Document No. 2008/001

DAI Job No. 1615

Missouri City Master Drainage Plan Update: Mustang Bayou & Lower Oyster Creek

MISSOURI CITY, TEXAS

Prepared for

The City of Missouri City

by

Dodson & Associates, Inc.

January 2008

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1. INTRODUCTION AND SUMMARY OF CONCLUSIONS

1.1 PURPOSE OF THIS REPORT

This report has been prepared for Missouri City in support of the analysis associated with and update to the Master Drainage Plan for Mustang Bayou and Lower Oyster Creek. The following sections of the report describe the results of hydrologic and hydraulic analyses of current conditions, the proposed improvements to the watersheds, and the impacts of the proposed improvements on the watersheds.

1.2 GENERAL PROJECT INFORMATION

The Mustang Bayou and Lower Oyster Creek watersheds are located mostly within the southern and eastern city limit of Missouri City. The Lower Oyster Creek watershed area examined in this study also includes the watershed of Long Point Creek, which combines with Lower Oyster Creek near its mouth at the Sienna External Channel. Each watershed has been previously studied. Lockwood, Andrews and Newnam, Inc. (LAN) completed the original Master Drainage Plan for the City in 1987. Since then, other engineering firms including Pate Engineers, Inc., Jones & Carter, Inc. and Snowden Engineering, Inc., have prepared supplemental reports for the study area for other agencies including the Ft. Bend County Drainage District (FBCDD), and property owners. Dodson & Associates, Inc. prepared an updated study for the watersheds in 2001. For purposes of this study, the LAN report is considered to be the City's original plan for the watersheds and is the report that this study is meant to update, as did the previous update study. This study, however, incorporated more detailed topographic data (2005 LiDAR) for each watershed, which allowed more detailed planning and modeling to take place. In addition, hydraulic modeling was performed using an unsteady flow model that provides a more detailed portrayal of water surface elevations and peak flows that exist in the main channels through the entire storm event modeled. With this approach, changes in flow direction and the effect of channel constrictions and changes on water surface elevations can be viewed in a more dynamic manner. Previous studies used a steady flow approach for modeling.

The proposed improvements to the Mustang Bayou watershed include channel modifications (typically widening and re-grading), the replacement and/or revisions to crossing structures such as bridges and culverts, and the use of Kitty Hollow Lake as a regional detention facility. There are no major improvements proposed for the Lower Oyster Creek watershed in this study. Maintenance of existing structures will be necessary in order to maintain conveyance and storage capacity in Lower Oyster Creek. There appears to be sufficient capacity in the channel to contain the peak flows in the 100-year ultimate condition, with limited modifications, typically involving fill along areas with low channel banks.

These improvements will be utilized to contain the 100-year peak flows within the channel banks of the main channels under ultimate development conditions within the watershed. **Exhibit 1** illustrates the location of the Mustang Bayou and Lower Oyster Creek watersheds, while **Exhibits 2 – 5** show the location of the watershed subareas and the general locations of the proposed improvements and **Exhibits 6 - 8** show the resulting water surface profiles in the main channels. **Appendices A** and **B** include model input, output, and supplemental information regarding the calculations included in the analysis, **Appendix C** includes selected photographs of conditions in the watersheds, and **Appendix D** includes detail on the cost estimates included in this study.

<u>It is important to note that all elevations referred to in this study are referenced to NAVD 88, 2001 adjustment, unless noted otherwise.</u> This datum adjustment is used for the ongoing Fort Bend County Flood Insurance Study (FIS) update. Previous studies referenced Missouri City Datum, which is <u>approximately</u> 2.4 feet higher than the datum used in this study in the general vicinity of Kitty Hollow Lake. The difference between the two datum adjustments will vary across the watersheds and Missouri City Datum benchmarks, and is included here to provide a relative understanding of the difference.

1.3 DESCRIPTION OF THE MUSTANG BAYOU WATERSHED

The portion of the Mustang Bayou watershed included within the city limit drains approximately 3080 acres (4.8 square miles). The watershed is flat, with overland slopes ranging from about 5 to 20 feet per mile. Under existing conditions, the watershed is about 40% developed. The development in the watershed consists mostly of subdivisions with single-family homes on small lots. Some commercial development is scattered throughout the watershed.

Mustang Bayou generally drains in a southerly direction from its beginning north of Cartwright Road. The ditch runs approximately 2.8 miles from its most upstream open ditch section to a point where it begins to flow to the east. At this point, a diversion (the Mustang Diversion Channel) carries the majority of the flow south toward Kitty Hollow Lake and allows only a small portion of the flow to remain in the original channel. The Mustang Bayou channel continues to the east for approximately one mile, crosses under the Fort Bend Tollway, and reaches the Missouri City Limit. The diversion channel flows south under Lake Olympia Parkway and Senior Road, then westward to its mouth at Kitty Hollow Lake. The diversion channel is approximately 1.3 miles long. Kitty Hollow Lake serves as the outlet for the majority of the flows in Mustang Bayou. A watershed map that shows these features is included as **Exhibit 2**.

1.4 DESCRIPTION OF THE LOWER OYSTER CREEK WATERSHED

The portion of the Lower Oyster Creek watershed included in this study drains approximately 1870 acres (2.9 square miles) of land in southern Missouri City, immediately below the Mustang Bayou watershed. The watershed is also flat. Under existing conditions, the watershed is about 60% developed. The density of existing development in the Lower Oyster Creek watershed is less than the Mustang Bayou watershed, with development primarily consisting of large-lot subdivisions and the use oxbow lakes as detention and amenity features. Currently, little commercial development exists in the watershed.

Some of the flow at the upstream end of Lower Oyster Creek comes from the outfall of Kitty Hollow Lake, and hence from the Mustang Bayou watershed. The upper portions of the watershed act as a ponding area with flows from Kitty Hollow Lake and local runoff being the chief constituents. Channel slopes in this area change direction and, during certain portions of rainfall events, cause accumulated runoff in the channel to flow in a northwesterly direction and outfall into Flat Bank Diversion channel. As the runoff events continue, the flow direction gradually reverses and the accumulated runoff travels in a southeasterly direction, which is considered the “downstream” direction, toward the Sienna External Channel and the Brazos River.

The upper end of Lower Oyster Creek begins at the end of Oyster Creek, near the Flat Bank Diversion channel. After passing under State Highway 6, Lower Oyster Creek drains in a southeasterly direction under Sienna Parkway Drive, Trammel-Fresno Road, and then south under Watts Plantation Road. At this point, the Lower Oyster Creek constructed channel begins and flows south and east to the BRA Canal crossing, where flow from the adjacent Long Point Creek is combined, then continues under McKeever Road, and travels approximately 1000 feet further downstream into the Sienna development external channel. The Sienna external channel carries flow from Lower Oyster Creek, Long Point Creek and the Sienna development interior drainage system to the Brazos River. The LAN study continued the Lower Oyster Creek Channel on to the Brazos River by way of the Sienna channel and recommended a series of improvements to the channel in this area. This study considers the Lower Oyster Creek watershed to end at the Sienna External Channel since the channel travels well outside the Missouri City Limit.

1.5 LONG POINT CREEK WATERSHED

As mentioned above, flows in Long Point Creek affect flows in Lower Oyster Creek due to the diversion channel constructed between the two channels just upstream of the BRA Canal and McKeever Road. The location of this channel is shown on Exhibit 2. A full study of Long Point Creek was outside the scope of this project, but sufficient information was gathered to include the effects of the creek upon the flows in Lower Oyster Creek.

