FORT BEND COUNTY
LEVEE IMPROVEMENT DISTRICT NO. 7
MASTER DRAINAGE PLAN UPDATE

May 2020

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MASTER DRAINAGE PLAN UPDATE

STATE OF TEXAS
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Prepared for
Levee Improvement District No. 7 of Fort Bend County

May 2020

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EXECUTIVE SUMMARY

Fort Bend County Levee Improvement District No. 7 (the "District") is in the City of Sugar Land in central Fort Bend County, Texas. The Brazos River flows along the southern boundary of the District. The District is also bounded by Fort Bend County Levee Improvement District No. 17 (Telfair) on the east, US 90A on the north and undeveloped pasture on the west.. Access to the District is provided by US 90A and State Highway 99 (the Grand Parkway).

The Fort Bend County Commissioners Court created the District November 5, 1984 for the following purposes:

- to construct and maintain a levee and other improvements on, along and contiguous to the Brazos River
- to reclaim land from the Brazos River floodplain and regulatory floodway
- to provide proper drainage and other improvements for the reclaimed land

The District contains approximately 2,239 acres of land that is bisected by the Grand Parkway. A levee was constructed to provide protection for approximately 2,050 acres of land that has been developed for residential, commercial, institutional, and recreational uses. The District's flood protection system also includes a 66,000 gallon per minute (gpm) firm capacity storm water pump station, channels, and storage facilities, such a lakes. The storm water pump station has a gated outfall structure that outfalls to the District's external channel approximately 1,600 feet north of the southwest corner of the District levee structure.

In order to satisfy the regulations for Fort Bend County, the flood protection system of the District shall:

- Protect development within the leveed areas of the District from storm events up to and including the 100-year event on the Brazos River.
- Adequately store and/or pump storm water within the District's levee protection system during high stages on the Brazos River that prevent gravity discharge while providing adequate freeboard within the District's channels and storage facilities (coincident event).
- Adequately convey storm water within the District's channels and storage facilities during a localized 100-year event while providing adequate freeboard within the District's channels and storage facilities (gravity event).

The existing levee has been accredited by the Federal Emergency Management Agency (FEMA) as protecting the District from the one-percent Exceedance Probability (100-year) event on the Brazos River. While this levee prevents the land from being flooded by the 100-year event on the Brazos River, it also acts as a barrier to storm water runoff resulting from local rainfall within the protected area. When the Brazos River water surface elevations prohibit gravity flow, the Fort Bend County Drainage Criteria requires pumping and/or storing the runoff from a local rainfall event. Therefore, storm water runoff within the District levee system is directed to a system of channels and storage facilities where it is stored and then pumped outside of the levee system.

The “coincident event” is defined as a combination of storm events where the combined chance of each event equals a 1-percent annual chance of occurring. For FBCLID 7, this event is approximately an 8.4-year, 24-hour event. The combination of the District’s storm water pump station, channels and storage facilities have been designed to pump and store the rainfall runoff from a local coincident rainfall while maintaining internal ponding elevations low enough to prevent flooding of structures.

During normal conditions, when water surface elevations on the Brazos River are low enough to permit gravity flow from within the levee, internal storm water runoff will be directed through underground pipes and the street system to internal channels and storage facilities, through the gated outfall structure of the storm water pump station, and into the Brazos River. This is known as the “gravity event”.

In October 2018, the National Oceanic and Atmospheric Administration (NOAA) released Volume 11 of the Atlas 14 Point Precipitation Frequency Estimates (Atlas 14). This technical paper redefined and increased the rainfall values for various storm frequencies. The rainfall depths using Atlas 14 are significantly higher than those provided in Technical Paper 40 and Hydrometeorological Report 35, which were the basis for the rainfall used in previous analyses to design the existing District flood protection system.

Understanding that the various local governments such as Fort Bend County intended to adopt Atlas 14 in their drainage criteria, the District requested that LJA prepare a drainage analysis of the existing District system based on the Atlas 14 rainfall to determine the level of service of the existing system. Additionally, the analysis was to determine cost efficient alternatives to improve the level of service within the District system with the higher rainfall rates while maintaining 18-inches of freeboard for the lowest slab elevations.

The hydrology method used to analyze the proposed internal drainage system is given in the Fort Bend County Drainage Criteria Manual (DCM) dated April 2011 and supplemented by the criteria manual that was adopted on January 2020. One-, four-, and ten-percent flows were computed using the U.S. Army Corps of Engineers HEC-HMS computer program. Hydraulics of the proposed channels and lakes were analyzed using the Innovyze computer program XP-STORM (v2018).

Based on the results of this study, the following improvements are recommended in order to maintain 18-inches of freeboard for structures in the District flood protection system during the coincident event with Atlas 14 rainfall depths:

- Construction of an additional 115 acre-feet of storage.
- Construction of an additional 210,000 gpm pump station
- Increase the level of protection to the 10-year coincident storm event.

When the Brazos River stages are high, the gates will be closed and the existing 66,000 gpm storm water pumping station and an additional 210,000 gpm station will begin operating. With these pump stations in operation and the addition of 115-acre feet of storage, the coincident event results in peak water surface elevations equal to or below elevation 71.5 feet (NAVD 88, 2001 adjustment) at critical locations. Other locations, such as residences in the vicinity of Lake Sartartia and Lake Clayton, will experience water surface elevations that exceed 71.5’, but will still provide 18 inches of freeboard for structures within these areas.

The evaluation of the localized Atlas 14 100-year storm gravity event with the recommended storage and pumping improvements did not result in a significant reduction in water surfaces in the District's channels and storage facilities when compared to existing conditions with Atlas 14 rainfall. This is due to the size of the existing storm sewers and control structures that convey storm water between storage facilities or from a storage facility to a channel and were designed with pre-Atlas 14 drainage criteria. Recommendations to resolve these potential drainage issues are outside the scope of this study, however, the results of this study have identified the location of some potential drainage issues and can be used to assist the District to plan for future storm sewer improvement projects to resolve these problem areas.

Finally, this study does not address drainage issues that may exist within the District that are outside the levee system.

1.0 BACKGROUND

1.1 Purpose and Objective

For development to occur in an orderly and economic manner, proper planning is essential. A master drainage plan provides the planning vehicle for drainage infrastructure. Created in November 5, 1984, the 2,239-acre Fort Bend County Levee Improvement District No. 7 (District or LID 7) provides funding for constructing flood plain reclamation, flood protection, and outfall drainage necessary for orderly development within the District. This report presents an overall updated analysis of the existing approximately 2,050 acres of development within the leveed area of the District, and a plan for drainage and flood protection improvements.

In a Plan of Reclamation (POR) dated April 1985 and sealed September 13, 1985, the District's engineer, VanSickle, Mickelson, and Klein, Inc. (VMK), used the regulations associated with the USACE to complete a master drainage plan for internal drainage and levee protection system of the District. This was before the FBCDD had formal criteria, but the POR was consistent with other Levee District PORs prepared at that time. The goal at that time was to design a system that provided a minimum freeboard of 1 foot from the maximum ponding elevation to the lowest slab elevation within the District's drainage system for the coincident and gravity events.

In October 2018, the National Oceanic and Atmospheric Administration (NOAA) released Volume 11 of the Atlas 14 Point Precipitation Frequency Estimates (Atlas 14). This technical paper redefined the rainfall depths for various storm frequencies, resulting in general increases for Fort Bend County. The rainfall depths using Atlas 14 are significantly higher than those provided in Technical Paper 40 (TP40), and Hydrometeorological Report 35 (Hydro 35) which were the basis for the rainfall used in previous analyses to design the existing District flood protection system.

Understanding that the various local governments such as Fort Bend County intended to adopt Atlas 14 in their drainage criteria, the District requested that LJA prepare a drainage analysis of the existing District system based on the Atlas 14 rainfall to provide the following data:

- Determine updated water surfaces within the existing system for both the coincident and gravity events.
- Identify potential drainage issues within the existing system for both the coincident and gravity events.
- Determine cost efficient alternatives to improve the freeboard within the District system with the higher rainfall rates while maintaining 18-inches of freeboard during the coincident event.

The hydrology method used to analyze the proposed internal drainage system is given in the Fort Bend County Drainage Criteria Manual (DCM) dated April 2011 and supplemented by the criteria manual that was adopted on January 2020. One-, four-, and ten-percent flows were computed using the U.S. Army Corps of Engineers HEC-HMS computer program. Hydraulics of the proposed channels and lakes were analyzed using the Innovyze computer program XP-STORM (v2018).

1.2 Site Location and Description

The District is located approximately 22 miles southwest of downtown Houston in Sugar Land, Fort Bend County, Texas. As shown on **Exhibit 1.1,** the District is bound on the north by US 90A and is bisected by SH 99 Grand Parkway. New Territory Boulevard crosses the District from east to west and provides access to the neighborhoods.

The District levee system encompasses approximately 2,050 acres that are drained by a major drainage channel, named Ellis Creek that conveys runoff from the leveed areas of the District to the levee outfall structure approximately 1600 feet north of the southwest corner of the levee. The runoff is conveyed through the levee by five 10-foot x10-foot reinforced concrete box culverts (RCB) into an external channel that runs south along the west levee, then turns east along the south levee where it drains into the Brazos River.

Annual rainfall in this area averages 48 inches, with periods of intense rainfall associated with tropical storms and localized thunderstorms occurring frequently throughout the year. Soils in the area are mostly Lake Charles clay and classified soil Group D by the Soil Conservation Service (SCS). Very low permeability and very slow surface runoff potential characterizes these soils. These factors have an impact on the drainage facilities needed to serve the District.

Typical of the Gulf Coast plain, the District is characterized by extremely flat topography. Existing ground contours on the site generally fall from northwest to southeast toward Ellis Creek or one of the storage ponds. According, Light Detecting and Ranging (LiDAR) topography of the area, elevations vary from approximately 79.5 to 70.3 feet inside the levee.

Exhibit 1.2 illustrates the FEMA Effective Special Flood Hazard Area (SFHA) in the vicinity of the District. The District levee is defined as a “U” shape levee, providing protection from the one percent (100-year) flood event on the Brazos River. While this levee protects the land from being flooded by the Brazos River, it also acts as a barrier to storm water runoff resulting from rainfall within the protected area. Storm water runoff within the leveed area is directed to a system of channels and storage facilities that convey and store rainfall runoff from a 100-year event within the internal drainage easements and at an elevation low enough not to cause flooding of dwellings. During normally low Brazos River stages, this major drainage system will direct the runoff to gated structures on the west side of the District where the runoff will flow through the levee to the external channel and into the Brazos River. When the Brazos River flood stages prevent gravity flow, gates will be closed to prevent high stages on the Brazos River from entering the levee system, and the runoff will be stored in the lakes and channels while maintaining internal water surface elevations necessary to provide flood protection for the development. In addition, a storm water pumping station will operate, augmenting the flood protection.

1.3 Proposed Development

The District is currently 100-percent developed. Development in the District is a mixture of residential and commercial/retail development, as shown on **Exhibit 1.3**. While the existing lakes and channels currently have capacity to store and convey rainfall runoff from the developed areas of District during a 12.5-inch, 24-hour rainfall, additional capacity is needed to accommodate the additional runoff generated by Atlas 14 rainfall.

This report presents drainage concepts to serve the current development. Modifications to the current development, or unanticipated field conditions may require changes to the drainage plan. If any changes do occur, additional detailed analysis will specifically address those changes.

1.4 Drainage Criteria

The District development is within the City of Sugar Land and Fort Bend County; the drainage design should comply with the adopted Fort Bend County Drainage District Criteria Manual (DCM) that was in effect at the time the District was developed. Although the District is exempt from having to comply with current Fort Bend County Drainage District criteria, the District has elected to improve the flood protection facilities to generally adhere to the Fort Bend County Drainage District Criteria Manual (DCM) dated April 2011 and portions of a supplemental DCM adopted January 1, 2020. The methods described in the DCMs were used to perform the hydrologic and hydraulic analyses determining the improvements needed to allow the proposed improvements to occur without adversely impacting existing developed areas.

The following criteria are discussed in detail in subsequent sections describing the specific analysis and design of the proposed drainage facilities within District.

- Point rainfall amounts for various durations and frequencies to establish hypothetical storms events to approximate rainfall depths
- Methodology for defining the physical characteristics of the watershed to establish infiltration loss rates using the Green and Ampt method
- The Clark Unit Hydrograph method to develop runoff hydrographs for areas greater than approximately 200 acres
- Rational Method equation to develop peak flows for areas less than approximately 200 acres.
- Hydrologic design criteria for the use of the Army Corps of Engineers Hydrologic Engineering Center Hydrology Modeling Software (HEC-HMS) computer program as the primary tool for simulating storm water runoff.

Besides establishing approved methods for analyzing rainfall runoff (hydrology) and conveyance (hydraulics), the DCM established a methodology for pump station design for leveed areas. The following criteria are discussed in detail in subsequent sections describing the specific analysis and design of pump stations within the District.

- Determination of allowable internal water surface elevation to establish a corresponding flow in the Brazos River
- Relationship of corresponding flow in the Brazos River to a storm event for establishing minimum design rainfall for a coincident event analysis
- Runoff volume that must be pumped from the District in 24 hours for establishing the minimum design pumping capacity

1.5 Previous Studies

A Plan of Reclamation report dated April 1985 and sealed September 13, 1985 was produced by VMK to present the proposed improvements needed to provide flood protection and outfall drainage necessary to accommodate development within the District.

Following Hurricane Harvey, the District contracted with Costello, Inc. to reevaluate the drainage system within the development that is protected from the Brazos River by the District's levee system. The District tasked Costello with updating the hydrology and hydraulics of the area and evaluating the drainage system for potential locations of improvement. The study area included approximately 2,050 acres of development within the levee plus approximately 1,747 acres of offsite area to the west.

Costello did not use any published previous studies for their drainage assessment. However, construction plans for various projects within the District were used for developing the hydrologic and hydraulic models.

The analysis presented in this report used the Costello models as the baseline condition models. The Costello models can be found in the Appendix of this report.

1.6 Datum Considerations

The construction plans used to establish some of the drainage elements used in the models for the District are referenced to NGVD 29 (1973 adjustment). The datum for the Fort Bend County LiDAR which was obtained in 2014 for Fort Bend County is the NAVD 88 (2001 adjustment). The datum adjustment from the NGVD 29 datum (1973 adjustment) to the NAVD 88 (2001 adjustment) datum is -0.97 feet. To convert to NAVD 88 (2001 adjustment), the following equation may be used:

NAVD 88 (2001 adjustment) = NGVD-29 (1973 adjustment) – 0.97 feet

This adjustment is referenced in a draft report provided by Costello and was verified by calculating the difference in multiple elevations between the baseline model and the construction plans. A difference of 0.97 feet was noted for every elevation that was compared.

In order to eliminate discrepancies due to the different datums, the current models for this study of the District's system were created based on the NAVD 88 (2001 adjustment).

The plan sets for previously constructed storage facilities and channel components within the District are based on the NGVD-29 (1973 adjustment) and the elevations from these plans were adjusted to NAVD 88 (2001 adjustment) for use in the models. All elevations provided in this report are based on the NAVD 88 (2001 adjustment) datum unless otherwise specified.

1.7 Design Water Surface Elevations

The Plan of Reclamation (POR) prepared by VMK established the maximum design water surface elevations for the District drainage system as Elevation 73.50' NGVD 29 (1973 adjustment), which equates to 72.53 (NAVD 88, 2001 adj); however the design water surface elevations have since been reduced per updated analyses and further review of more recent drainage studies and construction plans. A coincident water surface elevation of 71.5 feet (NAVD 88) in the area hydraulically connected to Lakewind Lake (sub-area "SUB 12A") was established based on known minimum gutter elevations in that area, and became the design coincident (pumped scenario) water surface elevation throughout the District's levee system.

