CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

THE CITY OF

Mont Belvieu

TEXAS

Prepared for the

CITY OF MONT BELVIEU, TEXAS

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EXECUTIVE SUMMARY

Project Description

The purpose of the Mont Belvieu Master Drainage Plan (MDP) is to provide a plan by which existing and anticipated drainage and flooding problems can be quantitatively described and conceptual solutions developed. The area of project focus of the MDP for Mont Belvieu (City) is generally bounded by the Union Pacific Railroad on the west, Interstate 10 (IH-10) on the south, a Coastal Water Authority (CWA) water canal on the east, and Old River and another CWA water canal on the north.

The major watersheds in the area are Smith Gully, Hackberry Gully, Cotton Bayou, Cherry Point Gully, and Old Ditch. The major thoroughfares within the project area are FM 565, State Highway (SH) 146, Eagle Drive (also referred to as FM 3360 and FM 3180), and Interstate (IH) 10 (see Exhibit 1-1). The topography of the City ranges from around 10 feet above sea level near the bayous of the City to around 78 feet above sea level at the large salt dome formation called Barbers Hill on the west side of town. The soils are clayey and loamy and classified as soil Group D by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS).

Statement of Problem

The City of Mont Belvieu experiences ponding near its major drainage channels such as Cherry Point Gully, Cotton Bayou, Hackberry Gully, Old Ditch, and Smith Gully, though very little structural damages to homes has been reported. The ponding analysis completed for this study confirms the ponding issues reported by the City and suggests study of additional ponding areas, especially in the upper portions of the major watersheds. In addition, Old Ditch and some of the Hackberry Gully tributaries also experience erosion.

The MDP is provided for the City to assist in the understanding of their drainage systems and in planning for improvements to these systems to reduce the effects of existing drainage problems and future development. These conceptual solutions address existing and future problems and issues. As development occurs or a need for improvements is identified, the existing conditions can be addressed by making the improvements for the particular area based on the recommendations of this plan. Upon completion of construction of all the recommendations, the ultimate conditions will be addressed. This allows for a phased approach that keeps the end result in mind. By planning for ultimate improvements, the City will have greater flexibility in tailoring specific solutions depending on the type, location, and timing of future growth and current needs.

A detailed evaluation of the drainage problems of the City was performed with input from the City, the Texas Department of Transportation (TxDOT), Chambers County, CWA, and the residents. This evaluation confirms the problems reported by the City and also finds additional problems, the latter mostly dealing with ponding and bridge/culvert capacity issues.

Evaluation of Conceptual Solutions

Hydrologic and hydraulic modeling following the Chambers County Drainage Criteria Manual criteria and procedures was used to evaluate both the existing and future conditions for Cherry Point Gully, Cotton Bayou, Hackberry Gully, and Old Ditch. Smith Gully was evaluated using an existing hydraulic model. Based on the type of problem and the watershed conditions, four primary types of conceptual solutions were considered for the MDP: conveyance improvements including mitigation for those improvements, detention basins, erosion protection, and buy-outs of properties. Locations for erosion protection and buy-outs were few, so the majority of conceptual solutions are based on conveyance improvements, detention basins, or a combination of these two solutions. The five major watersheds (Cherry Point Gully, Cotton Bayou, Hackberry Gully, Old Ditch, and Smith Gully) were evaluated and specific solutions determined for each watershed.

Cherry Point Gully Problems and Solutions

The major issues within the Cherry Point Gully watershed are ponding, bridge/culvert capacity, and channel problems. These issues affect mostly residential areas in the watershed. The recommended solutions for Cherry Point Gully are: conveyance improvement of the main channel, conveyance improvements of selected tributaries, and a proactive approach to regional detention. It should be noted that the cost of the regional detention solution merely provides a guide that the City can use for estimation purposes. The actual costs of this solution will depend on what the City is able to negotiate with future land developers and current residents.

Three solutions are proposed; their costs are as follows:

Recommendation #1 (Conveyance Solution): $2,913,000
Recommendation #2 (Selected Tributary Solution): $6,680,000
Recommendation #3 (Regional Detention Pond Solution): $23,514,000

It should be noted that the conveyance solution (Recommendation #1) is a main channel solution, while selected tributary solution (Recommendation #2) is meant to improve the smaller tributaries.

Cotton Bayou Problems and Solutions

The major issues within the Cotton Bayou watershed are ponding and bridge/culvert capacity problems. These issues affect mostly the schools along the east side of Eagle Drive and some residential areas west of Eagle Drive. The recommended solutions for Cotton Bayou are: conveyance improvements of selected tributaries, conveyance improvement of the main channel, and a proactive approach to regional detention. As previously mentioned, the cost of the regional detention solution merely provides a guide that the City can use for estimation purposes.

The actual costs of this solution will depend on what the City is able to negotiate with future land developers and current residents.

Three solutions are recommended; their costs are as follows:

Recommendation #1 (Conveyance Solution): $4,930,000
Recommendation #2 (Selected Tributary Solution): $1,888,000
Recommendation #3 (Regional Detention Pond Solution): $27,908,000

Hackberry Gully Problems and Solutions

The major issues within the Hackberry Gully watershed deal with ponding. These issues affect mostly the City's administration building and most residential areas west of Eagle Drive. The recommended solutions for Hackberry Gully are: conveyance improvements of selected tributaries, conveyance improvement of the main channel, and a proactive approach to regional detention. The associated cost of the regional detention solution provides a guideline that the City can use when deciding on detention needs. The actual costs of this solution will depend on what the City is able to negotiate with future land developers and current residents.

Three solutions are proposed; their costs are as follows:

Recommendation #1 (Conveyance Solution): $4,561,000
Recommendation #2 (Selected Tributary Solution): $6,090,000
Recommendation #3 (Regional Detention Pond Solution): $16,595,000

Old Ditch Problems and Solutions

The major issues within the Old Ditch watershed are ponding and bridge/culvert capacity issues. Erosion of the main channel of Old Ditch north of Oak Ridge Drive is also another problem.

These issues affect mostly the residential areas around Old Ditch. The recommended solutions for Old Ditch are: conveyance improvement in the main channel and a proactive approach to regional detention. Due to the high costs and low benefits, erosion controls or buy-outs for dealing with the stream erosion are not recommended. It should be noted that the costs associated with a proactive approach to regional detention provides a guideline that the City can use for estimation of costs. The actual costs of this solution will depend on what the City is able to negotiate with future land developers and current residents.

The estimated costs for the two recommended solutions are as follows:

Recommendation #1 (Conveyance Solution): $503,000
Recommendation #2 (Regional Detention Pond Solution): $1,382,000

Smith Gully Problems and Solutions

Though Smith Gully was not a main focus of the MDP, some preliminary solutions were proposed for this stream. The major issues within the Smith Gully watershed are ponding and bridge/culvert capacity issues. These issues affect mostly the industrial areas alongside Smith Gully, as well as a few residential areas. The recommended solution for Smith Gully is a conveyance improvement of the main channel.

The estimated cost for this conveyance solution is $2,960,000.

Preferred Watershed Order

Based on the number of affected residents and estimated costs, it is recommended that the drainage solutions be implemented in the following watershed order: Cherry Point Gully, Hackberry Gully, Cotton Bayou, Old Ditch, and, finally, Smith Gully. It should be noted that Hackberry Gully carries a higher priority than Cotton Bayou since the drainage solutions would

benefit more residents. However, the drainage issues in Cotton Bayou affect the schools, so the City should decide the level of priority between these two watersheds. Smith Gully carries the lowest priority since this watershed is mostly industrial tracts with a few residential neighborhoods and tracts.

Summary of Recommendations and Estimated Costs

Below is a table summarizing all the recommendations for each watershed. Specific information on each drainage improvement can be found in Tables 3-3 and 3-4 (Cherry Point Gully), Tables 4-3 and 4-4 (Cotton Bayou), Tables 5-3 and 5-4 (Hackberry Gully), Tables 6-3 and 6-4 (Old Ditch), and Tables 7-1 and 7-2 (Smith Gully).

The costs presented below are for complete improvements recommended for ultimate conditions. As development occurs, portions of the recommended improvements can be implemented that would mitigate the effects of the particular development. Much of the cost for constructing channel improvements, culvert and bridge improvements, and regional detention for future developments can be borne by the future development.

Estimated Costs of Recommended Solutions

Watershed	Solution Type	Total Cost
Cherry Point Gully	Conveyance	$ 2,913,000
Cherry Point Gully	Tributary (Selected)	$ 6,680,000
Cherry Point Gully	Regional Detention	$23,514,000
Cotton Bayou	Conveyance	$ 4,930,000
Cotton Bayou	Tributary (Selected)	$1,888,000
Cotton Bayou	Regional Detention	$27,908,000
Hackberry Gully	Conveyance	$ 4,561,000
Hackberry Gully	Tributary (Selected)	$ 6,090,000

Hackberry Gully	Regional Detention	$16,595,000
Old Ditch	Conveyance	$ 503,000
Old Ditch	Regional Detention	$1,382,000
Smith Gully	Conveyance	$2,960,000
	Total Improvement Cost =	*$ 99,924,000*

SECTION 1
INTRODUCTION

1.1 Purpose and Scope

The Mont Belvieu Master Drainage Plan (referenced subsequently herein for convenience as the MDP) was authorized by the City of Mont Belvieu (the City) on December 10, 2007. Notice to proceed was issued on December 12, 2007.

The purpose of the MDP is to provide a plan by which existing and anticipated drainage and flooding problems can be quantitatively described and conceptual solutions developed. Primary tasks for the MDP include project management, data collection, site visits, identification and/or confirmation of drainage problems, participation in a public meeting, determination of problem prioritization procedures for problem selection, identification and development of conceptual solutions, cost estimation, recommendations of preferred solutions, and preparation of a project report.

1.2 Project Description

The area of focus for the MDP is generally bounded by the Union Pacific Railroad on the west, Interstate 10 (IH-10) on the south, a Coastal Water Authority (CWA) water canal on the east, and Old River and another CWA water canal on the north (see Exhibit 1-1). The major watersheds in the area are Smith Gully, Hackberry Gully, Cotton Bayou, Cherry Point Gully, and Old Ditch, as shown on Exhibit 1-2. These watersheds were considered important due to the sizeable number of documented drainage problems, which warranted a more focused approach. Buck Gully, in the north side of the City, has few drainage problems and, therefore, did not meet the criteria for evaluation as a major watershed. It should also be noted that only a very small portion of the Buck Gully

watershed is within the City, so the majority of possible needed improvements would lie outside of the City.

The major thoroughfares within the project area are FM 565, State Highway (SH) 146, Eagle Drive (also referred to as FM 3360 and FM 3180), and Interstate (IH) 10 (see Exhibit 1-2). The topography of the City ranges from around 10 feet above sea level near Old River in the northeast portion of the City to around 78 feet above sea level at the large salt dome formation called Barbers Hill in the west side of town, with an average elevation of 30 feet above sea level for the majority of the City. The soils are mostly clayey and loamy, and are classified by the Natural Resources Conservation Service (NCRS) as Group D.

1.3 Data Sources

As shown in Appendix A, data were collected from various sources including earlier studies and reports provided by the City of Mont Belvieu, plans and data sheets provided by the City and the Texas Department of Transportation (TxDOT), hydrologic and hydraulic models collected from the City, field reconnaissance, survey information provided by Chambers Surveying and Mapping, and discussions and correspondence with area entities such as TxDOT, Chambers County, and CWA. Exhibit 1-2 shows the extent of previously developed hydraulic models collected from the City. As shown in the exhibit, Old Ditch has not been previously studied. Also, the Cotton Bayou hydraulic model was extended farther north as part of this MDP.

1.4 Overview of Methodology

The City of Mont Belvieu has seen considerable growth in development, especially in the eastern part of the City as the population moves to newer subdivisions and the properties in the older neighborhoods in the west are bought by chemical companies that operate

plants on the western side of the City. As a result of the increased development, a variety of drainage issues have been encountered. While some of these drainage issues have been previously addressed, there are still issues that have yet to be resolved.

The City already has a number of drainage facilities in place. These drainage facilities are: natural drainage channels, earthen drainage ditches, roadside ditches, culverts and bridges, storm sewer systems, detention facilities, canals, and siphons.

The City has decided to pursue a more proactive role in addressing the current and future drainage needs to more effectively address various drainage problems. Through the creation of a MDP, the City seeks to establish a prioritized list of potential solutions to drainage issues that the City can incorporate into their plans. This MDP provides guidance about the current and future drainage issues and methods and solutions to address those issues.

These conceptual solutions address existing and future problems and issues. As development occurs or a need for improvements is identified, the existing conditions can be addressed by making the improvements for the particular area based on the recommendations of this plan. Upon completion of construction of all the recommendations, the ultimate conditions will be addressed. This allows for a phased approach that keeps the end result in mind. By planning for ultimate improvements, the City will have greater flexibility in tailoring specific solutions depending on the type, location, and timing of future growth and current needs.

Discussions were held with the City personnel, TxDOT, Chambers County, and CWA relating to known and potential drainage problems of the City and any plans for improvements. Additionally, a significant effort was made to obtain available hydrologic and hydraulic models, reports, plans, analyses, topographic data, limited field reconnaissance, limited survey, and public input.

The recommendations of this MDP are based on the updated hydrologic and hydraulic models and other available data. Each watershed is evaluated and presented individually. The emphasis of the MDP is on Cherry Point Gully, Cotton Bayou, Hackberry Gully, and Old Ditch, with a lesser emphasis on Smith Gully. The solutions are conceptual in nature and will require more detailed analyses to develop final designs. Prior to development of a final design project; engineering investigation should be performed based upon more detailed survey, geotechnical investigation, environmental evaluation, and right-of-way (ROW) investigation, in addition to conducting applicable hydrologic and hydraulic analyses.

1.5 Acknowledgments

Klotz Associates would like to acknowledge the support and assistance of the following individuals who provided data or insight into the drainage systems and issues associated with the City's drainage facilities: Mr. Bryan Easum, Mr. Daniel Williams, Mr. Jef Farrell, and Mr. Bill Cobabe at the City, Mr. John Sudela at TxDOT, Mr. Tommy Bridwell at Chambers County, and Mr. Jerry Berry at CWA.

SECTION 2
METHOD AND PROCEDURES

2.1 Model Creation and Criteria Used

Previous hydrologic and hydraulic models were collected in order to gain additional insight into the drainage issues and to aid in determining appropriate solutions. Models were collected for Cherry Point Gully, Cotton Bayou, and Hackberry Gully. For Smith Gully, only a hydraulic model was available, while Old Ditch did not have any previous models available (see Exhibit 1-2).

The previous hydrologic models collected in HEC-1 format were updated to the current HEC-HMS version (Version 3.2 dated April 21, 2008), while the previous hydraulic models in HEC-2 format were updated to the current HEC-RAS version (Version 3.1.3 dated May 2005). These software packages were created by the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC). HEC-1 and HEC-HMS (Hydrologic Model System) are hydrologic modeling programs that simulate the runoff based on precipitation falling on a watershed. HEC-2 and HEC-RAS (River Analysis System) are hydraulic modeling programs that simulate the water flow through rivers and channels.

For hydrologic modeling, subbasins were delineated using a combination of LiDAR (**Li**ght **D**etention **a**nd **R**anging) data and existing plans. LiDAR data is topographic data collected with a remote sensing system that measures distances with the use of aircrafts equipped with special lasers. The LiDAR data was collected from the Texas Natural Resources Information System (TNRIS), and it covers all of Chambers County.

New parameters were calculated for the updated HEC-HMS models including percent development, percent imperviousness, time of concentration, and storage coefficient. For

the existing condition hydrologic models, the existing land use types as determined from 2006 aerials were used to calculate the percent of development and imperviousness. The percentage of imperviousness is related to the amount of development for an area and expresses the amount of land cover that does not allow surface runoff to infiltrate the ground.

Time of concentration is a measure of the time needed for a particular basin to completely contribute all of its flow to the basin outlet. It was estimated on the flow characteristics of a basin, such as land cover, flow velocities, distance to outlet from farthest point on the basin. The storage coefficient is a measure of the storm water storage volume in a basin and is dependent on the time of concentration following Chambers County Drainage Criteria Manual (CCDCM).

As part of the hydraulic modeling, the channel data from the previous HEC-2 models were merged with updated cross sections based on LiDAR data and updated survey information. The reason for model updates was to standardize the modeling procedures and methods and to take advantage of Geographic Information Systems (GIS) tools, techniques and information. A main advantage of these model updates is that the new models give a better representation of the existing conditions and channel configurations for use in the determination of issues and potential solutions. For the existing condition hydraulic models, the peak flows determined from the existing condition hydrologic models were distributed along the channels based on reach length. All the hydraulic models used a hydraulically normal slope as the starting boundary condition as based on the channel invert slope near the downstream end of the channel.

In effort to standardize and update previous hydrologic and hydraulic models, certain criteria had to be chosen and utilized. Per the City's guidance, the chosen criteria were taken from the CCDCM prepared by Dodson and Associates (dated August 9, 2005). The CCDCM establishes standards and criteria for the analysis, design, and constructions

of primary and secondary drainage systems in Chambers County. A review of the CCDCM determined that the manual criteria and methods were appropriate for the level of analysis needed for the MDP development.

The updated HEC-RAS and HEC-HMS models and calculations are included in the CD provided in Appendix J. Appendix E, F, G, H, and I show the water surface profiles from the HEC-RAS models for Cherry Point Gully, Cotton Bayou, Hackberry Gully, Old Ditch and Smith Gully, respectively, as well as hydraulic model output.

2.2 Use and Limitations of Topographic Data

As part of the modeling update of the hydraulic models, limited survey was conducted within the Cherry Point Gully, Cotton Bayou, Hackberry Gully, and Old Ditch watersheds. The survey was conducted by Chambers Surveying and Mapping using a combination of Global Positioning System (GPS) data and static positions utilizing On-line Positioning User Service (OPUS) solutions containing North American Datum of 1983 (NAD 83) for horizontal control and Geoid 03 North American Vertical Datum of 1988 (NAVD 88) for vertical control, both converted to feet. The GPS data are in 2001 GPS, while the static solutions are in 2001STAT.

Only a selected list of bridges, culvert, and cross sections were surveyed. The survey locations were selected to provide a better representation of the bridges, culverts, and channel configuration in order to provide a more accurate modeling update. Where new survey data were not collected, the channel data from the previous hydraulic models were used in conjunction with LiDAR data and limited field reconnaissance. Appendix C shows the locations of bridge, culvert, and channel cross sections that were surveyed as part of the MDP for Cherry Point Gully, Cotton Bayou, Hackberry Gully, and Old Ditch. The survey points and field notes are provided as part of the CD-ROM attached to this report (Appendix J).

It should be noted that the intent of this study was not to re-level the hydraulic models to a specific datum. Some effort was done to research the amount of subsidence in the area of Mont Belvieu. Based on Harris-Galveston Subsidence District (HGSD) information, the area around Mont Belvieu has experienced very little subsidence since 1995. Therefore, the various hydraulic models used in the MDP were not adjusted. It should be noted that only the channel sections from the old hydraulic models were used in the updated hydraulic modeling; the overbanks were based on the most recent LiDAR data. Selected survey sections were also used to compliment hydraulic modeling.

2.3 Determination and Application of Development

The existing condition hydrologic model was based on the existing development and imperviousness percentages. The existing land use types were determined from 2006 aerials and delineated with GIS tools. The land use types were based on CCDCM land use types and corresponded to particular development and imperviousness percentages. The percent development and percent impervious were then calculated for each subbasin based on the type and amount of cover. These percentages were then used to develop the existing condition hydrologic models for the watersheds in order to assess existing drainage problems.

In order to assess possible future drainage problems, an estimate of future development and land uses had to be determined. The City's Comprehensive Plan for 2010 was used as the basis for this estimate; it was updated with additional input from the City. According to the Comprehensive Plan, the City is broken into four districts: West Side Industrial, the Hill, New Town, and the IH-10 Corridor (see Appendix D). The West Side Industrial district is composed primarily of heavy industrial and undeveloped land use types. The Hill is composed of primarily heavy industrial land use type with some mixed interspersed commercial and residential areas, which are being bought and

converted to industrial areas. New Town is primarily undeveloped but does have some residential and commercial areas. The IH-10 Corridor is also largely undeveloped except for some commercial areas adjacent to IH-10. According to the Comprehensive Plan and City personnel, the primary future use of undeveloped land in the West Side Industrial and the Hill districts will be for industrial use. New Town is expected to develop into a primarily dense residential area with some commercial areas along the current thoroughfares of Eagle Drive/FM 3360 and SH 146 and along the future extension of the Grand Parkway. The IH-10 Corridor is expected to become a mostly commercial district, especially along IH-10 and SH 146, with some heavy industrial areas.

The future land use types were determined from the existing land use types using 2006 aerial photos and GIS tools. All the undeveloped and open tracts were then converted to a future land use type as described in the Comprehensive Plan. This was done for each of the four major watersheds of Cherry Point Gully, Cotton Bayou, Hackberry Gully, and Old Ditch as detailed in the following sections. These future land use types were then used to determine future condition hydrologic models for these watersheds. The future condition hydrologic models were created by modifying the percent of development and imperviousness of the existing condition model to account for the increase in development. No other parameters were updated in the hydrologic models. The resulting peak flows from these future condition hydrologic models were then used to create future condition hydraulic models. There is no change between the existing and future condition hydraulic models except for different peak flows.

2.4 General Information on Drainage Issues

The major types of drainage issues in the City can be broken into four categories: lack of channel capacity, restrictions at bridges or culverts (i.e., bridge or culvert overly restricts flow), erosion, and ponding. Some of the ponding, erosion, and bridge/culvert issues were identified from conversations with the City personnel and others, but the majority of

issues were determined from the hydraulic models updated as part of the MDP development or from the ponding analysis described in Section 2-5. Table 2-1 provides a summary of issues broken down by watershed and type of issue, while Exhibit 2-1 shows the general location of these issues. A more detailed discussion of the various issues can be found in the report section for a particular watershed (see Sections 3 through 7).

2.5 Determination of Ponding Issues

In an effort to gain a better insight into the drainage issues within the City, a ponding analysis was done for the whole area. This ponding analysis was based on LiDAR data collected from the Texas Natural Resources Information System (TNRIS) for Chambers County. This LiDAR data provided the topographic base for the area. In a ponding analysis, low-lying depressions and lakes are filled with rainwater until an outlet into the next downstream area is determined for that particular depression or lake. For example, if an area at elevation of 7 feet is surrounded by a berm at elevation of 10 feet, the ponding analysis would show a ponded area with a depth of 3 feet. This ponding depth should not be considered a flooding depth resulting from a channel or bayou being overtopped. Indeed, the ponding analysis is not tied to a specific storm event. The location, extent, and depth of ponding are shown in Exhibit 2-2.

It should be noted that this ponding analysis does not take into account the culvert or bridge openings which would relieve the ponding areas. Without use of additional GIS techniques or extensive survey, the LiDAR data will only provide an estimate of ponding issues. For example, subbasin CP100A shows a large ponded area west of SH 146 since only the road elevations, but not the culvert inverts under the road, are contained in the LiDAR data. Though this area does drain to Cherry Point Gully, the ponding analysis still provides insight into potential problems. For example, if the culverts under SH 146 do not have enough capacity to convey the flows from upstream, then the area west of SH 146 can be expected to pond in a similar fashion as shown in the ponding analysis. The

locations of major ponding were estimated and added as drainage issues (see Exhibit 2-2).

2.6 General Information on Conceptual Solutions

Four primary types of conceptual solutions were considered for the MDP: conveyance improvements including mitigation for the improvements, detention basins, erosion protection, and buy-outs of properties. Locations for erosion protection and buy-outs were few, so the majority of conceptual solutions are based on conveyance improvements, detention basins, or a combination of these two. A diversion channel option was also considered but not found to be a feasible solution.

These conceptual solutions address existing and future problems and issues. As development occurs or a need for improvements is identified, the existing conditions can be addressed by making the improvements for the particular area based on the recommendations of this plan. For example, if a plot of land that is currently undeveloped is made into a park, then the needed conveyance improvements downstream of this plot can be better optimized to account for the reduced runoff potential. By the same token, if a developer decides to build on-site detention for a development, then there is a lesser need for regional detention, so the regional detention pond can be made smaller. However, this MDP provides estimates of needed conveyance and detention improvements.

Upon completion of construction of all the recommendations, the ultimate conditions will be addressed. This allows for a phased approach that keeps the end result in mind. By planning for ultimate improvements, the City will have greater flexibility in tailoring specific solutions depending on the type, location, and timing of future growth and current needs.

As with any planning study, the City always has the option of not pursuing any solution. This "do-nothing" approach maintains the status quo, which has been found to be unacceptable to the City and residents from a drainage perspective. There may be instances when it could be better for the City to "do nothing" for a particular problem because of high costs or very limited benefits. However, for this MDP, all the major watersheds have viable solutions that the City can pursue. Therefore, a "do-nothing" approach was not considered for the MDP.

2.6.1 Types of Solutions

A conveyance improvement could entail improvements to the drainage channels, replacement of selected bridges or culverts, and building detention ponds to mitigate the impacts caused by the conveyance improvements. The proposed channel improvements involve widening and deepening the channel in selected reaches. When hydraulic modeling indicated bank overflow based on the water surface elevation of the channels, the models were used to enlarge the channel sufficiently to eliminate the overflow. Proposed trapezoidal sections in selected reaches of these channels were grass-lined and had sides slopes of six horizontal units to one vertical unit (6:1) where open land was available or 3:1 side slopes in locations with less available open land.

Selected bridge and culvert replacement was used where large head losses, as calculated by modeling, were determined at the bridge or culvert in question. The selected bridge or culvert crossing was enlarged to increase its conveyance capacity and allow the 100-year event peak flows to be conveyed through the structure without overtopping of the road.

A consequence of these improvements was an increase in the flow conveyance of the channel, which may result in flow and water surface elevation impacts downstream of the conveyance improvements. Therefore, detention basins were added at selected locations

in each watershed to mitigate for conveyance improvements. Open areas shown on aerial photos were used as preliminary detention basin sites. It should be noted that, depending on channel modifications and channel restrictions downstream of the improvement locations, the conveyance improvements may act as on-line storage. However, to be more conservative, this secondary function was not considered.

While the hydrologic and hydraulic models could be used to determine the needed conveyance improvements for the main channels, the small channels and tributaries to the main channels required a different analysis since no models were available for these drainage features. It should be noted that this tributary analysis, though slightly modified, is still a conveyance improvement solution.

The primary tributaries in each subbasin were determined based on a contributing area of approximately 200 acres for creation of new tributaries or a channel length of 500 feet for existing tributaries. The contributing area to each tributary was delineated with the aid of GIS. Peak flows for use in developing the tributary conveyance improvements were determined from the area-discharge relationship for each subbasin. It was assumed that 25% of the contributing flow to the tributary entered in the upstream end while the rest occurred at the downstream end. Based on a typical depth of ten feet and 6:1 side slopes, the bottom widths of the trapezoidal channel needed to convey the flows was estimated for both the upstream and downstream ends of the channel improvement. In areas where no tributary currently exists, new tributaries were determined for this analysis. The sizes of the channel improvements were then used to estimate the costs of that particular channel improvement based on excavation and right-of-way acquisition costs.

As part of the development of tributary conveyance improvements, the "Eagle Drive Drainage Study (FH 565 – I10)" by Claunch & Miller, Inc. dated June 2004 was reviewed to determine what improvements, if any, could be used as part of the MDP. This study provided a plan for lateral ditch and culvert improvements along Eagle Drive

from FM 565 to IH-10. These improvements serviced the eastern part of the Hackberry Gully watershed and the western part of the Cotton Bayou watershed. The laterals improvements proposed in the Claunch & Miller study were incorporated in the MDP though not directly because the proposed improvements recommend 3:1 side slopes, which, though adequate, are not the City's preferred 6:1 side slope.

Another conceptual solution that was evaluated for the MDP was a detention only solution. For this evaluation, the future condition hydrologic models were compared with the existing condition hydrologic models to determine the amount of detention storage needed to reduce the increased peak flows from the future condition to existing conditions level. Following the CCDCM requirements, the design storm frequency for this detention analysis was the 100-year storm event. The criteria manual also states that pond side slopes of 3:1 are the minimum requirement. However, a slightly more conservative value of 4:1 was chosen to account for some slope instability. Maintenance berms of 30 feet were used with each detention basin.

This detention solution serves subwatershed basins, so it can be considered a regional detention solution. However, another option is to construct a number of smaller detention ponds that could include on-site detention. This ties into the option of addressing localized needs as development occurs. Determining the appropriate option for detention should be based on availability of land, access to the detention site by other sites, and elevation issues. While the storage volumes calculated are for dry ponds, the City does have to option to build wet ponds depending on the priorities of a specific area.

Hydrographs were extracted for each subbasin from the existing condition models and compared to their respective future condition model discharge rates to determine the amount of detention storage needed to reduce the future condition peak flow to existing conditions level. Using this detention volume, a detention basin size was estimated. The detention basins were placed in open areas shown on aerial photos of the area. This

detention analysis was applied to every subbasin in the four major watersheds except where the subbasin was already completely developed in the existing condition model. In such instances, a detention basin solution was not considered.

Based on conversations with the City and input from the Mont Belvieu public meeting, there are a few channels and tributaries that have erosion problems. Only Hackberry Gully and Old Ditch have documented cases of erosion problems. A conceptual solution to dealing with these issues is to provide some form of erosion protection such as flatter side slopes, constructing retaining walls or placing rip-rap on the slopes.

A final conceptual solution considered was selected home buy-outs. In certain locations, a more viable solution to dealing with the drainage issues of the area is to buy the affected properties and return them to an undeveloped state for which flooding damage would be absent or minimal. Limited repetitive loss data was obtained from the National Flood Insurance Program (NFIP) web site. Complete data from the City was not available at the time of this report.

A conceptual solution that was not considered a viable solution was diversion channels. The intent of a diversion channel is to divert water from one stream to another, thereby reducing the flows from the source channel. Two locations were considered as potential diversion channel sites. The first location is in the northeast part of the City and would divert flow along an abandoned Coastal Water Authority (CWA) canal east of Old Ditch. This diversion channel was to alleviate the flooding around the intersection of Eagle Drive and FM 565. However, CWA has no plans to release the abandoned canal section since this section could be used as a future water access point, so this diversion channel was not feasible. The other location for a diversion channel is in the southeast part of the City. Beginning 850 feet north of IH-10, this diversion channel was to divert flow from Cotton Bayou to the east to an Old River tributary near Icet Cemetery. The difficulty with such a new diversion channel is that the channel would be outside of the city limits

and would entail coordinating the construction work with other entities and stakeholders such as the City of Baytown, Chambers County, FEMA, CWA, and Texas Commission on Environmental Quality (TCEQ). The diversion channel would cross two CWA canals, which would require the approval of and coordination with CWA. Both diversion channels would also require the approval of FEMA. Since flow is being diverted from one watershed to another, FEMA would require a drainage study on both channels to confirm that no negative impacts result from the diverted flow. Therefore, diversion channels were not considered viable options for the City to pursue at this time.

2.6.2 Advantages and Disadvantages of Conceptual Solutions

Each of the aforementioned solutions has inherent advantages and disadvantages that should be reviewed by the City in order to make informed decisions as to what solutions to pursue. Solutions can vary in character and, therefore, have their own specific sets of pros and cons, but general pros and cons can be identified.