Much of the Long Point Creek watershed lies outside of the Missouri City jurisdiction. The watershed included in this study consists of approximately 4175 acres (6.5 square miles) with a large portion of the watershed undergoing development. The watershed is approximately 50% developed with residential subdivisions and a limited amount of commercial area. Widespread use of on-site or sub-regional storm water detention for these developments is evident.

The Long Point Creek channel runs under Trammel-Fresno Road and State Highway 6, then to the BRA Canal, where a significant portion of the flows in the channel are diverted into Lower Oyster Creek along a diversion channel on the north side of the BRA Canal. The remaining flows travel under the BRA Canal, McKeever Road, and make their way to the Sienna External Channel. Much of the upper half of the Long Point Creek channel has been rectified and changed to fit into a development plan. The lower half of the channel is still in a mostly natural condition.

1.6 FIELD INVESTIGATIONS

Dodson & Associates, Inc. performed field investigations and reconnaissance on several occasions in 2006 and 2007. The purpose of this reconnaissance effort was to verify existing drainage patterns within the watershed, photograph crossing structures and other items of interest, and determine channel characteristics. Observations made during field investigations confirmed many of the assumptions (with some modifications) made for the existing drainage boundaries of the watersheds as described in the November 1987 LAN Study. However, due to our field observations, some of the subwatershed areas were changed to reflect the impact of current development and to better facilitate the objectives of this study. A representative sampling of photographs taken during these field visits is included in **Appendix C**.

1.7 CURRENT FLOODPLAIN STATUS

The regulatory floodplains are established by the current Flood Insurance Rate Maps (FIRMs) published and amended by the Federal Emergency Management Agency (FEMA). Currently, there is a detailed floodplain (Zone AE) shown for Mustang Bayou and an approximate floodplain (Zone A) identified for Lower Oyster Creek according to the *Flood Insurance Study* (FIS), *Fort Bend County, Texas and Incorporated Areas*, dated November 7, 2001). The effective FIRMs showing Mustang Bayou and Lower Oyster Creek included in the FIS are panel numbers 48157C0260J and 48157C0270J, both dated 01/03/1997. FEMA is currently restudying and remapping Fort Bend County as part of its nationwide Map Modernization Program. Although results of this current FIS restudy were not available at the time of this report, we understand that Lower Oyster Creek has been studied in detail and the Zone A floodplain will be replaced with a Zone AE floodplain when the new maps are published. Mustang Bayou was not restudied. Instead, the existing base flood elevations were remapped using the new LiDAR data.

The effective FIRMs for the area show that much of the Mustang Bayou and Lower Oyster Creek watersheds are included in the 100-year floodplain. Base Flood Elevations (BFEs) for the portion of Mustang Bayou included within Missouri City range from 74 feet at the downstream city limit to 75 feet at the GCWA Canal crossing, where the effective model ends. No BFEs have yet been established for Lower Oyster Creek. The Brazos River BFE within the study area is approximately 64.0 feet. These BFEs are based on the National Geodetic Vertical Datum (NGVD) 1973 releveling. The Brazos River floodplain affects a large part of the Lower Oyster Creek watershed where the watershed is not protected by levees. As noted earlier, the existing FIS is being revised as of the time of this report. It is anticipated that the floodplains shown for each of the main channels in this study will change from those shown on the effective FIRMs.

1.8 SUMMARY OF CONCLUSIONS

As noted above, the improvements planned for Mustang Bayou consist of channel widening and regrading, structural revisions to the GCWA Canal crossing, and replacement of the crossing structure at Turtle Creek Drive. Only limited improvements are planned for Lower Oyster Creek due to the existing capacity of the primary channel, the diversion of flows to Flat Bank Diversion channel in both existing and ultimate conditions, and the relatively developed nature of the watershed. The improvements to Lower Oyster Creek consist of filling low channel bank areas so that the ultimate flows are contained within the channel as well as regrading and restoring conveyance underneath the BRA Canal flume near the downstream end of Lower Oyster Creek.

Based on revised hydrologic and hydraulic analyses, the ultimate improvements, as proposed and noted in this report, contain the ultimate 100-year peak flows at water surface elevations that are below the elevation of the channel banks of the improved main channels included in this study.

The total estimated cost for each project (including land acquisition) is $6,484,890 for Mustang Bayou and $542,900 for Lower Oyster Creek. An assessment of the total cost compared with the amount of land available for development in each watershed yields an estimate of $2,106 and $291 per acre of new development for the Mustang Bayou and Lower Oyster Creek watersheds, respectively.

1.9 STUDY LIMITATIONS

This study has been conducted using high-definition LiDAR topographic data, augmented by surveyed channel cross sections and field reconnaissance to verify local drainage conditions. However, the study was performed for planning purposes, and will need to be augmented by site-specific engineering and modeling studies as portions of the MDP are designed and constructed. As noted in the text, each watershed was broken into several drainage areas in order to determine peak flows that reached the two main channels included in the study. It is assumed that the local drainage infrastructure and general ground slopes will convey these flows to the main channels during rainfall events. Isolated or local flooding outside of the main channels, as a result of inlet ponding, roadside ditch blockages, inadequate storm sewer capacity, or other conditions was not specifically addressed by this study. It is necessary therefore, to ensure that the local drainage infrastructure is properly designed, maintained, and operated so that peak flows can be conveyed to the channels that are designed to handle them.

In addition, it should be noted that the hydrologic and hydraulic modeling performed for this update of the MDP is broad in nature and should be supplemented by site-specific topography, modeling, and design before the project elements are constructed. Site-specific conditions may differ from those included in this study and should be accounted for as each element is designed and built.

2. HYDROLOGIC ANALYSIS

A hydrologic analysis was performed of the existing and ultimate conditions. The purpose of the analysis was to calculate hydrographs for input into the unsteady-flow model that will be discussed in the next section. This section describes the models, assumptions, and results of the hydrologic analysis. Supplemental information, including model output and calculation spreadsheets, is included in **Appendix A**.

2.1 EXISTING CONDITIONS MODELS

To quantify the impacts of the ultimate development and the associated improvements on the Mustang Bayou and Lower Oyster Creek watersheds, it was necessary to create models to analyze several hydrologic conditions. As a starting point, the watershed models used in the earlier Dodson study, were used as a base condition.

The base models were updated from the original to create an existing conditions model. Modifications to the existing conditions models included various watershed hydrologic parameters, and subwatershed adjustments. The model was updated from HEC-1 to HEC-HMS version 3.1.0, the newest version of hydrologic modeling software from the US Army Corps of Engineers Hydrologic Engineering Center (HEC). Updated development information was included based on aerials provided by the City of Missouri City dated 2005. Therefore, the "existing conditions" should be considered as conditions circa 2005.

2.1.1 Methodology

The Fort Bend County Drainage District methodology was used in establishing TC and R-values. Subwatershed parameters such as watershed slopes and channel slopes were estimated from existing models, the LiDAR topographic data, channel survey information, and other available data. **Tables 2-1 and 2-2** included at the end of this section show the existing conditions subwatersheds and their associated hydrologic parameters for Mustang Bayou, Lower Oyster Creek, and Long Point Creek.

2.1.2 Subwatershed Adjustment

The subwatersheds included in our earlier MDP update study were reviewed and revised as necessary to include drainage patterns and changes that have occurred since the publishing of the report. The use of the LiDAR data was helpful in better defining sheet flow patterns and the boundaries of some subwatersheds in both Mustang Bayou and Lower Oyster Creek. The construction of the Fort Bend Tollway also created an artificial boundary with conveyance under the tollway limited to crossing culverts constructed for Mustang Bayou and for the headwaters of Long Point Creek (near the Vicksburg subdivision). A portion of the upper subwatershed of Mustang Bayou (MB-1A) was removed from the watershed, as plans are underway to drain this portion of the watershed (approximately 50 acres) into an adjacent channel.

