Flood Protection Planning Study

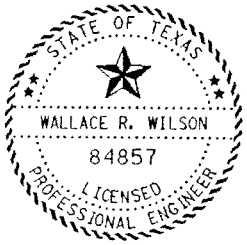
City of Beaumont, Texas

Jefferson County, Texas

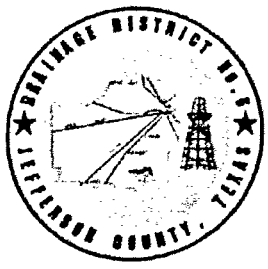
FINAL REPORT

Prepared for
Jefferson County Drainage District No. 6
and the
Texas Water Development Board

March 2011



Wallace R. Wilson P.E. 3/31/11



Leap Engineering, LLC
Texas Firm Registration
F-2601

Flood Protection Planning Study

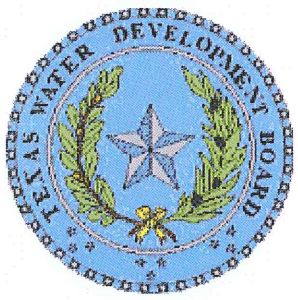
City of Beaumont, Texas

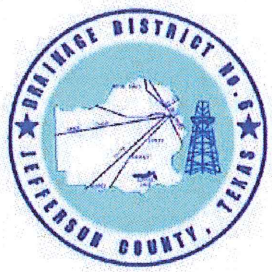
Jefferson County, Texas

FINAL REPORT

Prepared for
Jefferson County Drainage District No. 6
and the
Texas Water Development Board

March 2011





Wallace R. Wilson P.E. 3/31/11

Leap Engineering, LLC
Texas Firm Registration
F-2601

Table of Contents

Section ***Page***

Section ***Page***

Appendices

Appendix A – Report Figures

Appendix B – HEC-1 model data (Contained on CD)

Appendix C - HEC-HMS model data (Contained on CD)

Appendix D - HEC-RAS model data (Contained on CD)

Appendix E – GEOPAK Drainage (Contained on CD)

Appendix F – Letters (Contained on CD)

Appendix G - Drainage District No. 6 Master Drainage Plan (Contained on CD)

Appendix H - Drainage District No. 6 Criteria Manual (Contained on CD)

Appendix I – Original Plan Estimates (Contained on CD)

Appendix J – Environmental Assessments (Contained on CD)

Appendix K - Cost Benefit Calculations (Contained on CD)

Executive Summary

The purpose of this study is to assist Jefferson County Drainage District No. Six (DD6) in conducting a thorough study of the Hillebrandt Bayou watershed and to develop a Master Drainage Plan. In addition to the development of the Master Drainage Plan, the focus of this study is to complete an unstudied portion of the watershed that has experienced significant prior flooding – hereinafter referred to as the "Planning Area". See Figure 1 in Appendix A. This planning area is DD6's top priority due to the extent of prior flooding and the limited solutions based on currently available engineering data.

There have been studies completed on other parts of this watershed. With the completion of this study, all areas of the watershed will have been studied. Data from these studies was utilized to ensure that any proposed mitigation alternatives did not negatively impact any upstream or downstream areas of this watershed or adjacent watersheds.

Projects that have been targeted to improve the drainage in this study include:

▪ The Ridgewood Detention Basin Project	$878,000.00
▪ The Calder Improvement Project	$31,553,570.00
▪ Ditch 100 D Improvement Project	$4,750,000.00
▪ Ditch 104 B Drainage Project	$1,300,000.00
▪ Ditch 104 Improvement Project	$3,250,000.00
▪ Ditch 107 South11th Street Detention	$1,950,600.00
▪ Flood Gate Mitigation Project	$6,050,914.00
Total	$49,733,084.00

See Figure 2 in Appendix A for project locations.

The complete Hillebrandt Bayou watershed is comprised of approximately 152 square miles of land. This study is a regional flood control planning effort that will result in the elimination or significant reduction of flood damages within the watershed and provide a cost effective, implementable drainage plan to accommodate development in the watershed. This study combined with the development of a Master Drainage Plan will meet the following objectives:

1. Develop structural and non-structural alternatives of sufficient detail to serve as preliminary engineering designs of chosen alternatives for flood control protection needs for the Hillebrandt Bayou watershed.

2. Select from the various flood reduction alternatives a cost effective, implemental plan that will reduce or eliminate flood damage and minimize the environmental consequences while allowing continued watershed development.

3. Assess the site-specific environmental consequences of alternative flood control improvements and to determine the potential for mitigation of environmental damages.

4. Allow DD6 to meet the intent of the recently passed State of Texas House Bill 919 and Texas Water Code, Chapter 49.211.

During the course of this study the engineering data along with the Geo-Coding data developed in the process of finalizing this study, 4 of the 6 targeted projects have been completed and 2 projects are under construction and one is in planning.

This was accomplished by furnishing the engineering as required to develop the projects in order to get funding. Hurricane Rita which made landfall on September 24, 2005, made available funding that enabled these much needed projects to be constructed.

(*The Master Drainage Plan can be accessed at the Jefferson County website at http://www.dd6.info/*) and in Appendix G of this report.

The chart below shows the estimated cost, actual cost, and grant funds utilized on the projects in the Planning Study as of December 2010:

Project	Estimated Cost	Actual Cost	Grant Funds	Status
Calder	$31,553,570		44,022,928	Construction
Ridgewood	$878,000	$993,717	$658,500	Complete
100D	$4,750,000	$5,228,209	$3,884,532	Complete
104B	$1,300,000	$1,331,104	$975,000	Complete
104	$3,250,000	$2,820,624	$2,115,468	Complete
107	$1,950,600			In Planning
Flood Gates	$6,050,914		$4,535,187	Construction
Total	**$49,733,084**		**$56,191,615**	

Three (3) other projects in the planning area are directly related to the improvements from the projects completed in the planning study. The improvements allowed the following projects to be developed and constructed.

1. The Fannin Street Drainage Project (City of Beaumont)
2. The Corley Street Drainage Project (City of Beaumont)
3. The Willow Marsh Bridge over Walden (Jefferson County)

Without the improvements to the drainage system outlined in the Planning Area, these projects would have not been economically feasible to construct.

1.0 Introduction

1.1 Background

The area covered by Jefferson County Drainage District No. Six (DD6) is located in southeast Texas. DD6 is a conservation and reclamation district and a political subdivision of the State of Texas. DD6 was established January 21, 1920, after favorable vote on January 10, 1920. It was created primarily to provide drainage of over flow lands within DD6, including the construction and maintenance of drains, ditches and levees, and other improvements of the District. The District is governed by a five member Board of Directors that is appointed by the County Commissioners Court of Jefferson County, Texas

The Hillebrandt Bayou watershed is a major watershed in Jefferson County. The boundaries for this watershed are from the intersection of US 69 and the LNVA Canal in the northern portion of Jefferson County 18 miles south to where Hillebrandt Bayou ties into Taylor Bayou near State Highway 73 in the southern portion of Jefferson County. The westerly and easterly boundaries of the watershed are from US 90 at Keith Road 6 miles east to the easterly boundary just west of the Neches River Bridge on Interstate 10. The easterly boundary of the Hillebrandt Bayou watershed parallels the Neches River watershed. The northerly boundary parallels the Pine Island Bayou watershed. The westerly and southerly boundaries parallel the Taylors Bayou watershed. The upper end of the Hillebrandt watershed is at an elevation of approximately 30 feet above sea level and flows southerly to an elevation of approximately 5 feet above sea level at the lower end of the watershed. Hillebrandt Bayou is the major tributary of the watershed and drains approximately 152 square miles of Jefferson County. The Hillebrandt Bayou watershed contains five major tributaries that drain into Hillebrandt Bayou (76 sq mi): Willow Marsh (22 sq mi), Pevitot Gully (12 sq mi), Kidd Gully (10 sq mi), Bayou Din (22 sq mi), Johns Gully (10 sq mi). See Figure 3 in Appendix A.

There have been studies completed on other parts of this watershed. The Data from these studies have been utilized to ensure that any proposed mitigation alternatives will not negatively impact any up or downstream areas of this watershed or adjacent watersheds. The planning area is comprised of existing storm sewer systems and outfalls draining major traffic areas, including hospitals, retirement facilities, shopping centers and developed subdivisions in Beaumont.

The major tributaries and streams to be studied for this study are:

Ditch	**Tributaries**
100 (Hillebrandt) From Caldwood Cutoff to Taylors Bayou	100A (Sprot) 100A1
104 (Moore Ditch)	104A 104B 104C 104D 104E 104E1
105	105A
106	106A 106B(Usand)
107 (Landfill)	107A 107A1 107B 107C
108	108A 108A1 108B
109	109A1 109A2
110	110C
112	112A 112B
113	
114	
115	
116	
117	117A 117B 117C 117D

1.2 Goals and Objectives

The scope of work for the proposed planning area consisted of five phases: Phase I (Data Collection), Phase II (Existing Hydrology and Hydraulic Modeling), Phase III (Evaluation of Potential Areas of Improvements), Phase IV (Proposed Hydrology and Hydraulic Modeling), and Phase V (Recommendation for Improvements). Additionally, there are two tasks associated with the development of the Master Drainage Plan and study/grant administration. A detailed description of the phases and tasks are:

Task 1 – Phase I Data Collection This phase included collection of all existing data for the planning area. Since this planning area is in an urban watershed, data collection was an intense portion of the study. The area which was the subject of this study includes much of the first areas to develop in the City of Beaumont dating back to the early 1900's. Since that time, much development has occurred and hundreds of miles of drainage facilities constructed without a complete inventory of underground-and above-ground facilities being compiled, located, surveyed, and mapped. There was, however, a drainage study accomplished in 1980, which detailed much of the underground facilities as far as approximate location and size but no indication of elevations. Additionally, there have been a great number of facilities constructed since 1980. In order to accurately calculate the volume of water stored in the flooded areas, we utilized USGS DEM data and field surveying to accurately develop ground models. See Figure 1 in Appendix A. for contours developed for the project. A list of the tasks follows:

- Collect existing and historical flood data (from all sources)
- Attend neighborhood meetings, interview citizens, distribute and collect questionnaires
- Collect, consolidate, and review FEMA, Red Cross, and other related governmental data
- Survey high water elevations collected from recent floods
- Survey high water elevations from photographs
- Collect data on all existing drainage facilities
- Size, length, and elevation of all major under- and over-ground structures
- Compilation of street and drainage project plans and plan elevation checks
- Collect existing aerial mapping
- Collect existing topographic data (DEM data)
- Collect DD6 rain gauge and level gauge data
- Collect existing soil data for planning area
- Research future development in proposed planning area
- Survey existing channels
- Survey existing channel crossings
- Survey ground topography for contour refinement

Task 2 - Phase II Existing Hydrology and Hydraulic Modeling This phase consisted of compiling data collected during Task 1 above and constructing proposed models for surface runoff, channel modeling and storm sewer analysis. Each model was integrated with each other in order to provide an accurate representation of the hydrology and hydraulics of the watershed. A list of the tasks follows:

- Determine existing sub-watershed physical characteristics, drainage area, basin slope, soil parameters, impervious conditions, infiltration loss, etc.
- Build an accurate precipitation model from historical events
- Build a hypothetical precipitation model with 10yr, 50yr, 100yr, and 500 yr events
- Construct an integrated model with applicable channel routing (modified puls routing was the preferred method in order to balance with HEC-RAS volumes)
- Combine precipitation and basin models to provide runoff for actual and hypothetical precipitation events
- Build an integrated channel model utilizing HEC-RAS that coincides with the HEC-HMS model
- Include all crossing structures into HEC-RAS model
- Build an integrated storm sewer system and pipe network
- Combine storm sewer hydraulics into overall model to accomplish accurate flows and timings for total system
- Balance flows (HEC-HMS) and volumes (HEC-RAS) for existing conditions to assure models are accurate
- Utilize historical and field data for verification of existing model

Task 3 - Phase III Evaluation of Potential Areas of Improvements This phase was the most critical and intensive part of the study. Determination of potential mitigation alternatives involved coordination with entities and individuals that could be impacted by these projects. Implementation of proposed mitigation alternatives involved the cooperation of City, State, County, and other participants. All mitigation alternatives were evaluated to ensure there is no negative impact to areas upstream or downstream. DD6 has ongoing mitigation projects in the Hillebrandt watershed. Each of these projects were evaluated and included into the overall improvements to the watershed. A list of the tasks follows:

- Evaluate existing models during historical events and hypothetical storms
- Determine the areas of flooding
- Determine the impacts to the areas that are flooding
- Evaluate different alternatives of improvements including: detention, channel improvements, structure upgrades, diversion, and inlet and storm sewer upgrades
- Evaluate non-structural alternatives such as; flood plain management, acquisition, and elevation

Task 4 - Phase IV Proposed Hydrology and Hydraulic Modeling This phase incorporated the first three phases in order to determine which of the mitigation alternatives was most effective at reducing flooding in the planning area. A list of the tasks follows:

- Apply future drainage area coefficients, such as proposed impervious conditions that could accelerate runoff
- Construct a proposed integrated model with improvements to each system such as detention, channel improvements, structure upgrades, diversion, and inlet and storm sewer upgrades
- Each mitigation alternative was evaluated individually to quantify the individual effect on the system
- Evaluate the system with all of the mitigation alternatives to determine the overall improvements to the watershed and to verify how each mitigation alternative effected the other improvements
- Determine a sequence for implementing the different recommended mitigation alternatives

Task 5 - Phase V Recommendation for Improvements This phase consisted of compiling the study into a formal report. This report was compiled with inputs from all of the entities that will be involved in the required projects for improvements.