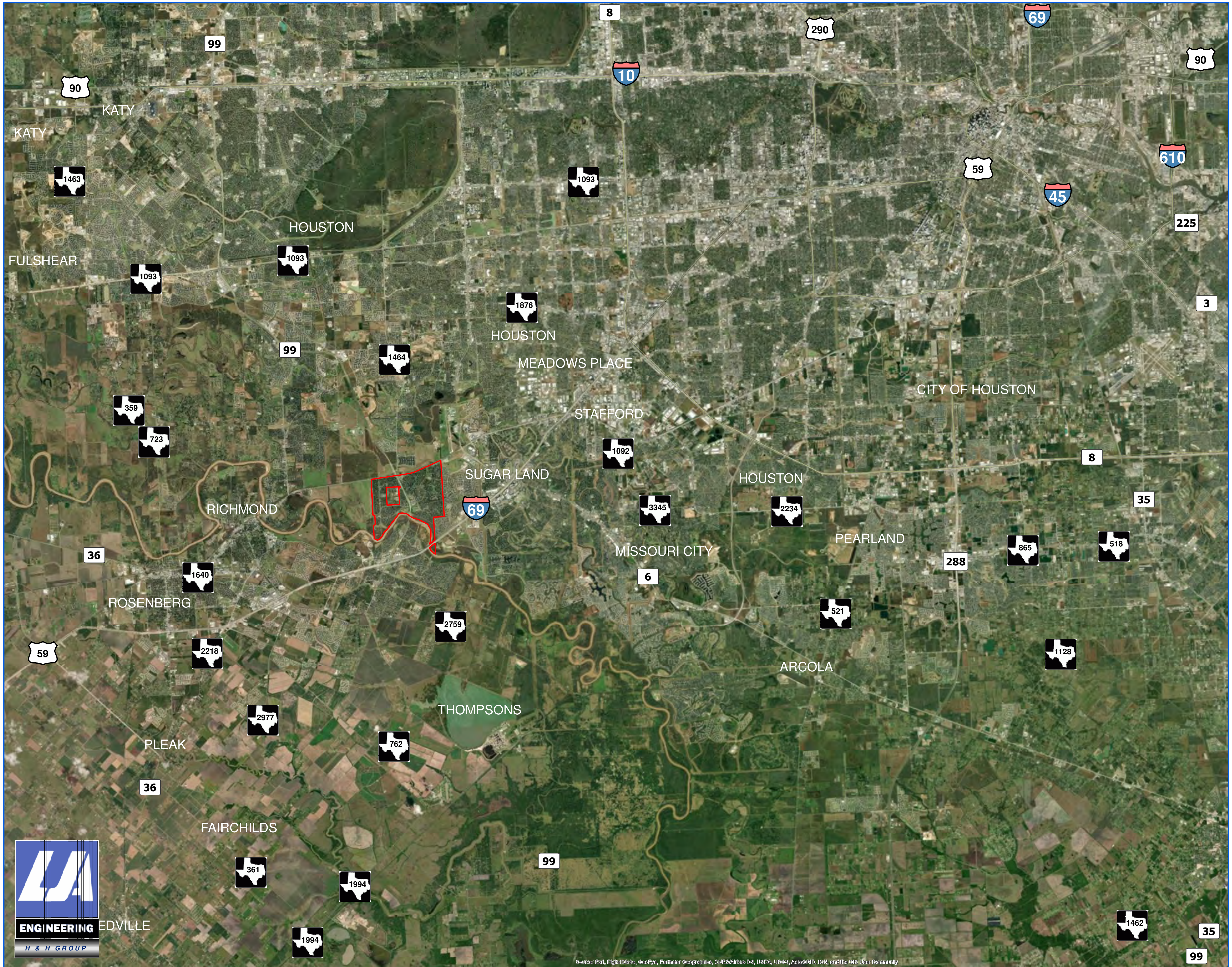
Although the design water surface elevation of 71.5 was established for determining the coincident rainfall event for the District, this is not the critical water surface elevation for the entire development. Developments in the vicinity of Lake Clayton and Lake Sartartia have higher existing ground elevations according to LiDAR topography. Therefore, the allowable water surface elevations are higher in this area.

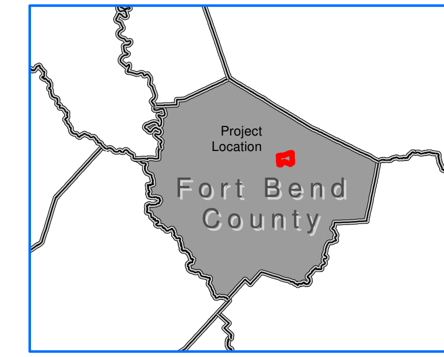
According to LiDAR topography, the lowest natural ground elevation in the vicinity of Lake Clayton is 74.80. The lowest natural ground elevation in the vicinity of Lake Sartartia is 74.90. Figure 1-1 and 1-2 illustrates these areas.

Figure 1-1 Lake Clayton Service Area

Figure 1-2 Lake Sartartia Service Area

All other areas within the levee use a design elevation of 71.5 during the coincident storm event





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Miles

0 1.5 3 6

One Inch Equals 3 Miles

Note:
This exhibit shows pertinent items necessary to illustrate the information described in the text and is not intended to include all physical characteristics of the area.

Data Source:
Aerial Photography 2018 Nearmap

LEGEND

LID 7 DISTRICT BOUNDARY

Exhibit 1.1

FORT BEND COUNTY LEVEE IMPROVEMENT DISTRICT NO. 7 MASTER DRAINAGE PLAN

VICINITY MAP

Date: April 2020

Job No. 2703-1906

LJA Engineering, Inc.

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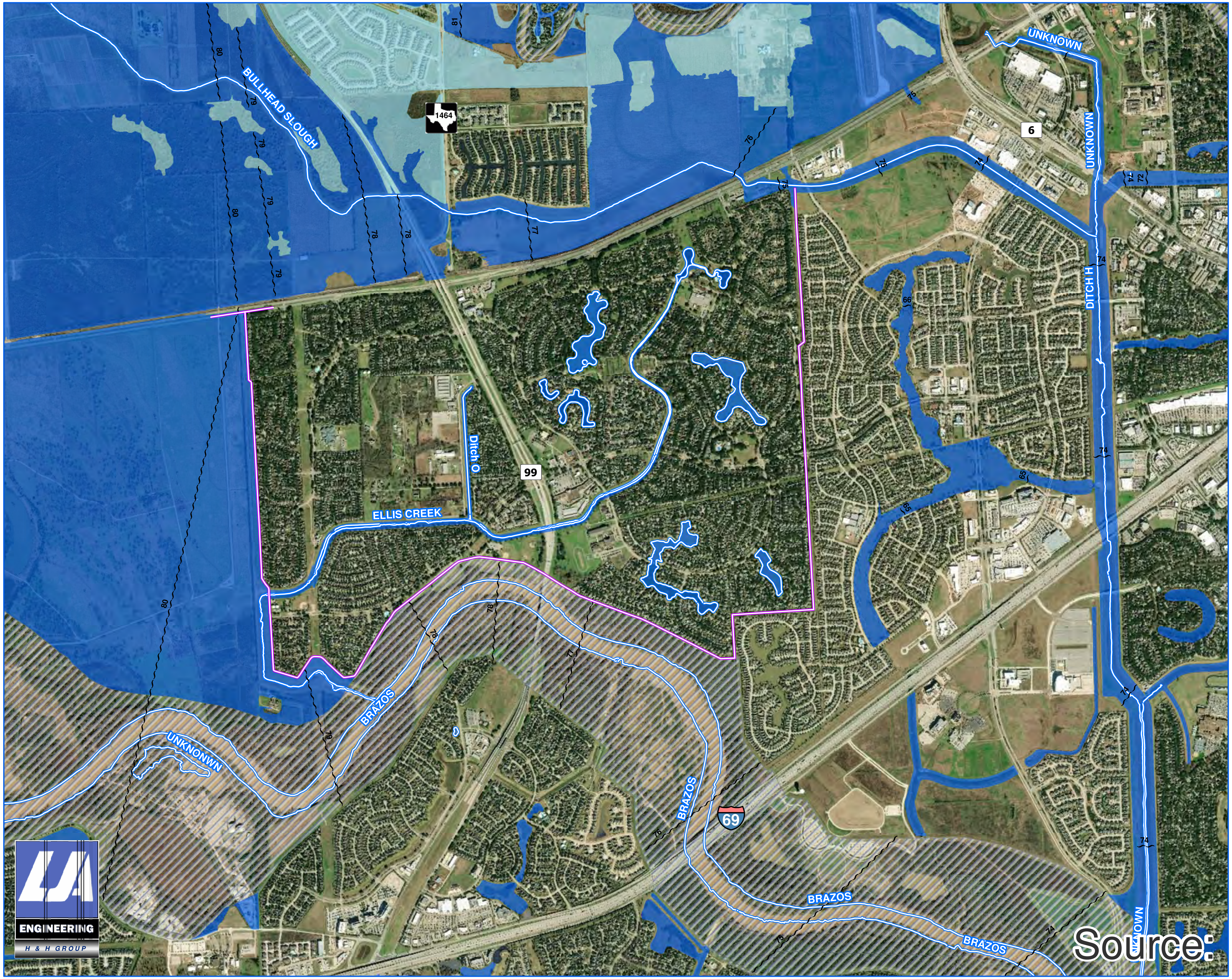

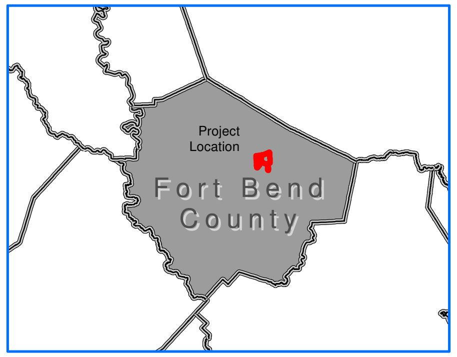

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Feet
0 1,000 2,000 4,000

One Inch Equals 2,000 feet

Note:
This exhibit shows pertinent items necessary to illustrate the information described in the text and is not intended to include all physical characteristics of the area.

Data Source:
Aerial Photography 2018 Nearmap

LEGEND

- LID 7 LEVEE
- EFFECTIVE FLOODWAY
- EFFECTIVE 100 YEAR FLOODPLAIN
- EFFECTIVE 500 YEAR FLOODPLAIN
- 198 EFFECTIVE BASE FLOOD ELEVATION

Exhibit 1.2

FORT BEND COUNTY LEVEE IMPROVEMENT DISTRICT NO. 7 MASTER DRAINAGE PLAN UPDATE

EFFECTIVE SPECIAL FLOOD HAZARD AREA (SFHA)

Date: April 2020 Job No. 2703-1906

LJA Engineering, Inc.

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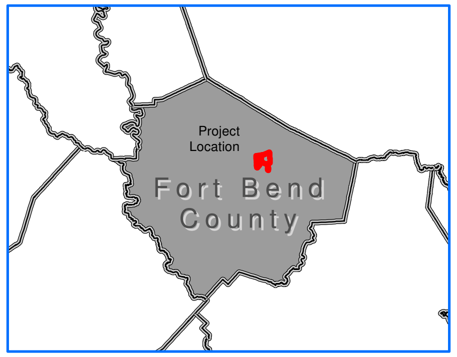

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Feet
0 500 1,000 2,000

One Inch Equals 1,000 feet

Note:
This exhibit shows pertinent items necessary to illustrate the information described in the text and is not intended to include all physical characteristics of the area.

Data Source:
Aerial Photography 2018 Nearmap

LEGEND

- LID 7 DISTRICT BOUNDARY
- LID 7 LEVEE
- EXISTING CHANNEL

Exhibit 1.3

FORT BEND COUNTY LEVEE IMPROVEMENT DISTRICT NO. 7 MASTER DRAINAGE PLAN UPDATE

CURRENT EXISTING LAND USE

Date: April 2020

Job No. 2703-1906

LJA Engineering, Inc.

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2.0 HYDROLOGY

2.1 Methodology

The U.S. Army Corps of Engineers HEC-HMS (Ver. 3.5) computer program was used to develop the flows for this analysis. HEC-HMS can simulate the precipitation-runoff process and compute flood hydrographs at desired locations within a watershed. The HEC-HMS program uses physical characteristics of the watershed that are represented by a system of geographic and hydrologic components to develop the runoff hydrographs for the watershed.

2.1.1 Hypothetical Storm Events

Because Fort Bend County and the Fort Bend County Drainage District use the results from the one- four-, and ten-percent, 24-hour frequency storms to regulate development, these storms were included in the analysis. The rainfall duration-depth relationships obtained from the DCM at the time the District drainage system was first designed were based on the National Weather Bureau (NWB) publications TP40 and Hydro 35. Since the time of that analysis, the Fort Bend County Drainage District has updated the rainfall values based on the NOAA Atlas 14 technical paper which was released for Texas in September of 2018. Point rainfall amounts for various durations and frequencies from the DCM are given in **Table 2.1** and the updated rainfall values adopted in November of 2018 are shown in **Table 2.2**.

Table 2.1
Fort Bend County Point Rainfall
Depth Duration-Frequency Values (TP40)

Duration	Depth (in)					
	2-Year	5-year	10-Year	25-Year	50-Year	100-Year
5 min	0.56	0.63	0.68	0.77	0.83	0.90
15 min	1.20	1.37	1.50	1.70	1.85	2.01
1 hr	2.30	2.82	3.18	3.72	4.14	4.55
2 hr	2.78	3.65	4.20	4.85	5.45	6.05
3 hr	3.15	4.00	4.70	5.45	6.10	6.85
6 hr	3.60	4.83	5.35	6.70	7.55	8.40
12 hr	4.20	5.75	6.80	8.20	9.25	10.45
24 hr	4.90	6.75	8.20	9.60	11.00	12.50

Table 2.2
Revised Fort Bend County Point Rainfall
Depth Duration-Frequency Values (Atlas 14)

Duration	Depth (in)					
	2-Year	5-year	10-Year	25-Year	50-Year	100-Year
5 min	0.591	0.727	0.842	1.00	1.13	1.26
15 min	1.19	1.46	1.69	2.00	2.25	2.50
1 hr	2.26	2.78	3.22	3.83	4.30	4.80
2 hr	2.83	3.53	4.19	5.16	5.99	6.91
3 hr	3.17	4.00	4.82	6.08	7.19	8.47
6 hr	3.77	4.86	5.97	7.72	9.33	11.20
12 hr	4.40	5.79	7.20	9.41	11.40	13.80
24 hr	5.09	6.82	8.55	11.20	13.70	16.50

2.1.2 Rainfall Distributions

In the HEC-HMS model, the hypothetical storm option was chosen to simulate a synthetic storm over the project site with the specified depth-duration data distributed based on a triangular precipitation distribution. The time distribution of rainfall was established using the U.S. Army Corps of Engineers critical pattern distribution from Civil Works Bulletin 52-8 and 30-minute increments. This method causes the peak intensity to occur in hour 15.5 of the 24-hour duration storm event which is the 67% duration peaking temporal rainfall distribution.

2.1.3 Infiltration Loss Rates

Infiltration loss is the quantity of rainfall expected to be absorbed into the soil throughout the duration of runoff. The precipitation losses due to infiltration and land surface interception are also stipulated in the DCM. For this study, infiltration losses were computed using the Green & Ampt Loss method (HEC-HMS Technical Reference Manual, 2000). This method computed infiltration by accounting for varying infiltration rate based on Initial Loss, Hydraulic Conductivity, Wetting Front Suction, Volume Moisture Deficit (also called Effective porosity), and Percentage of Imperviousness. The first four parameters used in this method were obtained from the Tropical Storm Allison Recovery project (Hydrology White papers, 2002) and are shown below:

STRKR	Initial Loss (in) = 0.075
DLTKR	Hydraulic Conductivity (in/hr) = 0.024
RTIOL	Wetting Front Suction (in) = 12.45
ERAIN	Volume Moisture Deficit = 0.46

For this analysis, the fifth parameter is the percent impervious cover of the basin (RTIMP). This value varies with the development assumed for each sub-watershed as shown in **Table 2.3**, taken from Table 2-2 in the DCM and updated draft DCM adopted January 2020**.**

Table 2.3
Typical Average Values for Impervious Cover

Type of Development	Percent Impervious
Lakes	100
Commercial and Business Areas	85
Industrial	72
Residential (based on average lot size):	
1/8 Acre or less	66
1/6 Acre	62
1/5 Acre	55
1/4 Acre	38
1/3 Acre	30
1/2 Acre	25
1 Acre	20

2.1.4 Clark's Unit Hydrograph Method

The runoff processes of the HEC-HMS model used in this analysis are based on runoff hydrographs developed using Clark's Unit Hydrograph method. This method uses the time of concentration (Tc) and storage coefficient (R) to develop the runoff hydrograph of the basin resulting from the excess precipitation during a storm event. These two parameters were calculated for each sub-watershed using the methodology presented in the DCM. The equations used to calculate Tc and R are shown below:

$$Tc + R = \frac{128(L/\sqrt{S})^{0.57} x(N)^{0.8}}{(So)^{0.11} x(10)^{I}}$$

$$Tc = (Tc + R) \text{ x } 0.38 \text{ x } \log(So)$$

$$R = (Tc + R) - Tc$$

$$I = CD \text{ x } 10^{-4}$$

where	Tc	=	Clark's time of concentration
	R	=	Clark's storage coefficient
	L	=	Length of the longest watercourse within the drainage area (miles)
	S	=	Average slope along the area's longest watercourse (ft/mile)
	N	=	Mannings weighted roughness coefficient
	So	=	Average slope of land draining into the longest watercourse (ft/mile)
	I	=	Effective impervious ratio
	C	=	Average percent of impervious cover of the developed area
	D	=	Percent of the sub-area developed

When ponding occurs in a sub-watershed, the R-value is adjusted to account for the additional storage. The adjustment factor (RM) varies according to the design storm and is based on the area of the ponding and the percentage of the watershed affected by the ponding. Because any ponding occurring within the leveed area is considered in the hydraulic model, no adjustments to R-values were made.

