Willowood Subdivision

Drainage Impact Analysis

Galveston County Drainage District Number Two
City of Texas City, Texas

April 2, 2024

BURTON JOHNSON ENGINEERING, INC
WATER RESOURCES ENGINEERING & PLANNING

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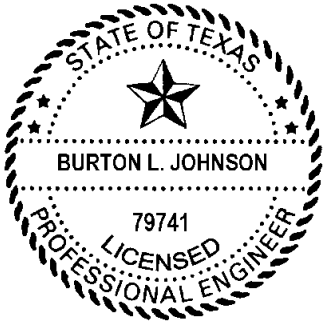

April 2, 2024

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EXHIBITS

ATTACHMENT 1 – Galveston County Drainage District Number Two Map

Note: Survey data and computer models may be downloaded at the following link within 90 days of date of report:

https://www.dropbox.com/s/ovz48f69zd7lch3/Ditch%207%20Models.zip?dl=0

1.0 Introduction

Willowood Subdivision is a proposed 116-acre single-family subdivision located within the City of Texas City and within the boundary of Galveston County Drainage District Number Two (District). This report summarizes and describes a drainage impact analysis for the proposed subdivision. This analysis has been conducted in consideration of the District's *Design Criteria Guidance*. This report considers the ultimate configuration of the proposed development in Section 2.0 and an initial phase of development referred to in this report as Phase One and is described in Section 4.0 (This initial phase consists of approximately 82.5 acres.

1.1 Description of Project Area

The Willowood Subdivision project is located on currently undeveloped properties generally south of the Emmett F. Lowry Expressway (FM 1764) and east of Highway 3. The location of the site is depicted in Exhibit 1. The project is entirely within the District's Ditch 7 system and is between Ditch 7A and Ditch 7B. These two ditches join to create Ditch 7 north of FM 1764. This confluence is approximately one mile downstream of the project. Ditch 7 then extends a short distance into Moses Lake.

Exhibit 2 provides an aerial photograph of the proposed development area. The project area is mostly undeveloped grassed areas with some intermittent wooded areas. The project is bisected by Willow Street (some maps label it as Phillips Street) a City of Texas City roadway that runs north-south through the site. The western portion of the north perimeter of the site is adjacent to the alignment of Ditch 7A, and the southeast perimeter of the site is along Ditch 7B. Small areas of the property are on the opposite (east) side of Ditch 7B. No development activity is proposed for these small tracts. A portion of the property east of Willow Street is bounded on the south by 5th Street. The remainder of the project to the south is bounded by older residential subdivisions, and portions to the north are adjacent to undeveloped property and an oil and gas facility.

There is a gravel farm road through the property. This road is labeled on maps as Roberts Road, as it is an extension of Roberts Road in the adjacent subdivision. This road is private and now owned or maintained by the City of Texas City.

1.2 FEMA Special Flood Hazard Areas

According to FEMA Flood Insurance Rate Map (FIRM) Panel No. 48167C0265G, dated August 15, 2019, the watershed is entirely in the Shaded Zone "X", which represents areas subject to flooding from a 0.2% annual probability event (also known as the 500-year event). A portion of the area is also in the Zone AE floodplain, which represents areas subject to inundation from the 1% annual probability event (also known as the 100-year event) that have computed Base Flood Elevations. Exhibit 3 depicts these Special Flood Hazard Areas.

Based on a review of the FIRM Panel and FEMA's *Flood Insurance Study, Galveston County and Incorporated Areas,* dated August 15, 2019, the inundation depicted on the FIRM is from coastal surge flooding and does not represent riverine flooding from rainfall in the watershed. The coastal elevations are computed along transect lines which are shown on the exhibit. The 100-year coastal surge elevation

is shown as a Base Flood Elevation on the FIRM Panel and is also shown, as elevation 5.0, on Exhibit 2. Transect Line 86 runs through the project area. The 100-year coastal surge elevation is 5.0. Based on a profile presented in the *Flood Insurance Study* and the 500-year coastal surge elevation is between elevation 15.0 and 17.0 within the Ditch 7 watershed.

The information provided on the FIRM panels and within the *Flood Insurance Study* confirms that Ditch 7 and its tributaries Ditch 7A and Ditch 7B are not FEMA studied streams.

1.3 Elevation Data

All source elevation data and all elevations cited in this report are in feet above Mean Sea Level based on the 1988 North American Vertical Datum (NAVD 88). Elevation data for this analysis is a blend of the Upper Coastal Lidar data acquired by a partnership between the Texas Water Development Board, Houston-Galveston Area Council, and United States Geologic Survey in 2018; and survey data acquired by Costello, Inc. (now part of Pape Dawson) in the fall of 2023. The lidar data was utilized for most of the elevation data, including overland areas and portions of the channel cross sections. The survey data was used to augment the lidar data in consideration of the limitations of the lidar data – specifically the capture of specific details and elevations associated with bridge and culvert crossings and the capture of bathymetry in areas where the lidar was unable to penetrate a water surface. For this study, the survey data in the channel was utilized to determine the outfall depth from the detention basins. All other calculations are based upon the lidar data.

Topographic contours utilized in the analysis are shown in Exhibit 4. Natural ground elevations generally range between elevation 10 (at the western perimeter) and elevation 5 near the eastern perimeter near Ditch 7B. There are some filled areas with elevations as high as elevation 14. The fill areas are spoil piles along the banks of Ditch 7A and Ditch 7B. There are also some fill areas related to the connection of the private road with Roberts Road in the adjacent subdivision. The drainage pattern is generally from west to east.

1.4 Galveston County Drainage District Number Two

The District has not completed a study of the Ditch 7 Watershed. A floodplain study of the Ditch watershed, including the computation of water surface elevations and flowrates for Ditch 7, Ditch 7A, and Ditch 7B has been prepared by Burton Johnson Engineering, Inc. under separate cover. This report, entitled *Ditch 7 Watershed (Ditch 7, Ditch 7A, Ditch 7B), Floodplain Mapping and Modeling* is dated April 3, 2024 and establishes 100-year water surface elevations in the vicinity of this project. The findings described in the report are based upon a combined 1d/2d HEC-RAS model using Atlas 14 rainfall.

The study described in this analysis considers the Willowood Subdivision and its supporting detention and floodplain fill mitigation, as described herein, as part of the existing watershed condition. As part of this Willowood Subdivision analysis, a pre-project 100-year floodplain was computed to determine the amount of floodplain fill to be mitigated. The resultant floodplain map is presented in Exhibit 5.

As part of the Ditch 7 analysis, it was recognized that Ditch 7A is not a natural drainage channel. It apparently was constructed to provide drainage to the State Highway 3 and/or other development in the area and does not have a “valley” section common to natural stream. When floodwaters exceed the

channel banks of Ditch 7A, they spill into the site and overflow toward Ditch 7B. The combined 1d/2d provided an opportunity to properly consider this overflow.

1.5 Proposed Project

The proposed project is illustrated in Exhibit 6. The area will be subdivided into residential lots with a minimum size of 6,000 square feet and an average lot size of about 1/6 acre. Four detention basins are proposed. Pond 1 and Pond 2 will outfall into Ditch 7A. Pond 4 will drain under Willow Street to Pond 3, and Pond 3 will outfall into Ditch 7B. The land will be elevated as required to ensure that it is above the 100-year flood elevation of Ditch 7A and Ditch 7B. The detention ponds will provide detention to offset runoff from the development and from the placement of fill in the computed 100-year floodplain.

1.6 Criteria

This analysis was conducted in consideration of the District's *Design Criteria Guidance*. This guidance defers to the Harris County Flood Control District's *Policy Criteria & Procedure Manual (PCPM)* for hydrologic methodologies and detention analyses. In addition, the District requires a minimum detention rate of 0.75 acre-feet per acre of development if using HCFCD Method 1 or 2, although this rate can be lowered to as low as 0.50 acre-feet per acre if a detailed study is performed (HCFCD Method 3). HCFCD recommends Method 2 for projects between 50 acres and 640 acres, therefore Method 2 was utilized in this study. This approach is discussed in greater detail in subsequent sections of this report.

2.0 Hydrology and Detention – Full Development

Hydrographs were developed for each of the subareas in accordance with the methodology described in the Harris County Flood Control District's *PCPM* as described in the following sections.

2.1 Site Runoff Curves and Small Watershed Method

For Detention Method 2, The *PCPM* requires the use of the Harris County Site Runoff Curves to compute peak flowrates for watersheds up to one square mile. In 2019, these curves were updated to consider Atlas 14 rainfall. The curves compute the peak flowrates for the 10-year event and 100-year event based upon the size of the drainage area and the computed impervious cover.

The *PCPM* recommends the utilization of the Small Watershed Method developed by H.R. Malcom to develop runoff hydrographs. Also known as the "Malcolm Method", this approach considers the computed peak flowrate, watershed area, and total runoff volume to develop a hydrograph shape.

Peak flowrates were developed for the pre-project and post-project 10-year and 100-year method using the Site Runoff Curves. The peak flowrate for the 25-year event was developed by interpolation using the relationship between 10-year, 25-year, and 100-year peak flowrates determined as part of the Ditch 7 watershed study. Runoff hydrographs for the post-project condition were developed using the Small Watershed Method. The runoff volume was determined from curves in the *PCPM* for Region 3, which includes the most southern Harris County watersheds.

2.2 Pre-Project Hydrology

There are four proposed detention basins and three outfall points. Ponds 1 and 2 drain to Ditch 7A, while Pond 3 drains to Ditch 7B and Pond 4 drains into Pond 3. For pre-project conditions, the drainage areas were determined for the areas to Ditch 7A (Area 12 recognizing post-project flows to Pond 1 and Pond 2) and Ditch 7B (Area 34 recognizing post-project flows to Pond 3 and Pond 4). These drainage areas and the assumed land use is presented in Exhibit 7. The determination of peak flowrates for the pre-project condition are summarized in Table 1. These peak flowrates establish the allowable post-project flowrate for the developed condition.

Table 1: Pre-Project Peak Flowrates

Drainage Subarea	P12	P34
Area (Ac)	32.6	65.1
Impervious (%)	0.1%	1.3%
Site Runoff Curve: 10-Year		
m	0.786	0.786
b	2.41	2.48
Peak Flowrate (cfs)	37.2	66.1
Interpolate: 25-Year		
Peak Flowrate (cfs)	49.5	87.6
Site Runoff Curve: 100-Year		
m	0.786	0.786
b	4.61	4.72
Peak Flowrate (cfs)	71.3	125.7

2.3 Post-Project Hydrology

Exhibit 6 also depicts the post-project land use assumption and drainage subareas for the development. Drainage subareas were assigned for each of the four detention basins as all developed condition runoff will be directed into one of the four basins. Table 2 summarizes the determination of the Post-Project peak flowrates and runoff volume for the 10-year, 25-year, and 100-year events.

Table 2: Post-Project Peak Flowrates and Runoff Volume

Drainage Subarea	P1	P2	P3	P4
Area (Ac)	26.4	26.3	21.6	38.7
Impervious (%)	49.9%	49.1%	64.7%	43.8%
Site Runoff Curve: 10-Year				
m	0.786	0.786	0.786	0.786
b	5.51	5.48	5.97	5.32
Peak Flowrate (cfs)	72.1	71.6	66.8	94.1
Interpolate: 25-Year				
Peak Flowrate (cfs)	90.2	89.6	83.0	118.0
Site Runoff Curve: 100-Year				
m	0.786	0.786	0.786	0.786
b	9.34	9.31	10.00	9.07
Peak Flowrate (cfs)	122.3	121.6	111.9	160.5
Runoff Volume (inches)				
10-Year	7.86	7.84	8.22	7.71
25-Year	10.92	10.90	11.25	10.79
100-Year	16.58	16.56	16.84	16.47

2.4 Detention Routing

The detention basins were initially sized and evaluated to ensure that the peak allowable flowrates from Table 1 and the minimum detention volumes (based on 0.75 acre-feet per acre) were provided for the 100-year event. These evaluations were performed in HEC-RAS. For Method 2, the *PCPM* requires a constant tailwater elevation at the top of the outfall pipe. As part of the analysis, the size of the basin and the configuration of the outfall structure was manipulated until a satisfactory result was obtained.

2.4.1 Detention Stage vs. Storage

The detention basins will be wet bottom basins with a permanent water surface. In this report, any references to the "bottom" of the basin refers to the permanent pool elevation, as all storage below the permanent pool does not contribute to the attenuation of runoff. The basins will all have 4:1 (h:v) side slopes and 30-foot maintenance berms.

Table 3 provides the stage vs. storage relationship for the four proposed detention basins.