Task 6 - Master Drainage Plan This task provided the documentation necessary for DD6 to exercise the authority granted to drainage districts under Chapter 49.211 of the Texas Water Code. Specifically, Chapter 49.211 requires districts to adopt master drainage plans before adopting rules relating to the review and approval of proposed development drainage plans. Implementing this authority will augment the District's existing purposes, will help manage drainage to reduce future flooding, and will supplement mitigation projects identified as part of flood reduction studies. The following tasks are proposed:

A. **Inventory Baseline Conditions** – the baseline conditions were developed as part of flood reduction studies and, where studies have not yet been conducted, by examination of available information related to drainage, development patterns, environmental features, and historical flooding and drainage problems. In areas with detailed studies, the results of proposed condition evaluations were examined to identify particularly sensitive areas of known flooding problems and likely future problems. For the purpose of the Master Drainage Plan, summaries were prepared and indexed to available studies and data to facilitate access by developers of available baseline and future condition data. The inventory also identifies particularly sensitive watersheds or sub-watersheds where additional requirements were considered during development of regulations.

B. **Examine Existing Coordination and Review Processes** – In order to develop efficient procedures under the authority granted in Chapter 49.211, this task evaluated DD6's existing processes and capacity to perform the work and to coordinate the development review process with the City of Beaumont and Jefferson County. The result will be recommendations to improve coordination and review processes, with particular attention to the time limits established in Chapter 49.211.

C. **Prepare Rules and Regulations for Drainage Plan Review** – As authorized in Chapter 49.211, a Master Drainage Plan may include rules relating to the plan and design criteria for drainage channels, facilities, and flood control improvements. These regulations, along with the Drainage Design Criteria, formed the basis on which proposed developments will be designed, and will be the criteria by which the District's review will be performed. The rules will define developments and construction activities that are subject to drainage regulation, the performance requirements for adequacy of post-development drainage (which may vary by sub-watershed as a function of existing flooding problems and the results of flood control and watershed studies), alternatives that may be considered (such as contribution to regional detention or other off-site compensation), the development review process, and procedures to enforce rules adopted by the District.

D. **Drainage Design Criteria** –A detailed Drainage Design Criteria Manual based on manuals from other jurisdictions and with technical input from DD6 in-house engineering staff, DD6 engineering contractor(s), and the Constituent Committee was developed. The Manual included design methodologies and computations that are specific to DD6 and that have been successfully applied to developments in the region.

E. **Constituent Committee and Public Involvement** – There are two elements to this task:

- The Constituent Committee was composed of interested members of the public, developers, surveyors, and engineers. The purpose of the committee was to provide input and to review and advise on the development of regulations, the preliminary design criteria manual, and the Master Drainage Plan.
- Public Involvement entailed a series of public meetings early in the planning process to inform the general public of the District's intention to develop a Master Drainage Plan and to solicit information and recommendations regarding drainage and development review procedures, design criteria, and the Master Drainage Plan. The public was afforded the opportunity to review and comment on the draft rules and regulations, and a formal public hearing on the rules and regulations, and the Master Drainage Plan, was conducted prior to adoption.

F. **Draft Master Drainage Plan; Adoption and Implementation** – The Master Drainage Plan was prepared based on the collected information. It was presented for adoption by the Board of Directors of DD6. The Plan specified periodic review and revision to reflect the results of new watershed and flood control studies and to address changes in regulations and procedures that are determined to be appropriate. The District worked with Jefferson County and the City of

Beaumont to review and revise the Inter-local Agreements to appropriately reflect the proposed coordinated review process.

Task 7 – Grant Administration This task involved the overall administrative and fiscal management of the project, including coordination of the project with the consultants and TWDB

- Oversee completion of contactor work elements to ensure the project is on schedule and within budget
- Oversee DD6 personnel in the completion of their tasks to ensure the project is on schedule and within budget
- Hold monthly project status meetings
- Preparing status reports to TWDB
- Preparing funding reimbursement requests for submittal to TWDB
- Participate in all Public forums to ensure public understands DD6's commitment to implement viable mitigation alternatives and to adopt the Master Drainage Plan

1.3 Organization and Planning

The development and adoption of a Master Drainage Plan allows DD6 to work closely with developers to ensure any proposed subdivisions will not have an adverse impact within or outside the watershed.

Existing projects that were incorporated into the over all project are:

Caldwood Cutoff and Ditch 121 study in the upper reaches of Hillebrandt watershed, prepared for DD6 by LEAP Engineering in conjunction with Drainage District 6, June 2003 - The purpose of this study was to provide solutions to flood problems made evident in during a flood event in October 2002 and to provide relief to downstream areas that were being aggravated by development upstream. The study resulted in three major projects for flood improvements.

Willow Marsh Drainage Study, prepared by Bob Shaw Consulting Engineers, June 2000- The purpose of this flood protection planning was to analyze the Willow Mash tributary to the Hillebrandt Bayou.

Gulf Terrace Detention Facility, prepared by Drainage District 6, June 2002- The purpose of this flood protection planning was to provide relief to the residents of the Amelia Area. The Study resulted in the project to construct a major detention basin in the upper reaches of the planning area.

Hillebrandt Watershed Drainage Study, prepared by Bernard Johnson, Inc, June 1986 -
The purpose of this study was to develop a master plan of the major tributaries and identify the physical attributes of the channels and the crossings located on them.

Hillebrandt Watershed Drainage Study, prepared by Kohler & Kohler Engineer, July 1981 - The purpose of this study was to identify the sub-basins and drainage features in the Hillebrandt watershed.

Flood Mitigation Plan Development, prepared by Jeffrey S. Ward & Associates, Inc., current – The purpose of this plan is to be in compliance with the National Flood Insurance Reform act of 1994 in which it states that a FEMA-approved Flood Mitigation Plan is required in order for a community to receive FMA project grants. This plan looked at historical and potential flooding throughout DD6's watersheds and identified potential mitigation actions that will reduce the potential for property damage and loss of life.

This study included all of the above protection plans as well as compiling construction as-built drawings. The primary objective of this study was to enhance the performance of earlier flood protection plans by decreasing flows in outfalls which are already exceeding capacity and utilizing available capacity where it exists. There exist two possible outfalls for the planning area, the first being Hillebrandt Bayou. In 1994 an $86million U. S. Army Corps of Engineers

project was completed on Lower Hillebrandt and Taylors Bayou which included enlargement of the Gulf Intracoastal Waterway, Taylors Bayou and Hillebrandt Bayou and included construction of a diversion channel and a salt water barrier. It is unlikely that Lower Hillebrandt Bayou's capacity will ever be increased beyond its' current capacity. The Corps project was studied and designed in the 50's and 60's. Preparation of this study incorporated strategies that will not exceed the capacity of the Corps project and provide some lowering of the flows through the Corp project by diversion or detention. The second possible outfall for this planning area is the Neches River. The Neches River has been excavated up to Beaumont as a deep-water river navigable by large ships. There exists no flood control plan on the Neches River however; the amount of run-off to be diverted to the river from this planning area would have no effect on the river at this point. The other facilities in the planning area are owned and maintained by DD6, the City of Beaumont, or LNVA and personnel from each of these entities were involved in this study to assure mutual cooperation.

This study compiled an integrated model including all tributaries. The previous flood planning was included along with the planning area of this study to describe an accurate representation of the flooding in the total watershed. This study continued the flood planning for the entire Hillebrandt watershed and built a master drainage plan and hydraulic model that can be upgraded with each improvement or change in the watershed in the future. The master drainage model utilized HEC-HMS, HEC-RAS and DD6's real time rain and level gauge system to accomplish this model. The real time rain and level gauge system has become an invaluable tool for flood prediction, planning and a source for determination of future projects. FEMA's Benefit Cost Analysis software was used to determine the potential cost effectiveness of proposed flood protection solutions.

1.4 History of Flooding

The City of Beaumont residents, residing in the planning area, have experienced major flooding in the past. Jefferson County, which includes the City of Beaumont, has had 12 Presidential Disaster Declarations since 1973. Each of these declarations was as a result of flooding. The flood hazards in the planning area are varied. Critical care facilities in the planning area have been affected in numerous ways: The Christus St. Elizabeth hospital emergency room was closed due to flood waters that rose up and into the hospital. Emergency vehicles traveling to and from the hospital were delayed and even re-routed to other care facilities due to high water. Nurses and doctors were unable to leave the hospital because relief workers were unable to get to the hospital. The Ridgewood Retirement Center was forced to evacuate the residents because floodwaters came into the facility. People trying to travel to and from work and school were stranded when their vehicles became flooded when high water made the roads impassable. The wrecker services were backed up for hours towing flooded vehicles after the rain events subsided. Streets and roadways became creeks and ponds, which were hazards to children that live in the residential neighborhoods. There was one flood related death in the City of Beaumont in the October 2002 flood event.

To provide data on the historical flooding and flood damage in the proposed planning area, Leap utilized the National Flood Insurance Program's (NFIP) *Total Paid Claims database, effective date September 30, 2003*. This data indicates there have been 11 major floods and several small events that have caused considerable damage within the planning area in the past 23 years. For the purposes of this evaluation, a major flood is defined as any single event that caused greater than $300,000 in damage. See the table on page 10 for details on the dollar value of paid claims within the City of Beaumont. For the purpose of determining the dollar value of paid claims within the planning area, we calculated the planning area at 31.5% of the entire City of Beaumont. We then applied this 31.5% to the total losses experienced within the City as a whole to derive an estimate of the dollar value of claims within the planning area. It should be noted that the actual losses within the planning area are likely significantly higher for the following reasons:

- The losses mentioned are only those of insured properties,
- The planning area is in the most densely populated area of Beaumont,
- One neighborhood within the planning area is by far the most expensive and highest dollar value of losses on the NFIP total paid claims list, which results in a dilution when using percentages/averages,
- 55% of the planning area is outside the City of Beaumont and no additional losses within this portion of the planning area have been factored into the detailed loss data shown the chart below.

	Total City of Beaumont	Project Area Within City Limits
Total Square miles	85.8	27
Project area as a percent of Total City		31.5%
Policies in force	6,664	2,097
Insurance In-force	$ 1,142,987,200	$ 359,681,287
Written Premiums In-Force	$ 2,215,507	$ 697,188
Total paid Claims	3,161	$ 995
Homes on Repetitive Loss List	423	$ 133
Homes on the Target Repetive Loss List	153	$ 48
Total $ value of Claims	$ 39,205,053	$ 12,337,254
In Large events	$ 36,723,342	$ 11,556,296
Total # of claims in these large events	2,793	$ 879
In smaller events	$ 2,481,711	$ 780,958
Actual Paid Claims per Event (Bldg and Contents)		
Apr-79	$ 2,690,192	$ 846,564
Jul-79	$ 317,122	$ 99,794
Sep-80	$ 1,111,684	$ 349,831
Oct-80	$ 1,498,249	$ 471,477
Jan-83	$ 996,848	$ 313,693
Jun-87	$ 1,961,432	$ 617,234
Jun-89	$ 3,590,386.00	$ 1,129,842
Oct-94	$ 3,503,556.00	$ 1,102,518
Sep-96	$ 1,397,428.00	$ 439,750
1-Jun	$ 11,125,588.00	$ 3,501,059
2-Oct	$ 8,530,857.00	$ 2,684,535
Misc smaller events	$ 2,481,711	$ 780,958
Total	$ 39,205,053	$ 12,337,254

Within the planning area, there are numerous critical care facilities such as EMS Stations, Fire Stations, Hospitals, Clinics, Retirement Homes, Day Care and School Facilities.