2.1.5 Rational Method

Because some sub-areas in District are less than 200 acres, peak discharges were calculated using Rational Method as presented in the Fort Bend County Drainage Criteria Manual to determine the rainfall runoff for the 100-year event. The Rational Method uses drainage area, a runoff coefficient, and rainfall intensity to calculate the peak runoff from a drainage area. The equation for calculating the peak flow using Rational Method is shown below:

$$Q=CiA$$

where	Q	=	peak runoff for a given storm event (cfs)
	c	=	runoff coefficient
	i	=	rainfall intensity (in/hr)
	A	=	area of the sub-watershed (acres)
	C_f	=	Runoff Factor (100yr = 1.25, 25yr = 1.1, 10yr = 1.0)

The rainfall intensity is based on the travel time, called Time of Concentration (Tc) for runoff to flow along the longest watercourse path in the drainage area. Tc is calculated by estimating the velocity and the longest travel path. The velocity is based on a relationship between ground cover and watercourse slope.

The average rainfall intensity was calculated using the equation below:

$$I = b/ (Tc + d)^{e}$$

Where;

I = Average Rainfall Intensity (in/hr)
Tc = Time of Concentration (min)
b, d, e = Rainfall Intensity Duration Frequency (IDF) Coefficients.

IDF coefficients shown in **Table 2.4** below were used in conjunction with the Time of Concentration (Tc) to compute the intensity (i). These values are based on the Harris County Policies, Criteria, and Procedures Manual (PCPM) dated July 9, 2019 for Atlas 14, and City of Friendswood DCM dated March 2020 for TP-40.

Table 2.4
IDF Coefficients

Return Period	e	b	d
10-Year	0.6771	55.66	7.43
25-Year	0.6222	51.65	5.09
100-Year	0.5274	42.99	1.08

The computed time of concentration from the Rational Method was used as the Clark's Time of Concentration to calculate the runoff hydrograph using Clark's Unit Hydrograph Method. To match the resulting peak flow from Clark's Unit Hydrograph Method to that computed from the Rational Method, the Storage Coefficient (R) was adjusted until the peak flow from HEC-HMS matched the peak flow calculated with the Rational Method.

2.2 Existing Conditions Hydrology

As mentioned in Section 1.3, District is 100-percent developed. The area draining to the District's drainage facilities was divided into sub-areas as shown in **Exhibit 2.1**, Drainage Area Map. The drainage areas were delineated based on previous analyses by Costello and were verified using storm sewer maps and construction plans. Watershed characteristics for theses subareas were calculated independently of any prior analyses and are shown in **Table 2.5**.

Table 2.5
Rational Method Parameters for LID 7 Drainage Subareas

Area ID	Area (ac)	c	L (mi.)	S (%)	V (fps)	Tc (hrs)	I_{10} (in/hr)	I_{25} (in/hr)	I_{100} (in/hr)
SUB 10	156.38	0.47	0.64	0.05	1.50	0.62	4.24	5.01	6.27
SUB 11A	25.54	0.46	0.20	0.05	1.00	0.30	6.24	7.34	9.10
SUB 11B	37.28	0.53	0.64	0.05	1.50	0.62	4.24	5.02	6.28
SUB 11C	73.34	0.50	0.57	0.05	1.50	0.56	4.51	5.33	6.64
SUB 11D	19.89	0.45	0.26	0.05	1.50	0.25	6.77	7.99	9.94
SUB 12A	39.08	0.54	0.61	0.05	1.50	0.59	4.36	5.15	6.44
SUB 12B	21.32	0.57	0.34	0.05	1.25	0.40	5.37	6.32	7.83
SUB 12C	86.18	0.52	0.58	0.05	1.50	0.57	4.48	5.29	6.59
SUB 12D	53.31	0.48	0.50	0.05	1.50	0.49	4.86	5.73	7.12
SUB 12E	25.14	0.53	0.27	0.05	1.50	0.27	6.60	7.77	9.65
SUB 13	58.15	0.51	0.51	0.05	1.50	0.50	4.81	5.67	7.05
SUB 14	33.52	0.54	0.70	0.05	1.50	0.68	4.02	4.76	5.98
SUB 15	17.17	0.52	0.15	0.05	1.50	0.23	6.99	8.24	10.28
SUB 16	21.40	0.54	0.25	0.05	1.50	0.24	6.85	8.07	10.05
SUB 17	38.03	0.49	0.42	0.05	1.50	0.41	5.35	6.29	7.80
SUB 18A	36.92	0.43	0.44	0.05	1.50	0.43	5.17	6.09	7.55
SUB 18B	38.74	0.51	0.55	0.05	1.00	0.80	3.67	4.36	5.51
SUB 18C	78.34	0.54	0.56	0.05	1.00	0.82	3.61	4.29	5.43
SUB 18D	20.77	0.54	0.23	0.05	1.00	0.40	5.39	6.34	7.86
SUB 8	87.70	0.49	0.76	0.05	1.50	0.75	3.83	4.54	5.72
SUB 9A	105.45	0.47	0.71	0.05	1.50	0.70	3.98	4.72	5.93
SUB 9B	49.26	0.51	0.39	0.05	1.00	0.57	4.47	5.28	6.58
Lake Clayton	14.57	0.90	0.00	0.00	0.00	0.25	8.04	7.99	9.94
Lake Sartartia	13.31	0.90	0.00	0.00	0.00	0.25	8.04	7.99	9.94
New Territory A&B	7.32	0.90	0.00	0.00	0.00	0.25	8.04	7.99	9.94
New Territory C&D	9.21	0.90	0.00	0.00	0.00	0.25	8.04	7.99	9.94
Point Royale A	2.01	0.90	0.00	0.00	0.00	0.25	8.04	7.99	9.94
Point Royale B	6.02	0.90	0.00	0.00	0.00	0.25	8.04	7.99	9.94
SUB 1	65.57	0.44	0.41	0.05	1.00	0.60	4.35	5.14	6.42
SUB 2	20.03	0.39	0.33	0.05	1.50	0.32	6.00	7.05	8.74
SUB 3	87.38	0.44	0.33	0.05	1.00	0.49	4.86	5.73	7.12
SUB 4A	19.34	0.46	0.32	0.05	1.50	0.31	6.09	7.16	8.87
SUB 4B	36.44	0.47	0.55	0.05	1.00	0.81	3.65	4.34	5.49
SUB 4C	52.68	0.48	0.58	0.05	1.50	0.57	4.45	5.26	6.56
SUB 5	146.79	0.43	0.69	0.05	1.00	1.01	3.20	3.82	4.89
SUB 6	86.84	0.46	0.69	0.05	1.50	0.67	4.07	4.81	6.04
SUB 7A	61.03	0.47	0.34	0.05	1.50	0.33	5.94	6.99	8.66
SUB 7B	18.79	0.50	0.24	0.05	1.50	0.24	6.95	8.20	10.22
SUB 19	39.03	0.49	0.45	0.05	1.50	0.44	5.12	6.02	7.47
SUB 20A	41.51	0.45	0.50	0.05	1.50	0.49	4.82	5.69	7.07
SUB 20B	71.47	0.49	0.59	0.05	1.50	0.58	4.41	5.21	6.50
SUB 20C	34.89	0.53	0.46	0.05	1.50	0.45	5.09	5.99	7.44
SUB 20D	35.32	0.49	0.31	0.05	1.50	0.31	6.17	7.26	9.00
SUB 20E	56.29	0.40	0.23	0.05	1.00	0.33	5.92	6.97	8.63
EXT 21	152.10	0.28	2.16	0.05	0.25	3.17	1.55	1.94	2.69
EXT 22	406.32	0.30	3.00	0.05	0.50	2.20	1.97	2.42	3.26
EXT 23	62.64	0.28	0.84	0.05	0.25	4.92	1.16	1.48	2.14
EXT 24	245.00	0.29	1.20	0.05	0.50	3.53	1.45	1.82	2.54
EXT 25	59.80	0.45	0.61	0.05	0.75	0.67	4.08	4.83	6.06

Table 2.5 Rational Method Parameters for LID 7 Drainage Subareas									
Area ID	Area (ac)	c	L (mi.)	S (%)	V (fps)	Tc (hrs)	I_{10} (in/hr)	I_{25} (in/hr)	I_{100} (in/hr)
EXT 26	628.80	0.27	1.90	0.05	0.50	5.59	1.07	1.37	2.00
EXT 27	192.40	0.25	0.98	0.05	0.50	2.87	1.66	2.06	2.84

A peak flow for each drainage area was calculated using Rational Method. Runoff hydrographs were calculated and calibrated in HEC-HMS using the Rational Method peak flow and Tc, then adjusting the R values for each sub-area until the HMS results matched the Rational Method results. The HEC-HMS existing condition flows are shown in **Table 2.6**.

Table 2.6 Updated Existing Condition HEC-HMS Peak Flows									
Sub-area ID	DA (sq. mi.)	Imp (%)	Tc	R_{10}	R_{25}	R_{100}	Q_{10} (cfs)	Q_{25} (cfs)	Q_{100} (cfs)
SUB 10	0.244	52.88%	0.62	1.29	1.19	1.02	310.3	401.9	574.4
SUB 11A	0.040	48.32%	0.30	0.70	0.63	0.54	73.8	94.0	132.1
SUB 11B	0.058	60.23%	0.62	1.01	0.91	0.75	84.9	109.0	156.7
SUB 11C	0.115	58.01%	0.56	1.04	0.94	0.80	166.4	214.8	305.6
SUB 11D	0.031	52.07%	0.25	0.64	0.56	0.46	60.9	77.7	111.3
SUB 12A	0.061	62.93%	0.59	0.92	0.84	0.69	94	120.4	172.3
SUB 12B	0.033	64.89%	0.40	0.61	0.53	0.44	66.2	84.7	120.4
SUB 12C	0.135	60.43%	0.57	0.97	0.88	0.73	202.8	261.6	373.2
SUB 12D	0.083	57.00%	0.49	0.98	0.88	0.76	125.1	160.8	228.1
SUB 12E	0.039	60.26%	0.27	0.48	0.42	0.32	88.6	112.9	160.8
SUB 13	0.091	57.54%	0.50	0.86	0.79	0.67	144.6	184.8	262.3
SUB 14	0.052	60.81%	0.68	1.07	0.96	0.80	73.1	94.1	135.8
SUB 15	0.027	59.59%	0.23	0.47	0.42	0.32	63.2	80.2	115.1
SUB 16	0.033	60.14%	0.24	0.33	0.28	0.20	80.4	102.9	149
SUB 17	0.059	57.59%	0.41	0.81	0.72	0.60	99.8	128.2	182.7
SUB 18A	0.058	35.28%	0.43	1.06	0.99	0.85	83	106.1	151.7
SUB 18B	0.061	55.09%	0.80	1.40	1.26	1.08	72.9	94.6	137
SUB 18C	0.122	59.69%	0.82	1.28	1.17	0.97	153.4	198.2	287.1
SUB 18D	0.032	61.02%	0.40	0.67	0.58	0.48	60.7	77.7	110.5
SUB 8	0.137	57.68%	0.75	1.36	1.25	1.08	167.3	216.1	310.1
SUB 9A	0.165	56.04%	0.70	1.40	1.29	1.11	199.1	258.0	370.1
SUB 9B	0.077	59.26%	0.57	1.05	0.96	0.82	113	145.1	207.2
Lake Clayton	0.023	100.00%	0.25	0.06	0.06	0.13	96.8	105.2	117.9
Lake Sartartia	0.021	100.00%	0.25	0.07	0.06	0.11	105.8	115.2	133.5
New Territory A & B	0.011	100.00%	0.25	0.02	0.02	0.10	53.4	57.9	65
New Territory C & D	0.014	100.00%	0.25	0.02	0.02	0.10	68	72.8	82.7
Point Royale Lake A	0.003	100.00%	0.25	0.02	0.02	0.10	14.6	15.9	17.7
Point Royale Lake B	0.009	100.00%	0.25	0.02	0.02	0.08	43.7	47.6	54.6
SUB 1	0.102	51.62%	0.60	1.35	1.25	1.11	128.1	164.8	235.3
SUB 2	0.031	37.56%	0.32	0.95	0.88	0.78	48.1	60.4	85.9
SUB 3	0.137	47.74%	0.49	1.15	1.05	0.91	188.2	242.9	344.7
SUB 4A	0.030	48.43%	0.31	0.71	0.63	0.53	55	69.6	99.6
SUB 4B	0.057	49.56%	0.81	1.60	1.49	1.29	63.9	82.4	119.9
SUB 4C	0.082	54.54%	0.57	1.11	1.02	0.88	114.1	146.3	208.3
SUB 5	0.229	37.08%	1.01	2.18	2.05	1.83	204.9	267.7	390.4

Table 2.6 Updated Existing Condition HEC-HMS Peak Flows									
Sub-area ID	DA (sq. mi.)	Imp (%)	Tc	R_{10}	R_{25}	R_{100}	Q_{10} (cfs)	Q_{25} (cfs)	Q_{100} (cfs)
SUB 6	0.136	55.46%	0.67	1.42	1.31	1.13	163.2	211.2	303.1
SUB 7A	0.095	56.44%	0.33	0.74	0.65	0.54	170.8	220.5	311.2
SUB 7B	0.029	56.24%	0.24	0.48	0.40	0.31	66	84.6	122
SUB 19	0.061	57.62%	0.44	0.87	0.80	0.66	99	126.3	179.8
SUB 20A	0.065	42.55%	0.49	1.09	0.99	0.87	91.9	117.7	167
SUB 20B	0.112	54.32%	0.58	1.11	1.00	0.86	155.8	201.7	287.1
SUB 20C	0.055	60.67%	0.45	0.77	0.69	0.56	95.3	122.1	173.2
SUB 20D	0.055	57.03%	0.31	0.63	0.55	0.45	107.4	137.8	196.6
SUB 20E	0.088	37.85%	0.33	1.00	0.92	0.81	133	170.9	242
EXT 21	0.238	5%	3.17	10.50	9.65	8.99	64.3	90.9	145.7
EXT 22	0.635	9%	2.20	6.84	6.75	6.45	240.9	324.2	494.7
EXT 23	0.098	9%	4.92	13.55	12.90	12.00	21.7	28.7	48.1
EXT 24	0.383	34%	3.53	1.43	10.16	1.15	109.9	142.0	204.3
EXT 25	0.093	11%	0.67	12.33	1.31	9.50	90.7	143.0	225.9
EXT 26	0.983	7%	5.59	16.55	15.60	14.10	178.5	256.5	425.5
EXT 27	0.301	0%	2.87	10.50	10.30	9.99	79.7	109.1	170.6

The flows in Table 2.6 were imported to XP-STORM v2018 as inflow hydrographs generated in HEC-HMS. These flows were used to analyze the hydraulics in the District for all the proposed improvement alternatives.

