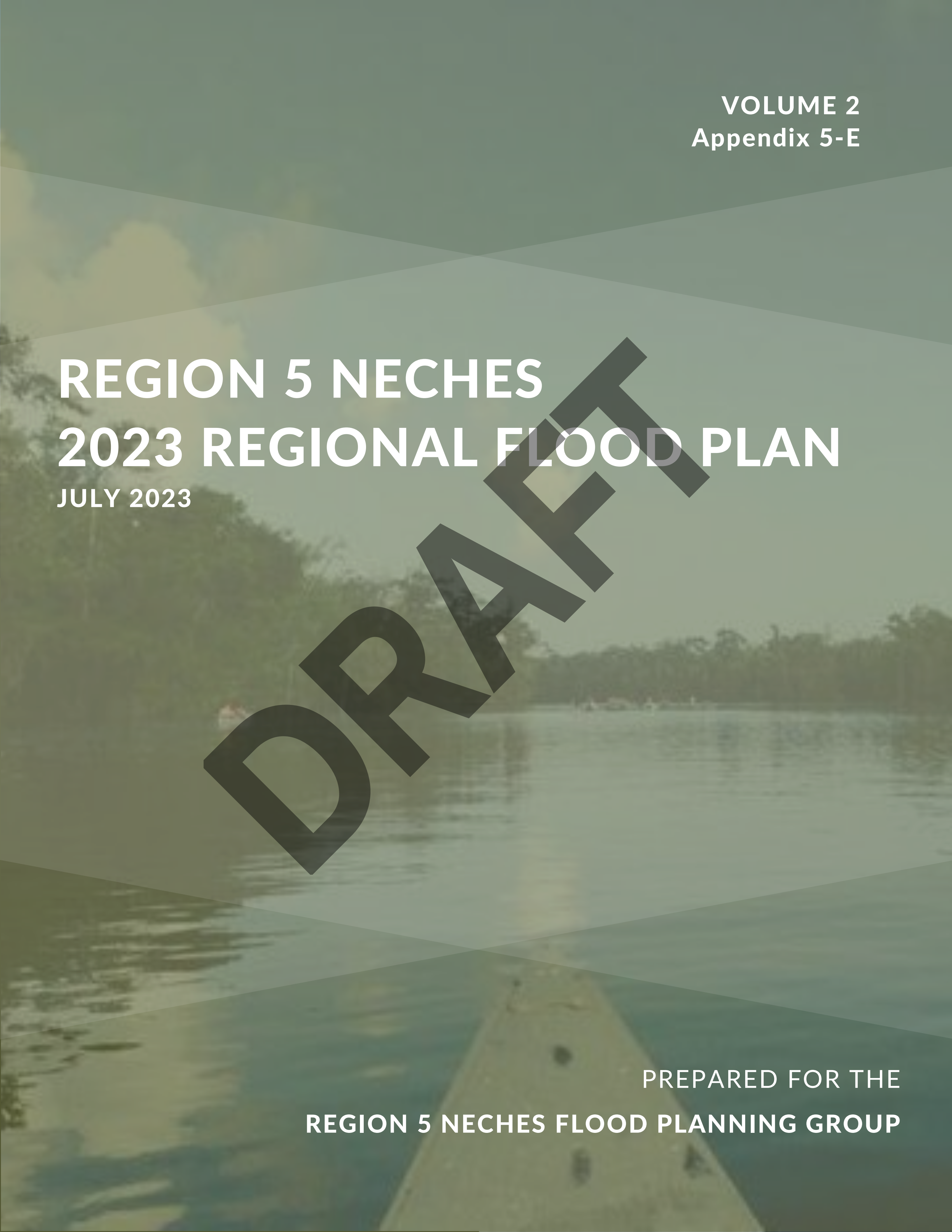

VOLUME 2

Appendix 5-E

REGION 5 NECHES 2023 REGIONAL FLOOD PLAN

JULY 2023

PREPARED FOR THE

REGION 5 NECHES FLOOD PLANNING GROUP

APPENDIX 5-E
SUPPORTING DOCUMENTATION FOR RECOMMENDED FLOOD MITIGATION PROJECTS

MASTER DRAINAGE PLAN
FINAL REPORT

Prepared for

BEAUMONT
TEXAS

Prepared by:

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August 2019

STATE OF TEXAS
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Date: 8/26/2019

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Acknowledgements

This study represents a key milestone towards the greater management and success of the City of Beaumont and is the product of massive interdisciplinary coordination – spanning the last four years – between the City of Beaumont, engineering consultants, Drainage District 6, and the general public. LAN is grateful to City of Beaumont staff, particularly Dr. Joseph Majdalani, Chace Mann, and Ernie Crochet for their invested time, effort, and commitment towards providing LAN with necessary data, background, interim deliverable reviews, logistical guidance, and general insights day-to-day. This coordination was instrumental for the success of the master drainage plan.

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Glossary

1D Model – A model that incorporates a system in one dimension. Examples of a one-dimensional system include storm sewers, manholes and inlets.

1D/2D Coupled Models – A model that incorporates the 1D and 2D network into one connected model. The two-dimensional flow enters the one-dimensional pipe network and vice versa.

100-Year Chance Exceedance Probability – An event that has a 1% chance of being equaled or exceeded in any one year at a given location. This can refer to both rainfall and flood events. It is shortened to 1% exceedance in this manual. Below is a table showing the comparison of the more commonly used exceedance probabilities and frequencies:

Frequency	Exceedance Probability
500-year	0.2% chance
100-year	1% chance
50-year	2% chance
25-year	4% chance
10-year	10% chance
5-year	20% chance
3-year	33% chance
2-year	50% chance

2D Model – A model that incorporates two-dimensional surface flow. A grid is developed to approximate the topography and calculate overland flow.

Acre-Feet – Used to express volume of storage usually in a detention basin. One Acre-Foot is equal to one acre times a one-foot depth or 43,560 cubic feet (325,850 gallons).

Channel – A course or passage through which stormwater may move or be directed. It is a generic term used in reference to ditches, bayous, creeks or other smaller tributaries. A channel can vary in shape and size and can be either natural or man-made.

Channel Modification – A man-made change to a channel's characteristics, typically for the purposes of reducing flood damages by increasing its overall conveyance. This can be accomplished by widening and/or deepening the channel, reducing the friction by removing woody vegetation or by lining the channel with various materials.

Confluence – The intersection of two or more streams, or where one flows into another.

Conveyance – The ability of a channel or other drainage element to move stormwater.

Detention – The temporary storage of stormwater.

Detention Basin – An area of land, usually adjacent to a channel, that is designed to receive and hold above-normal stormwater volumes. Most stormwater detention basins in Jefferson County are excavated. The detained stormwater then slowly drains, over time, out of the detention basin as the flow in the channel and associated water surface elevations recede.

Drainage – Runoff which flows over land as a result of precipitation. This includes sheet flow, flow in streets, and flows which concentrate in local drainage systems with or without defined channels.

Existing Conditions – Current conditions in a watershed, channel, or detention basin.

Federal Emergency Management Agency (FEMA) – The federal agency responsible for providing leadership and support to reduce loss of life and property and to protect our institutions from all types of hazards. This is accomplished through a comprehensive, risk based, all hazards emergency management program consisting of mitigation, preparedness, response, and recovery. In relation to flooding hazards, FEMA is the federal agency responsible for administering the National Flood Insurance Program (NFIP).

Flood Damage Reduction or Flood Reduction – Due to practical limitations, structural and nonstructural measures can only reduce flood damages by lowering flood levels or removing houses and businesses from flood prone areas. Floods can neither be prevented nor controlled.

Flood Insurance Rate Maps (FIRM) – Prepared by FEMA, Flood Insurance Rate Maps, or FIRMs, show areas that have the highest probability of flooding and illustrate the extent of flood hazards in a flood-prone community. These maps are used to determine flood insurance rates for communities participating in the National Flood Insurance Program (NFIP). Properties located in mapped zones AE, AO, A, or VE are required to have flood insurance if the owner has a federally backed mortgage on the property

Flood Insurance Study (FIS) – A study FEMA initiates to undertake a new hydraulic and/or hydrologic analysis for streams within a community. Often, these studies incorporate the new information into the FEMA Flood Insurance Rate Maps (FIRMs).

Floodplain – From time to time, bayous and creeks naturally come out of their banks due to heavy rainfall and inundate the adjacent land. This area that is inundated is referred to as a floodplain. Residences and businesses within the floodplain are considered to be at risk of being damaged by flooding. The floodplain is typically expressed by stating its frequency of occurrence. For example, the 1% (100-year) floodplain represents an area of inundation having a 1% chance of being equaled or exceeded in any given year, whereas the 2% (50-year) flood plain has a 2% chance of being equaled or exceeded in any given year. FEMA Flood Insurance Rate Maps (FIRMs) show the 1% (100-year) and 0.2% (500-year) floodplains.

Flowline – A line formed representing the lowest point in the bottom of and along a specified length of a channel or storm sewer.

Hydraulics – The study of moving fluid. In the case, hydraulics refers to analyzing the movement of stormwater flows in channels, pipes and detention basins to determine certain properties like stormwater depths and stormwater velocities.

Hydrology – The study of the rainfall-stormwater runoff process. Hydrological procedures are used to estimate the expected amount of stormwater entering a drainage system from a certain amount of rain falling over a certain watershed area.

Light Detection and Ranging (LiDAR) – A commercial technology that uses a laser mounted in an airplane to measure the elevation of the ground.

Outfall – An outfall is simply the pipe, channel, or opening where water "falls out" and then into another body of water, typically a drainage channel. In a typical stormwater detention basin, the outfall is at or connected to the lowest point of the basin so that detained water drains completely.

Peak Flow – The maximum flow of stormwater flowing through a channel at a given location, based on a certain amount of rainfall falling in that area.

Ponding – The process, occurring after a rainfall, when water gathers in low lying areas throughout a watershed. Frequently referring to water standing in the streets when the capacity of the storm sewer is exceeded.

Right-of-Way – Land used by a public agency for public purposes, such as building roads or improving channels. An interest in real property, either in fee or easement.

Runoff – The stormwater from rainfall not absorbed by the ground that flows in to the local drainage system, and ultimately, streams and bayous.

Structures at Risk – Structures at risk of structural flooding. A slab height of 0.5 feet was assumed for finished floor elevations. Therefore, any structural footprint that contained greater than 0.5 feet was assumed to be a structure at risk for the evaluated storm event.

Tailwater – The water surface elevation in the outfall channel at the outflow structure which varies with time. The tailwater affects both the outflow structure design and the stage-outflow relationship of the detention basin.

Watershed – A geographical region of land or "drainage area" that drains to a common channel or outlet, mostly creeks and bayous in Jefferson County. Drainage of the land can occur directly into a bayou or creek, or through a series of systems that may include storm sewers, roadside ditches, and/or tributary channels.

Water Surface Elevation – The distance the water surface in a creek or bayou is above mean sea level, measured at a given location along a creek or bayou

I. Executive Summary

A. Purpose and Scope

The purpose of the Master Drainage Plan (MDP) is to develop a comprehensive understanding of the City of Beaumont's (City) current drainage infrastructure in order to develop a strategic capital improvement plan (CIP) designed to reduce flooding risk. To accomplish this goal requires a comprehensive understanding of the limitations and deficiencies of the drainage systems that serve the City of Beaumont and the recommendation of improvement projects in the form of CIP projects that are both functionally efficient and financially effective and comply with the MDP. The City of Beaumont is an area with reported street flooding and problems due to varying storm sewer capacity, inadequate overland sheet flow paths, and limited channel capacity.

The City of Beaumont is a mixture of residential and commercial areas bounded by the Neches River to the north, the Neches River to the east, near Tyrell Park to the south, and as far west as the Beaumont Municipal Airport. In total, the City encompasses approximately 55,600 acres. Approximately 73,000 acres were analyzed for this study to capture overland flow from additional regions in the surrounding areas maintained by Drainage District 6 (DD6). The MDP is of a regional nature and includes a significant portion of the region in order to fully understand the interconnected nature of the systems. The study area ultimately outfalls to the Little Pine Island Bayou, Boggy Creek, Neches River, and Hillebrandt Bayou.

The scope of services includes general project management, data collection, digital drainage inventory development, condition assessment, initial analysis, survey, existing conditions evaluation, capital improvement identification, a plan for undeveloped zones, as well as the final report.

B. Existing Conditions Analysis

Detailed 1-dimensional/2-dimensional coupled models were developed with InfoWorks ICM to understand the complex drainage issues observed within the region. Two-dimensional models offer unique insight into how overland stormwater conveyance is tightly coupled to and influenced by the subsurface storm sewer system and roadside ditch conveyance system. The performance of the stormwater infrastructure within the region was evaluated for the 100-, 25-, 10-, 5-, and 2-year 24-hour storm events and found to be functionally deficient in several locations.

In general, the region is subject to wide spread roadway inundation during the 100-year, 24-hour event. Many of the roadways within the region are impassible during lesser events and subject to excessively long time to drain durations. Roadways can remain impassable for hours following the storm event leading to decreased mobility within the region. The region is also subject to high tailwater conditions in the western part of the City that drains to Hillebrandt Bayou. This high tailwater condition leads to structural flooding and excessively high ponding depths and durations. The highest magnitude of overland flow is experienced for the 100-year, 24-hour storm event, but occurs during the less intense storm events at lower volumes. The 2-year, 24-hour storm event produces ponding that exceeds the storm sewer capacity in most areas. In general, the capacity of the major systems designed to relieve flooding in the area is exceeded and ponding occurs. Drainage is further impeded by overland flow blockages such as canals, roadway crossings, and highways. Severe ponding generally occurs at low spots along major street thoroughfares.

C. Proposed Improvement Projects

Proposed improvement projects were developed with the desire to reduce flood risk for the City by targeting a 25-year level of service. Retrofitting existing neighborhoods to meet current design criteria for extreme events can be a difficult process. It is for this reason that the recommended improvement projects will greatly improve the drainage conditions and reduce flooding potential, but not always completely meet criteria in all areas.

In order to address the widespread stormwater conveyance issues of the region, multiple projects are proposed in order to address the deficiencies. All the recommended proposed improvement alternatives and ponding reductions are shown on Exhibits 15 through 122. The proposed improvement projects were given unique identifiers to represent the project's name and region of the city it is located. Project prioritization was determined by evaluating project benefit cost ratio, overall project cost, and impassable intersections.

II. Introduction and Background

A. Background Information

The purpose of the City of Beaumont Master Drainage Plan is to develop an accurate and current understanding of the City's drainage infrastructure and potential solutions for problem areas. Accomplishing this objective requires an understanding of the state of the drainage system that currently serves the City, including its limitations and deficiencies. This Master Drainage Plan comprises a comprehensive stormwater asset inventory, condition assessment, accurate simulation and assessment of both open channel and closed conduit drainage systems, problem area identification and problem source/cause, and a comprehensive list of the Capital Improvement Projects designed to address deficiencies in the existing system.

The Master Drainage Plan will serve as the City's guide for future drainage improvements. It includes an assessment of both open channel and closed conduit drainage systems and provides guidelines for future development.

B. Project Location and Study Limits

The study area includes the entire City of Beaumont and was divided into three regions for the purposes of data management and reduction of model run duration. Regions 1, 2, and 3 are geographic regions of the City, and Region 1 is further subdivided into three zones. Region 3 is split into two zones. The regions are shown in Exhibit 1.

C. Floodplain Information

The City of Beaumont is a member of the National Flood Insurance Program's (NFIP) Community Rating System (CRS). Few if any residential or commercial areas are located within flood zones A or X, though outfalls of some major storm drain systems are located within these zones. According to the FEMA Flood Insurance Study for the City (revised August 6, 2002), the principal drivers of flooding in Beaumont are stream overflow, low terrain, and tidal intrusion upstream. Conditions leading to flooding vary based on the direction and intensity of a storm, as well as antecedent soil moisture.

D. Study Datum

Horizontal coordinates for this study were based on the Texas State Plane Coordinate System, South Central Zone 4204 (1983 North American Datum). Vertical elevations were established based on the 1988 North American Vertical Datum (NAVD88). Both the horizontal and vertical controls are City-preferred datums. Elevations obtained from the current effective FEMA FIRMs, which established elevations based on the 1929 National Geodetic Vertical Datum, were orthometrically converted using the NOAA VERTCON 2.0 tool (Milbert, 1999).

E. Data Collection

Data sources for the existing storm sewer system primarily included City record drawings in digital format comprising both CAD files and scanned plan sheets, as well as printed documents and reports by others. Data was processed in three regions.

The City of Beaumont provided as-builts, available reports, GIS data, and existing models. Drainage District 6 (DD6) provided information about their pond locations and these ponds were integrated into the model.

1. Digital Drainage Inventory Development

A digital geographic information system (GIS) schema was developed to inventory the City's storm water infrastructure. The GIS was designed to provide a comprehensive and sustainable platform for cataloguing storm sewer asset information, connectivity, condition, and survey data. The digital data inventory formed the basis of the analysis portion of the MDP. The information gathered was directly utilized during the hydraulic modeling to determine storm sewer performance and further the City's goal of developing enterprise class GIS data.

LAN developed a GIS schema to store the City stormwater infrastructure. This includes pipes, manholes, inlet, and road side ditches. Open channels and detention basins owned and maintained by DD6 are included in the GIS schema to the necessary extent.

A data inventory was developed that organized and assessed City and DD6 provided as-builts and record drawings to determine their usefulness for populating the City-wide storm sewer schematic. A data hierarchy was determined to include the best data available. Existing survey was the first utilized followed by CAD files, other archives, drafter files, pdfs and then finally survey was requested for critical missing infrastructure. The previous Kohler Master Drainage plan was utilized to populate missing data.

2. Site Visits & Survey

Site visits were performed to verify and clarify limited systems throughout the City to determine the quality of the information that has been collected. Critical areas of the system were evaluated for survey needs. Critical areas were defined as major trunk-lines and outfalls. Additionally, information about systems with large gaps in data was acquired to aid in the data collection process.

F. Condition Assessment

The condition assessment identified the condition of the systems both structurally and in terms of degree of obstructions. Condition assessment evaluation forms were generated for capturing the field conditions of City stormwater infrastructure assets. Custom evaluation forms were created to aid in this process. The forms documented readily available information while in the field such as general condition, potential clogging, and photos.

Region 1 was documented using hard-copy forms generated for each asset located in the southeastern portion of the City. Each asset was given an ID number that can be referenced on an overview map to identify the condition of specific locations in the future. The structural adequacy needs for repair and needs for cleaning were determined during the assessment. Photos were taken to document the plan and profile of the infrastructure assets.

A digital collection method for performing the condition assessment was developed to include tablets that operate data collection applications such as ArcGIS. Future condition assessment for Region 2 and Region 3 of the City will be performed using this digital collection method.

G. Planning Process

1. Modeling Process

Advanced hydraulic and hydrologic modeling is needed to understand the performance of the current drainage infrastructure and identity capital improvement projects. InfoWorks ICM was selected for its ability to analyze storm sewer performance, overland flow paths, and evaluate pre and post project results. InfoWorks ICM is a coupled 1d/2d model which allows understanding of the relationships between the over land flow, channels, and storm sewers. Additionally, InfoWorks ICM is compatible with ArcGIS, which was used to digitize infrastructure and create easy to understand maps.

2. Existing Condition Evaluation

Existing conditions for the City of Beaumont was evaluated using ArcGIS, InfoWorks ICM, field visits, condition assessments and survey. InfoWorks ICM was used to analyze existing conditions to find pipes with high head loss and areas with excessive ponding depths and durations to better understand existing system deficiencies. Repetitive loss data, and problem areas mentioned by City staff were analyzed for deficiencies. ArcGIS was utilized to generate existing conditions metrics such as impassable intersections, system level of service, and areas needing condition assessment or survey.

3. System Level of Service

Conceptual solutions were developed based on the 25-year frequency storm, striking a balance between flood mitigation and solution affordability and practicality. Although a 25-year level of protection aids the City in less extreme events, an emphasis is still placed on targeting a reduction in structural flooding and structures at risk. Structures were considered at risk for a 25-year level of service if the ponding depth exceeded 0.5 feet at the structural footprints' intersection. Improvement projects that target a 25-year level of service will also provide benefit to other storm events such as the 100-year, 24-hour storm event.

4. Design Criteria Establishment

When considering new capital improvement projects, the primary factors evaluated were reduction of structures at risk of flooding as well as the removal of structures from flooding. This criterion was determined after extensive discussions with the City and was evaluated for all proposed improvement projects.

5. Conceptual Solution Alternative Schematic

InfoWorks ICM was primarily used to investigate complex, multi-faceted conceptual solutions. LAN used other 1-dimensional modeling software including FlowMaster and HY-8 to verify individual design components of the complex solutions. Multiple iterations of proposed conditions were completed to determine projects that would bring benefit to the region. Potential improvements were evaluated with constructability in mind. ROW was considered as well as trying to avoid complex crossings such as railroads.

6. Division of Modeling Regions

Due to the InfoWorks ICM modelling software constraints, a City-wide 2-dimensional model must be broken into parts or regions in order to provide a City-wide model. The boundaries between regions are determined by identifying natural and manmade topographic differences within the study area. Major roadways and drainage channels were used in generating divisions that helped in identifying appropriate region boundaries within the City of Beaumont. Appropriate hydrographic divisions help to minimize the interaction between the drainage areas of two regions that share boundaries.

7. Design Criteria Evaluated

Existing conditions were analyzed for multiple storm events to broadly evaluate the City's drainage deficiencies and needs. Therefore a 25-year level of service was targeted to improve drainage and reduce flood risk. This target level of service was determined to be the most feasible for the City to fund and construct under a realistic time line.

8. Public Meetings

Public Meetings were conducted to inform residents about the Master Drainage Plan as well as collect feedback. The first public meeting, held on May 22,2017, introduced the project, provided an overview about the Texas Water Development Board Grant, and answered questions. The second public meeting, held on December 4th, 2017, discussed the recent events of Hurricane Harvey as well as reviewed the project and grant. One additional public meeting will be held after the completion of the project. Details of who attended, and content covered can be found in **Appendix A.**

9. Problem Area Identification

Problem areas were identified based on the occurrence of extreme flooding for both frequent and extreme flood events. Rainfall hyetographs for all storms analyzed in this study can be found in **Appendix B**. Factors that were considered in determining these problem areas included identifying clusters of structures that have the potential to be impacted by flooding. In our analysis, potential structural impacts are defined as structural footprints that are inundated for any particular storm event evaluated in this study. This depth was chosen to approximate the height of the finished floor in relation to the natural ground of the LiDAR elevation. Additionally, areas that experienced low levels of roadways service and passable intersections were used to refine the areas that were analyzed for improvement. The recurrence interval of flooding was used to determine the severity of the problem. For example, if an area experienced flooding in less severe events, such as the 2-year storm, then that location was considered as a more critical problem than if an area only experienced flooding in a severe 100-year storm event. Taking into consideration the factors of structural flooding, impassable intersections, recurrence of flooding, and reported flooding, problem areas were identified and were considered in the high-level proposed improvement analysis.

10. Problem Type Index

To better understand the primary deficiencies of the problem areas identified, a problem type index has been developed for reference throughout the report. The problem types that are listed below are typical hydraulic and hydrologic issues that can be identified as the cause of a system's problems. In addition to these problem types, each problem area will have more information detailing the unique deficiencies related to that specific location.

1) Undersized Storm Sewer/Roadside Ditch:

   Undersized storm sewer/roadside ditch is defined as systems that have inadequate capacity to convey flow downstream. This lack of system capacity yields deeper ponding and longer ponding durations.

2) Elevated Tailwater Conditions:

   Elevated Tailwater conditions is defined as water surface elevations in the outfall channel that are at, or above, water surface elevations in the problem area. The problem area is not able to drain until tailwater conditions are lowered.

3) Cascading Offsite Overland Flow Impacts:

   Cascading offsite overland flow is defined as flow leaving its intended drainage system and entering another drainage system. This cascading offsite flow is often not accounted for during the design process and can lead to an undersized storm sewer system.

4) Lack of Stormwater Infrastructure:

   Lack of stormwater infrastructure is defined as a system that relies heavily on overland flow conveyance and minimally on storm sewer to relieve the problem area despite having an adequate outfall. The problem area is not able to drain until additions or improvements are made to the current stormwater infrastructure.

5) Lack of Adequate Outfall:

   Lack of an adequate outfall is defined as a system that has an undersized outfall conduit in relation to the amount of flow and volume leaving the problem area. This problem could be caused by additional stormwater infrastructure being added to the system without considering the additional capacity needed at the outfall to adequately relieve the system.

11. Problem Area Prioritization Criteria

The potential improvements for the problem areas identified have been prioritized using several different criteria. The criteria used in the prioritization includes project cost, benefit-cost ratio based on damages, and the reduction of impassable intersections within the problem area. In determining the benefit-cost ratio, several different factors were utilized in determining benefit values that are related to the reduction in structural damages in terms of dollar value. The full description of the benefit determination is described in section *II.H.12 Project Benefit Determination*.

12. Project Benefit Determination

Project benefit was determined by utilizing the spatial accuracy of the structural footprints, the Jefferson County Appraisal District (JCAD) parcel improvement values, and the 2D modeling output generated for both existing and proposed conditions. Using the improvement values provided by the JCAD parcels, structural footprints can be spatially related to this information in GIS to better approximate damages. This process prevents damage calculations from occurring based on ponding that intersects with only parcels. Using the USACE Depth-Damage relationships for structures and contents damages, the 2D modeling output relating the depths of ponding within a structure to a percentage of the overall improvement value of that same structure. By comparing these damage values from existing to proposed conditions, a net benefit in the reduction of structural and contents damages in terms of dollar amount was determined.

13. Planning Level Cost Estimates

The engineering basis for the proposed improvements remains conceptual, and thus cost estimates must also be regarded as conceptual. The cost estimates described should be refined as new information becomes available towards design and adjusted for external economic factors such as inflation.

Planning level cost estimates are based on the Texas Department of Transportation (TxDOT) Beaumont District average low bid unit prices published in March of 2019. The cost estimates include excavation, concrete, inlets, and sewer linear footages on a unit-price basis as well as easement and ROW-acquisition costs. The cost estimates also include a flat fee for mobilization, a 25% contingency fee to account for utility relocation, pavement reconstruction, and unforeseen design components, and a 22% engineering and survey fee to account for detailed design work. The planning level cost estimates for the improvements in each individual project area can be found in **Appendix C** at the end of the report.

H. Community Rating System (CRS)

The MDP supports the Community Rating System (CRS) program by providing critical stormwater background infrastructure such as outfall locations and providing new maps that could be adopted as regulatory products.