Geocoding results from questionnaires sent out to residents in the planning area combined with FEMA repetitive loss reports, and in field survey were utilized to identify flood prone areas. Information such as address, depth of flood and frequency of floods are easily generated from geocoding results in ARC-View. See Figure 8-13 in Appendix A for the Geocoding locations utilized in the Planning Area project selections.

Leap evaluated the FIRM and parcel maps to determine the number of homes within the study area that are in the FEMA mapped 100-year flood plain. This evaluation yielded 65 homes in the mapped flood plain. However, the detailed study limitations FEMA employs when mapping watersheds and tributaries results in a significant underestimation for population within the 100-year flood plain. Historically, FEMA has not studied and does not map tributaries that serve watersheds less than one square mile. This highly urbanized area is served by many such small ditches and underground storm sewers. It is estimated that 95% of the study area is comprised of small, unstudied tributaries. Further, the FIRM for this study area is from the early 1980s - and the aerial photography used to develop these maps is from the late 1970s. Since these maps were issued, significant development has occurred within the study that has affected the actual 100-year floodplain. See Figure 4 in Appendix A of the existing flood plain and corrected flood plain. The areas denoted as corrected existing flood plain shows targeted project areas. LEAP also developed a proposed flood plain map of the planning area that shows the improvements. See Figure 5 in Appendix A. The residual flood plains left in the upper reaches are minor street flooding. The depth of flooding was reduced more than three feet in the targeted areas. See Figure 6 and Figure 7 in Appendix A.

The estimates of the value of properties in the 100-year flood plain are:

City of Beaumont (within the study area)

- Number of homes estimated to be in the actual 100-year flood plain 1,300
- Average residential building value $62,500
- Total estimated residential building value $81.5M

Unincorporated Jefferson County (within the study area)

- Number of homes estimated to be in the 100-year flood plain 200
- Average residential building value $59,400
- Total estimated residential building value $11.9M
-
- Partial estimated value of commercial properties in 100-year flood plain
- Ridgewood Retirement Center $ 1.0M
- Christus St. Elisabeth Hospital $10.0M
- Grand Total estimate value of property in the 100-year flood plain **$104.4M**

- 2,097 policies within the study area (31.5% of total policies-in-force in the City of Beaumont)50 within the study area (3.6% of the total policies-in-force in Jefferson County)2,147 total policies-in-force in the study area.

- The average property value for the City of Beaumont obtained from the 2000 U.S. Census is $62,500; the average property value for unincorporated Jefferson County obtained for the U.S. Census is $59,400

- The study area located within unincorporated Jefferson County is mostly rural. It is estimated there are 200 homes within this area that are in the mapped floodplain and approximately one fourth (50) of those have policies.

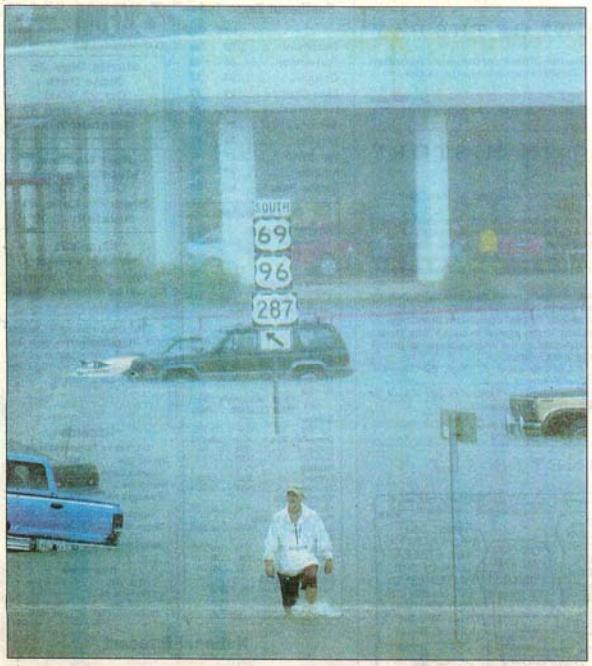
The planning area effort focused on identifying the cause of the flooding problems. The complicated system of inlets and storm sewer systems connecting to major networks of outfall structures including large conduits and open channels required investigation into solutions such as: inlet and storm sewer restoration, channelization, detention, diversion, and improved maintenance of drainage systems in the area. In addition to structural alternatives, the study evaluated non-structural alternatives such as flood plain management, acquisitions, and elevation of buildings above the base flood level.

Leap evaluated potential mitigation alternatives in order to determine the most feasible and cost effective solution with special attention on reducing or eliminating the dollar value of future flood damage and loss of life. Drainage planning for this area will in effect improve upstream water surface elevations and focus on achieving a level of no impact on downstream systems.

1.5 Flood of 2003

The flood in October of 2003 devastated Beaumont and surrounding areas hundreds of cars were flooded at intersections and streets and emergency facilities were impacted. See articles from the local newspaper on the following pages.

Experts try to get a grip on water



Scott Eslinger/The Enterprise

A motorist wades across the Eastex Freeway southbound access road near Lucas Street after his vehicle stalled in high water during the flood of Oct. 9 in Beaumont.

The brains of drainage

Workers charged with keeping water out of your house have flood for thought after recent downpour

By CHRISTINE RAPPLEYE
THE ENTERPRISE

BEAUMONT — When rain falls hard and fast in Jefferson County, Doug Canant doesn't head to higher ground.

Instead, the Drainage District 6 engineer heads out into the water.

It's how Canant and others at Drainage District 6 can see the fruits of their work to keep water flowing off of the 440 square miles of Jefferson County.

"That's the only way to test the systems that we put in," Canant said.

On Oct. 9, 10 inches of rain — totaling an estimated 12 billion gallons of water — fell on Beaumont and caused flooding similar to what Tropical Storm Allison caused in 2001.

Scott Eslinger/The Enterprise

Drainage district workers use excavators and dump trucks to continue work on the retention ponds being dug west of West Brook High School.

While most residents hunker down to ride out a savage storm, the workers of Drainage District 6, a Jefferson County tax-collecting entity that rarely, if ever, draws the public-ity spotlight, springs into action.

With its $10 million annual budget funded with a property tax rate

WATER, page 5A

Appendix 25

WATER:
'We want to do what we can to keep the runoff running off'

Continued from page 1A

of 20 cents per $100 valuation, District 6 sees its 440-square-mile jurisdiction as a world where engineering geology reigns supreme.

Water is to them what fire is to firefighters, and their weapons are 1,400 miles' worth of canals, drainage ditches and detention ponds. The district maintains and improves the water conduits and carefully monitors their work.

The objective is to get water away from roads, homes and businesses and quickly send it on its way to the Gulf of Mexico.

Nevertheless, the workers of District 6 are humble about their water-fighting efforts.

"We want to do what we can to keep the runoff running off," Canant said.

In the one-story building where he works on Walden Road, Canant watches lights when wet weather approaches.

There is a wall map in technician Jimmy Eason's office, and it is dotted with pencil-sized green and yellow lights for each of the 48 monitoring stations districtwide.

When it rains, the green light comes on. When the green light blinks, water is coming down faster than an inch an hour.

Lighted yellow lights mean there is water in a ditch.

Eason keeps an eye on the map and solar-powered monitors, which download local water-collection information to his computer that is put online.

On Oct. 9, the day of the deluge, two green lights were blinking close to the top of the map — near Bevil Oaks and Pine Island Bayou.

That was enough for Canant to head out, knowing these were notorious problem areas that needed watching.

"We try to eyewitness what's happening," Canant said.

Reacting to the flood potential, off-duty workers were quickly summoned.

Decked out in rubber boots and yellow rain gear, 14 two-man crews were sent to clear ditches of floating furniture, limbs and other debris that could inhibit drainage, said Jim Broussard, the drainage district's field supervisor.

Canant said workers are trained in negotiating flooded roads in their vehicles, making sure they don't kick up wakes that could wash into homes and businesses.

Beaumont Enterprise
pg. 1 of 2
10/12/2003

FROM PAGE 1A

STORM : Officers wade through water to make sure motorists not trapped in floating cars

Continued from page 1A

Patricia Velzeboer, a second-grade teacher at Curtis Elementary School, said a number of children were stuck there after hours waiting for their parents.

"But we're high and dry and safe and sound," she said. "The kids are doing their homework or visiting quietly. They're not distraught or anything."

Rose Hardy, principal of Regina-Howell Elementary School, said a crowd of students and parents were also stuck.

Some of them had to walk back to the school in the rain after their cars stalled, so Regina-Howell staff offered dry towels and dry clothes.

"We had a lot of wet heads," Hardy said, adding that a number of parents called to say they couldn't get through to pick up their children.

One parent with a vehicle more amphibious than most called to offer rides to the stranded families, she said.

Roads around schools such as Fehl Elementary and Vincent Middle schools, were less damp but parents were stuck all around town.

Most of the rush hour havoc was weather-related, said Crystal Holmes, a Beaumont Police Department spokeswoman.

"We've got cars floating, officers are wading through water to make sure no one is inside," Holmes said.

Cars, some knee deep in water, were abandoned all along Highway 69 and Interstate 10.

With 7-inches of rain reported in some areas, most of Beaumont's underpasses had been shut down, Holmes said.

It seemed that most drivers were trying to get onto the freeways — the driest spot — which were already jam-packed with traffic.

Some drivers tried to wade it out. Even though floodwaters lapped above their front bumpers, some of the braver subcompact car drivers kept going.

Some didn't go far.

"Over near Lucas (Drive) by the old Wal-Mart, a car is floating and bouncing into other vehicles," Holmes said. Dozens of vehicles were sitting in that parking lot at 4:45 p.m.

Four of those cars, lined up side-by-side, had stalled on Dowlen Road in front of the Parkdale Mall.

Throughout the afternoon, police and sheriff's deputies in Orange County responded to flooded underpasses and submerged streets.

Vidor police reported the underpass at Farm Road 105 and Interstate 10 was under several feet of water as was the intersection of North Dewitt Street and I-10.

The Orange County Sheriff's Department also reported that residents were getting sandbags at the county's precinct barns.

National Weather Service Meteorologist Kent Kuyper in Lake Charles, La., said this weather was expected.

Late Wednesday, two storm systems — one from the Texas Gulf Coast and another from the northwest — began converging on Southeast Texas and Southwest Louisiana, Kuyper said.

The storm struck at 2 p.m. Thursday.

"It's literally sitting right on top of the Beaumont area — that's the bull's-eye," Kuyper said.

The Jefferson County Drainage District's 6-hour rainwater gauges reported nearly 8 inches along Eastex Freeway at 6:15 p.m.

More than 7 inches fell in the northern part of Beaumont along Tram Road and nearly four inches fell along Washington Boulevard.

Most other areas had between three and five inches of rainfall, according to the drainage district.

Thursday's storm brings Beaumont's annual rainfall total this year up to 56 inches as officially measured at Southeast Texas Regional Airport, Kuyper said. Average annual rainfall is 58.89 inches.

The storms caused two tornadoes to touch down in Houston, Kuyper said.

While the weather service didn't receive reports of tornadoes in this region, the Department of Public Safety reported a tornado in Raywood, a Liberty County community about 30 miles west of Beaumont.

The tornado tore the roof off of an abandoned convenience store and tossed it across the street, taking a utility line and a transformer with it.

"The transformer was blowing up like crazy," said 26-year-old Sarah Jones who was working at the Post Office across the street. "It was like explosion after explosion."