Updated Existing Condition HEC-HMS Peak Flows

Sub-area ID	DA (sq. mi.)	Imp (%)	Tc	R_{10}	R_{25}	R_{100}	Q_{10} (cfs)	Q_{25} (cfs)	Q_{100} (cfs)
SUB 10	156.38	52.88%	0.62	1.29	1.19	1.02	310.3	401.9	574.4
SUB 11A	25.54	48.32%	0.30	0.70	0.63	0.54	73.8	94.0	132.1
SUB 11B	37.28	60.23%	0.62	1.01	0.91	0.75	84.9	109.0	156.7
SUB 11C	73.34	58.01%	0.56	1.04	0.94	0.80	166.4	214.8	305.6
SUB 11D	19.89	52.07%	0.25	0.64	0.56	0.46	60.9	77.7	111.3
SUB 12A	39.08	62.93%	0.59	0.92	0.84	0.69	94	120.4	172.3
SUB 12B	21.32	64.89%	0.40	0.61	0.53	0.44	66.2	84.7	120.4
SUB 12C	86.18	60.43%	0.57	0.97	0.88	0.73	202.8	261.6	373.2
SUB 12D	53.31	57.00%	0.49	0.98	0.88	0.76	125.1	160.8	228.1
SUB 12E	25.14	60.26%	0.27	0.48	0.42	0.32	88.6	112.9	160.8
SUB 13	58.15	57.54%	0.50	0.86	0.79	0.67	144.6	184.8	262.3
SUB 14	33.52	60.81%	0.68	1.07	0.96	0.80	73.1	94.1	135.8
SUB 15	17.17	59.59%	0.23	0.47	0.42	0.32	63.2	80.2	115.1
SUB 16	21.40	60.14%	0.24	0.33	0.28	0.20	80.4	102.9	149
SUB 17	38.03	57.59%	0.41	0.81	0.72	0.60	99.8	128.2	182.7
SUB 18A	36.92	35.28%	0.43	1.06	0.99	0.85	83	106.1	151.7
SUB 18B	38.74	55.09%	0.80	1.40	1.26	1.08	72.9	94.6	137
SUB 18C	78.34	59.69%	0.82	1.28	1.17	0.97	153.4	198.2	287.1
SUB 18D	20.77	61.02%	0.40	0.67	0.58	0.48	60.7	77.7	110.5
SUB 8	87.70	57.68%	0.75	1.36	1.25	1.08	167.3	216.1	310.1
SUB 9A	105.45	56.04%	0.70	1.40	1.29	1.11	199.1	258.0	370.1
SUB 9B	49.26	59.26%	0.57	1.05	0.96	0.82	113	145.1	207.2
Lake Clayton	14.57	100.00%	0.25	0.06	0.06	0.13	96.8	105.2	117.9
Lake Sartartia	13.31	100.00%	0.25	0.07	0.06	0.11	105.8	115.2	133.5
New Territory Lakes A & B	7.32	100.00%	0.25	0.02	0.02	0.10	53.4	57.9	65
New Territory Lakes C & D	9.21	100.00%	0.25	0.02	0.02	0.10	68	72.8	82.7
Point Royale Lake A	2.01	100.00%	0.25	0.02	0.02	0.10	14.6	15.9	17.7
Point Royale Lake B	6.02	100.00%	0.25	0.02	0.02	0.08	43.7	47.6	54.6
SUB 1	65.57	51.62%	0.60	1.35	1.25	1.11	128.1	164.8	235.3
SUB 2	20.03	37.56%	0.32	0.95	0.88	0.78	48.1	60.4	85.9
SUB 3	87.38	47.74%	0.49	1.15	1.05	0.91	188.2	242.9	344.7
SUB 4A	19.34	48.43%	0.31	0.71	0.63	0.53	55	69.6	99.6
SUB 4B	36.44	49.56%	0.81	1.60	1.49	1.29	63.9	82.4	119.9
SUB 4C	52.68	54.54%	0.57	1.11	1.02	0.88	114.1	146.3	208.3
SUB 5	146.79	37.08%	1.01	2.18	2.05	1.83	204.9	267.7	390.4
SUB 6	86.84	55.46%	0.67	1.42	1.31	1.13	163.2	211.2	303.1
SUB 7A	61.03	56.44%	0.33	0.74	0.65	0.54	170.8	220.5	311.2
SUB 7B	18.79	56.24%	0.24	0.48	0.40	0.31	66	84.6	122
SUB 19	39.03	57.62%	0.44	0.87	0.80	0.66	99	126.3	179.8
SUB 20A	41.51	42.55%	0.49	1.09	0.99	0.87	91.9	117.7	167
SUB 20B	71.47	54.32%	0.58	1.11	1.00	0.86	155.8	201.7	287.1
SUB 20C	34.89	60.67%	0.45	0.77	0.69	0.56	95.3	122.1	173.2
SUB 20D	35.32	57.03%	0.31	0.63	0.55	0.45	107.4	137.8	196.6
SUB 20E	56.29	37.85%	0.33	1.00	0.92	0.81	133	170.9	242
EXT 21	152.10	5%	3.17	10.50	9.65	8.99	64.3	90.9	145.7
EXT 22	406.32	9%	2.20	6.84	6.75	6.45	240.9	324.2	494.7
EXT 23	62.64	9%	4.92	13.55	12.90	12.00	21.7	28.7	48.1
EXT 24	245.00	34%	3.53	1.43	10.16	1.15	109.9	142.0	204.3
EXT 25	59.80	11%	0.67	12.33	1.31	9.50	90.7	143.0	225.9
EXT 26	628.80	7%	5.59	16.55	15.60	14.10	178.5	256.5	425.5
EXT 27	192.40	0%	2.87	10.50	10.30	9.99	79.7	109.1	170.6

Note:
This exhibit shows pertinent items necessary to illustrate the information described in the text and is not intended to include all physical characteristics of the area.

Data Source:
Aerial Photography 2016 (HGAC)

Exhibit 2.1

FORT BEND COUNTY LEVEE IMPROVEMENT DISTRICT NO. 7 MASTER DRAINAGE PLAN UPDATE

INTERNAL DRAINAGE AREAS

Date: April 2020

Job No. 2703-1906

LJA Engineering, Inc.

3.0 HYDRAULICS

3.1 Methodology

Because the major drainage system within the District is made up of interconnected channels and ponds, a dynamic modeling method was determined to be the most appropriate method for analyzing the system. The hydraulic analysis for the drainage system was analyzed using XP-STORM v2018 from Innovyze.

XP- STORM dynamically routes storm water through open channels and/or closed conduits and can simulate a variety of complex conveyance systems, including looped systems. The XP-STORM hydraulics engine solves the complete St. Venant (Dynamic Flow) equations for gradually varied, one dimensional, unsteady flow throughout the drainage network. The calculation accurately models backwater effects, flow reversal, surcharging, pressure flow, and interconnected ponds. This means that bi-directional flow can be modeled and the tail water elevation at an outfall is considered in the calculations. Therefore, for analyzing a series of lakes, connected by culverts or controlled by weirs, XP-STORM provides a more “real world” model.

XP- STORM uses a link→node concept to represent real-world systems. This concept requires that the drainage system be simplified into a network of nodes, or junctions, and links, or reaches.

A node is a discrete location in the drainage system where conservation of mass or continuity is maintained. Nodes are placed upstream and downstream of any structure (e.g., weirs, culverts, drop structures). In the XP- STORM model, a node is placed at each point where a stage calculation is needed. Runoff hydrographs are assigned to nodes. All of the lakes and dry storage facilities within the drainage system are specified as nodes. Additional nodes can be added at the upstream and downstream ends of culverts or channel reaches to properly model these connections.

Links are connections between nodes and are used to transfer or convey water through the system. The entire system of nodes and links forms the nodal network and serves as the computation framework for XP- STORM.

The latest version of XP-STORM also includes the ability to perform two-dimensional hydrodynamic modeling. It was decided that the use of this capability in portions of the system would provide a better estimation of the effects of the runoff patterns on the hydrographs and account for the storage in these areas better than a strictly 1-D model.

During Hurricane Harvey, a few residences in the Greystone Place subdivision experienced home or garage flooding. Additionally, many residents reported street ponding lasting over a day near the Lakes of New Territory, Lakewind Lake, and Lake Sartartia. Therefore, a 2D XP-STORM model was developed that could be used for both design and specific storm event calibration. The 2D model connected the lakes, the channels, and the overland flows, facilitating the interaction between all parts of the drainage system, and providing crucial information for developing potential solutions to reduce flooding in the future.

3.1.1 Boundary Conditions

Every drainage system must have boundaries, or limits. While the upstream boundaries of a system typically do not require special consideration, downstream boundaries are important. The drainage system for the District uses normal depth outfall at the downstream limits of the model for gravity discharge scenarios when the Brazos River is low. The boundary condition used for the District during high stages on the Brazos River is a constant tailwater elevation based on the Brazos River water surface elevation at the District outfall. During this condition, gravity outfall is impeded, and pumps must be utilized to drain the District against the high tailwater. The tailwater elevation downstream of the outfall used 80 feet (NAVD88, 2001 adjustment) during pumped conditions.

3.1.2 Lake Modeling

In XP-STORM lakes are modeled as level pools. This implies that the water surface within the storage area is flat and rises or falls uniformly across the surface. A single node was used to model each lake's sub-area using a stage-area relationship to describe the water holding capacity of the lakes. Stage-area nodes were used to represent each lake in the system.

Stage-area data for the existing ponds in the District was obtained from previous studies and verified using construction plans, LiDAR topography, and field reconnaissance. The surface area versus elevation relationships used for this analysis can be found in Table 3.1.

Table 3.1
LID 7 Lakes - Elevation Area Storage Relationship

Lake A			Lake B			Lake C		
Elevation	Area	Volume	Elevation	Area	Volume	Elevation	Area	Volume
69.00	2.79	0.00	69.00	2.68	0.00	69.00	4.25	0.00
69.50	2.91	1.42	69.50	2.83	1.38	69.50	4.40	2.16
70.00	3.03	2.91	70.00	2.98	2.83	70.00	4.56	4.40
70.50	3.16	4.46	70.50	3.15	4.37	70.50	4.72	6.72
71.00	3.30	6.07	71.00	3.32	5.99	71.00	4.91	9.13
71.50	3.43	7.75	71.50	3.50	7.69	71.50	5.10	11.63
72.00	3.54	9.50	72.00	3.66	9.48	72.00	5.29	14.23
72.50	3.62	11.29	72.53	3.74	11.44	72.52	5.43	17.02
Lake D			Lake Clayton			Lake Sartartia		
Elevation	Area	Volume	Elevation	Area	Volume	Elevation	Area	Volume
69.00	3.10	0.00	72.50	12.61	0.00	71.50	0.00	0.00
69.50	3.24	1.59	73.00	12.95	6.39	72.00	10.87	2.72
70.00	3.39	3.24	73.50	13.29	12.95	72.50	11.26	8.25
70.50	3.56	4.98	74.00	13.49	19.64	73.00	11.67	13.98
71.00	3.76	6.81				73.50	12.11	19.92
71.50	3.94	8.74				74.03	12.40	26.42
72.00	4.11	10.75						
72.52	4.23	12.92						
Point Royal A			Point Royal B			North Lake		
Elevation	Area	Volume	Elevation	Area	Volume	Elevation	Area	Volume
71.18	1.40	0.00	71.00	4.40	0.00	66.50	3.55	0.00

Table 3.1
LID 7 Lakes - Elevation Area Storage Relationship

71.50	1.50	0.46		71.50	4.63	2.26		67.00	3.63	1.79
72.00	1.58	1.23		72.00	4.86	4.63		67.50	3.73	3.64
72.50	1.70	2.05		72.50	5.31	7.18		68.00	3.87	5.54
73.00	1.85	2.94		73.00	5.72	9.94		68.50	4.07	7.52
73.50	2.01	3.91		73.50	5.99	12.86		75.50	8.42	51.24
74.10	2.12	5.14		74.10	6.14	16.50		76.00	8.43	55.46
	Lakewind									
Elevation	Area	Volume								
67.50	4.20	0.00								
68.00	4.35	2.14								
68.50	4.50	4.35								
69.00	4.64	6.64								
70.00	4.91	11.41								
70.50	5.05	13.90								
71.00	5.20	16.47								
71.52	5.28	19.19								

3.1.3 Major Surface Water Inflow Points

In XP-STORM, all inflows are assigned to nodes (point loading). This means that the rainfall runoff is assigned to specific nodes for routing through the proposed drainage system. Hydrographs generated by HEC-HMS discussed in Section 2 were imported directly into the XP-STORM model of the proposed drainage system. The locations of the inflow hydrographs into the drainage system are based on previous models and verified with construction plans and field reconnaissance.

For the District's major drainage system, the direct runoff is conveyed to Ellis Creek rather than the lakes. Therefore, the lakes are considered offline storage. This design results in higher peak water surface elevations in the channel than those in the ponds during gravity outfall scenarios. This gives the appearance of higher water surface elevations downstream than upstream, which is not a typical occurrence for a gravity discharge system. This is illustrated and discussed further in following sections.

3.1.4 Conduit Modeling

Generally, closed conduits, weirs, and channels comprise the links used to connect the lake system. In XP-STORM the flow direction can be set to both, positive only, or no flow. "Both" is the normal setting and allows for flow reversals to occur. The positive flow option allows flow only in the direction indicated by designating a "from" node and a "to" node. Flow reversals were allowed at all the connections in the storage system. The drainage elements were obtained from the Costello model, and verified using construction plans, survey, and field reconnaissance.

The proposed drainage improvements reflect existing drainage elements and the recommended additional storage and pumping added to the system to supplement the storage volume needed for the coincident storm event. Details of the existing major drainage elements within the District are summarized in **Table 3.2**.

Table 3.2
LID 7 Drainage System Components

XP-STORM Link ID	From Node (U/S)	To Node (D/S)	Flow line (U/S)	Flow line (D/S)	Link Type	No.	Width	Height	Length
			(NAVD)	(NAVD)			(ft)	(ft)	(ft)
Link261	North Lake	SUB9A+11B	73.57	73.44	Natural	1	---	---	60
XS 10894	10894	SUB1	69.04	68.05	Natural	1	---	---	662
XS 10162	SUB1	10123	68.05	67.96	Natural	1	---	---	61
XS 9920	9920	SUB2_8975	67.74	66.34	Natural	1	---	---	931
XS 8975	SUB2_8975	8735	66.34	66.22	Natural	1	---	---	77
Link247	Point Royale A	Point Royale B	66.18	66.18	Circular	1	3	3	220
XS 8500	8500	SUB3_8270	65.78	65.46	Natural	1	---	---	211
XS 8270	SUB3_8270	8030	65.46	65.45	Natural	1	---	---	68
Link224	Node407	10014	64.72	64.57	Circular	1	2.5	2.5	72
Link130	10014	SUB14	64.57	64.40	Circular	1	3.5	3.5	170
Link220	Node409	D-24	64.20	63.85	Circular	1	2	2	174
Link227	Lake D	Lake C	64.13	64.13	Circular	2	4	4	42
Link225	Lake A	Lake B	64.13	64.13	Circular	2	4	4	42
XS 7088	7088	5745	63.92	61.47	Natural	1	---	---	1529
Link124	SUB14	10041	63.90	63.78	Circular	1	4.5	4.5	122
Link90	D-24	SUB11C	63.85	63.77	Circular	1	6	6	188
Link125	10041	10013_IN	63.78	63.65	Circular	1	4.5	4.5	128
Link93	SUB11C	D-26	63.77	63.65	Circular	1	6	6	303
Link94	D-26	D-27	63.65	63.53	Circular	1	6	6	292
Link122	10013_IN	10043	63.65	63.62	Circular	1	4.5	4.5	31
Link123	10043	10044	63.62	63.57	Circular	1	4.5	4.5	54
Link121	10044	10046	63.57	63.39	Circular	1	4.5	4.5	178
Link229	Node401	10130	63.55	63.50	Box	1	8	5	95
Link95	D-27	D-28	63.53	63.50	Circular	1	6	6	79
Link101	Node405	MH-3	63.53	62.84	Circular	1	1.5	1.5	694
Link155	10130	SUB12B+12E	63.50	62.10	Box	1	8	5	316
Link96	D-28	SUB11D	63.50	63.41	Circular	1	6	6	229
Link103	SUB11D	D-30	63.41	63.35	Circular	1	6	6	159
Link120	10046	10045_IN	63.39	63.27	Circular	1	4.5	4.5	124
Link102	D-30	SUB9B	63.35	63.20	Circular	1	6	6	78
Link115	10045_IN	10047	63.27	63.17	Circular	1	4.5	4.5	103
Link116	10047	10048	63.17	62.92	Circular	1	4.5	4.5	254
XS 15113	SUB9A+11B	14607	62.66	60.57	Natural	1	---	---	526
Link117	10048	10050_IN	62.42	61.97	Circular	1	5	5	442
Link157	SUB12B+12E	Node413	62.10	61.97	Box	1	8	5	253
Link118	10050_IN	10052	61.97	61.86	Circular	1	5	5	112
Link253	Node413	10028	61.97	61.88	Box	1	8	5	167
Link156	10028	10035_IN	61.88	61.66	Box	1	10	5	403
Link223	Node410	SUB9A+11B	61.68	61.68	Box	1	10	10	70
Link154	10035_IN	SUB12C_IN	61.66	61.33	Box	1	10	5	656
XS 14113	SUB11A_14113	13636	61.64	61.54	Natural	1	---	---	496
XS 13636	13636	13569	61.54	61.52	Natural	1	---	---	70
XS 13569	13569	SUB9B	61.52	61.21	Natural	1	---	---	278
Link111	SUB12C_IN	10043_IN	61.33	60.92	Box	2	8	5	813

