TranSystems

2777 Allen Parkway
Suite 500
Houston, TX 77019
Tel 713-807-0600
Fax 713-807-0650

www.transystems.com

December 9, 2014

Elie Alkhoury, P.E.
Transportation Supervisor Engineer
Texas Department of Transportation (Houston)
7600 Washington Avenue
Houston, Texas 77007

Re: Conceptual Drainage Report and Impact Analysis for Gulf Coast Rail District West Belt Improvements, Houston, Texas

Mr. Alkhoury,

Enclosed for your review is the conceptual drainage report for Gulf Coast Rail District West Belt Improvements. Per our discussion at the meeting on September 29, 2014, we have revised our detention calculations to be based on the 100-year, 24-hour duration storm event.

We look forward to your approval of the conceptual drainage report. Should you have any questions or comments, please call me at (713) 807-4434.

Sincerely,

Eric Lisenbe, P.E., CFM

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CONCEPTUAL DRAINAGE REPORT & IMPACT ANALYSIS

WEST BELT IMPROVEMENTS

HARRIS COUNTY, TEXAS

Prepared for:

Gulf Coast Rail District

Prepared by:

TBPE FIRM # F-3557

DECEMBER

2014

STATE OF TEXAS
ERIC LISENBE
107501
LICENSED PROFESSIONAL ENGINEER

12.09.2014

TABLE OF CONTENTS

EXHIBITS

APPENDICES

1 INTRODUCTION

1.1 Project Description and Location

This report documents the drainage analysis for five proposed grade separation projects along the Houston Belt and Terminal (HB&T) Railroad's West Belt Subdivision. The grade separation projects (referred to as the West Belt Improvements) are located within City of Houston limits and east of the City of Houston downtown (Exhibit 1).

The West Belt Improvements include five proposed grade separations along the HB&T Railroad where the railroad crosses:

- Lyons Avenue
- Runnels Street
- Commerce Street and Navigation Boulevard
- York Street
- Leeland Street and Cullen Boulevard.

The proposed project areas are within the Brays Bayou (Harris County Flood Control District (HCFCD) Unit Number D100-00-00) and Buffalo Bayou (HCFCD Unit Number W100-00-00) watersheds. The West Belt Improvements are within storm sewer systems W0660, W0703, W0635, W0704, W0705, W0486, W0706, D0038 and D7005 as outlined in the City of Houston Comprehensive Drainage Plan (CDP) and illustrated in Exhibit 2. The existing land use in the project area is mainly urban.

This report discusses potential drainage issues and impacts due to the proposed roadway profile changes and railroad grade separation. This report also provides a conceptual drainage design for the West Belt Improvements.

The West Belt Improvements will incorporate input from various agencies including the Gulf Coast Rail District (GCRD), City of Houston, HB&T Railroad, and the Texas Department of Transportation (TxDOT). This analysis is primarily based on the requirements of TxDOT and the City of Houston. TxDOT is responsible for overseeing the West Belt Improvements as the projects will be partially federal funded. The City of Houston is responsible for maintenance of the roadways and the storm sewer systems.

The West Belt Improvements include lowering the roadway below the existing HB&T Railroad tracks at the project locations described previously. Although the improvements will result in minimal changes to impervious area, the project will provide detention ponds to protect the proposed underpass areas from flooding. The detention ponds will detain storm water that is pumped from the underpasses. In addition, the detention ponds will also detain overland runoff from the existing sheet flow patterns that are obstructed by the proposed underpasses.

Storm water within the underpass limits will drain into a curb or drop inlet. From the inlets, the storm water will flow into a storm sewer system and then will be pumped into a proposed detention pond. The proposed detention pond outfall rates were based on the capacity of the receiving storm sewer system. The design of inlets and storm sewer for the West Belt Improvements will be performed in final design.

1.2 Report Objectives

The objectives of the report are as follows:

- Establish existing and proposed drainage areas for the project locations.
- Determine the peak flow rate at pump station locations for conceptual pump sizing.
- Determine detention pond locations and approximate required storage for the 100-year, 24-hour duration storm event.
- Determine the detention pond outfall locations.
- Identify potential impacts to the existing storm sewers within each project location.
- Provide a conceptual drainage plan that identifies drainage infrastructure (primarily detention basins and pump station locations) where additional right-of-way will be required. The right-of-way limits are critical in defining the project limits and preparing for environmental clearance.

This report is not intended for final design purposes. Hydraulic calculations will be provided in final design to show that the final design is in conformance with the conceptual drainage plan presented in this report.

1.3 Drainage Design Criteria

The drainage design criteria for this analysis are based on the requirements of both TxDOT and City of Houston. Criteria for the design of the storm drainage improvements were established by the *TxDOT Hydraulic Design Manual*, Revised May 2014; Chapter 9, Stormwater Design Requirements of the *City of Houston Infrastructure Design Manual* (July 2012); the *City of Houston Technical Paper No. 101, Guidelines for Consideration of Overland Flow for the Extreme Event*, April 2005 (TP-101); and meeting minutes from project meetings with TxDOT.

The following is a list of the key project drainage criteria used in the study:

- The project will not adversely affect flooding for any adjacent properties.
- The project will provide a drainage design in accordance with the objectives of the City of Houston (following guidelines presented in TP-101) to provide a combined drainage system to protect from structural flooding during a 100-year event.
- At the request of TxDOT, the project detention requirements are be based on the 100-year, 24-hour duration storm event (instead of the 3-hour duration as recommended in TP-101).
- At the request of TxDOT, the peak flows are calculated using the TxDOT rainfall intensity-duration-frequency coefficients for Harris County (obtained from TxDOT's WinStorm software) instead of the coefficients found in the *City of Houston Infrastructure Design Manual*.

Underpass areas of the proposed grade separations require special safety considerations to protect against vehicular flooding and drowning. The inlets, storm sewer, and pump stations in the underpass area will be designed for the 100-year frequency storm event at the request of TXDOT,.

1.4 Drainage Design Assumptions

The conceptual design of the detention ponds, pump stations, sheet flow corridors, and other significant drainage infrastructure required for the proposed West Belt Improvements are made based on the previously mentioned design manuals and technical papers. In addition, some assumptions have been made to facilitate the creation of the conceptual drainage plan.

Outlined below are the assumptions made to facilitate the creation of the conceptual drainage plan:

- Peak flows calculated for conceptual pump station sizing are based on the 100-year storm event for the underpass areas.
- Peak runoff from underpass areas was calculated based on a fully impervious drainage area with a runoff coefficient of C = 1.0 and a time of concentration of 10 minutes.
- Offsite drainage areas conservatively assumed as business district land use with a runoff coefficient of C = 0.8.
- Detention ponds will discharge into existing storm sewer systems.
- Detention pond outfall release rates are based on the capacity of the receiving storm sewers. The existing storm sewer systems were assumed to have 2-year capacity.

2 DATA COLLECTION AND ELEVATION DATA

2.1 Data Collection

The data collected and used for the drainage analysis include United States Geological Survey (USGS) topographic maps and the City of Houston GIMS information. As-built record drawings of the existing storm sewer systems were reviewed to determine the sizes, capacity, and approximate depth of the existing storm sewers.

The floodplain maps in the vicinity of the project locations were obtained from the latest available Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM) and are included in Appendix B. The maps indicate that the West Belt project locations are located outside the FEMA effective 100-year floodplain.

2.2 Elevation Data

Elevation data used in this analysis includes topographic survey and as-built drawings (to approximate relative depths of existing storm sewers). In addition, contour data and overland flow paths from the City of Houston GIMS website was used.

3 METHODOLOGY

3.1 Hydrology

Peak flows were calculated using the rational method (Q=CIA). Rainfall intensity was calculated using the following equation from the City of Houston Design Manual. This equation is known as the rainfall intensity-duration-frequency (IDF) relationship. TxDOT's b, d, and e coefficients for Harris County were used in rational method calculations. The equation for rainfall intensity is:

$$I = \frac{b}{(t_c + d)^e}$$

where:

I = average rainfall intensity

t_c = time of concentration

The time of concentration equation from the City of Houston IDM was used to calculate the time of concentration of the project drainage areas to simplify drainage calculations. This equation is shown below:

$$t_c = 10A^{0.1761} + 15$$

The underpass drainage areas are small enough to have actual times of concentration shorter than what is produced using the equation above. In order to provide a higher factor of safety against underpass flooding, the TxDOT minimum time of concentration of 10 minutes was used in calculating peak flows for underpass drainage areas.