Plywood and the mangled line headed for a neighboring business, Southeast Texas Farm and Ranch, knocking out the back window of a pickup truck.

No one was reported injured.

Wind also damaged part of the tin roof and Post Office's roof.

Kuyper said that it may have been an F0 tornado, one that lasts between one to five minutes and produces winds up to 100 miles per hour.

Weekend weather is expected to be milder, Kuyper said.

"We'll have some scattered showers, but no where near what we had (Thursday)."

Staff reporters Vanessa Everett and Kevin Dwyer contributed to this report.

Reach this reporter at:
(409) 833-3311, ext. 424
lmehaynes@beaumontenterprise.com

Photos by Scott Eslinger/The Enterprise

Coty Jackson of Vidor gives Diana Cogbill of Vidor a piggy-back ride across the Eastex Freeway access road in front of the old Wal-Mart building in Beaumont Thursday.

Several men try to help the driver of a truck who had gotten stuck trying to escape the flooded access road and get up onto Eastex Freeway near the old Wal-Mart building in Beaumont.

A car drives through floodwaters on Pine Burr Street near Highway 96 in Lumberton Thursday afternoon.

THE BEAUMONT ENTERPRISE
A HEARST NEWSPAPER
FRIDAY
OCTOBER 10, 2003
VOL. CXXII, NO. 339
THE ADVOCATE FOR SOUTHEAST TEXAS SINCE 1880
50 Cents

In a flash

Half a foot of rainfall closes most underpasses | Scores of cars stranded in streets-turned-rivers | Weather wreaks havoc at hospital and schools

Scott Eslinger/The Enterprise

A kayaker paddles past flooded vehicles along the Eastex Freeway access road in front of the old Wal-Mart building in Beaumont Thursday afternoon. The deluge flooded underpasses and submerged streets throughout Southeast Texas.

Beaumont area is bull's-eye for storm

Motorists try their luck with floodwaters on Dowlen Road approaching Eastex Freeway on Thursday afternoon as they pick their way past stalled cars at the intersection of Dowlen and Crow roads. The Jefferson County Drainage District's 6-hour rainwater gauges reported nearly 8 inches of rain along Eastex Freeway at 6:15 p.m.

Jennifer Reynolds/ The Enterprise

By LA MONICA EVERETT-HAYNES
THE ENTERPRISE

Emergency patients were put on hold, hundreds of cars were stalled in the middle of streets, a tornado was spotted and school children were stranded after heavy rains deluged the Beaumont area Thursday afternoon.

Street flooding trapped people inside Christus St. Elizabeth Hospital and prevented others from getting in.

"We're unable to get vehicles in or out but we're still operating the facility," said Rebecca Patterson, the hospital's administrative supervisor.

"It's creating havoc with the patients trying to get in," Patterson. The emergency room had been closed down, she said.

"Our staff is going full force but, like everyone else, we're waiting to see what the weather is doing."

The weather also created havoc at Beaumont schools.

STORM, page 6A

Bryan S. Welborn/The Enterprise

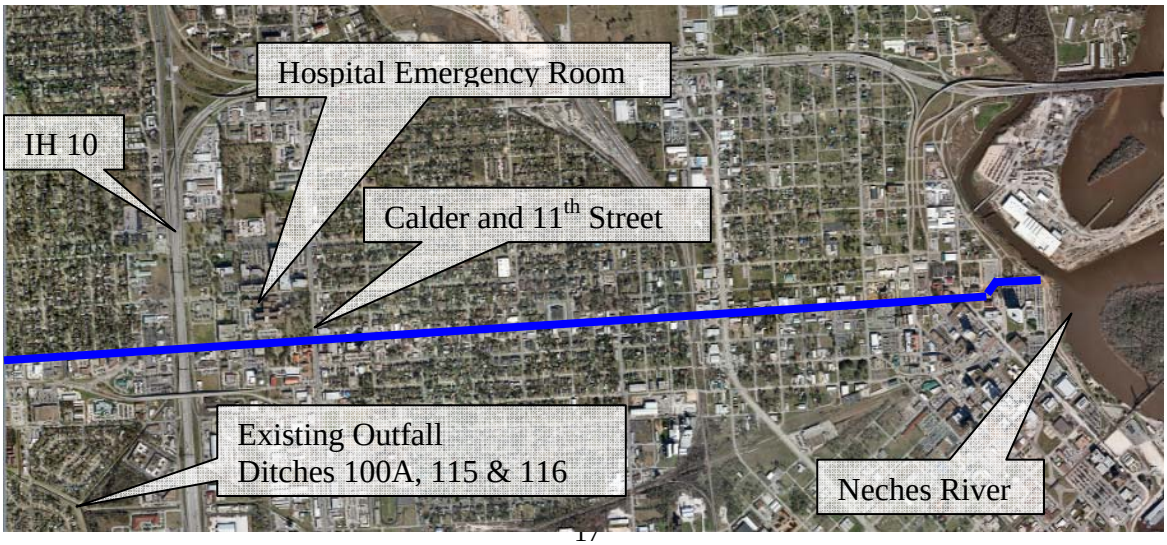
1.6 Calder Area

This watershed consists of approximately 2800 acres. This area is found in the upper most reaches of the water shed and is completely developed with businesses such as hospitals, retirement homes, hotels, apartments and fully developed subdivisions. Frequent rainfall runoff that inundates the streets and floods homes and businesses are competing for the outfalls that are already at capacity. The runoff that is generated from the developed areas have overwhelmed the systems causing flooding. Flooding of homes occur at the confluence of Ditch 100A, 115, & 116, along Calder St., between IH10 and MLK Pkwy. Flooding has also occurred in and around St. Elizabeth Hospital, making roads leading to the hospital impassable. The primary cause of the flooding near St. Elizabeth and near Calder is inadequately sized storm sewer systems. In addition, the tail waters of the storm sewer systems, which drain into Ditch No. 115 & 116, are high and do not allow the water to recede.

11th Street One Block from Calder

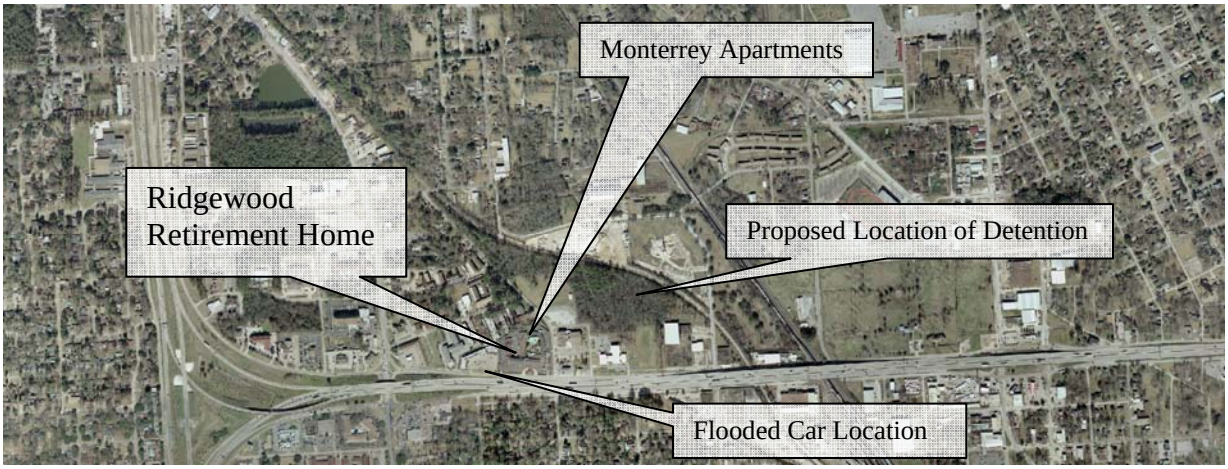
Emergency Room Entrance at Hospital

Entrance to Newly Constructed Out Patient Pavilion



1.7 Ridgewood Area

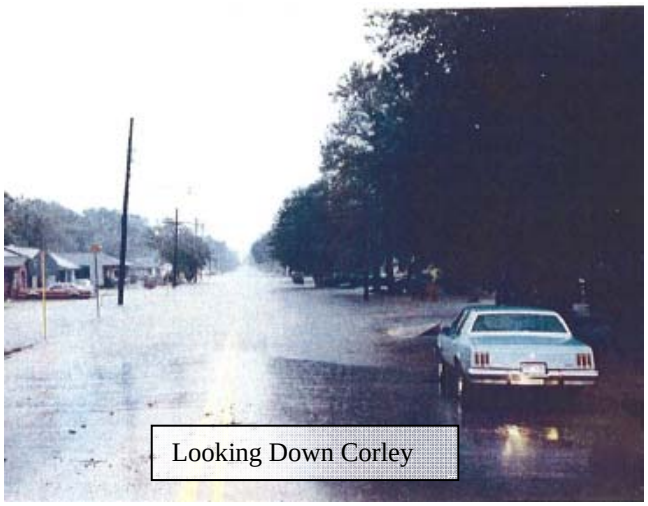
The 135 acre watershed in the City of Beaumont bound by IH 10 on the south, 11th Street on the west the Railroad near 7th Street on the east and Delaware on the north is the subject of this planning area. This area is developed with retirement homes, motels and hotels, businesses and apartment complexes. This area suffers frequent shallow home and business flooding which is caused by a combination of intense rainfall and inadequate outfall. Flooding of homes and businesses occurs in and around the Ridgewood Retirement Home, near IH10 and 9th St. The primary cause of the flooding near Ridgewood Retirement Home is inadequately sized storm sewer systems. In addition, the tail waters of the storm sewer systems, which drain into Ditch No. 116 are high, and therefore the water in the storm sewers back up and flood the areas around Ridgewood.

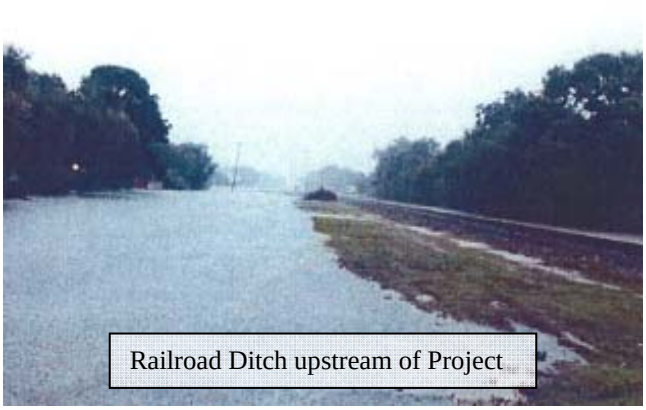


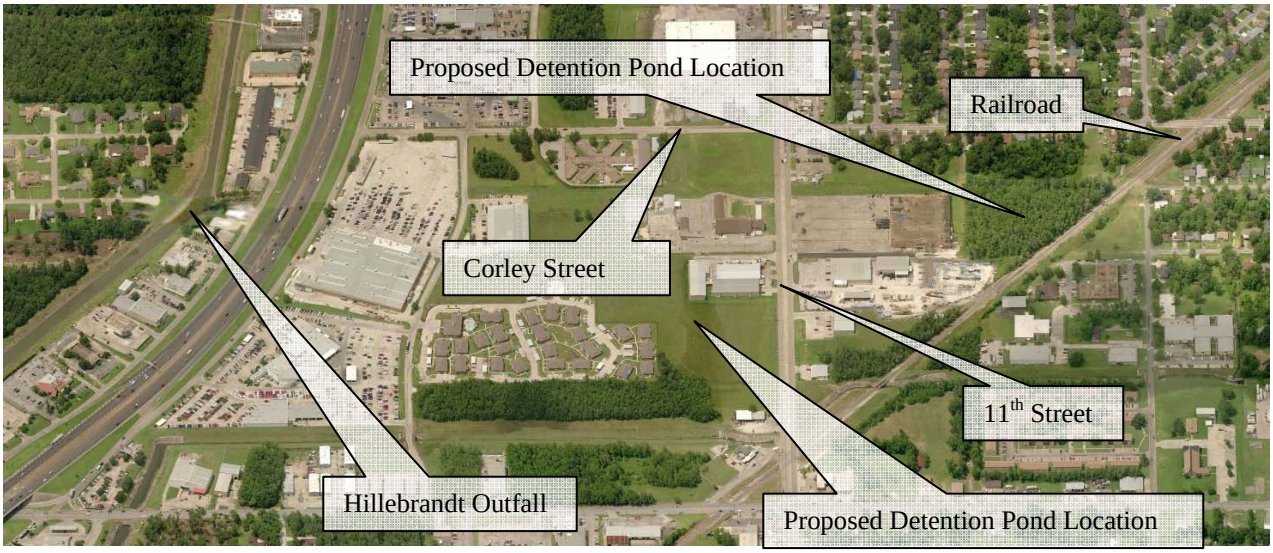
1.8 100D Area

The geographic area in which this home flooding is occurring is located in the south end of Beaumont, TX, in an area bounded by 11th Street on the west, College Street on the north, 4th Street on the east, and Cartwright Street on the south. The problem is frequent, shallow structure and street flooding.