Subwatersheds in Lower Oyster Creek were modified from the earlier Dodson study with the assistance of the LiDAR data and field reconnaissance. In each case, care was taken to verify the decision to alter subwatersheds with field visits to the affected areas. Subwatersheds in Long Point Creek were adjusted based on development patterns that had occurred since the original report. **Exhibit 2** includes the locations and configuration of the subwatersheds in each watershed in the existing condition.

It should be noted that much of the newer development that has been constructed in these watersheds uses on-site storm water detention to mitigate impacts on peak flows that occur from development. The models included in this study accounted for the effects of the detention facilities in two ways. Where the detention facility was observed (by aerial photograph or in the field) to be maintained and in operating condition, impervious cover for the particular subwatershed containing the detention was reduced to account for the size of the development served by the detention facility. In some cases in the Lower Oyster Creek watershed, oxbow lakes are used as detention facilities by adjacent development. In these cases, impervious cover percentages were not reduced and the effects of the detention facilities were directly modeled in the hydraulic model. The hydrologic parameters included in Tables 2-1 and 2-2 reflect the reductions or revisions to the impervious coverage of the subwatersheds based on these approaches.

Once the subwatersheds were adjusted, hydrologic parameters were modified to update them to current conditions, and the hydrologic model was executed in order to provide hydrographs for input into the hydraulic model for the calculation of the existing conditions water surface elevations and for comparison with the ultimate conditions.

2.2 ULTIMATE CONDITIONS MODELS

To determine the effect of ultimate development on the watersheds and the effectiveness of the proposed improvements to mitigate the impacts from ultimate development within the watershed, an ultimate conditions hydrologic model was created. This model reflected the full development of the watersheds and as a result reflects modifications to runoff parameters in the subwatersheds draining to Mustang Bayou and Lower Oyster Creek. Long Point Creek drainage parameters were not adjusted for ultimate development, since the majority of the watershed is outside of the City's jurisdiction.

The areas and types of anticipated development were identified based on a future land use map provided by Missouri City. **Exhibit 3** shows the subwatersheds and land use map with the expected types of development under ultimate conditions.

2.2.1 Model Setup

The existing conditions model was modified to include the effects of the ultimate development on each subarea. Typically, ultimate development included increasing the amount of impervious area in each watershed to the typical level noted in each category of land use. In addition, the channel parameters were changed to reflect the conveyance of the majority of flows in the channels, assuming that improvements had been constructed. **Table 2-3** shows the typical impervious coverage assigned to each zoning designation. **Tables 2-4 and 2-5** show the revised watershed parameters for Mustang Bayou and Lower Oyster Creek after incorporating the effects of ultimate development on the watersheds.

2.2.2 Model Results

As would be expected, peak flows from subwatersheds increase where development increases since the development was modeled without on-site mitigation. The purpose of the planned improvements to the watersheds was then to mitigate these impacts using a regional approach as much as possible in each watershed. The unsteady flow model discussed in the following section was used to model the proposed improvements to mitigate these impacts.

Table 2-1: Existing Conditions Runoff Parameters – Mustang Bayou

Subarea	Area (sq.mi.)	Area (acres)	L (mi)	S (ft/mi)	So (ft/mi)	I (%)	Nu	Nd	TC (hour)	R (hour)
MB1A	0.25	160	0.65	2.4	6.9	9.9	0.060	0.060	1.69	3.59
MB1	0.27	175	0.77	2.8	7.3	1.5	0.060	0.060	2.20	4.52
MB2	0.27	172	0.88	4.0	5.5	50.0	0.060	0.060	0.62	1.60
MB3	0.18	113	1.14	4.3	31.0	0.0	0.070	0.050	3.48	2.66
MB4	0.21	131	1.06	1.9	16.5	9.0	0.070	0.050	2.98	3.46
MB5	0.24	153	0.44	1.3	13.0	51.6	0.060	0.060	0.76	1.04
MB6	0.06	40	0.92	8.8	14.4	0.0	0.060	0.060	2.27	2.89
MB7	0.24	154	1.08	9.9	8.1	4.1	0.060	0.060	1.82	3.47
MB8	0.35	226	1.04	5.8	19.8	0.0	0.060	0.050	2.66	2.75
MB9	0.27	171	0.86	13.4	8.2	4.3	0.060	0.060	1.47	2.78
MB10	0.20	131	0.93	8.7	7.7	4.3	0.060	0.050	1.53	3.01
MB11	0.65	415	0.93	8.8	9.0	1.3	0.060	0.080	2.30	4.05
VICKS	1.08	693	2.76	3.3	3.1	28.0	0.045	0.045	1.19	5.12
VICKS2	0.09	56	0.49	8.9	5.6	32.1	0.045	0.045	0.43	1.08
LSH1	0.13	85	These values (and Tc & R) taken from RG Miller Engineers, Inc. Lakeshore Harbor Development Report 2004/2005						0.17	1.40
LSH2	0.32	205							0.50	4.60

Table 2-2: Existing Conditions Runoff Parameters – Lower Oyster Creek/Long Point Creek

Subarea	Area (sq.mi.)	Area (acres)	L (mi)	S (ft/mi)	So (ft/mi)	I (%)	Nu	Nd	TC (hour)	R (hour)
LOC1	0.50	318	1.51	2.0	22.0	8.5	0.080	0.080	5.26	5.05
LOC2	0.46	292	1.14	8.0	19.0	14.2	0.060	0.060	2.04	2.15
LOC3	0.34	220	0.38	18.0	18.0	20.3	0.060	0.080	0.89	0.97
LOC4	0.29	186	0.66	5.1	36.0	7.6	0.060	0.080	2.68	1.84
LOC5	0.15	97	0.66	4.0	5.0	20.0	0.060	0.060	1.01	2.78
LOC6	0.13	83	0.76	14.0	16.0	11.1	0.060	0.060	1.42	1.68
LOC7	0.41	260	0.23	3.0	3.0	14.0	0.060	0.080	0.59	2.68
LOC8	0.05	31	0.15	5.0	5.0	7.9	0.060	0.080	0.64	1.77
LOC9	0.26	168	0.76	2.0	13.0	8.5	0.060	0.060	2.49	3.39
LOC10	0.17	110	0.95	16.5	16.3	18.2	0.100	0.070	1.61	1.89
LOC11	0.09	56	0.57	5.0	58.0	0.0	0.080	0.070	3.09	1.52
COW	0.07	47	0.42	6.0	5.0	20.0	0.060	0.080	0.83	2.29
Long Point Creek										
LPC1	2.56	1637	2.27	5.0	6.0	2.9	0.150	0.060	3.99	9.50
LPC3	1.52	975	1.70	13.0	4.0	4.4	0.060	0.150	2.85	9.60
LPC4	1.01	645	1.55	11.0	17.0	1.0	0.150	0.150	6.08	6.93
LPC5	0.95	609	1.14	16.0	15.0	1.0	0.150	0.150	4.45	5.51
LPC6	0.48	309	1.48	11.0	32.0	1.0	0.150	0.150	6.77	5.06

Table 2-3: Impervious Percentages Used for Ultimate Conditions Landuse Map

Land Use Designation	Development Type Used	Impervious %
Low Density Residential	Large Lots (1 acre – 1/4 acre)	20-38%
Medium Density Residential	Medium Lots (1/4 acre – 1/5 acre)	38-50%
High Density Residential	Small Lots (1/5 acre – 1/8 acre)	50-65%
Community Facility	Parks/Open Space	10%
Neighborhood & Community Area	Commercial/Business	85%
Sub-Regional & Regional Area	Commercial/Business	85%