I. Flood Early Warning System (FEWS) Gap Analysis

The City of Beaumont has experienced repetitive flooding events. Specific areas of the City have been identified that experience heightened vulnerability to repetitive flooding. The City's current methods to mitigate flooding damages as storms develop relies on the experience of emergency responders. Experienced staff review public weather predictions, anticipated rainfall and storm surge along the coast to determine what roadways and subdivisions in the area are prone to flooding. Emergency responders will then close low water crossings, underpasses and strategically evacuate areas based on those assumptions. Although this organic approach to Flood Early Warning has benefitted the community in minimizing flooding at problem sites, this method relies a lot on the knowledge of the current emergency responders. To address this, the City has chosen to evaluate a range of improvements for their flood early warning system. Below is a review of alternatives for improvements to the City of Beaumont's Flood Early Warning System.

1. Existing Conditions

The City currently uses a combination of National Weather Service (NWS) 7-day forecasts, tidal gage information, and DD6 riverine stream gage readings to assess the need for pre-staging high-water rescue vehicles, flood barriers, and sand bags near problem sites. Problem sites can become an inundation concern when rainfall exceeds 4" per hour. Highway underpasses can flood within 20 minutes at a rate of 4" per hour at some locations when pumps are not operating at full capacity based on preliminary modeling and witness descriptions.

a. Existing Precipitation and Stream Gage Data

The City has access to DD6 stream and precipitation data through the DD6 public website. The DD6 public website exhibits a five-minute delay. As previously noted, some problem sites within the City flood in around 20 minutes of heavy rain. A five-minute delay, coupled with the time required to mobilize a response, represents a non-trivial period of time in the context of mounting a flood response. The elimination of this delay is a compelling motivation for upgrading the existing precipitation and stream gage data collection devices.

The existing network of DD6 gages does not provide full coverage within the city limits. Portions of the City, particularly the downtown and eastern areas, are not closely monitored by the DD6 gage network.

b. Highway Underpasses

Highway underpasses are the greatest risk for public safety. The City's Emergency Operations Coordinator (EOC) has identified improvements to the City's underpasses as a high priority action. Improving the quality of flooding warning response in highway underpasses will have a meaningful impact on reducing the City's flood vulnerability. Currently, six of the City's high-risk underpasses have been equipped with a pump alarm flood warning system. During a major storm event, if the pumps are overwhelmed by the rate of precipitation and unable to evacuate water from the underpass, an alarm will sound. When such an alarm goes out, the EOC will send out an emergency responder to verify that the alarm is not in error. Upon arrival, the emergency responder will barricade the crossing to deter motorists from entering the underpass. In the past, fatalities have occurred when motorists bypassed barricades.

False alarms from these pump stations are a significant issue for emergency responders. False alarms are typically associated with the pump alarm system being blocked with litter and other debris. The existing pump system requires regular maintenance to ensure that the pumps are not clogged with litter. Lightning strikes can also trigger a false alarm. During a rain event, it is not uncommon for the EOC to field 200 or more 911 calls. An alarm field verification by an emergency responder reduces manpower that could be better used elsewhere during a storm event. An automated FEWS would reduce this labor-inefficient practice and liberate labor resources for use elsewhere. To improve the quality of flood response, the EOC seeks to install automated road closure systems. The envisioned system would include automatically operated arms and flashing lights. The automated control of these flood warning systems would liberate emergency responders from the responsibility of field verifying every pump alarm.

2. Enhancement Alternatives

Meetings were held with the City EOC and emergency responders to discuss the limitations of the City's existing FEWS. Interviews were also held with DD6 to review their existing FEWS capabilities and how DD6 works with the City to communicate information as storms develop. In these discussions both benefits and limitations of the existing FEWS were reviewed. The following alternatives are intended to enhance the existing FEWS. Cost and implementation considerations are summarized for each alternative.

a. FEWS Alternative 1: Automation of Existing System

In an effort to reduce reliance on emergency responder man power, Alternative 1 will automate road closures at highway underpasses. If implemented, this automation of road closures could allow emergency responders to report to more pressing needs during a heavy rain or flooding event.

1) Underpasses:

Install master sensor stations at existing underpass pump locations and flooding problem sites. Install remote sensor stations in locations that will regulate entry into problem site areas. Master sensor stations will trigger the remote sensor stations to drop gate arms and flash lights when the water level at the master sensor station rises above a predetermined threshold. It will be necessary to install a remote sensor station for each point of entry into a problem site. This automation of the existing flood warning system will liberate emergency responder labor for use in more pressing concerns during a flood event.

2) Implementation:

The implementation of FEWS Alternative 1 would require an upgrade to the Alert 2 communications protocol. Fortunately, DD6 is already in the process of securing grant funding for an Alert 2 upgrade. DD6 has extended an invitation to the City to use the Alert 2 base station and software used in the DD6 Alert 2 upgrade. This partnership will mean that the City only needs to install the six gauge locations and traffic control equipment to achieve an Alert 2-compatible automation of existing capabilities.

Table II.1 Estimate of Probable Construction Cost for FEWS Alternative 1

Hardware	Estimated Quantity	Unit	Unit Price	Estimated Subtotal
Master Sensor Station	6	EA	$12,000	$72,000
Remote Sensor Station	12	EA	$11,000	$132,000
Road Closure Gate Arms	12	EA	$22,000	$264,000
FCC Licensing	1	LS	$2,640	$2,640
Installation	30	EA	$6,000	$180,000
			Subtotal	$650,640
			25% Contingency	$162,660
			Estimate of Probable Construction Cost	**$813,300**

These six Alert 2-capable stations will be able to integrate with the anticipated DD6 base station and software package.

3) Implementation Timeline:

The implementation of this alternative is dependent upon expected DD6 system upgrades. Based on the grant programs DD6 is pursuing, it is estimated that funding could be available for DD6 Alert 2 upgrades in the fourth quarter of 2019. If funding is secured, the upgrade to Alert 2 will take approximately 8-10 months. The DD6 Alert 2 upgrade is estimated to be completed by January 2021. Note this date is tentative based on the information provided by DD6.

The acquisition of funding for the City's Alert 2 upgrade could take approximately one year. If funding is secured, the construction of the Alert 2 upgrade is likely to take one additional year.

4) Funding Partners:

The Texas Water Development Board (TWDB) Flood Protection Grant (FPG) program provides funding for flood protection mitigation measures. FPG funds are provided on a 50/50 state/local basis, reducing the City's burden to an estimated $406,650.

The FEMA Hazard Mitigation Assistance (HMA) program provides 75/25 federal/local match funding for flood mitigation projects. The City funding burden under the HMA program would be an estimated $203,325.

b. FEWS Alternative 2: Expanded Capabilities

Install master sensor stations at existing pump locations and flooding problem sites. Install remote sensor stations in locations that will regulate entry into problem site areas. Master sensor stations will trigger the remote sensor stations to drop gate arms and flash lights when the water level at the master sensor station rises above a predetermined threshold. It will be necessary to install a remote sensor station for each point of entry into a problem site.

1) Implementation:

The City could potentially install a citywide precipitation and stream gauge system to monitor storms as they develop if the action items identified in Alternative 1 are completed.

DD6 is currently in the process of pursuing grant funding to upgrade DD6's rain and stream gauge system to the Alert 2 communications protocol. Under Alternative 2, the City would install twenty-six rain and stream gauges (six at existing pump sites and twenty additional gauges) compatible with the Alert 2 protocol. The City and DD6 anticipate being able to share the same base station and software. This interjurisdictional data sharing will allow both entities to track storm-related precipitation and hydrologic conditions in real time.

Six gauges would be added to locations that already have existing gauges, and twenty additional rain and stream gauges would be installed throughout the City. Coupled with the existing Jefferson County Drainage District 6 (DD6) gages, this will provide fourty-three sites throughout the City that track and report stream and precipitation levels.

Data gathered by rain and stream gauges will be used to trigger flood preparations by master sensor stations. In addition to stream elevation at master sensor stations, stream and rain levels at predetermined indicator locations will trigger flood warning closures by master sensor stations. The addition of supplemental rain and stream gauges will enable the prediction of hazardous conditions at problem sites. By predicting future hazardous conditions, emergency managers will be able to pre-position resources and reduce accessibility to hazardous areas, improving public safety and expediting emergency response.

Furthermore, the installation of stream and precipitation gauges that predict flooding in hotspot locations provides a check on false positives at flooding hotspots.

Table II.2 Estimate of Probable Construction Cost for FEWS Alternative 2

Hardware	Estimated Quantity		Unit	Unit Price	Estimated Subtotal
Master Sensor Station	26		EA	$12,000	$312,000
Remote Sensor Station	12		EA	$11,000	$132,000
Road Closure Gate Arm	12		EA	$22,000	$264,000
FCC Licensing	1		LS	$2,2640	$2,640
Installation	50		EA	$6,000	$300,000
				Subtotal	$1,010,640
				25% Contingency	$252,660
				Estimate of Probable Construction Cost	**$1,263,300**

Under FEWS Alternative 2, a minimum of twenty-six gauges would be installed. Additional gauges and traffic control gate arms may be installed. Locations for these installations would be determined by examining inundation mapping from the City's Master Drainage Plan effort as well as through an examination of roadway closure records from the Office of Emergency management.

2) Implementation Timeline:

The implementation of this alternative is dependent upon expected DD6 system upgrades. If funding is secured, the upgrade to Alert 2 could take approximately 8-10 months. The acquisition of funding for the City's Alert 2 upgrade could take approximately one year. If funding is secured, the construction of the Alert 2 upgrade is likely to take one additional year.

3) Funding Partners:

The Texas Water Development Board (TWDB) Flood Protection Grant (FPG) program provides funding for flood protection mitigation measures. FPG funds are provided on a 50/50 state/local basis, reducing the City's burden to an estimated $631,650.

The FEMA Hazard Mitigation Assistance program provides 75/25 federal/local match funding for flood mitigation projects. The City funding burden under the HMA program would be an estimated $315,825.

c. FEWS Alternative 3: Integrated Modeling

FEWS Alternative 3 expands on the hardware installations of FEWS Alternative 2 and integrates real-time 2D modelling to more completely inform emergency responders of conditions during a storm event. This fully integrated response would help emergency responders to better use resources to respond to flooding events or to sandbag structures in anticipation of worsening conditions.

Stream and precipitation data will be entered into a 2D hydraulic model of the City. Real-time modeling of conditions will allow emergency managers to define graduated zones of hazard risk based upon real-time, real-world conditions. The level of accuracy provided by this analysis will allow for rapid mobilization of flood control resources and efficient use of staffing resources.

Stream gauge data would be used in conjunction with the Master Drainage Plan ICM model create a real-time, web-based estimate for specific areas of inundation risk as storms are developing. This future condition prediction capability would rely heavily on the installation of FEWS Alternative 2 precipitation and stream gauge hardware. Consequently, a cost estimate has not been provided for FEWS Alternative 3. A detailed cost estimate would need to be evaluated following the implementation of FEWS Alternative 2.

d. Recommendations

New gage sites and software will improve the City's understanding of conditions in real-time. This will be particularly important in crafting a response to an extreme weather event.

All alternatives will decrease the reliance on in-person emergency responder verification of pump alarms. This liberation of manpower resources is important in flooding events when staffing is stretched thin. By eliminating the need for emergency responders to field verify flooding hotspots, those emergency responders are now able to address more pressing concerns.

Through the use of technological automation, FEWS Alternative 1 will liberate manpower resources during a severe storm event. FEWS Alternatives 2 and 3 will improve response times and the accuracy of flood response preparations. Compared to the existing conditions, higher quality data will allow emergency decision makers to make better-informed decisions faster and earlier in a storm event.

III. Hydrology and Hydraulics

A. Hydrology

Hypothetical rainfall hyetographs were developed in HEC-HMS version 4.0 using the USGS Water-Resources Investigations Report (WRIR) 94-4044 (Asquith, 1998) rainfall depth-duration-frequency data for Jefferson County. LAN used the frequency storm annual duration method with 50 percent intensity position to compute the hyetographs. **Table III.1** summarizes the rainfall depths used in the model for the corresponding storm durations.

Table III.1 HEC-HMS Storm Duration and Annual-Duration Depth

Duration	Depth (inches)				
	2-Year Storm	5-Year Storm	10-Year Storm	25-Year Storm	100-Year Storm
15 Minutes	1.11	1.37	1.54	1.77	2.13
1 Hour	2.06	2.61	2.99	3.5	4.4
2 Hours	2.72	3.56	4.18	5.05	6.65
3 Hours	3.01	4.04	4.79	5.89	7.9
6 Hours	3.65	4.99	6.02	7.57	10.6
12 Hours	4.27	5.95	7.24	9.19	13
1 Day	5.15	7.27	8.82	11	14.8

The Natural Resource Conservation Service (NRCS) classifies soil into four Hydrologic Soil Groups based on the soil's runoff potential; however, there are additional combinations of these four primary types. These four primary soil types and their descriptions are listed below in **Table III.2**. Soil type D was determined as the primary soil type for Beaumont as determined through the United States Department of Agriculture (USDA) Soil Survey Geographic Database (SSURGO) as seen in Exhibit 4. LAN used initial and constant loss parameters calibrated to match loss and peak discharge values from the Green and Ampt infiltration method for soil type D. The Green & Ampt parameters were obtained from the Harris County Flood Control District white paper "Recommendation for: Replacing HEC-1 Exponential Loss Function in HEC-HMS".

Table III.2 NRCS Soil Classification

Soil Classification	Description
A	Sand, loamy sand or sandy loam types of soils
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay or clay

A two-Dimensional modeling mesh was created to represent the topography based on LiDAR. A LiDAR Mosaic was generated from a combination of 2006 and 2017 data obtained through Texas Natural Recourses Information System (TNRIS). The 2006 LiDAR dataset was captured for the Texas Water Development Board and FEMA. TWDB and the Trinity River Authority (TRA) partnered to acquire the 2017 dataset. The resolution for the 2006 and 2017 was 140 and 50 cm respectively and was captured by Sanborn. Comparisons and calculations were done to compare between the new and old LiDAR. It appears the 2017 LiDAR was flown briefly after a rain event and many of the channels were at a high starting water surface elevation. This elevated starting water surface elevation artificially decreases the storm systems level of service by starting with an increased water surface elevation and decreased channel capacity. Therefore, where 2006 LiDAR was available it was utilized and supplemented with 2017 LiDAR to expand the DD6 area to the west of the City. The LiDAR surface was modified to reflect topographic conditions due to major earthwork projects such as post 2006 DD6 detention ponds. The LiDAR utilized for the modeling of the entire Beaumont study area can be seen in Exhibit 5.

InfoWorks ICM uses roughness zones to assign Manning's coefficients to specific areas on the 2D mesh, allowing water to flow quickly and easily through some areas or slowly through other areas. LAN based the roughness zone N-values on parcel and zoning data from Jefferson County, Jefferson County Appraisal District, City Zoning, and aerial imagery, in some cases inferring or generalizing which zoning codes characterize which types of land use. **Table III.3** summarizes the N-values used for the zoning codes and land use types found within the study area. Areas zoned A-R were assigned N-values on an individual basis.

Table III.3 Manning's N-Value and Land Use

Zoning Code	Land Use Type	N
A-R	Open Space	0.2 or 0.4
C-M	Commercial	0.0125
GC-MD	Commercial	0.0125
HI	Heavy Industrial	0.0125
LI	Light Industrial	0.0125
NC	**Undetermined	0.0125
NSC	Commercial	0.0125
OP	Public Open Space	0.2
PUD	**Undetermined	0.0125
R-S	Residential - Average	0.085
RCR	Residential - Average	0.085
RM-H	Residential - Multi Family	0.085
RM-M	Residential - Multi Family	0.085

B. Hydraulics

1. Model Development

An existing conditions hydraulic model was developed including modeling nodes, open channels, and conduits to represent culverts, cross culverts, bridges, storm sewer inlets, and storm sewer conduits within the City. The hydraulic network is based on the previously developed GIS data schematic, survey data, City GIS information, field visit data, and previously provided modeling data. Overland boundary conditions were set with a combination of normal depth as well as applied inflows and tailwater depths. Extensive model boundary analysis was performed to determine where inflows or tailwaters were necessary.

This City-wide model was "split" into three regions, and then eventually included three additional splits due to software constraints. InfoWorks ICM has a limit on the amount of infrastructure components that can be included within a single model. Due to this constraint as well as reducing simulation run times, it was logical to separate the models at ideal overland flow boundaries. Model boundaries were chosen intentionally as to truly represent existing conditions. For example, two boundary lines were necessary for Hillebrandt Bayou as it is split between the Region 2 and Region 3 models. On the upstream (Region 2) model, a tailwater condition is needed as to not overestimate the outflow. On the downstream (Region 3) model, an inflow is needed to account for the flow coming from the upstream model of Region 2. For non-channel boundary conditions, such as roadways, flow was compared from the intersection of the two models for the 100-year storm event and the model with the greater flow was given a tailwater and the other model was given an applied inflow. An iterative process was used to determine these ultimate flows and levels as flow and level are interrelated. Typically, for the same section, flow is reduced when tailwaters are applied and conversely, lower flows typically produce lower tailwater conditions.

The iteration process for six models with five different return frequencies yielded 60 different inflow and tailwater records for each iteration. For each model, data from the upstream and downstream models were extracted where boundary conditions were present to the model. Custom selections, results lines in InfoWorks ICM as well as individual Excel spreadsheets were created to aid in the iterative process. The process included three iterations in order to converge on an appropriate inflow and tailwater at the boundary condition locations. Ultimately, this process included six models, five storm-events, and three iterations for convergence totaling to 180 spreadsheet records generated for the purposes of detailing both inflows and tailwaters across model boundaries.

The spreadsheets were setup to extract the necessary data and not to double count any boundary line. For example, while a boundary line would have both flow and depth extracted from it, only one would be applied to the spreadsheet. Flow and highest depth across the line were extracted in this process. For results lines, InfoWorks ICM has no option for extracting water surface elevation incrementally across a line. Therefore, highest depth across the line was extracted and added to the minimum ground elevation across the line to represent water surface elevation. The minimum ground elevation determination was automated using the ArcGIS tool Zonal Statistics by attribute. This ground elevation was coded into the spreadsheets to be added to the results reported depth. For places where the LiDAR picked up the street crossing instead of a channel, manual adjustments were made to determine an appropriate ground elevation. CSV exports were conducted from InfoWorks ICM to Excel. Data was pasted into the appropriate Excel spreadsheet by model and design storm file. From there the data was validated to ensure conditions were set appropriately and then were reimported back into the model. This process was conducted a total of three iterations until the model converged and the elevations of the model split were approximately the same.

In addition to the 2D InfoWorks ICM model, overland flow and drainage areas were generated for Region 1 using Esri's Arc Hydro. This output includes a polygon shapefile that delineates general topographic watershed boundaries. Additionally, the output provides a line shapefile that shows the primary path of overland flow across each drainage area to their respective outfalls. An example output of the overland flow analysis can be seen in Exhibit 9.

Pipes were imported into InfoWorks ICM. Pipe systems in Beaumont are often interconnected and cross InfoWorks ICM model region boundaries. Therefore, it is important to establish inflows and tailwaters for "split" pipes. Flow from the upstream system is exported and applied to the downstream system. Conversely, level from the downstream system is extracted and applied to the upstream system. Since flow and level are influenced by each other, this process is iterative. The process is similar to the boundary line process; however, water surface elevation can be directly exported from the conduits within the ICM model requiring no ground levels to be added. This process was conducted a total of three iterations until the model converged and the elevations of the model split were approximately the same.

The results generated by the six individual InfoWorks ICM networks were combined and evaluated as a City-wide system. In combining each model that was used to generate the ultimate results, a total of 412 miles of storm sewer was modeled and evaluated to determine existing conditions throughout the entire City of Beaumont and surrounding modeled areas. In addition to storm sewer, approximately 175 miles of open channels were included in the overall combined model. By extending the InfoWorks ICM boundary further west, the area of privately-, city-, and county-owned stormwater detention and retentions basins totaled to 814 acres.

2. Model Validation

Model results were validated with repetitive loss data, FEMA floodplains, and known problem areas reported by the City. Comparing all known reported data to model outputs, it was determined that there is a close correlation between reported flood complaints and problem areas identified in the model. Additionally, the City evaluated model outputs to determine the validity of the results and confirmed its reported flooding areas with Drainage District 6 District Engineer Doug Canant.

IV. Modeling Region 1 – Southeast

A. Location & Description

As seen in Exhibit 1, Modeling Region 1 contains the Southeast portion of the City and is generally located south of I-10 W, west of I-10 E, north of US 287-N, and east of the city's limits. Covering approximately 17 square-miles, this region is the most developed portion of the City of Beaumont that boasts dense roadways that primarily utilize subsurface storm sewer to convey stormwater. This southeastern portion of the City's storm sewer system services the primarily residential and commercial properties present in this area. Region 1 includes 197 linear miles of storm sewer that outfalls to the Neches River to the east or to the system of DD6 owned open channels to the south and west. There are 14.2 miles of open channels and 136.5 acres of detention or retention basin footprints.

B. Existing Conditions

Region 1 is located primarily in two watersheds – Union Canal-Neches River and Hillebrandt Bayou watersheds. This area relies heavily on storm sewer conveyance to drain surface water to the Neches River to the east and to Hillebrandt Bayou to the west. Existing systems that flow to the west generally outfall into DD6 tributary channels to the main Hillebrandt Bayou. The portion of the region bordered by I-10 to the west and the Union Pacific Railroad to the east has low topographic elevations in relation to the area east of the Union Pacific Railroad. This low-lying area experiences surcharged storm sewers during extreme events, and the receiving Hillebrandt Bayou to the west is at capacity. Additionally, the southern portion of this region experiences similar problems due to lack of available capacity in Hillebrandt Bayou to the south of Beaumont. This yields long ponding durations, excessive ponding depths and potential structural flooding. These conditions can be found in more frequent and less severe events, such as the 2-yr storm event. However, the problem is exacerbated by heavy rainfall events that utilize downstream channel capacity that is necessary for local storm sewer systems to drain. This region is downstream of Region 2 and was found to be functionally deficient in several locations primarily due to undersized storm sewers. The Neches River has the potential to be utilized as an available outfall because the water surface elevations are advantageous in relation to the problem areas Region 1. Problem areas were identified with the largest potential for flood risk were selected throughout Region 1, but particularly areas that experience flooding issues in less severe events.

C. Problem Area – 1A

1. Location

Area 1A is in southeast Beaumont and Modeling Region 1. Specifically, the area is located east of Martin Luther King Jr. Parkway, west of Willow Street, north of Calder Avenue, and south of Gladys Avenue. Exact extents of the area can be seen in Exhibit 15. The storm sewer in the area drains to the east towards the Neches River. Area 1A is a primarily residential area with approximately 352 structures and is approximately 221 acres.

2. Existing Conditions

Area 1A is serviced by a combination of roadside ditches primarily draining east or west along Evalon Avenue, Miller Street, and Ashley Avenue and storm sewer on Long Avenue, Magnolia Avenue, Gladys Avenue and Harrison Avenue. These existing conveyance systems are undersized for the purposed of effectively conveying storm water downstream into the Neches River directly to the east of the area. Storm sewer and small-scale ditch systems fill up early in the storm and are unable to transport the necessary flow during peak stages of extreme rainfall events.

In the 25-year 24-hour storm, Area 1A experiences ponding ranging from 0.25 to 2.4 feet. This ponding is mostly confined to the streets, except for the area bound by Martin Luther King Jr. Parkway, Long Avenue, Ashley Street, and Stephenson Street. Approximately 150 structures in Area 1A are at risk of flooding under the existing conditions. The storm sewer system is undersized in relation to the amount of flow being conveyed by contributing ditch and overland flow systems. During the 100-year, 24-hour storm event flooding problems are worsened from the 25-year event and extend to areas along Ewing Street and Center Street near Long Avenue.

During the 2-year and 5-year, 24-hour storm event, ponding above 0.25 feet is contained primarily to low lying ditches and roadways within the existing right of way. The topography is relatively flat, making it difficult for the roadside ditches to convey flow effectively throughout the entirety of the rainfall event. Ponding depths and extents during the 10-year, 24-hour storm event are comparable to the 25-year storm event apart from slightly lower maximum depths of approximately 2.1 feet.

3. Proposed Improvement

The proposed improvements in Area 1A include a series of 36” reinforced concrete pipes (RCPs) between Gladys Street and Long Avenue. On Oakland Street, there is a 5’ x 5’ reinforced concrete box (RCB) proposed between Harrison Avenue and Calder Avenue. As seen in Exhibit 15, this improvement includes approximately 8,000 total linear feet of storm sewer upgrades and provides 2 acre-feet of additional storm sewer storage capacity that contributes to increased conveyance. The total inundated area for this proposed alignment is reduced by 35% for the 25-year, 24-hour storm event. The depth reduction provided by improvements in Area 1A range from 0.3 to 0.8 feet.

D. Problem Area – 1B

1. Location

Area 1B is in southeast Beaumont and Modeling Region 1. Specifically, the area is located east of I-10, south of Laurel Street, north of Washington Boulevard and west of the Neches River. Exact extents of the area can be seen in Exhibit 21. The storm sewer in the area drains to the east towards the Neches River. The streets that area recommended to be improved are Fulton Avenue, Sycamore Street, and Carroll Street. Area 1B is a primarily residential and minorly commercial area with approximately 3,317 structures and is approximately 2,138 acres.

2. Existing Conditions

Area 1B is serviced by a combination of roadside ditches, storm sewer, major open channels, and detention basins. This area relies on DD6 channels 110 and 100-D2 for conveyance, as well as three detention basins used for storm water storage. This area includes a complex storm sewer system that outfalls to the DD6 owned channels to the west and the Neches River to the east. Due to the large size of this improvement, it is helpful to separate Area 1B into three primary problem locations that have been targeted for improvement due to the severity of the flooding problem outside of the ROW with the potential for structural impacts.

The first area is located directly to the east of channel 100-D2, to the west of 4th Street, and to the north of Washington Boulevard. The flooding problem in this area for the 25-year, 24-hour storm event is primarily due to the tailwater conditions in the downstream channels caused by undersized bridge and roadway culvert crossings. This area experiences ponding depths ranging from 0.25 to 2.8 feet. The second area is located directly to the east of the Union Pacific Railroad, west of Avenue B, south of College Street, and north of Terrell Avenue. The flooding problem in this area for the 25-year, 24-hour storm event is related to the low-lying topography in relation to the east combined with undersized storm sewer conveying flow to the channels that are at capacity to in the western portion of Area 1B. This area experiences ponding depths ranging from 0.25 to 2.3 feet. The third area is located to the east of Union Pacific Railroad, the south of Kansas City Southern Railroad, and the northwest of College Street. The flooding problem in this area for the 25-year, 24-hour storm event is driven by undersized existing storm sewer necessary for conveying the amount of flow reaching this area due to its low-lying ground elevations. This area experiences ponding depths ranging from 0.25 to 1.6 feet. For the 25-year 24-hour storm, approximately 1,733 structures in Area 1B are at risk of flooding under the existing conditions.