A general pro of the main channel conveyance improvement option is that it tends to be a cheaper alternative to building a detention pond, for example. This is due to the fact that the majority of the conveyance improvements occur within the right-of-way of the existing channel, so less land acquisition is typically necessary. Another benefit of a conveyance improvement is that it provides an efficient method of increasing the channel capacity and, thereby, reducing water surface elevations on along and upstream of the improved channel. This improved capacity, however, is a detriment to areas downstream of the improvement since this solution results in higher flows and higher water surface elevations downstream of the conveyance improvement that must be mitigated.

This set of pros and cons is valid for both the main and tributary channels. However, a few of the tributaries may require additional right-of-way since they may lack a designated easement. Also, the tributary conveyance improvements result in larger

channels than is needed from a hydraulic perspective. This is due to the fact that it was the intent of the MDP to allow for an appropriate channel depth for future storm sewers. This minimum channel depth will provide more channel capacity than is needed for the smaller tributaries. However, allowing for the future storm sewers would reduce or avoid the need for roadside drainage ditches, which require periodic maintenance and can be easily blocked with debris at driveway culverts. It should be noted that the proposed tributary improvements with side slope of 6:1 will not require additional ROW compared to current design utilizing 3:1 side slopes. As shown on Figures 2-1 and 2-2, both the proposed channel section with side slopes of 6:1 and the typical current section with side slopes of 3:1 will result in the same top width (TW). Assuming a depth of 10 feet and a minimum bottom width of 6 feet, the minimum ROW required for both channels is 126 feet, due to the 30-foot maintenance berm requirements needed in on both banks of the typical channel section.

Figure 2-1

Proposed Channel with 6:1 Side Slopes

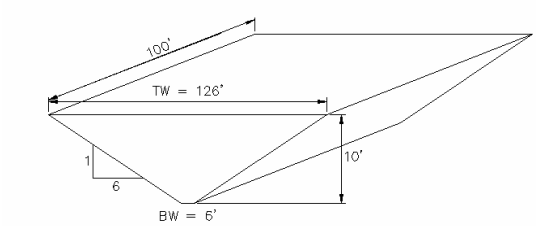
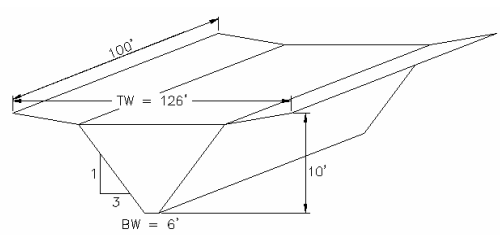


Figure 2-2

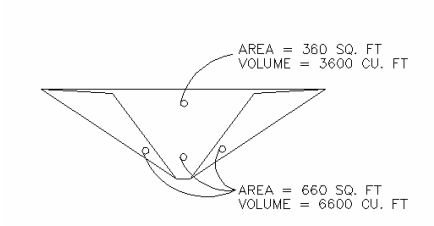
Typical Channel with 3:1 Side Slopes



However, it should be noted that the amount of excavation needed to construct the channel with 6:1 side slopes is approximately 83% larger than the current typical channel per unit length of channel as shown on Figure 2-3 (a unit length of 100 feet was used in the example below).

Figure 2-3

Area-Volume Comparison



A main disadvantage of detention ponds is that they tend to be more expensive than a conveyance solution, for example. This can be attributed to higher costs of acquiring property. This also touches another con. Depending on the area being serviced, detention ponds can be large. Therefore, there are limited locations where a detention pond can be built. Also, wet detention ponds can attract mosquitoes and vermin. Even dry detention ponds can become shallow wet ponds or marshland if not properly drained and maintained. Detention ponds do have a number of benefits. One main benefit is that detention ponds can capture flow discharge before it enters the channel, thereby avoiding the need to improve the channel conveyance downstream of the detention pond. Also, depending on their characteristics, detention ponds can provide water quality enhancements and be aesthetically pleasing.

2.6.3 Types of Detention Ponds

Detention ponds can vary in size, functionality, and effectiveness, which result in a variety of detention solutions, each with a number of pros and cons. Detention ponds can be wet or dry, on-line or off-line, regional or on-site, aboveground or underground or any combination thereof.

Both wet and dry ponds serves similar detention functions of capturing flow. However, wet ponds are built in such a manner such that they have a pool of water which does not drain. This characteristic makes wet ponds more aesthetically pleasing and can improve

water quality since biochemical reactions that remove pollutants can occur in the permanent pool. However, wet ponds are more likely to become mosquito breeding grounds than dry ponds. An advantage of dry ponds over wet ponds is that dry ponds can serve as a mixed-use facility for parks and sport fields when dry. Dry ponds, however, can trap debris after a storm event, so they require more maintenance. They also can become infested with mosquitoes if not properly maintained or drained.

Detention ponds can either be on-line or off-line. On-line detention ponds are built along the flow path of an area, such as along channels, so that all the flows pass through the detention pond. Off-line detention ponds are built away from the flow path of an area and only a portion of the flows pass through the detention pond. On-line detention ponds tend to be less efficient than off-line detention ponds, requiring more storage volume in some cases.

Regional detention ponds, as their name implies, service a larger area than on-site detention ponds. Regional detention ponds, therefore, are more efficient at reducing peak flows from a watershed. A disadvantage to regional detention is that larger conveyance improvements are needed upstream of the regional detention to mitigate for the upstream unattenuated flows. On-site detention may be a cheaper solution to the City than regional detention since generally a developer will construct the on-site detention as part of the development, while regional detention may or may not have a greater participation by the City in its development. Regional detention facilities are also large enough to serve as dual use facilities such as parks or playing fields.

Detention can be either aboveground or underground. Both aboveground and underground detention serve the same purpose of storing water and attenuating flows, the only difference being where they are located. Underground detention, due to the construction costs of building pipes or other specialized chambers, tends to be more expensive than aboveground detention. Underground detention, however, can be built

under parking lots or other facilities, thereby allowing more land to be used for development.

2.7 Procedures for Prioritizing Drainage Issues and Solutions

Part of the MDP development entailed determining a list of drainage priorities that the City could use to better address the drainage issues. Therefore, a method for prioritizing issues and solutions was determined. According to the National Flood Insurance Program (NFIP), there have been only eleven instances of repetitive loss claims in the City of Mont Belvieu, and these totaled approximately $23,000 in insurance claims paid. It should be noted that this limited repetitive loss data was collected from the NFIP website. Complete repetitive loss data from the City was not available at the time of this report. Often repetitive loss data is a good basis for determining major drainage problems and the associated costs. However, for Mont Belvieu, the sparse repetitive loss data required other ways of estimating the problems and potential solutions.

As previously mentioned, the major drainage issues were determined from conversations with City personnel, TxDOT, and Chambers County about the drainage issues in the area as explained in previous sections (see Section 2-4 and 2-5) and from a review of the hydrologic and hydraulic models. These issues were placed in four main categories in order of priority: existing issues identified by the City, existing issues identified from the updated models, existing ponding issues, and future issues from the updated models. This prioritization was chosen since existing issues that have already been documented should carry more weight than future issues that may or may not occur, depending on the actual future conditions. And while the existing model and existing ponding issues are important, they have not been confirmed so they should be less important than the existing documented issues.

The cost of a particular solution was estimated from the land and construction costs and assumes that the City would need to buy the needed right-of-way (ROW) for the needed improvement. This is especially true in some of the older subdivisions where there is no assigned drainage easement such as is the case of some lateral ditches of Hackberry Gully. Based on previous experience, an average value of $25,000 per acre-foot was used for the detention and mitigation pond excavations. A typical property value of $125,000 per acre was used for ROW and land acquisition in developed areas, which reflects a developed residential tract of land. Thirty-thousand dollars ($30,000) per acre was used for undeveloped residential land. For bridge or culvert improvements, an average cost per linear foot was used based on culvert sizes plus a lump sum of $20,000 for traffic control and storm water pollution prevention plan (SWPPP). Table 2-2 shows the unit prices that were used to estimate the costs of the various drainage improvements.

Using the list of prioritized issues and solution costs, various solutions were created for each watershed (see Section 3 through 7). If two improvement projects had similar associated costs, but one solved issues of higher priority than the other, then that project solution would have a higher priority. By the same token, if two improvement projects had issues with similar priorities, then the less expensive project solution would have the higher priority.

It should be noted that the improvements modeled the ultimate set of improvements for a watershed. Portions of the needed improvements can be built, but may require other interim improvements compared to the ultimate planned improvements. These improvements can be completely or partly paid for by the developers as development occurs. The City can coordinate with the developers to determine a fair compensation for the drainage improvements whether it be an actual payment, a drainage fee on the proposed development, or a land donation to the City for drainage easement purposes, for example. The improvements do not have to be built to ultimate conditions right away but can be constructed in phases as development occurs. For example, if only a portion of a

subbasin is being developed, then only a portion of the regional detention pond that will service the subbasin needs to be built. As additional areas develop, then the regional detention pond can be expanded to accommodate the increased runoffs.

SECTION 3
CHERRY POINT GULLY

3.1 Description

This section details the issues, conceptual solutions based on the methods and procedures described in Section 2, and estimated costs associated with the various solutions for Cherry Point Gully. The Cherry Point Gully watershed is located in north Mont Belvieu. It is bounded by the CWA water canals in the west and south, by Old Ditch and Old River in the east, and by Buck Gully in the north (see Exhibit 3-1). The Cherry Point Gully watershed has a total drainage area of 4.7 square miles (2988 acres), most of which is undeveloped as shown in the hydrologic parameters table (Table 3-1). The majority of the developed tracts are residential land use types, especially along Cherry Point Drive and along River Run Drive, with a few interspersed light industrial tracts and developed green areas (golf course) as shown on Exhibit 3-2. The average imperviousness of the watershed is approximately 7%.

Cherry Point Gully is approximately 23,000 feet (4.4 miles) long. This drainage channel begins just east of the elevated CWA water canal near the Union Pacific Railroad and drains in an easterly direction to its confluence point with Old River. Most of the Cherry Point Gully tributaries drain into Cherry Point Gully from the southwest to the northeast with the exception of one tributary upstream of Cherry Point Drive, which drains from a northwest to southeast direction. The approximate upper third of the channel is fairly shallow with tall grasses and trees in its overbanks. The middle third (between SH 146 and Cherry Point Drive) was recently improved to a trapezoidal grass-lined channel and is about eight to ten feet deep. The lower third of the channel (downstream of Cherry Point Drive) is characterized as a meandering natural channel with heavy underbrush and trees (but well maintained along the golf course) with steep channel and side slopes.

3.2 Drainage Issues

As shown in Table 2-1 and Exhibit 3-1, the drainage issues in the Cherry Point Gully watershed are almost evenly distributed among ponding, bridge/culvert, and channel issues. According to the City, the street ponding on Eagle Ridge Drive in the Eagle Pointe Estates subdivision is caused by a lack of channel capacity resulting from the flat slopes of the ditches. Also, the Fisher's Landing subdivision has standing water during a major storm event.

Many of the ponding issues were determined with the use of LiDAR data. As shown in Table 2-1 and summarized in Exhibit 3-1, the majority of the ponding issues are located upstream of SH 146 and Eagle Drive. It should be noted, however, that this ponding analysis merely estimates potential areas of ponding assuming that the downstream tributaries or culverts are unable to convey the drainage flows efficiently.

The bridge and culvert issues were determined from the updated HEC-RAS modeling. As shown in Table 2-1, a number of bridge and culvert crossing were overtopped starting at the 10-year storm events for the existing condition peak flows given in Table 3-2. Though a number of bridges within the golf course were overtopped, the 100-year floodplain top width through this area ranges from 100 to 200 feet. The river banks, too, are overtopped in both the existing and future condition models downstream of Station 8441, but these overtopping results in floodplains ranging from 100 to 200 feet for the 100-year storm event. This overtopping also includes Stations 7673, 7344, 6740, and 6091 near the Recreation Center, so the Recreation Center does not flood due to the overtopping of Cherry Point Gully. Appendix E provides more detailed hydrologic and hydraulic model outputs and water surface profiles, as well as the previous hydrologic and hydraulic models inputs collected from the City and selected photos. These same bridge and culvert locations were also overtopped in the future conditions models but starting at smaller storm events (5-year storm event for Golf Bridge #1, for example).

The future conditions peak flows used for this modeling are shown in Table 3-2, while Exhibit 3-3 shows the future land use estimates used to determine the future conditions peak flows.

3.3 Development of Conceptual Solutions

Due to the character of issues in the Cherry Point Gully watershed, three main solutions for dealing with those issues were identified: conveyance improvement for the main channel, conveyance improvement for the tributaries, and detention-only improvement for each subbasin. Exhibit 3-4 shows the various conceptual solutions created for Cherry Point Gully.

It should be noted that the conveyance solution for the main channel of Cherry Point Gully includes channel modifications, selected culvert replacements, and a mitigation basin to deal with the impacts caused by the channel modifications and culvert replacements. As shown in Table 3-3, the channel modifications for Cherry Point Gully include enlarging the channel near Cherry Point Drive and continuing upstream to SH 146 since the channel overtops its banks through this section (see Appendix E for water surface profiles). Since the area near Cherry Point Drive is already densely developed and has limited ROW, a concrete-lined trapezoidal channel with side slopes of 1.5:1 and bottom width of 8 feet was proposed through this portion of the stream. Between nodes CP#1 and CP#2, a trapezoidal grass-lined channel was used for the channel modifications with a bottom width of 6 feet, 6:1 side slopes, and a typical depth of 12 feet. The flat channel side slopes remove the need for maintenance berms, while increasing the flow capacity of the channel.

The culverts modified as part of the conveyance solution are at SH 146 and Eagle Drive. Currently, the SH 146 culvert crossing is composed of four 6'x4' reinforced-concrete

boxes (RCBs). It is proposed that these culverts be replaced with dual 8'x10' RCBs. At Eagle Drive, the three 7'x7' RCBs are to be replaced with dual 8'x10' RCBs. These culvert replacements will reduce the head loss through the crossings and prevent the roads from being overtopped during the 100-year event.

Due to these channel improvements, the increased channel conveyance may potentially result in adverse downstream flow impacts, which should be mitigated. Building a mitigation pond is a conservative approach for dealing with the potential increase in downstream channel flows. This mitigation pond within subbasin CP100B1 provides a mitigation volume of 29.9 acre-feet and requires a surface area of 4.9 acres, including maintenance berms and a total excavation volume of 34 acre-feet. Exhibit 3-4 shows the alignments and extents of the channel improvements, the culvert modification at SH 146 and Eagle Drive, and the general location of the mitigation pond. It should be noted that the location of the mitigation pond merely provides a reasonable location estimate based on aerial photos and should not be considered final. It should be noted that these improvements address the ponding and road overtopping issues due to future condition only, since those issues are not present in the existing condition HEC-RAS model.

For the tributary analysis, a number of tributaries were enlarged or new tributaries built to convey the contributing area flows. This tributary analysis is essentially a set of conveyance solution for the tributaries of Cherry Point Gully. Unlike the main channels of Cherry Point Gully, the channel geometries and flow characteristics of these tributaries were estimated. A typical depth of 10 feet, side slopes of 6:1, and bottom widths 6 feet were used in determining these trapezoidal grass-lined tributary sections as shown in Table 3-3. It should be noted that this trapezoidal channel configuration has a much larger capacity than is needed to convey the contributing area flows. The larger channel depth will permit future developments to build curb and gutter road sections with storm sewer instead of roadside ditches. The alignments and extents of these tributaries are shown on Exhibit 3-4.

The detention-only improvement entails constructing regional detention ponds within each subbasin to reduce the future condition peak flows at each subbasin to existing condition levels. The required detention volume for each subbasin was estimated from the updated hydrologic model for Cherry Point Gully. As shown in Table 3-3, the smallest detention pond is for subbasin CP100H (2.9 acre-feet), while the largest detention pond is for subbasin CP100A (270.4 acre-feet). This is to be expected since CP100A is mostly undeveloped and has a large drainage area (1.135 square miles), while CP100H is mostly developed and has a much smaller drainage area (0.140 square miles). Therefore, the difference between future conditions and existing conditions peak flows for CP100A are much greater than for CP100H, which results in a greater detention pond volume to mitigate for the flow impacts. The general location and size of the various detention basins for Cherry Point Gully are shown on Exhibit 3-4. As with the mitigation ponds in the conveyance solution, the locations of the detention ponds provide only reasonable locations of where the detention ponds could be built. The final location and configuration will depend on a more detailed analysis. This detention option can also be tailored to allow for a mixture of on-site and regional detention ponds depending on development patterns, funds, and the cooperation between the City and developers. Though no specifics are given as part of the MDP, these detention ponds can be built as dual purpose facilities that can be used as parks, sport fields, or other amenities when dry.

3.4 Preliminary Conceptual Solutions

The purpose of this MDP is to anticipate the drainage needs of the City and give the appropriate tools and guidance to City personnel to plan for the future. It should be noted that the solutions reviewed below allow the City the flexibility to deal with their own issues and plan for appropriate improvements within the City limits without relying upon other entities for funding sources or approval and permitting.

Option #1 (Conveyance Solution): A conveyance solution was found to be a cost-effective option available to the City. This conveyance solution entails enlarging the existing channel from SH 146 to CP#2 with a trapezoidal grass channel with 6:1 side slopes. The flatter side slopes would reduce the potential of erosion and make the maintenance of the channel easier. Near Cherry Point Drive, it is recommended that the City enlarge the channel with a trapezoidal concrete-lined section with 1.5:1 side slopes due to the limited right-of-way between the existing homes. A mitigation pond with a volume of 33.21 acre-feet is required to mitigate the conveyance improvements. The City should look into ways of acquiring the needed right-of-way for the channel and mitigation pond improvements. The total cost of this solution is estimated at $2,913,000 as shown in Table 3-4.

Option #2 (Tributary Solution): Due to the increased development occurring in a number of areas, it is recommended that the City begin acquiring land and ROW to improve the conveyance of a number of tributaries to Cherry Point Gully found in Table 3-3 and shown on Exhibit 3-4. These tributaries may already have some assigned drainage easements, but the City should confirm or acquire ownership so that future improvements to the tributaries can be pursued. This would also give greater access to City personnel for current maintenance of the ditches. As shown in Table 3-4, the total cost of this solution is estimated at $12,222,000 but ranges in price from $233,000 to $1,395,000 for individual tributary improvements. Based on Table 3-3, some tributaries were selected as good candidates for improvement. These tributaries are CP100C-1, CP100C-2, CP100D-1, CP100D-2, CP100E2-1, CP100E2-2, CP100E2-3, CP100F2-1, and CP100F2-2. These tributary areas were chosen since they have either recently been or will soon become developed. For example, the tributary in area CP100E2-3 can be improved to accommodate the Eagle Pointe Estates and reduce the amount of ponding on Eagle Ridge Drive, while CP100C-2 can improve the capacity of the ditch south of Cherry Point Gully subdivision. These tributaries may already have some assigned drainage easements, but the City should confirm or acquire ownership so that future improvements to the

tributaries can be pursued. This would also give greater access to City personnel for current maintenance of the ditches. The total cost of this selected tributary solution is estimated at $6,680,000 but does not include the costs of mitigation downstream impacts, which require a more detailed hydrologic and hydraulic analysis for each tributary. However, due to the overcapacity of the tributary channels, the cost of mitigation might only entail an appropriate outfall structure, essentially creating an on-line detention pond.

Option #3 (Regional Detention Ponds Solution): Due to the high costs and variability of the detention solution options, the City may not be able to construct the detention ponds immediately. However, it is recommended that the City continue to be proactive in pursuing detention solution options as more developments are built within the City. Since the Cherry Point Gully watershed has some available land at locations that can be used for regional detention, it is recommended that the City begin acquiring the land. Buying the land at current prices would reduce to overall costs of the detention solution since land values generally increase over time. The City could guide future developers toward a more regional plan that would help not only the developer but also the public. This plan would reduce some of the inefficiencies of developing detention solutions piecemeal and would give the City the ability to recoup some or all of the costs of constructing detention ponds with some sort of impact or drainage fee. Another variation to this regional detention plan would be to require on-site detention ponds on all future developments, which provide essentially the same protection. However, by having a regional detention plan, the City and developers have more flexibility in addressing the impacts of new developments since the developers would have the options of doing on-site detention or paying the City to use a regional detention pond. The total cost of this solution is $23,514,000 assuming all the regional detention ponds are built simultaneously (see Table 3-4).

3.5 Recommended Solutions

Based on the results of the MDP and engineering judgment, all three solutions (conveyance, tributary, and detention) are viable options and should be pursued by the City. For the tributary solution, the City should focus primarily on the selected tributaries if funds are limited. The conveyance and tributary solutions should be built before the regional detention solution since the latter is highly dependent on a number of variables, including the conveyance and tributary improvements. However, to avoid downstream impacts from the conveyance and tributary improvements, the necessary mitigation ponds, if needed, should be constructed before the conveyance improvements are made. A summary of the solutions and costs is provided below:

Conceptual Solution Cost Summary

Solution Type	Recommended	Total Cost
1. Conveyance	Yes	$ 2,913,000
2A. Tributary (All Tributaries)	No	$12,220,000
2B. Tributary (Selected Tributaries)	Yes	$ 6,680,000
3. Regional Detention	Yes	$23,514,000

It should be noted that the improvements modeled the ultimate set of improvements for the watershed. Portions of the needed improvements can be built, but may require other interim improvements compared to the ultimate planned improvements. These improvements can be completely or partly paid for by the developers as development occurs. The City can coordinate with the developers to determine a fair compensation for the drainage improvements whether it be an actual payment, a drainage fee on the proposed development, or a land donation to the City for drainage easement purposes, for example.

SECTION 4
COTTON BAYOU

4.1 Description

This section details the issues, conceptual solutions based on the methods and procedures described in Section 2, and estimated costs associated with the various solutions for Cotton Bayou. The Cotton Bayou watershed is located in east Mont Belvieu. It is bounded by the CWA water canals in the east, by FM 565 in the north, and Eagle Drive in the east, and IH-10 to the south (see Exhibit 4-1). While the Cotton Bayou watershed continues further south, only the portion north of IH-10 within the City of Mont Belvieu was considered for the MDP. The Cotton Bayou watershed has a total drainage area of 3.1 square miles (1974 acres), with the majority being undeveloped as shown in the hydrologic parameters table (Table 4-1). The majority of the developed tracts are light industrial land use types, especially along the east side of Eagle Drive, with a few interspersed residential tracts and developed green areas (baseball fields) as shown on Exhibit 4-2. The average imperviousness of the watershed is approximately 13%.

Cotton Bayou is about 30,000 feet (5.7 miles) long. This drainage channel begins just south of the elevated CWA water canal and drains in a southeasterly direction to its confluence point with Cotton Lake. There is an undefined swale that drains the area north of the CWA canal through a siphon under the canal into the upstream end of Cotton Bayou. There are a number of tributaries that drain toward Cotton Bayou from both the west and the east. Cotton Bayou was recently improved to a trapezoidal grass-lined channel starting at Prairie Avenue and continuing south toward IH-10. South of IH-10, Cotton Bayou becomes a meandering channel with heavy underbrush and tall grasses along the overbanks.

4.2 Drainage Issues

As shown in Table 2-1 and Exhibit 4-1, the drainage issues in the Cotton Bayou watershed are almost evenly distributed between ponding and bridge/culvert issues. According to the City, a number of subdivisions have reported street ponding, some of which were confirmed with the ponding analysis.

Many of the ponding areas were determined with the use of LiDAR data. As shown in Table 2-1 and summarized on Exhibit 4-1, the majority of the ponding issues are located between Eagle Drive and Cotton Bayou. This area includes the high, middle, and elementary schools of Barbers Hill Independent School District, which was confirmed by residents attending the public meeting conducted on September 4, 2008. It should be noted, however, that this ponding analysis merely estimates potential areas of ponding and assumes that the downstream tributaries or culverts are unable to convey the drainage flows efficiently.

The bridge and culvert issues were determined from the updated modeling. As shown in Table 2-1, a number of culvert crossings were overtopped for the existing conditions peak flows given in Table 4-2. These same culvert locations were also overtopped in the future conditions models but starting at smaller storm events. The future conditions peak flows used for this modeling are shown in Table 4-2, while Exhibit 4-3 shows the future development estimates used to determine the future conditions peak flows. Appendix F provides more detailed hydrologic and hydraulic model outputs and water surface profiles from the hydraulic model, as well as the previous hydrologic and hydraulic models inputs and selected photos.

4.3 Development of Conceptual Solutions

Due to the character of issues in the Cotton Bayou watershed, three main solutions for dealing with those issues were identified: conveyance improvement for the main channel, conveyance improvement for the tributaries, and detention-only improvement for each subbasin. Exhibit 4-4 shows the various conceptual solutions created for Cotton Bayou.

It should be noted that the conveyance solution for the main channel of Cotton Bayou includes channel modifications, selected culvert replacements, and a mitigation basin to deal with the impacts caused by the channel modifications and culvert replacements. As shown in Table 4-3, the channel modifications for Cotton Bayou included enlarging the channel starting near node CB100#3 and continuing upstream to just downstream of the water canal. Channel side slopes of 6:1 side slopes were used for these channel modifications. A trapezoidal grass-lined channel was used for the channel modifications with bottom widths ranging from 30 to 40 feet. The flat channel side slopes remove the need for maintenance berms, while increasing the flow capacity of the channel. Appendix F shows the water surface profiles for Cotton Bayou used to estimate the amount of channel improvements needed.

Three culvert crossings and one canal siphon crossing were modified as part of the conveyance solution. The three culvert crossings are at Perry Road, Kathleen Drive, and an access road, while the siphon crossing occurs at the CWA canal. At Perry Avenue, the existing dual 10'x8' RCBs were replaced with a bridge with the low chord at the existing soffit elevation of the culverts. At Kathleen Drive, two 8'x7' RCBs were added to the existing dual 8'x7' RCB system. At the access road, the single 36-inch corrugated metal pipe (CMP) was replaced with dual 9'x8' RCBs. For the siphon crossing under the canal, it is proposed that the existing dual 48-inch CMPs be replaced with four 72-inch CMPs. These culvert/siphon improvements will reduce the head loss through the road or canal crossings and prevent the road/canal from being overtopped during the 100-year event. It

should be noted that though there is a large head loss at IH-10, no improvements are proposed at this bridge crossing. TxDOT has recently rebuilt this crossing, so there are no plans to pursue any additional construction work.

Due to these channel improvements, the increased channel conveyance may potentially result in adverse downstream flow impacts, which should be mitigated. Building a mitigation pond is a conservative approach for dealing with the potential increase in downstream channel flows. A single mitigation basin is proposed for this conveyance solution. The mitigation pond for Cotton Bayou was placed just north of IH-10. This approximately 10-foot deep basin supplies a mitigation volume of 62 acre-feet and has a surface area of 9 acres, including a 30-foot maintenance berm around the mitigation pond.

Exhibit 4-4 shows the alignments and extents of the channel improvements, the bridge modification at various crossings, and the general location of the mitigation pond. It should be noted that the location of the mitigation pond merely provides a reasonable location based on aerial photos and should not be considered final. It should be noted that these improvements solve both the existing and future condition problems.

For the tributary analysis, a number of tributaries were enlarged or new tributaries built to convey the contributing area flows. This tributary analysis is essentially a set of conveyance solutions for the tributaries. Unlike the main channels of Cotton Bayou, the channel geometries and flow characteristics of these tributaries were estimated. A typical depth of 10 feet, side slopes of 6:1, and bottom widths 6 feet were used in determining these trapezoidal grass-lined tributary sections as shown in Table 4-3. It should be noted that this trapezoidal channel configuration has a much larger capacity than is needed to convey the contributing area flows. The larger channel depth will permit future developments to build curb and gutter road sections with storm sewer instead of roadside ditches. The alignments and extents of these tributaries are shown on Exhibit 4-4.

The detention-only improvement entails constructing regional detention ponds within each subbasin to reduce the future conditions peak flows at each subbasin to existing conditions levels. The required detention volume for each subbasin was estimated from the updated hydrologic model for Cotton Bayou. As shown in Table 4-3, the smallest regional detention pond is for subbasin CB100A (178 acre-feet), while the largest pond is for CB100D (275 acre-feet). The general location and size of the various detention basins for Cotton Bayou are shown on Exhibit 4-4. As with the mitigation ponds in the conveyance solution, the locations of the detention ponds provide only reasonable locations of where the detention ponds could be built. The final location and configuration will depend on a more detailed analysis. This detention option can also be tailored to allow for a mixture of on-site and regional detention ponds depending on development patterns, funds, and the cooperation between the City and developers. Though no specifics are given as part of the MDP, these detention ponds can be built as dual purpose facilities that can be used as parks, sport fields, or other amenities when dry.

4.4 Preliminary Conceptual Solutions

The purpose of this MDP is to anticipate the drainage needs of the City and give the appropriate tools and guidance to City personnel to plan for the future. It should be noted that the solutions reviewed below allow the City the flexibility to deal with their own issues and plan for appropriate improvements within the City limits without relying upon other entities for funding sources or approval and permitting. Three solutions are recommended for Cotton Bayou: conveyance, tributary, and detention solutions.

Option #1 (Conveyance Solution): It is recommended that the City enlarge Cotton Bayou from the CWA canal south to Prairie Avenue in order to reduce the ponding impacts near the schools east of Eagle Drive. The estimated cost of this recommendation is about $4,930,000 but it accounts for the ultimate mitigation pond size needed to address all of

the conveyance improvements. The main channel of Cotton Bayou will have side slopes of 6:1, which should reduce the amount of time and effort needed for maintenance of the channel and will reduce the likelihood of the side slopes failing or eroding. For future conditions, the siphon under the CWA and the culvert crossings at the access road and Perry Road should also be improved since these crossings have large head losses. It is also recommended that the City start planning for the drainage easement, ROW allocation, and land acquisition needs

Option #2 (Tributary Solution): Based on the tributary analysis, a number of drainage issues can be addressed by enlarging the existing tributaries or adding new ones as detailed in Table 4-3 and shown on Exhibit 4-4. The total cost of these tributary improvements is $9,140,000 and ranges in price from $208,000 to $1,076,000 (see Table 4-4). It is recommended that the City focus on improving the tributaries in areas CB100B-1, CB100B-2, CB100B-3, and CB100C-3 presented in Table 4-3. This should beneficially affect the drainage along the dump road and within the school in the area and reduce ponding (areas CB100B-2, CB100B-3, and CB100C-3). The total cost of this focused tributary recommendation improvement is estimated at to be $1,888,000. It should be noted that this analysis does not account for the downstream impacts due to the higher discharge; a more detailed analysis is needed to confirm the channel configuration and determine the needed mitigation. However, since the tributary channels are proposed to be built to overcapacity, the mitigation costs might be much less and could entail no more than an outfall structure to essentially create an on-line detention pond along the tributaries.