Table 2-4: Ultimate Conditions Runoff Parameters – Mustang Bayou

Subarea	Area (sq.mi.)	Area (acres)	L (mi)	S (ft/mi)	So (ft/mi)	I (%)	Nu	Nd	TC (hour)	R (hour)
MB1A	0.25	160	0.65	2.4	6.9	49.1	0.060	0.060	0.69	1.46
MB1	0.27	175	0.77	4.0	7.3	24.8	0.045	0.045	0.93	1.90
MB2	0.27	172	0.88	0.5	5.5	50.0	0.045	0.045	0.88	2.25
MB3	0.18	113	1.14	0.5	31.0	50.0	0.045	0.045	1.70	1.30
MB4	0.21	131	1.06	0.5	16.5	16.6	0.045	0.045	3.08	3.58
MB5	0.24	153	0.44	1.3	13.0	51.6	0.060	0.060	0.76	1.04
MB6	0.06	40	0.92	8.8	14.4	50.0	0.060	0.060	0.72	0.91
MB7	0.24	154	1.08	9.9	8.1	85.6	0.060	0.060	0.28	0.53
MB8	0.35	226	1.04	2.3	19.8	50.0	0.045	0.045	0.97	1.00
MB9	0.27	171	0.86	13.4	8.2	59.4	0.045	0.045	0.33	0.62
MB10	0.20	131	0.93	5.3	7.7	48.3	0.045	0.045	0.57	1.11
MB11	0.65	415	0.93	8.8	9.0	1.3	0.060	0.080	2.30	4.05
VICKS	1.08	693	2.76	3.3	3.1	60.3	0.045	0.045	0.56	2.44
VICKS2	0.09	56	0.49	8.9	5.6	50.0	0.045	0.045	0.28	0.72
LSH1	0.13	85	These values (and Tc & R) taken from RG Miller Engineers, Inc. Lakeshore Harbor Development Report 2004/2005						0.17	1.40
LSH2	0.32	205							0.50	4.60

Table 2-5: Ultimate Conditions Runoff Parameters – Lower Oyster Creek/Long Point Creek

Subarea	Area (sq.mi.)	Area (acres)	L (mi)	S (ft/mi)	So (ft/mi)	I (%)	Nu	Nd	TC (hour)	R (hour)
LOC1	0.50	318	1.51	2.0	22.0	45.5	0.080	0.080	2.24	2.15
LOC2	0.46	292	1.14	8.0	19.0	20.0	0.060	0.060	1.78	1.88
LOC3	0.34	220	0.38	18.0	18.0	21.7	0.060	0.080	0.86	0.94
LOC4	0.29	186	0.66	5.1	36.0	20.0	0.060	0.080	2.01	1.38
LOC5	0.15	97	0.66	4.0	5.0	20.0	0.060	0.060	1.01	2.78
LOC6	0.13	83	0.76	14.0	16.0	20.0	0.060	0.060	1.16	1.37
LOC7	0.41	260	0.23	3.0	3.0	20.0	0.060	0.080	0.52	2.33
LOC8	0.05	31	0.15	5.0	5.0	20.0	0.060	0.080	0.49	1.34
LOC9	0.26	168	0.76	2.0	13.0	20.0	0.060	0.060	1.91	2.60
LOC10	0.17	110	0.95	16.5	16.3	20.0	0.100	0.070	1.55	1.81
LOC11	0.09	56	0.57	5.0	58.0	20.00	0.080	0.070	1.95	0.96
COW	0.07	47	0.42	6.0	5.0	20.00	0.060	0.080	0.83	2.29
Long Point Creek – No Changes to Parameters in Ultimate Condition										

3. HYDRAULIC ANALYSIS

In order to determine the effects of the planned increase in development on the watersheds, it was necessary to model the main channels in each watershed. As discussed earlier, an unsteady flow model (HEC-RAS version 3.1.3) was chosen for this analysis. Unsteady flow allows a stage and flow hydrograph to be computed at points along each studied channel, and can better model some of the unique hydraulic conditions that are present in the watersheds. These conditions include the flat channel slopes (from about 1 to 5 feet per mile), diversion of flows between the Mustang Bayou channel and the diversion channel to Kitty Hollow Lake, the interaction between Vicksburg Ditch and Kitty Hollow Lake, the flow direction changes in the upper reaches of Lower Oyster Creek, and the influence of tailwater in the receiving water bodies on each of the main channels at different points in the storm. According to the US Army Corps of Engineers River Hydraulics Manual,

> *"Unsteady flow analyses should be used for all streams where the slope is less than 2 feet per mile. On these streams, the loop effect is predominant and peak stage does not coincide with peak flow. Backwater affects the outflow from tributaries and storage or flow dynamics may strongly attenuate flow; thus, the profile of maximum flow may be difficult to determine. For bed slopes from 2 to 5 feet per mile, the need for unsteady flow analysis may depend upon the study objectives. Large inflows from tributaries or backwater from a receiving stream may require the application of unsteady flow. Flow reversals may occur under such conditions, rendering hydrologic routing useless. For slopes greater than 5 feet per mile, steady flow analysis is usually adequate if the discharge is correct." (Reference 5)*

This section describes the models, assumptions, and results of the hydraulic analysis. Supplemental information, including model output and calculation spreadsheets, is included in **Appendix B.**

3.1 EXISTING CONDITIONS MODELS

Existing conditions models were developed for the main channels in each of the two watersheds. These models were developed in three separate ways. For Mustang Bayou, topographic data for the channel consisting of surveyed cross-sections and crossing structure information was obtained in May 2006 by West Belt Surveying, Inc. The topographic data was supplemented by the use of the LiDAR so that cross sections of the channel could be extended into the overbank areas. A hydraulic model was developed from this information and combined with the model developed for Kitty Hollow Lake.

The Kitty Hollow Lake model was developed using data developed during our earlier study and topographic survey data completed in August 2007 by Jakubik & Associates, LLC (Jakubik). This data included riser sizes and elevations as well as outfall pipe sizes and flowline elevations. These elevations, which had been obtained for the earlier study and were based on Missouri City Datum, were adjusted to the study datum and then used to create a hydraulic model of the Kitty Hollow Lake outfall system. Some work that had been performed on the Kitty Hollow Lake outfall since the previous report was also included. This work consisted of lengthening the outfall pipes and regrading the levee side slopes in the vicinity of the outfall.

As mentioned earlier, a detailed hydraulic model of Lower Oyster Creek was included as a portion of the FEMA Map Modernization Program, which is ongoing in Fort Bend County. In order to develop a hydraulic model for the Lower Oyster Creek watershed, the surveyed cross-sections and topographic data was obtained from Michael Baker Jr., Inc., the FEMA study contractor for the County. This data was augmented by a limited field survey by Dodson & Associates, Inc. to obtain spillway and structure elevations for structures adjacent to the main channel of Lower Oyster Creek.

The Vicksburg Ditch was included in the hydraulic model at the request of Fort Bend County MUDs 47 and 48. This model was created using two sets of topographic data. Channel survey data was provided by Jones & Carter, Inc. in an as-built survey completed in July 2007. These elevations were adjusted to the study datum and then used to create a hydraulic model of the Vicksburg Ditch. The overflow weir structure connecting the Vicksburg Ditch with Kitty Hollow Lake and the control structure were modeled using the data from the Jakubik survey. Channel overbank data was modeled using the LiDAR information. Fort Bend County MUDs 47 and 48 also requested a steady flow analysis be performed on Vicksburg Ditch. The results of this analysis are included in **Appendix C**.