Table 3: Detention Basin Stage vs. Storage

Pond 1		Pond 2		Pond 3		Pond 4	
Stage (elev)	Storage (ac-ft)	Stage (elev)	Storage (ac-ft)	Stage (elev)	Storage (ac-ft)	Stage (elev)	Storage (ac-ft)
2.0	0.0	0.5	0.0	0.5	0.0	0.5	0.0
3.0	3.7	1.0	1.6	1.0	3.8	1.0	1.0
4.0	7.7	2.0	5.0	2.0	11.8	2.0	3.3
5.0	11.8	3.0	8.6	3.0	20.1	3.0	5.8
6.0	16.2	4.0	12.4	4.0	28.7	4.0	8.5
7.0	20.7	5.0	16.4	5.0	37.7	5.0	11.5
8.0	25.5	6.0	20.7	6.0	47.1	6.0	14.8
9.0	30.5	7.0	25.1				
10.0	35.7	8.0	29.8				
		9.0	34.7				

Note that the storage volumes for Ponds 3 and Ponds 4 were increased by 100 acre-feet in the HEC-RAS model to facilitate the Pond 4 outfall pipe, which is below sea level. The resultant output was then decreased by 100 acre-feet.

2.4.2 Detention Basin Control Structures

The control structures of each basin were modified to optimize the performance of the basin and to ensure no downstream impact. The control structure for Pond 1 and Pond 2 will include an orifice restrictor in front of an outfall pipe. This orifice may be constructed over the inlet to the outfall or in a manhole. No restrictor is required for Pond 3 and Pond 4. The outfall structures are described in Table 4 and in Exhibit 8.

Pond 1, Pond 2, and Pond 3 will have earthen overflow weirs to allow ponds to safely drain to the receiving channel if design elevations are exceeded. Willow Street is between Pond 4 and Pond 3 and will act as the overflow into Pond 3. Willow Street overtops at an elevation of 7.18 between Pond 3 and Pond 4. Prior to this overflow, flows will potentially flow south along Willow Steet and adjacent areas. However, this phenomenon exists today behind the existing 42-inch culverts that drain this area, and the additional storage will decrease this relative to current conditions.

2.4.3 Detention Routing Results

The detention routing results are summarized in Table 4. The cumulative peak flow from Pond 1 and 2 was determined by adding the hydrographs for the basin outflow. This combined flow was compared to the pre-project peak flow for Area 12, as the ponds both outfall to Ditch 7A and they are in close proximity to each other. The peak outflow from Pond 3 was compared to the pre-project peak flowrate from Area 34, as Pond 4 drains into Pond 3 and does not have a separate outfall into Ditch 7B.

The detention configuration is shown in Exhibit 8.

Table 4: Detention Basin Routing Results

	Pond 1	Pond 2	Combined 1&2	Pond 3	Pond 4	Combined 3&4
Drainage Area (Ac)	26.4	26.3	52.7	21.6	38.7	60.3
Development Area (Ac)	26.4	26.3	52.7	21.6	36.2	57.8
Elev - Bottom of Storage Pool	2.0	0.5		0.5	0.5	
Elev -Top of Basin	10.0	9.0		5.8	6.0	
Control Structure Orifice Dia (in)	15	21		None	None	
Control Structure Orifice Invert Elev	2.0	0.5		n/a	n/a	
No. Outfall Pipes	1	1		3	2	
Outfall Pipe Diameter (in)	24	30		30	54	
Outfall Pipe Length (ft)	90	90		90	215	
Outfall Location	Ditch 7A	Ditch 7A	Ditch 7A	Ditch 7B	Pond 3	Ditch 7B
Outfall Pipe Elev US (Pond)	2.0	0.5		0.5	-4.0	
Outfall Pipe Elev DS	1.9	0.4		0.4	-4.00	
10-Year Event						
Stage Elevation	5.47	3.92		3.25	3.29	
Storage Volume (ac-ft)	13.9	12.1		22.2	6.6	
Allowable Peak Flowrate (cfs)			37.2			66.1
Proposed Peak Flowrate (cfs)	8.8	15.8	24.5	44.9	57.4	44.9
25-Year Event						
Stage Elevation	6.60	4.96		3.78	3.88	
Storage Volume (ac-ft)	18.9	16.3		26.8	8.2	
Allowable Peak Flowrate (cfs)			49.5			87.6
Proposed Peak Flowrate (cfs)	11.6	20.8	32.2	71.4	77.3	71.4
100-Year Event						
Stage Elevation	8.62	6.82		4.80	5.05	
Storage Volume Required* (Ac-Ft)	19.8	19.7	39.5	16.2	27.2	43.4
Storage Volume (ac-ft)	28.6	24.3	52.9	35.9	11.7	47.6
Allowable Peak Flowrate (cfs)			71.3			125.7
Proposed Peak Flowrate (cfs)	14.8	27.4	42.0	105.2	111.6	105.2

**Based on 0.75 acre-feet per acre*

2.4 Floodplain Fill and Detention Rate

The Ditch 7 model without the project was utilized to determine the 100-year elevations, floodplain fill volumes, and required slab elevations. The portion of the detention storage not required for floodplain fill mitigation was assigned as runoff mitigation, and the resultant detention rate was determined from the cumulative detention volume and development area. This rate was determined separately for areas to Ditch 7A (Pond 1 and 2) and Ditch 7B (Pond 3 and 4). This section summarizes these computations and presents the results.

2.4.1 Minimum Slab Elevations

The City of Texas City Floodplain Ordinance requires the lowest slab elevation to be 18 inches above the Base Flood Elevation as depicted on the Flood Insurance Rate Maps. As noted previously, a portion of the development is within the coastal flood zone and there is not a FEMA Base Flood Elevation representative of riverine flooding. However, it is recommended that new construction it the proposed development have slab elevations 18 inches above the 100-year flood elevation computed as part of the Ditch 7 analysis provided for the District. Exhibit 14 shows the 100-year floodplain and 100-year elevations from the Ditch 7 analysis along with the specification of minimum slab elevations for the proposed development.

2.4.2 Floodplain Fill

Floodplain fill volume was determined for the 100-year flood inundation associated with Ditch 7A and Ditch 7B. This includes the overflow area from Ditch 7A to 7B. This volume was determined from a HEC-RAS analysis of Ditch 7A without flow in Ditch 7B. The resultant inundation and corresponding floodplain fill was assigned to Ditch 7A and the reminder was assigned to Ditch 7B. Table 5 summarizes the floodplain fill and the resultant mitigation. Mitigation is provided by excess capacity (all capacity in addition to the 0.75 acre-feet per acre) in the detention basins below the 100-year flood elevation in the adjacent stream.

For Pond 3, the 100-year elevation of Ditch 7B will exceed the elevation of the pond high banks. During a riverine 100-year event, the pond will be inundated in a fashion similar to today. The adjacent development will be elevated above the 100-year elevation. The top of Pond 4 is also below the 100-year water surface of Ditch 7B. If the basin were to be elevated above the 100-year elevation it would potentially block sheet flow from the neighborhoods to the south. Most of Pond 4 is in areas with natural ground above the elevation of the top of the basin, and the excavation of the portion between the top of the basin (elevation 6.0) and the 100-year flood elevation will provide 8.4 acre-feet of additional floodplain excavation.

Floodplain fill and mitigation volumes were determined separately for Ditch 7A and Ditch 7B by combined calculations for Pond 1 and Pond 2 (Ditch 7A) and Pond 3 and Pond 4 (Ditch 7B). As the table indicates, there is adequate fill mitigation provided by the ponds and the excavation of the area “above” Pond 4 to offset the placement of fill in the floodplain of Ditch 7A and Ditch 7B.

The computed 100-year floodplain and floodplain mitigation table is provided as Exhibit 9.

Table 5: Floodplain Fill Mitigation and Detention Rate

	Pond 1	Pond 2	Combined 1&2	Pond 3	Pond 4	Combined 3&4
Floodplain Fill (Ac-Ft)	0.0	13.4	**13.4**	20.2	4.7	**24.9**
Fill Mitigation Available in Pond (Ac-Ft)	13.6	9.6	23.2	29.0	-12.4	16.7
Additional FP Excavation (Ac-Ft)	0.0	0.0	0.0	0.0	8.4	8.4
Total FP Fill Mitigation Available (Ac-Ft)	13.6	9.6	23.2	29.0	-4.0	25.0
Total FP Fill Mitigation Utilized (Ac-Ft)			**13.4**			**24.9**
Excess FP Fill Mitigation (Ac-Ft)			9.8			0.1
Required Detention (Ac-Ft)	19.8	19.7	39.5	16.2	27.2	43.4
Provided Detention (Ac-Ft)			49.3			43.5
Detention Rate (Ac-Ft/Ac)			**0.94**			**0.75**

The detention volume not required for floodplain mitigation is assigned to traditional stormwater detention in the determination of the total detention volume. This detention volume is then compared to the contributing development area to derive an effective detention rate. The resultant volumes and detention rates for Ponds 1 and 2 (Ditch 7A) and Ponds 3 and 4 (Ditch 7B) are also summarized in Table 5. For Ditch 7A, the project is providing detention at a rate of 0.94 acre-feet per acre; and for Ditch 7B, the project is providing detention at a rate of 0.75 acre-feet per acre.

3.0 Offsite Flow Considerations – Full Development

This section considers the management of offsite flow that the development may impact. These are illustrated in Exhibit 15.

3.1 Swale West of Pond 1 (Area A)

There is an offsite area from the south that drains the west portion of the site toward Ditch 7A. The swale runs up against the location of Pond 1. The development must accommodate these offsite flows. A total of 41.5 acres flows from offsite areas, most developed, through the site. The computed peak 100-year flowrate of the full acreage is 121.5 cfs. The project must accommodate this flow, either through a pipe system through the neighborhood, a perimeter swale system, or both. Exhibit 15 depicts a swale around the perimeter of the site. The specific method of managing offsite flow and the design and computations related to it will be provided with any future construction plans. The calculates for the offsite flow at the nodes depicted on Exhibit 15 are provided in Table 6.

3.2 Swale South and West of Pond 4 (Area B)

Area B consists of a small area at the rear of existing residential lots that currently drain toward the subject property. The total area is 1.7 acres. A perimeter swale will intercept this runoff and convey it to Pond 4.

Table 6: Offsite Flow

Swale	Area (ac)	Impervious	m	B	100 Yr Flowrate (cfs)
A1-A2	14.0	20%	1.000	3.4	47.6
A2-A3	30.0	20%	0.786	6.5	94.2
A3-A4	41.5	20%	0.786	6.5	121.5
B1-B2	1.7	20%	1.000	3.4	5.8

3.3 Area South of Pond 4 (Area C)

Area C consists of approximately 51 acres that drain to the existing swale that fees dual 42-inch pipes that convey flow under Willow Street and all the way to Ditch 7B. A portion of the existing swale is on the subject property. No additional infrastructure is required to accommodate this flow. The construction of the proposed project and Pond 4 will decrease the drainage are to this swale and the culverts considerably and should improve drainage associated with the undersized culverts.

3.4 Area North of Site along Willow Street (Area D)

Willow Street north of and adjacent to the project drains toward the south, and the area west of Willow Street drains to the existing swale behind the dual 42-inch culvert under Willow Street. This drainage pattern will be maintained. As noted in the preceding paragraph, the drainage area to these culverts will be reduced with the proposed project. The design plans will include the sizing of roadside culverts at the subdivision entrance and potentially improvements to the roadside ditch.

4.0 Hydrology and Detention – Phase 1 Development

Phase 1 represents the initial development of the site. The total area of the Phase 1 development is approximately 82.5 acres, and It includes most of the area described as full development. Exhibit 10 shows the Phase 1 concept. The Phase 1 development includes all four detention basins, however Pond 1 and Pond 2 have a smaller configuration. Pond 3 also has a slightly smaller configuration, as it does not include a small portion of a tract along Ditch 7B.

The methodology utilized to analyze Phase 1 is the same as that described for the full project in Section 3.0.

4.1 Pre-Project Hydrology

There are four proposed detention basins and three outfall points. Ponds 1 and 2 drain to Ditch 7A, while Pond 3 drains to Ditch 7B and Pond 4 drains into Pond 3. For pre-project conditions, the drainage areas were determined for the areas to Ditch 7A (Area 12 recognizing post-project flows to Pond 1 and Pond 2) and Ditch 7B (Area 34 recognizing post-project flows to Pond 3 and Pond 4). These drainage areas and the assumed land use is presented in Exhibit 7. The determination of peak flowrates for the pre-project condition are summarized in Table 1. These peak flowrates establish the allowable post-project flowrate for the developed condition.

Table 7: Pre-Project Peak Flowrates

Drainage Subarea	P12	P34
Area (Ac)	18.7	64.6
Impervious (%)	0.0%	1.3%
Site Runoff Curve: 10-Year		
m	0.786	0.786
b	2.40	2.48
Peak Flowrate (cfs)	24.0	65.7
Interpolate: 25-Year		
Peak Flowrate (cfs)	31.9	87.0
Site Runoff Curve: 100-Year		
m	0.786	0.786
b	4.60	4.72
Peak Flowrate (cfs)	45.9	125.0

4.2 Post-Project Hydrology

Exhibit 11 also depicts the post-project land use assumption and drainage subareas for the development. Drainage subareas were assigned for each of the four detention basins as all developed condition runoff will be directed into one of the four basins. Table 2 summarizes the determination of the Post-Project peak flowrates and runoff volume for the 10-year, 25-year, and 100-year events.