During the 2-year, 24-hour storm event, ponding depths are shallow outside of the right of way with no indications of significant structural flooding possibilities. For the 5-year and 10-year, 24-hour storm events, ponding depths begin to exceed 1 foot in depth and the problem types described for the 25-year event begin to apply, but to a lesser degree. Additionally, the 100-year, 24-hour storm event shows significant ponding depths exceeding 2 feet.

3. Proposed Improvement

The proposed improvements in Area 1B include dual 10' x 7' RCBs along South 4th Street beginning at Prairie Avenue. At Blanchette Street, the dual 10' x 7' RCBs connect to dual 10' x 8' RCBs and go along Fannin Street until Avenue A, where the dual 10' x 8' RCBs connect to triple 10' x 10' RCBs. ROW will need to be considered for this proposed improvement, because the triple 10' x 10' RCBs is proposed to have a railroad crossing along the alignment. The triple 10' x 10' RCBs ultimately discharge into the Neches River. RCPs ranging in size from 24" to 60" connect to the RCBs, as seen in Exhibit 21. Additionally, three 24" RCPs at 5th Street, 6th Street, and 7th Street drain into Jefferson County Drainage District 6 (DD6) channel 110-D. To provide better conveyance to DD6 channel 110, improvements to major roadway bridge and culvert crossings have been proposed at four locations. This improvement includes approximately

45,000 total linear feet of storm sewer upgrades and provides 83 acre-feet of additional storm sewer storage capacity that contributes to increased conveyance. The total inundated area for this proposed alignment is reduced by 23% for the 25-year, 24-hour storm event. The depth reduction provided by improvements in Area 1B range from 0.5 to 2.2 feet.

E. Problem Area – 1C

1. Location

Area 1C is in southeast Beaumont and Modeling Region 1 Specifically, the area is located east of Martin Luther King Parkway, north of Lee Avenue, west of Exxon Mobil, and east of Beaumont city limits. Exact extents of the area can be seen in Exhibit 27. The storm sewer in the area drains to the north towards the Neches River. Area 1C is a primarily residential and commercial area with approximately 823 structures and is approximately 642 acres.

2. Existing Conditions

Area 1C is serviced by primarily storm sewer systems that generally flow from the west near Martin Luther King Parkway to the outfalls into the Port of Beaumont to the north. The conveyance system downstream of the pump station at Martin Luther King Parkway and Irving Avenue is undersized for the peak discharges it is receiving. Due to this undersized system, there is an increase in the pressure head resulting in surcharged storm sewer that flows onto the surface.

For the 25-year 24-hour storm, Area 1C experiences ponding ranging from 0.25 to 1.8 feet. In most areas, the ponding is confined to the roadway, except in the southern part of Area 1C, especially along the intersection of Irving Avenue and TX-380 Spur. Approximately 327 structures in Area 1C are at risk of flooding under the existing conditions. For the 100-year, 24-hour storm event, there is widespread flooding to the area around Madison Avenue, Van Buren Avenue, and Fulton Avenue that reaches depths of approximately 2.5 feet.

Additionally, the storm sewer system that is receiving the discharge from the Irving pump station is undersized for less severe events such as the 5-year and 10-year, 24-hour storm events. Ponding extents for these lesser events flood outside of the existing right of way in the areas to the east of the Irving pump station and experience depths between 0.25 and 0.75 feet.

3. Proposed Improvement

The proposed improvements in Area 1C include a 10' x 10' RCB along Fulton Avenue, Carroll Street, Schwarner Street, and Verone Street that ultimately discharges into the Port of Beaumont. As seen in Exhibit 27, this improvement includes approximately 8,500 linear feet of storm sewer upgrades and provides 20 acre-feet of additional storm sewer storage capacity that contributes to increased conveyance. The total inundated area for this proposed alignment is reduced by 31% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 1C range from 0.7 to 1.2 feet.

F. Problem Area – 1D

1. Location

Area 1D is in southeast Beaumont and Modeling Region 1. Specifically, the area is located east of the Union Pacific railroad, south of Washington Boulevard, west of Burlington Northern Santa Fe railroad, and north of highway 287. Exact extents of the area can be seen in Exhibit 33. Area 1D is comprised of mostly residential property and open space areas which includes approximately 1010 structures and is 860 acres.

2. Existing Conditions

Area 1D is primarily serviced by roadside ditches that flow to storm sewer systems along more major roadway alignments such as 11th Street, Fannett Road, and Sarah Street. In addition to linear conveyance, there are two detention basins in Area 1D that provide additional storage in order to adjust the peak flow timing to the downstream DD6 channel 107. The systems in this area are undersized in existing conditions. However, to prevent exceeding available tailwater elevations in the downstream channel 107, any storm sewer upgrade requires appropriate mitigation in the form of channel or local detention improvements.

For the 25-year 24-hour storm, Area 1D experiences ponding typically between 0.25 and 2.4 feet. In most of Area 1D, the ponding extends past the roadway, especially east and west of 11th Street and north of Fannett Road. Approximately 487 structures in Area 1D are at risk of flooding under the existing conditions. The tailwater elevations within channel 107 are elevated with respect to the existing system. During the 100-year, 24-hour storm event ponding depths and extents worsen significantly as the downstream channel exceeds capacity, resulting in a surcharge of the upstream systems within Area 1D. Ponding depths for the 100-year event exceed 3 feet.

During the 2-year and 5-year, 24-hour storm events, ponding is relatively shallow, but collects in low areas outside of the existing right of way. The topography of this area is relatively flat with the problem spots being particularly low in ground elevation. This makes these areas difficult to drain without the appropriate infrastructure to capture and convey flow downstream. For the 10-year, 24-hour storm event ponding depths and extents worsen as tailwater conditions in channel 107 begin to influence the efficiency of the upstream storm sewer. Ponding depths for this event range from 0.25 to 1.6 feet.

3. Proposed Improvement

The proposed improvements in Area 1D begin with a 48'' RCP on Harriot Street that connects to a 7' x 4' RCB. The 7' x 4' RCB connects to a 5' x 5' RCB on Fannett Road, which then connects to a 10' x 5' RCB that ends at Sarah Street and drains into an approximately 101 acre-feet detention basin along DD6 channel 107. There are also 24" and 48" RCPs connecting to and along South 11th Street, and a 375 acre-feet detention basin near Edmonds Avenue. As seen in Exhibit 33, this improvement includes approximately 13,500 linear feet of storm sewer upgrades and provides 10 acre-feet of additional storm sewer storage capacity that contributes to increased conveyance. The total inundated area for this proposed alignment is reduced by 17% for the 25-

year, 24-hour storm event. The depth reduction provided by the improvements in Area 1D range from 0.5 to 1.4 feet.

G. Problem Area – 1E

1. Location

Area 1E is in southeast Beaumont and Modeling Region 1. Specifically, the area is located south of Nora St, west of Kenneth Avenue, east of Goliad St, and north of Beaumont city limits. Exact extents of the area can be seen in Exhibit 39. Area 1E is comprised of mostly residential property and open space areas to the north of Cardinal Drive and commercial land along and to the south of Cardinal Drive. This area includes approximately 1220 structures and is 963 acres.

2. Existing Conditions

Area 1E is serviced by minor roadside ditches, storm sewer systems, two open major DD6 open channels, and two detention basins. The first detention basin is located just southeast of the intersection at Lavaca Street and Usan Street. This basin drains into tributary channel 106-A and eventually flows into channel 106 which flows south across Cardinal Drive and leaves the Beaumont city limits. The second detention basin is located northwest of the Avenue A and Florida Avenue intersection. This basin drains into tributary channel 104-B which continues south across Cardinal Drive and leaves the Beaumont city limits. The problems in this area are heavily influenced by the elevated tailwater conditions in channels 106-A and 104-B during significant rainfall events.

In the 25-year 24-hour storm, Area 1E experiences ponding typically between 0.25 and 2 feet. There are large amounts of ponding in the areas along Florida Avenue and Virginia Street. Approximately 506 structures in Area 1E are at risk of flooding under the existing conditions. Due to the similar water surface elevations in these channels when compared to the problem areas, upsizing the storm sewer system requires significant mitigation to effectively maintain or reduce the tailwater conditions in the channels downstream. During the 100-year, 24-hour storm event, the tailwater conditions are worsened, resulting in deeper ponding depths exceeding 2.6 feet and widespread flooding extents.

During the less severe 2-year, 24-hour storm event, ponding depths are relatively shallow, and the extents are contained almost entirely within the low-lying ditches and roadway right of way. The 5-year and 10-year, 24-hour storm event display similar ponding depths between 0.25 and 1 foot which is primarily located along Virginia Street, and around the existing basin just north of Florida Avenue.

3. Proposed Improvement

The proposed improvements in Area 1E begin with an 8′ x 4′ RCB on the intersection of West Virginia Avenue and St Louis Street. At Beale Street, the 8′ x 4′ RCB connects to an 8′ x 5′ RCB before entering an existing inline detention basin for channel 104-B along Avenue A. There is an approximately 150 acre-feet detention basin extension proposed for the current inline basin. Dual 48″ RCPs connect to the 8′ x 5′ RCB on Bob Street and drains to the southside of Virginia

Avenue into an approximately 58 acre-feet detention basin to the east of Bob Street and a 23 acre-feet detention basin to the west of Bob Street. 36" and 30" RCPs connect to the existing conduits on Sarah Street and drain into an approximately 106 acre-feet detention pond along DD6 channel 106-A. 48" RCPs at Florida Avenue and Park Street, and a 24" RCP along the Union Pacific Railroad drain into an approximately 47 acre-feet detention pond at the intersection of Avenue A and Florida Avenue. There is an additional detention basin located along DD6 channel 106, near Mercantile Street which has the capacity to store approximately 39 acre-feet of storm water. As seen in Exhibit 39, this improvement includes approximately 5,800 linear feet of storm sewer upgrades and provides 6 acre-feet of additional storm sewer storage capacity that contributes to increased conveyance. The total inundated area for this proposed alignment is reduced by 27% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 1E range from 0.6 to 1.4 feet.

H. Problem Area – 1F

1. Location

Area 1F is in southeast Beaumont and Modeling Region 1. Specifically, the area is located east of Avenue A, north of Cardinal Drive, south of West Virginia Street, and west of Beaumont city limits. Exact extents of the area can be seen in Exhibit 45. Area 1F is comprised of mostly residential property and open space areas with commercial land near the eastern area border. This area includes approximately 1045 structures and is 836 acres.

2. Existing Conditions

Area 1F is serviced by a combination of roadside ditches, storm sewer systems, major open channels, and detention basins to convey storm water. Roadside ditches are the main form of conveyance for the residential roadways that run eastward and westward. Channel 104 begins just south of the Florida Avenue and Jimmy Simmons Boulevard intersection and flows through two inline detention basins before leaving the problem area and Beaumont city limits.

In the 25-year 24-hour storm, Area 1F experiences ponding typically between 0.25 and 2.3 feet. The primary concentration of flooding is located east of Highland Avenue and west of Rolfe Christopher Drive. Approximately 431 structures in Area 1F are at risk of flooding under the existing conditions. Flooding in this area is caused by elevated tailwater conditions in channel 106 with respect to the ground elevation in the surrounding areas. This area lacks open spaces for detention basins which means any potential upsizing of the existing storm sewer infrastructure would require an additional or separate outfall with available water surface elevations in the receiving channel. During the 100-year, 24-hour storm event, ponding extents worsen due to an increase in tailwater conditions which drives the entire upstream system to surcharge; exceeding flooding depths of approximately 2.6 feet.

During the 2-year and 5-year, 24-hour storm events, ponding is relatively shallow and kept within the right of way due to the available tailwater elevations that allows the storm sewer system to function more effectively than the severe storm events. For the 10-year, 24-hour storm event, ponding extents begin to overflow outside of the right of way as channel 104 reaches capacity and ponding depths are between 0.25 and 1.3 feet.

3. Proposed Improvement

The proposed improvement in Area 1F is a 10' x 6' RCB that begins on the intersection of Campus Street and Park Street. The RCB goes along Campus Street, Highland Avenue, East Florida Avenue, Jim Gilligan Way, Hunter Street, and View & R Drive until it discharges into a tributary of the Neches River. As seen in Exhibit 45 this improvement includes approximately 12,200 linear feet of storm sewer upgrades and provides 39 acre-feet of additional storm sewer storage capacity that contributes to increased conveyance. The total inundated area for this proposed alignment is reduced by 35% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 1F range from 0.6 to 1.3 feet.

I. Problem Area – 1G

1. Location

Area 1G is in southeast Beaumont and Modeling Region 1. Specifically, the area is located north of West Virginia Street, east of Avenue A, south of Washington Boulevard, and west of Beaumont city limits. Exact extents of the area can be seen in Exhibit 51. Area 1G is comprised of mostly residential property and open space areas with commercial land near the eastern area border. This area includes approximately 1,736 structures and is 622 acres.

2. Existing Conditions

Area 1G is serviced by a combination of roadside ditch and storm sewer systems mixed throughout the region. These existing conveyance systems are undersized for the purpose of conveying storm water to downstream systems. Storm sewer and ditches fill up early in the event and are unable to convey the necessary flow downstream during peak stages of major storm.

In the 25-year 24-hour storm, Area 1G experiences ponding typically between 0.25 and 1.9 feet. The area between Ector Avenue and Irving Avenue experiences significant ponding. Approximately 766 structures in Area 1G are at risk of flooding under the existing conditions. The storm sewer system is undersized and cannot effectively convey this flow. During the 100-year, 24-hour storm event, the ponding is even worse as the storm sewer system is further undersized and cannot capture and convey flow generated by this event. Ponding depths for this storm generally exceed 2.0 feet.

During the 2-year and 5-year, 24-hour storm events, ponding begins to breach the low-lying ditches and roadways extending outside of the existing right of way. The ponding depths for these events are typically between 0.25 and 0.7 feet. For the 10-year, 24-hour storm event, ponding depths and extents worsen due to an increase in head loss in the system. Ponding depths for this event are typically between 0.25 and 1 foot.

3. Proposed Improvement

Note that the proposed improvements in Area 1G also extend into Area 1F. These improvements begin with dual 10’ x 8’ RCBs at the intersection of Park Street and Lavaca Street. The dual RCBs continue along Lavaca Street and Highland Avenue, where it briefly transitions into a single 10’ x 8’ RCB before transitioning back to dual RCBs at East Virginia Avenue. The dual RCBs continue along and cross TX-380 Spur and the Union Pacific Railroad until they discharge into a tributary of the Neches River. 24” and 48” RCPs connect to the dual RCBs along Lavaca Street. ROW acquisition will need to be considered for portions of this alignment that may cross private and railroad properties. As seen in Exhibit 51, this improvement includes approximately 15,500 linear feet of storm sewer upgrades and provides 18 acre-feet of additional storm sewer storage capacity that contributes to increased conveyance. The total inundated area for this proposed alignment is reduced by 19% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 1G range from 1.1 to 1.4 feet.

V. Modeling Region 2 - Northern

A. Location & Description

As seen in Exhibit 1, Modeling Region 2 contains the northern portion of the City and is generally located south of Broussard Road, west of Keith Road, and north of Folsom Drive. Covering approximately 24 square-miles, this region includes a mix of undeveloped/wetland areas and developed residential and commercial segments. This northern portion of the City includes large diameter storm sewer trunk line systems along major roadways while relying heavily on roadside ditches for flow contributions to the subsurface system. Region 2 includes a total of 87.4 linear miles of storm sewer that outfall to the Neches River or to the systems evaluated in the southern Regions #1 and #3. Due to the large amount of open area in this region, there is approximately 57.6 miles of open channels available for conveyance and 116.2 acres of detention or retention basin footprints.

B. Existing Conditions

Region 2 is in three different watersheds- Little Pine Island Bayou, Black Creek and the Ten-mile Creek-Neches River watersheds. This area relies heavily on multiple ditches that run, generally to the north, to the Neches River. A small portion of Region 2 is located northwest of RFD Road, and southeast of TX-287 drains to Hillebrandt Bayou watershed. Water is conveyed to these ditches through various storm sewer systems and roadside ditches. Throughout the area, storm sewers are surcharged during extreme, events and receiving channels are at capacity. This yields to long ponding durations, excessive ponding depths, and in some cases structural flooding. Additionally, these conditions can be found in more frequent and less severe events, such as the 2-yr storm event. This region topographically is upstream of Region 1 and Region 3 and was found to be functionally deficient in several locations. The areas identified with the largest potential for flood risk were found throughout Region 2 but particularly through the more developed parts of the region such as south of East Lucas Drive, west of 287, and north of I-10.

C. Channel Modifications

Several of the problem areas in Modeling Region 2 include channel improvements. In the InfoWorks ICM model, these improvements were modeled as channels with rectangular cross-sections for simplicity's sake. Equivalent trapezoidal cross sections were calculated to reflect the true cross sections that would be constructed. Typical cross-sections were identified for each channel and assumed to be about halfway down the length of the improvement. The width and height of each typical section were determined using GIS and LiDAR. For realism and constructability purposes, these rectangular sections were converted to trapezoidal sections with 4:1 side slopes. The heights of the trapezoidal sections were assumed to be the same as the heights of the rectangular sections, but in most cases the bottom widths of the trapezoidal sections were narrower than the widths of the rectangular sections. Due to the nature of a trapezoidal section, there is now also a top width dimension. The specific geometry and capacity of each channel improvement will be discussed in the following sections.

D. Problem Area – 2A

1. Location

Area 2A is in north Beaumont and Modeling Region 2. Specifically, the area is located west of Voth Road, east of Vinson Street, north of DD6 ditch 1002-D, and south of Dusty Lane and Lewis Drive. Exact extents of the area can be seen in Exhibit 57. Area 2A is a residential area with approximately 180 structures and is approximately 145 acres.

2. Existing Conditions

During existing conditions, the roadside ditches become full early in the storm and lead to deep ponding and long times to drain during extreme storm events. The area is primarily serviced by roadside ditches that are undersized for the neighborhood. Additionally, the main ditch that drains the roadside ditches reaches capacity and further hinders the area.

In the 25-year 24-hour storm, Area 2A experiences ponding typically between 0.25 and 2.5 feet. Approximately 40 structures in Area 2A are at risk of flooding under the existing conditions during this storm event with ponding depths over 0.5 feet at the structural footprint. Water surface elevations are higher in the neighborhood than that of the outfall, and thus there is the opportunity to improve this region through conveyance improvement projects for this target level of service. All the beforehand issues mentioned above are exacerbated during the 100-year 24-hour storm event. Ponding on the western side of the neighborhood is over 2 feet of ponding depths near the ditch that runs north south. The eastern side of the neighborhood is less impacted than the western side as it is topographically higher in elevation.

In less severe events, such as the 2-year 24-hour storm events ponding is generally contained to the right of way and is less than 1 foot in depth. The 5-year storm event begins to see ponding depths exit the right of way onto surrounding properties. Ponding depths for this storm event are still generally less than 1 foot. For the 10-year, 24-hour storm event ponding deepens on the western side of the neighborhood as the receiving ditch is at capacity. Ponding depths for this storm event are still generally around 1 foot of ponding, but more than two feet of ponding is seen in some locations.

3. Proposed Improvement

The proposed improvements in Area 2A begin with enclosing existing roadside ditches, adding storm sewer improvements and a channel modification to DD6 ditch 1002-B. The purpose of these improvements is to improve conveyance. Proposed 60" RCPs are connected to the channel at the beginning and end of the modification and tie into an existing 8' x 4' RCB and proposed 8' x 5' RCB between Scotts Drive and Hurley Drive. The ditch enclosures along the south side of Lewis Drive, Click Drive, Scotts Drive, and Hurley Drive are intended to provide locations where storm sewer can be installed. The ditch enclosures along Lewis Drive, Click Drive, and Scotts Drive have 4' x 4' RCBs, while the ditch enclosure along Hurley Drive has a 4' x 3' RCB. These RCBs connect to 8' x 4', 8' x 8', and 4' x 3' RCBs perpendicular to these streets. As seen in Exhibit 58, this improvement includes approximately 7,600 linear feet of storm sewer upgrades and 11,000 linear feet of channel improvements which provide 4 acre-feet of additional storm sewer storage capacity and 13 acre-feet of additional channel storage capacity that contributes to increased conveyance. A typical cross-section in the ditch improvement has a height of 8 feet, a bottom width of 39 feet, a top width of 103 feet, and a cross-sectional area of approximately 568 square feet. This channel improvement extends approximately 1,000 linear feet. The total inundated area over 0.5 feet for this proposed alignment is reduced by 24% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 2A range from 0.4 to 1.1 feet for the 25-year 24-hour storm event. Ponding reductions for the 2-,5-,10-,25-,100-year, 24-hour storm can be found in Exhibits 58-62.

E. Problem Area – 2B

1. Location

Area 2B is in north Beaumont and Modeling Region 2. Specifically, the area is located west of Western Trail, east of Lori Lane, and south of Windemere Drive. Exact extents of the area can be seen in Exhibit 63. Area B is primarily residential with a few commercial structures and is approximately 240 acres. Approximately 450 structures are located within Area 2B.

2. Existing Conditions

Area 2B is serviced by storm sewers and open ditch that ultimately outfall to Ditch 1000-A1, a ditch owned by DD6. Under all evaluated storm conditions, the roadside ditches and storm sewers reach capacity and ponding collects in area. For extreme events, water surface elevation in the neighborhoods is controlled by the receiving ditch and is heavily tailwater influenced.

In the 25-year 24-hour storm, Area 2B experiences ponding typically between 0.25 and 3.4 feet. There is significant roadway ponding in the area between Windcastle Drive and Jill Lane. Approximately 120 structures in Area 2B are at risk of flooding under the existing conditions for the 25-year, 24-hour storm event. The existing storm sewer is at capacity, with water exiting the inlets are various locations along Windswept Drive and Windcastle Drive. In the 100-year, 24-hour storm event tailwater conditions worsen and ponding depths deepen to approximately four feet on Windemere Drive, and three feet on Alece Lane in various locations.

In less severe events, such as the 2- and 5-year, 24-hour storm event, Area 2B ponding is generally contained to the right of way and is less than 1 foot in depth. There are several locations, typically on the northern sides of the neighborhood where ponding is over 1 foot deep. The northern portion of the neighborhood is topographically lower and generally experiences deeper ponding than the rest of Area 2B. During the 10-year, 24-hour storm event ponding begins to exit the right of way and deepens to over 1 foot on Alece, Phyllis, Bret, and Emily Lane. Windswept Drive, Windsong Drive, and Windemere Drive are even more severely impacted with ponding depths experienced over 2-feet in ponding.

3. Proposed Improvement

The proposed improvements in Area 2B are two detention ponds located near DD6 ditch 1004 and Windsong Drive. The purpose of these improvements is to safely store the storm water during storm events, and later drain when there is capacity in the receiving channel. The detention pond at DD6 ditch 1004 is approximately 40 acre-feet and drains into the ditch. A 6' x 4' RCB drains to this detention from two existing RCPs that are 60" and 18". The detention pond near Windsong Drive is 12 acre-feet and ultimately drains to DD6 ditch 1004 through existing storm sewer. A proposed 24" RCP near Windsong Drive connects existing 24" RCP to the detention pond. At the southwest corner of the detention pond, an 18" RCP connects to existing storm sewer; at the southeast corner, 27" and 36" RCPs. Another proposed detention pond is south of Sheila Drive and is approximately 76 acre-feet. As seen in Exhibit 63, this improvement includes approximately 940 linear feet of storm sewer upgrades contribute to increased conveyance. Detention storage capacity has been increased by approximately 127 acre-feet. The total inundated area over 0.5 feet of ponding for this proposed alignment is reduced by 20% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 2B range from 0.6 to 0.9 feet. Approximately 104 structures that flood under the existing conditions in Area 2B do not flood with the proposed improvements.

F. Problem Area – 2C

1. Location

Area 2C is in north Beaumont and Modeling Region 2. Specifically, the area is located east of US-287, west of the Lower Neches Valley Authority Canal, north of Park Drive, and south of the city's limits. Exact extents of the area can be seen in Exhibit 69. Area C is primarily residential with a few commercial structures and is approximately 800 acres. Approximately 480 structures are located within Area 2C.

2. Existing Conditions

Area 2C is serviced by storm sewers, roadside ditches, and open channel that outfalls to the northeast at the Neches River. Under all evaluated storm conditions, the roadside ditches and storm sewers reach capacity and ponding collects in area. For extreme events, water surface elevation in the neighborhoods is controlled by the receiving ditch and is heavily tailwater influenced.

In the 25-year 24-hour storm, Area 2C experiences ponding typically between 0.25 and 2.5 feet. Approximately 80 structures in Area 2C are at risk of flooding under the existing conditions. The source of this flood risk is primarily tailwater related and homes near the channels are typically the most at risk. In the 100-year, 24-hour storm event tailwater conditions worsen and ponding depths deepen particularly along Lawrence Drive, Meadowview Road, Homer Drive, Falcon Lane, and Park North Drive.

In less severe events, such as the 2- and 5-year, 24-hour storm event, Area 2C ponding is generally contained to the right of way but deep ponding occurs along Meadowview Road, Homer Drive, and Post Oak Lane with ponding depth over 1 foot in many locations. During the 5-year, 24-hour storm event ponding extents expand and the ditch north of Lawrence Drive reaches capacity and influences the structures on Lawrence Drive southwest of Meadowview Drive. Ponding only deepens and expands for the 10-year, 24-hour storm event and Park North Drive and Roadrunner Lane has ponding outside of the right of way.

3. Proposed Improvement

The proposed improvements in Area 2C aim to reduce flood risk to the area by improving storage and conveyance. The proposed improvements consist of channel modifications to DD6 ditches 900, 901, 901-B, and 902 as well as storm sewer improvements and a small detention pond. The improvements to DD6 ditches 901 and 901-B were modeled as one continuous improvement, and the improvements to 900 and 902 were modeled as another continuous improvement. A typical cross-section in the 901/901-B improvement has a height of 12 feet, a bottom width of 40 feet, a top width of 136 feet, and a cross-sectional area of 1100 square feet. This channel improvement extends approximately 8,900 linear feet. The 900/902 improvement has a height of 10 feet, a bottom width of 30 feet, a top width of 110 feet, and a cross-sectional area of 700 square feet. This channel improvement extends approximately 11,200 linear feet. There is also a detention pond near DD6 ditch 902-B. A series of 24", 30", and 48" RCPs drain into the detention pond, and a 24" RCP drains out of the detention pond to DD6 ditch 901-B. As seen in Exhibit 69, this improvement includes approximately 1,400 linear feet of storm sewer upgrades and 20,000 linear feet of channel improvements. Detention storage capacity has been increased by 396 acre-feet through implementation of these channel improvements. The total inundated area for this proposed alignment is reduced by 21% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 2C range from 0.6 to 1.7 feet. Approximately 110 structures that flood under the existing conditions in Area 2C do not flood with the proposed improvements.