The four models were linked together into one unsteady flow model so that the effects of Lower Oyster Creek on the Kitty Hollow Lake outfall could be modeled, and that the interaction between Mustang Bayou, Kitty Hollow Lake, Vicksburg Ditch, Lower Oyster Creek and the Flat Bank Diversion Channel could be modeled.

Starting water surface elevation for the models was considered as normal depth at the confluence of Lower Oyster Creek and the Sienna External Channel. The 10-year water surface elevation of the Brazos River was also used as a test for the starting water surface elevation. Using the Brazos 10-year elevation as the start produced water surface elevations somewhat lower than the normal depth method, therefore, the normal depth method was chosen for use in this study. Manning's n-values and other channel parameters were set in accordance with engineering judgment, as appropriate for the conditions observed during field visits. As mentioned earlier, photographs showing the general condition of the channels are included in **Appendix C**.

3.2 ULTIMATE CONDITIONS MODELS

Ultimate conditions hydraulic models were developed from the peak flows of the ultimate hydrologic model. These flows were input into the existing hydraulic model and separate elements of the MDP, such as channel widening and structure replacement, were added and revised in order to determine their effect on both peak flows and water surface elevations. The final result, after a somewhat iterative process, became the ultimate elements of the MDP.

3.2.1 Model Setup

The ultimate conditions model used the existing model as a base and added data to model the increased runoff from the developed conditions and the proposed channel improvements along Mustang Bayou and Lower Oyster Creek. This was a somewhat iterative process, as the channel widths and associated storage and conveyance would affect the peak flows along the channels, which, as the channels were modified, would have the tendency to affect the peak flows again. Where bridges and culverts posed a constriction in the channel, the structures were either assumed to be enlarged to accommodate the increased flows and channel widths (such as at Turtle Creek Drive and Senior Road in Mustang Bayou), or the structures were assumed to remain the same and the channels were modified if necessary (such as the majority of the structures in Lower Oyster Creek).

Exhibit 4 shows the general location and configuration of the Master Drainage Plan elements for Mustang Bayou. **Exhibit 5** shows the general locations of fill required along the channel banks for the Lower Oyster Creek watershed, as well as the locations of the recommended conveyance improvements (channel excavation) in the vicinity of the BRA Canal.

There were areas of undeveloped land noted in the existing condition modeling where the average land elevation in the was generally lower than the channel banks of the main channels, creating ponding and flood storage in these areas in the existing condition. In these areas, typically in the upper and middle Mustang Bayou watershed, the ultimate development condition assumed that the land would be filled to or above the channel bank elevations as part of the development process. This approach ensured that storage that may have been included in these lower areas in the existing condition was removed from the modeling of the ultimate condition. These areas are not shown on the exhibits included in this report, but are included in the electronic copies of the models.

3.2.2 Model Results

The ultimate conditions (with improvements) HEC-RAS unsteady flow model demonstrates that the proposed improvements will produce 100-year peak water surface elevations at levels that are below the banks of the channels. There are isolated areas of low banks within the Lower Oyster Creek watershed which will need to be raised, but these areas are limited and are noted later in this report. **Tables 3-1 and 3-2**, included at the end of this section, show comparisons between the existing and the ultimate conditions models. **Exhibits 6 - 8** include the profiles for the channels studied under both existing and ultimate conditions. The results show that, generally, water surface elevations are reduced in Mustang Bayou as a result of the planned improvements. In Lower Oyster Creek, the water surface elevations are similar in both existing and ultimate conditions, with the exception of one area where water surface elevations increase, but are contained within the channel banks. No significant reductions in water surface elevations were designed for the channel of Lower Oyster Creek since the flows are currently contained within the channel banks and will remain so in the ultimate condition.

Table 3-1: Comparison of Hydraulic Conditions (100-Year Max. Discharges)

Location Description	Cross Section	100-Year Maximum Discharge Existing (cfs)	Ultimate (cfs)	Difference (cfs)
Mustang Bayou - Diversion Channel to Kitty Hollow Lake				
Downstream of Cartwright Road	19620	184	379	195
Upstream End of GCWA Canal	16355	287	403	116
Upstream Face of Turtle Creek Drive	15001	325	471	146
Upstream of Diversion to Kitty Hollow	7887	668	1046	378
Downstream of Diversion	7163	720	1830	1110
Upstream Face of Lake Olympia Parkway	6209	769	1939	1170
Upstream Face of Senior Road Bridge	4693	829	2068	1239
Final Section at Kitty Hollow Lake	1250	1037	2349	1312
Mustang Bayou from Diversion to Fort Bend Tollway				
Downstream of Diversion at Timber Bridge	4840	176	1352	1176
Upstream Face of Fort Bend Tollway Culverts	550	668	650	-18
At ETJ	0	667	640	-27
Oyster Creek from Kitty Hollow Lake to Flat Bank Diversion Channel				
Maximum Outflow from Kitty Hollow Lake	N/A	379	491	112
At Oyster Creek and Outfall Channel	2470	513	599	86
At Flat Bank Diversion	13.7	510	587	77
Lower Oyster Creek Below Kitty Hollow Outfall Channel				
At Oyster Creek and Outfall Channel	23713	180	237	57
Upstream Face of State Highway 6	21018	215	297	82
Upstream Face of Sienna Parkway	18296	139	108	-31
Upstream Face of Trammel-Fresno Culverts	17245	107	229	122
Upstream Face of Watts Plantation Culverts	12784	243	485	242
Upstream Face of BRA Canal Siphon	1213	2221	2354	133
Downstream Face of McKeever Road	1013	2221	2354	133
Mouth at Sienna External Channel	0	2745	2874	129
Vicksburg Ditch				
Upstream Face of Vicksburg Blvd	4853	555	1007	452
Upstream Face of Lake Shore Harbor Blvd	3322	667	1210	543
Upstream of Weir into Kitty Hollow	2603	668	1212	544
Downstream of Weir into Kitty Hollow	2300	90	117	27
Downstream of Weir Control Structure	1283	90	117	27

Note: Maximum discharge does not always occur at maximum water surface elevation shown in the next table.

Table 3-2: Comparison of Hydraulic Conditions (100-Year Max. Water Surface Elevations)

Location Description	Cross Section	100-Year Maximum Water Surface Elev.		
		Existing (feet)	Ultimate (feet)	Difference (feet)
Mustang Bayou - Diversion Channel to Kitty Hollow Lake				
Downstream of Cartwright Road	19620	75.9	74.9	-1.0
Upstream End of GCWA Canal	16355	74.5	74.9	0.4
Upstream Face of Turtle Creek Drive	15001	73.8	72.7	-1.1
Upstream of Diversion to Kitty Hollow	7887	73.0	71.3	-1.7
Downstream of Diversion	7163	73.0	71.1	-1.9
Upstream Face of Lake Olympia Parkway	6209	72.6	70.6	-2.0
Upstream Face of Senior Road Bridge	4693	72.2	69.9	-2.3
Final Section at Kitty Hollow Lake	1250	64.4	66.1	1.7
Mustang Bayou from Diversion to Fort Bend Tollway				
Downstream of Diversion at Timber Bridge	4840	73.0	71.3	-1.7
Upstream Face of Fort Bend Tollway Culverts	550	73.0	72.8	-0.2
At ETJ	0	72.5	72.4	-0.1
Oyster Creek from Kitty Hollow Lake to Flat Bank Diversion Channel				
Maximum Elevation in Kitty Hollow Lake	N/A	64.4	66.1	1.7
At Oyster Creek and Outfall Channel	2470	61.5	61.9	0.4
Into Flat Bank Diversion	13.7	61.3	61.7	0.4
Lower Oyster Creek Below Kitty Hollow Outfall Channel				
At Oyster Creek and Outfall Channel	23713	61.5	61.9	0.4
Upstream Face of State Highway 6	21018	61.5	61.9	0.4
Upstream Face of Sienna Parkway	18296	61.5	61.9	0.4
Upstream Face of Trammel-Fresno Culverts	17245	61.5	61.8	0.3
Upstream Face of Watts Plantation Culverts	12784	60.6	61.0	0.4
Upstream Face of BRA Canal Siphon	1213	58.8	59.1	0.3
Downstream Face of McKeever Road	1013	58.7	59.0	0.3
Mouth at Sienna External Channel	0	58.5	58.8	0.3
Vicksburg Ditch				
Upstream Face of Vicksburg Blvd	4853	65.2	66.6	1.4
Upstream Face of Lake Shore Harbor Blvd	3322	64.6	66.1	1.5
Upstream of Weir into Kitty Hollow	2603	64.4	66.1	1.7
Downstream of Weir into Kitty Hollow	2300	64.4	66.1	1.7
Downstream of Weir Control Structure	1283	62.2	62.8	0.6