Table 8: Post-Project Peak Flowrates and Runoff Volume

Drainage Subarea	P1	P2	P3	P4
Area (Ac)	15.1	12.8	21.0	34.1
Impervious (%)	51.8%	56.0%	63.7%	38.8%
Site Runoff Curve: 10-Year				
m	1.00	1.00	0.79	0.79
b	5.57	5.70	5.94	5.10
Peak Flowrate (cfs)	84.0	72.7	65.0	81.8
Interpolate: 25-Year				
Peak Flowrate (cfs)	104.9	90.7	80.9	102.8
Site Runoff Curve: 100-Year				
m	1.00	1.00	0.79	0.79
b	9.42	9.61	9.95	8.75
Peak Flowrate (cfs)	142.2	122.6	109.0	140.3
Runoff Volume (inches)				
10-Year	7.91	8.01	8.20	7.59
25-Year	10.96	11.06	11.23	10.68
100-Year	16.61	16.68	16.82	16.38

4.3 Detention Routing

The detention basins were initially sized and evaluated to ensure that the peak allowable flowrates from Table 1 and the minimum detention volumes (based on 0.75 acre-feet per acre) were provided for the 100-year event. These evaluations were performed in HEC-RAS. For Method 2, the *PCPM* requires a constant tailwater elevation at the top of the outfall pipe. As part of the analysis, the size of the basin and the configuration of the outfall structure was manipulated until a satisfactory result was obtained.

4.3.1 Detention Stage vs. Storage

The detention basins will be wet bottom basins with a permanent water surface. In this report, any references to the "bottom" of the basin refers to the permanent pool elevation, as all storage below the permanent pool does not contribute to the attenuation of runoff. The basins will all have 4:1 (h:v) side slopes and 30-foot maintenance berms.

Table 3 provides the stage vs. storage relationship for the four proposed detention basins. Note that the storage volumes for Ponds 3 and Ponds 4 were increased by 100 acre-feet in the HEC-RAS model to facilitate the Pond 4 outfall pipe, which is below sea level. The resultant output was then decreased by 100 acre-feet.

Table 9: Detention Basin Stage vs. Storage

Pond 1		Pond 2		Pond 3		Pond 4	
Stage (elev)	Storage (ac-ft)	Stage (elev)	Storage (ac-ft)	Stage (elev)	Storage (ac-ft)	Stage (elev)	Storage (ac-ft)
2.0	0.0	0.5	0.0	0.5	0.0	0.5	0.0
3.0	2.6	1.0	1.5	1.0	3.5	1.0	1.0
4.0	5.3	2.0	4.6	2.0	10.8	2.0	3.3
5.0	8.2	3.0	7.8	3.0	18.5	3.0	5.8
6.0	11.2	4.0	11.2	4.0	26.5	4.0	8.5
7.0	14.4	5.0	14.7	5.0	34.9	5.0	11.5
8.0	17.7	6.0	18.4	6.0	43.7	6.0	14.8
9.0	21.2	7.0	22.2				
10.0	24.8	8.0	26.2				
		9.0	30.4				

4.3.2 Detention Basin Control Structures

The control structures of each basin were modified to optimize the performance of the basin and to ensure no downstream impact. The control structure for Pond 1 and Pond 2 will include an orifice restrictor in front of an outfall pipe. This orifice may be constructed over the inlet to the outfall or in a manhole. No restrictor is required for Pond 3 and Pond 4. The outfall structures are described in Table 4 and in Exhibit 12.

Pond 1, Pond 2, and Pond 3 will have earthen overflow weirs to allow ponds to safely drain to the receiving channel if design elevations are exceeded. Willow Street is between Pond 4 and Pond 3 and will act as the overflow into Pond 3. Willow Street overtops at an elevation of 7.18 between Pond 3 and Pond 4. Prior to this overflow, flows will potentially flow south along Willow Steet and adjacent areas. However, this phenomenon exists today behind the existing 42-inch culverts that drain this area, and the additional storage will decrease this relative to current conditions.

Note that the control structures for the basin are unchanged from the full development scenario described in Section 3.0.

4.3.3 Detention Routing Results

The detention routing results are summarized in Table 4. The cumulative peak flow from Pond 1 and 2 was determined by adding the hydrographs for the basin outflow. This combined flow was compared to the pre-project peak flow for Area 12, as the ponds both outfall to Ditch 7A and they are in close proximity to each other. The peak outflow from Pond 3 was compared to the pre-project peak flowrate from Area 34, as Pond 4 drains into Pond 3 and does not have a separate outfall into Ditch 7B.

The detention configuration is shown in Exhibit 12.

Table 10: Detention Basin Routing Results

	Pond 1	Pond 2	Combined 1&2	Pond 3	Pond 4	Combined 3&4
Drainage Area (Ac)	15.1	12.8	27.8	21.0	34.1	55.1
Development Area (Ac)	15.1	12.7	27.8	20.8	26.8	47.6
Elev - Bottom of Storage Pool	2.0	0.5		0.5	0.5	
Elev -Top of Basin	10.0	9.0		5.8	6.0	
Control Structure Orifice Dia (in)	15	21		None	None	
Control Structure Orifice Invert Elev	2.0	0.5		n/a	n/a	
No. Outfall Pipes	1	1		3	2	
Outfall Pipe Diameter (in)	24	30		30	54	
Outfall Pipe Length (ft)	90	90		90	215	
Outfall Location	Ditch 7A	Ditch 7A	Ditch 7A	Ditch 7B	Pond 3	Ditch 7B
Outfall Pipe Elev US (Pond)	2.0	0.5		0.5	-4.0	
Outfall Pipe Elev DS	1.9	0.4		0.4	-4.00	
10-Year Event						
Stage Elevation	5.09	2.83		3.2	3.24	
Storage Volume (ac-ft)	8.5	2.8		120.1	6.2	
Allowable Peak Flowrate (cfs)			24.0			65.7
Proposed Peak Flowrate (cfs)	7.6	8.3	15.9	42.0	47.6	42.0
25-Year Event						
Stage Elevation	6.07	3.46		3.68	3.77	
Storage Volume (ac-ft)	11.5	9.4		123.9	7.9	
Allowable Peak Flowrate (cfs)			31.9			87.0
Proposed Peak Flowrate (cfs)	10.4	13.1	23.5	67.4	66.1	67.4
100-Year Event						
Stage Elevation	7.85	4.67		4.65	4.85	
Storage Volume Required* (Ac-Ft)	11.3	9.6	20.9	15.6	20.1	43.4
Storage Volume (ac-ft)	17.2	13.5	30.8	32.0	11.1	47.6
Allowable Peak Flowrate (cfs)			45.9			125.7
Proposed Peak Flowrate (cfs)	13.8	19.5	33.2	100.8	97.3	105.2

**Based on 0.75 acre-feet per acre*

4.4 Floodplain Fill and Detention Rate

The Ditch 7 model without the project was utilized to determine the 100-year elevations, floodplain fill volumes, and required slab elevations. The portion of the detention storage not required for floodplain fill mitigation was assigned as runoff mitigation, and the resultant detention rate was determined from the cumulative detention volume and development area. This rate was determined separately for areas to Ditch 7A (Pond 1 and 2) and Ditch 7B (Pond 3 and 4). This section summarizes these computations and presents the results.

4.4.1 Minimum Slab Elevations

See Section 3.4.1. The minimum slab elevations are applicable for the Phase 1 development.

4.4.2 Floodplain Fill

Floodplain fill volume was determined for the 100-year flood inundation associated with Ditch 7A and Ditch 7B. This includes the overflow area from Ditch 7A to 7B. This volume was determined from a HEC-RAS analysis of Ditch 7A without flow in Ditch 7B. The resultant inundation and corresponding floodplain fill was assigned to Ditch 7A and the reminder was assigned to Ditch 7B. Table 5 summarizes the floodplain fill and the resultant mitigation. Mitigation is provided by excess capacity (all capacity in addition to the 0.75 acre-feet per acre) in the detention basins below the 100-year flood elevation in the adjacent stream.

For Pond 3, the 100-year elevation of Ditch 7B will exceed the elevation of the pond high banks. During a riverine 100-year event, the pond will be inundated in a fashion like today. The adjacent development will be elevated above the 100-year elevation. The top of Pond 4 is also below the 100-year water surface of Ditch 7B. If the basin were to be elevated above the 100-year elevation it would potentially block sheet flow from the neighborhoods to the south. Most of Pond 4 is in areas with natural ground above the elevation of the top of the basin, and the excavation of the portion between the top of the basin (elevation 6.0) and the 100-year flood elevation will provide 8.4 acre-feet of additional floodplain excavation.

Floodplain fill and mitigation volumes were determined separately for Ditch 7A and Ditch 7B by combined calculations for Pond 1 and Pond 2 (Ditch 7A) and Pond 3 and Pond 4 (Ditch 7B). As the table indicates, there is adequate fill mitigation provided by the ponds and the excavation of the area "above" Pond 4 to offset the placement of fill in the floodplain of Ditch 7A and Ditch 7B.

The computed 100-year floodplain and floodplain mitigation table is provided as Exhibit 13.

Table 11: Floodplain Fill Mitigation and Detention Rate

	Pond 1	Pond 2	Combined 1&2	Pond 3	Pond 4	Combined 3&4
Floodplain Fill (Ac-Ft)	0.0	12.7	**12.7**	20.2	1.1	**21.3**
Fill Mitigation Available in Pond (Ac-Ft)	11.9	20.3	32.1	29.7	-5.3	24.4
Additional FP Excavation (Ac-Ft)	0.0	0.0	0.0	0.0	8.4	8.4
Total FP Fill Mitigation Available (Ac-Ft)	11.9	20.3	32.1	29.7	3.1	32.7
Total FP Fill Mitigation Utilized (Ac-Ft)			**12.7**			**21.3**
Excess FP Fill Mitigation (Ac-Ft)			19.5			11.4
Required Detention (Ac-Ft)	11.3	9.6	20.9	15.6	20.1	35.7
Provided Detention (Ac-Ft)			40.3			47.1
Detention Rate (Ac-Ft/Ac)			**1.45**			**0.99**

The detention volume not required for floodplain mitigation is assigned to traditional stormwater detention in the determination of the total detention volume. This detention volume is then compared to the contributing development area to derive an effective detention rate. The resultant volumes and detention rates for Ponds 1 and 2 (Ditch 7A) and Ponds 3 and 4 (Ditch 7B) are also summarized in Table 5. For Ditch 7A, the project is providing detention at a rate of 1.45 acre-feet per acre; and for Ditch 7B, the project is providing detention at a rate of 0.99 acre-feet per acre.

5.0 Results

Based on the analysis presented herein, the proposed development, including the full development scenario and the Phase 1 scenario, can be constructed as described without adversely impacting drainage and flood risk upstream, adjacent to, and downstream of the project.

For the full development, the project provides 0.94 acre-feet of detention per acre of development in two detention basins for the portion of the project draining to Ditch 7A; and provides 0.75 acre-feet of detention per acre of development in two detention basins for the portion of the project drainage to Ditch 7B. The detention basins also have additional capacity to adequately mitigate the placement of fill in the computed 100-year floodplain of Ditch 7A and Ditch 7B.

For the Phase 1 development, the project provides 1.45 acre-feet of detention per acre of development in two detention basins for the portion of the project draining to Ditch 7A; and provides 0.99 acre-feet of detention per acre of development in two detention basins for the portion of the project drainage to Ditch 7B. The detention basins also have additional capacity to adequately mitigate the placement of fill in the computed 100-year floodplain of Ditch 7A and Ditch 7B.

As a result of the analysis I hereby certify the project will have no adverse impact to flood risk along Ditch 7, Ditch 7A, Ditch 7B and other drainage infrastructure in adjacent areas.