G. Problem Area – 2D

1. Location

Area 2D is in north Beaumont and Modeling Region 2. Specifically, the area is located west of Helbig Road, north of Comstock Road, and south of Plant Road. Exact extents of the area can be seen in Exhibit 75. Area 2D is primarily residential and has approximately 100 structures and is approximately 280 acres. The focus on this improvement project was to benefit Jancar Drive and Larry Lane.

2. Existing Conditions

Area 2D is serviced by storm sewers, roadside and ditch. The ditch at the outfall has limited capacity and conveyance, and tailwater conditions influence the area and cause long ponding durations and depths.

In the 25-year 24-hour storm, Area 2D experiences ponding typically between 0.25 and 3 feet. Ponding is outside of the right of way on Larry Lane. For the 100-year, 24-hour storm event ponding is outside the right of way at Larry Lane and Jancar Drive and ponding depths are over 2 feet.

In less severe events, such as the 2- and 5-year, 24-hour storm events ponding is generally contained to the right of way and ponding depths are generally between 0.5- 1 foot. For the 10-year, 24-hour storm event ponding conditions deepen to approximately 0.5 feet to over 2 feet of ponding in some locations.

3. Proposed Improvement

The proposed improvements in Area 2D is a channel modification to DD6 ditch 905 beginning at the intersection of Helbig Road and Speer Road. A typical cross-section in this improvement has a height of 8.5 feet, a bottom width of 15 feet, a top width of 85 feet, and a cross-sectional area of 420 square feet. This channel improvement extends approximately 7,200 feet. A new channel begins at this intersection and goes along Helbig Road until Rebecca Lane. As seen in Exhibit 75, this improvement includes approximately 8,700 linear feet of channel improvements which provide 113 acre-feet of additional channel storage capacity that contributes to increased conveyance. The total inundated area for this proposed alignment is reduced by 16% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 2D range from 0.25 to 1 foot for the 25-year, 24-hour storm. Benefit for this storm event is for the 25-year and 100-year 24-hour event and is not present for the 2-,5-,10- year, 24-hour storm events.

H. Problem Area – 2E

1. Location

Area 2E is in north Beaumont and Modeling Region 2. Specifically, the area is located west of Bigner Road, east of Helbig Road, north of East Lucas Drive, and south of Perth Place. Exact extents of the area can be seen in Exhibit 81. The area is primarily residential, contains approximately 162 structures and is approximately 170 acres.

2. Existing Conditions

The main problem area identified was along Jenard Lane, Nelkin Lane, Roslyn Court. These neighborhood streets drain to DD6 Ditch 001. These areas are topographically low and are at, or below, top of bank elevation of DD6 Ditch 001. The elevations along Jenard Lane are approximately two feet below top of bank elevation- meaning that flow can only enter the channel through storm sewers or when the water surface elevation surpasses the channel top of bank elevation. DD6 Ditch 001 eventually reaches capacity and tailwater conditions further hinder these streets and homes during extreme events. Channel right of way is limited and many homes have the ditch immediately behind their backyard.

In the 25-year 24-hour storm, Area 2E typically experiences ponding typically between 1 and 2 feet. The area between Nelkin Lane and McHale Street experiences significant ponding. Approximately 70 structures in Area 2E are at risk of flooding under the existing conditions. In the 100-year 24-hour storm event, ponding depths greater than 2 feet are common and ponding is present outside of the right of way.

In less sever events such as the 2-year and 5-year storm event Kelkin Lane and Roslyn court experience ponding depths between 0.25 feet to 1.5 feet. For the 10-year storm event ponding extents worsen and exit the right of way. Ponding depths are generally over 1 foot for this storm event.

3. Proposed Improvement

The proposed improvements in Area 2E is a detention pond located northwest of Jenard Lane and east of Robinson Street. The detention proposed in this pond is approximately 240 acre-feet. This pond is intended to act as a diversion pond and provide relief to DD6 Ditch 001. The capacity freed up by the pond lowers water surface elevations in the ditch and provides capacity that the neighborhoods could use to convey flow. The pond ties into DD6 Ditch 001 at Lorilee Street through 4-8' x 4's and outfalls approximately 250 feet north of the northern outfall conduit at Jenard Lane to DD6 Ditch 001 through a 24" outfall conduit. The total inundated area for this proposed alignment is reduced by 21% for the 25-year, 24-hour storm event. Detention storage capacity has been increased by approximately 340 acre-feet.

Implementing the detention pond relieves the DD6 ditch and provides benefit for each storm analyzed- 2-,5-,10-,25-, and 100-year both in terms of extents and ponding depths.

I. Problem Area – 2F

1. Location

Area 2F is in north Beaumont and Modeling Region 2. Specifically, the area is located east of Helbig Road, west of Idylwood Street, north of Wilson Street, and south of Perth Place. Exact extents of the area can be seen in Exhibit 87. This area is primarily residential and has approximately 462 structures and is approximately 220 acres.

2. Existing Conditions

Area 2F is serviced by a combination of roadside ditch, along Lufkin Avenue, Laredo Avenue, Galveston Avenue, and Buffalo Street and storm sewer, on East Lucas Drive, and Abilene Avenue. These existing conveyance systems are undersized to convey storm water downstream. Storm sewer and ditches fill up early in the storm and are unable to convey the necessary flow downstream during the extreme storm events.

In the 25-year 24-hour storm, Area 2E experiences ponding typically between 0.25 and 2.0 feet. The area between McHale Street and Lucas Drive experiences significant ponding. Approximately 100 structures in Area 2E are at risk of flooding under the existing conditions. The storm sewer system is undersized to convey this flow. During the 100-year, 24-hour storm event problems the system is only further undersized to capture and convey flow generate by this event. Ponding depths for this storm are generally 1 to 2 feet.

During the 2-year and 5-year, 24-hour storm event ponding is relatively shallow, typically ~0.25 feet, and collects in low regions in and outside of the right of way. The topography is relative flat, making it challenging to capture and convey flow downstream. For the 10-year 24-hour storm event ponding depths and extents worsen compared to the 5-year due to an increase in head loss in the system. Ponding depths for this event are typically 0.5 feet to 1 foot.

3. Proposed Improvement

The proposed improvements in Area 2E involve the conversion of existing drainage ditches into single 6' x 3' RCBs along Lufkin Avenue, Laredo Avenue, and Galveston Avenue and dual 9' x 7' RCBs along Abilene Avenue. On Lucas Drive between Lufkin Avenue and Laredo Avenue, a 6' x 5' RCB connects to existing storm sewer, and then connect to dual 6' x 5' RCBs at Laredo Avenue. The RCBs along Laredo Avenue and Galveston Avenue connect to the dual RCBs along Lucas Drive, which then connects to the RCB along Abilene Avenue. The RCB along Abilene Avenue continues until Charles Street. DD6 ditch 010 is modified to have a typical cross-section with a height of 7 feet, a bottom width of 40 feet, a top width of 96 feet, and a cross-sectional area of 476 square feet. This channel improvement extends approximately 1,600 linear feet. As seen in Exhibit 87, this improvement includes approximately 6,500 linear feet of storm sewer upgrades and 8,100 linear feet of channel improvements which provide 11 acre-feet of additional storm sewer storage capacity and 17 acre-feet of additional channel storage capacity that contributes to increased conveyance. Detention storage capacity has been increased by 240 acre-feet. The total inundated area for this proposed alignment is reduced by 30% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 2E range from 0.4 to 2.1 feet. Approximately 46 structures that flood under the existing conditions in Area 2E do not flood with the proposed improvements for the 25-year, 24-hour storm event.

J. Problem Area – 2G

1. Location

Area 2F is in north Beaumont and Modeling Region 2. Specifically, the area is located east of Concord Road, west of Magnolia Avenue, north of Glasshouse Street, and south of Ledet Road. Exact extents of the area can be seen in Exhibit 93. This area is primarily multifamily residential and has 1418 structures.

2. Existing Conditions

Area 2G is serviced by a combination of roadside ditch, along Detroit Avenue, Ironton Avenue, Steekton Street, and portions of West Lynwood Drive and storm sewer, on East Lynwood Drive, Buffao Avenue, and Arthur Street. In general storm sewers and ditches in this region towards East Lynwood Drive and flow north through the ditch on East Lynwood Drive towards the Neches River. These existing conveyance systems are undersized to convey storm water downstream. Storm sewer and ditches fill up early in the storm and are unable to convey the necessary flow downstream during the extreme storm events. The area that experience the deepest ponding in this project area are just upstream of Lynwood ditch such as West Lynwood Drive, Arther Street, Hybrook Lane, Hayes Lane, and North Lynwood Drive.

In the 25-year 24-hour storm, Area 2G experiences ponding typically between 0.25 and 2.5 feet. There is significant street ponding in the area between Lynwood Drive and Arthur Lane. Approximately 250 structures in Area 2F are at risk of flooding under the existing conditions. During the 100-year, 24-hour storm event Area 2G has ponding depths over two feet throughout the project area. The most severely impacted streets are West Lynwood Drive, Arther Street, Hybrook Lane, Hayes Lane, and North Lynwood Drive.

During the 2-year and 5-year, 24-hour storm event ponding is generally contained to the right of way. However, deep ponding occurs at West Lynwood Drive with ponding depths over 1.5 feet for this event. The topography is relative flat, making it challenging to capture and convey flow downstream. Additionally, the receiving storm system is undersized to capture and convey the storm event. For the 10-year 24-hour storm event ponding depths and extents worsen due to an increase in head loss in the system. Ponding depths for this event are 2 feet for the most severe streets such as Arther Street and West Lynwood Drive.

3. Proposed Improvement

The proposed improvements involve dual 8' x 6' RCBs along Cleveland Avenue from Pope Street to Tyler Street. Along Hayes Lane, beginning at Buffalo Avenue, there is an 8' x 3.5' RCB that connects to an 8' x 4' RCB near Detroit Avenue, which then connects to 8' x 4.5' RCB between Steelton Avenue and West Lynwood Drive that ultimately connects to the dual RCBs along Cleveland Avenue. There is also a 5' x 5' RCB along North Lynwood Drive, a 48" RCP along Hybrook Lane, and a 4' x 4' RCB along Renaud Avenue. As seen in Exhibit 93, this improvement includes approximately 9,100 linear feet of storm sewer which provide 8 acre-feet of additional storm sewer storage capacity that contributes to increased conveyance. The proposed improvements in Area 2G include a channel modification to DD6 ditch 002 beginning at Lucas Drive. This channel improvement has a typical cross-section with a height of 13 feet, a bottom width of 65 feet, a top width of 169 feet, and a cross-sectional area of 1521 square feet. This channel improvement extends approximately 2,600 linear feet. Roadside ditches are removed along Lucas Drive, Fairway Street and Rivercrest Street in order to construct the proposed storm sewers. Additionally, there is a proposed 5' x 4' RCB along Windsor Drive between Trinidad Street and Lucas Drive. At Lucas Drive, the 5' x 4' RCB connects to an 8' x 8' RCB and that turns onto Lucas Drive and Pennock Avenue. Along Withers Lane and Gill Street, there is a 6' x 4' RCB that connects to a 7' x 5' RCB at Grand Avenue, which outfalls into DD6 ditch 004. As seen in Exhibit 93, this improvement includes approximately 5,400 linear feet of storm sewer upgrades and 4,700 linear feet of channel improvements which provide 4 acre-feet of additional storm sewer storage capacity and 91 acre-feet of additional channel storage capacity that contributes to increased conveyance. The total inundated area over 0.5 feet of ponding depth for this proposed alignment is reduced by 21% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 2G range from 0.3 to 0.6 feet for the 25-year, 24-hour storm event.

K. Problem Area – 2H

1. Location

Area 2H is in north Beaumont and Modeling Region 2. Specifically, the area is located east of Magnolia Avenue, west of Hester Street, north of Hale Lane, and south of La Salle Street. Exact extents of the area can be seen in Exhibit 99. This area is primarily multifamily residential and has 46 structures.

2. Existing Conditions

Area 2H is serviced by storm sewers that outfall to DD6 Ditch 004. The area that experience the deepest ponding for this project area is Withers Lane. Storm sewers along Withers Lane and Gill Street are undersized to capture and convey flow to DD6 Ditch 004 during all evaluated storm events, 2-,5-,10-,25-,100-year 24-hour storm events.

In the 25-year 24-hour storm, Area 2H experiences ponding typically between 0.25 and 2.6 feet. Withers Lane is the street the most severely impacted in the project zone with wester portions of Gill street being impacted. Approximately 24 structures in Area 2H are at risk of flooding under the existing conditions. Storm sewer is undersized to capture and convey flow to the ditch outfall. During the 100-year, 24-hour storm event the storm sewer system is only more severely undersized and ponding conditions worsen. Ponding depths for the 100-year, 24-hour storm event are over 3.0 feet on portions of Withers Lane.

In less severe events, such as the 2-year 24-hour storm event ponding depths vary typically between 0.25 and 1.75 feet. During the 5-year and 10-year, 24-hour storm event ponding depths vary been 0.25 feet and 2.5 feet. Ponding depths are adversely affected by undersized storm water conveyance.

3. Proposed Improvement

The proposed project involves upsizing the storm sewer system to 2- 6'x4's that increase in size to dual 7'x5' RCBs towards the outfall to DD6 ditch 006.These storm sewer improvements reduce head loss in the conduits and safely convey flow towards the ditch. Ponding depth and extent reductions are present for every storm evaluated, 2-,5-,10-,25-, and 100-year, 24-hour storm events. Ponding reductions for vary the 25-year, 24-hour storm event but are typically between 0.25 and 0.75 feet. Structural flooding risk is reduced for the 25-year storm event. The total inundated area for this proposed alignment is reduced by 23% for the 25-year, 24-hour storm event.

L. Problem Area – 2I

1. Location

Area 2I is in north Beaumont and Modeling Region 2. Specifically, the area is located east of Berkley Street, west of Coleman Street, north of La Salle Street, and south of the Neches River. Exact extents of the area can be seen in Exhibit 105. This area is primarily multifamily residential and has 305 structures.

2. Existing Conditions

Area 2I is serviced by storm sewers that ultimately outfall to DD6 Ditch 003. DD6 Ditch 003 has limited capacity and reaches capacity in evaluated storm events. These high tailwater conditions in combination with undersized storm sewers, lead to long ponding durations and deep ponding depths.

In the 25-year 24-hour storm, Area 2I experiences ponding typically between typically 0.25 and 2.5 feet. Approximately 132 structures in Area 2I are at risk of flooding under the existing conditions. The streets that are most severely impacted are Trinidad Street and Swift Drive. For the 100-year, 24-hour storm event ponding deepens to over 2.5 feet of ponding in some locations.

In less severe events, such as the 2- and 5-year, 24-hour storm event, ponding depths vary typically between 0.25 and 1 foot. Storm sewers fill up and the downstream receiving channel does not have the capacity to drain this flow.

3. Proposed Improvement

The proposed improvements involve upsizing the storm sewer on Parry street to the outfall north of Lucas Drive to a 5'x5' RCB. Additionally, the DD6 ditch would be expanded to larger and deeper cross section. This channel improvement has a typical cross-section with a height of 18 feet, a bottom width of 30 feet, a top width of 174 feet, and a cross-sectional area of 1836 square feet. This channel improvement extends approximately 2,600 linear feet.

These improvements lead to benefits in extents and depths for all evaluated storm events such as the 2-,5-,10-,25-, and 100-year, 24-hour storm events. Ponding depth reduction for the targeted 25-year level of service are typically around 0.3 to 0.5 feet of ponding. In addition to ponding depths, ponding reductions are present as seen in Exhibit 106-110. The total inundated area for this proposed alignment is reduced by 8% for the 25-year, 24-hour storm event for ponding depths over 0.5 feet. The improved conveyance allows the area to drain more efficiently. Additionally, the improved channel also provides 118 acre-feet of additional channel storage capacity that contributes to increased conveyance and reduces tailwater conditions.

VI. Modeling Region 3 - Southwest

A. Location & Description

As seen in Exhibit 1, Modeling Region 3 contains the southwestern portion of the City and is generally located east of the city limits, west of I-10, and north of Brooks Road. Covering approximately 55 square-miles, this region is highly developed in its northeast region that neighbors Modeling Regions #1 and #2. As Region 3 extends to the south and west, the land use leans heavily towards agricultural and rural uses. There are 127.5 linear miles of storm sewer conduit in this region for the City of Beaumont. Due to Region 3 containing primarily rural land, there is approximately 102.4 miles of open channels available for conveyance and 561.1 acres of detention or retention basin footprints.

B. Existing Conditions

Region 3 is entirely located in the Hillebrandt Bayou watershed. This bayou runs south where it eventually outfalls to the Neches River. All storm sewers and ditches are designed to convey flow to Hillebrandt Bayou. However, Hillebrandt Bayou has limited capacity and fills up early in the storm for extreme events. Hillebrandt Bayou has a less than 10-year level of service and, in some locations, Hillebrandt Bayou exceeds the channel capacity and overtops into surrounding neighborhoods during the 10-year, 24-hour storm event. The limited capacity of Hillebrandt Bayou elevates tailwater in the region, which causes long ponding duration, excessive ponding, and risk of structural flooding during extreme events. In the 2-year storm event there is elevated ponding, however it generally kept to the right of way. In the 10-year storm event, Hillebrandt Bayou reaches capacity and hinders the area through high tailwater conditions. These tailwater conditions only further hinder the area for extreme events such as the 25-year and 100-year 24-hour storm events.

C. Problem Area – 3A

1. Location

Area 3A is in southwest Beaumont and Modeling Region 3. Specifically, the area is located east of North Major Drive, west of North 11th Street, south of Folsom Drive, and north of Phelan Boulevard. Exact extents of the area can be seen in Exhibit 111. This project area is a mix of residential and commercial and includes approximately 2,520 total structural footprints.

2. Existing Conditions

This area is heavily influenced by tailwater conditions on Hillebrandt Bayou. When this channel becomes full, ponding stacks up on the street and flooding occurs. Some of the most flood prone streets include Belvedere Drive, Fan Street, Futara Street, Ventura Street, and Gladys Avenue.

In the 25-year 24-hour storm, Area 3A experiences ponding typically between 0.5 and 2 feet. Approximately 1,439 structures in Area 3A are at risk of flooding under the existing conditions in Area 3A. Hillebrandt Bayou causes elevated tailwater conditions and yields deep ponding and long ponding durations. These conditions are present for the 100-year, 24-hour storm as well and ponding depths and extents only increased compared to the 25-year, 24-hour storm event. Ponding depths vary but consistently over 2 feet of ponding.

For less severe events, such as the 2- and 5-year, 24-hour storm events ponding is generally contained to the right of way but is deep in certain topographically low areas such as Gladys Avenue. Ponding depths are typically under 1 foot for this storm event. For the 10-year, 24-hour storm event Hillebrandt Bayou becomes bank full and yields high tailwater conditions. This further hinders the area and ponding depths worsen to over 1 foot of ponding throughout the region.

3. Proposed Improvement

The proposed detention facilities and storm sewer improvement are intended to provide relief to Hillebrandt Bayou and free up capacity in the channels that the neighborhoods can drain to. The proposed improvements in Area 3A include two detention ponds near Delaware Street that outfall to DD6 ditch 121 and Hillebrandt Bayou. This improvement operates as a diversion system for Hillebrandt Bayou by directing flow through proposed triple 8' x 6' RCBs to the west along Delaware Street. The improvement forks off into the first detention pond near Valmont Avenue which provides approximately 1193 acre-ft of storage capacity before its outfall through a 48" RCP back into Hillebrandt Bayou. Additionally, starting at the entrance into the first basin, the second portion of the improvement continues along Delaware Street through a proposed 8'x5' RCB. This improvement ties into the Delaware Street and DD6 channel 121 existing crossing and continues to the second proposed detention pond which provides approximately 92 acre-feet of detention before its outfall into channel 121 via 48" RCP. As seen in Exhibit 111, this improvement includes approximately 13,545 linear feet of storm sewer upgrades which provide 4.3 acre-feet of additional storm sewer storage capacity. The total inundated area for this proposed alignment is reduced by 11% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 3A range from 0.25 to 0.8 feet.

D. Problem Area – 3B

1. Location

Area 3B is in southwestern Beaumont and Modeling Region 3. Specifically, the area is located east of Edson Drive, west of Shady Lane, north of Gladys Avenue, and south of the Folsom Drive. Exact extents of the area can be seen in Exhibit 117. This area is primarily residential with a few commercial structures and includes approximately 965 total structural footprints.

2. Existing Conditions

Area 3B is serviced by a combination of roadside ditches and storm sewer infrastructure. The complete system is undersized and head loss occurs throughout the system. This leads to deep ponding depths and long ponding durations during extreme storm events.

In the 25-year 24-hour storm, Area 3B experiences ponding typically between 0.25 and 1.5 feet. Approximately 331 structures in Area 3B are at risk of flooding under the existing conditions. The storm sewer system is undersized to capture and convey flow downstream. Conditions are only exuberated in the 100-year, 24-hour storm event and ponding depths extents worsen.

3. Proposed Improvement

The proposed improvements in Area 3B include storm sewer improvements and upgrades along Lucas Drive, Central Drive, Briarcliff Drive, and 23rd Street. The improvement along Lucas Drive includes an 8' x 4' RCB extending from Coolidge Street to Gladys Avenue where it ties into the existing system. Central Drive is proposed to have an 8' x 5' trunk line system that outfalls into channel 117. The proposed improvement to Briarcliff Drive involves 8' x 5' trunk line system that ties into the Central Drive improvements as well as the existing system along 23rd Street. Improvements to 23rd Street include an 8' x 5' storm sewer spanning from Delaware Street to the existing 23rd Street system near channel 107. As seen in Exhibit 117, this improvement includes approximately 14,690 linear feet of storm sewer upgrades which provide 4.2 acre-feet of additional storm sewer storage capacity that contributes to increased conveyance. The total inundated area for this proposed alignment is reduced by 11% for the 25-year, 24-hour storm event. The depth reduction provided by the improvements in Area 3B range from 0.25 to 0.9 feet.

VII. Project Cost and Prioritization

The potential improvements for the problem areas identified have been prioritized using several different criteria. The criteria used in the prioritization includes project cost, benefit-cost ratio based on damages, and the reduction of impassable intersections within the problem area. In determining the benefit-cost ratio, several different factors were utilized in determining benefit values that are related to the reduction in structural damages in terms of dollar value.

Each criterion used in the prioritization process was given a specific weight that is used in determining an overall weighted rank for the projects evaluated. Project cost is given a weight of 20%, benefit-cost ratio is 70%, and the amount of impassable intersections removed from flooding is given 10%. The process for the ranking determination of each criteria is listed in the following sections.

A. Project Cost

An estimated project construction cost was determined for each problem area based on evaluating the existing system to best meet 25-year LOS. As shown in **Table VII.1** below, the projects have been ranked in terms of total construction costs as the first step of prioritization.

Table VII.1 Rank by Project Cost Estimate

Rank	Project	Estimated Cost
1	2H	$ 1,860,000
2	2D	$ 3,590,000
3	1A	$ 3,750,000
4	2B	$ 3,810,000
5	2I	$ 4,090,000
6	2A	$ 6,370,000
7	1E	$ 9,760,000
8	3A	$ 11,460,000
9	2F	$ 12,790,000
10	2E	$ 13,570,000
11	2C	$ 13,640,000
12	1D	$ 13,840,000
13	1F	$ 14,550,000
14	1C	$ 14,730,000
15	2G	$ 17,490,000
16	1G	$ 35,570,000
17	3B	$ 45,570,000
18	1B	$ 51,310,000

The planning level cost estimates for each project summarized in the above table are based on the Texas Department of Transportation (TxDOT) Beaumont District average low bid unit prices published in March of 2019. The cost estimates include excavation, concrete, inlets, and sewer linear footages on a unit-price basis as well as easement and ROW-acquisition costs. The cost estimates also include a flat fee for mobilization, a 25% contingency fee to account for utility relocation, pavement reconstruction, and unforeseen design components, and a 22% engineering and survey fee to account for detailed design work.

The high-level cost estimates are displayed in **Appendix C** and describe the beforementioned line items and cost considerations.

B. Benefit Cost Ratio

A benefit-cost analysis (BCA) was conducted to help determine the monetary value of the proposed improvements. The BCA for this evaluation is generally based on the methodologies used by FEMA, which in turn references the Office of Management and Budget (OMB) Circular A-94. OMB Circular A-94 requires all costs and benefits be expressed as net present value (NPV).

Financial savings through flood risk and flood damage reduction form the basis of the economic analysis of this effort. Other benefits such as critical intersections removed from flooding, transportation conveyance, and temporarily losses of use were not included.

Flood damage was determined using flood depths from the InfoWorks ICM 2D model. The existing and proposed models were run using three separate events; the 2-year, 10-year, and 100-year 24-hour storm events. The three events are used to determine the relationship between the probability of these events and the damage costs.

The flooded structures were determined based on an assumed 6" slab elevation. In 2006, Gulf Engineers & Consultants provided USACE with an economic guidance report that gives generic, depth-damage relationships for both structural and contents damages due to flooding impacts. The depth-damage curves were used in association with improvement property values collected in 2017 by Harris County Appraisal District (HCAD) to determine the damage costs for each alternative at each return period. The HCAD data provides the necessary information to determine the structure and contents value. USACE depth-damage curves provide a relationship between structural inundation depths and damage values as a percentage of the overall improvement value of a structure.

The following case of the benefit-cost analysis process shows the results for the proposed improvements for problem area 1D. The improvements analyzed for this problem area will be used throughout this section as an example of the process utilized to determine the benefit-cost ratio. Damage costs were determined for both frequent and severe storm events. Existing conditions were evaluated and compared with the damages experienced under the conditions of the proposed improvement being fully constructed.

The estimated reduction of structural and contents damages between existing and proposed conditions is the basis of what is considered benefit throughout the benefit-cost analysis. The damage cost reductions for the existing and proposed conditions of problem area 1D under three of the modeled (2-, 10-, and 100-year) events can be seen in **Table VII.2** below:

Table VII.2 Modeled Damage Reduction Estimates – Problem Area 1D

Event (Years)	Existing Damage	Proposed Damage	Damage Reduction
100	$12,355,046	$9,710,548	$2,644,498
10	$7,474,393	$5,120,762	$2,353,631
2	$4,857,108	$3,341,327	$1,515,781

An average annual damage reduction can be determined by using the annual exceedance probability associated with each storm event. The calculation takes account of the damage costs for each event and its respective probability of occurring in any given year. For example, the 100-year event for problem area 1D has a damage reduction of approximately $2.6 million; however, the probability of realizing those savings in any one year is 0.01 or 1%. Therefore, the annual damage reduction is approximately $26,445.