3.2 Hydraulics and Conceptual Pump Station Sizing

Hydraulic calculations for proposed storm sewer infrastructure associated with the West Belt Improvements will be provided in final design. Hydraulic calculations will be performed based on the requirements of TxDOT and the City of Houston.

Pumps stations are required to pump the surface runoff within the underpass areas to the proposed detention ponds. Runoff outside the underpass areas will be captured prior to reaching the underpass and routed directly to the detention ponds. Table 3-1 lists the peak flow rate (cfs) for the 100-year event required to be pumped. The flow rates were calculated using the rational method for the underpass drainage areas. Rational method calculations for the areas to be pumped are shown in Appendix B. Wet wells will be sized in final design based on Small Watershed method hydrographs of the pumped drainage areas shown in Appendix C.

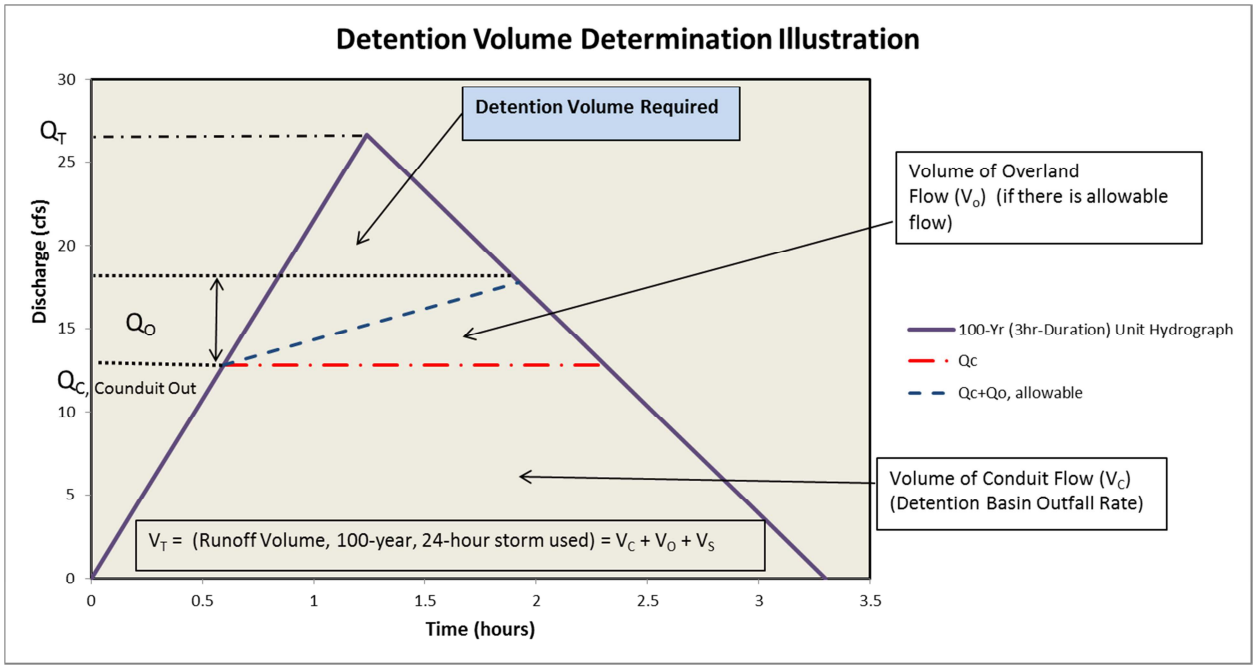
Table 3-1
Summary of Conceptual Pump Station
Flow Rates (100 Year Event)

Location	Peak Flow Rate (cfs)
Lyons	23.9
Runnels	32.2
Commerce and Navigation	55.8
York	49.9
Leeland and Cullen	81.9

3.3 Conceptual Detention Sizing

Volumetric calculations based on a triangular Soil Conservation Service (SCS) hydrograph were used to calculate the required detention pond volumes. The required detention volume is calculated by subtracting out the volumes of storm water runoff that is conveyed through conduit or overland flow from the total runoff volume. The methodology is described in detail in the City of Houston's TP-101 as a "Method 3 Analysis". However, at the request of TxDOT, the 100-year analysis was performed for the 24-hour duration storm event instead of the 3-hour duration storm event recommended in TP-101. The 100-year, 24-hour duration rainfall depths were obtained from Section 3.6.6 of the *Harris County Flood Control District Policy, Criteria, and Procedure Manual, December 2010* (HCFCD PCPM). The depths for Region 2 (Buffalo Bayou Watershed) were used in the analysis. The TP-101 methodology is graphically illustrated in the figure below. Detention volume calculations are shown in Appendix B.

Figure 3-1
Graphic Illustration of TP-101 Method 3



4 CONCEPTUAL DRAINAGE DESIGN

4.1 Objective

The grade separation of the roadway under the railroad tracks requires excavation in excess of twenty feet to allow vehicles to pass under the railway. This significant amount of excavation increases the risk of roadway flooding, possibly rendering the roadway inaccessible to drivers during major storm events. The following sections provide a drainage analysis and conceptual design of proposed drainage infrastructure required to protect the underpasses from flooding.

4.2 On-Site Detention

Detention ponds are best management practices (BMP) for detaining storm water runoff during peak storm events, provide flood protection, and reduce the peak flows to the existing storm sewer systems. Detained storm water is then released over a longer period of time into the storm water system.

Detention ponds are typically used to mitigate increases in storm runoff caused by development (i.e. increased impervious area). However, the primary purpose of detention for the West Belt Improvements is to provide storage volume for areas where storm runoff can no longer utilize existing sheet flow paths due to the proposed underpasses. The detention ponds will allow the sheet flow runoff to be detained while releasing the flow into the existing storm sewer at a rate that the storm sewer system can accommodate. Section 4.3 provides a detailed description of the drainage analysis for each of the five grade separations in the West Belt Improvements. Detention calculations are provided in Appendix B.

4.3 Conceptual Drainage Plan

The following approach was used in developing a conceptual drainage design for the proposed grade separations:

- Determine the drainage area for the proposed underpass limits and calculate the 100-year rational method peak flow. The peak flow from the underpass drainage area will be the required pump capacity for the 100-year storm event as discussed in Section 3.2.
- Delineate offsite drainage areas and evaluate overland sheet flow patterns to determine the following:
  1) The proposed sheet flow corridors that will need to be provided.
  2) The additional detention volume that needs to be provided for offsite drainage areas where existing sheet flow paths cannot be preserved.
- Determine the detention volume required for the proposed grade separations to detain storm runoff that is to be either of the following:
  1) Pumped from the underpass drainage areas of the proposed grade separations.
  2) Captured and detained prior to reaching the proposed underpasses (offsite drainage areas) where existing sheet flow paths cannot be preserved.

Overland sheet flow patterns were analyzed for each of the five project locations. The existing sheet flow patterns will be preserved as much as possible. In cases where the proposed underpasses will impede the existing sheet flow paths, the detention basins have been sized to detain runoff from the overland flow drainage areas. The volume of the proposed basins is based on the 100-year, 24-hour storm event in accordance with directives from TxDOT.

The following sections outline the conceptual drainage plans for each of the five grade separations in the West Belt Improvements. Table 4-2 below summarizes the detention requirements for each of the proposed grade separations.

Table 4-1
Summary of West Belt Improvements Required Detention Volumes

Grade Separation Location	Required Detention Volume (acre-ft)	Proposed Peak Outflow (cfs)	Proposed Pond Area and Depth	
			acre	ft.
Lyons	2.0(1)	21.5	2.1	4
Runnels	9.3	30.8(2)	1.6	10
Commerce/ Navigation	10.0	4.9	1.3	10
York	7.0	85.2(2)	0.9	10
Leeland/ Cullen	15.5	8.0	2.8	4

(1) Detention for offsite drainage areas of the Lyons grade separation is included in plans for the proposed Hardy Connector at Interstate 10. The detention required assumes detention for the proposed Hardy Connector is constructed prior to the proposed grade separation at Lyons. The detention required if the Hardy Connector has not yet been constructed is 12.5 acre-feet.

(2) Peak Outflow includes consideration of other storm sewers conveying flow from overland drainage area. Existing storm sewer systems assumed to have 2-year capacity in accordance with City of Houston TP-101 guidelines.