Option #3 (Regional Detention Pond Solution): Due to the high costs and variability of the detention solution options, the City will likely have to construct the regional detention ponds over an extended period of time. However, it is recommended that the City remain proactive in pursuing detention solution options as more developments are built within the City. There are a number of potential regional detention locations that the City can

buy in the near future. Acquiring the land at current prices would reduce to overall costs of the detention solution since land values generally increase over time. The City could guide future developers toward a more regional plan that would help not only the developer but also the public. This plan would reduce some of the inefficiencies of developing detention solutions piecemeal and would give the City the ability to recoup some or all of the costs of constructing detention ponds with some sort of impact or drainage fee. Another variation to this regional detention plan would be to require on-site detention ponds on all future developments, which provide essentially the same protection. However, by having a regional detention plan, the City and developers have more flexibility in addressing the impacts of new developments since the developers would have the options of doing on-site detention or paying the City to drain into a regional detention pond. The total cost of this solution is $27,908,000 assuming all the regional detention ponds at built simultaneously.

4.5 Recommended Solutions

Based on the results of the MDP and engineering judgment, all three solutions (conveyance, tributary, and detention) are viable options and should be pursued by the City. For the tributary solution, the City should focus initially on the selected tributaries. The conveyance and tributary solutions should be built before the regional detention solution since the latter is highly dependent on a number of variables, including the conveyance and tributary improvements. However, to avoid downstream impacts from the conveyance and tributary improvements, the necessary mitigation ponds, if needed, should be constructed before the conveyance improvements are made. A summary of the solutions and costs is provided below:

Conceptual Solution Cost Summary

Solution Type	Recommended	Total Cost
1. Conveyance	Yes	$ 4,930,000
2A. Tributary (All Tributaries)	No	$ 9,140,000
2B. Tributary (Selected Tributaries)	Yes	$ 1,888,000
3. Regional Detention	Yes	$27,908,000

It should be noted that the improvements modeled the ultimate set of improvements for the watershed. Portions of the needed improvements can be built, but may require other interim improvements compared to the ultimate planned improvements. These improvements can be completely or partly paid for by the developers as development occurs. The City can coordinate with the developers to determine a fair compensation for the drainage improvements whether it be an actual payment, a drainage fee on the proposed development, or a land donation to the City for drainage easement purposes, for example.

SECTION 5
HACKBERRY GULLY

5.1 Description

This section details the issues, conceptual solutions based on the methods and procedures described in Section 2, and estimated costs associated with the various solutions for Hackberry Gully. The Hackberry Gully watershed is located in south central area of Mont Belvieu. It is bounded by the CWA water canals in the north and west, by FM 565 and Eagle Drive in the east, and IH-10 in the south (see Exhibit 5-1). While the Hackberry Gully watershed continues farther south, only the portion north of IH-10 within the City of Mont Belvieu was considered for the MDP. The Hackberry Gully watershed has a total drainage area of 3.0 square miles (1921 acres), the majority of which is undeveloped as shown in the hydrologic parameters table (Table 5-1). The majority of the developed tracts are residential land use types, especially in the central part of the watershed, with some commercial tracts along IH-10 and Eagle Drive corridors as shown on Exhibit 5-2. The average imperviousness of the watershed is around 12%.

Hackberry Gully is approximately 28,000 feet (5.3 miles) in length. This drainage channel begins just north of the FM 565 and drains in a southeasterly direction to its confluence point with Cotton Bayou. There are a number of tributaries that drain toward Hackberry Gully from both the west and the east. Hackberry Gully was recently improved to a trapezoidal grass-lined channel starting at FM 565 and continuing south toward IH-10. South of IH-10, Hackberry Gully becomes a meandering channel with heavy underbrush and tall grasses along the overbanks.

5.2 Drainage Issues

As shown in Table 2-1 and Exhibit 5-1, the majority of the drainage issues in the Hackberry Gully watershed is due to ponding with a few channel, erosion, and bridge/culvert issues. According to the City, a number of subdivisions have reported street ponding, which was confirmed with the ponding analysis. The City also reported erosion issues with the drainage ditch just west of the Colony subdivision.

Many of the ponding issues were determined with the use of LiDAR data. As shown in Table 2-1 and summarized on Exhibit 5-1, the majority of the ponding problems were located north of FM 565. The ponding, channel, and erosion issues in the Colony subdivision were confirmed by residents attending the public meeting conducted on September 4, 2008. It should be noted, however, that this ponding analysis merely estimates potential areas of ponding and assumes that the downstream tributaries or culverts are unable to convey the drainage flows efficiently.

The bridge/culvert issues were determined from the updated modeling or conversations with the City. As shown in Table 2-1, the culvert crossing at the access road was overtopped starting at the 100-year storm events for the existing conditions peak flows given in Table 5-2. This same culvert location was also overtopped in the future conditions models but starting at smaller storm events. The future conditions peak flows used for this modeling are shown in Table 5-2, while Exhibit 5-3 shows the estimate future development conditions used to determine the future conditions peak flows. Appendix G provides more detailed hydrologic and hydraulic model outputs, as well as the previous hydrologic and hydraulic models inputs, water surface elevation profiles, and selected photos.

5.3 Development of Conceptual Solutions

Due to the character of issues in the Hackberry Gully watershed, three main options for dealing with those issues were determined: conveyance option for the main channel, conveyance option for the tributaries, and detention-only option for each subbasin. Though there are some issues with erosion along the drainage ditch west of the Colony subdivision, the tributary analysis determined the needed improvements to this ditch, which would remove the need for erosion protection. Table 5-3 and Exhibit 5-4 shows the various conceptual solutions created for Hackberry Gully.

It should be noted that the conveyance solution for the main channel of Hackberry Gully includes channel modifications, selected bridge/culvert replacements, and a mitigation basin to deal with the impacts caused by the channel modifications and bridge/culvert replacements. As shown in Table 5-3, the channel modifications for Hackberry Gully included enlarging the channel north of IH-10 and continuing upstream to FM 565. Channel side slopes of 6:1 side slopes were used for these channel modifications. A trapezoidal grass-lined channel was used for the channel modifications with bottom widths ranging from 40 to 60 feet. The flat channel side slopes remove the need for maintenance berms, while increasing the flow capacity of the channel.

Only the culvert crossing at the access road was modified. An additional 6'x8' RCB is to be added to the existing dual 6'x8' RCBs. This culvert improvement will reduce the head loss through the access road crossings and prevent the road from being overtopped during the 100-year event (see Appendix G for water surface elevation profiles). It should be noted that though there is a noticeable head loss at IH-10, no improvements are proposed at this bridge crossing. This crossing has been recently rebuilt by TxDOT, so there are no plans to pursue any additional construction work.

Due to these channel improvements, the increased channel conveyance may potentially result in adverse downstream flow impacts, which should be mitigated. Building a mitigation pond is a conservative approach for dealing with the potential increase in downstream channel flows. A single mitigation basin is proposed for this conveyance solution. The mitigation pond for Hackberry Gully was placed just north of IH-10. This approximately 10-foot deep basin supplies a mitigation volume of 89.9 acre-feet, has a surface area of 12.1 acres, including a 30-foot maintenance berm around the mitigation pond, and will require an excavation volume of 100 acre-feet. Exhibit 5-4 shows the alignments and extents of the channel improvements, the bridge modification at the access road crossing, and the general location of the mitigation pond. It should be noted that the location of the mitigation pond is merely a reasonable location based on aerial photos and should not be considered final.

For the tributary analysis, a number of tributaries were enlarged or new tributaries built to convey the contributing area flows. This tributary analysis is essentially a set of conveyance solution for the tributaries of Hackberry Gully. Unlike the main channel of Hackberry Gully, the channel geometries and flow characteristics of these tributaries were estimated. A typical depth of 10 feet, side slopes of 6:1, and bottom widths 6 feet were used in determining these trapezoidal grass-lined tributary sections as shown in Table 5-3. It should be noted that this trapezoidal channel configuration has a much larger capacity than is needed to convey the contributing area flows. The larger channel depth will permit future developments to build curb and gutter road sections with storm sewers instead of roadside ditches. The alignments and extents of these tributaries are shown on Exhibit 5-4.

The detention-only solution entails constructing regional detention ponds within each subbasin to reduce the future conditions peak flows at each subbasin to existing conditions levels. The required detention volume for each subbasin was estimated from the updated hydrologic model for Hackberry Gully. As shown in Table 5-3, the smallest

regional detention pond is for subbasin HB100C (62 acre-feet), while the largest regional pond is for HB100A (218 acre-feet). The general location and size of the various detention basins for Hackberry Gully are shown on Exhibit 5-4. As with the mitigation ponds in the conveyance solution, the locations of the detention ponds are only reasonable locations. The final location and configuration will depend on more detailed analysis. This detention option can also be tailored to allow for a mixture of on-site and regional detention ponds depending on development patterns, funds, and the cooperation between the City and developers. Though no specifics are given as part of the MDP, these detention ponds can be built as dual purpose facilities that can be used as parks, sport fields, or other amenities when dry.

5.4 Preliminary Conceptual Solutions

The purpose of this MDP is to anticipate the drainage needs of the City and give the appropriate tools and guidance to City personnel to plan for the future. It should be noted that the solutions reviewed below allow the City the flexibility to deal with their own issues and plan for appropriate improvements within the City limits without relying upon other entities for funding sources or approval and permitting. For Hackberry Gully, three main solutions are recommended: conveyance, tributary, and detention solutions.

Option #1 (Conveyance Solution): A conveyance option is a very cost-effective option available to the City. This conveyance solution entails enlarging the existing channel from FM 565 to IH-10 with a trapezoidal channel with 6:1 side slopes. The flatter side slopes would reduce the potential of erosion and make the maintenance of the channel easier. A total mitigation volume of 89.9 acre-feet is required to mitigate the conveyance improvements. The City should look into ways of acquiring the portions of the needed right-of-way for the channel and mitigation pond improvements to be built in a future date. The total cost of this option is estimated at $4,561,000.

Option #2 (Tributary Solution): Due to the increased development occurring in a number of areas, it is recommended that the City begin acquiring land and ROW in improve the conveyance of a number of tributaries found in Table 5-3 and shown on Exhibit 5-4. These tributaries already have some assigned drainage easement, but the City should acquire additional ROW so that future improvements to the tributaries can be pursued. This would also give greater access to City personnel for maintenance of the ditches and preventing the ditches from becoming overgrown with plants and shrubs. These tributary areas were chosen since they are currently experiencing issues with ponding. As shown in Table 5-4, the total cost of this option is estimated at $12,020,000 and ranges in price from $308,000 to $2,020,000 for each tributary component. From Table 5-3, a more focused list of tributaries includes HB100A-2, HB100A-3, HB100A-4, HB100B-1, and HB100C-1. Tributary improvements in subareas HB100A-2 and HB100A-3 should alleviate the excessive ponding along FM 565 near City Hall. Tributary improvement in subarea HB100A-4 will beneficially impact the area north of the CWA canal and allow for future development, while tributary improvements in subareas HB100B-1 along Trinity Drive and HB100C-1 west of the Crown Colony subdivision will improve the drainage in existing subdivisions. The total cost of this recommendation is estimated at $6,090,000. However, it should be noted that this cost does not include the costs of mitigation downstream impacts, which require a more detailed hydrologic and hydraulic analysis for each tributary area since this analysis did not possess enough detail to efficiently determine the mitigation volumes needed. However, since the tributary channels are proposed to be built to overcapacity, the mitigation costs might be much less and could entail no more than an outfall structure to essentially create an on-line detention pond along the tributaries.

Option #3 (Regional Detention Pond Solution): Though the City will likely have to construct the regional detention ponds over an extended period of time due to the high costs and variability, it is recommended that the City begin by acquiring land for detention. There are a number of potential regional detention locations that the City can

buy in the near future. Acquiring the land at current prices would reduce to overall costs of the detention solution since land values generally increase over time. However, it is recommended that the City remain proactive in pursuing detention solution options as more developments are built within the City. The City could guide future developers toward a more regional plan that would help not only the developer but also the public. This plan would reduce some of the inefficiencies of developing detention solutions piecemeal and would give the City the ability to recoup some or all of the costs of constructing detention ponds with some sort of impact or drainage fee. Another variation to this regional detention plan would be to require on-site detention ponds on all future developments, which provide essentially the same protection. However, by having a regional detention plan, the City and developers have more flexibility in addressing the impacts of new developments since the developers would have the options of doing on-site detention or paying the City to drain into a regional detention pond. The total cost of this solution is $16,595,000 assuming all the regional detention ponds at built simultaneously.

5.5 Recommended Solutions

Based on the results of the MDP and engineering judgment, all three solutions (conveyance, tributary, and detention) are viable options and should be pursued by the City. For the tributary solution, the City should focus initially on the selected tributaries. The conveyance and tributary solutions should be built before the regional detention solution since the latter is highly dependent on a number of variables, including the conveyance and tributary improvements. However, to avoid downstream impacts from the conveyance and tributary improvements, the necessary mitigation ponds, if needed, should be constructed before the conveyance improvements are done. A summary of the solutions and costs is provided below:

Conceptual Solution Cost Summary

Solution Type	Recommended	Total Cost
1. Conveyance	Yes	$ 4,561,000
2A. Tributary (All Tributaries)	No	$13,224,000
2B. Tributary (Selected Tributaries)	Yes	$ 6,090,000
3. Regional Detention	Yes	$16,595,000

It should be noted that the improvements modeled the ultimate set of improvements for the watershed. Portions of the needed improvements can be built, but may require other interim improvements compared to the ultimate planned improvements. These improvements can be completely or partly paid for by the developers as development occurs. The City can coordinate with the developers to determine a fair compensation for the drainage improvements whether it be an actual payment, a drainage fee on the proposed development, or a land donation to the City for drainage easement purposes, for example.

SECTION 6
OLD DITCH

6.1 Description

This section details the issues, conceptual solutions based on the methods and procedures described in Section 2, and estimated costs associated with the various solutions for Old Ditch. The Old Ditch watershed is located in north Mont Belvieu. It is bounded by the CWA water canals in the south and east, by Cherry Point Gully watershed in the west, and Old River in the north (see Exhibit 6-1). The Old Ditch watershed has a total drainage area of 0.3 square miles (178 acres) and is mostly developed (see Table 6-1). The majority of the developed tracts are residential land use types, especially in the areas north of FM 565, as shown on Exhibit 6-2. The area south of FM 565 is mostly undeveloped. The average imperviousness of the watershed is approximately 27%.

Old Ditch is approximately 3,700 feet (0.70 miles) in length. This drainage channel begins just south of the FM 565 and drains in a northerly direction to its confluence point with Old River. Old Ditch does not have any tributaries. South of Pin Oak Drive, Old Ditch is fairly shallow (3 to 5 feet deep) with flat channel slopes and well-maintained grassed side slopes. North of Pin Oak Drive, Old Ditch has a sharp drop in channel slope toward Old River. North of Oak Ridge Drive, there is thick underbrush and well-established trees near the channel.

6.2 Drainage Issues

As shown in Table 2-1 and Exhibit 6-1, the majority of the drainage issues in the Old Ditch watershed are due to ponding and culvert issues. According to the City, homes next to River Bend Drive have reported street ponding. The City also reported erosion

issues just south of Oak Ridge Drive, which was confirmed by residents attending the public meeting conducted on September 4, 2008.

Many of the ponding issues were determined with the use of LiDAR data. As shown in Table 2-1 and summarized on Exhibit 6-1, the ponding issues are located south of FM 565, along River Run Drive, and along River Bend Drive. The ponding issues in the watershed were confirmed by residents attending the public meeting. It should be noted, however, that this ponding analysis merely estimates potential areas of ponding and assumes that the downstream tributaries or culverts are unable to convey the drainage flows efficiently.

The bridge/culvert issues were determined from the updated modeling or conversations with the City. As shown in Table 2-1, three culvert crossing were overtopped starting at the 2-year storm events for the existing condition peak flows given in Table 6-2. A fourth culvert crossing was overtopped starting at the 25-year storm event for the existing condition. These same culvert locations were also overtopped in the future conditions models. The future conditions peak flows used for this modeling are shown in Table 6-2, while Exhibit 6-3 shows the future development estimates used to determine the future conditions peak flows. Appendix H provides more detailed hydrologic and hydraulic model outputs, as well as the previous hydrologic and hydraulic models inputs and selected photos.

6.3 Development of Conceptual Solutions

Due to the character of issues in the Old Ditch watershed, four main options for dealing with the problem issues were evaluated: conveyance option for the main channel, erosion protection option for a portion of the main channel, buy-outs of homes near affected locations, and detention-only solution for each subbasin. Table 6-3 and Exhibit 6-4 show the various conceptual solutions created for Old Ditch.

It should be noted that the conveyance option for the main channel of Old Ditch includes channel modifications, selected culvert replacements, and a mitigation basin to deal with the impacts caused by the channel modifications and bridge/culvert replacements. As shown in Table 6-3, the conveyance modifications for Old Ditch included enlarging the channel starting near Pin Oak Drive and continuing upstream to FM 565. Channel side slopes of 3:1 side slopes were used for this channel modification due to the limited ROW through the subdivision. Flatter side slopes of 4:1 were used near Oak Ridge Drive since the aerial photos show a wider channel topwidth though this area. A trapezoidal grass-lined channel was used for the channel modifications with a bottom width of 6 feet.

Four culvert crossing were chosen to be improved. These culvert crossings are at FM 565, River Bend Drive, River Ridge Drive, and Pin Oak Drive since they show signs of damage or reduced capacities due to siltation. At FM 565, the three existing 24-inch RCP's are to be replaced with five 24-inch RCPs. At River Bend Drive, the three existing 18-inch CMPs are to be replaced with five 30-inch RCPs. The three existing 18-inch RCPs at River Ridge Drive are to be replaced with five 36-inch RCPs. At Pin Oak Drive, the dual 18-inch and 24-inch RCPs are to be replaced with three 42-inch RCP's. These culvert improvements will reduce the ponding depths at the roads during the 100-year event. However, it will not prevent the roads from being overtopped during the 100-year event (see Appendix H for water surface profiles).

Due to these channel improvements, there is a loss of storage that will require mitigation in order to prevent downstream impacts. A single mitigation basin is proposed for this conveyance solution. The mitigation pond for Old Ditch was placed at the southeast corner of the watershed. This 3-foot deep basin supplies a mitigation volume of 2.1 acre-feet and has a surface area of approximately 0.8 acres, including a 30-foot maintenance berm as shown in Table 6-3. Exhibit 6-4 shows the alignments and extents of the channel improvements, the bridge modifications at the road crossings, and the general location of

the mitigation pond. It should be noted that the location of the mitigation pond merely provides a reasonable location based on aerial photos and should not be considered final.

For the erosion protection solution, a portion of the reach between Pin Oak Drive and Oak Ridge Drive was chosen. Stone rip-rap is to be added to the slopes of Old Ditch for about 1,200 feet along the channel in order provide erosion protection. Limited clearing and desnagging of the channel is also considered part of the erosion protection solution. Table 6-3 provides additional details on the erosion protection features. The alignments and extents of this solution are shown on Exhibit 6-4.

Though not generally a viable option, limited buy-outs of affected homes near Old Ditch were also reviewed. Based on aerial photographs of Old Ditch, about 20 homes near the area with erosion problems were identified as possible buy-out locations.

The detention-only solution entails constructing regional detention ponds within each subbasin to reduce the future conditions peak flows at each subbasin to existing conditions levels. The required detention volume for each subbasin was estimated from the updated hydrologic model for Old Ditch. Since the Old Ditch watershed is already fully developed north of FM 565, only the tract south of FM 565 was a viable location for a regional detention pond. As shown in Table 6-3, the detention pond needed for subbasin OD100A has a surface area of 0.52 acres and a storage volume of 0.58 acre-feet. The general location and size of the detention basin for Old Ditch are shown on Exhibit 6-4. As with the mitigation pond in the conveyance solution, the location of the detention pond provides only reasonable location of where the detention pond could be built. The final location and configuration will depend on a more detailed analysis. This detention option can also be tailored to allow for a mixture of on-site and regional detention ponds depending on development patterns, funds, and the cooperation between the City and developers. Though no specifics are given as part of the MDP, these detention ponds can

be built as dual purpose facilities that can be used as parks, sport fields, or other amenities when dry.

6.4 Preliminary Conceptual Solutions

The purpose of this MDP is to anticipate the drainage needs of the City and give the appropriate tools and guidance to City personnel to plan for the future. It should be noted that the solutions reviewed below allow the City the flexibility to deal with their own issues and plan for appropriate improvements within the City limits without relying upon other entities for funding sources or approval and permitting. As part of the MDP, four solutions are recommended for Old Ditch: conveyance, erosion control, home buy-outs, and detention solutions.

Option #1 (Conveyance Solution): A conveyance solution was the most cost-effective option available to the City. This is due partly to the fact that the channel improvement is only 1,000 feet and the amount of excavation is minimal. This conveyance solution entails enlarging the existing channel from FM 565 to Pin Oak Drive, replacing the culverts at FM 565, River Bend Drive, River Ridge Drive, and Pin Oak Drive, smoothing the channel near Oak Ridge Drive, and building a mitigation pond with a needed storage volume of 2.1 acre-feet. The channel is to be enlarged into a trapezoidal channel with 3:1 or 4:1 side slopes (due to limited ROW since the channel is next to people's homes). The total cost of this recommendation is estimated at $503,000. It should be noted that, due to a lack of available land north of FM 565 within the Old Ditch watershed, the mitigation pond will need to be place in the undeveloped tract south of FM 565.

Option #2 (Erosion Protection): This option entails installing rip-rap to the eroding slopes of Old Ditch south of Oak Ridge Drive. The estimated length of channel requiring rip-rap is 1,200 feet and does not include additional slope modifications. Limited clearing and desnagging is also included with this option, though the cost will increase if a large

portion of the channel needs to be cleared or desnagged. The cost of the erosion protection is $67,000 as shown in Table 6-4.

Option #3 (Buy-outs): This option requires that the City buy approximately 20 houses near the erosion area. Based on previous studies supplied by the City, this buy-out solution was reviewed to determine whether it was an effective solution. Due to the high costs and limited benefits, this option is not recommended. The total cost of this option is $2,500,000 (see Table 6-4).

Option #4 (Regional Detention Pond Solution): Since the detention pond for Old Ditch subbasin OD100A (see Exhibit 6-4) is small, this detention solution might be a viable solution. This 18.1 acre-feet pond would not only benefit subbasin OD100A, but would also benefit the areas downstream of the detention site by reducing peak flows on Old Ditch. It is recommended that the City purchase available land just south of FM 565 for use as a future regional detention pond. Acquiring the land at current prices would reduce to overall costs of the detention solution since land values generally increase over time. It is also recommended that the City remain proactive in pursuing detention solution options as more developments are built within the City. The City could guide future developers toward a more regional plan that would help not only the developer but also the public. This plan would reduce some of the inefficiencies of developing detention solutions piecemeal and would give the City the ability to recoup some or all of the costs of constructing detention ponds with some sort of impact or drainage fee. Another variation to this regional detention plan would be to require on-site detention ponds on all future developments, which provide essentially the same protection. However, by having a regional detention plan, the City and developers have more flexibility in addressing the impacts of new developments since the developers would have the options of doing on-site detention or paying the City to discharge to a regional detention pond. The total cost of this solution is $1,382,000 for this pond.

6.5 Recommended Solutions

Based on the results of the MDP and engineering judgment, the conveyance and regional detention solutions are viable options and should be pursued by the City. The home buy-out solution is prohibitively expensive. Erosion control, too, can result in disagreement between those residents that are being negatively impacted by the eroding banks and those that are not and wish to maintain the natural unaltered state of the channel. However, the City should continue to monitor this portion of Old Ditch to make sure that the erosion is not causing structural damage to nearby homes. The conveyance solution should be built before the regional detention solution since the latter is highly dependent on a number of variables, including the conveyance and tributary improvements. However, to avoid downstream impacts from the conveyance improvements, the necessary mitigation ponds, if needed, should be constructed before conveyance improvements are made. A summary of the solutions and costs is provided below:

Conceptual Solution Cost Summary

Solution Type	Recommended	Total Cost
1. Conveyance	Yes	$ 503,000
2. Erosion Control	No	$ 67,000
3. Home Buy-outs	No	$2,500,000
4. Regional Detention	Yes	$1,382,000

It should be noted that the improvements modeled the ultimate set of improvements for the watershed. Portions of the needed improvements can be built, but may require other interim improvements compared to the ultimate planned improvements. These improvements can be completely or partly paid for by the developers as development occurs. The City can coordinate with the developers to determine a fair compensation for the drainage improvements whether it be an actual payment, a drainage fee on the

proposed development, or a land donation to the City for drainage easement purposes, for example.

SECTION 7
SMITH GULLY AND OTHER WATERSHEDS

7.1 Description

As directed by the City, the main focus of the MDP is Cherry Point Gully, Cotton Bayou, Hackberry Gully, and Old Ditch. However, the Smith Gully watershed was also analyzed in order to identify some broad-based problems and determine conceptual solutions for these problems. Buck Gully, a watershed in north Mont Belvieu, lacks documented cases of drainage issues and only a small portion is within the city limits, so it was not be considered in the MDP.

The Smith Gully watershed is located in east Mont Belvieu. The watershed is bounded by the CWA water canals in the east, by SH 146 in the west, and IH-10 in the south (see Exhibit 7-1). The Smith Gully watershed has a total drainage area of 3.883 square miles (2485 acres) and is composed of mixed land use types (see Table 7-1). The majority of the developed tracts are light industrial land use areas near SH 146 and IH-10, interspersed with developed green areas and a few residential areas as shown on Exhibit 7-2. The eastern portion of the watershed near the CWA canal is mostly undeveloped. The average imperviousness of the watershed is approximately 20%.

Smith Gully is around 18,000 feet (3.4 miles) in length. Appendix I provides the hydraulic model data used, as well as some selected photos. This drainage channel begins just east of the SH 146 and drains towards the east, curves around the eastern side of the large salt dome, finally turning west and draining into Cedar Bayou. Smith Gully has two major tributaries that drain the eastern portion of the watershed. Smith Gully is generally characterized as a highly meandering channel with thick underbrush and well-established trees near the channel. Some channel improvements have recently been done on Smith Gully near FM 565.

7.2 Drainage Issues

As shown on Table 2-1 and Exhibit 7-1, the majority of the drainage issues in the Smith Gully are ponding issues, with some bridge/culvert issues. According to the City, ponding issues have been reported near Cedar Hill Road and the outfall pipe at Warren Road has deteriorated.

Many of the ponding issues were determined with the use of LiDAR data. As shown on Table 2-1 and summarized on Exhibit 7-1, the ponding issues are mostly north of Smith Gully and Railroad Basin #4. It should be noted, however, that this ponding analysis merely estimates potential areas of ponding and assumes that the downstream tributaries or culverts are unable to convey the drainage flows efficiently.

The bridge/culvert issues were determined from the existing hydraulic model. As shown on Table 2-1, three culvert crossing were overtopped as shown in the hydraulic model for Smith Gully. The overtopped culverts are at Sun Oil Road, FM 565, and Winfree Street.

7.3 Development of Conceptual Solutions

Due to the character of issues in the Smith Gully watershed and available data, only one type of solution was examined. This option was a conveyance option for the main channel of Smith Gully. Exhibit 7-4 shows the various conceptual solutions created for Smith Gully.

This conveyance option includes channel modifications, selected bridge/culvert replacements, and a mitigation basin to deal with the impacts caused by the channel modifications and bridge/culvert replacements. As shown on Table 7-1, the channel modifications for Smith Gully include enlarging the channel starting at Sun Oil Road and continuing upstream to Winfree Street. A trapezoidal grass-lined channel is used for the

channel modifications with a bottom width of 15 feet and side slopes of 6:1. Two culvert crossings required some form of modification to reduce the large head loss at these locations. At Sun Oil Road, an additional 84-inch RCP was added to the existing dual 84-inch RCPs. For FM 565, an additional 48-inch RCP was added to the existing 48-inch RCP and dual 7'x5' RCBs. These culvert improvements will reduce the head loss through road crossings and prevent the roads from being overtopped during the 100-year event. The flat channel side slopes remove the need for maintenance berms, while increasing the flow capacity of the channel.

Due to these channel improvements, the increased channel conveyance may potentially result in adverse downstream flow impacts, which should be mitigated. Building a mitigation pond is a conservative approach for dealing with the potential increase in downstream channel flows. A single mitigation basin is proposed for this conveyance solution. The mitigation pond for Smith Gully was placed just upstream of the Sun Oil Road. This approximately 10-foot deep basin supplies a mitigation volume of 56 acre-feet and has a surface area of 8.1 acres, including a 30-foot maintenance berm around the mitigation pond. Exhibit 7-4 shows the alignments and extents of the channel improvements, the bridge modifications at the road crossings, and the general location of the mitigation pond. It should be noted that the location of the mitigation pond merely provides a reasonable location based on aerial photos and should not be considered final.

7.4 Recommended Solutions

The purpose of this MDP is to anticipate the drainage needs of the City and give the appropriate tools and guidance to City personnel to plan for the future. It should be noted that the solutions reviewed below allow the City the flexibility to deal with their own issues and plan for appropriate improvements within the City limits without relying upon other entities for funding sources or approval and permitting. Based on the limited

analysis, only the conveyance solution is recommended for improving the drainage in the Smith Gully watershed.

Option #1 (Conveyance Solution): The hydraulic model for Smith Gully was used to determine the conveyance improvements needed to help reduce drainage problems. The City can start allocating funds to pay for the cost of these culvert modifications which are around $184,000 for both culverts. For bridge/culvert improvements, an average cost of $628 per linear foot was used plus a lump sum of $20,000 for traffic control and storm water pollution prevention plan (SWPPP). As shown on Table 7-2 the cost of the conveyance solution is around $2,960,000, with the majority of costs arising from land acquisition costs for the channel improvements and mitigation basin. The ultimate size of the mitigation pond required is 56 acre-feet and will cost around $1,818,000.

It should be noted that the improvements modeled the ultimate set of improvements for the watershed. Portions of the needed improvements can be built, but may require other interim improvements compared to the ultimate planned improvements. These improvements can be completely or partly paid for by the developers as development occurs. The City can coordinate with the developers to determine a fair compensation for the drainage improvements whether it be an actual payment, a drainage fee on the proposed development, or a land donation to the City for drainage easement purposes, for example.