Exhibits

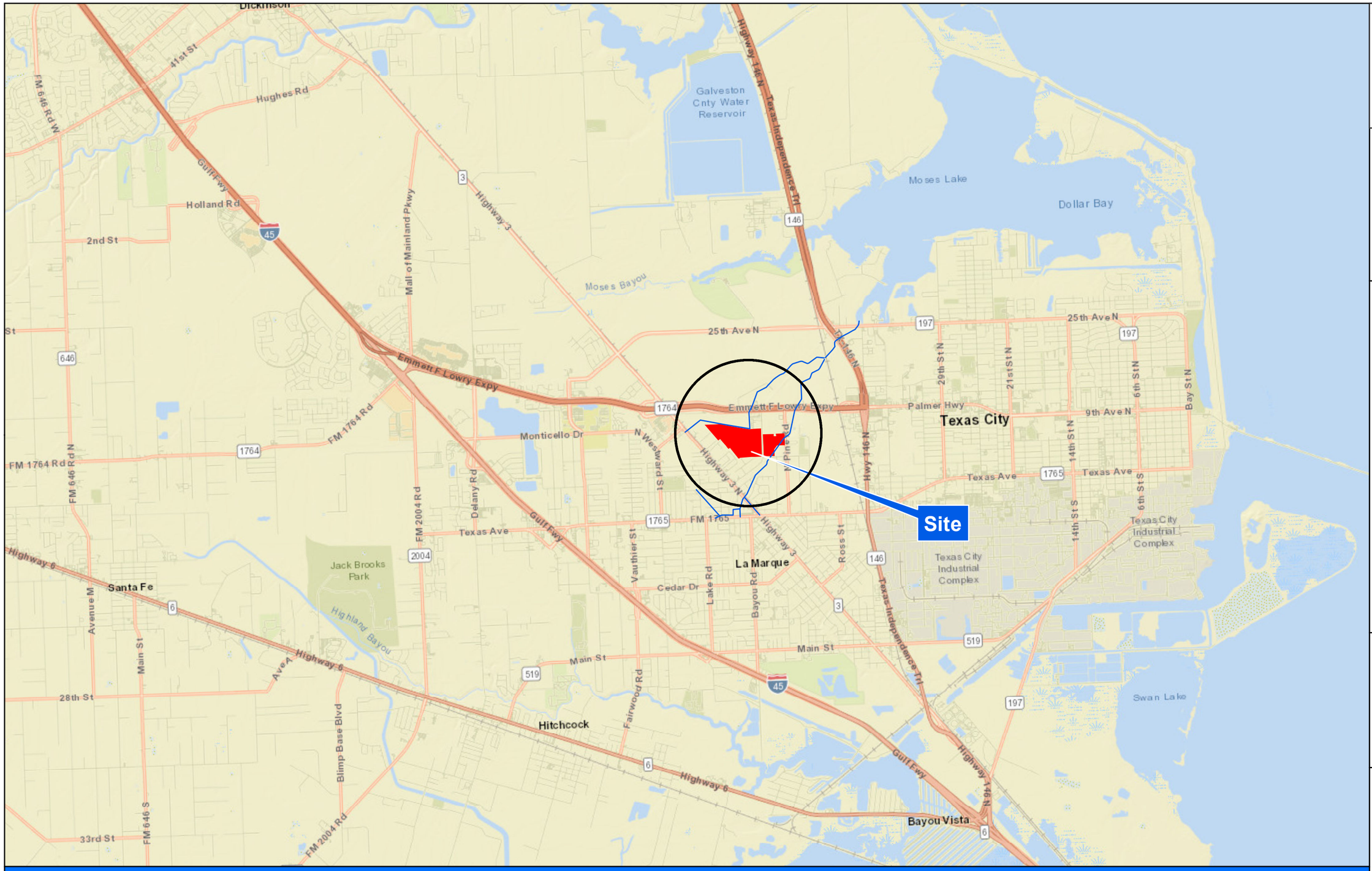
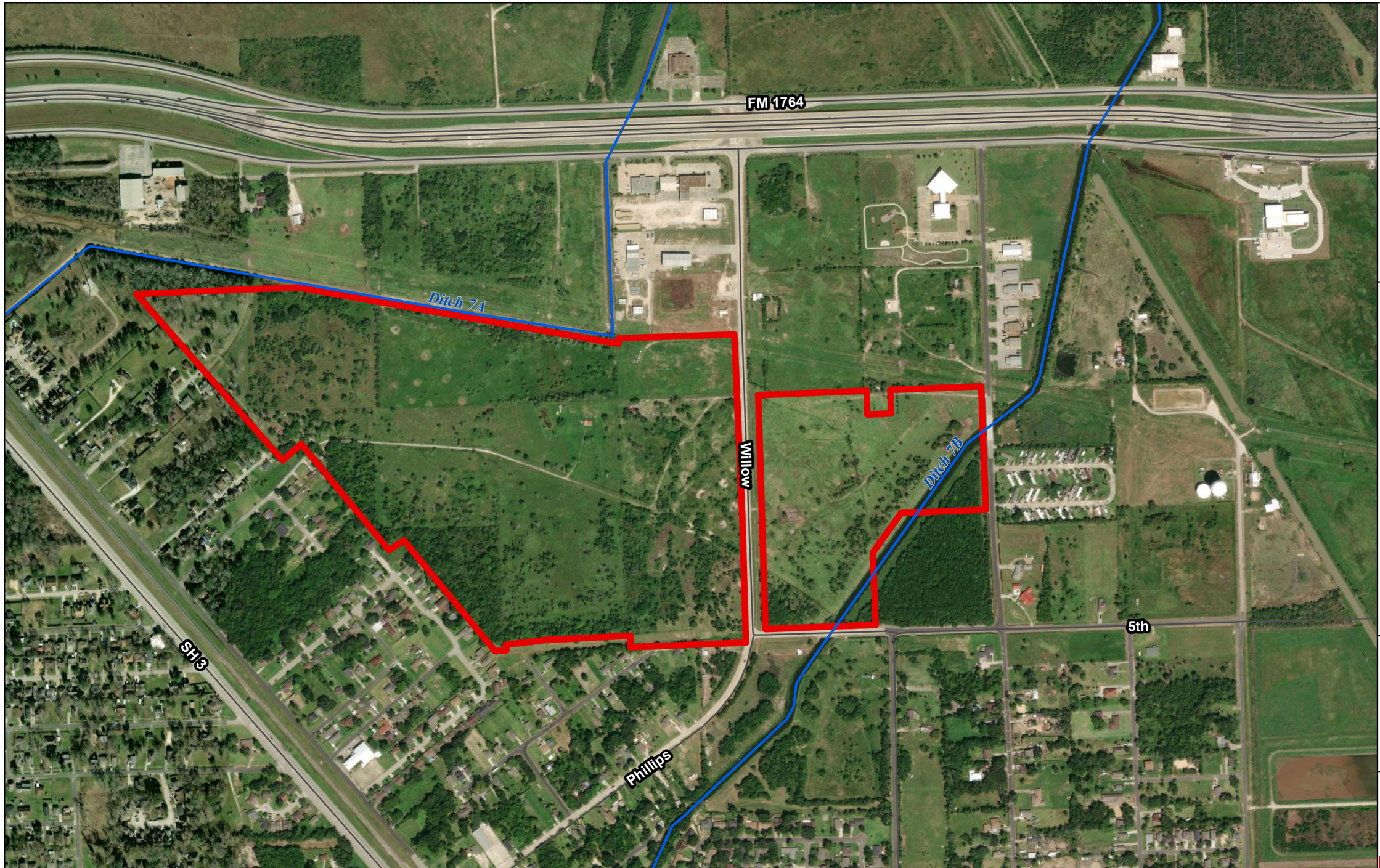


Exhibit 1 - Location Map

WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

Site



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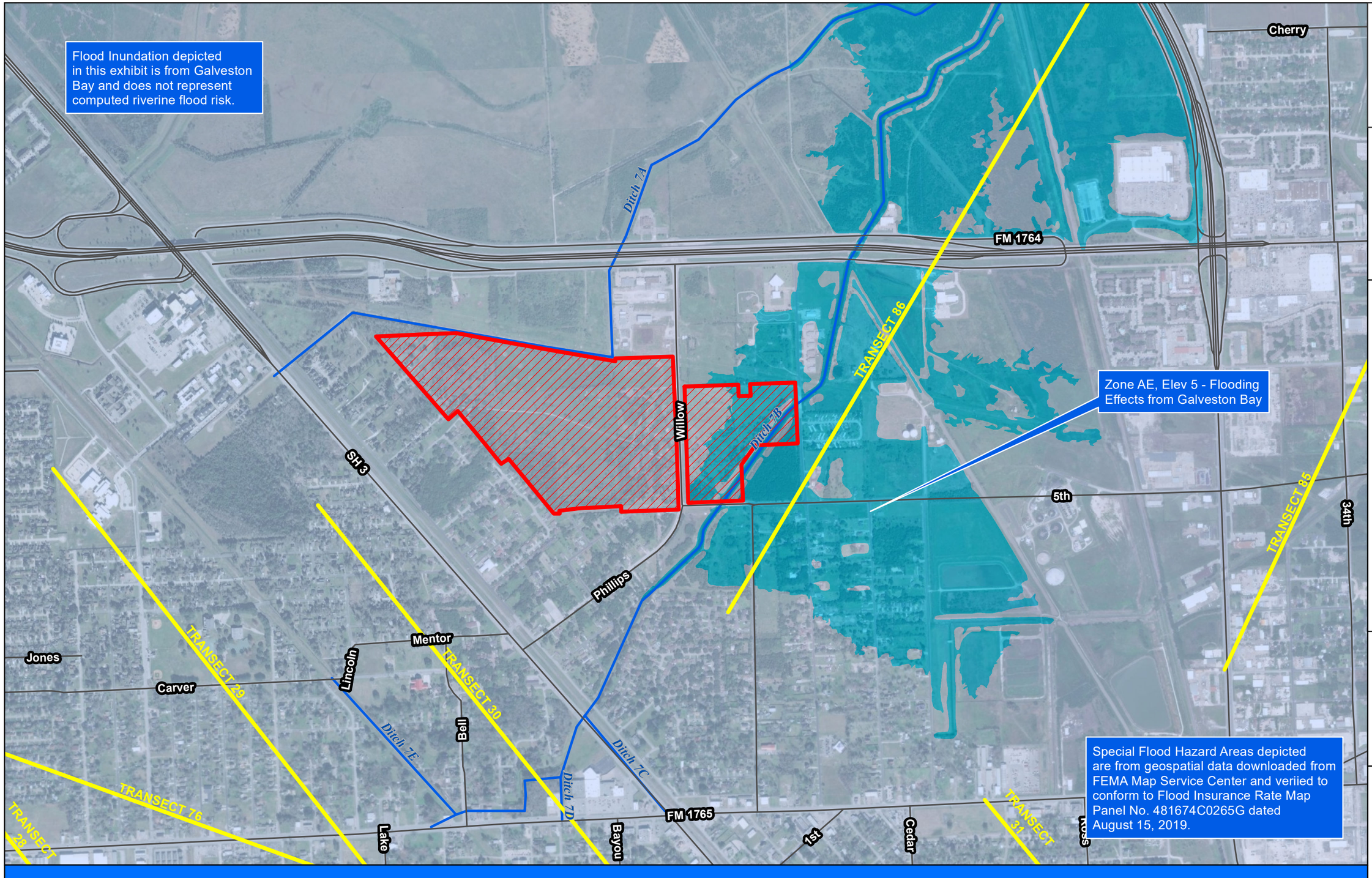
0 250 500 Feet

WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

Roads
Ditch 7 Channels
Willowood Subdivision

Exhibit 2 - Aerial Photo



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WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

- Transect Line
- Site
- Roads
- Ditch 7 Channels
- Zone AE (1%)
- Shaded Zone X (0.2%)