Table 3.2
LID 7 Drainage System Components

XP-STORM Link ID	From Node (U/S)	To Node (D/S)	Flow line (U/S)	Flow line (D/S)	Link Type	No.	Width	Height	Length
			(NAVD)	(NAVD)			(ft)	(ft)	(ft)
XS 13569.1	SUB9B	13926	61.21	60.89	Natural	1	---	---	287
Link98	MH-3	SUB9B	61.08	61.03	Circular	1	2	2	55
XS 2863	SUB6_2863	2377	60.97	59.48	Natural	1	---	---	503
Link252	10043_IN	10042_IN	60.92	60.77	Box	2	8	5	298
XS 13026	13926	12496	60.89	59.63	Natural	1	---	---	551
Link112	10042_IN	SUB12D_IN	60.77	60.50	Box	2	8	5	419
XS 14607	14607	SUB11A	60.57	61.64	Natural	1	---	---	514
Link281	SUB12D_IN	SUB12D	60.50	60.42	Box	2	10	5	198
Link113	SUB12D	10051_IN	60.42	60.28	Box	2	10	5	375
11032_BR	11032	10991.0	60.30	60.30	Natural	1	---	---	43
11032_BR	11032	10991.0	60.30	60.30	Bridge	1	---	---	10
XS 10991	10991	10964.0	60.30	60.30	Natural	1	---	---	28
10964_BR	10964	10926.0	60.30	60.15	Natural	1	---	---	40
10964_BR	10964	10926.0	60.30	60.15	Bridge	1	---	---	10
XS 10926	10926	10561.0	60.30	60.30	Natural	1	---	---	297
XS 10561	10561	SUB17	60.30	59.29	Natural	1	---	---	333
Link114	10051_IN	10926.0	60.28	60.15	Box	2	10	5	251
Link226	Node397	10129.0	60.28	60.20	Box	1	6	5	151
Link150	SUB18C	10129.0	60.27	60.20	Box	1	11	6	124
Link259	10129	SUB18B	60.19	60.04	Box	2	8	6	188
Link142	SUB18B	10124.0	60.04	59.89	Box	2	8	6	190
XS 12045	12045	SUB13_11594	59.90	59.69	Natural	1	---	---	469
Link143	10124	SUB18D	59.89	59.83	Box	2	8	6	139
Link272	SUB18D	10122.0	59.83	59.77	Box	2	8	6	67
XS 11102	11102	11032.0	59.79	60.30	Natural	1	---	---	73
Link144	10122	10119_IN	59.77	59.70	Box	2	8	6	251
Link145	10119_IN	SUB18A_IN	59.70	59.58	Box	2	8	6	400
XS 11594	SUB13_11594	11102.0	59.69	59.79	Natural	1	---	---	512
XS 12496	12496	12045.0	59.63	59.90	Natural	1	---	---	469
Link146	SUB18A_IN	10115.0	59.58	59.44	Box	2	8	6	259
XS 2377	2377	1877.0	59.48	59.04	Natural	1	---	---	518
Link119	10052	10561.0	59.47	59.23	Circular	1	6	6	118
Link147	10115	10121_IN	59.44	59.41	Box	2	8	6	87
Link148	10121_IN	9166.0	59.41	57.30	Box	2	8	6	184
XS 10241	SUB17	SUB15_9750	59.29	59.08	Natural	1	---	---	511
XS 9750	SUB15_9750	9529.0	59.08	57.09	Natural	1	---	---	230
XS 1877	1877	SUB7A_1378	59.04	58.76	Natural	1	---	---	517
XS 1378	SUB7A_1378	879.0	58.76	58.96	Natural	1	---	---	517
5814_BR	SUB19_5814	5778.0	57.83	57.83	Natural	1	---	---	37
5814_BR	SUB19_5814	5778.0	57.83	57.83	Bridge	1	---	---	10
XS 5778	5778	5751.0	57.83	57.09	Natural	1	---	---	28
XS 5615	SUB7B_5615	JCT A	57.83	57.72	Natural	1	---	---	149
DS JCT A	JCT A	5461.0	57.72	57.72	Natural	1	---	---	75
XS 8208	8208	SUB16_8121	57.62	57.44	Natural	1	---	---	104
8121_BR	SUB16_8121	8066.0	57.44	57.44	Natural	1	---	---	57
8121_BR	SUB16_8121	8066.0	57.44	57.44	Bridge	1	---	---	10
Link274	8066	Node434	57.44	57.43	Natural	1	---	---	29
XS 7846	7846	7216	57.44	59.31	Natural	1	---	---	198
XS 8066	Node434	Node435	57.43	57.43	Natural	1	---	---	166

Table 3.2
LID 7 Drainage System Components

XP-STORM Link ID	From Node (U/S)	To Node (D/S)	Flow line (U/S)	Flow line (D/S)	Link Type	No.	Width	Height	Length
			(NAVD)	(NAVD)			(ft)	(ft)	(ft)
XS 8066	Node434	Node435	57.43	57.43	Bridge	1	---	---	10
7901_BR	7901	7846	57.42	57.44	Natural	1	---	---	57
7901_BR	7901	7846	57.42	57.44	Bridge	1	---	---	10
XS 9529	9529	SUB8_9466	57.09	57.09	Natural	1	---	---	66
XS 9529	9529	SUB8_9466	57.09	57.09	Bridge	1	---	---	10
XS 9466	SUB8_9466	9166	57.09	58.27	Natural	1	---	---	208
XS 6122	6122	SUB19_5814	57.09	57.83	Natural	1	---	---	32
5751_BR	5751	SUB20E_5715	57.09	57.09	Natural	1	---	---	37
5751_BR	5751	SUB20E_5715	57.09	57.09	Bridge	1	---	---	10
XS 5715	SUB20E_5715	SUB7B_5615	57.09	57.83	Natural	1	---	---	104
XS 4808	4808	SUB20D_4337	57.02	57.10	Natural	1	---	---	461
XS 3860	SUB5_3860	SUB20C_3285	55.53	54.70	Natural	1	---	---	563
XS 2776	SUB4C_3285	2267	55.00	54.76	Natural	1	---	---	498
XS 2175	2175	SUB20B_1712	54.82	54.07	Natural	1	---	---	453
XS 3285	SUB20C_3285	SUB4C_3285	54.70	55.00	Natural	1	---	---	498
XS 463	SUB20A_463	339	54.55	54.35	Natural	1	---	---	97
XS 339	339	290	54.40	54.35	Box	5	10	10	95
XS 1712	SUB20B_1712	SUB4B	54.07	53.66	Natural	1	---	---	522
XS 1179	SUB4B	SUB4A	53.66	53.15	Natural	1	---	---	437
XS 733	SUB4A	SUB20A_463	53.15	54.09	Natural	1	---	---	234
XS 1100	1100	Outfall	26.39	27.16	Natural	1	---	---	111
Link261	North Lake	SUB9A+11B	73.57	73.44	Natural	1	---	---	60
XS 10894	10894	SUB1	69.04	68.05	Natural	1	---	---	662
XS 10162	SUB1	10123	68.05	67.96	Natural	1	---	---	61
XS 9920	9920	SUB2_8975	67.74	66.34	Natural	1	---	---	931
XS 8975	SUB2_8975	8735	66.34	66.22	Natural	1	---	---	77
Link247	Point Royale A	Point Royale B	66.18	66.18	Circular	1	3	3	220
XS 8500	8500	SUB3_8270	65.78	65.46	Natural	1	---	---	211
XS 8270	SUB3_8270	8030	65.46	65.45	Natural	1	---	---	68
Link224	Node407	10014	64.72	64.57	Circular	1	2.5	2.5	72
Link130	10014	SUB14	64.57	64.40	Circular	1	3.5	3.5	170
Link220	Node409	D-24	64.20	63.85	Circular	1	2	2	174
Link227	Lake D	Lake C	64.13	64.13	Circular	2	4	4	42
Link225	Lake A	Lake B	64.13	64.13	Circular	2	4	4	42
XS 7088	7088	5745	63.92	61.47	Natural	1	---	---	1529
Link124	SUB14	10041	63.90	63.78	Circular	1	4.5	4.5	122
Link90	D-24	SUB11C	63.85	63.77	Circular	1	6	6	188
Link125	10041	10013_IN	63.78	63.65	Circular	1	4.5	4.5	128
Link93	SUB11C	D-26	63.77	63.65	Circular	1	6	6	303
Link94	D-26	D-27	63.65	63.53	Circular	1	6	6	292
Link122	10013_IN	10043	63.65	63.62	Circular	1	4.5	4.5	31
Link123	10043	10044	63.62	63.57	Circular	1	4.5	4.5	54
Link121	10044	10046	63.57	63.39	Circular	1	4.5	4.5	178
Link229	Node401	10130	63.55	63.50	Box	1	8	5	95
Link95	D-27	D-28	63.53	63.50	Circular	1	6	6	79
Link101	Node405	MH-3	63.53	62.84	Circular	1	1.5	1.5	694
Link155	10130	SUB12B+12E	63.50	62.10	Box	1	8	5	316
Link96	D-28	SUB11D	63.50	63.41	Circular	1	6	6	229
Link103	SUB11D	D-30	63.41	63.35	Circular	1	6	6	159

Table 3.2
LID 7 Drainage System Components

XP-STORM Link ID	From Node (U/S)	To Node (D/S)	Flow line (U/S)	Flow line (D/S)	Link Type	No.	Width	Height	Length
			(NAVD)	(NAVD)			(ft)	(ft)	(ft)
Link120	10046	10045_IN	63.39	63.27	Circular	1	4.5	4.5	124
Link102	D-30	SUB9B	63.35	63.20	Circular	1	6	6	78
Link115	10045_IN	10047	63.27	63.17	Circular	1	4.5	4.5	103
Link116	10047	10048	63.17	62.92	Circular	1	4.5	4.5	254
XS 15113	SUB9A+11B	14607	62.66	60.57	Natural	1	---	---	526
Link117	10048	10050_IN	62.42	61.97	Circular	1	5	5	442
Link157	SUB12B+12E	Node413	62.10	61.97	Box	1	8	5	253
Link118	10050_IN	10052	61.97	61.86	Circular	1	5	5	112
Link253	Node413	10028	61.97	61.88	Box	1	8	5	167
Link156	10028	10035_IN	61.88	61.66	Box	1	10	5	403
Link223	Node410	SUB9A+11B	61.68	61.68	Box	1	10	10	70
Link154	10035_IN	SUB12C_IN	61.66	61.33	Box	1	10	5	656
XS 14113	SUB11A_14113	13636	61.64	61.54	Natural	1	---	---	496
XS 13636	13636	13569	61.54	61.52	Natural	1	---	---	70
XS 13569	13569	SUB9B	61.52	61.21	Natural	1	---	---	278
Link111	SUB12C_IN	10043_IN	61.33	60.92	Box	2	8	5	813
XS 13569.1	SUB9B	13926	61.21	60.89	Natural	1	---	---	287
Link98	MH-3	SUB9B	61.08	61.03	Circular	1	2	2	55
XS 2863	SUB6_2863	2377	60.97	59.48	Natural	1	---	---	503
Link252	10043_IN	10042_IN	60.92	60.77	Box	2	8	5	298
XS 13026	13926	12496	60.89	59.63	Natural	1	---	---	551
Link112	10042_IN	SUB12D_IN	60.77	60.50	Box	2	8	5	419
XS 14607	14607	SUB11A	60.57	61.64	Natural	1	---	---	514
Link281	SUB12D_IN	SUB12D	60.50	60.42	Box	2	10	5	198
Link113	SUB12D	10051_IN	60.42	60.28	Box	2	10	5	375
11032_BR	11032	10991.0	60.30	60.30	Natural	1	---	---	43
11032_BR	11032	10991.0	60.30	60.30	Bridge	1	---	---	10
XS 10991	10991	10964.0	60.30	60.30	Natural	1	---	---	28
10964_BR	10964	10926.0	60.30	60.15	Natural	1	---	---	40
10964_BR	10964	10926.0	60.30	60.15	Bridge	1	---	---	10
XS 10926	10926	10561.0	60.30	60.30	Natural	1	---	---	297
XS 10561	10561	SUB17	60.30	59.29	Natural	1	---	---	333
Link114	10051_IN	10926.0	60.28	60.15	Box	2	10	5	251
Link226	Node397	10129.0	60.28	60.20	Box	1	6	5	151
Link150	SUB18C	10129.0	60.27	60.20	Box	1	11	6	124
Link259	10129	SUB18B	60.19	60.04	Box	2	8	6	188
Link142	SUB18B	10124.0	60.04	59.89	Box	2	8	6	190
XS 12045	12045	SUB13_11594	59.90	59.69	Natural	1	---	---	469
Link143	10124	SUB18D	59.89	59.83	Box	2	8	6	139
Link272	SUB18D	10122.0	59.83	59.77	Box	2	8	6	67
XS 11102	11102	11032.0	59.79	60.30	Natural	1	---	---	73
Link144	10122	10119_IN	59.77	59.70	Box	2	8	6	251
Link145	10119_IN	SUB18A_IN	59.70	59.58	Box	2	8	6	400
XS 11594	SUB13_11594	11102.0	59.69	59.79	Natural	1	---	---	512
XS 12496	12496	12045.0	59.63	59.90	Natural	1	---	---	469
Link146	SUB18A_IN	10115.0	59.58	59.44	Box	2	8	6	259
XS 2377	2377	1877.0	59.48	59.04	Natural	1	---	---	518
Link119	10052	10561.0	59.47	59.23	Circular	1	6	6	118
Link147	10115	10121_IN	59.44	59.41	Box	2	8	6	87

Table 3.2
LID 7 Drainage System Components

XP-STORM Link ID	From Node (U/S)	To Node (D/S)	Flow line (U/S)	Flow line (D/S)	Link Type	No.	Width	Height	Length
			(NAVD)	(NAVD)			(ft)	(ft)	(ft)
Link148	10121_IN	9166.0	59.41	57.30	Box	2	8	6	184
XS 10241	SUB17	SUB15_9750	59.29	59.08	Natural	1	---	---	511
XS 9750	SUB15_9750	9529.0	59.08	57.09	Natural	1	---	---	230
XS 1877	1877	SUB7A_1378	59.04	58.76	Natural	1	---	---	517
XS 1378	SUB7A_1378	879.0	58.76	58.96	Natural	1	---	---	517
5814_BR	SUB19_5814	5778.0	57.83	57.83	Natural	1	---	---	37
5814_BR	SUB19_5814	5778.0	57.83	57.83	Bridge	1	---	---	10
XS 5778	5778	5751.0	57.83	57.09	Natural	1	---	---	28
XS 5615	SUB7B_5615	JCT A	57.83	57.72	Natural	1	---	---	149
DS JCT A	JCT A	5461.0	57.72	57.72	Natural	1	---	---	75
XS 8208	8208	SUB16_8121	57.62	57.44	Natural	1	---	---	104
8121_BR	SUB16_8121	8066.0	57.44	57.44	Natural	1	---	---	57
8121_BR	SUB16_8121	8066.0	57.44	57.44	Bridge	1	---	---	10
Link274	8066	Node434	57.44	57.43	Natural	1	---	---	29
XS 7846	7846	7216	57.44	59.31	Natural	1	---	---	198
XS 8066	Node434	Node435	57.43	57.43	Natural	1	---	---	166
XS 8066	Node434	Node435	57.43	57.43	Bridge	1	---	---	10
7901_BR	7901	7846	57.42	57.44	Natural	1	---	---	57
7901_BR	7901	7846	57.42	57.44	Bridge	1	---	---	10
XS 9529	9529	SUB8_9466	57.09	57.09	Natural	1	---	---	66
XS 9529	9529	SUB8_9466	57.09	57.09	Bridge	1	---	---	10
XS 9466	SUB8_9466	9166	57.09	58.27	Natural	1	---	---	208
XS 6122	6122	SUB19_5814	57.09	57.83	Natural	1	---	---	32
5751_BR	5751	SUB20E_5715	57.09	57.09	Natural	1	---	---	37
5751_BR	5751	SUB20E_5715	57.09	57.09	Bridge	1	---	---	10
XS 5715	SUB20E_5715	SUB7B_5615	57.09	57.83	Natural	1	---	---	104
XS 4808	4808	SUB20D_4337	57.02	57.10	Natural	1	---	---	461
XS 3860	SUB5_3860	SUB20C_3285	55.53	54.70	Natural	1	---	---	563
XS 2776	SUB4C_3285	2267	55.00	54.76	Natural	1	---	---	498
XS 2175	2175	SUB20B_1712	54.82	54.07	Natural	1	---	---	453
XS 3285	SUB20C_3285	SUB4C_3285	54.70	55.00	Natural	1	---	---	498
XS 463	SUB20A_463	339	54.55	54.35	Natural	1	---	---	97
XS 339	339	290	54.40	54.35	Box	5	10	10	95
XS 1712	SUB20B_1712	SUB4B	54.07	53.66	Natural	1	---	---	522
XS 1179	SUB4B	SUB4A	53.66	53.15	Natural	1	---	---	437
XS 733	SUB4A	SUB20A_463	53.15	54.09	Natural	1	---	---	234
XS 1100	1100	Outfall	26.39	27.16	Natural	1	---	---	111
Link261	North Lake	SUB9A+11B	73.57	73.44	Natural	1	---	---	60
XS 10894	10894	SUB1	69.04	68.05	Natural	1	---	---	662
XS 10162	SUB1	10123	68.05	67.96	Natural	1	---	---	61
XS 9920	9920	SUB2_8975	67.74	66.34	Natural	1	---	---	931
XS 8975	SUB2_8975	8735	66.34	66.22	Natural	1	---	---	77
Link247	Point Royale A	Point Royale B	66.18	66.18	Circular	1	3	3	220
XS 8500	8500	SUB3_8270	65.78	65.46	Natural	1	---	---	211
XS 8270	SUB3_8270	8030	65.46	65.45	Natural	1	---	---	68
Link224	Node407	10014	64.72	64.57	Circular	1	2.5	2.5	72
Link130	10014	SUB14	64.57	64.40	Circular	1	3.5	3.5	170
Link220	Node409	D-24	64.20	63.85	Circular	1	2	2	174
Link227	Lake D	Lake C	64.13	64.13	Circular	2	4	4	42