The Cartwright/Corley neighborhood sustained flooding that resulted in drainage infrastructure failure. The existing storm sewer infrastructure failed to function because the current system was unable to convey the volume of water generated during the storm. The outfall water surface elevation for Corley is to high to allow the waters to recede effectively. The failure of the drainage system to function threatened the public health, safety, and welfare of all served by this facility due to flooding. The city is also in need of adequately-sized drainage infrastructure to reduce flooding.


Looking Down Corley


Railroad Ditch upstream of Project

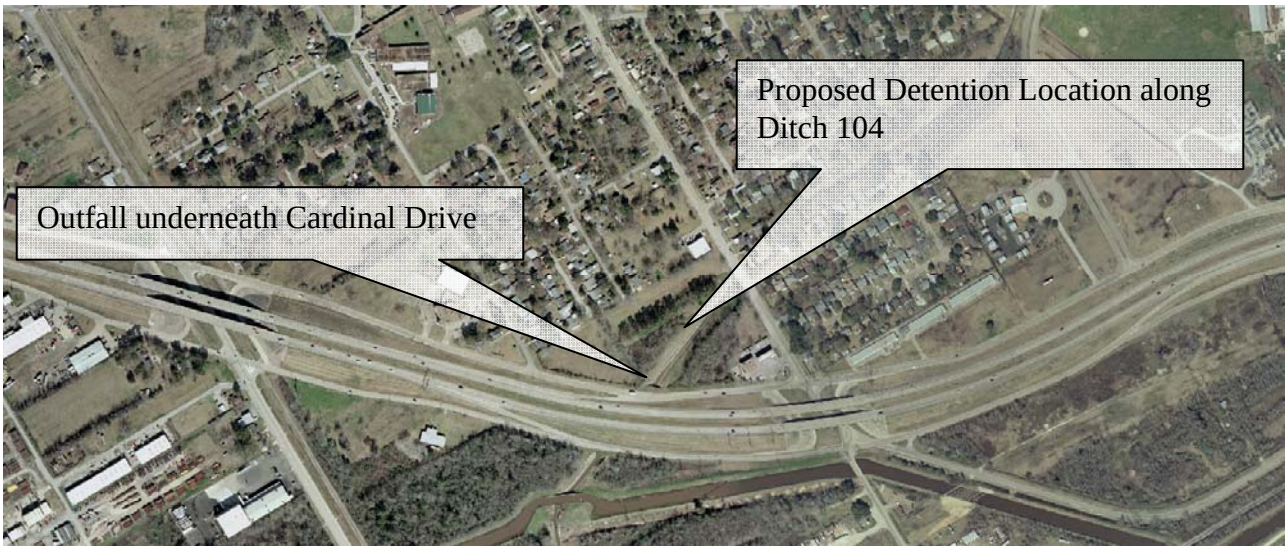


1.9 104B Area

The 454-acre watershed in the City of Beaumont, experiences frequent and severe structure flooding. The watershed is a fully-developed urban watershed and is known as "The Upper Ditch No. 104B Watershed." Some level of structure flooding occurs during rainfall events with a recurrence interval of 5 years. The primary cause of this flooding is an inadequate existing crossing coupled with an inadequate section of box culverts and open ditch approximately 130' upstream and 70' downstream of the existing crossing, which does not move the flood waters at adequate volumes to prevent home flooding. The solution to the flooding is to accelerate the flow of water in the vicinity of this crossing. The drainage system below this crossing, which consists of an open, concrete-lined ditch, 5 additional road crossings, and an irrigation canal crossing, is adequate to convey the flows in the existing conditions. However, once the existing crossing and adjacent ditch sections have been enlarged to convey higher flows and prevent the home flooding, the downstream system becomes inadequate to convey the flood flows without further flooding occurring.

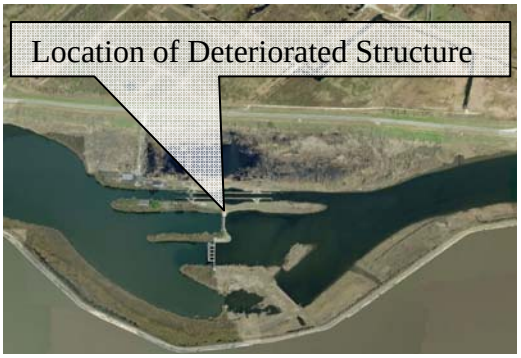
1.10 104 Area

The receiving channel Ditch No. 104, is already at maximum capacity due to the area it serves and enlarging the ditch would be a tremendous undertaking, it became apparent that detention basins would be the best solution needed to not overload this ditch. Additionally, the main outfall for this project area flows through four box culverts which lie underneath Cardinal Drive, which at this point is a 4-lane highway with service roads. Enlarging this culvert would also be a tremendous undertaking.



1.11 Flood Gates Area

The 512-square-mile watershed, which is the combination of Taylors Bayou, Hillebrandt Bayou, and Big Hill Bayou in Southeast Texas, drains from upland areas in and surrounding Beaumont, TX, Nome, TX, and Winnie, TX, in a southeasterly direction and enters the Gulf Intracoastal Waterway near Highway 87 See Figure 14 and Figure 15 in Appendix A. All of this runoff is directed through a set of flood gates and navigation locks, which perform the dual function of preventing salt water intrusion from the Intracoastal into the fresh water system, as well as conveying flood flows. The structure consists of two sets of modern tainter-gate-type structures--one set of 7 and one set of 4--and a set of out-dated wooden steel and flap-type structures, which is currently non-functional and has been isolated from the flood flow due to major erosion and gate inoperability problems The problems with these wooden flap gates has been accelerated in the last 7 years since we had floods in 1998, 2001, 2002, 2003, and, again, during Rita in 2005. These flap gates are an extremely important overall part of the drainage for the entire area and represent 27% of the total flow capacity of the entire system. The important function of maintaining a fresh water pool for irrigation purposes and protection of the fresh water marshes, as well as navigation, was in jeopardy due to bad erosion, leak problems, and gate malfunctions; so sheet piles were installed across the channel just upstream from the flap gate structure to prevent loss of fresh water. While this operation protected the fresh water supply, it decreased the flood flow capacity of the entire system dramatically.



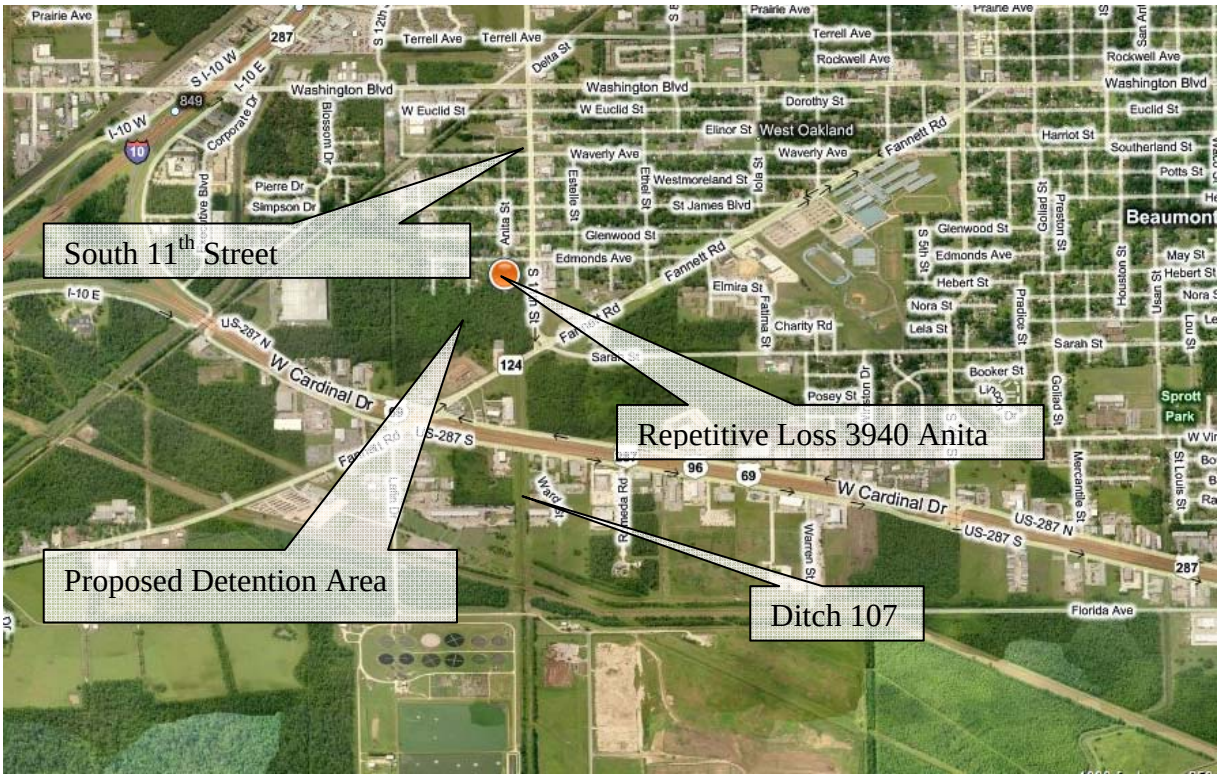
1.12 107 Area

Repetitive Loss properties were found during the analysis and evaluation of the Geocoding. Further investigation lead to the conclusion that a detention pond could be constructed upstream to alleviate the flooding causing the repetitive losses. The benefit area is shown on figure 35 in Appendix A delineated as the drainage boundary.

The area in question is 89 acres comprised of residential and urban properties in the south end of Beaumont. There are 273 houses in this area with at least one repetitive loss see the map below.

The proposed project will include the purchase of approximately 15.6 acres of property. The detention will require approximately 196,000 cubic yards of excavation. The 11th Sreet underground drainage will be connected to the detention basin, with backflow devices to prevent Ditch 107 from backing up onto 11th Street.

The Project will provide outfall capacity for the 100 year storm event and relieve ditch 107.



2.0 Hydrologic Analysis

2.1 Drainage Basin Overview

Jefferson County is bounded on the north by the Neches River and Pine Island Bayou, which form the border with Hardin and Orange Counties; on the east by Sabine Lake, which forms the border with Cameron Parish, Louisiana; on the South by the Gulf of Mexico; and on the west by Liberty and Chambers Counties. The City of Beaumont is the County seat and the largest City of Jefferson County. The City is situated approximately 85 miles east of Houston, approximately 70 miles northeast of Galveston, and 275 miles southeast of Dallas. Ground surface elevations across the District vary from approximately 37 feet to 5 feet above mean sea level. The topography is described as nearly flat prairie and the geologic structure is nearly flat strata. The bedrock types are comprised of deltaic sands and mud. Data from the Bureau of Economic Geology, The University of Texas at Austin, identifies the land as "expansive clay and mud – locally silty, locally calcareous, flat to low; hilly prairie; commonly tilled". The climate of the region is humid subtropical, with warm summers and moderate winters. Rainfall is abundant and on the average, evenly distributed throughout the year. The heaviest rains usually occur during the hurricane season, which extends from June through October. Average annual precipitation for the area is approximately 56 inches and the average annual temperature is about 69 degrees.

2.2 Flood Hydrology

Hydrology is the study of the movement of water across the watershed and the determination of the flows at the points of interest. HEC-HMS was used to develop the flows for this study.