Exhibit 3 - FEMA Speical Flood Hazard Areas

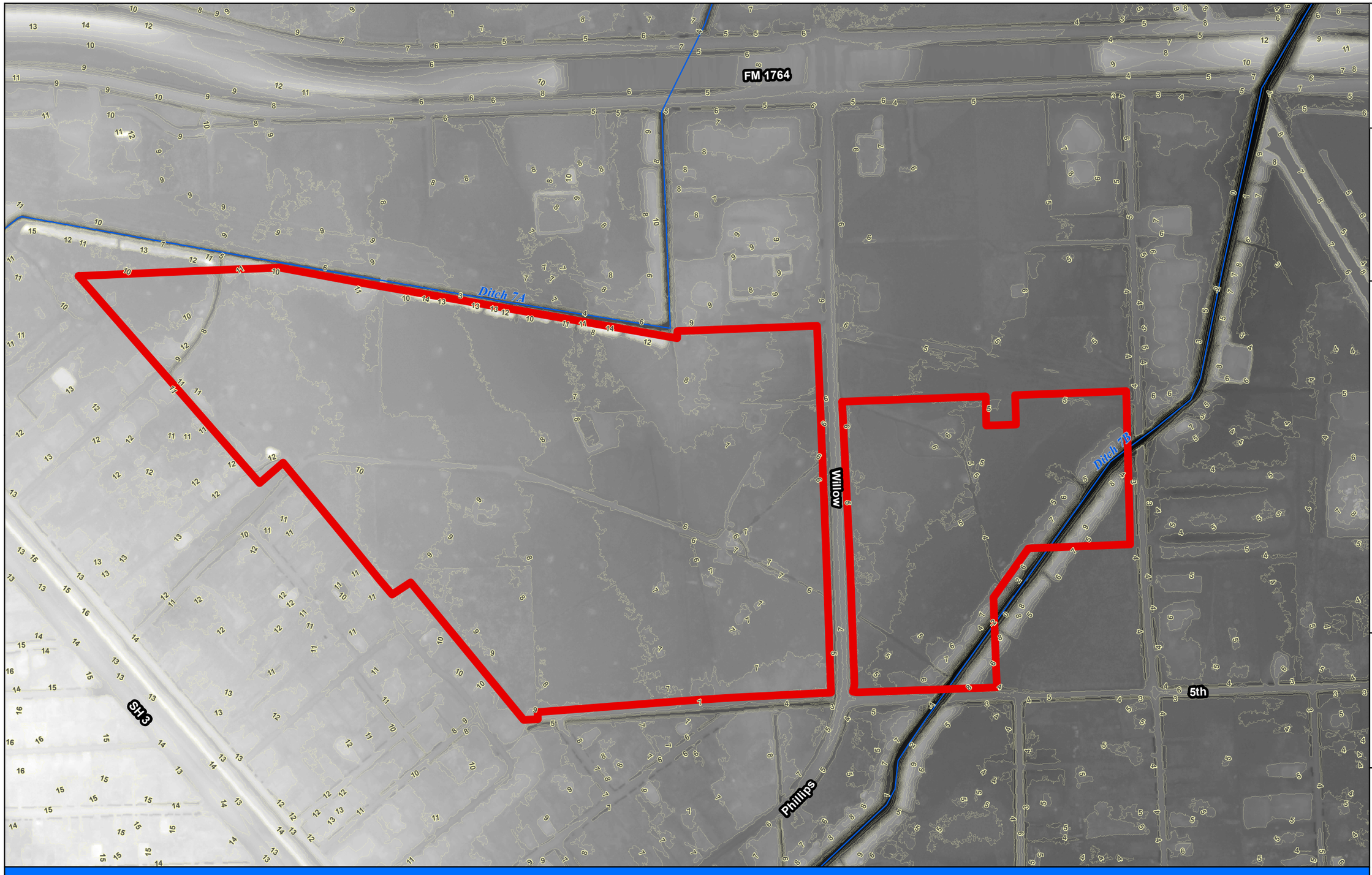

Exhibit 4 - Topography and Digital Elevation Model

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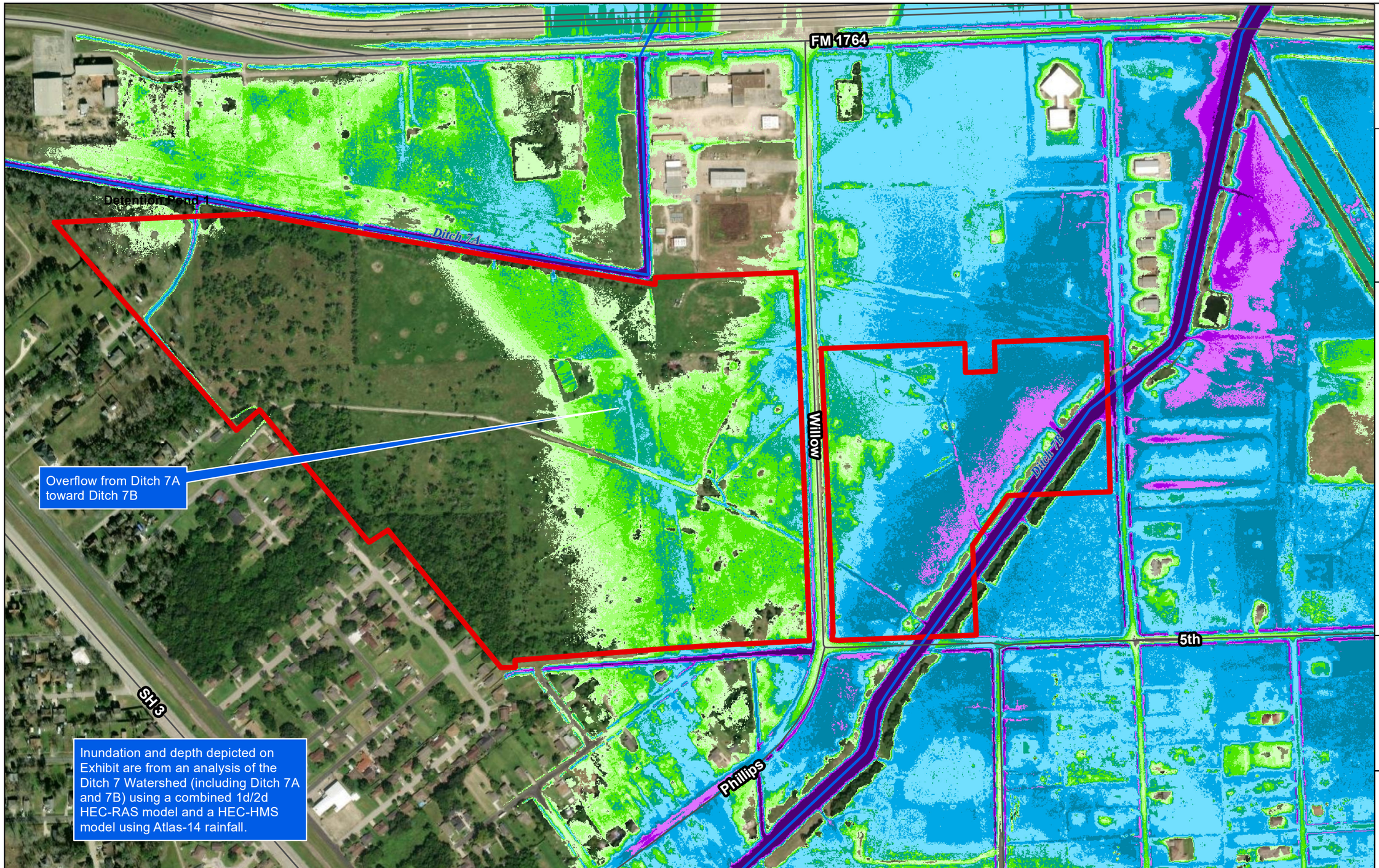
WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

Site
Study Channels
Elevation Contour
Roads

DEM Elevation
High : 40'
Low : -10'



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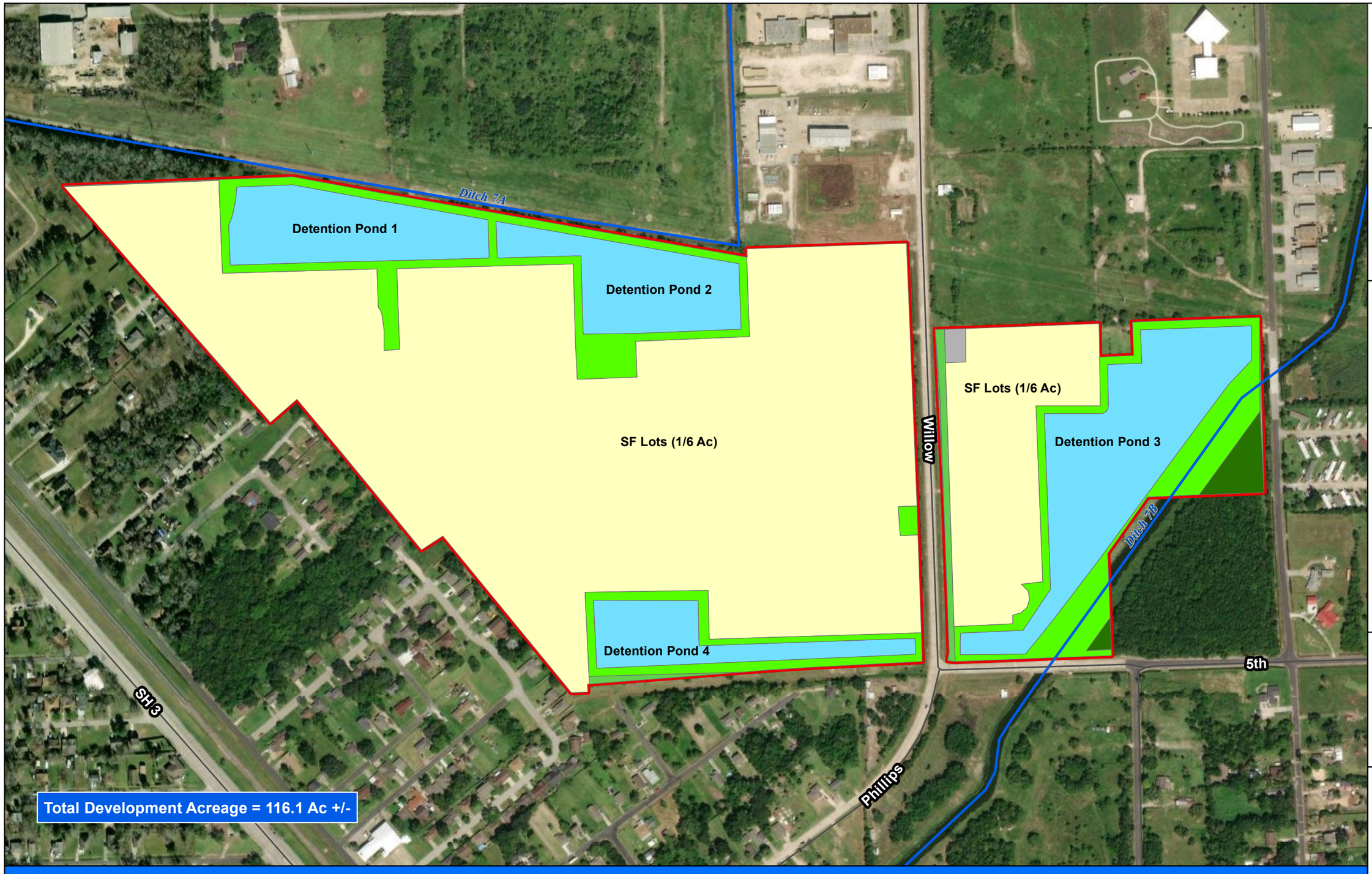
WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

100-Yr Inundation Depth

- 0.0' - 0.25'
- 0.25' - 0.5'
- 0.5' - 0.75'
- 0.75' - 1.0'
- 1.0' - 1.5'
- 1.5' - 2.0'
- 2.0' - 2.5'
- 2.5' - 3.0'
- 3.0' - 4.0'
- >4.0'