Note: Elevations shown are on the project datum, which is different that that used in the previous study.

4. DESCRIPTION OF ULTIMATE WATERSHED IMPROVEMENTS

4.1 MUSTANG BAYOU

The majority of the land that is available for development within the two watersheds is in Mustang Bayou. The level of existing development in Mustang Bayou is much denser than in Lower Oyster Creek, and Mustang Bayou experiences out-of-bank flooding during the 100-year design storm used in existing conditions, mostly in the upper portion of the watershed. In order to provide for additional development in the watershed, and to address existing flooding issues, the channel of Mustang Bayou is proposed to be widened and deepened where possible. Detention both upstream and downstream in the watershed is also proposed, in order to address peak runoff as the watershed develops. Finally, structures that tend to affect the flows in the channel will be revised or replaced as necessary. A detailed description of each of these plan elements is discussed below. **Exhibit 4** includes the location and general configuration of the MDP elements in Mustang Bayou.

4.1.1 Channel Improvements

The primary method of conveyance for the ultimate flows in the MDP is an increase in channel capacity. Where property existed on either side of the channel that would allow for the channel to be widened and/or deepened, these options were used. The channel improvements were based on the original MDP where appropriate. In several locations however, the channel improvements were modified from the original MDP due to the more detailed data available for this study.

The Mustang Bayou channel was broken into 5 separate reaches where channel improvements were performed. **Table 4-1**, included at the end of this section, includes a description of the configuration of each reach.

1. Cartwright Road to GCWA Canal;
2. GCWA Canal through Thunderbird North Subdivision;
3. Downstream of Thunderbird North Subdivision to Mustang Bayou Diversion Channel;
4. Mustang Diversion Channel to Kitty Hollow Lake; and,
5. Mustang Bayou Channel from Diversion Channel to Fort Bend Tollway.

Reach 1 includes a channel widening and deepening in order to provide sub-regional storage to the system and is described in more detail in the next section. Reach 2 is constricted by the existing Thunderbird North development on both sides of the channel. The channel in this reach will be deepened by approximately 1-2 feet and the existing side slopes of the channel will be graded to match the deeper channel section. In addition, the Turtle Creek Drive culvert crossing will be replaced by a bridge. Reach 3 will consist of a wider and deeper channel, with a bottom width of approximately 50 feet and a channel slope of 0.05%. Reach 4 will consist of a 60-foot bottom section and a channel slope of 0.05%. Reach 5 will also be widened with a bottom width of 50 feet and a channel slope of 0.05%. These improvements will provide sufficient capacity and channel storage to offset the ultimate development proposed for the watershed, when taken in context with the other improvements noted in this section.

4.1.2 Sub-regional Detention

There are two detention areas proposed as part of this plan. The first detention area should be considered sub-regional in nature, and consists of a widened and deepened channel section between Cartwright Road and the GCWA Canal crossing. This detention is included primarily to provide detention and outfall depth for upstream development, but will also slightly reduce downstream peak flows in the Thunderbird North subdivision. The amount of storage provided in this expanded channel section is approximately 90 acre-feet.

The detention will be provided by a channel with a bottom width of 110 feet at the GCWA Canal. This section will be extended at a slope of 0.075% and transitioned to meet the existing right-of-way for Mustang Bayou at Cartwright Road, including excavation to meet the flowline of the existing culverts underneath the road. In order to utilize the additional storage, the existing structure underneath the GCWA Canal will be revised by rehabilitating (sliplining or replacing) the existing crossing, which consists of two 72-inch steel pipes and two ±36-inch corrugated metal pipes, with two 66-inch reinforced concrete pipes. This will restrict the existing siphon to approximately two-thirds of its current area and allow the use of the additional volume in the expanded channel section upstream of the canal crossing.

4.1.3 Regional Detention

The second detention area proposed is in and around Kitty Hollow Lake. Currently, Kitty Hollow Lake serves as a Ft. Bend County Park and recreation area and is used for local detention for several developments within the immediate vicinity of the lake. Ft. Bend County owns and maintains the property through the Ft. Bend County Drainage District. Although the lake and surrounding area has a large storage capacity, it is unknown whether it was constructed with storm water detention in mind. The original LAN study called for the use of Kitty Hollow Lake as a regional detention facility for the Mustang Bayou watershed. This study is consistent in that recommendation. However, the outfall structure and configuration will need some modification to provide the necessary detention while mitigating increases in peak flows that will come from the ultimate development of the watershed.

An earlier report by Jones & Carter, Inc., dated July 1999 for Memorial Hermann Hospital System, detailed existing problems with the dam and recommended outfall structure improvements of extending the existing pipes in conjunction with dam rehabilitation and repair. The report also detailed the existing agreements and restrictions on the lake, specifically that the lake level must not exceed 69.0 feet (Missouri City Datum). The report concluded that the Lake could serve as regional detention but that the dam and outlet structure would need to be improved in order for safe operation. It is our understanding that the culverts have been extended and that some improvements in the vicinity of the outfall structure have been accomplished. However, it will be necessary to review the work that has been performed as well as determining the current condition of the dam as a condition of any future construction.

An analysis of the LiDAR data for the area around Kitty Hollow Lake showed that the amount of existing capacity in the lake was much larger than originally thought. The previous MDP update included an estimate, taken from earlier studies of the lake, of approximately 2000 acre-feet at the maximum allowable elevation of 69 feet (MCD). However, using the LiDAR data to generate an estimate of available storage showed that the existing capacity in the lake was approximately *2260* acre-feet at this elevation, using the corresponding datum adjustment from MCD to study datum. This increase in storage estimates is most likely due to the use of a limited amount of survey in obtaining the first estimate. **Table 4-2** includes elevation versus storage volume information for Kitty Hollow Lake, obtained from LiDAR data.

Under ultimate conditions development, the basin occupies approximately 380 acres and provides approximately 1725 acre-feet of storage at the maximum water surface elevation of 66.1 feet (study datum) for the design storm. This elevation is below the 69.0-foot (MCD) maximum as mentioned above. The available storage area includes Kitty Hollow Lake and the surrounding Kitty Hollow Lake County Park, much of which will be inundated at the ultimate conditions design storm elevation. **Table 4-3** includes information on existing and ultimate conditions inflows and outflows for Kitty Hollow Lake and its outfall structure.