2.3 Watersheds

The watersheds were developed from aerial maps, topographic maps, DEM data, and field surveying.

2.4 Rainfall Runoff Models

For evaluating flood flow frequency for Hillebrandt Watershed, rainfall-runoff models were developed to compute runoff hydrographs at various locations within each watershed. A rainfall-runoff model simulates the watershed response to precipitation. The USCOE Flood Hydrograph Package, HEC-HMS and HEC-1, was used to model the flood hydrograph in each of the watersheds.

Hypothetical rainfall models were developed utilizing TP40 rainfall depths for Jefferson County. See table below. The actual rainfall depth models were developed utilizing DD6's network of rain gages and stream gages. Actual storm events were modeled to determine the calibration of the models. See Figure 16 in Appendix A.

Depth-Duration-Frequency Data for Jefferson County

Duration (minutes)	***Rainfall Depth (inches)***				
	Storm Frequency				
	2-Year	***5-Year***	***10-Year***	***25-Year***	***100-Year***
5	0.70	0.89	1.00	1.15	1.37
15	1.37	1.73	1.95	2.23	2.66
60	2.50	3.10	3.42	3.82	4.70
120	3.10	3.80	4.40	5.00	6.20
180	3.40	4.25	4.80	5.65	7.00
360	4.00	5.10	6.10	7.00	8.80
720	4.60	6.20	7.50	8.60	11.00
1,440	5.50	7.50	8.80	10.20	13.00

2.5Channel Routing

Routing of flood flows from the outlet of an upstream sub-basin to the next sub-basin outlet downstream was accomplished using the Modified Puls method and Muskingum Routing as outlined in HEC-HMS and HEC-1.

2.6 Minor Watersheds

The area at the Calder Diversion was analyzed with GEOPAK drainage which uses WinStorm as its Hydraulic engine. WinStorm is the TxDOT accepted storm sewer modeling package. The flows were generated with HEC-HMS and applied to the appropriate nodes.

2.7 HEC-HMS and HEC-1

HEC-HMS and HEC-1 is the Corps of Engineers Hydrologic Modeling System. The program simulates precipitation-runoff and routing processes using the following parameters:

2.7.1 SCS Curve Number Loss Method

The Soil Conservation Service (SCS) Curve Number (CN) model estimates precipitation excess as a function of cumulative precipitation, soil cover, land use, and antecedent moisture. Three parameters are required for this method, the initial abstraction (I_a), the curve number (CN) and the percent impervious.

2.7.2 Initial abstraction (I_a)

The initial abstraction is defined as the amount of precipitation that must

accumulate before runoff occurs. For this project the initial abstraction is 0.5 in

2.7.3 Curve Number (CN)

The CN for a watershed can be estimated as a function of land use, soil type, and antecedent watershed moisture. The CN can be estimated using the tables published by the Soil Conservation Service (SCS) in Technical Report 55.

2.7.4 Percent Impervious

Percent impervious is the amount of the watershed that is completely developed and has surfaces such as concrete or paved parking lots.

2.7.5 Clark Unit Hydrograph Model

Clark's model derives a watershed Unit Hydrograph by explicitly representing two critical processes in the transformation of excess precipitation to runoff:

- Translation or movement of the excess from its origin throughout the drainage to the watershed outlet; and
- Attenuation or reduction of the magnitude of the discharge as the excess is stored throughout the watershed.

The Clark Unit Hydrograph Model requires the use of two parameters to generate the hydrograph, the Time of Concentration (t_c) and the basin storage coefficient (R).

2.7.6 Time of Concentration (t_c)

The time of concentration (t_c) is the time at which the entire watershed begins to contribute to runoff; this is calculated as the time taken for runoff to flow from the most hydraulically remote point of the drainage area to the point under investigation.

2.7.7Basin Storage Coefficient (R)

The basin storage coefficient, R, is an index of the temporary storage of precipitation excess in the watershed as it drains to the outlet point. The storage coefficient is unique to the watershed and the area. An acceptable formula for calculating the storage coefficient has been developed in Jefferson County.

The formula is $R = 1.6\ T_{c.}$
Where:

R = Clark's storage coefficient (hrs)
Tc = time of concentration (hrs)

All of the input and output of the Hydrology can be found in the Appendices of the Report.

3.0 Hydraulic Analysis

3.1 Stream Hydraulics

Hydraulics is the study of the watershed geometry in order to develop water surface profiles, compute velocities, and volumes in the channels and at the structures. Hydraulic models were developed for each of the major streams for the purpose of assessing flood conditions, including water surface elevations, channel capacities and hydraulic capacities of existing drainage structures. The resulting flood plains were mapped for the 100-year flood event for existing and future development conditions using the aerial topographic maps as a base for flood plain delineation. The following sections describe the key elements involved in hydraulic modeling of the stream segments in the planning area.

3.2 Selection of Stream Hydraulic Model

HEC-RAS is the US Army Corps of Engineers hydraulic modeling software. HEC-RAS is designed to perform one-dimensional hydraulic calculations. The basic computational procedure is based on the solution of the one dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the velocity head). Manning's equation is defined as:

Q = 1.486/n)(R2/3)(Sf1/2) where:

Q = flow (cu ft/sec)
n = roughness coefficient (Manning's "n")
A = cross sectional area (sq ft)
R = hydraulic radius (wetted perimeter)
Sf = slope of the hydraulic gradient

The requirements for the use of HEC-RAS include the existing and proposed channel, the roadway geometry, the existing and proposed structure geometry and the flow. Channel cross sections were extracted from a 3D model developed for the project. The models were constructed from DEM data from the USGS, field specific surveying, and existing data from constructed lined channels. See Figure 32 in Appendix A for the overall DEM contours.

3.3 Street Drainage

The Streets along the problem areas near Calder have severe flooding as can be seen from the adjacent picture. The volume of water had to be balanced with the capacity of the structure for the models to properly interpret the flows in GEOPAK Drainage. Geopak Drainage is a storm sewer modeling program that utilizes graphically drawn elements that can be easily adjusted to model the system.


11th Street near Calder

3.4 Storm Sewer System

Storm sewer systems serve to remove excess street flow and convey it underground to a major drainage way. There is a major network of underground infrastructure in the Calder Area that was traced in order to develop the Calder Diversion. See Figure 33 in Appendix A for a map of the storm sewer.

3.5 Storm Sewer System Conceptual Design

The major storm sewer drainage district for this project was developed for the 100 yr design flows. See section 6.2 in the DD6 drainage criteria manual. This was necessary because it will be major outfall for the City and DD6 and the chance to upgrade this structure in the future is unlikely.

3.6 Drainage Criteria

This study was focused on reliving major drainage problems. Therefore, the 100 yr storm was selected when developing the systems. Drainage District No. 6 requires all major outfalls and major structured to be designed for the 100 yr event.

The Drainage Design Criteria Manual was developed along with this study. The manual can be found on the DD6 web site http://www.dd6.org/ and in Appendix H. The Criteria manual was utilized in the preparation of the planning study.

All of the input and output of the Hydraulics can be found in the Appendices of the Report.

4.0 Hydrologic and Hydraulic Summary

The flood flows for this project were determined using a Corps of Engineers' hydrologic models known as HEC-HMS and GEOPAK Drainage. The water surfaces are calculated using the Corp of Engineers' computer program HEC-RAS. Water surfaces for each storm event are determined. In the course of the benefit/cost calculation, the elevation reference to mean sea level was shot of each house affected by the project and certified to by Doug Canant, P. E. (License #71285), R. P. L. S. (License # 5291). Mr. Canant is the District Engineer for Jefferson County Drainage District No. 6 and oversaw the flood study which was performed by Butch Wilson, P. E. (License # 84857), of LEAP Engineering. The computer models accomplished by LEAP Engineering were calibrated using prior rainfall events, and high water marks which were shot and recorded by the Jefferson County Drainage District No. 6 survey crew. All of the data was input into the Arc View and Geo-Coded to determine the flooding areas of concern. The data base is maintained and is utilized on projects throughout the planning area.

4.1 Calder Area

The primary cause of the flooding near St. Elizabeth and near Calder is inadequately sized storm sewer systems. In addition, the tail waters of the storm sewer systems, which drain into Ditch No. 115 & 116, are high. The project will benefit the areas along Calder, north and east along IH 10, and homes and businesses near the confluence of ditch 115, 116 and 100A (Hillebrandt Bayou) where the current flows will be diverted along Calder. A total of 1900 cfs will be removed from the already inundated system of Hillebrandt Bayou, alleviating flooding at the confluence of the ditches as well. See Figure 17 in Appendix A.

The reason this is the best alternative for this project is the tail water depths to which these flood waters are out falling will be reduced by more than 15'. The out fall of this project at the Neches River, which is the tailwater conditions for this project, is on average at elevation 1.5', whereas the conditions of the outfall at the confluence of the Ditches 100A, 115, and 116 vary from elevation 16' to 18.2'. The diversion reduces the flow at the confluence of Ditchs 100A, 115, & 116. This is important because it lowers the flood water surfaces at the confluence, and it lowers the tail water for the storm sewer which outfalls into Ditch No. 115, alleviating flooding in the area south of Calder. The diversion also catches the water from the area north of Calder and alleviates flooding in that area. The diversion alleviates flooding in a much broader area than a detention pond or channelization could, and it reduces the flow at the confluence, allowing the existing infrastructure to adequately convey the water it receives. Also, a detention pond is not a viable solution for the flooding both because the problem area is already highly

developed leaving little room for a detention pond, and because it would not alleviate flooding in all of the areas addressed by the diversion. Channelization is not a good option because it would ultimately increase the flow in Hillebrandt Bayou compounding the already inundated downstream channel. The alternative of a diversion running down Calder is the best alternative because it reduces flooding problems over a large area, lowers the volume and elevation of water at the confluence, and allows the existing storm sewers to adequately drain and convey the water it receives. In addition the City of Beaumont already has a roadway reconstruction project planned for Calder which would allow for the corridor for the drainage project, along with ancillary construction of laterals to be tied in to the drainage structure.

The ultimate goal of this project is to lower flood water surfaces. Engineering calculations indicate that the construction of the Calder Diversion will lower the 100-year water surface around Ditch 116 by 1.1', and the water surface near to St. Elizabeth Hospital will be 4.2' lower. The flood water surfaces from more frequent events will be lower by similar amounts. The lowered tail water condition at the Neches River is the reason for the significant water surface drop. See Figure 18 in Appendix A, for the benefit areas, and the proposed water surface elevations.

The area for the diversion experiences frequent flood events and the outfall discharge is at the already inundated confluence of ditches 100A, 115, and 116. During the study the alternative to take the excess flood waters to the lower water surface at the river revealed an ongoing project by the City of Beaumont to reconstruct Calder, which provided an economic and feasible corridor for the drainage structure. The alternative provided a hydraulically sound project that solved the flood issues in the area.

The Calder Diversion project is needed to alleviate the flooding that occurs along Calder St. between Lucas and the MLK Pkwy. and at the confluence of Ditch 100A, 115, & 116. Diverting this water to the Neches River will reduce the volume of water at the confluence of Ditch 100A, 115, & 116, thus alleviating the flooding problems in the homes around the confluence. In addition, the Calder Diversion will take in water from the area north of Calder, eliminating flooding problems around St. Elizabeth Hospital and in the homes and businesses north of Calder St. between IH-10 and MLK Pkwy. The Calder Diversion will also eliminate flooding in the area just south of Calder because it will allow the drainage system below the diversion to adequately convey the water it receives.

The Calder Diversion project will be implemented during a project that is proposed by the City of Beaumont. The City is in the process of developing plans to reconstruct Calder Street from Lucas Street to Main Street. This corridor provides the route in order to place the structures required to accomplish this project. This coincidental project alleviates multiple hurdles to provide the much needed drainage project. Right of Way will not be required to install the structures and the roadway will be reconstructed during the project therefore eliminating the redundancy of projects. The plans will be developed along with the roadway project and will be let in conjunction with the city's project for reconstruction of the roadway. The opportunity to provide the much needed project along with the reconstruction of the roadway is a one time opportunity and will only be economically feasible at the same time.