4.3.1 Lyons Grade Separation

Exhibit 3.1 shows the conceptual drainage plan for the proposed grade separation at Lyons Avenue. The Lyons Avenue grade separation will have an underpass drainage area (Drainage Area L1) of 2.0 acres. Drainage Area L1 will be pumped and requires a design pump capacity of approximately 23.9 cfs based on the 100-year peak flow from this area.

The Lyons Avenue grade separation will obstruct an existing overland flow path that runs north to south along West Street. The proposed Hardy Connector will extend the Hardy Toll Road from Interstate 610 to Interstate 10. The drainage plan for the Hardy Connector includes detention for the Lyons grade separation offsite drainage areas. Right-of-way for the Hardy Connector detention has been partially obtained by the Harris County Toll Road Authority (HCTRA). The Hardy Connector detention basins are expected to be constructed prior to the Lyons grade separation. The Lyons grade separation will only require detention for the Lyons underpass drainage area that is to be pumped.

The detention required for the Lyons grade separation is approximately **2.0 acre-feet** (See Appendix D for Lyons detention pond calculations). This assumes the detention for the Hardy Connector is constructed prior to the Lyons grade separation (See Appendix E for the Hardy Connector drainage plan at Lyons). Additional coordination with HCTRA is recommended. If the Hardy Connector detention is not constructed, the detention required for the Lyons grade separation is approximately 12.5 acre-feet (See Appendix B for calculations). The additional detention would be required for the offsite drainage areas L2 and L3 (See Exhibit 3.1) where overland flow paths would be obstructed.

4.3.2 Runnels Grade Separation

Exhibit 3.2 shows the conceptual drainage plan for the Runnels Street proposed grade separation. The Runnels Street grade separation has an underpass drainage area (drainage area R1) of 2.7 acres. Drainage area R1 will be pumped and requires a design pump capacity of approximately 32.2 cfs based on the 100-year peak flow from this area.

The Runnels Street grade separation will obstruct an existing sheet flow path that runs north along the existing Houston Belt & Terminal Railroad tracks to Buffalo Bayou. A proposed detention pond will be located south of Runnels and east of the Houston Belt & Terminal Railroad tracks. The detention pond will detain storm water that is pumped from the underpass area in addition to the runoff volume from contributing offsite drainage area R2 (See Exhibit 3.2).

The proposed detention pond will outfall into an existing 42-inch storm sewer (City of Houston Plan #16998) that is the main trunk line for City of Houston CDP drainage area W0660. The existing 42-inch storm sewer is approximately thirty feet deep (from natural ground to top-of-pipe) according to as-built drawings. The existing storm sewer will have approximately four feet of cover at Runnels after the proposed grade separation is constructed. The depth of the existing storm sewer will need to be verified prior to final design.

The conduit flow component in the TP-101 detention evaluation was determined based on the 2-year flow from the portion of the overland flow drainage area that is within City of Houston CDP drainage area W0660 (allocated W0660 area). The total allocated W0660 area is 10.4 acres with a 2-year flow of 30.8 cfs.

The detention basin volume required at Runnels Street is approximately **9.3 acre-feet**. See detention pond calculations in Appendix B.

4.3.3 Commerce / Navigation Grade Separation

Exhibit 3.3 shows the conceptual drainage plan for the Commerce Street and Navigation Boulevard proposed grade separation. The Commerce Street and Navigation Boulevard grade separation has an underpass drainage area (drainage area C1) of 4.7 acres. Drainage area C1 will be pumped and requires a design pump capacity of approximately 55.8 cfs based on the 100-year peak flow from this area.

The proposed detention pond will be located north of Navigation Boulevard and west of the Houston Belt & Terminal Railroad tracks. The detention pond will detain storm water that is pumped from the underpass area in addition to the runoff volume from contributing offsite drainage area C2. The overland flow path for offsite drainage area C2 (See Exhibit 3.3) will be obstructed by the proposed Runnels underpass (see Section 4.3.2). The proposed detention basin will outfall into the same existing 42-inch storm sewer as the Runnels detention pond (City of Houston Plan #16998).

The detention pond outfall rate was determined based on the 2-year flow from the portion of the detention pond drainage area that is within City of Houston CDP drainage area W0660 (allocated W0660 area). The total allocated W0660 area is 1.5 acres with a 2-year flow of 4.9 cfs. Proposed sheet flow corridors will be provided in the final design to preserve the natural direction of flow from overland drainage areas C3 and C4 draining away from the grade separation limits.

The detention pond volume required at Commerce / Navigation is approximately **10.0 acre-feet**. See detention pond calculations in Appendix B.

4.3.4 York Grade Separation

Exhibit 3.4 shows the conceptual drainage plan for the York Street proposed grade separation. The York Street grade separation has an underpass drainage area (drainage area Y1) of 4.2 acres. Drainage area Y1 will be pumped and requires a design pump capacity of approximately 49.9 cfs based on the 100-year peak flow from this area.

The York grade separation will obstruct an existing sheet flow path north of Rusk Street along the existing railroad corridor. A proposed detention pond will be located west of Sampson Street on property currently owned by the Union Pacific Railroad. The detention pond will detain storm water that is pumped from the underpass area in addition to the runoff volume from contributing offsite drainage area Y2 (See Exhibit 3.4). The proposed detention pond will outfall into existing storm sewer along Sampson Street (City of Houston Plan #4196).

An existing 84-inch storm sewer trunk line for CDP drainage area D0038 (City of Houston Plan #9495) crosses York Street at Lamar Street. The 84-inch storm sewer has been located in survey and appears to have sufficient depth to not require relocation for the proposed underpass at York Street.

Overland drainage area Y2 is served by several existing storm sewer systems that appear to be interconnected based on City of Houston GIMS data. For analysis purposes, the 2-year flow from offsite drainage area Y2 of 85.2 cfs was assumed to be conveyed in the existing storm sewer systems by conduit flow.

The detention pond volume required at York is approximately **7.0 acre-feet**. See detention pond calculations in Appendix B.

4.3.5 Leeland and Cullen Grade Separation

Exhibit 3.5 shows the conceptual drainage plan for the Leeland Street and Cullen Boulevard proposed grade separation. The Leeland Street and Cullen Boulevard grade separation has an underpass drainage area (drainage area LC1) of 6.9 acres. Drainage area LC1 will be pumped and requires a design pump capacity of approximately 81.9 cfs based on the 100-year peak flow from this area.

The existing 84-inch storm sewer trunk line along Leeland Street (City of Houston Plan #4227 and 4071) does not have sufficient depth for the proposed depressed roadway section and will need to be relocated. At the request of TxDOT, an option of upsizing the storm sewer trunk line (in lieu of providing detention) was evaluated. A conceptual hydraulic analysis (See Appendix F) was performed to determine the approximate amount of storm sewer upsizing that would be required. The analysis assumed the existing system was at capacity in the existing condition. Additional flow was added for the proposed condition to account for the 100-year flow that would be pumped from the grade separation limits and offsite drainage areas where overland flow paths were obstructed.

The analysis showed that approximately 2,100 linear feet of storm sewer would need to be upsized to a 10’ x 7’ box culvert to accommodate the additional flow. The cost of the proposed storm sewer alone would be approximately 1.3 million dollars (based on current TxDOT unit price of $625 per linear foot of 10’ x 7’ box culvert). This cost does not include the additional utility relocations and roadway reconstruction that would be required for the upsizing the storm sewer downstream of the current project limits. The right-of-way needed for the detention option will already need to be acquired due to access constraints caused by the construction of the Leeland Street and Cullen Boulevard underpasses. Therefore, the detention option was considered more economically feasible than the upsizing option.

The proposed detention pond will be located south of Leeland Street and west of the Houston Belt & Terminal Railroad tracks. The detention pond will detain storm water that is pumped from the underpass area in addition to the runoff volume from contributing overland drainage area LC2 (See Exhibit 3.5). The proposed detention pond will outfall into the existing 84-inch storm sewer along Leeland Street (City of Houston Plan # 4227 and 4071).

The detention pond release rate of 13.9 cfs was determined based on the 2-year flow from the portion of the detention pond drainage area that is within City of Houston CDP drainage area D0038 (allocated D0038 area). Proposed sheet flow corridors will be provided in the final design to preserve the natural direction of overland flow from overland drainage area LC3 (See Exhibit 3.5) along Hussion Street and Clay Street.

