flooded areas of Broadway between 43rd Street and 50th Street, and use 37th Street,51st Street, or they could take Seawall Blvd to a north-south connecting street to access the Harborside Drive evacuation route.

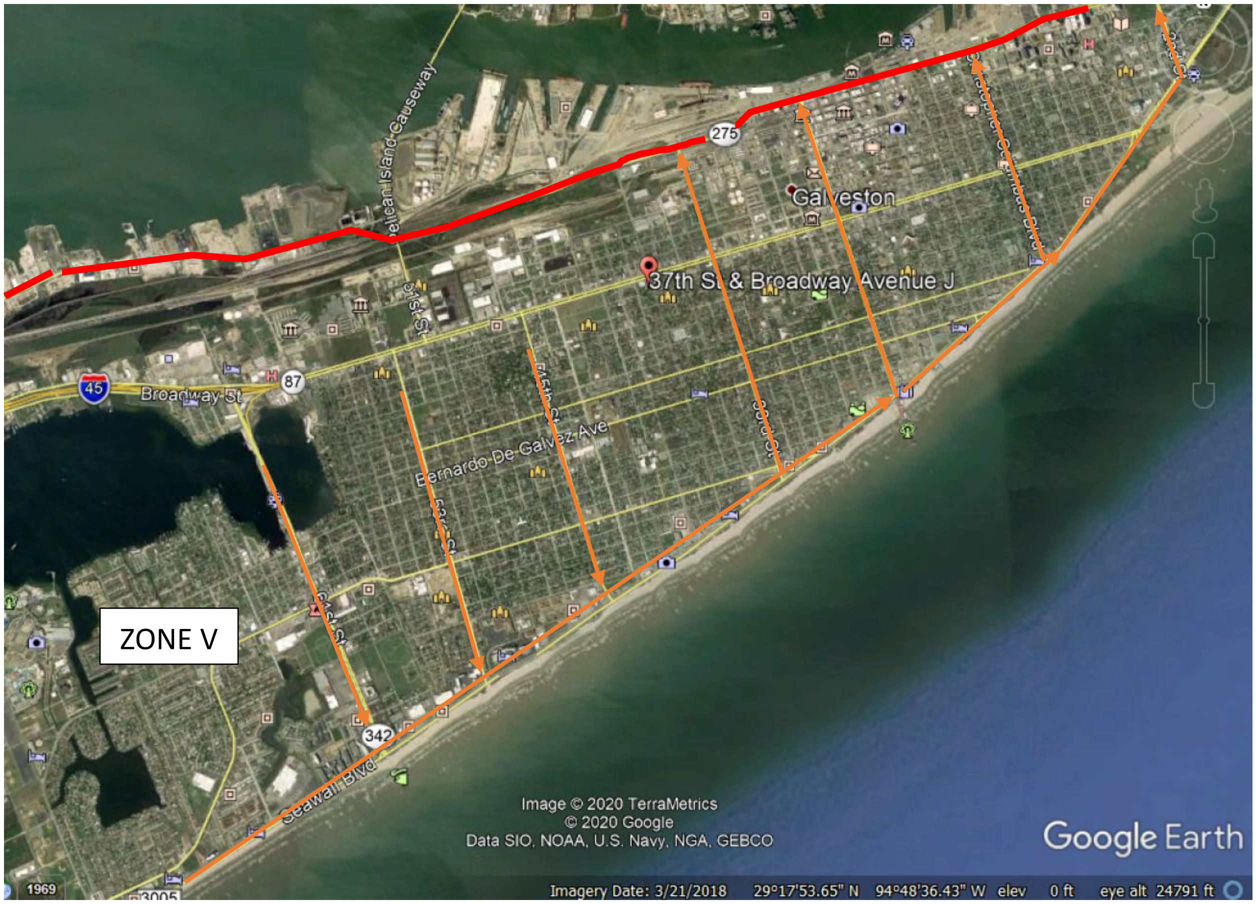

Figure 12 - Zone V

ZONE V (Area West of 61st Street): 61st Street, the evacuation route for the western areas of the City, is subject to flooding at the Broadway Avenue intersection. Hence, the Harborside Drive evacuation route provides a vital means of egress. These residents have the option of taking Seawall Boulevard east to Harborside Drive, or they could take Seawall Boulevard to access any of the north-south streets that connect to Harborside Drive.

Therefore, the 37th Street Drainage Project's flood mitigation benefits the population of the entire City by providing access to the Harborside evacuation route.

Some of the critical landmarks that will benefit from the 37th street Pump Station are shown on the following map:

Figure 13 - Critical Landmarks

Critical lifelines and facilities that will benefit from the 37th Street Pump Station include, but are not limited to the following:

1. Island Community Center Evacuation Hub @ 4700 Broadway
2. East and West Hub Evacuation Route
3. Biomedical Laboratory UTMB
4. Scholes Regional Airport
5. 59th and 30th Street Pump Stations
6. Main Wastewater Treatment Plant near 51st Street
7. City of Galveston Facilities
8. Major industries at the Port
9. Entertainment-Community Life Centers like the Cruise Industry

Hence, the 37th Street project will provide flood reduction along the major evacuation route along Harborside Drive, improve commuting and access to community lifelines during flood events. Therefore, the project benefits the entire City population, and the service area for this project is defined by the City's jurisdictional limits.

Therefore, I recommend design and installation of the following drainage infrastructure:

1. Pump Station adjacent to the Bay.
2. Pumping Main/large outfall pipe from the Pump Station to the Bay
3. Installation of a backflow valve in the Pump Station Outfall Pipe
4. Installation of inlets, leads and trunk lines to convey the drainage from the 37th Street Watershed to the Pump Station
5. A separate connection to the outfall for gravity drainage during low tide events
6. Sluice gates to separate drainage conveyance during low tide and high tide events
7. Utility conflict resolution for the proposed network of inlets and pipes which will require the installation of new or rerouting of existing utilities in conflict and new pavement

Respectfully,

Daniel Christodoss, Ph.D., P.E. City Engineer

Sincerely,

Daniel Christodoss, Ph. D., P.E.
City Engineer