The existing outlet structure for the lake consists of two, 66-inch corrugated steel pipes that are connected at their upstream end to vertical risers with slots for controlling the outflow from the lake. **Appendix C** includes photographs of the existing structure. It should be noted that some seepage into the culverts through the existing risers was observed during our field visit. Therefore, the entire structure should, at a minimum, be evaluated for structural integrity. Additionally, the recommendations for the structural stability of the dam and embankment around the lake as detailed in the Jones & Carter report dated July 1999 must be reviewed for applicability and implemented as necessary in order to provide the factor of safety necessary to use the lake as a regional detention basin. Further study will be necessary to design an emergency spillway in accordance with Texas Commission on Environmental Quality (TCEQ) criteria for dam safety. Such a design was beyond the planning-level scope of this report. It will also be necessary to coordinate all work with the Fort Bend County Drainage District, as the County is the owner of the lake.

4.1.4 Channel Crossing Structures

There are several structures that cross the Mustang Bayou channel. These structures include (from upstream to downstream) Cartwright Road, the GCWA Canal, Turtle Creek Drive, Lake Olympia Parkway, and Senior Road. There is also an abandoned wooden bridge that crosses the channel near the diversion to Kitty Hollow Lake and a low water crossing of the channel near the Fort Bend Tollway.

For the ultimate improvements, the GCWA Canal crossing will be revised as noted in Section 4.1.2. The Turtle Creek Drive structure was assumed to be raised above the 100-year water surface elevation in the channel using a two-span simple bridge structure (1 pier in the channel). The Senior Road Bridge was assumed to be removed and not replaced. No changes were proposed for the other crossing structures on Mustang Bayou and all crossings of the Vicksburg Ditch were adequate to convey the ultimate flows without modifications. Photographs of these structures (with the exception of the low water crossing) can be found in **Appendix C**.

4.2 LOWER OYSTER CREEK

As mentioned above, the improvements planned for Lower Oyster Creek are limited to the filling of low channel bank areas. Maintenance of the improved channel, as well as all crossing structures is assumed to take place so that the conveyance capacity of the channel is not degraded. It is anticipated that, given the extent of the future development planned for the watershed, the existing condition of the channels are adequate to convey these flows to the Sienna External Channel, with a few minor improvements. Furthermore, the typical development in the watershed has consisted of large-lot subdivisions that use existing oxbow lakes as amenity and storm water detention features. If this practice continues, then the ultimate conditions flows may be somewhat lower than anticipated in this study. **Exhibit 5** includes the location and general configuration of the limited MDP elements in Lower Oyster Creek.

4.2.1 Low Banks/Bank Fill Locations

There are three isolated areas where channel banks are noted as being markedly lower than adjacent channel banks, or otherwise lower than the surrounding area. These areas are typically in the vicinity of roadways, where the banks may be slightly depressed to meet the road shoulder or roadside ditch. Each of these areas is briefly described below.

1. Trammel Fresno Road – The upstream channel banks are approximately 2.5 feet below the ultimate 100-year ultimate water surface elevation. This area is predominantly low and poorly drained, especially between Sienna Parkway and Trammel-Fresno Road and the channel bank elevation likely is a result of the elevation of this lower area. If this area is to be developed, the low portion of the channel banks at Trammel-Fresno can be filled in order to prevent out-of-bank flooding. However, it may be such that this area will remain undeveloped and would not need to be filled. Filling of this area was not included in the ultimate improvements for Lower Oyster Creek.

2. Watts Plantation Road – The right bank upstream of Watts Plantation Road is noted as approximately 1 foot below the 100-year ultimate water surface elevation. This area is similar to the Trammel-Fresno area and can be filled as necessary, depending on the nature of development in the area. Filling of this area was not included in the ultimate improvements for Lower Oyster Creek.

3. Vicinity of 6000 feet upstream of McKeever Road – This area shows bank elevations from 0.5 to 2 feet (left bank and right bank, respectively) below the 100-year ultimate water surface elevation. The length of bank under this elevation stretches for approximately 2000 feet. This area is in the vicinity of undeveloped property along Lower Oyster Creek and should be filled along the left bank in order to prevent overtopping of a developing area. The right bank area should be filled as development

moves into the area or it becomes necessary to prevent localized flooding of the area. Fill in this area was considered as part of the ultimate improvements.

4.2.2 Channel Conveyance at BRA Canal

The BRA Canal flume crosses Lower Oyster Creek immediately upstream of McKeever Road. A photograph of the channel and flume is included in Appendix C. Although the water surface in the vicinity of the channel is within the channel banks, there is a significant amount of what appears to be sediment deposition in the vicinity of the siphon. Additionally, the inflow from the Long Point Creek Diversion Channel appears to have eroded the channel just upstream of the flume, which may have produced some of the sediment that has been deposited. Therefore, we have recommended that this sediment deposition and the erosion around the Long Point Creek channel be addressed by channel excavation and erosion control measures in the area around the channel confluence and flume.

We anticipate that the effect of this project will lower water surface elevations within the channel, but the more desired effect is to allow for a smoother transition between the diversion channel, the creek channel, and the flume during high flow events. An estimate of channel excavation and erosion control costs is included in the cost estimate for the ultimate improvements to Lower Oyster Creek.

4.2.3 Long Point Creek

Improvements to the conveyance or increases in flows due to the development of the Long Point Creek watershed were not addressed in this study, with the exception of the recommendation of right-of-way along the Long Point Creek diversion channel and the erosion control element noted above. Long Point Creek has developed with on-site detention serving most of the development. This trend was assumed to continue and, since the majority of the watershed is outside the jurisdiction of the City, improvements to the watershed were not considered as part of this study.

Table 4-1: Right-of-Way Requirements for Ultimate Development – Mustang Bayou

Section	Bottom Width Feet	Average Depth Feet	ROW Necessary* Feet
1	110	10	230
2	20-40	9	130
3	50	10	170
4	60	13	200
5	50	8.5	160
*Includes two 30-foot maintenance berms and 3:1 side slopes.			

Table 4-2: Kitty Hollow Lake Elevation – Volume Relationship

Elevation (ft)	Volume (acre-feet)
58.11	0
61	142
62	334
63	589
64	917
65	1292
66	1689
67	2097
68	2513

Table 4-3: Kitty Hollow Lake Model Results (100-Year)

Plan	Q in (cfs)	Q out (cfs)	Max. WSEL (ft)	Basin Volume at Max WSEL (ac-ft)	Q at Flat Bank Diversion (cfs)
Existing Conditions	1743	379	64.4	1061	510
Ultimate Conditions	3480	491	66.1	1723	587

5. RIGHT-OF-WAY REQUIREMENTS AND COST ESTIMATES

The following sections summarize the estimates for construction cost for the ultimate improvements. We have attempted to use current unit prices where they are available. However, these estimates should be used for planning purposes only as the quantities used in the estimates are approximate.

5.1 MUSTANG BAYOU ULTIMATE IMPROVEMENTS RIGHT-OF-WAY REQUIREMENTS

The necessary right-of-way to construct and maintain the ultimate improvements has been estimated for each reach of Mustang Bayou included in this study. The right-of-way estimates leave room for two, 30-foot maintenance berms on each side of the channels, unless current restrictions will not allow. In addition, side slopes of 3 (horizontal) to 1 (vertical) have been assumed for channel excavation, where restrictions were not present. For Mustang Bayou, the estimates are set up according to the following sections:

1. Cartwright Road to GCWA Canal
2. GCWA Canal through Thunderbird North Subdivision
3. Downstream of Thunderbird North to Confluence with Old Channel of Mustang Bayou
4. Confluence with Old Channel to Kitty Hollow Lake
5. Old Channel from Confluence to Quail Glen Ditch

Right-of-Way estimates are shown in **Table 5-1** at the end of this section. According to the table, approximately 23.5 acres of additional right-of-way will be necessary to construct and maintain the ultimate improvements for Mustang Bayou.