TABLE 2-1
Summary of Drainage Issues

Watershed	Type of Issue	Frequency (Year) (*E* xisting or *F* uture)	Source*	Primary Land Use	Subbasin Name	Tributary Name	Description of Problem
	Cherry Point Gully						
Cherry Point Gully	Bridge/Culvert		Field visit	Residential	CP100C	CP100C-1	Silted cross culverts
Cherry Point Gully	Bridge/Culvert		Field visit	Residential	CP100C	CP100C-3	Cherry Point Drive arch culvert has mound of silt in middle of channel
Cherry Point Gully	Bridge/Culvert		Field visit	Commercial	CP100E2	CP100E2-4	Tall reeds at 17th Fairway Ditch restrictingflow
Cherry Point Gully	Bridge/Culvert	100 (F)	Model	Comm/Residential	CP100B1	---	Eagle Drive overtopped at 100-yr (Future)
Cherry Point Gully	Bridge/Culvert	100 (F)	Model	Residential	CP100C	CP100C-3	Cherry Point Drive overtopped at 100-yr (Future)
Cherry Point Gully	Bridge/Culvert	10 (E), 5 (F)	Model	Golf course	CP100F1	---	Golf Course Bridge #2 overtopped at 10-yr (Existing), 5-yr (Future)
Cherry Point Gully	Bridge/Culvert	50 (E), 10 (F)	Model	Golf course	CP100F1	---	Golf Course Bridge #1 overtopped at 50-yr (Existing), 10-yr (Future)
Cherry Point Gully	Bridge/Culvert		Model	Undeveloped	CP100E1	---	Natural banks downstream of Station 7673 overtopped but narrow flood plain
Cherry Point Gully	Channel		City	Residential	CP100E2	CP100E2-3	Flat slopes at Eagle Pointe Estates causing street ponding on Eagle Ridge Drive
Cherry Point Gully	Channel	50 (F)	Model	Residential	CP100B1	---	Flooding upstream of Cherry Point Drive at 50-yr (Future)
Cherry Point Gully	Ponding		City	Residential	CP100H	---	Fisher's Landing has standing water during major event
Cherry Point Gully	Ponding		Field visit	Residential	CP100E2	CP100E2-3	No inlets to drain road to north & south ditches of Eagle Pointe Estates
Cherry Point Gully	Ponding		LiDAR	Undeveloped	CP100F2	CP100F2-1	LiDAR indicates excessive ponding
Cherry Point Gully	Ponding		LiDAR	Undeveloped	CP100F2	CP100F2-1	LiDAR indicates excessive ponding
Cherry Point Gully	Ponding		LiDAR	Undeveloped	CP100E2	CP100E2-1	LiDAR indicates excessive ponding
Cherry Point Gully	Ponding		LiDAR	Undeveloped	CP100D	CP100D-1	LiDAR indicates excessive ponding
Cherry Point Gully	Ponding		LiDAR	Undeveloped	CP100A	CP100A-1	LiDAR indicates excessive ponding
Cherry Point Gully	Ponding	50 (F)	Model	Industrial	CP100A	CP100A-2	Flooding upstream of SH 146 at 50-yr (Future)
	Cotton Bayou						
Cotton Bayou	Bridge/Culvert	50 (F)	Model	Commercial	CB100D	CB100D-4	IH-10 N. Frontage overtopped at 50-year (Future)
Cotton Bayou	Bridge/Culvert	10 (E), 2 (F)	Model	Comm/Residential	CB100A	CB100A-1	Canal overtopped at 10-yr (Existing), 2-yr (Future)
Cotton Bayou	Bridge/Culvert	2 (E), 2 (F)	Model	Comm/Residential	CB100B	CB100B-1	Access road overtopped at 2-yr (Existing), 2-yr (Future)
Cotton Bayou	Bridge/Culvert	25 (F)	Model	Comm/Residential	CB100B	CB100B-1	Perry Road overtopped at 25-yr (Future)
Cotton Bayou	Bridge/Culvert	100 (E), 5 (F)	Model	Comm/Residential	CB100B	---	Prairie Avenue overtopped at 100-yr (Existing), 5-yr (Future)
Cotton Bayou	Ponding		City	Commercial	CB100B	CB100B-1	Water doesn't drain to cul-de-sac causing ponding
Cotton Bayou	Ponding		City	Residential	CB100D	CB100D-1	Street flooding on Champions Gate (Gateway)
Cotton Bayou	Ponding		LiDAR	Commercial	CB100C	CB100C-3	LiDAR indicates excessive ponding
Cotton Bayou	Ponding		LiDAR	Commercial	CB100B	CB100B-3	LiDAR indicates excessive ponding
Cotton Bayou	Ponding		LiDAR	Commercial	CB100B	CB100B-2	LiDAR indicates excessive ponding
Cotton Bayou	Ponding		LiDAR	Undeveloped	CB100A	CB100A-1	LiDAR indicates excessive ponding
Cotton Bayou	Ponding		LiDAR	Undeveloped	CB100A	CB100A-2	LiDAR indicates excessive ponding
Cotton Bayou	Ponding		LiDAR	Undeveloped	CB100A	CB100A-2	LiDAR indicates excessive ponding

TABLE 2-1
Summary of Drainage Issues

Watershed	Type of Issue	Frequency (Year) (*E* xisting or *F* uture)	Source*	Primary Land Use	Subbasin Name	Tributary Name	Description of Problem
	Hackberry Gully						
Hackberry Gully	Bridge/Culvert		City	Residential	HB100C	HB100C-3	Issues with cross culverts on Royal Palm
Hackberry Gully	Bridge/Culvert		Model	Comm/Residential	HB100A	---	Access overtopped at 50-yr (Future)
Hackberry Gully	Channel		Residents	Residential	HB100C	HB100C-1	Sedimentation and maintenance needed
Hackberry Gully	Erosion		City	Residential	HB100C	HB100C-1	Ditch at west side of Crown Colony eroding
Hackberry Gully	Ponding		City	Commercial	HB100A	HB100A-2	Intersection drains slowly
Hackberry Gully	Ponding		City	Residential	HB100B	HB100B-1	Ponding behind homes north of Trinity Road
Hackberry Gully	Ponding		LiDAR	Undeveloped	HB100D	HB100D-4	LiDAR indicates excessive ponding
Hackberry Gully	Ponding		LiDAR	Industrial	HB100D	HB100D-5	LiDAR indicates excessive ponding
Hackberry Gully	Ponding		LiDAR	Undeveloped	HB100D	HB100D-3	LiDAR indicates excessive ponding
Hackberry Gully	Ponding		LiDAR	Residential	HB100C	HB100C-3	LiDAR indicates excessive ponding
Hackberry Gully	Ponding		LiDAR	Commercial	HB100A	HB100A-2	LiDAR indicates excessive ponding
Hackberry Gully	Ponding		LiDAR	Undeveloped	HB100A	HB100A-3	LiDAR indicates excessive ponding
Hackberry Gully	Ponding		LiDAR	Undeveloped	HB100A	HB100A-1	LiDAR indicates excessive ponding
Hackberry Gully	Ponding		LiDAR	Residential	HB100C	HB100C-1	LiDAR indicates excessive ponding
	Old Ditch						
Old Ditch	Bridge/Culvert	25 (E), 2 (F)	Field visit	Undeveloped	OD100A	---	FM 565 overtopped at 25-yr (Existing), 2-yr (Future); culverts damaged and silted
Old Ditch	Bridge/Culvert	2 (E), 2 (F)	Model	Residential	OD100B	---	River Bend overtopped at 2-yr (Existing), 2-yr (Future)
Old Ditch	Bridge/Culvert	2 (E), 2 (F)	Model	Residential	OD100B	---	River Ridge overtopped at 2-yr (Existing), 2-yr (Future)
Old Ditch	Bridge/Culvert	2 (E), 2 (F)	Model	Residential	OD100B	---	Pin Oak overtopped at 2-yr (Existing), 2-yr (Future)
Old Ditch	Erosion		Reports	Residential	OD100C	---	Slope failure due to undermining and erosion of ditch bottom
Old Ditch	Ponding		City	Residential	OD100B	---	Backyards of 12000 Riverbend don't drain well
Old Ditch	Ponding		LiDAR	Undeveloped	OD100A	---	LiDAR indicates excessive ponding
Old Ditch	Ponding		LiDAR	Residential	OD100C	---	LiDAR indicates excessive ponding
	Smith Gully						
Smith Gully	Bridge/Culvert	10 (E)	Model	Industrial	Smith Gully	---	Winfree St. overtopped at 10-yr (Existing)
Smith Gully	Bridge/Culvert	50 (E)	Model	Indust/Residential	Smith Gully	---	FM 565 overtopped at 50-yr (Existing)
Smith Gully	Bridge/Culvert	500 (E)	Model	Industrial	Smith Gully	---	Sun Oil overtopped at 500-yr (Existing)
Smith Gully	Ponding		City	Residential	Smith Gully	---	Ponding on Cedar Hill
Smith Gully	Ponding		LiDAR	Undeveloped	Smith Gully	---	LiDAR indicates excessive ponding
Smith Gully	Ponding		LiDAR	Undeveloped	Smith Gully	---	LiDAR indicates excessive ponding
Smith Gully	Ponding		LiDAR	Undeveloped	Smith Gully	---	LiDAR indicates excessive ponding
Smith Gully	Ponding		LiDAR	Residential	Smith Gully	---	LiDAR indicates excessive ponding
Smith Gully	Ponding		LiDAR	Industrial	Smith Gully	---	LiDAR indicates excessive ponding
Smith Gully	Ponding		LiDAR	Industrial	Smith Gully	---	LiDAR indicates excessive ponding

*Source * = Basis of information for determining problem*

TABLE 2-2
Unit Costs Summary

Item Description	Unit	Total Quantity	Unit Price ($)	Total Cost ($)
Land Costs				
Land Acquisition (Undeveloped Residential Tract)	ACRE	1	$ 30,000	$ 30,000
Land Acquistion (Developed Residential Tract)	ACRE	1	$125,000	$125,000
Channel Costs				
Clearing and Grubbing	LF	1	$ 2.50	$ 2.50
Excavation of Clay with 2.5 CY Back-Hoe and 4 20 CY Dump Trailers	CY	1	$ 5.70	$ 5.70
Seeding, General, Mechanical Seeding, 215lbs/Acre	ACRE	1	$ 1,000	$ 1,000
Concrete-Lining	SF	1	$ 2.50	$ 2.50
Rip-rap	CY	1	$ 21.00	$ 21.00
Detention Costs				
Typical Cost including Excavation, Seeding, and Outfall	AC-FT	1	$ 25,000	$ 25,000
Culvert Costs				
Removal of 24 inch Culvert	LF	1	$ 16	$ 16
Removal of 36 inch Culvert	LF	1	$ 22	$ 22
Removal of 60 inch Culvert	LF	1	$ 30	$ 30
Removal of 10'x8' Box Culvert	LF	1	$ 36	$ 36
Installation of 24 inch Culvert*	LF	1	$ 160	$ 160
Installation of 36 inch Culvert*	LF	1	$ 240	$ 240
Installation of 60 inch Culvert*	LF	1	$ 410	$ 410
Installation of 10'x8' Box Culvert*	LF	1	$ 845	$ 845

* Installation includes Trench Safety, Pavement Demolition, Pavement Restoration, Excavation, Selected Backfill, and the Culvert.

TABLE 3-1
Hydrologic Subbasin Parameters
Cherry Point Gully (CP100-00-00)

			Green & Ampt			Revised Existing		SCS (Revised Existing)				Future		SCS (Future)			
Subbasin	Area (acres)	Area (sq. mi.)	Volume Moisture Deficit	Wetting Front Suction (inches)	Hydraulic Conductivity (in/hr)	Tc (hr)	R (hr)	Weighted CN	Initial Retention (in)	Initial Abstraction (in)	Impervious (%)	Tc (hr)	R (hr)	Weighted CN	Initial Retention (in)	Initial Abstraction (in)	Impervious (%)
CP100A	726.6	1.135	0.385	12.45	0.024	3.075	9.225	81	2.35	0.47	8	1.458	4.374	89	1.24	0.25	51
CP100B1	369.4	0.577	0.385	12.45	0.024	1.744	5.232	81	2.35	0.47	5	1.703	5.109	88	1.36	0.27	42
CP100B2	246.2	0.385	0.385	12.45	0.024	2.493	7.479	81	2.35	0.47	5	1.186	3.558	86	1.63	0.33	31
CP100C	200.0	0.312	0.385	12.45	0.024	1.791	5.373	83	2.05	0.41	13	1.644	4.932	87	1.49	0.30	37
CP100D	213.5	0.334	0.385	12.45	0.024	1.666	4.998	80	2.50	0.50	2	1.547	4.641	88	1.36	0.27	44
CP100E1	100.0	0.156	0.385	12.45	0.024	0.906	2.718	80	2.50	0.50	1	0.461	1.383	86	1.63	0.33	30
CP100E2	353.4	0.552	0.385	12.45	0.024	3.657	10.971	82	2.20	0.44	9	1.605	4.815	89	1.24	0.25	47
CP100F1	104.1	0.163	0.385	12.45	0.024	1.180	3.540	81	2.35	0.47	9	0.548	1.644	83	2.05	0.41	20
CP100F2	303.3	0.474	0.385	12.45	0.024	1.459	4.377	81	2.35	0.47	3	1.286	3.858	88	1.36	0.27	44
CP100F3	250.0	0.391	0.385	12.45	0.024	0.954	2.862	80	2.50	0.50	1	0.427	1.281	87	1.49	0.30	38
CP100G	89.8	0.140	0.385	12.45	0.024	0.545	1.635	84	1.90	0.38	24	0.486	1.458	86	1.63	0.33	31
CP100H	44.2	0.069	0.385	12.45	0.024	0.363	1.089	85	1.76	0.35	28	0.293	0.879	86	1.63	0.33	36
Area (sq. mi.) =		4.688							**Weighted Impervious (%) =**		7				**Weighted Impervious (%) =**		42

TABLE 3-2
Peak Flows Summary
Cherry Point Gully (CP100-00-00)

Name	Drainage Area	Revised Existing Peak Flows (cfs)				Future Conditions Peak Flows (cfs)				Flow Difference (cfs) Revised Existing vs. Future				Flow Difference (%) Revised Existing vs. Future			
	(sq. mi.)	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year
Nodal Flows																	
CP#1	1.135	159	302	394	560	348	584	728	986	189	282	334	426	118%	93%	85%	76%
CP#2A	1.712	260	501	653	927	488	828	1038	1350	228	327	384	423	88%	65%	59%	46%
CP#2B	2.097	320	617	805	1143	601	1024	1285	1640	282	407	481	497	88%	66%	60%	43%
CP#3	2.409	379	730	952	1347	681	1162	1457	1861	302	432	505	514	80%	59%	53%	38%
CP#4	2.743	441	852	1113	1571	770	1316	1650	2105	329	464	537	534	75%	54%	48%	34%
CP#5A	2.899	471	913	1193	1681	810	1386	1740	2236	339	474	548	555	72%	52%	46%	33%
CP#5B	3.451	538	1040	1359	1919	955	1635	2054	2681	417	596	694	762	78%	57%	51%	40%
CP#6A	3.614	570	1102	1441	2034	995	1709	2147	2834	426	607	706	800	75%	55%	49%	39%
CP#6B	0.865	263	470	595	816	393	645	790	1051	130	174	195	235	49%	37%	33%	29%
CP#6C	4.479	744	1451	1895	2679	1235	2129	2674	3640	491	679	779	961	66%	47%	41%	36%
CP#7	4.619	771	1508	1970	2787	1273	2202	2766	3780	501	695	796	993	65%	46%	40%	36%
CP#8	4.688	781	1531	2001	2834	1286	2231	2802	3838	505	700	801	1004	65%	46%	40%	35%
Basin Flows																	
CP100A	1.135	159	302	394	560	348	584	728	986	189	282	334	426	118%	93%	85%	76%
CP100B1	0.577	131	240	306	427	153	261	328	449	22	22	22	23	16%	9%	7%	5%
CP100B2	0.385	64	120	156	221	132	224	279	377	67	103	123	157	105%	86%	79%	71%
CP100C	0.312	72	129	165	228	84	144	181	248	12	15	16	19	17%	11%	10%	8%
CP100D	0.334	78	143	183	254	96	163	204	278	18	20	21	24	23%	14%	12%	9%
CP100E1	0.156	61	106	133	179	110	175	211	274	49	69	79	96	80%	65%	60%	54%
CP100E2	0.552	67	128	168	240	155	263	330	449	88	135	162	209	131%	106%	96%	87%
CP100F1	0.163	52	92	116	158	99	162	197	258	47	70	81	100	90%	76%	70%	63%
CP100F2	0.474	125	225	287	396	157	264	329	445	33	39	42	49	26%	17%	15%	12%
CP100F3	0.391	146	256	320	433	293	462	557	720	147	206	236	287	101%	80%	74%	66%
CP100G	0.140	86	140	170	222	95	152	184	239	9	12	14	16	10%	8%	8%	7%
CP100H	0.069	57	90	108	139	67	103	123	157	10	13	15	18	17%	14%	14%	13%

TABLE 3-3
Conceptual Solutions
Cherry Point Gully (CP100-00-00)

Modification Type	Subbasin	Chan. Slope (ft/ft)	D/S Sta.	U/S Sta.	Length (ft)	Description	Depth (Typical) (ft)	Bottom Width (ft)	Side Slope (H:V)	Right-of-Way (ft)	N-value	Surface Area (ac)	Excavaction Volume (ac-ft)
Conveyance Solution													
Channel	CP100C	0.00058	9773	10096	323	Trapezoidal, concrete	12	8	1.5	74	0.04	0.5	0.8
Channel	CP100B1	0.00083	10096	16670	6574	Trapezoidal, earthen channel	13	6	6	162	0.04	23.5	137.7
Culvert	CP100A (SH 146)				88	Adding 10'x8' RCB	-	-	-	-	0.015	-	-
Culvert	CP100A (FM 3360)				125	Adding 10'x8' RCB	-	-	-	-	0.015	-	-
Mitigation Pond	CP100A				-	Dimensions: 460' x 460'	10	-	4	-	-	4.9	33.5
Tributary Solution													
Channel	CP100A-1	0.001	-	-	2450	Trapezoidal, earthen channel	10	6	6	126	0.04	7.1	37.1
Channel	CP100A-2	0.001	-	-	1675	Trapezoidal, earthen channel	10	6	6	126	0.04	4.8	25.4
Channel	CP100A-3	0.001	-	-	1675	Trapezoidal, earthen channel	10	6	6	126	0.04	4.8	25.4
Channel	CP100B1	0.001	-	-	3750	Trapezoidal, earthen channel	10	6	6	126	0.04	10.8	56.8
Channel	CP100B2	0.001	-	-	3000	Trapezoidal, earthen channel	10	6	6	126	0.04	8.7	45.5
Channel	***CP100C-1***	0.001	-	-	2100	Trapezoidal, earthen channel	10	6	6	126	0.04	6.1	31.8
Channel	***CP100C-2***	0.001	-	-	4250	Trapezoidal, earthen channel	10	6	6	126	0.04	12.3	64.4
Channel	CP100C-3	0.001	-	-	2000	Trapezoidal, earthen channel	10	6	6	126	0.04	5.8	30.3
Channel	***CP100D-1***	0.001	-	-	2400	Trapezoidal, earthen channel	10	6	6	126	0.04	6.9	36.4
Channel	***CP100D-2***	0.001	-	-	5000	Trapezoidal, earthen channel	10	6	6	126	0.04	14.5	75.8
Channel	CP100D-3	0.001	-	-	1000	Trapezoidal, earthen channel	10	6	6	126	0.04	2.9	15.2
Channel	***CP100E2-1***	0.001	-	-	1700	Trapezoidal, earthen channel	10	6	6	126	0.04	4.9	25.8
Channel	***CP100E2-2***	0.001	-	-	3400	Trapezoidal, earthen channel	10	6	6	126	0.04	9.8	51.5
Channel	CP100E2-3	0.001	-	-	2700	Trapezoidal, earthen channel	10	6	6	126	0.04	7.8	40.9
Channel	CP100E2-4	0.001	-	-	1000	Trapezoidal, earthen channel	10	6	6	126	0.04	2.9	15.2
Channel	***CP100F2-1***	0.001	-	-	6000	Trapezoidal, earthen channel	10	6	6	126	0.04	17.4	90.9
Channel	***CP100F2-2***	0.001	-	-	1200	Trapezoidal, earthen channel	10	6	6	126	0.04	3.5	18.2
Channel	CP100F3-1	0.001	-	-	2500	Trapezoidal, earthen channel	10	6	6	126	0.04	7.2	37.9
Channel	CP100F3-2	0.001	-	-	2200	Trapezoidal, earthen channel	10	6	6	126	0.04	6.4	33.3
Channel	CP100F3-3	0.001	-	-	1350	Trapezoidal, earthen channel	10	6	6	126	0.04	3.9	20.5
Detention Solution													
Detention Pond	CP100A	-	-	-	-	Dimensions: 1185' x 1185'	10	-	4	-	-	32.2	299.4
Detention Pond	CP100B1	-	-	-	-	Dimensions: 500' x 500'	10	-	4	-	-	5.7	36.9
Detention Pond	CP100B2	-	-	-	-	Dimensions: 690' x 690'	10	-	4	-	-	10.9	87.8
Detention Pond	CP100C	-	-	-	-	Dimensions: 370' x 370'	10	-	4	-	-	3.1	19.1
Detention Pond	CP100D	-	-	-	-	Dimensions: 440' x 440'	10	-	4	-	-	4.4	30.0
Detention Pond	CP100E1	-	-	-	-	Dimensions: 430' x 430'	10	-	4	-	-	4.2	28.3
Detention Pond	CP100E2	-	-	-	-	Dimensions: 860' x 860'	10	-	4	-	-	17.0	155.2
Detention Pond	CP100F1	-	-	-	-	Dimensions: 420' x 420'	10	-	4	-	-	4.0	26.6
Detention Pond	CP100F2	-	-	-	-	Dimensions: 520' x 520'	10	-	4	-	-	6.2	45.5
Detention Pond	CP100F3	-	-	-	-	Dimensions: 670' x 670'	10	-	4	-	-	10.3	83.3
Detention Pond	CP100G	-	-	-	-	Dimensions: 230' x 230'	10	-	4	-	-	1.2	4.7
Detention Pond	CP100H	-	-	-	-	Dimensions: 210' x 210'	10	-	4	-	-	1.0	3.4

Note: For the tributary option, selected tributary solutions are shown in ***red bold*** *.*

TABLE 3-4
Costs of Conceptual Solutions
Cherry Point Gully (CP100-00-00)

Modification Type	Subbasin	Description	Construction Costs ($)	Land Costs ($)	Component Costs ($)	Total Costs ($)
Conveyance Solution						
Channel	CP100C	Trapezoidal, concrete	36,000	8,000	44,000	2,913,000
Channel	CP100B1	Trapezoidal, earthen channel	1,306,000	352,000	1,658,000	
Culvert	CP100A (SH 146)	Adding 10'x8' RCB	97,000	-	97,000	
Culvert	CP100A (FM 3360)	Adding 10'x8' RCB	129,000	-	129,000	
Mitigation Pond	CP100A	Dimensions: 460' x 460'	839,000	146,000	985,000	
Tributary Solution						
Channel	CP100A-1	Trapezoidal, earthen channel	394,000	175,000	569,000	12,222,000
Channel	CP100A-2	Trapezoidal, earthen channel	270,000	160,000	430,000	
Channel	CP100A-3	Trapezoidal, earthen channel	270,000	160,000	430,000	
Channel	CP100B1	Trapezoidal, earthen channel	603,000	358,000	961,000	
Channel	CP100B2	Trapezoidal, earthen channel	482,000	286,000	768,000	
Channel	***CP100C-1***	Trapezoidal, earthen channel	338,000	150,000	***488,000***	
Channel	***CP100C-2***	Trapezoidal, earthen channel	683,000	304,000	***987,000***	
Channel	CP100C-3	Trapezoidal, earthen channel	321,000	191,000	512,000	
Channel	***CP100D-1***	Trapezoidal, earthen channel	386,000	172,000	***558,000***	
Channel	***CP100D-2***	Trapezoidal, earthen channel	804,000	358,000	***1,162,000***	
Channel	CP100D-3	Trapezoidal, earthen channel	161,000	72,000	233,000	
Channel	***CP100E2-1***	Trapezoidal, earthen channel	273,000	122,000	***395,000***	
Channel	***CP100E2-2***	Trapezoidal, earthen channel	547,000	243,000	***790,000***	
Channel	***CP100E2-3***	Trapezoidal, earthen channel	433,000	193,000	***626,000***	
Channel	CP100E2-4	Trapezoidal, earthen channel	161,000	72,000	233,000	
Channel	***CP100F2-1***	Trapezoidal, earthen channel	965,000	430,000	***1,395,000***	
Channel	***CP100F2-2***	Trapezoidal, earthen channel	193,000	86,000	***279,000***	
Channel	CP100F3-1	Trapezoidal, earthen channel	402,000	179,000	581,000	
Channel	CP100F3-2	Trapezoidal, earthen channel	353,000	158,000	511,000	
Channel	CP100F3-3	Trapezoidal, earthen channel	217,000	97,000	314,000	
Detention Solution						
Detention Pond	CP100A	Dimensions: 1185' x 1185'	7,486,000	967,000	8,453,000	23,514,000
Detention Pond	CP100B1	Dimensions: 500' x 500'	921,000	172,000	1,093,000	
Detention Pond	CP100B2	Dimensions: 690' x 690'	2,195,000	328,000	2,523,000	
Detention Pond	CP100C	Dimensions: 370' x 370'	477,000	94,000	571,000	
Detention Pond	CP100D	Dimensions: 440' x 440'	749,000	133,000	882,000	
Detention Pond	CP100E1	Dimensions: 430' x 430'	707,000	127,000	834,000	
Detention Pond	CP100E2	Dimensions: 860' x 860'	3,881,000	509,000	4,390,000	
Detention Pond	CP100F1	Dimensions: 420' x 420'	665,000	121,000	786,000	
Detention Pond	CP100F2	Dimensions: 520' x 520'	1,137,000	186,000	1,323,000	
Detention Pond	CP100F3	Dimensions: 670' x 670'	2,081,000	309,000	2,390,000	
Detention Pond	CP100G	Dimensions: 230' x 230'	117,000	36,000	153,000	
Detention Pond	CP100H	Dimensions: 210' x 210'	86,000	30,000	116,000	

Note: For the tributary option, selected tributary solutions are shown in ***red bold****.*

TABLE 4-1
Hydrologic Subbasin Parameters
Cotton Bayou (CB100-00-00)

			Green & Ampt			Revised Existing		SCS (Revised Existing)				Future		SCS (Future)			
Subbasin	Area (acres)	Area (sq. mi.)	Volume Moisture Deficit	Wetting Front Suction (inches)	Hydraulic Conductivity (in/hr)	Tc (hr)	R (hr)	Weighted CN	Initial Retention (in)	Initial Abstraction (in)	Impervious (%)	Tc (hr)	R (hr)	Weighted CN	Initial Retention (in)	Initial Abstraction (in)	Impervious (%)
CB100A	363	0.567	0.385	12.45	0.024	3.047	9.141	81	2.35	0.47	6	0.864	2.592	87	1.49	0.3	36
CB100B	686.8	1.073	0.385	12.45	0.024	1.982	5.946	83	2.05	0.41	17	0.756	2.268	88	1.36	0.27	41
CB100C	386.7	0.604	0.385	12.45	0.024	3.835	11.505	82	2.20	0.44	13	1.203	3.609	87	1.49	0.3	36
CB100D	537.8	0.840	0.385	12.45	0.024	4.661	13.983	82	2.20	0.44	11	1.494	4.482	89	1.24	0.25	48
Area (sq. mi.) =		3.084								**Weighted Impervious (%) =**	13					**Weighted Impervious (%) =**	41

TABLE 4-2
Peak Flows Summary
Cotton Bayou (CB100-00-00)

Name	Drainage Area	Revised Existing Peak Flows (cfs)				Future Conditions Peak Flows (cfs)				Flow Difference (cfs) Revised Existing vs. Future				Flow Difference (%) Revised Existing vs. Future			
	(sq. mi.)	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year
Nodal Flows																	
CB#1	0.567	80	151	197	281	252	416	513	682	172	265	316	401	216%	175%	160%	143%
CB#2	1.640	255	508	671	977	648	1193	1491	1999	394	685	820	1022	155%	135%	122%	105%
CB#3	2.244	325	643	847	1227	822	1508	1885	2459	498	865	1038	1232	153%	134%	122%	100%
CB#4	3.084	406	801	1056	1521	1047	1894	2388	3042	641	1093	1333	1520	158%	136%	126%	100%
Basin Flows																	
CB100A	0.567	80	151	197	281	252	416	513	682	172	265	316	401	216%	175%	160%	143%
CB100B	1.073	230	414	528	735	533	869	1064	1408	304	455	536	673	132%	110%	102%	92%
CB100C	0.604	72	136	178	254	207	350	436	589	135	214	258	334	189%	157%	145%	132%
CB100D	0.840	83	160	211	303	251	423	528	717	168	263	317	414	202%	164%	150%	137%

TABLE 4-3
Conceptual Solutions
Cotton Bayou (CB100-00-00)

Modification Type	Subbasin	Chan. Slope (ft/ft)	D/S Sta.	U/S Sta.	Length (ft)	Description	Depth (Typical) (ft)	Bottom Width (ft)	Side Slope (H:V)	Right-of-Way (ft)	N-value	Surface Area (ac)	Excavation Volume (ac-ft)
Conveyance Solution													
Channel	CB100D	0.00041	21224	23593	2369	Trapezoidal, earthen channel	10	40	6	160	0.04	8.4	62.8
Channel	CB100C	0.00173	23593	26006	2413	Trapezoidal, earthen channel	10	35	6	155	0.04	8.2	37.2
Channel	CB100B	0.00062	26006	30720	4714	Trapezoidal, earthen channel	10	30	6	150	0.04	15.6	41.1
Culvert	CB100B (Prairie Ave.)	-	-	-	40	Replace 2-10'x8' RCB with Bridge	10	30	6	150	0.04	-	-
Culvert	CB100B (Perry Rd.)	-	-	-	40	Add 2-8'x7' RCB	-	-	-	-	0.015	-	-
Culvert	CB100B (Access Rd.)	-	-	-	60	Replace 1-36" CMP with 2-9'x8' RCB	-	-	-	-	0.015	-	-
Culvert	CB100A (Canal)	-	-	-	190	Replace 2-48" CMP with 4-72" CMP	-	-	-	-	0.024	-	-
Mitigation Pond	CB100D	-	-	-	-	Dimensions: 670' x 670'	10	-	4	-	-	9.0	71.0
Tributary Solution													
Channel	CB100A-1	0.001	-	-	2650	Trapezoidal, earthen channel	10	6	6	126	0.04	7.7	40.2
Channel	CB100A-2	0.001	-	-	2700	Trapezoidal, earthen channel	10	6	6	126	0.04	7.8	40.9
Channel	***CB100B-1***	0.001	-	-	1500	Trapezoidal, earthen channel	10	6	6	126	0.04	4.3	22.7
Channel	***CB100B-2***	0.001	-	-	900	Trapezoidal, earthen channel	10	6	6	126	0.04	2.6	13.6
Channel	***CB100B-3***	0.001	-	-	1500	Trapezoidal, earthen channel	10	6	6	126	0.04	4.3	22.7
Channel	CB100B-4	0.001	-	-	1750	Trapezoidal, earthen channel	10	6	6	126	0.04	5.1	26.5
Channel	CB100B-5	0.001	-	-	1650	Trapezoidal, earthen channel	10	6	6	126	0.04	4.8	25.0
Channel	CB100C-1	0.001	-	-	3700	Trapezoidal, earthen channel	10	6	6	126	0.04	10.7	56.1
Channel	CB100C-2	0.001	-	-	4200	Trapezoidal, earthen channel	10	6	6	126	0.04	12.1	63.6
Channel	***CB100C-3***	0.001	-	-	1400	Trapezoidal, earthen channel	10	6	6	126	0.04	4.0	21.2
Channel	CB100D-1	0.001	-	-	3600	Trapezoidal, earthen channel	10	6	6	126	0.04	10.4	54.5
Channel	CB100D-2	0.001	-	-	4200	Trapezoidal, earthen channel	10	6	6	126	0.04	12.1	63.6
Channel	CB100D-3	0.001	-	-	3500	Trapezoidal, earthen channel	10	6	6	126	0.04	10.1	53.0
Channel	CB100D-4	0.001	-	-	1200	Trapezoidal, earthen channel	10	6	6	126	0.04	3.5	18.2
Detention Solution													
Detention Pond	CB100A	-	-	-	-	Dimensions: 980' x 980'	10	-	4	-	-	22.0	197.3
Detention Pond	CB100B	-	-	-	-	Dimensions: 1150' x 1150'	10	-	4	-	-	30.4	280.5
Detention Pond	CB100C	-	-	-	-	Dimensions: 995' x 995'	10	-	4	-	-	22.7	204.1
Detention Pond	CB100D	-	-	-	-	Dimensions: 1195' x 1195'	10	-	4	-	-	32.8	305.0