The detention pond volume required at Leeland Street and Cullen Boulevard is approximately **15.5 acre-feet**. See calculations in Appendix B.

5 SUMMARY AND CONCLUSIONS

The purpose of this report is to document the drainage analysis for the five proposed grade separation projects associated with the proposed West Belt Improvements. In addition, this report provides a the conceptual drainage analysis and conceptual drainage design for where the HB&T railroad crosses Lyons Avenue, Runnels Street, Commerce Street and Navigation Boulevard, York Street, and Leeland Street and Cullen Boulevard.

The West Belt Improvements will result in minimal changes in impervious area from the existing conditions. The conceptual detention basins are designed to outfall to the existing City of Houston storm sewers based on the existing system capacity. The conceptual detentions can provide storage volume for the following:

a. Overland drainage areas where the overland flow path is obstructed by the proposed grade separations.
b. Storm water that is pumped from underpass areas of the proposed grade separations.

2. Section 4.3 of this report outlines the conceptual drainage plans for the West Belt Improvements. The conceptual drainage plans for the West Belt Improvements are shown in Exhibit 3. Detention volume and pump sizing calculations are shown in Appendix B (Appendix D for the Lyons Grade Separation). The required pump station capacities for the grade separations are summarized in Table 4-1 and the required detention volumes are shown in Table 4-2.