The annual average damage reduction can be determined by simply using the damage cost estimates from the model events. Weighing the average damage reduction increment between each return period by the associated increment in the exceedance probability and taking the total gives the annual average damage reduction cost. An example of the procedure is shown in **Table VII.3** below:

Table VII.3 Average Annual Damage Reduction Calculations – Problem Area 1D

Event (Years)	Exceedance Probability	Damage Reduction	Probability Increment	Mean Damage Reduction Increment	Average Annual Damage Reduction
			0.01	$2,644,498	$26,445
100	1%	$2,644,498			
			0.09	$2,499,064	$224,916
10	10%	$2,353,631			
			0.4	$1,934,706	$773,882
2	50%	$1,515,781			
				NPV of Annual Damage Reduction (A):	$1,025,243

This annual damage reduction should be summed over the life of the project by amortizing or reducing the future value each year. In order to do this, the below equation is utilized to convert the net present value of the annual damage reduction to a net present value of total damage reduction:

$$PV = A * (\frac{1 - (1 + i)^{-n}}{i})$$

Where:
A = NPV of Annual Damage Reduction
PV = NPV of Total Damage Reduction
i = Annual interest rate
n = Project Lifetime in Years

Table VII.4 Benefit-Cost Calculation – Problem Area 1D

Parameter	Value
NPV of Annual Damage Reduction (A) =	$1,025,243
Annual Interest Rate (i) =	7%
Project Lifetime in Years (n) =	30
NPV Total Damage Reduction (PV) =	$12,722,285
NPV of Project Cost =	$13,840,000
Benefit-Cost Ratio =	0.919

As seen in the above **Table VII.4**, the proposed improvement for problem area 1D results in a net present value (NPV) of the Total Damage Reduction of approximately $12.7 million. Comparing that benefit to the estimated NPV project construction cost of $13.8 million for problem area 1D yields a benefit-cost ratio of 0.919.

Assumptions were made throughout the benefit-cost analysis to create a realistic representation of the flooding that the City experiences during frequent storm events. These assumptions are listed below:

1. Slab height for structures is assumed to be 6 inches above natural ground.
2. Structures with an area of less than 500 square feet are excluded from the benefit-cost analysis.
3. Single-family residential structures for this area are treated as two story for structural damage.
4. Multi-family residential buildings for this area are treated as commercial structures for structural damage.
5. The improvement value for a given parcel was divided amongst the total number of buildings located on the parcel.
6. Per FEMA recommendations, an interest rate of 7% and project life of 30 years are assumed in the analysis.

A benefit-cost ratio was calculated for each individual proposed improvement area and has been ranked from the highest to lowest BCR values. The ranking of the projects based on BCR is summarized in **Table VII.5** below:

Table VII.5 Rank by Project Benefit-Cost Ratio

Rank	Project	Benefit-Cost Ratio
1	2B	4.08
2	1E	1.59
3	3A	1.09
4	1D	0.92
5	2H	0.77
6	1F	0.72
7	2C	0.66
8	1B	0.65
9	1A	0.48
10	2I	0.35
11	2G	0.32
12	2A	0.31
13	1C	0.26
14	1G	0.18
15	2F	0.17
16	2E	0.16
17	3B	0.12
18	2D	0.04

Full benefit-cost analyses were performed for each individual project area. The full process used for determining the benefit-cost ratio based on damages is presented in **Appendix D** following the body of the report.

C. Reduction of Impassable Intersections

Impassable intersections for the purposes of this analysis is defined as any roadway intersection that experiences a ponding depth of greater than 0.5 feet at the centerlines. Intersections are defined as any location where three or more roadways converge, and the 0.5 feet of ponding depth is the estimated passable depth for an average roadway vehicle. By using the 2D modeling results from the existing and proposed conditions for the 2-year and 25-year storms, a reduction in impassable intersections was determined for each project area. In order to take multiple storm events into consideration, a weighted rank for impassable intersections was determined by giving the 2-year reductions a weight of 75% and the 25-year reductions a weight of 25%. By weighting the 2-year storm event more, the overall rank is based on problem areas that experience roadway flooding more frequently. The ranking of projects according to removal of impassable intersections is shown below in **Table VII.6**.

Table VII.6 Rank by Removal of Impassable Intersections

Rank	Project	2-YR Impassable Intersections Removed	25-YR Impassable Intersections Removed
1	1B	215	58
2	1G	114	66
3	1F	50	55
4	1C	52	51
5	1E	39	30
6	1A	32	33
7	2G	26	29
8	1D	41	0
9	2F	9	32
10	3B	15	14
11	2I	9	6
12	2E	6	0
13	2C	5	0
14	2H	0	3
15	2A	0	0
16	2B	3	0
17	2D	0	0
18	3A	0	0

D. Project Prioritization Summary

Taking project cost, benefit-cost ratios, and removal of impassable intersections into account, the overall rank of the projects is shown in **Table VII.7** on the following page. The weighted score shown in the table is a weighted average of each project's criteria rank. In order to consider potential outliers with an overall inflated by a single factor, each project was evaluated against other projects that ranked similarly to determine any further adjustments based on the judgement of the project engineers. As discussed previously, project cost was given a weight of 20% and removal of impassable intersections was given a weight of 10%. The overall rank is based on the benefit-cost ratio with a weight of 70%.

Table VII.7 Overall Project Ranking and Weighted Score

Overall Rank	Project	Weighted Score	Project Description
1	2B	3.1	Basin storage improvements near HWY-105 and channels 1000-A1 and 1004
2	1E	3.3	Basin storage and sewer conveyance improvements near W Virginia Street, Florida Avenue, and Avenue A
3	3A	5.1	Basin storage and sewer conveyance improvements near Delaware Street, Dowlen Road, and channel 121
4	1D	5.5	Basin storage and sewer conveyance improvements near channel 107 and Fannett Road
5	2H	6.0	Sewer conveyance improvements along Withers Lane and Gill Street
6	1F	7.1	Sewer conveyance improvements primarily along Campus Street, Highland Avenue, and E Florida Avenue
7	2C	7.5	Channel modification to channels 900, 901, 901-B and 902 with sewer conveyance improvements
8	1B	8.4	Sewer conveyance improvements primarily along Fannin Street, 4th Street, and Avenue G
9	1A	9.1	Sewer conveyance improvements tying into Long Avenue from Oakland Street to Grand Street
10	2I	9.3	Channel modification to channel 003 and sewer conveyance improvements along Swift Drive
11	2G	11.1	Channel modification to channel 002 and sewer conveyance improvements primarily along Hayes Lane and Cleveland Street
12	2A	11.4	Channel modification to channel 1002-B and sewer conveyance improvements
13	1C	12.3	Sewer conveyance improvements along Fulton Avenue, Carroll Street, and Verone Street
14	1G	13.2	Sewer conveyance improvements primarily along W Lavaca and E Virginia Street
15	2F	13.2	Channel modification to channel 010 and sewer conveyance improvements primarily along E Lucas Drive and Abilene Avenue
16	2E	14.4	Basin storage improvement for diversion of channel 001
17	3B	16.3	Sewer conveyance improvements primarily along W Lucas Drive, Central Drive, Briarcliff Drive, and 23rd Street
18	2D	14.7	Channel modification to channel 905

VIII. Undeveloped Areas

A. Identification of Undeveloped Areas

Based on aerial images of the City as well as discussions with the City of Beaumont, LAN identified and delineated 9 undeveloped areas, as shown in Exhibit 123 that could be used for future development. Existing wetlands were layered on top of the undeveloped areas. Development should not occur in a wetland, and therefore any land that overlapped with wetlands was excluded from the total area. City officials provided a development strategies diagram and commented on the intended land use (residential, commercial, or industrial) for some of the developed areas. For many of the areas, precise future land use was unknown.

B. Detention Requirements

Based on standard criteria in the region, it was assumed that 0.65 acre-feet of detention were required for each acre of undeveloped area. The required detention volume for each undeveloped area is shown in Exhibit 123.

To meet the detention requirements, channels running through or near each undeveloped area should be at least 8-10 feet deep. The depths of the channels were determined using 3D Analyst tools and LiDAR in ArcGIS. Canals and ditches were not considered in this analysis. All areas except Undeveloped Area 1 had channels that met or exceeded this requirement. Proposed channel modifications for Undeveloped Area 2 are detailed below.

C. Channel Modifications – Undeveloped Area

Undeveloped Area 1 is the only area that did not have a channel 8-10 feet deep. Area 1 located on the western part of the City, as seen in Exhibit 123. Specifically, this area is located north of Folsom Drive, west of North Major Drive, east of Keith Road, and south of Tolivar Road. Excluding wetlands, this area is 917 acres and would require 504 acre-feet of detention post-development. The only channel running through the area is only 3 feet deep and appears to be a canal, so channel design construction would be necessary to meet the future detention requirements as well as provide appropriate outfall depths.

Runoff for the 100-year storm was calculated using the Omega EM Regression equation in the TxDOT Hydraulic Design Manual. The flow for the area is 475 cubic feet per second (cfs). The required channel depth was assumed to be 10 feet based on the depth of nearby channels and provide an outfall for future storm sewer systems. Channel dimensions and flows were calculated using Manning's equation. Both a grass-lined and concrete-lined channel were considered.

Based on typical channel design criteria from, the channel was assumed to be trapezoidal with 4:1 side slopes, a slope of 0.08%, and a minimum bottom width of 6 feet.

Two calculations were performed to determine channel sizing. First, the maximum flow capacity of the channel was calculated, assuming that the channel was full. For a grass-lined channel, the maximum capacity would be 1,451 cfs, and for a concrete-lined channel, the maximum capacity would be 3,869 cfs. Second, assuming a flow of 475 cfs, the minimum depth of the channel was calculated. A grass-lined channel would need to be at least 6.4 feet deep, while a concrete-lined channel would need to be at least 4.2 feet deep. These numbers are approximate and should be used for planning purposes only. Detailed design would be needed in the future in order to understand true detention and channel needs.

IX. Conclusion and Recommendations

The City of Beaumont region is served by multiple drainage channels with numerous, often interconnected storm sewer systems. This complex region was evaluated using a 2-dimensional InfoWorks ICM model to fully understand the region's subsurface and overland flow patterns to identify stormwater infrastructure deficiencies. The existing conditions simulation model was confirmed against flooding reports and known problem areas identified by the City and was found to be in agreement. The region was evaluated for the 100-, 25-, 10-, 5-, and 2-year, 24-hour design storm events and found to be functionally deficient in several locations throughout the region.

Proposed improvement projects were developed in accordance with the targeted 25-year level of service and the desire to reduce flood risk. Retrofitting existing neighborhoods for extreme events can be a difficult process without substantial reconstruction of the entire neighborhood. It is for this reason that the recommended improvement projects seek to meet current design criteria, but not meet 25-year level of service in all areas. The improvements recommended offer a great deal of benefit over existing conditions and provide a higher level of service. Due to the complex, interconnected and topographically challenging characteristics it is not possible to solve the region's stormwater deficiencies through a standalone improvement project. It is for this reason that a combination of projects is recommended to improve the region's drainage issues. These projects work in tandem to convey stormwater currently stored within streets and neighborhoods to downstream receiving waters or detention basins.

Proposed structural improvement projects were evaluated on numerous factors including: the project's dependence on other projects or phasing to operate, critical roadways removed from flooding, reduction in ponding time, and reduction in ponding extents. Projects were divided into regions according to the above referenced factors to promote the highest or most beneficial improvement projects as well as the projects that serve as the "backbone" for other future improvements. Proposed improvement projects, ranking, and exhibit locations are summarized in **Table IX.1** on the next page.

The Master Drainage Plan is intended to serve as a living, breathing document for the purposes of improving drainage within the City of Beaumont. As such, it is recommended that the MDP be updated annually to account for changes in developments, projects implemented, costs, and any pertinent new information. Additionally, it is also recommended that an annual stormwater inspection program be developed in tandem with other ongoing inspection programs to inspect approximately 5-15% of the total system annually. The ongoing inspections and continued updates of the MDP ensures its vitality and roadmap for drainage in the City.

Table IX.1 Summary of Project Rankings

Overall Rank	Project	Project Exhibits	Project Description
1	2B	63 - 68	Basin storage improvements near HWY-105 and channels 1000-A1 and 1004
2	1E	39 - 44	Basin storage and sewer conveyance improvements near W Virginia Street, Florida Avenue, and Avenue A
3	3A	111 - 116	Basin storage and sewer conveyance improvements near Delaware Street, Dowlen Road, and channel 121
4	1D	33 - 38	Basin storage and sewer conveyance improvements near channel 107 and Fannett Road
5	2H	99 - 104	Sewer conveyance improvements along Withers Lane and Gill Street
6	1F	45 - 50	Sewer conveyance improvements primarily along Campus Street, Highland Avenue, and E Florida Avenue
7	2C	69 - 74	Channel modification to channels 900, 901, 901-B and 902 with sewer conveyance improvements
8	1B	21 - 26	Sewer conveyance improvements primarily along Fannin Street, 4th Street, and Avenue G
9	1A	15 - 20	Sewer conveyance improvements tying into Long Avenue from Oakland Street to Grand Street
10	2I	105 - 110	Channel modification to channel 003 and sewer conveyance improvements along Swift Drive
11	2G	93 - 98	Channel modification to channel 002 and sewer conveyance improvements primarily along Hayes Lane and Cleveland Street
12	2A	57 - 62	Channel modification to channel 1002-B and sewer conveyance improvements
13	1C	27 - 32	Sewer conveyance improvements along Fulton Avenue, Carroll Street, and Verone Street
14	1G	51 - 56	Sewer conveyance improvements primarily along W Lavaca and E Virginia Street
15	2F	87 - 92	Channel modification to channel 010 and sewer conveyance improvements primarily along E Lucas Drive and Abilene Avenue
16	2E	81 - 86	Basin storage improvement for diversion of channel 001
17	3B	117 - 122	Sewer conveyance improvements primarily along W Lucas Drive, Central Drive, Briarcliff Drive, and 23rd Street
18	2D	75 - 80	Channel modification to channel 905

X. References

1. Hydrographic Data:
    a. United States Geological Survey (USGS). "National Hydrography Dataset (NHD)." 2004. <https://www.usgs.gov/core-science-systems/ngp/national-hydrography/national-hydrography-dataset>
2. LiDAR Elevation Data:
    a. Texas Natural Resources Information System. "StratMap Elevation - LiDAR." June 2018. <https://tnris.org/stratmap/elevation-lidar/>
3. FEMA Floodplain Info:
    a. Federal Emergency Management Agency (FEMA). "FEMA Flood Map Service Center." 6 August 2002 <https://msc.fema.gov/portal/search?AddressQuery=beaumont#searchresultsanchor>
4. Soil Information:
    a. Soil Survey Geographic Database (SSURGO). "Web Soil Survey (WSS)." United States Department of Agriculture (USDA). 30 September 2014. <https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx>
5. Elevation Conversion Methodology:
    a. Milbert, Dennis G. "National Geodetic Survey (NGS) Height Conversion Methodology." National Oceanic and Atmospheric Administration (NOAA). 12 May 1999. <http://www.ngs.noaa.gov/TOOLS/Vertcon/vert_method.html>.
6. TxDOT bid prices:
    a. Texas Department of Transportation (TxDOT). "Average Low Bid Unit Prices." January 2019. <https://www.txdot.gov/business/letting-bids/average-low-bid-unit-prices.html>
7. Hyetograph Info - Rainfall Depth-Duration-Frequency:
    a. Asquith, William H. "Depth-Duration Frequency of Precipitation for Texas." USGS Water-Resources Investigations Report (WRIR) 94-4044. 1998. <https://pubs.usgs.gov/wri/wri98-4044/>
8. Green & Ampt Parameters for Infiltration:
    a. Storey, Arthur L.; Talbott, Michael D. "Hydrology & Hydraulics Guidance Manual" Harris County Flood Control District (HCFCD). December 2009. <https://www.hcfcd.org/media/1482/hcfcd_hydrology-hydraulics_manual_12-2009.pdf>
9. Benefit-Cost Analysis:
    a. Ralph A. Wurbs and Wesley P. James, Pearson Education (2002). "Water Resources Engineering" [Chapter 11: Water Resources Systems Analysis]
    b. Gulf Engineers & Consultants, Inc. (2006). "Final Report: Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) In Support of the Donaldsonville to the Gulf, Louisiana, Feasibility Study: Prepared for U.S. Army Corps of Engineers New Orleans District," updated March 2006

APPENDIX A –
Public Meetings

Comprehensive Flood Protection Plan Public Meeting

City of Beaumont
Public Works Department

City Representatives: Dr. Joseph Majdalani, PE
Chace Mann

DD6 Representative: Doug Canant, PE

Engineering Consultant: Lockwood, Andrews, & Newnam, Inc.

May 22,2017

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

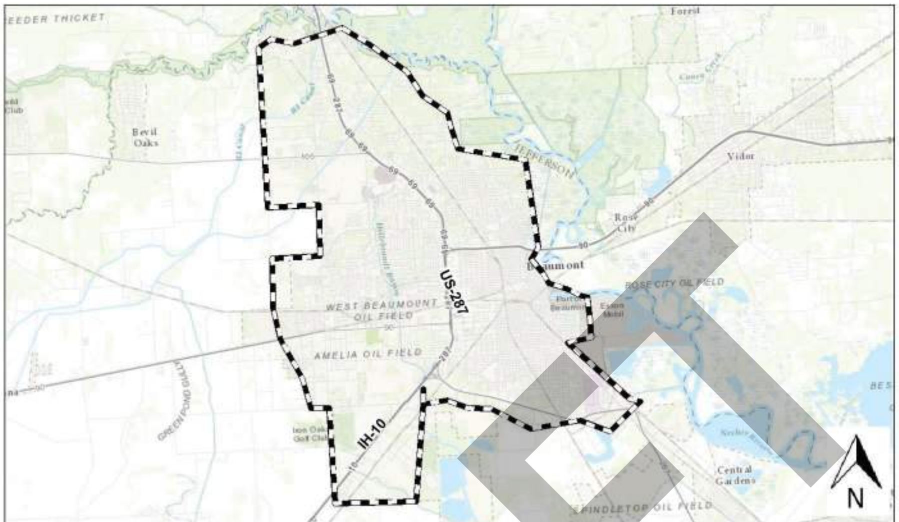
BEAUMONT TEXAS

Agenda

- Project Introduction
- Texas Water Development Board Grant Overview
- Questions

2

Project Location



BEAUMONT TEXAS DD6

3

Project Introduction

- Master Drainage Plan
  - Describes City's Drainage Characteristics
  - Recommends Drainage System Improvements
  - Develops a Plan for Future Growth

BEAUMONT TEXAS DD6

4

Master Drainage Plan Background

- Why update the master plan?
  - 30+ Years Since Last Update
  - Several Regional Changes
    - New Development
    - Calder Avenue

LAN BEAUMONT TEXAS DD6

5

Master Drainage Plan Goals

- Roadmap to Address Flooding
- Better Define Flood Risk

LAN BEAUMONT TEXAS DD6

6

Master Drainage Plan Objectives

- Prioritization of Problem Areas
- Improvement Projects – Reduce Flood Risk

Funding Partnership

- Texas Water Development Grant (TWDB)
  - Financial Assistance for Communities to Reduce Flood Risk
  - Obtained through Flood Protection Grant Application Process
- $862,000- Total Project Cost
  - $500,000 - City of Beaumont
  - $287,000 - TWDB Flood Protection Grant
  - $75,000 - Jefferson County Drainage District No.6 (DD6)

TWDB Grant Components

- Watershed Based Approach to Flood Risk Reduction
- Data Collection
- Incorporate Previous Studies
- Define Flooding
- Flood Early Warning Initiatives & Improvements
- Flood Prevention Plan Development
- City Coordination with DD6 and TWDB

BEAUMONT TEXAS DD6

9

Reducing Flood Risk

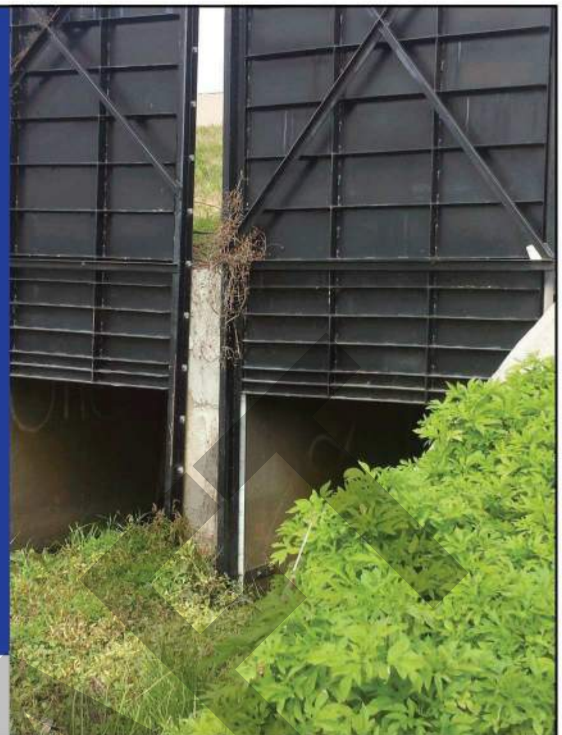
- Drainage Improvement Projects
- Flood Prevention Plan
  - Flood Early Warning System

Source: Bexar County

BEAUMONT TEXAS DD6

10

Questions



DD6

lan BEAUMONT TEXAS

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

DESIGN NOTES AND COMPUTATIONS

SUBJECT: Comprehensive Flood Protection Plan Public Meeting SHEET NO. OF

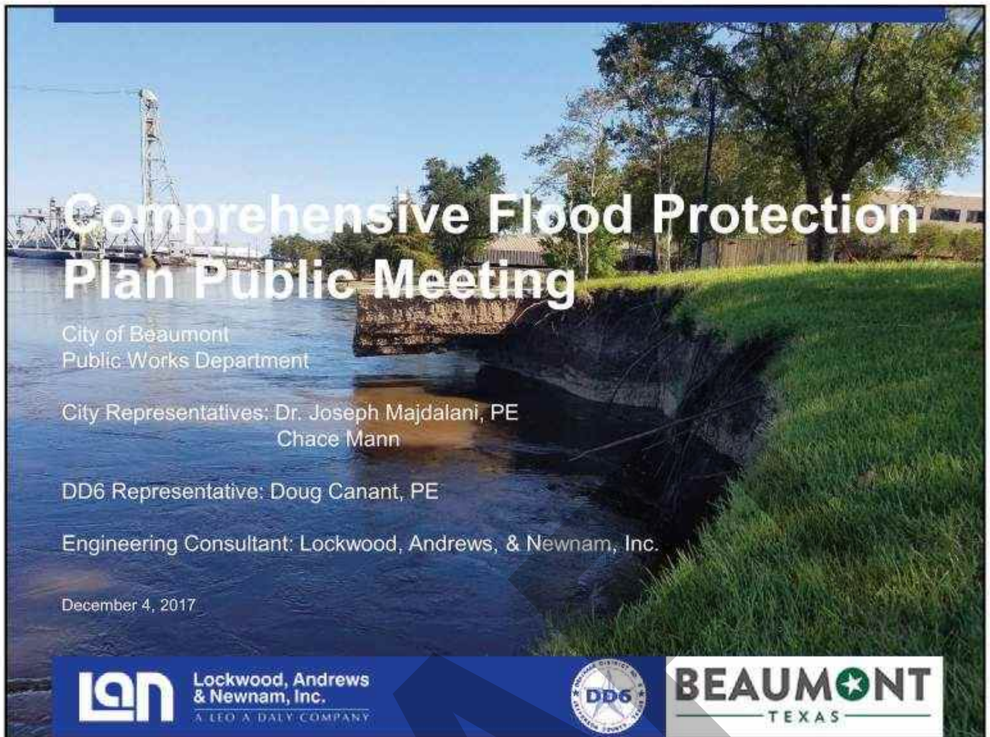
Please Sign In

May 22, 2017 5:00 to 7:00

Name	Email	Phone	Organization (if applicable)
Tom Rowe	[redacted]	[redacted]	Mark W. Whiteley & Associates, Inc.
Zach Rowe	[redacted]	"	"
Zheng Tan	[redacted]	[redacted]	City of Beaumont
Ivan Ortiz	[redacted]	[redacted]	TWDB
Matt Mandes	[redacted]	[redacted]	LAN
Chace Mann	[redacted]	[redacted]	CITY BMT.
Laura Cosset	[redacted]	[redacted]	LAN
Sam Parigi	[redacted]	[redacted]	
Dr. Joe Majdalani	[redacted]	[redacted]	City of Beaumont

PREPARED BY DATE CHECKED BY DATE PROJECT NUMBER

D-005


Comprehensive Flood Protection Plan Public Meeting
City of Beaumont
Public Works Department
City Representatives: Dr. Joseph Majdalani, PE
Chace Mann
DD6 Representative: Doug Canant, PE
Engineering Consultant: Lockwood, Andrews, & Newnam, Inc.
December 4, 2017
Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY
DD6
BEAUMONT
TEXAS


Agenda
Hurricane Harvey Event Summary
Project Introduction
Texas Water Development Board Grant Overview
Questions
DD6
BEAUMONT
TEXAS
2

ISC Industrial Specialty Contractor

Hurricane Harvey

IH-10 near Old US-90

Hurricane Harvey

Neches River by Beaumont Children Museum

US90 near Oriole St

Flood Record for Beaumont

Hurricane Harvey

Category	Old Record		New Record	
	Date	Rainfall (in)	Date	Rainfall (in)
Wettest Day	5/19/1923	12.76	8/29/2017	26.03
Wettest Month	Nov 1902	22.74	Aug 2017	54.74
Wettest Summer	1989	31.67	2017	71.42
Wettest Year	1946	83.82	2017	89.6

County Impacts

Hurricane Harvey

- Record Event County Wide
  - 1-hour Max – 5.0” (100-250 year event)
  - 1-hour AVG – 3.2” (10-25 year event)
  - 24-hour Max – 27.4” (~5,000 year event)
  - 24-hour AVG – 19.2” (250-500 year event)

County Impacts Hurricane Harvey

- Record Event County Wide
  - 2-day Max – 35.7" (~12,000 year event)
  - 2-day AVG – 26.3" (~12,000 year event)
  - 4-day Max – 48.6" (~50,000 year event)
  - 4-day AVG – 38.2" (~3,000-20,000 year event)

County Impacts Hurricane Harvey

- 4-Day Max, Specific Watersheds
  - Pine Island Bayou: 46.4"
  - Hillebrandt Bayou: 48.6"
  - Neches River: 40.2"
  - Spindletop Bayou: 37"
  - Taylor Bayou: 47"