Note: For the tributary option, selected tributary solutions are shown in ***red bold*** *.*

TABLE 4-4
Costs of Conceptual Solutions
Cotton Bayou (CB100-00-00)

Modification Type	Subbasin	Description	Construction Costs ($)	Land Costs ($)	Component Costs ($)	Total Costs ($)
Conveyance Solution						
Channel	CB100D	Trapezoidal, earthen channel	590,000	125,000	715,000	4,930,000
Channel	CB100C	Trapezoidal, earthen channel	354,000	124,000	478,000	
Channel	CB100B	Trapezoidal, earthen channel	402,000	234,000	636,000	
Culvert	CB100B (Prairie Ave.)	Replace 2-10'x8' RCB with Bridge	192,000	-	192,000	
Culvert	CB100B (Perry Rd.)	Add 2-8'x7' RCB	88,000	-	88,000	
Culvert	CB100B (Access Rd.)	Replace 1-36" CMP with 2-9'x8' RCB	123,000	-	123,000	
Culvert	CB100A (Canal)	Replace 2-48" CMP with 4-72" CMP	654,000	-	654,000	
Mitigation Pond	CB100D	Dimensions: 670' x 670'	1,775,000	269,000	2,044,000	
Tributary Solution						
Channel	CB100A-1	Trapezoidal, earthen channel	426,000	253,000	679,000	9,140,000
Channel	CB100A-2	Trapezoidal, earthen channel	433,000	258,000	691,000	
Channel	***CB100B-1***	Trapezoidal, earthen channel	241,000	107,000	***348,000***	
Channel	***CB100B-2***	Trapezoidal, earthen channel	144,000	64,000	***208,000***	
Channel	***CB100B-3***	Trapezoidal, earthen channel	241,000	447,000	***688,000***	
Channel	CB100B-4	Trapezoidal, earthen channel	282,000	167,000	449,000	
Channel	CB100B-5	Trapezoidal, earthen channel	265,000	158,000	423,000	
Channel	CB100C-1	Trapezoidal, earthen channel	595,000	265,000	860,000	
Channel	CB100C-2	Trapezoidal, earthen channel	675,000	301,000	976,000	
Channel	***CB100C-3***	Trapezoidal, earthen channel	226,000	418,000	***644,000***	
Channel	CB100D-1	Trapezoidal, earthen channel	579,000	344,000	923,000	
Channel	CB100D-2	Trapezoidal, earthen channel	675,000	401,000	1,076,000	
Channel	CB100D-3	Trapezoidal, earthen channel	562,000	334,000	896,000	
Channel	CB100D-4	Trapezoidal, earthen channel	193,000	86,000	279,000	
Detention Solution						
Detention Pond	CB100A	Dimensions: 980' x 980'	4,933,000	661,000	5,594,000	27,908,000
Detention Pond	CB100B	Dimensions: 1150' x 1150'	7,012,000	911,000	7,923,000	
Detention Pond	CB100C	Dimensions: 995' x 995'	5,102,000	682,000	5,784,000	
Detention Pond	CB100D	Dimensions: 1195' x 1195'	7,624,000	983,000	8,607,000	

Note: For the tributary option, selected tributary solutions are shown in ***red bold****.*

TABLE 5-1
Hydrologic Subbasin Parameters
Hackberry Gully (HB100-00-00)

			Green & Ampt			Revised Existing		SCS (Revised Existing)				Future		SCS (Future)			
Subbasin	Area (acres)	Area (sq. mi.)	Volume Moisture Deficit	Wetting Front Suction (inches)	Hydraulic Conductivity (in/hr)	Tc (hr)	R (hr)	Weighted CN	Initial Retention (in)	Initial Abstraction (in)	Impervious (%)	Tc (hr)	R (hr)	Weighted CN	Initial Retention (in)	Initial Abstraction (in)	Impervious (%)
HB100A	511.90	0.800	0.385	12.45	0.024	2.697	8.091	82	2.20	0.44	10	1.087	3.261	91	0.99	0.20	58
HB100B	301.90	0.472	0.385	12.45	0.024	1.346	4.038	81	2.35	0.47	6	0.613	1.839	88	1.36	0.27	40
HB100C	427.60	0.668	0.385	12.45	0.024	1.135	3.405	83	2.05	0.41	17	0.813	2.439	87	1.49	0.30	35
HB100D	679.80	1.062	0.385	12.45	0.024	2.890	8.670	82	2.20	0.44	13	2.011	6.033	89	1.24	0.25	49
Area (sq. mi.) =		3.002								**Weighted Impervious (%) =**	12					**Weighted Impervious (%) =**	47

TABLE 5-2
Peak Flows Summary
Hackberry Gully (HB100-00-00)

Name	Drainage Area	Revised Existing Peak Flows (cfs)				Future Conditions Peak Flows (cfs)				Flow Difference (cfs) Revised Existing vs. Future				Flow Difference (%) Revised Existing vs. Future			
	(sq. mi.)	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year
Nodal Flows																	
HB#1	0.800	128	238	308	436	313	512	631	844	185	274	323	407	145%	115%	105%	93%
HB#2	1.272	227	434	563	792	510	843	1042	1274	282	409	479	482	124%	94%	85%	61%
HB#3	1.940	392	746	960	1324	767	1244	1545	1948	376	498	585	624	96%	67%	61%	47%
HB#4	3.002	552	1045	1332	1856	996	1609	1996	2476	443	564	663	620	80%	54%	50%	33%
Basin Flows																	
HB100A	0.800	128	238	308	436	313	512	631	844	185	274	323	407	145%	115%	105%	93%
HB100B	0.472	134	240	304	417	274	441	537	703	140	201	233	286	104%	84%	77%	69%
HB100C	0.668	227	393	492	667	310	511	629	835	83	119	137	168	37%	30%	28%	25%
HB100D	1.062	162	301	390	553	252	431	542	744	90	130	152	191	56%	43%	39%	35%

TABLE 5-3
Conceptual Solutions
Hackberry Gully (HB100-00-00)

Modification Type	Subbasin	Chan. Slope (ft/ft)	D/S Sta.	U/S Sta.	Length (ft)	Description	Depth (Typical) (ft)	Bottom Width (ft)	Side Slope (H:V)	Right-of-Way (ft)	N-value	Surface Area (ac)	Excavation Volume (ac-ft)
Conveyance Solution													
Channel	HB100D	0.00042	17776	23614	5838	Trapezoidal, earthen channel	10	60	6	180	0.04	23.2	94.3
Channel	HB100C	0.0009	23614	27949	4335	Trapezoidal, earthen channel	10	40	6	160	0.04	15.3	15.8
Culvert	HB100A (Access Rd.)	-	-	-	66	Add 6'x8' RCB	-	-	-	-	0.015	-	-
Mitigation Pond	HB100D	-	-	-	-	Dimensions: 725' x 725'	10	-	4	-	-	12.1	100.0
Tributary Solution													
Channel	HB100A-1	0.001	-	-	2000	Trapezoidal, earthen channel	10	6	6	126	0.04	5.8	30.3
Channel	***HB100A-2***	0.001	-	-	3250	Trapezoidal, earthen channel	10	6	6	126	0.04	9.4	49.2
Channel	***HB100A-3***	0.001	-	-	2600	Trapezoidal, earthen channel	10	6	6	126	0.04	7.5	39.4
Channel	***HB100A-4***	0.001	-	-	2600	Trapezoidal, earthen channel	10	6	6	126	0.04	7.5	39.4
Channel	***HB100B-1***	0.001	-	-	3000	Trapezoidal, earthen channel	10	6	6	126	0.04	8.7	45.5
Channel	HB100B-2	0.001	-	-	2800	Trapezoidal, earthen channel	10	6	6	126	0.04	8.1	42.4
Channel	***HB100C-1***	0.001	-	-	4400	Trapezoidal, earthen channel	10	6	6	126	0.04	12.7	66.7
Channel	HB100C-2	0.001	-	-	1200	Trapezoidal, earthen channel	10	6	6	126	0.04	3.5	18.2
Channel	HB100C-3	0.001	-	-	4350	Trapezoidal, earthen channel	10	6	6	126	0.04	12.6	65.9
Channel	HB100D-1	0.001	-	-	2900	Trapezoidal, earthen channel	10	6	6	126	0.04	8.4	43.9
Channel	HB100D-2	0.001	-	-	2700	Trapezoidal, earthen channel	10	6	6	126	0.04	7.8	40.9
Channel	HB100D-3	0.001	-	-	2200	Trapezoidal, earthen channel	10	6	6	126	0.04	6.4	33.3
Channel	HB100D-4	0.001	-	-	2500	Trapezoidal, earthen channel	10	6	6	126	0.04	7.2	37.9
Channel	HB100D-5	0.001	-	-	4200	Trapezoidal, earthen channel	10	6	6	126	0.04	12.1	63.6
Detention Solution													
Detention Pond	HB100A	-	-	-	-	Dimensions: 1075' x 1075'	10	-	4	-	-	26.5	242.0
Detention Pond	HB100B	-	-	-	-	Dimensions: 740' x 740'	10	-	4	-	-	12.6	104.8
Detention Pond	HB100C	-	-	-	-	Dimensions: 620' x 620'	10	-	4	-	-	8.8	69.4
Detention Pond	HB100D	-	-	-	-	Dimensions: 910' x 910'	10	-	4	-	-	19.0	167.3

Note: For the tributary option, selected tributary solutions are shown in ***red bold****.*

TABLE 5-4
Costs of Conceptual Solution
Hackberry Gully (HB100-00-00)

Modification Type	Subbasin	Description	Construction Costs ($)	Land Costs ($)	Component Costs ($)	Total Costs ($)
Conveyance Solution						
Channel	HB100D	Trapezoidal, earthen channel	898,000	348,000	1,246,000	4,561,000
Channel	HB100C	Trapezoidal, earthen channel	168,000	229,000	397,000	
Culvert	HB100A (Access Rd.)	Add 6'x8' RCB	56,000	-	56,000	
Mitigation Pond	HB100D	Dimensions: 725' x 725'	2,500,000	362,000	2,862,000	
Tributary Solution						
Channel	HB100A-1	Trapezoidal, earthen channel	321,000	143,000	464,000	13,224,000
Channel	***HB100A-2***	Trapezoidal, earthen channel	523,000	310,000	***833,000***	
Channel	***HB100A-3***	Trapezoidal, earthen channel	418,000	248,000	***666,000***	
Channel	***HB100A-4***	Trapezoidal, earthen channel	418,000	776,000	***1,194,000***	
Channel	***HB100B-1***	Trapezoidal, earthen channel	482,000	895,000	***1,377,000***	
Channel	HB100B-2	Trapezoidal, earthen channel	450,000	200,000	650,000	
Channel	***HB100C-1***	Trapezoidal, earthen channel	707,000	1,313,000	***2,020,000***	
Channel	HB100C-2	Trapezoidal, earthen channel	193,000	115,000	308,000	
Channel	HB100C-3	Trapezoidal, earthen channel	700,000	1,298,000	1,998,000	
Channel	HB100D-1	Trapezoidal, earthen channel	466,000	277,000	743,000	
Channel	HB100D-2	Trapezoidal, earthen channel	433,000	258,000	691,000	
Channel	HB100D-3	Trapezoidal, earthen channel	353,000	210,000	563,000	
Channel	HB100D-4	Trapezoidal, earthen channel	402,000	239,000	641,000	
Channel	HB100D-5	Trapezoidal, earthen channel	675,000	401,000	1,076,000	
Detention Solution						
Detention Pond	HB100A	Dimensions: 1075' x 1075'	6,050,000	796,000	6,846,000	16,595,000
Detention Pond	HB100B	Dimensions: 740' x 740'	2,619,000	377,000	2,996,000	
Detention Pond	HB100C	Dimensions: 620' x 620'	1,735,000	265,000	2,000,000	
Detention Pond	HB100D	Dimensions: 910' x 910'	4,183,000	570,000	4,753,000	

Note: For the tributary option, selected tributary solutions are shown in ***red bold****.*

TABLE 6-1
Hydrologic Subbasin Parameters
Old Ditch (OD100-00-00)

			Loss Method: Green & Ampt			Revised Existing		Loss Method: SCS (Revised Existing)				Future		Loss Method: SCS (Future)			
Subbasin	Area (acres)	Area (sq. mi.)	Volume Moisture Deficit	Wetting Front Suction (inches)	Hydraulic Conductivity (in/hr)	Tc (hr)	R (hr)	Weighted CN	Initial Retention (in)	Initial Abstraction (in)	Impervious (%)	Tc (hr)	R (hr)	Weighted CN	Initial Retention (in)	Initial Abstraction (in)	Impervious (%)
OD100A	48.3	0.075	0.385	12.45	0.024	0.862	2.586	81	2.35	0.47	7	0.264	0.792	90	1.11	0.22	53
OD100B	56.0	0.087	0.385	12.45	0.024	0.864	2.592	87	1.49	0.30	38	0.864	2.592	87	1.49	0.30	38
OD100C	63.0	0.098	0.385	12.45	0.024	0.208	0.624	86	1.63	0.33	35	0.208	0.624	86	1.63	0.33	35
OD100D	12.2	0.019	0.385	12.45	0.024	0.157	0.471	84	1.90	0.38	10	0.157	0.471	84	1.90	0.38	10
Area (sq. mi.) =		0.279								**Weighted Impervious (%) =**	27					**Weighted Impervious (%) =**	39

TABLE 6-2
Peak Flows Summary
Old Ditch (OP100-00-00)

Name	Drainage Area	Revised Existing Peak Flows (cfs)				Future Conditions Peak Flows (cfs)				Flow Difference (cfs) Revised Existing vs. Future				Flow Difference (%) Revised Existing vs. Future			
	(sq. mi.)	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year	2-Year	10-Year	25-Year	100-Year
Nodal Flows																	
OD#1	0.075	26	53	66	89	69	118	143	181	43	66	77	92	163%	125%	116%	103%
OD#2	0.162	58	115	144	193	94	169	206	267	36	54	62	74	61%	47%	43%	39%
OD#3	0.260	117	222	274	363	165	300	364	468	48	78	89	105	42%	35%	33%	29%
OD#4	0.279	136	257	317	416	178	327	397	511	42	70	80	95	31%	27%	25%	23%
Basin Flows																	
OD100A	0.075	26	53	66	89	69	118	143	181	43	66	77	92	163%	125%	116%	103%
OD100B	0.087	33	63	79	105	33	63	79	105	0	0	0	0	0%	0%	0%	0%
OD100C	0.098	103	176	213	267	103	176	213	267	0	0	0	0	0%	0%	0%	0%
OD100D	0.019	24	40	48	60	24	40	48	60	0	0	0	0	0%	0%	0%	0%

TABLE 6-3
Conceptual Solutions
Old Ditch (OD100-00-00)

Modification Type	Subbasin	Chan. Slope (ft/ft)	D/S Sta.	U/S Sta.	Length (ft)	Description	Depth (Typical) (ft)	Bottom Width (ft)	Side Slope (H:V)	Right-of-Way with Berm (ft)	N-value	Surface Area (ac)	Excavation Volume (ac-ft)
Conveyance Solution													
Channel	OD100B	0.00434	2615	3765	1150	Trapezoidal, earthen channel	5	6	3	61	0.04	1.5	1.4
Channel	OD100C	0.01135	949	1082	133	Trapezoidal, earthen channel	8	6	4	70	0.04	0.2	0.7
Culvert	OD100B (FM 565)	-	-	-	40	Replace 3-24" RCP with 5-24" RCP	-	-	-	-	0.013	-	-
Culvert	OD100B (River Bend)	-	-	-	40	Replace 3-18" CMP with 5-30" RCP	-	-	-	-	0.013	-	-
Culvert	OD100B (River Ridge)	-	-	-	61	Replace 3-18" RCP with 5-36" RCP	-	-	-	-	0.013	-	-
Culvert	OD100B (Pin Oak)	-	-	-	58	Replace 1-24" & 2-18" RCP with 3-42" RCP	-	-	-	-	0.013	-	-
Mitigation Pond	OD100A	-	-	-	-	Dimensions: 190' x 190' with berms	3	-	4	-	-	0.8	3.0
Erosion Protection													
Channel (Erosion)	OD100C	-	-	-	1200	Slope-stabilization (Rip-rap)	12	-	3	-	-	-	-
Buy-Outs													
Buy-Out	OD100C	-	-	-	-	Selected buying of properties (20 homes)	-	-	-	-	-	-	-
Detention Solution													
Detention Pond	OD100A	-	-	-	-	Dimensions: 525' x 525' with berms	3	-	4	-	-	6.3	23.6

TABLE 6-4
Costs of Conceptual Solutions
Old Ditch (OD100-00-00)

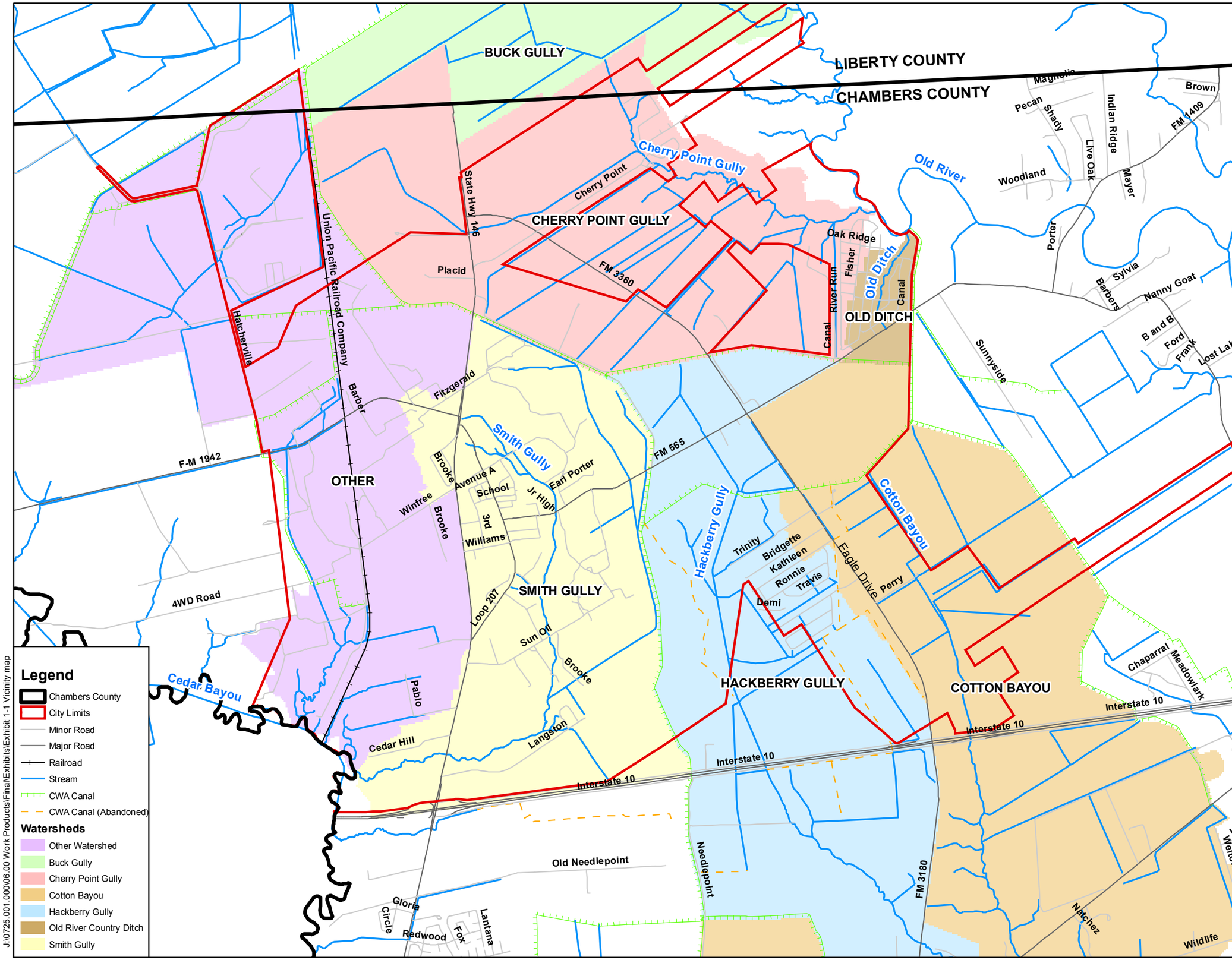
Modification Type	Subbasin	Description	Construction Costs ($)	Land Costs ($)	Component Costs ($)	Total Costs ($)
Conveyance Solution						
Channel	OD100B	Trapezoidal, earthen channel	16,000	97,000	113,000	503,000
Channel	OD100C	Trapezoidal, earthen channel	7,000	13,000	20,000	
Culvert	OD100B (FM 565)	Replace 3-24" RCP with 5-24" RCP	54,000	-	54,000	
Culvert	OD100B (River Bend)	Replace 3-18" CMP with 5-30" RCP	54,000	-	54,000	
Culvert	OD100B (River Ridge)	Replace 3-18" RCP with 5-36" RCP	72,000	-	72,000	
Culvert	OD100B (Pin Oak)	Replace 1-24" & 2-18" RCP with 3-42" RCP	63,000	-	63,000	
Mitigation Pond	OD100A	Dimensions: 190' x 190' with berms	75,000	52,000	127,000	
Erosion Protection						
Channel (Erosion)	OD100C	Slope-stabilization (Rip-rap)	67,000	-	67,000	67,000
Buy-Outs						
Buy-Out	OD100C	Selected buying of properties (20 homes)	-	2,500,000	2,500,000	2,500,000
Detention Solution						
Detention Pond	OD100A	Dimensions: 525' x 525' with berms	591,000	791,000	1,382,000	1,382,000

TABLE 7-1
Conceptual Solutions
Smith Gully (SG100-00-00)

Modification Type	Subbasin	Chan. Slope (ft/ft)	D/S Sta.	U/S Sta.	Length (ft)	Description	Depth (Typical) (ft)	Bottom Width (ft)	Side Slope (H:V)	Right-of-Way with Berm (ft)	N-value	Surface Area (ac)	Excavation Volume (ac-ft)
Conveyance Solution													
Channel	Smith Gully	0.002	10952	18205	7253	Trapezoidal, earthen channel	10	15	6	115	0.04	18.4	73.0
Culvert	Smith Gully (Sun Oil)	-	-	-	50	Add 84" RCP to existing 2-84" RCP	-	-	-	-	0.013	-	-
Culvert	Smith Gully (FM 565)	-	-	-	61	Add 48" RCP to existing 48" RCP and 2-7'x5' RCB	-	-	-	-	0.013	-	-
Mitigation Pond	Smith Gully	-	-	-	-	Dimensions: 595' x 595'	10	-	4	-	-	8.1	62.9

TABLE 7-2
Costs of Conceptual Solutions
Smith Gully (SG100-00-00)

Modification Type	Subbasin	Description	Construction Costs ($)	Land Costs ($)	Component Costs ($)	Total Cost ($)
Conveyance Solution						
Channel	Smith Gully	Trapezoidal, earthen channel	709,000	276,000	985,000	2,960,000
Culvert	Smith Gully (Sun Oil)	Add 84" RCP to existing 2-84" RCP	62,000	-	62,000	
Culvert	Smith Gully (FM 565)	Add 48" RCP to existing 48" RCP and 2-7'x5' RCB	95,000	-	95,000	
Mitigation Pond	Smith Gully	Dimensions: 595' x 595'	1,574,000	244,000	1,818,000	



Legend

- Chambers County
- City Limits
- Minor Road
- Major Road
- Railroad
- Stream
- CWA Canal
- CWA Canal (Abandoned)

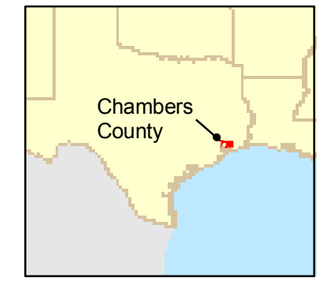
Watersheds

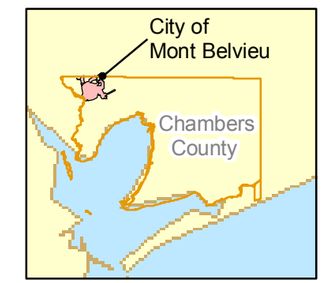
- Other Watershed
- Buck Gully
- Cherry Point Gully
- Cotton Bayou
- Hackberry Gully
- Old River Country Ditch
- Smith Gully

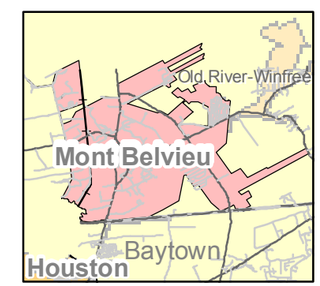
N

0 3,000

Feet







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VICINITY MAP

CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 3,000'
DATE: FEBRUARY 2009

EXHIBIT
1-1

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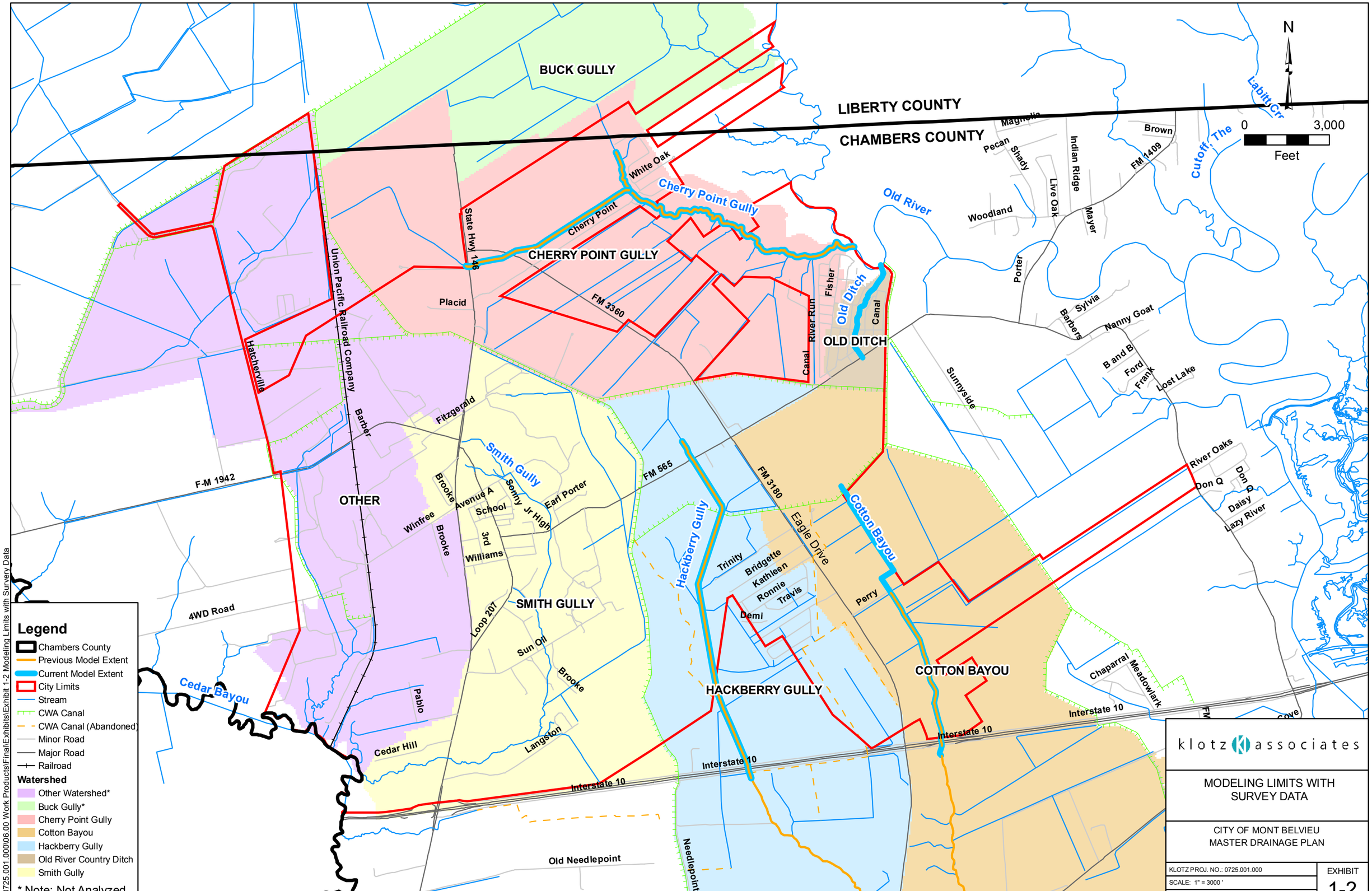

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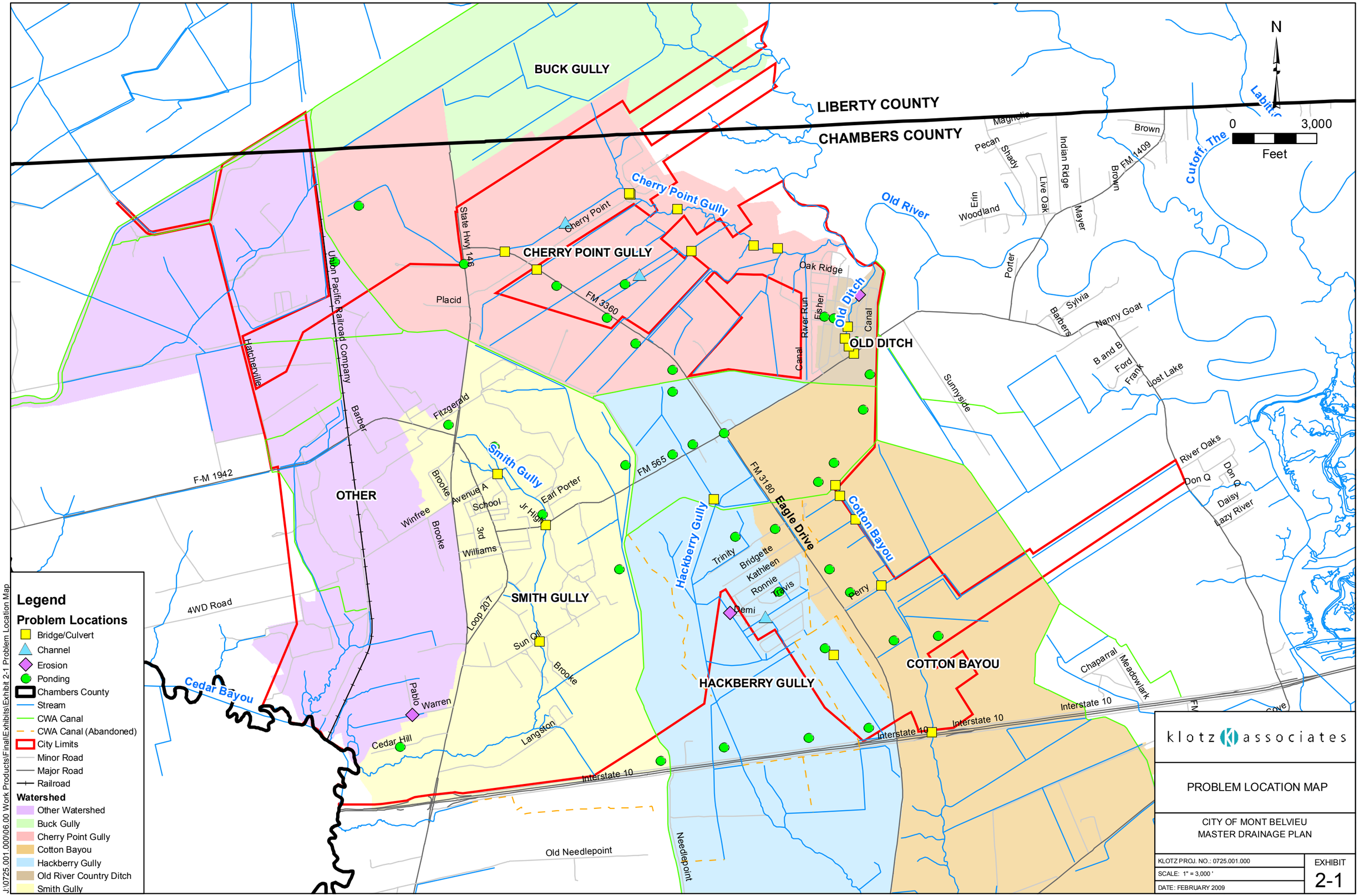
MODELING LIMITS WITH SURVEY DATA

CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 3000 '
DATE: FEBRUARY 2009

EXHIBIT
1-2


N
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3,000
Feet
LIBERTY COUNTY
CHAMBERS COUNTY
BUCK GULLY
CHERRY POINT GULLY
Cherry Point Gully
Cherry Point
State Hwy 146
Placid
FM 3360
Union Pacific Railroad Company
Hatcherville
Barber
Fitzgerald
Smith Gully
Brooke
Avenue A
School
Jr High
Earl Porter
Winfree
3rd
Williams
Loop 207
SMITH GULLY
Sun Oil
Langston
Pablo
Warren
Cedar Hill
OTHER
F-M 1942
4WD Road
Cedar Bayou
Interstate 10
Old Needlepoint
Needlepoint
FM 565
Oak Ridge
Fisher
River Run
Canal
Old Ditch
OLD DITCH
Old River
Hackberry Gully
HACKBERRY GULLY
Trinity
Bridgette
Kathleen
Ronnie
Travis
Demi
FM 3180
Eagle Drive
Cotton Bayou
Perry
COTTON BAYOU
Sunnyside
Porter
Erin
Woodland
Live Oak
Indian Ridge
Mayer
Brown
FM 1409
Pecan
Shady
Magnolia
Cutoff, The
Sylvia
Barbers
Nanny Goat
B and B
Ford
Frank
Lost Lake
River Oaks
Don Q
Daisy
Lazy River
Chaparral
Meadowlark
Legend
Problem Locations
Bridge/Culvert
Channel
Erosion
Ponding
Chambers County
Stream
CWA Canal
CWA Canal (Abandoned)
City Limits
Minor Road
Major Road
Railroad
Watershed
Other Watershed
Buck Gully
Cherry Point Gully
Cotton Bayou
Hackberry Gully
Old River Country Ditch
Smith Gully
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 2-1 Problem Location Map
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PROBLEM LOCATION MAP
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 3,000 '
DATE: FEBRUARY 2009
EXHIBIT
2-1

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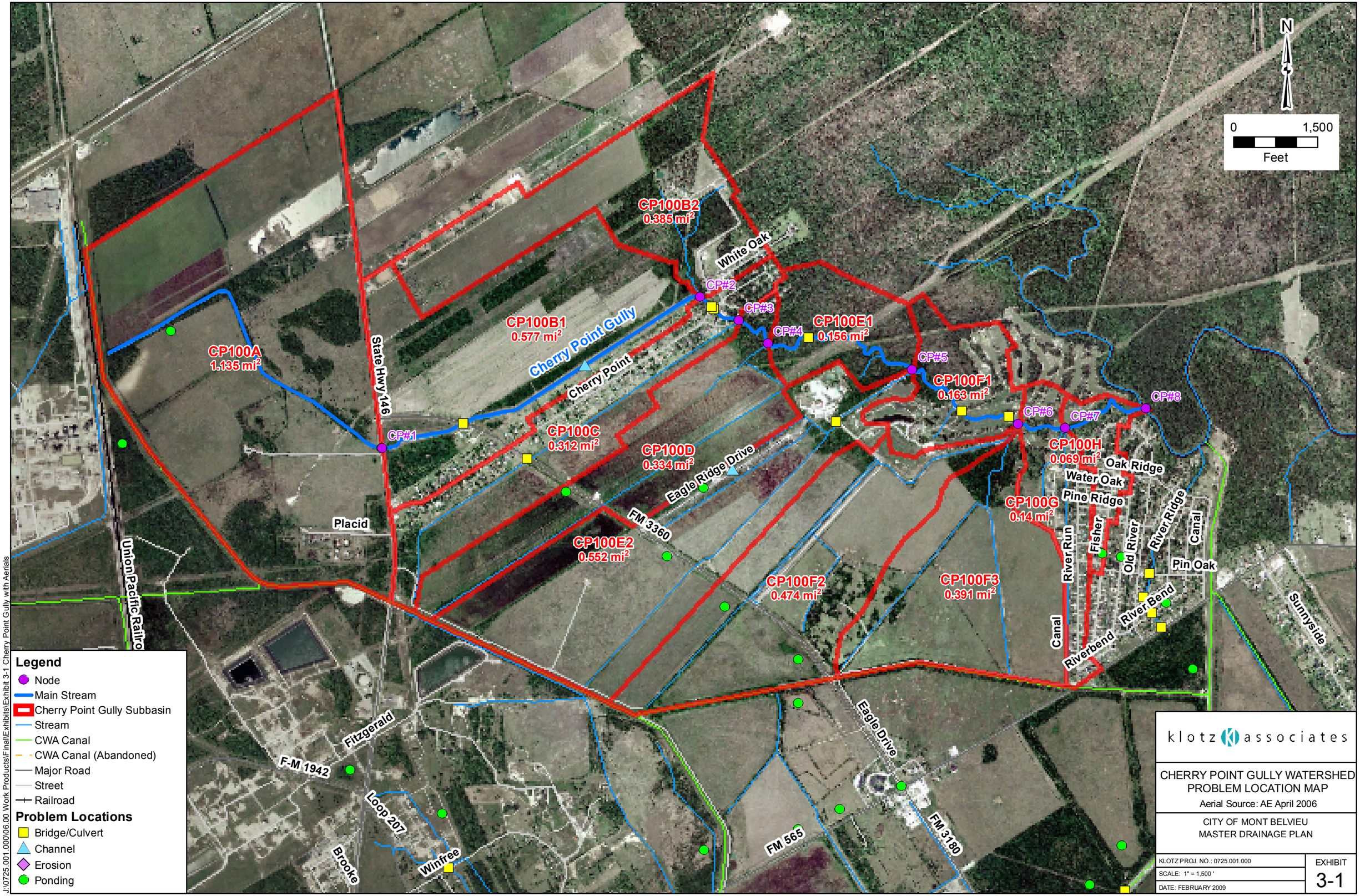
PONDING MAP

CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

KLOTZ PROJ. NO.: 0725.001.000	EXHIBIT
SCALE: 1" = 3,000 '	2-2
DATE: FEBRUARY 2009	

J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 2-2 Ponding Map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0
1,500
Feet
CP100B2
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White Oak
CP#2
CP#3
CP#4
CP100E1
0.156 mi²
CP100B1
0.577 mi²
Cherry Point Gully
Cherry Point
CP100A
1.135 mi²
State Hwy 146
CP#5
CP100F1
0.163 mi²
CP#6
CP#7
CP#8
CP#1
CP100C
0.312 mi²
CP100D
0.334 mi²
Eagle Ridge Drive
CP100H
0.069 mi²
Oak Ridge
Water Oak
Pine Ridge
CP100G
0.14 mi²
FM 3360
Placid
CP100E2
0.552 mi²
River Ridge
Canal
Fisher
Old River
Pin Oak
River Run
CP100F2
0.474 mi²
CP100F3
0.391 mi²
River Bend
Riverbend
Canal
Sunnyside
Union Pacific Railro
Eagle Drive
Fitzgerald
F-M 1942
Loop 207
Brooke
Winfree
FM 565
FM 3180
Legend
Node
Main Stream
Cherry Point Gully Subbasin
Stream
CWA Canal
CWA Canal (Abandoned)
Major Road
Street
Railroad
Problem Locations
Bridge/Culvert
Channel
Erosion
Ponding
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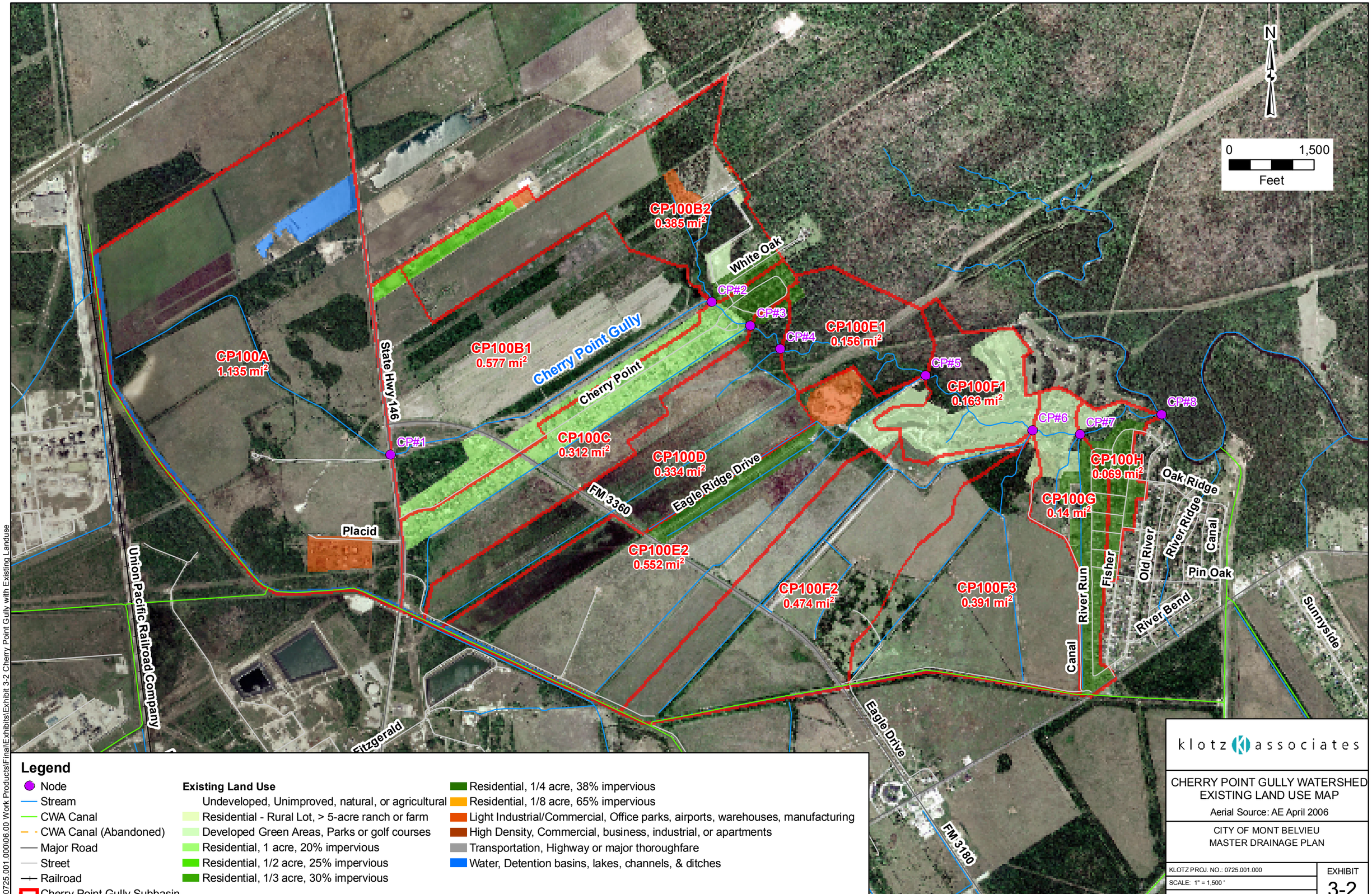
CHERRY POINT GULLY WATERSHED
PROBLEM LOCATION MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 1,500 '
DATE: FEBRUARY 2009
EXHIBIT
3-1
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 3-1 Cherry Point Gully with Aerials



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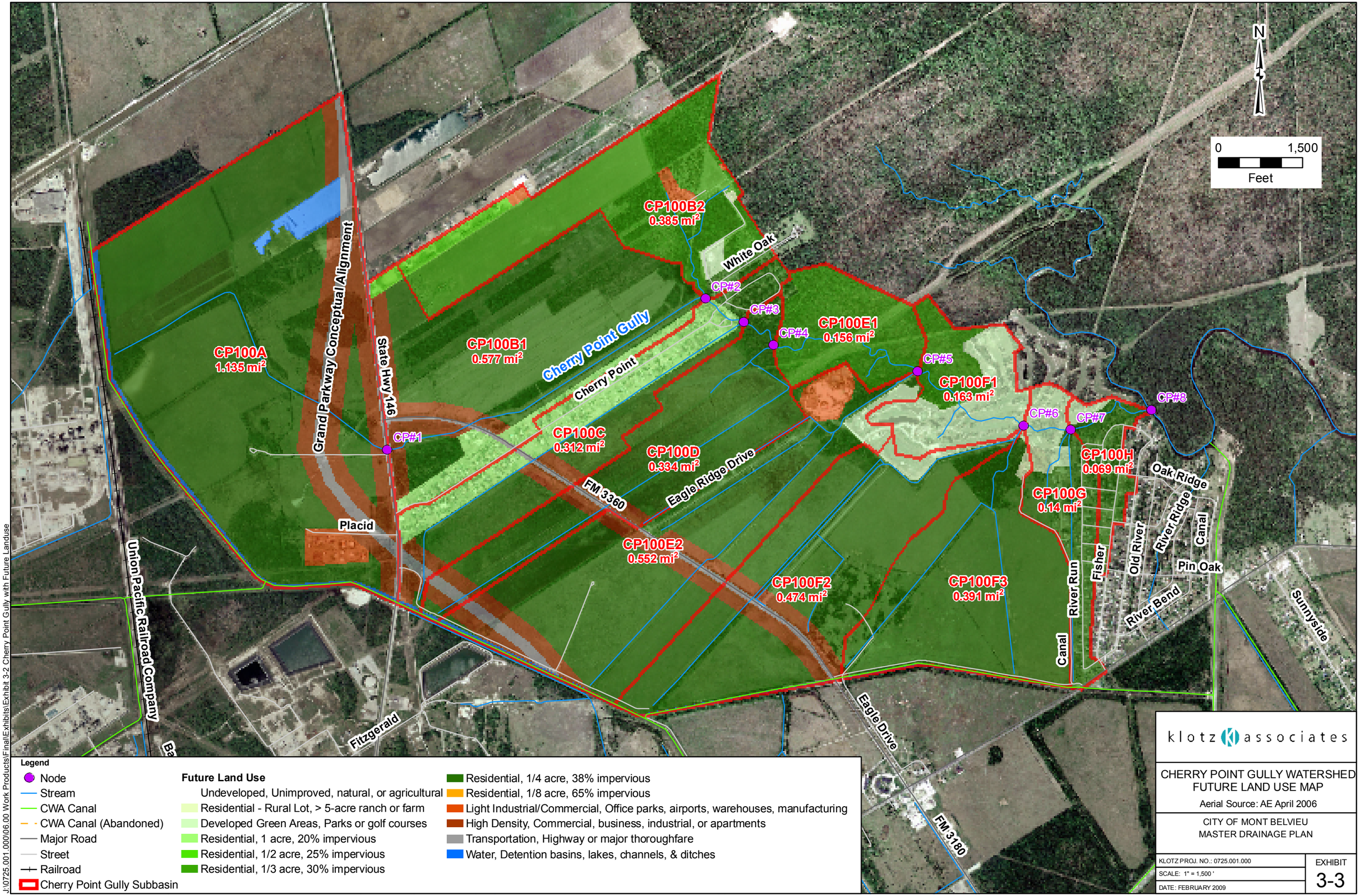

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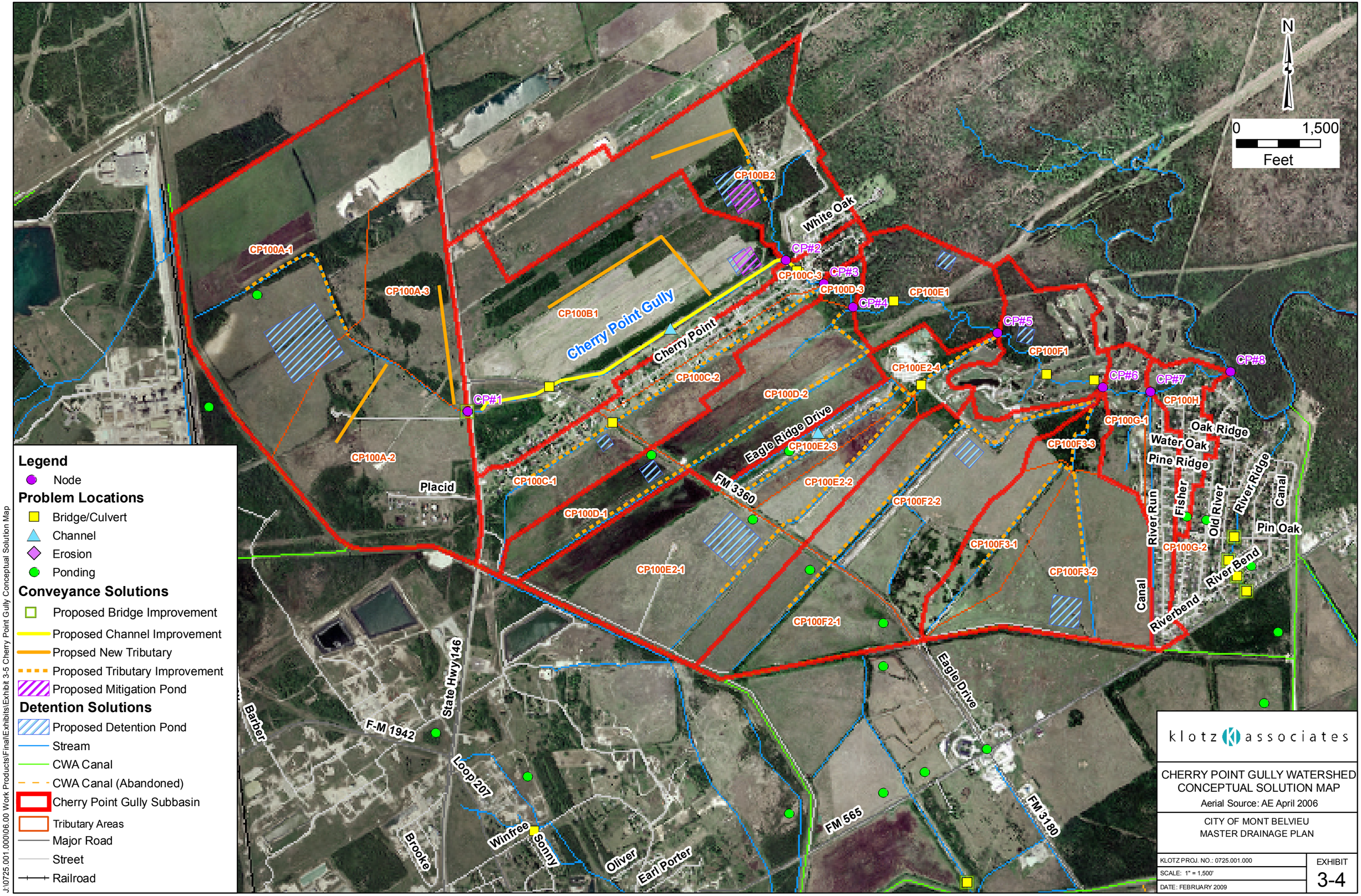
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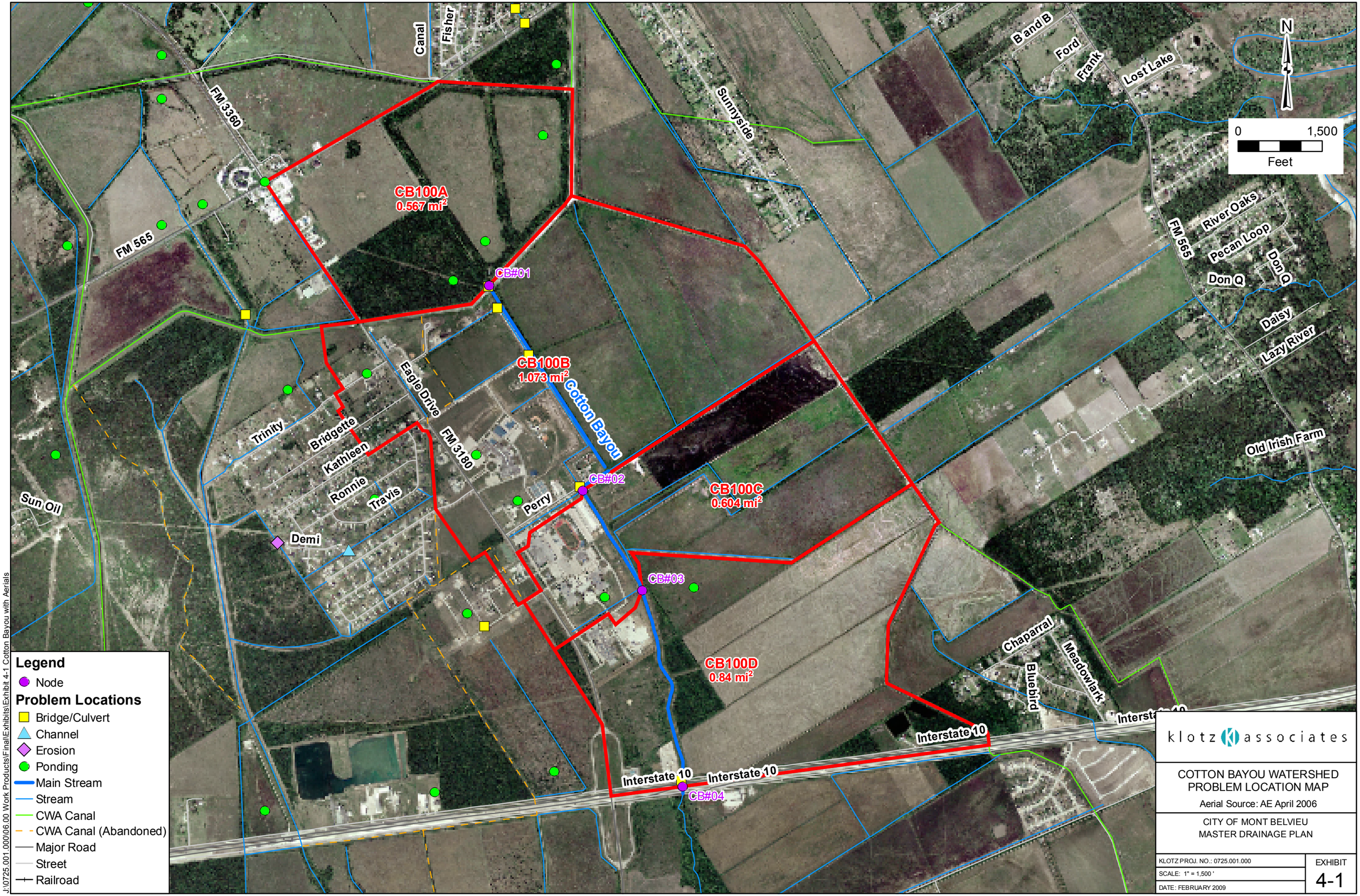
Feet
CP100B2
White Oak
CP#2
CP100C-3
CP#3
CP100D-3
CP#4
CP100E1
CP#5
CP100F1
CP#6
CP#7
CP#8
CP100H
CP100G-1
CP100F3-3
CP100A-1
CP100A-3
CP100B1
Cherry Point Gully
Cherry Point
CP100C-2
CP100D-2
CP100E2-4
CP#1
Eagle Ridge Drive
CP100E2-3
CP100A-2
Placid
CP100C-1
FM 3360
CP100E2-2
CP100F2-2
CP100D-1
CP100F3-1
CP100E2-1
CP100F3-2
CP100F2-1
Oak Ridge
Water Oak
Pine Ridge
River Ridge
Canal
Fisher
Old River
Pin Oak
River Run
CP100G-2
River Bend
Canal
Riverbend
Eagle Drive
Barber
State Hwy 146
F-M 1942
Loop 207
Brooke
Winfree
Sonny
Oliver
Earl Porter
FM 565
FM 3180
Legend
Node
Problem Locations
Bridge/Culvert
Channel
Erosion
Ponding
Conveyance Solutions
Proposed Bridge Improvement
Proposed Channel Improvement
Propsed New Tributary
Proposed Tributary Improvement
Proposed Mitigation Pond
Detention Solutions
Proposed Detention Pond
Stream
CWA Canal
CWA Canal (Abandoned)
Cherry Point Gully Subbasin
Tributary Areas
Major Road
Street
Railroad
klotz associates
CHERRY POINT GULLY WATERSHED
CONCEPTUAL SOLUTION MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 1,500'
DATE: FEBRUARY 2009
EXHIBIT
3-4
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 3-5 Cherry Point Gully Conceptual Solution Map



klotz associates

COTTON BAYOU WATERSHED
PROBLEM LOCATION MAP

Aerial Source: AE April 2006

CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

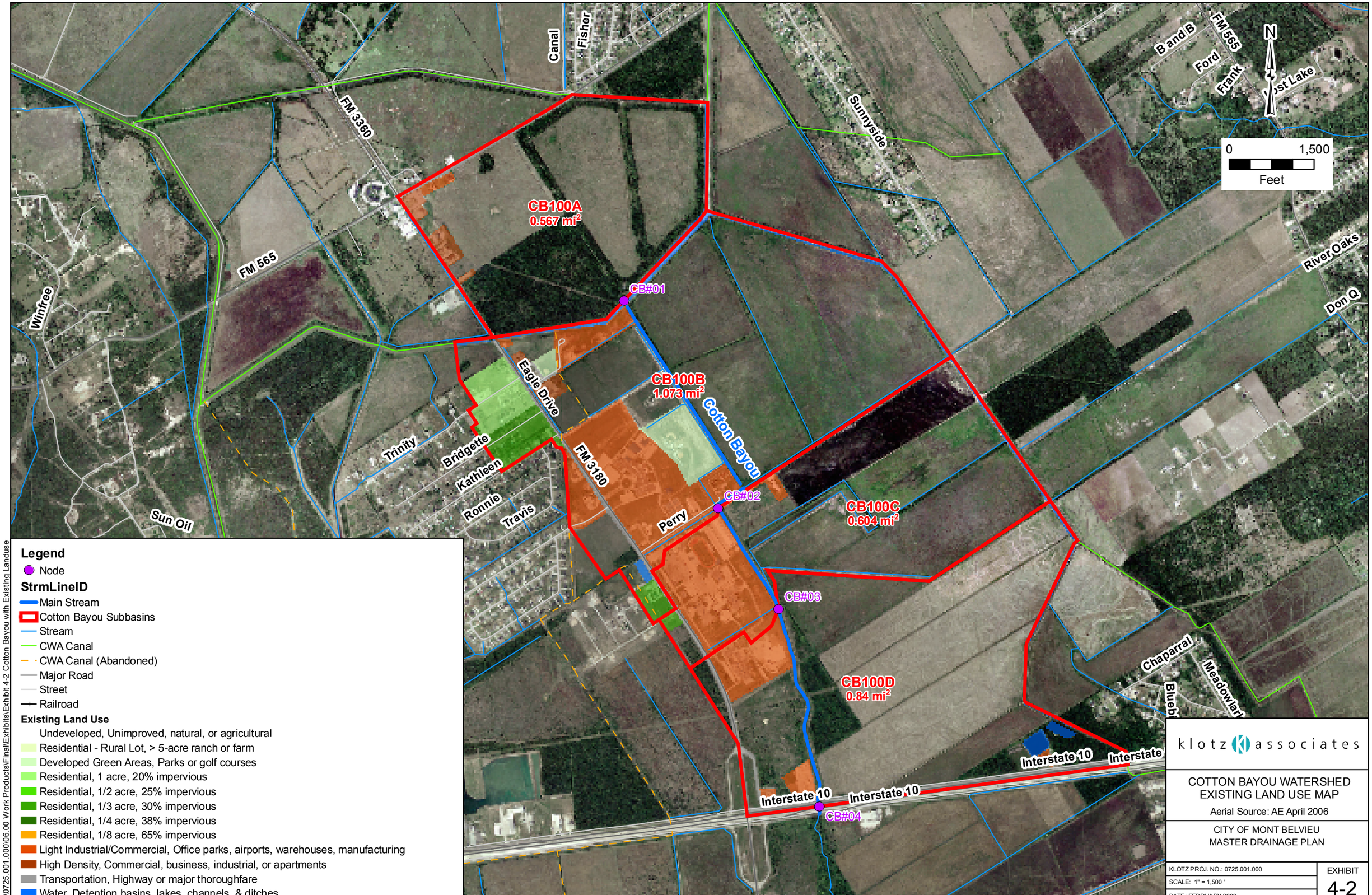
KLOTZ PROJ. NO.: 0725.001.000

SCALE: 1" = 1,500 '

DATE: FEBRUARY 2009

EXHIBIT
4-1

J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 4-1 Cotton Bayou with Aerials