Table 3.2
LID 7 Drainage System Components

XP-STORM Link ID	From Node (U/S)	To Node (D/S)	Flow line (U/S)	Flow line (D/S)	Link Type	No.	Width	Height	Length
			(NAVD)	(NAVD)			(ft)	(ft)	(ft)
Link225	Lake A	Lake B	64.13	64.13	Circular	2	4	4	42
XS 7088	7088	5745	63.92	61.47	Natural	1	---	---	1529
Link124	SUB14	10041	63.90	63.78	Circular	1	4.5	4.5	122
Link90	D-24	SUB11C	63.85	63.77	Circular	1	6	6	188
Link125	10041	10013_IN	63.78	63.65	Circular	1	4.5	4.5	128
Link93	SUB11C	D-26	63.77	63.65	Circular	1	6	6	303
Link94	D-26	D-27	63.65	63.53	Circular	1	6	6	292
Link122	10013_IN	10043	63.65	63.62	Circular	1	4.5	4.5	31
Link123	10043	10044	63.62	63.57	Circular	1	4.5	4.5	54
Link121	10044	10046	63.57	63.39	Circular	1	4.5	4.5	178
Link229	Node401	10130	63.55	63.50	Box	1	8	5	95
Link95	D-27	D-28	63.53	63.50	Circular	1	6	6	79
Link101	Node405	MH-3	63.53	62.84	Circular	1	1.5	1.5	694
Link155	10130	SUB12B+12E	63.50	62.10	Box	1	8	5	316
Link96	D-28	SUB11D	63.50	63.41	Circular	1	6	6	229
Link103	SUB11D	D-30	63.41	63.35	Circular	1	6	6	159
Link120	10046	10045_IN	63.39	63.27	Circular	1	4.5	4.5	124
Link102	D-30	SUB9B	63.35	63.20	Circular	1	6	6	78
Link115	10045_IN	10047	63.27	63.17	Circular	1	4.5	4.5	103
Link116	10047	10048	63.17	62.92	Circular	1	4.5	4.5	254
XS 15113	SUB9A+11B	14607	62.66	60.57	Natural	1	---	---	526
Link117	10048	10050_IN	62.42	61.97	Circular	1	5	5	442
Link157	SUB12B+12E	Node413	62.10	61.97	Box	1	8	5	253
Link118	10050_IN	10052	61.97	61.86	Circular	1	5	5	112

Exhibit 3.1 illustrates the drainage schematic as it relates to the XP-STORM model and **Table 3.1.**

3.1.5 2D Model Parameters

The 2D grid used in XP-STORM was developed from the 2014 FBC LiDAR, which was supplemented with additional survey data to capture more detail in the surface. The cell size of the parent data used 5-foot x 5-foot grids.

The lakes were modeled as inactive areas within the 2D grid to avoid duplicating the storage provided in the lakes. The lakes were modeled as 1D storage nodes using elevation-area curves and were connected to the 2D grid with 1D/2D interface lines and 1D/2D connections. The storm sewer nodes were connected to the 2D grid at ground level, which permitted the water to exit the storm sewer system at inlets and manholes and inundate the surrounding streets. The storm sewer outfalls were directly connected to the channels to transfer flow between the two different types of systems.

The 100-year 2D model used normal depth as the tailwater condition.

3.1.6 Hydrology-Hydraulic Relationship

The exiting drainage system consists of an interconnected series of channels and lakes that are used to convey runoff from the area within the levee when the Brazos River stage is low enough to allow gravity flow through the levee. These channels and lakes serve as storage for the interior runoff when the Brazos River stage prevents gravity flow through the levee. For the hydraulic analysis of the drainage system, the runoff hydrographs from the HEC-HMS models were entered at the appropriate points of the LID 7 XP-STORM.

LID 7 Drainage System Components

XP-STORM Link ID	From Node (U/S)	To Node (D/S)	Flow line (U/S)	Flow line (D/S)	Link Type	No.	Width	Height	Length
			(NAVD)	(NAVD)			(ft)	(ft)	(ft)
Link261	North Lake	SUB9A+11B	73.57	73.44	Natural	1	---	---	60
XS 10894	10894	SUB1	69.04	68.05	Natural	1	---	---	662
XS 10162	SUB1	10123	68.05	67.96	Natural	1	---	---	61
XS 9920	9920	SUB2_8975	67.74	66.34	Natural	1	---	---	931
XS 8975	SUB2_8975	8735	66.34	66.22	Natural	1	---	---	77
Link247	Point Royale A	Point Royale B	66.18	66.18	Circular	1	3	3	220
XS 8500	8500	SUB3_8270	65.78	65.46	Natural	1	---	---	211
XS 8270	SUB3_8270	8030	65.46	65.45	Natural	1	---	---	68
Link224	Node407	10014	64.72	64.57	Circular	1	2.5	2.5	72
Link130	10014	SUB14	64.57	64.40	Circular	1	3.5	3.5	170
Link220	Node409	D-24	64.20	63.85	Circular	1	2	2	174
Link227	Lake D	Lake C	64.13	64.13	Circular	2	4	4	42
Link225	Lake A	Lake B	64.13	64.13	Circular	2	4	4	42
XS 7088	7088	5745	63.92	61.47	Natural	1	---	---	1529
Link124	SUB14	10041	63.90	63.78	Circular	1	4.5	4.5	122
Link90	D-24	SUB11C	63.85	63.77	Circular	1	6	6	188
Link125	10041	10013_IN	63.78	63.65	Circular	1	4.5	4.5	128
Link93	SUB11C	D-26	63.77	63.65	Circular	1	6	6	303
Link94	D-26	D-27	63.65	63.53	Circular	1	6	6	292
Link122	10013_IN	10043	63.65	63.62	Circular	1	4.5	4.5	31
Link123	10043	10044	63.62	63.57	Circular	1	4.5	4.5	54
Link121	10044	10046	63.57	63.39	Circular	1	4.5	4.5	178
Link229	Node401	10130	63.55	63.50	Box	1	8	5	95
Link95	D-27	D-28	63.53	63.50	Circular	1	6	6	79
Link101	Node405	MH-3	63.53	62.84	Circular	1	1.5	1.5	694
Link155	10130	SUB12B+12E	63.50	62.10	Box	1	8	5	316
Link96	D-28	SUB11D	63.50	63.41	Circular	1	6	6	229
Link103	SUB11D	D-30	63.41	63.35	Circular	1	6	6	159
Link120	10046	10045_IN	63.39	63.27	Circular	1	4.5	4.5	124
Link102	D-30	SUB9B	63.35	63.20	Circular	1	6	6	78
Link115	10045_IN	10047	63.27	63.17	Circular	1	4.5	4.5	103
Link116	10047	10048	63.17	62.92	Circular	1	4.5	4.5	254
XS 15113	SUB9A+11B	14607	62.66	60.57	Natural	1	---	---	526
Link117	10048	10050_IN	62.42	61.97	Circular	1	5	5	442
Link157	SUB12B+12E	Node413	62.10	61.97	Box	1	8	5	253
Link118	10050_IN	10052	61.97	61.86	Circular	1	5	5	112
Link253	Node413	10028	61.97	61.88	Box	1	8	5	167
Link156	10028	10035_IN	61.88	61.66	Box	1	10	5	403
Link223	Node410	SUB9A+11B	61.68	61.68	Box	1	10	10	70
Link154	10035_IN	SUB12C_IN	61.66	61.33	Box	1	10	5	656
XS 14113	SUB11A_14113	13636	61.64	61.54	Natural	1	---	---	496
XS 13636	13636	13569	61.54	61.52	Natural	1	---	---	70
XS 13569	13569	SUB9B	61.52	61.21	Natural	1	---	---	278
Link111	SUB12C_IN	10043_IN	61.33	60.92	Box	2	8	5	813
XS 13569.1	SUB9B	13926	61.21	60.89	Natural	1	---	---	287
Link98	MH-3	SUB9B	61.08	61.03	Circular	1	2	2	55
XS 2863	SUB6_2863	2377	60.97	59.48	Natural	1	---	---	503
Link252	10043_IN	10042_IN	60.92	60.77	Box	2	8	5	298
XS 13026	13926	12496	60.89	59.63	Natural	1	---	---	551
Link112	10042_IN	SUB12D_IN	60.77	60.50	Box	2	8	5	419
XS 14607	14607	SUB11A	60.57	61.64	Natural	1	---	---	514
Link281	SUB12D_IN	SUB12D	60.50	60.42	Box	2	10	5	198
Link113	SUB12D	10051_IN	60.42	60.28	Box	2	10	5	375
11032_BR	11032	10991.0	60.30	60.30	Natural	1	---	---	43
11032_BR	11032	10991.0	60.30	60.30	Bridge	1	---	---	10
XS 10991	10991	10964.0	60.30	60.30	Natural	1	---	---	28
10964_BR	10964	10926.0	60.30	60.15	Natural	1	---	---	40
10964_BR	10964	10926.0	60.30	60.15	Bridge	1	---	---	10
XS 10926	10926	10561.0	60.30	60.30	Natural	1	---	---	297
XS 10561	10561	SUB17	60.30	59.29	Natural	1	---	---	333
Link114	10051_IN	10926.0	60.28	60.15	Box	2	10	5	251
Link226	Node397	10129.0	60.28	60.20	Box	1	6	5	151
Link150	SUB18C	10129.0	60.27	60.20	Box	1	11	6	124
Link259	10129	SUB18B	60.19	60.04	Box	2	8	6	188
Link142	SUB18B	10124.0	60.04	59.89	Box	2	8	6	190
XS 12045	12045	SUB13_11594	59.90	59.69	Natural	1	---	---	469
Link143	10124	SUB18D	59.89	59.83	Box	2	8	6	139
Link272	SUB18D	10122.0	59.83	59.77	Box	2	8	6	67
XS 11102	11102	11032.0	59.79	60.30	Natural	1	---	---	73
Link144	10122	10119_IN	59.77	59.70	Box	2	8	6	251
Link145	10119_IN	SUB18A_IN	59.70	59.58	Box	2	8	6	400
XS 11594	SUB13_11594	11102.0	59.69	59.79	Natural	1	---	---	512
XS 12496	12496	12045.0	59.63	59.90	Natural	1	---	---	469
Link146	SUB18A_IN	10115.0	59.58	59.44	Box	2	8	6	259
XS 2377	2377	1877.0	59.48	59.04	Natural	1	---	---	518
Link119	10052	10561.0	59.47	59.23	Circular	1	6	6	118
Link147	10115	10121_IN	59.44	59.41	Box	2	8	6	87
Link148	10121_IN	9166.0	59.41	57.30	Box	2	8	6	184
XS 10241	SUB17	SUB15_9750	59.29	59.08	Natural	1	---	---	511
XS 9750	SUB15_9750	9529.0	59.08	57.09	Natural	1	---	---	230
XS 1877	1877	SUB7A_1378	59.04	58.76	Natural	1	---	---	517
XS 1378	SUB7A_1378	879.0	58.76	58.96	Natural	1	---	---	517
5814_BR	SUB19_5814	5778.0	57.83	57.83	Natural	1	---	---	37
5814_BR	SUB19_5814	5778.0	57.83	57.83	Bridge	1	---	---	10
XS 5778	5778	5751.0	57.83	57.09	Natural	1	---	---	28
XS 5615	SUB7B_5615	JCT A	57.83	57.72	Natural	1	---	---	149
DS JCT A	JCT A	5461.0	57.72	57.72	Natural	1	---	---	75
XS 8208	8208	SUB16_8121	57.62	57.44	Natural	1	---	---	104
8121_BR	SUB16_8121	8066.0	57.44	57.44	Natural	1	---	---	57
8121_BR	SUB16_8121	8066.0	57.44	57.44	Bridge	1	---	---	10
Link274	8066	Node434	57.44	57.43	Natural	1	---	---	29
XS 7846	7846	7216	57.44	59.31	Natural	1	---	---	198
XS 8066	Node434	Node435	57.43	57.43	Natural	1	---	---	166
XS 8066	Node434	Node435	57.43	57.43	Bridge	1	---	---	10
7901_BR	7901	7846	57.42	57.44	Natural	1	---	---	57
7901_BR	7901	7846	57.42	57.44	Bridge	1	---	---	10
XS 9529	9529	SUB8_9466	57.09	57.09	Natural	1	---	---	66
XS 9529	9529	SUB8_9466	57.09	57.09	Bridge	1	---	---	10
XS 9466	SUB8_9466	9166	57.09	58.27	Natural	1	---	---	208
XS 6122	6122	SUB19_5814	57.09	57.83	Natural	1	---	---	32
5751_BR	5751	SUB20E_5715	57.09	57.09	Natural	1	---	---	37
5751_BR	5751	SUB20E_5715	57.09	57.09	Bridge	1	---	---	10
XS 5715	SUB20E_5715	SUB7B_5615	57.09	57.83	Natural	1	---	---	104
XS 4808	4808	SUB20D_4337	57.02	57.10	Natural	1	---	---	461
XS 3860	SUB5_3860	SUB20C_3285	55.53	54.70	Natural	1	---	---	563
XS 2776	SUB4C_3285	2267	55.00	54.76	Natural	1	---	---	498
XS 2175	2175	SUB20B_1712	54.82	54.07	Natural	1	---	---	453
XS 3285	SUB20C_3285	SUB4C_3285	54.70	55.00	Natural	1	---	---	498
XS 463	SUB20A_463	339	54.55	54.35	Natural	1	---	---	97
XS 339	339	290	54.40	54.35	Box	5	10	10	95
XS 1712	SUB20B_1712	SUB4B	54.07	53.66	Natural	1	---	---	522
XS 1179	SUB4B	SUB4A	53.66	53.15	Natural	1	---	---	437
XS 733	SUB4A	SUB20A_463	53.15	54.09	Natural	1	---	---	234
XS 1100	1100	Outfall	26.39	27.16	Natural	1	---	---	111

Exhibit 3.1

FORT BEND COUNTY LEVEE IMPROVEMENT DISTRICT NO. 7 MASTER DRAINAGE PLAN UPDATE

XP-STORM SCHEMATIC

Note:
This exhibit shows pertinent items necessary to illustrate the information described in the text and is not intended to include all physical characteristics of the area.

Data Source:
Aerial Photography 2016 (HGAC)

Date: April 2020

Job No. 2703-1906

LJA Engineering, Inc.

4.0 UPDATED EXISTING CONDITIONS

The current drainage system for the District was designed to accommodate up to 12.5 inches of rain in 24 hours during conditions that allow gravity discharge. The resulting peak flow through the gravity outfall totals 3,700 cfs. During conditions that prohibit gravity discharge from the leveed area, such as high stages on the Brazos River, a pump station conveys runoff from the interior while storing runoff that exceeds the pumping capacity until the capacity is available.

The DCM requires minimum pumping capacity in the District that is based on the number of acres of development being served by the pump station. The minimum pumping rate must convey 1.5 inches of rainfall runoff for every acre of development within the levee, and 1 inch of runoff for every acre of undeveloped area within the levee in a 24 hour period. The District is fully developed, so the minimum pump rate should be able to pump 1.5 inches of runoff depth over 2,049 acres, or 256 acre-feet, in 24 hours. This rate equates to 129.1 cfs, or 57,953 gpm; the District provides 147 cfs, or 66,000 gpm pump capacity.

4.1 Updates to the Original Model

Atlas 14 Rainfall data was released by the NOAA in September 2018. The new precipitation depths increase the one-percent annual exceedance probability within Fort Bend County by approximately 30-percent. This increase results in higher peak flows that need to be conveyed through the District's major drainage facilities. It was, therefore, necessary to determine the magnitude of water surface changes based on the increased precipitation depths, and to determine a cost-effective plan to upgrade the District's facilities to bring the expected water surface elevations back to acceptable levels for development within the District.

To determine the effect of the increased precipitation depth from Atlas 14 rainfall, the original hydrology model was modified by updating the rainfall runoff data used in the storage routing. Modifications to the models include the following new Fort Bend County Drainage District (FBCDD) criteria:

- Atlas 14 rainfall
- Updated percent impervious values
- New rainfall intensity computations (e,b,d values)
- Loss rate methodology
- Freeboard requirements

These changes will allow the District to obtain approval by the City of Sugar Land and Fort Bend County, as well as to maintain certification status of the District levee by FEMA. The updated models will also provide a basis for establishing projects to reduce the District's risk of internal flooding.