Exhibit 5 - Computed 100-Yr Inundation



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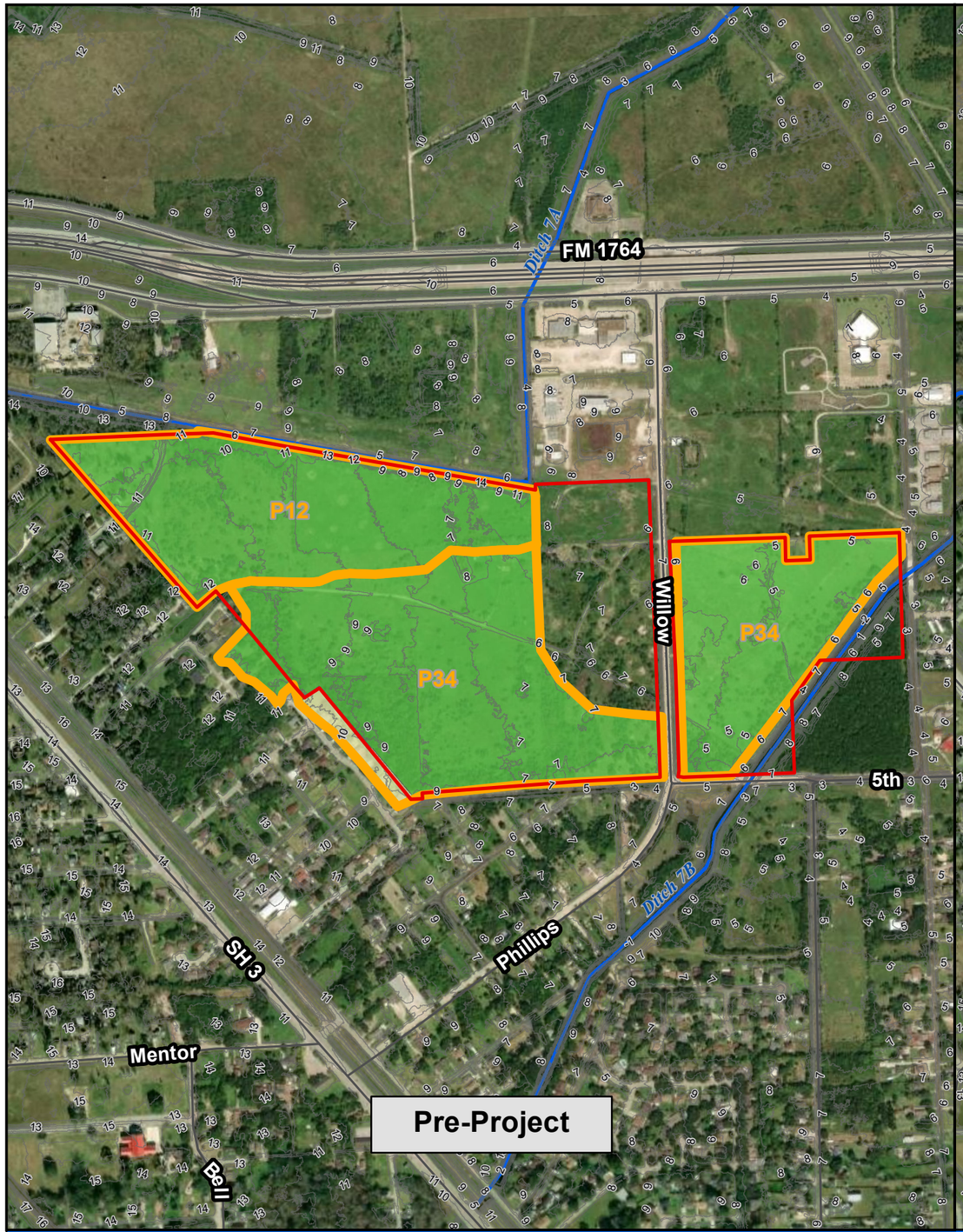
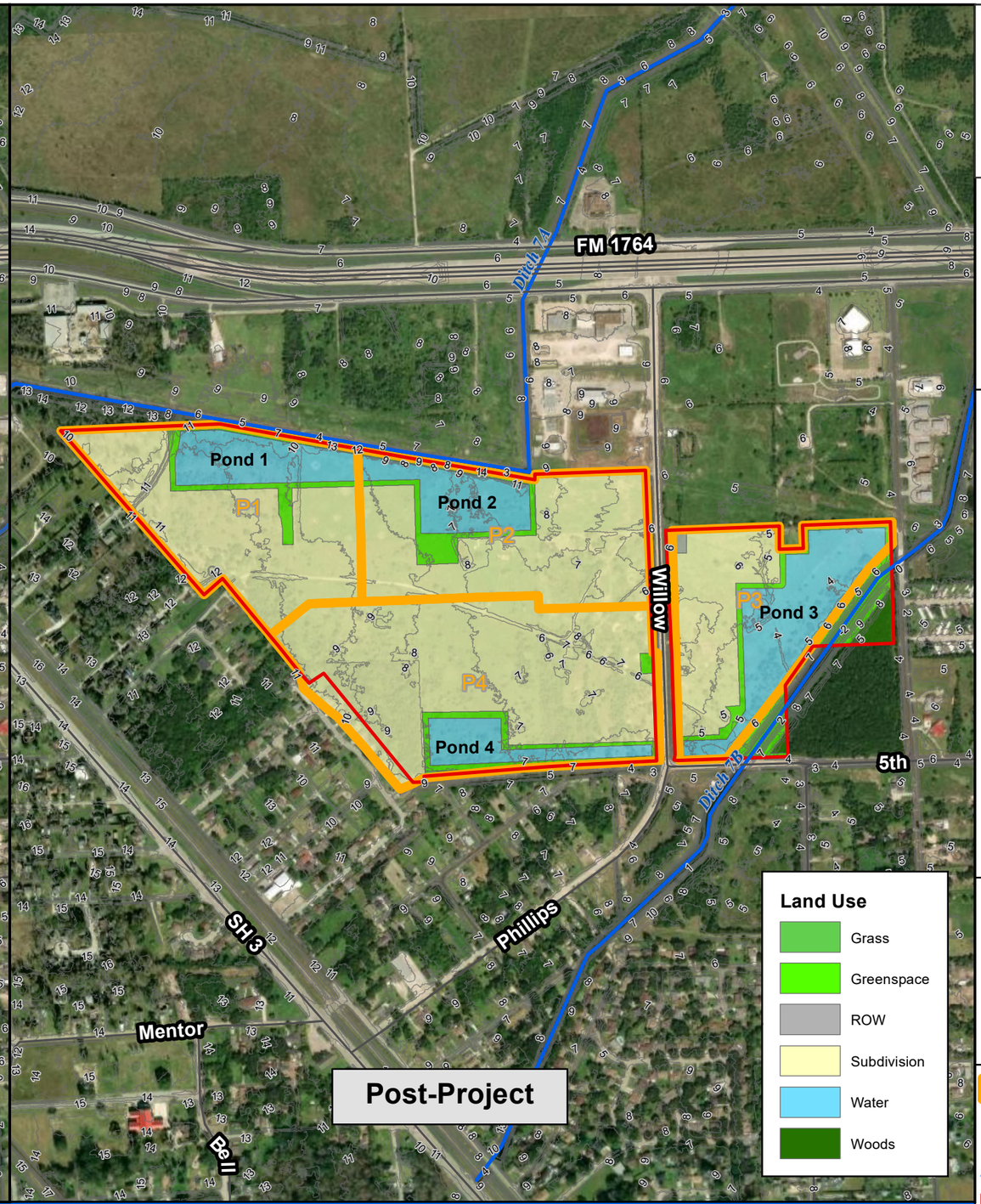
WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

Land Use
- Grass
- Greenspace
- ROW
- Subdivision
- Water
- Woods

Exhibit 6 - Proposed Development





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WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

- Drainage Subarea
- Elev Contour
- Road
- Channels
- Site

Exhibit 7 - Drainage Subarea Map

Exhibit 8 - Proposed Detention

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0 200 400 Feet

WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

- Detention Outfall
- Detention Contour
- Site

Land Use

- Grass
- Greenspace
- ROW
- Subdivision
- Water
- Woods

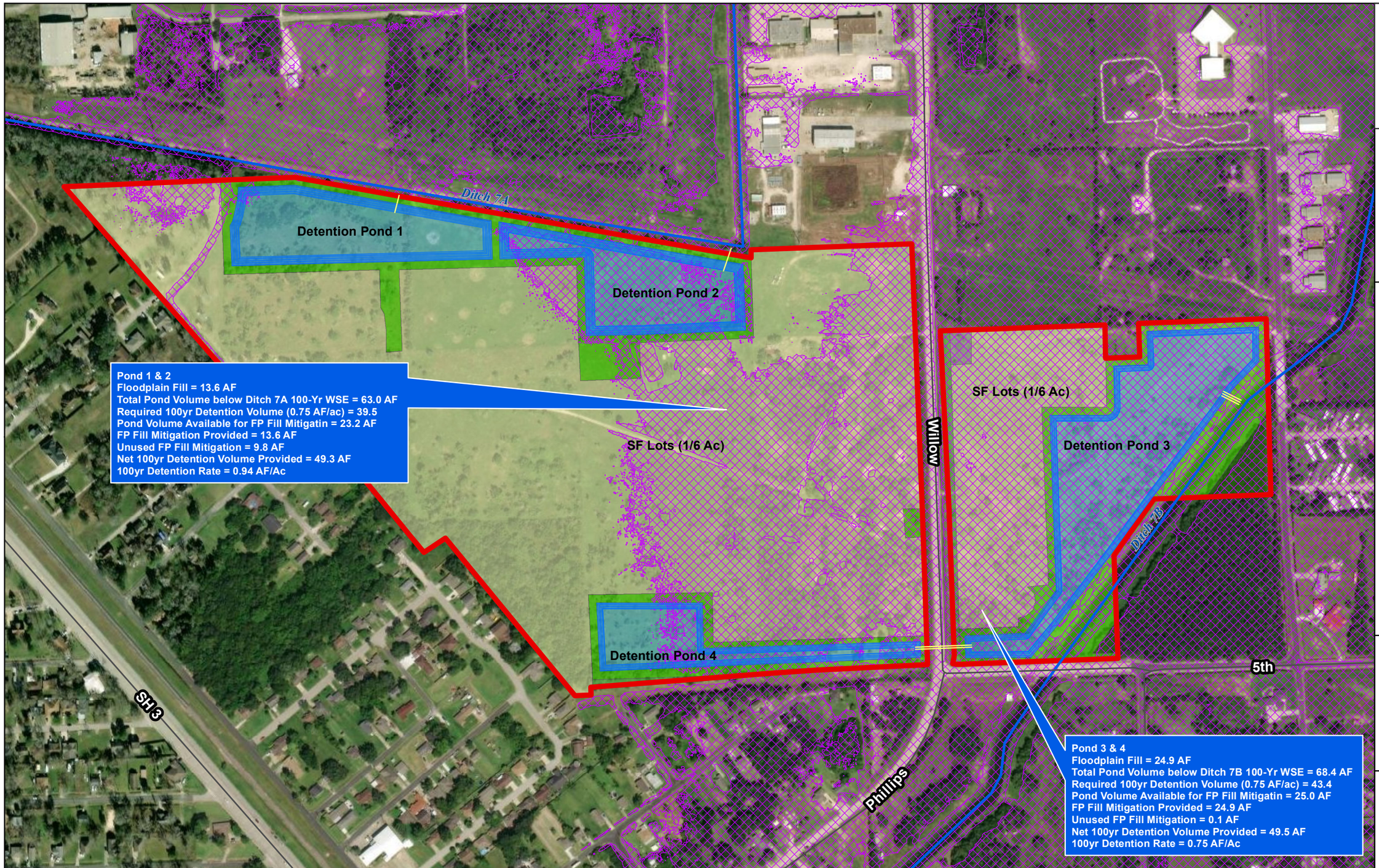

Exhibit 9 - FP Fill Mitigation & Detention Rate

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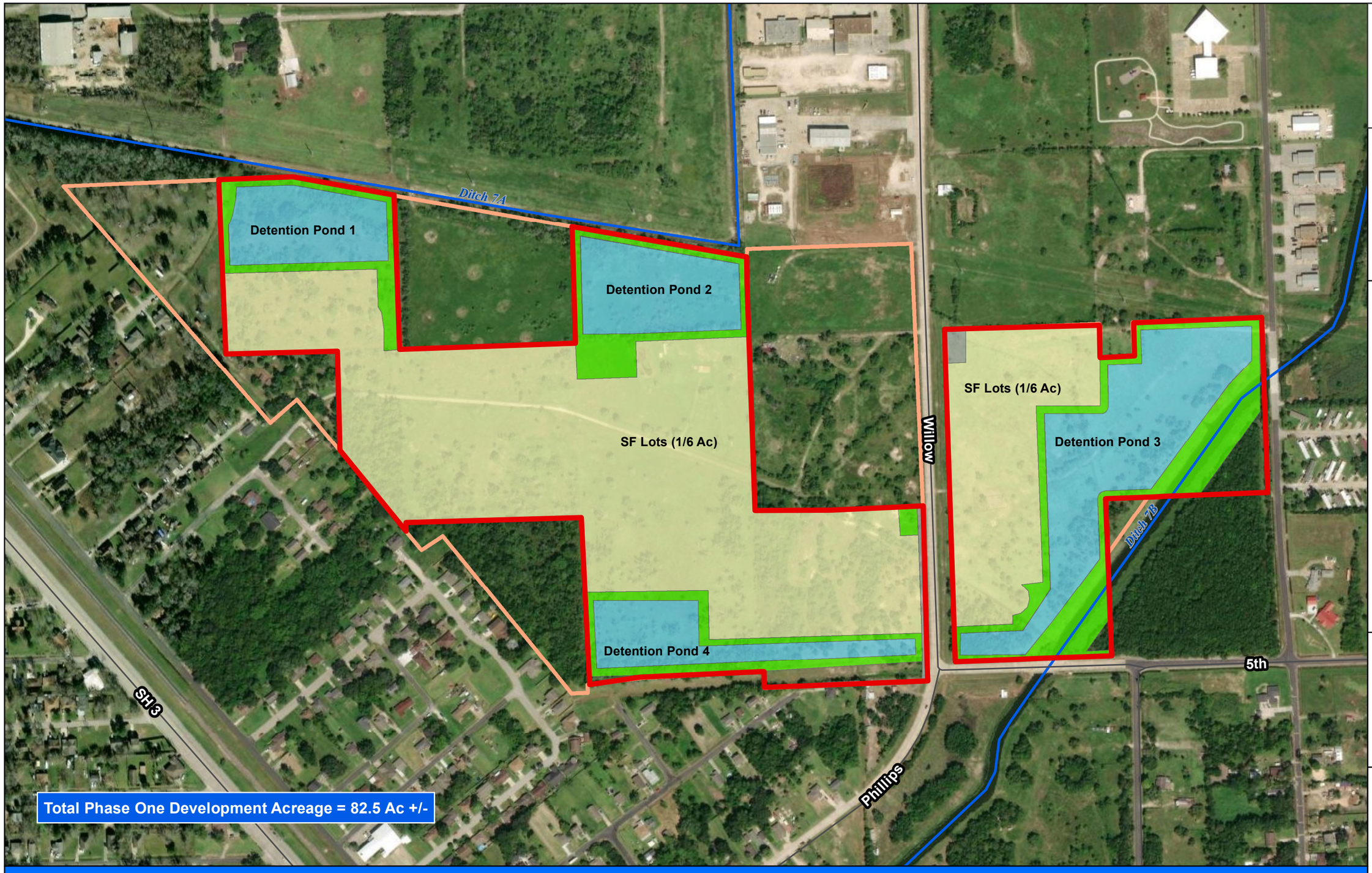
WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX Galveston County DD No. 2