J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 4-2 Cotton Bayou with Existing Landuse

klotz associates

COTTON BAYOU WATERSHED
EXISTING LAND USE MAP

Aerial Source: AE April 2006

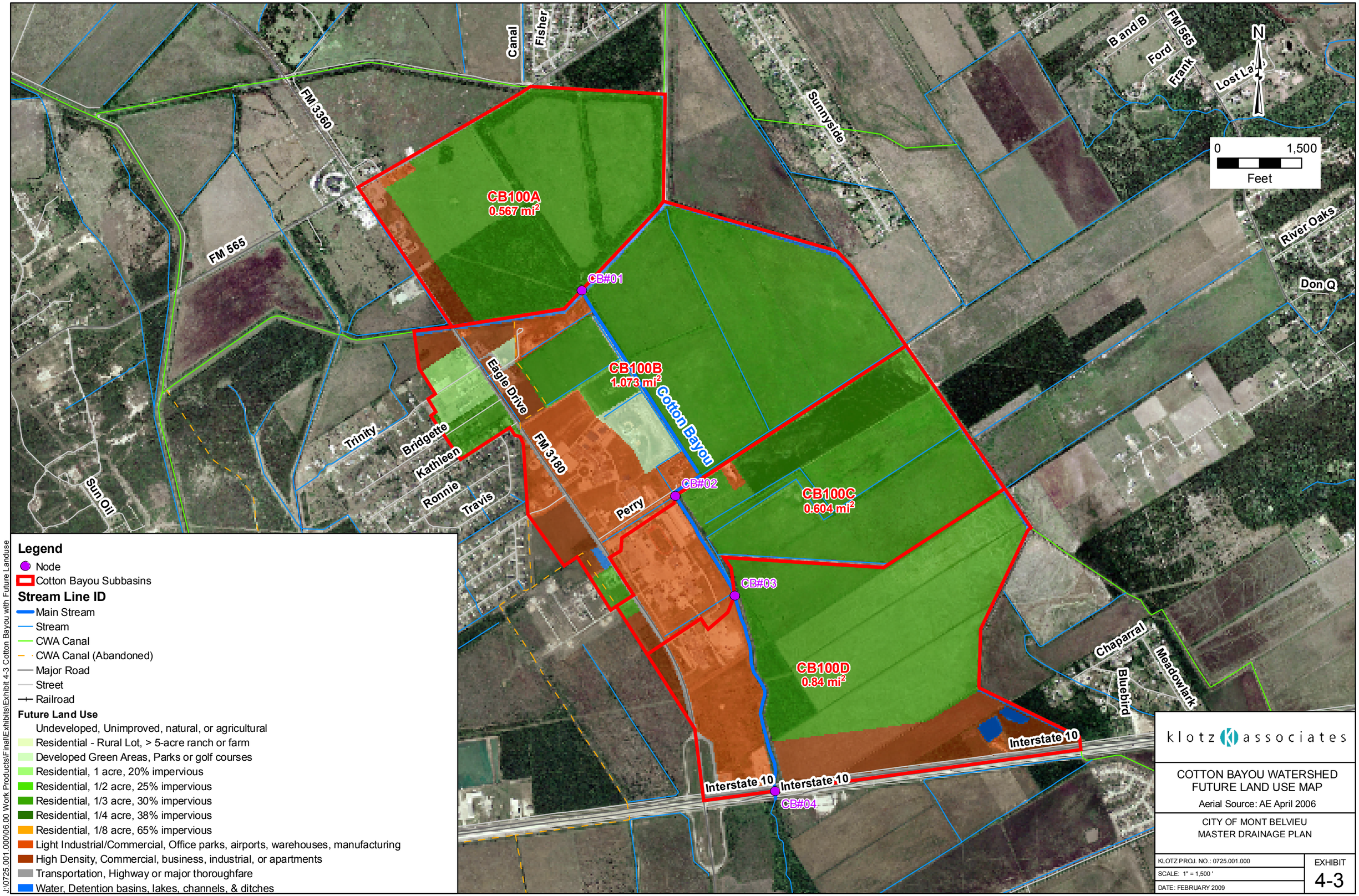
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

KLOTZ PROJ. NO.: 0725.001.000

SCALE: 1" = 1,500 '

DATE: FEBRUARY 2009

EXHIBIT
4-2



klotz associates

COTTON BAYOU WATERSHED
FUTURE LAND USE MAP

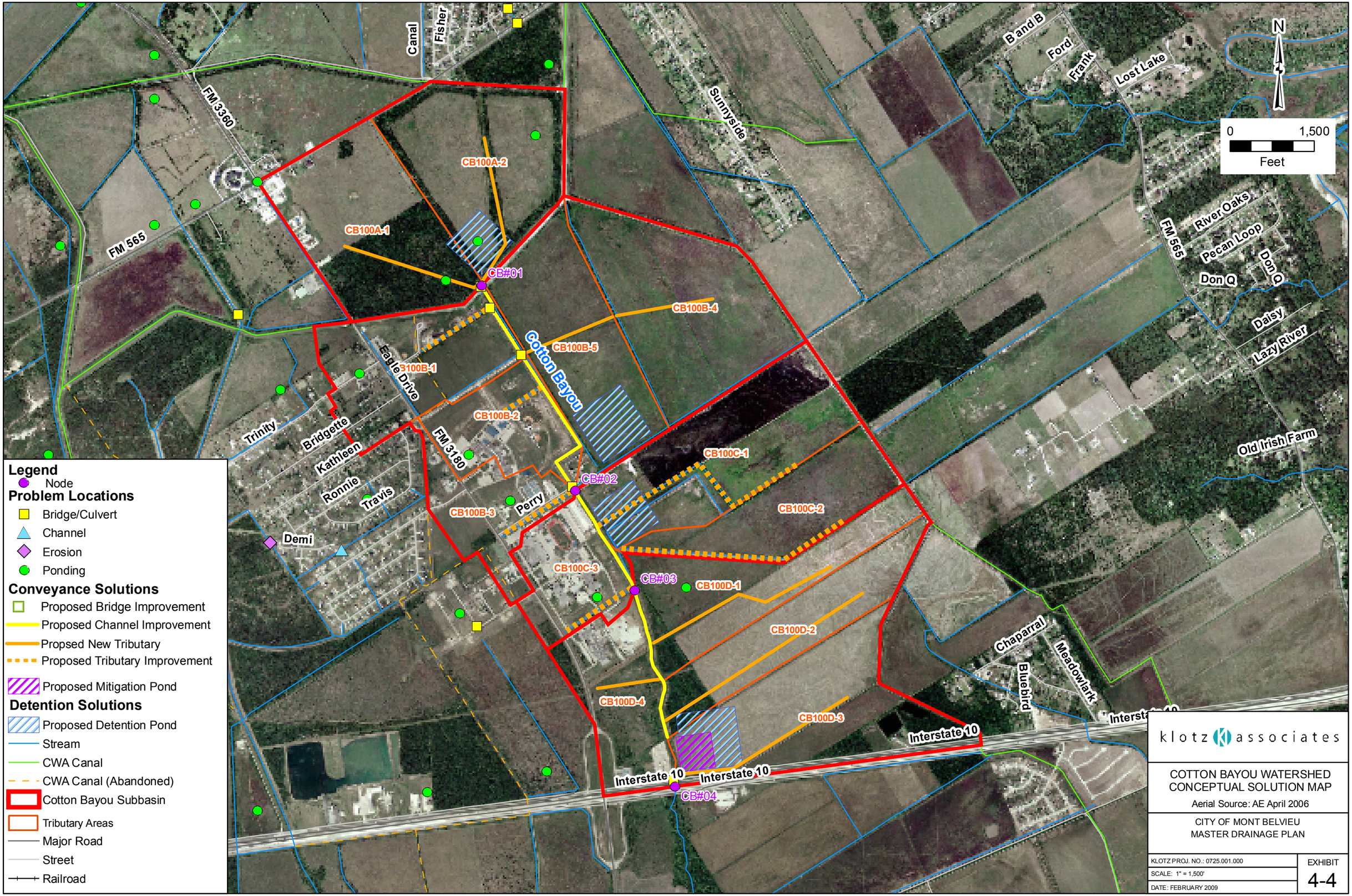
Aerial Source: AE April 2006

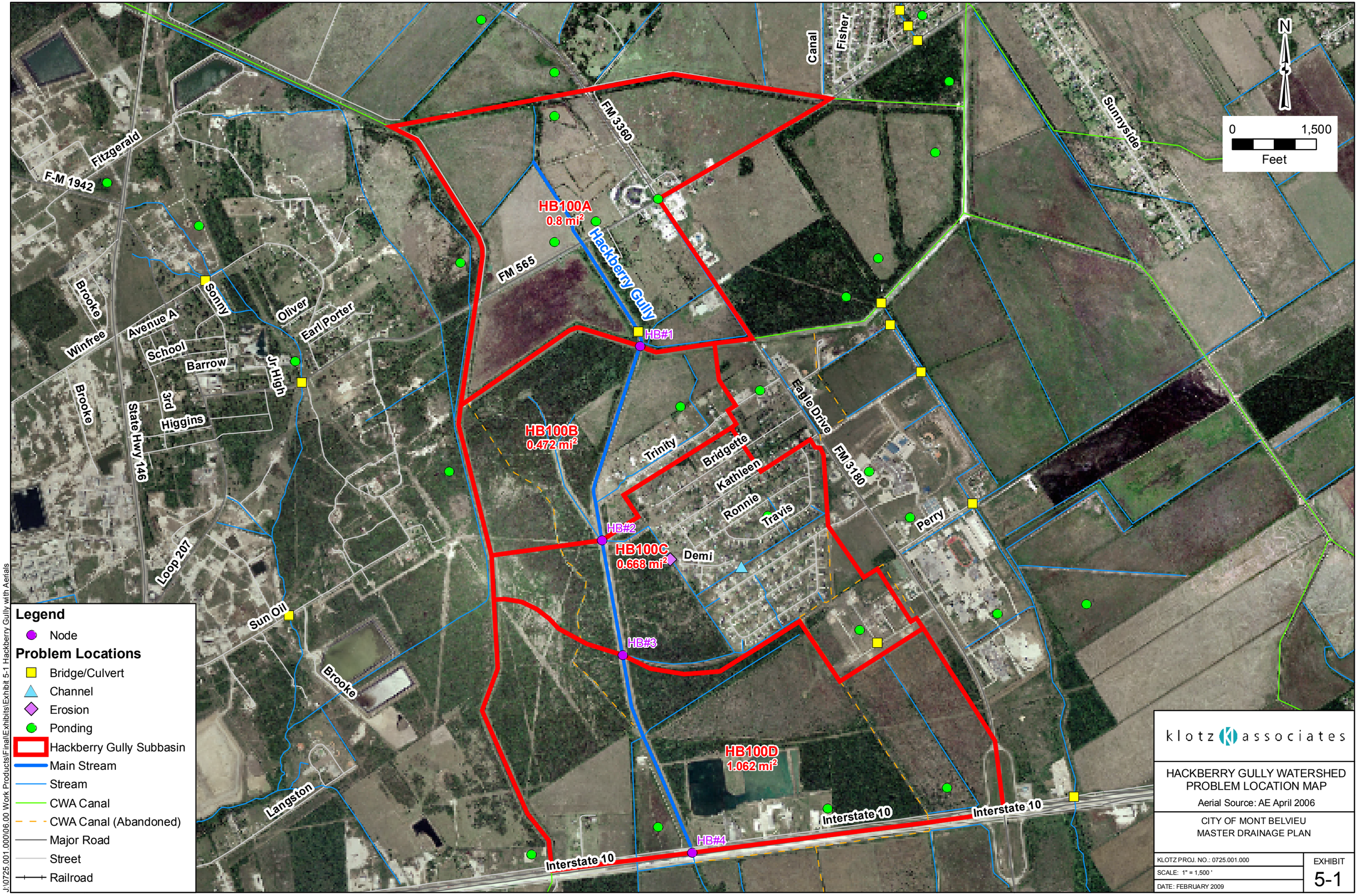
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 1,500 '
DATE: FEBRUARY 2009

EXHIBIT
4-3

J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 4-3 Cotton Bayou with Future Landuse


N
0
1,500
Feet
Canal
Fisher
FM 3360
FM 565
Sunnyside
B and B
Ford
Frank
Lost Lake
River Oaks
Pecan Loop
Don Q
Daisy
Lazy River
Old Irish Farm
CB100A-2
CB100A-1
CB#01
CB100B-4
CB100B-5
Cotton Bayou
Eagle Drive
3100B-1
CB100B-2
Trinity
Bridgette
Kathleen
Ronnie
Travis
Demi
FM 3180
Perry
CB100B-3
CB#02
CB100C-1
CB100C-2
CB100C-3
CB#03
CB100D-1
CB100D-2
CB100D-3
CB100D-4
Chaparral
Bluebird
Meadowlark
Interstate 10
CB#04
Legend
Node
Problem Locations
Bridge/Culvert
Channel
Erosion
Ponding
Conveyance Solutions
Proposed Bridge Improvement
Proposed Channel Improvement
Propsed New Tributary
Proposed Tributary Improvement
Proposed Mitigation Pond
Detention Solutions
Proposed Detention Pond
Stream
CWA Canal
CWA Canal (Abandoned)
Cotton Bayou Subbasin
Tributary Areas
Major Road
Street
Railroad
klotz associates
COTTON BAYOU WATERSHED
CONCEPTUAL SOLUTION MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 1,500'
DATE: FEBRUARY 2009
EXHIBIT
4-4
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 4-4 Cotton Bayou Conceptual Solution Map



klotz associates

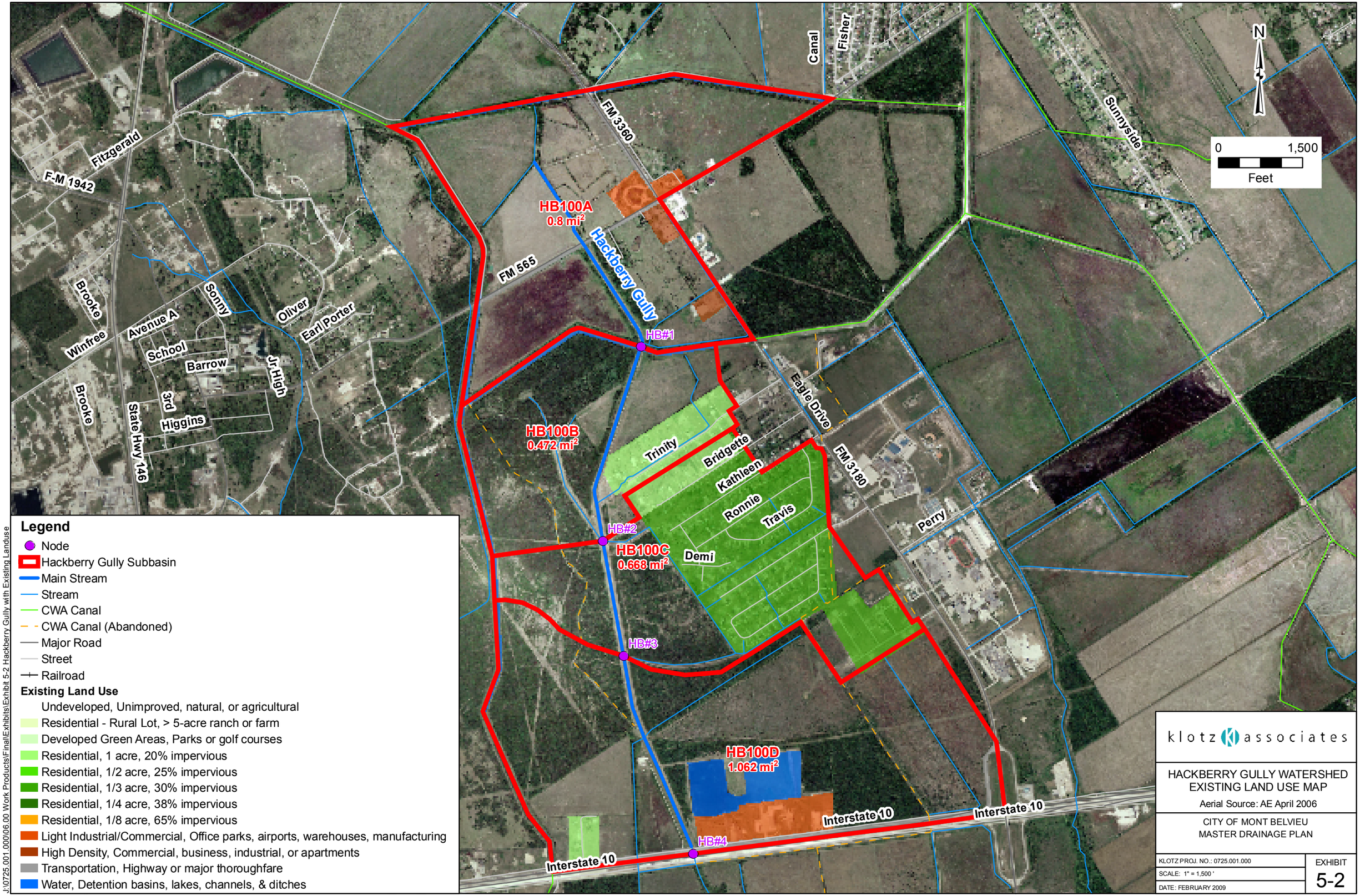
HACKBERRY GULLY WATERSHED
PROBLEM LOCATION MAP

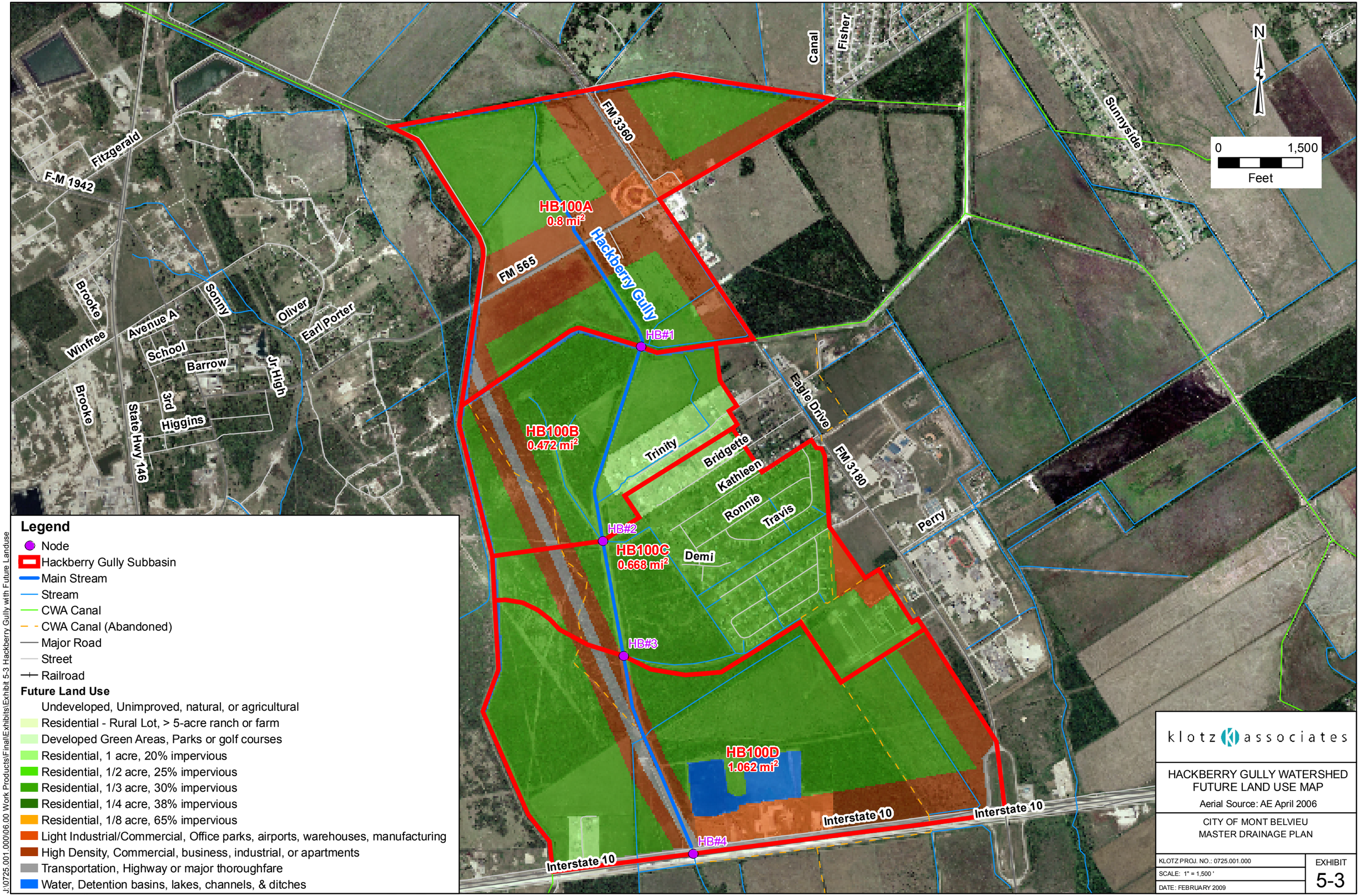
Aerial Source: AE April 2006

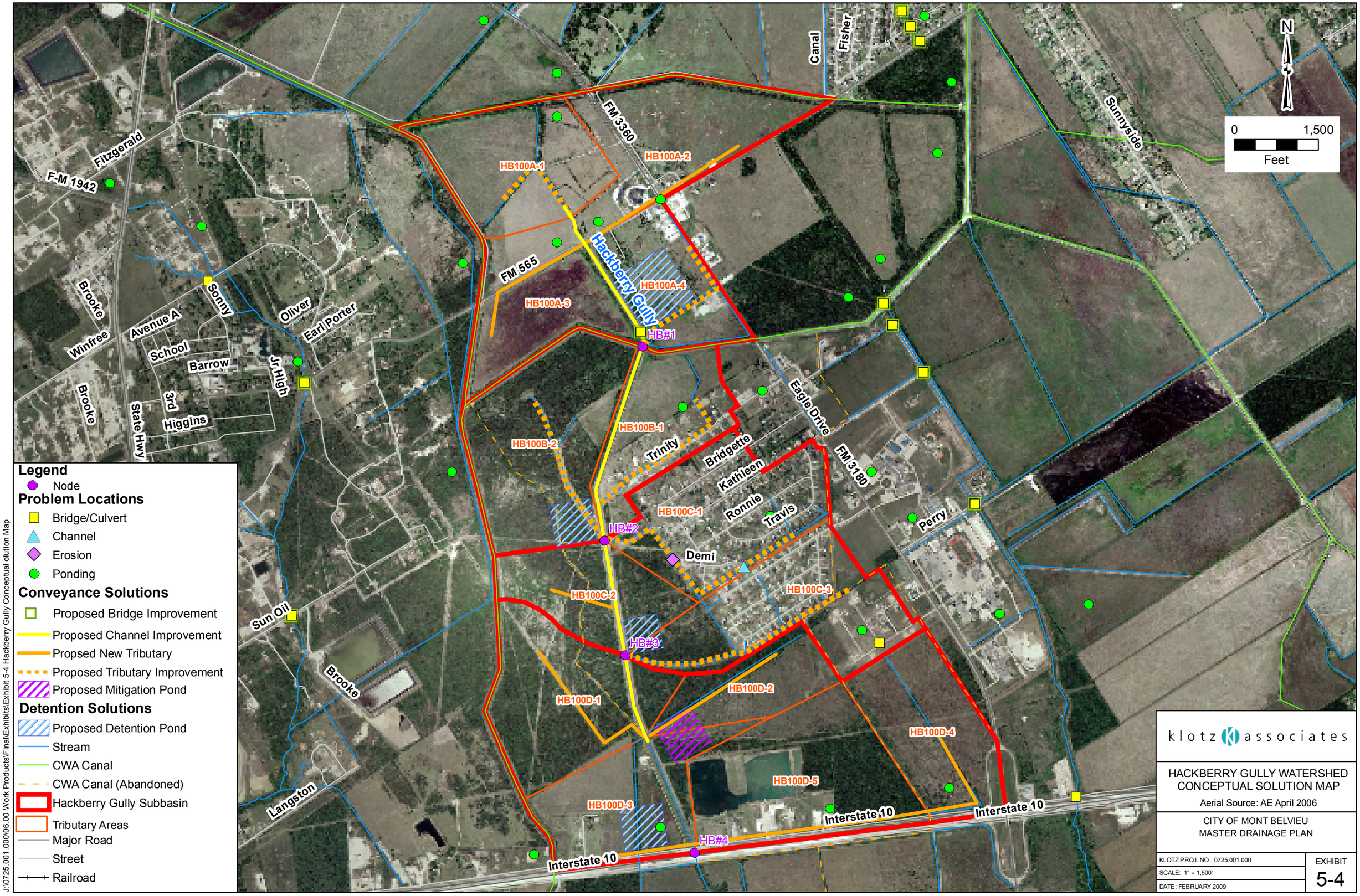
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

KLOTZ PROJ. NO.: 0725.001.000	EXHIBIT
SCALE: 1" = 1,500 '	5-1
DATE: FEBRUARY 2009	

J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 5-1 Hackberry Gully with Aerials


N
0
1,500
Feet
Canal
Fisher
Sunnyside
FM 3360
Fitzgerald
F-M 1942
HB100A
0.8 mi²
Hackberry Gully
FM 565
HB#1
Brooke
Winfree
Avenue A
Sonny
Oliver
Earl Porter
School
Barrow
Jr High
3rd
Higgins
State Hwy 146
Eagle Drive
HB100B
0.472 mi²
Trinity
Bridgette
Kathleen
Ronnie
Travis
Demi
FM 3180
Perry
HB#2
HB100C
0.668 mi²
HB#3
HB100D
1.062 mi²
Interstate 10
HB#4
Legend
Node
Hackberry Gully Subbasin
Main Stream
Stream
CWA Canal
CWA Canal (Abandoned)
Major Road
Street
Railroad
Existing Land Use
Undeveloped, Unimproved, natural, or agricultural
Residential - Rural Lot, > 5-acre ranch or farm
Developed Green Areas, Parks or golf courses
Residential, 1 acre, 20% impervious
Residential, 1/2 acre, 25% impervious
Residential, 1/3 acre, 30% impervious
Residential, 1/4 acre, 38% impervious
Residential, 1/8 acre, 65% impervious
Light Industrial/Commercial, Office parks, airports, warehouses, manufacturing
High Density, Commercial, business, industrial, or apartments
Transportation, Highway or major thoroughfare
Water, Detention basins, lakes, channels, & ditches
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 5-2 Hackberry Gully with Existing Landuse
klotz associates
HACKBERRY GULLY WATERSHED
EXISTING LAND USE MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 1,500 '
DATE: FEBRUARY 2009
EXHIBIT
5-2


N
0
1,500
Feet
Canal
Fisher
Sunnyside
FM 3360
Fitzgerald
F-M 1942
HB100A
0.8 mi²
Hackberry Gully
FM 565
HB#1
Brooke
Sonny
Oliver
Earl Porter
Avenue A
Winfree
School
Barrow
Jr High
3rd
Higgins
State Hwy 146
Brooke
HB100B
0.472 mi²
Trinity
Bridgette
Kathleen
Ronnie
Travis
Demi
Eagle Drive
FM 3180
Perry
HB#2
HB100C
0.668 mi²
HB#3
HB100D
1.062 mi²
Interstate 10
Interstate 10
Interstate 10
HB#4
Legend
Node
Hackberry Gully Subbasin
Main Stream
Stream
CWA Canal
CWA Canal (Abandoned)
Major Road
Street
Railroad
Future Land Use
Undeveloped, Unimproved, natural, or agricultural
Residential - Rural Lot, > 5-acre ranch or farm
Developed Green Areas, Parks or golf courses
Residential, 1 acre, 20% impervious
Residential, 1/2 acre, 25% impervious
Residential, 1/3 acre, 30% impervious
Residential, 1/4 acre, 38% impervious
Residential, 1/8 acre, 65% impervious
Light Industrial/Commercial, Office parks, airports, warehouses, manufacturing
High Density, Commercial, business, industrial, or apartments
Transportation, Highway or major thoroughfare
Water, Detention basins, lakes, channels, & ditches
klotz associates
HACKBERRY GULLY WATERSHED
FUTURE LAND USE MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 1,500 '
DATE: FEBRUARY 2009
EXHIBIT
5-3
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 5-3 Hackberry Gully with Future Landuse