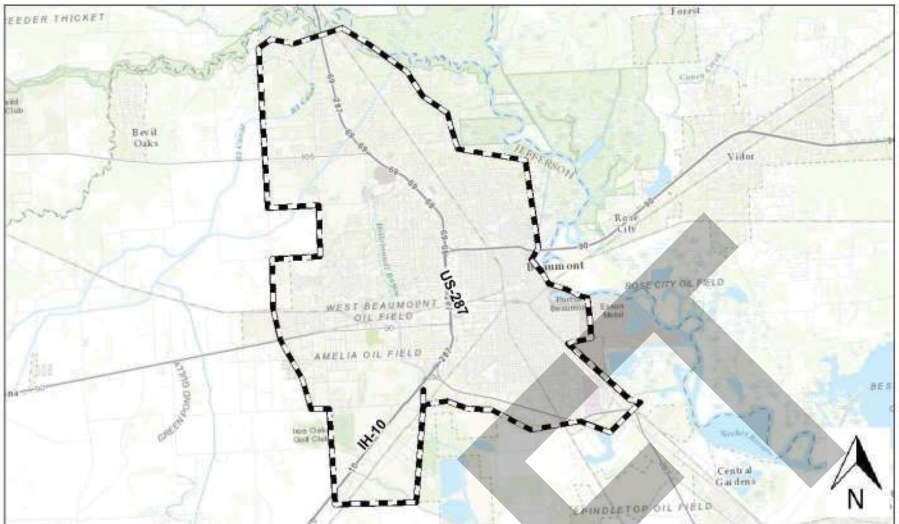
County Impacts — Hurricane Harvey

- 4-Day Max, Specific Watersheds
  - Mayhaw Bayou: 43.6”
  - Gulf Intracoastal Waterway: 34.8”
  - Keith Lake: 34.7”
  - Trinity Bay: 45.1”

Summary — Hurricane Harvey

- Hurricane Harvey Summary
  - Rain Event of Record
  - Vast Regional Impact

Project Location



BEAUMONT TEXAS DD6

13

Project Introduction

- Master Drainage Plan
  - Describes City's Drainage Characteristics
  - Recommends Drainage System Improvements
  - Develops a Plan for Future Growth

BEAUMONT TEXAS DD6

14

Master Drainage Plan Background

- Why update the master plan?
  - 30+ Years Since Last Update
  - Several Regional Changes
    - New Development
    - Calder Avenue

BEAUMONT TEXAS DD6

15

Master Drainage Plan Goals

- Roadmap to Address Flooding
- Better Define Flood Risk

BEAUMONT TEXAS DD6

16

Master Drainage Plan Objectives

- Prioritization of Problem Areas
- Improvement Projects – Reduce Flood Risk

BEAUMONT TEXAS DD6

17

Funding Partnership

- Texas Water Development Grant (TWDB)
  - Financial Assistance for Communities to Reduce Flood Risk
  - Obtained through Flood Protection Grant Application Process
- $862,000- Total Project Cost
  - $500,000 - City of Beaumont
  - $287,000 - TWDB Flood Protection Grant
  - $75,000 - Jefferson County Drainage District No.6 (DD6)

BEAUMONT TEXAS DD6

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TWDB Grant Components

- Watershed Based Approach to Flood Risk Reduction
- Data Collection
- Incorporate Previous Studies
- Define Flooding
- Flood Early Warning Initiatives & Improvements
- Flood Prevention Plan Development
- City Coordination with DD6 and TWDB

BEAUMONT TEXAS DD6 19

TWDB Grant Components

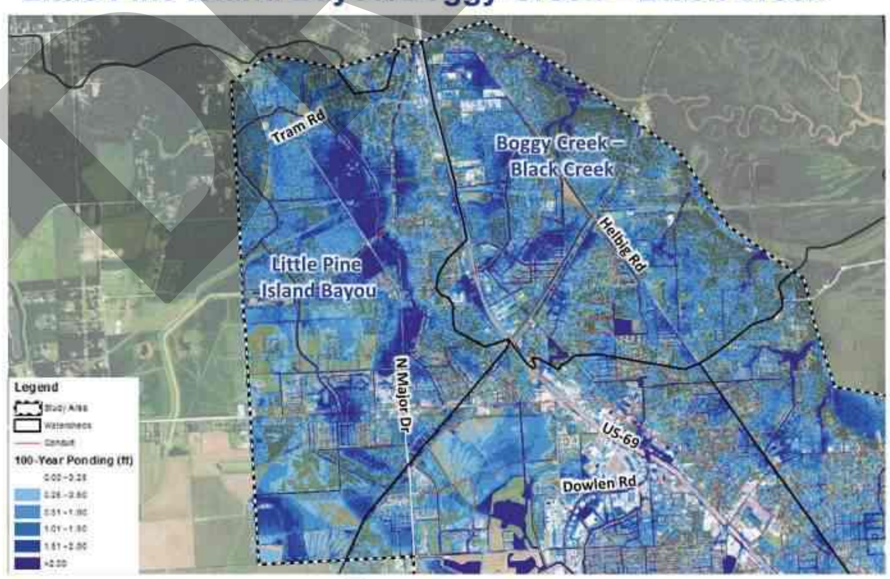
- **Watershed Based Approach to Flood Risk Reduction**
- **Data Collection**
- **Incorporate Previous Studies**
- Define Flooding
- Flood Early Warning Initiatives & Improvements
- Flood Prevention Plan Development
- City Coordination with DD6 and TWDB

BEAUMONT TEXAS DD6 20

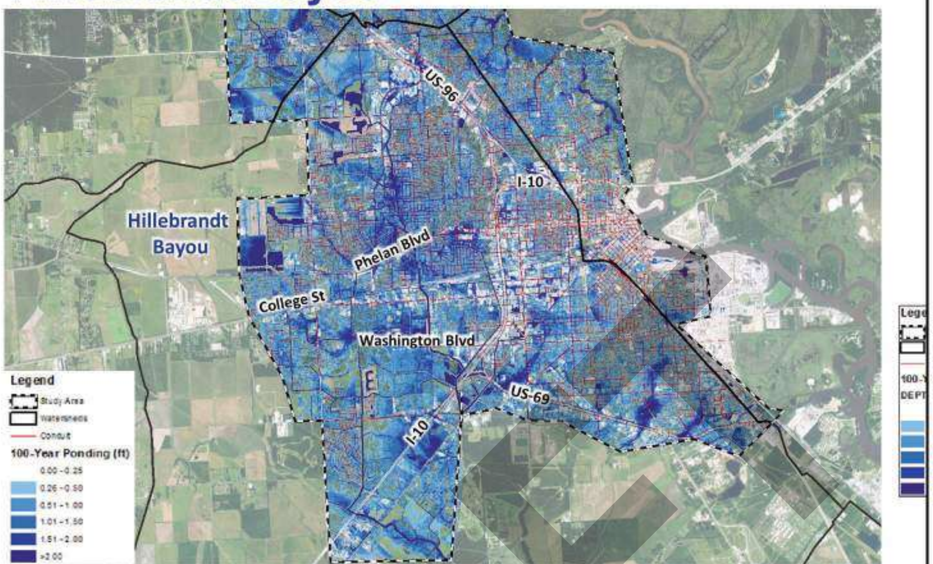
Define Flooding

- Analyzed for 2-yr, 5-yr, 10-yr, 25-yr and 100-yr Events
- Compared to City/County/DD6 Criteria
- General Insufficiencies
  - Undersized Storm Sewers
  - Limited Detention

Little Pine Island Bayou/Boggy Creek – Black Creek



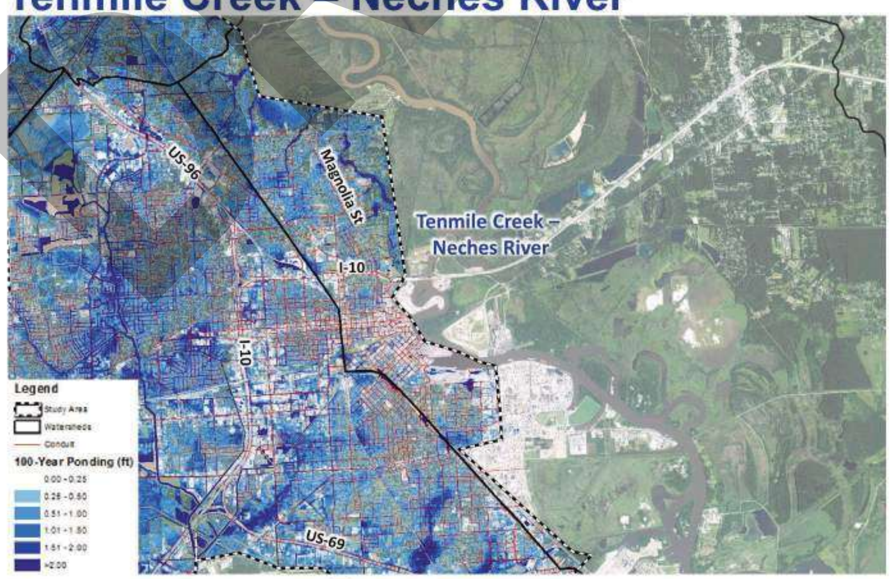
Hillebrandt Bayou



BEAUMONT TEXAS DD6

23

Tenmile Creek – Neches River



BEAUMONT TEXAS DD6

24

Reducing Flood Risk

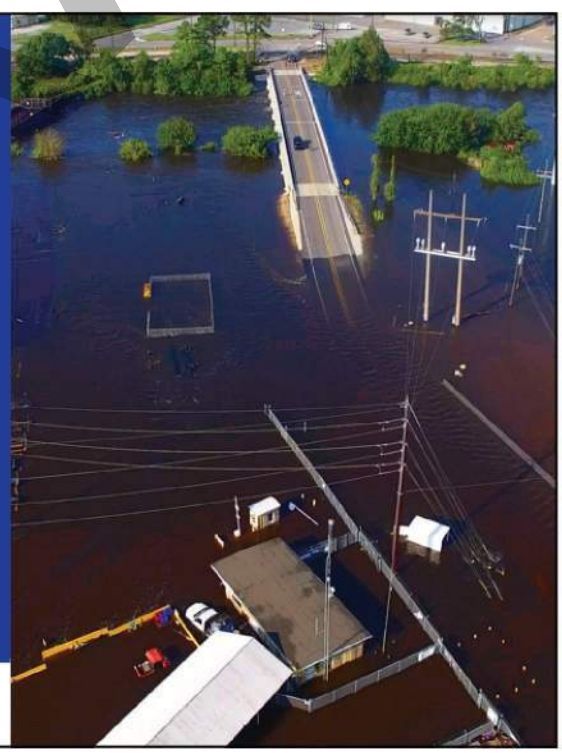
- Drainage Improvement Projects
- Flood Prevention Plan
  - Flood Early Warning System

Source: Bexar County

BEAUMONT TEXAS DD6

25

Questions



DD6 BEAUMONT TEXAS

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

MEETING ATTENDANCE

Subject:	Comprehensive Flood Protection Plan	**Date:**	May 22, 2017
Hosted by:	LAN	**Time:**	5:00 pm to 7:00 pm
Description:	Public Meeting		

	Name	E-mail	Phone	Organization
1	Tom Rowe	trowe@mwwassoc.com	409-892-0421	Mark W. Whiteley & Associates, Inc.
2	Zach Rowe	zowe@mwwassoc.com	409-892-0421	Mark W. Whiteley & Associates, Inc.
3	Zheng Tan	ztan@ci.beaumont.tx.us	409-880-3725	City of Beaumont
4	Ivan Ortiz	Ivan.ortiz@twdb.texas.gov	512-463-8184	TWDB
5	Matt Manges	mjmanges@lan-inc.com	713-821-0366	LAN
6	Chace Mann	cmann@beaumont.texas.gov	409-880-3725	City of Beaumont
7	Laura Casset	LMCasset@lan-inc.com	512-633-7606	LAN
8	Sam Parigi	scp@parigiproperty.com	409-284-7613	Parigi Property
9	Dr. Joe Majdalani	jmajdalani@ci.beaumont.tx.us	409-880-3725	City of Beaumont
10				
11				
12				
13				

Comprehensive Flood Protection Plan Public Meeting

City of Beaumont
Public Works Department

City Representatives: Dr. Joseph Majdalani, PE
Chace Mann

DD6 Representative: Doug Canant, PE

Engineering Consultant: Lockwood, Andrews, & Newnam, Inc.

Lockwood, Andrews & Newnam, Inc.
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BEAUMONT TEXAS

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Agenda

- Hurricane Harvey Event Summary
- Project Introduction
- Texas Water Development Board Grant Overview
- Questions

BEAUMONT TEXAS

2

2

ISC Industrial Specialty Contractor

Hurricane Harvey

3

IH-10 near Old US-90

Hurricane Harvey

4

Neches River by Beaumont Children Museum

5

US90 near Oriole St

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10

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Summary | Hurricane Harvey

- Hurricane Harvey Summary
  - Rain Event of Record
  - Vast Regional Impact

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Project Location

BEAUMONT TEXAS DD6 13

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Project Introduction

- Master Drainage Plan
  - Describes City's Drainage Characteristics
  - Recommends Drainage System Improvements
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BEAUMONT TEXAS DD6 14

14

Master Drainage Plan Background

- Why update the master plan?
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    - Calder Avenue

BEAUMONT TEXAS DD6

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15

Master Drainage Plan Goals

- Roadmap to Address Flooding
- Better Define Flood Risk

BEAUMONT TEXAS DD6

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16

Master Drainage Plan Objectives

- Prioritization of Problem Areas
- Improvement Projects – Reduce Flood Risk

BEAUMONT TEXAS DD6 17

17

Funding Partnership

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  - $500,000 - City of Beaumont
  - $287,000 - TWDB Flood Protection Grant
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BEAUMONT TEXAS DD6 18

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TWDB Grant Components

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- Flood Prevention Plan Development
- City Coordination with DD6 and TWDB

BEAUMONT TEXAS DD6 19

19

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- General Insufficiencies
  - Undersized Storm Sewers
  - Limited Detention

BEAUMONT TEXAS DD6 20

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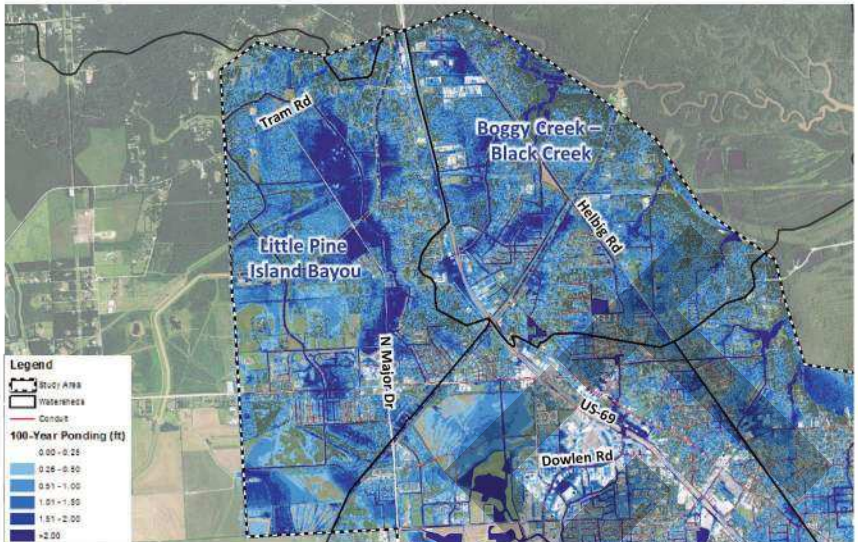
Little Pine Island Bayou/Boggy Creek – Black Creek



BEAUMONT TEXAS DD6

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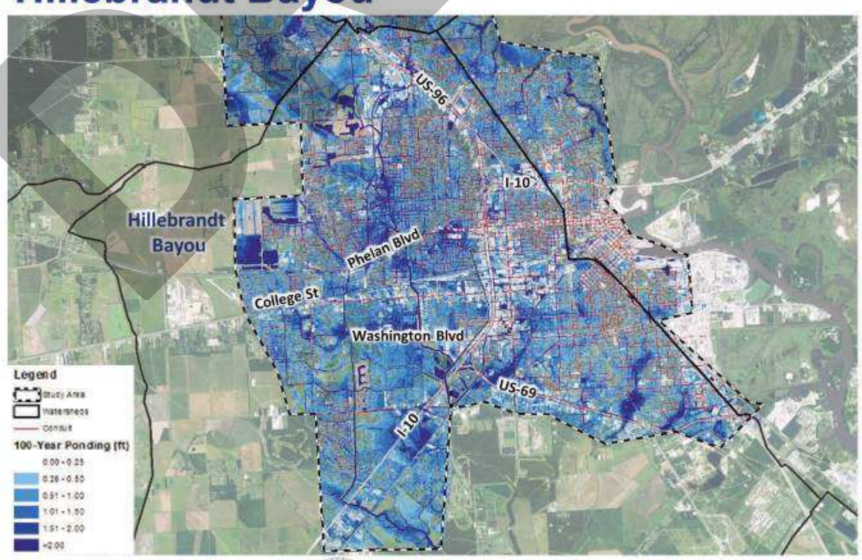
Hillebrandt Bayou



BEAUMONT TEXAS DD6

22

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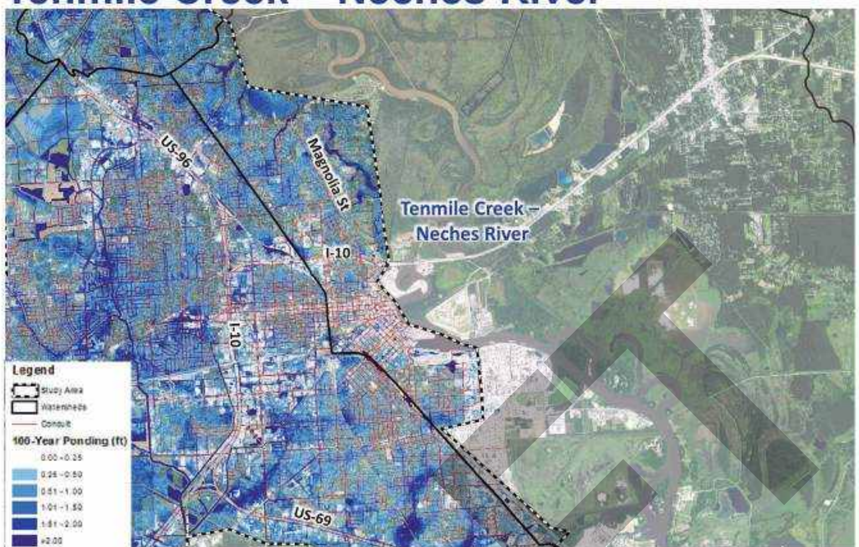
Tenmile Creek – Neches River



BEAUMONT TEXAS DD6

23

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Proposed Conditions Modeling

- Targets
  - 25-year LOS
  - Reduce flood risk
- Evaluations
  - Insufficient systems
  - Open areas

BEAUMONT TEXAS DD6

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Proposed Improvement Projects

- 18 Projects Identified
  - Storm Sewer Improvements
  - Channel Modifications
  - Detention Basins

BEAUMONT TEXAS DD6

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Proposed Improvement Projects

Project ID	General Project Location	Project Improvement Type		
		Storm Sewer	Channel Modification	Detention Basin
1A	Long Avenue - East of MLK Parkway	X		
1B	4th Street and Avenue G	X		
1C	Irving Avenue Lift Station Connection	X		
1D	Fannett Road and 11th Street	X		X
1E	W Virginia Street and Avenue A	X		X
1F	Campus Street and Florida Avenue	X		
1G	Lavaca Street and E Virginia Street	X		
2A	Lewis/Click/Scotts/Hurley Drive	X	X	
2B	Highway 105 - West of Major Drive			X
2C	Eastex Freeway and Sherwood Drive	X	X	
2D	Speer Road and Helbig Road		X	
2E	Lorilee Street and Jenard Lane			X
2F	Lucas Drive and Abilene Avenue	X	X	
2G	Cleveland Street and Hayes Lane	X	X	
2H	Gill Street - East of Magnolia Avenue	X		
2I	Swift Drive and Lucas Drive	X	X	
3A	Delaware Street and Dowlen Road	X		X
3B	Lucas Drive and Briarcliff Drive	X		

BEAUMONT TEXAS DD6

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Reducing Flood Risk

- Drainage Improvement Projects
- Flood Prevention Plan
  - Flood Early Warning System

Source: Bexar County

BEAUMONT TEXAS DD6

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Proposed Flood Early Warning System

- New gauge sites and software
- Decrease reliance on in-person emergency responder for pump alarms
- Help inform better decisions
  - Faster Response during Storm Events

BEAUMONT TEXAS DD6

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Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

MEETING ATTENDANCE

Subject:	Comprehensive Flood Protection Plan	**Date:**	June 26, 2019
Hosted by:	LAN	**Time:**	5:30 pm to 6:30 pm
Description:	Public Meeting		

	Name	E-mail	Phone	Organization
1	Chace Mann	[redacted]	[redacted]	CITY OF BEAUMONT
2	Elizabeth O'Brien	[redacted]	[redacted]	LAN
3	Matt Manges	[redacted]	[redacted]	LAN
4	REMINGTON WHITT	[redacted]	[redacted]	COB
5	Ivan Ortiz	[redacted]	[redacted] 8184	TWDB
6	ERNIE CROCHET	[redacted]	[redacted]	City of Beaumont
7				
8				
9				
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APPENDIX B –
Rainfall Data

BEAUMONT TEXAS

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

Rainfall					
Time	Return Period				
-	**2.00**	**5.00**	**10.00**	**25.00**	**100.00**
15 Minutes	1.11	1.37	1.54	1.77	2.13
1 Hour	2.06	2.61	2.99	3.60	4.60
2 Hours	2.72	3.56	4.18	5.05	6.65
3 Hours	3.01	4.04	4.79	5.89	7.90
6 Hours	3.65	4.99	6.02	7.57	10.60
12 Hours	4.27	5.95	7.24	9.19	13.00
1 Day	5.15	7.27	8.82	11.00	14.80

Date	Time	Precipitation (in)				
-	-	**2-YR**	**5-YR**	**10-YR**	**25-YR**	**100-YR**
1-Jan-16	0.00	0.00	0.00	0.00	0.00	0.00
1-Jan-16	0.01	0.01	0.02	0.03	0.03	0.03
1-Jan-16	0.02	0.01	0.02	0.03	0.03	0.03
1-Jan-16	0.03	0.02	0.02	0.03	0.03	0.03
1-Jan-16	0.04	0.02	0.02	0.03	0.03	0.03
1-Jan-16	0.05	0.02	0.02	0.03	0.03	0.03
1-Jan-16	0.06	0.02	0.02	0.03	0.03	0.03
1-Jan-16	0.07	0.02	0.02	0.03	0.03	0.03
1-Jan-16	0.08	0.02	0.02	0.03	0.03	0.03
1-Jan-16	0.09	0.02	0.03	0.03	0.03	0.03
1-Jan-16	0.10	0.02	0.03	0.03	0.03	0.03
1-Jan-16	0.11	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.13	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.14	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.15	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.16	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.17	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.18	0.02	0.03	0.04	0.04	0.04
1-Jan-16	0.19	0.02	0.03	0.04	0.04	0.04
1-Jan-16	0.20	0.02	0.03	0.04	0.04	0.04
1-Jan-16	0.21	0.02	0.03	0.04	0.04	0.04
1-Jan-16	0.22	0.02	0.03	0.04	0.04	0.05
1-Jan-16	0.23	0.02	0.03	0.04	0.05	0.05
1-Jan-16	0.24	0.02	0.03	0.04	0.05	0.05
1-Jan-16	0.25	0.02	0.04	0.04	0.05	0.05
1-Jan-16	0.26	0.02	0.03	0.04	0.05	0.08
1-Jan-16	0.27	0.02	0.03	0.04	0.06	0.08
1-Jan-16	0.28	0.02	0.03	0.04	0.06	0.09
1-Jan-16	0.29	0.02	0.04	0.04	0.06	0.09
1-Jan-16	0.30	0.02	0.04	0.05	0.06	0.09
1-Jan-16	0.31	0.02	0.04	0.05	0.06	0.09
1-Jan-16	0.32	0.03	0.04	0.05	0.07	0.10
1-Jan-16	0.33	0.03	0.04	0.05	0.07	0.10

Date	Time	Precipitation (in)				
-	-	2-YR	5-YR	10-YR	25-YR	100-YR
1-Jan-16	0.34	0.03	0.04	0.05	0.07	0.11
1-Jan-16	0.35	0.03	0.05	0.06	0.08	0.11
1-Jan-16	0.36	0.03	0.05	0.06	0.08	0.12
1-Jan-16	0.38	0.03	0.05	0.06	0.08	0.12
1-Jan-16	0.39	0.04	0.06	0.08	0.12	0.19
1-Jan-16	0.40	0.05	0.07	0.09	0.12	0.20
1-Jan-16	0.41	0.05	0.07	0.10	0.13	0.21
1-Jan-16	0.42	0.05	0.08	0.10	0.14	0.22
1-Jan-16	0.43	0.06	0.09	0.11	0.15	0.24
1-Jan-16	0.44	0.06	0.09	0.12	0.16	0.26
1-Jan-16	0.45	0.06	0.11	0.14	0.19	0.29
1-Jan-16	0.46	0.07	0.12	0.16	0.22	0.32
1-Jan-16	0.47	0.14	0.21	0.26	0.32	0.46
1-Jan-16	0.48	0.17	0.25	0.31	0.37	0.53
1-Jan-16	0.49	0.22	0.28	0.33	0.42	0.57
1-Jan-16	0.50	0.47	0.61	0.71	0.90	1.21
1-Jan-16	0.51	1.11	1.37	1.54	1.77	2.13
1-Jan-16	0.52	0.27	0.35	0.41	0.51	0.69
1-Jan-16	0.53	0.19	0.27	0.34	0.41	0.58
1-Jan-16	0.54	0.15	0.22	0.28	0.34	0.49
1-Jan-16	0.55	0.08	0.13	0.17	0.23	0.34
1-Jan-16	0.56	0.07	0.12	0.15	0.20	0.30
1-Jan-16	0.57	0.07	0.10	0.13	0.17	0.27
1-Jan-16	0.58	0.06	0.09	0.12	0.16	0.25
1-Jan-16	0.59	0.06	0.08	0.11	0.15	0.23
1-Jan-16	0.60	0.05	0.08	0.10	0.13	0.22
1-Jan-16	0.61	0.05	0.07	0.09	0.13	0.21
1-Jan-16	0.63	0.04	0.07	0.09	0.12	0.19
1-Jan-16	0.64	0.03	0.05	0.07	0.09	0.13
1-Jan-16	0.65	0.03	0.05	0.06	0.08	0.12
1-Jan-16	0.66	0.03	0.05	0.06	0.08	0.12
1-Jan-16	0.67	0.03	0.04	0.06	0.07	0.11
1-Jan-16	0.68	0.03	0.04	0.05	0.07	0.11
1-Jan-16	0.69	0.03	0.04	0.05	0.07	0.10
1-Jan-16	0.70	0.02	0.04	0.05	0.07	0.10
1-Jan-16	0.71	0.02	0.04	0.05	0.06	0.09
1-Jan-16	0.72	0.02	0.04	0.05	0.06	0.09
1-Jan-16	0.73	0.02	0.03	0.04	0.06	0.09
1-Jan-16	0.74	0.02	0.03	0.04	0.06	0.08
1-Jan-16	0.75	0.02	0.03	0.04	0.05	0.08
1-Jan-16	0.76	0.02	0.04	0.04	0.05	0.05
1-Jan-16	0.77	0.02	0.03	0.04	0.05	0.05
1-Jan-16	0.78	0.02	0.03	0.04	0.05	0.05
1-Jan-16	0.79	0.02	0.03	0.04	0.05	0.05
1-Jan-16	0.80	0.02	0.03	0.04	0.04	0.04