After reviewing construction plans and survey data, and performing field visits, the following revisions to the models were made to the XP-STORM as needed:

- Verified and adjusted drainage areas
- Adjusted storm sewer sizes and lengths
- Recalculated peak discharges
- Added the 10- and 25-year storm events
- Applied Atlas 14 rainfall to the drainage areas
- Verified and adjusted lake storage with LiDAR topography and survey

The increased rainfall depths based on the Atlas 14 precipitation, updated runoff criteria, and updates to the original hydraulic model resulted in significantly higher flows and runoff volume within the District drainage system than the previous criteria based on Hydro 35 and TP 40 from the National Weather Service (NWS). The higher flow rates and additional volume result in water surface elevations ranging from 0.3 feet to 1.2 feet higher than those used previously within the District for determining slab elevations for development within the District. The changes in water surface elevations are shown in **Table 4.1,** which compares the original model results with the updated existing conditions. Only the 100-year storm event was compared since it was the only event available in the original Costello models.

Table 4.1
Water Surface Elevation Comparisons
TP-40 vs Atlas 14

XP-STORM Node ID	Description	Gravity (100-Year)			Coincident Pump (8.4-year)		
		TP-40	Atlas 14	Diff	TP-40	Atlas 14	Diff
North Lake		72.64	73.46	0.82	73.00	74.05	1.05
Lake Clayton		72.89	73.24	0.35	72.60	73.09	0.48
Lake Sartartia		72.93	73.46	0.52	72.64	73.46	0.82
Lakewind Lake		72.32	73.09	0.77	72.58	73.77	1.19
Point Royale A		72.48	72.95	0.46	72.54	73.70	1.16
Point Royale B		72.48	72.94	0.46	72.54	73.70	1.16
Lake A		71.64	71.90	0.27	72.56	73.75	1.19
Lake B		71.64	71.90	0.27	72.56	73.75	1.19
Lake C		71.64	71.90	0.27	72.56	73.75	1.19
Lake D		71.64	71.90	0.27	72.56	73.75	1.19
SUB11A	Ellis Creek	71.53	72.38	0.85	72.96	74.04	1.08
SUB9B	Ellis Crk @ Clayton and Sartartia Outfall	71.35	72.25	0.90	72.96	74.03	1.08
SUB 13	Ellis Creek	70.99	71.92	0.93	72.95	74.03	1.08
11102	Ellis Crk U/S Bridges	70.86	71.84	0.99	72.95	74.03	1.08
10926	Ellis Crk @ Lakewind Outfall	70.70	71.68	0.97	72.94	74.02	1.08
10561	Ellis Crk @ Point Royal Outfall	70.62	71.58	0.96	72.94	73.75	0.81
9166	Ellis Crk @ Lake A,B,C,D Outfall	70.36	71.34	0.98	72.94	74.02	1.08
Sub 16	Ellis Crk U/S Bridges	70.24	71.21	0.97	72.94	74.02	1.08
7846	Ellis Crk D/S Bridges	70.17	71.16	0.99	72.94	74.02	1.08
Sub 19	Ellis Crk U/S Bridges	69.81	70.87	1.06	72.95	74.02	1.08
Sub 20E	Ellis Crk D/S Bridges	69.03	69.95	0.92	72.95	74.03	1.08
Jct A	Ellis Crk @ Corridor Confl	68.41	69.39	0.98	72.95	74.03	1.08
Sub 20A	Ellis Creek	68.23	69.15	0.93	72.95	74.03	1.08
339	Ellis Crk U/S Outfall	68.14	68.99	0.86	72.95	74.03	1.08
290	Ellis Crk D/S Outfall	65.16	65.95	0.80	72.95	74.03	1.08

Exhibit 4.1 illustrates the drainage schematic and peak water surface elevations for the updated existing conditions gravity scenario and pumped discharge scenario.

Updated Existing Peak Water Surface Elevations				
Node ID	10-yr	25-yr	100-yr	Coinc.
SUB14	72.33	72.49	75.23	73.97
10041	71.83	72.27	74.92	73.98
10014	72.14	72.43	74.67	73.72
SUB11C_D-19_IN	73.32	74.03	74.62	74.05
D-24	73.31	74.02	74.60	74.04
10013_IN	71.57	72.03	74.59	73.98
10043	71.29	71.97	74.50	73.98
10044	71.00	71.88	74.36	73.98
D-26	72.80	73.55	74.31	74.05
Node401	70.61	72.07	74.11	74.80
D-27	71.99	72.83	74.05	74.04
10046	70.48	71.56	73.90	73.99
D-28	71.33	72.25	73.87	74.04
10045_IN	70.18	71.36	73.58	73.99
SUB11D	70.83	71.79	73.49	74.04
Node409	72.37	72.64	73.48	73.46
Lake Sartartia	71.92	72.59	73.46	73.46
North Lake (SUB10)	70.55	71.47	73.46	74.05
Node407	71.57	72.29	73.41	73.71
10047	70.05	71.19	73.31	73.99
Lake Clayton	72.63	72.82	73.24	73.09
SUB12B+12E	70.56	72.05	73.22	73.76
SUB12C_IN	70.27	71.79	73.22	73.75
10130	70.59	72.07	73.20	73.87
Node405	72.25	72.72	73.18	73.09
10035_IN	70.37	71.88	73.14	73.75
10028	70.43	71.93	73.14	73.76
Node413	70.48	71.98	73.14	73.76
Node410	70.47	71.29	73.11	74.05
Lakewind Lake/SUB12A	70.66	72.08	73.09	73.77
D-30	70.42	71.33	73.03	74.03
Point Royale A	71.25	72.09	72.95	73.70
Point Royale B	71.25	72.09	72.94	73.70
10043_IN	69.93	71.28	72.81	73.82
10048	69.73	70.81	72.73	74.00
10042_IN	69.80	71.08	72.66	73.84
SUB9A+11B	70.21	71.02	72.62	74.04
14607	70.00	70.85	72.48	74.04
SUB12D_IN	69.64	70.83	72.47	73.88
SUB12D	69.58	70.74	72.40	73.91
SUB11A_14113	69.90	70.75	72.38	74.04
13636	69.82	70.68	72.31	74.03
MH-3	69.93	70.76	72.31	73.95
13569	69.81	70.67	72.30	74.03
SUB9B	69.75	70.62	72.25	74.03
10050_IN	69.43	70.46	72.21	74.01
13926	69.65	70.53	72.18	74.03
10051_IN	69.40	70.45	72.08	73.94
12496	69.52	70.42	72.07	74.03
12045	69.44	70.34	71.99	74.03
SUB18C	69.31	70.29	71.93	73.75
SUB13_11594	69.36	70.27	71.92	74.03
Lake A	69.23	70.27	71.90	73.75
Lake B	69.23	70.27	71.90	73.75
Lake C	69.23	70.27	71.90	73.75
Lake D	69.23	70.27	71.90	73.75
Node397	69.25	70.25	71.90	73.75
10129	69.26	70.24	71.89	73.75
SUB18B	69.24	70.22	71.86	73.75
10052	69.21	70.18	71.85	74.02
SUB18D	69.16	70.12	71.85	73.75
11102	69.27	70.19	71.84	74.03
11032	69.26	70.18	71.83	74.03
10124	69.20	70.16	71.80	73.75
10122	69.13	70.08	71.78	73.75
10991	69.21	70.13	71.76	74.03
10964	69.21	70.12	71.75	74.03
10926	69.16	70.07	71.68	74.02
10119_IN	69.06	70.00	71.64	73.75
10561	69.03	69.95	71.58	74.02
SUB18A_IN	68.96	69.90	71.55	73.75
SUB17	68.93	69.87	71.50	74.02
10115	68.84	69.78	71.42	73.75
SUB15_9750	68.76	69.70	71.36	74.02
10121_IN	68.77	69.71	71.35	73.77
9529	68.73	69.67	71.34	74.02
SUB8_9466	68.63	69.57	71.21	74.02
9166	68.58	69.52	71.16	74.02
8686	68.40	69.34	71.00	74.02
8208	68.27	69.22	70.89	74.02
SUB16_8121	68.25	69.20	70.87	74.02
8066	67.97	68.88	70.50	74.03
Node434	67.96	68.88	70.49	74.03
Node435	67.86	68.75	70.32	74.03
7901	67.86	68.75	70.32	74.03
7846	67.58	68.44	69.95	74.03
7216	67.49	68.35	69.87	74.03
6717	67.16	68.05	69.63	74.03
6122	66.88	67.79	69.40	74.03
SUB19_5814	66.87	67.78	69.39	74.03
5751	66.76	67.65	69.24	74.03
5778	66.74	67.64	69.23	74.03
SUB6_2863	66.74	67.62	69.17	74.03
SUB20E_5715	66.70	67.58	69.15	74.03
2377	66.66	67.55	69.12	74.03
1877	66.63	67.53	69.10	74.03
SUB7B_5615	66.63	67.52	69.10	74.03
SUB7A_1378	66.61	67.51	69.09	74.03
879	66.57	67.46	69.05	74.03
376	66.52	67.43	69.01	74.03
154	66.50	67.40	69.00	74.03
JCT A	66.50	67.40	68.99	74.03
5461	66.44	67.35	68.94	74.03
5280	66.25	67.17	68.79	74.03
4808	65.89	66.84	68.50	74.03
SUB20D_4337	65.54	66.52	68.23	74.03
SUB5_3860	65.11	66.13	67.91	74.03
SUB20C_3285	64.66	65.70	67.54	74.03
SUB4C_3285	64.36	65.42	67.28	74.03
2267	63.92	65.01	66.94	74.03
2175	63.85	64.95	66.88	74.03
SUB20B_1712	63.57	64.68	66.65	74.03
SUB4B	63.23	64.37	66.39	74.03
SUB4A	62.87	64.04	66.11	74.03
SUB20A_463	62.68	63.86	65.95	74.03
339	62.53	63.73	65.85	74.03
External Channel				
EXT21_11320	76.42	76.62	76.93	80.00
Node138	75.93	76.08	76.32	80.00
Node139	72.19	72.51	73.17	80.00
10894	71.68	71.98	72.81	80.00
SUB1	71.57	71.93	72.75	80.00
10123	71.54	71.90	72.72	80.00
9920	71.08	71.56	72.50	80.00
SUB2_8975	70.42	71.01	72.00	80.00
8735	70.40	70.98	71.98	80.00
8500	70.28	70.88	71.88	80.00
SUB3_8270	70.23	70.83	71.84	80.00
8030	70.18	70.78	71.79	80.00
EXT22_7553	69.60	70.19	71.21	80.00
7088	68.84	69.39	70.35	80.00
5745	63.41	63.63	64.16	80.00
EXT23&26_JCT	61.06	62.10	63.86	80.00
240	61.07	62.10	63.86	80.02
290	61.06	62.44	63.83	80.02
EXT24&27_4865	60.97	62.00	63.76	80.00
EXT25_3186	58.66	59.68	61.45	80.00
2836	57.71	58.74	60.58	80.00
2537	56.29	57.34	59.21	80.00
2057	51.94	53.01	54.71	80.00
1787	48.00	49.01	50.72	80.00
1527	41.11	41.85	43.09	80.00
1100	35.25	36.26	37.95	80.00
Outfall	33.80	34.67	36.10	80.00

LEGEND

LID 7 LEVEE

XP-STORM NODE

XP-STORM LINK

Exhibit 4.1

FORT BEND COUNTY LEVEE IMPROVEMENT DISTRICT NO. 7 MASTER DRAINAGE PLAN UPDATE

XP-STORM RESULTS UPDATED EXISTING CONDITIONS ATLAS 14 RAINFALL

Note:
This exhibit shows pertinent items necessary to illustrate the information described in the text and is not intended to include all physical characteristics of the area.

Data Source:
Aerial Photography 2016 (HGAC)

Date: April 2020

Job No. 2703-1906

LJA Engineering, Inc.

5.0 PLAN REVISIONS TO ACCOMMODATE ATLAS 14 RAINFALL

This Master Drainage Plan Update is intended to incorporate the Atlas 14 rainfall and to determine the impacts on development within the New Territory leveed area and recommend improvements to mitigate the increases in order to provide a minimum freeboard of 18 inches between the lowest slab elevation and peak water surface elevation during the coincident event. Mitigation for the increased water surface elevations will be provided with additional storage in the drainage system, and additional pumping capacity at the outfall.

Hydrologic analysis of the interior areas is complicated by the potential for interior flooding combined with the uncertainty of stages on the river side of the levee. At one extreme it is possible that there will be complete non-coincidence and interior and exterior stages will not be high or low at the same time. At the other extreme, it is possible that there will be complete coincidence and that high exterior stages are always present when rain falls over the interior area. The likely occurrences are somewhere in between these two extremes and is called the “coincident rainfall” event.

A coincident event is based on several factors:

- Allowable pond elevation
- 24-hour rainfall event
- Pump capacity
- Available storage

The allowable pond elevation is based on the highest water surface elevation within the entire drainage system that still provides the required freeboard for the lowest slab elevation. In the District, elevation 71.5’ was chosen as the design water surface elevation for establishing the coincident rainfall.

Although the design water surface elevation of 71.5 was established for determining the coincident rainfall event for the District as discussed in Section 1.7, this is not the critical water surface elevation for the entire development. Developments in the vicinity of Lake Clayton and Lake Sartartia have higher natural ground elevations according to LiDAR topography. Therefore, the allowable water surface elevations are higher in this area.

Elevation 71.5’ correlates to a flow on the Brazos River at the location of the District outfall. The flow on the Brazos River correlates to an 8.4-year 24-hour rainfall. This is the minimum rainfall event that must be applied to the coincident storm analysis to design the pumping and storage for the District.

While District meets the minimum pumping rate, it does not provide adequate storage to detain the excess runoff volume that is not pumped out during an Atlas 14 8.4-year storm event (8.22-inches in 24 hours). As shown in Table 4.1, the Atlas 14 rainfall for a coincident event resulted in peak water surface elevations that produced freeboard depths less than 18 inches. Rather than achieving the minimum pumping and storage requirement to accommodate the 8.4-year storm event, it is recommended that the 10-year storm event be analyzed to establish the proposed improvements for District. The following sections discuss recommended improvements to reduce the peak water surface elevations so that a minimum freeboard of 18 inches is provided for the lowest finished floor elevations during a 10-year (8.55-inches in 24 hours) coincident storm event.

5.1 Storage Areas

The District has ten storage areas as well as storage in Ellis Creek to maintain acceptable water surface elevations. With the greater runoff volume due to the Atlas 14 rainfall depth increases, there is insufficient volume in the storage areas to contain the 1-percent annual event runoff below the minimum slab elevation in the District. The increased runoff volume from Atlas 14 rainfall caused unacceptable water surface elevations in the storage facilities and channels. Some modifications to the internal levee drainage system were needed in order to lower the Atlas 14 rainfall water surface elevation in the storage areas in the already developed portions of the District to below minimum slab elevations. Since the District is fully developed, expanding the existing storage facilities was not feasible; however, adding storage in undeveloped areas that remain along Ellis Creek were investigated.

Additional storage was obtained by adding a hydraulic connection from Ellis Creek to a proposed dry storage facility adjacent to Ellis Creek. This design will allow additional runoff volume to flow into the facility as water surface elevations in Ellis Creek rise and drain back into Ellis Creek when water surface elevations recede. It was determined through multiple iterations that approximately 115 acre-feet of additional storage capacity was the recommended volume when combined with increased pump capacity. This design was shown to be beneficial at any location, but the most beneficial option from a design standpoint is closer to the downstream reaches in Ellis Creek. An exact location and configuration of this improvement was beyond the scope of this study.

5.2 Pump Capacity

The greatest increases in water surface elevations as a result of Atlas 14 rainfall occurred during the coincident event when drainage relied entirely on pumped discharge. An average increase in the District of over one (1) foot, compared to the original Costello model, resulted during pumping operations when high stages on the Brazos River prevented gravity discharge.

The current pump capacity for the District is 147 cfs, or 66,000 gallons per minute (gpm). Analysis of various pumping and storage combinations resulted in a needed increase of 210,000 gpm, for a total pump capacity of 276,000 gpm total discharge. This added pump capacity, combined with the 115 acre-feet of added storage volume, will reduce the peak internal water surface elevations to acceptable levels and provide at least 18 inches of freeboard for the lowest finished floor elevations in the District during a 10-year storm event (8.55 inches in 24 hours). **Table 5.1** compares the water surface elevations at key locations within the District for the current existing scenario and the proposed improved scenario. All scenarios reflect Atlas 14 rainfall.