The Calder Diversion project will be constructed along with a proposed reconstruction project on Calder that allows for the corridor. This project will involve the installation of concrete boxes that will run under Calder from Lucas St. to the Neches River. It will require 3,225 linear feet of 1-10'x10' box culverts from Lucas Street to west of IH 10 (18^{th} street), 700 linear feet of 2-10'x10' box culverts from 18^{th} street to east of IH10 (north bound Frontage Road) and 12,900 linear feet of 3-10' x 10' box from the north bound frontage road at IH 10 to Neches River. The preliminary route of the structure is east along Calder to Main Street then north one block to Elizabeth Street and East along Elizabeth St. to the Neches River. The estimated cost of the drainage structure along Calder is $31,553,570. The City of Beaumont will bear the cost of the roadway reconstruction. Ancillary construction of laterals will be accomplished in conjunction with the City of Beaumont Calder Street Reconstruction project.

The proposed profiles were necessitated and developed in this study to determine the depth of the structure and along Calder. The City of Beaumont is approximately 80% complete with the diversion project. See Figure 19 - Figure 26 in Appendix A for the proposed profiles.

The project footprint will be in the existing City right of ways and under the existing pavement structure. The project will require two railroad crossings, one near MLK Parkway and the other near the Neches River at the discharge point.

Four alternatives were considered during the project development.

1. No Action alternative is unacceptable because flooding of homes, businesses, and emergency facilities are costly to the community.

2. Channelization aggravates the downstream conditions.

3. There is not a viable detention area available.

4. The diversion along Calder will provide a complete solution to the flooding problems in this area.

There is a great need for this proposed action. The project area not only has repetitive home and business flooding, but the area contains emergency facilities such as hospitals and doctor offices that cannot be accessed during rain events.

4.2 Ridgewood Area

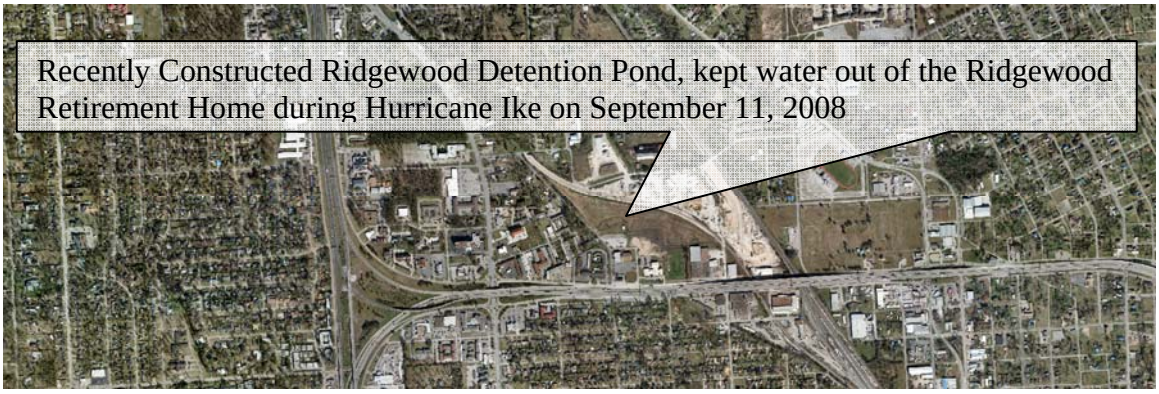
The area for the detention basin experiences frequent flood events and the outfall discharge is at the capacity. The study presented the alternative to store the already available flood waters in a below ground detention.

The project is to construct a 13.88 acre 81 acre-ft detention basin north of the Ridgewood Retirement Home. Four 36" inlet structures and one concrete spillway and a 24" outlet structure will be required, along with re-grading some existing roadside ditches. The detention pond to the north of the Ridgewood Retirement Home will alleviate flooding around the Ridgewood Retirement Home, near IH-10 and 9th St. See Figure 27 in Appendix A.

The solution of a detention basin for flood control will address the flood problems around the Ridgewood Retirement Home by holding a large volume of water which runs off the upper part of the watershed. It will allow the drainage system below the basin to function more efficiently during rain events.

The detention basin is by far the best alternative for this problem area. It will dampen the peak runoff from the area, allowing the existing infrastructure to convey the flood flows adequately, and the detention basin alternative does not increase downstream flows like a channelization project would, and constructing the adequate storm system would not be economically feasible. Increasing downstream flows would be disastrous because this area is already suffering frequent and severe structure flooding and the receiving channels are already at capacity.

The ultimate goal of this project is to lower flood water surfaces. Engineering calculations indicate that the construction of the detention pond will lower the 100-year water surface near the Ridgewood Retirement Home by 3.4'. The flood water surfaces from more frequent events will be lower by similar amounts. See Figure 28 in Appendix A for the improved water surface elevations developed utilizing HEC-RAS and Geopak Drainage.



The detention pond project was implemented using funds, equipment, and personnel from Jefferson County Drainage District No. 6 with assistance from grant awards.

Four alternatives were considered during the project development.

1. The No Action alternative is unacceptable because flooding of homes, businesses, and emergency facilities are costly to the community.

2. Channelization aggravates the downstream conditions and the outfall is an existing trunk line that is overwhelmed by existing runoff

3. Buy out of existing retirement centers and apartments are too costly and this would displace many citizens.

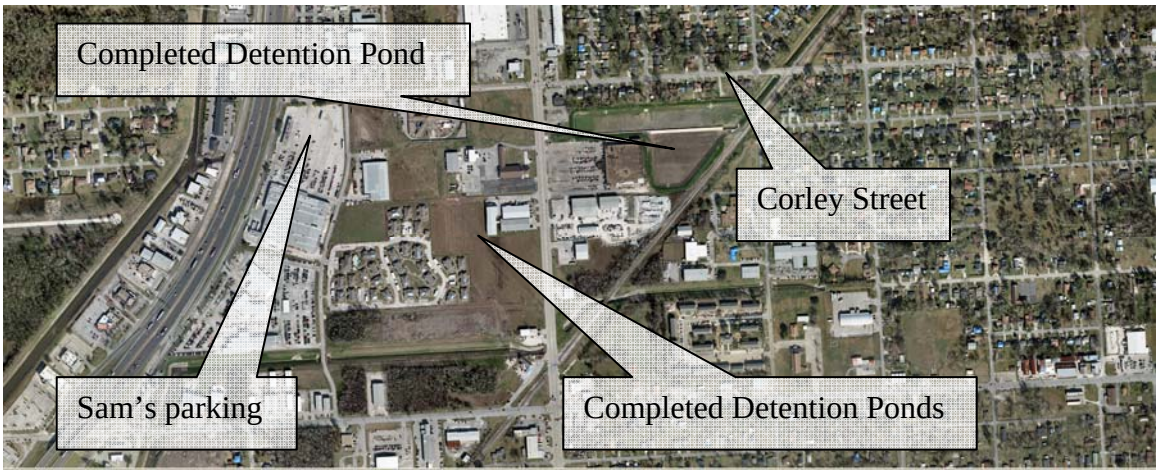
4. Detention is the best alternative because there is available vacant undeveloped property and the existing water during flood events are easily diverted to the detention basin without interruption of the existing drainage system.

There is a great need for this proposed action. The project area not only has repetitive home and business flooding, but the area contains retirement home facilities such as the Ridgewood retirement home when during rain events emergency access is limited.

4.3 100D Area

The problem is frequent, shallow structure and street flooding. The geographic area in which this home flooding is occurring is located in the south end of Beaumont, TX, in an area bounded by 11th Street on the west, College Street on the north, 4th Street on the east, and Cartwright Street on the south.

A hydrologic computer model was constructed which proved the inefficiencies of the existing system. Since the receiving channel, the Hillebrandt oxbow is at maximum capacity it became apparent that detention basins would be the best solution. Additionally, the main outfall for this project area flows through two box culverts which lie underneath the Sam's Wholesale Club parking lot. After leaving the Sam's parking lot, these culverts go under IH-10, which at this point is a 6-lane highway with feeders. Enlarging this culvert would also be a unrealistic and cost prohibitive. The availability of land for detention is scattered and bringing water to these areas is essential in making this solution successful. Therefore, using the flow corridors of Blanchette Street and the Corley Street right-of-way was an idea that quickly presented itself. Once the cost estimate was derived to accomplish this work, a benefit/cost analysis was performed, proving the alternative was cost beneficial - much more beneficial than buy-outs, elevations, or other potential structural solutions. Due to the high benefit/cost ratio and the land availability, the proposed mitigation solution is the best alternative



Drainage District 6 and the City of Beaumont has been able to alleviate more flooding with two more projects that were made possible by the detention pond projects targeted in this study. One project was let by DD6 which included jacking large structures under the railroad just east of the detention ponds. The other project was let by the City of Beaumont where two parallel structures are going to be placed in Corley to alleviate the home flooding. All of the water will be detained in the detention ponds targeted in this study. See Figure 29 in Appendix A for the improved water surface elevations and flows.

Four alternatives were considered during the project development.

1. The No Action alternative is unacceptable because flooding of homes, businesses, and emergency facilities are costly to the community.

2. Buy out of existing structures would be significantly more expensive than the proposed solution and would displace many citizens - in fact, the estimated cost of acquisition of all structures that would benefit from this project exceeded 34 million dollars..

3. Channelization is not a possibility because the existing outlet is constrained where the outfall at where the two box culverts are under the existing parking lot and continues across IH 10.

4. Detention was an economical alternative because there was vacant land down stream of the Corley Street out fall and a series of pipe lines made location to provide detention.

4.4 104B Area

On October 9, 2003, the 104B Area experienced structure flooding with a rain event which produced flows equivalent to a 7-year event. Jefferson County itself experiences a relatively high level of rainfall. The National Weather Service statistics currently have our annual rainfall at 56". We have had ALERT stations in 2001 which measured 103 total inches of rainfall, and we have gauges in various years measuring 80". The weather service statistics indicate that our 24-hour rain event with 100 year recurrence interval is 13". The highest point rainfall for a 24-hour period that Jefferson County Drainage District No. 6 has recorded is 24", which occurred on June 7, 2001. Our area suffers a wide range of intense rainfalls at any given point. The study watershed suffers flooding from a rainfall event which may only last two hours. Therefore, rainfalls of various durations are of interest when analyzing the amount of rain which caused any given flooding situation. Using National Weather Service statistics, for example, a 1-hour rain event with a 10-year recurrence interval is 3.23". The 2-hour event would be 4.4". Rainfall events never occur as the statistic average calculates. Additionally, Jefferson County Drainage District No. 6 has learned through analysis of its' 58 rain gauges that one gauge may receive 10" while a second gauge less than 2 miles away will receive 2". In the case of this study area, we believe that the rain events which are causing these floods are of the nature that we should attempt a solution to provide some relief for not only the extreme cost of flooding but also the inconvenience and potential dangers. On October 9, 2003, the study area experienced structure flooding with a rain event which produced flows equivalent to a 7-year event.

Utilizing this data and the HEC RAS models contained in the appendices of this report provided the information leading to the conclusion that detention was the best alternative. See Figure 30 in Appendix A for improved water surface elevations.

When analyzing the solution for the flooding problem, there were 4 alternatives considered:

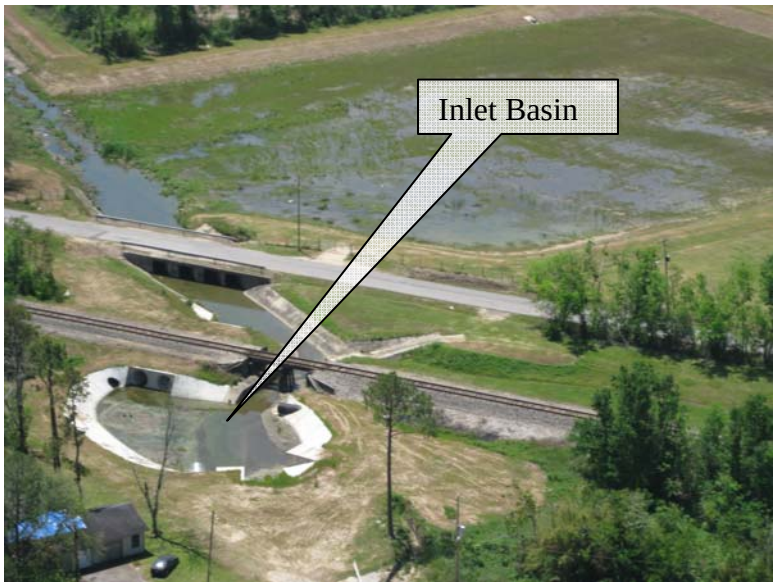
(1) The "no action" alternative is unacceptable due to the frequent and severity of the home flooding.