Date	Time	Precipitation (in)				
-	-	2-YR	5-YR	10-YR	25-YR	100-YR
1-Jan-16	0.81	0.02	0.03	0.04	0.04	0.04
1-Jan-16	0.82	0.02	0.03	0.04	0.04	0.04
1-Jan-16	0.83	0.02	0.03	0.04	0.04	0.04
1-Jan-16	0.84	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.85	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.86	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.88	0.02	0.03	0.03	0.04	0.04
1-Jan-16	0.89	0.02	0.03	0.03	0.04	0.04
1-Jan-16	21:30	0.02	0.03	0.03	0.04	0.04
1-Jan-16	21:45	0.02	0.03	0.03	0.04	0.03
1-Jan-16	22:00	0.02	0.03	0.03	0.03	0.03
1-Jan-16	22:15	0.02	0.02	0.03	0.03	0.03
1-Jan-16	22:30	0.02	0.02	0.03	0.03	0.03
1-Jan-16	22:45	0.02	0.02	0.03	0.03	0.03
1-Jan-16	23:00	0.02	0.02	0.03	0.03	0.03
1-Jan-16	23:15	0.02	0.02	0.03	0.03	0.03
1-Jan-16	23:30	0.02	0.02	0.03	0.03	0.03
1-Jan-16	23:45	0.01	0.02	0.03	0.03	0.03
2-Jan-16	0:00	0.01	0.02	0.03	0.03	0.03

Date	RAINFALL	Precipitation Intensity (in/hr)				
-	-	2-YR	5-YR	10-YR	25-YR	100-YR
1-Jan-16	0:00	0.00	0.00	0.00	0.00	0.00
1-Jan-16	0:15	0.06	0.09	0.11	0.12	0.12
1-Jan-16	0:30	0.06	0.09	0.11	0.12	0.12
1-Jan-16	0:45	0.06	0.09	0.11	0.12	0.12
1-Jan-16	1:00	0.06	0.09	0.11	0.13	0.12
1-Jan-16	1:15	0.06	0.09	0.11	0.13	0.12
1-Jan-16	1:30	0.06	0.10	0.11	0.13	0.13
1-Jan-16	1:45	0.06	0.10	0.12	0.13	0.13
1-Jan-16	2:00	0.07	0.10	0.12	0.13	0.13
1-Jan-16	2:15	0.07	0.10	0.12	0.14	0.13
1-Jan-16	2:30	0.07	0.10	0.12	0.14	0.14
1-Jan-16	2:45	0.07	0.10	0.12	0.14	0.14
1-Jan-16	3:00	0.07	0.11	0.13	0.14	0.14
1-Jan-16	3:15	0.07	0.11	0.13	0.15	0.15
1-Jan-16	3:30	0.07	0.11	0.13	0.15	0.15
1-Jan-16	3:45	0.08	0.11	0.13	0.15	0.15
1-Jan-16	4:00	0.08	0.11	0.14	0.16	0.16
1-Jan-16	4:15	0.08	0.12	0.14	0.16	0.16
1-Jan-16	4:30	0.08	0.12	0.14	0.17	0.17
1-Jan-16	4:45	0.08	0.12	0.15	0.17	0.17
1-Jan-16	5:00	0.08	0.13	0.15	0.17	0.18
1-Jan-16	5:15	0.09	0.13	0.15	0.18	0.18
1-Jan-16	5:30	0.09	0.13	0.16	0.18	0.19
1-Jan-16	5:45	0.09	0.14	0.16	0.19	0.19
1-Jan-16	6:00	0.09	0.14	0.17	0.19	0.20
1-Jan-16	6:15	0.08	0.13	0.16	0.22	0.32
1-Jan-16	6:30	0.08	0.13	0.17	0.22	0.33
1-Jan-16	6:45	0.09	0.14	0.17	0.23	0.34
1-Jan-16	7:00	0.09	0.14	0.18	0.24	0.35
1-Jan-16	7:15	0.09	0.15	0.19	0.25	0.37
1-Jan-16	7:30	0.10	0.15	0.19	0.26	0.38
1-Jan-16	7:45	0.10	0.16	0.20	0.27	0.39
1-Jan-16	8:00	0.11	0.16	0.21	0.28	0.41
1-Jan-16	8:15	0.11	0.17	0.22	0.29	0.43
1-Jan-16	8:30	0.12	0.18	0.23	0.30	0.45
1-Jan-16	8:45	0.12	0.19	0.24	0.32	0.47
1-Jan-16	9:00	0.13	0.20	0.26	0.34	0.50
1-Jan-16	9:15	0.17	0.26	0.34	0.46	0.76
1-Jan-16	9:30	0.18	0.27	0.36	0.49	0.80
1-Jan-16	9:45	0.20	0.29	0.38	0.52	0.84
1-Jan-16	10:00	0.21	0.32	0.41	0.56	0.90
1-Jan-16	10:15	0.23	0.34	0.44	0.60	0.96
1-Jan-16	10:30	0.26	0.38	0.49	0.66	1.04
1-Jan-16	10:45	0.26	0.43	0.55	0.77	1.15
1-Jan-16	11:00	0.30	0.49	0.63	0.86	1.28

Date	RAINFALL	Precipitation Intensity (in/hr)				
-	-	2-YR	5-YR	10-YR	25-YR	100-YR
1-Jan-16	11:15	0.57	0.83	1.05	1.28	1.82
1-Jan-16	11:30	0.68	0.98	1.23	1.50	2.11
1-Jan-16	11:45	0.87	1.14	1.33	1.69	2.29
1-Jan-16	12:00	1.86	2.43	2.84	3.59	4.84
1-Jan-16	12:15	4.44	5.48	6.16	7.08	8.52
1-Jan-16	12:30	1.07	1.39	1.63	2.05	2.75
1-Jan-16	12:45	0.77	1.10	1.36	1.66	2.32
1-Jan-16	13:00	0.62	0.89	1.13	1.37	1.95
1-Jan-16	13:15	0.32	0.53	0.67	0.92	1.36
1-Jan-16	13:30	0.28	0.46	0.59	0.81	1.21
1-Jan-16	13:45	0.27	0.40	0.51	0.69	1.09
1-Jan-16	14:00	0.24	0.36	0.46	0.63	1.00
1-Jan-16	14:15	0.22	0.33	0.43	0.58	0.93
1-Jan-16	14:30	0.20	0.30	0.39	0.54	0.87
1-Jan-16	14:45	0.19	0.28	0.37	0.51	0.82
1-Jan-16	15:00	0.18	0.27	0.35	0.48	0.78
1-Jan-16	15:15	0.14	0.21	0.26	0.35	0.51
1-Jan-16	15:30	0.13	0.20	0.25	0.33	0.49
1-Jan-16	15:45	0.12	0.19	0.24	0.31	0.46
1-Jan-16	16:00	0.11	0.18	0.22	0.30	0.44
1-Jan-16	16:15	0.11	0.17	0.21	0.28	0.42
1-Jan-16	16:30	0.10	0.16	0.20	0.27	0.40
1-Jan-16	16:45	0.10	0.15	0.20	0.26	0.39
1-Jan-16	17:00	0.10	0.15	0.19	0.25	0.37
1-Jan-16	17:15	0.09	0.14	0.18	0.24	0.36
1-Jan-16	17:30	0.09	0.14	0.18	0.23	0.35
1-Jan-16	17:45	0.09	0.13	0.17	0.23	0.34
1-Jan-16	18:00	0.08	0.13	0.16	0.22	0.33
1-Jan-16	18:15	0.10	0.14	0.17	0.20	0.20
1-Jan-16	18:30	0.09	0.14	0.17	0.19	0.19
1-Jan-16	18:45	0.09	0.13	0.16	0.19	0.19
1-Jan-16	19:00	0.09	0.13	0.16	0.18	0.18
1-Jan-16	19:15	0.09	0.13	0.15	0.18	0.18
1-Jan-16	19:30	0.08	0.12	0.15	0.17	0.17
1-Jan-16	19:45	0.08	0.12	0.15	0.17	0.17
1-Jan-16	20:00	0.08	0.12	0.14	0.16	0.16
1-Jan-16	20:15	0.08	0.12	0.14	0.16	0.16
1-Jan-16	20:30	0.08	0.11	0.14	0.16	0.16
1-Jan-16	20:45	0.07	0.11	0.13	0.15	0.15
1-Jan-16	21:00	0.07	0.11	0.13	0.15	0.15
1-Jan-16	21:15	0.07	0.11	0.13	0.15	0.14
1-Jan-16	21:30	0.07	0.10	0.13	0.14	0.14
1-Jan-16	21:45	0.07	0.10	0.12	0.14	0.14
1-Jan-16	22:00	0.07	0.10	0.12	0.14	0.14
1-Jan-16	22:15	0.07	0.10	0.12	0.14	0.13

Date	RAINFALL	Precipitation Intensity (in/hr)				
-	-	2-YR	5-YR	10-YR	25-YR	100-YR
1-Jan-16	22:30	0.06	0.10	0.12	0.13	0.13
1-Jan-16	22:45	0.06	0.10	0.11	0.13	0.13
1-Jan-16	23:00	0.06	0.09	0.11	0.13	0.13
1-Jan-16	23:15	0.06	0.09	0.11	0.13	0.12
1-Jan-16	23:30	0.06	0.09	0.11	0.12	0.12
1-Jan-16	23:45	0.06	0.09	0.11	0.12	0.12
2-Jan-16	0:00	0.06	0.09	0.11	0.12	0.12

APPENDIX C –
Project Construction Cost Estimates

BEAUMONT
TEXAS

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 1A

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 3,070,000	$ 675,400
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 2,220,000	$ 222,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 2,220,000	$ 11,100
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,864.90
5	TRENCH EXCATION SAFETY & SUPPORT	LF	8,702	$ 5	$ 43,509
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	15	$ 5,257	$ 78,857
8	MANH (COMPL)(TY A)	EA	13	$ 4,465	$ 58,044
9	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	19	$ 4,038	$ 76,721
10	RC PIPE (CL III)(18 IN)	LF	136	$ 51	$ 6,974
11	RC PIPE (CL III)(24 IN)	LF	163	$ 69	$ 11,329
12	RC PIPE (CL III)(36 IN)	LF	6,536	$ 123	$ 802,155
13	CONC BOX CULV (5 FT X 5 FT)	LF	1,866	$ 291	$ 542,449
14	ROADWAY BASE MATERIAL*	SY	11,602	$ 3	$ 34,807
15	CONC PVMT (CONT REINF - CRCP) (8")	SY	11,602	$ 47	$ 548,007
16	ROADWAY RESTRIPING*	LF	8,702	$ 1	$ 8,702
Construction Subtotal					**$ 2,450,000**
Contingency (25%)					**$ 620,000**
Construction Total					**$ 3,070,000**
Construction Cost Estimate Total					**$ 3,750,000**

"Unit Price" for construction material items are based on their TxDOT three-month statewide item average bid price, Jan 2019 - Mar 2019. Descriptions followed by "*" denote unit prices that were extracted from past LAN cost estimates, and do not reflect up-to-date TxDOT bid prices.

The item "Soft Cost" includes engineering services, construction material testing and inspection, geotechnical engineering, program management, construction management and survey.

Any and all estimates provided by Consultant are opinions of probable costs based on information that is reasonably available to Consultant. Client acknowledges and agrees that Consultant has no control over the cost of labor, materials, equipment or services, or the means and methods used by others in determining prices, competitive bidding, or market conditions. Client further acknowledges and understands that proposals, bids, and/or actual project costs may, and probably will vary from the estimates and opinions of probable costs provided by Consultant under the Agreement.

City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 1B

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 42,050,000	$ 9,251,000
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 30,350,000	$ 3,035,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 30,450,000	$ 152,250
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	52,160	$ 5	$ 260,799
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	87	$ 5,257	$ 457,371
8	MANH (COMPL)(TY A)	EA	75	$ 4,465	$ 334,870
9	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	37	$ 4,038	$ 149,404
10	RC PIPE (CL III)(24 IN)	LF	15,873	$ 69	$ 1,101,157
11	RC PIPE (CL III)(36 IN)	LF	5,505	$ 123	$ 675,587
12	RC PIPE (CL III)(48 IN)	LF	2,050	$ 199	$ 407,402
13	RC PIPE (CL III)(60 IN)	LF	1,331	$ 280	$ 373,165
14	CONC BOX CULV (7 FT X 7 FT)	LF	110	$ 561	$ 61,760
15	CONC BOX CULV (8 FT X 8 FT)	LF	674	$ 817	$ 550,158
16	CONC BOX CULV (9 FT X 6 FT)	LF	292	$ 838	$ 244,671
17	CONC BOX CULV (10 FT X 7 FT)	LF	3,158	$ 964	$ 3,043,320
18	CONC BOX CULV (10 FT X 8 FT)	LF	16,941	$ 791	$ 13,407,373
19	CONC BOX CULV (10 FT X 10 FT)	LF	6,227	$ 920	$ 5,726,677
20	ROADWAY BASE MATERIAL*	SY	69,546	$ 3	$ 208,639
21	CONC PVMT (CONT REINF - CRCP) (8")	SY	69,546	$ 47	$ 3,284,827
22	ROADWAY RESTRIPING*	LF	52,160	$ 1	$ 52,160
23	OUTFALL STRUCTURE*	EA	2	$ 50,000	$ 100,000
Construction Subtotal					**$ 33,640,000**
Contingency (25%)					**$ 8,410,000**
Construction Total					**$ 42,050,000**
Construction Cost Estimate Total					**$ 51,310,000**

"Unit Price" for construction material items are based on their TxDOT three-month statewide item average bid price, Jan 2019 - Mar 2019. Descriptions followed by "*" denote unit prices that were extracted from past LAN cost estimates, and do not reflect up-to-date TxDOT bid prices.

The item "Soft Cost" includes engineering services, construction material testing and inspection, geotechnical engineering, program management, construction management and survey.

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 1C

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 12,070,000	$ 2,655,400
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 8,730,000	$ 873,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 8,730,000	$ 43,650
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	8,506	$ 5	$ 42,531
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	15	$ 5,257	$ 78,857
8	MANH (COMPL)(TY A)	EA	13	$ 4,465	$ 58,044
9	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	6	$ 4,038	$ 24,228
10	CONC BOX CULV (10 FT X 10 FT)	LF	8,506	$ 920	$ 7,822,623
11	ROADWAY BASE MATERIAL*	SY	11,342	$ 3	$ 34,025
12	CONC PVMT (CONT REINF - CRCP) (8")	SY	11,342	$ 47	$ 535,689
13	ROADWAY RESTRIPING*	LF	8,506	$ 1	$ 8,506
14	OUTFALL STRUCTURE*	EA	1	$ 50,000	$ 50,000
15	PUMP & MOTOR*	EA	2	$ 33,000	$ 66,000
Construction Subtotal					**$ 9,650,000**
Contingency (25%)					**$ 2,420,000**
Construction Total					**$ 12,070,000**
Construction Cost Estimate Total					**$ 14,730,000**

"Unit Price" for construction material items are based on their TxDOT three-month statewide item average bid price, Jan 2019 - Mar 2019. Descriptions followed by "*" denote unit prices that were extracted from past LAN cost estimates, and do not reflect up-to-date TxDOT bid prices.

The item "Soft Cost" includes engineering services, construction material testing and inspection, geotechnical engineering, program management, construction management and survey.

Any and all estimates provided by Consultant are opinions of probable costs based on information that is reasonably available to Consultant. Client acknowledges and agrees that Consultant has no control over the cost of labor, materials, equipment or services, or the means and methods used by others in determining prices, competitive bidding, or market conditions. Client further acknowledges and understands that proposals, bids, and/or actual project costs may, and probably will vary from the estimates and opinions of probable costs provided by Consultant under the Agreement.

City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 1D

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 11,340,000	$ 2,494,800
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 8,210,000	$ 821,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 8,210,000	$ 41,050
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	17,228	$ 5	$ 86,138
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	29	$ 5,257	$ 152,457
7	MANH (COMPL)(TY A)	EA	25	$ 4,465	$ 111,623
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	9	$ 4,038	$ 36,342
9	RC PIPE (CL III)(24 IN)	LF	4,974	$ 69	$ 345,068
10	RC PIPE (CL III)(48 IN)	LF	2,871	$ 199	$ 570,645
11	RC PIPE (CL III)(60 IN)	LF	121	$ 280	$ 33,924
12	CONC BOX CULV (5 FT X 5 FT)	LF	419	$ 291	$ 121,833
13	CONC BOX CULV (7 FT X 4 FT)	LF	3,450	$ 364	$ 1,256,499
14	CONC BOX CULV (10 FT X 5 FT)	LF	4,556	$ 621	$ 2,830,628
15	CONC BOX CULV (10 FT X 6 FT)*	LF	836	$ 564	$ 471,335
16	ROADWAY BASE MATERIAL*	SY	22,970	$ 3	$ 68,910
17	CONC PVMT (CONT REINF - CRCP) (8")	SY	22,970	$ 47	$ 1,084,925
18	ROADWAY RESTRIPING*	LF	17,228	$ 1	$ 17,228
19	EXCAVATION (CHANNEL)	CY	93,498	$ 10	$ 940,808
20	POND INFLOW/OUTFLOW STRUCTURE*	EA	3	$ 15,000	$ 45,000
21	HEADWALL (CH - PW - 0) (DIA= 72 IN)	EA	2	$ 15,086	$ 30,172
Construction Subtotal					**$ 9,070,000**
Contingency (25%)					**$ 2,270,000**
Construction Total					**$ 11,340,000**
Construction Cost Estimate Total					**$ 13,840,000**

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 1E

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 8,000,000	$ 1,760,000
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 5,790,000	$ 579,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 5,790,000	$ 28,950
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	10,293	$ 5	$ 51,467
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	18	$ 5,257	$ 94,629
7	MANH (COMPL)(TY A)	EA	15	$ 4,465	$ 66,974
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	21	$ 4,038	$ 84,797
9	RC PIPE (CL III)(18 IN)	LF	34	$ 51	$ 1,723
10	RC PIPE (CL III)(24 IN)	LF	684	$ 69	$ 47,438
11	RC PIPE (CL IV)(30 IN)	LF	201	$ 97	$ 19,459
12	RC PIPE (CL III)(36 IN)	LF	631	$ 123	$ 77,392
13	RC PIPE (CL III)(48 IN)	LF	2,235	$ 199	$ 444,232
14	RC PIPE (CL III)(72 IN)*	LF	134	$ 550	$ 73,700
15	CONC BOX CULV (7 FT X 4 FT)	LF	931	$ 364	$ 338,970
16	CONC BOX CULV (8 FT X 4 FT)	LF	1,029	$ 434	$ 446,371
17	CONC BOX CULV (8 FT X 5 FT)*	LF	4,416	$ 540	$ 2,384,424
18	ROADWAY BASE MATERIAL*	SY	13,725	$ 3	$ 41,174
19	CONC PVMT (CONT REINF - CRCP) (8")	SY	13,725	$ 47	$ 648,241
20	ROADWAY RESTRIPING*	LF	10,293	$ 1	$ 10,293
21	EXCAVATION (CHANNEL)	CY	72,664	$ 10	$ 731,175
22	POND INFLOW/OUTFLOW STRUCTURE*	EA	8	$ 15,000	$ 120,000
23	OUTFALL STRUCTURE*	EA	2	$ 50,000	$ 100,000
Construction Subtotal					**$ 6,400,000**
Contingency (25%)					**$ 1,600,000**
Construction Total					**$ 8,000,000**
Construction Cost Estimate Total					**$ 9,760,000**

"Unit Price" for construction material items are based on their TxDOT three-month statewide item average bid price, Jan 2019 - Mar 2019. Descriptions followed by "*" denote unit prices that were extracted from past LAN cost estimates, and do not reflect up-to-date TxDOT bid prices.

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 1F

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 11,920,000	$ 2,622,400
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 8,620,000	$ 862,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 8,620,000	$ 43,100
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	14,259	$ 5	$ 71,295
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	24	$ 5,257	$ 126,171
7	MANH (COMPL)(TY A)	EA	21	$ 4,465	$ 93,764
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	6	$ 4,038	$ 24,228
9	RC PIPE (CL III)(18 IN)	LF	87	$ 51	$ 4,453
10	RC PIPE (CL III)(24 IN)	LF	201	$ 69	$ 13,972
11	RC PIPE (CL III)(48 IN)	LF	1,699	$ 199	$ 337,776
12	CONC BOX CULV (10 FT X 6 FT)*	LF	12,271	$ 564	$ 6,920,844
13	ROADWAY BASE MATERIAL*	SY	19,012	$ 3	$ 57,036
14	CONC PVMT (CONT REINF - CRCP) (8")	SY	19,012	$ 47	$ 897,973
15	ROADWAY RESTRIPING*	LF	14,259	$ 1	$ 14,259
16	OUTFALL STRUCTURE*	EA	1	$ 50,000	$ 50,000
Construction Subtotal					**$ 9,530,000**
Contingency (25%)					**$ 2,390,000**
Construction Total					**$ 11,920,000**
Construction Cost Estimate Total					**$ 14,550,000**

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 1G

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 29,150,000	$ 6,413,000
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 21,100,000	$ 2,110,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 21,100,000	$ 105,500
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	27,214	$ 5	$ 136,070
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	46	$ 5,257	$ 241,829
8	MANH (COMPL)(TY A)	EA	39	$ 4,465	$ 174,132
9	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	12	$ 4,038	$ 48,455
10	RC PIPE (CL III)(24 IN)	LF	1,288	$ 69	$ 89,354
11	RC PIPE (CL III)(36 IN)	LF	70	$ 123	$ 8,591
12	RC PIPE (CL III)(48 IN)	LF	1,538	$ 199	$ 305,695
13	RC PIPE (CL III)(60 IN)	LF	2,065	$ 280	$ 578,953
14	CONC BOX CULV (10 FT X 8 FT)	LF	22,253	$ 791	$ 17,611,581
15	ROADWAY BASE MATERIAL*	SY	36,285	$ 3	$ 108,856
16	CONC PVMT (CONT REINF - CRCP) (8")	SY	36,285	$ 47	$ 1,713,838
17	ROADWAY RESTRIPING*	LF	27,214	$ 1	$ 27,214
18	OUTFALL STRUCTURE*	EA	1	$ 50,000	$ 50,000
Construction Subtotal					**$ 23,320,000**
Contingency (25%)					**$ 5,830,000**
Construction Total					**$ 29,150,000**
Construction Cost Estimate Total					**$ 35,570,000**

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 2A

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 5,220,000	$ 1,148,400
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 3,780,000	$ 378,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 3,780,000	$ 18,900
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	8,957	$ 5	$ 44,787
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	15	$ 5,257	$ 78,857
7	MANH (COMPL)(TY A)	EA	13	$ 4,465	$ 58,044
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	23	$ 4,038	$ 92,873
9	RC PIPE (CL III)(24 IN)	LF	754	$ 69	$ 52,339
10	RC PIPE (CL III)(60 IN)	LF	114	$ 280	$ 31,938
11	CONC BOX CULV (4 FT X 3 FT)	LF	1,940	$ 203	$ 394,078
12	CONC BOX CULV (4 FT X 4 FT)	LF	4,600	$ 273	$ 1,257,276
13	CONC BOX CULV (5 FT X 5 FT)	LF	205	$ 291	$ 59,560
14	CONC BOX CULV (8 FT X 4 FT)	LF	377	$ 434	$ 163,495
15	CONC BOX CULV (8 FT X 5 FT)	LF	205	$ 437	$ 89,640
16	CONC BOX CULV (8 FT X 8 FT)	LF	763	$ 817	$ 623,315
17	EXCAVATION (CHANNEL)	CY	21,079	$ 10	$ 212,106
18	ROADWAY BASE MATERIAL*	SY	11,943	$ 3	$ 35,830
19	CONC PVMT (CONT REINF - CRCP) (8")	SY	11,943	$ 47	$ 564,105
20	ROADWAY RESTRIPING*	LF	8,957	$ 1	$ 8,957
Construction Subtotal					**$ 4,170,000**
Contingency (25%)					**$ 1,050,000**
Construction Total					**$ 5,220,000**
Construction Cost Estimate Total					**$ 6,370,000**

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 2B

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 3,120,000	$ 686,400
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 2,250,000	$ 225,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 2,250,000	$ 11,250
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	940	$ 5	$ 4,699
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	2	$ 5,257	$ 10,514
7	MANH (COMPL)(TY A)	EA	2	$ 4,465	$ 8,930
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	1	$ 4,038	$ 4,038
9	RC PIPE (CL III)(18 IN)	LF	114	$ 51	$ 5,814
10	RC PIPE (CL III)(24 IN)	LF	476	$ 69	$ 33,051
11	RC PIPE (CL III)(27 IN)	LF	201	$ 92	$ 18,532
12	RC PIPE (CL III)(36 IN)	LF	66	$ 123	$ 8,101
13	CONC BOX CULV (6 FT X 4 FT)	LF	82	$ 296	$ 24,326
14	EXCAVATION (CHANNEL)	CY	204,893	$ 10	$ 2,061,706
15	ROADWAY BASE MATERIAL*	SY	1,253	$ 3	$ 3,759
16	CONC PVMT (CONT REINF - CRCP) (8")	SY	1,253	$ 47	$ 59,181
17	ROADWAY RESTRIPING*	LF	940	$ 1	$ 940
Construction Subtotal					**$ 2,490,000**
Contingency (25%)					**$ 630,000**
Construction Total					**$ 3,120,000**
Construction Cost Estimate Total					**$ 3,810,000**