EXHIBIT 1 – Location Map

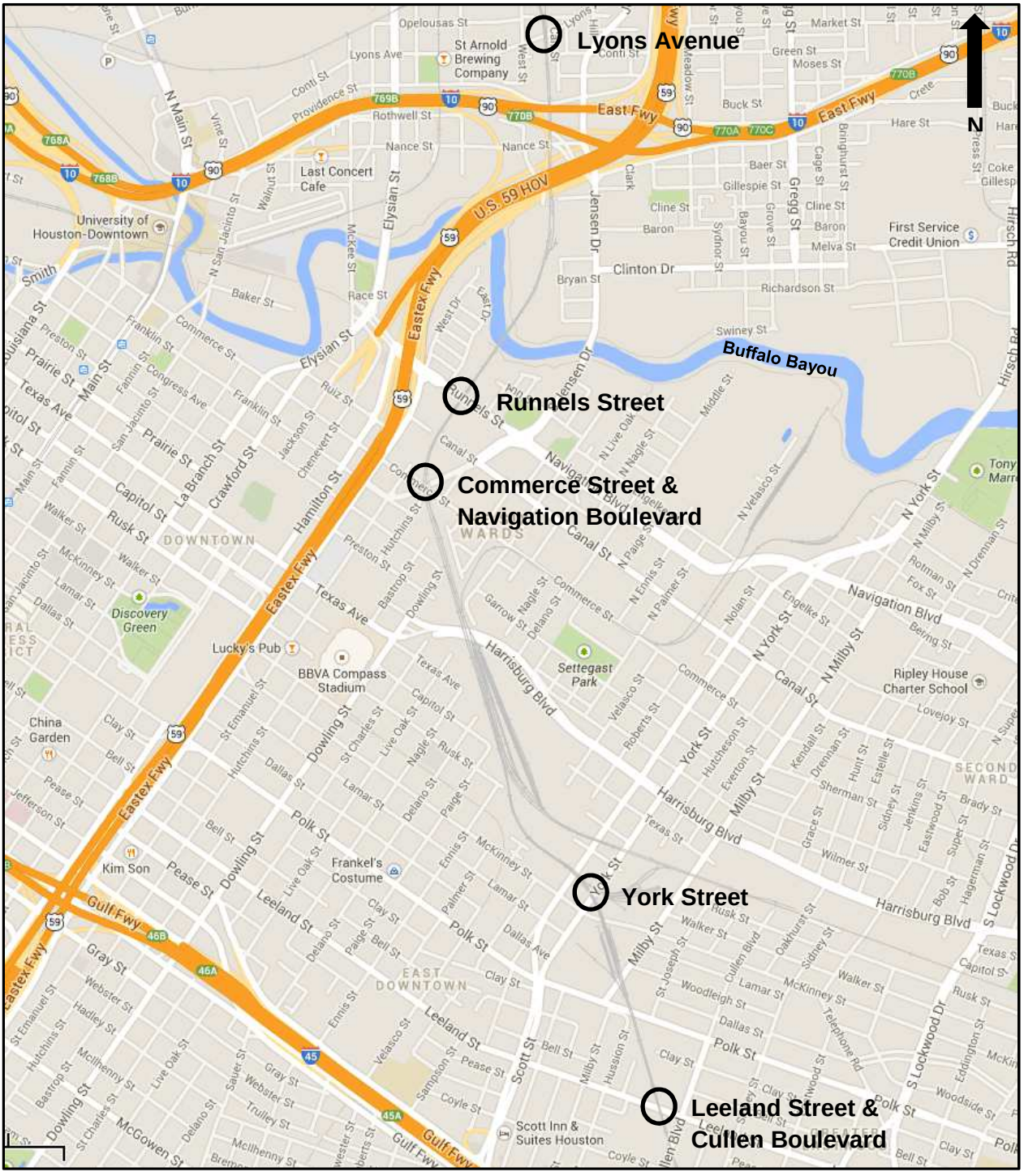


EXHIBIT 2 - City of Houston Comprehensive Drainage Plan Drainage Areas

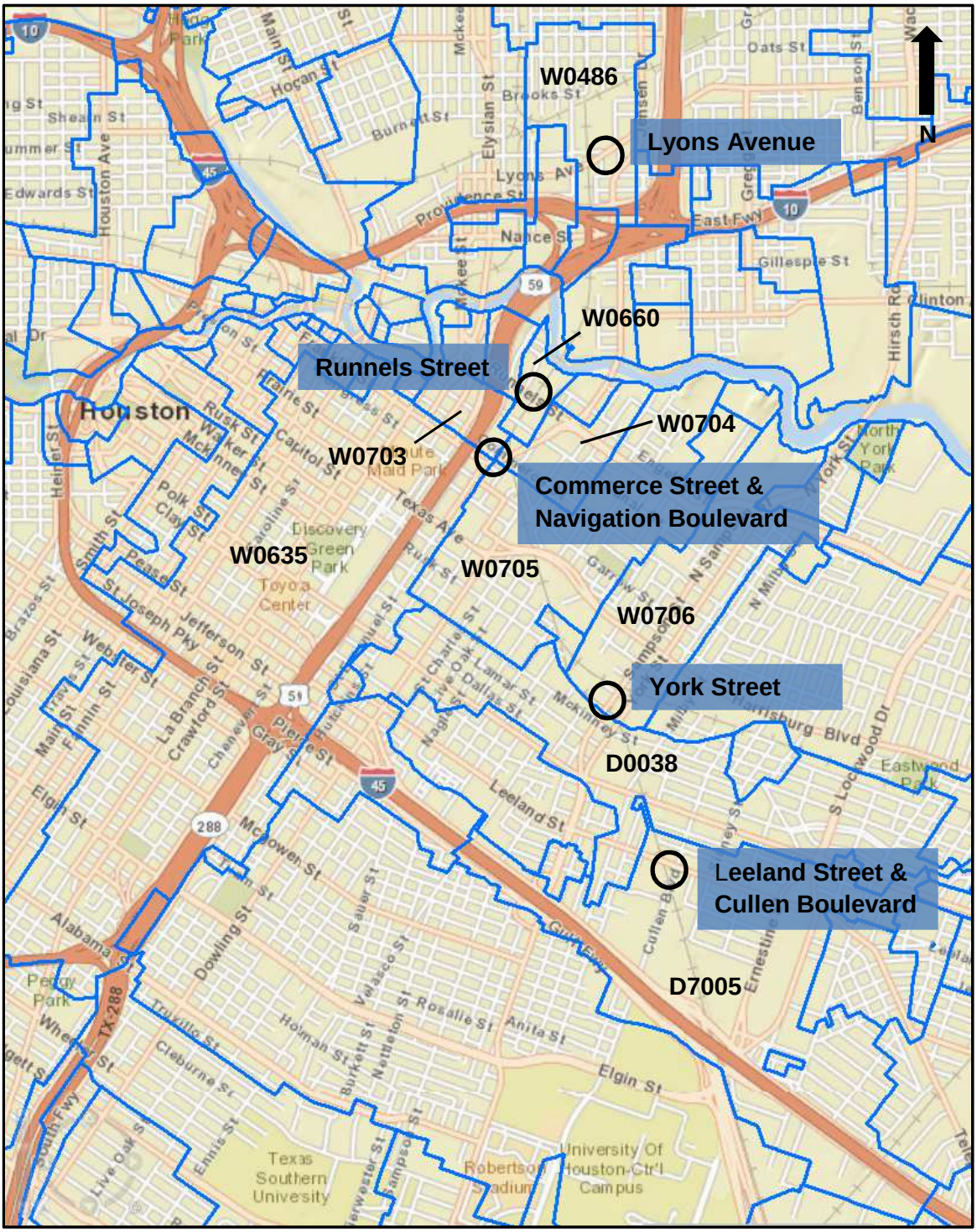


EXHIBIT 3 – Preliminary Drainage Plan

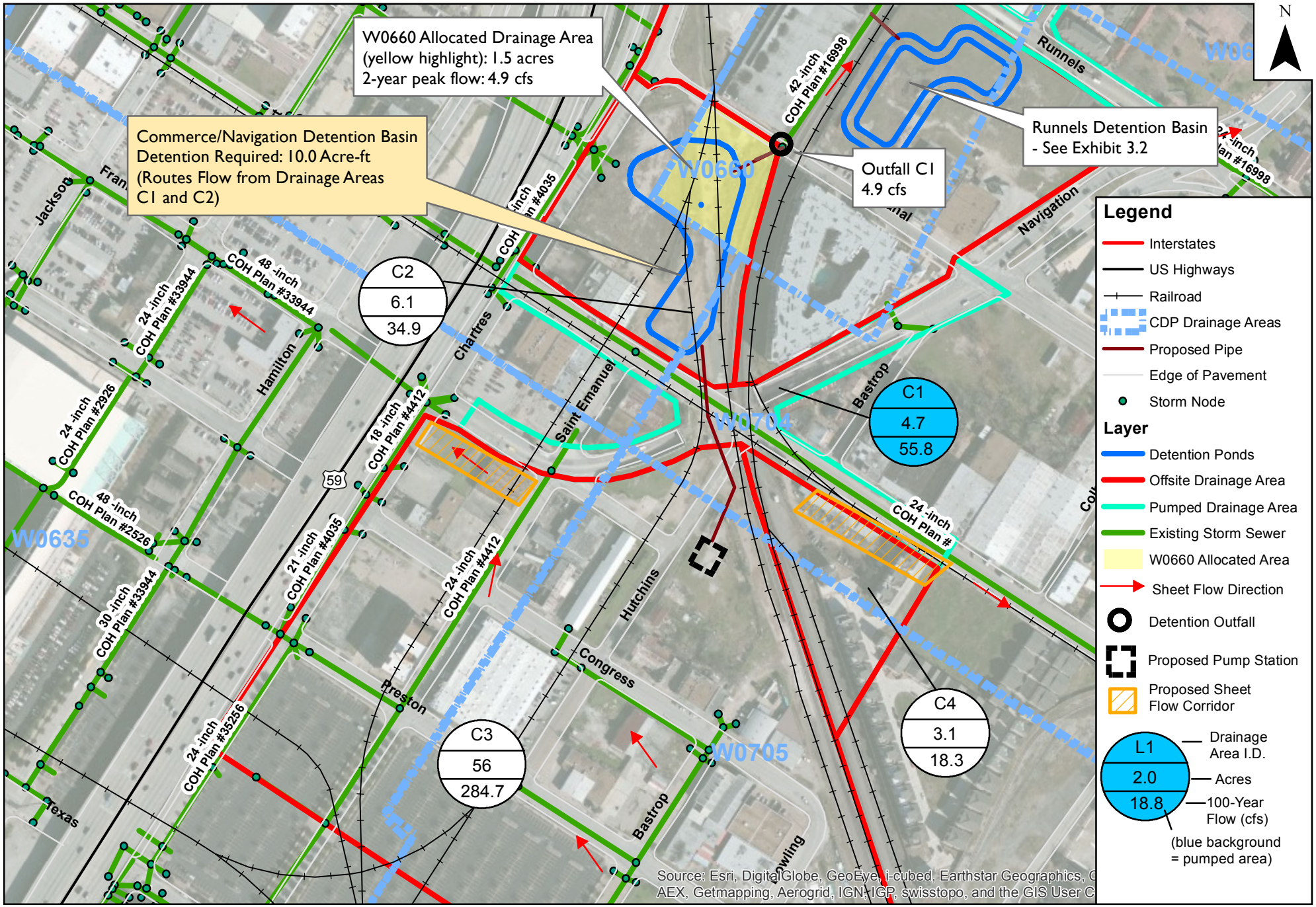
EXHIBIT 3.1 – Lyons Avenue Grade Separation Preliminary Drainage Plan

EXHIBIT 3.2 – Runnels Street Grade Separation Preliminary Drainage Plan

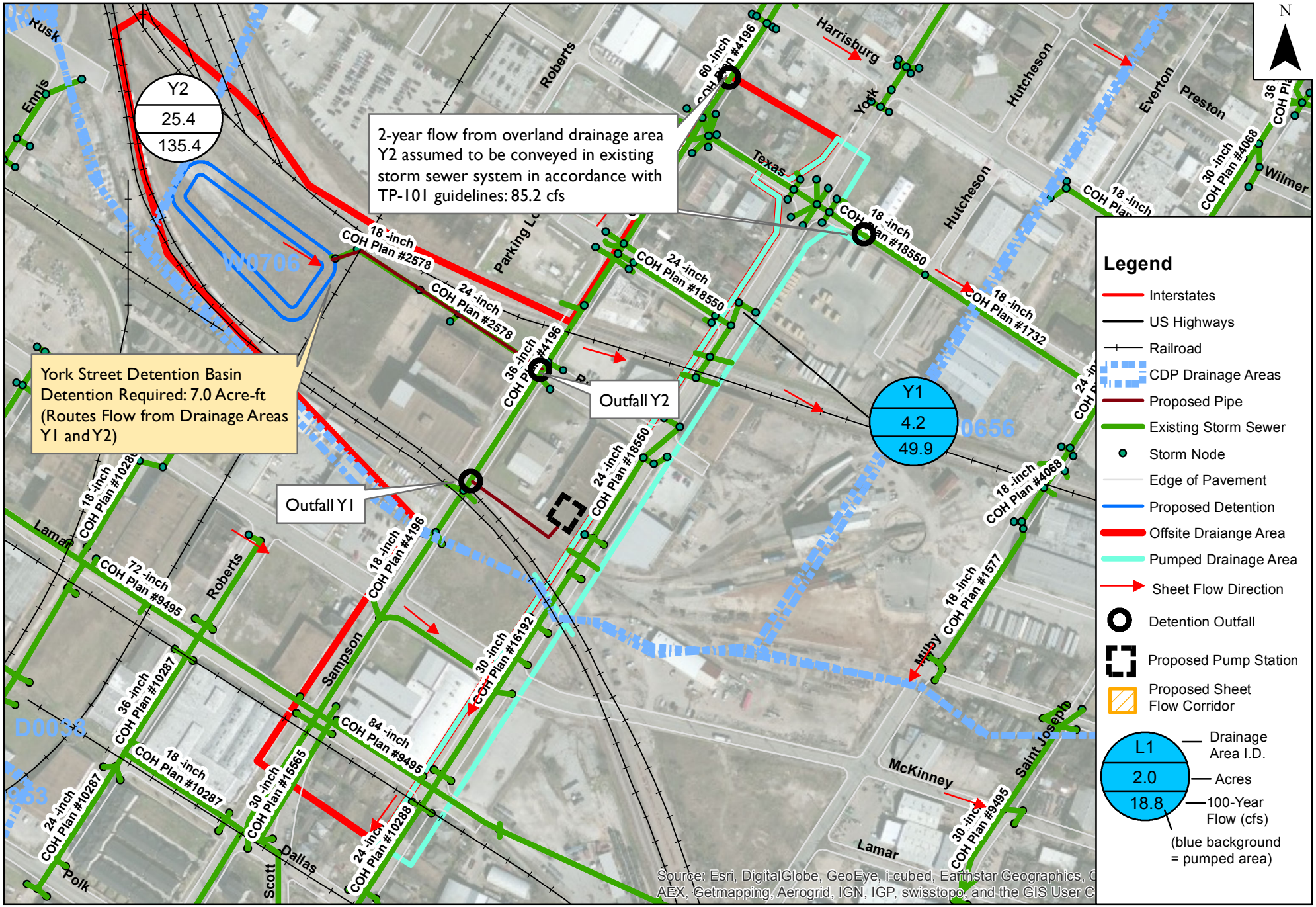
EXHIBIT 3.3 – Commerce / Navigation Grade Separation Preliminary Drainage Plan