Table 5.1
Water Surface Elevations
Current Existing vs Proposed Improvements

XP-STORM Node ID	Description	25yr WSEL			100yr WSEL			Coincident WSEL		
		Exist	Prop	Diff	Exist	Prop	Diff	Exist	Prop	Diff
North Lake		71.47	71.41	-0.06	73.46	73.37	-0.08	74.05	71.43	-2.62
Lake Clayton		72.82	72.82	0.00	73.24	73.24	0.00	73.09	72.63	-0.46
Lake Sartartia		72.59	72.58	-0.01	73.46	73.45	-0.01	73.46	72.25	-1.21
Lakewind Lake		72.08	72.05	-0.02	73.09	73.07	-0.02	73.77	71.47	-2.30

Table 5.1
Water Surface Elevations
Current Existing vs Proposed Improvements

XP-STORM Node ID	Description	25yr WSEL			100yr WSEL			Coincident WSEL		
		Exist	Prop	Diff	Exist	Prop	Diff	Exist	Prop	Diff
Point Royale A		72.09	72.09	0.00	72.95	72.95	0.00	73.70	71.73	-1.96
Point Royale B		72.09	72.09	0.00	72.94	72.95	0.00	73.70	71.73	-1.96
Lake A		70.27	70.19	-0.08	71.90	71.84	-0.07	73.75	71.42	-2.34
Lake B		70.27	70.19	-0.08	71.90	71.84	-0.07	73.75	71.42	-2.34
Lake C		70.27	70.19	-0.08	71.90	71.84	-0.07	73.75	71.42	-2.34
Lake D		70.27	70.19	-0.08	71.90	71.84	-0.07	73.75	71.42	-2.34
SUB11A	Ellis Creek	70.75	70.67	-0.08	72.38	72.28	-0.10	74.04	71.41	-2.63
SUB9B	Ellis Crk @ Clayton and Sartartia Outfall	70.62	70.53	-0.09	72.25	72.15	-0.10	74.03	71.41	-2.63
SUB 13	Ellis Creek	70.27	70.17	-0.10	71.92	71.80	-0.12	74.03	71.40	-2.63
11102	Ellis Crk U/S Bridges	70.19	70.09	-0.11	71.84	71.72	-0.12	74.03	71.40	-2.63
10926	Ellis Crk @ Lakewind Outfall	70.07	69.96	-0.11	71.68	71.55	-0.12	74.02	71.39	-2.63
10561	Ellis Crk @ Point Royal Outfall	69.95	69.84	-0.11	71.58	71.45	-0.13	73.75	71.39	-2.36
9529	Ellis Crk U/S Homeward Way	69.67	69.55	-0.13	71.34	71.20	-0.14	74.02	71.39	-2.64
Sub 8	Ellis Crk D/S Homeward Way	69.57	69.44	-0.13	71.21	71.06	-0.14	74.02	71.39	-2.64
9166	Ellis Crk @ Lake A,B,C,D Outfall	69.52	69.39	-0.13	71.16	71.02	-0.14	74.02	71.38	-2.64
Sub 16	Ellis Crk U/S Bridges	69.20	69.05	-0.15	70.87	70.71	-0.16	74.02	71.38	-2.65
7846	Ellis Crk D/S Bridges	68.44	68.27	-0.17	69.95	69.77	-0.18	74.03	71.36	-2.67
Sub 19	Ellis Crk U/S Bridges	67.78	67.57	-0.21	69.39	69.18	-0.22	74.03	71.36	-2.67
Sub 20E	Ellis Crk D/S Bridges	67.58	67.37	-0.21	69.15	68.93	-0.22	74.03	71.35	-2.68
Jct A	Ellis Crk @ Corridor Confl	67.40	67.18	-0.22	68.99	68.77	-0.23	74.03	71.35	-2.68
Sub 20A	Ellis Creek	63.86	63.57	-0.28	65.95	65.64	-0.31	74.03	71.33	-2.70
339	Ellis Crk U/S Outfall	63.73	63.45	-0.28	65.85	65.54	-0.31	74.03	71.33	-2.70
290	Ellis Crk D/S Outfall	62.44	61.00	-1.44	63.83	63.67	-0.16	80.00	80.00	0.00

Although Lake Clayton and Lake Sartartia were not reduced to 71.50’ or less, natural ground elevations in areas effected by these lakes show a minimum elevation of approximately 74.8’ based on LiDAR topography, indicating that the minimum freeboard requirements are met in these areas.

Exhibit 5.1 illustrates the drainage schematic and peak water surface elevations for the improved conditions gravity scenario and pumped discharge scenario.

Proposed Condition Peak Water Surface Elevations				
Node ID	10-year	25-year	100-year	Coincident
SUB14	72.85	72.54	75.16	71.51
10041	72.25	72.32	74.84	71.50
10014	72.51	72.86	74.61	71.52
SUB11C_D-19_IN	73.19	74.03	74.61	**73.20**
D-24	73.18	74.01	74.60	**73.19**
10013_IN	71.65	71.97	74.50	71.49
10043	71.53	71.91	74.42	71.49
D-26	72.63	73.53	74.29	**72.64**
10044	71.27	71.81	74.27	71.48
Node401	70.64	72.04	74.04	71.47
D-27	71.74	72.79	74.02	71.75
D-28	71.10	72.20	73.82	71.50
10046	70.79	71.49	73.81	71.47
10045_IN	70.56	71.28	73.48	71.46
Node409	72.37	72.64	73.47	**72.37**
Lake Sartartia	72.23	72.58	73.45	**72.25**
SUB11D	70.54	71.72	73.42	71.47
Node407	71.93	72.25	73.39	71.53
North Lake (SUB10)	70.22	71.41	73.37	71.43
Lake Clayton	72.62	72.82	73.24	**72.63**
10130	70.61	72.04	73.24	71.46
10047	70.39	71.10	73.21	71.45
SUB12C_IN	70.22	71.73	73.18	71.44
Node405	72.07	72.72	73.18	**72.56**
SUB12B+12E	70.58	72.02	73.14	71.46
10028	70.43	71.89	73.12	71.45
Node413	70.49	71.95	73.12	71.46
10035_IN	70.35	71.83	73.12	71.45
Lakewind Lake/SUB12A	70.69	72.05	73.07	71.47
Node410	70.13	71.23	73.03	71.43
Point Royale A	71.79	72.09	72.95	71.73
D-30	70.17	71.25	72.95	71.44
Point Royale B	71.79	72.09	72.95	71.73
10043_IN	69.82	71.20	72.74	71.43
10048	70.03	70.72	72.60	71.43
10042_IN	69.67	71.00	72.58	71.42
SUB9A+11B	69.92	70.95	72.54	71.42
14607	69.72	70.77	72.38	71.41
SUB12D_IN	69.47	70.73	72.37	71.41
SUB12D	69.40	70.64	72.30	71.41
SUB11A_14113	69.62	70.67	72.28	71.41
MH-3	69.66	70.68	72.21	71.49
13636	69.54	70.59	72.21	71.41
13569	69.53	70.58	72.20	71.41
SUB9B	69.48	70.53	72.15	71.41
10050_IN	69.47	70.36	72.08	71.42
13926	69.39	70.44	72.07	71.40
10051_IN	69.19	70.35	71.97	71.40
12496	69.26	70.32	71.96	71.40
12045	69.18	70.24	71.88	71.40
10122	69.03	69.99	71.87	71.41
SUB18C	69.28	70.20	71.86	71.42
Lake A	69.30	70.19	71.84	71.42
Lake B	69.30	70.19	71.84	71.42
Lake C	69.30	70.19	71.84	71.42
Lake D	69.30	70.19	71.84	71.42
Node397	69.23	70.17	71.83	71.42
10129	69.23	70.16	71.82	71.42
SUB18D	69.08	70.03	71.81	71.41
SUB13_11594	69.10	70.17	71.80	71.40
SUB18B	69.20	70.13	71.79	71.42
10124	69.13	70.08	71.73	71.41
10052	69.09	70.08	71.72	71.40
11102	69.02	70.09	71.72	71.40
11032	69.01	70.08	71.71	71.40
10991	68.96	70.02	71.63	71.40
10964	68.96	70.02	71.63	71.40
10119_IN	68.94	69.91	71.56	71.41
10926	68.92	69.96	71.55	71.39
SUB18A_IN	68.80	69.80	71.45	71.40
10561	68.78	69.84	71.45	71.39
SUB17	68.69	69.75	71.37	71.39
10115	68.65	69.67	71.31	71.40
10121_IN	68.57	69.60	71.24	71.39
SUB15_9750	68.51	69.58	71.23	71.39
9529	68.48	69.55	71.20	71.39
SUB8_9466	68.39	69.44	71.06	71.39
9166	68.34	69.39	71.02	71.38
8686	68.14	69.20	70.85	71.38
8208	68.00	69.07	70.73	71.38
SUB16_8121	67.99	69.05	70.71	71.38
8066	67.70	68.73	70.33	71.37
Node434	67.70	68.72	70.32	71.37
Node435	67.60	68.59	70.15	71.37
7901	67.59	68.59	70.15	71.37
7846	67.32	68.27	69.77	71.36
7216	67.22	68.18	69.69	71.36
6717	66.87	67.86	69.43	71.36
6122	66.57	67.58	69.19	71.36
SUB19_5814	66.55	67.57	69.18	71.36
5751	66.45	67.44	69.03	71.35
5778	66.43	67.42	69.01	71.35
SUB6_2863	66.43	67.39	68.94	71.35
SUB20E_5715	66.39	67.37	68.93	71.35
2377	66.33	67.32	68.89	71.35
SUB7B_5615	66.31	67.30	68.88	71.35
1877	66.31	67.29	68.87	71.35
SUB7A_1378	66.28	67.27	68.85	71.35
879	66.24	67.24	68.82	71.35
376	66.20	67.20	68.79	71.35
154	66.18	67.18	68.77	71.35
JCT A	66.18	67.18	68.77	71.35
5461	66.12	67.12	68.72	71.35
5280	65.92	66.94	68.56	71.35
4808	65.55	66.59	68.26	71.35
Pond 1	65.54	66.59	68.26	71.35
Pond 2	65.54	66.59	68.26	71.35
SUB20D_4337	65.19	66.26	67.97	71.35
SUB5_3860	64.75	65.87	67.65	71.34
SUB20C_3285	64.29	65.44	67.27	71.34
SUB4C_3285	63.99	65.15	67.00	71.34
2267	63.54	64.73	66.65	71.34
2175	63.47	64.67	66.59	71.34
SUB20B_1712	63.19	64.40	66.36	71.34
SUB4B	62.86	64.09	66.09	71.33
SUB4A	62.49	63.76	65.80	71.33
SUB20A_463	62.30	63.57	65.64	71.33
339	62.15	63.45	65.54	71.33
External Channel				
EXT21_11320	76.42	76.62	76.93	80.00
Node138	75.93	76.08	76.32	80.00
Node139	72.19	72.51	73.17	80.00
10894	71.68	71.98	72.81	80.00
SUB1	71.57	71.93	72.75	80.00
10123	71.54	71.90	72.72	80.00
9920	71.08	71.56	72.50	80.00
SUB2_8975	70.42	71.01	72.00	80.00
8735	70.40	70.98	71.98	80.00
8500	70.28	70.88	71.88	80.00
SUB3_8270	70.23	70.83	71.84	80.00
8030	70.18	70.78	71.79	80.00
EXT22_7553	69.60	70.19	71.21	80.00
7088	68.84	69.39	70.34	80.00
5745	63.41	63.63	64.09	80.00
EXT23&26_JCT	60.80	61.91	63.70	80.00
240	60.80	61.91	63.70	80.06
290	59.80	61.00	63.67	80.09
EXT24&27_4865	60.71	61.81	63.60	80.00
EXT25_3186	58.40	59.49	61.28	80.00
2836	57.44	58.55	60.40	80.00
2537	56.03	57.14	59.03	80.00
2057	51.68	52.81	54.56	80.00
1787	47.71	48.83	50.58	80.00
1527	40.93	41.71	42.97	80.00
1100	34.97	36.09	37.81	80.00
Outfall	33.56	34.53	35.99	80.00

Note:
This exhibit shows pertinent items necessary to illustrate the information described in the text and is not intended to include all physical characteristics of the area.

Data Source:
Aerial Photography 2016 (HGAC)

Exhibit 5.1

FORT BEND COUNTY LEVEE IMPROVEMENT DISTRICT NO. 7 MASTER DRAINAGE PLAN UPDATE

XP-STORM RESULTS PROPOSED CONDITIONS ATLAS 14 RAINFALL

Date: April 2020

Job No. 2703-1906

LJA Engineering, Inc.

6.0 RESULTS AND CONCLUSIONS

In October 2018, NOAA released Volume 11 of the Atlas 14 Point Precipitation Frequency Estimates. The Atlas 14 rainfall depths are significantly higher than those provided in Technical Paper 40 and Hydrometeorological Report 35, which were the basis for the rainfall used in previous analyses in Fort Bend County. LJA, as Engineer for the District was tasked to prepare a drainage analysis of the existing District major drainage system based on the Atlas 14 rainfall to provide the following information:

- Determine updated water surfaces within the existing system for both the coincident and gravity events.
- Identify potential drainage issues within the existing system for both the coincident and gravity events.
- Determine cost efficient alternatives to improve the freeboard within the District system with the higher rainfall rates while maintaining 18-inches of freeboard during the coincident event.

Analysis of the existing system was performed using the new Atlas 14 rainfall in order to determine the effects of the increased runoff volume on the system. Model results produced unacceptable increases in both the gravity discharge scenario and the pumped discharge scenario. For the existing condition, the coincident storm event resulted in the highest water surface elevations within the District's facilities and did not provide 18 inches of freeboard for the lowest finished floors in the District. As a result, improvements to the pump capacity and storage volume were investigated.

In order to maintain an appropriate level of service within the existing development with the Atlas 14 rainfall rates, and to allow future development, the following components are recommended:

- Increasing the level of protection in the coincident storm event to a 10-year storm.
- Constructing an additional 115 acre-feet of storage within the District.
- Constructing an additional 210,000 gpm pump station

When the Brazos River water surface elevations prohibit gravity flow the Fort Bend County Drainage Criteria requires pumping and/or storing the runoff from a local rainfall event, which, when combined with a coincident event on the Brazos River, equals a combined one-percent event. For the District, this event is approximately an 8.4-percent, 24-hour event. When the Brazos River stages are high, the gates will be closed and the existing 66,000 gpm storm water pumping station and the recommended 210,000 gpm pump station will begin operation.

With these pump stations in operation and the additional proposed 115 acre-feet of storage, the coincident event generally results in water surface elevations at or below the maximum allowable pond elevations during a local 10-year storm event when gravity discharge is prohibited. The maximum allowable coincident water surface elevation for the District is 71.5' with the exception of areas around Lake Clayton and Lake Sartartia, where higher natural ground elevations allow Lake Clayton and Lake Sartartia to pond to 72.6 and 72.3 respectively and still provide 18 inches of freeboard for the lowest slab.

While attempts were made to reduce the updated water surface elevations for gravity flow conditions, the evaluation of the gravity event with the proposed storage did not result in a significant reduction in water surfaces in the District's channels and storage facilities during the localized 100-year storm gravity event. This is due to the existing storm sewer system and control structures, which were designed using pre-Atlas 14 drainage criteria, to convey storm water between ponds or from a storage facility to a channel. Recommendations to resolve these potential drainage issues are outside the scope of this study; however, the results of this study have identified some potential drainage issues and can be used to assist the District to plan for future storm sewer improvement projects to resolve these problem areas.

This analysis did not encompass all levee system components. It does not address the capacity of all the street inlets, and underground storm sewers, since a detailed analyses of the minor drainage system is not within the scope of this study. Additionally, the levee connections to natural ground at the northeast and northwest locations within the District were not part of this investigation and should be analyzed to determine proposed improvements to increase the freeboard between the Brazos River water surface elevations and the levee connections points to natural ground. Finally, this study does not address drainage issues that may exist within the District that are outside the levee system.

Drainage of the High Meadow neighborhood, which outfalls directly into the external channel, was not evaluated in this study. However, this study did confirm that adequate storage is provided within the District's channels and storage facilities to serve this area. Future investigation is required to determine what drainage improvements in the High Meadow subdivision are needed. Additional conveyance infrastructure should be provided to improve drainage to Ellis Creek in order to take advantage of the additional storage provided.

The proposed improvements discussed in this report will provide numerous benefits in addition to added flood protection. Levee accreditation by FEMA will continue to be maintained with the higher standards imposed on the internal drainage system. The increased pump capacity will reduce the drain time for the District so that storage capacity is restored more quickly in the event of consecutive events, such as rain bands that occur during hurricanes.

The proposed improvements are based on theoretical design with attention to feasibility but cannot replicate the exact conditions until a location of the proposed storage facility is finalized and the pumping capacity is designed. Therefore, changes to the results, although probably minor, may occur as details of the proposed improvements become available.

For drainage improvements to occur orderly and economically, proper planning is essential. The drainage analysis presented in this report shows that the proposed improvements to the District's facilities is feasible from a hydraulic perspective. The proposed system will maintain water surfaces during the coincident event and improve freeboard to no less than 18-inches if the required storage and pump capacity is provided as determined by this study.