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 2C

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 11,180,000	$ 2,459,600
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 8,090,000	$ 809,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 8,090,000	$ 40,450
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	5,331	$ 5	$ 26,657
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	9	$ 5,257	$ 47,314
7	MANH (COMPL)(TY A)	EA	8	$ 4,465	$ 35,719
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	9	$ 4,038	$ 36,342
9	RC PIPE (CL III)(24 IN)	LF	328	$ 69	$ 22,770
10	RC PIPE (CL IV)(30 IN)	LF	543	$ 97	$ 52,430
11	RC PIPE (CL III)(36 IN)	LF	723	$ 123	$ 88,741
12	RC PIPE (CL III)(48 IN)	LF	530	$ 199	$ 105,292
13	CONC BOX CULV (6 FT X 4 FT)	LF	342	$ 296	$ 101,086
14	CONC BOX CULV (8 FT X 5 FT)	LF	2,866	$ 437	$ 1,253,704
15	EXCAVATION (CHANNEL)	CY	590,772	$ 10	$ 5,944,564
16	ROADWAY BASE MATERIAL*	SY	7,109	$ 3	$ 21,326
17	CONC PVMT (CONT REINF - CRCP) (8")	SY	7,109	$ 47	$ 335,752
18	ROADWAY RESTRIPING*	LF	5,331	$ 1	$ 5,331
Construction Subtotal					**$ 8,940,000**
Contingency (25%)					**$ 2,240,000**
Construction Total					**$ 11,180,000**
Construction Cost Estimate Total					**$ 13,640,000**

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 2D

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 2,940,000	$ 646,800
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 2,120,000	$ 212,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 2,120,000	$ 10,600
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	EXCAVATION (CHANNEL)	CY	210,267	$ 10	$ 2,115,787
Construction Subtotal					**$ 2,350,000**
Contingency (25%)					**$ 590,000**
Construction Total					**$ 2,940,000**
Construction Cost Estimate Total					**$ 3,590,000**

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 2E

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 11,120,000	$ 2,446,400
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 8,050,000	$ 805,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 8,050,000	$ 40,250
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	6,298	$ 5	$ 31,491
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	11	$ 5,257	$ 57,829
7	MANH (COMPL)(TY A)	EA	9	$ 4,465	$ 40,184
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	1	$ 4,038	$ 4,038
9	RC PIPE (CL III)(24 IN)	LF	2,122	$ 69	$ 147,216
13	CONC BOX CULV (8 FT X 4 FT)	LF	4,176	$ 434	$ 1,812,431
14	EXCAVATION (CHANNEL)	CY	548,532	$ 10	$ 5,519,527
15	ROADWAY BASE MATERIAL*	SY	8,398	$ 3	$ 25,193
16	CONC PVMT (CONT REINF - CRCP) (8")	SY	8,398	$ 47	$ 396,634
17	ROADWAY RESTRIPING*	LF	6,298	$ 1	$ 6,298
Construction Subtotal					**$ 8,890,000**
Contingency (25%)					**$ 2,230,000**
Construction Total					**$ 11,120,000**
Construction Cost Estimate Total					**$ 13,570,000**

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 2F

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 10,480,000	$ 2,305,600
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 7,580,000	$ 758,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 7,580,000	$ 37,900
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	10,191	$ 5	$ 50,955
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	17	$ 5,257	$ 89,371
7	MANH (COMPL)(TY A)	EA	15	$ 4,465	$ 66,974
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	11	$ 4,038	$ 44,417
9	RC PIPE (CL III)(24 IN)	LF	194	$ 69	$ 13,455
10	RC PIPE (CL III)(36 IN)	LF	117	$ 123	$ 14,349
11	CONC BOX CULV (6 FT X 3 FT)	LF	3,698	$ 322	$ 1,189,403
12	CONC BOX CULV (6 FT X 5 FT)	LF	1,670	$ 320	$ 534,669
14	CONC BOX CULV (9 FT X 7 FT)	LF	4,512	$ 955	$ 4,308,701
15	EXCAVATION (CHANNEL)	CY	26,497	$ 10	$ 266,626
16	ROADWAY BASE MATERIAL*	SY	19,604	$ 3	$ 58,812
17	CONC PVMT (CONT REINF - CRCP) (8")	SY	19,604	$ 47	$ 925,940
18	ROADWAY RESTRIPING*	LF	10,191	$ 1	$ 10,191
Construction Subtotal					**$ 8,380,000**
Contingency (25%)					**$ 2,100,000**
Construction Total					**$ 10,480,000**
Construction Cost Estimate Total					**$ 12,790,000**

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 2G

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 14,330,000	$ 3,152,600
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 10,370,000	$ 1,037,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 10,370,000	$ 51,850
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	20,472	$ 5	$ 102,358
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	35	$ 5,257	$ 184,000
7	MANH (COMPL)(TY A)	EA	30	$ 4,465	$ 133,948
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	26	$ 4,038	$ 104,987
9	RC PIPE (CL III)(24 IN)	LF	510	$ 69	$ 35,366
10	RC PIPE (CL III)(48 IN)	LF	5,328	$ 199	$ 1,059,085
11	CONC BOX CULV (4 FT X 4 FT)	LF	1,035	$ 273	$ 282,973
12	CONC BOX CULV (5 FT X 5 FT)	LF	645	$ 291	$ 187,629
13	CONC BOX CULV (6 FT X 6 FT)	LF	471	$ 392	$ 184,898
14	CONC BOX CULV (8 FT X 4 FT)	LF	1,071	$ 434	$ 464,878
15	CONC BOX CULV (8 FT X 5 FT)	LF	1,440	$ 437	$ 630,042
16	CONC BOX CULV (8 FT X 6 FT)	LF	9,970	$ 412	$ 4,109,467
17	EXCAVATION (CHANNEL)	CY	148,382	$ 10	$ 1,493,073
18	ROADWAY BASE MATERIAL*	SY	27,296	$ 3	$ 81,887
19	CONC PVMT (CONT REINF - CRCP) (8")	SY	27,296	$ 47	$ 1,289,232
20	ROADWAY RESTRIPING*	LF	20,472	$ 1	$ 20,472
Construction Subtotal					**$ 11,460,000**
Contingency (25%)					**$ 2,870,000**
Construction Total					**$ 14,330,000**
Construction Cost Estimate Total					**$ 17,490,000**

"Unit Price" for construction material items are based on their TxDOT three-month statewide item average bid price, Jan 2019 - Mar 2019. Descriptions followed by "*" denote unit prices that were extracted from past LAN cost estimates, and do not reflect up-to-date TxDOT bid prices.

The item "Soft Cost" includes engineering services, construction material testing and inspection, geotechnical engineering, program management, construction management and survey.

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 2H

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 1,520,000	$ 334,400
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 1,100,000	$ 110,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 1,100,000	$ 5,500
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	2,595	$ 5	$ 12,973
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	5	$ 5,257	$ 26,286
7	MANH (COMPL)(TY A)	EA	4	$ 4,465	$ 17,860
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	2	$ 4,038	$ 8,076
9	CONC BOX CULV (6 FT X 4 FT)	LF	1,997	$ 296	$ 590,500
10	CONC BOX CULV (7 FT X 5 FT)	LF	597	$ 428	$ 255,564
11	ROADWAY BASE MATERIAL*	SY	3,460	$ 3	$ 10,379
12	CONC PVMT (CONT REINF - CRCP) (8")	SY	3,460	$ 47	$ 163,403
13	ROADWAY RESTRIPING*	LF	2,595	$ 1	$ 2,595
Construction Subtotal					**$ 1,210,000**
Contingency (25%)					**$ 310,000**
Construction Total					**$ 1,520,000**
Construction Cost Estimate Total					**$ 1,860,000**

"Unit Price" for construction material items are based on their TxDOT three-month statewide item average bid price, Jan 2019 - Mar 2019. Descriptions followed by "*" denote unit prices that were extracted from past LAN cost estimates, and do not reflect up-to-date TxDOT bid prices.

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 2I

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 3,350,000	$ 737,000
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 2,430,000	$ 243,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 2,430,000	$ 12,150
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	1,185	$ 5	$ 5,923
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	2	$ 5,257	$ 10,514
7	MANH (COMPL)(TY A)	EA	2	$ 4,465	$ 8,930
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	2	$ 4,038	$ 8,076
9	RC PIPE (CL III)(36 IN)	LF	64	$ 123	$ 7,861
10	CONC BOX CULV (5 FT X 5 FT)	LF	1,121	$ 291	$ 325,763
11	EXCAVATION (CHANNEL)	CY	195,704	$ 10	$ 1,969,244
12	ROADWAY BASE MATERIAL*	SY	1,580	$ 3	$ 4,739
13	CONC PVMT (CONT REINF - CRCP) (8")	SY	1,580	$ 47	$ 74,606
14	ROADWAY RESTRIPING*	LF	1,185	$ 1	$ 1,185
Construction Subtotal					**$ 2,680,000**
Contingency (25%)					**$ 670,000**
Construction Total					**$ 3,350,000**
Construction Cost Estimate Total					**$ 4,090,000**

"Unit Price" for construction material items are based on their TxDOT three-month statewide item average bid price, Jan 2019 - Mar 2019. Descriptions followed by "*" denote unit prices that were extracted from past LAN cost estimates, and do not reflect up-to-date TxDOT bid prices.

The item "Soft Cost" includes engineering services, construction material testing and inspection, geotechnical engineering, program management, construction management and survey.

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 3A

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 9,390,000	$ 2,065,800
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 6,790,000	$ 679,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 6,790,000	$ 33,950
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	13,544	$ 5	$ 67,719
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	23	$ 5,257	$ 120,914
7	MANH (COMPL)(TY A)	EA	20	$ 4,465	$ 89,299
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	5	$ 4,038	$ 20,190
9	RC PIPE (CL III)(48 IN)	LF	1,057	$ 199	$ 210,071
10	CONC BOX CULV (8 FT X 5 FT)	LF	1,996	$ 437	$ 873,319
11	CONC BOX CULV (8 FT X 6 FT)	LF	10,491	$ 412	$ 4,323,875
12	EXCAVATION (CHANNEL)	CY	15,643	$ 10	$ 157,404
13	ROADWAY BASE MATERIAL*	SY	18,058	$ 3	$ 54,175
14	CONC PVMT (CONT REINF - CRCP) (8")	SY	18,058	$ 47	$ 852,933
15	ROADWAY RESTRIPING*	LF	13,544	$ 1	$ 13,544
Construction Subtotal					**$ 7,510,000**
Contingency (25%)					**$ 1,880,000**
Construction Total					**$ 9,390,000**
Construction Cost Estimate Total					**$ 11,460,000**

"Unit Price" for construction material items are based on their TxDOT three-month statewide item average bid price, Jan 2019 - Mar 2019. Descriptions followed by "*" denote unit prices that were extracted from past LAN cost estimates, and do not reflect up-to-date TxDOT bid prices.

The item "Soft Cost" includes engineering services, construction material testing and inspection, geotechnical engineering, program management, construction management and survey.

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City of Beaumont Master Drainage Plan
Construction Cost Estimate - Project Area 3B

Item #	Description	Unit	Quantity	Unit Price	Amount
1	SOFT COSTS	PCNT	22.0%	$ 37,350,000	$ 8,217,000
2	MOBILIZATION & DEMOBILIZATION	PCNT	10.0%	$ 27,040,000	$ 2,704,000
3	STORMWATER POLLUTION PREVENTION (SWPP)	PCNT	0.5%	$ 27,040,000	$ 135,200
4	BARR, SIGNS, TRAFFIC HANDLING	EA	1	$ 3,865	$ 3,865
5	TRENCH EXCATION SAFETY & SUPPORT	LF	14,690	$ 5	$ 73,452
6	INLET (COMPL)(CURB)(5 FT)(SPECIAL)	EA	25	$ 5,257	$ 131,429
7	MANH (COMPL)(TY A)	EA	21	$ 4,465	$ 93,764
8	JCTBOX(COMPL)(PJB)(4FTX4FT)	EA	3	$ 4,038	$ 12,114
9	RC PIPE (CL III)(15 IN)	LF	43	$ 54	$ 2,315
10	RC PIPE (CL III)(24 IN)	LF	37	$ 69	$ 2,539
11	RC PIPE (CL III)(36 IN)	LF	40	$ 123	$ 4,848
12	CONC BOX CULV (8 FT X 4 FT)	LF	7,750	$ 434	$ 3,363,471
13	CONC BOX CULV (8 FT X 5 FT)	LF	6,822	$ 437	$ 2,984,280
14	EXCAVATION (CHANNEL)	CY	1,924,923	$ 10	$ 19,369,271
15	ROADWAY BASE MATERIAL*	SY	19,587	$ 3	$ 58,762
16	CONC PVMT (CONT REINF - CRCP) (8")	SY	19,587	$ 47	$ 925,148
17	ROADWAY RESTRIPING*	LF	14,690	$ 1	$ 14,690
Construction Subtotal					**$ 29,880,000**
Contingency (25%)					**$ 7,470,000**
Construction Total					**$ 37,350,000**
Construction Cost Estimate Total					**$ 45,570,000**

"Unit Price" for construction material items are based on their TxDOT three-month statewide item average bid price, Jan 2019 - Mar 2019. Descriptions followed by "*" denote unit prices that were extracted from past LAN cost estimates, and do not reflect up-to-date TxDOT bid prices.

The item "Soft Cost" includes engineering services, construction material testing and inspection, geotechnical engineering, program management, construction management and survey.

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APPENDIX D –
Benefit-Cost Analyses

BEAUMONT TEXAS

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 1A

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 1,006,695.85	$ 10,066.96
100yr	0.01	$ 2,988,929.97	$ 1,982,234.12	$ 1,006,695.85			
					0.09	$ 619,464.52	$ 55,751.81
10yr	0.1	$ 1,757,384.06	$ 1,525,150.86	$ 232,233.20			
					0.4	$ 201,650.86	$ 80,660.34
2yr	0.5	$ 1,437,558.77	$ 1,266,490.25	$ 171,068.52			
						Total Annual Damage Reduction Value=	$ 146,479.11
						Annualized Cost Value=	$ 302,199.01
						Annualized BCR=	**0.485**
						Present Damage Reduction=	$ 1,817,665.29
						Present Cost Value=	$ 3,750,000.00
						Present BCR=	**0.485**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 1B

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 9,236,853.45	$ 92,368.53
100yr	0.01	$ 72,176,534.68	$ 62,939,681.23	$ 9,236,853.45			
					0.09	$ 8,060,414.90	$ 725,437.34
10yr	0.1	$ 53,042,863.60	$ 46,158,887.25	$ 6,883,976.35			
					0.4	$ 4,703,095.00	$ 1,881,238.00
2yr	0.5	$ 42,259,804.95	$ 39,737,591.30	$ 2,522,213.65			
						Total Annual Damage Reduction Value=	$ 2,699,043.88
						Annualized Cost Value=	$ 4,134,888.36
						Annualized BCR=	**0.653**
						Present Damage Reduction=	$ 33,492,546.62
						Present Cost Value=	$ 51,310,000.00
						Present BCR=	**0.653**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 1C

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 838,415.82	$ 8,384.16
100yr	0.01	$ 3,648,001.37	$ 2,809,585.56	$ 838,415.82			
					0.09	$ 838,278.92	$ 75,445.10
10yr	0.1	$ 2,585,888.89	$ 1,747,746.87	$ 838,142.02			
					0.4	$ 560,565.03	$ 224,226.01
2yr	0.5	$ 1,644,003.26	$ 1,361,015.22	$ 282,988.04			
						Total Annual Damage Reduction Value=	$ 308,055.27
						Annualized Cost Value=	$ 1,187,037.72
						Annualized BCR=	0.260
						Present Damage Reduction=	$ 3,822,670.57
						Present Cost Value=	$ 14,730,000.00
						Present BCR=	0.260

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 1D

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 2,644,497.87	$ 26,444.98
100yr	0.01	$ 12,355,045.50	$ 9,710,547.63	$ 2,644,497.87			
					0.09	$ 2,499,064.36	$ 224,915.79
10yr	0.1	$ 7,474,393.34	$ 5,120,762.49	$ 2,353,630.85			
					0.4	$ 1,934,705.96	$ 773,882.38
2yr	0.5	$ 4,857,108.42	$ 3,341,327.35	$ 1,515,781.07			
						Total Annual Damage Reduction Value=	$ 1,025,243.15
						Annualized Cost Value=	$ 1,115,315.82
						Annualized BCR=	**0.919**
						Present Damage Reduction=	$ 12,722,284.52
						Present Cost Value=	$ 13,840,000.00
						Present BCR=	**0.919**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 1E

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 5,329,325.39	$ 53,293.25
100yr	0.01	$ 12,101,006.81	$ 6,771,681.42	$ 5,329,325.39			
					0.09	$ 4,182,887.32	$ 376,459.86
10yr	0.1	$ 7,006,907.36	$ 3,970,458.11	$ 3,036,449.25			
					0.4	$ 2,054,542.33	$ 821,816.93
2yr	0.5	$ 3,895,867.15	$ 2,823,231.74	$ 1,072,635.41			
						Total Annual Damage Reduction Value=	$ 1,251,570.04
						Annualized Cost Value=	$ 786,523.30
						Annualized BCR=	**1.591**
						Present Damage Reduction=	$ 15,530,784.22
						Present Cost Value=	$ 9,760,000.00
						Present BCR=	**1.591**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 1F

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 2,431,461.98	$ 24,314.62
100yr	0.01	$ 9,494,216.88	$ 7,062,754.90	$ 2,431,461.98			
					0.09	$ 2,346,246.58	$ 211,162.19
10yr	0.1	$ 6,063,456.50	$ 3,802,425.32	$ 2,261,031.18			
					0.4	$ 1,521,055.21	$ 608,422.09
2yr	0.5	$ 3,608,977.18	$ 2,827,897.94	$ 781,079.24			
						Total Annual Damage Reduction Value=	$ 843,898.90
						Annualized Cost Value=	$ 1,172,532.17
						Annualized BCR=	**0.720**
						Present Damage Reduction=	$ 10,471,976.17
						Present Cost Value=	$ 14,550,000.00
						Present BCR=	**0.720**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 1G

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 1,207,617.67	$ 12,076.18
100yr	0.01	$ 8,320,574.24	$ 7,112,956.58	$ 1,207,617.67			
					0.09	$ 1,213,134.29	$ 109,182.09
10yr	0.1	$ 5,166,102.57	$ 3,947,451.66	$ 1,218,650.91			
					0.4	$ 994,625.12	$ 397,850.05
2yr	0.5	$ 3,053,962.98	$ 2,283,363.64	$ 770,599.33			
						Total Annual Damage Reduction Value=	$ 519,108.31
						Annualized Cost Value=	$ 2,866,458.37
						Annualized BCR=	0.181
						Present Damage Reduction=	$ 6,441,636.41
						Present Cost Value=	$ 35,570,000.00
						Present BCR=	0.181

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 2A

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 363,851.84	$ 3,638.52
100yr	0.01	$ 2,743,339.43	$ 2,379,487.59	$ 363,851.84			
					0.09	$ 373,108.66	$ 33,579.78
10yr	0.1	$ 1,727,125.24	$ 1,344,759.76	$ 382,365.48			
					0.4	$ 302,046.23	$ 120,818.49
2yr	0.5	$ 1,187,679.11	$ 965,952.12	$ 221,726.99			
						Total Annual Damage Reduction Value=	$ 158,036.79
						Annualized Cost Value=	$ 513,335.39
						Annualized BCR=	**0.308**
						Present Damage Reduction=	$ 1,961,085.04
						Present Cost Value=	$ 6,370,000.00
						Present BCR=	**0.308**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 2B

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 3,395,939.61	$ 33,959.40
100yr	0.01	$ 14,422,283.08	$ 11,026,343.47	$ 3,395,939.61			
					0.09	$ 3,579,554.87	$ 322,159.94
10yr	0.1	$ 7,530,166.41	$ 3,766,996.27	$ 3,763,170.13			
					0.4	$ 2,239,396.82	$ 895,758.73
2yr	0.5	$ 3,280,679.64	$ 2,565,056.14	$ 715,623.50			
						Total Annual Damage Reduction Value=	$ 1,251,878.06
						Annualized Cost Value=	$ 307,034.20
						Annualized BCR=	**4.077**
						Present Damage Reduction=	$ 15,534,606.43
						Present Cost Value=	$ 3,810,000.00
						Present BCR=	**4.077**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 2C

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 4,813,759.74	$ 48,137.60
100yr	0.01	$ 8,806,723.98	$ 3,992,964.24	$ 4,813,759.74			
					0.09	$ 3,198,847.83	$ 287,896.30
10yr	0.1	$ 3,414,257.98	$ 1,830,322.06	$ 1,583,935.92			
					0.4	$ 972,735.68	$ 389,094.27
2yr	0.5	$ 1,272,099.22	$ 910,563.79	$ 361,535.43			
						Total Annual Damage Reduction Value=	$ 725,128.17
						Annualized Cost Value=	$ 1,099,198.54
						Annualized BCR=	**0.660**
						Present Damage Reduction=	$ 8,998,145.35
						Present Cost Value=	$ 13,640,000.00
						Present BCR=	**0.660**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 2D

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 201,520.49	$ 2,015.20
100yr	0.01	$ 1,358,715.22	$ 1,157,194.73	$ 201,520.49			
					0.09	$ 100,760.25	$ 9,068.42
10yr	0.1	$ 585,655.03	$ 719,045.89	$ -			
					0.4	$ -	$ -
2yr	0.5	$ 321,647.56	$ 453,907.55	$ -			
						Total Annual Damage Reduction Value=	$ 11,083.63
						Annualized Cost Value=	$ 289,305.19
						Annualized BCR=	**0.038**
						Present Damage Reduction=	$ 137,537.19
						Present Cost Value=	$ 3,590,000.00
						Present BCR=	**0.038**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 2E

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 539,527.62	$ 5,395.28
100yr	0.01	$ 1,660,421.88	$ 1,120,894.26	$ 539,527.62			
					0.09	$ 495,209.53	$ 44,568.86
10yr	0.1	$ 1,093,568.60	$ 642,677.15	$ 450,891.45			
					0.4	$ 307,353.75	$ 122,941.50
2yr	0.5	$ 493,844.93	$ 330,028.88	$ 163,816.05			
						Total Annual Damage Reduction Value=	$ 172,905.64
						Annualized Cost Value=	$ 1,093,557.50
						Annualized BCR=	**0.158**
						Present Damage Reduction=	$ 2,145,593.15
						Present Cost Value=	$ 13,570,000.00
						Present BCR=	**0.158**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 2F

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 879,729.79	$ 8,797.30
100yr	0.01	$ 2,810,745.94	$ 1,931,016.16	$ 879,729.79			
					0.09	$ 662,506.19	$ 59,625.56
10yr	0.1	$ 1,765,723.89	$ 1,320,441.29	$ 445,282.60			
					0.4	$ 263,361.41	$ 105,344.56
2yr	0.5	$ 977,063.34	$ 895,623.13	$ 81,440.21			
						Total Annual Damage Reduction Value=	$ 173,767.42
						Annualized Cost Value=	$ 1,030,700.10
						Annualized BCR=	**0.169**
						Present Damage Reduction=	$ 2,156,287.05
						Present Cost Value=	$ 12,790,000.00
						Present BCR=	**0.169**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 2G

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 1,497,998.77	$ 14,979.99
100yr	0.01	$ 8,809,169.64	$ 7,311,170.87	$ 1,497,998.77			
					0.09	$ 1,480,527.63	$ 133,247.49
10yr	0.1	$ 5,458,182.56	$ 3,995,126.07	$ 1,463,056.49			
					0.4	$ 753,680.29	$ 301,472.11
2yr	0.5	$ 2,644,024.76	$ 2,599,720.68	$ 44,304.08			
						Total Annual Damage Reduction Value=	$ 449,699.59
						Annualized Cost Value=	$ 1,409,456.20
						Annualized BCR=	**0.319**
						Present Damage Reduction=	$ 5,580,340.71
						Present Cost Value=	$ 17,490,000.00
						Present BCR=	**0.319**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 2H

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 58,042.59	$ 580.43
100yr	0.01	$ 1,165,776.88	$ 1,107,734.29	$ 58,042.59			
					0.09	$ 157,664.07	$ 14,189.77
10yr	0.1	$ 902,601.53	$ 645,315.97	$ 257,285.56			
					0.4	$ 250,861.41	$ 100,344.57
2yr	0.5	$ 607,037.27	$ 362,599.99	$ 244,437.27			
						Total Annual Damage Reduction Value=	$ 115,114.76
						Annualized Cost Value=	$ 149,890.71
						Annualized BCR=	**0.768**
						Present Damage Reduction=	$ 1,428,463.78
						Present Cost Value=	$ 1,860,000.00
						Present BCR=	**0.768**

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 2I

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 379,880.37	$ 3,798.80
100yr	0.01	$ 1,552,193.01	$ 1,172,312.65	$ 379,880.37			
					0.09	$ 319,982.00	$ 28,798.38
10yr	0.1	$ 1,023,073.54	$ 762,989.91	$ 260,083.63			
					0.4	$ 208,120.70	$ 83,248.28
2yr	0.5	$ 725,555.96	$ 569,398.19	$ 156,157.77			
						Total Annual Damage Reduction Value=	$ 115,845.46
						Annualized Cost Value=	$ 329,598.39
						Annualized BCR=	**0.351**
						Present Damage Reduction=	$ 1,437,531.11
						Present Cost Value=	$ 4,090,000.00
						Present BCR=	**0.351**

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Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 3A

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 18,161,535.89	$ 181,615.36
100yr	0.01	$ 137,352,219.95	$ 119,190,684.06	$ 18,161,535.89			
					0.09	$ 9,080,767.94	$ 817,269.11
10yr	0.1	$ 65,771,725.42	$ 66,120,054.77	$ -			
					0.4	$ 28,866.99	$ 11,546.80
2yr	0.5	$ 51,011,552.11	$ 50,953,818.12	$ 57,733.99			
						Total Annual Damage Reduction Value=	$ 1,010,431.27
						Annualized Cost Value=	$ 923,520.18
						Annualized BCR=	1.094
						Present Damage Reduction=	$ 12,538,483.25
						Present Cost Value=	$ 11,460,000.00
						Present BCR=	1.094

Beaumont Master Drainage Plan
Benefit-Cost Ratio
Project Area 3B

Event	Exceedance Probability	Exist Damage	Prop Damage	Damage Reduction Increment	Probability Increment	Mean Damage Reduction Increment	**Annual Damage Reduction Value**
					0.01	$ 957,289.19	$ 9,572.89
100yr	0.01	$ 18,259,706.33	$ 17,302,417.14	$ 957,289.19			
					0.09	$ 996,482.94	$ 89,683.47
10yr	0.1	$ 12,299,880.28	$ 11,264,203.58	$ 1,035,676.70			
					0.4	$ 820,698.36	$ 328,279.34
2yr	0.5	$ 8,515,402.73	$ 7,909,682.71	$ 605,720.02			
						Total Annual Damage Reduction Value=	$ 427,535.70
						Annualized Cost Value=	$ 3,672,322.41
						Annualized BCR=	0.116
						Present Damage Reduction=	$ 5,305,308.11
						Present Cost Value=	$ 45,570,000.00
						Present BCR=	0.116