EXHIBIT 3.4 – York Street Preliminary Drainage Plan

EXHIBIT 3.5 – Leeland / Cullen Preliminary Drainage Plan

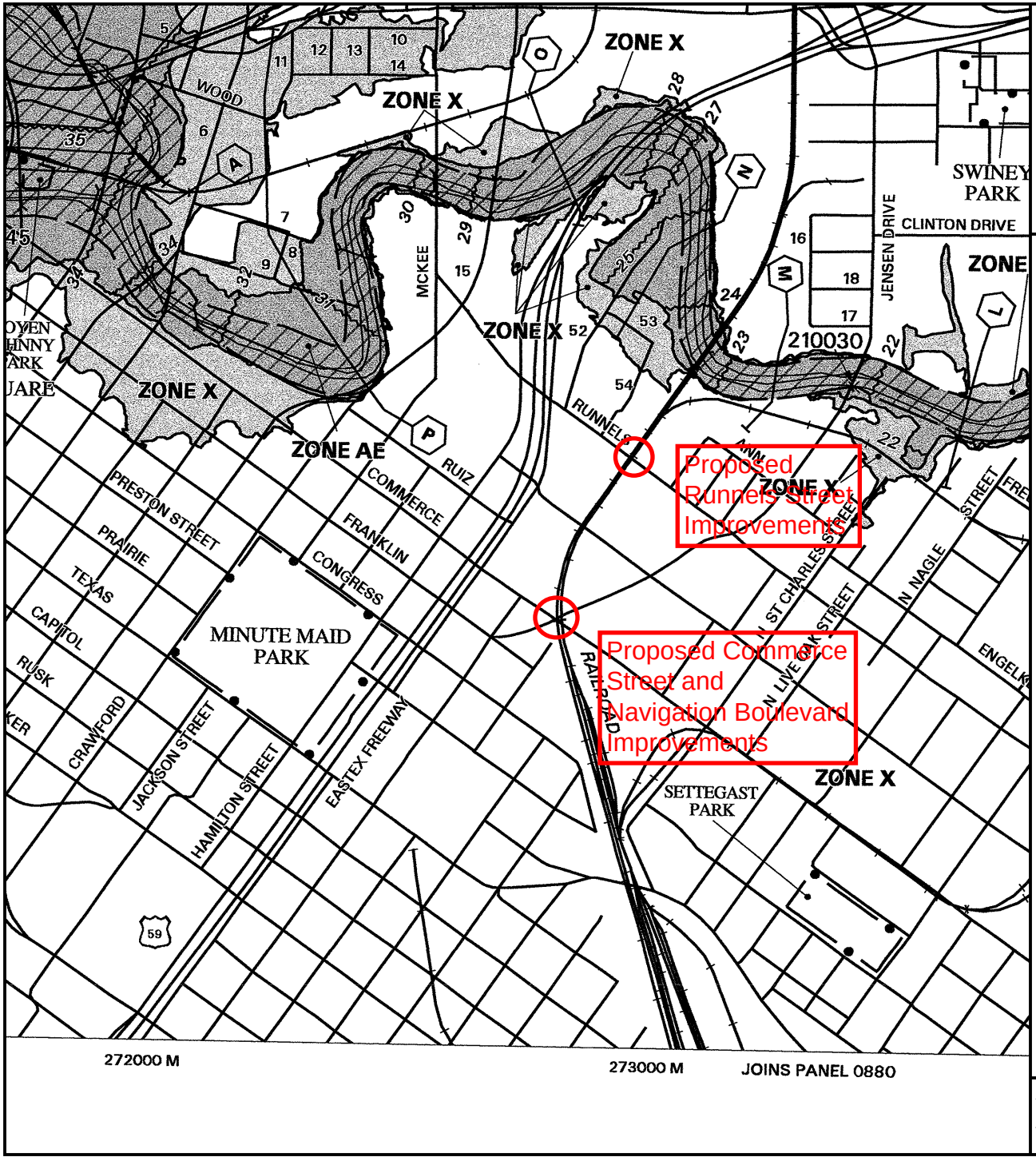


TranSystems	Commerce / Navigation Conceptual Drainage Plan (Detention Using 100-year, 24-hour Storm Runoff Depths)	City of Houston, Harris County, Texas	August 2014 1 in = 300 ft	Exhibit 3.3



TranSystems	York Street Conceptual Drainage Plan (Detention Using 100-year, 24-hour Storm Runoff Depths)	City of Houston, Harris County, Texas	August 2014 1 in = 300 ft	Exhibit 3.4

APPENDIX A – FEMA Flood Maps



MAP SCALE 1" = 1000'

500 0 1000 2000 FEET

PANEL 0690L

FIRM

FLOOD INSURANCE RATE MAP

HARRIS COUNTY,
TEXAS
AND INCORPORATED AREAS

PANEL 690 OF 1150

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

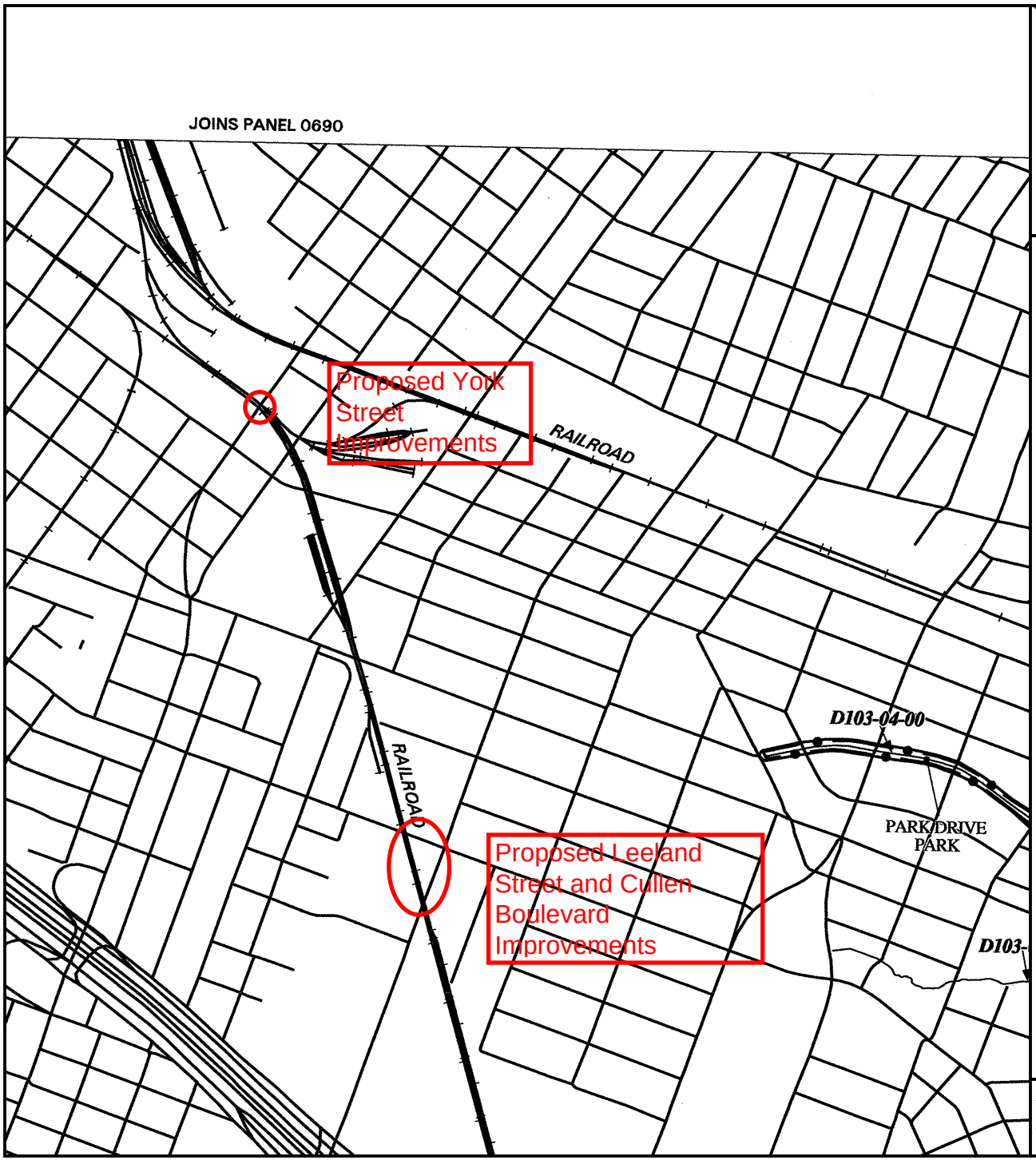
COMMUNITY	NUMBER	PANEL	SUFFIX
HOUSTON, CITY OF	480296	0690	L

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
48201C0690L

MAP REVISED:
JUNE 18, 2007

Federal Emergency Management Agency



MAP SCALE 1" = 1000'