N
0
1,500
Feet
Fitzgerald
F-M 1942
Brooke
Winfree
Avenue A
School
Barrow
Sonny
Oliver
Earl Porter
Jr High
3rd
Higgins
State Hwy
Brooke
FM 3360
Canal
Fisher
Sunnyside
HB100A-1
HB100A-2
HB100A-3
HB100A-4
FM 565
Hackberry Gully
HB#1
HB100B-1
HB100B-2
Trinity
Bridgette
Kathleen
Ronnie
Travis
Eagle Drive
FM 3180
Perry
HB100C-1
HB#2
Demi
HB100C-2
HB100C-3
HB#3
Sun Oil
Brooke
HB100D-1
HB100D-2
HB100D-3
HB100D-4
HB100D-5
Langston
HB#4
Interstate 10
Interstate 10
Interstate 10
Legend
Node
Problem Locations
Bridge/Culvert
Channel
Erosion
Ponding
Conveyance Solutions
Proposed Bridge Improvement
Proposed Channel Improvement
Propsed New Tributary
Proposed Tributary Improvement
Proposed Mitigation Pond
Detention Solutions
Proposed Detention Pond
Stream
CWA Canal
CWA Canal (Abandoned)
Hackberry Gully Subbasin
Tributary Areas
Major Road
Street
Railroad
klotz associates
HACKBERRY GULLY WATERSHED
CONCEPTUAL SOLUTION MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 1,500'
DATE: FEBRUARY 2009
EXHIBIT
5-4
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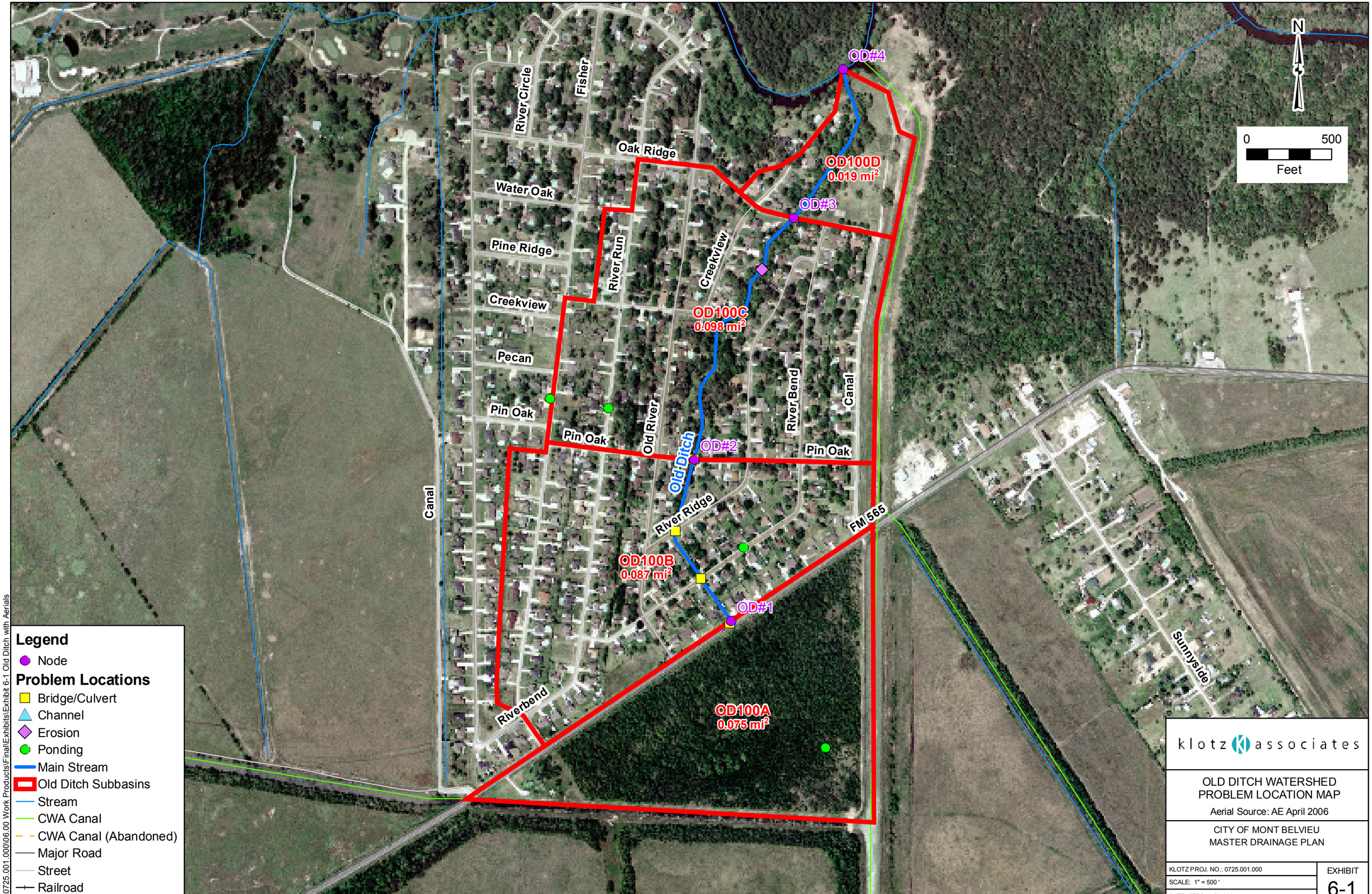
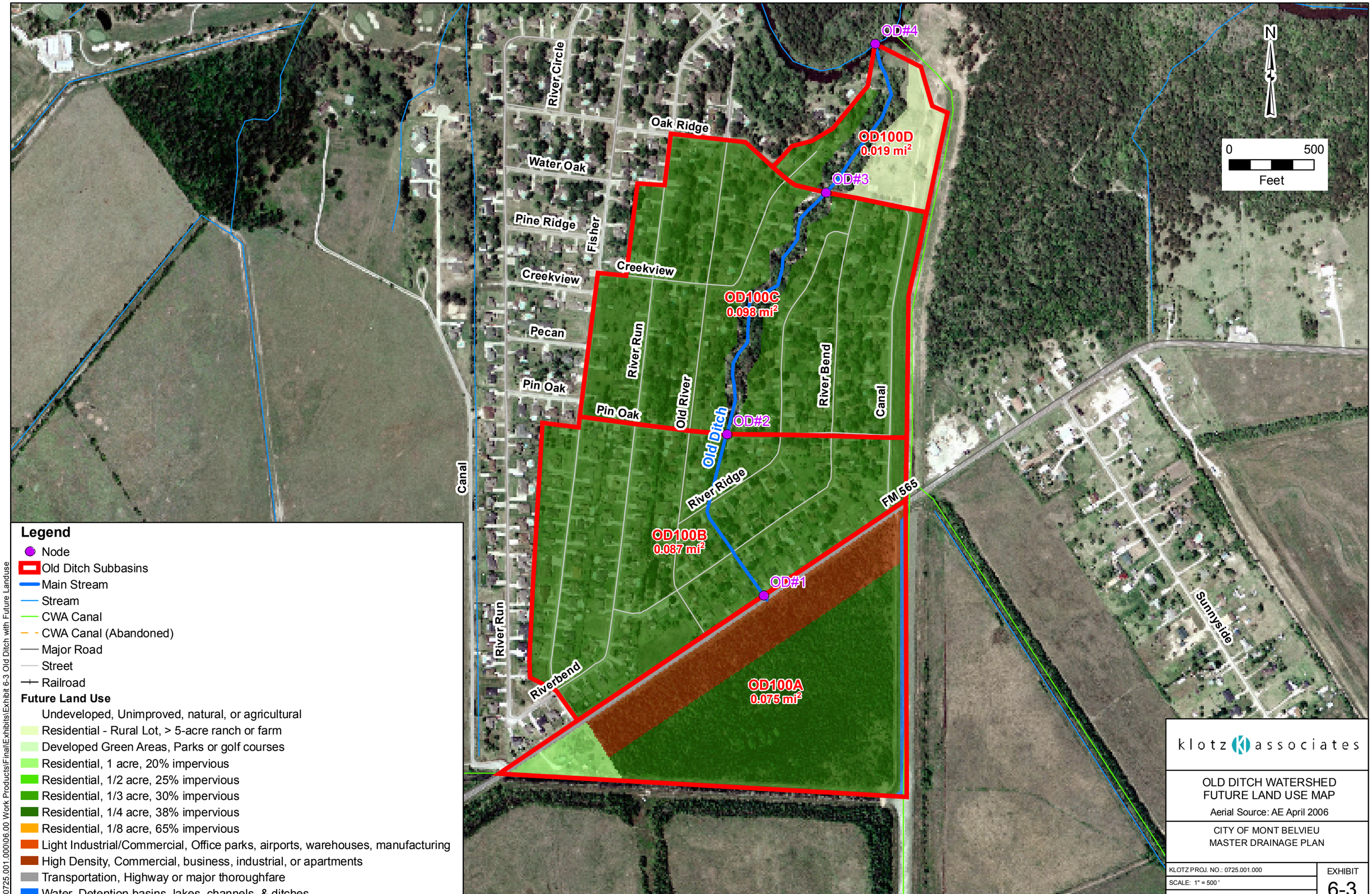
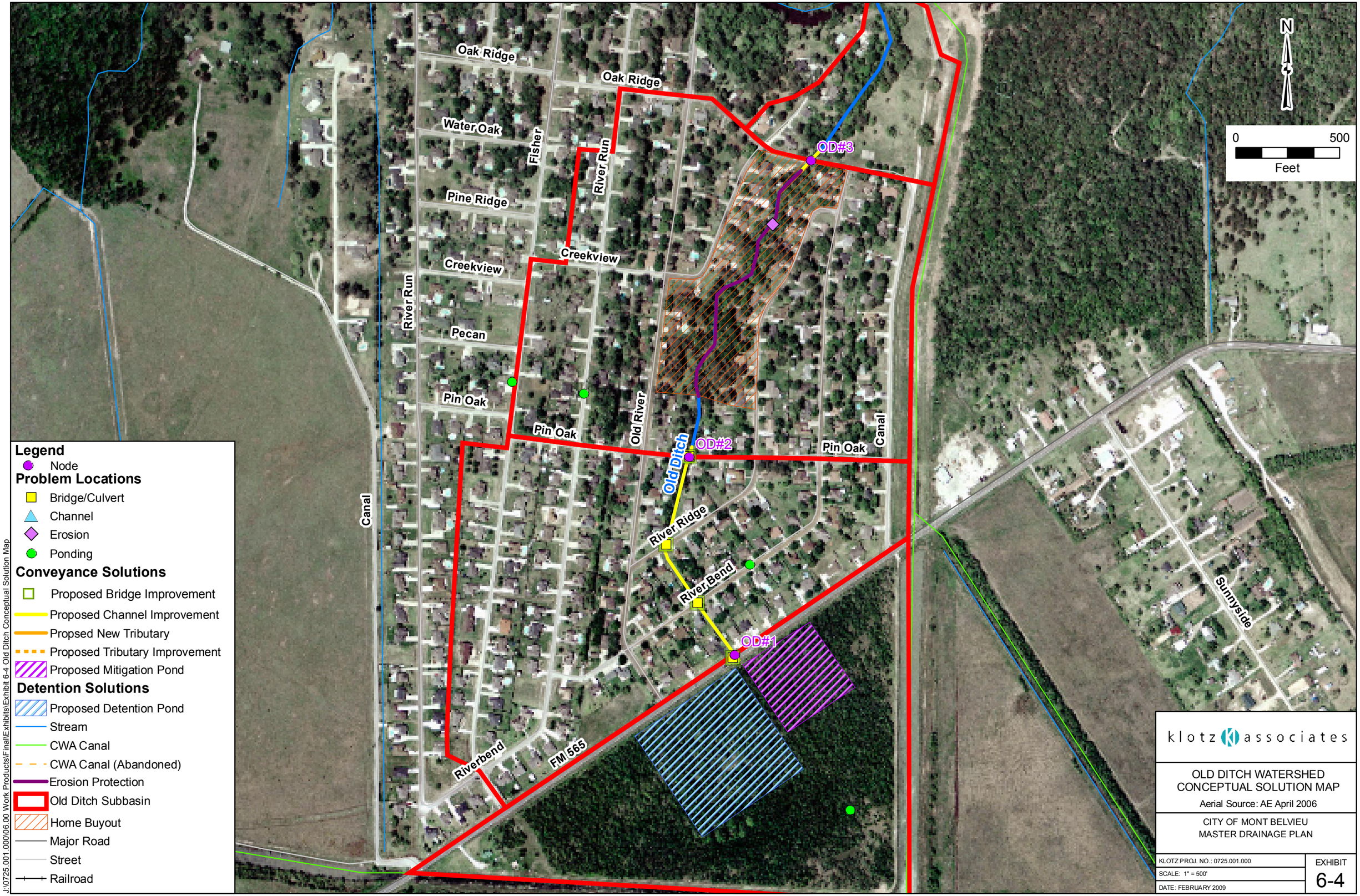
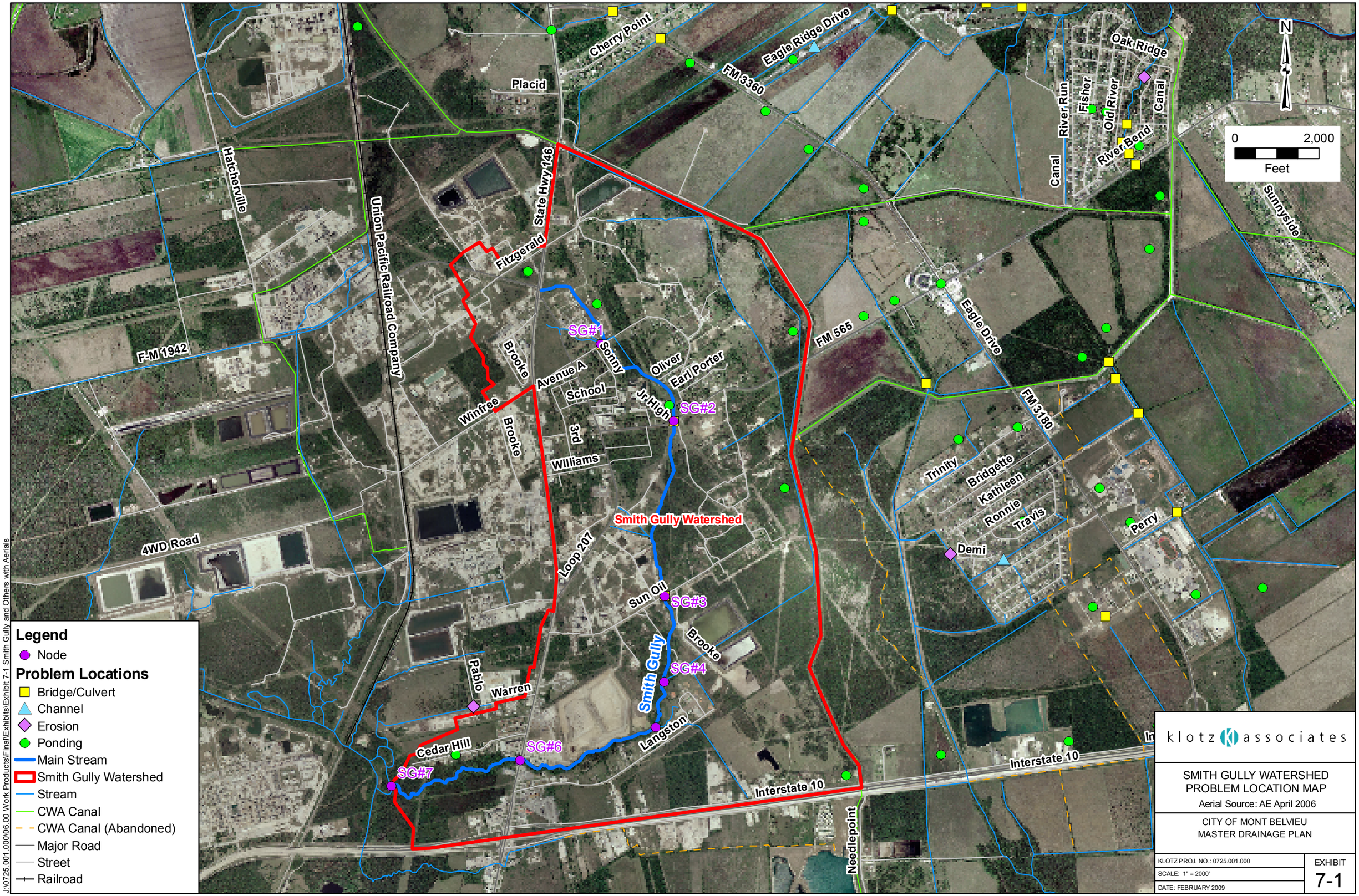

N
0
500
Feet
OD#4
OD100D
0.019 mi²
OD#3
OD100C
0.098 mi²
OD#2
OD100B
0.087 mi²
OD#1
OD100A
0.075 mi²
River Circle
Fisher
Oak Ridge
Water Oak
Pine Ridge
River Run
Creekview
Creekview
Pecan
Pin Oak
Pin Oak
Old River
Old Ditch
River Bend
Canal
Pin Oak
River Ridge
Canal
FM 565
Riverbend
Sunnyside
Legend
Node
Problem Locations
Bridge/Culvert
Channel
Erosion
Ponding
Main Stream
Old Ditch Subbasins
Stream
CWA Canal
CWA Canal (Abandoned)
Major Road
Street
Railroad
klotz associates
OLD DITCH WATERSHED
PROBLEM LOCATION MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 500 '
DATE: FEBRUARY 2009
EXHIBIT
6-1
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 6-1 Old Ditch with Aerials

N
0
500
Feet
OD#4
OD100D
0.019 mi²
OD#3
OD100C
0.098 mi²
OD#2
OD100B
0.087 mi²
OD#1
OD100A
0.075 mi²
Old Ditch
River Circle
Fisher
Oak Ridge
Water Oak
Pine Ridge
Creekview
Pecan
Pin Oak
River Run
Old River
River Bend
Canal
River Ridge
Riverbend
FM 565
Sunnyside
Legend
Node
Old Ditch Subbasins
Main Stream
Stream
CWA Canal
CWA Canal (Abandoned)
Major Road
Street
Railroad
Existing Land Use
Undeveloped, Unimproved, natural, or agricultural
Residential - Rural Lot, > 5-acre ranch or farm
Developed Green Areas, Parks or golf courses
Residential, 1 acre, 20% impervious
Residential, 1/2 acre, 25% impervious
Residential, 1/3 acre, 30% impervious
Residential, 1/4 acre, 38% impervious
Residential, 1/8 acre, 65% impervious
Light Industrial/Commercial, Office parks, airports, warehouses, manufacturing
High Density, Commercial, business, industrial, or apartments
Transportation, Highway or major thoroughfare
Water, Detention basins, lakes, channels, & ditches
klotz associates
OLD DITCH WATERSHED
EXISTING LAND USE MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 500 '
DATE: FEBRUARY 2009
EXHIBIT
6-2
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 6-2 Old Ditch with Exisitng Landuse



J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 6-3 Old Ditch with Future Landuse


Oak Ridge
Oak Ridge
Water Oak
Fisher
River Run
Pine Ridge
Creekview
Creekview
River Run
Pecan
Pin Oak
Pin Oak
Old River
Pin Oak
Canal
Canal
OD#3
OD#2
Old Ditch
River Ridge
River Bend
OD#1
Riverbend
FM 565
Sunnyside
N
0
500
Feet
Legend
Node
Problem Locations
Bridge/Culvert
Channel
Erosion
Ponding
Conveyance Solutions
Proposed Bridge Improvement
Proposed Channel Improvement
Propsed New Tributary
Proposed Tributary Improvement
Proposed Mitigation Pond
Detention Solutions
Proposed Detention Pond
Stream
CWA Canal
CWA Canal (Abandoned)
Erosion Protection
Old Ditch Subbasin
Home Buyout
Major Road
Street
Railroad
klotz associates
OLD DITCH WATERSHED
CONCEPTUAL SOLUTION MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 500'
DATE: FEBRUARY 2009
EXHIBIT
6-4
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 6-4 Old Ditch Conceptual Solution Map



klotz associates

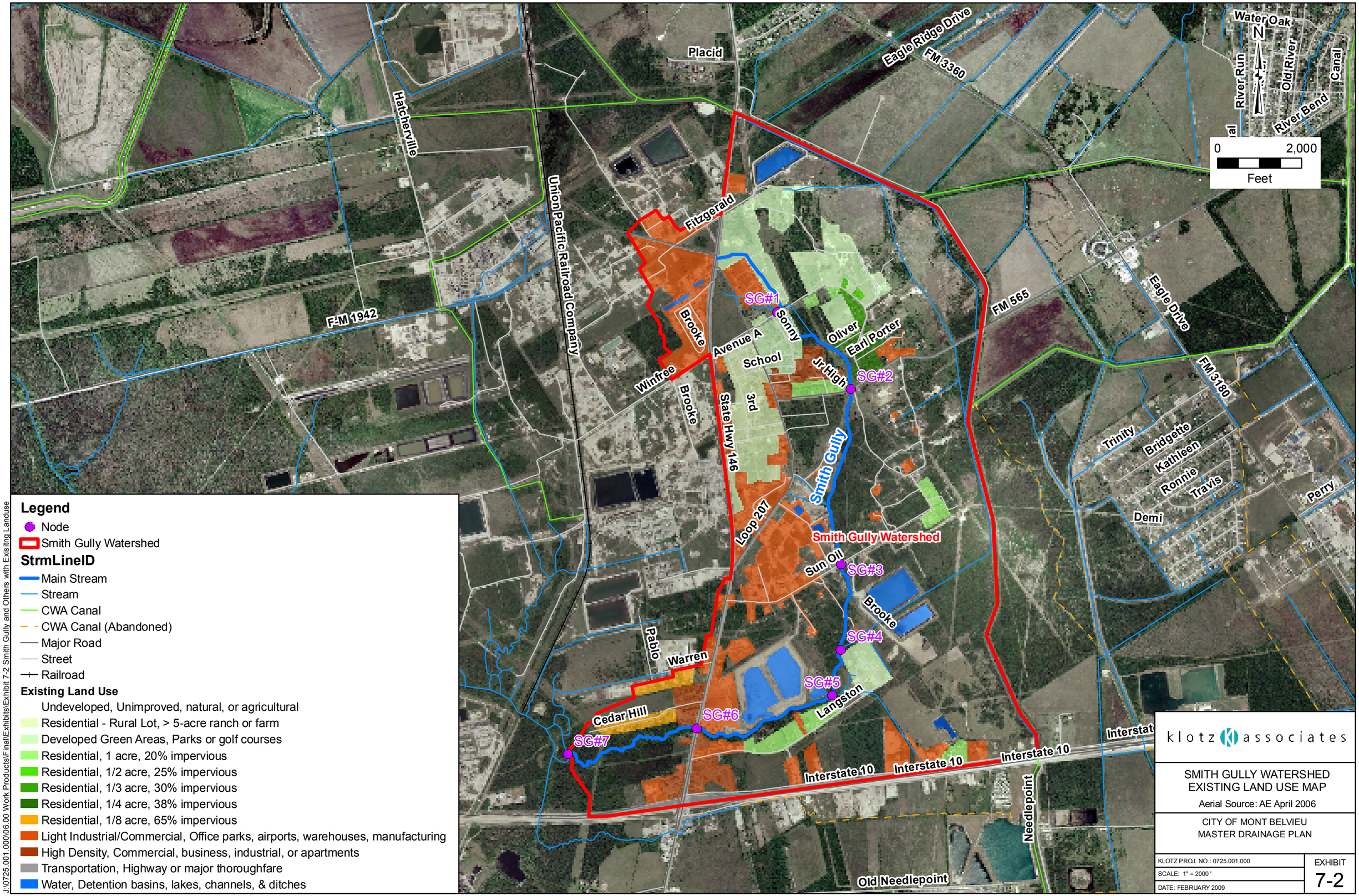
SMITH GULLY WATERSHED
PROBLEM LOCATION MAP

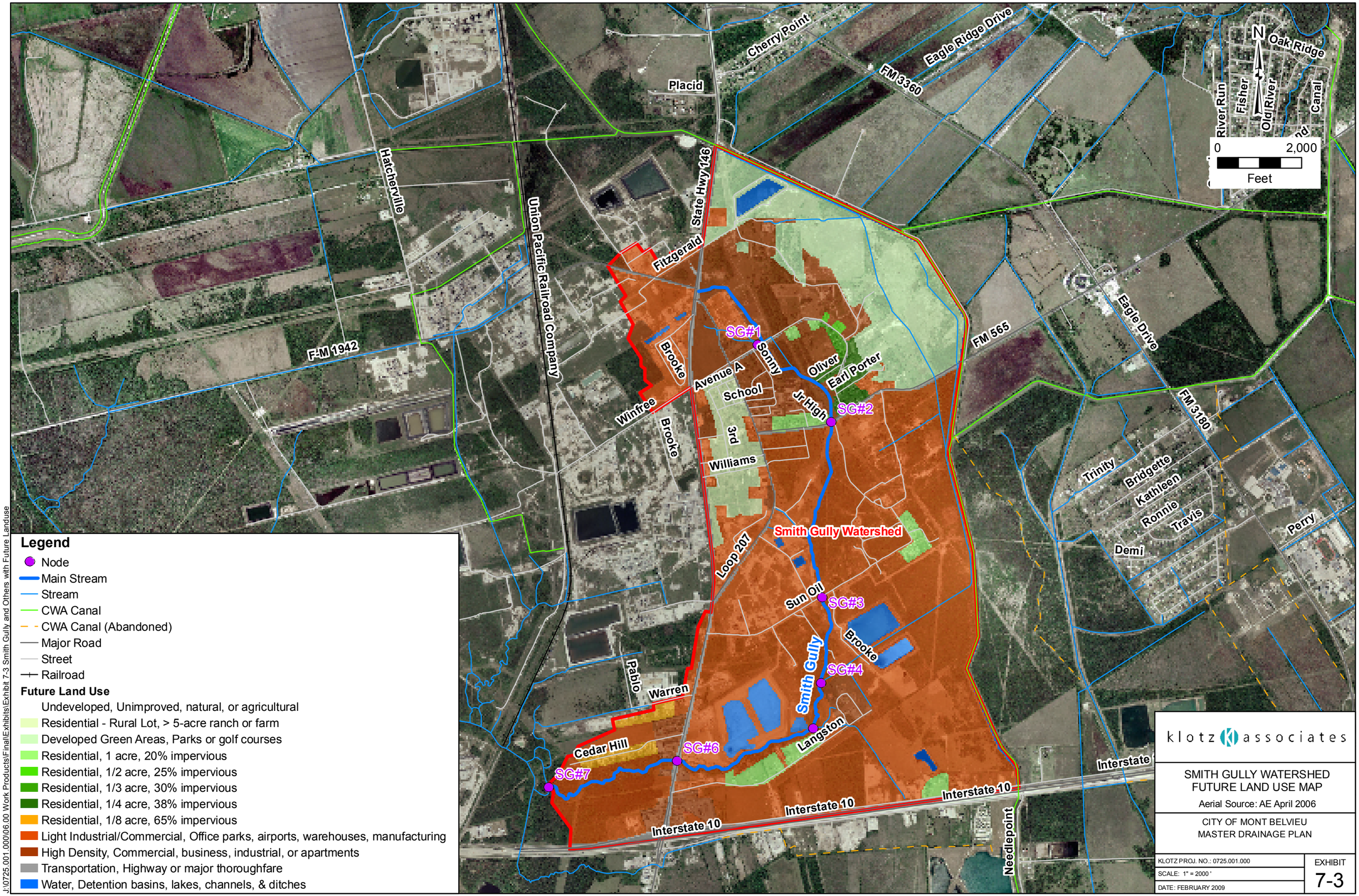
Aerial Source: AE April 2006

CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

KLOTZ PROJ. NO.: 0725.001.000	EXHIBIT
SCALE: 1" = 2000'	7-1
DATE: FEBRUARY 2009	

J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 7-1 Smith Gully and Others with Aerials


Placid
Eagle Ridge Drive
FM 3360
Water Oak
N
River Run
Old River
Canal
River Bend
0
2,000
Feet
Hatcherville
Union Pacific Railroad Company
Fitzgerald
F-M 1942
SG#1
Sonny
Oliver
Earl Porter
Brooke
Avenue A
School
Jr High
SG#2
Winfree
Brooke
3rd
State Hwy 146
FM 565
Eagle Drive
FM 3180
Trinity
Bridgette
Kathleen
Ronnie
Travis
Perry
Demi
Smith Gully
Loop 207
Smith Gully Watershed
Sun Oil
SG#3
Brooke
SG#4
Pablo
Warren
SG#5
Langston
Cedar Hill
SG#6
SG#7
Interstate 10
Interstate 10
Interstate 10
Needlepoint
Old Needlepoint
Legend
Node
Smith Gully Watershed
StrmLineID
Main Stream
Stream
CWA Canal
CWA Canal (Abandoned)
Major Road
Street
Railroad
Existing Land Use
Undeveloped, Unimproved, natural, or agricultural
Residential - Rural Lot, > 5-acre ranch or farm
Developed Green Areas, Parks or golf courses
Residential, 1 acre, 20% impervious
Residential, 1/2 acre, 25% impervious
Residential, 1/3 acre, 30% impervious
Residential, 1/4 acre, 38% impervious
Residential, 1/8 acre, 65% impervious
Light Industrial/Commercial, Office parks, airports, warehouses, manufacturing
High Density, Commercial, business, industrial, or apartments
Transportation, Highway or major thoroughfare
Water, Detention basins, lakes, channels, & ditches
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 7-2 Smith Gully and Others with Existing Landuse
klotz associates
SMITH GULLY WATERSHED
EXISTING LAND USE MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 2000 '
DATE: FEBRUARY 2009
EXHIBIT
7-2



klotz associates

SMITH GULLY WATERSHED
FUTURE LAND USE MAP

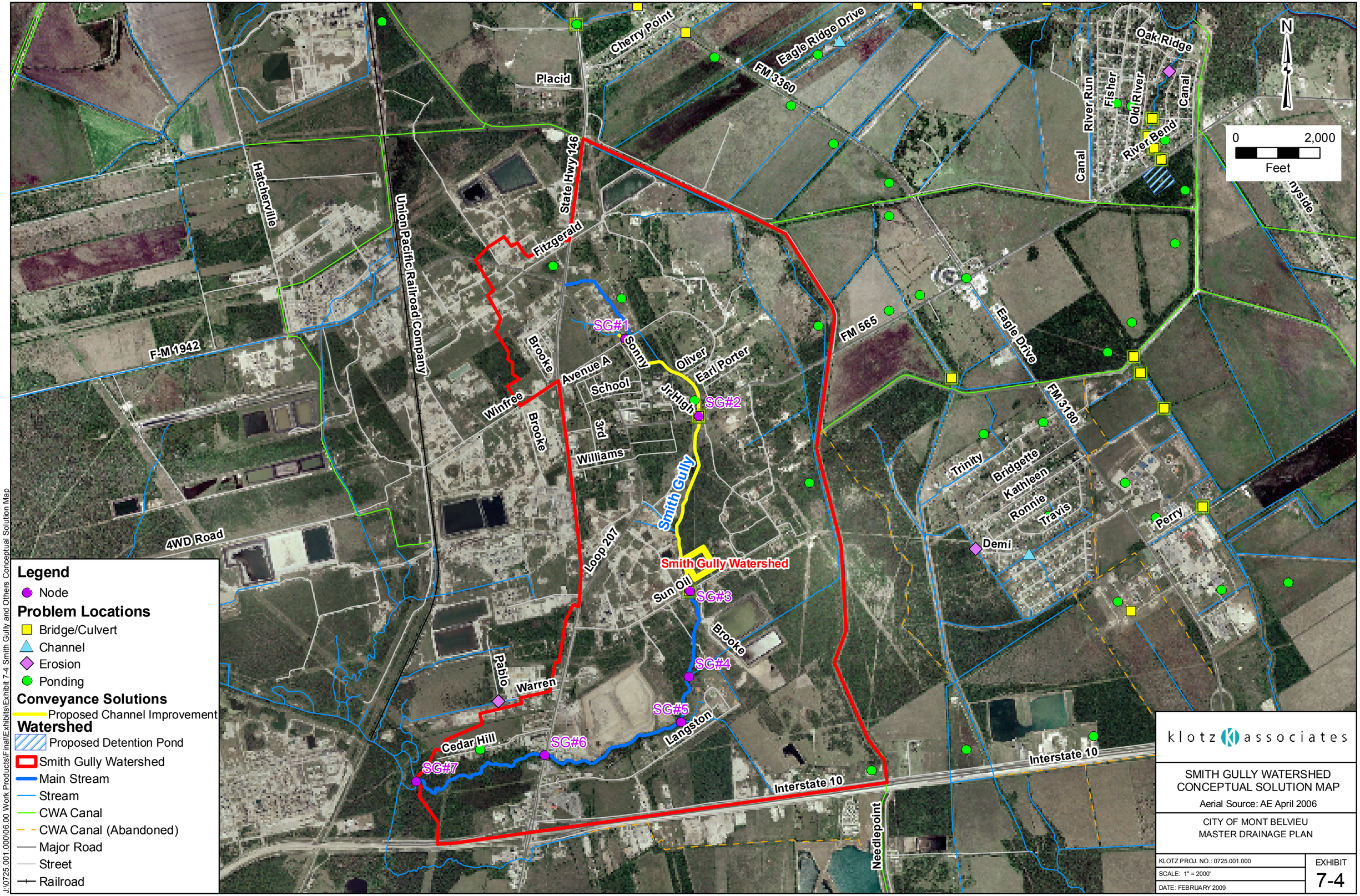
Aerial Source: AE April 2006

CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN

KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 2000 '
DATE: FEBRUARY 2009

EXHIBIT
7-3

J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 7-3 Smith Gully and Others with Future Landuse


Cherry Point
Eagle Ridge Drive
FM 3360
Placid
Oak Ridge
River Run
Fisher
Old River
Canal
River Bend
Canal
N
0
2,000
Feet
Hatcherville
Union Pacific Railroad Company
State Hwy 146
Fitzgerald
F-M 1942
SG#1
Sonny
Oliver
Earl Porter
Brooke
Avenue A
School
Jr High
SG#2
Winfree
Brooke
3rd
Williams
FM 565
Eagle Drive
FM 3180
Trinity
Bridgette
Kathleen
Ronnie
Travis
Perry
Demi
Smith Gully
Loop 207
Smith Gully Watershed
Sun Oil
SG#3
Brooke
SG#4
Pablo
Warren
SG#5
Langston
Cedar Hill
SG#6
SG#7
Interstate 10
Interstate 10
Needlepoint
4WD Road
Legend
Node
Problem Locations
Bridge/Culvert
Channel
Erosion
Ponding
Conveyance Solutions
Proposed Channel Improvement
Watershed
Proposed Detention Pond
Smith Gully Watershed
Main Stream
Stream
CWA Canal
CWA Canal (Abandoned)
Major Road
Street
Railroad
klotz associates
SMITH GULLY WATERSHED
CONCEPTUAL SOLUTION MAP
Aerial Source: AE April 2006
CITY OF MONT BELVIEU
MASTER DRAINAGE PLAN
KLOTZ PROJ. NO.: 0725.001.000
SCALE: 1" = 2000'
DATE: FEBRUARY 2009
EXHIBIT
7-4
J:\0725.001.000\06.00 Work Products\Final\Exhibits\Exhibit 7-4 Smith Gully and Others Conceptual Solution Map