Drainage Impact Analysis

- Detention Outfall
- Detention Contour
- Site
- Computed 100-Yr FP

Land Use

- Grass
- Greenspace
- ROW
- Subdivision
- Water
- Woods



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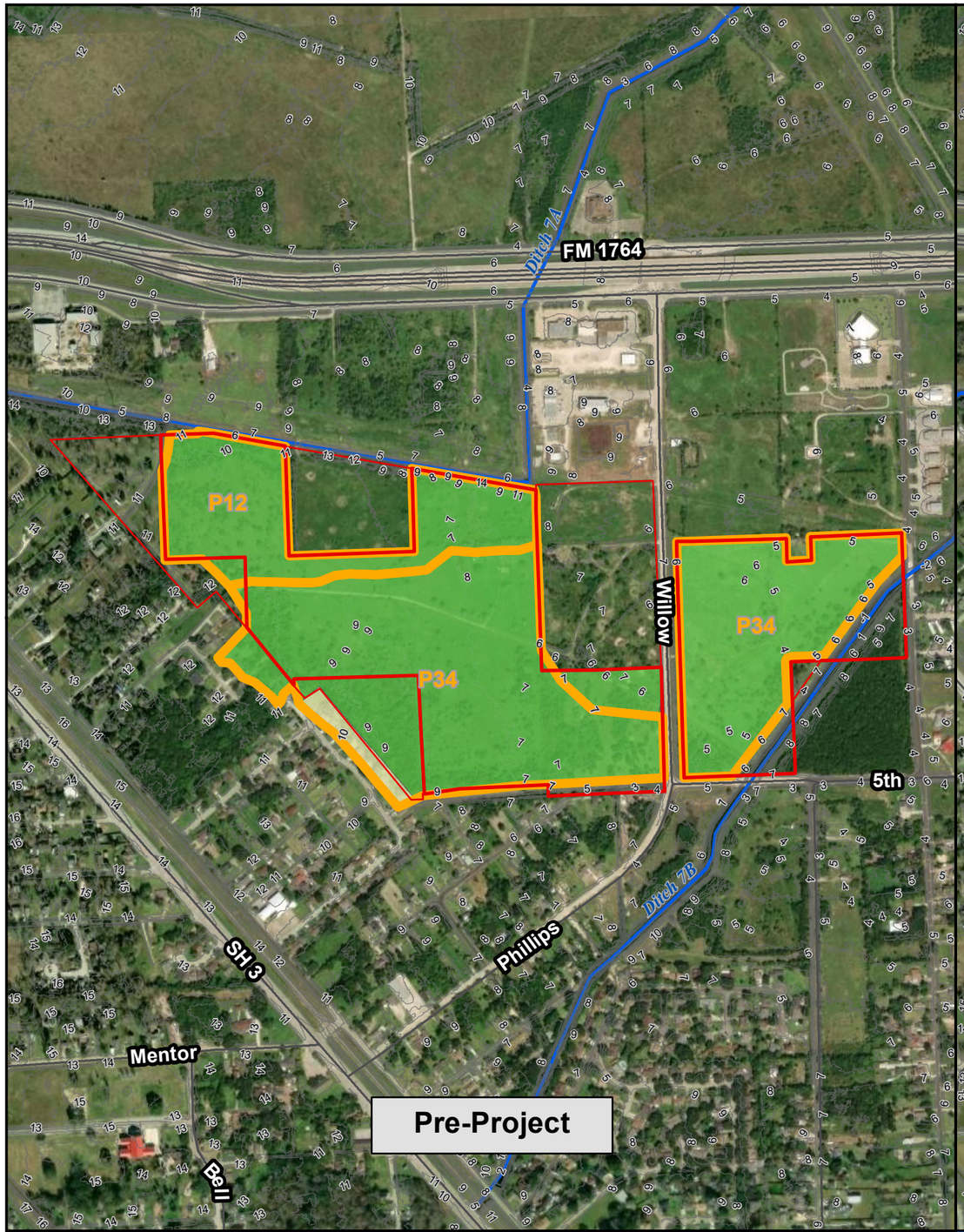
WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

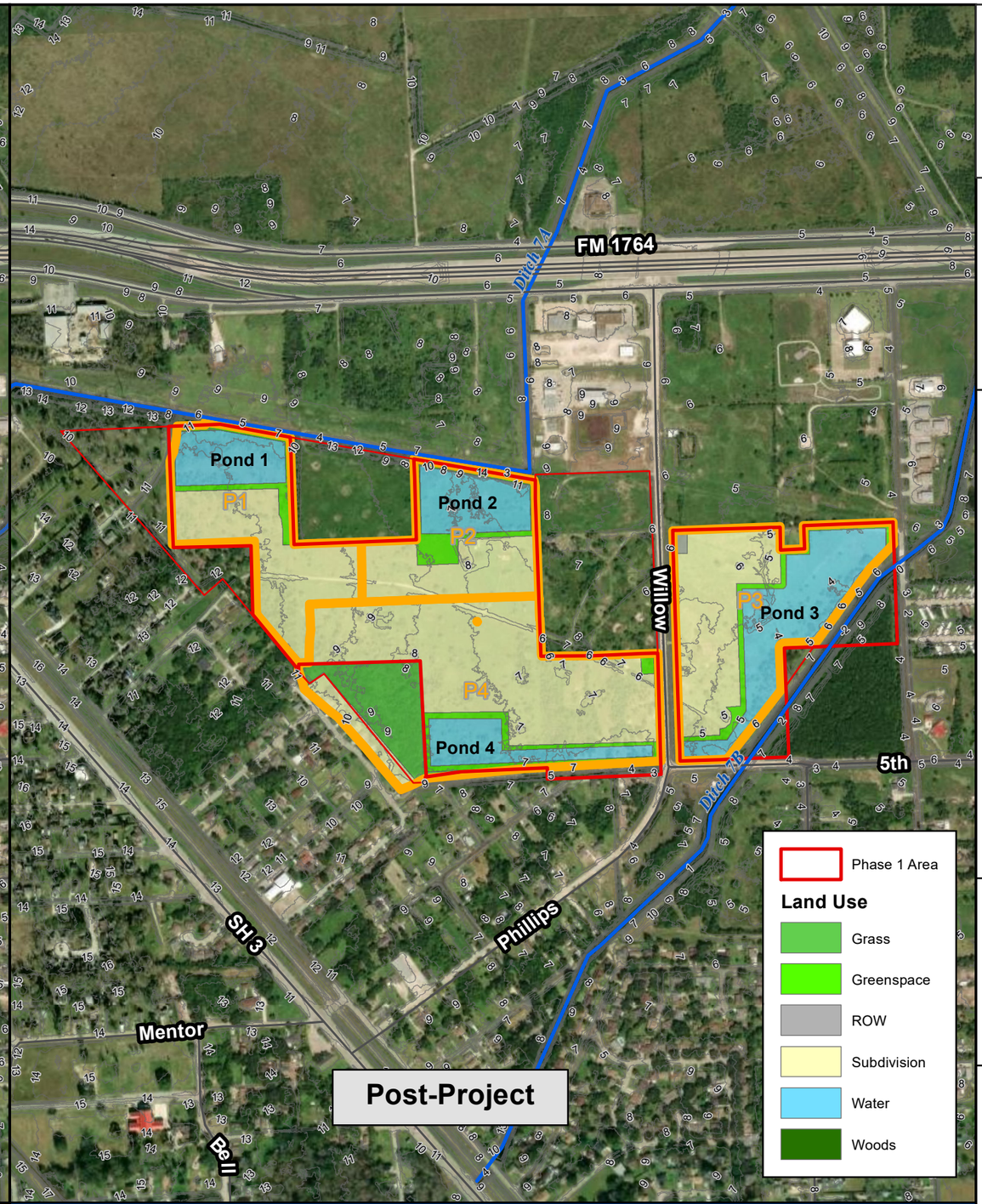
Drainage Impact Analysis

Land Use
- Greenspace
- ROW
- Subdivision
- Water
- Site

Exhibit 10 - Phase 1 Development



Pre-Project



Post-Project

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WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