500 0 1000 2000 FEET

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0880L

FIRM

FLOOD INSURANCE RATE MAP

HARRIS COUNTY, TEXAS AND INCORPORATED AREAS

PANEL 880 OF 1150

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
HOUSTON, CITY OF	480296	0880	L

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER 48201C0880L

MAP REVISED: JUNE 18, 2007

Federal Emergency Management Agency

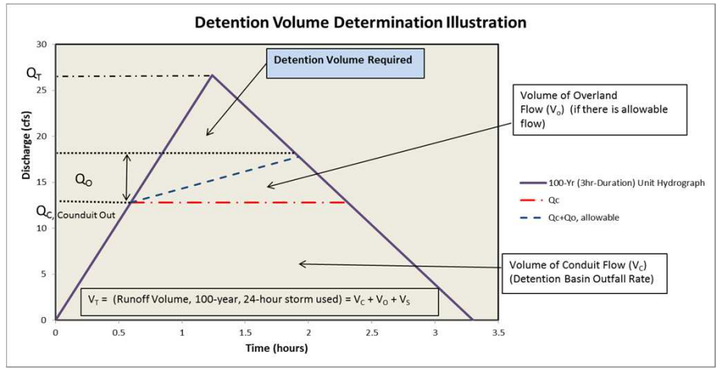
APPENDIX B – Detention and Pump Sizing Calculations

Commerce Street and Navigation Boulevard Intersection

Runoff Calculations for Individual Drainage Areas								Required Pump Rates	
				Intensity		Peak Flow			
Drainage Area ID	Area (ac)	Runoff Cofficient 'C' -	Tc (min)	2-Year (in/hr)	100-Year (in/hr)	2-Year (cfs)	100-Year (cfs)	Pumped Area (Yes/No)	Pump Capacity Required (cfs)
C1	4.7	1	10.00	6.76	11.87	31.8	55.8	Yes	55.8
C2	6.1	0.8	28.80	3.81	7.15	18.6	34.9	No	None
C3	56.0	0.8	35.48	3.33	6.35	149.3	284.7	No	None
C4	3.1	0.8	27.23	3.94	7.38	9.8	18.3	No	None
Allocated W0660 Area	1.5	0.8	25.75	4.08	7.60	4.9	9.1	No	None

See Below for Detention Calculation

Lyons Avenue Detention Basin Outlet Locations	
Outlet #	Description
C1	Commerce/Navigation Detention Outfall into Exist 42" RCP (COH Plan # 16998)



Detention Basin Description		Runoff						Detention Volume				TP-101 Method 3 Check					
						Intensity		Peak Flow									
Detention Basin	Description	Contributing Drainage Areas	Area (ac)	Weighted Runoff Cofficient 'C' -	Tc (min)	2-Year (in/hr)	100-Year (in/hr)	2-Year (cfs)	100-Year (Q_T) (cfs)	Storm Outlet #	Conduit Flow Component Q_c (cfs)	Basis for Determination of Conduit Flow Component	Proposed Detention Storage Volume ($V_{s\ avail}$) (ac-ft)	Percent Impervious %	Runoff Depth (in)	Runoff Volume (V_T) (ac-ft)	Maximum Allowable Overland Flow (Q_{Oallow}) (cfs)	Required Overland Flow (Q_{oreqd}) (cfs)	CHECK Is Qoallow >= Qoreqd? Yes = Acceptable No = Unacceptable
Commerce/Navigation	Proposed basin north of Commerce Street and west of West Belt Line	C1, C2	10.8	0.89	30.28	3.69	6.95	35.35	66.63	C1	4.9	2-year flow from Allocated W0660 Area	**10.0**	75%	12.5	11.27	0.0	-2.07	Yes
n.a.	Sub-Area C3 (Provide Sheetflow Corridor)	C3	56	0.80	35.48	3.33	6.35	149.26	284.70	n.a	149.6			75%	12.5	58.45	143.4	158.30	No
n.a.	Sub-Area C4 (Provide Sheetflow Corridor)	C4	1.5	0.80	25.75	4.08	7.60	4.90	9.12	n.a.	4.9			75%	12.5	1.57	4.3	5.09	No

Inlet Tc as Determined by engineer. 10A^0.1781+15

Intensity = b/(Tc+d)^e (TxDOT Values for Harris County)

Rainfall Intensity	
2-Year	
b	68
d	7.9
e	0.8
100-Year	
b	91
d	7.9
e	0.706

Q = CIA

Detention basin storm outlet identifier and basin outfall rate for determining detention volume. Refer to **Exhibit 3.3.**

Technical basis for determining the allowable outfall rate from the detention basin.

Detention Volume Required (based on allowable detention basin outfall rate to storm sewer). Sized for100-year, 3-hour storm event.

Percent Impervious = ($C_{composite}$ - 0.2)/0.6

HCFCD Direct Runoff Depths for 24-hour, 1% Probability Rainfall Event (100-year)

Rainfall Depth (in)	
24-Hr Duration	
0%	11.10
40%	12.00
100%	12.90

V_T = Runoff Depth x A_{CUM}

Allowable overland flow release rate out of overland drainage area.

Qoreqd = Q_T - $Q_{C\text{-}Basin\ Out}$ - ((V_{Savail} x Q_T^2)/(V_T (Q_T - $Q_{C\text{-}Basin\ Out}$)) Vsavail and V_T) are cumulative values.

If "**Yes**", design for storm sewer segment meets City of Houston Requirements.

If "**No**", design for storm sewer segment does not meet City of Houston requirements and adjustment in storm sewer size or additional analysis are needed.

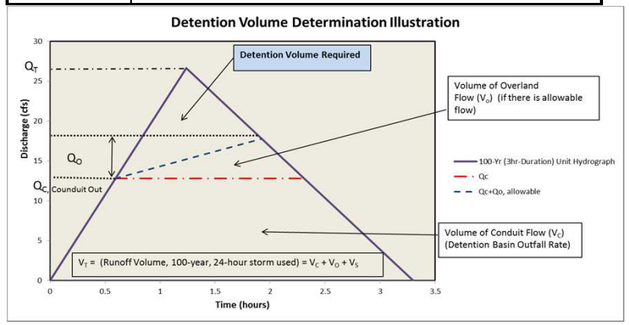
Gulf Coast Rail District
West Belt Improvements
Appendix B - Detention and Pump Sizing Calculations

York Street Intersection

Runoff Calculations for Individual Drainage Areas								Required Pump Rates	
				Intensity		Peak Flow			
Drainage Area ID	Area (ac)	Runoff Cofficient 'C' -	Tc (min)	2-Year (in/hr)	100-Year (in/hr)	2-Year (cfs)	100-Year (cfs)	Pumped Area (Yes/No)	Pump Capacity Required (cfs)
Y1	4.2	1	10.00	6.76	11.87	28.4	49.9	Yes	49.9
Y2	25.4	0.8	32.68	3.51	6.66	71.4	135.4	No	None

See Below for Detention Calculation

Lyons Avenue Detention Basin Outlet Locations	
Outlet #	Description
Y1 & Y2	Existing 36" Storm Sewer on Sampson COH Plan # 4196