(2) Channelization alone would increase water surface elevations downstream.

(3) The buy-out and complete channelization alternative were excluded because of economic reasons.

(4) Detention provided the flood water storage without aggravating downstream water surface elevations


Inlet Basin
Completed 104B Detention


Inlet Basin

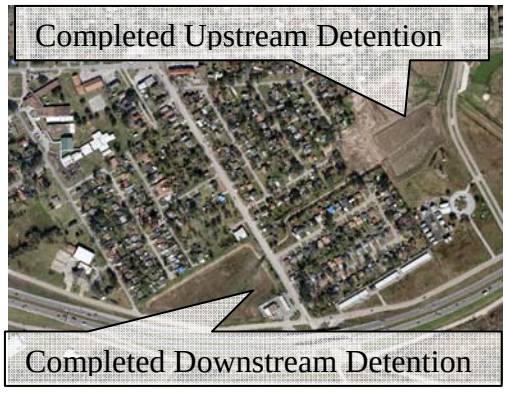
4.5 104 Area

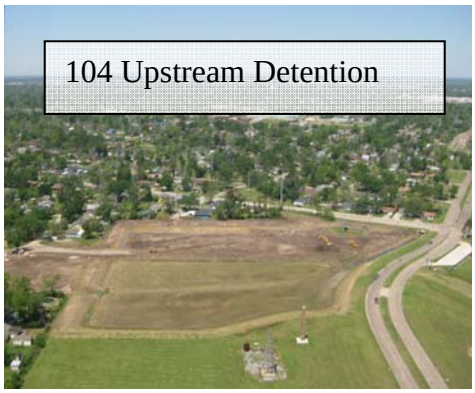
The availability of land for detention is scattered and bringing water to these areas is essential in making the plans work. The City of Beaumont is making plans to improve Rolfe Christopher Drive in this area; and, in meeting with its engineers, the idea of using that project to convey runoff to a series of detention basins presented itself.

The water surfaces are calculated using the Corp of Engineers' computer program HEC-RAS. Water surfaces for each storm event are determined and are contained in the models in the Appendices of this report.

The problem to be mitigated is frequent, shallow home flooding. The geographic area in which this home flooding is occurring is located in the south end of Beaumont, TX, in an area bounded by Cardinal Drive on the south, Kenneth Street on the west, Florida Avenue on the north, and University on the east. See Figure 31 in Appendix A for the overall drainage area and the improved water surface elevations.

.





Four alternatives were considered during the project development.

1. The No Action alternative is unacceptable because continual structure flooding and street flooding is costly to all stakeholders.

2. Buy out of existing structures would be significantly more expensive than the proposed solution and would displace many citizens. It is estimated that the cost of acquisition of the 200 homes within the project area that will benefit from this project would be greater than $16M.

3. Channelization would only aggravate the downstream conditions.

4. Detention was the alternative selected to improve this area.

4.6 Flood Gate Area

We used the benefits that were easily quantifiable in this analysis, and they are meticulously broken down in the benefit/cost analysis. They consist of avoided damages to homes, savings from road repairs, damages to crops, damages to cattle, and increased cost of cattle operations. There is also a very real possibility that the eroded state of this structure could cause a disastrous situation if the whole structure completely washed out. If this was to occur, and it may in the next flood, the solution to the problem at that time would be more expensive than addressing the situation now. Wash-out of this structure would also cause damage to the nearby control building, as well as the Navigation gates. The integrity of this system is vital to the precious natural environment of this ecosystem and also the economy of the area. There are 118,686 acres directly impacted by the functionality of these flood gates. With these flood gates being inoperable, the flood waters must reach higher elevations in order to force the flood flows through the structures at higher velocities. This higher flood water elevation "backup" inundates many more acres than would be inundated were the gates functional. In addition to the direct economic hardships caused by these floods, extended inundation times and higher depths of water are very damaging to the 35,000 acres of marsh that are dependent also on these gates for drainage. These floods affect the nature of the vegetation and wildlife that inhabit the area.

Different storm scenarios were analyzed in the process of this project development; and, the flood waters on the 118,000+ acres are around a foot higher as a result of these flood gates not operating. There are 77,215 acres of prime productive farmland below Elevation 10 that are directly impacted by this project. The primary agricultural crop in this area is rice. This area has the ideal topography, climate, and soil characteristics for rice production and some of the best rice lands in the U. S. The only drawback to this area is the periodic flooding which occurs, which will completely destroy a crop. Typically, a rice crop is rotated on a 3-year basis; and, at any given time, 1/3 of this acreage is under rice production. The other 2/3 typically is utilized as grazing for the also vital cattle industry in our area. Besides the possibility of drowning cattle and causing distress, the flooding of these ranches causes increased expenses to the ranchers because the cattle must be fed hay and supplements because the floods cause the grasses to be worthless as a nutritional value for a month after the flood recedes. Therefore, this cattle must be fed for a month, plus the duration of the flood, which can be anywhere from 4 days to 2 weeks. All of these factors are considered in the benefit/cost analysis. A vital facility to the security of the U.S. exists in this watershed, which is known as the Big Hill Strategic Petroleum Reserve. Big Hill is a unique geologic formation where crude oil is being stored underground. This location is isolated from public highways and the county road which accesses this facility often floods. This project will decrease the number of times this road floods, as well as the length of time the road stays flooded. While the cost of these hardships to Big Hill has not been quantified, this is a very important consideration in this project. There exists 51.9 miles of public road in the project benefit area, which

vary from Elevation 5 above mean sea level to 10' above mean sea level. The county precincts responsible for these roads spend $1.5 million per year maintaining and overhauling the roads, and a good deal of this money is spent repairing damages from floods. There are a number of homes in the benefit area which exist between Elevation 3 and 10 which will benefit from the project. Included in Appendix F are testimonials from farmers and ranchers who concur with this project and the benefits to be achieved.

The proposed solution is to construct new gates to replace the closed off deteriorating structure.

See Figure 34 in Appendix A for the improved water surface elevations due to proposed gate improvements.

Four alternatives were considered during the project development.

1. The No Action alternative is unacceptable because this is the outfall to the entire study area, if the outfall fails, the upstream improvements would be jeopardized.

2. Buy out of existing structures would not accomplish the improvements needed to provide downstream relief.

3. Channelization is not an option because the outfall is adequate to convey the flows

4. Reconstruction of the structure is the only solution that would allow the improvements to the downstream system.

5.0 Recommendations

This study includes implementable structural and non-structural mitigation alternatives, such as flood plain management, acquisitions, elevations, channel enhancements, inlet and storm sewer improvements, and detention and diversion as a system. DD6 will ensure that mitigation alternatives will effectively interact with the complete watershed and will provide long-term benefits.

Dating back to 1979, the planning area has experienced structure flooding that caused damage to insured and uninsured properties. Through evaluation of the National Flood Insurance Paid Claims database for the City of Beaumont, DD6 has determined there have been 11 major floods and several small events that have caused considerable damage within the planning area in the past 23 years. NFIP claims for the entire City of Beaumont total over $39,000,000 ($12,285,000 of claims are within the planning area – 31.5%). It should be noted that the two most recent events, June 2001, and October 2002 resulted in over $19M in paid claims ($5,985,000 of claims within the planning area – 31.5%). Both of these events were less than an actual 100-year event for the City of Beaumont, in fact, they were less than 25 year events. Growth and development within the planning area continues. This growth and continued absence of careful drainage planning only exacerbate flooding problems.

In addition to the above statistics, the floodwaters in the events mentioned above caused serious damage to hospitals, critical care facilities, businesses, and homes in the planning area. The inconvenience and danger associated with these events could be lessened or eliminated with an overall drainage plan that addresses the problems and alternative solutions.

5.1 Non Structural Recommendations

Non structural Recommendations include:

- Continued Flood Plain management by DD6 which includes enforcement of rules and regulations.
- Continual update and enhancement of the hydrologic and hydraulic models developed in this study. Future development will continue. Proper advance modeling will help avoid potential flood problems
- The Arc-View data base developed during this study should be maintained and updated. This data base contains valuable information for determining flood prone areas. The updates should include periodic questionnaires sent out like the one in this study. The questionnaires should be sent out after major rain events.
- Implementation and use to the drainage criteria manual developed during this study will provide the developers invaluable information. Adherence to this manual is an important and invaluable non structural solution for flood plain management. The manual can be located on the DD6 website at http://www.dd6.org/ and in Appendix G.

5.2 Structural Recommendations

Seven major structural projects were identified in this study. See Figure ES-2 in the Executive Summary.

The estimated costs of these projects are:

The Ridgewood Detention Basin Project	$878,000.00
The Calder Improvement Project	$31,553,570.00
Ditch 100 D Improvement Project	$4,750,000.00
Ditch 104 B Drainage Project	$1,300,000.00
Ditch 104 Improvement Project	$3,250,000.00
Ditch 107 Detention Basin	$1,950,600.00
Flood Gate Mitigation Project	$6,050,914.00
Total	**$49,733,084.00**

The estimated net avoided damages after implementation are:

The Ridgewood Detention Basin Project	$8,668,441.00
The Calder Improvement Project	$60,365,910.00
Ditch 100 D Improvement Project	$23,687,717.00
Ditch 104 B Drainage Project	$7,156,611.00
Ditch 104 Improvement Project	$5,550,695.00
Flood Gate Mitigation Project	$21,124,381.00
Total	**$126,553,755.00**

The original estimates of construction are contained in Appendix I of this report.

6.0 Funding Alternatives

Due to the seriousness of existing flooding problems within this watershed and the anticipated degree of difficulty associated with developing drainage plans for many areas already heavily urbanized, the costs associated with the proposed study area planning are substantial. Further, with the recent passage of H.B. 919 DD6 has the desire and responsibility to complete a master drainage plan, as described in H.B. 919 and Texas Water Code 49.211. DD6 does not feel that it can bear the full financial obligation of these study activities without increasing existing tax rates. State funding assistance is requested in order to avoid such increases, which would be politically difficult and a burden to the citizens of the City of Beaumont and Jefferson County. DD6 has initiated planning, design, and implementation of numerous flood mitigation projects within the District over the past ten plus years. However, the financial burden of undertakings such as this study, in conjunction with ongoing maintenance activities, is making it increasingly difficult for DD6 to perform adequate flood mitigation planning.

DD6 has the financial capability to implement viable flood protection measures, to be determined through this study, to be cost beneficial solutions to current flooding. Since taking all work in-house in 1997, DD6 has completed approximately $12,500,000 in capital projects. DD6 is on the cusp of receiving a permit from the Corp of Engineers to construct 3rd phase of Taylors Bayou Project, which is estimated to be a $25 million project. Further, the Gulf Terrace Detention Project, estimated at $2.6 million, is currently under construction. (DD6's Moody bond rating is Aa3.) The funds to implement recommended flood protection measures come for DD6's General Reserve Fund. This fund is approximately $5,700,000 (FY04 DD6 Budget). The FY04 budget is based on a tax rate of .200039 per $100 valuation based on a net taxable assessed valuation of $5,273,357,516. which produces a $10,232,309 total budget.

DD6 has been actively participating in federal mitigation programs to obtain grants to augment flood mitigation projects and planning. Specifically;

- Recently awarded an HMGP grant for an acquisition project
- Recently awarded an FMA planning grant for the development of a Flood Mitigation Plan
- FMA award pending for a structural project
- Submitted a PDM application for a structural project.

DD6 will continue to apply for federal assistance through these and other mitigation programs to further augment their budget, thus allowing them to implement more mitigation projects. In addition, the City of Beaumont, LNVA, and TXDOT have indicated a willingness to assist with the implementation mitigation alternatives that may result from this study.

7.0 Environmental

7.1 Environmental Assessments

LEAP Engineering worked in conjunction with Horizon Environmental services to develop the environmental assessments for the projects targeted in this study. Each of these assessments can be found in the Appendix J.