- Drainage Subarea
- Elev Contour
- Phase 1 Area
- Road
- Channels
- Site

Exhibit 11 - Phase 1 Drainage Subarea Map

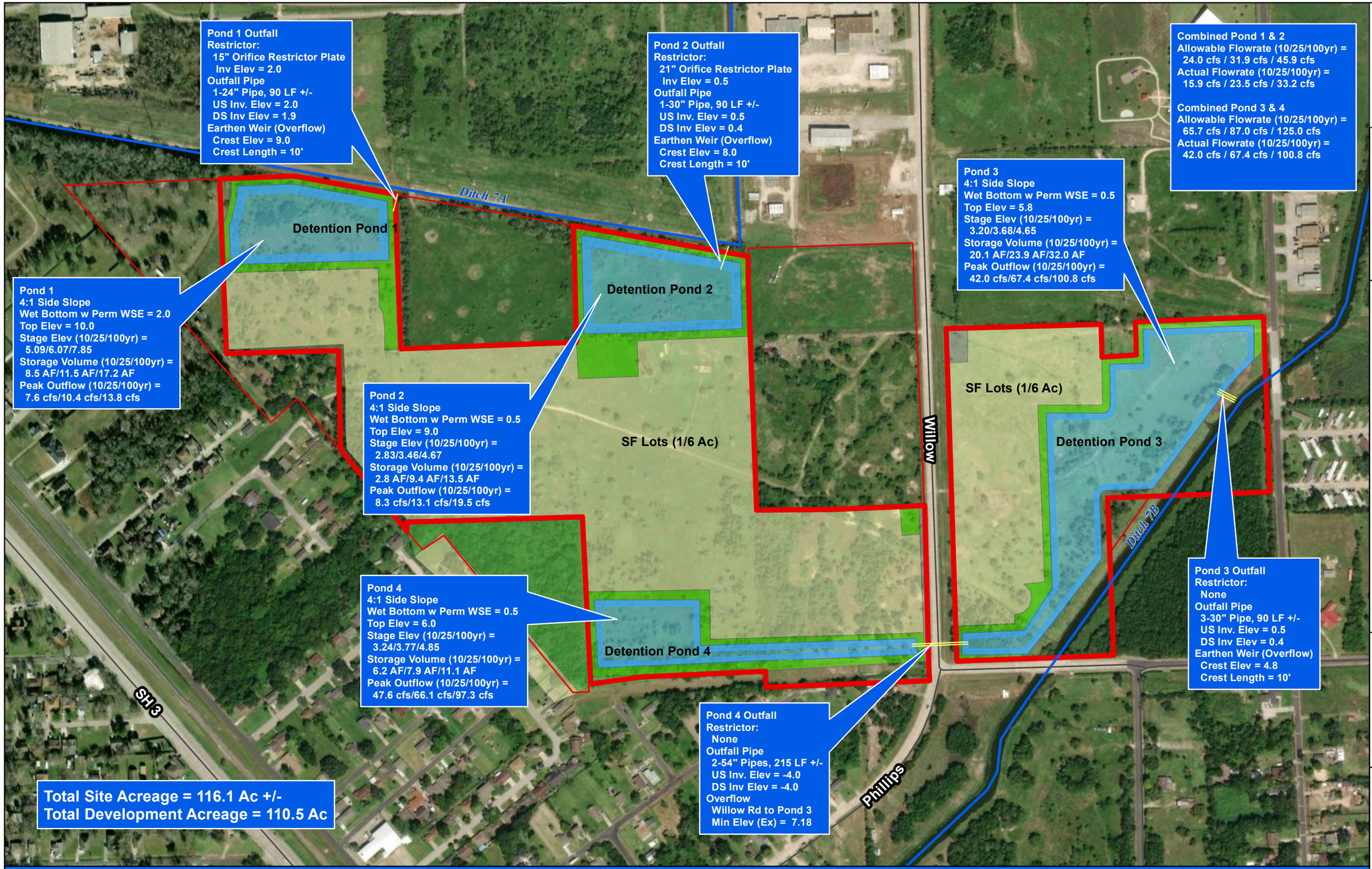

Exhibit 12- Phase 1 Detention

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0 200 400 Feet

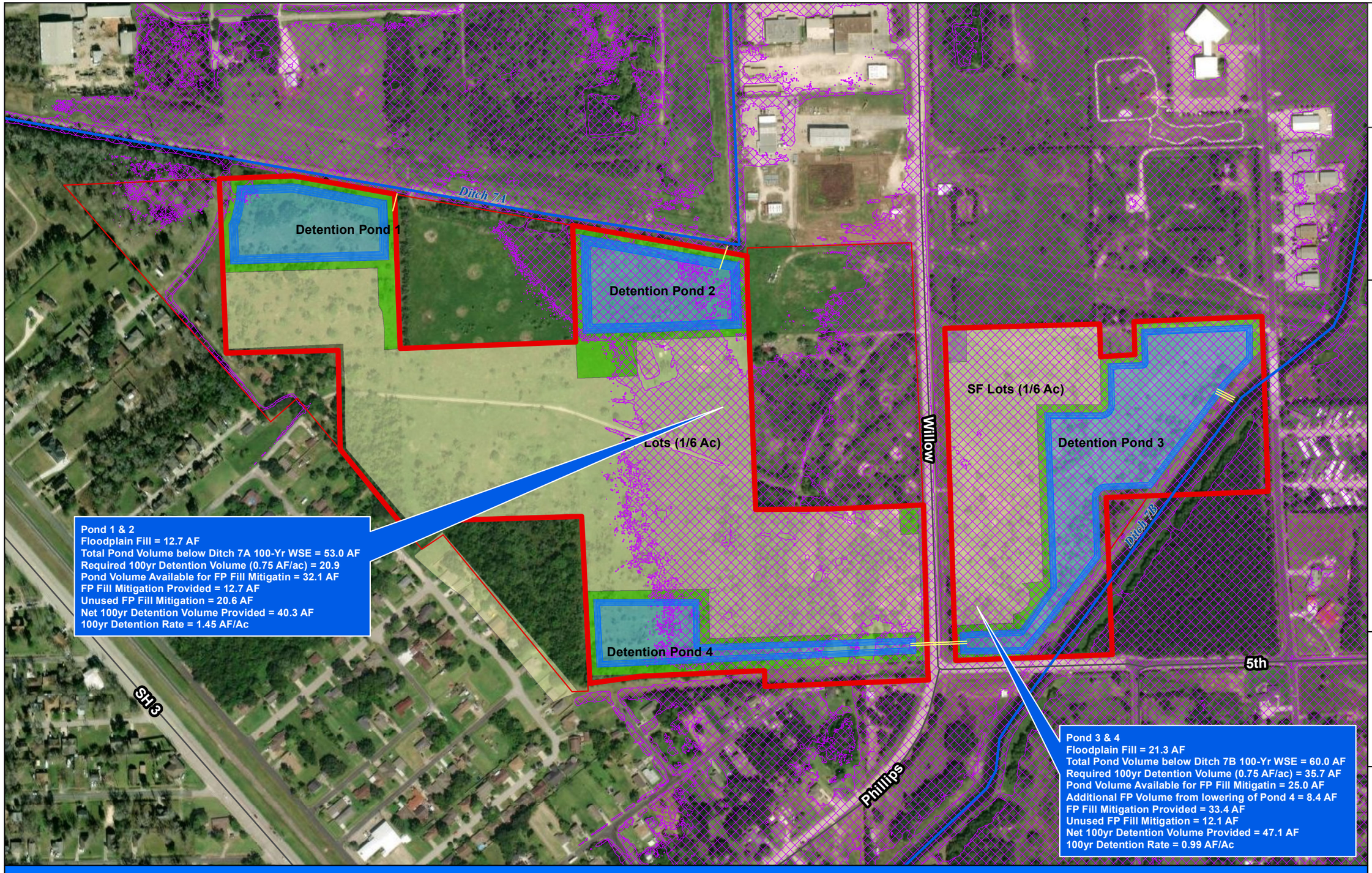
WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

- Detention Outfall
- Phase 1 Area
- Full Development

Land Use

- Grass
- Greenspace
- ROW
- Subdivision
- Water
- Woods
- Detention Contour



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WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

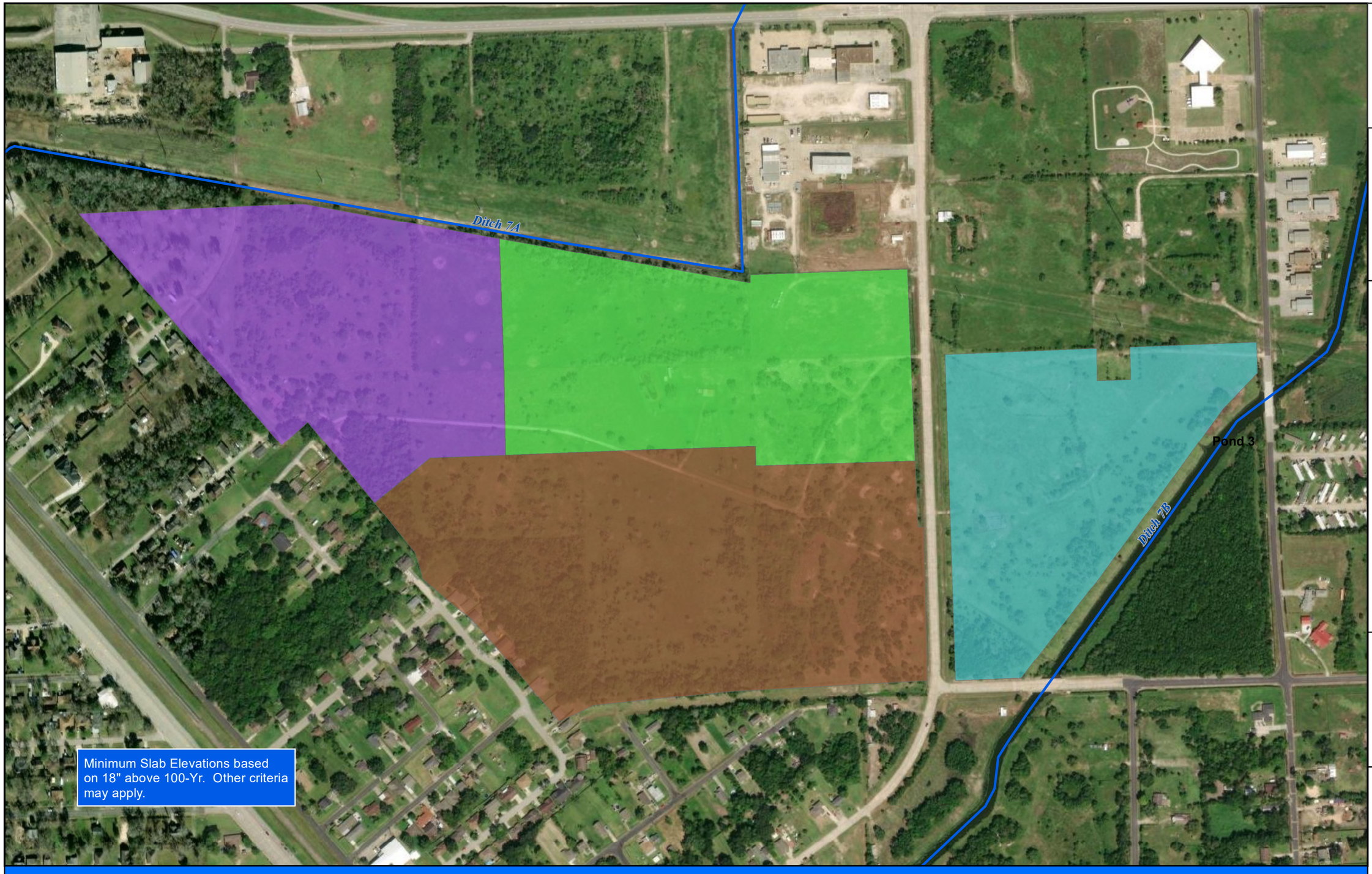
Drainage Impact Analysis

- Detention Outfall
- Detention Contour
- Phase 1 Area
- Site
- Computed 100-Yr FP

Land Use

- Greenspace
- ROW
- Subdivision
- Water

Exhibit 13 - Ph 1 FP Fill Mitigation & Detention Rate



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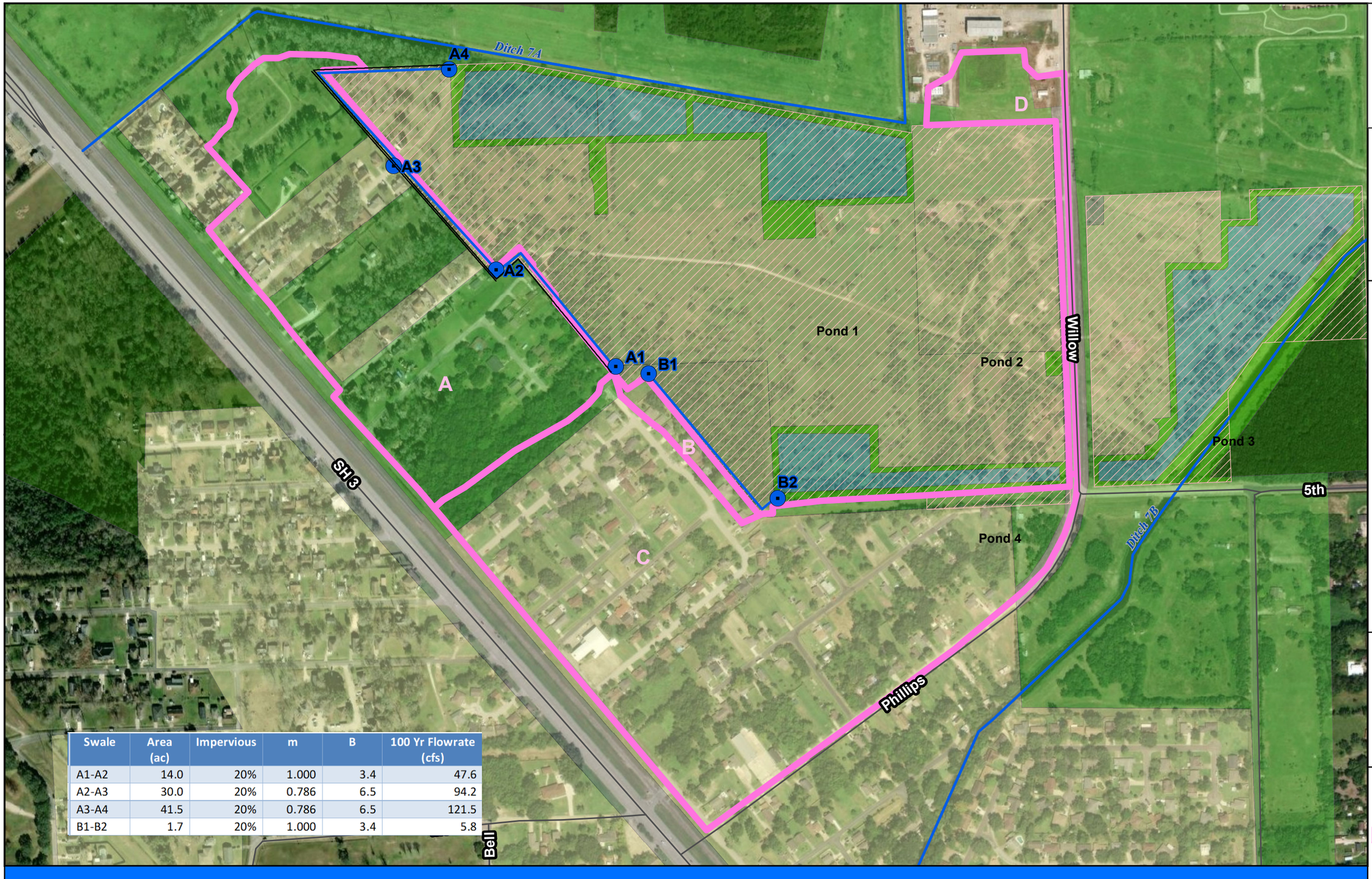
WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX
Galveston County DD No. 2

Drainage Impact Analysis

Minimum Slab Elev
- 10.5
- 11.5
- 8.7
- 9.0

Exhibit 14 - Minimum Slab Elevations



Swale	Area (ac)	Impervious	m	B	100 Yr Flowrate (cfs)
A1-A2	14.0	20%	1.000	3.4	47.6
A2-A3	30.0	20%	0.786	6.5	94.2
A3-A4	41.5	20%	0.786	6.5	121.5
B1-B2	1.7	20%	1.000	3.4	5.8

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Feet
0 200 400

WILLOWOOD DEVELOPMENT
Proposed Single Family Subdivision in Texas City, TX Galveston County DD No. 2

Drainage Impact Analysis

- Reference Nodes
- Perimeter Swale
- Offsite Areas
- Road
- Channels
- Site

Exhibit 15 - Offsite Flow Management