Detention Basin Description		Runoff								Detention Volume				TP-101 Method 3 Check					
						Intensity		Peak Flow											
Detention Basin	Description	Contributing Drainage Areas	Area (ac)	Weighted Runoff Cofficient 'C' -	Tc (min)	2-Year (in/hr)	100-Year (in/hr)	2-Year (cfs)	100-Year (Q_T) (cfs)	Storm Outlet #	Conduit Flow Component Q_c (cfs)	Basis for Determination of Conduit Flow Component	Proposed Detention Storage Volume ($V_{s\ avail}$) (ac-ft)	Percent Impervious %	Runoff Depth (in)	Runoff Volume (V_T) (ac-ft)	Maximum Allowable Overland Flow (Q_{Oallow}) (cfs)	Required Overland Flow (Q_{oreqd}) (cfs)	CHECK Is Qoallow >= Qoreqd? Yes = Acceptable No = Unacceptable
York Basin	Proposed basin west of York Street and south of the West Belt Line	Y1, Y2	29.6	0.83	33.28	3.47	6.59	85.2	161.6	Y1	85.2	2-Year flow from contributing drainage area (contributing drainage area is overland sheet flow drainage area, storm sewer infrastructure exists in the overland drainage area and it is assumed to have capacity for 2-year flow). This is not the actual detention basin outfall rate.	**7.0**	75%	12.5	30.90	0.0	-0.92	Yes

Inlet Tc as Determined by engineer. $10A^{0.1781}+15$

Intensity = b/(Tc+d)^e (TxDOT Values for Harris County)

Rainfall Intensity	
2-Year	
b	68
d	7.9
e	0.8
100-Year	
b	91
d	7.9
e	0.706

Q = CIA

Detention basin storm outlet identifier and basin outfall rate for determining detention volume. Refer to **Exhibit 3.4**

Technical basis for determining the allowable outfall rate from the detention basin.

Detention Volume Required (based on allowable detention basin outfall rate to storm sewer). Sized for100-year, 3-hour storm event.

Percent Impervious = $(C_{composite} - 0.2)/0.6$

HCFCD Direct Runoff Depths for 24-hour, 1% Probability Rainfall Event (100-year)

Rainfall Depth (in)	
24-Hr Duration	
0%	11.10
40%	12.00
100%	12.90

V_T = Runoff Depth x A_{CDM}

Allowable overland flow release rate out of overland drainage area.

Qoreqd = $Q_T - Q_{C,Basin\ Out} - ((V_{Savail} \times Q_T^2)/(V_T (Q_T - Q_{C,\ Basin\ Out}))$ Vsavail and V_T) are cumulative values.

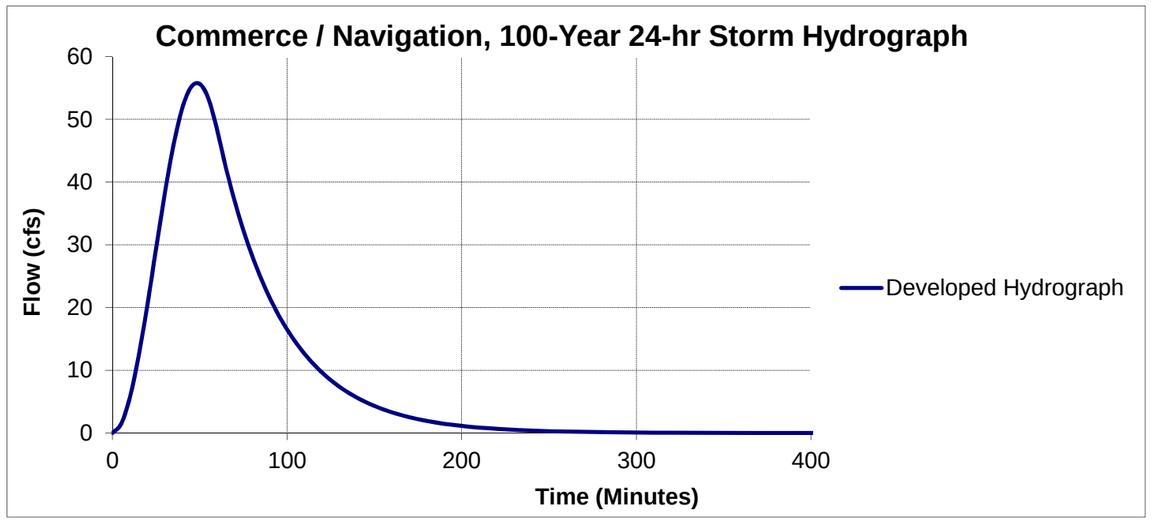
If "**Yes**", design for storm sewer segment meets City of Houston Requirements.

If "**No**", design for storm sewer segment does not meet City of Houston requirements and adjustment in storm sewer size or additional analysis are needed.

APPENDIX C – Small Watershed Hydrographs of Pumped Areas

Gulf Coast Rail District
West Belt Improvements
Appendix C - Small Watershed Hydrographs of Pumped Areas

Watershed Name:	Commerce/Navigation
Area (acres):	4.7
Rainfall Excess (inches):	13.2
% Impervious:	100%
Peak Discharge (cfs):	55.8
Time to Peak (min):	48
Recommended Time Interval (min):	5
Calculation Time Interval (min):	5

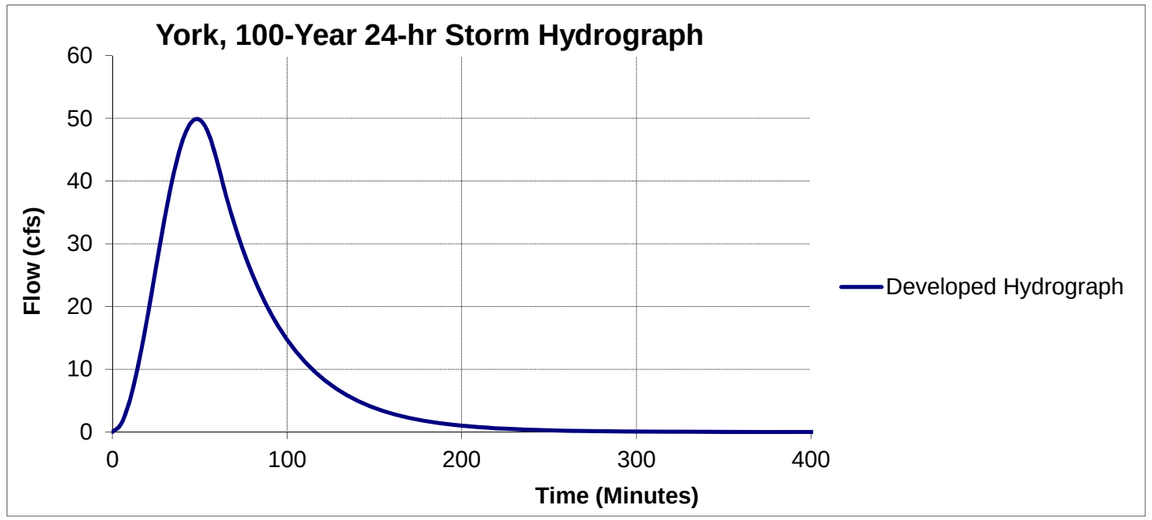


Time (min)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
Dev. Discharge	0	1.5	5.7	12.2	20.4	29.4	38.2	45.9	51.8	55.1	55.6	53.3	48.2	42.2	36.9	32.3	28.2	24.7	21.6	18.9

Time (min)	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195
Dev. Discharge	16.5	14.4	12.6	11.0	9.6	8.4	7.4	6.4	5.6	4.9	4.3	3.8	3.3	2.9	2.5	2.2	1.9	1.7	1.5	1.3

Gulf Coast Rail District
West Belt Improvements
Appendix C - Small Watershed Hydrographs of Pumped Areas

Watershed Name:	York
Area (acres):	4.2
Rainfall Excess (inches):	13.2
% Impervious:	100%
Peak Discharge (cfs):	49.9
Time to Peak (min):	48
Recommended Time Interval (min):	5
Calculation Time Interval (min):	5



Time (min)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
Dev. Discharge	0	1.3	5.1	10.9	18.3	26.3	34.2	41.1	46.3	49.3	49.8	47.6	43.1	37.7	33.0	28.8	25.2	22.0	19.3	16.8

Time (min)	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195
Dev. Discharge	14.7	12.9	11.3	9.8	8.6	7.5	6.6	5.7	5.0	4.4	3.8	3.4	2.9	2.6	2.2	2.0	1.7	1.5	1.3	1.1