5.2 MUSTANG BAYOU ULTIMATE IMPROVEMENTS COST ESTIMATE

Cost estimates have been prepared for each reach of the ultimate improvements. These estimates were based on unit prices given in recent bid tabulations in Harris County and vicinity. An estimate of engineering costs and a 20 percent contingency has been added to the total. The total cost for Mustang Bayou is shown in **Table 5-2** and totals $6,484,890. A breakdown of unit costs by each section is included in **Appendix D** of this report.

5.3 LOWER OYSTER CREEK RIGHT-OF-WAY REQUIREMENTS

Although this update study recommends only limited improvements to Lower Oyster Creek, we have included an estimate for right-of-way in order to repair channels and perform periodic maintenance. This right of way is similar to that proposed by LAN in the original study. The recommended right-of-way is included in **Table 5-3** and includes the acquisition of an additional 3.8 acres for the watershed**.**

5.4 LOWER OYSTER CREEK ULTIMATE IMPROVEMENTS COST ESTIMATES

The estimate for Lower Oyster Creek includes the land acquisition noted above as well as channel bank fill and the recommended improvements at the BRA Canal flume. An estimate for this work is included in **Table 5-4** and totals $542,900. A breakdown of unit costs by each section is included in **Appendix D** of this report.

Table 5-1: Additional Right-of-Way - Mustang Bayou

Section	Existing ROW Feet	Ultimate ROW Feet	Additional ROW Feet	Length Feet	Additional Area Acres
1	210-240	230	0	3000	0.0
2	130	130	0	3300	0.0
3	110-140	170	30-60	5100	5.3
4	125	200	75	6600	11.4
5	100	160	60	4900	6.8
Total Additional R-O-W					**23.5**

Table 5-2: Ultimate Improvements Cost Estimate – Mustang Bayou

Item	Section					
	1	2	3	4	5	**TOTAL**
Construction Cost	$851,200	$494,300	$371,500	$1,004,200	$298,600	**$3,019,800**
Engineering Cost 10%	$85,120	$49,430	$37,150	$100,420	$29,860	$301,980
Contingency Estimate 20%	$170,240	$98,860	$74,300	$200,840	$59,720	$603,960
Construction Total	$1,106,560	$642,590	$482,950	$1,305,460	$388,180	**$3,925,740**
R-O-W Acquisition*	$0	$0	$577,170	$1,241,460	$740,520	**$2,559,150**
TOTALS	$1,106,560	$642,590	$1,060,120	$2,546,920	$1,128,700	**$6,484,890**

*R-O-W Estimated at $2.50 per square foot

Table 5-3: Additional Right-of-Way – Lower Oyster Creek

Section	Existing ROW Feet	Ultimate ROW Feet	Additional ROW Feet	Length Feet	Additional Area Acres
KHL Outfall to Watts Plantation	170	170	0	11000	0.0
Watts Plantation to LP Diversion	180	180	0	11500	0.0
Long Point Diversion Channel	0	100	100	1500	3.4
LP Diversion to McKeever Road	150	200	50	350	0.4
McKeever Road to Sienna Channel	200	200	0	1000	0.0
Total Additional R-O-W					**3.8**
ROW widths are recommended for maintenance purposes along channels					

Table 5-4: Ultimate Improvements Cost Estimate – Lower Oyster Creek

Item	TOTAL
Construction Cost	**$95,500**
Engineering cost 10%	$9,550
Contingency Estimate 20%	$19,100
Construction Total	**$124,150**
R-O-W Acquisition*	**$418,750**
TOTALS	**$542,900**

*R-O-W estimated at $2.50 per square foot

6. COST ASSESSMENT

Costs have been calculated to determine a per-acre charge for new development that will assist the city in developing the ultimate improvements presented in this update. For reference, the LAN study recommended impact fees of $3235 and $1400 per acre for Mustang Bayou and Lower Oyster Creek, respectively. Costs in the Dodson 2001 study were estimated at $2783 and $774 per acre. Due to the increased development, the majority of Lower Oyster Creek is now developed and Mustang Bayou is in the process of development, so the majority of the project costs cannot be attributed to new development. These costs would have to be borne by the city as improvements for existing development.

Areas considered developed included existing development, development in the platting process, existing infrastructure, and areas reserved for storage and conveyance of runoff as described in this report. A breakdown of developed areas for each watershed is included in **Appendix D.**

6.1 MUSTANG BAYOU COST CALCULATION

Total Cost Estimate	**$6,484,890**
Total Acreage in Ultimate Conditions	3079 Acres
Undeveloped Acreage in Watershed (see Appendix D)	1275.1 Acres
Percent Undeveloped (Available for New Development)	41.4%
Project Cost Attributable to New Development (41.4% of Total Cost)	**$2,685,574**
Cost Per Acre (New Development Cost/Acres Available)	**$2,106.17 per Acre**

6.2 LOWER OYSTER CREEK COST CALCULATION

Total Cost Estimate	**$542,900**
Total Acreage in Ultimate Conditions	1868 Acres
Undeveloped Acreage in Watershed (see Appendix D)	541.8 Acres
Percent Undeveloped (Available for New Development)	29.0%
Project Cost Attributable to New Development (23.2% of Total Cost)	**$157,564**
Cost Per Acre (New Development Cost/Acres Available)	**$290.82 per Acre**

7. CONCLUSIONS AND RECOMMENDATIONS

Based on the HEC-HMS and HEC-RAS analyses performed for ultimate conditions, it appears that the expected ultimate development within the Mustang Bayou and Lower Oyster Creek watersheds can be mitigated as described in this report. The total estimated cost associated with this project is $6,484,890 for Mustang Bayou and $542,900 for Lower Oyster Creek. A cost assessment (or impact fee) of $2,106 and $291 per acre of new development could be applied to the Mustang Bayou and Lower Oyster Creek watersheds, respectively, in order to fund a portion of this plan. This cost assessment would cover the percentage of the total project costs attributable to new development in each watershed, but is only a fraction of the project total cost, which would have to be borne by the city as part of a capital improvement plan.

Further study will be required as the watersheds develop in order to determine the incremental changes in peak flows due to each development and when necessary improvements and modifications will be required to be installed in order to compensate for these incremental increases as noted below.

7.1 INTERMEDIATE PLAN

No intermediate implementation plan was developed for this project. Construction of any of the channel improvements in part is likely to produce impacts on downstream properties not evaluated by this study. Therefore, if an intermediate plan is to be pursued based on regional development or other programs, further detailed analysis of some combination of channel improvements and detention will be necessary. The channel improvements should be constructed in a downstream-to-upstream fashion where possible, so that the increased conveyance in the system does not impact downstream properties due to channel constrictions.

8. REFERENCES

1. **Dodson & Associates, Inc.,** ***Missouri City Master Drainage Plan Update –Mustang Bayou & Lower Oyster Creek,*** **February 2001.**

2. **Jones & Carter, Inc.,** ***Kitty Hollow Lake Detention Analysis for Memorial Hermann Hospital System,*** **July 1999.**

3. **Lockwood, Andrews & Newnam, Inc. (LAN),** ***Master Drainage Plan – Missouri City, Mustang Bayou Watershed Final Report & Lower Oyster Creek Watershed Final Report,*** **November 1987.**

4. **Miller, R.G., Engineers, Inc.,** ***Lakeshore Harbor – Detention Phase II (Response to Comments Submittal), December 2004.***

5. ***US Army Corps of Engineers, EM1110-2-1416, Engineering and Design-River Hydraulics (Chapter 5-Unsteady Flow), October 1993.***